Appendix A
Southern Resident Killer Whales

Table of Contents

A SOUTHERN RESIDENT KILLER WHALES 3
A.1 CURRENT RANGEWIDE STATUS 3
A.1.1 Status & Trends 3
A.1.2 Listing Status 4
A.1.3 Range & Distribution 5
A.1.4 Life History 7
A.2 ENVIRONMENTAL BASELINE 9
A.3 EFFECTS OF THE REASONABLE AND PRUDENT ALTERNATIVE ON SOUTHERN RESIDENT KILLER WHALES 14
A.3.1 Short-term Effects on Southern Resident Killer Whales 14
A.3.2 Long-term Effects on Southern Resident Killer Whales 16
A.4 CUMULATIVE EFFECTS 17
A.5 CONCLUSION 18

Table of Figures

Figure A.1-1 Population size and trend of Southern Resident killer whales 4
Figure A.1-2 Geographic Range of the Southern Resident Killer Whale Population 5
Figure A.1-3 Monthly occurrence of the three Southern Resident killer whale pods in the inland waters of Washington and British Columbia, 1976-2005 6

SOUTHERN RESIDENT KILLER WHALES

A.1 Current Rangewide Status

The Southern Resident killer whale DPS consists of three pods, identified as J, K, and L pods. In this section, the status of the Southern Resident killer whales throughout their range is summarized. Although the entire Southern Resident DPS has potential to occur in the coastal waters at any time during the year, occurrence is more likely from November through April when Southern Residents are only occasionally found in the inland waters of Washington State. The information on the rangewide status of the species is generally representative of the status of the species in coastal waters. The final recovery plan for Southern Residents was issued in January 2008 (NMFS 2008Vg). This section summarizes information taken largely from the recovery plan, as well as new data that became available more recently. For more detailed information about this population, please refer to the Final Recovery Plan for Southern Resident Killer Whales, which can be found on the internet at www.nwr.noaa.gov.

A.1.1 Status & Trends

Although there is little information available regarding the historical abundance of Southern Resident killer whales, two methods have been used to estimate a historical population size of 140 to 200. The minimum estimate (~140) is the number of whales killed or removed for public display in the 1960s and 1970s added to the remaining population at the time of the captures. The maximum estimate (~200) is based on a recent genetic analysis of microsatellite DNA (NMFS 2003f).

At present, the Southern Resident population has declined to essentially the same size that was estimated during the early 1960s, when it was considered as likely depleted (Olesiuk et al. 1990) (Figure A.1-1). Since censuses began in 1974, J and K pods have steadily increased their sizes. However, the population suffered approximately a 20 percent decline from 1996-2001, largely driven by declines in L pod. There have been recent increases in the population from 2002-2006 indicating that L pod's decline may have ended, however such a conclusion is premature. The 2007 census counted 87 Southern Resident killer whales, 25 in J pod, 19 in K pod and 43 in L pod.

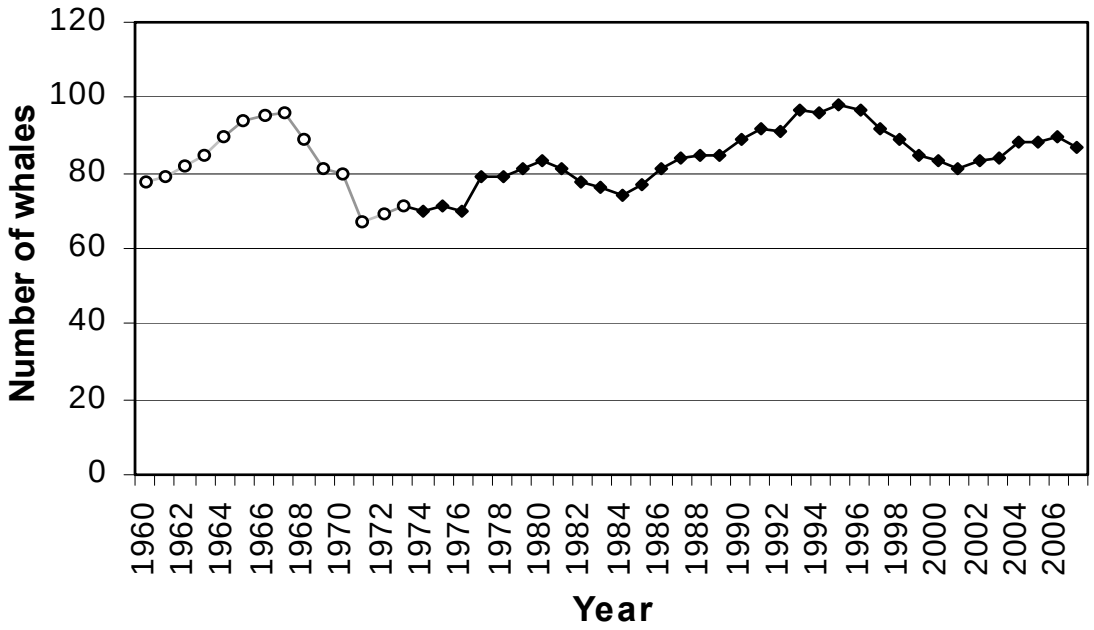

Figure A.1-1 Population size and trend of Southern Resident killer whales, 1960-2007. Data from 1960-1973 (open circles, gray line) are number projections from the matrix model of Olesiuk et al. (1990). Data from 1974-2007 (diamonds, black line) were obtained through photo-identification surveys of the three pods (J, K, and L) in this community and were provided by the Center for Whale Research (unpubl. data) and NMFS (2008g). Data for these years represent the number of whales present at the end of each calendar year except for 2007, when data extend only through October.

A.1.2 Listing Status

The Southern Resident killer whale Distinct Population Segment (DPS) was listed as endangered under the ESA on November 18, 2005 (NMFS 2005e). The final rule included information on the population decline in the 1990s and identified several potential factors that may have caused the decline or may be limiting recovery. These are: quantity and quality of prey, toxic chemicals which accumulate in top predators, and disturbance from sound and vessel traffic. The rule also identified oil spills as a potential risk factor for this species. Southern Residents are designated as “depleted” and “strategic” under the Marine Mammal Protection Act (MMPA) (NMFS 2003f). Critical habitat for the Southern Resident killer whale DPS was proposed on June 15, 2006 (NMFS 2006g) and the final designation of critical habitat was published November 29, 2006 (NMFS 2006d). Critical habitat includes approximately 2,560 square miles of inland waters in three specific areas: 1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca. Southern Resident critical habitat does not occur in the coastal waters, and is therefore not considered further in this consultation.

A.1.3 Range & Distribution

Southern Residents are found throughout the coastal waters off Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as the Queen Charlotte Islands, British Columbia (Figure A.1-2).

Figure A.1-2 Geographic Range (light shading) of the Southern Resident Killer Whale Population. Reprinted from Wiles (2004).

Southern Residents are highly mobile and can travel up to 86 miles (160 km) in a single day (Erickson 1978; Baird 2000). To date, there is no evidence that Southern Residents travel further than 50 km offshore (Ford et al. 2005). Although the entire Southern Resident DPS has potential to occur in coastal waters at any time during the year, occurrence is more likely during November to May.

Southern Residents spend the majority of their time from late spring to early autumn in inland waterways of Washington State and British Columbia (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound) (Bigg 1982; Ford et al. 2000; Krahn et al. 2002) (Figure A.1-3). Typically, J, K and L pods arrive in May or June and spend most of their time in the core area of Georgia Basin and Puget Sound until departing in October. K and L pods also make frequent trips to the outer coasts of Washington and southern Vancouver Island during this time, which generally last a few days (Ford et al. 2000).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976				J,K								
1977												
1978			J,K									
1979											J,K	
1980												
1981				J,K								
1982						J,K				J,K		
1983										J,K	J,K	
1984						J,K						
1985						J,K						
1986					J,K							
1987										J,K	J,K	J,K
1988					J,K							
1989			J,K							J,K	J,K	J,K
1990												
1991					J,K					J,K		
1992												
1993					J,K							
1994										J,L		
1995												
1996										J,K	J,K	
1997										J,L	J,L	J,K
1998											J,K	
1999												
2000												
2001												
2002			J,K,L?									
2003												J,K
2004					J,L	J,L						J,K
2005		J?			J,L							
2006	J?											
2007	none					J,L						

Only J Pod present	Two pods present, as indicated	J, K, and L pods present	Data not available

Figure A.1-3 Monthly occurrence of the three Southern Resident killer whale pods (J, K, and L) in the inland waters of Washington and British Columbia, 1976-2005. This geographic area is defined as the region east of Race Rocks at the southern end of Vancouver Island and Port Angeles on the Olympic Peninsula. Pods were recorded as present during a month if they were sighted on at least one day (Hanson 2008).

Late summer and early fall movements of Southern Residents in the Georgia Basin have remained fairly consistent since the early 1970s, with strong site fidelity shown to the region as a whole. However, presence in inland waters in the fall has increased in recent years (NMFS 2008g). It is uncertain whether potential variability in sighting effort over time has contributed to this trend. During early autumn, Southern Residents, and J pod in particular, expand their routine movements into Puget Sound, likely to take advantage of chum and Chinook salmon runs (Osborne 1999). During late fall, winter, and early spring, the ranges and movements of the Southern Residents are less well known. Sightings through the Strait of Juan de Fuca in late fall suggest that activity shifts to the outer coasts of Vancouver Island and Washington (Krahn et al. 2002).

The Southern Residents were formerly thought to range southward along the coast to about Grays Harbor (Bigg et al. 1990) or the mouth of the Columbia River (Ford et al. 2000). However, recent sightings of members of K and L pods in Oregon (in 1999 and 2000) and California (in 2000, 2003, 2005, 2006 and 2008) have considerably extended the southern limit of their known range (NMFS 2008g). There have been 40 verified sightings or strandings of J, K or L pods along the outer coast from 1975 to present with most made from January to May. These include 16 records off Vancouver Island and the Queen Charlottes, 11 off Washington, four off Oregon, and nine off central California. Most records have occurred since 1996, but this is more likely because of increased viewing effort along the coast for this time of year. Sightings in Monterey Bay, California coincided with large runs of salmon, with feeding witnessed in 2000 (Black et al. 2001). L pod was also seen feeding on unidentified salmon off Westport, Washington, in March 2004 during the spring Chinook run in the Columbia River (M. B. Hanson, personal observation, as cited in Krahn et al. 2004).

A.1.4 Life History

Southern Resident killer whales are a long lived species, with late onset of sexual maturity (review in NMFS 2008g). Females produce a low number of surviving calves over the course of their reproductive life span (5.4 surviving calves over 25 years) (Olesiuk et al. 1990; Bain 1990). Mothers and offspring maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the Southern Resident population (Bigg et al. 1990; Baird 2000; Ford et al. 2000). Groups of related matrilines form pods. Three pods – J, K, and L, make up the Southern Resident community. Clans are composed of pods with similar vocal dialects and all three pods of the Southern Residents are part of J clan.

Southern Resident killer whales are known to consume 22 species of fish and one species of squid (Scheffer and Slipp 1948; Ford et al. 1998, 2000; Ford and Ellis 2006; Saulitis et al. 2000). A long-term study of resident killer whale diet identified salmon as their preferred prey (96 percent of prey consumed during spring, summer and fall) (Ford and Ellis 2006). Feeding records for Southern and Northern Residents show a strong preference for Chinook salmon (72 percent of identified salmonids) during late spring to fall (Ford and Ellis 2006). Chum salmon (23 percent) are also taken in significant amounts, especially in autumn. Other salmon eaten include coho (2 percent), pink (3 percent) steelhead and sockeye (*O. mykiss*, *O. nerka* < 1 percent). The non-salmonids included Pacific herring, sablefish, Pacific halibut, and quillback and yelloweye rockfish. Chinook were preferred despite the much lower abundance of Chinook

in the study area in comparison to other salmonids, probably because of the species' large size, high fat and energy content and year-round occurrence in the area. Killer whales also captured older (i.e., larger) than average Chinook (Ford and Ellis 2006).

Ongoing research continues to identify prey of Southern Residents through direct observation and scale sampling. More recently, researchers have started collecting fecal samples for analysis to address the potential biases of scale sampling. Although studies and analyses are not yet complete, preliminary results of ongoing sampling efforts are the best available information on diet composition of Southern Residents. When Southern Residents are generally concentrated in their "core summer area" (San Juan Islands) from May to September, their diet consists of approximately 86 percent Chinook salmon and 14 percent other salmon species (n=125 samples; Hanson et al. 2007, NWFSC unpubl. data). During all months combined their diet is approximately 69 percent Chinook and 31 percent other salmon species (n=160 samples). Sampling indicates an apparent shift to chum salmon in fall months when some Southern Residents are sighted inside Puget Sound (Hanson et al. 2007). Early results from genetic analysis of fecal and prey samples indicate that Southern Residents consume Fraser River origin Chinook, as well as salmon from Puget Sound, Washington and Oregon coasts, the Columbia River, and Central Valley California (Hanson et al. 2007). As further data are analyzed, they will provide information on which specific runs of salmon the whales are consuming in certain locations and seasons.

There are no fecal or prey samples or direct observations of predation events (where the prey was identified to species) when the whales are in coastal waters. Although less is known about diet preferences of Southern Residents off the Pacific Coast, it is likely that salmon are also important during late fall and winter when Southern Residents more predictably occur in coastal waters. Based on the best available information, Southern Residents may also prefer Chinook salmon when available in coastal waters. Chemical analyses also support the importance of salmon in the year-round diet of Southern Residents (Krahn et al. 2002, 2007). Krahn et al. (2002), examined the ratios of DDT (and its metabolites) to various PCB compounds in the whales, and concluded that the whales feed primarily on salmon throughout the year rather than other fish species. Krahn et al. (2007) analyzed stable isotopes from tissue samples collected in 1996 and 2004/2006. Carbon and nitrogen stable isotopes indicated that J and L pods consumed prey from similar trophic levels in 2004/2006 and showed no evidence of a large shift in the trophic level of prey consumed by L pod between 1996 and 2004/2006.

Researchers have estimated the energy requirements of killer whales and caloric values for salmon to calculate the number of fish needed per day. Salmon differ significantly in size across species and runs, and prey preference among salmon would affect annual consumption rates. Fewer salmon per day would be required from a larger preferred prey species such as Chinook salmon. NOAA Fisheries provides an estimate of the biological requirements of Southern Residents using the best available information on metabolic needs of the Southern Resident population and the caloric content of salmon (i.e., NMFS 2008h; NMFS 2008b).

A.2 Environmental Baseline

Because the entire listed entity is found in the coastal waters during some portion of the year, the status of the species in this area is the same as the range-wide status of the species, described above. The following discussion summarizes the conditions in coastal waters that are known to affect the likelihood that Southern Resident killer whales will survive and recover in the wild. The small size of the population increases the level of concern about any risks to Southern Resident killer whales (NMFS 2008g).

Natural Mortality

Seasonal mortality rates among Southern and Northern Resident whales are believed to be highest during the winter and early spring, based on the numbers of animals missing from pods returning to inland waters each spring. Olesiuk et al. (2005) identified high neonate mortality that occurred outside of the summer field research seasons. At least 12 newborn calves (9 in southern community and 3 in northern community) were seen outside the summer field season and disappeared by the next field season. Additionally, stranding rates are higher in winter and spring for all killer whale eco-types in Washington and Oregon (Norman et al. 2004). Southern Resident strandings in coastal waters include three separate events (1995 and 1996 off of Northern Vancouver Island and the Queen Charlotte Islands, and 2002 offshore of Long Beach, Washington State), and the causes of death are unknown (NMFS 2008g).

In recent years, sighting reports indicate anecdotal evidence of thin killer whales returning to inland waters in the spring. For example, in March 2006 a thin female from the Southern Resident population (L54) with a nursing calf was sighted off Westport, WA. The sighting report indicated she had lost so much blubber that her ribs were showing under the skin (Cascadia Research 2008).

Prey Availability

Salmon, particularly Chinook salmon, are the preferred prey of Southern Resident killer whales in inland waters of Washington State during spring, summer and early fall. Chemical analyses support the importance of salmon in the year round diet of Southern Residents. Based on the best available information, Southern Residents may equally prefer Chinook salmon in inland and coastal waters. This analysis therefore focuses on effects of the proposed action and RPA on Chinook abundance in coastal waters. Focusing on Chinook provides a conservative estimate of potential effects of the proposed action and RPA on Southern Residents within coastal waters. The total abundance of all salmon and other potential prey species is difficult to quantify, but is orders of magnitude larger than the total abundance of Chinook in coastal waters.

When prey abundance is low, killer whales may spend more time and energy foraging than when prey abundance is high, with the potential for fitness consequences including reduced reproductive rates and higher mortality rates. Ford and Ellis (2006) correlated coastwide reduction in Chinook abundance (Alaska, British Columbia, and Washington) with decreased survival of resident whales (Northern and Southern Residents), but changes in killer whale abundance have not been linked to local areas or changes in salmon stock groups. No recent changes in salmon populations are obviously apparent that may be responsible for the recent

decline in the Southern Resident population between 1996 and 2001 (NMFS 2008i). However, potential prey limitation is an area of ongoing research, and new information will be considered as it becomes available.

The availability of prey to Southern Resident killer whales is affected by a number of natural and human actions. Details regarding rangewide status of Chinook salmon in the Columbia River basin that are listed under the Endangered Species Act are described in Chapter 3 of this Opinion. NMFS expects the status of SR, UCR, LCR, and to some extent UWR- Chinook salmon to improve over the next ten years with implementation of the RPA described in the FCRPS Biological Opinion (NMFS 2008a). The baseline also includes Chinook ESUs that are not ESA-listed, notably the typically abundant Hanford Reach fall Chinook ESU and the Mid-Columbia spring Chinook ESU. Adult salmon are also affected by fisheries harvest in fresh and marine waters. In addition, climate effects from Pacific decadal oscillation and El Nino/Southern oscillation conditions and events cause changes in ocean productivity which can affect natural mortality of salmon, as described in more detail in Chapter 4 (4.1 General Basinwide Perspective). Predation in the ocean also contributes to natural mortality of salmon. Salmonids are prey for pelagic fishes, birds, and marine mammals.

The abundance of Chinook stocks across the coastal range of Southern Residents varies on an annual basis due to a combination of factors including ocean conditions and harvest management decisions (implementing the regulations for ocean salmon fisheries include ESA section 7 consultation, i.e., NMFS 2008b). For example, recent consultation on the Pacific Salmon Plan estimated there may be approximately 1.2 million adult Chinook salmon available in the coastal range of Southern Residents during the 2008-2009 regulatory cycle (NMFS 2008h). NOAA Fisheries found that PFMC salmon fisheries during the 2008-2009 regulatory cycle would cause a negligible reduction in prey resources with no detectible change in the ratio of prey availability to needs for Southern Residents within their coastal range (NMFS 2008h).This estimate includes estimated annual reductions in prey availability from fisheries harvest in coastal waters.

Contribution of Willamette River Chinook to ocean abundance in recent years is on the order of approximately 100,000 Chinook (NMFS 2008b), and recent returns to Willamette Falls range from approximately 20,000 to 96,000 Chinook (Kruzic 2008). Spring Chinook (hatchery and natural) returning to the Willamette River are younger than spring Chinook returns to the Willamette River prior to 1950 (Nicholas 1995). Currently, there is a higher percentage of age-4 fish, whereas historically there were more 5 year-old fish returning. Thus, UWR Chinook are less available to killer whales and smaller than historically, because older fish would stay in the ocean longer before returning to spawn and increase in size with increased age. However, a downward trend in size and age is generally applicable in many salmon populations (Quinn 2005). Size of individual salmon could affect the number of prey required by Southern Residents.

In general, the literature indicates a historical decrease in salmon age, size, or size at a given age. Hypotheses advanced to explain declining body size are density-dependent growth and selection of larger, older fish by selective fisheries. For example, Bigler et al. (1996) found a decreasing average body size in 45 of 47 salmon populations in the Northern Pacific. They also found that body size was inversely related to population abundance, and speculated that enhancement

programs during the 1980s and 1990s increased population sizes, but reduced growth rates due to competition for food in the ocean. Recently, PFMC reported an increasing trend in coho and Chinook dressed weight (i.e., measured weight after the internal organs and blood are removed) over time, which could reflect increasing body size or size selectivity in the fisheries (PFMC 2006).

Fish size is influenced by factors such as environmental conditions, selectivity in fishing effort through gear type, fishing season or regulations, and hatchery practices. The available information on size is also confounded by factors including inter-population difference, when the size was recorded, and differing data sources and sampling methods (review in Quinn 2005). As a result, a comparative measure of prey biomass across the range of U.S. west coast salmon stocks for Southern Residents is not available and, for purposes of this Opinion, NOAA Fisheries relies on abundance estimates as a proxy measure (as in past consultation, i.e., NMFS 2006i).

Based on the best available information regarding diet composition for Southern Residents killer whales (which suggests that Chinook salmon are their preferred prey), their metabolic needs, and the caloric content of salmon, NOAA Fisheries estimates that the Southern Resident population (based on 2007 population size and structure) could need approximately 221,000 Chinook on an annual basis in coastal waters of their range (NMFS 2008b). Whether the whales' metabolic needs can be equally satisfied by hatchery fish versus wild fish depends on a comparison of the ocean distribution, run timing, and size of hatchery versus wild fish.

Southern Resident killer whales consume both natural and hatchery salmon (Barre 2008). Hatchery fish may differ from natural fish; however, the best available information indicates that the ocean distribution, run timing and size of hatchery and wild salmon does not follow a general pattern, but is case-specific with differences apparent in some populations but not others (NMFS 2008b). Therefore, the best available information does not indicate general differences in size, run-timing, or ocean distribution of hatchery and wild salmon for stocks available to Southern Residents across their range.

In the case of UWR Chinook, there is no known difference in the ocean distribution of hatchery and natural fish (PSC 2008). There are no significant differences between the present run-timing of hatchery and natural UWR Chinook (Schroder et al. 2006); however, there is a slight difference in size. On average, wild UWR Chinook return slightly longer than hatchery UWR Chinook (Firman et al. 2005), which translates to approximately 12.8% difference in the weight of individual hatchery and wild fish (Kruzic 2008).

Prey Quality

Contaminants enter fresh and marine waters and sediments from numerous sources, but are typically concentrated near populated areas of high human activity and industrialization. Recent studies have documented high concentrations of PCBs, DDTs, and PBDEs in killer whales (Ross et al. 2000; Ylitalo et al. 2001; Reijnders and Aguilar 2002; Krahn et al. 2004). As top predators, when killer whales consume contaminated prey they accumulate the contaminants in their blubber. When prey is scarce, killer whales metabolize their blubber and the contaminants are mobilized (Krahn et al. 2002). Nursing females transmit large quantities of contaminants to their offspring. The mobilized contaminants can reduce the whales' resistance to disease and can affect reproduction.

Chinook salmon contain higher levels of some contaminants (i.e., PCBs) than other salmon species (O'Neill et al. 2005). Only limited information is available for contaminant levels of Chinook along the west coast (i.e., higher PCB and PBDE levels may distinguish Puget Sound-origin stocks, whereas higher DDT-signature may distinguish California origin stocks; Krahn et al. 2007). Adult Chinook that originate from the Willamette River basin may accumulate contaminants through development and growth in the freshwater and marine environment, and become a source of contaminants if consumed by Southern Residents.

Vessel Activities & Sound

Killer whales can be affected by the physical presence of vessels and by the sound the vessels generate. Several studies in the inland waters of Washington State and British Columbia have observed changes in killer whale behavior in the presence of vessels (Kruse 1991; Williams et al. 2002a, 2002b; Foote et al. 2004; Bain et al. 2006). These behavioral changes can affect the whales' foraging efficiency and the amount of energy they expend in migrating, foraging, and other activities. Sound from vessels can also interfere with communication and prey location. For a variety of reasons, vessel effects in coastal waters are likely small.

Commercial shipping, military vessels and recreational vessels occur in the coastal range of Southern Residents, but the area is vast in comparison to the numbers of vessels present. In addition, such vessels do not target whales, move at relatively slow speed and are likely detected and avoided by Southern Residents. Vessel sounds in coastal waters also likely have minor effects on killer whales. Most sound would be from large ships, tankers and tugs, and would be generate low frequency (5 to 500 Hz) (NRC 2003). While ships generate some broadband noise in the hearing range of whales, the majority of energy is below their peak hearing sensitivity.

Non-Vessel Sound

Anthropogenic (human-generated) sound in coastal waters within the range of Southern Residents is generated by sources besides vessels, including oil and gas exploration, construction activities, and military operations. Natural sounds in the marine environment include wind, waves, surf noise, precipitation, thunder, and biological noise from other marine species. The intensity and persistence of certain sounds (both natural and anthropogenic) in the vicinity of marine mammals vary by time and location and have the potential to interfere with important biological functions (e.g., hearing, echolocation, communication).

Sound from in-water construction activities could potentially occur through permits issued by the Army Corps of Engineers under section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act of 1899 and by the State of Washington under its Hydraulic Project Approval (HPA) program. Several consultations on federal projects in the coastal range of Southern Residents have been conducted and conservation measures have been included to minimize or eliminate potential effects to marine mammals. Sound, such as sonar generated by military vessels, also has the potential to disturb killer whales in coastal waters. As with vessel sounds, there are likely only minor effects on killer whales in the ocean from anthropogenic sounds because of the vastness of the area and low density of sound sources.

Oil Spills

Oil spills have occurred in the coastal range of Southern Residents in the past, and there is potential for spills in the future. Oil can be discharged into the marine environment in any number of ways, including shipping accidents, refineries and associated production facilities, and pipelines. The coastal range of Southern Residents is primarily at risk from shipping accidents involving transiting oil tankers.

Southern Residents may also be affected by long-term repeated ingestion of sub-lethal quantities of petroleum hydrocarbons, although the effects are not well understood. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion, pneumonia, liver disorders, and neurological damage (Wursig 1990; Geraci 1990). In addition, oil spills have the potential to adversely impact habitat and prey populations, and, therefore, may adversely affect Southern Residents by reducing food availability.

Scientific Research

Most of the scientific research conducted on Southern Resident killer whales occurs in inland waters of Washington State and British Columbia. In general, the primary objective of this research is population monitoring or data gathering for behavioral and ecological studies. In 2006, NOAA Fisheries issued scientific research permits to seven investigators who intend to study Southern Resident killer whales. Research activities are typically conducted between May and October in inland waters. However, some permits include authorization to conduct research in coastal waters.

In the biological opinion NOAA Fisheries prepared to assess the impact of issuing the permits, we determined that the effects of these disturbances on Southern Residents were likely to adversely affect, but not jeopardize the continued existence of, the Southern Resident killer whales (NMFS 2006h). The annual authorized takes by harassment of Southern Residents under these permits totaled 1,935 non-invasive takes (e.g., surveys and photo-identification); 70 takes from biopsying, tagging, or breath sampling; and 820 takes due to unintentional harassment, although actual anticipated takes are substantially lower. While most of the authorized takes would occur in inland waters, a small portion of this disturbance is part of the baseline in the coastal range of Southern Residents.

Activities Outside U.S. Jurisdiction

The Southern Resident killer whales are highly migratory and may transit in and out of the waters of the United States and the high seas. NOAA Fisheries does not presently have information to assess the impact on Southern Residents of scientific research or boating activities within Canadian jurisdictional waters. NOAA Fisheries included information on Canadian fisheries within the coastal range of Southern Residents using the same methods to quantify U.S. fisheries in this area (NMFS 2008j).

Summary of the Environmental Baseline

Southern Resident killer whales are exposed to a wide variety of past and present state, federal and private actions in their coastal range as well as federal projects in this area that have already undergone formal section 7 consultation, and state or private actions that are contemporaneous

with this consultation. All of the activities discussed in the above section are likely to have some level of impact on Southern Residents when they are in coastal waters of their range.

Reductions in food availability, increased exposure to pollutants, and human disturbance have all been identified as potential threats to killer whales in Washington and British Columbia (Ford and Ellis 1999, 2005; Ford et al. 2000; Baird 2001; Krahn et al. 2002, 2004; Taylor 2004; Wiles 2004). Researchers are unsure about which threats are most significant to the Southern Resident population, and none of the threats have been identified as the cause of the recent decline of the Southern Resident killer whales (Krahn et al. 2002). There is limited information on how these factors or additional unknown factors may be affecting Southern Resident killer whales when in coastal waters in winter. It is possible that two or more of these factors may act together to harm the whales. The small size of the population increases the level of concern about all of these risks (NMFS 2008g).

A.3 Effects of the Reasonable & Prudent Alternative on Southern Resident Killer Whales

The RPA includes some aspects of the Proposed Action, and is referred to as the Proposed Action and RPA. We focus our effects analysis for Southern Resident killer whales on effects of the Proposed Action and RPA anticipated to be adopted by the Action Agencies. The potential effects of the Proposed Action and RPA on Southern Resident killer whales relate to prey availability. Chapters 2 and 9 describe the federal actions in the Proposed Action and RPA, respectively: the operation and configuration of the Willamette Project, maintenance of 42 miles of revetments, and related artificial propagation programs in the Willamette Basin as described in the 2000 Biological Assessment 2007 Supplemental Biological Assessment (USACE 2000, 2007a).

Most of the direct effects of the Proposed Action and RPA occur within the freshwater system of the Willamette Basin; effects experienced by Southern Residents in the coastal area are indirect. That is, the Proposed Action and RPA may affect the abundance of killer whale prey in the ocean. Changes in prey abundance would affect the entire DPS of Southern Resident killer whales. The best available information indicates that salmon are the preferred prey of killer whales year round (Krahn et al. 2002, 2007), including in coastal waters, and that Chinook are the preferred salmon species (Ford and Ellis 2006). Prey abundance is a concern for killer whales both in the near and long term. To survive in the near term, killer whales require regular supplies of adult Chinook prey in the ocean, and to recover over the longer term, killer whales require abundant Chinook stocks coast-wide, likely including stocks from the Willamette River (Status of the Species). This analysis considers the short-term and long-term effects of the Proposed Action and RPA.

A.3.1 Short-term Effects on Southern Resident Killer Whales

The Proposed Action and RPA combined include the operation and configuration of the Willamette Project including substantive measures for fish passage, water quality, flow management, and water contracting, maintenance of 42 miles of revetments, and operation of the hatchery mitigation programs. Hatchery measures include continued funding of hatchery

programs and improvements to program management and facilities for hatcheries in the Willamette Basin. The RPA sets implementation schedules for each action over the 15 year time frame of the Opinion (Table 9.10-1). NMFS has quantified short-term effects of hatchery production and project operations on Chinook prey available to Southern Residents.

Effects of Artificial Production

The Proposed Action and RPA include continued funding for artificial propagation of Chinook salmon, which produces killer whale prey. Therefore, this analysis uses the current levels of funding and production which will continue over the short term. Action Agency (BPA, Corps, and Reclamation) funding accounts for approximately 79 percent of the Chinook smolts released in the upper Willamette basin as mitigation for loss of habitat above the Corps dams as well as ongoing operations and maintenance (Simmons 2008). In recent years, hatchery returns to Willamette Falls represented approximately 90 percent of the total Chinook run (ODFW 2008c). If approximately 90 percent of the Chinook returns to Willamette Falls are hatchery produced, and if the Proposed Action and RPA produce approximately 79 percent of all returning hatchery Chinook, then approximately 71 percent of the total annual return of Chinook above Willamette Falls can be attributed to the Proposed Action and RPA.

Effects of Project Operations for Flood Control, Hydropower, Water Supply & Maintenance of Revetments

In addition to production via hatchery mitigation programs, project operations cause mortality of adult and juvenile Chinook, which when considered alone would reduce the number of adult Chinook in the ocean and reduce prey availability. To determine whether the Chinook prey base for killer whales is adversely affected by the Proposed Action and RPA, we compare the decrease in the prey base for killer whales resulting from project-caused mortality to the increase in the prey base resulting from the hatchery programs funded by the action agencies.

The effect of the hatchery programs is to produce 71 percent of the UWR Chinook available to the killer whales. In order for decreases caused by the Willamette Project to exceed this production, the project would have to cause a greater reduction in the total number of UWR Chinook available to killer whales. For the reasons discussed below, it is unlikely that mortality from the Willamette Project results in a net reduction in the killer whale prey base. In this analysis, NMFS compares the percent of adult Chinook produced from hatchery actions to the percent reduction of <u>naturally</u> produced Chinook.

Naturally produced Chinook salmon in the upper Willamette system are perpetuated by returning adults that spawn below Project dams, or are transported above Project dams. Project operations cause high levels of mortality of spawners or their progeny both below the dams and as a result of transport. By releasing flows with elevated water temperatures during fall reservoir evacuation, operations contribute to high levels of mortality to adult Chinook before they spawn and to incubating eggs in the downstream reaches. Additionally, adult Chinook transported above the dams experience some mortality from trapping and handling, and the progeny of those that do spawn experience high mortality during outmigration through the reservoirs and past the concrete. Currently, approximately 61 percent of Chinook returning to Willamette Falls that would have naturally spawned are not contributing progeny (Kruzic 2008). A conservative assumption for relatively healthy systems is that spawner-to-spawner rates are on the order of

one-to-one. Given this assumption, project operations reduce naturally produced Chinook in subsequent years by as much as 61 percent.

The 61 percent reduction includes wild and hatchery-origin fish, many of which are produced as part of the action. To assess the effects of the action, NOAA Fisheries considers the net production of hatchery-origin fish that survive and naturally-produce as adults and the net loss of wild fish that do not survive to replace themselves. Recall that 90 percent of the Chinook returns to Willamette Falls are hatchery produced, and the remaining 10 percent are wild. Assuming that wild and hatchery fish are equally susceptible to the effects of project operations, the net gain in the abundance of fish in the next generation as a result of the action agency's hatchery production is 16 percent (0.71 hatchery production-(0.90 returning hatchery fish*0.61 mortality)), and the net loss in the abundance of fish in the next generation as a result of the mortalities of wild fish is 6 percent (0.61 mortality*0.10 returning wild fish). Although the wild fish are slightly larger than hatchery fish, the net gain in the total number of hatchery adults is almost three times the loss of wild adults.

Therefore, the hatchery production contained in the Proposed Action and RPA more than offsets losses to the killer whale prey base. As the Proposed Action and RPA are implemented, the survival and numbers of natural-origin Chinook are expected to increase, which may increase the prey base and biomass of prey for killer whales as discussed below in long-term effects.

A.3.2 Long-term Effects on Southern Resident Killer Whales

The analysis of effects of the Proposed Action and RPA on UWR Chinook salmon – prey of Southern Resident killer whales -- concludes that the species is expected to survive with an adequate potential for recovery. Additionally, the Proposed Action and RPA will not adversely modify the designated critical habitat of the ESU. These conclusions were derived by reviewing the effects of the Proposed Action and RPA, the effects of the environmental baseline, and any cumulative effects. To this end, NMFS anticipates that the Proposed Action and RPA measures will substantially improve the status of the UWR Chinook ESU (Chapters 2 and 9). Many of the RPA measures will specifically address lack of passage and degraded remaining habitat, which are the key limiting factors for natural production of UWR Chinook. Although all RPA measures will be implemented over the 15-year term of the consultation, significant improvements in the ESU status will accrue over the next 30 years.

The Proposed Action and the RPA include continued funding of hatchery programs and improvements to program management and facilities for hatcheries in the Willamette Basin. The potential harmful effects of continued artificial production on long-term fitness of salmon populations are discussed in Chapter 5, Effects of the Proposed Action (Section 5.1.5). Specifically, hatcheries can negatively affect population viability by reducing abundance, productivity, spatial distribution and/or diversity of natural-origin fish (described in McElhany et al. 2000).

As discussed further in Section 9.6, hatchery RPA actions are necessary to reduce short- and long-term risks and to increase the long-term viability of the UWR Chinook ESU. These measures include implementation of the actions described in the Hatchery and Genetic Management Plan for spring Chinook, which describes detailed management practices for each

hatchery. Additional actions include improvements of hatchery facilities basin-wide (including those associated with broodstock collection and outplanting), continued mass-marking of hatchery-produced juveniles, a new sorting facility at Leaburg Dam on the McKenzie River, and after the sorting facility is built, limiting hatchery-origin Chinook to areas downstream of Cougar Dam on the South Fork McKenzie. Levels of hatchery production could be reduced once natural production increases. For example, the existing hatchery programs are being used to reintroduce Chinook back into historical habitat to restore natural production above Project dams. Once natural returns rebuild in the areas above the dams the proportion of artificially produced salmon in the Willamette Basin would decrease. Some hatchery production will likely be continued indefinitely to mitigate for the loss of Chinook habitat inundated by reservoirs, but long term hatchery mitigation will be consistent with the management goals to conserve and recover natural fish (Section 5.1.5 and Figure 5.1-1).

As discussed previously, hatchery UWR Chinook currently weigh slightly less than wild UWR Chinook (Environmental Baseline Section). Provided actions of the Proposed Action and RPA are anticipated to increase natural production in the long term, there could be an increase in biomass available to Southern Residents as the proportion of wild UWR Chinook increases.

Over the long term, the abundance of UWR Chinook, and thus of Southern Resident killer whale prey, may be affected by climate change. The Proposed Action and measure #1 in the RPA describe a coordination mechanism that will enable the Action Agencies to synthesize, update, and modify implementation to respond to new information, including the effects of climate change on listed salmonids. This will ensure conditions needed for adequate production of listed salmonids from the Upper Willamette Basin.

A.4 Cumulative Effects

Cumulative effects are those effects of future tribal, state, local or private activities, not involving Federal activities, reasonably certain to occur within the action area (50 CFR 402.02). For the purpose of the Southern Resident killer whale analysis, this area is the coastal range of the species. Future Federal actions will be reviewed through separate section 7 consultation processes.

Future tribal, state and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives and fishing permits. Activities are primarily those conducted under state, tribal or federal government management. These actions may include changes in ocean policy and increases and decreases in the types of activities that currently occur, including changes in the types of fishing activities, resource extraction, or designation of marine protected areas, any of which could impact listed species or their habitat. Government actions are subject to political, legislative and fiscal uncertainties. These realities, added to the geographic scope, which encompasses several government entities exercising various authorities, and the changing economies of the region, make analysis of cumulative effects speculative. A Final Recovery Plan for Southern Resident Killer Whales was published January 24, 2008 (NMFS 2008k). Although state, tribal and local governments have developed plans and initiatives to benefit marine fish species, ESA listed salmon, and the listed Southern Residents, they must be applied and sustained in a comprehensive way before NOAA Fisheries can consider

them "reasonably certain to occur" in its analysis of cumulative effects. Details regarding cumulative effects for Chinook salmon in the Willamette Basin are described in Chapter 6 for the ESUs affected.

Private activities are primarily associated with commercial and sport fisheries, construction, and marine pollution. These potential factors are ongoing and expected to continue in the future, and the level of their impact is uncertain. For these reasons, it is not possible to predict beyond what is included in Chapter 6 whether future non-Federal actions will lead to an increase or decrease in prey available to Southern Resident killer whales, or have other effects on their survival and recovery.

A.5 Conclusion

The Willamette Project operations cause high levels of mortality to returning UWR Chinook and the progeny of spawners, which in turn results in fewer adult Chinook in the ocean and reduced prey availability for Southern Resident killer whales. At the same time, hatchery production contained in the proposed action and RPA increases the adult Chinook salmon available to Southern Resident killer whales as prey. Hatchery production more than offsets project mortality with the net result that killer whale prey base is not reduced, and the Southern Resident killer whales are not likely to be adversely affected by the proposed action and RPA. Longer term, the proposed action and RPA will reduce the potential negative effects of hatchery production and support the survival and recovery of listed salmonids. The long term improvement of UWR Chinook is a benefit to Southern Resident killer whales in the long term. Therefore, NOAA Fisheries concurs with the Action Agency determination that the proposed action and RPA may affect, but are not likely to adversely affect Southern Resident killer whales for purposes of an informal ESA consultation, 50 C.F.R. § 402.14(a). If additional information on Southern Resident killer whales becomes available, then this determination may be reconsidered pursuant to 50 C.F.R. § 402.16.

Appendix B
Southern DPS of North American Green Sturgeon

Table of Contents

B SOUTHERN DPS OF NORTH AMERICAN GREEN STURGEON 3
B.1 STATUS OF THE SPECIES 3
B.1.1 Listing 3
B.1.2 Life History 3
B.1.3 Status/Population Trend 4
B.1.4 Key Limiting Factors for Green Sturgeon 4
B.1.5 Harvest Effects 4
B.1.5 Other Effects in the Environmental Baseline 6
B.2 EFFECTS OF THE PROPOSED ACTION & RPA 6
B.2.1 Effects of Artificial Propagation 6
B.2.2 Effects of Project Operations for Flood Control, Hydropower, and Water Supply 6
B.2.3 Effects of Maintaining Revetments 6
B.3 CONCLUSION 7

Table of Tables

Table B.1-1 Lower Columbia River Green Sturgeon Catch, 1991-2007 5

SOUTHERN DPS OF NORTH AMERICAN GREEN STURGEON

Purpose

This Chapter provides discusses the status of the Southern DPS of North American green sturgeon (*Acipenser medirostris*) and the effects of the Proposed Action and RPA on the species. Much of this information was provided by the Action Agencies in USACE et al. (2008b) and in USACE (2008c).

B.1 Status of the Species

B.1.1 Listing

Upon completion of a status review, NOAA Fisheries determined that green sturgeon comprise two DPSs that qualify as species under ESA: 1) a northern DPS, consisting of populations in coastal systems from the Eel River, California northward, that was determined to not warrant listing; and 2) a southern DPS consisting of coastal and Central Valley populations south of the Eel River, with the only known spawning population in the Sacramento River (Adams et al. 2002). NMFS listed the southern distinct population segment (DPS) of green sturgeon as threatened under the ESA on April 7, 2006 (NMFS 2006c). Take prohibitions via section 4(d) of the ESA have not yet been promulgated, nor has critical habitat yet been designated for the southern DPS of green sturgeon, although both actions are expected to occur later in 2008.

B.1.2 Life History

Green sturgeon are the most marine-oriented of the North American sturgeon species. Juveniles of this species are able to enter estuarine waters after only one year in freshwater. During this time, they are believed to feed on benthic invertebrates, although little is known about rearing habitats and feeding requirements. Green sturgeon are known to range in nearshore marine waters from Mexico to the Bering Sea, and are commonly observed in bays and estuaries along the west coast of North America, including the Columbia River (NMFS 2008l). McLain (2006) noted that Southern DPS green sturgeon were first determined to occur in Oregon and Washington waters in the late 1950s when individuals tagged San Pablo Bay were recovered in the Columbia River estuary. The proportion of the Southern relative to Northern DPS is high (~67-82%; 121 of 155 fish sampled) (Israel and May 2007). Aggregations of adults occupy deeper water within the lower Columbia River and estuary, up to the Bonneville Dam, primarily during summer months (WDFW and ODFW 2002, Moser and Lindley 2007). Beamis and Kynard (1997) suggested that green sturgeon move into estuaries of non-natal rivers to feed.

Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States. Green sturgeon are known to enter Washington estuaries during summer (Moser and Lindley 2007). There is no evidence of spawning in the lower Columbia and little information on the type(s) of habitat occupied during the period of residence. Green sturgeon in the lower Columbia River, including those that are known to be part of the Southern DPS, are most likely feeding, but, to date, all stomachs examined (n>50) have been empty (Grimaldo and Zeug 2001). Wydoski and Whitney (1979), reported that green sturgeon in the Columbia River estuary were known to feed on

anchovies and clams. Although the DPS affiliation of these fish is unknown, it is likely that the two groups have similar feeding habitats.

B.1.3 Status/Population Trend

Quality data on current population sizes and trends for green sturgeon is non-existent. Lacking any empirical abundance information, Beamesderfer et al. (2007) recently attempted to characterize the relative size of the Sacramento-San Joaquin green sturgeon population (Southern DPS) by comparison with the Klamath River population (Northern DPS). Using harvest rate data for the Klamath River tribal fishery and assuming adults represent 10% of the population at equilibrium, they roughly estimate the Klamath population at 19,000 fish with an annual recruitment of 1,800 age-1 fish. Given the relative abundance of the two stocks in the Columbia River estuary based on genetic samples, they speculate that the abundance of the Sacramento population may equal or exceed the Klamath population estimate. Beamesderfer et al. (2007) estimate that collective abundance of the various green sturgeon populations may be larger than previously thought due to seasonal high abundances in the Columbia River, Willapa Bay, and Grays River estuaries and other coastal tributaries, historical high harvest in different areas at different times, and the assumption that a significant portion of each population remains in the ocean at any given time.

B.1.4 Key Limiting Factors for Green Sturgeon

The principal factor in the decline of the Southern DPS is the reduction of the spawning habitat to a limited section of the Sacramento River (NMFS 2006c). The potential for catastrophic events to affect such a limited spawning area increases the risk of the green sturgeon's extirpation. Insufficient freshwater flow rates in spawning areas, contaminants (e.g., pesticides), bycatch of green sturgeon in fisheries, potential poaching (e.g., for caviar), entrainment of juveniles by water projects, influence of exotic species, small population size, impassable migration barriers, and elevated water temperatures in the spawning and rearing habitat also pose threats to this species (NMFS 2006c).

B.1.5 Harvest Effects

In the past, take of green sturgeon may have occurred from direct harvest in sport and commercial fisheries and from catch and release mortality in commercial fisheries. In the more recent years, the take of green sturgeon in the Columbia River was incidental to fisheries directed at white sturgeon. The numerous management actions implemented by the states of Oregon and Washington since 1994 to control white sturgeon harvest also reduced harvest of green sturgeon, including a reduction of impacts to the listed Southern DPS. The reduced catch of green sturgeon in recent years is believed to be the result of these collective management actions by the states resulting in lower catch, and is not considered indicative of lower abundance of the stock (TAC 2008).

Incidental take of green sturgeon primarily occurs during the early-fall (August) and late-fall (September-November) seasons, concurrent with peak abundance of white sturgeon in the lower Columbia River. Sturgeon angler effort and catch in the estuary increased steadily during the 1990s and peaked in 1998 when anglers made 86,400 trips and caught 30,300 white sturgeon, or 73% of the total catch below Bonneville Dam (TAC 2008). Since 1989, all fisheries affecting

lower Columbia River white sturgeon have been managed for Optimum Sustainable Yield (OSY) to provide sustainable broodstock recruitment and ensure the overall health of the white sturgeon population. Beginning in 1996, the states formally adopted a three-year Joint State management agreement based on OSY to guide Columbia River sturgeon fisheries and management decisions. Although the majority of the tenets within the current Joint State sturgeon management agreement focus on white sturgeon, a few objectives specific to benefit green sturgeon management were also included. Beginning July 7, 2006, and in response to the ESA listing of the Southern DPS, retention of green sturgeon in the commercial fisheries was disallowed (TAC 2008). Beginning in January 2007, the states changed the regulations in the recreational fishery to also disallow retention of green sturgeon (TAC 2008). The delay in the implementation of non-retention requirements in the recreational fishery were related to the prescribed process for changing sport regulations and the need for a concurrent public education process.

Harvest of green sturgeon has declined from an average of 1,388 fish annually during 1991-2000 to 154 fish per year since 2001 due to these changes in regulations and season structure (Table B.1-1). During 1996-2006, an average of 61 green sturgeon were harvested in the recreational fishery (Table B.1-1). During 1996-2006, anglers released an average of seven green sturgeon each year (2.7 sub legal-, 3.1 legal-, and 1.3 over legal-sized) (TAC 2008).

Table B.1-1 Lower Columbia River Green Sturgeon Catch, 1991-2007 (TAC 2008).

Green Sturgeon						
Year	Sport	Commercial				
		Winter	Summer	Early Fall	Late Fall	Total
1991	22	4	--	2	3,180	3,208
1992	73	10	--	1,750	400	2,233
1993	15	1	--	--	2,220	2,236
1994	132	1	--	--	240	373
1995	21	--	--	--	390	411
1996	63	1	--	--	610	674
1997	41	2	--	1,474	138	1,655
1998	73	0	--	743	151	967
1999	93	2	--	508	279	882
2000	32	0	--	568	636	1,236
2001	50	4	--	338	--	392
2002	51	7	--	--	156	214
2003	52	1	--	11	27	91

Green Sturgeon						
Year	Sport	Commercial				
		Winter	Summer	Early Fall	Late Fall	Total
2004	29	1	--	6	51	87
2005	119	0	38	32	21	210
2006	70	16	0	--	--	86
2007						0

B.1.6 Other Effects in the Environmental Baseline

In addition to these harvest effects on green sturgeon, the general discussion of the environmental baseline in the estuary in Section 4.11, and in the further discussions in Section 5.11, also apply and inform these decisions.

B.2 Effects of the Proposed Action & RPA

B.2.1 Effects of Artificial Propagation

Green sturgeon are principally bottom (benthic) feeders and are not known to rely on salmonids as prey. Thus, artificial propagation of UWR Chinook or of summer steelhead is not likely to affect this species.

B.2.2 Effects of Project Operations for Flood Control, Hydropower, and Water Supply

- Green sturgeon only encounter the effects of the Willamette Project between the confluence of the Willamette River and the Columbia River plume, including the Columbia River estuary.

- Adults have been found in this portion of the action area only during late summer and fall. At this time, operation of the Willamette Project has a small effect on streamflow in the lower Columbia (i.e., flows are increased about 2.9 kcfs (<2%) in August and 5.4 kcfs (5.4%) in September). Such very small flow reductions are likely to have slight to negligible effects on the deeper water habitat used by green sturgeon or on the fish themselves.

- Green sturgeon are bottom (benthic) feeders and are not known to rely on salmonids as prey.

B.2.3 Effects of Maintaining Revetments

The USACE has entered into agreements to maintain about 42 miles of revetments along the mainstem Willamette River and its tributaries (USACE 2000). These structures limit natural channel migration and the formation of complex and diverse habitats, limiting salmonid productivity. Because green sturgeon are principally bottom (benthic) feeders and are not known to rely on salmonids as

prey maintaining revetments in the mainstem Willamette and its tributaries is not likely to affect this species.

B.3 Conclusion

By changing flow in the Columbia River estuary, the proposed action may affect the Southern DPS of North American green sturgeon. However, effects on the species are likely to be slight to negligible. Adults, the only life stage known to occupy the lower Columbia River, prefer deep water habitats that are generally unaffected by flow changes of this magnitude (very small). NMFS therefore concludes that proposed action and RPA may affect, but is not likely to adversely affect the Southern DPS of North American green sturgeon. If additional information on this DPS becomes available, then this determination may be reconsidered.

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Appendix C
Willamette Project Rule Curves, revised 2007

U.S. Army Corps of Engineers

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Rule Curves for All Willamette Projects received 1/15/2008, email from Mary-Karen Scullion, USACE to John K Johnson, NMFS

STORAGE (IN KAF)

	HCR	LOP	FAL	COT	DOR	FRN	CGR	BLU	GPR	FOS	DET
1-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
2-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
3-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
4-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
5-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
6-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
7-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
8-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
9-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
10-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
11-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
12-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
13-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
14-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
15-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
16-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
17-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
18-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
19-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
20-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
21-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
22-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
23-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
24-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
25-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
26-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
27-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
28-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
29-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
30-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
31-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383
1-Feb	158.693	123.973	9.621	3.139	7.094	4.078	54.210	3.970	164.177	31.317	159.009
2-Feb	162.013	129.185	11.354	3.407	7.695	5.356	56.220	5.158	168.495	31.568	163.635
3-Feb	165.333	134.396	13.088	3.674	8.297	6.633	58.230	6.346	172.813	31.819	168.261
4-Feb	168.653	139.607	14.821	3.942	8.898	7.910	60.240	7.534	177.131	32.070	172.887
5-Feb	171.973	144.819	16.554	4.210	9.500	9.187	62.250	8.722	181.449	32.321	177.513
6-Feb	175.293	150.030	18.287	4.478	10.101	10.465	64.260	9.910	185.767	32.572	182.139
7-Feb	178.613	155.242	20.021	4.745	10.703	11.742	66.270	11.098	190.085	32.823	186.765
8-Feb	181.933	160.453	21.754	5.013	11.304	13.019	68.280	12.286	194.402	33.074	191.391
9-Feb	185.253	165.664	23.487	5.281	11.906	14.297	70.290	13.474	198.720	33.325	196.017
10-Feb	188.573	170.876	25.221	5.548	12.507	15.574	72.300	14.662	203.038	33.576	200.643
11-Feb	191.893	176.087	26.954	5.816	13.109	16.851	74.310	15.850	207.356	33.827	205.269
12-Feb	195.213	181.298	28.687	6.084	13.710	18.128	76.320	17.038	211.674	34.078	209.895
13-Feb	198.533	186.510	30.421	6.351	14.312	19.406	78.330	18.226	215.992	34.329	214.521
14-Feb	201.854	191.721	32.154	6.619	14.913	20.683	80.340	19.414	220.310	34.580	219.147
15-Feb	205.174	196.932	33.887	6.887	15.515	21.960	82.350	20.602	224.628	34.831	223.772
16-Feb	208.494	202.144	35.620	7.155	16.116	23.238	84.360	21.790	228.946	35.082	228.398
17-Feb	211.814	207.355	37.354	7.422	16.718	24.515	86.370	22.978	233.264	35.333	233.024
18-Feb	215.134	212.566	39.087	7.690	17.319	25.792	88.380	24.166	237.582	35.584	237.650
19-Feb	218.454	217.778	40.820	7.958	17.921	27.069	90.390	25.354	241.900	35.835	242.276
20-Feb	221.774	222.989	42.554	8.225	18.522	28.347	92.400	26.542	246.218	36.086	246.902
21-Feb	225.094	228.201	44.287	8.493	19.124	29.624	94.410	27.730	250.536	36.337	251.528
22-Feb	228.414	233.412	46.020	8.761	19.725	30.901	96.420	28.918	254.853	36.588	256.154
23-Feb	231.734	238.623	47.754	9.028	20.327	32.179	98.430	30.106	259.171	36.839	260.780
24-Feb	235.054	243.835	49.487	9.296	20.928	33.456	100.440	31.294	263.489	37.090	265.406
25-Feb	238.374	249.046	51.220	9.564	21.530	34.733	102.450	32.482	267.807	37.341	270.032
26-Feb	241.694	254.257	52.953	9.832	22.131	36.010	104.460	33.670	272.125	37.592	274.658
27-Feb	245.014	259.469	54.687	10.099	22.733	37.288	106.470	34.858	276.443	37.843	279.284
28-Feb	248.334	264.680	56.420	10.367	23.334	38.565	108.480	36.046	280.761	38.094	283.910
1-Mar	249.690	267.191	58.154	10.635	23.935	39.842	109.614	37.234	282.579	38.345	286.215

ELEVATION (IN FEET)

	HCR	LOP	FAL	COT	DOR	FRN	CGR	BLU	GPR	FOS	DET
1-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
2-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
3-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
4-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
5-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
6-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
7-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
8-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
9-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
10-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
11-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
12-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
13-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
14-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
15-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
16-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
17-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
18-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
19-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
20-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
21-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
22-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
23-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
24-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
25-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
26-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
27-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
28-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
29-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
30-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
31-Jan	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
1-Feb	1450.1	827.5	728.0	750.0	770.5	354.1	1535.5	1180.0	924.1	613.3	1452.7
2-Feb	1452.2	829.9	731.5	750.9	771.6	355.1	1538.8	1188.4	926.1	613.6	1455.3
3-Feb	1454.2	832.2	734.7	751.7	772.8	355.9	1542.1	1196.0	928.1	613.8	1457.8
4-Feb	1456.2	834.5	737.6	752.5	773.9	356.6	1545.4	1202.8	930.1	614.1	1460.4
5-Feb	1458.2	836.8	740.4	753.3	774.9	357.2	1548.6	1209.1	932.0	614.4	1462.9
6-Feb	1460.2	839.0	743.1	754.0	776.0	357.8	1551.8	1214.9	933.9	614.7	1465.3
7-Feb	1462.2	841.1	745.8	754.7	777.0	358.3	1554.9	1220.3	935.8	614.9	1467.7
8-Feb	1464.1	843.3	748.5	755.4	778.0	358.8	1558.0	1225.3	937.7	615.2	1470.1
9-Feb	1466.0	845.3	751.2	756.0	779.0	359.3	1561.1	1230.0	939.5	615.5	1472.5
10-Feb	1467.9	847.4	753.7	756.6	780.0	359.7	1564.1	1234.6	941.3	615.8	1474.9
11-Feb	1469.8	849.4	756.2	757.2	780.9	360.1	1567.1	1238.8	943.1	616.0	1477.2
12-Feb	1471.6	851.3	758.5	757.8	781.9	360.5	1570.0	1242.9	944.9	616.3	1479.5
13-Feb	1473.4	853.3	760.8	758.4	782.8	360.9	1572.9	1246.8	946.6	616.6	1481.8
14-Feb	1475.2	855.2	763.0	758.9	783.7	361.2	1575.8	1250.5	948.3	616.8	1484.0
15-Feb	1477.0	857.0	765.1	759.5	784.5	361.6	1578.6	1254.0	950.0	617.1	1486.2
16-Feb	1478.7	858.8	767.2	760.0	785.4	361.9	1581.4	1257.3	951.7	617.4	1488.3
17-Feb	1480.4	860.6	769.3	760.5	786.2	362.2	1584.1	1260.6	953.4	617.6	1490.5
18-Feb	1482.1	862.4	771.2	761.0	787.0	362.6	1586.9	1263.6	955.0	617.9	1492.6
19-Feb	1483.8	864.2	773.1	761.5	787.8	362.9	1589.6	1266.6	956.6	618.2	1494.6
20-Feb	1485.5	865.9	775.0	762.0	788.6	363.2	1592.2	1269.4	958.2	618.4	1496.7
21-Feb	1487.2	867.6	776.7	762.5	789.4	363.5	1594.9	1272.0	959.8	618.7	1498.7
22-Feb	1488.8	869.3	778.4	762.9	790.2	363.7	1597.5	1274.6	961.4	619.0	1500.7
23-Feb	1490.4	871.0	780.1	763.4	790.9	364.0	1600.1	1277.1	962.9	619.2	1502.6
24-Feb	1492.1	872.6	781.7	763.9	791.7	364.3	1602.6	1279.5	964.4	619.5	1504.6
25-Feb	1493.7	874.3	783.3	764.3	792.4	364.5	1605.2	1281.8	965.9	619.8	1506.5
26-Feb	1495.2	875.9	784.8	764.8	793.1	364.8	1607.7	1284.1	967.4	620.0	1508.4
27-Feb	1496.8	877.5	786.4	765.2	793.8	365.1	1610.1	1286.3	968.9	620.3	1510.2
28-Feb	1498.4	879.0	788.0	765.6	794.5	365.3	1612.6	1288.4	970.4	620.5	1512.1
1-Mar	1499.0	879.8	789.5	766.1	795.2	365.6	1613.9	1290.5	971.0	620.8	1513.0

2-Mar	251.045	269.703	58.994	10.902	24.537	41.120	110.748	37.876	284.397	38.596	288.519		2-Mar	1499.6	880.6	790.3	766.5	795.8	365.8	1615.1	1291.6	971.6	621.1	1513.9
3-Mar	252.401	272.214	59.835	11.170	25.138	42.397	111.882	38.518	286.215	38.847	290.824		3-Mar	1500.2	881.3	791.0	766.9	796.5	366.0	1616.4	1292.7	972.2	621.3	1514.8
4-Mar	253.757	274.725	60.675	11.438	25.740	43.674	113.016	39.160	288.033	39.098	293.128		4-Mar	1500.9	882.0	791.7	767.3	797.2	366.2	1617.6	1293.7	972.9	621.6	1515.7
5-Mar	255.113	277.237	61.516	11.706	26.341	44.951	114.150	39.802	289.851	39.349	295.433		5-Mar	1501.5	882.8	792.4	767.7	797.8	366.5	1618.9	1294.8	973.5	621.8	1516.6
6-Mar	256.468	279.748	62.356	11.973	26.943	46.229	115.285	40.444	291.669	39.600	297.737		6-Mar	1502.1	883.5	793.2	768.1	798.4	366.7	1620.1	1295.8	974.1	622.1	1517.5
7-Mar	257.824	282.259	63.197	12.241	27.544	47.506	116.419	41.086	293.487	39.851	300.042		7-Mar	1502.7	884.3	793.9	768.5	799.0	366.9	1621.4	1296.9	974.7	622.3	1518.4
8-Mar	259.180	284.771	64.037	12.509	28.146	48.783	117.553	41.728	295.304	40.102	302.346		8-Mar	1503.4	885.0	794.6	768.9	799.7	367.1	1622.6	1297.9	975.3	622.6	1519.2
9-Mar	260.536	287.282	64.877	12.777	28.747	50.060	118.687	42.370	297.122	40.353	304.651		9-Mar	1504.0	885.7	795.2	769.3	800.3	367.3	1623.8	1298.9	975.9	622.8	1520.1
10-Mar	261.891	289.793	65.718	13.044	29.349	51.338	119.821	43.012	298.940	40.604	306.955		10-Mar	1504.6	886.4	795.9	769.7	800.9	367.5	1625.0	1299.9	976.5	623.1	1521.0
11-Mar	263.247	292.305	66.558	13.312	29.950	52.615	120.955	43.654	300.758	40.855	309.260		11-Mar	1505.2	887.2	796.6	770.1	801.5	367.7	1626.2	1300.9	977.1	623.3	1521.8
12-Mar	264.603	294.816	67.399	13.580	30.552	53.892	122.089	44.296	302.576	41.106	311.564		12-Mar	1505.8	887.9	797.2	770.5	802.0	367.9	1627.4	1301.8	977.7	623.6	1522.7
13-Mar	265.959	297.327	68.239	13.848	31.153	55.169	123.223	44.938	304.394	41.357	313.869		13-Mar	1506.4	888.6	797.9	770.8	802.6	368.1	1628.6	1302.8	978.3	623.8	1523.6
14-Mar	267.314	299.839	69.080	14.115	31.755	56.447	124.357	45.580	306.212	41.608	316.173		14-Mar	1507.0	889.3	798.5	771.2	803.2	368.3	1629.8	1303.8	978.9	624.1	1524.4
15-Mar	268.670	302.350	69.920	14.383	32.356	57.724	125.491	46.222	308.030	41.859	318.478		15-Mar	1507.6	890.0	799.2	771.6	803.8	368.5	1631.0	1304.7	979.4	624.3	1525.3
16-Mar	270.026	304.861	70.760	14.651	32.958	59.001	126.625	46.864	309.848	42.110	320.783		16-Mar	1508.2	890.7	799.8	771.9	804.3	368.7	1632.2	1305.7	980.0	624.6	1526.1
17-Mar	271.382	307.373	71.601	14.918	33.559	60.279	127.759	47.506	311.666	42.361	323.087		17-Mar	1508.8	891.4	800.4	772.3	804.9	368.9	1633.4	1306.6	980.6	624.8	1527.0
18-Mar	272.737	309.884	72.441	15.186	34.161	61.556	128.894	48.148	313.484	42.612	325.392		18-Mar	1509.4	892.1	801.1	772.6	805.4	369.0	1634.5	1307.5	981.2	625.0	1527.8
19-Mar	274.093	312.396	73.282	15.454	34.762	62.833	130.028	48.790	315.302	42.863	327.696		19-Mar	1510.0	892.8	801.7	773.0	806.0	369.2	1635.7	1308.4	981.8	625.3	1528.6
20-Mar	275.449	314.907	74.122	15.721	35.364	64.111	131.162	49.432	317.119	43.114	330.001		20-Mar	1510.6	893.5	802.3	773.3	806.5	369.4	1636.9	1309.4	982.4	625.5	1529.4
21-Mar	276.805	317.418	74.963	15.989	35.965	65.388	132.296	50.074	318.937	43.365	332.305		21-Mar	1511.2	894.2	802.9	773.7	807.1	369.6	1638.0	1310.3	983.0	625.8	1530.3
22-Mar	278.160	319.930	75.803	16.257	36.567	66.665	133.430	50.716	320.755	43.616	334.610		22-Mar	1511.8	894.9	803.5	774.0	807.6	369.7	1639.2	1311.2	983.5	626.0	1531.1
23-Mar	279.516	322.441	76.644	16.525	37.168	67.943	134.564	51.358	322.573	43.867	336.914		23-Mar	1512.4	895.6	804.1	774.3	808.1	369.9	1640.3	1312.1	984.1	626.3	1531.9
24-Mar	280.872	324.952	77.484	16.792	37.770	69.220	135.698	52.000	324.391	44.118	339.219		24-Mar	1513.0	896.3	804.7	774.7	808.6	370.0	1641.5	1313.0	984.7	626.5	1532.7
25-Mar	282.228	327.464	78.324	17.060	38.371	70.497	136.832	52.642	326.209	44.369	341.523		25-Mar	1513.6	896.9	805.3	775.0	809.1	370.2	1642.6	1313.8	985.3	626.7	1533.5
26-Mar	283.583	329.975	79.165	17.328	38.973	71.774	137.966	53.284	328.027	44.620	343.828		26-Mar	1514.2	897.6	805.9	775.3	809.7	370.4	1643.8	1314.7	985.8	627.0	1534.3
27-Mar	284.939	332.487	80.005	17.595	39.574	73.052	139.100	53.926	329.845	44.871	346.132		27-Mar	1514.8	898.3	806.5	775.6	810.2	370.5	1644.9	1315.6	986.4	627.2	1535.2
28-Mar	286.295	334.998	80.846	17.863	40.175	74.329	140.234	54.568	331.662	45.122	348.437		28-Mar	1515.3	899.0	807.1	775.9	810.7	370.7	1646.0	1316.5	987.0	627.4	1536.0
29-Mar	287.651	337.509	81.686	18.131	40.777	75.606	141.368	55.210	333.480	45.373	350.741		29-Mar	1515.9	899.6	807.7	776.3	811.2	370.9	1647.1	1317.3	987.5	627.7	1536.7
30-Mar	289.006	340.021	82.527	18.398	41.378	76.884	142.503	55.852	335.298	45.624	353.046		30-Mar	1516.5	900.3	808.2	776.6	811.7	371.0	1648.2	1318.2	988.1	627.9	1537.5
31-Mar	290.362	342.532	83.367	18.666	41.980	78.161	143.637	56.494	337.116	45.875	355.350		31-Mar	1517.1	901.0	808.8	776.9	812.1	371.2	1649.3	1319.0	988.7	628.2	1538.3
1-Apr	291.718	345.043	84.207	18.934	42.581	79.438	144.771	57.136	338.934	44.888	357.655		1-Apr	1517.7	901.6	809.4	777.2	812.6	371.3	1650.4	1319.9	989.2	627.2	1539.1
2-Apr	293.073	347.555	85.048	19.201	43.183	80.716	145.905	57.778	340.752	43.900	359.959		2-Apr	1518.2	902.3	810.0	777.5	813.1	371.5	1651.5	1320.7	989.8	626.3	1539.9
3-Apr	294.429	350.066	85.888	19.469	43.784	81.993	147.039	58.420	342.570	42.913	362.264		3-Apr	1518.8	902.9	810.5	777.8	813.6	371.7	1652.6	1321.5	990.3	625.3	1540.7
4-Apr	295.785	352.578	86.729	19.737	44.386	83.270	148.173	59.062	344.388	41.926	364.568		4-Apr	1519.4	903.6	811.1	778.1	814.1	371.8	1653.7	1322.4	990.9	624.4	1541.5
5-Apr	297.141	355.089	87.569	20.005	44.987	84.547	149.307	59.704	346.206	40.938	366.873		5-Apr	1520.0	904.3	811.6	778.4	814.5	372.0	1654.8	1323.2	991.5	623.4	1542.2
6-Apr	298.496	357.600	88.410	20.272	45.589	85.825	150.441	60.346	348.024	39.951	369.177		6-Apr	1520.5	904.9	812.2	778.7	815.0	372.1	1655.9	1324.0	992.0	622.5	1543.0
7-Apr	299.852	360.112	89.250	20.540	46.190	87.102	151.575	60.988	349.842	38.964	371.482		7-Apr	1521.1	905.6	812.7	779.0	815.4	372.3	1657.0	1324.8	992.6	621.5	1543.8
8-Apr	301.208	362.623	90.091	20.808	46.792	88.379	152.709	61.630	351.659	37.977	373.786		8-Apr	1521.7	906.2	813.3	779.3	815.9	372.4	1658.0	1325.6	993.1	620.6	1544.5
9-Apr	302.564	365.135	90.931	21.076	47.393	89.656	153.843	62.272	353.477	36.989	376.091		9-Apr	1522.2	906.9	813.8	779.6	816.3	372.6	1659.1	1326.4	993.7	619.7	1545.3
10-Apr	303.919	367.646	91.772	21.343	47.995	90.934	154.977	62.914	355.295	36.002	378.395		10-Apr	1522.8	907.5	814.4	779.9	816.8	372.7	1660.2	1327.2	994.2	618.7	1546.0
11-Apr	305.275	370.157	92.612	21.611	48.596	92.211	156.112	63.556	357.113	35.015	380.700		11-Apr	1523.4	908.1	814.9	780.2	817.2	372.9	1661.2	1328.0	994.8	617.8	1546.8
12-Apr	306.631	372.669	93.453	21.879	49.198	93.488	157.246	64.198	358.931	34.027	383.004		12-Apr	1523.9	908.8	815.4	780.4	817.7	373.1	1662.3	1328.8	995.3	616.8	1547.5
13-Apr	307.987	375.180	94.293	22.147	49.799	94.765	158.380	64.840	360.749	33.040	385.309		13-Apr	1524.5	909.4	816.0	780.7	818.1	373.2	1663.3	1329.6	995.9	615.9	1548.2
14-Apr	309.342	377.692	95.134	22.414	50.401	96.043	159.514	65.482	362.567	32.053	387.613		14-Apr	1525.0	910.1	816.5	781.0	818.5	373.4	1664.4	1330.4	996.4	614.9	1549.0
15-Apr	310.698	380.203	95.974	22.682	51.002	97.320	160.648	66.124	364.385	31.065	389.918		15-Apr	1525.6	910.7	817.0	781.3	819.0	373.5	1665.4	1331.1	996.9	614.0	1549.7
16-Apr	312.054	382.714	96.814	22.950	51.604	97.320	161.782	66.766	366.203	31.066	392.223		16-Apr	1526.2	911.3	817.6	781.6	819.4	373.5	1666.4	1331.9	997.5	614.0	1550.4
17-Apr	313.409	385.226	97.655	23.217	52.205	97.320	162.916	67.408	368.021	31.066	394.527		17-Apr	1526.7	912.0	818.1	781.8	819.8	373.5	1667.5	1332.7	998.0	614.0	1551.1
18-Apr	314.765	387.737	98.495	23.485	52.807	97.320	164.050	68.050	369.839	31.066	396.832		18-Apr	1527.3	912.6	818.6	782.1	820.2	373.5	1668.5	1333.4	998.6	614.0	1551.8
19-Apr	316.121	390.248	99.336	23.753	53.408	97.320	165.184	68.692	371.657	31.066	399.136		19-Apr	1527.8	913.2	819.1	782.4	820.6	373.5	1669.5	1334.2	999.1	614.0	1552.6
20-Apr	317.477	392.760	100.176	24.020	54.010	97.320	166.318	69.334	373.475	31.066	401.441		20-Apr	1528.3	913.8	819.6	782.7	821.1	373.5	1670.5	1335.0	999.6	614.0	1553.3
21-Apr	318.832	395.271	101.017	24.288	54.611	97.320	167.452	69.976	375.293	31.066	403.745		21-Apr	1528.9	914.5	820.1	782.9	821.5	373.5	1671.5	1335.7	1000.2	614.0	1554.0
22-Apr	320.188	397.782	101.857	24.556	55.213	97.320	168.586	70.618	377.111	31.066	406.050		22-Apr	1529.4	915.1	820.6	783.2	821.9	373.5	1672.5	1336.5	1000.7	614.0	1554.7
23-Apr	321.544	400.294	102.698	24.823	55.814	97.320	169.721	71.260	378.928	31.066	408.354		23-Apr	1530.0	915.7	821.2	783.5	822.3	373.5	1673.6	1337.2	1001.2	614.0	1555.4
24-Apr	322.900	402.805	103.538	25.091	56.415	97.320	170.855	71.902	380.746	31.066	410.659		24-Apr	1530.5	916.3	821.7	783.7	822.7	373.5	1674.6	1337.9	1001.7	614.0	1556.1
25-Apr	324.255	405.316	104.379	25.359	57.017	97.320	171.989	72.544	382.564	31.066	412.963		25-Apr	1531.1	917.0	822.2	784.0	823.1	373.5	1675.5	1338.7	1002.3	614.0	1556.8
26-Apr	325.611	407.828	105.219	25.626	57.618	97.320	173.123	73.186	384.382	31.066	415.268		26-Apr	1531.6	917.6	822.7	784.3	823.5	373.5	1676.5	1339.4	1002.8	614.0	1557.4
27-Apr	326.967	410.339	106.060	25.894	58.220	97.320	174.257	73.828	386.200	31.066	417.572		27-Apr	1532.1	918.2	823.2	784.5	823.8	373.5	1677.5	1340.1	1003.3	614.0	1558.1
28-Apr	328.323	412.850	106.900	26.162	58.821	97.320	175.391	74.470	388.018	31.066	419.877		28-Apr	1532.7	918.8	823.7	784.8	824.2	373.5	1678.5	1340.9	1003.8	614.0	1558.8
29-Apr	329.678	415.362	107.741	26.429	59.423	97.320	176.525	75.112	389.836	31.066	422.181		29-Apr	1533.2	919.4	824.2	785.1	824.6	373.5	1679.5	1341.6	1004.4	614.0	1559.5
30-Apr	331.034	417.873	108.581	26.697	60.024	97.320	177.659	75.754	391.654	31.066	424.486		30-Apr	1533.7	920.0	824.7	785.3	825.0	373.5	1680.5	1342.3	1004.9	614.0	1560.2
1-May	332.390	420.384	109.421	26.965	60.626	97.320	178.793	76.396	393.472	31.066	426.791		1-May	1534.3	920.6	825.1	785.6	825.4	373.5	1681.4	1343.0	1005.4	614.0	1560.8
2-May	333.745	422.896	110.262	27.232	61.227	97.320	179.927	77.039	395.290	31.066	429.095		2-May	1534.8	921.2	825.6	785.8	825.7	373.5	1682.4	1343.7	1005.9	614.0	1561.5
3-May	335.101	425.407	111.102	27.500	61.829	97.320	181.061	77.681	397.108	31.066	431.400		3-May	1535.3	921.8	826.1	786.1	826.1	373.5	1683.4	1344.4	1006.4	614.0	1562.2
4-May	336.457	427.919	111.943	27.768	62.430	97.320	182.195	78.323	398.926	31.066	433.704		4-May	1535.8	922.4	826.6	786.3	826.5	373.5	1684.3	1345.1	1007.0	614.0	1562.8

5-May	337.813	430.430	112.783	28.036	63.032	97.320	183.330	78.966	400.744	31.066	436.009		5-May	1536.4	923.0	827.1	786.6	826.8	373.5	1685.3	1345.8	1007.5	614.0	1563.5
6-May	339.168	432.941	113.624	28.303	63.633	97.320	184.464	79.608	402.561	31.066	436.009		6-May	1536.9	923.6	827.6	786.8	827.2	373.5	1686.2	1346.5	1008.0	614.0	1563.5
7-May	340.524	435.453	114.464	28.571	64.235	97.320	185.598	80.250	404.379	31.066	436.009		7-May	1537.4	924.2	828.1	787.1	827.5	373.5	1687.2	1347.2	1008.5	614.0	1563.5
8-May	341.880	437.964	115.305	28.839	64.836	97.320	186.732	80.892	406.197	31.066	436.009		8-May	1537.9	924.8	828.6	787.3	827.9	373.5	1688.1	1347.9	1009.0	614.0	1563.5
9-May	343.235	440.476	116.145	29.107	65.438	97.320	187.866	81.535	408.015	31.066	436.009		9-May	1538.4	925.4	829.0	787.6	828.3	373.5	1689.1	1348.6	1009.5	614.0	1563.5
10-May	344.591	442.987	116.986	29.374	66.039	97.320	189.000	82.177	409.833	31.066	436.009		10-May	1539.0	926.0	829.5	787.8	828.6	373.5	1690.0	1349.3	1010.0	614.0	1563.5
11-May	345.947	442.987	117.826	29.642	66.641	97.320	189.000	82.820	409.833	31.066	436.009		11-May	1539.5	926.0	830.0	788.1	829.0	373.5	1690.0	1350.0	1010.0	614.0	1563.5
12-May	347.303	442.987	117.826	29.910	67.242	97.320	189.000	82.820	409.833	31.066	436.009		12-May	1540.0	926.0	830.0	788.3	829.3	373.5	1690.0	1350.0	1010.0	614.0	1563.5
13-May	348.658	442.987	117.826	30.178	67.844	97.320	189.000	82.820	409.833	31.066	436.009		13-May	1540.5	926.0	830.0	788.6	829.6	373.5	1690.0	1350.0	1010.0	614.0	1563.5
14-May	350.014	442.987	117.826	30.445	68.445	97.320	189.000	82.820	409.833	31.066	436.009		14-May	1541.0	926.0	830.0	788.8	830.0	373.5	1690.0	1350.0	1010.0	614.0	1563.5
15-May	350.014	442.987	117.826	30.713	69.047	97.320	189.000	82.820	409.833	31.066	436.009		15-May	1541.0	926.0	830.0	789.0	830.3	373.5	1690.0	1350.0	1010.0	614.0	1563.5
16-May	350.014	442.987	117.826	30.981	69.648	97.320	189.000	82.820	409.833	31.066	436.009		16-May	1541.0	926.0	830.0	789.3	830.7	373.5	1690.0	1350.0	1010.0	614.0	1563.5
17-May	350.014	442.987	117.826	31.249	70.250	97.320	189.000	82.820	409.833	31.066	436.009		17-May	1541.0	926.0	830.0	789.5	831.0	373.5	1690.0	1350.0	1010.0	614.0	1563.5
18-May	350.014	442.987	117.826	31.516	70.851	97.320	189.000	82.820	409.833	31.066	436.009		18-May	1541.0	926.0	830.0	789.8	831.3	373.5	1690.0	1350.0	1010.0	618.6	1563.5
19-May	350.014	442.987	117.826	31.784	71.453	97.320	189.000	82.820	409.833	31.066	436.009		19-May	1541.0	926.0	830.0	790.0	831.7	373.5	1690.0	1350.0	1010.0	623.2	1563.5
20-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	31.066	436.009		20-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	627.8	1563.5
21-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	31.066	436.009		21-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	632.4	1563.5
22-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	31.066	436.009		22-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
23-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	31.066	436.009		23-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
24-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	43.470	436.009		24-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
25-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		25-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
26-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		26-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
27-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		27-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
28-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		28-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
29-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		29-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
30-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		30-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
31-May	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		31-May	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
1-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		1-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
2-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		2-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
3-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		3-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
4-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		4-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
5-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		5-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
6-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		6-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
7-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		7-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
8-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		8-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
9-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		9-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
10-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		10-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
11-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		11-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
12-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		12-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
13-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		13-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
14-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		14-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
15-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		15-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
16-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		16-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
17-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		17-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
18-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		18-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
19-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		19-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
20-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		20-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
21-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		21-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
22-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		22-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
23-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		23-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
24-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		24-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
25-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		25-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
26-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		26-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
27-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		27-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
28-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		28-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
29-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		29-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
30-Jun	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		30-Jun	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
1-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		1-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
2-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		2-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
3-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		3-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
4-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		4-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
5-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		5-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
6-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		6-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
7-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		7-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5

8-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		8-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
9-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		9-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
10-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		10-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
11-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		11-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
12-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		12-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
13-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		13-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
14-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		14-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
15-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		15-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
16-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		16-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
17-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		17-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
18-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		18-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
19-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		19-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
20-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		20-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
21-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		21-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
22-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		22-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
23-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		23-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
24-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		24-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
25-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		25-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
26-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		26-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
27-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		27-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
28-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		28-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
29-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		29-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
30-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		30-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
31-Jul	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		31-Jul	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
1-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		1-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
2-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		2-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
3-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		3-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
4-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		4-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
5-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		5-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
6-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		6-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
7-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		7-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
8-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		8-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
9-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		9-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
10-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		10-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
11-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		11-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
12-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		12-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
13-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		13-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
14-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		14-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
15-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		15-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
16-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		16-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
17-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		17-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
18-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		18-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
19-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		19-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
20-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		20-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
21-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		21-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
22-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		22-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
23-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		23-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
24-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		24-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
25-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		25-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
26-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		26-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
27-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		27-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
28-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		28-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
29-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		29-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
30-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		30-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
31-Aug	350.014	442.987	117.826	31.784	72.054	97.320	189.000	82.820	409.833	55.873	436.009		31-Aug	1541.0	926.0	830.0	790.0	832.0	373.5	1690.0	1350.0	1010.0	637.0	1563.5
1-Sep	348.177	439.716	117.826	31.784	72.054	97.320	187.539	82.820	407.465	55.873	433.159		1-Sep	1540.3	925.2	830.0	790.0	832.0	373.5	1688.8	1350.0	1009.3	637.0	1562.7
2-Sep	346.340	436.445	116.402	31.314	70.989	97.320	186.079	81.782	405.097	55.873	430.309		2-Sep	1539.6	924.5	829.2	789.6	831.4	373.5	1687.6	1348.9	1008.7	637.0	1561.8
3-Sep	344.502	433.173	114.978	30.845	69.924	97.320	184.618	80.744	402.729	55.873	427.458		3-Sep	1538.9	923.7	828.4	789.2	830.8	373.5	1686.3	1347.8	1008.0	637.0	1561.0
4-Sep	342.665	429.902	113.555	30.375	68.859	97.320	183.158	79.706	400.361	55.873	424.608		4-Sep	1538.2	922.9	827.6	788.7	830.2	373.5	1685.1	1346.7	1007.4	637.0	1560.2
5-Sep	340.827	426.630	112.131	29.906	67.794	97.320	181.670	78.668	397.993	55.873	421.758		5-Sep	1537.5	922.1	826.7	788.3	829.6	373.5	1683.8	1345.5	1006.7	637.0	1559.4
6-Sep	338.990	423.359	110.707	29.436	66.729	97.320	180.237	77.630	395.625	55.873	418.907		6-Sep	1536.8	921.3	825.9	787.9	829.0	373.5	1682.6	1344.4	1006.0	637.0	1558.5
7-Sep	337.153	420.088	109.283	28.966	65.664	97.320	178.776	76.592	393.257	55.873	416.057		7-Sep	1536.1	920.5	825.1	787.5	828.4	373.5	1681.3	1343.2	1005.3	637.0	1557.7
8-Sep	335.315	416.816	107.860	28.497	64.599	97.320	177.316	75.554	390.889	55.873	413.207		8-Sep	1535.4	919.8	824.2	787.0	827.8	373.5	1680.1	1342.1	1004.7	637.0	1556.8
9-Sep	333.478	413.545	106.436	28.027	63.535	97.320	175.855	74.516	388.520	55.873	410.356		9-Sep	1534.7	919.0	823.4	786.6	827.1	373.5	1678.8	1340.9	1004.0	637.0	1556.0

10-Sep	331.641	410.274	105.012	27.558	62.470	97.320	174.395	73.478	386.152	55.873	407.506		10-Sep	1534.0	918.2	822.5	786.1	826.5	373.5	1677.5	1339.7	1003.3	637.0	1555.1
11-Sep	329.803	407.002	103.588	27.088	61.405	97.320	172.934	72.440	383.784	55.873	404.656		11-Sep	1533.2	917.4	821.7	785.7	825.8	373.5	1676.2	1338.6	1002.6	637.0	1554.3
12-Sep	327.966	403.731	102.165	26.619	60.340	97.320	171.474	71.402	381.416	55.873	401.805		12-Sep	1532.5	916.6	820.8	785.2	825.2	373.5	1674.9	1337.4	1001.9	637.0	1553.4
13-Sep	326.128	400.459	100.741	26.149	59.275	97.320	170.013	70.364	379.048	55.873	398.955		13-Sep	1531.8	915.8	820.0	784.8	824.5	373.5	1673.6	1336.2	1001.3	637.0	1552.5
14-Sep	324.291	397.188	99.317	25.679	58.210	97.320	168.553	69.326	376.680	55.873	396.105		14-Sep	1531.1	914.9	819.1	784.3	823.8	373.5	1672.3	1335.0	1000.6	637.0	1551.6
15-Sep	322.454	393.917	97.893	25.210	57.145	97.320	167.082	68.288	374.312	55.873	393.254		15-Sep	1530.3	914.1	818.2	783.9	823.1	373.5	1671.0	1333.7	999.9	637.0	1550.7
16-Sep	320.616	390.645	96.470	24.740	56.080	97.320	165.632	67.250	371.944	55.873	390.404		16-Sep	1529.6	913.3	817.3	783.4	822.4	373.5	1669.7	1332.5	999.2	637.0	1549.8
17-Sep	318.779	387.374	95.046	24.271	55.015	97.320	164.171	66.212	369.576	55.873	387.553		17-Sep	1528.9	912.5	816.5	782.9	821.7	373.5	1668.3	1331.3	998.5	637.0	1548.9
18-Sep	316.942	384.103	93.622	23.801	53.950	97.320	162.711	65.174	367.208	55.873	384.703		18-Sep	1528.1	911.7	815.6	782.4	821.0	373.5	1667.0	1330.0	997.8	637.0	1548.0
19-Sep	315.104	380.831	92.198	23.331	52.885	97.320	161.250	64.136	364.840	55.873	381.853		19-Sep	1527.4	910.9	814.6	782.0	820.3	373.5	1665.7	1328.7	997.1	637.0	1547.1
20-Sep	313.267	377.560	90.775	22.862	51.820	97.320	159.789	63.098	362.472	55.873	379.002		20-Sep	1526.6	910.0	813.7	781.5	819.5	373.5	1664.3	1327.4	996.4	637.0	1546.2
21-Sep	311.429	374.288	89.351	22.392	50.755	95.632	158.329	62.060	360.104	55.873	376.152		21-Sep	1525.9	909.2	812.8	781.0	818.8	373.3	1662.9	1326.2	995.7	637.0	1545.3
22-Sep	309.592	371.017	87.927	21.923	49.690	93.944	156.868	61.022	357.736	55.873	373.302		22-Sep	1525.1	908.4	811.9	780.5	818.0	373.1	1661.6	1324.9	994.9	637.0	1544.4
23-Sep	307.755	367.746	86.503	21.453	48.626	92.257	155.408	59.984	355.367	55.873	370.451		23-Sep	1524.4	907.5	810.9	780.0	817.2	372.9	1660.2	1323.5	994.2	637.0	1543.4
24-Sep	305.917	364.474	85.080	20.984	47.561	90.569	153.947	58.946	352.999	55.873	367.601		24-Sep	1523.6	906.7	810.0	779.5	816.5	372.7	1658.8	1322.2	993.5	637.0	1542.5
25-Sep	304.080	361.203	83.656	20.514	46.496	88.881	152.487	57.908	350.631	55.873	364.751		25-Sep	1522.9	905.8	809.0	779.0	815.7	372.5	1657.4	1320.9	992.8	637.0	1541.5
26-Sep	302.243	357.932	82.232	20.044	45.431	87.193	151.026	56.870	348.263	55.873	361.900		26-Sep	1522.1	905.0	808.0	778.4	814.9	372.3	1656.0	1319.5	992.1	637.0	1540.6
27-Sep	300.405	354.660	80.808	19.575	44.366	85.505	149.566	55.832	345.895	55.873	359.050		27-Sep	1521.3	904.1	807.1	777.9	814.0	372.1	1654.6	1318.1	991.4	637.0	1539.6
28-Sep	298.568	351.389	79.385	19.105	43.301	83.818	148.105	54.794	343.527	55.873	356.200		28-Sep	1520.6	903.3	806.1	777.4	813.2	371.9	1653.2	1316.8	990.6	637.0	1538.6
29-Sep	296.730	348.117	77.961	18.636	42.236	82.130	146.648	53.756	341.159	55.873	353.349		29-Sep	1519.8	902.4	805.1	776.9	812.3	371.7	1651.8	1315.4	989.9	637.0	1537.6
30-Sep	294.893	344.846	76.537	18.166	41.171	80.442	145.184	52.718	338.791	55.873	350.499		30-Sep	1519.0	901.6	804.0	776.3	811.5	371.5	1650.4	1313.9	989.2	637.0	1536.7
1-Oct	293.056	341.575	75.113	17.696	40.106	78.754	143.724	51.681	336.423	55.334	347.649		1-Oct	1518.2	900.7	803.0	775.7	810.6	371.3	1648.9	1312.5	988.4	636.5	1535.7
2-Oct	291.218	338.303	73.690	17.227	39.041	77.066	142.263	50.643	334.055	54.794	344.798		2-Oct	1517.5	899.8	802.0	775.2	809.7	371.0	1647.5	1311.1	987.7	636.1	1534.7
3-Oct	289.381	335.032	72.266	16.757	37.976	75.378	140.803	49.606	331.687	54.255	341.948		3-Oct	1516.7	899.0	800.9	774.6	808.8	370.8	1646.0	1309.6	987.0	635.6	1533.7
4-Oct	287.543	331.760	70.842	16.288	36.912	73.691	139.342	48.568	329.318	53.716	339.098		4-Oct	1515.9	898.1	799.9	774.0	807.9	370.6	1644.6	1308.1	986.2	635.2	1532.7
5-Oct	285.706	328.489	69.418	15.818	35.847	72.003	137.882	47.531	326.950	53.177	336.247		5-Oct	1515.1	897.2	798.8	773.4	806.9	370.4	1643.1	1306.6	985.5	634.7	1531.7
6-Oct	283.869	325.218	67.995	15.348	34.782	70.315	136.421	46.493	324.582	52.637	333.397		6-Oct	1514.3	896.3	797.7	772.8	806.0	370.2	1641.6	1305.1	984.7	634.2	1530.7
7-Oct	282.031	321.946	66.571	14.879	33.717	68.627	134.961	45.456	322.214	52.098	330.547		7-Oct	1513.5	895.4	796.6	772.2	805.0	370.0	1640.1	1303.6	984.0	633.8	1529.6
8-Oct	280.194	318.675	65.147	14.409	32.652	66.939	133.500	44.418	319.846	51.559	327.696		8-Oct	1512.7	894.5	795.5	771.6	804.0	369.8	1638.6	1302.0	983.2	633.3	1528.6
9-Oct	278.356	315.403	63.723	13.940	31.587	65.251	132.039	43.381	317.478	51.020	324.846		9-Oct	1511.9	893.6	794.3	771.0	803.0	369.6	1637.1	1300.4	982.5	632.8	1527.6
10-Oct	276.519	312.132	62.300	13.470	30.522	63.563	130.579	42.343	315.110	50.480	321.996		10-Oct	1511.1	892.7	793.1	770.3	802.0	369.3	1635.6	1298.8	981.7	632.4	1526.6
11-Oct	274.682	308.861	60.876	13.000	29.457	61.875	129.118	41.306	312.742	49.941	319.145		11-Oct	1510.3	891.8	791.9	769.6	801.0	369.1	1634.1	1297.2	981.0	631.9	1525.5
12-Oct	272.844	305.589	59.452	12.531	28.393	60.188	127.658	40.268	310.373	49.402	316.295		12-Oct	1509.5	890.9	790.7	769.0	799.9	368.8	1632.5	1295.5	980.2	631.4	1524.5
13-Oct	271.007	302.318	58.028	12.061	27.328	58.500	126.197	39.231	308.005	48.863	313.445		13-Oct	1508.7	890.0	789.4	768.3	798.8	368.6	1631.0	1293.8	979.4	630.9	1523.4
14-Oct	269.169	299.046	56.605	11.592	26.263	56.812	124.737	38.193	305.637	48.323	310.594		14-Oct	1507.8	889.1	788.1	767.6	797.7	368.4	1629.4	1292.1	978.7	630.4	1522.3
15-Oct	267.332	295.775	55.181	11.122	25.198	55.124	123.276	37.156	303.269	47.784	307.744		15-Oct	1507.0	888.1	786.9	766.8	796.6	368.1	1627.9	1290.3	977.9	629.9	1521.3
16-Oct	265.495	292.504	53.757	10.652	24.133	53.436	121.816	36.119	300.901	47.245	304.894		16-Oct	1506.2	887.2	785.6	766.1	795.4	367.8	1626.3	1288.5	977.1	629.4	1520.2
17-Oct	263.657	289.232	52.334	10.183	23.068	51.748	120.355	35.082	298.533	46.705	302.043		17-Oct	1505.4	886.3	784.3	765.3	794.2	367.6	1624.7	1286.7	976.3	628.9	1519.1
18-Oct	261.820	285.961	50.910	9.713	22.003	50.061	118.895	34.045	296.165	46.166	299.193		18-Oct	1504.5	885.3	783.0	764.6	792.9	367.3	1623.2	1284.8	975.6	628.4	1518.0
19-Oct	259.983	282.690	49.486	9.244	20.938	48.373	117.434	33.008	293.797	45.627	296.343		19-Oct	1503.7	884.4	781.7	763.8	791.7	367.0	1621.6	1282.8	974.8	627.9	1516.9
20-Oct	258.145	279.418	48.062	8.774	19.873	46.685	115.974	31.971	291.429	45.087	293.492		20-Oct	1502.9	883.4	780.4	763.0	790.4	366.8	1620.0	1280.8	974.0	627.4	1515.8
21-Oct	256.308	276.147	46.639	8.305	18.808	44.997	114.513	30.934	289.061	44.548	290.642		21-Oct	1502.0	882.5	779.0	762.1	789.0	366.5	1618.3	1278.8	973.2	626.9	1514.7
22-Oct	254.470	272.875	45.215	7.835	17.743	43.309	113.053	29.897	286.693	44.009	287.791		22-Oct	1501.2	881.5	777.6	761.3	787.6	366.2	1616.7	1276.7	972.4	626.4	1513.6
23-Oct	252.633	269.604	43.791	7.366	16.679	41.622	111.592	28.860	284.325	43.470	284.941		23-Oct	1500.4	880.5	776.2	760.4	786.2	365.9	1615.1	1274.5	971.6	625.9	1512.5
24-Oct	250.796	266.333	42.367	6.896	15.614	39.934	110.132	27.823	281.956	42.930	282.091		24-Oct	1499.5	879.5	774.8	759.5	784.7	365.6	1613.4	1272.2	970.8	625.4	1511.4
25-Oct	248.958	263.061	40.944	6.426	14.549	38.246	108.671	26.786	279.588	42.391	279.240		25-Oct	1498.7	878.6	773.3	758.5	783.1	365.3	1611.8	1269.9	970.0	624.8	1510.2
26-Oct	247.121	259.790	39.520	5.957	13.484	36.558	107.211	25.749	277.220	41.852	276.390		26-Oct	1497.8	877.6	771.7	757.6	781.5	364.9	1610.1	1267.5	969.2	624.3	1509.1
27-Oct	245.284	256.519	38.096	5.487	12.419	34.870	105.750	24.712	274.852	41.312	273.540		27-Oct	1496.9	876.6	770.1	756.5	779.8	364.6	1608.4	1265.0	968.4	623.8	1507.9
28-Oct	243.446	253.247	36.672	5.018	11.354	33.182	104.289	23.675	272.484	40.773	270.689		28-Oct	1496.1	875.6	768.5	755.4	778.1	364.2	1606.7	1262.4	967.6	623.3	1506.7
29-Oct	241.609	249.976	35.249	4.548	10.289	31.495	102.829	22.638	270.116	40.234	267.839		29-Oct	1495.2	874.6	766.8	754.2	776.3	363.9	1605.0	1259.6	966.8	622.7	1505.6
30-Oct	239.771	246.704	33.825	4.079	9.224	29.807	101.368	21.601	267.748	39.694	264.988		30-Oct	1494.3	873.5	765.1	752.9	774.4	363.5	1603.3	1256.8	965.9	622.2	1504.4
31-Oct	237.934	243.433	32.401	3.609	8.159	28.119	99.908	20.564	265.380	39.155	262.138		31-Oct	1493.4	872.5	763.3	751.5	772.5	363.1	1601.6	1253.9	965.1	621.6	1503.2
1-Nov	236.097	240.162	30.977	3.139	7.094	26.431	98.447	19.527	263.012	38.616	259.288		1-Nov	1492.6	871.5	761.5	750.0	770.5	362.7	1599.8	1250.8	964.3	621.1	1502.0
2-Nov	234.259	236.890	29.554	3.139	7.094	24.743	96.987	18.490	260.644	38.076	256.437		2-Nov	1491.7	870.4	759.7	750.0	770.5	362.3	1598.1	1247.6	963.4	620.5	1500.8
3-Nov	232.422	233.619	28.130	3.139	7.094	23.055	95.526	17.453	258.276	37.537	253.587		3-Nov	1490.8	869.4	757.8	750.0	770.5	361.9	1596.3	1244.3	962.6	620.0	1499.6
4-Nov	230.584	230.347	26.706	3.139	7.094	21.368	94.066	16.416	255.908	36.998	250.737		4-Nov	1489.9	868.3	755.8	750.0	770.5	361.4	1594.6	1240.8	961.7	619.4	1498.3
5-Nov	228.747	227.076	25.282	3.139	7.094	19.680	92.605	15.379	253.540	36.459	247.886		5-Nov	1489.0	867.3	753.8	750.0	770.5	360.9	1592.8	1237.2	960.9	618.8	1497.1
6-Nov	226.910	223.805	23.859	3.139	7.094	17.992	91.145	14.342	251.172	35.919	245.036		6-Nov	1488.1	866.2	751.7	750.0	770.5	360.4	1591.0	1233.4	960.0	618.3	1495.9
7-Nov	225.072	220.533	22.435	3.139	7.094	16.304	89.684	13.305	248.804	35.380	242.186		7-Nov	1487.2	865.1	749.5	750.0	770.5	359.9	1589.1	1229.4	959.2	617.7	1494.6
8-Nov	223.235	217.262	21.011	3.139	7.094	14.616	88.224	12.267	246.435	34.841	239.335		8-Nov	1486.2	864.0	747.4	750.0	770.5	359.4	1587.3	1225.2	958.3	617.1	1493.3
9-Nov	221.397	213.990	19.587	3.139	7.094	12.928	86.763	11.230	244.067	34.302	236.485		9-Nov	1485.3	862.9	745.2	750.0	770.5	358.8	1585.5	1220.8	957.4	616.5	1492.0
10-Nov	219.560	210.719	18.164	3.139	7.094	11.240	85.303	10.193	241.699	33.762	233.635		10-Nov	1484.4	861.8	742.9	750.0	770.5	358.1	1583.6	1216.2	956.5	616.0	1490.7
11-Nov	217.723	207.448	16.740	3.139	7.094	9.552	83.842	9.156	239.331	33.223	230.784		11-Nov	1483.5	860.7	740.7	750.0	770.5	357.4	1581.7	1211.3	955.6	615.4	1489.4
12-Nov	215.885	204.176	15.316	3.139	7.094	7.865	82.382	8.119	236.963	32.684	227.934		12-Nov	1482.5	859.6	738.5	750.0	770.5	356.5	1579.8	1206.0	954.8	614.8	1488.1

13-Nov	214.048	200.905	13.892	3.139	7.094	6.177	80.921	7.082	234.595	32.145	225.084		13-Nov	1481.6	858.4	736.1	750.0	770.5	355.6	1577.9	1200.3	953.9	614.2	1486.8
14-Nov	212.210	197.633	12.469	3.139	7.094	4.489	79.461	6.045	232.227	31.605	222.233		14-Nov	1480.6	857.3	733.6	750.0	770.5	354.5	1576.0	1194.1	953.0	613.6	1485.5
15-Nov	210.373	194.362	11.045	3.139	7.094	2.801	78.000	5.008	229.859	31.066	219.383		15-Nov	1479.7	856.1	730.9	750.0	770.5	353.0	1574.1	1187.4	952.0	613.0	1484.1
16-Nov	206.706	189.322	9.621	3.139	7.094	2.801	76.280	3.970	228.337	31.066	215.050		16-Nov	1477.8	854.3	728.0	750.0	770.5	353.0	1571.5	1180.0	951.5	613.0	1482.0
17-Nov	203.040	184.282	9.621	3.139	7.094	2.801	74.560	3.970	226.815	31.066	210.716		17-Nov	1475.8	852.4	728.0	750.0	770.5	353.0	1568.9	1180.0	950.9	613.0	1479.9
18-Nov	199.373	179.242	9.621	3.139	7.094	2.801	72.840	3.970	225.293	31.066	206.383		18-Nov	1473.9	850.6	728.0	750.0	770.5	353.0	1566.2	1180.0	950.3	613.0	1477.7
19-Nov	195.706	174.202	9.621	3.139	7.094	2.801	71.120	3.970	223.771	31.066	202.050		19-Nov	1471.9	848.7	728.0	750.0	770.5	353.0	1563.6	1180.0	949.7	613.0	1475.6
20-Nov	192.040	169.162	9.621	3.139	7.094	2.801	69.400	3.970	222.249	31.066	197.716		20-Nov	1469.8	846.7	728.0	750.0	770.5	353.0	1560.9	1180.0	949.1	613.0	1473.4
21-Nov	188.373	164.122	9.621	3.139	7.094	2.801	67.680	3.970	220.727	31.066	193.383		21-Nov	1467.8	844.7	728.0	750.0	770.5	353.0	1558.2	1180.0	948.5	613.0	1471.2
22-Nov	184.706	159.082	9.621	3.139	7.094	2.801	65.960	3.970	219.205	31.066	189.050		22-Nov	1465.7	842.7	728.0	750.0	770.5	353.0	1555.4	1180.0	947.9	613.0	1468.9
23-Nov	181.040	154.042	9.621	3.139	7.094	2.801	64.240	3.970	217.683	31.066	184.716		23-Nov	1463.6	840.7	728.0	750.0	770.5	353.0	1552.6	1180.0	947.3	613.0	1466.7
24-Nov	177.373	149.002	9.621	3.139	7.094	2.801	62.520	3.970	216.161	31.066	180.383		24-Nov	1461.5	838.6	728.0	750.0	770.5	353.0	1549.8	1180.0	946.7	613.0	1464.4
25-Nov	173.706	143.962	9.621	3.139	7.094	2.801	60.800	3.970	214.639	31.066	176.050		25-Nov	1459.3	836.4	728.0	750.0	770.5	353.0	1546.9	1180.0	946.1	613.0	1462.1
26-Nov	170.040	138.922	9.621	3.139	7.094	2.801	59.080	3.970	213.117	31.066	171.716		26-Nov	1457.1	834.2	728.0	750.0	770.5	353.0	1544.0	1180.0	945.4	613.0	1459.7
27-Nov	166.373	133.882	9.621	3.139	7.094	2.801	57.360	3.970	211.595	31.066	167.383		27-Nov	1454.8	832.0	728.0	750.0	770.5	353.0	1541.1	1180.0	944.8	613.0	1457.3
28-Nov	162.706	128.842	9.621	3.139	7.094	2.801	55.640	3.970	210.073	31.066	163.050		28-Nov	1452.6	829.7	728.0	750.0	770.5	353.0	1538.1	1180.0	944.2	613.0	1454.9
29-Nov	159.040	123.802	9.621	3.139	7.094	2.801	53.920	3.970	208.551	31.066	158.716		29-Nov	1450.3	827.4	728.0	750.0	770.5	353.0	1535.1	1180.0	943.6	613.0	1452.5
30-Nov	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	207.029	31.066	154.383		30-Nov	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	943.0	613.0	1450.0
1-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	205.507	31.066	154.383		1-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	942.3	613.0	1450.0
2-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	203.986	31.066	154.383		2-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	941.7	613.0	1450.0
3-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	202.464	31.066	154.383		3-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	941.1	613.0	1450.0
4-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	200.943	31.066	154.383		4-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	940.4	613.0	1450.0
5-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	199.421	31.066	154.383		5-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	939.8	613.0	1450.0
6-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	197.899	31.066	154.383		6-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	939.2	613.0	1450.0
7-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	196.378	31.066	154.383		7-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	938.5	613.0	1450.0
8-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	194.856	31.066	154.383		8-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	937.9	613.0	1450.0
9-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	193.334	31.066	154.383		9-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	937.2	613.0	1450.0
10-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	191.813	31.066	154.383		10-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	936.6	613.0	1450.0
11-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	190.291	31.066	154.383		11-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	935.9	613.0	1450.0
12-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	188.770	31.066	154.383		12-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	935.2	613.0	1450.0
13-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	187.248	31.066	154.383		13-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	934.6	613.0	1450.0
14-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	185.726	31.066	154.383		14-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	933.9	613.0	1450.0
15-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	184.205	31.066	154.383		15-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	933.2	613.0	1450.0
16-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	182.683	31.066	154.383		16-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	932.6	613.0	1450.0
17-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	181.162	31.066	154.383		17-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	931.9	613.0	1450.0
18-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	179.640	31.066	154.383		18-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	931.2	613.0	1450.0
19-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	178.118	31.066	154.383		19-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	930.5	613.0	1450.0
20-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	176.597	31.066	154.383		20-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	929.8	613.0	1450.0
21-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	175.075	31.066	154.383		21-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	929.1	613.0	1450.0
22-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	173.554	31.066	154.383		22-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	928.4	613.0	1450.0
23-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	172.032	31.066	154.383		23-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	927.7	613.0	1450.0
24-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	170.510	31.066	154.383		24-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	927.0	613.0	1450.0
25-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	168.989	31.066	154.383		25-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	926.3	613.0	1450.0
26-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	167.467	31.066	154.383		26-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	925.6	613.0	1450.0
27-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	165.945	31.066	154.383		27-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	924.9	613.0	1450.0
28-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	164.424	31.066	154.383		28-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	924.2	613.0	1450.0
29-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	162.902	31.066	154.383		29-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	923.5	613.0	1450.0
30-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	161.381	31.066	154.383		30-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.7	613.0	1450.0
31-Dec	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383		31-Dec	1448.0	825.0	728.0	750.0	770.5	353.0	1532.0	1180.0	922.0	613.0	1450.0
1-Jan	155.373	118.762	9.621	3.139	7.094	2.801	52.200	3.970	159.859	31.066	154.383									1532.0				

Appendix D

Willamette Mainstem Flow Operations Strategy

Submitted by:

U.S. Army Corps of Engineers, Portland District
Bonneville Power Administration
Bureau of Reclamation

Submitted to:

National Marine Fisheries Service
U.S. Fish and Wildlife Service

Final May 2007

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Willamette Mainstem Flow Operations Strategy

1. Introduction

In March 2001, the National Marine Fisheries Service (NMFS) provided to the Portland District, U.S. Army Corps of Engineers (USACE) preliminary drafts of Reasonable and Prudent Alternative (RPA) and Incidental Take Statement (ITS) sections of a joint [with the U.S. Fish and Wildlife Service (USFWS), in combination called the Services] draft Willamette Project Biological Opinion (BiOp) for review and comment [1]. The second measure under the draft BiOp's RPA dealt with continuation (since 1999) of the spring and early summer mainstem minimum flow levels (i.e. biological flow objectives) needed to support salmon and steelhead migration.

In the Portland District response back to the Services, concern was expressed that under drier than average conditions (such as were experienced in 2001), it would be impossible to implement the proposed flow objectives. The USACE agreed to develop a decision-making protocol and operational criteria for meeting the flow objectives across a range of different hydrologic conditions for further consideration by the Services.

This paper describes the conceptual basis for an approach to operating the Willamette projects in a way that will satisfy the biological requirements for mainstem flows for species listed under the Endangered Species Act (ESA) while allowing the USACE to continue to meet, when possible, other authorized project purposes across a range of varying annual hydrologic conditions. The intent of this paper is to promote coordination between the Action Agencies [USACE, Bonneville Power Administration (BPA) and Bureau of Reclamation (Reclamation)] and the Services regarding possible alternative flow management approaches.

At the time of this update, the USACE has successfully implemented the essential aspects of this flow management strategy since the year 2000. Over the ensuing time period, the interagency process used to implement the operating strategy each year has continued to evolve and mature. We anticipate that this cooperative process will continue into the foreseeable future. The Action Agencies have used monthly meetings and weekly coordination teleconferences to provide updates on current environmental and flow conditions in the Willamette Basin and to discuss appropriate courses of action over the ensuing management period.

2. Spring Mainstem Flow Objectives

Starting in 2000, the Services recommended implementation of biologically based, weekly average and instantaneous minimum flow objectives for the Willamette River at Salem, Oregon. These flows are defined for April 1 to June 30 (Table D-1) each year. The biological minimum flow objectives were first recommended by Oregon Department of Fish and Wildlife (ODFW) and then recognized and adopted by the Services. They were the basis of consideration for operations beginning in 1999, through to the present.

[1] Federal Review Draft – Biological and Conference Opinion on the Effects of the Operation of 13 Flood Control Dams and Maintenance of 93 Miles of Streambank Revetments, Upper Willamette Basin, Oregon, on various fishery. USACE, NMFS, and USFWS, September 22, 2000.

Table D-1. Biological Minimum Flow Objectives for the Willamette River at Salem from April 1 to June 30

Time Period	Weekly Average Minimum Flow (cfs)	Instantaneous Minimum Flow (cfs)
April 1-15	17,800	14,300
April 16-30	17,800	14,300
May 1-31	15,000	12,000
June 1-15	13,000	10,500
June 16-30	8,700	7,000

The USACE was unable to meet all of the flow objectives in 2001 because of extreme low water conditions that year. The biological minimum flow objectives are based on the best currently available information regarding the biological needs of ESA-listed fish species, as described in a report prepared by the ODFW.[2] The NMFS Science Center has reviewed the ODFW research and concurs with the mainstem flow objectives as biologically justified. In addition to April through June flow objectives for fish, the Services recognized the need for continuation of the summer and fall (June-October) flows shown in Table D-2. Continuation of the minimum flow at Albany in the summer is important for meeting the USACE responsibility to help in maintaining suitable water quality.

Table D-2. Congressionally Authorized Minimum Flow Objectives for the Willamette River at Salem and at Albany (extending September flow objective through October 31)

Time Period	Average Flow at Albany (cfs)	Average Flow at Salem(cfs)
June 1-30	4,500	N/A
July 1-31	4,500	6,000
August 1-15	5,000	6,000
August 16-31	5,000	6,500
September 1-30	5,000	7,000
October 1-31	5,000	7,000

3. Effectiveness Monitoring

Monitoring, evaluation and reporting requirements related to the provision of mainstem flows will be developed in collaboration with the Services and may be incorporated into the BiOps. It is important to recognize that the mainstem spring flow objectives described in Table 1 may be temporary actions and are subject to review and revision in accordance with the results of appropriate monitoring and evaluation.

[2] Biological and Technical Justification for the Willamette River Flow Proposal of the Oregon Department of Fish and Wildlife, Mamoyac, Buckman, and Tinus, Draft August 8, 2000.

4. Definition of Key Terms

"Biological minimum flow objective" refers to the minimum level of flow that the fisheries agencies have indicated are needed for migrating adult and juvenile salmon and steelhead during the spring (April through June) runoff period. Spring biological flow objectives for fish are based on the best currently available scientific information. The spring flow objectives, or minimum levels of flow recommended to sustain anadromous fish populations in the Willamette Basin on a long-term basis, do not change based on the availability of water. When possible, it is preferable for mainstem Willamette River flows to exceed these biological minimum flow objectives. However, in some years there will be insufficient water available to meet the flow objectives.

"Congressionally authorized minimum flow objectives" during summer and fall (July through September), as measured in the mainstem Willamette River at Salem and at Albany are those that were included in the original formulation and authorization of the Willamette System Project. The Congressionally authorized flow levels during summer and fall were originally based on depths for navigation in the Willamette. They have become base flows used to maintain water quality standards in the mainstem Willamette. Minimum flow objectives for September have been used through low flow periods extending into October.

"Operational flow target" refers to the actual level of flow that managers will attempt to achieve during a given time period in the mainstem Willamette River at Salem. Flow targets are guided by corresponding flow objectives but may differ from them depending on the availability of water in any given water year and on other operational constraints and concerns. Flow targets will meet or exceed biological minimum flow objectives whenever possible. In low flow years, flow targets may be less than their corresponding biological flow objectives. This strategy recognizes that even under natural (i.e. unaltered) environmental conditions, there were some years in which flows were insufficient to meet the flow needs of migrating fish populations.

"Deficit flow thresholds" were those used (achieved or exceeded) on the mainstem Willamette River at Salem during the 2001 water year. This water year was the driest encountered to date since implementation of this flow management strategy in 2000. These 2001 flow levels were agreed upon following extensive hydrologic modeling analysis and multi-agency efforts to carefully balance risks associated with the multiple uses for Willamette Basin flow and storage, including the needs of ESA-listed species. The flow levels were developed under the ongoing ESA Section 7 consultation activity. Use of the Deficit Flow Thresholds recognizes, in part, the historic physical limitations of the Willamette Basin ecosystem over the period of record. However, 16% of the period-of-record years have actually been drier than 2001.

"Storage volume targets" are those volumes of system-wide storage (with regard to the combined Willamette River federal projects) that are determined to be necessary to meet specified project purposes in a particular type of water year. Storage volume targets are defined for four levels of storage availability: "deficit," "insufficient," "adequate," and "abundant." The Willamette Valley Project total available active storage is 1.594 million acre feet (MAF). Table D-3 identifies the storage ranges for each of these levels by May 10-20 of any given year.

"Interim draft limits" are storage limits that the projects will be operated at, or above, in order to meet minimum tributary and mainstem flows later in the summer and early fall months. These limits will be most important in the "insufficient" and "deficit" runoff years when a balance between spring and summer flows will be more difficult to manage.

5. Willamette Conservation Plan Development

The designation of a conservation season runoff forecast as abundant, adequate, insufficient, or deficit will lead to differing management tactical approaches. Table D-3[3] summarizes the designation of Willamette Basin runoff observed over a 64-year period of record.

Table D-3. Evaluation of Spring Runoff and Conservation Operation (period of record 1936-1999 using Tables 1 and 2 flow objectives)

Volume in Storage by 10-20 May (MAF)	Designation	Occurrences (years)	Percent of Years
< 900	Deficit	10	16
900 – 1.19	Insufficient	6	9
1.20 – 1.48	Adequate	11	17
> 1.48	Abundant	37	58
1.59	Maximum *	---	---

* Maximum useable conservation storage. Total transient system storage is somewhat more.

For years designated as **abundant** or **adequate**, minimum flow objectives during spring, summer, and fall (Tables D-1 and D-2) would be met or exceeded whenever possible (e.g., considering factors such as the accuracy of weather forecasts, constraints in the accuracy of operational adjustments at dams, and delayed system response time between the points of storage release and Salem). During an **insufficient** runoff season, it will likely be necessary to reduce flow targets at Salem and Albany to levels below the biological and Congressional minimum flow objectives. The flow targets would be less than the minimum flow objectives, proportional to the expected mid-May system-wide storage capability, down to a minimum of the deficit flow thresholds shown in Table D-4. For **deficit** runoff years, it is unlikely that even the weekly average deficit flow thresholds (Table D-4) would be attainable. Extensive coordination, cooperation, and adaptive management will be required in such years to balance storage use between flows needed to protect ESA-listed fish species and other uses. In both insufficient and deficit runoff years, it will be increasingly important to balance flows needed to protect ESA-listed fish species against other uses that, in general, are important for protecting human health and safety (e.g., maintaining water quality later in the year). Reservoir-specific draft limits will likely constrain flow releases in such years. Four of the 10 identified deficit years (from 1936-1999) resulted in less than 600,000 acre-feet of storage by mid-May.

Abundant. An *abundant* system-wide conservation storage volume is characterized by the expectation of having greater than 1.48 MAF in system storage by mid-May and having a relatively high probability of filling the three high-priority recreation reservoirs (Detroit, Fern Ridge, and Foster) throughout the summer (May through August) while fully meeting flow objectives at Salem (see Tables D-1 and D-2). When hydrologic modeling indicates that the system-wide storage volume is expected to reach or exceed 1.48 MAF between 10-20 May, weekly average flow targets will be established which fully meet or exceed the biological minimum flow objectives shown in Table D-1. Due to the high level of runoff, it is anticipated that these objectives would be exceeded without specific operational input. Under these

[3] This information was developed using HEC-5 reservoir system operation model of the Willamette Project. The results are based on meeting unmodified biological minimum flow objectives regardless of effects on other authorized purposes. Details are published in a study report.

conditions, it is expected that all lakes will fill at close to the prescribed (i.e., rule curve) rate while passing additional flow downstream. Lower priority recreation reservoirs could be drafted later in the summer to meet flow objectives, possibly reducing the extent of their recreation season.

Table D-4. Weekly Average Minimum Flow Objectives and Minimum Deficit Flow Targets for the Willamette River at Salem

Time Period	Minimum Flow Objective Weekly Averages (Biological and Congressional from Tables 1 & 2 in cfs)	Deficit Flow Threshold Weekly Averages (based on 2001 flows in cfs)
April 1-15	17,800	15,000
April 16-30	17,800	15,000
May 1-31	15,000	15,000
June 1-15	13,000	11,000
June 16-30	8,700	5,500
July 1-31	6,000	5,000
August 1-15	6,000	5,000
August 16-31	6,500	5,000
September 1-30	7,000	5,000
October 1-31	7,000	5,000

Adequate. An adequate system-wide conservation storage volume is characterized by the expectation of having 1.20 to 1.48 MAF in system storage by mid-May and having a relatively high probability of filling the three high-priority recreation reservoirs through most but not necessarily all of the summer while fully meeting flow objectives at Salem (see Tables D-1 and D-2). In these years, it is anticipated that spring flow objectives on the mainstem Willamette at Salem will be met or exceeded to enhance survival of migrating listed species. When it is determined that 1.20 MAF has been stored on or before mid-May, we will continue to store additional water on a system-wide basis only when we are exceeding mainstem flow objectives at Salem (Table D-1) by at least 10% (e.g., when we are meeting or exceeding 16,500 cfs in May).

Insufficient and Deficit. For these categories, there would not be a sufficient amount of runoff to meet all of the flow objectives in Tables D-1 and D-2 while permitting high priority Willamette reservoirs to fill to a level that would support recreational use throughout most of the summer. This situation occurs when the system-wide conservation storage level in the Willamette Basin is not anticipated to reach 1.20 MAF by mid-May. Below this level of system-wide conservation storage, inflow to reservoirs will be shared between that needed for storage to address summer and fall flow targets. Reservoir-specific interim draft limits will be used to avoid over-draft of stored water during the early part of the flow management season.

An insufficient designation for system-wide conservation storage volume occurs when the anticipated storage by mid-May is expected to be between 0.90 and 1.20 MAF, while attempting to fully meet biological and Congressional minimum flow objectives presented in Tables D-1 and D-2. In these years, mainstem operational flow targets for spring, summer, and fall will be based on a sliding-scale proportion of the minimum flow objectives presented in Table D-4 between minimum flow objectives and deficit flow thresholds. The proportion of flow provided between

the minimum flow objectives and the deficit flow thresholds will be equal to the proportion of system-wide storage anticipated to be obtained by mid-May between 0.90 MAF and 1.20 MAF. This threshold volume is based on results of water management actions implemented in 2001 to carefully balance risks associated with the multiple uses for Willamette Basin flow and storage, including the needs of ESA-listed fish species.

A deficit designation occurs when the runoff season is so low that the projected system storage by mid May is less than 0.90 MAF. Under these circumstances, it may not be possible to meet the biological and Congressional minimum flow objectives in Tables D-1 and D-2. Mainstem operational flow targets for spring, summer, and fall will be determined through the annual Willamette Conservation Plan development process, as described below, but are likely to be below the deficit flow thresholds shown in Table D-4. Under such severe conditions, coordination, cooperation, and adaptive management based on modeling of reservoir inflow and releases and on use of interim reservoir draft limits will be used to monitor and adjust flows, balance needs, and minimize impacts to ESA-listed fish species while meeting other water uses related, in general, to human health and safety. It will be especially important during deficit years to balance needs for flows during spring to support spawning and incubation of ESA-listed winter steelhead with needs for storage to provide flows during summer for water quality and during fall for spawning and incubation of ESA-listed spring Chinook salmon.

In both insufficient and deficit year cases, storage for recreational use would be considered a low priority. Hydropower generation, irrigation, and other authorized uses will be met to the fullest extent possible through both discharges of reservoir inflows during spring and release of storage during summer and fall to meet mainstem flow management targets. Priority will be given to those flow needs directly related to human health and safety. Reservoir inflow in excess of that needed to meet the mainstem operational flow targets during spring will be stored in a manner that maximizes the likelihood of being able to meet minimum discharge rates, mainstem Willamette River flow objectives at Albany and Salem during June through October, and Willamette Basin hydropower production needs.

6. Flow Management Coordination

As required by Congressional authorities, the USACE has traditionally managed the Willamette Project to meet multiple responsibilities, including flood control, power production, pollution abatement, recreation, irrigation, municipal and industrial water supply, navigation, and conservation of fish and wildlife within the project area. The approach in this strategy will help to meet the USACE responsibility under the ESA to avoid jeopardy to the continued existence of ESA-listed fish species. In making operational decisions to meet the requirements of the ESA, the Action Agencies must take all appropriate actions within their authorities to protect ESA-listed species. In some years, water resources will be insufficient to completely meet all of the traditional USACE responsibilities as well as the ESA responsibilities for the Willamette Project.

In accordance with individual project operation limits, the USACE prepares each year an operating plan for the conservation storage and release seasons (February-October) in the Willamette Basin. This plan is called the Willamette Conservation Plan (WCP). The WCP describes how the authorized project purposes will be accomplished during the conservation storage and release seasons given the volume of water forecasted to be available during the water year. The preparation of the WCP is initiated in January following the release of the initial water supply forecast for the basin from the Natural Resources Conservation Service (NRCS). The WCP is finalized by late May. Historically, the USACE has prepared the WCP in coordination

with state and federal agencies, including the Services. In the future, it is anticipated that a technical Flow Management (FM) Committee of the Willamette Action Team for Ecosystem Restoration (WATER) will play a key role in coordinating with the USACE for development of the WCP.

Willamette Action Team for Ecosystem Restoration (WATER). The preliminary draft BiOps called on the USACE to convene a forum of the Action Agencies, Services and other agencies responsible for planning and implementing flow management in the Willamette Basin. Among other actions, WATER will be responsible for working with the USACE to coordinate annual development of the WCP and real-time operations for the projects during the conservation season (April through October). It is anticipated that a flow management subcommittee of WATER will supplant the ad-hoc interagency committee that has been coordinating with the USACE on Willamette Project operations since 1999.

Flow Management Planning. The following paragraphs describe a protocol for developing the WCP across a full range of water years. The protocol is based on adaptive management that will spread risk of insufficient water among all authorized project purposes. Included among these uses are minimum tributary flows needed to protect ESA-listed fish species.

Adaptive management of flows involves making adjustments to reservoir operations and flow releases based on current and forecasted hydrologic conditions and will spread risk of insufficient water among all authorized project purposes. These purposes are described in detail in Chapter 2 of the USACE Willamette Project Biological Assessment (BA; update to new BA supplement)[4]. The Services, Action Agencies, and other WATER members will continue to work cooperatively each year during the conservation storage and release season to adjust flows to meet requirements of ESA species and other project purposes. Adaptive management is preferable to establishing fixed operating criteria because the Willamette Basin is a highly rain-dependent system with variable springtime flows. Current forecast methods do not differentiate between the significant contribution of snowmelt and the highly variable rainfall contribution. It is not possible to foresee, describe, and model all of the possible management scenarios and contingencies.

Under the protocol, beginning in or before January of each year, the USACE will determine if there is likely to be a sufficient volume of water in the Willamette Basin throughout the conservation season (February through October) to meet all of the identified flow and storage needs, including both the spring minimum flow objectives in Table D-1 and Congressionally authorized summer and fall flow objectives in Table D-2. Development of a flow management plan for the conservation season will be guided by the forecasted availability of water. It is important to recognize that in a rain-driven system like the Willamette Basin the best available hydrologic modeling early in the season may result in forecasts that differ significantly from actual conditions later in the conservation season. Since the plan calls for setting operational flow targets at Salem beginning on April 1, based on a storage forecast for mid-May, flows may be adjusted through the season. The availability of water will be re-assessed monthly or as necessary during January through May and related changes in management strategy will be made.

The USACE will use hydrologic modeling techniques to convert water supply forecasts for the Willamette Basin, provided by the NRCS, and perhaps other sources into an estimate of runoff volume available for the ensuing conservation management season. The estimate of runoff

[4] Biological Assessment of the Effects of the Willamette River Basin Flood Control Project on Species Listed Under the Endangered Species Act; Portland District, USACE, April 2000.

volume will be used to guide development of an annual flow management operational plan (WCP). The WCP will estimate mainstem flows and reservoir storage volumes likely to occur over the conservation season based on system operational alternatives and constraints. Consideration will be given to system operational constraints and to the resulting operation of the USACE Willamette reservoirs for the impending spring, summer, and fall periods. The modeling will consider the likelihood of meeting the spring flow objectives in Table D-1 and the Congressionally authorized summer and fall flow objectives at Salem and Albany in Table D-2, in conjunction with the likelihood that each of the reservoirs will fill.

7. Strategy Statement

The operational flow targets as determined under the process described above, and the associated flow management guidelines, are intended to balance the risks to listed fish species under low water year conditions with the risks to other uses authorized by Congress for the Willamette Valley Project. Key among these authorized uses are those significant to human health and safety. These include flood damage reduction, hydropower production for use within the Willamette Basin, and summer and fall low flow augmentation for maintenance of local water supply and water quality.

Appendix E
Biological Requirements & the Viability of Anadromous Salmonid Populations Rangewide Status

TABLE OF CONTENTS

E.1 Disturbance Regime and Land Cover 3
E.2 Access to Historical Habitat 4
E.3 Flow and Hydrology 4
E.4 Riparian Vegetation and Floodplain Function 7
E.5 Large Wood, Sediment Transport, and Channel Complexity 9
E.5.1 Role of Upland Vegetation, Land Use, and Disturbance in Habitat-forming Processes 9
E.5.2 Large Wood and Sediment Input Processes 10
E.5.3 Role of Large Wood and Sediment in Habitat-Forming Processes 11
E.5.4 Biological Importance of Channel Complexity Formed by Large Wood and Sediment 12
E.5.5 General Effects of Dams on Channel Complexity 13
E.6 Water Quality 13
E.6.1 Temperature 13
E.6.2 Dissolved Oxygen 19
E.6.3 Total Dissolved Gas 19
E.6.4 Nutrients 20
E.6.5 Turbidity 21
E.6.6 Toxics 22

TABLE OF TABLE

Table E-1 General Flow Guidelines 5

Table E-2 Summary of temperature considerations for salmon & steelhead life stages 16

Table E-3 Temperature criteria for salmonid uses during the summer maximum period 18

Table E-4 Temp criteria for salmonid uses that occur outside the summer maximum period 18

Appendix E

BIOLOGICAL REQUIREMENTS & THE VIABILITY OF ANADROMOUS SALMONID POPULATIONS

The following sections describe, in general terms that apply throughout the action area for this consultation, the relationships between biological requirements and the viability of anadromous salmonids.

E.1 Disturbance Regime and Land Cover

Prior to European settlement, Oregon Cascade Mountain forests were dominated by large conifers (Franklin and Dyrness 1973). Typically, most forests below 3,000 feet are composed of the Western hemlock plant association, primarily of Douglas fir, Western hemlock, and Western red cedar. Younger forests (early seral or successional phase) are dominated by Douglas fir. Western hemlock and Western red cedar develop under the Douglas fir canopy, but do not become the dominant overstory tree for several hundred years (Franklin and Dyrness 1973). Forests above 3,000 feet consist of either the Pacific silver fir or mountain hemlock association, including grand fir, Engelman spruce, and most of the species found in the Western hemlock association.

Upland disturbance regimes in Cascade forests were historically associated with fire, windstorms, insects, and disease. The spatial extent and intensity of these disturbance processes creates patches with different community compositions and physical structures. The disturbances that create new open patches provide a mechanism for secondary succession to occur, wherein early seral species (such as Douglas fir) are followed by mid-seral species, with the stand eventually developing into a complex late seral or old-growth community (Franklin and Dyrness 1973). As discussed in section 5.2.1.2.4, these disturbances not only affect vegetative cover, but in turn affect soil erosion and rates of sediment, large wood, and nutrient delivery to aquatic ecosystems (Wissmar et al. 1994).

At lower elevations in the Willamette basin, vegetation during the pre-development period was dominated by Oregon white oak woodlands, oak savannah, and prairie community types (Johannessen et al. 1970). Many areas of the valley were frequently burned by native Americans to create open habitat that supported game and plants that were staples of their diet (Gregory et al. 2002).

Local vegetation, geology, climate, and upland disturbance regimes produce aquatic systems with channel characteristics, fluvial disturbances, and aquatic biota unique to each subbasin. The composition of upland and riparian plant communities and the disturbance processes necessary to maintain them have been altered since European settlement. European settlement introduced new disturbances, such as timber harvesting, road building, agriculture, and urbanization, which affect existing plant communities and the disturbance processes necessary to maintain properly functioning aquatic habitat.

E.2 Access to Historical Habitat

The viability of a population is linked to spatial structure in several ways. There must be enough high-quality habitat to support reproduction, rearing, and migration, and habitat areas must be connected so that fish can move from one area to the next as their life history requires. Spatial structure also affects viability in more subtle ways:

- Diversity in population structure promotes genetic diversity, a key component of long-term viability
- Depending on the trend in habitat quality at any given time, some areas of current high abundance may actually be population "sinks" (productivity is in decline), while other areas that have fewer spawners may be responsible for most of the production (Pulliam 1988)
- Rates of migration, local extinction, and colonization between areas occupied by a population are typically unknown; thus the actual size of the wild population may be smaller than otherwise assumed (Whitlock and Barton 1997)

As an example of the third point, the spawning aggregation in the mainstem McKenzie River could be in decline but reseeded with strays from the South Fork McKenzie spawning aggregation, or (before all hatchery fish were marked) from the hatchery population.

- In general, the more dispersed the population, the less likely a landslide, volcanic eruption, or similar event will have a catastrophic effect.

E.3 Flow and Hydrology

To the extent practical, the USACE currently operates each of its Willamette Project facilities in conformance with recently established flow guidelines that are developed with the assistance of ODFW for the protection of aquatic resources in downstream river reaches (see Table E-1). These guidelines are somewhat more protective of UWR winter steelhead and spring chinook than the proposed action considered in this biological opinion and constitutes the existing conditions considered in Chapter 4, "Environmental Baseline."

Operations at each Willamette Project dam affect four primary streamflow characteristics, which in turn provide biological requirements of listed fish: peak flows, monthly average flows, minimum flows, and ramping rates. Downstream water withdrawls also affect both streamflow characteristics and anadromous fish habitat and survival. Several of the Willamette project reservoirs store water for out-of-stream use through USBR water service contracts. These streamflow characteristics and their influence on biological requirements are described below.

Table E-1 General Flow Guidelines (Source: USACE (2000), Table 2-1)

	High Flow					Low Flow			Minimum Conservation Pool	Maximum Conservation Pool
	Min	Normal Evacuation Rate	Max Evacuation Rate	Increase per hour	Decrease per hour	Min	Increase	Decrease		
							Increase per hour	Decrease per day		
Hills Creek	300 cfs	6000 cfs	8000 cfs	100-1000cfs : 300cfs 1000-5000cfs : 500cfs 5000-8000cfs : 800cfs Maximum : 1500cfs	4000 per half hour	400 cfs	200 cfs	(1.5'/day tailwater restriction) 1200cfs : 900cfs 1500cfs : 1000cfs 2500cfs : 1500cfs	1448.0	1541.0
							Increase and Decrease			
Dexter	1200 cfs	12000 cfs	15000 cfs	500-1000cfs : 500cfs 1000-4000cfs: 1000cfs 4000-15000cfs: 1500cfs	500-2000cfs : 700cfs 2000-5000cfs : 1500cfs 5000-10000cfs : 2500cfs 10-20 kcfs : 5000cfs	July 1 - Jan 31 1200 cfs Feb 1 - June 30 1200 cfs	Flow per Hr (.3') 1000 300 2000 400 3000 500 4000 600 5000 600	per Day (.5' tailwater) 500 700 800 800 900	LOP: 825.0	LOP: 926.0
							Increase per hour	Decrease per hour		
Fall Creek	50 cfs	3800 cfs	4500 cfs	50-1000cfs : 300cfs 1000-4000cfs : 500cfs Maximum : 800 cfs	No Limit	50 cfs May-Aug:150cfs	200 cfs	100 cfs	728.0	830.0
							Increase per hour	Decrease per hour		
Cottage Grove	50 cfs	2500 cfs	3000 cfs	350 cfs	No Limit	Feb-Jun:75cfs Jul-Oct:50cfs Nov-Jan:Inflow	100 cfs per hour 300 cfs max per day	100 cfs	750.0	790.0
							Increase per hour	Decrease per hour		
Dorena	100 cfs	4000 cfs	5000 cfs	100-2000cfs : 500cfs 2000-5000cfs : 750cfs Max per 2hrs : 1500cfs	No Limit	Feb-Jun:190cfs Jul-Oct:100cfs Nov-Jan:Inflow	200 cfs per hour 500 cfs max per day	200 cfs per hour 500 cfs max per day	770.5	832.0
							Increase per hour	Decrease per hour		
Fern Ridge	50 cfs	MNRO = 4650 cfs	MNRO = 6000 cfs	Normal : 750 cfs Maximum : 1000 cfs	No Limit	Feb-Jun:50cfs Jul-Nov:30cfs Dec-Jan:Inflow	200 cfs	200 cfs	353.0	373.5
							Increase per hour	Decrease per hour		
Cougar	100 cfs	5000 cfs	6500 cfs	100-500cfs : 250cfs 500-6500cfs : 500cfs Maximum : 750cfs	500 cfs	300 cfs	200 cfs	200 cfs	1532.0	1690.0
							Increase per hour	Decrease per hour		
Blue River	50 cfs	3000 cfs	3700 cfs	50 - 100cfs : 50 cfs 100-500cfs : 100cfs 500-1000cfs : 200cfs 1000-2000cfs : 400cfs 2000-3700cfs : 600cfs	30%	50 cfs	50-100cfs : 50 cfs 100-500cfs : 100cfs 500-1000cfs : 200cfs 1000-2000cfs : 400cfs 2000-3700cfs : 600cfs	30% (Below 200 cfs 30% per 15 min. - less is better)	1180.0	1350.0
							Increase per hour	Decrease per hour		
Foster	Inflow up to 10000 cfs	12000 - 15000 cfs	18000 cfs	500-1000cfs : 500cfs 1000-3000cfs : 1000cfs 3000-18000cfs : 1500cfs Maximum : 2500cfs	30%	Nov-Jun: 800cfs July: 750cf Aug: 650cfs Sep-Oct: 700cfs	300 cfs	300 cfs	GPR: 922.0 FOS: 613.0	GPR: 1010.0 FOS: 637.0
							Increase and Decrease			
Big Cliff	1000 cfs	10000 cfs	17000 cfs	100-1000cfs : 500cfs 1000-3000cfs : 1000cfs 3000-17000cfs:1500cfs Maximum : 2000cfs		1000 cfs	Flow per Hr (.3') 1000 300 2000 400 3000 500 4000 600 5000 700	per Day (.5' tailwater) 500 700 900 1000 1100	DET: 1450.0	DET: 1563.5

Note: Actual project operating criteria may differ. Source: USACE, 2003

- *Frequency of channel-forming and over-bank flows* Natural high flows occur in response to rainstorms and snowmelt runoff. Magnitude (expressed in cubic meters per second [cms] and cubic ft per second [cfs]), frequency (how often a flood of a given magnitude occurs, usually expressed in years), duration (length of the flood event), and seasonal timing are common descriptors of high-flow regimes. Peak flows influence geomorphic and ecological elements of stream channels by transporting and depositing fine and coarse sediments, preventing riparian encroachment and channel narrowing, affecting fish migrations, and maintaining connectivity between channels and floodplains. Floods of certain magnitudes have a geomorphic significance; for example, the bankfull discharge, which has an average recurrence interval of 1.5 to 2 years in many unregulated rivers, is considered the dominant discharge or channel-forming flow in many systems. Higher flows would have a more pronounced effect on channel form but are so infrequent that their effects are generally masked by those of lesser magnitude but higher frequency.

  High flows can influence the behavior and survival of adult and juvenile anadromous salmonids. The timing of adult migration often occurs as high flows decrease, and migration typically ceases during peak high flows. Juveniles seek velocity refuge during winter high flows, potentially a significant source of mortality, and often emigrate during spring high flows. Low-magnitude high flows can provide feeding opportunities for juvenile salmonids.

- *Flow fluctuations* Minimum flows are periodic or seasonal low flows. Minimum flows influence the quality and quantity of stream habitat, determine the amount of wetted stream channel area, and influence temperature and other water quality parameters. Minimum flows can present bottlenecks to population growth by limiting habitat availability (e.g., dewatering spawning and incubation habitat). Low flows can interfere with fish migrations by reducing stream depths at critical riffles (shallows). Low flows can also contribute to adverse water temperature and fish disease effects that can cause rapid and severe die-offs. A ramping event is defined as a natural or human-induced event in which river discharge and water surface elevation increase or decrease. Project operations influence the frequency, magnitude, timing, and rate of ramping events. Ramping rates are typically defined by the rate of change in the stream's water surface elevation (stage), for example, 15 cm/hr (6 in/hr) or 0.3 m/day (1 ft/day). The relationship between change in discharge and change in stage is strongly influenced by cross-sectional channel morphology; confined channels typically experience more rapid stage fluctuations than unconfined channels. Storm events cause natural flow changes, and precipitation and runoff processes in a given watershed influence these rates, but at dams, flows are often ramped in ways that exceed the rate, magnitude, and/or frequency of natural flow changes. In addition to increasing or decreasing stage, flow changes alter the velocity, depth, and shear stress[1] characteristics of rivers, altering physical habitat for aquatic species. Increases in stage (upramping) can displace eggs, juveniles, or adults of aquatic species, increase turbidity as rising water mobilizes sediments, and alter other

[1] "Sheer stress" in this case refers to the force exerted by flowing water on the channel boundaries (floor and walls).

aspects of water quality such as temperature and dissolved oxygen. Decreases in stage (downramping) can move active spawners off gravel bars and can strand eggs or juveniles of aquatic species in shallow pools in dewatered areas of a channel. Frequent and/or rapid ramping can also reduce benthic (bottom-dwelling) species diversity, density, and biomass by reducing the populations of species that are less mobile or less tolerant of dessication and other effects.

- *Seasonal flows* Monthly average flows describe the seasonal hydrograph, the distribution of runoff within a watershed over the course of the year. The characteristics of a stream's seasonal flow pattern strongly affect its suitability as habitat for various aquatic species. For example, migration patterns of locally-adapted anadromous fish often coincide with peaks and valleys in annual streamflow. Changes in these patterns affect a stream's suitability for indigenous anadromous fish, which are highly dependent on the characteristics of the undisturbed hydrologic regime, and can also encourage the growth of non-indigenous populations, which compete with or prey on the indigenous species. Diverting water for out-of-stream water use influences the four streamflow characteristics discussed above. Juvenile fish can become entrained into diversions for out-of-stream use. Water use in the Willamette River basin is administered by the Oregon Water Resources Department (OWRD) through a system of water use permits or water rights based on the prior appropriations doctrine of water allocation. OWRD has defined water availability for over 2,500 streams and stream reaches including several drainages in the Willamette basin. The OWRD determines water availability on a month-by-month basis, allocating water to new water uses until the water needs of the most junior user is satisfied at least 80% of the time. These water availability calculations are useful in identifying when water use conflicts are likely, including conflicts between out-of-stream and instream use (e.g., fisheries needs). The USBR markets water stored in the Willamette Project for irrigation throughout the basin via water service contracts.

E.4 Riparian Vegetation and Floodplain Function

Due to wide variation in physical characteristics, life history strategies, and successional patterns, riparian zones are complex ecological systems (Naiman and Decamps 1997), which can be viewed in terms of patterns of hydrologic and geomorphic processes, terrestrial plant succession, and aquatic ecosystems (Gregory et al. 1991). In addition to reflecting the history of fluvial disturbance from floods, the composition of a specific riparian community reflects the disturbance regimes from the nearby upland areas, including fire, wind disease, and insect outbreaks (Gregory et al. 1991).

Physical processes often provide the setting for a type of riparian communities, but the actual pattern of colonization, establishment, and succession results from interactions between the species and the physical processes (Walker et al. 1986). For example, in unconfined reaches, lateral migration of the stream channel cuts into older plant communities along the outer bend of a meander, mobilizing gravel and fine sediment, which deposit downstream, creating surfaces suitable for colonization by new riparian vegetation (Fonda 1974). Where channel migration is prevalent, riparian plant communities form a heterogeneous mosaic of patches with varying

species composition in different successional stages. In alluvial reaches within the Willamette valley, opportunistic, shade-intolerant species, such as black cottonwoods (*Populus trichocarpa*) and various willow species (*Salix spp*.), are often the first woody species to establish new riparian forests, establishing only on bare, moist, open surfaces. As these species mature, shade tolerant species, such as Oregon ash (*Fraxinus latifolia*) and big leaf maple (*Acer macrophyllum*) develop under the canopy of the initial species.

Riparian vegetation in alluvial reaches establishes on bare, open surfaces than can be created by lateral point bar migration (Nanson and Beach 1977), over-bank flooding (Scott et al. 1997), and channel narrowing or avulsion. McBride and Strahan (1984) describe establishment of new cottonwood communities on gravel bars, particularly those associated with large wood accumulations (Abbe and Montgomery 1996). Dykaar and Wigington (2000) report that mid-channel gravel bars are likely the origin for most of the floodplains along the upper Willamette River. Many of the abovementioned landforms are created during high flow events, and these landforms must be created at elevations that are low enough so roots maintain contact with the water table throughout the summer, but high enough to prevent flood damage (Rood and Mahoney 1990) (Nilsson et al. 1991). Due to the complex interaction of these variables affecting survival, willow/cottonwood communities do not establish annually, but rather in 2-10 year intervals that are dependent on channel-shaping events and weather conditions; Mahoney and Rood 1998).

Reducing the magnitude and frequency of peak flows allows vegetation to encroach on and stabilize existing surfaces and prevents the creation of new bars and islands that would be suitable colonization sites for young riparian forests (Ligon et al. 1995).Numerous studies have documented changes in riparian communities in river reaches downstream of dams, and most report a decline in establishment of young riparian forests, which are essential for generation of new floodplain forests and the benefits associated with them (Rood and Mahoney 1990; Rood and Heinze-Milne 1989).

Riparian forests provide many valuable functions to aquatic and terrestrial ecosystems. Riparian vegetation in small streams plays a significant role in controlling primary production within small streams by controlling food sources for macroinvertebrates, which are the food supply for some fish, including juvenile salmonids (Vannote et al. 1980). Riparian forests provide large wood that is necessary for a properly functioning aquatic ecosystem (section E.5). Section E.5 describes how large, key pieces of wood maintain habitat-forming processes in large rivers, illustrating the need for riparian vegetation of appropriate age and size. The successional stage and distance from riparian forest patches to the active channel also controls the amount and intensity of incoming solar radiation into the stream, moderating water temperature, as described in section E.6.

Junk et al. (1989) describe the importance of the exchange of aquatic and terrestrial energy sources during a flood-pulse in a riparian forest, and suggest that the flood-pulse produces and maintains a highly diverse and dynamic habitat structure within floodplains. Vegetated floodplains reduce water velocities during over-bank flows, providing refugia for aquatic organisms, including salmonids, and facilitating deposition of nutrient-rich silt and sediment during high-water events. Floodplains are created and maintained by a dynamic equilibrium

involving erosion, transport, and deposition of sediment, and the maintenance of a healthy floodplain forest is dependent of maintenance of these processes.

E.5 Large Wood, Sediment Transport, and Channel Complexity

Upland and riparian vegetation in headwaters and tributaries of the Willamette affect habitat-forming processes involving large wood and sediment. The interaction between properly functioning upland, riparian, large wood, sediment and hydrological processes creates and maintains fish habitat in all sizes of streams.

E.5.1 Role of Upland Vegetation, Land Use, and Disturbance in Habitat-forming Processes

As mentioned in section E.1, a primary upland disturbance affecting aquatic habitat is fire-related input of large wood. High intensity fires consume organic matter that binds the soil together, can reduce the ability of the soil to absorb water, and can increase surface runoff. When combined, these factors can increase the frequency of debris flows that deliver large quantities of sediment into stream channels (Wissmar et al. 1994). Low intensity fires can burn the understory, leaving downed wood available for recruitment into the stream channel, the benefits of which are described in detail in section E.5.3. Fires contributed large wood to stream systems either directly, due to falling burned trees, or indirectly, through the creation of fire-associated landslides that delivered large quantities of large wood. Fire-associated landslides are capable of delivering large quantities of sediment, in unharvested systems, which would be stabilized by the concurrent influx of large wood. Additionally, large wood in the riparian areas frequently burned less intensely, usually leaving enough riparian trees to provide continuous input until the next fire. This influx of sediment and large wood was responsible for patterns of rapid streambed aggradation and slow degradation throughout watersheds that created and maintained quality habitat (Reeves et al. 1995). Fire history studies at the HJ Andrews Experimental Forest in the McKenzie subbasin described historical fire frequency and determined that fire frequency in the study area has increased dramatically since fire suppression began in the early 1910s (Teensma 1987). Fires historically were more frequent, yet episodic in the presettlement era, and varied in extent and intensity, resulting in older-growth stands with multiple age classes, complex structural diversity, multiple-level canopies, and downed wood (BLMS 1997).

While fire frequency has decreased in the Cascades due to fire suppression, a new form of upland disturbance, timber harvesting and associated road building, have dominated the landscape over the latter part of the 20th century. Effects of disturbance due to timber harvesting differ in many ways from those caused by wildfires. While fires and associated landslides introduced both sediment and large wood to streams, timber harvesting usually removes most standing and downed wood. Thus, landslides associated with harvest or roads deliver large quantities of sediment to streams that lack the large wood necessary to retain it (Reeves et al. 1995). Without large wood, sediment is flushed rapidly downstream, often scouring the streambed to bed rock, or resulting in continuous riffle habitat poorly suited for anadromous salmonids. Additionally, wildfires tended to generate large, concentrated areas of disturbance, while timber harvests tend to result in many small, disturbed patches dispersed throughout the

landscape. Thus, the spatial pattern of sediment recruitment and the lack of concurrent large wood influx due to timber harvesting do not result in the same habitat-forming processes associated with natural wildfires, and actually degrade salmonid habitat (Reeves et al. 1995). Other land uses can also affect disturbance, habitat processes, and water quality. Many oak savannah, oak woodland, and prairies at lower elevations within the Willamette basin have been converted to agricultural, rural residential, or urban use (Gregory et al. 2002). Areas converted to agriculture were frequently cleared of vegetation and rapidly drained, reducing the amount of water stored within the hillslopes and floodplains and hindering recharge of local groundwater supplies, which provide base flows throughout the low flow season. Waterways adjacent to agriculturally-dominated areas can be contaminated with residues from chemical pesticides and herbicides that are harmful to aquatic biota.

E.5.2 Large Wood and Sediment Input Processes

Large wood can enter streams due to fire-associated landslides (described above), windfall, and natural tree mortality within the riparian area or adjacent hillslope (Grette 1985; Nakamura and Swanson 1993), but tree toppling during natural bank undercutting is the primary input process when the channel migrates across the floodplain in an unconfined reach (Leinkaemper and Swanson 1987; Bilby and Bisson 1998). Larger windthrow events, fires, floods, and landslides can episodically recruit high volumes of large wood and sediment into streams (Keller and Swanson 1979). In steep watersheds, heavy precipitation can trigger hillslope failures, which can enter stream channels and cause massive debris flows. In a debris flow, large quantities of soil, alluvium, large wood and organic material enter the channel and maintain momentum as they rapidly move downstream, gaining mass with increasing amounts of bed material and large wood. While the channel experiencing a debris flow is often scoured down to bedrock, debris flows ultimately deposit the mass of sediment, alluvium, and wood downstream in the channel or at a tributary junction, contributing massive quantities of sediment and large wood to the downstream reaches of the system over a relatively short period of time (Keller and Swanson 1979). Sediment is also supplied to streams through local bank erosion, wherein hydraulic forces scour both the face and the base of the bank, gradually contributing sediment to the system. Excessive scour at the base of the bank can lead to oversteepening and eventual slumping of the bank into the stream channel (Reid and Dunne 2003), delivering more sediment than the initial bank erosion. Toppling of riparian trees into or adjacent to the stream can also introduce sediment.

Large wood is broken down into smaller pieces and transported downstream in high flow events when rising water levels dislodge it from its resting location, or it can be transported episodically from headwater streams and deposited downstream during debris flows. Large wood transported out of headwater and tributary streams serves as source wood for downstream tributaries. However, due to the relatively small size of wood that is transported out of headwaters, the supply must be augmented by local input downstream in order for large wood to function hydraulically in large rivers. Benner and Sedell (1997) describe USACE snag removal efforts along the Willamette River where large wood pieces up to 6 feet in diameter were commonly encountered. Large wood of this size was likely recruited from floodplain forests in alluvial river reaches, rather than transported from headwater streams.

E.5.3 Role of Large Wood and Sediment in Habitat-Forming Processes

Physical habitat within stream and river channels is influenced by complex interactions between sediment supply, transport capability of the river, retention by large wood, and riparian vegetation (Montgomery and Buffington 1998). In small streams, large wood controls the distribution of sediment, bed material, and particulate organic matter in the channel. Large wood impacts streambank stability either by stabilizing the banks through a channel margin (where the bank meets the water) accumulation, or redirecting flow towards channel margins and facilitating streambank erosion (Montgomery and Buffington 1998). In-channel deposits of large wood create both areas of low velocity and shear stress that facilitate sediment deposition, and localized scour that eventually forms pools (Bilby and Bisson 1998). In small, high-gradient streams, large wood forms step-pool sequences that cause deposition upstream of the step and along the margins of the plunge pool downstream of the step (Montgomery and Buffington 1998). Pool spacing is strongly correlated to large wood loading in small to moderate gravel bed channels (Montgomery et al. 1995), and large wood is often associated with small, frequent depositional areas in small streams that become less frequent, but larger as channel size increases (Bilby and Ward 1989). Adequate size and composition of large wood necessary to perform these processes are described by Keller and Swanson (1979) and Bilby and Wasserman (1989).

Farther downstream in a river network, large wood plays a different role in habitat-forming processes. Large wood accumulations and jams are more common than the single trunks commonly found in smaller systems, but channel-spanning jams or accumulations are less common, as large wood accumulations are preferentially deposited on banks, bars, and in secondary channels (Piegay et al. 1999). The increased ability of the channel to transport small pieces of wood out of the system causes the average size of large wood pieces to be greater in larger rivers than in smaller streams (Bilby and Ward 1989). Large, key pieces of wood are necessary to significantly affect local hydraulic forces to create habitat features associated with large wood in larger rivers.

In larger rivers, gravel deposits typically form downstream of large wood accumulations (Keller and Swanson 1979), which can also facilitate creation of pools (Abbe and Montgomery 1996). Large wood jams were associated with 70% of pools observed in a 25 km reach of the relatively pristine Queets River in the Olympic Peninsula in Washington. Those pools associated with large wood tended to be deeper and have greater variance in depth than free-formed pools (Abbe and Montgomery 1996). In addition to creating pool habitat, stable large wood jams create localized sites of sediment aggradation. The aggradation increases the size of the bar and promotes deposition of fine particulate organic material, and the bar eventually becomes colonized by riparian vegetation. Vegetation increases the ability of the bars to accumulate organic matter and fine sediment, facilitating formation of islands and side channels. These vegetated islands can eventually rejoin the floodplain, forming isolated pockets of old-growth floodplain vegetation (Abbe and Montgomery 1996), which can be recruited into the system as key pieces of large wood if the channel migrates into the floodplain. Habitat and floodplain are also formed when high-velocity water (usually during a high flow event) erodes the bank on outside bends of meanders and transports sediment to the inside bend of meanders, where water velocities are slow enough for deposition to occur (Klingeman 1979). Repeated deposition of bed material on the inside of meander bends contributes to floodplain formation (Leopold et al.

1964), and possible stabilization by riparian vegetation. During high flows, sediment can also be deposited in hydraulically-complex areas associated with mid-channel bars, alcoves, side channels (Abbe and Montgomery 1996), and tributary junctions. Where a channel becomes clogged with large wood, the channel can cut directly across the bend, separate the bend from the main flow, and create a horseshoe-shaped, isolated "oxbow lake." As new channels are cut through the floodplain, riparian trees topple into the river and enrich the river with large wood and additional sediment. Most of the channel-shaping processes described above typically occur during high flow events. As described in section E.3, (Flow and Hydrology), Wolman and Miller (1960) identify the flow at which the majority of sediment transport occurs as bankfull discharge, which typically corresponds to a flow with a return interval of 1.5 to 2 years in an unregulated system.

E.5.4 Biological Importance of Channel Complexity Formed by Large Wood and Sediment

The large wood and its geomorphic influences on channels of all sizes have numerous biological impacts. In addition to retention of sediment, the hydraulic complexity caused by large wood facilitates the deposition and retention of particulate organic matter (Naiman and Sedell 1979; Wallace et al. 1995; Bilby and Likens 1980) and even salmon carcasses (Cederholm et al. 1989). Retention of particulate organic matter is necessary for adequate conversion of coarse particulate organic matter by shredder macroinvertebrates into finer particles to be consumed by collector/gatherer macroinvertebrates (Merritt and Cummins 1975). Macroinvertebrates serve as a food source for rearing salmonids that feed in the water column or at the surface on drifting food (Mundi 1969; Chapman and Bjornn 1969). Additionally, pools formed by large wood provide a location where fish can maintain their position with a minimal expenditure of energy to obtain food carried by the current (Fausch 1984). Numerous studies have documented the use of large wood-related habitat by juvenile salmonids. Shirvell (1990) found that 83% of steelhead parr and 99% of juvenile coho were associated with root wads placed in mid-channel areas where previously cover had been sparse, and Sedell et al. (1984) determined that complex wood structures, such as root wads or accumulations, tended to attract more fish than single logs.

Complex networks of gravel bars, side channels, and islands formed by large wood and sediment transport in alluvial reaches provide complex habitat useful to salmonids in many life stages. Large wood accumulations in large channels form pool habitat useful as holding habitat for adult salmon, facilitate spawning gravel deposition, and create areas of slow-water refugia during high flow events. Alcoves and side channels are utilized for refuge and feeding areas by rearing salmonids (Landers et al. 2002). Lateral channel migration, large wood accumulations, and mid-channel bar formations also increase erosion and subsequent deposition of gravel necessary for spawning. The formation and maintenance of a complex network of side channels in unconfined streams and rivers also benefits the aquatic ecosystem by providing increased opportunities for floodplain inundation (assuming ample flood flows), providing increased off-channel habitat for rearing and spawning and opportunities for energy and nutrient exchange between the river and floodplain.

The repeated transport and deposition of gravel and cobble is critical in maintaining connections between surface water and hyporheic water, which flows within the gravel and material beneath

a river. Water flowing hyporheically experiences many changes, including a significant reduction in temperature. In the Willamette River between Harrisburg and Corvallis, a volume equal to approximately 70% of the surface volume of the Willamette flows hyporheically (Enright et al. 2002, Landers et al. 2002). On hot summer days, water in the head of alcoves in the Willamette, consisting of water resurfacing from hyporheic flow, was between 3.6 and 9.0 degrees F (2.0 and 5.0 degrees C) cooler than water in the main channel of the Willamette (Enright et al. 2002, Landers et al. 2002). Thus, the formation of new gravel bars through which water can flow hyporheically is critical to maintaining appropriate water temperatures within gravel-bed rivers.

Maintenance of proper sediment and large wood processes is inherently linked to processes associated with riparian and floodplain vegetation, as well as hydrologic function and processes described in sections E.3 and E.4. When these processes function in concert, they provide habitat for salmonids at all life stages in all sizes of streams within the watershed network.

E.5.5 General Effects of Dams on Channel Complexity

As described above, aquatic habitat is created and maintained by a balance between sediment and large wood retention and transport. This balance depends on adequate sources of sediment and large wood, sufficient storage mechanisms, and flows necessary to mobilize particles downstream. In reaches downstream of flood control dams, the river is no longer supplied with sediment and large wood from upstream areas, and the frequency of peak flows capable of moving large bed material decreases. When fine bed material is transported downstream without being replenished from upstream, the channel bed coarsens (the materials are coarser) and downcuts (is cut lower) so that the bed material is larger and more stable than in the pre-dam condition (Williams and Wolman 1984). In braided river reaches, the river stabilizes and narrows due to an encroachment of riparian vegetation, and in meandering sections of the river, meandering rates decrease (Friedman et al. 1998). Channelization and revetments further prevent lateral migration of the channel and decrease the ability of the river to recruit sediment from its banks and the floodplain. The result is a straightened and simplified river, which lacks the hydraulic complexity to deposit and retain sediment. This increases the river's capacity to continue transporting bed material out of the system, which can result in further downcutting. A decrease in large wood due to blocked upstream input or lack of recruitment from floodplain forests further prevents the channel from storing what fine material, such as gravel, remains in the system (Williams and Wolman 1984).

E.6 Water Quality

E.6.1 Temperature

Salmonids are ectothermic (cold-blooded) and experience adverse effects, including mortality, when exposed to temperatures outside a relatively narrow optimal range.[2] Logging, farming,

[2] Although historical summer water temperatures probably exceeded optimal conditions on some rivers at times, the natural temporal and spatial diversity of habitat probably provided enough cold water during summer to allow salmonid populations to thrive.

mining, hydropower development, and other activities have altered the natural thermal characteristics of rivers and streams in the Pacific Northwest in the following ways (McCullough et al. 2001; Sauter et al. 2001):

- Increasing summer maximum temperatures; interfering with migrations, feeding, growth, reproductive success, competitive ability, physiological condition (including disease resistance), and predator avoidance
- Reducing or eliminating cold-water refugia, which provide protection from maximum summer temperatures and the habitat diversity needed for behavioral thermoregulation
- Changing the natural seasonal temperature patterns (seasonal thermograph) of rivers and streams, disrupting the adaptive life history strategies of salmonid populations

The EPA has recently recommended numerical water temperature criteria for each salmon and steelhead life stage that occurs during summer maximum temperature conditions. These considerations are based on the information summarized in Table E-1. NOAA Fisheries focuses on summer conditions because actions that achieve these goals would also be likely to reduce temperatures throughout the summer and during late spring and early fall. NOAA Fisheries also presents temperature maxima for salmonid uses that occur outside the summer period such as spawning, egg incubation, and steelhead smoltification (i.e., during spring through early summer or late summer through fall; Tables E-2 and E-3).

Not all temperature problems are related to overly warm temperatures. Unseasonably cool water released from Willamette Project reservoirs during late spring and summer is thought to block or delay the migration of adult salmonids into the mid- to upper reaches of some tributaries. According to USACE (1995b), discussions with resource agencies and previous studies have identified 52 degrees F (11 degrees C) as the optimal temperature that prompts spring chinook and steelhead to move upstream. Anadromous salmonids do not feed during their spawning migration and must rely on stored energy reserves. Prolonged delay can deplete these reserves to the degree that fish die before spawning.

The change in the seasonal thermograph is due to stratification, a phenomenon that occurs in most mid-latitude lakes. Due mainly to increased solar radiation, a warmer, less dense layer of water forms near the surface of lakes and reservoirs and a cold, more dense layer forms below the upper layer. The upper layer is called the epilimnion; the lower layer is termed the hypolimnion. Stratification typically begins in April and subsides by November. Because water is withdrawn from near the bottom of the reservoirs, water released from the project during the stratified period is typically colder than pre-project water temperatures. Water discharged in autumn is typically warmer than pre-project temperatures because, when the reservoir drawdown for flood damage reduction season, warmer epilimnotic waters are discharged. Stratification may be insignificant in very shallow lakes and reservoirs where wind mixes the water nearly to the bottom.

McCullough et al. (2001) and Sauter et al. (2001) discuss the following effects of temperature on the physiology and behavior of Pacific Northwest salmonids:

- Within an acceptable range, incubating eggs develop faster at higher temperatures, shortening the time to emergence. A thermal regime that cools rapidly from 53.6 degrees F (12 degrees C) and achieves low winter temperatures (according to natural cooling processes and rates) is essential for acquiring the necessary thermal units to ensure proper emergence timing and high egg survival.
- Feeding rates and growth rates can increase with temperature assuming that food is not limiting and water temperatures do not exceed the range for feeding. At temperatures above that range, feeding (and growth) rates can decrease. If growth rates are too low during the summer rearing period, body fat is not sufficient to sustain a fish during the winter rearing period. Optimum growth during the warm, maximum growth season (generally summer) is linked with high survival.
- Larvae and juveniles are generally attracted to warmer temperatures for feeding and growth than are larger juveniles or adult fish. The higher thermal preferences of young-of-the-year salmonids may attract them to warmer downstream temperatures, improving growth early in the season. However, as seasonal temperatures increase and the thermal preferences of these juveniles decrease, these fish may not be capable of moving upstream into cooler reaches.
- Water temperature controls the timing and duration of smoltification by controlling the rates of biochemical and physiological processes. High water temperatures inhibit the gill ATPase osmoregulatory enzyme, leading to the loss of migratory behavior.
- Adult salmonids reduce the energetic cost of over-summering in freshwater before spawning by holding in cold-water refugia, typically deep pools, which may be selected early in the season based on non-thermal cues such as groundwater flow. If water temperature is high (or oxygen concentrations are low) and there are no refugia, swimming speed can be impaired and fish may refuse to migrate or migrate back downstream.
- Adult salmonids with summer and fall spawning migrations are most likely to be exposed to high water temperatures outside their optimal range. Prolonged exposure to elevated temperatures can reduce the viability of gametes and is significantly related to prespawning mortality.
- The timing of spawning is genetically controlled and local stocks are probably adapted to temperatures that enhance their survival and reproductive success.
- Spawning temperatures may reflect the optimal physiological temperatures for incubation and egg development rather than the preferred temperatures of spawning adults.

Table E-2. Summary of temperature considerations for salmon and steelhead life stages. These parameters were developed with the assistance of the Services, the Northwest states, and the member Tribes of the Columbia River Inter-tribal Fish Commission. (Source: EPA 2003a)

Life Stage	Temperature Consideration	Temperature (Unit)	Reference
Spawning and Egg Incubation	• Temp. Range at which Spawning is Most Frequently Observed in the Field	39-57 degrees F(4-14°C) daily avg	Sauter et al. (2001); pp 17-18 McCullough et al. (2001); p 81
	• Egg Incubation Studies - Results in Good Survival - Optimal Range	 39-54 degrees F (4-12°C) constant 43-50 degrees F (6-10°C) constant	 McCullough et al. (2001); p 16
	• Reduced Viability of Gametes in Holding Adults	>55°F (>13ºC) constant	McCullough et al. (2001); pp 16 and 75
Juvenile Rearing	• Lethal Temp. (1 Week Exposure)	73-79 degrees F(23-26ºC) constant	McCullough et al. (2001); pp 12, 14 (Table 4), 17, and 83-84
	• Optimal Growth - unlimited food - limited food	 55-68 degrees F (13-20°C) constant 50-61 degrees F (10-16°C) constant	McCullough et al. (2001); pp 3-6 (Table 1), and 38-56
	• Rearing Preference Temp. in Lab and Field Studies	50-63 degrees F (10-17°C) constant <64 degrees F (<18°C) 7DADM	Sauter et al. (2001); p. 4 (Table 2). Welsh et al. 2001.
	• Impairment to Smoltification	54-59 degrees F (12-15°C) constant	McCullough et al. (2001); pp 7 and 57-65 McCullough et al. (2001); pp 7 and 57-65
	• Impairment to Steelhead Smoltification	>54°F (>12ºC) constant	
	• Disease Risk (lab studies) - High - Elevated - Minimized	 >64-68°F (>18-20ºC) constant 57-63°F (14-17ºC) constant 54-55°F (12-13ºC) constant	Materna (2001), pp 12 - 23
Adult Migration	• Lethal Temp. (1 Week Exposure)	70-72°F (21-22 degrees C) constant	McCullough et al. (2001); pp 17, 83 - 87

Life Stage	Temperature Consideration	Temperature (Unit)	Reference
	• Migration Blockage and Migration Delay	70-72°F (21-22 degrees C) average	McCullough et al. (2001); pp 9, 10, 72-74. Sauter et al. (2001); pp 15 - 16
	• Disease Risk (lab studies) - High - Elevated - Minimized	 >64-68 degrees F (>18-20°C) constant 57-63 degrees F (14-17°C) constant 54-55 degrees F (12-13°C) constant	Materna (2001); pp 12 - 23
	• Adult Swimming Performance - Reduced - Optimal	 > 68 degrees F (> 20°C) constant 54- 66 degrees F (15-19°C) constant	McCullough et al. (2001); pp 8, 9, 13, 65 - 71
	• Overall Reduction in Migration Fitness due to Cumulative Stresses	>63-64 degrees F (>17-18°C) prolonged exposures	McCullough et al. (2001); p 74

Table E-3. Temperature criteria for salmonid uses during the summer maximum period. (Source: EPA 2003a)

Salmonid Uses During Summer Maximum Temperature Conditions	Recommended Maxima
Salmon/steelhead "core" juvenile rearing[1]	61 degrees F (16°C) 7DADM[2]
Salmon/steelhead juvenile migration plus non-core rearing[3]	64°F (18°C) 7DADM
Salmon/steelhead migration[4]	68°F (20°C) 7DADM with a provision to take all feasible steps to protect and restore the natural thermal regime
.	

[1] In general, "core" juvenile rearing areas are defined as the moderate to high density summertime salmonid rearing areas in the mid-to-upper reaches in Northwest river basins (downstream from areas used by juvenile bull trout). However, EPA (2003a) suggests that in colder climates, such as the west slopes of the Cascades, it may be appropriate to apply this criterion all the way to the estuary. This criterion can also be applied to adult holding prior to spawning.

[2] 7DADM = 7-day average of the daily maxima. EPA (2003a) recommends this metric because it describes the maximum temperatures in a stream but is not overly influenced by the maximum temperature of a single day. It can be used to protect against acute effects such as lethality and migration blockages, and against sub-lethal or chronic effects.

[3] "Non-core" juvenile rearing areas are defined as moderate to low density summertime salmonid rearing areas, generally found in the mid- to lower basin, downstream of the core juvenile rearing areas. By setting this use designation, EPA (2003a) recognized that salmonid juveniles will use areas outside of their optimal thermal range.

[4] EPA (2003a) recommends this use for waterbodies that are used almost exclusively for migrating salmonids during the period of summer maximum temperatures (i.e., in the lower part of river basins where, based on the best available scientific information, natural background maximum temperatures probably reached 68ç (20 degrees C).

Table E-4. Temperature criteria for salmonid uses that occur outside the summer maximum period. (Source: EPA 2003a)

Other Salmonid Uses	Recommended Maxima
Salmon/steelhead spawning, egg incubation, and fry emergence[1]	55 degrees F (13 degrees C) 7DADM
Steelhead smoltification[2]	57 degrees F (14 degrees C) 7DADM

[1] Generally, this use occurs in late summer-fall for spring chinook and in spring-early summer for steelhead.

[2] Generally, steelhead begin to smolt in April and May as yearling fish make their way to the ocean. Steelhead smoltification can be impaired from exposure to greater than 54çF (12 degrees C) constant temperatures. Fish may cease migration or may migrate to the ocean undeveloped, thereby reducing their estuary and ocean survival.

E.6.2 Dissolved Oxygen

Adult salmonids require adequate concentrations of dissolved oxygen (DO) to sustain the high energy expenditure required for upstream swimming. Reductions in DO can decrease swimming performance in both adult and juvenile fish, affecting the ability to migrate, forage, and avoid predators (ODEQ 1995; Spence et al. 1996). Thus, any reduction in DO below saturation increases the risk of adverse sublethal or lethal effects. For many fish species, embryonic and larval stages often require the highest DO concentrations; as DO decreases, the time to hatching increases, and growth and survival decrease. Low DO concentrations increase the acute toxicity of various toxicants (toxic materials) such as metals (e.g., zinc) and ammonia (ODEQ 1995). At low intergravel DO (IGDO) and water velocity, ammonia exposure can adversely affect eggs in redds. Adverse effects of toxicants can be compounded by low DO. Also, toxicants can increase sensitivity to low concentrations of DO. For example, any toxicant that damages the gill epithelium can decrease the efficiency of oxygen uptake.

Productive streams exhibit diurnal cycles in water-column DO concentrations due to photosynthesis and respiration. Although fish can detect and attempt to avoid areas of low DO, the damage that can occur during diurnal minima depends on the length and frequency of exposure.

The Oregon Department of Environmental Quality (ODEQ) established a cold water DO standard for salmonid spawning and incubation of 11 mg/L as a 7-day average minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 11.0 mg/L criterion, DO levels must not be less than 95% saturation. The ODEQ also established an absolute minimum DO standard for waters supporting cold water aquatic life of 8.0 mg/L (or 90% saturation). NMFS (1999g) evaluated the U.S. Environmental Protection Agency's (EPA) proposal to approve these standards and concluded that the cold-water DO standard was likely to adversely affect both UWR chinook salmon and steelhead because it would apply in migratory corridors or in habitat used for both rearing and migration. However, NMFS concluded that take associated with approval of the DO standard was not likely to be of a magnitude or duration that would appreciably diminish the likelihood of survival and recovery of either species.

E.6.3 Total Dissolved Gas

Dam operations that create falling water (e.g., regulating outlet spill) can entrain volumes of air. As the water plunges, the hydrostatic pressure at depth forces entrained gases into solution, causing supersaturation of total dissolved gas (TDG). Supersaturated TDG conditions can persist for some distance below a dam before the gases dissipate at the air/water interface (e.g., the river surface, wave action on the surface, or air bubbles from rapids and riffles), and TDG in excess of 110% saturation can produce hazardous conditions for aquatic organisms. Fish absorb gas into the bloodstream during respiration, which passes from the dissolved state into the gaseous phase as internal bubbles or blisters. Susceptibility to this condition, called gas bubble trauma, is highest near the surface, where the reduced hydrostatic pressure allows the gas to come out of solution. The ODEQ water quality standards require that the concentration of TDG relative to atmospheric pressure at the point of sample collection not exceed 110% of saturation, except when stream flow exceeds the ten-year, seven-day average flood (OAR 340-041-0031;

ODEQ 2008). However, depth exerts additional pressure that increases the solubility of dissolved gases in the bloodstream, sufficiently to compensate for approximately 10% of saturation. Therefore, a total gas pressure of 120% of saturation at the surface is actually on 110% at 1 m and 100% at 2 m (Weitkamp and Katz 1980).

Chinook salmon are particularly vulnerable to gas bubble disease during the yolk sac fry stage. Once the yolk is fully absorbed and the body cavity has "buttoned up," fry are generally very tolerant to high dissolved gas concentrations. Typically, chinook salmon fry are in the yolk sac stage during late February through April, although incubation and emergence probably occur earlier in the mainstem tributaries immediately below the USACE dams. Weitkamp and Katz (1980) review the dissolved gas supersaturation literature and describe the following signs of gas bubble disease in chinook salmon larvae and fry:

- Bubbles formed between the yolk sac and the perivitelline membrane, causing fry to swim head up. As the bubbles expanded and moved posteriorly, the fry swam tail up and eventually belly up. Death occurred when the vitelline membrane ruptured (combined observations of Embody 1934, Wood 1968, Rucker and Kangas 1974, and Stroud et al. 1975, described in Weitkamp and Katz 1980).
- Large gas bubbles formed in the posterior portion of the yolk sac of chinook salmon sac fry. Dead fish had frayed fins and coagulated yolks (Zirges and Curtis 1975, cited in Weitkamp and Katz 1980).

The compensation depth described above applies to eggs and fry in the redds, as well as fish swimming in the water column. Depth compensation is equal to 10% reduction in TDG for each meter of water depth so, if TDG measured in the water over the highest redds is 115%, there must be at least one meter of water covering the redds to give an effective TDG of 105% at the redd level. The ODEQ water quality standards require that TDG in hatchery receiving waters and waters less than two feet deep not exceed 105% of saturation (OAR 340-041-0031; ODEQ 2008).

E.6.4 Nutrients

Phosphorus, carbon, and nitrogen are primary nutrients required by plants and animals to make tissue. Given adequate levels of light, temperature, and water, these nutrients control the amount of primary production in an ecosystem, which in turn determines the productivity of invertebrates and vertebrates. Small streams in many forested watersheds of the upper Willamette basin typically have very low concentrations of nitrogen, which is therefore the limiting nutrient (Triska et al. 1984). Anadromous salmonids are an important source of nitrogen to watersheds across their ranges, especially in the volcanic geologies of the Cascade Mountains (Cederholm et al. 1999; Gresh et al. 2000). This marine-derived nitrogen is heavily used by terrestrial plants and animals as well as aquatic organisms (Bilby et al. 1996; Willson et al. 1998; Hilderbrand et al. 1999).

In the lower elevations of the Willamette Valley, farmers apply nutrients such as phosphorus, nitrogen, and potassium in the form of fertilizers, manure, sludge, irrigation water, legumes, and crop residues to the soil to enhance production. Nutrients applied in excess of plant needs can

wash into aquatic ecosystems and cause excessive plant growth. At extreme levels, aquatic plant growth can increase the biological oxygen demand enough to create a hypoxic condition that kills fish (EPA 2003a).

E.6.5 Turbidity

Turbidity describes the amount of suspended and dissolved matter in a water body, measured as the amount of light intercepted by these particles. Turbidity is affected by water velocity and therefore is measured *in situ*, but once a water sample is collected, the suspended and dissolved fractions can be separated by a standardized filtration process (with the dissolved portion passing through the filter). Both turbidity, due to the effect it has on light penetration through the water column, and suspended sediment affect fish condition, and the effects reported in the literature as range from beneficial to detrimental. However, elevated suspended solids have been reported to enhance cover, reduce rates of predation by piscivorous fishes and birds Gregory and Levings (1998), and improve survival. Elevated suspended solids can also cause physiological stress, reducing growth and adversely affecting survival. Newly emerged salmonid fry may be more vulnerable to the effects of even moderate levels of turbidity than are older fish (Bjornn and Reiser 1991). Where velocity slows and fine materials settle out of the water column into the redds, they can reduce incubation success (Bell 1991). Other behavioral effects on fish, such as gill flaring and feeding changes, have been observed in response to pulses of suspended sediment (Berg and Northcote 1985).

The actual effects depend on the season, frequency, and duration of the exposure, as well as the suspended solids concentration or turbidity. Salmonids have evolved in systems that periodically experience short-term pulses (days to weeks) of high suspended sediment loads, often associated with flood events, and are adapted to such high pulse exposures. Adult and larger juvenile salmonids appear to be little affected by the high concentrations of suspended sediments that occur during storm and snowmelt runoff episodes (Bjornn and Reiser 1991). However, other research demonstrates that feeding and territorial behavior can be disrupted by even short-term exposure to turbid water, and chronic exposure can cause physiological stress responses that increase the expenditure of maintenance energy and reduce feeding and growth (Lloyd 1987; Redding et al. 1987; Servizi and Martens 1991).

Behavioral avoidance may be one of the most important effects of suspended sediments (DeVore et al. 1980; Birtwell et al. 1984; Scannell 1988). Salmonids have been observed to move laterally and downstream to avoid turbid plumes (McLeay et al. 1984; Sigler et al. 1984; Lloyd 1987; Scannell 1988; Servizi and Martens 1991). Juvenile salmonids tend to avoid streams that are chronically turbid, such as glacial streams or those disturbed by human activities, except when the fish need to traverse these streams along migration routes (Lloyd et al. 1987).

In systems with intense predation pressure, enhanced survival due to protection from predators may balance any physiological effects such as reduced growth. Gregory (1993) reported that turbidity levels of about 23 Nephelometric Turbidity Units (NTU) minimize predation risk.

E.6.6 Toxics

A toxic substance is one that has the potential to cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, or physical deformities in organisms or their offspring (NCSU 2008). Organisms are exposed to toxicants either directly in the environment or indirectly by ingestion through food chains. In aquatic systems, toxic substances are generally grouped into metals and organic compounds, including pesticides. Metals and toxic organic substances have entered waterways through point source discharges, although permissible discharges of these materials are now regulated under the Federal Clean Water Act of 1972 (as amended in 1977).

The EPA's National Water Quality Inventory reported that agricultural nonpoint source pollution was the leading source of water quality impacts to surveyed rivers and lakes nationwide, the third largest source of impairment to surveyed estuaries, and a major contributor to ground water contamination and wetlands degradation (EPA 2003b). Agricultural activities that cause nonpoint source pollution include confined animal facilities, grazing, plowing, pesticide spraying, irrigation, fertilizing, planting, and harvesting. The major toxic pollutants that result from these activities are chemical pesticides, including organophosphates (carbamates, organochlorine insecticides, and pyrethroids) (EPA 2003 c)