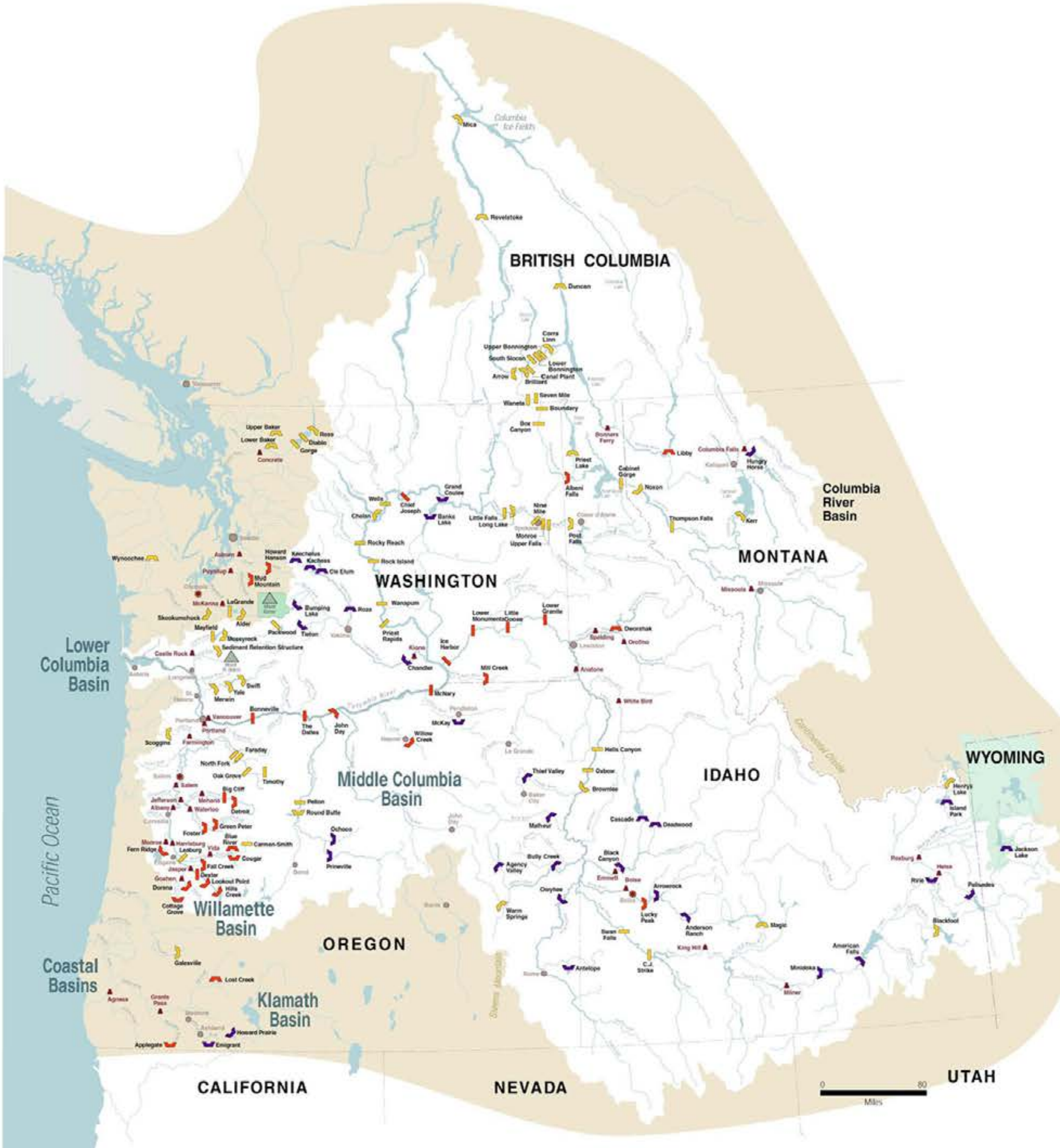
HOWARD A. HANSON DAM

U.S. Army Engineers, Seattle District
Corps of Engineers, Seattle, WA

PACIFIC NORTHWEST RESERVOIR SYSTEM



WATER CONTROL MANUAL

HOWARD A. HANSON DAM

GREEN RIVER, WASHINGTON

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

SEPTEMBER 2011

NOTICE TO USERS OF THIS MANUAL

Regulations specify that this water control manual be published in loose leaf form and only those sections or parts thereof requiring changes will be revised and printed. Therefore, this copy should be preserved in good condition so that insertions can be made to keep the manual current.

REVISIONS TO MANUAL

As a continuing program, portions of this manual may occasionally be revised and updated. Changes in the plan of operation or in the project development will be reported. Whenever revisions are made, new pages containing the revised material will be issued to holders of the manual.

WATER CONTROL ASSISTANCE PERSONNEL

In the event that unusual conditions arise during non-duty hours, contact can be made by telephone to personnel of the Water Management Section, in the order listed:

REDACTED CONTENT

EMERGENCY INSTRUCTION FOR HOWARD A. HANSON DAM

For instructions in case of emergency situations at Howard A. Hanson Dam, refer to Section 7.04c, Emergency Regulation Procedures.

METRIC CONVERSION

Conversion of standard inch-pound (IP) units of measurement to the metric international system (SI) units is included in this document in accordance with Public Law 94-168, the Metric Conversion Act of 1975, as amended by PL 100-418, the Omnibus Trade and Competitiveness Act of 1988; Executive Order 12770, dated July 25, 1991, Metric Usage in Federal Government Programs; and Department of the Army regulation, ETL 1110-1-4, Metric Measurements In USACE Publication Media, dated March 31, 1994. A metric conversation guideline is also provided in **Exhibit i-1** for conversion of IP measurements.

LIST OF ABBREVIATIONS

AWSP	Additional Water Storage Project
APD	Agricultural Production District
CENWS	Northwest Seattle
DM	Design Memorandum
DO	Dissolved Oxygen
DRS	Discharge Regulation Schedule
DSHS	Department of Social and Health Services
ESA	Endangered Species Act
FPB	Forest Practices Board
FWS	U.S. Fish and Wildlife Service
GRFMCC	Green River Flow Management Coordination Committee
HHD	Howard A. Hanson Dam
MMD	Mud Mountain Dam
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Units
NWD	Northwest Division
NWRFC	Northwest River Forecast Center
NWS	National Weather Service
OCE	Office of the Chief of Engineers
PMF	Probable Maximum Flood
QPF	Quantitative Precipitation Forecast
RCC	Reservoir Control Center
RK	River Kilometer
RM	River Mile
SDF	Spillway Design Flood
SNOTEL	Snowpack Telemetry
SPF	Standard Project Flood
SSARR	Streamflow Synthesis and Reservoir Regulation
SSWR	Secondary Supply Water Right
USGS	U.S. Geological Survey
WDOE	Washington State Department of Ecology
WM	Water Management Section of Hydrology and Hydraulics Branch
WSCMO	Weather Service Contracted Meteorological Observatory
WDFW	Washington State Department of Fish and Wildlife

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Corps of Engineers
September 2011

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HOWARD A. HANSON DAM

PERTINENT DATA[1/]

Drainage area at dam site	572.39 km^2	221 sq. mi.
Conservation Pool		
Elevation	347.78 m	1,141.0 feet
Storage	2982.3 ha-m	24,178 acre-feet
Conservation Pool with Phase I AWSP		
Elevation	355.70 m	1167.0 feet
Storage	6,075.8 ha-m	49,257 acre-feet
Project design flood pool		
Elevation	367.59 m	1,206.0 feet
Storage	12,861 ha-m	104,266 acre-feet
Spillway design flood pool		
Elevation	373.04 m	1,223.9 feet
Storage	17,070 ha-m	138,391 acre-feet
Dam		
Type: Rolled earth and rock fill		
Length (including abutment and spillway)	205.74 m	675 feet
Crown width	7.01 m	23 feet
Crest elevation (minimum)	374.29 m	1,228.0 feet
Maximum height	71.63 m	235 feet
Freeboard (above spillway design flood pool)	1.25 m	4.1 feet
Volume of fill		
Sand and gravel core	514,452 m^3	672,878 yd^3
Gravel drain	37,508 m^3	49,057 yd^3
Rolled rock fill (rock from excavation)	335,625 m^3	438,981 yd^3
Quarry rock fill (rock shell, rock drain, and rock toe)	197,388 m^3	258,175 yd^3
Spillway		
Type: Concrete gravity section founded on rock. Concrete-lined channel. Flow controlled by tainter gates		
Gate height	9.14 m	30 feet
Gate width	13.72 m	45 feet
Elevation, top of gate	367.59 m	1,206.0 feet
Crest elevation	358.44 m	1,176.0 feet
Crest length (cumulative)	27.43 m	90 feet

Discharge capacity at spillway design flood	3058.21 m^3/s	108,000 cfs

Outlet Works

Type: Gated, semi-horseshoe, concrete-lined tunnel.
Additional 1.22 m (48-inch) bypass with valves.

Inlet Invert Elevation	315.46 m	1,035 feet
Tunnel diameter	5.79 m	19 feet
Normal maximum flood release	283.17 m^3/s	10,000 cfs
Maximum capacity at spillway design flood	339.80m^3/s	12,000 cfs

Stilling basin

Length	66.14 m	217 feet
Maximum width	12.19 m	40 feet
Maximum depth	10.66 m	35 feet

Completion date 1962

[1/] All elevations in this manual are referenced to National geodetic vertical datum (NGVD) of 1929

1 – INTRODUCTION

1.01 Authorization. This manual is prepared in accordance with the following regulations and guidance:

> ER 1110-2-240, Water Control Management, paragraph 7, dated 8 October 1982, which assigns to District Engineers the responsibility for development of plans and manuals for operation of reservoirs.
>
> EM 1110-2-3600, Management of Water Control Systems, dated 30 November 1987, which provides technical guidance on management and operation of water control systems and general guidance on content of Water Control Manuals (WCM).
>
> ER 1110-2-8156, Preparation of Water Control Manuals, dated 31 August 1995, which provides specification on WCM content and format.
>
> ER 1110-1-4, Metric Measurements in USACE Publication Media, dated 31 March 1994.

Seattle District (CENWS) is delegated primary responsibility for regulation of Howard A. Hanson Dam project by NPDR 1165-2-2, "Water Resources Policies and Authorities, WATER MANAGEMENT RESPONSIBILITIES", dated 2 January 1990, **Exhibit 1-1**.

1.02 Purpose and Scope. This manual serves as a reference source for higher authority and a guidance manual for U.S. Army Corps of Engineers (USACE) personnel involved in real-time regulation of the Howard A. Hanson Dam project. The manual describes the basin, project features, data collection facilities, forecasting procedures, reservoir regulation plans and the effects of regulation.

1.03 Related Manuals and Reports. A list of the published design memoranda for the project and pertinent reports is provided in **Exhibit 1-2**. Of special interest are the Operation and Maintenance (O&M) Manual, dated October 1964, revised in June 1972, and the Additional Water Storage Project, Draft Feasibility Report & EIS, dated April 1998.

1.04 Project Owner. The owner is the U.S Army Corps of Engineers, an agency of the

U.S. Government.

1.05 Operating Agency. The U.S. Army Corps of Engineers, Seattle District operates Howard A. Hanson Dam project under the general supervision of the Corps Northwestern Division (NWD) office. Prior to 1997, NWD and CENWS were known as North Pacific Division (NPD) and Seattle District (NPS). Normally, the project is attended on a 5-day week basis, from Monday through Friday, 8 hours a day. Under specific abnormal or emergency conditions as defined in the O&M Manual and in paragraph 7.04 of this manual, the project will be attended as conditions dictate and/or as directed by the appropriate authority. The project office is located at Mud Mountain Dam (MMD).

1.06 Regulating Agency. As owner and operator of the project, the Corps is responsible for its regulation. The CENWS Water Management Section (WM) of the Hydrology and Hydraulics Branch, Engineering Division, regulates flows at Howard A. Hanson Dam. During floods, weather and river information is provided by the National Weather Service (NWS) River Forecast Center (RFC). WM is located in the CENWS Office, 4735 East Marginal Way South, Seattle, Washington (telephone 206-764-6702). Direct correspondence may be addressed to:

Department of the Army, Seattle District
ATTN: Water Management Section
Post Office Box 3755
Seattle, WA 98124-3755

2 – DESCRIPTION OF PROJECT

2.01 Location. Howard A. Hanson Dam project (HHD) is located in King County, in western Washington on the Green River approximately 72 kilometers (km) (45 miles) southeast of Seattle, Washington. The locations of the project and the Green River are shown on **Plate 2-1**. The dam is located at river kilometer (RK) 103.7 (river mile (RM) 64.5) in Section 28, Township 21N, Range 8E, Willamette Meridian.

2.02 Purpose. The primary purpose of the project is to control floods in the lower Green River and Duwamish River reach. A secondary purpose is to provide for augmentation of the low summer and fall flows for the enhancement of the fishery. Additional conservation storage for municipal water supply and augmenting low flows for the protection of the instream resources are also authorized project purposes.

2.03 Physical Components. Major components at HHD include the dam, spillway, railroad notch, outlet tunnel, bypass pipe, reservoir, debris collection and disposal facilities, drainage tunnel and buildings. A general layout of the project is shown in **Plates 2-2.1 and 2-2.2**. Details are provided below.

a. Dam. Howard A. Hanson Dam is an earth-and-rockfill embankment, with the outlet works and a gated spillway in the left abutment. The embankment has an inclined core of sand and gravel material and riprap protection (**Figure 2-1**), as shown on **Plates 2-2.1 and 2-2.2**. The embankment is 137.16 meters (m) (450 feet) long and 71.63 m (235 feet) high from bedrock to crest. Its thickness is 292.61 m (960 feet) at the base, decreasing to 7.01 m (23 feet) at the crest, and contains 1,085,732 m^3 (1,420,000 cubic yards) of material. Total length of the dam, including spillway and abutment structures, is 205.74 m (675 feet).

Figure 2-1. Downstream side of embankment dam.

b. Spillway. The spillway is a gate controlled, concrete ogee overflow section with a downstream chute. The spillway is anchored in rock on the left abutment and a concrete monolith on the right adjacent to the dam. Two tainter gates 13.72 m by 9.14 m (45 feet wide by 30 feet high) permit storage to 367.59 m (1,206 feet) without spillway discharge. The upstream side of the spillway and tainter gates are shown in **Figure 2-2**. Maximum spillway discharge is 3,058.21 m^3/s (108,000 cfs) at maximum spillway design flood (SDF) pool elevation 373.04 m (1223.9 feet). The spillway chute (**Figure 2-3**), which lies between a railroad and the dam, has a curved alignment and is paved for a distance of 217.02 m (712 feet) downstream from the weir. The spillway layout and sections are shown on **Plate 2-3** and the spillway rating curve is shown on **Chart 2-1**.

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f. Reservoir. The reservoir extends approximately 7.25 km (4.5 miles) eastward along the main river channel and 3.22 km (2 miles) northerly up the main tributary, the North Fork, and impounds 6,075.1 ha-m (49,257 acre-feet) at pool elevation 355.7 m (1167 feet). The reservoir was cleared below elevation 347.78 m (1,141 feet) when the project was built to protect the quality of water stored over the summer and fall period. Lands above that elevation were not cleared since they were originally expected to be subjected to flooding so infrequently and for such short durations that vegetation would not be damaged appreciably and water quality not adversely affected to the extent it would not be acceptable. Following implementation of the Section 1135 optional storage to elevation 349.61 m (1,147 feet), a determination was made that environmental benefits are optimized by not clearing above elevation 347.78 m (1,141 feet). As part of the Feasibility and Environmental Impact Statement for the Howard Hanson Additional Water Storage Project, it was again determined that the environmental benefits are optimized by not clearing above elevation 347.78 m (1,141 feet). The reservoir is currently closed to any recreational activity. Reservoir capacity data are presented in **Table 2-1** (U.S. Customary units – see page T2-1-1) and **Table 2-2** (Metric units – see page T2-2-1). Area and capacity data are presented on **Chart 2-6**.

g. Debris Collection and Disposal.

(1) Collection. During periods of high water most of the floating debris is collected at the two stationary log booms shown on **Plate 2-5**. Larger floating and sunken debris passing the booms may lodge against the intake structure trashrack bars; however, most debris passes through the outlet tunnel and on out downstream. Additional debris storage areas exist along the North Fork confluence with the reservoir and in the upstream part of the reservoir. When reservoir conditions permit, debris trapped by the stationary booms is collected in sack booms and towed by working boats to the temporary holding areas. Debris lodged against the trashrack bars is removed by sweeping with the work boats and collection in sack booms during a pool elevation of approximately 329.2 meters (1,080 feet). Debris removal at pool elevations lower than 329.2 meters (1,080 feet) is currently hampered by the construction of the fish collection facility. The current plan is to construct a working platform in fiscal year 2012 at elevation 348.1 meters (1,142 feet) to facilitate the removal of debris down to elevation 315.5 meters (1,035 feet).

(2) Disposal. During periods after storage for flood control and when the conservation pool is at its maximum elevation, currently 1,167 feet, the debris is towed with the working boats and the sack booms to a designated holding area. When the pool elevation has been lowered and the ground given an opportunity to dry sufficiently, the debris is sorted by species and temporarily stockpiled. The wood is then distributed for use among various habitat projects as described in the Tacoma HCP (Tacoma is the owner of all grounded wood by agreement between the Corps and Tacoma). Wood deemed unsuitable with the habitat project priority list is piled and burned to rid the reservoir and the holding area of all debris. During winter time operations, when the pool is at elevation between 326.1 meters and 327.7 meters (1,070 feet and 1,075 feet), debris that became waterlogged during the conservation pool period becomes exposed to the elements. The waterlogged debris entrapped by the floating log boom in the temporary storage area at the dam basin is gathered and piled at the highest elevation possible for transfer to multiple locations within the watershed for enhancement of habitat.

h. Drainage Tunnel. To help control excessive seepage in the right abutment, a drainage tunnel and multiple drainage wells were constructed. The drainage tunnel was excavated in May 1969, and the concrete tunnel lining was completed in November 1969. Multiple horizontal drains and vertical drainage wells collect groundwater from the right abutment and direct it to the drainage tunnel. The drainage tunnel portal (entrance) is shown in **Figure 2-10** and an interior view of the tunnel is shown in **Figure 2-11**. A plan view showing the location of the drainage tunnel and portal is shown in **Plate 2-2.1**. On 4 December 1975, the reservoir reached a maximum elevation of 358.66 m (1,176.7 feet) and stayed above 353.57 m (1,160 feet) for about 3 days. In December 1977, the reservoir again exceeded 353.57 m (1,160 feet), reaching elevation 357.77 m (1,173.8 feet) on 4 December. During both of these occasions, abutment seepage was controlled effectively by the relief tunnel and drainage well system. Total outflow from the tunnel was less than one cfs, and the piezometric surface was effectively lowered downstream from the relief tunnel.

Figure 2-10. Drainage tunnel outlet.

Figure 2-11. Interior view of drainage tunnel.

i. Buildings. The project contains an administration building (**Figure 2-12**) located at the east end of the embankment dam and a storage/staging building located south of the dam along the west side of the reservoir.

Figure 2-12. Administration building.

j. Right Abutment Seepage**.** Seepage through the right abutment was a recognized problem when design studies began. A 560-foot long blanket was placed on the right abutment as part of the original construction to control seepage through the ancient buried river channel. The blanket consists of a compacted sand and gravel core covered by a rock shell. When the reservoir reached elevation 354.12 m (1,161.8 feet) on 1 February 1965, a spring appeared in the right abutment approximately 140.21 m (460 feet) downstream from the axis at elevation 345.58 m (1,133.8 feet). An estimated flow of 302.83 to 378.54 Liters (L) (80 to 100 gallons) per minute was observed emanating from the spring. The spring area was blanketed with gravel to prevent erosion. An effort was made to obtain drainage relief of the abutment by horizontal drains; however, they did not prove effective, and the exercise was abandoned. Based upon observed piezometric conditions and geologic configuration, it was recommended that a drainage tunnel be constructed. The details of the drainage tunnel are provided in **Section 2-03 (h)** above. Since completion of construction, 119 automated piezometers have been installed in the right abutment (automation of piezometer readings commenced in 1985). The data are normally collected daily by the automated data acquisition system and transmitted to the district office.

The project experienced a flood event in February 1996 which resulted in a maximum pool elevation of 360.64 meters (1,183.2 feet) which was 2.26 meters (7.4 feet) above the previous record of 358.4 meters (1,175.8 feet) set in December 1975. During the 1996 event, an estimated flow of 4,352 Liters (L) (1,150 gallons) per minute was observed emanating from the drainage tunnel. Water flowing through a construction joint near vertical well #25 and the elbow of the drainage tunnel was observed to carry fine sediments. The location from which the sediments were derived was not confirmed. It was considered a possibility that a short path seepage area may have developed between the embankment and the tunnel elbow. For this reason, a 91.4-meter (300-foot) long single-row grout curtain was constructed in 2001 at a location upstream of the administration building at about elevation 365.8 meters (1,200 feet).

In January 2009, heavy rainfall caused flooding that resulting in a record maximum pool level of elevation 362.35 meters (1,188.8 feet). During the 2009 flood event, a number of observations were made regarding conditions within the right abutment including: large seepage flow from wells and drains in the drainage tunnel and downstream abutment, an increase in piezometer readings in the right abutment and the dam, high turbidity in seepage water from several drains and wells, and the formation of two sink holes on the upstream side of the right abutment. As a result, drainage tunnel improvements and an additional 137.2 meter (450-foot) long double row grout curtain (**Figure 2-13**) were completed in early 2010.

Figure 2-13. Grout injection along right abutment.

2.04 Related Control Facilities. There are no other water control facilities on the Green River related to Howard A. Hanson Dam.

2.05 Real Estate Acquisition. The project required the acquisition of real estate interests in 895.3 hectares (ha) (2,212.44 acres) of public and private land. Of this total, 253.5 ha (626.59 acres) were acquired in fee from private ownership primarily in connection with railroad relocation, 614.6 ha (1,518.74 acres) have perpetual flowage easements for the reservoir, 0.02 ha (0.05 acres) are under perpetual easement for the Humphrey turbidimeter site, 26.7 ha (66 acres) are under license for using a log haul road for access to the site, 0.33 ha (0.83 acres) have a perpetual easement to build and maintain drainage wells and the drainage tunnel in the right abutment; and 0.09 ha (0.23 acres) are for the Newaukum Creek streamgaging facilities.

2.06 Public Facilities. Howard A. Hanson Dam project lies entirely within the municipal watershed of the City of Tacoma (Tacoma) and for this reason is closed to public use. Tacoma is responsible for enforcement of security and pollution prevention for the Green River within the watershed. Furthermore, Tacoma owns land surrounding the reservoir and controls access to much of the municipal watershed above the diversion with wide discretionary powers granted by the state. In 1968, Tacoma completed a land acquisition program aimed at providing sanitary control and improvement in their source. Tacoma now owns about 4,047 ha (10,000 acres) in the Green River watershed, from their headworks upstream.

3 – HISTORY OF PROJECT

3.01 Authorization. "The Eagle Gorge Reservoir was authorized by the River and Harbor Act of 1950 (Public Law 516, 81st Congress, 2nd Session, 17 May 1950)"...substantially in accordance with the recommendations of the Chief of Engineers in House Document Numbered 271, Eighty-first Congress, first session, at an estimated cost of $16,300,000." The project recommended in the authorizing document consisted of a concrete gravity dam 70.10 m (230 feet) high with an ungated spillway and conservation storage for domestic water supply and irrigation. The project name was changed to Howard A. Hanson Dam by Act of Congress, 28 July 1958, signed by the President, 6 August 1958, to honor the late Howard A. Hanson, a prominent attorney and civic leader who had been active in local sponsorship of the project.

3.02 Planning and Design. Two reports were made by the Corps in the interest of controlling floods in the Green and Duwamish Rivers and recommending a survey to obtain necessary data for the preparation of a plan of improvement and an estimate of cost. These reports were published as House Document No. 286, Seventy-third Congress, second session, covering the report submitted November 10, 1933, and House Document No. 377, Seventy-fourth Congress, second session covering the report submitted July 24, 1935. The Flood Control Act approved June 22, 1936, authorized a preliminary examination and survey for flood control. The result was the report that formed the basis of the project and is published in the authorizing document. Other authorizations and reports pertain to navigation but are not directly related to this manual and therefore not referenced. The authorizing document recommended no modification or extension of the then existing navigation project. Prior to authorization of the project, the Federal Power Commission and the Bureau of the Budget, in reviewing the survey report, discussed the possibility of a multiple purpose flood control and power project. Post authorization studies included the determination as to: (1) whether inclusion of power facilities at Eagle Gorge Dam would be justified and (2) whether special provisions should be incorporated in the flood control dam for possible future power development. Eagle Gorge Project Design Memo (DM) No. 1 presented the results of studying seven methods of developing power and concluded that the project should be designed and constructed primarily for flood control as authorized without modification for future power installations. The results of studies and investigations on the location and type of dam are presented in DM No. 3. The recommendation was that a rockfill dam be constructed at the report site with design refinements to be developed for the dam design memo.

As design of the authorized project proceeded, continuing investigations resulted in numerous design changes. The major changes pertinent to reservoir regulation are summarized as follows:

a. Project document. Concrete gravity dam; spillway uncontrolled overflow type with ogee crest at elevation 367.28 m (1,205 ft), spillway design flood (SDF) 4105.94 m^3/s (145,000 cfs); outlet works utilizing a 6.10 m (20-foot) concrete lined tunnel regulated by three 2.59 m (102-inch) Howell Bunger valves, reservoir storage 13,069.8 ha-m (106,000 acre-feet) at elevation 367.28 m (1,205 ft), maximum surcharge elevation 374.90 m (1,230 feet).

b. DM 3. Rockfill dam; spillway uncontrolled with crest elevation 367.59 m (1,206 ft), SDF 4,389.10 m^3/s (155,000 cfs); outlet works utilizing a 7.62 m (25-foot) concrete-lined tunnel regulated by three 2.06 m by 3.66 m (6-foot 9-inch by 12-foot) high-pressure radial gates; reservoir storage 13,069.8 ha-m (106,000 acre-feet) at elevation 367.59 m (1,206 ft), maximum surcharge elevation 373.38 m (1,225.0 feet).

c. DM 7. Outlet works tunnel 6.71 m by 6.71 m (22-foot by 22-foot) modified horseshoe; reservoir maximum conservation elevation 347.78 m (1,141 feet).

d. DM 12. Spillway with crest elevation 358.44 m (1,176 ft) controlled by two tainter gates 13.72 m by 9.14 m (45-feet wide by 30 feet high), SDF 3,029.90 m^3/s (107,000 cfs); outlet works with tunnel controlled by two 3.05 m by 3.66 m (10-foot by

12-foot) tainter gates and with a 1.22 m (48-inch) steel pipe with a ball valve for shutoff service and a slide gate for regulating service.

e. DM 12 - Supplement 1. Outlet works tunnel 5.79 m by 5.79 m (19-foot by 19-foot) horseshoe-shape. Maximum surcharge elevation 372.59 m (1,222.4 feet).

3.03 Construction. The first $1,000,000 for construction was appropriated by Congress in July 1955. The $1,500,000 Washington State pledge and the $500,000 King County contribution were presented to the Federal Government by the CENWS in August 1955. Prior to construction of the dam, relocations of facilities were required for the Northern Pacific Railway, Puget Sound Power and Light Company, Bonneville Power Administration, Forest Service, King County, and the City of Tacoma (Tacoma). The major relocation of the railroad main line began in November 1955 and culminated in opening ceremonies on 28 June 1959. Construction of the dam began after groundbreaking ceremonies on 3 February 1959 and was officially completed on 5 April 1962 with public dedication ceremonies on 12 May 1962. The main dam was completed six months ahead of schedule, despite a 3-month setback by flooding late in 1959, and storage began on 5 December 1961 enabling flood control benefits to be realized one full season earlier than scheduled.

3.04 Related Projects. The Howard A. Hanson Dam project is the only project in the Green-Duwamish River basin providing storage, and no potential storage sites are currently under investigation.

3.05 Modifications to Regulations. Formal changes to the water control plan since the project went in to operation include the following:

a. Section 1135 Fish and Wildlife Restoration Project. This project allows storage of an additional 616.7 ha-m (5,000 ac-ft) to elevation 349.6 m (1,147 feet) to augment instream flows for fish during the summer months in 1 out of every 5 years on average depending on weather conditions. This modification was approved by NWD letter dated 8 April 1997. Interim operation in accordance with the plan was approved for the 1999 conservation season. The Project Cooperation Agreement (PCA) with the City of Tacoma was signed in 2000. Full implementation of the Section 1135 water control operation is now possible in any given year, depending upon conditions.

b. Additional Water Storage Project. The Howard Hanson Dam Additional Water Storage Project is a dual purpose water supply and ecosystem restoration project. The purpose of this project is to meet the Municipal and Industrial (M&I) water supply needs of the Puget Sound area, and provide downstream and upstream ecosystem restoration for fish and wildlife in the Green River watershed. The project was authorized by Congress in Section 101(b)(15) of the Water Resources Development Act (WRDA) of 1999. The Project Cooperation Agreement (PCA) with the City of Tacoma was signed in 2003. The dual-purpose phased plan of improvement recommended by the Chief of Engineers is the National Economic Development plan and consists of the following features:

1. The Phase I pool raise includes construction of all mitigation features having to do with raising the pool to elevation (el.) 355.70 m (1,167 feet), and all ecosystem restoration features. This includes a fish passage facility, right dam abutment seepage mitigation, and fish and wildlife habitat mitigation. It also includes annual storage of the 5,000 ac-ft Section 1135 water Phase I pool raise has partially been implemented. Because the AWSP has not been fully implemented, and in particular not all mitigation measures have been accomplished, water stored for M&I purposes is considered to be relegated to a subordinate level of priority as compared to requirements imposed by natural resource concerns, in the event that conflict arises between these two considerations.
2. The Phase II pool raise includes construction of all remaining project mitigation features required for a pool raise to el. 358.75 m (1,177 feet). With the additional 296.0 ha-m (2,400 ac-ft) of M&I water plus 1,184.1 ha-m (9,600 ac-ft) of LFA water to be stored under Phase II, a combined total of 3,947.2 ha-m (32,000 ac-ft) of additional water will be stored at Howard Hanson Dam. The Phase II pool raise has not yet been implemented.

3.06 Principal Regulation Problems. Although the list of principal regulation problems has not changed since the project went in to operation, the emphasis given the various regulation problems and the time and expertise required to address the problems has changed significantly. Near real time project operation data is available on the internet to improve information availability and coordination. Some additional information on regulation issues is available in **Section 9**. The following summarizes the principal problems:

a. Spring Refill. During spring refill the need exists to balance both present demands and future needs through the water year. Refill must occur at a rate to allow for sufficient instream flows below the project for fish production and other water uses. Prior to 1992, outmigration of smolts received a higher priority. Since 1992, steelhead spawning during the spring has become a higher priority for flow management. When instream flows are reduced during the spring refill, the potential exists for steelhead redds to be dewatered, resulting in egg mortality and reduced available spawning habitat. The refill plan must also consider other impacts related to downramping rates and timing. In development of the yearly water control plan, WM and the Environmental Resources Branch of CENWS conduct regular meetings with representatives from the Green River Flow Management Coordination Committee (GRFMCC) as discussed in **Section 9.04**. During these meetings, all parties share information and reach a general consensus about the upcoming or current water control plan. These meetings are one aspect of a process referred to as adaptive management.

b. Turbidity control. Turbidity is the only water quality parameter that has seasonally exceeded “Core Summer Habitat” standards in the Green River above HHD. Periods of high turbidity are generally associated with elevated runoff during periods of heavy rainfall or rapid snowmelt. The concept of winter flood control is to empty the reservoir during the flood season to provide maximum space for storage during a flood emergency. In practice the reservoir drawdown is limited to prevent high turbidity levels associated with sediment accumulation in the lowest portion of the reservoir. The lower limit of drawdown is variable and is determined by careful monitoring of discharge turbidity as the reservoir approaches empty. In recent years the "turbidity pool" control level has been in the elevation 327.05 m (1,073 feet) to 327.66 m (1,075 feet) range. During the winter flood control period, when reservoir inflow turbidity is high, an attempt is made to pass accumulated sediment through the dam outlet to minimize sediment accumulation and keep the turbidity pool at the lowest practical elevation. Turbidity levels in the tailwater of HHD are the only known parameter that has exceeded the Department of Social and Health Services raw water quality standards.

While turbidities were excessive during high flow conditions without the dam, due to stored water being released after flood regulation activity, the periods of high turbidity are extended until the storage is evacuated or sufficiently diluted by cleaner inflows. In the lower Green River, turbidity is not thought to be limiting to fish, but it may limit other uses such as water supply and recreation. Turbidity is of greatest concern during flood events and when HHD reservoir levels are low, both of which can result in river water at the Tacoma Headworks (5.63 km [3.5 miles] below the dam) being too turbid for use by Tacoma Water. When this occurs, Tacoma uses water from the North Forks Wells located in the upper North Fork Green River basin until turbidity falls to an acceptable level. This involves the coordination of the operation of the HHD with the City of Tacoma and monitoring of upstream and downstream turbidity. Typically, every attempt is made to avoid negative turbidity impacts downstream. Additional information is provided in **Section 8.04** on water quality.

c. Levee erosion. Most of the area downstream of Auburn is protected by levees that have been constructed by local interests. As a result, levee erosion is a continuing issue with local interests. The levees are susceptible to erosion especially during the recession period of floods when the reservoir is being drawn down and river stage is decreasing adjacent to levees. Rate of dam discharge reduction is controlled as feasible to be gradual to minimize levee sloughing so long as flood control potential is not jeopardized.

4 – WATERSHED CHARACTERISTICS

4.01 General Characteristics. The Green River basin, total drainage area 1,251 square kilometer (km^2) (483 square miles), is shown on the hydrologic station map, **Plate 4-1**. The river flows westward about 64.37 km (40 miles) from its headwaters near Stampede Pass to the City of Auburn (Auburn), then turns and flows northwestward 32.19 km (20 miles) to the confluence of the Black River where it becomes known as the Duwamish River. The Duwamish continues northwestward about 17.70 km (11 miles) and enters Elliott Bay through two distributaries known as the East and West Waterways. The drainage basin above the dam site is about 16.09 km (10 miles) wide by 35.41 km (22 miles) long and has an area of 572 km^2 (221 square miles). From its headwaters to the project, the Green River flows through steep mountain valleys with forested slopes.

Downstream from the project, the basin is about 72.42 km (45 miles) long and varies in width from about 14.48 km (9 miles) to a maximum of about 22.53 km (14 miles) near Auburn and a minimum of about 3.22 km (2 miles) near Elliott Bay. From the project, downstream about 11.27 km (7 miles) to the City of Palmer (Palmer), the basin is similar to the headwater region above the dam. A diversion dam and intake for the Tacoma water supply, located 5.63 km (3.5 miles) downstream from Howard A. Hanson Dam, constitutes the only major development in this reach. Between Palmer and Newaukum Creek, the terrain transitions from a mountainous, sparsely populated headwater region to highly developed agricultural lands and housing developments. This area of about 181.30 km^2 (70 square miles) features rolling gravelly hills and contains railroad branch lines, a network of local roads, and several communities. From Newaukum Creek downstream to the Duwamish Waterway, most of the valley lands were subject to periodic flooding prior to completion of Howard A. Hanson project and were primarily agricultural. Since the dam became operational, business and light industrial applications have displaced most of the farms. Most of this 310.8 km^2 (120 square mile) area is a broad, flat valley which includes portions of Auburn, most of the City of Kent (Kent), several smaller communities, and many miles of highways, railroads, and power and telephone lines. The balance of the basin, from the head of the Duwamish Waterway to Elliott Bay, comprises the principal heavy industrial zone of the City of Seattle (Seattle).

4.02 Topography. Elevations along the eastern boundary of the basin range from 1,066.80 m to 1,752.60 m (3,500 feet to 5,750 feet). Along the northern and southern boundaries of the basin, altitudes range from over 1,524.00 m (5,000 feet) at the eastern end to about 914.40 m (3,000 feet) at a north-and-south line in the vicinity of Palmer. This upper portion of the basin is characterized by sharply incised valleys and prominent ridges. To the west, the boundaries are at a much lower elevation, seldom exceeding 304.80 m (1,000 feet) and generally below 152.40 m (500 feet). At one point just south of Auburn, the divide is slightly over 30.48 m (100 feet) above sea level.

4.03 Geology and Soils. The Green River Valley was invaded at least once by valley ice, spreading from the Cascade crest and terminating as an expanded foot glacier in the Puget Lowland, giving the Green River Valley its broad "U" profile. In addition, the Puget Lobe of the Continental glaciers invaded the entire Puget Lowland at least three times to an elevation of about 1,066.80 m (3,500 feet) in the vicinity of Seattle and sent a tongue of ice up each valley, blocking the rivers and forming large lakes. The lake that once filled the Green River Valley accumulated large quantities of lake clay and silt, which were eventually capped with sand and gravel deposits. The large amount of glacial and glacial stream and lake debris is a common characteristic of areas having undergone heavy glaciation with consequent stripping of most of the residual soil.

In the drainage upstream of Howard A. Hanson Dam, the rock is highly diverse. Much of the rock is of volcanic origin, such as Miocene andesite, found in hard, dense blocks, or some igneous granite blocks. About 14.48 km (9 miles) above the dam, the river has cut through the volcanics to a much older underlying Eocene sedimentary rock consisting of sandstone streambed tuff, and shale with some coal-bearing seams.

4.04 Sediment. Suspended sediment samples were obtained by CENWS on the Green River near Palmer for a two-year period, 1950-1951, for a wide range of river flows. Based on samples obtained, mean annual suspended sediment movement by the Green River was estimated to be about 10.24 ha-m (83 acre-feet) per year. No measurements of bedload were made. Because the majority of sediments, including bedload, will be transported during the winter with high flows and no pool, no allowance was considered necessary for loss of storage due to deposits in the reservoir. Although there will be some deposition during flood control storage operations, immediate drawdown in preparation for a potential flood event should move the majority of the material on through the discharge tunnel. Sedimentation ranges, as shown on **Plate 4-2**, have been established to permit assessment of reservoir aggradation, possible degradation, and the potential channel changes below the stilling basin. Based on the 2007 bathymetry survey, a loss in storage of 170.71 ha-m (1,384 acre-feet) has occurred since the original survey in 1961. A loss of 235.97 ha-m (1,913 acre-feet) has occurred in the conservation pool below 347.78 m (1,141 feet), a loss of 7.3 percent of the storage below this elevation. The apparent greater loss in storage below the conservation storage elevation compared to the total loss in storage maybe the result of the differing accuracies of the methods used to estimate the various storage volumes. A summary of the storage capacities of Howard A. Hanson Reservoir since the original survey in 1961 is presented in **Table 4-1.1** in metric units and **Table 4-1.2** in U.S. Customary units.

TABLE 4-1.1

SUMMARY OF RESERVOIR STORAGE CAPACITIES

HECTARE-METERS

Elevation (m)	1961	1979	1993	2007
367.6	13,032	12,890	12,813	12,862
347.8	3,218.2[1/]	3,212.9	3,203.4	2,982.6
326.1	196.1	140.6[2/]	108.8	26.64

[1/] Interpolated between reported capacity values at elevations 344.4 and 349.0 meters.

[2/] Value is from 1993 Sedimentation Study. 1984 Sedimentation Study shows a value of 97.3 hectare-m.

TABLE 4-1.2

SUMMARY OF RESERVOIR STORAGE CAPACITIES

ACRE-FEET

Elevation (ft)	1961	1979	1993	2007
1,206	105,650	104,500	103,880	104,270
1,141	26,090[1/]	26,047	25,970	24,180
1,070	1,590	1,140[2/]	882	216

[1/] Interpolated between capacity values at elevations 1,130 and 1,145 feet.

[2/] Value is from 1993 Sedimentation Study. 1984 Sedimentation Study shows a value of 789 ac-ft.

Core samples of the reservoir bed material taken in 2006 indicate that the majority of the sediment deposited nearest the dam is composed of sand and silt sized material. In the middle portion of the reservoir near the confluence with Charley Creek, the reservoir bed material consists of mostly sand and gravel sized material.

In addition, several large landslides have recently been reactivated, increasing the amount of fine sediment being input to the lower Green River. The largest of these, located near river kilometer 67.63 (RM 42), is estimated to have delivered about 38,050 cubic meters (50,000 cubic yards) of fine sediment to the lower Green River. The combined effect of the recent landslides and HHD operations has been to increase fine sediment levels in the lower Green River.

4.05 Climate.

a. General. The Green River basin lies on the west side of the Cascade Range approximately 161 km (100 miles) east of the Pacific Ocean. Westerly air currents from the ocean prevail in these latitudes, bringing the region considerable moisture, cool summers, and comparatively mild winters. Climate throughout the basin varies markedly due to topography. Major storm activity occurs during the fall and winter when the basin is subject to rather frequent, heavy frontal rains associated with cyclonic disturbances from the Pacific Ocean. During the summer months, weather is relatively warm and dry due to decreased activity of the semi-permanent Aleutian low and increased moisture-bearing capacity of incoming marine air as it is warmed by passage over land. Meteorological stations in or near the Green River basin together with a tabulation showing their elevation and period of record are shown on **Plate 4-1**.

b. Temperature. Normal annual temperatures for stations in or near the basin range from 4.3°Celsius (°C) (39.8°Fahrenheit (°F)) at Stampede Pass WSCMO to 11.0°C (51.8°F) at Seattle Tacoma WSCMO AP. Normal monthly temperatures vary from a January minimum of -6.1°C (21.0°F) at Stampede Pass WSCMO and 1.7°C (35.1°F) at Seattle Tacoma WSCMO AP to an August maximum of 18.4°C and 23.8°C (65.2°F and 74.8°F), respectively, for these stations. Extreme temperatures have varied from a maximum of 40.0°C (104 °F) at Kent to a minimum of -29.4° C (-21° F) at Stampede Pass WSCMO. Normal monthly temperatures for four representative stations are presented in metric units in **Table 4-2.1** and in U.S. Customary units in **Table 4-2.2**.

c. Precipitation. In the Green River basin, precipitation is a function of location and elevation and varies greatly over the basin. Normal annual precipitation ranges from less than 914 mm (36 inches) near the mouth of the river to more than 3,150 mm (124 inches) along the highest elevations of the basin divide. Normal annual basin precipitation above Auburn and at Howard A. Hanson Dam is 1.9 and 2.2 m (76 and 86 inches), respectively. A normal annual isohyetal map based upon computed 30-year normal annual precipitation for the period 1931-60 is presented on **Plate 4-3**. Approximately 75% of the annual amount falls during the 6-month period October through March. Mean monthly precipitation for stations in the basin varies from 19.05 mm (0.75 inches) for July at Seattle Tacoma WSCMO AP to 350.27 mm (13.79 inches) for December at Stampede Pass WSCMO. The maximum precipitation recorded for one month is 862.58 mm (33.96 inches) at Palmer 3ESE in December 1933. A maximum of 211.84 mm (8.34 inches) in 24 hours has been recorded at Stampede Pass WSCMO in November 2006. Normal monthly precipitation for four representative stations in the basin is presented in metric units in **Table 4-3.1** and in U.S. Customary units in **Table 4-3.2**.

d. Snowfall. Snowfall amounts in the Green River basin are dependent upon elevation and distance from the modifying influence of Puget Sound. Mean annual snowfall varies from 119.4 mm (4.7 inches) at Kent to 11,158 mm (439.3 inches) at Stampede Pass WSCMO, which recorded a maximum amount of 17,894 mm (704.5 inches) during the winter of 1971-1972. Snow surveys have been made in the basin since 1940. There are four active snow pillows in the basin. Locations, elevations, and periods of record for snow courses are presented on **Plate 4-1**. Mean monthly snowfalls for three representative stations are presented in metric units in **Table 4-4.1** and in U.S. Customary units in **Table 4-4.2**.

e. Wind. Winds in the basin are the result of the pressure gradient resulting from the relative positions of the semi-permanent high and low pressure cells, storm intensity and topographic effects. Prevailing winds in the lower basin are from the south quadrant generally from September through May and from the north quadrant June through August. Moving up the river valley above Palmer, the air flow is subject to a topographic "funneling" effect and the prevailing winds become westerly. Occasionally cold continental air from eastern Washington will flow through Stampede Pass creating cold east winds down the valley in the winter. In the winter season, winds will be in the range of 32 to 48 km/h (20 to 30 miles per hour (mph)) during storms. The maximum recorded velocities at Seattle Tacoma WSCMO AP and Stampede Pass WSCMO were 125 km/h (78 mph) from the southwest and 151 km/h (94 mph) from the west respectively.

TABLE 4-2.1
NORMAL MONTHLY TEMPERATURE
METRIC UNITS
1971 to 2000
DEGREES CELSIUS

Month	STATIONS			
	Stampede Pass WSCMO Elevation 1,206 m	Palmer 3ESE Elevation 280 m	Seattle Tacoma WSCMO AP Elevation 137 m	Howard A. Hanson Dam [1/] Elevation 368 m
Jan	-3.4	3.1	4.9	2.0
Feb	-2.1	4.5	6.3	3.0
Mar	0.2	6.1	7.9	4.6
Apr	2.7	8.3	10.1	6.9
May	6.2	11.3	13.2	10.2
Jun	9.7	13.9	15.9	12.8
Jul	13.4	16.7	18.5	15.9
Aug	13.9	17.1	18.7	15.7
Sep	10.9	14.7	16.2	13.4
Oct	5.9	10.3	11.5	8.9
Nov	-0.7	5.6	7.3	4.2
Dec	-3.4	3.1	4.8	1.7
Annual	4.4	9.6	11.3	8.3

[1/] Temperature recorded at Howard A. Hanson Dam for period 1982 to 2000.

TABLE 4-2.2
NORMAL MONTHLY TEMPERATURE
US CUSTOMARY UNITS
1971 to 2000
DEGREES FAHRENHEIT

Month	STATIONS			
	Stampede Pass WSCMO Elevation 3,958 Feet	Palmer 3ESE Elevation 920 Feet	Seattle Tacoma WSCMO AP Elevation 450 Feet	Howard A. Hanson Dam[1/] Elevation 1,206 Feet
Jan	25.9	37.6	40.9	35.6
Feb	28.2	40.1	43.3	37.5
Mar	32.3	42.9	46.2	40.2
Apr	36.9	46.9	50.2	44.4
May	43.1	52.4	55.8	50.3
Jun	49.4	57.1	60.7	55.1
Jul	56.1	62.0	65.3	60.6
Aug	57.0	62.7	65.6	60.3
Sep	51.7	58.4	61.1	56.2
Oct	42.6	50.5	52.7	48.0
Nov	30.7	42.1	45.2	39.6
Dec	25.8	37.6	40.7	35.0
Annual	40.0	49.2	52.3	46.9

[1/] Temperature recorded at Howard A. Hanson Dam for period 1982 to 2000.

TABLE 4-3.1

NORMAL MONTHLY PRECIPITATION
METRIC UNITS
1971 to 2000
MILLIMETERS

Month	Stations			
	Stampede Pass WSCMO Elevation 1,206 m	Palmer 3ESE Elevation 280 m	Seattle Tacoma WSCMO AP Elevation 137 m	Howard A. Hanson Dam Elevation 368 m
Jan	316.74	275.84	130.30	309.75
Feb	227.33	228.85	106.17	238.49
Mar	186.69	220.73	95.25	211.23
Apr	144.53	188.21	65.79	174.57
May	109.73	153.16	45.21	135.49
Jun	101.09	130.05	37.85	115.51
Jul	47.24	75.18	20.07	55.82
Aug	55.88	68.33	25.91	59.17
Sep	105.66	108.71	41.40	105.13
Oct	163.83	171.70	81.03	191.95
Nov	326.14	305.05	149.86	327.92
Dec	352.55	279.15	142.75	307.92
Annual	2,137.41	2,204.97	941.58	2,232.63

TABLE 4-3.2
NORMAL MONTHLY PRECIPITATION
US CUSTOMARY UNITS
1971 to 2000
INCHES

Month	Stations			
	Stampede Pass WSCMO Elevation 3,958 feet	Palmer 3ESE Elevation 920 feet	Seattle Tacoma WSCMO AP Elevation 450 feet	Howard A. Hanson Dam Elevation 1,206 feet
Jan	12.47	10.86	5.13	12.20
Feb	8.95	9.01	4.18	9.39
Mar	7.35	8.69	3.75	8.32
Apr	5.69	7.41	2.59	6.87
May	4.32	6.03	1.78	5.33
Jun	3.98	5.12	1.49	4.55
Jul	1.86	2.96	0.79	2.20
Aug	2.20	2.69	1.02	2.33
Sep	4.16	4.28	1.63	4.14
Oct	6.45	6.76	3.19	7.56
Nov	12.84	12.01	5.90	12.90
Dec	13.88	10.99	5.62	12.12
Annual	84.15	86.81	37.07	87.90

TABLE 4-4.1
NORMAL MONTHLY SNOWFALL
METRIC UNITS
1971 to 2000
MILLIMETERS

Month	Stations		
	Stampede Pass WSCMO Elevation 1,206 m	Palmer 3ESE Elevation 280 m	Seattle Tacoma WSCMO Elevation 137 m
Jan	1,775	180	61
Feb	1,334	112	33
Mar	1,410	69	15
Apr	1,003	13	3
May	470	0	0
Jun	41	0	0
Jul	8	0	0
Aug	0	0	0
Sep	36	0	0
Oct	437	5	3
Nov	1,915	36	28
Dec	1,902	155	64
Annual	10,330	569	206

TABLE 4-4.2
NORMAL MONTHLY SNOWFALL
US CUSTOMARY UNITS
1971 to 2000
INCHES

Month	Stations		
	Stampede Pass WSCMO Elevation 3,958 feet	Palmer 3ESE Elevation 920 feet	Seattle Tacoma WSCMO AP Elevation 450 feet
Jan	69.9	7.1	2.4
Feb	52.5	4.4	1.3
Mar	55.5	2.7	0.6
Apr	39.5	0.5	0.1
May	18.5	0.0	0.0
Jun	1.6	0.0	0.0
Jul	0.3	0.0	0.0
Aug	0.0	0.0	0.0
Sep	1.4	0.0	0.0
Oct	17.2	0.2	0.1
Nov	75.4	1.4	1.1
Dec	74.9	6.1	2.5
Annual	406.7	22.4	8.1

4.06 Storms and Floods. Flood producing storms occur chiefly from late fall through winter and occasionally in early spring. The sharp increase in frequency, duration, and severity of storms in late fall is a result of a southward displacement and renewed activity of the semi-permanent Aleutian low-pressure system. Frequently, a series of waves develops along the polar front. As the waves move landward, the unstable, moist air masses are orographically lifted by the mountains. This results in general, often heavy, precipitation that increases with elevation. All general winter storms of the Northwest are of this one basic type, having similar origins, air mass trajectories, and a moisture source in the Pacific Ocean. The storms of December 1933, November 1959, January 1965, December 1977, February 1996, November 2006 and January 2009 produced, or would have produced under natural conditions, the maximum floods of record on the Green River. Precipitation data from Stampede Pass WSCMO, Palmer 3ESE, and Seattle Tacoma WSCMO AP for these seven storms are listed in metric units in **Table 4-5.1** and in U.S. Customary units in **Table 4-5.2.**

All events that had, or would have had under natural conditions, flows in excess of the bank-full capacity of 339.80 m^3/s (12,000 cfs) are considered to be floods. A flow in excess of 339.80 m^3/s (12,000 cfs) has occurred in each of the months from October through April, but floods requiring any significant amount of storage capacity for control to non-damaging discharge have occurred only in the period November through February. In less than 18 hours, the main river can rise from base flow stage to flood stage with very little advance warning aside from weather forecast information. The maximum instantaneous flow is generally 20-30% greater than the maximum daily flow. Double-crested peaks are sometimes experienced during larger flood flows and are produced generally by a major storm followed within 48 hours by a minor storm or by temporal variations in precipitation within a single storm. The largest recorded flood peaks in the Green River basin occurred in December 1933, December 1946, and November 1959 before regulation began at the dam. The 1959 flood had the highest peak of record, but would have required less storage to control than the other two floods. The 1946 flood was larger than the 1933 event in the upper reaches, but was lower and did less damage in the lower reaches. The largest floods recorded since regulation for flood control began in water year (WY) 1961 occurred in December 1977 and January 2009. The December 1977 flood would have had the highest flood peak of known experience under natural conditions. Natural peak discharges for the largest floods are compared in metric units in **Table 4-6.1** and in U.S. Customary units in **Table 4-6.2**. Frequency curves, representing inflow to Howard A. Hanson Dam and flow near Auburn are shown on **Plates 4-13, 4-14,** and **4-15**.

TABLE 4-5.1
STORM PRECIPITATION
METRIC UNITS (mm)

Station	December 1933		November 1959		January 1965		December 1977		February 1996		November 2006		January 2009	
	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total
Stampede Pass WSCMO	106.68	182.88	171.70	419.10	72.14	261.11	150.62	391.16	102.36	310.90	211.84	298.70	1/	1/
Palmer 3ESE	116.84	193.04	85.85	292.10	110.74	268.22	61.47	95.50	98.55	295.66	144.78	233.68	1/	1/
Seattle Tacoma WSCMO AP	30.48	54.61	76.45	148.59	25.65	67.06	5.08	16.51	83.57	150.88	83.56	104.39	58.17	86.36

1/ Entire month of January 2009 missing at Stampede Pass WSCMO and Palmer 3 ESE

TABLE 4-5.2
STORM PRECIPITATION
US CUSTOMARY UNITS (inches)

Station	December 1933		November 1959		January 1965		December 1977		February 1996		November 2006		January 2009	
	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total	Max 24-Hr Total	40-Hr Storm Total
Stampede Pass WSCMO	4.20	7.20	6.76	16.50	2.84	10.28	5.93	15.40	4.03	12.24	8.34	11.76	1/	1/
Palmer 3ESE	4.60	7.60	3.38	11.50	4.36	10.56	2.42	3.76	3.88	11.64	5.70	9.20	1/	1/
Seattle Tacoma WSCMO AP	1.20	2.15	3.01	5.85	1.01	2.64	0.20	0.65	3.29	5.94	3.29	4.11	2.29	3.40

1/ Entire month of January 2009 missing at Stampede Pass WSCMO and Palmer 3 ESE

TABLE 4-6.1
PEAK DISCHARGES
M^3/SEC

Station	1933	1946	1959	1975	1977	1996	2009
Green River near Palmer	614.5	659.8	787.2	685.3[1/]	1025.1[1/]	829.7[1/]	871.6[1/]
Green River near Auburn	679.6	620.1	795.7	741.9[1/]	1070.4[1/]	957.1[1/]	1048.0[1/]

[1/] Estimated natural flood peak

TABLE 4-6.2
PEAK DISCHARGES
FT^3/SEC

Station	1933	1946	1959	1975	1977	1996	2009
Green River near Palmer	21,700	23,300	27,800	24,200[1/]	36,200[1/]	29,300[1/]	30,780[1/]
Green River near Auburn	24,000	21,900	28,100	26,200[1/]	37,800[1/]	33,800[1/]	37,010[1/]

[1/] Estimated natural flood peak

4.07 Runoff Characteristics. The heaviest rainfall and, consequently, the highest runoff generally occurs during the winter storm season from November through March. Runoff during this period is characterized by frequent sharp peaks of short duration. However, peaks may be separated by periods of relatively low flow when temperatures drop and precipitation falls as snow. Intense winter rainstorms with warm winds and occasional accompanying snowmelt cause the river to swell from relatively low flow to flood levels within 24 to 36 hours. After a storm has passed, flows generally recede relatively rapidly. In April, heavy winter rains begin to abate, temperatures rise, and runoff is generally due to a combination of rainfall and snowmelt. Spring runoff is characterized by peaks that are generally smaller in magnitude than rainflood peaks, but can be of much longer duration. Generally by late May or June the snowpack is depleted and flows recede rapidly, reaching minimum flow during August or September. The unusually low minimum flow of the Green River upstream of Howard A. Hanson Dam reflects the absence of storage in glacial ice and the meager contribution from ground water. The locations of streamgaging stations in the basin, together with their periods of record, are shown on **Plate 4-4**.

Although the drainage area increases from 595.7 km^2 (230 square miles) for the streamgaging station Green River near Palmer (near Palmer) to 1033 km^2 (399 square miles) for the station Green River near Auburn (near Auburn), an increase of 73%, the average annual runoff volume increases only 20%. The lower incremental runoff downstream of Palmer is reflective of the lower precipitation in the lower basin. The annual stream flow pattern for the Green River is shown by the summary hydrographs for the mean daily inflow to Howard A. Hanson reservoir, the regulated mean daily discharge below the dam, the mean daily local runoff between the dam and Auburn, and the mean daily regulated discharge near Auburn (**Plates 4-5, 4-6, 4-7, and 4-8,** respectively) and by the daily reservoir inflows and the discharge hydrographs for the Green River stations below Howard A. Hanson Reservoir, and near Auburn (**Plates 4-9, 4-10, and 4-11,** respectively). Mean annual flow near Palmer varied from 14.47 m^3/s to 42.59 m^3/s (511 cfs to 1,504 cfs) during the period of record from 1913 to 1962. Extremes of discharge recorded were a maximum of 787.31 m^3/s (27,800 cfs) in November 1959 and a minimum of 2.29 m^3/s (81 cfs) in September 1934. Significant historical floods have been noted in the vicinity of the Palmer gage, going back to one in November 1892. Although discharges for these floods cannot be determined with any degree of reliability, none are believed to have had a higher peak than the 1959 event. A summary of streamflow data is presented in metric units in **Table 4-7.1** and in US Customary units in **Table 4-7.2** for the gages on the Green River near Lester, below Howard A. Hanson Reservoir, and near Auburn. **Tables 4-8.1 and 4-8.2** list the mean monthly flows for these same stations in metric and U.S. Customary units respectively.

Table 4-7.1

SUMMARY OF STREAMFLOW DATA

METRIC UNITS (m^3/sec)

Stream	Station Location	Drainage Area	Period of Record	Annual Runoff			Extreme Discharge		
		Km^2		Mean	Max	Min	Max Inst.	Max Daily	Min Daily
Green River	near Lester	249	1946 - 1993	11	17	6	623	425	0.6
Green River	near Palmer	596	1931 - 1961 1/	31	43	14	787	541	2.3
Green River	at purification plant near Palmer	598	1964 - 2009 2/	27	44	16	354	309	0.6
Newaukum Creek	near Black Diamond	71	1944 - 1949, 1952 - 2009	1.7	2.4	1	75	47	0.2
Big Soos Creek	above Hatchery near Auburn	173	1960 - 2009	3	6	2	119	101	0.5
Green River	near Auburn	1033	1936 - 1961 1/	38	50	19	796	606	2.3
Green River	near Auburn	1033	1962 - 2009 2/	38	59	22	351	328	4.3

1/ Natural flows

2/ Regulated flows

Table 4-7.2

SUMMARY OF STREAMFLOW DATA

US CUSTOMARY UNITS (ft^3/sec)

Stream	Station Location	Drainage Area	Period of Record	Annual Runoff			Extreme Discharge		
		Mi^2		Mean	Max	Min	Max Inst.	Max Daily	Min Daily
Green River	near Lester	96.2	1946 - 1993	381	588	219	22,000	15,000	20
Green River	near Palmer	230	1931 - 1961 [1/]	1,100	1,504	511	27,800	19,100	81
Green River	at purification plant near Palmer	231	1964 - 2009[2/]	946	1,562	573	12,500	10,900	20
Newaukum Creek	near Black Diamond	27.4	1944 - 1949, 1952 - 2009	58.6	85.9	33.7	2,640	1,670	8.3
Big Soos Creek	above Hatchery near Auburn	66.7	1960 - 2009	123	195	63.5	4,200	3,580	18
Green River	near Auburn	399	1936 - 1961 [1/]	1,346	1,783	662	28,100	21,400	81
Green River	near Auburn	399	1962 - 2009 [2/]	1,331	2,071	785	12,400	11,600	152

[1/] Natural flows

[2/] Regulated Flows

Table 4-8.1

MEAN MONTHLY STREAMFLOW DATA

METRIC UNITS (m^3/sec)

Stream	Station Location	Period	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Green River	near Lester	1946 - 1993	4.3	11.9	15.1	13.6	12.7	11.1	17.6	21.8	13.3	4.4	1.8	2.0
Green River	near Palmer	1931 - 1961 [1/]	17.7	41.2	50.8	41.8	36.6	36.0	47.0	47.6	52.9	11.9	5.6	7.0
Green River	at purification plant near Palmer	1964 - 2009[2/]	13.4	36.2	41.9	45.9	39.6	32.3	36.5	36.0	20.3	8.9	4.6	6.7
Newaukum Creek	near Black Diamond	1944 - 1949, 1952 - 2009	0.7	1.8	2.7	3.3	2.9	2.5	1.9	1.4	1.1	0.7	0.6	0.5
Big Soos Creek	above Hatchery near Auburn	1960 - 2009	1.2	3.2	5.8	7.2	6.6	5.6	4.3	2.7	2.0	1.2	0.9	0.9
Green River	near Auburn	1936 - 1961 [1/]	18.3	45.9	61.9	51.9	54.8	46.4	57.7	55.2	36.2	15.1	7.1	8.2
Green River	near Auburn	1962 - 2009 [2/]	18.1	46.4	58.9	66.5	58.0	47.9	50.4	45.6	28.3	14.7	8.7	10.6

[1/] Natural flows

[2/] Regulated Flows

Table 4-8.2

MEAN MONTHLY STREAMFLOW DATA

US CUSTOMARY UNITS (ft^3/sec)

Stream	Station Location	Period	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Green River	near Lester	1946 – 1993	153	421	532	480	449	393	623	771	471	155	65	70
Green River	near Palmer	1931 - 1961 [1/]	624	1,454	1,793	1,476	1,291	1,270	1,659	1,682	1,869	419	199	247
Green River	at purification plant near Palmer	1964 - 2009 [2/]	473	1,280	1,480	1,620	1,400	1,140	1,290	1,270	716	314	161	238
Newaukum Creek	near Black Diamond	1944 - 1949, 1952 – 2009	24	65	95	115	101	87	68	48	39	26	20	19
Big Soos Creek	above Hatchery near Auburn	1960 – 2009	41	113	204	256	233	199	151	97	69	43	32	32
Green River	near Auburn	1936 - 1961 [1/]	646	1,621	2,185	1,832	1,936	1,640	2,039	1,950	1,280	533	252	288
Green River	near Auburn	1962 - 2009 [2/]	638	1,640	2,080	2,350	2,050	1,690	1,780	1,610	1,000	520	308	376

[1/] Natural flows

[2/] Regulated Flows

4.08 Water Quality. The Washington State Department of Ecology (Ecology) has established surface water quality standards pursuant to Chapter 90.48 RCW (Water Pollution Control Act) and Chapter 90.54 RCW (Water Resources Act of 1971) to protect uses of water beneficial to wildlife and humans. Water quality standards affected by forest practices are addressed by the Washington Forest Practices Board Manual, which states "whereas Ecology is solely responsible for establishing water quality standards for waters of the state, both the Forest Practices Board (FPB) and Ecology shall jointly regulate water quality issues related to silviculture in the State of Washington (RCW 90.48.420)." As a result, WAC 173-202, Washington Forest Practices Rules and Regulations to Protect Water Quality, was jointly developed and adopted by the FPB and Ecology so that compliance with Forest Practices Rules and Regulations would in turn achieve compliance with water pollution control laws.

Water quality standards for the State of Washington are described in the Washington Administrative Code, Chapters 173-201A. Washington State water quality standards use aquatic life use categories to provide protection for key fish and non-fish species to be protected in waters of the state. In addition, the state uses recreation use categories to provide protection for water contact recreation in fresh waters. The Duwamish-Green River has three designated aquatic life use categories and three designated recreation use categories as shown below:

a. <u>Aquatic Life Use Categories</u>

1. Core summer salmonid habitat: The key identifying characteristics of this use are summer (June 15 – September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char.
2. Salmonid spawning, rearing, and migration: The key identifying characteristic of this use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 – June 14).
3. Salmonid rearing and migration only: The key identifying characteristic of this use is use only for rearing or migration by salmonids (not used for spawning).

b. <u>Recreation Use Categories</u>

1. Extraordinary Primary Contact Recreation
2. Primary Contact Recreation
3. Secondary Contact Recreation.

Each aquatic life use and recreation use has a unique set of water quality standards as shown in **Table 4-9**. The Green River from the headwaters downstream to the west boundary of Flaming Geyser State Park is designated as a Core Summer Salmonid Habitat aquatic life use and an Extraordinary Primary Contact recreation use. The Green River from the west boundary of Flaming Geyser State Park downstream to approximately river kilometer (RK) 38.3 (river mile (RM) 23.8) (latitude 47.3699 longitude -122.2461) is designated as a Core Summer Salmonid Habitat aquatic life use and a Primary Contact recreation use. The Green River from approximately RK 38.3 (RM 23.8) downstream to its junction with the Black River at approximately RK 17.7 (RM 11.0) (Duwamish River continues after junction of Green River with Black River) is designated as a Salmonid Spawning, Rearing, and Migration habitat and a Primary Contact recreation use. The Duwamish River from approximately RK 17.7 (RM 11.0) to the mouth is designated as a Salmonid Rearing and Migration Only aquatic life use and a Secondary Contact recreation use.

In general, water quality problems that potentially contribute to the decline of salmonids in the Green River increase in severity as the water flows downstream. In the upper watershed, the primary factors affecting water quality and fish production are increased turbidity and fine sediment loading associated with commercial forest management and the associated road network.

Table 4-9

Washington Department of Ecology Water Quality Criteria for the Duwamish-Green River

Aquatic Life Uses					
Use Category	**Temperature (Highest 7-DADMax) [1/]**	**Dissolved Oxygen (Lowest 1-Day Minimum)**	**Turbidity (NTU)**	**pH**	**Bacteria (Indicator Species)**
Core Summer Salmonid Habitat	16°C (60.8°F)	9.5 mg/L	Shall not exceed 5 NTU over background when the background is 50 NTU or less; or a 10 percent increase in turbidity when the background turbidity is more than 50 NTU	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units	—
Salmonid Spawning, Rearing, and Migration	17.5°C (63.5°F)	8.0 mg/L	Shall not exceed 5 NTU over background when the background is 50 NTU or less; or a 10 percent increase in turbidity when the background turbidity is more than 50 NTU	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units	—
Salmonid Rearing and Migration Only	17.5°C (63.5°F)	6.5 mg/L	Shall not exceed 10 NTU over background when the background is 50 NTU or less; or a 20 percent increase in turbidity when the background turbidity is more than 50 NTU	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units	—

[1/] 7-day average of daily maximum temperatures.

Table 4-9 (continued)

Washington Department of Ecology Water Quality Criteria for the Duwamish-Green River

Recreational Uses					
Use Category	**Temperature (Highest 7-DADMax)**	**Dissolved Oxygen (Lowest 1-Day Minimum)**	**Turbidity (NTU)**	**pH**	**Bacteria (Indicator Species)**
Extraordinary Primary Contact Recreation	—	—	—	—	Fecal coliform organism level must not exceed a geometric mean value of 50 colonies/100mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 mL
Primary Contact Recreation	—	—	—	—	Fecal coliform organism level must not exceed a geometric mean value of 100 colonies/100mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100 mL
Secondary Contact Recreation	—	—	—	—	Fecal coliform organism level must not exceed a geometric mean value of 200 colonies/100mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 400 colonies/100 mL

4.09 Channel and Floodway Characteristics. In terms of areal extent, the majority of the Green River floodplain lies in the portion of the valley from Auburn downstream to the Black River. Much of this river reach is protected by levees constructed by local interests and the bank-full capacity is approximately 339 m^3/s (12,000 cfs). There are 189 km^2 (73 square miles) of drainage area outside the levees that contribute to interior runoff. This runoff normally discharges into the Green River through openings in the levees. However, during periods of high river stages, flows through the openings may be slowed, shut off or reversed, depending upon the relative water surface levels on the two sides of the levee. At several sites, pump stations discharge interior runoff into the river provided that the carrying capacity is available. For peak discharges less than 141.58 m^3/s (5,000 cfs) near Auburn, the flow through the main valley remains unchanged. For peak flows between 141.58 m^3/s and 339.80 m^3/s (5,000 cfs and 12,000 cfs), a slight reduction in peak occurs through this reach because the inflow is insufficient to balance the reduction resulting from channel storage. This reduction is even greater with peaks in excess of 339.80 m^3/s (12,000 cfs). Flooding of the valley area begins at this flow, and at 651.29 m^3/s (23,000 cfs), the river floodplain extends to the base of adjacent foothills, yielding an appreciably reduced peak at the lower end of the valley. Below Black River, the Green River is within tidal influence of Puget Sound, and therefore the flow varies with the tidal cycle.

4.10 Upstream Structures. There are no regulating structures upstream of Howard A. Hanson Dam.

4.11 Downstream Structures. There are no Corps' owned regulating structures downstream of Howard A. Hanson Dam. However, the City of Tacoma owns and operates a water diversion facility which is located approximately 5.6 kilometers (3.5 miles) downstream of HHD. The diversion dam is 5.18-meters (17-feet) high by 46.3-meters (152-feet) long and was completed in 1913. The intake structure at the north end of the dam carries water through a short tunnel into a settling basin. From the settling basin, water is conveyed by gravity through a transmission pipeline to McMillin reservoir near the City of Puyallup and then into the City of Tacoma.

4.12 Economic Data.

a. Population. The Green River basin lies wholly within King County, which had a population of 1,916,441 in 2009. The area contiguous to Duwamish Waterway comprises the principal industrial zone of the Seattle metropolitan area, which had an estimated population of 602,000 in 2009. Kent and Auburn, with populations of 88,380 and 67,485, respectively, are the largest towns within the basin.

b. Agriculture. The Green River Valley is divided into two Agricultural Production Districts (APD). The Upper Green APD covers approximately 1,416 hectares (3,500 acres) and is generally located upstream of Auburn. Land uses are primarily forest, livestock/forage and horse pasture. The Lower Green APD covers approximately 568 hectares (1,403 acres) and is generally located downstream of Auburn. Land uses are primarily market crops and livestock/forage.

c. Industry. Operation of Howard A. Hanson Dam has reduced the flood threat to the valley, allowing higher value crops and expansion of Seattle's industrial district. Prior to construction of Howard A. Hanson dam, the Green River Valley, from the Duwamish Waterway to Newaukum Creek was predominantly agricultural land with numerous small farms involved in production of dairy products, berries, and vegetables. The dam has significantly lowered the risk of flooding in the valley and facilitated a dramatic change in utilization of valley acreage that was previously in the floodplain. Although significant wetland and agricultural areas remain, open space is rapidly being converted to applications having higher economic value including commercial, light industrial, warehousing and shopping centers. Seattle's industrial district, commonly known as the Duwamish Waterway, is in the lower section of the valley. The district's heavy industry consists of steel mills, shipbuilding and repair, truck and bus manufacturing, and the majority of Boeing Company's extensive Seattle aircraft plant. Light industry in the area includes lumber mills, wood-product plants, machine shops, metal product plants, machinery servicing facilities, and other miscellaneous manufacturing concerns.

d. Minerals. Production and reserves of minerals in the Green River basin include coal, stone, sand and gravel, clay, silica, peat, and small amounts of mercury, arsenic, iron, and oil and gas. Coal and stone are the leading commodities produced. Coal production has been estimated at a little more than 22.68 million metric tons (25 million tons) from 1882 to 1964, with estimated reserves of 323.80 million metric tons (357 million tons). No significant coal mining has occurred since 1964. Although no production figures are available for stone, it is probable that more stone is produced from the Green River basin than any other basin in the Puget Sound region. Of the remaining commodities, only clay, peat, and sand and gravel are produced in any sizable amounts. No mineral deposits of value are known to exist in the reservoir area.

e. Flood Damages. Some minor flooding occurs in the reach downstream of Auburn near Mill Creek/Mullen Slough when the flow reaches 283.17 m^3/s (10,000 cfs), and also in areas upstream of Auburn on the Middle Green. Damage in the lower valley does not become significant unless the flow exceeds 339.80 m^3/s (12,000 cfs). The flow includes that measured at the stream gage near Auburn plus any free-flow or pumped discharge from interior runoff. The area subject to flood damages in the Green river downstream of Highway 18, located at approximately river kilometer 47.5 (river mile 29.5), consists of urban and suburban land uses ranging from agricultural land to, increasingly, commercial and industrial properties. Approximately 7,284.6 ha (18,000 acres) of land are exposed to hazards of flooding. Large portions of Kent, Auburn and Tukwila are flooded as flows reach approximately 481.39 m^3/s (17,000 cfs). Agricultural land is composed of rich alluvial soil presently adapted to truck and dairy farming. With a few exceptions, roads in the valley are not raised above the level of surrounding ground, making them subject to overflow in many places. Major floods occurred in this area in 1933, 1946, and 1959. The damages, based on 1960 price levels, were estimated at $3,150,000, $2,594,000, and $4,354,000, respectively. In 1996 and in 2009 major floods occurred with unregulated flows for the Green River at Auburn calculated to be 33,800 cfs and 37,000 cfs respectively. In 2010 dollars, estimated damages prevented were $3.1 billion for 1996 and $4.1 billion for 2009.

5 – DATA COLLECTION AND COMMUNICATIONS NETWORK

5.01 Hydrometeorological Stations. There are 21 active hydrometeorological (hydromet) stations in the Green River hydromet network. **Plates 4-1 and 4-4** show the locations of active and inactive stations in the basin and surrounding area and have tabulations of the stations with their periods of record.

a. Meteorological Stations. For this manual, all weather stations, cooperative climatological stations and snow courses are considered meteorological stations. Twelve such stations are currently active in the hydromet network and are listed in **Table 5-1**. The stations Kent, Palmer 3ESE, Seattle Tacoma AP, and Stampede Pass are operated and maintained by the NWS and Cougar Mountain by the Natural Resources Conservation Service (NRCS). The remainder are operated and maintained by the Corps.

b. Streamgaging Stations. There are nine active streamgaging stations in the basin which are listed in **Table 5-2**. Eight of the streamgaging stations are operated and maintained by the U.S. Geological Survey (USGS) with five stations funded fully and one partially by project funds transferred annually under the Cooperative Streamgaging Program. Two gages operated and maintained by the USGS, Green River below Howard A. Hanson Dam and Newaukum Creek near Black Diamond, are funded fully by the Corps through the Other Federal Agency Program. The Corps operates and maintains the reservoir gage and reimburses the USGS under the Cooperative Streamgaging Program for publication of the data under the station name Howard A. Hanson Reservoir near Palmer, Washington.

5.02 Water Quality Stations. There are two permanent stations that collect water temperature data. Turbidity is taken manually at these sites year round. During the summer water quality data is collected manually at an additional 6 sites throughout the reservoir. The locations for the permanent and summer sites are listed in **Table 5-3**

5.03 Sediment Stations. There are no automated sediment collection stations for the project.

TABLE 5-1
METEOROLOGICAL STATIONS

STATION		DATA	ELEVATION		RECORD
			m	feet	
COUGAR MOUNTAIN (21B42S)	(S)(P)(AR)	P,WC,T	975.4	3,200	1967-
GRASS MOUNTAIN #2 (21B27)	(SC)	WC	883.9	2,900	1961-2009
HOWARD A. HANSON DAM	(C)(AR)	P,T,W	374.9	1,230	1964-
KENT (454169)		P,T	12.2	30	1912-
LESTER CREEK (21B29)	(SC)	WC	944.9	3,100	1961-2009
LYNN LAKE (21B50S)	(S)(AR)	P,WC,T	1,219.2	4,000	1961-
PALMER 3ESE (456295)	(C)	P,T	280.4	920	1924-
RAVENSDALE	(AR)	P,W,T, A	237	778	2002-
SAWMILL RIDGE (21B31)	(S)(AR)	P,WC,T	1,432.6	4,700	1961-
SEATTLE TACOMA WSCMOAP	(C) (AR)	P,T	117.7	386	1948-
STAMPEDE PASS (21B10S)	(S)(P)(AR)	P,WC,T	1,176.5	3,860	1945-
STAMPEDE PASS WSCMO	(C)(AR)	P,T	1,206.4	3,958	1944-
TWIN CAMP (21B30)	(SC)	WC	1,249.7	4,100	1961-2009

LEDGEND: (C)=Recording Gage, (AR)=Automatic Reporting, (S)=Snotel Gage, (P)=Snow Pillow, (SC)=Manual Snow Course P=Precipitation, T=Temperature, W=Wind, WC=Snow Water Content, A=Atmospheric Pressure

TABLE 5-2
STREAMGAGING STATIONS

STATION	USGS NUMBER	RECORD
GREEN RIVER ABOVE TWIN CAMP NEAR LESTER – LTCW (S)	12103380	USGS: OCT 1992 – SEP 1999 USACE: DEC 2001-
HOWARD A. HANSON RESERVOIR NEAR PALMER – HAH (AR)	12105800	DEC 1961-
GREEN RIVER BELOW HOWARD A. HANSON RESERVOIR– HAHW (AR)	12105900	OCT 1960-
GREEN RIVER AT PURIFICATION PLANT NEAR PALMER – GPUW (AR)	12106700	JUL 1963-
NEWAUKUM CREEK NEAR BLACK DIAMOND - BKDW (AR)	12108500	JUL 1944-NOV 1950; Sep 1952-
BIG SOOS CREEK ABOVE HATCHERY NEAR AUBURN – SOOW (AR)	12112600	SEP 1960-
GREEN RIVER NEAR AUBURN - AUBW (AR)	12113000	AUG 1936-
SPRING BROOK CREEK NEAR ORILLIA (AR)	12113346	OCT 1993-
GREEN RIVER AT TUKWILA – TUKW (S)	12113350	[1/]SEP 1998-
MILL CREEK AT EARTHWORKS PARK AT KENT (AR)	12113347	JAN 1994-
MILL CREEK NEAR MOUTH AT ORILLIA (AR)	12113349	FEB 1994-

LEGEND: (AR)=Automatic Reporting or Real-time, (S)=Stage Only

1/ Discharge available from 1960 to 1984. USACE recorded stage from 1985 – 1998.

TABLE 5-3
WATER QUALITY STATIONS

STATIONS	DATA	RECORD
PERMANENT SITES		
UPSTREAM OF RESERVOIR (R) (HUMPHREY, HAQW)	T, TUR	1970-
DOWNSTREAM OF DAM (R) (HAHW)	T, S, TUR	1960-
SUMMER SITES		
UPSTREAM OF RESERVOIR (R) (HUMPHREY, HAQW, GRAP)	T, DO, pH, C, N, A	1973- 2002-
NORTH FORK ABOVE POOL (R)	T, DO, pH, C	1973-Discontinued
UPPER REACH (P) (9UPNR)	T, DO, pH, C N, A, Chl a	1973- 2002-
CHARLEY CREEK (P) (6CHCK)	T, DO, pH, C	1973-
NORTH FORK (P) (5NFK)	T, DO, pH, C	1973-
LOWER REACH (P) (3LWNR)	T, DO, pH, C	1973-2004
FOREBAY (P) (1DAM)	T, DO, pH, C N, A, Chl a	1973- 2002-
DOWNSTREAM OF DAM (R) (HAHW)	T, S, TUR, DO, pH, C N, A	1973- 2008-

LEGEND: T=Temperature, S=Stage, TUR=Turbidity, DO=Dissolved Oxygen, C=Conductivity, pH=Acidity, N=Nutrients A=Alkalinity, Chl a=Chlorophyll a
(P)=Water Quality Profile in Reservoir, (R)=Water Quality Grab Sample in River

5.04 Recording Hydrologic Data. The hardware systems that collect, process, store and disseminate water control information are collectively called the hydromet system. The Howard A. Hanson Dam project automated hydromet network includes data collected from multiple sources including CENWS, USGS, Northwest River Forecast Center, National Weather Service, LRGS/DOMSAT Satellite, and Tacoma Water. CENWS owns and maintains four streamgaging stations, two precipitation stations, and the project station (see **Tables 5-1 and 5-2, and Plate 5-1**) to support operations at Howard Hanson Dam.

Each data station is tied via VHF radio and microwave into the hydromet data collection system (collection system) located in the Reservoir Control Center (RCC) in the CENWS office. Data are telemetered from the network in response to an interrogation from the collection system. Interrogation can be initiated either manually at any time or automatically at preset intervals. The length of time intervals can be set according to need. All automatically interrogated data received by the collection system are relayed directly into the Columbia River Operational Hydromet Management System's Crohm's Automated Front End (CAFÉ) for data processing.

Data that is collected at the project includes climatological (precipitation and temperature), forebay elevation, and tailwater stage. This data is transmitted directly to the project operations building and directly to the RCC collection system for redundancy. Data telemetered to the project operations building is transmitted across a land line selsys system to the Stevens recorder. Data telemetered to the RCC occurs through interrogation by the collection system. This redundancy is required in the case of a communications outage.

5.05 Communications Network. The CENWS office and Howard A. Hanson Dam project are linked together through commercial telephone lines for voice communication. A five-channel VHF voice system is available for communication between the project and CENWS office or Corps' vehicles equipped with two-way radio equipment.

5.06 Maintenance. Maintenance and repair of any of the sensing equipment which is part of the hydromet network will be the responsibility of the Water Management Section. Maintenance and repair of the communications and data transmission system will be the responsibility of Project Operation Branch of Operations Division.

5.07 Communications with the Project. Guidance for communication with the project is included in **Section 7.04**.

5.08 Project Reporting Instructions. The operators report project data on a daily basis to WM. Reported data include climatological data (daily precipitation, minimum and maximum air temperature), forebay elevation, tailwater stage, and upstream and downstream water temperature and turbidity. Additional project reporting requirements for emergency situations (i.e., post earthquake inspection reporting) are outlined in the Emergency Action and Notification Subplan (EAP). Copies of the EAP are located at the project, NWD and CENWS RCC.

5.09 Warnings. The EAP provides notification protocol for special operations and emergencies. Copies are located at the project, NWD and CENWS RCC.

6 - HYDROLOGIC FORECASTS

6.01 General. The two basic types of forecasts used in the regulation of Howard A. Hanson Dam are short-term streamflow forecasts for real-time and near real-time operations including flood control and longer-term forecasts such as National Weather Service (NWS) Northwest River Forecast Center (NWRFC) Extended Streamflow Prediction (ESP) forecasts and spring runoff volume forecasts used for longer-term operations such as for conservation storage filling.

6.02 Flood Conditions Forecasts.

a. Requirements. Flood forecasts are necessary to allow adequate lead time for regulation of flows at the project to be effective in timely reduction of flows in the lower Green River valley. Travel time between the project and Auburn is approximately 8 hours during high flows. Therefore, forecasts of local inflow between the project and near Auburn must be made expeditiously so that the regulated outflow from the project plus the forecasted local inflow will not exceed the desired control flow near Auburn, as described in **Section 7.03a**, approximately 8 hours later. Flood forecasts by the NWS NWRFC are routinely produced in sufficient time to formulate an effective reservoir regulation plan with backup methods used when their forecasts are not available or are not updated in a timely manner.

Rainfall that produces floods in the basin varies considerably depending upon the sequence of the total storm precipitation and the hour-to-hour rainfall intensity. The local inflow drainage has fairly steep gradients near the project but is quite flat with some small lakes and swampy areas just upstream of Auburn. Of the 461 km^2 (178 square miles) between the project and near Auburn, two sub-basins are gaged; 172.8 km^2 (66.7 square miles) of the Big Soos Creek basin which empties into the Green River 2.9 RK (1.8 RM) above the near Auburn gage, and 70.9 km^2 (27.4 square miles) of the Newaukum Creek basin which empties into the Green River 14.8 RK (9.2 RM) above the near Auburn gage. Big Soos Creek peaks from 4 to 20 hours after Newaukum Creek depending upon the magnitude of antecedent flow, precipitation pattern, and soil moisture. Hence, Newaukum Creek is considered to be a conservative indicator of local inflow. The precipitation recorded at the project and at other nearby sites (e.g., Ravensdale) is used to indicate what the local inflow hydrograph will do in the ensuing 6 to 8 hours.

b. Methods. The NWRFC uses the National Weather Service Community Hydrologic Prediction System computer model to forecast inflow to the project and local inflow between the project and Auburn. These 240-hour forecasts are produced year-round. The forecasts are in 6-hour increments and are based on quantitative precipitation and temperature forecasts. The forecasts are normally accessed by CENWS at 0900 hours daily for input of discharge estimates from the project. NWRFC incorporates the planned regulation into the forecast of reservoir elevation and discharge at Auburn. Once the forecast is complete, NWRFC releases the forecast to the public and it is collected automatically by the RCC Water Control Data System. The forecasts are updated on an as-needed basis if, for example, observed precipitation departs significantly from the forecast amount.

During a flood alert or actual flood control regulation period, the NWRFC forecast may not be updated frequently enough, considering the roughly 8-hour travel time from the project to near Auburn and the concentration time of local inflow. One check on the reliability of the local inflow forecast is to monitor the observed hydrographs from the stream gages on Newaukum Creek and Big Soos Creek. If precipitation has ceased, or is very low, local inflows generally start to recede although the initial recession rate after a large storm event is often very slow.

6.03 Conservation Purpose Forecasts.

a. Requirements. Runoff forecasts are required input to decisions affecting the timing and the rate of filling of conservation, Section 1135, and municipal and industrial storage. See paragraph 3.05 for details regarding Section 1135 storage. In general, the refill sequence is designed to account for changing inflow and weather conditions, provide additional flows to protect fisheries resources and with consideration of white water recreation opportunities and other community activities. Primary considerations are to assure refill of conservation storage, while minimizing adverse impacts on downstream migrating fish and the fishery in the river below the dam.

b. Methods. Two spring runoff volume forecasts are used in storage decisions. The Natural Resources Conservation Service produces April through July and April through September runoff volume forecasts monthly from January through June. Measurements of snow water equivalent at selected manual snow courses and automated SNOTEL sites along with precipitation, antecedent streamflow and the El Nino Southern Oscillation indices are used in computerized statistical and simulation models to produce these forecasts. Additionally, the NWRFC uses their ESP model to produce spring runoff volume forecasts. Their model is based on snowpack and soil moisture conditions plus historical precipitation and temperature patterns. Predictions from both systems are considered when planning longer-term operations during spring refill.

6.04 Long-Range Forecasts. Long-range forecasts are part of the Conservation Purpose Forecasting described in **Section 6.03b**.

6.05 Drought Forecasts. Drought forecasts are part of the Conservation Purpose Forecasting described in **Section 6.03b**.

7 – WATER CONTROL PLAN

7.01 General Objectives. Howard A. Hanson Dam project is regulated primarily to provide flood risk management to the valley downstream of the near Auburn gage. Conservation storage is released during the summer and fall months to augment low flows for fishery enhancement and for water supply purposes. Regulation for flood control (flood risk management) and conservation has historically been non-conflicting because each is applicable to separate seasons. Generally, the reservoir will be held near or below elevation 327.66 m (1,075 feet) during the November through late February flood control season, except during periods of actual flood regulation or prolonged dry weather requiring conservation storage after 1 November. As the potential for floods diminishes in the late winter and spring, the reservoir will be filled to elevation 355.70 m (1,167 feet) to fulfill the Additional Water Storage Project (AWSP) Phase I needs.

7.02 Constraints. Operating constraints for regulation of Howard A. Hanson Dam project are listed in **Table 7-1**. During flood control regulation, releases should not cause the Green River discharge to exceed the natural peak that would have occurred without the project.

TABLE 7-1

PROJECT OPERATING LIMITS

	Metric	U.S. Customary
1. Lake Elevation		
Full pool	367.6 m	1,206 feet
Maximum conservation pool*	347.8 m	1,141 feet
Normal minimum pool	327.7 m±	1,075 feet±
* AWSP Phase I storage to 355.70 m (1,167 ft).		
2. Discharge		
Minimum instantaneous	1/	
Maximum instantaneous	2/	
Maximum, flood control outlet works 3/	283.17 m^3/s	10,000 cfs.
3. Tailwater rate-of-rise 4/	0.3 m/hr	1 ft/hr
4. Flood Control Requirements near Auburn 5/		
Authorized control flow	339.84 m^3/s	12,000 cfs
Maximum regulated target rising hydrograph	283.17 m^3/s	10,000 cfs
Maximum regulated target falling hydrograph	339.84 m^3/s	12,000 cfs
Stage rate-of-fall during flood recession	0.3 m/hr	1 ft/hr

NOTES:

1/ Minimum discharge is based on 3.12 m^3/s (110 cfs) for inflow augmentation plus 3.20 m^3/s (113 cfs) or reservoir inflow, whichever is least, for City of Tacoma First Diversion Water Right.

2/ Although there is no specified maximum instantaneous discharge at the project, maximum release is subject to the tailwater rate-of-rise criteria, Auburn flood control discharge, and special gate regulation requirements.

3/ Maximum desired discharge through the sluices (regulating outlets) is 10,000 cfs. However, discharge through the sluices can exceed 10,000 cfs if specific approval is given, e.g. dam safety concerns associated with a high pool outweigh concerns of tunnel pressurization and stilling basin damage at elevated discharges.

4/ Except during flood situations.

5/ The control station for flood control regulation at Howard A. Hanson Dam is the USGS stream gage, Green River near Auburn, WA. On a rising hydrograph the control station is regulated to 283.20 m^3/s (10,000 cfs) to provide a margin of safety against errors in forecasted local inflow and weather. Since the travel time between the dam and near Auburn is about 8 hours during high water, releases from the dam plus forecast local inflow between the dam and near Auburn must be combined to determine the Auburn discharge. On a flood recession the regulated discharge near Auburn may be increased to 339.84 m^3/s (12,000 cfs) when conditions assure an accurate local inflow forecast.

In addition to the operating guidelines listed in **Table 7-1**, ramp rate guidelines provided in **Table 7-2** should be followed to the extent possible when reducing project outflows to reduce the stranding of fish. The guidelines in **Table 7-2** apply as follows:

(1) When flow is being reduced by operation of gates. The limits do not apply to river fluctuations that occur downstream with no gate changes.

(2) When discharge is less than 42.5 m^3/s (1,500 cfs).

(3) Limits do not apply to operations required during flood emergencies.

TABLE 7-2

DOWN RAMPING GUIDELINES

Period	**Daylight Hours (1 hour before sunrise to 1 hour after sunset)**		**Night Time Hours (1 hour after sunset to 1 hour before sunrise)**	
	in/hr	**cm/hr**	**in/hr**	**cm/hr**
February 16-May 31	0	0	2	5
June 1-October 31	1	2.5	1	2.5
November 1-February 15	2	5	2	5

7.03 Overall Plan for Water Control. Howard A. Hanson Dam project will be operated in accordance with guidance provided by the reservoir operating curves shown on **Charts 7-1** and **7-2**. Seasonal regulations to maintain reservoir elevations indicated by the curves are separated into three functional periods: winter flood control, spring reservoir filling, and summer conservation. Regulation during each of these periods is discussed in following paragraphs. WM will make operational forecasts during each of these periods and issue instructions to operating personnel relative to project releases required to obtain desired reservoir elevations.

a. Winter Flood Control. The winter flood control period spans the period of approximately November through late February. During the winter season, the reservoir elevation will be maintained at or near elevation 327.7 m (1,075 feet) to provide a minimum of roughly 12,705 ha-m (103,000 acre-feet) of storage for the regulation of floods. This storage provides the maximum possible effective reduction of the standard project flood for near Auburn. The project regulates only 55% of the total drainage area above the station near Auburn. Therefore, it is not possible to provide total control of all floods in the basin. Flood events that require flood control regulation are expected to have a 50% chance of occurrence each year. However, flood alerts may be more numerous because of the requirement to monitor all developing storms with flood producing potential. Flood alerts will be declared by WM whenever the NWRFC forecasts flooding, the CENWS meteorologist predicts a flood producing storm potential, or an unexpected amount of precipitation or a rapidly rising discharge on the Green River is observed by project or WM personnel. Flood flow forecasts for the Green River will be made using procedures and methods described in **Section 6.02**.

Flood control operations will make maximum beneficial use of available storage during each flood event and will be based upon a channel capacity that will safely carry a discharge of 339.84 m^3/s (12,000 cfs) near Auburn. To provide a margin of safety against errors in forecasted local inflow, the project outflow will be regulated to control flows near Auburn to an objective flow of 283.20 m^3/s (10,000 cfs) on a rising hydrograph. The objective flow will be increased during recession to evacuate storage as rapidly as practicable, the amount of increase to be based upon observed and forecasted precipitation and the shape of the recession hydrograph. The maximum objective flow is equal to the control flow of 339.84 m^3/s (12,000 cfs).

During rare high runoff floods, continued regulation according to the normal flood control procedures could result in a premature filling of the reservoir requiring discharges exceeding the peak that would have occurred under pre-project conditions. The Discharge Regulation Schedule (DRS), expressing discharge in terms of reservoir inflow, **Chart 7-3**, or hourly reservoir rise, **Chart 7-4**, will be used to determine the minimum release rate for large floods that might otherwise result in a reservoir elevation exceeding design conditions or in releases that could constitute a major hazard to downstream interests. The use of **Chart 7-3** is preferred. The sluices (regulating outlets) will normally be operated at the maximum desired discharge of 283.17 m^3/s (10,000 cfs) before discharging over the spillway. For falling reservoir levels after using the DRS, the maximum gate openings of sluices and spillway utilized will be maintained until the reservoir recedes to elevation 367.6 m (1,206 feet) and/or it is possible to regulate to control the near Auburn discharge to an applicable objective flow. See **Section 2.03d** for special instructions regarding operation of the sluices.

The threat of flooding diminishes through the late winter and spring period. **Chart 7-2** specifies the variable minimum reservoir space which must be reserved to assure flood control through this period. Consistent with flood control requirements, spring refill may begin as early as 15 February.

b. Spring Reservoir Filling. The spring reservoir filling period spans the period of approximately late February through June. Refill will be scheduled to not conflict with reservation of reservoir space required by flood control as specified by **Chart 7-2**. Beginning in January, inflow volume forecasts will be made in accordance with **Section 6.03b**. Utilizing the runoff forecast as a starting point, the refill plan will be formulated through coordination with the various resource agencies. In concept the plan, referred to as proportional capture, will be to store a percentage of the inflow hydrograph so the shape of the reservoir discharge hydrograph will be similar to the natural inflow hydrograph. Dam discharge will always conform as feasible to the minimum discharge, rate-of-rise and rate-of-fall constraints listed in **Table 7-1**.

The percentage of runoff stored will be determined by using various tools including use of an operations model using either historic runoff hydrographs or Extended Streamflow Prediction (ESP) traces to simulate reservoir operations. Inputs to the model include the start and target dates for refill, the desired refill reliability, and the upper and lower 95 percent confidence limits of the April through July inflow volume forecast. The model can use either historical inflow datasets or ESP traces and selects the years with April through July inflow volumes between the upper and lower 95 percent confidence limits of the current year forecast. The target capture rate is determined as the smallest percentage of capture that would have filled the reservoir to 355.7 m (1,167 ft) using the selected inflow dataset and with the specified reliability. The refill plan is updated regularly, incorporating updated runoff forecasts, to vary the percent of capture to achieve refill.

c. Additional Water Storage Project (AWSP). Phase I of the AWSP provides an additional 2,467 ha-m (20,000 acre-feet) of storage for the City of Tacoma's Second Supply Water Right (SSWR). The total full pool under Phase I of the AWSP is 355.7 m (1,167 feet). Storage to elevation 355.7 m (1,167 feet) also includes the additional 616.7 ha-m (5,000 acre-feet) of storage reserved for the Section 1135 Storage Project. Phase I of the AWSP is presently being implemented, and seasonal storage to elevation 355.7 m (1,167 feet) began in the spring of 2007. Because the AWSP has not been fully implemented, and in particular not all mitigation measures have been accomplished, water storage for municipal and industrial purposes is considered to be relegated to a subordinate level of priority as compared to requirements imposed by natural resource concerns, as principally reflected in requests made by the Green River Flow Management Coordination Committee, in the event that conflict arises between these two considerations. The maximum refill rate specific to AWSP Phase I storage, per the City of Tacoma's water right with the Washington State Department of Ecology, is 2.83 cms (100 cfs). Seasonal restrictions on the withdrawal of SSWR water from the river are outlined in Tacoma Water's Habitat Conservation Plan (July, 2001), which specifically requires instream flows to be met at Palmer year-round and at Auburn from 15 July to 15 September. Specific to AWSP operations, it is noted that these restrictions are only applicable when water is placed into storage in the reservoir. As such, SSWR water stored for municipal supply in Howard A. Hanson reservoir can be used at any time since it represents a prior exercise of the SSWR (i.e., minimum instream flow conditions do not need to be met as a condition for releasing stored water from the reservoir).

Tacoma's ability to divert water from the river per their SSWR is also restricted by the City's 1995 agreement with the Muckleshoot Indian Tribe. That agreement, which is also discussed in the Tacoma Habitat Conservation Plan, establishes minimum instream flows at both the Palmer and Auburn gages on the Green River. Tacoma can only divert water from the Green River per their SSWR if flows are above the thresholds outlined in the 1995 agreement.

d. Summer Conservation. The summer conservation period spans the period of approximately July through October. The reservoir will be held at maximum summer conservation elevation of 355.7 m (1167 feet) until storage releases are required to augment flows or, in the case of considerable summer rainfall, it is apparent full storage will not be required. Normally, drawdown of the reservoir to meet low flow augmentation demands usually begins in July and continues through October. In the event of an exceptionally dry fall, if storage is available, augmentation will continue until winter precipitation increases river base flow to a level adequate to sustain discharge below the Tacoma diversion above the 3.12 m^3/s (110 cfs) minimum instream flow requirement. As soon as conditions indicate conservation storage is no longer needed, the reservoir will be drafted to be near elevation 327.7 m (1,075 feet) for flood control.

During the summer-fall low flow period; the minimum release rate will be of 3.12 m^3/s (110 cfs) for low flow augmentation plus 3.20 m^3/s (113 cfs) or the reservoir inflow rate, whichever is least, for use by Tacoma. During this period, the outflow will be passed through the 1.22 m (48-inch) bypass as long as its capacity is adequate. Very small openings of sluice gates are to be avoided because of the potential for clogging by debris. During the spring and fall, the Washington State Department of Fish and Wildlife (WDFW) and/or Muckleshoot Tribe may request higher than the normal release for several days to encourage the upstream migration of anadromous fish and to improve spawning conditions in the river. The 5,000 ac-ft of Section 1135 water is specifically stored for such purposes. Such requests are often honored provided adequate water is available in storage.

7.04 Standing Instructions to Dam Tenders

a. General. The project shall normally be attended on a 5-day-week basis, from Monday through Friday, roughly 8 hours per day. Project personnel will man the project continuously during a declared flood alert as required. A list of project personnel to be contacted in emergency situations is provided in the notification list disseminated each year (see **Exhibit 7-1**). Dam tenders will implement only reservoir regulation instructions received directly from WM unless communication is interrupted, in which case regulation will be in accordance with emergency regulation procedures provided in **Section 7.04c**. All instructions pertaining to reservoir regulation will be implemented as expeditiously as possible and recorded, along with physical data, personnel involved, contacts made, etc., in the Howard A. Hanson Dam Operating Log book.

b. Normal Operating Procedures. Collecting, recording, and reporting data are routine functions required at all Corps projects. Each normal workday, project personnel will collect the maximum and minimum temperature, snowfall and snow depth, and precipitation in the manual gage and record the data on Form WSE-15, Record of Climatological Observations. These data will also be reported to WM together with the daily precipitation and turbidity reading obtained from Tacoma's headworks station, during a morning telephone call at about 0800 hours. The data may be cumulative for one day or for up to a 4-day period depending upon weekends and holidays.

In flood situations when communication with major hydromet stations is lost, dam tenders may be required to go to critical stations as directed by RCC staff to observe stream stage and/or weather data at-site and transmit this information by portable radio to the dam and the RCC.

The project shall be attended during periods of flood alert and/or flood control regulation as required for monitoring of the reservoir level and regulation of the discharge. During these periods, dam tenders will compute reservoir inflow on an hourly basis to develop expertise for monitoring the reservoir in case of total loss of communication with WM. The dam tender will immediately notify WM personnel if either of the following conditions should occur:

1) Rainfall in excess of 50.8 mm (2 inches) during any consecutive 3 hour period or 76.20 mm (4 inches) during any consecutive 24-hour period.

2) Computed reservoir inflow approaches 169.92 m^3/s (6,000 cfs) or is rapidly rising to this level.

c. Emergency Regulation Procedures. It is impossible to anticipate every unusual flood, power or physical feature emergency or combination of events that may require special attention. If an emergency develops requiring immediate action to protect human life or prevent damage to the project, the dam tender will take appropriate action following guidance in the HHD Emergency Action and Notification Plan and then immediately contact WM. Should an emergency develop or appear to be imminent which will affect reservoir regulation functions, the dam tender will promptly contact WM, report on the existing conditions, and request instructions.

In the event that telephone and VHF communication facilities should fail during a flood alert or period of flood control regulation, emergency regulation procedures will be followed by the dam tender until WM personnel arrive at the project or communications are restored. The dam tender will have been monitoring reservoir elevations and computing inflows and will operate according to the following instructions:

1) If flood control regulation has not yet begun, continue to pass inflow until it reaches 127.43 m^3/s (4,500 cfs). Then hold the discharge at 127.43 m^3/s (4,500 cfs) until either (a) changes are required by the DRS; or (b) inflow has receded and storage has been evacuated to an elevation which precludes a 127.43 m^3/s (4,500 cfs) discharge. In the latter case, pass inflow if the reservoir elevation falls to 327.7 m (1,075) feet.

2) If passing inflow above 127.43 m^3/s (4,500 cfs) or if flood control regulation has already begun, but the discharge is greater than 127.43 m^3/s (4,500 cfs), reduce the discharge at the rate of 28.32 m^3/s (1,000 cfs) per hour until it reaches 127.43 m^3/s (4,500 cfs) and hold that discharge until changes are required as in (1) above.

3) If flood control regulation was in progress, the discharge is below 127.43 m^3/s (4,500 cfs), and the last instruction was for a decrease in discharge, decrease the discharge at the rate of 28.32 m^3/s (1,000 cfs) per hour until it reaches 84.96 m^3/s (3,000 cfs) and hold that discharge unless increases are required by the DRS or the inflow recedes to 127.43 m^3/s (4,500 cfs) In the latter case, increase the discharge 28.32 m^3/s (1,000 cfs) per hour until it reaches 127.43 m^3/s (4,500 cfs) and hold to evacuate storage.

4) If flood control regulation was in progress, the discharge is below 127.43 m^3/s (4,500 cfs) and the last regulation instruction was to maintain a constant discharge or increase the discharge, maintain the last specified discharge unless increases are required by the DRS, or the inflow recedes to 127.43 m^3/s (4,500 cfs). In the latter case, increase the discharge 28.32 m^3/s (1,000 cfs) per hour until it reaches 127.43 m^3/s (4,500 cfs) and hold to evacuate storage.

5) If any of the procedures described above result in using the DRS, do not decrease the discharge based on the DRS, but maintain the maximum discharge obtained by using the DRS to evacuate storage until (1)(b) above applies.

7.05 Flood Control. Winter flood control operations are presented in **Section 7.03a**.

7.06 Recreation. There are no recreation opportunities within the Green River watershed above the City of Tacoma diversion facility. The watershed is closed to public use to help preserve water quality. The river downstream of the City of Tacoma diversion facility provides recreation opportunities, however, recreation is not an authorized project purpose.

7.07 Water Quality. In the watershed above HHD, the primary factors affecting water quality are increased turbidity and fine sediment loading associated with commercial forest management. In the winter flood season, especially during regulation for flood control, sediments are deposited on the floor of the reservoir. If the reservoir is completely emptied, these sediments are eroded and the turbidity increases. Therefore a small pool, near elevation 327.7 m (1,075 feet), is normally maintained during the winter flood season to avoid excessive erosion of sediment in the lowest portion of the reservoir which would cause excessive turbidity.

Water quality in the watershed below HHD is influenced by a number of land and water uses and is degraded in the form of:

- Increased summer water temperatures due to removal of riparian vegetation, diversion of the White and Black Rivers, and release of warmer water later in the summer from HHD storage. Water temperatures exceeding the state standard have been recorded frequently enough to warrant registering lower segments of the Green River on the state's 303(d) list. Under section 303(d) of the 1972 Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. Impaired waters are those that do not meet water quality standards that states, territories, and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Loads (TMDLs) of pollutants for these waters. Water impounded in Howard A. Hanson Dam reservoir becomes thermally stratified in early summer, a condition which continues through fall, the onset and duration depending upon the amount of water in storage and hydroclimatological conditions. Selective withdrawal facilities are not available, but withdrawing water through either the sluices or 1.22 m (48-inch) bypass, at 325.83 m (1,069 feet) or below, provides water temperatures below natural conditions which are actually better for the fishery.

- Reduced DO due to elevated water temperatures and increased biochemical oxygen demand associated with high nutrient and pollutant inputs. DO levels that fail to comply with state standards have also been recorded in the lower watershed during sustained low-flow periods. However, these failures have not been recorded frequently enough to warrant placement on the state's 303(d) list.

7.08 Fish and Wildlife. Nine species are known to occur in the vicinity of HHD or could potentially occur there in the future that are listed as threatened or endangered under the ESA. The Chinook salmon and steelhead are listed as threatened and are present in the Green River below HHD. Chinook and steelhead historically used the upper watershed as well. The bull trout is listed as threatened and although it has not been documented in the upper Green River, it is occasionally found in the downstream river and can thus be affected by the operation of HHD. The bald eagle is known to occur in small numbers upstream and downstream of HHD at all times of the year. This species was de-listed under the ESA, but is still protected under the Eagle Act and the Migratory Bird Treaty Act. The northern spotted owl and marbled murrelet both use the coniferous forest in the Green River watershed above HHD and are listed as threatened. Although the grizzly bear and gray wolf are extremely rare in the Washington Cascades, on-going efforts to recover both species creates the potential for either to make use of the upper Green River watershed at some time in the future. The grizzly bear is listed as threatened and the gray wolf as endangered under the ESA. Similarly, the Canada lynx is a rare species on the west slopes of the Cascades that is listed as threatened.

a. <u>Fish.</u> In addition to Chinook salmon and steelhead mentioned above, the Green River drainage supports runs of coho, pink, and chum salmon. Spawning and rearing occur throughout much of the river downstream of the City of Tacoma diversion and in accessible tributaries. The Washington Department of Fish and Wildlife maintains and operates the Green River Salmon Hatchery on Big Soos Creek near Auburn and rearing ponds at Palmer. The Muckleshoot Tribe maintains and operates the Keta Creek hatchery due east of Auburn. The majority of the fish produced are Chinook and Coho that are released into the Green River, although large numbers of juveniles are released in other drainages. Steelhead use the Green River and its tributaries, in particular the Big Soos Creek and Newaukum Creek drainages. Resident fish include cutthroat and rainbow trout and white fish. Suckers, northern pike minnow and other non-game species are also present.

The operation for fishery enhancement requires releasing sufficient water to provide a minimum of 3.12 m^3/s (110 cfs) below Tacoma's diversion facility. This regulation is discussed in paragraph 7.03d. The Section 1135 Fish and Wildlife Restoration Project includes 616.75 h-m (5,000 acre-feet) of additional water storage between elevations 347.78 m (1141.0 feet) and 349.72 m (1147.1 feet) to supplement flow for fishery enhancement. The initial assumption was that the storage would be utilized only to supplement droughts having an average recurrence interval of approximately 1 year in 5. This additional storage for fisheries enhancement is now implemented on an annual basis provided that sufficient inflows are available during the spring refill period and is incorporated into Phase I of the AWSP.

Biological opinions completed in 2000 include reasonable and prudent measures that restrict discharges of sediment from the dam, and require management of refill and discharge in consideration of endangered species. Discharge related measures include:

- maximizing the outflow by minimizing the reservoir refill rate during smolt out-migration and the potential use of periodic artificial freshets that mimic natural freshets;
- increasing downstream survival of out migrating salmonids by maintaining a target base flow in coordination with the Green River Flow Management Coordination Committee (GRFMCC) and providing the option to release periodic freshets during peak out-migration;
- partially mitigating downstream effects of storage by maintaining a coordinated target base flow that improves side channel and lateral mainstem rearing habitats.

b. Wildlife. Black-tailed deer, elk, black bear, mountain lion and a few mountain goats inhabit the timbered area of the basin. Deer are by far the most numerous and widespread of the big-game animals, but elk and black bear are common in the closed portion of the watershed above the City of Tacoma diversion facility. Native upland game includes blue and ruffed grouse, band-tailed pigeon, mourning dove and snowshoe hare. Fur bearing animals native to the Green River basin are beaver, muskrat, mink and river otter located in and along lowland watercourses and sloughs; red fox, opossum, weasel and skunk are located primarily in the valley lands; bobcat and coyote are located in the foothills; and lynx and martin are located in the more remote regions of the Cascade Range. Mallard and wood ducks and teal nest in the valley, but the majority of the waterfowl using the basin are fall and winter migrants.

7.09 Water Supply. The Green River is the principal source of municipal and industrial water supply for Tacoma. During the summer-fall low flow period, the minimum release from Howard A. Hanson reservoir is made up of the 3.12 m^3/s (110 cfs) for the fishery plus 3.20 m^3/s (113 cfs) or reservoir inflows, whichever is least, for diversion by Tacoma via their First Diversion Water Right. The conservation storage was designed to be sufficient to continuously supply the 3.12 m^3/s (110 cfs) from June through early December (if needed) without interfering with flood control regulation. Tacoma has no entitlement to stored conservation water. There are no other storage projects in the basin and the conservation storage is single purpose for fishery enhancement only.

7.10 Hydroelectric Power. HHD does not provide hydroelectric power.

7.11 Navigation. HHD is not operated for navigational purposes.

7.12 Drought Contingency Plan. A drought is said to occur whenever summer conservation storage has been, or soon will be, exhausted and the flow in the river below Tacoma's diversion will no longer be able to be maintained above 3.12 m^3/s (110 cfs). The contingency plan is to continue to operate to assure 3.12 m^3/s (110 cfs) unless CENWS, fisheries interests and Tacoma agree to operate differently. Historically, in severe drought situations, the three parties have agreed to reduce their respective water entitlements and arrive at a consensus by adaptive management to make best use of the available water resource.

7.13 Flood Emergency Action Plans. In the event of a controllable or uncontrollable emergency which could present a significant hazard to life and/or property, the procedures in the Project's emergency action plan, EMERGENCY ACTION AND NOTIFICATION SUBPLAN, FLOOD EMERGENCY PLAN, HOWARD A. HANSON DAM, should be followed. This plan is typically updated annually. Copies are located at HHD and in the Northwest Division and Seattle District Reservoir Control Centers. Specifically, the plan is to be implemented in the following situations:

a. Uncontrollable Emergency. Defined as a condition in which the occurrence of a significant hazard to life and/or property is certain to occur, and no time is available to repair and/or modify operational procedures to prevent dam failure.

b. Controllable Emergency. Defined as a condition, not normally encountered in the routine operation of the dam, in which the occurrence of a significant hazard to life and/or property is possible unless timely repairs and/or modification to operational procedures are conducted to prevent dam failure. Time must be available to eliminate the condition in order for the condition to be declared controllable.

c. Post-Earthquake Condition. If an earthquake is felt at the dam, a post-earthquake condition exists and a project inspection is required.

d. Security Alert. A security alert relates to incidents at a project which could threaten the safety of the project.

7.14 Other. There are no other features of the water control plan.

7.15 Deviation from Normal Regulation. Some deviation from normal operation and regulation can be expected during construction periods, either downstream of the project or in the reservoir, during inspection of gates and other operational equipment, and during operations and testing for the fishery that may be performed from time to time by the Corps or other interests. There have also been occasions in the past when special requests have been received from law enforcement agencies for reduced flows to search the river for drowning victims. These deviations will be considered on a case-by-case basis and any regulation coordinated between all parties concerned before being submitted to the NWD for approval. Due to the ESA, any deviation from normal regulation is coordinated with USFWS and NMFS.

7.16 Rate of Release Change. All reservoir releases at HHD are subject to the condition that no release shall be made at rates or in a manner that would be inconsistent with operating rules and regulations required for the purpose of protecting the dam and critical project features from damage. Specific tailwater rate-of-rise guidelines for the purpose of protecting public safety are provided in **Table 7-1**. Specific tailwater down ramping guidelines to help protect fish are provided in **Table 7-2**.

8 – EFFECTS OF WATER CONTROL PLAN

8.01 General. The Howard A. Hanson Dam project provides flood flow reduction in the lower Green River valley, low flow augmentation for fishery enhancement, and water supply storage for the City of Tacoma. The effect of the project regulation for these purposes, based upon procedures discussed in **Section 7**, is described in the following paragraphs.

8.02 Flood Control.

a. Spillway Design Flood (SDF). The SDF is based upon routing the probable maximum flood (PMF) through the reservoir utilizing the sluices (regulating outlets) and spillway. A revised PMF was developed in 1994 based upon a probable maximum precipitation developed utilizing Hydrometeorological Report 57 (HMR 57). A conservative assumption is made that the reservoir is full at the onset of the PMF as a result of storage operation or inaccurate flood prediction during a major flood preceding the PMF. The maximum spillway outflow is 3,058.2 m^3/s (108,000 cfs) with 339.80 m^3/s (12,000 cfs) through the sluices (slightly higher than the desired maximum of 10,000 cfs) and 124.59 m^3/s (4,400 cfs) through the railroad notch at a maximum reservoir surcharge elevation of 373.04 m (1223.9 feet). The result of routing the PMF is shown on **Plate 8-1**.

b. Standard Project Flood (SPF). The SPF for near Auburn was presented in 4th Endorsement, subject: "Standard Project Flood for Flood Control Survey Report of Green River, Washington (Basic 16 June 1947 CENWS to NWD)" and approved by HQUSACE in the 6th endorsement dated 11 March 1949. The flood was obtained by the storm transposition method and has a peak discharge of 1,839.5 m^3/s (65,000 cfs) and a 5-day volume of 23,427 ha-m (190,000 acre-feet).

c. Flood of Record. The flood with the maximum known peak was regulated by the project in December 1977. The maximum discharge from the project was 283.17 m^3/s (10,000 cfs) and the peak near Auburn was 280.7 m^3/s (9,920 cfs). The estimated peak inflow to the project was 1,025.1 m^3/s (36,200 cfs) and the estimated natural peak near Auburn was 990.5 m^3/s (35,000 cfs). Although the December 1977 flood had the highest peak inflow of record, the February 1996 flood and the January 2009 flood were both higher volume floods, with much higher than normal local inflows below the project; therefore, more storage was required to control these flood events. On 4 December 1977, the reservoir pool peaked at elevation 357.71 m (1,173.6 feet). On 10 February 1996 the reservoir pool peaked at elevation 360.64 m (1,183.2 feet). The estimated peak inflow to the project was 828.8 m^3/s (29,270 cfs) and the estimated natural peak near Auburn was 986.0 m^3/s (34,820 cfs). Hydrographs for the February 1996 flood are shown on **Plate 8-2**. The pool of record occurred on 9 January 2009. The reservoir pool peaked at 362.35 m (1,188.8 feet). The estimated peak inflow to the project was 871.7 m^3/s (30,784 cfs) and the estimated natural peak near Auburn was 1,048 m^3/s (37,010 cfs). Hydrographs for the January 2009 flood are-shown on **Plate 8-3**. Damages prevented for the WY 1996 and 2009 floods are estimated at $3.1 billion and $4.1 billion respectively, in 2010 dollars.

8.03 Recreation. Use of the watershed above the dam is currently restricted and the reservoir is not open to recreation because of the potential for degrading the water quality of Tacoma's M&I water supply.

8.04 Water Quality. Water quality field data (temperature, turbidity, dissolved oxygen, pH, and conductivity) have been collected at Howard Hanson Reservoir at various permanent and summer locations since 1960 (see **Table 5-3**). A more extensive water quality data collection program was started in 2002 at two (2) in-reservoir stations and two (2) river stations located upstream and downstream of the dam (see **Table 5-3**). The upstream river station (GRAP) is located at about RK 112.7 (RM 70.0) near Railroad Bridge 71, approximately 8.9 km (5.5 miles) upstream from the dam. The downstream river station (HAHW) is located at RK 102.7 (RM 63.8) about 1.1 km (0.7 miles) downstream of the dam at the site of the existing USGS Green River below Howard Hanson Dam gaging station (No. 12105900). The in-reservoir stations consist of one (1) up-reservoir station located about 6.4 km (4 miles) upstream of the Dam (9UPNR) and one (1) forebay station located immediately upstream of the dam (1DAM). Water quality chemical parameters monitored at these locations include temperature, pH, conductivity, dissolved oxygen, alkalinity, nutrients (i.e. phosphorus and nitrogen), and chlorophyll a (Chlorophyll a is collected only at the in-reservoir stations 1DAM and 9UPNR).

Analysis of water samples collected by the Seattle District since 2002 shows that water impounded in Howard A. Hanson Reservoir is of very good chemical quality with low nutrient and chlorophyll a concentrations, and excellent water clarity. Based on data collected since 2002, the trophic state of the reservoir is classified as oligotrophic. Trophic state classifies the biological productivity of a lake based on physical, chemical, and biological data. Three water quality parameters are generally used to assess trophic status: total phosphorus, chlorophyll a, and transparency. Lakes with low concentrations of nutrients and low primary productivity are classified as oligotrophic, lakes with moderate concentrations of nutrients and moderate primary productivity are classified as mesotrophic, while lakes with high concentrations of nutrients and high primary productivity are classified as eutrophic. Chemical analyses performed annually by Tacoma, at the Tacoma diversion, 5.63 km (3.5 miles) downstream of the dam, to evaluate the chemical composition of the reservoir release are shown in **Table 8-1**. These data indicate that waters released from Howard Hanson Dam meet National Primary Drinking Water Standards.

Currently, Tacoma Public Utilities treats Green River water with chlorine, ozone, caustic soda, and fluoride. Chlorine is used as the primary disinfection treatment while ozone is used as both a secondary disinfectant and to reduce objectionable taste and odors. Caustic soda is added to the water to raise the pH to reduce the amount of lead and copper leaching from pipes in homes, and fluoride is added for dental health. Because of the high quality of Green River water and the watershed control, Tacoma does not currently filter Green River water. However, to comply with new EPA rules for the control of cryptosporidium, Tacoma plans to build a water filtration system to treat raw Green River water by 2014.

The Washington Department of Ecology (WDOE) determines surface water quality standards for the Green River at Howard Hanson Dam in Washington. The WDOE classified the Green River downstream of Howard Hanson Dam as a Core Summer Habitat aquatic life use. Water quality standards for Core Summer Habitat water bodies are presented in **Table 8-2**. In general, water released from the reservoir meets the WDOE surface water standards for Core Summer Habitat aquatic life use for all parameters except temperature and turbidity. Temperatures can exceed 16°C (61°F) during the late summer and fall period because of the thermal stratification in the forebay of the reservoir results in a thermal lag in temperatures as the Green River cools down in the fall. Turbidities can exceed standards in the winter when (1) the reservoir pool is low and high inflows result in re-suspending sediments from the bottom, (2) when turbid inflows are released downstream and (3) after high flow events when turbid water is stored for flood control and released later.

TABLE 8-1

TACOMA CITY WATER, INORGANIC ANALYSIS

INORGANIC COMPOUND	**MCL	GREEN RIVER 10/23/08	GREEN RIVER 5/12/09
ACIDITY-As CaCO3	N/A	1.33	1.86
ALKALINITY-As CaCO3	N/A	20	17
AMMONIA-NITROGEN	N/A	0.05	0.104
ANTIMONY	0.006	<0.005	<0.005
ARSENIC	0.01	<0.01	<0.01
ALUMINUM	N/A	<0.05	<0.05
BARIUM	2.0	<0.01	<0.01
BERYLLIUM	0.004	<0.003	<0.003
CADMIUM	0.005	<0.002	<0.002
CALCIUM	N/A	5.75	3.66
CHLORIDE	250.0	<20	2.39
CHROMIUM	0.1	<0.01	<0.01
COLOR (Color Units)	15	10	5
CONDUCTIVITY (UMHOS/CM)	700	65	53.9
COPPER	AL=1.3	<0.2	<0.2
CYANIDE	0.2	<0.05	<0.05
FLUORIDE	4.0	0.88	0.738
HARDNESS- As CaCO3	N/A	18.3	19
IRON	0.3	0.13	<0.1
LEAD	AL=.015	<0.002	<0.002
MAGNESIUM	N/A	1.01	0.627
MANGANESE	0.05	0.083	0.0111
MERCURY	0.002	<0.0002	<0.0005
NICKEL	0.100	<0.04	<0.04
NITRATE NITROGEN	10	<0.5	<0.5
NITRITE NITROGEN	1	<0.5	<0.5
ORTHO PHOSPHATE	N/A	<0.10	<0.5
pH	N/A	7.7	8.04
SELENIUM	0.05	<0.005	<0.005
SILICA	N/A	12.7	13.3
SILVER	0.1	<0.01	<0.01
SODIUM	N/A	5.87	5.91
SULFATE	250	<10	1.12
TEMPERATURE	N/A	13.1	9.9
THALLIUM	0.002	<0.002	<0.002
TOTAL DISSOLVED SOLIDS	500	47	79
TOTAL SOLIDS	N/A	NA	NA
TOTAL SUSPENDED SOLIDS	N/A	5	6
TURBIDITY unfiltered systems	5.0	1.03	2.75
ZINC	5.0	<0.2	<0.02

Tested at Green River Diversion Headworks
NA : not tested for
"<": not detected at this level for this lab
**MCL: maximum contaminant level of National Primary Drinking Water Standard
Units of measure = MG/L

TABLE 8-2

WASHINGTON DEPARTMENT OF ECOLOGY

WATER QUALITY STANDARDS

Classification	Parameter	Standard
Core Summer Salmonid Habitat	Temperature	Temperature shall not exceed 16°C as measured by the 7-day average of the daily maximum temperatures (7-DADMax) due to human activities. When natural conditions exceed a 7-DADMax of 16°C, no temperature increase will be allowed which will raise the receiving water 7-DADMax temperature by greater than 0.3°C.
	pH	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.
	Turbidity	Turbidity shall not exceed 5 NTU over background when the background is 50 NTU or less; or a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.
	Dissolved Oxygen	A 1-day minimum of 9.5 mg/L.
	Total Dissolved Gas	Shall not exceed 110% of saturation at any point of sample collection.

a. Temperature. The impoundment becomes thermally stratified in late spring or early summer and remains in this condition through early fall. The stratification results in layers of water at elevated temperatures occurring at the surface and overlaying colder bottom waters. Mixing of the layers is prevented by density gradients. As the release from the reservoir is achieved through low level outlets, downstream temperatures during the early summer period are colder and warmer in later summer than those that would have occurred without the project. Because releases are made via low level outlets, colder waters are used up during the early summer period resulting in migration of the warmer upper layer waters downward during the summer period. Profile measurements made in the forebay over the 6-year time span 1 May 2002 through 8 August 2007 recorded a maximum surface temperature of 24.53°C (76.15° F) and a maximum bottom temperature of 5.47°C (41.84°F). **Plate 8-4** shows reservoir inflow and outflow temperatures for 2008, a typical year. **Plate 8-5** shows the progressive warming of the conservation pool through the summer and fall of 2009 at monthly intervals. The profile for October shows the effect of rapid reservoir cooling in the fall.

b. Turbidity. As previously noted, turbidity levels in the tailwater of Howard A. Hanson Reservoir can exceed the Washington State Department of Ecology surface water quality standards. Releases from the reservoir can exceed standards, usually in the winter or spring months due to high rainfall or snowmelt events. During high flows, Howard Hanson Dam stores turbid inflow waters to prevent downstream flooding. Because of stored water being released after flood regulation activity, a period of high turbidity is extended until the storage is evacuated or sufficiently diluted by cleaner inflows. Turbidity standards can also be exceeded at low reservoir levels as the flow is channelized through the large sediment flats that have developed over time. As flow increases, erosion of accumulated sediment increases dramatically. This is accompanied by a sharp rise in turbidity of the reservoir discharge. The reservoir elevation at which significant erosion begins is known as the "turbidity pool" elevation. Typically, every attempt is made to maintain the water level behind HHD so that it is above the turbidity pool, thus avoiding turbidity impacts downstream. **Plate 8-6** shows daily turbidity values for the Green River above and below the reservoir for water year 2007. **Plate 8-7** shows the daily turbidity values for the Green River above the reservoir for years 2005 - 2009.

c. Dissolved Oxygen. Dissolved oxygen (D.O.) profiles in the forebay at the dam collected between 2004 to 2010 yielded a profile average of 9.41 mg/l. Extremes ranged from a maximum surface concentration of 15.98 mg/l to a lake bottom minimum of 1.99 mg/l. Outflows from the project, due to re-aeration in the tailrace, have generally ranged higher than reservoir D.O. levels. Statistics of D.O. concentrations for the monitoring station below the dam indicate a mean of 10.34 mg/l with a maximum of 13.08 mg/l and a minimum of 8.53 mg/l. These figures indicate that D.O. is not a problem in release waters.

8.05 Fish and Wildlife. The migration, spawning and rearing of fish in the Green River below the project during the summer and fall low flow period is improved by the release from storage of sufficient water to maintain a minimum flow of 3.11 m^3/s (110 cfs) below Tacoma's diversion facility. Prior to regulation by the project, the minimum discharge recorded at the near Palmer gage, above the Tacoma's diversion, was 2.29 m^3/s (81 cfs). Diversion by Tacoma in accordance with their historical usage would leave nothing in the river until local inflow began to contribute further downstream. Therefore, the provision of a minimum of 3.11 m^3/s (110 cfs) below the diversion is of great value to maintain fish resources. The pre- and post-project summary hydrographs, **Plates 4-5 and 4-6**, show the significance of project regulation. The addition of the Phase I AWSP (which includes the Section 1135 storage) provides additional water to supplement flows for fish.

There is a strong commitment by state resource agencies, Native American tribes, special interest groups and the Corps for preserving and enhancing the anadromous fishery resources in the Green River basin. The Section 1135 storage described in **Sections 3.06, 7.03 and 7.06** supplements flows provided under the initial authorization and has been incorporated into Phase I of the AWSP. The AWSP project includes the potential for providing additional conservation storage for fisheries enhancement if Phase II is implemented.

The primary fishery management issues include fall spawning conditions for Chinook and other salmonids species, spring spawning and incubation conditions for steelhead, spring flow conditions for outmigration of juvenile salmonids, and minimum flows during the summer and early fall. Refill and use of stored water is managed in an adaptive manner in real time in coordination with the various stakeholders to maximize benefits to the fishery resources.

8.06 Water Supply. Conservation storage at Howard A. Hanson dam and implementation of the Drought Contingency Plan has served to alleviate the effects of several droughts since the project became operational.

Operation during the spring, summer and fall of 1992 is a good example. In the spring, an extremely low snowpack made reservoir refill problematic. On that basis, intensive drought coordination with fisheries resource agencies and the City of Tacoma was begun prior to the beginning of refill and continued through October, when river flow reached acceptable levels with the beginning of fall rains. With consideration of the drought conditions, NWD authorized a deviation from the Water Control Plan and permitted retention of water stored to elevation 349.36 m (1,146.2 feet) for debris control to be used later for low flow augmentation. The City of Tacoma restricted diversions to the minimum required for water supply. Because of the intensive coordination effort and cooperation by all parties, flow below the Tacoma diversion never dropped below the 3.11 m^3/s (110 cfs) minimum, even though drought conditions caused flows at that point to be near the minimum level from late June through mid September.

8.07 Hydroelectric Power. Hydroelectric power was considered for Howard A. Hanson Dam before authorization, but was found not to be economically justifiable. However, with the growth of demand for electrical energy in the region, there has been increased interest in the potential at the project. Tacoma was issued a preliminary permit (Project No. 4014) by the Federal Energy Regulatory Commission for priority of application for a license to construct and to operate a hydroelectric project at Howard A. Hanson Dam. Their draft reconnaissance report, completed in May 1982, recommended detailed studies of a hydropower facility based upon a conservation pool raised from 347.78 m to 361.19 m (1,141 to 1,185 feet).

8.08 Navigation. This section does not apply to HHD.

8.09 Drought Contingency Plans. A formal Drought Contingency Plan does not exist for HHD. Modifications to regulation resulting from a potential drought are coordinated with resource agencies and the City of Tacoma. See **Section 8.06** for additional discussion and example of regulation during a drought period.

8.10 Flood Emergency Action Plans. Following the procedures outlined in the EAP could reduce the threat to the project's structural integrity or reduce downstream hazards to human life or property in the event of high flows (see **Section 7.13**). Copies of the project's emergency action plan, EMERGENCY ACTION AND NOTIFICATION SUBPLAN, FLOOD EMERGENCY PLAN, HOWARD A. HANSON DAM, are located at HHD and in the Northwest Division and Seattle District Reservoir Control Centers.

8.11 Frequencies.

a. Peak Inflow Probability. Peak flow frequency curves for the station Green River below Howard A. Hanson Dam, adjusted for storage and the record extended based upon data at other stations in the basin, is used to determine the probability of peak inflows to the reservoir (**Plates 4-13 and 4-14**).

b. Maximum Reservoir Frequency. A frequency curve for maximum annual reservoir elevations is shown on **Plate 8-8**.

c. Control Station. The effect of flood control regulation by the project on the peak flow at the near Auburn control station is illustrated by the regulated discharge frequency curve for near Auburn, **Plate 4-15**. The curve indicates that the desirable control flow of 339.80 m^3/s (12,000 cfs) will be exceeded by uncontrolled local inflow and/or as a result of insufficient remaining flood storage in the reservoir at an annual frequency of 0.7 percent or less.

8.12 Other Studies. No reservoir regulation is scheduled for recreation, navigation or hydroelectric power. However, a water supply project has been implemented as follows:

a. Water Supply. In December 1980, Tacoma Water Division developed a Water System Plan that depends primarily upon the Green River as the source of water supply to meet projected demands. The Water Division concluded that the average annual municipal and industrial (M&I) demand will require storage at 2,467 hectare-meters (20,000 acre-feet) in Howard A. Hanson Dam by at least year 2005 to firm up their overall water system reliability. Tacoma is presently the official sponsor of two increased water supply projects.

1) Section 1135 project. The Section 1135 Fish and Wildlife Restoration Project was approved in April 1997 and became an authorized project in April 2000 with the project sponsor, the City of Tacoma, signing the Project Cooperation Agreement. See additional information on this project in **Sections 3.05, 6.03, 7.03c and 7.08**.

2) Additional Water Storage Project (AWSP). The AWSP was authorized in the Water Resource Development Act in 1999. Phase I of the project, which is presently being implemented, commenced storage to elevation 355.7 m (1,167 feet) in 2007. Phase II of the project, which has yet to be implemented, consists of storage to 358.8 m 1,177 feet. The additional water is allocated for additional water supply for the City of Tacoma and additional flow augmentation for fish resources.

9 – WATER CONTROL MANAGEMENT

9.01 Responsibilities and Organization.

a. Corps of Engineers. The Corps of Engineers is the owner, operator and regulator for the Howard A. Hanson Dam project which is the only project that regulates flows in the lower reaches of the Green River basin. Congressional authorizations include responsibility for the Corps to operate projects under its jurisdiction for all authorized purposes. The Corps is responsible for regulation and for all continuing studies which will ensure the maximum sustained public benefit from project operation. HQUSACE approved a Reservoir Control Center for the NWD in May 1968 and delegated responsibility for reservoir regulation activities in the NWD area to the Division Engineer. Additional details of the Corps' water management history and organization are provided in the report, Reservoir Control Center, Guidance Memorandum, U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon, January 1972. Reservoir regulation is a function of the Engineering Division, in accordance with EM 1110-2-3600, which has direct responsibility on all matters concerning regulation of water with regard to timing, quantity, and quality and is assigned to WM. Project operation and maintenance activities are assigned to Operations Division and the physical operation of project facilities to effect the regulation directed by WM and the performance of maintenance is the responsibility of the Operations Project Manager. A CENWS organization chart is shown as **Exhibit 9-1**.

9.02 Interagency Coordination. There are a number of agencies that collect data and/or provide information that is invaluable to the efficient and effective regulation at Howard A. Hanson Dam. In addition, information regarding regulation is provided to some interests in case action may be required on their part.

a. U.S. Geological Survey (USGS). The USGS has a water resources division which collects and processes water quantity and/or quality records for 9 stations in the Green River basin. These stations are listed in **Table 5-2** and are shown on **Plate 4-4**. Five of these stations are funded totally and one in part by the Corps through the Cooperative Stream Gaging Program. In addition to their regular periodic streamflow measurements to maintain current stage-discharge relationships, the USGS will, upon request from the Corps, make special measurements if a shift in a rating table is suspected. The USGS also operates a northwest water resources data center, which publishes streamflow, storage, and water quality data obtained from the data collection system. Administrative and maintenance services are provided by the Tacoma, Washington office.

b. National Weather Service (NWS). The NWS operates three stations, which provide data used in planning and scheduling regulation at Howard A. Hanson Dam. The National Weather Service Forecast Office issues quantitative precipitation forecasts (QPFs) in local text tables and national maps showing isohyetal lines of expected precipitation The NWS Forecast Office, Seattle, issues QPFs that are site specific for the Seattle-Tacoma Airport, Enumclaw, and Stampede Pass. The QPFs are made daily during the flood season and provide precipitation amounts by 6-hour increments for the first 72 hours after forecast time. The site specific QPFs are used as indicators of flood threats only because of the potential for wide variations in precipitation distribution depending upon storm track, topographic influences, storm type, etc. The NWS RFC in Portland, Oregon is officially charged with the preparation of flood forecasts and the dissemination of flood warnings to the public. These forecasts are made available to the Corps as discussed in **Section 6.02**.

c. Natural Resources Conservation Service (NRCS). The NRCS operates and maintains the Cougar Mountain, Lynn Lake, and Sawmill Ridge Snotel sites in the basin, which provide daily measurements of snow water equivalent, precipitation, and temperature. Additionally, the NRCS developed a program to construct a series of pumping plants under Public Law 566 to relieve the Green River valley of flooding by interior runoff. Two of these plants were constructed by the NRCS. The major project is the pumping installation at Black River, known as the Eastside Project, which has a rated capacity of 83.39 m^3/s (2,945 cfs). It currently operates at its maximum rated capacity. The second project is on the west side of Tukwila and has a rated capacity of 2.83 m^3/s

(100 cfs). It currently operates at its maximum rated capacity. Both of these projects are operated and maintained by King County under a Green River Management Agreement (GRMA), dated July 18, 1985, between the cities of Auburn, Kent, Renton, and Tukwila, and King County.

d. U.S Fish and Wildlife Service (FWS). FWS is the Federal agency primarily responsible for ensuring, at the Federal level, the conservation and management of the nation's wild birds, mammals, and fishes, both for their recreational and their economic values. The regional office is located in Portland, Oregon. Included in the major program areas of the FWS are: technical assistance to federal, state, and private organizations in the development and administration of fish and wildlife management programs; administration and operation of a national system of fish hatcheries engaged in the propagation and distribution of sport fish; and cooperation with other federal and non-federal agencies engaged in water resource development projects to determine the effects of such projects on fish and wildlife resources and recommending measures for the protection and improvement of these resources. It manages one ESA listed species found in the HHD project area, the bull trout. FWS completed a biological opinion in 2000 that addresses effects of HHD operations on bull trout in accordance with Section 7 of the Endangered Species Act.

e. Washington State Department of Fish and Wildlife (WDFW). The WDFW is a co-manager of fish and wildlife resources in the Green River basin. This agency collects data and conducts studies to evaluate the effects of Howard A. Hanson Dam project, exchange information with the Corps, and make recommendations on potentially beneficial changes in project regulation. WDFW issued criteria for down-ramp rates in 2002 which are provided in **Table 7-2**.

f. NOAA's National Marine Fisheries Service (NOAA Fisheries Service). The NOAA Fisheries Service is part of the National Oceanic and Atmospheric Administration (NOAA). NOAA Fisheries Service administers NOAA's programs that support domestic and international conservation and management of living marine resources. It provides services and products to support domestic and international fisheries management operations, fisheries development, trade and industry assistance activities, enforcement, protected species and habitat conservation operations, and the scientific and technical aspects of NOAA's marine fisheries. NOAA's Fisheries Service Northwest Region is responsible for marine and anadromous fishes under the Endangered Species Act. Two species under NOAA's jurisdiction, the Chinook salmon and steelhead, are found in the Green River and are listed as threatened species. NOAA Fisheries completed a biological opinion in 2000 that addresses effects of HHD operations on Chinook salmon in accordance with Section 7 of the Endangered Species Act. Consultation with NOAA to address effects on steelhead has not yet been completed.

g. <u>Washington State Department of Ecology (WDOE)</u>. The WDOE is the responsible agency for assigning water rights for both groundwater and surface water in the Green River basin. WDOE has issued a permit to Tacoma for pumping 236,562 liters (62,500 gallons) per minute from the North Fork well field. Tacoma diverts up to 3.20 m^3/s (113 cfs) from the natural flow of the Green River at its diversion facility located 5.6 km (3.5 miles) downstream of Howard A. Hanson Dam. This present diversion right is one of historical appropriation acquired by Tacoma prior to the 1917 Water Code Act that requires filing of water rights. The exact extent of Tacoma's appropriated water right has never been adjudicated. Tacoma also reactivated an old application filed with the State in the 1930's requesting that the WDOE grant a right for the diversion of an additional 2.83 m^3/s (100 cfs) at their existing facility. In August 1981, WDOE approved the additional diversion subject to instream flow regulations. However, the approval was appealed to the Washington State Pollution Control Hearings Board and later to the State Supreme Court by the Northwest Steelhead and Salmon Council, with the then Washington State Departments of Fisheries and Game joining as interveners. A compromise was reached out of court and Tacoma was issued a water permit in 1986. In 1995, Tacoma reached agreement with the Muckleshoot Indian Tribe for use of the additional diversion permit.

A number of irrigation and domestic permits have been approved from time to time by WDOE and, while they are not for large amounts individually, the total amounts to about 2.58 m^3/s (91 cfs).

The WDOE is the agency responsible for the instream resources protection program in accordance with Chapter 173-500 of the WAC (Water Resources Management Program of the Washington Administrative Code). Chapter 173-509 of the WAC applies specifically to all waters within the Green-Duwamish River basin, the provisions of which apply, as a matter of state law, to future water right authorizations issued pursuant to the State's water rights codes. The purpose of this chapter is to retain perennial rivers, streams and lakes in the basin with instream flows and levels necessary for the preservation and protection of wildlife, fish, scenic, aesthetic and other environmental values, recreational and navigational values, and to preserve water quality. A copy of Chapter 173-509 of the WAC is presented as **Exhibit 9-2**. Of special interest to reservoir regulation at Howard A. Hanson Dam are paragraphs -030(2)(b), -030(4) and -070(l).

The WDOE is also responsible for the water quality criteria in the state and for a surveillance and enforcement program. The Federal Clean Water Act of 1977 requires that State Water Quality Standards be reviewed periodically and that agencies and the public be allowed to participate in the review.

h. <u>Muckleshoot Indian Tribe.</u> The Muckleshoot Indian Tribe has treaty fishery rights on the Green-Duwamish river system. The tribe, along with WFDW, are co-managers for fish and wildlife resources in the Green River basin. Executive Order 13175 and policy directives issued by the Corps and the Department of Defense, requires preservation and protection of trust resources, and coordination and consultation with the tribe regarding possible impacts to treaty rights.

i. <u>King County Flood Control Zone District.</u> King County Flood Control Zone District (KCFCZD) is responsible for the operation and maintenance of the two pumping plants (Black River and Tukwila) constructed by the NRCS (see paragraph 9.02 c). A third, Segale Pump Station, was constructed by KCFCZD in 1997 to help control groundwater saturation that previously affected the stability of the Segale Levee foundation soils. In addition to the pump stations, KCFCZD is responsible for flood fighting and maintenance of various levees and revetments along the Green River. King County will be advised whenever the discharge near Auburn is forecast to exceed 141.58 m^3/s (5,000 cfs). Notification will be made in accordance with the notification list provided in **Exhibit 7-1**.

j. City of Tacoma. Tacoma diverts its principal water supply from the Green River by means of a headworks located 5.6 km (3.5 miles) downstream from Howard A. Hanson Dam. Since the quantity and turbidity of the discharge from the dam is important to Tacoma, any significant change will be reported in accordance with the notification list provided in **Exhibit 7-1**.

k. City of Kent. The City of Kent operates and maintains multiple stormwater pump stations that are used to control flooding within the City of Kent. The Horseshoe Acres Pump Station has a rated capacity of 2.52 m^3/s (89 cfs) with four pumps. There are currently three pumps installed with total operating capacity of 1.89 m^3/s (67 cfs). There are at least two additional pump stations that provided flood protection within the city. Information regarding the current pumping capacity was not available.

l. Others. There are a number of local interests in the lower basin who have requested notification under various flow conditions and at various times (see **Exhibit 7-1**).

9.03 Interagency Agreements There are no interagency agreements related to HHD operations.

9.04 Commissions, River Authorities, Compacts and Committees

a. Green River Flow Management Coordination Committee (GRFMCC). This is a group of agencies that the Corps routinely coordinates with regarding flow management issues on the Green River during the period when water is stored in the reservoir for conservation purposes. The group typically discusses flow management issues during biweekly conference calls that begin each year in late February or early March and continue through October. The focus of these calls is mostly related to the spring storage of conservation water and the subsequent release of stored water during the summer and fall for instream flow enhancement for fisheries purposes. Membership in the group includes the Washington State Department of Fish and Wildlife, Muckleshoot Indian Tribe, City of Tacoma, U.S. Fish and Wildlife Service, Washington State Department of Ecology, NOAA Fisheries Service, King County, and the Corps.

9.05 Non-Federal Hydropower. This section does not apply to HHD.

9.06 Reports. CENWS maintains an operating log for Howard Hanson Dam. The log records all operational decisions and correspondence related to operational decisions at the project.

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1050	1	1	2	2	2	2	2	2	2	2
1051	2	2	2	2	2	2	2	2	2	2
1052	2	2	2	2	2	2	2	2	2	2
1053	2	2	2	2	2	2	2	2	2	2
1054	3	3	3	3	3	3	3	3	3	3
1055	3	3	3	3	3	3	3	3	3	3
1056	3	3	4	4	4	4	4	4	4	4
1057	4	4	4	4	5	5	5	5	5	5
1058	5	5	6	6	6	6	6	7	7	7
1059	7	8	8	8	8	9	9	9	10	10
1060	10	11	11	11	12	12	13	13	14	14
1061	14	15	15	16	17	17	18	18	19	20
1062	20	21	22	23	24	25	26	27	28	29
1063	30	31	32	33	35	36	37	39	40	41
1064	43	44	46	48	49	51	53	54	56	58
1065	59	61	64	66	68	70	72	74	76	78
1066	80	82	85	87	90	92	94	97	99	102
1067	104	107	110	113	116	119	122	125	127	130
1068	133	137	141	144	148	152	155	159	163	166
1069	170	174	179	184	188	193	197	202	206	211
1070	216	221	226	232	237	243	248	253	259	264
1071	270	277	283	290	297	304	310	317	324	331
1072	338	346	355	363	371	380	388	397	405	414
1073	422	432	441	451	460	470	479	489	498	508
1074	517	528	538	548	558	568	578	588	599	609
1075	619	630	641	651	662	673	684	695	706	716
1076	727	739	750	762	773	784	796	807	819	830

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1077	842	854	866	878	890	902	914	926	937	949
1078	961	974	986	999	1011	1024	1036	1049	1061	1074
1079	1086	1099	1112	1125	1138	1151	1164	1177	1190	1203
1080	1216	1230	1243	1257	1271	1284	1298	1311	1325	1339
1081	1352	1366	1380	1394	1409	1423	1437	1451	1465	1479
1082	1493	1508	1523	1537	1552	1567	1581	1596	1611	1625
1083	1640	1655	1671	1686	1701	1717	1732	1747	1762	1778
1084	1793	1809	1825	1840	1856	1872	1888	1904	1920	1936
1085	1951	1968	1984	2001	2017	2034	2050	2067	2083	2100
1086	2116	2133	2151	2168	2185	2202	2219	2236	2253	2270
1087	2287	2305	2323	2341	2358	2376	2394	2412	2430	2447
1088	2465	2484	2502	2521	2540	2558	2577	2595	2614	2633
1089	2651	2671	2690	2710	2729	2748	2768	2787	2807	2826
1090	2846	2866	2886	2907	2927	2947	2967	2988	3008	3028
1091	3049	3070	3091	3112	3133	3154	3175	3196	3217	3238
1092	3259	3281	3302	3324	3345	3367	3389	3410	3432	3453
1093	3475	3497	3519	3542	3564	3586	3608	3630	3653	3675
1094	3697	3720	3742	3765	3788	3811	3833	3856	3879	3902
1095	3924	3948	3971	3994	4018	4041	4064	4087	4111	4134
1096	4157	4181	4205	4229	4252	4276	4300	4324	4348	4371
1097	4395	4419	4444	4468	4492	4517	4541	4565	4589	4614
1098	4638	4663	4687	4712	4737	4762	4787	4811	4836	4861
1099	4886	4911	4936	4962	4987	5012	5038	5063	5088	5114
1100	5139	5165	5191	5217	5242	5268	5294	5320	5346	5372
1101	5398	5424	5451	5477	5503	5530	5556	5583	5609	5636
1102	5662	5689	5716	5743	5770	5797	5824	5850	5877	5904
1103	5931	5959	5986	6014	6041	6069	6096	6124	6151	6179

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1104	6206	6234	6263	6291	6319	6347	6375	6403	6431	6459
1105	6488	6516	6545	6574	6603	6632	6660	6689	6718	6747
1106	6776	6805	6834	6864	6893	6922	6952	6981	7011	7040
1107	7069	7099	7129	7159	7189	7219	7249	7279	7309	7339
1108	7369	7400	7430	7461	7492	7522	7553	7584	7614	7645
1109	7676	7707	7739	7770	7801	7833	7864	7896	7927	7959
1110	7990	8022	8055	8087	8119	8152	8184	8216	8249	8281
1111	8313	8347	8380	8413	8447	8480	8513	8546	8580	8613
1112	8646	8681	8715	8749	8783	8818	8852	8886	8920	8955
1113	8989	9024	9060	9095	9131	9166	9202	9237	9272	9308
1114	9343	9380	9416	9453	9490	9526	9563	9599	9636	9672
1115	9709	9747	9784	9822	9860	9897	9935	9973	10010	10048
1116	10086	10125	10164	10202	10241	10280	10319	10358	10397	10436
1117	10474	10515	10555	10595	10635	10675	10715	10755	10795	10836
1118	10876	10917	10958	11000	11041	11082	11124	11165	11206	11248
1119	11289	11332	11375	11417	11460	11503	11545	11588	11631	11673
1120	11716	11760	11804	11848	11893	11937	11981	12025	12069	12113
1121	12157	12203	12249	12294	12340	12385	12431	12477	12522	12568
1122	12613	12661	12708	12755	12802	12850	12897	12944	12991	13038
1123	13086	13134	13183	13232	13281	13329	13378	13427	13476	13524
1124	13573	13624	13674	13724	13774	13825	13875	13925	13976	14026
1125	14076	14128	14180	14232	14284	14335	14387	14439	14491	14543
1126	14594	14648	14701	14754	14808	14861	14914	14968	15021	15074
1127	15128	15182	15237	15292	15346	15401	15455	15510	15565	15619
1128	15674	15730	15786	15843	15899	15955	16011	16067	16123	16179
1129	16236	16293	16351	16409	16466	16524	16582	16639	16697	16755
1130	16813	16872	16931	16990	17049	17108	17167	17226	17285	17344

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1131	17403	17463	17523	17583	17644	17704	17764	17825	17885	17945
1132	18006	18068	18129	18191	18253	18315	18376	18438	18500	18562
1133	18624	18687	18750	18814	18877	18940	19004	19067	19131	19194
1134	19257	19322	19388	19453	19518	19583	19648	19713	19778	19844
1135	19909	19976	20043	20110	20177	20244	20311	20378	20444	20511
1136	20578	20647	20716	20785	20854	20923	20991	21060	21129	21198
1137	21267	21337	21408	21478	21549	21620	21690	21761	21831	21902
1138	21973	22045	22117	22189	22261	22333	22405	22477	22549	22621
1139	22693	22766	22839	22912	22986	23059	23132	23205	23278	23351
1140	23425	23500	23575	23651	23726	23801	23877	23952	24027	24103
1141	24178	24255	24333	24410	24488	24565	24642	24720	24797	24875
1142	24952	25031	25111	25190	25269	25349	25428	25507	25586	25666
1143	25745	25826	25908	25989	26071	26152	26233	26315	26396	26478
1144	26559	26642	26726	26809	26893	26976	27059	27143	27226	27310
1145	27393	27478	27563	27649	27734	27819	27904	27989	28075	28160
1146	28245	28332	28418	28505	28591	28678	28764	28851	28937	29024
1147	29110	29198	29286	29373	29461	29549	29637	29725	29812	29900
1148	29988	30077	30166	30256	30345	30434	30523	30612	30702	30791
1149	30880	30971	31061	31152	31242	31333	31423	31514	31604	31695
1150	31785	31877	31969	32061	32153	32245	32336	32428	32520	32612
1151	32704	32797	32891	32984	33077	33171	33264	33357	33450	33544
1152	33637	33732	33826	33921	34015	34110	34205	34299	34394	34488
1153	34583	34679	34775	34871	34967	35064	35160	35256	35352	35448
1154	35544	35642	35739	35837	35934	36032	36129	36227	36324	36422
1155	36519	36618	36717	36816	36915	37014	37112	37211	37310	37409
1156	37508	37608	37709	37809	37909	38010	38110	38210	38310	38411
1157	38511	38613	38714	38816	38918	39020	39121	39223	39325	39426

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1158	39528	39631	39734	39838	39941	40044	40147	40250	40354	40457
1159	40560	40665	40769	40874	40979	41084	41188	41293	41398	41502
1160	41607	41713	41819	41925	42031	42137	42243	42349	42455	42561
1161	42667	42774	42881	42988	43095	43202	43309	43416	43523	43630
1162	43737	43845	43953	44062	44170	44278	44386	44494	44603	44711
1163	44819	44928	45038	45147	45256	45366	45475	45584	45693	45803
1164	45912	46022	46133	46243	46354	46464	46574	46685	46795	46906
1165	47016	47128	47239	47351	47462	47574	47685	47797	47908	48020
1166	48131	48244	48356	48469	48581	48694	48807	48919	49032	49144
1167	49257	49371	49485	49598	49712	49826	49940	50054	50167	50281
1168	50395	50510	50625	50740	50855	50970	51084	51199	51314	51429
1169	51544	51660	51776	51892	52008	52125	52241	52357	52473	52589
1170	52705	52822	52940	53057	53174	53292	53409	53526	53643	53761
1171	53878	53996	54115	54233	54352	54470	54588	54707	54825	54944
1172	55062	55182	55301	55421	55540	55660	55779	55899	56018	56138
1173	56257	56378	56499	56619	56740	56861	56982	57103	57223	57344
1174	57465	57587	57709	57831	57953	58075	58196	58318	58440	58562
1175	58684	58807	58930	59054	59177	59300	59423	59546	59670	59793
1176	59916	60041	60165	60290	60414	60539	60664	60788	60913	61037
1177	61162	61288	61414	61540	61666	61793	61919	62045	62171	62297
1178	62423	62551	62678	62806	62933	63061	63189	63316	63444	63571
1179	63699	63828	63957	64086	64215	64344	64473	64602	64731	64860
1180	64989	65120	65250	65381	65511	65642	65772	65903	66033	66164
1181	66294	66426	66558	66690	66822	66954	67086	67218	67350	67482
1182	67614	67748	67881	68015	68148	68282	68415	68549	68682	68816
1183	68949	69084	69219	69354	69489	69624	69758	69893	70028	70163
1184	70298	70435	70571	70708	70844	70981	71117	71254	71390	71527

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1185	71663	71801	71939	72077	72215	72353	72491	72629	72767	72905
1186	73043	73183	73322	73462	73601	73741	73880	74020	74159	74299
1187	74438	74579	74720	74861	75002	75143	75284	75425	75566	75707
1188	75848	75991	76133	76276	76418	76561	76704	76846	76989	77131
1189	77274	77418	77562	77706	77850	77995	78139	78283	78427	78571
1190	78715	78861	79007	79152	79298	79444	79590	79736	79881	80027
1191	80173	80321	80468	80616	80763	80911	81059	81206	81354	81501
1192	81649	81798	81948	82097	82247	82396	82545	82695	82844	82994
1193	83143	83294	83446	83597	83748	83900	84051	84202	84353	84505
1194	84656	84809	84962	85115	85268	85421	85574	85727	85880	86033
1195	86186	86341	86496	86651	86806	86961	87115	87270	87425	87580
1196	87735	87892	88049	88205	88362	88519	88676	88833	88989	89146
1197	89303	89462	89620	89779	89938	90097	90255	90414	90573	90731
1198	90890	91051	91211	91372	91532	91693	91853	92014	92174	92335
1199	92495	92657	92820	92982	93145	93307	93469	93632	93794	93957
1200	94119	94283	94448	94612	94776	94941	95105	95269	95433	95598
1201	95762	95928	96094	96261	96427	96593	96759	96925	97092	97258
1202	97424	97592	97760	97929	98097	98265	98433	98601	98770	98938
1203	99106	99276	99446	99616	99786	99956	100126	100296	100466	100636
1204	100806	100978	101150	101322	101494	101667	101839	102011	102183	102355
1205	102527	102701	102875	103049	103223	103397	103570	103744	103918	104092
1206	104266	104442	104618	104794	104970	105146	105322	105498	105674	105850
1207	106026	106204	106382	106560	106738	106916	107094	107272	107450	107628
1208	107806	107986	108166	108346	108526	108706	108886	109066	109246	109426
1209	109606	109788	109970	110151	110333	110515	110697	110879	111060	111242
1210	111424	111608	111791	111975	112158	112342	112525	112709	112892	113076
1211	113259	113444	113629	113814	113999	114184	114369	114554	114739	114924

TABLE 2-1 HOWARD A. HANSON RESERVOIR CONTENTS IN ACRE-FEET

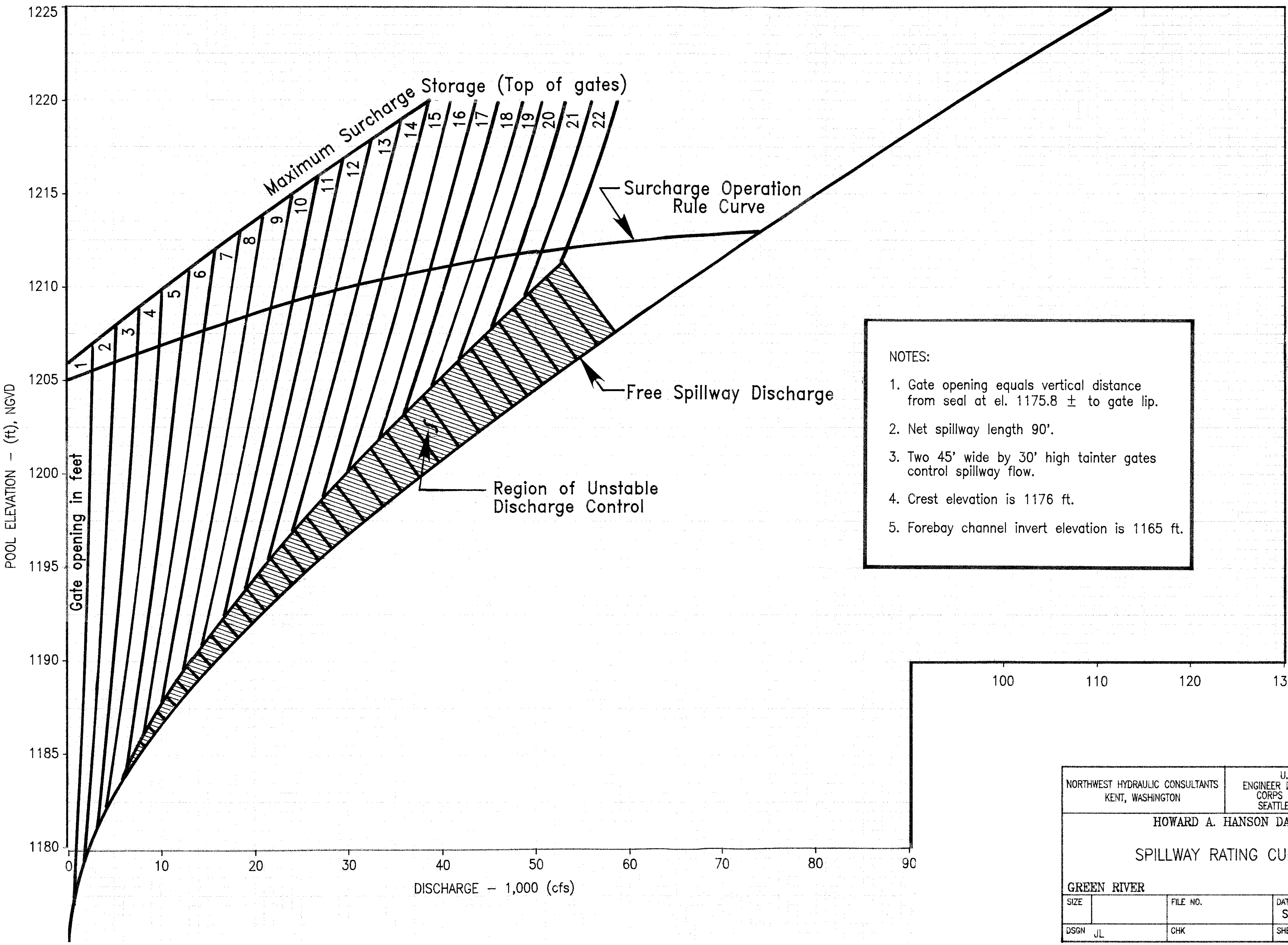
Elev. (Ft)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1212	115109	115296	115482	115669	115855	116042	116228	116415	116601	116788
1213	116974	117162	117350	117538	117726	117914	118102	118290	118478	118666
1214	118854	119044	119233	119423	119612	119802	119991	120181	120370	120560
1215	120749	120940	121131	121322	121513	121704	121895	122086	122277	122468
1216	122659	122852	123044	123237	123429	123622	123814	124007	124199	124392
1217	124584	124778	124972	125166	125360	125554	125748	125942	126136	126330
1218	126524	126720	126915	127111	127306	127502	127697	127893	128088	128284
1219	128479	128676	128873	129070	129267	129464	129661	129858	130055	130252
1220	130449	130649	130848	131048	131248	131448	131647	131847	132047	132246
1221	132446	132648	132851	133053	133256	133458	133660	133863	134065	134268
1222	134470	134675	134880	135085	135290	135496	135701	135906	136111	136316
1223	136521	136729	136937	137144	137352	137560	137768	137976	138183	138391
1224	138599	138810	139020	139231	139441	139652	139862	140073	140283	140494
1225	140704	140917	141130	141344	141557	141770	141983	142196	142410	142623
1226	142836	143052	143268	143484	143700	143916	144131	144347	144563	144779
1227	144995	145214	145432	145651	145869	146088	146307	146525	146744	146962
1228	147181	147402	147624	147845	148066	148288	148509	148730	148951	149173
1229	149394									

TABLE 2-2 HOWARD A. HANSON RESERVOIR CONTENTS IN HECTARE-METERS

Elev. (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
320	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
321	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
322	0.4	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1
323	1.1	1.4	1.6	1.9	2.1	2.4	2.6	2.9	3.1	3.4
324	3.6	4.4	5.1	5.8	6.5	7.2	8.0	8.7	9.4	10.1
325	10.8	12.2	13.6	15.0	16.4	17.8	19.2	20.5	21.9	23.3
326	24.7	27.2	29.7	32.1	34.6	37.1	39.6	42.0	44.5	47.0
327	49.5	53.5	57.5	61.5	65.5	69.6	73.6	77.6	81.6	85.6
328	89.7	94.6	99.6	104.6	109.5	114.5	119.4	124.4	129.4	134.3
329	139.3	145.0	150.7	156.4	162.1	167.7	173.4	179.1	184.8	190.5
330	196.2	202.7	209.1	215.6	222.1	228.6	235.0	241.5	248.0	254.5
331	260.9	268.3	275.7	283.1	290.5	297.9	305.3	312.7	320.1	327.5
332	334.9	342.9	350.9	359.0	367.0	375.0	383.1	391.1	399.1	407.1
333	415.2	423.9	432.7	441.5	450.3	459.1	467.9	476.7	485.5	494.2
334	503.0	513.0	522.9	532.8	542.8	552.7	562.7	572.6	582.5	592.5
335	602.4	613.1	623.8	634.4	645.1	655.8	666.5	677.1	687.8	698.5
336	709.2	720.6	732.1	743.5	754.9	766.4	777.8	789.3	800.7	812.1
337	823.6	835.9	848.2	860.4	872.7	885.0	897.3	909.6	921.8	934.1
338	946.4	959.8	973.2	986.5	999.9	1013.3	1026.7	1040.0	1053.4	1066.8
339	1080.2	1093.4	1106.7	1119.9	1133.1	1146.4	1159.6	1172.9	1186.1	1199.4
340	1212.6	1228.8	1245.1	1261.3	1277.5	1293.8	1310.0	1326.3	1342.5	1358.7
341	1375.0	1393.0	1411.0	1429.0	1447.1	1465.1	1483.1	1501.2	1519.2	1537.2
342	1555.2	1575.4	1595.6	1615.7	1635.9	1656.1	1676.2	1696.4	1716.6	1736.7
343	1756.9	1779.1	1801.3	1823.5	1845.6	1867.8	1890.0	1912.2	1934.4	1956.6
344	1978.8	2002.9	2027.0	2051.2	2075.3	2099.4	2123.6	2147.7	2171.8	2196.0
345	2220.1	2243.6	2267.0	2290.5	2314.0	2337.4	2360.9	2384.4	2407.8	2431.3
346	2454.7	2483.2	2511.6	2540.0	2568.4	2596.8	2625.2	2653.6	2682.0	2710.4
347	2738.8	2769.4	2800.0	2830.6	2861.2	2891.8	2922.4	2953.0	2983.6	3014.2

TABLE 2-2 HOWARD A. HANSON RESERVOIR CONTENTS IN HECTARE-METERS

Elev. (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
348	3044.8	3078.0	3111.3	3144.6	3177.9	3211.2	3244.4	3277.7	3311.0	3344.3
349	3377.6	3413.2	3448.9	3484.5	3520.2	3555.9	3591.5	3627.2	3662.9	3698.5
350	3734.2	3771.7	3809.2	3846.7	3884.1	3921.6	3959.1	3996.6	4034.1	4071.6
351	4109.1	4148.5	4187.8	4227.2	4266.6	4305.9	4345.3	4384.7	4424.1	4463.4
352	4502.8	4539.9	4577.0	4614.1	4651.2	4688.3	4725.4	4762.5	4799.6	4836.7
353	4873.8	4916.9	4960.0	5003.1	5046.2	5089.3	5132.4	5175.5	5218.6	5261.7
354	5304.8	5349.5	5394.2	5438.9	5483.6	5528.3	5572.9	5617.6	5662.3	5707.0
355	5751.7	5797.9	5844.1	5890.3	5936.5	5982.7	6028.9	6075.1	6121.3	6167.5
356	6213.7	6261.5	6309.3	6357.1	6405.0	6452.8	6500.6	6548.4	6596.2	6644.0
357	6691.8	6741.2	6790.6	6840.0	6889.3	6938.7	6988.1	7037.5	7086.9	7136.3
358	7185.6	7231.6	7277.5	7323.4	7369.4	7415.3	7461.2	7507.1	7553.1	7599.0
359	7644.9	7697.8	7750.8	7803.7	7856.6	7909.5	7962.4	8015.3	8068.2	8121.1
360	8174.1	8229.0	8284.0	8339.0	8394.0	8448.9	8503.9	8558.9	8613.9	8668.9
361	8723.8	8780.9	8837.9	8894.9	8951.9	9009.0	9066.0	9123.0	9180.1	9237.1
362	9294.1	9353.2	9412.4	9471.5	9530.6	9589.7	9648.8	9708.0	9767.1	9826.2
363	9885.3	9946.9	10008.5	10070.0	10131.6	10193.1	10254.7	10316.3	10377.8	10439.4
364	10501.0	10558.5	10616.0	10673.6	10731.1	10788.6	10846.2	10903.7	10961.2	11018.8
365	11076.3	11142.6	11209.0	11275.4	11341.7	11408.1	11474.5	11540.8	11607.2	11673.6
366	11739.9	11808.9	11877.8	11946.8	12015.7	12084.7	12153.6	12222.5	12291.5	12360.4
367	12429.4	12501.1	12572.7	12644.4	12716.1	12787.8	12859.5	12931.1	13002.8	13074.5
368	13146.2	13220.5	13294.8	13369.1	13443.5	13517.8	13592.1	13666.4	13740.8	13815.1
369	13889.4	13965.9	14042.5	14119.0	14195.5	14272.1	14348.6	14425.1	14501.6	14578.2
370	14654.7	14731.3	14808.0	14884.6	14961.2	15037.9	15114.5	15191.1	15267.7	15344.4
371	15421.0	15495.6	15570.1	15644.6	15719.2	15793.7	15868.3	15942.8	16017.4	16091.9
372	16166.4	16250.2	16333.9	16417.7	16501.4	16585.1	16668.9	16752.6	16836.4	16920.1
373	17003.9	17091.3	17178.7	17266.1	17353.5	17440.9	17528.3	17615.7	17703.1	17790.5
374	17877.9	17967.7	18057.6	18147.4	18238.4	18329.3	18420.0			



NORTHWEST HYDRAULIC CONSULTANTS KENT, WASHINGTON	U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON
HOWARD A. HANSON DAM	
SPILLWAY RATING CURVE	
GREEN RIVER	WASHINGTON

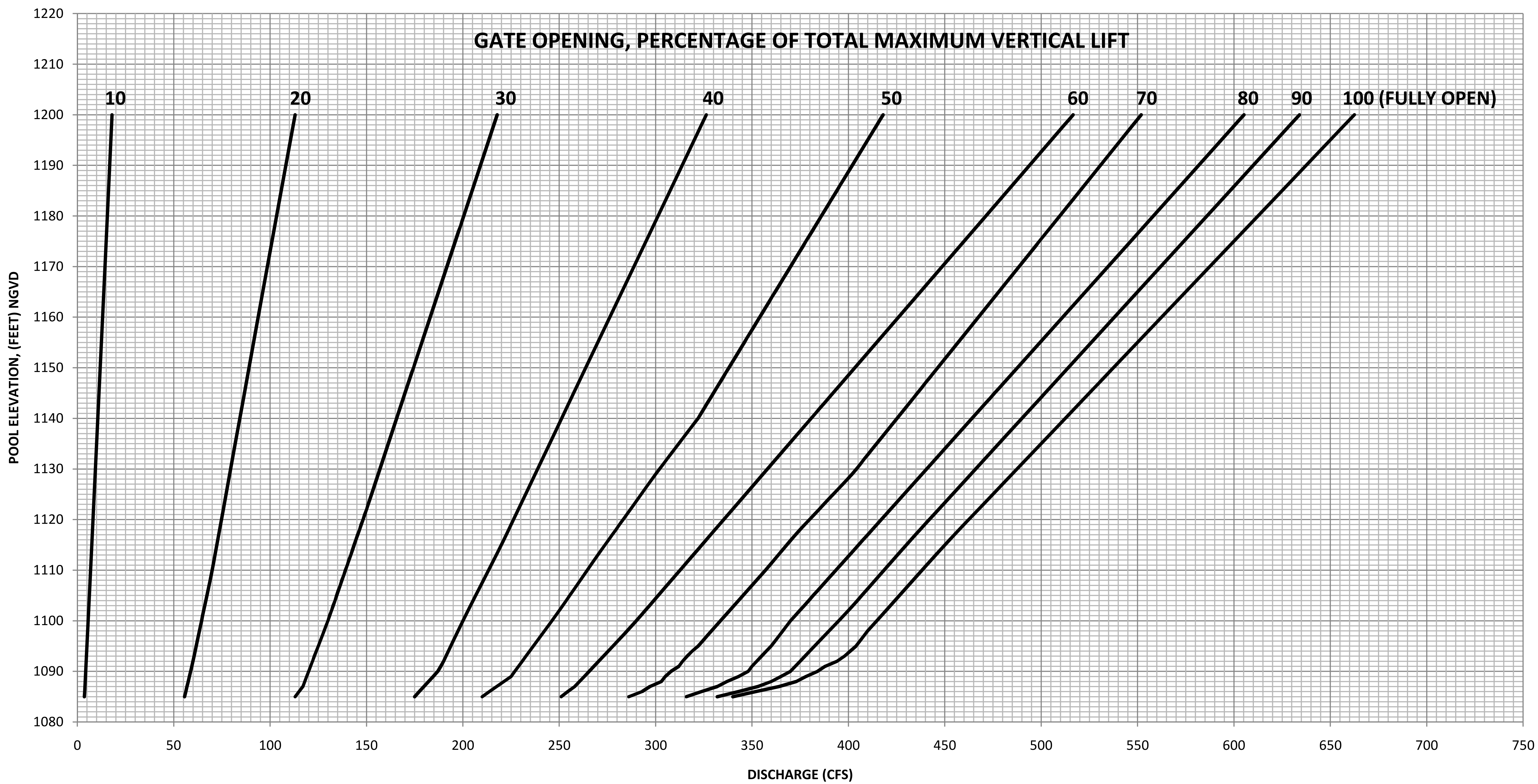
SIZE	FILE NO.	DATE Sept 1993	PLATE
DSGN JL	CHK	SHEET	

CHART 2-1

REDACTED CONTENT

CHART 2-2

REDACTED CONTENT

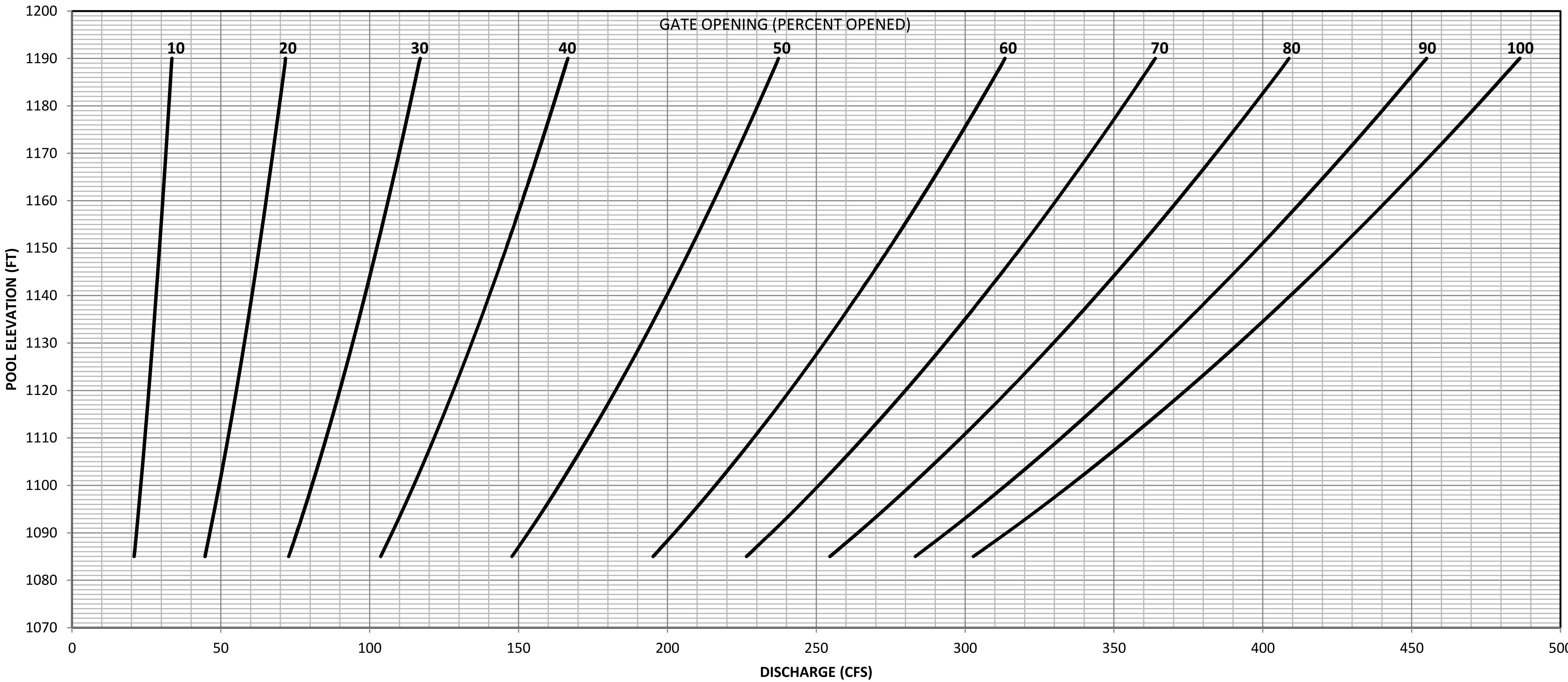


NOTES:

1. FLOW VALUES BASED ON OBSERVED FLOW CONDITIONS (RATING INFORMATION COMPILED JUNE, 1998).
2. OPERATION OF BYPASS BELOW POOL ELEVATIONS OF 1095 FEET MIGHT RESULT IN VORTEXING NEAR THE BYPASS INLET. INLET CONDITIONS SHOULD BE CONFIRMED PRIOR TO EXTENDED USE AT THIS AND LOWER ELEVATIONS.
3. OPERATION OF BYPASS BELOW POOL ELEVATIONS OF 1085 FEET IS NOT ADVISED DUE TO FLOW CONTROL SHIFTING FROM OUTLET TO INLET CONTROL.
4. LISTED GATE OPENINGS ARE PERCENTAGE OF TOTAL MAXIMUM VERTICAL LIFT (NOT PERCENTAGE AREA OPENING) OF THE GATE.

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HOWARD A. HANSON DAM
DISCHARGE RATING CURVES
48-INCH DIAMETER BYPASS



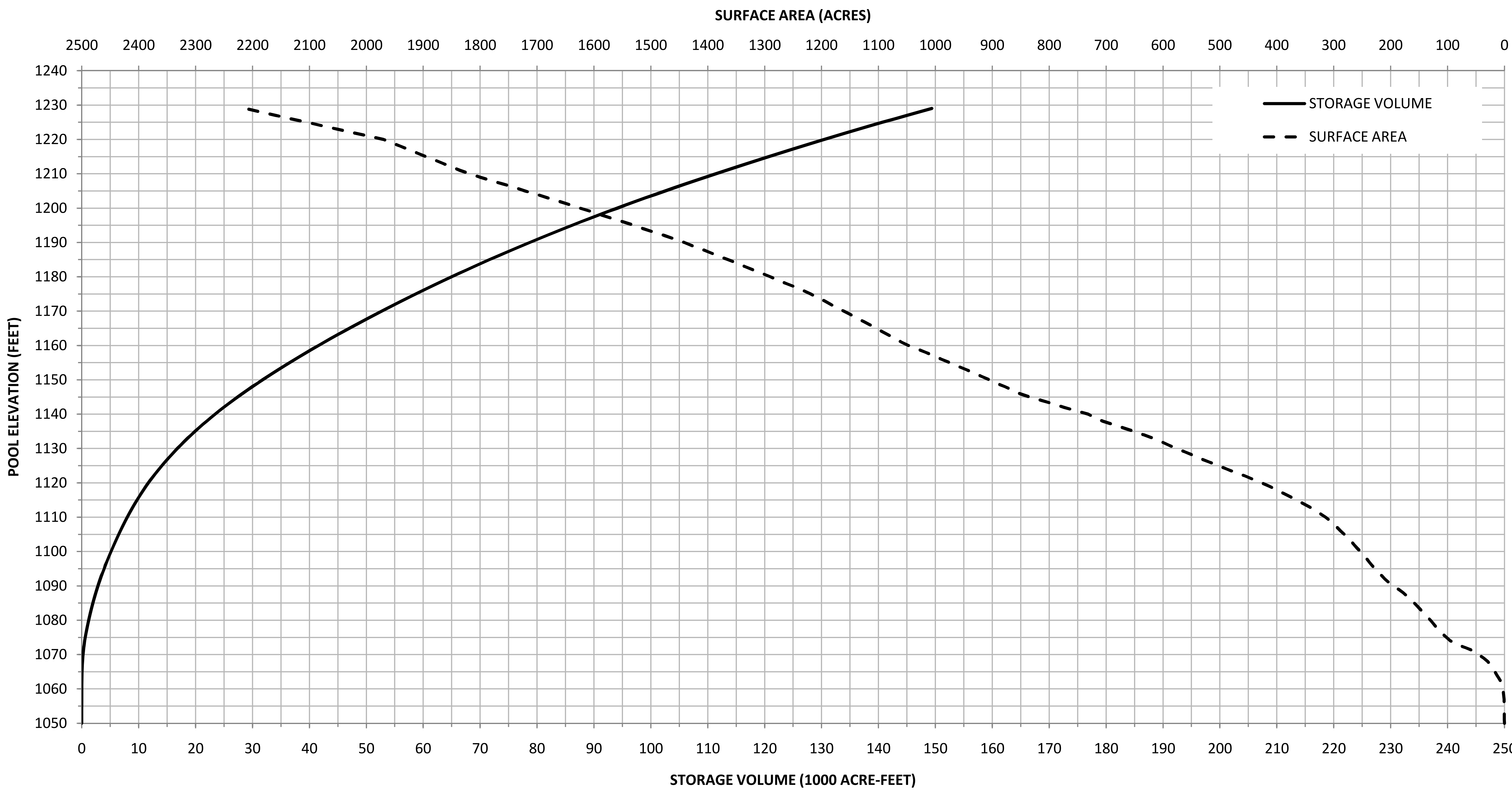
NOTES:

1. 36" BYPASS SHOULD NOT BE OPERATED AT POOLS GREATER THAN 1,190 FEET AS THIS EXCEEDS THE MAXIMUM PRESSURE RATING OF THE OUTLET VALVE
2. OPERATION OF BYPASS BELOW POOL ELEVATION 1,095 FEET MIGHT RESULT IN VORTEXING NEAR THE BYPASS INLET. INLET CONDITIONS SHOULD BE CONFIRMED PRIOR TO ESTENDED USE AT THIS AND LOWER ELEVATIONS.
3. OPERATION OF BYPASS BELOW POOL ELEVATION 1,085 FT IS NOT ADVISED DUE TO FLOW CONTROL SHIFTING FROM OUTLET TO INLET CONDITIONS.
4. CALCULATED VALUES HAVE BEEN CALIBRATED FOR LIMITED DATA BETWEEN POOL ELEVATIONS 1,150.8 FEET AND 1,158.3 FEET USING A HYDRAULIC SPREADSHEET MODEL OF THE SYSTEM. THE CURVE SHOULD BE UPDATED WHEN MORE DATA IS AVAILABLE.
5. CAVITATION NOISE CAN BE HEARD AT GATE OPENINGS OF 65% AND GREATER, BUT IS ACCEPTABLE FOR STILLING BASIN INSPECTIONS 1 MONTH EVERY 5 YEARS.

U.S. ARMY COPRS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WA

HOWARD A. HANSON DAM
DISCHARGE RATING CURVE
36-INCH DIAMETER BYPASS

CHART 2-5



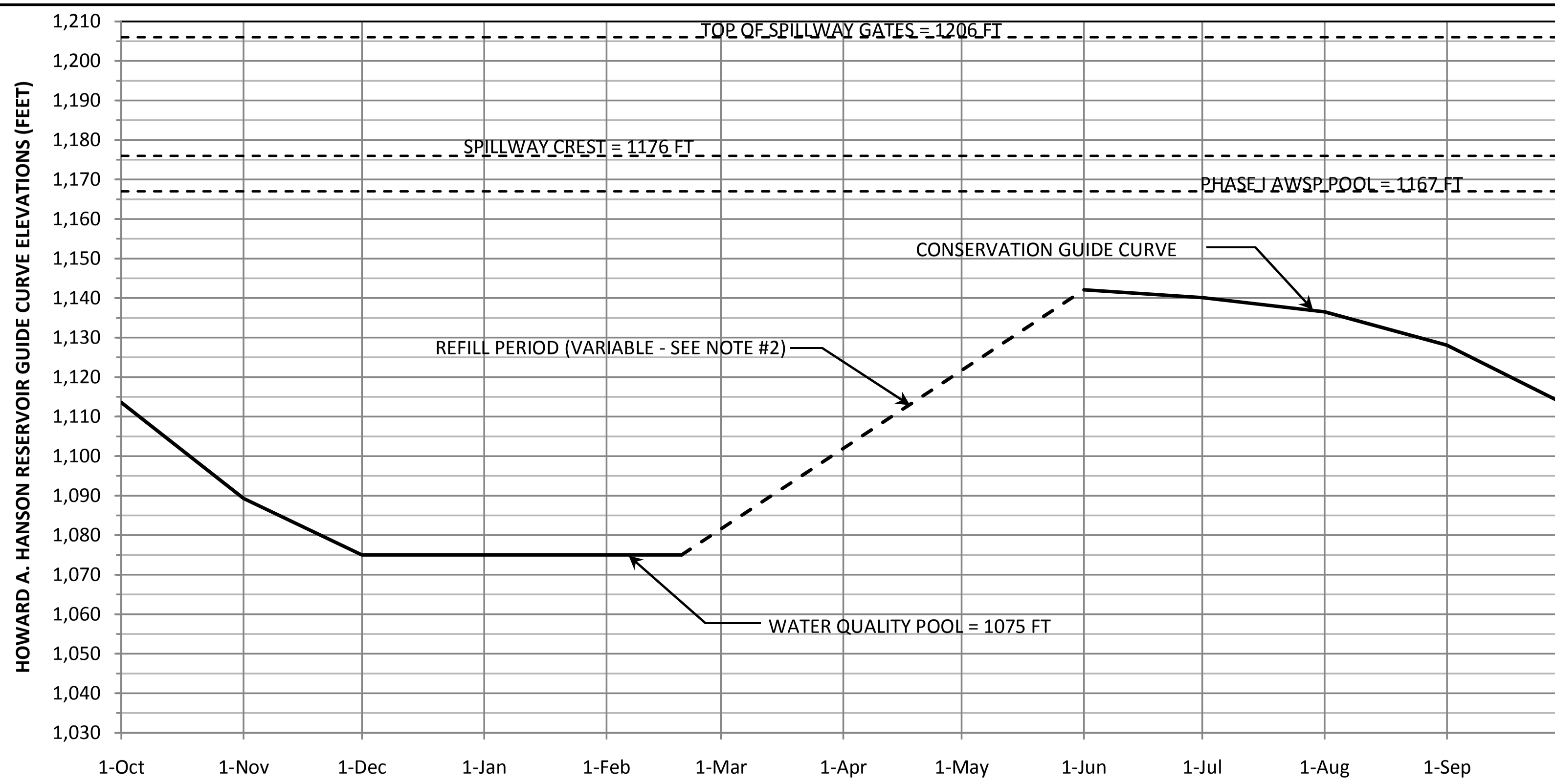
NOTES:

1. STORAGE VOLUME AND SURFACE AREA BELOW ELEVATION 1,140 FEET FROM 2007 BATHYMETRY
2. STORAGE VOLUME AND SURFACE AREA ABOVE 1,140 FEET FROM 2001 STORAGE CURVE ADJUSTED FOR LOSS OF STORAGE BELOW 1,140 FEET.
3. STORAGE VOLUME AND SURFACE AREA ABOVE ELEVATION 1,210 FEET AJUSTED TO REMOVE ANOMALY IN SURFACE AREA DATA AT ELEVATION 1,210 FEET

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HOWARD A. HANSON DAM
RESERVOIR AREA AND CAPACITY CURVES

DEVELOPED: H. HADLEY	CHECKED: K. Brettmann	25 AUG 2011



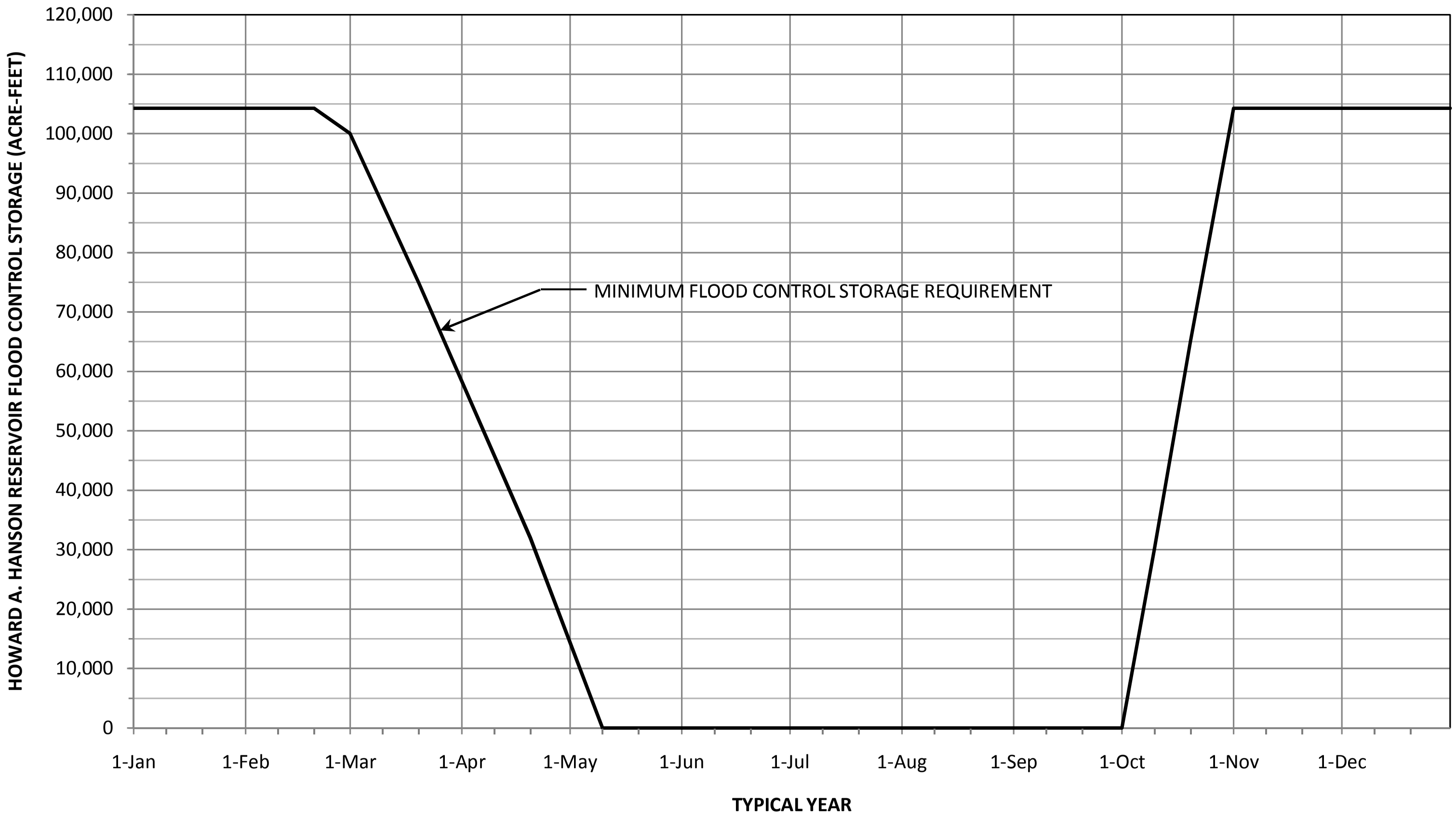
NOTES:

1. CONSERVATION GUIDE CURVE BASED ON NEED TO PROVIDE 113 CFS FOR CITY OF TACOMA FIRST DIVERSION WATER RIGHT AND PROVIDE A MINIMUM FLOW OF 110 CFS AT THE PALMER GAGE.
2. REFILL GUIDANCE VARIES DEPENDING ON FORCASTED INFLOWS. REFILL TYPICALLY OCCURS BETWEEN LATE FEBRUARY AND 1 JUNE.

U.S ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HOWARD A. HANSON DAM
RESERVOIR OPERATION GUIDE CURVE

CHART 7-1

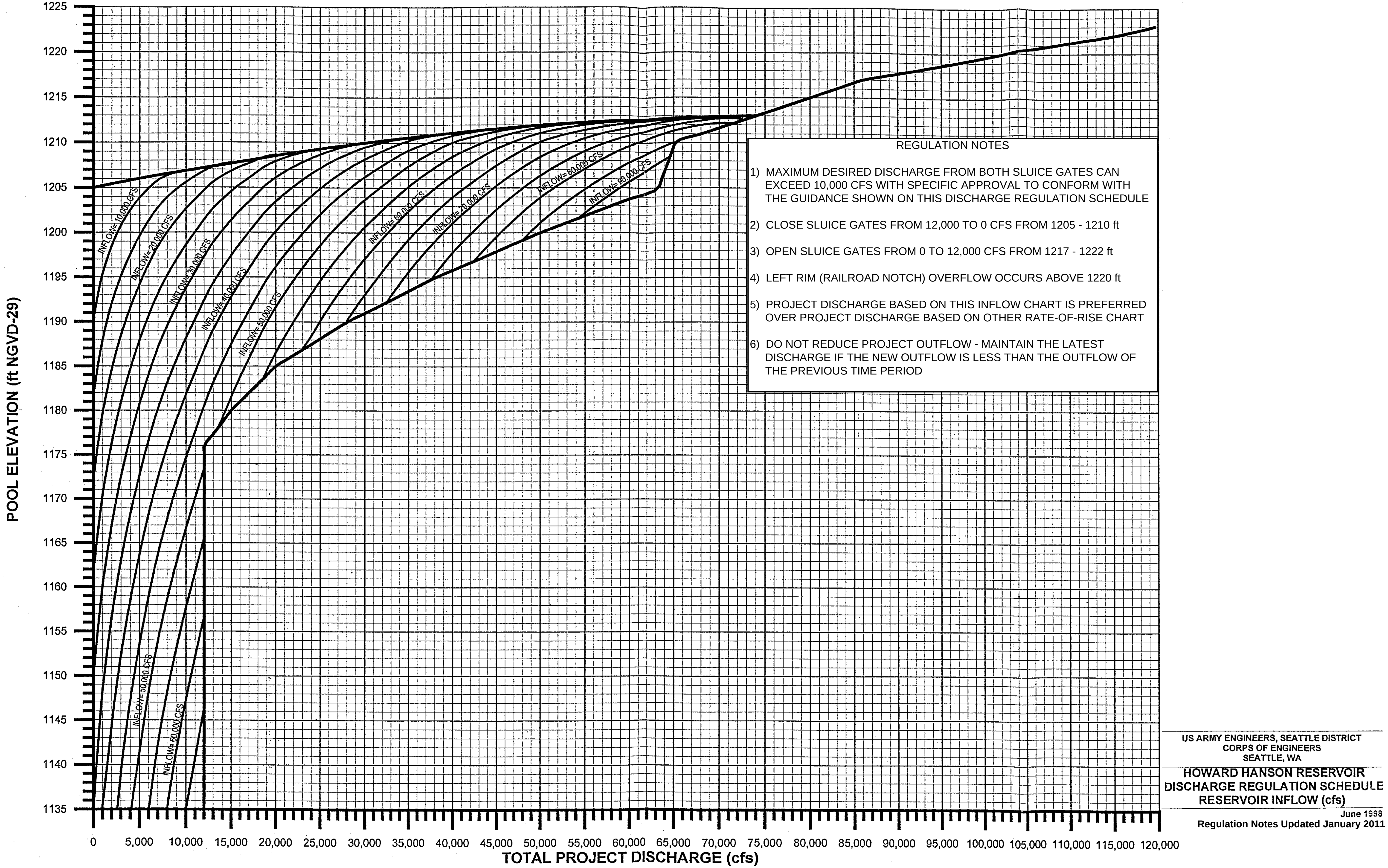


NOTES:

1. MAXIMUM AVAILABLE FLOOD CONTROL STORAGE IS ABOUT 104,000 ACRE-FEET AT PROJECT DESIGN FLOOD POOL ELEVATION 1206 FEET.

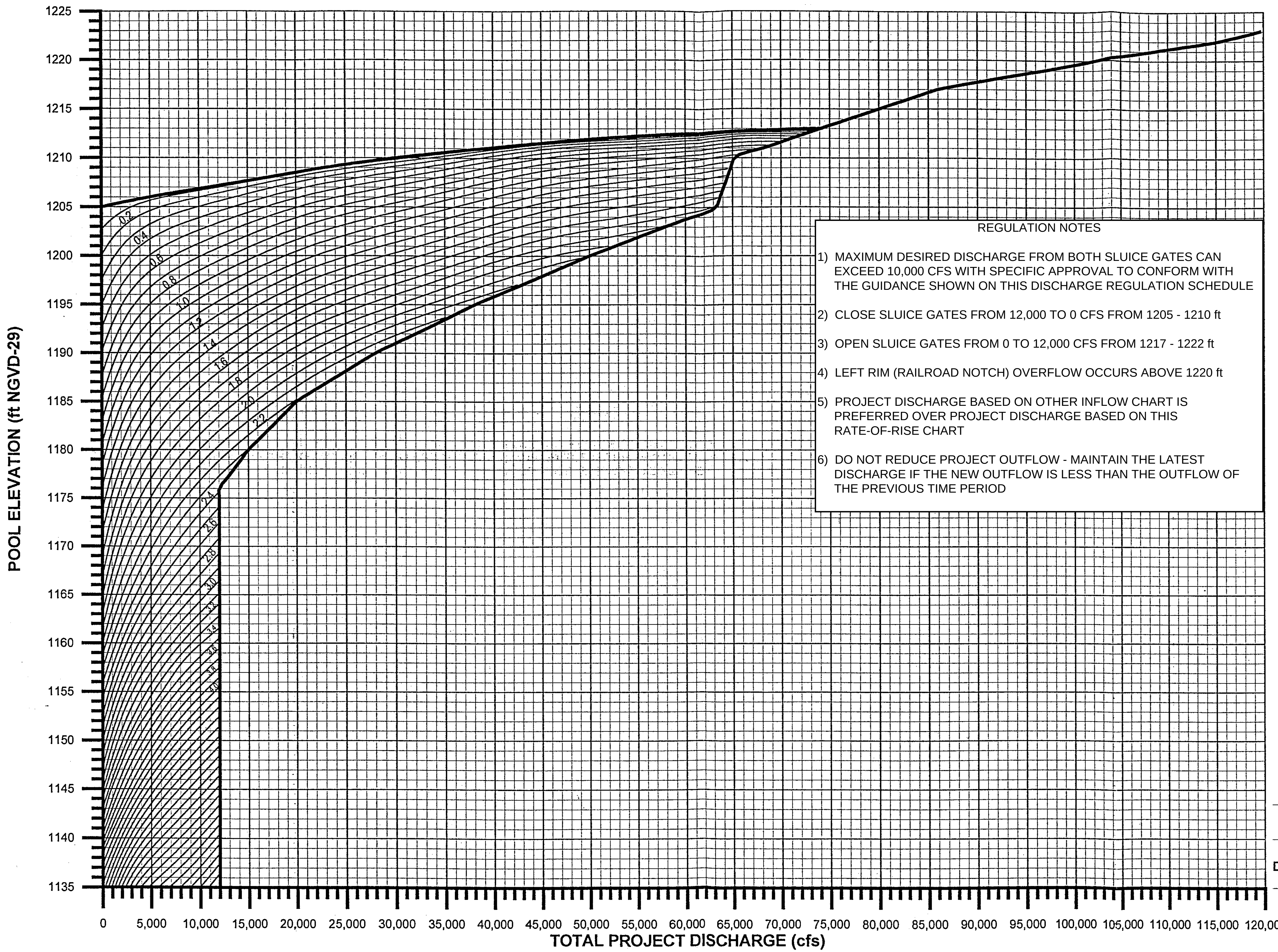
U.S ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HOWARD A. HANSON DAM
FLOOD CONTROL STORAGE REQUIREMENT



POOL ELEVATION (ft NGVD-29)
TOTAL PROJECT DISCHARGE (cfs)
1225
1220
1215
1210
1205
1200
1195
1190
1185
1180
1175
1170
1165
1160
1155
1150
1145
1140
1135
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
65,000
70,000
75,000
80,000
85,000
90,000
95,000
100,000
105,000
110,000
115,000
120,000
INFLOW=10,000 CFS
INFLOW=20,000 CFS
INFLOW=30,000 CFS
INFLOW=40,000 CFS
INFLOW=50,000 CFS
INFLOW=60,000 CFS
INFLOW=70,000 CFS
INFLOW=80,000 CFS
INFLOW=90,000 CFS
INFLOW=50,000 CFS
INFLOW=60,000 CFS
REGULATION NOTES
1) MAXIMUM DESIRED DISCHARGE FROM BOTH SLUICE GATES CAN EXCEED 10,000 CFS WITH SPECIFIC APPROVAL TO CONFORM WITH THE GUIDANCE SHOWN ON THIS DISCHARGE REGULATION SCHEDULE
2) CLOSE SLUICE GATES FROM 12,000 TO 0 CFS FROM 1205 - 1210 ft
3) OPEN SLUICE GATES FROM 0 TO 12,000 CFS FROM 1217 - 1222 ft
4) LEFT RIM (RAILROAD NOTCH) OVERFLOW OCCURS ABOVE 1220 ft
5) PROJECT DISCHARGE BASED ON THIS INFLOW CHART IS PREFERRED OVER PROJECT DISCHARGE BASED ON OTHER RATE-OF-RISE CHART
6) DO NOT REDUCE PROJECT OUTFLOW - MAINTAIN THE LATEST DISCHARGE IF THE NEW OUTFLOW IS LESS THAN THE OUTFLOW OF THE PREVIOUS TIME PERIOD
US ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WA
HOWARD HANSON RESERVOIR
DISCHARGE REGULATION SCHEDULE
RESERVOIR INFLOW (cfs)
June 1998
Regulation Notes Updated January 2011

CHART 7-3

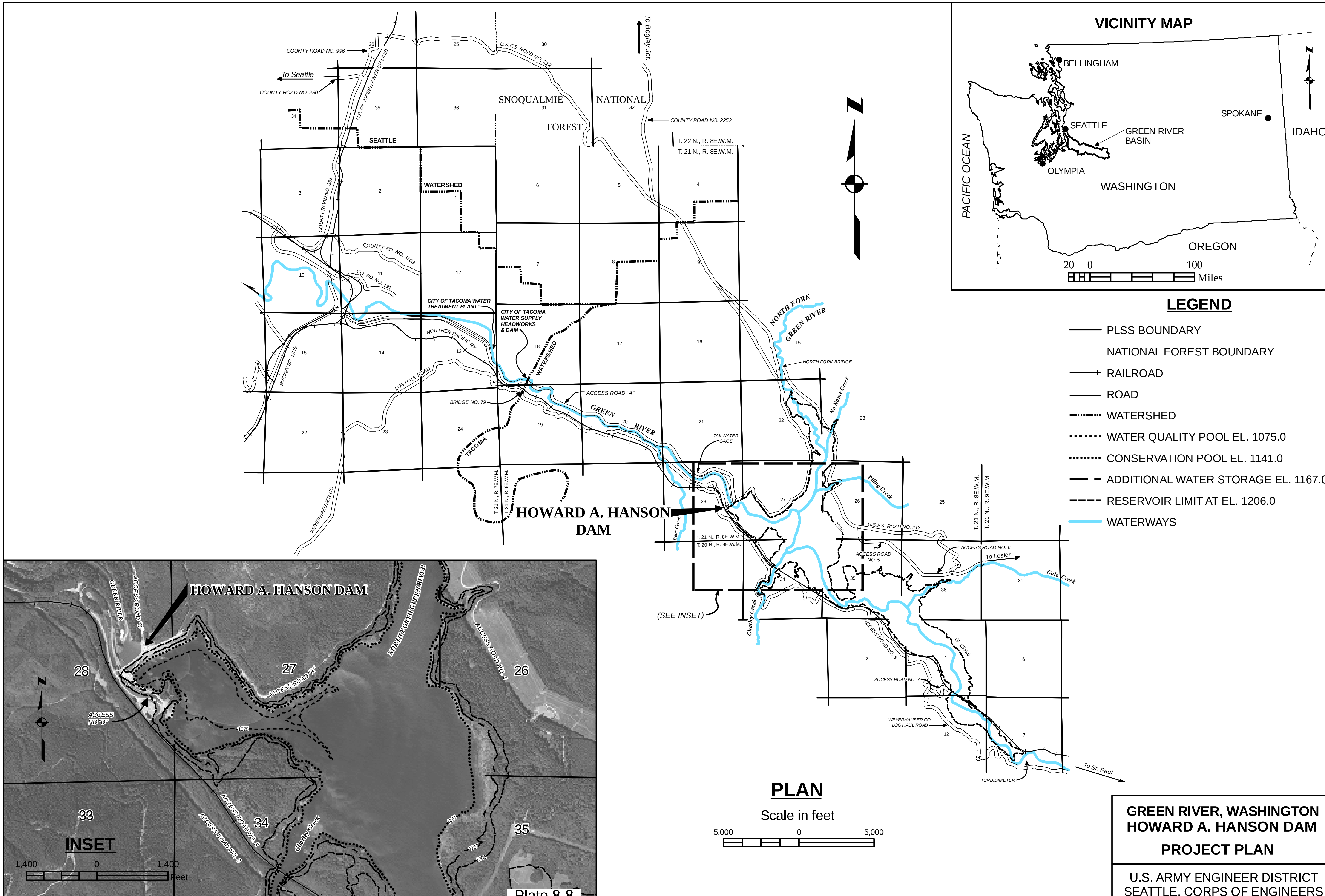


US ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WA

HOWARD HANSON RESERVOIR
DISCHARGE REGULATION SCHEDULE
RESERVOIR RATE OF RISE (ft/hr)

JUNE 1998
Regulation Notes Updated January 2011

CHART 7-4


VICINITY MAP
BELLINGHAM
SEATTLE
GREEN RIVER BASIN
SPOKANE
IDAHO
OLYMPIA
PACIFIC OCEAN
WASHINGTON
OREGON
20 0 100
Miles
LEGEND
PLSS BOUNDARY
NATIONAL FOREST BOUNDARY
RAILROAD
ROAD
WATERSHED
WATER QUALITY POOL EL. 1075.0
CONSERVATION POOL EL. 1141.0
ADDITIONAL WATER STORAGE EL. 1167.0
RESERVOIR LIMIT AT EL. 1206.0
WATERWAYS
COUNTY ROAD NO. 996
To Seattle
COUNTY ROAD NO. 230
N.P. RY. (GREEN RIVER BR LINE)
U.S.F.S. ROAD NO. 212
To Bogley Jct.
SNOQUALMIE
NATIONAL
FOREST
COUNTY ROAD NO. 2252
SEATTLE
T. 22 N., R. 8E.W.M.
T. 21 N., R. 8E.W.M.
WATERSHED
COUNTY ROAD NO. 381
COUNTY RD. NO. 1108
CO. RD. NO. 191
CITY OF TACOMA WATER TREATMENT PLANT
CITY OF TACOMA WATER SUPPLY HEADWORKS & DAM
NORTHERN PACIFIC RY.
NORTH FORK GREEN RIVER
NORTH FORK BRIDGE
BUCKEY BR. LINE
LOG HAUL ROAD
BRIDGE NO. 79
ACCESS ROAD "A"
GREEN RIVER
No Name Creek
TAILWATER GAGE
TACOMA
WEYERHAEUSER CO.
T. 21 N., R. 7E.W.M.
T. 21 N., R. 8E.W.M.
HOWARD A. HANSON DAM
Bear Creek
Piling Creek
U.S.F.S. ROAD NO. 212
T. 21 N., R. 8E.W.M.
T. 21 N., R. 9E.W.M.
T. 21 N., R. 8E.W.M.
T. 20 N., R. 8E.W.M.
ACCESS ROAD NO. 5
ACCESS ROAD NO. 6
To Lester
Gale Creek
(SEE INSET)
Charley Creek
ACCESS ROAD NO. 8
EL. 1206.0
ACCESS ROAD NO. 7
WEYERHAUSER CO. LOG HAUL ROAD
TURBIDIMETER
To St. Paul
HOWARD A. HANSON DAM
GREEN RIVER
ACCESS ROAD "B"
NORTH FORK GREEN RIVER
ACCESS ROAD "F"
ACCESS ROAD NO. 4
ACCESS RD "D"
ACCESS ROAD NO. 8
ACCESS ROAD NO. 9
Charley Creek
INSET
1,400 0 1,400
Feet
Plate 8-8
PLAN
Scale in feet
5,000 0 5,000
GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
PROJECT PLAN
U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS

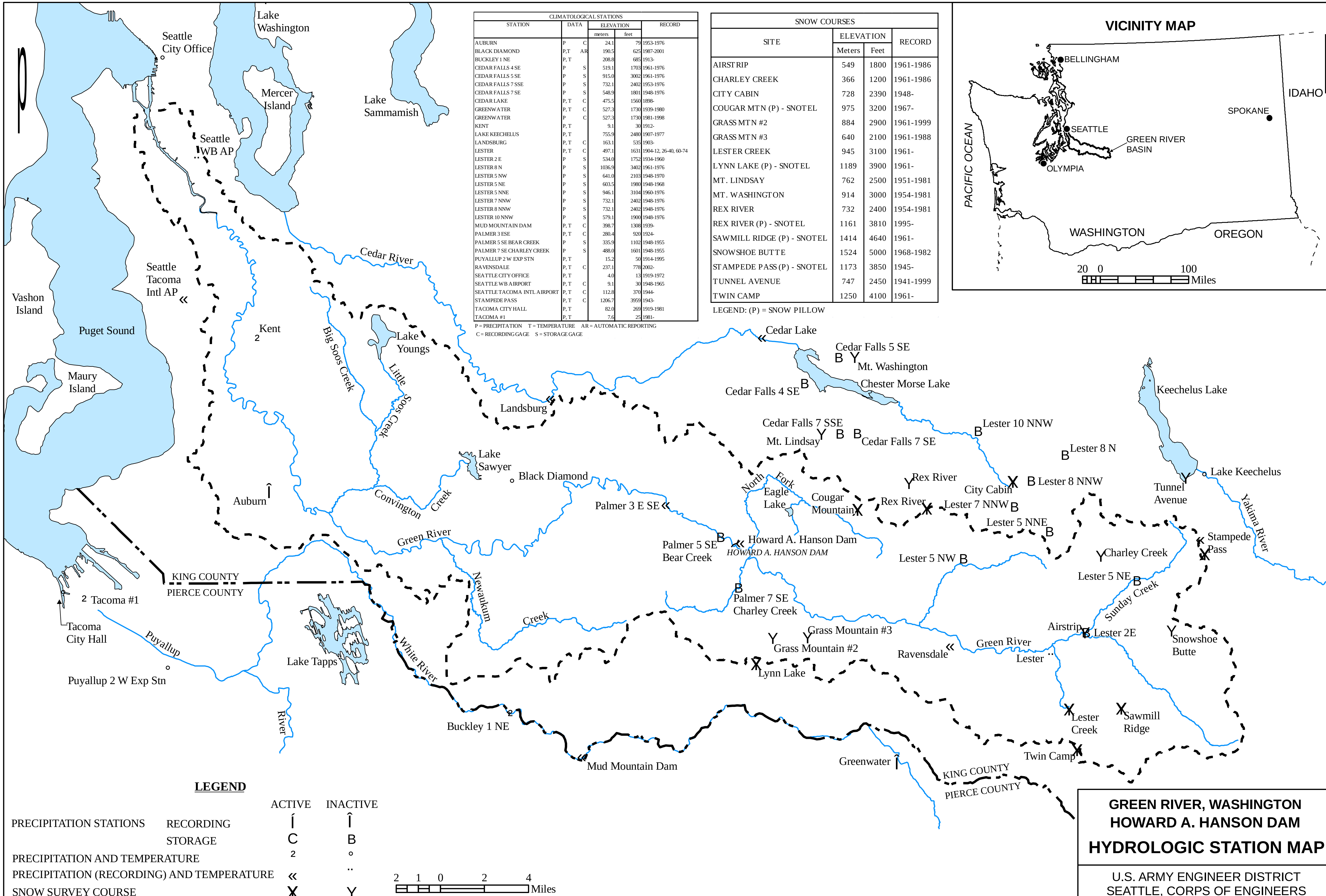
REDACTED CONTENT

REDACTED CONTENT

REDACTED CONTENT

REDACTED CONTENT

GREEN RIVER
ACCESS ROAD "B"
HOWARD A. HANSON DAM
ACCESS ROAD NO. 1
27
STATIONARY LOG BOOM NO. 1
ACCESS ROAD "D"
ACCESS ROAD "A"
STATIONARY LOG BOOM NO. 2
TEMPORARY HOLDING AREA
28
T. 21 N., R. 8E.W.M.
T. 20 N., R. 8E.W.M.
34
NORTHERN PACIFIC RY.
ACCESS ROAD NO. 3
PLAN
250 0 500
Feet
LEGEND
PLSS BOUNDARY
RAILROAD
WATER QUALITY POOL EL. 1075.0
CONSERVATION POOL EL. 1167.0
RESERVOIR LIMIT AT EL. 1206.0
GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM PROJECT
OPERATION AND MAINTENANCE MANUAL
DRIFT CONTROL FACILITIES
U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS



CLIMATOLOGICAL STATIONS					
STATION	DATA		ELEVATION		RECORD
			meters	feet	
AUBURN	P	C	24.1	79	1953-1976
BLACK DIAMOND	P,T	AR	190.5	625	1987-2001
BUCKLEY 1 NE	P, T		208.8	685	1913-
CEDAR FALLS 4 SE	P	S	519.1	1703	1961-1976
CEDAR FALLS 5 SE	P	S	915.0	3002	1961-1976
CEDAR FALLS 7 SSE	P	S	732.1	2402	1953-1976
CEDAR FALLS 7 SE	P	S	548.9	1801	1948-1976
CEDAR LAKE	P, T	C	475.5	1560	1898-
GREENWATER	P, T	C	527.3	1730	1939-1980
GREENWATER	P	C	527.3	1730	1981-1998
KENT	P, T		9.1	30	1912-
LAKE KEECHELUS	P, T		755.9	2480	1907-1977
LANDSBURG	P, T	C	163.1	535	1903-
LESTER	P, T	C	497.1	1631	1904-12, 26-40, 60-74
LESTER 2 E	P	S	534.0	1752	1934-1960
LESTER 8 N	P	S	1036.9	3402	1961-1976
LESTER 5 NW	P	S	641.0	2103	1948-1970
LESTER 5 NE	P	S	603.5	1980	1948-1968
LESTER 5 NNE	P	S	946.1	3104	1960-1976
LESTER 7 NNW	P	S	732.1	2402	1948-1976
LESTER 8 NNW	P	S	732.1	2402	1948-1976
LESTER 10 NNW	P	S	579.1	1900	1948-1976
MUD MOUNTAIN DAM	P, T	C	398.7	1308	1939-
PALMER 3 ESE	P, T	C	280.4	920	1924-
PALMER 5 SE BEAR CREEK	P	S	335.9	1102	1948-1955
PALMER 7 SE CHARLEY CREEK	P	S	488.0	1601	1948-1955
PUYALLUP 2 W EXP STN	P, T		15.2	50	1914-1995
RAVENSDALE	P, T	C	237.1	778	2002-
SEATTLE CITY OFFICE	P, T		4.0	13	1919-1972
SEATTLE WB AIRPORT	P, T	C	9.1	30	1948-1965
SEATTLE TACOMA INTL AIRPORT	P, T	C	112.8	370	1944-
STAMPEDE PASS	P, T	C	1206.7	3959	1943-
TACOMA CITY HALL	P, T		82.0	269	1919-1981
TACOMA #1	P, T		7.6	25	1981-

P = PRECIPITATION T = TEMPERATURE AR = AUTOMATIC REPORTING
C = RECORDING GAGE S = STORAGE GAGE

SNOW COURSES			
SITE	ELEVATION		RECORD
	Meters	Feet	
AIRSTRIP	549	1800	1961-1986
CHARLEY CREEK	366	1200	1961-1986
CITY CABIN	728	2390	1948-
COUGAR MTN (P) - SNOTEL	975	3200	1967-
GRASS MTN #2	884	2900	1961-1999
GRASS MTN #3	640	2100	1961-1988
LESTER CREEK	945	3100	1961-
LYNN LAKE (P) - SNOTEL	1189	3900	1961-
MT. LINDSAY	762	2500	1951-1981
MT. WASHINGTON	914	3000	1954-1981
REX RIVER	732	2400	1954-1981
REX RIVER (P) - SNOTEL	1161	3810	1995-
SAWMILL RIDGE (P) - SNOTEL	1414	4640	1961-
SNOWSHOE BUTTE	1524	5000	1968-1982
STAMPEDE PASS (P) - SNOTEL	1173	3850	1945-
TUNNEL AVENUE	747	2450	1941-1999
TWIN CAMP	1250	4100	1961-

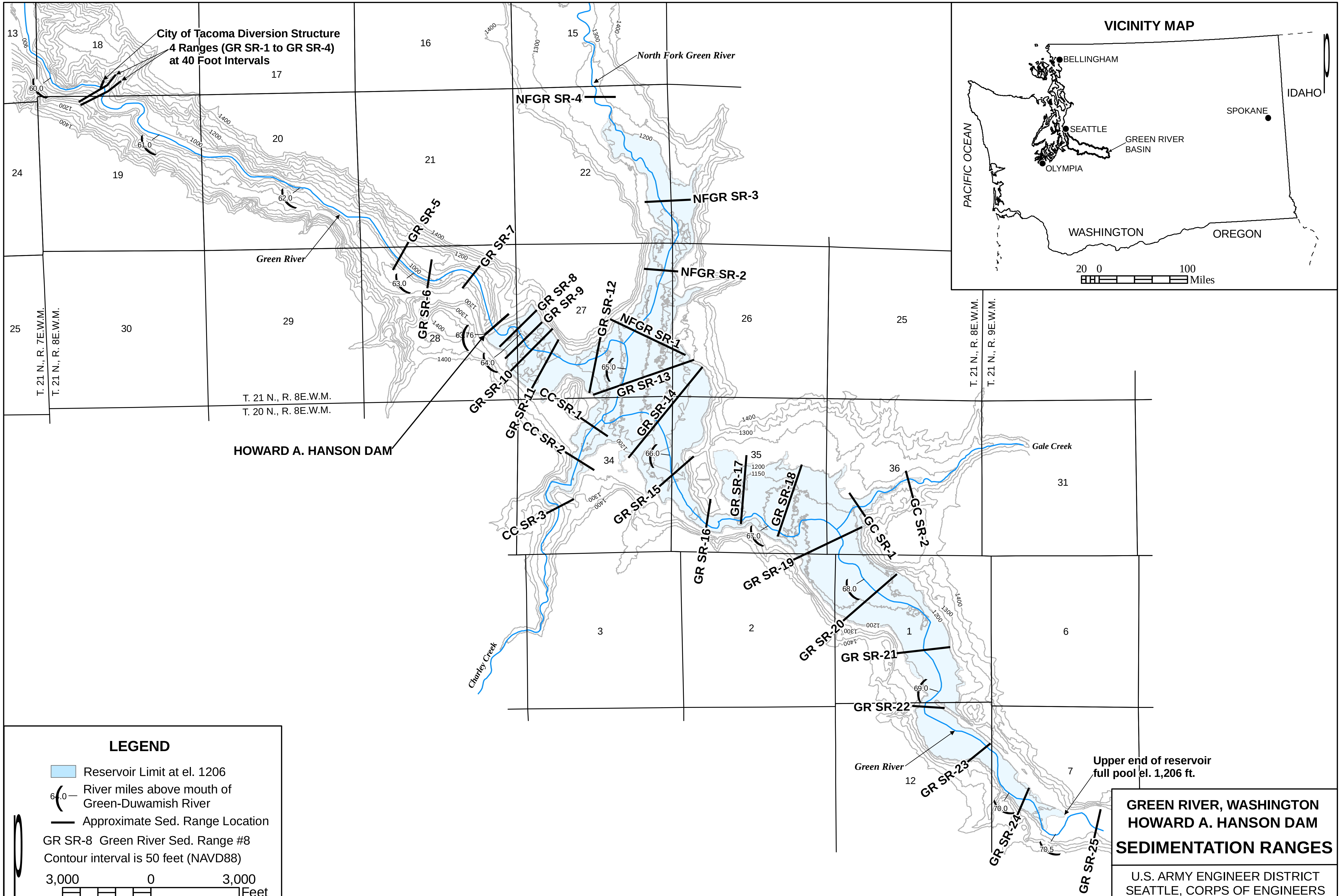
LEGEND: (P) = SNOW PILLOW

GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM

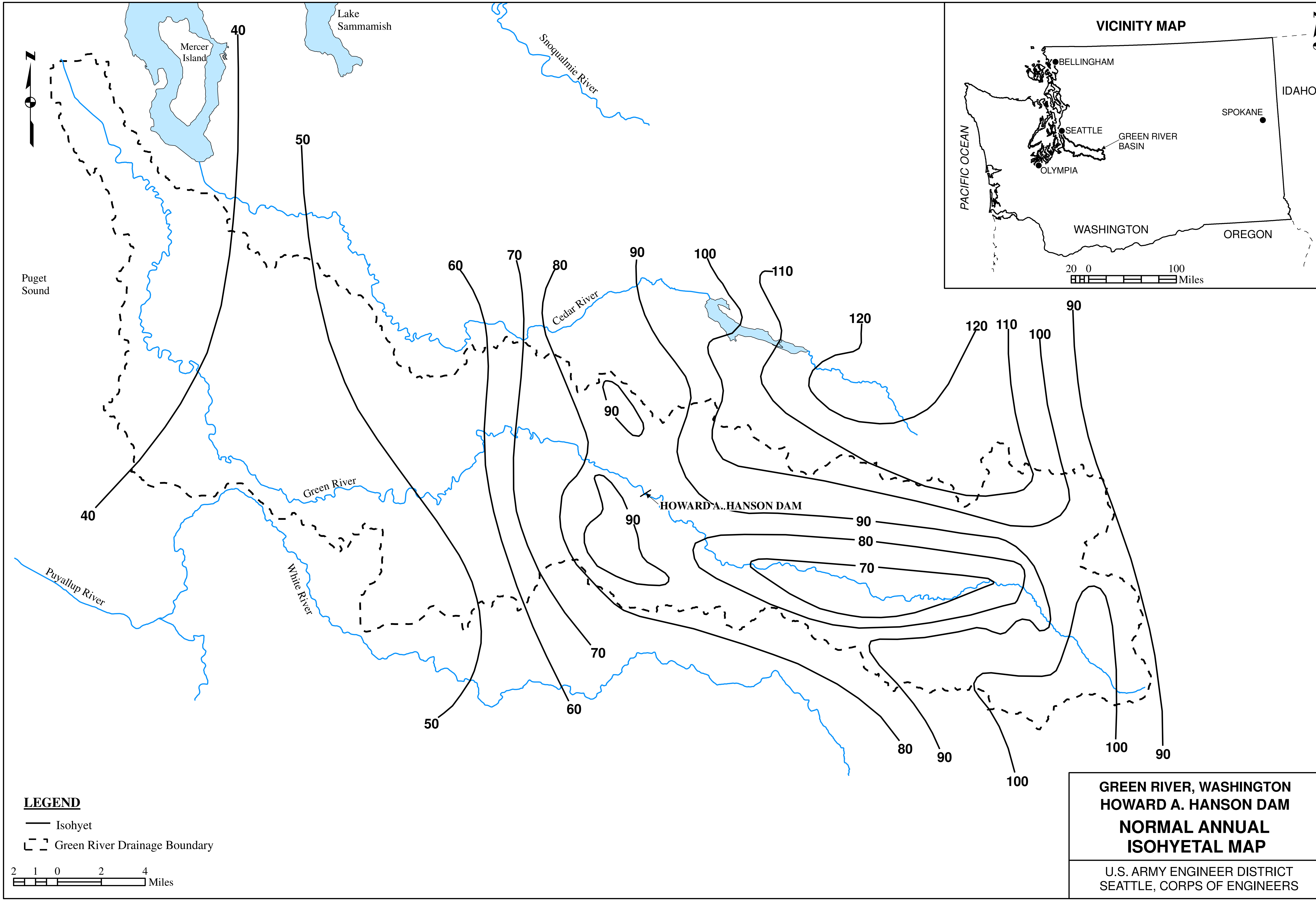
HYDROLOGIC STATION MAP

U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS

PLATE 4 - 1



City of Tacoma Diversion Structure
4 Ranges (GR SR-1 to GR SR-4)
at 40 Foot Intervals
North Fork Green River
NFGR SR-4
NFGR SR-3
NFGR SR-2
NFGR SR-1
Green River
GR SR-5
GR SR-6
GR SR-7
GR SR-8
GR SR-9
GR SR-10
GR SR-11
GR SR-12
GR SR-13
GR SR-14
GR SR-15
GR SR-16
GR SR-17
GR SR-18
GR SR-19
GR SR-20
GR SR-21
GR SR-22
GR SR-23
GR SR-24
GR SR-25
CC SR-1
CC SR-2
CC SR-3
GC SR-1
GC SR-2
Gale Creek
Charley Creek
HOWARD A. HANSON DAM
T. 21 N., R. 7E.W.M.
T. 21 N., R. 8E.W.M.
T. 20 N., R. 8E.W.M.
T. 21 N., R. 9E.W.M.
Upper end of reservoir
full pool el. 1,206 ft.
VICINITY MAP
BELLINGHAM
SEATTLE
OLYMPIA
SPOKANE
GREEN RIVER BASIN
PACIFIC OCEAN
WASHINGTON
OREGON
IDAHO
20 0 100 Miles
LEGEND
Reservoir Limit at el. 1206
River miles above mouth of Green-Duwamish River
Approximate Sed. Range Location
GR SR-8 Green River Sed. Range #8
Contour interval is 50 feet (NAVD88)
3,000 0 3,000 Feet
GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
SEDIMENTATION RANGES
U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS



VICINITY MAP
BELLINGHAM
SEATTLE
GREEN RIVER BASIN
OLYMPIA
SPOKANE
IDAHO
PACIFIC OCEAN
WASHINGTON
OREGON
20 0 100
Miles
Lake Sammamish
Mercer Island
Snoqualmie River
Puget Sound
Cedar River
Green River
HOWARD A. HANSON DAM
Puyallup River
White River
40
50
60
70
80
90
100
110
120
LEGEND
Isohyet
Green River Drainage Boundary
2 1 0 2 4
Miles
GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
NORMAL ANNUAL ISOHYETAL MAP
U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS

Number	Station	Record
12103380	Green River Above Twin Camp Creek Near Lester	1992-1999
12103400	Green River Below Intake Creek Near Lester	1966-1977
12103500	Snow Creek Near Lester	1945-1965
12104000	Friday Creek Near Lester	1945-1977
12104500	Green River Near Lester	1946-90, 1993
12104700	Green Canyon Creek Near Lester	1960-1970
12105000	Smay Creek Near Lester	1947-1970
12105500	Charley Creek Near Eagle Gorge	1947-1955
12105700	North Fork Green River Near Palmer	1957-1965
12105710	North Fork Green River Near Lemolo	1965-1987
12105800	Howard A. Hanson Reservoir Near Palmer	1961-
12105900	Green River Below Howard A. Hanson Dam	1960-
12106000	Bear Creek Near Eagle Gorge	1947-1956
12106500	Green River Near Palmer	1932-1963
12106700	Green River At Purification Plant Near Palmer	1963-
12107300	Icy Creek Near Black Diamond	1963-1968
12107500	Green River Near Black Diamond	1939-1948
12107950	North Fork Newaukum Creek Near Enumclaw	1977-1978
12108500	Newaukum Creek Near Black Diamond	1944-50, 1952-
12109500	Little Soos Creek Near Kent	1945-1986
12110000	Big Soos Creek Above Jenkins Creek Near Auburn	1944-1986
12110003	Wilderness Lake Outlet Near Maple Valley	1977
12110400	SF Jenkins Creek Near Covington	1985-1986
12111000	Lake Sawyer Near Black Diamond[1]	1973
12111500	Covington Creek Near Black Diamond	1953-1960
12112000	Covington Creek Near Auburn	1944-1945
12112500	Big Soos Creek Near Auburn	1944-1956
12112550	Soosette Creek Near Auburn	1985-1986
12112600	Big Soos Creek Above Hatchery near Auburn, WA	1960-
12113000	Green River Near Auburn	1936-
12113346	Springbrook Creek At Orillia	1993-
12113347	Mill Creek At Earthworks Park At Kent	1994-
12113349	Mill Creek Near Mouth At Orillia	1994-
12113350	Green River At Tukwila	1960-1984
12113375	Springbrook Creek At Tukwila[1]	1996-1997
12113390	Duwamish River At Golf Course At Tukkwila[1]	1996-2004

[1] Water Quality Readings Only

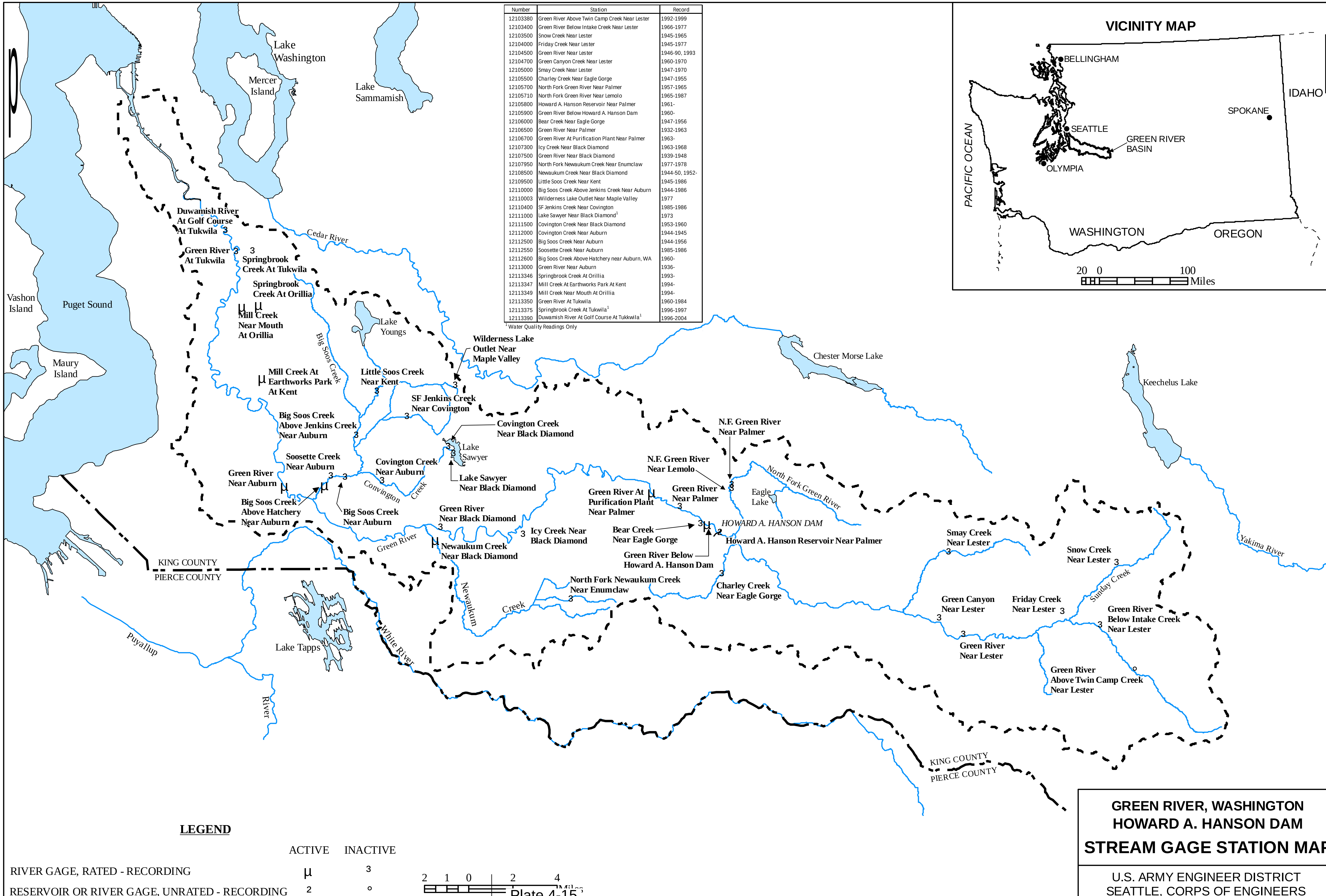
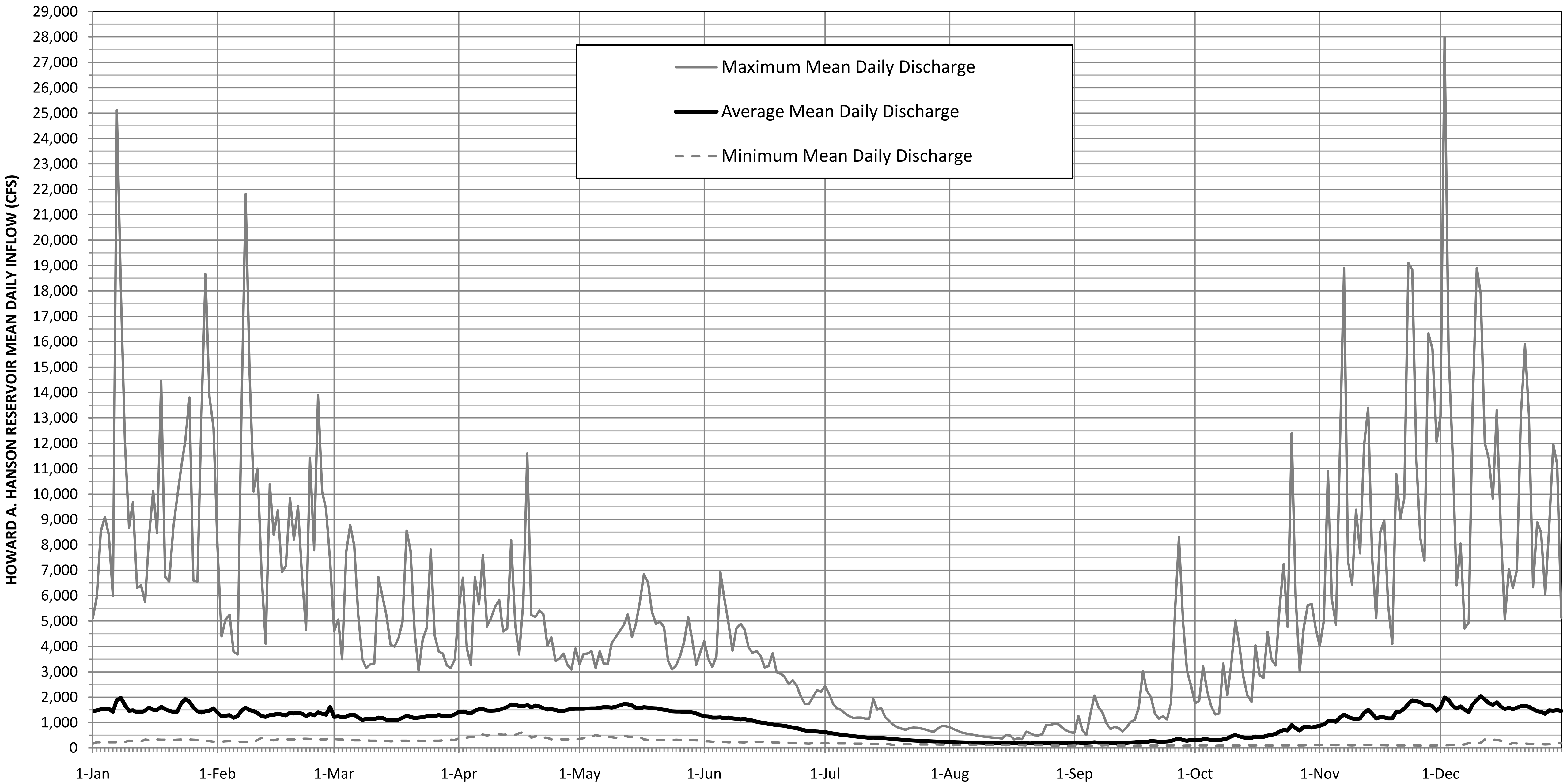


Plate 4-15

GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
STREAM GAGE STATION MAP

U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS

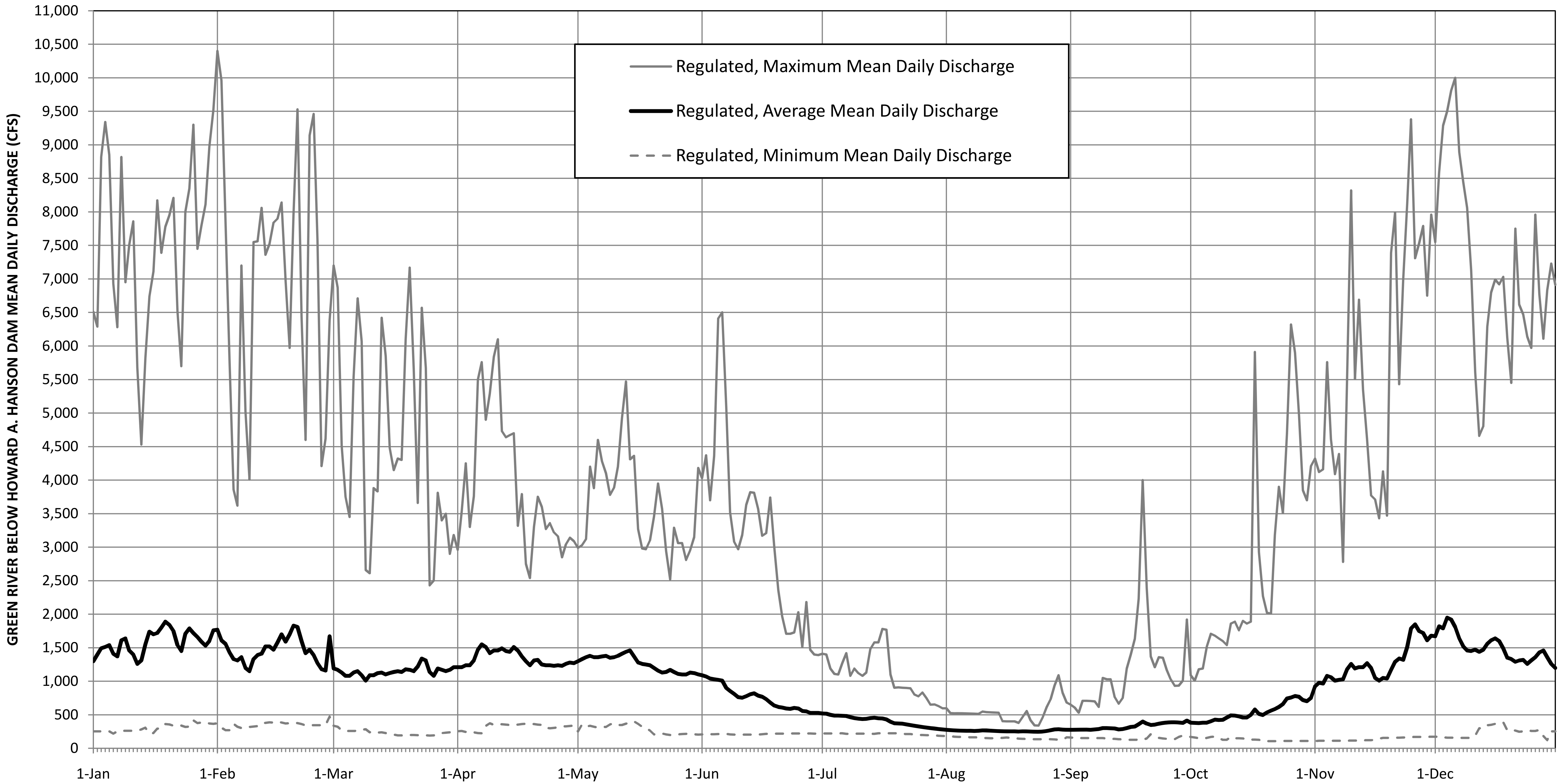


NOTES:

1. DATA OBTAINED FROM USGS GAGE #12106500 FOR THE TIME PERIOD: 1 OCT 1931 - 31 DEC 1961
2. INFLOW DATA CALCULATED FROM DAILY HAH VOLUME CHANGES, AND HAH MEAN DAILY DISCHARGE FOR TEH TIME PERIOD 1 JAN 1962 - 14 OCT 2009
3. PERIOD OF RECORD RECORD FOR SUMMARY HYDROGRAPH: 1 OCT 1931 - 14 OCT 2009
4. DRAINAGE AREA AT HAH DAM = 220 SQUARE MILES,
   DRAINAGE AREA AT USGS GAGE 312106500 = 230 SQUARE MILES

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HOWARD A. HANSON RESERVOIR
MEAN DAILY INFLOW
SUMMARY HYDROGRAPH

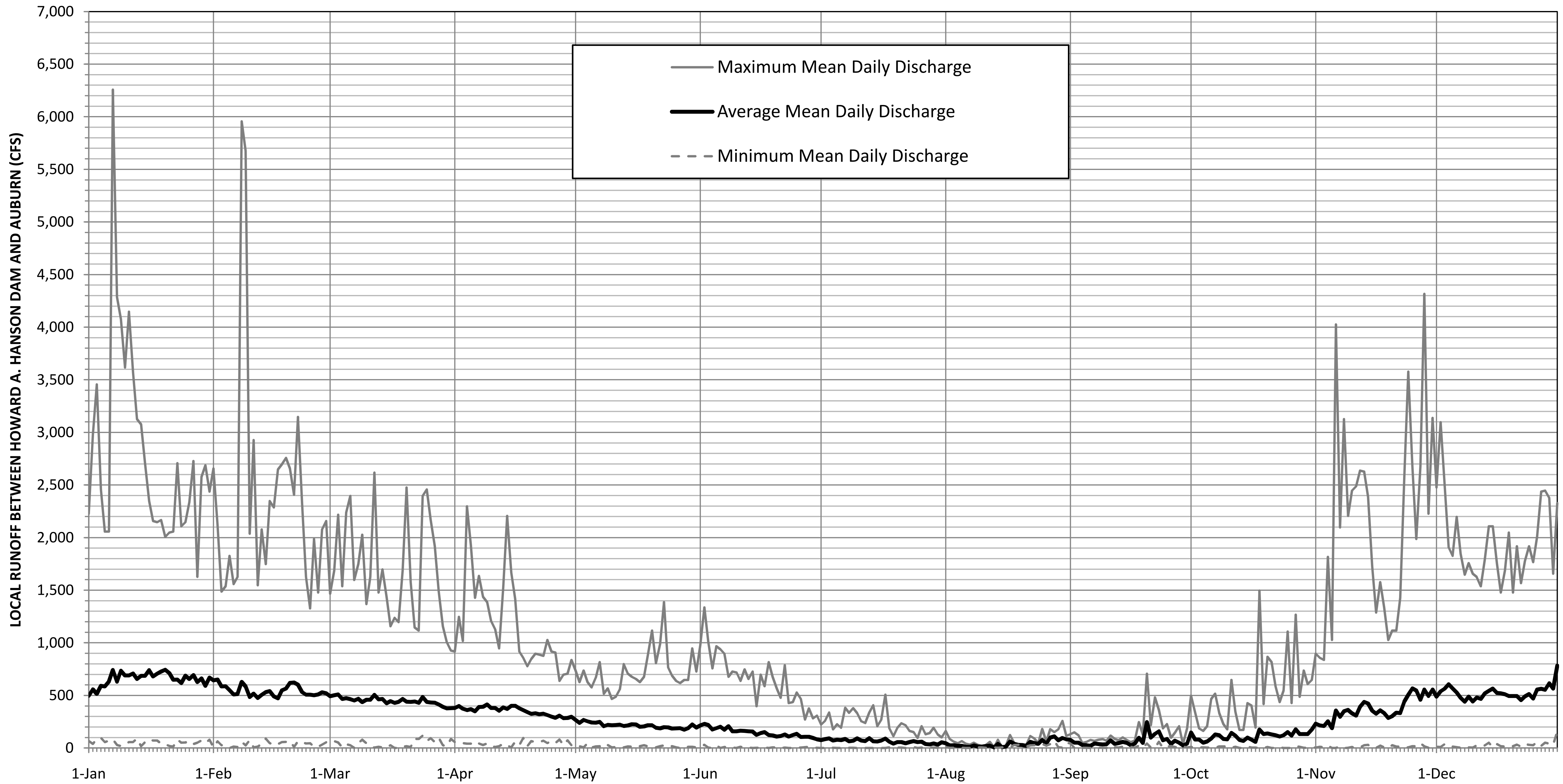


NOTES:

1. DATA OBTAINED FROM USGS GAGE #12105900 FOR THE TIME PERIOD: 1 JAN 1962 - 30 SEPT 2005
2. PERIOD OF RECORD RECORD FOR SUMMARY HYDROGRAPH: 1 JAN 1962 - 30 SEPT 2005
3. DRAINAGE AREA = 221 SQUARE MILES

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

GREEN RIVER BELOW HAH DAM
REGULATED MEAN DAILY DISCHARGE
SUMMARY HYDROGRAPH

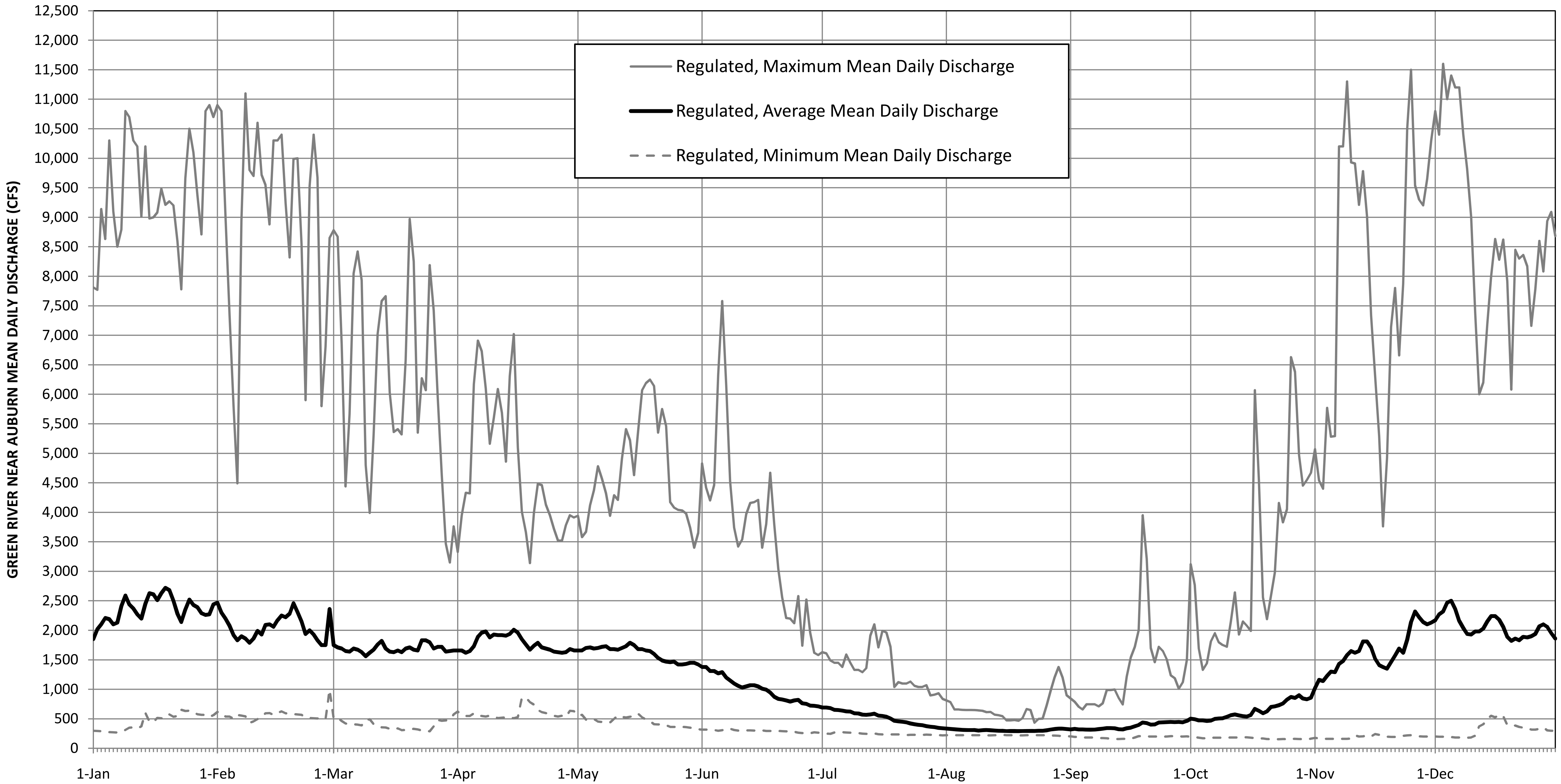


NOTES:

1. DATA OBTAINED FROM USGS GAGE #12113000 AND #12105900 FOR THE TIME PERIOD: 1 JAN 1962 - 31 DEC 2009
2. ASSUMES 113 CFS CONSTANT WITHDRAWAL BY CITY OF TACOMA
3. PERIOD OF RECORD RECORD FOR SUMMARY HYDROGRAPH: 1 JAN 1962 - 31 DEC 2009
4. NEGATIVE VALUES TREATED AS MISSING DATA

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HANSON DAM TO AUBURN LOCAL RUNOFF SUMMARY HYDROGRAPH

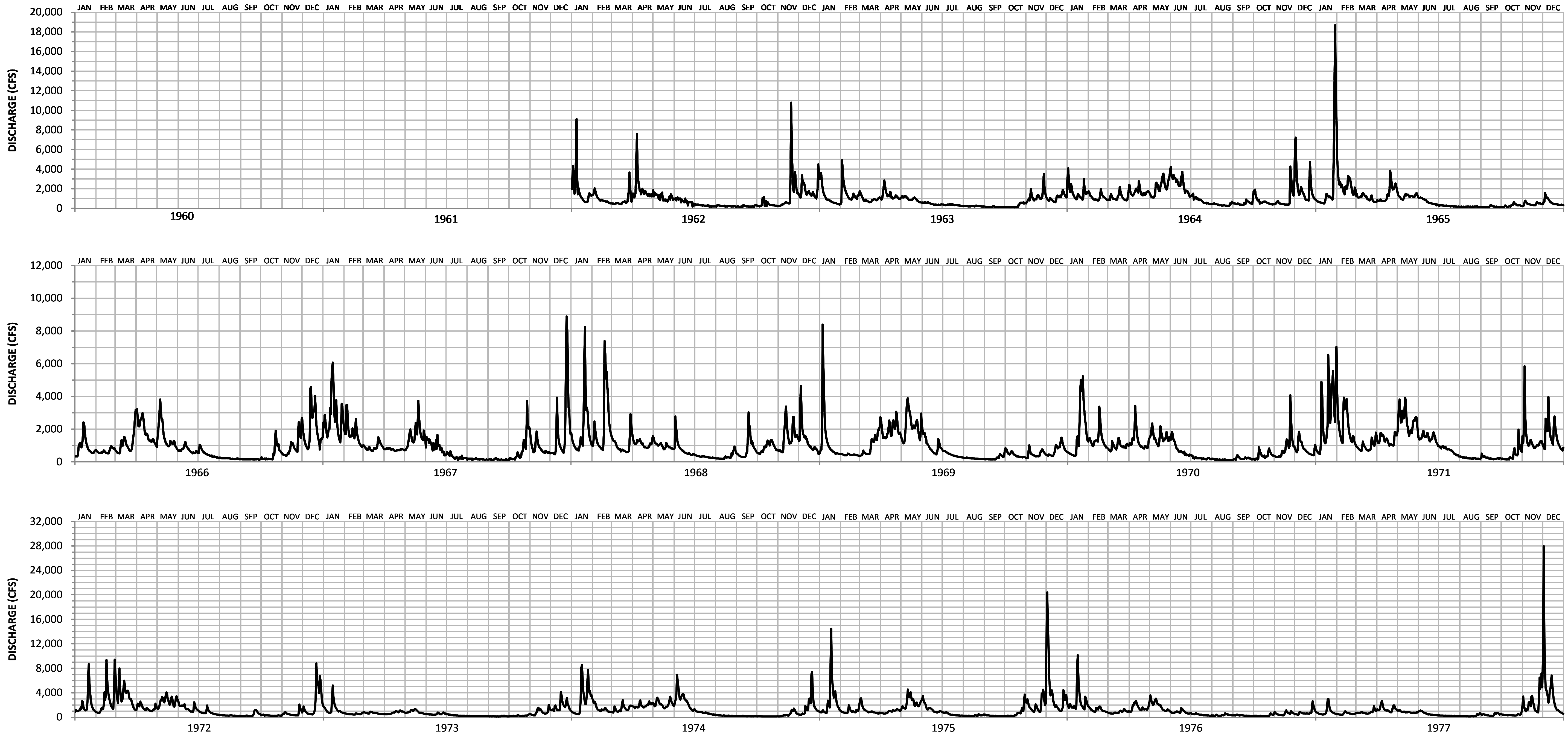


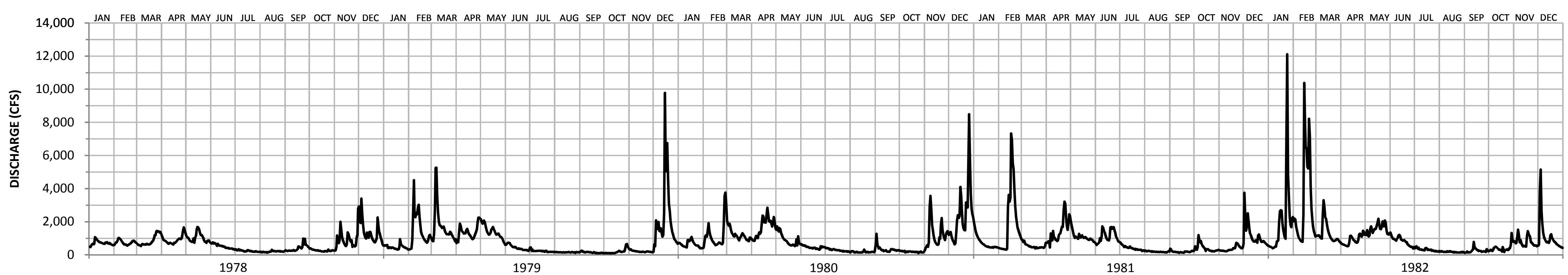
NOTES:

1. DATA OBTAINED FROM USGS GAGE #12113000 FOR THE TIME PERIOD: 1 JAN 1962 - 30 SEPT 2005
2. PERIOD OF RECORD RECORD FOR SUMMARY HYDROGRAPH: 1 JAN 1962 - 30 SEPT 2005
3. DRAINAGE AREA = 399 SQUARE MILES
4. MAXIMUM CITY OF TACOMA FIRST DIVERSION WATER RIGHT = 113 CFS (SINCE 1913)
5. MAXIMUM CITY OF TACOMA SECOND DIVERSION WATER RIGHT = 100 CFS (SINCE 2007)

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

GREEN RIVER NEAR AUBURN
REGULATED MEAN DAILY DISCHARGE
SUMMARY HYDROGRAPH



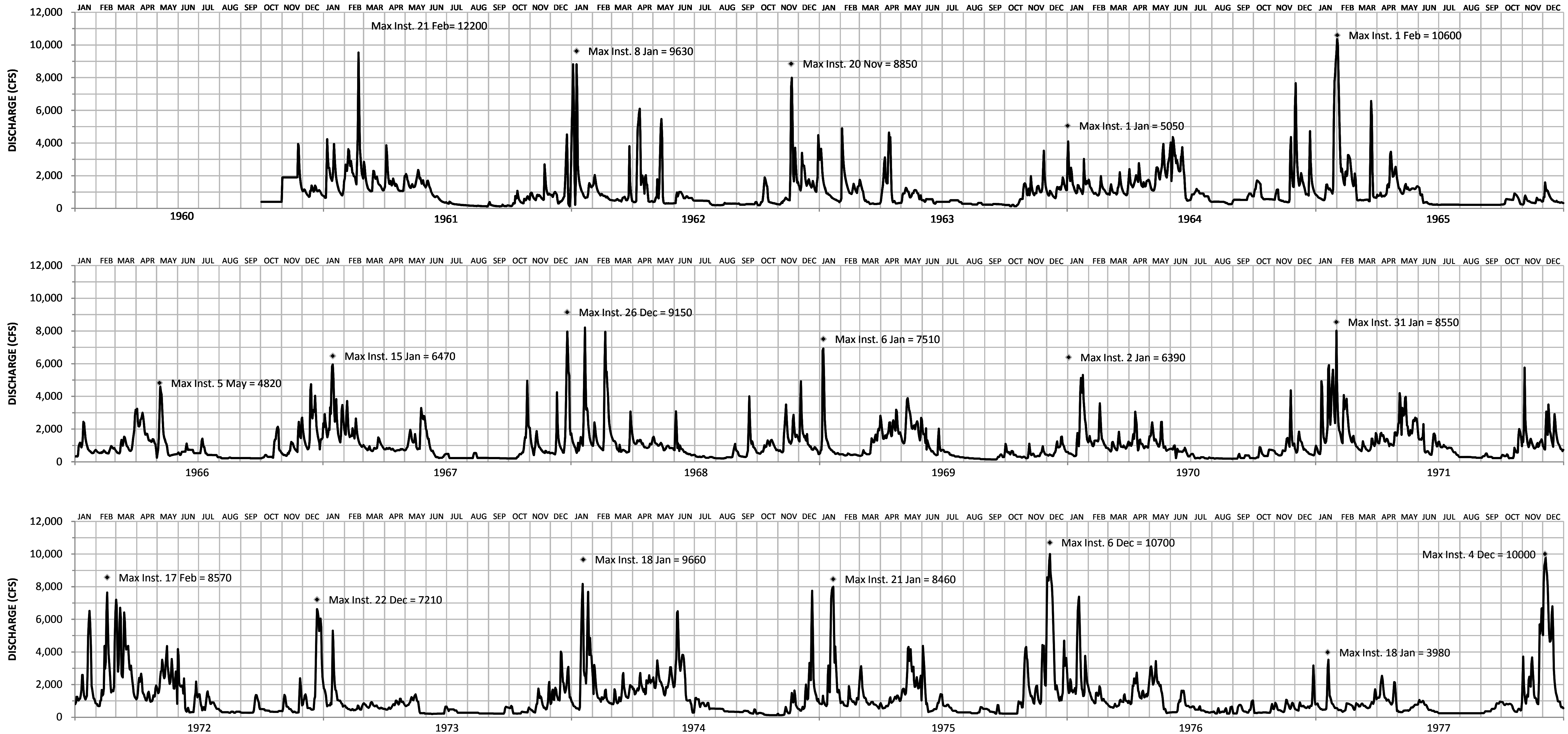


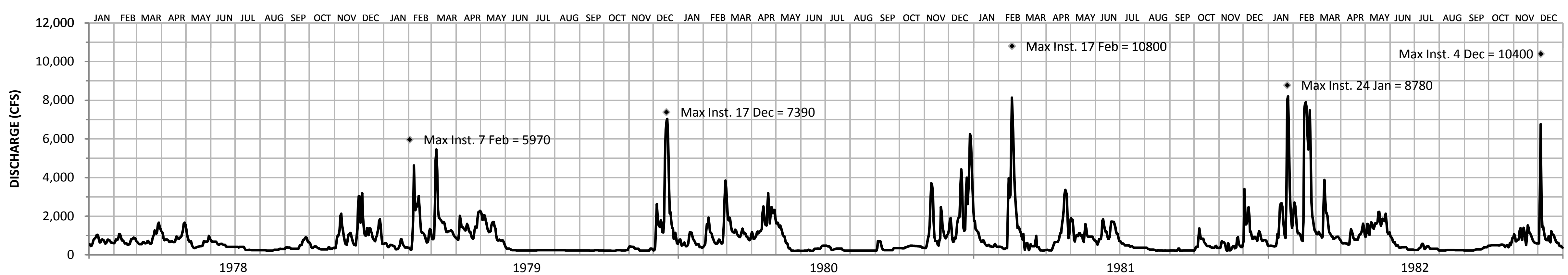
Notes:
1. Source of Information: CENWS
2. Drainage Area = 220 square miles
3. Period of Record: 1962 - 2009
4. Mean Annual Discharge = 991 cfs
5. Mean Annual Volume = 718,000 acre-feet
6. Based on Outflow at Gage and Change in Storage

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT
SEATTLE, WASHINGTON

Green River Inflow to Howard A. Hanson Reservoir
Mean Daily Discharge Hydrographs

Developed	Checked	Date	Sheet
HRH		JUL 2010	1 of 3





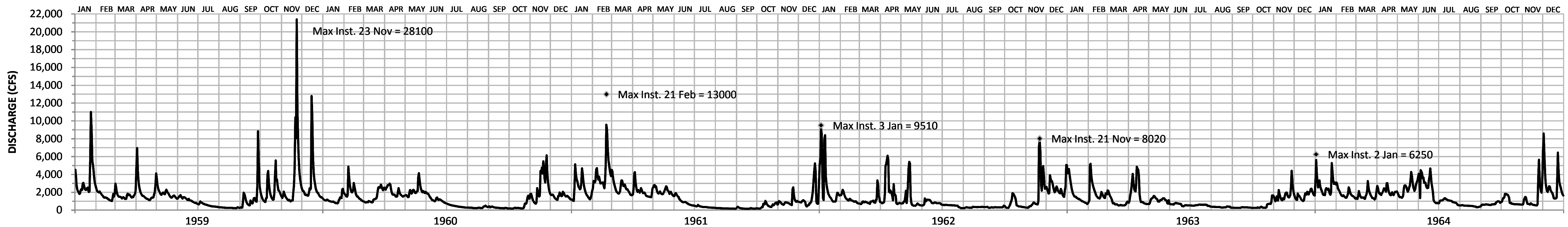
Notes:
1. Source of Information: USGS Water Supply Papers
2. Drainage Area = 221 square miles
3. Period of Record: 1960 - 2009
4. Mean Annual Discharge = 991 cfs
5. Mean Annual Volume = 718,000 acre-feet
6. Flow Regulated by Howard A. Hanson Reservoir

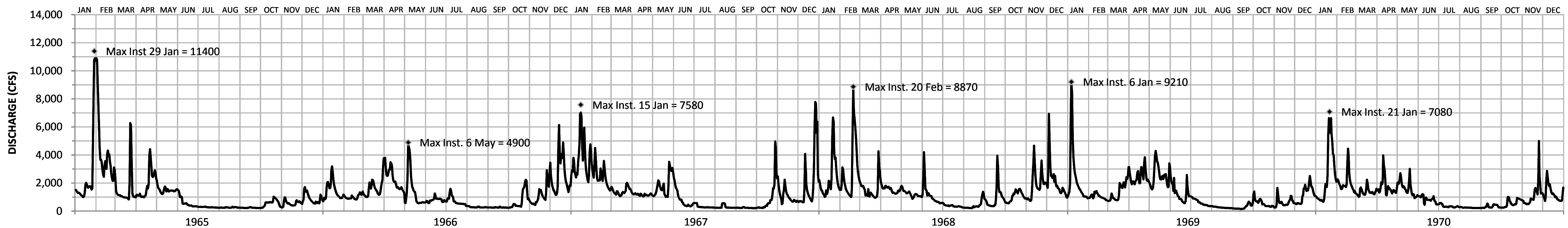
U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT
SEATTLE, WASHINGTON

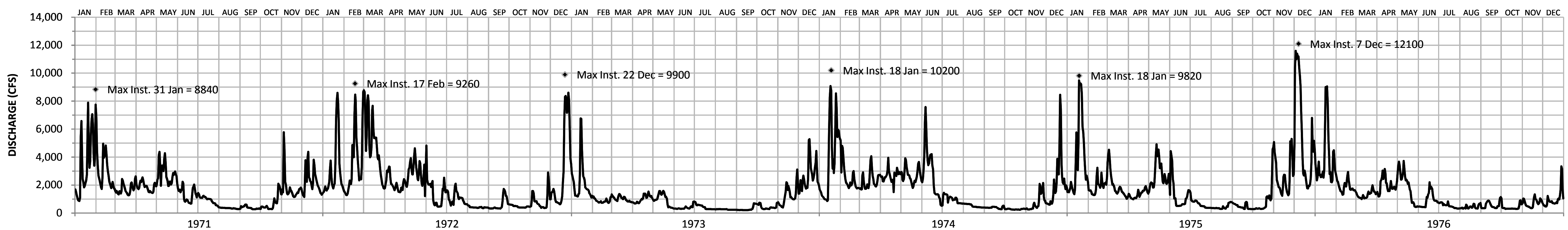
Green River Below Howard A. Hanson Reservoir
Mean Daily Discharge Hydrographs
U.S.G.S. Gage No. 12105900

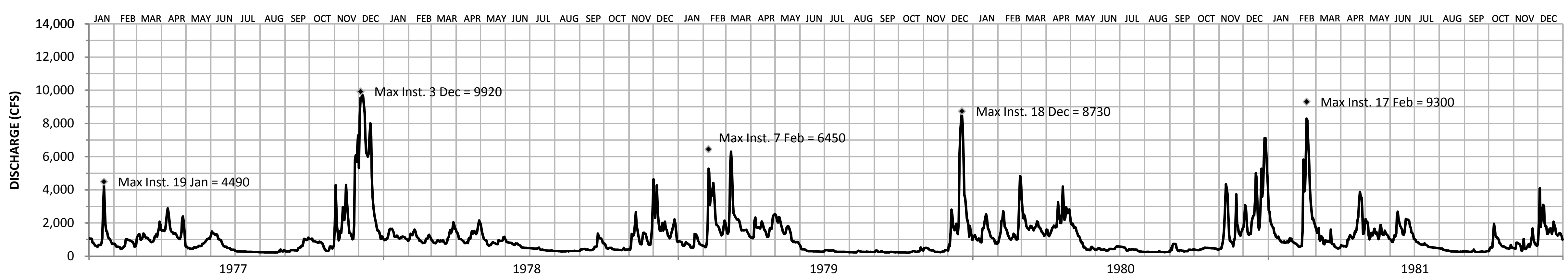
Developed	Checked	Date	Sheet
HRH		JUN 2010	1 of 3

Plate 4-10







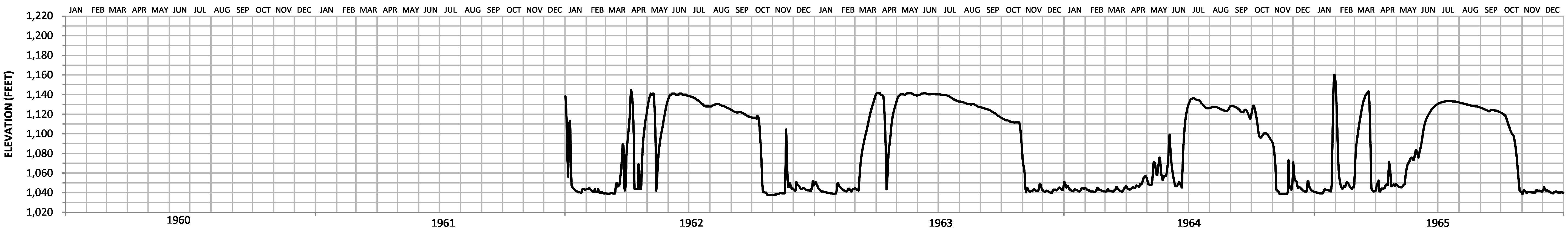


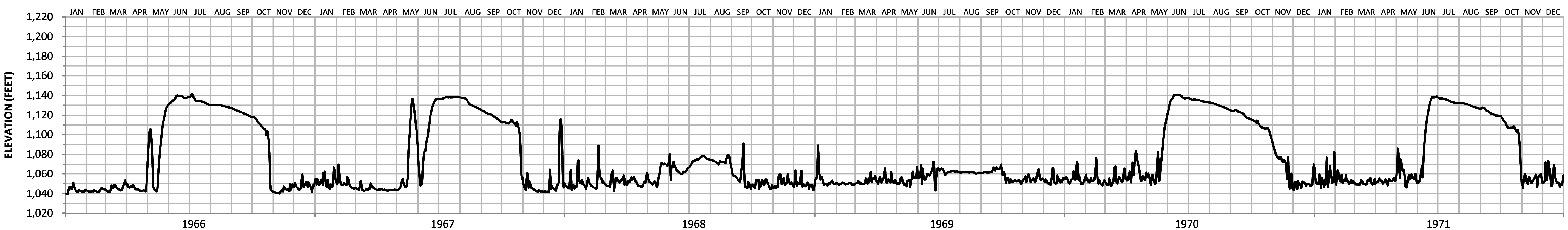
Notes:
1. Source of Information: USGS
2. Drainage Area = 399 square miles
3. Period of Record: 1937 - 2009
4. Mean Annual Discharge = 1,331 cfs
5. Mean Annual Volume = 964,200 acre-feet
6. Flow Regulated by Howard A. Hanson Reservoir

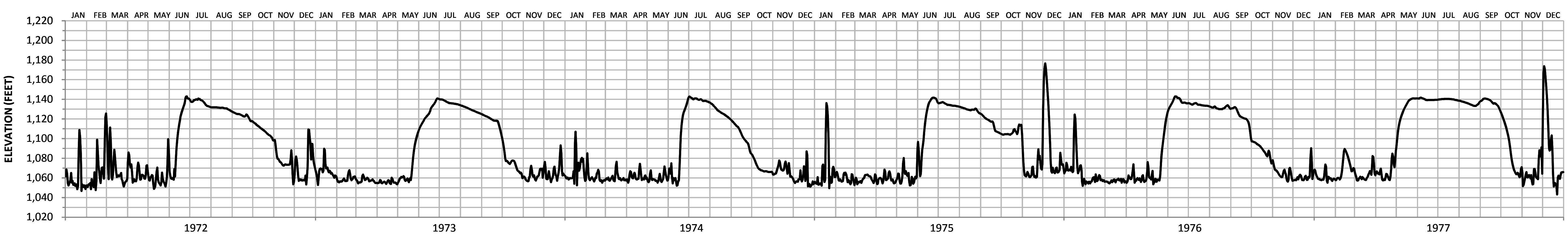
U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT
SEATTLE, WASHINGTON

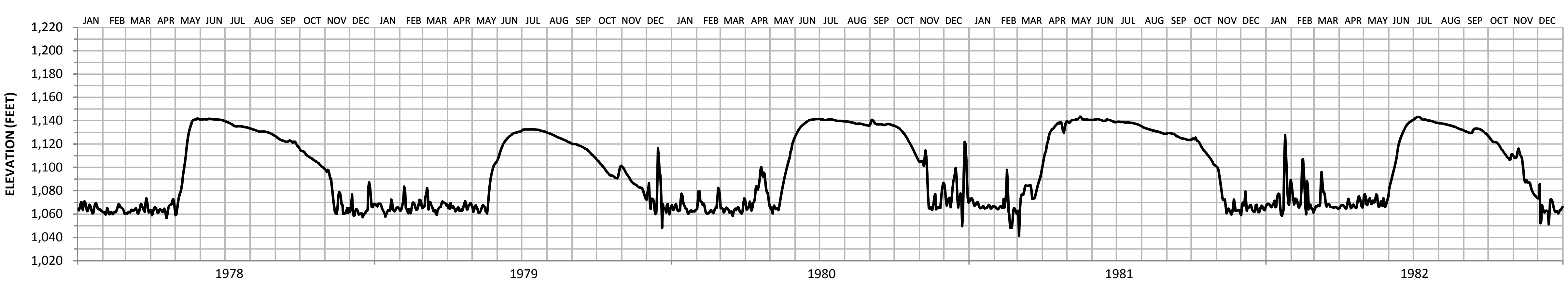
Green River Near Auburn, Washington
Mean Daily Discharge Hydrographs
U.S.G.S. Gage No. 12113000

Developed	Checked	Date	Sheet
HRH		JUL 2010	2 of 4







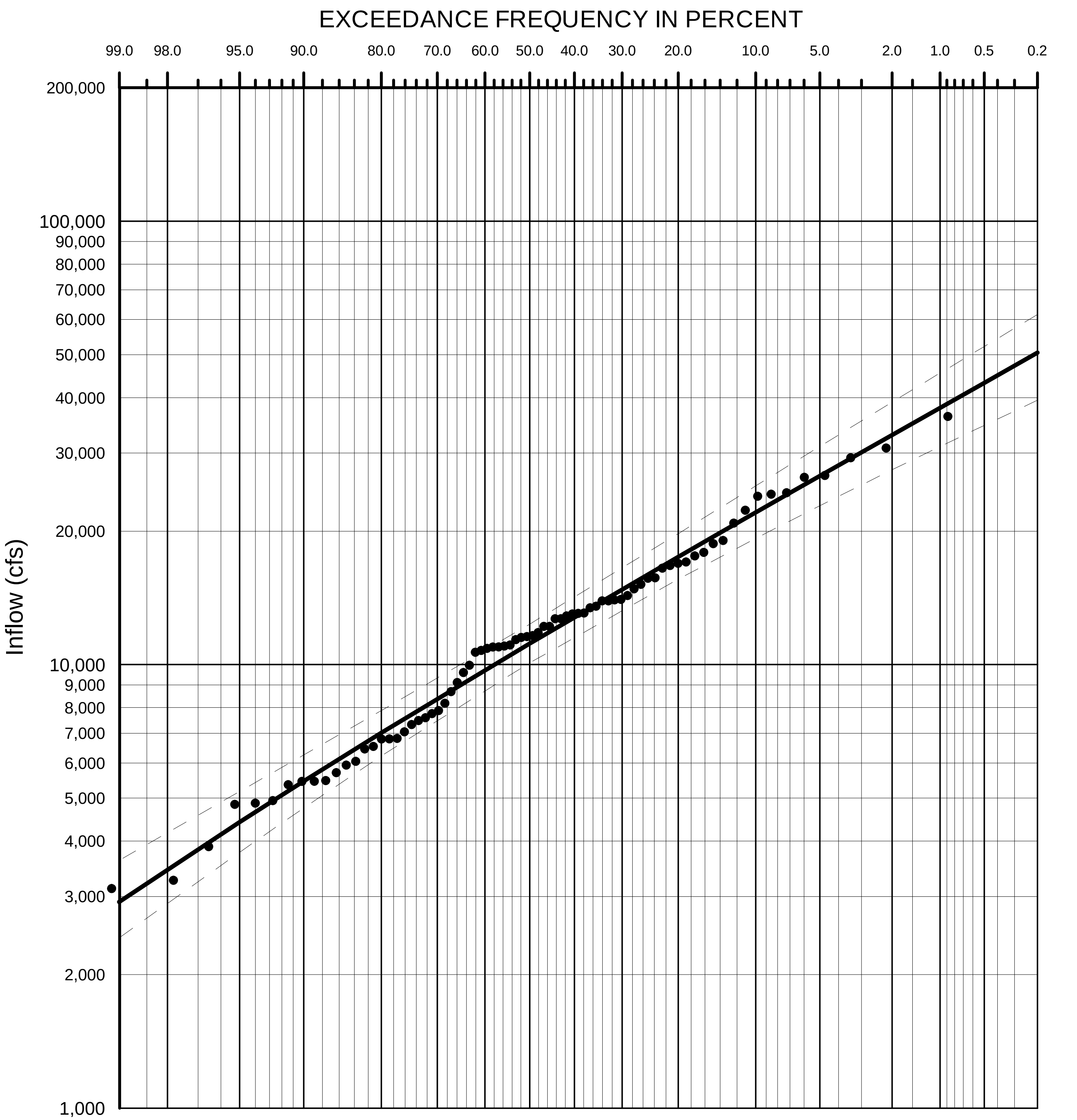


Notes:
1. Source of Information: CENWS
2. Drainage Area = 220 square miles
3. Period of Record: 1962 - 2009
4. Daily Elevation Readings Taken at 00:00 hours
5. Missing Data are Indicated by Gaps

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT
SEATTLE, WASHINGTON

Green River at Howard A. Hanson Reservoir
Daily Reservoir Elevations

Developed	Checked	Date	Sheet
HRH		JUL 2010	1 of 3



FLOW FREQUENCY WITH EXPECTED PROBABILITY

MEDIAN PLOTTING POSITIONS

5% AND 95% CONFIDENCE LIMITS

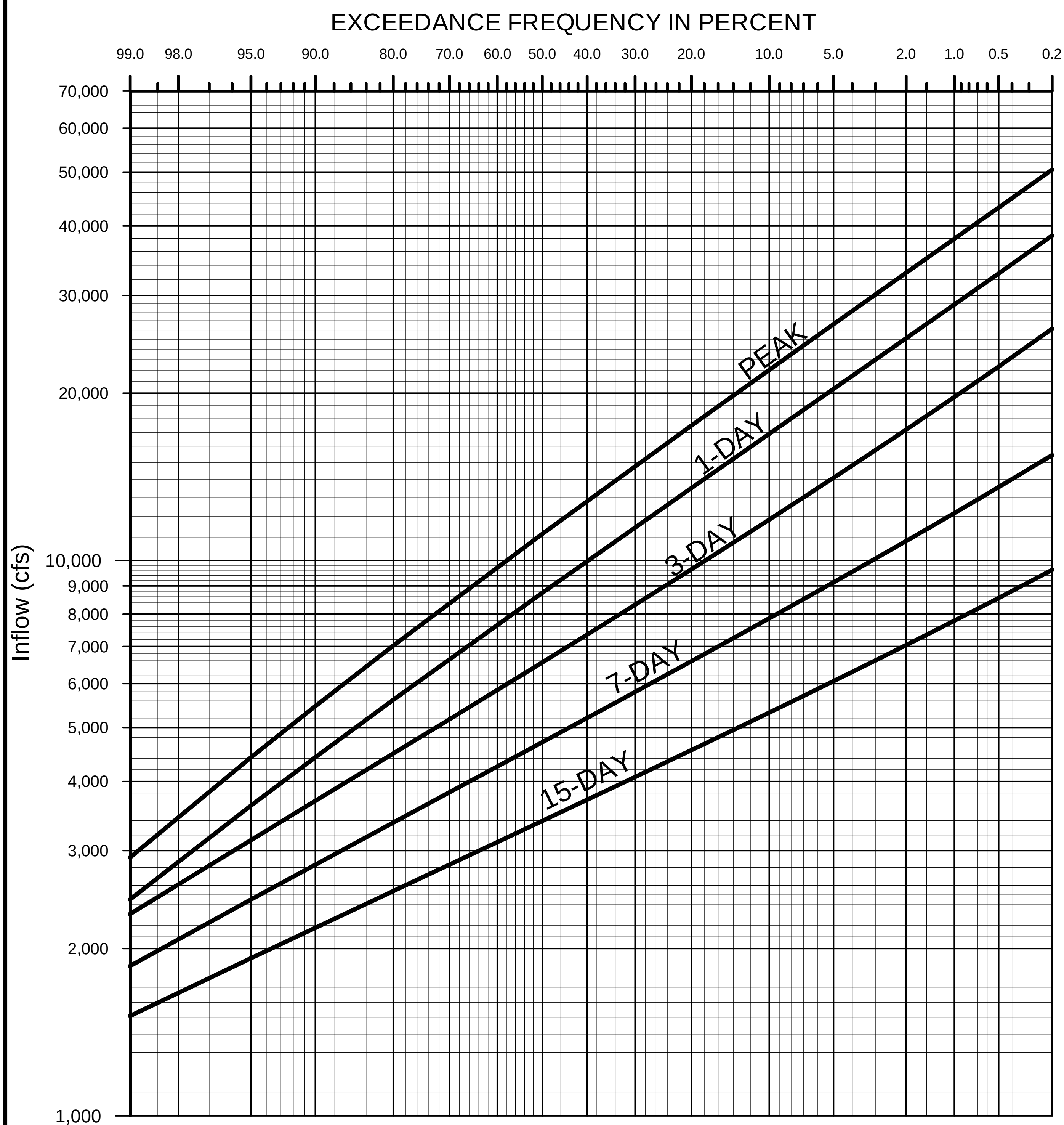
Maximum Annual Peak Frequency Curve
Inflow to H.A. Hanson Reservoir
Fit based on Pearson Type III Distribution
R.M. 64.5
Lat. 47.277 Long 121.784

CORPS OF ENGINEERS, SEATTLE DISTRICT
30 OCTOBER 2009
BASIN AREA = 220.0 SQ. MI.
WATER YEARS OF RECORD
1932-2009

SYSTEMATIC STATISTICS LOG TRANSFORM OF FLOW	
MEAN=	4.043
ST. DEV.=	0.233
STATION SKEW=	-0.144
REGIONAL SKEW=	0.000
WEIGHTED SKEW=	-0.115
ADOPTED SKEW=	-0.115

NUMBER OF EVENTS	
HISTORIC EVENTS=	0
HIGH OUTLIERS=	0
LOW OUTLIERS=	0
ZERO OR MISSING=	0
SYSTEMATIC EVENTS=	78

CONSTRUCTED BY:	APPROVED BY:
K. Shaffer, E.I.T.	K. Brettmann, P.E.



FLOW FREQUENCY WITH EXPECTED PROBABILITY

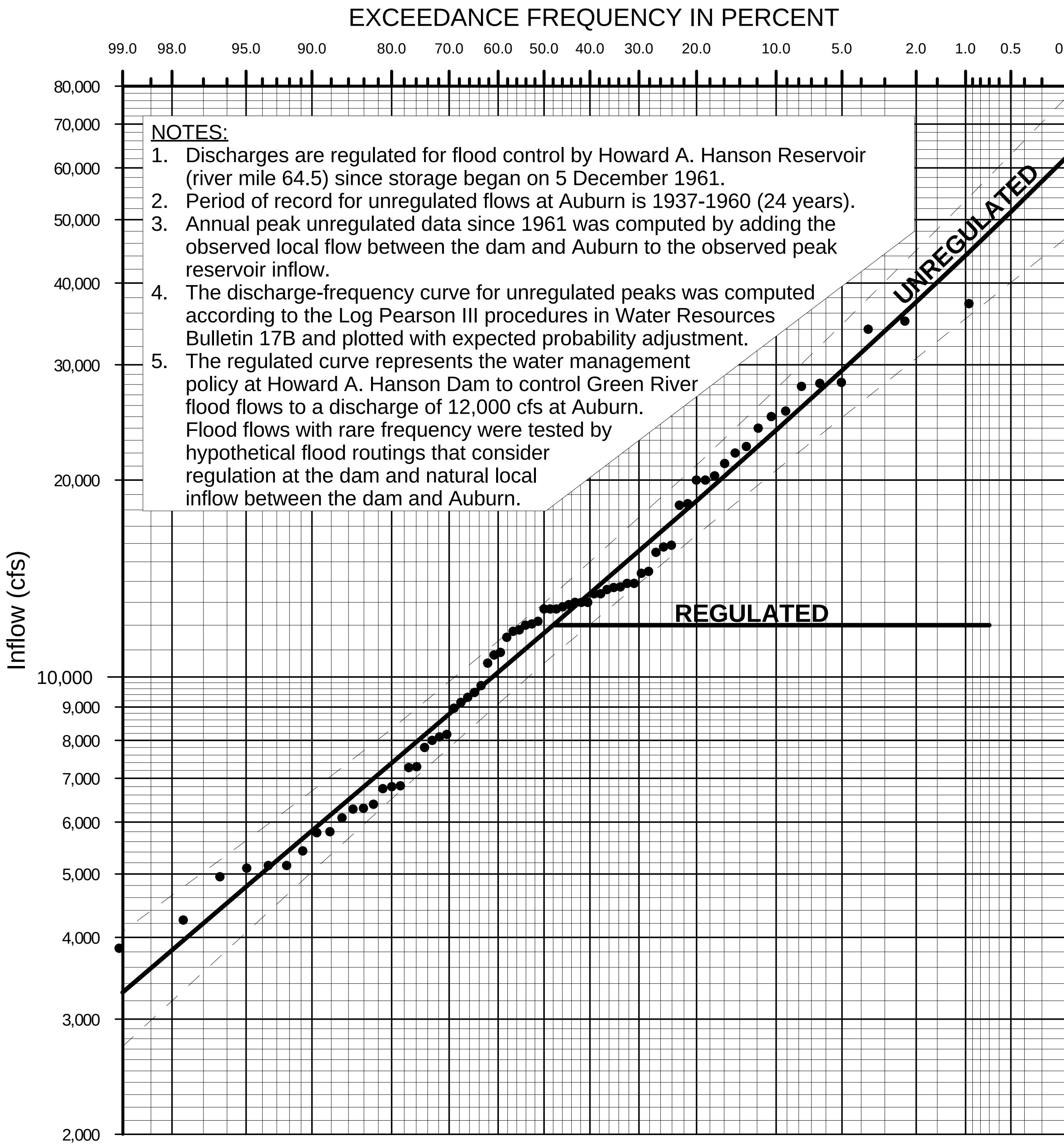
NUMBER OF EVENTS

HISTORIC EVENTS= 0
HIGH OUTLIERS= 0
LOW OUTLIERS= 0
ZERO OR MISSING= 0
SYSTEMATIC EVENTS= 78

Maximum Annual Inflow Frequency Curves
H.A. Hanson Reservoir
Fits based on Pearson Type III Distribution
R.M. 64.5 Elev. 1070 ft.
Lat. 47.277 Long 121.784

CORPS OF ENGINEERS, SEATTLE DISTRICT
5 NOVEMBER 2009
BASIN AREA = 220.0 SQ. MI.
WATER YEARS OF RECORD
1932-2009

CONSTRUCTED BY:	APPROVED BY:
K. Shaffer, E.I.T.	K. Brettmann, P.E.



FLOW FREQUENCY WITH EXPECTED PROBABILITY

MEDIAN PLOTTING POSITIONS

5% AND 95% CONFIDENCE LIMITS

Maximum Annual Peak Frequency Curve
Green River near Auburn
Regulated and Unregulated Peaks for USGS Site 12113000
Fit based on Pearson Type III Distribution
River Mile 32.0 Elevation 60 feet

CORPS OF ENGINEERS, SEATTLE DISTRICT
10 NOVEMBER 2009
BASIN AREA = 399 SQ. MI.
WATER YEARS OF RECORD
1937-2009

SYSTEMATIC STATISTICS LOG TRANSFORM OF FLOW		NUMBER OF EVENTS	
MEAN=	4.069	HISTORIC EVENTS=	0
ST. DEV.=	0.235	HIGH OUTLIERS=	0
STATION SKEW=	0.079	LOW OUTLIERS=	0
REGIONAL SKEW=	0.000	ZERO OR MISSING=	0
WEIGHTED SKEW=	0.063	SYSTEMATIC EVENTS=	73
ADOPTED SKEW=	0.063		

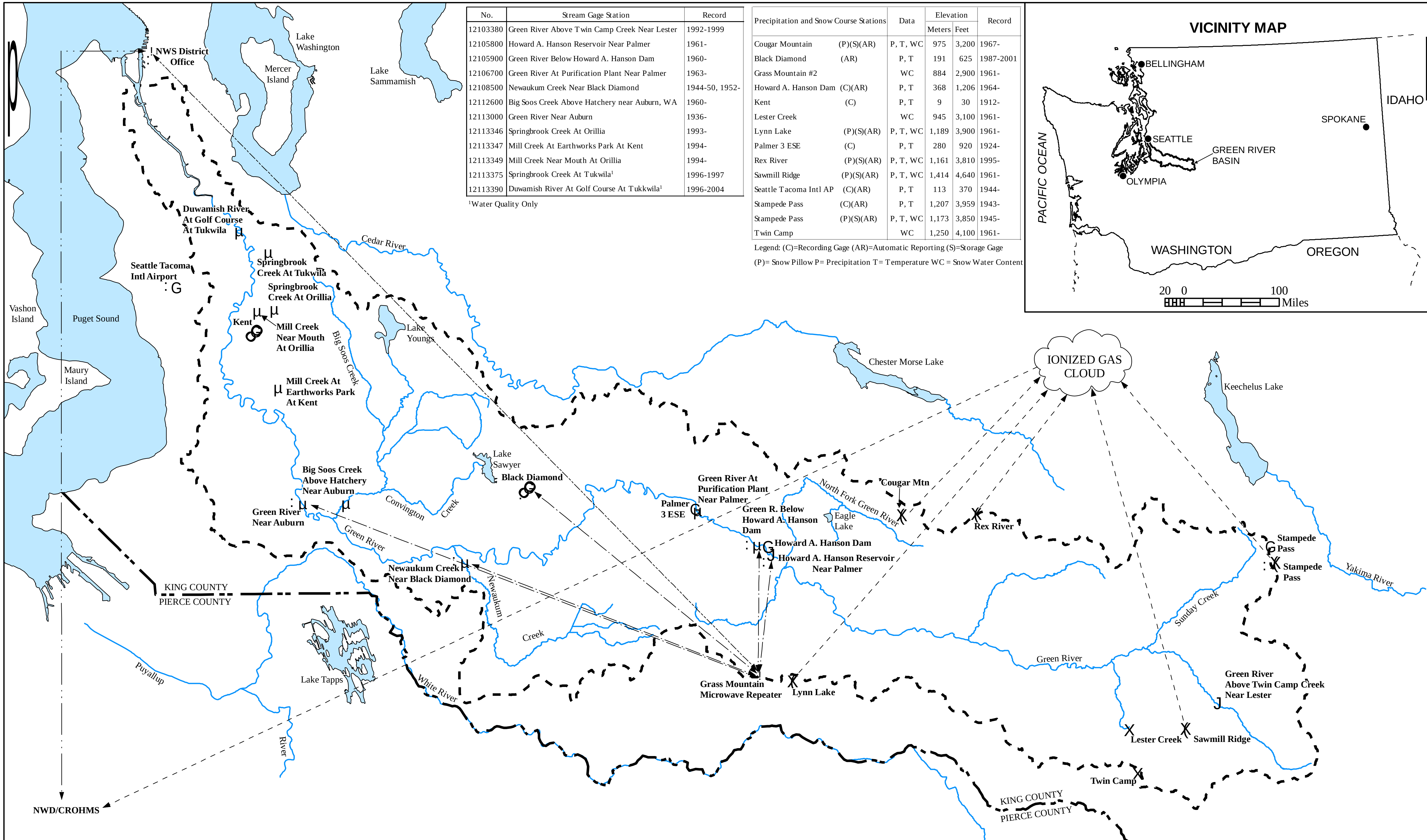
CONSTRUCTED BY:	APPROVED BY:
K. Shaffer, E.I.T.	K. Brettmann, P.E.

No.	Stream Gage Station	Record
12103380	Green River Above Twin Camp Creek Near Lester	1992-1999
12105800	Howard A. Hanson Reservoir Near Palmer	1961-
12105900	Green River Below Howard A. Hanson Dam	1960-
12106700	Green River At Purification Plant Near Palmer	1963-
12108500	Newaukum Creek Near Black Diamond	1944-50, 1952-
12112600	Big Soos Creek Above Hatchery near Auburn, WA	1960-
12113000	Green River Near Auburn	1936-
12113346	Springbrook Creek At Orillia	1993-
12113347	Mill Creek At Earthworks Park At Kent	1994-
12113349	Mill Creek Near Mouth At Orillia	1994-
12113375	Springbrook Creek At Tukwila[1]	1996-1997
12113390	Duwamish River At Golf Course At Tukkwila[1]	1996-2004

[1]Water Quality Only

Precipitation and Snow Course Stations		Data	Elevation		Record
			Meters	Feet	
Cougar Mountain	(P)(S)(AR)	P, T, WC	975	3,200	1967-
Black Diamond	(AR)	P, T	191	625	1987-2001
Grass Mountain #2		WC	884	2,900	1961-
Howard A. Hanson Dam	(C)(AR)	P, T	368	1,206	1964-
Kent	(C)	P, T	9	30	1912-
Lester Creek		WC	945	3,100	1961-
Lynn Lake	(P)(S)(AR)	P, T, WC	1,189	3,900	1961-
Palmer 3 ESE	(C)	P, T	280	920	1924-
Rex River	(P)(S)(AR)	P, T, WC	1,161	3,810	1995-
Sawmill Ridge	(P)(S)(AR)	P, T, WC	1,414	4,640	1961-
Seattle Tacoma Intl AP	(C)(AR)	P, T	113	370	1944-
Stampede Pass	(C)(AR)	P, T	1,207	3,959	1943-
Stampede Pass	(P)(S)(AR)	P, T, WC	1,173	3,850	1945-
Twin Camp		WC	1,250	4,100	1961-

Legend: (C)=Recording Gage (AR)=Automatic Reporting (S)=Storage Gage
(P)= Snow Pillow P= Precipitation T= Temperature WC = Snow Water Content



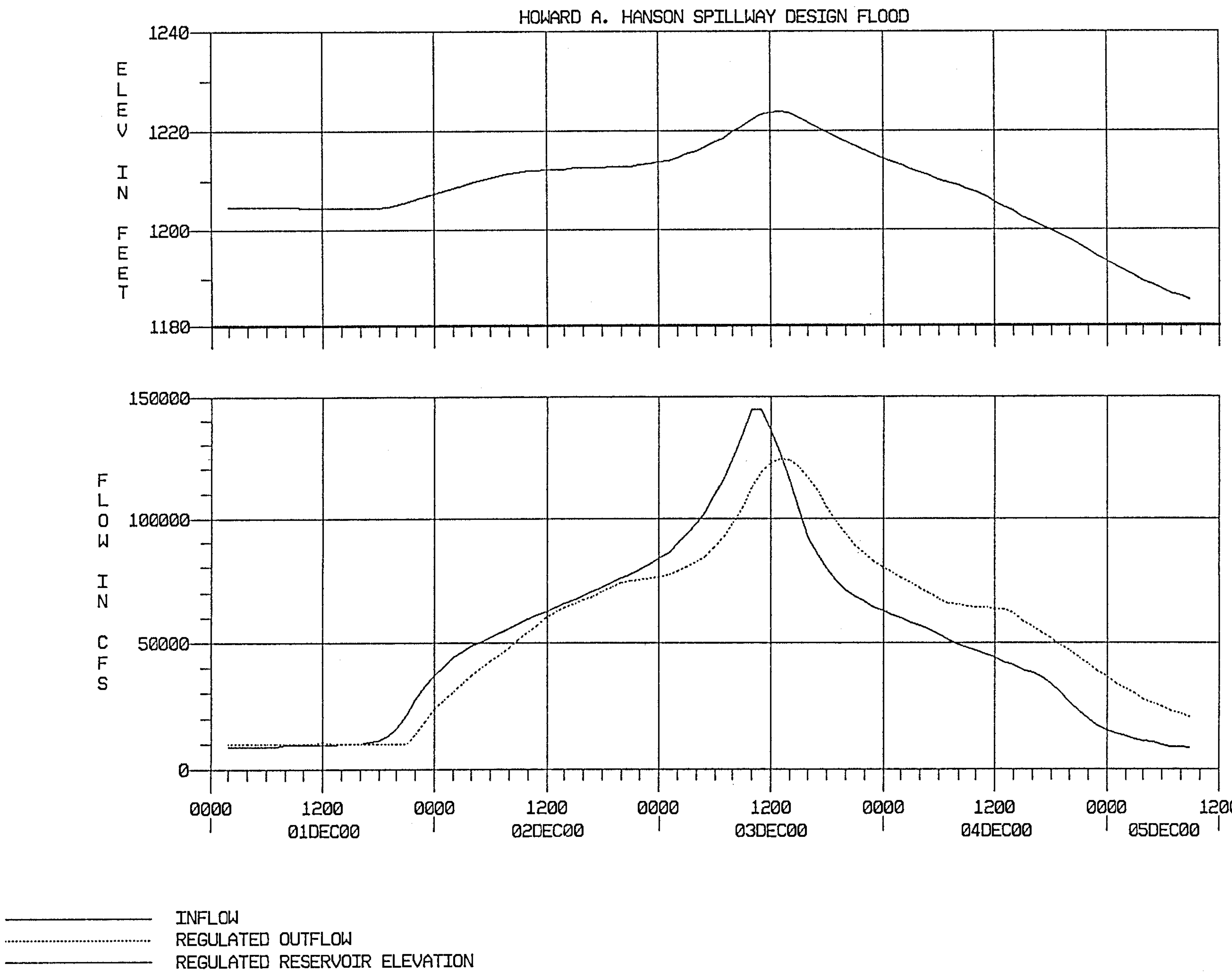
LEGEND

PRECIPITATION STATIONS
PRECIPITATION (RECORDING) AND TEMPERATURE
SNOW COURSE
SNOTEL STATION
RIVER GAGE, RATED - RECORDING
RESERVOIR OR LAKE GAGE, UNRATED - RECORDING

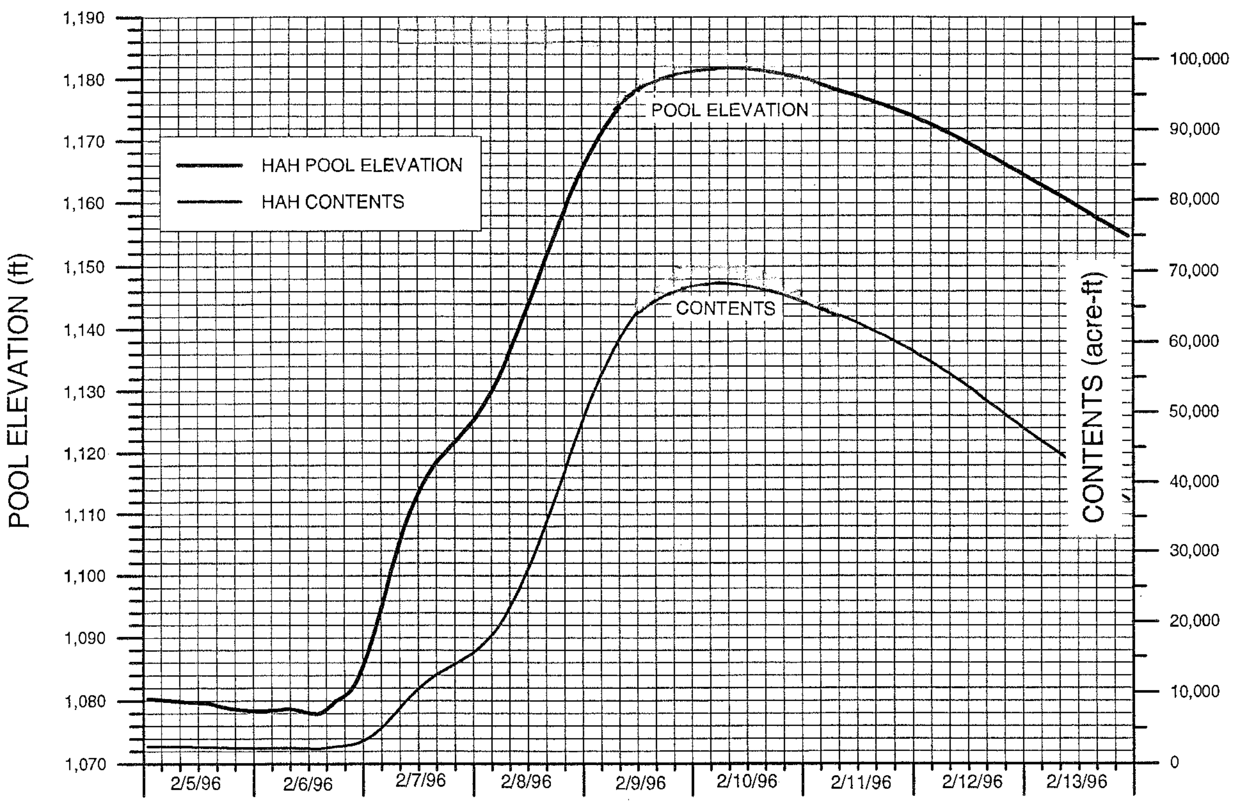
: TELEPHONE TELEMETRY
! MICROWAVE REPEATER
MICROWAVE TELEMETRY
RADIO TELEMETRY
METEORBURST TELEMETRY
T - 1 LINE

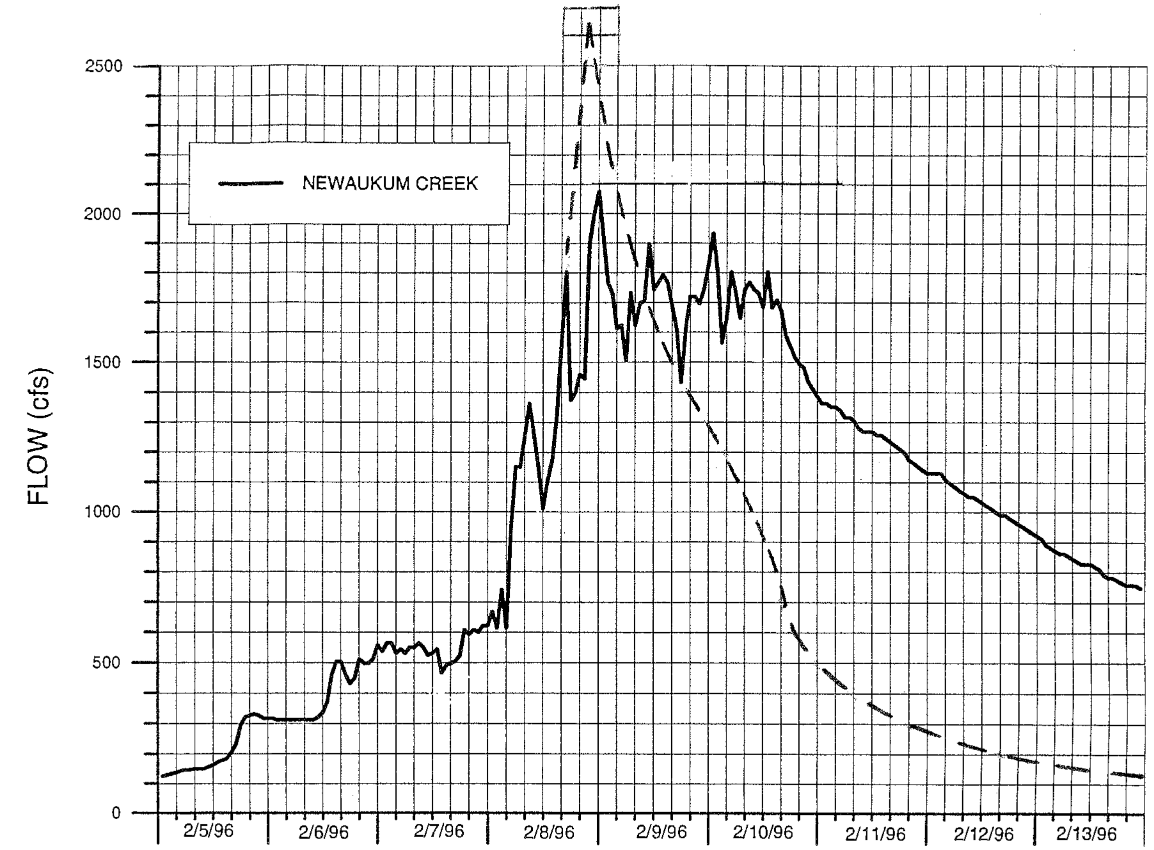
GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
HYDROMET COMMUNICATIONS NETWORK

U.S. ARMY ENGINEER DISTRICT
SEATTLE, CORPS OF ENGINEERS

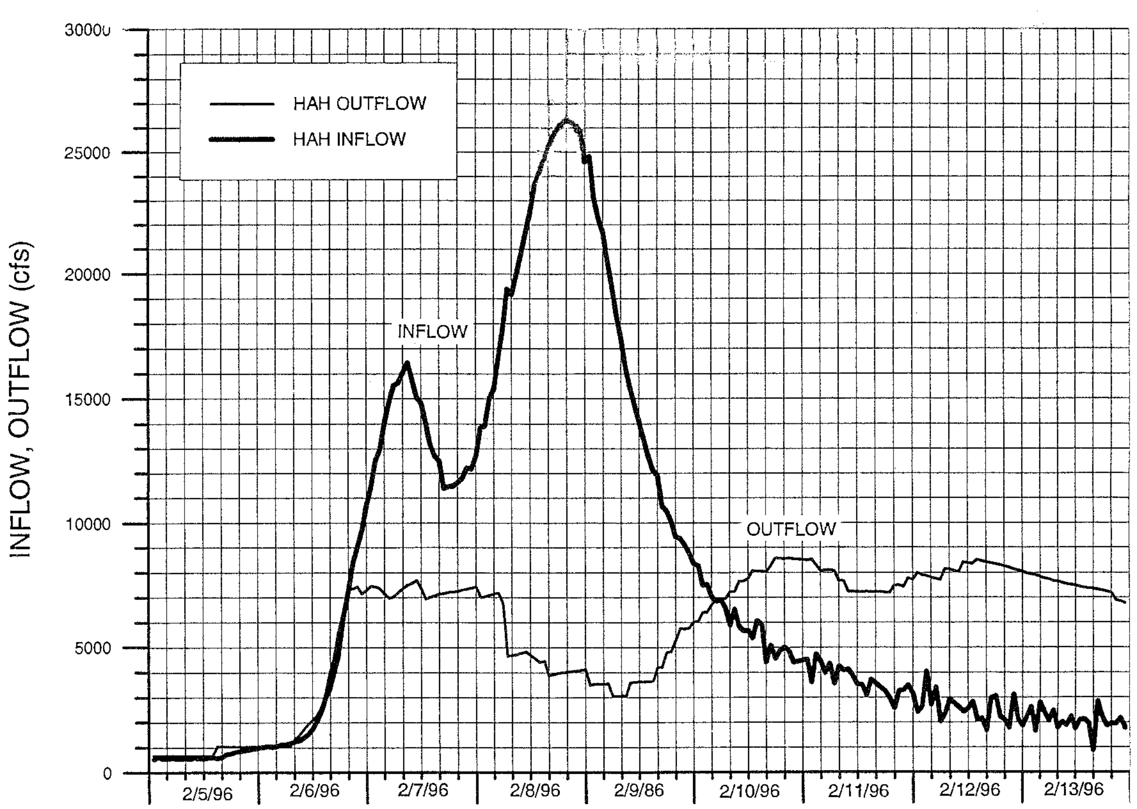


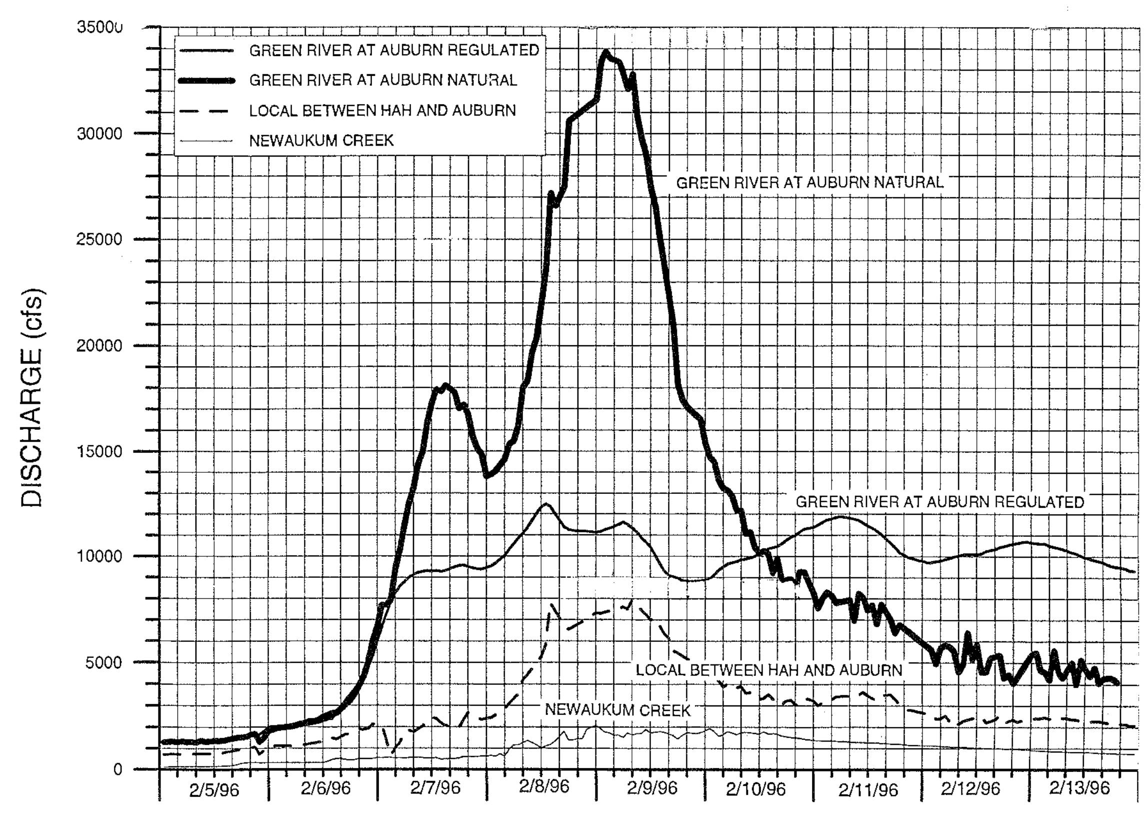
HOWARD A. HANSON SPILLWAY DESIGN FLOOD
ELEV IN FEET
1240
1220
1200
1180
FLOW IN CFS
150000
100000
50000
0
0000
1200
01DEC00
0000
1200
02DEC00
0000
1200
03DEC00
0000
1200
04DEC00
0000
05DEC00
1200
INFLOW
REGULATED OUTFLOW
REGULATED RESERVOIR ELEVATION





⇐ The solid line on the Newaukum hydrograph is based on flows observed at the Reservoir Control Center during the flood. The dashed line after 8 February is based on peak and daily flows published by the USGS after the flood.





NOTES:

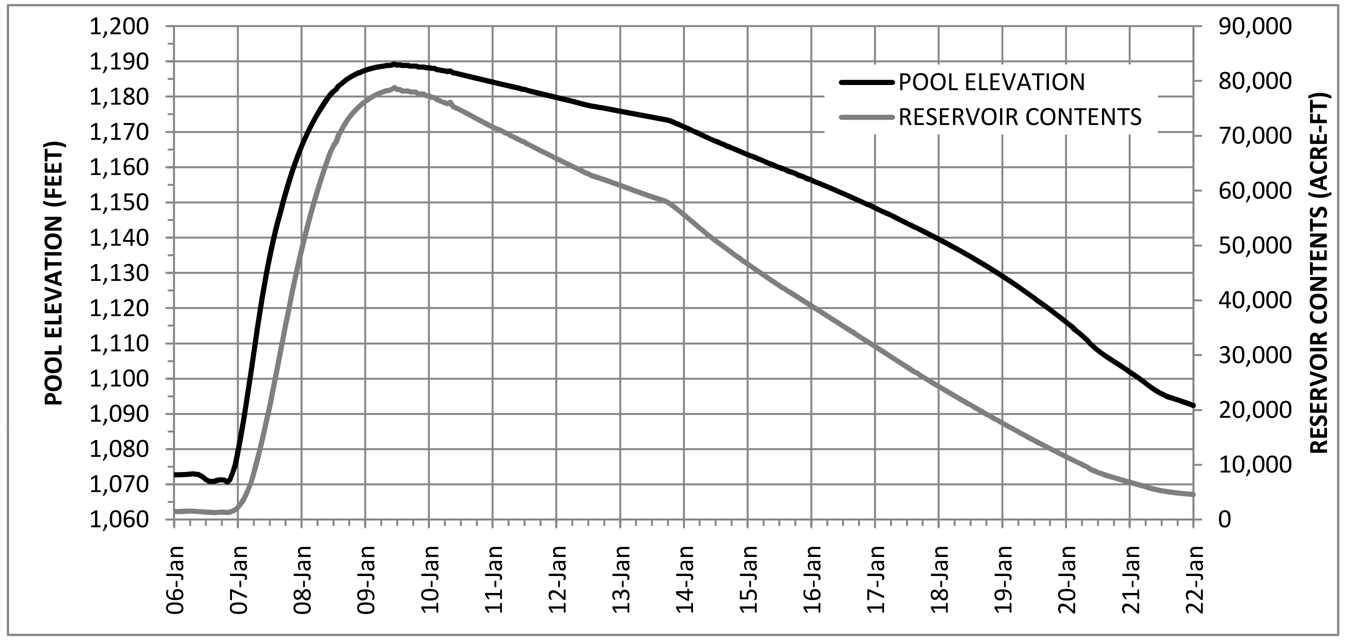
1. Source of Information is the Reservoir Control Center.
2. Pool Elevation and Contents are at Hanson Reservoir.
3. Inflow is computed from outflow and hourly change of storage.
4. Newaukum Creek is at the USGS gage near Black Diamond
5. Local discharge is computed from Auburn minus routed outflow.
6. Natural discharge is computed from inflow plus local flow.

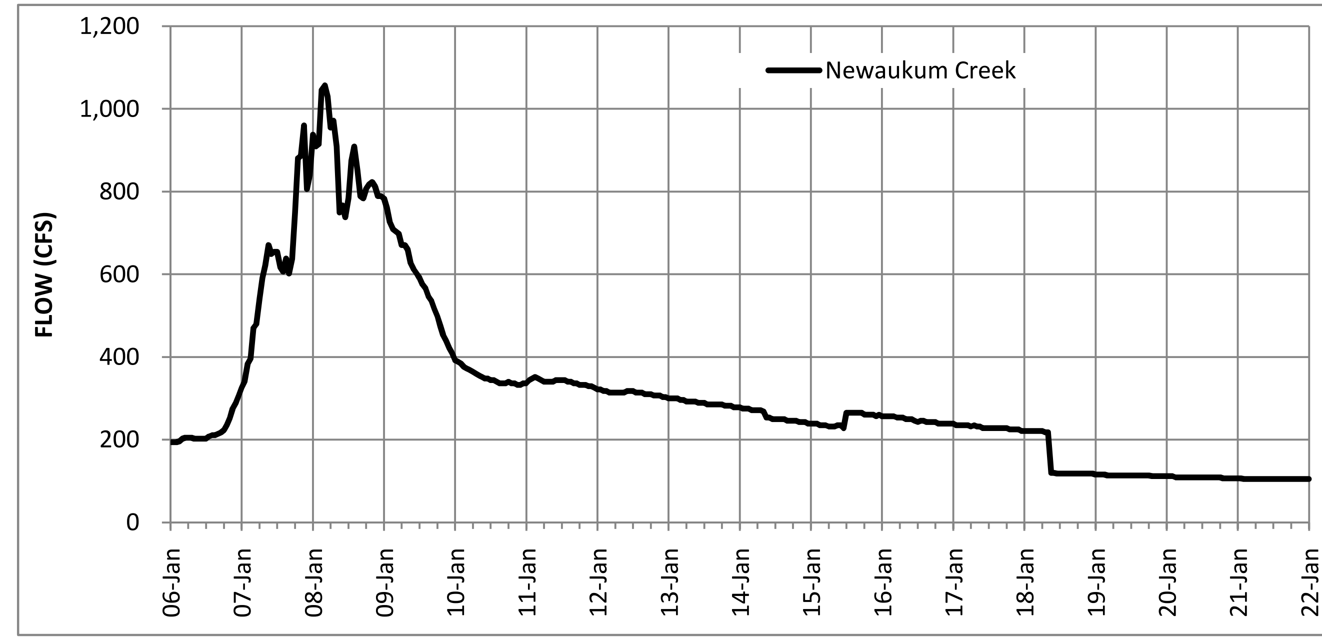
U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT
SEATTLE, WASHINGTON

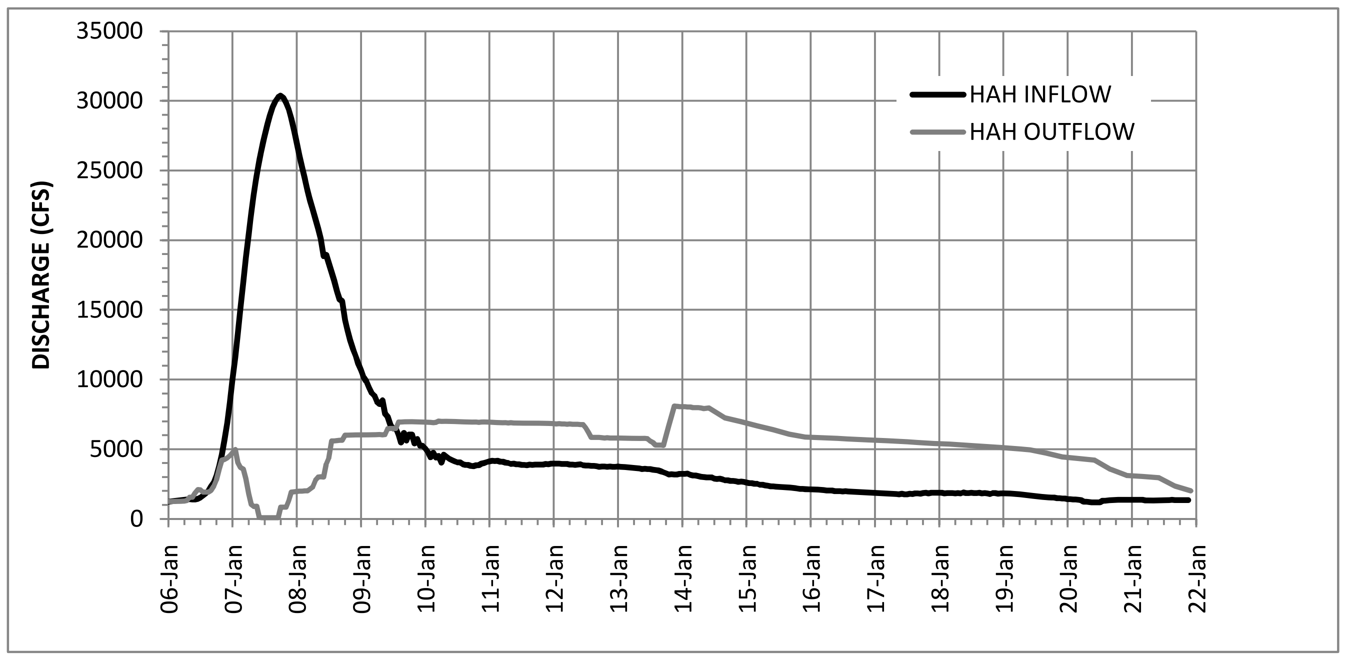
FEBRUARY 1996 FLOOD HYDROGRAPHS
Green River from Hanson Dam to Auburn

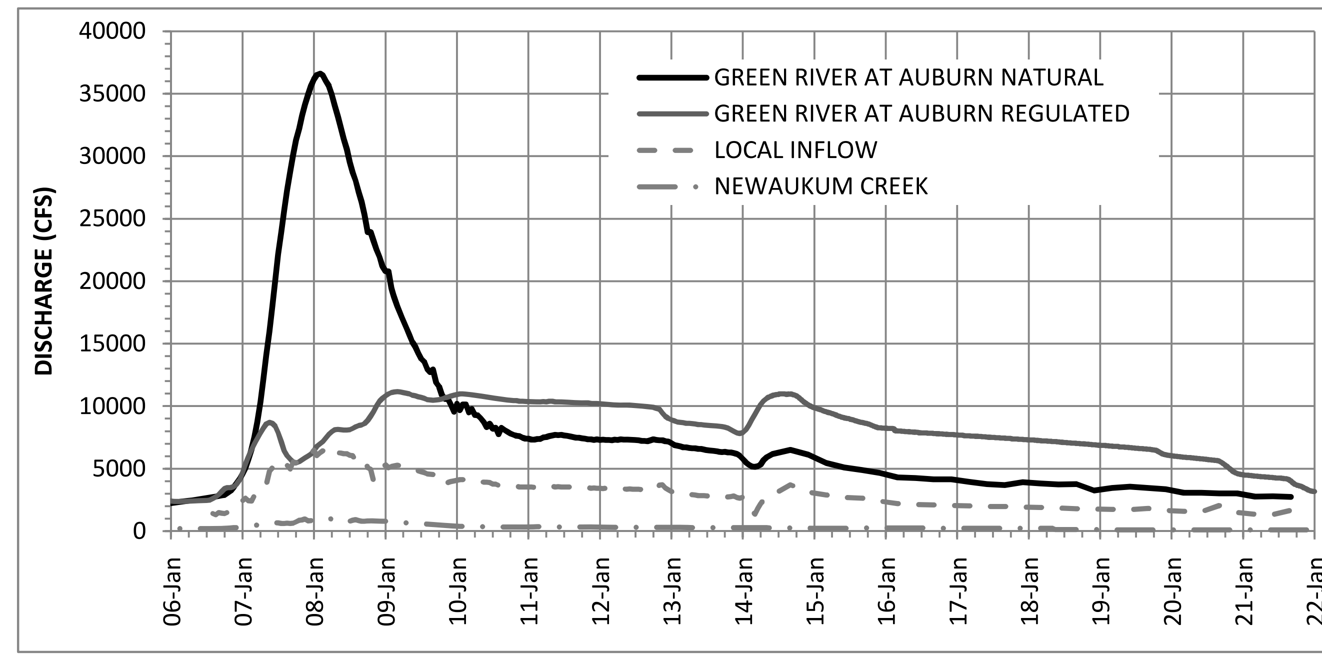
DEVELOPED	CHECKED	DATE	SHEET
L. Jangaard		November 1997	1 OF 1

PLATE 8-2







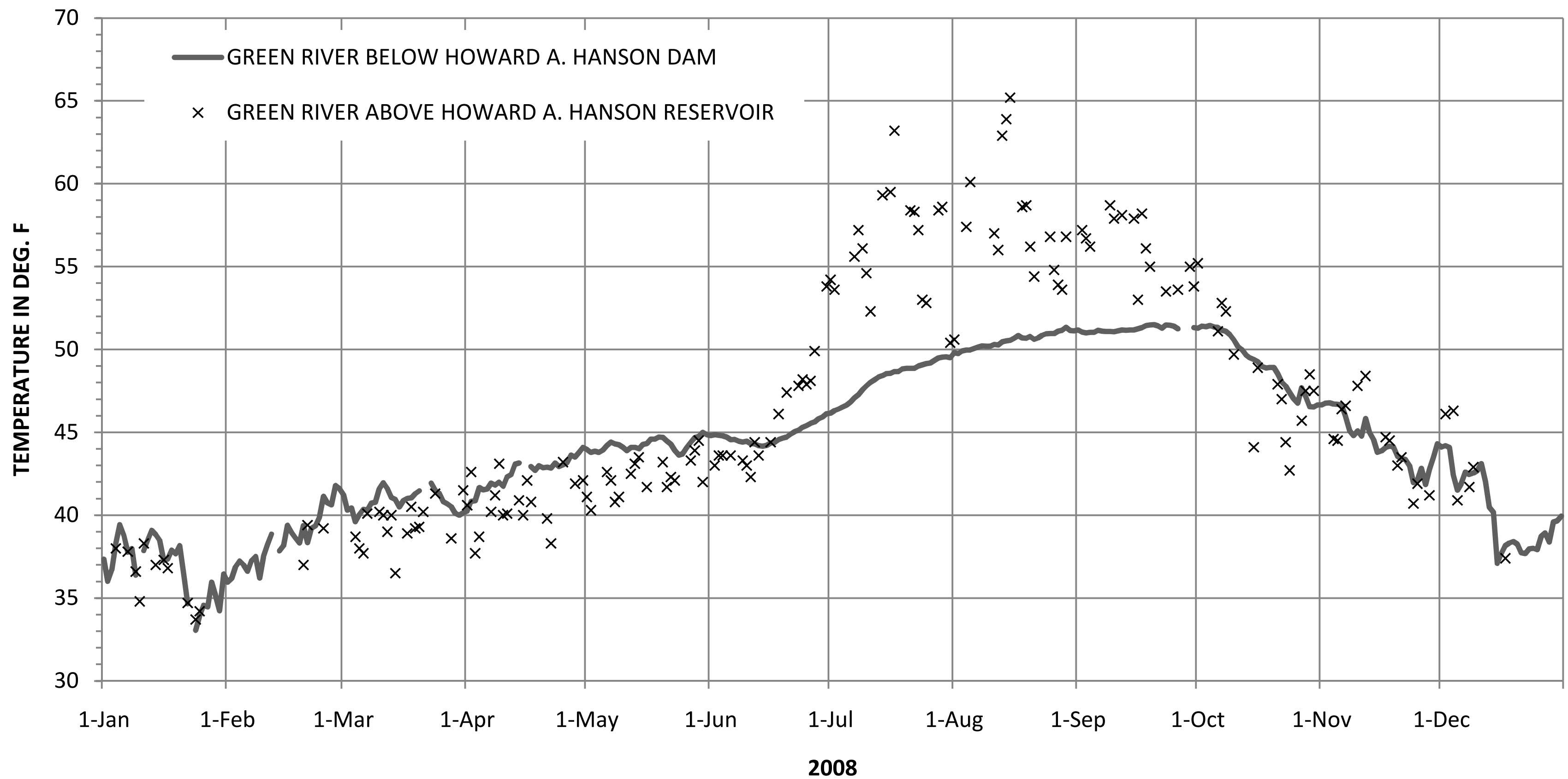


NOTES:

1. SOURCE OF INFORMATION IS THE RESERVOIR CONTROL CENTER
2. POOL ELEVATION AND CONTENTS ARE AT HOWARD A. HANSON RESERVOIR
3. INFLOW COMPUTED FROM OUTFLOW AND HOURLY CHANGE IN STORAGE
4. NEWAUKUM CREEK IS AT THE USGS GAGE NEAR BLACK DIAMOND
5. LOCAL INFLOW IS COMPUTED FROM AUBURN MINUS ROUTED OUTFLOW
6. NATURAL DISCHARGE IS COMPUTED USING HAH INFLOW AND LOCAL INFLOW

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

JANUARY 2009 FLOOD HYDROGRAPHS
GREEN RIVER FROM HAH DAM TO AUBURN

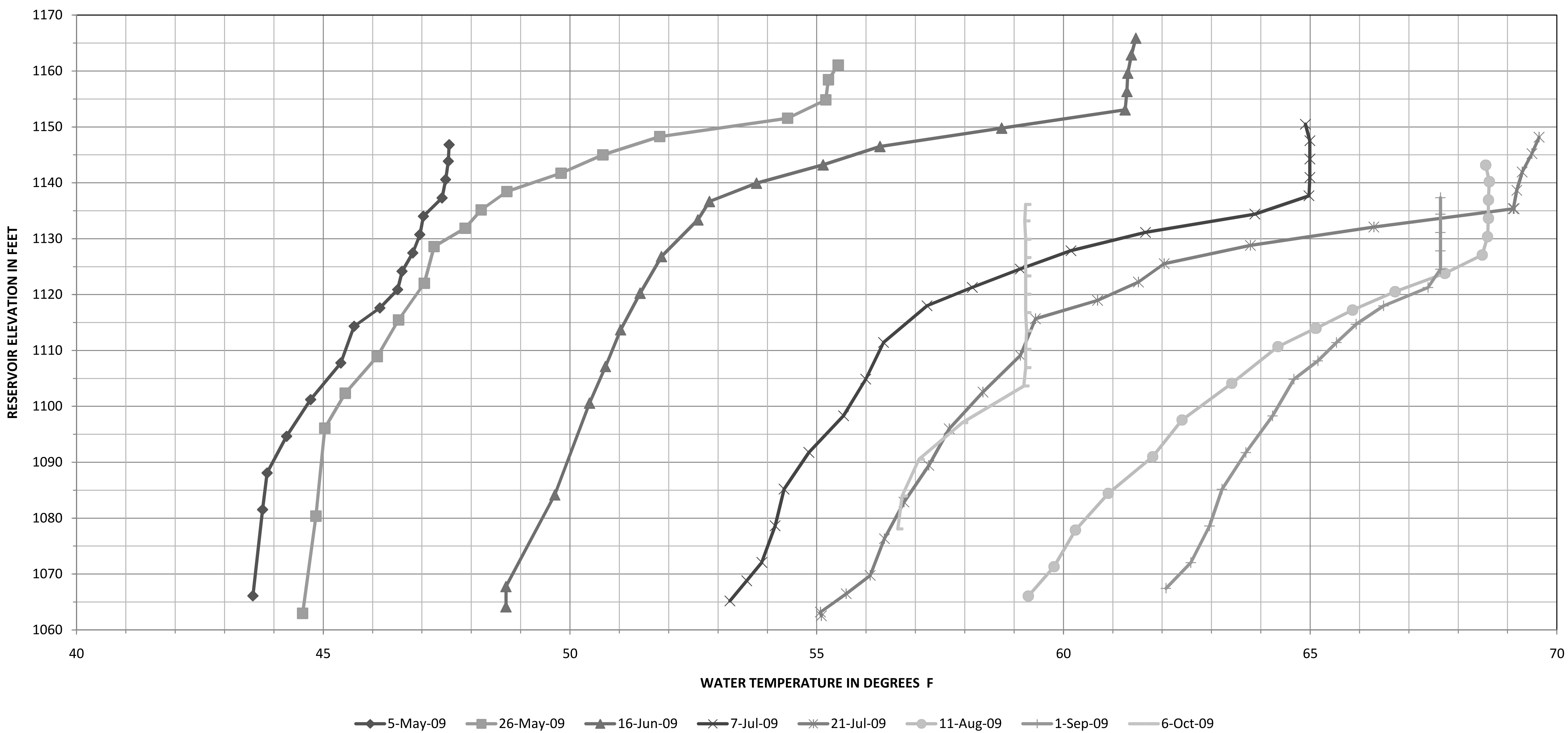


NOTES:

1. SOURCE OF INFORMATION IS THE U.S. ARMY CORPS OF ENGINEERS

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

GREEN RIVER
DAILY WATER TEMPERATURES, 2008

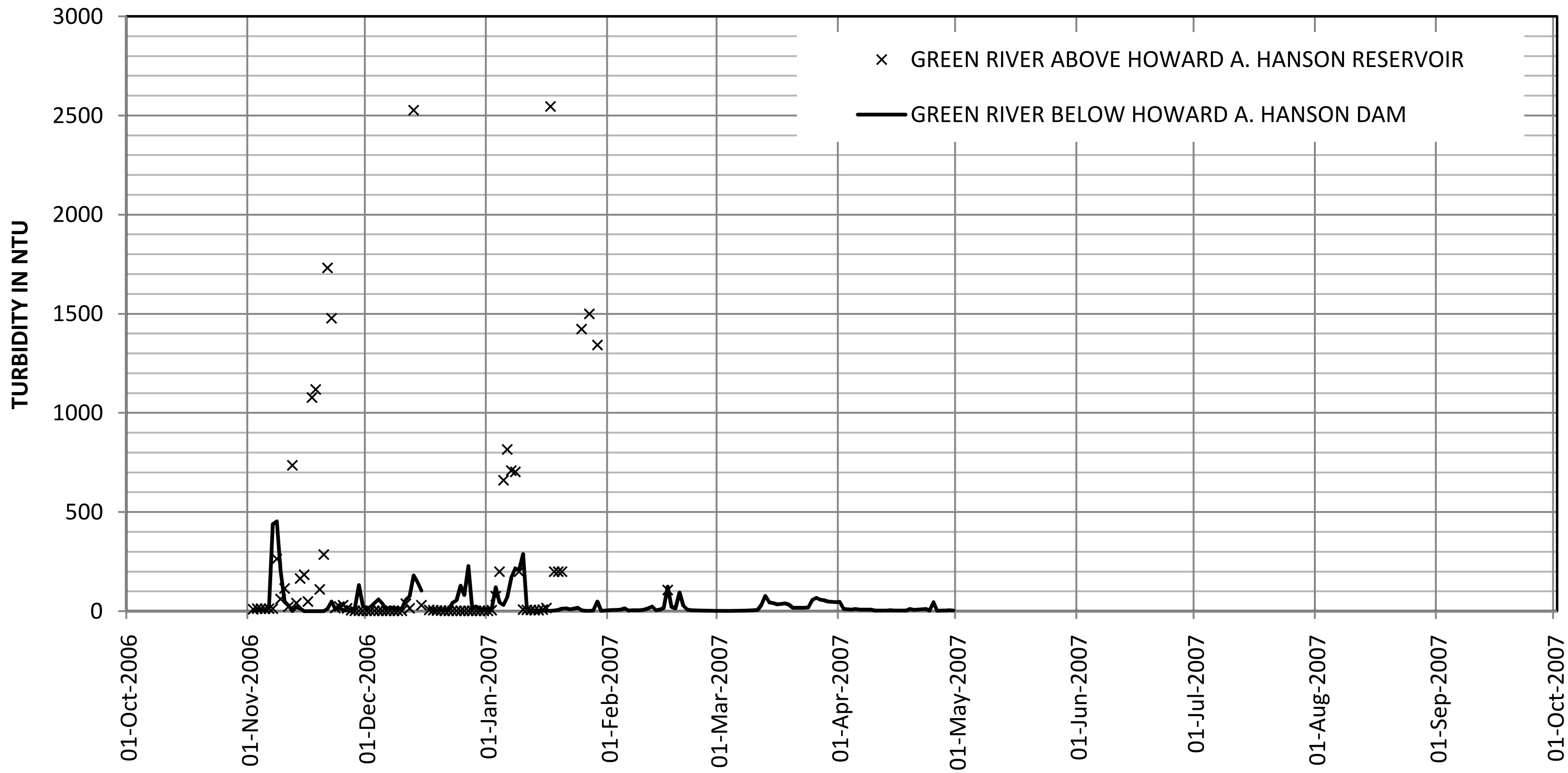


NOTES:

1. SOURCE OF INFORMATION IS THE U.S. ARMY CORPS OF ENGINEERS

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

HOWARD A. HANSON RESERVOIR
WATER TEMPERATURE PROFILES, 2009

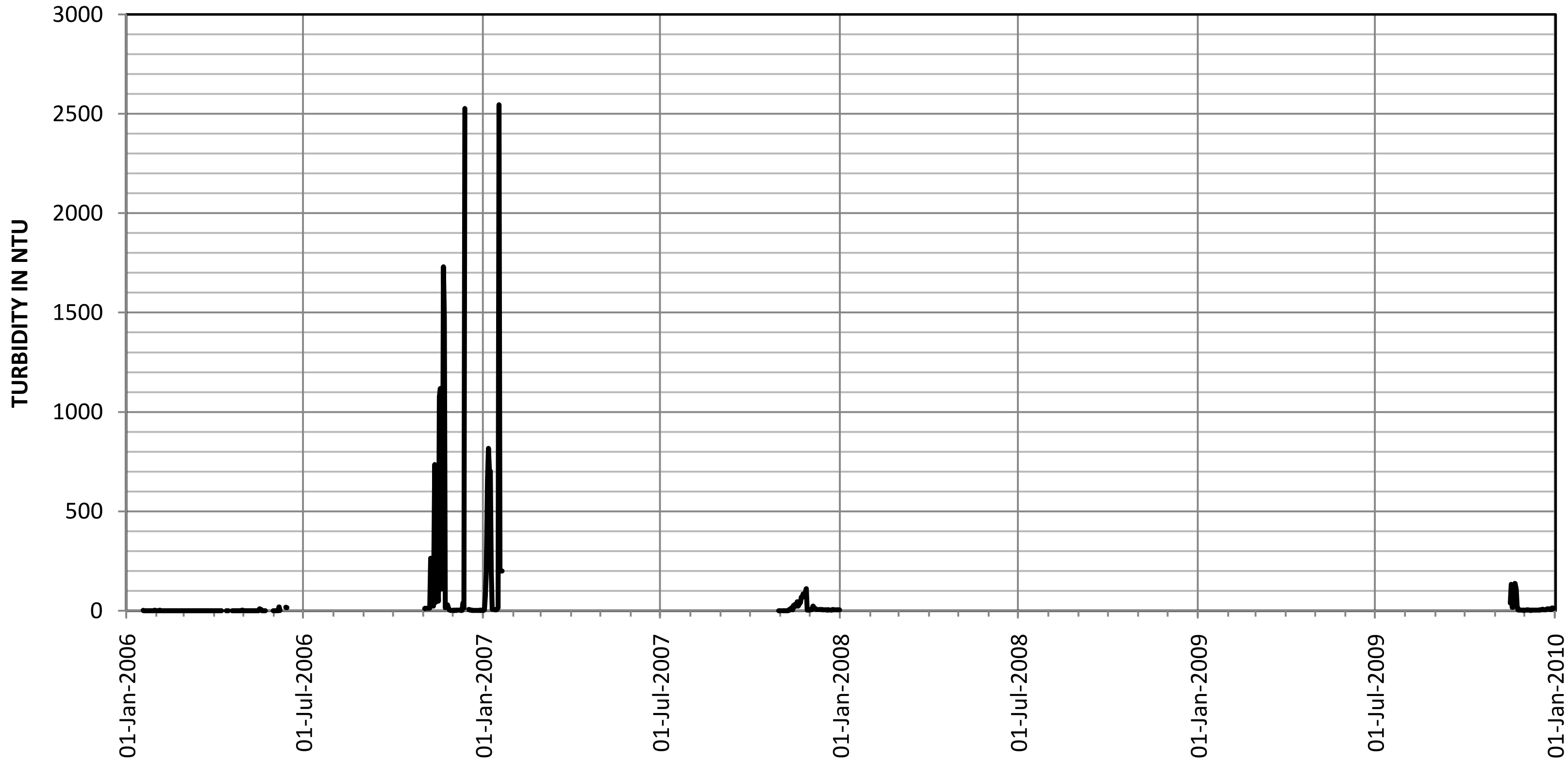


NOTES:

1. SOURCE OF INFORMATION IS THE U.S ARMY CORPS OF ENGINEERS
2. MISSING VALUES TREATED AS ZERO

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

GREEN RIVER
DAILY TURBIDITY, WATER YEAR 2007

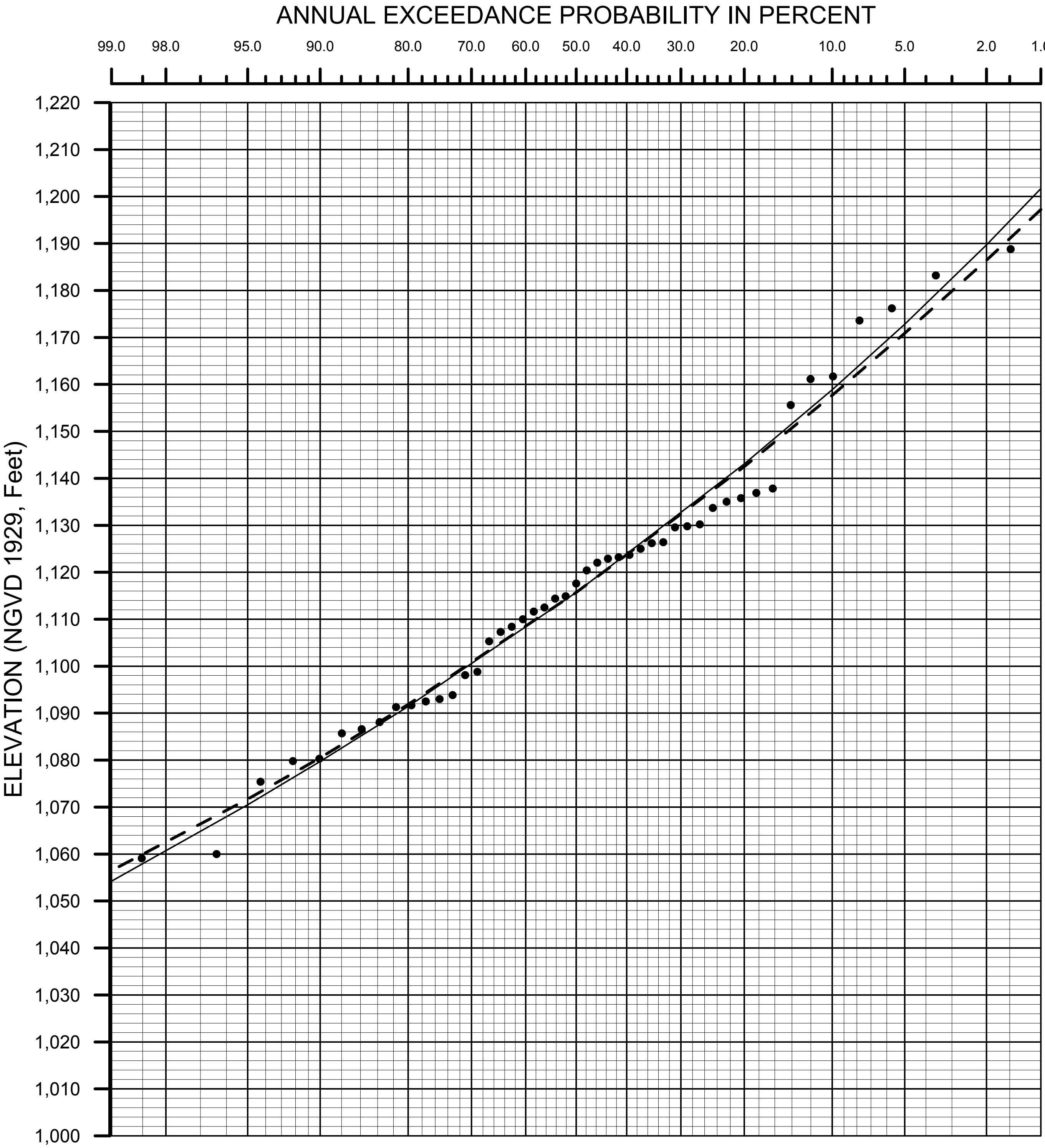


NOTES:

1. SOURCE OF INFORMATION IS THE U.S. ARMY CORPS OF ENGINEERS
2. MISSING VALUES TREATED AS ZERO

U.S. ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

GREEN RIVER
ABOVE HOWARD A. HANSON RESERVOIR
DAILY TURBIDITY, 2005 - 2009



HEC-FFA COMPUTED CURVE

EXPECTED PROBABILITY ADJUSTMENT

MEDIAN PLOTTING POSITIONS

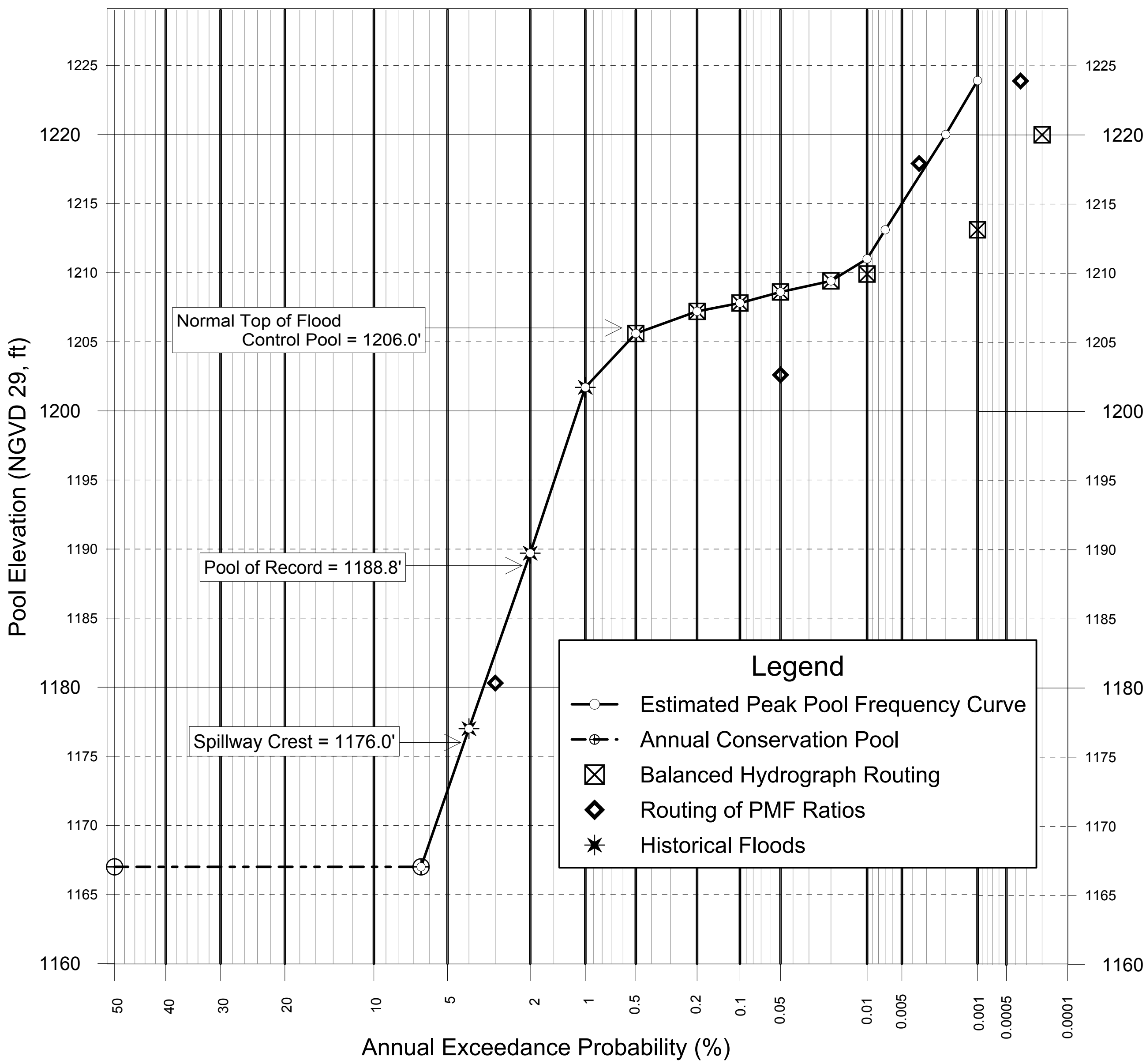
Observed H.A. Hanson Reservoir Stages
Max. Winter Stage-Frequency
Fit based on Pearson Type III Distribution
Max. Flood Control Pool is 1206 ft.
R.M. 64.5
Lat. 47.277 Long 121.784

CORPS OF ENGINEERS, SEATTLE DISTRICT
3 MAY 2013
BASIN AREA= 220.0 SQ MI
WATER YEARS OF RECORD
1963-2009

SYSTEMATIC STATISTICS	
MEAN=	1117.8
ST. DEV.=	30.3050
COMPUTED SKEW=	0.4096
ADOPTED SKEW=	0.4096

NUMBER OF EVENTS	
HISTORIC EVENTS=	0
HIGH OUTLIERS=	0
LOW OUTLIERS=	0
ZERO OR MISSING=	0
SYSTEMATIC EVENTS=	47

CONSTRUCTED BY:	APPROVED BY:	
S. Marxen	K. Brettmann, P.E.	Plate 8-8.i



NOTES:

1. THIS CURVE REPRESENTS A COMBINATION OF THE PEAK ANNUAL POOL FROM THE CONSERVATION POOL AND FROM FLOOD POOLS. FLOOD POOLS WERE DETERMINED USING OBSERVED HISTORICAL POOLS (1963-2009) AS WELL AS ROUTING OF HYPOTHETICAL HYDROGRAPHS FOR THE MOST EXTREME EVENTS.

2. SOURCE OF INFORMATION IS THE U.S. ARMY CORPS OF ENGINEERS.

3. THIS CURVE WAS CONSTRUCTED BY ADAM PRICE AND APPROVED BY KEN BRETTMANN, P.E.

U.S ARMY ENGINEERS, SEATTLE DISTRICT
CORPS OF ENGINEERS
SEATTLE, WASHINGTON
December, 2013

Peak Annual Pool Frequency Curve
H.A. Hanson Reservoir

EXHIBIT i-1
METRIC CONVERSION TABLE

LENGTH	ABBREVIATION	NUMBER OF METERS	US EQUIVALENT
kilometer	km	1000	0.62137 miles
mile	mi	1,609.35 m	1 mile
meter	m	1 m	39.37 inches
foot	ft	0.3048 m	1 feet
meter	m	1	1.09361 yards
decimeter	dm	0.1	3.937 inches
centimeter	cm	0.01	0.3937 inches
millimeter	mm	0.001	.03937 inches
AREA		**NUMBER OF SQ. METERS**	
Square kilometer	sq km or km²	1,000,000	0.3861 square miles
Hectare	ha	10,000	2.47 acres
Are	a	100	119.6 sq yds
Square centimeter	sq cm or cm²	0.0001	0.155 sq inch
VOLUME		**NUMBER OF CUBIC METERS**	
Cubic centimeter	cu cm, cm³, cc	0.000001	0.061 cubic inches
cubic decimeter	dm³	0.0001	61.023 cubic inches
cubic meter	m³	1	1.307 yards
CAPACITY		**NUMBER OF LITERS**	
kiloliter	kl	1,000	1.31 cubic yds
hectoliter	hl	100	3.53 cubic yds
dekaliter	dal	10	0.35 cubic foot
liter	l	1	61.02 cubic inches
cubic decimeter	dm³	1	61.02 cubic inches
deciliter	dl	0.1	6.1 cubic inches
centiliter	cl	0.01	0.61 cubic inches
milliter	ml	0.001	0.061 cubic inches
WEIGHT		**NUMBER OF GRAMS**	
metric ton	t	1,000,000	1.102 short tons
kilogram	kg	1,000	2.2046 pounds
hectogram	hg	100	3.527 ounces
dekagram	dag	10	0.353 ounces
gram	g	1	0.035 ounces
decigram	dg	0.10	1.543 grains
centigram	cg	0.01	0.154 grain
milligram	mg	0.001	0.015 grain

EXHIBIT i-1
METRIC CONVERSION TABLE (CONTINUED)

The following standard to metric conversion factors are used in this manual:

Length and Distance
1 inch = 2.54 centimeters.
1 foot = 0.3048 meter
1 mile =1.609 kilometer

Slope
1 foot per mile = 0.1894 meters per kilometer

Area
1 hectare (ha) = 2.471 acres
1 acre (ac) = 43,560 sq ft = 1 ha / 2.471 ac = 0.40469 ha
1 square mile = 2.588888 sq km

Volume
1 cubic yard = 0.76455 cubic meters
1 acre foot (AF) = 43,560 ft^3 = (0.40469 ha)(.3048 m) = 0.12335 ha-m

Flow Rate
1 cubic foot per second (cfs) = 0.028316 cubic meters per second
1 cfs per day= 1.98347 AF = 0.24466 ha-m
1cfs per year = 723.9666 AF = 89.3009 ha-m

Runoff per square mile
1 inch of runoff per square mile = 53.333 AF = 6.5786 ha-m

Miscellaneous
1 US gallon = 3.785 liters
1 short ton = 0.907 metric tons
1 pound = 453.59 2 grams
1 hp = 0.746 kW

Temperature
Fahrenheit (F) temperature = (9/5)C + 32
Celsius (C) temperature = (5/9)(F – 32)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION, CORPS OF ENGINEERS
P. O. Box 2870
Portland, Oregon 97208-2870

CENPD-EN-WM
Regulation
Number 1165-2-2

2 January 1990

Water Resource Policies and Authorities
WATER MANAGEMENT RESPONSIBILITIES

1. PURPOSE. This regulation pertains to the management of the Columbia River reservoir system through the regulation and operation of Corps of Engineers dams and those owned by other agencies. The purpose of this regulation is to clarify the organizational structure of and define specific responsibilities for the Division, districts, and project offices engaged in this activity. It also defines the Water Management Board and associated procedures for Division-district interface on water management activities.

2. APPLICABILITY. This regulation is applicable to Engineering and Operations elements in Headquarters North Pacific Division (HQNPD), and in Portland, Seattle, and Walla Walla Districts (including Planning Division in CENPW).

3. REQUIRED PUBLICATIONS.

a. ER 1110-2-240 (Water Control Management). Cited in paragraph 5a, 6b, 11b, 12 and 13.

b. ER 1110-2-241 (Use of Storage Allocated for Flood Control and Navigation at Non-Corps Projects). Cited in paragraph 5a.

c. ER 1110-2-249 (Management of Water Control Data Systems). Cited in paragraph 12a.

d. ER 1110-2-1400 (Reservoir Control Centers). Cited in paragraph 4.

e. EM 1110-2-3600 (Management of Water Control Systems). Cited in paragraph 5a.

f. Columbia River Master Water Control Manual. Cited in paragraph 5c.

g. CENPD Master Plan for Water Control Data Systems. Cited in paragraph 11.

*Supersedes NPDR 1165-2-2, 10 January 1967

4. BACKGROUND AND DEFINITIONS.

a. Water control management of dams and reservoirs in North Pacific Division (NPD) is the responsibility of both district and division offices. In the Columbia River basin, which encompasses three district jurisdictions, a need exists for centralized management of reservoir regulation activities, since the system of reservoirs requires unified coordination and operation. Accordingly, a system management organization, now the Water Management Branch, was established in 1968 in the HQNPD. The duties and responsibilities of the Branch, which includes a Reservoir Control Center, are defined by ER 1110-2-1400. District offices also remain involved with the Columbia basin reservoirs, but in a secondary capacity. In certain geographic areas that are independent from the Columbia River basin, however, district offices assume primary regulation responsibilities. Jurisdiction for district/division responsibilities for each major project within the NPD boundaries have been defined and are shown in Appendix A. Responsibilities have generally been assigned to the district office in which the project exists unless the project is connected electrically and/or hydraulically to the Columbia system.

b. Certain key terms used in this regulation are defined in Appendix B. Some of these terms are used very explicitly in defining the responsibilities covered by this regulation.

5. WATER MANAGEMENT POLICIES, GUIDANCE.

a. General Policies and Guidance. Corps of Engineers' projects will be regulated to conform with basic provisions in authorizing documents and water management policies and criteria. Corps of Engineers' policies with regard to water management are contained in ER 1110-2-240 and ER 1110-2-241. Technical guidance in carrying out reservoir regulation is contained in EM 1110-2-3600.

b. Project Regulation Guidance. Project water control plans have been developed to define and describe regulation procedures for each Corps project and for non-Corps projects for which the Corps has primary regulation responsibility. These are usually contained in the project water control manuals.

c. Policies and Guidance for System Management. The Master Water Control Manual for the Columbia River (reference 3f) contains policy and guidance for regulating the dams and reservoirs in the Columbia basin to fulfill integrated system objectives. Since the projects in the Columbia system are interrelated, regulation for individual projects must be coordinated with objectives for the system as a whole. Project obligations to meet system objectives are broadly defined in authorizing documents, with specific requirements contained in contractual agreements which are described in the CENPD Master Water Control Manual (reference 3f).

6. DIVISION OFFICE ORGANIZATION AND RESPONSIBILITIES.

a. Organization. The organizational chart for those elements in the HQNPD associated with water management is shown in Appendix C. Also shown are the other agencies with which coordination is required. Water management activities are carried out by the Water Management Branch in Engineering Division. The Branch is organized into three sections which carry out the various responsibilities relating to the water management mission described below. These are also summarized on the organizational chart.

b. Responsibilities. HQNPD is responsible for:

(1) Preparing the annual operating plan for the Columbia system in accordance with Pacific Northwest Coordination Contract and Columbia River Treaty, including performing system regulation studies and coordination as shown in Appendix A.

(2) Preparing the annual operating plan for the Willamette basin.

(3) Primary regulation of the Columbia reservoir system, including coordination with BPA, USBR, district offices, fishery agencies, electrical utilities, etc.; performing back-up analyses; and issuing instructions to projects. Also performing secondary regulation for other projects as necessary. See specified projects in Appendix A.

(4) Implementing the Columbia River Treaty in accordance with Treaty documents, through the Treaty Operating Committee and Hydrometeorological Committee, including performing required studies as well as daily regulation activities.

(5) Representing the Corps of Engineers on the Coordination Contract Committee and NWPP Operating Committee, for water management responsibilities.

(6) Developing, coordinating, planning and implementing the juvenile fish passage plan and water budget plan on the Columbia and Snake Rivers.

(7) Coordinating water supply forecasts with NWRFC, BPA and other agencies, overseeing forecast integrity, and preparing forecasting procedures for projects listed in Appendix A.

(8) Performing system flood control, power, water quality, and conservation storage studies to improve regulation procedures or analyze problem areas for projects for which water control plan responsibilities exist.

(9) Maintaining and implementing the CROHMS System, including the central computer facility hardware and software (in conjunction with CENPD-IM). Includes maintenance of communications facilities such as the CBT

network and the GOES system; coordination of remote stations; and the processing of real-time data.

(10) Performing public information/involvement activities in accordance with annual plans.

(11) Participating in activities associated with the Water Management Board.

(12) Assuming necessary dam safety responsibilities relating to reservoir regulation and flood warning and notification, including conducting and participating in emergency action plan exercises.

(13) Preparing and maintaining master water control manuals for the Columbia and Willamette River basins and portions of other water control manuals for projects designated in Appendix A.

(14) Implementing water quality programs required for mainstem Columbia and Snake River projects.

(15) Preparing the Columbia River Treaty and Columbia River Water Management Group Annual Reports, and special after-action reports such as post-flood reports, as defined in Appendix A.

(16) Performing oversight and approval of district Water Control Data System (WCDS) development as required by ER 1110-2-240.

(17) Performing oversight and approval of District water control plans and manuals as required by ER 1110-2-240.

(18) Performing oversight of district reservoir regulation activities.

7. DISTRICT OFFICE ORGANIZATION AND RESPONSIBILITIES.

a. Organization. Appendix C contains separate organizational charts for those parts of the organizations associated with water management. This activity resides as a section within the Districts' Hydrology and Hydraulics branches.

b. Jurisdiction. Projects and responsibilities that fall within the jurisdiction of each District Office are shown in Appendix A.

c. Responsibilities. District Offices will be responsible for:

(1) Maintaining and updating as necessary the water control plan for projects shown in Appendix A, including making studies and coordinating with other agencies as appropriate.

(2) Primary and secondary regulation of those projects specified in Appendix A, including the necessary coordination and back-up analyses.

(3) Preparing and updating water control manuals or projects specified in Appendix A.

(4) Performing flood control and conservation storage studies to improve regulation procedures or analyze problem areas for projects for which water control plan responsibility exists (Appendix A).

(5) Operating and maintaining designated Water Control Data Systems, including data controllers and remote stations.

(6) Developing and implementing water supply and streamflow forecasting procedures for those projects listed in Appendix A.

(7) Preparing special after-action reports such as post-flood reports for projects shown in Appendix A.

(8) Participating in activities associated with the Water Management Board.

(9) Assuming necessary dam safety responsibilities.

(10) Performing public information activities in accordance with annual plans.

(11) Conducting and participating in emergency action plan exercises.

(12) Water quality studies and activities for tributary and coastal streams.

(13) Collecting snow cover data from aerial flights and satellite imagery for use in spring flood forecasting (CENPS and CENPW).

8. PROJECT OFFICE ORGANIZATION AND RESPONSIBILITIES.

a. Organization and Coordination. Project offices are within the purview of CENPD Construction-Operations Division, with Operations organizations in district offices providing oversight to project engineers and staff. Interface with water management personnel in district or division offices occurs in the project regulation process. In routine regulation situations this is normally accomplished by direct contact between district or division reservoir regulation personnel and project personnel. In unusual situations, district or division managers may be brought into the communication line. For Columbia Basin projects, the NPD Reservoir Control Center communicates directly with project personnel, unless otherwise agreed or if special circumstances arise that would be of significance to the District (e.g., regulation that would be sensitive to local communities, or a change in operating plans).

b. Responsibilities. Project offices will be responsible for the following actions, with regard to water management.

(1) Carrying out instructions from Division/District water control managers.

(2) Reporting project status and hydromet data as required.

(3) Coordinating with water control managers regarding O&M activities that will affect project regulation.

(4) Carrying out responsibilities with regard to dam safety.

(5) Carrying out public information activities with regard to project regulation.

9. WATER MANAGEMENT BOARD. The Water Management Board is composed of district (excluding CENPA) and HQNPD representatives who consult with the Chief, CENPD-EN, on water management of the Columbia River reservoir system by CENPD-EN-WM. The purpose of the Board is to provide consultation on this Division-wide activity, to assist in resolving differences between division and district offices on setting policy, and to keep district offices better informed on the management of the Columbia River. The Board is an independent consultative body, reporting to the Chief, CENPD-EN and assisting him by presenting a perspective on the management of the Columbia River that reflects points of view of district offices and CENPD-CO. The Board receives overall direction from the Chief, CENPD-EN.

a. Composition. The HQNPD will be represented by the Chief, CENPD-EN and by the Chief, CENPD-CO-O or their representatives. Each District Office will be represented by the District Commander or his representative. These will be designated in writing to the Chief, CENPD-EN. Each office may have additional supporting staff to assist in the Board's activities, but there will be only one official spokesperson for each of the five organizations represented.

b. Board Chair. The Board meetings will be chaired by the Chief, CENPD-EN.

c. Meetings. The Board will have a formal meeting at least once a year, generally in the month of January or February. This time-frame is desirable because it provides the best opportunity to address matters pertaining to the current operational outlook, the development of the next year's Operating Plan, and the O&M budget submittal. Additional meetings may be requested by Board members and set by the Chief, CENPD-EN.

d. Responsibilities. The Board will address both routine items as listed below, and special issue topics requested by Board members or by Chief, CENPD-EN. Routine items are to include:

(1) The Corps' input to the Annual Operating Plan prepared by the Pacific Northwest Coordination Agreement Contract Committee.

(2) Requests for changes by board members to the current year's operating plan and actual system regulation, as driven by current water supply forecasts and operating requirements.

(3) The annual public information program.

(4) Water Management Branch's staffing expenditures, and budget, including staffing, budget, and expenditures for operating and maintaining the NPD CROHMS computer facility.

(5) CENPD-EN-WM (and other participants as appropriate) will prepare the necessary information to address agenda topics. Technical information will be distributed to Board members at least one week prior to the meeting.

e. Procedures. Prior to the scheduled Board meeting, the following will be implemented. For special Board meetings, similar procedures will be followed as appropriate.

(1) Chief, CENPD-EN will set the date of the meeting.

(2) Chief, CENPD-EN will solicit issue papers from Board members, which will be considered as agenda topics for the meeting. Additionally, the Chief, CENPD-EN will circulate to Board members his desires for agenda topics. The meeting agenda will be set by the Chief, CENPD-EN at least one month prior to the meeting/date.

(3) CENPD-EN-WM will provide an update of financial, budgetary, and staffing information to Board members at least two weeks prior to the meeting date.

(4) CENPD-EN-WM will provide the annual power operating plan and summary of the supporting refill study data for the current operating year two months before the meeting.

(5) CENPD-EN-WM (and other participants as appropriate) will prepare the necessary information to address agenda topics. Technical information will be distributed to Board members at least one week prior to the meeting.

f. Documentation. Minutes of Board meetings, along with any formal correspondence relating to the Board, will constitute the record of the Board's activities and actions. HQNPD will be responsible for recording, preparing, and distributing the minutes of the Board's meetings.

g. Resolution of Issues. Where there are unresolved issues, the Chief, CENPD-EN will submit a copy of the minutes along with his plan to address these issues to the Division Commander and the Board members.

10. PUBLIC INFORMATION. A reservoir regulation outlook will be developed by CENPD-EN-WM each year in January, reflecting Corps of Engineers obligations to the system, the first water supply forecasts for runoff in the northwest, projected reservoir regulation, and other factors. The reservoir regulation outlook is to address in particular the potential impacts of reservoir regulation on local users of the projects, such as reservoir and downstream river users. This outlook will be reviewed by the Water Management Board at its January/February meeting and a plan will be established with agreed-upon procedures for informing and involving the public regarding the regulation of reservoirs for the forthcoming winter-spring-summer period. In years having especially low or high runoff, or if other circumstances are expected to result in unusual project regulation, the board may recommend special public meetings. Otherwise routine procedures to inform the public would suffice. The Districts have the lead responsibility for public information, including gathering input from the public disseminating information, and organizing public meetings. Technical assistance will be provided by CENPD-EN-WM as necessary.

11. WATER CONTROL PLANS AND MANUALS.

a. Responsibilities. District offices have the responsibility for preparing and maintaining project water control plans and manuals, and HQNPD is responsible for reviewing and approving those manuals. In the case of several projects on the mainstem of the Columbia River which involve extensive system-wide coordination, HQNPD will also be involved in the preparation and maintenance of the plans and manuals. Appendix A indicates the Division/District responsibilities by project. HQNPD will also be responsible for preparing and maintaining two master water control manuals, for the Willamette and Columbia River basins.

b. Requirements. The following requirements and procedures apply to project water control manuals, with the objective of maintaining the most important parts of the manuals (including the water control plan) in an accurate and up-to-date status while utilizing a minimum of personnel resources.

(1) The water control plan for the project is to be current and accurate.

(2) The water control manual will be considered functional and officially acceptable if it contains at least an up-to-date plan. Preferably, it would also contain other chapters that are of a technical nature. It need not contain other chapters with general information to be a functional manual.

(3) Water control manuals will be updated such that the more important parts are given a higher priority.

(4) The manual will be contained in a loose-leaf binder with cover sheets at the front that indicate status of the chapters in the manual.

(5) District offices will prepare their annual status report to HQNPD in accordance with ER 1110-2-240. A division-wide report will be submitted to HQUSACE.

12. WATER CONTROL DATA SYSTEMS.

a. Responsibilities. General responsibilities as defined in ER 1110-2-240 and ER 1110-2-249 are for district offices to develop and maintain Water Control Data Systems, while HQNPD maintains approval authority for systems and networks through the submittal of the Master Plan for Water Control Data Systems and its annual updates. Because of the necessity of having a centralized data collection and processing system for the management of the Columbia River, the HQNPD has developed the Columbia River Operational Hydromet and Management System (CROHMS) in conjunction with district offices and other federal agencies. The maintenance of CROHMS, along with the Columbia Basin Telecommunications (CBT) system requires that the Division be involved with data collection at some projects. Appendix A defines specific areas of responsibility for each project.

b. Requirements and Procedures. ER 1110-2-240 gives specific requirements for submittal and updating of district and Division WCDS mater plans.

13. AFTER-ACTION REPORTING.

a. Routine Reports. ER 1110-2-240 requires that a Division report on water management activities be submitted to HQUSACE annually. For NPD, HQUSACE has permitted the Columbia River Water Management Group Annual Report to fulfill this requirement. This report is prepared by HQNPD at the end of each water year, with input requested from district offices. Another routine water management report prepared by HQNPD that may require district input is the Columbia River Treaty Annual Report.

* b. Special after-action reports. After the occurrence of large floods and other unusual events such as natural disasters, an after-action report may be required. General guidance on responsibilities for these are shown in Appendix A. *

FOR THE COMMANDER:

CLIFTON P. JACKSON, JR.
Executive Assistant

3 Appendices
App A - District/Division Water Management Responsibilities
App B - Definitions and Acronyms
App C - Division/District Organizations for Water Management

Distribution:
A and B

PROJECT	OWNER	AUTHORITY	PRIMARY REGULATION	SECONDARY REGULATION	WATER CNTRL PLAN.	WAT SUPL FORECAST	STREAMFLOW FORECAST	WATER CNTRL DATA SYSTEM	WATER CNTRL MANUAL	AFTER-ACTION REPORTING
.... UPPER COLUMBIA										
Mica	BCH	Treaty	NPD		NPD	NWS*	NWS	NPD*		NPD
Revelstoke	BCH	Power Coord	NPD		NPD	NWS*	NWS	NPD*		NPD
Hugh Keenleyside	BCH	Treaty	NPD		NPD	NWS*	NWS	NPD*		NPD
LIBBY	CE	Congress.	NPD	NPS	NPD/NPS	NPD/NWS	NWS	NPS/NPD*	NPS	NPD
Duncan	BCH	Treaty	NPD		NPD	NWS*	NWS	NPD*		NPD
Corra Linn	W KOOT P&L	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Kootenay Projects	BCH/W KOOT	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Hungry Horse	USBR	Section 7	NPD	NPS	NPD	NWS*	NWS	NPD*	NPS/NPD*	NPD
Kerr	MONT P&L	FERC License	NPD	NPS	NPD	NWS	NWS	NPD*		NPD
Thompson Falls	MONT P&L	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Noxon Rapids	WASH WP	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Cabinet Gorge	WASH WP	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
ALBENI FALLS	CE	Congress.	NPD	NPS	NPD	NWS	NWS	NPD	NPS/NPD	NPD
Box Canyon	PEND PUD	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Boundry	SEATTLE CL	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Seven Mile	BCH	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Waneta	W KOOT P&L	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Spokane Projects	WASH WP	Power Coord	NPD		NPD	NWS	NWS	NPD*		NPD
Grand Coulee	USBR	Section 7	NPD		NPD	NWS	NWS	NPD*	NPD*/NPS	NPD
.......MID-COLUMBIA										
CHIEF JOSEPH	CE	Congress.	NPD	NPS	NPD	NWS	NWS	NPD	NPS/NPD	NPD
Wells	DOUGLAS PUD	FERC License	NPD	NPS	NPD	NWS	NWS	NPD*	NPS/NPD*	NPD
Rocky Reach	CHELAN PUD	FERC License	NPD		NPD	NWS	NWS	NPD*	NPS/NPD*	NPD
Rock Island	CHELAN PUD	FERC License	NPD		NPD	NWS	NWS	NPD*	NPS/NPD*	NPD
Wanapum	GRANT PUD	FERC License	NPD		NPD	NWS	NWS	NPD*	NPS/NPD*	NPD
Priest Rapids	GRANT PUD	FERC License	NPD		NPD	NWS	NWS	NPD*	NPS/NPD*	NPD
Yakima Projects	USBR		NPD	NPS	NPD	NWS	NWS	NPD*		NPS/NPD
.... LOWER COLUMBIA										
MILL CREEK	CE	Congress.	NPW		NPW			NPW	NPW	NPW
MCNARY	CE	Congress.	NPD	NPW	NPW	NWS	NWS	NPD	NPW	NPD
WILLOW CREEK	CE	Congress.	NPP		NPP		NWS	NPP	NPP	NPP
JOHN DAY	CE	Congress.	NPD	NPP	NPD/NPP	NWS	NWS	NPD	NPP	NPD
Prineville	USBR	Section 7	NPP		NPP	NWS		NPP	NPP	NPP
Ochoco	USBR	Section 7	NPP		NPP	NWS		NPP	NPP	NPP
THE DALLES	CE	Congress.	NPD	NPP	NPP	NWS	NWS	NPD	NPP	NPD
BONNEVILLE	CE	Congress.	NPD	NPP	NPP	NWS	NWS	NPD	NPP	NPD
Swift #1 & #2	PP&L/COWLITZ	FERC License	NPD	NPP	NPD/NPP		NWS	NPP	NPP*	NPP
Yale V	PP&L	FERC License	NPD	NPP	NPD/NPP		NWS	NPP	NPP*	NPP
Mossyrock/ Mayfield	TACOMA CL	FERC License	NPD	NPP	NPD/NPP		NWS	NPP	NPP/NPD*	NPP

APPENDIX A
NPDR 1165-2-2
DISTRICT/DIVISION WATER MANAGEMENT RESPONSIBILITIES

PROJECT	OWNER	AUTHORITY	PRIMARY REGULATION	SECONDARY REGULATION	WATER CNTRL PLAN	WAT SUPL FORECAST	STREAMFLOW FORECAST	WATER CNTRL DATA SYSTEM	WATER CNTRL MANUAL	AFTER-ACTION REPORTING
.... WILLAMETTE										
HILLS CREEK	CE	Congress.	NPD	NPP	NPP/NPD	NPP	NWS/NPD	NPP	NPP	NPP/NPD
LOOKOUT POINT	CE	Congress.	NPD	NPP	NPP/NPD	NPP	NWS/NPD	NPP	NPP	NPP/NPD
DEXTER	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
FALL CREEK	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
COTTAGE GROVE	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
DORENA	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
COUGAR	CE	Congress.	NPD	NPP	NPP/NPD	NPP	NWS/NPD	NPP	NPP	NPP/NPD
BLUE RIVER	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
FERN RIDGE	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
GREEN PETER	CE	Congress.	NPD	NPP	NPP/NPD	NPP	NWS/NPD	NPP	NPP	NPP/NPD
FOSTER	CE	Congress.	NPD	NPD	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
DETROIT	CE	Congress.	NPD	NPP	NPP/NPD	NPP	NWS/NPD	NPP	NPP	NPP/NPD
BIG CLIFF	CE	Congress.	NPD	NPP	NPP/NPD		NWS/NPD	NPP	NPP	NPP/NPD
Scoggins	USBR	Section 7	NPP	NPD	NPP		NWS			
.... UPPER SNAKE										
Jackson Lake	USBR	Section 7	NPW	NPD	NPW	NWS/NPW*	NWS	NPW/NPD*	NPW*	NPW
Palisades	USBR	Section 7	NPW	NPD	NPW	NWS/NPW*	NWS	NPW/NPD*	NPW*	NPW
Ririe	USBR	Section 7	NPW	NPD	NPW	NWS*	NWS	NPW/NPD*	NPW*	NPW
American Falls	USBR			NPW	NPW	NWS*	NWS	NPW/NPD*		NPW
Little Wood	USBR	Section 7	NPW		NPW	NWS*	NWS	NPW/NPD*		NPW
Owyhee	USBR			NPW	NPW	NWS*	NWS	NPW/NPD*		NPW
Anderson Ranch	USBR	Section 7	NPW	NPD	NPW	NWS/NPW*	NWS	NPW*	NPW*	NPW
Arrowrock	USBR	Section 7	NPW	NPD	NPW	NWS/NPW*	NWS	NPW*	NPW*	NPW
LUCKY PEAK	CE	Congress.	NPW	NPD	NPW	NWS/NPW*	NWS	NPW*	NPW	NPW
Warm Springs	USBR	Section 7	NPW		NPW	NWS*	NWS	NPW*	NPW*	NPW
Agency Valley	USBR	Section 7	NPW		NPW	NWS*	NWS	NPW*	NPW*	NPW
Bully Creek	USBR	Section 7	NPW		NPW	NWS*	NWS	NPW*	NPW*	NPW
Cascade	USBR			NPW	NPW	NWS*	NWS	NPW*	NPW*	NPW
Deadwood	USBR			NPW	NPW	NWS*	NWS	NPW*	NPW*	NPW
Mason	USBR	Section 7	NPW		NPW	NWS*	NWS	NPW*	NPW*	NPW
.......MID, LOWER SNAKE										
Brownlee	IDAHO POW	FERC License	NPD	NPD/NPW	NPD	NWS	NWS	NPD*	NPW/NPD*	NPD/NPW
Oxbow	IDAHO POW	FERC License	NPW	NPD/NPW	NPD	NWS	NWS	NPD*	NPW/NPP*	NPD/NPW
Hells Canyon	IDAHO POW	FERC License	NPD	NPD/NPW	NPD	NWS	NWS	NPD*	NPW/NPD*	NPD/NPW
DWORSHAK	CE	Congress.	NPD	NPW	NPD/NPW	NPW/NPD	NWS	NPW	NPW	NPD/NPW
LOWER GRANITE	CE	Congress.	NPD	NPW	NPD	NWS	NWS	NPW	NPW	NPD/NPW
LITTLE GOOSE	CE	Congress.	NPD	NPW	NPD	NWS	NWS	NPD	NPW	NPD/NPW
LOWER MONUMENTAL	CE	Congress.	NPD	NPW	NPD	NWS	NWS	NPD	NPW	NPD/NPW
ICE HARBOR	CE	Congress.	NPD	NPW	NPD	NWS	NWS	NPD	NPW	NPD/NPW

'ENDIX A
1165-2-2
DISTRICT/DIVISION ...cR MANAGEMENT RESPONSIBILITIES

PROJECT	OWNER	AUTHORITY	PRIMARY REGULATION	SECONDARY REGULATION	WATER CNTRL PLAN	WAT SUPL FORECAST	STREAMFLOW FORECAST	WATER CNTRL DATA SYSTEM	WATER CNTRL MANUAL	AFTER-ACTION REPORTING
.......PUGET SOUND										
Ross/Diablo	SEATTLE CL	FERC License	NPS		NPS		NWS	NPS*	NPS*	NPS
Upper/Lower Baker	PUGET P&L	FERC License	NPS		NPS		NWS	NPS*	NPS*	NPS
LAKE WASHINGTON	CE	Congress.	NPS		NPS		NWS	NPS	NPS	NPS
HOWARD A HANSON	CE	Congress.	NPS		NPS	NPS	NPS/NWS	NPS	NPS	NPS
MUD MOUNTAIN	CE	Congress.	NPS		NPS		NPS/NWS	NPS	NPS	NPS
WYNOOCHEE	CE	Congress.	NPS		NPS	NPS	NPS/NWS	NPS	NPS	NPS
.......COASTAL										
Galesville	DOUGLAS COUNTY	Section 7	NPP		NPP		NWS	NPP*	NPP*	NPP
LOST CREEK	CE	Congress.	NPP	NPD	NPP	NPP	NWS/NPP	NPP	NPP	NPP
ELK CREEK	CE	Congress.	NPP	NPD	NPP		NWS/NPP	NPP	NPP	NPP
Emigrant	USBR	Congress.	NPP	NPP	NPP					
APPLEGATE	CE	Congress.	NPP	NPD	NPP	NPP	NWS/NPP	NPP	NPP	NPP

NOTES

1. Corps of Engineers projects are listed in capital letters

2. Asterisks (*) indicate that coordination with another agency is required in carrying out the responsibility. This notation was not used for the regulation function, since interagency coordination is assumed to be inherent in the process.

3. When joint responsibilities are shown, the office with lead responsibility is shown first.

4. Headings: "Primary Regulation" - prime responsibility for day-to-day regulation of the project, or coordination required to regulate the project as a part of a system.

   "Secondary Regulation" - periodic regulation responsibilities along with continuous monitoring of the project's operation.

   "Water Control Plan" - development and updating of the project's Water Control Plan. This may be for either the project's Water Control Manual or for coordinated system operation.

   "Water Supply Forecast" - development and updating of water supply forecast procedure for the project.

   "Streamflow Forecast" - Development, updating and implementation of streamflow forecasting procedure for project.

   "Water Control Data System" - Development, maintenance, and implementation of project's WCDS.

   "Water Control Manual" - Development and updating of project's Water Control Manual.

   "After-Action Reporting" - Routine or special reports such as post-flood reports.

APPENDIX B
DEFINITIONS AND ACRONYMS

Primary Regulation. For the purposes of this regulation the term primary regulation is meant to indicate the lead regulation responsibility for a project. This involves frequent monitoring of the project, the issuing of operating instructions, and personal contact with project operators. It also involves the necessary analysis required to make regulating decisions.

Secondary Regulation. For purposes of this regulation the term "secondary regulation" means the responsibility to maintain surveillance of their project's regulation to provide information to others and to participate in periodic coordination that may be necessary.

Regulation/Operation. The term "regulation" as applied to water management means the activity of regulating reservoirs, including receiving information and data on reservoir status, making analysis and decisions, coordinating with affected parties/agencies, and issuing instructions to dam operators. In this NPDR the term "regulation" is kept distinct from "operation" which refers to the actions by field personnel of maintaining and physically operating equipment at projects.

Water Control Data Systems (WCDS). A system of gages, telemetry, and computer processors that collects hydrometeorological data from remote sites and sends it to computer controllers for processing and use by water control managers.

Water Control Manual. A manual used as reference for regulating a reservoir project or system of projects. It contains a Water Control Plan, a specific plan of regulation for that project.

BPA Bonneville Power Administration

CBT Columbia Basin Telecommunications Network. A data communication network within CROHMS.

CROHMS The Columbia River Operational Hydromet and Management System, the name given to the Water Control Data System for the Columbia River.

GOES Geostationary Operational Environmental Satellite. A hydromet data collection system within CROHMS.

NWPP Northwest Power Pool.

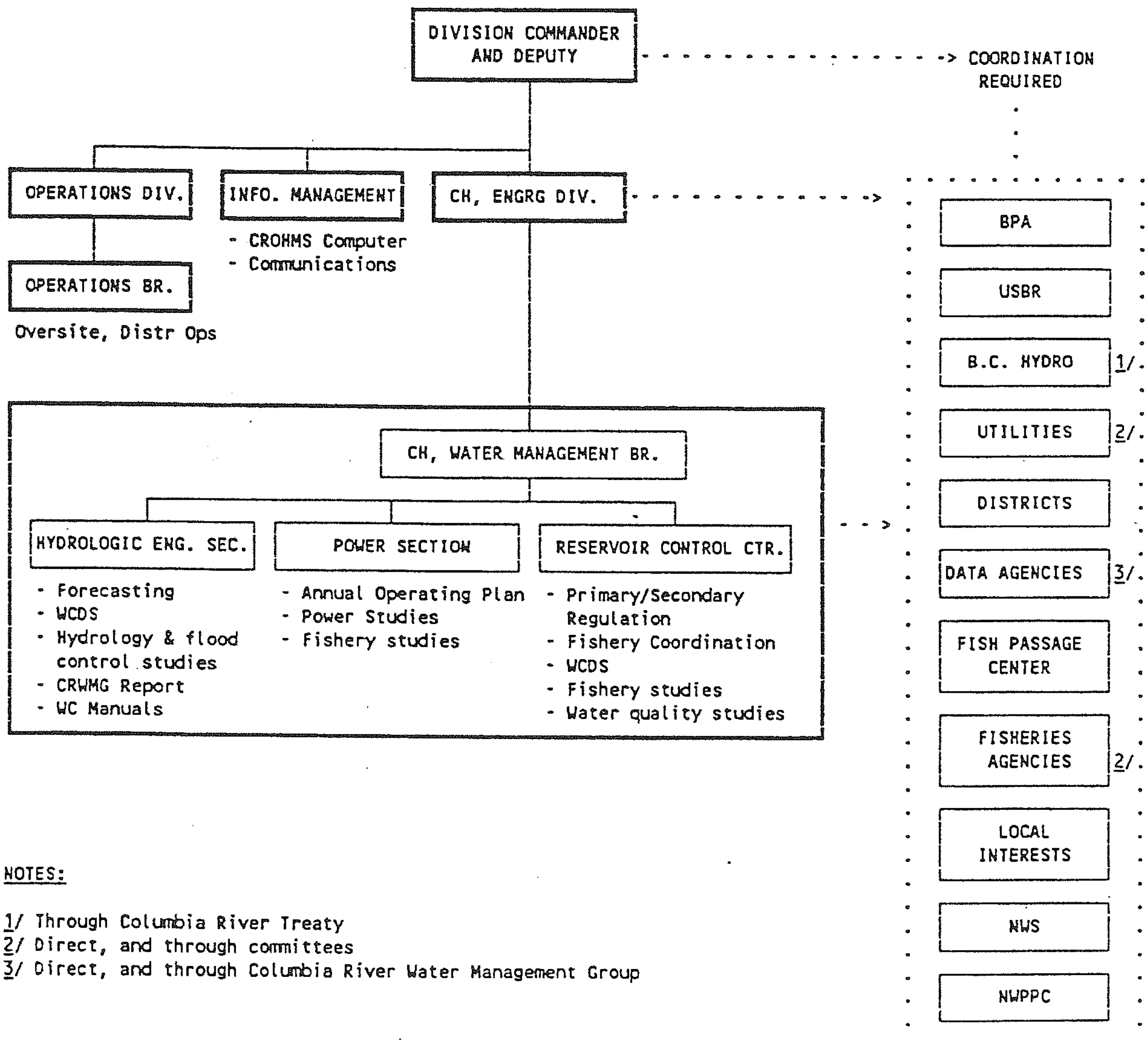
NWRFC Northwest River Foreast Center, National Weather Service.

USBR Bureau of Reclamation

APPENDIX C

DIVISION/DISTRICT ORGANIZATION FOR WATER MANAGEMENT

DIVISION OFFICE



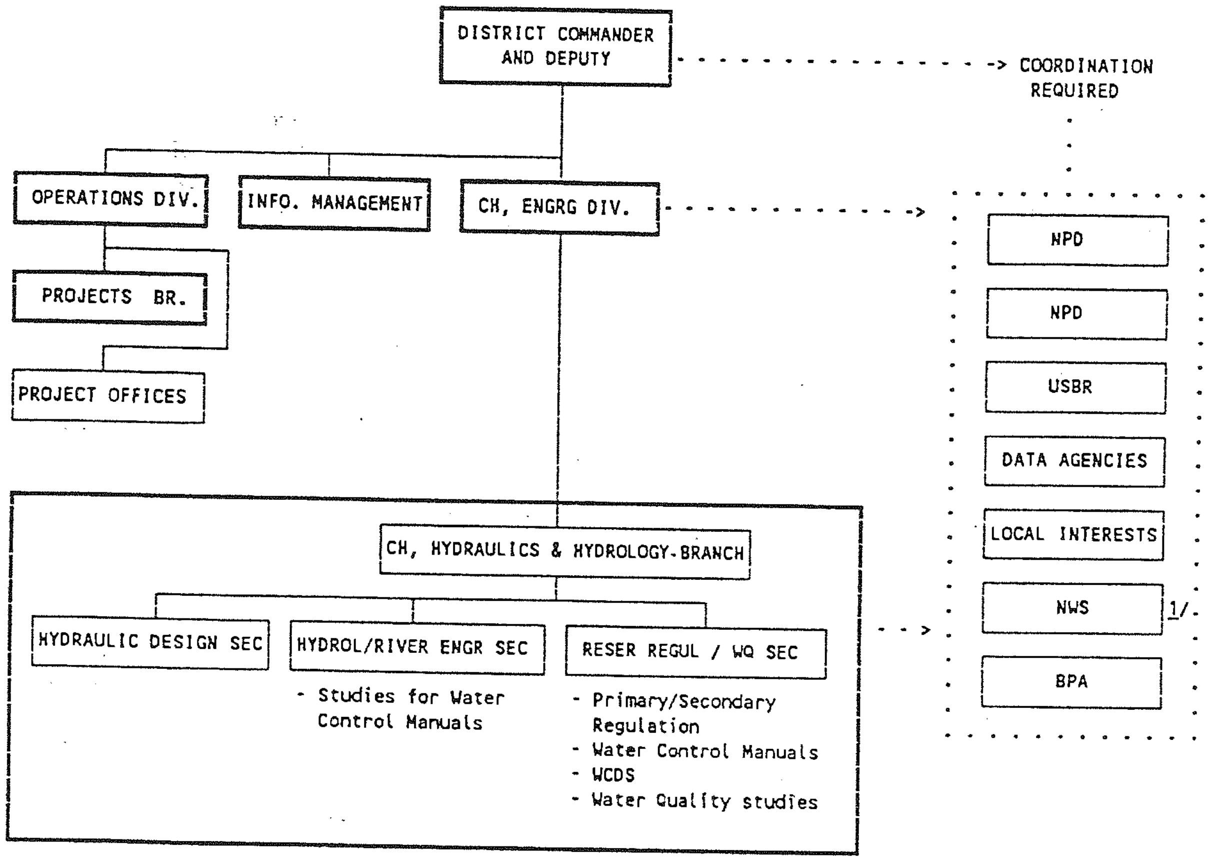
NOTES:

1/ Through Columbia River Treaty
2/ Direct, and through committees
3/ Direct, and through Columbia River Water Management Group

APPENDIX C (CONTINUED)

DIVISION/DISTRICT ORGANIZATION FOR WATER MANAGEMENT

PORTLAND DISTRICT OFFICE



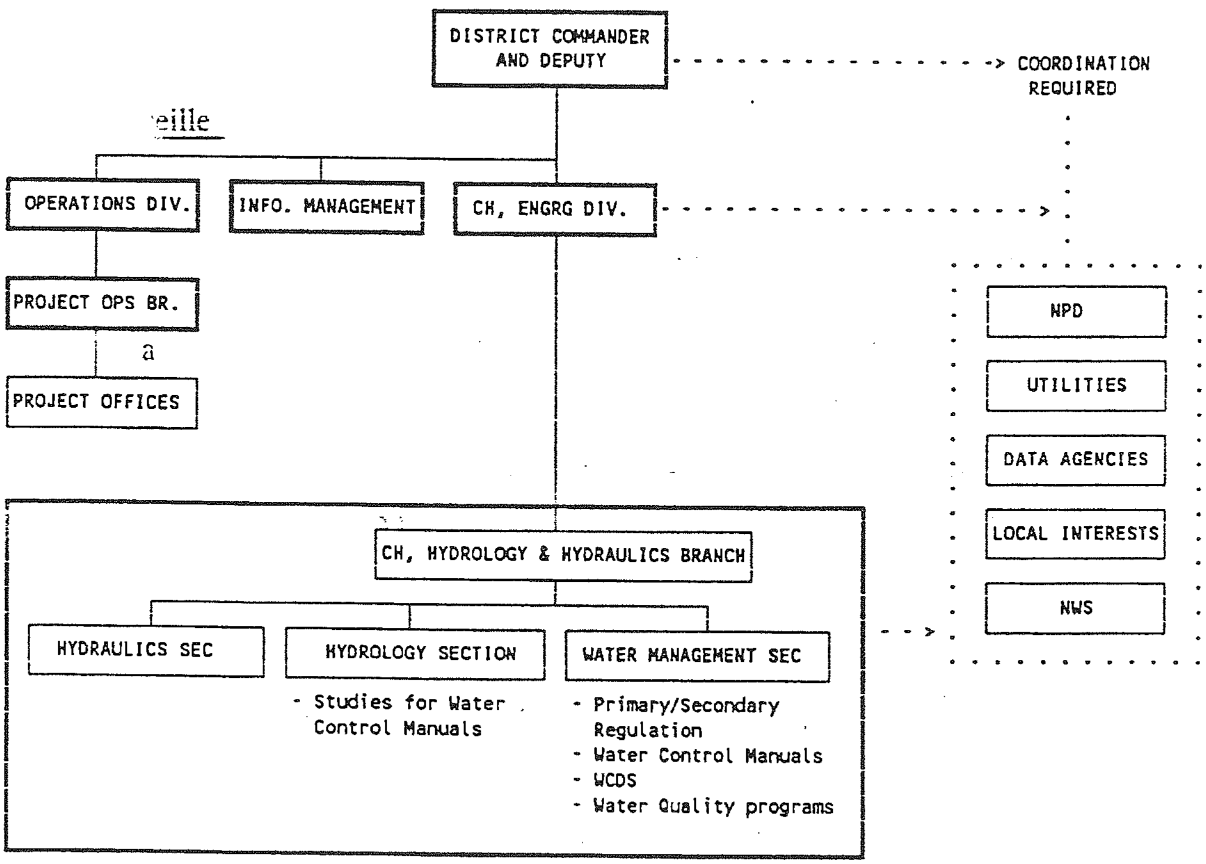
NOTES:

1/ Coordination at Lost Creek

APPENDIX C (CONTINUED)

DIVISION/DISTRICT ORGANIZATION FOR WATER MANAGEMENT

SEATTLE DISTRICT OFFICE



APPENDIX C (CONTINUED)

DIVISION/DISTRICT ORGANIZATION FOR WATER MANAGEMENT

WALLA WALLA DISTRICT OFFICE

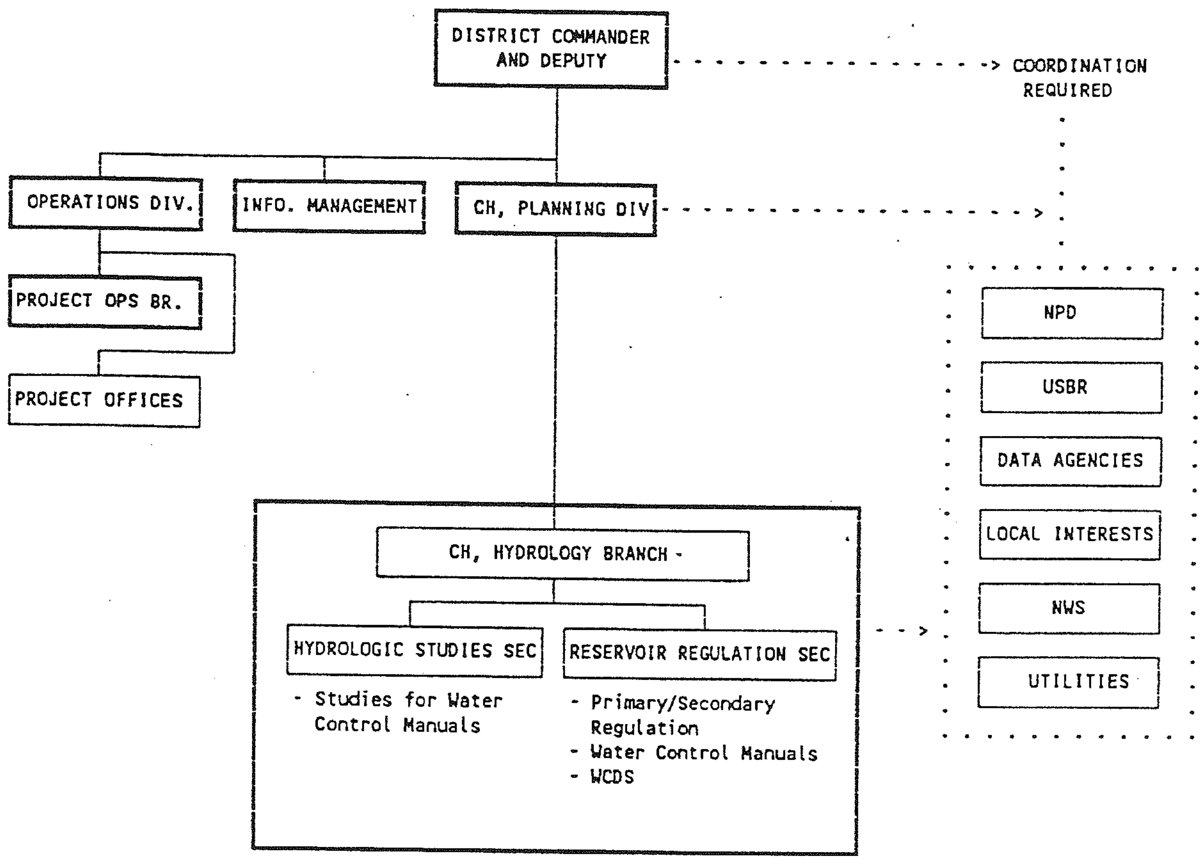


EXHIBIT 1-2

DESIGN MEMORANDUMS

No.	Subject	Date Issued	Date Approved by HQUSACE
1	Hydroelectric Power Development	13 Feb 53	19 May 53
2	Derivation of Spillway Design Flood	3 Mar 53	10 Jun 53
3	Location and Type of Dam	16 Feb 54	15 Jul 54
4	Relocation of Northern Pacific Railway Company's Facilities; Addendum to Design Memo	23 Jul 54	7 Oct 54
	Supplements to Design Memo 4		
	1 Bridge No. 1, Upper Crossing of Green River	20 Jan 55	10 Mar 55
	2 Bridge No. 2, Charley Creek	20 Jan 55	10 Mar 55
	3A Bridge No. 3, Lower Crossing of Green River	20 Apr 56	15 Jun 56
	Addendum No. 1	20 Jun 56	24 Jul 56
	4 Bridge No. 4 (Deleted)		
	5 Design Analysis on Determination of Culvert Capacity	25 Apr 56	15 Jun 56
	Addendum No. 1	28 May 56	20 Jul 56
	Addendum No. 2—Drainage	7 Dec 56	11 Jan 57
	6 Design Analysis on Stability of Embankment and Cut Slopes, Humphrey to Charley Creek	(Rev 5 Aug 55)	
	Addendum No. 1—Stability of Embankment and Cut Slopes	20 Sep 55	12 Oct 55
	Addendum No. 2—Rock Cut Slopes	14 Nov 55	
	7 Design Analysis on Stability of Embankment and Cut Slopes, Charley Creek, Station 10654+30 to Station 11073+00	28 May 56	20 Jul 56
	8 Design Analysis on Stability of Embankment Slopes, Bridge No. 81 Abutments, Station 11122+25 to Station 11131+21	17 Aug 56	8 Oct 56
	Addendum No. 1—Stability of Embankment and Cut Slopes	16 Oct 56	15 Nov 56
	9 Design Analysis on Stability of Embankment and Cut Slopes	8 Nov 56	12 Jun 57

5	City of Tacoma Water Supply	15 Oct 54	
	Supplement 1 to Design Memorandum 5	12 Jan 55	11 Apr 55
6	Relocation of Power Transmission Lines—BPA	20 Oct 54	2 Dec 54
7	General Design Memo	1 Dec 54	17 Feb 55
8	Real Estate Memo—Northern Pacific Railway Relocation Segment "A", Humphrey to Charley Creek	14 Jan 55	28 Apr 55
9	Relocation of Long Distance Telephone Lines, Pacific Telephone and Telegraph Company	18 Feb 55	20 Apr 55
10	Real Estate Memo—Northern Pacific Railway Relocation, Segment "B", Charley Creek to Tacoma Headworks	19 Aug 55	28 Oct 55
11	Report on Necessity for Relocation of Facilities, Puget Sound Power and Light Company	13 Dec 55	21 Feb 56
12	Rockfill Dam, Spillway, Outlet Works, and Related Project Facilities	14 Jun 56	1 Aug 56
	<u>Supplements to Design Memo 12</u>		
	1	7 Dec 56	
	2	8 Aug 58	
	3	8 Jan 60	
	4	15 Jun 60	10 Jan 61
	5 (Letter Report)	5 Nov 62	21 Jan 63
	6	1 Apr 65	18 May 65
	7	26 Jan 66	15 Mar 66
	8	15 Mar 67	11 May 67
13	Real Estate Memo—Northern Pacific Railway Relocation, Segment "C", Tacoma Headworks to Kanaskat; Segment "E"—Dam site Construction Area	27 Aug 56	(Rev 14 Dec 56)
14	Concrete Aggregate Investigation	30 Aug 56	
15	Report on Necessity for Relocation of County Roads Nos. 1224, 381, and 191, King County, Washington	6 Sep 56	
16	Real Estate Memo—Reservoir Area, Segments "F" and "G"	22 Mar 56	

17	Report on Necessity for Relocation of U.S. Forest Service Road No. 212 (rescinded and superseded by Design Memo 18	10 Apr 58	
18	Relocation U.S. Forest Service Road, No. 212	4 Jun 58 Rev 10 Aug 59	Disapproved 5 Nov 59
19	Reservoir Clearing	15 May 59	30 June 59
20	Hydrologic and Communication Facilities for Project Operations	Sep 59	3 Dec 59
21	Drift Control Facilities	Jul 60	Sep 60
22	Plan for Sedimentation Observation	11 Feb 60	6 Apr 60
23	Real Estate Memo—Land Requirements for Segment "K", Newaukum Creek Gaging Station	17 Nov 60	4 Jan 61
24	Real Estate Memo—Segments, "E", "F", and "G", Operations Access Roads	11 May 1962	20 June 1962
25	Real Estate Memo—Right Abutment Seepage Control Easement	10 Apr 1968	29 Apr 1968
26	Earthquake Analysis of Howard Hanson Dam	September 1983	
27	Right Abutment Seepage, Single-Row Grout Curtain Foundation Report	April 2003	
28	Section 1135 Fish and Wildlife Restoration Project, Final Project Modification Report/Environmental Assessment	September 1996	8 April 1997
29	Post Flood Report, Howard A. Hanson Dam	8 April 1997	
30	Additional Water Storage Project, Draft Feasibility Report & EIS	April 1998	
31	Evaluation of Right Bank Seepage/Filter Criteria for Howard A. Hanson Dam	15 November 2006	
32	Right Abutment Seepage. Test Pool Report, 1167-Foot Reservoir, 2002	December 2006	

33	Potential Failure Modes Analysis Study Report	May 2008
34	Evaluation of Embankment and Right Abutment Stability, Howard Hanson Dam	9 July 2008
35	Right Abutment Seepage, Conservation Pool Report, 1167-Foot Reservoir, 2007	September 2008
36	Right Abutment Revised Conceptual Site Model	September 2008
37	Post-Flood Pool of Record Data Report, Howard Hanson Dam, Green River, WA	February 2009

REDACTED CONTENT

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REDACTED CONTENT

Chapter 173–509 WAC
INSTREAM RESOURCES PROTECTION PROGRAM—GREEN–DUWAMISH RIVER BASIN, WATER RESOURCE INVENTORY AREA (WRIA) 9

WAC 173–509–010 **Purpose.** The purpose of this chapter is to retain perennial rivers, streams, and lakes in the Green–Duwamish drainage basin with instream flows and levels necessary for preservation and protection of wildlife, fish, scenic, aesthetic and other environmental values, recreational and navigational values, and to preserve water quality. Nothing in this chapter shall preclude the future issuance of regulations and/or signing of intergovernmental agreements which attempt to optimize the total public use of the basin water resources, providing they are consistent with the intent of this chapter. The instream flow rules presented here are for preservation of the existing resources so that when future planning or development occurs on this river these resources will be available. [Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–010, filed 6/6/80.]

WAC 173–509–015 **Background.** The Green–Duwamish River basin has been modified significantly since settlement of the area. Urbanization in the lower basin has influenced water quality and diversions for municipal and industrial water supply have altered the stream flow of the Green–Duwamish River. Ground water has been developed for consumptive use within the basin. The White River originally had a confluence with the Green River near Auburn but since 1906 it has been diverted into the Puyallup River. A dam on the Black River near Tukwila prevents water from the Green River from flowing into Lake Washington during periods of high flow. In 1913 the city of Tacoma commenced diversions for municipal and industrial uses. Since 1962 the Green–Duwamish River has been influenced by the operation of the Howard A. Hanson Dam, a Corps of Engineers flood control project with authorization to provide instream flow maintenance of at least 110 cfs for fisheries conservation purposes. The operation has also considered drinking water quality requirements of the city of Tacoma.

The Green–Duwamish River basin is a natural rearing and spawning area primarily for steelhead trout and chinook, coho and chum salmon. Fish hatcheries are located on tributary streams and these contribute to total numbers of fish produced by the river system. The river itself and the shoreline also offer easily accessible recreational opportunities. [Statutory Authority: RCW 90-.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–015, filed 6/6/80.]

WAC 173–509–020 **General provision.** These rules apply to all waters within the Green–Duwamish River basin, WRIA 9 (see WAC 173–500–040). This chapter is promulgated pursuant to chapter 90.54 RCW (Water Resources Act of 1971), chapter 90.22 RCW (minimum water flows and levels), and in accordance with chapter 173–500 WAC (water resources management program). The provisions of this chapter apply, as a matter of state law, to future water right authorizations issued pursuant to the state's water rights codes. [Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–020, filed 6/6/80.]

WAC 173–509–030 **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[1] by River Mile and Section, Township and Range	Affected Stream Reach Including Tributaries
12.1130.00 Green River near Auburn, WA	32.0 17–21–5	From influence of mean annual high tide at low instream flow levels (approximately River Mile 11.0) to USGS Gage #12.1067.000
12.1067.00 Gage Green River near Palmer, WA	60.4 13–21–7	From USGS #12.1067.000 to headwaters.

The Palmer gage will be used to condition future water rights upstream from that gage. The Auburn gage will be used to condition future water right appropriations downstream from the Palmer gage. If it becomes necessary to change a control station location to improve measurement accuracy or management capability, the department shall do so under provisions in WAC 173-500-060(6).

(2) Instream flows established for the stream management units in WAC 173-509-030(1) are as follows:

INSTREAM FLOWS FOR FUTURE WATER RIGHTS IN THE GREEN-DUWAMISH RIVER BASIN
(in Cubic Feet per Second)

Month	Day	12.1130.00 Normal Year Green River Near Auburn	12.1067.00 Normal Year Green River Near Palmer	12.1067.00 Critical Year Green River Near Palmer
Jan.	1	650	300	300
	15	650	300	300
Feb.	1	650	300	300
	15	650	300	300
Mar.	1	650	300	300
	15	650	300	300
Apr.	1	650	300	300
	15	650	300	300
May	1	650	300	300
	15	650	300	300
June	1	650	300	300
	15	650	300	210
July	1	550	300	150
	15	300	150	150
Aug.	1	300	150	150
	15	300	150	150
Sept.	1	300	150	150
	15	300	150	150
Oct.	1	300	190	150
	15	350	240	150
Nov.	1	550	300	190
	15	550	300	240
Dec.	1	650	300	300
	15	650	300	300

(a) Future water right holders subject to regulation by the Palmer gage will not be allowed to continue diversions when flows fall below the normal year instream flows at the Palmer gage 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 will diversions subject to regulation by the Palmer gage be continued when flows fall below the critical year instream flows at Palmer. At no time will diversions subject to regulation by the Auburn gage be continued when flows fall below the normal year instream flows at Auburn. When a declaration of overriding considerations of public interest is made by the director, these requirements may be modified or waived. A declaration of overriding consideration because of drought conditions shall not be made when natural flows equal or exceed the one-in-fifty year low flow condition. The director shall consult with the directors of the state departments of wildlife and fisheries before making a declaration of overriding consideration. Any declaration of critical conditions or overriding considerations of public intere made by the director shall be communicated to all bas resource agencies, water purveyors, and local gener purpose governments, and include the reason for suc declaration and its expected duration.

(b) The director will consider declaring a critical pe riod when:

(1) In the spring the basin runoff volume forecast c May 1 is not adequate to meet the sum of any righ which the city of Tacoma may have established throug historical usage prior to the adoption of this regulatio plus the normal year instream flows plus the volume re quired to replenish the conservation storage.

(2) In the summer and fall the sum of the reservo inflows extrapolated from current observations plus th volume of water in storage at Howard A. Hanson Dar is not adequate to meet the sum of any rights which th city of Tacoma may have established through historica usage prior to the adoption of this regulation plus th normal year instream flows. Within five days the direc tor will inform the major affected water right holders o the extent of the allowed deviation from the normal yea instream flows. Once a deviation from normal year in stream flows is allowed, the water resources shall b evaluated at least every 7 days to see if additional devi ation is warranted. Before allowing deviation from th normal year instream flows, water conservation practice and use of other sources shall be considered.

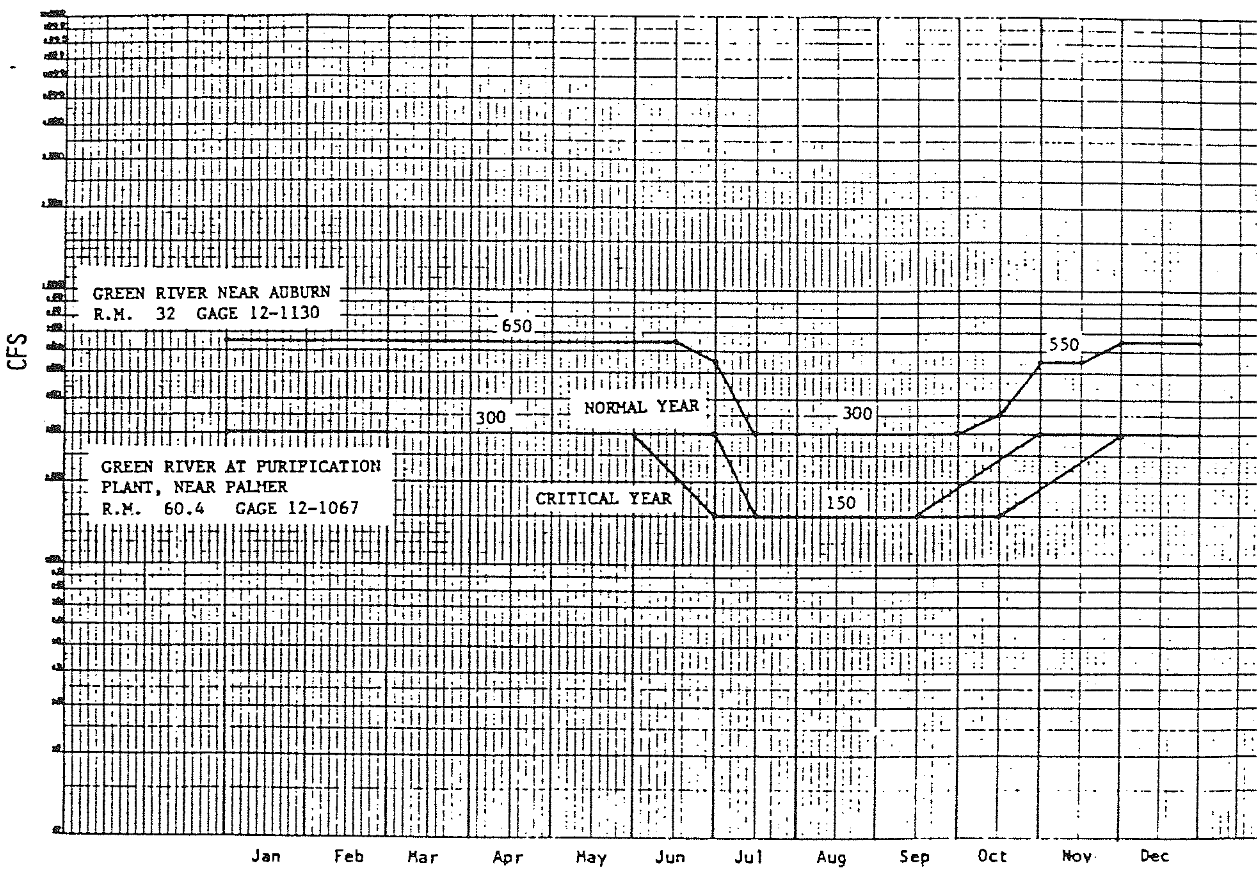
(c) In addition to other necessary provisions, any di version of the natural flow, including diversion to storag under future water rights shall cease (or be regulated t the extent necessary) when the flow at the applicabl control station falls below (or is less than) the instrean flows established by this regulation and made a condi tion of said future water right. Said future water right are subject to the rights and authority of the Corps o Engineers to utilize for storage and conservation flows the natural inflow to the Howard A. Hanson reservoi and to all other prior water right holders' authorized us of natural flows, including any rights that the city o Tacoma may have established through historical usage The use of stored waters is not to be impaired, limited or diminished by this regulation.

The department recognizes that from time to time th Corps of Engineers may establish a minimum reservoi level which is necessary to provide conservation flow with a high measure of assurance. When the reservoi falls below this level it may be necessary for the Corp of Engineers to replenish conservation storage. Whe this occurs, water rights subject to the provisions of thi chapter may be temporarily regulated or diminished an the actual stream discharge diminished.

(3) Instream flows, as represented in Figure 1, shal be used for definition of instream flows on those day not specifically identified in WAC 173-509-030(2).

FIGURE 1 - PROPOSED INSTREAM FLOWS FOR FUTURE WATER RIGHTS IN THE GREEN-DUWAMISH RIVER BASIN

FIGURE 1 INSTREAM FLOWS FOR FUTURE WATER RIGHTS IN THE GREEN–DUWAMISH RIVER BASIN



(4) All consumptive water rights hereafter established shall be expressly subject to the instream flows established in WAC 173–509–030 (1) through (3). However, nothing in this section shall prohibit the release or diversion of stored water or the use of any water course as a means for its conveyance in accordance with RCW 90.03.030. [Statutory Authority: Chapters 43.21B, 43-.27A, 90.22 and 90.54 RCW. 88–13–037 (Order 88–11), § 173–509–030, filed 6/9/88. Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–030, filed 6/6/80.]

WAC 173–509–040 **Surface water source limitations to further consumptive appropriations.** (1) 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 Administrative Closure	Period (Administra Closur
All tributaries of Green River SE1/4SE1/4 sec. 14, T.32 N., R.4E.	8/19/53	All yea
Deep Creek (including Hyde Lk.), tributary to Deep Lake NW1/4SE1/4 sec. 18, T.21N., R.7E.	4/17/53	All yea
Unnamed stream (Des Moines Creek, Tributary to Puget Sound SW1/4SW1/4 sec. 8, T.22N., R.4E.	8/22/52	All yea
Unnamed stream (Garrison Creek), Tributary to Black River (indirect) NW1/4NW1/4NW1/4 sec. 6, T.22N., R.5E.	10/18/51	All yea
Unnamed stream (Miller Creek) (Maybrook Creek), Tributary to Puget Sound NE1/4NE1/4 sec. 36, T.23N., R.3E.	1/7/46	All yea
Unnamed stream (Spring-brook Creek), Tributary to Black River NE1/4SE1/4SW1/4 sec. 13, T.23N., R.4E.	11/14/45	All yea

(2) The department, having determined that maximum lake levels have been established by court decree for certain lakes in WRIA 9, adopts the following lake levels. These maximum lake levels confirm lake levels previously established by order of the superior court for King County.

MAXIMUM LAKE LEVELS

Lakes	Lake Level Established	Date of Order
Angle Lake	349.27 ft. at MSL	4/21/75
Star Lake	324.46 ft. at MSL	9/20/50
Lake Sawyer (Tributary to Covington Creek)	518.94 ft. at MSL	8/5/52

[Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–040, filed 6/6/80.]

WAC 173–509–050 Ground water. Future groundwater withdrawal permits will not be affected by this chapter unless such withdrawal would clearly have an adverse impact upon the surface water system contrary to the intent and objectives of this chapter. [Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–050, filed 6/6/80.]

WAC 173–509–060 Future rights. No right to divert or store public waters of the Green–Duwamish River basin, WRIA 9, shall be granted which shall conflict with the purposes of this chapter: *Provided however,* Withdrawals of water which would conflict with said purposes may be authorized in those situations where it is clear that overriding considerations of the public interest will be served. [Statutory Authority: RCW 90.22-.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–060, filed 6/6/80.]

WAC 173–509–070 Exemptions. (1) Nothing in this chapter shall affect water rights, riparian, appropriative, or otherwise, existing on the effective date of this chapter, nor shall it affect existing rights relating to the operation of any navigation, hydroelectric or water storage reservoir or related facilities, including but not limited to: (a) Howard Hanson Dam storage and operation as authorized in the Flood Control Act of May 17, 1950; (b) any existing right the city of Tacoma may have.

(2) Domestic inhouse use for a single residence and stock watering, except that related to feed lots, shall be exempt from the provisions of this chapter.

(3) Storage projects may be approved if they are not in conflict with the purposes of this chapter. [Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–070, filed 6/6/80.]

WAC 173–509–080 Enforcement. In the 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), § 173–509–080, filed 6/9/88. Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–080, filed 6/6/80.]

WAC 173–509–085 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), § 173–509–085, filed 6/9/88.]

WAC 173–509–090 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. The director shall initiate a review of the rules by appointing a committee of major affected water right holders, basin resource management interests, and governmental agencies. [Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88–13–037 (Order 88–11), § 173–509–090, filed 6/9/88. Statutory Authority: RCW 90.22.020, 90.54-.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–090, filed 6/6/80.]

WAC 173–509–100 Implementation. In the event the COE is authorized to change the operation of Howard Hanson Dam in order to meet the stream flows established in this chapter and so advises the director, these regulations shall be reviewed by the department within 180 days of the COE authorization to determine, what, if any, amendments are required to maintain the integrity and purpose of this chapter. [Statutory Authority: RCW 90.22.020, 90.54.020 and 90.54.040. 80–07–005 (Order DE 79–32), § 173–509–100, filed 6/6/80.]