US Army Corps of Engineers
Northwestern Division

2007 DISSOLVED GAS AND WATER TEMPERATURE MONITORING REPORT

COLUMBIA RIVER BASIN

John Day Forebay TDG Monitoring Site

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

December 2007

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Reservoir Control Center, Columbia Basin Water Management Division
U. S. Army Corps of Engineers Northwestern Division
Portland, Oregon

Including Material Provided by:
Portland District – U.S. Geological Survey (Portland Office)
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Fish Passage Center

2007 TOTAL DISSOLVED GAS AND WATER TEMPERATURE MONITORING COLUMBIA RIVER BASIN

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List of Acronyms

The following acronyms are used throughout this report.

BiOp = Biological Opinion
Cfs = cubic feet per second
Corps = US Army Corps of Engineers
CRT = Columbia River Treaty
ESA = Endangered Species Act
FCRPS = Federal Columbia River Power System
FMS = fixed monitoring station
FPE = Fish Passage Efficiency
FOP = Fish Operations Plan
FPP = Fish Passage Plan
Kcfs = thousand cubic feet per second
Maf = Million acre feet
NMFS = National Marine Fisheries Service
NOAA Fisheries = National Oceanic and Atmospheric Administration, Fisheries
PUDs = Public Utility Districts
RO = regulating outlet
ROCASOD = Record of Consultation and Summary of Decision
ROD = Record of Decision
RPA = Reasonable and Prudent Alternative listed in the Biological Opinion
RSW = removable spillway weir
TDG = total dissolved gas
TMT = Technical Management Team
TMDLs = Total Maximum Daily Loads
USF&WS = United States Fish and Wildlife Service
VARQ = Variable Q which means a variable flow associated with Libby flood control
WDOE = Washington Department of Ecology

Terminology

The US Army Corps of Engineers (Corps) has noted different agencies applying various definitions to common terminology. The following are the Corps definitions, which are used throughout this report and the 2007 Water Management Plan.

Voluntary Spill: It is agreed that passing water through a project to assist juvenile salmon passage past dam projects in the Lower Columbia and Lower Snake rivers is beneficial. Voluntary spill is done to decrease the residence time of juvenile salmon in the forebay of dams, which increases their passage and survival in the Federal Columbia River Power System (FCRPS). Spill, as a fish passage strategy may have a higher survival rate than most other routes of passage at the dam. The amount of voluntary spill is adjusted so that the resulting TDG levels associated with spill are consistent with applicable State water quality criteria.

The amount of voluntary spill is influenced by the flow augmentation activities of international and federal water management agencies to the extent that spill levels vary with flow. For example, the Canadian projects and Grand Coulee flow augmentation influences the Lower Columbia flow and spill. Hells Canyon releases influence flow on the Lower Snake River. The National Oceanographic and Atmospheric Administration, Fisheries (NOAA Fisheries) and United States Fish and Wildlife Service (USF&WS) BiOps call for flow augmentation in the Columbia and Snake rivers. There are instances where spill at some projects is required to obtain the flow objectives called for in the Fish Passage Implementation Plan or the BiOps.

Involuntary Spill: Involuntary spill is caused primarily by project and/or system operational limitations. There are two primary causes for involuntary spill:

1. When hydrologic conditions result in flows which exceed the hydraulic capacity of power generation facilities, and

2. When potential power generation from high flow exceeds the available market, especially during light market hours at night and on weekends.

Other causes for involuntary spill include management of reservoirs upstream, scheduled or unscheduled turbine unit outages of various durations, passing debris, or any other operational and/or maintenance activities required to manage project facilities. For example, in managing the project for flood control, the water supply forecast may underestimate the seasonal streamflows and cause the project operators to leave too little space in the reservoirs to catch the water. In other instances, unusually high winter precipitation may force the operators to store water in the reservoirs above the flood control elevations, causing involuntary spill to occur later as the water is evacuated to get back to the reservoir flood control elevations.

Intertie Line Derating: The intertie line is the transmission system that transfers electricity between the Pacific Northwest and California. It is de-rated when its ability to transfer the electricity is decreased due to stability, thermal or environmental factors.

Unit Outage: A unit outage is a period of time when a generating unit cannot be in operation because of maintenance or repairs.

Lack of Load: There is a lack of customer need for power resulting in a lack of market for electricity generated.

TMT: An interagency technical group responsible for making recommendations on dam and reservoir operations. This group is comprised of representatives from five U.S. Federal agencies (Bonneville Power Administration; Bureau of Reclamation; NOAA Fisheries; US Army Corps of Engineers; and US Fish and Wildlife Service) and four states (Idaho, Montana, Oregon, and Washington).

Part 1 Program Description

1.0 Introduction

This report describes the Corps' Columbia River Basin Water Quality Monitoring Program for 2007 and covers the Lower Columbia and Snake River projects. The report was developed to meet the Corps total dissolved gas and temperature water quality program responsibilities. The report provides information consistent with the total dissolved gas variance issued by the state of Oregon and the rule modification by the state of Washington, meeting the objectives of the NOAA Fisheries Biological Opinion. This report also provides a summary of information relative to the Total Dissolved Gas (TDG) waiver and rule modification, in response to a check list provided by the state of Oregon. The additional requested technical information included accuracy of the gages and data, the number of TDG exceedances at each project, average and total amount of Biological Opinion (BiOp) spill and more detail on the Corps actions taken to meet the TDG Total Maximum Daily Load (TMDL). This requested information is provided for states' use in the processing a waiver and rule modification to the state Water Quality Standards (WQS) for TDG.

The report focuses on the water quality monitoring of total dissolved gas (TDG) and temperature at the 12 Corps dams in the Columbia River Basin (which includes Bonneville, The Dalles, John Day, McNary, Chief Joseph, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, Dworshak, Libby and Albeni Falls).

Total dissolved gas and water temperatures are the two areas of the water quality program where this document provides a detailed review with graphs of the data. Appendix A provides a general overview of the monitoring system with information on the fixed monitoring stations. Appendix B provides the monitoring plan of action for 2007. The Fish Operation Plan (FOP) that was used as the guideline for 2007 spill season can be found as Appendix C. Appendix D provides graphs and data about how much FOP spill should have occurred and how much did. Appendix E contains the 2007 monthly court reports filed with the court during spill season. There are graphs of flow, spill and high 12 hour %TDG average along with variance tables. Appendix F provides summary tables of TDG levels and exceedance types. Appendix G provides a detailed evaluation of how well SYSTDG performed during the 2007 spill season. Appendix H provides graphs of hourly water temperature data. The Dworshak operations are summarized in Appendix I. Walla Walla District wrote Appendix J, which provides a review of the QA/QC for the TDG and temperature monitoring gages at Lower Granite; Little Goose; Lower Monumental; Ice Harbor; and McNary. The U. S. Geological Survey (USGS) wrote Appendix K for the Corps Portland District. Appendix K provides a review of the QA/QC for the TDG and temperature monitoring gages at John Day, The Dallas, Bonneville, Warrendale and Camas/Washougal site. Seattle District wrote Appendix L which provides a review of the QA/QC for the TDG and temperature monitoring gages at Libby, Chief Joseph and Albeni Falls. The Fish Passage Center completed a report called Gas Bubble Trauma Monitoring and Data Reporting which can be found in Appendix M. The Corps TDG TMDL Implementation Summary provides an overview of the status of the Corps TDG TMDL activities and it is Appendix N.

1.1 Clean Water Act and Endangered Species Act

1.1.1 General

The Corps' water quality monitoring program at 12 Corps dams performs two functions and they are:

1. Monitor project performance in relation to water quality standards,
2. Provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams.

The monitoring performed by the Corps is part of a larger interagency water quality monitoring system operated by the Corps that also includes the Bureau of Reclamation monitoring system, and the Washington Public Utility District monitoring systems (as conducted by Chelan County Public Utility District, the Public Utility District of Douglas County, and the Grant County Public Utility District).

The monitoring program is considered an integral part of the Corps' Reservoir Control Center water management activities. TDG and water temperature are the primary water quality parameters monitored in the mainstem Columbia and Snake rivers in the states of Idaho, Montana, Oregon and Washington. TDG may be influenced by project water management operations (e.g. water released over the dam spillways, releases through the powerhouses and other facilities, and forebay and tailwater water surface elevations) as well as environmental factors including water temperature and wind conditions.

1.1.2 Corps Goals

The Corps policy is to comply with water quality standards to the extent practicable regarding nationwide operation of water resources projects. The general policies of the Corps are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated 30 July 1999. Section 18-3.b, page 18-5 of this document reads,

> "Although water quality legislation does not require permits for discharges from reservoirs, downstream water quality standards should be met whenever possible. When releases are found to be incompatible with state standards they should be studied to establish an appropriate course of action for upgrading release quality, for the opportunity to improve water quality in support of ecosystem restoration, or for otherwise meeting their potential to best serve downstream needs. Any physical or operational modification to a project (for purposes other than water quality) shall not degrade water quality in the reservoir or project discharges."

1.1.3 Biological Opinion (BiOp)

1.1.3.1 Background

Data from the Corps Dissolved Gas Monitoring Program before 1984 was used to monitor consistency with water quality standards. In 1984, the Corps Dissolved Gas Monitoring Program was enhanced to serve the dual purposes stated in Section 1.1.1.

With the listing of certain Snake River salmonids in 1991 under the Endangered Species Act (ESA), the Corps implemented a variety of operational and structural measures to improve the survival of listed stocks. The NMFS 1992 BiOp called for providing summer spill of available water for flow augmentation for migrating juvenile salmon. Spill for fish at the lower Snake River projects was limited to Lower Monumental and Ice Harbor dams. In 1994, the program was further expanded in response to the NMFS request to release water over the spillways at the lower eight Columbia and Snake rivers mainstem dams up to a level of 120% TDG where state rule modifications, variances or waivers had been provided.

Water management operations to reduce water temperature in the lower Snake River for the benefit of adult Snake River fall Chinook salmon were also considered. The NMFS BiOps concluded that although the priority for cool water releases from Dworshak Dam were for migrating juvenile fall Chinook in July and August, releases to reduce water temperatures in September could be considered on an annual basis through the NMFS Regional Forum Process.

1.1.3.2 NOAA Fisheries and USF&WS Biological Opinions

USF&WS 2000 BiOp

According to the USF&WS 2000 Biological Opinion (BiOp) for the Lower Columbia and Snake Rivers, operational and structural changes are to be made to reduce uncontrolled spill and the effects of high levels of TDG at lower Columbia River dams if it is determined that bull trout are affected by the Federal Columbia River Power System.

NOAA Fisheries 2000 and 2004 BiOps

The NOAA Fisheries 2000 and 2004 BiOp identified metrics that are indicative of juvenile fish survival to meet system-wide performance objectives consistent with actions likely to avoid jeopardizing the continued existence of 12 listed fish species in the Columbia River Basin. To achieve the objectives of the BiOp, NOAA Fisheries developed the jeopardy analysis framework. It was recognized that, in many instances, actions taken for the conservation of ESA-listed species also move toward attainment of State TDG and water temperature standards. There are 14 RPAs actions (RPAs 130 to 143) identified as part of a water quality strategy in the NOAA Fisheries 2000 BiOp. Specifically, RPA actions 131 and 132 deal with water quality monitoring. RPA action 131 indicates that the physical and biological monitoring programs are to be developed in consultation with the NOAA Fisheries Regional Forum Water Quality Team and the Mid-Columbia Public Utility Districts (PUDs). RPA action 132 specifies that a plan must be developed to perform a systematic review and evaluation of the TDG fixed monitoring stations (FMSs) in the forebays of all the mainstem Columbia and Snake River dams.

In response to the remand of the NOAA Fisheries *2000 Federal Columbia River Power System Biological Opinion* under *National Wildlife Federation vs. National Marine Fisheries Service*, NOAA Fisheries prepared a Final Biological Opinion on November 30, 2004. The Corps, Bonneville Power, and the Bureau of Reclamation submitted a Final Updated Proposed Action (UPA) in November 2004, which incorporated the water quality actions called for in the 2000 BiOp including a Water Quality Plan. The Final 2004 BiOp and UPA were refined in response to comments received on NOAA Fisheries' draft Biological Opinion.

The Final 2004 NOAA Fisheries and FWS Biological Opinions state: "The two agencies intend the recommendations and requirements of these opinions to be mutually consistent. They represent the federal biological resource agencies' recommendations of measures that are most likely to ensure the survival and recovery of all listed species and that are within the current authorities of the Action Agencies."

Invalidation of 2004 Biological Opinion
In February 2005, the National Wildlife Federation and several other parties moved to invalidate the 2004 FCRPS BiOp. In October 2005, US District Court Judge James Redden found the 2004 FCRPS BiOp invalid and remanded it to NOAA Fisheries.
The Court did not vacate the 2004 BiOp, however, in June 2005, Judge James Redden granted a preliminary injunction requested by plaintiffs in <u>NWF v. NMFS</u> and ordered the Corps to provide additional summer spill for migrating juvenile salmon and steelhead at Federal Columbia River Power System dams on the Columbia and Snake rivers. In December 2005, Judge James Redden ordered the Corps to operate in accordance with the Corps' proposed plan with limited exceptions during the 2006 spill season. For the 2007 spill season operations, the Corps developed the Fish Operations Plan which was approved by the court outlining the spill operations. This Fish Operations Plan can be found as Appendix C.

1.1.4 TDG Standards

<u>State of Idaho:</u>
IDAPA 58.01.02-250: Surface water Quality Criteria for Aquatic Life Use Designations. 01(b): The total concentration of dissolved gas not exceeding one hundred and ten percent (110%) of saturation at atmospheric pressure at the point of sample collection.

<u>State of Montana:</u>
ARM 17.30.637(9): No pollutants may be discharged and no activities may be conducted which, either alone or in combination with other wastes or activities, result in the total dissolved gas pressure relative to the water surface exceeding 110% of saturation.

<u>State of Oregon:</u>
The Oregon **OAR 340-041-0031** regulation on Total Dissolved Gas TDG water quality standards state:

- Waters will be free from dissolved gases, such as carbon dioxide, hydrogen sulfide, or other gases, insufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life navigation, recreation, or other reasonable uses made of such water.

- Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 110 percent of saturation. However, in hatchery-receiving waters and other waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 105 percent of saturation.

State of Washington:
In its 1997 water quality standards, the State of Washington modified its rule on total dissolved gas to allow for adjusted TDG criteria when spilling water over dams to aid fish passage. This new rule (WAC 173-201A-060(4)(a)), states that, subject to approval of a gas abatement plan, and submission of a fisheries management plan, and plans for physical and biological monitoring, TDG levels in the river may be elevated to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The exemption requires that, when spilling water at dams is necessary to aid fish passage, total dissolved gas must not exceed an average of one hundred fifteen percent as measured at Camas/Washougal below Bonneville dam or as measured in the forebays of the next downstream dams. Total dissolved gas must also not exceed an average of one hundred twenty percent, as measured in the tailraces of each dam. These averages are based on the twelve highest hourly readings in any one day of total dissolved gas. In addition, there is a maximum total dissolved gas one hour average of one hundred twenty-five percent, relative to atmospheric pressure, during spillage for fish passage.

1.1.5 TDG Waiver History
The Corps receives TDG waivers from the states of Oregon and Washington. The following sections provide the history of the waivers from each state.

State of Oregon
The first Federal request for a TDG waiver was submitted to the Oregon Department of Environmental Quality in 1996. The Corps took appropriate actions for attaining a water quality waiver from the State of Oregon for the 2002-2007 spill seasons. The most recent request, in 2002, included a report of the 2001 TDG monitoring program accompanied by a request for a waiver for the 2002 spill season. The Oregon Environmental Quality Commission met on March 8, 2002 and approved a waiver for the upcoming spill season, subject to specific conditions, assigned by Stephanie Hallock on March 8, 2001. A waiver of the TDG standard for the Columbia River was provided from midnight on April 1, 2002 to midnight August 31, 2002. The Commission approved a TDG waiver for the Columbia River of a daily (12 highest hours) average of 115% as measured in the forebays of McNary, John Day, The Dalles, and Bonneville dams, and at the Camas/Washougal monitoring stations. They approved a cap on TDG for the Columbia River during the spill program of 120% measured at the McNary, John Day, The Dalles, and Bonneville dam tailwater monitoring stations, based on the average of the 12 highest hourly measurements per calendar day. The Commission also approved a cap on TDG for the Columbia River during the spill program of 125%, based on the highest two hours per calendar day. The Commission also required that if 15% of the juvenile fish examined showed signs of gas

bubble disease in their non-paired fins, where more than 25% of the surface area of the fin was occluded by gas bubbles, the waiver would be terminated.

The following conditions were incorporated into the Commission's waiver. The Corps was to provide written notice within 24 hours to the Oregon Department of Environmental Quality on any exceedances of the conditions in the waiver as it relates to voluntary spill. The Corps was to provide a written report of the 2002 spill program by December 31, 2002 and supply information on the levels of TDG, fish monitoring, and incidence and severity of GBT. Additionally, any proposal for a modification to the TDG standard in 2003 was to be received by the Oregon Department of Environmental Quality no later than December 31, 2002.

On December 23rd, 2002, the Corps submitted information for a multi-year TDG waiver to the Oregon Department of Environmental Quality. The Oregon Environmental Quality Commission met on March 11th, 2003 and approved a 5-year TDG waiver subject to the same restrictions and conditions as the previous variance. This new waiver was in effect from April 1 through August 31 of each year through the 2007 spill season.

The Federal Agencies provided information on November 30, 2006 to the Oregon Department of Environmental Quality for a new TDG waiver again. The waiver request went through a public comment process. Final approval of a TDG waiver for two years (2008 and 2009 spill seasons) was completed by Oregon’s Environmental Quality Commission in June of 2007.

State of Washington:
In December 2002, the Corps submitted a package to the WDOE to satisfy the requirements for a TDG rule modification. In a letter to the Corps of Engineers dated March 28, 2003, the WDOE approved the gas abatement plan for all activities related to fish passage for a period of one year. In December 2003, the Corps submitted another package to the WDOE which contained a Water Quality Plan which was greatly expanded and covered a period extending through 2015. In response to this submittal, the WDOE approved another one-year TDG rule exemption beginning February 27.

On January 14, 2005, the Corps submitted another package of documents intended to satisfy the State of Washington’s requirement for a TDG rule modification. In this package, the gas abatement plan was updated as of December 2004. Based on this submittal and additional coordination with the Corps and Oregon DEQ, the WDOE approved the rule modification for a period of three years (through February 2008).
In addition to the TDG requirements described above, as part of the approval of the Water Quality Plan and granting of the rule modification for three years, the Corps was expected to continue to investigate and pursue TDG reduction and monitoring improvement as new information becomes available, continue to investigate biological effects of TDG, make reasonable attempts to reduce gas entrainment during all flows during the spill season, plan maintenance schedules and activities as much as possible to minimize TDG production, notify WDOE within 48 hours of initiation of spring, summer, and other spills for fish, and

provide the WDOE with an annual written report detailing TDG issues and characteristics for each year of spill season.

Colville Tribe TDG Standards:
4-8-5(e): The Water Quality Standards herein established for the total dissolved gas shall not apply when the stream flow exceeds the seven (7) day, ten (10) year frequency flood.

4-8-6(b)(3)(E): Total Dissolved gas shall not exceed one hundred-ten (110%) percent of saturation at any point of sample collection.

1.1.6 Operating Guidelines

The Water Quality Unit of the Corps Reservoir Control Center is responsible for monitoring the TDG and water temperature conditions in the forebays and the tailwaters of the lower Columbia River/lower Snake River dams, and selected river sites. The District water quality staff operates and maintains the gages. The USACE Northwestern Division operational water management guidelines are to change spill levels and, potentially, spill patterns at the dams (daily if necessary) so that the forebays are as close to, but do not exceed, daily (12 highest hours) average of 115% TDG, and the tailwater levels are close to, but do not exceed, daily (12 highest hours) average of 120% TDG. When these adjustments are made, the water volume, water elevation (where applicable), project powerhouse and spillway characteristics (where applicable), current and near-future special operations, current TDG levels in the forebays and tailwaters, water temperatures, and short- and long-term weather forecasts were included in the evaluation.

1.2 Monitoring Stations

TDG and temperature are monitored throughout the Columbia River Basin using FMSs (fixed monitoring stations). There are a total of 42 FMSs in the U. S. portion of the Columbia River basin. The Corps of Engineers has 28 gages. The Bureau of Reclamation, Chelan and Grant County PUDs maintain four stations each. Two stations are maintained by Douglas County PUD. The Corps maintained the remaining stations. Appendix A contains general information about each FMS operated by the Corps and a map of their locations.

1.3 Monitoring Plan of Action

The Corps prepares a dissolved gas Plan of Action each year. It is a supporting document for the NOAA Fisheries Regional Forum Technical Management Team to make recommendations on dam and reservoir operations.

A web site description of the TMT can be found at:
http://www.nwd-wc.usace.army.mil/TMT/

The 2007 Plan of Action can be found listed under the TDG category of the Reservoir Control Center Water Quality Team page on the following web site:

http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm

The Monitoring Plan of Action for 2007 is also attached as Appendix B. The Plan summarizes the roles and responsibilities of the Corps as they relate to dissolved gas monitoring. The Plan stipulates what to measure, how, where, and when to take the measurements and how to analyze and interpret the resulting data. The Plan also provides for periodic review and alteration or redirection of efforts when monitoring results and/or new information from other sources justifies a change. The Plan identifies channels of communications with other cooperating agencies and interested parties.

Part 2 Program Operating Conditions

2.1. Water Year Runoff Conditions

2.1.1 Weather

The 2007 Water Year, which began in October 2006, was below average in precipitation. The accumulative precipitation during water year 2007 in the upper Columbia River Basin was 98 percent of normal (1971-2000) above Grand Coulee Dam, 79 percent of normal in the Snake River above Ice Harbor Dam, and 94 percent of normal in the Columbia River above The Dallas, Oregon (Western Region Climate Center). The following month-by-month discussion of the weather provides more detailed information.

In October 2006, the Pacific high pressure area that had moved inland in September shifted westward, and this blocked significant precipitation from reaching the Basin. It also resulted in cooler temperatures, via a northerly flow. Yet, there were no record high or low temperatures. Regional temperatures departed a meager +0.1 ºC (+0.1 ºF). October precipitation was 87 percent of normal at Columbia above Grand Coulee, 101 percent of normal at the Snake River above Ice Harbor, and 88 percent of normal at Columbia above The Dalles. Later in the month, the Pacific high shifted well to the west, and was replaced by a low pressure area. This transition was quick and strong resulting in an abrupt precipitation increase the first part of November, and the rest of November experienced an all-time record precipitation.

November 2006 had a significant temperature duality, with many above normal readings during the first half and many below normal readings thereafter. This big swing averaged to a mean departure of +0.3 ºC (+0.6 ºF), regionwide, for the month. As a result of these extremes, November had record high temperatures early on; then, record lows. November precipitation was 182 percent of normal at Columbia above Grand Coulee, 135 percent of normal at the Snake River above Ice Harbor, and 176 percent of normal at Columbia above The Dalles. The warm storms prevented the initial building of the snowpack, but the onset of colder weather, with continued precipitation, made up for the slow start.

December closed 2006 with a little more typical winter storm pattern, with periods of heavy and record precipitation as tropical El Niño began to peak, but overall milder than normal temperatures. The jetstream, crossed the Columbia Basin from the southwest, remained quite active in December, and two noteworthy fronts stalled within it: The result was another run at record daily temperatures and precipitation. December precipitation was 78 percent of normal at Columbia above Grand Coulee, 100 percent of normal at the Snake River above Ice Harbor, and 99 percent of normal at Columbia above The Dalles. December 2006 closed on a wet note.

January 2007 transitioned to drier and colder weather. The first week was mild; the second week of January 2007 an Arctic front moved into most of the Columbia Basin. Temperatures fell to between 5.6 and 8.3 ºC (10-15 ºF) below normal. As moisture arrived, and with cold air in place, snow fell to sea level. Snow accumulation occurred along the Oregon and Washington coasts. Arctic high pressure kept central and eastern districts colder than normal for most of the month, while west of the Cascades, temperatures moderated. Regional temperatures departed -0.7 ºC (-1.3 ºF). January precipitation was 76 percent of normal at Columbia above Grand Coulee, 37 percent of normal at the Snake River above Ice Harbor, and 64 percent of normal at Columbia above The Dalles.

In February 2007, there was a sharp pattern change as a very cold airmass settled in east of the Rockies and a mild one settled via strong high pressure aloft over the Columbia Basin. As such, February experienced record high temperatures, similar to the three previous months, but for a different reason. Regional departures averaged +1.1 ºC (+1.9 ºF). Similar in some ways to January, the jetstream brought quite a bit of precipitation to southern Oregon, and the main storm track across the region missed the southeastern part of Idaho. At the end of the month, a more substantial storm with cooler air produced heavy coastal mountain snowfall. The region did not have too many record daily precipitation events this month. Monthly precipitation was 107 percent of normal at Columbia above Grand Coulee, 104 percent of normal at the Snake River above Ice Harbor, and 99 percent of normal at Columbia above The Dalles.

High pressure aloft broadened west to east into March, and this resulted in a generally warm and dry start to spring. In March 2007, there were exceptions to the overall mild and drier theme, as two significant storm systems crossed northwest Washington into British Columbia. These resulted in record daily amounts of 3.05 in., 3.52 in., and 2.78 in. at Quillayute and 1.20 in. at Porthill, Idaho. These storms contained tropical air, as the pattern was again reminiscent to the concurrent, yet weakening El Niño. The tropical airmass remained even after precipitation ended with the storms, and the result was more daily, record high temperatures. Regional temperatures departed +2.1 ºC (+3.6 ºF) for March, and precipitation was 159 percent of normal at Columbia above Grand Coulee, only 57 percent of normal at the Snake River above Ice Harbor, and 107 percent of normal at Columbia above The Dalles. The see-saw temperature pattern of the winter carried into the first full month of spring.

April 2007 started out cold, but warmed from the middle to late in the month. The April chill brought record low temperatures to Redmond, at -11.7 ºC (11 ºF), Meacham with -8.3 ºC (17 ºF), Pendleton, -5.6 ºC (22 ºF), Yakima, -6.7 ºC (20 ºF), Hillsboro at -2.8 ºC (27 ºF), and Idaho Falls, -6.7 ºC (20 ºF). To balance things out, there were record highs at Olympia and Hillsboro, with 26.1 ºC (79 ºF), Portland, 25.6 ºC (78 ºF), and Dworshak with 26.1 ºC (79 ºF). April 2007 regional temperatures showed a +0.2 ºC (+0.4 ºF) departure. Western Montana was the warmest region, with respect to normal, even with the early April cold air. Precipitation for the month was 93 percent of normal at Columbia above Grand Coulee, 87 percent of normal at the Snake River above Ice Harbor, and 84 percent of normal at Columbia above The Dalles.

A drier trend became more prominent across the Columbia Basin in May 2007. Strengthening upper level high pressure ridged up from California, and developed 80 and 90 ºF weather in U.S. valleys to the Pacific coast. The regional temperatures departed +0.9 ºC (+1.6 ºF) with some record daily high temperatures; for example, Pendleton at 34.4 ºC

(94 ºF). Precipitation was 94 percent of normal at Columbia above Grand Coulee, 40 percent of normal at the Snake River above Ice Harbor, and 65 percent of normal at Columbia above The Dalles. Toward the end of May, the weather pattern adjusted to a summer upper level high pressure pattern strengthening over the interior West rather than California. As such, June 2007 temperatures spiked indicating a very warm start to summer 2007, followed by a prolonged heat wave.

In early and late in June the bulk of the heat came, causing regional temperature departures of only +0.5 ºC (+0.9 ºF). Precipitation was governed by low pressure systems that tracked along the Canada-U.S. border, similar to May. They slowed down near the Rockies, and consequently abundant, northern-tier, precipitation occurred in that vicinity. Again, as in May, localized heavier precipitation helped to contribute to the overall monthly average, which accumulated 89 percent of normal at Columbia above Grand Coulee, 65 percent of normal at the Snake River above Ice Harbor, and 99 percent of normal above The Dalles.

July 2007 was one of the hottest months ever across the Pacific Northwest. Upper air high pressure peaked in strength during this month and engaged the region, especially east of the Cascades, in a prolonged heat wave. Inland locations were very dry with heat, but strong low pressure well offshore picked up some moisture from west Pacific typhoon, Man-Yi, and delivered heavy northwest Washington precipitation, while the rest of the region stayed much drier. The heat predominated this month, with regional departures a robust 3.3 ºC (+5.9 ºF). For some sites, this was the hottest month on record, for any month of the year: Boise, Missoula, Pocatello, Kalispell and Butte fell into this category. In terms of precipitation, the western quarter of the region led the way: July 2007 precipitation was 39 percent of normal at Columbia above Grand Coulee, 44 percent of normal at the Snake River above Ice Harbor, and 46 percent of normal at Columbia above The Dalles.

August 2007 cooled dramatically, back to normal, across most of the Columbia Basin. The warmest departures were over central and southern Idaho, across western Montana, and in southeast Oregon. The strong high pressure ridge that brought the July heat weakened in August, and allowed some weak cool fronts to transit the Basin. Some of these intercepted Southwest U.S. monsoonal moisture, and as such, were fairly wet for August. This activity largely took place over eastern Basins, close to the Continental Divide. Regional temperatures, meanwhile, average +0.4 °C (+0.8 °F), with both record high and low readings balancing out the average. August precipitation was 46 percent of normal at Columbia above Grand Coulee, 65 percent of normal at the Snake River above Ice Harbor, and 56 percent of normal at Columbia above The Dalles.

September contained two significant stormy periods, reminiscent more of October: One early in the month, and a more aggressive pattern, late. The latter was part of a pattern shift that would carry into October. Regional temperatures for September were normal, at +0.06 °C (+0.1 °F), with some daily record warmth offsetting any cooling. We had a slightly wetter than normal September, with precipitation at 102 percent of normal at Columbia above Coulee, 105 percent of normal at the Snake River above Ice Harbor, and 96 percent of normal at the Columbia River above The Dalles.

2.1.2 Streamflow

The 1 April 2007 forecast of January through July runoff for the Columbia River above The Dalles was 123 km^3 (100.0 Maf) and the actual observed runoff was 118 km^3 (95.7 Maf). The average January-July runoff volume for the 1971-2000 period is 132.4 km^3 (107.3 Maf).

The Columbia River was operated to meet chum needs below Bonneville Dam from November 5, 2006 through May 17th, 2007. As required by the 2004 NMFS Biological Opinion, when chum are present, chum operations begin which included a minimum instantaneous tailrace elevation of 11.3 ft minimum at Bonneville Dam during all hours and 11.3 - 11.7 feet during the day operation. Due to high flows in river during November and December it was not possible to maintain the desired range of 11.3 - 11.7 feet during the day. The minimum tailwater elevation was raised to 13 ft on November 7th, 2006. High flow pulses of water were made at night to pass water downstream. On November 15th, 2006 the minimum tailwater elevation range was reduced to 12 - 12.7 ft. during the day. On November 17th the day time tailwater range was reduced to 11.8 - 12.3 ft. On December 6th the tailwater range was increased to 12.3 - 12.8 ft. The chum tailwater elevations were not able to be achieved from December 14 - 17 ft. due to high flows in the river. On December 20th the tailwater elevation range was increased to 12.8 to 13.3 ft. Several changes to these ranges were made for a chum spawning study but they were of a short duration. On December 22nd, 2006 the tailwater restriction was changed to a minimum tailwater elevation of 13 ft as the operation change from supporting chum spawning to supporting chum emergence. The minimum tailwater limit was reduced to 12 ft for several short periods in order install equipment. On May 17th, 2007 the minimum tailwater constrain was removed as chum emergence was complete. The daily average flow during the Chum operations was 188 kcfs with a range between 109 Kcfs and 301 Kcfs.

Composite operating year unregulated streamflows in the Basin above The Dalles were below normal and approximately 13 percent below last year's slightly above average streamflows. Table 1 provides the unregulated flows for each month at Grand Coulee and The Dalles. Month average unregulated inflows during spring runoff were highest in May 2007 at 89 percent of average at The Dalles. The August 2006 through July 2007 runoff for The Dalles was 150.9 km^3 (122.4 Maf), 89 percent of the 1971-2000 average. The peak-unregulated discharge for the Columbia River at The Dalles was 13,011 m^3/s (459,500 cfs) on 7 June 2007. The 2006-2007 average monthly unregulated streamflows and their percentage of the 1971-2000 average monthly flows are shown in Tables 1 for the Columbia River at Grand Coulee and The Dalles. These flows have been adjusted to exclude the effects of regulation provided by storage reservoirs.

TABLE 1

Columbia River Flow in 2006-2007				
	At Grand Coulee (in cfs)		At The Dalles (in cfs)	
Time Period	**Unregulated flow**	**% of Average**	**Unregulated flow**	**% of Average**
October 2006	27,687	62	58,431	71
November 2006	66,696	137	130,452	138
December 2006	40,889	95	89,631	91
January 2007	36,938	88	84,688	83
February 2007	37,404	79	96,426	79
March 2007	107,758	173	196,202	126
April 2007	128,234	105	214,654	90
May 2007	258,845	97	387,202	89
June 2007	300,686	97	383,477	82
July 2007	187,114	98	222,492	87
August 2007	71,505.4	68	95,063.5	69
September 2007	41,279.5	66	65,185.2	70
Average (Oct 06 – Sep 07)	108,753	97	168,659	90

2.1.3 Reservoir Operation

2.1.3.1 General

The 2005 – 2006 operating year began with Grand Coulee storage at 88 % full. The 2006 – 2007 operating year was one of below water supply across the basin, and the shape of the runoff was gradual so that no significant peaks were observed. The 2006-2007 operating year began with Canadian storage at 97.1 percent full. Libby reservoir (Lake Koocanusa) was near full elevation 748.9 m (2,456.87 ft), at the start of the operating year and releasing water to meet objectives for flow augmentation for listed salmon species in the U.S.

The 2006–07 operating year was one where water supply in the Columbia Basin above Grand Coulee was average. However, the Snake River water supply was well below average. The streamflow in March was well above average because of several storms in the Basin. These storms were characterized by warm temperatures as well. The remainder of the snowmelt season through July was characterized by average runoff above Grand Coulee.

The Libby project was operated according to the Libby Coordination Agreement (LCA) dated February 2000, including the 21 April 2006 update to the Libby Operating Plan, and U.S. requirements for power and guidelines set forth in the U.S. Fish and Wildlife Service (USF&WS) and U.S. National Marine Fisheries Service (NMFS) 2000 and 2004 Biological Opinions (BiOps). The Libby Reservoir began July 2006 at elevation 748.84 m (2,456.87 ft) and drafted through the fall and winter period. By 31 December, the reservoir was at elevation 734.9 m (2,411 ft) and operated during the winter to the VARQ storage reservation diagram. The reservoir drafted to its lowest elevation of 727.28 m (2,386.1 ft) on 30 April. During the refill period, Libby Dam operated in strict accordance to the VARQ operating procedures and provided 1.44 km^3 (1.17 Maf) of storage for sturgeon releases. The reservoir filled to its maximum elevation of 748.03 m (2,454.16 ft) on 20 July 2007 and continued to draft to elevation 743.41 m (2,439 ft) by 31 August.

The Federal system was operated to meet the needs of listed chum downstream of Bonneville Dam beginning November 5, 2006 and lasted through May 17, 2007. The operation meant maintaining the tailwater elevation at Bonneville Dam at, or above, elevation 11.3 feet, so as to keep the areas downstream of Bonneville wetted while the chum moved into the area and spawned. A tailwater elevation of 11.3 ft was the minimum allowable for Bonneville through the emergence of the chum but due to high flows, the minimum tailwater elevation of 11.3 ft was changed many times from November through May to as high as 13 ft. A minimum tailwater elevation provides optimum spawning conditions

Operations consistent with for the National Marine Fisheries Service, (now referred to as “NOAA Fisheries”) BiOp, and the US Fish and Wildlife Service BiOp were completed in 2006-2007. The operations included refilling reservoirs to the April 10^{th} flood control elevation. If inflow was great enough, refill on, or about, June 30^{th}; and drafting reservoirs to summer draft limits. The spring flow objectives were met at Priest Rapids and McNary but were not met at Lower Granite. Usual spring spill was executed at the Lower Columbia and Snake River projects. In accordance with the court order, summer spill occurred at the Lower Columbia and Snake River projects. The Lower Snake River projects were operated within one foot of their minimum operating pools (MOP) for the season: Ice Harbor; Little Goose, Lower Granite, and Lower Monumental were all operated between MOP and MOP+1 ft.

2.1.3.2 Flood Control

The 2007 water supply forecasts averaged below normal across the Columbia River Basin, while the upper Columbia Basin averaged above normal and the Snake River Basin averaged well below normal. The reservoir system, including the Columbia River Treaty projects, was required to draft for flood control in preparation for the spring freshet. Projects were operated according to the May 2003 Flood Control Operating Plan (FCOP). The unregulated peak flow at The Dalles, Oregon, shown on Chart 13, is estimated at 3,011 cubic meters per second (m^3/s) (459,500 cfs) on 7 June 2007, and a regulated peak flow of 8.02 m^3/s (283,200 cfs) occurred on 14 May 2007 as measured at the United States Geological Survey gage at The Dalles, Oregon. The unregulated peak stage at Vancouver, Washington, was calculated to be 4.83 m (15.8 ft) on 8 June 2007, and the highest observed stage was 2.77 meters (m) (9.1 ft) on 16 May 2007.

In the 2007 spill season, there were such low flows on the Lower Columbia and Snake Rivers that there was no spilling for flood control. There were only a few hours when runoff peaked at 312 to 324 kcfs total river flow on the Lower Columbia River, which occurred on May 8th through May 14th. On the Lower Snake River, runoff peaked at 105 to 119 kcfs total river flow between May 13th and 15th.

During very large natural runoff events, the resulting high river flows make it impossible for dam operators to abate dissolved gas. Washington and Oregon’s water quality standards exempt these occurrences, since they are of natural origin and occur relatively infrequently. The typical criterion for expressing the water quality standards exemption is called the 7Q10. The 7Q10 is the average peak annual flow for seven consecutive days that has a recurrence interval of ten years. The 7Q10 daily average flows for the various projects are shown on Table 2. At the 7Q10 flow levels, there is involuntary spill at the projects and the water quality standards for total dissolved gas no longer apply. The 7Q10 flow levels were calculated based on the flow that projects can physically handle with all turbines except one operating. These flows were established through negotiations with Oregon and Washington.

TABLE 2
7Q10 FLOWS

Project	7Q10 flows (kcfs) - as a daily average	Power house capacity within 1% efficiency	Power house capacity without one unit	The volume of Spill at 7Q10 flows
BON	467.03	257	242	225.03
TDA	461.18	288	267	194.18
JDA	454.37	331	310	144.37
MCN	446.76	172	160	286.76
IHR	214.00	92	77	137.00
LMN	214.00	115	94	120.00
LGS	214.00	115	94	120.00
LWG	214.00	115	94	120.00

The 2007 peak flows on the Lower Columbia and Snake Rivers did not exceed the 7Q10 flow and haven't since 1997 when the Columbia River at Bonneville reached an average daily flow of 519 kcfs from June 1, through June 21, 1997. Flows at the Columbia River at Bonneville did not reach the 7Q10 flow again until 1974. The 7Q10 flow was frequently reached during 1960's and 1970's, but not since then.

The BiOp spill graphs in Appendix D illustrate the effects of when the shape of the runoff is gradual and its effect on voluntary and involuntary spill at the various projects. During the peak runoff period, Lower Granite and Little Goose had no involuntary spill since the river flow was so low. There was involuntary spill at Lower Monumental and Ice Harbor.

2.2 Water Releases

2.2.1 Spill

Prior to 2007, the NOAA Fisheries' 2004 BiOp provided the guidelines for the spill program. This changed in December 2005 when the District Court of Oregon issued an order requiring the Corps of Engineers to change the spill regime for most of the projects and include summer spill. As a result, the 2006 Fish Passage Implementation Plan (FPIP) was developed and used as the guideline for the 2006 spill season. For the 2007 spill season, the 2007 Fish Operation Plan (FOP) was developed which is Appendix C of this report or you can find it at http://www.nwd-wc.usace.army.mil/tmt/documents/ops/

Spring Spill

During 2007, there was spring spill at the Lower Columbia and Snake Rivers projects as called for in the 2007 Fish Operations Plan. Spring spill began April 3rd and continued through June 21st at the Snake River projects. Spring spill began April 10th and continued through June 21st at McNary, John Day, and Bonneville and to June 30th at The Dalles.

The 2007 Fish Operations Plan called for the following spill regime during the spring: On the Snake River, the spill at Lower Granite was 20 kcfs; Little Goose spill was 30% of river flow; Lower Monumental spill was 27 kcfs or to the spill cap and Ice Harbor spill alternating between 30% of the river flow and up to the spill cap. On the Columbia River, McNary spilled alternating between forty percent (40) vs. sixty (60) percent of the project outflow ,The Dalles spilled forty (40) percent of the project outflow, at John Day, sixty (60) percent of the project outflow and at Bonneville 100 kcfs or to the 120% gas cap. At no time was a project to voluntarily spill above the 120%/115% TDG criteria specified in the state variances.

Total river flows remained somewhat elevated on the Columbia River from the first week of May to the first week of June when the freshet occurred. Total river flows on the Columbia River during this period were between a daily average flow of 250 and 300 kcfs with an overall daily average flow of 262 kcfs. These flows were lower than 2006 when the daily average flow was between 270 and 399 kcfs. Flow began to taper off in June, July and August. Total river flows remained somewhat elevated on the Snake River from the late April to late May when the freshet occurred there. Total river flows on the Snake River during the late April to late May period were between a daily average flow of 53 and 100 kcfs, which is low compared to 2006 when the flow was between 98 and 193 kcfs. The TDG exceedances that resulted from these low flows are discussed in the 3.1.1 Total Dissolved Gas section of this report.

Summer Spill

The June 2005 court decision called for summer spill from June 20 to August 31 on the Lower Snake River projects during the 2005 spill season. The December 2005 court decision called for summer spill from June 21 to August 31 on the Lower Snake River projects and from July 1 to August 31 on the Lower Columbia projects in 2006. The summer spill program from 2005 and 2006 continued in 2007. The summer spill program was characterized by low river flows. The Snake River total river flows were between 18 and 45 kcfs as a daily average, which is low compared to 2006 when daily average flows were between 22 and 80 kcfs. The Columbia River total river flows were between approximately 117 and 210 kcfs as a daily average, which was typical.

The 2007 Fish Operation Plan called for the following spill regime during the summer: On the Snake River, the spill at Lower Granite was 18 kcfs; Little Goose spill was 30% of river flow; Lower Monumental spill was up to 17 kcfs, or up to the spill cap and Ice Harbor spilled 45 kcfs during the day and up to the spill cap at night. On the Columbia River, McNary spilled alternating between forty percent (40) vs. sixty (60) percent of the project outflow, The Dalles spilled forty (40) percent of the project outflow, at John Day, thirty (30) percent of the project outflow and at Bonneville spill 75 kcfs during the day and up to 120 kcfs or to the 120% gas cap at night. At no time was a project to voluntarily spill above the 120%/115% TDG criteria specified in the state variances. When river flows are low during the summer, the FOP called for minimum generation and spill. The TDG exceedances are discussed in the 3.1.1 Total Dissolved Gas section of this report.

Total river flows tapered off on the Columbia River during July and August. Total river flows on the Columbia River during this period were between a daily average flow of 117 and 210 kcfs with an overall daily average flow of 163 kcfs, which was the same as 2006. Total river flows began to taper off in June, July and August on the Snake River. Total river flows on the Snake River during the June - August period were between a daily average flow of 18 and 45 kcfs with a summer average flow of 28. The TDG exceedances that resulted from these flows are discussed in the 3.1.1 Total Dissolved Gas section of this report.

Spring Creek Hatchery Spill
Beginning on March 1st 1400 hr 4.9 kcfs spill occurred at the Bonneville dam through the second powerhouse corner collector (B2CC) as part of the kelt passage study and continued throughout the Spring Creek Hatchery release operation on March 5 through March 9. 6.6 million subyearling fall Chinook smolts were released on March 5, 2007 and 1.2 million on March 9, 2007. The Bonneville B2CC spill continued throughout March to aid adult and juvenile fish passage and resulted in 111 to 116% TDG levels [as measured at Cascades Island fixed monitoring station]. Spring Creek National Fish Hatchery is located in Underwood, Washington upstream from Bonneville dam.

In March 2003, the State of Oregon issued the Corps of Engineers modification to the TDG criteria for spill in order to assist out-migrating threatened and endangered salmon smolts. However, since this action was only in effect from April 1 through August 31, it was not in effect for any potential spill operations associated with the Spring Creek Hatchery Release which typically occurred in March. As a result, the U.S. Fish and Wildlife Service submitted the necessary materials for a TDG rule modification on its own. In March 2004, the State of Oregon granted this modification to the TDG criteria for a 10-day period in March in the years 2004 through 2007.

In March 2004, the State of Washington issued a three year joint adjustment to the Total Dissolved Gas criteria to the Corps of Engineers and the US Fish and Wildlife Service to allowed spill at lower Columbia and Snake rivers to assist downstream migration of juvenile salmonids. Since this waiver was a year-round waiver, any potential increases in TDG levels due to spill operations associated with the Spring Creek Hatchery Release were covered under this action. This action covered spill activities from March 31, 2004 through February 29, 2008.

2.2.1.1 Special Spill Operations
During 2007, there were three special spill operations that varied from the regular spill operations for fish passage as described in the 2007 Fish Operations Plan (FOP). The FOP describes the Corps project operations for fish passage at its Federal Columbia River Power System dams during the April – August 2007 fish migration season. Consistent with the 2004 Biological Opinion adaptive management strategy, this plan incorporates the project operations contained in the “Agreement Regarding 2007 Federal Columbia River Power System Fish Operations” (Agreement). Water management operations not addressed in the Agreement will continue to be consistent with the operations considered in the 2004 Biological Opinion and in particular, the 2007 Water Management Plan and

2007 Fish Passage Plan (FPP). In response to the April 16, 2007 court order, the 2007 Fish Operations Plan (FOP) was developed and used as the guiding document for the spill program. Three of these operations were related to fish passage research studies and the fourth special operation was associated with unit outages. For the research studies, the Corps coordinated through the Anadromous Fish Evaluation Program Studies Review Work Group (AFEP-SRWG), and interacted with NOAA Fisheries to obtain their concurrence. The special spill operations were:

1. Ice Harbor fish survival test
2. McNary fish survival test
3. Turbines Out of Service

Ice Harbor Fish Survival Tests

There was a fish survival test performed at Ice Harbor from April 30th to July 16th with spill alternating between two days of spilling 30% of the total project discharge 24 hours a day and two days of spilling to the 120% spill cap during the night and 45kcfs during the day. The purpose of the fish survival test was to evaluate the performance of the RSW. Some additional spill occurred August 29th in order to test RSW vibration. Spill ended September 1st at 0001 hours.

The test resulted in spill ranging from 15 to 96 kcfs, which produced TDG levels fluctuating between 111 and 120% as shown on the weekly graphs in Appendix C. To find the Ice Harbor graphs, see the April report, Figures 4, 8, 16, and 24. The weekly graphs for May and July at Ice Harbor are Figure 4, 12, 20 and 28 of the May and July reports. The weekly graphs for June at Ice Harbor are Figure 4, 12, 20, and 28 of the June reports. The weekly graphs for August at Ice Harbor are Figure 4, 12, 20, 28 and 36 of the June and August reports.

McNary Fish Survival Tests

There was a fish passage and survival test performed at McNary from June 22th at 600 hours to August 31th with spill alternating between two days of 40% spill for 24hr per day and two days of 60% spill for 24hr per day. The purpose of the spill survival test was to compare the survival when the spill volume is 40% of the river flow vs. 60% of the total river flow. The test resulted in spill ranging from 26 to 150 kcfs which produced TDG levels fluctuating between 110.9 and 119.4% as shown on the weekly graphs in Appendix C. To find the McNary graphs in Appendix E, see the April report, Figures 9, 17, and 25. The weekly graphs for May at McNary are Figure 5, 13, 21, 29 and 37 of the May report in Appendix E. The weekly graphs for June at McNary are Figure 5, 13, 21, and 29 of the June report in Appendix E.The weekly graphs for July at McNary are Figure 5, 13, 21, and 29 of the July report in Appendix E. The weekly graphs for August at McNary are Figure 5, 13, 21, 29 and 37 of the August report in Appendix E. There was only voluntary spill during the test because the powerhouse capacity with the spill was greater than the total project discharge.

Turbines out of service: On a weekly or daily basis, there are unit outages that will affect the spill volume at the projects. To get the daily updates, go to https://npr71.nwd-wc.usace.army.mil/rccweb/RCCLIST/ and click on the BPA Unit Outages. There are ten turbines on the Columbia or Snake River that were out of service for two to ten months and they are:

- Lower Granite: Unit 2 was out of service throughout 2007 spill season due to a damaged rotor and is scheduled to be out of service through April 2008. Unit 3 was out of service from July 2007 and is scheduled to be out of service through April 2008 due to a major rebuild.
- McNary: Units 11 and 12 are scheduled out of service July through September for a transformer replacement.
- John Day - Unit 2 was forced out of service due to major damage. Unit 16 was out of service from April 2007 through 2008 due to internal turbine linkages. Unit 10 was out of service during 2007 spill season and is expected to return to service at the end of 2007.
- The Dalles: TDA U-18 was out of service for a transformer rebuild from May through August.
- Bonneville: Unit 8 was out of service for a turbine rebuild since June 2007 and will remain out of service until 2008. Unit 7 has been out of service since June 2007 and is expected to return to service in 2008.

2.2.1.2 Voluntary and Involuntary Spill

During most spill seasons, there is voluntary and involuntary spill on the Lower Columbia and Snake Rivers even during a low water year like 2001 when the spill was greatly reduced. Table D-12 provides the total outflow (sum of the eight project outflows) for each year with the eight year total outflow average. Based on the total outflow amounts, the 2002 and 2006 water years had high amount of total project discharge and a larger than average amount of involuntary spill. The amount of runoff is the primary factor that determines how much voluntary and involuntary spill will occur, although unit outages can also played an influential role.

Voluntary Spill

During 2007, the vast majority of spill on the Lower Columbia and Snake Rivers was voluntary spill. The FOP spill, voluntary spill occurred from April 3rd to August 31st at the Lower Snake River projects and from April 10th to August 31st at the Lower Columbia projects. Table D-9 in Appendix D provides the exact amount of BiOp/FOP or voluntary spill that occurred at the various projects. Table D-10 provides the total outflow from each project and a total of all the projects were added together.

Involuntary Spill

Involuntary spill didn't occur at the Lower Columbia River projects from April 10th through August 31st. There was involuntary spill at two of the four Lower Snake River projects. The amount of involuntary spill at Ice Harbor had a range of 6.5 to 7.0 kcfs on May 16th. The amount of involuntary spill at Lower Monumental had a range of 16 to 18 kcfs on May 2nd.

The FOP spill tables in Appendix D show the days and amounts that the Lower Columbia and Snake River projects spilled and the appropriate FOP spill levels, which is the theoretical amount of spill that would be generated at a project if there were no physical restrictions to the requested spill regime. As Table D-10 shows, actual spill is usually lower than the theoretical FOP spill because of various factors that limit spill, which were summarized in the FOP spill report tables in Appendix E. Involuntary spill effects the amount of difference between the two. However, the amount of involuntary spill can not be calculated from the difference between BiOp spill and actual spill due to various factors effecting spill.

<u>Involuntary Spill's Effect on TDG:</u>
Spring freshet flows peaked one time with the largest peak during May 9th to May 15th with daily average flows between 281 and 301 kcfs on the Lower Columbia River, which is low compared to previous years. These flows were so low, that no involuntary spill occurred on the Lower Columbia River. There was involuntary spill at Ice Harbor and Lower Monumental between May 2 and 16th. The amount of involuntary spill that occurred was so low that there were no high 12 hour average TDG exceedances due to involuntary spill on the Lower Snake River. No project exceeded the hourly value of 125% TDG. The highest hourly reading was at McNary with 122.0 % as shown on Table F-4 in Appendix F. Graphs of the Snake and Columbia River projects' 12 hours average TDG levels shown in Appendix D illustrate the impact of involuntary spill levels on TDG levels during the freshet period.

<u>Lower Columbia and Snake River Projects Unit Outages</u>
As mentioned in the special operations section 2.2.1.1, there were ten unit outages at five projects that continued between two and 16 months in duration. These unit outages didn't resulted in more involuntary spill though because of the below average water year and the shape of the runoff being gradual.

<u>FOP Spill Amounts Calculated</u>
In 1998, the Corps Reservoir Control Center staff developed a BiOp spill program for daily operational monitoring of BiOp spill and to calculate the amount of BiOp spill that should occurs at the various projects. Since the spill regime at many of the projects change each year, the program that calculated BiOp spill must be modified to calculate the corresponding FOP spill. The amount of FOP spill is shown on Tables D-1 through D-8 and in graphs in Appendix E. For more information, the FOP spill can be compared to the TDG levels shown in Appendix C, which contains graphs of spill, flow, and TDG.

2.2.2 Dworshak Releases
Throughout the year, releases from Dworshak are manipulated for both flow augmentation and temperature control. From mid-September through June, releases from Dworshak are modified to meet the temperature needs of the Dworshak hatchery located approximately two miles downstream. From the beginning of July through mid-September, releases from Dworshak Dam were manipulated to provide flow augmentation and to control temperature of the Lower Snake River, especially Lower Granite tailwater. Appendix I has graphs showing temperatures for the Lower Snake Corps projects. Water releases from

Dworshak Dam for flow augmentation/temperature control began on July 2, 2007 when Dworshak forebay elevation was at 1599.0 ft and continued through September 16, when the forebay elevation of 1519.8 ft was reached.

<u>Flow Augmentation and Temperatures</u>
Dworshak summer flow augmentation and temperature control operations began on July 2nd when it was observed that Lower Granite tailwater temperatures were rising rapidly and was expected to exceed 68^{o} F within a few days. In response, on July 2nd Dworshak releases were increased to 7.4 kcfs with water temperatures between 44.0 – 45.0 ^{o}F. Since Lower Granite temperatures continued to climb; on July 3rd flows were increased to 9.4 kcfs with a water temperature 43 ^{o}F. Due to extreme high temperature conditions of 100^{o}F and more in the Snake Basin and a 5-day travel time for Dworshak cool water to reach Lower Granite, Dworshak outflows were increased to 12.0 kcfs on July 5th. As Figures I-7 and I-9 in Appendix I shows, the 12 kcfs with 43 ^{o}F water temperature releases produced the desired effect of lowering Lower Granites tailwater below 68 ^{o}F. On July 14th, flow augmentation was reduced to 11 kcfs and then was further reduced to 9.6 kcfs on July 15th. Dworshak water temperatures continued to be between 42.8 and 43.0 ^{o}F. The operation of 9.6 kcfs and 43 ^{o}F water released from Dworshak continued until August 11th and produce the desired effects of maintaining the Lower Granite temperature below 68 ^{o}F as Figures I-7 and I-9 in Appendix I shows. The Lower Granite temperatures began to significantly decline; therefore, on August 11th the water temperature of Dworshak releases were raised to 45 to 46 ^{o}F and outflow was reduced to 7.8 kcfs. The Dworshak water temperature began to creep above the 46 ^{o}F on August 20th as the Lower Granite temperatures were declining. The 7.8 kcfs Dworshak outflow continued until September 9th, when it was reduced to 5.5 kcfs and water temperature of 49 to 50 ^{o}F continued. On September 13th outflows were reduced again to 2.4 kcfs and on September 16th, outflows were reduced again to minimum flows of 1.5 kcfs while the lowest possible temperature of 45 ^{o}F was maintained. TMT's request for specific Dworshak release temperatures and outflows were satisfied during the entire flow augmentation and temperature control operation.

The water temperature at Lower Granite tailwater peaked on July 5th at 68.7 ^{o}F, the highest during the 2007 spill season. Lower Granite tailwater temperatures reached 68 ^{o}F on July 5th and 6th and then remained under 68 ^{o}F until August 1st when it once again rose above 68 ^{o}F. The Dworshak 43 ^{o}F water releases arrived at Lower Granite approximately July 8th and exerted a cooling influence on Lower Granite tailwater water temperature maintaining it just below 68 ^{o}F until August 1st. With the high Dworshak flows and cold temperatures, Lower Granite tailwater temperatures exceed the 68 ^{o}F state standard only a total of 31 hours which is low compared to the eight year (2000 to 2007) average of 67 hours. See Tables I-3 and I-4 in Appendix I for more information on Lower Granite temperature exceedances. With cooler weather in August and September, Lower Granite tailwater remained under 68 ^{o}F and began a gradual decline. Figure I-9 of Appendix I provides a graph of Lower Granite and Dworshak temperatures with TMT request dates and Table I-1 provides a list that summarizes the Dworshak operations.

The flow from Dworshak averaged 8.8 kcfs (Table I-2) with a range from 2.4 to 12 kcfs for the augmentation period of July 2nd to September 16th, when project discharge dropped to minimum flow of 1.5 kcfs (Table I-1). The water temperatures of the Dworshak release continued between 42.8 and 43.0 ^{o}F from beginning of flow augmentation on July 2 through August 11th when it began to gradually rise. Because of the early cold water release from Dworshak with aggressive flow rates, the Lower Granite tailwater hourly water temperature exceeded the 68^{o} F State standard for only one day as a 24 hour average as shown on Table I-3 of Appendix I. Figures I-7 through I-9 provides a graphic view of the tailwater temperatures for the Lower Granite with Dworshak release temperature and outflow changes

<u>Operational Trends</u>

There are several operational trends that can be observed and they are:

- The number of days that augmentation occurs has increased over the last eight years. Before 2003, there was an average of 62 days of augmentation and after 2003, there was an average of 78 days. This represents a 16 day longer flow augmentation period compared to 2000 – 2002 periods, due to releases in September as agreed upon in the 2004 BiOp and Nez Perce Tribe's agreement.
- The overall trend towards cooler water being released from Dworshak reservoir for longer periods of time during summer operations continues and has been used as completely as possible. As a result, the seasonal average outflow temperature for Dworshak during the augmentation period has significantly dropped from 47 to 48^{o} F range during the 2000 – 2002 time periods to the 45^{o} F range during 2003 – 2007, refer to Figure I-10.
- The number of cooler days that the Dworshak release temperatures were between 43^{o} to 44^{o} F increased dramatically from eight days in 2004 to 15 days in 2005, 29 days in 2006, and 31 days in 2007; refer to Figure I-11. This confirms the trend toward releasing cooler water from Dworshak Dam.

It is unknown whether releasing cooler water from Dworshak produces a permanent effect on the pool's thermocline. Currently there is not enough historical data from the floating temperature strings, which measure the thermoclines, to draw a conclusion about the long-term reservoir temperatures. The effects from the flow augmentation operation on the overall Dworshak reservoir temperatures will be closely monitored in years to come.

2.2.3 Statistical Evaluation of the SYSTDG Model for 2007

During the 2007 spill season, the RCC Water Quality unit used the SYSTDG model to forecast the TDG levels at the Corps Columbia and Snake River projects for the purpose of setting daily spill caps. The parameters that SYSTDG incorporates into its forecast are total river flow; spill; wind; water temperature; forebay and tailwater elevations; barometric and total gas pressures; and tributary data. The RCC Water Quality unit continued to develop expertise on the effective use of SYSTDG for real time operations. The SYSTDG user's manual written to provide a step-by-step guide on how to use SYSTDG was further refined with additional information on how to use SYSTDG in different real time operations. Based on RCC Water Quality Unit's experiences potential future improvements to the model were identified. In general, SYSTDG worked very well and the RCC Water Quality Unit looks forward to using it during future spill seasons.

Since SYSTDG is a decision support tool that the Corps used to estimate total dissolved gas (TDG) pressures resulting from project operations on the Columbia, Snake, and Clearwater Rivers, it was considered important to establish its accuracy and reliability. In an effort to quantify the uncertainty of SYSTDG estimates and improve modeling accuracy and reliability, a statistical evaluation of the predictive errors was performed on observed TDG levels during the 2007 fish passage season on the Columbia and Snake Rivers. This evaluation was conducted by comparing SYSTDG-calculated total dissolved gas pressures to observed TDG pressures measured by the fixed monitoring stations (FMS) located in the forebays and tailwaters of Corps operated dams within the Columbia Basin. The dams of interest included Bonneville Dam, The Dalles Dam, John Day Dam, McNary Dam, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, Lower Granite Dam and Dworshak Dam.

The RCC Water Quality Unit believes that a statistical evaluation of SYSTDG performance in previous years (2004 through 2007) would be useful to continue to establish the model as a credible tool in managing spill and will help identify areas for future improvements. The following is a short summary of the statistical evaluation for 2007 that Dr. Mike Schneider, research scientist with the Corps of Engineer's Engineering Research Development Center (ERDC) wrote. The full statistical evaluation can be found in Appendix G.

Statistical Evaluation

A statistical evaluation of the predictive errors was performed for the 2007 spill season which spanned from April 1st through August 31st. This evaluation was done by comparing SYSTDG-calculated total dissolved gas pressures to observe TDG pressures measured by the fixed monitoring stations (FMS) located in the forebays and tailwaters of Corps operated dams within the Columbia Basin. The dams of interest included Bonneville Dam, The Dalles Dam, John Day Dam, McNary Dam, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, Lower Granite Dam and Dworshak Dam.

SYSTDG simulations were run one project and river reach at a time so that predictive errors could be calculated independently for each dam and river reach. Predictive errors were calculated by subtracting the observed TDG pressures from calculated forebay or tailwater fixed monitoring station TDG pressures on an hourly basis. The predictive errors were calculated only during active spillway operations at each project at the tailwater FMS. The TDG pressures transported to the forebay of the next downstream dam were used to determine the predictive error during the period from April 15 –August 31 for the Lower Columbia Snake Rivers Projects. A detailed description of model input parameters and coefficients can be found in the SYSTDG user's manual (USACE, 2004). The final predictive errors results are shown on Table 3 and Table 4.

TABLE 3

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at forebay fixed monitoring station									
Parameters		Predictive Error at Forebay FMS* (mmHg)							
Station		LGSA	LMNA	IHRA	MCNA	JDY	TDA	BON	CWMW
Number of Observations		3646	3638	3646	3646	3554	3625	3672	3636
Average		1.5	-17.6	-0.8	4	5.1	2.8	-0.8	1.6
Standard Deviation		18.1	14.9	9.9	9.7	10.6	7.8	7.3	9.5
Maximum		54.8	17.5	31.9	74.8	38.3	37.3	36.4	37.3
Minimum		-48.2	-51.1	-35	-18.2	-16.9	-19.6	-25.6	-25.9
TDG Predictive Error for Percentile Occurrence (mm Hg)	5%	-33	-38.5	-17	-7.9	-9.7	-9.5	-10.9	-9.6
	10%	-25.5	-36.3	-12.7	-5.6	-7.6	-6.9	-8.7	-7.5
	25%	-8.4	-30.4	-7.5	-1.9	-3.6	-2.6	-5.2	-4.6
	50%	2.5	-19.8	-1.1	3.1	4.5	2.4	-1.1	-0.7
	75%	13.4	-4	6.7	8.3	11.9	7.7	3.7	5.1
	90%	23.5	1.8	11.7	13.6	19.8	12.7	7.5	15.6
	95%	29.3	5.2	14.5	17.6	25.2	15.9	9.5	22.8

*Predictive error is the observed minus calculated TDG pressure where negative values reflect an overestimation and positive values reflect an underestimation.

TABLE 4

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at tailwater fixed monitoring stations.											
Parameters		Predictive Error at Tailwater FMS* (mm Hg)									
		DWQI	LGNW	LGSW	LMNW	IDSW	MCPW	JHAW	TDDO	CCIW	WRNO
Number of Observations		248	3324	3622	3341	3447	3672	2468	3648	3672	1462
Average		-1.5	3.2	-11	-4.6	-10.4	7.9	-7.4	-0.3	0	-6.1
Standard Deviation		5.2	13.4	16.4	13.9	12.5	17.8	11.4	13	9.4	8.9
Maximum		15.6	42.8	56	66.2	29.2	103.8	27.7	39.1	57.8	17.5
Minimum		-36.8	-76.9	-92.9	-113.9	-89.4	-36.8	-87.3	-51.7	-58.8	-56.3
TDG Predictive Error for Percentile Occurrence (mm Hg)	5%	-8.7	-14.6	-36.2	-25.7	-30.5	-12	-26	-24.5	-16.2	-20.2
	10%	-7.5	-12.1	-32.3	-21.5	-28.1	-9.1	-20.6	-19.2	-8	-16.9
	25%	-5.3	-6	-24.1	-14.1	-21.3	-4.6	-13.2	-8.3	-3	-11.4
	50%	-1.3	1.1	-11.3	-5.3	-8.1	2.6	-7.2	3	1.4	-6.1
	75%	2.1	8.6	2.8	5.1	-0.1	19.1	-0.8	7.9	4.2	-0.6
	90%	4.2	26.4	10.4	12.8	4.3	31.7	6.5	12.9	6.6	5.2
	95%	5.9	32.4	13.3	17.7	6.9	36.7	11.1	18	9.6	8.3

*Predictive error is the observed minus calculated TDG pressure where negative values reflect an overestimation and positive values reflect an underestimation.

Highlights of Statistical Evaluation

The following are some highlights from the statistical evaluation:

- The applications of spillway operations throughout the basin in 2007 were dominated by voluntary spill operations throughout most of the year. The operational policy involving spilling water on the Snake and Lower Columbia

Rivers during the summer months was continued in 2007 with TDG levels generally within the state water quality standards for TDG during the fish passage season. The spill patterns were modified at a number of projects in 2007 season to evaluate benefits to fish guidance. These unique operations resulted in conditions outside of the normal operating range under which the SYSTDG model was developed. The predictive error was computed by subtracting the hourly estimates of TDG pressure from observed conditions.

- In general, the forebay station comparisons generated smaller predictive errors (See Appendix G, Tables G5 and G6) than the tailwater station comparisons (See Appendix G, Tables G7 and G8). The average predictive errors at forebay stations were less than 1 percent of saturation (7.6 mm Hg) with the exception of John Day and Lower Monumental Dams. The overestimation of forebay TDG pressures at John Day Dam was attributed to misrepresenting the production of TDG conditions at McNary Dam. The larger estimation errors in the forebay of Lower Monumental Dam were largely attributed to estimates misrepresenting TDG production at Little Goose Dam during the use of the uniform spill pattern during the summer. The correlation between strong winds and declining TDG pressure at forebay stations was evident during the 2007 spill season and was an important determinant of calculated forebay TDG levels. In several reaches, the inclusion of alternative weather station data for wind may improve the model results.

- The larger predictive errors determined at the tailwater FMS were likely associated with the TDG heterogeneities generated in spillway flows and monitored at many tailwater FMS, the timing and duration required to establish steady-state TDG levels at monitoring stations, and the application of accurate spill pattern operations. The standard deviation of predictive error at the tailwater stations ranged from 0.7 percent saturation (5.2 mm Hg) at Dworshak Dam tailwater station DWQI to 2.4 percent saturation (17.8 mm Hg) at McNary tailwater station (MCPW). The large errors observed during the month of August at the Little Goose Dam tailwater were associated with the incorrect designation of the applied spill pattern.

- Bonneville Dam operations during the 2007 season incorporated a new spill pattern for flows less than 100 kcfs. These new spill patterns generated more moderate TDG levels than the bulk spill pattern used in 2006. The SYSTDG model over estimates the TDG response at the CCIW station during higher spillway flows. These estimates were based on the average cross sectional response observed in the spillway exit channel during sampling in 2002. The sampling bias evident at CCIW for higher flows is likely to be present under existing conditions because the spill pattern has not changed for flows above 100 kcfs since 2002.

- The spill policy at The Dalles Dam in 2007 called for 40 percent of the river to pass through the spillway. On several occasions this spill policy could not be met because of TDG saturation in the forebay of Bonneville Dam exceeding the TDG criteria of 115 percent. The estimated TDG content in spill releases undiluted by powerhouse flow were generally greater than 120 percent and as high as 126 percent. The tailwater stage elevation and not the spill pattern or discharge is the primary determinant of TDG exchange at The Dalles Dam.

- The spill operations at John Day Dam followed a normal pattern throughout the 2007 fish passage season with daytime spill at 60 percent of river flow in the spring and a continuous 30 percent of river spilled during the summer. The predictions of forebay TDG levels at The Dalles Dam in 2007 were improved through the revision of estimates of powerhouse entrainment at John Day Dam as a percentage of spillway discharge.

- The operations at McNary Dam involved spilling water through two of TSWs throughout the entire fish passage season. The TDG levels at the tailwater station increased in magnitude when spill levels dropped below 80 kcfs. This property was likely related the mixing zone from the TSW releases reaching the north shore during lower spillway discharges. McNary Dam spilled more water than any project except Bonneville Dam on the Columbia River in 2007 but had no incidences of TDG levels exceeding the tailwater 120 percent criteria or the 115 percent criteria at John Day Dam.

- Ice Harbor Dam continues to have the smallest TDG uptake for a comparable spill discharge of any project on the Columbia or Snake Rivers. The combination of spillway flow deflectors with a shallow tailwater channel are thought to account for this property. The operation of the spillway at Ice Harbor Dam in 2007 involved biological testing of the RSW where day to day changes in total spill discharge were often large. However, the variation in the generation of TDG supersaturation was modest in comparison to spill discharge.

- The frequency of hourly TDG supersaturation above 115 percent at the tailwater station below Lower Monumental Dam was the highest of the four Snake River projects. The spill policy at Lower Monumental Dam resulted in the TDG saturation in the Ice Harbor forebay to exceed 115% over 17.1 percent of the time. The predictive of TDG pressures in the Lower Monumental pool were improved in 2007 over previous years. The bulk spill pattern at Lower Monumental Dam contributes to the larger addition to TDG loading of the Snake River when compared to other projects.

- The 2007 spill patterns at Little Goose Dam included both a bulk and uniform pattern. The bulk spill generated significantly higher TDG levels when compared to the uniform pattern. The small rates of spill coupled with the uniform spill pattern during the summer resulted in small changes to the TDG loading in the Snake River. In several instances, spill operation at Little Goose Dam lowered the TDG levels in the Snake River.

- The spillway operations at Lower Granite Dam featured the prominent use of the raised weir crest and continuous spill using the standard and bulk spill patterns during the summer months. The bulk spill pattern resulted in higher TDG levels when compared with the standard pattern. Both spill patterns resulted in tailwater TDG levels below the spillway capacity as limited by the 120 percent criteria.

- Project releases through the regulating outlet were limited at Dworshak Dam during the 2007 spill season were scheduled to support temperature management activities in the Snake River during July. The mixing zone between powerhouse flow and spill is well developed at the tailwater FMS in the North Fork of the Clearwater River. The TDG content in RO flow of 2.2 kcfs was estimated to exceed 120% prior to mixing with powerhouse release.

- The reliability of the SYSTDG model continues to improve as a wider range of operations, structural configurations, and environment events are sampled at fixed monitoring stations. The reliability of the SYSTDG model also continues to improve as in site specifics TDG exchange studies using an array of remotely logging sensors occur. In some cases, the TDG response at a singular point of sample does not reflect past trends of TDG exchange at a project. Without additional data, it is impossible to determine if the observed TDG response is representative of spillway flows or a consequence of a localized processes resulting in a biased sample.

Future Improvements Identified

The following improvements to the SYSTDG model are recommended for the next year.

- The description of TDG exchange at all projects within the study area should be updated to reflect the current spill patterns and structural configurations.

- The objective of tailwater fixed monitoring stations is to accurately reflect aggregate TDG exchange in spillway releases. As major changes to spillway structures and spill patterns are implemented, site specific field studies should be conducted to quantify the TDG exchange and degree of sampling bias at these monitoring locations.

- The SYSTDG decision support system will continue to improve the ability to handle alternative spill patterns into predictions of TDG loading in the Columbia River basin.

- Continue to update and document model parameters and programming tools needed to maintain the database and workbook.

- The inclusion of a daily TDG metrics involving the highest 12 consecutive hourly observations in a day as required by the State of Washington should be incorporated into the workbook.

- The data quality control and assurance tools should be put into practice. A data screening program has been developed to help identify erroneous data.

- The uncertainty of TDG predictions should be factored into a risk based management policy for spill.

- The identification of consistent sampling bias at tailwater fixed monitoring stations should be documented and incorporated into management activities.

Part 3 Program Results

3.1. Total Dissolved Gas

Operation of the Federal Columbia River Power System to meet multiple purposes often necessitates spill operations that can result in exceedances of state water quality standards for TDG. The Corps, in accordance with the NOAA Fisheries Biological Opinion and FPIP, provides voluntarily spills for fish passage. In addition, spill at Corps projects occurs when there are physical or mechanic circumstances that necessitate it. For instance, when powerhouse capacity is exceeded, the intertie lines need repair, or unit outages, water is released through the spillway resulting in increased TDG levels.

The NOAA Fisheries 2004 BiOp and FOP applicable voluntary spill for fish program was implemented consistent with the State water quality standards waiver or rule modifications. During spill season, adjustments, when necessary, were made to the upstream project spill levels to maintain the average of the 12 highest values in 24 hours in project forebays at less than 115% TDG and the average of the 12 highest values in 24 hours in project tailwaters at less than 120%.

Changes in the Fixed Monitoring System

There were several noteworthy changes to the Corps TDG fixed monitoring system during previous years that were not documented in the narrative of the annual reports and during 2007. These changes were:

- Moved Albeni Falls tailwater to new location 2005
- Change of re-calibration interval for the Lower Columbia River gages in 2006
- Change of re-calibration interval for the Lower Snake River gages during 2007

The original tailwater station at Albeni Falls Dam (ALFW) had data quality problems caused by shallow water and bed load movement in the vicinity of the station. As a result, the tailwater station was moved during the 2005 monitoring season about 1 mile farther upstream towards the dam to a deeper location at the end of July and is now called ALQI.

In 2006, the Portland District Corps of Engineers changed the re-calibration interval from every two weeks to every three weeks for the Lower Columbia River gages that are used during the spill season. The Lower Columbia River winter time monitoring system gage re-calibration interval was changed from every two weeks to every four weeks. The change in gage re-calibration interval did not result in a reduction of data quality accuracy as documented in Appendix K.

In 2007, the Walla Walla District Corps of Engineers changed the re-calibration interval from every two weeks to every three weeks for the Lower Snake River gages that are used during the spill season. The Lower Snake River winter time monitoring system gage re-calibration interval was changed from every two weeks to every four weeks. The change in gage re-calibration interval did not result in a reduction of data quality accuracy as documented in Appendix J.

115% and 120% Total Dissolved Gas Exceedances

The Corps tracks the number and type of high 12 hour average TDG exceedances during spill season. During the 2007 spill season, Washington and Oregon state TDG criteria were exceeded 99 days at the projects on the Lower Columbia and Snake rivers out of a possible 2504 days ([number of TDG gages] x [days in spill season, 3 April through 31 August]). The 99 high 12 hour average TDG exceedances are far below the 239 nine year average TDG exceedances for a spill season. Table 5 provides a summary of TDG exceedances during 1999-2007 spill seasons. The 99 high 12-hour averages of TDG exceedances during 2007 spill season include only voluntary TDG exceedances.

In 2003, the Corps was requested to track the causes of high 12 hour average TDG exceedances so fourteen causes was identified which are shown on Table 1 of Appendix F. The TDG exceedances were classified during 2003 through 2007 spill seasons and the results are shown on Table 7. During 2007, there were a very few hours of involuntary spill; and as a result, there were no TDG exceedances attributed with the cause of "Exceedance due to high runoff flows and flood control efforts" which was classified as exceedance type # 1. Appendix F Table F-2 shows the TDG exceedance type during 2007. No #1 TDG exceedance type is primarily because of low river flows and the shape of the runoff being gradual. Appendix F Table F-3 provides the total number of TDG exceedances types at each project. The forebay TDG exceedances varied from 115.1 to 118.1%. The tailwater TDG exceedances varied from 120.1 to 121.5%.

TABLE 5
1999 - 2007 SPILL SEASONS
NUMBER OF TDG EXCEEDANCES
HIGH 12 HOUR AVERAGES

	2007	2006	2005	2004	2003	2002	2001	2000	1999
Water Quality Gages	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**
Lower Granite Forebay *	0	0	0	0	0	0	5	2	0
Lower Granite Tailwater	0	28	0	0	15	17	0	4	15
Little Goose Forebay *	0	24	0	3	10	17	0	2	39
Little Goose Tailwater	0	19	0	0	6	6	0	9	6
Lower Monumental Forebay *	11	56	6	1	19	49	0	28	44
Lower Monumental Tailwater	7	29	7	1	10	6	0	12	26
Ice Harbor Forebay *	31	51	3	4	35	24	0	34	44
Ice Harbor Tailwater	0	22	3	2	4	6	0	4	12
McNary Forebay - Wa. *	6	31	8	10	24	43	1	14	22
McNary Forebay - Or.	--	--	11	23	32	45	5	22	19
McNary Tailwater	1	32	1	7	12	31	0	17	50
John Day Forebay	0	20	2	0	10	11	0	1	8
John Day Tailwater	3	38	3	0	0	29	0	12	43
The Dalles Forebay	8	40	6	5	11	18	0	5	1
The Dalles Tailwater	0	10	0	0	4	11	0	5	5
Bonneville Forebay	3	51	3	1	17	30	0	14	19
Cascade Island	0	61	0	---	---	---	---	---	---
Warrendale	--	--	---	0	1	19	0	6	2
Camas/Washougal	29	63	16	14	33	65	2	58	51
Total Number of Exceedances	**99**	**575**	**69**	**71**	**243**	**427**	**13**	**249**	**406**

As Table 5 shows, the Ice Harbor forebay, Camas/Washougal, and Lower Monumental forebay FMSs had the highest number of high 12 hour average TDG exceedances during 2007 and were the most difficult to maintain below the 115% or 120% TDG standard. The Ice Harbor forebay station recorded 31 TDG exceedances, the most TDG exceedances of the FMS system monitoring stations during 2007. The Camas/Washougal gage had 29 TDG exceedances, which was the second most in the FCRPS system. Camas/Washougal is typically a location that records a higher number of exceedances than other FMS locations. The Lower Monumental forebay station recorded 11 TDG exceedances, the third most TDG exceedances of the FMS system monitoring stations. For further discussion of the individual gages that have high TDG exceedance, see section 3.1.2 through 3.1.7 of this report.

125% Total Dissolved Gas Exceedances

During the 2007 spill season, there were zero hourly TDG exceedances of the Oregon or Washington state standards of 125% TDG (a one hour standard in Oregon and a two hour standard in Washington.) 2007 is the fourth year with no 125% hourly exceedances since tracking of the hourly exceedances began in 2001 as Table F-5 in Appendix F shows.

Comparison of Annual Exceedances

Spill season involves spilling water for migrating fish which is considered “voluntary”, but in years with high flows, there is involuntary spill as well and as a result, most spill seasons have TDG exceedances from voluntary and involuntary spill. Table 5 provides a summary comparison of the total number of voluntary and involuntary spill related TDG exceedances for 1999 through 2007. As shown on Table 5, the 1999 – 2007 nine year average of TDG exceedances during a spill season is 239 exceedances. The 2007 spill season occurrence of 99 TDG exceedances is 41.4% of the nine-year average. This “very low” number of TDG exceedance is attributed to low flows and the shape of the runoff. The percent of normal runoff at The Dalles was in the “below average” range with 89 percent of normal (1971-2000). The runoff for the Snake River was 63% of average (1971-2000) at Lower Granite.

TABLE 6
SUMMARY COMPARISON OF TDG EXCEEDANCES WITH PREVIOUS YEARS

Year	Days In Spill Season	Number of Days	Percent Exceeding TDG Standard (%)	Percent Consistent With TDG Standard	% of Normal runoff at TDA [1]
2007	2504	99	4.0	96.0	89.2
2006	2504	575	23.0	77.0	131.4
2005	2754	69	2.5	97.5	93.5
2004	2754	71	2.6	97.4	95.3
2003	2754	243	8.8	91.2	100.8
2002	2754	427	15.5	84.5	119.3
2001	2754	13	0.5	99.5	66.9
2000	2754	249	9.0	91.0	112.7
Average	**2692**	**218**	**8.2**	**91.8**	**101.1**
[1] The Dalles Jan-Juj Avg (1971-2000) =107.3 MAF					
Note: Number of spill days are based on 18 gages X 153 days from April 1 - August 31					
(except 2006 & 2007 had 17 gages and spill season started Apr 3 for Snake R and April 10 L.Col R).					

Type of TDG Exceedances

The type of TDG exceedances for the forebay and tailwater of each Corps project was tracked daily during the 2007 spill season. The Corps Reservoir Control Center used the previous year's list of TDG exceedance type definitions shown on Table 2 in Appendix F and applied them to the 2007 spill season. The types of exceedances represent conditions that caused TDG exceedances and are shown on Table 6. Table 6 also provides a summary of the types of exceedances tracking results from 2003 through 2007 spill seasons. A more detailed list of when and where the exceedance types occurred is provided in Table F-2 in Appendix F. The exceedance type designation given to each TDG exceedance is based on the Corps subjective determination of causation.

During the 2007 spill season, TDG exceedances were attributed to three causes: the uncertainties associated with applying the spill guidance criteria (93 exceedances), high TDG levels coming from the Mid Columbia River Dam (5 exceedances); and unit outages during repair or maintenance (1 exceedance). The vast majority (94%) of the 99 TDG exceedances were caused by the uncertainties when using best professional judgment to apply the spill guidance criteria.

Certain trends can be observed from the 2003 – 2007 TDG exceedances tracking data. For example, as Table 7 shows, there are two kinds of exceedances usually involved in the high number of exceedances: exceedance type 6 (uncertainties associated with applying the spill guidance criteria) and exceedance type 1 (high runoff and flood control efforts). Table 7 also shows that 2007 is the first year in the five years we have recorded exceedance types that there were no type 1 exceedance which emphasizes how unusual this occurrence is. Because the shape of the runoff was gradual and runoff was 89 % of normal for the region, the flows were relatively low during the freshet, resulting in very little involuntary spill.

TABLE 7
2003-2007 SPILL SEASONS
TYPES AND NUMBERS OF TDG EXCEEDANCES

5 Year Totals	2007	2006	2005	2004	2003	TYPE #	DEFINITION
389	0	306	11	4	68	1	Exceedance due to high runoff flows and flood control efforts.
0	0	0	0	0	0	2	Exceedance due to Intertie line outages.
46	1	45	0	0	0	3	Exceedance due to unit outages during repair or maintenance.
109	0	106	3	0	0	4	Exceedance due to BPA inability to handle load so water was spilled.
1	0	0	0	0	1	5	Exceedance due to a break down in communication. Teletype went out but no change occurred or Project operator interpreted teletype differently than what was intended.
316	93	69	32	16	106	6	Exceedance due to uncertainties when using best professional judgment to apply the spill guidance criteria (travel time; degassing; water temperature effects; spill patterns).
67	5	29	15	0	18	7	Exceedance due to high TDG levels coming from the Mid Columbia River Dam (see Pasco FMS readings).
3	0	0	0	3	0	8	Exceedance due to high TDG levels coming from the Snake River projects (see Ice Harbor Dam FMS readings).
0	0	0	0	0	0	9	Exceedance due to a load rejection. The powerhouse was not working and the river was spilled.
15	0	1	1	6	7	10	Exceedance due to lack of information: the FMS gage malfunctioning and we had no information at the time of making spill change decisions.
9	0	0	0	0	9	11	Exceedance due to mechanical problems (gate was stuck open, passing debris etc.).
55	0	3	7	25	20	12	Exceedance due to sharp rise in water temperature (a 3 degree F. or greater change in a day).
43	0	3	0	7	33	13	Exceedance due to bulk spill pattern being used which generated more TDG than expected.
13	0	13	0	0	0	14	Exceedance due to non-functioning of flow deflectors during tailwater elevation above 19 ft and especially above 26 ft.
1076	**99**	**575**	**69**	**71**	**262**		**Totals**

3.1.1 Recurring High TDG Exceedances

There were two locations that were difficult to avoid TDG exceedances from voluntary and involuntary spill, leading to high recurring TDG exceedances in 2007. As the 2007 data in Table 5 shows, there were high recurring exceedances at Ice Harbor forebay and Camas/Washougal gage. These two FMS sites typically have high TDG exceedances which are usually attributed to high flows, and unit outages. But this year, there were TDG exceedances at these FMS without high flows or a large number of unit outages at the upstream project that caused involuntary spill. It is for this reason that the vast majority of the TDG exceedances were attributed to uncertainties when using best professional judgment to apply the spill guidance criteria which includes travel time; degassing; water temperature effects; and spill patterns.

A review of the 1999-2007 TDG exceedances summarized on Table 5 highlights that the Ice Harbor forebay and Camas/Washougal gages have a history of recurring TDG exceedances. From a historical perspective, these two gages have the highest total number of TDG exceedances over the last nine years. Ice Harbor forebay had the most exceedances during 2007 with 31 TDG exceedances. Historically, Ice Harbor forebay has the second most TDG exceedances over the 1999 – 2007 period with 226 while Lower Monumental forebay is a very close third with 214 TDG exceedances. Camas/Washougal had the second most TDG exceedances during the 2007 spill season with 29 TDG exceedances but the most during the last nine years (1999 – 2007) with 331 total TDG exceedances. As Table 5 shows, the other gages' total numbers of TDG excceedances over the last nine years (1999 – 2007) are far less than these two gages' except for Lower Monumental forebay.

3.1.2 Ice Harbor Forebay

As shown on Table 5, the Ice Harbor forebay, had 31 days of exceeding the 12 hour average for TDG, the most TDG exceedances for the FMS system during the 2007 spill season. Historically, Ice Harbor forebay is among the top TDG exceedance FMS site locations as Table 5 shows, and the frequency of exceedances of 115% (12hr daily average) at Ice Harbor forebay was similar to Lower Monumental forebay. This suggest that the high TDG water coming from Lower Monumental dam plays a role in increasing the difficulty in managing the Ice Harbor forebay's TDG exceedances. The cumulative impacts of spill operations on the Snake River also contribute to the higher TDG in the river as you move downstream.

3.1.3 Camas/Washougal

Historically, Camas/Washougal FMS site has had a high number of TDG exceedance and the 2007 spill season continued in this trend. As shown on Table 5, the Camas/Washougal site had 29 days of exceeding the 12 hour average for TDG, the second most TDG exceedances for the FMS system during the 2007 spill season. The Camas FMS represents a theoretical forebay in the lowest reach of the Columbia River. Because the Camas FMS is located in a shallow open river reach, it responds more quickly to environmental influences such as gorge winds, barometric pressures, changes in daily solar radiation, and swings in water temperatures. Production of oxygen by aquatic plants is also believed to be involved in causing diurnal variations in TDG. Consequentially, these factors contributed to the difficulty in making adjustment on how much to spill at Bonneville and still remain at or below the 115 percent TDG limit at Camas/Washougal. The TDG exceedances at this gage are usually classified as type 6 exceedances: "uncertainties associated with applying the spill guidance criteria". This year, all of the TDG exceedances at the Camas gage were classified as a type 6. For 100% of TDG exceedances to be classified as type 6 is high compared to other years. This is high compared to the five year average of 70 %. For instance, in 2006, 24% of the TDG exceedances were classified as type 6, in 2005, 15 of the 16 TDG exceedances or 94% were, in 2004 seven of the 14 TDG exceedances or 50 % were and in 2003, 27 of the 33 TDG exceedances or 82% were classified as type 6.

3.2 TDG Monitoring Results

3.2.1 TDG – Average of the High 12 values in 24 hours

Consistency with state water quality standards for TDG in Oregon and Washington is based on the calculation of the average of the 12 highest values in a 24-hour period. Consistency with state water quality standards for TDG in Idaho is based on the instantaneous TDG level not exceeding 110%.

Appendix E contains graphs of the high 12 hour average TDG values for each monitoring station for the 2007 spill season. The graphs also include representation of the applicable standard (110% for Idaho stations, and Oregon and Washington forebays at 115% or tailwaters at 120%).

As shown on Table 5, there were a combined total of 99 exceedances of the average of the high 12 values in 24 hour measured at the FMS on all Columbia and Snake Rivers projects. There were eight gages with no TDG exceedances during the 2007 spill season. As the Table FA and FB shows, 93 of the 99 TDG exceedances were classified as type 6 TDG exceedances which are 94% of the total TDG exceedances.

3.3 Water Temperature

This report contains three appendices that summarize or use water temperature data: Appendix H shows hourly water temperatures in the forebays and the tailwaters of the Corps projects and Appendix H has Table H-1 which shows the number of days that 68^{o} F is exceeded on a daily average and for one hour or more at the Corps projects. Appendix I contains graphs of Dworshak and Lower Granite water temperatures with a summary of the Dworshak spill operations. Appendix E contains temperature graphs that were in the court reports.

The NOAA Fisheries 2004 BiOp calls for cold-water releases from Dworshak reservoir. These releases are to reduce and/or maintain cooler water temperatures in the Snake River in the July through September time period when ambient conditions would typically cause the temperature to rise above 68^{o} F. As discussed in 2.2.2 Dworshak Releases, the Corps achieved the objective of drafting Dworshak from 1600 ft elevation to 1520 ft between July and mid-September for water temperature reductions and flow augmentation on the Snake River. As discussed in Appendix I, the cold-water releases produced the desired effect of reducing and maintaining cooler water temperatures on the Snake River.

The water temperature standards for the states of Idaho, Oregon, and Washington are shown below in Table 8.

TABLE 8
State Water Quality Standards
The Lower Snake Projects

Projects	Washington Standard	Idaho Standard
Lower Granite Dam, Snake River, RM 107.5 **AND** Little Goose Dam, Snake River, RM 70.3 **AND** Lower Monumental Dam, Snake River, RM 41.6 **AND** Ice Harbor Dam, Snake River, RM 9.7	"Temperature shall not exceed 20° C (68 F) due to human activities. When natural conditions exceed 20° C (68 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F) nor shall such temperature increases, at any time exceed t=34/(T+9)." WAC 173-210A-130(98)(a)	Lower Snake – Asotin (Idaho/Oregon border) to Lower Granite Dam pool, Hydrologic Unit Code (HUC) 17060103, Rule Section 130.02. Aquatic Life: COLD (Cold Water Communities) "Water temperatures of twenty-two (22) degrees C or less with a maximum daily average of no greater than nineteen (19) degrees C."

TABLE 8
State Water Quality Standards
The Lower Columbia River Projects

Project	Washington Standard	Oregon Standard
McNary Dam. Columbia River, RM 292.0 **AND** John Day Dam, Columbia River, RM 215.6 **AND** Bonneville Dam, Columbia River, RM 146.1 **AND** The Dalles Dam, Columbia River, RM 191.5	"Temperature shall not exceed 20° C (68 F) due to human activities. When natural conditions exceed 20° C (68 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F) nor shall such temperature increases, at any time exceed 0.3 C (0.5 F) due to a single source or 1.1° C (2.0 F) due to all such activities combined." WAC 173-210A-130(20)	From June 1 to September 30, "To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable (defined as 0.25° F) surface water temperature increase resulting from anthropogenic activities is allowed:… (ii)when surface water temperatures exceed 68° F (20.0° C)." (OAR 340-041-0205(2)(b)(A). From October 1 to May 31, , "To accomplish the goals identified in OAR 340-041-0120(11), unless specifically allowed under a Department-approved surface water temperature management plan as required under OAR 340-41-026(3)(a)(D), no measurable (defined as 0.25° F) surface water temperature increase resulting from anthropogenic activities is allowed:…(iii) In waters and periods of the year determined by the Department to support native salmonid spawning, egg incubation, and fry emergence from the egg and from the gravels in a basin which exceeds 55° F(12.8° C)…" (OAR 340-041-205(2)(b)(A).(v) In water determined by the Department to support or to be necessary to maintain the viability of the native Oregon bull trout, when surface water temperatures exceed 50.0°F (10.0°C);

Part 4 Fish Passage Summary

4.1 Biological Monitoring

The spill cap levels recognized in the FOP plan, and consistent with state and tribal water quality variances, are: a daily average (based on the12 highest hours) of 115 percent in the project forebays, a daily average (based on the 12 highest hours) of 120 percent in the project tailwaters, and a maximum high 2-hour average of 125 percent anywhere in the river. The NOAA Fisheries 2004 BiOp and the state TDG variances call for biological monitoring for Gas Bubble Trauma Disease, which the Action Agencies performed in accordance with RPA action 131.

The monitoring of juvenile salmonids in 2007 for gas bubble trauma (GBT) was conducted at Mid Columbia, Lower Columbia and Snake River sites. Fish were collected and examined for signs of GBT at Bonneville Dam and McNary Dam on the Lower-Columbia River, and at Rock Island Dam on the Mid-Columbia River. The Snake River monitoring sites were Lower Monumental Dam, Little Goose Dam, and Lower Granite Dam. Prior to 2005, monitoring was conducted at all sites during the spring spill season and at Mid Columbia and lower Columbia River sites during the summer spill program. However, beginning in 2005 summer monitoring at the Snake River sites started as a result of the Court ordered summer spill program. This year summer spill in the Snake River occurred from June 20, 2007 until August 31, 2007.

In all, 13,054 juvenile salmonids were examined for GBT between April and August of 2007 (See Table M2 of Appendix M). Fin signs were found in 319 or 2.4% of the fish sampled at all sites (see Table 3 of Appendix M). Four fish were found with severe fin signs (rank 3 or higher) while, 47 and 268 fish had less severe fin signs of rank 2 and 1, respectively. Table M4 of Appendix M compares the 2007 estimates of the overall percentage of fish with signs of GBT to past years' estimates.

The Biological Opinion Spill Program was managed using the data collected for total dissolved gas (TDG) levels. However, signs of GBT in fins of juvenile fish, examined as part of the biological monitoring, were used to complement the physical monitoring program. NOAA Fisheries originally established the action criteria for the biological monitoring program at 15% prevalence of total fish having fin signs **or** 5% with severe signs (rank 3 or greater) in fins. At times these criteria were exceeded in 2007. The criteria were exceeded in the Snake River at Little Goose Dam during early and mid-June and again in late July. The criteria were also exceeded at Lower Monumental Dam sporadically throughout June and July.

In past years' the Snake River GBT sampling program typically ended on June 20th (or earlier) since, until 2005, there was no summer spill program at the fish transportation sites in the Snake River. In the few years of monitoring at the Snake River projects since 2005 it has been observed that typically the incidence of GBT in steelhead tends to increase slightly towards the end of the season, although not to the degree that occurred in 2007. The question then arose as to why the higher incidence was being observed in 2007.

In an effort to understand the implications of the increase in incidence of Rank 1 signs of GBT, the frequency of monitoring was increased at Little Goose and Lower Monumental dams. During this time the projects were requested to initiate the collection of subyearling Chinook for GBT monitoring, as their passage numbers had begun to increase.

Table M5 in Appendix M shows the percent GBT for steelhead at Little Goose Dam and Table M6 in Appendix M shows that data for Lower Monumental Dam. Three things can be noted regarding the observations:

- An increased proportion of steelhead smolts were observed with mostly Rank 1 signs of GBT, but at the same time very few subyearling migrants exhibited signs of GBT.
- The goal of obtaining 100 individuals of the predominate species was often not achieved.
- With the exception of the first June observation at either site, the TDG levels observed in the forebays were below the state and federal standards of 110% and not within the range of the waiver standards.

From the data it was apparent that the late migrating juvenile steelhead were disproportionately displaying the signs of GBT. The Salmon Managers were addressing a situation that affected the tail end of the steelhead migration, where water quality standards were not being exceeded, and where there was a desire to maintain protection for the increasing subyearling population. Given the low TDG levels at the projects the Salmon Managers investigated the potential causes of this occurrence from a project operations and migration conditions perspective.

Historically steelhead smolt passage at Lower Granite Dam peaks in early May (50% passage date) with over 90% of steelhead migrants passing by late May, which was the migration pattern exhibited in 2007 (See Figure M2 in Appendix M).

In general, the incidence of GBT in migrating salmonids was low in 2007, with the exception of a short time period in the Snake River where higher incidence of mostly Rank 1 GBT signs were observed among late arriving steelhead. The higher levels were observed for steelhead smolts passing in the tail of the migration (>95% passed) when TDG levels were generally below the 110% standard for TDG in the forebay of the projects where fish were sampled. From the observations presented above, it is clear that the high incidence of GBT among steelhead juveniles in 2007 was likely due to the prolonged exposure to non-lethal TDG due to longer travel times, as a result of low flows in the Snake River. Finally, according to survival studies conducted by NOAA Fisheries juvenile steelhead survival in 2007 was comparable to the high levels of survival observed in 2006 and among the highest observed in recent years.