Appendix 4

2010

Total Dissolved Gas

Management Plan

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1.0 Introduction

In various parts of the Columbia and Snake River systems, elevated levels of total dissolved gas (TDG) saturation are observed where spill at dams occurs. A total dissolved gas (TDG) Management Plan to manage TDG is developed annually and is included as Appendix 4 in the annual Water Management Plan, which is adopted by the Technical Management Team (TMT) . The TDG management measures vary depending on whether the spill is voluntary fish spill, involuntary, or due to lack of market. These terms are defined in Section 1.1. This TDG Management Plan provides detailed definitions of spill, spill conditions, TDG management measures, the rationale and process for setting spill caps, the TDG management policies, and the TDG monitoring program, and modeling. This plan is consistent with both the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (NMFS) Federal Columbia River Power System (FCRPS) Biological Opinions (BiOps).

1.1 Background

In the late 1990's, it was recognized that development of a systemwide TDG model would assist with in-season management of voluntary spill. This idea was incorporated into the NMFS 2000 Biological Opinion, RPA Action 133 which encouraged the development of a TDG model for spill management. As a result, the Corps began developing a TDG model called SYSTDG, which is an hourly time step model used to forecast the TDG levels at the Columbia and Snake River projects and set daily spill caps. SYSTDG estimates TDG production resulting from project operations on the Columbia from Grand Coulee Dam to Bonneville Dam, Snake River from Lower Granite Dam to the confluence with the Columbia River, and from Dworshak Dam on the Clearwater to its confluence with the Snake River. The equations SYSTDG uses are based on 50 TDG research studies that the Corps Engineering Research and Development Center (ERDC) performed from 1995 to 2008. The parameters of total river flow; spill; wind; water temperature; forebay and tailwater elevations; barometric and total gas pressures; tributary data and spill patterns are incorporated into the SYSTDG forecasts. It also takes into consideration the hydraulic design of the projects, unique river hydrologic conditions and the accumulative effects of project management of the river.

During the 2004 spill season, SYSTDG was used for the first time as a river operations management tool to evaluate TDG on the Columbia and Snake rivers and to assist in the setting of spill caps at each of the projects where voluntary spill for fish occurred. At the conclusion of the spill season, a review of the performance of SYSTDG was completed and included in the 2004 Dissolved Gas and Water Temperature Monitoring Report. The same statistical evaluation of SYSTDG was done for the 2005 through 2009 spill seasons. These reports are included in the annual "Total Dissolved Gas and Temperature Annual Report" for each of those seasons and are available on the RCC Water Quality Programs webpage at, http://www.nwd-wc.usace.army.mil/TMT/wqwebpage/mainpage.htm .

The 2008 BiOp recommends continued use of the SYTDG model. In 14.5.2 of the 2008 BiOp, "SYSTDG applications and results shall be coordinated through the Water Quality Team, the Technical Management Team, the Transboundary Gas Group and the Mid-Columbia Public Utility Districts. Continued refinement of the SYSTDG gas model reduce take by improving spill management at the mainstem projects." RPA Action 15 is dedicated to TDG and temperature modeling and states "The Action Agencies will continue to update the *Water Quality Plan for Total Dissolved Gas and Water Temperature in the Mainstem Columbia and Snake Rivers* (WQP) and implement water quality measures to enhance ESA-listed juvenile and adult fish survival and mainstem spawning and rearing habitat. TheWQP is a comprehensive document which contains water quality measures needed to meet both ESA and Clean Water Act responsibilities. For purposes of this RPA Action, the WQP will include the following measures to address TDG and water temperature to meet ESA responsibilities:

- Update the SYSTDG model to reflect modifications to spillways or spill operations,
- Continued development and use of SYSTDG model for estimating TDG production to assist in real-time decision making, including improved wind forecasting capabilities as appropriate,"

SYSTDG will continue be used as a TDG management tool into the foreseeable future. Modifications of the model occur as necessary when there are modifications to the spillway, new spill patterns or new TDG research that can be used to refine the model.

2.0 TDG Management

The TDG management measures differ depending on the category of spill so it is important to understand the definitions of voluntary and involuntary spill.

2.1 Voluntary, and Involuntary Spill

There are two categories of spill: voluntary and involuntary. Voluntary spill occurs when spill is implemented in accordance with the Endangered Species Act (ESA) spill operations and applicable state water quality criteria shown on Table 1. Voluntary spill is defined as the passing of water through the spillway gates of a dam to facilitate passage of juvenile salmon past the project or passage of water to aid fish downstream. Spill at projects that pass juvenile salmonids decreases the residence time of juvenile salmon in the forebay of dams.. Voluntary spill is also used at Dworshak Dam to provide for flow augmentation and to improve temperature conditions in the lower Snake River. The amount of voluntary spill is adjusted daily so that the resulting TDG levels associated with spill are consistent with applicable state water quality criteria. The Oregon water quality TDG criteria specify that TDG levels are not to exceed 120% in the tailwaters as measured as the average of the twelve highest hourly readings in any one day. Oregon no longer includes criteria for TDG in the forebays. The Washington TDG criteria specify that TDG levels are not to exceed 120% in the tailwaters and 115% in the forebays of downstream projects as the average of the twelve highest consecutive hourly readings in any one day. They also specify that TDG levels are not to exceed 125% on a one-hour basis (State of Washington) or on a two-hour basis (State of Oregon). These TDG levels are referred to as "gas caps". The term "spill cap" is defined as the amount of spill necessary for TDG levels to reach the gas cap.

Involuntary spill occurs when hydrologic conditions result in flows which exceed the hydraulic capacity of power generation facilities and may or may not exceed the 115% and 120% TDG levels shown on Table 1. Involuntary spill is driven largely by local conditions at the project (i.e.

turbine capacity plus available storage is less than inflow). Other causes for involuntary spill include management of reservoirs for flood control, wind generation, 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 safety and multiple uses. For example, in managing the project for flood control, the water supply forecast may underestimate the seasonal streamflows resulting in inadequate space available in the reservoirs to capture incoming water. In other instances, unusually high winter precipitation in January through March may force the operators to store water in the reservoirs above the flood control elevations during those months, causing involuntary spill to occur later in the month as the water is evacuated in an attempt to achieve end of the month reservoir flood control elevations.

2.2 Two Approaches to Managing TDG

There are two general approaches to TDG management: setting spill caps and setting the order of projects to spill on the spill priority list.

- Voluntary spill TDG is managed using 110%, 115% and 120% TDG spill caps. The spill priority list is not used for voluntary spill events.
- Involuntary spill TDG is managed using 125%, 130% and 135% TDG spill caps.
- There are times when not all of the units are operating at full capacity because BPA is not able to sell the energy and it becomes necessary to spill water. In these situations, TDG is managed by spilling according to the order provided on the spill priority list. During involuntary spill due to lack of market, there is the ability to move generation between projects, spilling at non-mainstem projects according to the spill priority list so that TDG is lower on the mainstem. This TDG management measure is implemented by initiating spill at projects according to the spill priority list in a top-to-bottom, and left-to-right fashion. The total amount spilled will depend on the magnitude of the lack of market condition and will vary hourly. An example is spilling 2 kcfs at Dworshak instead of 15 kcfs at Bonneville which could result in a reduction of TDG levels below Bonneville dam.

Since TDG spill caps are an important in managing TDG management, this plan provides detail explanations of why and how the spill caps are set.

2.2.1 Setting Spill Caps

The Corps Reservoir Control Center (RCC) Water Quality Unit set daily spill caps to accommodate objectives set out in various governing documents. The following list provides a summary of this information:

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1. <u>State TDG Standards:</u> The state standards, including state waiver or adjustment establish management of TDG levels to 110% in Idaho and Montana or to 115% in the forebay and 120% in the tailwater in Washington or to 120% in Oregon. NOAA Fisheries 2008 Biological Opinion, RPA 29 also calls for providing spill so that TDG do not exceed the

110% or to the 115 and 120% TDG criteria. Setting daily spill caps ensure that TDG levels are to these objectives.

2. Reduce incidental take: Section 14.5 of the 2008 Biological Opinion requires the "Action Agencies to monitor the levels of TDG and associated biological impacts in the lower Snake and lower Columbia rivers. This will reduce take by ensuring that juvenile and adult fish have sufficient levels of both spill and water quality for migrating through the FCRPS." Setting daily spill caps ensure that spill is managed consistently with this requirement.
3. Prevent unsafe TDG levels in shallow areas: Section 8.9.5.1 of the 2008 Biological Opinion calls for "the overall mainstem hydro strategy to be one that will provide adequate surface water elevations for chum salmon in redds downstream from Bonneville Dam; ensure that voluntary spill does not result in unsafe TDG levels for fish in shallow water areas; and provide safe passage for adults that migrate past Bonneville Dam." Setting daily spill caps ensure that spill is managed consistently with this requirement.
4. Protection of and limiting damage to the physical dam structure: The Water Control Manual for Chief Joseph, Section 7.15 states that "all reservoir releases are subject to the condition that no release shall be made at rates or in a manner that would be inconsistent with operating rules and regulations required for the purpose of protecting the dam and reservoir from damage." Spilling at Chief Joseph at too high flows or with an inappropriate spill pattern can cause damage to the stilling basin of the dam. Setting spill caps is the Corps approach to ensure that voluntary or involuntary spill does not result in damage to any part of the physical structure of the dam.
5. Minimize TDG production: The 2008 Biological Opinion, Table 1, Grand Coulee storage project, calls for the Action Agencies to "operate to minimize TDG production". Spill through the outlet tubes generate significantly more TDG than through the drumgates. Setting spill caps for Grand Coulee's outlet tubes and drumgates is the Corps approach to minimizing TDG production from voluntary spill.
6. Variability in Determinant Factors: Section 3.1 describes the 15 factors that determine spill caps and there is a wide variability in many of these factors that cause the spill caps to change frequently. For example, there can be daily fluctuations in spill operations; wind; water temperature, flows, forecasts; and SYSTDG model results that trigger spill caps changes. As a result, spill caps are assessed every day during spill season.

2.2.2 Target Spill Caps

When systemwide TDG is at or below 120%, provide spill for fish passage on the lower Columbia and lower Snake Rivers up to the 120% TDG tailwater and 115% TDG in the forebays of downstream projects. The 110%, 115% and 120% spill caps are the main TDG management measures used for voluntary spill. During voluntary spill, it is possible to spill the appropriate amount and remain below 120% because spill volumes are determined by spill operations instead of spill caps. When there are high flows so that projects aren't able to restrict spill within the 115% and 120% TDG spill levels, then the spill priority list is used to manage total dissolved gas (TDG) to 120%, or 125%, or 130% or 135%. When systemwide TDG exceeds 120% and higher TDG, then the higher spill caps are used in the order of the projects listed on the spill priority list.

Spill caps for various applicable TDG levels and the order for the projects to spill during involuntary spill events are provided on Table 1. The spill caps are updated, as needed based on real-time TDG information.

TABLE 1
Target Spill Caps for 2010 in kcfs

Project	**Spill Cap to Generate Specific Percentage of Total Dissolved Gas (TDG)**					
	110%	**115%**	**120%**	**125%**	**130%**	**135%**
LWG	20	30	41	90	125	200
LGS	10	15	32	80	110	250
LMN	10	15	31	55	110	250
IHR	30	45	95	125	135	240
MCN	40	80	145	230	290	450
JDA	20	60	120	240	300	600
BON	50	65	100	150	250	270
CHJ	19	50	100	160	160	160
GCL-outlet tubes	0	5	10	20	35	50
GCL-drumgates	0	20	40	75	120	130
DWR	37%	42%	50%	60%	70%	75%
TDA	20	60	125	250	260	600

2.2.3 The Spill Order on the Spill Priority List

Since the order for spilling listed on the spill priority list is important for managing TDG levels when spill occurs due to lack of load, it must be established before the high flows occur which is usually in mid-May. Before the beginning of spill season on April 3, a spill priority list is developed and this list may change several times during the spill season depending on river conditions and other circumstances. The spill priority lists are discussed in the TMT regional forum and revised according to final decisions reached there.

When establishing the order of which dams should spill first, the following factors are what the Corps considers:

- <u>Location of Fish:</u> Consider where the fish are. If TDG levels are at or below 120% with high involuntary spill put the projects with the most fish first on the priority list so the fish are benefited the most with the high spill and flows.
- <u>Location of High TDG:</u> When TDG levels are above 120 % with high involuntary spill, put the projects with the most fish last on the priority list so the fish are harmed the least with the high spill and flows.

- Location of Fish Studies: Consider where there are special fish studies and put those projects low on the priority list so the studies can remain intact as designed.
- River Reaches: Consider projects in one of three blocks: Lower Snake; Lower Columbia and Middle Columbia. For example, if several Lower Snake projects need to be moved to low priority on the list, then move the whole block of projects (LWG; LGS; LMN and IHR) to the last.
- Special Operations: Place projects with special operations such as construction, maintenance or repair last on priority list.
- Collector Projects: During low flow years, place the collector projects (LGS; LWG; LMN; MCN) low on the priority list so that spill is away from them.
- Special Fish Conditions: If there are special fish conditions, such as disease or a special release, then move the project to first place on the priority list so the fish receive the maximum spill.

3.0 Process for Setting Spill Caps

This section provides a detailed explanation of how spill caps are set. There are several steps involved in setting daily spill caps, including evaluating the various factors that determine spill caps; review the real time flow, spill and TDG data, run several simulations with the SYSTDG model to see what spill caps the model suggest; discuss the review results and negotiate proposed spill caps internally, then negotiate new spill caps externally with NOAA Fisheries.

3.1 Factors That Determine Spill Caps

The determination of spill caps at each individual project is dependent upon an array of variables:

1. SYSTDG Model – The SYSTDG model is used as a real time operations tool to forecast the TDG levels for all the projects with the assumption that the following day conditions will be the same as today's. With these model results and information obtained from the other factors listed above, a new spill cap can be determined.

2. Projects Spill Operations: Fish spill operations for the projects are included in the Biological Opinion subject to adaptive management. These spill operations can be a percent of the total river flow (Little Goose 30%; McNary 50%; The Dalles 40% and John Day 30%); a flat spill rate (Lower Granite 20 kcfs); or spill to the spill cap (Lower Monumental, Ice Harbor and Bonneville). The spill operations are among the most influential factors for determining the spill caps.

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Monumental, Ice Harbor and Bonneville). The spill operations are among the most influential factors for determining the spill caps.

4. High 12 Hour Average TDG Reading: A review of the previous day's high 12 hour average TDG reading of the project forebay and tailwater fixed monitoring station (FMS) is used to indicate whether the spill caps needs to be increased or decreased. The high 12 hour average TDG readings are among the most influential factors for determining the spill caps.

5. Web Reports Used in Spill Review: The Corps has developed many web reports that summarize project and water quality data, which are used in spill review and spill cap change decisions. These are
    a. A program that calculates the amount of BiOp voluntary spill compared to how much BiOp voluntary spill actually occurred.
    b. A report that calculates the percentage of spill at certain projects
    c. Data on flow, generation, spill, forebay elevation, TDG levels, and water temperature
    d. Tributary data for the Columbia River Basin
    e. Unit generation and spill bay data
    f. Water temperature string data
    g. 10 day flow forecasts for the lower Columbia and Snake rivers

6. Physical Design and Characteristics of Projects: TDG levels that are generated in the tailwaters of each project depend upon many factors including the amount of spill passing through the spillway, the pattern of spill through the spillway, the amount of flow through the powerhouse, structure of the stilling basin, the presence (or absence) and elevation of flow deflectors, the presence (or absence) of divider walls, and river characteristics immediately below each project. These individual characteristics are taken into account when assigning spill caps.

7. Travel Time: The time it takes water to move from one project to the next depends upon the distance between projects and the flow rate in the river. Because of this, changes in spill at an upstream project and the resulting change in TDG levels will not be seen in the forebays of the downstream project for several hours or days.

8. Water Temperature: Climatic conditions can cause increases in water temperatures, which in turn can cause increases in TDG levels. The rule of thumb for water temperature is that a $1^{o}C$ ($1.8^{o}F$) increase in water temperature can result in a 2 to 3% increase in TDG. The impact of changing climactic conditions on water temperature is difficult to predict so air temperature is used as a surrogate. If it is expected that significant increases in air temperature are expected in a specific region, then it will be assumed that water temperatures would also be increasing and spill caps will be adjusted appropriately.

9. Degassing: As waters flow from one project to another, degassing can occur. Experience has shown that winds above 10 mph enhance degassing. Therefore, wind conditions are used to predict levels of degassing and is included in the SYSTDG model used to

determine daily spill caps. In addition, with flows below 200 kcfs, significant degassing of TDG occurs in the river between the Bonneville Dam and the Camas/Washougal FMS. However, when flows increase above 200 kcfs, little or no degassing has been observed.

10. Flow Variations: Spill decisions are often affected by forecasts of flows. Also, there are variations in flow on a weekly basis. On weekends, demand for power typically drops as compared to during the workweek, so flows may drop on weekends.

11. Maintenance and Repairs: During an average spill season, there are many units that are out of service for various reasons. Scheduled maintenance and repair activities will reduce the amount of powerhouse capacity of a project. The type of maintenance and repair activity and how it will affect flows through the project is taken into account in order to assign appropriate spill caps.

12. Experimental Test Schedules: The scheduling of various investigative studies can result in alterations in the normal operation of a project. Examples of such alterations including modified spill pattern tests, Removable Spillway Weir tests, and modified spill operations (e.g. at Ice Harbor, 50% spill operations for 24 hours for two days and then BiOp spill operations for the next two days).

13. Minimum Spill: During low flow conditions, there are minimum voluntary spill levels at Ice Harbor (15.2 kcfs); 25% at John Day and at Bonneville (75 kcfs).

14. Minimum Generation: A minimum amount of flow for power generation is needed for electrical grid stability. During low flows, the minimum generation requirement will limit the spill rate from projects.

15. Definition of Daytime and Nighttime: The definition of daytime and nighttime effects how long the spill level is maintained so a spill cap can be set a little higher knowing that it will be in effect for only a few hours. This factor is especially true for Bonneville where the definition changes frequently throughout the spill season.

3.2 How Daily Spill Caps Are Set

Spill caps are set for each project and are adjusted daily or as needed, depending on actual TDG readings and the variability of the factors that determine spill caps listed in Section 3.1. These factors are reviewed daily and spill cap adjustments are made daily to ensure that TDG concentrations are consistent with state water quality criteria. The following is a more detailed description of how the spill caps are adjusted and set:

Step 1-Review Data: The various web reports that show flow forecast, weather forecast, flow, spill, generation, forebay elevation, unit outage information and water quality data are reviewed. The previous day data in terms of the determinant factors are compared against the ESA operation requirements. When there are discrepancies between actual spill and expected spill, RCC Water Quality team investigates the causes.

Step 2-Investigation of Discrepancies: When there are discrepancies between actual spill and expected spill, RCC Water Quality talk to the following people:

> A. Unit Outage Coordinator – Are there unit or line outages occurring that are effecting spill operation? If there are, how many units or lines are down and how long, will it be until they return to service.
> B. Fish Biologist – Sometime there are special operations about a fish test or special fish operations that RCC Water Quality needs to be informed about.
> C. The Project Operators – RCC Water Quality discusses spill operations discrepancies to find out the reason. Based on this information, RCC Water Quality will need to talk to either Unit Outage Coordinator or the Fish Biologist.

Step 3 - Document Spill Review: As RCC Water Quality performs Step 2 data review, the spill change decision is documented on a form with information about what type of TDG exceedance occurred, the current spill cap, which projects need to have their spill caps changed, the rational for the spill cap change, spill and flow ranges and what are the new proposed spill caps. The spill change decision form documents the results of the data review and the final decisions that were made on spill caps.

Step 4 - Run SYSTDG Model: RCC Water Quality checks the proposed spill caps with what the SYSTDG model suggest. It may be necessary to run several simulations until the right spill caps for all of the projects are obtained since a change at one location effects the next one downstream.

Step 5 - Spill Cap Change Discussion: The RCC Water Quality team members who performed Step 2 data review discuss the SYSTDG model results and data review findings. Typically the team members negotiate to reach an agreement on what the new spill caps should be.

Step 6 - Comments from NOAA Fisheries: The final completed spill change decision form is faxed to NOAA Fisheries water quality/spill specialist by 10:00 to allow them time to review our decisions. RCC Water Quality waits until 12:00 for their phone call or email comments about our proposed spill cap changes. If the NOAA Fisheries representative has questions or wants to discuss or negotiate changes to the spill caps, a RCC Water Quality team member answers their questions and enters into negotiations. The RCC Water Quality team member negotiates and resolves technical issues with the NOAA Fisheries representative. All questions and issues that are non-technical and are policy in nature are referred to the RCC Chief. Final spill caps will be sent out once the RCC Chief and the NOAA Fisheries representative reach an agreement.

Step 7 - Send The New Spill Priority List Out: RCC Water Quality team member calls BPA real time scheduling and the projects to inform them that a new spill priority will be sent out with the new spill cap. RCC Water Quality sends out the new spill priority list with the new spill caps by 13:00.

4.0 TDG Management Policies

The highlights of the 2010 TDG Management policies are as follows:

- Since the states of Oregon and Washington have different TDG standards, the Corps will manage spill at the Lower Columbia and Snake River projects to the more stringent of the two. The Washington standard is more stringent most of the time, but on a few days at certain locations, the Oregon standard will be more stringent. As a result, spill will be managed to the 115%/120% TDG criteria based on the average of the twelve highest consecutive hourly readings most of the time unless the Oregon standard is more stringent at a particular location.
- Manage projects operations to the extent practical in accordance with CWA
- Provide voluntary spill for fish consistent with ESA requirements
- Project will be operated to authorized multi-purposes

Voluntary spill policies:

a. Flows will be regulated to maximize potential for voluntary spill.
b. Experiment with promising new spill patterns.
c. Discontinue or postpone field research and non-critical unit service and maintenance schedules that create (or have potential for creating) high localized TDG levels, especially when and where high numbers of listed fish are present.
d. Spill to improve juvenile fish passage while avoiding high TDG supersaturation levels or adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each project that will be consistent with applicable State TDG criteria.
e. When project voluntary spill occurs, the projects will be operated to manage TDG consistent with variance criteria without jeopardizing flood control objectives. When TDG cannot be managed within variance criteria, the river will be adaptively managed in salmon stocks (see Sections 3.4 and 3.5). It is recognized that measures to reduce TDG could impact migrating salmon. Therefore, coordination with Federal, State and Tribal salmon managers will occur.
f. Accommodate special spill requirements/restrictions for research, adult passage, etc. that have the full endorsement of all concerned parties.

Involuntary spill policies:

- The Corps will manage involuntary spill to 125% TDG as measured on an hourly basis.
- If systemwide TDG exceed 120%, implement the spill priority discussed in Section 3.4 and 3.5. Unless and until a different reach priority is recommended by the TMT, spill will start as specified in the Spill Priority List.

The management of spill at each project is based on TDG levels measured at specific forebay and tailwater fixed monitoring stations. The current locations of these gauges are based on extensive studies that have been conducted since 1996. At the present time, there are regional discussions occurring regarding the use of these fixed monitoring stations for the management of TDG within the mainstem Columbia and Snake Rivers. The Corps will continue to participate in these discussions, coordinate with the States of Oregon and Washington on voluntary spill for fish passage, and provide technical information to inform the process. Future spill operations may be modified through the implementation planning process and adaptive management. The Corps' decision on the spill program will consider water quality effects along with the results of spill studies, biological evaluations, and the relationship to achieving BiOp performance standards.

5.0 TDG Monitoring Program

In support of the spill management program, a TDG monitoring program has been established and is described in the TDG Monitoring Plan of Action. This monitoring program is revised to include changes in the fixed monitoring station system and evaluated by regional representatives. The draft plan for 2010-2014 was included in the TDG waiver and adjustment package that was submitted to the states of Oregon and Washington in 2009. Based on discussions and written comments, the TDG waiver and adjustment package and TDG monitoring plan of Action for 2010-2014 was accepted by the state of Oregon in June 2009 and the state of Washington is expected to accept it before March of 2010. With Oregon's issuance and Washington anticipated issuance, the Oregon TDG waiver, Washington adjustment and TDG Monitoring Plan of Action will be in effect for five years spanning from 2010 to 2014.

A copy of the 2010-2014 TDG monitoring plan of Action can be obtained from the RCC Water Quality Programs webpage found at:

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