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INITIAL WATERSHED ASSESSMENT WATER RESOURCES INVENTORY AREA 7 SNOHOMISH RIVER WATERSHED

Open-File Technical Report 95-06

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1 Introduction

1.1 Background

Population growth within the past several decades has imposed significant pressure upon Washington State's limited water resources. Washington Department of 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 of these water right applications on an individual basis. This case-by-case approach requires a substantial amount of time and often lends itself to duplication of effort. In addition, this process may result in inconsistent and less defensible conclusions because the evaluation does not consider a regional or long-term perspective on the natural hydrogeologic system.

It has become apparent to most resource planners that water rights decisions can best be evaluated from the context of a drainage-basin-wide analysis of the 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"initial" because they are based on readily available information and do not include collection or analysis of new or unpublished data.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 Snohomish 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 Snohomish 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 Summary and Conclusions

Water Rights / Water Use

- Water right allocations in the Snohomish WRIA, reported as maximum allowable annual withdrawals (Qa’s), are on the order of 570,000 acre-feet per year. Surface-water permits and certificates comprise 94% of these allocations.

- Ecology currently has applications for 61 ground-water and 26 surface-water rights. The ground-water applications are requesting a total of 73,500 gallons per minute (164 cubic feet per second) maximum instantaneous withdrawal (Qi). Of the surface-water applications, 22 are for non-power uses and are requesting 1,000 cubic feet per second in total. The remaining

4 surface-water applications for power are requesting a combined Qi which exceeds the total streamflow in the watershed. *(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.)*

- Surface-water permits and certificates (for consumptive use) are primarily allocated for municipal and domestic multiple uses (72% and 21% of Qa, respectively). Disregarding power generation, surface-water applications are requested for municipal (79% of Qi) and commercial and industrial (21 % of Qi) uses.

- Ground-water permits and certificates are primarily allocated for municipal and domestic multiple uses (66% of Qa). Irrigation use comprises 13% of Qa, and commercial and industrial use comprises 16%. Ground-water applications are requested primarily for domestic municipal (82% of Qi) and domestic multiple (131% of Qi) uses.

- Water right claims in the WRIA are on the order of 26,200 acre-feet per year. Surface-water claims comprise 54% of the total annual volume. Claims are registered largely for irrigation, and to a lesser degree domestic and stock watering purposes.

- Actual water use was estimated and compared to allocations. Estimated ground-water withdrawals (14,792 af/yr) are about half the currently allocated ground-water permits and certificates. Surface-water diversions could only be estimated for municipal use, which is almost entirely attributed to the Seattle Water Department and the City of Everett Water System. The current level of actual use by these two municipal diversions (138,340 acre-feet/year) amounts to only 36% of the surface-water permits/certificates allocated for municipal use and 26% of total surface-water permits/certificates. Presumably much of the remainder of the large municipal allocations will be used as Seattle and Everett continue to grow.

Surface-Water Hydrology

- Minimum instream flow requirements were enacted by the State in 1979 for 10 control points on the Snohomish, Skykomish, Snoqualmie, Sultan and Pilchuck Rivers. In addition, conditional and unconditional closures were issued for 30 other streams and lakes. All water rights issued after the instream flow requirements were enacted are considered junior to the maintenance of minimum instream flows.

- Analysis of *total* annual streamflow at seven gages within the WRIA showed declining streamflow (normalized to precipitation) on the Snohomish, Snoqualmie and Tolt Rivers. Normalized streamflow trends could reflect changes due to land-use activities or water withdrawals. The apparent streamflow declines are too large to be explained by allocated withdrawals alone, and may be partly related to limitations inherent in the analysis. The data show considerable scatter, and conclusions should be drawn with caution.

- Analysis of minimum annual streamflow at seven gages within the WRIA showed little change over time at four of the seven gages. Minimum streamflow on the Sultan River actually increased since 1985 due to changes in Spada Lake reservoir storage and operating practices. Two gages, the Snohomish River near Monroe and the Snoqualmie River near Snoqualmie shoved below average minimum flows since 1985. It is premature to attribute these declines to increased withdrawals, as similar trends previously observed at other gages have proven to be short-term. Existing *ground-water* withdrawals are not expected to be distinguishable in minimum streamflow trends as total pumping from wells is significantly less than annual baseflow.

- The minimum instream flow requirements for the six of the seven gages are typically not met in 10% to 50% of all years (flow requirements are currently met on the Sultan gage). The flow requirements appear to be set within the natural range of streamflow variation. Days on which instream flows are not met occur throughout the year, but are most likely to occur in the late summer and fall. The frequency of such days has remained essentially unchanged over the records of four gages, but has increased at the two gages mentioned above. A more rigorous assessment would be required to ascertain the causes of minimum flow trends at these two gages.'

Ground-Water Hydrology

- Major aquifers occur within the unconsolidated sediments of the western WRIA. Localized aquifers occur within alluvial deposits (Qal) along major rivers and streams and within the Vashon recessional deposits (Qvr). Regional aquifers occur in the Qva and Olympia Gravel deposits; and are typically overlain/underlain by low permeability aquitards.

- A high degree of hydraulic continuity exists between shallow aquifers (Qal & Qvr) and local rivers and streams. Hydraulic continuity ranges from moderate to high between the Qva aquifer and river, streams, and the Puget Sound. Hydraulic continuity between the Olympia Gravel aquifer and local surface water is likely low to moderate due to its depth and the presence of overlying aquitards. The Olympia Gravel aquifer is also in continuity with the Puget Sound. In general, additional (consumptive) ground-water development from hydraulically connected aquifers will reduce river flows and/or discharge to Puget Sound.

- An analysis of water budget components for the Snohomish WRIA shows significant inconsistencies between the precipitation, runoff, and recharge components of the climatic water budget. This problem is likely attributed to errors in approximating the spatial distribution of precipitation, particularly in high-altitude areas. The surface-water budget shows that estimated runoff from the WRIA exceeds stream diversion's by one to two orders of magnitude. However, the majority of runoff occurs during the winter months when diversions are at their lowest. The ground-water budget did not yield substantial conclusions due to unavailable or imprecise estimates of hydrologic components.

- Ground-water level trends were assessed to determine if long-term declines (critical indicators of over-extraction) were evident. Water-level data are limited for the basin, both spatially and over time. Stable trends were noted for shallow aquifers in the Marysville Trough and for the Qva aquifer beneath the Tulalip Plateau. Significant recent short-term (5-year) declining trends were identified for wells completed in the Qvr deposits near Snoqualmie Falls and the Qva deposits near Carnation and on the eastern edge of the

Sammamish Plateau. The declines do not appear to be attributable to precipitation trends, and warrant additional investigation.

- Ground-water quality in the Snohomish WRIA is generally good. However, localized and elevated concentrations of anthropogenic or naturally occurring ground-water constituents may affect ground-water development in some areas. Seawater intrusion has not been shown to be a significant problem, but could become problematic with additional ground-water development in coastal areas. Concentrations of arsenic exceeding drinking water standards have limited ground-water development, and appear to be associated with the natural chemistry bedrock and derived sediments. Naturally occurring high levels of iron and manganese are noted in aquifers throughout the WRIA, and bacterial contamination occurs in a spotty distribution.

Stream-Water Quality and Fisheries

- Water quality and fish habitat are closely tied to water quantity. As instream flows drop, pollutants make up a greater proportion of the total flow. Even low levels of naturally occurring materials can become toxic without adequate streamflow to provide dilution. Fish habitat depends a great deal on both the depth and velocity of water in a stream. Decreases in streamflow can result in reducing the amount of suitable habitat and raising summer stream temperatures, with a concomitant reduction in the fish population.

- Although water, quality throughout the Snohomish WRIA is generally good, increasing population and human activity is contributing to deterioration of water quality. Streams flowing through urban areas of the WRIA generally showed the greatest degree of contamination, particularly in fecal coliform and dissolved oxygen levels. Water quality problems associated with industrial waste disposal have also been reported in the lower Snohomish and Pilchuck Rivers and in estuary waters. Temperature may be a concern in agricultural areas, where shading streamside vegetation has been removed.

- The most recent 303(d) water quality limited list submitted to EPA by Ecology includes l portions of the Snohomish River which have exceeded standards for organics, PCBs, phenols, temperature, fecal coliform and dissolved oxygen violations; and portions of the Snoqualmie, Skykomish and Pilchuck Rivers for temperature and fecal coliform violations. Temperature, fecal coliform and/or dissolved oxygen violations were also reported on several smaller creeks inn the watershed.

- Among the water bodies included in information sources analyzed for this report, Quilceda and Allen Creeks, French Creek, Woods Creek, Cherry Creek and Patterson Creek were identified as having the most degraded water quality in the watershed with respect to turbidity, fecal coliform, dissolved oxygen and nutrients. These creeks flow through agricultural, urbanized and/or rapidly developing areas.

- Many of the steam-water quality problems noted in the WRIA are related to land-use activities and pollutant releases. Reduced streamflows exacerbate these problems by allowing pollutants to comprise a greater proportion of the total flow. In some cases, however, modest increases in streamflow will not solve water- quality problems. Reductions in the release of pollutants and changes in land-use practices (e.g. restoring streamside vegetation) will be required to substantially improve stream-water quality

- The condition of three fish stocks in the WRIA, the Bridal Veil Creek fall Chinook, the Snoqualmie fall chum, and North Fork Skykomish summer steelhead, is unknown, as too little information exists to assess stock status. The Snohomish fall and summer Chinook, Snohomish coho and Tolt summer steelhead are considered depressed stocks, meaning they are close to or below the, population size where permanent loss of distinct genetic material is a risk. The Tolt summer steelhead stock has also been listed as at a high risk of extinction by the American Fisheries Society due to habitat degradation and overutilization.

- Low flow conditions were reported to limit fish resources on the Pilchuck River, Snoqualmie River below Snoqualmie Falls, Cherry and Patterson Creeks, mainstem Skykomish and tributaries, Olney Creek, May Creek and the Wallace River. Most of the information reviewed for this report did not identify specific stream reaches and some of this information is dated (i.e. may not reflect current conditions). Fish habitat depends a great deal on both the depth and velocity of water in a stream. Low flows can limit fish production by reducing juvenile rearing area, prohibiting upstream adult migration and contributing to water-quality impairments to salmon health. Reduced flows can result in increased contaminant concentrations and higher summer stream temperatures.

- Although most salmonid stocks in the WRIA are rated as healthy, continued habitat degradation, along with low flows that are aggravated by water withdrawals from drainages in the basin, may lead to declines in water quality and/or fish stocks in the future.

- The watershed also supports fish of special concern including bull trout, sea-run cutthroat trout and pygmy whitefish. These species are found predominantly in the mainstem Snoqualmie, Snohomish, Pilchuck and Skykomish River and tributaries and in smaller creeks flowing directly into the northern portion of Everett Harbor.

1.3 Recommendations

Monitoring and Data Collection

- Streamflow monitoring should continue at existing gages in order to accrue long-term, uninterrupted records. Particular emphasis should be on locations critical to habitat or where trends are occurring. Data collection on the recently established Pilchuck gage is particularly relevant to habitat concerns, and renewed data collection from the Snohomish River near Snohomish gage would provide improved understanding of basin-wide runoff.

- Long-term monitoring of regional water level trends should occur within a network of monitoring wells completed in all of the principal aquifer systems. Wells previously monitored by the USGS should receive first priority since they have established data records. Additional monitoring points will likely be required, especially in areas of proposed future development. Data collection should be coordinated between involved agencies and purveyors, and may be integrated with wellhead protection programs.

- 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 flow statistics.

- Seepage studies should be considered in areas of proposed ground-water development along potentially affected stretches of rivers and streams. The need for seepage studies will depend on the relative degree of hydraulic continuity between the proposed aquifer and nearby surface water, and whether mitigation will be a condition of development.

- Collection of additional water quality data is recommended, especially for water bodies where data were unavailable. Future water quality data collection and monitoring efforts should be particularly focused on rapidly developing areas in the basin, as these are the places new problems are likely to arise.

- Additional water temperature data should be gathered (especially during low flow periods) for areas where Class A temperature violations have been recorded. Violations have typically occurred in the lower reaches of the basin, particularly in agricultural areas where water velocities slow and shading riparian vegetation has been removed.

- Additional information on both point and non-point sources of fecal coliform should be collected, particularly in agricultural and urbanizing areas (middle and lower reaches of the basin) where state standards have been violated.

- Additional information on the status of fish stocks should be collected where currently unavailable. Little information on the status of sockeye salmon, sea-run cutthroat, Bridal or Veil fall chinook or Snoqualmie fall chum stock was identified in preparation of this report. The status of the North Fork Skykomish summer steelhead is also unknown, but it was significantly depressed in the 1980's.

- Continued monitoring of the Tolt summer steelhead stock should occur, as this stock is at high risk of extinction due to habitat degradation and over-utilization according to the American Fisheries Society.

- Additional and updated information on the location and extent of chronic and periodic low flow conditions should be collected to verify these conditions and to more accurately assess effects on fish socks. Some of the existing information which relates flow conditions to fisheries habitat was collected over 20 years ago, however additional data are available which have not been compiled.

Additional Analysis

- The existing analysis of average annual streamflow trends should be expanded to improve understanding of the reduced runoff observed over time. Analysis should be performed for including gages below undeveloped "control basins" which better reflect natural background conditions. The expanded analysis should use a more sophisticated approach to normalize runoff to precipitation upstream of the selected gage, and should be based on the water year rather than the calendar year.

- 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.

- Recent ground-Water level declines in the vicinities of Snoqualmie Falls, Carnation, and the eastern edge of a Sammamish Plateau should be investigated. Ground-water withdrawals should be determined in these areas and compared to water-level declines.

- More detailed hydrologic (streamflow) analysis should be performed where fisheries are shown to be specifically affected by low flows over significant portions of a stream (systemic impacts). The analysis should focus particularly on periods of low flow that are critical to fish. Characterization of instream flow needs for fish species which inhabit these water bodies may require improvement.

Regional Planning:

Long-term data collection programs, data management, and other resource protection activity and studies should be accomplished through a regional management approach. The Snohomish Basin

Planning Group, a collection of major purveyors, city/county governments, Indian tribes, regulatory agencies, and other interested parties, is currently attempting to cooperatively address issues involving water quality and water supply. Efforts of this group could extend into integrated data collection, management, and resource protection activities.

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. Transfers of valid water rights should be encouraged throughout the watershed as a means of putting allocated water to the best possible use. Transfers are only granted on the valid portions of water rights (i.e. that portion used within the preceding five years).

2 Watershed Description

The Snohomish WRIA is located in the north-central Puget Sound region of Washington and includes portions of Snohomish and King Counties. The land surface of the WRIA encompasses 1,867 square miles, of which 1,780 square miles is drained by the Snohomish River. Other drainage within the WRIA occurs to Quilceda Creek on the Tulalip Plateau, and to Puget Sound along the coast. The Snohomish River carries the combined flow of the Snoqualmie and Skykomish Rivers, which in turn support the flows of major tributaries such as the Tolt, Sultan and Pilchuk Rivers. Major dams, located on the Sultan and South Fork of the Tolt Rivers, and are used for power generation and water supply. Major communities include Everett, Marysville, Snohomish, Monroe, North Bend and Snoqualmie; with other (smaller) towns typically located along the rivers. A map of the Snohomish WRIA is shown on Figure 2-1.

Two distinct physiographic provinces occur within the WRIA. The "Puget-Willamette Lowland Province" occupies the far-western portions of the WRIA and is characterized by topographic upland plateaus dissected by broad river valleys. The drainage pattern is deranged, as the carving of river valleys sometimes followed the edges of glaciers. The major plateaus in the Puget-Willamette Lowland Province typically range in elevation from 200-600 feet mean sea level (msl). In places along the eastern edge of the province, the plateaus form a transition to the foothills of the Cascade Mountains. The "Cascade-Sierra Province" occupies the eastern and southeastern portions of the WRIA, and is characterized by rugged mountainous terrain with bedrock dissected in a mature stage of erosion. Summit elevations are typically 6,000 to 7,000 feet msl, with mountain slopes between 2,000 and 4,000 feet msl.

The climate is characterized by warm, dry summers and cool, wet winters. Temperatures are moderated by maritime air from the west. Rainfall is typically light to moderate intensity and continuous over extended periods during the wet season (winter). Precipitation is discussed in greater detail in Section 4.

Land uses in the WRIA range from timber harvesting operations in the upper basin to agriculture and residential development through middle reaches to urban uses along Puget Sound. Table 2-1 presents land-cover statistics for the Snohomish WRIA. About 68% of the WRIA is forested, and 20% has alpine and other natural cover. Less than 3% is agricultural, and about 2% contains municipal, industrial, and domestic build-up. The area is experiencing rapid urban development, particularly in the lower basin near Puget Sound.

3 Water Allocation and Use

The State of Washington regulates ground-water and surface-water withdrawals through a legal system of water allocations. Water withdrawals for all but limited small ground-water uses must be registered with 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 required 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. In the Snohomish WRIA these permissible quantities have not been perfected, and a significant discrepancy exists 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.

This section addresses both water allocations and water use. Section 3.1 describes a unique and specific regulatory allocation designed to protect water resources in the Snohomish WRIA. Sections 3.2 through 3.4 provide information regarding public water allocations, applications for water rights, and estimates of actual water use. The implications of these rates and quantities, as well as their relation to observed hydrologic trends, will be explored later in the report.

3.1 Instream Resource Protection Program

The Instrearn Resource Protection Program (IRPP) for the Snohomish River Basin (Chapter 173-507 WAC) was enacted in 1979. The intent, in accordance with RCW 90.54 and 90.22, is to retain base flows in perennial streams, rivers and lakes at levels necessary to protect wildlife, fish, scenic, aesthetic, recreation, environmental and navigational values. Due to the large number of control stations and associated limitations, it is a very complex law to administer.

The IRPP for the Snohomish River Basin establishes instrearn flow requirements at nine control stations within the WRIA, with a tenth control station added later via the water rights process. The IRPP also lists twenty streams which are closed to diversions when their flows drop below single specified levels, as well as two streams which must have at least one-half of their low flow bypassed.

Finally, the IRPP imposes year-round closures on several other specific drainages. An in-depth discussion of these regulatory requirements is provided in Section 5.2 of this report.

The IRPP is based on a Department of Ecology methodology for selecting minimum instream flow requirements. This methodology involved statistical analysis of streamflow records and consideration of other instream values. In choosing streams for regulatory protection, each stream was rated by the Departments of Ecology, Fish and Game. A stream rated to have greater environmental and scenic values required higher levels of flow protection. Ecology can initiate a review of the IRPP whenever new information, changing conditions, or statutory modifications make it necessary to consider revision.

The subject IRPP states that from its establishment forward, all consumptive water rights shall be expressly subject to the instream flows, and that no surface-water right granted thereafter shall be in conflict with the instream flows and closures established in that chapter. With respect to ground water withdrawals, the IRPP states that during future permitting actions the natural interrelationship of surface and ground water shall be fully considered to assure compliance with the meaning and intent of the regulation. The IRPP also states that no water rights in existence at the time of its establishment shall be affected.

3.2 Water Rights and Claims

Water permits and certificates within the Snohomish WRIA are recorded in the WRIS 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 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.

3.2.1 Water Rights and Claims Over Time

The cumulative increase in water permits and certificates over time in the Snohomish WRIA is shown in Figure 3-1. This cumulative increase reflects growing stress on the hydrologic system due to withdrawals. Quantities are reported as maximum allowable annual withdrawals (Qa) in acre-feet/year (af/yr). As previously mentioned, surface-water allocations may be somewhat underestimated due to database entries without registered Qa values. As of 1994, reported Qa's for surface-water permits/certificates in the Snohomish WRIA amount to 537,895 af/yr. Total Qa's for ground-water permits/certificates as of 1994 amount to 32,199 of/yr.

Water right permits and certificates are issued with permissible quantities of instantaneous and annual withdrawals. The instantaneous allocation (Qi) represents the capacity of the system to divert/withdraw water from the source. Qi's are expressed in cfs for surface water and gallons per minute (gpm) for ground water. The annual allocation (Qa) represents the maximum amount of water allowed over a year's time for a specified use(s), and is expressed in of/yr. Research of water right records indicates that for most permits/certificates, the Qa is not withdrawn continuously but is taken seasonally or sporadically at instantaneous rates approaching the Qi.

Claims to a water right generally do not specify quantities of water claimed, so for the purpose of this watershed assessment instantaneous (Qi) and annual (Qa) quantities were estimated based on stated purpose of use. For single domestic supply and/or stockwatering, values of 0.02 cfs and 1.0 af/yr were assigned. Claims for irrigation were assigned 0.02 cfs and 2 af/yr per acre. Based on these water duty assignments, claims within the WRIA are summarized in the table below (groundwater Qi's are converted to cfs for purposes of comparison). Comparisons between claims and permits/certificates are summarized in this table and presented graphically on Figure 3.2a.

	PERMITS AND CERTIFICATES				CLAIMS				TOTALS
	Number of Rights	Qi (cfs)	Qa (af/yr)	Irrigated Acres	Number of Claims	Qi (cfs)	Qa (af/yr)	Irrigated Acres	Qa (af/yr)
Surface Water	901	1,284	537,895	7,484	1,592	156	14,239	6,437	552,134
Ground Water	454	119	32,199	2,836	4,680	163	11,957	3,807	44,156
TOTAL	1,355	1,403	570.094	10,320	6,272	319	26,196	10,244	596,290

The amount of water allocated as water rights is much greater than the amount claimed. Surface-water rights (as Qa) account for 94% of the total water-resource allocations in the WRIA. Claims are almost evenly divided between surface water and ground water, based on the estimated formulas.

3.2.2 Water Rights and Claims by Use

Water rights and claims are registered by purpose of use. The WRIS (Water Rights Information System) database typically lists one, if not several, stated purposes per water right. Examining the distribution of water rights and claims 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 3.2b. For study purposes, percentages of total use were estimated in terms of maximum allowable annual withdrawals (Qa's) as of 1994. Surface-water resources in the Snohomish WRIA are primarily allocated for municipal (72%) and domestic multiple (21%) uses. The remaining surface-water rights are predominantly allocated for irrigation, fish propagation, and power generation.

The relative distribution of ground-water rights by use is presented on Figure 3.2c. Ground-water resources in the Snohomish WRIA are primarily allocated for domestic multiple (36%) and municipal (30%) use. Irrigation accounts for 13% of the allocations, commercial and industrial uses account for 8%, heat exchange accounts for 7%, and other uses account for the remaining 6%.

The largest quantity claimed within the Snohomish WRIA is for irrigation use, which reflects the historical circumstances of claims registration. Based on the irrigated acreages and the formulas for water duty assignments discussed above, over 90 percent of the volume of surface-water claims (as Qa) and 64 percent of the volume of ground-water claims (as Qa) can be attributed to irrigation. The remainder of registered claims are for domestic or stock uses.

3.2.3 Spatial Distribution of Rights and Claims

The spatial distribution of water permits/certificates and claims (as 1994 values of Qa) is depicted in Figures 3-3 through 3-6. In general, spatial distributions of water rights follows the pattern of settlement, with most of the population occurring in the western WRIA and along the major rivers to the east. Surface-water permits and certificates (Figure 3-3) are primarily distributed along the Snoqualmie, Skykomish, Snohomish and Pilchuck Rivers. Large permits/certificates are visible along these rivers, as well as the Tolt and Sultan Rivers. The overall distribution of surface-water claims (Figure 3-4) is similar, however the claims are spread out over a wider area. The symbol density on Figure 3-4 gives the impression that total claims exceed permits/certificates, however the opposite is true due to a number of large (>1,000 af/yr) permits/certificates.

Ground-water allocations also follow major patterns of settlement, largely occurring in the western WRIA and along rivers to the east. Ground-water permits/certificates (Figure 3-5) show this general pattern, with notable allocations along the Snoqualmie, Skykomish and Snohomish Rivers, and in the northwestern WRIA on the Tulalip Indian Reservation near the Stillaguamish River. Large ground-water withdrawals along the major rivers reflect the productivity of aquifers in these areas (discussed later in this report). Ground-water claims (Figure 3-6) follow a similar pattern to permits/certificates, but are spread out over a larger area.

3.3 Water Right Applications

There are currently 87 applications for new water rights within the Snohomish 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 Snohomish WRIA, expressed as requested Qi's. Applications cannot be directly compared to allocations. Requested Qi's are not granted for continuous withdrawal, and the Qa's allocated by Ecology are typically much smaller than the calculated volumes associated with continual withdrawal of Qi's over an annual period.

Source	Number of Applications	Total Qi (cfs)
Surface Water	26	16,194
Ground Water	61	164
Total	87	16,358

Applications for surface-water rights comprise the largest component of potential future water allocations. Applications exist for 16,194 cfs of surface water, of which 15,194 cfs (94%) are requested under 4 applications for power generation. Some power applications are speculative in nature, and power withdrawals are likely to be consumptive only over very short distances. Applications exist for 164 cfs of ground water.

Figure 3.2d presents (non-power) water-rights applications by requested purpose of withdrawal. Surface-water applications for municipal and commercial & industrial uses respectively comprise 68% and 18% of the total requested Qi. Ground-water applications for municipal and domestic multiple uses respectively comprise 12% and 2% of the total requested Qi. Applications for surface-water rights (disregarding power uses) are about six times greater than the sum of ground-water applications (as Qi): A similar ratio is observed between combined surface-water rights and claims (1,440 cfs as Qi) and combined ground-water rights and claims (282 cfs as Qi).

The geographic distributions of surface-water and ground-water right applications are presented in Figures 3-7 and 3-8, respectively. The largest surface-water request (>1,000 cfs) occurs on the Snoqualmie River at Snoqualmie Falls. Other large (100-1,000 cfs) requests occur along the Tolt, Sultan, Skykomish, and (N. Fork) Snoqualmie Rivers. Ground-water applications are generally concentrated along the coast and rivers of the western WRIA, with the largest requested Qi's along the middle fork and main stem of the Snoqualmie River.

3.4 Estimation of Water Use and Comparison with Rights and Claims

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. Complete data records of this type are rare, but are available from the major surface-water users (Seattle Water Department, Everett/Snohomish PUD). Surface-water extractions were therefore easy to estimate for municipal use, however data were lacking for other purposes of use. Ground-water withdrawals were estimated for all major uses based on recent studies.

3.4.1 Ground-Water Use

Estimates of ground-water use have been prepared by the U.S. Geological Survey (USGS) in separate studies of East King County and Snohomish County. Both studies are not yet in press, and ground-water use estimates were obtained via personal communication with USGS personnel. The following table presents ground-water use estimates for the Snohomish WRIA from the USGS studies:

	East King County Portion of the WRIA	Snohomish County Portion of the WRIA	Entire Snohomish WRIA
Public Supply	1380 af/yr	7,640 af/yr	9,020 af/yr
Domestic	1021 af/yr	1,995 af/yr	3,016 af/yr
Irrigation	401 af/yr	1,115 af/yr	1,516 af/yr
Livestock	251 af/yr	1,086 af/yr	1,337 af/yr
Industrial & Mining	83 af/yr	65 af/yr	148 af/yr
Total for All Uses	3,136 af/yr	11,901 af/yr	15,037 af/yr

The ground-water use estimates shown above are limited to withdrawals from wells, and do not include water captured from springs (which discharge naturally, regardless of use). Withdrawals were estimated in slightly different manners for the two portions of the WRIA. Estimated withdrawals in the East King County portion of the WRIA are entirely limited to the Snoqualmie Watershed. The USGS did not estimate ground-water withdrawals from the Skykomish Watershed within King County, however ground-water extractions along this upland reach of the river are likely to be minimal (Towns of Baring, Grotto, Miller River, Skykomish). The public supply estimate includes both Class I and II systems. The domestic estimate includes Class IV systems and single private wells, and considers water used for lawn irrigation. The irrigation estimate includes both crop and non-crop (parks, golf-courses, etc) applications, and is likely a minimum value because not all irrigators could be contacted (pers. comm. G. Turney, 1995). Livestock use is dominated by dairy operations, and mining & industrial withdrawals are dominated by a single sand and gravel operation.

Estimated ground-water withdrawals in the Snohomish County portion of the WRIA are largely based on estimates for the entire county. Only two categories, Group A public supply arid industrial & mining, were directly estimated from data specific to the WRIA portion of the County. Group A public supply withdrawals were listed in the State Department of Health (DOH) database. Industrial & mining withdrawals consist of a few sand and gravel operations within the watershed. Domestic (single-user), Group B public supply, and livestock withdrawals were approximated by multiplying county-wide estimates prepared by the USGS by the percentage of the County occupied by the Snohomish watershed (44%). This approximation assumes that the distribution of withdrawals is uniform between southern and northern portions of the county. The livestock withdrawals are primarily associated with dairies, of which there are about 100 in the county. Irrigation withdrawals were estimated by multiplying the USGS county-wide estimate by the ratio of the zoned agricultural acreage in the WRIA portion of the county to the zoned agricultural acreage in the entire county. Irrigation withdrawals are primarily (84%) for crop use, however non-crop applications are included in the USGS estimate.

Estimated ground-water withdrawals from wells within the Snohomish WRIA is on the order of 15,000 acre-feet/year. The majority of these withdrawals (79%) occur in Snohomish County, although Snohomish County occupies only about half the WRIA area. Public supply is the dominant use, comprising about 60% of total pumping. Domestic withdrawals (e.g. single wells or small private systems) comprise about 20% of total estimated pumpage, and irrigation and livestock comprise about 10% and 9%, respectively.

Comparison of ground-water allocations (Section 3.1) to ground-water use shows that ground-water permits and certificates amount to about twice the annual volume (Qa) of current ground-water use. Ground-water permits, certificates and claims combined amount to about three times the estimated current ground-water use. It should be noted that water right allocations do not account for exempt (<5,000 gallons/day) withdrawals, whereas exempt withdrawals are included in the public supply and domestic categories discussed above.

3.4.2 Surface-Water Use

Surface-water withdrawals are associated with a number of uses, however use could be estimated only for municipal diversions. Municipal diversions are believed to comprise the largest withdrawal within the WRIA. This is reflected in surface-water rights allocations, 72% of which are for municipal use. There are two major surface-water users in the WRIA which account for the majority of the municipal surface-water allocation: Seattle Water Department diverts water from the South Fork of the Tolt River; and the City of Everett diverts water from the Spada Reservoir on the Sultan River. Both purveyors sell water to a number of municipalities and industrial operations.

Seattle Water Department has been diverting water, from the Tolt River since 1964. Annual diversions vary greatly based on weather conditions. Average diversion between 1989 and 1994 was approximately 49,560 acre-feet. This value is similar to the 10-year average (1984-1994) of 47,570 acre-feet. Total withdrawal from the Spada Reservoir was available only for 1993 (City of Everett and CH2M Hill,, 1994), and amounted to approximately 88,780 acre-feet. The sum of these two municipal diversions (138,340 acre-feet) amounts to only 36% of surface-water permits and certificates allocated for municipal use (388,580 of/yr) and 26% of total surface-water permits/certificates (537,895 af/yr). There is a difference between allocation and actual use by these municipalities largely because the municipal allotment was allocated to cover future growth.

Estimates were not available for other surface-water uses. Water rights issued for domestic multiple use amount to 114,630 af/yr, however actual use is unknown. Water permits and certificates issued for irrigation amount to 14,420 af/yr, which is quite small in comparison. The remaining water rights are primarily issued for fish propagation and power generation, neither of which are generally consumptive.

4 Precipitation

Quantification of precipitation is an important component of the watershed assessment process. Precipitation provides the input that supplies stream runoff and ground water recharge. Variation in precipitation must be taken into account when assessing trends in streamflow and ground-water levels. A long-term value for precipitation, averaged over the WRIA, is necessary for performing basin-wide water-budget analysis. A discussion of the spatial distribution and temporal trends of precipitation in the Snohomish WRIA is presented below.

4.1 Spatial Distribution

The mean annual precipitation throughout the WRIA is 86.7 inches, but varies spatially from 25 inches in the northwestern WRIA to 180 inches in the eastern WRIA. Localized areas of high precipitation, one in the southeastern WRIA near Cascade Mountain and another in the northeastern WRIA near Troublesome and Elcelsior Mountains, result from the lifting and cooling of moist maritime air. Figure 4-1 shows the spatial distribution of precipitation in the WIA based on 19301957 data and empirical topographic adjustments (USDA, 1965).

Precipitation data were available from 19 gages within the WRIA. Figure 4-2 shows the locations of these gages, and Table 4-1 presents associated summary information. Long-term (>40 years) records are available for 5 of the 19 gages. Comparison of annual record averages to values shown on the isohyetal map showed fairly good agreement. Gages, however, were not available in high elevation areas to confirm the high precipitation (>140 in/yr) shown on Figure 4-1.

4.2 Precipitation Trends

Temporal variation and trends in precipitation occur on seasonal, short-term, and long-term scales. On a seasonal basis, 72% of the precipitation at Snoqualmie Falls occurs in the 6-month period from October through March. Additionally, total rainfall for the driest months of June, July, and August is 10% 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 4-3 which presents precipitation at Snoqualmie Falls between 1899 and 1994. 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 1905 was followed by an extended period of below average precipitation between 1905-1945 (excluding 4 consecutive above average years in the early 1930's). An extended period of above average precipitation is noted between 1945 and 1976.

Short-term variations occur over periods of several years, and are also demonstrated on Figure 4-3. These short-term departures from the average generally do not follow discernable patterns. Recent precipitation has been generally below average, with a downward trend evident between a 1990 extreme-high and 1993.

5 Surface-Water Hydrology

5.1 Description of Drainage Network

The Snohomish River system, with its multitude of tributary streams, is the principal drainage network in the WRIA and the second-largest drainage system in the Puget Sound region; only the Skagit River system is larger. The Snohomish WRIA. in total includes approximately 1,730 identified rivers and streams providing over 2,700 linear miles of drainage. The main-stem Snohomish River is about 20 mules in length, representing less than 0.5% of the total river miles in the basin. It originates south and east of Everett at the confluence of its two major tributaries, the Snoqualmie and Skykomish Rivers, and drains into Puget Sound immediately north of Everett. Another major tributary, the Pilchuck River, enters the main-stem Snohomish about 7 miles below the confluence of the Snoqualmie and Skykomish Rivers.

Figure 5-1 reproduces a U.S. Geological Survey (USGS) schematic of the major rivers in the Snohomish River basin, together with locations of active stream gages in 1993 and the locations of major water systems and diversions. This figure was extracted from the USGS Water Supply Report WA-93-1, "Water Resources Data; Washington; Water Year 1993." This schematic does not include six additional streams in the Snohomish WRIA lowlands which drain directly to Puget Sound. The total basin area for the latter streams is 120 square miles, or about 6% of the WRIA's total area.

The Skykomish River basin drains 844 square miles of the northern portion of the WRIA, accounting for about 43% of the total WRIA area. Principal tributaries to the Skykomish, progressing from downstream to upstream, include Woods Creek, the Sultan River, Wallace River, and the North and South Forks of the Skykomish River.

The Snoqualmie River basin drains 693 square miles of the southern portion of the WRIA, accounting for about 35% of the total WRIA area. Principal tributaries to the Snoqualmie, progressing from downstream to upstream, include Cherry Creek, Harris Creek, The Tolt River, Griffin Creek, Patterson Creek, Raging River, Tokul Creek, and the South, Middle, and North Forks of the Snoqualmie River.

Excellent detailed descriptions of the river systems and most tributary streams in the Snohomish WRIA may be found in the November 1975 Washington Department of Fisheries publication, "A Catalog of Washington Streams and Salmon Utilization; Volume 1, Puget Sound Region." That publication was a principal source of information for the brief drainage network overview presented above.

Portions of tributary areas to the WRIA's two major river systems (the Snoqualmie and the Skykomish) have been developed as sources of municipal water supply for the greater Seattle and Everett metropolitan areas. These water supply developments are discussed below.

The most significant surface-water development in the Snoqualmie River system is the South Fork Tolt Reservoir project located on the South Fork Tolt River, which is a tributary to the Snoqualmie River. The South Fork Tolt Reservoir project is operated by the Seattle Water Department to provide municipal water supply, primarily for north Seattle and other communities located on the east side of Lake Washington. This project is a major source of supply for the Seattle Water Department, which in total (from all sources) supplies water to approximately 1.2 million customers in the greater Seattle region.

The South Fork Tolt Reservoir system includes a 56,200 acre-feet (18.3 billion gallons) storage reservoir located about 18 miles east of Duvall on the South Fork Tolt River. It presently has the capacity to provide a reliable water supply of 49 million gallons per day (mgd), which is equivalent to 76 cfs or about 55,000 acre-feet per year. The South Fork Tolt Reservoir water supply system first became operational in 1964. As of 1995, the Seattle Water Department was exploring the possibility of developing the North Fork Tolt River as an additional source for the region's future water supply needs.

The most significant surface-water development in the Skykomish River system is the Spada Lake Reservoir (and Henry M. Jackson Hydroelectric Project) on the Sultan River, which is a tributary to the Skykomish River. This project is operated by Snohomish County Public Utility District No. 1 and the City of Everett to provide municipal water supply and for hydroelectric power generation. The Sultan River was first developed in 1917 as a source of water supply for the City of Everett. Major system improvements were constructed in 1965 and 1984 as discussed below. Currently, the Sultan River is the primary source of water supply for approximately 410,000 people in the City of Everett and elsewhere in Snohomish County.

The Spada Lake Reservoir was created in 1965 with completion of the Culmback Dam on the Sultan River, primarily to provide water supply storage. In 1984, the dam was raised by 90 feet as part of the Henry M. Jackson Hydroelectric Project. Currently, the Spada Lake Reservoir has a storage capacity of about 153,000 acre-feet; additional storage capacity is provided off-channel by the Chaplain Lake Reservoir, from which municipal water supplies are drawn. The present system capacity to deliver water is 100 mgd (155 cfs) of treated (filtration plant) water, plus an additional 50 mgd of untreated industrial water. These capacities are equal to the hydraulic capacity of existing pipelines, which are undersized relative to existing water treatment facilities. The system's water treatment plant currently has the capacity to treat 140 mgd (about 220 cfs) and could be upgraded in the future to treat up to 246 mgd (about 380 cfs) which is the City of Everett's current municipal and industrial water right.

Municipal supplies from the South Fork Tolt and Sultan Rivers are a significant feature in the existing drainage network because water is effectively removed from the Snohomish River drainage system. Much of the water delivered from the South Fork Tolt River system is used outside of the Snohomish WRIA. Much of the water delivered from the Sultan River system is used in the lower Snohomish basin with (treated) wastewater flows mostly being discharged to tidally influenced reaches of the Snohomish River or directly to Puget Sound. Both systems are regulated for compliance with instream flow standards established to prevent adverse downstream impacts.

5.2 Established Regulatory Instream Flows

Instream flow regulations, and other rules which limit surface-water withdrawals in the Snohomish WRIA, are published in the Washington Administrative Code (WAC) Chapter 173-507, titled "Instream Resources Protection Program - Snohomish River Basin, Water Resource Inventory Area (WRIA) 7." These rules were promulgated in 1979 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). The pertinent portions of the WAC are reproduced in Appendix A of this report.

Instream flows have been established for ten locations in the Snohomish WRIA. The locations of the control stations and the stream reaches to be regulated for compliance with the instream flows are listed in Table 5-1 and shown on Figure 4-2. The control station number for each of the instream flow control points (Table 5-1) is intended to correspond to a U.S. Geological Survey (USGS) stream gage number for the same location. However, stream gage data are not available for all control points. No stream gage was ever established for the Snoqualmie River control point at river mile 2.5. A stream gage numbered "12155400" was established by the USGS for the Pilchuck River, but no data. have been published by the USGS for this gage. Stream gage 12141100 was established on the Skykomish River near Monroe in October 1968 but was discontinued after less than one year of operation.

Instream flows for each of the instream control points are established on a daily basis for the entire year, mostly as presented in Ecology's Western Washington Instream Resources Protection Program (W.W.I.R.P.P.) Series No 2: "Snohomish River Basin Instream Resources Protection Program," dated August 1979. WAC 173-507 refers to this document for determining minimum flows on days not specifically identified in the WAC. As of February 1995, instream flows had not been published in the WAC for control station No. 12.1381.50 on the Sultan River at river mile 5.1.

Data presented in this report for Sultan River instream flows are taken from the water rights certificate dated October 1987 for the Snohomish County PUD No. 1 and the City of Everett. The flows presented in this certificate are the defacto instream flows for the Sultan River. Instream flows are presented by the certificate for two locations: river mile 9.7 below the City of Everett's diversion dam, and river mile 4.3 below the hydroelectric plant powerhouse. This report assesses only the second (downstream) of the two instream flow control points as this corresponds most closely to the control station location identified in the WAC and includes hydroelectric plant return flows.

Two "levels" of instream flows are published by the WAC for instream flow control stations on the Tolt and North Fork Snoqualmie Rivers. The two "levels" of instream flows are:

1) "Normal year" flows which must be maintained at all times unless a critical condition is declared by the director of Ecology.

2) "Critical year" flows which may be authorized if a declaration of "overriding conditions of public interest" is made by the director of Ecology. "Critical year" instream flows are lower than "normal year" flows, and represent minimum flows below which the department of Ecology believes substantial damage to instream values will occur.

"Critical year" flows have never been authorized in the Snohomish WRIA in the 15 years since the instream flow rules were promulgated in 1979.

The regulatory instream flows, for both "normal" and "critical" year conditions where applicable, are presented graphically together with actual streamflow data later in this report.

Surface-water source limitations are presented by WAC 173-507 for 30 other streams or lakes in the Snohomish WRIA in addition to the instream flow control stations described above. Of these, the WAC lists 20 creeks and streams which are closed to diversions when their flows drop below single specified levels, as well as two streams which must have at least one-half of their low flow bypassed. The WAC also lists six creeks, one stream, and the Raging River as being closed to all surface-water diversions. An undetermined number of additional sources are subject to flow limitations through conditions attached to water rights certificates. Due to scope and budget limitations, this report does not discuss or assess any of these other sources subject to flow restrictions.

5.3 Quantification of Streamflow

Streamflow data considered in this preliminary assessment comprised all continuous streamflow records recorded and published for the Snohomish WRIA by the U.S. Geological Survey (USGS). In total, the USGS has established approximately 65 continuous recording stream gages in the Snohomish basin. A list of these gages is presented in Table 5-2. Approximately 20 of these stream gages (and 2 lake level gages) were active as of 1993, which is the date of the most recent hard-cover USGS water resources data report for Washington.

Due to scope and budget limitations, it was not possible to assess all of the streamflow data which are available for the Snohomish WRIA. Specific gages were selected for analysis to:

1. provide flow data at the instream flow control points identified in the WAC; and,

2. provide flow data at the downstream ends of selected sub-basins (including the entire WRIA), for assessment of sub-basin wide development impacts and comparison with water rights allocations.

The gages initially considered for detailed analysis, after screening with the above criteria, are listed below. Three of these stations, while at important locations for the proposed analyses, could not be used due to short periods of record (note that 1993 was the final year available at the time of this writing). Data for the Pilchuck River are available for less than two years, data from the Snohomish River at Snohomish are available for less than one year, and data for the Skykomish River at Monroe are available for only nine months.

Gage ID	Name	Basin Area sq mi	Years of Record
12133000	S.F. Skykomish River near Index	355	1902-1905; 1911-1982
12138150	Sultan River below Chaplain Creek near Sultan	93	1974-1984
12138160	Sultan River below Powerplant near Sultan	94	1983-1992
12141100	Skykomish River at Monroe	834	1968-1969
12143000	N.F. Snoqualmie River near North Bend	96	1907-1926; 1929-1938; 1961-1971
12144500	Snoqualmie River near Snoqualmie	375	1898-1900; 1902-1904; 1926-1927;1958-1993
12148500	Tolt River near Carnation	81	1928-1931; 1937-1993
12149000	Snoqualmie River near Carnation	603	1929-1993
12150800	Snohomish River near Monroe	1537	1963-1993
12155400	Pilchuck River, Tributary to Snohomish River	127	1992-1993
12155500	Snohomish River at Snohomish	1720	10/65-7/66; incomplete

Data for the two gages on the Sultan River (below Chaplain Creek and below Powerplant) were assessed jointly because their contributing basin areas 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 on the Sultan River.

In total, streamflow data were assessed for seven sites: one site on the main-stem Snohomish River upstream of the Pilchuck River; two sites in the Skykomish basin (Sultan River and main-stem Skykomish River; and four sites in the Snoqualmie basin (North Fork Snoqualmie River, Tolt River, and two sites on the main-stem Snoqualmie River).

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 established regulatory instream flows and to assess the frequency with which the regulatory instream flows are actually met.

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 were processed to determine average and minimum flows for the period of record, and then analyzed for time-series trends and variations relative to the established instream flows. The average and minimum streamflow data are presented graphically together with rainfall and other information in Figures 5-2 through 5-15. The streamflow data for these figures, together with summary statistics, are listed in tables in Appendix B of this report.

Figures 5-16 through 5-36 present flow hydrographs and exceedance statistics for seven of the instream flow control stations, together with the instream flows published by the WAC 173-513 for each location.

Our interpretation of these data is presented in the following report section.

5.4 Streamflow Trends and Critical Indicators

For each of the seven gages selected for analysis, assessments were made to determine whether there are any indications of declining streamflow over time, unrelated to natural climatic fluctuations. Also, the data for each gage were reviewed to assess the day-to-day and long-term variability of flows relative to the regulatory instream flows.

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

5.4.1 Average Flows and Trends Analysis

The annual runoff volume (average annual flow) analysis was made using annual precipitation at Snoqualmie Falls to correct for climatic fluctuations. Due to orographic effects, annual precipitation at Snoqualmie Falls is only about one half of the annual precipitation which falls over the watersheds of the stream gages considered in the analysis. However, long-term data to better describe overall basin precipitation are not available from other stations. Reliable long-term precipitation data are especially scarce for the high-precipitation upper watershed areas which are a primary source of basin flows.

The Snoqualmie Falls precipitation data were adjusted to approximate the actual basin precipitation by using a multiplier determined for each watershed. The multiplier was determined so that the long-term average annual basin precipitation was equal to the average recorded runoff at each gage plus 20 inches per year of evapotranspiration. A more detailed (and accurate) assessment of actual basin precipitation was beyond the scope of this study.

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). The difference between rainfall and runoff in any given year is also affected by changes in the volume of water stored in shallow and deep aquifers and in snowpack (where present) 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. Basin land development activities such as logging, paving, and other creation of impervious areas, will cause an increase in the annual volume of runoff by reducing plant transpiration and infiltration to ground water. Water development activities, particularly withdrawals from streams or from shallow ground water, will cause a decrease in the annual volume of runoff, especially if the water is consumed (i.e., turned into a gaseous state by plants or industrial activity) or is exported for use at a location where wastewater flows are not returned to the stream.

Development activities may also influence the timing of runoff, and might cause annual flows to increase but simultaneously cause minimum flows to decrease. For example,. if large areas of a basin were paved and converted to impervious surfaces, the annual runoff volume (and average annual flows) would increase because more of the rainfall would go directly to runoff. Simultaneously, however, the minimum daily flows would decrease because less of the rainfall would infiltrate to groundwater which is the source of stream base flows during periods of no rain. This report section deals with an assessment of annual flow volumes only. Minimum flows are presented and discussed in the following section.

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 impact would result if activities causing a decrease in average annual runoff were not balanced by other activities causing an increase in average annual runoff.

Figures 5-2 through 5-8 each show two graphs to analyze annual runoff volume trends for the seven basins. The lower graph shows the recorded average annual streamflow together with approximate annual basin precipitation, 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 basin. For precipitation, the right axis shows the approximate annual basin precipitation in inches, and the left axis shows the equivalent average annual flow rate in cfs which would result if the annual rainfall fell on the basin and was expressed as runoff without loss to evaporation or deep groundwater recharge.

The upper graph on each of Figures 5-2 through 5-8 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 plotted 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. 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 may be declining with time.

Inspection of Figures 5-2 through 5-8 suggests increasing losses (defined here as the difference between rainfall and runoff) with time at six of the seven gages. No trend is indicated for the Sultan River (Figure 5-3), which is known to be intensively developed upstream of the gage for municipal supply, but for which there is a relatively short (1975 to 1991) period of record. Although a long-term reduction in Sultan River flows at this site would be expected due to upstream municipal water withdrawals, time and budget limitations did not allow the data reduction required to confirm whether there has been any significant increase in the amount of withdrawal over the period of stream gage record.

In reviewing Figures 5-2 through 5-8, it is very important to consider the "fit" of the data to the regression line. In general, there is a considerable amount of scatter in the plotted points, and the least-squares linear regression equation, considered without regard to the actual data, would be misleading. The scatter is probably due primarily to use of a single rain gage (at Snoqualmie Falls) with a simple multiplier to estimate average basin precipitation. Additional scatter is undoubtedly introduced by the use of a calendar year (in which end-of-year snowpack and ground-water storage is significant) rather than a water year convention. In summary, the fit of the data is generally poor, and the "findings" of the linear regression analysis need to be interpreted with caution.

Increasing losses, which would probably imply decreasing flows, are most strongly indicated for the Tolt River near Carnation (Figure 5-6), which is downstream of the South Fork Tolt River Reservoir project. That project became operational in 1964 and, by 1990, was diverting about 70 cfs, on average, for use outside of the basin. Review of Figures 3-3 through 3-7 (the locations and magnitudes of existing consumptive water allocations) suggests that all other withdrawals above the Tolt River stream gage probably total less than 10 cfs. Our knowledge of this water development leads us to expect a decrease in annual flows of at least 70 cfs since 1963; but not more than 80 cfs. The data presented by Figure 5-6 suggest an increase in losses (decrease in flows) of about 160 cfs since 1930, which is about double the maximum expected loss. Therefore, while decreasing Tolt River flows are logically expected, the linear regression results presented by Figure 5-8 appear to significantly overstate the loss.

A clear explanation of the rainfall-minus-runoff trends indicated for the stream gages in the Snohomish River Basin is not apparent. The rainfall-minus-runoff data for the North Fork Snoqualmie River (Figure 5-4) suggest a loss rate similar to that on the Tolt River, but there are no known upstream withdrawals sufficient to account for this, and the trend is not visually apparent from the average annual flows before adjustment for rainfall. A trend is visually apparent from data for the two main-stem Snoqualmie River gages (Figures 5-5 and 5-7), but the magnitude of loss seems too large in relation to the known water rights allocations.

For the Skykomish basin, there is no clear indication of declining streamflows over time. The linear regression on Figure 5-2 does suggests such an increase in losses over time. However, the fit of the regression line to the actual data is very poor, and a visual inspection of the actual flow data, both with and without adjustment for rainfall, does not show any trends.

Figure 5-8 shows the results of the analyses for the Snohomish River, which will reflect the effects of all water and land use development in both the Skykomish and Snoqualmie basins. A trend for increasing losses (decreasing streamflows) over time is visually apparent from the raw flow data, and is supported by the linear regression on the rainfall-minus-runoff data. The suggested magnitude of flow losses, about 750 cfs since 1964, is approximately equal to the sum of all ground and surface-water allocations issued in the entire Snohomish WRIA since 1930. As with many of the other gages, the data indicate a tendency for declining streamflows, but the linear regression on the rainfall-minus-runoff data appears to exaggerate the magnitude of the actual loss.

In conclusion, trends of declining annual streamflows are indicated on the Snohomish River, the Snoqualmie River and the Tolt River. However, the methods of analysis used in this preliminary assessment are inadequate to accurately quantify the rate and amount of streamflow reduction in these rivers. The data show too much scatter and/or the available periods of records are too short to draw any conclusions about trends (i.e., the data do not show any obvious trends) in flow rates on the North Fork Snoqualmie River, the Sultan River, or the Skykomish River. The uncertainty in these conclusions is in large part a reflection of the methodology used for this preliminary assessment; more definitive findings should be possible with a more detailed study.

5.4.2 Minimum Flows and Trend Analysis

An assessment was also made on trends in the minimum daily streamflows recorded at each of the seven gages. As discussed in the previous section, trends in minimum flows (if any exist) may not be the same as trends in annual flows (if any exist). Under certain hypothetical scenarios of basin land development it is for example possible that average annual flows could increase over time while minimum daily flows could decrease over the same period.

Due to scope and budget limitations for this study, the minimum flow trend assessment was conducted by a simple visual analysis and was not adjusted for climatic variability. 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 5-9 through 5-15 each show two graphs to analyze minimum streamflow trends at the seven gages. The lower graph shows the minimum mean flow recorded during the single day with the lowest flow for that year during each year of record. The upper graph shows the departure of flow from the average of all minimum flows at each gage. Inspection of these graphs shows an obvious trend (actually a break) in minimum flows for only one gage: the Sultan River (Figure 5-10). In the case of the Sultan River gage, minimum flows substantially increased after 1985 with storage changes at the Spada Lake Reservoir, implementation of instream flow regulations, and a revised operating plan for the Henry M. Jackson Hydroelectric Project under the requirements of its Federal Energy Regulatory Commission (FERC) license.

Figure 5-15 shows that lower than average minimum flows have regularly occurred since about 1985 in the Snohomish River near Monroe. Figure 5-12 shows a similar pattern of low flows since 1985 (with the exception of year 1990) in the Snoqualmie River near Snoqualmie. These figures do not however indicate an obvious trend of decreasing minimum flows with time, due to the relatively short periods of continuous record available for these gages. Review of Figures 5-9 and 5-14 for the South Fork Skykomish River near Index and the Snoqualmie River near Carnation shows a prolonged period of lower than average minimum flows in the 1930s through the mid 1940s.

It is possible that the recent low flows observed since 1985 at the Snohomish and Snoqualmie River gages are simply the result of natural climatic variability. However, from visual inspection of daily flow hydrographs for these gages, and the Snoqualmie River in particular (see Figures 5-25 and 526), it does appear that recent late-summer flows may be lower now than in the past. The level of minimum flow analysis made for this initial watershed assessment is inadequate to conclude whether or not minimum flows on some streams are declining independently of natural climatic variations.

5.4.3 Regulatory Instream Flows and Actual Flows

Finally, an assessment was made of flow hydrographs and flow statistics for each of the instream control points for which sufficient continuous streamflow data were available. Seven control points were assessed, corresponding to the same seven stream gage stations presented above.

Figures 5-16 through 5-36 present the data and analyses used to compare the regulatory instream flows presented by the WAC with the actual streamflows at the control points. A set of three figures is presented for each of the instream flow control points; each of these figures includes the regulatory instream flow(s) which are established for the control point. The first figure presents actual daily flow hydrographs for the earliest six years of record, to represent "pre-development" conditions. The second figure presents actual daily flow hydrographs for the most recent six years of record, representing current conditions. The third figure presents flow exceedence statistics computed from the entire period of streamflow record.

Different years are presented for different gages due to differences in the periods of record available for each gage. The selection of six years of hydrographs per figure was, although somewhat arbitrary, made to provide a visual overview of the natural flow variability without excessive clutter or numbers of graphs.

A review of the instream flow figures shows that, with the exception of the Sultan River, a single set of summary observations is common to all stations. The Sultan River (Figure 5-20) is unique in that it is the only instream flow control point at which the regulatory instream flows are now actually being met throughout the year. Early period Sultan River flows (Figure 5-19) did not meet the regulatory instream flows; the regulatory instream flows are currently being met through the operational practices of the Spada Lake Reservoir which serves to control basin flows immediately above the gaging station. All of the other control points are below basins which are at least partially uncontrolled.

The regulatory instream flows are frequently not met in the earliest streamflow records available ("pre-development" conditions) for all of the instream flow control sites. With the exception of the Sultan River, the regulatory instream flows are similarly not met in the most recent streamflow records. Regulatory instream flows are currently being met for the Sultan River as a result of the operating plan for the (recent) Henry M. Jackson Hydroelectric Project as discussed in the previous section. At all of the other sites, there is no strong indication that the instream flows are being met any less frequently under current conditions than they were in the past.

The average number of days the regulatory instream flows have not been met since establishment of those flows is as follows:

- S.F. Skykomish River near Index, gage 12133000: 70 days per year, based on data for water years 1979 through 1981.

- Sultan River below Powerplant, gage 12138160: 1.5 days per year since 1984. The instream flows were not met for four days in each of years 1987 (December) and 1988 (January), but
have been consistently met on all days of all years since January 1988.

- N.F. Snoqualmie River near North Bend, gage 12143000: streamflow data not available for period with established regulatory instream flows.

- Snoqualmie River near Snoqualmie, gage 12144500: 114 days per year, based on data for water years 1979 through 1992.

- Tolt River near Carnation, gage 1214850: 88 days per year, based on data for water years 1979 through 1992.

- Snoqualmie River near Carnation, gage 1211490: 112 days per year, based on data for water years 1979 through 1992.

- Snohomish River near Monroe, gage 12150800: 121 days per year, based on data for water years 1979 through 1992.

Through natural streamflow fluctuations, the regulatory instream flow standards for each of the control points are typically not met, on any given day, in from 10% to 50% of all years. It should be noted that the standards are generally not consistently met or not met throughout an entire year or season as suggested by the flow exceedance curves, but that, in-any given year, actual flows are above the instream flow standards on some days and below the standards on other days. As indicated previously, a more rigorous assessment of minimum flows would be required to determine whether the regulatory instream flows are being met any less often now than in the past. Initial indications are that variations above and below the regulatory instream flows are primarily a feature of natural climatic variability.

6 Ground-Water Hydrology

The ground-water hydrology of the Snohomish River Watershed was assessed based on review of existing hydrogeologic reports and published (or digitally compiled) data. The major documents which contributed to this study include: water resource publications prepared by the USGS (Newcomb, 1952; Drost, 1983; and Turney et al, in press); consultant reports addressing the hydrogeology of Snohomish County (EES & Sweet-Edwards EMCON, 1991) and the North Bend vicinity (CH2M-Hill and Carr Associates, 1983; Hart Crowser, 1994; and Golder, 1994); and a number of other documents addressing water-quality conditions and sole-source aquifer designations. Ground-water level data were obtained from the USGS WATSTOR database.

6.1 Aquifer Descriptions

Geology, physiography and climate control patterns of ground-water occurrence, flow, recharge and discharge. Regionally extensive aquifer systems are found in the western WRIA, where significant thicknesses of coarse-grained sediments were deposited during Pleistocene times. Within this western lowland province, major rivers and streams dissect the Pleistocene sediments leaving a pattern of plateaus and intervening river valleys. Floodplain sediments within these river valleys often contain coarse alluvial sediments which make potentially good aquifers. Ground-water flow occurs within the alluvial sediments along the direction of river flow, and beneath the plateaus from interior regions towards the incised valleys and the coast. Ground-water occurrence is likely to be minor in the eastern WRIA, where bedrock exposures dominate the land surface.

6.1.1 Geologic Framework

The physiography of the Snohomish WRIA is of key importance to understanding its geologic framework. Although the physiography is a reflection of geologic features, it has also served to constrain patterns of recent geologic deposition. The high foothills and steep mountain slopes in the eastern WRIA are predominantly bedrock. Sediment deposition on bedrock is generally limited to the lower elevations, where a thin mantle of Pleistocene sediments is associated with glaciation from the lowlands. Multiple glaciations in the western WRIA lowlands have deposited a thick sequence of unconsolidated Pleistocene sediments. Sedimentary thicknesses (depth to bedrock) reach as much as 1,200 feet in the southwestern WRIA (pers. comm., G. Turney, 1995) and potentially over 2,000 feet farther north (Newcomb, 1952). The major geologic units within the WRIA are listed below. A generalized geologic cross section is provided on Figure 6-1.

Quaternary Alluvium (Qal)
Vashon Recessional Deposits (Qvr)
Vashon Till (Qvt)
Vashon Advance Deposits (Qva)
- Transitional Sediments (Q(A)f)
• Olympia Gravel or First Pre-Frasier Coarse Deposits (Q(A)c)

- Other Pre-Frasier Glaciation Deposits
- Tertiary (and older) Bedrock '(Br) . ,

Quaternary alluvium (Qal) is found within river valleys and stream channels throughout the WRIA. Older Qal occurs as terraces above existing floodplains, and is largely composed of sand and gravel. Younger Qal occurs in existing floodplains, ranging in texture from sand and gravel in upper river reaches, to sand, silt and clay in lower reaches. Coarser sediments are noted in deeper portions of some alluvial deposits (EES & Sweet-Edwards EMCON, 199 1). Younger Qal in tributary streambeds consists of sand, gravel and silt. The younger Qal deposits range in thickness from several feet in downgrading reaches, to 100 feet on average in lower reaches of the main river valleys. Maximum observed thickness is over 200 feet in the upper Snoqualmie River Valley (pers. comm., G. Turney, 1995) and is likely greater in the alluvial fan at the mouth of the Snohomish River.

The Vashon recessional outwash (Qvr) was deposited by streams emanating from the receding Vashon glacier near the end of the Frasier glaciation. The deposits are generally discontinuous and occur at the land surface as ice contact deposits, valley fill, and localized fluvially deposited patches. Although typically coarse sand and gravel, localized beds of silt and clay are noted as inclusions in the coarser materials. Additionally, a separate more extensive fine-grained member was deposited by ice-damned lakes in East King County (pers. comm., G. Turney, 1995). Reported thicknesses of the Qvr range from several feet to as much as 100 feet (EES & Sweet-Edwards EMCON, 1991). Notable Qvr deposits include valley fill in the Marysville Trough and portions of the Pilchuck River Valley, terrace deposits north of Sultan and south of Bryant, and portions of thick ice contact "embankments" along the upper reaches of the Snoqualmie River. Qvr deposits commonly overlie Vashon till, although the till may also be absent in places.

The Vashon till covers much of the western WRIA, deposited both as lodgement beneath the advancing ice and as spoils left by the sediment-rich ice mass as it melted away. It consists of a compact mixture of clay, silt, sand, gravel, cobbles, and boulders - locally referred to as hardpan. Portions of the till contain water-lain beds of sand and gravel associated with local melting and wasting. Although the till is exposed over much of the upland plateaus, it is rarely encountered in the river valleys. Till is present beneath the Qvr deposits in southern portions of the Marysville trough, where it was glacially smeared over pre-existing topography. Smearing of the till accounts for its presence on the marginal slopes of some plateau blocks, such as the eastern slope of the Tulalip Plateau. Till thicknesses are highly variable, generally ranging from 60 to 100 feet but approaching 300 feet (pers. comm., G. Turney, 1995). The till has been eroded from some river valleys and from other areas, sometimes leaving "windows" which permit direct contact between the Qvr and the underlying Qva.

The Vashon advance outwash (Qva) was deposited by glacial meltwater flowing over relatively flat topography as braided streams. The Qva deposits coarsen upward, with layered sands overlain by sand and gravel. The Qva deposits also include discontinuous silt beds, especially in lower layered sands. The Qva underlies Vashon till over much of the western WRIA (especially beneath the upland plateaus) and overlies the transitional beds (described below). Typical thicknesses are on the order of 200 feet, although thicknesses approaching 350 feet have been observed beneath the Tulalip and Intercity Plateaus. The Qva is missing in places where it has been eroded by the advancing Vashon glacier and in river valleys where it was dissected during downcutting. Qva deposits are noted east of Monroe, east of Snoqualmie Falls, and southeast of Granite Falls; however eastern deposition was limited by higher elevations associated with the Cascades.

Thick sequences of undifferentiated sediments have been reported in the major mountain valleys of Snohomish County. Thicknesses of up to 1,000 feet were reported by Newcomb (1952) to be large, water-lain terminal moraines (Qvr) based on occurrence of silt, clay, unsorted sediments, and pods of till. Recent studies, however, suggest that this thickness may be an overestimation and that the sediments are more likely a mixture of unconsolidated deposits (considered "undifferentiated") which may include Qva, Qvt, Qvr and other sediments (pers. comm., B. Thomas, 1995).

The transitional beds underlie the Qva and are largely comprised of laminated clay and silt, with localized sand and gravel beds, peat and wood deposits. The transitional beds were deposited in a large lake, presumably when the advancing Vashon glacier dammed outflow from the Puget Sound Basin. The transitional beds are ubiquitous throughout the western (lowland) portion of the WRIA. Reported thicknesses reach 300 feet (EES, 1990) and in one instance as much as 550 feet (pers. comm., G. Turney, 1995).

Beneath the transitional beds lie a series of pre-Frasier glacial and interglacial deposits. The uppermost (and perhaps best documented) unit is the Olympia Gravel. The unit is reportedly extensive beneath the western WRIA and is exposed in places along the Possession Sound shoreline (EES & Sweet-Edwards EMCON, 1991; EPA, 1988). It is comprised of layered interglacial sand and gravel, with thicknesses averaging 140 feet and reaching 240 feet in wells in East King County (pers. comm., G. Turney, 1995). Well data in western Snohomish County are insufficient to report the thickness and occurrence of this unit (pers. comm., B. Thomas, 1995). It has been encountered beneath the Tulalip Plateau at elevations near -200 feet mean sea level.

As many as four older glacial and interglacial units have been identified beneath the Olympia Gravel which comprise the remainder of the Pleistocene unconsolidated deposits. Several stratigraphic divisions and nomenclature systems are currently in use for these deeper units. The deposits include marine/glacial drift, till, and interglacial units. Varying interpretations have not yet been resolved due to lack of deep wells for extensive documentation over the study area. Because these units are not yet well correlated or investigated, discussion will be limited only to their mention.

The bedrock beneath the Pleistocene deposits is composed of pre-Tertiary igneous and metamorphic rocks, volcanic rocks of possibly Tertiary age, and Tertiary sedimentary rocks. The pre-Tertiary igneous and metamorphic rocks are representative of the general composition of the Northern Cascade mountains. The Tertiary (?) volcanic rocks occur in a band along the western flank of the Cascade Mountains, and are largely unmetamorphosed. The Tertiary sedimentary rocks consist of shale, siltstone, sandstone, and coarse gravel, and can be over 1,500 feet thick (EES & Sweet Edwards EMCON, 1991).

6.1.2 Principal Aquifers

This section provides a description of those aquifers which are relatively well documented beneath the Snohomish WRIA. Principal aquifers occur within the Qal, Qvr, Qva, and Olympia Gravel deposits. The Qvt, transitional beds, and bedrock generally function as aquitards, but can yield water in small quantities for domestic purposes. Unconsolidated deposits beneath the Olympia Gravels may also be capable of yielding usable amounts of ground water, however information is generally lacking as to their capacities.

The quaternary alluvium contains highly productive zones along mid to upper river reaches where sedimentary textures are relatively coarse and permeabilities relatively high. Aquifer conditions are typically unconfined and significant hydraulic continuity may exist with adjacent surface water. Productive (or potentially productive) zones identified in the WRIA's alluvial aquifers occur: along the Snoqualmie River (especially above Snoqualmie Falls); along the Skykomish River between Monroe and Goldbar; and along the Pilchuck River from Granite Falls to about one mile southeast of Snohomish. Lesser yielding zones suitable for domestic use may occur in other locations along the major rivers and tributary streams.

The Vashon recessional outwash is generally quite permeable and contains potentially good aquifers. Qvr aquifers are typically unconfined and limited in yield by degree of saturation. Moderate yields are obtained from the Qvr east of Fall City, northeast of Snoqualmie, in terrace deposits north of Sultan and south of Bryant, and within the Marysville trough between Arlington and Marysville.

The Vashon advance outwash is the most extensively developed regional aquifer in the WRIA. It is present beneath all the physiographic plateaus in the western WRIA. Significant saturated Qva deposits are also present along the Snoqualmie River. The Qva aquifer is predominantly unconfined in Snohomish County (Newcomb, 1952), although confined conditions occur where saturation above the underlying transitional beds reaches the overlying till. Such confined conditions are reported beneath much of East King County (pers. comm., G. Turney, 1995), on the east side of the Tulalip Plateau (northwest of Marysville), locally on the northwest and south slopes of Getchell-Snohomish Plateau (northeast of Marysville), and on the northwest side of the Pilchuck Valley north of Lochloy. Older alluvial deposits near Roosevelt Corner are reported to confine ground water in the Qva deposits.

The Olympia Gravels, separated from the Qva deposits by the relatively low permeability Transitional Beds, comprises the next regionally significant aquifer within the WRIA. Little information is written describing ground-water occurrence in the Olympia Gravels. The aquifer occurs under mostly confined conditions where present beneath southern portions of the WRIA (pers. comm., G. Turney, 1995).

Minor aquifers within the WRIA provide quantities of water sufficient for domestic purposes, and are noted within the Vashon till, the transitional beds, and from bedrock. The upper portion of the Qvt is often more porous due to weathering, thereby supporting a perched aquifer condition which is tapped by domestic wells. In some areas the upper thicknesses of the till were deposited by ablation, and are therefore less tightly packed than underlying lodgement till. Domestic wells also tap coarser-grained zones within the transitional deposits and fractured zones in the bedrock to obtain small yields.

6.1.3 Hydraulic Continuity

Hydraulic continuity refers to the interconnection between water bearing units, both 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 can occur 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. Where hydraulic continuity exists, changing hydraulic conditions in a ground-water body will result in changes to connected surface-water bodies. For instance, pumping a well may result in reduced ground-water discharge to adjacent surface water or increased seepage from surface water. Similarly, lowering the water level in a river or lake may result in decreased seepage to ground water or increased discharge from adjacent aquifers.

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 impacted surface-water bodies must first be identified. Because shallow aquifers are generally dominated by local ground-water flow systems, withdrawals from shallow wells are more likely to influence local 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 could therefore be manifested on distant river reaches, discharge rates to coastal saltwater bodies, or could be spread out diffusely over a large area to affect numerous 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 effects of reduced or discontinued pumping.

Characterization of hydraulic continuity in the Snohomish WRIA ranges in complexity based on the variables described above. This section addresses the relative hydraulic continuity potentials of major aquifers within the WRIA. Current understanding of local and subregional ground-water flow systems is sufficient to provide qualitative insight into stream-aquifer relations, however knowledge of deep regional flow systems is often insufficient to allow such infernal.

Hydraulic continuity between alluvial (Qal) aquifers and adjacent streams or rivers is typically high. The effects of pumping a shallow well near a river will be felt most quickly and locally where aquifer materials are coarse-grained and riverbed materials provide little "skin effect" (resistance) to impede seepage. A high degree of hydraulic continuity is expected of alluvial aquifers that occur along the Snoqualmie River (especially above Snoqualmie Falls); along the Skykomish River; and along the Pilchuck River.

A relatively high degree of hydraulic continuity between Vashon recessional (Qvr) aquifers and surface-water bodies occurs where rivers or streams dissect Qvr deposits containing water-table aquifers and where Qvr deposits occupy hummocky depressions (glacial kettles) along with ponds or lakes. Qvr sediments in the Marysville trough are reported to be in continuity with surface waters. Winter recharge to the trough occurs from nearby surface water (EES & Sweet-Edwards EMCON, 1991), and summer discharge occurs northerly to springs along Portage Creek and southerly to tributaries of Ebey Slough (Newcomb, 1952). Saturated Qvr may exhibit continuity with the Pilchuck River east of Lake Stevens and southwest of Granite Falls. Examples of lakes present within deposits of Qvr sediments include Echo Lake, Kellog Lake, and Lake Chaplain.

Relatively high hydraulic continuity occurs between Vashon advance (Qva) aquifers and surface-water bodies where streams or rivers dissect saturated Qva deposits; where spring discharge from the Qva feeds surface-water bodies; and where saturated Qva deposits are in direct subsurface contact (subcrop) with Qal and Qvr sediments along streams or rivers. Within the Qva flow system, all ground water which flows naturally towards inland discharge points (i.e. excluding saltwater discharge) is likely to be in ultimate hydraulic continuity with surface water. Development of ground water flowing towards inland discharge will alter stream-aquifer relations. In addition (and to a lesser extent), development of ground water in the Qva naturally flowing towards saltwater bodies may affect fresh surface-water features by shifting ground-water divides and reducing recharge capture areas. Because the Qva aquifers form a sub-regional component of the flow system, estimation of the surface-water impacts of Qva pumpage is fairly complex. Continuity may be relatively high, or may be moderated by till aquitards which occur along between the point of withdrawal and surface water. In addition, distances from points of withdrawal to points of impact may be great and time lags significant.

Relatively high hydraulic continuity is likely to occur along North Creek, Swamp Creek, and several streams on the Tulalip Plateau which dissect the Qva deposits (pers. comm., B. Thomas, 1995). Springs which discharge from the Qva aquifers are common throughout the WRIA. Examples include springs at Fall City, Snoqualmie, North Bend, Carnation, along the edge of the Intercity Plateau south of Everett, and on the east side of the Tulalip plateau. Many of the major springs are developed for water supply, however some spring discharge reaches streams and augments their flows. Springs, for instance, support the summer/fall low flows of Bear Creek and Woods Creek (Newcomb, 1952). Moderate to high hydraulic continuity is likely to occur along the western and northern boundaries of the Marysville trough where Qva subcrops against Qvr, in the Snoqualmie River Valley where Qva subcrops against Qal, and possibly the Pilchuck River south of Granite Falls where water-level trends in the riverside Qvr aquifer suggest significant influence from the adjacent Qva aquifer (Newcomb, 1952).

Ground-water flow in the deep Olympia Gravel aquifer is more regional than flow in the overlying Qva. Accordingly, this ground water will most likely to discharge to saltwater along the coast or to major (low elevation) inland surface-water features. Hydraulic continuity with surface-water features is moderated by overlying aquitards. Hydrologic conditions in East King County are sufficiently documented to show that some of the ground water in the Olympia Gravels flows towards the Snoqualmie River Valley (pers. comm., G. Turney, 1995). In places, upward vertical gradients suggest discharge towards the Snoqualmie River (pers. comm., G. Turney, 1995). Groundwater conditions in the Olympia Gravels are not sufficiently well known in Snohomish County to accurately establish inland discharge patterns (pers. comm., B. Thomas, 1995).

6.1.4 Ground-Water Flow

Ground-water flow patterns within the Snohomish WRIA are not well documented in currently available publications. Flow patterns in East King County have recently been documented by the USGS, and will be published in Spring of 1995. The USGS is also in the process of documenting flow patterns in Snohomish County, but conclusion of these efforts is farther off. In general, groundwater flow patterns within the WRIA reflect local, sub-regional, and regional flow systems. Local flow systems typically occur within shallow aquifers, and flow directions tend to mimic local topography. Regional flow systems occur within deep aquifers, with flow directions influenced only by major topographic features such as Puget Sound and the principal river valleys. Sub-regional flow systems characteristically fall between these two extremes. Flow in the shallow Qal and Qvr aquifers is local, whereas flow in the Qva aquifer is sub-regional. Flow systems in aquifers beneath the Qva may range from sub-regional to regional. The more regional the flow system, the longer the flowpath between points of recharge and points of discharge.

Ground-water flow patterns within Qal along streams and rivers vary depending on stream aquifer interactions. In stretches where a river or stream is gaining water from ground-water discharge, flow occurs towards the valley bottom and along the direction of river flow. Such gaining conditions are documented along the Snoqualmie River upstream of Carnation (pers. comm., G. Turney, 1995). In stretches where a river or stream is losing water through riverbed seepage, flow occurs away from the river and along the direction of river flow. Losing conditions are documented along the Snoqualmie River between Carnation and Monroe, and along the Raging and Tolt Rivers (pers. comm., G. Turney, 1995). Data are unavailable concerning stream seepage in Snohomish County.

Ground water in the Qvr deposits is likely to follow similar flow patterns along river valleys and is likely to follow local topography elsewhere. Flow patterns are influenced by the distribution of ground-water recharge and discharge, with ground-water divides occurring between discharge areas. Ground water in the Qvr aquifer within the Marysville trough flows both southward and northward from a divide in the vicinity of Edgecomb (Newcomb, 1952). Similarly, a ground-water divide is noted northwest of Lochsloy in Qvr deposits along the Pilchuck River (Newcomb, 1952). In both cases, ground water discharges to springs to the north and to local surface water to the south.

Ground-water flow in the Qva aquifers generally occurs from the interiors of upland plateaus towards their outer edges. Recharge occurs really over the plateaus, and discharge occurs to major river valleys or along the steep sea cliffs of Puget Sound. Ground-water divides typically occur beneath the interiors of the plateaus. Discharge at the plateau margins occurs to Qal or Qvr deposits which flank the rivers, or to springs where aquifer materials are exposed at the land surface. The plateaus and uplands in the eastern WRIA flank the foothills and slopes of the Cascade mountains. Ground-water flow in the Qva deposits (where present) beneath these uplands occurs towards the major drainages, generally to the west. Flow in saturated Qva deposits along the Snoqualmie River upstream of North Bend likely follows the topography of the steep foothill slopes.

Ground-water flow in the Olympia Gravels is also dominated by discharge along the major surface-water features. In East King County, a significant portion of ground water-in the Olympia Gravels flows towards the Snoqualmie River (pers. comm., G. Turney, 1995). Ground-water flow then parallels the river, and in the lower river reaches, flows vertically upward toward the river. A ground-water divide is reported beneath the Sammamish Plateau, with western flow towards Lake Sammamish and eastern flow towards the Snoqualmie River. Ground-water flow directions in Snohomish County have not been documented for the Olympia Gravels, but are likely to respond to similar influences.

Ground-water flow patterns have both horizontal and vertical components. In general, downward vertical flow occurs in recharge areas, such as beneath the plateaus and uplands. Upward vertical flow occurs in discharge areas along the valley bottoms, and has been observed along the lower Snoqualmie River downstream of Snoqualmie Falls (pers. comm., G. Turney, 1995).

Along the edges of the WRIA, ground-water divides in the sub-regional and regional aquifers may not correspond with surface-water divides. Ground-water flow in unconsolidated sediments beneath the eastern WRIA is entirely contained within watershed divide, as aquifers pinch out upon bedrock west of these divides. This is also the case within the southeastern WRIA boundary. Along the southwestern boundary and the western boundary within King County, shallow ground water and surface-water divides are generally coincident. Subflow across the western WRIA boundary in King County appears to be minimal in the Qva aquifer, although subflow into the WRIA occurs in the Olympia Gravels across the boundary west of Carnation (pers. comm., G. Turney, 1995, 1995). Subflow across the western WRIA boundary in Snohomish County has not been rigorously assessed, however flow towards Possession Sound is known to occur beneath the western plateaus. A groundwater divide documented beneath the Intercity Plateau shows subflow out of the basin towards the Sound from significant portions of the Qva aquifer (Newcomb, 1952); and water budget calculations for the Tulalip plateau also suggest that ground water is lost to the Sound (Drost, 1983). Groundwater flow directions along the northern WRIA boundary are not well documented, however subflow across the boundary toward the Stillaguamish River is likely in both deep and shallow aquifers.

Northerly flow towards the Stillaguamish River occurs in the Qvr deposits of the Marysville Trough from a ground-water divide located near Edgecomb (Newcomb, 1952).

6.2 Quantification of Water Budget Components

Water budget analysis is a useful tool to relate 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. The effects of additional development are largely independent of the original magnitudes of recharge or discharge, and may be estimated by predictive models or long-term testing or monitoring.

Water budgets are balanced based on the assumption of dynamic equilibrium: that hydrologic systems can be viewed as being in a quasi-steady state. In steady state, inflows are equivalent to outflows with negligible changes in system storage. Balancing the water budget is beyond the scope of this study for two reasons. First, many water budget components within the Snohomish WRIA have not been estimated or sufficiently characterized in the available literature. Second, inconsistencies between available estimates and measurements do not allow elements of the water budget to be balanced. Additional data collection and analysis will be required to resolve these inconsistencies. Nevertheless, existing estimates and measurements are presented and discussed below.

The water budget can be divided into three elements: the climatic, surface water, and ground water portions. Each of these elements are linked to the others through shared water-budget components. For instance, the climatic element is linked to the surface-water element through runoff from precipitation and is linked to the ground-water element through recharge. The tables presented below present hydrologic component estimates for each element and provide data references as needed. Where possible, estimates are normalized to the area of the entire WRIA.

Component	Inflow (af/yr)	Outflow (af/yr)	Comments
Climatic:			
Precipitation	8,620,000	----	87 in/yr areal average (see Section 4.1)
Evapotranspiration	----	2,280,000	23 in/yr in USGS E. King Co. study area
Total Runoff (includes storm runoff and baseflow)	----	6,910,000 - 8,400,000	min from Snohomish River @ Monroe; max is adjusted to the entire WRIA area
Ground-Water Recharge (excludes baseflow)	----	not estimated	includes all recharge which does not support baseflows in watershed streams

Component	Inflow (af/yr)	Outflow (af/yr)	Comments
Surface Water:			
Total Runoff (includes storm runoff and baseflow)	6,910,000 - 8,400,000	----	min from Snohomish River @ Monroe; max is adjusted to the entire WRIA area
Stream Diversions	----	138,000 - 552,134	min = known diversion (Section 3.4.2); max -total allocation (Section 3.1)
Miscellaneous	not estimated	----	includes spring and treated sewage inflows

Component	Inflow (af/yr)	Outflow (af/yr)	Comments
Ground Water:			
Total Recharge (includes recharge which discharges to streams)	2,800,000	----	28 in/yr, upper limit (see text below)
Subflow	not estimated	not estimated	includes ground-water flow across WRIA boundaries and discharge to saltwater bodies
Stream Interaction	not estimated	not estimated	see hydraulic continuity in Section 6.1.3
Well Withdrawals	----	15,040	see water use in section 3.4
Spring Discharge	----	>20,500 (minimum)	compiled estimate from USGS E. King County Study and Newcomb, 1952
Miscellaneous	not estimated	not estimated	lake seepage, direct evapotranspiration

As the sole input to the climatic water budget, precipitation was estimated over the WRIA by integrating the spatial distribution shown on Figure 4.1. "Total runoff' includes both storm runoff and baseflow components, and is presented as a value range. The lower value is a long-term average of annual streamflow measured on the Snohomish River near Monroe. The upper value was estimated by multiplying this measured value by the ratio of land-surface area in the entire WRIA and the drainage area upstream of the Monroe gage. This value assumes a uniform runoff efficiency throughout the WRIA, and may be somewhat overestimated . (runoff efficiency downstream of Monroe is likely less than upstream). Evapotranspiration was estimated by applying a value used by the USGS for the East King County study area (pers. comm., G. Turney, 1995) to the entire WRIA. The USGS value of 23 inches/year is within a range typical for western Washington. The remainder of the water budget goes to the portion of ground-water recharge which does not provide baseflow to watershed streams.

An attempt to balance the climatic water budget reveals that the estimated precipitation inflow is less than the combined estimated outflows of evapotranspiration and total runoff. This imbalance is not possible, especially since sufficient ground-water recharge must occur to supply pumpage, coastal spring discharge, and ground-water subflow. The climatic water-budget estimates therefore include some degree of error, of which the most likely sources are associated with estimates of precipitation and evapotranspiration. The precipitation and the runoff estimates are taken from differing periods of record, however this is unlikely to cause significant error because average precipitation values over the two periods are within 3 percent. The spatial distribution of precipitation on the isohyetal map may provide significant error. Spot checks between five precipitation gages with long-term record and the isohyetal map showed good agreement, however there are no gages in high-elevation areas. Isohyetal values in high-altitude areas are estimated with an empirical altitude adjustment, and are not field verified. The estimate of evapotranspiration is related to pan evaporation, but may not be indicative of conditions in the field. Field measurement of evaporation is both expensive and difficult to achieve.

The surface-water budget shows that total runoff (average annual streamflow) exceeds diversions by ratios which range from 12:1 to 60:1. Measured streamflow includes both baseflow and stormflow components, and therefore accounts for all interaction with ground water (streambed seepage) upstream of the gaging point. Estimates of streamflow diversion are presented as a range, the lower member based on known diversions upstream of Monroe (discussed in Section 3.4.2) and the upper member based on allocated water rights and claims (discussed in Section 3.3.1). Although total runoff greatly exceeds diversions, the majority of this runoff occurs during the winter months when diversions are at their lowest. Diversions have the greatest impact during the summer months, when streamflow (i.e. baseflow) is at its lowest.

The ground-water budget cannot be assessed rigorously because the value for total recharge is an upper limit. The degree to which this upper limit exceeds actual recharge is unknown. Total recharge to the WRIA was estimated based on separate analyses prepared by the USGS for their East King County and Snohomish County study areas. This estimate (28 in/yr) was calculated by applying the East King County recharge value (31 in/yr) to the WRIA within King County and applying the Snohomish County recharge value (25 in/yr) to the WRIA within Snohomish County. The USGS estimates include all water that percolates below the root zone, including recharge to thin bedrock soils (which soon re-emerges as runoff to small streams). There is some question as to whether the USGS recharge method should be applied to broad expanses of bedrock terrain, as occur in the eastern portions of the WRIA (pers. comm., G. Turney, 1995). The USGS did not extend their recharge estimation areas far into bedrock terrain.

Rigorous assessment of the ground-water budget is also problematic because surface-water interactions are unknown. The USGS estimates of total recharge include the portion of ground water that discharges to streams as baseflow. If the recharge value discussed above is used, net seepage loss to surface water must be known in order to estimate the volume left over for well withdrawal, springflow, and subflow out of the basin (including discharge to saltwater). Ground-water / surface-water interactions are not well quantified within the Snohomish WRIA.

Although a rigorous assessment is problematic, it may be noted that well withdrawals are small compared to estimated recharge. If recharge were assumed to occur only in portions of the WRIA where significant water-bearing sediments occur, it is reasonable to assume a value of at least 25 percent of the estimate discussed above based on bedrock occurrence. Ground-water withdrawals (discussed in Section 3.4.1) comprise less than 2 percent of this reduced estimate of ground-water recharge.

Based on the water-budget approach, increases in ground-water pumping will result in decreased stream discharge (baseflows), springflows, and subflow out of the basin (including discharge to saltwater). It should be noted, however, that estimated ground-water withdrawals are quite small relative to both annual and minimum streamflows. Estimated pumpage is approximately 0.2% of the average annual streamflow and 1.3% of the average minimum flow measured in the Snohomish

River at Monroe. Assuming that the average minimum flow over the 1963-1993 period of record (1,604 cfs on Figure 5-15) is representative of the summer baseflow, current measuring devices could not detect a withdrawal of the magnitude of year-round ground-water Pumpage.

6.3 Critical Indicators: Ground-Water Level Trends

Long-term ground-water level records from multiple locations in a basin are useful for understanding the timing and effects of recharge and withdrawals from monitored aquifer(s). From the perspective of ground-water quantity management, ground-water level monitoring can be used to: 1) ensuring a reliable source of supply, and 2) maintaining adequate streamflow where aquifers discharge to streams. Ground-water levels in selected wells have been monitored over varying time periods by the USGS. A review of these data from the USGS WATSTORE database revealed only 7 wells with records extending over more than 6 years.

Hydrographs from most of the wells monitored within the WRIA showed no significant ground-water level decline. Figures 6-2a through 6-2c present hydrographs of eight wells that are of interest either due to their long period of record or due to water-level decline (the well locations are shown on Figure 6-3). Annual precipitation at Snoqualmie Falls is also presented, as departure from the long-term mean, to assess the influence of ground-water recharge. Small time scale fluctuations (from year to year) are observed in the precipitation data. Longer time scale trends indicate higher-than-average precipitation between 1945 to 1976, and lower-than-average precipitation between 1976 to 1980 and 1985 to 1994 (with the exception of very high rainfall in 1991).

Figure 6-2a presents the long-term (>20-year) hydrographs available for the WRIA. Well 30N/05E22A01, completed in Qvr deposits in the Marysville Trough, shows a considerable seasonal water-level fluctuation but an overall stable trend. Well 31N/05E-10JO3, completed in the Qvr or Qva in the northeast corner of the Marysville trough near Arlington (just outside the WRIA boundary), shows apparently stable water levels between 1945-1976, followed by a several-foot decline in the late 1970's. Single water levels from 1988 and 1993 are within historical seasonal variations.

Figure 6-2b shows available intermediate-term (6-20 year) hydrographs for the WRIA, all of which are for wells on the Tulalip Plateau. Well 29N/04E-O1B02, completed in the Qva aquifer along the southern coast of the Tulalip Plateau, shows a relatively stable trend with a 1992 measurement inferring a minor water-level decline. Wells 30N/04E-IOLOI and 30N/04E-10LO2 are located essentially on the same location in the interior of the Tulalip Plateau but are completed in slightly different aquifers. Well 30N/04E-1OL01 is a flowing well apparently completed in the Transitional Beds immediately below the Qva aquifer. Its hydrograph shows a 6-foot water-level rise between 1975-1983. Nearby well 30N/04E-IOL02 is completed in the bottom of Qva aquifer. Water levels in this well are over 20 feet beneath the land surface, and its hydrograph shows several feet of water-level decline in the late 1970's with apparent stabilization by the early 1980's. The differing hydrologic conditions between the two wells are dramatic given their proximity. The disparity in water-level trends may be partly related to varying pumping from the two completion aquifers. Other records for wells beneath the Tulalip Plateau, although short-term (2-3 years) show relatively stable water levels during the late 1970's and early 1980's.

Figure 6-2c shows selected short-term (<5-year) hydrographs within the WRIA. Well 23N/08E-27N01, completed in the Qvr aquifer south of North Bend, shows a gently rising water level between 1988-1990 which may correspond to increasing precipitation. Water levels in well 24N/07E-14D, completed in the Qvr deposits north of the Snoqualmie River near Fall City, are fairly stable between 1990 and 1995, although a gentle decline may be masked by high variability between measurements. Finally, well 24N/08E-20M, completed in the Qvr deposits above the Snoqualmie River near the falls, shows a 15-foot decline between 1991 and 1995 with minor recoveries in early 1992 and 1994. Similar trends are seen in other wells not presented in this report. Well 25N/07E-1587, completed in the Qva deposits near Carnation, shows a 24-foot decline between 1991 and 1995. A 13-foot decline over the same period (with similar recoveries) is seen in Well 24N/06E-11 L, which is also completed in the Qva deposits on the eastern edge of the Sammamish Plateau.

The water-level declines in wells 24N/08E-20M, 25N/07E-1587 and 24N/06E-11 L, while observed only over short-term records, warrant greater attention. The reduction in precipitation between 19901993 may account for some of this decline, but is not likely responsible for the entire 13-24 feet of decline. The three wells are sufficiently far apart that regional declines do not appear to be a likely explanation. Well 24N/08E-20M is completed in Qvr deposits above the Snoqualmie River, and is likely locally isolated from the Qva deposits in this location. Regional declines were not observed in well 24N/07E-14D, completed in Qvr deposits near Fall City. Similar trends in the three wells are more likely due to independent ground-water development in these areas, with declines occurring as the hydrologic system adjusts to a new equilibrium. Simultaneous (short-term) recoveries within all three declining trends may be due to regional climatic influences on demand. Because new equilibria may involve altered fluxes to/from surface water and adjacent aquifers, additional evaluation (i.e. estimation of pumping trends and comparison with hydrographs) is recommended in these areas.

6.4 Environmental Health: Ground-Water Quality

The quality of ground water can be impaired by ground-water development, and ground-water development can be limited by ground-water quality problems. The development (withdrawal) of ground water can cause water-quality problems by drawing sea-water into once freshwater aquifers or by extending the area of contaminant plumes. Alternatively, extensive man-made contaminant plumes and naturally occurring ground-water constituents can limit or prevent development over significant portions of an aquifer system. This section discusses ground-water quality problems that are associated with, or may potentially limit, ground-water development.

Saltwater intrusion is not currently a serious problem beneath the Snohomish WRIA. Intrusion occurs when the dynamic balance between freshwater and seawater in coastal aquifers is shifted. Freshwater fluxes and ground-water elevations are reduced by pumpage, thus causing the interface between saltwater and freshwater to advance inland. Saltwater intrusion is typically indicated by increasing chloride concentrations in ground water. High chloride concentrations have been reported as a natural feature in seaward portions of the Snohomish River floodplain. High chloride concentrations have also been reported in Qva (and deeper) aquifers beneath Priest point, a peninsula-like feature on the Tulalip Reservation. Three wells in the Priest Point vicinity showed chloride concentrations exceeding 100 mg/l. Time-series data are unavailable to determine if concentrations are increasing (i.e. intrusion is occurring). Nevertheless, the potential exists for saltwater intrusion associated with increased ground-water extraction along the coast.

Ground-water contaminants associated with human activity have been noted beneath the WRIA, but are not present in sufficient concentrations or extent to pose significant limitation to ground-water development. Contaminants fall under three categories: inorganic, biological, and organic. The most commonly noted inorganic contaminant is nitrate, which is largely associated with septic tanks and fertilizers. Nitrate contamination problems noted within the WRIA are local in scale and generally below State primary drinking water standards (10 mg/1). Biological contaminants include bacteria that are associated with septic tanks and animal farms. Bacterial contamination is typical localized and limited to shallow aquifers. The Snohomish County Health District observed that about 525 wells inspected between 1978 and 1983 contained coliform bacteria exceeding recommended levels (EES & Sweet-Edwards EMCON, 1991). The depth and distribution of contaminated wells was not pursued as part of this scope of work. The USGS found bacterial contamination in less than fifteen percent of 121 sampled wells in their recent study of East King County (pers. comm., G. Turney,1995). Although local sources of bacterial contamination are most likely, well depth and distribution data did not consistently suggest either local or distant sources.

Organic contaminants can include fuel derivatives, solvents, and pesticides. The literature reviewed for this report revealed several localized organic contaminant detections, none of which were described as regionally extensive. Within Snohomish County ethylene dibromide was detected in a well in the Marysville area; a leaky underground storage tank contaminated ground water with benzene at a mobile home park near Startup; and a pentachlorophenol/oil spill in Arlington is suspected to contaminate ground water (EES & Sweet-Edwards EMCON, 1991). In East King

County, the USGS detected the pesticides dicamba and 2,4-D in four non-adjacent wells. Three of the wells are shallow, and were therefore likely contaminated by local land-use practices. The fourth detection is from a flowing well in a deep aquifer. The source of contamination is assumed more distant, but could not be identified. Additional contaminant problems may occur within the WRIA. Listings of suspected and confirmed contaminated sites were not reviewed, as they are outside the scope of this reporting effort.

Naturally occurring ground-water contaminants have been noted beneath the WRIA, and may limit ground-water development in some areas. The most notable constituent is arsenic, which has been detected at concentrations above the recommended primary drinking water standard of 0.05 mg/1 in the vicinities of Granite Falls, Lake Roesiger, the Snoqualmie/Skykomish River confluence, and several miles north of Marysville (EES & Sweet-Edwards EMCON, 1991). Significant concentrations were also detected by the USGS in wells along (and east of) the Snoqualmie River between Carnation and Duvall (pers. comm., G. Turney, 1995). The source of dissolved arsenic appears to be naturally occurring minerals in the local bedrock and in sediments derived from bedrock. Additional investigation is required before the subsurface extent of arsenic contamination is sufficiently characterized. The U.S. Environmental Protection Agency maximum contaminant level (MCL) for arsenic is currently under review, and may be lowered by an order of magnitude or more (pers. comm., G. Turney, 1995). Definition of aquifer contamination based on a reduced MCL could largely expand the apparent extent of the problem.

Iron and manganese are two naturally occurring contaminants that have a lesser potential to limit ground-water development. The Washington State Department of Health recommends secondary drinking water standards for these constituents, concentrations beyond which the aesthetic quality of water may be impaired. Above these recommended standards, iron can affect the taste of water and stain porcelain fixtures, and manganese can cause staining and precipitate in pipes. The subsurface distribution of iron and manganese is highly variable, and is dependent on the pH and dissolved oxygen content of ground water, the mineralogy and grain size of aquifer materials, and the presence of organic matter. Relatively high iron and manganese concentrations have been noted in the Qal, Qvr, Qva and deeper aquifers.

Radon has been investigated and detected in East King County ground water by the USGS. Observed radon concentrations are somewhat less than in other areas of western Washington, and are significantly less than in areas of national concern such as the northern Atlantic coast (pers. comm., G. Turney, 1995). The majority of detections were below the proposed USEPA MCL of 300 picocuries/liter, and the distribution of detections showed no apparent areal or hydrogeologic pattern.

7 Stream-Water Quality and Fisheries Habitat

7.1 Stream-Water Quality Assessment

A water quality assessment of the WRIA was completed to summarize existing water quality data and to provide an overview of water quality conditions. Much of the data contained in this section was summarized from the Watershed Briefing Paper prepared for the Island/Snohomish County Water Quality Management Area (Cusimano, 1994). Other data sources used to complete this section include the Washington Department of Fish and Wildlife's Washington Rivers Information System (WARIS) database (Washington Department of Fish and Wildlife 1994), the U.S. Environmental Protection Agency (EPA) STORET database and data provided by the U.S. Geological Survey (LTSGS, 1994a). Surface-water quality classifications and water bodies listed on the " 303d" water quality limited list are also indicated.

7.1.1 Water Quality Classifications

Surface waters in the WRIA are classified in Chapter 173-210A WAC to establish water quality standards for various parameters. The State of Washington classifies surface water by characteristic use and quality. Class AA is considered of extraordinary quality which markedly and uniformly exceeds the requirements for all uses. Examples of typical uses include public water supplies and salmonid rearing and recreation. Class A water is deemed of excellent quality and meets or exceeds the requirements for all or near-all uses. Typical uses of Class A water are similar to Class AA uses, but the water does not meet the same stringent standards. Class B water is considered good quality water which meets or exceeds the requirements of most uses. Characteristic uses are similar to Class AA and A, with the exception of domestic water supplies. Class C water is considered fair quality water which meets or exceeds the requirements of selected uses. Typical uses include industrial water supplies, fish migration and non-contact recreation.

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:

- Everett Harbor, inner, northeast of a line bearing from the southwest corner of the pier: Marine Class B

- Pilchuck River from the City of Snohomish Waterworks Dam (RM 26.8) to the headwaters: Class AA

- Puget Sound through Admiralty Inlet and South Puget Sound (west side of Whidbey Island): marine Class AA

- Snoqualmie River, Middle Fork: Class AA

- Snoqualmie River, North Fork: Class AA

- Snoqualmie River, South Fork, from west boundary of Twin Falls State Park (RM 9.1) to headwaters: 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 where existing management practices have not been adequate to maintain water-quality standards. The state is then required to establish maximum daily limits on pollutant discharge to these areas. Fecal coliform and temperature violations caused the greatest number of listings for streams in the state 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. The list also indicates a decision whether to retain a segment on the list or to remove it due to insufficient or inaccurate data or an improvement in water quality. Water body segments located in the Snohomish WRIA contained in Ecology's May 13, 1994 303(d) list submitted to the EPA are included in this report (Table 7-1, Figure 7-1).

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 Snohomish WRIA and reported to EPA. The STORET results show that over the periods of record, water quality violations have occurred in the WRIA with respect to water temperature, dissolved oxygen, pH, ammonia, copper, lead, zinc, cadmium and chromium. Fecal coliform counts were also high and may exceed state standards. These results, along with state water quality criteria, are shown in Table 7-2. Water quality data provided by the USGS also indicated violations of temperature, dissolved oxygen and pH, as well as high fecal coliform counts at various stations throughout the WRIA (Table 7-3).

Snohomish River

Mainstem Snohomish River sites generally met Class A water quality standards. Dissolved oxygen and temperature met standards at least 90 percent of the time, turbidities were low and mean pH fell within the Class A range (Thornburgh et al., 1991). Elevated fecal coliform and summer water temperatures (July and August) were recorded at RM 12.7 (Fricke, 1994). A maximum summer temperature of 24° C was recorded at Snohomish (Table 3). Nutrient and turbidity levels are generally within normal ranges (Fricke, 1994).

Quilceda and Allen Creeks

High levels of fecal coliform have been found in the past in both creeks by Snohomish County, Ecology and the Tulalip Tribe. Both wet and dry season fecal coliform counts have exceeded Class A standards of 100 colonies/100m1. Dissolved oxygen levels in these drainages also frequently violate the Class A standard of 8 mg/1, with concentrations below 6.5 mg/1 not uncommon in the summer. High levels of mercury, cadmium and lead have also been reported by Snohomish County. Snohomish County sampled these creeks from May 1993 to April 1994 and found fecal coliform violations at most sites, high nitrate-nitrite levels, high sediment loads in the wet season and high levels of copper and lead (Cusimano, 1994).

Pilchuck River

Pilchuck River water quality is generally good. A few excursions below the Class A dissolved oxygen criterion and a few fecal coliform concentrations exceeding 200 colonies/ 100ml have been measured (Cusimano,1994). Fricke (1994) reported that 17 percent of Pilchuck River fecal coliform and turbidity samples were in the upper range of those typically found in the Puget Sound basin.

French Creek

French Creek is a tributary to the Pilchuck River that drains an area to the northwest of the City of Monroe. Violations in fecal coliform and dissolved oxygen standards have been reported by Snohomish County. Turbidity and nutrient levels are also high, and dissolved oxygen levels below 5 mg/1 have been recorded (Cusimano, 1994). Thornburgh et al. (1991) reported low water quality throughout the creek, with degradation occurring from upstream to downstream. Fecal coliform levels exceeded Class A standards upstream and greatly exceeded standards downstream. Dissolved oxygen was below Class A standards 65 percent of the time at the downstream site (Thornburgh et al., 1991).

Skykomish River

The water quality of the Skykomish River is good, but there is the potential for degradation from increased development and agriculture. Only one water quality violation from data collected at Monroe was reported in the last seven years (Fricke, 1994). Some fecal coliform readings violated Class A standards in lower reaches of the river, downstream of the town of Sultan (Cusimano, 1994). Temperature and fecal coliform violations have also been recorded at a sampling station near Gold Bar (U.S. Geological Survey, 1994) (Table 7-3).

Woods Creek

Woods Creek appears to be the most degraded tributary to the Skykomish River. Fecal coliform concentrations consistently violate water quality criteria in wet and dry seasons, and the creek carries high levels of sediment during storm events. Nutrient levels are also high (Cusimano, 1994). Fricke (1994) reported that Woods Creek had fair to poor water quality, with 58 percent of fecal coliform bacteria data collected over the last seven years exceeding Class A standards. Nutrient levels were also reported high (Thornburgh et al., 1991).

Cherry and Ames/Sikes Creeks

Upstream Cherry Creek met Class A fecal coliform standards most of the time, but downstream areas exceeded fecal coliform standards. Both upstream and downstream areas met Class A dissolved oxygen and temperature standards. Turbidities were occasionally high at both sites (Thornburgh et al., 1991). In the water quality assessment reported by Joy et al. (1991), samples from Ames/Sikes Creek delivered the largest fecal coliform load of the monitored tributaries and point sources.

Patterson Creek

Poor water quality was recorded in Patterson Creek near Fall City, particularly in downstream areas. Approximately 67 percent of fecal coliform data recorded violated Class AA state water quality standards in 1994. Approximately 42 percent of dissolved oxygen levels were in violation of Class AA standards, and nutrient and turbidity levels were high. However, temperature and turbidities were low (Thornburgh et al., 1991).

Raging River

Fricke (1994) reported that Raging River water quality was fair to poor. Approximately 25 percent of fecal coliform readings were in violation of Class AA standards. Approximately 17 percent of temperature and pH readings were also in violation.

Snoqualmie River System

Ecology has conducted several water quality studies in the lower Snoqualmie River basin since 1989 to define present and potential water quality problems during the low flow season. Most reaches of the Snoqualmie River currently meet applicable Class A or AA standards during low flow periods. Temperature, pH and dissolved oxygen concentrations at some mainstem sites do not meet Class A criteria (Table 7-3), but the contribution of human-generated pollutants are not well understood. Two sites sampled by Thornburgh et al. (1991) met Class A dissolved oxygen standards and Class AA temperature standards at least 90 percent of the time. Joy et al. (1991) reported fecal coliform violations between RM 27.2 and 35.3, between 10.3 and 18.7 and between 2.7 and 9.8. These violations are contributed to by livestock in the river, bankside manure storage, failing sewage systems and careless placement of manure guns (Joy et al., 1991).

Several metals were detected in North Bend Waste Water Treatment Plant (WWTP) effluent samples. Copper, silver and zinc exceeded acute and chronic toxicity levels. Concentrations of copper from the Snoqualmie WWTP exceeded chronic and acute toxicity levels, as did some cadmium and silver concentrations. Copper, silver, zinc, lead and mercury all exceeded chronic toxicity standards in Snoqualmie WWTP effluent. Critical conditions for ammonia toxicity also occur near wastewater sources in low flow months when high pH, elevated background ammonia concentrations, low dilution and high temperature conditions are present. The highest ammonia concentrations were recorded near the Duvall WWTP (Joy, 1993).

Non-point source runoff and poorly dispersed treated effluent create most of the localized bacterial and nutrient enrichment problems on the mainstem and in some tributaries (Cusimano, 1994). With increasing population in the basin, wastewater and non-point source inputs will probably increase (Joy, 1993).

Field data and model results show dissolved oxygen concentrations in the pool above Snoqualmie Falls drop below the Class A criterion during critical conditions. Field data and model results for the Snoqualmie River at the confluence with the Skykomish River also indicate susceptibility to Class A dissolved oxygen criterion (Cusimano, 1994).

7.2 Fisheries Assessment

This fisheries assessment of the Snohomish 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 (Washington Department of Fish and Wildlife, 1994). The information provided in this report is limited to a general systemic discussion of fisheries issues. Additional information regarding fish use and habitat concerns may be available for specific stream reaches, but was not reviewed for this report. These data should be evaluated before recommendations are made concerning site-specific instream flows.

Major fish-bearing tributaries to the Snoqualmie River include the Tolt and Raging Rivers plus the North, South and Middle Forks upstream of Snoqualmie Falls. Major fish-bearing tributaries to the Skykomish include the Sultan, Beckler, Foss, Miller, South and North Fork Rivers. The Pilchuck River enters the Snohomish River downstream of the confluence of the Snoqualmie and Skykomish Rivers. Numerous other smaller but highly productive rivers, creeks and streams are also found in the basin.

7.2.1 Salmonid Distribution and Abundance

The SASSI is part of a statewide effort to identify distinct salmon and steelhead stocks and to determine their relative status. A review of the SASSI report was made to determine the abundance and distribution of genetically distinct stocks present in the Snohomish WRIA. Figure 7-2 shows key river reaches of known spawning areas. 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 spawning and/or run-timing distribution
- distinct biological characteristics (e.g. genetics, size age structure, etc.)

Chinook

Chinook salmon are generally divided into three races: spring, summer and fall chinook. In the Snohomish system, the natural spawning population has been sub-divided into four distinct stocks based on spawning distribution and timing (SASSI, 1994). The Snohomish hatchery on the Wallace River has both a summer and fall chinook program.

The Snohomish summer stock spawns primarily in September in the mainstem Snohomish and Skykomish Rivers from just downstream of the Pilchuck River confluence, to just below the confluence of the North and South Fork Skykomish Rivers. Some spawning also occurs in tributaries within this reach. The stock is considered depressed with annual escapements (based on redd counts) averaging 1,661 from 1979 to 1991 (SASSI, 1994).

The Wallace River summer/fall chinook is a mixture of stocks consisting of hatchery strays from the Skykomish Hatchery on the Wallace River. The fish spawn in September in the lower Wallace River below the hatchery rack. The stock is considered healthy with escapements averaging 1,015 fish between 1979 and 1991.

Snohomish fall chinook spawn from mid-September through October in the mainstem Snoqualmie, Sultan, Tolt, Raging and Pilchuck Rivers and Elwell, Quilceda and Woods Creeks. Spawning in each river ranges upstream to the limit imposed by either natural or man-made barriers. The stock is considered depressed with annual escapements (based on redd counts) averaging 1,722 from 1979 to 1991 (Figure 7-3) (SASSI, 1994).

Bridal Veil Creek fall chinook spawn in October in the Skykomish River and accessible tributaries upstream of Sunset Falls. Although Sunset Falls is a fish barrier, salmon are collected in a trap at the base of the falls, trucked upstream and released. Principal spawning locations include the mainstem of the North Fork upstream to near Bear Creek, the mainstem of the South Fork up to Alpine Falls and the lower reaches of Miller, Foss and Beckler Rivers. Too little information exists to assess stock status (SASSI, 1994).

Coho

Coho salmon are distributed in nearly all accessible rivers and tributaries in the Snohomish WRIA. Stocks are a mixture of native and non-native hatchery fish. Hatcheries on the Wallace River and Tulalip Bay annually release large numbers of fish to various locations on the rivers. Four primary stocks have been identified based on geographical spawning locations (SASSI, 1994). The fish all spawn from approximately late October through January (SASSI, 1994).

The Snohomish coho stock spawns primarily in the Pilchuck River and French Creek systems, although some spawning also occurs in the mainstem Snohomish River downstream of the Snoqualmie-Skykomish confluence. The stock status is considered depressed based on a severe decline in escapement observed between 1984 and 1992 (Figure 7-3). An average escapement of 2,811 fish was noted during this period in comparison with 15,174 fish observed in 1983.

The Skykomish coho stock is found in all accessible stream reaches from the mouth of the Skykomish River upstream to the confluence of the North and South Forks of the Skykomish River. This stock also utilizes the North Fork upstream to about Bear Creek. Hatchery fish are released in significant numbers in this area. The stock status is considered healthy based on records from 1981 through 1992 (SASSI, 1994).

The South Fork Skykomish coho stock uses all accessible stream reaches of the South Fork of the Skykomish River and tributaries above Sunset Falls. The stock is not considered native, as there were no natural coho spawning in this area prior to hatchery introductions. The stock is considered healthy based on steady passage counts at Sunset Falls from 1958 to 1991.

The Snoqualmie coho stock consists of those fish which use the mainstem Snoqualmie River and all accessible tributaries. A substantial number and variety of hatchery stocks have been released in the area which mixed with any native fish. The stock is considered healthy based on comprehensive escapement data collected since 1977 (SASSI, 1994).

Steelhead

Six steelhead stocks have been identified in the Snohomish system; three summer and three winter stocks. The stocks are separated based on geographical isolation of the spawning population and are not known to be genetically distinct. Summer runs spawn primarily in the upper reaches accessible to fish in the Tolt and Skykomish basins. The winter runs are much larger and spawn in all other suitable areas in the WRIA. State steelhead hatcheries on Tokul Creek off the Snoqualmie and the Wallace River off the Skykomish collect steelhead for spawning (SASSI, 1994).

The Tolt summer steelhead stock has been listed as at high risk of extinction by the American Fisheries Society (Nehlsen et al., 1991). Habitat degradation and overutilization are noted as two major threats to the stock. The fish are thought to spawn between February and April in the uppermost accessible reaches of both the North and South Forks of the Tolt River (Schuh, pers. comm., 24 January 1995; Weyerhaeuser Company, 1993). Stock status is listed as depressed based on a chronically low escapement trend (Figure 7-3). It is estimated the escapement goal of 121 fish is not met.

The North Fork Skykomish summer steelhead run spawns only upstream of Bear Creek Falls on the upper North Fork. The fish are believed to spawn between February and April. The stock status is currently listed as unknown but was depressed in the late 1980s when only 20 to 30 fish were observed (Figure 7-3) (SASSI, 1994).

The South Fork Skykomish summer steelhead run spawns upstream of Sunset Falls in the mainstem and larger tributaries up to the anadromous fish barriers. The fish are believed to spawn between

February and April. The stock status is currently listed as healthy based on a long record of hauling fish above the falls. The average number of fish trucked upstream has exceeded 1,000 over the last 10 years.

The Snohomish/Skykomish winter steelhead stock spawn primarily in the upper several miles of the mainstem Snohomish River, the mainstem Skykomish River and tributaries and the North Fork of the Skykomish River and tributaries. Isolated pairs spawn almost everywhere accessible in the Skykomish basin. Spawning generally occurs between March and mid-June. The stock is considered healthy with escapement counts stable and abundant since 1982. Mean escapement was 6,278 spawners from 1982 through 1992 (SASSI, 1994).

The Pilchuck winter steelhead stock spawn entirely in the Pilchuck River and tributaries between March and mid-June. The stock is considered healthy with the escapement trend increasing slowly since 1981.

The Snoqualmie winter steelhead spawn in the mainstem Snoqualmie, Tolt and Raging Rivers and tributaries. The majority of spawning activity starts in the mainstem Snoqualmie at about the confluence of Cherry Creek near Duvall and continues upstream to Snoqualmie Falls. Spawning typically occurs from March through mid-June. The stock is considered healthy with escapement usually meeting or exceeding goals. Estimated escapement averaged about 1,780 from 1981 to 1992 (SASSI, 1994).

Pink

Pink salmon spawn throughout the Snohomish basin in all accessible mainstem rivers and larger tributaries. Two stocks have been identified: odd-year and even-year spawners. The odd-year stock spawns from mid-September through mid-October, while the even-year stock spawns primarily in September.

The Snohomish odd-year pink stock spawns in all accessible mainstem rivers and the larger tributaries throughout the WRIA. Spawning activity is concentrated in the upper 2 miles of the Snohomish River, the lower 6 miles of the Skykomish River, above Sunset Falls on the South Fork of the Skykomish, the Snoqualmie River near Carnation and the lower reaches of the Wallace and Sultan Rivers. The stock is closely related to other Puget Sound pink stocks. Stock status is healthy with estimated escapement ranging from 66,000 to 300,000 between 1967 and 1991.

The Snohomish even-year pink stock is the only known self-sustaining run of even-year pinks in the state. They spawn in the Snohomish River from the town of Snohomish upstream to the confluence of the Snoqualmie and Skykomish Rivers. Spawning has also been observed in the lower 4 miles of the Skykomish River. The fish is distinctly different from all other pink stocks in the state and may be the result of stocking of Alaska or British Columbia stocks between 1920 and 1952. Although the stock consists of relatively few fish, with escapements ranging from 137 to 2,187 between 1980 and 1992, the stock is considered healthy based on the increasing trend.

Chum

Chum salmon in the Snohomish River have been tentatively divided into three stocks; Skykomish, Snoqualmie and Wallace. The division is based on geographic location. Fish enter the system between October and December with spawning during November and December.

The Skykomish chum run spawns primarily between Monroe and Proctor Creek, with the heaviest spawning taking place in side channels at the upper end of the range between Sultan and Gold Bar. The stock is considered to be healthy based on a long-term trend of abundant fish. Escapements range from 5,400 to 44,000 in odd years and 31,000 to 67,000 in even years.

Very little is known about the Snoqualmie chum stock. Individual fish have been observed spawning near Fall City and in the Tolt River, but no organized spawning surveys have been conducted. The stock status is unknown.

The Wallace chum stock spawns in the Wallace River and tributaries with the majority of spawning occurring in the lower 6 miles. The stock is considered healthy with escapements of 345 to 7,000 noted in odd years and 2,900 to 16,000 in even years (1968-1992).

Other Runs

Other salmon runs including sockeye (O. *nerka)* and sea-run cutthroat trout *(O. clarki)* are known to use the Snohomish basin in various locations. Because these fish are not commercially exploited, no substantial stock information is available.

Resident Fish

Resident fish are found in suitable habitat throughout the Snohomish basin in all waters capable of supporting fish life. Fish species common in the basin include rainbow trout *(O. mykiss),* cutthroat trout *(O. clarki),* mountain whitefish *(Prosopium williamsoni),* eastern brook trout *(Salvelinus fontinalis),* sculpin *(Cottus* sp.), dace *(Rhynicthys* sp.), redside shiner *(Richardsonius balteatus),* largescale sucker *(Catostomus macrocheilus),* three-spine stickleback *(Gasterosteus aculeatus),* pacific lamprey *(Lampetra ayresi),* western brook lamprey *(L. richardsoni),* black crappie *(Pomoxis nigromaculatus),* largemouth bass *(Micropterus salmoides),* peamouth *(Lepomis gibbosus)* and pumpkinseed *(Mylocheilus caurinus).*

Also possibly occurring or known to occur include a number of species of special interest including bull trout (S. *conyuentus),* sea-run cutthroat trout and pygmy whitefish *(P. coulteri).* These species may be found predominantly in the mainstem Snoqualmie, Snohomish, Pilchuck, Skykomish Rivers and tributaries, in sloughs and in smaller creeks flowing directly into the northern portion of Everett Harbor (Figure 7-2) (Washington Department of Fish and Wildlife, 1994).

Critical Spawning Habitat

Critical spawning habitat has been identified by the Washington Department of Fish and Wildlife in reaches throughout the WRIA (Figure 7-2). Critical habitat includes areas which provide habitat necessary for the perpetuation of regional fish populations.

7.2.2 General Habitat Description and Limiting Factors

Snohomish River - Confluence to the Mouth and Tributaries

The lower mainstem Snohomish River and tributaries are located in an area heavily influenced by municipal, agricultural and industrial land use. Water quality problems associated with surface-water runoff and industrial waste disposal have been reported in the lower mainstem, lower Pilchuck and estuary waters around Everett Harbor. Removal of riparian shade from throughout the WRIA has increased water temperatures in the lower river areas during the summer low flow period. As a result, higher biological oxygen demand has reduced dissolved oxygen levels at times to critical levels. These conditions have been recorded in the lower Snohomish River, Pilchuck River and French Creek. Heavy fish mortalities have been observed in Everett Harbor. Extreme low flow conditions have limited fish production in the Pilchuck River by reducing juvenile rearing area and prohibiting upstream adult fish migration. Water removal for agricultural, municipal and industrial purposes has resulted in further reduction in flows, especially in the Pilchuck River (Figure 7-3) (SASSI, 1994).

Other major man-influenced limiting factors on the lower Snohomish Basin include; extensive flood control diking, which prohibits natural channel meandering and side channel development; upstream logging, which reduces habitat-forming large woody debris (LWD) input; and gravel mining, which decreases the availability of spawning-sized gravels and increases the proportion of finer sediments. Log rafting and channel dredging activities may destroy the channel bottom, influence bank stability and increase fine sediment levels, and development along streambanks reduces shading and nutrient input and limits the habitat quality of the nearshore environment.

Snoqualmie River - Confluence to Snoqualmie Falls
(Includes the Tolt River, Raging River and Cherry and Patterson Creeks)

The Snoqualmie River below Snoqualmie Falls flows through generally rural agricultural land with only three small communities along the banks. Extensive dairy farming in the floodplain contributes to a chronic water quality problem in this area. Low summer flows and high water temperatures may also contribute to increased stress on fish residing or spawning in the reach. Particular problems have been cited in the Cherry and Patterson Creek drainages (Figure 7-3). Instream flows are controlled in the Tolt River below the City of Seattle's water reservoir on the South Fork, however, low summer flows were not cited as a limiting factor in a recent watershed assessment of the Tolt basin (Weyerhaeuser Company, 1993).

Other problems noted in the mainstem Snoqualmie and tributaries include poaching of migrating salmon in the smaller tributaries and diking and channelization in the mainstem Snoqualmie, Tolt and some tributaries. Timber harvesting activities have resulted in increased fine sediments and decreased LWD. Gravel mining in the Tolt River, tree removal from much of the mainstem Snoqualmie and some tributaries and mass wasting in the steeper basins have also contributed excess fine and coarse sediments to the river (SASSI, 1994; Washington Department of Fisheries, 1975).

Snoqualmie River - Upstream of Snoqualmie Falls

Snoqualmie Falls is a complete barrier to upstream fish migration. No anadromous salmon inhabit the Snohomish WRIA upstream of the falls. Capturing fish at the falls and trucking them upstream has been contemplated for years but has not been implemented because. of controversy surrounding potential impacts to the resident fishery (Puget Sound Power & Light, 1991). The North, South and Middle Forks of the Snoqualmie River are in relatively good condition. A number of small hydroelectric projects throughout the upper basins divert water around some of the steeper sections of creeks but do not likely result in a significant loss of habitat.

The Cities of Snoqualmie and North Bend are the only densely populated communities in the upper Snoqualmie basin. Riparian tree removal and bank protection associated with residential development decrease habitat quality somewhat in these areas. Other limiting factors include fine sediment production associated with roads and changes in hydrology from extensive land-clearing and timber harvesting in the watershed (Washington Department of Fisheries, 1975).

Skykomish River - Confluence to North and South Forks

Low summer flows in the mainstem Skykomish River and tributaries frequently impact fish use of the area. Water withdrawal impacts have also been noted on Olney. and May Creeks and the Wallace River (Figure 7-3).

To protect a number of small communities along these rivers, levees were constructed to keep the river in a restricted area. Timber harvesting practices in the upper basin have contributed to periodic fine sediment increases in some of the lower gradient reaches. Gravel removal from the lower basin has also impacted habitat (Washington Department of Fisheries, 1975).

Extreme flow conditions were present in the Sultan River prior to the construction of the Henry M. Jackson hydroelectric facility in 1984. This facility includes Culmback Dam, a powerhouse, a tunnel and a pipeline. The project impounds approximately 153,000 acre feet of water in Spada Lake. Pre-project flows in the river ranged from 48 to 34,500 cfs. To comply with instream flow agreements with federal and state agencies, post-project flows have averaged 736 cfs while ranging between 126 and 22,300 cfs (Schuh and Metzgar, 1994). Water temperatures lethal to fish were also recorded in the lower Sultan River during pre-project low flow conditions. However, these temperatures have been moderated by the increased flows and cooler water drawn from Spada Lake.

Skykomish River - Above the Confluence of the North and South Forks

Both the North and South Forks of the Skykomish River and tributaries are in relatively good condition. Because most of the upstream drainage is owned by the U.S. Forest Service, impacts are primarily due to timber harvesting activities. Riparian tree removal has impacted bank stability, nutrient input and rearing habitat. Logging roads fail on occasion, introducing large pulses of sediment. Fine sediment deposition in spawning riffles may impact fall spawners (SASSI, 1994; Washington Department of Fisheries, 1975).

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

Class	Description	Acreage	Percent
11	low density built-up and other developed	26,315	2.22%
12	high density built-up	504	0.04%
21	active agriculture	26,372	2.23%
24	other open agricultural land	6,798	0.57%
34	alpine cover	2,452	0.21%
35	other natural cover	242,603	20.48%
41	deciduous forest land	46,429	3.92%
42	coniferous forest land	666,035	56.24%
43	mixed forest land	122,991	10.38%
71	bare soil, gravel and sandy areas	18,966	1.60%
74	bare exposed rock	23,844	2.01%
90	perennial snow and ice	1,058	0.09%
	total for WRIA	1,184,367	100.00%

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

Table 4-1- Summary of Weather Stations
Snohomish WRIA

Station Name	Station ID	Period of Record		Years of Record	Percent of Record
		Begin	End		
BARING	456	Feb-70	Jun-93	24	96
CARNATION 4 NW	1146	Apr-50	Sep-51	2	74
EVERETT	2675	Jun-48	Jun-93	46	97
GOLD BAR 2 SE	3214	Nov-48	Apr-49	2	25
GROTTO	3386	Sep-55	Dec-69	15	96
INDEX	3909	Jun-48	Dec-55	8	92
INDEX 1 SSE	3910	Feb-56	Jun-57	2	41
MONROE	5525	Jun-48	. Jun-93	46	97
MOUNTAIN LAKES	2309	Jun-48	Jun-49	2	50
MOUNTAIN LAKES	5680	Jun-48	Jun-49	2	50
SCENIC	7379	Jun-48	Jul-70	23	94
SKYKOMISH	7708	Jun-48	Aug-55	8	68
SNOQUALMIE FALLS	7773	Jan-31	Jun-93	63	99
SNOQUALMIE PASS 4 W	7786	Jun-48	Nov-49	2	75
STARTUP 1 E	8034	Nov-48	Jun-93	46	96
STEVENS PASS	8089	Oct-50	Jun-93	44	89
TOLT 1 NW	1142	Oct-48	Mar-51	4	35
TOLT 1 NW	8506	Oct-48	Mar-51	4	35
TOLT SO FORK RESERVOIR	8508	Dec-62	Jun-93	32	89

Notes:

1) Data source is the National Climate Data Center.

Table 5-1 Stream Management Unit Information
Washington Administrative Code Chapter 173-507

Control Station No. Stream Management Unit Name	Location by River Mile; Sec-Twp-Rge	Affected Stream Reach Including Tributaries
12.1330.00 So. Fk. Skykomish River	51.6 28-27-10E	From confluence with N. Fk Skykomish River to headwaters.
12.1381.50 Sultan River	5.1 17-28-8E	From mouth to headwaters.
12.1411.00 Skykomish River	25.0 12-27-6E	From mouth to headwaters, excluding So. Fk. Skykomish River and Sultan River.
12.1430.00 No. Fk. Snoqualmie	2.2 26-24-8E	From mouth to headwaters.
12.1445.00 Snoqualmie River	40.0 19-24-8E	From Snoqualmie Falls to head-waters, excluding No. Fork Snoqualmie River.
12.1485.00 Tolt River	8.7 31-26-8E	From mouth to headwaters.
12.1490.00 Snoqualmie River	23.0 9-25-7E	From confluence with Harris Creek to Snoqualmie Falls, excluding Tolt River.
12. Snoqualmie River	2.5 26-27-6E	From mouth to confluence with Harris Creek, including Harris Creek.
12.1554.00 Pilchuck River	1.9 18-28-6E	From mouth to headwaters.
12.1508.00 Snohomish River	20.4 16-27-6E	From influence of mean annual high tide at low base flow levels to confluence with Skykomish River and Snoqualmie River, excluding Pilchuck River.

Table 5-2 Summary of Streamflow Gaging Stations
Snohomish WRIA

Station Name	Station ID	Latitude	Longitude	Period of Record	Length of Record (yrs)	IRPP Control Pt
TYE RIVER NEAR SKYKOMISH, WASH.	12129000	4742 20	121 17 40	1929 1946	4	F
S. F. SKYKOMISH RIVER NEAR SKYKOMISH, WASH.	12130500	47 42 20	121 18 30	1929 1950	8	F
ECKLER RIVER NEAR SKYKOMISH, WASH.	12131000	47 44 20	121 19 10	1930 1949	8	F
MILLER RIVER AT MILLER RIVER, WASH.	12132000	47 42 30	121 23 50	1911 1946	12	F
S.F. SKYKOMISH RIVER NEAR INDEX, WASH.	12133000	47 48 20	121 32 44	1903 1982	74	T
TROUBLESOME CREEK NEAR INDEX, WASH.	12133500	47 54 00	121 23 40	1929 1941	13	F
NORTH FORK SKYKOMISH RIVER AT INDEX, WASH.	12134000	47 49 10	121 33 10	1911 1948	24	F
SKYKOMISH RIVER NEAR GOLD BAR, WASH.	12134500	47 50 15	121 34 25	1929 1994	66	F
WALLACE RIVER AT GOLD BAR, WASH.	12135000	47 51 50	121 41 47	1929 1994	53	F
OLNEY CREEK NEAR GOLD BAR, WASH.	12135500	47 56 40	121 42 30	1946 1950	5	F
OLNEY CREEK NEAR STARTUP, WASH.	12136000	47 55 35	121 43 10	1923 1933	9	F
Y CREEK NEAR GOLD BAR, WASH.	12136500	47 51 30	121 36 30	1929 1947	9	F
ELK CREEK NEAR SULTAN,WASH	12137200	47 58 14	121 33 12	1977 1984	8	F
SOUTH FORK SULTAN RIVER NEAR SULTAN	12137290	47 56 51	121 37 32	1991 1994	3	F
WILLIAMSON CREEK NEAR SULTAN,WASH	12137260	47 59 09	121 36 00	1977 1984	8	F
SULTAN RIVER NEAR STARTUP, WASH.	12137500	47 58 27	121 46 47	1934 1971	38	F
SULTAN RIVER BLW DIVERSION DAM NR SULTAN, WA.	12137800	47 57 34	121 47 46	1983 1994	12	F
SULTAN RIVER NEAR SULTAN, WASH.	12138000	47 55 40	121 47 50	1912 1931	19	F
SULTAN RIVER BLW CHAPLAIN CR NR SULTAN, WASH.	12138150	47 54 52	121 48 36	1975 1985	11	T
SULTAN RIVER BLW POWERPLANT NEAR SULTAN, WA.	12138160	47 54 27	121 48 51	1983 1994	11	F
MCCOY CREEK NEAR SULTAN, WASH.	12138500	47 49 50	121 49 40	1946 1951	6	F
ROESIGER CREEK NEAR MACHIAS, WASH.	12139500	47 57 50	121 55 00	1946 1948	3	F
WOODS CREEK NEAR MONROE, WASH.	12141000	47 52 08	121 55 31	1946 1972	27	F
SKYKOMISH RIVER AT MONROE, WA.	12141100	47 51 08	121 57 29	1969 1969	1	T
MIDDLE FORK SNOQUALMIE RIVER NEAR TANNER, WA.	12141300	47 29 10	121 38 48	1961 1994	33	F
MIDDLE FORK SNOQUALMIE R NR NORTH BEND, WASH.	12141500	47 29 20	121 45 35	1907 1932	22	F
.F. SNOQUALMIE RIVER NR SNOQUALMIE FALLS, WA.	12142000	47 36 54	121 42 44	1930 1994	53	F
CALLIGAN CREEK NR SNOQUALMIE, WASH.	12142200	47 36 05	121 41 20	1964 1970	7	F
HANCOCK CREEK NR SNOQUALMIE, WASH.	12142300	47 34 21	121 41 12	1964 1971	8	F
.F. SNOQUALMIE R AT CABLE BR NR NORTH BEND, WA.	12142500	47 34 20	121 42 50	1914 1915	2	F
.F. SNOQUALMIE RIVER NEAR NORTH BEND, WASH.	12143000	47 32 15	121 44 26	1907 1971	40	T
SF SNOQUALMIE R AB ALICE CR NR GARCIA, WASH.	12143400	47 24 50	121 35 10	1961 1994	34	F
S.F. SNOQUALMIE RIVER NR GARCIA, WASH.	12143500	47 25 00	121 35 20	1910 1915	6	F
SF SNOQUALMIE E AT EDGEWICK WASH	12143600	47 27 10	121 43 10	1962 1994	13	F
BOXLEY CREEK NEAR CEDAR FALLS, WASH.	12143700	47 25 58	121 45 04	1945 1994	49	F
OXLEY CREEK NEAR EDGEWICK, WASH.	12143900	47 26 56	121 43 50	1980 1994	13	F
S.F. SNOQUALMIE RIVER AT NORTH BEND, WASH.	12144000	47 29 18	121 47 03	1907 1994	55	F
SNOQUALMIE RIVER NEAR SNOQUALMIE, WASH.	12144500	47 32 43	121 50 28	1898 1994	64	T
BEAVER C NR SNOQUALMIE WN	12144800	47 37 55	121 45 00	1964 1967	4	F
TOKUL CREEK NEAR SNOQUALMIE, WASH.	12145000	47 33 20	121 50 15	1907 1945	13	F
RAGING RIVER NEAR FALL CITY, WASH.	12145500	47 32 24	121 54 28	1945 1994	33	F
PATTERSON CREEK NEAR FALL CITY, WASH.	12146000	47 34 52	121 56 23	1947 1972	22	F
GRIFFIN CREEK NEAR CARNATION, WASH.	12147000	47 36 58	121 54 15	1945 1970	26	F
NORTH FORK TOLT RIVER NEAR CARNATION, WASH.	12147500	47 42 45	121 47 15	1953 1994	37	F
SOUTH FORK TOLT RIVER NEAR INDEX, WASH.	12147600	47 42 25	121 35 56	1960 1994	29	F
PHELPS CREEK NEAR INDEX, WASH.	12147700	47 42 20	121 36 05	1961 1961	1	F
S F TOLT RIVER AT UPPER STA. NR CARNATION, WA.	12147800	47 42 30	121 36 50	1958 1959	2	F

Table 5-2 Summary of Streamflow Gaging Stations (continued)
Snohomish WRIA

Station Name	Station ID	Latitude	Longitude	Period of Record	Length of Record (yrs)	IRPP Control Pt
SOUTH FORK TOLT RIVER NR CARNATION, WASH.	12148000	47 41 22	121 42 44	1953 1994	38	F
S F TOLT R BLW REGULATING BASIN NR CARNATION, W	12148300	47 41 52	121 47 05	1982 1994	12	F
OLT RIVER NEAR CARNATION, WASH.	12148500	47 38 15	121 54 55	1928 1994	60	T
STOSSEL CREEK NEAR CARNATION, WASH.	12148700	47 41 45	121 49 50	1957 1963	7	F
SNOQUALMIE RIVER NEAR CARNATION, WASH.	12149000	47 39 58	121 55 27	1929 1994	66	T
CHERRY CREEK NEAR DUVALL, WASH.	12150500	47 44 40	121 56 35	1945 1964	8	F
SNOHOMISH RIVER NEAR MONROE, WASH.	12150800	47 49 52	122 02 50	1963 1994	31	T
PILCHUCK RIVER NEAR GRANITE FALLS, WASH.	12152500	48 03 15	121 57 25	1911 1958	17	F
LITTLE PILCHUCK C NEAR LAKE STEVENS, WASH.	12153000	48 02 00	122 03 04	1947 1970	23	F
STEVENS CREEK AT LAKE STEVENS, WASH.	12154000	480100	122 03 10	1946 1950	5	F
DUBUQUE CR NR LAKE STEVENS WASH	12154500	47 58 25	122 01 40	1946 1951	6	F
PILCHUCK RIVER NEAR SNOHOMISH, WASH.	12155300	47 56 06	122 04 19	1992 1994	3	F
SNOHOMISH R AT SNOHOMISH	12155500	47 54 38	122 05 52	1966 1966	1	F
WOOD CREEK NEAR EVERETT, WASH.	12156000	47 55 25	122 11 00	1946 1948	3	F
QUILCEDA CREEK NEAR MARYSVILLE, WASH.	12157000	48 06 20	122 09 40	1946 1977	27	F
QUILCEDA CR ABV WEST FORK NR MARYSVILLE, WASH.	12157005	48 05 08	122 10 26	1985 1985	1	F
MISSION CR NR TULALIP	12157250	48 03 31	122 15 58	1975 1977	3	F
TULALIP CR AT TULALIP	12158040	48 04 09	122 17 08	1975 1977	3	F

Notes:
1) Data sources include the Washington State Department of Ecology, Water Resources Division and the US Geological Survey
2) IRPP indicates whether the station is a Instream Resource Protection Program control point (i.e. "T").

Table 7-1 Water quality limited water body segments in the Snohomish WRIA.

Waterbody Segment	Water Body	Parameter in Violation
WA-07-0010	Port Gardner and Inner Everett Harbor	Dissolved Oxygen
		PCBs
		Petroleum Hydrocarbons
		Mercury
		Organics
		Metals
WA-07-1010	Snohomish River	Organics
		PCBs
		Phenols
WA-07-1011	Ebey Slough	Dissolved Oxygen
WA-07-1012	Allen Creek	Fecal Coliform
WA-07-1015	Quilceda Creek	Dissolved Oxygen
		Fecal Coliform
WA-07-1020	Snohomish River	Temperature
		Fecal Coliform
WA-07-1030	Pilchuck River	Fecal Coliform
		Temperature
WA-07-1040	Pilchuck River	Temperature
WA-07-1050	Snohomish River	Dissolved Oxygen
		Fecal Coliform
WA-07-1052	French Creek	Dissolved Oxygen
		Fecal Coliform
WA-07-1060	Snoqualmie River	Temperature
		Fecal Coliform
WA-07-1062	Cherry Creek	Fecal Coliform
WA-07-1066	Ames Creek	Fecal Coliform
WA-07-1100	Snoqualmie River	Fecal Coliform
WA-07-1102	Patterson Creek	Dissolved Oxygen
		Fecal Coliform

Waterbody Segment Number	Water Body	Parameter in Violation
WA-07-1104	Raging River	Fecal Coliform
WA-07-1106	Tokul Creek	Temperature
WA-07-1108	Kimball Creek	Fecal Coliform
WA-07-1160	Skykomish River	Fecal Coliform
		Temperature
WA-07-1163	Woods Creek	Fecal Coliform
WA-07-1200	Skykomish River	Fecal Coliform
		Temperature
WA-07-9060	Blackman's lake	Phosphorus
WA-07-9190	Crabapple Lake	Phosphorus
WA-07-9280	Lake Goodwin	Phosphorus
WA-07-9440	Lake Loma	Phosphorus
WA-07-9680	Lake Shoecraft	Phosphorus

Table 7-2 EPA STORET water quality database search results for the Snohomish River basin.

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)	6817	9.5	28.4	0	7/59 to 9/93	None	16	18
Turbidity (NTU)†	560	3.6	57	.1	9/85 to 9/93	<1 unit chg.	<5 unit chg. or <10% increase[2]	
Diss. Oxygen (mg/I)	4687	11.32	20	.1	7/59 to 9/93	None	>9.5	>8
pH	5101	7.1	10	3.6	1/48 to 9/93	None	6.5-8.5	6.5-8.5
Fecal Coliform	609	48.8	2400	0	8/66 to 9/82	0	50	100
Ammonia (mg/1)	3149	.22	140	0	10/70 to 8/93	None	24	24
N02 and N03	2343	.27	4.4	0	5/71 to 8/93	None	10	10
Copper (ug/1)	396	11.4	150	0	3/66 to 10/91	1000	5.29*	
Lead (ug/1)	337	136	6250	0	11/70 to 9/87	50	13.4*	
Zinc(ug/1)	389	26.2	850	0	3/66 to 10/91	5000	40.23*	
Mercury (ug/1)	344	.34	1	0	11/70 to 9/87	2	2.4	
Cadmium (ug/1)	175	2.43	50	0	5/73 to 9/87	10	.95*	
I Chromium (ug/1) I	282 I	6.32	100	0	3/66 to 10/86	50	691.7*	

†Nephelometric Turbidity Units
[2]Dependent on background turbidity levels
*Acute standards based on a recorded hardness of 32.5.

Table 7-3 Water quality data collected at stations throughout the Snohomish WRIA.

	Location						
Parameter	**Sammammish River near Bothell**	**Skykomish River Near Gold Bar**	**Tolt River Near Carnation**	**Snoqualmie River Near Carnation**	**Tulalip Creek Near Tulalip**	**Snohomish River Near Snohomish**	**Snohomish River Near Monroe**
Temperature (ºC, min/max)	0.7-24	1-18.3	3.7-23.2	0.3-22.2	0.7-16	0.1-24	0.9-21."7
Dissolved Oxygen (mg/l, min/max)	6.9-13.2	9.6-13.9	8.7-14.7	8.2-15.2	9.7-10.8	8.1-17	3.8-13.5
Fecal Coliform (/100m1, min/max)	50-2400	N/A	N/A	N/A-120	19-570	27-37	1-1100
Turbidity (NTU, max/min)	3-12	1-25	N/A	1-50	N/A	1-60	1-32
Mean Nitrate+ Nitrite (mg/1)	0.5	0.2	N/A	0.2	1.5	0.3	0.3
pH (min/max)	6.6-7.9	6.1-7.7	6.3-7.7	3.6-8.2	6.9-7.3	6.1-8.7	5.8-7.8

Source: U.S. Geological Survey 1994.

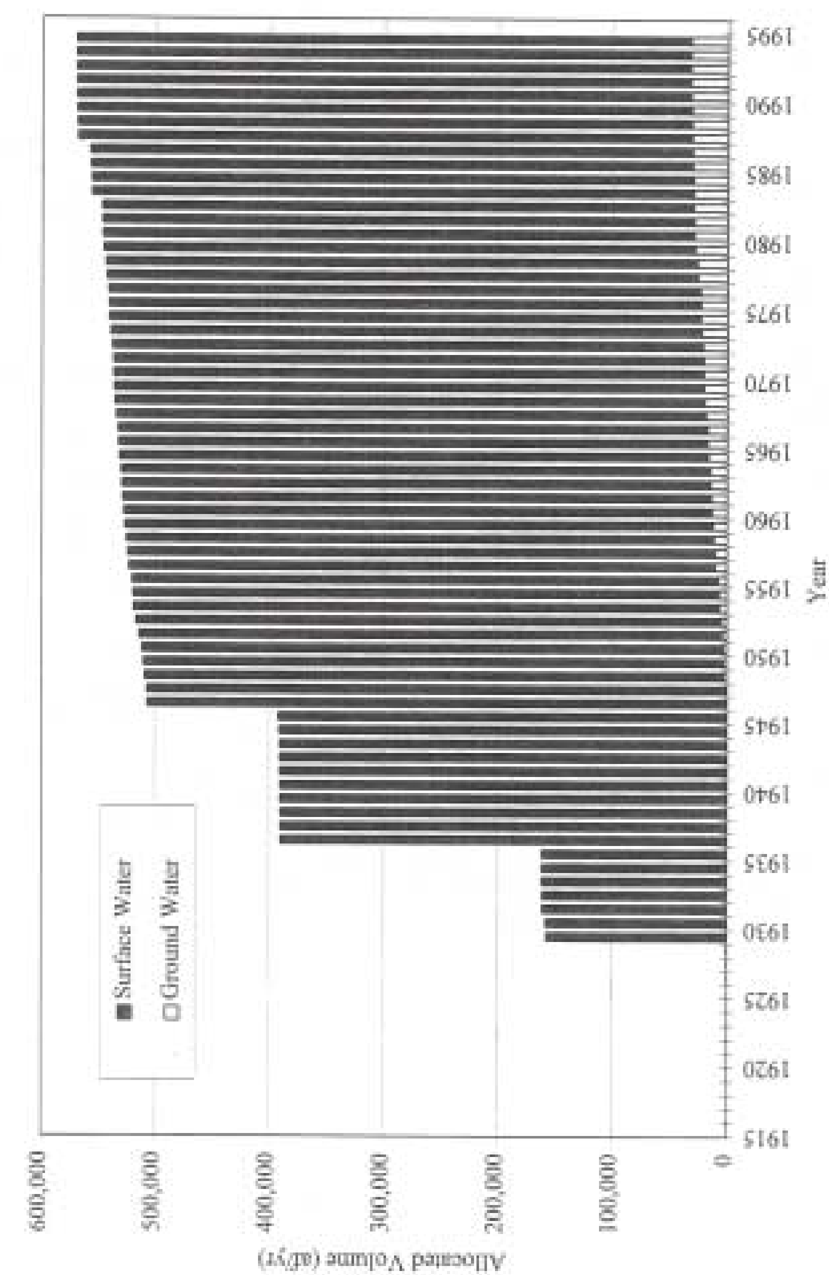


FIGURE 3-1

Water Rights Versus Time

Initial Watershed Assessment Program
Snohomish Basin

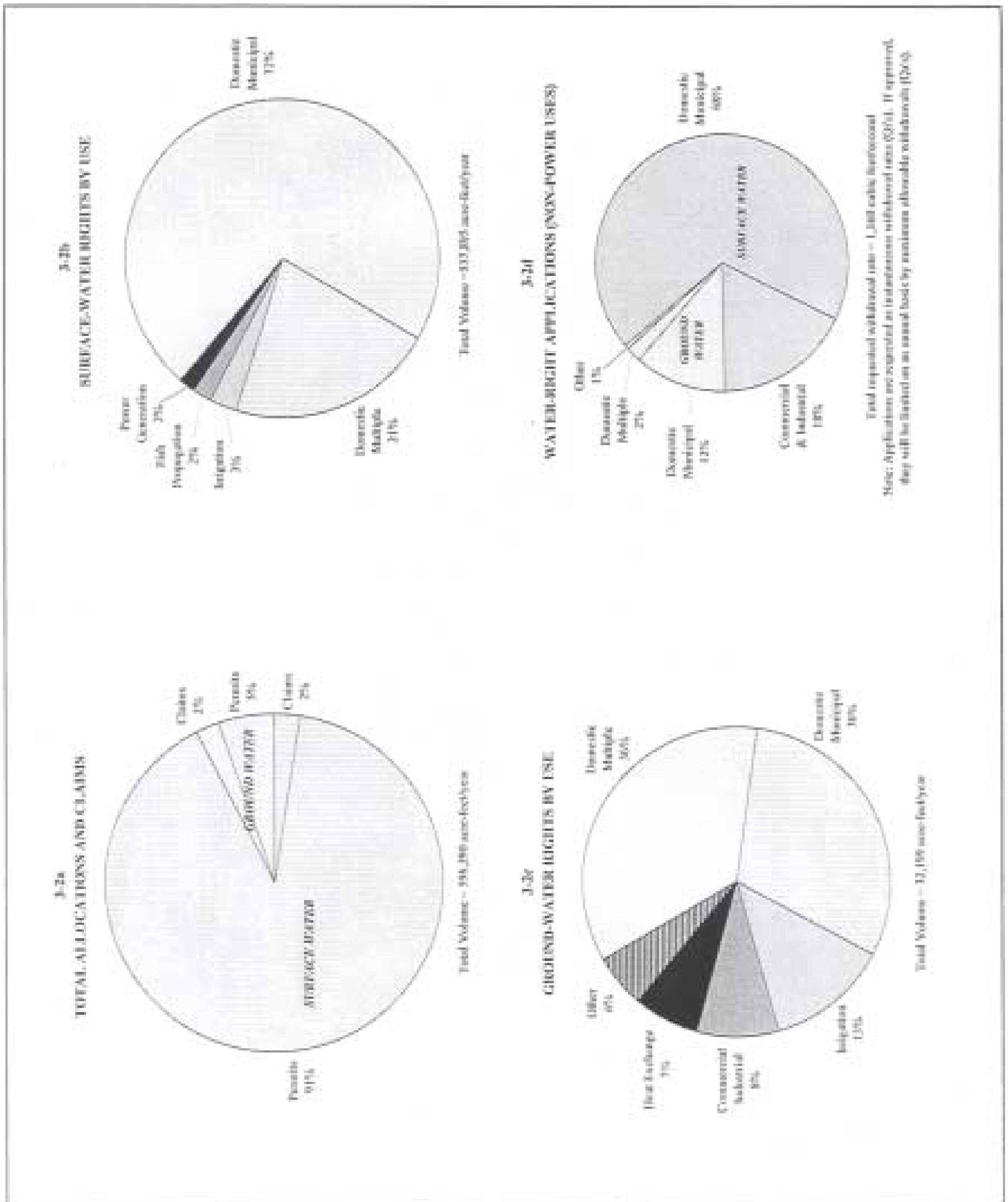


FIGURE 3-2(a-d)

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

Initial Waterhed Assessment Program
Snohomish Basin

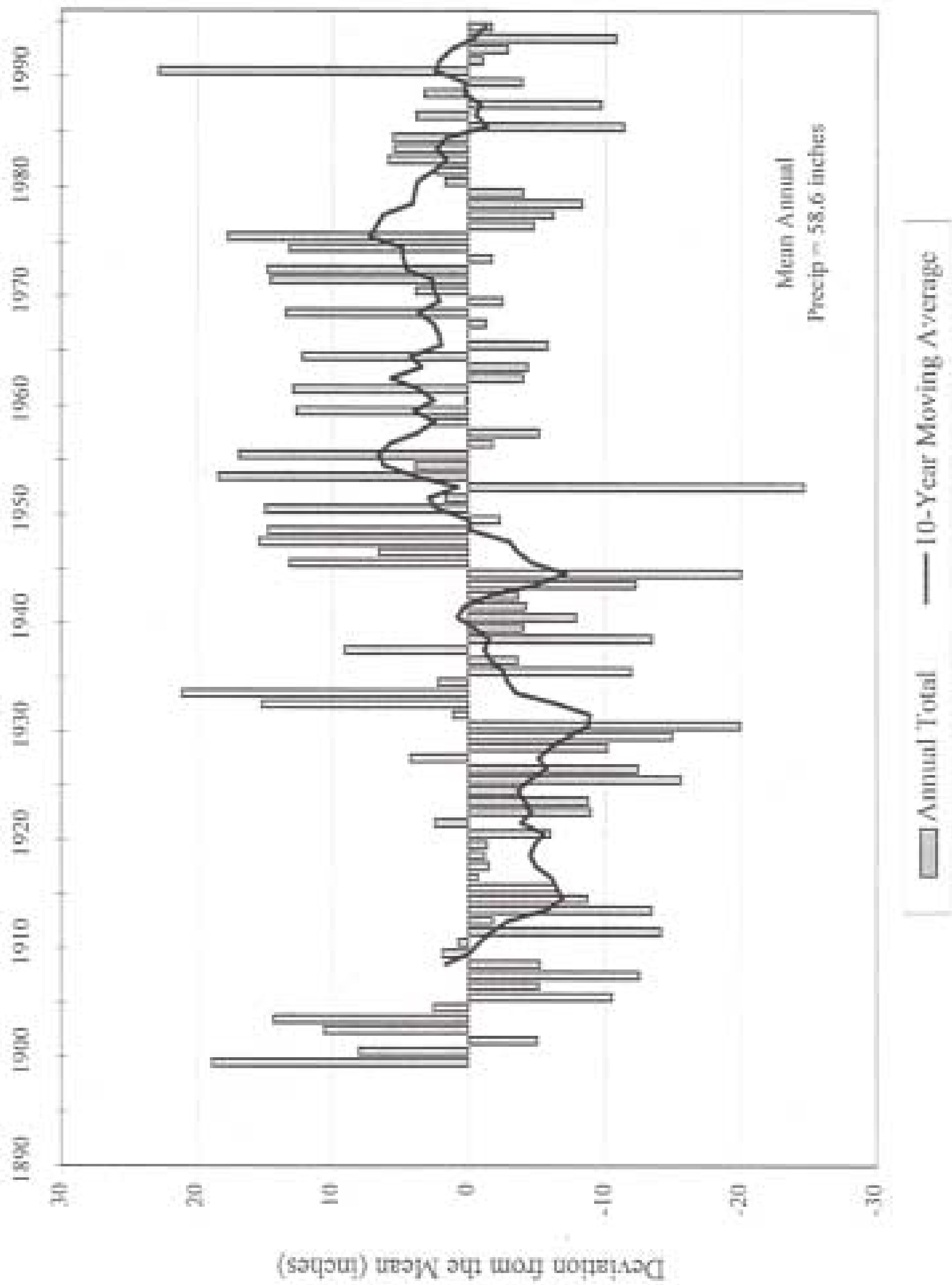


FIGURE 4-3

Annual Precipitation at Snoqualmie Falls

Initial Watershed Assessment Program
Snohomish Basin

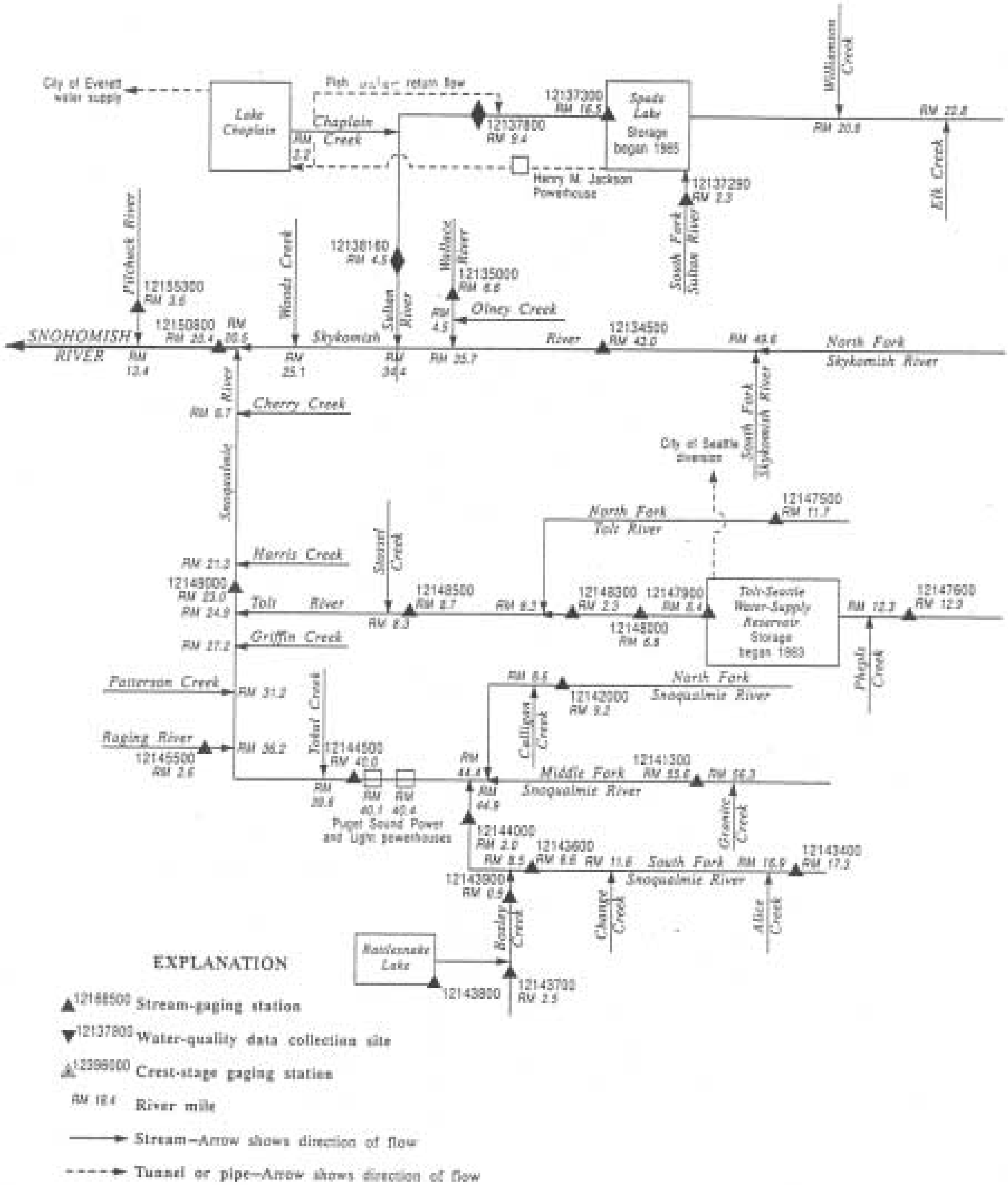


Figure 5-1. Gaging Stations in Snohomish River Basin
(From U.S.G.S. Water Resources Data, 1993)

S.F. Skykomish River near Index, Gage 12133000
Average Annual Streamflows and Departures from Average

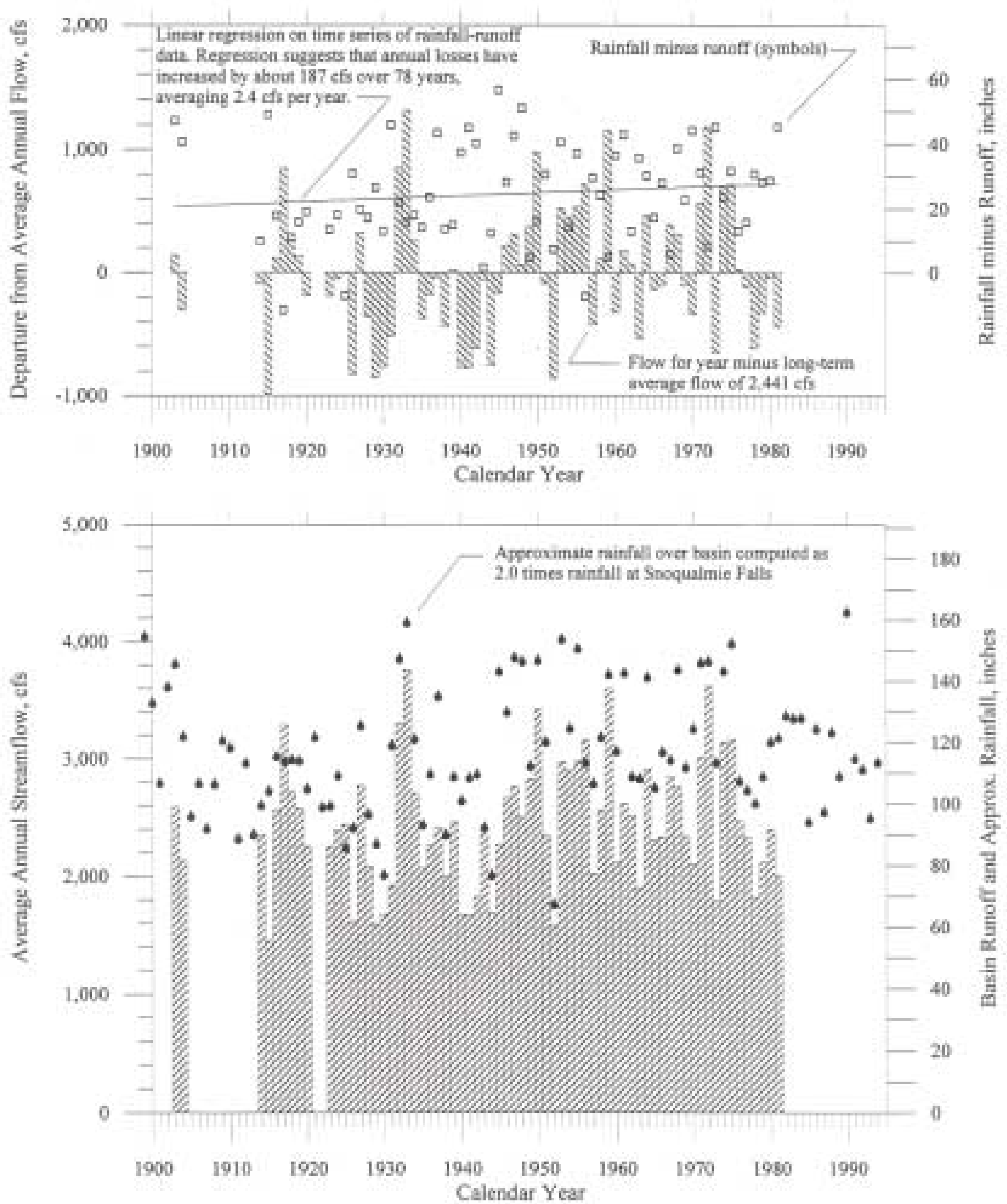


FIGURE 5-2
Average Flows and Trend Analysis
South Fork Skykomish River near Index
Basin Area 355 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

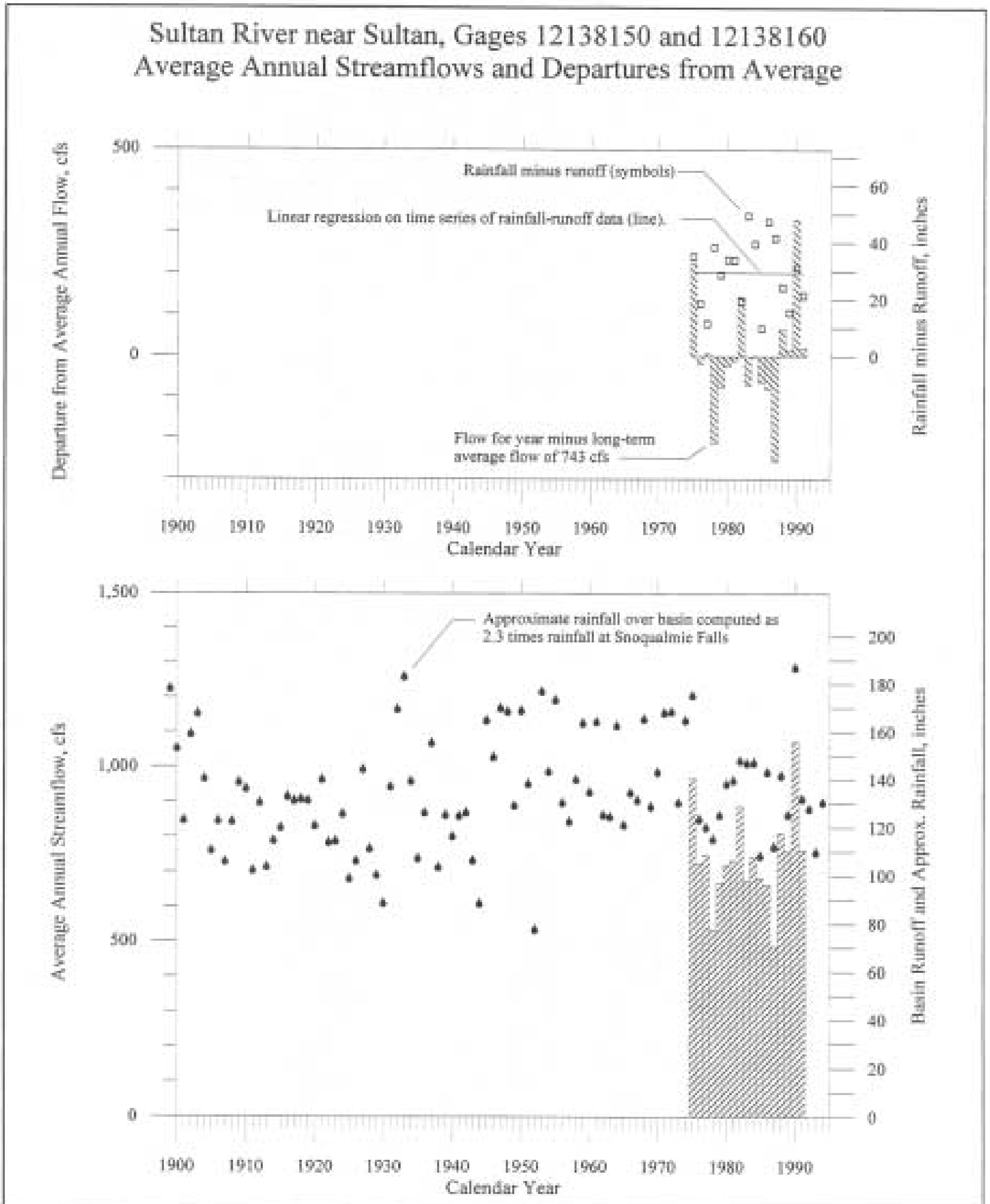


FIGURE 5-3
Average Flows and Trend Analysis
Sultan River near Sultan
Basin Area 93.5 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

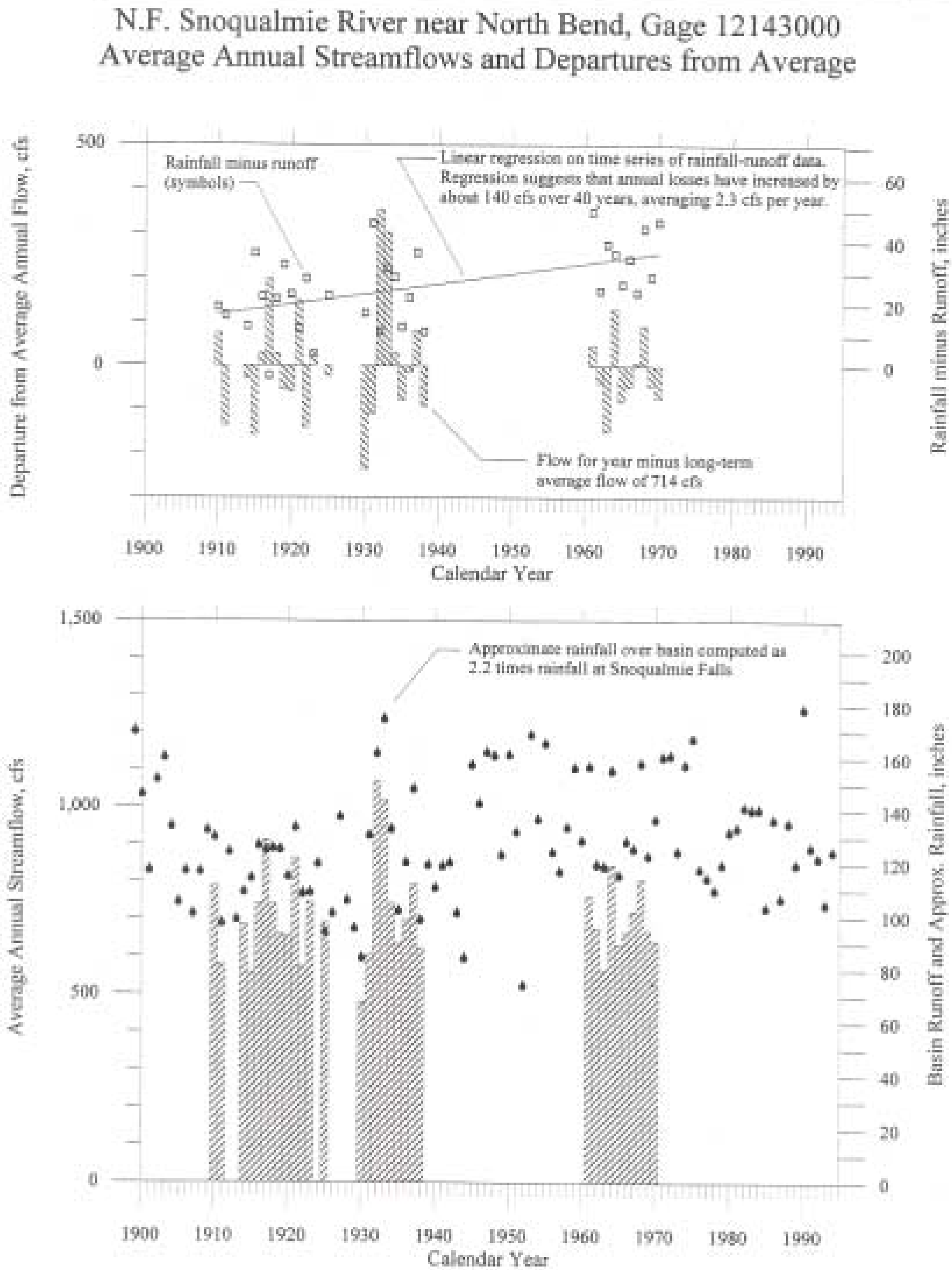


FIGURE 5-4
Average Flows and Trend Analysis
N.F. Snoqualmie River near North Bend
Basin Area 96 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

Snoqualmie River near Snoqualmie, Gage 12144500
Average Annual Streamflows and Departures from Average

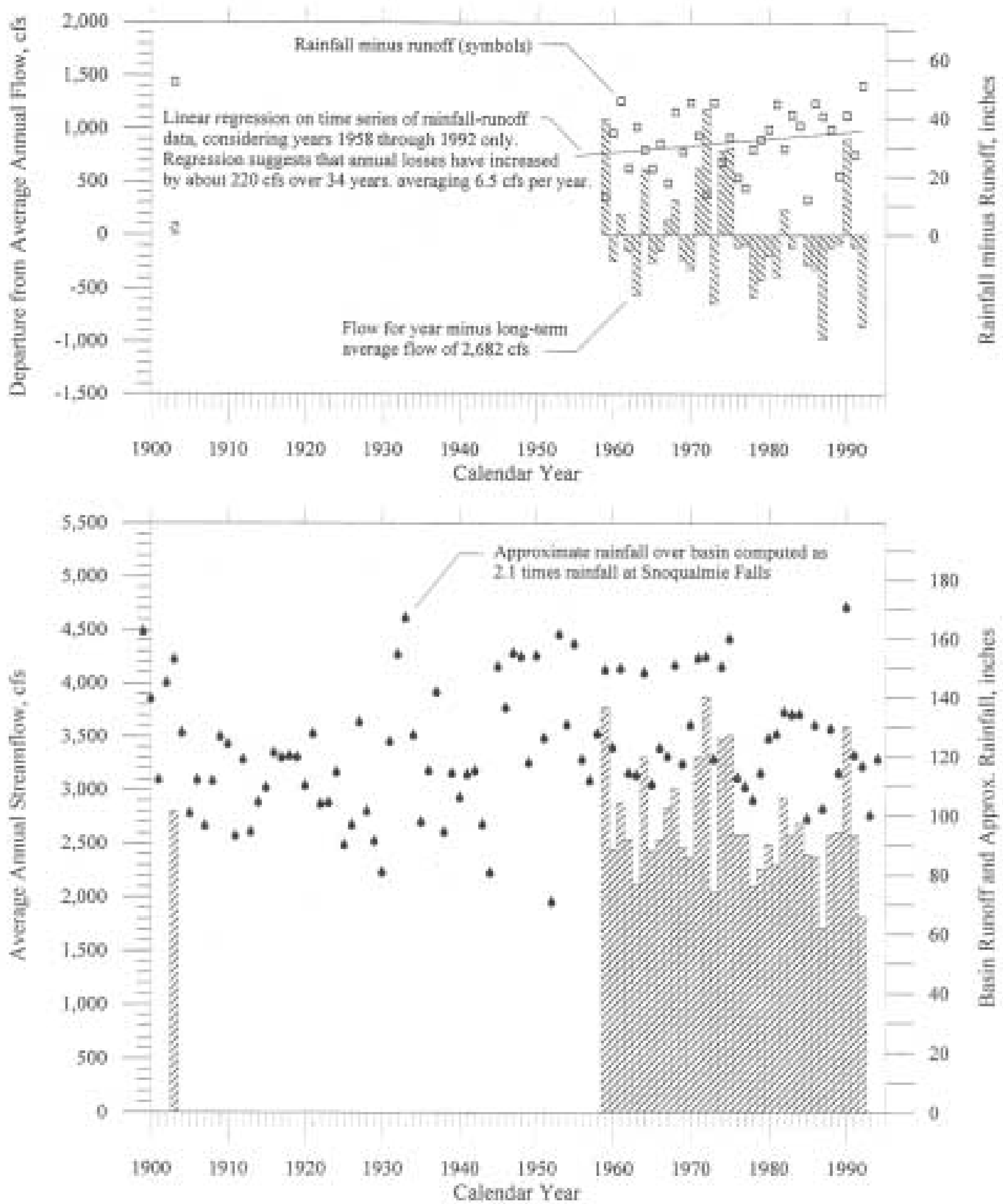


FIGURE 5-5
Average Flows and Trend Analysis
Snoqualmie River near Snoqualmie
Basin Area 375 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

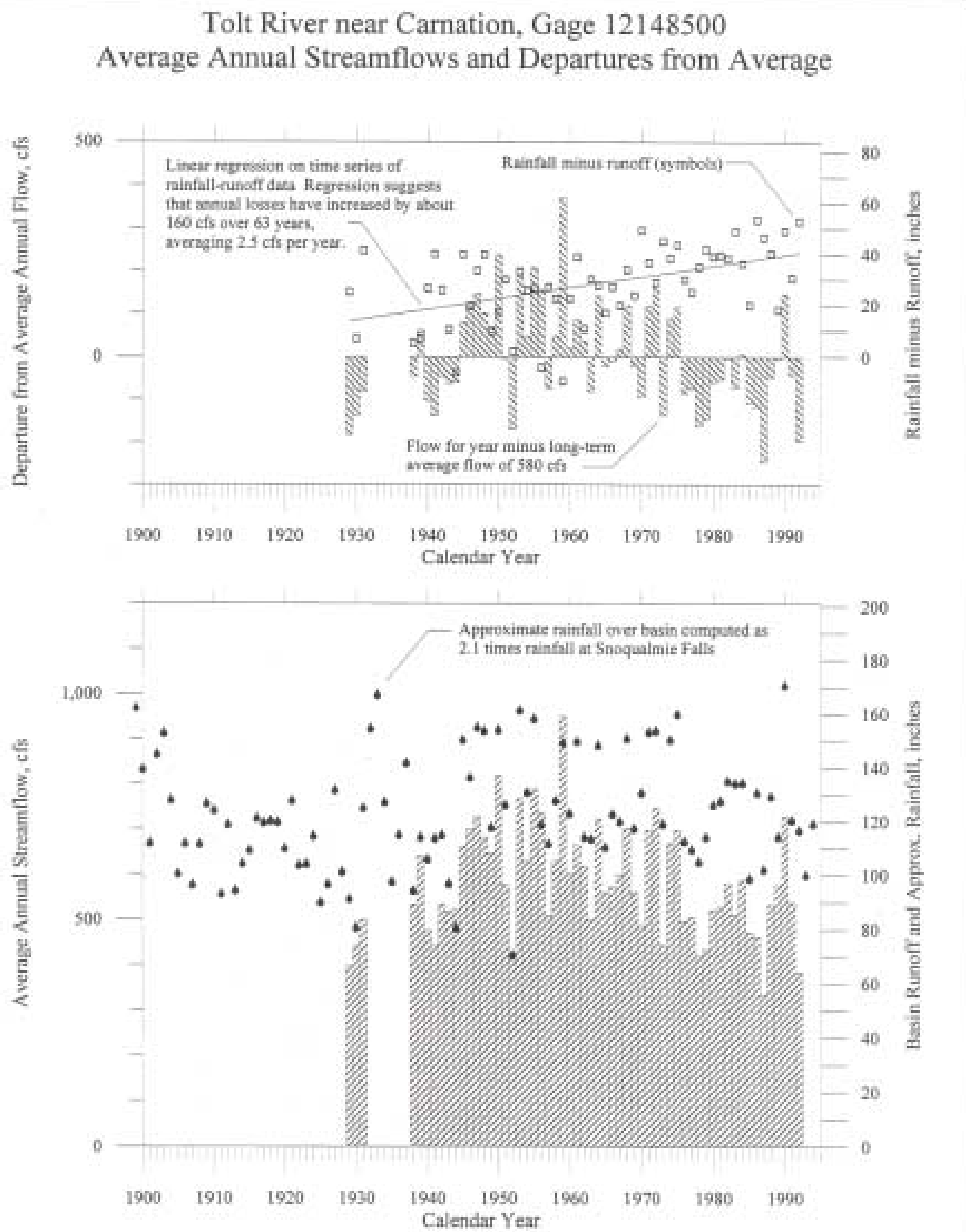


FIGURE 5-6
Average Flows and Trend Analysis
Tolt River near Carnation
Basin Area 81 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

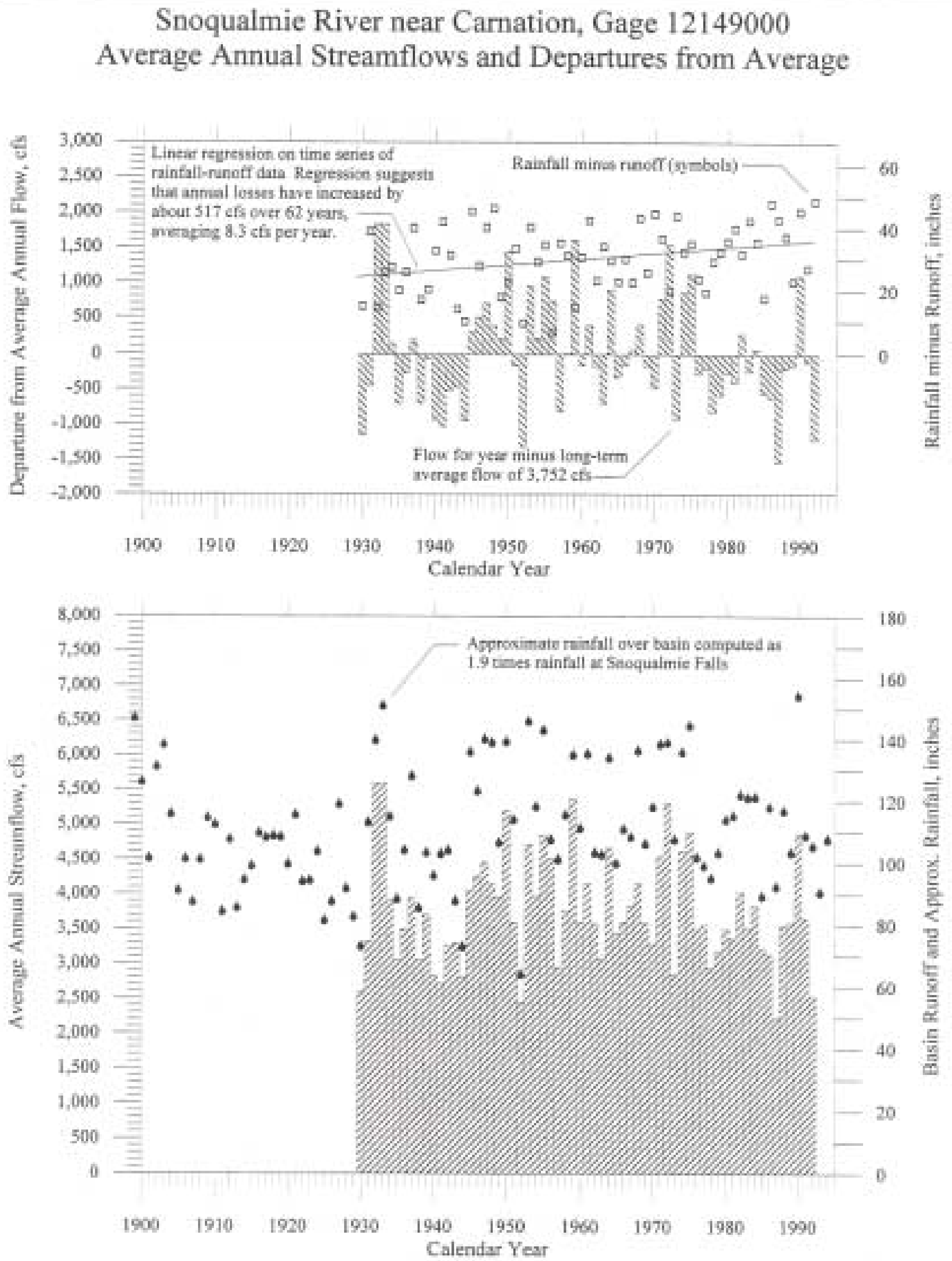


FIGURE 5-7
Average Flows and Trend Analysis
Snoqualmie River near Carnation
Basin Area 603 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

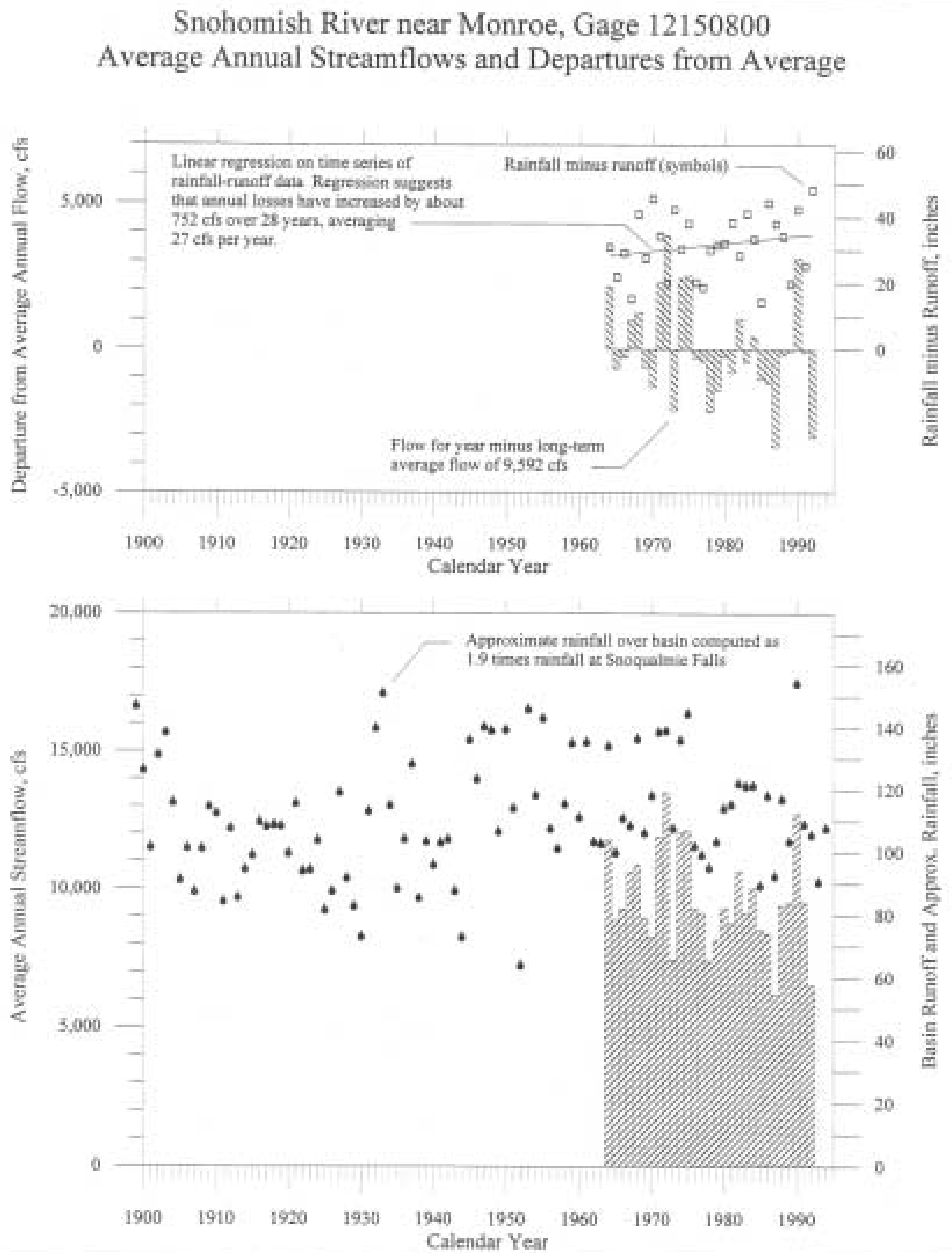


FIGURE 5-8
Average Flows and Trend Analysis
Snohomish River near Monroe
Basin Area 1,537 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

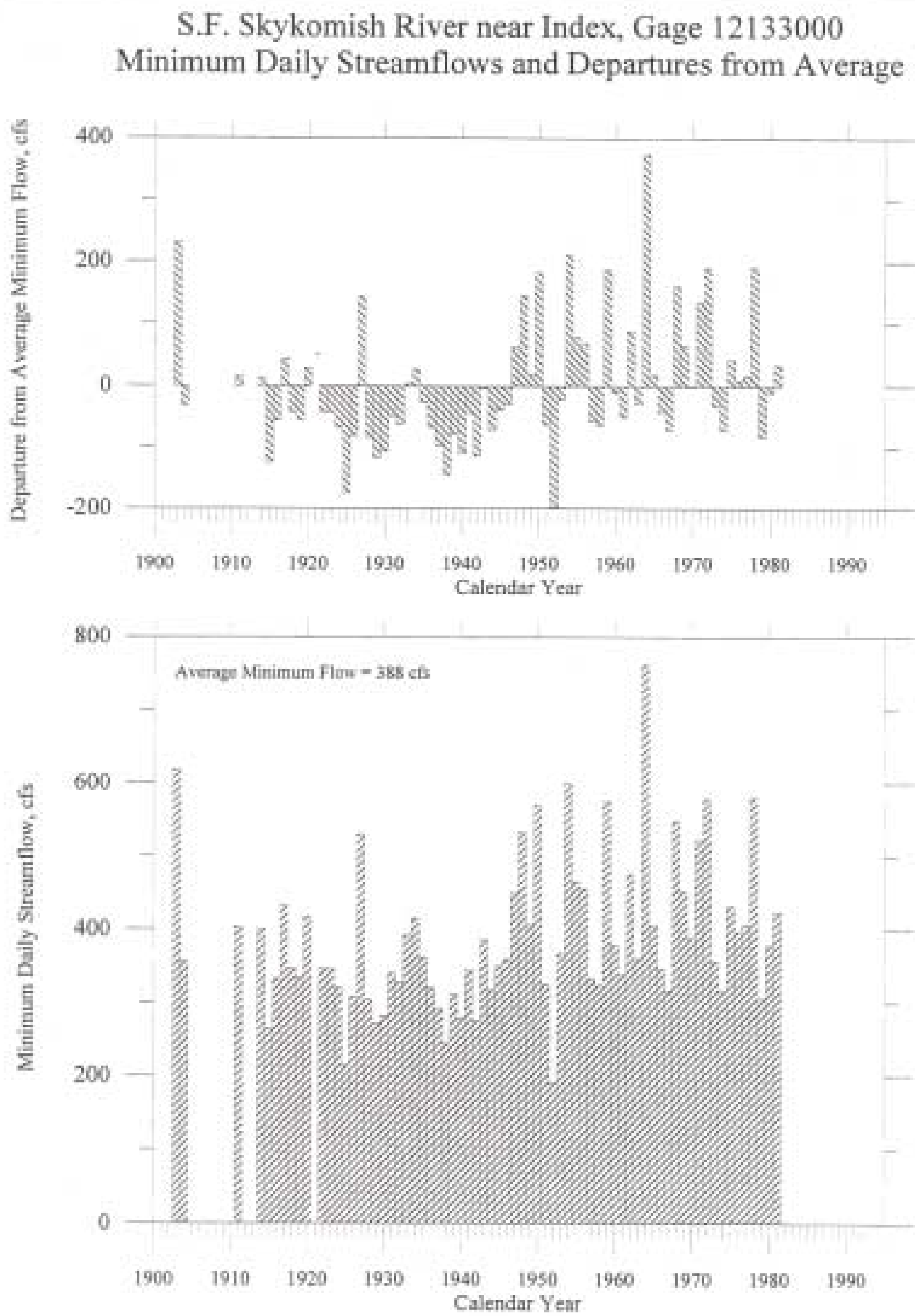


FIGURE 5-9
Minimum Flows and Trend Analysis
South Fork Skykomish River near Index
Basin Area 355 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

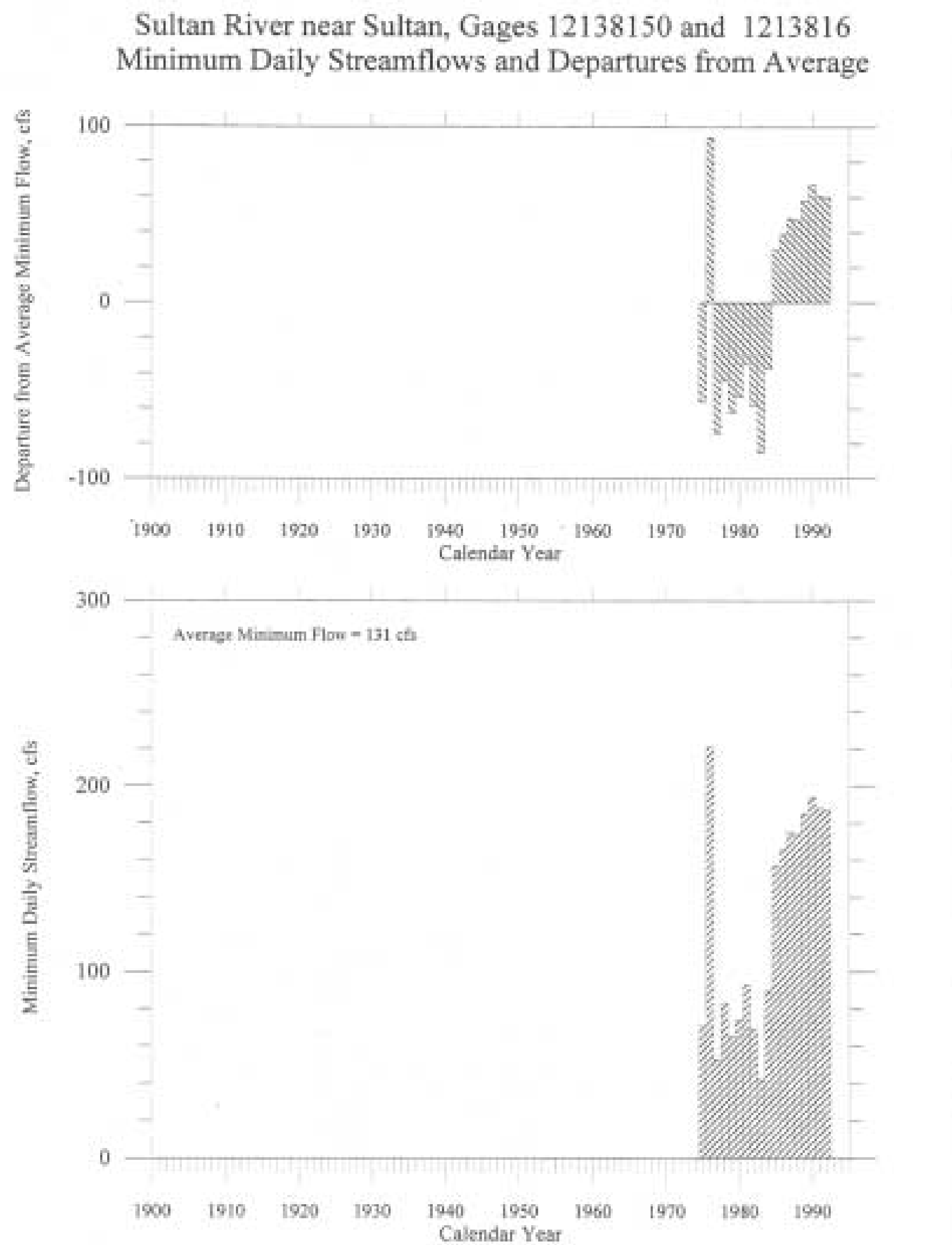


FIGURE 5-10
Minimum Flows and Trend Analysis
Sultan River near Sultan
Basin Area 93.5 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

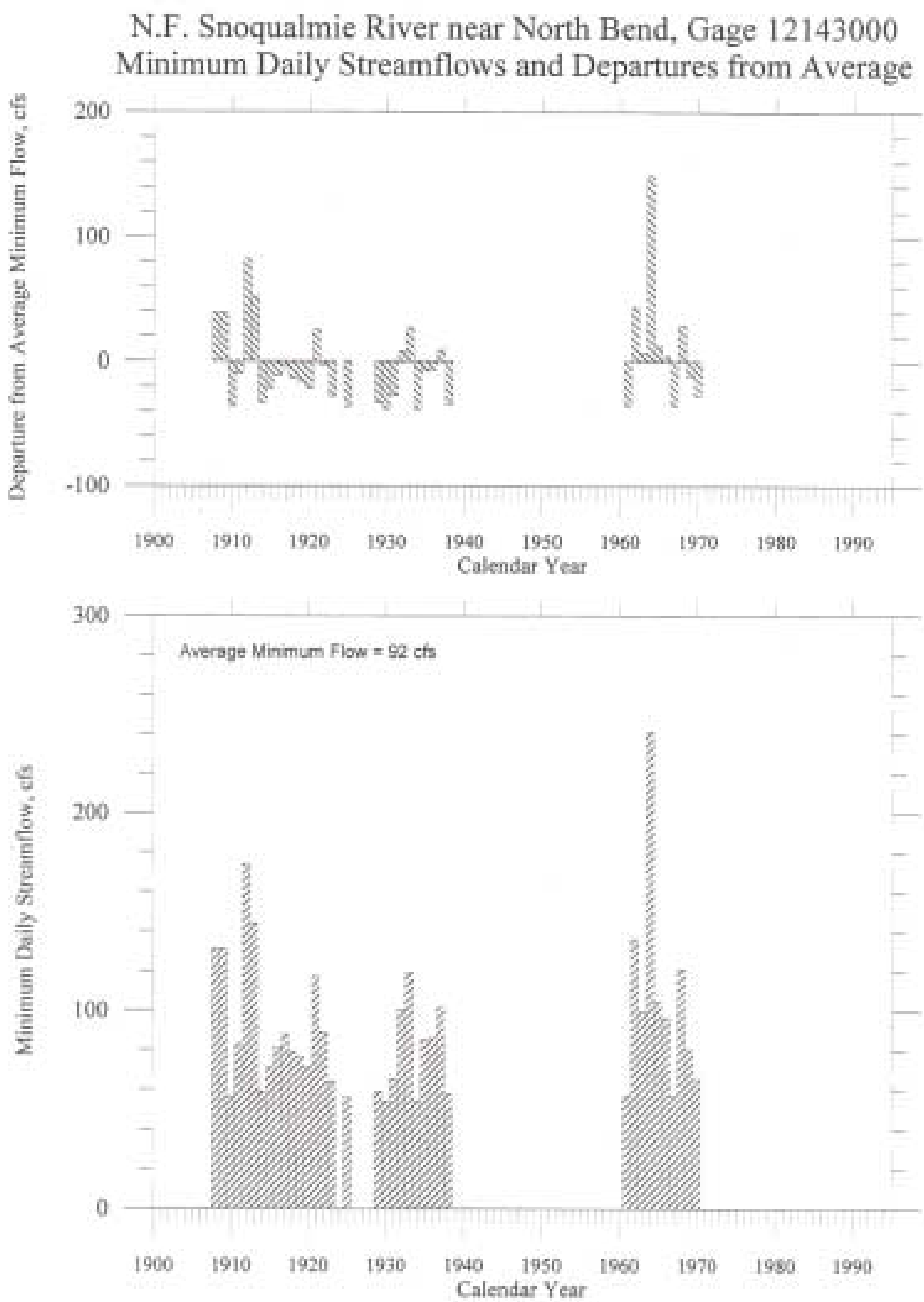


FIGURE 5-11
Minimum Flows and Trend Analysis
N.F. Snoqualmie River near North Bend
Basin Area 96 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

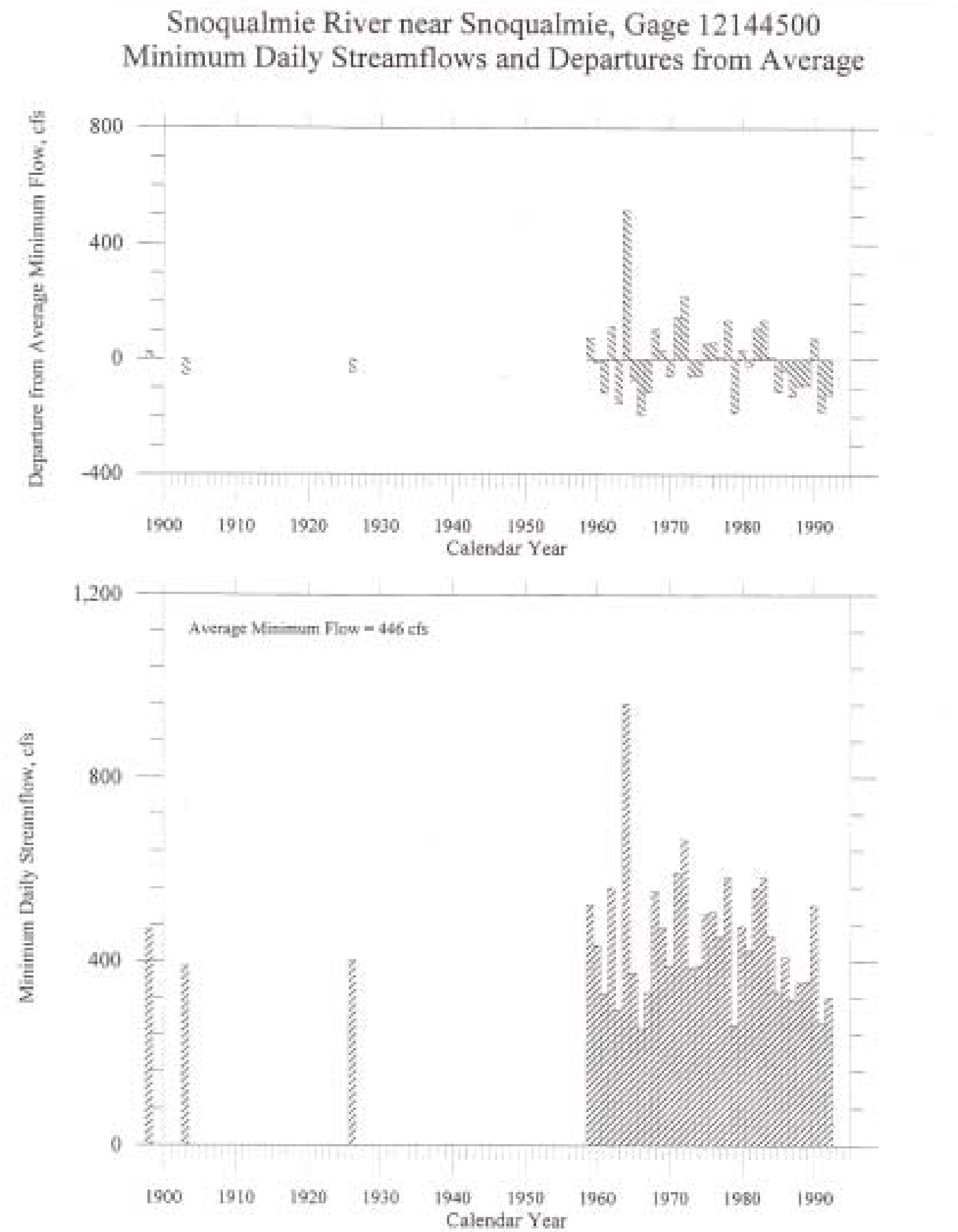


FIGURE 5-12
Minimum Flows and Trend Analysis
Snoqualmie River near Snoqualmie
Basin Area 375 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

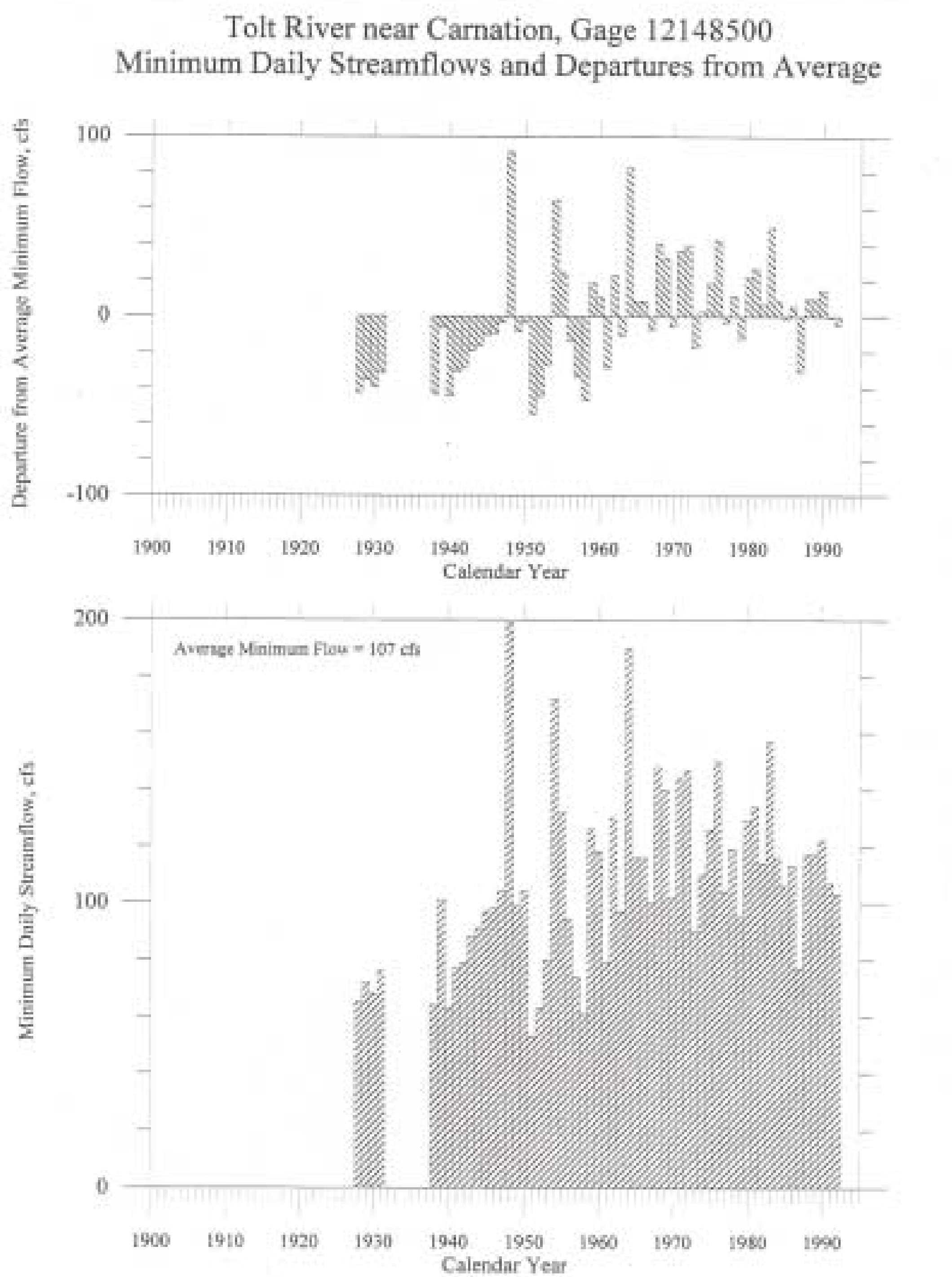


FIGURE 5-13
Minimum Flows and Trend Analysis
Tolt River near Carnation
Basin Area 81 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

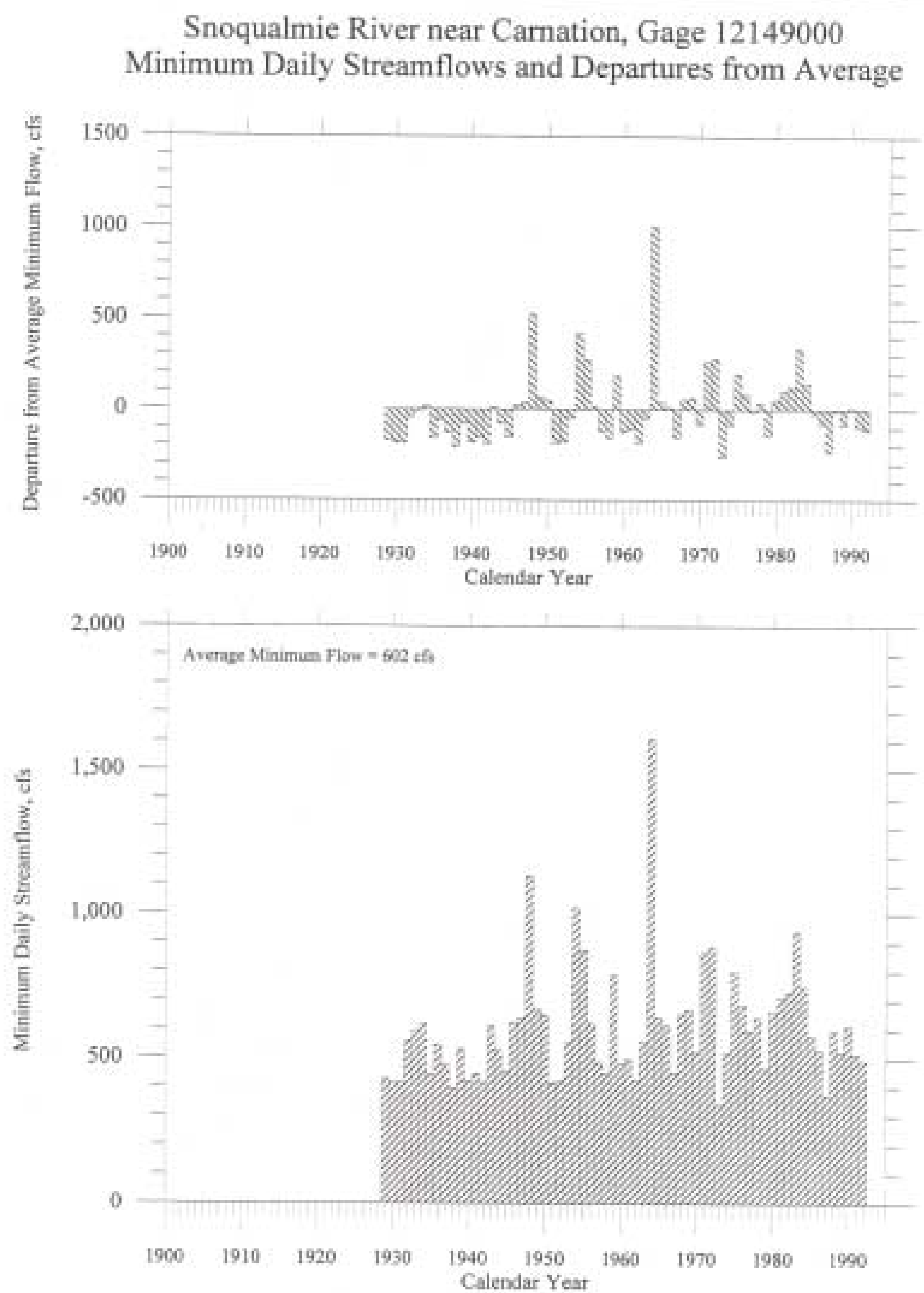


FIGURE 5-14
Minimum Flows and Trend Analysis
Snoqualmie River near Carnation
Basin Area 603 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

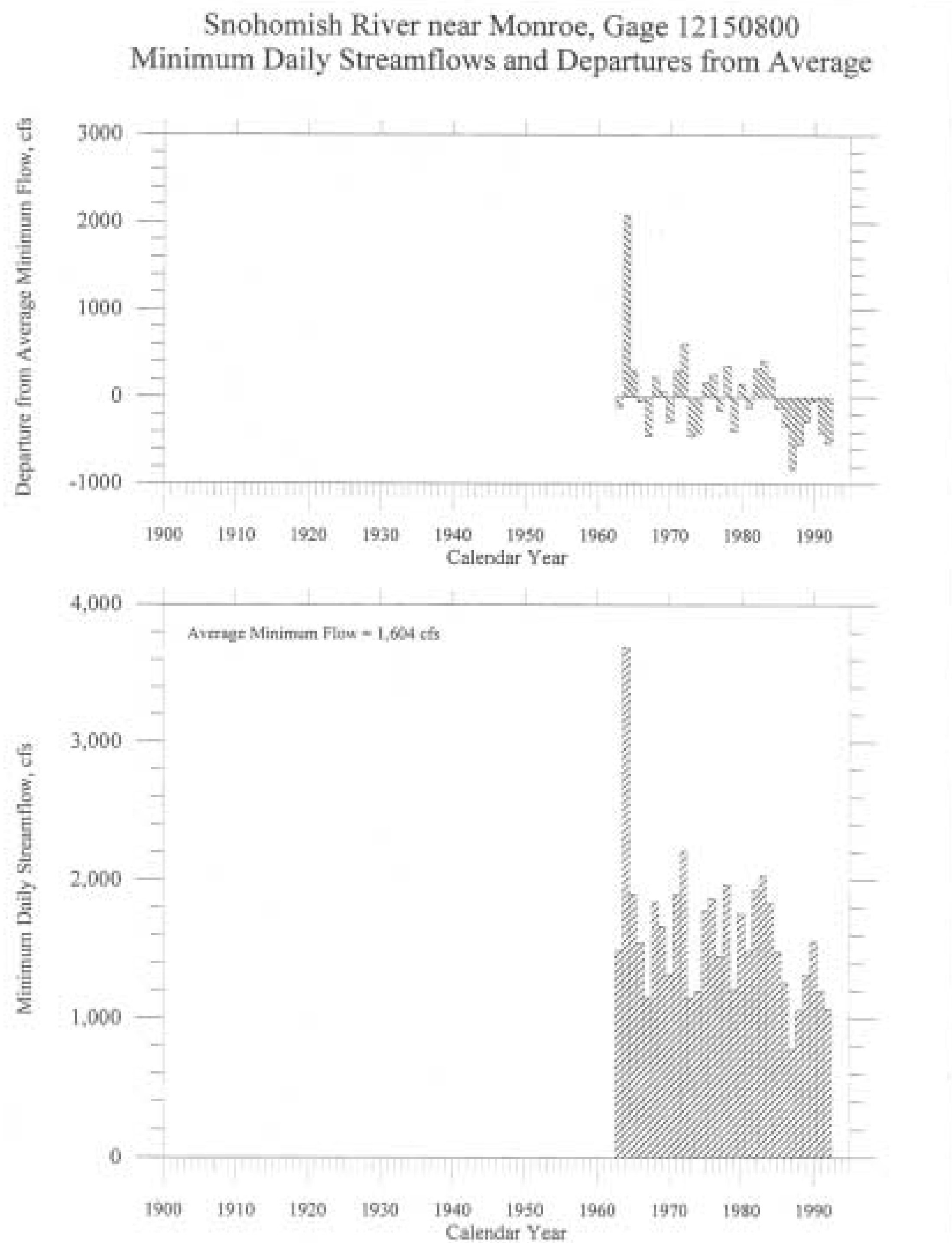


FIGURE 5-15
Minimum Flows and Trend Analysis
Snohomish River near Monroe
Basin Area 1,537 sq. mi.

Initial Watershed Assessment Program
Snohomish Basin

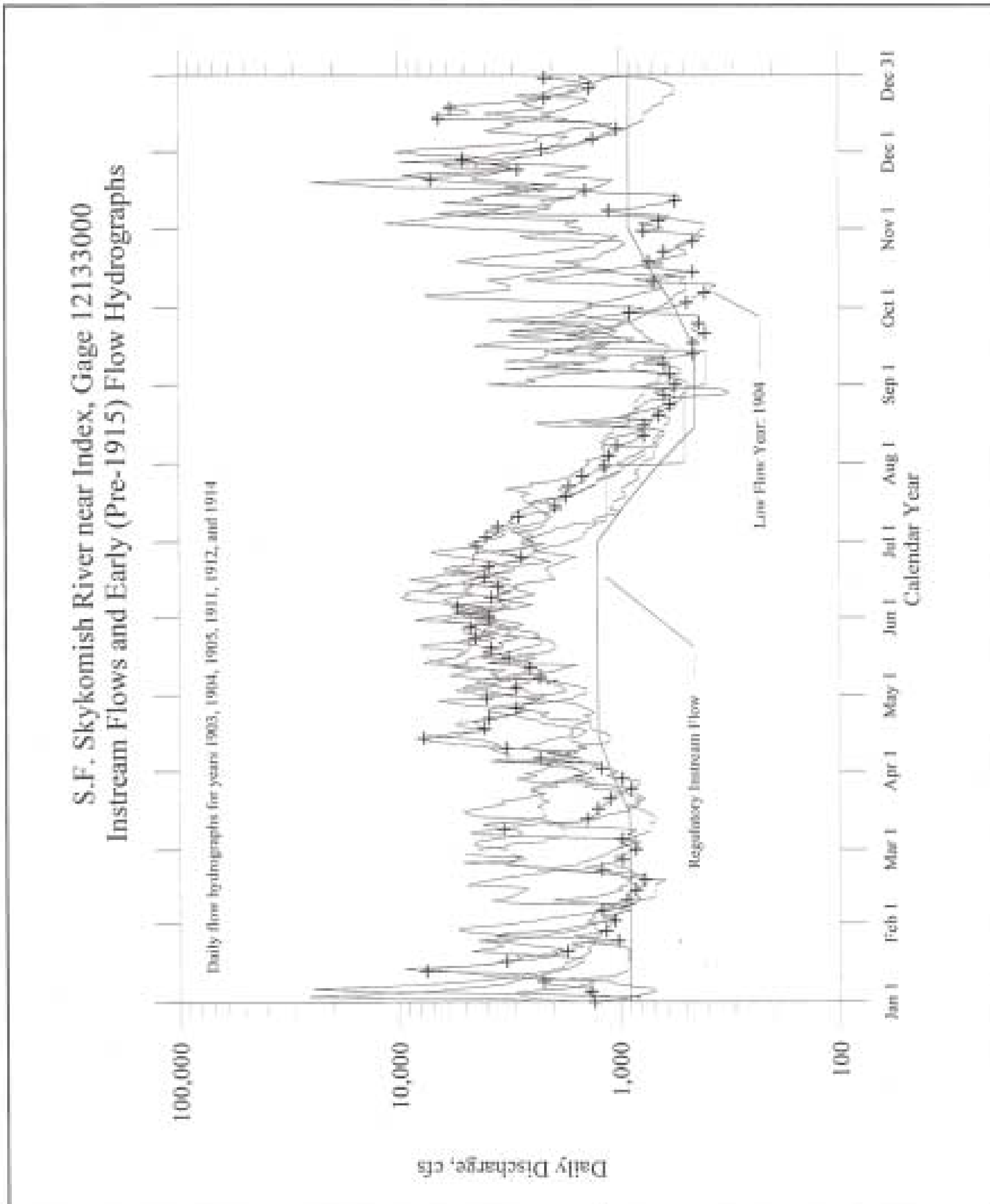


FIGURE 5-16
Instream Flows and Actual Flows
S.F. Skykomish River near Index
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

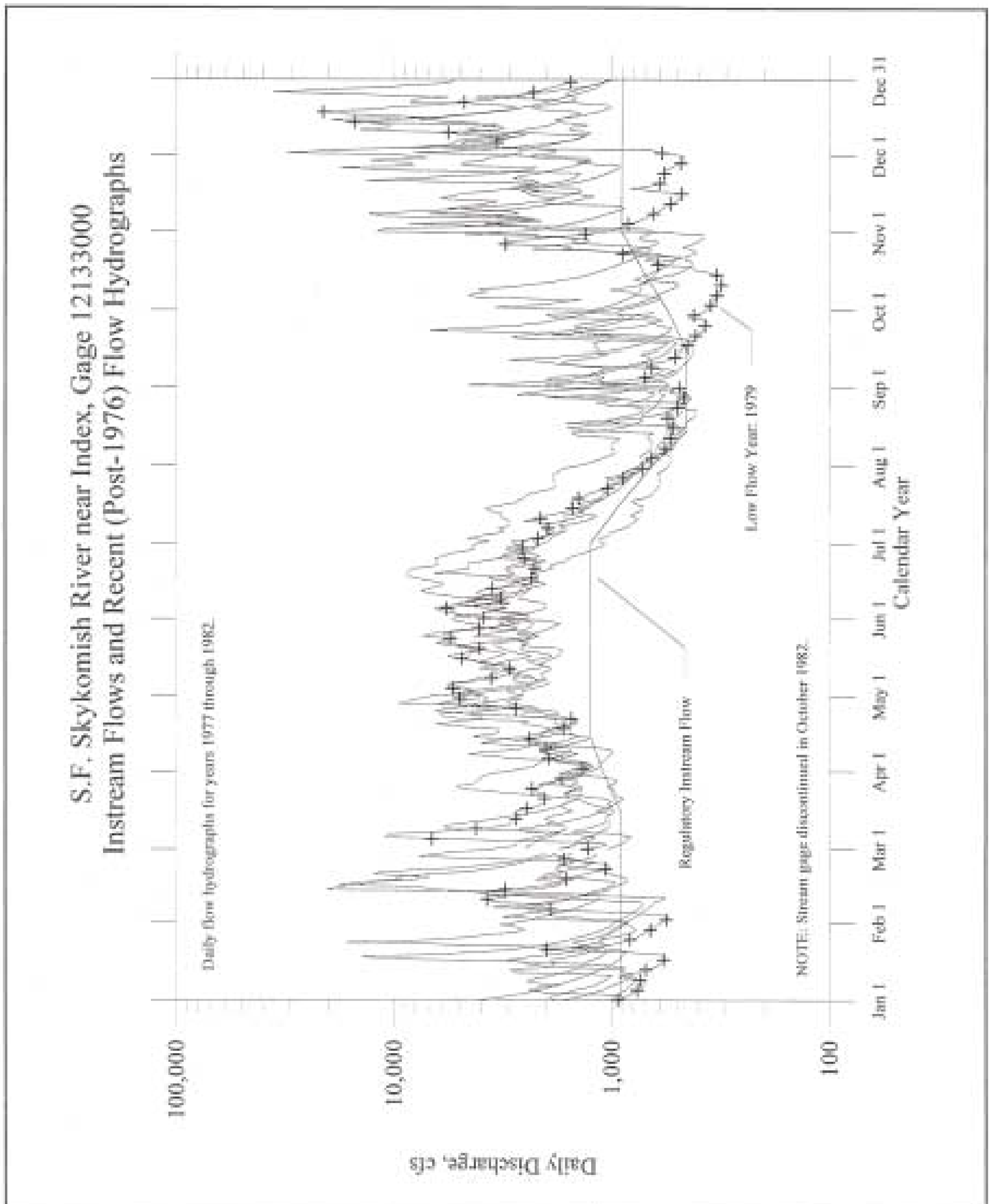


FIGURE 5-17

Instream Flows and Actual Flows
S.F. Skykomish River near Index
Recent Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

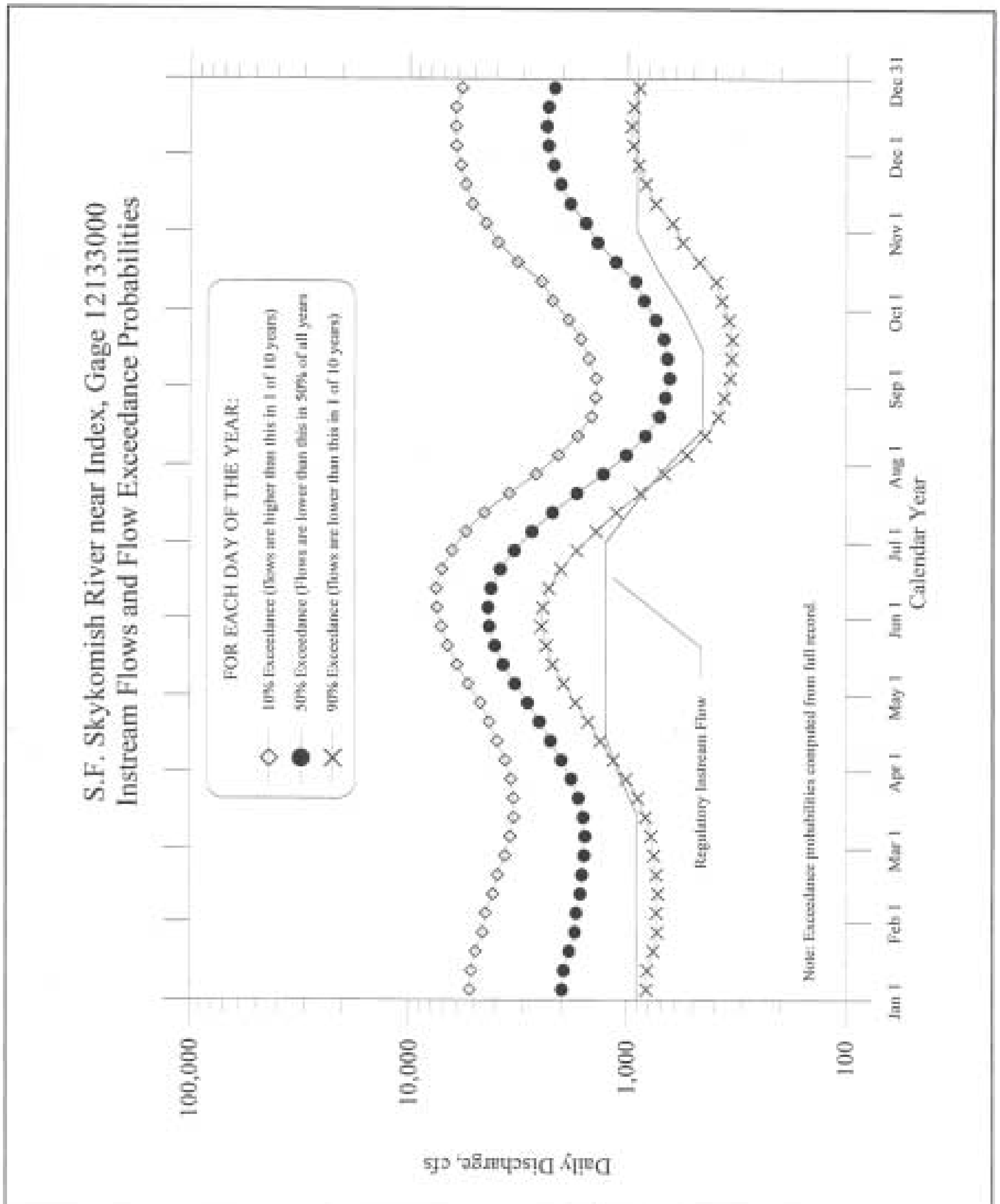


FIGURE 5-18
Instream Flows and
Flow Exceedance Probabilities
S.F. Skykomish River near Index

Initial Watershed Assessment Program
Snohomish Basin

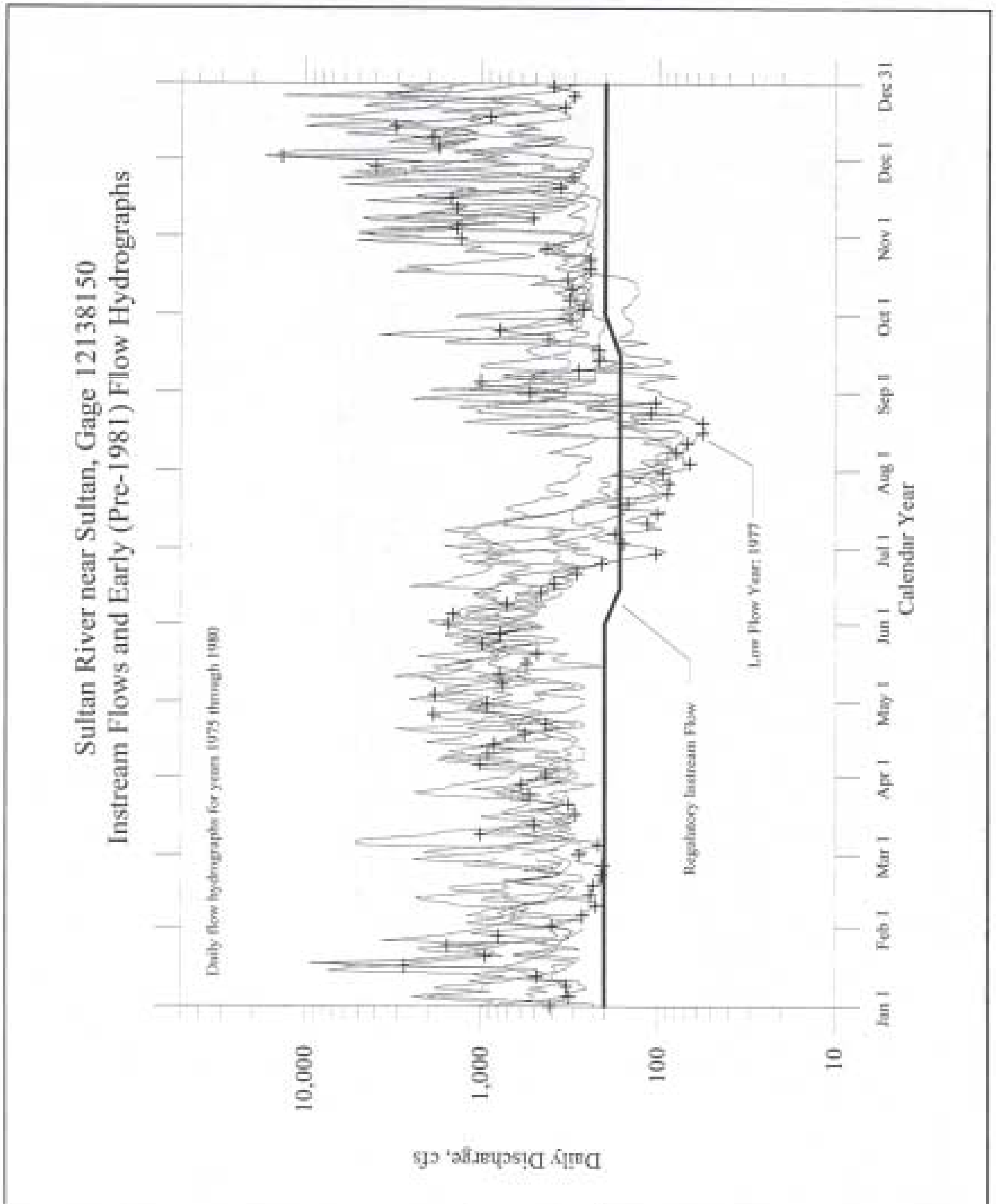


FIGURE 5-19
Instream Flows and Actual Flows
Sultan River near Sultan
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

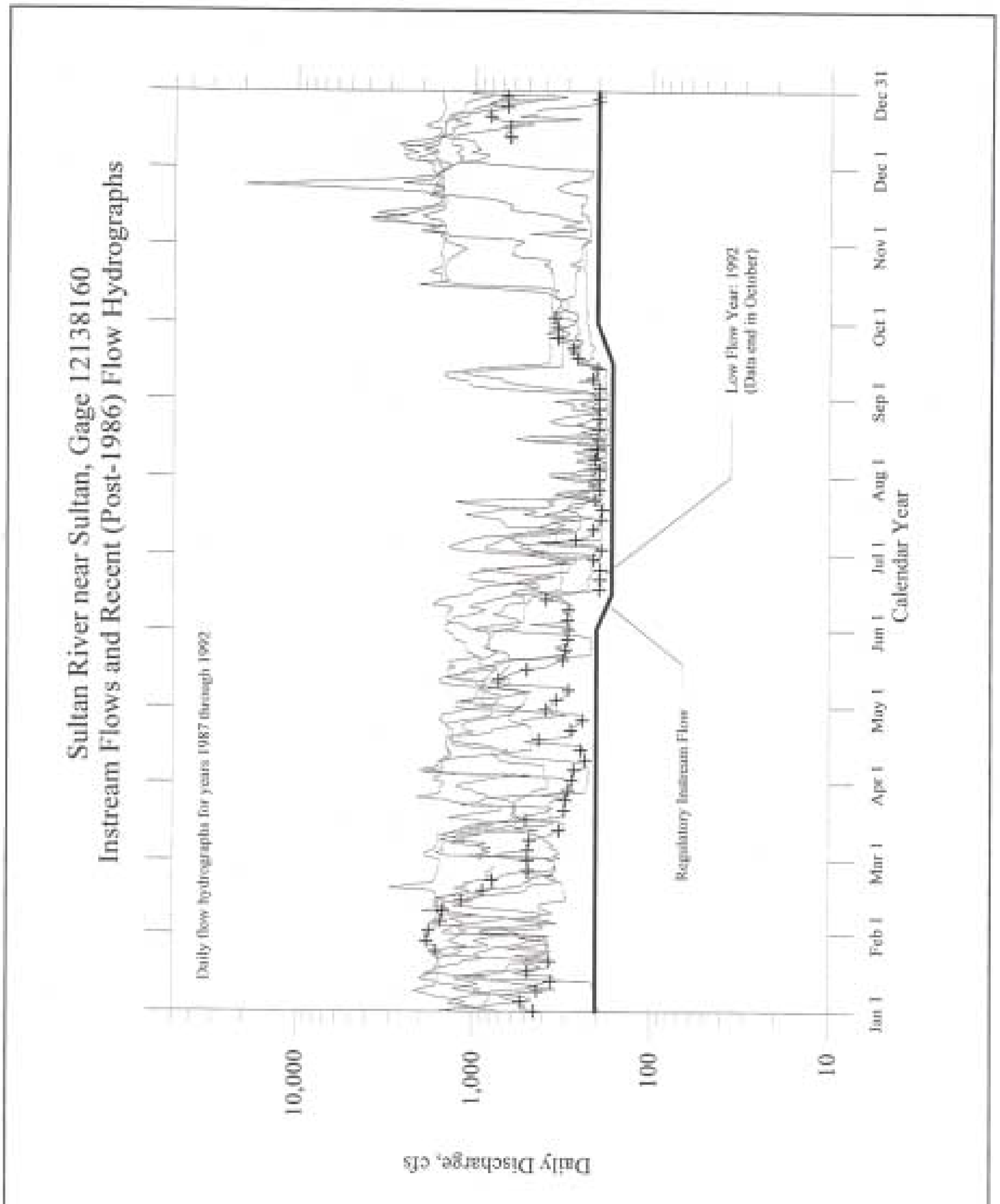


FIGURE 5-20
Instream Flows and Actual Flows
Sultan River near Sultan
Recent Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

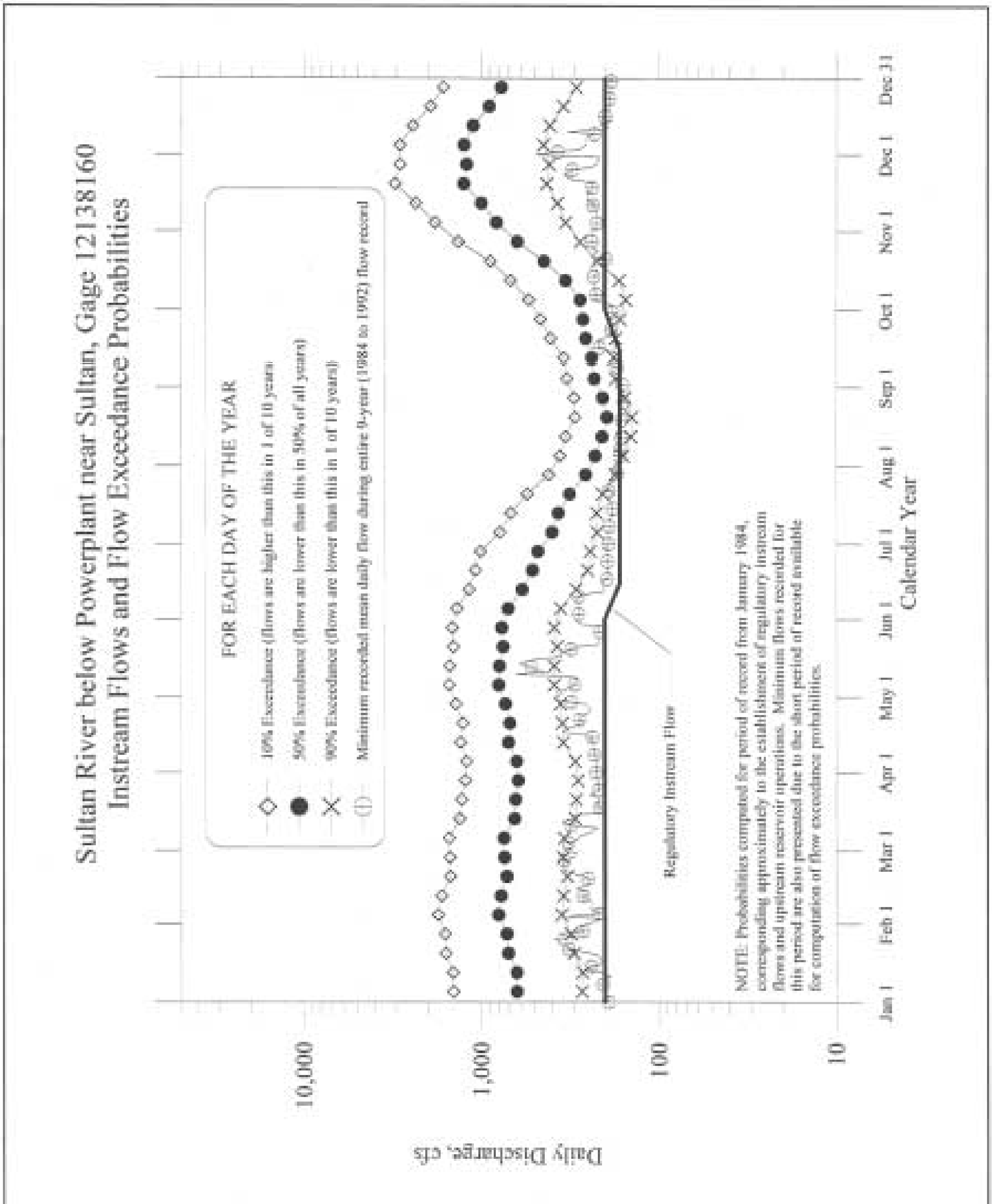


FIGURE 5-21
Instream Flows and
Flow Exceedance Probabilities
Sultan River near Sultan

Initial Watershed Assessment Program
Snohomish Basin

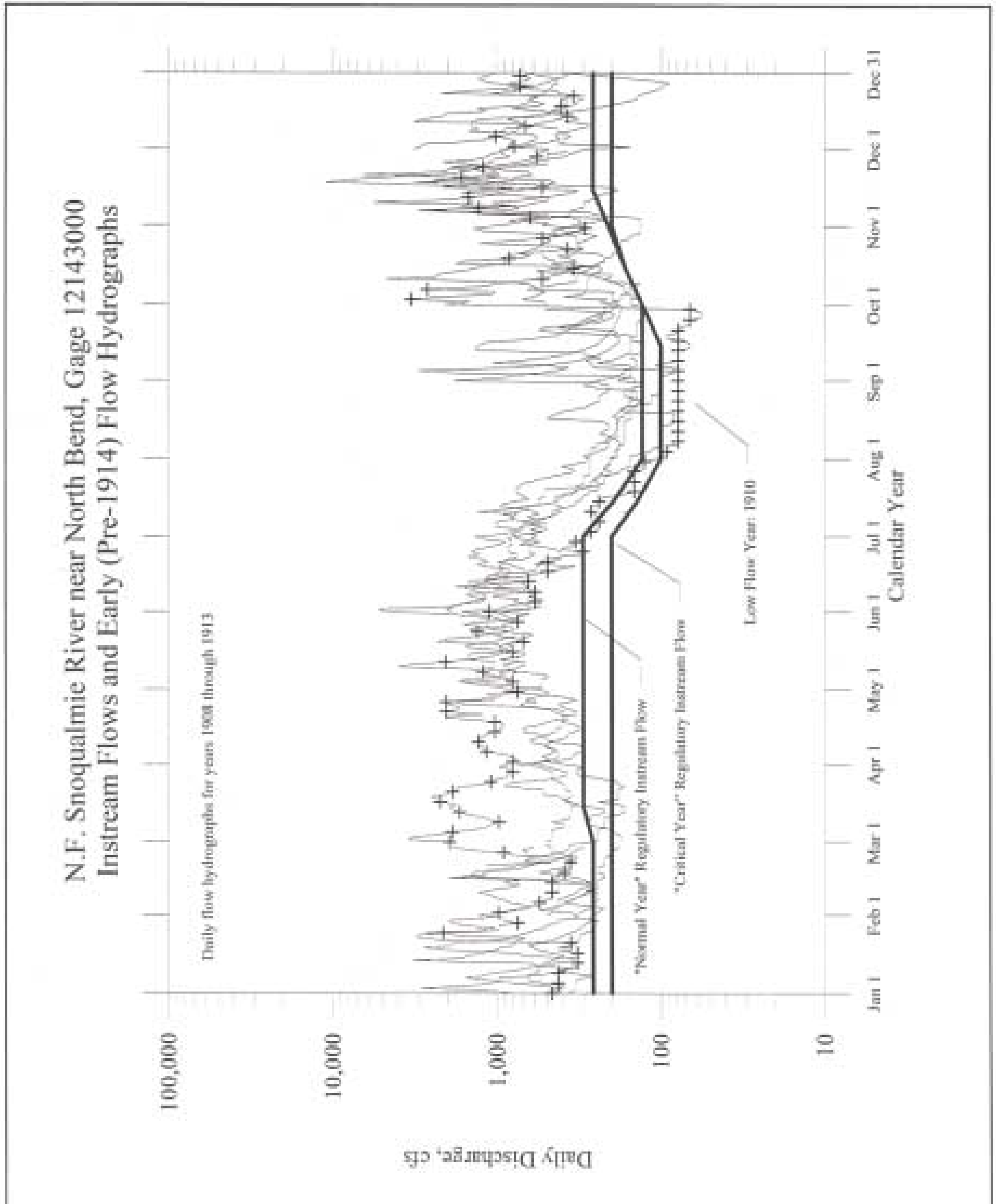


FIGURE 5-22
Instream Flows and Actual Flows
N.F. Snoqualmie River near North Bend
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

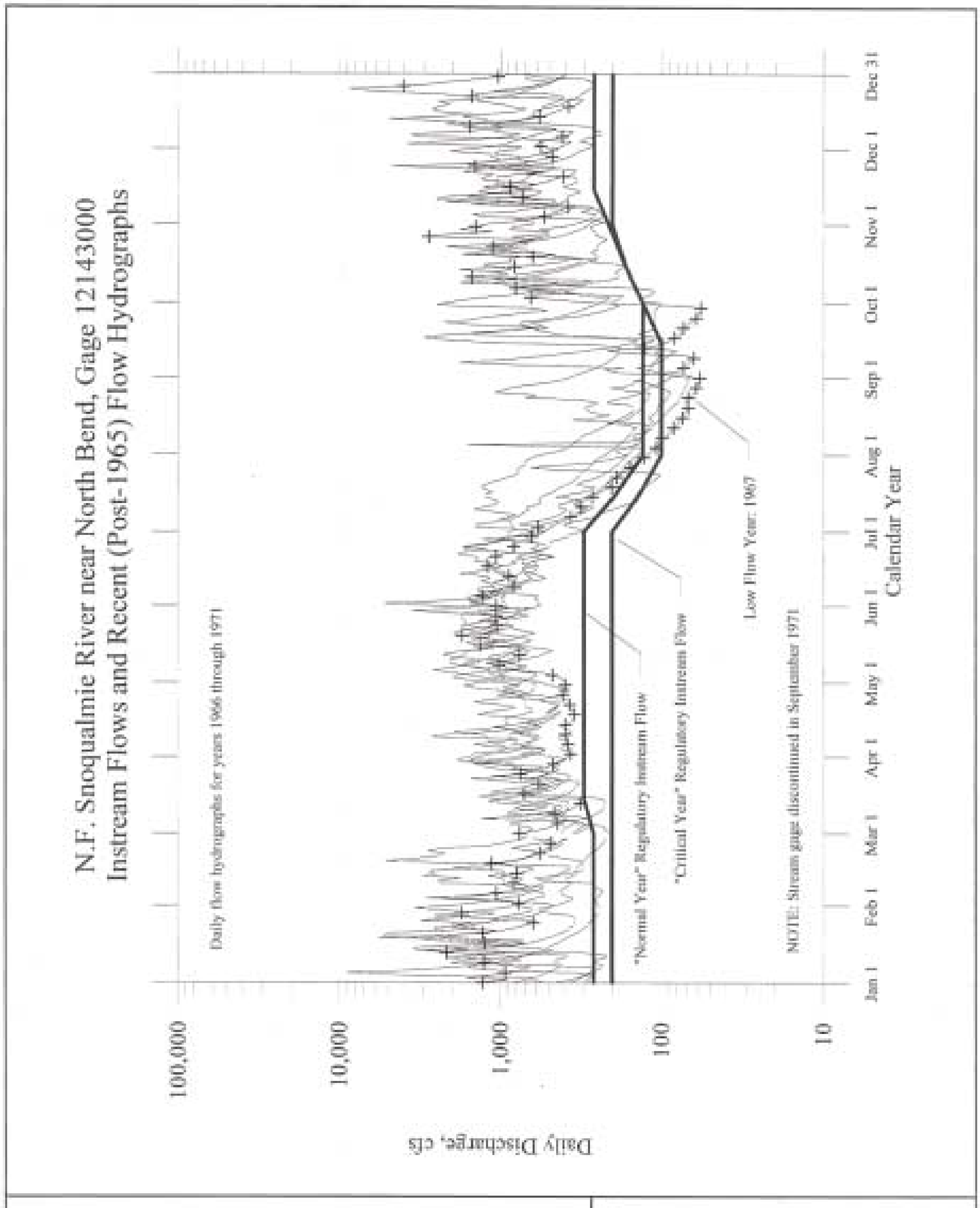


FIGURE 5-23
Instream Flows and Actual Flows
N.F. Snoqualmie River near North Bend
Recent Flow Hydrographs

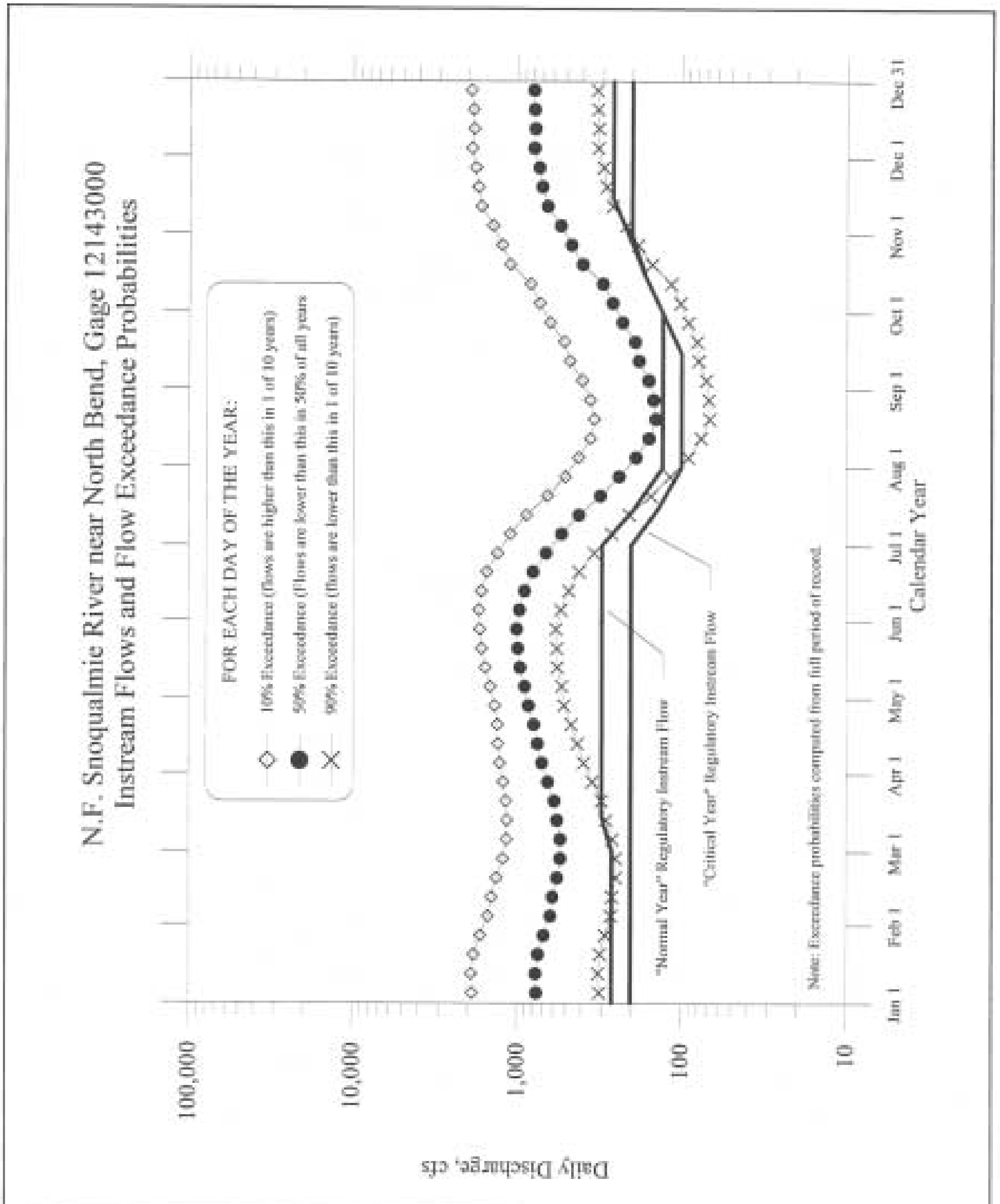


FIGURE 5-24
Instream Flows and
Flow Exceedance Probabilities
N.F. Snoqualmie River near North Bend

Initial Watershed Assessment Program
Snohomish Basin

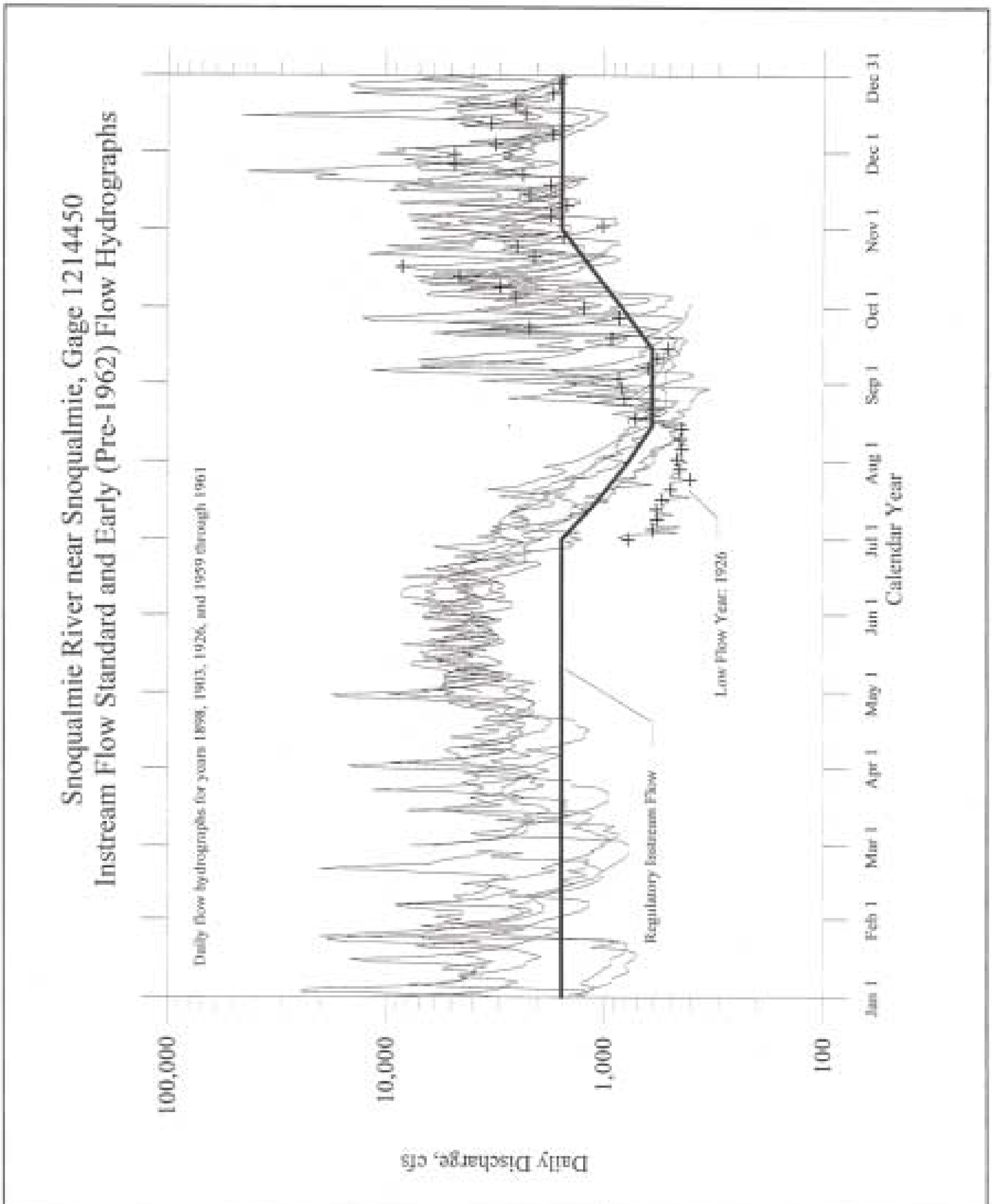


FIGURE 5-25
Instream Flows and Actual Flows
Snoqualmie River near Snoqualmie
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

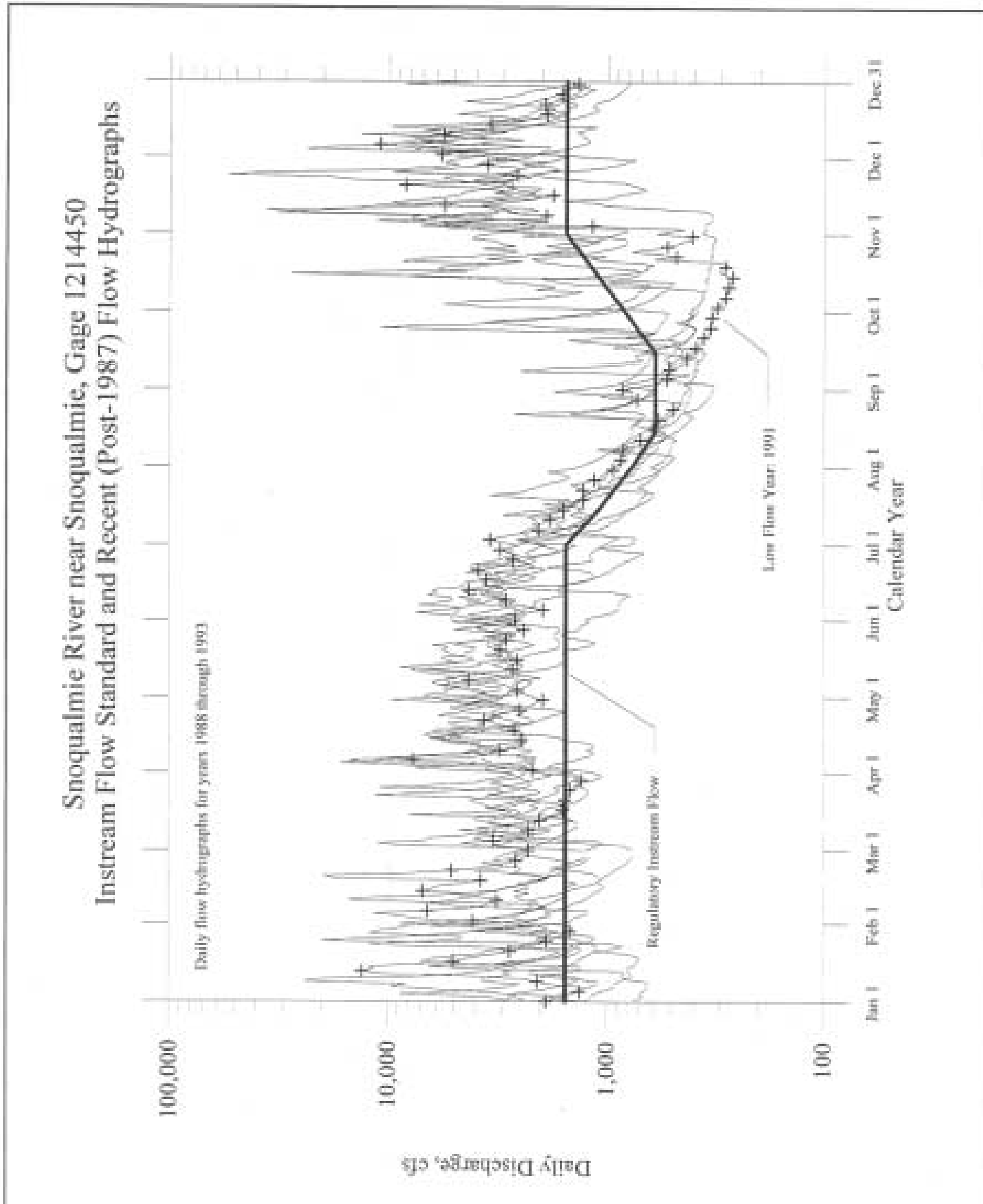


FIGURE 5-26
Instream Flows and Actual Flows
Snoqualmie River near Snoqualmie
Recent Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

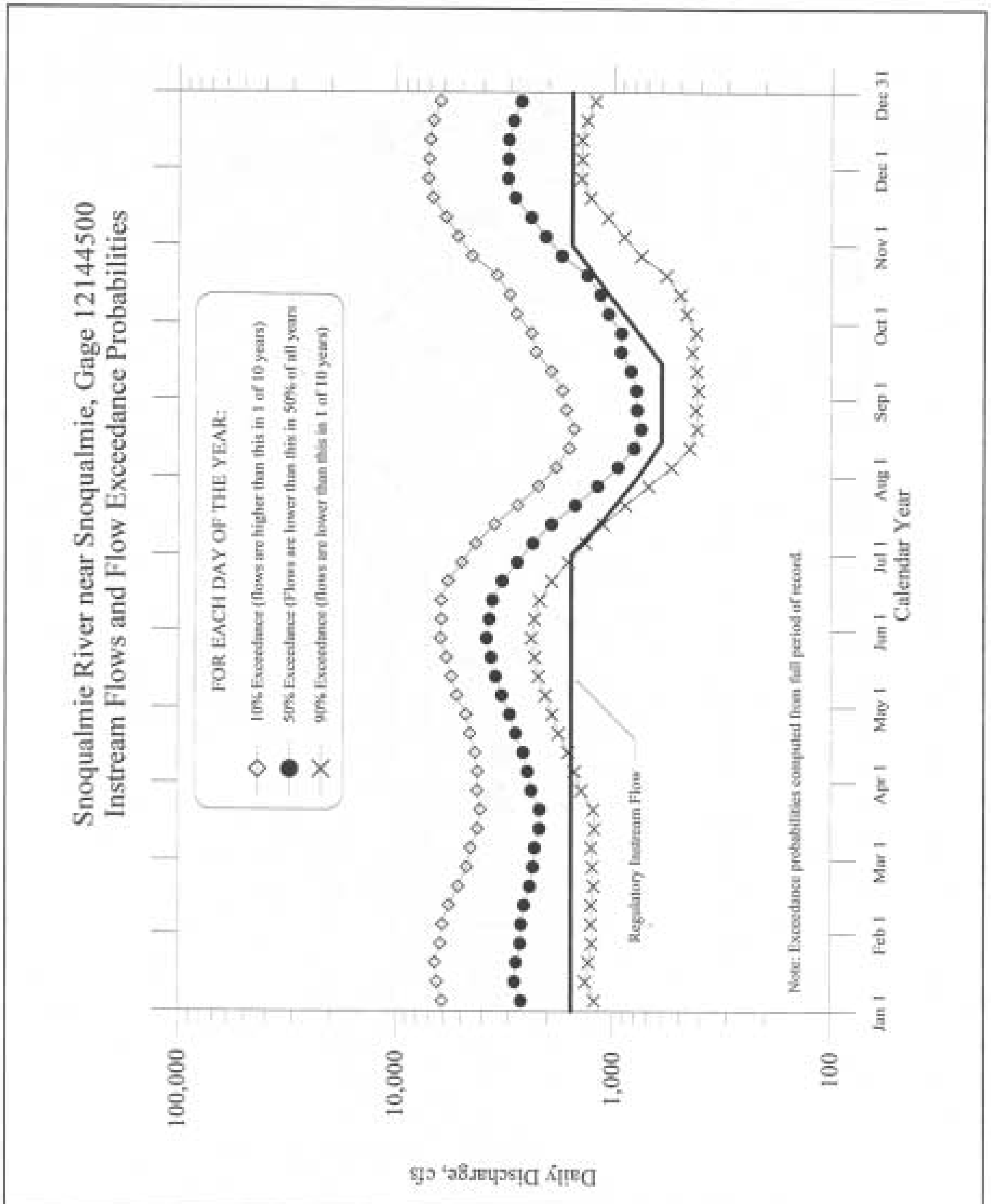


FIGURE 5-27
Instream Flows and Flow Exceedance Probabilities Snoqualmie River near Snoqualmie

Initial Watershed Assessment Program
Snohomish Basin

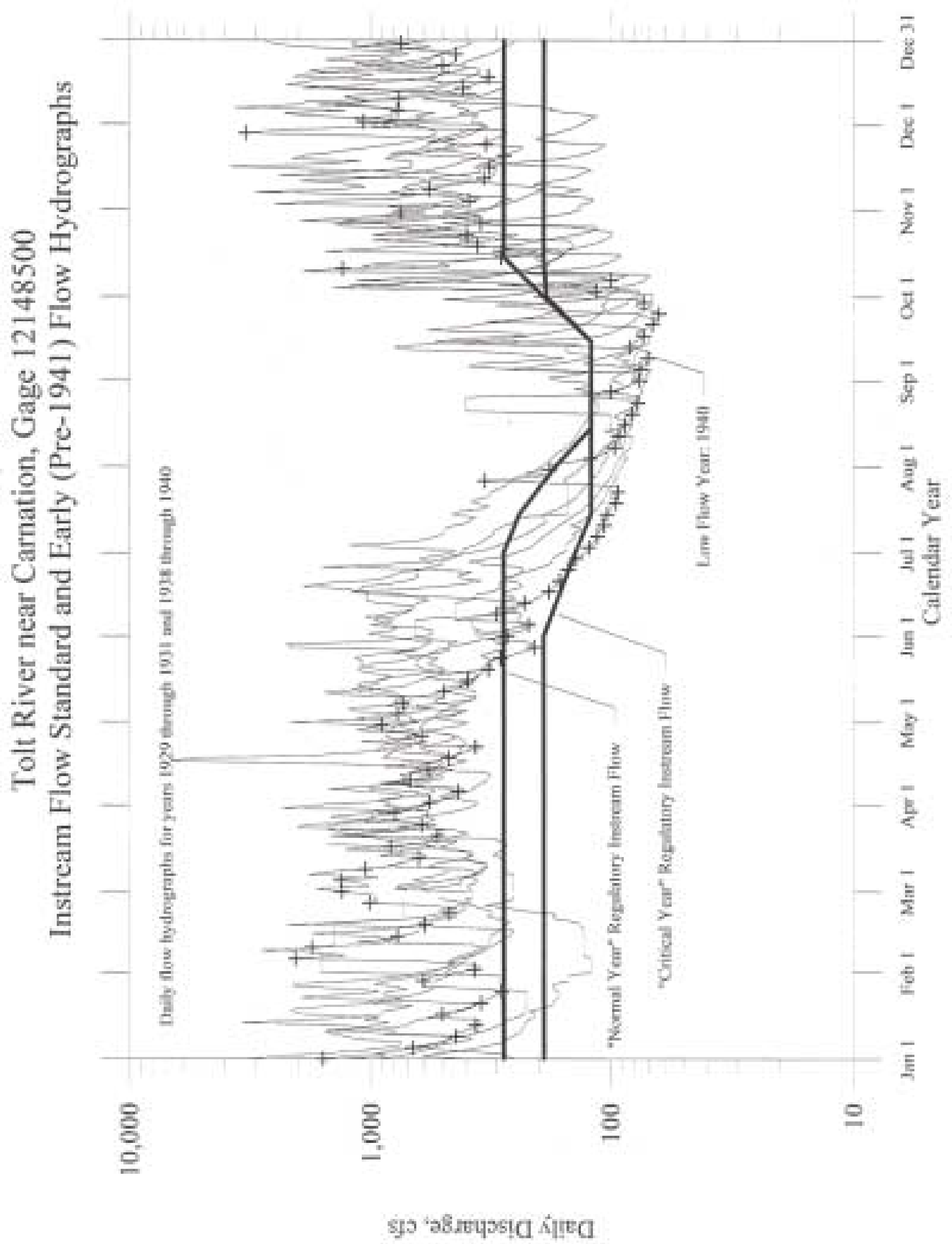


FIGURE 5-28
Instream Flows and Actual Flows
Tolt River near Carnation
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

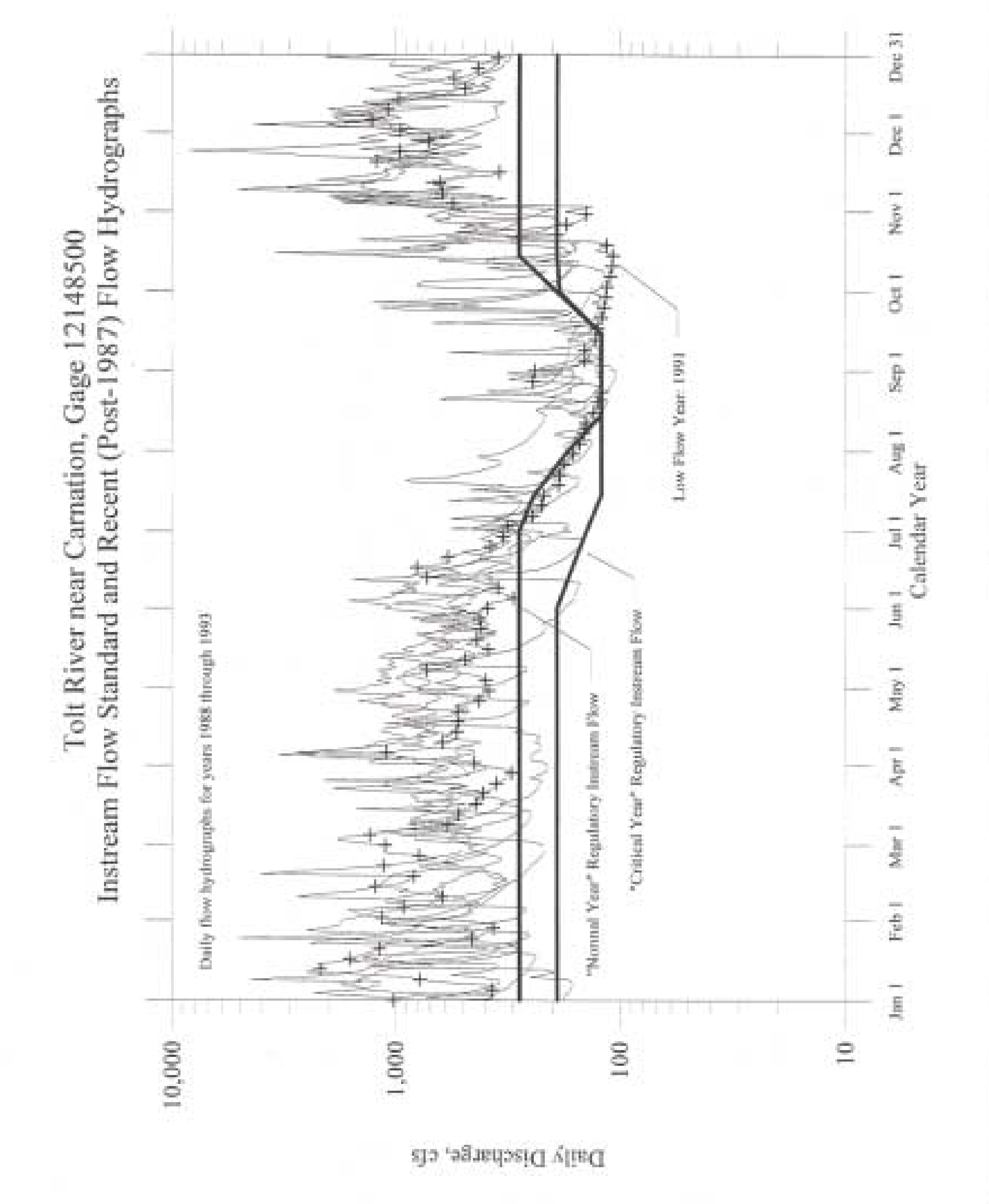


FIGURE 5-29
Instream Flows and Actual Flows
Tolt River near Carnation
Recent Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

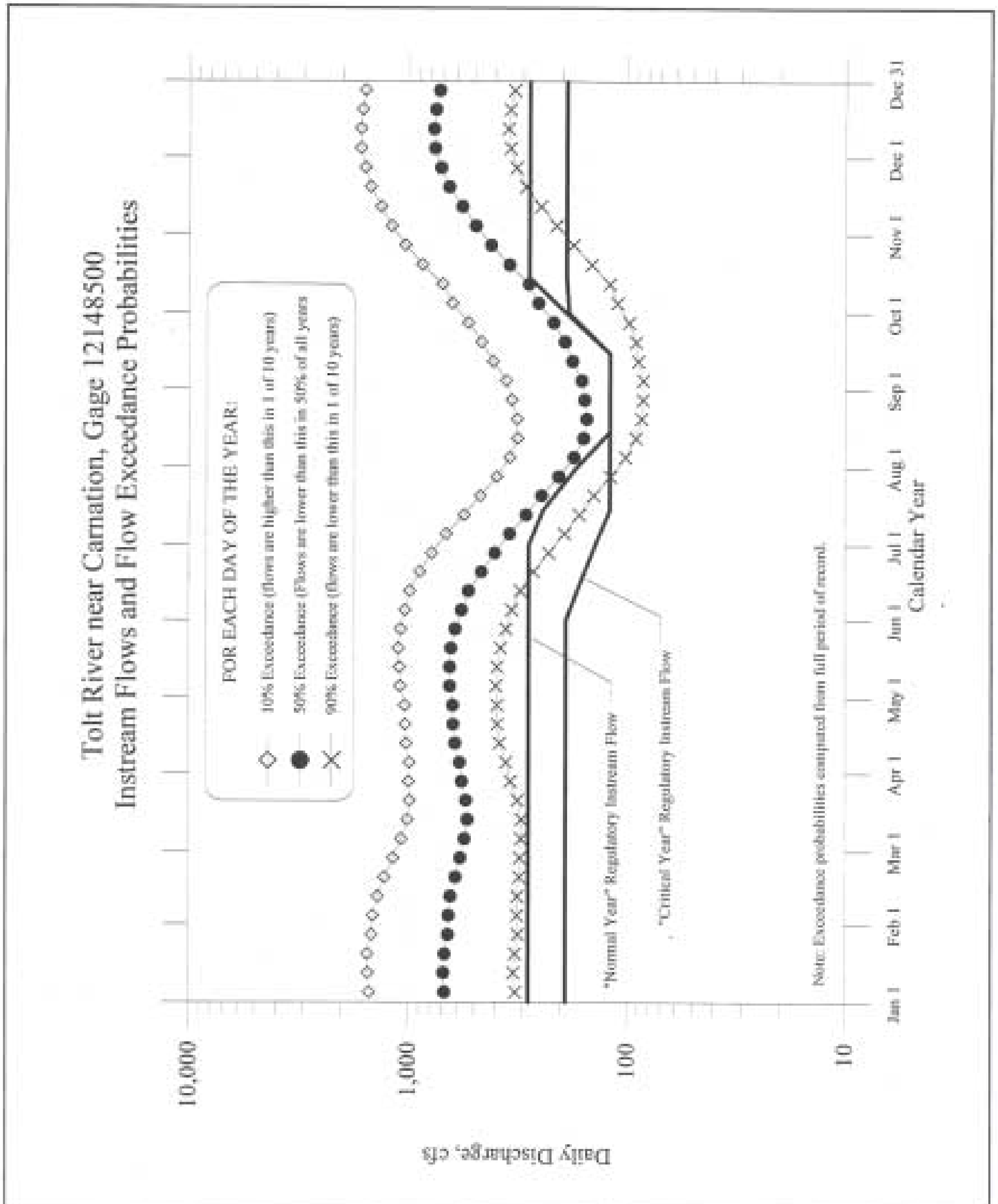


FIGURE 5-30
Instream Flows and Flow Exceedance Probabilities Tolt River near Carnation

Initial Watershed Assessment Program
Snohomish Basin

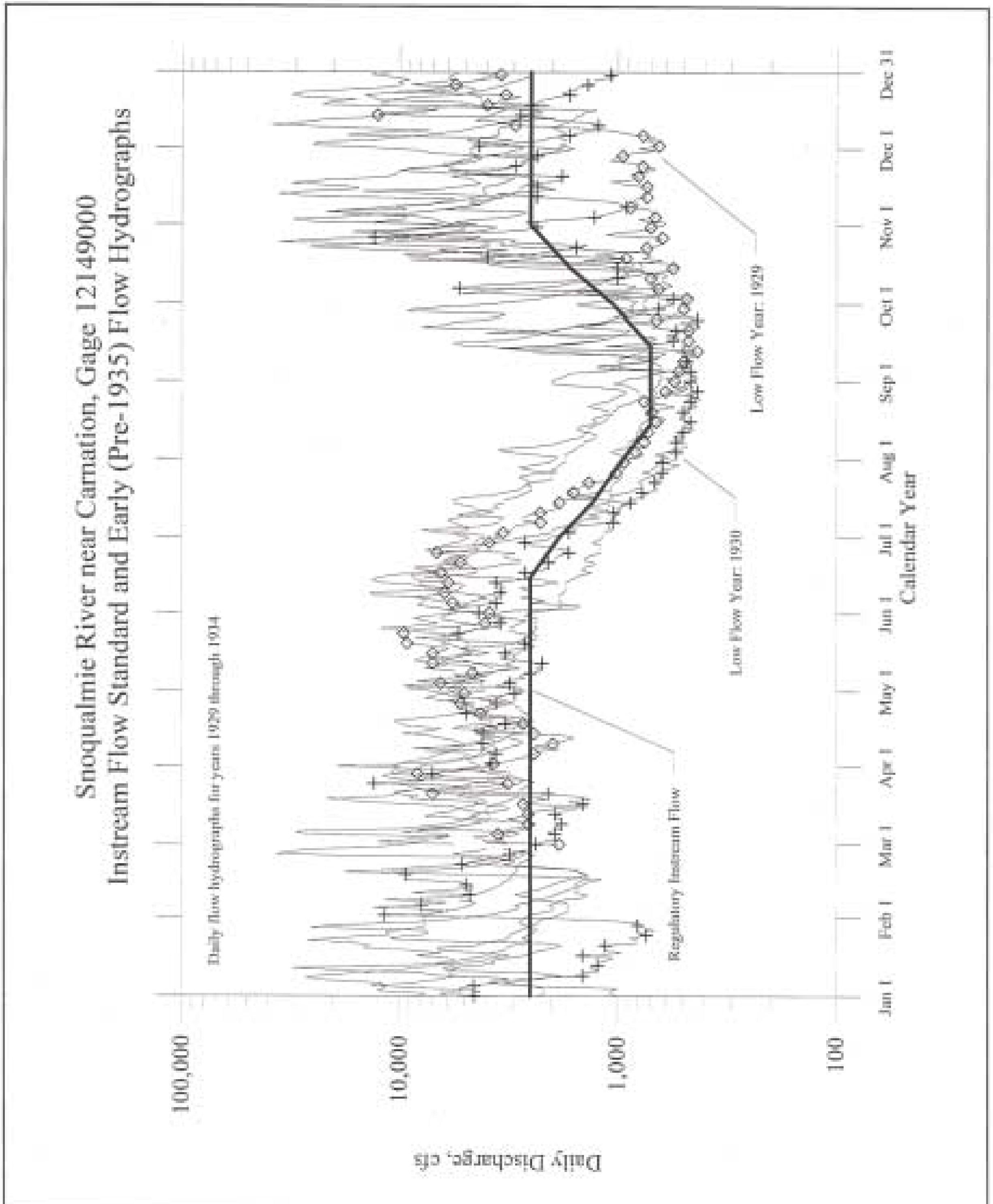


FIGURE 5-31
Instream Flows and Actual Flows
Snoqualmie River near Carnation
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

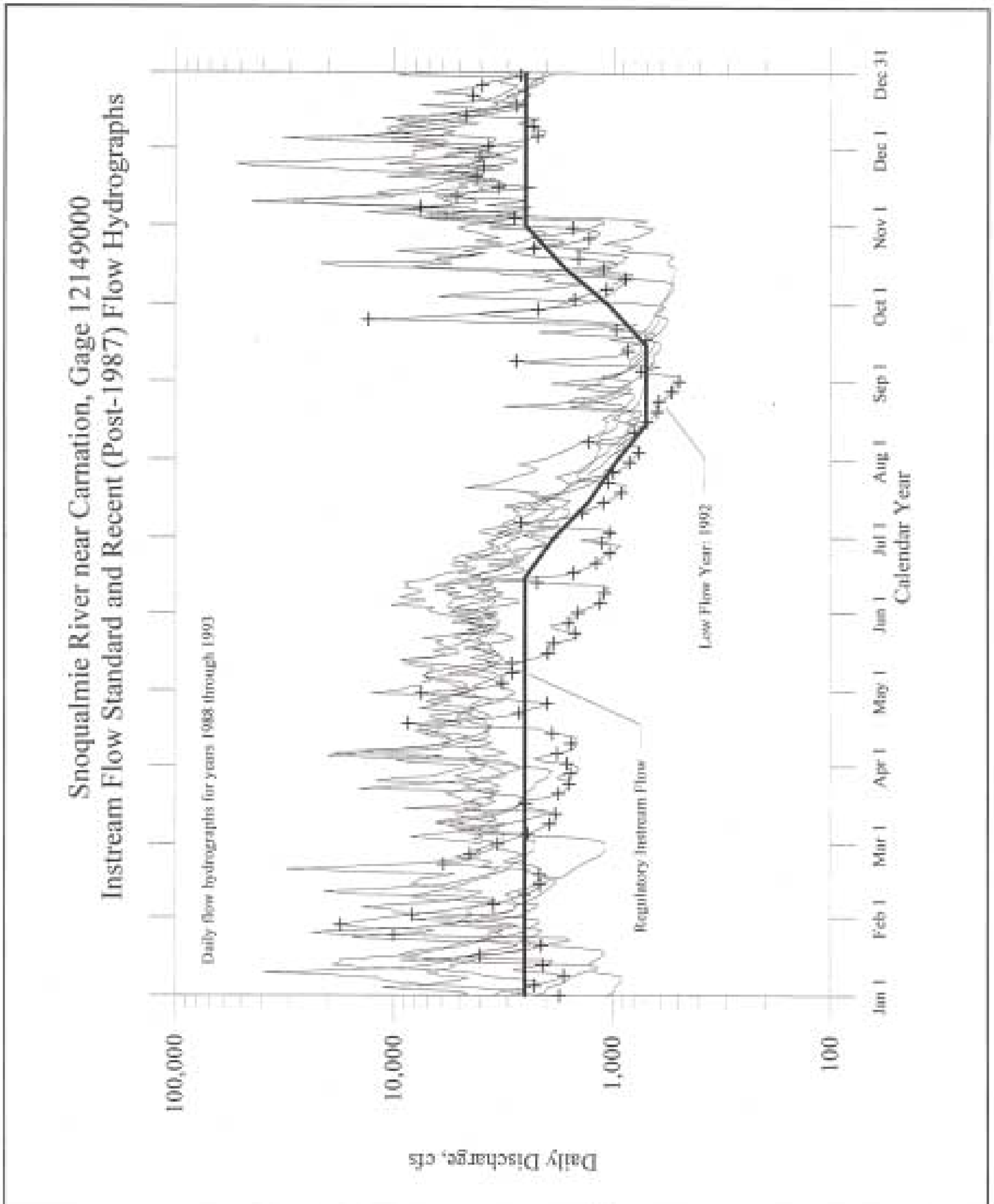


FIGURE 5-32
Instream Flows and Actual Flows
Snoqualmie River near Carnation
Recent Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

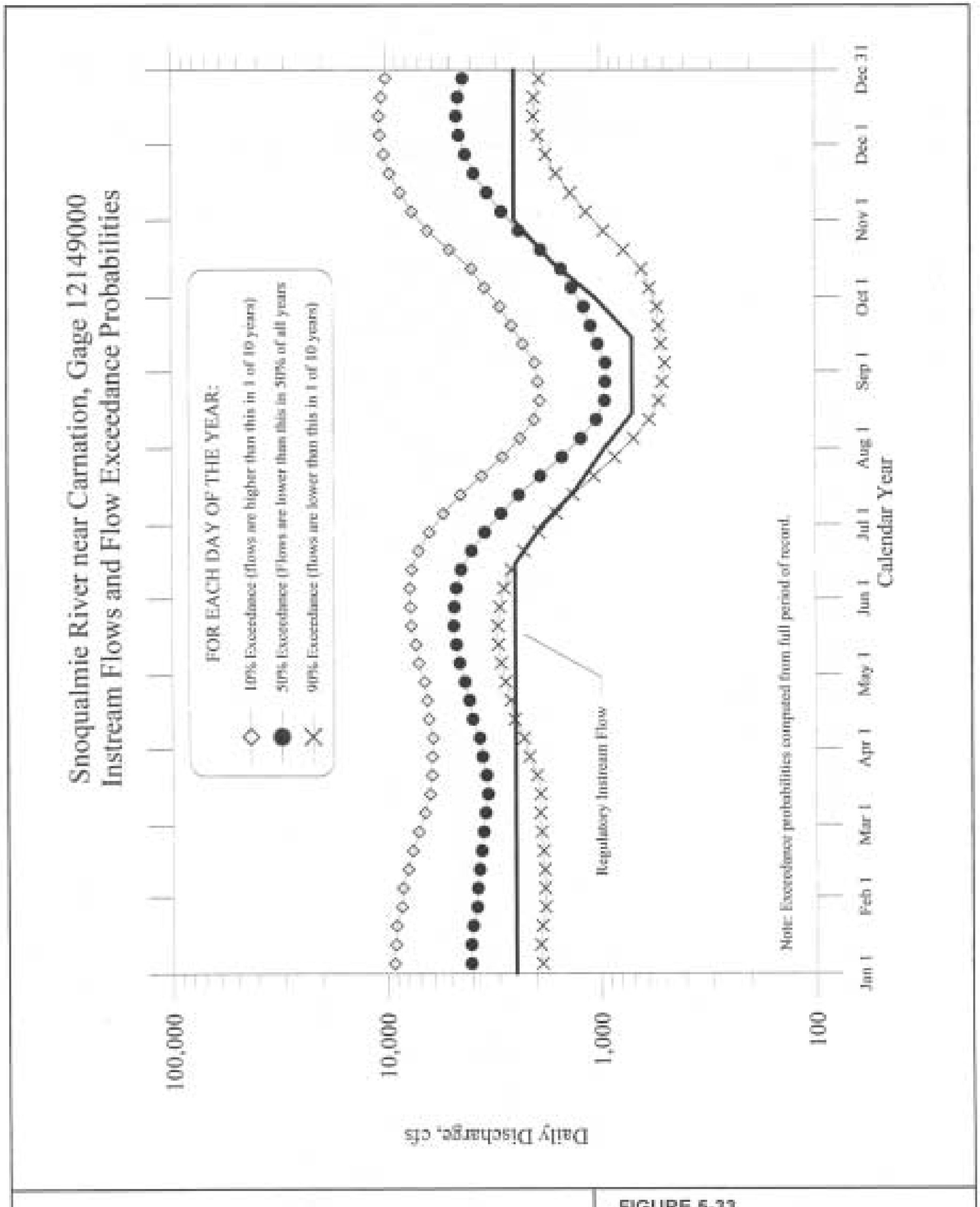


FIGURE 5-33
Instream Flows and
Flow Exceedance Probabilities
Snoqualmie River near Carnation

Initial Watershed Assessment Program
Snohomish Basin

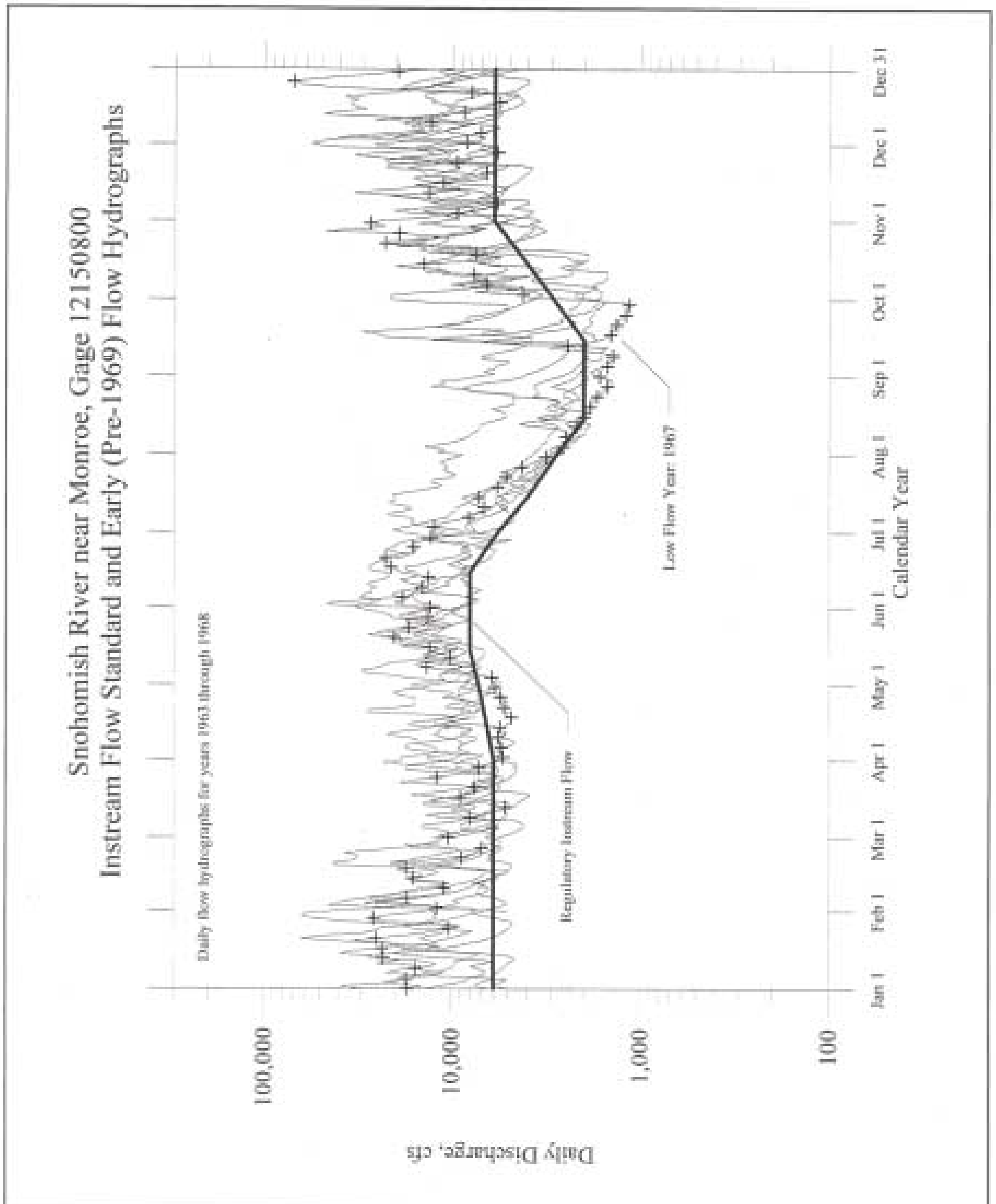


FIGURE 5-34
Instream Flows and Actual Flows
Snohomish River near Monroe
Early Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

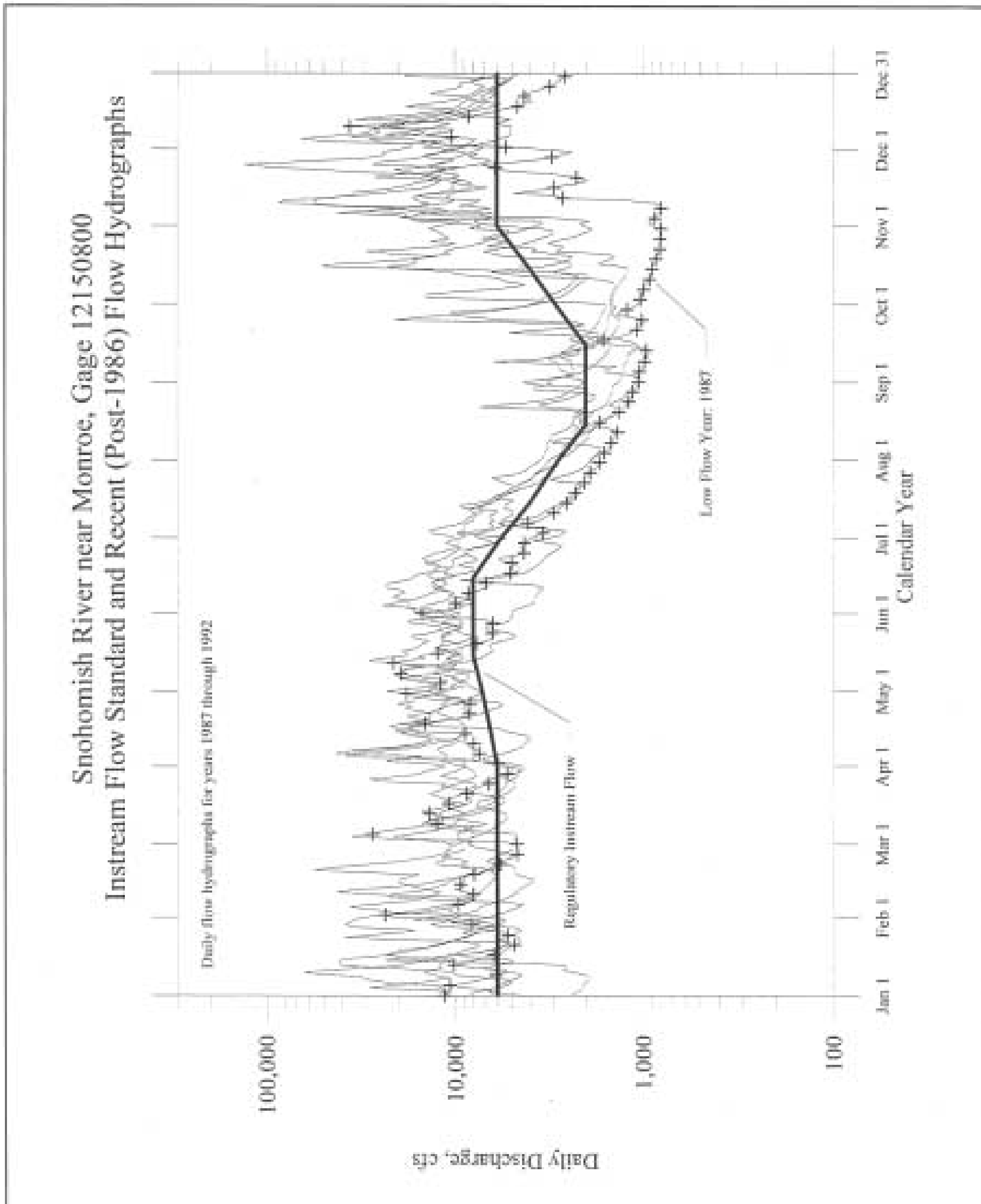


FIGURE 5-35
Instream Flows and Actual Flows
Snohomish River near Monroe
Recent Flow Hydrographs

Initial Watershed Assessment Program
Snohomish Basin

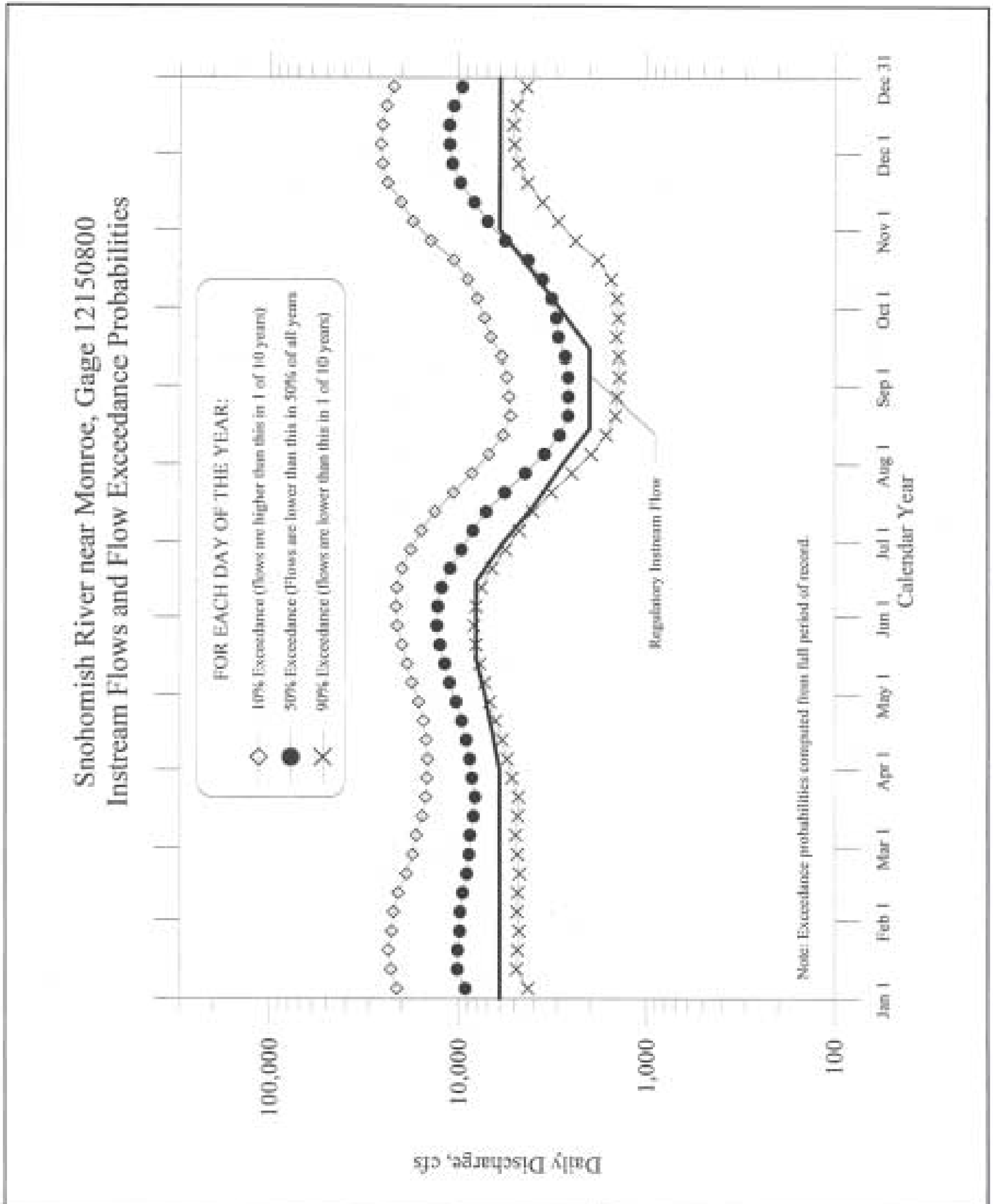
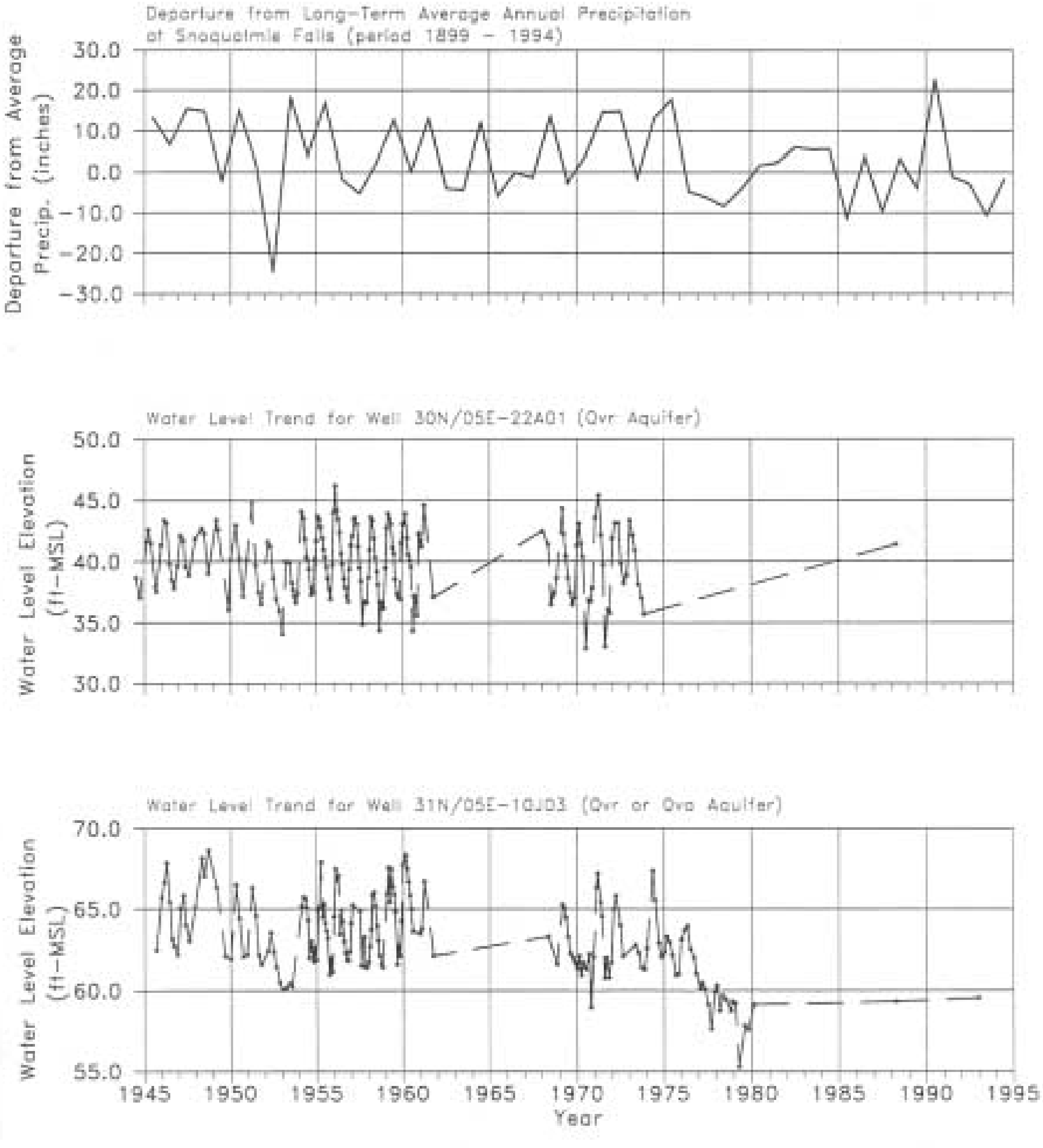


FIGURE 5-36
Instream Flows and
Flow Exceedance Probabilities
Snohomish River near Monroe

Initial Watershed Assessment Program
Snohomish Basin



Pacific Groundwater Group

FIGURE 6-2a
WATER LEVEL AND
PRECIPITATION TREND DATA

Initial Watershed Assessment Program
Snohomish Basin

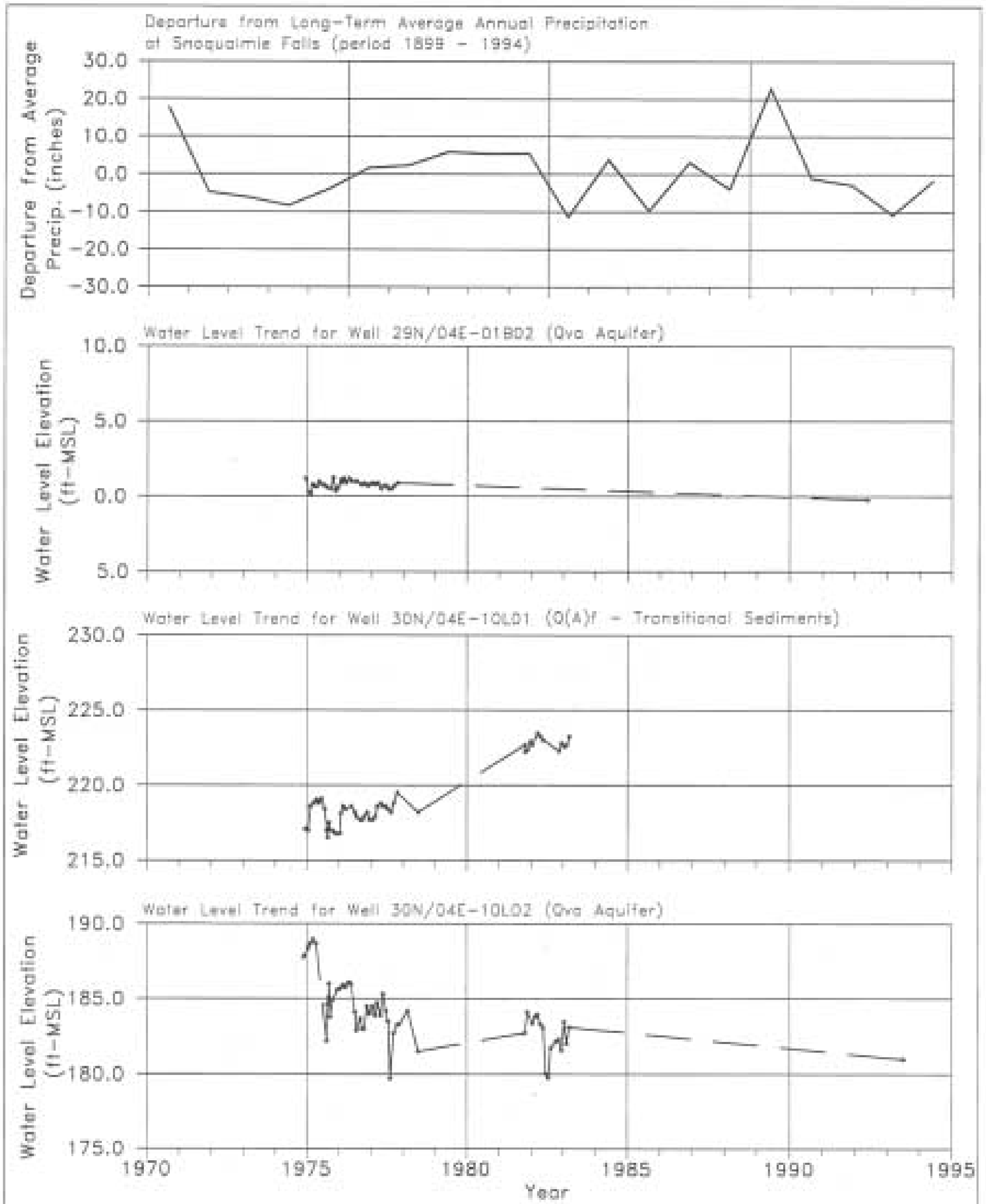
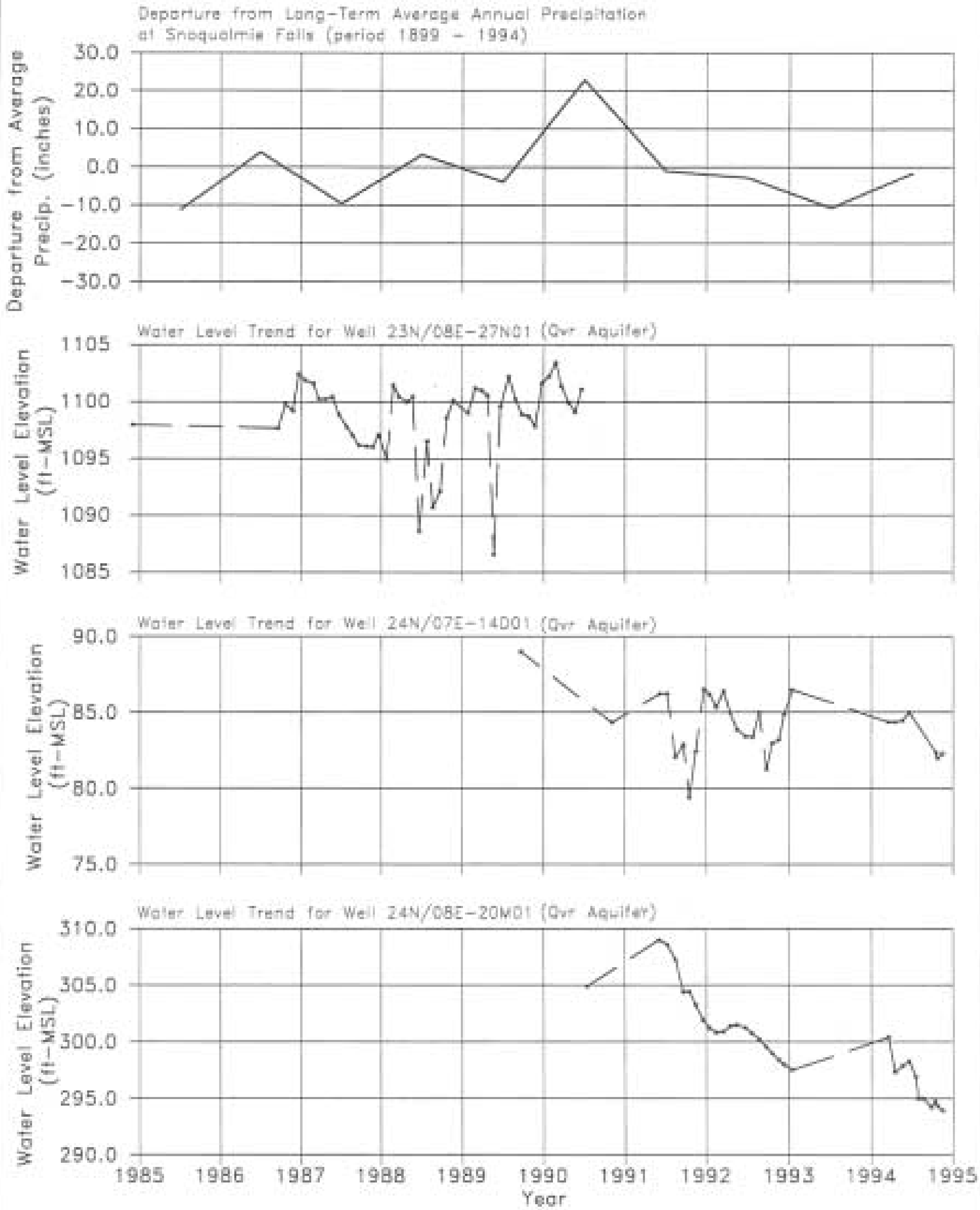


FIGURE 6-2b
WATER LEVEL AND
PRECIPITATION TREND DATA

Pacific Groundwater Group

Initial Watershed Assessment Program
Snohomish Basin



Pacific Groundwater Group

FIGURE 6-2c
WATER LEVEL AND PRECIPITATION TREND DATA

Initial Watershed Assessment Program
Snohomish Basin

APPENDIX A
RESOURCE PROTECTION AND MANAGEMENT

Chapter 173–507 WAC

INSTREAM RESOURCES PROTECTION PROGRAM—SNOHOMISH RIVER BASIN, WATER RESOURCE INVENTORY AREA (WRIA) 7

WAC 173–507–010 General provision. These rules apply to surface waters within the Snohomish River basin, WRIA–7 (see WAC 173–500–040). Chapter 173–500 WAC, the general rules of the department of ecology for the implementation of the comprehensive water resources program, applies to this chapter 173–507 WAC. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 79–10–003 (Order DE 79–8), § 173–507–010, filed 9/6/79.]

WAC 173–507–020 Establishment of instream flows. (1) Instream flows are established for stream management units with monitoring to take place at certain control stations as follows:

STREAM MANAGEMENT UNIT INFORMATION

Control Station No. Stream Management Unit Name	Control Station by River Mile and Section, Township and Range	Affected Stream Reach Including Tributaries
12.1330.00 So. Fk. Skykomish River	51.6 28–27–10E	From confluence with N. Fk. Skykomish River to headwaters.
12.1381.50 Sultan River	5.1 17–28–8E	From mouth to headwaters.
12.1411.00 Skykomish River	25.0 12–27–6E	From mouth to headwaters, excluding So. Fk. Skykomish River and Sultan River.
12.1430.00 No. Fk. Snoqualmie	2.2 26–24–8E	From mouth to headwaters.
12.1445.00 Snoqualmie River	40.0 19–24–8E	From Snoqualmie Falls to headwaters, excluding No. Fork Snoqualmie River.
12.1485.00 Tolt River	8.7 31–26–8E	From mouth to headwaters.
12.1490.00 Snoqualmie River	23.0 9–25–7E	From confluence with Harris Creek to Snoqualmie Falls, excluding Tolt River.
12. Snoqualmie River	2.5 26–27–6E	From mouth to confluence with Harris Creek, including Harris Creek.
12.1554.00 Pilchuck River	1.9 18–28–6E	From mouth to headwaters.
12.1508.00 Snohomish River	20.4 16–27–6E	From influence of mean annual high tide at low base flow levels to confluence with Skykomish River and Snoqualmie River, excluding Pilchuck River.

(2) Instream flows established for the stream management units in WAC 173–507–020(1) are as follows:

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

Month	Day	12.1330.00 So.Fk. Skykomish	12.1411.00 Skykomish	12.1430.00 No.Fk* Snoqualmie	No.Fk.** Snoqualmie
Jan.	1	900	2200	260	200
	15	900	2200	260	200
Feb.	1	900	2200	260	200
	15	900	2200	260	200
Mar.	1	900	2200	260	200
	15	900	2200	300	200
Apr.	1	1100	2650	300	200
	15	1250	3250	300	200
May	1	1250	4000	300	200
	15	1250	4900	300	200
June	1	1250	4900	300	200
	15	1250	4900	300	200
July	1	1250	3250	300	200
	15	950	2170	195	140
Aug.	1	650	1450	130	100
	15	450	1000	130	100
Sept.	1	450	1000	130	100
	15	450	1000	130	100
Oct.	1	550	1300	130	130
	15	700	1700	165	165
Nov.	1	900	2200	210	200
	15	900	2200	260	200

Month	Day	12.1330.00 So.Fk. Skykomish	12.1411.00 Skykomish	12.1430.00 No.Fk* Snoqualmie	No.Fk.** Snoqualmie
Dec.	1	900	2200	260	200
	15	900	2200	260	200

*Normal year flows must be maintained at all times unless a critical condition is declared by the director. The director, or his designee, may authorize, in consultation with the state departments of fisheries and wildlife, a reduction in instream flows during a critical condition period. At no time are diversions subject to this regulation permitted for any reason when flows fall below the following critical year flows, except where a declaration of overriding considerations of public interest is made by the director.

**Critical year flows represent flows below which the department believes substantial damage to instream values will occur.

Month	Day	12.1381.50 Sultan	12.1445.00 Snoqualmie (above Falls)	12.1485.50 Tolt River*	Tolt River**
Jan.	1		1550	280	190
	15		1550	280	190
Feb.	1		1550	280	190
	15		1550	280	190
Mar.	1		1550	280	190
	15		1550	280	190
Apr.	1		1550	280	190
	15		1550	280	190
May	1		1550	280	190
	15		1550	280	190
June	1		1550	280	190
	15		1550	280	165
July	1		1550	280	140
	15		1100	240	120
Aug.	1		770	170	120
	15		600	120	120
Sept.	1		600	120	120
	15		600	120	120
Oct.	1		820	190	185
	15		1100	280	190
Nov.	1		1550	280	190
	15		1550	280	190
Dec.	1		1550	280	190
	15		1550	280	190

*Normal year flows must be maintained at all times unless a critical condition is declared by the director. The director, or his designee, may authorize, in consultation with the state departments of fisheries and wildlife, a reduction in instream flows during a critical condition period. At no time are diversions subject to this regulation permitted for any reason when flows fall below the following critical year flows, except where a declaration of overriding considerations of public interest is made by the director.

**Critical year flows represent flows below which the department believes substantial damage to instream values will occur.

Month	Day	12.1490.00 Snoqualmie (Carnation)	12. Snoqualmie (mouth)	12.1554.00 Pilchuck R.	12.1508.00 Snohomish R.
Jan.	1	2500	2800	300	6000
	15	2500	2800	300	6000
Feb.	1	2500	2800	300	6000
	15	2500	2800	300	6000
Mar.	1	2500	2800	300	6000
	15	2500	2800	300	6000
Apr.	1	2500	2800	300	6000
	15	2500	2800	300	6500
May	1	2500	2800	300	7200
	15	2500	2800	300	8000
June	1	2500	2800	300	8000
	15	2500	2800	300	8000
July	1	1850	2180	220	5700
	15	1300	1550	160	4000
Aug.	1	950	1080	120	2800
	15	700	800	85	2000
Sept.	1	700	800	85	2000
	15	700	800	85	2000
Oct.	1	1050	1200	130	2900
	15	1650	1850	200	4000
Nov.	1	2500	2800	300	6000
	15	2500	2800	300	6000
Dec.	1	2500	2800	300	6000
	15	2500	2800	300	6000

(3) Instream flow hydrographs, as represented in the document entitled "Snohomish River instream resource protection program," shall be used for definition of instream flows on those days not specifically identified in WAC 173-507-020(2).

(4) All consumptive water rights hereafter established shall be expressly subject to the instream flows established in WAC 173-507-020 (1) through (3).

(5) At such time as the departments of fisheries and/or wildlife and the department of ecology agree that additional stream management units should be defined, other than those specified in WAC 173-507-020(1), the department of ecology shall identify additional control stations and management units on streams and tributaries within the basin and shall set instream flows where possible for those stations as provided in chapters 90.22 and 90.54 RCW. [Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-507-020, filed 6/9/88. Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-020, filed 9/6/79.]

WAC 173-507-030 Surface water source limitations to further consumptive appropriations. (1) The department, having determined further consumptive appropriations would harmfully impact instream values, adopts instream flows as follows confirming surface water source limitations previously established administratively under authority of chapter 90.03 RCW and RCW 75.20.050.

LOW FLOW LIMITATIONS

Stream	Limitation	Point of Measurement
Evans Creek, Tributary to Lake Beecher	No diversion when flow drops below 2.0 cfs.	800 ft. So. and 800 ft. east of center of Sec. 7, T. 27 N., R. 6 E.W.M.
Foye Creek Tributary to Riley Slough	No diversion when flow drops below 4.0 cfs.	750 ft. So. and 325 ft. east of N1/4 cor. of Sec. 18, T. 27 N., R. 6 E.W.M.

Stream	Limitation	Point of Measurement
French Creek, Tributary to Snohomish River	No diversion when flow drops below 0.75 cfs.	125 ft. No. and 1300 ft. west of E1/4 of Sec. 20, T. 28 N., R. 6 E.W.M.
Langlois Creek Tributary to Tolt River	No diversion when flow drops below 3.0 cfs.	1040 ft. No. and 1250 ft. east of SW1/4 cor. of Sec. 22, T. 25 N., R. 7 E.W.M.
Tate Creek, Tributary to No. Fk. Snoqualmie River	No diversion when flow drops below 2.0 cfs.	900 ft. east and 870 ft. No. of W1/4 cor. of Sec. 26, T. 24 N., R. 8 E.W.M.
Tulalip Creek, Tributary to Tulalip Bay	No diversion when flow drops below 2.5 cfs.	1125 ft. west and 125 ft. No. of S1/4 cor. of Sec. 22, T. 30 N., R. 4 E.W.M.
Unnamed Stream (Coon Creek), Tributary to Pilchuck River.	No diversion when flow drops below 1.0 cfs.	400 ft. No. and 240 ft. west of center of Sec. 19, T. 30 N., R. 7 E.W.M.
Unnamed Stream (Coon Creek), Tributary to Pilchuck River	One-half of low flow must be bypassed.	800 ft. east and 1100 ft. So. of W1/4 cor. of Sec. 19, R. 30 N., R. 7 E.W.M.
Unnamed Stream, Tributary to Cherry Creek	No diversion when flow drops below 1.0 cfs.	1000 ft. So. and 400 ft. west of NE cor. of Sec. 16, T. 26 N., R. 7 E.W.M.
Unnamed Stream, Tributary to McCoy Creek	No diversion when flow drops below 0.5 cfs.	600 ft. west and 100 ft. No. of SE cor. of Sec. 5, T. 27 N., R. 8 E.W.M.
Unnamed Stream, Tributary to Snoqualmie River	No diversion when flow drops below 30.0 cfs.	330 ft. west and 900 ft. No. of SE cor. of Sec. 5, T. 27 N., R. 8 E.W.M.
Unnamed Stream (Solberg Creek), Tributary to Snoqualmie River	No diversion when flow drops below 2.0 cfs.	600 ft. west and 1050 ft. No. of E cor. of Sec. 12, T. 25 N., R. 6 E.W.M.
Unnamed Stream, Tributary to Snoqualmie River	One-half of low flow must be bypassed.	500 ft. So. and 1120 ft. east of center Sec. 28, T. 25 N., R. 7 E.W.M.
Unnamed Stream, Tributary to Snoqualmie River	No diversion when flow falls below 1.0 cfs.	600 ft. No. of E1/4 cor. of Sec. 28, T. 25 N., R. 7 E.W.M.
Wood Creek, Tributary to Snohomish River	No diversion when flow drops below 0.75 cfs.	335 ft. No. and 130 ft. east of S1/4 cor. of Sec. 8, T. 28 N., R. 5 E.W.M.
Woods Creek Tributary to Skykomish River	No diversion when flow drops below 11.0 cfs.	Immediately below confl. of West Fork in SE1/4NW1/4 Sec. 33, T. 28 N., R. 7 E.W.M.
Woods Creek, Tributary to Skykomish River	No diversion when flow drops below 6.0 cfs.	Immediately above said confl. of West Fork.
Woods Creek, Tributary to Skykomish River	No diversion when flow drops below 2.5 cfs.	Immediately above confl. of Roesigner Cr. in NE1/4NW1/4 of Sec. 3, T. 28 N., R. 7 E.W.M.
Woods Creek, Tributary to Skykomish River	No diversion when flow drops below 0.5 cfs.	Roesigner Creek, immediately above said confl. with Woods Creek.
Woods Creek, Tributary to Skykomish River	No diversion when flow drops below 3.0 cfs.	West Fork, immediately above said confl. with Woods Creek.
Woods Creek, Tributary to Skykomish River	No diversion when flow drops below 2.5 cfs.	West Fork when it crosses the No. line of Sec. 5, T. 28 N., R. 7 E.W.M.
Unnamed Lake (Morris Lake), Tributary to Horseshoe Lake	No diversion when flow drops below 1.0 cfs.	Lake outlet at NE1/4NE1/4 of Sec. 9, T. 25 N., R. 7 E.W.M.

Note: Affected stream reaches extend from mouth to headwaters and include all tributaries in the contributing drainage area unless specifically excluded.

(2) The department, having determined there are no waters available for further appropriation through the establishment of rights to use water consumptively, closes the following streams to further consumptive appropriation for the periods indicated. These closures confirm surface water source limitations previously established administratively under authority of chapter 90.03 RCW and RCW 75.20.050.

SURFACE WATER CLOSURES

Stream	Date of Closure	Period of Closure
Griffin Creek, Tributary to Snoqualmie River	9/22/53	All year
Harris Creek, Tributary to Snoqualmie River	1/20/44	All year
Little Pilchuck Creek, Tributary to Pilchuck River	5/6/52	All year
May Creek, Tributary to Wallace River	10/13/53	All year
Patterson Creek, Tributary to Snoqualmie River	2/19/52	All year
Quilceda Creek, Tributary to Ebey Slough	6/10/46	All year
Raging River, Tributary to Snoqualmie River	9/20/51	All year
Unnamed Stream (Bodell Creek), Tributary to Pilchuck River	9/6/51	All year

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-030, filed 9/6/79.]

WAC 173-507-040 Ground water. In future permitting actions relating to ground water withdrawals, the natural interrelationship of surface and ground waters shall be fully considered in water allocation decisions to assure compliance with the meaning and intent of this regulation. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-040, filed 9/6/79.]

WAC 173-507-050 Exemptions. (1) Nothing in this chapter shall affect existing 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 inhouse use for a single residence and stock watering, except that related to feed lots, shall be exempt. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-050, filed 9/6/79.]

WAC 173-507-060 Future rights. No right to divert or store public surface waters of the Snohomish WRIA 7 shall hereafter be granted which shall conflict with the instream flows and closures established in this chapter. Future rights for nonconsumptive uses, subject to the conditions herein established, may be granted. [Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-060, filed 9/6/79.]

WAC 173-507-070 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 90.03.600. [Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-507-070, filed 6/9/88. Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-070, filed 9/6/79.]

WAC 173-507-075 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), § 173-507-075, filed 6/9/88.]

WAC 173-507-080 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), § 173-507-080, filed 6/9/88. Statutory Authority: Chapters 90.22 and 90.54 RCW. 79-10-003 (Order DE 79-8), § 173-507-080, filed 9/6/79.]

APPENDIX B
STREAMFLOW DATA

Average Rows at Gage 12133000, S.F. Skykomish River near Index
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	Nov	DEC	YEAR	Departure From Mean
1902										697	2,094	2,526		
1903	3,880	1,069	1,275	1,826	3,796	6,264	2,695	1,003	1,598	2,415	2,568	2,547	2,585	144
1904	2,342	1,004	1,513	3,711	3,538	4,091	2,379	790	527	546	2,59	2 2,515	2,134	-307
1905	1,571	1,441	2,685	2,079	2,381	2,756	1,096	811	1,039					
1911					3,553	4,007	1,940	642	1,252	593	4,695	2,072		
1912	2,890	926	2,336 .	1,799	4,559	4,368	1,815	853	1,343					
1913										2,405	2,947	1,273		
1914	3,312	1,524	2,658	3,535	4,331	3,077	1,403	500	934	1,796	4,196	919	2,349	-92
1915	749	780	1,723	3,264	1,745	1,048	657	421	334	2,006	2,277	2,385	1,452	-989
1916	941	2,593	3,405	3,153	4,200	6,302	4,513	1,500	793	464	1,896	960	2,562	121
1917	1,296	2,024	898	2,279	4,508	7,455	6,018	1,463	680	615	1,026	11,035	3,290	849
1918	5,061	2,091	1,768	2,833	3,631	4,747	1,610	980	446	2,128	2,045	5,110	2,711	270
1919	3,842	1,324	1,558	3,347	4,753	4,117	2,678	882	580	612	4,050	3,097	2,575	134
1920	3,587	1,658	1,627	1,650	2,549	3,104	1,548	634	2,561	3,590	2,049	2,373	2,252	-189
1921	2,718	3,682	2,900	.2,546	4,774	6,378	2,756	904	1,590					
1922		560	683	1,788	4,450	4,983	1,317	596	773	1,073	1,338	2,871		
1923	4,382	884	1,395	3,256	4,176	3,890	2,225	719	442	884	1,646	2,988	2,251	-190
1924	2,161	5,412	1,240	1,835	4,750	2,585	1,060	536	491	2,115	2,483	4,045	2,389	-52
1925	2,847	3,745	1,562	3,208	5,337	3,451	1,419	558	351	750	1,310	4,793	2,438	-3
1926	2,173	2,111	1,909	2,139	2,127	963	424	419	674	2,499	1,820	2,121	1,613	-828
1927	1,733	1,714	1,297	2,351	4,265	5,665	2,046	802	1,716	3,060	5,742	2,899	2,771	330
1928	4,566	1,098	2,701	2,222	5,076	2,960	1,310	474	407	1,950	1,067	976	2,083	-358
1929	595	454	1,717	1,830	4,805	4,564	1,669	540	350	461	426	1,612	1,592	-849
1930	770	3,970	2,085	3,359	2,645	2,335	962	406	380	1,281	1,162	1,009	1,677	-764
1931	2,142	2,039	2,723	2,624	3,705	2,808	961	404	597	1,210	2,457	1,457	1,924	-517
1932	2,211	3,934	4,061	3,692	4,341	4,661	2,349	812	581	1,634	7,910	3,377	3,292	851
1933	2,792	780	1,719	2,645	4,119	6,860	4,682	1,693	1,962	4,326	3,786	9,440	3,757	1316
1934	5,334	2,262	4,278	4,244	3,158	1,627	839	498	588	2,610	4,132	2,843	2,705	264
1935	5,093	2,651	1,630	1,641	3,688	4,322	2,072	635	491	528	938	1,153	2,068	-373
1936	2,081	695	1,881	3,867	7,005	5,017	1,424	535	536	479	365	3,092	2,261	-180
1937	595	897	1,858	2,464	4,424	6,309	2,013	687	449	997	4,910	3,258	2,405	-36 ,
1938	2,158	802	1,551	3,725	4,169	3,352	1,122	434	341	740	2,399	3,151	2,000	-441
1939	3,524	1,394	1,986	3,322	4,827	3,730	2,364	755	506	1,135	2,055	3,838	2,462	21
1940	1,611	2,248	2,481	2,467	3,538	1,651	655	408	322	1,232	1,477	1,974	1,676	-765
1941	1,435	1,068	1,209	1,640	2,167	1,414	646	383	1,578	3,035	2,238	3,155	1,668	-773
1942	819	1,010	1,209	2,859	3,298	3,922	1,563	557	360	642	3,058	2,608	1,824	-617
1943	1,760	1,709	2,348	4,336	3,969	4,933	3,263	898	506	717	1,151	2,999	2,384	-57
1944	1,376	1,254	1,553	2,317	3,516	2,607	889	471	1,297	1,011	1,637	2,280	1,688	-753
1945	3,605	2,811	1,460	1,815	5,027	3,013	1,197	480	1,004	1,786	2,806	2,322	2,274	-167
1946	2,040	1,432	1,950	3,129	6,260	5,552	2,686	782	502	1,695	1,515	4,331	2,666	225
1947	2,977	2,932	2,538	3,750	4,656	3,413	1,625	637	704	3,539	3,590	2,778	2,759	318
1948	1,655	1,559	1,283	2,383	5,797	7,130	2,327	1,095	944	1,725	2,374	1,700	2,502	61
1949	748	1,569	2,258	3,395	6,758	4,740	2,807.	1,142	952	2,273	4,104	3,047	2,821	380
1950	1,942	1,899	3,131	2,777	4,579	7,966	4,926	1,758	781	2,945	3,926	4,321	3,420	
1951	2,268	4,844	1,419	3,059	4,622	3,614	1,363	536	589	2,682	2,048	1,386	2,349	
1952	873	1,891	1,123	2,973	4,563	3,340	1,728	587	376	267	316	892	1,578	-863
1953	6,868	3,375	1,398	2,410	4,057	3,860	3,172	925	603	1,410	2,843	4,652	2,967	526
1954	2,126	2,778	1,593	2,564	4,893	5,477	5,075	2,007	1,264	1,534	3,502	1,948	2,894	453
1955	1,354	2,188	913	1,964	3,710	6,865	4,643	1,663	668	3,383	5,022	3,373	2,978	537
1956	1,450	746	1,429	4,031	6,929	6,034	4,032	948	885	2,928	2,625	5,679	3,162	721
1957	1,029	1,652	1,887	3,214	5,694	3,825	1,403	622	403	603	1,251	2,600	2,017	-424
1958	2,429	2,455	1,334	2,522	5,023	2,642	832	434	714	1,855	5,603	4,860	2,556	115
1959	4,146	1,446	2,055	4,621	4,491	5,509	3,096	831	2,971	3,875	6,040	4,051	3,599	1158
1960	1,170	1,997	1,655	3,041	3,860	4,043	1,516	709	610	1,519	3,532	1,778	2,118	-323
1961	3,613	4,435	2,479	2,617	4,262	4,727	1,542	554	655	2,033	1,858	2,821	2,620	179
1962	4,091	2,006	1,099	3,445	2,770	4,017	2,192	1,169	788	1,367	3,795	3,424	2,512	71
1963	2,129	3,640	1,662	2,025	2,841	2,304	1,096	560	632	1,242	2,701	2,195	1,905	-536
1964	2,628	1,517	1;661	2,327	4,034	6,953	5,088	2,128	1,468	1,909	2,035	3,019	2,909	469
1965	2,768	3,231	1,803	3,386	3,853	3,940	1,930	852	766	1,225	2,227	1,819	2,306	-135
1966	1,923	1,078	1,892	3,242	4,552	4,001	2,269	777	394	1,470	1,965	4,332	2,334	-107
1967	3,921	2,542	1,651	1,261	4,094	6,210	2,447	679	437	3,956	2,706	4,148	2,842	401
1968	3,967	4,533	2,393	2,093	3,568	4,123	1,664	879	1,822	2,230	3,565	2,285	2,756	316
1969	2,684	735	1,606	3,178	6,251	5,252	1,437	600	1,169	1,890	1,524	1,638	2,339	-102
1970	2,473	2,147	1,810	2,361	3,501	4,797	1,405	506	983	1,094	2,474	1,796	2,106	-335
1971	3,632	3,912	1,627	2,188	6,102	5,248	4,946	1,526	885	1,296	2,962	1,857	3,010	569
1972	2,459	4,326	5,672	3,008	6,653	6,749	4,838	1,597	1,748	943	1,403	3,969	3,624	1183
1973	2,527	933	1,231	1,422	3,113	2,720	1,131	528	586	1,678	2,287	3,224	1,789	-652
1974	5,136	1,886	2,232	2,724	4,215	8,266	4,997	1,925	747	383	1,860	3,215	3,139	698
1975	3,281	1,394	1,605	1,227	4,466	5,680	3,722	1,305	745	1,932	4,609	7,806	3,163	722
1976	3,684	1,921	1,218	2,270	5,027	4,403	3,892	1,917	900	616	1,570	2,087	2,470	29
1977	2,181	1,610	1,515	2,742	2,429	2,505	769	727	1,037	956	5,274	6,133	2,323	-118
1978	1,408	1,392	1,981	2,109	3,018	3,476	1,439	801	1,706	742	2,137	1,693	1,823	-618
1979	800	1,886	3,030	2,207	4,346	3,211	1,574	548	530	798	628	5,754	2,116	-325
1980	1,408	2,160	1,858	3,203	3,400	2,650	1,352	707	1,271	543	4,067	6,126	2,399	f42
1981	1,484	3,924	1,129	2,978	2,759	3,297	1,262	554	737	1,880	1,820	2,396	2,000	-441
1982	2,480	5,339	2,310	1,956	4,105	5,730	2,798	896	862					
Min	595	454	683	1,227	1,745	963	424	383	322	267	316	892	1,452	-989
Avg	2,524	2,142	1,903	2,705	4,218	4,319	2,224	845	868	1,617	2,674	3,142	2,441	0
Max	6,868	5,412	5,672	4,621	7,005	8,266	6,018	2,128	2,971	4,326	7,910	11,035	3,757	1316

Average Flows at Gage 12138150, Sultan River below Chaplain Creek near Sultan
and Gage 12138160, Sultan River below Powerplant near Sultan
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
I. Sultan River below Chaplain Creek: Basin Area 93 sq mi.														
1974											649	1,266		
1975	1,207	454	533	331	1,143	969	533	296	246	969	1,766	3,091	967	224
1976	1,719	671	414	772	1,299	950	667	420	347	295	349	751	725	-18
1977	1,039	259	480	888	860	. 590	127	258	408	371	1,760	1,931	750	7
1978	620	533	671	559	711	440	188	201	806	251	788	623	531	-212
1979	362	820	1,081	666	866	519	415	99	137	237	254	2,526	667	-76
1980	446	652	629	934	611	570	244	120	512	311	1,587	2,014	719	24
1981	579	1,316	331	1,276	781	1,305	298	138	225	992	684	934	732	-11
1982	1,320	2,255	811	612	1,088	1,115	696	237	311	414	737	1,163	888	145
1983	1,576	622	784	794	663	716	1,027	78	469	224	897	231	673	-70
1984	1,020	815	774	509	695	231	171	115	140					
II. Sultan River below Powerplant near Sultan: Basin Area 94 sq mi.														
1983								82	438	227	928	268		
1984	1,067	840	743	520	1,257	1,181	684	194	222	322	1,168	699	743	-0
1985	401	310	344	1,094	962	965	430	167	203	1,008	2,028	261	680	-03
1986	926	819	905	460	807	421	242	180	212	407	1,468	1,117	662	-81
1987	648	731	964	601	694	394	198	179	204	234	246	754	487	-256
1988	406	793	910	1,284	1,105	685	483	219	250	921	1,590	1,073	811	68
1989	1,016	418	617	1,271	834	505	323	256	231	398	1,693	1,542	760	17
1990	1,416	1,164	772	936	725	963	480	236	482	956	3,080	1,727	1,074	331
1991	1,228	1,568	893	755	658	454	467	207	540	289	891	1,274	763	20
1992	819	1,100	387	276	389	256	210	199	251					
1993	405													
Min	362	259	331	276	389	231	127	78	137	224	246	231	487	256
Avg	903	850	683	779	827	669	400	200	332	506	1,202	1,277	743	0
Max	1,719	2,255	1,081	1,284	1,299	1,305	1,027	420	806	1,008	3,080	3,091	1,074	331

Average Flows at Gage 12143000, N.F. Snoqualmie River near North Bend
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
1907								197	320	189	672	770		
1908	466	353					477	174	159	358	664	576		
1909	917	594	420	657	959	1,357	527	189	229	373		1,173		
1910	773	630	1,636	1,241	1,169	577	202	81	83	973	1,367	713	788	74
1911	511	242	377	438	954	769	379	111	415	203	1,765	760	577	-137
1912	1,001	823	223	466	1,018	734	374	247	407	377	944			
1913		575				1,232	714	190	404	861	849	312		
1914	979	754	1,039	1,002	934	804	283	87	310	601	1,106	352	686	-28
1915	520	472	654	986	657	403	294	112	92	691	840	954	557	-157
1916	380	1,113	1,414	933	990	1,234	975	286	245	129	731	476	742	28
1917	653	977	325	850	1,203	1,858	1,171	271	143	195	393	2,891	911	198
1918	1,600	861	652	825	871	755	208	389	115	685	670	1,246	741	27
1919	1,180	469	493	1,017	1,050	706	358	130	155	287	1,184	882	660	-54
1920	1,236	410	522	638	771	788	255	110	721	911	661	800	655	-59
1921	1,064	1,073	898	880	1,165	1,244	484	149	439	551	907	1,522	863	149
1922	251	210	264	702	1,526	1,261	277	131	363	459	459	947	572	-141
1923	1,385	416	566	930	1,026	999	372	123	80	815	958	1,240	745	32
1925	1,094	1,073	522	952	1,085	652	193	96	78	235	624	1,705	691	-23
1926	822	826	714	549	610	300	125	135	300					
1929			690	660	1,428	1,276	334	107	78	157	184	651		
1930	351	1,242	570	751	649	567	180	70	101	569	408	366	479	-234
1931	898	612	971	854	701	669	189	83	306	626	756	599	605	-109
1932	759	928	1,548	1,511	1,396	1,370	695	197	241	840	2,246	1,075	1068	354
1933	1,159	281	693	756	1,154	1,529	827	283	695	1,159	1,043	2,555	1017	304
1934	1,859	662	954	775	642	212	119	77	166	1,051	1,269	1,087	742	28
1935	1,493	797	621	668	877	834	466	200	156	222	603	704	636	-77
.1936	1,140	372	769	1,152	1,671	1,060	319	115	242	167	125	1,202	699	-15
1937	229	428	792	1,026	1,319	1,551	374	216	168	497	1,813	1,126	794	81
1938	907	333	555	1,210	1,003	498	143	72	71	704	1,270	696	623	-91
1961	1,057	1,475	856	1,043	1,147	764	214	76	203	724	667	972	762	48
1962	1,271	518	334	993	742	789	428	400	267	407	941	1,014	676	-38
1963	584	936	464	749	643	556	352	174	181	388	1,032	774	566	-148
1964	933	568	596	781	1,178	1,733	875	576	563	510	734	1,063	845	131
1965	1,335	1,092	482	855	833	618	277	184	325	462	596	587	634	-80
1966	704	393	645	952	1,102	795	566	159	112	485	757	1,306	667	-47
1967	1,427	819	555	388	1,020	992	288	81	83	887	680	1,421	721	8
1968	1,218	1,288	630	718	984	981	312	329	614	764	993	862	807	94
1969	1,034	297	529	893	1,399	1,019	337	164	523	562	518	718	668	-45
1970	1,044	792	564	738	828	755	230	109	497	551	870	750	642	-72
1971	1,379	1,211	580	636	1,475	1,220	971	234						
Min	229	210	223	388	610	212	119	70	71	129	125	312	479	-234
Avg	963	708	679	843	1032	933	414	178	273	543	873	996	714	0
Max	1859	1475	1636	1511	1671	1858	1171	576	721	1159	2246	2891	1068	354

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Average Flows at Gage 12144500, Snoqualmie River near Snoqualmie
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From, Mean
1898					4,480	4,708	2,035	691	1,035	2,217	3,608	3,222		
1899	5,269	4,803	1,803	2,967	5,117	6,932								
1900	3,794	2,756	3,823	2,575	3,057	2,813								
1901														
1902										840	2,711	3,729		
1903	5,141	1,292	1,459	1,958	4,143	5,291	2,238	745	2,439	2,240	3,252	3,241	2,794	112
1904	3,328	1,380	1,965	4,215	3,304	3,593	1,780							
1926							536	585	1,059	2,852	2,302	2,740		
1927	2,448	2,776	2,051	2,784	4,729	5,294	2,033	830	2,386					
1958									938	2,355	6,126	5,288		
1959	5,286	1,969	2,623	4,678	4,163	4,156	2,013	764	3,937	3,931	6,958	4,782	3,774	1092
1960	1,635	2,612	2,184	3,140	4,119	3,537	1,212	829	861	2,188	4,586	2,422	2,443	239
1961	4,065	5,545	3,208	3,511	4,242	3,466	1,191	483	789	2,295	2,386	3,607	2,881	199
1962	4,272	1,927	1,367	3,419	2,765	3,035	1,802	1,325	974	1,780	3,932	3,795	2,534	-148
1963	2,391	3,991	1,850	2,624	2,635	2,031	1,316	679	594	1,295	3,616	2,635	2,122	-560
1964	3,656	2,238	2,322	2,925	4,381	6,792	3,989	2,263	1,991	2,069	2,629	4,233	3,302	620
1965	4,870	4,208	1,939	3,279	3,226	2,746	1,398	816	1,009	1,562	2,252	2,036	2,432	-250
1966	2,664	1,541	2,428	3,554	4,335	3,367	2,176	684	429	1,742	2,515	4,913	2,538	-144
1967	5,276	3,203	2,052	1,478	3,723	4,269	1,513	585	478	3,344	2,691	5,325	2,832	150
1968	4,600	4,911	2,554	2,638	3,525	3,661	1,351	1,208	2,342	2,658	3,535	3,238	3,016	334
1969	3,905	1,215	1,981	3,250	5,304	4,134	1,466	634	1,507	1,935	1,710	2,391	2,461	-221
1970	3,695	2,765	2,117	2,894	3,221	3,376	1,144	556	1,438	1,658	2,995	2,602	2,365	-317
1971	4,949	4,529	2,351	2,434	5,526	4,815	4,039	1,263	1,133	1,880	3,787	3,051	3,306	624
1972	3,929	5,813	6,735	3,477	6,055	5,578	3,821	1,272	1,964	991	1,923	4,868	3,876	1194
1973	3,147	1,216	1,533	1,821	2,964	2,674	1,099	551	718	1,678	2,857	4,205	2,046	-636
1974	5,991	2,899	3,336	3,430	4,437	7,568	4,393	1,790	797	455	2,437	4,102	3,473	791
1975	5,157	2,228	2,257	1,559	4,499	4,691	2,868	1,470	942	2,482	4,894	8,886	3,510	828
1976	5,311	2,285	1,602	2,651	4,311	3,614	2,832	1,757	1,014	890	1,966	2,577	2,579	-103
1977	2,428	1,723	1,852	3,025	2,768	2,486	861	809	1,392	1,294	5,272	7,147	2,590	-92
1978	2,265	2,028	2,282	2,337	3,192	2,587	1,168	933	2,193	854	2,714	2,729	2,104	-578
1979	1,162	3,135	3,438	2,719	3,992	2,585	1,534	477	538	892	716	5,956	2,262	-420
1980	1,848	2,702	2,274	3,476	2,767	2,418	1,274	770	1,826	663	3,966	5,938	2,494	-188
1981	1,542	4,414	1,385	3,977	2,989	3,652	1,388	617	937	2,214	1,737	2,941	2,296	-386
1982	3,860	6,676	2,951	2,083	3,630	4,108	2,222	894	1,384	1,733	2,271	3,556	2,922	240
1983	4,920	2,403	2,727	2,115	2,954	2,582	2,769	966	1,766	918	4,812	1,991	2,576	-106
1984	6,414	2,284	2,699	2,162	4,127	4,220	1,986	706	783	1,261	3,023	2,415	2,684	2
1985	1,522	1,534	1,438	4,327	4,270	4,335	1,224	485	797	3,633 ,	4,128	1,211	2,405	277
1986	2,818	3,718	2,837	2,074	3,708	1,933	1,213	554	976	1,212	5,631	1,952	2,372	310
1987	1,737	2,405	3,179	2,928	3,200	1,733	815	503	436	348	858	2,415	1,710	-972
1988	1,570	2,524	2,954	4,409	3,985	2,802	1,504	564	886	2,777	3,719	3,235	2,581	-101
1989	3,569	1,503	2,299	4,696	3,431	3,045	1,286	778	503	934	5,517	3,715	2,606	-76
1990	4,429	3,604	2,845	4,101	3,382	4,495	1,688	868	707	3,726	10,097	3,309	3,591	909
1991	3,627	5,778	2,003	3,565	2,866	3,048	1,746	711	441	369	3,391	3,676	2,575	-107
1992	3,607	2,497	1,565	2,220	1,895	1,077	930	500	1,544	1,016	2,926	2,056	1,819	-863
1993	2,526	1,469	3,064	3,382	5,009	2,996	1,784	864	504					
Min	1,162	1,215	1,367	1,478	1,895	1,077	536	477	429	348	716	1,211	1,710	-972
Avg	3,616	2,963	2,433	3,021	3,815	3,713	1,841	866	1,210	1,774	3,499	3,644	2,682	-0
Max	6,414	6,676	6,735	4,696	6,055	7,568	4,393	2,263	3,937	3,931	10,097	8,886	3,876	1194

Average Flows at Gage 12148500, Tolt River near Carnation
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure from Mean
1928									91	679	333	344		
1929	246	163	671	574	882	785		228	162	166	155	606	397	-184
1930	404	1,256	581	587	509	411	148	83	121	462	395	421	442	-138
1931	794	512	848	671	417	460	189	95	293	470	674	582	500	-80
193?										343	1,417	990		
1938	841	362	504	1,058	625	2?5	121	84	7?	255	1,017	1,172	533	-47
1939	1,207	381	642	731	829	805	424	138	167	450	664	1,029	640	60
1940	534	869	898	609	560	216	128	97	73	451	589	689	476	-104
1941	560	329	289	289	468	361	145	93	529	787	529	916	442	-138
1942	398	485	496	563	624	867	295	145	94	329	1,029	1,085	534	-47
1943	543	740	646	866	736	582	296	136	113	335	376	862	518	-62
1944	519	481	482	712	894	458	162	125	587	356	755	711	521	.60
1945	1,086	706	657	715	1,102	424	173	113	472	553	1,097	839	661	81
1946	869	719	800	782	888	909	378	151	131	536	752	1,460	698	118
1947	1,084	1,044	654	979	509	613	268	142	219	891	1,333	1,024	727	147
1948	687	710	509	709	1,208	942	339	409	398	465	1,101	689	681.	101
1949	355	730	816	794	1,078	551	397	196	226	663	900	1,036	645	65
1950	859	1,070	1,189	886	917	1,064	506	302	193	686	1,050	1,112	818	238
1951	882	1,534	522	601	598	375	134	80	135	853	722	547	576	-5
1952	417	728	500	718	831	585	300	129	103	81	123	432	412	-168
1953	2,058	928	524	711	753	606	300	135	165	522	846	1,648	767	187
1954	810	975	487	598	626	887	504	301	460	333	892	709	628	48
1955	572	860	333	702	996	1,177	802	358	177	896	1,317	1,274	787	207
1956	831	420	623	996	1,078	894	405	155	310	903	819	1,354	736	156
1957	361	688	774	893	805	525	248	175	94	203	545	792	507	-73
1958	994	918	438	719	485	244	120	75	167	538	1,478	1,405	629	49
1959	1,533	679	823	1,275	1,022	809	381	166	954	933	1,485	1,332	950	369
1960	554	765.	580	739	987	604	211	233	227	569	1,076	654	600	20
1961	997	1,372	822	894	764	372	177	107	184	649	602	1,076	664	84
1962	1,252	548	435	634	628	495	466	358	269	372	916	1,038	619	38
1963	635	856	463	764	488	416	327	168	204	291	825	593	499	-81
1964	942	617	554	632	89?	1,204	604	485	524	538	653	987	722	142
1965	1,217	1,252	571	555	462	311	175	186	351	451	642	595	559	-21
1966	775	502	522	638	593	495	451	207	215	524	728	1,193	571	-9
1967	1,463	879	557	371	598	521	204	135	124	570	599	1,164	599	18
1968	1,036	918	626	762	774	710	281	322	508	647	864	939	699	119
1969	1,070	368	616	705	779	598	439	282	376	457	417	591	560	-20
1970	754	653	469	601	491	353	195	127	321	498	652	736	486	-94
1971	1,476	1,186	625	548	756	725	505	188	258	442	956	734	697	117
1972	872	1,315	1,472	779	984	769	569	204	457	232	355	938	746	166
1973	764	328	379	379	403	352	173	110	167	434	828	983	443	-137
1974	1,415	802	788	747	892	1,015	502	211	156	122	555	832	669	89
1975	1,144	708	536	368	653	507	288	243	222	519	1,255	1,897	696	116
1976	1,375	534	413	593	632	461	339	274	193	244	376	474	494	-86
1977	514	305	404	564	566	363	195	195	248	257	949	1,491	506	-75
1978	611	481	380	409	419	266	191	223	558	301	542	665	420	-160
1979	377	733	732	545	546	280	223	114	132	202	181	1,147	433	-147
1980	517	638	524	709	402	379	231	214	367	202	809	1,258	521	-59
1981	410	1,007	398	895	616	724	280	165	240	532	417	685	527	-54
1982	1,022	1,634	821	464	558	396	249	157	235	268	437	775	578	-2
1983	1,231	516	495	368	332	286	482	203	383	240	1,038	538	509	-71
1984	1,545	564	594	495	811	679	253	139	173	285	75?	712	586	6
1985	424	413	358	745	700	665	186	125	196	585	981	305	472	-108
1986	589	593	523	404	685	248	254	137	217	254	1,061	569	461	-119
1987	574	597	695	487	401	243	162	114	97	. 79	172	399	334	-246
1988	338	520	572	898	650	432	257	143	252	485	990	845	532	-48
1989	1,094	427	668	1,030	616	375	236	192	141	234	1,024	867	576	-5
1990	1,087	942	698	700	676	702	235	161	140	590	1,781	1,036	726	146
1991	1,015	1,137	641	666	455	451	219	149	134	143	671	808	537	-44
1992	856	608	267	352	310	205	207	128	264	221	639	534	383	-198
1993	614	367	610	798	798	589	393	237	160					
Min	246	163	267	289	310	205	120	75	73	79	123	305	334	-246
Avg	847	738	602	678	691	560	297	181	252	443	786	885	580	0
Max	2,058	1,634	1,472	1,275	1,208	1,204	902	485	954	933	1,781	1,897	950	369

Average Flows at Gage 12149000, Snoqualmie River near Carnation
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From Mean
1929			3,850	3,471	6,357	3,959	1,926	693	521	761	792	3,935		
1930	1,923	6,781	3,508	4,044	3,428	3,000	%3	492	547	2,763	2,227	1,874	2,597	-1155
1931	5,287	3,418	4,718	4,846	4,279	3,4%	1,1%	509	1,247	2,826	4,403	3,530	3,310	-442
1932	5,176	5,341	9,979	6,797	5,623	5,452	3,324	1,341	1,181	3,080	12,802	6,645	5,583	1831
1933	6,958	2,383	4,362	4,056	5,723	7,741	4,000	1,424	3,024	3,760	6,712	14,531	5,584	1832
1934	9,550	4,003	5,122	4,244	3,178	1,567	1,067	773	1,106	4,434	6,381	5,319	3,901	148
1935	8,530	3,974	3,282	2,842	3,626	3,584	2,126	1,001	779	994	2,681	3,199	3,050	-702
1936	6,055	2,207	4,228	4,934	7,847	5,570	1,881	716	%3	871	667	5,688	3,490	262
1937	1,291	3,233	4,052	5,414	5,646	6,856	2,197	1,059	794	1,909	8,851	6,019	3,933	180
1938	4,814	2,065	2,946	5,962	4,585	2,780	1,090	583	493	1,1%	3,942	6,105	3,052	700
1939	6,376	3,516	3,711	4,112	5,031	4,906	2,811	902	851	2,325	3,509	6,277	3,699	-53
1940	3,019	4,640	5,089	4,043	4,422	1,803	840	626	517	2,012	2,923	3,894	2,822	930
1941	2,941	2,001	1,933	2,230	3,072	2,250	966	523	3,032	4,309	3,401	5,929	2,721	-1031
1942	2,7.22	2,648	2,646	3,677	4,117	6,035	2,206	899	576	1,018	6,979	6,000	3,245	-507
1943	3,110	3,772	3,638	5,546	4,921	4,881	2,713	1,023	791	1,869	2,101	5,123	3,286	-466
1944	2,511	2,658	2,721	3,869	5,224	3,263	1,153	734	2,563	1,664	3,402	3,883	2,807	.945
1945	6,161	4,860	3,740	4,144	6,588	3,626	1,472	613	2,574	3,309	6,693	4,835	4,043	290
1946	4,861	3,862	4,315	4,655	6,333	6,733	3,081	1,028	811	3,039	4,081	8,690	4,257	505
1947	6,198	5,674	3,833	5,601	4,263	3,994	1,846	899	1,614	5,811	8,282	5,634	4,457	704
1948	4,632	3,981	3,207	4,037	7,738	7,372	2,740	2,015	1,933	2,739	5,494	4,168	4,135	383
1949	2,118	4,264	4,546	4,747	7,191	4,541	3,087	1,528	1,228	3,520	5,279	5,427	3,954	202
1930	4,729	5,545	7,093	5,235	5,872	7,850	4,410	2,133	1,109	4,281	6,642	7,502	5,197	1445
1951	5,203	9,219	3,012	3,800	4,955	3,524	1,376	578	719	4,374	3,424	3,362	3,591	-161
1952	2,098	4,030	2,686	4,392	5,578	3,884	2,327	790	593	479	619	1,756	2,435	-1318
	11,137	6,169	3,012	4,413	5,302	4,703	2,955	1,126	871	2,518	5,133	9,176	4,708	955
1954	5,017	6,044	3,181	3,962	4,856	6,254	4,221	2,030	2,150	1,843	4,716	3,518	3,963	210
1953	3,172	4,684	2,212	4,208	5,676	7,871	5,629	2,226	1,125	5,444	7,885	7,906	4,833	1081
1956	4,544	2,279	3,817	5,704	7,103	6,273	3,698	1,138	1,436	4,722	4,558	8,388	4,4%	743
1957	2,116	3,674	4,287	4,929	5,701	3,452	1,534	910	576	1,026	2,625	4,547	2,943	-809
1958	5,208	4,974	2,446	4,022	4,152	2,246	895	517	1,170	3,067	8,931	7,641	3,759	7
1959	8,424	3,323	4,211	6,793	5,985	5,272	2,617	1,019	5,128	5,248	9,342	6,%3	5,363	1611
1%0	2,845	4,241	3,137	4,692	6,040	4,627	1,594	1,197	1,236	3,153	6,894	3,495	3,394	-158
1%1	5,824	8,219	5,149	5,244	5,661	4,282	1,518	613	1,086	3,209	3,759	5,475	4,143	391
1%2	6,380	2,9%	2,435	4,685	3,947	3,847	2,404	1,628	1,170	2,225	5,454	5,724	3,577	-175
1%3	3,734	5,406	2,794	3,987	3,411	2,688	1,795	967	893	1,786	5,426	4,063	3,058	-694
1964	6,002	3,645	3,695	4,226	5,677	8,603	4,991	2,992	2,829	2,914	3,765	6,382	4,659	907
1%3	7,093	6,898	3,054	4,248	4,139	3,348	1,734	1,106	1,432	2,181	3,214	3,067	3,436	-317
1966	4,444	2,640	3,531	4,830	5,440	4,260	2,969	1,072	800	2,304	3,645	7,172	3,602	-130
1%7	8,027	4,954	3,177	2,258	4,672	5,091	1,807	763	642	3,854	3,510	7,102	3,823	71
1%8	6,482	6,579	3,726	3,938	4,635	4,737	1,642	1,536	2,899	3,613	4,932	5,106	4,151	398
1%9	6,441	2,585	3,250	4,701	6,572	5,171	2,123	1,028	2,010	2,790	2,488	3,784	3,587	-166
1970	5,487	4,089	3,055	4,176	4,063	3,903	1,440	745	1,890	2,332	4,048	4,213	3,278	-474
1971	7,557	6,529	3,860	3,321	6,729	5,883	4,778	1,553	1,506	2,488	5,389	4,775	4,536	784
1972	6,044	8,2%	9,780	5,1%	7,578	6,846	4,784	1,640	2,586	1,368	2,577	6,839	5,303	1551
1973	4,707	1,860	2,319	2,518	3,671	3,321	1,391	575	816	2,192	4,197	6,394	2,839	-913
1974	8,595	4,627	5,208	4,886	5,857	8,983	5,126	2,045	1,036	629	3,033	5,335	4,615	862
1975	7,597	3,839	3,605	2,511	5,849	5,536	3,345	1,897	1,372	3,368	6,846	12,635	4,884	1132
1976	8,261	3,515	2,473	3,871	5,308	4,376	3,336	2,056	1,259	1,115	2,321	3,330	3,485	-268
1917	3,369	2,731	2,777	4,033	3,705	3,187	1,1%	1,077	1,800	1,745	6,828	10,610	3,553	-199
1978	3,652	3,029	3,084	3,111	4,188	3,051	1,465	1,170	3,069	1,372	3,822	4,258	2,935	-817
1979	1,911	4,928	4,793	3,880	5,064	3,101	1,910	705	787	1,215	1,042	8,771	3,172	-381
1980	3,020	3,946	3,616	4,895	3,514	3,050	1,639	1,052	2,358	982	3,543	8,273	3,493	-259
1981	2,621	6,108	2,269	5,581	4,451	5,075	1,956	933	1,341	3,218	2,597	4,466	3,359	-393
1982	3,855	9,743	4,590	2,978	4,612	4,848	2,644	1,129	1,716	2,181	3,170	5,305	4,027	275
1983	7,158	3,437	3,739	2,826	3,514	3,032	3,484	1,322	2,411	1,312	6,797	3,167	3,514	-238
1984	8,973	3,540	4,013	3,274	5,583	5,522	2,539	1,060	1,113	1,706	4,487	3,%9	3,829	77
1985	2,286	2,384	2,146	5,612	5,348	5,391	1,577	770	1,142	4,427	5,745	1,694	3,203	-549
1986	3,811	4,716	3,824	2,813	4,798	2,390	1,601	749	1,198	1,552	7,490	2,825	3,131	X22
1987	2,685	3,688	4,467	3,754	3,855	1,903	%3	619	518	40,7	%7	2,853	2,216	-1536
1988	2,405	3,804	4,372	6,143	4,827	3,329	1,841	860	1,221	3,531	5,632	4,613	3,352	-200
1989	5,587	2,498	3,761	6,268	4,315	3,517	1,587	1,007	701	1,180	7,100	5,561	3,590	-162
1990	6,905	5,513	4,165	5,192	4,353	6,210	2,183.	995	794	4,149	12,847	5,154	4,851	1099
1991	3,655	7,820	3,330	5,179	3,738	3,946	2,182	1,038	753	636	4,496	5,394	3,647	-105
1992	3,140	3,852	2,038	2,843	2,434	1,362	1,224	715	1,863	1,421	4,139	3,391	2,537	-1216
1993	3,691	2,142	4,058	4,709	6,255	4,004	2,528	1,245						
Min	1,291	1860	1,933	2,230	2,434	1,362	840	492	493	407	619	1,694	2,216	-1536
Avg	5,088	4,371	3,795	4,359	5,044	4,533	2,333	1,103	1,410	2,528	4,842	5,511	3,752	0
Max		9,743	9,979	6,797	7,847	8,983	5,629	2,992	5,128	5,811	12,847	14,531	5,584	1832

Average Flows at Gage 12150800, Snohomish River near Monroe
Average Discharges in cfs for Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Depature From Mean
1963		14,909	6,705	9,368	9,547	7,498	4,455	2,361	2,529	5,042	12,448	10,486		
1964	14,106	7,768	8,148	10,416	14,942	23,530	15,294	7,885	6,348	7,553	9,118	15,223	11,741	2149
1965	14,882	17,605	7,175	11,088	12,077	10,788	5,530	3,037	3,358	4,912	8,872	8,026	8,879	-713
1966	10,512	6,030	8,655	12,340	14,620	12,243	7,765	2,827	1,898	5,890	8,862	19,580	9,300	292
1967	19,995	12,479	7,974	5,430	13,358	17,090	6,936	2,074	1,559	12,375	9,760	17,960	10,590	998
1968	16,707	16,889	9,527	9,114	12,392	13,502	5,158	3,567	7,572	9,441	13,808	12,759	10,865	1273
1969	14,125	5,304	6,738	11,387	18,652	15,527	5,265	2,296	4,646	7,715	6,588	8,899	8,952	-640
1970	12,416	9,992	7,554	10,062	10,911	12,663	4,275	1,926.	4,366	5,068	10,274	9,915	8,260	-1332
1971	19,009	17,227	9,313	9,008	18,900	16,457	14,932	4,744	3,416	5,649	13,182	10,862	11,863	2271
1972	12,944	18,389	25,705	12,424	20,453	19,360	14,583	4,537	6,202	3,461	5,931	17,628	13,505	3913
1973	11,780	4,606	6,112	6,131	10,396	9,326	3,927	1,811	2,473	6,349	10,763	15,405	7,449	-2143
1974	21,887	10,886	12,308	11,889	15,037	24,733	14,935	6,285	2,801	1,495	8,013	13,794	12,016	2424
1975	16,747	8,122	8,078	5,340	14,848	16,080	10,251	4,523	3,114	8,761	19,356	29,584	12,111	2319
1976	18,168	8,630	6,619	9,991	16,039	13,285	11,044	6,224	3,667	2,823	6,024	8,430	9,285	-307
1977	9,265	5,831	7,248	10,368	9,748	8,645	2,960	2,999	4,621	4,456	18,381	25,044	9,143	-449
1978	8,186	7,195	8,177	8,366	10,519	9,530	4,485	3,082	7,646	3,271	9,283	9,175	7,397	2195
1979	4,401	10,609	12,282	9,209	13,439	9,225	5,441	1,839	1,984	3,275	2,823	23,364	8,163	-1429
1980	7,283	9,556	8,890	12,255	10,310	8,755	4,743	2,712	5,656	2,778	15,621	23,156	9,320	272
1981	6,980	16,234	5,449	13,801	11,827	13,872	4,997	2,073	3,089	8,914	7,588	11,163	8,763	-829
1982	13,945	24,301	11,012	7,905	12,901	15,857	8,941	3,285	3,928	5,292	7,865	13,642	10,648	1056
1983	18,251	9,100	9,827	7,596	10,326	9,221	9,655	3,021	5,339	3,112	17,386	6,783	9,127	-465
1984	22,003	8,719	9,821	7,597	14,776	16,853	8,652	2,885	3,143	4,361	11,855	9,086	10,015	423
1985	5,137	5,089	4,859	14,554	14,656	15,716	4,807	1,994	2,998	12,087	16,709	3,966	8,533	-1059
1986	11,557	12,562	10,445	7,120	12,689	7,624	3,995	1,756	2,486	3,691	19,376	7,946	8,395	-1196
1987	7,366	9,003	11,901	10,355	12,229	6,779	2,683	1,413	1,133	894	2,624	8,097	6,194	-3398
1988	5,526	8,842	10,817	15,967	14,326	10,740	5,694	1,923	2,836	9,104	15,204	11,749	9,403	-189
1989	13,209	5,898	8,561	16,045	12,167	11,161	4,903	2,662	1,636	3,401	19,404	14,973	9,503	-89
1990	16,432	12,975	10,084	14,300	11,627	16,042	6,290	2,535	2,222	11,909	34,804	13,956	12,718	3126
1991	13,742	20,504	8,612	12,520	10,461	10,859	7,115	2,708	2,104	1,757	11,787	12,980	9,509	-83
1992	12,698	10,763	6,203	7,513	7,743	4,070	2,945	1,672	3,959	3,444	9,671	7,573	6,518	-3074
1993	8,190	5,171	9,285	10,919	16,787	9,627	5,374							
Min	4,401	4,606	4,859	5,340	7,743	4,070	2,683	1,413	1,133	894	2,624	3,966	6,194	-3398
Avg	12,915	11,006	9,164	10,335	13,184	12,795	7,033	3,089	3,624	5,609	12,113	13,374	9,592	0
Max	22,003	24,301	25,705	16,045	20,453	24,733	15,294	7,885	7,646	12,375	34,804	29,584	13,505	3913

Minimum Flows at Gage 12133000, S.F. Skykomish River near Index
Minimum Daily Discharges in cfs far Calendar Year

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	Departure From mean
1902									457	1,310	888			
1903	1,410	846	806	1,110	2,150	3,620	1,410	766	618	930	1,060	1,060	618	230
1904	930	766	806	1,020	2,150	2,680	1,110	550	403	356	518	1,020	356	-32
1905	888	618		1,410	1,260	1,410	1,560	806	550	518				
1911					2,520	2,440	930	487	487	429	403	974	403	15
1912	690	930	690	1,310	1,740	2,150	974	313	690					
1913									690	1;110	728			
1914	806	812	1,300	1,520	2,700	2,030	1,150	500	400	622	1,870	556	400	12
1915	524	692	692	1,520	1,230	764	492	360	264.	374	1,040	1,000	264	-124
1916	524	622	1,180	2,110	2,540	3,200	2,370	918	402	332	732	550	332	-56
1917	620	732	620	894	2,100	4,130	2,530	787	488	432	550	1,070	432	44
1918	1,780	920	685	1,500	2,100	2,460	920	640	346	387	1,070	1,250	346	-42
1919	775	920	820	1,920	2,510	2,880	1,250	560	359	333	990	713	333	-55
1920	940	713	713	1,040	1,580	1,720	713	417	483	1,440	776	866	417	29
1921	990	915	1,480	1,440	2,120	3,700	1,440	575	483					
1922		466	433	1,020	1,920	2,760	673	483	417	346	594	594	346	-42
1923	990	560	965	2,390	2,210	2,480	990	556	346	346	483	1,260	346	-42
1924	990	1,880	843	843	2,300	1,650	633	387	320	753	1,320	1,090	320	-a
1925	1,040	1,200	1,040	1,140	2,960	2,300	798	417	271	214	519	1,720	214	-174
1926	1,090	990	990	1,260	1,380	556	333	308	387	843	735	1,040	308	-80
1927	830	830	980	1,160	2,660	3,060	1,040	530	645	1,420	2,040	780	$30	142
1928	830	645	605	1,350	2,390	1,960	690	374	304	575	575	575	304	.84
1929	420	370	930	830	2,570	3,160	830	399	271	271	350	327	271	-117
1930	380	1,420	830	2,390	1,720	1,560	540	327	282	304	610	510	282	-106
1931	510	895	1,430	1,500	1,990	1,990	535	350	340	400	895	615	340	-48
1932	745	535	1,640	2,380	2,750	2,950	1,130	575	400	327	2,230	1,370	327	-61
1933	640	392	730	1,580	2,500	4,700	2,590	730	600	885	1,230	1,420	392	4
1934	3,030	1,290	1,840	2,850	2,190	1,050	630	438	415	418	1,940	1,360	415	27
1935	830	1,420	835	728	2,340	2,790	925	491	402	362	432	567	362	-26
1936	651	410	752	591	4,090	7,430	665	468	421	367	320	327	320	-68
1937	390	370	1,030	1,510	1,970	4,740	884	517	330	292	932	1,370	292	-96
1938	1,150	612	1,110	1,030	2,110	2,280	605	345	272	244	978	956	244	-144
1939	1,520	963	877	2,280	2,990	2,780	1,360	519	323	311	923	1,610	311	-77
1940	860	1,210	1,490	1,690	2,010	930	490	338	279	303	570	1,020	279	-109
1941	756	700	868	1,330	1,210	975	444	344	491	878	829	1,070	344	-44
1942	656	554	565	1,940	1,890	2,480	759	454	310	275	1,060	1,260	275	-113
1943	985	950	915	2,320	2,120	3,380	1,470	605	395	386	649	830	386	•2
1944	714	666	606	1,450	2,290	1,660	562	386	317	550	638	920	317	-71
1945	920	906	913	1,210	3,170	1,770	632	377	350	415	1,550	896	350	-38
1946	1,110	745	1,190	1,190	3,190	3,290	1,190	548	387	359	695	1,300	359	-29
1947	854	1,580	1,360	1,980	3,130	2,340	980	454	454	449	1,700	1,300	449	61
1948	945	596	812	1,050	1,660	4,050	1,360	812	532	746	889	764	532	144
1949	460	406	1,400	1,400	3,230	2,820	1,960	710	495	570	1,050	1,020	406	18
1950	792	848	1,520	1,620	2,120	4,970	2,200	930	570	660	1,280	1,960	570	182
1951	1,140	1,210	852	1,760	2,000	2,710	715	400	325	1,010	988	830	325	-63
1952	500	792	754	1,320	2,200	2,040	853	420	302	221	190	197	190	-198
1953	590	1,100	948	1,000	2,640	2,750	1,370	640	367	640	1,330	2,090	367	-21
1954	870	1,060	1,070	1,120	1,440	3,900	2,940	1,410	768	600	792	1,250	600	212
1955	780	864	678	1,230	1,390	3,440	2,950	828	465	502	1,480	1,330	465	77
1956	745	602	617	1,500	3,540	3,880	1,540	617	455	629	1,540	1,400	455	67
1957	700	682	1,240	2,040	3,580	2,080	758	425	333	351	530	1,390	333	-55
1958	1,150	1,480	870	1,170	2,890	1,570	540	375	324	400	974	2,550	324	-64
1959	2,090	835	1,280	1,560	2,950	3,330	1,260	575	625	1,260	1,280	1,160	575	187
1960	539	765	627	1,750	2,110	2,560	770	470	428	378	1,210	984	378	-10
1961	952	2,020	1,750	1,700	2,230	2,080	764	366	338	515	1,130	957	338	-50
1962	1,310	940	764	1,650	1,970	2,860	1,410	680	475	792	685	1,530	475	87
1963	627	699	1,040	1,470	1,700	1,310	681	440	384	360	1,450	1,140	360	-28
1964	1,440	1,130	1,190	1,840	1,680	4,220	3,120	1,350	935	945	761	1,100	762	374
1966	670	1,910	1,120	1,320	2,050	2,080	1,040	645	406	414	785	800	406	18
1966	780	800	770	1.970	z,o70	z,550	1,250	510	346	347	920	1s50	346	-42
1967	1,640	1,310	1,030	1,140	1,200	4,290	1,120	448	317	826	1,390	1,090	317	-71
1968	1,110	1,390	1,380	1,450	2,240	2,560	872	548	553	755	1,470	800	548	160
1969	720	615	607	2,080	2,180	2,060	751	466	451	728	684	840	451	63
1970	668	1,420	1,050	1,350	1,440	2,040	724	388	394	520	754	806	388	-0
1971	786	1,740	1,070	1,670	3,400	3,550	3,550	796	529	522	1,460	985	522	134
1972	1,040	891	2,080	1,720	2,350	4,890	2,680	914	649	579	696	700	579	191
1973	1,050	737	871	794	1,390	1,790	683	412	356	471	990	1,560	356	-32
1974	690	1,120	1,030	2,230	2,320	4,710	4,120	1,130	454	316	318	970	316	-72
1975	975	995	805	791	1,660	3,190	1,290	809	447	431	1,850	1,410	431	43
1976	1,830	1,080	782	1,100	2,970	2,210	2,280	1,390	599	397	556	782	397	9
1977	796	716	1,000	1,210	1,680	1,100	559	405	500	505	1,400	1,000	405	17
1978	868	839	808	1,440	1,930	2,130	778	633	975	580	647	1,000	580	192
1979	563	540	1,050	1,290	2,790	2,110	719	454	363	306	465	469	306	-82
1980	770	897	1,350	1,250	2,170	1,990	689	461.	542	378	706	1,320	378	-10
1981	854	564	880	1,260	1,870	2,000	790	434	423	659	884	1,040	423	35
1982	763	1,140	1,330	990	2,340	3,000	1,630	565	509					
Min	380	370	433	591	1,200	556	333	308	264	214	190	197	190	-198
Avg	916	915	1,005	1,463	2,247	2,624	1,205	568	441	533	969	1,049	388	0
Max	3,030	2,020	2,080	2,850	4,090	4,970	4,120	1,410	975	1,440	2,230	2,550	762	374

Minimum Flows at Gage 12138150, Sultan River below Chaplain Creek near Sultan
and Gage 12138160, Sultan River below Powerplant near Sultan
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
I. Sultan River below Chaplain Creole: Basin Area 93 sq mi.														
1974											78	350		
1975	336	295	309	260	260	530	176	71	198	233	334	688	71	-60
1976	701	308	287	365	715	482	274	221	247	240	249	237	221	90
1977	317	194	217	360	481	90	83	53	128	229	305	270	53	-78
1978	228	262	270	288	297	194	101	83	330	224	236	313	83	-48
1979	270	262	228	279	445	273	120	65	78	129	213	249	65	-66
1980	249	323	455	303	209	222	94	74	174	249	267	375	74	-57
1981	262	292	266	335	497	380	115	93	115	233	243	352	93	-38
1982	296	817	288	273	325	411	126	69	107	156	237	360	69	-62
1983	350	297	288	321	370	266	166	42	136	176	266	176	42	-89
1984	202	258	217	245	284	146	140	90	91					
II. Sultan River below Powerplant near Sultan: Basin Area 94 sq mi.														
1983								48	132	175	321	190		
1984	212	250	237	271	443	397	169	178	182	198	568	335	169	38
1985	208	214	210	517	352	242	176	157	159	183	1,090	184	157	26
1986	207	377	260	317	460	196	181	168	166	218	362	327	166	35
1987	360	337	225	219	214	191	184	175	177	228	214	183	175	44
1988	191	344	344	571	531~	229	192	174	189	256	1,320	303	174	43
1989	380	293	318	464	725	286	196	185	199	262	520	802	185	54
1990	814	747	375	375	617	294	216	194	201	293	1,460	1,500	194	63
1991	462	547	283	293	279	262	205	188	194	247	223	451	188	57
1992	334	474	279	230	288	188	187	194	194				187	56
1993	186													
Min	186	194	210	219	209	90	83	42	78	129	78	176	42	-89
Avg	334	369	284	334	408	271	163	128	171	221	455	414	131	-0
Max	814	817	455	571	725	530	274	221	330	293	1,460	1,500	221	90

Minimum Flows at Gage 12143000, N.F. Snoqualmie River near North Bend
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
1907								141	167	147	167	328		
1908	271	223					202	141	131	131	183	153	131	39
1909	328	271	328	394	601	750	271	131	131	223		430	131	39
1910	328	360	803	?50	693	300	126	78	56	292	448	346	56	-36
1911	243	176	176	292	576	411	155	83	83	134	134	377	83	-9
1912	265	368	167	331	489	545	207	180	174	180	304		174	82
1913		257				819	284	144	144	183	219	88	144	52
1914	470	449	563	513	650	508	124	64	59	205	470	226	59	-33
1915	340	372	388	456	401	288	178	74	71	78	296	443	71	21
1916	238	292	412	646	613	862	537	161	134	81	278	258	81	-11
1917	254	355	245	331	704	1,180	510	123	88	98	156	476	88	
1918	688	322	234	443	577	302	157	153	79	81	319	358	79	-13
1919	250	333	277	488	617	404	177	80	76	104	452	199	76	•16
1920	259	182	173	311	456	475	123	71	103	345	199	301	71	21
1921	338	324	369	369	738	802	192	117	143	156	399	277	11?	25
1922	18?	161	159	395	715	667	118	89	128	114	229	159	89	-3
1923	375	220	355	650	650	563	149	87	64	' 253	385	327	64	-28
1925	364	390	327	381	518	385	99	77	65	56	199	455	56	-36
1926	331	445	360	36?	298	300	125	135	300					
1929			236	284	793	700	158	78	59	68	127	144	59	-33
1930	154	342	218	487	346	290	94	54	54	96	196	198	54	-38
1931	196	257	410	453	415	346	105	65	70	151	330	244	65	-27
1932	289	187	665	940	870	960	250	127	112	100	767	543	100	8
1933	331	190	370	463	756	1,010	421	119	125	197	340	516	119	27
1934	815	311	320	554	369	134	84	55	54	100	525	564	54	-38
1935	337	430	262	398	616 _	510	189	127 .	90	85	161	341	85	-7
1936	442	186	328	262	959	415	151	86	125	113	100	100	86	-6
1937	140	132	390	588	691	886	177	132	102	101	366	460	101	9
1938	446	247	366	350	564	284	71	60	58	128	404	364	58	-34
1961	308	614	516	560	734	293	96	57	88	161	308	308	57	-35
1962	319	247	228	495	495	596	209	179	136	176	152	371	136	44
1963	170	286	254	418	432	366	213	122	99	99	448	353	99	7
1964	490	394	398	594	506	839	564	268	278	241	254	344	241	149
1965	275	588	289	320	512	340	134	105	104	120	261	263	104	12
1966	266	305	273	608	602	548	240	117	96	101	253	456	96	4
1967	597	459	308	347	390	585	128	58	57	236	338	304	57	-35
1968	380	367	376	445	656	485	168	121	179	207	408	400	121	29
1969	240	217	211	592	592	460	148	88	80	214	224	235	80	-12
1970	214	395	293	370	475	370	101	68	65	172	222	263	65	27
1971	253	472	320	422	918	878	628	115						
Min	140	132	159	262	298	134	71	54	54	56	100	88	54	-38
Avg	329	319	334	461	594	549	207	108	108	151	298	324	92	0
Max	815	614	803	940	959	1180	628	268	300	345	767	564	241	149

Minimum Flows at Gage 12144500, Snoqualmie River near Snoqualmie
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
1898					2,890	2,280	1,090	520	468	915	1,680	970	468	22
1899	1,290	1,770	1,160	1,220	2,060	5,020								
1900	1,510	1,510	1,860	1,220	2,060	1,860								
1901														
1902										615	1,550	1,220		
1903	1,920	995	850	1,160	2,160	3,110	1,100	520	388	850	1,220	1,620	388	-58
1904	1,410	995	945	1,620	2,000	2,250	895							
1926							400	414	493	1,180	865	1,550	400	-46
1927	840	1,220	1,630	1,590	2,890	2,840	950	504	672					
1958									245	491	1,070	2,620		
1959	2,450	1,180	1,750	1,720	2,830	2,360	865	524	782	1,380	1,560	1,400	524	78
1960	778	1,070	925	2,070	2,060	2,200	598	588	540	486	1,500	1,380	486	40
1961	1,200	2,730	2,130	2,050	2,620	1,370	609	328	416	615	1,190	1,170	328	-118
1962	1,280	984	867	1,710	1,950	2,310	996	766	560	805	717	1,590	560	114
1963	694	1,270	1,060	1,690	1,890	1,330	835	293	441	334	1,580	1,320	293	-153
1964	1,960	1,550	1,580	2,240	1,910	3,570	2,550	1,240	1,080	961	974	1,500	961	515
1965	1,130	2,360	1,210	1,290	2,020	1,490	849	597	374	462	971	961	374	-72
1966	1,090	1,230	1,070	2,310	2,230	2,250	1,010	326	253	387	991	1,840	253	-193
1967	2,310	1,780	1,200	1,280	1,440	2,810	747	443	331	868	1,380	1,260	331	-115
1968	1,550	1,420	1,550	1,810	2,550	2,120	784	552	705	942	1,400	1,500	552	106
1969	1,020	923	914	2,160	2,200	2,170	773	489	474	852	861	957	474	28
1970	940	1,610	1,240	1,660	1,820	1,680	658	392	388	663	911	1,050	388	-58
1971	1,110	2,140	1,480	1,750	3,240	3,460	2,880	757	592	616	11840	1,460	592	146
1972	1,750	1,360	2,220	2,100	2,530	3,690	1,940	840	685	664	794	940	664	218
1973	1,280	947	1,130	1,060	1,680	1,510	695	442	386	441	1,010	2,160	386	-60
1974	920	1,900	1,840	2,820	2,730	3,780	3,540	1,160	501	390	438	1,390	390	-56
1975	1,500	1,330	1,160	1,120	2,090	2,810	1,160	821	531	502	1,900	2,050	502	56
1976	2,410	1,580	1,110	1,490	2,530	1,880	1,540	1,290	684	507	728	987	507	61
1977	906	835	1,270	1,540	2,000	989	635	453	638	689	1,530	1,490	453	7
1978	1,260	1,300	1,090	1,520	2,140	1,720	708	583	1,330	614	784	1,100	583	137
1979	774	700	1,650	1,540	2,320	1,730	660	343	325	260	495	608	260	-186
1980	1,000	1,170	1,670	1,510	1,800	1,740	665	485	689	476	840	1,530	476	30
1981	956	717	1,020	1,740	2,160	2,040	900	448	423	701	830	1,360	423	-23
1982	991	1,480	1,470	1,150	2,290	2,610	1,260	559	629	1,020	1,120	1,170	559	113
1983	1,130	1,280	1,510	1,410	1,940	1,960	1,360	664	790	583	1,260	1,040	583	137
1984	1,360	1,560	1,390	1,540	. 1,700	2,790	1,120	483	503	455	1,380	1,130	455	9
1985	1,030	784	1,030	2,120	2,170	1,940	591	333	354	388	990	940	333	-113
1986	1,080	1,040	1,670	1,490	1,960	1,060	720	455	408	500	1,250	1,160	408	-38
1987	1,110	1,200	1,280	1;460	1,640	1,100	569	410	382	317	329	788	317	-129
1988	642	1,220,	1,480	2,460	2,200	1,480	781	438	353	493	1,760	1,150	353	-93
1989	1,660	1,030	1,040	2,330	2,160	1,670	743	530	391	355	805	1,220	355	-91
1990	1,520	1,840	2,200	2,810	2,580	2,610	974	668	533	522	2,740	1,370	522	76
1991	1,280	1,970	1,270	1,960	2,120	1,960	941	455	326	264	442	1,300	264	-182
1992	1,100	1,370	1,060	1,150	1,130	674	578	330	321	633	1,680	1,130	321	-125
1993	701	757	759	2,040	3,130	1,920	1,190	630	411					
Min	642	700	759	1,060	1,130	674	400	293	245	260	329	608	253	-193
Avg	1,271	1,353	1,344	1,723	2,191	2,199	1,046	566	520	620	1,163	1,317	446	0
Max	2,450	2,730	2,220	2,820	3,240	5,020	3,540	1,290	1,330	1,380	2,740	2,620	961	515

Minimum Flows at Gage 12148500, Tolt River near Carnation
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
1928									65	234	204	170	65	-42
1929	150	120	372	319	552	438	136	89	72	75	105	114	72	35
1930	225	730	255	409	352	231	97	72	68	92	194	251	68	39
1931	254	254	359	402	274	220	110	76	78	143	331	274	76	31
1937										80	275	465		
1938	457	264	328	361	338	168	92	72	64	67	384	352	64	-43
1939	620	340	326	522	484	545	204	110	102	101	261	470	101	-6
1940	286	349	495	367	209	133	92	76	63	85	232	323	63	-44
1941	337	207	192	202	197	227	100	77	144	250	220	381	77	-30
1942	274	236	278	410	448	410	176	104	79	82	365	465	79	-28
1943	301	304	232	421	455	385	160	105	88	96	180	259	88	-19
1944	294	275	230	486	481	256	117	101	91	185	230	236	91	-16
1945	280	270	334	476	734	272	118	97	98	143	567	349	97	-10
1946	458	349	481	416	584	530	204	110	98	105	302	463	98	-9
1947	338	490	445	535	302	305	187	104	110	122	550	467	104	-3
1948	300	250	322	384	510	550	207	199	199	222	330	353	199	92
1949	194	180	448	448	545	337	253	130	99	, 139	236	364	99	-8
1950	270	420	540	555	625	790	289	178	104	139	376	610	104	-3
1951	512	416	282	390	344	206	93	65	53	250	280	. 324	53	-54
1952	186	330	297	488	464	340	164	105	77	63	78	77	63	-44
1953	200	376	368	400	534	460	161	105	80	188	376	704	80	-27
1954	344	529	270	264	297	560	242	172	234	199	175	427	172	65
1955	335	339	253	468	472	646	370	177	132	149	465	558	132	25
1956	427	315	305	605	690	468	197	118	94	199	413	377	94	-13
1957	228	253	476	540	535	293	162	103	74	75	147	388	74	-33
1958	535	585	320	317	301	170	82	61	63	96	279	650	61	.46
1959	690	418	550	476	707	460	182	126	165	336	365	407	126	19
1960	231	336	280	530	444	350	140	118	144	127	387	383	118	11
1961	320	686	540	492	515	191	125	79	103	147	299	336	79	-28
1962	390	300	270	403	407	313	152	163	130	170	140	395	130	23
1963	220	334	264	453	280	248	217	128	97	114	300	320	97	-10
1964	510	340	368	525	420	657	428	190	290	370	356	400	190	83
1965	360	732	363	293	367	199	130	116	191	280	348	384	116	9
1966	416	366	311	499	358	292	263	161	116	116	280	550	116	9
1967	656	556	388	338	366	302	155	113	100	190	412	420	100	-7
1968	485	324	334	565	497	301	172	148	238	258	460	415	148	41
1969	300	280	360	525	571	334	270	142	140	255	255	280	140	33
1970	280	396	336	400	357	228	121	102	102	249	313	302	102	-5
1971	292	550	412	404	530	508	302	144	180	190	445	422	144	37
1972	470	360	479	491	526	404	250	156	147	171	192	238	147	40
1973	344	270	297	288	292	222	121	96	90	142	273	531	90	-17
1974	296	490	494	555	527	481	302	170	127	110	121	300	110	3
1975	380	390	332	299	424	296	159	126	166	167	475	719	126	19
1976	639	366	296	398	398	314	185	176	150	162	167	238	150	43
1977	233	214	297	351	387	182	139	104	149	177	417	412	104	3
1978	346	305	252	276	302	198	140	119	278	183	211	382	119	12
1979	262	247	339	322	360	200	132	103	105	95	132	199	95	-12
1980	285	323	373	408	271	244	156	129	182	166	270	372	129	22
1981	243	220	289	446	423	349	205	138	134	232	247	403	134	27
1982	298	448	375	301	413	272	157	114	138	151	225	298	114	7
1983	288	315	305	288	273	210	213	157	252	175	440	305	157	50
1984	388	420	400	396	521	423	172	116	120	135	340	398	116	9
1985	288	237	266	441	449	254	139	106	110	123	275	231	106	-1
1986	278	260	339	305	429	194	166	121	113	131	250	302	113	6
1987	313	309	317	352	248	173	133	98	91	77	78	186	77	-30
1988	162	260	326	468	379	226	159	119	117	153	480	346	117	10
1989	466	315	394	629	354	247	167	138	120	117	198	308	117	10
1990	374	425	460	415	514	306	173	142	122	136	504	506	122	15
1991	358	545	301	383	352	297	161	120	114	107	132	332	107	-0
1992	320	320	209	210	180	146	143	103	104	162	321	325	103	-4
1993	235	216	218	441	411	349	270	188	136					
Min	150	120	192	202	180	133	82	61	53	63	78	77	53	-54
Avg	343	357	345	416	423	327	178	122	125	157	294	370	107	-0
Max	690	732	550	629	734	790	428	199	290	370	567	719	199	92

Minimum Flows at Gage 12149000, Snoqualmie River near Carnation
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
1929			1,350	1,390	3,350	3,870	930	470	430	446	598	645	430	-173
1930	670	2,500	1,330	2,960	2,210	1,670	316	430	415	555	910	1,040	415	-188
1931	995	1,180	2,330	2,450	2,450	1,480	645	415	430	620	1,730	1,230	415	-188
1932	2,140	1,360	4,250	4,820	4,440	4,060	1,730	910	655	560	4,250	2,050	560	-43
1933	2,320	1,360	2,720	2,420	3,740	5,090	1,880	795	595	890	2,420	2,720	593	-8
1934	5,400	2,400	2,400	3,040	2,320	1,190	931	634	618	812	3,000	5,100	618	13
1935	1,930	2,550	1,660	1,840	2,730	2,370	1,120	730	542	441	984	1,890	441	-162
1936	2,540	1,080	2,280	1,950	5,000	2,650	926	568	598	615	546	588	546	-57
1937	821	854	2,200	3,450	3,330	4,960	1,110	750	535	475	1,780	2,740	475	-128
1938	2,650	1,680	1,910	2,150	3,030	1,960	691	472	3%	450	1,700	1,900	3%	-207
1939	3,620	2,070	1,950	2,940	3,320	3,700	1,480	680	536	532	1,630	2,800	532	-71
1940	1,630	2,080	2,890	2,720	2,010	1,020	630	462	420	579	1,320	1,970	420	-183
1941	1,970	1,410	1,460	1,840	1,660	1,560	543	446	590	1,430	1,460	2,550	446	-157
1942	1,650	1,300	1,390	2,630	2,710	3,550	1,180	667	467	416	2,040	2,950	416	-187
1943	1,500	1,400	1,370	2,710	3,120	3,740	1,320	787	636	612	1,110	1,310	612	9
1944	1,370	1,570	1,470	2,780	3,150	1,990	745	556	526	978	1,190	1,520	526	77
1943	1,730	1,760	2,040	2,880	4,940	2,260	772	453	463	952	3,480	1,880	453	-150
1946	2,820	2,320	2,680	2,390	4,200	4,290	1,540	719	623	667	1,760	3,070	623	20
1947	2,260	2,910	2,540	3,480	2,910	2,610	1,200	640	732	1,010	3,820	3,230	640	37
1948	2,400	1,710	2,070	2,330	2,990	4,810	1,610	1,340	1,130	1,380	1,760	2,180	1,130	527
1949	1,320	1,120	2,810	2,660	4,310	3,040	2,180	928	672	800	1,540	2,250	672	69
1950	2,050	2,250	3,440	3,360	3,610	5,460	2,450	1,270	650	1,020	2,320	4,310	650	47
1951	3,120	2,710	1,840	2,710	2,480	2,480	750	472	416	1,600	1,630	2,040	416	-187
1952	1,130	1,740	1,660	2,800	2,800	2,110	1,080	597	454	423	444	451	423	-180
1953	1,060	2,250	2,160	2,310,	3,860	3,620	1,490	853	556	1,260	2,060	4,200	556	-47
1954	2,560	3,870	2,010	1,920	2,010	4,340	2,230	1,430	1,310	1,040	1,020	2,440	1,020	417
1955	1,830	2,120	1,690	2,680	2,720	4,950	3,310	1,120	874	1,100	3,260	3,760	874	271
1956	2,340	1,780	1,870	3,470	4,240	4,050	1,610	856	620	1,120	2,410	2,100	620	17
1957	1,160	1,450	2,610	3,040	4,000	2,070	979	574	486	546	818	2,280	486	-117
1958	2,800	3,200	1,750	1,800	2,730	1,600	614	446	446	656	1,450	4,210	446	-157
1959	4,000	2,110	3,050	2,620	4,110	3,030	1,240	788	1,110	1,950	2,200	2,380	788	185
1%0	1,320	1,620	1,360	3,230	3,040	2,820	900	480	805	750	2,200	1,940	480	-123
1%1	1,720	4,440	3,440	3,170	4,140	1,750	840	496	655	926	1,600	1,890	4%	-107
1%2	2,210	1,530	1,400	2,930	3,110	3,060	1,350,	753	424	844	727	2,570	424	-179
1%3	1,290	1,870	1,690	2,780	2,590	1,910	1,150	678	630	558	2,330	2,210	558	-45
1964	3,480	2,340	2,590	3,300	2,770	4,650	3,300	1,610	1,710	1,620	1,710	2,390	1,610	1007
1965	2,150	3,990	1,900	1,930	2,880	1,930	1,020	786	642	774	1,510	1,600	642	39
1966	2,060	2,130	1,750	3,240	3,110	2,940	1,470	671	614	614	1,530	3,110	614	11
1%7	3,850	2,790	1,950	2,040	2,220	3,400	1,010	545	452	776	1,940	1,770	452	-151
1968	2,670	2,270	2,100	2,860	3,300	2,560	953	655	930	1,220	2,040	1,900	655	52
1%9	1,900	1,800	1,770	3,370	3,500	2,780	1,470	707	668	1,350	1,330	1,510	668	63
1970	1,580	2,380	1,880	2,330	2,490	2,000	866	524	322	1,030	1,330	1,750	522	-81
1971	1,780	3,290	2,350	2,440	3,900	4,280	3,310	991	866	926	2,680	2,420	866	263
1972	2,940	2,140	3,270	3,340	3,790	4,520	2,400	1,050	898	884	1,100	1,300	884	281
1973	2,080	1,500	1,750	1,630	2,250	1,900	814	354	341	506	1,410	3,490	341	-262
1974	1,580	2,700	3,120	4,030	3,860	4,490	3,960	1,430	6%	520	590	1,810	520	-83
1975	2,440	2,200	2,000	1,940	3,150	3,440	1,590	1,130	800	862	2,650	3,710	800	197
1976	3,870	2,110	1,630	2,280	3,290	2,230	1,690	1,480	851	685	902	1,260	685	82
1977	1,220	1,250	1,920	2,230	2,530	1,370	837	594	904	1,030	2,330	2,320	594	-9
1978	1,930	1,850	1,640	1,880	2,670	2,050	875	642	1,800	947	1,180	1,850	642	39
1979	1,190	1,280	2,200	2,140	2,920	2,060	914	502	493	466	740	903	466	-137
1980	1,470	1,730	2,580	2,270	2,240	2,060	903	660	958	740	1,030	2,420	660	57
1981	1,590	1,310	1,660	3,020	3,120	2,740	1,330	709	718	1,210	1,320	2,280	709	106
1982	1,590	2,580	2,270	1,720	3,040	3,210	1,500	730	830	1,320	1,520	1,980	730	127
1983	1,900	1,890	2,050	1,980	2,410	2,230	1,600	%0	1,290	940	2,020	1,350	940	337
1984	2,160	2,600	2,220	2,270	2,530	3,860	1,510	765	769	748	1,830	1,990	748	145
1985	1,550	1,250	1,590	2,990	2,880	2,360	916	580	625	722	1,450	1,310	580	-23
1986	1,590	1,530	2,370	2,090	2,740	1,390	973	584	528	623	1,700	1,720	528	-75
1987	1,720	2,070	2,170	2,300	2,250	1,240	705	497	454	372	388	1,090	372	-231
1988	904	2,160	2,480	3,300	3,320	1,870	1,090	710	5%	810	2,770	2,060	5%	-7
1989	2,690	1,790	2,24(1	3,800	2,780	2,020	979	729	335	521	1,090	2,080	521	-82
1990	2,500	3,310	3,030	3,500	3,290	3,450	1,240	752	612	619	3,720	2,710	612	9
1991	2,150	2,730	1,890	2,680	2,860	2,650	1,250	793	592	514	689	1,870	514	-89
1992	1,670	1,%0	1,420	1,450	1,420	921	834	502	492	842	2,680	2,030	492	-111
1993	1,080	1,070	1,070	2,770	3,930	2,650	1,740	854						
Min	670	854	1,070	1,450	1,420	921	516	354	341	372	388	431	341	-262
Avg	2,057	2,056	2,122	2,649	3,092	2,836	1,334	741	682	832	1,729	2,166	603	0
Max	5,400	4,440	4,250	4,820	5,000	5,460	3,%0	1,610	1,800	1,950	4,250	4,310	1,610	1007

Minimum Flows at Gage 12150800, Snohomish River near Monroe
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
1963		5,000	3,840	6,300	6,700	4,860	2,760	1,870	1,490	1,500	6,100	5,500	1,490	-114
1964	7,080	5,480	5,600	7,900	7,600	13,700	9,520	4,700	3,800	3,690	3,780	6,000	3,690	2086
1965	4,630	9,220	4,500	4,630	7,030	6,030	3,100	2,350	1,900	2,000	3,420	3,930	1,900	296
1966	4,710	4,730	4,140	7,730	7,410	7,540	3,930	2,100	1,550	1,700	3,760	7,940	1,550	-54
1967	9,130	6,440	4,910	4,840	5,510	12,000	3,200	1,400	1,150	1,960	5,150	4,480	1,150	454
1968	6,160	4,980	5,680	6,670	8,850	7,810	2,860	1,840	2,370	3,300	6,230	4,500	1,840	236
1969	3,700	3,600	3,480	7,850	8,480	8,840	3,080	1,760	1,670	3,300	3,240	3,750	1,670	66
1970	3,400	5,810	4,420	5,390	6,530	5,990	2,430	1,340	1,320	2,410	3,300	4,050	1,320	284
1971	4,080	8,270	5,720	6,320	10,200	12,100	11,700	2,650	1,900	2,130	6,560	5,750	1,900	296
1972	6,650	5,200	7,890	7,800	9,310	13,300	7,500	2,820	2,210	2,270	2,830	3,110	2,210	606
1973	5,300	3,680	4,350	4,030	5,690	5,690	2,360	1,320	1,150	1,990	3,910	8,110	1,150	454
1974	3,730	6,510	7,590	9,870	9,680	13,500	11,900	3,910	1,790	1,200	1,350	4,880	1,200	-404
1975	6,130	4,840	4,410	4,010	6,340	10,600	4,230	2,660	1,840	1,780	7,550	7,710	1,780	176
1976	9,100	5,730	4,270	5,940	10,300	7,380	6,300	4,700	2,540	1,870	2,410	3,400	1,870	266
1977	3,400	3,240	5,250	5,800	6,780	3,640	2,110	1,450	2,280	2,680	5,820	5,650	1,450	-154
1978	4,800	4,630	4,230	5,520	7,180	6,260	2,610	1,970	4,520	2,350	2,760	4,800	1,970	366
1979	3,070	2,900	5,880	5,280	8,450	6,190	2,480	1,490	1,390	1,210	1,990	2,310	1,210	-394
1980	3,950	4,360	6,650	5,740	6,990	6,370	2,550	1,760	2,610	2,010	2,560	7,180	1,760	156
1981	4,080	3,100	4,120	7,110	8,260	7,640	3,250	1,490	1,310	3,070	3,580	5,680	1,490	-114
1982	3,890	6,010	5,750	4,460	8,780	10,100	5,090	1,930	2,080	2,870	4,070	4,790	1,930	326
1983	4,360	4,870	5,320	5,120	6,730	6,930	4,600	2,060	2,690	2,030	5,490	3,500	2,030	426
1984	5,190	6,040	5,200	5,650	5,980	12,500	4,650	2,000	2,100	1,830	7,410	4,960	1,830	226
1985	3,510	2,720	3,540	8,030	7,650	7,200	2,640	1,480	1,560	1,800	4,850	3,080	1,480	-124
1986	3,700	4,130	6,330	5,290	7,260	4,540	2,350	1,420	1,260	1,440	4,360	4,030	1,260	-344
1987	4,520	4,600	4,720	5,150	6,270	4,140	1,690	1,060	941	777	798	2,510	777	-827
1988	1,950	4,350	5,470	9,080	8,370	5,790	2,830	1,420	1,060	1,980	7,310	5,040	1,060	-544
1989	6,200	3,830	4,740	8,730	8,200	6,310	2,790	1,830	1,320	1,410	3,440	4,870	1,320	284
1990	5,790	7,840	7,740	9,110	9,160	9,650	3,240	1,990	1,560	1,570	9,330	6,970	1,560	-44
1991	5,040	6,310	4,510	5,910	7,420	7,830	3,650	1,780	1,460	1,200	1,920	4,650	1,200	-404
1992	4,410	5,960	4,350	3,990	4,790	2,680	1,930	1,120	1,070	2,180	5,660	5,060	1,070	-534
1993	2,670	2,880	2,860	6,500	10,700	6,420	3,910							
Min	1,950	2,720	2,860	3,990	4,790	2,680	1,690	1,060	941	777	798	, 2,310	777	-827
Avg	4,811	5,073	5,079	6,315	7,697	7,856	4,105	2,056	1,870	2,050	4,365	4,940.	1,604	-0
Max	9,130	9,120	7,890	9,870	10,700	13,700	11,900	4,700	4,520	3,690	9,330	8,110	3,690	2086

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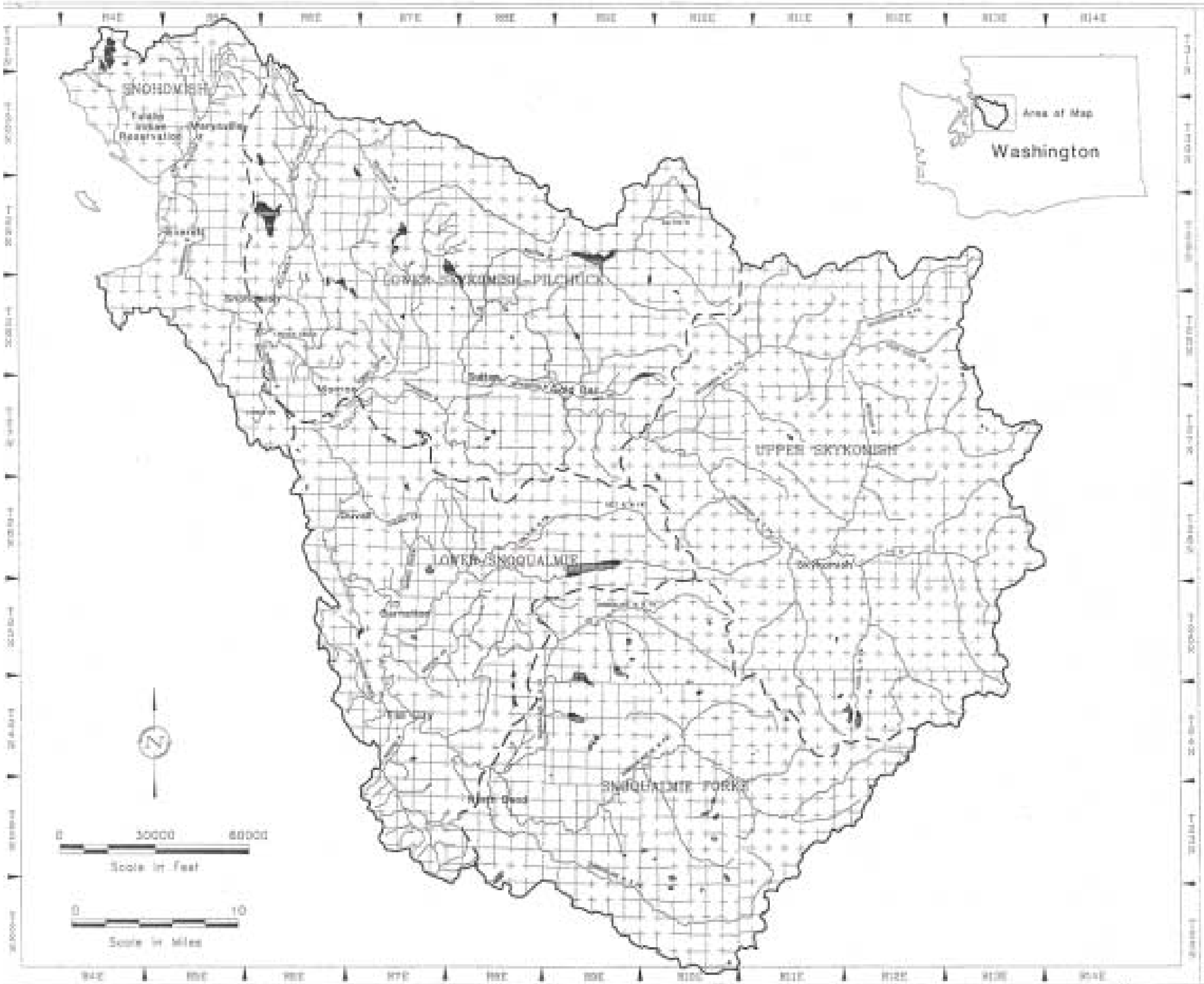


FIGURE 2-1

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

Initial Watershed Assessment Program
Snohomish River Basin

Pacific Groundwater Group

EXPLANATION

Snohomish WRIA Boundary

WRIA Sub-basin Boundary

Stream

Section Lines

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

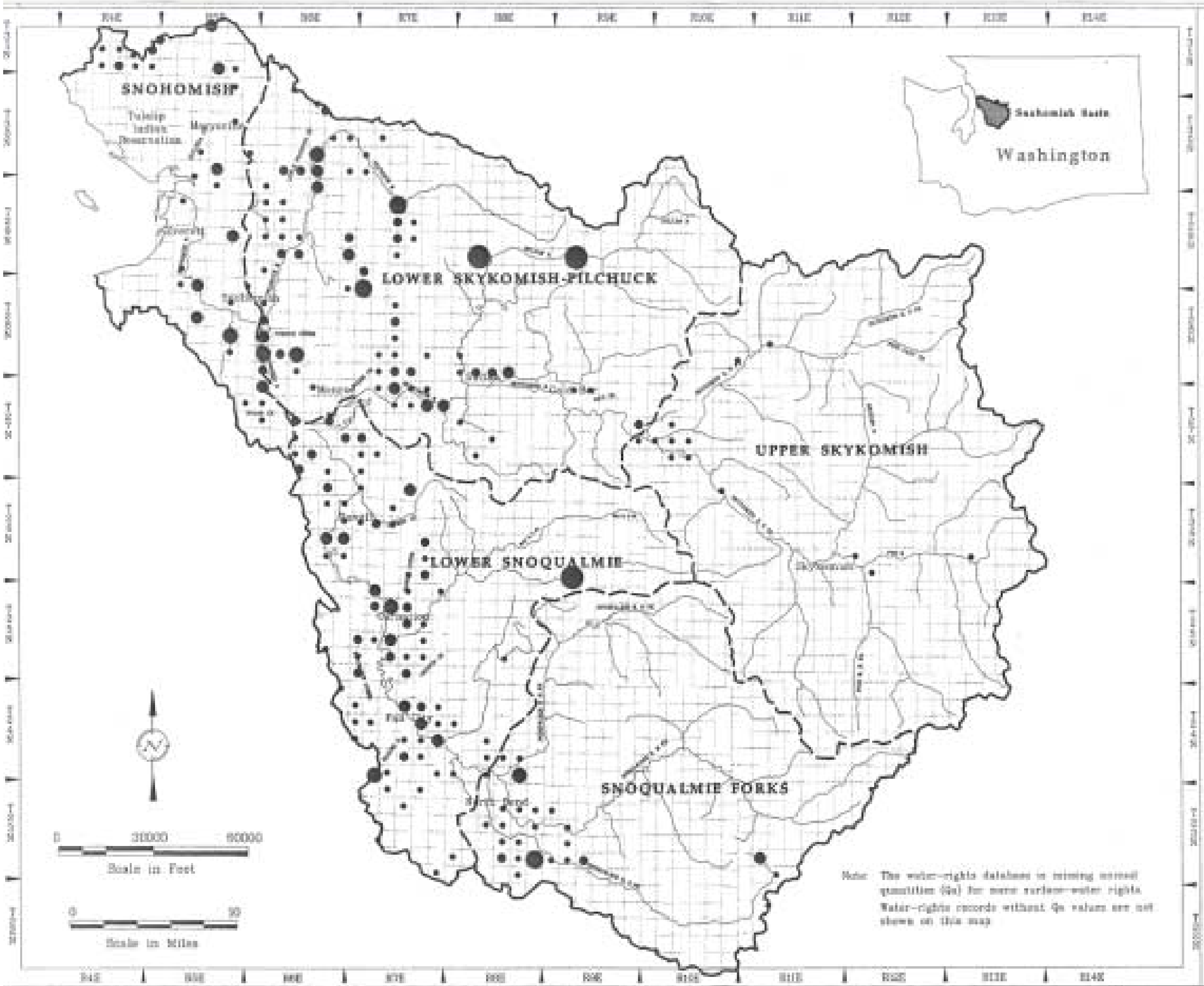


FIGURE 3-3

Distribution of Surface-Water Permits/Certificates

Initial Watershed Assessment Program
Snohomish Basin

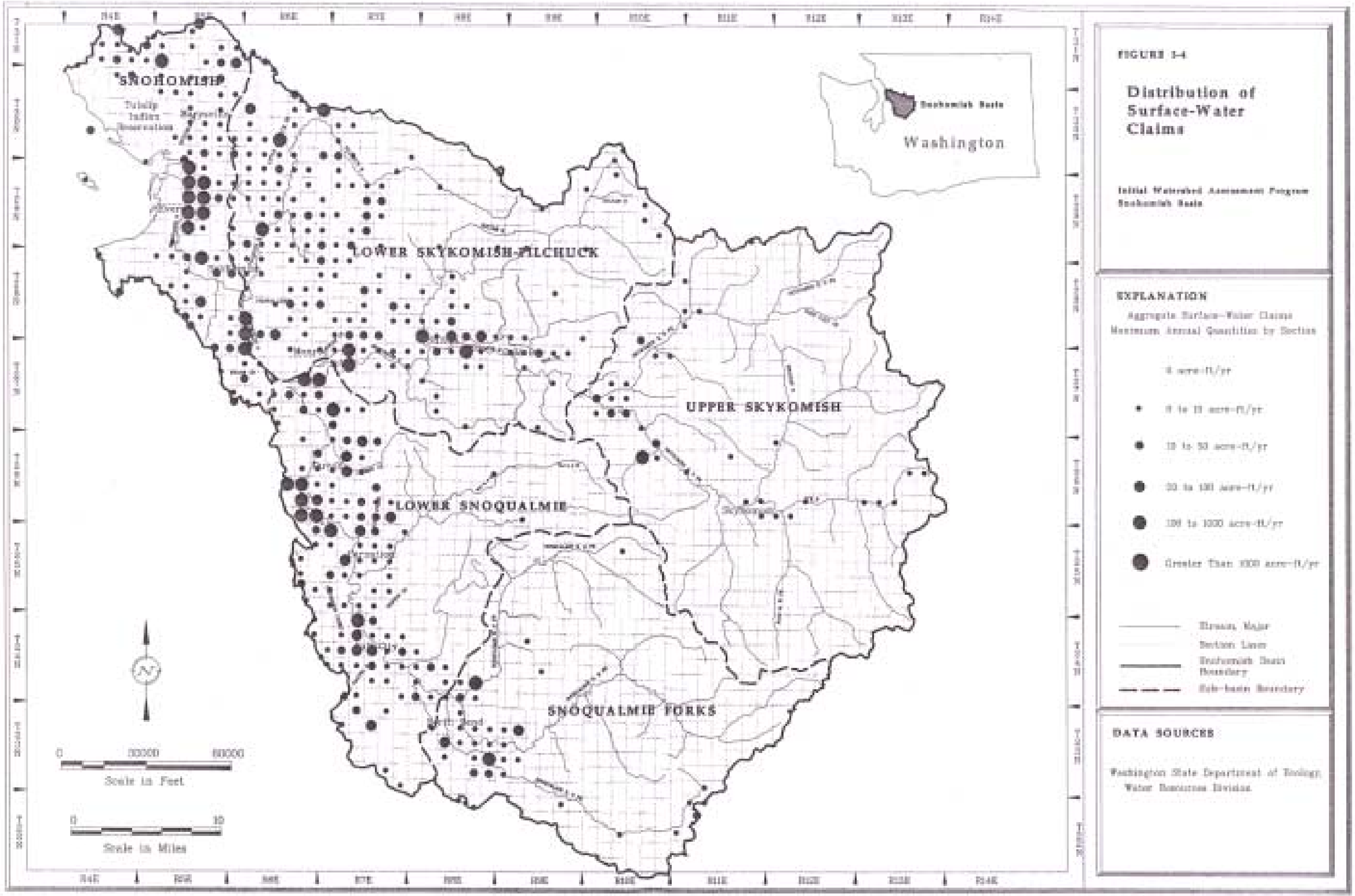
EXPLANATION

Aggregate Surface-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 250 acre-ft/yr
- 250 to 1000 acre-ft/yr
- 1000 to 50,000 acre-ft/yr
- Greater Than 50,000 acre-ft/yr
- Stream, Major
- Section Lines
- Snohomish Basin Boundary
- Sub-basin Boundary

DATA SOURCES

Washington State Department of Ecology,
Water Resources Division



Distribution of Surface-Water Claims
Snohomish Basin
Washington
SNOHOMISH
LOWER SKYKOMISH-PILCHUCK
UPPER SKYKOMISH
LOWER SNOQUALMIE
SNOQUALMIE FORKS
Scale in Feet
Scale in Miles
EXPLANATION
DATA SOURCES

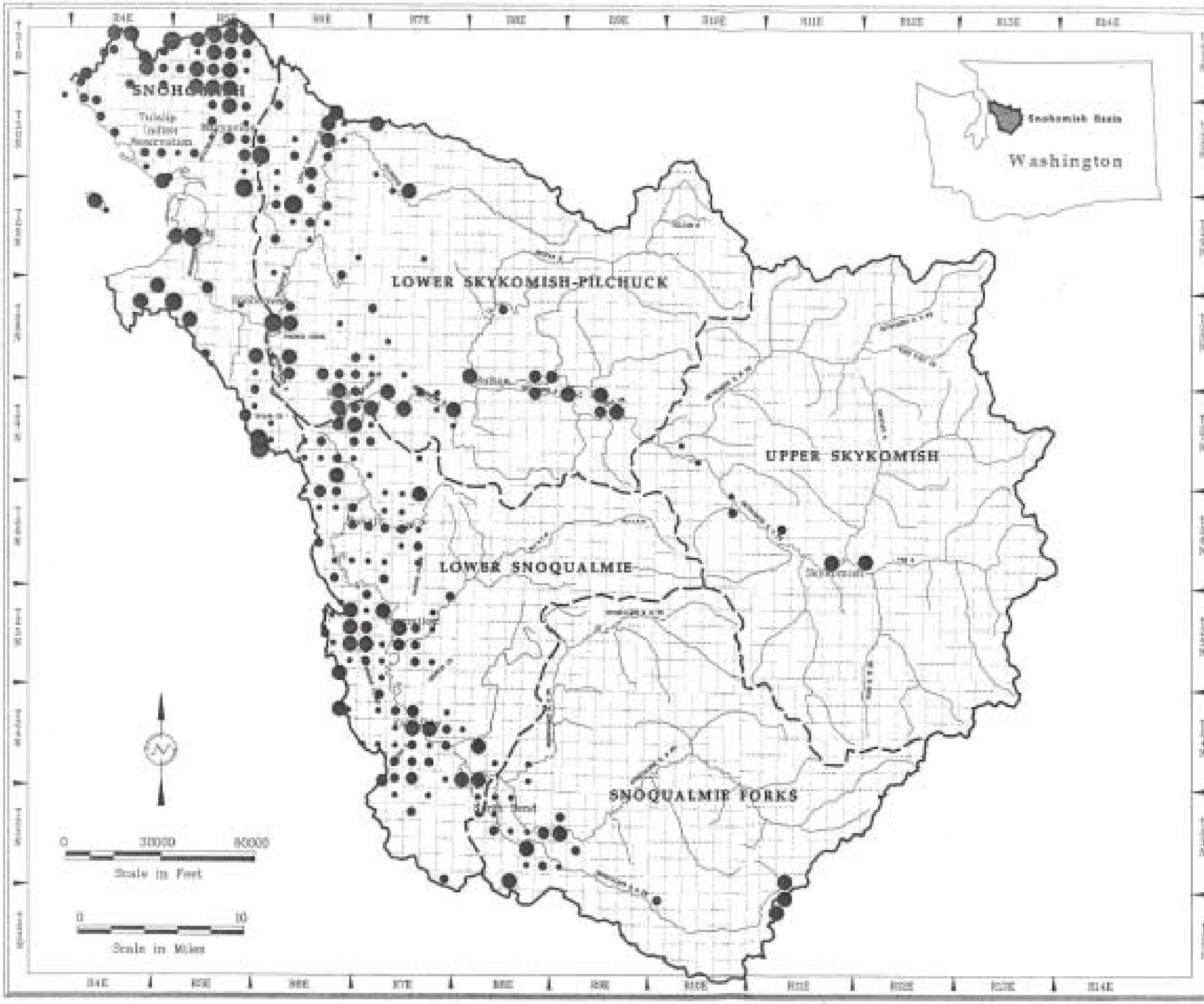


FIGURE 5-5

Distribution of Ground-Water Permits/Certificates

Initial Watershed Assessment Program
Snohomish 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, Major

Section Lines

Snohomish Basin Boundary

Sub-basin Boundary

DATA SOURCES

Washington State Department of Ecology,
Water Resources Division

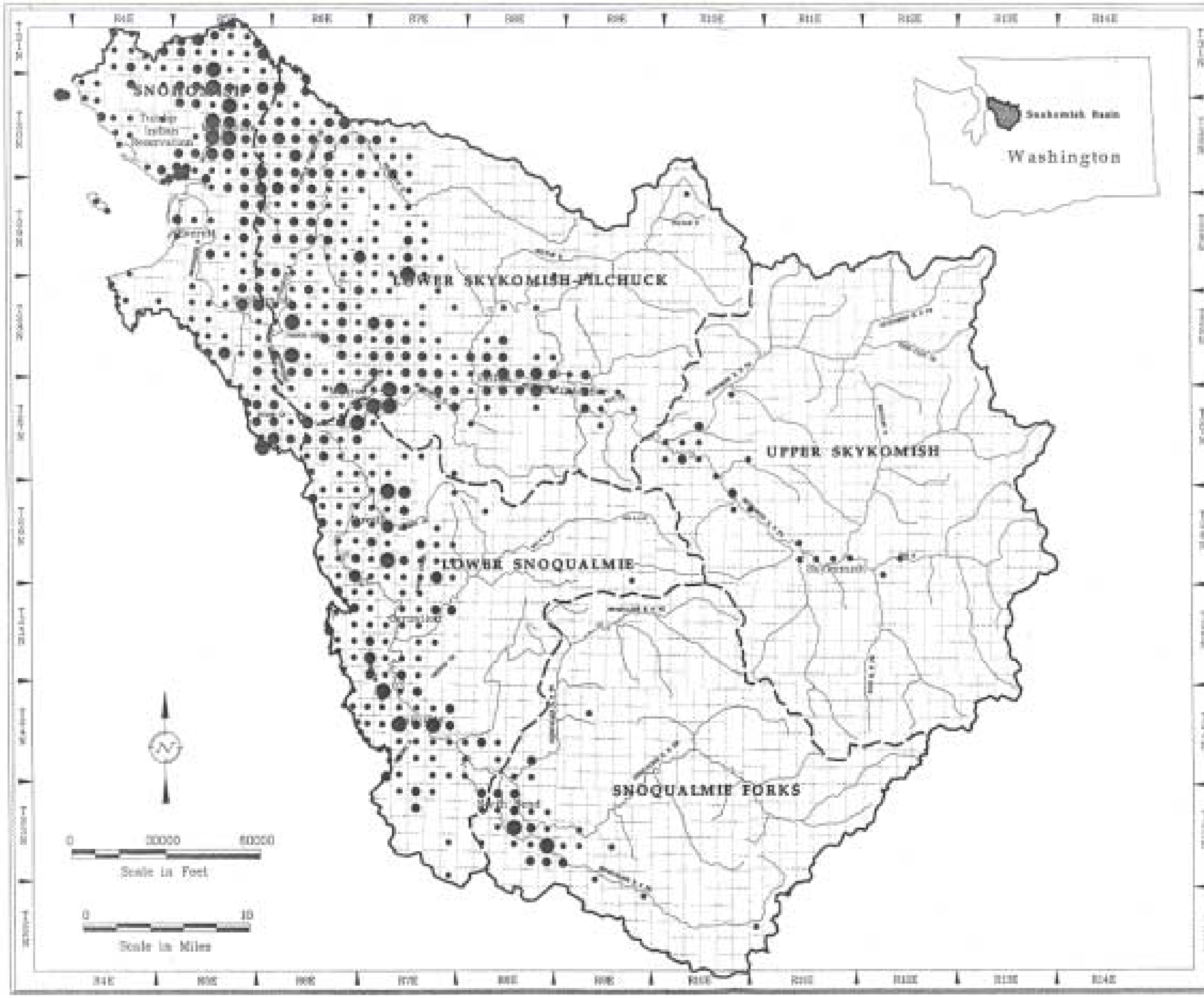


FIGURE 3-6

Distribution of Ground-Water Claims

Initial Watershed Assessment Program
Snohomish 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, Major

Section Lines

Snohomish Basin Boundary

Sub-basin Boundary

DATA SOURCES

Washington State Department of Ecology,
Water Resources Division

FIGURE 3-7

Distribution of Surface-Water Applications

Initial Watershed Assessment Program
Snohomish Basin

EXPLANATION

Aggregate Surface-Water Applications
Instantaneous Quantities by Section

0 cfs

0 to 1 cfs

1 to 10 cfs

10 to 100 cfs

100 to 1000 cfs

15,000 cfs

Stream, Major

Section Lines

Snohomish Basin Boundary

Sub-basin Boundary

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

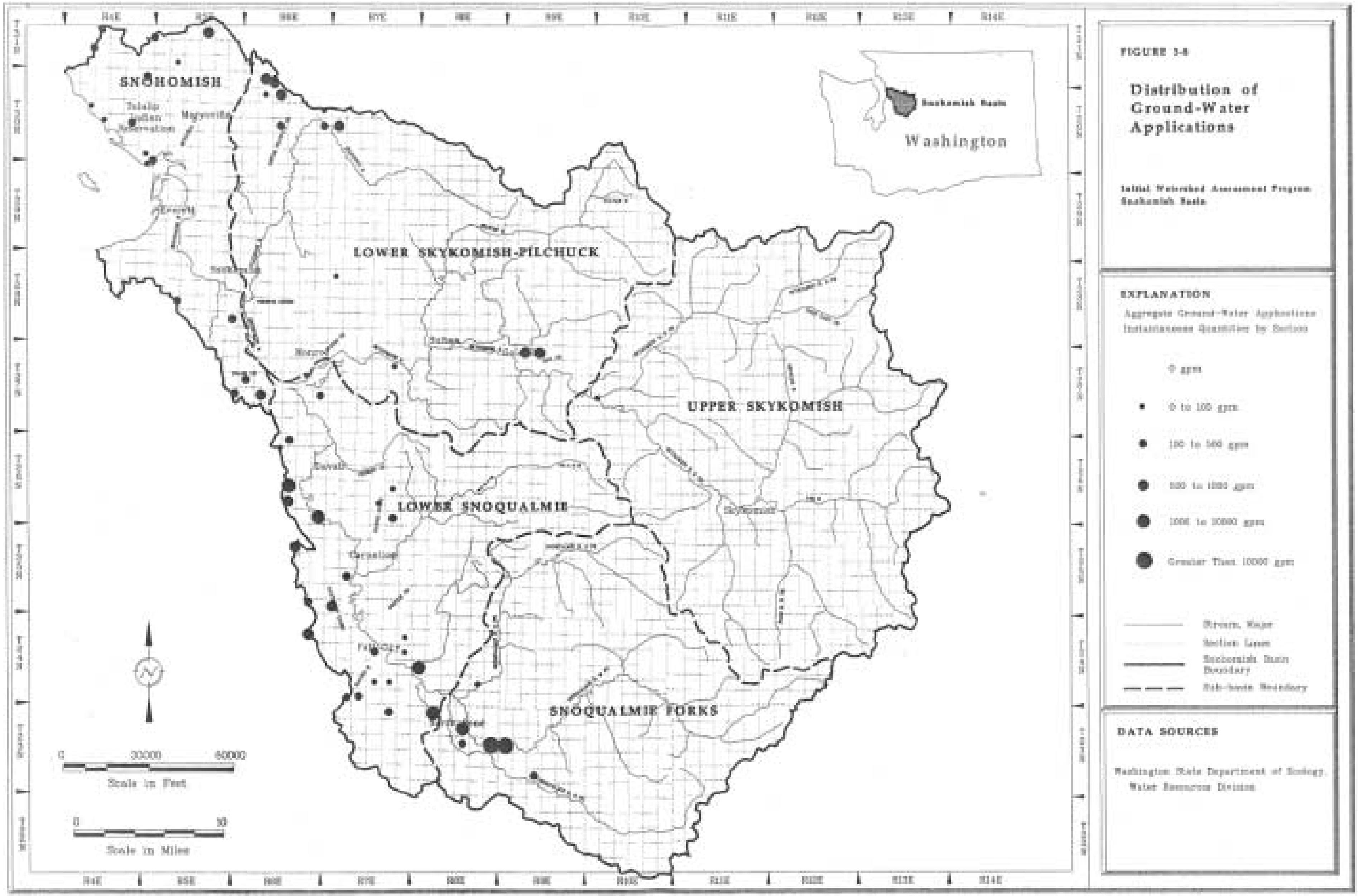


FIGURE 3-8
Distribution of Ground-Water Applications
Initial Watershed Assessment Program
Snohomish Basin
Snohomish Basin
Washington
SNOHOMISH
LOWER SKYKOMISH-PILCHUCK
UPPER SKYKOMISH
LOWER SNOQUALMIE
SNOQUALMIE FORKS
Tulalip Indian Reservation
Marysville
Everett
Snohomish
Monroe
Sultan
Duvall
Carnation
Fall City
Skykomish
EXPLANATION
Aggregate Ground-Water Applications
Instantaneous Quantities by Section
0 gpm
0 to 100 gpm
100 to 500 gpm
500 to 1000 gpm
1000 to 10000 gpm
Greater Than 10000 gpm
Stream, Major
Section Lines
Snohomish Basin Boundary
Sub-basin Boundary
DATA SOURCES
Washington State Department of Ecology, Water Resources Division
0 30000 60000
Scale in Feet
0 10
Scale in Miles
R4E
R5E
R6E
R7E
R8E
R9E
R10E
R11E
R12E
R13E
R14E

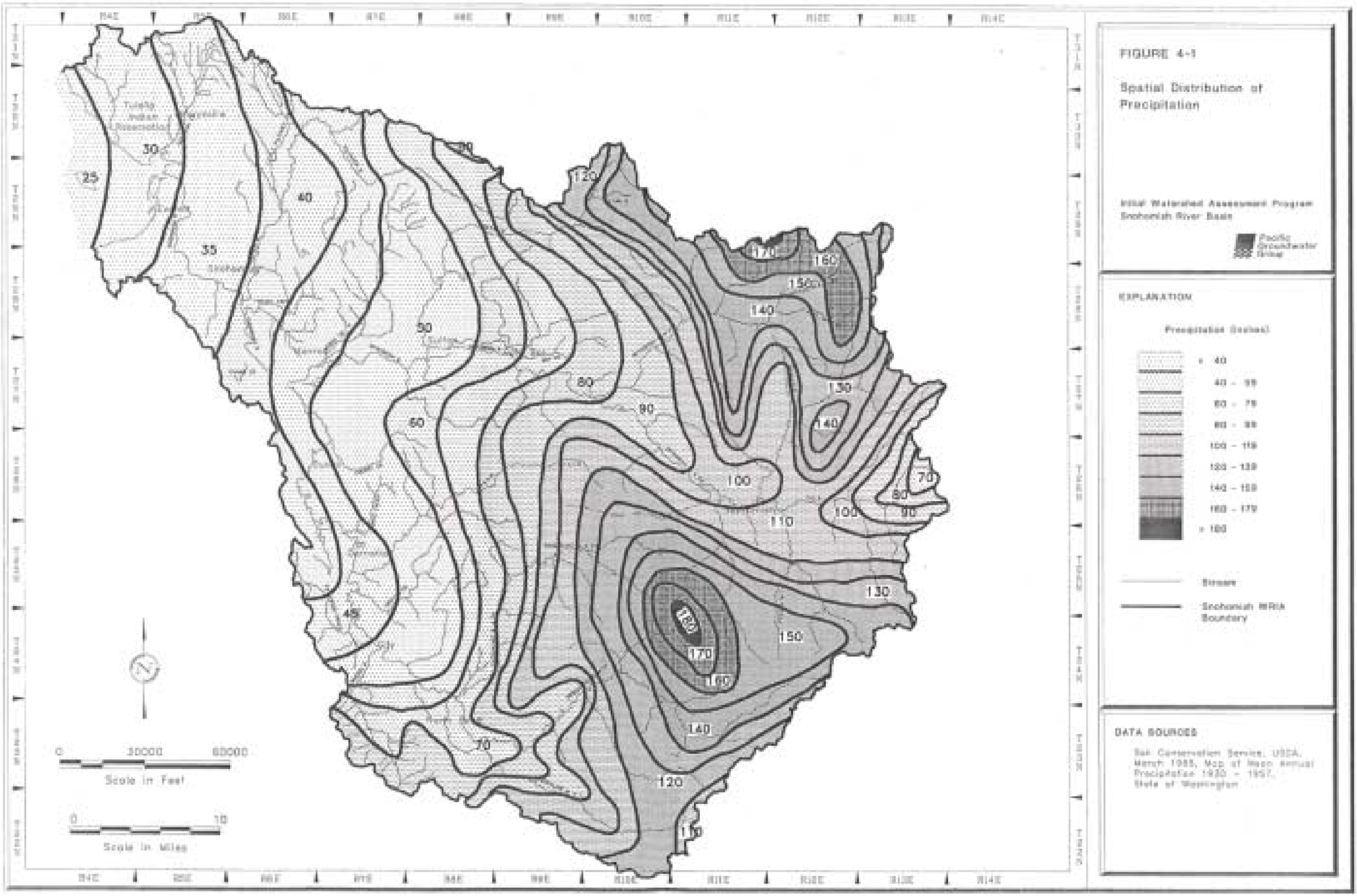


FIGURE 4-1
Spatial Distribution of Precipitation
Initial Watershed Assessment Program
Snohomish River Basin
Pacific Groundwater Group
EXPLANATION
Precipitation (inches)
< 40
40 - 59
60 - 79
80 - 99
100 - 119
120 - 139
140 - 159
160 - 179
> 180
Stream
Snohomish WRIA Boundary
DATA SOURCES
Soil Conservation Service, USDA, March 1965, Map of Mean Annual Precipitation 1930 - 1957, State of Washington
Tulalip Indian Reservation
0 30000 60000
Scale in Feet
0 10
Scale in Miles

FIGURE 4-2

Monitoring Stations and Regulated Instream Flow Control Points

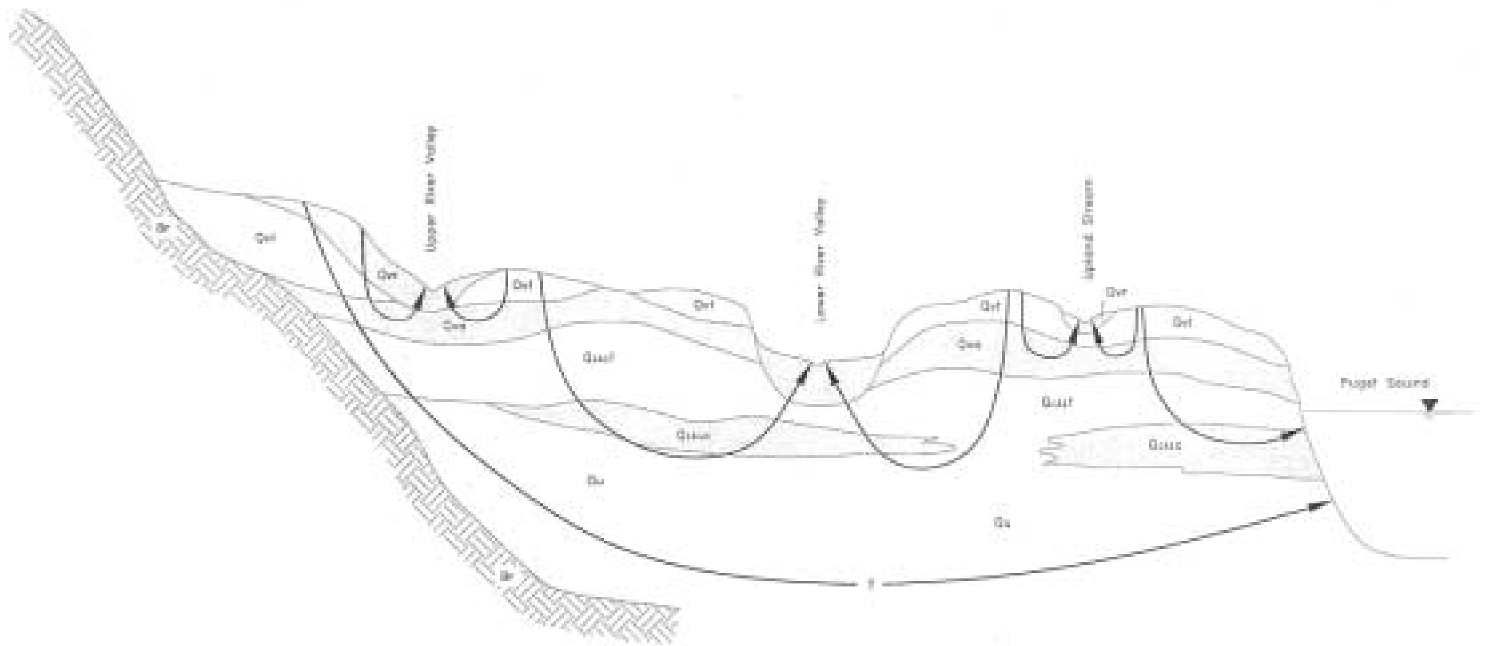
Initial Watershed Assessment Program
Snohomish River Basin

Pacific Groundwater Group

DATA SOURCES

Washington State Department of Ecology, Water Resources Division

Chapter 173-507, WAC



Note: Not to Scale

DATA SOURCES

EXPLANATION

Qal	Recent Alluvial Deposits
Qvr	Quaternary Vashon Recessional Outwash
Qvt	Quaternary Vashon Till
Qva	Quaternary Advance Outwash
Qtf	Transitional Sediments
Qpoc	Olympia Gravel or First Pre-Fraser Deposits
Qu	Other Pre-Fraser Glaciation Deposits

Tertiary (and Older) Bedrock

Principal Aquifer Systems

Generalized Ground-Water Flow Pathlines

FIGURE 6-1

Generalized Hydrogeologic Cross Section Snohomish Basin

Initial Watershed Assessment Program Snohomish Basin

Pacific Groundwater Group

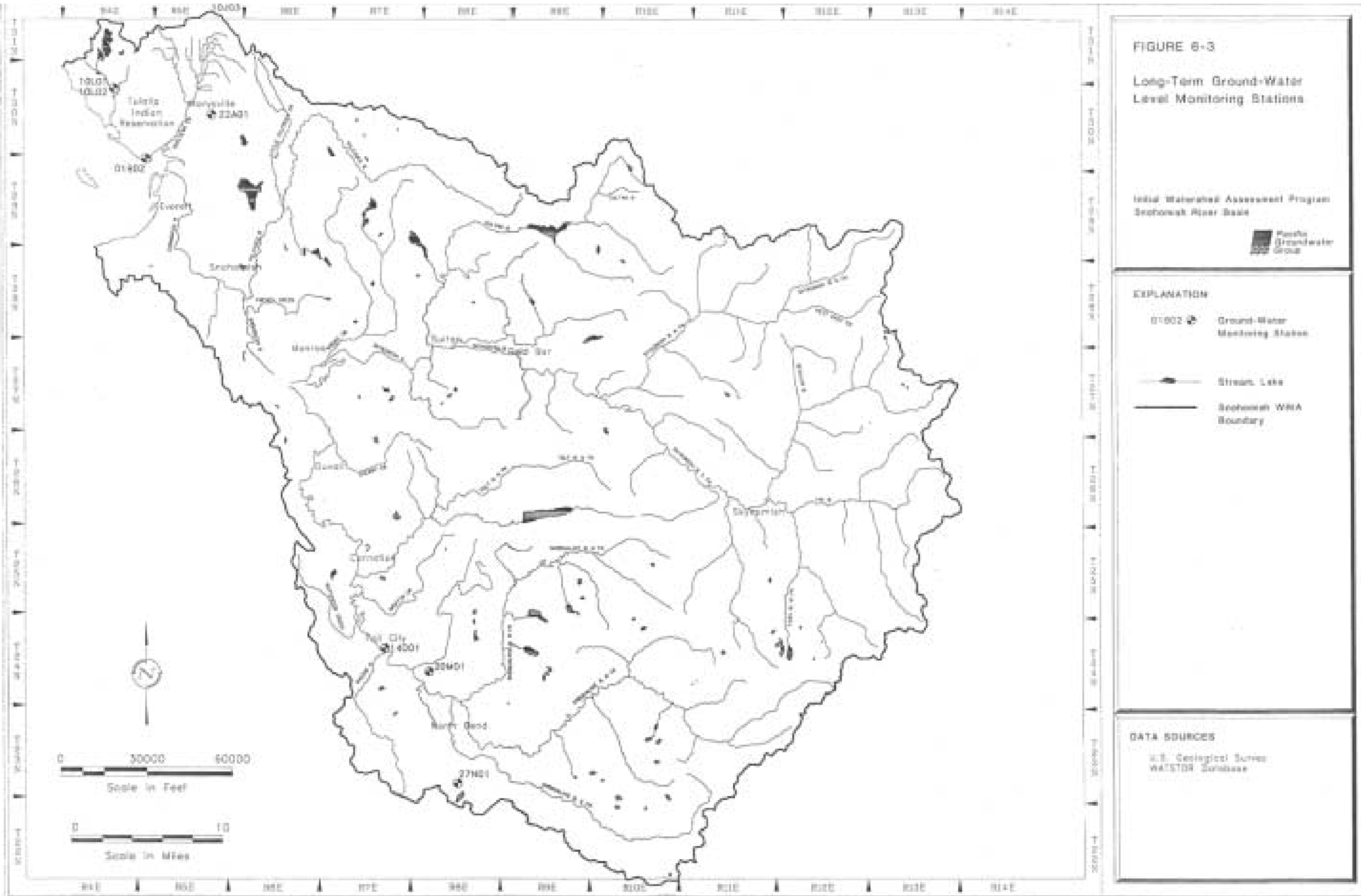


FIGURE 6-3

Long-Term Ground-Water Level Monitoring Stations

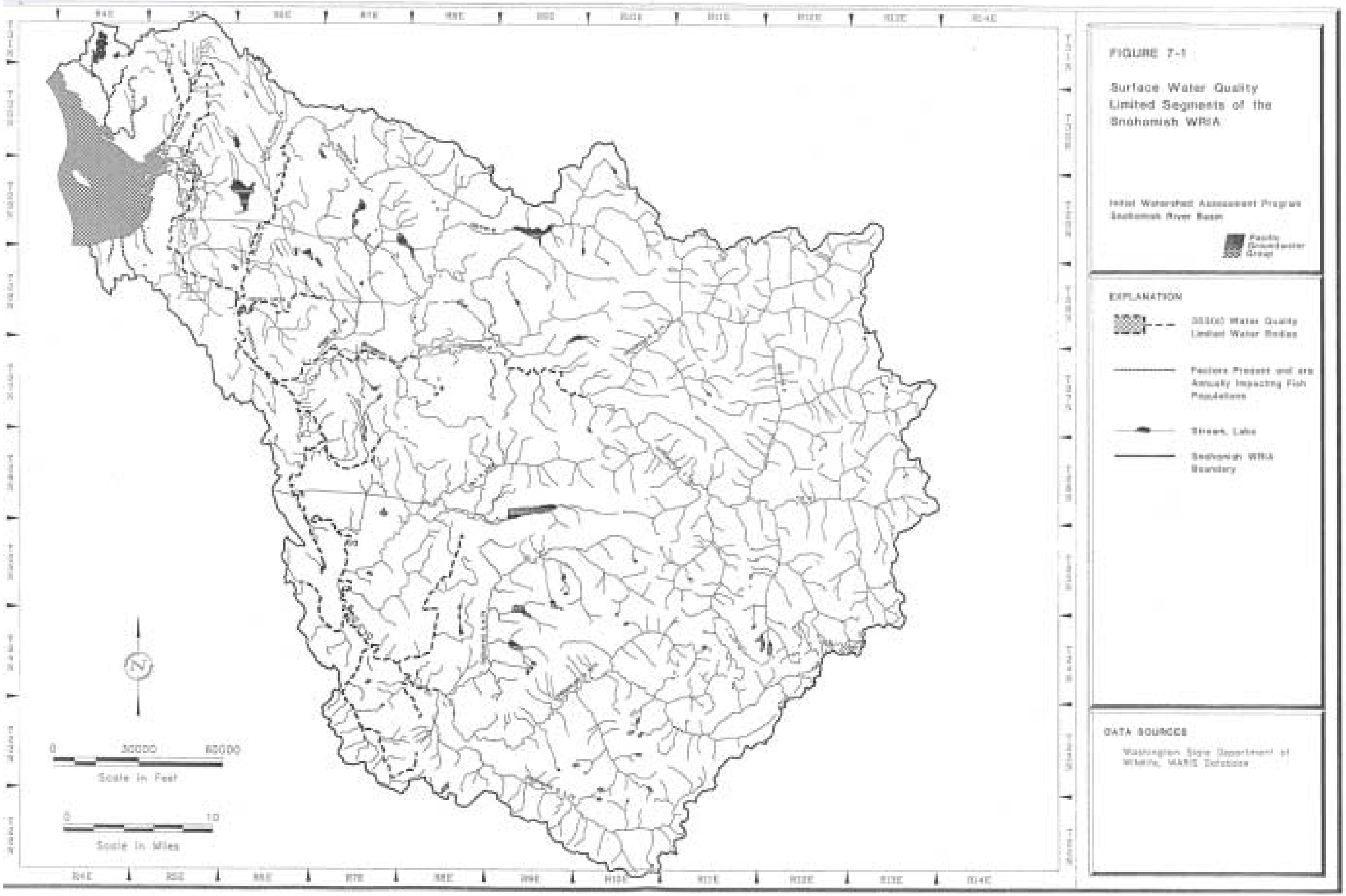


FIGURE 7-1

Surface Water Quality Limited Segments of the Snohomish WRIA

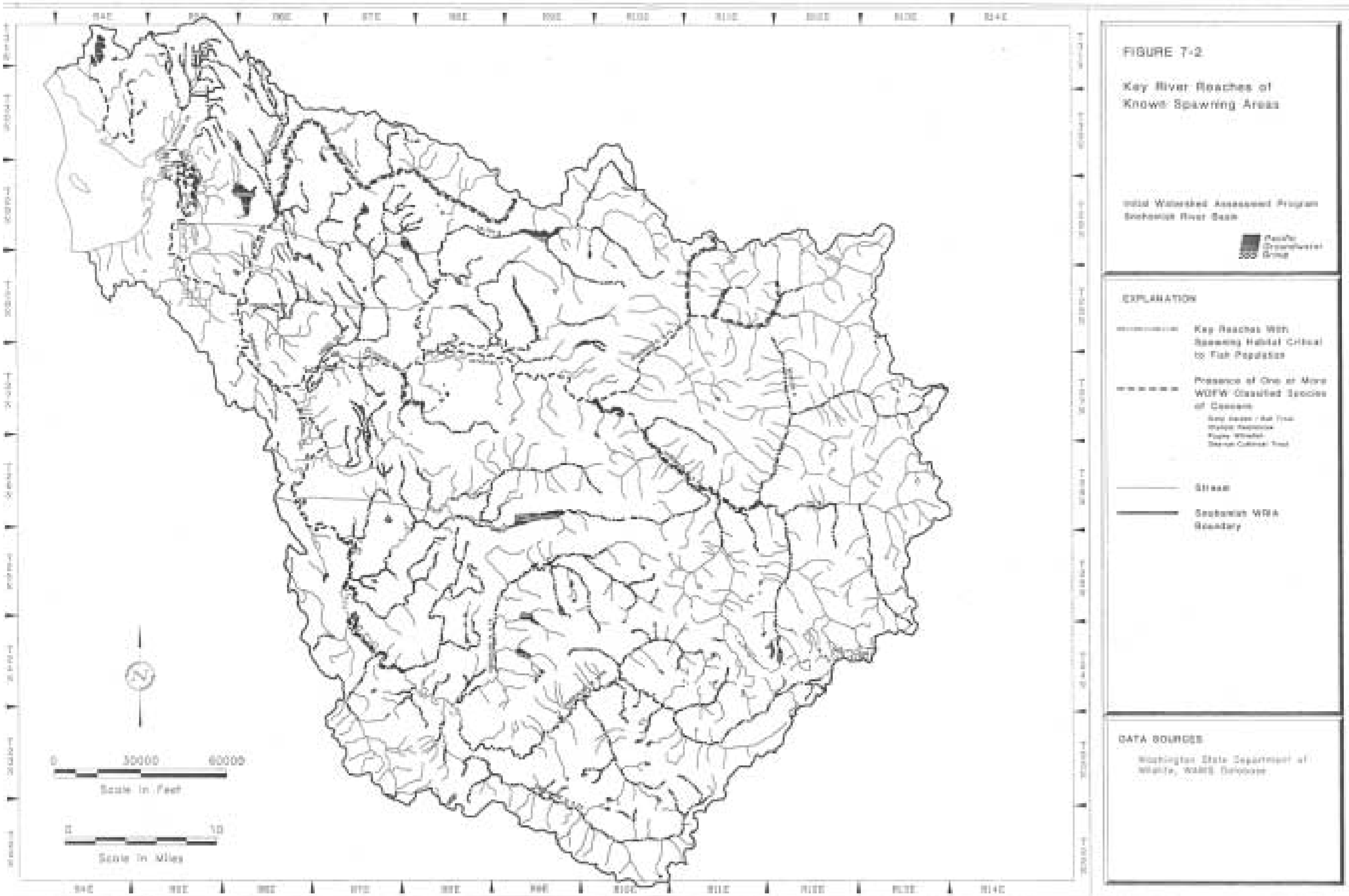


FIGURE 7-2
Key River Reaches of Known Spawning Areas
Initial Watershed Assessment Program
Snohomish River Basin
Pacific Groundwater Group
EXPLANATION
Key Reaches With Spawning Habitat Critical to Fish Population
Presence of One or More WDFW Classified Species of Concern
Stream
Snohomish WRIA Boundary
DATA SOURCES
Washington State Department of Wildlife
0
30000
60000
Scale In Feet
0
10
Scale In Miles

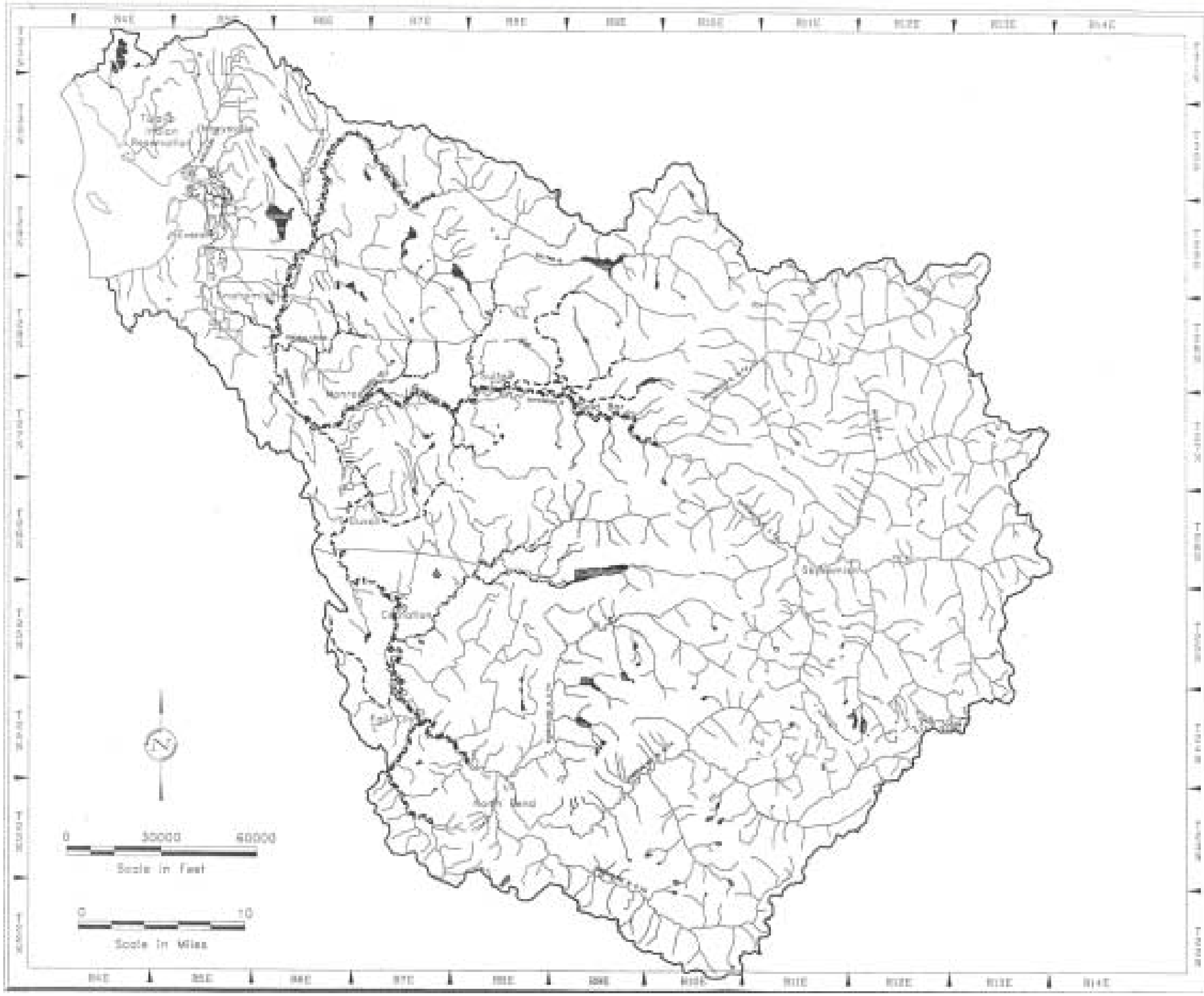


FIGURE 7-3

Location of Reported Low-Flow Areas and Depressed Stocks

Initial Watershed Assessment Program
Snohomish River Basin

Pacific Groundwater Group

EXPLANATION

Location of Reported Low Flow Areas Impacting Fish Use

Presence of Depressed Stocks

Streams

Snohomish WRIA Boundary

DATA SOURCES

Washington State Department of Wildlife, WARIS Database