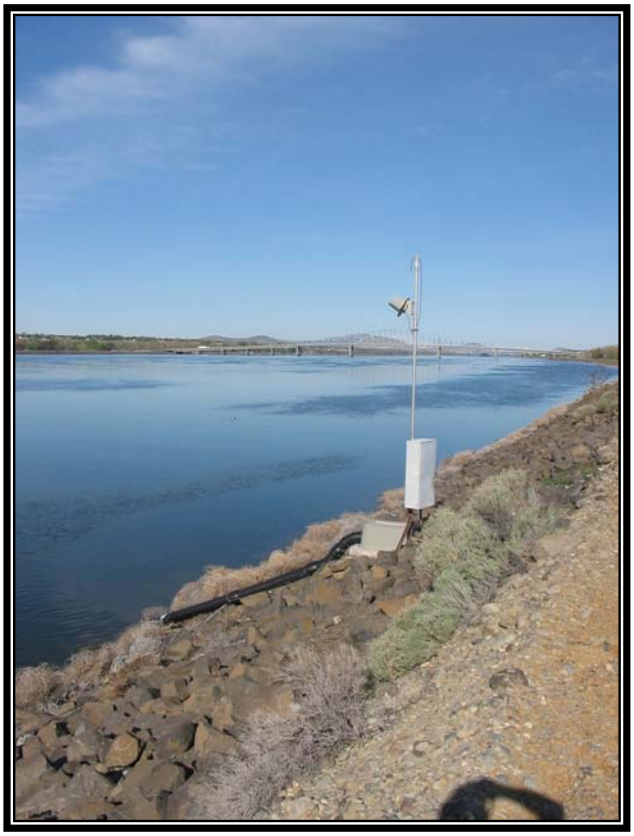
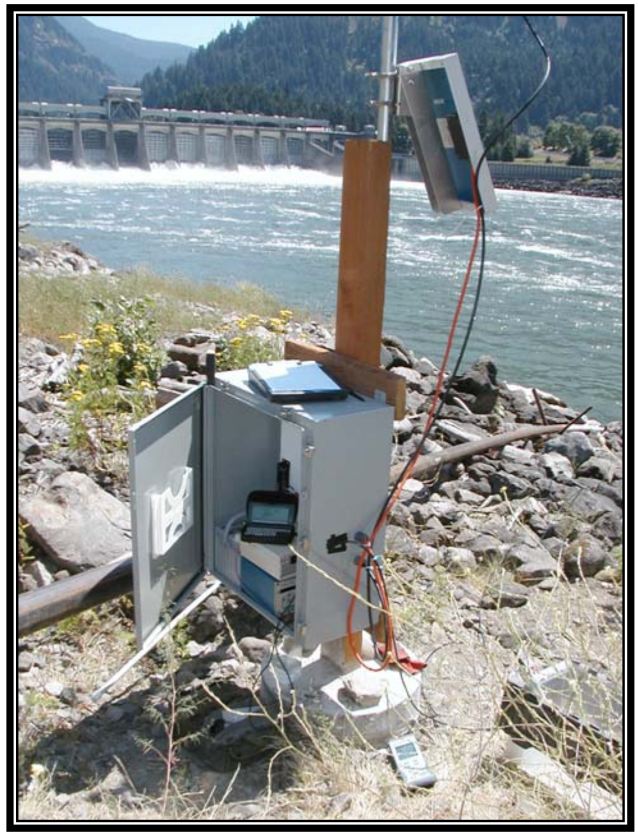
US Army Corps of Engineers
Northwestern Division

2005 DISSOLVED GAS AND WATER TEMPERATURE MONITORING REPORT

COLUMBIA RIVER BASIN



Pasco TDG Monitoring Station



Cascades Island TDG Monitoring Station

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

December 2005

DEPARTMENT OF THE ARMY
NORTHWESTERN DIVISION, CORPS OF ENGINEERS
P.O. BOX 2870
PORTLAND, OREGON 97208-2870

Reply to
Attention of:

DEC 23 2005

Columbia Basin Water Management Division

Dear Interested Party:

Enclosed is the U.S. Army Corps of Engineers 2005 Dissolved Gas and Temperature Monitoring Report, Columbia River Basin. It was prepared to describe operation of the Corps' mainstem projects on the Columbia and lower Snake River and reports on total dissolved gas and water temperature for 2005.

Please contact Mr. James Adams, (503) 808-3938, if you have any questions or comments.

Sincerely,

Cathryn L. Hlebechuk

Cathryn L. Hlebechuk, P.E.
Chief, Reservoir Control Center

Enclosure

2005 DISSOLVED GAS AND WATER TEMPERTURE MONITORING REPORT

COLUMBIA RIVER BASIN

December 2005

Water Quality Unit
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)
Walla Walla District – U.S. Geological Survey (Pasco Office)
Seattle District – Columbia Basin Environmental.
Corps of Engineers' Engineering Research and Development Center
Fish Passage Center

2005 DISSOLVED GAS AND WATER TEMERATURE 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
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 Agency, Fisheries (Formerly NMFS)
PUDs = Public Utility Districts
RO = regulating outlet
ROCASOD = Record of Consultation and Summary 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 Daily Maximum 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 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 2005 Water Management Plan.

Voluntary Spill: Passing water through a project (either over the spillway or through regulating outlets (RO's)) to assist juvenile salmon passage past dam projects in the Lower Columbia and Lower Snake rivers. 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 FCRPS. Spill, as a fish passage strategy, has 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.

Another reason for voluntary spill is for flow augmentation. The National Oceonographic 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 these 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 above average water supplies exceeds the available market, especially during light market hours at night and on weekends.

Other causes for involuntary spill include management of reservoirs for flood control, 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 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; US 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

1.1 CLEAN WATER ACT AND ENDANGERED SPECIES ACT

1.1.1 General

This report describes the Corps' Columbia River Basin Water Quality Monitoring Program for 2005 and was developed to meet the Corps 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.

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

The Corps' water quality monitoring program at these dams performs two functions:

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 US 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. Both TDG and water temperature 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).

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

The 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 releases 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 to a level of 120% TDG where state rule modifications, variances or waivers had been provided. This spill level has become an annual operation for the benefit of listed juvenile fish.

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&W Biological Opinion

The Final 2000 NOAA Fisheries and FWS Biological Opinions states: “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.”

USFWS 2000 BiOp

According to the USFWS 2000 BiOp, 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 (FCRPS).

NOAA Fisheries 2000 and 2004 BiOp's

The NOAA Fisheries 2000 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 court 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 Opinions in 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 BiOp and UPA were refined in response to comments received on NOAA Fisheries' draft Biological Opinion.

In June 2005, Judge James Redden of the Oregon Federal District Court granted a preliminary injunction requested by plaintiffs in NWF v. NMFS and ordered the U.S. Army Corps of Engineers (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.

The NOAA Fisheries 2000 and 2004 Federal Columbia River Power System (FCRPS) biological opinions (BiOps) call for spring and summer spill for fish, but no summer spill at the Lower Granite, Little Goose, Lower Monumental, and McNary dams. Instead, the BiOp calls for maximum collection and transport of juvenile fish at those dams in the summer.

The June 20 court order directed the Corps to spill for fish as follows:

1. From June 20, 2005 through August 31, 2005, spill all water in excess of that required for station service, on a 24-hour basis, at the Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams on the lower Snake River; and
2. From July 1, 2005 through August 31, 2005, spill all flow above 50,000 cubic feet per second, on a 24-hour basis, at the McNary Dam on the Columbia River.

A result of the additional spill was relatively more fish left to migrate in-river and less fish transported. The judge encouraged regional parties to discuss issues and reach consensus on how to implement the court-ordered spill operation. The Corps, working with the plaintiffs and others through existing Regional Forum committees, addressed a number of implementation issues, including:

- A decision to operate the powerhouse turbines at the low end of 1 percent peak efficiency.
- Operating consistent with the total dissolved gas (TDG) levels provided by Washington and Oregon. The daily 12-hour maximum allowable TDG level is 120 percent in the tailrace of each dam, and 115 percent in the forebay of the next dam downstream.
- A decision to operate the project pools to manage gas levels rather than meet loads.
- Reducing spill and then adjusting the spill pattern at Little Goose Dam to compensate for disruption of adult passage that occurred from June 20 to July 1.

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>
OAR 340-041-0031(2): Total Dissolved Gas. 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.

In a letter to the Oregon Department of Environmental Quality (ODEQ) dated December 28^{th}, 2002, the Corps of Engineers requested a variance to the State's water quality standard for dissolved gas. In response to this request, the Oregon Environmental Quality Commission (OEQC) met on March 11^{th}, 2003 met to consider this request, justification, and public comment. At this meeting, the OEQC approved, under Oregon Administrative Rules (OAR) 340-41-205, 445, 485, and 525(2)(n) [340-041-0061 and 340-041-0104 under current OAR's], a modification to the Total Dissolved Gas standard for spill over McNary, John Day, The Dalles, and Bonneville dams on the Lower Columbia River subject to the following conditions:

(i) A revised total dissolved gas standard for the Columbia River for the period from midnight on April 1 to midnight on August 31;

(ii) The revised criteria will apply for 2003, 2004, 2005, 2006, and 2007.

(iii) a total dissolved gas standard for the Columbia River of a daily (12 highest hours) average of 115 percent as measured in the forebays of McNary, John Day, The Dalles, and Bonneville dams, and at the Camas/Washougal monitoring stations;

(iv) a cap on total dissolved gas for the Columbia River during the spill program of 120 percent measured in the tailraces of McNary, John Day, The Dalles, and Bonneville dams' monitoring stations based on the highest 12 highest hourly measurements per calendar day; and

(v) A cap on total dissolved gas for the Columbia River during the spill program of 125 percent, based on the highest two hours during the 12 highest hourly measurements per calendar day during these times;

(vi) a requirement that if 15 percent of the juvenile fish examined show signs of gas bubble disease in their non-paired fins where more than 25 percent of the surface area of the fin is occluded by gas bubbles, the Director will terminate the variance; and

(vii) A requirement that the Corps provide written notice to the Department within 24 hours of any violations of the conditions in the variance as it relates to voluntary spill. Such notice shall include actions proposed to reduce total dissolved gas levels or the reason(s) for no action;

(viii) No later than December 31 for each year of this variance, the Corps shall provide a written report to the Department detailing the following:

a) Flow and runoff descriptions for the spill season;
b) Spill quantities and durations;
c) Quantities of water spilled for fish versus spill for other reasons for each project;
d) Data from the physical and biological monitoring programs, including incidences of gas bubble disease;
e) Progress on implementing the measures contained in the Lower Columbia River Total Dissolved Gas TMDL.

(ix) The Corps shall provide the Commission with an annual written report and, if requested, the Corps shall appear before the Commission to report on any of the above matters, or such other pertinent matters relating to total dissolved gas as the Commission may determine;

(x) The Commission reserves the right to terminate or modify this variance at any time during its currency.

Note: Completion and submittal of this document by 31 December 2005 satisfies requirement viii (a-d).

State of Washington:

WAC 173-201A-030(2)(c)(iii): Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.

WAC 173-201A-060(4)(a)(i): The water quality criteria herein established for total dissolved gas shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

WAC 173-201A-060(4)(b): The TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan. This gas abatement plan must be accompanied by fisheries management and physical and biological monitoring plans. The elevated total dissolved gas levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The specific allowances for total dissolved gas exceedances are listed as special conditions for sections of the Snake and Columbia rivers in WAC 173-201A-130 and as shown in the following exemption:

> **Special fish passage exemption for sections of the Snake and Columbia rivers:** 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. These special conditions for total dissolved gas in the Snake and Columbia rivers are viewed as temporary and are to be reviewed by the year 2003.

Under the provision provided in WAC 173-201A-060(4)(b), in a letter dated March 31, 2005, the Washington Department of Ecology approved the gas abatement plan that they had on file for a period of three years and approved a special fish passage exemption so that dissolved gas levels may be raised above 110 percent saturation to aid fish passage. As part of this adjustment to the Washington State TDG criteria, the USACE is expected to conduct several activities, including,

a) Investigate and pursue TDG reduction and monitoring improvements as new information becomes available.
b) Investigate biological effects data gaps for total dissolved gas for all species, especially between the end of the aerated zone and the fixed tailrace monitor at each dam. Plan for studies identified during this investigation. Provide yearly progress reports.

c) Investigate TDG reduction improvements to the outfall of the Bonneville corner collector. Provide a yearly report on the results of this investigation.
d) Make reasonable attempts to reduce gas entrainment during all flows during the spill season.
e) Plan maintenance schedules and activities as much as possible to minimize TDG production resulting from spill to within water quality standards. Plan turbine outages as much as possible for outside the high flow season when this will not cause more harm to the environment or to the structural integrity of the dam.
f) Notify Ecology within 48 hours of initiation of spring, summer, and other spills for fish. The notification may be electronic or written.
g) Provide Ecology with an annual written report by December 31 of each year for the activities outlined in this letter and detailing the following:
    - Flow and runoff descriptions for the spill season.
    - Spill quantities and duration.
    - Quantities of water spilled for fish versus spill for other reasons for each project.
    - Data from the physical and biological monitoring programs including a summary of exceedances for each dam, and a description of what was done to correct the exceedances.
    - Progress on TDG abatement implementation measures.

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.

1.1.5 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 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 41 FMSs in the U. S. portion of the Columbia River basin. The U. S. 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 2005 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 2005 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 2005 Water Year, which began in October 2004, was slightly below average in precipitation. The accumulative precipitation during water year 2005 in the upper Columbia River Basin was 97 percent of normal (1971-2000) above Grand Coulee Dam, 95 percent of normal in the Snake River above Ice Harbor Dam, and 90 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 2004, a ridge of high pressure started out the month, and carried on toward mid month. In the middle of October, this regime resulted in record high temperatures at Pendleton, 30 °C (86 °F), and at Portland, 27.2 °C (81 °F), and the month's average temperature departed +0.7 °C (+1.2 °F). Then storms arrived via a jet stream incoming from the northwest. With a much cooler Gulf of Alaska airstream, temperature departures dropped off, and precipitation rose. Precipitation accumulated to 110 percent of normal at Columbia above Coulee, 123 percent of normal at Columbia above The Dalles, and 163 percent of normal at the Snake River above Ice Harbor.

In November, the region saw a split develop in the jet stream. As a result, flows trailed off, and precipitation ended up at 72 percent of normal at Columbia above Coulee, 60 percent of normal at Columbia above The Dalles, and 50 percent of normal at the Snake River above Ice Harbor. Were it not for a tropically feed frontal system about mid month, the precipitation percentages would have been lower. Temperatures were cooler than normal over Oregon and Idaho, and warmer than normal elsewhere during November, a regime typical of a split-flow pattern. Overall, regional temperatures departed +0.6 °C (+1.0 °F) from normal, with absolutes from -1.7 ° C to 3.8 ° C (-2.1 °F to +6.9 °F).

The split in the flow continued into December. The region received most of its precipitation from a frontal system that tapped tropical moisture. Overall, the split flow carried above normal precipitation into California and far north along the northern B.C. coast and into the Alaskan Peninsula. Only parts of southern Oregon and far south Idaho caught slightly above normal precipitation. As a result of this split, precipitation was 76 percent of normal at Columbia above Coulee, 75 percent of normal at Columbia above The Dalles, and 80 percent of normal at the Snake River above Ice Harbor. For the second month in a row, the tropical moisture tap offset the threat of abysmal precipitation totals, and also contributed to a large streamflow increase from the 5^{th} through 15^{th}. December was a very mild month, as well, so only higher elevation snow managed to sufficiently accumulate. On the cool side, departures bottomed out at +1°C (+1.8 °F) and topped out at 5.6 °C (+10.1 °F), bringing the average departure to 2.8 °C (+5.1 °F).

In January 2005, some much cooler weather occurred as the split flow from November and December pulled a bit to the west, allowing Arctic air to briefly move into the Basin, during January, via a northerly flow. Even with precipitation in this kind of a pattern, amounts are generally light. And that was the case until about mid month as the southern part of the split in the jet stream once again tapped tropical moisture. This was courtesy of a large Gulf of Alaska low-pressure area that really managed to arc the northern part of the split flow in over the Basin. Combined with the delivered precipitation from the tropics, this warming airmass came with a very deep southerly flow. This sent temperatures to record levels in January. Portland, Seattle, Olympia, Bellingham, Quillayute, Medford, Hillsboro, and Corvallis all broke their record high temperatures, with most broken between the 12th and 21st. Basin-wide temperatures departed swung wide due to the extremes of the month: On the cold end, they met -2.2 °C (-4.0 °F), and at the other extreme, +3.3 °C (+5.9 °F). January averaged +0.7°C (+1.2 °F) from normal. January precipitation was 100 percent of normal at Columbia above Coulee, 78 percent of normal at Columbia above The Dalles, and 81 percent of normal at the Snake River above Ice Harbor.

In February the weather pattern reverted to a more definitive split flow, and consequently much below normal precipitation. The Basin gleaned most of its meager February amounts early on, and the accumulation resulted in 23 percent of normal at Columbia above Coulee, 30 percent of normal at Columbia above The Dalles, and 73 percent of normal at the Snake River above Ice Harbor. February 2005 regional temperatures continued above normal, averaging +0.6 °C (+1.0 °F) from normal, and containing a range from -1.9 °C to +3.4 °C (-3.5 °F to +6.2 °F). In February, we saw both high and low temperature records broken: Olympia reached 20.6 °C (65 °F) and Astoria, 22.5 °C (68 °F), while Olympia broke a low temperature record three times during the month.

In March the split flow pattern continued. But, by the middle of that month, the weather pattern began to change, perhaps as a consequence of a large change in the pressure pattern across the Equatorial Pacific. As March wore on, precipitation increased due to a series of cold fronts crossed the region, with a notably strong weather system late in the month. Cumulatively, this resulted in a sharp rise in streamflows from the 27th onward, singularly from 115 percent of normal precipitation at Columbia above Coulee, 109 percent of normal at Columbia above The Dalles, and 108 percent of normal at the Snake River above Ice Harbor. With this increase in precipitation, we saw several daily records, including 3.0 cm (1.19”) at Portland, 3.8 cm (1.51”) at Seattle, 1.1 cm (0.45”) at Lewiston, and 2.2 cm (0.88”) at Spokane. Many high temperature records were broken, and these occurred early in the month, within the split flow pattern. Some of these included 21.9 °C (67 °F) at Seattle, 27.5 °C (76 °F) at Portland and Redmond, 21.9 °C (67 °F) at Astoria and Olympia, and 30 °C (80 °F) at Medford. Ironically, Olympia broke its low temperature record on the same day that it broke its high: the capital city started out at -4.4 °C (25 °F) that day! Overall, March was warmer than normal, departing +1.4 °C (+2.5 °F), with mean departures ranging from -1.7 °C to +4.8 °C (-3.1 °F to +8.3 °F).

The back and forth temperature swing that began in March continued through most of the summer. March’s wet pattern continued into the first part of April. More storms brought above normal precipitation region wide for the first half of the month, but a return of the split flow regime dried out northern areas, yet kept southern districts wetter than normal. As a result, April precipitation was 86 percent of normal at Columbia above Coulee, 101 percent of normal at Columbia above The Dalles, and 119 percent of normal at the Snake River above Ice Harbor. More precipitation records were broken in April. Astoria broke a daily record by measuring 4.9 cm (1.92”), and another, with 2.2 cm (0.86”). Yakima, Redmond, and Pocatello broke daily records, accumulating 1.1-2.3 cm (0.45-0.90”). With temperature swings from -1.4 °C to + 2.3 °C (-2.5 °F to +5.1 °F), April averaged very close to normal, departing 0.4 °C (+0.8 °F).

In May, the largely wetter-than-normal spring continued, even with a split in the jet stream. The northern arm of the split forced precipitation into the Canadian Upper Columbia and into the Canadian and U.S. Kootenay, while the southern part of the split brought above normal amounts across the southern tier basins. Above normal precipitation continued through May, as the Columbia above Coulee measured 109 percent of normal, the Columbia above The Dalles at 150 percent of normal, and the Snake River above Ice Harbor totaled a robust 194 percent of normal. Streamflows continued a steep rise, from April, and peaked late in May. Several more daily precipitation records were broken in May, including, Portland, at 1.5 cm (0.59”) and Spokane at 2.2 cm (0.88”). May was warmer than normal, due mainly to milder than normal overnight temperatures, and high pressure ridging toward the latter part of the month. The month averaged +1 °C (+1.8 °F), with mean temperatures departures ranging from -0.7 °C to +4.0 °C (-1.2 to +7.2 °F). This warmth caused Medford to break a daily record at 39.4 °C (95 °F), as did Portland, with Seattle at 35.6 °C (89 °F). Warm temperatures turned much cooler as June arrived, but it remained wet due to a little more consolidation of the upper air flow.

In June, many regions of the Basin had above normal precipitation. A series of chilly storms, out of the ordinary for June, kept flows alive for the month, with only a small recession. Precipitation totaled 178 percent of normal at Columbia above Coulee, 141 percent of normal at Columbia above The Dalles, and 133 percent of normal at the Snake River above Ice Harbor. Again, several daily precipitation records fell: at Portland, Sand Point (Seattle), Idaho Falls and Kalispell. Western Montana was particularly hard hit with this weather pattern, thanks to a cool northwesterly flow, a by-product of the consolidation of the upper air flow. Regional temperatures departed -0.7 °C (-1.2 °F), and skewed chilly even on the range: -2.4 °C to only +0.9 °C (-4.4 °F to only +1.7 °F).

In July, cooler than normal weather continued as more cold fronts traversed the region. By mid to late in the month, higher pressure covered the U.S. part of the Basin, pretty much on time for the start of the Pacific Northwest’s summer. As such, the storm track ended up in Canada. July precipitation ended at 72 percent of normal at Columbia above Coulee, 65 percent of normal at Columbia above The Dalles, and 40 percent of normal at the Snake River above Ice Harbor. July ended warmer than normal, with daily temperature records set at Burns and Boise, at 42.5 °C and 45.6 °C (100 °F and 105 °F), respectively. The warm weather carried over into August, as an upper air high pressure area dominated for most of the month. With the high in place, the storm track remained across the Canadian Upper Columbia, with even that area receiving below normal precipitation amounts. As such, and collectively, precipitation totaled 63 percent of normal at Columbia above Coulee, 58 percent of normal at Columbia above The Dalles, and 62 percent of normal at the Snake River above Ice Harbor.

August's high-pressure system sat over the western part of the Basin, which allowed a cooler temperature pattern to maintain over eastern districts, like the Kootenay and Upper Snake. Late in August, a low-pressure system managed to drop into the Basin from the northwest, and the resultant unstable airmass produced numerous, and occasionally heavy, regional showers. For example, Troutdale set a 24-hour precipitation record of 3.9 cm (1.55") on the 29^{th} of the month. Although most of the Basin saw above normal temperatures for the month, areas on the eastern edge of the upper high were cooler than normal. Overall, regional temperatures departed +0.8 °C (+1.4 ° F).

Although September managed to start quite mild, thanks to a westerly flow and high pressure aloft, temperatures turned cool and stayed cool from about the 5^{th} through the 25^{th}. Combined temperature departures of Spokane, Portland and Seattle came in at -0.8 °C (-1.5 °F). Precipitation averaged 223 percent of normal at Columbia above Coulee, 153 percent of normal at Columbia above The Dalles, and 75 percent of normal at the Snake River above Ice Harbor.

2.1.2 Streamflow

The April 1, 2005 forecast of January through July runoff for the Columbia River above The Dalles was 91.0-km^3 (73.8-Maf) and the actual observed runoff was 100.3-km^3 (81.3-Maf). The average January-July runoff for the 1971-2000 period was 132.35 km^3 (107.3 Maf).

The seasonal precipitation for the water year (2004 winter and spring of 2005) was below average above The Dalles with a 89 percent of average. The actual January through July volume at The Dalles was 100.35 km^3 (81.35 Maf), 76 percent of the 1971-2000 average. The peak unregulated flow at The Dalles in 2005 was estimated at 12,704 cubic meters per second (m^3/s) (448,672 cfs) on 22-May 2005 and a regulated peak flow of 8,184 m^3/s (286,500 cfs) on 18-May 2005.

The Columbia River was operated to meet chum needs below Bonneville Dam from November 8, 2004 through May 5, 2005. U.S. reservoirs were operated to target the April 10^{th} flood control elevation per the NOAA Fisheries 2004 BiOp for juvenile fish needs, but low inflow from January through March prevented this from happening. For 2005 Libby Dam released the volume of water requested by the U.S. Fish and Wildlife Service to meet downstream Kootenai River white sturgeon needs. The U.S. storage projects targeted full by June 30, 2005 per the Biological Opinion. Libby, Dworshak, Hungry Horse and Grand Coulee were all within 2.5 feet from full on June 30. Projects were then drafted to the NOAA Fisheries 2000 BiOp draft limits for 31 August. Libby, Grand Coulee and Hungry Horse all reached their end of August BiOp elevations of 743.9 m (2439 feet), 389.79 m (1278 feet) and 1079.7 m (3540 feet). Dworshak reached the draft limit in September.

Composite operating year unregulated streamflows in the basin above The Dalles were below normal, and were approximately 12-percent above last year's below average streamflows. Inflows during spring runoff were highest in May at 81-percent of average. The October 2004 through September 2005 runoff for The Dalles was 151.1-km^3 (109.4 Maf), 79 percent of the 1971-00 average. The peak-unregulated discharge for the Columbia River at The Dalles was 12,705-m^3/s (448,700-cfs) and occurred on 22-May 2005. The 2004-05 average monthly unregulated streamflows and their percentage of the 1971-00 average monthly flows are shown in Table 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 2004-2005

	At Grand Coulee (in cfs)		**At The Dalles (in cfs)**	
Time Period	**Natural Flow**	**% of Average**	**Natural Flow**	**% of Average**
October-04	59,118	132	95,987	116
November-04	53,274	109	90,901	96
December-04	57,605	134	106,753	108
January-05	61,703	147	115,796	113
February-05	54,702	115	100,725	83
March-05	54,596	88	98,378	63
April-05	107,085	87	177,551	75
May-05	225,297	85	351,420	81
June-05	243,580	79	315,911	67
July-05	154,259	80	188,900	73
August-05	74,992	71	95,568	70
September-05	49,781	80	72,054	77
Operating Year Average (Oct 04 – Sep 05)	99,797	89	151,066	79

2.1.3 Reservoir Operation

2.1.3.1 General

According to the Annual Report of The Columbia River Treaty between Canadian and United States Entities, the 2004-2005 operating year began with Canadian storage at 89.1 per cent of full. Libby reservoir (Lake Koocanusa) was not full on 1 August 2004 as the dam was releasing water to meet the objectives for flow augmentation for listed salmon species in the U.S.

The September through November period is typically a time of base flow at the reservoirs, but due to rainfall there were high inflows in September and October (192% and 123% of normal at Libby and 105% and 130% at Mica), which caused Canadian reservoirs and Libby reservoir to fill slightly. The January water supply forecast at the Canadian basins was slightly below average and dropped to around 90% in the spring. Canadian storage ended the year at 99.0 per cent full.

Two Columbia River Treaty Operating Committee (CRTOC) operating agreements enhanced fishery operations at Arrow. Libby Dam operated to meet the needs of both U.S. Fish and Wildlife Service 2000 Biological Opinion, and the NOAA Fisheries 2004 Biological Opinion. Libby operated in accordance with Appendix B (the Libby Operating Plan) of the Libby Coordination Agreement (LCA).

The Federal system was operated to meet the needs of listed chum downstream of Bonneville Dam beginning October 28, 2004 and lasted through May 5, 2005. The operation meant maintaining the tailwater elevation at Bonneville Dam at, or above, elevation 11.0 feet, so as to keep the areas downstream of Bonneville wetted while the chum moved into the area and spawned. A tailwater elevation of 10.5 ft was the minimum allowable for Bonneville through the emergence of the chum in May.

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 2004-2005. The operations included refilling reservoirs to the April 10th flood control elevation. If inflow was great enough, refill on, or about, June 30th; and drafting reservoirs to summer draft limits. Because March and April were below average, the spring flow objectives at Priest Rapids, Lower Granite, and McNary were not met. Usual spring spill was not executed at the Lower Snake River projects because the projected seasonal average was below 70 kcfs. Summer spill at McNary occurred from July 1st through August 31st and at Lower Granite; Little Goose; Lower Monumental from June 20th through August 31st in accordance with the court order. Spring and summer spill was executed at the other projects. The Lower Snake River projects were operated slightly above their minimum operating pools (MOP) for the season: Ice Harbor; Little Goose and Lower Granite were operated between MOP+1ft and MOP+2ft. Lower Monumental was maintained between MOP and MOP+1.

2.1.3.2 Flood Control

While the 2005 water supply forecasts averaged below normal across the Columbia River Basin, the reservoir system, including the Columbia River Treaty projects were still required to draft for flood control in preparation for the spring freshet. Inflow forecasts and reservoir regulation modeling were done weekly throughout the winter and spring. Projects were operated according to the 2003 Flood Control Operating Plan. The unregulated peak flow at The Dalles, Oregon, shown on Chart 13, is estimated at 12,704 m^3/s (448,672 cfs) on 22 May 2005 and a regulated peak flow of 8,113 m^3/s (286,500 cfs) occurred on 18 May 2005. The unregulated peak stage at Vancouver, Washington was calculated to be 4.62 m (15.1 ft) on 23 May 2005 and the highest-observed stage was 2.94 m (9.7 ft) on 22 May 2005.

In the 2005 spill season, there were only a few hours when runoff peaked at 330 to 350 kcfs total river flow on the Lower Columbia River, which prompted some spilling for flood control. The peaks occurred on May 28th. On the Snake River, runoff peaked at 100 to 143 kcfs total river flow between May 17th and 26th, which prompted some spilling for flood control. The BiOp spill graphs in Appendix F illustrate the effects the one peak runoff period had on voluntary and involuntary spill at the various projects. During the peak runoff period, Lower Granite; Little Goose; Lower Monumental; Ice Harbor and McNary had involuntary spill since the river flow exceeded generation capacity.

2.2 Water Releases

2.2.1 Spill

Spring Spill

During 2005, there was no spring spill program at the Snake River projects because the projected seasonal average flows at Lower Granite for the 2005 spills season were below 70 kcfs and the project seasonal average flow provision described in the UPA, Hydrosystem Actions, Lower Granite section. When seasonal average flows are projected to meet or exceed 85 kcfs, the UPA, Hydrosystem Actions, Lower Granite section calls for voluntary spill for fish passage to be implemented at the three Snake River projects through June 20th. When the seasonal average flows drop below 85 kcfs and greater than 70 kcfs, then spill on the three Snake River projects would be implemented through April 20th. When the seasonal average flows drop below 70 kcfs, then no spill on the three Snake River projects would be occur.

Total river flow on the Snake was low (between 33and 143 kcfs) from mid-May to mid-June, when flow began to taper off. There was voluntary spill for juvenile fish passage at Ice Harbor, which began April 7th and continued through to August 31.

The spring spill program in the Lower Columbia River started April 10th at McNary and John Day, on April 11th at The Dalles and April 15th at Bonneville dams. The spring spill program for these projects ended on June 21. The 2004 NOAA Fisheries BiOp calls for spilling forty (40) percent of the project outflow at The Dalles, sixty (60) percent of the project outflow at John Day and to the 120% gas cap at McNary and Bonneville. Because of mechanical failures at the Dalles, the spill regimes at The Dalles and John Day were changed. For more details, see the special spill operations section under The Dalles.

The website http://www.nwd-wc.usace.army.mil/tmt/ contained NOAA Fisheries regional forum TMT documents that outlined the rationale for determining which Columbia River projects to spill at and in what order.

Summer Spill

The Summer Spill Program was characterized by below average river flows, which resulted in spill formally discontinuing at McNary on June 22nd. According to the UPA, Spill Operations, Table 4, the switch from spring to summer operation at McNary occurs on or about June 20 when conditions are no longer spring like. Spring-like is defined as favorable flow and water temperature conditions; i.e., river flows are at or above the spring flow target (220 to 260 kcfs) at McNary Dam, and ambient water temperatures are below 62°F (17°C). At the June 22, 2005 TMT meeting, it was agreed that spring like conditions no longer existed at McNary and transport of fish would begin. Although McNary formally discontinued spill, the project continued to intermittently spill between 0 and 118 kcfs for the next nine days when the total project outflow exceeded hydraulic capacity. Summer spill at McNary began again on July 1st as called for in the court order and continued through August 31st. Spill also continued at Ice Harbor, John Day, The Dalles and Bonneville until August 31st. There was summer spill at Lower Granite, Little Goose and Lower Monumental beginning June 20th as called for in the court order. For more information on the court order spill program, see the special spill operations section under "Court Ordered Summer Spill."

Spring Creek Hatchery Spill

Spill through the second powerhouse corner collector (B2CC) occurred at the Bonneville dam during the first week of March to facilitate 7.4 million juvenile Tule fall Chinook salmon passage. Spring Creek National Hatchery is located in Underwood, Washington upstream from Bonneville dam. From March 3rd 1600 hr to March 5th 1700 hr, there was 5.5 kcfs spill released from Bonneville dam B2CC resulting in 105 to 113% TDG levels. In March 2004, the Corps and US Fish and Wildlife Service received a multi-year TDG variance from Washington and Oregon DEQ that allows for the elevated TDG levels associated with spill released in support of the hatchery release. The TDG variance applies for a ten day period in March 2004 through 2007.

2.2.1.1 Special Spill Operations

During 2005, there were five special spill operations that varied from the regular spill operations for fish passage as described in the NOAA Fisheries' 2004 BiOp. These operations included spill levels that were either higher or lower than those specified in the BiOp. Four of these operations were related to fish passage investigations and the fifth was directed by court order. For the investigations, 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. Lower Granite dam summer spill test
2. Lower Monumental fish tests (2)
3. Ice Harbor fish spill tests (2)
4. The Dalles spillway gates mechanical problems
5. Court Order summer spill

Lower Granite Dam Summer Spill Test
The Lower Granite summer spill test was conducted from June 20th to July 22. It consisted of two randomized blocks: 1) use of the RSW, spilling approximately 18.6 kcfs with the remainder of the flow put through the turbines, and 2) provided enough flow to generate from only one turbine at the low end of the peak efficiency table and then spilling to the gas cap before generating more. The purpose of this test was to compare the performance and survival of fish between RSW spill and spilling to the gas cap operations. The test resulted in spill ranging from 15 to 42 kcfs, which produced TDG levels fluctuating between 108 and 120% as shown on Figure C-11 of Appendix C.

Lower Monumental Spill Tests
There were two fish tests performed at Lower Monumental: a spill survival test and a balloon tag test.

The spill survival test occurred from May 3rd to May 27th spilling 18 kcfs between 1000 hours and 1500 hours. The test spill regime of spilling only 18 kcfs between 1000 hours and 1500 hours was modified by a spill operation that was conducted from May 17th to May 24th when a large number of fish were passing the project. To encourage fish passage, a spill operation occurred from May 9th at 14 to May 13th at 1500, spilling during non-testing hours about 19 kcfs. The purpose of the spill survival test was to compare fish relative survival between spillbay seven and spillbay eight. The test resulted in spill ranging from 12 to 52 kcfs, which produced TDG levels fluctuating between 115 and 118% as shown on Figure C-15 of Appendix C.

The balloon tag test occurred from May 29th to June 6th and involved spilling 18.2 kcfs between 800 hours and 1800 hours. The purpose of the balloon tag test was to estimate direct fish survival and injury rates at spillbay seven and eight. The test resulted in spill ranging from 1 to 12 kcfs, which produced TDG levels fluctuating between 102 and 118% as shown on Figure C-15 of Appendix C.

Ice Harbor Fish Tests
There were two fish tests performed at Ice Harbor: a balloon tag test and a RSW spill test.

The balloon tag test occurred from April 4th to April 17th and involved spilling 18 kcfs between 700 hours and 1800 hours. The spill operation consisted of spilling up to the 120% gas cap at night and spilling 45 kcfs during the day when not balloon tag testing. The purpose of the balloon tag test was to estimate direct fish survival and injury rates through the RSW. The test resulted in spill ranging from 5 to 70 kcfs, which produced TDG levels fluctuating between 102 and 117% as shown on Figure C-17 of Appendix C.

The RSW spill test occurred from April 22th to June 20th. The test had two randomly selected two-day blocks with the first condition as spilling to 30% of the total river through the RSW and the second condition as spilling up to the 120% gas cap 24 hours a day. The purpose of this test was to compare the performance and survival of fish between RSW spill and spilling to the BiOp spill levels using large gate opening. The test resulted in spill ranging from 10 to 92 kcfs, which produced TDG levels fluctuating between 108 and 121% as shown on Figure C-17 of Appendix C.

The Dalles Spillway Gates Mechanical Problems

During the 2005 spill season, 21 of the 23 spillway gates at The Dalles could not be properly operated because the cables were deteriorated so badly that there was concern that they could break. So on May 18th, a System Operations Request (SOR) was submitted to TMT requesting additional spill from John Day to compensate for the loss of spill at The Dalles. The Corps position is that "compensate" for lost spill is not appropriate, however agreed to provide additional spill to assist fish migration. The May 18th SOR was amended to remove the concept of "compensation" and the Corps agreed to spill 40% of the total project flow during the daytime at John Day (normally there was no daytime spill) beginning May 21st and continued for one week to May 27th. During that week, it was not physically possible to spill to 40% of the total project flow and remain below the 120% and 115% TDG state standards. As a result, the gas caps that the Corps establishes daily limited the daytime spill to 30% of the total project flow. Spilling at The Dalles was furthered complicated with a dam safety issue involving the stilling basin. When river velocities are greater than 20 feet per second (ft/s) there are erosion concerns of the stilling basin.

During the week of May 21-27, gates 1 and 2 at The Dalles were open to 12ft, while gates 3 through 6 were open to the 8 foot pendants. With the higher opening at gates 1 and 2 and the high flows, The Dalles reached the 300 hr threshold with velocities greater than 20 ft/s. In order to prevent further stilling basin erosion from high velocities, gates 1 and 2 were lowered to 8 ft openings on May 25th. With the 8 foot pendants, The Dalles project could spill a maximum of 80 kcfs. The Lower Columbia flows exceeded 220 kcfs, which meant that the 80 Kcfs of available spill at The Dalles was less than the 40% of total river flow called for in the UPA. As a result, the action agencies agreed to provide 40% daytime spill at John Day Dam, beginning May 20th and continue to May 30th. By June 22nd acoustic measurements were taken to check the status of the stilling basin and found it was in good status so spill restrictions on spillbay gates 1 and 2 were lifted. The later part of spill season, spill at The Dalles was 40% as called for in the BiOp. A graphic illustration of BiOp spill during the 2005 spill season is shown on Figure F-2 for The Dalles and Figure F-3 for John Day of Appendix F. The repair of the gates will be completed before 2006 spill season.

Court Ordered Summer Spill

On June 10, 2005 Judge Redden issued a court order requiring the Corps of Engineers to perform summer spill at Lower Granite; Little Goose; Lower Monumental, Ice Harbor from June 20th to August 31st and McNary from July 1st to August 31st. The order also specified the amount to be spilled: the total project discharge minus “station service”, which for Lower Granite; Little Goose; Lower Monumental is 11.5 kcfs; Ice Harbor was 9.5 kcfs and McNary it is 50 kcfs. The station service was to provide enough flow to generate from one turbine at the low end of 1% peak efficiency table and spill the rest up to the 120% gas cap before generating more. As exceedances of the high 12-hour TDG average began to occur, the gas caps were lowered.

This initial spill operation was followed at all the projects until the numbers of adult fish migrating upstream past Little Goose dropped significantly. On June 24th, the spill operations at Little Goose were changed to spill up to the gas cap with station service but if river flow were greater than 43.4kcfs, a second generator could be used. Increasing the flow through the generators was thought to encourage fish passage. This change did not produce the desired effects. Therefore, on June 28th spill operations were modified again to spill 50% of the total river flow from 500 to 2100 hrs (“daytime” hours) and from 2100 to 0500 hrs (“nighttime” hours) spill to the gas cap with 11.5 kcfs station service. This change also did not stimulate adult fish passage. So on June 30th spill operations were modified again to spill 30% of the total river flow from 1200 to 2000 hrs and from 2000 to 500 hrs to spill to the gas cap with 11.5 kcfs station service. This operation increased the number of fish passing Little Goose dam significantly so this spill operation remained in effect the rest of spill season, except for some minor changes like the hours when the spill regimes changed.

During the court order summer spill, the Lower Snake River flows began as high as 70 kcfs as an hourly reading with a daily average flow of 56 kcfs at Lower Granite. These were much higher flows than anticipated based on the STP runs. This resulted in high spill amounts and TDG levels using the spill operations described in the court order. Daily average flows remained above 50 kcfs through July 1st and remained above 40 kcfs through July 14th with an exception of a random day or two. These high flows and spill resulted in high TDG levels: 117 to 118% in Lower Monumental forebay; 121% in Lower Monumental tailwater and 116% in the Ice Harbor forebay. Appendix G shows the high 12-hour TDG averaged data in graphical form. As shown in Table M-2 of Appendix M, exceedances of the high 12 hour TDG average occurred on June 25th through July 2nd in both the forebay and tailwater of Lower Monumental and in the forebay of Ice Harbor. Since the court order summer spill began on June 20th and there is about a four to five day travel time for water to travel from one dam to the next at those flows, exceedances on June 25th is the result of the initial spill operations during high flows. The Lower Monumental forebay was the site with the most TDG exceedances associated with the court order summer spill. This was anticipated, based on SYSTDG model simulations.

2.2.1.2 Voluntary and Involuntary Spill

Voluntary 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. The amount of runoff is primary factor that determines how much voluntary and involuntary spill will occur. When the runoff is low, then the project seasonal average flow provision described in the UPA, Hydrosystem Actions, Lower Granite section takes effect. This provision provides that when the seasonal average flow drop below 70 kcfs, then no voluntary spill on the three Snake River projects will occur. Since the projected seasonal average flows at Lower Granite for 2005 were below 70 kcfs, this provision took affect and no spill was to occur at the upper three Lower Snake River projects. However, as a result of the court ordered spill, voluntary spill occurred from June 20th to August 31st at Lower Granite; Little Goose; Lower Monumental and McNary. There was spring voluntary spill from April 10th to June 22nd and then from July 1st to August 31st at McNary. There was spring and summer voluntary spill at Ice Harbor from April 7th to August 31st; from April 10th to August 31st at John Day; from April 11th to August 31st at The Dalles and from April 15th to August 31st at Bonneville.

Involuntary Spill

Involuntary spill occurred on the Snake and Columbia River projects from May 17th through June 9th. The BiOp spill graphs and tables in Appendix F show McNary and Lower Snake River projects had some level of spill above the BiOp spill levels from May 17th to June 9th. Because of the below average runoff with unit outages, the amount of spill above the BiOp levels were somewhat high, ranging from 0 kcfs at Bonneville to 118 kcfs at McNary. The amount of involuntary spill at McNary ranged from 17 to 119 kcfs, the largest amount of spill above the BiOp level. This was attributed to the limited hydraulic capacity of the McNary powerhouse. The amount of involuntary spill at Lower Granite ranged from 0 to 62 kcfs, the second highest amount, was due to one to three units being out of service during the peak runoff and the BiOp's provision of 0 spill when the average seasonal flow is below 70 kcfs. The Lower Granite unit outages caused much more involuntary spill than what would have normally occurred. For instances, on May 21st, the total river flow was 148 kcfs and because two units were out of service, there was 62 kcfs spilled.

Involuntary Spill's Effect on TDG:

Spring freshet flows peaked from May 17th to May 26th. During this time period, a maximum of only 3 TDG gauges recorded exceedances of the 115%/120% standard on any given day (out of a total of 18 gauges operating on the lower Columbia and Snake rivers).

The 2005 freshet flows were similar to the 2004 freshet flows in that they were both very weak in comparison with the 2003 spill season where 14 of the 18 TDG gauges showed exceedances of the 115/120% gas cap during the freshet. As Table M-3 of Appendix M shows, there were 6 TDG gauges on the Lower Columbia and Snake River projects with no exceedances during the entire 2005 spill season, which is similar to the 2004 spill season when there were seven gages with no exceedances. Involuntary spill was predominately on the Snake River. From May 17th to May 26st the Ice Harbor and Lower Monumental tailwater and The Dalles forebay TDG gauges exceeded the high 12 hours average TDG 115%/120% standard three, seven and two days respectively because of spilling involuntary for flood control. Graphs of the Snake and Columbia River projects' 12 hours average TDG levels shown in Appendix G illustrate the impact of involuntary spill levels on TDG levels during the May 17th to May 26st period.

Snake River Projects Unit Outages

There were unit outages at several Snake River projects that resulted in involuntary spill at Lower Granite, Little Goose, and Lower Monumental. From April 30th to June 9th there was intermittent involuntary spill at Lower Granite because of one to three units were out of service for various reasons, such as cleaning the trash racks; dive operations; and contractor inspection. From May 18th to May 24th there was intermittent involuntary spill at Little Goose because of one to two units were out of service. From May 17th to May 26th there was intermittent involuntary spill at Lower Monumental because one to two units were out of service.

BiOp Spill Amounts Calculated

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 occurs at the various projects. The amount of BiOp spill is shown on Tables F-1 through F-8 and in graphs in Appendix F. For more information, the BiOp 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 or for just temperature control. From Mid-September through June, releases from Dworshak are modified to meet the temperature needs of the Drowshak hatchery located approximately two miles downstream. From early July through mid September, releases from Dworshak Dam were manipulated to provide flow augmentation and to temperature control of the lower Snake River. Water releases from Dworshak Dam for this purpose began on July 1, 2005 when Dworshak forebay elevation was at 1600.0 ft and continued through September 17, when the forebay elevation of 1520.1 ft was reached.

Flow Augmentation and Temperatures

A 4.2 kcfs water release from Dworshak Dam began on July 1st with a water temperature 45 °F. Flows increased to 8.6 kcfs on July 6th with a water temperature 45 °F and these operations were maintained until July 14th. The 8.6 kcfs outflow with 45 °F water provided a mild cooling affect and the resultant Lower Granite tailwater daily average water temperatures are shown on Figure D-6 in Appendix D. The water temperature at Lower Granite tailwater peaked on July 9 and July 11 at 67.8 °F, the highest during the 2005 spill season. On July 15th, the water releases were increased to 12 kcfs with a water temperature 44 °F. As the Dworshak 44 °F water releases arrived at Lower Granite, it excreted a noticeable cooling influence on Lower Granite tailwater water temperature dropping it to 65.9 °F by July 22 and maintained the temperatures at 65 to 66 °F through August 5th. The Lower Granite tailwater water temperature did not creep back up even after the Dworshak water release temperatures were raised to 46 °F on August 4th with a constant flow of 12 kcfs. Through August and September, the Dworshak releases temperatures were maintained between 45 and 47 °F while the outflow decreased to 10 kcfs on August 11 then 7 kcfs on August 18th then 3.5 kcfs on September 15th and finally 1.5 on September 18th. Figure D-6 of Appendix D provides a summary of this information in a graphic style.

In 2005, the Lower Granite tailwater hourly water temperature did not exceeded the 68^{o} F State standard. As shown on Table H-1 of Appendix H, the Lower Granite tailwater daily average water temperature did not exceeded the 68^{o} F State standard during 2005 either. Figure D-6 provides a graphic view of the tailwater temperatures for the Lower Snake projects with Dworshak release temperature changes

Dworshak Release Temperature changes

TMT requested that the project outflow temperatures be maintained at 45 to 46^{o} F from July 1 through July 14; 43 to 44 ^{o}F from July 15 to August 3rd, and 45 to 47 ^{o}F from August 4 to September 12th. These requests were satisfied. TMT made the request that 48 to 50 ^{o}F, but not to exceed 52 ^{o}F be maintained after September 12 which was physically impossible, so this request was not satisfied. The Dworshak hatchery had to select between water temperatures of 45^{0}F (one unit in undershot mode, which is when water is drawn from underneath the selector gate) or 59^{0}F (one unit in overshot mode, which is when water is drawn from above the selector gate). They choose undershot with 45^{0}F.

Dworshak Release Temperatures at the End of Flow Augmentation

The 2005 choice of picking between 46^{o} F (undershot) and 59^{o} F (overshot) at the end of Dworshak flow augmentation is a 13^{o} F range; a wide range when compared to the average range in the six previous years. The 2000 – 2005 average undershot temperature is 46^{o} F and the average undershot temperature is 54^{o} F with an average range between overshot and undershot of 8^{o} F. The 2005 range between undershot and overshot is almost twice the six year average. It is helpful to look at the 2000 - 2005 undershot and overshot temperature ranges. The undershot temperatures are fairly constant from year to year, but the overshot temperatures are not. Reviewing the 2000 – 2005 temperatures, the undershot temperature available at the end of flow augmentation was fairly constant, ranging from 44 to 47^{o} F with an average of 46^{o} F. The 2005 undershot temperature falls in this range and is the same as the six-year average. The six-year range of overshot temperatures available at the end of flow augmentation was variable, ranging from 49 to 59^{o} F with an average of 54^{o} F. The 2005 overshot temperature is at the top of this range and is 6^{o} F above the six-year average of 54^{o} F. Since Dworshak water release temperatures have been cooler and cooler, the range between overshot and undershot at the end of Dworshak flow augmentation have been becoming wider. Whether this wide range can be attributed to the Dworshak low release temperatures is unknown, but it is a reasonable speculation that releasing 43 to 46^{o} F for 10 weeks could produce this type of effects.

Operational Trends

There are several operational trends that Figure D-2 and Figure D-3 highlight and they are:

- The number of days that augmentation occurs has been increasing since 2000.
- The overall trend towards cooler water being released from Dworshak reservoir for longer periods of time during summer operations continues.
- The overall temperature during the augmentation period is dropping. The augmentation seasonal average temperature has significantly dropped from the 47 to 48^{o} F during 2000 – 2002 period to the 45^{o} F range during 2003 - 2005.

- The number of days that the Dworshak release temperatures were between 43^{o} to 44^{o} F is also increasing
- The number of days with daily average temperatures of 42^{o} F is also increasing.

2.2.3 Beta Testing The SYSTDG Model

During the 2005 spill season, the RCC Water Quality unit used the SYSTDG model to forecast the TDG levels at the Corps projects Columbia and Snake River projects for the purpose of setting daily spill caps. SYSTDG is a decision support tool used to estimate total dissolved gas (TDG) pressures resulting from project operations on the Columbia, Snake, and Clearwater Rivers. 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 2004 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 during the 2004 - 2005 spill seasons, 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.

The RCC Water Quality Unit believes that a statistical evaluation of SYSTDG performance in previous years (2004 and 2005) 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 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 E.

<u>Statistical Evaluation</u>

A statistical evaluation of the predictive errors was performed for the 2005 spill season which spanned from April 7th 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. The final predictive errors results are shown on Table 2 and Table 3.

TABLE 2

Statistical summary of the predictive errors of the observed and calculated total dissolved gas pressures at forebay fixed monitoring stations.										
		Predictive Error at Forebay FMS* (mm Hg)								
		LGSA	**LMNA**	**IHRA**	**MCNA**	**MCQO**	**JDY**	**TDA**	**BON**	**CWMW**
Number of Observations		3330	3327	3330	3334	3334	3334	3334	3316	3299
Average		-8.7	-6.3	-3.4	-15.2	-12.1	1.9	-4.2	-2.6	1.9
Standard Deviation		15.6	8.5	9	14.5	17.8	8.1	8.3	7.1	10.5
Maximum		49.8	17.7	20.6	30.9	74.6	29.1	33.7	23.5	36.2
Minimum		-64.6	-55.6	-40.2	-50.7	-74.4	-22.9	-36.4	-23.6	-27.5
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-40.1	-22.1	-19.7	-34.7	-39.5	-10.4	-15.7	-14.4	-13.6
	10%	-31.4	-16.7	-16.1	-31.4	-35	-8.2	-13.4	-11	-10.5
	25%	-17.1	-9.9	-8.3	-25.4	-25.7	-3.9	-9.3	-7.1	-5.5
	50%	-5	-5.2	-2.3	-18	-12.5	1.3	-4.7	-2.9	0.4
	75%	1.8	-1.4	2.5	-6.7	-0.1	7.6	-0.3	2.1	8.9
	90%	7.9	2.6	6.9	6.2	11.5	12.9	4.7	6.4	16.1
	95%	11.9	5.6	10.1	13.4	18.1	15.7	11.2	9.6	20.5

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

TABLE 3

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		1013	2141	1895	2143	3319	2912	2428	3332	3299	3300
Average		-5.7	-25.6	15.7	-3.8	-5.6	2.4	-3.1	-1	-12.1	9.4
Standard Deviation		10.9	36.3	11.8	13.1	10.5	11	10.7	7.2	7.6	15.1
Maximum		34.2	26	100	61	36.5	58.8	23.7	20.3	21.4	65.7
Minimum		-54.9	-182.4	-20.9	-55	-54.7	-41.1	-46.9	-41.2	-62.1	-33
TDG Predictive Error for Percentile Occurrence (mm Hg)	**5%**	-24.2	-93.7	0.8	-26.6	-25	-13.7	-23.7	-13.1	-25	-12.5
	10%	-21.5	-85.4	3.6	-24	-22.3	-11.6	-17.5	-10.1	-18.1	-9.7
	25%	-15.2	-31.8	8.7	-12.7	-11.6	-6.9	-8.9	-5.4	-13.9	-2.2
	50%	-2	-16.2	13.7	-0.9	-3.9	2.8	-2.9	-0.2	-11.5	8.3
	75%	2.8	-6	20.4	5.8	1	9.7	4.2	4	-9	21.4
	90%	6.2	2.9	31.5	10.3	6.5	16.5	10.8	7.4	-5.4	29.7
	95%	8.2	8.8	36.7	13.1	10.4	21.1	13.1	9.6	-2.2	33.9

* 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 operational policy involving spilling water on the Snake and Lower Columbia Rivers during the summer months was conducted for the first time in 2005. These unique operations resulted in conditions outside of the normal operating range under which the SYSTDG model was developed. At some project, revised spill patterns were employed to aid fish passage during low summer time river flows. 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 (Tables E1 and E2) than the tailwater station comparisons (Tables E3 and E4). The average predictive errors at forebay stations were less than 1 percent of saturation with the exception of Little Goose and McNary Dams. The overestimation of forebay TDG pressures at McNary Dam was attributed to misrepresenting TDG levels originating from the Mid-Columbia River. The larger estimation errors in the forebay of Little Goose were largely attributed to estimates misrepresenting TDG production at Lower Granite Dam during August. The location of forebay stations away from the dam and at greater depth, resulted in fewer temperature induced spikes in TDG pressure and smaller predictive errors at these stations. The correlation between strong winds and declining TDG pressure at forebay stations was evident during the 2005 spill season and was an important determinant of calculated TDG levels.

- Of all the tailwater FMS gauges reviewed, The Dalles Dam simulations produced the smallest predictive error based on the standard deviation statistic, while Lower Granite tailwater simulations produced the largest amount of predictive error as shown in Figure E42. In the plot shown in Figure E42, the box reflects the predictive error of the 25th, 50th, and 75th percentile, the whiskers show the 10th and 90th percentiles, and the circular symbols reflect observations outside of the 10th and 90th percentiles. The small size of the predictive error at The Dalles and Bonneville tailwater station was partially associated with the contribution from powerhouse releases that were determined from observed forebay conditions. The large predictive error below Lower Granite Dam was associated with the high entrainment discharge during low river flows.

- 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 operating conditions. The standard deviation of predictive error at the tailwater stations ranged from 7.2 mm Hg at The Dalles Dam tailwater station TDDO to 36.3 mm Hg at Lower Granite tailwater station (LGNW). The large errors observed during the month of August at the Lower Granite Dam tailwater were associated with the estimated size of the entrainment discharge.

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 SYSTDG decision support system will incorporate real-time spill pattern data in the upcoming 2006 fish passage season where this information is available.

- The TDG data collected below Dworshak Dam during the 2005 spill season should be used to improve the TDG exchange algorithm.

- A modified entrainment algorithm for powerhouse releases is recommended for the Snake River Projects for low river flow environments. The proposed description for entrainment as developed for Lower Granite dam should be extended to other projects for low flow conditions.

- The surface exchange coefficients should be adjusted to reduce the predictive error bias as determined at forebay stations. There exists experimental evidence that the exchange coefficient of atmospheric gasses in river systems has a temperature dependency. This formulation should be investigated in selected river reaches. In some cases, the application of wind magnitude and direction data from alternative stations should be examined to see if predictions could be improved.

Part 3 Program Results

3.1. Water Quality Review

Total dissolved gas and water temperatures are the two areas of the water quality program that this document provides a detailed review with graphs of the data. Appendices C, G, and M provide graphs and tables of TDG data. Appendix H provide graphs and tables of temperature data. Appendices A and B provide a general overview of the monitoring system with information on the fixed monitoring stations and the monitoring plan of action. Appendix D describes the operations and results of Dworshak summer operations. Appendix I provide a review of the QA/QC for the TDG and temperature monitoring gages at John Day, The Dallas, Bonneville, Warrendale and Camas/Washougal site. The U. S. Geological Survey (USGS) wrote the report for the Corps Portland District. Walla Walla District wrote Appendix J, which provide a review of the QA/QC for the TDG and temperature monitoring gages at Lower Granite; Little Goose; Lower Monumental; Ice Harbor; McNary and Dworshak. Seattle District wrote Appendix K, which provide a review of the QA/QC for the TDG and temperature monitoring gages at Libby, Chief Joseph and Albeni Falls. Appendix E provides a detailed evaluation of how well SYSTDG performed this year and it is written by Mike Schneider, ERDC researcher and Kathryn Barko, Corps contractor.

3.1.1 Total Dissolved Gas

Operation of the Federal Columbia River Power System (FCRPS) 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, 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 applicable voluntary spill for fish program was implemented consistent with the State water quality standards variances 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%. TDG in the Dworshak tailwaters was monitored to manage operations to avoid exceedances of the Idaho state standard of 110%.

Changes in the Fixed Monitoring System

Forebay fixed monitoring stations were relocated for the 2005 fish passage season at McNary Dam and at four Snake River projects to provide more representative measures of TDG saturation. An evaluation of alternative locations of forebay fixed monitoring stations (FMS) was conducted in conjunction with RPA 132 (NOAA Fisheries 2000 BiOp). The surface oriented water quality conditions monitored at the old forebay FMS were biased by TDG pressure fluctuations induced by the heat exchange into the forebay surface layers. The forebay FMS were repositioned away from the vertical face of the dam on the upstream lock guide wall and at a greater depth (15 meters) for the 2005 fish passage season. The forebay station at Lower Granite Dam remained in it original location on the upstream lock guide wall but its depth was changed from 5 meters to 15 meters. The location of the forebay FMS on the Oregon side of McNary dam did not change. The forebay data collected during the 2005 season were more representative of average forebay conditions in the Snake River and in the Columbia River at McNary Dam. This information provided improved boundary conditions for SYSTDG forecasts and hindcasts of river conditions and provided more accurate information regarding the TDG loading arriving at a project in response to the TDG loading, transport, and dissipation of upstream sources and a better measure of the reliability of SYSTDG simulations.

In 2005, the Cascade Island station (CCIW) located in the spillway exit channel on the banks of Cascade Island was used to manage spill at Bonneville Dam in place of the Warrendale station located 6 miles downstream. The CCIW FMS provides a direct measure of the TDG pressures in spillway flows, a more comprehensive description of habitat impacted by TDG supersaturation generated in spill, and more consistent and reliable information to support spill management decisions. The Warrendale FMS is located in a mixed river environment and is thereby influenced by both spillway and powerhouse flows. TDG levels observed at Warrendale infrequently exceeded the tailwater TDG criteria of 120 percent during voluntary spill conditions because the TDG content of powerhouse releases dilute the TDG loading originating from the Bonneville spillway. Detailed TDG exchange studies have clearly established consistent patterns of average and peak TDG pressures in spillway releases that differ from shore based observations from the fixed monitoring station at CCIW. The TDG exchange algorithm used by SYSTDG at Bonneville Dam provides estimates of the average TDG loading produced during spill that are consistently greater than the observed conditions at CCIW for higher discharges. The temperature, TDG levels and high 12 hour TDG average exceedances for both Cascade Island and Warrendale gauges were tracked throughout the spill season. The data is shown in Appendixes C; G; H and M

115% and 120% Total Dissolved Gas Exceedances

Washington and Oregon state standards during the 2005 spill season were exceeded 69 days at the projects on the Lower Columbia and Snake rivers out of a possible 3,020 days ([number of TDG gauges] x [days in spill season, 3 April through 31 August]). Table 4 provides a summary of TDG exceedances during 1999-2005 spill seasons (Note: the totals shown on Table 4 may not be consistent with the number contained in the Corps Districts' appendices I, J, and K. These inconsistencies are attributed in part to differences in numerical rounding methodologies). The 69 high 12-hour averages of TDG exceedances during 2005 spill season includes both voluntary and involuntary TDG exceedances and greater detail is provided on Table M-2 and Table M-3 in Appendix M. The forebay TDG exceedances varied from 115.1 to 119.5%. The tailwater TDG exceedances varied from 120.1 to 121.6%.

TABLE 4

1999 - 2005 Spill Seasons
Number of TDG Exceedances

AVERAGE HIGH 12 HR %TDG EXCEEDANCES AT FMS FROM 1999 - 2005								
	2005	2004	2003	2002	2001	2000	1999	Totals
Water Quality Gages	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**
Lower Granite Forebay *	0	0	0	0	5	2	0	7
Lower Granite Tailwater	0	0	15	17	0	4	15	51
Little Goose Forebay *	0	3	10	17	0	2	39	71
Little Goose Tailwater	0	0	6	6	0	9	6	27
Lower Monumental Forebay *	6	1	19	49	0	28	44	147
Lower Monumental Tailwater	7	1	10	6	0	12	26	62
Ice Harbor Forebay *	3	4	35	24	0	34	44	144
Ice Harbor Tailwater	3	2	4	6	0	4	12	31
McNary Forebay - Wa. *	8	10	24	43	1	14	22	122
McNary Forebay - Or.	11	23	32	45	5	22	19	157
McNary Tailwater	1	7	12	31	0	17	50	118
John Day Forebay	2	0	10	11	0	1	8	32
John Day Tailwater	3	0	0	29	0	12	43	87
The Dalles Forebay	6	5	11	18	0	5	1	46
The Dalles Tailwater	0	0	4	11	0	5	5	25
Bonneville Forebay	3	1	17	30	0	14	19	84
Cascade Island	0	---	---	---	---	---	---	0
Warrendale	---	0	1	19	0	6	2	28
Camas/Washougal	16	14	33	65	2	58	51	239
Total Number of Exceedances	**69**	**71**	**243**	**427**	**13**	**249**	**406**	**1478**

As Table 4 shows, the McNary Oregon and Washington sides and Camas/Washougal forebay FMSs had the majority number of exceedances during 2005 and were the most difficult to maintain below the 115% TDG standard. The Camas/Washougal gauge recorded 16 exceedances, the most for any gauge in the system for the season. Camas/Washougal is typically a location that records a higher number of exceedances than other FMS locations. The McNary Oregon side station recorded the second most TDG exceedances of the FMS system monitoring stations with 11 exceedances. The McNary forebay location on the Washington side had 8 exceedances. Exceedances at the McNary forebay gauges were attributed to the effects of solar radiation on water temperature and TDG levels.

Washington and Idaho TDG state standards were exceeded at Libby tailwater; Chief Joseph, Albeni Falls forebay and tailwaters as shown on Table M-4. There were no TDG exceedances at Dworshak during flow augmentation period of July 1 through September 18^{th}. Appendix M contains a listing of the maximum and minimum TDG values measured at each FMS for each month of the spill season as well as the number of hours and days the TDG standards were exceeded each month. Appendix K of the Seattle District TDG Report also provides more information on these projects.

125% Total Dissolved Gas Exceedances

During the 2005 spill season, there were no exceedances of either the Oregon or Washington state standards of 125% TDG (a one hour standard in Oregon and a two hour standard in Washington). As Table M-5 shows, having no 125% TDG exceedances is somewhat common since the 2004 and 2001 spill seasons had none too. The 2002 and 2003 spill seasons had several 125% or greater hourly TDG exceedances ranging from 125.1 to 145.8%. These typically occur during the peak of the freshet from May 21st to June 11th and are attributed to spilling water for flood control purposes.

Comparison of Annual Exceedances

Table 5 provides a summary comparison of the total number of voluntary and involuntary spill related TDG exceedances for 1999 through 2005. As shown on Table 5, the 1999 – 2005 seven year average of TDG exceedances during a spill season is 221 exceedances. The 2005 spill season occurrence of 69 TDG exceedances is 31% of the seven-year average. This "lower than average" TDG exceedance rate is attributed in part to a lower than average water year. The accumulative precipitation was in the "below average" range with 97 percent of normal (1971-2000) above Grand Coulee Dam, 95 percent of normal in the Snake River above Ice Harbor Dam, and 90 percent of normal in the Columbia River above The Dallas, Oregon.

TABLE 5
SUMMARY COMPARISON OF EXCEEDANCES WITH PREVIOUS YEARS

Year	Days In Spill Season	Number of Days	Percent Exceeding TDG Standard (%)	Percent Consistent With TDG Standard (%)
2005	2754	69	2.5	**97.5**
2004	2754	71	2.6	**97.4**
2003	2754	243	8.8	**91.2**
2002	2754	427	15.5	**84.5**
2001	2754	13	0.5	**99.5**
2000	2754	249	9.0	**91.0**
1999	2754	406	14.7	**85.3**
Average	2754	**211**	**7.28**	**92.72**

Note: Number of spill days are based on 18 gages X 153 days from April 1 - August 31.

Type of TDG Exceedances

The type of TDG exceedances for the forebay and tailwater of each Corps project was daily tracked during the 2005 spill season. After some refinement, the Corps Reservoir Control Center used the previous year's list of TDG exceedance type definitions and applied them to the 2005 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 2005 spill seasons. A more detailed list of when and where the exceedance types occurred is provided in Table M-3 in Appendix M. The exceedance type designation given to each TDG exceedance is based on the Corps subjective determination of causation.

During the 2005 spill season, TDG exceedances were attributed to three main causes: uncertainties when using best professional judgment to apply the spill guidance criteria (32 exceedances); sharp rises in high TDG levels coming from the Mid Columbia River (15 exceedances); and high runoff flows and flood control effects (11 exceedances). Almost half of 69 TDG exceedances were caused by factors outside of the Water Quality Unit control, such as flood control and spill at Priest Rapids.

Certain trends can be observed from the 2003 – 2005 TDG exceedances tracking data. For instance, exceedance type 6 (uncertainties when using best professional judgment to apply the spill guidance criteria) is consistently among the top three causes for exceedances during the last three years with 154 total exceedances. Exceedance type 1 (high runoff and flood control efforts) is the second most common exceedance during the last three years with 83 total exceedances. Exceedance type 12 (Exceedance due to sharp rise in water temperature (a 3^{o} F or greater change in a day)) is the third most common exceedance during the last three years with 52 total exceedances.

TABLE 6
2003-2004 Spill Seasons
Types and Number of TDG Exceedances

3 Yr Totals	2005	2004	2003	TYPE #	DEFINITION
83	11	4	68	1	Exceedance due to high runoff flows and flood control efforts.
0	0	0	0	2	Exceedance due to Intertie line outages.
0	0	0	0	3	Exceedance due to unit outages during repair or maintenance.
3	3	0	0	4	Exceedance due to BPA inability to handle load so water was spilled.
1	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.
154	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).
33	15	0	18	7	Exceedance due to high TDG levels coming from the Mid Columbia River Dam (see Pasco FMS readings).
3	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	9	Exceedance due to a load rejection. The powerhouse was not working and the river was spilled.
14	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	9	11	Exceedance due to mechanical problems (gate was stuck open, passing debris etc.).
52	7	25	20	12	Exceedance due to sharp rise in water temperature (a 3 degree F. or greater change in a day).
40	0	7	33	13	Exceedance due to bulk spill pattern being used which generated more TDG than expected.
10	0	10	0	12/7	Exceedance due to combination of exceedance type 12 and 7.
402	**69**	**71**	**262**		**Totals**

3.1.2 Recurring High TDG Exceedances

There were three locations that were difficult to avoid TDG exceedances from voluntary and involuntary spill, leading to high recurring TDG exceedances in 2005. As the 2005 data in Table 4 shows, there were high recurring exceedances at McNary forebays, Oregon and Washington sides and Camas/Washougal forebay. These three FMS sites have two similarities: all three are forebay FMS and experience thermal cycling. There is a distinction that should be made: The thermal cycling that occurs at Camas/Washougal is representative of the entire river where the thermal cycling at McNary is just representative of the thermal layers. The McNary forebay, Oregon and Washington sides both suffer from surface water influences and can experience temperature spikes up to 10^{o}F in one day. Camas/Washougal forebay can also experience temperature spikes although not as large as McNary forebays. McNary is also unique because it resided downstream of two projects (Ice Harbor and Priest Rapids) that spill a high percent of the river.

A review of the 1999-2005 TDG exceedances summarized on Table 4 highlights that these three FMS sites and Lower Monumental and Ice Harbor forebays have a history of recurring TDG exceedances. Camas/Washougal had the most exceedances during the last eight years (1999 – 2005) with 239 exceedances. McNary forebay, Oregon side had the second most exceedances during the 1999 – 2005 periods with 157 exceedances. Lower Monumental and Ice Harbor forebay were almost tied for third place with 147 and 144 TDG exceedances during the 1999 – 2005 periods.

3.1.3 Camas/Washougal

Historically, Camas/Washougal FMS site has had a high number of TDG exceedance and 2005 spill season continues in this trend. As shown on Table 4, the Camas/Washougal site had 16 days of exceeding the 12 hour average for TDG, the most TDG exceedances for the FMS system during the 2005 spill season. The Camas FMS represents a theoretical forebay in the lowest reach of the Columbia River. Because the Camas FMS is located in an open river reach which is more shallow, it responses more quickly to environmental influences. This site was significantly affected by environmental conditions such as changes in gorge winds, barometric pressures, changes in daily solar radiation, which resulted in swings in water temperatures. The aquatic plants' production of oxygen 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. Most (15 out of 16) of the total number of exceedances at Camas/Washougal in 2005 were Type 6 exceedances: "uncertainties when using best professional judgment to apply the spill guidance criteria". In 2004, half (7 out of 14) of the total number of exceedances at Camas/Washougal were Type 6 exceedances. In 2003, 82% the number of Type 6 exceedances were much greater (27 out of 33).

3.1.4 McNary Forebay – Oregon Side

Historically, McNary forebay, Oregon Site FMS site has had a high number of TDG exceedance and 2005 spill season continues in this trend. As shown on Table 4, the McNary forebay – Oregon side had 11 days of exceeding the 12 hour average for TDG, the second most TDG exceedances for the FMS system during the 2005 spill season. The McNary forebay is at the confluence of the Snake and Columbia rivers and receives waters that have not been fully mixed. Consequently, the water coming from the mainstem Columbia on the Washington side of the river often contains different TDG levels and water temperatures from the water entering from the Snake River on the Oregon side. Solar radiation heated the warmer water coming from the Snake River further, resulting in wide water temperature swings and TDG levels that were difficult to manage. With the low river flows and warm climate, the TDG exceedances due to sharp rises in water temperature alone or sharp rises in water temperature with high TDG levels coming from the Mid Columbia River became prominent in 2005.

3.1.5 McNary Washington Side

As shown on Table 4, the McNary forebay, Washington side had 8 days of exceeding the 12 hour average for TDG, the third most TDG exceedances for the FMS system during the 2005 spill season. Historically, McNary forebay, Washington side is among the top TDG exceedance FMS site locations, as Table 4 shows, and it continued to be in 2005 spill season. Since the thermal cycling that occurs at McNary is representative of the thermal layers, it is understandable that during low river flows and warm climate, the thermal layers could experience large temperature spikes resulting in TDG exceedances. Because McNary is located downstream of two projects (Ice Harbor and Priest Rapids) that spill a high percent of the river, McNary forebay gages are impacted by the variation in flow regimes and the TDG levels they produced. This impact is accounted for in the TDG exceedances tracking where there are two TDG exceedance types just for TDG levels coming from Ice Harbor or Priest Rapids. All eight McNary forebay, Washington side's TDG exceedances for the 2005 spill season were attributed to this impact (see Appendix M, Table M-3). During 2004 and 2005 spill seasons, the McNary forebay, Washington side FMS experiences more impacts from upstream TDG levels than the McNary forebay, Oregon side FMS.

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 G contains graphs of the high 12 hour average TDG values for each monitoring station for the 2005 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 4, there were a combined total of 69 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 six gages with no TDG exceedances during the 2005 spill season: Lower Granite forebay; Little Goose forebay and tailwater; The Dalles tailwater and Cascade Island. As the 1999-2005 summary of TDG exceedances on Table 4 shows, no exceedances at Lower Granite forebay is somewhat typical.

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 D contains graphs of Dworshak and Lower Granite water temperatures with a summary of the Dworshak spill operations.

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 and August 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 for water temperature reductions and flow augmentation on the Snake River. As discussed in Appendix D, 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 7.

TABLE 7
State Water Quality Standards
Chief Joseph Dam

Project	Washington Standard	Colville Tribe Standard
Chief Joseph Dam, Columbia River, RM 545.1	"Temperature shall not exceed 18° C (64.4 F) due to human activities. When natural conditions exceed 18° C (64.4 F) no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C (0.5 F). Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/T+7). Incremental increase resulting from nonpoint source activities shall not exceed 2.8° C (5.4 F)." WAC 173-210A-130(21) and WAC 173-201A-030(2)	**4-8-6 General Water Use and Criteria Classes:** (a) Class I (Extraordinary): From Northern Reservation Boundary to Chief Joseph Dam 4-8-6(a)(3)(F): Temperature shall not exceed 16.0 C (freshwater) and 13.0 C (saline water) due to human activities. Temperature increases shall not, at any time, exceed t=23/(T+5) (freshwater) or t=8/(T-4) (saline water). (b) Class II (Excellent): From Chief Joseph Dam to Wells Dam 4-8-6(b)(3)(F): Temperature shall not exceed 18.0 C (freshwater) and 16.0 C (saline water) due to human activities. Temperature increases shall not, at any time, exceed t=28/(T+7) (freshwater) or t=12/(T-2) (saline water).

TABLE 7
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 7
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 2004 Biological Opinion, 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 calls for biological monitoring for Gas Bubble Trauma Disease, which the Action Agencies performed in accordance with RPA action 131.

"Gas Bubble Trauma Monitoring and Data Reporting for 2005" by the Fish Passage Center is shown in Appendix L. Sampling of juvenile salmonids for gas bubble disease was conducted at Bonneville and McNary dams on the lower Columbia River, and at Rock Island Dam on the mid-Columbia River. The monitoring sites on the lower Snake River included Lower Monumental, Little Goose and Lower Granite dams. Sampling occurred two days per week at the lower Columbia and Snake River sites. Sampling of fish occurred between June 20th and August 31st at Lower Granite Dam, Little Goose Dam, and Lower Monumental Dam. Sampling of yearling chinook and steelhead occurred through the spring at the Columbia River sites. Once subyearling chinook predominated smolt collections the sampling of subyearling chinook occurred at Columbia River sites to the end of August.

A total of 11,428 juvenile salmonids were examined between April and August 2003. A total of 55 or 0.48 % showed some signs of gas bubble trauma in fins or eyes. Fin signs were found in 52 or 0.46% of the fish sampled at all sites (See Table L- 2). Only one fish were found with severe fin signs (rank 3 or higher) while, 1 fish had fin rank 2, with the remainder having rank 1 signs. The prevalence of GBT signs at Rock Island Dam was higher than any other Columbia River site during the 2005 monitoring season as is typically the case each season. Because the Rock Island data may obscure other inter-annual trends in the occurrence of GBT signs among sites, it will be treated separately in the remainder of this report.

At the lower Columbia and lower Snake dams operated by the Corps, a total of 8,861 juvenile fish were examined, with 10 or 0.11% exhibiting signs of gas bubble disease, compared to 0.18% in 2004; 0.5% in 2003, 0.7% in 2002, 0.1% in 2001, 0.2% in 2000, 1.4% in 1999, 1.6% in 1998, 4.3% in 1997, 4.2% in 1996 and 1.3% in 1995. One fish were found with severe fin gas bubble trauma. This low level of occurrence is similar to 2004, 2003, 2002, 2001, 2000, 1999, and 1995 when no severe fin GBT was found. Other years showed higher incidence of severe fin GBT; in 1998 four (0.01%) fish displayed severe fin signs, 1997 when 117 fish (0.27%) had severe fin signs (again excluding Rock Island) and 47 fish (0.12%) in 1996.

The Biological Opinion Spill Program was managed using the data collected for total dissolved gas levels. However, signs of GBT in fins of juvenile fish, examined as part of the biological monitoring, were used to compliment the physical monitoring program. The

NOAA Fisheries set the action criteria for the biological monitoring program at 15% prevalence of fish having fin signs or 5% with severe signs (rank 3 or greater) in fins. The NOAA Fisheries action criteria were never exceeded in 2005. This is similar to all past years since 1995, with the exception of the high flow years (1996 and 1997) when uncontrolled spill occurred. In contrast there were 23 dates when GBT levels surpassed the action criteria in 1997 and 20 in 1996.