EFFECTS OF WATER LEVEL FLUCTUATIONS ON NATURAL RESOURCES WITHIN THE WELLS PROJECT: A REVIEW OF EXISTING INFORMATION

WELLS HYDROELECTRIC PROJECT

FERC NO. 2149

October, 2006

Prepared By:
Devine Tarbell & Associates
1111 North Forest Street
Bellingham, WA 98225

Prepared for:
Public Utility District No. 1 of Douglas County
East Wenatchee, Washington

For copies of this document, please contact:

Public Utility District No. 1 of Douglas County
Relicensing
1151 Valley Mall Parkway
East Wenatchee, WA 98802-4497
Phone: (509) 884-7191
E-Mail: relicensing@douglaspud.org

Table of Contents

List of Tables

List of Figures

List of Appendices

ABSTRACT

This document presents an assessment of the effects of Wells Reservoir operations on natural resources of the Wells Project. The objectives of this study were to describe the effects of these operations on aquatic resources, with emphasis on salmonids and Pacific lamprey; terrestrial resources, with emphasis on waterfowl, amphibians, wetlands and riparian habitat; and erosion. This review found that typical operations within the Wells Project lead to daily reservoir fluctuations of one to two feet. Infrequent reservoir operations necessitated by unusual circumstances, such as extreme runoff from the Methow or Okanogan rivers, can result in fluctuations of greater than four feet. These infrequent operations occurred only 1.1% of the time between 1990 and 2005.

The effect of consistent daily fluctuations on natural resources appears negligible on aquatic and terrestrial resources. This investigation suggested that the effects of daily fluctuations and infrequent reservoir operations on anadromous salmon and bull trout are limited, due to their minimal use of habitat within the project boundary. Pacific lamprey juveniles and adults are highly mobile and do not appear to be affected by fluctuations, although a small portion of less mobile ammocoete larvae may have an increased risk of stranding and entrapment. Wetlands are well-suited to handling changes in soil moisture and water content and the short duration of infrequent reservoir operations did not pose a threat. Waterfowl may be temporarily displaced from preferred habitat, but numerous alternative food resources and the short duration of infrequent reservoir operations appears to have a negligible effect on thriving waterfowl populations. Small amounts of erosion are occurring within the Project, but the contributions of reservoir operations on erosion were judged to be minor.

1.0 INTRODUCTION

The normal operation of the Wells Project results in daily fluctuations of the Wells Reservoir water surface elevation of 1 to 2 feet (see Appendix A). Greater magnitude drops in reservoir elevation occur but are somewhat infrequent. It has been reported in the literature that reservoir fluctuations may potentially affect shoreline stability, aquatic resources, associated riparian and wetland vegetation, or wildlife. The purpose of this review is to assess known or potential effects of fluctuations in the Wells Reservoir due to plant operations, in light of relevant studies and related literature.

2.0 GOALS AND OBJECTIVES

The goal of the study was to assess and describe the effects of reservoir fluctuations on the natural resources found within the Wells Project. The specific study objectives were to:

1) Review, evaluate and summarize existing information on the effects of Wells Project water level fluctuations on aquatic resources, with emphasis on salmonids and Pacific lamprey;

2) Review, evaluate and summarize existing information on the effects of Wells Project water level fluctuations on terrestrial resources, with emphasis on waterfowl, amphibians, wetland and riparian habitat; and

3) Review, evaluate and summarize existing information on the effects of Wells Project water level fluctuations on erosion within the Wells Project.

3.0 STUDY AREA

Wells Dam is located at river mile (RM) 515.8 on the Columbia River in the State of Washington (Figure 3.0-1). It is located approximately 30 river miles downstream from Chief Joseph Dam which is owned and operated by the United States Army Corps of Engineers (COE), and 42 miles upstream from Rocky Reach Dam which is owned and operated by Public Utility District No. 1 of Chelan County (Chelan PUD). The nearest town is Pateros, Washington, which is located approximately 8 miles upstream from Wells Dam. Wells Dam impounds 29.5 miles of the Columbia River upstream to the tailrace of the Chief Joseph Hydroelectric Project at RM 545.1. The drainage area of the Columbia River Basin upstream of Wells Dam is approximately 85,300 square miles.

The Wells Reservoir has riverine characteristics in the upper 5-mile section downstream from the Chief Joseph Dam tailrace. In contrast, the middle ten-mile section, as well as the lower Okanogan River, Methow River confluence, and the Wells Forebay, is more typically lacustrine. The lowermost 15-mile section is relatively narrow and fast flowing, compared to the middle section, but eventually slows and deepens as it nears the forebay of Wells Dam (Beak, 1999). Low-gradient, alluvial shorelines are concentrated around the Okanogan River confluence, including Cassimer Bar and Bridgeport Bar. The normal maximum surface area of the reservoir is 9,740 acres with a gross storage capacity of 331,200 acre-feet and usable storage of 97,985 acre feet at an elevation of 781. The normal maximum water surface elevation of the reservoir is 781 feet (Figure 3.0-1). The two major tributaries within the Wells Project are the Methow and Okanogan rivers.

The Methow River enters the Columbia River (RM 524) at the town of Pateros, Washington. The Wells Project impoundment affects 1.5 miles of the Methow River upstream from its confluence with the Wells Reservoir. The Okanogan River originates near Armstrong, British Columbia and flows south through a series of lakes to the Columbia River. It enters the Wells Reservoir at RM 534, approximately 18 miles upstream of Wells Dam. The Wells Project impoundment affects approximately 15.5 miles of the Okanogan River upstream from its confluence with the Columbia River.

The study area will include all water bodies within the Wells Reservoir, including the mainstem Columbia River between Chief Joseph Dam and the forebay of Wells Dam and sections of the Methow and Okanogan rivers below the Wells Project Boundary.

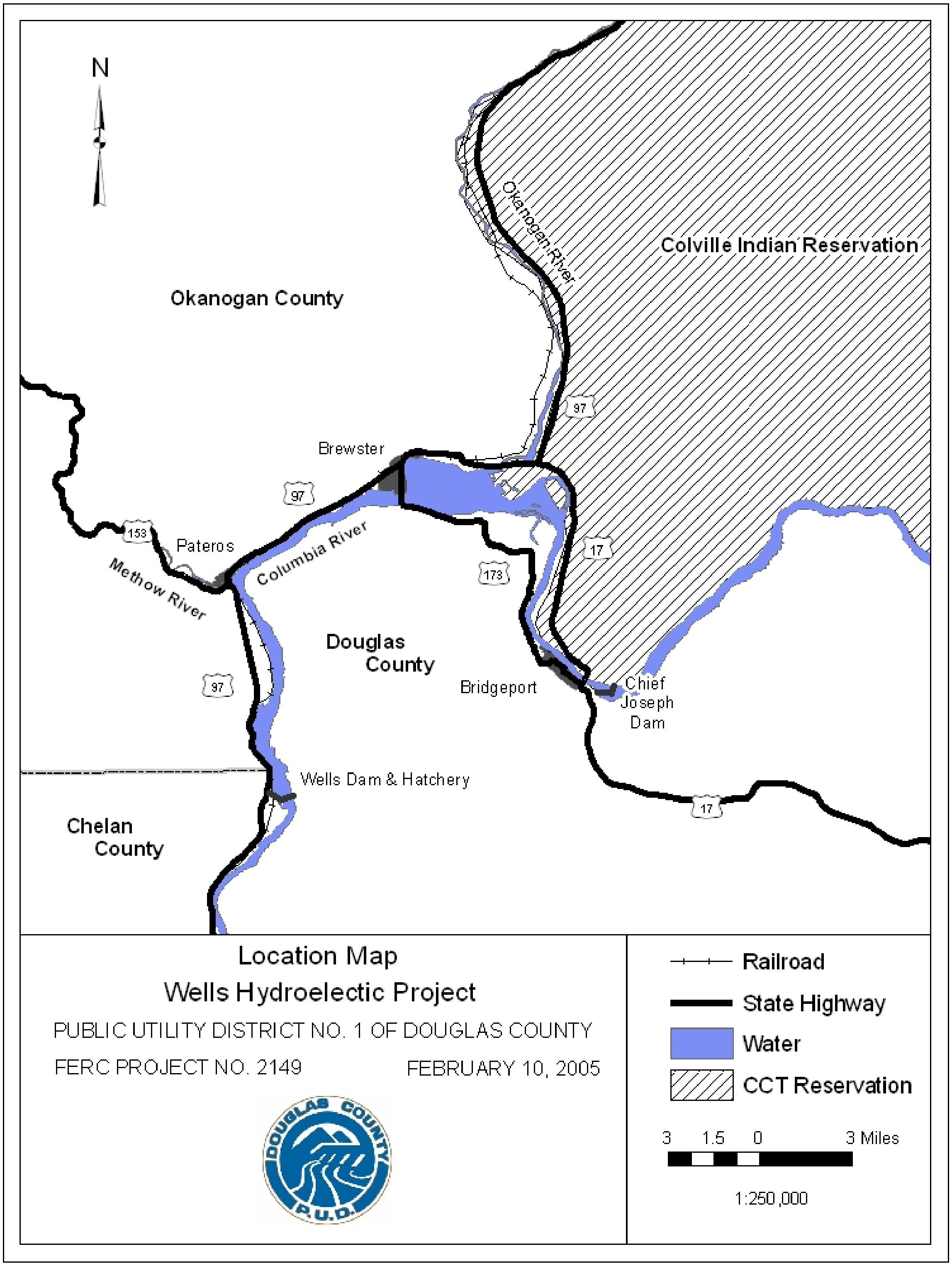


Figure 3.0-1 **Location Map of the Wells Project**

4.0 WATER FLUCTUATIONS AS A RESULT OF OPERATIONS

4.1 Daily Operations

The Project generally operates as “run-of-the-river”, meaning that daily inflow is approximately equal to daily outflow. By the terms of the current FERC license, the Project is constrained to operate within a relatively narrow operational range from elevation 781 feet to elevation 771 feet (see Figure 4.1-1). At 781 feet elevation, total storage capacity is approximately 331,200 acre-feet, of which about 30% (97,985 acre-feet) can be used.

Inflow to the Project originates from both regulated and unregulated sources. Sources of unregulated inflows include the two largest tributaries, the Methow and Okanogan rivers. Regulated sources of inflow are the projects upstream of Wells along the Columbia River and its tributaries in the US and Canada. The Chief Joseph Project, immediately upstream of the Wells Project, is also a run-of-the-river project, but releases from Grand Coulee and other large storage projects in the system largely dictate the flow regimes of the downstream projects including Wells. Wells Project operations reflect these inputs as well as FERC license requirements, coordination of water releases on an hourly basis with other Mid-Columbia River hydropower projects, fish and wildlife management requirements, and the local power demands of Douglas County and power purchasers.

Daily operations are largely governed by the Mid-Columbia Hourly Coordination Agreement (HCA). The HCA provides for coordinated releases between the seven mid-Columbia hydroelectric dams (Grand Coulee, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids) to efficiently use the river, supply energy during times of peak public demand, and maintain adequate flow to protect natural resources (HCA, 1997). In effect, the HCA manages upstream releases and ensures downstream reservoirs make room to receive and release upstream flows. As a result of these coordinated operations, water fluctuations within the Wells Reservoir are minimized, generally not exceeding one to two feet throughout the day. The Project has operated under the terms of the HCA since 1972, and is currently operating within a 20-year agreement (effective through 2017).

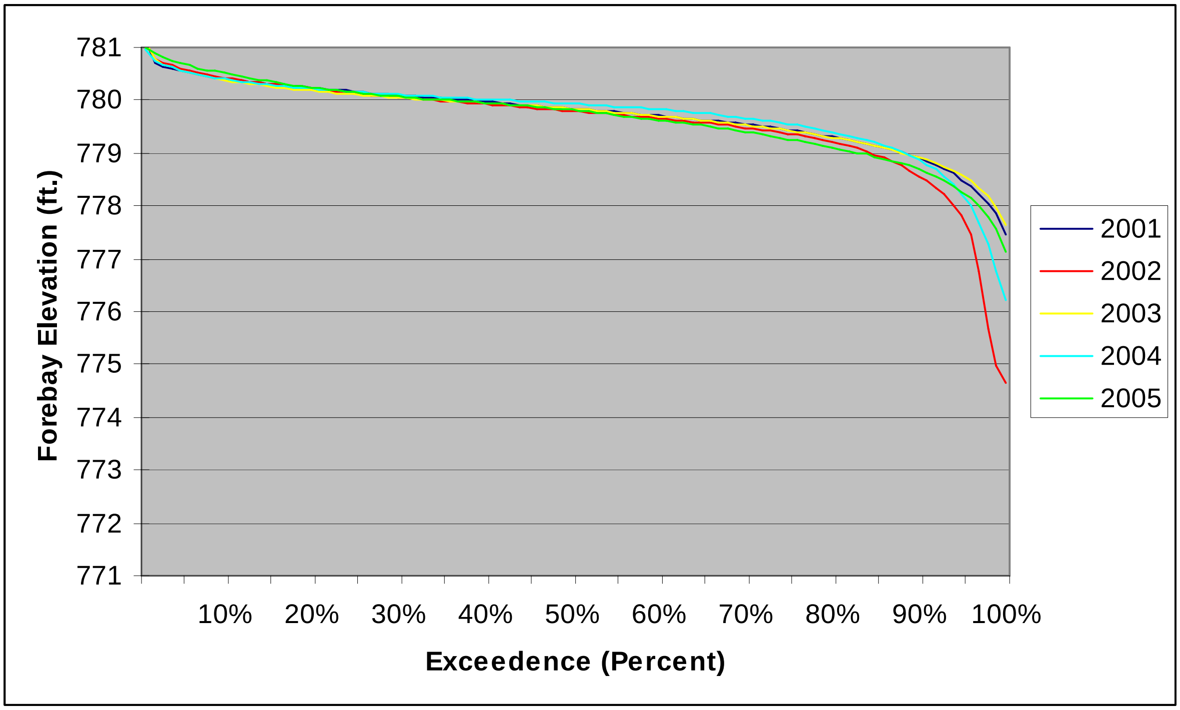


Figure 4.1-1 Headwater duration curves, Wells Forebay (hourly data) 2001-2005.

Researchers investigating water elevation fluctuations in other hydropower projects have used descriptors such as, “unnaturally rapid” (Hunter, 1992). In contrast, typical operational fluctuations of the Wells Project are gradual, repetitive changes in reservoir stage that occur on a daily basis. These predictable changes in water stage elevation define the upper water line, which establishes a persistent dynamic zone. The persistent dynamic zone defines the littoral habitat boundary. Repetitive and consistent fluctuations in flow tend to reduce the potential for beaching or trapping fish (Phinney, 1974, in Hunter et al., 1992), in contrast to a stable water stage followed by a sudden and unpredictable water level fluctuation. Repetitive fluctuations create a predictable environment for establishment of aquatic and terrestrial organisms within the littoral zone.

4.2 Infrequent Reservoir Operations

Although daily operations generally result in reservoir elevation fluctuations of one to two feet, infrequent reservoir operations also occur in unusual circumstances. For this discussion, “infrequent reservoir operations” are defined as changes in water elevation which exceed twice the normal daily operation fluctuations (i.e., a change of more than four feet in a 24-hour period). The majority of these events are necessitated when intense precipitation or rapid snowmelt increases inflow from the Methow and Okanogan tributaries, subsequently requiring flood control operations of the Wells Reservoir. In addition, the Wells Project must accommodate inflow from upstream spill events at Chief Joseph Dam by drafting water. Past environmental management actions that required infrequent reservoir operations have included flushing flows to move sediment from the lower Methow River; increased discharge and resultant reservoir drafting to support downstream spawning, incubation and emergence for Hanford Reach fall

Chinook; and lowered water level elevations to facilitate construction of islands for waterfowl habitat.

Review of hourly data monitoring has shown that the Wells Project operations remain well within the allowable limits established by its FERC license (see Table 4.2-1 and Appendix A). During the past five years of operation, the daily fluctuation frequency of the reservoir was less than three feet 93.3% of the time and minimum elevations fell below 777 feet only 3.8% of the time. Infrequent reservoir operations resulting in fluctuations over four feet in a 24 hour period have occurred only 1.1% of the time. In the last 15 years (1990-2005), the Forebay maintained a minimum water surface elevation of at least 777 feet 95.1% of the time and infrequent reservoir operations occurred only 0.8% of the time.

The effects of infrequent reservoir operations are limited by the operational requirements of the Project: because Forebay elevation cannot fall below 771 feet, the maximum possible fluctuation is ten feet (i.e., between 781 and 771 ft). However, in the past, infrequent reservoir operations generally result in fluctuations of less than five feet. This is because the Project is required to maintain sufficient storage to provide minimum flows if called upon by downstream projects. As a result, over the last 15 years (1990-2005) infrequent reservoir operations have resulted in fluctuations beyond six feet only 0.1% of the time and never resulted in fluctuations past seven feet.

Infrequent reservoir operations are generally brief in duration (i.e., 1 to 5 hrs), and reservoir stage may rise and fall several times in the course of an event (see Figure 4.2-1). Infrequent reservoir operations occurred a total of 21 times between 2000 and 2005, ranging in frequency from one in 2003 to seven in 2005 (see Tables 4.2-1 and 4.2-2). In order to characterize the features of individual occurrences of infrequent reservoir operations, eleven randomly selected events that occurred between 2000 and 2005 were examined. The periods immediately preceding and following each of the eleven occurrences were also examined to accurately portray the drafting and recharging of the reservoir. The mean duration for these occurrences was 7.1 hours, and the median value was 3.0 hours. Six of the eleven occurrences of infrequent reservoir operations were less than five hours duration, and only two of the eleven exceeded ten hours. During these occurrences, successive changes in water elevation sometimes dewatered and immersed a zone of two to three vertical feet numerous times.

Infrequent reservoir operations have occurred in each month except February, August, September, and Decembers in the course of the last five years, and occurred most frequently in July (5 events) and April (4 events) (Table 4.2-2). However, the pattern of occurrence was highly variable, and infrequent reservoir operations rarely occurred in the same month in successive years.

Table 4.2-1 Five year summary and five and fifteen year averages of operations in relation to reservoir fluctuation frequency and changes to minimum water elevation as a result of operations. Note: A small portion of values were not available and total number of days reflects missing values.

Year	Reservoir Fluctuation Frequency			Minimum Water Elevation Frequency		
	Elevation Change (ft.)	Days	Frequency	Min. Water Stage (ft.)	Days	Frequency
2001	0 to 2	245	67.1%	781 to 779	339	92.9%
	2 to 3	91	24.9%	779 to 777	26	7.1%
	3 to 4	23	6.3%	777 to 775	0	0.0%
	4 to 6	6	1.6%	775 to 773	0	0.0%
	6 to 10	0	0.0%	773 to 771	0	0.0%
2002	0 to 2	272	74.5%	781 to 779	148	40.5%
	2 to 3	74	20.3%	779 to 777	192	52.6%
	3 to 4	15	4.1%	777 to 775	11	3.0%
	4 to 6	3	0.8%	775 to 773	13	3.6%
	6 to 10	1	0.3%	773 to 771	1	0.3%
2003	0 to 2	235	64.4%	781 to 779	132	36.2%
	2 to 3	108	29.6%	779 to 777	223	61.1%
	3 to 4	21	5.8%	777 to 775	9	2.5%
	4 to 6	0	0.0%	775 to 773	1	0.3%
	6 to 10	1	0.3%	773 to 771	0	0.0%
2004	0 to 2	279	76.2%	781 to 779	182	49.7%
	2 to 3	67	18.3%	779 to 777	163	44.5%
	3 to 4	17	4.6%	777 to 775	18	4.9%
	4 to 6	2	0.5%	775 to 773	3	0.8%
	6 to 10	1	0.3%	773 to 771	0	0.0%
2005	0 to 2	229	62.7%	781 to 779	128	35.1%
	2 to 3	103	28.2%	779 to 777	223	61.1%
	3 to 4	26	7.1%	777 to 775	12	3.3%
	4 to 6	6	1.6%	775 to 773	2	0.5%
	6 to 10	1	0.3%	773 to 771	0	0.0%

Year	Reservoir Fluctuation Frequency			Minimum Water Elevation Frequency		
	Elevation Change (ft.)	Days	Frequency	Min. Water Stage (ft.)	Days	Frequency
5 yr. Average (2001-2005)	0 to 2	1260	69.0%	781 to 779	929	50.9%
	2 to 3	443	24.3%	779 to 777	827	45.3%
	3 to 4	102	5.6%	777 to 775	50	2.7%
	4 to 6	17	0.9%	775 to 773	19	1.0%
	6 to 10	4	0.2%	773 to 771	1	0.1%

Year	Reservoir Fluctuation Frequency			Minimum Water Elevation Frequency		
	Elevation Change (ft.)	Days	Frequency	Min. Water Stage (ft.)	Days	Frequency
15 yr. Average (1990-2005)	0 to 2	4715	81.9%	781 to 779	3464	60.2%
	2 to 3	807	14.0%	779 to 777	2008	34.9%
	3 to 4	182	3.2%	777 to 775	177	3.1%
	4 to 6	43	0.7%	775 to 773	81	1.4%
	6 to 10	7	0.1%	773 to 771	24	0.4%

Table 4.2-2 Frequency and month of infrequent reservoir operations from 2001 through 2005. Infrequent reservoir operations are defined in Section 4.2.

Month	Frequency and Year					Total
	2001	2002	2003	2004	2005	
January	2	0	0	0	0	2
February	0	0	0	0	0	0
March	0	0	1	0	2	3
April	2	1	0	1	0	4
May	1	0	0	0	0	1
June	0	1	0	0	0	1
July	1	2	0	0	2	5
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	1	2	3
November	0	0	0	1	1	2
December	0	0	0	0	0	0
Total	6	4	1	3	7	21

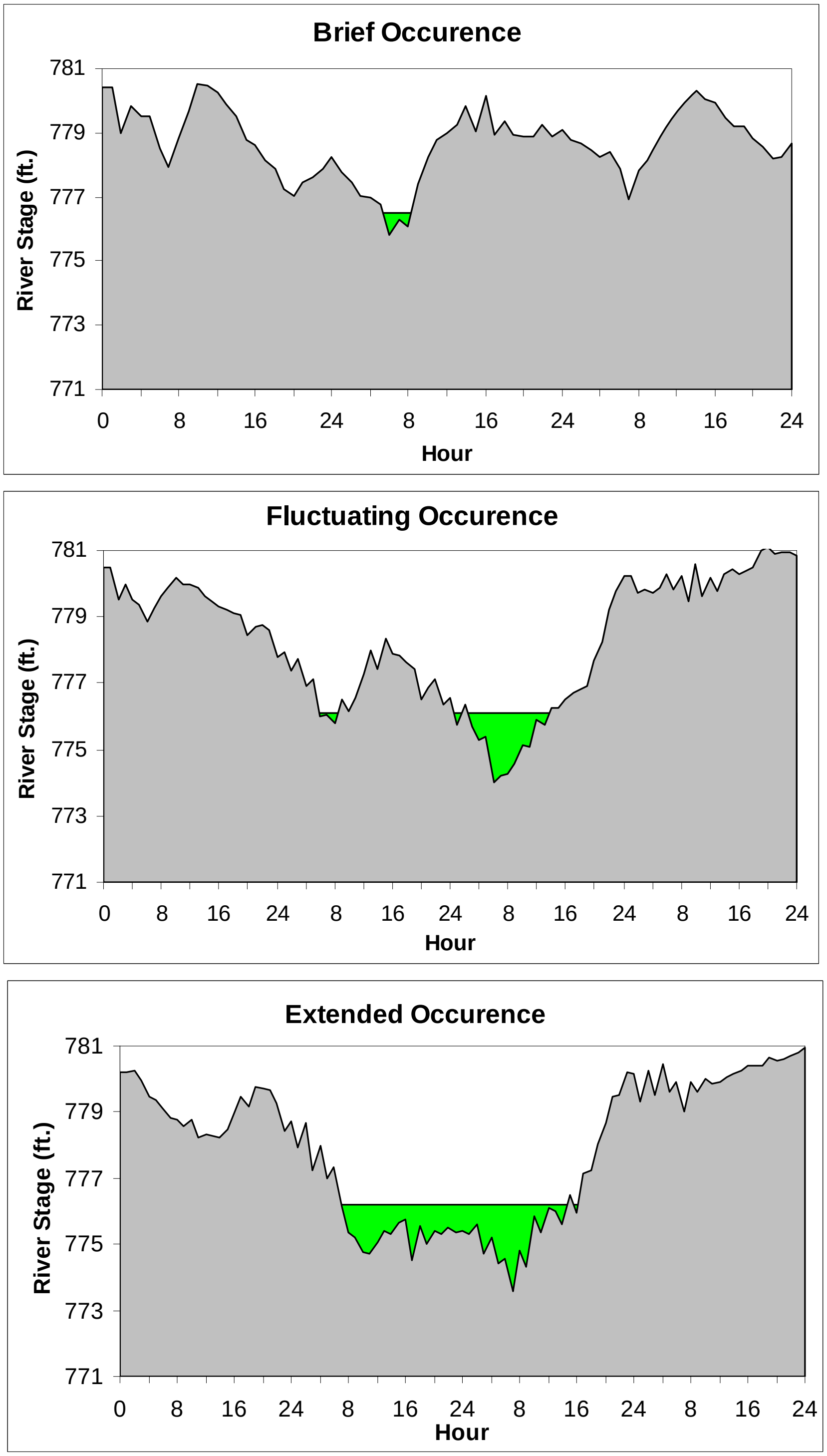


Figure 4.2-1 **Three representative occurrences of infrequent reservoir operations from 2001, 2002, and 2005 illustrating the duration, magnitude, and rate of change in water elevation. Green area represents water elevation change of four feet from the relative high water line.**

5.0 AQUATIC RESOURCES

5.1 Anadromous Salmonids and Bull Trout

The mid-Columbia River and surrounding tributaries provide substantial habitat for a diverse population of anadromous salmonids including: spring-run Chinook, summer-run Chinook, fall-run Chinook, summer steelhead, sockeye, and coho (NMFS, 2002). In addition, the Project supports a population of fluvial and potentially adfluvial bull trout (USFWS, 2004). Douglas PUD has undertaken a number of measures to modify and adapt facilities and operations to continuously improve salmonid passage. Management and protection of anadromous salmonids are addressed by the FERC-approved Habitat Conservation Plan and bull trout are addressed under the Bull Trout Monitoring and Management Plan (BTMMP). In order to fully assess the potential effects of daily fluctuations and infrequent reservoir operations on salmonids, the following issues are considered herein: spawning and incubation, available usable habitat, migration passage and stranding.

5.1.1 Spawning and Incubation

Anadromous salmonids and bull trout do not spawn within the Project (with the exception of summer/fall Chinook) because of the steep surrounding banks and lack of low-gradient gravel bars. The majority of spawning occurs within the upper portions of the Methow and Okanogan Rivers or other natal tributaries that lie outside of the Project boundary (NMFS, 2002). Spawning is limited to summer/fall Chinook salmon that spawn in the Wells Tailrace in a gravel bar area on the west riverbank 1.0 to 1.5 miles downstream of Wells Dam and in the Wells Hatchery outfall (Giorgi, 1992; Rensel Associates, 2000). Rensel Associates (2000) found that the majority of the redds deposited by summer/fall Chinook occurred in water 15 to 28 feet deep. Similarly, Giorgi (1992) determined that most of the redds were deposited between 18 to 24 feet deep. Because the tailrace is located below Wells Dam, there is no potential for Project reservoir fluctuations to affect these redds. The Wells Hatchery outfall is a controlled environment with multiple rearing ponds and outfall locations and is not susceptible to reservoir fluctuation. When acclimated and ready for release, the juvenile Chinook within the Wells Fish Hatchery rearing ponds are allowed access to the main hatchery outfall channel and are volitionally released directly into the Columbia River below Wells Dam (NMFS, 2002).

5.1.2 Available Habitat

For most anadromous salmonids the Wells Project is used only as a migration corridor, with relatively brief residence time by returning adults and outmigrating juveniles. Summer/fall Chinook salmon are the only anadromous salmonids that use Wells Reservoir for juvenile rearing. Adult bull trout use the reservoir for extended periods of time (primarily in deep, cool, well-oxygenated water), however sub-adult bull trout have not been collected, counted or observed at Wells Dam and as such their use of the reservoir may be limited. Instead, the majority of the sub-adult bull trout, found upstream of Wells Dam, are expected to rear in high elevation streams outside of the Wells Project Boundary, (LGL Limited and Douglas PUD, 2006).

Infrequent reservoir operations might affect salmonids by limiting the availability of littoral areas which represent juvenile spring/summer Chinook salmon rearing habitats. Periodic displacement from littoral habitat may have energetic costs to juvenile salmon due to diminished foraging time and may increase exposure to predation. However, the infrequency and short duration of infrequent reservoir operations (see Section 4.2) is likely to limit the potential adverse effects on summer/fall Chinook habitat.

5.1.3 Migration

The Project serves as a passage corridor during freshwater bull trout migrations and ocean-bound juvenile anadromous salmonids and adult return migrations. Extensive literature review did not indicate any negative effects of reservoir elevation fluctuations on adult migration behavior. However, younger lifestages are more sensitive to changes and may be adversely affected.

Studies have shown that the rate of flow, which is a factor in reservoir stage elevations, is related to migration rates in juvenile salmonids. Berggren and Filardo (1993) showed steelhead in the mid-Columbia River were able to increase migration rate slightly as flow increased. Other research has shown that extremely low reservoir elevations can concentrate predators into a smaller channel volume, resulting in increased predator-prey interaction (Heman and Redmond, 1969).

In regards to passage during migration, Wells Dam is equipped with five juvenile fish bypass systems and with two adult fishway systems that provide tested and highly efficient passage rates for migrating juvenile and adult salmonids (NMFS, 2002). The adult fish ladders are tiered and designed to operate throughout the entire range of authorized reservoir elevations. Video monitoring systems count passing fishes. Adult PIT-tag detection systems detect and register PIT-tagged adult fish. Assumed adult survival through the Project, including the ladder system, is estimated to be between 98-100% (NMFS, 2002). Recent PIT-tag data indicates that this assumed rate of survival is accurate (DART, 2006). The juvenile bypass structure has a fish passage efficiency of 92.0 percent for spring migrating salmon and steelhead and 96.2 percent for summer migrating Chinook salmon (Skalski et al., 1993). The juvenile bypass system is the most efficient in the Columbia River system (NMFS, 2002). Both of these passage systems are designed to operate at a high efficiency through the full range of daily fluctuations and infrequent reservoir operations. Juvenile Project survival (reservoir, forebay dam and tailrace survival combined) for spring migrating Chinook and steelhead averaged 96.2 percent during three years of study (Bickford et al., 2001). Survival through Wells Dam for summer migrating subyearling Chinook is expected to range from 95.9 to 97.4 % (NMFS, 2002).

5.1.4 Stranding and Entrapment

The risk of stranding and entrapment in small off-channel pools in salmonids is strongly related to life history stage. Younger salmonids, particularly fry that have recently emerged from gravel nests and have just absorbed the yolk sac, are the most vulnerable. For Chinook, the risk of stranding and entrapment greatly decreases when they reach 50 to 60 mm in length (Hunter, 1992). Similarly, steelhead vulnerability drops significantly when fry reach 40 mm (Beck Associates, 1989). As salmonids mature, patterns of habitat use also change. Larger juveniles use deeper pools, glides, overhanging banks, and mid-channel substrates more frequently than shallower littoral habitat (Hunter, 1992). The risk of adults being stranded is very low, but entrapment in large pools may still occur if reservoir elevations are lowered rapidly and shoreline characteristics are conducive to the formation of pools (Hamilton and Buell, 1976).

Tributary channel and shoreline morphology can greatly influence the risk of stranding and entrapment. Long side-channels, low-gradient sand bars, and other gradually sloping surfaces pose an elevated risk of stranding compared to steep banks. Bauersfeld (1978) suggested that gravel or sand bars with slope of less than 4% represented notable areas of stranding. Both side-channels and gravel bars are important areas that are used by juvenile salmonids for feeding and rearing. Entrapment can take place wherever small or large depressions along the shorelines hold or pool water when the reservoir is drawn down.

As indicated previously, only summer/fall Chinook spawn within the Wells Project, and these stocks tend to spawn and rear in water depths that are unlikely to be affected by reservoir elevation changes. Migrating juveniles and adults passing through the Project are unlikely to be adversely affected by small-scale, daily reservoir fluctuations. However, infrequent reservoir operations may lead to stranding and entrapment by rearing Chinook fry, particularly if reservoir elevations are lowered rapidly. Small numbers of Chinook salmon fry have been observed by Douglas PUD biologists to become entrapped in small and large pools located near Park Island. The mortality associated with these sites depends upon the duration and time of year of infrequent reservoir operations. The potential significance of stranding mortality to salmonid populations is not directly known, but reviews of current operations and past monitoring suggests that salmonid stranding and entrapment is not a significant issue within the Wells Project.

5.1.5 Conclusions

The effects of daily fluctuations and infrequent reservoir operations on anadromous salmon and bull trout are limited, due to their minimal use of habitat within the project boundary. Those species and life stages that do reside within Project habitat are typically found in low-risk areas. A limited amount of stranding and entrapment of Chinook fry may take place during infrequent reservoir operations occuring during the spring, when Chinook fry are utilizing shallow, low gradient areas. Standing and entrapment may increase stress levels and risk of predation. The amount of direct mortality associated with such an event is contingent upon the extent and duration of lower reservoir elevations and the thermal loading of each pool.

5.2 Pacific Lamprey

5.2.1 Background

The Pacific lamprey (*Lampetra tridentata*) has a complex life history with life cycle stages that might be sensitive to reservoir fluctuations. Pacific lamprey are present throughout the majority of Columbia River tributaries and use the mainstem Columbia River during juvenile and adult migration. Within the Wells Project, lamprey rearing has been observed within the Methow River but has not been documented within the Okanogan River (BioAnalysts, 2000a; NMFS, 2002). Pacific lamprey do not occur upstream of Chief Joseph Dam, which is not equipped with a fishway (Close et al., 1995).

The Pacific lamprey is an important species for cultural, utilitarian, and ecological reasons (Jackson et al., 1996; Close et al., 2002). Local Native Americans have historically used lamprey for subsistence, ceremonial, and medicinal applications. Lamprey are also ecologically important in facilitating suspended organic nutrient conversion (Moore and Mallatt, 1984) and they represent a high caloric food source for predators (Whyte et al., 1993). As such, lamprey constitute an alternative prey, alleviating predation pressure on migrating juvenile (Poe et al., 1991) and adult salmonids (Close et al., 2002).

Pacific lamprey life history is comprised of two distinct morphological and physiological periods. As larvae (called ammocoetes), lamprey are generally stationary and found lodged in shallow sandy or muddy areas (Moyle, 1976); however, they are able to move between sandy habitats. During this stage ammocoetes are blind and filter feed upon suspended detritus and other organic matter (Moyle, 1976). After approximately five years, the larvae undergo a physiological and morphological metamorphosis (Beamish and Northcote, 1989; Beamish and Levings, 1991). Juveniles develop eyes and a buccal mouth, become highly mobile, and migrate to the ocean to feed as ectoparasites on ocean fish and mammals (Close et al., 2002). After up to 3.5 years at sea, adult lamprey migrate back to freshwater to spawn (Beamish. 1980). Spawning occurs in fast-flowing water (e.g., tailouts of pools or riffles) when temperatures reach 50° to 60°F (Beamish and Levings, 1991; Luzier and Silver, 2004). Nests are constructed in shallow gravel or sandy substrates, usually in water less than three feet deep, but occasionally as deep as 13 feet (Farlinger and Beamish, 1984). During spawning, eggs are only mildly adhesive and can be washed downstream of the nest settling into rock crevices. After spawning, female lamprey die within hours and males die within three weeks (Beamish, 1980). Incubation occurs for two to three weeks after spawning and hatching likely occurs between late July and mid-August (BioAnalysts, 2000b).

5.2.2 Spawning and Incubation

Spawning Pacific lamprey are commonly found in swift water near the tailout of riffles and pools in coarse substrates, generally between May and mid-August, and often in shallow water (Farlinger and Beamish, 1984; Luzier and Silver, 2004). The majority of adult Pacific lamprey using the Wells Reservoir are expected to spawn outside of the Project, because few areas within the Project appear to fulfill habitat requirements for spawning (Douglas PUD, 2006). Spawning is expected to take place during the months of May and June based upon water temperatures within the Project. Incubation is rapid taking less than 20 days on average at 15°C. However, if lamprey spawning is taking place within the Project, spawning could be affected by infrequent reservoir operations, especially during the May through July incubation period.

5.2.3 Available Usable Habitat

Based upon Pacific lamprey life history, returning adults and ammocoetes reside in freshwater environments for extended periods of time (BioAnalysts, 2000a). Juvenile and adult life-stages migrate to and from freshwater environments, spending a portion of their adult life with the marine environment. Returning adults likely use Wells Reservoir to overwinter before spawning; however, during this time they generally do not feed or frequent littoral habitat (Beamish, 1980).

Ammocoetes are closely associated with silt or mud substrates in shallow littoral habitats (Moyle, 1976). Highest densities of ammocoetes were found within shallow areas along the banks of a British Columbia stream (Richards, 1980). Ammocoetes may drift to different locations, but have poor directional control over their mobility. During metamorphosis mobility improves and late ammocoetes/early juveniles move to areas with higher water velocity (Richards and Beamish, 1981).

Normal daily operations within the Wells Reservoir create predominantly consistent one to two foot water stage variations (see Appendix A) defining the habitat zone where lamprey naturally reside. These small-scale fluctuations likely have a negligible effect on the amount of available habitat for rearing ammocoetes. Lower reservoir elevations resulting from infrequent reservoir operations are sporadic and brief (see Section 4.2), and do not represent a long-term loss of potential habitat (although potential stranding is an issue; see Section 5.2.5).

5.2.4 Migration

Lamprey are anadromous and undergo two migration events: out-migrating as juveniles and returning to freshwater to spawn as adults. The Project has specialized facilities that allow safe passage for both juvenile and adult anadromous species including lamprey. Passage facilities, including five juvenile fish bypass systems and two adult fish ladders, are continuously monitored to accommodate all stages of reservoir elevation and ensure appropriate passage conditions.

Construction of the Project’s juvenile fish bypass system was completed in 1989 (Douglas PUD, 2006). The bypass system was developed to guide downstream migrating fish away from the turbines and through the spillways. The bypass system has a fish passage efficiency rate of 92.0 percent for spring migrating salmon and steelhead and 96.2 percent for summer migrating Chinook salmon (Skalski et al., 1993). Passage efficiency as related directly to juvenile lamprey is not known. Regardless, the Project’s fish bypass system is the most efficient juvenile fish bypass system on the mainstem Columbia River and is likely beneficial for juvenile lamprey passage.

Until recently, there was little detailed information available regarding adult lamprey return migration. However, a radio-telemetry investigation was recently conducted by Douglas PUD to evaluate migratory behavior of Pacific lamprey at Wells Dam (Nass et al., 2005). Although only 18 fish were detected in the Wells tailrace during this study, median time required to pass through the fishway was 0.3 days and accounted for 8% of total passage time (from detection in tailrace to fishway exit; Nass et al., 2005).

Returning adult Pacific lamprey have been counted at Wells Dam since 1998 (Douglas PUD, 2006). Over an eight-year period (1998 to 2005), the annual number of lamprey passing Wells Dam has ranged from 73 fish (1999) to 1,417 (2003). Lamprey pass Wells Dam from early July until late November with peak passage times between mid-August and late October. It is important to note that counting protocols were designed to assess adult salmonids and do not necessarily conform to lamprey migration behavior (Moser and Close, 2003). As such, the passage numbers should be interpreted as portraying relative abundance for comparing years. Nonetheless, the research and monitoring at the Project facilities suggest that passage is not inhibited for either juvenile or adult Pacific lamprey over the observed operating range of reservoir water elevations.

5.2.5 Stranding and Entrapment

The greatest risk of stranding and entrapment occurs in species and lifestages that are less mobile and reside in shallow or off channel habitat. Ammocoetes are highly prone to stranding because of poor mobility and their documented use of shallow littoral areas. Juvenile (macropthalmia) and adult lamprey are less likely to be found in shallow areas and are highly mobile. While rapid drops in reservoir elevations during infrequent reservoir operations have the potential to strand and entrap even mobile adults, the potential for this to occur in the Wells reservoir is low (see Section 4.0).

Rearing ammocoetes are found embedded in fine sediment within the depositional areas of eddies and backwaters within the lower Methow River and the Wells Reservoir. During normal operations, repetitive and predictable daily fluctuations are likely to define a zone where ammocoete larvae will not embed. However, occurrences of infrequent reservoir operations are not predictable and are not expected to alter habitat selection by ammocoetes. As a result, infrequent reservoir operations do pose some risk of dewatering to already-embedded ammocoetes.

Direct research on the effect of infrequent reservoir operations on lamprey stranding has not been conducted, because review of past operations and past observations have not identified lamprey stranding as a significant risk or issue within the Wells Project. Instances of infrequent reservoir operations at the Wells Project do not entail rapid stage change, which may provide ample time for ammocoetes to move into deeper water before becoming entrapped or stranded. Measures to reduce the potential for ammocoete stranding include reducing the rate of water elevation change, and executing the operations overnight. Anecdotal information from lamprey researchers have shown that such measures allow ammocoetes to vacate dewatered areas (Bianca Streif, USFWS, personal communication). Furthermore, infrequent reservoir operations are typically brief in duration and dewatered areas are often immersed again during the course of the event (see Section 4.2); this may also allow ammocoetes to survive the event.

5.2.6 Conclusions

The effect of infrequent reservoir operations on Pacific lamprey is expected to be negligible on juvenile and adult lamprey. Ammocoetes are the only Pacific lamprey lifestage that uses littoral habitat and also has limited mobility, suggesting some risk of stranding. However, the nature of infrequent reservoir operations at the Wells Project likely limits the potential for stranding and associated impacts to the Pacific lamprey population.

5.3 Smallmouth Bass

5.3.1 Background

The Project supports a healthy population of smallmouth bass, a non-native game fish of recreational importance (Beak and Rensel, 1999). Largemouth bass are also present, although they are caught less frequently (Burley and Poe, 1994; Beak and Rense, 1999; DE&S, 2001) and less is known regarding their current status. Both game fish are priority species in Washington State, because of their recreational importance and susceptibility to over fishing and harvest.

Smallmouth bass are mainly found in warm backwater areas near rocky shoals, banks, and gravel bars. Optimal temperature for this species ranges from 70° to 81°F (Wydoski and Whitney, 2003), which is uncommon in the mainstem of the reservoir; however, the lower Okanogan River (within the Project boundary) does display warmer temperatures and habitat closer to preferred life history requirements. Resident fish inventories of the Wells Project have documented a strong preference by smallmouth bass for the lower Okanogan River and the mainstem Columbia River within 5 miles of the confluence of the Columbia and Okanogan rivers (Beak and Rensel Associates, 1999).

The majority of Wells Reservoir is poorly suited for smallmouth bass spawning (Douglas PUD, 2006), because suitable water temperatures (60° to 65°F) generally do not occur until late summer. In addition, the steep banks along most of Wells Reservoir represent poor habitat for smallmouth bass, which prefer sloughs and littoral areas with sand and gravel substrates. Based upon these factors, it is expected that the majority of local spawning occurs within the lower Okanogan River.

5.3.2 Effects of Fluctuations

During normal operations, the lower Okanogan River offers substantial warm littoral and backwater habitat, but during infrequent reservoir operations low gradient littoral habitat may be exposed. Anecdotal reports from recreational fishers suggest that some bass redds on the lower Okanogan River have been dewatered during infrequent reservoir operations (personal communication, Douglas PUD). Although dewatering does not necessarily imply complete nest desiccation, it does reduce the chance of survival and increase the risk of oxygen depletion, siltation, wave disturbance, rapid water temperature change, predation, or fungal infection (Lee, 1999). The magnitude of the impact is contingent upon the extent and timing of the occurrence, gradient of the littoral zone, and amount of available inundated quality habitat (Lee, 1999).

Past research has shown that dewatering may affect the success of exposed redds, but often does not constitute a significant loss for the spawning season. Investigators determined that instances of substantial water fluctuation had negligible effect on spawning adult bass, which were able to move into deeper waters (Jones and Rogers, 1998). Kramer and Smith (1962) reported a correlation between bass spawn depths and median depth of water fluctuations. They observed that exposed redds were abandoned by guarding males after dewatering, but that new nests were created at increased depths. Thus, although there are energetic costs in lost reproductive effort (Emig, 1966), successful reproduction is not invariably prevented by water fluctuations.

Furthermore, consistent daily water fluctuations likely cause nest construction to be concentrated in deeper waters, reducing risk of dewatering.

5.3.3 Conclusions

Smallmouth bass are an exotic fish that consume native salmonids and lamprey (Ward and Zimmerman, 1999). Their population abundance appears to be in excellent condition in the Wells Project and in other mid-Columbia reservoirs (Burley and Poe, 1994; Beak and Rensel Associates, 1999; DE&S, 2001). Sporadic redd dewatering probably occurs in the Project; however, the infrequent nature of these events (see Section 4.2) and the capacity of smallmouth bass to adapt suggest that operations do not pose a threat to the status of the population.

5.4 Benthic Macroinvertebrates

5.4.1 Background

Benthic macroinvertebrates (BMI) are a primary food resource for numerous resident and anadromous fish species, and also play an important role in processing organic matter and maintaining water quality. The Project includes lacustrine environments with soft substrates, as well as areas of shallower water and higher flows (i.e., areas more characteristic of riverine environments), suggesting that BMI community composition is not likely to be uniform throughout the reservoir. Information describing BMI communities in the Project is limited, particularly in regards to areas that may be affected by reservoir fluctuations. Limited sampling of five low-flow sites in the Wells Reservoir found chironomids, gastropods (snails), trichopterans (caddis fly nymphs), crustaceans (amphipods, isopods, and crayfish), annelids (segmented worms), and tubellaria (flatworms) to be the most abundant taxa (BioAnalysts, 2006). (However, the sampling technique (colonization baskets) used in this effort may not be well suited for sampling soft substrates, and the depths sampled (1-5 meters) represents a subset of potential BMI habitat.)

5.4.2 Effects of Fluctuations

BMI taxa associated with aquatic vegetation and detritus are often the most numerous organisms in littoral areas affected by water fluctuations (Oak Ridge National Laboratory, 1980; Biowest, 2002). These taxa are also generally intolerant of desiccation and become susceptible to predation as they attempt to migrate into suitable habitat. In contrast, burrowing BMI, including some types of chironomids and oligochaetes, are more likely to survive dewatering by withdrawing into moist substrates; perhaps as a consequence, the latter taxa sometimes dominate BMI communities where repeated water fluctuations occur (Brusven and MacPhee, 1976; Oak Ridge National Laboratory, 1980). Nonetheless, BMI biomass and density is typically much reduced in these zones with fluctuating water levels (Oak Ridge National Laboratory, 1980; Biowest, 2002; Furey et al., 2006), whereas the area just below the lowest pool elevation is typically the most productive for BMI in these regulated reservoirs. Although Furey et al. (2006) found no overall difference in benthic density and biomass between a regulated and unregulated lake system, some differences in BMI community structure were evident.

5.4.3 Conclusions

Based on the literature, it is reasonable to suggest that BMI are scarcer within shallow water areas of the Project where daily fluctuations occur. Infrequent reservoir operations may also reduce or modify the composition of BMI communities. However, because infrequent reservoir operations are uncommon and typically of short-duration, they are unlikely to permanently affect BMI (particularly taxa with short generation times and those that occur in adjacent unaffected areas), because there would be no impediment to recolonization.

5.5 Mollusks

5.5.1 Background

The Project is residence to an array of mollusks. A total of twenty species were documented in a recent survey (BioAnalysts, 2006), ten bivalve (mussels and clams) species and ten species of gastropods. All but two of the species are native and one of the species, the Ashy pebblesnail (*Fluminicola fuscus*) is a state species of concern.

5.5.2 Effects of Fluctuations

Most species of mussels prefer shallow water habitat. Freshwater mussels and other bivalves, such as sphaeriid clams can respond to progressively drying conditions by burrowing into the substrate, movement in search of more suitable conditions, or tightly closing shells to reduce loss of water. However, not all mollusks are able to move to deeper water and many are left stranded as water levels recede. Under conditions of stress resulting from the lack of oxygen such as would occur during periods of emersion, some mussels will exhibit mantle edge exposure as they attempt to maximize oxygen exchange. Mortality can result from desiccation or thermal stress as the temperature buffering capacity of the water is reduced in shallower pools (Vaughn, 2005). Even if mussels survive, they may have a reduced growth and reproductive capacity as a result of physiological stress during conditions of severe low water and emersion (Vaughn, 2005). Indirect effects of emersion might include increased predation.

Tolerance to emersion and desiccation appear to be highly variable, depending on the species. For example, the Asian clam appears to be less tolerant than freshwater mussels (McMahon and Ussery, 1995). Turner et al. (2004) found that the duration of shoreline exposure had a significant affect on distribution of the Asian clam on the Hanford Reach.

5.5.3 Conclusions

The mollusk community within the shallow-water littoral zone area of the Project does not appear to be susceptible to daily reservoir fluctuations but may be affected by infrequent reservoir operations, depending on their timing, extent and duration as well as the species present within exposed littoral areas. Direct effects include stress and mortality due to stranding and desiccation. Indirect effects include increased predation and reduced spawning and recruitment success. The community of mollusks found within the Wells Project appears to be well adapted to the daily fluctuations of the reservoir.

5.6 Aquatic Macrophytes

5.6.1 Daily Fluctuations

In regulated rivers, limited annual water fluctuations and reservoir conditions generally support the development and maintenance of aquatic macrophyte beds, which represent important habitats for a suite of native aquatic organisms. Daily water fluctuations are not described in the reviewed literature as restricting macrophyte distributions. In the Wells Reservoir, aquatic macrophytes occurred in over 58% of samples of 61 transects taken in 2005 (Lê and Kreiter, 2005), suggesting aquatic macrophytes successfully tolerate daily operations at the Wells Project. (Survey transects were nonrandom, sampling lower-gradient near-shore areas thought to have potential to support aquatic macrophytes.) However, few macrophytes occur at depths of 1-4 feet, suggesting that daily fluctuations do restrict macrophytes from some shallow-water habitats.

Although some authors contend that reservoir water fluctuations support exotic species to the detriment of natives (e.g., Hudon, 1997), macrophyte beds in the Wells Reservoir are primarily composed of native species, which were dominant in over 89% of samples taken in 2005 (Lê and Kreiter, 2005). Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) were the only exotics found. Other authors have reported that moderate environmental variability, such as episodes of low water levels (Keddy and Reznicek, 1986) or local ice-scour (Shipley et al., 1990) contribute to species diversity by destabilizing well-established, low-diversity plant communities.

5.6.2 Infrequent Reservoir Operations

Infrequent reservoir operations likely have the potential to more substantially affect the distribution of aquatic macrophytes in the Wells Reservoir. Lowered water elevations such as those occurring during infrequent reservoir operations are often cited as an effective control method for Eurasian water-milfoil and other aquatic species (e.g., WDOE, 2006), and modified species composition has been reported after some severe events (Cooke, 1980). In addition, Eurasian water-milfoil often produces a substantial seed bank (unusual among aquatic macrophytes) that may be cued to germinate following extended dewatering. However, aquatic macrophytes are generally considered to be well-adapted to short-term dewatering lasting hours or days (Cooke 1980), and the median duration of infrequent reservoir operations at the Wells Project was three hours (see Section 4.2). In addition, macrophyte control strategies most often involve long-term (1 month) exposure to subfreezing conditions that can kill aquatic macrophyte root-crowns (WDOE, 2006). Infrequent reservoir operations at the Wells Project most often occur during above-freezing conditions, although winter events have also been recorded (see Table 4.2-2). The average duration of these infrequent reservoir operations has been well below the threshold expected to kill most aquatic macrophyte species (Cooke, 1980).

5.6.3 Conclusions

Aquatic macrophyte beds in the Wells Reservoir are well-distributed in suitable habitats and reliably dominated by native species. Daily reservoir fluctuations may restrict aquatic macrophytes from near-shore habitats shallower than 4 feet in depth, but are unlikely to affect those in deeper areas. Infrequent reservoir operations have the potential to affect aquatic macrophytes, but under recent operations at Wells Dam, such events were generally not of the duration or timing to suggest the potential to result in substantial change in aquatic macrophyte species composition or distribution.

6.0 WILDLIFE AND BOTANICAL RESOURCES

6.1 Amphibians

6.1.1 Background

A total of seven species of amphibians have been documented in the northern Columbia Basin and adjacent Okanogan Highlands: long-toed salamander (*Ambystoma macrodactylum*), tiger salamander (*Ambystoma tigrinum*), Great Basin spadefoot (*Spea* [*Scaphiopus*] *intermontana*), western toad (*Anaxyrus*[1] [*Bufo*] *boreas*), Pacific treefrog (also known as Pacific chorus frog) (*Pseudacris pacifica*[2]) (= *Hyla regilla*), Columbia spotted frog (*Rana luteiventris*), and bullfrog (*Lithobates*[1] *catesbeianus* [*Rana catesbeiana*]). Each of these species requires still- or quiescent water for breeding and larval rearing; oviposition tends to occur in shallow, vegetated areas; and larval stages also favor shallows with vegetative cover (Jones et al., 2006). However, other natural history aspects differ, including the timing of breeding, rate of embryonic development, length of larval period, and tendency to breed in seasonal or permanently flooded habitats (Metter, 1960; Munger et al. 1998; Monello and Wright, 1999; Maxell, 2000; Jones et al. 2006), suggesting that the species are not equally susceptible to reservoir fluctuation effects. Notably, only one of these species, the bullfrog, requires permanently flooded habitats because of a two-year larval period, and a close association to aquatic habitats during all other life phases. The bullfrog is not native to Washington and is generally regarded as ecologically undesirable.

A variety of sites potentially suitable for amphibians occur in the Wells Project, most without direct surface connection to Wells Reservoir (shallows along the fringe of Wells Reservoir and sub-impoundments along Highway 97 with surface water connection to it represent poor habitat for native amphibians because of the presence of predatory fish in the Reservoir.). Amphibian surveys of the Wells Project in 2005 indicated amphibian presence at 14 of 39 sites, including five sites in the Bridgeport Bar Unit of the Wells Wildlife Area (WWA) and three sites on Cassimer Bar. Pacific treefrog eggs or larvae were found at five sites, and this species was heard at five additional sites; only one of these sites is connected by surface water to the reservoir. Bullfrog detections were primarily observations or captures of frogs or auditory detections (total of 10 sites, none of which is connected by surface water to the reservoir); direct evidence of breeding (eggs or larvae) was documented at only one of these sites, in a diked slough on Cassimer Bar. Two other species were documented (long-toed salamander by egg masses, and Great Basin spadefoot by vocalization), each at one site, neither of which are connected by surface water to the reservoir (EDAW 2006a). These results are generally consistent with amphibian survey results in three other Columbia River reservoirs (Rocky Reach, Wanapum, and Priest Rapids), where amphibians occurred adjacent to the reservoirs, but not where surface water connections existed (DE&S, 2000; Framatome ANP DE&S, 2003).

---

[1] Recently revised taxonomic nomenclature (see Frost et al. 2006).

[2] Recently revised taxonomic nomenclature (see Recuero et al. 2006).

6.1.2 Daily Fluctuations

The presence of predatory fish limits the suitability of Wells Reservoir for all amphibians except bullfrog and western toad. However, daily water fluctuations may be an additional deterrent to amphibian use of shoreline habitats or other sites directly connected to the reservoir. Unstable water levels are likely to be most detrimental during oviposition (egg laying) and the subsequent period of embryonic development, although small, weakly swimming larvae may also be at risk of stranding. Amphibian egg masses are not mobile and cannot escape unfavorable conditions. Furthermore, amphibian eggs are generally laid in shallow water or attached to vegetation high in the water column. As such, water level fluctuations of even a few inches may expose developing eggs to desiccation, freezing, or increased predation. Bullfrog egg masses float at the surface, loosely anchored to emergent or floating aquatic vegetation, often in deeper water than used by the native species, and thus may be less susceptible to daily fluctuation effects. Nonetheless, daily fluctuations are likely less important than other factors governing habitat suitability in habitats connected to the reservoir, such as the presence of predatory fish, wave action, scant vegetative cover, and water temperature. It may be significant that the only site where amphibians were documented with surface water connection to the reservoir was along a shallow, side-channel adjacent to Park Island (EDAW 2006a), where flow-through is blocked by an earthen causeway, possibly allowing for warmer water and diminished wave action.

Amphibians in wetlands without surface water connection to the reservoir could be affected by daily fluctuations in the same ways, but the likelihood of such effects is substantially lower. In these areas, response time to reservoir fluctuation is likely to be dampened unless wetland substrates are highly permeable.

6.1.3 Infrequent Reservoir Operations

Observations by Douglas PUD biologists suggest that rare instances of infrequent reservoir operations are capable of dewatering sites used by amphibians in the Wells Project. Some of the sites on Cassimer Bar, the Kirk Islands, and Bridgeport Bar Unit islands are separated from the reservoir only by narrow dikes and thus may respond more quickly to infrequent reservoir operations than wetlands located in topographic depressions further from the reservoir. When native amphibians are not likely to be present (i.e., after larvae have metamorphosed in late summer or early fall and before breeding occurs again the following spring), infrequent reservoir operations would not be detrimental, and may in fact benefit native species if bullfrog larvae are killed by dewatering. Occasional loss of eggs or larvae may not eliminate a species from a site because post-larval life stages are unlikely to be adversely affected, and live for several years. Only one of the native species potentially occurring, Columbia spotted frog, is persistently aquatic during non-breeding phases. However, this species is known to move from seasonal wetlands as they dry.

6.1.4 Conclusions

Regardless of fluctuations, habitats with a surface water connection to the reservoir are not suitable for most native amphibians, due to water temperature and the presence of predatory fish. For sites without surface water connection, daily fluctuations are likely dampened, suggesting only a limited potential for impacts to native amphibians. Infrequent reservoir operations that dewater amphibian habitats have the potential to eliminate an amphibian age class. However, these may be tolerable to populations because adult amphibians live for several years. The frequency and duration of infrequent reservoir operations have been highly variable over the past five years: in some years few or no instances of such operations have occurred during the period when native amphibian eggs or larvae would have been present.

6.2 Waterfowl

6.2.1 Background

Information concerning waterfowl occurrence in the Wells Project includes long-term seasonal survey data, nesting and brood data, and the results of intensive avian surveys conducted in 2005. These data indicate relatively large numbers of Canada geese (*Branta canadensis*) nesting on Wells Reservoir: from 1995 to 2004, the mean number of nests was 128 and the mean number of goslings was 659 (Hallet, 1981–2005; Washington Department of Game, 1978, 1979). Nests are located on elevated platforms and on islands built specifically for waterfowl use. Smaller numbers of mallards (*Anas platyrhynchos*), wood ducks (*Aix sponsa*), and common mergansers (*Mergus merganser*) reportedly nest in the Project Reservoir at various locations (Douglas PUD, 2006).

During migrations and in winter, much larger numbers of waterfowl and other water-birds gather in open water areas of the Project. Washington Department of Fish and Wildlife (WDFW) fall-winter survey data indicate that the number of waterfowl on the reservoir on a single day often exceeded 25,000 and the number of American coots usually exceeded 15,000. Surveys conducted by EDAW in autumn 2005 found that birds were particularly abundant near the mouth of the Okanogan River, but large rafts also occurred just upstream of Wells Dam (EDAW, 2006b). A diverse array of species was found, but American coot (*Fulica americana*) was especially abundant, followed by American wigeon (*Anas americana*) and lesser scaup (*Aythya affinis*). WDFW data indicate that the most common wintering waterfowl are lesser scaup, American wigeon (*Anas platyrhynchos*), ring-necked duck (*Aythya collaris*), redhead (*Aythya americana*), and mallard. Major foraging areas are believed to be associated with aquatic macrophyte beds. Corn, wheat, and other grains grown on the Bridgeport Bar Unit and Washburn Island Unit of WWA also provide food for Canada geese and dabbling ducks, such as mallards (Douglas PUD, 2006).

Differences in foraging behaviors among these species may influence susceptibility to fluctuation effects. Dabbling ducks feed without diving in shallow water or where aquatic macrophytes are near the surface. Geese are similar, but can feed in deeper water because of larger size. Sea-ducks (“diving ducks”) and mergansers tend to feed in deeper water. Ideal foraging habitats for dabbling ducks are located where shallow, open water areas are in close proximity to vegetative cover (emergent vegetation). Vegetative cover represents hiding cover from predators and shelter from adverse weather. During brood-rearing, access to hiding cover is particularly important. In addition, open water habitats are important resting areas for both resident and migratory water-birds.

6.2.2 Daily Fluctuations

Daily fluctuations may cause shifts in foraging habitats for adult dabbling ducks, Canada geese, and other water-birds associated with shallow water (e.g., pied-billed grebes). In general, fluctuations cause shallow water habitat to shift away from the shoreline when water levels recede and back towards the shorelines as water levels rise. Although this shift in habitat location may increase waterfowl energetic costs (e.g., if there is significant lost feeding time) it also likely increases available forage. For example, waterfowl frequently congregate along the shoreline during lower reservoir elevations, likely feeding on newly exposed BMI and aquatic macrophytes (personal communication, Jim McGee, Douglas PUD biologist). In addition, water fluctuations maintain emergent wetlands in parts of the Wells Project, which serve as key waterfowl habitats.

Adult waterfowl associated with open water or aquatic macrophyte beds are unlikely to be detrimentally affected by daily fluctuations. The depth profiles associated with aquatic macrophyte occurrence in the Project suggests that the magnitude of daily fluctuations is insufficient to displace waterfowl feeding over aquatic beds. Similarly, waterfowl resting in open water are not likely to be detrimentally affected by water level fluctuation because resting birds focus on expanses of open water and are not generally concerned with water depths. Many species may benefit from daily fluctuations. In particular, diving ducks may be allowed access to new food sources that were previously too deep to be accessed.

6.2.3 Infrequent Reservoir Operations

Infrequent reservoir operations are likely to cause greater displacement of waterfowl from preferred habitats, because the magnitude of these fluctuations will dewater more extensive areas, including some aquatic macrophyte beds. This suggests that the potential energetic costs induced by infrequent reservoir operations will be greater than smaller, daily fluctuations. However, they will also allow the use of forage areas not previously accessible, likely offsetting such energetic costs. In addition, infrequent reservoir operations may not be distinctly different from other events (e.g., storms or boat traffic) that temporarily disrupt waterfowl foraging.

6.2.4 Conclusions

Daily reservoir fluctuations may minimally increase energetic costs for some shallow-water species. However, there is some indication that fluctuations also serve to maintain emergent wetland habitats for these same species (see Section 6.3). Waterfowl may also be temporarily displaced from preferred habitats by infrequent reservoir operations, potentially disrupting foraging activities. These disruptions are relatively brief in duration (See Section 4) and as a result are unlikely to have significant consequences for waterfowl wintering or in migration, as evidenced by the waterfowl use and production in the Wells Reservoir. The cultivation of alternate food sources for waterfowl, funded by Douglas PUD in the Bridgeport Bar and Washburn Island Units of the WWA, are designed to offset any detrimental effects of the Wells Project.

6.3 Wetlands and Riparian Habitats

6.3.1 Background

The creation of Wells Reservoir has allowed the development of a suite of wetland and riparian habitats otherwise uncommon in the semi-arid mid-Columbia region. The extent of riparian and wetland vegetation closely reflects shoreline topography and substrates, forming its greatest extent in areas with low-gradient shorelines. Cover type classification and mapping of the Wells Project in 2005 mapped 788.7 acres of riparian and wetland habitats, the majority of which are concentrated on the low-gradient shorelines near Cassimer Bar, the Bridgeport Bar Unit of the WWA, and along the Okanogan River.

Within the riparian zone, persistently flooded shorelines in low-gradient areas generally support emergent herbaceous species, often clonal hydrophytes such as narrowleaf cattail (*Typha angustifolia*) and soft-stem bulrush (*Schoenoplectus tabernaemontani*). Emergent wetlands in the Project also occur in association with topographic depressions away from the reservoir shoreline. In addition, low gradient mudflats dominated by herbaceous annual species such as needle spikerush (*Eleocharis acicularis*) and water pygmyweed (*Crassula aquatica*). Woody vegetation is typically situated at a higher position in the riparian zone, outside the zone of daily water fluctuation. Of particular note are large, structurally diverse stands of black cottonwood (*Populus trichocarpa* ssp. *balsamifera*) along the Okanogan River, which provide high quality wildlife habitat. While riparian and wetland communities in the Wells Reservoir are dominated by native species, they also support a suite of exotics, including the state-listed noxious weeds purple loosestrife (*Lythrum salicaria*), reed canarygrass (*Phalaris arundinacea*) and yellow-flag (*Iris pseudacorus*) (EDAW 2006b).

6.3.2 Daily Fluctuations

Water level fluctuations are a fundamental source of the ecological variance that maintains structural and biological diversity in wetland and riparian habitats. In particular, emergent wetland areas generally require fluctuating water levels, because repeated flooding and dewatering generally precludes the development of woody shrubs and trees (Toner and Keddy 1997, Keddy and Reznicek 1986). For example, in many parts of the mid-Columbia region, annual wetland plants (including some special-status species) are largely restricted to low-gradient mudflats that are maintained by daily water level fluctuations (Grant PUD, 2000). Since existing wetland and riparian habitats reflect recent operating conditions, daily water level fluctuations can be said to support these habitats, at least minimally. However, wetland and riparian habitats are also affected by a complex suite of other, often related factors, including depth, duration and frequency of inundation (Casanova and Brock 2000), seed bank densities (Keddy and Rezineck 1986), groundwater (Rains et al. 2004), and others.

Woody riparian shrub and tree habitats, excluded from frequently inundated areas, are nevertheless abundant in some parts of Wells Reservoir. While moderated water fluctuations under reservoir conditions generally support the development of woody wetland riparian species, certain key species such as black cottonwood may still be precluded from reproduction. Daily reservoir fluctuations often induce cottonwood seed germination at inappropriate elevations, or produce river stage declines that are too fast to support cottonwood seedling establishment

(Mahoney and Rood 1998). As a result, black cottonwoods or similarly affected species may be restricted from lands on which they would otherwise establish, or the long-term viability of some existing stands could be impaired. Wells Reservoir currently supports approximately 142 acres of riparian deciduous tree habitat (with black cottonwood as a primary component), or approximately 6% of the FERC Project shoreline (EDAW, 2006b).

Wetland and riparian habitats supported by Wells Reservoir also provide habitat for a number of noxious weeds. However, no available literature suggests a direct connection between water level fluctuations *per se* and noxious weed distributions. In addition, water level fluctuations likely restrict noxious weeds from some emergent areas, as was observed for purple loosestrife on Priest Rapids Reservoir (Grant PUD 2000). Similarly, reed canarygrass seeds are intolerant of prolonged inundation (Lyons 1998), and perennial pepperweed (*Lepidium latifolium*) can be controlled with flooding (Renz 2000).

6.3.3 Infrequent Reservoir Operations

Infrequent reservoir operations at the Wells Project are of such brief duration (median = 3.0 hours) that they are unlikely to induce desiccation, fruit abortion, or other potential impacts of water loss in plants, because soils are expected to remain wetted in the rooting zones of most wetland and riparian species during this time. In addition, infrequent reservoir operations often occur outside the growing season, limiting their potential to affect botanical resources. Some authors have suggested that occasional instances of dewatering, appropriately timed, can enhance riparian and wetland diversity by providing unusual opportunities for germination and establishment (e.g., Schneider 1994). Similarly, Woo and Zedler (2002) suggest that water level fluctuations can support sexually reproducing wetland species over clonal plants such as cattail, resulting in greater diversity. Despite this potential, clonal species are a dominant component of the emergent flora of Wells Reservoir.

Extended dewatering (lasting months) has been associated with substantial changes in species distributions in wetland and riparian habitats (Hudon 2004, Rains et al. 2004). However, infrequent reservoir operations of this duration did not occur on Wells Reservoir during the years examined for this study.

6.3.4 Conclusions

Existing vegetation patterns on Wells Reservoir reflect recent operating conditions, including daily fluctuations that serve to support existing wetland and riparian habitats. In particular, emergent wetland species are well-adapted to pronounced seasonal changes in soil moisture and inundation, and require fluctuations to successfully compete with woody species. Daily fluctuations may also preclude the development of certain desirable habitats (i.e., black cottonwood riparian forests) from areas in which they do not currently occur, or impair the replacement of such habitats over time. Infrequent reservoir operations at Wells Reservoir are unlikely to bring about immediate changes to wetland and riparian habitats, because they are typically of very short duration.

6.4 Special-Status Plants

6.4.1 Background

Botanical surveys of Wells Reservoir in 2005 (EDAW, 2006b) documented four special status plants occurring in the Project: little bluestem (*Schizachyrium scoparium*, listed as Threatened by the Washington Natural Heritage Program), northern sweetgrass (*Hierochloe odorata*, listed as a Review species [one for which more information is required on its rarity]), chaffweed (*Centunculus minimus*, Review), and brittle prickly-pear (*Opuntia fragilis*, Review). None are listed under the federal Endangered Species Act.

Among these species, little bluestem, chaffweed and northern sweetgrass occur in habitats influenced by the Project. (Brittle prickly-pear, a cactus, occurs only in uplands.) Little bluestem occurs along a small part of the shoreline just downstream of Chief Joseph Dam. Plants in this population were estimated to be growing approximately 2 to 5 feet above the normal pool level.

Northern sweetgrass and chaffweed both occur in habitats that are frequently inundated and exposed by fluctuating reservoir levels. The habitat for each of the four documented occurrences of chaffweed consists of gently sloping, muddy shorelines with little competing vegetation. Northern sweetgrass occurs on a steep sandy beach with little vegetative cover as well as on a gravelly shoreline with dense cover of herbaceous wetland vegetation.

6.4.2 Daily Fluctuations

Daily fluctuations of Wells Reservoir likely affect each special-status plant differently. Because chaffweed occurs on frequently inundated mudflats that are maintained by reservoir fluctuations, this species can be viewed as supported by Project operations. Unsuitable conditions for chaffweed would be quickly followed by local extirpation, because it is an annual species. Little bluestem occurs in upland conditions within the Project boundary and is considered an upland species elsewhere in Washington and North America (WNHP 2006a). It occurs well above the normal pool level of Wells Reservoir, beyond the rooting depth of the species (Fargione and Tilman 2005). As a result, it is likely unaffected by normal pool fluctuations.

The expected effects of normal pool fluctuations on northern sweetgrass are less clear. Because it is usually restricted to wetlands (NRCS 2006), it should be expected to tolerate frequent flooding and dewatering. However, the effects of water fluctuations on its local habitat and competing species are unknown, and the potential exists that aspects of the local fluctuation regime could favor competing species, to the detriment of northern sweetgrass (EDAW 2006b). However, Wells Reservoir is one of fewer than 15 sites in Washington supporting northern sweetgrass (WNHP 2006b), suggesting that other factors besides reservoir fluctuations are involved in its rarity, and the fact that they are present and persist at the current location is an indication that the current operating regime of Wells Reservoir is at least partially suitable for the species.

6.4.3 Infrequent Reservoir Operations

Infrequent reservoir operations at the Wells Project are of short enough duration (median = 3.0 hours) that they are unlikely to induce desiccation, fruit abortion, or other potential impacts of water loss on existing plants, because soils will remain wetted in the rooting zones of most wetland and riparian species during this time. In addition, infrequent reservoir operations often occur outside the growing season, limiting their potential to affect existing botanical resources. Extended dewatering (lasting months) has been associated with substantial changes in species distributions in wetland and riparian habitats (Hudon 2004), potentially affecting special-status plants indirectly. However, infrequent reservoir operations of this duration did not occur at the Wells Project during the years examined for this study.

6.4.4 Conclusions

Daily reservoir fluctuations are unlikely to detrimentally affect the special-status plants currently found within the Wells Project. However, local effects of water level fluctuations can be idiosyncratic, potentially affecting special-status plant habitats or competing species. Infrequent reservoir operations are unlikely to detrimentally affect special-status plants because they are generally of short duration.

7.0 EROSION

7.1 Background

Shoreline conditions vary throughout the Project. The majority of shoreline is stable and vegetated, or consists of exposed bedrock or riprap (Douglas PUD, 2006). Other areas have varying degrees of erosion ranging from actively eroding to nearly stabilized. Erosion of the reservoir banks has occurred since the Project was constructed, particularly along the left bank of the Columbia River between Pateros and Wells Dam, on the left bank downstream from the Brewster Bridge, on the right bank downstream from the mouth of the Okanogan River, and along the banks of the lower Okanogan River (Bechtel 1970; Demish, 2003).

An erosion evaluation completed in 2003 (Demich, 2003) assessed shorelines within the Project for active erosion sites. The intent was to identify areas of active erosion for the purposes of developing 50-year erosion projections. This report did not identify the mechanisms of erosion. A total of 83 tracts of land were assessed and rates of erosion were quantified based on shoreline regression over time in locations of active erosion. Most of the erosion was less than 1 ft/year. Where erosion exceeded 1 ft/yr, it appeared to be largely due to undermining of poorly protected slopes. These slopes were not necessarily steep and often the erosion was along the base of a flat terrace.

Total Number of Tracts:	83 tracts
Actively Eroding (maximum rate exceeds 1ft/yr):	10 tracts (12%)
Moderate Erosion (maximum rate between 0.5 and 1 ft/yr):	29 tracts (35%)
Low Erosion (maximum rate less than 0.5 ft/yr):	16 tracts (19%)
Little to No Erosion:	28 tracts (34%)

Bank-face erosion and bank recession along reservoir shorelines are natural, inter-related processes. The rate and extent of these processes are influenced by an array of factors broadly categorized as passive (inherent in the physical parameters of the site) or activating (things which trigger erosion) (Reid, 1992). Reservoir operations can be an activating factor and may result in erosion (Allen and Tingle, 1993). Passive factors associated with bank erosion include substrate characteristics, such as a clay-rich composition, alternating layers of weak and strong beds, and dense jointing in the parent material (especially vertical joints); high moisture content (e.g., in areas protected from sunlight); bank topography (steep slopes, relatively low height, and narrow beaches lacking toe-slope protection); lack of protection from wind-driven waves; and inadequate vegetative cover. In addition to dewatering, activating factors that can trigger bank erosion are (in order of importance): wave action, frost thaw, rainsplash/runoff, groundwater sapping, human disturbance and wind.

In the Project, a few of the active sites were at bends in the lower Okanogan River (an expected location), and due to high clay content. All were at the water level and experienced undermining of the existing vegetation, clay content, and wave action were not discussed and can only be implicated. A high potential for erosion in the Project exists where there are steep slopes (which are common on the reservoir), erodible soils, high soil moisture, long fetch (leading to enhanced wave action), un-protected toes, and narrow beaches. However, few of the examples in the Demich report showed steep slopes as a characteristic.

An example of active erosion is on the lower Okanogan River. The river both within and upstream of the Project has experienced considerable erosion and recent attempts to control it have been only partially successful (Douglas PUD, 2006). The banks are composed of fine alluvial material which is easily eroded by wave and current action, making the formation of a stable beach a difficult and sometimes lengthy process. Erosion along the Okanogan River, as is customary for alluvial streams, likely occurs primarily as a result of flood flows when tractive forces exceed the shear forces necessary to begin to mobilize the alluvial deposits.

7.2 Effects of Daily Fluctuations and Infrequent Reservoir Operations

Erosion rates are influenced both by the extent of fluctuations and the speed of water elevation change. During water fluctuations, antecedent moisture may be the factor most likely to influence erodibility. If stage change is rapid, soils are more likely to retain moisture when exposed. In some types of soils (e.g., non-cohesive), high moisture content reduces internal strength (Hanks and Ashcroft, 1980). Other soil types, such as soils rich in fine-grained and/or expandable clay minerals, can be highly erodible when saturated and subjected to mobilizing forces such as waves (Reid, 1992; Chelan PUD, 2000).

Wave action may intercept steep slopes higher on the bank if the reservoir level is high, and, along with numerous and inter-related causes, can lead to enhanced erosion. Changes in water level can aggravate wave erosion processes as particles are moved downslope by progressive small steps as a result of waves impacting various levels of the slope (Chelan PUD, 2000).

Many studies have assessed the effects of wave energy on bank erosion (see Allen and Tingle, 1993). Wave action undercuts the toe of the slope, which reduces the stability of the upper slope (Chelan PUD, 2000). Although some studies have failed to show a statistically significant relationship between wave energy and bank erosion, other studies found a relationship between the critical wave height and bank erosion. No single activating factor can account for bank erosion, but Reid (1992) and Ferguson (1999) concluded that wave erosion is by far the most important. Of all the passive factors, composition of the bank material and orientation to wave-generating winds are most important.

7.3 Conclusions

Project operations may have modified the rate and location of shoreline erosion, but cannot be viewed independent of other factors, particularly wave action, vegetation, and undermining of banks. Only about 12% of the tracts reviewed in the Project are actively eroding at a higher rate (over 1 ft/yr). About half (53%) of the shorelines along the Project are currently stable and any ongoing erosion appears to be progressing relatively slowly (less than 0.5 ft/yr Demich, 2003). It appears that riparian vegetation, riprap, and cobble bars provide slope protection if the protection is at the water line; e.g., the toe of the slope is protected from active shear stress supplied by waves or flowing water. Additionally, cover type mapping conducted in 2005 identified a total of 19 acres (0.8 percent of lands within the FERC Project Boundary) as eroding (EDAW, 2006b). Rapidly fluctuating or changing water levels can cause some slopes to be more erodible if bank protection is poor wherever the waterline is maintained. Saturation due to a raised water of poorly protected banks may increase the rate of sloughing, and active bank erosion. Nonetheless, the effects of daily fluctuations and infrequent reservoir operations are judged to be minor.

8.0 REFERENCES

Allen, H.H. and J.L. Tingle (editors). 1992. Proceedings, U.S. Army Corps of Engineers Workshop on Reservoir Shoreline Erosion: A National Problem. Final Report. Miscellaneous Paper W-93-1.

Bauersfeld, K. 1978. Stranding of juvenile salmon by flow reductions at Mayfield Dam on the Cowlitz River. WDF, Olympia, WA, Technical Report. 36. pp. 36.

Beak Consultants, Inc. and Rensel Associates. 1999. Assessment of resident fish in Lake Pateros, Washington. Final Report. Prepared for Public Utility District No. 1 of Douglas County. Beak Consultants, Inc. in cooperation with Rensel Associates. Arlington, Washington.

Beamish, R.J. 1980. Adult biology of the river lamprey (Lampetra ayersi) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences. 37: 1906-1923.

Beamish, R.J. and C. Levings. 1991. Abundance and freshwater migrations of the anadromous parasitic lamprey, *Lampetra tridentata*, in a tributary of the Fraser River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences, 48. pp. 1250-1263.

Beamish, R. and T. Northcote. 1989. Extinction of a population of anadromous parasitic lamprey, *Lampetra tridentate*, upstream of an impassable dam. Canadian Journal of Fisheries and Aquatic Sciences 46. 420-425.

Bechtel Corporation. 1970. Wells Hydroelectric Project - Report on Reservoir Erosion. Prepared by Bechtel Corporation, San Francisco, California, for Douglas PUD. September 1970.

Beak Consultants and Rensel Associates. 1999. Assessment of resident fish in Lake Pateros, Washington. Report prepared for Public Utility District No. 1 of Douglas County, East Wenatchee, Washington.

Beck Associates, R. W. 1989. Skagit River Salmon and Steelhead Fry Stranding Studies. Prepared R. W. Beck Associates for the Seattle City Light Environmental Affairs Division, March 1989. Seattle, Washington. 300 pp.

Berggren, T.J. and M.J. Filardo. 1993. An analysis of variables influencing the migration of juvenile salmonids in the Columbia River Basin. North American Journal of Fisheries Management 13: 48-63.

Bickford, S.A., J. Skalski, R. Townsend, S. McCutcheon, R. Richmond, R. Firth, D. Park, and R. Fechhelm. 2001. Project survival estimates for yearling summer steelhead migrating through the Wells hydroelectric facility, 2000. Research funded by Public Utility District No. 1 of Douglas County, East Wenatchee, Washington. 100 pp.

BioAnalysts, Inc. 2006. Aquatic Macroinvertebrate Inventory and RTE Assessment. Prepared for Douglas Public Utility District No. 1. FERC No. 2149. 21 pp.

BioAnalysts, Inc. 2000a. A status of Pacific lamprey in the mid-Columbia region. Report for Public Utility District No. 1 of Chelan County, Wenatchee, Washington. 34 pp.

BioAnalysts, Inc. 2000b. Effects of pool fluctuations on natural resources in the Rocky Reach project area. Report for Public Utility District No. 1 of Chelan County, Wenatchee, Washington. 21 pp

BioWest, Inc. 2002. Draft Provo River Flow Study: Flow habitat and flow-ecological relationships within the riverine ecosystem: aquatic habitat, riparian vegetation, recreational uses, fluvial processes. Prepared for Utah Reclamation, Mitigation, and Conservation Commission, Salt Lake City, Utah.

Brusven, M.A., and C. MacPhee. 1976. The effect of river fluctuations resulting from hydroelectric peaking on selected aquatic invertebrates and fish. Idaho Water Resources Research Institute, University of Idaho, Moscow, Idaho.

Burley, C.C. and T.P. Poe. 1994. Significance of predation in the Columbia River from Priest Rapids Dam to Chief Joseph Dam, predator consumption indexing. Contract 430-486. Prepared for PUD No 1 of Chelan County, PUD No. 1 of Douglas County, and PUD No. 2 of Grant County.

Casanova, M.T., and M.A. Brock. 2000. How do depth, duration, and frequency of flooding influence the establishment of wetland plant communities? Plant Ecology 147: 237-250.

Chelan PUD. 2000. Inventory of shoreline erosion Lake Chelan and bypass reach study report, first draft. Lake Chelan Hydroelectric Project FERC Project No. 637. Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Close, D., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River basin. Project No. 94-026, Contract No. 95BI39067. Report to the U. S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Close, D., M. Fitzpatrick, and H. Li. 2002. The Ecological and Cultural Importance of a Species at Risk of Extinction, Pacific Lamprey. Fisheries, 27(7).

Cooke, G.D. 1980. Lake level drawdown as a macrophyte control technique. Water Resources Bulletin 16:317-322.

DART (Columbia River Data Access in Real Time). 2006. DART PIT-Tag Adult Returns by Observation Year Detail Report. See link: http://www.cbr.washington.edu/dart/pit_obs_adult_conrate.html (accessed October 2006).

Demich Engineering. 2003. Lower Okanogan River Erosion Evaluation Project. Prepared for PUD No. 1 of Douglas County, Wells Hydroelectric Project. Prepared by Demich Engineering for Jacobs Civil Inc. July 2003.

Duke Engineering & Services, Inc. (DE&S). 2001. Rocky Reach fish presence and habitat use survey. Report prepared for the Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Duke Engineering & Services, Inc. (DE&S). 2000. Rocky Reach Hydroelectric Project RTE Wildlife and Cover Type Mapping Final Report. Report by Duke Engineering and Services for Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

EDAW, Inc. 2006a. Wildlife resources final study report – avian, amphibian, reptile, and small mammal surveys, Wells Hydroelectric Project, FERC No. 2149. Prepared for PUD No. 1 of Douglas County, East Wenatchee, Washington.

EDAW, Inc. 2006b. Botanical resources final study report – cover type mapping, rare, threatened and endangered plant surveys, and invasive plant species surveys, Wells Hydroelectric Project, FERC No. 2149. Prepared for PUD No. 1 of Douglas County, East Wenatchee, Washington.

Emig, J. W. 1966. Chapter 44. Largemouth Bass *In:* Inland Fisheries Management, Calhoun, A. (editor), California Department of Fish and Game. pp. 295-305.

Farlinger, S. and R. Beamish. 1984. Recent colonization of a major salmon-producing lake in British Columbia by the Pacific Lamprey (*Lampetra tridentata*). Canadian Journal of Fisheries and Aquatic Sciences 41: 278-285.

Fargione, J. and D. Tilman. 2005. Niche differences in phenology and rooting depth promote coexistence with a dominant C4 bunchgrass. Oecologia 143:598-606.

Ferguson, B. K. 1999. Shoreline erosion and its potential control on Thurmond Lake. http://www.forester.net/ec_9911_shoreline.html (accessed October 2006).

Framatome ANP DE&S. 2003. Terrestrial Habitat Assessment - Priest Rapids Project. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, Washington. License Application Technical Appendix E-5.C.

Frost, D.R., T. Grant, J.N. Faivovich, R.H. Bain, A. Haas, C.F.B. Haddad, R.O. De Sá, A. Channing, M. Wilkinson, S.C. Donnellan, C.J. Raxworthy, J.A. Campbell, B.L. Blotto, P. Moler, R.C. Drewes, R.A. Nussbaum, J.D. Lynch, D.M. Green, and W.C. Wheeler. 2006. The Amphibian Tree of Life. Bulletin of the American Museum of Natural History 297: 1-370.

Furey, P.C., R.N. Nordin, and A. Mazumder. 2006. Littoral benthic macroinvertebrates under contrasting drawdown in a reservoir and a natural lake. Journal of the North American Benthological Society 25: 19-31.

Giorgi, A. 1992. Fall Chinook spawning in Rocky Reach pool; Effects of three-foot increase in pool elevation. Don Chapman Consultants, Inc., research report for the Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Grant County Public Utility District (Grant PUD). 2000. Exhibit E – Environmental Report. Final application for new license, Priest Rapids Project, FERC No. 2114. Ephrata, Washington.

Hamilton, R. and J.W. Buell. 1976. Effects of modified hydrology on Campbell River salmonids. Fisheries and Marine Services, Tech. Rep. Ser. No. PAC/T-76-20. 156 pp.

Hanks, R.J. and G.L. Ashcroft. 1980. Applied Soil Physics. Springer-Verlag Berlin Heidelberg. 159 pp.

Heman, M. and L. Redmond. 1969. Manipulation of fish populations through reservoir drawdown. Transactions of the American Fisheries Society, 98: 293-304.

Hourly Coordination Agreement for the Mid-Columbia River (HCA). 1997. Agreement for the hourly coordination of seven mid-Columbia hydroelectric dams.

Hudon, C. 1997. Impact of water level fluctuation on St. Lawrence River aquatic vegetation. Canadian Journal of Fisheries and Aquatic Sciences 54: 2853-2865.

Hudon, C. 2004. Shift in wetland plant composition and biomass following low-level episodes in the St. Lawrence River: looking into the future. Canadian Journal of Fisheries and Aquatic Sciences 61: 603-617.

Hunter, M.A. 1992. Hydropower flow fluctuations on salmonids: A review of the biological effects, mechanical causes and options for mitigation. Washington Department of Fisheries. 46 pp.

Jackson, A., P. Kissner, D. Hatch, B. Parker, M. Fitzpatrick, D. Close, and H. Li. 1996. Pacific lamprey research and restoration. Annual Report 1996. Project, No. 94-026, Contract No. 95BI39067. Report to U. S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Jones, L.L.C., W.P Leonard, and D.H. Olson, editors. 2005. Amphibians of the Pacific Northwest. Seattle Audubon Society, Seattle, Washington. 227pp.

Jones, M. and K. Rogers. 1998. Palmetto bass movements and habitat use in a fluctuating Colorado irrigation reservoir. North American Journal of Fisheries Management 18: 640-648.

Keddy, P.A. and A. A. Reznicek. 1986. Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seeds. Journal of Great Lakes Research 12: 25-36.

Kramer, R. and L. Smith. 1962. Formation of Year Classes in Largemouth Bass. Transaction of the American Fisheries Society 91: 29-41.

Lê, B. and S. Kreiter. 2005. Wells Project macrophyte identification and distribution study, 2005. Public Utility District No. 1 of Douglas County, East Wenatchee, Washington.

Lee, D. P. 1999. Water Level Fluctuation Criteria for Black Bass in California Reservoirs. Reservoir Research and Management. No. 12.

LGL Limited Environmental Research Associates and Douglas PUD. 2006. Wells Bull trout Monitoring and Management Plan, 2005 Annual Report, Wells Project, FERC No. 2149.

Luzier, C. and G. Silver. 2004. Evaluate Habitat Use and Population Dynamics of Lamprey in Cedar Creek. Annual Report for 2004 Sampling Season. BPA Project #2000-014-00. Prepared for: U. S. Fish and Wildlife Service. 36 pp.

Lyon, K.E. 1998. Element stewardship abstract for *Phalaris arundinacea* L., reed canarygrass. Report prepared for the Nature Conservancy, Davis, California.

Mahoney, J.M., and S.B. Rood. 1998. Streamflow requirements for cottonwood seedling recruitment – an integrative model. Wetlands 18: 634-645.

Maxell, B.A. 2000. Management of Montana’s amphibians: a review of factors that may present a risk to population viability and accounts on the identification, distribution, taxonomy, habitat use, natural history, and the status and conservation of individual species. Report to USFS Region 1, Order Number 43-0343-0-0224. University of Montana, Wildlife Biology Program. Missoula, Montana. 161 pp.

McMahon, R., and T. Ussery. 1995. Thermal tolerance of zebra mussels (*Dreissena polymorpha*) relative to rate of temperature increase and acclimation temperature. Prepared for the Army Corps of Engineers. 19 pp.

Metter, D.E. 1960. The distribution of amphibians in eastern Washington. Masters Thesis, Washington State University, Pullman, Washington.

Monello, R.J. and R.G. Wright. 1999. Amphibian habitat preferences among artificial ponds in the Palouse Region of Northern Idaho. Journal of Herpetology 33:298-303.

Moore, J. and J. Malatt. 1980. Feeding of larval lamprey. Canadian Journal of Fisheries and Aquatic Sciences 37: 1658-1664.

Moser, M. and D. Close. 2003. Assessing Pacific Lamprey Status in the Columbia River Basin. Northwest Science 77: 116-125.

Moyle, P. B. 1976. Inland Fishes of California. University of California Press, Berkeley. 405 pp.

Munger, J.C., M. Gerber, K. Madrid, M. Carroll, W. Petersen, and L. Heberger. 1998. U.S. National Wetland Inventory classifications as predictors of the occurrence of Columbia spotted frogs (*Rana luteiventris*) and Pacific treefrogs (*Hyla regilla*). Conservation Biology 12:320-330.

Nass, B., C. Sliwinski, and D. Robichaud. 2005. Assessment of Adult Pacific Lamprey Migratory Behavior at Wells Dam Using Radio-telemetry Techniques, 2004. Prepared by LGL Limited Environmental Research Associates for Public Utility District No. 1 of Douglas County, East Wenatchee, Washington.

National Marine Fisheries Service (NMFS). 2002. Anadromous Fish Agreements and Habitat Conservation Plans: Final Environmental Impact Statement for the Wells, Rocky Reach, and Rock Island Hydroelectric Projects. U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Marine Fisheries Service, Northwest Region, Portland, Oregon. December 2002.

Natural Resources Conservation Service (NRCS). 2006. Wetland indicator status. http://plants.usda.gov/wetland.html. Accessed 20 September 2006.

Oak Ridge National Laboratory (ORNL) Environmental Sciences Division. 1980. Hildebrand, S. G. (editor). Analysis of environmental issues related to small-scale hydroelectric development. III: Water Level Fluctuation. Contributing Authors, R.R. Turner, R.R., L.D. Wright, A.T. Szluha, B. Tschantz, and S. Tam. Publication No. 1581. 78 pp.

Phinney, L.A. 1974. Report on the 1972 Study of the Effect of River Flow Fluctuations Below Merwin Dam on Downstream Migrant Salmon. Washington Department of Fisheries. 23 pp.

Poe, T. H. Hansel, S. Vigg, D. Palmer and L. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120: 405-420.

Rains, M.C., J.F. Mount, and E.W. Larsen. 2004. Simulated changes in groundwater and vegetation distributions under difference reservoir operations scenarios. Ecological Applications 14: 192-207.

Recuero, E., I. Martinez-Solano, G. Parra-Olea, and M. Garcia-Paris. 2006. Phylogeography of *Pseudacris regilla* (Anura: Hylidae) in western North America, with a proposal for a new taxonomic rearrangement. Molecular Phylogenetics and Evolution 39:293-304.

Rensel Associates. 1993. Nutrients, algae and salmon farming in Rufus Wood Lake of the middle Columbia River, final report. Prepared for Pacific Catch Co., Brewster, Washington. Stolt Sea Farm, Port Angeles, Washington.

Renz, M.J. 2000. Element stewardship abstract for *Lepidium latifolium* L., perennial pepperweed. Report prepared for the Nature Conservancy, Davis, California.

Reid, J.R. 1992. Mechanisms of shoreline erosion along lakes and reservoirs. As cited in: Allen and Tingle, 1992.

Richards, J. 1980. Freshwater life history of the anadromous Pacific lamprey, *Lampetra tridentata*. Masters thesis. University of Guelph, Guelph, Ontario. As cited in*:* BioAnalysts, 2000.

Schneider, R.L. 1994. The role of hydrologic regime in maintaining rare plant communities of New York's coastal plain pondshores. Biological Conservation 68:253-260.

Shipley, B., P.A. Keddy, D.R.J. Moore and K. Lemky. 1990. Regeneration and establishment strategies of emergent macrophytes. Journal of Ecology 77: 1093-1110.

Skalski, J.R. 1993. Additional summaries of 3-year bypass efficiency study at Wells Dam. Center for Quantitative Science, Seattle, Washington.

Toner, M., and P. Keddy. 1997. River hydrology and riparian wetlands: a predictive model for ecological assembly. Ecological Applications 7: 236-246.

Turner, G. 2004. Factors affecting the shoreline distribution of Asiatic clams, Corbicula fluminea (Muller), in the Hanford Reach, Columbia River. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory under contract DE-AC06-76RLO1830.

United States Fish and Wildlife Service (USFWS). 2004. Biological Opinion and Conference Opinion for the License Amendments to incorporate the Rocky Reach, Rock Island and Wells Anadromous Fish Agreements and Habitat Conservation Plans. U.S Fish and Wildlife Service, Central Washington Field Office, Wenatchee, Washington. May 2004.

Vaughn, C. C. 2005. Freshwater mussel populations in southeastern Oklahoma: population trends and ecosystem services. Proceedings of Oklahoma Water 2005, Tulsa, OK. Paper #18. Oklahoma Water Resources Institute, Stillwater, Oklahoma. 12 pp.

Ward, D., and M. Zimmerman. 1999. Response of smallmouth bass to sustained removals of northern pikeminnow in the lower Columbia and Snake rivers. Transaction of the American Fish Society. Vol. 128, pp. 1020-1035.

Washington Natural Heritage Program (WNHP). 2006a. *Schizachyrium scoparium* (Michx.) Nash var. scoparium. Olympia, Washington.

Washington Natural Heritage Program (WNHP). 2006b. *Hierochloe odorata* L. Olympia, Washington.

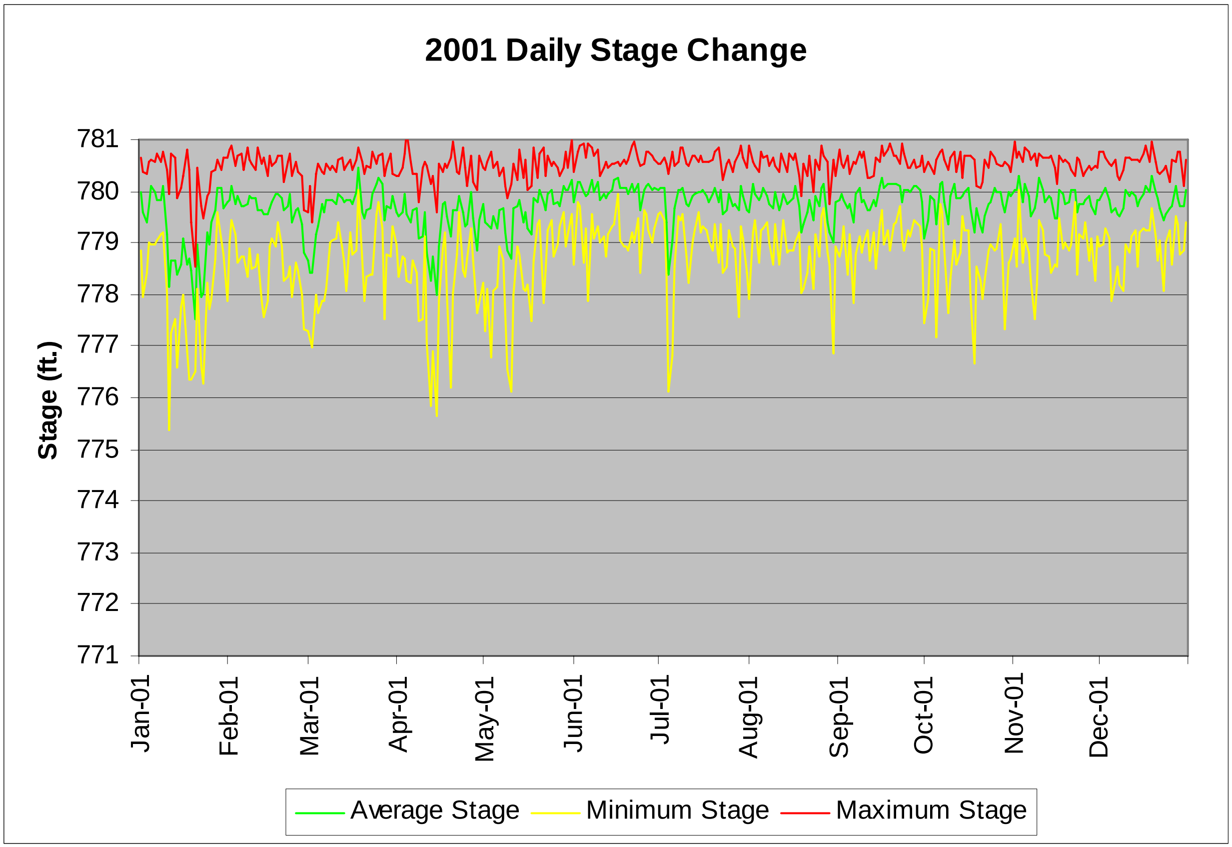
Whyte, J. R. Beamish, N. Ginther and C. Neville. 1993. Nutritional condition of the Pacific lamprey (*Lampetra tridentata*) deprived of food for periods of up to two years. Canadian Journal of Fisheries and Aquatic Sciences 50: 591-599.

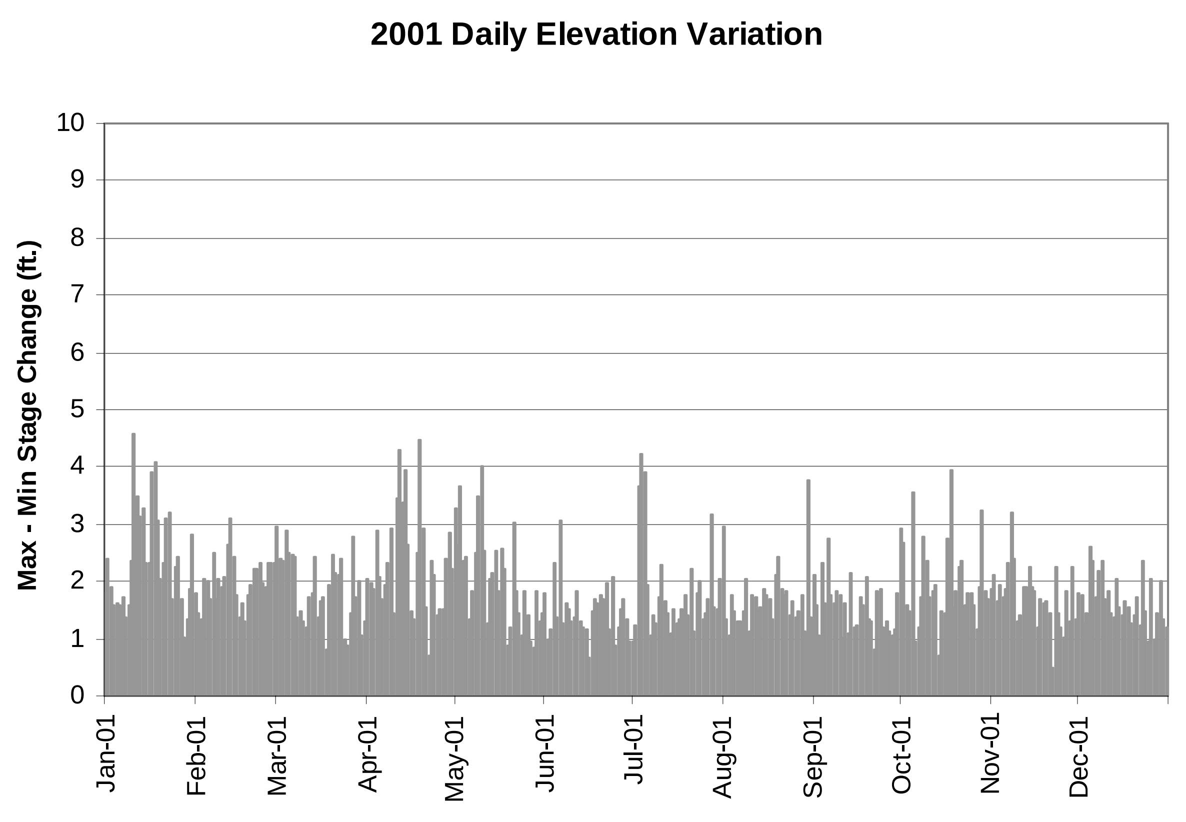
Wydoski, R.S., and R.R. Whitney. 2003. Inland Fishes of Washington. Second edition. University of Washington Press, Seattle, Washington.

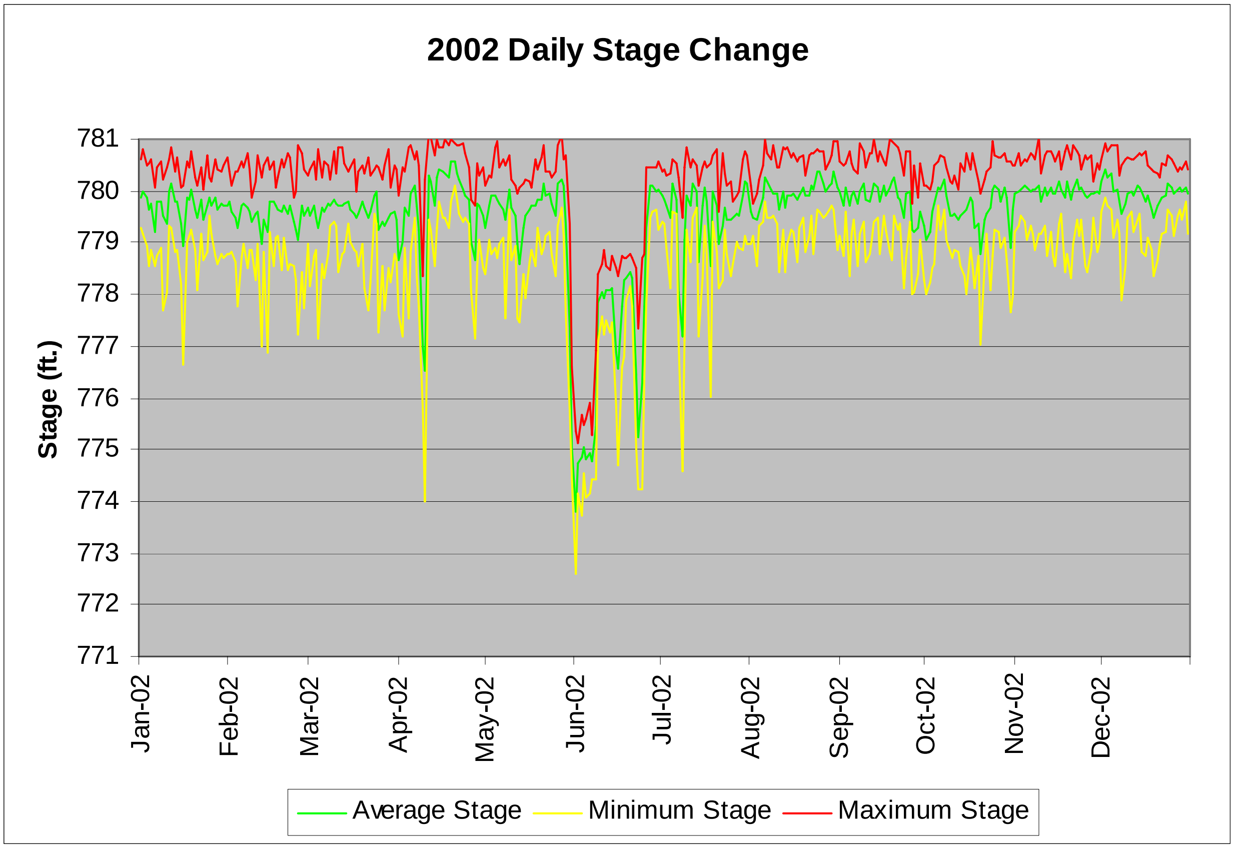
Woo, I., and J. B. Zedler. 2002. Can nutrients alone shift a sedge meadow towards the invasive *Typha* x *glauca*? Wetlands 22:509-521.

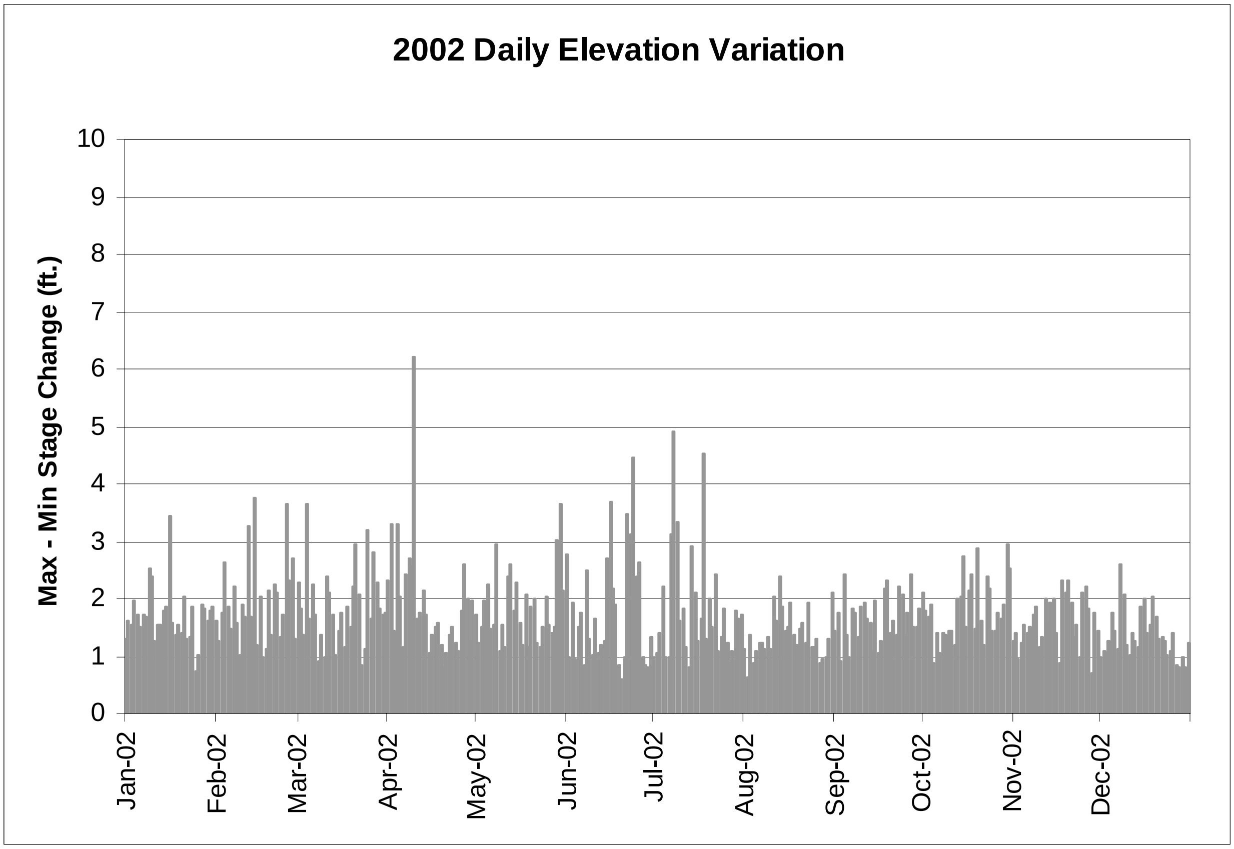
Appendix A

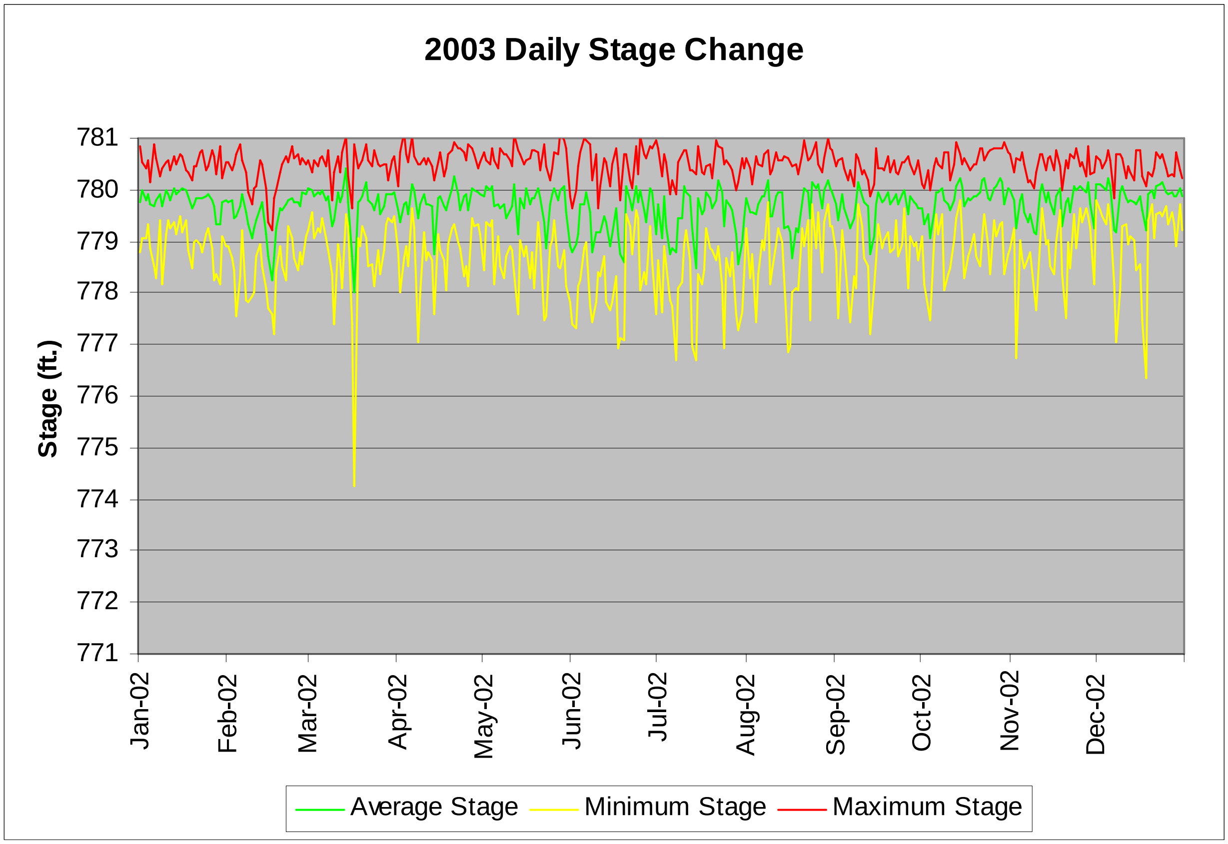
Five Year Operational Summary

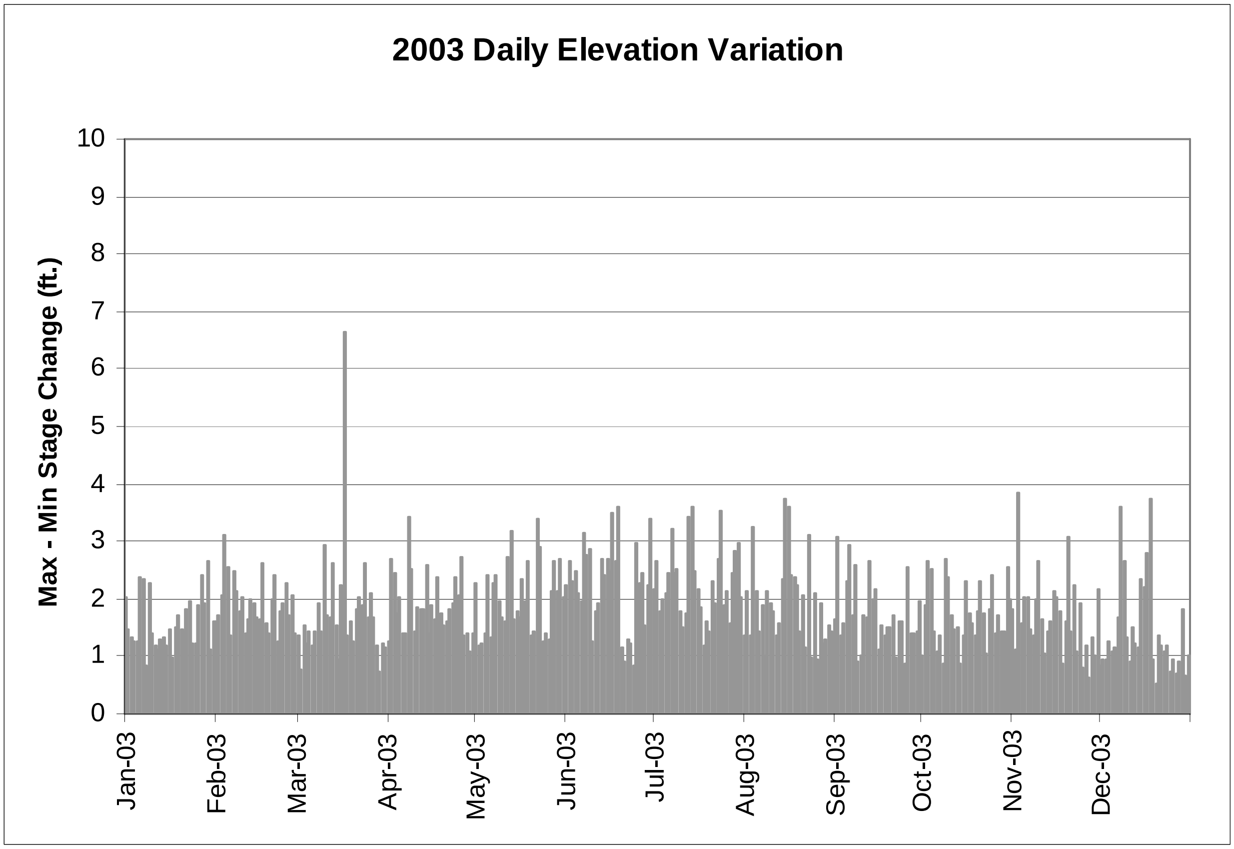

2001 Daily Stage Change
Stage (ft.)
781
780
779
778
777
776
775
774
773
772
771
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Average Stage
Minimum Stage
Maximum Stage

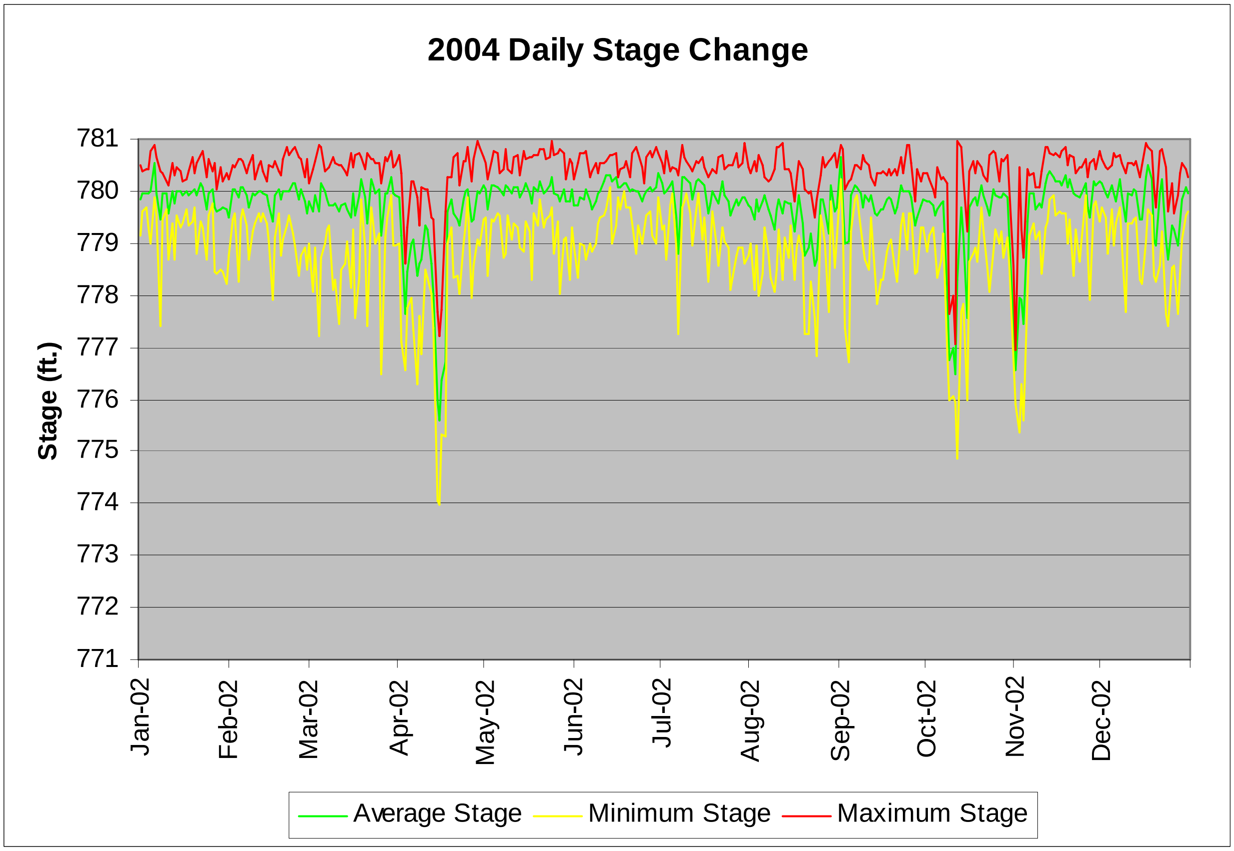

2001 Daily Elevation Variation
Max - Min Stage Change (ft.)
10
9
8
7
6
5
4
3
2
1
0
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01

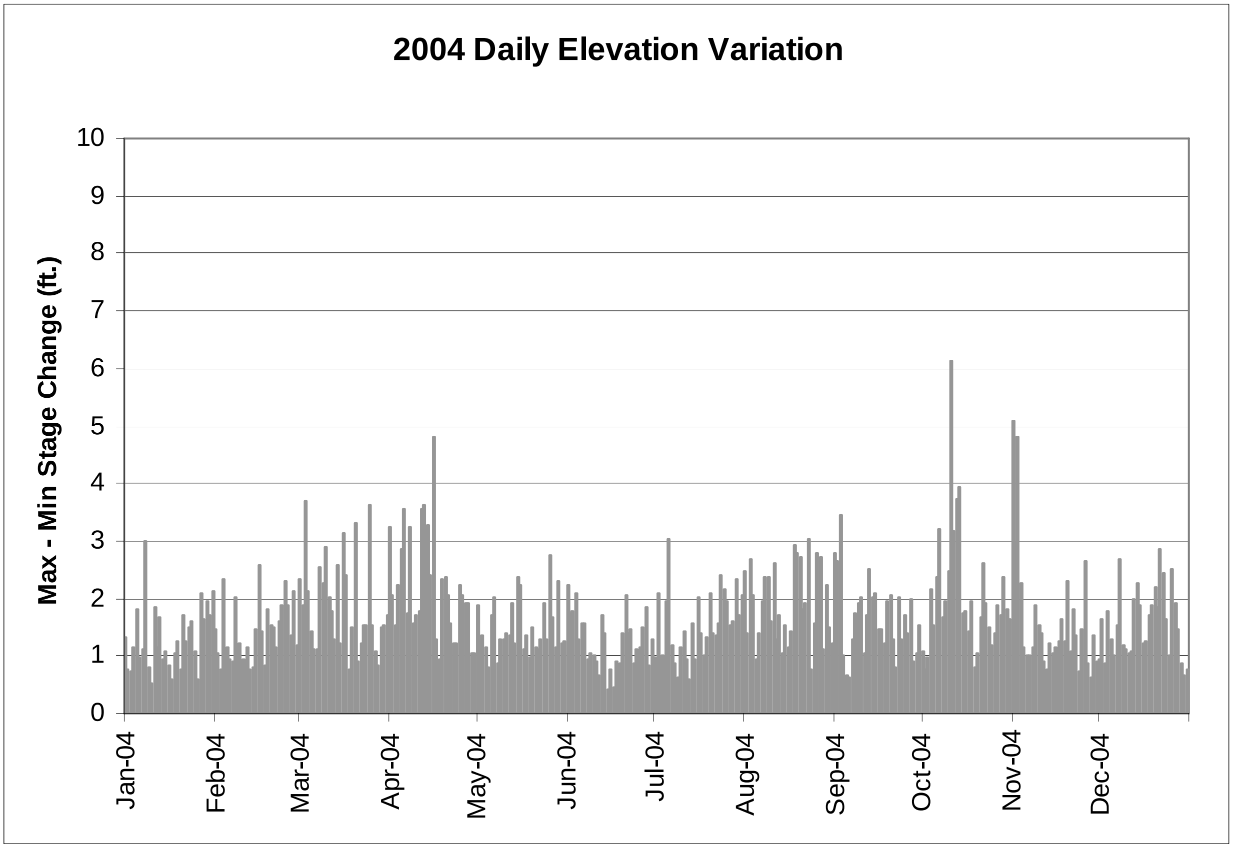

2002 Daily Stage Change
Stage (ft.)
781
780
779
778
777
776
775
774
773
772
771
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Average Stage
Minimum Stage
Maximum Stage

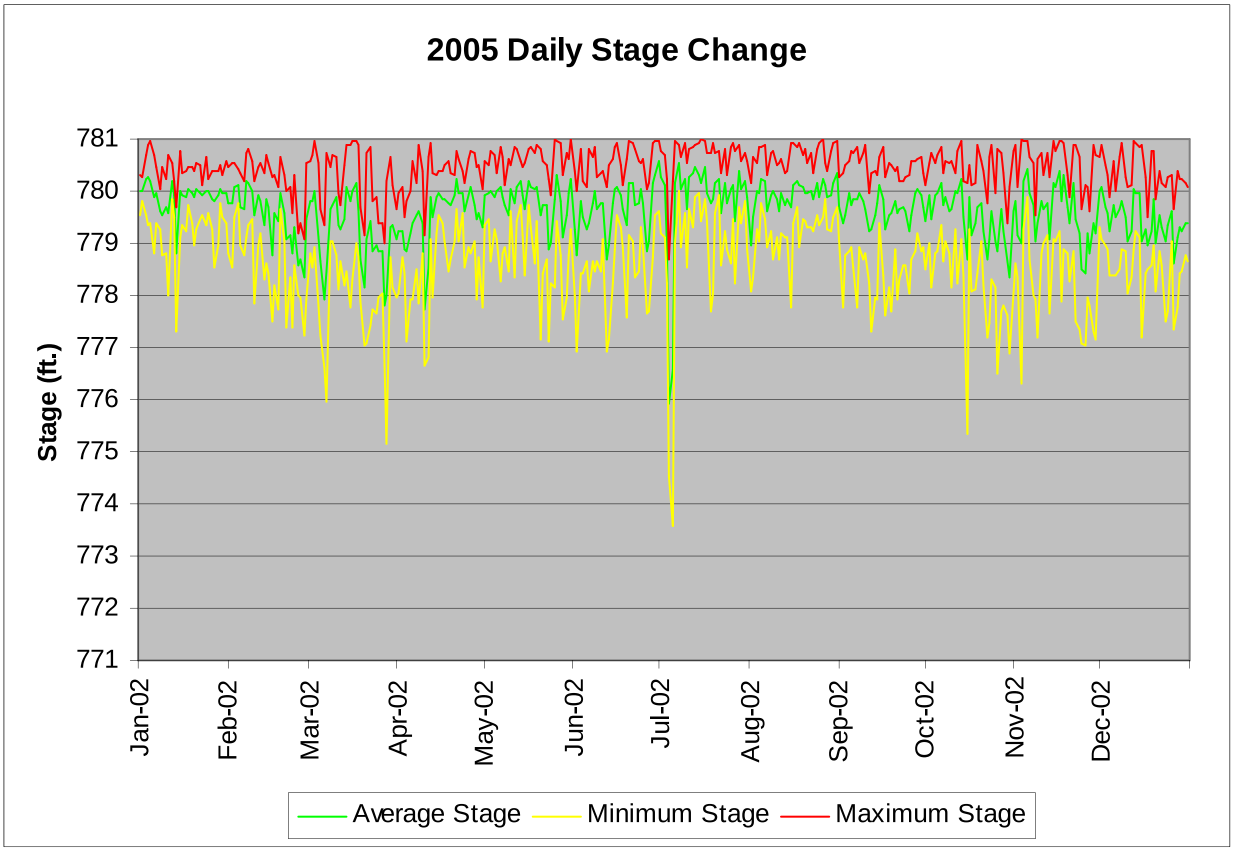

2002 Daily Elevation Variation
Max - Min Stage Change (ft.)
10
9
8
7
6
5
4
3
2
1
0
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02

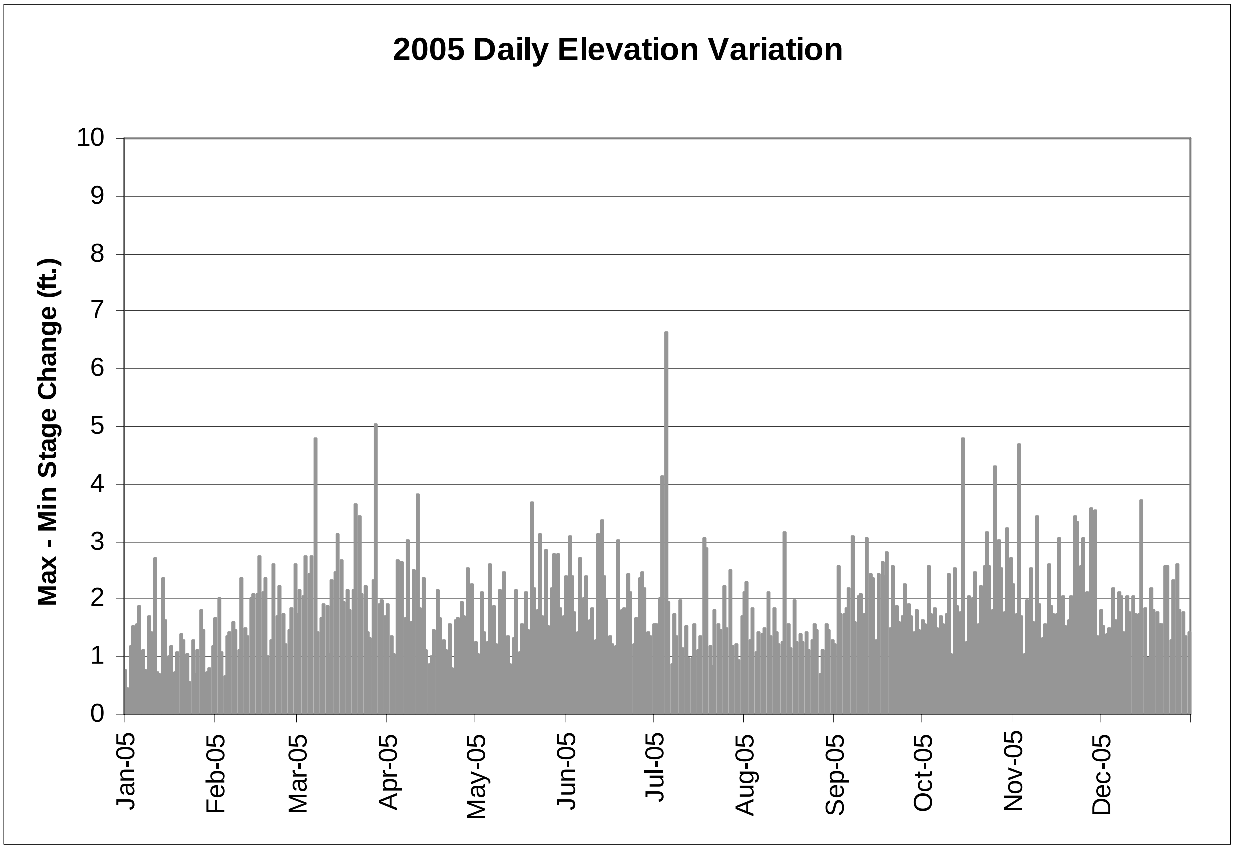

2003 Daily Stage Change
Stage (ft.)
781
780
779
778
777
776
775
774
773
772
771
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Average Stage
Minimum Stage
Maximum Stage


2003 Daily Elevation Variation
Max - Min Stage Change (ft.)
10
9
8
7
6
5
4
3
2
1
0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03


2004 Daily Stage Change
Stage (ft.)
781
780
779
778
777
776
775
774
773
772
771
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Average Stage
Minimum Stage
Maximum Stage


2004 Daily Elevation Variation
Max - Min Stage Change (ft.)
10
9
8
7
6
5
4
3
2
1
0
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04


2005 Daily Stage Change
Stage (ft.)
781
780
779
778
777
776
775
774
773
772
771
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Average Stage
Minimum Stage
Maximum Stage


2005 Daily Elevation Variation
Max - Min Stage Change (ft.)
10
9
8
7
6
5
4
3
2
1
0
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05