UAAs and Other Tools for Managing Designated Uses

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United States Environmental Protection Agency
Office of Water
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Use Attainability Analyses and Other Tools for Managing Designated Uses

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 13 2006

MEMORANDUM

OFFICE OF WATER

SUBJECT: Improving the Effectiveness of the Use Attainability Analysis (UAA) Process

FROM: Ephraim S. King, Director
Office of Science and Technology

TO: Regional Water Division Directors,
Regions 1-10

I am writing you to reinforce the importance of working together with our state and tribal partners to make the UAA process operate more effectively. As you know, appropriate and defensible water quality standards (WQS) are essential for achieving the Clean Water Act (CWA) goals of maintaining and restoring water quality -- and getting WQS right starts with getting designated uses right.

With this memo, I am attaching a set of case studies which demonstrate a number of UAAs that are associated with a designated use change. These case studies illustrate the breadth and variety of successful UAAs in terms of the types of waterbodies and uses addressed, the factors involved (i.e., natural, human-caused, or economic conditions), and the complexity and depth of analysis. You can expect to receive additional UAA-related materials from the Office of Science and Technology (OST) this calendar year, such as sets of frequently asked questions and answers about UAAs, to help support implementation of the UAA process in your Region.

Our goal is to make the WQS program work better. Our priority is to improve clarity in the WQS process including better communication, understanding, efficiency, and increased public awareness. Making the UAA process operate effectively is an important step towards achieving these priorities. Once states and tribes designate the appropriate uses, the right water quality criteria, permits and targets for Total Maximum Daily Loads (TMDLs) will follow to move us towards improving water quality.

I appreciate your continued support in this area and ask that you share and reinforce with our co-regulators and stakeholders the following five key points:

- **Getting the uses right requires both a useful set of designated uses and an effective process for conducting credible and defensible UAAs.** EPA realizes that deciding what uses are attainable is critical, and views the UAA process, properly applied and implemented, as a vital tool in making those decisions. Early coordination among states and EPA is critical to making the process more efficient. UAAs are meant to assess what is attainable, it is not simply about documenting the current water quality condition and use (although documenting current conditions is often part of the analysis).

- **A credible UAA can result in a change in designated use in either direction.** A credible UAA can lead to refinements or changes in use that lead to either more or less protective criteria. The goal is that the new use is more accurate.

- **There is nothing wrong with changing designated uses after completion of a credible UAA.** It is an expected part of the process. If a credible and defensible UAA indicates a need for a WQS change, then a change to WQS is appropriate to effectively implementing the WQS program. Sometimes these changes are on the critical path to making real environmental progress.

- **The UAA process should be better integrated with TMDL development.** We need to work together with states and tribes to ensure that as we develop TMDLs, we also coordinate on issues related to use attainability as needed. In practice, the information gathered to develop a TMDL, and the allocations in a TMDL, may point to the need to pursue a UAA. While in some cases it may be more effective to ensure that the right uses are in place prior to completing the TMDL, it is also important not to let uncertainty about a specific water quality endpoint delay implementation of needed water quality improvements. Scarce resources should be directed where they will be most effective and avoid duplicative efforts. We should continue to share ideas/examples, develop and promote best practices.

- **Improved public communication leads to improved public acceptance.** It is critical for EPA, states and tribes to engage the public in meaningful discussions regarding the importance and value of getting uses right in maintaining and restoring water quality. WQS that reflect the best available data and information should be used to direct the process of managing water quality. They are essential to informed decision making. Just as important, public understanding and acceptance of WQS is central to broader community support for addressing potentially difficult pollution control management decisions.

In the long run, water quality programs will be most successful if the public understands their underlying goals, the process by which those goals are set, and is engaged and able to effectively contribute to that process. Getting the uses right is on the critical path to effective water quality standards implementation. Accomplishing this can be a significant challenge but it is also an essential need. I look forward to continuing to address these issues with you.

Attachment

cc: Regional Water Quality Standards Branch Chiefs, Regions 1-10
Diane Regas, OWOW
Lee Schroer, OGC

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Preface

Setting water quality goals through assigning “designated uses” is best viewed as a process for states and tribes to review and revise over time rather than as a one-time exercise. A key concept in assigning designated uses is “attainability,” or the ability to achieve water quality goals under a given set of natural, human-caused, and economic conditions. The overall success of pollution control efforts depends on a reliable set of underlying designated uses in water quality standards.

EPA’s water quality standards regulation provides a process for reviewing and revising designated uses, described as a “use attainability analysis,” as well as several rationales or factors that may be invoked as the reason for changing a use. In implementing the regulation, EPA provides outreach and support to states and tribes to assist them in working through this process. The goal is for every waterbody to have a designated use that is scientifically and legally defensible and supported by the local community.

In recognition of the strong role that designated uses have in driving monitoring, assessments, Total Maximum Daily Loads (TMDLs), and permits, EPA has been promoting public dialogue on designated uses and UAAs. In 2002, EPA held a Designated Use Symposium. Participants generally agreed that it is important to have the right uses designated to each waterbody segment, and we also learned that states needed to invest in putting in place more refined use designations along with differentiated criteria to protect those uses. From this symposium, we realized that states and EPA need a credible and efficient process for making use decisions in a timely manner that allows progress toward the best water quality possible. After making designated uses a priority, we issued our *Plan for Supporting States and Tribes on Designated Use Issues* in 2004, which called for:

- More outreach, training, workshops, and other support for states and tribes on critical issues regarding designating appropriate uses; and

- Continued discussions with stakeholders on designated use issues.

Over the past year, EPA has facilitated several workshops with our state, inter-state, and tribal partners. EPA Regional Offices have been heavily involved and invested in these efforts. We have heard about some innovative and successful approaches, as well as some common frustrations. In addition, EPA has co-sponsored multi-stakeholder public meetings to obtain views from interested parties. Overall, we heard a desire to reduce debate and to make progress toward reaching attainable goals. We heard a desire for EPA to provide more precise and specific answers to what are in some cases some pretty generic questions about how we interpret certain provisions of our regulations.

Over the course of implementing the WQS program, many designated use changes have occurred as a result of informative and compelling demonstrations provided by UAAs. The enclosed case studies display the breadth and variety of UAAs. In some cases, such as the one provided for Chesapeake Bay, the UAA is extensive and resource-intensive. However, we have also seen effective UAAs that are much simpler, for example by conveying the appropriate designated use expectations principally through a set of photographs documenting the physical characteristics of the waterbody.

The most significant misperception about designated uses and UAAs is that UAAs need only address the current condition of a waterbody: that a designated use may be removed simply by documenting that protective criteria are exceeded. However, it is the prospective analysis of future attainability of designated uses that provides the demonstration necessary to support a use change. A related misconception is that UAAs are only a means to remove a designated use. In fact, UAAs have supported both removing uses and adding uses. The program experience and future direction reflects a growing practice of "sub-categorizing" or "refining" designated uses; that is, making them more specific and precise as opposed to removing them.

Often, we are confronted with the fundamental question of why we should promote refining designated uses, particularly if the current designated uses are "fishable/swimmable." Our intent is to help the public act to improve water quality. We believe that setting attainable water quality goals is important in stimulating action to improve water quality. We do not believe that setting unattainable uses advances actions to improve water quality.

The WQS program is intended to protect and improve water quality beyond what is provided for through technology controls under the effluent guidelines program. WQS are supposed to guide actions to reduce pollutant releases regulated under the CWA. WQS are supposed to help us decide what needs to be done. The reality is that as more assessments are being done and TMDLs are being contemplated, we are facing attainability questions with current standards. This is in part related to the evolution of the WQS Program; in the early days, use attainability analyses were not usually performed when uses were originally designated. We are encountering more difficult issues, such as how to address the recreational use issue during wet weather events (CSOs) and how to address aquatic life uses in effluent dependent and ephemeral waters. These attainability questions can contribute to delays in achieving pollutant reductions (especially for nonpoint source control) because people often believe that the water quality goals are incorrect and perceive that revising WQS is a complex process. This is why we have been investigating the best ways to utilize UAAs and related tools, like variances, to make progress in getting designated uses right.

Many of our waters do not meet the water quality goals envisioned by the Clean Water Act. Many of the problems have been produced over many years and may take many years to resolve. Some problems may take substantial changes in resource management to implement solutions. A process of setting incremental water goals through refined designated uses, that in turn advances progress toward an ultimate goal, can help us achieve our long term goals faster. One way to achieve efficiency in the process of assigning attainable designated uses is to better synchronize UAA analyses with the TMDL process. In practice, UAAs may be conducted prior to, concurrently with, or after the development and implementation of a TMDL. In many cases, the data generated during a TMDL could well serve as the foundation for deciding whether a change in a use is warranted.

Finally, whenever we contemplate a use change, there should be thoughtful and informed public involvement in the process and throughout the process. States should communicate to the public about use changes early in the process and EPA should publicly support the states' actions to engage the local community in these discussions of what is attainable. These are important decisions, and the best decisions reflect consideration of all perspectives.

Overview of Case Studies: UAAs and Other Tools for Managing Designated Uses

What is a UAA and what are the 40 CFR 131.10(g) factors?

A Use Attainability Analysis (UAA) is a structured scientific assessment of the factors affecting the attainment of uses specified in Section 101(a)(2) of the Clean Water Act (the so called "fishable/swimmable" uses). The factors to be considered in such an analysis include the physical, chemical, biological, and economic use removal criteria described in EPA' s water quality standards regulation (40 CFR 131.10(g)(1)-(6)).

Under 40 CFR 131.10(g) states may remove a designated use which is not an existing use, as defined in § 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or

2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or

3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or

5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or

6. Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

UAAs and Other Tools for Managing Designated Uses
Selection of Case Studies

Case Study (State, EPA Region)	Complexity	Type of Action	131.10(g) Factor(s)
Kansas & New York UAA Worksheets: Crosby Creek (Kansas, EPA Region 7)	very simple	Assign primary contact recreational use	n/a
Kansas & New York UAA Worksheets: Antelope Creek (Kansas, EPA Region 7)	very simple	Redefined as ephemeral stream	2
Kansas & New York UAA Worksheets: Tributary of Seneca River (New York, EPA Region 2)	very simple	Aquatic life use support	2
Suspension of Recreational Beneficial Uses in Engineered Channels During Unsafe Wet Weather Conditions (California, EPA Region 9)	simple	Temporary suspension of recreational use	2, 4
Valley Creek UAA (Alabama, EPA Region 4)	simple	Assign limited warmwater fishery use	3, 5
New York Harbor Complex UAA (New York, EPA Region 2)	medium	Assign aquatic life & recreational uses	3
Red Dog Mine UAA (Alaska, EPA Region 10)	medium	Removal of aquatic life uses & development of site-specific criterion	1, 3
Montana's Temporary Water Quality Standards—New World Mining District (Montana, EPA Region 8)	complex	Temporary standards for multiple uses during remediation	3
Chesapeake Bay UAAs and Restoration Variance (Maryland, EPA Region 3)	very complex	Refined aquatic life uses and restoration variance	1, 3, 6

Case Studies
Brief Descriptions

KANSAS AND NEW YORK UAA WORKSHEETS: CROSBY CREEK IN KANSAS

Complexity: Very simple **Type of Action:** Assign primary contact recreational use
Region: 7 **131.10(g) Factors:** n/a

The Kansas Department of Health and Environment (KDHE) has developed a worksheet to conduct many simple use attainability analyses (UAAs). The worksheet provides reviewers with information such as the name, location, and description of the waterbody; an assessment of its current recreational uses; and observations of aquatic life. Users can evaluate this information and develop a justification for retaining or changing designated uses. One example of using this worksheet is the Crosby Creek UAA conducted in 2001. In the UAA KDHE proposed primary contact recreation use for Crosby Creek, an upgrade from the secondary contact recreation use designated previously. KDHE also proposes to maintain the current aquatic life use designation. Kansas adopted this change their water quality standards and EPA approved it.

KANSAS AND NEW YORK UAA WORKSHEETS: ANTELOPE CREEK IN KANSAS

Complexity: Very simple **Type of Action:** Redefined as ephemeral stream
Region: 7 **131.10(g) Factors:** 2

KDHE's UAA worksheet was used for the Antelope Creek UAA conducted in 2001. In that UAA, KDHE did not recommend primary contact recreation as a designated use for this water because of the low flow conditions in the stream (131.10(g) factor 2). The segment fits Kansas' definition of an ephemeral stream, grass or vegetative waterway, culvert, or ditch. Photos are provided with the worksheet to show the dry conditions in the streambed. This change was adopted into Kansas' water quality standards and approved by EPA.

KANSAS AND NEW YORK UAA WORKSHEETS: TRIBUTARY OF THE SENECA RIVER IN NEW YORK

Complexity: Very simple **Type of Action:** Aquatic life use support
Region: 2 **131.10(g) Factors:** 2

The New York State Department of Environmental Conservation (NYSDEC) has used a simple worksheet to document UAAs for aquatic life use support. These worksheets were developed as part of an overall 1985 State "Water Quality Standards Attainability Strategy," which included specific guidance for field biologists on assessing fish propagation for various habitats. The worksheet contains the name and location of the waterbody, a checklist of reasons why the waterbody cannot attain full aquatic life designated uses, and space for additional comments or recommendations. One example is a 1992 UAA for a tributary of the Seneca River in New York. Some segments were changed from Class D to Class C (supportive of both aquatic life and recreational uses), and others were determined incapable of attaining Class C on the basis of

131.10(g) factor 2. The worksheet documents the Department's proposed changes to the designated uses.

SUSPENSION OF RECREATIONAL BENEFICIAL USES IN ENGINEERED CHANNELS DURING UNSAFE WET WEATHER CONDIDTIONS

Complexity: Simple
Region: 9
Type of Action: Temporary suspension of recreational use
131.10(g) Factors: 2, 4

The Los Angeles Region has many rivers and streams that have been straightened, concrete-lined, or both to move floodwaters from urban areas to the ocean. These channels transport large volumes of water that might not be of adequate quality to support Clean Water Act (CWA) section 101(a) uses (i.e., "fishable/swimmable"). The water quality goals set forth in the Los Angeles Region's Basin Plan specify that all waters in the state should be "fishable/swimmable."

Under certain conditions recreational uses are inappropriate for these channels. During high flow flood conditions, it is not safe to swim in the waters. The Los Angeles Region has opted to issue a suspension of recreational use during periods of high flow. Through a revision to its water quality control plan, the Los Angeles Region established that during high flow events, when it is not safe to be in the modified channels, these waterbodies do not have to meet bacteria criteria. The suspension of recreational uses applies under the rainfall conditions that trigger the Region's swift-water protocols (i.e., rescue squads are on alert if someone should happen to enter the water). With this use attainability analysis (UAA), EPA approved the revision to the Water Quality Control Plan for the Los Angeles Region.

VALLEY CREEK UAA

Complexity: Simple
Region: 4
Type of Action: Assign limited warmwater fishery use
131.10(g) Factors: 3, 5

In this 2001 use attainability analysis (UAA), the Alabama Department of Environmental Management (ADEM) provided evidence to support the proposed change for the upper segment of Valley Creek from Agricultural and Industrial Water Supply (A&I) to Limited Warmwater Fishery (LWF). The corresponding water quality criteria are more stringent for waters classified as LWF than for A&I waters. The key element of the LWF classification establishes seasonal uses and water quality criteria for waters that otherwise cannot maintain the more protective Fish & Wildlife (F&W) classification year-round. The LWF classification does not fully meet the water quality uses and criteria associated with the "fishable/swimmable" goal, and therefore a UAA was necessary. In the UAA, ADEM provided information on the physical, biological, and chemical characteristics of Valley Creek; water quality data from sampling stations; discharge monitoring reports from the point source dischargers; and water quality modeling results. EPA approved the revision to Alabama's water quality standards to reclassify Upper Valley Creek for LWF and Lower Valley Creek for F&W.

NEW YORK HARBOR COMPLEX UAA

Complexity: Medium **Type of Action:** Assign aquatic life & recreational uses
Region: 2 **131.10(g) Factors:** 3

A 1985 use attainability analysis (UAA) documents the assessment of waters in the New York Harbor Complex that were not thought to meet Clean Water Act (CWA) section 101(a)(2) goals. In the UAA the New York State Department of Environmental Conservation (NYSDEC) presents historical data on total and fecal coliform and dissolved oxygen, as well as the results of steady-state modeling. The segments considered are effluent-limited waters (i.e., the technology-based effluent limitations required by the CWA are inadequate to meet the water quality standards), with impairment from urbanization, combined sewer overflows (CSOs), and other point and nonpoint source discharges. In the UAA NYSDEC recommends that several segments should be assigned both aquatic life and recreational uses. NYSDEC also recommends that some uses be retained and proposes future monitoring and assessment.

RED DOG MINE UAA

Complexity: Medium **Type of Action:** Removal of aquatic life uses & development of site-specific criterion
Region: 10 **131.10(g) Factors:** 1, 3

A use attainability analysis (UAA) was performed on Red Dog Creek, which runs through the site of Red Dog mine, the largest zinc mine in the world. Red Dog Creek flows only 3–4 months of the year. Several parts of the creek are affected by mining discharges and some acid rock drainage. In addition, the area contains natural ore bodies, resulting in naturally high concentrations of cadmium, lead, zinc, aluminum, and other metals. Pre-mining surveys done in this area indicated that aquatic life uses were not present because of the toxic concentrations of metals, as well as naturally low pH. The UAA for Red Dog Creek demonstrated that aquatic life uses should be removed because of the naturally occurring pollutants. Because of the natural conditions, the criteria for cadmium, lead, zinc, aluminum, and pH cannot be met without human intervention, precluding that aquatic life uses being met. However, treatment of mine wastewater had led to the presence of Arctic grayling that should be protected. A site-specific criterion for total dissolved solids (TDS) was developed to protect the grayling when spawning. EPA approved these changes to Alaska's water quality standards.

MONTANA'S TEMPORARY WATER QUALITY STANDARDS—NEW WORLD MINING DISTRICT

Complexity: Complex **Type of Action:** Temporary standards for multiple uses during remediation
Region: 8 **131.10(g) Factors:** 3

Montana's Water Quality Act allows for application of temporary modification of water quality standards where a waterbody is not meeting its designated use. The ultimate goal of the temporary modification is to improve water quality to the point where designated uses are fully supported. As such, temporary standards play a key role in the remediation of damaged water resources, because the underlying designated uses and criteria are established as goals which drive water quality improvements. The duration of temporary standards is set based on an estimate of the time needed for remediation at a specific site, and because the clean up of legacy pollutants often takes time, temporary standards can be and are issued for multiple years. The state uses 20 years as its time horizon for estimating future watershed remediation opportunities, and therefore, temporary standards could be issued for as much as 20 years. The New World Mining District is an example of a well-funded and successful project. The waters were classified as suitable for a number of uses, including drinking water, recreational, and aquatic life uses.

CHESAPEAKE BAY UAAS AND RESTORATION VARIANCE

Complexity: Very complex	**Type of Action:** Refined aquatic life uses and restoration variance
Region: 3	**131.10(g) Factors:** 1, 3, 6

Chesapeake Bay waters have been impaired by nutrients and sediment from point and nonpoint sources. These impairments have led to low levels of dissolved oxygen and inability to meet designated uses. Two use attainability analyses (UAAs) were conducted, with several states involved, to evaluate three of the 131.10(g) factors: natural conditions, human-caused conditions, and economics. Maryland collected a significant amount of monitoring data and developed a model to use the data to assess whether the bay's waters were meeting their designated uses. One result of the UAAs was the decision to refine the aquatic life uses. Five designated uses were identified, and the seasonality of each was considered. Maryland promulgated these designated uses in its water quality standards, and EPA approved the new standards in 2005.

In addition, restoration variances were added to Maryland's proposed water quality standards as refinements to proposed criteria. These variances can be applied over an entire segment of the Bay, rather than directed at a specific discharger or group of dischargers. The temporary modifications allow for realistic recognition of current and attainable conditions while retaining the designated use and setting full attainment as a future goal. In addition, the variance allows for incremental improvements in water quality goals.

Kansas and New York UAA Worksheets

Abstracts

Crosby Creek, Kansas

<u>Complexity</u>: Very simple
<u>Region</u>: 7
<u>Type of Action</u>: Assign primary contact recreational use
<u>131.10(g) Factors</u>: n/a

The Kansas Department of Health and Environment (KDHE) has developed a worksheet to conduct many simple use attainability analyses (UAAs). The worksheet provides reviewers with information such as the name, location, and description of the waterbody; an assessment of its current recreational uses; and observations of aquatic life. Users can evaluate this information and develop a justification for retaining or changing designated uses. One example of using this worksheet is the Crosby Creek UAA conducted in 2001. In the UAA KDHE proposed primary contact recreation use for Crosby Creek, an upgrade from the secondary contact recreation use designated previously. KDHE also proposes to maintain the current aquatic life use designation. Kansas adopted this change their water quality standards and EPA approved it.

Antelope Creek, Kansas

<u>Complexity</u>: Very simple
<u>Region</u>: 7
<u>Type of Action</u>: Redefined as ephemeral stream
<u>131.10(g) Factors</u>: 2

KDHE’s UAA worksheet was used for the Antelope Creek UAA conducted in 2001. In that UAA, KDHE did not recommend primary contact recreation as a designated use for this water because of the low flow conditions in the stream (131.10(g) factor 2). The segment fits Kansas’ definition of an ephemeral stream, grass or vegetative waterway, culvert, or ditch. Photos are provided with the worksheet to show the dry conditions in the streambed. This change was adopted into Kansas’ water quality standards and approved by EPA.

Tributary of the Seneca River, New York

<u>Complexity</u>: Very simple
<u>Region</u>: 2
<u>Type of Action</u>: Aquatic life use support
<u>131.10(g) Factors</u>: 2

The New York State Department of Environmental Conservation (NYSDEC) has used a simple worksheet to document UAAs for aquatic life use support. These worksheets were developed as part of an overall 1985 State “Water Quality Standards Attainability Strategy,” which included specific guidance for field biologists on assessing fish propagation for various habitats. The worksheet contains the name and location of the waterbody, a checklist of reasons why the waterbody cannot attain full aquatic life designated uses, and space for additional comments or recommendations. One example is a 1992 UAA for a tributary of the Seneca River in New York. Some segments were changed from Class D to Class C (supportive of both aquatic life and recreational uses), and others were determined incapable of attaining Class C on the basis of 131.10(g) factor 2. The worksheet documents the Department’s proposed changes to the designated uses.

Background

Use attainability analyses (UAAs) can vary in terms of complexity. Some assessments are complex and require extensive data collection and complex UAAs, whereas others are simple and straightforward and require simple UAAs. Kansas and New York are two states that have developed UAA worksheets for use in simple, straightforward assessments of designated uses.

Kansas UAA Reports

In 2001 Kansas conducted many UAAs using the expedited stream recreational use UAA protocol (http://www.kdhe.state.ks.us/befs/uaas/UAAGuidance.pdf). The Kansas UAA Guidance was developed through an extensive stakeholder process and provides consistent methodologies for the Kansas Department of Health and Environment (KDHE) or third parties to follow in assessing designated uses. To present the results of these UAAs, Kansas developed a simple formatted worksheet. For an individual stream segment, the assessment team documents a variety of information such as the name, location, and description of the waterbody; an assessment of its current uses; and observations of existing conditions. Users evaluate this information and develop a justification for retaining or changing designated uses. Photos of the site are also attached to visually document the conditions of the waterbody. KDHE is required to evaluate the classification status of stream segments against the criteria for classification of stream segments provided in state law.

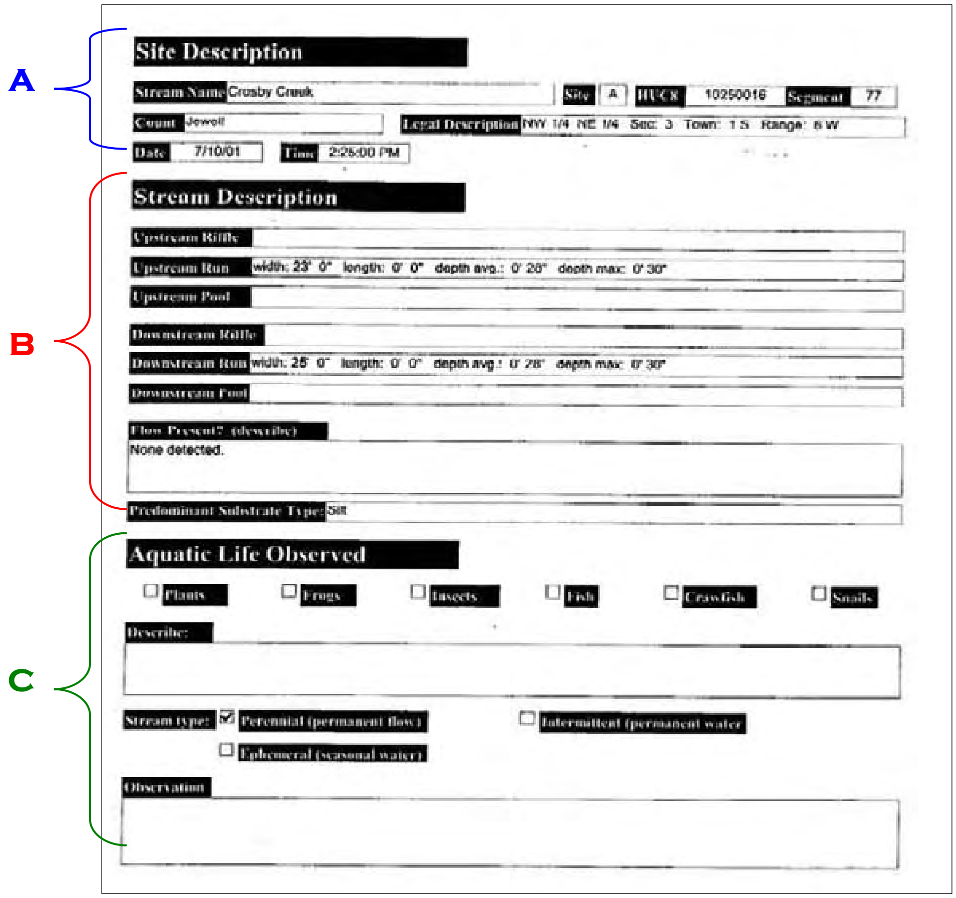
Kansas maintains a Surface Water Registry, which lists specific waters that carry specific designated uses with numeric criteria in addition to general narrative criteria. These are called “classified” streams in Kansas, and generally include stream segments that have the most recent 10-year median flow of equal to or in excess of 1 cubic foot per second, among other considerations. Waters that are not “classified” in this manner are afforded protection through narrative criteria, including: “Hazardous materials derived from artificial sources, including toxic substances, radioactive isotopes, and infectious microorganisms derived directly or indirectly from point or nonpoint sources, shall not occur in surface waters at concentrations or in combinations that jeopardize the public health or the survival or well-being of livestock, domestic animals, terrestrial wildlife, or aquatic or semiaquatic life.”

A committee reviews the information collected to assist in making decisions about use classification changes. KDHE may recommend refining the designated use within the state water quality standards. For recreational UAAs, the state determines whether the stream is swimmable (primary contact recreation) or fishable/wadable (secondary contact recreation).[1] If a stream has no water or is an ephemeral stream, the review committee recommends removing primary contact recreation by removing the stream from the list of “classified” streams. This term is not related in any way to jurisdiction as a “water of the United States;” it merely refers to the designated uses and type of criteria that apply, as well as the manner in which Kansas keeps records of its waters. If changes to designated uses are subsequently approved, the classifications of individual stream segments are updated in the *Kansas Surface Water Register*. Any revisions to the Kansas Surface Water Register are subject to approval for Clean Water Act purposes by the U.S. EPA Region 7 office.

One example of use of the Kansas worksheet is the Crosby Creek UAA conducted in 2001. In this UAA, evaluators documented several pieces of information (Figure 1):

[1] The state has subclasses of primary and secondary contact recreation for classified stream segments.

- **A.** Site Description: The exact location of the site and the date and time of the assessment were included.
- **B.** Stream Description: The dimensions of the runs, both upstream and downstream of the site, were given, and the substrate type was listed as silt.
- **C.** Aquatic Life Observed: Information about aquatic life observed in the streambed. No aquatic life was documented, but the evaluator indicated that the stream was perennial. Other observations were not included.


A
B
C

Site Description
Stream Name Crosby Creek | Site A | HUC8 10250016 | Segment 77
Count Jewell | Legal Description NW 1/4 NE 1/4 Sec: 3 Town: 1 S Range: 6 W
Date 7/10/01 | Time 2:25:00 PM

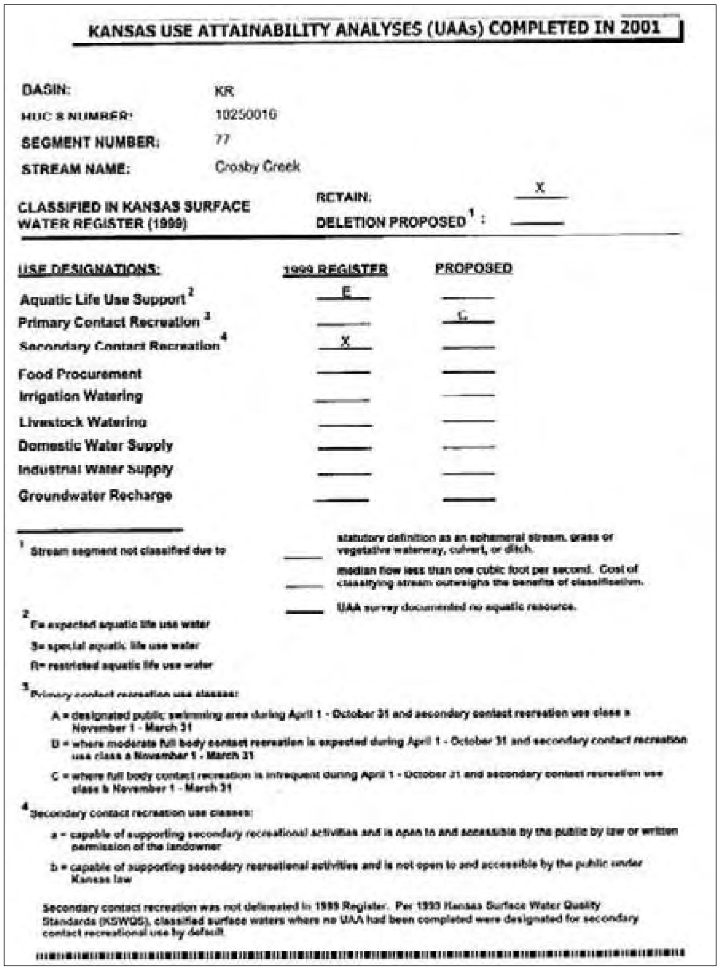
Stream Description
Upstream Riffle
Upstream Run width: 23' 0" length: 0' 0" depth avg.: 0' 20" depth max: 0' 30"
Upstream Pool
Downstream Riffle
Downstream Run width: 25' 0" length: 0' 0" depth avg.: 0' 28" depth max: 0' 30"
Downstream Pool
Flow Present? (describe)
None detected.
Predominant Substrate Type: Silt

Aquatic Life Observed
☐ Plants ☐ Frogs ☐ Insects ☐ Fish ☐ Crawfish ☐ Snails
Describe:
Stream type: ☑ Perennial (permanent flow) ☐ Intermittent (permanent water)
☐ Ephemeral (seasonal water)
Observation

Figure 1. Crosby Creek UAA: Basic site information.

On the basis of the data collected in the Crosby Creek UAA, KDHE proposed a change to the designated uses set in 1999 (Figure 2). KDHE recommended primary contact recreation for Crosby Creek, an upgrade from the secondary contact recreation use designated previously. Specifically, the analysis proposed primary contact recreation "where full body contact recreation is infrequent during April 1–October 31, and secondary contact recreation use class b November 1–March 31." The UAA also proposed that the 1999 aquatic life use designation, "expected aquatic life use water," should be maintained. These changes were adopted in the *Kansas Surface Water Register*.

A second example of the use of Kansas' UAA worksheet was the Antelope Creek UAA conducted in 2001. In that UAA KDHE concluded that the stream was ephemeral and provided photos to document the dry conditions. Notations in the UAA added that some ephemeral pools existed but that terrestrial vegetation covered the channel. Additional notes indicated that the channel was poorly defined in some places. On the basis of the assessment, KDHE did not recommend primary contact recreation as a designated use for this water, due to the low flow conditions in the stream (131.10(g) factor 2). The segment fit Kansas' statutory definition of an ephemeral stream, grass or vegetative waterway, culvert, or ditch.



KANSAS USE ATTAINABILITY ANALYSES (UAAs) COMPLETED IN 2001

BASIN:	KR
HUC 8 NUMBER:	10250016
SEGMENT NUMBER:	77
STREAM NAME:	Crosby Creek

CLASSIFIED IN KANSAS SURFACE WATER REGISTER (1999)

RETAIN: X

DELETION PROPOSED[1]:

USE DESIGNATIONS:	1999 REGISTER	PROPOSED
Aquatic Life Use Support[2]	E	
Primary Contact Recreation[3]		C
Secondary Contact Recreation[4]	X	
Food Procurement		
Irrigation Watering		
Livestock Watering		
Domestic Water Supply		
Industrial Water Supply		
Groundwater Recharge		

[1] Stream segment not classified due to
- ___ statutory definition as an ephemeral stream, grass or vegetative waterway, culvert, or ditch.
- ___ median flow less than one cubic foot per second. Cost of classifying stream outweighs the benefits of classification.
- ___ UAA survey documented no aquatic resource.

[2] E= expected aquatic life use water
S= special aquatic life use water
R= restricted aquatic life use water

[3] Primary contact recreation use classes:
- A = designated public swimming area during April 1 - October 31 and secondary contact recreation use class a November 1 - March 31
- B = where moderate full body contact recreation is expected during April 1 - October 31 and secondary contact recreation use class a November 1 - March 31
- C = where full body contact recreation is infrequent during April 1 - October 31 and secondary contact recreation use class b November 1 - March 31

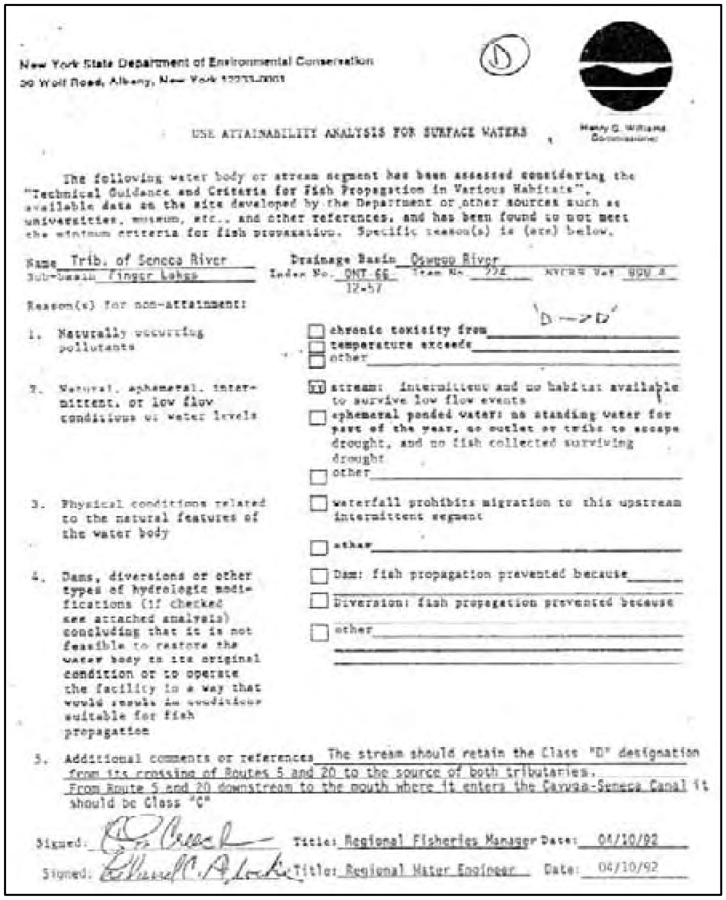
[4] Secondary contact recreation use classes:
- a = capable of supporting secondary recreational activities and is open to and accessible by the public by law or written permission of the landowner
- b = capable of supporting secondary recreational activities and is not open to and accessible by the public under Kansas law

Secondary contact recreation was not delineated in 1999 Register. Per 1999 Kansas Surface Water Quality Standards (KSWQS), classified surface waters where no UAA had been completed were designated for secondary contact recreational use by default.

Figure 2. Crosby Creek UAA results.

New York Worksheets

The New York State Department of Environmental Conservation (NYSDEC) has used a brief worksheet to document UAAs for aquatic life uses (Figure 3). These worksheets were developed as part of an overall 1985 State "Water Quality Standards Attainability Strategy," which included specific guidance for field biologists on assessing fish propagation in various habitats. The worksheet contains the name and location of the waterbody, a checklist of reasons why the waterbody is not attaining its designated uses, and space for additional comments or recommendations. The worksheet documents the NYSDEC's proposed changes to the designated uses.


New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233-0001

Henry G. Williams
Commissioner

USE ATTAINABILITY ANALYSIS FOR SURFACE WATERS

The following water body or stream segment has been assessed considering the "Technical Guidance and Criteria for Fish Propagation in Various Habitats", available data on the site developed by the Department or other sources such as universities, museum, etc., and other references, and has been found to not meet the minimum criteria for fish propagation. Specific reason(s) is (are) below.

Name Trib. of Seneca River Drainage Basin Oswego River
Sub-Basin Finger Lakes Index No. ONT 66 12-57 Item No. 224 NYCRR Vol. 900 A

Reason(s) for non-attainment:

1. Naturally occurring pollutants
   - [ ] chronic toxicity from
   - [ ] temperature exceeds
   - [ ] other
2. Natural, ephemeral, intermittent, or low flow conditions or water levels
   - [x] stream: intermittent and no habitat available to survive low flow events
   - [ ] ephemeral ponded water: no standing water for part of the year, no outlet or tribs to escape drought, and no fish collected surviving drought
   - [ ] other
3. Physical conditions related to the natural features of the water body
   - [ ] waterfall prohibits migration to this upstream intermittent segment
   - [ ] other
4. Dams, diversions or other types of hydrologic modifications (if checked see attached analysis) concluding that it is not feasible to restore the water body to its original condition or to operate the facility in a way that would result in conditions suitable for fish propagation
   - [ ] Dam: fish propagation prevented because
   - [ ] Diversion: fish propagation prevented because
   - [ ] other
5. Additional comments or references The stream should retain the Class "D" designation from its crossing of Routes 5 and 20 to the source of both tributaries. From Route 5 and 20 downstream to the mouth where it enters the Cayuga-Seneca Canal it should be Class "C"

Signed: [signature] Title: Regional Fisheries Manager Date: 04/10/92
Signed: [signature] Title: Regional Water Engineer Date: 04/10/92

Figure 3. New York UAA worksheet.

One example of use of this worksheet is a 1992 UAA for a tributary of the Seneca River in New York. NYSDEC used the assessment to find that a portion of the stream was not in attainment due to CFR 131.10(g) factor 2, natural ephemeral, intermittent, or low flow conditions or water levels. NYSDEC proposed that this segment in non-attainment retain the Class D designation; however, one segment was proposed for an upgrade from Class D to Class C.[2]

Conclusion

The Kansas and New York worksheets are two examples where states have streamlined their documentation for UAAs. These types of rapid-reporting worksheets might allow states to quickly document simple assessments that do not require complex evidence.

Supporting materials for this case study are available in Appendix A.

[2] The best usage of Class C waters is fishing. Water quality should be suitable for fish propagation and survival as well as for primary and secondary contact recreation. Other factors, however, might limit the use for these purposes. The best usage of Class D waters is fishing. Because of such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or streambed conditions, the waters will not support fish propagation. These waters shall be suitable for fish survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors might limit the use for these purposes.

Suspension of Recreational Beneficial Uses in Engineered Channels during Unsafe Wet Weather Conditions

Abstract

Complexity: Simple
Region: 9
Type of Action: Temporary suspension of recreational use
131.10(g) Factors: 2, 4

The Los Angeles Region has many rivers and streams that have been straightened, concrete-lined, or both to move floodwaters from urban areas to the ocean. These channels transport large volumes of water that might not be of adequate quality to support Clean Water Act (CWA) section 101(a) uses (i.e., "fishable/swimmable"). The water quality goals set forth in the Los Angeles Region's Basin Plan specify that all waters in the state should be "fishable/swimmable."

Under certain conditions recreational uses are inappropriate for these channels. During high flow flood conditions, it is not safe to swim in the waters. The Los Angeles Region has opted to issue a suspension of recreational use during periods of high flow. Through a revision to its water quality control plan, the Los Angeles Region established that during high flow events, when it is not safe to be in the modified channels, these waterbodies do not have to meet bacteria criteria. The suspension of recreational uses applies under the rainfall conditions that trigger the Region's swift-water protocols (i.e., rescue squads are on alert if someone should happen to enter the water). With this use attainability analysis (UAA), EPA approved the revision to the *Water Quality Control Plan for the Los Angeles Region*.

Background

Figure 4. High-flow conditions in Ballona Creek (DeShazo, 2005).

Currently, all waterbodies in the Los Angeles Region include use designations for water contact recreation (REC-1) and, in most cases, for non-contact water recreation (REC-2). There are no seasonal restrictions on recreational uses in Los Angeles. The uses apply at all times, regardless of weather conditions or any other condition that might make recreational activities unsafe or infeasible. Figure 4 shows high-flow conditions in a creek in the Los Angeles Region.

Current conditions physically prevent full attainment of the recreational beneficial uses during high-flow or high-velocity conditions. Many waterbodies in the Los Angeles Region have been straightened, concrete-lined, or both to reduce the occurrence of flooding in urbanized areas by moving stormwater from those areas to the ocean (or an alternative outfall). These channels transport large amounts of water that might not be of adequate quality to support Clean Water Act (CWA) section 101(a) uses. This condition does not meet the water quality goals set forth in California's Basin Plan, which specifies that all waters in the state should be designated for recreational use and should be "fishable/swimmable."

Designating recreational uses for highly modified channels in the Los Angeles Region is complicated by the fact that under certain conditions recreational uses are not appropriate for some waterbodies. Channel modifications can create life-threatening conditions during and immediately following storm events. The steep-sided slopes of the channels also make them very difficult to exit when the water if slowing swiftly. During high-flow conditions, it is not safe to swim in the channels.

Approach

The Los Angeles Regional Water Quality Control Board (RWQCB) opted to issue a temporary suspension of the designated use (recreation) during and immediately after defined storm events (periods of high-flow). By suspending recreational uses during high-flow conditions, the RWQCB acknowledges the danger of recreating in the channels during wet weather conditions. Through a revision to its water quality control plan, the Region indicated that during high-flow events (when it is unsafe to be in the channels) waterbodies do not have to meet bacteria criteria. The aquatic life standards for these channels have not been revised, although subcategories of aquatic life uses might be developed in the future. This approach—using revisions to the basin plan to further specify designated uses—is a flexible means to establish water quality goals.

The high-flow suspension applies only to water contact recreation activities regulated under the REC-1 use, non-contact water recreation involving incidental water contact regulated under the REC-2 use, and the associated bacteriological criteria set to protect those activities. The suspension of uses is applied when there is rainfall greater than or equal to ½ inch and remains in effect during the 24 hours following the rain event, which is consistent with the Los Angeles County Level 1 Alert threshold.

The inherent danger of recreating in engineered channels during and immediately after storm events is widely recognized and has already been addressed by Los Angeles and Ventura counties through county policies. Los Angeles County's Multi-Agency Swift Water Rescue Committee has set protocols for locking access gates to flood control channels and preparing for possible swift-water rescues in the channels during defined storm events. In Ventura County, access gates to such channels are always locked, which prevents people from engaging in recreational activities in the channels during swift-water conditions.

The RWQCB's suspension would apply to inland, flowing, engineered channels where it is possible to restrict access during the defined conditions. Water quality criteria set to protect other recreational uses associated with the fishable goals, as expressed in CWA section 101(a)(2) and regulated under the REC-1 use and other REC-2 uses (e.g., uses involving the aesthetic aspects of water) still remain in effect.

Downstream REC uses must continue to be protected. Suspension of portions of the REC-1 and REC-2 uses during swift-water conditions reflects the current conditions in certain engineered channels; it does not relieve or diminish obligations to reduce bacteria loading at the beaches.

The RWQCB remains committed to reevaluating the attainability of the REC-1 and REC-2 uses in the future, supporting efforts to reclaim engineered channels as natural watercourses, and supporting the beneficial reuse of stormwater. Within 3 years of the amendment's effective date, the RWQCB will reconsider the continued appropriateness of the suspension of recreational uses in engineered channels during and immediately following the defined storm events.

Data Collection and Analysis

To support the suspension of the recreational uses, the RWQCB conducted a use attainability analysis (UAA) for each waterbody where the suspension would apply. The RWQCB used two of the 40 CFR 131.10(g) factors as the basis for the UAA:

> **Factor 2:** Natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met.
> **Factor 4:** Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use.

RWQCB staff evaluated whether to conduct waterbody-by-waterbody UAAs or a categorical UAA covering all waterbodies meeting certain criteria. For this situation, the staff proposed a regional approach because all waterbodies subject to the suspension of recreational uses had similar features. The waterbodies to which the suspension would apply (during the defined conditions) include inland waterbodies, flowing waterbodies, engineered channels, and waterbodies where access can be restricted or prohibited (through fencing or signs).[3]

The staff first identified all inland, flowing waterbodies listed in Table 2-1 of the Basin Plan for which the REC uses were qualified due to restricted or prohibited access. They then circulated the list internally to confirm that each of the waterbodies met the criteria for inclusion in the proposed amendment. Where necessary, the staff followed up with field surveys of the candidate waterbodies to confirm physical characteristics and access restrictions. They specifically noted GPS coordinates, channel flow, the geometry and construction materials of the channel bottom and sides, and the presence of restricted access in terms of gates and signage.

The staff evaluated several possible triggers for the suspension of REC uses in engineered channels with restricted or prohibited access. These included (1) flow and velocity (e.g., swift water conditions); (2) depth (e.g., outside low flow channel); and (3) rainfall (e.g., total daily rainfall).

On the basis of their evaluation, the staff concluded that rainfall is the most appropriate trigger for the temporary suspension of recreational uses. The RWQCB outlined three reasons for this decision. First, the Los Angeles County, California, Multi-Agency Swift Water Rescue Committee uses rainfall prediction as the basis for routinely locking access gates to county flood control channels and putting swift-water rescue personnel on alert. Written guidance outlines protocols to prepare for and provide swift-water rescues for county personnel and other involved agencies. Under the “Water Rescue Pre-Deployment Section,” three storm levels are defined based on storm warnings with an 80 percent prediction of specified levels of rain over 24 hours. The three alert levels are as follows:

[3] Although not adequate alone to trigger a suspension of recreational uses, restricted or prohibited access to the channels is proposed as a requirement for the suspension to ensure that people cannot access a waterbody during the defined wet weather period.

- Level 1: 1 inch of rain if unsaturated ground or ½ inch if saturated ground
- Level 2: 1½ inches of rain if unsaturated ground or 1 inch if saturated ground
- Level 3: rainfall/saturation levels exceeding those listed for Level 2; generalized flash floods, urban flooding, or mud and debris flows; urban flooding with possible life hazards.

At the Level 1 Alert threshold, Los Angeles county personnel routinely lock all access gates to flood control channels for at least 24 hours after the storm event.

Second, there are numerous rain gauges throughout Los Angeles and Ventura counties that can provide precipitation data. Flow is not used because velocity and depth data are not available for all candidate channels.

Third, rainfall is an adequate proxy for high flows and high velocities that result in unsafe conditions, given the reliance on rainfall prediction by the Multi-Agency Swift Water Rescue Committee. To confirm this, the staff used 5 years of data (water years 1998–2002) to match days above the Level 1 Alert rainfall thresholds of ½ inch or 1 inch with corresponding flow, velocity, and depth data in several local channels and compared these data with swift water rescue data from the same channels, as well as other agencies' protocols for evaluating when conditions in the channels are unsafe. The staff specifically relied on a protocol used by the U.S. Geological Survey (USGS) and Orange County, in which in-stream conditions are evaluated using the following calculation to determine whether it is safe for monitoring personnel to be in a stream or channel: peak depth (in feet) multiplied by peak velocity (in feet per second). If the result is greater than or equal to 10, conditions are considered unsafe.

The results of the analysis show that 63 percent of unsafe days followed days with more than ½ inch of rainfall. Therefore, using days with greater than ½ inch of rainfall and the 24 hours following the event provides protection by suspending recreational use during 63 percent of unsafe days. This trigger appears appropriate and justifiable because, on average, 82 percent of the days on which the preceding day's rainfall was greater than ½ inch were considered unsafe.

On the basis of the data analysis described above, the staff proposed to use the Level 1 Alert threshold (rainfall greater than or equal to ½ inch as measured at the closest rain gage with saturated conditions) as the trigger for suspending the REC uses assigned to a particular engineered channel. This fits with Los Angeles' policy to keep all access gates locked for at least 24 hours following the specified rain event.

In the UAA the RWQCB showed that recreation is not an existing use because the channels were modified before 1965 and the swift water conditions existed before this the present. In addition, the study showed that the use would not be attained through effluent limits or best management practices (BMPs) because the physical characteristics of the waterbody, rather than the water quality, preclude the use.

Conclusion

Following this UAA, EPA approved the revision to the *Water Quality Control Plan for the Los Angeles Region*.

Supporting materials for this case study are available in Appendix B.

References

DeShazo, R. 2005. Summary: Basin Plan Amendment to Suspend the Recreational Beneficial Uses in Engineered Channels during Unsafe Wet Weather Conditions (Los Angeles Region). Presented at the Designated Use Co-Regulator Workshop, San Francisco, July 2005.

Valley Creek, Alabama UAA

Abstract

Complexity: Simple
Region: 4
Type of Action: Assign limited warmwater fishery use
131.10(g) Factors: 3, 5

In this 2001 use attainability analysis (UAA), the Alabama Department of Environmental Management (ADEM) provided evidence to support the proposed change for the upper segment of Valley Creek from Agricultural and Industrial Water Supply (A&I) to Limited Warmwater Fishery (LWF). The corresponding water quality criteria are more stringent for waters classified as LWF than for A&I waters. The key element of the LWF classification establishes seasonal uses and water quality criteria for waters that otherwise cannot maintain the more protective Fish & Wildlife (F&W) classification year-round. The LWF classification does not fully meet the water quality uses and criteria associated with the “fishable/swimmable” goal, and therefore a UAA was necessary. In the UAA, ADEM provided information on the physical, biological, and chemical characteristics of Valley Creek; water quality data from sampling stations; discharge monitoring reports from the point source dischargers; and water quality modeling results. EPA approved the revision to Alabama’s water quality standards to reclassify Upper Valley Creek for LWF and Lower Valley Creek for F&W.

Background

The Valley Creek watershed is in north-central Alabama. Valley Creek originates in Birmingham and flows west to Bankhead Lake, an impoundment of the Black Warrior River. Valley Creek is 46 miles long and has a total drainage area of 257 square miles. Its tributaries include Blue Creek, Fivemile Creek, and Opossum Creek; all of which are designated for Fish and Wildlife (F&W) use with the exception of Opossum Creek, which is designated for Agricultural and Industrial Water Supply (A&I) use.

> ***The best uses of LWF waters include:*** agricultural irrigation, livestock watering, industrial cooling, and process water supply, and any other use except fishing, bathing, recreational activities, or as a source of water supply for drinking or food-processing purposes.
> ***The best uses of F&W waters include:*** fishing, propagation of fish, aquatic life, and wildlife, and any other use except swimming and water-contact sports or as a source of water supply for drinking or food-processing.

In August 2000 the Alabama Department of Environmental Management’s (ADEM’s) Environmental Management Commission adopted new water quality standards regulations that eliminated the Industrial Operations use classification. At that time the use designation of Valley Creek was changed to A&I. In 2001 ADEM conducted a use attainability analysis (UAA) to provide evidence to support a proposed use classification change for Upper Valley Creek from A&I to limited warmwater fishery (LWF). Because LWF is not a “fishable/swimmable” use as defined in Clean Water Act (CWA) section 101(a)(2), the proposed change requires a UAA. At that time ADEM also proposed that Lower Valley Creek be classified for the F&W use, which meets the goals of CWA section 101(a)(2).

Attainment of the F&W use in Upper Valley Creek is precluded by two of the 40 CFR 131.10(g) factors:

> **Factor 3:** Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.

Factor 5: Physical conditions related to the natural features of the waterbody, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude the attainment of aquatic life protection.

Limited Warmwater Fishery Classification

ADEM developed the LWF use classification in 2000 to establish seasonal uses and water quality criteria for waters that otherwise could not maintain the F&W criteria year-round. All provisions of the F&W use apply to the LWF use, with the exception of the criteria for dissolved oxygen (DO), bacteria, and chronic aquatic life. Table 1 provides the key differences between the F&W and LWF uses.

Table 1. Differences between F&W and LWF Uses

Classification	Criteria		
	Dissolved oxygen	Bacteria (fecal)	Chronic aquatic life
F&W	≥5.0 mg/L	For freshwater Geometric mean: ≤1000/100 mL	7-day, 10-year ($7Q_{10}$) low flow used to establish the chronic aquatic life criteria for point source discharges
		For freshwater Geometric mean: ≤200/100 mL (Incidental water contact and recreation, June through September)	
LWF	≥3.0 mg/L[a]	For Freshwater Geometric mean: ≤1000/100 mL[b]	7-day, 2-year ($7Q_2$) low flow used to establish the chronic aquatic life criteria for point source discharges

[a] Criterion applies May–November. Dissolved oxygen criterion associated with F&W classification is used December–April.
[b] Bacteriological criteria for incidental water contact and recreation during June–September are not required.

Water Quality Impairment and Pollutant Sources in the Upper Valley Creek

The Opossum Creek watershed is one of the most highly industrialized areas of Birmingham, and it contributes point source and nonpoint source pollutants to Valley Creek. In addition, a number of land uses in the Valley Creek watershed have the potential to degrade water quality. In Upper Valley Creek, industrial and commercial activities and residential land uses adversely affect water quality. The upper segment exhibits characteristics typical of an urban stream, including poor habitat, degraded water quality, and stressed biological communities due to the large amounts of impervious landscape. In addition, much of the stream has been concrete-lined, adding to algae production and fluctuations in DO.

Key Characteristics of Upper Valley Creek
• Poor DO levels • High pathogen levels • Elevated BOD • Elevated nutrient concentrations

This segment has poor DO levels, high pathogen levels, and elevated biochemical oxygen demand (BOD) and nutrient concentrations.

Three point sources operating under National Pollutant Discharge Elimination System (NPDES) permits are located in the Valley Creek watershed. The Valley Creek wastewater treatment plant (WWTP) is on Valley Creek, and two other point sources are on Opossum Creek.

Conditions in Lower Valley Creek

In the lower segment, the area is primarily rural, with silvicultural, agricultural, and mining land uses. The lower segment has improved chemical, physical, and biological conditions suitable for classification as F&W use.

Data Collection and Analysis

ADEM, the U.S. Geological Survey (USGS), and EPA conducted water quality monitoring. In a 1989 study, EPA examined biological conditions in Village, Valley, Opossum, and Fivemile creeks. Opossum Creek was cited as having poor habitat and deposits of tar-like substances, with growth impairment to the fathead minnow. In addition, the study showed mortality to daphnia at two sampling points on Valley Creek. A biological survey conducted by EPA in 1997 documented degraded habitat at two of three sampling stations in Upper Valley Creek (habitat scores of 66 and 64 versus 118 in the reference F&W stream), and fewer fish species were reported than in the lower segment. On the basis of this information, EPA suggested that Upper Valley Creek would need significant enhancements to improve stream habitat and removal of excess nutrients to be able to achieve the F&W designated use.

USGS data from the Birmingham Watershed Project confirmed the water quality impacts that EPA and ADEM had found. Sampling at several locations from 1998 to 2001 showed that sewer overflows, leaking sewer lines, and other regulated and nonregulated stormwater runoff were contributing the high pathogen loads. EPA, USGS, and ADEM data showed that conditions improved downstream such that F&W uses could be met in Lower Valley Creek. USGS benthic macroinvertebrate data from 1999–2000 showed poor taxa richness in Upper Valley Creek, consistent with the degraded physical and chemical characteristics. These data exhibited:

- Poor Ephemeroptera, Plecoptera, or Trichoptera (EPT) family richness and poor total taxa richness at both sampling sites
- Low benthic invertebrate diversity and low fish community diversity (Shannon's index of diversity)
- Absence of sculpin (intolerant of contaminated waters) and spotted sucker (intolerant of turbid or silty waters)

In a review of these data, EPA concluded that the aquatic community structure showed degraded water quality, negatively affected by anthropogenic impacts in the watershed over an extended period.

In another study, USGS monitored DO at three stations on Valley Creek. One station was monitored continuously, and DO concentrations at that site ranged from 3.8 to 19.6 mg/L. The daily minimum concentrations at the site were between 4 and 5 mg/L for 39 days between June 25, 2000 and February 22, 2001, with concentrations less than 4 mg/L on one day. Dissolved oxygen measurements at two other sampling sites reached as low as 3.3 and 4.3 mg/L. In a 1998 survey, EPA and ADEM found DO concentrations less than 5 mg/L at a sampling gauge 5 miles upstream from the Valley Creek WWTP. This station was downstream of a channelized stream segment, which provides an ideal surface for periphytic and other microbial growths that produce a large diurnal swing in DO through photosynthesis and respiration.

ADEM conducted water quality modeling for the three point sources to predict the effluent limits needed to meet the various use classifications (A&I, LWF, and F&W). Modeling showed that LWF would be achievable in Upper Valley Creek through effluent limits on the three point sources (with the most stringent limits on the Valley Creek WWTP). ADEM also considered discharge monitoring report data from the facilities and found that at the time of the UAA, the Valley Creek WWTP was operating at very efficient levels and providing a high degree of treatment. ADEM concluded that the Valley Creek WWTP would be able to achieve effluent limits for the LWF, and that the F&W designation would require much more stringent limits for the summer months. With the LWF classification, each facility would be required to conduct chronic toxicity biomonitoring.

ADEM also provided an analysis that showed highly elevated bacteria levels and demonstrated correspondence of bacteria levels with the patterns of precipitation in the Valley Creek watershed. This pattern indicates a strong relationship to nonpoint sources.

Conclusion

The biological health of Valley Creek is dependant on good physical and hydrological characteristics, including proper flow, adequate zones, and diverse substrate. The urbanization of the watershed has fostered habitat destruction through erosion, channelization, concrete substrate, and excessive light and heat penetration.

In their UAA document, ADEM concluded, in part:

> Leaking sewer lines, domestic animals and wildlife populations, and leaking septic tanks are nonpoint sources of both nutrients and bacteria to Valley Creek. Sewer overflows are also a source of both nutrients and bacteria to Village Creek that is driven by precipitation. The Valley Creek WWTP currently achieves an extremely high level of treatment. Jefferson County is estimated to expend $800 million to resolve sewer overflows and replace leaking sewer lines. It is anticipated that this substantial capital investment will improve water quality.
>
> It is not currently possible to determine the percent contribution from the known categories of nonpoint sources, nor is it possible to project the degree of success in terms of measurable water quality improvements that will result from ongoing efforts to resolve sewer overflows and replace leaking sewer lines. The available information suggests that the magnitude of nutrient and bacteria levels, the variety of sources, and the physical characteristics of the waterbody indicate that the F&W use classification is not attainable, and the highest attainable use is LWF. Therefore, F&W is not designated at this time as a result of a combination of human-caused conditions (that may not be feasible to fully remedy) and natural physical conditions of the watershed unrelated to water quality (e.g., high water table). However, as new information becomes available that pertains to attainability of the F&W use classification, it will be considered and water quality standards revised accordingly.

EPA approved the revision of Alabama's water quality standards to include the new classification of LWF for Upper Valley Creek and F&W for Lower Valley Creek. This is an example of a UAA for both aquatic life and recreational uses for an urbanized stream, where significant investment is being made to improve water quality, and the results are anticipated to reach certain goals but may still fall short of a full "fishable/swimmable" designated use.

Supporting materials for this case study are available in Appendix C.

References

ADEM. 2001. *Use Attainability Analysis: Valley Creek.* Alabama Department of Environmental Management.

USEPA. 2002. Section 303(c) Review of State-adopted Use Classifications. Memorandum from Gail Mitchell to James Giatanna. U.S. Environmental Protection Agency, Region 4, Atlanta, GA.

New York Harbor Complex UAA

Abstract

Complexity: Medium
Region: 2
Type of Action: Assign aquatic life & recreational uses
131.10(g) Factors: 3

A 1985 use attainability analysis (UAA) documents the assessment of waters in the New York Harbor Complex that were not thought to meet Clean Water Act (CWA) section 101(a)(2) goals. In the UAA the New York State Department of Environmental Conservation (NYSDEC) presents historical data on total and fecal coliform and dissolved oxygen, as well as the results of steady-state modeling. The segments considered are effluent-limited waters (i.e., the technology-based effluent limitations required by the CWA are inadequate to meet the water quality standards), with impairment from urbanization, combined sewer overflows (CSOs), and other point and nonpoint source discharges. In the UAA NYSDEC recommends that several segments should be assigned both aquatic life and recreational uses. NYSDEC also recommends that some uses be retained and proposes future monitoring and assessment.

Background

The New York Metropolitan Area, with its dense population and development, severely affected the marine ecosystems of the Hudson, the East River, and other waterbodies in the New York Harbor System. Historically, these waters were forced to assimilate large discharges of municipal and industrial waste, as well as intermittent waste from wet weather discharges. A large portion of the waste had not been treated prior to discharge. In addition to conventional pollutants, the discharges contained a wide assortment of toxic substances that polluted the water and sediments in the harbor.

Sources of pollution in the New York Harbor System included stormwater discharges, combined sewer overflows (CSOs), discharges from water pollution control plants, untreated sewage discharges, urban runoff, wastewater treatment plant and sewer leaks, and bypasses on both sides of the river. In 1985 New York Department of Environmental Conservation (NYSDEC) conducted a use attainability analysis (UAA) to further identify the sources of pollution and water quality conditions. In the UAA the NYSDEC found impairment from total and fecal coliforms, suspended solids, dissolved oxygen (DO), biochemical oxygen demand (BOD), and sediment.

Applicable New York Water Quality Standards

Marine waters in New York are classified on a best use basis. The best uses are ranked according to the water quality requirements of the use. Four designated uses are considered in the classification scheme—shellfishing (SA), bathing/primary recreation (SB), fishing (SC), finfish propagation (I), and fish survival (SD). General aquatic uses (e.g., aesthetic enjoyment and maintenance of fish and wildlife) are assumed in all classifications. A best use classification includes all the uses in the lower classifications and excludes the uses specified in the higher classifications. For example, a primary recreation classification would show all uses except the taking of shellfish for market purpose, which is a higher use specified in the shellfishing classification. The classification system also precludes a higher use if the standards of a lower use are being used. For example, if the waterbody is not suitable for fishing, it is also unsuitable for swimming.

For best use classification, the state has water quality standards that must be met to protect and preserve the intended use of the water, and criteria for DO, coliform bacteria, pH, temperature, dissolved solids, turbidity, color, taste and odor, floating materials, oil, and toxic wastes apply. Because all waters in New York are intended for general uses, such as aesthetic enjoyment and maintenance of fish and wildlife, most criteria apply to all the marine waterbodies regardless of classification. Only the DO, coliform bacteria, and toxic waste criteria vary among different classifications.

Data Collection and Analysis

In 1985 NYSDEC performed a UAA because several portions of the Harbor did not meet the section 101(a)(2) goals of the CWA (fishable/swimmable). The UAA used data from the New York City 208 planning process, as well as an environmental impact statement from the North River Pollution Control Project, a final report for the Red Hook Water Pollution Control Project, New York State Department of Health pre-classified studies of the Lower Hudson and Lower East River, a NYSDEC study of water quality and waste assimilative capacity of the Hudson River, a water quality assessment of marine CSO abatement along the New Jersey shore, surface water quality standards for New Jersey, facility plans for the Coney Island and Owls Island water pollution control plants, a New York Harbor Complex UAA performed by New Jersey Department of Environmental Protection in 1985, and the New York State Water Quality Standards Attainable Strategy.

In the 1985 UAA, the authors estimated wastewater flow to the New York Harbor Complex from sources such as CSOs, untreated sewage discharges (point sources), other urban nonpoint sources, and treated effluent (not disinfected in winter) from New York and New Jersey. The goal of the UAA was to refine water classifications, create new criteria, and modify standards. The New York City Department of Environmental Protection assessed attainable uses in each of the waterbodies and evaluated various water quality alternatives to determine the amount of treatment necessary to attain the objectives of each alternative. In some cases, it was determined that treatment would allow the classification and use to be upgraded.

Various treatment alternatives were examined for each waterbody in an effort to upgrade each waterbody’s classification and use when possible. Such alternatives included the secondary treatment alternative (all water pollution control plants achieve secondary treatment of waste) and the zero discharge alternative (zero discharge of pollution with 90 percent CSO control).

Hudson River and Upper New York Bay

On the basis of its analysis, the New York City Department of Environmental Protection did not believe that there were potentially exploitable commercial shellfish populations in the Hudson River within New York City and Westchester and Rockland counties. The assessment was based on a review of biological data collected by a number of institutions and consultants documenting that there was not an extensive population of commercially important shellfish species in the area. At the time of the study, it was not clear whether the absence of shellfish was due to pollutants or to physical or environmental reasons.

For the Hudson River and Upper New York Bay (classified as I), the authors assessed shellfish and bathing potential. Designation of the swimming use for the Hudson River and Upper New York Bay depended on attaining the coliform standard of 200 most probable number (MPN) fecal coliforms per 100 mL. At the time of the UAA, significant bacterial pollution was present in most of the metropolitan Hudson, especially below its confluence with the Harlem River. The principal sources of bacterial pollution were heavy discharges of untreated and inadequately treated sewage from New York and New Jersey. Other sources of coliforms might have included CSOs, urban runoff, treatment plant and sewer leaks, and bypasses on both sides of the river. It was estimated that with the secondary treatment level alternative (all plants at the secondary level), fecal coliform levels in the Hudson River between the state line and its confluence near the Harlem River would fall below the criterion for SB classification (swimmable). On the basis on anticipated future improvements, it was recommended that the Hudson River segment between the state line and its confluence with the Harlem River be upgraded to SB classification.

For the Hudson River segment between the Harlem River junction, the Battery, and the Upper New York Bay, secondary treatment was predicted to lower the fecal coliform level to less than the existing Class I criterion, but not enough to meet the SB classification. Only the zero discharge alternative with 90 percent CSO control was predicted to reduce coliforms to achieve swimmable goals (but not enough to attain shellfish goals).

East River and Harlem River

The East River (classified as SD) was assessed for fish passage. At the time of the UAA, the river had strong tidal currents and a deep hard substrate, which provided a limited and harsh environment. River encroachment by a landfill, dredging, blasting, and pollution had caused severe physical changes to the river. However, several studies indicated that fish, benthic organism, phytoplankton, zooplankton, and periphyton populations existed in the East River. In fact, the community in 1985 was similar to that which had existed 200 years before and consisted of species that can tolerate a harsh environment. On the basis of this information, the authors concluded that the classifications for the East River and Harlem River should be upgraded to Class I for fish propagation.

The principal sources of bacterial pollution in the East River were discharges of untreated sewage from the Red Hook drainage area in Brooklyn. Other sources of coliforms might have included CSOs, urban runoff, plant and sewer leaks, and bypasses on both sides of the river. Analyses showed that with the secondary treatment alternative (all plants at the secondary treatment level), fecal coliform would not fall below the criterion for SB classification. Even the zero discharge alternative with 90 percent CSO control was not predicted to achieve sufficient reduction of coliforms to meet swimmable or shellfishing goals.

Jamaica Bay

At the time of the UAA, Jamaica Bay was classified for swimming (SB). It was noted that hard clams existed in the bay. For the bay to be designated SA (direct shellfish harvesting), a coliform standard of 70 MPN total coliform per 100 mL had to be met. The principal sources of bacterial pollution in Jamaica Bay were attributed to CSOs. Various treatment alternatives were considered in the analysis. The secondary treatment alternative was not predicted to lower total coliform levels below the criterion for direct shellfishing (SA). In addition, the zero discharge alternative with 90 percent CSO control was not predicted to achieve sufficient coliform reduction to meet swimmable or shellfishing goals.

Lower New York Bay

Lower New York Bay was classified for swimming (SB). As in Jamaica Bay, hard clams were present. For the bay to be designated SA (direct shellfish harvesting), a coliform standard of 70 MPN total coliform per 100 mL had to be met. The principal source of bacterial pollution in Lower New York Bay was carry-over discharges of untreated and inadequately treated sewage from New York and New Jersey. Other sources of coliforms might have included CSOs, urban runoff, plant and sewer leaks, and bypasses on both sides of the river. The secondary treatment alternative was not predicted to lower total coliform levels below the criterion for direct shellfishing (SA). However, the zero discharge alternative with 90 percent CSO control was predicted to achieve sufficient coliform reduction to meet direct shellfishing goals.

Table 2 describes classifications pre-UAA and recommended classifications post-UAA, based on water quality in the waterbodies and anticipated future improvements.

Table 2. Classification and Best Use Specification of Waterbodies Not Meeting CWA Section 101(a)(2) Goals and Recommended Classification Upgrades (from the 1985 UAA)

Waterbody	Classification (pre-UAA)	Recommended classification (post-UAA)	Change
Hudson River - From the Harlem River confluence to the New Jersey/New York border	I (Fishing)	SB (Bathing)	Use upgrade
- From the Harlem River to Battery	I (Fishing)	I (Fishing)	No change
Upper New York Bay	I (Fishing)	I (Fishing)	No change
Lower New York Bay	SB (Bathing)	SB (Bathing)	No change
Jamaica Bay	SB (Bathing)	SB (Bathing)	No change
East River (from the Battery to Flushing Bay)	SD (Fish Passage)	I (Fishing)	Use upgrade
Harlem River - East River to Washington Bridge	SD (Fish Passage)	I (Fishing)	Use upgrade
- Washington Bridge to Hudson River	I (Fishing)	I (Fishing)	No change

Assessment of Alternatives

In assessing possible alternatives, only the zero discharge alternative with 90 percent CSO control was predicted to achieve sufficient coliform reduction to achieve the shellfishing/swimming goals for most of the New York Harbor Complex. In some cases, the zero discharge alternative was not predicted to produce sufficient coliform reductions to achieve shellfishing goals. However, the New York City 208 report, from which data were taken for the 1985 UAA, concluded that environmental, technical, and institutional factors made this alternative unfeasible. If the alternative were implemented, projected improvements in water quality might not occur because the precision of the model used to predict the improvements was not demonstrated for total and fecal coliforms. In addition, the remaining 10 percent of CSOs not controlled by the alternative would still affect the Lower New York Bay. The estimated reductions in coliforms (from chlorination of primary-treated captured CSOs) might also have been overestimated. The New York City 208 report also noted that the applicability of steady-state models to CSO and coliform bacteria analysis is limited.

To meet the fishable/swimmable water quality goals of the CWA, CSO abatement in the New York Harbor area was found to be crucial. The zero discharge alternative would entail in-line (sewer) and off-line storage, followed by primary treatment and disinfection. The total cost of this control method was found to be significant, and the engineering feasibility had not yet been established at the time of the 1985 UAA. A detailed study throughout the harbor was deemed necessary to demonstrate the feasibility of the control option.

Conclusions

The 1985 UAA had several conclusions. First, NYSDEC recommended an upgrade of classification and best use for several waterbodies analyzed in the UAA. NYSDEC concluded that a CSO abatement program might be necessary to comply with current water quality standards and to protect the designated uses. A more detailed evaluation of CSO problems and abatement alternatives for the New York Harbor Complex was deemed necessary. Finally, the study showed that additional research should be performed because other treatment/abatement alternatives for CSOs, which had not been evaluated in the New York City 208 planning process, might result in the goal of water quality suitable for swimming and shellfishing. EPA approved the changes to designated uses as part of a water quality standards review.

Supporting materials for this case study are available in Appendix D.

References

NYNYSDEC. 1985. *Use Attainability Analysis of the New York Harbor Complex*. New York State Department of Environmental Conservation, Division of Water.

Red Dog Mine UAA

Abstract

Complexity: Medium

Type of Action: Removal of aquatic life uses & development of site-specific criterion

Region: 10

131.10(g) Factors: 1, 3

A use attainability analysis (UAA) was performed on Red Dog Creek, which runs through the site of Red Dog mine, the largest zinc mine in the world. Red Dog Creek flows only 3–4 months of the year. Several parts of the creek are affected by mining discharges and some acid rock drainage. In addition, the area contains natural ore bodies, resulting in naturally high concentrations of cadmium, lead, zinc, aluminum, and other metals. Pre-mining surveys done in this area indicated that aquatic life uses were not present because of the toxic concentrations of metals, as well as naturally low pH. The UAA for Red Dog Creek demonstrated that aquatic life uses should be removed because of the naturally occurring pollutants. Because of the natural conditions, the criteria for cadmium, lead, zinc, aluminum, and pH cannot be met without human intervention, precluding that aquatic life uses being met. However, treatment of mine wastewater had led to the presence of Arctic grayling that should be protected. A site-specific criterion for total dissolved solids (TDS) was developed to protect the grayling when spawning. EPA approved these changes to Alaska's water quality standards.

Background

Red Dog Mine, in the DeLong Mountains of northwestern Alaska (Figure 5), is the largest zinc mine in the world. The mine discharges treated water into Red Dog Creek, a tributary to Ikalukrok Creek, which feeds the Wulik River. The Wulik River drains into the Chukchi Sea and is the drinking water source for Kivalina, a native village 54 miles southwest of the mine. Several parts of Red Dog Creek are affected by mining discharges and some acid rock drainage.

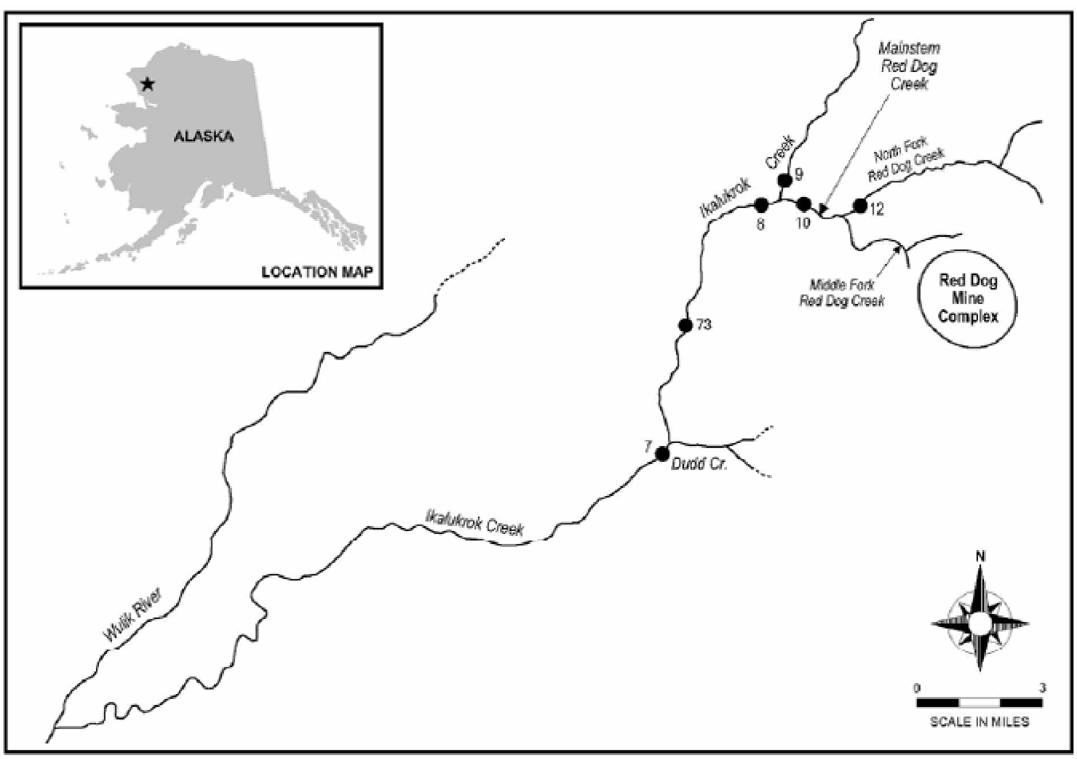


Figure 5. Red Dog Area (Alaska Department of Environmental Conservation, 2005).

In addition, the area contains natural ore bodies with naturally high concentrations of cadmium, lead, zinc, aluminum, and other metals. Pre-mining surveys performed in the early 1980s indicated that aquatic life uses were not present because of the toxic concentrations of metals, as well as naturally low pH.

Data Collection and Analysis

By default, Alaska designates all waters for all uses (Table 3). A use attainability analysis (UAA) was performed on Red Dog Creek to assess whether its aquatic life uses were being met. In 1997 Alaska submitted the UAA to EPA for review. On the basis on the information presented in the UAA, EPA approved the removal of the aquatic life uses for Red Dog Creek in February 1998. A site-specific criterion for total dissolved solids (TDS) was applied to the main stem of the creek to protect Arctic grayling when spawning. The entire process of performing the UAA through EPA approval of changes to Alaska's water quality standards took 3 years.

Table 3. Designated Uses for Alaska

Fresh water uses		**Marine water uses**	
Water supply	Drinking, culinary, and food processing	**Water supply**	Aquaculture
	Agriculture, including irrigation and stock watering		Seafood processing
	Aquaculture		Industrial
	Industrial		
Water recreation	Contact recreation	**Water recreation**	Contact recreation
	Secondary recreation		Secondary recreation
Growth and propagation of fish, shellfish, other aquatic life, and wildlife		**Growth and propagation of fish, shellfish, other aquatic life, and wildlife**	
		Harvesting for consumption of raw mollusks or other raw aquatic life	

The aquatic life use removal was based on naturally occurring pollutant concentrations, 40 CFR 131.10(g) factor 1. Water quality and biological data collected during baseline studies were used to describe pre-mining conditions. Many of the same monitoring stations that had been used in the original studies were used to conduct monitoring after the development of Red Dog Mine. These studies showed toxic concentrations of cadmium, zinc, lead, aluminum, and other metals. Poor water quality resulted from the natural chemical breakdown of sulfide minerals, a process that contributes to acid rock drainage. The observed reddish-orange color of the creek water indicated a metal sulfide deposit.

In the Red Dog Creek UAA, aquatic life was defined to include all aspects of the aquatic community, including fish, macroinvertebrates, microinvertebrates, periphyton, and macrophytes. Pre- and post-mining surveys done at this location indicated limited aquatic life in Red Dog Creek due to the toxic concentrations of metals and the naturally low pH. Fish use of Red Dog Creek was limited to migration to the North Fork Red Dog Creek, upstream of Red Dog Creek, during spring high flows. Fish experienced high mortalities in Red Dog Creek during downstream migration because of the high levels of metals and low pH. There are also few subadult-age grayling in the North Fork Red Dog Creek, which is hypothesized to be the result of the poor conditions in Red Dog Creek, in which migrating adults must swim.

Site-specific Criterion for TDS

Red Dog Mine discharges into the Lower Middle Fork of Red Dog Creek. Mine drainage water is collected in the tailings pond, treated with lime to remove harmful heavy metals, and discharged in the summer. Although this treatment is appropriate to keep heavy metals out of surface waters, it results in higher concentrations of dissolved solids that are discharged into the creek. High levels of TDS can affect some aquatic species, particularly salmonids, during critical life stages such as spawning. As a result of the treatment to reduce metals in the effluent from the mine, the TDS levels exceed the current water quality criterion of 500 mg/L. Lowering the TDS in the effluent would reduce the effectiveness of the wastewater treatment and cause higher metal concentrations and higher toxicity in the mine wastewater discharge and downstream waters.

Discharge from the mine has led to more consistent (non-ephemeral) flows in the main stem of Red Dog Creek and has allowed aquatic life to develop in the segment. In the absence of the effluent from the mine, the main stem would flow only 3–4 months of the year. If the discharge were to be discontinued, the aquatic productivity in the stream would decrease. Ten years of aquatic surveys have demonstrated that aquatic productivity in the main stem has increased from pre-mining conditions due to effective water management practices and treatment. Arctic grayling spawn in the main stem of the creek from late May to mid-June. Because TDS has been shown to adversely effect fish fertilization, a fish barrier was constructed across the main stem of Red Dog Creek to block the passage of fish up the Middle Fork of Red Dog Creek, which leads to the point of discharge of the mine.

In January 2001 a site-specific criterion was proposed for the main stem of Red Dog Creek to allow higher levels of TDS during most of the year while limiting TDS and protecting the grayling while they spawn. A site-specific criterion is a water quality limit that pertains to only a specific area in a stream, lake, or bay. In this case it applies to only the main stem of Red Dog Creek. Studies showed that Arctic grayling were the only salmonids spawning in Red Dog Creek. Because fertilization was observed to be the most critical and vulnerable life stage for salmonids, a site-specific TDS criterion of 500 mg/L during spawning was proposed. A criterion of calcium-dominated TDS of 1500 mg/L was proposed for all other times. Calcium-dominated TDS contain calcium greater than 50 percent by weight of all cations. Although studies showed that 1500 mg/L was protective of salmonids and aquatic invertebrates, there were no data on protective levels for fertilization.

Conclusion

The site-specific criterion for TDS was adopted into the Alaska Water Quality Standards in June 2003 and submitted to EPA for approval. EPA approved the 1500 mg/L TDS during non-spawning but requested additional testing on the effects of TDS on the spawning success of Artic grayling. Additional studies were developed in consultation with EPA, the Alaska Department of Natural Resources' Office of Habitat Management and Permitting, the Alaska Department of Fish and Game, and the Alaska Department of Environmental Conservation. In 2004 and 2005 studies were conducted on site at the Red Dog Mine. The results indicated that calcium-dominated TDS levels up to 1500 mg/L would be protective during Arctic grayling spawning. A change to Alaska's water quality standards is in progress to incorporate the 1500 mg/L TDS level for Red Dog Creek at all times. Water quality monitoring data indicated that setting the

1500 mg/L TDS level in the main stem of Red Dog Creek would be protective of all downstream uses in Ikalukrok Creek and the Wulik River as well.

Supporting materials for this case study are available in Appendix E.

References

ADEC. 2005. *Basis for Total Dissolved Solids Site Specific Criterion Update in Main Stem Red Dog Creek*. Alaska Department of Environmental Conservation, Division of Water.

Sonafrank, N. 2005. *Red Dog and Ikalukrok Creeks Use Attainability Analysis*. Alaska Department of Environmental Conservation.

Montana's Temporary Water Quality Standards—New World Mining District

Abstract

Complexity: Complex

Type of Action: Temporary standards for multiple uses during remediation

Region: 8

131.10(g) Factors: 3

Montana's Water Quality Act allows for application of temporary modification of water quality standards where a waterbody is not meeting its designated use. The ultimate goal of the temporary modification is to improve water quality to the point where designated uses are fully supported. As such, temporary standards play a key role in the remediation of damaged water resources, because the underlying designated uses and criteria are established as goals which drive water quality improvements. The duration of temporary standards is set based on an estimate of the time needed for remediation at a specific site, and because the clean up of legacy pollutants often takes time, temporary standards can be and are issued for multiple years. The state uses 20 years as its time horizon for estimating future watershed remediation opportunities, and therefore, temporary standards could be issued for as much as 20 years. The New World Mining District is an example of a well-funded and successful project. The waters were classified as suitable for a number of uses, including drinking water, recreational, and aquatic life uses.

Background

In the Water Quality Act, Montana has adopted a provision for temporary water quality standards (75-5-312, Montana Code Annotated, MCA). The standards allow the Board of Environmental Review (the Board) to temporarily modify a water quality standard for a specific waterbody or segment on a parameter-by-parameter basis. The goal of this tool is to "improve water quality to the point at which all the beneficial uses designated for that waterbody or segment are supported."

Establishment of Temporary Water Quality Standards

To obtain a temporary modification of the water quality standards, a petitioner must submit supporting documentation that shows that the waterbody or segment is not supporting its designated use. This documentation must consider (1) the chemical, biological, and physical condition of the waterbody; (2) the specific water quality-limiting factors affecting the waterbody; (3) the existing water quality standards that are not being met; (4) the temporary modifications of the existing water quality standards being requested; (5) the existing beneficial uses; and (6) the designated uses considered attainable in the absence of the water quality-limiting factors.

In addition, the petitioner must provide a preliminary implementation plan that outlines what the petitioner will do to return the waterbody back to full support of the original water quality standards. The implementation plan must contain (1) a description of the proposed actions that will eliminate the water quality-limiting factors identified to the extent achievable and (2) a schedule for implementing the proposed actions that ensures that the current water quality standards for the parameter or parameters at issue are met as soon as reasonably practicable.

After the petition is submitted, the Board goes through a public process and decides whether to move forward and the appropriate length of time the new standards will be in effect. If the Board adopts the temporary water quality standards, then the petitioner must modify the preliminary implementation plan as instructed by the Board and develop a detailed work plan each year until remediation is complete. The statute sets a maximum of 20 years for the temporary standards. The Board reviews the temporary standards and implementation plan—including progress made toward water quality improvements—at least every 3 years until the waterbody reaches full support of the designated use or the standards expire.

Temporary standards may be terminated if the values for the modified parameter or parameters improve to conditions that support all designated uses for the classification, the water for which the temporary standards were adopted is reclassified, or the plan submitted in support of the temporary water quality standards is not being implemented according to the plan's schedule or modifications to that plan or schedule made by the Board or by the Montana Department of Environmental Quality (DEQ).

Example: The New World Mining District

One example of temporary standards in Montana is for the New World Mining District, approximately 4 miles northeast of Yellowstone Park (Figure 6). Three rivers flow through this area—the Clarks Fork of the Yellowstone, the Stillwater, and the Lamar. The site covers approximately 40 square miles. This area has hard rock mining wastes and acidic discharges that contain elevated levels of heavy metals. U.S. Department of Agriculture's Forest Service is conducting remediation with oversight by the Montana Department of Environmental Quality (DEQ).

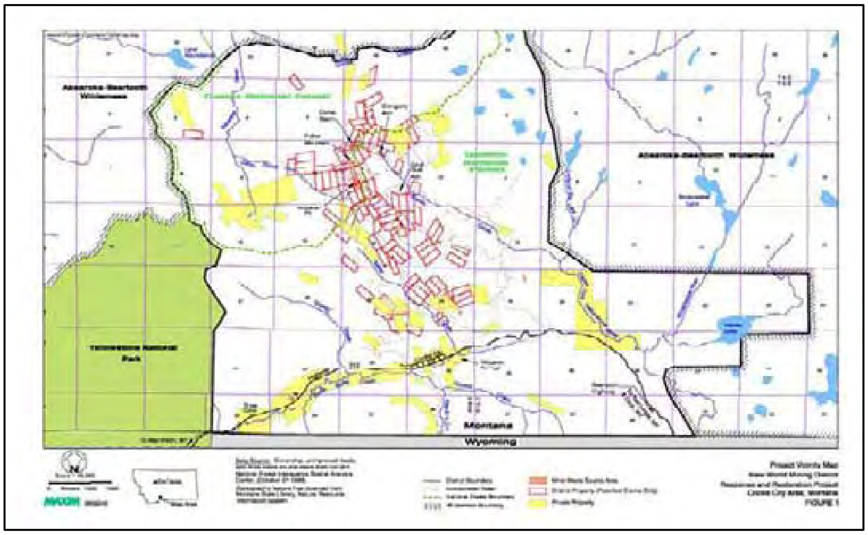


Figure 6. New World Mining District (USDA, 2002).

Data Collection and Analysis

Streams in the District have been classified B-1, with the following designated uses: the water quality is to be maintained suitable for drinking, culinary and food processing (after conventional treatment), bathing, swimming and recreation, growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers, and agricultural and industrial water supply. For class B-1 waters, standards have been set for *Escherichia coli* (*E. coli*) bacteria, dissolved oxygen, pH, turbidity, temperature, sediment or floating solids, color, and toxic, carcinogenic, or harmful parameters. Some stream segments in the mining district have not been able to achieve some designated uses due, in part, to historical mining activities.

The major sources of water quality impairment at the site include heavy metals present in mine waste pits, acidic water discharging from mine openings, and underground sulfide ore deposits that have been exposed to the atmosphere. Metal-laden mine wastes are transported to surface waters through mechanisms such as erosion, infiltration, dissolution of contaminants in runoff, and groundwater discharge. Since 1977 state and federal agencies have conducted several investigations to determine the nature and extent of metal impacts on surface waters in the District. Earlier studies have shown that metal loadings in streams are derived from groundwater inflow, adit (a nearly horizontal passage from the surface in a mine) discharges, tributary inputs, and leachate from waste dumps. Waste sources, however, are widely scattered throughout the District, and contributions from individual sources are difficult to quantify.

In 1996 the United States and Crown Butte Mining, Inc. (CBMI) signed a Settlement Agreement under which the United States would purchase the company's holdings in the District. Under the agreement, all proposed mining operations were ended, and $22.5 million was provided to clean up the historical mining impacts. A consent decree was signed in 1998 by all interested parties to finalize the terms of the Agreement and make the funds for cleanup activities available. Of the total amount provided, $2.5 million was earmarked for remediation of natural resource damage in this area. The consent decree specified that "performance of response and restoration actions will initially address release of hazardous substances, natural resources lost, and conditions affecting water quality and natural resources that are related to District Property." The Forest Service was designated as the lead agency in charge of administering the cleanup.

The Forest Service and CBMI completed supporting documentation and petitioned for temporary standards for Fisher Creek, Daisy Creek, and a portion of the upper Stillwater River on January 22, 1999. The accompanying support document provided the necessary information required by the Montana Water Quality Act. The Board approved and adopted the temporary standards for the petitioned stream segments following public comment in July 1999. These standards are in effect for 15 years. The goal of using the temporary standards is to allow remediation activities to have time to yield water quality improvements that will result in all waters supporting B-1 uses. Modified criteria were established for aluminum, cadmium, copper, iron, manganese, zinc, and pH for Daisy Creek and for aluminum, copper, iron, lead, manganese, zinc, and pH for Fisher Creek and a portion of the upper Stillwater River (Table 4).

Table 4. Original and Modified Numeric Criteria (Montana DEQ, 2005)

<table>
<tr><th rowspan="2">Waterbody</th><th colspan="8">Original criteria</th><th colspan="8">Modified criteria[a]</th></tr>
<tr><td>Al</td><td>Cd</td><td>Cu</td><td>Fe</td><td>Mn</td><td>Pb</td><td>Zn</td><td>pH</td><td>Al</td><td>Cd</td><td>Cu</td><td>Fe</td><td>Mn</td><td>Pb</td><td>Zn</td><td>pH</td></tr>
<tr><td>Daisy Creek</td><td rowspan="3">750</td><td rowspan="3">1.05[b]</td><td rowspan="3">7.3[b]</td><td rowspan="3">1000</td><td rowspan="3">--</td><td rowspan="3">82[c]</td><td rowspan="3">67[b]</td><td rowspan="3">d</td><td>9510</td><td>4</td><td>3530</td><td>6830</td><td>1710</td><td>n/a</td><td>540</td><td>>4.6</td></tr>
<tr><td>Stillwater River</td><td>670</td><td>n/a</td><td>200</td><td>1320</td><td>86</td><td>13</td><td>49</td><td>>5.5</td></tr>
<tr><td>Fisher Creek</td><td>470</td><td>n/a</td><td>110</td><td>750</td><td>82</td><td>2</td><td>44</td><td>>5.7</td></tr>
</table>

[a] All criteria except pH are shown as micrograms per liter (μg/L); pH is measured in standard units (su).
[b] At 50 mg/L hardness.
[c] At 100 mg/L hardness.
[d] Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

As required by the Board for approval of temporary standards, a work plan was developed and approved under the direction of the Forest Service. The work plan described existing conditions at the site, set forth the goals and objectives of cleanup activities, and established an 8-year schedule under which activities would be completed.

Project activities in the District began in 1999 under the direction of the Forest Service. The general schedule was to finalize the site characterization work in 1999, begin cleanup activities in 2000 and 2001, and complete active cleanup activities by 2002. Years five through eight were dedicated to monitoring surface water quality, groundwater quality, and revegetation at the reclaimed sites and to performing any necessary maintenance. Annual work plans have been developed to reflect changing remediation activities.

Triennial Review of Temporary Standards

Water quality monitoring is ongoing and is conducted several times each year at numerous monitoring stations. The monitoring is done to detect and measure improvements that result from cleanup actions and to comply with the rules in place for water quality standards related to the project. The 2002 Progress Report results include the following:

1. Monitoring on Fisher Creek showed that water quality had been in compliance with the temporary standards since 1999 and several criteria associated with the B-1 standards were being met. Zinc concentrations were below the chronic and acute aquatic standards for B-1, and copper concentrations had fallen below chronic aquatic standards during winter base flow conditions since 1999 at one monitoring location. However, copper exceeded acute and chronic aquatic standards during spring runoff at this station, when flows increase and scoured sediments with high metals concentrations significantly affect water quality. During base flow conditions in the fall, only copper exceeded acute or chronic aquatic standards. Aluminum exceeded chronic aquatic standards during high-flow conditions in 1999 but did not exceed these standards in 2000 or 2001. Zinc exceeded the narrative standard on only two occasions since the standard was established; both exceedences occurred during low-flow periods (May 1999 and October 2000). Water quality in Fisher Creek generally improved downstream, as shown in the lower concentrations measured at several downstream monitoring locations.
2. No temporary standards have been exceeded at the monitoring station on the Stillwater River since the standards became effective in 1999. For the B-1 standards, copper exceeded chronic and acute aquatic standards at this station during each of the three high-flow events monitored since 1999. Copper fell below the chronic aquatic standard generally during low-flow conditions. Aluminum exceeded the chronic aquatic standard during each of the high-flow events and one of the winter base flow events. Zinc concentrations were lower than the acute/chronic aquatic standard at this station since monitoring began in 1990, and iron concentrations were lower than the chronic aquatic standard since the early 1990s. During fall base flow at this station, there were no exceedences of aquatic criteria.
3. Monitoring at two locations on Daisy Creek showed that all metal concentrations measured since 1999 were below both temporary and narrative water quality standards for the majority of the sampling events conducted and the parameters analyzed, with only two exceptions. In terms of the B-1 standards, aluminum, copper, and zinc exceeded the acute and chronic aquatic standards during all monitoring events (except zinc in April 2000) since 1999. Iron exceeded the chronic aquatic standard consistently at one location, and lead exceeded the chronic aquatic standard on one occasion in the past 3 years. At one location, copper exceeded aquatic standards for all events. Iron exceeded the chronic aquatic standard all the time, and lead exceeded the chronic aquatic standard on most sampling events. Metal concentrations at both stations have declined since 1996.

As of the 2005 project summary, water quality monitoring results show that improvements are beginning to be realized at the farthest downstream stations on Fisher Creek and the Stillwater River, and additional water quality improvements are expected to be measured in the near future as the major cleanup projects are completed. Some improvements are also beginning to be realized in the most upstream stations in the headwaters of Fisher Creek and Daisy Creek. The full impact of this comprehensive cleanup project on water quality will not be evident for several years.

Conclusion

The Montana Department of Environmental Quality has found the use of temporary modifications of water quality standards and the associated implementation plan to be a very useful tool to restore water quality. The requirement for an implementation plan with progress reports is an important incentive to attaining the goals initially set out. The cleanup activities were initially scheduled to be completed in 8 years, but this process is iterative. Once remediation activities outlined in the project work plan are completed, analysis and monitoring will determine whether Fisher Creek, Daisy Creek, and the portion of the upper Stillwater River meet the B-1 classification. The 2005 project summary prepared by the Forest Service indicates that work will be completed in 2007, with additional monitoring in 2008. After monitoring, USFS and Montana DEQ will decide what further work needs to be done to complete the cleanup within the 15 year timeline set forth in the temporary standards.

Use of temporary standards for the New World Mining District has been successful, in part, because adequate funding was available for remediation efforts. Resource availability and jurisdictional complexities associated with the Upper Blackfoot Mining Complex have lessened the effectiveness of using temporary water quality standards in that case.

References

Bukantis, B. 2005. Montana's Temporary Water Quality Standards. Presentation at the Designated Use Co-Regulator Workshop, Denver, CO, October 2005.

Montana Department of Environmental Quality. 2005. Water Quality Standards and Classifications. http://deq.mt.gov/wqinfo/Standards/Index.asp. Accessed January 2005.

USDA Forest Service. 2002. *Progress Report: Temporary Water Quality Standards 3-Year Review, New World Mining District Response and Restoration Project*. USDA Forest Service, Missoula, MT. http://www.maximtechnologies.com/newworld. Accessed January 2005.

USDA Forest Service. 2005. P*roject Summary 2005: New World Mining District Response and Restoration Project*. USDA Forest Service, Missoula, MT. http://www.maximtechnologies.com/newworld. Accessed January 2005.

Chesapeake Bay UAAs

Abstract

Complexity: Very complex
Region: 3
Type of Action: Refined aquatic life uses and restoration variance
131.10(g) Factors: 1, 3, 6

Chesapeake Bay waters have been impaired by nutrients and sediment from point and nonpoint sources. These impairments have led to low levels of dissolved oxygen and inability to meet designated uses. Two use attainability analyses (UAAs) were conducted, with several states involved, to evaluate three of the 131.10(g) factors: natural conditions, human-caused conditions, and economics. Maryland collected a significant amount of monitoring data and developed a model to use the data to assess whether the bay's waters were meeting their designated uses. One result of the UAAs was the decision to refine the aquatic life uses. Five designated uses were identified, and the seasonality of each was considered. Maryland promulgated these designated uses in its water quality standards, and EPA approved the new standards in 2005.

In addition, restoration variances were added to Maryland's proposed water quality standards as refinements to proposed criteria. These variances can be applied over an entire segment of the Bay, rather than directed at a specific discharger or group of dischargers. The temporary modifications allow for realistic recognition of current and attainable conditions while retaining the designated use and setting full attainment as a future goal. In addition, the variance allows for incremental improvements in water quality goals.

Background

Over the past 22 years, since the creation of the Chesapeake Bay Program, progress has been made toward restoring the Chesapeake Bay (Figure 7), but a number of problems remain. Portions of the bay and its tidal tributaries are listed as impaired primarily because of low dissolved oxygen levels, which do not support the living resources of the bay. Nutrients emanate from many activities—agriculture, urbanization, septic systems, deforestation and removal of streamside buffers, air deposition, and point sources (e.g., wastewater treatment plant discharges). Many of the nutrients entering the bay are dissolved in runoff; some are associated with sediment in runoff. The result of the excessive nutrients in the bay are increased algae growth (measured as chlorophyll *a*), decreased water clarity (measured as turbidity), and decreased dissolved oxygen levels.

Figure 7. Chesapeake Bay watershed (USEPA, 2003b).

Through the collaboration of the Chesapeake Bay Program, states, the District of Columbia, citizens, and EPA are striving to develop strategies, tools, and activities to reduce nutrient and sediment pollution inputs to the bay. The *Chesapeake 2000* agreement sets an aggressive goal of reducing nutrients and sediment inputs to the Chesapeake Bay to levels that will support the restoration of the bay's living resources by 2010. An indicator for meeting this goal is the removal of the Chesapeake Bay and its tidal tributaries from the list of impaired waters required under Clean Water Act (CWA) section 303(d) (i.e., the 303(d) list).

EPA Guidance

In April 2003 EPA Region 3 issued *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries* (Regional Criteria Guidance) as technical guidance to help the jurisdictions surrounding the Chesapeake Bay to better achieve and maintain the water quality conditions necessary to protect the existing uses in the bay. This Regional Criteria Guidance provides states with two important mechanisms to help them implement an overall nutrient reduction strategy. First, it defines the water quality conditions for nutrients called for in *Chesapeake 2000* through the development of Chesapeake Bay-specific water quality criteria for dissolved oxygen, water clarity, and chlorophyll *a*. EPA intended the Regional Criteria Guidance to assist the Chesapeake Bay jurisdictions in adopting revised state water quality standards for these critical parameters. Second, the Regional Criteria Guidance provides states with suggestions for revised tidal water designated uses within the Chesapeake Bay. The water quality criteria and refined designated uses presented in the Regional Criteria Guidance represent the collaboration of the various partners and stakeholders of the Chesapeake Bay region.

EPA developed the *Technical Support Document for Identifying Chesapeake Bay Designated Uses and Attainability* (Technical Support Document) to help the states document and justify the recommended refined designated uses for the Chesapeake Bay and its tributaries. The Technical Support Document outlined the following objectives:

- Document why current aquatic life designated uses are not protective and are unattainable in all parts of the Chesapeake Bay system because of natural and human-caused conditions that cannot be remedied.
- Document the rationale and scientific basis for the proposed refined designated uses.
- Document that the refined designated uses are attainable.
- Provide technical background information for Maryland, Virginia, Delaware, and the District of Columbia to develop UAAs in support of changing their respective current designated uses (as of 2003).

The Regional Criteria Guidance and Technical Support Document identify five designated uses that, if adequately protected, will lead to the improvement and protection of the living resources of the Chesapeake Bay and its tidal tributaries. Figure 8 illustrates these five designated uses, which are coupled with the three water quality criteria (dissolved oxygen, water clarity, and chlorophyll *a*) to form the basis of the Chesapeake Bay Program's strategy to safeguard the bay from nutrient pollution. To protect the bay's aquatic resources, program managers must accurately delineate locations to apply these tidal-water designated uses, which are the following:

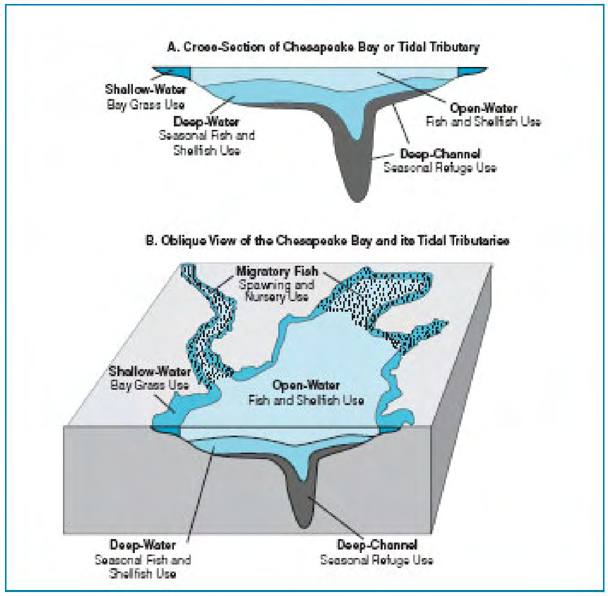


Figure 8. Conceptual illustration of the five Chesapeake Bay tidal water designated use zones (USEPA, 2003b).

- ***Migratory fish spawning and nursery designated use*** protects migratory and resident tidal freshwater fish during the late winter to late spring spawning and nursery season in tidal freshwater to low-salinity habitats. Located primarily in the upper reaches of many bay tidal rivers and creeks and the upper main stem Chesapeake Bay, this use will benefit several species, including striped bass, perch, shad, herring, sturgeon, and largemouth bass.
- ***Shallow-water bay grass designated use*** protects underwater bay grasses and the many fish and crab species that depend on the vegetated shallow-water habitat provided by underwater grass beds.
- ***Open-water fish and shellfish designated use*** focuses on surface water habitats in tidal creeks, rivers, embayments, and the main stem Chesapeake Bay and protects diverse populations of sport fish, including striped bass, bluefish, mackerel and sea trout, as well as important bait fish such as menhaden and silversides.
- ***Deep-water seasonal fish and shellfish designated use*** protects animals inhabiting the deeper transitional water column and bottom habitats between the well-mixed surface waters and the very deep channels. This use protects many bottom-feeding fish, crabs and oysters, and other important species such as the bay anchovy.
- ***Deep-channel seasonal refuge designated use*** protects bottom sediment-dwelling worms and small clams that bottom-feeding fish and crabs consume naturally. Low to occasional no dissolved oxygen conditions occur in this habitat zone during the summer.

Water Quality Criteria

The Regional Criteria Guidance reflects EPA's *National Strategy for the Development of Regional Nutrient Criteria* by establishing waterbody-specific (estuarine) and nutrient eco-region specific criteria. The three Chesapeake Bay criteria—dissolved oxygen, water clarity, and chlorophyll *a*—should be viewed as an integrated set of criteria applied to their respective sets of designated use habitats and addressing similar and varied ecological conditions and water quality impairments. The criteria provide the basis for defining the water quality conditions necessary to protect the five essential Chesapeake Bay tidal-water designated uses.

Dissolved Oxygen Criteria. In the Chesapeake Bay's deeper waters, there is a natural tendency toward reduced dissolved oxygen conditions because of the bay's physical morphology and estuarine circulation. The Chesapeake Bay's highly productive shallow waters, coupled with strong density stratification, long residence times (weeks to months), low tidal energy, and a tendency to retain, recycle, and regenerate nutrients from the surrounding watershed, set the stage for low dissolved oxygen conditions. Specifically, three dissolved oxygen criteria were established for the five designated uses:

- Criteria for the migratory fish spawning and nursery, shallow-water bay grass, and open-water fish and shellfish designated uses were set at levels to prevent impairment of growth and to protect the reproduction and survival of all organisms.
- Criteria for deep-water seasonal fish and shellfish designated use habitats during seasons when the water column is significantly stratified were set at levels to protect juvenile and adult fish, shellfish, and the recruitment success of the bay anchovy.
- Criteria for deep-channel, seasonal-refuge designated use habitats in summer were set to protect the survival of bottom sediment-dwelling worms and clams.

Water Clarity Criteria. The water clarity criteria establish the minimum level of light penetration required to support the survival, growth, and continued propagation of underwater bay grasses. The decline of underwater bay grasses is mainly attributed to nutrient over-enrichment and increased suspended sediments in the water, as well as associated reductions in light availability. Other factors such as climatic events and herbicide toxicity might also have contributed to the loss of bay grasses. To restore these critical habitats and food sources, enough light must penetrate the shallow waters to support the survival, growth, and repropagation of diverse, healthy underwater bay grass communities. The water clarity criteria are applied only during the bay grass growing seasons.

Chlorophyll a. From a water quality perspective, chlorophyll *a* is the best available, most direct measure of the amount and quality of phytoplankton and the potential to lead to reduced water clarity and low dissolved oxygen impairments. The Chesapeake Bay's ability to produce and maintain a diversity of species depends in large part on how well phytoplankton meet the nutritional needs of their consumers. Chlorophyll *a* is the primary photosynthetic pigment in algae and cyanobacteria (blue-green algae), a measure of photosynthesis, and a measure of the primary food source of aquatic food webs. Chlorophyll *a* also plays a direct role in reducing light penetration in shallow-water habitats, which has a direct impact on underwater bay grasses. Uneaten by zooplankton and filter-feeding fish or shellfish, excess dead algae are consumed by bacteria, and in the process they remove oxygen from the water column. Phytoplankton assemblages can become dominated by single species that represent poor food quality or even produce toxins. States are encouraged to adopt numerical chlorophyll *a* criteria for application to tidal waters in which algae-related designated use impairments are likely to persist even after the applicable dissolved oxygen and water clarity criteria are attained.[4]

[4] The technical information supporting states' quantitative interpretation of the narrative chlorophyll *a* criteria is published in the body of the Chesapeake Bay water quality criteria document.

Maryland UAAs

Maryland's Designated Uses and Water Quality Criteria

Maryland's designated uses for the Chesapeake Bay included aquatic life, commercial shellfish harvest, and water contact recreation uses. To protect the aquatic life uses in the bay and its tidal tributaries, Maryland set its dissolved oxygen criteria at 5 mg/L applied year-round throughout all tide-influenced waters. Caps on nitrogen and phosphorus loads were established through the 1992 Amendment to the Chesapeake Bay Agreement and were allocated to each of the 10 major tributary basins in Maryland. In 1996 Maryland listed all portions of the Chesapeake Bay and most of its tidal tributaries as impaired by nutrients or sediment on the state's 303(d) list. With the signing of the Chesapeake 2000 Agreement, Maryland had committed to "correct the nutrient- and sediment-related problems in the Chesapeake Bay and its tidal tributaries sufficiently to remove the bay and the tidal portions of its tributaries from the list of impaired waters (303(d) list) under the Clean Water Act."

In 2004 Maryland published two documents, the *Use Attainability Analysis for Tidal Waters of the Chesapeake Bay Mainstem and Its Tributaries Located in the State of Maryland* and *Use Attainability Analysis for the Federal Navigation Channels Located in Tidal Portions of the Patapsco River*, to aid in this process. Prior water quality criteria were based on the assumption that all areas in the bay were identical, and they did not take into account the natural variability of the bay's waters. These documents provide the technical background and scientific data used to develop new water quality standards.

The *Use Attainability Analysis for Tidal Waters of the Chesapeake Bay Mainstem and Its Tributaries Located in the State of Maryland* explains why the current designated uses cannot be attained in all parts of Maryland's Chesapeake Bay and associated tidal tributaries. Maryland used natural conditions, human-caused conditions, and hydrologic modifications (40 CFR 131.10(g) factors 2, 3, and 4, respectively) to demonstrate that attaining the designated uses was not feasible. The document also provides scientific data indicating that refined designated uses are attainable and would continue to protect existing uses. Finally, the document summarizes economic analyses, including cost estimates for implementing the appropriate control scenarios.

Data Collection and Analysis

When Maryland was assessing attainability, it considered natural conditions by examining paleological evidence and using water quality monitoring data. Water quality models were used to determine bay water quality under forest and pristine conditions. Biological and chemical studies conducted over the past 10 years offered a wealth of data that showed a greater frequency and duration of seasonal anoxic conditions beginning in the 1930s. Maryland Department of the Environment (MDE) personnel documented that extensive land clearance during the 18th and 19th centuries had led to dissolved oxygen depression in the Chesapeake Bay below dissolved oxygen levels characteristic of the previous 2000 years. Although better than present conditions, pre-17th century dissolved oxygen proxy data suggested that dissolved oxygen levels in the deep channel of the bay were not above 5 mg/L all the time. The modeling showed that even under pristine conditions, the designated uses set for the bay would not be met.

Human-caused conditions were also examined by modeling theoretical levels of best management practice (BMP) implementation. MDE scientists were able to establish that anthropogenic impacts, such as all forms of nutrient enrichment caused by agriculture, urban nonpoint sources, and other nonpoint sources, could not be remedied. The theoretical levels of implementation tested in the water quality models included new technologies, management programs, and best practices not currently part of the state or local jurisdictional pollutant control strategies. Three scenarios were considered:

1. All-forest
2. Pristine
3. Everything, everywhere by everyone[5]

The results of these modeling scenarios demonstrated that, even under pristine conditions, the desired dissolved oxygen criteria could not be attained in the deep channels and deep waters of the Chesapeake Bay during the summer. For the Maryland portion of the Chesapeake Bay that is affected by hydrologic modification (i.e., deep water segments of the Patapsco River), MDE scientists collected and analyzed the following data:

- Data from the Chesapeake Bay Water Quality Model
- Data from the Maryland Department of the Environment and Department of Natural Resources Core Monitoring Programs
- Total Maximum Daily Load (TMDL) data gathered 1992–1997

The results showed 77 percent non-attainment in this segment due to federally authorized hydrologic modification under the Rivers and Harbors Act and a complex pattern of tidal circulation that moves hypoxic and anoxic waters within the Chesapeake Bay system.

Three types of economic analyses were performed in conjunction with developing revised water quality criteria for the Chesapeake Bay and its tidal waters. An analysis was undertaken to estimate the costs of implementing the hypothetical control scenarios. The same type of economic analysis was performed on the implementation plan for meeting the new bay water quality standards. An analysis was also performed to consider the substantial and widespread economic and social impacts if controls that were more stringent than those required by CWA sections 301 and 306 were implemented.

The total projected cost, including capital and operating costs, is approximately $10 billion through 2010. This is the statewide evaluation of sewage treatment upgrades and BMP implementation levels necessary to attain the water quality standards in the bay and tidal tributaries. However, there is considerable uncertainty about the cost estimates, the effectiveness

[5] Both the “all-forest” and the “pristine” scenarios were designed to represent pre-European settlement conditions to capture natural pollutant levels. The “all-forest” scenario incorporates nutrient and sediment loads reflecting pre-colonial land clearance, an atmospheric deposition reduced to 10 percent of current load, nitrogen soil storage that is elevated and incorporates some delivery to the Bay, and shoreline erosion at current levels. The “pristine” scenario is similar to the “all-forest” scenario except that the nitrogen storage level does not incorporate delivery to the bay and the shoreline erosion is set at 10 percent of current levels to account for pre-settlement distribution of Bay grasses. The “everything, everywhere by everyone,” or E3, scenario represents the boundary of what is considered physically implausible. It represents BMP implementation with no cost factors and few physical limitations. It also includes new technologies and management programs and practices not currently part of the state or local jurisdictional pollutant control strategies.

of the BMPs, and the level of implementation that will actually be needed. It is anticipated that as innovative and more effective management practices are developed, the implementation will evolve and affect the costs.

The potential economic benefits of improving water quality in the Chesapeake Bay and its tidal tributaries were considered to determine whether controls more stringent than those required by CWA sections 301(b)(1)(A) and (B) and 306 would result in substantial and widespread economic and social impacts. To estimate the potential economic benefits, a regional forecasting model and an economic impact model were used. Results indicated that the regional economy should expand as a result of restoration efforts. Although there is no comprehensive estimate of the benefits, data suggest that the bay affects industries that generate approximately $20 billion and 340,000 jobs.

Use Refinement

Because Maryland determined that the designated uses for the Chesapeake Bay and its tidal tributaries did not fully reflect natural conditions, MDE opted to refine the uses. Through the refinement of Maryland's tidal-water designated uses, the state hopes to replace nonattainable uses and general criteria with specific uses and criteria based on the actual needs of the biological community. Maryland engaged stakeholders early in the process and used the Chesapeake Bay Program's Regional Criteria Guidance and Technical Development Document as a basis for analyses and decision-making. As a result, Maryland was able to upgrade designated uses on some waters and downgrade designated uses on others (from the current bay-wide general aquatic life designation) as needed. Maryland set designated uses for segments of the Chesapeake Bay and its tidal tributaries so that the state would be able to assess and delist (from the 303(d) list of impaired waters) appropriate individual segments.

The first step MDE took in deriving attainable designated uses was delineating of areas where different uses exist. The refined uses were based on habitats of living resources that have different dissolved oxygen requirements and tolerance. In addition, some of the refined uses were based on water clarity requirements for submerged aquatic vegetation. Designated uses can be multi-dimensional in space and time. Temporal variation results in a seasonal application that occurs because of different living resources' life history requirements. For example, the seasonal spawning and early life habitat requirements of American shad would not require spawning and early life stage habitats year-round but only during the spring when shad spawn in the tributaries. Spatial variation occurs in both the horizontal and vertical dimensions of the bay. Horizontal components are based on bathymetry and geography; vertical components are based on bathymetry and pycnocline[6] delineation. The five designated uses outlined in the EPA *Regional* Criteria Guidance and Technical Support Document were proposed to reflect the habitat of an array of recreationally, commercially, and ecologically important species and biological communities.

MDE and its state partners, in collaboration with the Chesapeake Bay Program, took explicit steps to ensure that existing uses would continue to be protected. For the migratory spawning and

[6] The pycnocline is a natural zone of rapid salinity increase that marks the boundary between fresh river water flowing toward the ocean and "salty" ocean water flowing into the bay. The pycnocline acts as a barrier to mixing of surface waters and the deeper waters below (Beaman, 2005a).

nursery use, deep-water seasonal use, and deep-channel seasonal uses, the application of new dissolved oxygen criteria will result in improvements to existing water quality conditions. The refined open water fish and shellfish designated use will continue to provide a level of protection equal to that under the current state water quality standard. The shallow-water bay grass designated use will ensure protection of existing uses through the application of the single best year methodology that MDE developed. The single best year methodology is based on historical data starting in the 1930s and more recent underwater bay grass distributions. This method goes beyond the requirements of the Clean Water Act.

The Chesapeake Bay Program and Maryland assessed attainability for the refined designated uses by collecting a significant amount of monitoring data and developing a mathematical model to assess the bay's waters to determine whether they were meeting their designated uses. Biologically based reference curves were also established for each designated use to allow for scientifically defensible assessments that considered the natural variability of the waterbody.

The attainability of these uses was based on dissolved oxygen criteria for the migratory and spawning, open-water, deep-water, and deep-channel designated uses. Attainability for the shallow-water designated use was assessed based on historical and recent data on the existence of underwater bay grass acreage. The attainability for the chlorophyll *a* criteria was not assessed because this criterion is expressed in narrative terms and does not provide numeric values on which to perform analyses.

Restoration Variance

Even after achievement of nutrient and sediment cap load allocations, portions of the Chesapeake Bay mainstem were found to be unable to meet their designated uses. On the basis of Chesapeake Bay Water Quality Model simulations and analysis of existing water quality data, the deep-water and deep-channel uses in the middle of the Chesapeake Bay mainstem were shown to be unattainable. Maryland officials recognized that partial attainment would be possible, but making this change to the water quality standard was not politically or publicly palatable. In addition, the state did not believe that traditional approaches such as use removal, specific discharger variance, or establishment of less protective criteria would be consistent with the state's long-term water quality goals. To solve this problem, a restoration variance was added to Maryland's proposed water quality standards as a refinement to proposed criteria.

A restoration variance allows dissolved oxygen criteria to slightly exceed the requirement up to 7% in a couple of the deepest areas of the Bay. This modification to the Bay water quality standards was necessary because in those few deep areas, we may not meet the dissolved oxygen requirements. Even after spending billions of dollars to reduce nitrogen, phosphorus, and sediment pollution to clean up the rest of the Bay, essentially doing everything we know how to do at this time, the deep areas still could not attain the dissolved oxygen standard. This is a better, more protective alternative than lowering the standard based on current understanding. The information will be updated periodically to keep the water quality standard focused on protecting living resources, rather than proposing something less protective. The State is required to review the restoration variances at least every three years (based on EPA regulations), and adjust it accordingly. (Note: this paragraph was taken from MDE's website http://www.mde.state.md.us/programs/waterprograms/tmdl/wqstandards/faqs.asp on March 9, 2006)

An example of how this appears in Maryland's adopted and approved water quality standards is: "For the dissolved oxygen criteria restoration variance for Chesapeake Bay Mainstem Segment 4 mesohaline (CB4MH) seasonal deep-water fish and shellfish subcategory, not lower for dissolved oxygen in segment CB4MH than the stated criteria for the seasonal deep-water seasonal fish and shellfish use for more than 7 percent spatially and temporally (in combination), from June 1 to September 30."

A restoration variance is a temporary modification that allows for the realistic recognition of current conditions, while retaining the designated use and setting attainment as a future goal. The variance allows for iterative refinements using quantified implementation, measured reductions, and monitoring data during triennial reviews. The restoration variance is applied to a designated use over an entire waterbody segment, rather than directed at a specific discharger or group of dischargers. Segments of the Chesapeake Bay that require variances are the Chesapeake Bay Mainstem under the deep-water seasonal fish and shellfish and deep-channel seasonal refuge use and the Patapsco River under the deep-water seasonal fish and shellfish use.

In addition to a restoration variance, MDE has also proposed a subcategory for the Patapsco River section of the Chesapeake Bay. An analysis of existing water quality data indicates that the dissolved oxygen criteria for the deep-channel seasonal refuge use cannot be met in this segment, even with projected nutrient reductions from point sources and the application of the Tributary Strategies reduction for nonpoint sources. Maryland developed a UAA to support this proposed subcategory.

The *Use Attainability Analysis for the Federal Navigation Channels Located in Tidal Portions of the Patapsco River* describes a number of federally authorized hydrologic modifications under the Rivers and Harbors Act and a complex pattern of tidal circulation that has caused nonattainment of existing designated uses in the Patapsco River. MDE ran six sensitivity scenarios of the Chesapeake Bay Model to estimate the influence of the different loading sources and estimate the extent of impairments due to natural- and human-caused conditions. Results showed 77 percent nonattainment, even at a simulated point source reduction level of "everything, everywhere, by everybody," or E3. Due to this significant nonattainment, MDE proposed that there be further refinement of water quality criteria in this segment with the applicable dissolved oxygen criteria being 0 mg/L from June 1 to September 30, inclusively. Both the restoration variance and the limited use designation for the navigation channel will be revised in the next Maryland triennial Water Quality Standards review in 2007. Maryland will promulgate adjustment to these new portions of the water quality standards, as appropriate.

Conclusion

Maryland promulgated new water quality standards that included refined aquatic life uses. In 2005 EPA approved the changes to the state's water quality standards.

Supporting materials for this case study are available in Appendix F.

References

Beaman, J. 2005a. Chesapeake Bay Segments WQS Designated Uses Refinement: Process, Utility and Lessons Learned. Maryland Department of the Environment, Designated Use Co-Regulators Workshop, Philadelphia, PA, February 2005.

Beaman, J. 2005b. Regulatory Options for Chesapeake Bay Segments that Will not Attain New WQS Even After Proposed Nutrient Reductions Targets ate Achieved. Maryland Department of the Environment, Designated Use Co-Regulators Workshop, Philadelphia, PA, February 2005.

Beaman, J. 2005c. UAA Factors: Natural Conditions, Human Caused Conditions, and Economic Factors. Maryland Department of the Environment, Designated Use Co-Regulators Workshop, Philadelphia, PA, February 2005.

Chesapeake Executive Council. 2000. *Chesapeake 2000 Agreement*. Chesapeake Bay Program, Annapolis, Maryland. http://www.chesapeakebay.net/agreement.htm. Accessed January 2006.

Maryland Department of the Environment. 2004a. Use Attainability Analysis for the Federal Navigation Channels Located in Tidal Portions of the Patapsco River. http://www.mde.state.md.us/assets/document/wqstandards/UAA_patapsco.pdf. Accessed January 2006.

Maryland Department of the Environment. 2004b. Use Attainability Analysis for Tidal Waters of the Chesapeake Bay Mainstem and Its Tributaries Located in the State of Maryland. http://www.mde.state.md.us/assets/document/wqstandards/UAA_tidalbayandtribs.pdf. Accessed January 2006.

USEPA (U.S. Environmental Protection Agency). 2003a. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll* a *for the Chesapeake Bay and Its Tidal Tributaries*. EPA 903-R-03-002. USEPA, Region 3. http://www.chesapeakebay.net/baycriteria.htm. Accessed January 2006.

USEPA (U.S. Environmental Protection Agency). 2003b. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*. USEPA Region 3, Chesapeake Bay Program Office. http://www.chesapeakebay.net/uaasupport.htm Accessed January 2006.

Appendix A:
Kansas and New York UAA Worksheets

Crosby Creek UAA Worksheet

Site Description

Stream Name Crosby Creek **Site** A **HUC8** 10250016 **Segment** 77

Count Jewell **Legal Description** NW 1/4 NE 1/4 Sec: 3 Town: 1 S Range: 6 W

Date 7/10/01 **Time** 2:25:00 PM

Stream Description

Upstream Riffle

Upstream Run width: 23' 0" length: 0' 0" depth avg.: 0' 28" depth max: 0' 30"

Upstream Pool

Downstream Riffle

Downstream Run width: 25' 0" length: 0' 0" depth avg.: 0' 28" depth max: 0' 30"

Downstream Pool

Flow Present? (describe)

None detected.

Predominant Substrate Type: Silt

Aquatic Life Observed

☐ Plants ☐ Frogs ☐ Insects ☐ Fish ☐ Crawfish ☐ Snails

Describe:

Stream type: ☑ Perennial (permanent flow) ☐ Intermittent (permanent water

☐ Ephemeral (seasonal water)

Observation

KANSAS USE ATTAINABILITY ANALYSES (UAAs) COMPLETED IN 2001

BASIN:	KR
HUC 8 NUMBER:	10250016
SEGMENT NUMBER:	77
STREAM NAME:	Crosby Creek

CLASSIFIED IN KANSAS SURFACE WATER REGISTER (1999)	**RETAIN:**	X
	DELETION PROPOSED[1]:	

USE DESIGNATIONS:	**1999 REGISTER**	**PROPOSED**
Aquatic Life Use Support[2]	E	
Primary Contact Recreation[3]		C
Secondary Contact Recreation[4]	X	
Food Procurement		
Irrigation Watering		
Livestock Watering		
Domestic Water Supply		
Industrial Water Supply		
Groundwater Recharge		

1 Stream segment not classified due to

- ____ **statutory definition as an ephemeral stream, grass or vegetative waterway, culvert, or ditch.**
- ____ **median flow less than one cubic foot per second. Cost of classifying stream outweighs the benefits of classification.**
- ____ **UAA survey documented no aquatic resource.**

2
E= expected aquatic life use water
S= special aquatic life use water
R= restricted aquatic life use water

3 Primary contact recreation use classes:

A = designated public swimming area during April 1 - October 31 and secondary contact recreation use class a November 1 - March 31

B = where moderate full body contact recreation is expected during April 1 - October 31 and secondary contact recreation use class a November 1 - March 31

C = where full body contact recreation is infrequent during April 1 - October 31 and secondary contact recreation use class b November 1 - March 31

4 Secondary contact recreation use classes:

a = capable of supporting secondary recreational activities and is open to and accessible by the public by law or written permission of the landowner

b = capable of supporting secondary recreational activities and is not open to and accessible by the public under Kansas law

Secondary contact recreation was not delineated in 1999 Register. Per 1999 Kansas Surface Water Quality Standards (KSWQS), classified surface waters where no UAA had been completed were designated for secondary contact recreational use by default.

Antelope Creek UAA Worksheet

HUC: 11040008   Seg: 16   Stream: Antelope Creek   Site: A   Date: 5/15/01

Upstream View

Downstream View

Stream Name Antelope Creek **Site** A **HUC8** 11040008 **Segment** 16

Count Clark **Legal Description** SE 1/4 SW 1/4 Sec: 21 Town: 33 S Range: 24 W

Date 5/15/01 **Time** 10:55:00 AM

Stream Description

Upstream Riffle

Upstream Run

Upstream Pool width: 2' " length: ' " depth avg.: ' " depth max: ' 2"

Downstream Riffle

Downstream Run

Downstream Pool

Flow Present? (describe)

No. Channel is dry downstream.

Predominant Substrate Typ Silt

Aquatic Life Observe

☐ Plants ☐ Frogs ☐ Insects ☐ Fish ☐ Crawfish ☐ Snails

Describe:

Stream type: ☐ Perennial (permanent flow) ☐ Intermittent (permanent water

☑ Ephemeral (seasonal water)

Observation

Ephemeral pool in channel upstream. Very poorly defined, dry channel downstream with terrestrial vegetation spanning channel.

HUC: 11040008 Seg: 16 Stream: Antelope Creek Site: B Date: 5/15/01

Upstream View

Downstream View

Stream Name Antelope Creek **Site** B **HUC8** 11040008 **Segment** 16

Count Clark **Legal Description** SE 1/4 SE 1/4 Sec: 7 Town: 33 S Range: 24 W

Date 5/15/01 **Time** 11:10:00 AM

Stream Description

Upstream Riffle

Upstream Run

Upstream Pool

Downstream Riffle

Downstream Run

Downstream Pool

Flow Present? (describe)

No. Completely dry.

Predominant Substrate Typ

Aquatic Life Observe

☐ **Plants** ☐ **Frogs** ☐ **Insects** ☐ **Fish** ☐ **Crawfish** ☐ **Snails**

Describe:

Stream type: ☐ **Perennial (permanent flow)** ☐ **Intermittent (permanent water**

☑ **Ephemeral (seasonal water)**

Observation

Terrestrial grasses and forbs span width of channel. Channel very pooly defined/absent.

HUC: 11040008 Seg: 16 Stream: Antelope Creek Site: C Date: 5/15/01

Upstream View

Downstream View

Stream Name Antelope Creek **Site** C **HUC8** 11040008 **Segment** 16

Count Clark **Legal Description** SE 1/4 NW 1/4 Sec: 1 Town: 33 S Range: 25 W

Date 5/15/01 **Time** 11:15:00 AM

Stream Description

Upstream Riffle

Upstream Run

Upstream Pool

Downstream Riffle

Downstream Run

Downstream Pool

Flow Present? (describe)

No. Completely dry.

Predominant Substrate Typ Silt

Aquatic Life Observe

- [ ] Plants
- [ ] Frogs
- [ ] Insects
- [ ] Fish
- [ ] Crawfish
- [ ] Snails

Describe:

Stream type:

- [ ] Perennial (permanent flow)
- [ ] Intermittent (permanent water
- [x] Ephemeral (seasonal water)

Observation

Rain puddle upstream is not on channel. Terrestrial vegetation spans channel. Windmill and stock tank in very poorly defined channel downstream.

KANSAS USE ATTAINABILITY ANALYSES (UAAs) COMPLETED IN 2001

BASIN: CIMARRON RIVER BASIN

HUC 8 NUMBER: 11040008

SEGMENT NUMBER: 16

STREAM NAME: Antelope Cr

CLASSIFIED IN KANSAS SURFACE WATER REGISTER (1999)

RETAIN: ____

DELETION PROPOSED[1] : X

USE DESIGNATIONS:	1999 REGISTER	PROPOSED
Aquatic Life Use Support [2]	E	
Primary Contact Recreation [3]		
Secondary Contact Recreation [4]	X	
Food Procurement		
Irrigation Watering		
Livestock Watering		
Domestic Water Supply		
Industrial Water Supply		
Groundwater Recharge		

[1] **Stream segment not classified due to**

- X **Statutory definition as an ephemeral stream, grass or vegetative waterway, culvert, or ditch.**
- ____ **Zero flow with pooling. Cost of classifying stream outweigh the benifts of classification.**
- ____ **UAA survey documented no aquatic resource.**

[2] **E= expected aquatic life use water**
S= special aquatic life use water
R= restricted aquatic life use water

[3] **P means primary contact recreation.**

[4] **Q means secondary contact recreation. Secondary contact recreation was not delineated in 1999 Register. Per 1999 Kansas Water Quality Standards (KSWQS), all classified surface waters where no UAA had been completed were designated for secondary contact recreational use by default.**

New York UAA Worksheet

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233-0001

D

Henry G. Williams
Commissioner

USE ATTAINABILITY ANALYSIS FOR SURFACE WATERS

The following water body or stream segment has been assessed considering the "Technical Guidance and Criteria for Fish Propagation in Various Habitats", available data on the site developed by the Department or other sources such as universities, museum, etc., and other references, and has been found to not meet the minimum criteria for fish propagation. Specific reason(s) is (are) below.

Name Trib. of Seneca River Drainage Basin Oswego River
Sub-basin Finger Lakes Index No. ONT-66-12-57 Item No. 224 NYCRR Ref. 898.4

Reason(s) for non-attainment:

D ---> D

1. Naturally occurring pollutants
   - [ ] chronic toxicity from ____
   - [ ] temperature exceeds ____
   - [ ] other ____

2. Natural, ephemeral, intermittent, or low flow conditions or water levels
   - [XX] stream: intermittent and no habitat available to survive low flow events
   - [ ] ephemeral ponded water: no standing water for part of the year, no outlet or tribs to escape drought, and no fish collected surviving drought
   - [ ] other ____

3. Physical conditions related to the natural features of the water body
   - [ ] waterfall prohibits migration to this upstream intermittent segment
   - [ ] other ____

4. Dams, diversions or other types of hydrologic modifications (if checked see attached analysis) concluding that it is not feasible to restore the water body to its original condition or to operate the facility in a way that would result in conditions suitable for fish propagation
   - [ ] Dam: fish propagation prevented because ____
   - [ ] Diversion: fish propagation prevented because ____
   - [ ] other ____

5. Additional comments or references The stream should retain the Class "D" designation from its crossing of Routes 5 and 20 to the source of both tributaries. From Route 5 and 20 downstream to the mouth where it enters the Cayuga-Seneca Canal it should be Class "C"

Signed: [signature] Title: Regional Fisheries Manager Date: 04/10/92

Signed: [signature] Title: Regional Water Engineer Date: 04/10/92

Appendix B:
Suspension of Recreational Beneficial Uses

Draft Staff Report

Amendment to the *Water Quality Control Plan for the Los Angeles Region* to Suspend the Recreational Beneficial Uses in Engineered Channels during Unsafe Wet Weather Conditions

Prepared by
California Regional Water Quality Control Board, Los Angeles Region

May 15, 2003

Photo on cover of Ballona Creek storm conditions on March 15, 2003
(Courtesy of Culver City)

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I. INTRODUCTION

The Regional Board is proposing to amend its Basin Plan to acknowledge the inherent danger of recreating in engineered flood control channels during unsafe conditions characterized by high velocities and deep water. Specifically, the Regional Board proposes to suspend the recreational beneficial use(s) in engineered flood control channels where access can be restricted during and immediately following significant storm events to address the physically unsafe conditions in these channels. At present, the recreational beneficial uses (Water Contact Recreation or REC-1 and Non-contact Water Recreation or REC-2) assigned to these channels apply at all times, regardless of weather conditions or any other condition that could make recreational activities unsafe or infeasible. The proposed amendment would revise the recreational beneficial use designations (REC uses) for these engineered channels to reflect recreational use(s) that are temporarily suspended during and immediately following defined storm events.

Engineered flood control channels are constructed to reduce the incidence of flooding in urbanized areas by conveying stormwater runoff to the ocean or other discharge point as efficiently as possible. To accomplish this, the channels are usually lined, on the sides and/or bottom, with rip-rap or concrete. This modification creates “swiftwater” conditions during and immediately following storm events (see Exhibit 1, Photo 1). The vertical walls or steep-sided slopes of these channels in conjunction with restrictive fencing limit direct access to channelized creeks and streams for the purpose of recreational use (see Exhibit 1, Photos 2, 3, and 4).

The inherent danger of recreating in these channels during and immediately following storm events is widely recognized and is already addressed by Los Angeles and Ventura Counties through county policies. In Los Angeles County, protocols for locking access gates to flood control channels and preparing for possible swift-water rescues in these channels during defined storm events have been set by the Los Angeles County, California Multi-Agency Swift Water Rescue Committee. In Ventura County, access gates to these channels are kept locked at all times.

Since the suspension of the REC use(s) during defined storm events reduces the level of protection for the water body, the USEPA requires the Regional Board to conduct a use attainability analysis (UAA) for each water body to which the suspension would apply (USEPA, 2002, 1998, 1994). To meet these requirements, the Regional Board has developed this categorical UAA for all engineered flood control channels during defined storm events.

II. BACKGROUND

A. Designation of Beneficial Uses

According to 40 C.F.R. § 131.3(f), designated uses are those uses specified in water quality standards for each water body or segment whether or not they are being attained. Section 101(a)(2) of the federal Clean Water Act (CWA) says, "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983."

40 C.F.R. §131.10 directs States on the designation of uses:

> (a) Each State must specify appropriate water uses to be achieved and protected. The classification of the waters of the State must take into consideration the use and value of water for public water supplies, protection and propagation of fish, shellfish and wildlife, recreation in and on the water, agricultural, industrial and other purposes including navigation. In no case shall a State adopt waste transport or waste assimilation as a designated use for any waters of the United States.
>
> (b) In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall provide for the attainment and maintenance of the water quality standards of downstream waters.
>
> (c) States may adopt sub-categories of a use and set the appropriate criteria to reflect varying needs of such sub-categories of uses, for instance, to differentiate between cold water and warm water fisheries.
>
> (d) At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under sections 301(b) and 306 of the Act and cost-effective and reasonable best management practices for nonpoint source pollution.

B. Recreational Use Designations in the Los Angeles Region

Existing and potential uses of inland surface waters in the region are listed in Table 2-1 of the Basin Plan (CRWQCB, 1994). The Basin Plan defines recreational uses as follows:

> Water Contact Recreation (REC-1): "Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs." (CRWQCB, 1994, p. 2-2)

> Non-contact Water Recreation (REC-2): "Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities." (CRWQCB, 1994, p. 2-2)

Per 40 C.F.R. 131.3(f), existing beneficial uses refer to those beneficial uses that have been attained for a water body on, or after, November 28, 1975. Potential use designations are based on a number of factors, including:

a) plans to put the water to such future use,
b) potential to put the water to such future use,
c) designation of a use by the Regional Board as a regional water quality goal, or
d) public desire to put the water to such future use (CRWQCB, 1994).

C. Historical Basis for Recreational Use Designations in the Los Angeles Region

As stated earlier, section 101(a)(2) of the federal Clean Water Act (CWA) states that, "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water will be achieved by July 1, 1983." This formed a broad basis for the beneficial use designations for surface waters of the State.

In addition to this consideration, a comprehensive review of existing data and solicited input from stakeholders was conducted in the early 1970s to determine the existing and potential beneficial uses for the waters of the Los Angeles Region. These were the bases for the beneficial uses as designated in the 1975 Water Quality Control Plans for the Los Angeles River Basin and Santa Clara River Basin (Basin Plans). Data and reports for this assessment were obtained from the California Departments of Health, Fish and Game, Conservation, and Water Resources, as well as the Southern California Association of Governments, County of Los Angeles, Los Angeles County Flood Control District, and various regional and local water agencies. Comments received from public agencies, public utilities, industrial organizations, water companies and private citizens were also considered (CRWQCB, 1975). Beneficial uses identified included existing or potential water contact recreation (REC-1) for virtually all waters in the region, and non-contact water recreation (REC-2) for most waters in the region.

Prior to the 1994 update of the Basin Plans, researchers at California State University, Fullerton conducted a comprehensive review of the Region's beneficial uses under a contract with the Regional Board (Saint, Prem K., *et al.*, 1993). The review included an evaluation of existing data, detailed field investigations and surveys of agencies and interest groups. Over 350 sites were surveyed as part of the field investigations and 50 agencies and interest groups were contacted and asked to provide input to the study. Based on the study results, the researchers recommended the addition of 126 rivers, 44 lakes and reservoirs, 45 groundwater basins, 9 coastal features and 108 wetlands and accompanying beneficial uses to the revised Basin Plan. On the basis of field surveys and interviews, “existing”, “intermittent” or “potential” REC-1 and REC-2 uses were proposed for many of these newly included water bodies.

D. Regional and National Developments Regarding Recreational Use Designations

The 1994 Basin Plan preserved these recreational beneficial uses. Recently, however, the validity and appropriateness of the REC use(s) assigned to engineered flood control channels where access is restricted or prohibited due to public safety concerns has been questioned by public agencies such as the Los Angeles County Department of Public Works (LACDPW) (County of Los Angeles DPW, 2001, 2002a, 2002b, 2002c). In light of these concerns and similar concerns expressed by the State Water Resources Control Board (State Board), the Regional Board submitted a letter to the State Board outlining possible alternatives for re-evaluating the REC beneficial use(s) assigned to these engineered channels (LARWQCB, 2002).[1] One of these alternatives was to conduct a categorical UAA for the REC use(s) of all engineered flood control channels with restricted or prohibited access during defined storm events corresponding to physically unsafe conditions.

The USEPA has also recently recognized potential circumstances where REC use(s) may be inappropriate due to high wet weather flows that result in dangerous conditions physically precluding recreation (USEPA, 2002). Specifically, USEPA states in its Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft, that “an intermittent REC-1 use may be appropriate when the water quality criteria [referred to in State terminology as "objectives"] associated with REC-1 are not attainable for all wet weather events” (p. 32). One example used by USEPA is high wet weather flows that result in dangerous conditions physically precluding recreation such as arroyo washes in the arid west. In light of this type of situation, USEPA suggests that meeting the REC-1 bacteriological objectives may be suspended during defined periods of time, usually after a specified hydrologic or climatic event, or for a specified number of events or days per year.

[1] Most recently, during a public hearing to consider approval of a Basin Plan amendment updating the Region’s bacteria objectives set to protect the REC-1 use, State Board expressed concerns about the appropriateness of assigning recreational beneficial uses to engineered flood control channels where access is restricted or prohibited (see State Board Resolution No. 2002-0142).

III. PROPOSED ACTION

The Regional Board proposes to suspend the REC use(s) assigned to engineered flood control channels during and immediately after defined storm events where access to the channel can be restricted during the defined conditions. The rationale for this suspension is, first, that these storm events result in high flows/velocities that create physically unsafe conditions that cannot be remedied. Second, during these storm events, it is the policy of Los Angeles County to lock the access gates to these channels due to the inherent danger of recreating in these channels during wet weather, thus preventing individuals from engaging in recreational activities in the channel. The policy of Ventura County is to keep access gates to these flood control channels locked at all times.

A. Water Bodies Covered by Amendment

Staff evaluated whether to conduct water body-by-water body UAAs or a categorical UAA covering all water bodies meeting certain criteria. For this limited circumstance, staff proposes a regional approach, since all water bodies subject to the suspension of REC use(s) have similar features that justify it. Specifically, water bodies to which the suspension of the REC use(s) would apply during the defined conditions include those meeting all of the following criteria:

a) inland water bodies
b) flowing water bodies
c) engineered channels
d) water bodies where access can be restricted or prohibited (through fencing/signs)

See Appendix 1 for a list and map of the 61 inland, flowing water body segments in Los Angeles and Ventura Counties to which the suspension would apply.[2]

A categorical suspension of REC use(s) during and immediately following defined storm events for inland, flowing engineered channels where access is restricted or prohibited is a practical approach and does not reduce public health protection in these channels, since the recreational use(s) do not exist under the proposed conditions for the suspension.[3] Furthermore, as discussed in section VI.A, downstream REC uses must continue to be protected. As described earlier, engineered channels are designed to convey water rapidly out to a discharge point, making conditions unusually unsafe for recreational activities during high flows/velocities associated with storm events. While not sufficient alone to

[2] These water bodies were selected using a two-step approach. First, staff identified all inland, flowing water bodies listed in Table 2-1 of the Basin Plan where the REC use(s) were qualified due to restricted or prohibited access. Second, staff circulated this list internally among staff knowledgeable about the proposed water bodies to confirm that each of the water bodies met the criteria for inclusion in the proposed amendment. Staff will follow-up with field surveys of the candidate water bodies where necessary to confirm physical characteristics and access restrictions.

[3] The recreational uses do not exist because (1) during the defined wet weather conditions, the velocity and depth of the water in these channels renders them unsafe for recreation and (2) under the defined wet weather conditions, Los Angeles County routinely locks all access gates to these flood control channels and Ventura County keeps access gates to flood control channels locked at all times.

trigger a suspension of the REC uses, restricted or prohibited access to these channels is also proposed as a complementary prerequisite for the suspension to ensure that people cannot access a water body during the defined wet weather periods.[4]

Staff evaluated, but does not recommend applying the suspension of REC use(s) to all inland water bodies for the following reasons.[5] Inland water bodies include those that would not be subject to the high flows/velocities that occur in engineered channels. For example, lakes obviously are not characterized by high flows/velocities during storm events that would result in unsafe conditions. As for other inland, flowing water bodies, they may have neither (1) conditions of an engineered channel that would make recreation unsafe during storm events nor (2) restricted or prohibited access.

B. Condition Triggering Suspension of REC Use(s)

Staff evaluated several possible triggers for the suspension of REC use(s) in engineered channels with restricted or prohibited access. These included:

a) flow and velocity (e.g., "swiftwater" conditions),
b) depth (e.g., outside of low flow channel), and
c) rainfall (e.g., total daily rainfall).

A summary of staff's evaluation regarding the feasibility and appropriateness of using each of these triggers is provided in Appendix 2.

Based on this evaluation, staff concludes that rainfall is the most appropriate trigger. The reason for this is three-fold. First, the Los Angeles County, California Multi-Agency Swift Water Rescue Committee uses rainfall prediction as the basis for routinely locking access gates to County flood control channels and putting swiftwater rescue personnel on alert. Written guidance for County personnel and other involved agencies is provided by the Committee in the "Operational Standards and Guidelines Document" (dated December 10, 1999). This document outlines the protocols used by the City of Los Angeles Fire Department, County of Los Angeles Fire Department, Sheriff's Department, Lifeguards and Department of Public Works to prepare for and provide swift-water rescues. Under the "Water Rescue Pre-Deployment Section" (Sec. 6.00, p. 13), three storm levels are defined (Levels 1-3) based on storm warnings with an 80% prediction of specified levels (e.g., ½ inch, 1 inch, 1½ inches) of rain over 24 hours.[6] The following are the three alert levels:

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[4] USEPA states, "For states and authorized tribes using this [high-flow cutoff] approach, EPA encourages the development of an plan to communicate to the public the conditions under which recreation should not occur" (USEPA, 2002, p. 34).

[5] Furthermore, staff evaluated, but does not recommend applying the suspension to coastal water bodies, since there is use during and immediately following storm events (e.g. surfing) and access is not restricted.

[6] According to LA County Flood Control, these protocols are implemented in the following way. There are 12 superintendents who are responsible for closing gates to flood control channels in LA County when they deem appropriate. Each superintendent looks at Doppler information generally and estimates for their geographic region whether they should close the gates.

Level 1	1 inch of rain (if unsaturated ground) or ½ inch (if saturated ground)
Level 2	1 ½ inch of rain (if unsaturated ground) or 1 inch (if saturated ground)
Level 3	Rainfall/saturation levels exceeding those listed for Level 2 Generalized flash floods, urban flooding and/or mud and debris flows Urban flooding with possible life hazards.

Other factors that the agencies consider when determining deployment levels include:

1) The effect of major wildland and interface burn areas. Large burn areas result in increased runoff and high potential for mud and debris flows and flash floods.
2) Flood watches and flood warnings.
3) Real time effects of the storm, which may differ from weather forecasts, resulting in severe conditions in particular geographic areas.
4) Releases in the flood control channels.

At the Level 1 Alert threshold, County personnel routinely lock all access gates to flood control channels. Access gates are kept locked for at least 24 hours after the storm event (Burke, J., 2003, personal communication).

The second reason that rainfall is selected as the most appropriate trigger is because there are numerous rain gages throughout Los Angeles and Ventura Counties making precipitation data readily available whereas flow, velocity and depth data are not available for all candidate channels (see Appendix 2 for more details). Third, rainfall is an adequate proxy for high flows/velocities resulting in unsafe conditions, given the reliance on rainfall prediction by the Multi-Agency Swift Water Rescue Committee. To confirm this, staff used five years of data (water years 1998-2002) to match days above the Level 1 Alert rainfall thresholds of ½ inch or 1 inch with corresponding flow, velocity and depth data in several local channels and compared this data to swift-water rescue data from these same channels as well as other agencies' protocols for evaluating when conditions in these channels are unsafe. Specifically, staff relied upon a protocol used by the USGS and the County of Orange in which in-stream conditions are evaluated using the following calculation to determine whether it is safe for monitoring personnel to be in a stream or channel. The calculation is the peak depth (in feet) multiplied by the peak velocity (in feet/second). If the result is greater than or equal to 10, then it is considered unsafe (Caldwell, A., 2003, personal communication; County of Orange, 2001).

The results of this analysis demonstrate that a significant percentage (63% on average and as much as 83%) of unsafe days (as determined using the USGS protocol described above) occur on days where the preceding day's rainfall was greater than ½ inch, regardless of whether ground conditions were saturated or unsaturated.[7] See Appendix 3, Table 1. (The counterpoint to this is that on average 37% of unsafe days occur on days

[7] In the data analysis, staff compared the preceding day's rainfall to conditions on the target day. Staff chose this approach due to the lag time associated with storm flows. See Appendix 3, Figures 1 to 3, for an example of this lag time. Had staff compared both the preceding day's rainfall as well as rainfall on the target day to conditions on the target day, the percentages above may have been slightly higher.

outside of the defined wet weather conditions.) Additionally, 36 percent of documented swift-water rescues from 2001 to 2002 occurred on days with rainfall greater than or equal to ½ inch, while 71% occurred on days considered "unsafe".[8] See Appendix 3, Table 2. Finally, our analysis shows that, on average, 82% of days and as high as 100% of days where the preceding day's rainfall was greater than ½ inch were considered unsafe per the USGS protocol, regardless of whether the ground was saturated. See Appendix 3, Table 1. (Again, the counterpoint to this is that on average 18% of days where the preceding day's rainfall was greater than ½ inch were *not* considered unsafe.) The results of this analysis show that using days with greater than ½ inch of rainfall and the following day will provide protection by suspending the use during 63% of unsafe days. Additionally, this trigger appears appropriate and justifiable based on this analysis, since on average 82% of days where the preceding day's rainfall was greater than ½ inch were considered unsafe. See Appendix 3 for a more detailed discussion and presentation of this analysis.

On the basis of the detailed data analysis described above and in Appendix 3, staff proposes to use the Level 1 Alert (with saturated conditions) threshold [rainfall greater than or equal to ½ inch as measured at the closest rain gage] as the trigger for suspension of the REC use(s) assigned to a particular engineered channel.[9] Staff proposes to use the Level 1 Alert (with saturated conditions) threshold because rainfall in Southern California tends to be concentrated over a short "wet season" during November to March and, in particular, from January to March, leading to a greater likelihood of saturated conditions as compared to unsaturated conditions. Furthermore, staff's analysis indicates that days deemed "unsafe" based on other agencies' protocols are more likely to occur on days where the preceding day's rainfall is between ½ to 1 inch than on days where the preceding day's rainfall is greater than 1 inch, regardless of ground conditions (i.e. saturated vs. unsaturated).[10] See Appendix 3, Table 1. Therefore, it is more protective of public safety to use the ½ inch rain threshold than the 1 inch rain threshold (i.e., the recreational use(s) will be suspended on a greater number of unsafe days if the ½ inch threshold is used as compared to the 1 inch threshold). In addition, due to the lag time associated with storm flows, staff proposes to apply the suspension for 24 hours after the specified rain event. (See Appendix 3, Figures 1 to 3.) This comports with the policy of Los Angeles County to keep all access gates locked for a minimum of 24 hours following the specified rain event (Burke, J., 2003, personal communication).

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[8] Eighty-two percent of swift-water rescues from 2001 to 2002 occurred on days with rainfall greater than 0.1 inch or days following rainfall of greater than 0.1 inch.

[9] Staff evaluated several methods for identifying the precipitation corresponding to a particular engineered channel. These included using one centralized rain gage per county, one gage per watershed, or the closest gage to the engineered channel. Due to the variability in rainfall in the region, as confirmed by our analysis of these different methods, staff concluded that the closest rain gage to the engineered channel should be used. Consideration should be given to the completeness and quality of the data from that gage. If the data are incomplete or of poor quality, the next closest gage should be used.

[10] This can be explained by the fact that there tend to be more days with rainfall between ½ to 1 inch than days with rainfall greater than 1 inch. However, it is also insightful that the percentage of unsafe days where the preceding day's rainfall was between ½ inch and 1 inch (32%) is similar to the percentage of unsafe days where the preceding day's rainfall was greater than 1 inch (26%).

IV. LEGAL JUSTIFICATION FOR SUSPENSION OF REC USE(S)

A. Legal Requirements for Removal of Designated Uses

Per 40 C.F.R. § 131.10(g), States may remove a designated use that is not an existing use, as defined in 40 C.F.R. § 131.3, or establish subcategories of use if the State can demonstrate that attaining the designated use is not feasible for one or more of the following reasons:

1. Naturally occurring pollutant concentrations prevent the attainment of the use,
2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met;
3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use;
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by sections 301(b) [Effluent Limitations] and 306 [National Standards of Performance] of the Act would result in substantial and widespread economic and social impact.

1. Restrictions on Removal of Use: 40 C.F.R. § 131.10

Federal regulations restrict States from removing designated beneficial uses. Specifically 40 C.F.R. § 131.10 (h) prohibits States from removing designated uses if:

1. They are existing uses, as defined in 40 C.F.R. § 131.3, unless a use requiring more stringent criteria is added; or
2. Such uses will be attained by implementing effluent limits required under sections 301(b) and 306 of the Act and by implementing cost-effective and reasonable best management practices.

Furthermore, 40 C.F.R. § 131.10(i) states that where existing water quality standards specify designated uses less than those which are presently being attained, the State shall revise its standards to reflect the uses actually being attained.

2. *Use Attainability Analyses: 40 C.F.R. § 131.3(g)*

40 C.F.R. § 131.3(g) defines a use attainability analysis (UAA) as a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in § 131.10(g).

Under section 40 C.F.R. § 131.10(j) of the Water Quality Standards Regulation, States are required to conduct a UAA whenever a State wishes to remove a designated use that is specified in section 101(a)(2) of the Act or adopt subcategories of uses specified in section 101(a)(2) that require less stringent criteria.

USEPA (2002) provides guidance on conducting UAAs for recreational uses and provides the following factors that may be addressed:

a) physical analyses considering the actual use (as of November 28, 1975), public access to the water body, facilities promoting the use of recreation, proximity to residential areas, safety considerations, and substrate, depth, width, etc. of a water body;
b) chemical analyses of existing water quality ;
c) potential for water quality improvements including an assessment of nutrients and bacteriological contaminants; and
d) economic/affordability analyses.

This reaffirms previous USEPA guidance in which USEPA suggested that, when evaluating recreational uses, States look at a suite of factors such as whether the water body is actually being used for primary contact recreation, existing water quality, water quality potential, access, recreational facilities, location, proximity to residential areas, safety considerations, and physical conditions of the water body in making any use attainability decision (USEPA, 1994).

On the subject of physical analyses, USEPA has previously stated that, “physical factors, which are important in determining attainability of aquatic life uses, may not be used as the basis for removing or not designating a recreational use consistent with the CWA section 101(a)(2) goal” (US EPA, 1994). This precludes States from relying upon either factor 2 (low flows) or factor 5 (physical factors in general) as the *sole* basis for determining attainability of recreational uses. The reason for this preclusion is that States and USEPA have an obligation to do as much as possible to protect the health of the public. In certain instances, people will use whatever water bodies are available for recreation, regardless of the physical conditions (USEPA, 1994).

USEPA is in the process of considering whether the regulation or Agency guidance should be amended to allow consideration of physical factors, alone, as the basis for removing, or not designating primary contact recreational uses (USEPA, 1998). As part of this process, USEPA has convened a national workgroup to discuss recreational use designations. A key topic being vetted by the workgroup is Use Attainability Analyses for recreational uses.

B. Legal Justification for Suspension of REC Use(s) during Defined Rain Events

Suspension of REC use(s) in engineered channels with restricted or prohibited access during rainfall of greater than or equal to ½ inch and the 24 hours following the rain event is legally justified for three reasons. These are:

(1) During the defined wet weather events, recreation is not an existing use in engineered channels,

(2) Under the defined wet weather conditions during which the suspension would apply, recreational uses in these channels are not attainable through effluent limitations under CWA section 301(b)(1)(A) and (B) and section 306 or through cost effective and reasonable best management practices, and

(3) These water bodies meet two of the six conditions listed in 40 C.F.R. 131.10(g) during the defined wet weather conditions.

The logic underlying each of these reasons is discussed in detail below.

1. During the defined wet weather events, recreation is not an existing use in engineered channels.

During the defined wet weather conditions, recreation is not an existing use in engineered flood control channels with restricted access, for two related reasons.[11] First, during the defined wet weather conditions, the rate of flow, velocity and depth of the water in engineered channels renders them unsafe for individuals to engage in recreational activities. This is particularly true for REC-1 activities because REC-1 involves body contact recreation. As presented earlier, the definition of REC-1 is:

> *"Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing or use of natural hot springs."* (CRWQCB, 1994, p. 2-2)

While REC-2 does not normally involve body contact with water, it does involve recreational activities in close proximity to water. As a result, REC-2 activities may result in accidental contact with water. Due to the extreme danger associated with recreation in or near these channels during the defined wet weather conditions, REC-2 activities, which may involve accidental contact with the water, are also unsafe. This is because if someone recreating near the water body fell into the water, they could be quickly swept downstream due to the high velocities, flow rates, and depths characterizing the defined

[11] Note that while some of the water bodies proposed for inclusion in this amendment have "existing" REC uses assigned to them, these uses have never been "existing" during the defined wet weather conditions for the reasons discussed below.

wet weather conditions. Furthermore, the geometry of these flood control channels (i.e. vertical or steeply sloped sides) makes it extremely difficult to get out of the channel during these conditions. See section III.B and Appendix 3 for a detailed analysis of unsafe conditions. (See Exhibit 1, Photos 4 and 5.)

Second, under the defined wet weather conditions including the 24 hours after the rain event, Los Angeles County routinely locks all access gates to these flood control channels per the protocols outlined in the "Operational Standards and Guidelines Document" (December 10, 1999) prepared by the Multi-Agency Swift Water Rescue Committee. Access gates to engineered flood control channels in Ventura County are always locked. Therefore, recreational activities are prohibited in these channels under the defined wet weather conditions. (See Exhibit 1, Photos 6 and 7.)

2. Under the defined wet weather conditions during which the suspension would apply, recreational uses are not attainable through effluent limitations under CWA section 301(B)(1)(A) and (B) and section 306 or through cost effective and reasonable best management practices.

Due to the design of the engineered flood control channels, recreational uses are not attainable during the defined wet weather conditions that would trigger the suspension even if water quality was adequate to support the uses. In other words, it is not water quality that ultimately precludes attainment of the REC uses, but rather the physical conditions during the defined wet weather conditions in hydrologically modified (engineered) channels. This is because, as described earlier, engineered flood control channels are constructed to reduce the incidence of flooding in urbanized areas by conveying stormwater runoff to the ocean or other discharge point as efficiently as possible. To accomplish this, the channels are usually lined, on the bottom and sides, with rip-rap or concrete. Furthermore, the channel sides are usually vertical or steeply sloped. These modifications, necessary for flood control, create "swiftwater" conditions during and immediately following storm events. Due to the need for flood control during storm events, these channels cannot be modified to eliminate the physical danger associated with recreation in or near these channels during wet weather conditions.

3. These water bodies meet two of the six conditions listed in 40 C.F.R. 131.10(g).

As described earlier, there are six factors that may be used to justify removal of a designated use that is not an existing use or the establishment of sub-categories of a use. Federal regulation (40 C.F.R. 131.10(g)) requires that at least one of these six factors be met. These six factors are as follows:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated

for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or

3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

The suspension of the REC use(s) in engineered flood control channels with restricted access is justified by factors 2 and 4 above. Regarding factor 2, southern California streams are naturally flashy systems due to the predominantly dry climate and short, concentrated wet season. These natural flashy conditions result in intermittent dangerous flow volumes and velocities after rain events that prevent the attainment of the use during and for the 24 hours after a ½-inch rain event.[12]

In addition, the natural conditions in the factor 2 analysis are further exacerbated in engineered flood control channels, which are designed to contain and convey water rapidly to a discharge point. This results in the use being unattainable under factor 4 as well. These hydrologic modifications, made for the purpose of flood control, in combination with natural conditions (i.e., characteristically flashy systems during wet weather) physically preclude the attainment of the recreational use during and immediately following a ½-inch or greater storm event. Further, it is not feasible to restore the water body to its original condition or operate the modifications in such a way as to attain the use during the defined wet-weather events.

[12] Furthermore, regarding factor 2, because the natural conditions of concern are high flow/velocity conditions, these conditions cannot be compensated for by the discharge of sufficient volume of effluent discharges to enable uses to be met.

V. DISCUSSION OF ALTERNATIVES

Below staff presents four sets of alternatives, including (1) which recreational uses to suspend, (2) which trigger to use to identify periods subject to the suspension, (3) which associated water quality objectives to suspend, and (4) a "no action" alternative. Alternatives within each set are mutually exclusive, but alternatives between sets 1, 2 and 3 are intended to be considered in combination.

A. To Which Recreational Uses Should the Suspension Apply?

1. REC-1 Use Only

Due to the inherent danger of recreating in the water during high flow, velocity and depth conditions associated with storm events and the fact that the access gates are locked during these conditions, there is little likelihood that REC-1 uses could occur in these circumstances. Under this recommendation, the REC-2 use and the associated objectives set to protect the REC-2 use would still apply during periods when the REC-1 use was suspended.

2. REC-1 and REC-2 Uses

Suspending both REC-1 and REC-2 uses is reasonable and can be justified by the inability of the channels to support REC-2 activities under the defined conditions. To examine whether REC-2 uses are supported under these conditions, it is useful to examine again the definition of REC-2.

> *Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.* (CRWQCB, 1994, p. 2-2)

The REC-2 use involves activities in proximity to water bodies and, therefore, may involve accidental contact with water, which under the defined wet weather conditions is unsafe. As discussed earlier, this is because if someone recreating near the water body fell into the water, they could be quickly swept downstream due to the high velocities, flow rates, and depths characterizing the defined wet weather conditions. Furthermore, the geometry of these flood control channels (i.e. vertical or steeply sloped sides) makes it extremely difficult to get out of the channel during these conditions. See section III.B and Appendix 3 for a detailed analysis of unsafe conditions. Furthermore, it is unlikely that any of the REC-2 activities are possible where access to the water is barred by fencing and locked access gates during the defined wet weather conditions. On the other hand, where access is prohibited, individuals could come in proximity to a channel (i.e., as close as the fencing would allow). This proximity may result in the incidental ingestion of water (e.g., from splashing). It is the incidental/accidental ingestion of water that is being protected against with the REC-2 use.

B. Which Trigger Should Be Used to Initiate the Suspension?

1. Days of Rainfall greater than or equal to ½ inch plus the 24 Hours Following the Rain Event (Level 1 Alert threshold).

Analysis showing that a trigger of greater than or equal to ½ inch of rainfall, including the 24 hours following the rain event, will capture 63% of "unsafe days" supports this alternative. From another standpoint, analysis showing that 82% of days with rainfall greater than ½ inch were followed by "unsafe" days also supports this alternative. Due to the lag time associated with storm flows, continuing to apply the suspension for 24 hours after the specified rain event is reasonable and justified. This also comports with the Level 1 Alert threshold used by Los Angeles County and its policy to keep all access gates locked for a minimum of 24 hours following the specified rain event.

Under this alternative, the suspension would typically apply 16 to 22 days per year (or 4 to 6% of the year) based on an evaluation of historical rainfall data from LAX and three representative rain gages in Ventura County.[13] See Appendix 3, Table 4.

2. Days of Rainfall greater than 1 inch plus the 24 Hours Following the Rain Event (Level 1 Alert threshold with antecedent unsaturated conditions).

This approach is less conservative from the public safety standpoint than Alternative B.1 in that the recreational use(s) would still apply on a number of days with rainfall of ½ inch to 1 inch when conditions would be deemed "unsafe." (It is, however, more conservative from a water body protection standpoint.) As discussed earlier, the average percentage of unsafe days occurring on days where rainfall of ½ to 1 inch fell on the preceding day (32%) was nearly the same as the average percentage of unsafe days where rainfall of greater than 1 inch fell on the preceding day (26%). Using the more conservative ½ inch trigger captures 63% of unsafe days, on average, while using the less conservative 1 inch trigger only captures 29% of unsafe days, on average. Furthermore, looking at the data from another standpoint, the majority (69%) of days where rainfall of ½ to 1 inch fell the preceding day were deemed unsafe.

Under this alternative, the suspension would typically apply 6 to 12 days per year (or 2 to 3% of the year) based on an evaluation of historical rainfall data from LAX and three representative rain gages in Ventura County.[14] See Appendix 3, Table 5.

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[13] This may be an overestimate because staff has assumed that no day with rainfall greater than or equal to ½ inch was followed by a second consecutive day of rainfall greater than or equal to ½ inch. If one or more days of rainfall greater than or equal to ½ inch were followed consecutively by a day(s) of rainfall greater than or equal to ½ inch, these numbers would be smaller.

[14] This may be an overestimate because staff has assumed that no day with rainfall greater than or equal to 1 inch was followed by a second consecutive day of rainfall greater than or equal to 1 inch. If one or more

C. To Which Water Quality Objectives [Set to Protect Recreational Uses] Should the Suspension Apply?

Under either Alternative A.1 or A.2, the associated objectives set to protect the REC use(s) that should be concurrently suspended should only include those that satisfy the following conditions:

1) The constituents should degrade over a relatively short period of time; conversely, those that are stable or bioaccumulate should not be exempted due to the potential for extended and cumulative downstream impacts beyond the period of the suspension.
2) High levels of these constituents should be of concern to those partaking in only those recreational activities where ingestion of water is possible, for these are the uses that are precluded by the defined wet weather events. Conversely, constituents that could have an effect on other beneficial uses that still occur during wet weather events, should not be suspended, e.g. fish consumption.
3) High levels of these constituents should not in any way affect the non-proximal aesthetic enjoyment of the water body.

Therefore, the bacteria objectives set to protect the REC use(s) are the only objectives that should be concurrently suspended along with the REC use(s). This comports with USEPA guidance, which only envisioned applying a “high flow/velocity” exemption to recreational uses and the associated bacteriological criteria (USEPA, 2002).

D. No Action

Another alternative would be to do nothing and, as such, continue to apply the REC use(s) to all water bodies at all times. Recreational uses would be fully protected; however, the beneficial use designations will not reflect the actual or potential use of these channels under the defined wet weather conditions. Some stakeholders may view this alternative as unreasonably protective.

days of rainfall greater than or equal to 1 inch were followed consecutively by a day(s) of rainfall greater than or equal to 1 inch, these numbers would be smaller.

VI. OTHER CONSIDERATIONS

A. Protection of Downstream Recreational Uses

40 C.F.R. Part 131.10(b) states that "in designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall provide for the attainment and maintenance of the water quality standards of downstream waters." Many of the candidate channels in this proposed amendment flow directly, or indirectly as tributaries to other water bodies, to coastal water bodies and beaches. Many of these coastal water bodies (e.g. beaches) are currently listed as impaired due to bacteria. The Regional Board must ensure that the downstream coastal recreational uses are protected during wet weather events (subject to any other pertinent implementation procedures for the bacteria objectives) and that the recreational uses of the candidate channels are protected when normal/safe conditions return.

On the coast, in Santa Monica Bay, a reference system approach[15] is employed as the regulatory mechanism to protect the REC-1 use of the Bay's beaches. Tables 4 and 5 in Appendix 3 provide estimates of the number of days on which a suspension of the REC use(s) would apply. Because the number of allowable exceedance days under the reference system approach will be re-evaluated in four years based on data from the wave wash (the point of compliance for the TMDL), staff cannot draw definitive conclusions as to whether the recommendations here conflict with the reference system approach. It appears that Alternative A.1 to suspend the REC-1 use only would not be in conflict with the reference system approach under most conditions. It is not clear whether Alternative A.2 to suspend both the REC-1 and REC-2 uses would be in conflict with the downstream reference system approach or not. To assess this, staff would need better information on bacterial degradation rates and transport times from each of the engineered channels to which the suspension would apply.

B. Antidegradation Requirements

Per the State Anti-degradation Policy (State Board Resolution 68-16), there may be no lowering of water quality from that currently attained. The policy states, "Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality shall be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed

[15] Under this approach, a reference system is selected on the coast, which is influenced less than any other area in the watershed by human activities. The number of exceedances for that coastal area is considered to be a result of natural or background conditions. That number is then set as the allowable exceedance days for the rest of the coast unless a particular location has fewer exceedance days than the reference site, in which case antidegradation provisions apply.

in the policies" (SWRCB, 1968). In other words, existing water quality must be maintained even after the effective date of the proposed amendment.

C. Anti-backsliding Requirements

When the Regional Board reissues NPDES permits, the effluent limitations generally must be as stringent as the prior permit. This concept is known as anti-backsliding and it is codified in federal Clean Water Act section 402(o) and separately in 40 C.F.R. § 122.44(l). There are several exceptions to the anti-backsliding provisions of Federal law. In general, the relaxation water quality objectives, as permitted by the proposed Basin Plan amendment, does not exempt a discharger from the anti-backsliding provisions of the federal Clean Water Act. The Regional Board must evaluate NPDES permits on a case-by-case basis when the permits are reissued to determine whether an applicable anti-backsliding exception applies.

D. Future Uses

Suspending the recreational use(s) of the candidate engineered channels does not preclude a lifting of this suspension should conditions within these channels change in the future. While such changes seem unlikely in most cases due to the necessary use of these channels for flood control, none of the alternatives would preclude a return to fully protecting all recreational uses at all times, if warranted.

VII. RECOMMENDED ALTERNATIVE

The Regional Board recommends suspending the water contact recreational activities associated with the swimmable goal as expressed in the federal Clean Water Act section 101(a)(2) and regulated under the REC-1 use, non-contact water recreation involving incidental water contact regulated under the REC-2 use, and the associated bacteriological objectives set to protect those activities, using as a trigger days of rainfall greater than or equal to ½ inch and the 24 hours following the rain event, which comports with the Los Angeles County Level 1 Alert threshold with antecedent saturated conditions. This alternative is justified by the unsafe conditions in engineered flood control channels during storm events of greater than or equal to ½ inch, regardless of ground conditions (i.e. saturated or unsaturated). Furthermore, the candidate channels are routinely locked by Los Angeles County under these conditions, while Ventura County keeps its access gates locked at all times, preventing individuals from engaging in recreational activities in these channels during these conditions.[16] The suspension would apply to inland, flowing, engineered channels where it is possible to restrict access during the defined conditions. Water quality objectives set to protect (1) other recreational uses associated with the fishable goal as expressed in the federal Clean Water Act section 101(a)(2) and regulated under the REC-1 use and (2) other REC-2 uses (e.g., uses involving the aesthetic aspects of water) shall still remain in effect.

In making this recommendation, staff has considered all factors set forth in §13241 of the Porter Cologne Water Quality Control Act:

a) Past, present and probable future beneficial uses of the candidate engineered channels have been, are and will be limited by the hydrologic modifications and other physical factors (i.e. natural conditions).
b) Bacteriological water quality objectives set to protect recreational uses are not being met in 62 percent of the assessed candidate water bodies, however, TMDLs will rectify this in the future, taking into account any suspension of the recreational uses per this amendment.
c) Stormwater is the primary source of bacterial contamination in these channels, particularly during the wet weather conditions under which the suspension would apply. Historically, stormwater has been difficult to control, particularly during wet weather conditions. Furthermore, given the role these channels serve for flood control, it will be particularly difficult to control flows during and immediately following large storm events.
d) With regard to economic considerations, the recommended alternative is not expected to impose any additional cost and will likely reduce future costs by

[16] Regional Board staff recognizes a potential gap between current Los Angeles County policies and the proposed amendment on days with between ½ inch and 1 inch of rainfall where there are unsaturated ground conditions. On these days, current Los Angeles County policies would not require locking access gates, though our analysis shows conditions to be unsafe on the majority of these days. Ways of addressing this gap are discussed in section VIII “Implementation Provisions”.

suspending the recreational uses and associated bacteria objectives during some wet weather events.

e) The recommended alternative will have no impact on the need for developing housing within the region.

f) The need to develop and use recycled water will not be affected by the proposed modifications and, in fact, the ability to reuse stormwater may be facilitated by this amendment by providing flexibility as to where stormwater controls must be implemented.

VIII. IMPLEMENTATION PROVISIONS

The Regional Board is proposing to suspend REC-1 and REC-2 uses in engineered channels on days of greater than or equal to ½ inch of rain and the 24 hours following in acknowledgement of the inherent danger of recreating in these channels during these periods. Staff's recommendation is based on analysis presented in section III.B and Appendix 3, which shows that in general rainfall greater than ½ inch results in unsafe conditions (based on velocity and depth considerations) regardless of whether there are saturated or unsaturated conditions.

The current protocols used in Los Angeles County for locking access gates to engineered channels during storm events provide an effective mechanism for preventing access to these channels when conditions are unsafe. However, staff recognizes a potential gap between current County policies and the proposed amendment on days with between ½ inch and 1 inch of rainfall where there are unsaturated ground conditions. On these days, current County policies would not require locking access gates, though our analysis shows conditions to be unsafe on the majority of these days.

To address this gap, the Regional Board proposes to work in coordination with Los Angeles County Flood Control as well as the Multi-Agency Swift-Water Rescue Committee to identify a mechanism for letting the public know that conditions in these channels are unsafe on days of greater than or equal to ½ inch of rain and the 24 hours following and, therefore, recreational use of these channels is being suspended in the interest of public safety. Potential mechanisms may include permanent signage, press releases, and public outreach in coordination with other public education programs (e.g., the municipal storm water permit public outreach program).

IX. REFERENCES

1. Burke Jerry, Staff of the Los Angeles County Flood Maintenance Division. Personal communication. 2003.

2. California Regional Water Quality Control Board, Los Angeles Region (CRWQCB-LA), Letter from Dennis Dickerson to Art Baggett, Chair of State Water Board, dated July 10, 2002.

3. California Regional Water Quality Control Board, Los Angeles Region (CRWQCB-LA) Total Maximum Daily Load to Reduce Bacterial Indicator Densities during Dry Weather at Santa Monica Bay Beaches. January, 2002.

4. California Regional Water Quality Control Board, Los Angeles Region, 1996 California Water Quality Assessment - 305(b) Report, Supporting Documentation for Los Angeles Region.

5. California Regional Water Quality Control Board (CRWQCB). Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties. 1994.

6. California Regional Water Quality Control Board (CRWQCB). Water Quality Control Plan Report. Los Angeles River Basin (4A). Part I. March 1975.

7. California Regional Water Quality Control Board (CRWQCB). Water Quality Control Plan Report. Los Angeles River Basin (4B). Parts I, II, III, IV, V. March 1975.

8. County of Los Angeles, Department of Public Works. Letter to the California State Water Resources Control Board dated April 29, 2002.

9. County of Los Angeles, Department of Public Works. Letter to the California State Water Resources Control Board dated May 13, 2002.

10. County of Los Angeles, Department of Public Works. Letter to the California State Water Resources Control Board dated July 15, 2002.

11. County of Los Angeles, Department of Public Works. Letter to the California Regional Water Quality Control Board dated September 18, 2001.

12. County of Orange, Public Facilities and Resources Department. Program Development Division. Environmental Resources Section. Water Quality Unit. "Water Quality Sampling Manual for the NPDES Stormwater Permit Program." Revised March 6, 2001.

13. Los Angeles County Department of Public Works, Water Resources Division (Records), hydrologic and meteorological data.

14. Los Angeles County Fire Department, National Fire Incident Reporting System Unit, Information Management Division. Swift Water Rescue Data.

15. Los Angeles County Multi-Agency Swift Water Rescue Committee (LACMSWRC) Operational Standards & Guidelines. December 10, 1999.

16. Saint, Prem K., Hanes, Ted L., Lloyd, William J., Waterbodies, Wetlands, and their Beneficial Uses in the Los Angeles Region (4). Volume 1. Waterbodies and their Beneficial Uses. California State University, Fullerton. July 1993.

17. State Water Resources Control Board, State Board Resolution 68-16, Statement of Policy With Respect to Maintaining High Quality Waters in California. October 28, 1968.

18. United States Environmental Protection Agency (USEPA) "Ambient Water Quality Criteria for Bacteria – 1986". Report No. EPA 330/5-84-002. January 1986.

19. United States Environmental Protection Agency (USEPA)."Water Quality Standards Handbook: Second Edition". Report No. EPA-823-8-94-005a. August 1994.

20. United States Environmental Protection Agency (USEPA). Federal Register, 40 CFR Part 131. "Water Quality Standards Regulation; Proposed Rules". Tuesday, July 7, 1998.

21. United States Environmental Protection Agency (USEPA). EPA-833-R-01-002. "Guidance: Coordinating CSO Long Term Planning with Water Quality Standards Reviews." July 31, 2001.

22. United States Environmental Protection Agency (USEPA) "Implementation Guidance for Ambient Water Quality Criteria for Bacteria". May 2002 Draft.

APPENDIX 2: SUMMARY OF EVALUATION OF POSSIBLE CONDITIONS TRIGGERING SUSPENSION OF REC USE(S)

The Regional Board proposes to suspend the REC-1 beneficial uses for those water bodies where high velocities and deep water create unsafe conditions that preclude individuals from partaking in REC-1 activities. Various implementation options were evaluated with respect to this action.

Water Bodies to be Covered

Water bodies to be covered by a high-flow suspension could include any of the following criteria:

a) inland water bodies
b) flowing water bodies (not lakes)
c) engineered channels
d) water bodies where access is restricted or prohibited (through fencing/signs)

Criteria (a) and (b) must be met for water bodies to be covered by this suspension, but alone they are not enough. Inland water bodies include those that may not be subject to the unsafe conditions that occur in engineered channels. For example, clearly lakes are not subject to high velocities that would cause unsafe conditions. Additionally, access to many lakes cannot be restricted during storm events. Flowing water bodies also could include those that flow more slowly (e.g. due to natural meanders and vegetation). Slow flowing water bodies do not necessarily have the conditions of an engineered channel that make recreation inherently dangerous during storm events.

Therefore, in addition to criteria (a) and (b), criteria (c) and (d) must also be met. Engineered channels are designed to convey water rapidly out to a discharge point, making conditions unusually unsafe for recreation. Therefore, engineered channels (criterion c) should be categorically exempt. Restricted or prohibited access to the engineered channels (criterion d) should also be a complementary prerequisite for employing the suspension because only then is there an assurance that people cannot access a water body in order to engage in recreational activities. See Appendix 1 for a list of engineered water bodies in the region to which access is restricted or prohibited.

The Los Angeles Regional Water Quality Control Board's "Basin Plan" contains a list of inland surface water bodies where access is restricted or prohibited in Los Angeles and Ventura Counties. Staff conducted a search for readily available flow data for each of the inland flowing water bodies where access is restricted or prohibited.

The Los Angeles County Department of Public Works maintains comprehensive information on facilities by channel type. This enabled Regional Board staff to confirm our list of candidate water bodies with the County's to isolate those water bodies to which this amendment would apply.

The Ventura County Flood Control District (VCFCD) does not have a comprehensive list of facilities by channel type. The County currently has a GIS coverage showing channel location and length with basic information (drawing number, project name, year of construction, etc.) of all VCFCD facilities. The County is currently developing a database that would break the list of channels down by channel type and dimensions, but it was not available for use in developing the proposed amendment. There is no record provided by the VCFCD as to which channels are engineered or have restricted access. Therefore, Regional Board staff cannot confirm our list with the County's to isolate those water bodies to which this amendment would apply.

Conditions Triggering Suspension

The possible triggers for a suspension include:

1) Velocity-basis (requires flow and area data) (e.g., "swift water" conditions).

   Velocity can be calculated by dividing the flow by the area (V=Q/A).
   Area can be calculated by multiplying the depth by the cross-sectional area (A=D*(Cross-Sectional Area)).

2) Depth Basis

3) Rainfall-basis (e.g., total daily rainfall).

The following section analyzes the feasibility of each of these three options for Ventura County and Los Angeles County, given readily available data.

Ventura County

1). Velocity Data (flow and area)

a). Flow Data
The Ventura County Flood Control District (VCFCD) provides peak flow data over the most current 24-hour period at http://www.ventura.org/vcpwa/fc/fws/ for a limited number of water bodies. Real-time data is recorded at the county offices. Ventura County is in the process of developing Internet access to historical rainfall and hydrologic data. Also the USGS web-site (http://water.usgs.gov) is helpful for gages in Ventura County as it has real-time as well as historical flow data.

Of the list of 61 water bodies to be covered by this amendment, none are in Ventura County. There may be other water bodies that should be on the list. However, Ventura County's effort to break the list of channels down by channel type and dimensions was not available at the time of writing. There is no record provided by the VCFCD as to which channels are engineered or have restricted access. Therefore, Regional Board staff cannot confirm our list of candidate water bodies with Ventura County's inventory.

b). Area Data (Depth and Cross-Sectional Area)
The VCFCD web-site (listed above) provides peak depth data for the most current 24-hour period. The USGS web-site (listed above) provides annual maximum instantaneous peak stream flow and gage heights. Ventura County is in the process of developing Internet access to historical rainfall and hydrologic data. Cross-sectional area data can be found on as-built plans via request from VCFCD.

2). Depth Data
Depth data is described above.

3). Rainfall Data
The VCFCD web-site (listed above) provides rainfall totals over various time intervals, i.e. last hour, last 3 hours, last 6 hours, last 12 hours, last day and last 2 days. Ventura County is in the process of developing Internet access to historical rainfall and hydrologic data. Historical data was obtained for three representative gages in the county.

Los Angeles County

1). Velocity Data (flow and area)

a). Flow Data
Regional Board Staff has a list of facilities by channel type for Los Angeles County. Staff conducted a search for available flow data for each of the inland flowing water bodies where access is restricted or prohibited. Flow data is available from the Los Angeles County Department of Public Works (LACDPW) web site at: http://www.ladpw.com/wrd/report/9899/runoff/discharge.cfm. In looking at this web-site, staff concluded that less than ½ of the 61 candidate water bodies in Los Angeles County where access is restricted or prohibited have corresponding flow data. Therefore, it is not feasible to rely upon this data as a trigger to determine when to begin the suspension.

b). Area Data (Depth and Cross-Sectional Area)
In most cases depth data is used to determine the flow rate. Therefore, in most channels where a county has flow data, depth data also exists. Cross-sectional area data can be found from looking at particular as-built plans via request from LACDPW.

2). Depth Data
Depth data is described above.

3). Rainfall Data
Los Angeles County displays real-time data for 62 rain gages located throughout the county for 1, 3, 6, 12, 24, 36, and 48-hour increments and for the last 30 days on their web-site. The web-site is updated every 10 minutes. This rain data can be viewed at: http://ladpw.org/wrd/precip/.

Existing Protocol for Restricting Access

In Ventura County, there are no water rescue pre-deployment criteria that result in the closing of flood control access gates. All access gates to flood control channels and access roads are always locked. There are a few exceptions, where Ventura County Flood Control District (VCFCD) has a specific written agreement with a city for joint use of a VCFCD right-of-way. For these few areas where the public has access (most often, bike paths), the access road is not in an area that is at risk for flooding.

In Los Angeles County, the Los Angeles County, California Multi-Agency Swift Water Rescue Committee has published an "Operational Standards and Guidelines Document" (dated December 10, 1999). This guidance provides a framework for the City of Los

APPENDIX 2: SUMMARY OF EVALUATION OF POSSIBLE CONDITIONS TRIGGERING SUSPENSION OF REC USE(S)

Angeles Fire Department, County of Los Angeles Fire Department, Sheriff's Department, Lifeguards and Department of Public Works to provide water rescue. Under the "Water Rescue Pre-Deployment Section" (Sec. 6.00 on page 13), three storm levels are defined (Levels 1-3) based on storm warnings with an 80% prediction of certain quantities of rain over 24-hours. The following are the three alert levels:

Level 1	1 inch of rain (unsaturated ground) or ½ inch (saturated ground)
Level 2	1 ½ inch of rain (unsaturated ground) or 1 inch (saturated ground)
Level 3	Rainfall/saturation levels exceeding those listed for Level 2 Generalized flash floods, urban flooding and/or mud and debris flows Urban flooding with possible life hazards.

Other factors LA County considers when determining deployment levels include:
1) The effect of major wildland and interface burn areas. Large burn areas result in increased runoff and high potential for mud and debris flows and flash floods.
2) Flood Watches and Flood Warnings.
3) Real time effects of the storm (may differ from weather forecasts, resulting in severe conditions in particular geographic areas).
4) Releases in the Flood Control Channels.

Rainfall as Most Practical Trigger for Suspension

Velocity is probably the best direct measure, followed by depth, of unsafe conditions. However, from a practical standpoint, rainfall is the easiest to implement in a region-wide manner and is an adequate proxy for flow as indicated by the reliance on rainfall prediction by the Swift Water Rescue Committee. Rainfall is the factor that determines when Los Angeles County closes its access gates to many engineered channels. Ventura County has its access gates closed at all times, precluding access to channels. Rainfall data is readily available to county personnel and is measured by the county agencies among others. Los Angeles County has staff allocated and funded to close the gates that are county property using rainfall prediction as the basis for closure. In addition, as discussed earlier, flow meters or depth gages are not available for all engineered channels with restricted or prohibited access. Finally, based on our analysis, rainfall appears to correlate well with unsafe conditions as further described in Appendix 3.

Appendix 3 provides a description of the analysis staff conducted to determine that rain was an adequate proxy for unsafe conditions. In sum, unsafe conditions were estimated using a "rule of thumb" employed by USGS and also adopted by Orange County personnel, where if peak velocity * peak depth >= 10, then it is "unsafe." Unsafe days were compared to the preceding day's rainfall (i.e. rain >0.5 or >1.0 inch) to determine whether rainfall was an appropriate implementation trigger.

APPENDIX 2: SUMMARY OF EVALUATION OF POSSIBLE CONDITIONS TRIGGERING SUSPENSION OF REC USE(S)

Rainfall Estimation Methods

There are multiple methods for determining the amount of rainfall at any particular location. All are based on using rain gage data. Three methods are as follows:

1) Use of one centrally located gage per county.
2) Use of one centrally located gage per watershed (one gage per watershed with location within watershed to be determined based on availability of automatically recording rain gages and other factors).
3) Use of the nearest rain gage.

Staff analysis indicated that rainfall is highly variable and that the nearest rain gage should be used to estimate rainfall for particular water body segments.

APPENDIX 3: DATA ANALYIS RESULTS

Correlation between Unsafe Conditions and Rainfall at Select Locations in Three Watersheds

Staff conducted an analysis of the correlation between "unsafe conditions" (using velocity and depth) and daily rainfall amounts to determine whether rainfall is an adequate proxy for unsafe conditions. Specifically, staff used five years of data (water years 1998-2002) to match days above the Level 1 Alert rainfall thresholds of ½ inch or 1 inch (depending on local antecedent moisture condition) with corresponding physical conditions in several local channels. The physical conditions examined were those that could result in "unsafe" conditions, i.e. velocity and depth.

The results of this analysis demonstrate that a significant percentage (63% on average and as much as 83%) of unsafe days (as determined using the USGS protocol [1]) occur on days where rainfall the prior day was greater than ½ inch. [2] (The counterpoint to this is that on average 37% of unsafe days occur on days outside of the defined wet weather conditions.) Finally, the analysis shows that on average 82% of days and as high as 100% of days with rainfall greater than ½ inch were followed by "unsafe" days. (Again, the counterpoint to this is that on average 18% of days with rainfall greater than ½ inch were *not* followed by unsafe days.) See Table 1 below.

This analysis supports the use of rainfall events of greater than 1/2 inch, regardless of ground conditions (saturated vs. unsaturated) as a reasonable proxy for "unsafe" conditions in engineered channels the day following the rain event.

To compare the benefit of using a 1/2-inch rain event versus the 1-inch event, it is important to compare the respective statistics using both rain events. Both statistics are important:

- % "Unsafe" Days Preceded by Rain Days > X inch
- % Days with Rain > X inch that were Followed by "Unsafe" Days

Regarding the first bullet, the results of this analysis show that 63% of days that were considered unsafe occurred when greater than ½ inch of rain fell the preceding day. This statistic drops to 29% when rainfall was greater than 1 inch on the preceding day. Regarding the second bullet, on average 82% of days with rain greater than ½ inch were followed by "unsafe" days. This statistic rises to 94% for days with rainfall greater than 1 inch. Since both statistics listed are important, it is clear that using a 1/2 inch of rain as a trigger for the suspension results in higher percentages when considered cumulatively than the cumulative statistics for 1 inch. Therefore, it is more appropriate to use 1/2 inch of rain as a proxy for unsafe conditions; that is, a significant number of unsafe days would not be captured using 1 inch of rainfall as a proxy for unsafe conditions. While it is necessary to use a prediction of rain to allow time to prepare for unsafe conditions, the implementation of the suspension would be based on actual rainfall data from the closest rain gage with adequate data.

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[1] The USGS uses the following calculation as a "rule of thumb" for determining whether it is safe for monitoring personnel to be in a channel (Al Caldwell, USGS, San Diego office, personal communication, 2003). The calculation is the peak depth (ft) * peak velocity (ft/sec). If the result is greater than or equal to 10 then it is considered unsafe. The County of Orange, Environmental Resources Division, has adopted this "rule of thumb" into their practices (County of Orange, 2001).

[2] In the data analysis, staff compared the preceding day's rainfall to conditions on the target day. Staff chose this approach due to the lag time associated with storm flows. See Figures 1 through 3 for examples of this lag time. Had staff compared both the preceding day's rainfall as well as rainfall on the target day to conditions on the target day, the percentages above may have been slightly higher.

APPENDIX 3: DATA ANALYIS RESULTS

Table 1: High Flow Conditions at Select Stations in Three Watersheds In Region 4 (Water Years 1998-2002)

Station*	Watershed	# "Unsafe" Days	# Days with Rain >0.5 in.	# Days with Rain >1.0 in.	# Unsafe Days preceded by days with rain >0.5 inch	% "Unsafe" Days preceded by days with rain >0.5 inch	% Days with Rain >0.5 in. followed by "Unsafe" days	# Unsafe Days preceded by days with rain >1.0 inch	% "Unsafe" Days preceded by days with rain >1.0 inch	% Days with Rain >1.0 in. followed by "Unsafe" days
F34	LAR	19	25	11	13	68%	52%	10	53%	91%
F342	LAR	45	32	11	29	64%	91%	11	24%	100%
F285	LAR	35	30	13	29	83%	97%	13	37%	100%
F37	LAR	39	21	7	20	51%	95%	7	18%	100%
AVG	***LAR***	35	27	11	23	67%	84%	10	33%	98%
F274	SGR	30	23	9	17	57%	74%	8	27%	89%
F304	SGR	25	23	8	20	80%	87%	8	32%	100%
F312	SGR	21	20	7	12	57%	60%	5	24%	71%
AVG	***SGR***	25	22	8	16	65%	74%	7	27.7%	86.7%
F38	B	56	23	8	23	41%	100%	8	14%	100%
AVG	**ALL**	34	25	9	20	63%	82%	9	29%	94%

Notes: *See Table 1A for a description of each station.

APPENDIX 3: DATA ANALYIS RESULTS

Table 1A. Description of Stream Gaging Stations used in Data Analysis

Station	Watershed	Name	Channel Dimensions*	Assumptions
F34D-R	LAR	LOS ANGELES RIVER below Firestone Blvd	Concrete, with rip-rap side slopes, trapezoidal in section, with trapezoidal low flow channel. Top width is 265 feet. Height is 17 feet. Side slopes not given nor bottom width.	Low flow channel is 28 feet wide, no height given. Assumption that flows will not go out of low flow channel except during extreme events, none of which occurred during this five-year period. So treated cross section as a rectangle with width of 28 feet.
F342-R	LAR	BRANFORD STREET CHANNEL below Sharp Avenue	Trapezoidal, 10 feet wide at bottom and 7.5 feet deep with 1.5 to 1 side slopes.	No assumptions needed.
F285-R	LAR	BURBANK WESTERN STORM DRAIN at Riverside Dr.	Concrete rectangular section with 60 feet width and 12 feet in height.	No assumptions needed.
F37B-R	LAR	COMPTON CREEK near Greenleaf Drive	Concrete rectangular section, 60 feet wide by 13 feet deep.	No assumptions needed.
F274B-R	SGR	DALTON WASH at Merced Avenue	Concrete rectangular section, 60 feet wide, 14.5 feet tall.	No assumptions needed.
F304-R	SGR	WALNUT CREEK above Puente Avenue	Concrete rectangular section, 50 feet wide, 13.5 feet tall.	No assumptions needed.

APPENDIX 3: DATA ANALYIS RESULTS

Station	Watershed	Name	Channel Dimensions*	Assumptions
F312B-R	SGR	SAN JOSE CHANNEL below Seventh Avenue	Grouted rip-rap side slopes with natural bottom, trapezoidal section.	225 feet wide as the upper width, 16 and 17 feet as the maximum height on two sides. No dimensions for channel base or side slopes given. Assumed that side slope was 1.5:1 with base of 175 feet.
F38C-R	Ballona	BALLONA CREEK above Sawtelle Blvd.	Concrete ruble, trapezoidal in section	95 feet wide as the upper width, 23 feet tall in middle of channel. No base width given nor side slopes given. Assumed that side slope was 1.5:1 with base of 26 feet.

*Channel dimensions obtained from the Los Angeles Department of Public Works web site at http://www.ladpw.org/wrd/runoff/.

APPENDIX 3: DATA ANALYIS RESULTS

Illustration of Lag Time between Rainfall and Runoff

Figure 1: Ballona Creek above Sawtelle Blvd.

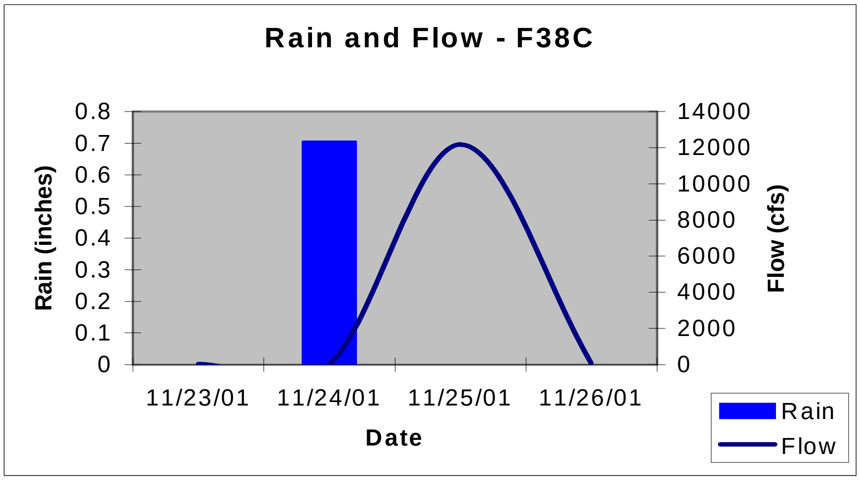
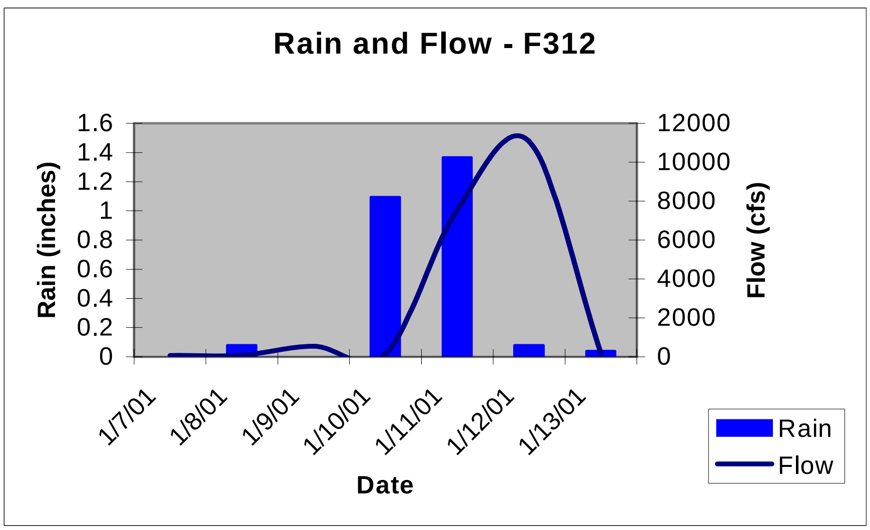
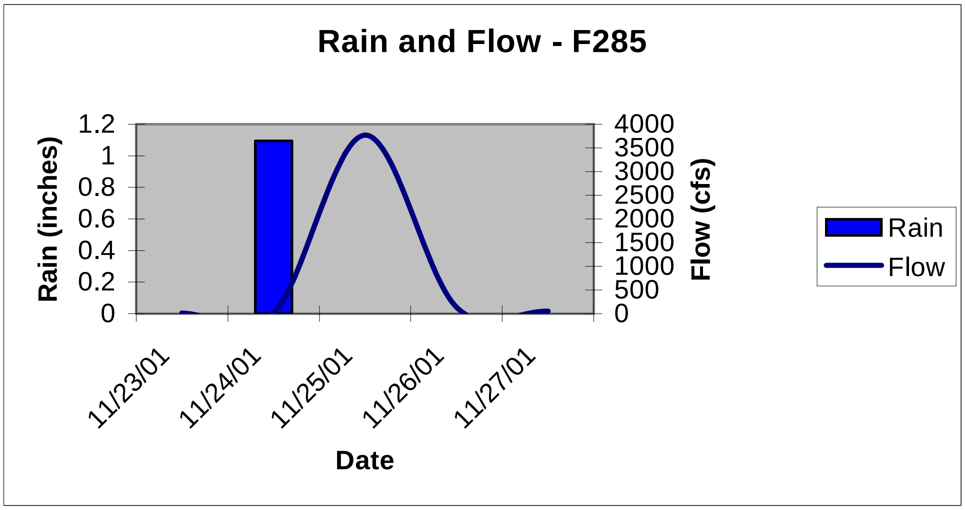


Figure 2: San Jose Channel below Seventh Ave.



APPENDIX 3: DATA ANALYIS RESULTS

Figure 3: Burbank Western Channel at Riverside Dr.



APPENDIX 3: DATA ANALYIS RESULTS

Rescue Dates, Locations and Conditions for 2001 and 2002

In Los Angeles County, protocols for locking access gates to flood control channels and preparing for possible swift-water rescues in these channels during defined storm events have been set by the Los Angeles County, California Multi-Agency Swift Water Rescue Committee. This committee is made up of the County and City Fire Departments, the Sheriff's Department, Lifeguards and the Department of Public Works. The Los Angeles County Fire Department is the chair of the committee and retains records of the locations, dates and times of historic swift-water rescues.

Staff analyzed two years of rescue data (water years 2001-2002) to match days on which there were swift-water rescues with corresponding flow, depth, velocity and rainfall data in several local channels. Staff concluded that 71 percent of the rescues occurred on days that were considered "unsafe".[3] Thirty-six percent of swift-water rescues from 2001 to 2002 occurred on days when the rainfall on that day or the preceding day was greater than ½ inch, while 27 percent occurred on days when the rainfall on that day or the preceding day was greater than 1 inch.[4] See Table 2 below. Table 3 provides minimum, maximum and mean statistics for the flow, velocity and depth values associated with the rescue data.

[3] Staff could not evaluate all rescue dates with respect to the USGS rule-of-thumb, since in some cases the necessary flow data was not recorded.

[4] Eighty-two percent of swift-water rescues from 2001 to 2002 occurred on days when rainfall on that day or the preceding day was greater than 0.1 inch.

APPENDIX 3: DATA ANALYIS RESULTS

Table 2: Rescue Dates, Locations[5] and Conditions for 2001 and 2002

Rescue Date	Nearest Stream-gage	Water Body	Water-shed	Total Daily Rain	Rain Day B/F	"Unsafe" V*D>10	Peak Flow	Peak Depth	Peak Velocity
01/11/01	F354	Coyote Creek	SGR	1.02	1.30	not recorded			
01/12/01	F354	Coyote Creek	SGR	0.32	1.02	not recorded			
03/05/01	F34D-R	LA River	LAR	0.39	0.039	81.82	2290.98	3.13	26.14
03/06/01	F34D-R	LA River	LAR	0.31	0.39	543.45	15216.62	5.14	105.73
04/07/01	F34D-R	LA River	LAR	0.71	0	8.42	235.70	2.13	3.95
04/27/01	F274B-R	San Dimas Wash	SGR	0	0	3.77	226.47	0.84	4.49
04/30/01	F262-R	San Gabriel R.	SGR	0	0	not recorded			
12/21/01	F64R	Rio Hondo	LAR	0.27	0.08	Gage taken off-line in 1996.			
11/30/01	F274B-R	San Dimas Wash	SGR	.078	0.24	63.33	3800	3.83	16.54
11/30/01	F274B-R	San Dimas Wash	SGR	.078	0.24	63.33	3800	3.83	16.54
12/16/02	F354	Coyote Creek	SGR	1.41	0	11.05	16200	7.81	34.57

SGR = San Gabriel River
LAR = Los Angeles River

[5] Exact locations were provided by the LACFD but are not included on this table.

APPENDIX 3: DATA ANALYIS RESULTS

Flow, Velocity and Depth Conditions during "Unsafe" Conditions, Rescues and Specified Rain Events

Staff analyzed some basic hydrologic parameters associated with select channels of concern during various weather and safety conditions. These hydrologic conditions included flow, velocity and depth. The minimum, maximum and mean peaks of these three parameters were recorded.

It is interesting to note that the averages for peak flow, peak velocity and peak depth were similar in magnitude for the "unsafe" days and for the days following a rain event greater than 1/2 inch, regardless of ground conditions (i.e. saturated vs. unsaturated). This seems to support the idea that rain events greater than 1/2 inch are a good proxy for "unsafe conditions."

The correlation between these parameters for days with rescues and days following rain events greater than 1/2 inch is not so strong. While the ranges are comparable, the averages for peak flow, peak velocity and peak depth are approximately 1.5 - 2 times larger during rescue conditions as compared to events where rain the day prior is greater than 1/2 inch. In other words, most rescue days seem to have conditions that are far more dangerous than those associated with the average 1/2-inch rain event.

APPENDIX 3: DATA ANALYIS RESULTS

Table 3: Flow, Velocity and Depth Conditions during "Unsafe" Events, Days with Rescues and Specified Rain Events (Los Angeles River, San Gabriel River and Ballona Creek Sites)

Condition	Peak flow (range & average)	Peak velocity (range & average)	Peak depth (range & average)
Days “unsafe”	(117.31 - 12,483.72) 2,143.29	(4.06 - 121.31) 13.15	(0.19 - 9.33) 2.59
Days w/ rescues	(226.47 - 16,200.00) 5,967.11	(3.95 - 105.73) 28.90	(0.26 - 7.81) 3.37
Days following rain>0.5	(27.02 - 12,483.72) 2,150.59	(0.42 - 58.83) 12.44	(0.37 - 9.33) 2.57
Days following rain >1.0	(27.02 - 12,483.72) 3059.68	(0.42 - 58.83) 15.34	(0.37 - 9.33) 3.10

APPENDIX 3: DATA ANALYIS RESULTS

Summary of Days of Rainfall ≥1/2 inch and ≥1 inch plus the 24-hours following based on Historical Records

At each of four rain gage stations in Los Angeles and Ventura Counties, rainfall greater than or equal to 1/2 inch occurred an average of 18 days per year over the periods of record. This number drops to 7.75 days, where the rainfall criterion is greater than or equal to 1 inch. In percentages, 4.75% of the 365 days per year were days over the rain criterion of 1/2 inch. The percentage drops to 2.25% when using the criterion of 1.0 inch of rainfall.

The ranges and medians are broken down by station in the two tables below. Table 4 applies to the 1/2-inch threshold. Table 5 applies to the 1-inch threshold.

The significance of these tables is that they indicate the number of days per year that the high flow suspension of the REC-1 and REC-2 beneficial uses would apply.

APPENDIX 3: DATA ANALYIS RESULTS

Table 4: Summary of Days of Rainfall ≥ ½ Inch plus the 24 Hours Following Based on Historical Records[6]

Rain Gage	Max No. of Days / year (% of Year)	No. of Days in 1993 (% of Year)	Min No. of Days / year (% of Year)	Median No. of Days / year (% of Year)
LAX[7]	48 (13%)	26 (7%)	2 (0.5%)	16 (4%)
Ojai – Stewart	64 (18%)	Not calculated	0 (0%)	22 (6%)
Simi	56 (15%)	Not calculated	2 (0.5%)	18 (5%)
VD	34 (9%)	Not calculated	0 (0%)	16 (4%)

Notes: The Max, Min, and Median numbers may be overestimates because staff has assumed that no day with rainfall greater than or equal to ½ inch was followed by a second consecutive day of rainfall greater than or equal to ½ inch. If one or more days of rainfall greater than or equal to ½ inch were followed consecutively by a day(s) of rainfall greater than or equal to ½ inch, these numbers would be smaller. The number of days in 1993 is an exact calculation.

Table 5: Summary of Days of Rainfall ≥ 1 Inch plus 24 Hours Following Based on Historical Records[8]

Rain Gage	Max No. of Days / year (% of Year)	No. of Days in 1993 (% of Year)	Min No. of Days / year (% of Year)	Median No. of Days / year (% of Year)
LAX[9]	24 (7%)	15 (4%)	0 (0%)	6 (2%)
Ojai – Stewart	38 (10%)	Not calculated	0 (0%)	12 (3%)
Simi	30 (8%)	Not calculated	0 (0%)	8 (2%)
VD	18 (5%)	Not calculated	0 (0%)	7 (2%)

Notes: The Max, Min, and Median numbers may be overestimates because staff has assumed that no day with rainfall greater than or equal to 1 inch was followed by a second consecutive day of rainfall greater than or equal to 1 inch. If one or more days of rainfall greater than or equal to 1 inch were followed consecutively by a day(s) of rainfall greater than or equal to 1 inch, these numbers would be smaller. The number of days in 1993 is an exact calculation.

[6] Note that the period of record for the LAX analysis was from 1948 to 2000. For the Ventura Downtown (VD) and Ojai-Stewart gages the period of record was 1956 to 2001. For the Simi gage the period of record was 1956 to 1971.
[7] Note that the water year used for the LAX analysis was from November 1 through October 31st. The rest of the rain gage analyses were based on a water year that runs from October 1 through September 30th.
[8] See Footnote 6 above.
[9] See Footnote 7 above.

Appendix C:
Valley Creek UAA

USE ATTAINABILITY ANALYSIS

VALLEY CREEK

Alabama Department of Environmental Management
December 2001

Table of Contents

1.0 Introduction

The purpose of this Use Attainability Analysis (UAA) is to provide evidence that supports the proposed use classification change for the upper segment of Valley Creek being upgraded from Agricultural and Industrial Water Supply (A&I) to Limited Warmwater Fishery (LWF). More specifically, a UAA is required by EPA when States assign a use classification to surface waters that is considered less than the "fishable/swimmable" goal as defined in Section 101(a)(2) of the Clean Water Act. The use classification change for Valley Creek is considered an upgrade because the water uses and corresponding water quality criteria are more stringent for waters classified as LWF as opposed to A&I. However, the LWF classification does not fully meet the water quality uses and criteria associated with the "fishable/swimmable" goal, therefore a UAA is necessary. Alabama's Fish and Wildlife (F&W) use classification, is considered a "fishable/swimmable" designated use by EPA, therefore the objective of this analysis is to document the conditions that prevent the upper segment of Valley Creek from attaining Fish and Wildlife status.

On August 1, 2000, the Environmental Management Commission adopted new regulations (effective September 7, 2000) which eliminated the Industrial Operations (IO) category from the use classification regulations as defined by ADEM's Water Quality Program. At the same time, a segment of Valley Creek (9.7 miles) and all of Opossum Creek (8.5 miles) were upgraded from Industrial Operations to Agricultural and Industrial Water Supply. At that time, a UAA was prepared by ADEM for Valley Creek and Opossum Creek (October 2000) for the purpose of documenting the reasons why the streams could not attain F&W status. The October 2000 UAA continues to be the supporting document for Opossum Creek's current A&I classification. Tables 1-1 & 1-2 below provide a summary of how the rule revisions changed the use classification structure for Valley Creek and Opossum Creek from their previous classification to their current classification.

Table 1-1-Previous Classification

Stream Segment	Basin	Geographic Description	Length (miles)	Previous Classification
Valley Creek	Black Warrior	from Bankhead Lake (confluence of Mud Creek) to county road crossing $1^1/_2$ miles NE of Johns (Jefferson County Rd. 36)	24.7	A&I
Valley Creek	Black Warrior	from county road crossing $1^1/_2$ miles NE of Johns (Jefferson County Rd. 36) to Opossum Creek	9.7	IO
Valley Creek	Black Warrior	from Opossum Creek to its source	11.9	A&I
Total A&I/IO length for Valley Creek ⇒			**46.3**	
Opossum Creek	Black Warrior	from Valley Creek to its source	8.5	IO

Table 1-2-Current Use Classification as of September 7, 2000.

Stream Segment	Basin	Geographic Description	Length (miles)	Classification (as of 9/7/00)
Valley Creek	Black Warrior	from Bankhead Lake (confluence of Mud Creek) to its source	46.3	A&I
Opossum Creek	Black Warrior	from Valley Creek to its source	8.5	A&I

Table 1-3-Proposed Use Classification as of December 23, 2001.

Stream Segment	Basin	Geographic Description	Length (miles)	Proposed Classification
Valley Creek	Black Warrior	from Bankhead Lake (confluence of Mud Creek) to Blue Creek	22.6	F&W
Valley Creek	Black Warrior	from Blue Creek to its source	23.7	LWF

As shown in Table 3 above, the proposed use classification changes of Valley Creek split the stream approximately in half, with the lower segment of Valley Creek being proposed for Fish and Wildlife and upper segment of Valley Creek being proposed for Limited Warmwater Fishery (See Attachment 1, Figure 1). Blue Creek was chosen as the geographic boundary between F&W and LWF as a result of ADEM's water quality modeling. According to the modeling results, Blue Creek was the approximate location at which dissolved oxygen levels rebounded from the sag to back above 5.0 mg/l, which is the required criteria for waters designated Fish and Wildlife. (See Attachment 5, Summer A&I Model Run)

In accordance with the Federal Water Quality Standards Regulation (40 CFR 131.3), a use attainability analysis is a structured scientific assessment of the factors affecting the attainment of a use which may include physical, chemical, biological, and economic factors as described in Section 131.10(g). As indicated below, results of this use attainability analysis indicate at least two of the six applicable factors as defined in Section 131.10(g) are preventing the segment of Valley Creek from attaining ADEM's Fish and Wildlife use classification.

Applicable Factors for Valley Creek (40 CFR Part 131.10(g)):

(1) Naturally occurring pollutant concentrations prevent the attainment of the use; or

(2) Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or

➡ (3) Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

(4) Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or

➡ (5) Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude the attainment of aquatic life protection uses; or

(6) Controls more stringent than those required by Sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

2.0 Overview of the Limited Warmwater Fishery Classification

On August 1, 2000, the Environmental Management Commission (EMC) adopted regulations (effective September 7, 2000) which created a new use classification, Limited Warmwater Fishery (LWF), within ADEM's Use Classification System (Administrative Code 335-6-11). On December 23, 2001, ADEM proposed regulations that would reclassify the upper portion of Valley Creek to LWF. The key element of the LWF classification is that it establishes seasonal uses and water quality criteria for waters that otherwise cannot maintain the Fish & Wildlife criteria on a year-round basis. The following italicized paragraphs provide the specific water quality criteria associated with the LWF use classification as it appears in ADEM's Water Quality Criteria (Administrative Code 335-6-10-.09(6)).

(6) LIMITED WARMWATER FISHERY

(a) The provisions of the Fish and Wildlife water use classification at Rule 335-6-10-.09(5) shall apply to the Limited Warmwater Fishery water use classification, except as noted below. Unless alternative criteria for a given parameter are provided in paragraph (e) below, the applicable Fish and Wildlife criteria at paragraph 10-.09(5)(e) shall apply year-round. At the time the Department proposes to assign the Limited Warmwater Fishery classification to a specific waterbody, the Department may apply criteria from other classifications within this chapter if necessary to protect a documented, legitimate existing use.

(b) Best usage of waters (May through November): agricultural irrigation, livestock watering, industrial cooling and process water supplies, and any other usage, except fishing, bathing, recreational activities, including water-contact sports, or as a source of water supply for drinking or food-processing purposes.

(c) Conditions related to best usage (May through November):

1. The waters will be suitable for agricultural irrigation, livestock watering, and industrial cooling waters. The waters will be usable after special treatment, as may be needed under each particular circumstance, for industrial process water supplies. The waters will also be suitable for other uses for which waters of lower quality will be satisfactory.

2. This category includes watercourses in which natural flow is intermittent, or under certain conditions non-existent, and which may receive treated wastes from existing municipalities and industries. In such instances, recognition is given to the lack of opportunity for mixture of the treated wastes with the receiving stream for purposes of compliance. It is also understood in considering waters for this classification that urban runoff or natural conditions may impact any waters so classified.

(d) Other usage of waters: none recognized.

(e) Specific criteria:

1. Dissolved oxygen (May through November): treated sewage, industrial wastes, or other wastes shall not cause the dissolved oxygen to be less than 3.0 mg/l. In the application of dissolved oxygen criteria referred to above, dissolved oxygen shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth, dissolved oxygen criteria will be applied at mid-depth.

2. Toxic substances and taste-, odor-, and color-producing substances attributable to treated sewage, industrial wastes, and other wastes: only such amounts as will not render the waters unsuitable for agricultural irrigation, livestock watering, industrial cooling, and industrial process water supply purposes; interfere with downstream water uses; or exhibit acute toxicity or chronic toxicity, as demonstrated by effluent toxicity testing or by application of numeric criteria given in Rule 335-6-10-.07, to fish and aquatic life, including shrimp and crabs in estuarine or salt waters or the propagation thereof. For the purpose of establishing effluent limitations pursuant to Chapter 335-6-6 of the Department's regulations, the minimum 7-day low flow that occurs once in 2 years ($7Q_2$) shall be the basis for applying the chronic aquatic life criteria. The use of the $7Q_2$ low flow for application of chronic criteria is appropriate based on the historical uses and/or flow characteristics of streams to be considered for this classification.

3. Bacteria: bacteria of the fecal coliform group shall not exceed a geometric mean of 1000/100 ml; nor exceed a maximum of 2000/100 ml in any sample. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours.

The above water quality criteria are commensurate with surface waters designated Limited Warmwater Fishery. In general, the water quality criteria associated with the Limited Warmwater Fishery classification are the same as the Fish and Wildlife criteria except for the following:

- Minimum dissolved oxygen requirements are reduced from 5 mg/l to 3 mg/l during May through November.

- The seven-day, two-year ($7Q_2$) low flow instead of the seven-day, ten-year ($7Q_{10}$) low flow is used to establish the chronic aquatic life criteria for point source discharges.
- Bacteriological criteria for incidental water contact and recreation during the months of June through September are not required.

3.0 Physical Characteristics of Valley Creek

Valley Creek originates in the City of Birmingham, Jefferson County, Alabama and meanders to the west until it reaches the impounded waters of Bankhead Lake of the Black Warrior River. The Valley Creek watershed lies within two distinct physiographic provinces of north central Alabama, namely the Valley and Ridge and the Appalachian Plateau. The Valley and Ridge drains the eastern portion of Valley Creek (Upper Valley) and is characterized by parallel ridges and valleys having a wide variety of widths, heights and geologic materials, including limestone, dolomite, shale, siltstone, sandstone, chert and marble. The stream primarily exhibits a dendritic drainage pattern as it flows across gently dipping rocks in the basin. The western portion (Lower Valley) of the watershed lies within the Cumberland Plateau section of the Southwestern Appalachian province and is underlain by horizontal sedimentary bedrock layers that are deeply dissected by streams. The types of geology typically encountered are interbedded dark-gray shale, siltstone, medium-gray sandstone and numerous coal seams. The landscape consists of low hills in an irregular pattern, which have broad, gently rolling summits and steep slopes. Relief is on the order 200 to 250 feet and the hills are generally capped with massive beds of sandstone.

Valley Creek is a major tributary of the Black Warrior River and has a total drainage area of 257 square miles and has a total length of approximately 46 miles. The 7-day, 10-year ($7Q_{10}$) and 7-day, 2-year ($7Q_2$) low flows of Valley Creek at its mouth are 12.9 cubic feet per second (cfs) and 27.2 cfs, respectively. Major tributaries of Valley Creek within the proposed Limited Warmwater Fishery segment include Blue Creek, Fivemile Creek, and Opossum Creek with drainage areas of 19.3, 16.5, and 13.2 square miles respectively. Of the tributaries mentioned, Opossum Creek has considerable impact on Valley Creek due to the major point and nonpoint sources of pollution located within its watershed. In addition, the Opossum Creek watershed is one of the most highly industrialized areas of Birmingham and the stream has been on Alabama's 303(d) use impairment list since 1998 for organic enrichment and low dissolved oxygen. Nonpoint sources are believed to be the most significant source of CBOD in the Opossum Creek watershed. The overall land use in the Opossum Creek subwatershed is 52% urban, 40% forested, 8% open area. Opossum Creek originates in Fairfield, Jefferson County, Alabama and travels 8.5 miles until it enters Valley Creek just upstream of the St. Louis/San Francisco Railway bridge. The $7Q_{10}$ and $7Q_2$ low flows at the mouth of Opossum Creek are 0.6 cfs and 1.7 cfs, respectively. See Figure 1 for the location of Opossum Creek within the Valley Creek watershed.

The Valley Creek watershed includes a broad spectrum of land-use activities. In general, the land use transforms considerably from Upper Valley Creek to Lower Valley Creek. Heavy industrial and commercial activities as well as high/low intensity residential land uses dominate the landscape within Upper Valley Creek. Upper Valley Creek drains a major metropolitan area and has typical urban stream characteristics such as poor habitat and degraded water quality and stressed biological communities. The degraded condition of Upper Valley Creek is primarily due to the extensive industrial and commercial land use within its watershed. The urbanized landscape creates dynamic flow events, reduced riparian zones, increased siltation, and other conditions that destroy habitat and impair water quality, thus making it difficult to sustain a healthy aquatic community. In contrast, the Lower Valley Creek watershed is predominantly rural, with sivicultural, agricultural, and some mining operations comprising the land use. The less intensive land use activities contribute to the improved chemical, physical and biological conditions within Lower Valley Creek. Table 3-1 below is a summary of land use activity within the three subwatersheds that define Valley Creek. The land use information was obtained from the EPA Region 4 Land Cover Data Set, South Central Portion, Version 1. Figure 2 of Attachment 1 provides a pictorial representation of the land uses within the Valley Creek watershed.

Table 3-1 – Land Use Activity within the Valley Creek Watershed

Code	Land Use	Subwatershed			Total
		Upper Valley	Lower Valley	Shoal	
11	Open Water	0.54%	0.38%	5.88%	1.35%
21	Low Intensity Residential	19.40%	2.09%	0.15%	7.32%
22	High Intensity Residential	7.20%	0.22%	0.00%	2.43%
23	Commercial/Industrial/Transport	10.46%	0.33%	0.27%	3.57%
31	Bare Rock/Sand	---	---	---	---
32	Quarry/Strip Mine/Gravel Pits	1.03%	0.70%	1.24%	0.90%
33	Transitional Barren	0.58%	0.92%	0.28%	0.70%
41	Deciduous Forest	20.02%	38.17%	38.84%	32.46%
42	Evergreen Forest	9.18%	22.75%	22.78%	18.40%
43	Mixed Forest	19.90%	29.11%	28.71%	26.09%
81	Pasture/Hay	4.47%	2.90%	1.06%	3.10%
82	Row Crops	2.23%	1.69%	0.74%	1.70%
85	Other Grasses	4.99%	0.73%	0.04%	1.98%
91	Forested Wetland	0.01%	---	---	0.00%
92	Emergent Wetland	0.01%	---	0.01%	0.01%

The overall health of Valley Creek is dependent upon good physical characteristics such as proper flow, adequate riparian zones, diverse substrate, and other features that offer good habitat to sustain a healthy aquatic community. Upper Valley Creek is a typical urban stream, containing large amounts of impervious landscape, which in turn allow flash floods to easily occur during rain events that destroy habitat via erosion and sedimentation. Over the years, urbanization of Valley Creek has created many channelized areas within the stream which offer little, if any, habitat for a healthy aquatic community. Subsequently, the concrete channels, coupled with high nutrient loads and excessive light/heat penetration, allow dense periphytic algae and microbial communities to form, which in turn produce significant fluctuations in dissolved oxygen levels via photosynthesis and respiration.

When comparing the physical characteristics of Upper and Lower Valley Creek, the differences that distinguish the two watersheds are primarily land use activity. The less intensive land uses of Lower Valley Creek lend to its ability to attain a Fish and Wildlife use classification. In contrast, it is primarily the poor physical characteristics of Upper Valley Creek that are preventing the stream from attaining a Fish and Wildlife use classification. For this reason, the proposed Limited Warmwater Fishery classification is appropriate for Upper Valley Creek.

4.0 Chemical Characteristics of Valley Creek

The chemical characteristics of Upper Valley Creek demonstrate the influence a major metropolitan area (i.e. heavy industrial, commercial, and residential land use) has on water quality. When comparing the water quality data and associated land uses between the Upper and Lower Valley Creek subwatersheds, it can be shown that land use activity provides a good indication of the types of water quality impacts to be expected within the stream. Upper Valley Creek is characterized as having significant industrial, commercial and residential land uses; likewise it has poor dissolved oxygen levels, high pathogen levels, and elevated biochemical oxygen demand (BOD) and nutrient concentrations. Lower Valley Creek is characterized as having primarily a forested and low-intensity residential land use; therefore it has healthier dissolved oxygen levels, lower pathogen and BOD concentrations.

The USGS data collected as part of the ongoing Birmingham Watershed Project confirms the previous water quality impacts encountered by EPA and ADEM within Upper Valley Creek. Review of the data indicates the key parameters preventing a Fish and Wildlife use classification are dissolved oxygen, nutrients, and bacteria. As illustrated in Table 4-1 below, samples collected at stations VAL-1 and VAL-2 reported dissolved oxygen levels less than 5.0 mg/L, which is the required concentration for streams classified as Fish and Wildlife. Fecal Coliform levels at these stations were elevated well above ADEM's required criteria for a Fish and Wildlife stream. Review of bacteriological data collected, indicate the fecal coliform criteria (200 colonies/100 ml) necessary to protect swimming and other whole-body water contact recreation during the months of June through September would easily be exceeded. These high pathogen levels can be attributed primarily to sewer overflows, leaking sewer lines, and other regulated and nonregulated stormwater runoff. See Attachment 1, Figure 1 for sampling station locations within the Valley Creek subwatershed. See Attachment 2 for a complete list of field/laboratory data and sampling station descriptions. See Attachment 6 for a detailed recreational use attainability analysis for Village and Valley Creeks using data and analysis from Village Creek that is applicable to Valley Creek.

Table 4-1: Selected USGS Water Quality Data, 2000-2001.

Station ID	Date (yy/mm/dd)	Flow (cfs)	DO (mg/L)	BOD (mg/L)	Fecal Coliform (col/100 ml)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
VAL-1	2000/03/01	1.83	8.2		3700	2.2	0.096
VAL-1	2000/03/31	1.77	7.12		22000	2.8	0.158
VAL-1	2000/06/29	33.4	5.1		> 33001	2	0.166
VAL-1	2000/08/02	2.25	5.3	4.9	64000K	2.3	0.252
VAL-1	2000/08/31	1.12	5	4.8	4000	2.5	0.244
VAL-1	2000/10/03	1.12	3.3	1.7	2100	2.2	0.269
VAL-1	2000/11/09	37	8.2		85000K	1.4	0.123
VAL-1	2000/12/12	1.64	4.2	4.8	44000E	2.6	0.162
VAL-1	2001/01/23	2.49	7.8	2.4	3800	2.8	0.236
VAL-1	2001/02/12	120	10.4	4.4	5900	0.77	0.136
VAL-2	2000/02/29	13	13.1		41K	1.4	0.034
VAL-2	2000/03/31	20.7	8		1000	1.6	0.167
VAL-2	2000/05/16	9.7	6.8		400	0.36	0.033
VAL-2	2000/06/29	22.6	5.6		> 6001	1.2	0.093
VAL-2	2000/08/03	18.2	7.8	1.2	1700	1.6	0.079
VAL-2	2000/08/29	6.03	4.3	2.4	640K	0.64	0.034
VAL-2	2000/10/05	5.2	4.7	0.9	150	0.57	0.058
VAL-2	2000/11/15	8.73	9.9	0.9	16000K	1.9	0.085
VAL-2	2000/12/13	7.84	11	0.8	720	1.4	0.05
VAL-2	2001/01/25	13.98	9.3		80K	3	0.057
VAL-2	2001/02/09	374	6.1			2.9	0.421

Note: shaded areas indicate sample was collected during a rain event. E = non-ideal colony count K=estimated value

As you travel downstream from the headwaters of Upper Valley Creek to Lower Valley Creek, water quality appears to be improving. As shown in the following Tables 4-2 & 4-3, samples collected at stations VAL-3, VA1 and VC-5 show improvement in dissolved oxygen, fecal coliform, and biochemical oxygen demand (BOD) concentrations as compared to Stations VAL-1 and VAL-2. Some of the improvement is most likely due to dilution effects as base flow increases due to the addition of incremental flow between the upper and lower sampling stations.

Table 4-2: Selected USGS Water Quality Data, 2000-2001.

Station ID	Date (yy/mm/dd)	Flow (cfs)	DO (mg/L)	BOD (mg/L)	Fecal Coliform (col/100 ml)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)
VAL-3	00/02/29	27.3	10.07		72K	1.2	0.025
VAL-3	00/03/29	42	10.4		120	1.5	0.021
VAL-3	00/06/28	14.7	7		330	1.3	0.056
VAL-3	00/08/03	32.9	7.2	1	1400	1.2	0.087
VAL-3	00/08/31	11.7	11.1	8.6	71K	0.6	0.028
VAL-3	00/10/02	12.3	10.2	0.5	40K	0.41	0.021
VAL-3	00/11/09	240	6.5		16000	1.2	0.117
VAL-3	00/12/13	13.67	13.9	0.7	75	0.96	0.018

Station ID	Date (yy/mm/dd)	Flow (cfs)	DO (mg/L)	BOD (mg/L)	Fecal Coliform (col/100 ml)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)
VAL-3	01/01/25	33	11.1		10K	2.2	0.027
VAL-3	01/02/13	960	10.1	8.4	4700	1.2	0.203

Note: shaded areas indicate sample was collected during a rain event. E = non-ideal colony count K=estimated value

Station VAL-3 indicates that sanitary sewer overflows during rain events are a likely cause of elevated fecal coliform levels. During the 2000-2001 winter season USGS collected two fecal coliform samples during wet weather conditions. At the time samples were collected, stream flows were recorded at 240 cfs and 960 cfs and fecal coliform concentrations of 16,000-col/100 ml and 4700-col/100 ml, respectively. These are high pathogen concentrations considering the large volume of water in the stream. However, high fecal coliform levels during low flow conditions indicate that leaking sewers and/or septic tanks coupled with a shallow groundwater table may be the primary cause of elevated pathogen levels in the upper reaches of the watershed. The shallow groundwater table is not unexpected due to the proximity of Red Mountain, which comprises the southeastern portion of the Upper Valley Creek subwatershed.

Table 4-3: Selected ADEM Trend Station Data, 1997-2001.

Station Number	Date (yy/mm/dd)	Dissolved Oxygen (mg/l)	T-PO4 (mg/l)	NO2/NO3 (mg/l)	BOD-5 (mg/l)	NH3 (mg/l)	Fecal Coliform (col/100 ml)
VC-5	97/06/05	6.33	0.151	1.753	1.9	0.148	3600
VC-5	97/08/14	6.97	0.089	0.519	1.9	0.005	340
VC-5	97/11/19	10.20	0.095	1.069	1.5	0.005	
VC-5	98/08/19	6.25	0.084	0.774	1.1	0.005	164
VC-5	98/10/14	7.15	0.005	0.649	0.5	0.005	114
VC-5	99/06/02	5.82		0.624	0.1		240
VC-5	99/08/04	6.12	0.029	0.5644	0.3		124
VC-5	99/10/13	6.73	0.043	0.052	1.5	0.878	240
VC-5	00/06/07	7.00	0.004	0.015	0.7	1.15	370
VC-5	00/08/09	7.50	0.018	0.551	0.6	0.015	310
VC-5	00/10/11	9.40	0.005	0.68	0.8	0.015	124
VC-5	01/06/06	7.25	0.07	0.221	1	0.015	270
VC-5	01/08/08	5.88	0.02	0.73	0.4	0.26	760
VA1	97/01/22	5.00	0.141	2.846	1.2		116
VA1	97/03/19	7.00	0.107	2.821	2.1		58
VA1	97/04/23	5.70	0.107	4.061	1.7		148
VA1	97/05/14	8.80	0.457	6.163	1.1		
VA1	97/06/04	6.50	0.278	3.022	0.8		500
VA1	97/08/14	7.55	0.443	6.518	0.9	0.102	350
VA1	97/11/19	8.30	0.474	6.237	1.4	0.123	
VA1	98/08/19	6.15	0.302	3.957	1.1	0.005	108

Station Number	Date (yy/mm/dd)	Dissolved Oxygen (mg/l)	T-PO4 (mg/l)	NO2/NO3 (mg/l)	BOD-5 (mg/l)	NH3 (mg/l)	Fecal Coliform (col/100 ml)
VA1	98/10/14	7.24	0.409	5.382	0.6	0.005	27
VA1	99/06/02	5.80	0.115	2.009	0.2		184
VA1	99/08/04	5.58	0.478	5.2564	0.9	0.055	63
VA1	99/10/13	6.30	0.249	0.107	2	2.166	240
VA1	00/06/07	6.20	0.45	0.015	0.9	2.838	188
VA1	00/08/09	7.50	0.446	5.146	0.9	0.015	164
VA1	00/10/11	6.40	0.602	0.618	1.5	0.3	44
VA1	01/06/06	6.68	0.37	3.98	1.2	0.015	176
VA1	01/08/08	6.57	0.15	1.59	0.3	0.2	500

In summary, the primary chemical characteristics preventing Upper Valley Creek from attaining ADEM's Fish and Wildlife use classification are dissolved oxygen and fecal coliform. Data collected by USGS, EPA and ADEM during the past several years validate the differences in water quality between Upper and Lower Valley Creek. The Department believes the fundamental reason for the degraded water quality in Upper Valley Creek is the widespread and intense urbanization of its watershed. These impacts are a result of primarily non-point sources of pollution, such as urban runoff and sanitary sewer overflows/leaks, which typically accompany older metropolitan areas such as Birmingham.

Jefferson County, the operator of the regional collection and treatment systems, is in the sixth year of a scheduled activities included in a Consent Agreement with the U.S. EPA. Mitigation efforts by Jefferson County include rehabilitation of the sewer collection system and installation of additional treatment facilities for wet weather flows at the Village Creek and Valley Creek WWTP's, as well as other WWTP's in the Birmingham Metropolitan area. The overflows from the system are currently a significant source of nutrients and other pollutants to receiving streams in the watershed, including Village Creek. Also, the City of Birmingham is currently conducting a flood water control study with the U.S. Corps of Engineers and the U.S. Geological Survey. This study should be completed by December 2002. The aforementioned mitigation activities should result in improved management of water quality and quantity of the Village Creek watershed.

5.0 Biological Characteristics of Valley Creek

In 1989, the U.S. EPA conducted a comparative study of Village, Valley, Opossum, and Fivemile Creeks. As a result of the study, EPA reported that Opossum Creek, a tributary to Upper Valley Creek, appeared to be the most-stressed of the systems examined. Poor habitat and deposits of tar-like substances were the key factors limiting aquatic life. Short-term toxicity tests using the fathead minnow revealed growth impairment at one station on Opossum Creek. The 1989 toxicity tests also revealed significant mortality to the Daphnid on two of the five stations within Valley Creek.

In 1997, a U.S. EPA biological survey of Valley Creek documented significantly degraded habitat at two of the three sampling stations in Upper Valley Creek with habitat scores of 66 and 64 versus 125 in the reference F&W stream. In addition, there were limited pollution sensitive species present in the upper two sampling stations as evidenced by the EPT index scores of 0 and 1. Fewer species of fish were also reported in the upper watershed versus the lower. EPA biologists recommended not upgrading the segment to F&W unless significant enhancements could be made to improve the stream habitat and remove the sources of excess nutrients. Results of the study revealed that Opossum Creek, scored the lowest, with a 0 EPT index, in comparison to the reference F&W stream, which scored a 3.

In 1999-2000, USGS collected benthic macroinvertebrate data at two locations within Upper Valley Creek. As shown in the following Table 5-1, evaluation of the macroinvertebrate data collected indicate poor results in both EPT Family Richness and Total Taxa Richness at stations VAL-1 and VAL-2, compared to the reference F&W stream. USGS Station VAL-1 had the worst macroinvertebrate scores with EPT Family Richness = 0 and Total Taxa Richness = 10. The USGS Station VAL-2, downstream of VAL-1, also had degraded benthic macroinvertebrates, with EPT Family Richness = 2 and Total Taxa Richness = 24. The low scores reported at these stations are not unexpected due to the degraded physical and chemical characteristics as discussed in previous sections. The recent biological data collected for Upper Valley demonstrate the significant improvements that will be necessary to improve stream habitat and water quality to achieve the Fish and Wildlife use classification. The chronic aquatic life protections required under Limited Warmwater Fishery, even though less restrictive than F&W requirements, will be difficult to achieve. However, the Department believes with continued remediation efforts by Jefferson County and the City of Birmingham to improve stream habitat and water quality, the LWF classification is attainable for the subject segment of Valley Creek.

Table 5-1: Birmingham Watershed Project, USGS Benthic Macroinvertebrate Data, 2000-2001

Station ID	Station Location	EPT Family Richness	Total Taxa Richness
VAL-1	Valley Creek at 5th Ave and 7th Street	0	10
VAL-2	Valley Creek at Cleburne Avenue	2	24
Reference	Five Mile Creek at Nevel Road	8	38

6.0 Point Source Analysis & Water Quality Modeling of Valley Creek WWTP, USX Fairfield, and Koppers Organics

A total of three point sources operating under NPDES permits are located within the Valley Creek watershed. Of the three, two are major industrial discharges located on Opossum Creek, namely USX Fairfield Works and Koppers Organics. Valley Creek

WWTP is the third discharge and is located on Valley Creek approximately 1.4 miles upstream of the Fivemile Creek confluence. Valley Creek WWTP is considered a major municipal facility and is owned and operated by Jefferson County. Refer to Attachment 1, Figure 1 for the location of these point sources.

Water quality modeling was conducted for the above mentioned point sources to predict effluent limits that would be required for the various use classifications, namely, A&I, LWF, and F&W. The study reach for the model extends from just above the USX outfall on Opossum Creek to Bankhead Lake of the Black Warrior River. Results of the water quality modeling indicate that the Limited Warmwater Fishery classification is achievable. According to the modeling results, Valley Creek WWTP would receive the most stringent effluent limits as a result of the use classification upgrade of Valley Creek. However, USX Fairfield Works and Koppers Organics would also receive some permit modifications as a result of the upgrade due to their close proximity to Valley Creek. These changes would primarily result in each facility being required to conduct chronic toxicity biomonitoring at 7Q2 flow conditions. USX would also receive a slightly more stringent BOD limit during the winter season. Water quality modeling shows the dissolved oxygen sag below the USX and Koppers outfalls to be occurring in the proposed LWF segment of Valley Creek, therefore the CBOD limit (winter only) for USX was adjusted slightly to meet the dissolved oxygen concentration of 5 mg/l during the winter season. See Attachment 4 for the current and predicted effluent limits of USX, Koppers, & Valley Creek WWTP. Refer to Attachment 5 for the schematic diagrams and model runs supporting the predicted limits.

The current design capacity of the Valley Creek WWTP is 65 million gallons per day (MGD), however they were recently authorized by the Department to expand their capacity to 85 MGD. The treatment system consists of mechanical screening, aerated grit removal, pre-aeration and primary clarification. Biological treatment follows with two stages of aeration and clarification. Effluent is metered, chlorinated and dechlorinated prior to discharge. Biosolids are treated in the anaerobic digesters prior to being dewatered by filter belt presses and/or drying beds. Dried biosolids are blended with lime and then applied at the County's beneficial land use site. According to Valley Creek WWTP's discharge monitoring reports (DMRs) the plant is operating at very efficient levels and providing a high degree of treatment. For the period January 1998 through June 2001 the facility had an average wasteflow of 42.3 MGD, and average effluent carbonaceous biochemical oxygen demand-5 day test ($CBOD_5$), ammonia nitrogen (NH_3-N) and dissolved oxygen (DO) values of 2.0, 0.2 and 7.2 mg/l, respectively (See Attachment 3).

The facility's current treatment performance, demonstrates their capability to meet the effluent limits necessary to achieve the water quality criteria required for the Limited Warmwater Fishery classification. The Valley Creek WWTP will be required to conduct chronic toxicity test based on a 7Q10 flow (F&W requirement) instead of the 7Q2 flow usually required for LWF classified waters. The more stringent chronic toxicity biomonitoring is required due to the close proximity (i.e. within 24-hour travel time) of the WWTP's outfall to the downstream F&W segment of Valley Creek. Table 6-1 that follows provides the current and predicted effluent limits for the Valley Creek WWTP.

Table 6-1: Current and Predicted Effluent Limits for Valley Creek WWTP, Water Quality Modeling, ADEM 2001.

2001 Modeling Results @ 85 MGD

	Current A&I Limits		***Predicted LWF Limits***		***Predicted F&W Limits***	
Parameter	***Summer***	***Winter***	***Summer***	***Winter***	***Summer***	***Winter***
$CBOD_5$ (*mg/l*)	8	14	8	8	4	8
NH_3-N (*mg/l*)	1	2	1	1	0.5	1
TKN (*mg/l*)	3	5	3	3	2.5	3
DO (*mg/l*)	5	5	5	6	6	6

7.0 Conclusion

Results of the use attainability analysis indicate the following applicable factors as defined by EPA are preventing the LWF segment of Valley Creek from attaining ADEM's Fish and Wildlife use classification.

- Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

- Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude the attainment of aquatic life protection uses; or

The use classification upgrade of Upper Valley Creek from Agricultural and Industrial Water Supply (A&I) to Limited Warmwater Fishery (LWF) will provide the necessary criteria to protect existing uses within the stream. The Department believes the LWF classification is appropriate because it adequately characterizes the water quality conditions that are reasonably attainable for this waterbody.

No currently available information exists that suggests that the F&W use classification is attainable. Data presented in this document demonstrate nutrient enrichment and highly elevated bacteria levels from monitoring locations in upper Valley Creek, both upstream and downstream of permitted discharges. In general, water quality corresponds to land use patterns in the upper and lower portions of Valley Creek. Nutrient concentrations (nitrogen and phosphorus) are particularly high in monitoring locations upstream of permitted discharges in upper Valley Creek. Excess nutrients, combined with shallow depth, high water table, and increased light and heat penetration from lack of shading produce dense periphytic algae and microbial communities whose photosynthesis and respiration result in dissolved oxygen concentrations that frequently fall below criteria levels for F&W.

In the proposed LWF segment, bacteria levels are consistently elevated above those required for primary contact recreation, as provided in the F&W use classification during June-September. The pattern illustrated by the data from Valley Creek show variable levels at monitoring locations at various points along Valley Creek similar to the variable pattern exhibited by data from nearby Village Creek. The analysis presented in Attachment 6 demonstrates the correspondence of bacteria levels with the pattern of precipitation in Village Creek, a pattern that indicates a strong relationship to nonpoint sources.

Leaking sewer lines, domestic animal and wildlife populations, and leaking septic tanks are nonpoint sources of both nutrients and bacteria to Valley Creek. Sewer overflows are also a source of both nutrients and bacteria to Valley Creek that is driven by precipitation. The Valley Creek WWTP currently achieves an extremely high level of treatment. Jefferson County is estimated to expend $800 million to resolve sewer overflows and replace leaking sewer lines. It is anticipated that this substantial capital investment will improve water quality.

It is not currently possible to determine the percent contribution from the known categories of nonpoint sources, nor is it possible to project the degree of success in terms of measurable water quality improvements that will result from ongoing efforts to resolve sewer overflows and replace leaking sewer lines. The available information suggests that the magnitude of nutrient and bacteria levels, the variety of sources, and the physical characteristics of the waterbody indicate that the F&W use classification is not attainable, and the highest attainable use is LWF. Therefore, F&W is not designated at this time as a result of a combination of human-caused conditions (that may not be feasible to fully remedy) and natural physical conditions of the watershed unrelated to water quality (e.g., high water table). However, as new information becomes available that pertains to attainability of the F&W use classification, it will be considered and water quality standards revised accordingly.

Attachment 1

WATERSHED MAPS

Attachment 2

Valley Creek Sampling Stations & Water Quality Data

Table 2-1: USGS Sampling Station Locations and Types of Data Collected.

Station ID	Station Description	Drainage Area (mi^2)	Stream Flow	Type & Frequency of Water-Quality Parameters Sampled				Type of Biological Parameters Sampled		
				Field, Nutrients, and Bacteria	Pesticides	PAHs	Trace Elements	Fish, Benthic Invertebrate, and Algal Community Surveys	Bed Sediment and Fish Tissue	Habitat Survey
VAL-1	Valley Creek at 5th Street and 7th Avenue	4.94	Partial	y	y	y	y	y	y	y
VAL-2	Valley Creek at Cleburne Avenue	20.1	Partial	y	y	y	y	y	y	y
VAL-3	Valley Creek at Route 11	30.0	Partial	y	y	y	y	n	n	n

Table 2-2: ADEM Trend Station Locations and Types of Data Collected.

Station ID	Station Description	Drainage Area (mi^2)	Stream Flow	Type & Frequency of Water-Quality Parameters Sampled				Type of Biological Parameters Sampled		
				Field, Nutrients, and Bacteria	Pesticides	PAHs	Trace Elements	Fish, Benthic Invertebrate, and Algal Community Surveys	Bed Sediment and Fish Tissue	Habitat Survey
VC-5	Valley Creek at 18th Avenue Bridge (upstream of WWTP)	34.9	visual	y	n	n	n	n	n	n
VA-1	Valley Creek at Jefferson County Road 36 (downstream of WWTP)	93.0	visual	y	n	n	n	n	n	n

Table 2-3: Birmingham Watershed Project, USGS Water Quality Data, 2000-2001.

Station ID	Date (yy/mm/dd)	Water Temp (C)	Flow (cfs)	pH (s.u.)	Cond. (umhos @25C)	TOC (mg/L)	DO (mg/L)	BOD (mg/L)	Fecal Coliform (col/100 ml)	Total Nitrogen (mg/l)	Total Phosphorous (mg/l)
VAL-1	2000.03.01	17.8	1.83	8.053	473	4.124	8.2		3700	2.2	0.096
VAL-1	2000.03.31	19.03	1.77	7.764	674	5.352	7.12		22000	2.8	0.158
VAL-1	2000.06.29	24.6	33.4	7.425	175	16.561	5.1		> 33001	2	0.166
VAL-1	2000.08.02	25.1	2.25	7.883	415	27.07	5.3	4.9	64000K	2.3	0.252
VAL-1	2000.08.31	24.3	1.12	7.878	421	3.448	5	4.8	4000	2.5	0.244
VAL-1	2000.10.03	21.8	1.12	7.817	396	3.644	3.3	1.7	2100	2.2	0.269
VAL-1	2000.11.09	21.2	37	7.845	135	5.88	8.2		85000K	1.4	0.123
VAL-1	2000.12.12	14	1.64	7.576	415	7.048	4.2	4.8	44000E	2.6	0.162
VAL-1	2001.01.23	13.3	2.49	7.97	498	4.236	7.8	2.4	3800	2.8	0.236
VAL-1	2001.02.12	10.9	120	7.77	77.7	8.211	10.4	4.4	5900	0.77	0.136
VAL-2	2000.02.29	18.9	13	8.497	510	2.207	13.1		41K	1.4	0.034
VAL-2	2000.03.31	15.4	20.7	7.932	459	2.398	8		1000	1.6	0.167
VAL-2	2000.05.16	18.9	9.7	8.08	509		6.8		400	0.36	0.033
VAL-2	2000.06.29	26.6	22.6	7.155	266	6.979	5.6		> 6001	1.2	0.093
VAL-2	2000.08.03	28.6	18.2	7.918	422	3.136	7.8	1.2	1700	1.6	0.079
VAL-2	2000.08.29	30	6.03	8.357	416	4.55	4.3	2.4	640K	0.64	0.034
VAL-2	2000.10.05	19.8	5.2	7.905	402	2.705	4.7	0.9	150	0.57	0.058
VAL-2	2000.11.15	8.8	8.73	7.813	548	2.893	9.9	0.9	16000K	1.9	0.085
VAL-2	2000.12.13	5.5	7.84	7.985	485	3.394	11	0.8	720	1.4	0.05
VAL-2	2001.01.25	7.3	13.98	7.9	518	2.816	9.3		80K	3	0.057
VAL-2	2001.02.09	15	374	7.37	145	29.161	6.1			2.9	0.421
VAL-3	2000.02.29	13.2	27.3	7.935	431	5.173	10.07		72K	1.2	0.025
VAL-3	2000.03.29	15.2	42	8.179	452	1.935	10.4		120	1.5	0.021
VAL-3	2000.06.28	26	14.7	7.878	349	3.309	7		330	1.3	0.056
VAL-3	2000.08.03	24.1	32.9	7.653	279	5.415	7.2	1	1400	1.2	0.087
VAL-3	2000.08.31	27.9	11.7	7.828	384	2.634	11.1	8.6	71K	0.6	0.028
VAL-3	2000.10.02	21.7	12.3	8.137	354	2.751	10.2	0.5	40K	0.41	0.021
VAL-3	2000.11.09	21	240	7.738	168	5.454	6.5		16000	1.2	0.117
VAL-3	2000.12.13	7	13.67	8.209	461	2.34	13.9	0.7	75	0.96	0.018
VAL-3	2001.01.25	9.8	33	8.07	503	2.805	11.1		10K	2.2	0.027
VAL-3	2001.02.13	10.1	960	7.63	110	9.644	10.1	8.4	4700	1.2	0.203

Table 2-4: ADEM Trend Station Data, 1997-2001.

Station ID	Date (yy/mm/dd)	Air Temp (C)	Water Temp (C)	pH (su)	Cond. (umhos @25C)	Dissolved Oxygen (mg/l)	Turb. (NTU)	Weather	Velocity	TDS (mg/l)	TSS (mg/l)	Cl (mg/l)	T-PO4 (mg/l)	NO2 & NO3 (mg/l)	BOD-5 (mg/l)	NH3 (mg/l)	Fecal Coliform (col/100 ml)
VC-5	970605	22.00	21.80	7.80	385.00	6.33	3.30			369	10	1	0.151	1.753	1.9	0.15	3600
VC-5	970814	30.00	26.20	7.90	343.00	6.97	1.70			258	1	5	0.089	0.519	1.9	0.01	340
VC-5	971119	14.00	11.50	7.80	388.00	10.20	1.40			309	1	1	0.095	1.069	1.5	0.01	
VC-5	980819	30.00	26.00	8.30	343.00	6.25	1.00	clear	moderate	267	1	1	0.084	0.774	1.1	0.01	164
VC-5	981014	15.00	17.90	7.90	397.00	7.15	1.00	clear	moderate	277	1	1	0.005	0.649	0.5	0.01	114
VC-5	990602	23.00	23.30	7.45	360.00	5.82	2.40	pc		234	1	1		0.624	0.1		240
VC-5	990804	27.00	26.10	7.40	324.00	6.12	1.10	clear		258	2		0.029	0.5644	0.3		124
VC-5	991013	20.00	20.70	7.60	397.00	6.73	1.20	cloudy		309	3	16	0.043	0.052	1.5	0.88	240
VC-5	000607	25.00	21.00	7.40	238.00	7.00	2.70	clear	moderate	219	7	4.8	0.004	0.015	0.7	1.15	370
VC-5	000809		27.00	7.70	427.00	7.50	1.80	clear		273	3	6	0.018	0.551	0.6	0.02	310
VC-5	001011	12.00	11.82	7.61		9.40	0.40	clear	moderate	250	2	6.9	0.005	0.68	0.8	0.02	124
VC-5	010606	25.00	22.70	7.84	385.00	7.25	4.10	cloudy	moderate	257	6	7.77	0.07	0.221	1	0.02	270
VC-5	010808	23.00	24.70	7.89	354.00	5.88	4.50	cloudy	moderate	197	8	5.63	0.02	0.73	0.4	0.26	760
VA1	970122	10.00	12.00	7.40	319.00	5.00	3.90			257	1	20	0.141	2.846	1.2		116
VA1	970319	19.00	18.40	7.50	314.00	7.00	2.20			280	1	16.7	0.107	2.821	2.1		58
VA1	970423	12.00	14.50	7.70	384.00	5.70	2.40			300	1	29.8	0.107	4.061	1.7		148
VA1	970514	20.00	19.40	7.80	382.00	8.80	1.60			313	1	29.9	0.457	6.163	1.1		
VA1	970604	22.00	20.70	7.50	351.00	6.50	4.90			251	5	13	0.278	3.022	0.8		500
VA1	970814	30.00	26.20	6.70	427.00	7.55	1.60			327	4	24	0.443	6.518	0.9	0.1	350
VA1	971119	10.10	13.60	7.30	377.00	8.30	1.20			306	1	1	0.474	6.237	1.4	0.12	
VA1	980819	30.00	26.00	7.10	346.00	6.15	1.40	clear	moderate	274	1	1	0.302	3.957	1.1	0.01	108
VA1	981014	25.00	17.30	7.70	421.00	7.24	1.00	clear	moderate	304	1	1	0.409	5.382	0.6	0.01	27
VA1	990602	24.00	24.10	7.50	379.00	5.80	2.70	pc		242		1	0.115	2.009	0.2		184
VA1	990804	28.00	27.00	6.50	368.00	5.58	1.50	clear		291	4	39	0.478	5.2564	0.9	0.06	63
VA1	991013	22.30	21.50	7.50	355.00	6.30	2.40	cloudy		384	10	25	0.249	0.107	2	2.17	240
VA1	000607	26.00	22.00	6.60	314.00	6.20	2.30	clear	moderate	281	6	29.1	0.45	0.015	0.9	2.84	188
VA1	000809		27.00	7.60	482.00	7.50	1.80	clear		308	4	26	0.446	5.146	0.9	0.02	164
VA1	001011	14.00	15.18	7.56	451.00	6.40	0.80	clear	moderate	282	1	32.8	0.602	0.618	1.5	0.3	44
VA1	010606	27.00	24.00	8.09	331.70	6.68	3.20	cloudy	moderate	271	8	24.54	0.37	3.98	1.2	0.02	176
VA1	010808	23.00	23.52	7.74	372.00	6.57	10.90	cloudy	moderate	217	15	15.2	0.15	1.59	0.3	0.2	500

Attachment 3

DISCHARGE MONITORING REPORTS

Attachment 4

CURRENT & PREDICTED EFFLUENT LIMITS: JEFFERSON COUNTY-VALLEY CREEK WWTP USX FAIRFIELD WORKS KOPPERS ORGANICS

Table 4-1: Jefferson County-Valley Creek WWTP Effluent Limits.

Agricultural and Industrial		
	May-November	**December-April**
Flow:	85 MGD	85 MGD
$CBOD_U$:	24 mg/L	33 mg/L
$CBOD_5$:	8 mg/L	11 mg/L
NH_3-N:	1 mg/L	2 mg/L
TKN:	3 mg/L	4 mg/L
D.O.:	5 mg/L	5 mg/L

Limited Warmwater Fishery		
	May-November	**December-April**
Flow:	85 MGD	85 MGD
$CBOD_U$:	24 mg/L	24 mg/L
$CBOD_5$:	8 mg/L	8 mg/L
NH_3-N:	1 mg/L	1 mg/L
TKN:	3 mg/L	3 mg/L
D.O.:	5 mg/L	6 mg/L

Fish and Wildlife		
	May-November	**December-April**
Flow:	85 MGD	85 MGD
$CBOD_U$:	12 mg/L	24 mg/L
$CBOD_5$:	4 mg/L	8 mg/L
NH_3-N:	0.5 mg/L	1 mg/L
TKN:	2.5 mg/L	3 mg/L
D.O.:	6 mg/L	6 mg/L

Current Permit Limits		
	May-November	**December-April**
Flow:	85 MGD	85 MGD
$CBOD_U$:	24 mg/L	42 mg/L
$CBOD_5$:	8 mg/L	14 mg/L
NH_3-N:	1 mg/l	2 mg/L
TKN:	3 mg/L	5 mg/L
D.O.:	5 mg/L	5 mg/L

Table 4-2: USX Fairfield Works Effluent Limits[1].

Agricultural and Industrial		
	May-November	**December-April**
Flow:	11 MGD	11 MGD
$CBOD_U$:	16 mg/L	26 mg/L
$CBOD_5$:	8 mg/L	13 mg/L
NH_3-N:	1 mg/L	2 mg/L
TKN:	2 mg/L	4 mg/L
D.O.:	6 mg/L	6 mg/L

Limited Warmwater Fishery		
	May-November	**December-April**
Flow:	11 MGD	11 MGD
$CBOD_U$:	16 mg/L	20 mg/L
$CBOD_5$:	8 mg/L	10 mg/L
NH_3-N:	1 mg/L	1 mg/L
TKN:	2 mg/L	3 mg/L
D.O.:	6 mg/L	6 mg/L

Fish and Wildlife		
	May-November	**December-April**
Flow:	11 MGD	11 MGD
$CBOD_U$:	8 mg/L	20 mg/L
$CBOD_5$:	4 mg/L	10 mg/L
NH_3-N:	0.75 mg/L	1 mg/L
TKN:	1.5 mg/L	3 mg/L
D.O.:	6 mg/L	6 mg/L

Current Permit Limits		
Flow:	11 MGD	11 MGD
$CBOD_U$:	16 mg/L	26 mg/L
$CBOD_5$:	8 mg/L	13 mg/L
NH_3-N:	1 mg/L	2 mg/L
TKN:	2 mg/L	4 mg/L
D.O.:	6 mg/L	6 mg/l

[1] The predicted effluent limits for USX are based solely on use classification changes to Valley Creek and leaving Opossum Creek at A&I. Due to the close proximity of USX's outfall to Upper Valley Creek, their effluent has influence on instream dissolved oxygen levels within Upper Valley Creek.

Table 4-3: Koppers Organics Effluent Limits.

Agricultural and Industrial		
	May-November	**December-April**
Flow:	0.036 MGD	0.036 MGD
$CBOD_U$:	37.5 mg/L	37.5 mg/L
$CBOD_5$:	15 mg/L	15 mg/L
NH_3-N:	20 mg/L	20 mg/L
TKN:	50 mg/L	50 mg/L
D.O.:	5 mg/L	5 mg/L

Limited Warmwater Fishery		
	May-November	**December-April**
Flow:	0.036 MGD	0.036 MGD
$CBOD_U$:	37.5 mg/L	37.5 mg/L
$CBOD_5$:	15 mg/L	15 mg/L
NH_3-N:	20 mg/L	20 mg/L
TKN:	50 mg/L	50 mg/L
D.O.:	5 mg/L	6 mg/L

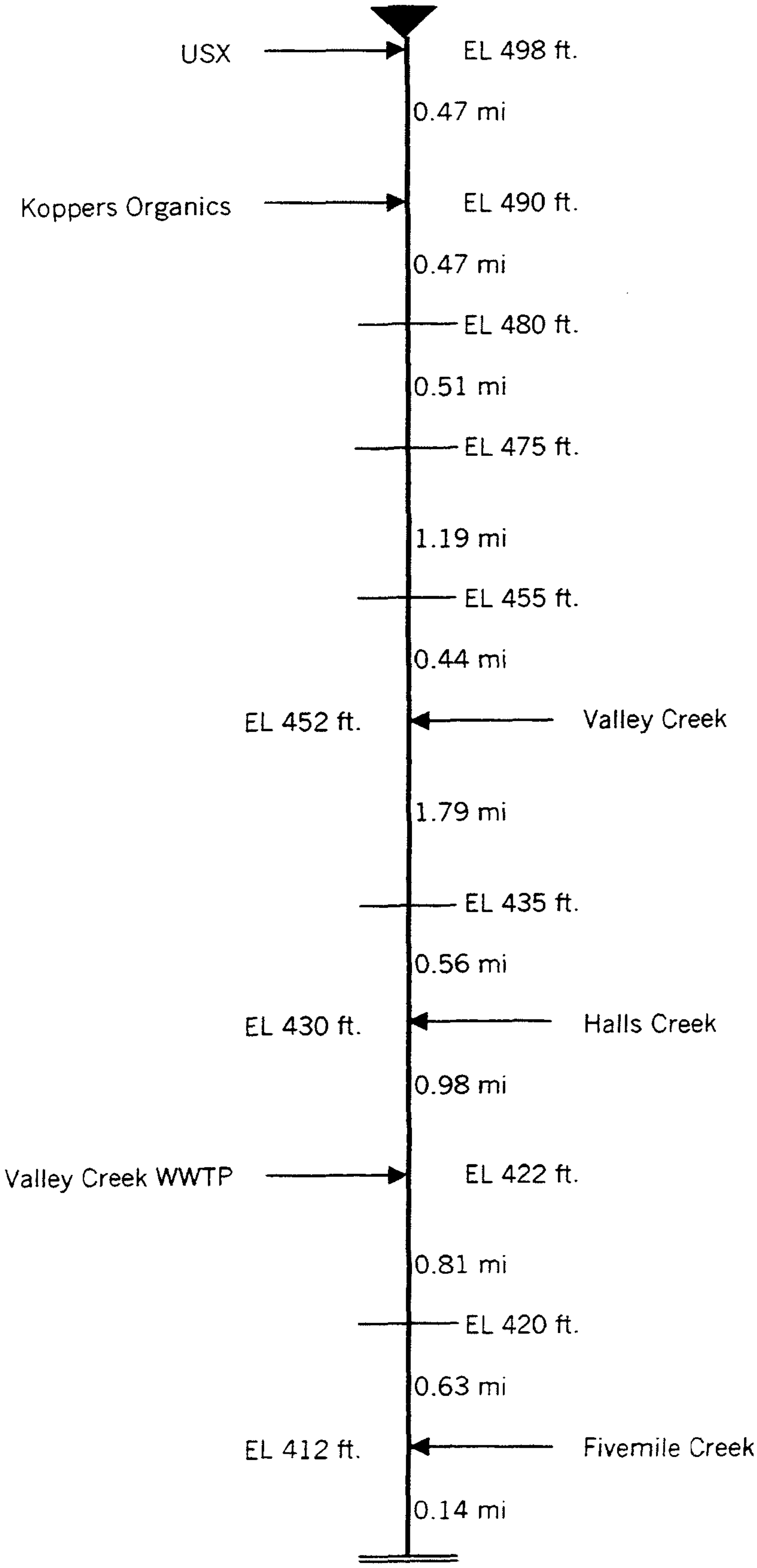
Fish and Wildlife		
	May-November	**December-April**
Flow:	0.036 MGD	0.036 MGD
$CBOD_U$:	27.5 mg/L	37.5 mg/L
$CBOD_5$:	11 mg/L	15 mg/L
NH_3-N:	20 mg/L	20 mg/L
TKN:	50 mg/L	50 mg/L
D.O.:	6 mg/L	6 mg/L

Current Permit Limits		
	May-November	**December-April**
$CBOD_U$:	37.5 mg/L	37.5 mg/L
$CBOD_5$:	15 mg/L	15 mg/L
NH_3-N:	20 mg/L	20 mg/L
TKN:	50 mg/L	50 mg/L
D.O.:	5 mg/L	5 mg/L

Attachment 5

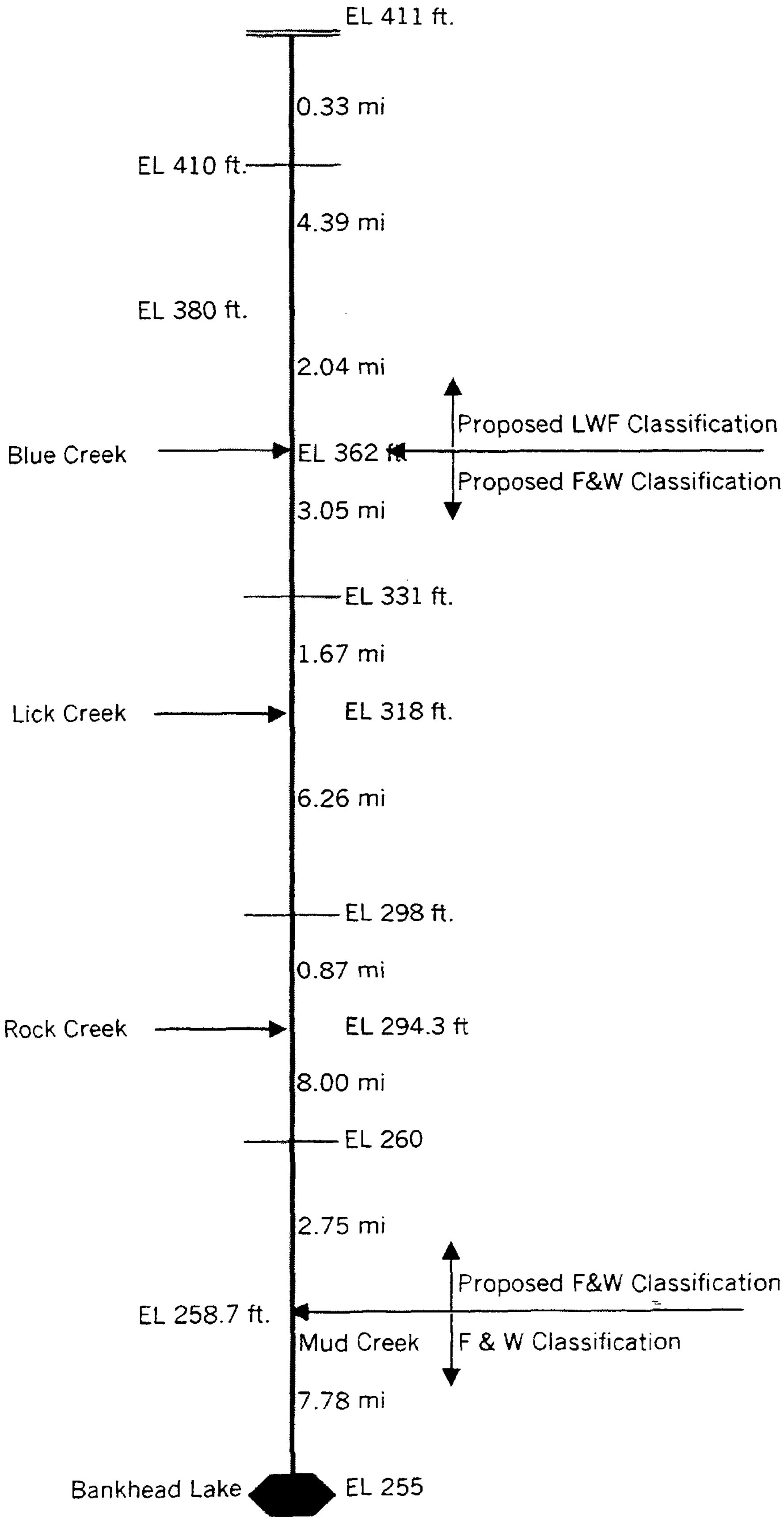
Water Quality Modeling Results

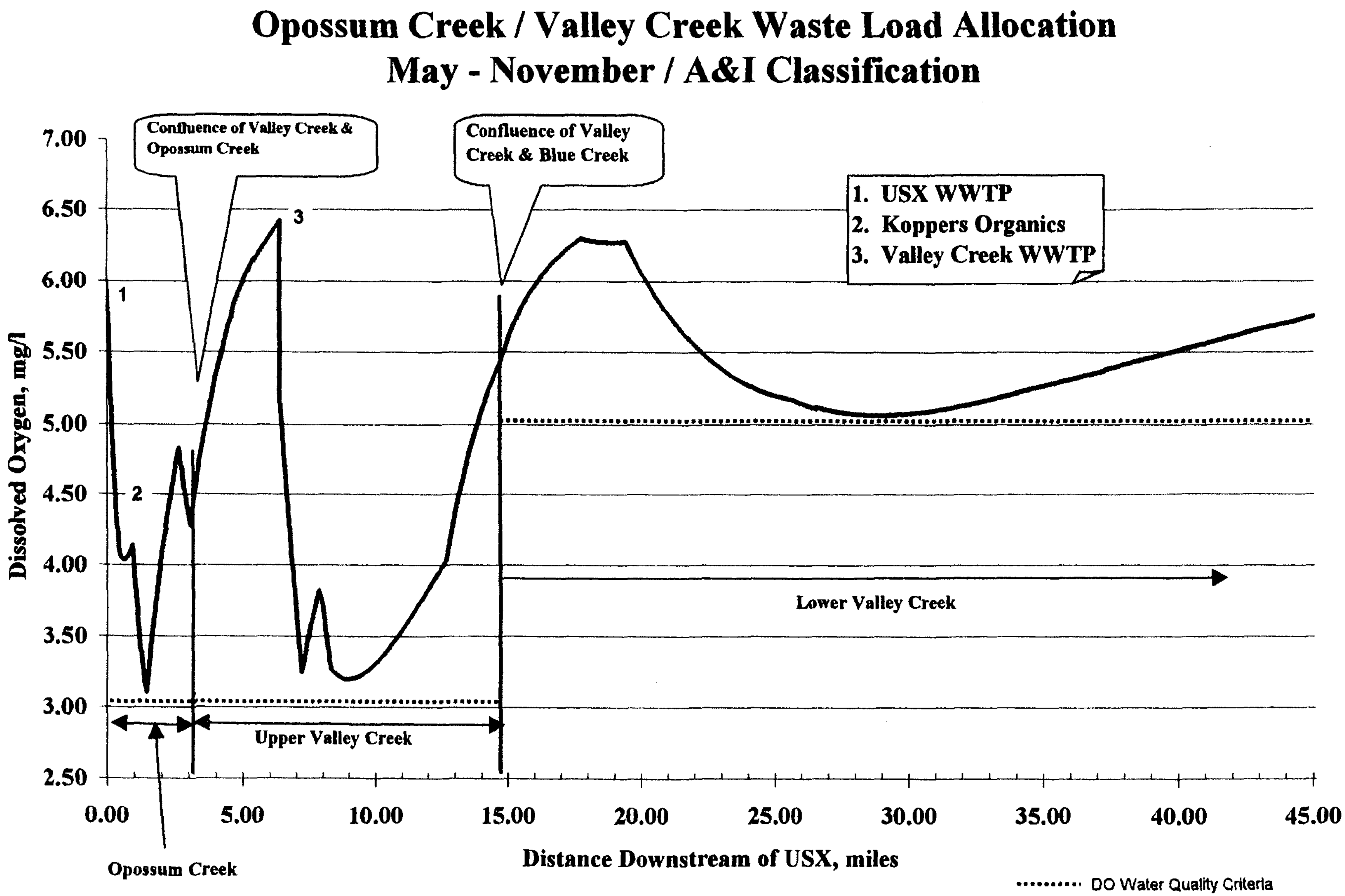
Valley Creek Use Attainability Analysis
Schematic of Modeled Reach



Prepared by ADEM
12/18/2001

Modeled Stream Reach (continued)




Opossum Creek / Valley Creek Waste Load Allocation
May - November / A&I Classification
Confluence of Valley Creek & Opossum Creek
Confluence of Valley Creek & Blue Creek
1. USX WWTP
2. Koppers Organics
3. Valley Creek WWTP
1
2
3
Dissolved Oxygen, mg/l
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
Lower Valley Creek
Upper Valley Creek
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Opossum Creek
Distance Downstream of USX, miles
DO Water Quality Criteria

Water Quality
Steady-State Stream Model

Enter the Number of Sections = 21.000
Total Length (miles) = 45.230

Opossum Creek / Valley Creek Waste Load Allocation - Summer WLA / A&I Classification

Valley Creek WWTP Effluent Conditions				
Design Flow, MGD	$CBOD_5$, mg/l	NH_3-N, mg/l	TKN, mg/l	D.O. (minimum), mg/l
85.00	8.0	1.0	3.0	5.0

HeadWater Data

Recession Index (G) =	60.000	
Mean Annual Prec. (P) =	60.000	
Drainage Area (M^2) =	0.000	Flow Multiplier
Temp (C°) =	30.000	1.00
CHL =	0.000	
Headwater Flow (cfs) =	0.360	
CBODU (mg/l) =	2.000	
NH_3ODU (mg/l) =	0.457	
TONODU (mg/l) =	4.570	
Headwater D.O.$_{(mg/l)}$ =	6.00	

Tributary Flows (cfs)
0.36
1.59
0.28
0.72
0.85
1.48
2.38

Stream flow @ Valley Creek WWTP (cfs)
20.0750

Dam Data

Dam Located at Beginning of Section =	0.00
Water Quality Factor =	1.80
Wier Dam Coefficient =	0.80
Difference in Water Level (ft) =	1.00

	Use Goal Seek
Minimum Dissolved Oxygen Concentration (mg/l) (Opossum Creek) =	3.10
Minimum Dissolved Oxygen Concentration (mg/l) (Upper Valley Creek) =	3.20
Minimum Dissolved Oxygen Concentration (mg/l) (Lower Valley Creek) =	5.07
CBODu Concentration at End of Modeled Reach (mg/l) =	2.44

Enter Tributary Conditions (If none, leave blank)

Sections	G	P	TONODU (mg/l)	CBODU (mg/l)	NH3ODU (mg/l)	DO (mg/l)	$7Q_{10}$ (cfs)	Temp. (C°)	Drainage Area (M^2)
1.00						0.000	0.00	0.00	0.00
2.00						0.000	0.00	0.00	0.00
3.00						0.000	0.00	0.00	0.00
4.00						0.000	0.00	0.00	0.00
5.00						0.000	0.00	0.00	0.00
6.00			4.57	2.00	0.4570	5.000	1.59	30.00	0.00
7.00						0.000	0.00	0.00	0.00
8.00			4.57	2.00	0.4570	5.000	0.28	30.00	0.00
9.00			91.40	37.80	45.7000	3.000	0.00	30.00	0.00
10.00						0.000	0.00	0.00	0.00
11.00			4.57	2.00	0.4570	6.000	0.72	30.00	0.00
12.00						0.000	0.00	0.00	0.00
13.00						0.000	0.00	0.00	0.00
14.00						0.000	0.00	0.00	0.00
15.00			4.57	2.00	0.4570	6.000	0.85	30.00	0.00
16.00						0.000	0.00	0.00	0.00
17.00	65.000	56.00	4.57	2.00	0.4570	6.000	0.68	30.00	15.60
18.00						0.000	0.00	0.00	0.00
19.00	65.000	56.00	4.57	2.00	0.4570	6.000	1.48	30.00	32.70
20.00						0.000	0.00	0.00	0.00
21.00	65.000	56.00	4.57	2.00	0.4570	6.000	2.38	30.00	51.20
22.00						0.000	0.00	0.00	0.00

Enter Incremental Inflow Conditions (If none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (°C)	Q10 (cfs)	Drainage Area (mi^2)
1.00	3.000	0.46	4.57	5.00	0.0097	30.000	0.00	
2.00	2.000	0.46	4.57	5.00	0.0097	30.000	0.00	
3.00	2.000	0.46	4.57	5.00	0.0106	30.000	0.00	
4.00	2.000	0.46	4.57	5.00	0.1477	30.000	0.00	
5.00	2.000	0.46	4.57	5.00	0.0546	30.000	0.00	
6.00	2.000	0.46	4.57	6.00	0.2903	30.000	0.00	
7.00	2.000	0.46	4.57	5.00	0.0908	30.000	0.00	
8.00	2.000	0.46	4.57	5.00	0.1689	30.000	0.00	
9.00	2.000	0.46	4.57	5.00	0.1016	30.000	0.00	
10.00	2.000	0.46	4.57	5.00	0.0790	30.000	0.00	
11.00	2.000	0.46	4.57	5.00	0.0176	30.000	0.00	
12.00	2.000	0.46	4.57	5.00	0.0414	30.000	0.00	
13.00	2.000	0.46	4.57	6.00	0.6105	30.000	0.00	
14.00	2.000	0.46	4.57	5.00	0.2033	30.000	0.00	
15.00	2.000	0.46	4.57	6.00	0.2628	30.000	0.00	
16.00	2.000	0.46	4.57	6.00	0.1439	30.000	0.00	
17.00	2.000	0.46	4.57	5.00	0.6500	30.000	0.00	
18.00	2.000	0.46	4.57	5.00	0.0937	30.000	0.00	
19.00	2.000	0.46	4.57	6.00	0.7700	30.000	0.00	
20.00	2.000	0.46	4.57	6.00	0.2647	30.000	0.00	
21.00	2.000	0.46	4.57	6.00	0.7499	30.000	0.00	
22.00				6.43	0.0000	30.000	0.00	

Enter Effluent Conditions (If none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (° C)	pH	Max. Instream NH3 (mg/l)	NH3 Toxicity (mg/l)	NH3 WQ Limit (mg/l)
1.00	16.000	4.57	4.57	6.00	17.0170	30.000	7.00	3.08	3.15	1.00
2.00	37.500	91.40	137.10	5.00	0.0557	30.000				0.00
3.00		0.00		0.00						0.00
4.00		0.00		0.00						0.00
5.00		0.00		0.00						0.00
6.00		0.00		0.00						0.00
7.00		0.00		0.00						0.00
8.00		0.00		0.00						0.00
9.00	24.000	4.57	9.14	5.00	131.5000	30.000	7.00	3.08	3.54	1.00
10.00		0.00		0.00						0.00
11.00		0.00		0.00						0.00
12.00		0.00		0.00						0.00
13.00		0.00		0.00						0.00
14.00		0.00		0.00						0.00
15.00		0.00		0.00						0.00
16.00		0.00		0.00						0.00
17.00		0.00		0.00						0.00
18.00		0.00		0.00						0.00
19.00		0.00		0.00						0.00
20.00		0.00		0.00						0.00
21.00		0.00		0.00						0.00
22.00		0.00		0.00						0.00

The most stringent of the two values will be implemented as the discharge limit.

Enter Section Characteristics (if none, leave blank)

Sections	Beginning Elev. (ft)	Ending Elev. (ft)	Elev.Change (ft)	Length (miles)	Average Elev. (ft)	Section Slope (ft/mi)	Average Flow (cfs)	Average Vel. (ft/sec)
1.00	498.000	490.00	8.00	0.4700	494.0000	17.021	17.38	0.304
2.00	490.000	480.00	10.00	0.4700	485.0000	21.277	17.45	0.304
3.00	480.000	475.00	5.00	0.5100	477.5000	9.804	17.46	0.305
4.00	475.000	455.00	20.00	1.1900	465.0000	16.807	17.54	0.305
5.00	455.000	452.00	3.00	0.4400	453.5000	6.818	17.64	0.306
6.00	452.000	435.00	17.00	1.7900	443.5000	9.497	19.40	0.304
7.00	435.000	430.00	5.00	0.5600	432.5000	8.929	19.59	0.306
8.00	430.000	422.00	8.00	0.9800	426.0000	8.163	20.00	0.310
9.00	422.000	420.00	2.00	0.8100	421.0000	2.469	151.63	0.488
10.00	420.000	412.00	8.00	0.6300	416.0000	12.698	151.72	0.488
11.00	412.000	411.00	1.00	0.1400	411.5000	7.143	152.48	0.490
12.00	411.000	410.00	1.00	0.3300	410.5000	3.030	152.51	0.491
13.00	410.000	380.00	30.00	4.3900	395.0000	6.834	152.79	0.491
14.00	380.000	362.00	18.00	2.0400	371.0000	8.824	153.15	0.691
15.00	362.000	331.00	31.00	3.0500	346.5000	10.164	154.23	0.694
16.00	331.000	318.00	13.00	1.6700	324.5000	7.784	154.43	0.695
17.00	318.000	298.00	20.00	6.2600	308.0000	3.195	155.51	0.699
18.00	298.000	294.30	3.70	0.8700	296.1500	4.253	155.68	0.700
19.00	294.300	260.00	34.30	8.0000	277.1500	4.288	157.78	0.706
20.00	260.000	258.70	1.30	2.7500	259.3500	0.473	158.30	0.740
21.00	258.700	255.00	3.70	7.8800	256.8500	0.470	161.19	0.745
22.00					0.0000	0.000	0.00	0.00

Sections	Reaction Rates @ 20° C					Corrected Rates @ New Temp.				
	Kd	KNH3	KON	T. Coefficient	Reaeration	Kd	KNH3	KON	Ave. Reaeration	Mixed Temp.(° C)
1.00	1.300	1.50	0.80	1.30	6.7228	2.058	3.08	1.27	8.52	30.00
2.00	1.300	1.50	0.80	1.30	8.4216	2.058	2.91	1.27	10.68	30.00
3.00	1.300	1.50	0.80	1.30	3.8818	2.058	2.82	1.27	4.92	30.00
4.00	1.300	1.50	0.80	1.30	6.6718	2.058	2.59	1.27	8.46	30.00
5.00	1.300	1.50	0.80	1.30	2.7158	2.058	2.94	1.27	3.44	30.00
6.00	0.400	1.50	0.10	1.30	3.7633	0.633	2.86	0.16	4.76	30.00
7.00	0.400	1.50	0.10	1.30	3.5507	0.633	3.08	0.16	4.50	30.00
8.00	0.400	1.50	0.10	1.30	3.2893	0.633	3.10	0.16	4.17	30.00
9.00	0.400	1.50	0.10	0.88	1.0601	0.633	2.99	0.16	1.34	30.00
10.00	0.400	1.50	0.10	0.88	5.4549	0.633	2.63	0.16	6.91	30.00
11.00	0.400	1.50	0.10	0.88	3.0828	0.633	2.76	0.16	3.91	30.00
12.00	0.400	1.50	0.10	0.88	1.3081	0.633	2.74	0.16	1.66	30.00
13.00	0.400	1.50	0.10	0.88	2.9549	0.633	2.63	0.16	3.75	30.00
14.00	0.400	1.50	0.10	0.88	5.3631	0.633	2.80	0.16	6.80	30.00
15.00	0.400	1.50	0.10	0.88	6.2107	0.633	3.02	0.16	7.87	30.00
16.00	0.400	1.50	0.10	0.88	4.7615	0.633	3.11	0.16	6.04	30.00
17.00	0.400	1.50	0.10	0.88	1.5600	0.633	3.11	0.16	1.98	30.00
18.00	0.400	1.50	0.10	0.88	1.3700	0.633	2.99	0.16	1.74	30.00
19.00	0.400	1.50	0.10	0.88	1.3700	0.633	2.98	0.16	1.74	30.00
20.00	0.300	1.50	0.10	0.88	1.1400	0.475	3.00	0.16	1.45	30.00
21.00	0.300	1.50	0.10	0.88	1.1400	0.475	3.01	0.16	1.45	30.00
22.00	0.000	0.00	0.00	0.00	0.0000	0.000	0.00	0.00	0.00	0.00

Model Output

Section 1 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.000	17.377	0.00	0.00	1.4037	6.0000	4.485	15.71	4.57
0.024	17.377	0.00	0.00	1.5610	5.8427	4.447	15.56	4.54
0.047	17.378	0.01	0.01	1.7100	5.6936	4.410	15.41	4.52
0.071	17.378	0.01	0.01	1.8512	5.5524	4.373	15.26	4.49
0.094	17.379	0.02	0.02	1.9849	5.4187	4.336	15.11	4.46
0.118	17.379	0.02	0.02	2.1114	5.2923	4.300	14.96	4.44
0.141	17.380	0.03	0.03	2.2310	5.1727	4.264	14.82	4.41
0.165	17.380	0.03	0.03	2.3440	5.0597	4.228	14.67	4.38
0.188	17.381	0.04	0.04	2.4506	4.9531	4.193	14.53	4.36
0.212	17.381	0.04	0.04	2.5512	4.8525	4.159	14.39	4.33
0.235	17.382	0.05	0.05	2.6460	4.7577	4.124	14.25	4.30
0.259	17.382	0.05	0.05	2.7352	4.6685	4.090	14.11	4.28
0.282	17.383	0.06	0.06	2.8191	4.5846	4.056	13.98	4.25
0.306	17.383	0.06	0.06	2.8979	4.5058	4.023	13.84	4.23
0.329	17.384	0.07	0.07	2.9719	4.4318	3.990	13.71	4.20
0.353	17.384	0.07	0.07	3.0411	4.3626	3.957	13.57	4.18
0.376	17.385	0.08	0.08	3.1059	4.2978	3.925	13.44	4.15
0.400	17.385	0.08	0.08	3.1665	4.2372	3.892	13.31	4.13
0.423	17.386	0.09	0.09	3.2229	4.1808	3.861	13.18	4.10
0.447	17.386	0.09	0.09	3.2755	4.1282	3.829	13.05	4.08
0.470	17.387	0.09	0.09	3.3243	4.0794	3.798	12.93	4.05

Section 2 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.47	17.442	0.00	0.09	3.3240	4.0824	4.078	13.01	4.48
0.49	17.443	0.00	0.10	3.3356	4.0708	4.051	12.88	4.45
0.52	17.443	0.01	0.10	3.3461	4.0612	4.024	12.75	4.43
0.54	17.444	0.01	0.11	3.3527	4.0537	3.997	12.63	4.40
0.56	17.444	0.02	0.11	3.3583	4.0480	3.970	12.51	4.37
0.59	17.445	0.02	0.12	3.3622	4.0441	3.944	12.39	4.35
0.61	17.445	0.03	0.12	3.3645	4.0419	3.918	12.27	4.32
0.63	17.446	0.03	0.13	3.3651	4.0412	3.892	12.15	4.30
0.66	17.446	0.04	0.13	3.3643	4.0421	3.866	12.03	4.27
0.68	17.447	0.04	0.14	3.3620	4.0443	3.840	11.91	4.24
0.71	17.447	0.05	0.14	3.3586	4.0479	3.815	11.80	4.22
0.73	17.448	0.05	0.15	3.3537	4.0527	3.790	11.69	4.19
0.75	17.448	0.06	0.15	3.3477	4.0586	3.765	11.57	4.17
0.78	17.449	0.06	0.16	3.3407	4.0657	3.740	11.46	4.14
0.80	17.449	0.07	0.16	3.3326	4.0737	3.715	11.35	4.12
0.82	17.450	0.07	0.17	3.3236	4.0828	3.691	11.24	4.10
0.85	17.450	0.08	0.17	3.3136	4.0927	3.666	11.13	4.07
0.87	17.451	0.08	0.17	3.3028	4.1036	3.642	11.02	4.05
0.89	17.451	0.08	0.18	3.2912	4.1151	3.618	10.92	4.02
0.92	17.452	0.09	0.18	3.2789	4.1274	3.595	10.81	4.00
0.94	17.452	0.09	0.19	3.2659	4.1405	3.571	10.706	3.98

Section 3 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.94	17.452	0.00	0.19	3.2691	4.1406	3.571	10.71	3.98
0.97	17.453	0.01	0.19	3.3491	4.0605	3.545	10.59	3.95
0.99	17.453	0.01	0.20	3.4245	3.9840	3.520	10.48	3.92
1.02	17.454	0.02	0.20	3.4976	3.9109	3.495	10.37	3.90
1.04	17.454	0.02	0.21	3.5674	3.8412	3.470	10.26	3.87
1.07	17.455	0.03	0.21	3.6339	3.7746	3.445	10.16	3.85
1.09	17.455	0.03	0.22	3.6973	3.7112	3.420	10.05	3.82
1.12	17.456	0.04	0.22	3.7577	3.6508	3.396	9.94	3.80
1.14	17.456	0.04	0.23	3.8152	3.5934	3.371	9.84	3.77
1.17	17.457	0.05	0.23	3.8698	3.5388	3.347	9.74	3.75
1.20	17.457	0.05	0.24	3.9216	3.4870	3.324	9.63	3.73
1.22	17.458	0.06	0.25	3.9708	3.4378	3.300	9.53	3.70
1.25	17.458	0.06	0.25	4.0173	3.3913	3.276	9.43	3.68
1.27	17.459	0.07	0.26	4.0613	3.3473	3.253	9.33	3.65
1.30	17.460	0.07	0.26	4.1029	3.3057	3.230	9.24	3.63
1.32	17.460	0.08	0.27	4.1421	3.2665	3.207	9.14	3.61
1.35	17.461	0.08	0.27	4.1790	3.2296	3.184	9.04	3.58
1.37	17.461	0.09	0.28	4.2136	3.1950	3.162	8.95	3.56
1.40	17.462	0.09	0.28	4.2461	3.1625	3.139	8.85	3.54
1.42	17.462	0.10	0.29	4.2765	3.1321	3.117	8.76	3.52
1.45	17.463	0.10	0.29	4.3049	3.1037	3.095	8.67	3.49

Section 4 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
1.45	17.463	0.00	0.29	4.3055	3.1037	3.095	8.67	3.49
1.51	17.470	0.01	0.30	4.1838	3.2291	3.052	8.46	3.44
1.57	17.477	0.02	0.32	4.0650	3.3479	3.010	8.25	3.39
1.63	17.485	0.04	0.33	3.9517	3.4612	2.968	8.05	3.34
1.69	17.492	0.05	0.34	3.8434	3.5694	2.927	7.85	3.29
1.75	17.500	0.06	0.35	3.7397	3.6730	2.887	7.66	3.24
1.81	17.507	0.07	0.36	3.6406	3.7722	2.847	7.47	3.19
1.87	17.514	0.08	0.37	3.5453	3.8673	2.807	7.29	3.15
1.93	17.522	0.10	0.39	3.4539	3.9587	2.768	7.11	3.10
1.99	17.529	0.11	0.40	3.3661	4.0465	2.730	6.93	3.05
2.05	17.537	0.12	0.41	3.2816	4.1309	2.692	6.76	3.01
2.10	17.544	0.13	0.42	3.2003	4.2123	2.654	6.60	2.96
2.16	17.551	0.14	0.43	3.1218	4.2907	2.617	6.44	2.92
2.22	17.559	0.15	0.45	3.0461	4.3663	2.581	6.28	2.88
2.28	17.566	0.17	0.46	2.9730	4.4394	2.545	6.12	2.84
2.34	17.573	0.18	0.47	2.9024	4.5100	2.509	5.98	2.79
2.40	17.581	0.19	0.48	2.8341	4.5783	2.474	5.83	2.75
2.46	17.588	0.20	0.49	2.7680	4.6444	2.439	5.69	2.71
2.52	17.596	0.21	0.51	2.7039	4.7084	2.405	5.55	2.67
2.58	17.603	0.23	0.52	2.6418	4.7705	2.371	5.41	2.63
2.64	17.610	0.24	0.53	2.5816	4.8307	2.338	5.28	2.59

Section 5 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
2.64	17.610	0.00	0.53	2.5849	4.8307	2.338	5.28	2.59
2.66	17.613	0.00	0.53	2.6229	4.7927	2.322	5.23	2.58
2.68	17.616	0.01	0.54	2.6599	4.7559	2.307	5.19	2.57
2.71	17.619	0.01	0.54	2.6954	4.7202	2.291	5.14	2.55
2.73	17.621	0.02	0.55	2.7299	4.6857	2.276	5.09	2.54
2.75	17.624	0.02	0.55	2.7633	4.6523	2.260	5.04	2.52
2.77	17.627	0.03	0.56	2.7955	4.6201	2.245	5.00	2.51
2.79	17.630	0.03	0.56	2.8267	4.5890	2.230	4.95	2.50
2.82	17.632	0.04	0.56	2.8568	4.5589	2.215	4.91	2.48
2.84	17.635	0.04	0.57	2.8858	4.5299	2.200	4.86	2.47
2.86	17.638	0.04	0.57	2.9138	4.5018	2.185	4.82	2.46
2.88	17.640	0.05	0.58	2.9409	4.4748	2.171	4.77	2.44
2.90	17.643	0.05	0.58	2.9668	4.4488	2.156	4.73	2.43
2.93	17.646	0.06	0.59	2.9919	4.4238	2.142	4.69	2.42
2.95	17.649	0.06	0.59	3.0160	4.3997	2.127	4.65	2.40
2.97	17.651	0.07	0.60	3.0392	4.3765	2.113	4.60	2.39
2.99	17.654	0.07	0.60	3.0614	4.3542	2.099	4.56	2.38
3.01	17.657	0.07	0.60	3.0828	4.3328	2.085	4.52	2.37
3.04	17.660	0.08	0.61	3.1033	4.3123	2.071	4.48	2.35
3.06	17.662	0.08	0.61	3.1230	4.2927	2.058	4.44	2.34
3.08	17.665	0.09	0.62	3.1418	4.2739	2.044	4.40	2.33

Section 6 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
3.08	19.255	0.00	0.62	3.0847	4.3339	1.913	4.20	2.51
3.17	19.270	0.02	0.64	2.9668	4.4503	1.823	4.15	2.51
3.26	19.284	0.04	0.65	2.8573	4.5616	1.738	4.10	2.50
3.35	19.299	0.05	0.67	2.7506	4.6692	1.657	4.05	2.50
3.44	19.313	0.07	0.69	2.6482	4.7706	1.580	4.01	2.49
3.53	19.328	0.09	0.71	2.5501	4.8686	1.507	3.96	2.48
3.62	19.342	0.11	0.73	2.4562	4.9623	1.438	3.91	2.48
3.71	19.357	0.13	0.74	2.3662	5.0523	1.372	3.87	2.47
3.80	19.371	0.14	0.76	2.2800	5.1384	1.310	3.82	2.47
3.89	19.386	0.16	0.78	2.1974	5.2209	1.251	3.78	2.46
3.98	19.400	0.18	0.80	2.1184	5.2999	1.195	3.73	2.46
4.06	19.415	0.20	0.82	2.0427	5.3756	1.141	3.69	2.45
4.15	19.429	0.22	0.83	1.9702	5.4480	1.090	3.65	2.45
4.24	19.444	0.23	0.85	1.9008	5.5173	1.042	3.61	2.44
4.33	19.458	0.25	0.87	1.8344	5.5837	0.997	3.56	2.44
4.42	19.473	0.27	0.89	1.7708	5.6472	0.953	3.52	2.43
4.51	19.487	0.29	0.90	1.7100	5.7080	0.912	3.48	2.43
4.60	19.502	0.31	0.92	1.6517	5.7662	0.873	3.44	2.42
4.69	19.516	0.32	0.94	1.5960	5.8219	0.836	3.40	2.41
4.78	19.531	0.34	0.96	1.5427	5.8752	0.800	3.36	2.41
4.87	19.545	0.36	0.98	1.4916	5.9262	0.767	3.32	2.40

Section 7 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
4.87	19.546	0.00	0.98	1.4955	5.9262	0.767	3.32	2.40
4.90	19.550	0.01	0.98	1.4831	5.9385	0.756	3.31	2.40
4.93	19.554	0.01	0.99	1.4707	5.9508	0.745	3.30	2.40
4.95	19.559	0.02	0.99	1.4584	5.9631	0.734	3.29	2.40
4.98	19.563	0.02	1.00	1.4462	5.9753	0.724	3.27	2.40
5.01	19.568	0.03	1.00	1.4341	5.9874	0.714	3.26	2.40
5.04	19.573	0.03	1.01	1.4221	5.9994	0.704	3.25	2.39
5.07	19.577	0.04	1.02	1.4101	6.0114	0.694	3.24	2.39
5.09	19.582	0.04	1.02	1.3983	6.0232	0.684	3.23	2.39
5.12	19.586	0.05	1.03	1.3866	6.0349	0.674	3.21	2.39
5.15	19.591	0.06	1.03	1.3749	6.0466	0.665	3.20	2.39
5.18	19.595	0.06	1.04	1.3633	6.0582	0.656	3.19	2.39
5.21	19.600	0.07	1.04	1.3519	6.0696	0.646	3.18	2.39
5.23	19.604	0.07	1.05	1.3405	6.0810	0.637	3.17	2.38
5.26	19.609	0.08	1.06	1.3292	6.0923	0.629	3.16	2.38
5.29	19.613	0.08	1.06	1.3180	6.1035	0.620	3.15	2.38
5.32	19.618	0.09	1.07	1.3069	6.1146	0.611	3.13	2.38
5.35	19.622	0.10	1.07	1.2959	6.1256	0.603	3.12	2.38
5.37	19.627	0.10	1.08	1.2850	6.1365	0.595	3.11	2.38
5.40	19.632	0.11	1.08	1.2742	6.1473	0.587	3.10	2.37
5.43	19.636	0.11	1.09	1.2635	6.1580	0.579	3.09	2.37

Section 8 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
5.43	19.916	0.00	1.09	1.2820	6.1417	0.577	3.07	2.40
5.48	19.924	0.01	1.10	1.2668	6.1564	0.564	3.05	2.40
5.53	19.932	0.02	1.11	1.2518	6.1714	0.551	3.04	2.40
5.58	19.940	0.03	1.12	1.2369	6.1863	0.538	3.02	2.39
5.63	19.948	0.04	1.13	1.2221	6.2011	0.526	3.00	2.39
5.67	19.956	0.05	1.14	1.2074	6.2157	0.514	2.98	2.39
5.72	19.964	0.06	1.15	1.1929	6.2303	0.502	2.96	2.39
5.77	19.972	0.07	1.16	1.1785	6.2447	0.491	2.94	2.39
5.82	19.980	0.08	1.17	1.1642	6.2589	0.480	2.92	2.38
5.87	19.988	0.09	1.18	1.1501	6.2731	0.470	2.91	2.38
5.92	19.996	0.10	1.19	1.1361	6.2870	0.460	2.89	2.38
5.97	20.003	0.11	1.20	1.1223	6.3008	0.450	2.87	2.37
6.02	20.011	0.12	1.20	1.1086	6.3145	0.440	2.85	2.37
6.07	20.019	0.13	1.21	1.0951	6.3280	0.431	2.83	2.37
6.12	20.027	0.14	1.22	1.0818	6.3413	0.422	2.82	2.36
6.16	20.035	0.14	1.23	1.0686	6.3545	0.413	2.80	2.36
6.21	20.043	0.15	1.24	1.0556	6.3675	0.404	2.78	2.36
6.26	20.051	0.16	1.25	1.0427	6.3804	0.396	2.76	2.36
6.31	20.059	0.17	1.26	1.0301	6.3930	0.388	2.75	2.35
6.36	20.067	0.18	1.27	1.0176	6.4055	0.380	2.73	2.35
6.41	20.075	0.19	1.28	1.0052	6.4179	0.373	2.71	2.35

Section 9 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
6.41	151.578	0.00	1.29	2.2373	5.1878	4.014	21.18	8.24
6.45	151.580	0.01	1.29	2.3500	5.0751	3.960	21.11	8.23
6.49	151.585	0.01	1.29	2.4609	4.9642	3.907	21.04	8.23
6.53	151.590	0.02	1.30	2.5700	4.8551	3.855	20.98	8.22
6.57	151.595	0.02	1.30	2.6774	4.7478	3.803	20.91	8.21
6.61	151.600	0.03	1.31	2.7830	4.6421	3.753	20.84	8.21
6.65	151.605	0.03	1.31	2.8869	4.5382	3.703	20.77	8.20
6.69	151.611	0.04	1.32	2.9892	4.4359	3.653	20.71	8.19
6.73	151.616	0.04	1.32	3.0898	4.3353	3.605	20.64	8.19
6.77	151.621	0.05	1.33	3.1888	4.2363	3.557	20.57	8.18
6.81	151.626	0.05	1.33	3.2862	4.1390	3.510	20.50	8.17
6.86	151.631	0.06	1.34	3.3820	4.0432	3.464	20.44	8.17
6.90	151.636	0.06	1.34	3.4762	3.9489	3.418	20.37	8.16
6.94	151.641	0.07	1.35	3.5689	3.8562	3.373	20.31	8.15
6.98	151.646	0.07	1.35	3.6601	3.7651	3.329	20.24	8.15
7.02	151.651	0.08	1.36	3.7498	3.6764	3.285	20.18	8.14
7.06	151.656	0.08	1.36	3.8380	3.5872	3.242	20.11	8.13
7.10	151.661	0.09	1.37	3.9248	3.5004	3.200	20.04	8.13
7.14	151.666	0.09	1.37	4.0101	3.4151	3.158	19.98	8.12
7.18	151.672	0.10	1.38	4.0940	3.3312	3.117	19.92	8.11
7.22	151.677	0.10	1.38	4.1765	3.2487	3.077	19.85	8.11

Section 10 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.22	151.677	0.00	1.38	4.1779	3.2487	3.077	19.85	8.11
7.25	151.681	0.00	1.39	4.1456	3.2811	3.050	19.80	8.10
7.28	151.684	0.01	1.39	4.1137	3.3129	3.024	19.75	8.10
7.31	151.688	0.01	1.40	4.0823	3.3443	2.997	19.70	8.09
7.35	151.692	0.02	1.40	4.0514	3.3752	2.972	19.65	8.09
7.38	151.696	0.02	1.40	4.0209	3.4057	2.946	19.60	8.08
7.41	151.700	0.02	1.41	3.9908	3.4358	2.921	19.55	8.08
7.44	151.704	0.03	1.41	3.9612	3.4654	2.895	19.50	8.07
7.47	151.708	0.03	1.42	3.9320	3.4946	2.871	19.46	8.07
7.50	151.712	0.04	1.42	3.9032	3.5234	2.846	19.41	8.06
7.53	151.716	0.04	1.42	3.8749	3.5518	2.822	19.36	8.06
7.57	151.720	0.04	1.43	3.8469	3.5797	2.798	19.31	8.05
7.60	151.724	0.05	1.43	3.8193	3.6073	2.774	19.26	8.05
7.63	151.728	0.05	1.43	3.7921	3.6345	2.750	19.21	8.04
7.66	151.732	0.06	1.44	3.7652	3.6614	2.727	19.16	8.03
7.69	151.736	0.06	1.44	3.7388	3.6878	2.704	19.11	8.03
7.72	151.740	0.06	1.45	3.7127	3.7140	2.681	19.07	8.02
7.76	151.744	0.07	1.45	3.6869	3.7397	2.658	19.02	8.02
7.79	151.748	0.07	1.45	3.6616	3.7651	2.636	18.97	8.01
7.82	151.752	0.07	1.46	3.6364	3.7902	2.613	18.92	8.01
7.85	151.756	0.08	1.46	3.6117	3.8150	2.591	18.87	8.00

Section 11 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.85	152.475	0.00	1.46	3.6026	3.8253	2.581	18.80	7.99
7.86	152.476	0.00	1.46	3.6069	3.8210	2.576	18.79	7.99
7.86	152.477	0.00	1.46	3.6112	3.8167	2.571	18.77	7.99
7.87	152.478	0.00	1.46	3.6154	3.8125	2.566	18.76	7.98
7.88	152.479	0.00	1.47	3.6196	3.8083	2.561	18.75	7.98
7.89	152.480	0.00	1.47	3.6238	3.8042	2.556	18.74	7.98
7.89	152.481	0.01	1.47	3.6279	3.8000	2.551	18.73	7.98
7.90	152.482	0.01	1.47	3.6320	3.7959	2.546	18.72	7.98
7.91	152.483	0.01	1.47	3.6360	3.7918	2.541	18.71	7.98
7.91	152.484	0.01	1.47	3.6401	3.7878	2.536	18.70	7.98
7.92	152.484	0.01	1.47	3.6441	3.7838	2.531	18.69	7.98
7.93	152.485	0.01	1.47	3.6480	3.7799	2.526	18.68	7.98
7.93	152.486	0.01	1.47	3.6520	3.7759	2.521	18.67	7.97
7.94	152.487	0.01	1.47	3.6559	3.7720	2.516	18.66	7.97
7.95	152.488	0.01	1.47	3.6598	3.7681	2.511	18.65	7.97
7.95	152.489	0.01	1.48	3.6636	3.7643	2.506	18.64	7.97
7.96	152.490	0.01	1.48	3.6674	3.7605	2.501	18.63	7.97
7.97	152.491	0.01	1.48	3.6712	3.7567	2.496	18.62	7.97
7.98	152.491	0.02	1.48	3.6750	3.7529	2.491	18.61	7.97
7.98	152.492	0.02	1.48	3.6787	3.7492	2.486	18.60	7.97
7.99	152.493	0.02	1.48	3.6824	3.7455	2.481	18.59	7.97

Section 12 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.99	152.493	0.00	1.48	3.6827	3.7455	2.481	18.59	7.97
8.01	152.495	0.00	1.48	3.7082	3.7200	2.470	18.56	7.96
8.02	152.497	0.00	1.48	3.7335	3.6947	2.459	18.54	7.96
8.04	152.499	0.01	1.49	3.7587	3.6695	2.447	18.51	7.96
8.06	152.501	0.01	1.49	3.7836	3.6446	2.436	18.49	7.96
8.07	152.504	0.01	1.49	3.8084	3.6198	2.425	18.47	7.95
8.09	152.506	0.01	1.49	3.8331	3.5952	2.414	18.44	7.95
8.11	152.508	0.01	1.49	3.8576	3.5707	2.403	18.42	7.95
8.12	152.510	0.02	1.50	3.8817	3.5465	2.392	18.39	7.94
8.14	152.512	0.02	1.50	3.9058	3.5224	2.381	18.37	7.94
8.16	152.514	0.02	1.50	3.9297	3.4985	2.370	18.34	7.94
8.17	152.516	0.02	1.50	3.9535	3.4749	2.359	18.32	7.94
8.19	152.518	0.02	1.50	3.9770	3.4512	2.349	18.30	7.93
8.20	152.520	0.03	1.51	4.0004	3.4278	2.338	18.27	7.93
8.22	152.522	0.03	1.51	4.0236	3.4046	2.328	18.25	7.93
8.24	152.524	0.03	1.51	4.0467	3.3815	2.317	18.22	7.93
8.25	152.526	0.03	1.51	4.0696	3.3587	2.306	18.20	7.92
8.27	152.528	0.03	1.51	4.0923	3.3360	2.296	18.18	7.92
8.29	152.530	0.04	1.52	4.1149	3.3134	2.286	18.15	7.92
8.30	152.533	0.04	1.52	4.1372	3.2910	2.276	18.13	7.92
8.32	152.535	0.04	1.52	4.1594	3.2688	2.265	18.10	7.91

Section 13 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
8.32	152.535	0.00	1.52	4.1639	3.2689	2.266	18.10	7.91
8.54	152.560	0.03	1.55	4.2029	3.2301	2.142	17.79	7.88
8.76	152.586	0.05	1.58	4.2249	3.2081	2.027	17.48	7.84
8.98	152.611	0.08	1.60	4.2322	3.2008	1.920	17.18	7.81
9.20	152.637	0.11	1.63	4.2268	3.2062	1.821	16.89	7.78
9.42	152.662	0.14	1.66	4.2106	3.2223	1.728	16.59	7.74
9.64	152.688	0.16	1.68	4.1850	3.2480	1.641	16.31	7.71
9.86	152.713	0.19	1.71	4.1516	3.2814	1.561	16.03	7.67
10.08	152.739	0.22	1.74	4.1116	3.3213	1.485	15.75	7.64
10.30	152.764	0.25	1.77	4.0659	3.3671	1.415	15.48	7.61
10.52	152.790	0.27	1.79	4.0157	3.4173	1.350	15.21	7.57
10.73	152.815	0.30	1.82	3.9617	3.4713	1.289	14.95	7.54
10.95	152.841	0.33	1.85	3.9046	3.5284	1.232	14.69	7.51
11.17	152.866	0.35	1.88	3.8452	3.5878	1.179	14.43	7.47
11.39	152.892	0.38	1.90	3.7839	3.6491	1.129	14.18	7.44
11.61	152.917	0.41	1.93	3.7213	3.7117	1.083	13.94	7.41
11.83	152.943	0.44	1.96	3.6577	3.7753	1.040	13.70	7.38
12.05	152.969	0.46	1.98	3.5935	3.8394	0.999	13.46	7.34
12.27	152.994	0.49	2.01	3.5291	3.9038	0.962	13.23	7.31
12.49	153.020	0.52	2.04	3.4647	3.9683	0.927	13.00	7.28
12.71	153.045	0.55	2.07	3.4005	4.0324	0.894	12.78	7.25

Section 14 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
12.71	153.045	0.00	2.07	3.4074	4.0324	0.894	12.78	7.25
12.81	153.055	0.01	2.08	3.2966	4.1431	0.882	12.70	7.24
12.91	153.065	0.02	2.08	3.1921	4.2476	0.870	12.63	7.23
13.02	153.076	0.03	2.09	3.0930	4.3469	0.859	12.56	7.22
13.12	153.086	0.04	2.10	2.9990	4.4408	0.847	12.48	7.21
13.22	153.096	0.05	2.11	2.9101	4.5298	0.836	12.41	7.20
13.32	153.106	0.05	2.12	2.8257	4.6142	0.826	12.34	7.19
13.42	153.116	0.06	2.13	2.7457	4.6941	0.815	12.27	7.17
13.53	153.126	0.07	2.14	2.6699	4.7700	0.805	12.20	7.16
13.63	153.137	0.08	2.15	2.5979	4.8419	0.795	12.13	7.15
13.73	153.147	0.09	2.16	2.5296	4.9103	0.786	12.06	7.14
13.83	153.157	0.10	2.17	2.4647	4.9751	0.776	11.99	7.13
13.93	153.167	0.11	2.18	2.4031	5.0367	0.767	11.92	7.12
14.04	153.177	0.12	2.18	2.3446	5.0953	0.759	11.85	7.11
14.14	153.187	0.13	2.19	2.2889	5.1509	0.749	11.78	7.10
14.24	153.198	0.14	2.20	2.2360	5.2038	0.741	11.72	7.09
14.34	153.208	0.14	2.21	2.1856	5.2542	0.732	11.65	7.08
14.44	153.218	0.15	2.22	2.1377	5.3021	0.724	11.58	7.07
14.55	153.228	0.16	2.23	2.0920	5.3478	0.716	11.52	7.06
14.65	153.238	0.17	2.24	2.0485	5.3913	0.708	11.45	7.05
14.75	153.248	0.18	2.25	2.0071	5.4327	0.701	11.39	7.04

Section 15 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
14.75	154.099	0.00	2.25	2.0112	6.4358	0.699	11.33	7.03
14.90	154.112	0.01	2.26	1.9269	6.5201	0.686	11.24	7.01
15.06	154.125	0.03	2.27	1.8498	6.5972	0.674	11.14	7.00
15.21	154.138	0.04	2.29	1.7792	6.6678	0.662	11.04	6.98
15.36	154.151	0.05	2.30	1.7145	6.7325	0.651	10.95	6.97
15.51	154.164	0.07	2.31	1.6550	6.7919	0.640	10.86	6.95
15.67	154.177	0.08	2.33	1.6004	6.8466	0.629	10.76	6.94
15.82	154.190	0.09	2.34	1.5501	6.8968	0.619	10.67	6.92
15.97	154.204	0.11	2.35	1.5038	6.9432	0.609	10.58	6.91
16.12	154.217	0.12	2.37	1.4609	6.9860	0.599	10.49	6.89
16.28	154.230	0.13	2.38	1.4213	6.0256	0.590	10.40	6.88
16.43	154.243	0.15	2.40	1.3846	6.0623	0.581	10.31	6.86
16.58	154.256	0.16	2.41	1.3506	6.0964	0.573	10.22	6.85
16.73	154.269	0.17	2.42	1.3189	6.1280	0.564	10.14	6.83
16.89	154.282	0.19	2.44	1.2894	6.1575	0.556	10.05	6.82
17.04	154.295	0.20	2.45	1.2619	6.1851	0.549	9.97	6.80
17.19	154.309	0.21	2.46	1.2361	6.2108	0.541	9.88	6.79
17.34	154.322	0.23	2.48	1.2120	6.2349	0.534	9.80	6.77
17.50	154.335	0.24	2.49	1.1894	6.2576	0.528	9.71	6.76
17.65	154.348	0.26	2.50	1.1681	6.2789	0.521	9.63	6.75
17.80	154.361	0.27	2.52	1.1480	6.2990	0.515	9.55	6.73

Section 16 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
17.80	154.361	0.00	2.52	1.1646	6.2990	0.515	9.55	6.73
17.88	154.368	0.01	2.52	1.1593	6.2942	0.511	9.50	6.72
17.97	154.376	0.01	2.53	1.1635	6.2900	0.507	9.46	6.72
18.05	154.383	0.02	2.54	1.1672	6.2862	0.503	9.41	6.71
18.13	154.390	0.03	2.55	1.1706	6.2829	0.500	9.37	6.70
18.22	154.397	0.04	2.55	1.1734	6.2801	0.496	9.33	6.69
18.30	154.404	0.04	2.56	1.1759	6.2776	0.493	9.28	6.68
18.39	154.412	0.05	2.57	1.1780	6.2755	0.489	9.24	6.68
18.47	154.419	0.06	2.57	1.1797	6.2738	0.486	9.20	6.67
18.55	154.426	0.07	2.58	1.1811	6.2724	0.483	9.15	6.66
18.64	154.433	0.07	2.59	1.1822	6.2713	0.480	9.11	6.65
18.72	154.440	0.08	2.60	1.1829	6.2706	0.477	9.07	6.64
18.80	154.448	0.09	2.60	1.1834	6.2701	0.473	9.03	6.64
18.89	154.455	0.10	2.61	1.1836	6.2699	0.470	8.98	6.63
18.97	154.462	0.10	2.62	1.1835	6.2700	0.468	8.94	6.62
19.05	154.469	0.11	2.63	1.1831	6.2704	0.465	8.90	6.61
19.14	154.476	0.12	2.63	1.1826	6.2709	0.462	8.86	6.61
19.22	154.484	0.12	2.64	1.1817	6.2717	0.459	8.82	6.60
19.30	154.491	0.13	2.65	1.1807	6.2729	0.456	8.78	6.59
19.39	154.498	0.14	2.66	1.1795	6.2740	0.454	8.73	6.58
19.47	154.505	0.15	2.66	1.1781	6.2754	0.451	8.69	6.57

Section 17 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
19.47	155.185	0.00	2.66	1.1942	6.2742	0.451	8.88	6.57
19.79	155.218	0.03	2.69	1.3028	6.1553	0.443	8.51	6.54
20.10	155.250	0.05	2.72	1.4120	6.0462	0.435	8.37	6.51
20.41	155.283	0.08	2.74	1.5123	5.9459	0.427	8.22	6.48
20.72	155.315	0.11	2.77	1.6042	5.8540	0.421	8.08	6.45
21.04	155.348	0.14	2.80	1.6884	5.7698	0.414	7.94	6.42
21.35	155.380	0.16	2.83	1.7652	5.6930	0.408	7.80	6.39
21.66	155.413	0.19	2.85	1.8352	5.6230	0.402	7.67	6.37
21.97	155.445	0.22	2.88	1.8988	5.5594	0.397	7.53	6.34
22.29	155.478	0.25	2.91	1.9565	5.5018	0.392	7.40	6.31
22.60	155.510	0.27	2.94	2.0085	5.4498	0.387	7.27	6.28
22.91	155.543	0.30	2.96	2.0552	5.4032	0.383	7.15	6.26
23.23	155.575	0.33	2.99	2.0969	5.3614	0.379	7.02	6.23
23.54	155.608	0.36	3.02	2.1341	5.3243	0.375	6.90	6.20
23.85	155.640	0.38	3.05	2.1669	5.2914	0.371	6.78	6.17
24.17	155.673	0.41	3.07	2.1957	5.2626	0.367	6.67	6.15
24.48	155.705	0.44	3.10	2.2207	5.2376	0.364	6.55	6.12
24.79	155.738	0.47	3.13	2.2422	5.2161	0.361	6.44	6.09
25.10	155.770	0.49	3.16	2.2604	5.1978	0.358	6.32	6.07
25.42	155.803	0.52	3.18	2.2755	5.1828	0.355	6.22	6.04
25.73	155.835	0.55	3.21	2.2876	5.1706	0.352	6.11	6.01

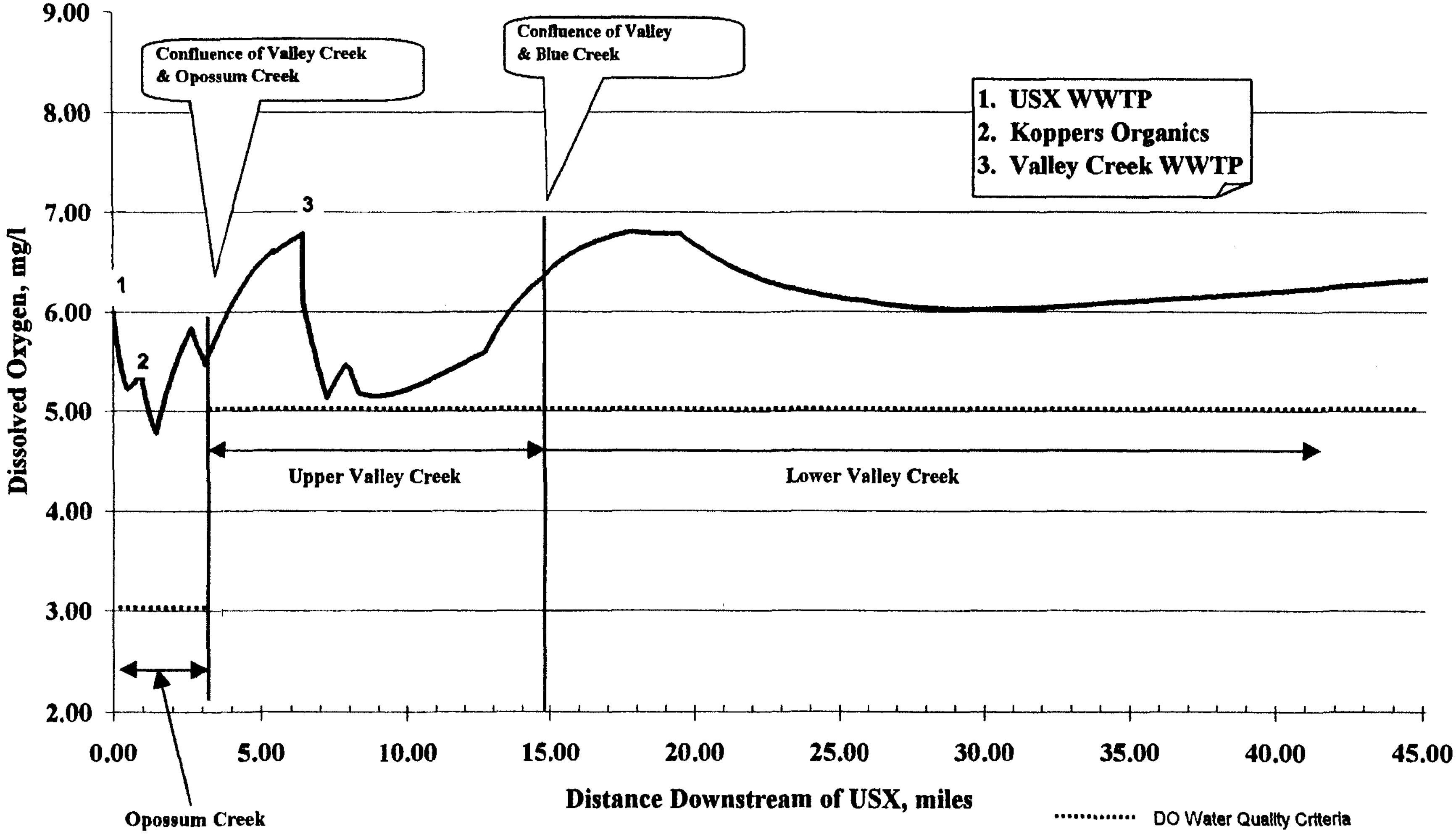
Section18 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
25.73	155.835	0.00	3.21	2.2913	5.1706	0.352	6.11	6.01
25.77	155.839	0.00	3.21	2.2948	5.1670	0.351	6.09	6.01
25.82	155.843	0.01	3.22	2.2983	5.1636	0.351	6.08	6.01
25.86	155.848	0.01	3.22	2.3017	5.1602	0.351	6.06	6.00
25.90	155.852	0.02	3.23	2.3050	5.1569	0.350	6.05	6.00
25.95	155.856	0.02	3.23	2.3083	5.1536	0.350	6.03	6.00
25.99	155.860	0.02	3.23	2.3115	5.1504	0.350	6.02	5.99
26.03	155.864	0.03	3.24	2.3146	5.1472	0.349	6.00	5.99
26.08	155.869	0.03	3.24	2.3177	5.1442	0.349	5.99	5.98
26.12	155.873	0.03	3.24	2.3208	5.1411	0.349	5.98	5.98
26.17	155.877	0.04	3.25	2.3237	5.1382	0.348	5.96	5.98
26.21	155.881	0.04	3.25	2.3267	5.1352	0.348	5.95	5.97
26.25	155.885	0.05	3.26	2.3295	5.1324	0.348	5.93	5.97
26.30	155.889	0.05	3.26	2.3323	5.1296	0.347	5.92	5.97
26.34	155.894	0.05	3.26	2.3350	5.1269	0.347	5.90	5.96
26.38	155.898	0.06	3.27	2.3377	5.1242	0.347	5.89	5.96
26.43	155.902	0.06	3.27	2.3404	5.1215	0.346	5.88	5.96
26.47	155.906	0.06	3.27	2.3429	5.1189	0.346	5.86	5.95
26.51	155.910	0.07	3.28	2.3455	5.1164	0.346	5.85	5.95
26.56	155.915	0.07	3.28	2.3479	5.1140	0.345	5.83	5.94
26.60	155.919	0.08	3.29	2.3503	5.1116	0.345	5.82	5.94

Section 19 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
26.60	157.399	0.00	3.29	2.3476	5.1199	0.346	5.78	5.93
27.00	157.437	0.03	3.32	2.3652	5.1023	0.345	5.66	5.90
27.40	157.476	0.07	3.36	2.3790	5.0885	0.343	5.53	5.86
27.80	157.514	0.10	3.39	2.3892	5.0783	0.342	5.41	5.83
28.20	157.553	0.14	3.42	2.3962	5.0713	0.340	5.29	5.80
28.60	157.591	0.17	3.46	2.4001	5.0674	0.338	5.18	5.77
29.00	157.630	0.21	3.49	2.4012	5.0663	0.337	5.07	5.73
29.40	157.668	0.24	3.53	2.3997	5.0678	0.335	4.96	5.70
29.80	157.707	0.28	3.56	2.3958	5.0717	0.334	4.85	5.67
30.20	157.745	0.31	3.60	2.3897	5.0778	0.332	4.74	5.64
30.60	157.784	0.35	3.63	2.3816	5.0859	0.330	4.64	5.61
31.00	157.822	0.38	3.67	2.3716	5.0959	0.329	4.54	5.58
31.40	157.861	0.42	3.70	2.3599	5.1076	0.327	4.44	5.55
31.80	157.899	0.45	3.74	2.3467	5.1208	0.325	4.34	5.52
32.20	157.938	0.48	3.77	2.3321	5.1354	0.324	4.25	5.49
32.60	157.976	0.52	3.81	2.3161	5.1513	0.322	4.15	5.46
33.00	158.015	0.55	3.84	2.2990	5.1685	0.320	4.06	5.43
33.40	158.053	0.59	3.87	2.2809	5.1866	0.318	3.97	5.40
33.80	158.092	0.62	3.91	2.2617	5.2058	0.317	3.89	5.37
34.20	158.130	0.66	3.94	2.2417	5.2257	0.315	3.80	5.34
34.60	158.169	0.69	3.98	2.2209	5.2465	0.313	3.72	5.31

Section 20 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
34.60	158.169	0.00	3.98	2.2263	5.2468	0.313	3.72	5.31
34.74	158.182	0.01	3.99	2.2203	5.2528	0.313	3.70	5.30
34.88	158.195	0.02	4.00	2.2143	5.2588	0.312	3.68	5.29
35.01	158.208	0.03	4.01	2.2082	5.2648	0.311	3.66	5.28
35.15	158.222	0.05	4.02	2.2021	5.2709	0.310	3.64	5.27
35.29	158.235	0.06	4.03	2.1960	5.2767	0.309	3.62	5.26
35.43	158.248	0.07	4.05	2.1898	5.2829	0.308	3.60	5.25
35.56	158.261	0.08	4.06	2.1837	5.2891	0.307	3.58	5.24
35.70	158.275	0.09	4.07	2.1774	5.2953	0.306	3.56	5.23
35.84	158.288	0.10	4.08	2.1712	5.3016	0.305	3.54	5.22
35.98	158.301	0.11	4.09	2.1649	5.3078	0.305	3.52	5.21
36.11	158.314	0.12	4.10	2.1586	5.3142	0.304	3.50	5.20
36.25	158.328	0.14	4.11	2.1522	5.3205	0.303	3.49	5.19
36.39	158.341	0.15	4.13	2.1459	5.3268	0.302	3.47	5.18
36.53	158.354	0.16	4.14	2.1395	5.3332	0.301	3.45	5.18
36.66	158.367	0.17	4.15	2.1331	5.3396	0.301	3.43	5.17
36.80	158.381	0.18	4.16	2.1267	5.3461	0.300	3.41	5.16
36.94	158.394	0.19	4.17	2.1202	5.3525	0.299	3.39	5.15
37.08	158.407	0.20	4.18	2.1138	5.3590	0.298	3.37	5.14
37.21	158.420	0.22	4.19	2.1073	5.3654	0.298	3.36	5.13
37.35	158.433	0.23	4.21	2.1008	5.3719	0.297	3.34	5.12

Section 21 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
37.35	160.813	0.00	4.21	2.0923	5.3812	0.299	3.32	5.11
37.74	160.851	0.03	4.24	2.0734	5.4000	0.298	3.27	5.09
38.14	160.888	0.06	4.27	2.0545	5.4189	0.296	3.22	5.06
38.53	160.926	0.10	4.30	2.0355	5.4379	0.294	3.17	5.03
38.93	160.963	0.13	4.33	2.0166	5.4568	0.293	3.12	5.01
39.32	161.001	0.16	4.37	1.9976	5.4758	0.291	3.07	4.98
39.71	161.038	0.19	4.40	1.9787	5.4947	0.290	3.02	4.96
40.11	161.076	0.23	4.43	1.9598	5.5136	0.288	2.98	4.93
40.50	161.113	0.26	4.46	1.9409	5.5325	0.287	2.93	4.91
40.90	161.150	0.29	4.50	1.9221	5.5513	0.285	2.89	4.88
41.29	161.188	0.32	4.53	1.9033	5.5701	0.284	2.84	4.86
41.68	161.225	0.36	4.56	1.8846	5.5888	0.282	2.80	4.83
42.08	161.263	0.39	4.59	1.8660	5.6074	0.281	2.76	4.81
42.47	161.300	0.42	4.63	1.8474	5.6259	0.279	2.72	4.78
42.87	161.338	0.45	4.66	1.8290	5.6444	0.278	2.67	4.76
43.26	161.375	0.48	4.69	1.8106	5.6627	0.276	2.63	4.73
43.65	161.413	0.52	4.72	1.7924	5.6810	0.275	2.59	4.71
44.05	161.450	0.55	4.75	1.7742	5.6991	0.273	2.55	4.69
44.44	161.487	0.58	4.79	1.7562	5.7172	0.272	2.51	4.66
44.84	161.525	0.61	4.82	1.7383	5.7351	0.271	2.48	4.64
45.23	161.562	0.65	4.85	1.7205	5.7529	0.269	2.44	4.61

Opossum Creek / Valley Creek Waste Load Allocation
May - November / F&W Classification



Water Quality
Steady-State Stream Model

Enter the Number of Section: 21.000
Total Length (miles) = 46.230

Opossum Creek / Valley Creek Waste Load Allocation - Summer WLA / F&W Classification

Valley Creek WWTP Effluent Conditions				
Design Flow, MGD	$CBOD_5$, mg/l	NH_3-N, mg/l	TKN, mg/l	D.O. (minimum), mg/l
85.00	4.0	0.5	2.5	6.0

HeadWater Data

Recession Index (G) =	60.000		Tributary Flows (cfs)	
Mean Annual Prec. (P) =	60.000	Flow Multiplier	0.36	
Drainage Area (M^2) =	0.000		1.59	
Temp (C°) =	30.000	1.00	0.28	
CHL =	0.000		0.72	
Headwater Flow (cfs) =	0.360		0.85	Stream flow @ Valley Creek WWTP (cfs)
CBODU (mg/l) =	2.000		1.48	20.0750
NH_3ODU (mg/l) =	0.457		2.38	
TONODU (mg/l) =	4.570			
Headwater $D.O._{(mg/l)}$ =	6.00			

Dam Data

Dam Located at Beginning of Section =	0.00
Water Quality Factor =	1.80
Wier Dam Coefficient =	0.80
Difference in Water Level (ft) =	1.00

	Use Goal Seek
Minimum Dissolved Oxygen Concentration (mg/l) (Opossum Creek) =	**4.79**
Minimum Dissolved Oxygen Concentration (mg/l) (Upper Valley Creek) =	**5.13**
Minimum Dissolved Oxygen Concentration (mg/l) (Lower Valley Creek) =	**6.02**
CBODu Concentration at End of Modeled Reach (mg/l) =	**1.25**

Enter Tributary Conditions (if none, leave blank)

Sections	G	P	TONODU (mg/l)	CBODU (mg/l)	NH3ODU (mg/l)	DO (mg/l)	$7Q_{10}$ (cfs)	Temp. (C°)	Drainage Area (M^2)
1.00						0.000	0.00	0.00	0.00
2.00						0.000	0.00	0.00	0.00
3.00						0.000	0.00	0.00	0.00
4.00						0.000	0.00	0.00	0.00
5.00						0.000	0.00	0.00	0.00
6.00			4.57	2.00	0.4570	6.000	1.59	30.00	0.00
7.00						0.000	0.00	0.00	0.00
8.00			4.57	2.00	0.4570	6.000	0.28	30.00	0.00
9.00			91.40	37.60	45.7000	3.000	0.00	30.00	0.00
10.00						0.000	0.00	0.00	0.00
11.00			4.57	2.00	0.4570	6.000	0.72	30.00	0.00
12.00						0.000	0.00	0.00	0.00
13.00						0.000	0.00	0.00	0.00
14.00						0.000	0.00	0.00	0.00
15.00			4.57	2.00	0.4570	6.000	0.85	30.00	0.00
16.00						0.000	0.00	0.00	0.00
17.00	65.000	56.00	4.57	2.00	0.4570	6.000	0.68	30.00	15.60
18.00						0.000	0.00	0.00	0.00
19.00	65.000	56.00	4.57	2.00	0.4570	6.000	1.48	30.00	32.70
20.00						0.000	0.00	0.00	0.00
21.00	65.000	56.00	4.57	2.00	0.4570	6.000	2.38	30.00	51.20
22.00						0.000	0.00	0.00	0.00

Enter Incremental Inflow Conditions (if none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (° C)	Q10 (cfs)	Drainage Area (mi^2)
1.00	2.000	0.46	4.57	6.00	0.0097	30.000	0.00	
2.00	2.000	0.46	4.57	6.00	0.0097	30.000	0.00	
3.00	2.000	0.46	4.57	6.00	0.0106	30.000	0.00	
4.00	2.000	0.46	4.57	6.00	0.1477	30.000	0.00	
5.00	2.000	0.46	4.57	6.00	0.0546	30.000	0.00	
6.00	2.000	0.46	4.57	6.00	0.2903	30.000	0.00	
7.00	2.000	0.46	4.57	6.00	0.0908	30.000	0.00	
8.00	2.000	0.46	4.57	6.00	0.1689	30.000	0.00	
9.00	2.000	0.46	4.57	6.00	0.1016	30.000	0.00	
10.00	2.000	0.46	4.57	6.00	0.0790	30.000	0.00	
11.00	2.000	0.46	4.57	6.00	0.0176	30.000	0.00	
12.00	2.000	0.46	4.57	6.00	0.0414	30.000	0.00	
13.00	2.000	0.46	4.57	6.00	0.5105	30.000	0.00	
14.00	2.000	0.46	4.57	6.00	0.2033	30.000	0.00	
15.00	2.000	0.46	4.57	6.00	0.2629	30.000	0.00	
16.00	2.000	0.46	4.57	6.00	0.1439	30.000	0.00	
17.00	2.000	0.46	4.57	6.00	0.6500	30.000	0.00	
18.00	2.000	0.46	4.57	6.00	0.0637	30.000	0.00	
19.00	2.000	0.46	4.57	6.00	0.7700	30.000	0.00	
20.00	2.000	0.46	4.57	6.00	0.2647	30.000	0.00	
21.00	2.000	0.46	4.57	6.00	0.7488	30.000	0.00	
22.00				6.43	0.0000	30.000	0.00	

Enter Effluent Conditions (if none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (°C)	pH	Max. Instream NH3 (mg/l)	NH3 Toxicity (mg/l)	NH3 WQ Limit (mg/l)
1.00	8.000	3.43	3.43	6.00	17.0170	30.000	7.00	3.08	3.16	1.00
2.00	27.600	81.40	137.10	6.00	0.0557	30.000	7.00			20.00
3.00		0.00		0.00						0.00
4.00		0.00		0.00						0.00
5.00		0.00		0.00						0.00
6.00		0.00		0.00						0.00
7.00		0.00		0.00						0.00
8.00		0.00		0.00						0.00
9.00	12.000	2.29	9.14	6.00	131.6000	30.000	7.00	3.08	3.55	0.50
10.00		0.00		0.00						0.00
11.00		0.00		0.00						0.00
12.00		0.00		0.00						0.00
13.00		0.00		0.00						0.00
14.00		0.00		0.00						0.00
15.00		0.00		0.00						0.00
16.00		0.00		0.00						0.00
17.00		0.00		0.00						0.00
18.00		0.00		0.00						0.00
19.00		0.00		0.00						0.00
20.00		0.00		0.00						0.00
21.00		0.00		0.00						0.00
22.00		0.00		0.00						0.00

The most stringent of the two values will be implemented as the discharge limit.

Enter Section Characteristics (if none, leave blank)

Sections	Beginning Elev. (ft)	Ending Elev. (ft)	Elev.Change (ft)	Length (miles)	Average Elev. (ft)	Section Slope (ft/mi)	Average Flow (cfs)	Average Vel. (ft/sec)
1.00	498.000	490.00	8.00	0.4700	494.0000	17.021	17.38	0.304
2.00	490.000	480.00	10.00	0.4700	485.0000	21.277	17.45	0.304
3.00	480.000	475.00	5.00	0.5100	477.5000	9.804	17.46	0.305
4.00	475.000	455.00	20.00	1.1900	465.0000	16.807	17.54	0.305
5.00	455.000	452.00	3.00	0.4400	453.5000	6.818	17.64	0.306
6.00	452.000	435.00	17.00	1.7900	443.5000	9.497	19.40	0.304
7.00	435.000	430.00	5.00	0.5600	432.5000	8.929	19.59	0.308
8.00	430.000	422.00	8.00	0.9800	426.0000	8.163	20.00	0.310
9.00	422.000	420.00	2.00	0.8100	421.0000	2.469	151.63	0.488
10.00	420.000	412.00	8.00	0.6300	416.0000	12.698	151.72	0.488
11.00	412.000	411.00	1.00	0.1400	411.5000	7.143	152.48	0.490
12.00	411.000	410.00	1.00	0.3300	410.5000	3.030	152.51	0.491
13.00	410.000	380.00	30.00	4.3900	395.0000	6.834	152.79	0.491
14.00	380.000	362.00	18.00	2.0400	371.0000	8.824	153.15	0.691
15.00	362.000	331.00	31.00	3.0500	346.5000	10.164	154.23	0.694
16.00	331.000	318.00	13.00	1.6700	324.5000	7.784	154.43	0.695
17.00	318.000	298.00	20.00	6.2600	308.0000	3.195	155.51	0.699
18.00	298.000	294.30	3.70	0.8700	296.1500	4.253	155.88	0.700
19.00	294.300	260.00	34.30	8.0000	277.1500	4.288	157.78	0.706
20.00	260.000	258.70	1.30	2.7500	259.3500	0.473	159.30	0.740
21.00	258.700	255.00	3.70	7.8800	256.8500	0.470	161.19	0.746
22.00					0.0000	0.000	0.00	0.00

Sections	*Reaction Rates @ 20° C*					*Corrected Rates @ New Temp.*				
	Kd	*KNH3*	*KON*	*T. Coefficient*	*Reaeration*	*Kd*	*KNH3*	*KON*	**Ave. Reaeration**	*Mixed Temp.(° C)*
1.00	1.300	1.50	0.80	1.30	8.7228	2.059	3.09	1.27	8.52	30.00
2.00	1.300	1.50	0.80	1.30	8.4216	2.058	2.99	1.27	10.69	30.00
3.00	1.300	1.50	0.80	1.30	3.8919	2.059	3.01	1.27	4.92	30.00
4.00	1.300	1.50	0.80	1.30	6.6716	2.059	2.93	1.27	8.46	30.00
5.00	1.300	1.50	0.80	1.30	2.7156	2.058	3.07	1.27	3.44	30.00
6.00	0.400	1.50	0.10	1.30	3.7533	0.633	3.02	0.16	4.76	30.00
7.00	0.400	1.50	0.10	1.30	3.5507	0.633	3.13	0.16	4.50	30.00
8.00	0.400	1.50	0.10	1.30	3.2893	0.633	3.14	0.16	4.17	30.00
9.00	0.400	1.50	0.10	0.88	1.0601	0.633	3.09	0.16	1.34	30.00
10.00	0.400	1.50	0.10	0.88	5.4549	0.633	2.99	0.16	6.91	30.00
11.00	0.400	1.50	0.10	0.88	3.0828	0.633	3.02	0.16	3.91	30.00
12.00	0.400	1.50	0.10	0.88	1.3081	0.633	3.02	0.16	1.66	30.00
13.00	0.400	1.50	0.10	0.88	2.9549	0.633	2.99	0.16	3.75	30.00
14.00	0.400	1.50	0.10	0.88	5.3631	0.633	3.04	0.16	6.80	30.00
15.00	0.400	1.50	0.10	0.88	6.2107	0.633	3.12	0.16	7.87	30.00
16.00	0.400	1.50	0.10	0.88	4.7615	0.633	3.16	0.16	6.04	30.00
17.00	0.400	1.50	0.10	0.88	1.5600	0.633	3.16	0.16	1.98	30.00
18.00	0.400	1.50	0.10	0.88	1.3700	0.633	3.10	0.16	1.74	30.00
19.00	0.400	1.50	0.10	0.88	1.3700	0.633	3.09	0.16	1.74	30.00
20.00	0.300	1.50	0.10	0.88	1.1400	0.475	3.09	0.16	1.45	30.00
21.00	0.300	1.50	0.10	0.88	1.1400	0.475	3.10	0.16	1.45	30.00
22.00	0.000	0.00	0.00	0.00	0.0000	0.000	0.00	0.00	0.00	0.00

Model Output

Section 1 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.000	17.377	0.00	0.00	1.4037	6.0000	3.366	7.96	3.45
0.024	17.377	0.00	0.00	1.4708	5.9329	3.338	7.80	3.43
0.047	17.378	0.01	0.01	1.5341	5.8696	3.310	7.72	3.41
0.071	17.378	0.01	0.01	1.5937	5.8099	3.282	7.65	3.39
0.094	17.379	0.02	0.02	1.6500	5.7537	3.255	7.57	3.37
0.118	17.379	0.02	0.02	1.7029	5.7008	3.228	7.50	3.35
0.141	17.380	0.03	0.03	1.7526	5.6511	3.201	7.43	3.33
0.165	17.380	0.03	0.03	1.7993	5.6044	3.175	7.36	3.31
0.188	17.381	0.04	0.04	1.8431	5.5606	3.149	7.29	3.29
0.212	17.381	0.04	0.04	1.8841	5.5196	3.122	7.21	3.27
0.235	17.382	0.05	0.05	1.9225	5.4812	3.097	7.14	3.25
0.259	17.382	0.05	0.05	1.9583	5.4454	3.071	7.08	3.23
0.282	17.383	0.06	0.06	1.9917	5.4120	3.046	7.01	3.21
0.306	17.383	0.06	0.06	2.0227	5.3810	3.021	6.94	3.20
0.329	17.384	0.07	0.07	2.0516	5.3521	2.996	6.87	3.18
0.353	17.384	0.07	0.07	2.0782	5.3254	2.972	6.80	3.16
0.376	17.385	0.08	0.08	2.1029	5.3008	2.947	6.74	3.14
0.400	17.385	0.08	0.08	2.1256	5.2780	2.924	6.67	3.12
0.423	17.386	0.09	0.09	2.1465	5.2572	2.900	6.61	3.10
0.447	17.386	0.09	0.09	2.1656	5.2381	2.876	6.54	3.08
0.470	17.387	0.09	0.09	2.1830	5.2207	2.853	6.48	3.06

Section 2 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.47	17.442	0.00	0.09	2.1831	5.2232	3.136	6.55	3.49
0.49	17.443	0.00	0.10	2.1805	5.2258	3.112	6.48	3.47
0.52	17.443	0.01	0.10	2.1770	5.2293	3.089	6.42	3.45
0.54	17.444	0.01	0.11	2.1728	5.2335	3.067	6.36	3.43
0.56	17.444	0.02	0.11	2.1680	5.2384	3.044	6.30	3.41
0.59	17.445	0.02	0.12	2.1624	5.2439	3.022	6.24	3.39
0.61	17.445	0.03	0.12	2.1563	5.2500	2.999	6.18	3.37
0.63	17.446	0.03	0.13	2.1496	5.2567	2.977	6.12	3.35
0.66	17.446	0.04	0.13	2.1424	5.2640	2.955	6.06	3.33
0.68	17.447	0.04	0.14	2.1346	5.2717	2.934	6.00	3.31
0.71	17.447	0.05	0.14	2.1264	5.2799	2.912	5.94	3.29
0.73	17.448	0.05	0.15	2.1178	5.2885	2.891	5.88	3.27
0.75	17.448	0.06	0.15	2.1087	5.2976	2.870	5.83	3.25
0.78	17.449	0.06	0.16	2.0993	5.3070	2.849	5.77	3.23
0.80	17.449	0.07	0.16	2.0895	5.3168	2.828	5.71	3.21
0.82	17.450	0.07	0.17	2.0794	5.3269	2.808	5.66	3.19
0.85	17.450	0.08	0.17	2.0690	5.3373	2.787	5.60	3.17
0.87	17.451	0.08	0.17	2.0583	5.3481	2.767	5.55	3.16
0.89	17.451	0.08	0.18	2.0473	5.3590	2.747	5.50	3.14
0.92	17.452	0.09	0.18	2.0361	5.3702	2.727	5.44	3.12
0.94	17.452	0.09	0.19	2.0247	5.3816	2.707	5.391	3.10

Section 3 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.94	17.452	0.00	0.18	2.0269	5.3816	2.707	5.39	3.10
0.97	17.453	0.01	0.19	2.0731	5.3354	2.686	5.33	3.08
0.99	17.453	0.01	0.20	2.1174	5.2912	2.665	5.28	3.06
1.02	17.454	0.02	0.20	2.1596	5.2490	2.644	5.22	3.04
1.04	17.454	0.02	0.21	2.1998	5.2087	2.623	5.17	3.02
1.07	17.455	0.03	0.21	2.2382	5.1703	2.602	5.11	3.00
1.09	17.455	0.03	0.22	2.2748	5.1338	2.582	5.06	2.98
1.12	17.456	0.04	0.22	2.3096	5.0990	2.561	5.01	2.96
1.14	17.456	0.04	0.23	2.3426	5.0659	2.541	4.95	2.94
1.17	17.457	0.05	0.23	2.3740	5.0345	2.521	4.90	2.92
1.20	17.457	0.05	0.24	2.4038	5.0048	2.502	4.85	2.91
1.22	17.458	0.06	0.25	2.4320	4.9766	2.482	4.80	2.89
1.25	17.458	0.06	0.25	2.4586	4.9499	2.463	4.75	2.87
1.27	17.459	0.07	0.26	2.4838	4.9247	2.443	4.70	2.85
1.30	17.460	0.07	0.26	2.5076	4.9009	2.424	4.65	2.83
1.32	17.460	0.08	0.27	2.5300	4.8786	2.406	4.60	2.81
1.35	17.461	0.08	0.27	2.5510	4.8575	2.387	4.55	2.80
1.37	17.461	0.09	0.28	2.5707	4.8378	2.368	4.51	2.78
1.40	17.462	0.09	0.28	2.5892	4.8194	2.350	4.46	2.76
1.42	17.462	0.10	0.29	2.6064	4.8021	2.332	4.41	2.74
1.45	17.463	0.10	0.29	2.6225	4.7861	2.314	4.37	2.72

Section 4 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
1.45	17.463	0.00	0.29	2.6261	4.7861	2.314	4.37	2.72
1.51	17.470	0.01	0.30	2.5504	4.8616	2.274	4.26	2.68
1.57	17.477	0.02	0.32	2.4783	4.9340	2.236	4.16	2.64
1.63	17.485	0.04	0.33	2.4094	5.0028	2.198	4.05	2.61
1.69	17.492	0.05	0.34	2.3436	5.0686	2.161	3.95	2.57
1.75	17.500	0.06	0.35	2.2806	5.1315	2.126	3.86	2.53
1.81	17.507	0.07	0.36	2.2203	5.1918	2.089	3.76	2.49
1.87	17.514	0.08	0.37	2.1624	5.2496	2.054	3.67	2.46
1.93	17.522	0.10	0.39	2.1069	5.3052	2.020	3.58	2.42
1.99	17.529	0.11	0.40	2.0535	5.3585	1.986	3.50	2.39
2.05	17.537	0.12	0.41	2.0022	5.4099	1.953	3.41	2.35
2.10	17.544	0.13	0.42	1.9527	5.4593	1.920	3.33	2.32
2.16	17.551	0.14	0.43	1.9050	5.5069	1.889	3.25	2.28
2.22	17.559	0.15	0.45	1.8590	5.5529	1.857	3.17	2.25
2.28	17.566	0.17	0.46	1.8146	5.5973	1.827	3.09	2.22
2.34	17.573	0.18	0.47	1.7717	5.6402	1.797	3.01	2.18
2.40	17.581	0.19	0.48	1.7302	5.6817	1.767	2.94	2.15
2.46	17.588	0.20	0.49	1.6901	5.7218	1.738	2.87	2.12
2.52	17.596	0.21	0.51	1.6512	5.7607	1.710	2.80	2.09
2.58	17.603	0.23	0.52	1.6135	5.7983	1.682	2.73	2.06
2.64	17.610	0.24	0.53	1.5770	5.8349	1.655	2.67	2.03

Section 5 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
2.64	17.610	0.00	0.53	1.5807	5.8348	1.655	2.67	2.03
2.66	17.613	0.00	0.53	1.6029	5.8126	1.644	2.64	2.02
2.68	17.616	0.01	0.54	1.6244	5.7911	1.633	2.62	2.01
2.71	17.619	0.01	0.54	1.6451	5.7703	1.622	2.59	2.00
2.73	17.621	0.02	0.55	1.6652	5.7502	1.611	2.57	1.99
2.75	17.624	0.02	0.55	1.6847	5.7308	1.600	2.55	1.98
2.77	17.627	0.03	0.56	1.7035	5.7120	1.590	2.52	1.97
2.79	17.630	0.03	0.56	1.7217	5.6938	1.579	2.50	1.96
2.82	17.632	0.04	0.56	1.7392	5.6762	1.569	2.48	1.95
2.84	17.635	0.04	0.57	1.7562	5.6593	1.559	2.46	1.94
2.86	17.638	0.04	0.57	1.7726	5.6429	1.548	2.43	1.92
2.88	17.640	0.05	0.58	1.7883	5.6272	1.538	2.41	1.91
2.90	17.643	0.05	0.58	1.8035	5.6120	1.528	2.39	1.90
2.93	17.646	0.06	0.59	1.8182	5.5973	1.518	2.37	1.89
2.95	17.649	0.06	0.59	1.8323	5.5832	1.508	2.35	1.88
2.97	17.651	0.07	0.60	1.8458	5.5696	1.498	2.33	1.87
2.99	17.654	0.07	0.60	1.8589	5.5566	1.488	2.31	1.86
3.01	17.657	0.07	0.60	1.8714	5.5441	1.479	2.28	1.85
3.04	17.660	0.08	0.61	1.8834	5.5321	1.469	2.26	1.84
3.06	17.662	0.08	0.61	1.8950	5.5205	1.459	2.24	1.83
3.08	17.665	0.09	0.62	1.9060	5.5095	1.450	2.22	1.82

Section 6 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
3.08	19.255	0.00	0.62	1.9511	5.4674	1.359	2.20	2.05
3.17	19.270	0.02	0.64	1.8847	5.5334	1.301	2.18	2.05
3.26	19.284	0.04	0.65	1.8200	5.5980	1.237	2.16	2.04
3.35	19.299	0.05	0.67	1.7573	5.6607	1.177	2.13	2.04
3.44	19.313	0.07	0.69	1.6964	5.7216	1.120	2.11	2.04
3.53	19.328	0.09	0.71	1.6374	5.7806	1.066	2.09	2.03
3.62	19.342	0.11	0.73	1.5802	5.8378	1.015	2.06	2.03
3.71	19.357	0.13	0.74	1.5250	5.8928	0.966	2.04	2.02
3.80	19.371	0.14	0.76	1.4718	5.9462	0.921	2.01	2.02
3.89	19.386	0.16	0.78	1.4201	5.9977	0.877	1.99	2.02
3.98	19.400	0.18	0.80	1.3703	6.0474	0.836	1.97	2.01
4.06	19.415	0.20	0.82	1.3224	6.0953	0.797	1.94	2.01
4.15	19.429	0.22	0.83	1.2762	6.1414	0.761	1.92	2.01
4.24	19.444	0.23	0.85	1.2318	6.1859	0.726	1.90	2.00
4.33	19.458	0.25	0.87	1.1890	6.2286	0.693	1.88	2.00
4.42	19.473	0.27	0.89	1.1478	6.2697	0.662	1.86	1.99
4.51	19.487	0.29	0.90	1.1083	6.3093	0.632	1.84	1.99
4.60	19.502	0.31	0.92	1.0703	6.3472	0.604	1.82	1.99
4.69	19.516	0.32	0.94	1.0338	6.3837	0.578	1.80	1.98
4.78	19.531	0.34	0.96	0.9987	6.4188	0.553	1.78	1.98
4.87	19.545	0.36	0.98	0.9651	6.4524	0.529	1.76	1.98

Section 7 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
4.87	19.545	0.00	0.98	0.9694	6.4524	0.529	1.76	1.98
4.90	19.550	0.01	0.98	0.9608	6.4606	0.522	1.75	1.97
4.93	19.554	0.01	0.99	0.9523	6.4691	0.514	1.74	1.97
4.95	19.559	0.02	0.99	0.9438	6.4776	0.507	1.74	1.97
4.98	19.563	0.02	1.00	0.9355	6.4859	0.500	1.73	1.97
5.01	19.568	0.03	1.00	0.9272	6.4942	0.493	1.73	1.97
5.04	19.573	0.03	1.01	0.9189	6.5025	0.486	1.72	1.97
5.07	19.577	0.04	1.02	0.9108	6.5106	0.480	1.71	1.97
5.09	19.582	0.04	1.02	0.9027	6.5187	0.473	1.71	1.97
5.12	19.586	0.05	1.03	0.8946	6.5268	0.467	1.70	1.96
5.15	19.591	0.06	1.03	0.8867	6.5347	0.460	1.70	1.96
5.18	19.595	0.06	1.04	0.8788	6.5426	0.454	1.69	1.96
5.21	19.600	0.07	1.04	0.8709	6.5504	0.448	1.68	1.96
5.23	19.604	0.07	1.05	0.8632	6.5582	0.442	1.68	1.96
5.26	19.609	0.08	1.06	0.8555	6.5659	0.436	1.67	1.96
5.29	19.613	0.08	1.06	0.8478	6.5735	0.430	1.67	1.96
5.32	19.618	0.09	1.07	0.8404	6.5810	0.424	1.66	1.96
5.35	19.622	0.10	1.07	0.8329	6.5885	0.419	1.65	1.96
5.37	19.627	0.10	1.08	0.8255	6.5959	0.413	1.65	1.95
5.40	19.632	0.11	1.08	0.8182	6.6032	0.408	1.64	1.95
5.43	19.636	0.11	1.09	0.8109	6.6104	0.402	1.64	1.95

Section 8 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
5.43	19.916	0.00	1.09	0.8358	6.5878	0.403	1.64	1.99
5.48	19.924	0.01	1.10	0.8251	6.5979	0.394	1.63	1.99
5.53	19.932	0.02	1.11	0.8144	6.6086	0.386	1.62	1.99
5.58	19.940	0.03	1.12	0.8039	6.6191	0.377	1.61	1.98
5.63	19.948	0.04	1.13	0.7934	6.6296	0.369	1.60	1.98
5.67	19.956	0.05	1.14	0.7831	6.6399	0.361	1.59	1.98
5.72	19.964	0.06	1.15	0.7729	6.6501	0.353	1.58	1.98
5.77	19.972	0.07	1.16	0.7629	6.6601	0.346	1.57	1.98
5.82	19.980	0.08	1.17	0.7529	6.6701	0.338	1.57	1.97
5.87	19.988	0.09	1.18	0.7431	6.6799	0.331	1.56	1.97
5.92	19.996	0.10	1.19	0.7334	6.6896	0.324	1.55	1.97
5.97	20.003	0.11	1.20	0.7238	6.6991	0.318	1.54	1.97
6.02	20.011	0.12	1.20	0.7144	6.7086	0.311	1.53	1.97
6.07	20.019	0.13	1.21	0.7051	6.7178	0.305	1.52	1.96
6.12	20.027	0.14	1.22	0.6960	6.7270	0.299	1.51	1.96
6.16	20.035	0.14	1.23	0.6869	6.7360	0.293	1.50	1.96
6.21	20.043	0.15	1.24	0.6780	6.7449	0.287	1.49	1.96
6.26	20.051	0.16	1.25	0.6693	6.7537	0.282	1.48	1.96
6.31	20.059	0.17	1.26	0.6606	6.7623	0.277	1.47	1.95
6.36	20.067	0.18	1.27	0.6521	6.7708	0.271	1.47	1.95
6.41	20.075	0.19	1.28	0.6438	6.7792	0.266	1.46	1.95

Section 9 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
6.41	151.575	0.00	1.28	1.3219	6.1032	2.016	10.60	8.19
6.45	151.580	0.01	1.28	1.3782	6.0469	1.993	10.57	8.18
6.49	151.585	0.01	1.29	1.4336	5.9916	1.968	10.54	8.17
6.53	151.590	0.02	1.30	1.4881	5.9370	1.944	10.50	8.17
6.57	151.595	0.02	1.30	1.5418	5.8833	1.920	10.47	8.16
6.61	151.600	0.03	1.31	1.5946	5.8305	1.897	10.43	8.15
6.65	151.605	0.03	1.31	1.6466	5.7785	1.874	10.40	8.15
6.69	151.611	0.04	1.32	1.6977	5.7274	1.851	10.37	8.14
6.73	151.616	0.04	1.32	1.7481	5.6770	1.829	10.33	8.13
6.77	151.621	0.05	1.33	1.7977	5.6274	1.807	10.30	8.13
6.81	151.626	0.05	1.33	1.8464	5.5787	1.785	10.27	8.12
6.86	151.631	0.06	1.34	1.8944	5.5307	1.764	10.23	8.11
6.90	151.636	0.06	1.34	1.9417	5.4834	1.743	10.20	8.11
6.94	151.641	0.07	1.35	1.9881	5.4370	1.722	10.17	8.10
6.98	151.646	0.07	1.35	2.0339	5.3912	1.702	10.13	8.09
7.02	151.651	0.08	1.36	2.0789	5.3462	1.682	10.10	8.09
7.06	151.656	0.08	1.36	2.1232	5.3020	1.662	10.07	8.08
7.10	151.661	0.09	1.37	2.1667	5.2584	1.642	10.04	8.07
7.14	151.666	0.09	1.37	2.2096	5.2155	1.623	10.00	8.07
7.18	151.672	0.10	1.38	2.2518	5.1734	1.604	9.97	8.06
7.22	151.677	0.10	1.38	2.2932	5.1319	1.586	9.94	8.05

Section 10 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.22	151.677	0.00	1.38	2.2947	5.1319	1.586	9.94	8.05
7.25	151.681	0.00	1.39	2.2757	5.1509	1.572	9.91	8.05
7.28	151.684	0.01	1.39	2.2570	5.1696	1.559	9.89	8.04
7.31	151.688	0.01	1.40	2.2386	5.1880	1.546	9.86	8.04
7.35	151.692	0.02	1.40	2.2205	5.2061	1.533	9.84	8.03
7.38	151.696	0.02	1.40	2.2026	5.2240	1.520	9.81	8.03
7.41	151.700	0.02	1.41	2.1850	5.2416	1.507	9.79	8.02
7.44	151.704	0.03	1.41	2.1677	5.2589	1.494	9.76	8.02
7.47	151.708	0.03	1.42	2.1506	5.2759	1.482	9.74	8.01
7.50	151.712	0.04	1.42	2.1338	5.2927	1.470	9.72	8.01
7.53	151.716	0.04	1.42	2.1173	5.3093	1.457	9.69	8.00
7.57	151.720	0.04	1.43	2.1010	5.3256	1.445	9.67	8.00
7.60	151.724	0.05	1.43	2.0849	5.3417	1.433	9.64	7.99
7.63	151.728	0.05	1.43	2.0691	5.3575	1.422	9.62	7.99
7.66	151.732	0.06	1.44	2.0535	5.3731	1.410	9.59	7.98
7.69	151.736	0.06	1.44	2.0381	5.3885	1.398	9.57	7.98
7.72	151.740	0.06	1.45	2.0229	5.4036	1.387	9.55	7.97
7.76	151.744	0.07	1.45	2.0080	5.4186	1.376	9.52	7.97
7.79	151.748	0.07	1.45	1.9933	5.4333	1.365	9.50	7.96
7.82	151.752	0.07	1.46	1.9788	5.4478	1.354	9.47	7.96
7.85	151.756	0.08	1.46	1.9645	5.4621	1.343	9.45	7.95

Section 11 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.85	152.476	0.00	1.46	1.9633	6.4647	1.339	9.42	7.94
7.86	152.476	0.00	1.46	1.9653	6.4626	1.336	9.41	7.94
7.86	152.477	0.00	1.46	1.9673	6.4606	1.334	9.40	7.93
7.87	152.478	0.00	1.46	1.9693	6.4586	1.331	9.40	7.93
7.88	152.479	0.00	1.47	1.9713	6.4566	1.329	9.39	7.93
7.89	152.480	0.00	1.47	1.9732	6.4547	1.327	9.39	7.93
7.89	152.481	0.01	1.47	1.9752	6.4527	1.324	9.38	7.93
7.90	152.482	0.01	1.47	1.9771	6.4509	1.322	9.38	7.93
7.91	152.483	0.01	1.47	1.9790	6.4489	1.319	9.37	7.93
7.91	152.484	0.01	1.47	1.9809	6.4470	1.317	9.37	7.93
7.92	152.484	0.01	1.47	1.9828	6.4451	1.315	9.36	7.93
7.93	152.485	0.01	1.47	1.9847	6.4432	1.312	9.36	7.92
7.93	152.486	0.01	1.47	1.9866	6.4413	1.310	9.35	7.92
7.94	152.487	0.01	1.47	1.9884	6.4395	1.307	9.35	7.92
7.95	152.488	0.01	1.47	1.9902	6.4377	1.305	9.34	7.92
7.96	152.489	0.01	1.48	1.9920	6.4359	1.303	9.34	7.92
7.96	152.490	0.01	1.48	1.9938	6.4341	1.300	9.33	7.92
7.97	152.491	0.01	1.48	1.9956	6.4323	1.298	9.33	7.92
7.98	152.491	0.02	1.48	1.9974	6.4305	1.296	9.32	7.92
7.98	152.492	0.02	1.48	1.9991	6.4288	1.293	9.32	7.92
7.99	152.493	0.02	1.48	2.0009	6.4270	1.291	9.31	7.91

Section 12 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.99	152.493	0.00	1.48	2.0012	6.4270	1.291	9.31	7.91
8.01	152.495	0.00	1.48	2.0144	6.4138	1.286	9.30	7.91
8.02	152.497	0.00	1.48	2.0276	6.4006	1.280	9.29	7.91
8.04	152.499	0.01	1.49	2.0407	6.3875	1.275	9.27	7.91
8.06	152.501	0.01	1.49	2.0536	6.3746	1.270	9.26	7.90
8.07	152.504	0.01	1.49	2.0665	6.3617	1.264	9.25	7.90
8.09	152.506	0.01	1.49	2.0793	6.3489	1.259	9.24	7.90
8.11	152.508	0.01	1.49	2.0920	6.3362	1.254	9.23	7.90
8.12	152.510	0.02	1.50	2.1046	6.3236	1.249	9.21	7.89
8.14	152.512	0.02	1.50	2.1171	6.3111	1.243	9.20	7.89
8.16	152.514	0.02	1.50	2.1296	6.2988	1.238	9.19	7.89
8.17	152.516	0.02	1.50	2.1419	6.2863	1.233	9.18	7.89
8.19	152.518	0.02	1.50	2.1541	6.2741	1.228	9.17	7.88
8.20	152.520	0.03	1.51	2.1663	6.2619	1.223	9.15	7.88
8.22	152.522	0.03	1.51	2.1784	6.2498	1.218	9.14	7.88
8.24	152.524	0.03	1.51	2.1903	6.2379	1.213	9.13	7.88
8.25	152.526	0.03	1.51	2.2022	6.2260	1.208	9.12	7.87
8.27	152.528	0.03	1.51	2.2141	6.2142	1.203	9.11	7.87
8.29	152.530	0.04	1.52	2.2258	6.2024	1.198	9.09	7.87
8.30	152.533	0.04	1.52	2.2374	6.1908	1.193	9.08	7.87
8.32	152.535	0.04	1.52	2.2490	6.1792	1.189	9.07	7.86

Section 13 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
8.32	152.535	0.00	1.52	2.2835	6.1782	1.189	9.07	7.96
8.54	152.560	0.03	1.55	2.2708	6.1821	1.129	8.91	7.83
8.76	152.586	0.05	1.58	2.2791	6.1636	1.075	8.76	7.79
8.98	152.611	0.08	1.60	2.2802	6.1626	1.024	8.61	7.76
9.20	152.637	0.11	1.63	2.2749	6.1678	0.977	8.46	7.73
9.42	152.662	0.14	1.66	2.2643	6.1685	0.934	8.31	7.69
9.64	152.688	0.16	1.68	2.2491	6.1837	0.894	8.17	7.66
9.86	152.713	0.19	1.71	2.2300	6.2027	0.857	8.03	7.62
10.08	152.739	0.22	1.74	2.2078	6.2249	0.823	7.89	7.59
10.30	152.764	0.25	1.77	2.1829	6.2498	0.791	7.75	7.56
10.52	152.790	0.27	1.79	2.1559	6.2768	0.761	7.62	7.53
10.73	152.815	0.30	1.82	2.1271	6.3056	0.734	7.49	7.49
10.95	152.841	0.33	1.85	2.0970	6.3357	0.709	7.36	7.46
11.17	152.866	0.35	1.88	2.0658	6.3669	0.686	7.23	7.43
11.39	152.892	0.38	1.90	2.0338	6.3989	0.664	7.11	7.39
11.61	152.917	0.41	1.93	2.0014	6.4313	0.644	6.99	7.36
11.83	152.943	0.44	1.96	1.9685	6.4642	0.625	6.86	7.33
12.05	152.968	0.46	1.99	1.9356	6.4971	0.608	6.75	7.30
12.27	152.994	0.49	2.01	1.9026	6.5301	0.592	6.63	7.27
12.49	153.020	0.52	2.04	1.8697	6.5630	0.577	6.52	7.23
12.71	153.045	0.55	2.07	1.8370	6.5956	0.563	6.40	7.20

Section 14 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
12.71	153.045	0.00	2.07	1.8442	6.5956	0.563	6.40	7.20
12.81	153.055	0.01	2.08	1.7846	6.6551	0.558	6.37	7.19
12.91	153.065	0.02	2.08	1.7283	6.7116	0.553	6.33	7.18
13.02	153.076	0.03	2.09	1.6750	6.7648	0.548	6.29	7.17
13.12	153.086	0.04	2.10	1.6245	6.8153	0.544	6.26	7.16
13.22	153.096	0.05	2.11	1.5767	6.8630	0.539	6.22	7.15
13.32	153.106	0.05	2.12	1.5315	6.9083	0.535	6.19	7.14
13.42	153.116	0.06	2.13	1.4886	6.9512	0.530	6.15	7.13
13.53	153.126	0.07	2.14	1.4480	6.9918	0.526	6.11	7.12
13.63	153.137	0.08	2.15	1.4095	7.0303	0.522	6.09	7.11
13.73	153.147	0.09	2.16	1.3730	7.0668	0.518	6.04	7.10
13.83	153.157	0.10	2.17	1.3383	7.1014	0.514	6.01	7.09
13.93	153.167	0.11	2.18	1.3055	7.1343	0.510	5.98	7.08
14.04	153.177	0.12	2.18	1.2743	7.1655	0.507	5.94	7.07
14.14	153.187	0.13	2.19	1.2446	7.1951	0.503	5.91	7.06
14.24	153.198	0.14	2.20	1.2165	7.2233	0.500	5.87	7.05
14.34	153.208	0.14	2.21	1.1897	7.2500	0.496	5.84	7.04
14.44	153.218	0.15	2.22	1.1643	7.2755	0.493	5.81	7.03
14.55	153.229	0.16	2.23	1.1401	7.2996	0.489	5.77	7.02
14.65	153.239	0.17	2.24	1.1171	7.3227	0.486	5.74	7.01
14.75	153.249	0.18	2.25	1.0952	7.3446	0.483	5.71	7.00

Section 15 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
14.75	154.098	0.00	2.25	1.1044	6.3427	0.483	5.69	6.98
14.90	154.112	0.01	2.26	1.0592	6.3879	0.478	5.64	6.97
15.06	154.125	0.03	2.27	1.0160	6.4309	0.473	5.59	6.95
15.21	154.138	0.04	2.29	0.9775	6.4694	0.469	5.54	6.94
15.36	154.151	0.05	2.30	0.9423	6.5046	0.464	5.49	6.92
15.51	154.164	0.07	2.31	0.9101	6.5368	0.460	5.45	6.91
15.67	154.177	0.08	2.33	0.8806	6.5663	0.456	5.40	6.89
15.82	154.190	0.09	2.34	0.8535	6.5934	0.451	5.36	6.88
15.97	154.204	0.11	2.35	0.8286	6.6183	0.448	5.31	6.86
16.12	154.217	0.12	2.37	0.8057	6.6412	0.444	5.26	6.85
16.28	154.230	0.13	2.38	0.7846	6.6623	0.440	5.22	6.83
16.43	154.243	0.15	2.40	0.7651	6.6818	0.437	5.18	6.82
16.58	154.256	0.16	2.41	0.7470	6.6999	0.433	5.13	6.80
16.73	154.269	0.17	2.42	0.7303	6.7166	0.430	5.09	6.79
16.89	154.282	0.19	2.44	0.7148	6.7321	0.427	5.04	6.78
17.04	154.295	0.20	2.45	0.7003	6.7466	0.424	5.00	6.76
17.19	154.309	0.21	2.46	0.6869	6.7600	0.421	4.96	6.75
17.34	154.322	0.23	2.48	0.6743	6.7726	0.418	4.92	6.73
17.50	154.335	0.24	2.49	0.6625	6.7844	0.415	4.87	6.72
17.65	154.348	0.25	2.50	0.6515	6.7954	0.412	4.83	6.70
17.80	154.361	0.27	2.52	0.6411	6.8057	0.409	4.79	6.69

Section 16 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
17.80	154.361	0.00	2.52	0.6478	6.8057	0.409	4.79	6.69
17.88	154.368	0.01	2.52	0.6507	6.8027	0.408	4.77	6.68
17.97	154.376	0.01	2.53	0.6534	6.8001	0.406	4.75	6.67
18.05	154.383	0.02	2.54	0.6558	6.7977	0.405	4.73	6.66
18.13	154.390	0.03	2.55	0.6580	6.7955	0.403	4.70	6.66
18.22	154.397	0.04	2.55	0.6599	6.7935	0.402	4.68	6.65
18.30	154.404	0.04	2.56	0.6616	6.7918	0.400	4.66	6.64
18.38	154.412	0.05	2.57	0.6631	6.7903	0.399	4.64	6.63
18.47	154.419	0.06	2.57	0.6645	6.7890	0.397	4.62	6.63
18.55	154.426	0.07	2.58	0.6656	6.7879	0.396	4.59	6.62
18.64	154.433	0.07	2.59	0.6665	6.7869	0.394	4.57	6.61
18.72	154.440	0.08	2.60	0.6673	6.7861	0.393	4.55	6.60
18.80	154.448	0.09	2.60	0.6679	6.7855	0.392	4.53	6.59
18.89	154.455	0.10	2.61	0.6684	6.7850	0.390	4.51	6.59
18.97	154.462	0.10	2.62	0.6687	6.7847	0.389	4.49	6.58
19.05	154.469	0.11	2.63	0.6689	6.7845	0.388	4.47	6.57
19.14	154.476	0.12	2.63	0.6690	6.7845	0.386	4.45	6.56
19.22	154.484	0.12	2.64	0.6689	6.7845	0.385	4.43	6.56
19.30	154.491	0.13	2.65	0.6687	6.7847	0.384	4.41	6.55
19.39	154.498	0.14	2.66	0.6684	6.7850	0.383	4.38	6.54
19.47	154.505	0.15	2.66	0.6680	6.7854	0.382	4.36	6.53

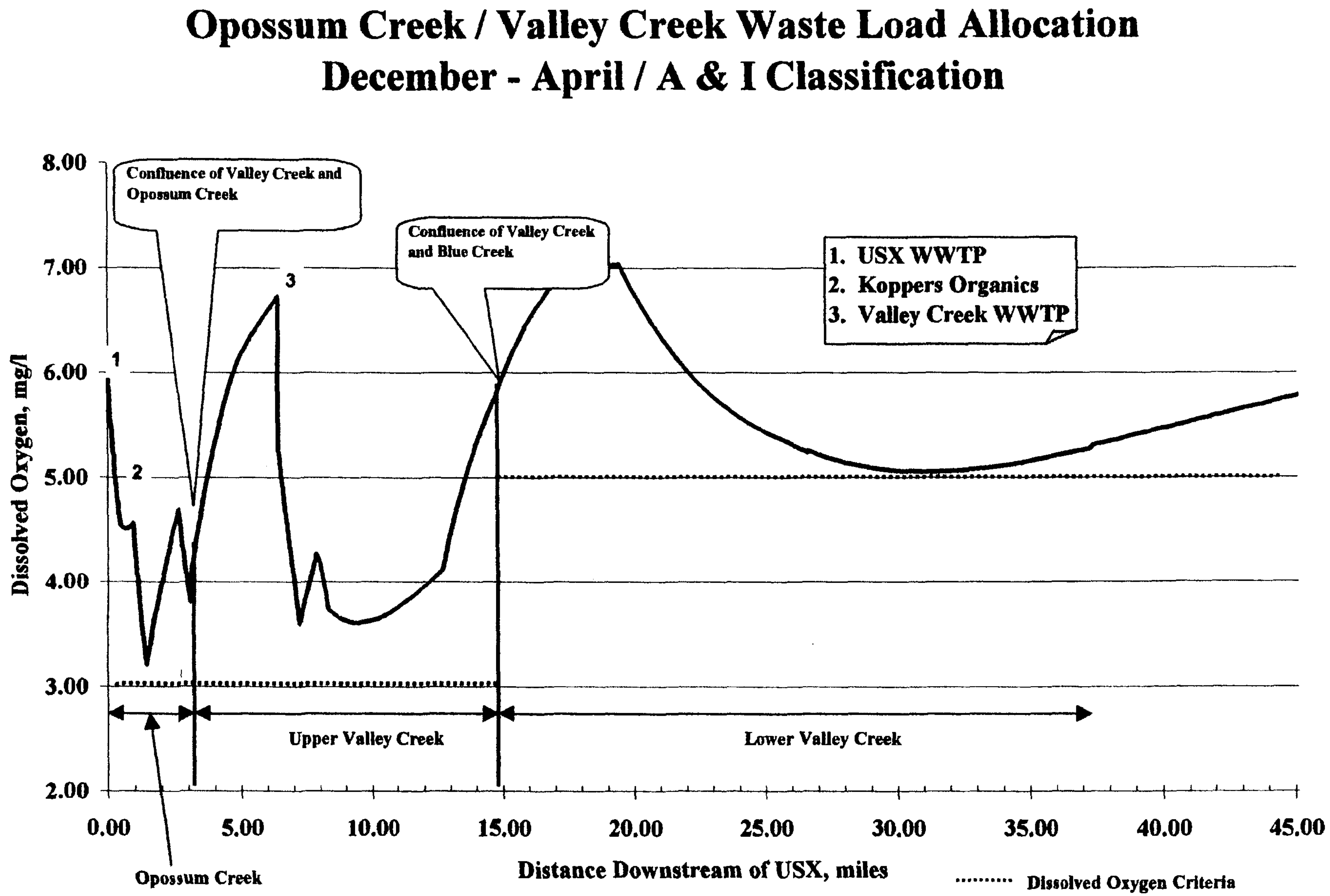
Section 17 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
19.47	155.185	0.00	2.66	0.6764	6.7820	0.382	4.35	6.52
19.78	155.218	0.03	2.69	0.7447	6.7133	0.379	4.28	6.50
20.10	155.250	0.05	2.72	0.8079	6.6502	0.375	4.20	6.47
20.41	155.283	0.08	2.74	0.8662	6.5918	0.372	4.13	6.44
20.72	155.315	0.11	2.77	0.9200	6.5381	0.369	4.06	6.41
21.04	155.348	0.14	2.80	0.9695	6.4886	0.366	3.99	6.38
21.35	155.380	0.16	2.83	1.0150	6.4431	0.364	3.92	6.35
21.66	155.413	0.19	2.85	1.0567	6.4014	0.361	3.85	6.33
21.97	155.445	0.22	2.88	1.0949	6.3633	0.358	3.79	6.30
22.29	155.478	0.25	2.91	1.1297	6.3284	0.356	3.72	6.27
22.60	155.510	0.27	2.94	1.1614	6.2968	0.354	3.66	6.24
22.91	155.543	0.30	2.96	1.1901	6.2680	0.351	3.59	6.22
23.23	155.575	0.33	2.99	1.2161	6.2421	0.349	3.53	6.19
23.54	155.608	0.36	3.02	1.2395	6.2187	0.347	3.47	6.16
23.85	155.640	0.38	3.05	1.2604	6.1977	0.345	3.41	6.14
24.17	155.673	0.41	3.07	1.2791	6.1791	0.343	3.35	6.11
24.48	155.705	0.44	3.10	1.2956	6.1626	0.341	3.29	6.08
24.79	155.738	0.47	3.13	1.3102	6.1480	0.339	3.24	6.05
25.10	155.770	0.49	3.16	1.3228	6.1353	0.337	3.18	6.03
25.42	155.803	0.52	3.18	1.3338	6.1244	0.335	3.13	6.00
25.73	155.835	0.55	3.21	1.3430	6.1151	0.333	3.07	5.98

Section18 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
25.73	155.835	0.00	3.21	1.3467	6.1151	0.333	3.07	5.98
25.77	155.839	0.00	3.21	1.3492	6.1127	0.333	3.07	5.97
25.82	155.843	0.01	3.22	1.3516	6.1103	0.333	3.06	5.97
25.86	155.848	0.01	3.22	1.3539	6.1080	0.333	3.05	5.96
25.90	155.852	0.02	3.23	1.3562	6.1057	0.332	3.04	5.96
25.95	155.856	0.02	3.23	1.3585	6.1034	0.332	3.04	5.96
25.99	155.860	0.02	3.23	1.3607	6.1012	0.332	3.03	5.95
26.03	155.864	0.03	3.24	1.3629	6.0990	0.331	3.02	5.95
26.08	155.869	0.03	3.24	1.3651	6.0968	0.331	3.01	5.95
26.12	155.873	0.03	3.24	1.3672	6.0947	0.331	3.01	5.94
26.17	155.877	0.04	3.25	1.3693	6.0926	0.330	3.00	5.94
26.21	155.881	0.04	3.25	1.3713	6.0905	0.330	2.99	5.94
26.25	155.885	0.05	3.26	1.3734	6.0885	0.330	2.99	5.93
26.30	155.889	0.05	3.26	1.3754	6.0865	0.330	2.98	5.93
26.34	155.894	0.05	3.26	1.3773	6.0846	0.329	2.97	5.93
26.38	155.898	0.06	3.27	1.3792	6.0826	0.329	2.96	5.92
26.43	155.902	0.06	3.27	1.3811	6.0807	0.329	2.96	5.92
26.47	155.906	0.06	3.27	1.3830	6.0789	0.328	2.95	5.91
26.51	155.910	0.07	3.28	1.3848	6.0771	0.329	2.94	5.91
26.56	155.915	0.07	3.29	1.3866	6.0753	0.328	2.94	5.91
26.60	155.919	0.08	3.29	1.3884	6.0735	0.328	2.93	5.90

Section 19 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
26.60	157.399	0.00	3.29	1.3947	6.0728	0.329	2.92	6.89
27.00	157.437	0.03	3.32	1.4073	6.0600	0.328	2.86	6.86
27.40	157.476	0.07	3.36	1.4176	6.0494	0.326	2.79	6.83
27.80	157.514	0.10	3.39	1.4263	6.0416	0.325	2.73	6.79
28.20	157.553	0.14	3.42	1.4328	6.0348	0.324	2.67	6.76
28.60	157.591	0.17	3.46	1.4376	6.0297	0.323	2.62	6.73
29.00	157.630	0.21	3.49	1.4407	6.0266	0.321	2.56	6.70
29.40	157.668	0.24	3.53	1.4423	6.0249	0.320	2.50	6.67
29.80	157.707	0.28	3.56	1.4426	6.0247	0.318	2.45	6.64
30.20	157.745	0.31	3.60	1.4416	6.0258	0.317	2.40	6.61
30.60	157.784	0.35	3.63	1.4392	6.0281	0.316	2.34	6.57
31.00	157.822	0.38	3.67	1.4358	6.0314	0.314	2.29	6.54
31.40	157.861	0.42	3.70	1.4314	6.0359	0.312	2.24	6.51
31.80	157.899	0.45	3.74	1.4261	6.0412	0.311	2.19	6.48
32.20	157.938	0.49	3.77	1.4199	6.0474	0.309	2.15	6.45
32.60	157.976	0.52	3.81	1.4129	6.0544	0.308	2.10	6.42
33.00	158.015	0.55	3.84	1.4051	6.0621	0.306	2.05	6.39
33.40	158.053	0.59	3.87	1.3968	6.0705	0.305	2.01	6.36
33.80	158.092	0.62	3.91	1.3878	6.0795	0.303	1.97	6.33
34.20	158.130	0.66	3.94	1.3783	6.0890	0.301	1.92	6.30
34.60	158.169	0.69	3.98	1.3682	6.0990	0.300	1.88	6.29

Section 20 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
34.60	158.169	0.00	3.98	1.3738	6.0990	0.300	1.88	6.28
34.74	158.182	0.01	3.99	1.3718	6.1009	0.299	1.87	6.27
34.88	158.195	0.02	4.00	1.3698	6.1029	0.298	1.86	6.26
35.01	158.208	0.03	4.01	1.3677	6.1049	0.297	1.85	6.25
35.15	158.222	0.05	4.02	1.3656	6.1070	0.296	1.84	6.24
35.29	158.235	0.06	4.03	1.3635	6.1092	0.296	1.83	6.23
35.43	158.248	0.07	4.05	1.3613	6.1114	0.295	1.82	6.22
35.56	158.261	0.08	4.06	1.3590	6.1137	0.294	1.81	6.21
35.70	158.275	0.09	4.07	1.3567	6.1160	0.293	1.80	6.20
35.84	158.288	0.10	4.08	1.3544	6.1183	0.292	1.79	6.19
35.98	158.301	0.11	4.09	1.3520	6.1207	0.292	1.78	6.18
36.11	158.314	0.12	4.10	1.3496	6.1231	0.291	1.77	6.17
36.25	158.328	0.14	4.11	1.3472	6.1256	0.290	1.76	6.16
36.39	158.341	0.15	4.13	1.3447	6.1280	0.289	1.75	6.15
36.53	158.354	0.16	4.14	1.3421	6.1306	0.289	1.75	6.14
36.66	158.367	0.17	4.15	1.3396	6.1331	0.288	1.74	6.13
36.80	158.381	0.18	4.16	1.3370	6.1357	0.287	1.73	6.12
36.94	158.394	0.19	4.17	1.3344	6.1383	0.287	1.72	6.12
37.08	158.407	0.20	4.18	1.3317	6.1409	0.286	1.71	6.11
37.21	158.420	0.22	4.19	1.3291	6.1436	0.285	1.70	6.10
37.35	158.433	0.23	4.21	1.3263	6.1463	0.285	1.69	6.09

Section 21 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
37.35	160.813	0.00	4.21	1.3293	6.1442	0.287	1.69	5.08
37.74	160.851	0.03	4.24	1.3208	6.1523	0.286	1.67	5.05
38.14	160.888	0.06	4.27	1.3123	6.1609	0.284	1.64	5.03
38.53	160.926	0.10	4.30	1.3038	6.1696	0.283	1.62	5.00
38.93	160.963	0.13	4.33	1.2948	6.1784	0.281	1.59	4.98
39.32	161.001	0.16	4.37	1.2859	6.1873	0.280	1.57	4.95
39.71	161.038	0.19	4.40	1.2769	6.1963	0.279	1.55	4.93
40.11	161.076	0.23	4.43	1.2679	6.2053	0.277	1.52	4.90
40.50	161.113	0.26	4.46	1.2588	6.2145	0.276	1.50	4.88
40.90	161.150	0.29	4.50	1.2496	6.2236	0.275	1.48	4.85
41.29	161.188	0.32	4.53	1.2404	6.2329	0.273	1.45	4.83
41.68	161.225	0.36	4.56	1.2311	6.2421	0.272	1.43	4.80
42.08	161.263	0.39	4.59	1.2218	6.2514	0.270	1.41	4.78
42.47	161.300	0.42	4.63	1.2125	6.2607	0.269	1.39	4.75
42.87	161.338	0.45	4.66	1.2032	6.2700	0.268	1.37	4.73
43.26	161.375	0.48	4.69	1.1939	6.2793	0.266	1.35	4.70
43.65	161.413	0.52	4.72	1.1845	6.2887	0.265	1.33	4.68
44.05	161.450	0.55	4.75	1.1752	6.2980	0.264	1.31	4.65
44.44	161.487	0.58	4.79	1.1659	6.3073	0.262	1.29	4.63
44.84	161.525	0.61	4.82	1.1565	6.3166	0.261	1.27	4.61
45.23	161.562	0.65	4.85	1.1472	6.3260	0.260	1.25	4.58


Opossum Creek / Valley Creek Waste Load Allocation
December - April / A & I Classification
Confluence of Valley Creek and Opossum Creek
Confluence of Valley Creek and Blue Creek
1. USX WWTP
2. Koppers Organics
3. Valley Creek WWTP
1
2
3
Dissolved Oxygen, mg/l
8.00
7.00
6.00
5.00
4.00
3.00
2.00
Upper Valley Creek
Lower Valley Creek
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Opossum Creek
Distance Downstream of USX, miles
Dissolved Oxygen Criteria

Water Quality
Steady-State Stream Model

Enter the Number of Sections = 21.000
Total Length (miles) = 45.230

Opossum Creek / Valley Creek Waste Load Allocation - December - April WLA / A&I Classification

Valley Creek WWTP Effluent Conditions				
Design Flow, MGD	$CBOD_5$, mg/l	NH_3-N, mg/l	TKN, mg/l	D.O. (minimum), mg/l
85.00	11.0	2.0	4.0	5.0

HeadWater Data

Recession Index (G) =	60.000
Mean Annual Prec. (P) =	60.000
Drainage Area (M^2) =	0.000
Temp (C°) =	20.000
CHL =	0.000
Headwater Flow (cfs) =	1.100
CBODU (mg/l) =	3.000
NH_3ODU (mg/l) =	0.686
TONODU (mg/l) =	6.855
Headwater D.O.(mg/l) =	7.00

Flow Multiplier
1.00

Tributary Flows (cfs)
1.10
4.16
0.89
2.06
2.38
1.95
3.91
5.97

Dam Data

Dam Located at Beginning of Section =	0.00
Water Quality Factor =	1.80
Wier Dam Coefficient =	0.60
Difference in Water Level (ft) =	1.00

Stream flow @ Valley Creek WWTP (cfs)
24.347

	Use Goal Seek
Minimum Dissolved Oxygen Concentration (mg/l) (Opossum Creek) =	3.20
Minimum Dissolved Oxygen Concentration (mg/l) (Upper Valley Creek) =	3.59
Minimum Dissolved Oxygen Concentration (mg/l) (Lower Valley Creek) =	5.05
CBODu Concentration at End of Modeled Reach (mg/l) =	7.20

Enter Tributary Conditions (if none, leave blank)

Sections	G	P	TONODU (mg/l)	CBODU (mg/l)	NH3ODU (mg/l)	DO (mg/l)	TQ_{10} (cfs)	Temp. (C°)	Drainage Area (M^2)
1.00						0.000	0.00	0.00	0.00
2.00						0.000	0.00	0.00	0.00
3.00						0.000	0.00	0.00	0.00
4.00						0.000	0.00	0.00	0.00
5.00						0.000	0.00	0.00	0.00
6.00			4.57	2.00	0.457	5.000	4.16	20.00	0.00
7.00						0.000	0.00	0.00	0.00
8.00			4.57	2.00	0.457	6.000	0.89	20.00	0.00
9.00			91.40	37.60	45.7000	3.000	0.00	0.00	0.00
10.00						0.000	0.00	0.00	0.00
11.00			4.57	2.00	0.457	6.000	2.06	20.00	0.00
12.00						0.000	0.00	0.00	0.00
13.00						0.000	0.00	0.00	0.00
14.00						0.000	0.00	0.00	0.00
15.00			4.57	2.00	0.457	6.000	2.38	20.00	0.00
16.00						0.000	0.00	0.00	0.00
17.00	65.000	56.00	4.57	2.00	0.457	6.000	1.95	20.00	15.60
18.00						0.000	0.00	0.00	0.00
19.00	65.000	56.00	4.57	2.00	0.457	6.000	3.91	20.00	32.70
20.00						0.000	0.00	0.00	0.00
21.00	65.000	56.00	4.57	2.00	0.457	6.000	5.97	20.00	51.20
22.00						0.000	0.00	0.00	0.00

Enter Incremental Inflow Conditions (if none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (°C)	Q10 (cfs)	Drainage Area (mi^2)
1.00	3.000	0.69	6.86	7.73	0.028	20.000	0.00	
2.00	3.000	0.69	6.86	7.73	0.028	20.000	0.00	
3.00	3.000	0.69	6.86	7.73	0.030	20.000	0.00	
4.00	3.000	0.69	6.86	7.73	0.345	20.000	0.00	
5.00	3.000	0.69	6.86	7.73	0.128	20.000	0.00	
6.00	3.000	0.69	6.86	7.73	0.304	20.000	0.00	
7.00	3.000	0.69	6.86	7.73	0.095	20.000	0.00	
8.00	3.000	0.69	6.86	7.73	0.166	20.000	0.00	
9.00	3.000	0.69	6.86	7.73	0.146	20.000	0.00	
10.00	3.000	0.69	6.86	7.73	0.114	20.000	0.00	
11.00	3.000	0.69	6.86	7.73	0.025	20.000	0.00	
12.00	3.000	0.69	6.86	7.73	0.059	20.000	0.00	
13.00	3.000	0.69	6.86	7.73	0.734	20.000	0.00	
14.00	3.000	0.69	6.86	7.73	0.236	20.000	0.00	
15.00	3.000	0.69	6.86	7.73	0.305	20.000	0.00	
16.00	3.000	0.69	6.86	7.73	0.167	20.000	0.00	
17.00	3.000	0.69	6.86	7.73	0.751	20.000	0.00	
18.00	3.000	0.69	6.86	7.73	0.101	20.000	0.00	
19.00	3.000	0.69	6.86	7.73	0.928	20.000	0.00	
20.00	3.000	0.69	6.86	7.73	0.319	20.000	0.00	
21.00	3.000	0.69	6.86	7.73	0.902	20.000	0.00	
22.00				7.73	0.000	20.000	0.00	

Enter Effluent Conditions (if none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (°C)	pH	Max. Instream NH3 (mg/l)	NH3 Toxicity (mg/l)	NH3 WQ Limit (mg/l)
1.00	26.000	9.14	9.14	6.00	17.017	20.000	7.00	3.08	3.27	2.00
2.00	37.500	91.40	137.10	5.00	0.0557	20.000				0.00
3.00		0.00		0.00						0.00
4.00		0.00		0.00						0.00
5.00		0.00		0.00						0.00
6.00		0.00		0.00						0.00
7.00		0.00		0.00						0.00
8.00		0.00		0.00						0.00
9.00	33.000	9.14	9.14	5.00	131.500	20.000	7.00	3.08	3.56	2.00
10.00		0.00		0.00						0.00
11.00		0.00		0.00						0.00
12.00		0.00		0.00						0.00
13.00		0.00		0.00						0.00
14.00		0.00		0.00						0.00
15.00		0.00		0.00						0.00
16.00		0.00		0.00						0.00
17.00		0.00		0.00						0.00
18.00		0.00		0.00						0.00
19.00		0.00		0.00						0.00
20.00		0.00		0.00						0.00
21.00		0.00		0.00						0.00
22.00		0.00		0.00						0.00

The most stringent of the two values will be implemented as the discharge limit.

Enter Section Characteristics (if none, leave blank)

Sections	Beginning Elev. (ft)	Ending Elev. (ft)	Elev.Change (ft)	Length (miles)	Average Elev. (ft)	Section Slope (ft/mi)	Average Flow (cfs)	Average Vel. (ft/sec)
1.00	498.000	490.00	8.00	0.4700	494.000	17.021	18.13	0.311
2.00	490.000	480.00	10.00	0.4700	485.000	21.277	18.21	0.312
3.00	480.000	475.00	5.00	0.5100	477.500	9.804	18.24	0.312
4.00	475.000	455.00	20.00	1.1900	465.000	16.807	18.43	0.314
5.00	455.000	452.00	3.00	0.4400	453.500	6.818	18.67	0.317
6.00	452.000	435.00	17.00	1.7900	443.500	9.497	23.04	0.340
7.00	435.000	430.00	5.00	0.5600	432.500	8.929	23.24	0.342
8.00	430.000	422.00	8.00	0.9800	426.000	8.163	24.26	0.353
9.00	422.000	420.00	2.00	0.8100	421.000	2.469	155.92	0.501
10.00	420.000	412.00	8.00	0.6300	416.000	12.698	156.05	0.501
11.00	412.000	411.00	1.00	0.1400	411.500	7.143	158.18	0.508
12.00	411.000	410.00	1.00	0.3300	410.500	3.030	158.22	0.509
13.00	410.000	380.00	30.00	4.3900	395.000	6.834	158.62	0.509
14.00	380.000	362.00	18.00	2.0400	371.000	8.824	159.10	0.711
15.00	362.000	331.00	31.00	3.0500	346.500	10.164	161.75	0.720
16.00	331.000	318.00	13.00	1.6700	324.500	7.784	161.99	0.721
17.00	318.000	298.00	20.00	6.2600	308.000	3.195	164.40	0.729
18.00	298.000	294.30	3.70	0.8700	296.150	4.253	164.82	0.730
19.00	294.300	260.00	34.30	8.0000	277.150	4.288	169.25	0.745
20.00	260.000	258.70	1.30	2.7500	259.350	0.473	169.67	0.767
21.00	258.700	255.00	3.70	7.8800	256.850	0.470	176.45	0.780
22.00	255.000		255.00		127.500	#DIV/0!	0.00	#DIV/0!

	Reaction Rates @ 20° C					Corrected Rates @ New Temp.				
Sections	**Kd**	**KNH3**	**KON**	**T. Coefficient**	**Reaeration**	**Kd**	**KNH3**	**KON**	**Ave. Reaeration**	**Mixed Temp.(° C)**
1.00	1.300	1.50	0.80	1.30	6.889	1.300	1.43	0.80	6.89	20.00
2.00	1.300	1.50	0.80	1.30	8.634	1.300	1.34	0.80	8.63	20.00
3.00	1.300	1.50	0.80	1.30	3.982	1.300	1.34	0.80	3.98	20.00
4.00	1.300	1.50	0.80	1.30	6.867	1.300	1.21	0.80	6.87	20.00
5.00	1.300	1.50	0.80	1.30	2.807	1.300	1.35	0.80	2.81	20.00
6.00	0.400	1.50	0.10	1.30	4.203	0.400	1.30	0.10	4.20	20.00
7.00	0.400	1.50	0.10	1.30	3.975	0.400	1.43	0.10	3.97	20.00
8.00	0.400	1.50	0.10	1.30	3.742	0.400	1.45	0.10	3.74	20.00
9.00	0.400	1.50	0.10	0.88	1.088	0.400	1.39	0.10	1.09	20.00
10.00	0.400	1.50	0.10	0.89	5.600	0.400	1.26	0.10	5.60	20.00
11.00	0.400	1.50	0.10	0.88	3.190	0.400	1.32	0.10	3.19	20.00
12.00	0.400	1.50	0.10	0.88	1.354	0.400	1.31	0.10	1.35	20.00
13.00	0.400	1.50	0.10	0.88	3.060	0.400	1.27	0.10	3.06	20.00
14.00	0.400	1.50	0.10	0.88	5.520	0.400	1.31	0.10	5.52	20.00
15.00	0.400	1.50	0.10	0.88	6.440	0.400	1.42	0.10	6.44	20.00
16.00	0.400	1.50	0.10	0.99	4.937	0.400	1.47	0.10	4.94	20.00
17.00	0.400	1.50	0.10	0.88	1.560	0.400	1.47	0.10	1.56	20.00
18.00	0.400	1.50	0.10	0.89	1.370	0.400	1.39	0.10	1.37	20.00
19.00	0.400	1.50	0.10	0.88	1.370	0.400	1.39	0.10	1.37	20.00
20.00	0.300	1.50	0.10	0.88	1.140	0.300	1.39	0.10	1.14	20.00
21.00	0.300	1.50	0.10	0.88	1.140	0.300	1.39	0.10	1.14	20.00
22.00	0.000	0.00	0.00	0.00	#DIV/0!	0.000	0.00	0.00	#DIV/0!	0.00

Model Output

Section 1 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.000	19.117	0.00	0.00	2.8466	6.061	9.627	24.60	9.00
0.024	19.118	0.00	0.00	2.9561	5.949	9.602	24.45	8.97
0.047	19.120	0.01	0.01	3.0651	5.842	9.578	24.31	8.93
0.071	19.121	0.01	0.01	3.1677	5.740	9.554	24.16	8.90
0.094	19.123	0.02	0.02	3.2661	5.641	9.530	24.01	8.87
0.118	19.124	0.02	0.02	3.3603	5.547	9.506	23.87	8.84
0.141	19.125	0.03	0.03	3.4506	5.457	9.482	23.72	8.80
0.165	19.127	0.03	0.03	3.5371	5.370	9.458	23.58	8.77
0.188	19.128	0.04	0.04	3.6199	5.288	9.434	23.44	8.74
0.212	19.130	0.04	0.04	3.6990	5.208	9.410	23.30	8.71
0.235	19.131	0.05	0.05	3.7747	5.133	9.386	23.16	8.67
0.259	19.132	0.05	0.05	3.8471	5.060	9.362	23.02	8.64
0.282	19.134	0.06	0.06	3.9162	4.991	9.338	22.88	8.61
0.306	19.135	0.06	0.06	3.9821	4.925	9.315	22.74	8.58
0.329	19.137	0.06	0.06	4.0450	4.862	9.291	22.60	8.55
0.353	19.138	0.07	0.07	4.1050	4.802	9.267	22.46	8.51
0.376	19.139	0.07	0.07	4.1622	4.745	9.244	22.33	8.48
0.400	19.141	0.08	0.08	4.2166	4.691	9.220	22.19	8.45
0.423	19.142	0.08	0.08	4.2683	4.639	9.197	22.06	8.42
0.447	19.144	0.09	0.09	4.3175	4.590	9.173	21.93	8.39
0.470	19.145	0.09	0.09	4.3642	4.543	9.150	21.79	8.36

Section 2 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.47	19.201	0.00	0.09	4.3657	4.545	9.404	21.84	8.75
0.49	19.202	0.00	0.10	4.3737	4.537	9.384	21.71	8.72
0.52	19.203	0.01	0.10	4.3806	4.530	9.364	21.58	8.69
0.54	19.205	0.01	0.11	4.3863	4.524	9.344	21.45	8.66
0.56	19.206	0.02	0.11	4.3910	4.520	9.324	21.32	8.62
0.59	19.208	0.02	0.12	4.3945	4.516	9.304	21.19	8.59
0.61	19.209	0.03	0.12	4.3971	4.514	9.284	21.06	8.56
0.63	19.210	0.03	0.12	4.3986	4.512	9.264	20.94	8.53
0.66	19.212	0.04	0.13	4.3993	4.511	9.244	20.81	8.50
0.68	19.213	0.04	0.13	4.3991	4.512	9.224	20.68	8.47
0.71	19.215	0.05	0.14	4.3980	4.513	9.204	20.56	8.43
0.73	19.216	0.05	0.14	4.3961	4.515	9.184	20.44	8.40
0.75	19.217	0.06	0.15	4.3934	4.517	9.164	20.31	8.37
0.78	19.219	0.06	0.15	4.3900	4.521	9.144	20.19	8.34
0.80	19.220	0.06	0.16	4.3860	4.525	9.124	20.07	8.31
0.82	19.222	0.07	0.16	4.3812	4.529	9.104	19.95	8.28
0.85	19.223	0.07	0.17	4.3758	4.535	9.084	19.83	8.25
0.87	19.224	0.08	0.17	4.3698	4.541	9.064	19.71	8.22
0.89	19.226	0.09	0.18	4.3631	4.547	9.044	19.59	8.19
0.92	19.227	0.09	0.18	4.3560	4.555	9.024	19.47	8.16
0.94	19.229	0.09	0.18	4.3483	4.562	9.004	19.354	8.13

Section 3 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.94	18.229	0.00	0.18	4.3506	4.563	8.004	19.35	8.13
0.97	18.230	0.00	0.19	4.4416	4.472	7.983	19.23	8.10
0.99	18.232	0.01	0.19	4.5296	4.384	7.961	19.10	8.06
1.02	18.233	0.01	0.20	4.6151	4.298	7.939	18.98	8.03
1.04	18.235	0.02	0.20	4.6979	4.216	7.918	18.85	8.00
1.07	18.236	0.02	0.21	4.7781	4.135	7.896	18.73	7.97
1.09	18.238	0.03	0.21	4.8559	4.057	7.875	18.61	7.94
1.12	18.239	0.03	0.22	4.9311	3.982	7.853	18.49	7.90
1.14	18.241	0.04	0.22	5.0040	3.909	7.832	18.36	7.87
1.17	18.242	0.04	0.23	5.0746	3.839	7.810	18.24	7.84
1.20	18.244	0.05	0.23	5.1427	3.771	7.789	18.13	7.81
1.22	18.245	0.05	0.24	5.2087	3.705	7.767	18.01	7.78
1.25	18.247	0.06	0.24	5.2724	3.641	7.746	17.89	7.75
1.27	18.248	0.06	0.25	5.3340	3.579	7.725	17.77	7.72
1.30	18.250	0.07	0.25	5.3935	3.520	7.703	17.66	7.69
1.32	18.251	0.07	0.26	5.4510	3.462	7.682	17.54	7.66
1.35	18.253	0.08	0.26	5.5064	3.407	7.661	17.43	7.62
1.37	18.255	0.08	0.27	5.5598	3.354	7.639	17.31	7.59
1.40	18.256	0.09	0.27	5.6114	3.302	7.618	17.20	7.56
1.42	18.258	0.09	0.28	5.6610	3.252	7.597	17.09	7.53
1.45	18.259	0.10	0.28	5.7088	3.205	7.576	16.98	7.50

Section 4 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
1.45	18.259	0.00	0.28	5.7128	3.205	7.576	16.98	7.50
1.51	18.276	0.01	0.30	5.6174	3.304	7.533	16.71	7.43
1.57	18.294	0.02	0.31	5.5250	3.396	7.490	16.45	7.36
1.63	18.311	0.03	0.32	5.4354	3.486	7.448	16.19	7.30
1.69	18.328	0.05	0.33	5.3484	3.573	7.405	15.94	7.23
1.75	18.345	0.06	0.34	5.2639	3.657	7.362	15.69	7.16
1.81	18.363	0.07	0.35	5.1819	3.739	7.320	15.44	7.10
1.87	18.380	0.08	0.37	5.1020	3.819	7.277	15.20	7.03
1.93	18.397	0.09	0.38	5.0243	3.897	7.235	14.96	6.97
1.99	18.414	0.10	0.39	4.9487	3.972	7.192	14.73	6.90
2.05	18.432	0.12	0.40	4.8749	4.046	7.150	14.49	6.84
2.10	18.449	0.13	0.41	4.8029	4.118	7.107	14.27	6.77
2.16	18.466	0.14	0.42	4.7327	4.188	7.065	14.04	6.71
2.22	18.483	0.15	0.43	4.6642	4.256	7.023	13.82	6.65
2.28	18.501	0.16	0.45	4.5972	4.323	6.980	13.61	6.59
2.34	18.518	0.17	0.46	4.5318	4.389	6.938	13.40	6.53
2.40	18.535	0.19	0.47	4.4677	4.453	6.896	13.19	6.47
2.46	18.552	0.20	0.48	4.4051	4.515	6.854	12.98	6.41
2.52	18.570	0.21	0.49	4.3438	4.576	6.812	12.78	6.35
2.58	18.587	0.22	0.50	4.2837	4.636	6.770	12.58	6.29
2.64	18.604	0.23	0.52	4.2249	4.695	6.729	12.38	6.24

Section 5 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
2.64	18.604	0.00	0.52	4.2260	4.695	6.728	12.38	6.24
2.66	18.610	0.00	0.52	4.2809	4.641	6.709	12.31	6.21
2.68	18.617	0.01	0.52	4.3347	4.588	6.690	12.24	6.19
2.71	18.623	0.01	0.53	4.3873	4.535	6.671	12.17	6.17
2.73	18.630	0.02	0.53	4.4387	4.484	6.651	12.10	6.15
2.75	18.636	0.02	0.54	4.4890	4.433	6.632	12.03	6.13
2.77	18.642	0.03	0.54	4.5383	4.384	6.613	11.96	6.11
2.79	18.649	0.03	0.55	4.5864	4.336	6.594	11.89	6.09
2.82	18.655	0.03	0.55	4.6335	4.289	6.575	11.82	6.07
2.84	18.661	0.04	0.55	4.6795	4.243	6.556	11.75	6.05
2.86	18.668	0.04	0.56	4.7245	4.198	6.537	11.69	6.03
2.88	18.674	0.05	0.56	4.7684	4.154	6.518	11.62	6.01
2.90	18.681	0.05	0.57	4.8113	4.111	6.499	11.55	5.99
2.93	18.687	0.06	0.57	4.8533	4.069	6.480	11.49	5.97
2.95	18.693	0.06	0.57	4.8942	4.028	6.461	11.42	5.95
2.97	18.700	0.06	0.58	4.9342	3.988	6.443	11.35	5.93
2.99	18.706	0.07	0.58	4.9733	3.949	6.424	11.29	5.91
3.01	18.713	0.07	0.59	5.0114	3.911	6.405	11.22	5.89
3.04	18.719	0.08	0.59	5.0485	3.874	6.387	11.16	5.87
3.06	18.725	0.08	0.60	5.0848	3.838	6.369	11.09	5.85
3.08	18.732	0.08	0.60	5.1202	3.802	6.350	11.03	5.83

Section 6 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
3.08	22.892	0.00	0.60	4.9047	4.020	5.279	9.38	5.60
3.17	22.907	0.02	0.62	4.7456	4.182	5.176	9.33	5.59
3.26	22.922	0.03	0.63	4.5944	4.333	5.075	9.26	5.59
3.35	22.937	0.05	0.65	4.4509	4.476	4.977	9.20	5.58
3.44	22.952	0.06	0.66	4.3143	4.612	4.880	9.14	5.57
3.53	22.968	0.08	0.68	4.1846	4.742	4.786	9.07	5.56
3.62	22.983	0.10	0.70	4.0611	4.866	4.693	9.01	5.55
3.71	22.998	0.11	0.71	3.9435	4.983	4.603	8.95	5.55
3.80	23.013	0.13	0.73	3.8316	5.095	4.514	8.89	5.54
3.89	23.028	0.14	0.74	3.7247	5.202	4.428	8.83	5.53
3.98	23.044	0.16	0.76	3.6229	5.303	4.343	8.77	5.52
4.06	23.059	0.18	0.78	3.5257	5.401	4.260	8.71	5.51
4.15	23.074	0.19	0.79	3.4329	5.493	4.179	8.65	5.51
4.24	23.089	0.21	0.81	3.3442	5.582	4.099	8.59	5.50
4.33	23.104	0.22	0.83	3.2594	5.667	4.021	8.53	5.49
4.42	23.120	0.24	0.84	3.1783	5.748	3.945	8.47	5.48
4.51	23.135	0.26	0.86	3.1007	5.825	3.870	8.41	5.47
4.60	23.150	0.27	0.87	3.0263	5.900	3.797	8.36	5.47
4.69	23.165	0.29	0.89	2.9550	5.971	3.726	8.30	5.46
4.78	23.180	0.31	0.91	2.8867	6.039	3.656	8.24	5.45
4.87	23.196	0.32	0.92	2.8211	6.105	3.587	8.19	5.44

Section 7 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
4.87	23.196	0.00	0.92	2.8238	6.105	3.587	8.18	5.44
4.90	23.200	0.00	0.93	2.8095	6.119	3.564	8.17	5.44
4.93	23.205	0.01	0.93	2.7953	6.134	3.540	8.15	5.44
4.95	23.210	0.01	0.94	2.7811	6.148	3.517	8.13	5.43
4.98	23.215	0.02	0.94	2.7670	6.162	3.494	8.12	5.43
5.01	23.219	0.02	0.95	2.7531	6.176	3.471	8.10	5.43
5.04	23.224	0.03	0.95	2.7392	6.190	3.449	8.08	5.43
5.07	23.229	0.03	0.96	2.7253	6.204	3.426	8.06	5.43
5.09	23.234	0.04	0.96	2.7116	6.217	3.404	8.05	5.42
5.12	23.238	0.04	0.97	2.6979	6.231	3.382	8.03	5.42
5.15	23.243	0.05	0.97	2.6844	6.245	3.360	8.01	5.42
5.18	23.248	0.05	0.98	2.6709	6.258	3.338	8.00	5.42
5.21	23.253	0.06	0.98	2.6574	6.271	3.316	7.98	5.41
5.23	23.257	0.06	0.99	2.6441	6.285	3.295	7.96	5.41
5.26	23.262	0.07	0.99	2.6309	6.298	3.274	7.95	5.41
5.29	23.267	0.07	1.00	2.6177	6.311	3.252	7.93	5.41
5.32	23.272	0.08	1.00	2.6046	6.324	3.231	7.91	5.40
5.35	23.276	0.08	1.01	2.5916	6.337	3.211	7.90	5.40
5.37	23.281	0.09	1.01	2.5786	6.350	3.190	7.88	5.40
5.40	23.286	0.09	1.02	2.5658	6.363	3.169	7.86	5.40
5.43	23.291	0.10	1.02	2.5530	6.376	3.149	7.84	5.39

Section 8 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
5.43	24.181	0.00	1.02	2.5688	6.362	3.050	7.63	5.38
5.48	24.189	0.01	1.03	2.5501	6.381	3.016	7.60	5.36
5.53	24.197	0.02	1.04	2.5314	6.400	2.983	7.57	5.36
5.58	24.206	0.03	1.05	2.5129	6.418	2.951	7.55	5.35
5.63	24.214	0.03	1.06	2.4946	6.437	2.918	7.52	5.35
5.67	24.222	0.04	1.06	2.4762	6.455	2.887	7.49	5.34
5.72	24.231	0.05	1.07	2.4580	6.473	2.855	7.47	5.34
5.77	24.239	0.06	1.08	2.4399	6.491	2.824	7.44	5.34
5.82	24.247	0.07	1.09	2.4219	6.509	2.793	7.41	5.33
5.87	24.256	0.08	1.10	2.4040	6.527	2.763	7.39	5.33
5.92	24.264	0.08	1.11	2.3863	6.545	2.733	7.36	5.32
5.97	24.272	0.09	1.11	2.3686	6.563	2.704	7.33	5.32
6.02	24.281	0.10	1.12	2.3511	6.580	2.675	7.31	5.32
6.07	24.289	0.11	1.13	2.3337	6.598	2.646	7.28	5.31
6.12	24.297	0.12	1.14	2.3164	6.615	2.617	7.25	5.31
6.16	24.306	0.13	1.15	2.2992	6.632	2.589	7.23	5.30
6.21	24.314	0.14	1.16	2.2821	6.649	2.562	7.20	5.30
6.26	24.322	0.14	1.17	2.2652	6.666	2.534	7.18	5.30
6.31	24.331	0.15	1.17	2.2484	6.683	2.507	7.15	5.29
6.36	24.339	0.16	1.18	2.2317	6.700	2.480	7.13	5.29
6.41	24.347	0.17	1.19	2.2151	6.716	2.454	7.10	5.28

Section 9 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
6.41	155.847	0.00	1.19	3.6645	5.268	8.095	28.95	8.54
6.45	155.854	0.00	1.20	3.7570	5.176	8.044	28.90	8.53
6.49	155.862	0.01	1.20	3.8485	5.084	7.993	28.84	8.53
6.53	155.869	0.01	1.21	3.9390	4.994	7.942	28.78	8.52
6.57	155.876	0.02	1.21	4.0287	4.904	7.892	28.72	8.52
6.61	155.884	0.02	1.22	4.1173	4.815	7.841	28.66	8.52
6.65	155.891	0.03	1.22	4.2051	4.726	7.792	28.61	8.51
6.69	155.898	0.03	1.23	4.2919	4.641	7.742	28.55	8.51
6.73	155.906	0.04	1.23	4.3778	4.555	7.693	28.49	8.50
6.77	155.913	0.04	1.24	4.4627	4.470	7.644	28.43	8.50
6.81	155.920	0.05	1.24	4.5468	4.386	7.596	28.38	8.49
6.86	155.927	0.05	1.25	4.6300	4.303	7.548	28.32	8.49
6.90	155.935	0.06	1.26	4.7122	4.220	7.500	28.26	8.49
6.94	155.942	0.06	1.26	4.7936	4.139	7.453	28.20	8.49
6.98	155.949	0.07	1.26	4.8742	4.059	7.406	28.15	8.48
7.02	155.957	0.07	1.27	4.9538	3.979	7.359	28.09	8.47
7.06	155.964	0.08	1.27	5.0326	3.900	7.312	28.03	8.47
7.10	155.971	0.08	1.28	5.1105	3.822	7.266	27.98	8.46
7.14	155.979	0.09	1.28	5.1876	3.745	7.220	27.92	8.46
7.18	155.986	0.09	1.29	5.2639	3.669	7.175	27.86	8.46
7.22	155.993	0.10	1.29	5.3393	3.593	7.130	27.81	8.45

Section 10 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.22	155.993	0.00	1.29	5.3406	3.593	7.130	27.81	8.45
7.25	155.999	0.00	1.29	5.3032	3.631	7.098	27.76	8.45
7.28	156.005	0.01	1.30	5.2661	3.668	7.067	27.72	8.45
7.31	156.010	0.01	1.30	5.2296	3.705	7.036	27.68	8.44
7.35	156.016	0.02	1.31	5.1937	3.741	7.006	27.63	8.44
7.38	156.022	0.02	1.31	5.1583	3.776	6.975	27.59	8.44
7.41	156.027	0.02	1.31	5.1235	3.811	6.944	27.55	8.43
7.44	156.033	0.03	1.32	5.0892	3.845	6.914	27.50	8.43
7.47	156.039	0.03	1.32	5.0555	3.879	6.884	27.46	8.43
7.50	156.044	0.03	1.32	5.0222	3.912	6.854	27.42	8.42
7.53	156.050	0.04	1.33	4.9894	3.945	6.824	27.38	8.42
7.57	156.056	0.04	1.33	4.9572	3.977	6.794	27.33	8.42
7.60	156.061	0.05	1.34	4.9254	4.009	6.764	27.29	8.41
7.63	156.067	0.05	1.34	4.8941	4.040	6.735	27.25	8.41
7.66	156.073	0.05	1.34	4.8632	4.071	6.705	27.20	8.41
7.69	156.078	0.06	1.35	4.8328	4.102	6.676	27.16	8.40
7.72	156.084	0.06	1.35	4.8028	4.132	6.647	27.12	8.40
7.76	156.090	0.07	1.36	4.7733	4.161	6.618	27.08	8.40
7.79	156.095	0.07	1.36	4.7442	4.190	6.589	27.03	8.39
7.82	156.101	0.07	1.36	4.7156	4.219	6.560	26.99	8.39
7.85	156.107	0.08	1.37	4.6873	4.247	6.532	26.95	8.39

Section 11 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.85	158.167	0.00	1.37	4.6659	4.270	6.453	26.62	8.34
7.86	158.168	0.00	1.37	4.6695	4.266	6.446	26.61	8.34
7.86	158.169	0.00	1.37	4.6730	4.263	6.440	26.61	8.34
7.87	158.171	0.00	1.37	4.6765	4.259	6.433	26.60	8.33
7.88	158.172	0.00	1.37	4.6800	4.256	6.427	26.59	8.33
7.89	158.173	0.00	1.37	4.6835	4.252	6.420	26.58	8.33
7.89	158.174	0.01	1.37	4.6870	4.249	6.414	26.57	8.33
7.90	158.176	0.01	1.37	4.6904	4.245	6.407	26.56	8.33
7.91	158.177	0.01	1.37	4.6938	4.242	6.401	26.55	8.33
7.91	158.178	0.01	1.37	4.6972	4.239	6.394	26.54	8.33
7.92	158.179	0.01	1.38	4.7006	4.235	6.388	26.53	8.33
7.93	158.181	0.01	1.38	4.7040	4.232	6.382	26.52	8.33
7.93	158.182	0.01	1.38	4.7073	4.229	6.375	26.51	8.33
7.94	158.183	0.01	1.38	4.7107	4.225	6.369	26.51	8.33
7.95	158.184	0.01	1.38	4.7140	4.222	6.362	26.50	8.33
7.95	158.186	0.01	1.38	4.7173	4.219	6.356	26.49	8.33
7.96	158.187	0.01	1.38	4.7205	4.215	6.350	26.48	8.33
7.97	158.188	0.01	1.38	4.7238	4.212	6.343	26.47	8.32
7.98	158.189	0.02	1.38	4.7270	4.209	6.337	26.46	8.32
7.98	158.191	0.02	1.38	4.7302	4.206	6.330	26.45	8.32
7.99	158.192	0.02	1.38	4.7334	4.202	6.324	26.44	8.32

Section 12 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.99	158.192	0.00	1.38	4.7337	4.202	6.324	26.44	8.32
8.01	158.195	0.00	1.39	4.7584	4.178	6.309	26.42	8.32
8.02	158.198	0.00	1.39	4.7829	4.153	6.294	26.40	8.32
8.04	158.201	0.01	1.39	4.8073	4.129	6.279	26.38	8.32
8.06	158.204	0.01	1.39	4.8316	4.105	6.265	26.36	8.32
8.07	158.207	0.01	1.39	4.8557	4.081	6.250	26.33	8.31
8.09	158.210	0.01	1.40	4.8797	4.057	6.235	26.31	8.31
8.11	158.213	0.01	1.40	4.9037	4.033	6.220	26.29	8.31
8.12	158.216	0.02	1.40	4.9274	4.009	6.206	26.27	8.31
8.14	158.219	0.02	1.40	4.9511	3.985	6.191	26.25	8.31
8.16	158.222	0.02	1.40	4.9747	3.962	6.177	26.23	8.31
8.17	158.225	0.02	1.41	4.9981	3.938	6.162	26.21	8.30
8.19	158.228	0.02	1.41	5.0214	3.915	6.147	26.19	8.30
8.20	158.231	0.03	1.41	5.0446	3.892	6.133	26.16	8.30
8.22	158.234	0.03	1.41	5.0677	3.869	6.119	26.14	8.30
8.24	158.237	0.03	1.41	5.0907	3.846	6.104	26.12	8.30
8.25	158.240	0.03	1.42	5.1136	3.823	6.090	26.10	8.30
8.27	158.243	0.03	1.42	5.1362	3.800	6.076	26.08	8.29
8.29	158.246	0.04	1.42	5.1589	3.777	6.061	26.06	8.29
8.30	158.248	0.04	1.42	5.1814	3.755	6.047	26.04	8.29
8.32	158.251	0.04	1.42	5.2038	3.733	6.033	26.02	8.29

Section 13 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
8.32	158.251	0.00	1.42	5.2091	3.733	6.033	26.02	8.29
8.54	158.288	0.03	1.45	5.2573	3.685	5.855	25.74	8.27
8.76	158.325	0.05	1.48	5.2935	3.649	5.683	25.46	8.24
8.98	158.361	0.08	1.50	5.3186	3.624	5.516	25.19	8.22
9.20	158.398	0.11	1.53	5.3337	3.609	5.355	24.92	8.20
9.42	158.435	0.13	1.56	5.3399	3.603	5.200	24.65	8.18
9.64	158.472	0.16	1.58	5.3379	3.605	5.049	24.39	8.16
9.86	158.508	0.18	1.61	5.3288	3.614	4.903	24.13	8.13
10.08	158.545	0.21	1.63	5.3131	3.629	4.763	23.87	8.11
10.30	158.582	0.24	1.66	5.2916	3.651	4.626	23.62	8.09
10.52	158.618	0.26	1.69	5.2648	3.678	4.494	23.36	8.07
10.73	158.655	0.29	1.71	5.2334	3.709	4.367	23.12	8.05
10.95	158.692	0.32	1.74	5.1979	3.745	4.244	22.87	8.03
11.17	158.728	0.34	1.77	5.1589	3.784	4.124	22.62	8.01
11.39	158.765	0.37	1.79	5.1166	3.826	4.009	22.38	7.98
11.61	158.802	0.40	1.82	5.0714	3.871	3.897	22.14	7.96
11.83	158.838	0.42	1.85	5.0238	3.919	3.789	21.91	7.94
12.05	158.875	0.45	1.87	4.9742	3.968	3.685	21.67	7.92
12.27	158.912	0.47	1.90	4.9227	4.020	3.584	21.44	7.90
12.49	158.948	0.50	1.92	4.8[illegible]	4.073	3.486	21.21	7.88
12.71	158.985	0.53	1.95	4.8155	4.127	3.391	20.99	7.86

Section 14 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
12.71	158.985	0.00	1.95	4.8230	4.127	3.391	20.99	7.86
12.81	158.997	0.01	1.96	4.7043	4.246	3.359	20.91	7.85
12.91	159.009	0.02	1.97	4.5906	4.360	3.328	20.84	7.84
13.02	159.020	0.03	1.98	4.4816	4.469	3.298	20.76	7.84
13.12	159.032	0.04	1.99	4.3773	4.573	3.268	20.69	7.83
13.22	159.044	0.04	1.99	4.2772	4.673	3.235	20.61	7.82
13.32	159.056	0.05	2.00	4.1813	4.769	3.205	20.54	7.82
13.42	159.068	0.06	2.01	4.0894	4.861	3.176	20.47	7.81
13.53	159.079	0.07	2.02	4.0012	4.949	3.146	20.39	7.80
13.63	159.091	0.08	2.03	3.9166	5.033	3.118	20.32	7.80
13.73	159.103	0.09	2.04	3.8355	5.115	3.089	20.25	7.79
13.83	159.115	0.10	2.05	3.7576	5.193	3.059	20.18	7.78
13.93	159.127	0.11	2.06	3.6828	5.267	3.031	20.10	7.77
14.04	159.138	0.11	2.06	3.6110	5.339	3.003	20.03	7.77
14.14	159.150	0.12	2.07	3.5421	5.409	2.975	19.96	7.76
14.24	159.162	0.13	2.08	3.4759	5.474	2.948	19.89	7.75
14.34	159.174	0.14	2.09	3.4122	5.538	2.921	19.82	7.75
14.44	159.186	0.15	2.10	3.3511	5.599	2.895	19.75	7.74
14.55	159.197	0.16	2.11	3.2922	5.658	2.868	19.68	7.73
14.65	159.209	0.17	2.12	3.2357	5.714	2.842	19.61	7.73
14.75	159.221	0.18	2.13	3.1813	5.769	2.817	19.54	7.72

Section 15 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
14.75	161.601	0.00	2.13	3.1862	5.772	2.782	19.28	7.67
14.90	161.616	0.01	2.14	3.0753	5.883	2.741	19.18	7.66
15.06	161.632	0.03	2.16	2.9720	5.987	2.701	19.08	7.65
15.21	161.647	0.04	2.17	2.8758	6.083	2.661	18.98	7.64
15.36	161.662	0.05	2.18	2.7861	6.172	2.623	18.88	7.63
15.51	161.677	0.06	2.19	2.7024	6.256	2.585	18.78	7.62
15.67	161.693	0.08	2.20	2.6243	6.334	2.548	18.68	7.61
15.82	161.708	0.09	2.22	2.5512	6.407	2.511	18.58	7.60
15.97	161.723	0.10	2.23	2.4829	6.476	2.475	18.49	7.59
16.12	161.738	0.12	2.24	2.4190	6.540	2.440	18.39	7.58
16.28	161.754	0.13	2.26	2.3591	6.599	2.405	18.29	7.57
16.43	161.769	0.14	2.27	2.3029	6.656	2.371	18.20	7.56
16.58	161.784	0.16	2.28	2.2501	6.708	2.337	18.10	7.55
16.73	161.799	0.17	2.29	2.2005	6.758	2.305	18.01	7.54
16.89	161.815	0.18	2.31	2.1539	6.805	2.272	17.91	7.53
17.04	161.830	0.19	2.32	2.1099	6.849	2.241	17.82	7.52
17.19	161.845	0.21	2.33	2.0684	6.890	2.209	17.72	7.51
17.34	161.860	0.22	2.35	2.0293	6.929	2.179	17.63	7.51
17.50	161.876	0.23	2.36	1.9923	6.966	2.149	17.54	7.50
17.65	161.891	0.25	2.37	1.9572	7.001	2.119	17.45	7.49
17.80	161.906	0.26	2.39	1.9240	7.034	2.090	17.36	7.48

Section 16 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
17.80	161.906	0.00	2.39	1.9316	7.034	2.090	17.36	7.48
17.88	161.914	0.01	2.39	1.9348	7.031	2.074	17.31	7.47
17.97	161.923	0.01	2.40	1.9375	7.028	2.058	17.26	7.47
18.05	161.931	0.02	2.41	1.9399	7.026	2.041	17.21	7.46
18.13	161.939	0.03	2.41	1.9418	7.024	2.025	17.16	7.45
18.22	161.948	0.04	2.42	1.9434	7.023	2.010	17.11	7.45
18.30	161.956	0.04	2.43	1.9447	7.021	1.994	17.06	7.44
18.38	161.965	0.05	2.43	1.9456	7.021	1.978	17.01	7.44
18.47	161.973	0.06	2.44	1.9461	7.020	1.963	16.96	7.43
18.55	161.981	0.06	2.45	1.9464	7.020	1.948	16.91	7.43
18.64	161.990	0.07	2.46	1.9464	7.020	1.933	16.86	7.42
18.72	161.998	0.08	2.46	1.9461	7.020	1.918	16.82	7.42
18.80	162.006	0.08	2.47	1.9455	7.021	1.903	16.77	7.41
18.89	162.015	0.09	2.48	1.9446	7.021	1.889	16.72	7.41
18.97	162.023	0.10	2.48	1.9435	7.023	1.874	16.67	7.40
19.05	162.031	0.11	2.49	1.9421	7.024	1.860	16.62	7.40
19.14	162.040	0.11	2.50	1.9405	7.026	1.846	16.58	7.39
19.22	162.048	0.12	2.51	1.9387	7.027	1.832	16.53	7.39
19.30	162.056	0.13	2.51	1.9367	7.029	1.818	16.48	7.38
19.39	162.065	0.13	2.52	1.9345	7.032	1.805	16.43	7.38
19.47	162.073	0.14	2.53	1.9321	7.034	1.791	16.39	7.37

Section 17 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
19.47	164.023	0.00	2.53	1.9501	7.022	1.775	16.22	7.34
19.79	164.061	0.03	2.56	2.1035	6.868	1.727	16.04	7.32
20.10	164.098	0.05	2.58	2.2472	6.725	1.680	15.87	7.30
20.41	164.136	0.08	2.61	2.3816	6.590	1.635	15.70	7.28
20.72	164.173	0.10	2.63	2.5072	6.465	1.592	15.54	7.26
21.04	164.211	0.13	2.66	2.6246	6.348	1.551	15.37	7.24
21.35	164.248	0.16	2.68	2.7338	6.239	1.511	15.21	7.22
21.66	164.286	0.18	2.71	2.8355	6.137	1.472	15.05	7.20
21.97	164.323	0.21	2.74	2.9300	6.042	1.435	14.89	7.18
22.29	164.361	0.24	2.76	3.0177	5.954	1.399	14.73	7.16
22.60	164.399	0.26	2.79	3.0990	5.873	1.365	14.57	7.15
22.91	164.436	0.29	2.82	3.1740	5.798	1.332	14.42	7.13
23.23	164.474	0.31	2.84	3.2433	5.729	1.300	14.26	7.11
23.54	164.511	0.34	2.87	3.3070	5.665	1.269	14.11	7.09
23.85	164.549	0.37	2.89	3.3654	5.607	1.239	13.96	7.07
24.17	164.586	0.39	2.92	3.4189	5.553	1.211	13.82	7.05
24.48	164.624	0.42	2.95	3.4676	5.505	1.183	13.67	7.03
24.79	164.661	0.45	2.97	3.5117	5.461	1.157	13.52	7.02
25.10	164.699	0.47	3.00	3.5517	5.421	1.131	13.38	7.00
25.42	164.737	0.50	3.03	3.5876	5.385	1.107	13.24	6.98
25.73	164.774	0.52	3.05	3.6197	5.353	1.083	13.10	6.96

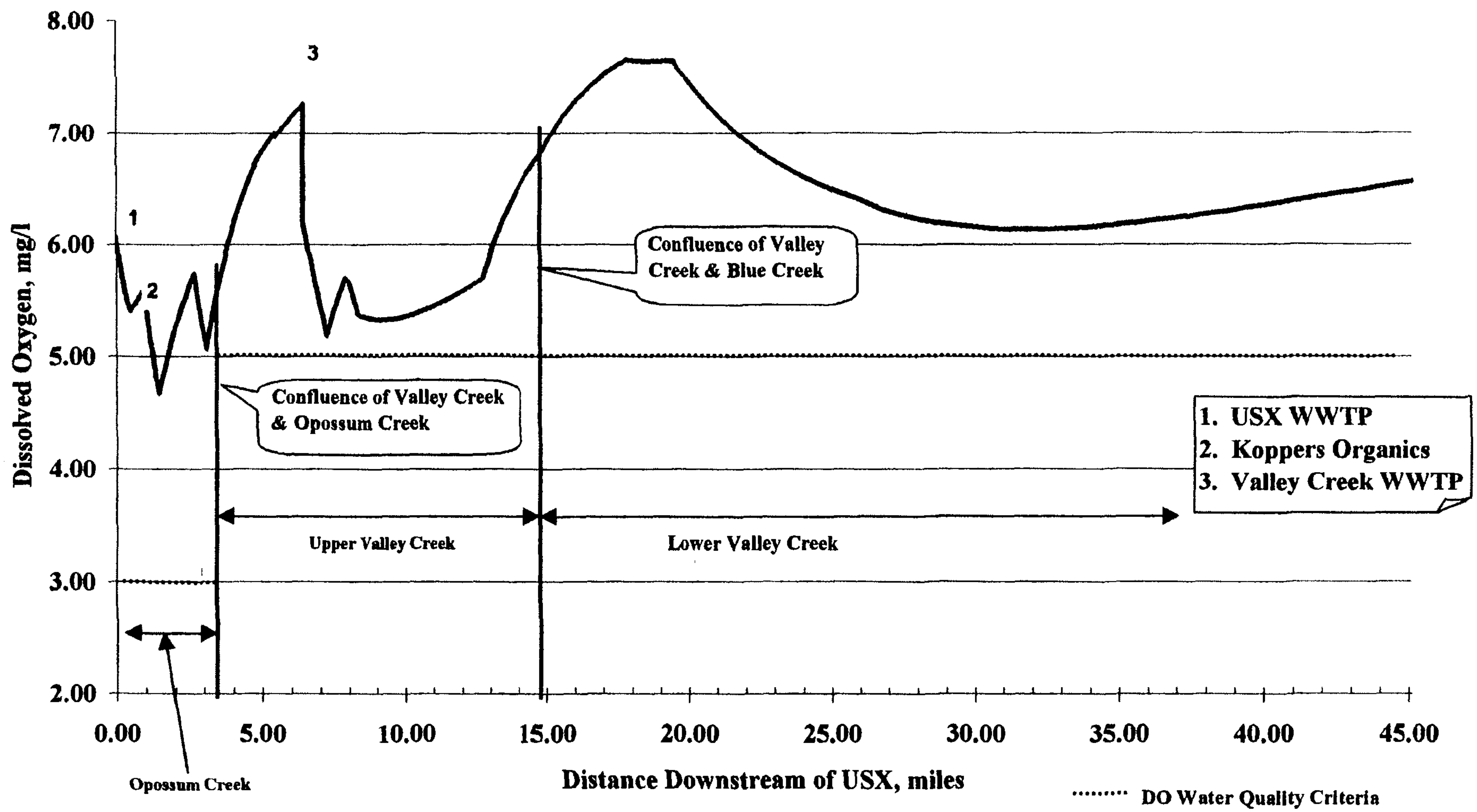
Section 18 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
25.73	164.774	0.00	3.05	3.6233	5.353	1.083	13.10	6.96
25.77	164.779	0.00	3.06	3.6297	5.346	1.080	13.08	6.96
25.82	164.784	0.01	3.06	3.6360	5.340	1.077	13.06	6.96
25.86	164.789	0.01	3.06	3.6422	5.334	1.074	13.04	6.95
25.90	164.794	0.01	3.07	3.6484	5.328	1.071	13.02	6.95
25.95	164.799	0.02	3.07	3.6545	5.322	1.068	13.00	6.95
25.99	164.804	0.02	3.07	3.6605	5.316	1.065	12.98	6.95
26.03	164.809	0.03	3.08	3.6664	5.310	1.062	12.96	6.94
26.08	164.814	0.03	3.08	3.6723	5.304	1.060	12.94	6.94
26.12	164.819	0.03	3.08	3.6781	5.298	1.057	12.92	6.94
26.17	164.825	0.04	3.09	3.6838	5.292	1.054	12.91	6.94
26.21	164.830	0.04	3.09	3.[illegible]94	5.287	1.051	12.89	6.93
26.25	164.835	0.04	3.10	3.6950	5.281	1.048	12.87	6.93
26.30	164.840	0.05	3.10	3.7005	5.275	1.045	12.85	6.93
26.34	164.845	0.05	3.10	3.7060	5.270	1.043	12.83	6.92
26.39	164.[illegible]	0.05	3.11	3.7113	5.265	1.040	12.81	6.92
26.43	164.855	0.06	3.11	3.7166	5.259	1.037	12.79	6.92
26.47	164.[illegible]	0.06	3.11	3.7219	5.254	1.034	12.77	6.92
26.51	164.865	0.07	3.12	3.7270	5.249	1.032	12.75	6.91
26.56	164.870	0.07	3.12	3.7321	5.244	1.029	12.73	6.91
26.60	164.875	0.07	3.12	3.7372	5.239	1.026	12.72	6.91

Section 19 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
26.60	168.785	0.00	3.12	3.7261	5.256	1.013	12.47	6.86
27.00	168.831	0.03	3.16	3.7647	5.219	0.990	12.30	6.83
27.40	168.878	0.07	3.19	3.7985	5.185	0.969	12.14	6.81
27.80	168.924	0.10	3.22	3.8277	5.155	0.948	11.98	6.79
28.20	168.971	0.13	3.26	3.8528	5.130	0.928	11.82	6.77
28.60	169.017	0.16	3.29	3.8738	5.109	0.908	11.66	6.74
29.00	169.063	0.20	3.32	3.8911	5.092	0.890	11.51	6.72
29.40	169.110	0.23	3.35	3.9048	5.078	0.872	11.36	6.70
29.80	169.156	0.26	3.39	3.9153	5.068	0.855	11.21	6.68
30.20	169.202	0.30	3.42	3.9226	5.061	0.839	11.06	6.66
30.60	169.249	0.33	3.45	3.9270	5.056	0.824	10.91	6.63
31.00	169.295	0.36	3.49	3.9287	5.055	0.809	10.77	6.61
31.40	169.342	0.39	3.52	3.9278	5.056	0.794	10.63	6.59
31.80	169.388	0.43	3.55	3.9245	5.059	0.781	10.49	6.57
32.20	169.434	0.46	3.58	3.9189	5.064	0.767	10.35	6.55
32.60	169.481	0.49	3.62	3.9113	5.072	0.755	10.21	6.53
33.00	169.527	0.52	3.65	3.9017	5.082	0.742	10.07	6.51
33.40	169.574	0.56	3.68	3.8902	5.093	0.731	9.94	6.48
33.80	169.620	0.59	3.71	3.8771	5.106	0.719	9.81	6.46
34.20	169.666	0.62	3.75	3.8624	5.121	0.708	9.68	6.44
34.60	169.713	0.66	3.78	3.8462	5.137	0.698	9.55	6.42

Section 20 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
34.60	169.713	0.00	3.78	3.8517	5.137	0.698	9.55	6.42
34.74	169.729	0.01	3.79	3.8452	5.144	0.695	9.52	6.41
34.88	169.745	0.02	3.80	3.8387	5.150	0.691	9.49	6.41
35.01	169.761	0.03	3.81	3.8320	5.157	0.688	9.46	6.40
35.15	169.777	0.04	3.82	3.8253	5.164	0.684	9.43	6.39
35.29	169.793	0.05	3.83	3.8185	5.170	0.681	9.39	6.39
35.43	169.809	0.07	3.85	3.8117	5.177	0.678	9.36	6.38
35.56	169.824	0.08	3.86	3.8049	5.184	0.675	9.33	6.37
35.70	169.840	0.09	3.87	3.7978	5.191	0.672	9.30	6.37
35.84	169.856	0.10	3.88	3.7908	5.198	0.669	9.27	6.36
35.98	169.872	0.11	3.89	3.7837	5.205	0.665	9.24	6.35
36.11	169.888	0.12	3.90	3.7766	5.212	0.662	9.21	6.35
36.25	169.904	0.13	3.91	3.7694	5.220	0.659	9.18	6.34
36.39	169.920	0.14	3.92	3.7621	5.227	0.656	9.15	6.33
36.53	169.936	0.15	3.93	3.7548	5.234	0.654	9.11	6.32
36.66	169.952	0.16	3.94	3.7474	5.242	0.651	9.08	6.32
36.80	169.968	0.18	3.96	3.7400	5.249	0.648	9.05	6.31
36.94	169.984	0.19	3.97	3.7325	5.256	0.645	9.02	6.30
37.08	170.000	0.20	3.98	3.7250	5.264	0.642	8.99	6.30
37.21	170.016	0.21	3.99	3.7175	5.271	0.639	8.96	6.29
37.35	170.032	0.22	4.00	3.7099	5.279	0.637	8.93	6.28

Section 21 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
37.35	176.002	0.00	4.00	3.6861	5.304	0.631	8.70	6.23
37.74	176.047	0.03	4.03	3.6628	5.327	0.623	8.62	6.21
38.14	176.092	0.06	4.06	3.6394	5.351	0.616	8.54	6.19
38.53	176.137	0.09	4.09	3.6157	5.375	0.609	8.46	6.17
38.93	176.182	0.12	4.12	3.5919	5.398	0.603	8.38	6.15
39.32	176.227	0.15	4.15	3.5679	5.422	0.597	8.30	6.13
39.71	176.272	0.19	4.19	3.5437	5.446	0.590	8.22	6.11
40.11	176.318	0.22	4.22	3.5194	5.471	0.584	8.14	6.09
40.50	176.363	0.25	4.25	3.4951	5.495	0.579	8.07	6.07
40.90	176.408	0.28	4.28	3.4706	5.520	0.573	7.99	6.06
41.29	176.453	0.31	4.31	3.4461	5.544	0.568	7.92	6.04
41.68	176.498	0.34	4.34	3.4216	5.569	0.563	7.84	6.02
42.08	176.543	0.37	4.37	3.3970	5.593	0.557	7.77	6.00
42.47	176.588	0.40	4.40	3.3724	5.618	0.553	7.70	5.98
42.87	176.633	0.43	4.43	3.3478	5.642	0.548	7.62	5.96
43.26	176.678	0.46	4.46	3.3232	5.667	0.543	7.55	5.95
43.65	176.724	0.49	4.49	3.2986	5.692	0.539	7.48	5.93
44.05	176.769	0.52	4.52	3.2741	5.716	0.534	7.41	5.91
44.44	176.814	0.56	4.55	3.2495	5.741	0.530	7.34	5.89
44.84	176.859	0.59	4.59	3.2251	5.765	0.526	7.27	5.87
45.23	176.904	0.62	4.62	3.2007	5.789	0.522	7.20	5.86

Opossum Creek / Valley Creek Waste Load Allocation
December - April / F&W Classification



Enter the Number of Sections =	21.000
Total Length (miles) =	45.230

Opossum Creek / Valley Creek Waste Load Allocation - December - April WLA / F&W Classification

Valley Creek WWTP Effluent Conditions				
Design Flow, MGD	$CBOD_5$, mg/l	NH_3-N, mg/l	TKN, mg/l	D.O. (minimum), mg/l
85.00	6.0	1.0	3.0	6.0

HeadWater Data

Recession Index (G) =	60.000
Mean Annual Prec. (P) =	60.000
Drainage Area (M^2) =	0.000
Temp (C°) =	20.000
CHL =	0.000
Headwater Flow (cfs) =	1.100
CBODU (mg/l) =	3.000
NH_3ODU (mg/l) =	0.686
TONODU (mg/l) =	6.855
Headwater D.O. (mg/l) =	7.00

Flow Multiplier
1.00

Tributary Flows (cfs)
1.10
4.16
0.89
2.06
2.38
1.95
3.91
5.97

Dam Data

Dam Located at Beginning of Section =	0.00
Water Quality Factor =	1.80
Wier Dam Coefficient =	0.80
Difference in Water Level (ft) =	1.00

Stream flow @ Valley Creek WWTP (cfs)
24.347

Use Goal Seek

Minimum Dissolved Oxygen Concentration (mg/l) (Opossum Creek) =	4.67
Minimum Dissolved Oxygen Concentration (mg/l) (Upper Valley Creek) =	5.07
Minimum Dissolved Oxygen Concentration (mg/l) (Lower Valley Creek) =	6.13
CBODu Concentration at End of Modeled Reach (mg/l) =	5.30

Enter Tributary Conditions (if none, leave blank)

Sections	G	P	TONODU (mg/l)	CBODU (mg/l)	NH3ODU (mg/l)	DO (mg/l)	$7Q_{10}$ (cfs)	Temp. (C°)	Drainage Area (M^2)
1.00						0.000	0.00	0.00	0.00
2.00						0.000	0.00	0.00	0.00
3.00						0.000	0.00	0.00	0.00
4.00						0.000	0.00	0.00	0.00
5.00						0.000	0.00	0.00	0.00
6.00			4.57	2.00	0.457	6.000	4.16	20.00	0.00
7.00						0.000	0.00	0.00	0.00
8.00			4.57	2.00	0.457	6.000	0.89	20.00	0.00
9.00			91.40	37.50	45.7000	3.000	0.00	0.00	0.00
10.00						0.000	0.00	0.00	0.00
11.00			4.57	2.00	0.457	6.000	2.06	20.00	0.00
12.00						0.000	0.00	0.00	0.00
13.00						0.000	0.00	0.00	0.00
14.00						0.000	0.00	0.00	0.00
15.00			4.57	2.00	0.457	6.000	2.38	20.00	0.00
16.00						0.000	0.00	0.00	0.00
17.00	65.000	56.00	4.57	2.00	0.457	6.000	1.95	20.00	15.60
18.00						0.000	0.00	0.00	0.00
19.00	65.000	56.00	4.57	2.00	0.457	6.000	3.91	20.00	32.70
20.00						0.000	0.00	0.00	0.00
21.00	65.000	56.00	4.57	2.00	0.457	6.000	5.97	20.00	51.20
22.00						0.000	0.00	0.00	0.00

Enter Incremental Inflow Conditions (if none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (°C)	Q10 (cfs)	Drainage Area (mi^2)
1.00	3.000	0.69	6.86	7.73	0.028	20.000	0.00	
2.00	3.000	0.69	6.86	7.73	0.026	20.000	0.00	
3.00	3.000	0.69	6.86	7.73	0.030	20.000	0.00	
4.00	3.000	0.69	6.86	7.73	0.345	20.000	0.00	
5.00	3.000	0.69	6.86	7.73	0.128	20.000	0.00	
6.00	3.000	0.69	6.86	7.73	0.304	20.000	0.00	
7.00	3.000	0.69	6.86	7.73	0.085	20.000	0.00	
8.00	3.000	0.69	6.86	7.73	0.166	20.000	0.00	
9.00	3.000	0.69	6.86	7.73	0.146	20.000	0.00	
10.00	3.000	0.69	6.86	7.73	0.114	20.000	0.00	
11.00	3.000	0.69	6.86	7.73	0.026	20.000	0.00	
12.00	3.000	0.69	6.86	7.73	0.059	20.000	0.00	
13.00	3.000	0.69	6.86	7.73	0.734	20.000	0.00	
14.00	3.000	0.69	6.86	7.73	0.236	20.000	0.00	
15.00	3.000	0.69	6.86	7.73	0.305	20.000	0.00	
16.00	3.000	0.69	6.86	7.73	0.167	20.000	0.00	
17.00	3.000	0.69	6.86	7.73	0.751	20.000	0.00	
18.00	3.000	0.69	6.86	7.73	0.101	20.000	0.00	
19.00	3.000	0.69	6.86	7.73	0.926	20.000	0.00	
20.00	3.000	0.69	6.86	7.73	0.318	20.000	0.00	
21.00	3.000	0.69	6.86	7.73	0.902	20.000	0.00	
22.00				7.73	0.000	20.000	0.00	

Enter Effluent Conditions (if none, leave blank)

Sections	CBODU (mg/l)	NH3ODU (mg/l)	TONODU (mg/l)	DO (mg/l)	Flow (cfs)	Temp. (°C)	pH	Max. Instream NH3 (mg/l)	NH3 Toxicity (mg/l)	NH3 WQ Limit (mg/l)
1.00	20.000	4.57	9.14	6.00	17.017	20.000	7.00	3.08	3.27	0.00
2.00	37.500	91.40	137.10	6.00	0.0557	20.000				0.00
3.00		0.00		0.00						0.00
4.00		0.00		0.00						0.00
5.00		0.00		0.00						0.00
6.00		0.00		0.00						0.00
7.00		0.00		0.00						0.00
8.00		0.00		0.00						0.00
9.00	24.000	4.57	9.14	6.00	131.500	20.000	7.00	3.08	3.59	2.00
10.00		0.00		0.00						0.00
11.00		0.00		0.00						0.00
12.00		0.00		0.00						0.00
13.00		0.00		0.00						0.00
14.00		0.00		0.00						0.00
15.00		0.00		0.00						0.00
16.00		0.00		0.00						0.00
17.00		0.00		0.00						0.00
18.00		0.00		0.00						0.00
19.00		0.00		0.00						0.00
20.00		0.00		0.00						0.00
21.00		0.00		0.00						0.00
22.00		0.00		0.00						0.00

The most stringent of the two values will be implemented as the discharge limit.

Enter Section Characteristics (if none, leave blank)

Sections	Beginning Elev. (ft)	Ending Elev. (ft)	Elev.Change (ft)	Length (miles)	Average Elev. (ft)	Section Slope (ft/mi)	Average Flow (cfs)	Average Vel. (ft/sec)
1.00	498.000	490.00	8.00	0.4700	494.000	17.021	18.13	0.311
2.00	490.000	480.00	10.00	0.4700	485.000	21.277	18.21	0.312
3.00	480.000	475.00	5.00	0.5100	477.500	9.804	18.24	0.312
4.00	475.000	455.00	20.00	1.1900	465.000	16.807	18.43	0.314
5.00	455.000	452.00	3.00	0.4400	453.500	6.818	18.67	0.317
6.00	452.000	435.00	17.00	1.7900	443.500	9.497	23.04	0.340
7.00	435.000	430.00	5.00	0.5600	432.500	8.929	23.24	0.342
8.00	430.000	422.00	8.00	0.9800	426.000	8.163	24.26	0.353
9.00	422.000	420.00	2.00	0.8100	421.000	2.469	155.92	0.501
10.00	420.000	412.00	8.00	0.6300	416.000	12.698	156.05	0.501
11.00	412.000	411.00	1.00	0.1400	411.500	7.143	158.18	0.508
12.00	411.000	410.00	1.00	0.3300	410.500	3.030	158.22	0.508
13.00	410.000	380.00	30.00	4.3900	395.000	6.834	158.62	0.509
14.00	380.000	362.00	18.00	2.0400	371.000	8.824	159.10	0.711
15.00	362.000	331.00	31.00	3.0500	346.500	10.164	161.75	0.720
16.00	331.000	318.00	13.00	1.6700	324.500	7.784	161.99	0.721
17.00	318.000	298.00	20.00	6.2600	308.000	3.195	164.40	0.729
18.00	298.000	294.30	3.70	0.8700	296.150	4.253	164.82	0.730
19.00	294.300	260.00	34.30	8.0000	277.150	4.288	169.25	0.745
20.00	260.000	258.70	1.30	2.7500	259.350	0.473	169.87	0.767
21.00	258.700	255.00	3.70	7.8800	256.850	0.470	176.45	0.780
22.00	255.000		255.00		127.500	#DIV/0!	0.00	#DIV/0!

Sections	Reaction Rates @ 20° C					Corrected Rates @ New Temp.				
	Kd	KNH3	KON	T. Coefficient	Reaeration	Kd	KNH3	KON	Ave. Reaeration	Mixed Temp.(° C)
1.00	1.300	1.50	0.80	1.30	6.889	1.300	1.43	0.80	6.89	20.00
2.00	1.300	1.50	0.80	1.30	8.634	1.300	1.40	0.80	8.63	20.00
3.00	1.300	1.50	0.80	1.30	3.982	1.300	1.41	0.80	3.98	20.00
4.00	1.300	1.50	0.80	1.30	6.667	1.300	1.35	0.80	6.67	20.00
5.00	1.300	1.50	0.80	1.30	2.807	1.300	1.42	0.80	2.81	20.00
6.00	0.400	1.50	0.10	1.30	4.203	0.400	1.38	0.10	4.20	20.00
7.00	0.400	1.50	0.10	1.30	3.975	0.400	1.46	0.10	3.97	20.00
8.00	0.400	1.50	0.10	1.30	3.742	0.400	1.47	0.10	3.74	20.00
9.00	0.400	1.50	0.10	0.88	1.088	0.400	1.44	0.10	1.09	20.00
10.00	0.400	1.50	0.10	0.88	5.600	0.400	1.38	0.10	5.60	20.00
11.00	0.400	1.50	0.10	0.88	3.190	0.400	1.41	0.10	3.19	20.00
12.00	0.400	1.50	0.10	0.88	1.354	0.400	1.41	0.10	1.35	20.00
13.00	0.400	1.50	0.10	0.88	3.060	0.400	1.39	0.10	3.06	20.00
14.00	0.400	1.50	0.10	0.88	5.520	0.400	1.41	0.10	5.52	20.00
15.00	0.400	1.50	0.10	0.88	6.440	0.400	1.46	0.10	6.44	20.00
16.00	0.400	1.50	0.10	0.88	4.937	0.400	1.50	0.10	4.94	20.00
17.00	0.400	1.50	0.10	0.88	1.560	0.400	1.49	0.10	1.56	20.00
18.00	0.400	1.50	0.10	0.88	1.370	0.400	1.46	0.10	1.37	20.00
19.00	0.400	1.50	0.10	0.88	1.370	0.400	1.44	0.10	1.37	20.00
20.00	0.300	1.50	0.10	0.88	1.140	0.300	1.44	0.10	1.14	20.00
21.00	0.300	1.50	0.10	0.88	1.140	0.300	1.44	0.10	1.14	20.00
22.00	0.000	0.00	0.00	0.00	#DIV/0!	0.000	0.00	0.00	#DIV/0!	0.00

Model Output

Section 1 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.000	18.117	0.00	0.00	2.8466	6.061	4.334	18.97	9.00
0.024	18.118	0.00	0.00	2.8971	6.010	4.339	18.85	8.97
0.047	18.120	0.01	0.01	2.9454	5.962	4.343	18.74	8.93
0.071	18.121	0.01	0.01	2.9916	5.916	4.347	18.63	8.90
0.094	18.123	0.02	0.02	3.0358	5.872	4.351	18.51	8.87
0.118	18.124	0.02	0.02	3.0777	5.830	4.354	18.40	8.84
0.141	18.125	0.03	0.03	3.1178	5.790	4.358	18.29	8.80
0.165	18.127	0.03	0.03	3.1560	5.751	4.361	18.18	8.77
0.188	18.128	0.04	0.04	3.1924	5.715	4.365	18.07	8.74
0.212	18.130	0.04	0.04	3.2270	5.680	4.368	17.96	8.71
0.235	18.131	0.05	0.05	3.2599	5.648	4.371	17.85	8.67
0.259	18.132	0.05	0.05	3.2912	5.616	4.374	17.74	8.64
0.282	18.134	0.06	0.06	3.3208	5.587	4.377	17.64	8.61
0.306	18.135	0.06	0.06	3.3489	5.559	4.379	17.53	8.58
0.329	18.137	0.06	0.06	3.3756	5.532	4.382	17.42	8.55
0.353	18.138	0.07	0.07	3.4008	5.507	4.384	17.32	8.51
0.376	18.139	0.07	0.07	3.4246	5.483	4.386	17.21	8.48
0.400	18.141	0.08	0.08	3.4470	5.460	4.388	17.11	8.45
0.423	18.142	0.08	0.08	3.4681	5.439	4.390	17.01	8.42
0.447	18.144	0.09	0.09	3.4880	5.419	4.392	16.90	8.39
0.470	18.145	0.09	0.09	3.5067	5.401	4.394	16.80	8.36

Section 2 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.47	18.201	0.00	0.09	3.5078	5.403	4.660	16.87	8.75
0.49	18.202	0.00	0.10	3.4989	5.412	4.662	16.76	8.72
0.52	18.203	0.01	0.10	3.4897	5.421	4.664	16.66	8.69
0.54	18.205	0.01	0.11	3.4804	5.430	4.666	16.56	8.66
0.56	18.206	0.02	0.11	3.4708	5.440	4.667	16.46	8.62
0.59	18.208	0.02	0.12	3.4610	5.450	4.669	16.36	8.59
0.61	18.209	0.03	0.12	3.4510	5.460	4.670	16.26	8.56
0.63	18.210	0.03	0.12	3.4409	5.470	4.671	16.17	8.53
0.66	18.212	0.04	0.13	3.4306	5.480	4.673	16.07	8.50
0.68	18.213	0.04	0.13	3.4201	5.490	4.674	15.97	8.47
0.71	18.215	0.05	0.14	3.4094	5.501	4.674	15.88	8.43
0.73	18.216	0.05	0.14	3.3987	5.512	4.675	15.78	8.40
0.75	18.217	0.06	0.15	3.3878	5.523	4.676	15.69	8.37
0.78	18.219	0.06	0.15	3.3767	5.534	4.676	15.59	8.34
0.80	18.220	0.06	0.16	3.3656	5.545	4.677	15.50	8.31
0.82	18.222	0.07	0.16	3.3543	5.556	4.677	15.40	8.28
0.85	18.223	0.07	0.17	3.3430	5.568	4.677	15.31	8.25
0.87	18.224	0.08	0.17	3.3316	5.579	4.677	15.22	8.22
0.89	18.226	0.08	0.18	3.3199	5.591	4.677	15.13	8.19
0.92	18.227	0.09	0.18	3.3083	5.602	4.677	15.04	8.16
0.94	18.229	0.09	0.18	3.2966	5.614	4.677	14.946	8.13

Section 3 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
0.94	18.229	0.00	0.18	3.2990	5.614	4.677	14.95	8.13
0.97	18.230	0.00	0.19	3.3620	5.551	4.676	14.85	8.10
0.99	18.232	0.01	0.19	3.4231	5.490	4.675	14.75	8.06
1.02	19.233	0.01	0.20	3.4824	5.431	4.674	14.65	8.03
1.04	18.235	0.02	0.20	3.5400	5.373	4.673	14.56	8.00
1.07	18.236	0.02	0.21	3.5957	5.317	4.672	14.46	7.97
1.09	18.238	0.03	0.21	3.6497	5.263	4.671	14.37	7.94
1.12	18.239	0.03	0.22	3.7021	5.211	4.669	14.28	7.90
1.14	18.241	0.04	0.22	3.7528	5.160	4.668	14.18	7.87
1.17	18.242	0.04	0.23	3.8019	5.111	4.666	14.09	7.84
1.20	18.244	0.05	0.23	3.8494	5.064	4.664	14.00	7.81
1.22	18.245	0.05	0.24	3.8954	5.018	4.662	13.91	7.78
1.25	18.247	0.06	0.24	3.9399	4.973	4.660	13.82	7.75
1.27	18.248	0.06	0.25	3.9829	4.930	4.658	13.73	7.72
1.30	18.250	0.07	0.25	4.0245	4.889	4.656	13.64	7.69
1.32	18.251	0.07	0.26	4.0646	4.849	4.654	13.55	7.66
1.35	18.253	0.08	0.26	4.1034	4.810	4.651	13.46	7.62
1.37	18.255	0.08	0.27	4.1409	4.772	4.649	13.37	7.59
1.40	18.256	0.09	0.27	4.1770	4.736	4.646	13.28	7.56
1.42	18.258	0.09	0.28	4.2118	4.701	4.643	13.20	7.53
1.45	18.259	0.10	0.28	4.2454	4.666	4.641	13.11	7.50

Section 4 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
1.45	18.259	0.00	0.28	4.2494	4.666	4.641	13.11	7.50
1.51	18.276	0.01	0.30	4.1794	4.741	4.634	12.91	7.43
1.57	18.294	0.02	0.31	4.1118	4.808	4.627	12.70	7.36
1.63	18.311	0.03	0.32	4.0463	4.874	4.620	12.51	7.30
1.69	18.328	0.05	0.33	3.9830	4.937	4.612	12.31	7.23
1.75	18.345	0.06	0.34	3.9216	4.998	4.603	12.12	7.16
1.81	18.363	0.07	0.35	3.8621	5.058	4.594	11.93	7.10
1.87	18.380	0.08	0.37	3.8044	5.115	4.585	11.74	7.03
1.93	18.397	0.09	0.38	3.7483	5.171	4.575	11.56	6.97
1.99	18.414	0.10	0.39	3.6938	5.226	4.565	11.38	6.90
2.05	18.432	0.12	0.40	3.6407	5.279	4.554	11.20	6.84
2.10	18.449	0.13	0.41	3.5890	5.331	4.543	11.03	6.77
2.16	18.466	0.14	0.42	3.5387	5.381	4.532	10.85	6.71
2.22	18.483	0.15	0.43	3.4895	5.430	4.520	10.68	6.65
2.28	18.501	0.16	0.45	3.4416	5.478	4.507	10.52	6.59
2.34	18.518	0.17	0.46	3.3949	5.525	4.495	10.35	6.53
2.40	18.535	0.19	0.47	3.3491	5.570	4.482	10.19	6.47
2.46	18.552	0.20	0.48	3.3045	5.615	4.469	10.03	6.41
2.52	18.570	0.21	0.49	3.2609	5.658	4.455	9.88	6.35
2.58	18.587	0.22	0.50	3.2180	5.701	4.441	9.72	6.29
2.64	18.604	0.23	0.52	3.1761	5.743	4.427	9.57	6.24

Section 5 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
2.64	18.604	0.00	0.52	3.1783	5.743	4.427	9.57	6.24
2.66	18.610	0.00	0.52	3.2187	5.703	4.420	9.52	6.21
2.68	18.617	0.01	0.52	3.2593	5.664	4.413	9.46	6.19
2.71	18.623	0.01	0.53	3.2970	5.626	4.407	9.41	6.17
2.73	18.630	0.02	0.53	3.3350	5.587	4.400	9.35	6.15
2.75	18.636	0.02	0.54	3.3721	5.550	4.393	9.30	6.13
2.77	18.642	0.03	0.54	3.4085	5.514	4.386	9.25	6.11
2.79	18.649	0.03	0.55	3.4441	5.478	4.380	9.19	6.09
2.82	18.655	0.03	0.55	3.4789	5.443	4.373	9.14	6.07
2.84	18.661	0.04	0.55	3.5130	5.409	4.366	9.09	6.05
2.86	18.668	0.04	0.56	3.5463	5.376	4.359	9.04	6.03
2.88	18.674	0.05	0.56	3.5790	5.343	4.352	8.99	6.01
2.90	18.681	0.05	0.57	3.6108	5.311	4.345	8.93	5.99
2.93	18.687	0.06	0.57	3.6420	5.280	4.338	8.88	5.97
2.95	18.693	0.06	0.57	3.6725	5.250	4.331	8.83	5.95
2.97	18.700	0.06	0.58	3.7023	5.220	4.324	8.78	5.93
2.99	18.706	0.07	0.58	3.7314	5.191	4.317	8.73	5.91
3.01	18.713	0.07	0.59	3.7598	5.162	4.310	8.68	5.89
3.04	18.719	0.08	0.59	3.7875	5.135	4.303	8.63	5.87
3.06	18.725	0.08	0.60	3.8147	5.108	4.296	8.58	5.85
3.08	18.732	0.08	0.60	3.8411	5.081	4.289	8.53	5.83

Section 6 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
3.08	22.892	0.00	0.60	3.8564	5.088	3.592	7.35	5.60
3.17	22.907	0.02	0.62	3.7283	5.200	3.521	7.30	5.59
3.26	22.922	0.03	0.63	3.6010	5.326	3.451	7.25	5.59
3.35	22.937	0.05	0.65	3.4823	5.444	3.383	7.20	5.58
3.44	22.952	0.06	0.66	3.3696	5.557	3.316	7.15	5.57
3.53	22.968	0.08	0.68	3.2626	5.664	3.251	7.10	5.56
3.62	22.983	0.10	0.70	3.1610	5.765	3.187	7.05	5.55
3.71	22.998	0.11	0.71	3.0644	5.862	3.125	7.00	5.55
3.80	23.013	0.13	0.73	2.9726	5.953	3.064	6.96	5.54
3.89	23.028	0.14	0.74	2.8853	6.041	3.004	6.91	5.53
3.98	23.044	0.16	0.76	2.8021	6.124	2.946	6.86	5.52
4.06	23.059	0.18	0.78	2.7229	6.203	2.889	6.82	5.51
4.15	23.074	0.19	0.79	2.6475	6.278	2.833	6.77	5.51
4.24	23.089	0.21	0.81	2.5756	6.350	2.778	6.72	5.50
4.33	23.104	0.22	0.83	2.5069	6.419	2.725	6.68	5.49
4.42	23.120	0.24	0.84	2.4414	6.484	2.673	6.63	5.48
4.51	23.135	0.26	0.86	2.3788	6.547	2.622	6.59	5.47
4.60	23.150	0.27	0.87	2.3190	6.606	2.572	6.54	5.47
4.69	23.165	0.29	0.89	2.2618	6.664	2.524	6.50	5.46
4.78	23.180	0.31	0.91	2.2071	6.718	2.476	6.46	5.45
4.87	23.196	0.32	0.92	2.1547	6.771	2.429	6.41	5.44

Section 7 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
4.87	23.196	0.00	0.92	2.1579	6.771	2.429	6.41	5.44
4.90	23.200	0.00	0.93	2.1454	6.783	2.414	6.40	5.44
4.93	23.205	0.01	0.93	2.1331	6.795	2.399	6.39	5.44
4.95	23.210	0.01	0.94	2.1209	6.808	2.384	6.37	5.43
4.98	23.215	0.02	0.94	2.1088	6.820	2.369	6.36	5.43
5.01	23.219	0.02	0.95	2.0968	6.832	2.354	6.34	5.43
5.04	23.224	0.03	0.95	2.0849	6.844	2.339	6.33	5.43
5.07	23.229	0.03	0.96	2.0731	6.856	2.324	6.32	5.43
5.09	23.234	0.04	0.96	2.0614	6.867	2.310	6.30	5.42
5.12	23.238	0.04	0.97	2.0498	6.879	2.295	6.29	5.42
5.15	23.243	0.05	0.97	2.0384	6.890	2.281	6.28	5.42
5.18	23.248	0.05	0.98	2.0270	6.902	2.267	6.27	5.42
5.21	23.253	0.06	0.98	2.0157	6.913	2.253	6.25	5.41
5.23	23.257	0.06	0.99	2.0045	6.924	2.239	6.24	5.41
5.26	23.262	0.07	0.99	1.9934	6.935	2.225	6.23	5.41
5.29	23.267	0.07	1.00	1.9824	6.946	2.211	6.21	5.41
5.32	23.272	0.08	1.00	1.9715	6.957	2.197	6.20	5.40
5.35	23.276	0.08	1.01	1.9606	6.968	2.184	6.19	5.40
5.37	23.281	0.09	1.01	1.9499	6.979	2.170	6.17	5.40
5.40	23.286	0.09	1.02	1.9393	6.989	2.157	6.16	5.40
5.43	23.291	0.10	1.02	1.9287	7.000	2.143	6.15	5.39

Section 8 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
5.43	24.181	0.00	1.02	1.9676	6.963	2.081	6.00	5.36
5.48	24.189	0.01	1.03	1.9513	6.980	2.060	5.97	5.36
5.53	24.197	0.02	1.04	1.9351	6.996	2.038	5.95	5.36
5.58	24.206	0.03	1.05	1.9191	7.012	2.017	5.93	5.35
5.63	24.214	0.03	1.06	1.9032	7.028	1.996	5.91	5.35
5.67	24.222	0.04	1.06	1.8876	7.043	1.976	5.89	5.34
5.72	24.231	0.05	1.07	1.8721	7.059	1.955	5.87	5.34
5.77	24.239	0.06	1.08	1.8568	7.074	1.935	5.85	5.34
5.82	24.247	0.07	1.09	1.8416	7.089	1.915	5.83	5.33
5.87	24.256	0.08	1.10	1.8266	7.104	1.895	5.81	5.33
5.92	24.264	0.08	1.11	1.8118	7.119	1.876	5.79	5.32
5.97	24.272	0.09	1.11	1.7972	7.134	1.857	5.76	5.32
6.02	24.281	0.10	1.12	1.7827	7.148	1.838	5.74	5.32
6.07	24.289	0.11	1.13	1.7683	7.163	1.819	5.72	5.31
6.12	24.297	0.12	1.14	1.7542	7.177	1.801	5.70	5.31
6.16	24.306	0.13	1.15	1.7401	7.191	1.782	5.68	5.30
6.21	24.314	0.14	1.16	1.7263	7.205	1.764	5.66	5.30
6.26	24.322	0.14	1.17	1.7126	7.219	1.747	5.64	5.30
6.31	24.331	0.15	1.17	1.6990	7.232	1.729	5.62	5.29
6.36	24.339	0.16	1.18	1.6856	7.245	1.712	5.60	5.29
6.41	24.347	0.17	1.19	1.6723	7.259	1.695	5.58	5.28

Section 9 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
6.41	155.847	0.00	1.19	2.7358	6.197	4.121	21.12	8.54
6.45	155.854	0.00	1.20	2.7919	6.141	4.096	21.08	8.53
6.49	155.862	0.01	1.20	2.8473	6.086	4.071	21.04	8.53
6.53	155.869	0.01	1.21	2.9021	6.031	4.046	21.00	8.52
6.57	155.876	0.02	1.21	2.9564	5.976	4.021	20.95	8.52
6.61	155.884	0.02	1.22	3.0102	5.922	3.997	20.91	8.52
6.65	155.891	0.03	1.22	3.0633	5.869	3.973	20.87	8.51
6.69	155.898	0.03	1.23	3.1160	5.817	3.949	20.83	8.51
6.73	155.906	0.04	1.23	3.1681	5.765	3.925	20.78	8.50
6.77	155.913	0.04	1.24	3.2197	5.713	3.901	20.74	8.50
6.81	155.920	0.05	1.24	3.2707	5.662	3.877	20.70	8.49
6.85	155.927	0.05	1.25	3.3213	5.611	3.854	20.66	8.49
6.90	155.935	0.06	1.25	3.3713	5.561	3.831	20.62	8.49
6.94	155.942	0.06	1.26	3.4207	5.512	3.808	20.58	8.48
6.98	155.949	0.07	1.26	3.4697	5.463	3.785	20.53	8.48
7.02	155.957	0.07	1.27	3.5182	5.414	3.762	20.49	8.47
7.06	155.964	0.08	1.27	3.5661	5.367	3.739	20.45	8.47
7.10	155.971	0.08	1.28	3.6136	5.319	3.717	20.41	8.46
7.14	155.979	0.09	1.28	3.6606	5.272	3.695	20.37	8.46
7.18	155.986	0.09	1.29	3.7070	5.226	3.673	20.33	8.46
7.22	155.993	0.10	1.29	3.7530	5.180	3.651	20.29	8.45

Section 10 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.22	155.993	0.00	1.29	3.7530	5.180	3.651	20.29	8.45
7.25	155.999	0.00	1.29	3.7246	5.210	3.634	20.26	8.45
7.28	156.005	0.01	1.30	3.6951	5.239	3.618	20.22	8.45
7.31	156.010	0.01	1.30	3.6660	5.268	3.602	20.19	8.44
7.35	156.016	0.02	1.31	3.6375	5.297	3.586	20.16	8.44
7.38	156.022	0.02	1.31	3.6094	5.325	3.570	20.13	8.44
7.41	156.027	0.02	1.31	3.5818	5.353	3.555	20.10	8.43
7.44	156.033	0.03	1.32	3.5546	5.380	3.539	20.07	8.43
7.47	156.039	0.03	1.32	3.5279	5.406	3.523	20.03	8.43
7.50	156.044	0.03	1.32	3.5017	5.433	3.508	20.00	8.42
7.53	156.050	0.04	1.33	3.4759	5.459	3.492	19.97	8.42
7.57	156.056	0.04	1.33	3.4504	5.484	3.477	19.94	8.42
7.60	156.061	0.05	1.34	3.4255	5.509	3.462	19.91	8.41
7.63	156.067	0.05	1.34	3.4009	5.534	3.446	19.88	8.41
7.66	156.073	0.05	1.34	3.3767	5.558	3.431	19.85	8.41
7.69	156.078	0.06	1.35	3.3529	5.581	3.416	19.82	8.40
7.72	156.084	0.06	1.35	3.3295	5.605	3.401	19.79	8.40
7.76	156.090	0.07	1.36	3.3064	5.628	3.386	19.75	8.40
7.79	156.095	0.07	1.36	3.2837	5.651	3.371	19.72	8.39
7.82	156.101	0.07	1.36	3.2614	5.673	3.357	19.69	8.39
7.85	156.107	0.08	1.37	3.2394	5.695	3.342	19.66	8.39

Section 11 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.85	158.167	0.00	1.37	3.2369	5.699	3.304	19.43	8.34
7.86	158.168	0.00	1.37	3.2387	5.697	3.301	19.42	8.34
7.86	158.169	0.00	1.37	3.2405	5.695	3.298	19.42	8.34
7.87	158.171	0.00	1.37	3.2422	5.694	3.295	19.41	8.33
7.88	158.172	0.00	1.37	3.2439	5.692	3.292	19.40	8.33
7.89	158.173	0.00	1.37	3.2456	5.690	3.288	19.40	8.33
7.89	158.174	0.01	1.37	3.2474	5.689	3.285	19.39	8.33
7.90	158.176	0.01	1.37	3.2490	5.687	3.282	19.38	8.33
7.91	158.177	0.01	1.37	3.2507	5.685	3.279	19.38	8.33
7.91	158.178	0.01	1.37	3.2524	5.683	3.275	19.37	8.33
7.92	158.179	0.01	1.38	3.2541	5.682	3.272	19.36	8.33
7.93	158.181	0.01	1.38	3.2557	5.680	3.269	19.36	8.33
7.93	158.182	0.01	1.38	3.2574	5.678	3.266	19.35	8.33
7.94	158.183	0.01	1.38	3.2590	5.677	3.263	19.34	8.33
7.95	158.184	0.01	1.38	3.2606	5.675	3.259	19.34	8.33
7.95	158.186	0.01	1.38	3.2622	5.674	3.256	19.33	8.33
7.96	158.187	0.01	1.38	3.2638	5.672	3.253	19.32	8.33
7.97	158.188	0.01	1.38	3.2654	5.670	3.250	19.32	8.32
7.98	158.189	0.02	1.38	3.2670	5.669	3.247	19.31	8.32
7.98	158.191	0.02	1.38	3.2686	5.667	3.243	19.30	8.32
7.99	158.192	0.02	1.38	3.2701	5.666	3.240	19.30	8.32

Section 12 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
7.99	158.192	0.00	1.38	3.2705	5.666	3.240	19.30	8.32
8.01	158.195	0.00	1.39	3.2860	5.650	3.233	19.28	8.32
8.02	158.198	0.00	1.39	3.3015	5.635	3.225	19.27	8.32
8.04	158.201	0.01	1.39	3.3169	5.619	3.218	19.25	8.32
8.06	158.204	0.01	1.39	3.3322	5.604	3.210	19.24	8.32
8.07	158.207	0.01	1.39	3.3474	5.589	3.203	19.22	8.31
8.09	158.210	0.01	1.40	3.3626	5.574	3.196	19.20	8.31
8.11	158.213	0.01	1.40	3.3777	5.559	3.188	19.19	8.31
8.12	158.216	0.02	1.40	3.3927	5.544	3.181	19.17	8.31
8.14	158.219	0.02	1.40	3.4077	5.529	3.174	19.16	8.31
8.16	158.222	0.02	1.40	3.4226	5.514	3.166	19.14	8.31
8.17	158.225	0.02	1.41	3.4374	5.499	3.159	19.13	8.30
8.19	158.228	0.02	1.41	3.4521	5.484	3.152	19.11	8.30
8.20	158.231	0.03	1.41	3.4667	5.469	3.145	19.10	8.30
8.22	158.234	0.03	1.41	3.4813	5.455	3.138	19.08	8.30
8.24	158.237	0.03	1.41	3.4958	5.440	3.130	19.07	8.30
8.25	158.240	0.03	1.42	3.5103	5.426	3.123	19.05	8.30
8.27	158.243	0.03	1.42	3.5247	5.412	3.116	19.03	8.29
8.29	158.246	0.04	1.42	3.5390	5.397	3.109	19.02	8.29
8.30	158.248	0.04	1.42	3.5532	5.383	3.102	19.00	8.29
8.32	158.251	0.04	1.42	3.5673	5.369	3.095	18.99	8.29

Section 13 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
8.32	158.251	0.00	1.42	3.5727	5.369	3.095	18.99	8.29
8.54	158.288	0.03	1.45	3.5939	5.348	3.004	18.79	8.27
8.76	158.325	0.05	1.48	3.6083	5.334	2.917	18.58	8.24
8.98	158.361	0.08	1.50	3.6166	5.326	2.833	18.39	8.22
9.20	158.398	0.11	1.53	3.6193	5.323	2.752	18.19	8.20
9.42	158.435	0.13	1.56	3.6170	5.325	2.674	18.00	8.18
9.64	158.472	0.16	1.58	3.6102	5.332	2.598	17.80	8.16
9.86	158.508	0.18	1.61	3.5994	5.343	2.526	17.61	8.13
10.08	158.545	0.21	1.63	3.5850	5.357	2.455	17.43	8.11
10.30	158.582	0.24	1.66	3.5673	5.375	2.388	17.24	8.09
10.52	158.618	0.26	1.69	3.5469	5.395	2.322	17.05	8.07
10.73	158.655	0.29	1.71	3.5239	5.419	2.259	16.87	8.05
10.95	158.692	0.32	1.74	3.4988	5.443	2.199	16.69	8.03
11.17	158.729	0.34	1.77	3.4714	5.471	2.140	16.51	8.01
11.39	158.765	0.37	1.79	3.4425	5.500	2.084	16.34	7.98
11.61	158.802	0.40	1.82	3.4121	5.530	2.029	16.16	7.96
11.83	158.838	0.42	1.85	3.3805	5.562	1.977	15.99	7.94
12.05	158.875	0.45	1.87	3.3477	5.594	1.926	15.82	7.92
12.27	158.912	0.47	1.90	3.3140	5.628	1.877	15.65	7.90
12.49	158.948	0.50	1.92	3.2795	5.663	1.830	15.48	7.88
12.71	158.985	0.53	1.95	3.2444	5.698	1.784	15.32	7.86

Section 14 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
12.71	158.985	0.00	1.95	3.2522	5.698	1.784	15.32	7.86
12.81	158.997	0.01	1.96	3.1722	5.778	1.769	15.26	7.85
12.91	159.009	0.02	1.97	3.0956	5.854	1.754	15.21	7.84
13.02	159.020	0.03	1.98	3.0223	5.928	1.739	15.16	7.84
13.12	159.032	0.04	1.99	2.9521	5.998	1.725	15.10	7.83
13.22	159.044	0.04	1.99	2.8848	6.065	1.710	15.05	7.82
13.32	159.056	0.05	2.00	2.8204	6.130	1.696	14.99	7.82
13.42	159.068	0.06	2.01	2.7586	6.191	1.682	14.94	7.81
13.53	159.079	0.07	2.02	2.6995	6.251	1.668	14.89	7.80
13.63	159.091	0.08	2.03	2.6427	6.307	1.654	14.84	7.80
13.73	159.103	0.09	2.04	2.5884	6.362	1.640	14.78	7.79
13.83	159.115	0.10	2.05	2.5362	6.414	1.627	14.73	7.78
13.93	159.127	0.11	2.06	2.4862	6.464	1.614	14.68	7.77
14.04	159.138	0.11	2.06	2.4382	6.512	1.601	14.63	7.77
14.14	159.150	0.12	2.07	2.3921	6.558	1.588	14.57	7.76
14.24	159.162	0.13	2.08	2.3479	6.602	1.575	14.52	7.75
14.34	159.174	0.14	2.09	2.3054	6.645	1.562	14.47	7.75
14.44	159.186	0.15	2.10	2.2647	6.685	1.550	14.42	7.74
14.55	159.197	0.16	2.11	2.2255	6.724	1.537	14.37	7.73
14.65	159.209	0.17	2.12	2.1878	6.762	1.525	14.32	7.73
14.75	159.221	0.18	2.13	2.1516	6.798	1.513	14.26	7.72

Section 15 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
14.75	161.601	0.00	2.13	2.1718	6.787	1.497	14.08	7.67
14.90	161.616	0.01	2.14	2.0948	6.864	1.479	14.01	7.66
15.05	161.632	0.03	2.16	2.0233	6.935	1.461	13.94	7.65
15.21	161.647	0.04	2.17	1.9567	7.002	1.444	13.86	7.64
15.36	161.662	0.05	2.18	1.8949	7.064	1.428	13.79	7.63
15.51	161.677	0.06	2.19	1.8373	7.121	1.409	13.72	7.62
15.67	161.693	0.08	2.20	1.7836	7.175	1.393	13.65	7.61
15.82	161.708	0.09	2.22	1.7336	7.225	1.376	13.58	7.60
15.97	161.723	0.10	2.23	1.6870	7.271	1.360	13.50	7.59
16.12	161.738	0.12	2.24	1.6434	7.315	1.345	13.43	7.58
16.28	161.754	0.13	2.26	1.6027	7.356	1.329	13.36	7.57
16.43	161.769	0.14	2.27	1.5647	7.394	1.314	13.29	7.56
16.58	161.784	0.16	2.28	1.5290	7.429	1.299	13.22	7.55
16.73	161.799	0.17	2.29	1.4956	7.463	1.284	13.15	7.54
16.89	161.815	0.18	2.31	1.4643	7.494	1.270	13.09	7.53
17.04	161.830	0.19	2.32	1.4348	7.524	1.256	13.02	7.52
17.19	161.845	0.21	2.33	1.4072	7.551	1.242	12.95	7.51
17.34	161.860	0.22	2.35	1.3811	7.577	1.228	12.88	7.51
17.50	161.876	0.23	2.36	1.3566	7.602	1.215	12.81	7.50
17.65	161.891	0.25	2.37	1.3335	7.625	1.202	12.75	7.49
17.80	161.906	0.26	2.39	1.3116	7.647	1.189	12.68	7.48

Section 16 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
17.80	161.906	0.00	2.39	1.3192	7.647	1.189	12.68	7.48
17.88	161.914	0.01	2.39	1.3215	7.645	1.182	12.64	7.47
17.97	161.923	0.01	2.40	1.3234	7.643	1.174	12.61	7.47
18.05	161.931	0.02	2.41	1.3251	7.641	1.167	12.57	7.46
18.13	161.939	0.03	2.41	1.3266	7.639	1.160	12.54	7.45
18.22	161.948	0.04	2.42	1.3279	7.638	1.153	12.50	7.45
18.30	161.956	0.04	2.43	1.3289	7.637	1.146	12.46	7.44
18.38	161.965	0.05	2.43	1.3298	7.636	1.140	12.43	7.44
18.47	161.973	0.06	2.44	1.3304	7.636	1.133	12.39	7.43
18.55	161.981	0.06	2.45	1.3309	7.635	1.126	12.36	7.43
18.64	161.990	0.07	2.46	1.3311	7.635	1.119	12.32	7.42
18.72	161.998	0.08	2.46	1.3312	7.635	1.113	12.29	7.42
18.80	162.006	0.08	2.47	1.3311	7.635	1.106	12.25	7.41
18.89	162.015	0.09	2.48	1.3309	7.635	1.100	12.22	7.41
18.97	162.023	0.10	2.48	1.3305	7.636	1.094	12.18	7.40
19.05	162.031	0.11	2.49	1.3300	7.636	1.087	12.15	7.40
19.14	162.040	0.11	2.50	1.3293	7.637	1.081	12.11	7.39
19.22	162.048	0.12	2.51	1.3284	7.638	1.075	12.08	7.39
19.30	162.056	0.13	2.51	1.3275	7.639	1.069	12.04	7.38
19.39	162.065	0.13	2.52	1.3264	7.640	1.063	12.01	7.38
19.47	162.073	0.14	2.53	1.3252	7.641	1.057	11.97	7.37

Section 17 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
19.47	164.023	0.00	2.53	1.3504	7.621	1.050	11.85	7.34
19.78	164.061	0.03	2.55	1.4571	7.516	1.028	11.73	7.32
20.10	164.098	0.05	2.58	1.5573	7.415	1.008	11.60	7.30
20.41	164.136	0.08	2.61	1.6514	7.320	0.988	11.48	7.28
20.72	164.173	0.10	2.63	1.7398	7.232	0.969	11.36	7.26
21.04	164.211	0.13	2.66	1.8226	7.149	0.951	11.24	7.24
21.35	164.249	0.16	2.69	1.9002	7.072	0.933	11.12	7.22
21.66	164.286	0.18	2.71	1.9727	6.999	0.916	11.00	7.20
21.97	164.323	0.21	2.74	2.0405	6.932	0.900	10.88	7.18
22.29	164.361	0.24	2.76	2.1037	6.868	0.884	10.77	7.16
22.60	164.399	0.26	2.79	2.1626	6.809	0.869	10.65	7.15
22.91	164.436	0.29	2.82	2.2174	6.755	0.854	10.54	7.13
23.23	164.474	0.31	2.84	2.2683	6.704	0.840	10.43	7.11
23.54	164.511	0.34	2.87	2.3154	6.657	0.826	10.32	7.09
23.85	164.549	0.37	2.89	2.3590	6.613	0.813	10.21	7.07
24.17	164.586	0.39	2.92	2.3992	6.573	0.800	10.10	7.05
24.48	164.624	0.42	2.95	2.4362	6.536	0.788	9.99	7.03
24.79	164.661	0.45	2.97	2.4702	6.502	0.776	9.89	7.02
25.10	164.699	0.47	3.00	2.5012	6.471	0.765	9.78	7.00
25.42	164.737	0.50	3.03	2.5295	6.443	0.753	9.68	6.98
25.73	164.774	0.52	3.05	2.5552	6.417	0.743	9.58	6.96

Section18 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
25.73	164.774	0.00	3.05	2.5590	6.417	0.743	9.58	6.96
25.77	164.779	0.00	3.06	2.5640	6.412	0.741	9.56	6.96
25.82	164.784	0.01	3.06	2.5690	6.407	0.740	9.55	6.96
25.86	164.789	0.01	3.06	2.5739	6.402	0.739	9.54	6.95
25.90	164.794	0.01	3.07	2.5788	6.397	0.737	9.52	6.95
25.95	164.799	0.02	3.07	2.5836	6.392	0.736	9.51	6.95
25.99	164.804	0.02	3.07	2.5884	6.388	0.735	9.49	6.95
26.03	164.809	0.03	3.08	2.5931	6.383	0.733	9.48	6.94
26.08	164.814	0.03	3.08	2.5977	6.378	0.732	9.47	6.94
26.12	164.819	0.03	3.08	2.6024	6.374	0.731	9.46	6.94
26.17	164.825	0.04	3.09	2.6069	6.369	0.729	9.44	6.94
26.21	164.830	0.04	3.09	2.6114	6.365	0.728	9.42	6.93
26.25	164.835	0.04	3.10	2.6159	6.360	0.727	9.41	6.93
26.30	164.840	0.05	3.10	2.6203	6.356	0.725	9.40	6.93
26.34	164.845	0.05	3.10	2.6247	6.351	0.724	9.38	6.92
26.38	164.850	0.05	3.11	2.6290	6.347	0.723	9.37	6.92
26.43	164.855	0.06	3.11	2.6333	6.343	0.722	9.35	6.92
26.47	164.860	0.06	3.11	2.6375	6.338	0.720	9.34	6.92
26.51	164.865	0.07	3.12	2.6416	6.334	0.719	9.33	6.91
26.56	164.870	0.07	3.12	2.6458	6.330	0.718	9.31	6.91
26.60	164.875	0.07	3.12	2.6498	6.326	0.717	9.30	6.91

Section 19 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
26.60	168.785	0.00	3.12	2.6640	6.319	0.710	9.13	6.86
27.00	168.831	0.03	3.16	2.6950	6.288	0.700	9.01	6.83
27.40	168.878	0.07	3.19	2.7227	6.260	0.690	8.89	6.81
27.80	168.924	0.10	3.22	2.7472	6.236	0.680	8.77	6.79
28.20	168.971	0.13	3.26	2.7686	6.214	0.671	8.66	6.77
28.60	169.017	0.16	3.29	2.7873	6.196	0.662	8.54	6.74
29.00	169.063	0.20	3.32	2.8032	6.180	0.654	8.43	6.72
29.40	169.110	0.23	3.35	2.8168	6.166	0.646	8.32	6.70
29.80	169.156	0.26	3.39	2.8277	6.155	0.638	8.21	6.68
30.20	169.202	0.30	3.42	2.8364	6.147	0.630	8.10	6.66
30.60	169.249	0.33	3.45	2.8431	6.140	0.623	7.99	6.63
31.00	169.295	0.36	3.49	2.8478	6.135	0.616	7.89	6.61
31.40	169.342	0.39	3.52	2.8506	6.132	0.609	7.78	6.59
31.80	169.388	0.43	3.55	2.8517	6.131	0.602	7.68	6.57
32.20	169.434	0.46	3.58	2.8511	6.132	0.596	7.58	6.55
32.60	169.481	0.49	3.62	2.8489	6.134	0.590	7.48	6.53
33.00	169.527	0.52	3.65	2.8453	6.138	0.584	7.38	6.51
33.40	169.574	0.56	3.68	2.8404	6.143	0.578	7.28	6.48
33.80	169.620	0.59	3.71	2.8341	6.149	0.573	7.19	6.46
34.20	169.666	0.62	3.75	2.8267	6.156	0.568	7.09	6.44
34.60	169.713	0.66	3.78	2.8181	6.165	0.562	7.00	6.42

Section 20 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
34.60	169.713	0.00	3.78	2.8239	6.165	0.562	7.00	6.42
34.74	169.729	0.01	3.79	2.8203	6.169	0.561	6.98	6.41
34.88	169.745	0.02	3.80	2.8166	6.172	0.559	6.95	6.41
35.01	169.761	0.03	3.81	2.8128	6.176	0.557	6.93	6.40
35.15	169.777	0.04	3.82	2.8090	6.180	0.556	6.91	6.39
35.29	169.793	0.05	3.83	2.8051	6.184	0.554	6.89	6.39
35.43	169.809	0.07	3.85	2.8012	6.188	0.552	6.86	6.38
35.56	169.824	0.08	3.86	2.7972	6.192	0.551	6.84	6.37
35.70	169.840	0.09	3.87	2.7932	6.196	0.549	6.81	6.37
35.84	169.856	0.10	3.88	2.7892	6.200	0.547	6.79	6.36
35.98	169.872	0.11	3.89	2.7850	6.204	0.546	6.77	6.35
36.11	169.888	0.12	3.90	2.7809	6.208	0.544	6.75	6.35
36.25	169.904	0.13	3.91	2.7767	6.212	0.543	6.72	6.34
36.39	169.920	0.14	3.92	2.7724	6.216	0.541	6.70	6.33
36.53	169.936	0.15	3.93	2.7681	6.221	0.540	6.68	6.32
36.66	169.952	0.16	3.94	2.7638	6.225	0.538	6.66	6.32
36.80	169.968	0.18	3.96	2.7594	6.229	0.537	6.63	6.31
36.94	169.984	0.19	3.97	2.7550	6.234	0.535	6.61	6.30
37.08	170.000	0.20	3.98	2.7505	6.238	0.534	6.59	6.30
37.21	170.016	0.21	3.99	2.7460	6.243	0.533	6.57	6.29
37.35	170.032	0.22	4.00	2.7415	6.247	0.531	6.55	6.28

Section 21 Distance (miles)	Flow (cfs)	Section Time (day)	Cumulative Time (day)	O2 Deficit (mg/l)	DO (mg/l)	NH3ODU (mg/l)	CBODU (mg/l)	TONODU (mg/l)
37.35	176.002	0.00	4.00	2.7506	6.239	0.529	6.39	6.23
37.74	176.047	0.03	4.03	2.7356	6.254	0.526	6.33	6.21
38.14	176.092	0.06	4.06	2.7204	6.270	0.521	6.27	6.19
38.53	176.137	0.09	4.09	2.7051	6.285	0.518	6.22	6.17
38.93	176.182	0.12	4.12	2.6896	6.300	0.514	6.16	6.15
39.32	176.227	0.15	4.15	2.6740	6.316	0.511	6.10	6.13
39.71	176.272	0.18	4.18	2.6582	6.332	0.508	6.04	6.11
40.11	176.318	0.22	4.22	2.6424	6.348	0.504	5.99	6.09
40.50	176.363	0.25	4.25	2.6264	6.364	0.501	5.93	6.07
40.90	176.408	0.28	4.28	2.6104	6.380	0.498	5.87	6.06
41.29	176.453	0.31	4.31	2.5943	6.396	0.495	5.82	6.04
41.68	176.498	0.34	4.34	2.5781	6.412	0.492	5.77	6.02
42.08	176.543	0.37	4.37	2.5619	6.428	0.490	5.71	6.00
42.47	176.588	0.40	4.40	2.5457	6.444	0.487	5.66	5.98
42.87	176.633	0.43	4.43	2.5294	6.461	0.484	5.61	5.96
43.26	176.678	0.46	4.46	2.5131	6.477	0.482	5.55	5.95
43.65	176.724	0.49	4.49	2.4967	6.493	0.479	5.50	5.93
44.05	176.769	0.52	4.52	2.4804	6.510	0.477	5.45	5.91
44.44	176.814	0.55	4.55	2.4640	6.526	0.474	5.40	5.89
44.84	176.859	0.59	4.59	2.4477	6.542	0.472	5.35	5.87
45.23	176.904	0.62	4.62	2.4314	6.559	0.469	5.30	5.86

Attachment 6

Detailed Recreational Use Attainability Analysis for Village and Valley Creeks, EPA Region 4

INTRODUCTION

The segments of Village and Valley Creeks drain adjacent watershed in Jefferson County, Alabama. The land usage is predominantly urban and their watersheds are virtually identical in their physical characteristics and pollution stressors. Sources of bacteria in the watersheds include leaking sewer lines, discharge and overflows from wastewater treatment plants, domestic animals, wildlife, and leaking septic systems. In addition, there are little to no vegetated riparian zones to filter runoff, a high water table, and a generally steep slope to the landscape. These factors reduce travel time and increase delivery ratio (fraction of bacteria deposited on land that arrives in stream water) of bacteria to the creeks from runoff. Climate and landscape factors also tend to mitigate the process of natural decay, increasing the likelihood of delivery of bacteria to the creek waters from land-based sources. Bacteria enter the creeks from point source discharge of treated domestic sewage and overflow generated by stormwater, as well as land-based non-point sources from overland runoff and through baseflow from infiltration. The municipal dischargers currently operate disinfection processes and would meet F&W discharge limits end of pipe. Sewer overflows and leaking sewer lines are a known problem in the watersheds and Jefferson County is currently under a consent decree that involves expenditure of $800 million to fix those problems by 2006.

DATA ANALYSIS

There are three data sets available for analysis:

1) Weekly measurements of fecal coliform bacteria during 2000 from two monitoring locations in Village Creek, one upstream from the WWTP and one downstream
2) Flow records from the same monitoring locations on the same days
3) Daily precipitation measurements during 2000 from a nearby airport

These data can help address three questions:

1) What pattern of bacteria levels are exhibited in Village Creek and likely exhibited in Valley Creek?
2) What influence do point source discharges have on bacteria levels in Village Creek and likely have in Valley Creek?
3) To what extent do precipitation events and patterns affect bacteria levels in Village Creek and likely in Valley Creek?

Figure 1 depicts upstream and downstream single sample bacteria measurements taken during 2000 plotted again the corresponding stream flow. The data range is restricted to measures below 2000 Colony Forming Units (CFU)/100 ml to better observe the relationship. Fecal concentrations do not correlate well with flow. It is apparent that flow is greatly augmented by discharge with downstream measures associated with much higher flows. Concentrations tend to be higher upstream of the discharge.

Figure 2 depicts downstream bacteria levels plotted against upstream bacteria levels. The data range is restricted to measures below 1000 CFU/100 ml to better observe the relationship and avoid measures that are likely associated with sewer overflow events. The unity line helps show that, regardless of magnitude, the concentration downstream does not exceed concentration upstream. This plot helps indicate that discharge of treated sewage from the WWTP is not a significant contributor to downstream bacteria levels.

Figure 3a is a plot of the running geometric mean (using five weekly measures taken over approximately the previous 30 days) over the course of the year for both the upstream and downstream monitoring locations. It shows an irregular pattern with downstream levels tending to follow upstream levels with an effluent dilution effect, with a notable exception of downstream geometric means plotted in early April, where highly elevated levels are likely indicative of raw sewage from a sewer overflow event. In general, bacteria levels are low in winter months, rise in early spring, remain variable yet high into the summer months, fall somewhat in late summer/early autumn, then rise again in late autumn. Values above the 1000 CFU/100 ml geometric mean bacteria criteria for LWF occur both the upstream and downstream monitoring locations.

Figure 3b is the same plot depicting only data from the months of June-September. The June-September 200 CFU/100 ml bacteria criteria for F&W is consistently exceeded at both monitoring locations.

Figures 4a-c are frequency distribution plots of year round single sample data, year round running geometric mean data, and June-September running geometric mean data. At both monitoring locations, approximately 85 percent of single sample measures are below the 2000 CFU/100 ml single sample bacteria criteria for LWF, and about 90 percent of the running geometric mean values are below the 1000 CFU/100 ml geometric mean bacteria criteria for LWF. During June-September, the running geometric mean consistently exceeded 200 CFU/100 ml and exceeded 400 CFU/100 ml almost half of the time at the downstream monitoring station and almost all of the time at the upstream monitoring station.

Figure 5 depicts daily precipitation measurements during 2000 from a nearby airport that should accurately reflect precipitation in the Village Creek watershed. Periods of relatively heavy rains occurred in March, late July/early August, and mid November.

Figure 6a plots single sample bacteria measurements throughout the year on one axis and precipitation totals from the five days prior to bacteria measurement on the other axis. The plot reveals a relationship between bacteria measurements and accumulated rainfall during the few days prior to measurement during the period from mid-March through late November, where rainfall peaks correspond to either upstream or downstream (or both typically) spikes in bacteria levels. In general, approximately one inch of accumulated rainfall over 5 days corresponds to measured bacteria levels above 1000 CFU/100 ml. In particular, the heavy rains of March and November match the very high spikes in bacteria levels. Two measures appear anomalous: the upstream and downstream bacteria spike on May 10 is not associated with significant prior rainfall and the upstream measurement on June 5 seems disproportionately high in comparison to the past five days rainfall. **Figure 6b** is a close up of the plot for the mid June-September time period when relatively heavy rains appear to result in smaller bacteria spikes in comparison to other seasons. Season and temperature may play an important role in the relationship between precipitation and instream bacteria concentration. Low temperatures in winter may not be favorable for bacteria survival, whereas warmer temperatures in late summer may result in a general higher level of bacteria growth but also an increased decay rate that results in smaller bacteria concentration spikes.

Figure 7a plots the running geometric mean values also depicted in Figure 3a on one axis and precipitation totals from the 30 days prior to bacteria measurement on the other axis. Each point thus represents a composite of conditions over the previous month. This plot reveals a general relationship between bacteria measurements and accumulated rainfall during the same month, with the exception of data from early May to early June (plotted as values from early June-early July). This deviation reflects the influence of the measurements taken on May 10 and June 5. **Figure 7b** depicts the same data displayed in Figure 7a without those measures participating in the geometric mean calculations. This does not imply that those measures are incorrect: only that they don't fit the pattern with precipitation as do the other measures.

DISCUSSION AND CONCLUSION

Bacteria measurements taken at the location downstream of the WWTP in Village Creek are either be equal to or lower than upstream measurement, except in instances where sewer overflows appear to have occurred. It is clear from the data analysis that discharge of treated sewage from the WWTP is not a significant contributor to the measured downstream bacteria levels. The correlation of downstream spikes in bacteria levels above 1000 CFU/100 ml with rainfall events, and the high spike in response to heavy March rains in particular, suggest that sewer overflows are the most likely cause. The correlation of upstream spikes in bacteria levels above 1000 CFU/100 ml with rainfall events could result from land-based sources such as domestic animals and wildlife affected by overland flow, or from non-point sources such as leaking sewer lines and leaking septic systems that are relatively close to the creek bed with short delivery times from groundwater to baseflow in the creek. The high upstream spikes in response to significant rainfall events suggest leaking sewer lines as the most likely cause. Although a running geometric mean of 1000 CFU/100 ml and single sample maximum of 200 CFU/ 100 ml were exceeded approximately 10-15 percent of the time at both monitoring locations, it is anticipated that work to resolve the sewer overflows and replace leaking sewer lines will result in attainability of the LWF use classification with respect to bacteria criteria.

The pattern of correlation between precipitation over the previous 30 days and the running geometric mean of 5 weekly bacteria measures (monthly plots) suggest that non-point sources such as leaking sewer lines, domestic animals, wildlife, and leaking septic systems are the dominant contributors of bacteria levels to creek waters over longer periods of time, and that favorable conditions in the watershed for delivery may also play an important role. During the June-September period, when rainfall was generally low, the running geometric mean consistently exceeded 200 CFU/100 ml and exceeded 400 CFU/100 ml almost half of the time at the downstream monitoring station and almost all of the time at the upstream monitoring station. It is clear from the data and analysis that the primary contact recreation aspect of F&W is not attainable under the current conditions which include leaking sewer lines.

No currently available information suggests that primary contact recreation is attainable. In fact, the available information suggests that the magnitude of bacteria levels, the variety of sources, and the physical characteristics of the waterbody indicate that primary contact recreation to the degree of protection provided by the F&W use classification is not attainable, and the highest attainable use is LWF. Therefore, a primary contact recreation use (such as F&W) is not designated at this time as a result of a combination of human-caused conditions (that may not be feasible to fully remedy), natural physical conditions of the watershed unrelated to water quality (e.g., high water table), and likely to a lesser extent natural sources of pollution. However, it is anticipated that the substantial capital investment to resolve sewer overflows and replace leaking sewer lines will improve water quality. It is not currently possible to determine the percent contribution from the known categories of non-point sources, nor is it possible to project the degree of success in terms of bacteria levels that will result from replacing the leaking sewer lines. As new information becomes available that pertains to attainability of recreation in and on the water, it will be considered and water quality standards revised accordingly.

Figure 1: Bacteria Levels and Flow (Village Creek, 2000)

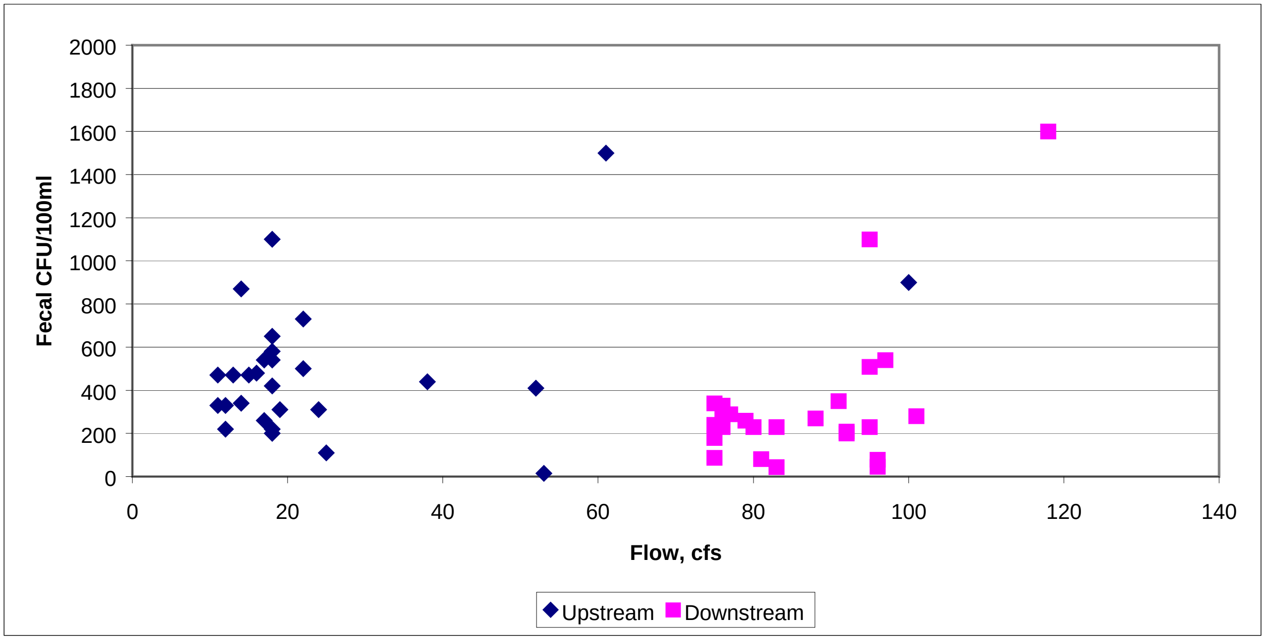


Figure 2: Upstream vs. Downstream Bacteria Levels (Village Creek, 2000)

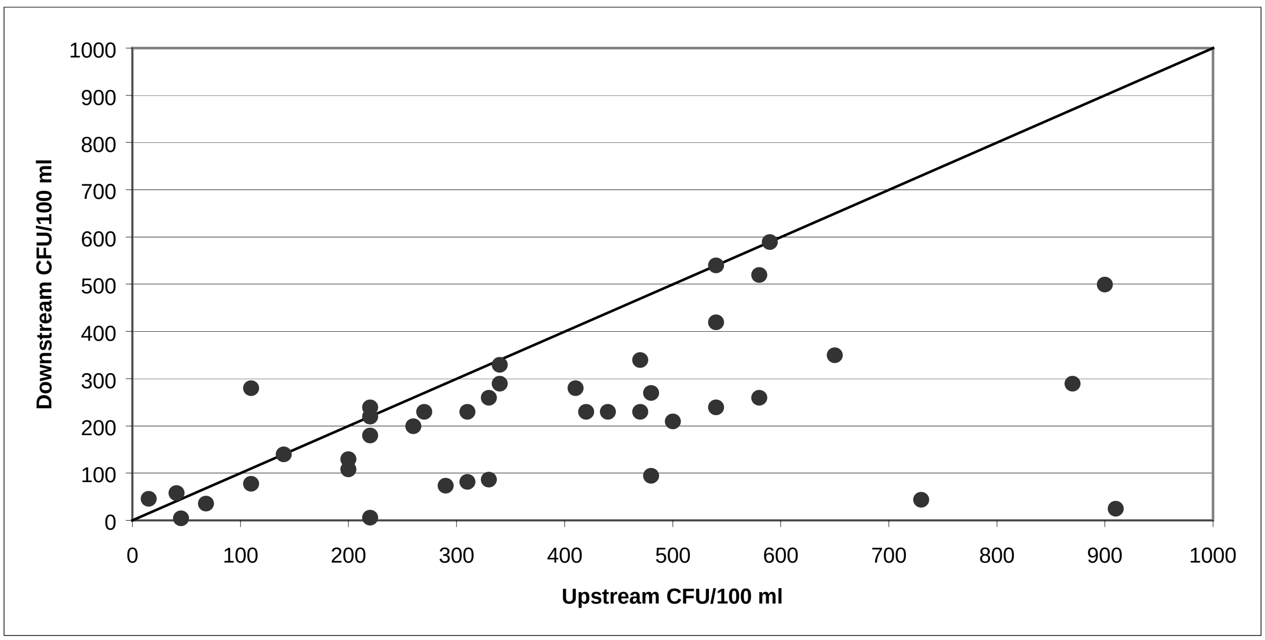


Figure 3a: Monthly Bacteria Levels (Village Creek, 2000)

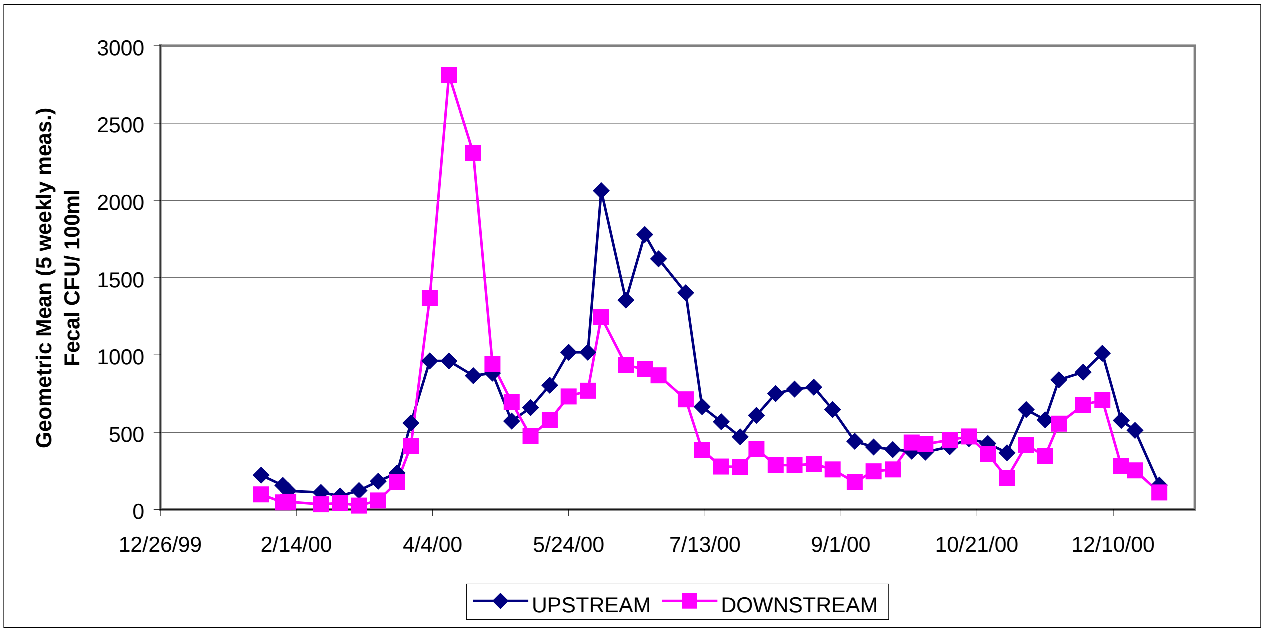


Figure 3b: Monthly Bacteria Levels (Village Creek, June-Sep 2000)

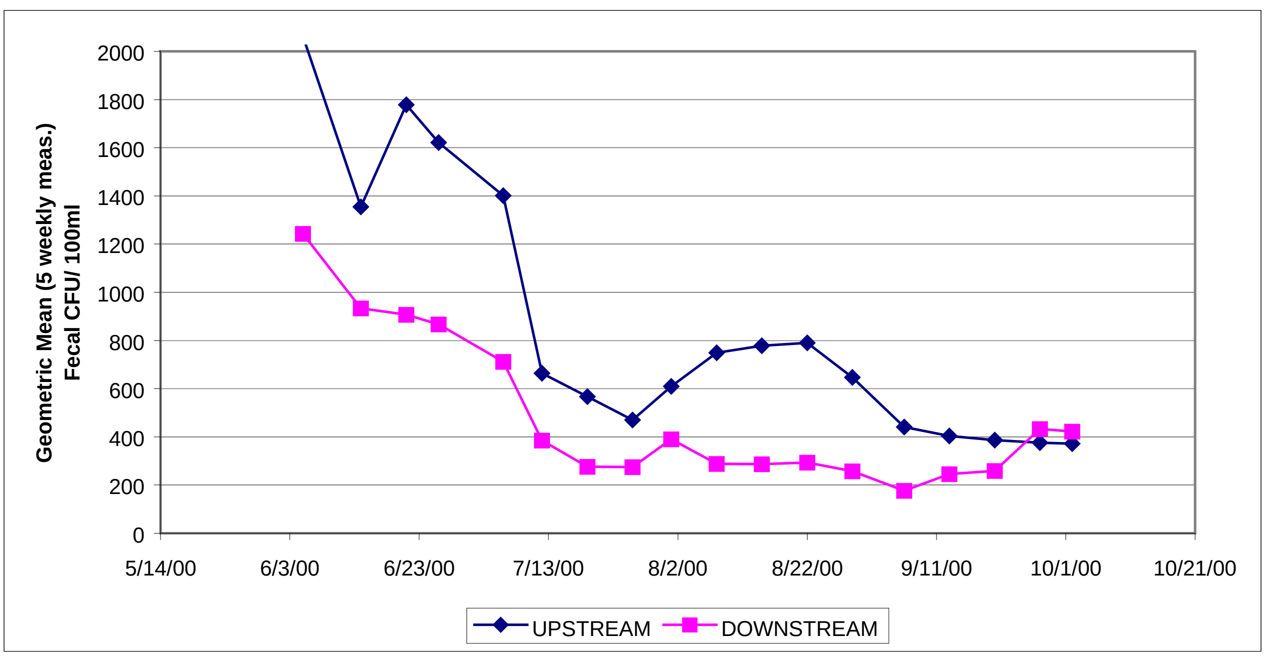


Figure 4a: Single Sample Frequency Distribution (Village Creek, 2000)

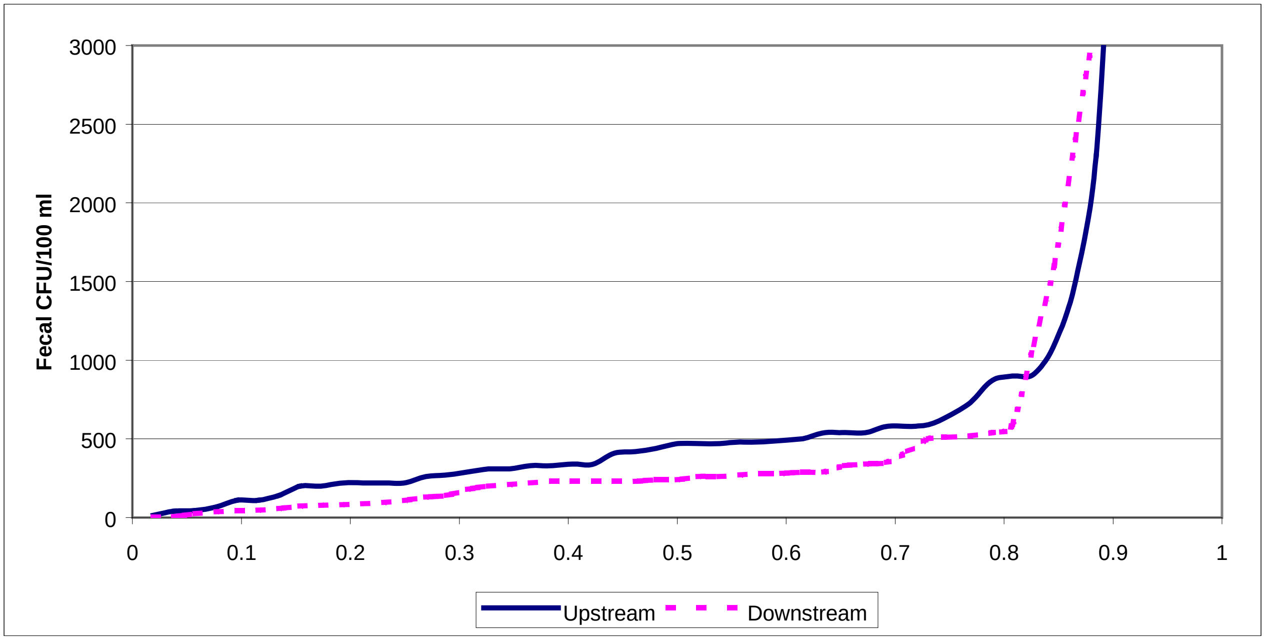


Figure 4b: Running Geometric Mean Frequency Distribution (Village Creek, 2000)

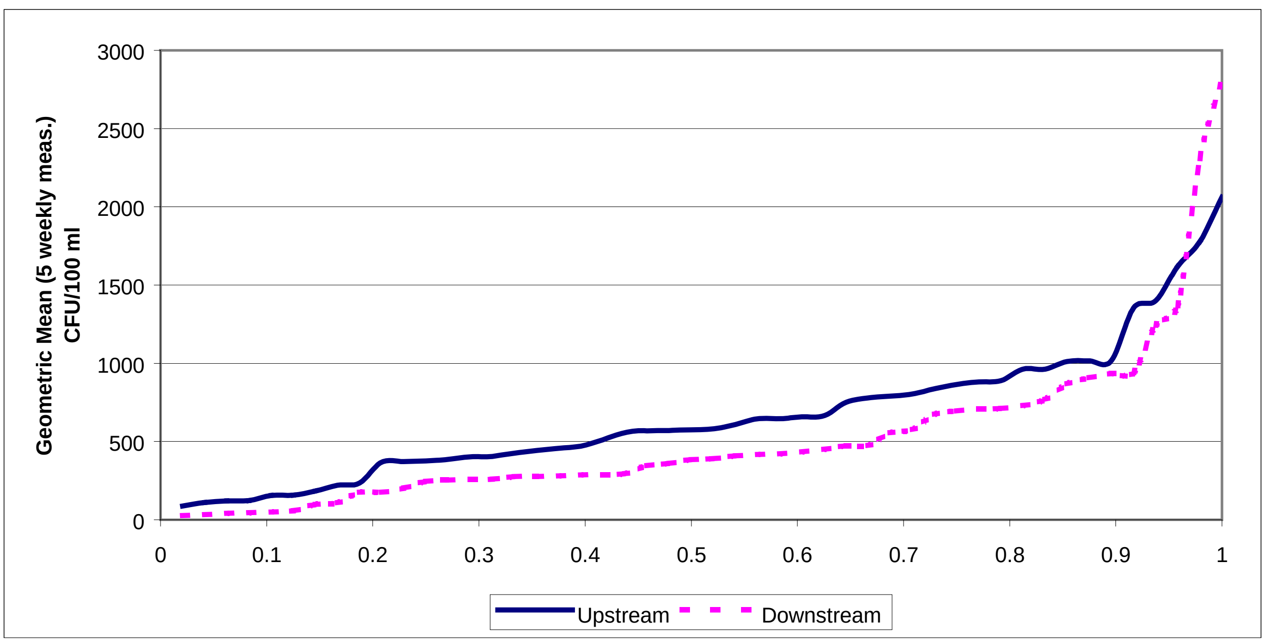


Figure 4c: Running Geometric Mean Frequency Distribution (Village Creek, June-Sep 2000)

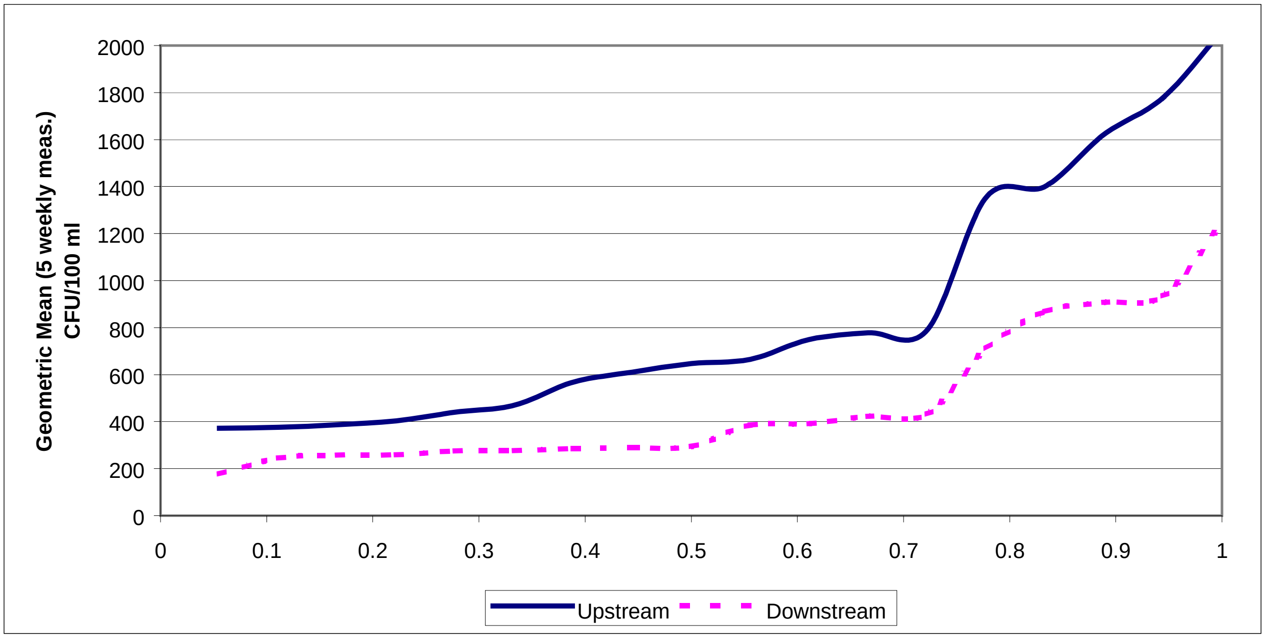


Figure 5: Daily Precipitation (Village Creek Watershed, 2000)

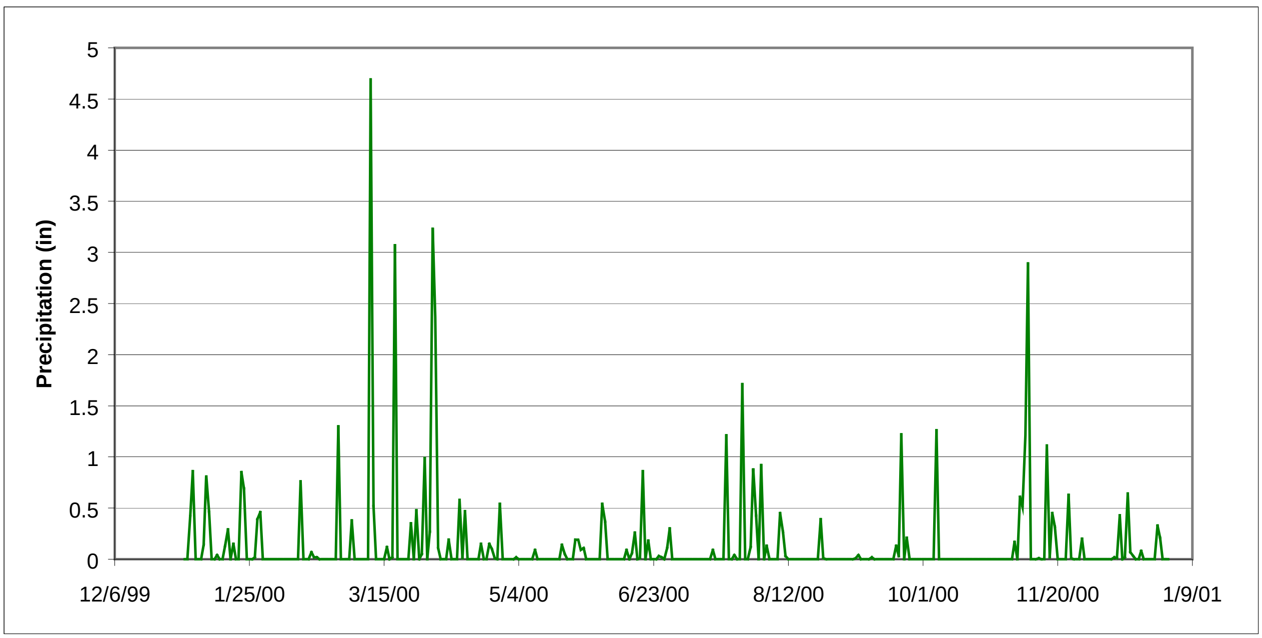


Figure 6a: Weekly Bacteria Levels and Precipitation (Village Creek, 2000)

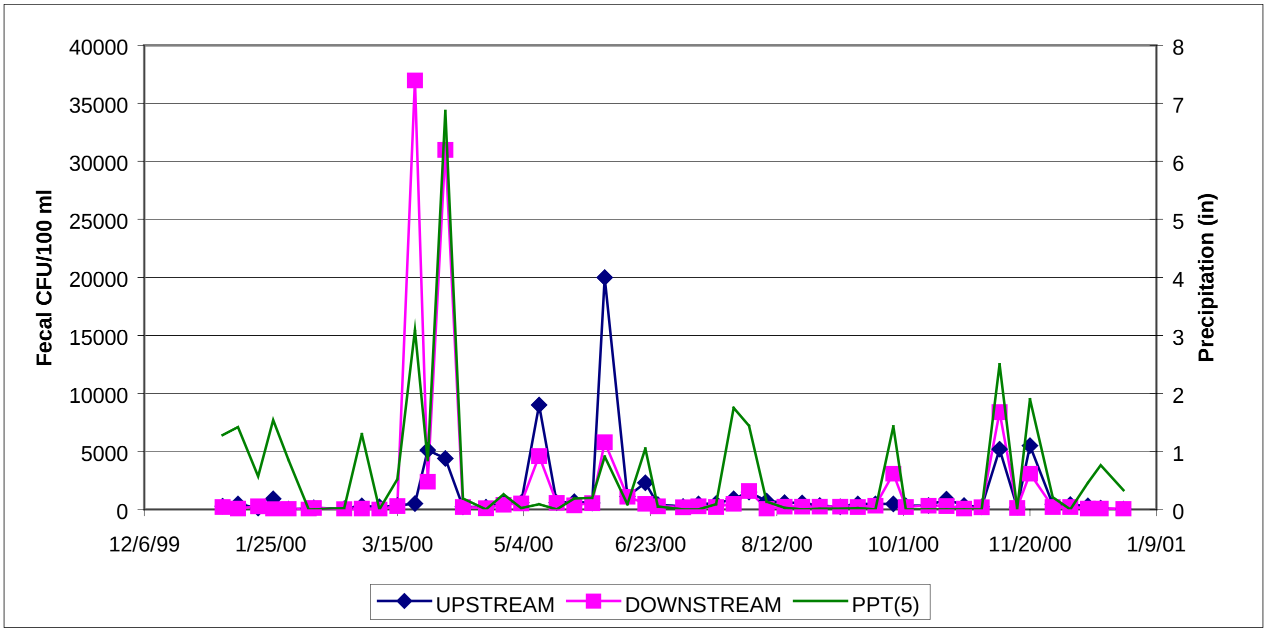


Figure 6b: Weekly Bacteria Levels and Precipitation (Village Creek, 2000)

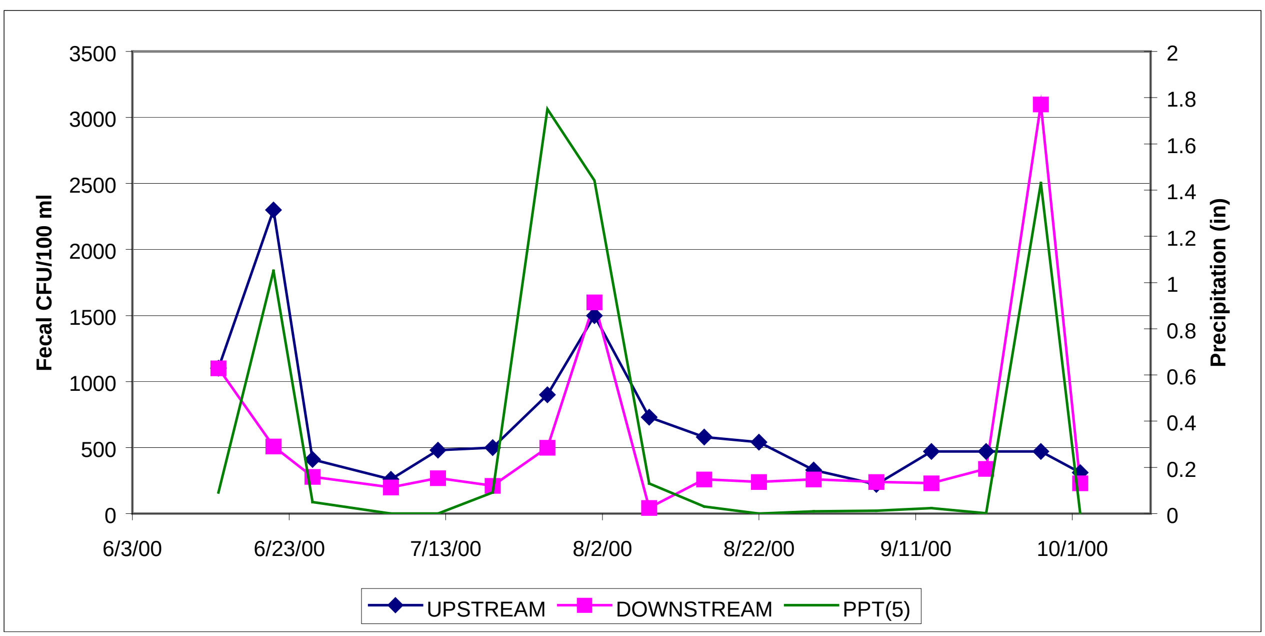


Figure 7a: Monthly Bacteria Levels and Precipitation (Village Creek, 2000)

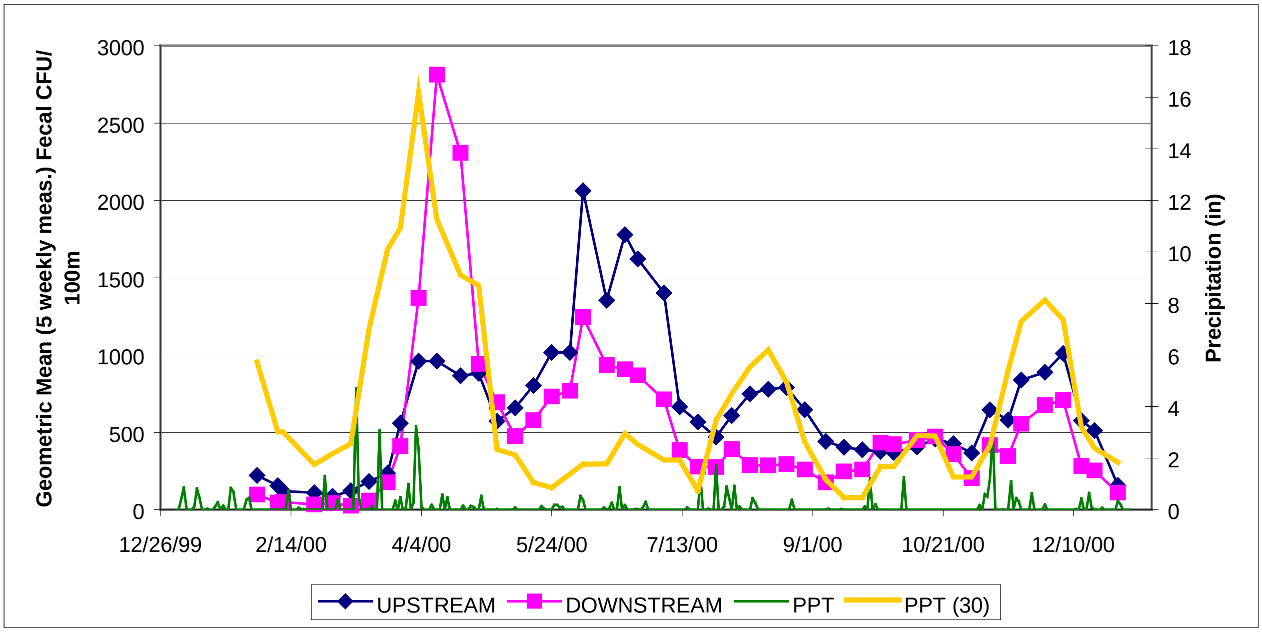
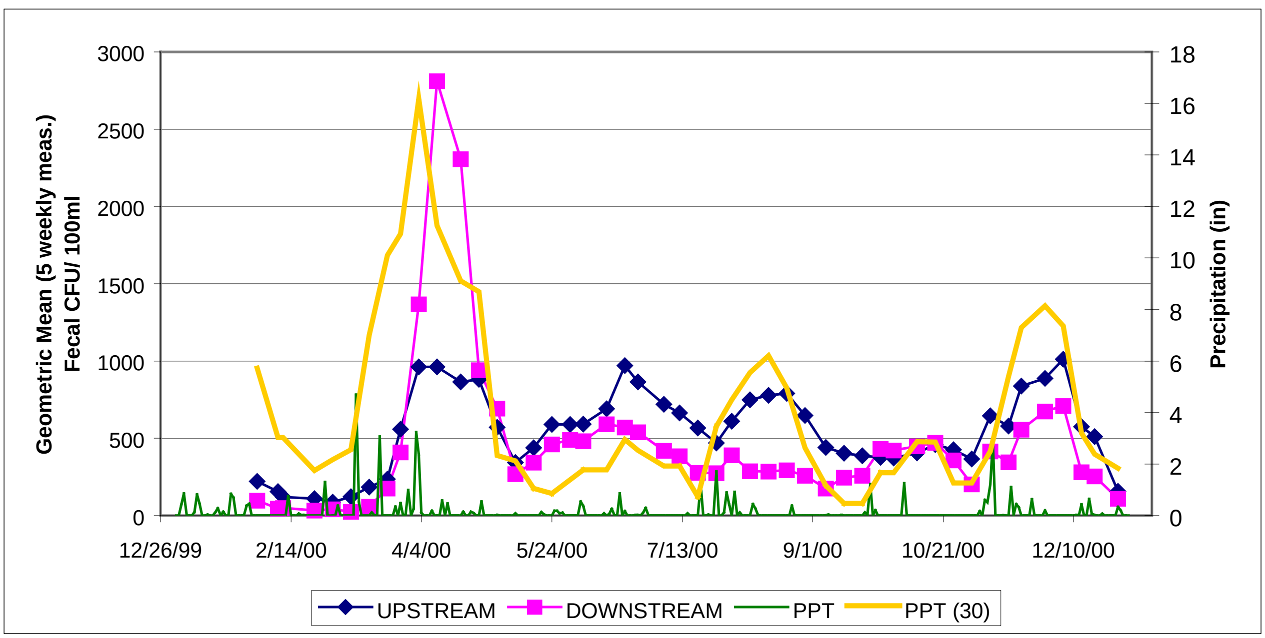


Figure 7b: Monthly Bacteria Levels and Precipitation (Village Creek, 2000)
[excluding 5/10 and 6/5 bacteria measurements]



Attachment 7

List of References

List of References

- Biological and Chemical Study of Opossum, Valley, Village, and Five Mile Creeks, EPA Region 4 & ADEM, 1978.
- Water Quality Assessment – Opossum, Valley, Village and Five Mile Creeks, EPA Region 4 & ADEM, 1989.
- Ground-Water Availability in Jefferson County, Alabama, Geological Survey of Alabama (GSA), Special Map 224, 1990
- Opossum Creek-Valley Creek Waste Load Allocation Study, ADEM, 1992
- Rapid Bioassessment: Benthic Macroinvertebrates (RBP III) and Fish (RBP V), Five Mile, Valley, Village, and Opossum Creeks, EPA Region 4, 1997.
- Valley Creek – Water Quality Report, EPA Region 4 & ADEM, 1998.
- Opossum Creek Sediment Study, EPA Region 4 & ADEM, 1998.
- Birmingham Watershed Project, Watershed Reconnaissance of the Water-Quality and Aquatic Health Conditions of Village and Valley Creeks, USGS & USACE, 2000-2002 (data only report unavailable).

Appendix D:
New York Harbor
Complex UAA

USE ATTAINABILITY ANALYSIS

of the

NEW YORK HARBOR COMPLEX

August 1985

Table of Contents

INTRODUCTION

The Federal Clean Water Act (PL 92-500) requires the State, from time to time, but at least once every three years, to hold public hearings to review the State Surface Water Quality Standards and to make appropriate modification to these standards. For all water bodies, for which the approved standards do not include all of the uses described in Section 101(a)(2) of the Act, the Water Quality Standards Regulation (40 CFR 131) requires the State to provide an analysis which demonstrates that the Section 101(a)(2) uses are unattainable. Section 101(a)(2) sets an interim goal of "water quality which provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in and on the water." A use attainability analysis meets this requirement of the Regulation and must be submitted to the US Environmental Protection Agency (EPA) by the State for all water bodies in which the State: "(a) is designating uses for the water body, such that the water body will not have all the uses which are included in Section 101(a)(2) of the Act, (b) maintaining uses for the water body which do not include all of the uses in Section 101(a)(2) of the Act, (c) removing a use included in Section 101(a)(2) of the Act or (d) modifying a use, included in Section 101(a)(2) of the Act, to require less stringent criteria" (48 FR 51401). A full use attainability study is required only for each water body and designated uses. As part of each subsequent triennial review of the Water Quality Standards, the State is required to re-examine the basis that was used to exclude specific uses, given in Section 101(a)(2) of the Act, and to consider any new information that is available which could indicate that a revision of the applicable standard is warranted.

The Water Quality Standards Regulation describes a use attainability analysis as a "multi-step scientific assessment of the physical, chemical, biological and economic factors affecting the attainment of the use. It includes a water body survey and assessment, a wasteload allocation, and an economic analysis, if appropriate" (48 FR 51401). The State may designate uses for a water, which do not reflect the Section 101(a)(2) goals, if the use attainability analysis demonstrates that the use is not attainable because of any of the following:

"(1) Naturally occurring pollutant concentrations prevent the attainment of the use; or

(2) Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for, by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements, to enable uses to be met; or

(3) Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

(4) Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or

(5) Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or

(6) Controls more stringent than those required by Sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact."

NYS's Surface Water Quality Standards incorporate designated uses for Class "I" and "SD" water that do not include all of the Section 101(a)(2) uses. Class "I" waters are fishable, but are not swimmable; Class "SD" are neither swimmable nor fishable and are not designated for shellfishing.

The key parameters in the determination of use are coliform bacteria and dissolved oxygen. Bacterial concentrations restrict swimming and shellfishing uses, while low dissolved oxygen levels limit the aquatic biota.

The purpose of this report is to present a Use Attainability Analysis (UAA) for the following waters in the New York Harbor Complex which do not meet the Section 101(a)(2) goals of the Clean Water Act. These waters include:

Hudson River, from the New York - New Jersey line to Upper N.Y. Bay

Upper N.Y. Bay

Lower N.Y. Bay

Jamaica Bay

East River, from Flushing Bay to Upper N.Y. Bay

Harlem River

For such waters, a UAA is a requisite to complete the Water Quality Standards review/revision process, consistent with the Federal Clean Water Act. This is also necessary for compliance with Section 24 of the Federal Municipal Wastewater Treatment Construction Grants Amendments of 1981 thus permitting Federal Construction Grants for the following projects which impact these waters:

North River WPCP

Red Hook WPCP

Coney Island WPCP

Owls Head WPCP

This is part of New York States overall program to assess Water Quality Standards and Classifications and is described in the Water Quality Standards Attainability Strategy which details the plan to the employed by New York State Department of Environmental Conservation in meeting the swimmable/fishable water quality goals of section 101(a)(2) of the CWA.

USE ATTAINABILITY ANALYSIS FOR THE

NEW YORK HARBOR

Study Area Description

The Lower Hudson River is actually a fjord or drowned river. In its geological formation the Hudson River above its current mouth was actually a lake. As the level of water in the lake increased with glacial melt it breached the narrow strip of land on its southern border (currently the Narrows between Staten Island and Brooklyn) and began flowing to the ocean. Later the ocean rose and covered the lower third of the Hudson (now known as the Hudson rift and canyon).

As a result of this formation, sections of the Hudson above the Narrows are deeper than the waters in the New York bight and the Atlantic ocean. The depths used in the steady state model of New York Harbor which was developed by Hydroscience Inc. are shown in Figure 1. The center line, plotting transects used in this plot and in subsequent plots, is shown in Figure 2.

With the effects of tide felt as far north as Troy, the lower 150 miles of the Hudson is swept by a semi diurnal tide. The mean tidal range in the Lower Hudson ranges from 2.9 ft. to 4.4 ft. The average maximum flood current varies from 0.8 to 1.7 knots (1.3 to 2.9 fps) and the maximum ebb current varies from 1.1 to 2.3 knots (1.9 to 3.8 fps) The tides carry salinity up the Hudson River approximately 45 miles to Bear Mountain thus creating an estuarine environment in this reach of the river.

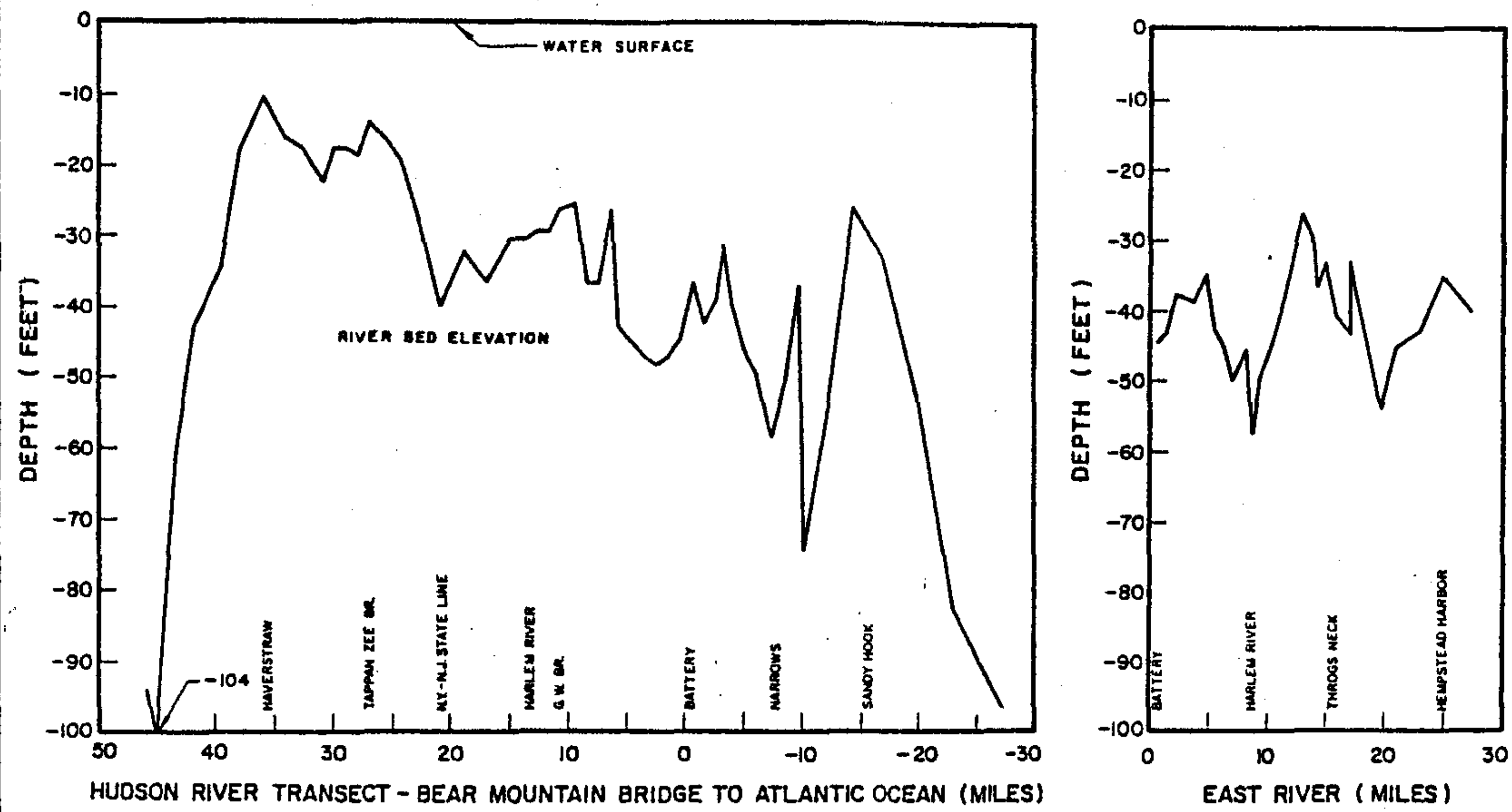


FIGURE 1. DEPTHS USED IN THE HYDROSCIENCE MODEL

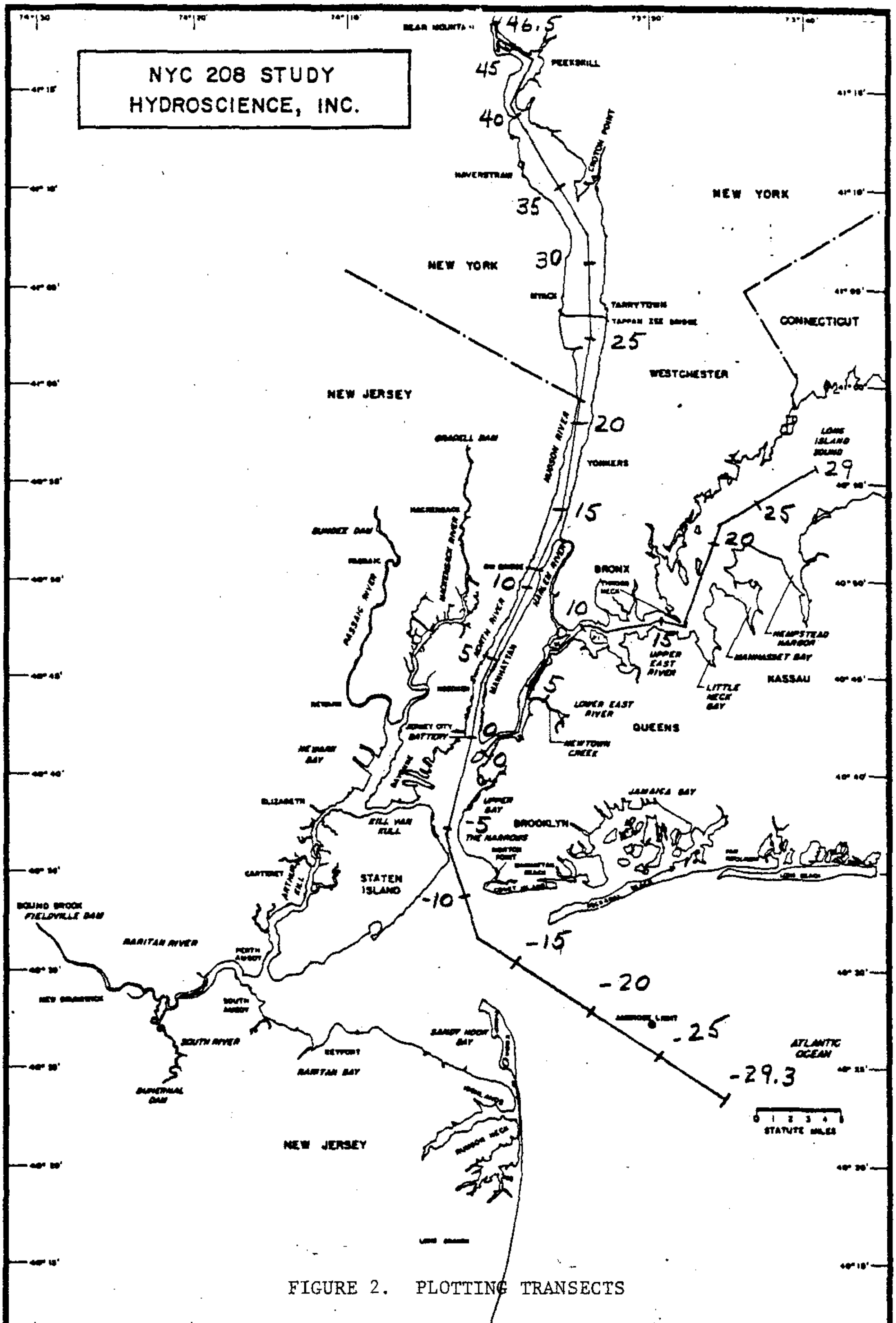


FIGURE 2. PLOTTING TRANSECTS

Troy is the first point upstream of the mouth where the fresh water flow in the Hudson can be measured. The fresh water flows for the Lower Hudson have to be approximated using measured tributary flows and a unit runoff per drainage area method. According to the Hydroscience analysis at low flows, the fresh water flow at Bear Mountain is 120 percent of the flow measured at Troy.

The Lower Hudson is considered a moderately stratified estuary. The stratification occurs when the freshwater flowing downstream meets the more dense saline water which flows upstream with the tide. The freshwater flows over the saline water causing a wedge of saline water of flow upstream under the freshwater. The difference in densities minimizes the mixing of the waters. This creates a two layered system in the estuary which does effect the distribution of water quality constituents.

The salinity intrusion in the Lower Hudson also creates a estuarine ecosystem in the area. The aquatic life indigenous to such an environment must be able to withstand daily and seasonal fluctuations in salinity. The aquatic population of the Lower Hudson is made up of resident and non-resident species. The non resident species include those species of marine fish which spawn in fresh waters and fish which spawn in marine waters but spend a portion of there life in fresh water. The resident species are those which are confined by their lack of mobility or their intolerance to salinity variations.

Unlike the Hudson the East River is not a river at all. The East River is actually a strait between Upper Bay and Long Island Sound. It is substantially a dispersive system driven by the tide.

The mean tidal range in the East River ranges from 4.1 to 6.4 feet. The flood currents vary from 1.2 to 3.8 knots (2.0 to 6.4 fps) and the ebb currents vary from 0.6 to 4.7 knots (1.0 to 7.9 fps). The East River floods from the Battery towards Long Island Sound.

Both the Hudson and the Upper Bay flow into the East River during the first two hours of flooding and the East River flows into both systems for the first hour of ebbing. During other times the East River either flows into or from the Upper Bay. The interaction with the Hudson does introduce fresh water to the East River but not enough to cause stratification.

The depths used in the East River portion of the steady state model are also shown in Figure 1.

The Upper Bay which forms the major port facilities in New York City, is the common mouth of the Hudson River, East River, and the Kill Van Kull. The Upper Bay discharges through the Narrows into the Lower Bay.

The Upper Bay and the Narrows encompass approximately 21 square miles and has an average depth at mean low water of approximately 22 feet. The mean tidal range at the Battery is 4.6 feet. The neap and spring tidal ranges are 3.6 and 5.2 feet respectively. The maximum flood current at the Narrows varies from .3 to 2.1 knots (.5 to 2.5 fps). The maximum ebb tide varies from .7 to 2.4 knots (1.2 to 4.1 fps). The average tidal prism through the Narrows is approximately 20 percent of the Upper Bay volume at low flow.

The Upper Bay is usually completely mixed vertically. However, certain flow and temperature conditions can cause short term vertical stratification. In general past studies indicate that the biological community in the Bay is similiar to that found in the Hudson and East Rivers.

The Narrows flow into the Lower Bay and then to the Atlantic. The Lower Bay also receives water from Jamaica Bay and Raritan Bay. The waters from Newark Bay and the Arthur Kill enters the Lower Bay through Raritan Bay. Newark Bay also discharges into the Upper Bay through the Kill Van Kull.

Jamaica Bay is a shallow bay which supports an extensive system of tidal marshes. The bay covers an area of approximately 20 square miles and has a mean depth of approximately 16 feet. The daily freshwater input to the bay is less than 1 percent of the total volume and the interchange with the ocean is restricted to the Rockaway Inlet. Approximately a third of the bay's volume flows in and out of the inlet on the flood and ebb tides. The volume of the Bay is 7×10^9 cubic feet at the mean tide level.

The Jamaica Bay waters and most of the land in and surrounding the Bay make up the Gateway National Recreation Area. It is an ecologically sensitive area and protected natural environment. Estuaries like Jamaica Bay with their salt water marshes and tidal wetlands are noted for their high productivity and their importance as a spawning, nursery and feeding ground for juvenile fish. The estuaries also provide an excellent habitat for marine invertebrates, mollusks, birds and mammals.

The New York Metropolitan Area with its dense population and development has severely impacted the marine ecosystems of the Hudson, the East River and the other water bodies in the New York Harbor System. These waters are forced to assimilate large discharges of municipal and industrial wastes as well as intermittent wastes entering the system through wet weather discharges. A large portion of these wastes are currently untreated. An estimation of the waste water flows entering the harbor is shown in Table 1. In addition to conventional pollutants, those discharges contain a wide assortment of toxic substance which have been polluting both the water and sediments in the harbor.

In addition to these discharges, the Harbor is impacted by the port activities. The shipping channels, ports, marinas and fuel storage and transfer points are shown in Figure 3. The movement to container shipping has affected the Port of New York by concentrating the shipping activities at the container ports. Many of the smaller ports have been abandoned and are in disrepair. The decrease in commercial shipping has been offset by recreational boating and the harbor is quite active. The risk of oil spills and spillage of other pollutants which could affect the aquatic and recreational uses are high in such a port.

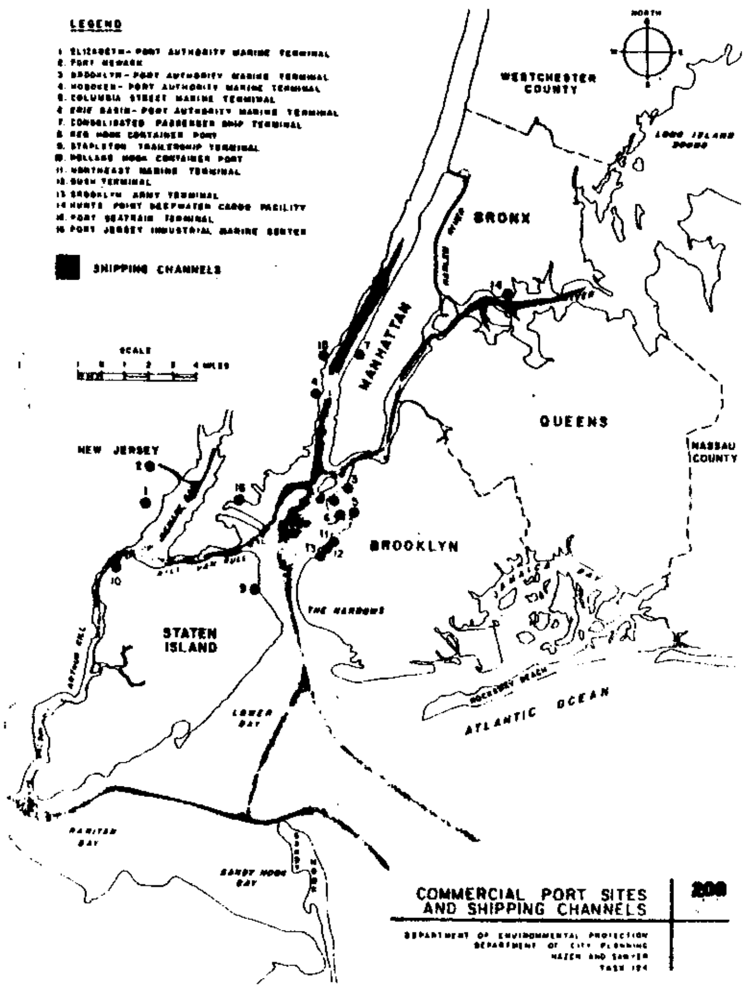
TABLE 1

Estimation of Wastewater Flow to the New Jersey/New York Harbor Complex

Pollution Source	Daily Flow (MGD)*
Combined Sewer Overflow (CSO)	500
Raw Sewage Discharge (Point Source)	203
Other Urban Non-point Sources	125
New York/New Jersey Treated Effluent (undisinfected in winter)	1,830

*Flows are based on annual average rainfall.

Table taken from Water Quality Management Assessment Due to Marine CSO Abatement Along the New Jersey Shore prepared by the Bureau of System Analysis and Wasteload Allocation N.J. DEP.


LEGEND
1 ELIZABETH-PORT AUTHORITY MARINE TERMINAL
2. PORT NEWARK
3 BROOKLYN-PORT AUTHORITY MARINE TERMINAL
4. HOBOKEN-PORT AUTHORITY MARINE TERMINAL
5. COLUMBIA STREET MARINE TERMINAL
6 ERIE BASIN-PORT AUTHORITY MARINE TERMINAL
7. CONSOLIDATED PASSENGER SHIP TERMINAL
8 RED HOOK CONTAINER PORT
9. STAPLETON TRANSHIPMENT TERMINAL
10. HOWLAND HOOK CONTAINER PORT
11. NORTHEAST MARINE TERMINAL
12. BUSH TERMINAL
13 BROOKLYN ARMY TERMINAL
14 HUNTS POINT DEEPWATER CARGO FACILITY
15. PORT SEATRAIN TERMINAL
16 PORT JERSEY INDUSTRIAL MARINE CENTER
SHIPPING CHANNELS
SCALE
WESTCHESTER COUNTY
BRONX
MANHATTAN
QUEENS
NASSAU COUNTY
NEW JERSEY
BROOKLYN
STATEN ISLAND
THE NARROWS
LOWER BAY
ATLANTIC OCEAN
RARITAN BAY
SANDY HOOK BAY
COMMERCIAL PORT SITES AND SHIPPING CHANNELS
208
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER
TASK 124

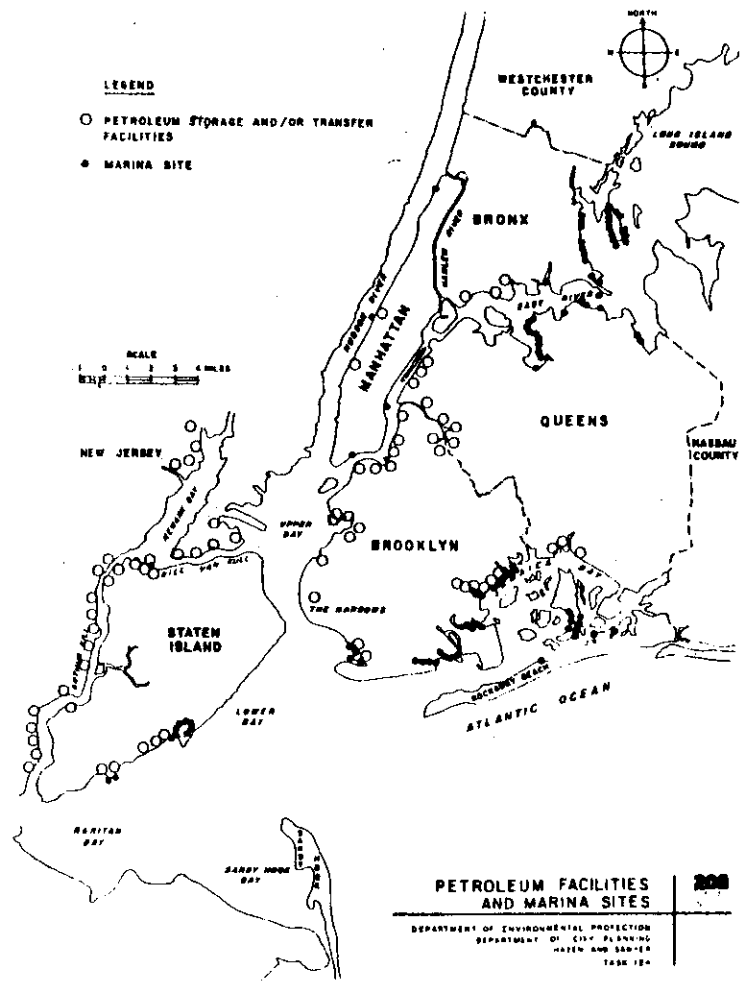

LEGEND
PETROLEUM STORAGE AND/OR TRANSFER FACILITIES
MARINA SITE
SCALE
WESTCHESTER COUNTY
BRONX
MANHATTAN
QUEENS
NASSAU COUNTY
NEW JERSEY
UPPER BAY
BROOKLYN
STATEN ISLAND
THE NARROWS
LOWER BAY
ATLANTIC OCEAN
RARITAN BAY
SANDY HOOK BAY
PETROLEUM FACILITIES AND MARINA SITES
208
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER
TASK 124

FIGURE 3

NYS Classifications and Standards for Marine Waters

The marine waters in New York State are classified on a best use basis. The best uses are ranked according to the water quality requirements of the usage. There are four designated uses considered in the classification scheme, shellfishing, bathing (primary recreation), fishing (finfish propagation) and fish survival. The general aquatic uses such as aesthetic enjoyment and the maintenance of fish and wildlife are assumed in all classifications. A best use classification includes all uses of the lower classifications and excludes the uses specified in the higher classifications. For example, a primary recreation classification would allow all uses except for the taking of shellfish for market purposes which is a higher use specified in the shellfishing classification. The classification system also precludes a higher usage if the standards of a lower use are being used. For example, if the water body is not suitable for fishing it is not suitable for swimming either.

For each best use classification there are water quality criteria or standards which have to be met in order to protect and preserve the intended use of the water. These standards apply to the following parameters; dissolved oxygen, coliform bacteria, pH, temperature, dissolved solids, turbidity color, taste and odor, floating materials, oil and toxic wastes.

Since all waters are intended for general uses such as aesthetic enjoyment and maintenance of fish and wild life most of the standards apply to all the

marine water bodies regardless of the classification. Only the Dissolved Oxygen, coliform bacteria, and toxic waste standards vary from classification to classification.

TABLE 2

SUMMARY OF WATER QUALITY STANDARDS FOR NEW YORK HARBOR

Use Classification	Shellfishing SA	Bathing SB	Fishing SC	Fishing I	Navigation SD	Bathing
	NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION					NEW YORK CITY (1)
Parameter						
Dissolved Oxygen (mg/l)	5	5	5	4	3	NS
Coliforms (per 100 ml)						
Total	70M	2,400MM (2)	10,000MGM	10,000MGM	NS	2,400GM
Fecal	14M (3)	200MGM (2)	2,000MGM	2,000MGM	NS	NS
pH	Normal ±0.1					NS
Temperature (°F)	90°F and ±4°F of ambient and +1.5°F if ambient is over 83°F					
Dissolved Solids	NS	NS	NS	NS	NS	NS
Turbidity	No unnatural increase					NS
Color	No unnatural color which interferes with use					NS
Taste and Odor	None that interfere with use, or injure of made inedible, fish or shellfish					NS
Oil and Floating Substances	No residue due to wastes and no visible film or globules					NS
Fecal Material	NS	NS	NS	NS	NS	None on or adjacent to beach
Suspended, Colloidal & Settleable Solids	No deposition or interference with use					
Toxic Wastes	None that interfere with use, or injure, or make inedible, fish or shellfish				None that interfere with use or fish survival	NS

NS = No Standard, M = Median, GM = Geometric Mean, MM = Monthly Median, MGM = Monthly Geometric Median. greater than or equal to, less than or equal to, ± plus or minus

(1) NYC Health Department Standards. They are the same as the N.Y. State Health Department Standards for Bathing.

(2) This standard shall be met when disinfection is practiced (May 15-Sept. 30 in NYC year-round in New Jersey).

(3) This standard represents the addition of a fecal coliform standard for Class SA as proposed by NYS-DEC.

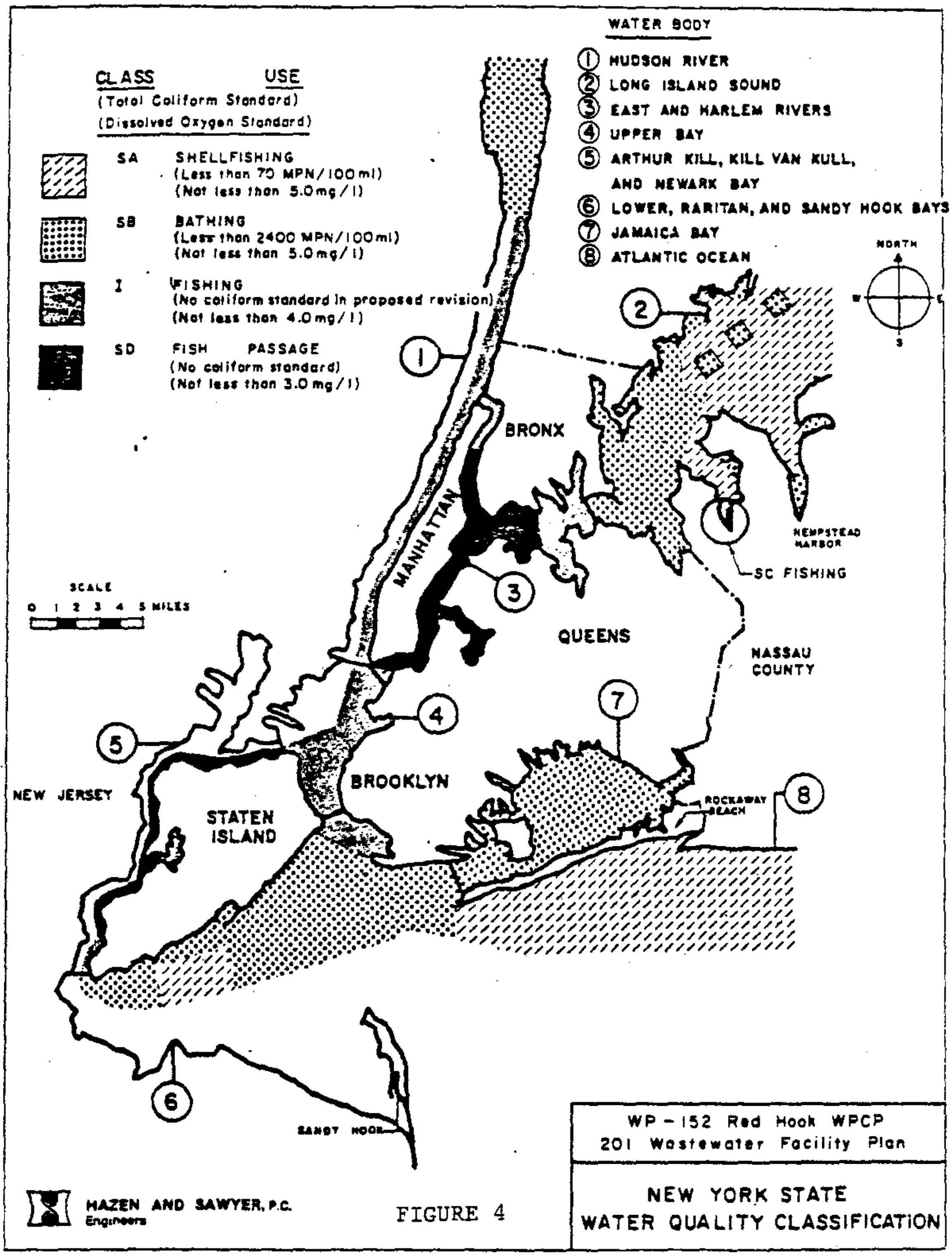


FIGURE 4

WP - 152 Red Hook WPCP
201 Wastewater Facility Plan

NEW YORK STATE
WATER QUALITY CLASSIFICATION

The classifications and standards are shown in Table 2. Note that Class SC and Class I have the same best use specification, the difference between the classes lies in the Dissolved Oxygen standard.

All the waters in the New York Harbor system which are under New York State Department of Environmental Conservation's jurisdiction are also under the jurisdiction of the Interstate Sanitation Commission. In addition the Hudson River, Upper Bay, Lower Bay, Raritan Bay, the Authur Kill and the Kill Van Kull fall under the jurisdiction of New Jersey's Department of Environmental Protection. Each agency has its own water quality classification system. The best use designations of these classification systems are consistent for Harbor waters.

The New York State Classifications for the waters of New York Harbor are shown in figure 4.

Existing Uses

The Department of Environmental Conservation considers The Harbor waters to be effluent limited waterbody segments. This means that the technology based effluent limitations required by the Clean Water Act are sufficient to meet the present water quality standards. This does not mean, however, that the applicable standards are presently being met in these water bodies. What it does mean is that when the existing and proposed pollution control projects are at the technological treatment required by the Clean Water Act, the expected instream water quality will meet the current standards.

The Hudson River below the New York - New Jersey line is currently classified as a Class I waterway. The best use specification for a Class I water body states, "The waters shall be suitable for secondary contact recreation and other usage except for primary contact recreation and shellfishing for market purposes." The Hudson above the New York - New Jersey line is classified "SB".

The East River is classified as an SD water body. The best use specification for the SD class is, "All waters not primarily for recreational purposes, shellfish culture or the development of fishlife and because of natural or man-made conditions cannot meet the requirements of these uses."

The water quality in the Lower Hudson and the East River is below the designated standards for the respective water bodies. Both presently receive large quantities of raw sewage. The Red Hook Water Pollution Control Project and the North River Pollution Control Project are designated to eliminate these raw sewage discharges.

The North River sewage treatment plant and the Red Hook sewage treatment plant are the last two plants to be built in New York City to provide secondary treatment for currently untreated wastes. The North River STP will eliminate approximately 150 million gallons a day of raw sewage currently being discharged to the Hudson River. The Red Hook treatment Plant will eliminate about 53 million gallons a day of raw sewage which is now being discharged into the Buttermilk Channel and the Gowanus Canal (tributaries to the East River).

According to the North River facility plan the water quality improvement brought about by this project and other proposed projects in the area will promote the survival and reproduction of most, if not all, species of fish native to the Hudson. According to the Red Hook facilities plan, the completion of both projects will result in summer dissolved oxygen concentrations in the East River greater than 4.2 mg/l. The present summer dissolved oxygen concentrations in the Lower East River are between 2.1 and 2.6 mg/l.

The Upper Bay including the Narrows like the Lower Hudson is classified Class I with the same best usage described above.

At the common mouth of the Hudson River, East River and Kill Van Kull the Upper Bay indirectly receives and to some degree dilutes most of the waste from the metropolitan area. The Bay also receives a direct discharge from the Owls Head water pollution control plant located in Brooklyn. The plant discharges into the Bay Ridge Shipping Channel on the east side of the Bay. The Owls Head plant serves an area of approximately 13,664 acres with a population of about 785,000. At present the plant treats 100 MGD of waste. The plant is over thirty years old and removes 69 percent of the suspended solids and 57 percent of the BOD influent load. The plant is being upgraded to attain 85 percent removal of these parameters as required by the Federal Clean Water Act.

The water quality in the Upper Bay is highly correlated with the freshwater flow and temperature of the Hudson River. During low flow periods the water quality tends to degrade because of a loss of dilution and high temperatures tend to degrade the quality by intensifying the oxygen demand in the system. The dissolved oxygen standard of 4.0 mg/l is frequently violated during the summer months.

The Lower Bay and Jamaica Bay have an "SB" Classification. The best use specification for an "SB" water body reads as follows: "The waters shall be suitable for primary and secondary contact recreation and any other use except for the taking of shellfish for market purposes."

The standards for this classification are often violated in Jamaica Bay and Lower Bay. Based on comprehensive sets of data collected during the summers of 1974, 1975 and 1976 the dissolved oxygen concentrations were below the 5.0 mg/l standard 25 percent of the time in the Lower Bay and 32 percent of the time in the bottom waters of Jamaica Bay. The coliform standards are also violated in the Lower Bay. Some of the Coney Island and Staten Island Beaches are posted (i.e., swimming is not recommended) because of coliform standard contraventions. The coliform standards were met in Jamaica Bay except near Howard Beach.

Subsequent routine sampling in this area indicates an improvement in the dissolved oxygen concentrations, however, violations of the standard still occur. The improvement is probably due to improvements made to the water pollution control plants which discharge to this area.

The Coney Island Water Pollution Control Plant discharges into the Rockaway Inlet which connects Jamaica Bay with the Atlantic Ocean. The plant services an area of 14,200 acres with a population of approximately 690,000. The plant currently treats 97 MGD and removes 50 to 60 percent of the influent BOD and suspended solids.

The Coney Island plant is not the only plant in the Jamaica Bay area. The Bay also receives continuous discharges from the 26th Ward, Jamaica, Rockaway Inwood and Cedarhurst Water Pollution Control Plants. Seventy percent of the freshwater input to the bay is the result of these discharges. The remaining thirty percent enters the system through storm water overflows and storm water runoff.

The Atlantic Ocean off Rockaway is classified "SA" with a best use that reads as follows: "The waters shall be suitable for shellfishing for market purposes and primary and secondary recreation." The coliform standards for shellfishing are not met in portions of this area.

Dry weather sewage discharges are not the only way raw sewage enters the harbor system. Shock loadings of pollutants enter the system through storm water discharges and combined sewer overflows. These additional loadings may negate the protection provided by the dry weather discharge control approach. During the critical summer months rain events usually occur every 3 to 4 days. The resulting combined sewer overflows and storm water discharges from these storms often have higher pollutant concentrations than the continuous discharges to the system.

The duration of the intermittent water quality caused by these discharges depends on the intensity and duration of the rain event. The intermittent effect can disappear over one or two tidal cycles or persist for several weeks. The intermittent water quality problems and problem areas are shown in Figure 5.

According to the 208 intermittent water quality evaluation the coliform (total and fecal) levels in New York Harbor were often 2 to 6 times higher during wet periods than dry periods. The evaluation also estimated that in the Hudson River, on 57 percent of the 122 summer days (June 1 - September 30) the intermittent coliform levels were present. This estimation considered only rainfall events greater than .11 inches/hr in intensity.

Due to the frequency of the summer storm events the Harbor is rarely found to be in the steady state dry weather condition which is used to set the continuous discharge limits.

Intermittent discharges (i.e., CSO's and storm overflows) are of special significance to the water quality of Jamaica Bay.

According to the 208 analysis the intermittent discharges do not appear to contribute to dissolved oxygen violations in the Harbor. The BOD loads entering the harbor during these wet periods do not significantly alter the dry weather BOD concentrations. However, New York State Department of Environmental Conservation has determined that further study of CSO impacts with respect to dissolved oxygen is necessary.

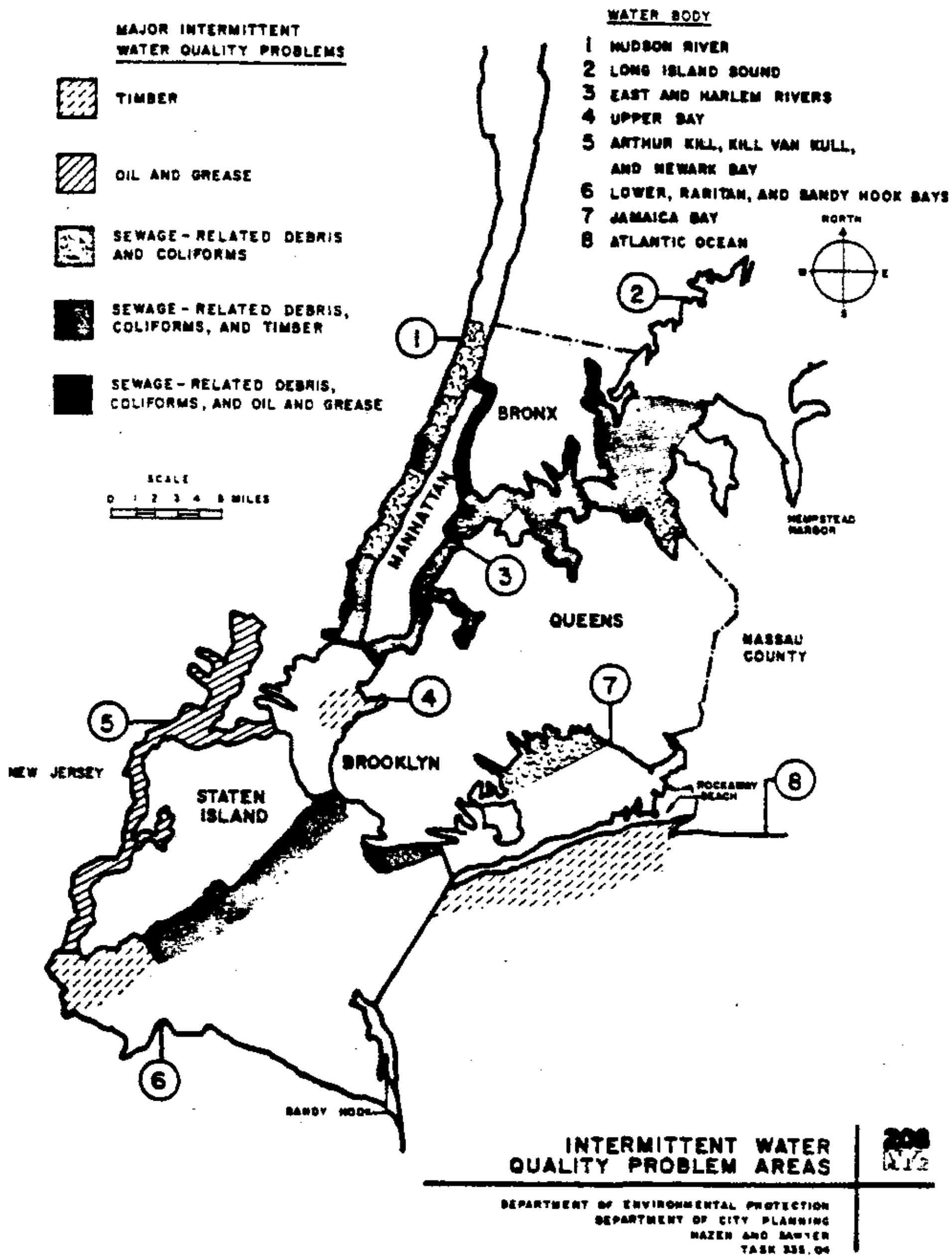

MAJOR INTERMITTENT WATER QUALITY PROBLEMS
TIMBER
OIL AND GREASE
SEWAGE - RELATED DEBRIS AND COLIFORMS
SEWAGE - RELATED DEBRIS, COLIFORMS, AND TIMBER
SEWAGE - RELATED DEBRIS, COLIFORMS, AND OIL AND GREASE
SCALE
0 1 2 3 4 5 MILES
WATER BODY
1 HUDSON RIVER
2 LONG ISLAND SOUND
3 EAST AND HARLEM RIVERS
4 UPPER BAY
5 ARTHUR KILL, KILL VAN KULL, AND NEWARK BAY
6 LOWER, RARITAN, AND SANDY HOOK BAYS
7 JAMAICA BAY
8 ATLANTIC OCEAN
NORTH
BRONX
MANHATTAN
QUEENS
BROOKLYN
STATEN ISLAND
NEW JERSEY
NASSAU COUNTY
HEMPSTEAD HARBOR
ROCKAWAY BEACH
SANDY HOOK
INTERMITTENT WATER QUALITY PROBLEM AREAS
208 NYC
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER
TASK 335.04

FIGURE 5

These discharges do however impact the coliform concentrations in the Harbor. The predicted coliform concentrations shown in figure 6 are due to these discharges. The projections shown in figure 6 were made using the 208 steady state model. The steady state combined sewer overflow loads and stormwater runoff loads were generated using a storm intensity of .12 inches/day (a daily average of the annual rainfall). Secondary treatment with chlorination was assumed at all the municipal treatment plants so the plants effect on the projected coliform levels are insignificant.

In order to insure compliance with current water quality standards and protect the designated aquatic uses some sort of combined sewer overflow abatement program may be necessary. However, the details of such a program need further study and definition. In order to accomplish this, New York State has required the City of New York to undertake a more detailed evaluation of CSO problems and abatement alternatives for the New York Harbor Complex. This study has just begun and will be critical in assessing the degree of CSO abatement measures which must be implemented to attain water quality goals.

The effects of combined sewer overflow abatement programs were previously analyzed along with other waste treatment alternatives as part of the 208 area-wide wastetreatment management planning process. One of the alternatives studied by the NYC Department of Environmental Protection was "the present requirement alternative". The object of this alternative was compliance with all Federal, State, inter-state water quality/effluent standards for the metropolitan area. The objective standards and a summary of the treatment required to meet those standards are shown in Figure 7. In assessing "the present requirement alternatives" the New York City Department of Environmental Protection assumed a 90 percent capture and

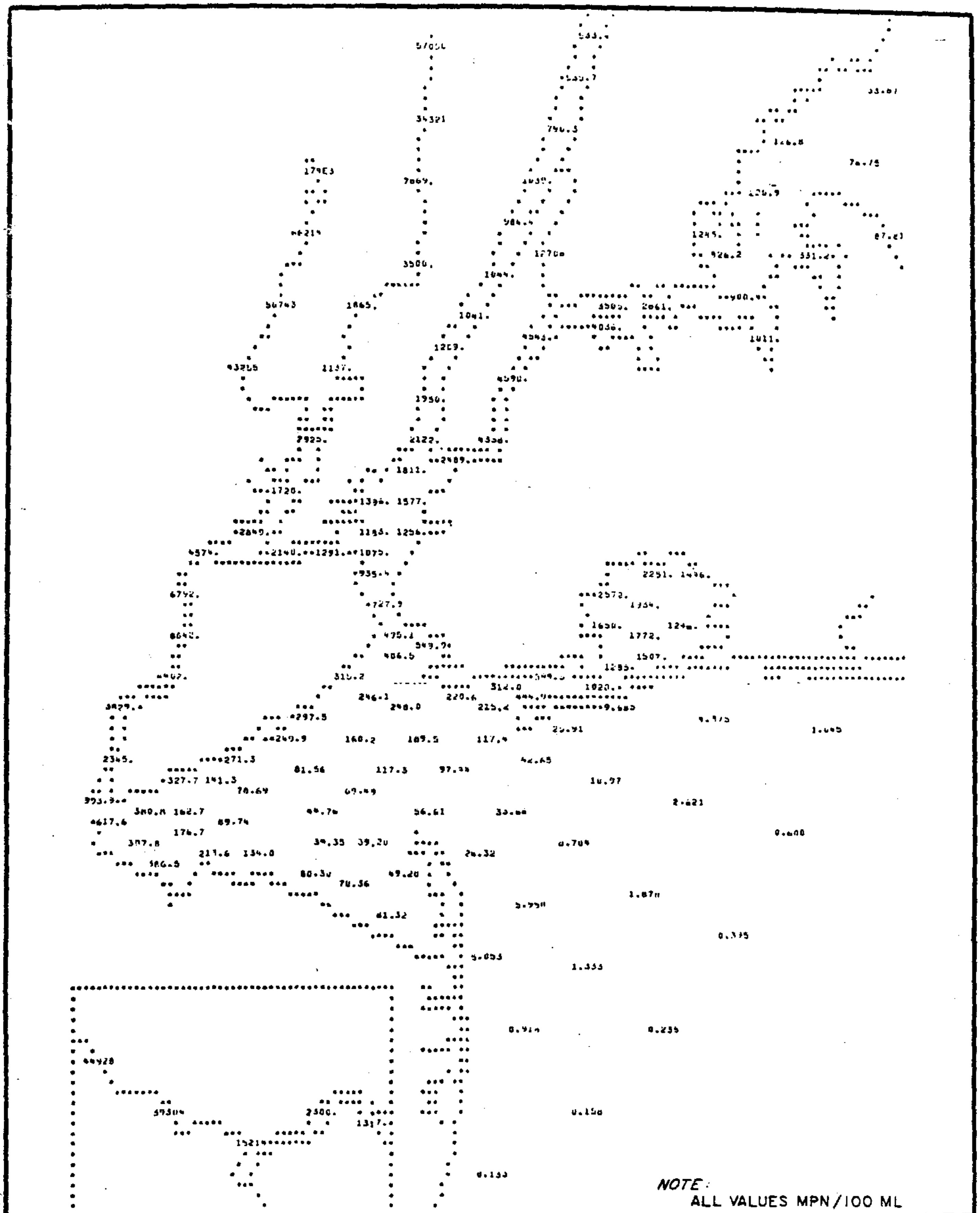


Figure 6
Stormwater Discharge Effect
Median Total Coliform Bacteria Concentrations

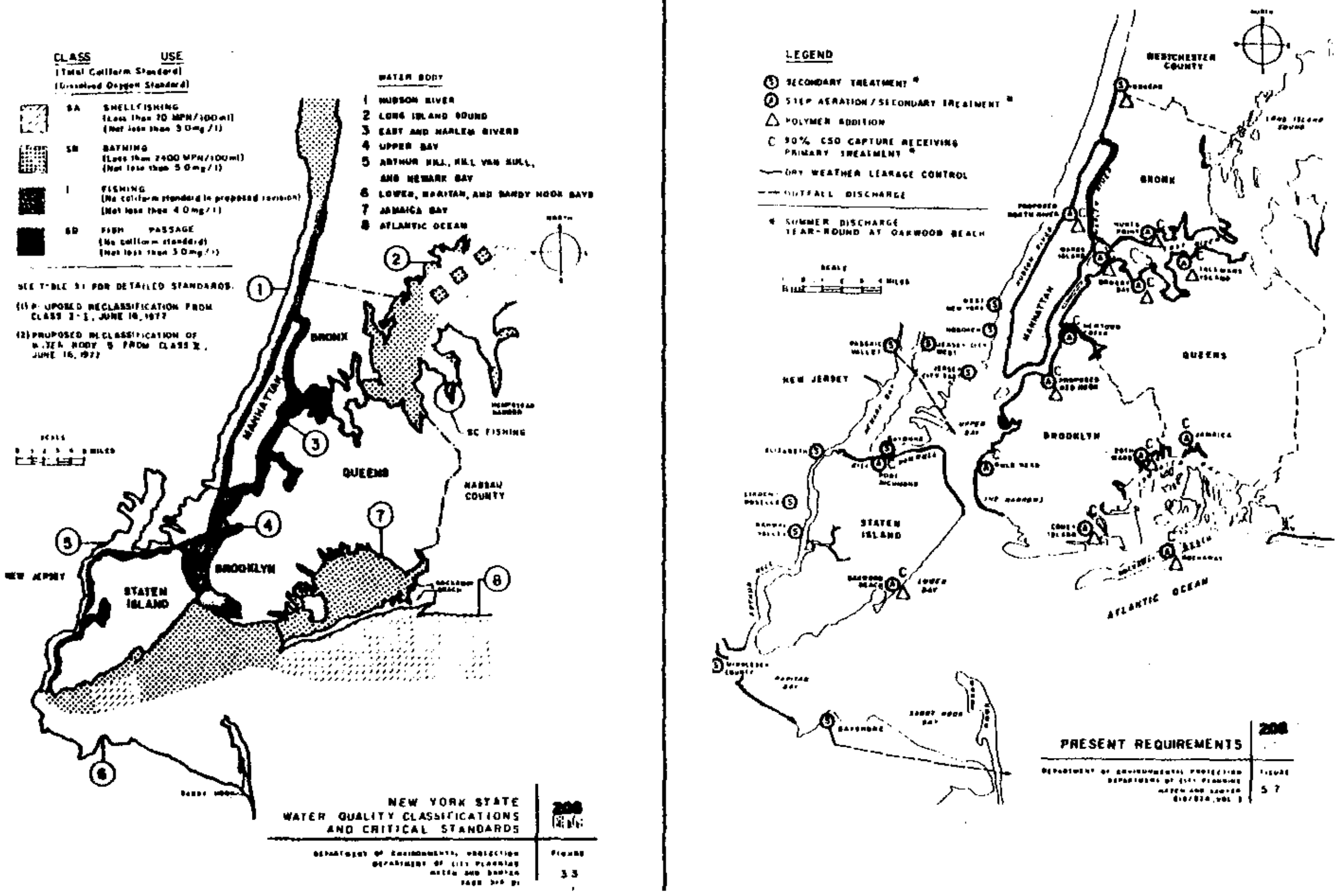

CLASS
USE
SHELLFISHING
BATHING
FISHING
FISH PASSAGE
SEE TABLE 51 FOR DETAILED STANDARDS.
WATER BODY
1 HUDSON RIVER
2 LONG ISLAND SOUND
3 EAST AND HARLEM RIVERS
4 UPPER BAY
5 ARTHUR KILL, KILL VAN KULL, AND NEWARK BAY
6 LOWER, RARITAN, AND SANDY HOOK BAYS
7 JAMAICA BAY
8 ATLANTIC OCEAN
MANHATTAN
BRONX
QUEENS
BROOKLYN
STATEN ISLAND
NEW JERSEY
NASSAU COUNTY
SC FISHING
NEW YORK STATE
WATER QUALITY CLASSIFICATIONS
AND CRITICAL STANDARDS
LEGEND
SECONDARY TREATMENT
STEP AERATION / SECONDARY TREATMENT
POLYMER ADDITION
C 90% CSO CAPTURE RECEIVING PRIMARY TREATMENT
DRY WEATHER LEAKAGE CONTROL
OUTFALL DISCHARGE
SUMMER DISCHARGE
YEAR-ROUND AT OAKWOOD BEACH
WESTCHESTER COUNTY
BRONX
QUEENS
BROOKLYN
MANHATTAN
STATEN ISLAND
NEW JERSEY
ATLANTIC OCEAN
PRESENT REQUIREMENTS

FIGURE 7

storage of all combined sewer overflows for an average year's rainfall. The stored overflows would receive primary treatment or better before being discharged.

The 208 model predictions for the base line conditions (1980) can be used to predict the current condition of the Harbor waters since there have been no significant changes to that treatment senario and none will occur until the Red Hook and North River Water Pollution Control plants go on line. The dissolved oxygen baseline concentrations are shown in figure 8 and 9. Figure 10 shows the baseline total coliform concentrations in the Harbor. Figure 11 shows the areas of the Harbor where the coliform standards are violated.

Assessment of Attainable Uses

Approach to Use Attainability

New York Harbor has been the subject of many investigations in the past and therefore this analysis is based on existing data and the current assessment of the Department of Environmental Conservation (DEC) personnel who are familiar with the system. Since the Harbor is an interstate waterbody the Interstate Sanitation Commission, the State of New Jersey, EPA Region II and EPA Headquarters were also consulted.

The primary sources of information for the analysis are the documents generated by the New York City 208 Area-Wide Waste Treatment Management Planning Program. As part of the 208 process, the NYC Department of Environmental Protection evaluated various water quality alternatives and determined the amount of treatment necessary to attain the objectives of each alternative. The alternatives investigated were based on desired aquatic uses. Therefore, the results of the 208 analysis can readily be used in a Use Attainability Analysis.

A list of reports which were reviewed or consulted in preparing this report are contained in Appendix 1.

Analysis Conducted

The reports reviewed treat the physical and biological factors in a general way. All reports indicate that historically the New York Harbor System was a productive marine ecosystem with a diverse biota. Presently, however, the diversity and productivity of the system is severely impacted.

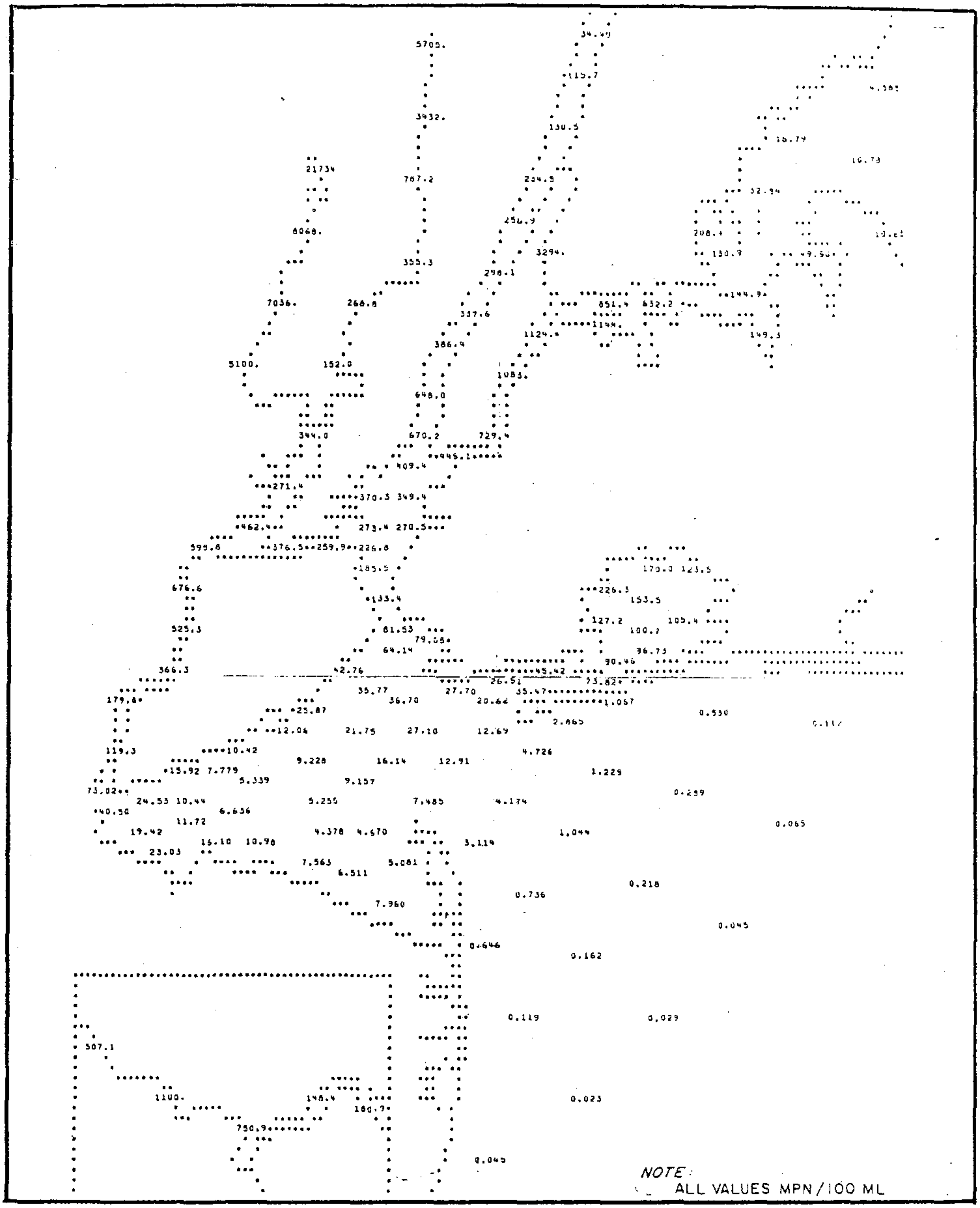


FIGURE 23
PREDICTED MEDIAN TOTAL COLIFORM BACTERIA CONCENTRATIONS
ZERO DISCHARGE ALTERNATIVE

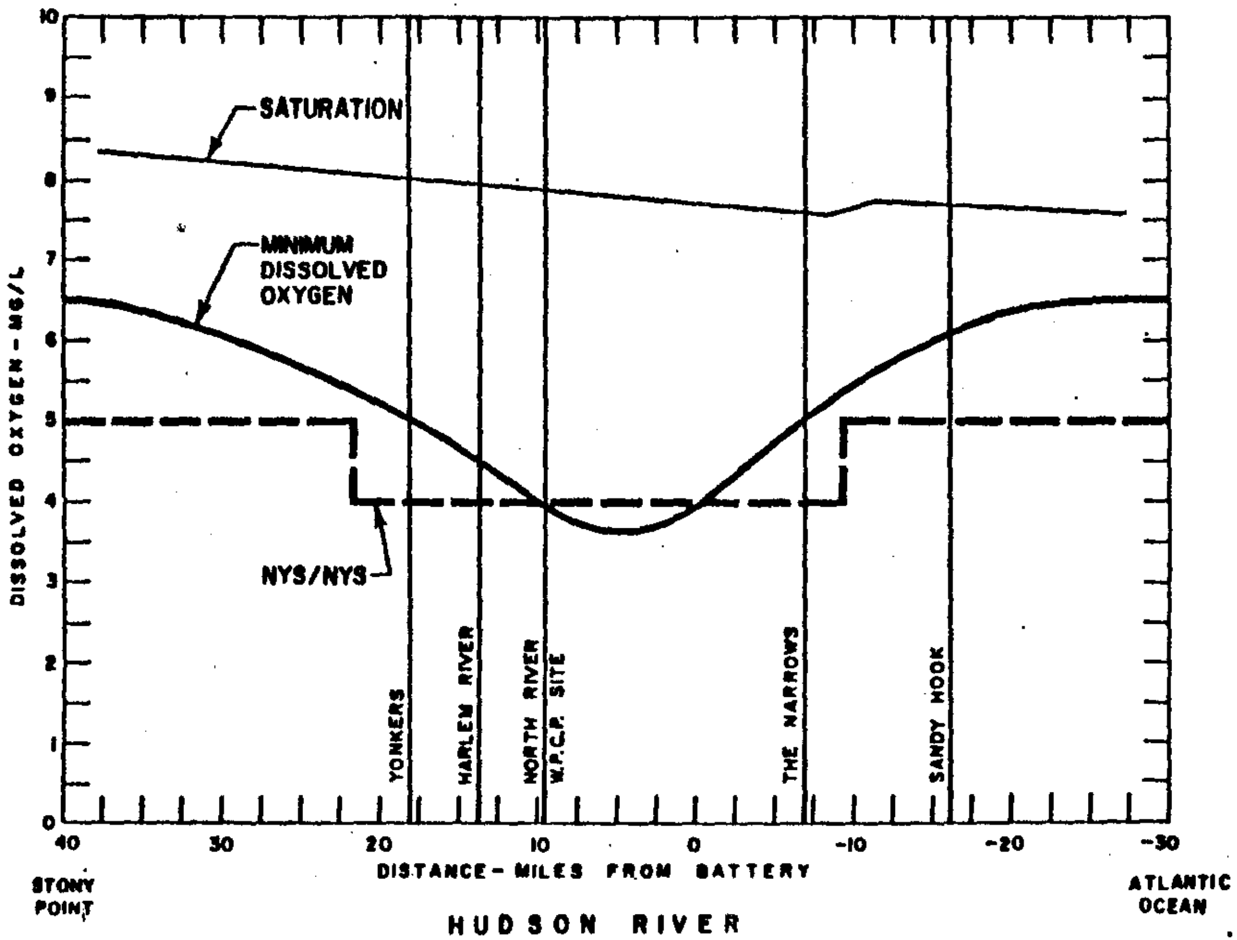


Figure 8

CITY OF NEW YORK 208 STUDY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BASELINE
DISSOLVED OXYGEN TRANSECT

WATER RESOURCES
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER

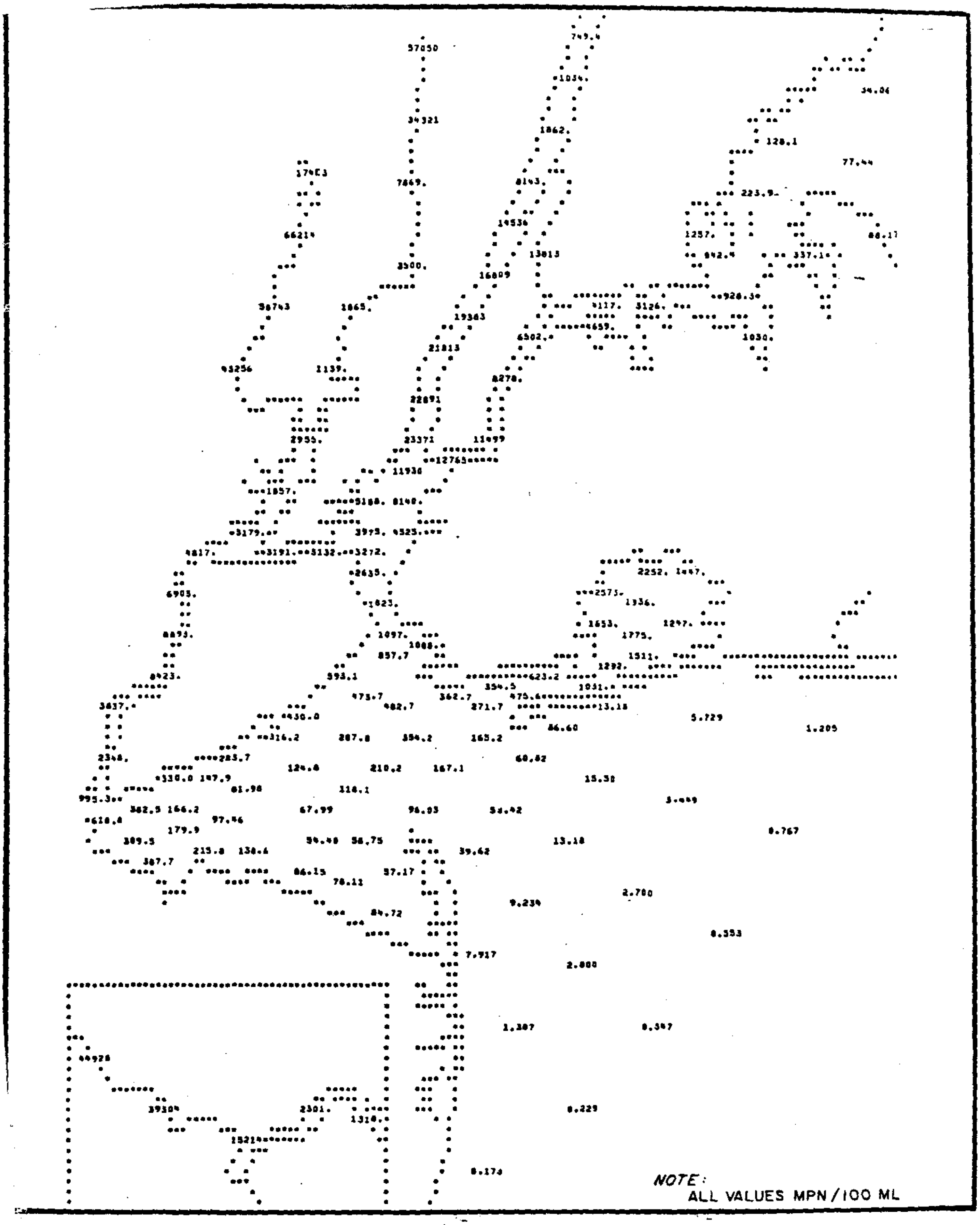


Figure 10
Baseline Condition
Median Total Coliform Bacteria Concentrations

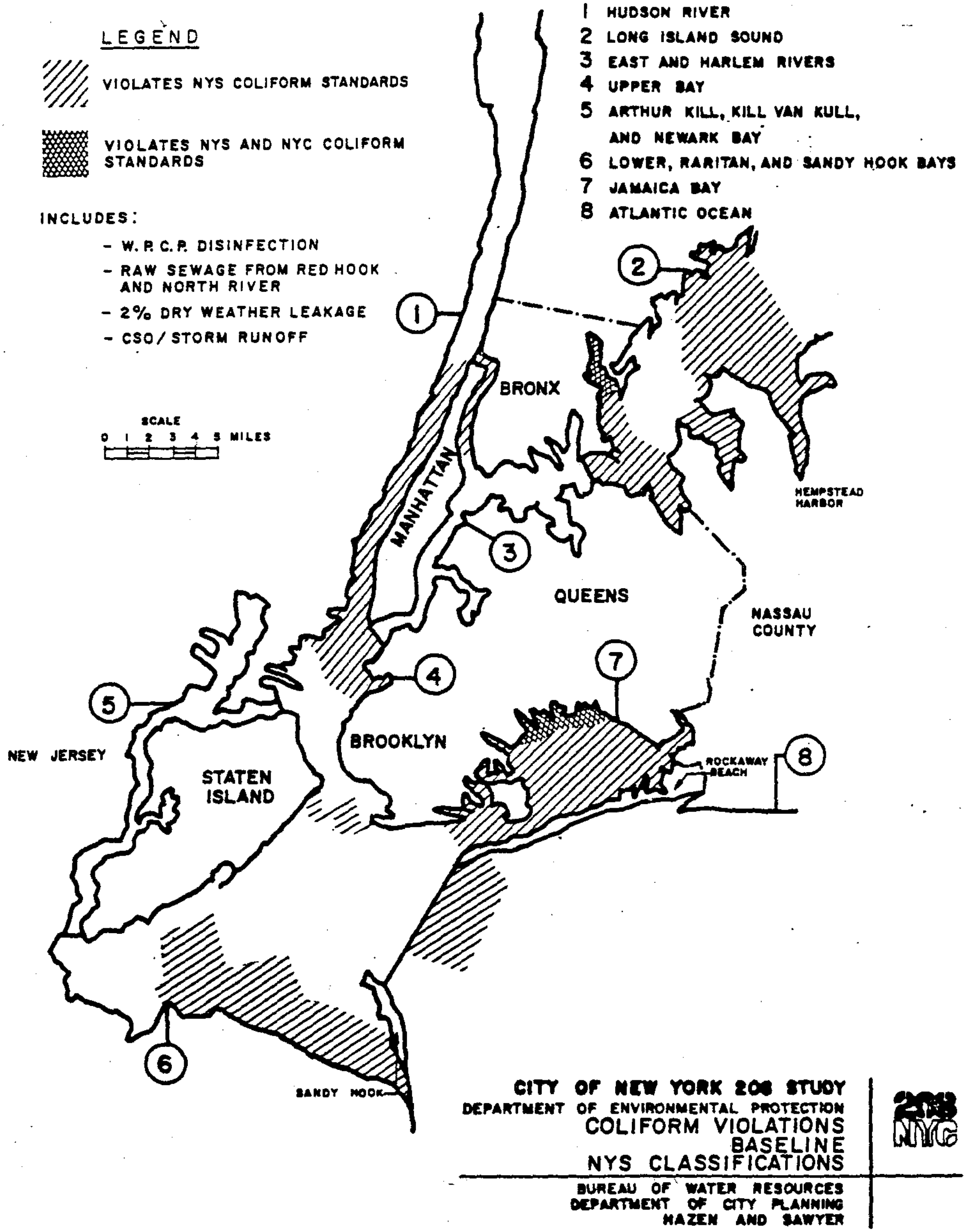

LEGEND
VIOLATES NYS COLIFORM STANDARDS
VIOLATES NYS AND NYC COLIFORM STANDARDS
INCLUDES:
- W.P.C.P. DISINFECTION
- RAW SEWAGE FROM RED HOOK AND NORTH RIVER
- 2% DRY WEATHER LEAKAGE
- CSO/STORM RUNOFF
SCALE
0 1 2 3 4 5 MILES
1 HUDSON RIVER
2 LONG ISLAND SOUND
3 EAST AND HARLEM RIVERS
4 UPPER BAY
5 ARTHUR KILL, KILL VAN KULL, AND NEWARK BAY
6 LOWER, RARITAN, AND SANDY HOOK BAYS
7 JAMAICA BAY
8 ATLANTIC OCEAN
BRONX
MANHATTAN
QUEENS
BROOKLYN
STATEN ISLAND
NEW JERSEY
NASSAU COUNTY
HEMPSTEAD HARBOR
ROCKAWAY BEACH
SANDY HOOK
CITY OF NEW YORK 208 STUDY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
COLIFORM VIOLATIONS
BASELINE
NYS CLASSIFICATIONS
BUREAU OF WATER RESOURCES
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER

Figure 11

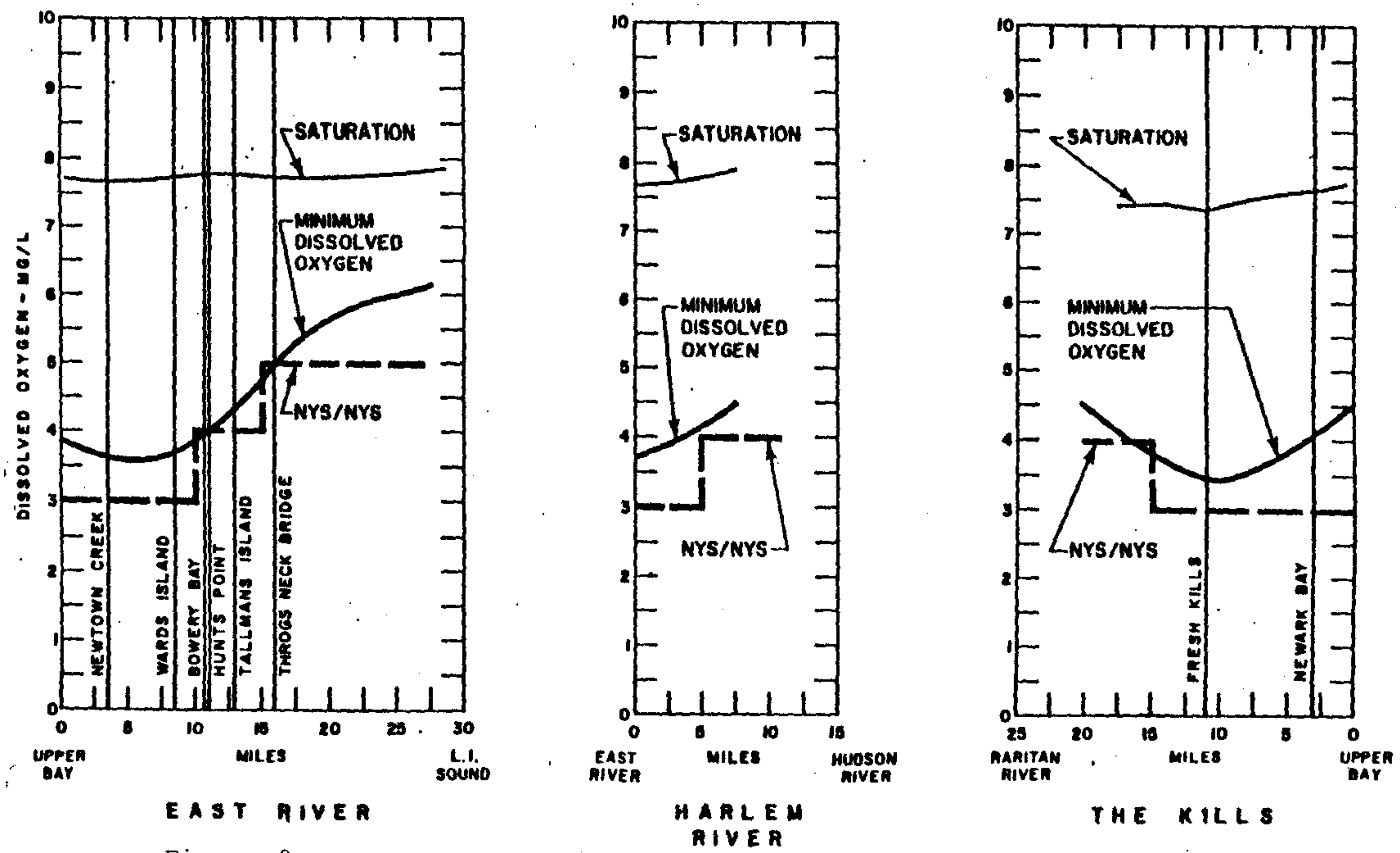


Figure 9

CITY OF NEW YORK 208 STUDY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BASELINE
DISSOLVED OXYGEN TRANSECT

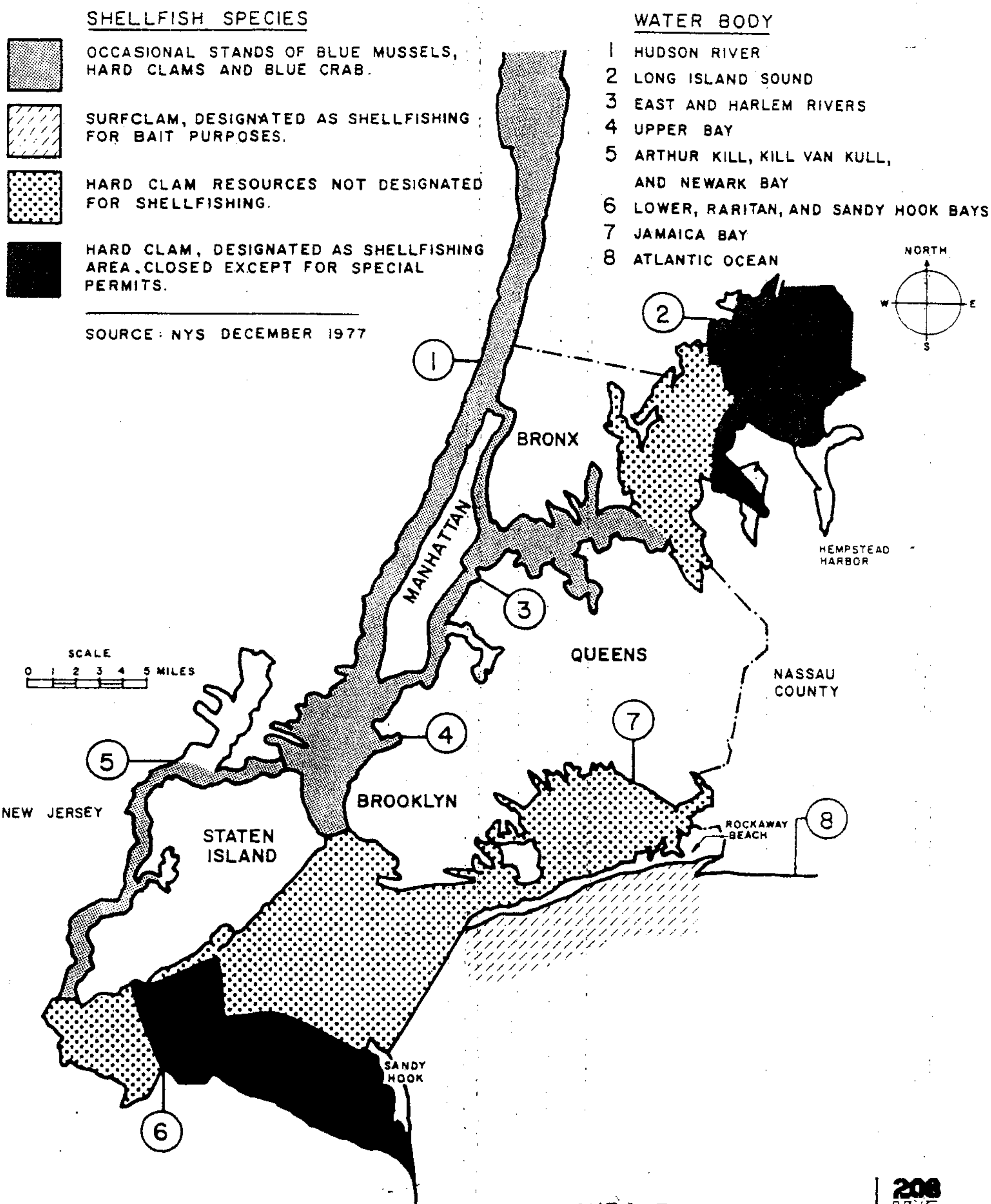
WATER RESOURCES
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER

The Department does not believe there are potentially exploitable commercial shellfish population in the Hudson River within New York City and Westchester/Rockland Counties. This assessment is based upon a review of biological data collected by various institutions and consultants which do not document extensive population of commercially important shellfish species in the areas. It is not clear at this time if this absence of shellfish is due to physical, environmental or pollutional reasons.

The designation of a swimming use for the Hudson River and Upper New York Bay is dependent upon attainment of the coliform standard of 200 MPN fecal coliform/100 ml.

Heavy bacterial pollution is currently present in most of the metropolitan Hudson, especially below its confluence with the Harlem River. These high fecal coliform levels are substantiated from data observations illustrated in Figures 17 through 19. As shown, the fecal coliform density peaks at about 40,000 in the neighborhood of the Battery Park.

The principal sources of bacterial pollution in the Hudson River are the heavy discharges of untreated and inadequately treated sewage from New York and New Jersey. Approximately 200 MGD of untreated sewage flows into the Hudson River and Upper New York Bay from New York City. Other sources of coliform pollution may be attributed to CSOs, urban runoff, plant and sewerline leakages and by-passes on both sides of the river. Figures 20 through 23 present the coliform projections in the Harbor complex, based on the NYC 208 report. Various treatment alternatives were considered in this projection analysis.



SHELLFISH RESOURCES

208 NYC

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER
TASK 315.03

FIGURE 13

The chemical factors and the physical factors which affect the transport and distribution of the chemical pollutants were analyzed through the use of a steady state mathematical model developed by Hydroscience, Inc., as part of the 208 program.

The steady state model simulates tidal movements which occur in the system by taking into account the distribution of the various parameters brought about by that movement through the use of dispersion coefficients. The model used a two layered segment scheme in the Hudson estuary portion of the model to address the vertical stratification which exists in the estuary. The model segmentation of the harbor is shown in Figure 12.

The N.Y.C. 208 study surveyed seasonal dry weather water quality in New York Harbor during the late summer (August-September 1975), late fall/winter (November-December, 1976), and late spring/summer (June-July, 1977). Surface and bottom samples were taken at 87 stations through out the Harbor. Surveys conducted in the summers of 1965 and 1970 were also used in the model development. The flows during the summer of 1965 approximated the 7-day, 10-year low flow which is traditionally used as a critical condition in wasteload allocations.

In addition to the dry weather surveys, two storm events were monitored as part of the 208 study. The 208 water-quality sampling stations are also shown in Figure 12.

Hudson River & Upper New York Bay

As indicated previously the Hudson River and Upper New York Bay are currently classified for fish propogation (Class "I"). Therefore, an assessment of the potential for shellfishing and bathing use must be addressed.

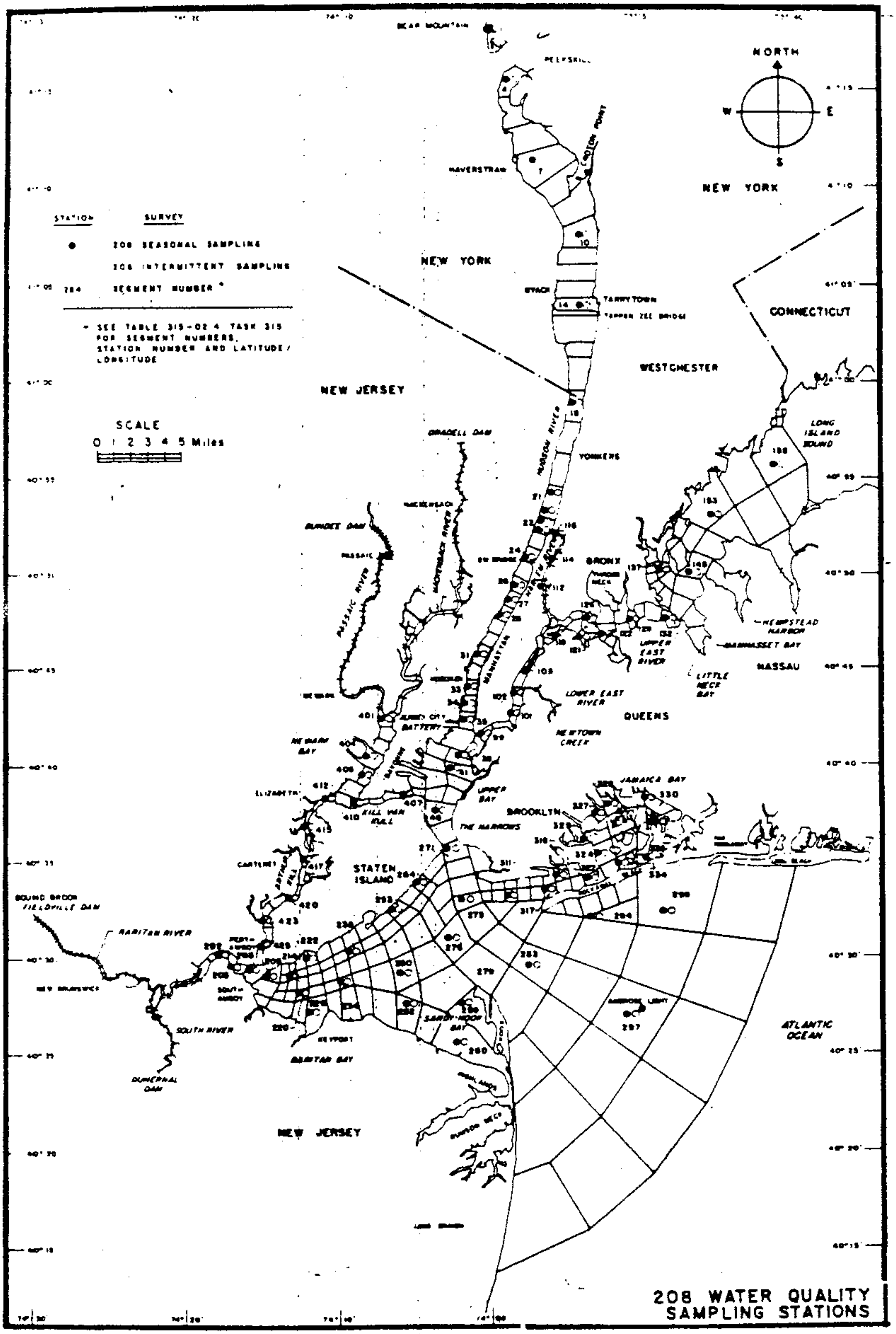

NORTH
NEW YORK
CONNECTICUT
WESTCHESTER
NEW JERSEY
SCALE
0 1 2 3 4 5 Miles
HUDSON RIVER
BRONX
QUEENS
BROOKLYN
NASSAU
STATEN ISLAND
JAMAICA BAY
UPPER BAY
THE NARROWS
RARITAN BAY
SANDY HOOK BAY
ATLANTIC OCEAN
RARITAN RIVER
SOUTH RIVER
PASSAIC RIVER
HACKENSACK RIVER
NEWARK BAY
KILL VAN KULL
LOWER EAST RIVER
UPPER EAST RIVER
NEWTOWN CREEK
LONG ISLAND SOUND
YONKERS
TARRYTOWN
HAVERSTRAW
208 WATER QUALITY
SAMPLING STATIONS

FIGURE 12

As seen, with the secondary treatment alternative (all plants at the secondary level) the fecal coliform levels (assuming fecal coliform = total coliform/4) in the Hudson River, between the State line and its confluence with the Harlem River, will fall below the criterion for SB classification (200 MPN/100 ml). Therefore, in view of these anticipated improvements in the near future, the Hudson River segment between the State line and its confluence with the Harlem River, is recommended to be upgraded to SB classification, hence, made swimmable.

However, for the Hudson River segment between the Harlem River junction, and the Battery, and Upper New York Bay itself, the secondary treatment alternative is predicted to only lower the fecal coliform levels to less than the existing Class I criterion (2,000 MPN/100 ml) but the criterion for SB classification (FC = 200 MPN/100 ml) will still not be met. According to the NYC 208 Report, only the zero discharge alternative, with 90% CSO control, predicts sufficient coliform reductions to achieve the swimmable goals. Furthermore, even the zero discharge alternative does not predict sufficient coliform reductions to attain shellfish goals (total coliform less than 70 MPN/100 MPN for direct harvesting).

East River & Harlem River

The East River between the Battery and Flushing Bay is presently classified for Fish Passage (SD).

The East River with its strong tidal currents and deep hard substrate provides a somewhat limited and harsh environment. Mans activities have caused severe changes to the physical characteristics of the East River. These changes include river enroachment (landfill), dredging, blasting and pollution.

Yet recent studies indicate fish, benthic, phytoplankton, zooplankton and periphyton populations exist in the East River. The various communities are made up of species which can tolerate such an environment, but those communities are balanced and with some exceptions not so different from the communities which existed two hundred years ago.

The Newton Creek 301(h) Report prepared by Hazen and Sawyer Engineers states that "With the exception of oysters and possible communities associated with shallows and tidal areas, the bio-system comprised primarily of non-resident species, is similar today to what it was two hundred years ago. Pollution stresses may limit growth of certain species of phytoplankton and zooplankton as well as residence time for various fish species. Channelization and removal of rocks and reefs may limit feeding areas fo the non-resident species.

The loss of oyster beds is permanent due to the loss of habitat, freshwater inflow, shallows, tidal areas and wetlands."

As part of the same report Hazen and Sawyer conducted an angler survey between August and December of 1982. Twenty-four fish species were caught during that period. Most were considered migratory species, however, three species were considered to be residents of the East River.

Based upon this information it appears that upgrading of the use designation to Fish Propagation (Class I) is appropriate. Analysis performed as part of the N.Y.C. 208 and Newtown Creek 301(h) indicate that the D.O. standard of never less than 4 mg/l, coliform standard of 10,000 MPN/100 ml and fecal coliform of 2,000 MPN/100 ml are attainable with the application of secondary treatment to municipal point sources.

Therefore, the Department as part of a separate hearing process has proposed to reclassify this portion of the East River and Harlem River to Class I (Fish Propogation).

The designation of a swimming use for this portion of the East River and Harlem River is dependent upon attainment of the coliform standard of 200 MPN fecal coliform/100 ml.

Heavy bacterial pollution is currently present in most of East River and Harlem River. High fecal coliform levels are substantiated from data observation, as illustrated in Figures 17 through 19. As shown, the fecal coliform density peaks at about 40,000 in the neighborhood of the Battery and 100,000 in portions of the Harlem River.

The principal sources of bacterial pollution in the East River are the discharge of untreated sewage from the Red Hook drainage area in Brooklyn. Approximately 50 MGD of raw sewage flows into the East River from New York City. Other sources of coliform pollution may be attributed to CSOs, urban runoff, plant and sewerline leakages and by-passes on both sides of the river. Figures 20 through 23 present the coliform projections in the Harbor complex, based on the NYC 208 report. Various treatment alternatives were considered in this projection analysis. As seen, with the secondary treatment alternative (all plants at the secondary level) the fecal coliform levels (assuming fecal coliform = total coliform/4) in the East River, and Harlem, will not fall below the criterion for SB classification (200 MPN/100 ml). According to the NYC 208 Report, even the zero discharge alternative, with 90% CSO control, does not predict sufficient coliform reductions to achieve the swimmable goals or direct shellfishing goals.

Jamaica Bay

Jamaica Bay is currently classified for swimming (SB). However, as indicated in Figure 13 a hard clam resource exists within Jamaica Bay.

The designation of a shellfishing use (SA Direct Shellfish Harvesting) is dependent upon the attainment of coliform standard of 70 MPN total coliform/100 ml.

The principal sources of bacterial pollution in Jamaica Bay are attributed to CSO.

High coliform levels are substantiated from periods of data observation, as illustrated in Figures 14 through 16.

Figures 20 through 23 present the coliform projections in the Harbor complex, based on the NYC 208 report. Various treatment alternatives were considered in this projection analysis. However, for the Jamaica Bay, the secondary treatment alternative is not predicted to lower the total coliform levels below criterion (70 MPN/100 ml) for direct shellfishing. According to the NYC 208 Report, even the zero discharge alternative, with 90% control, does not predict sufficient coliform reductions to achieve the direct shellfishing goals.

Lower New York Bay

Lower New York Bay is currently classified for swimming (SB). However, as indicated in Figure 13 a hard clam resource exists in lower N.Y. Bay.

The designation of a shellfishing use (SA Direct Shellfish Harvesting) is dependent upon the attainment of the total coliform criteria of 70 MPN/100 ml.

High total coliform levels are substantiated from data observation, illustrated in Figures 14 through 16.

The principal sources of bacterial pollution in the Lower New York Bay are the carry over discharges of untreated and inadequately treated sewage from New York and New Jersey. Approximately 200 MGD of raw sewage flows into the Hudson River from New York City. Other sources of coliform pollution may be attributed to CSOs, urban runoff, plant and sewerline leakages and by-passes on both sides of the river. Figures 20 through 23 present the coliform projections in the Harbor complex, based on the NYC 208 report. Various treatment alternatives were considered in this projection analysis. As seen, with the secondary treatment alternative (all plants at the secondary level) the total coliform levels in the Lower New York Bay, will not be below the criterion for SA classification (70 MPN/100 ml). According to the NYC 208 Report, only the zero discharge alternative, with 90% CSO control, predicts sufficient coliform reductions to achieve the direct shellfishing goals.

Assessment of Alternatives

Based on the NYC 208 report, only the zero discharge alternative, with 90% CSO control, predicts sufficient coliform reductions to achieve the shellfishing/swimming goals for water in the New York Harbor Complex. In fact, in some cases, even the zero discharge does not predict sufficient coliform-reductions to achieve shellfishing goals. However, the NYC 208 report concluded that based on environmental, technical and institutional factors, this alternative is not feasible. Even if implemented, the projected improvements in the water quality may still not materialize, since the precision of the NYC 208 water quality model to predict total and fecal coliform levels has not been demonstrated for the bacterial levels in question. Furthermore, the remaining 10% of the CSOs will still have some impact on the Lower New York Bay. The alternative provides that the CSOs are to be captured and then given primary treatment followed by disinfection. The estimated reductions in the coliform bacteria, via chlorination of primary treated captured CSO, may have been overstated. It is also recognized that the applicability of steady state models to CSO and/or coliform bacteria analysis is limited.

CSO abatement is the crucial factor in meeting the swimmable/fishable water quality goals. The zero discharge alternative entails in-line (sewers) and off-line storage, followed by primary treatment and disinfection. Based on the NYC 208 study, the current costs associated with this CSO control scheme are estimated to be over 7 billion dollars (updated from the original (1975) 3.5 billion dollars). The engineering feasibility of this CSO control program has not been established. A detailed study, involving over 600 major CSO points, generally distributed throughout the harbor region, is required. Therefore, pending detailed engineering evaluations of this alternative (90% of CSO control) and others, it is judged that its feasibility has not been demonstrated.

CONCLUSIONS AND RECOMMENDATIONS

Recognizing the scope and limitations of the analyses to date, further studies are underway and will be continued. It is possible that other treatment/abatement alternatives for CSOs, which were not evaluated in the New York City 208 planning process, could produce the desired result of attaining swimmable and shellfishing water quality. New Jersey is currently actively pursuing Marine CSO abatement funding under Section 201(n) for local communities. Additionally, New York State has required the City of New York to undertake a more detailed evaluation of CSO problems and abatement alternatives for the New York Harbor Complex. This study has just begun.

During the same time period as the CSO study, the North River and Red Hook Water Pollution Control Facilities will begin to treat and provide disinfection for flows which are currently discharged without treatment to the Hudson River and the Lower East River.

Continued monitoring during the time period will help to evaluate the predictive capability of the New York City 208 model and provide an up-to-date data base in order to determine if the swimmable/shellfishing goals are attainable.

more summary

Based upon this report, the following waters are recommended for upgrading:

1. The East River (from the Battery to Flushing Bay) and the Harlem River (East River to Washington Bridge) from SD to I

2. The Hudson River (from the Harlem River confluence to the N.J. - N.Y. border) from I to SB

(cont)

(cont)

The existing classification of the following waters should be retained:

1. Hudson River (from the Harlem River to Battery) - Class I
2. Upper New York Bay - Class I
3. Harlem River (Washington Bridge to Hudson River) - Class I
4. Jamica Bay - Class SB
5. Lower New York Bay - Class SB

It is further recommended that the following programs and studies be instituted or continued:

1. On-going studies to determine the extent of water quality improvements resulting from low cost and technically feasible programs, such as regulator leakage correction, and non-structural controls, such as street sweepings, etc.

2. Enhancement of the Harbor Complex monitoring network, tailored to determine the water quality improvements resulting from the anticipated upgrading of public wastewater plants.

3. Consideration of area-wide and site-specific studies and/or corrective actions to restore the intended uses, such as shellfishing, bathing, etc.

4. Continuation of interstate cooperation in water quality improvement programs in the Harbor complex. Continuation of steering committee coordination in assessment of specific problems, such as upgrading of stream uses, if and when warranted.

(cont)

(cont)

5. Confirmation and implementation of ongoing and required efforts, such as New York City regulator leakage control. New Jersey - City wide abatement studies and New Jersey CSO abatement studies.

6. Implementation of the permits program.

Based upoon this additional monitoring information and water quality management studies, the conclusion on attainability in this report should be reviewed during the next three years.

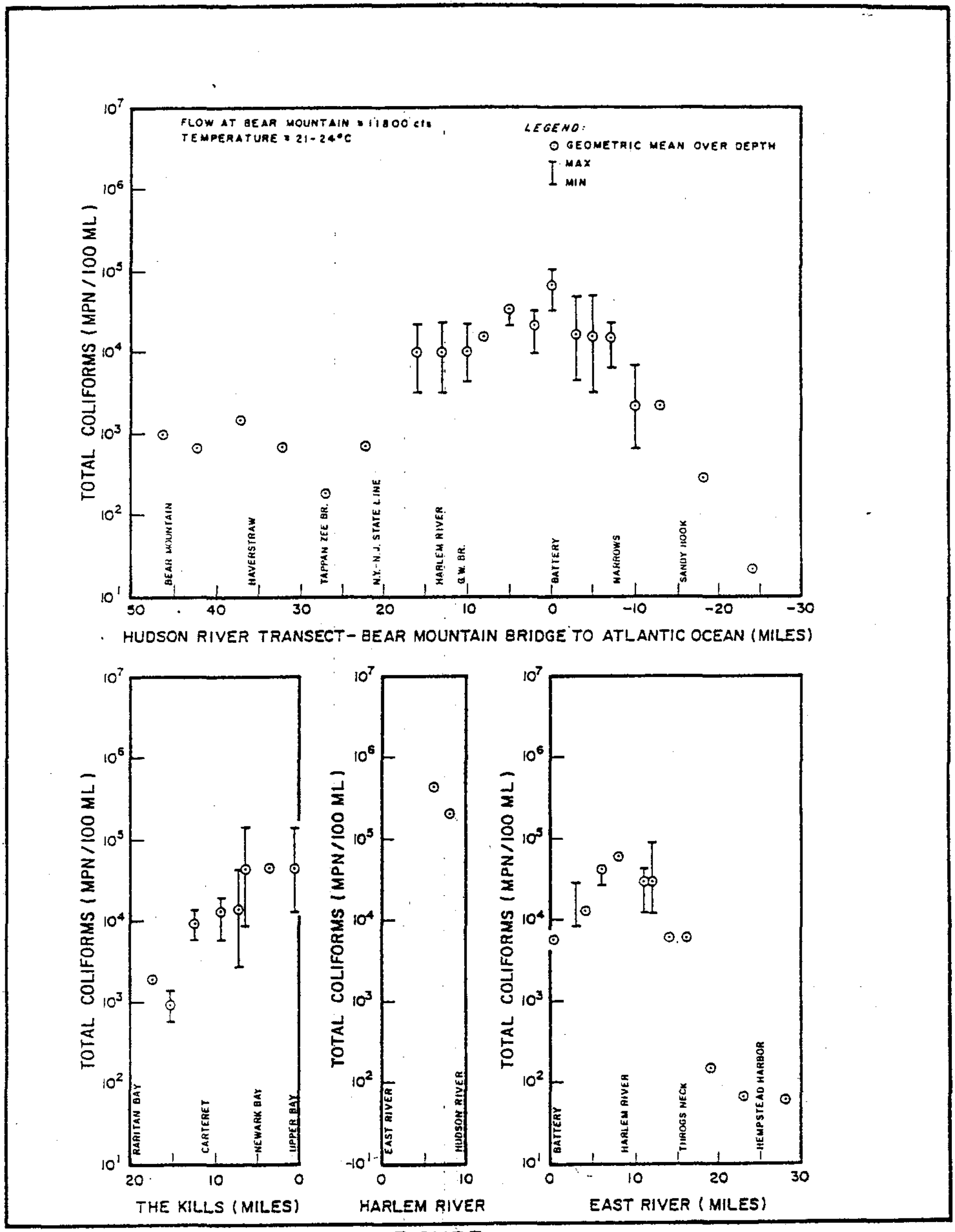


FIGURE 14
N.Y.C. 208 TOTAL COLIFORM DATA
(SEPTEMBER 15-22, 1975)

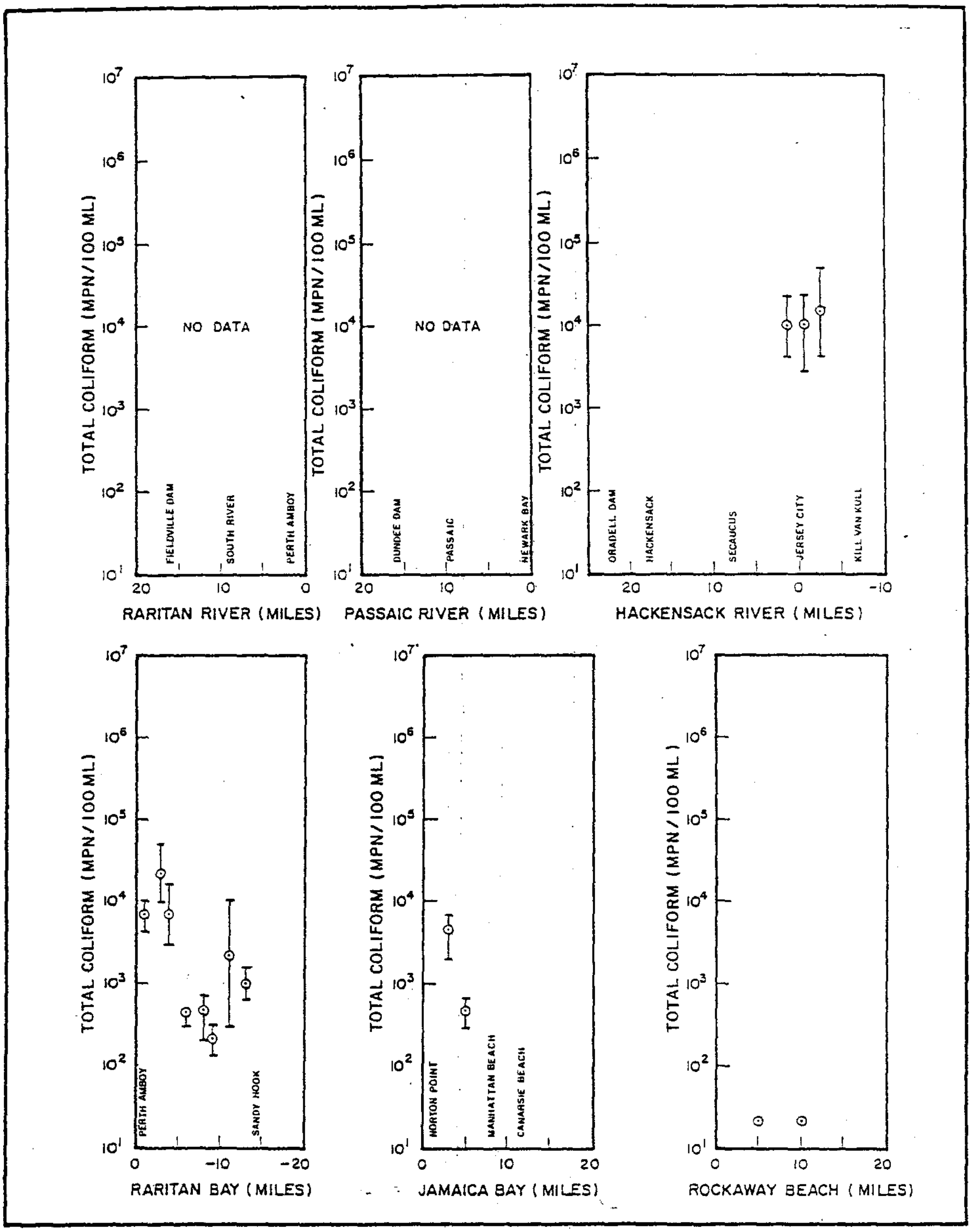


FIGURE 14
N.Y.C. 208 TOTAL COLIFORM DATA
(SEPTEMBER 15-22, 1975)

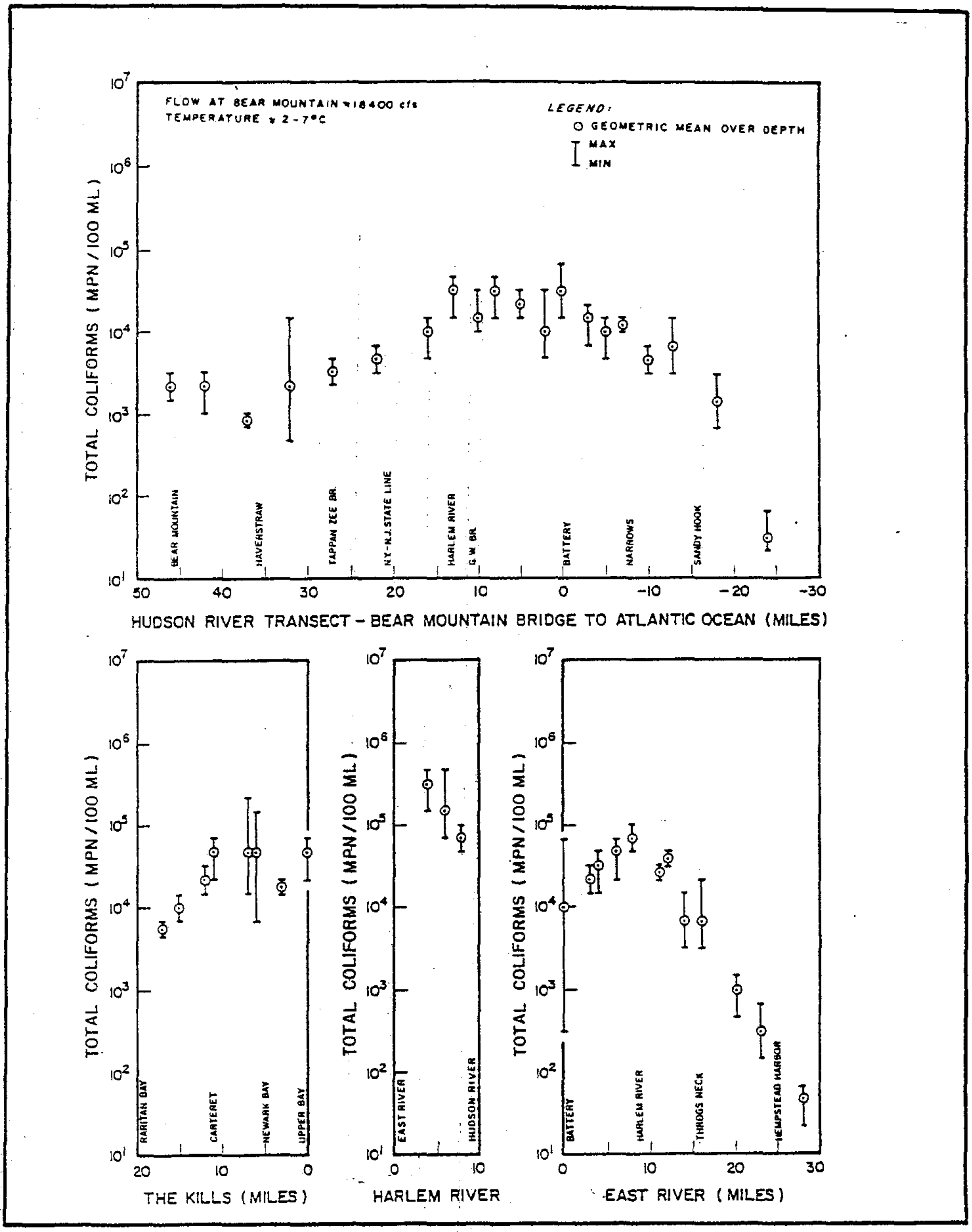


FIGURE 15
N.Y.C. 208 TOTAL COLIFORM DATA
(NOVEMBER 29 TO DECEMBER 17, 1976)

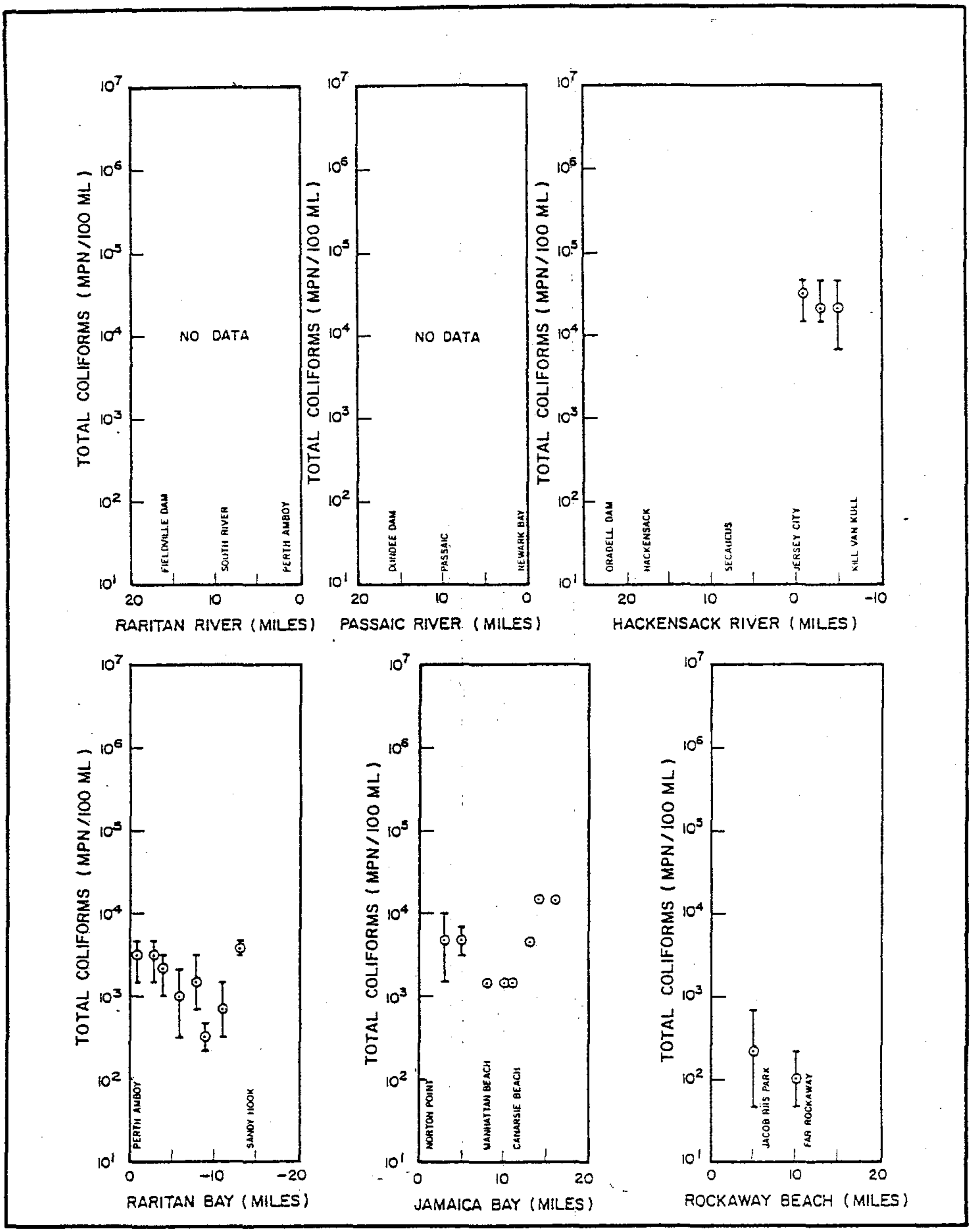


FIGURE 15
N.Y.C. 208 TOTAL COLIFORM DATA
(NOVEMBER 29 TO DECEMBER 17, 1976)

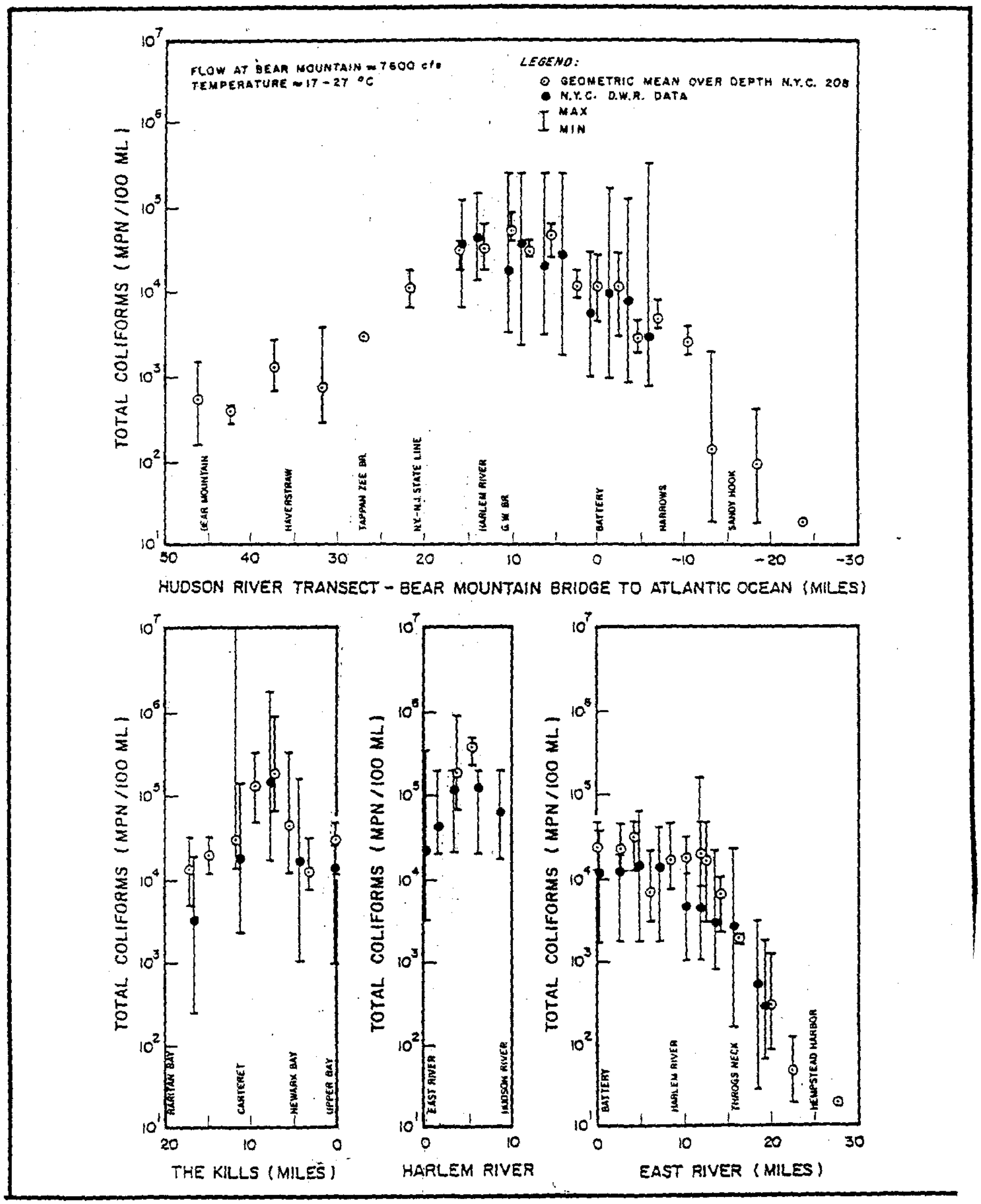


FIGURE 16

TOTAL COLIFORM DATA

(JUNE 15 TO SEPTEMBER 28, 1977)

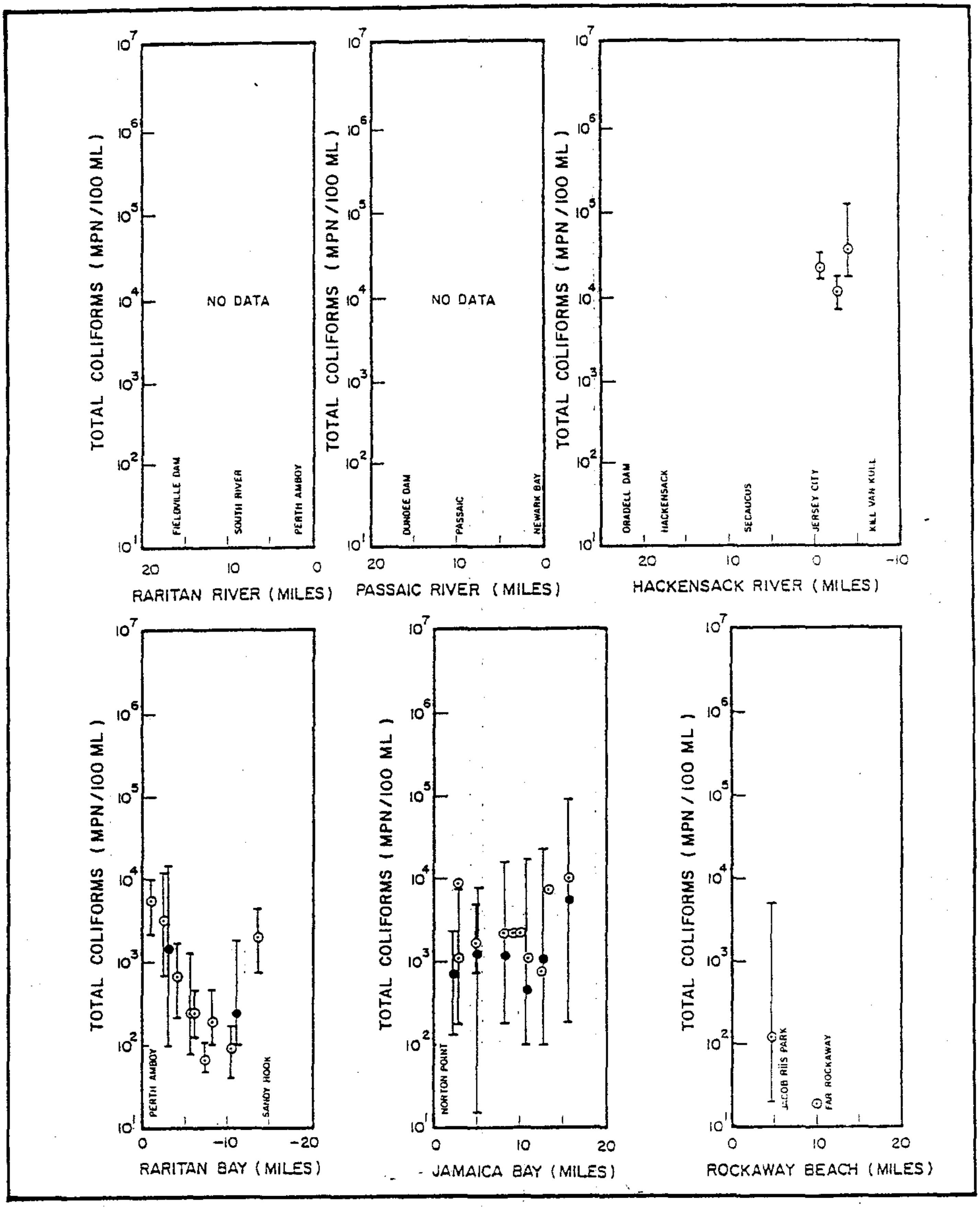


FIGURE 16
TOTAL COLIFORM DATA
(JUNE 15 TO SEPTEMBER 28, 1977)

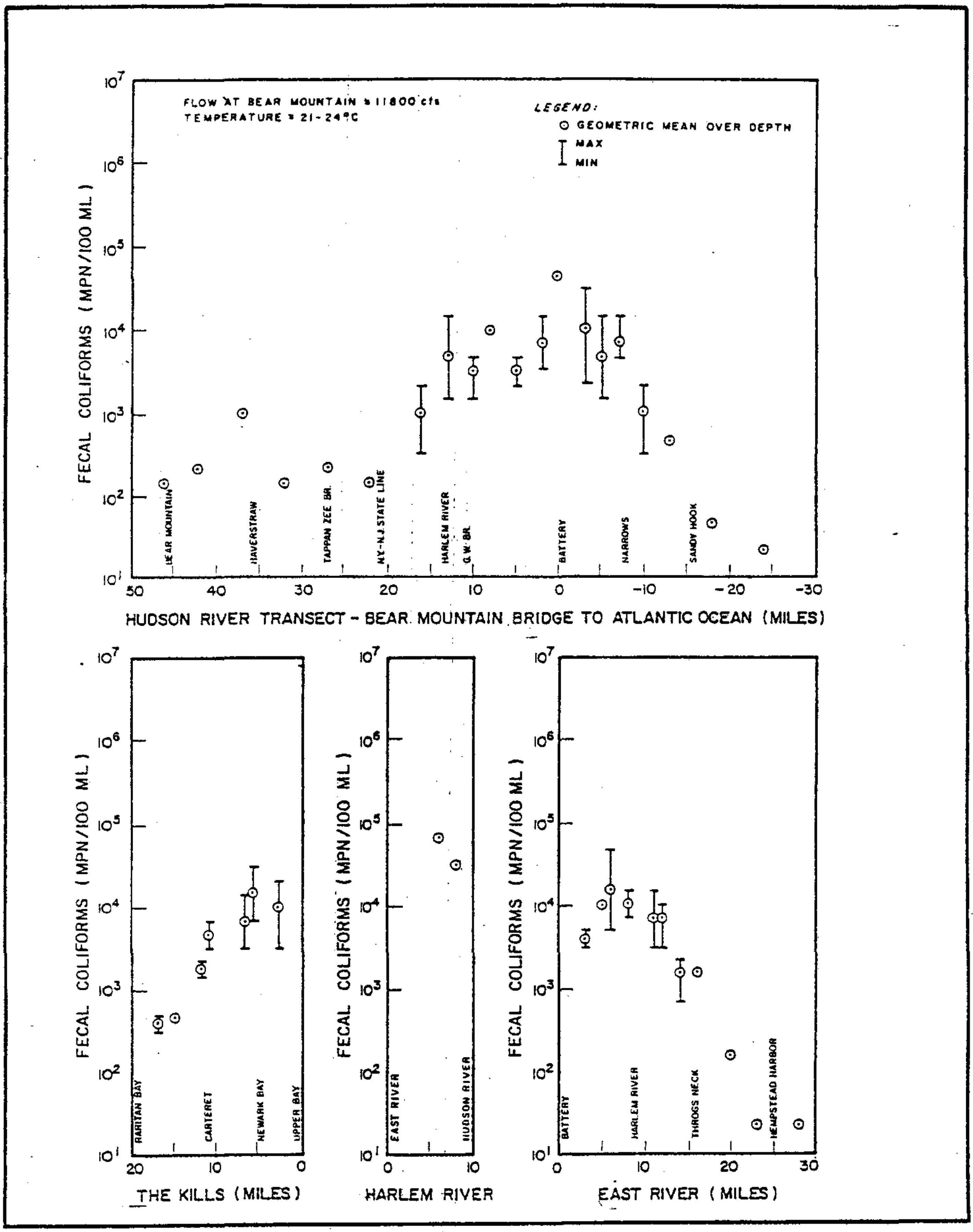


FIGURE 17
N.Y.C. 208 FECAL COLIFORM DATA
(SEPTEMBER 15-22, 1975)

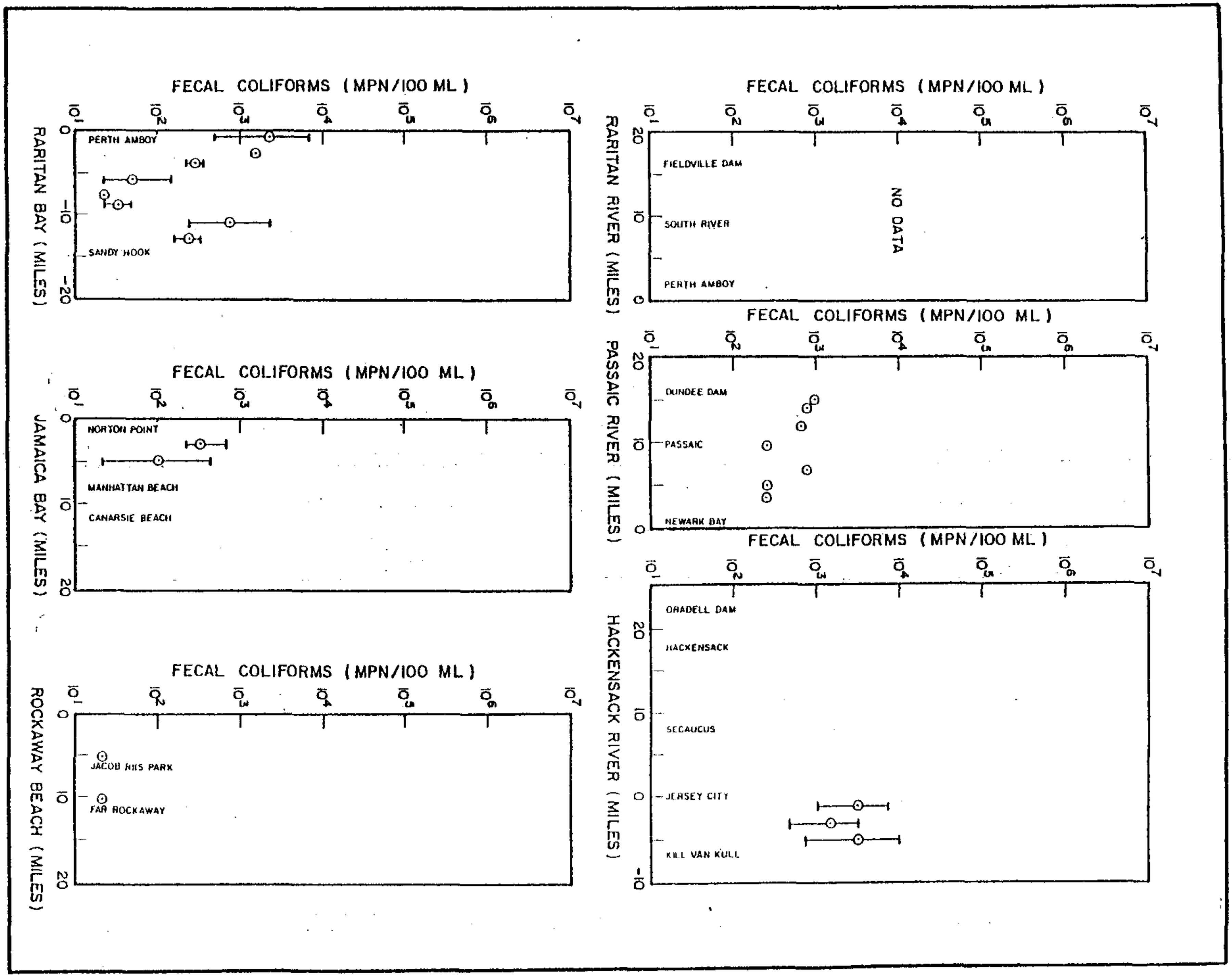


FIGURE 17
N.Y.C. 208 FECAL COLIFORM DATA
(SEPTEMBER 15-22, 1975)

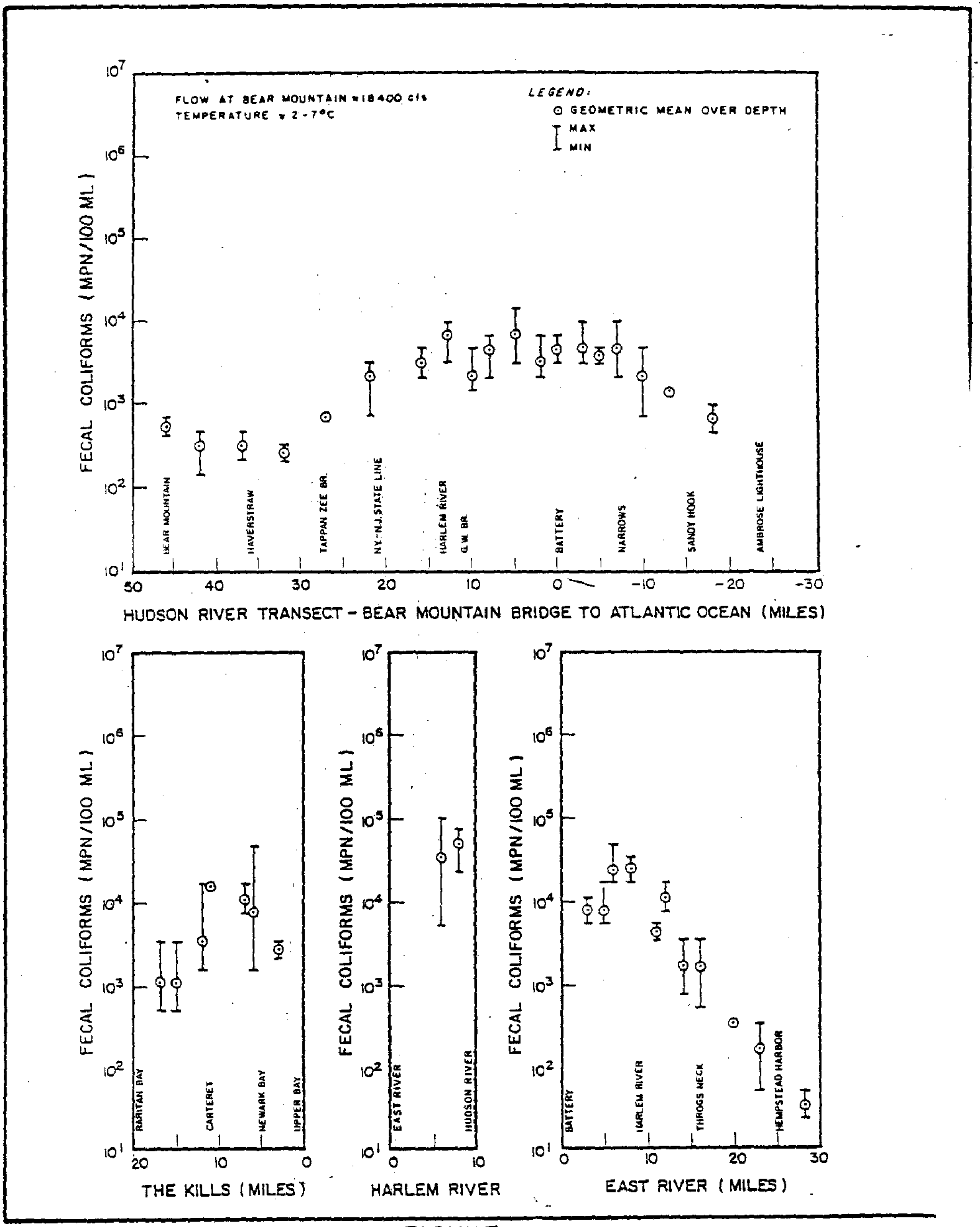


FIGURE 18

N.Y.C. 208 FECAL COLIFORM DATA

(NOVEMBER 29 TO DECEMBER 17, 1976)

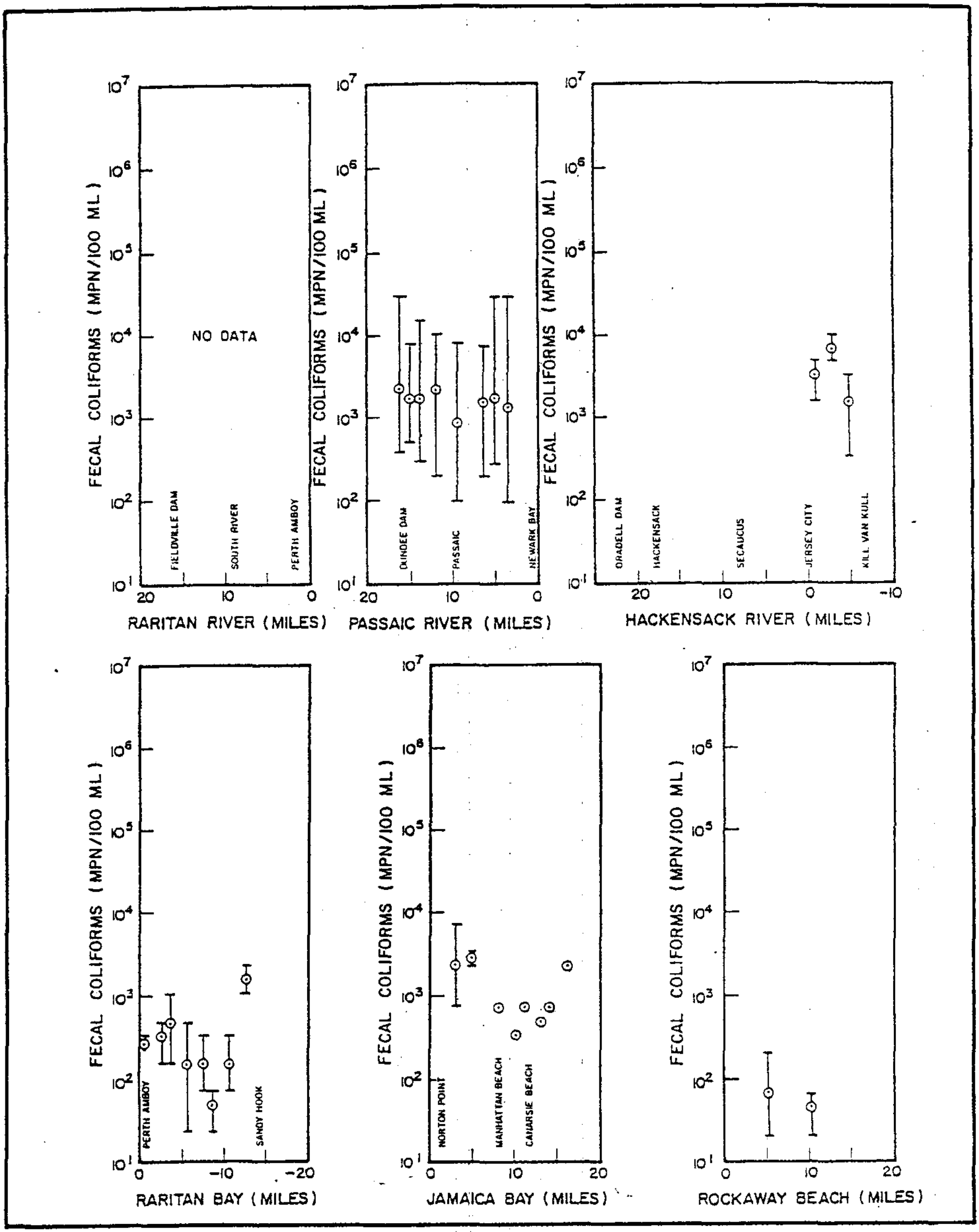


FIGURE 18
N.Y.C. 208 FECAL COLIFORM DATA
(NOVEMBER 29 TO DECEMBER 17, 1976)

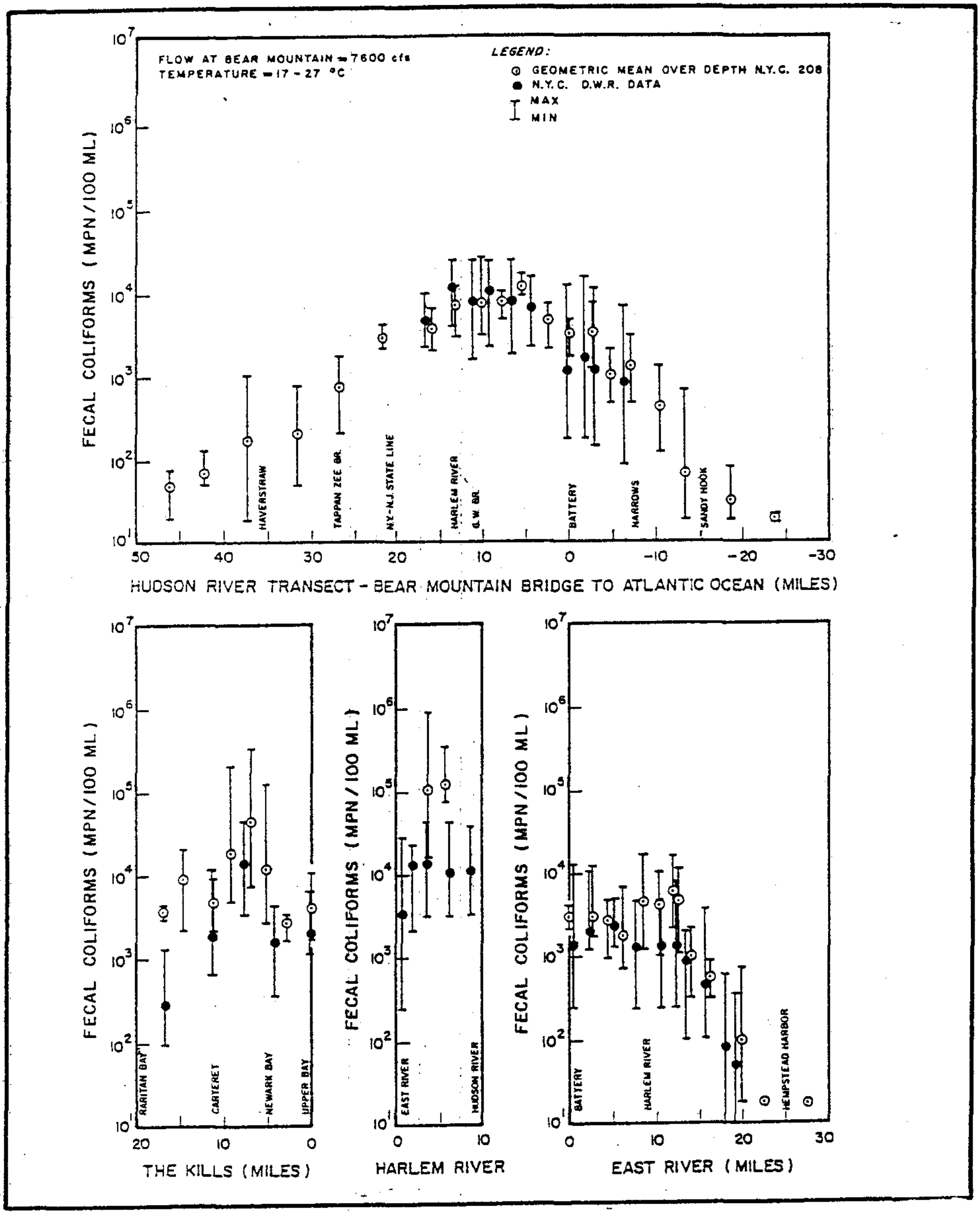


FIGURE 19
FECAL COLIFORM DATA
(JUNE 15 TO SEPTEMBER 28, 1977)

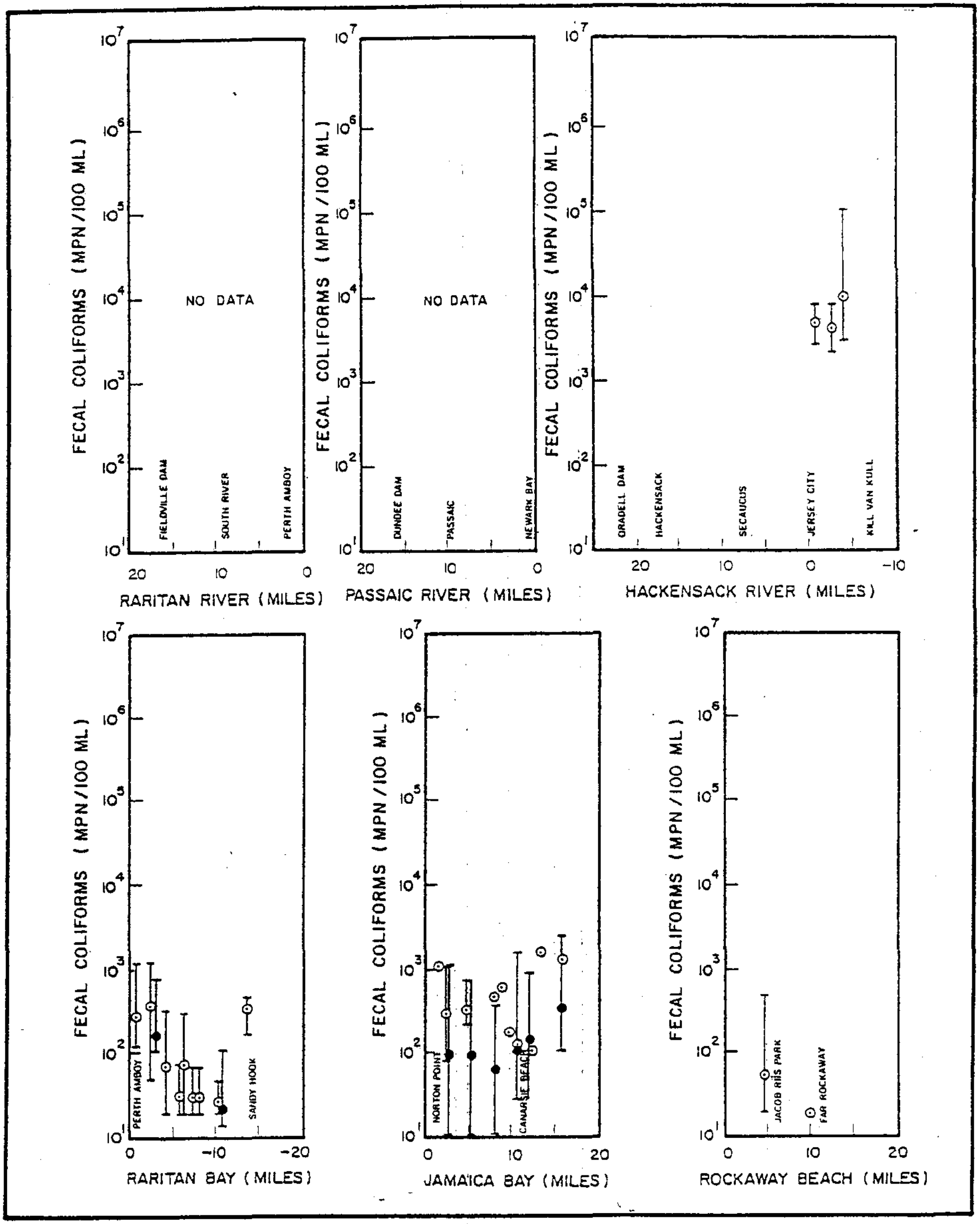


FIGURE 19
FECAL COLIFORM DATA
(JUNE 15 TO SEPTEMBER 28, 1977)

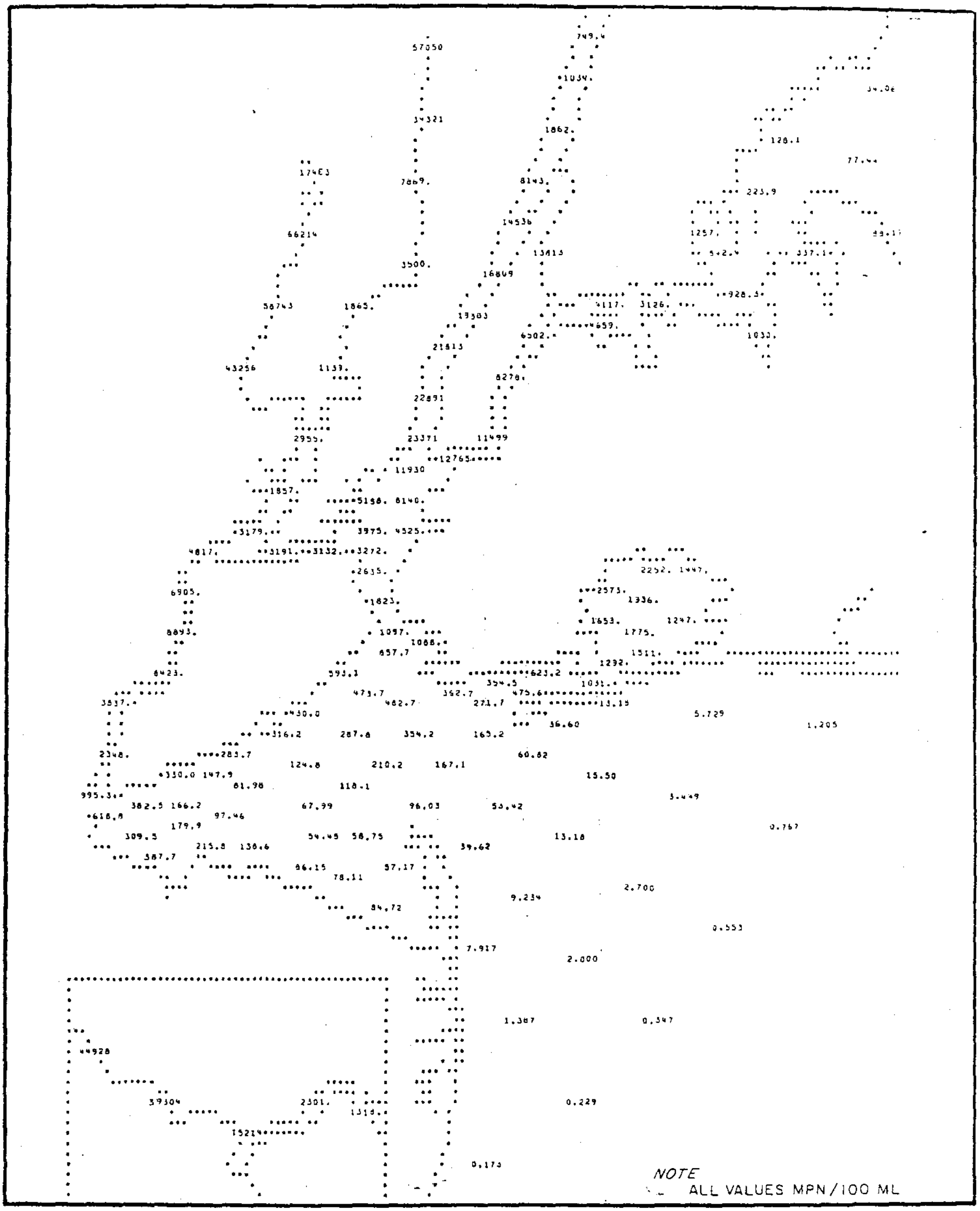


FIGURE 20
PREDICTED MEDIAN TOTAL COLIFORM BACTERIA CONCENTRATIONS
BASELINE CONDITION

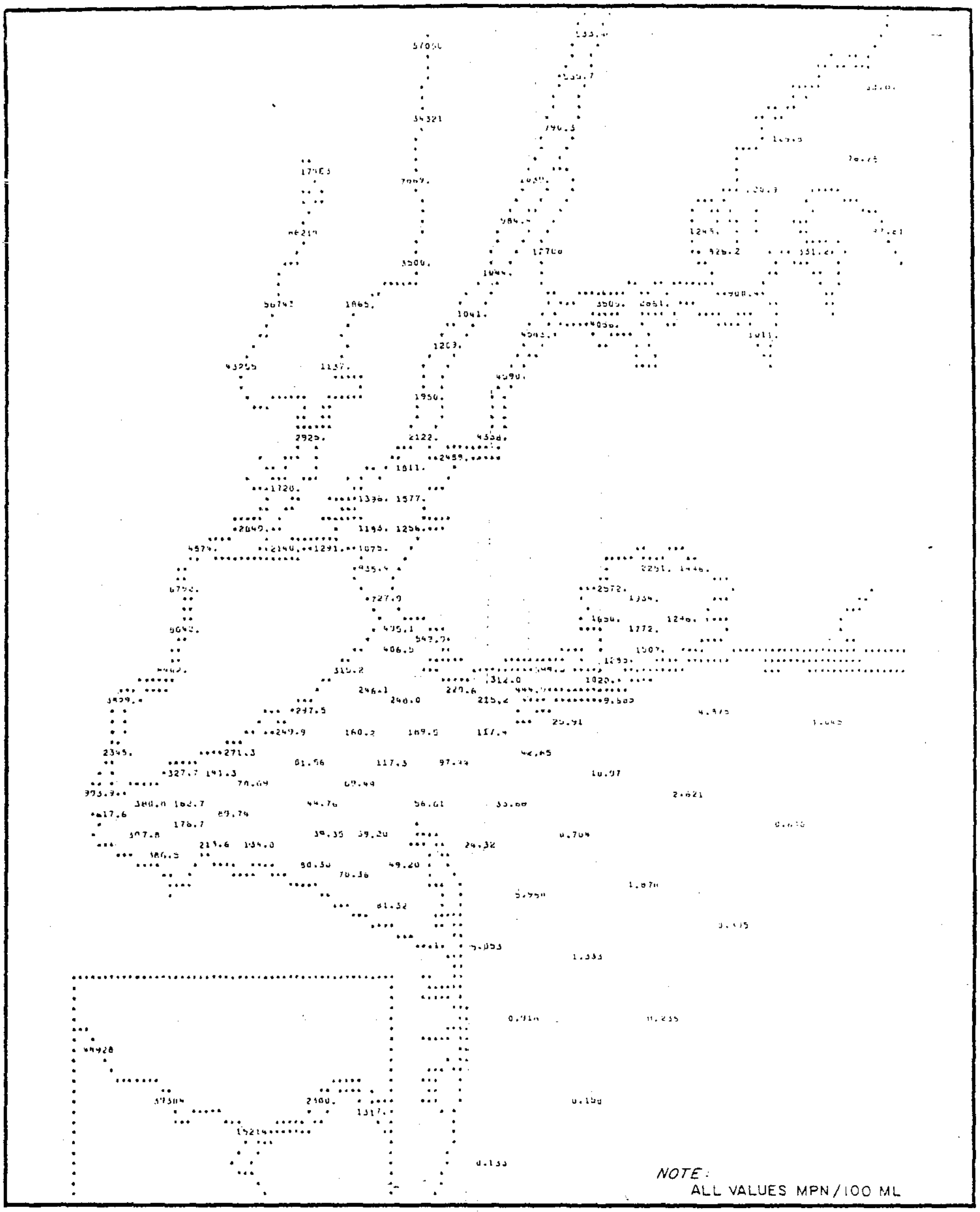


FIGURE 21
PREDICTED MEDIAN TOTAL COLIFORM BACTERIA CONCENTRATIONS
SECONDARY TREATMENT ALTERNATIVE

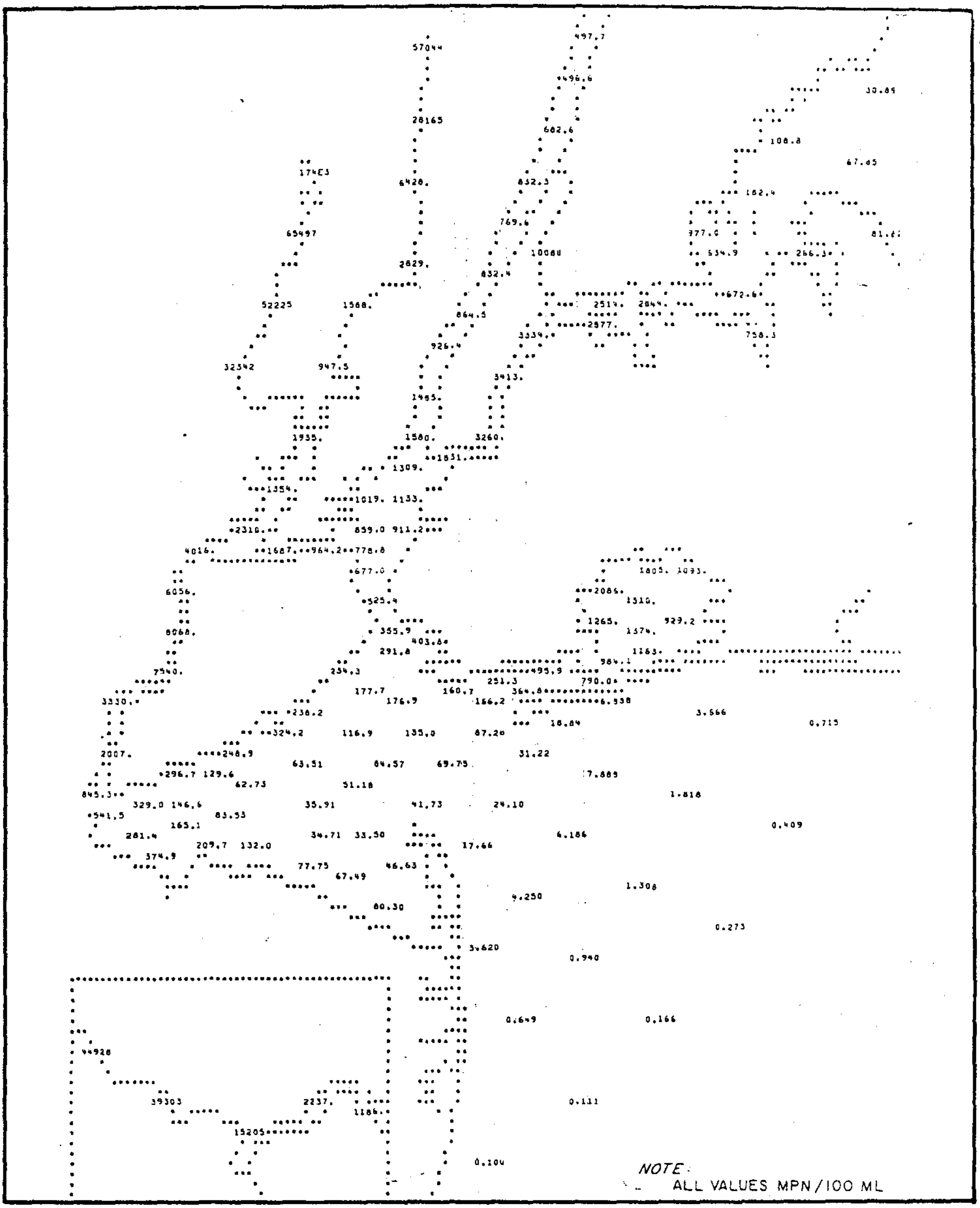


FIGURE 22
PREDICTED MEDIAN TOTAL COLIFORM BACTERIA CONCENTRATIONS
SECONDARY TREATMENT + 50 PERCENT CSO
TREATMENT ALTERNATIVE

Appendix 1

Source Documents

1. New York City 208 Reports

   a. the Final Report

   b. task 710 Description of the Final Plan

   c. task 315 Seasonal Water Quality Evaluation

   d. task 314 Seasonal Steady State Modeling

   e. tasks 516/526 Baseline/alternatives: Summary Volume 1

   f. tasks 512/522 Baseline and Alternatives: Modeling

   g. task 335 Intermittent Water Quality Evaluation

2. North River Water Pollution Control Project, 201 Facility Plan, Volume 4, Environmental Assessment Statement

3. Red Hook Water Pollution Control Project, 201 Facility Plan Final Report

4. N.Y.S. Department of Health pre-classification Study - Lower Hudson River from mouth to Northern Westchester-Rockland county lines.

5. N.Y.S. Department of Health pre-classification study - Lower East River

6. N.Y.S.D.E.C. Hudson River Water Quality and Waste Assimilative Capacity Study. Prepared by Quirk Lawler and Matusky Engineers

7. Water Quality Management Assessment Due to Marine CSO Abatement along the New Jersey Shore - prepared by Bureau of System Analysis and Waste Load Allocation N.J. DEP.

8. Surface Water Quality Standards for New Jersey - N.J. Department of Environmental Protection/Division of Water Resources (4/85)

9. Coney Island Water Pollution Control Plant Facility Plan

10. Owls Head Water Pollution Control Plant Facility Plan.

11. Use attainability analysis of the NY Harbor Complex - N.J. DEP Division of Water Resources June 1985.

12. New York State Water Quality Standards Attainability Strategy

ACKNOWLEDGEMENTS

The Division of Water gratefully acknowledges the contribution of the following individuals in the preparation of this report:

Philip M. DeGaetano	- Project Director
Philip O'Brien	- Principal Investigator
Richard Newman	- Technical Assistance
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Stacy Kmen	- Typing
Susan Stuart	- Typing
Mark Kruszona	- Report Reproduction

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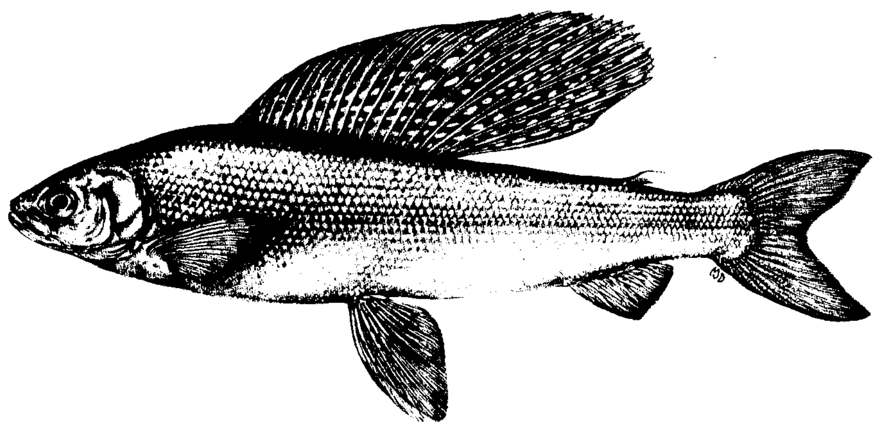
Appendix E:
Red Dog Mine UAA

RED DOG USE ATTAINABILITY ANALYSIS AQUATIC LIFE COMPONENT

By

Phyllis Weber Scannell

Technical Report No. 96-1



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February 1996

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Red Dog Creek Use Attainability Analysis
Aquatic Life Component

Introduction

Authority

The US Environmental Protection Agency's (USEPA) water quality standards regulation (40 CFR 131.1.(j)) establishes the requirement that states or tribes conduct a use attainability analysis when either designating uses which do not include the "fishable/swimable" uses or when designating new subcategories of the "fishable/swimable" uses which require less stringent criteria.

Purpose

The purpose of this Use Attainability Analysis is to identify streams in the Wulik River drainage that do not support the currently designated uses for aquatic life. Natural background water quality and metals concentrations may limit aquatic populations. Aquatic life is defined in this document to include all aspects of the aquatic community: fish, macroinvertebrates, microinvertebrates, periphyton, and macrophytes. Existing uses are defined under 18 AAC.70.990 (20):

> "existing uses" means those uses actually attained in a waterbody on or after November 28, 1975.

and under 40 CFR Sec. 131 E:

> "existing uses" means those uses actually attained in the waterbody on or after November 28, 1975.

Description of Streams Considered for Reclassification

All of the streams considered for reclassification in the Wulik River drainage are located in northwest Alaska, approximately 95 km (59 mi) north of Kotzebue (Figure 1). Middle Fork Red Dog Creek flows adjacent to the Red Dog ore body, a large lead - zinc deposit that currently is mined by Cominco Alaska Inc. The following is a description of the streams considered in this document for reclassification to eliminate the aquatic life criteria. Water quality and fisheries data collected during baseline studies (1979-1982) represent pre-mining conditions because no disturbance had occurred in these drainages at that time.

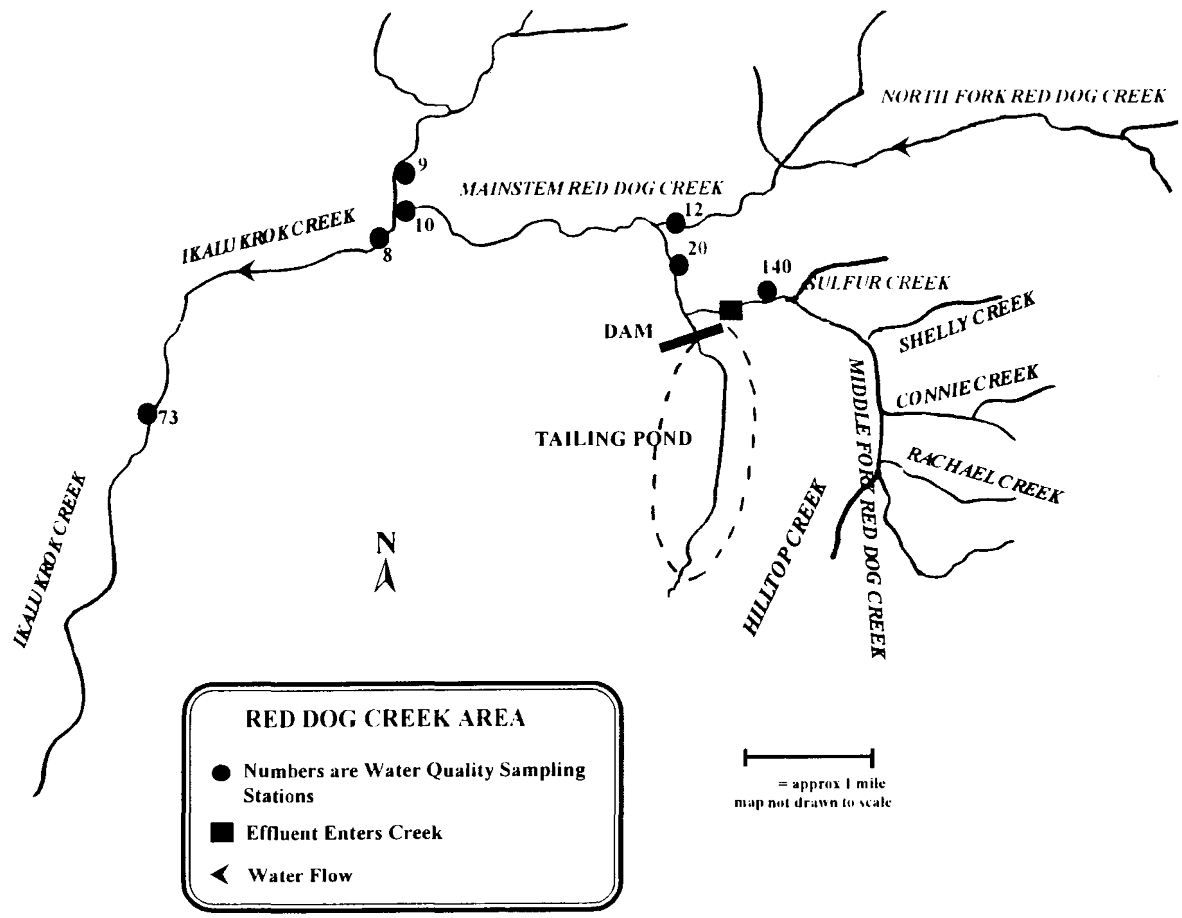


Figure 1. Locations of streams considered for reclassification of aquatic life use. Water quality sampling stations are shown on the map.

Ikalukrok Creek

Three segments of Ikalukrok Creek were considered in this study: Ikalukrok Creek from the headwaters to the confluence with Red Dog Creek, Ikalukrok Creek below the confluence with Red Dog Creek to Dudd Creek, and Ikalukrok Creek below Dudd Creek.

Ikalukrok Creek above the confluence with Red Dog Creek (Figure 2) has a drainage area of 150 km^2 (59.2 mi^2). The creek flows through mineralized zones and red iron flocculant and white aluminum flocculant are prevalent in side channels, smaller tributaries, and backwater areas. Stream bed rocks frequently are stained orange from iron precipitate. During 1992, Ikalukrok Creek above Red Dog Creek had a high mean monthly flow of 17.3 m^3/s (610 cfs) and a low flow of 0.02 m^3/s (0.58 cfs). At Station 9, stream width ranges from 2 to 7 m (7 to 24 ft) (up to 21 m or 68 feet in high flow years), with depths ranging from 0.15 to 1.2 m (0.5 to 4 feet). The stream bed at Station 9 consists of gravel, cobbles, and rocks. This section of Ikalukrok Creek has not been disturbed by mining or other human activity.

Ikalukrok Creek from the confluence with Red Dog Creek downstream to Dudd Creek contains periodic elevated concentrations of metals from the natural mineralization upstream and from mineralization along Red Dog Creek. At Dudd Creek (Station 7), widths range from approximately 3.5 to 40 m (12 to 130 feet) and depths range from 0.3 to 1.2 m (1 to 4 ft). Temperatures range from 0 to 10°C during open flow. Ikalukrok Creek (Figure 2) has a 485.8 km^2 (184 mi^2) drainage area, with 320 km^2 (124 mi^2) below the confluence of Red Dog Creek.

Mainstem Red Dog Creek

Mainstem Red Dog Creek (Figure 3) has a drainage area of 64 km^2 (24.6 mi^2) of which 10 km^2 (3.8 mi^2) does not contribute to the flow because it is impounded behind the tailing dam. During 1992, Red Dog Creek had a high mean monthly flow of 5.4 m^3/s (191 cfs) and a low flow of 0.0045 m^3/s (0.16 cfs). Widths of the creek range from 3.5 to 18 m (12 to 60 ft), with depths ranging from 0.06 to 0.5 m (0.2 to 1.7 feet) (R. Kemnitz, pers. comm., USGS Water Resources Division, Fairbanks). The stream bed contains gravel, small cobble, and a few small boulders. The creek has some meander and areas where it has shifted locations. Temperatures range from 0°C in the winter to 10°C in summer.

Figure 2. Ikalukrok Creek at Station 8.

Figure 3. Mainstem Red Dog Creek at Station 10.

Middle Fork Red Dog Creek

Middle Fork Red Dog Creek (Figure 4 at Station 20 and Figure 5 at Station 140) has a drainage area of 12 km^2 (4.74 mi^2), of which 1 km^2 (0.4 mi^2) does not contribute to the flow. During the 1991 water year, Middle Fork had a high mean monthly flow of 1.25 m^3/s (44.0 cfs) and a low flow of 0.004 m^3/s (0.15 cfs). The creek has wide meanders with average channel widths from 3 to 10 m (10 to 30 ft), with depths from 0.03 and 0.45 m (0.1 and 1.5 feet). Cominco Engineering Services Ltd. (reported in EBA Engineering Inc [1991]) reported that Red Dog Creek continues to flow with subsurface water flow at a rate of about 0.03 m^3/s (1 cfs) through the winter months.

Cominco Engineering Services Ltd. (1983) described the water quality in Middle Fork Red Dog Creek:

> The mainstem on Red Dog Creek [above North Fork of Red Dog Creek, now called Middle Fork Red Dog Creek] adjacent to, and running over the ore body is currently a zone of natural degradation which is hostile to aquatic life. High metal concentrations, particularly zinc, lead, and cadmium prevail in this part of the creek largely as a result of direct contact with exposed mineralization and, more significantly, from surface drainage emanating from the main part of the orebody on the west side of the creek. As an illustrative example, concentrations of zinc in the summer average in the 15 to 20 mg/L range and a typical mass loading of this metal discharged downstream can be in excess of one half ton per day.

The creek was diverted into a lined, perched ditch in March 1991 to separate upstream water from water seeping through the ore body. Below the ditch is a constructed French drain to allow subsurface water from both sides of the lined ditch to flow into the seepage ditch. The substrate of the diversion ditch is constructed of a gravel layer and a surface of coarse rip rap to protect the synthetic liner. Prior to diversion, Middle Fork Red Dog Creek flowed over some of the more highly mineralized and leachable zones of the Red Dog deposit.

Tributaries to Middle Fork Red Dog Creek

Information on tributaries flowing into the north side of the ore body (Figure 1) is limited to a few measurements of water quality collected in the baseline studies (Dames and Moore 1983 and EVS and Ott Water Engineers 1983). These are small tributaries of <1 to <10 cfs summer flow. Dames and Moore (1983) described the tributaries:

Figure 4. Middle Fork Red Dog Creek at Station 20.

Figure 5. Middle Fork Red Dog Creek at Station 140.

> Many of the tributaries exhibited high quality water compared to the mainstem. Water at stations 34 [Sulfur Creek], 38 [Shelly Creek], 40 [Connie Creek], and 47 (Rachael Creek) during summer was highly oxygenated with 11.0 to 13.0 mg/L of dissolved oxygen. . . . Conductivity levels ranged from 70 to 330 *u*mho/cm at 25°C. pH was slightly low, ranging from 6.3 to 7.1, and alkalinity concentrations were generally low (7.9 to 74 mg/L).

Tributaries flowing into the northeast side of the ore body are not affected by mineral development. Except during periods of high rainfall, these creeks were reported in baseline studies to have clear water with low turbidity. Turbidity ranged from 0.37 to 24 NTU. The high value (24 NTU) was measured at station 38 in July when flow was high.

Sulfur Creek

Sulfur Creek is a small, intermittent stream (Figure 1 and 6) flowing into the northwest side of the ore body. The creek is steep, with stair-step pools. Flows are intermittent; the creek stopped flowing in late July 1995. The stream bed is medium sized cobble with orange stain from iron precipitate.

Shelly Creek

Shelly Creek flows into Middle Fork Red Dog Creek from the northeast (Figures 1 and 7). The creek is small, densely vegetated by willows, and stained with iron precipitate. Few water quality data have been collected on Shelly Creek.

Connie Creek

Connie Creek is the largest of the tributaries (Figures 1 and 8). The creek flows through a wide, shallow channel. Water depths are less than 20 cm during summer flows. The creek bottom is medium cobble with some staining.

Rachael Creek

Rachael Creek, at the headwaters of Middle Fork Red Dog Creek is a small, partially undercut stream flowing from the base of Deadlock Mountain. In 1994 the creek was sampled and found to contain high concentrations of Al and Zn. Elevated Al and Zn concentrations in the bypass ditch (Station 140) and in Rachael Creek in August 1994 suggests that high rainfall during this time period increased metals concentrations in Rachael Creek.

Figure 6. Sulfur Creek.

Figure 7. Shelly Creek.

Figure 8. Connie Creek.

Figure 9. Rachael Creek.

Hilltop Creek

Hilltop Creek is a small, possibly intermittent, creek flowing from the southeast side of the ore deposit north to Red Dog Creek. The creek flows into Red Dog Creek near the headwaters, near Connie and Rachael Creeks.

Reference Stream: North Fork Red Dog Creek

North Fork Red Dog Creek (Figure 10) was selected as a reference stream because it is in the same drainage and has limited mineralization. Therefore, climatic conditions and types of species expected to occur would be similar to the streams being considered for reclassification, with the exception of the effects of elevated metals concentrations from mineralization in the other streams.

North Fork Red Dog Creek has a drainage area of 41 km^2 (15.9 mi^2). During the 1992 water year, North Fork Red Dog Creek had a high mean monthly flow of 3.5 m^3/s (125 cfs) and low summer flows of 0.34 m^3/s (12 cfs). Widths range from 7 to 15 m (24 to 50 ft) and depths from 0.09 to 2 m (0.3 to 6 ft). The stream bed is characterized by gravel, rocks, and small boulders and is subject to shifting. Temperatures range from 0 to 10°C during open water flow. Mineral staining is not evident in North Fork Red Dog Creek.

Figure 10. North Fork Red Dog Creek.

Geology

The Red Dog Mine is located at approximately 68°13' N latitude by 163° W longitude in the southwestern DeLong Mountains, a component of the Brooks Range in Alaska's Arctic. Lying within the DeLong Mountains Quadrangle, the area termed the Red Dog Prospect is a rich surficial showing of copper, lead, zinc, and silver ore located throughout the upper reaches of the Red Dog Creek drainage. The geology was described by Dames and Moore (1983):

> The DeLong Mountains lie within the Rocky Mountain System and are characterized by low mountains, plateaus, and highlands of a rolling topography with summits between 300 and 1500 m. Most peaks in the southwestern area are less than 900 m in height and unglaciated; lower hills have been rounded by extreme weathering, although upthrust rock formations with jagged peaks are not uncommon. The area is underlain by continuous permafrost to depths in excess of 60 m. The regional geology is sedimentary with some evidence of later volcanic activity. The geology is Mesozoic, characterized by sandstone and shale of marine and non-marine origin.

Climate/Population

The area is treeless, frequently windswept with a mean annual temperature of 2 to 4°C. The area is remote, with access by airplane or summer barge. The mine site is approximately 90 km (55 miles) by gravel road from the ocean port.

Existing Classification

The State of Alaska classified all streams and rivers in the Wulik River drainage, including the Wulik River, Ikalukrok Creek, and Red Dog Creek and its tributaries for all uses under 40 CFR, Chapter 1, part 131, 131.10, and 18 AAC 70.055.

Recommended Changes to Aquatic Life Classification

The purpose of this study is to examine the appropriateness of the aquatic life classification for Mainstem Red Dog Creek; Middle Fork Red Dog Creek and its tributaries Rachael, Sulfur, Connie, and Shelly Creeks; and Ikalukrok Creek. Water quality and biological data collected during baseline studies were used to describe pre-mining conditions. Water quality and biological data from 1991 through 1995 were used to describe conditions after development of the Red Dog Mine. Water quality data collected between 1984 and 1990 were not used because the data were collected sporadically and because no comparable biological data were collected.

Water Quality Monitoring Stations

Water quality monitoring has been conducted throughout the Wulik River drainage since 1979, before development of the Red Dog Mine. Water quality monitoring after development of the Red Dog Mine was conducted at many of the same stations (Figure 1), using the same station numbers, as baseline monitoring conducted by Dames and Moore. Baseline monitoring conducted by EVS and Ott Water Engineers (1983) was done at many of the same stations; however, different station numbers were assigned. Where stations are at the same location, the station numbers established by Dames and Moore are used for the EVS and Ott Water Engineers (1983) data. Only limited baseline water quality monitoring was conducted in tributaries to Middle Fork Red Dog Creek.

Water quality monitoring stations referenced in this report are Ikalukrok Creek at Station 8 and Station 73, Mainstem Red Dog Creek at Station 10, Middle Fork Red Dog Creek at Stations 20 and 140, Shelly Creek , Connie Creek, Sulfur Creek, Rachael Creek, and North Fork Red Dog Creek.

Wastewater Dischargers

The Red Dog Mine is currently the only industrial development in the Wulik River drainage that discharges to waters of the state.

Problem Definition

Studies to date have shown that Middle Fork Red Dog Creek has not supported fish or other aquatic populations. The absence of aquatic communities is because of natural mineralization, naturally occurring high concentrations of metals, and low pH. Intermittent flows and poor water quality in tributaries to Middle Fork Red Dog Creek probably limit aquatic life. Fish use in tributary streams also is limited by lack of overwintering habitat and inability to access these tributaries through the naturally degraded water quality of Middle Fork Red Dog Creek.

The water treatment system at the Red Dog Mine uses calcium hydroxide to remove sulfide metals. The resulting effluent is high in total dissolved solids in the form of calcium sulfate. Treating seepage water from the ore body has resulted in water in both Middle Fork and Mainstem Red Dog Creek that is lower in Cd, Cu, Pb, and Zn but higher in pH, total dissolved solids and sulfate than under natural, undisturbed conditions.

Approach to Use Attainability

The Wulik River and its tributaries currently are classified under 18 AAC 70.050 as protected for all uses. Red Dog Creek historically has had periodic high concentrations of metals. Fish kills were reported in Mainstem Red Dog Creek and in Ikalukrok Creek at the confluence with Red Dog Creek before development of the Red Dog Mine (EVS and Ott Water Engineers 1983). Baseline sampling found no evidence of fish use of Middle Fork Red Dog Creek, South Fork Red Dog Creek (now the tailing dam), or any tributaries to Middle Fork Red Dog Creek.

Extensive sampling by the Alaska Department of Fish and Game has not shown fish to occur in Middle Fork Red Dog Creek, upstream of North Fork Red Dog Creek (Weber Scannell and Ott 1995). The Alaska Department of Fish and Game does not believe that Middle Fork Red Dog Creek contains water of sufficient quality to support fish (Weber Scannell and Ott 1995).

The objective of this study was to sample Mainstem Red Dog Creek, Middle Fork Red Dog Creek, and tributary streams downstream of and adjacent to the Red Dog Mine for macro- and microinvertebrates, periphyton, and macrophytes. Ikalukrok Creek below Red Dog Creek (at Station 8) and North Fork Red Dog Creek (the reference stream) also were sampled. This survey provides information on relative abundance and relative diversity of aquatic taxa to fulfill the aquatic life analysis of a use attainability analysis for reclassifying Middle Fork Red Dog Creek and other appropriate tributaries. Information on the taxonomic groups present in Mainstem Red Dog Creek and Ikalukrok Creek can be used to develop site-specific criteria for total dissolved solids and sulfate.

Data Analysis

Hydrology

Red Dog Creek from its source to Ikalukrok Creek, tributaries to Middle Fork Red Dog Creek, and portions of Ikalukrok Creek freeze in late October; by mid-winter there is no flowing surface water. Isolated pools may form in Ikalukrok Creek; this water usually has low (<1 mg/L) dissolved oxygen and high metals and dissolved solids concentrations. Fish could not survive in these conditions. North Fork Red Dog Creek may contain some spring water input, but probably does not contain any flowing water suitable for overwintering fish. The winter distribution of fish appears to be limited to Ikalukrok Creek downstream of the confluence with Dudd Creek and in the Wulik River.

When breakup occurs (usually in late May), Arctic graying migrate upstream in Ikalukrok Creek to Mainstem Red Dog Creek and into North Fork Red Dog Creek.

Stream Flow Evaluation

Water Quality Evaluation, Baseline Conditions

The following is a summary of the water quality conditions measured in the study streams before development of the Red Dog Mine. Included is a discussion of the number of occasions metals concentrations exceeded amounts reported toxic to salmonid fish. Refer to Appendix 1 for a summary of 1979-1983 hardness, total dissolved solids (TDS), sulfate, pH, and temperature data; Appendix 2 for a summary of 1979-1983 dissolved oxygen, conductivity, flow, and alkalinity data; and Appendix 3 for a summary of 1979-1983 metals data. Appendix 11 contains all available baseline water quality and metals data.

Metals concentrations reported for the water quality sampling stations were compared with concentrations reported to cause acute or chronic toxicity on species of salmonid fish and with concentrations currently listed by US EPA as the Maximum Allowable Concentration (Table 1). The acute and chronic concentrations and the references for each concentration are listed below.

The following criteria were used to select values for chronic toxicity from published literature: at least 50% mortality of salmonid fish, tests conducted in moderately hard to hard water from 100-350 mg $CaCO_3$/L, and test conducted over at least 96 hours. Chronic toxic values for zinc were reported as 2 to 4 mg/L; in comparing toxic values with stream water samples we used the lower value of 2 mg/L.

Table 1. Chronic/acute and Maximum Allowable Concentrations of Metals.

Metal	Chronic/Acute Toxicity adult salmonid fish mg/L	Maximum Allowable Conc. aquatic life mg/L	Reference
Aluminum	0.1		Ontario Minis. of the Environ. (1984)
Cadmium	0.027	0.0039	Alabaster and Lloyd 1982 US EPA 1992
Copper	0.28	0.018	Alabaster and Lloyd 1982 US EPA 1992
Lead	0.19	0.082	USEPA 1985 US EPA 1992
Zinc	2	0.12	Alabaster and Lloyd 1982 US EPA 1992

Ikalukrok Creek: Station 8

Baseline data showed Ikalukrok Creek at Station 8 contained moderately hard water with circumneutral pH. During winter (measured in March), water is high in total dissolved solids and hardness; this is a result of ionic exclusion during ice formation. Data collected during the winter are not included in this report because they are not considered to represent conditions other than ionic exclusion from ice formation. Low conductivity in late May was due to snow melt.

Water occasionally contained elevated concentrations of aluminum, cadmium, and zinc (Table 2). The maximum reported concentrations were 0.17 mg Al/L, 0.04 mg Cd/L, and 4.2 mg Zn/L.

Table 2. Ikalukrok Creek (Station 8), percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	30		10
Cadmium	11	67	18
Copper	0	10	10
Lead	0	0	18
Zinc	17	78	18

Mainstem Red Dog Creek, Station 10

Baseline data showed Mainstem Red Dog Creek at Station 10 contained moderately hard water with neutral to acidic pH. During winter (measured in March), water was high in total dissolved solids, sulfate, and hardness; this was a result of ice formation.

Concentrations of Zn were elevated above the reported chronic/acute toxic concentrations of 2 mg/L for salmonid fish and often contained elevated concentrations of Al and Cd (Table 3). Concentrations of Pb were not elevated: the maximum concentration was 0.1 mg/L and median concentration was 0.08 mg/L (the Limit of Detection). The chronic/acute level for Zn (from Alabaster and Lloyd 1982, Table 1) is conservative; higher values also were reported. Baseline studies (Dames and Moore 1983) reported that Arctic graying migrated through Mainstem Red Dog Creek to North Fork Red Dog Creek during spring high flows when metals concentrations were lower.

Table 3. Mainstem Red Dog Creek (Station 10), percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	37		38
Cadmium	44	LOD[1] too high	43
Copper	0	0	15
Lead	0	0	43
Zinc	100	100	43

[1]LOD = Limit of Detection

Middle Fork Red Dog Creek, Station 20

Baseline data showed water in Middle Fork Red Dog Creek contained elevated concentrations of aluminum, cadmium, and zinc, and frequently elevated concentrations of Pb. The maximum reported concentrations were 0.91 mg Al/L, 0.14 mg Cd/L, 0.36 mg Pb/L, and 17 mg Zn/L. The number of times water samples exceeded chronic/acute toxicity concentrations (Table 4) suggests that this water is not suitable to support fish.

Table 4. Middle Fork Red Dog Creek (Station 20), percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	57		28
Cadmium	97	100	34
Copper	insufficient data		4
Lead	24	56	34
Zinc	100	100	34

Middle Fork Red Dog Creek, Station 140

Baseline data showed water in Middle Fork Red Dog Creek at Station 140 frequently contained elevated concentrations of aluminum, cadmium, lead, and zinc. The maximum reported concentrations were 2.31 mg Al/L, 0.21 mg Cd/L, 1.11 mg Pb/L, and 28.5 mg Zn/L. Median concentrations were 0.73 mg Al/L, 0.12 mg Cd/L, 0.33 mg Pb/L, and 15.7 mg Zn/L. The number of times water samples exceeded chronic/acute toxicity concentrations (Table 5) and the extremely high metals concentrations suggest that this water is not suitable to support fish.

Table 5. Middle Fork Red Dog Creek (Station 140), percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	100		20
Cadmium	100	100	20
Copper	No data available		0
Lead	80	95	20
Zinc	100	100	20

Shelly Creek

There were no baseline data collected on hardness, TDS, flow, dissolved oxygen, or other water quality factors in Shelly Creek. Samples for metals concentrations were limited to one sample in 1981 and four in 1982 (Appendix 11). Concentrations of both Cd and Zn exceeded Maximum Allowable Concentrations in all of the samples collected, Pb was not elevated. The maximum concentration of Cd was 0.028 mg/L, of Pb 0.08 mg/L, and Zn 2.3 mg/L.

Table 6. Shelly Creek, percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	no data available		0
Cadmium	20	100	5
Copper	No data available		0
Lead	0	0	5
Zinc	20	100	5

Connie Creek

Limited water quality and metals data (Appendix 11 and Table 7) collected in Connie Creek during baseline studies showed this creek to have moderately good water quality. However, Cd concentrations were above but close to the Maximum Allowable Concentration, and ranged from 0.002 to 0.021 mg/l.

Table 7. Connie Creek, percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	No data available		0
Cadmium	0	83	6
Copper	No data available		0
Lead	0	0	6
Zinc	17	83	6

Sulfur Creek

Limited water quality data collected by Dames and Moore (1981) portray Sulfur Creek as having elevated concentrations of Pb and Zn (average of three samples = 0.128 mg Pb/L and 0.754 mg Zn/L) and slightly elevated concentrations of Cd (average of three samples = 0.007 mg/L) (Table 8, Appendix 11). Flow ranged from 0.07 to 1.2 cfs, dissolved oxygen concentrations were near saturation, and pH was slightly acidic. The highest zinc concentration measured (of 3 samples) was 1.167 mg/L.

Table 8. Sulfur Creek, percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	No data available		
Cadmium	0	100	3
Copper	No data available		
Lead	33	33	3
Zinc	0	100	3

Rachael Creek

Water sampling in Rachael Creek was limited to four samples in 1982 (Appendix 11 and Table 9). The water was described by Dames and Moore (1983) as clear, of low turbidity, and high dissolved oxygen concentrations. Cd and Zn concentrations were low, ranging from 0.002 to 0.008 mg Cd/L and 0.079 to 0.142 mg Zn/L. No baseline data on Al concentrations were found.

Table 9. Rachael Creek, percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	No data available		
Cadmium	0	25	4
Copper	No data available		
Lead	0	0	4
Zinc	0	25	4

Hilltop Creek
No historic data were available for Hilltop Creek.

North Fork Red Dog Creek
North Fork Red Dog Creek was described by Dames and Moore (1983) as being of high water quality and supporting a diverse community of flora and fauna. The creek is a clear water stream with high dissolved oxygen concentrations during summer and low levels of total suspended solids, total dissolved solids, and settleable solids. Alkalinity was higher than in any of the other creeks monitored. Dames and Moore measured concentrations of Cu, Pb, Ag, and Zn in the sediments. They reported concentrations considerably lower than Middle Fork or Mainstem Red Dog Creek. During summer, Al concentrations are moderately high (Table 10).

Table 10. North Fork Red Dog Creek, percent of water samples exceeding chronic/acute levels, 1979-1983.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Number of Samples
Aluminum	36		25
Cadmium	0	LOD too high	29
Copper		0	5
Lead	0	0	29
Zinc	0	7	29

LOD = Limit of Detection. Unless samples are at least 5 times the LOD, the values are considered to be qualitative.

Water Quality Evaluation, after development of the Red Dog Mine.

The following is a summary of the water quality conditions measured in the study streams from 1991 to summer 1995. This time period begins with completion of the mine seepage water collection system in 1991. Collection and treatment of mine seepage water had the most profound effect on water quality of Red Dog Creek. Water quality of the mine effluent was further improved by installation of the sand filters in 1994 and improvements in the water treatment plant. Included is a discussion of the number of times metals concentrations exceeded amounts reported toxic to salmonid fish (Reference toxic amounts listed on Table 1) and identification of the metals believed to be exerting the most toxicity during the time period from 1991 through 1995. Refer to Appendix 4 for a summary of 1991-1995 water quality data, including hardness, TDS, sulfate, pH, temperature, dissolved oxygen, conductivity, and flow, and Appendix 5 for a summary of 1991-1995 metals data. Appendix 12 contains all of the baseline water quality and metals data.

Ikalukrok Creek: Station 8

Ikalukrok Creek at Station 8 has moderately hard water with circumneutral pH (Appendix 4). During periods of discharge from the mine effluent, water hardness reached a maximum concentration of 666 mg/L and TDS a maximum concentration of 906 mg/L. The treated mine effluent appears to moderate the lowest pH values. In 1992, the minimum pH was 5.7 and in 1994 and 1995 the minimum values were 7.2 and 7.1. Flow data from Station 8 were limited to two measurements.

During open water periods, temperatures ranged from a low of 0°C to 13.6°C (measured in 1992). Maximum water temperatures in 1995 during periods of maximum discharge from the Red Dog Mine do not appear to alter downstream temperature regimes (Appendices 4 and 12). Maximum and median temperatures in 1995 are not higher than in years 1991-1993 when discharge volumes were low or zero.

Water occasionally contained slightly elevated concentrations of aluminum, cadmium, and zinc (Appendices 5 and 12 and Table 11). Metals concentrations measured in 1995 were generally lower than in 1991 through 1993, when there was minimal discharge. Al concentrations were higher in 1995; however, these concentrations are related to high rainfall and increased erosion in the headwaters of Middle Fork Red Dog Creek and do not correspond to concentrations found in the mine effluent.

Table 11. Ikalukrok Creek, after mining. Percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	26		92
Cadmium	1	7	96
Copper	0	0	58
Lead	0	4	96
Zinc	6/0*	100	96

*6% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, none of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Mainstem Red Dog Creek, Station 10

Mainstem Red Dog Creek contains moderately hard water. Both hardness and TDS are elevated during periods of maximum discharge from the mine. Concentrations of TDS reached a maximum of 1100 mg/L in 1994 and 1070 mg/L in 1995 (Appendix 4 and Appendix 12). Median TDS concentrations in 1995 also were higher than in 1991 and 1992, when discharge was minimal. Periods of high discharge during open water months also correspond to higher pH values: median pH values were 7.7 in 1994 and 7.6 in 1995, compared with median values of 7.0 in 1991 and 7.4 in 1992. Stream flow (based on 6 measurements in 1993) ranged from 32.7 cfs to 400 cfs.

Metals concentrations at Station 10 were elevated in Al, Cd, and Zn (Table 12 and Appendices 5 and 12).

Table 12. Mainstem Red Dog Creek, after mine development. Percent of water samples exceeding chronic/acute criteria.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	16		85
Cadmium	33	LOD too high	95
Copper	0	0	60
Lead	2	4	94
Zinc	55/19*	100	94

*55% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 19% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

LOD = Limit of Detection. Unless samples are at least 5 times the LOD, the values are considered to be qualitative.

Middle Fork Red Dog Creek, Station 20

Hardness, TDS, and sulfate concentrations in Middle Fork Red Dog Creek below the mine effluent are elevated by the effluent (Appendix 4). In 1995, the maximum hardness was 1170 mg/L, maximum TDS was 2190 mg/L, and maximum sulfate was 1500 mg/L. The highest measured pH of 9.0 was in 1994. The median pH for 1994 and 1995 is slightly higher than in 1992 but not higher than median values for 1991 and 1993.

Water temperatures during the open flow periods range from 0°C to 19.4°C. Temperature does not appear to be elevated by discharge (Appendix 4).

Metals concentrations, except for Al, have shown a steady decline between 1991 and 1995 (Appendix 5). When compared to levels reported in the literature (Table 1) for chronic/acute toxicity, water at Station 20 is toxic for Cd and Zn most of the time, and toxic for Al 25% of the time and Pb 36% of the time (Table 13). High Al concentrations occurred in fall 1995 after abnormally high rainfall. Elevated Al was not found in 1991-1994. (Refer to Appendices 5 and 12 for comparisons of metals concentrations for each year.)

The concentrations of Cd and Zn are sufficiently elevated to prevent fish from successfully spawning and rearing in this creek, and to limit primary and macroinvertebrate production.

Table 13. Middle Fork Red Dog Creek, below mine effluent. Percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	25		99
Cadmium	76	90	118
Copper	0	1	76
Lead	9	36	118
Zinc	93/61*	98	118

*93% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 61% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Middle Fork Red Dog Creek, Station 140

Station 140 is located in a channel constructed to bypass Red Dog Creek around the active ore body, above the mine discharge. Although construction of the bypass channel has decreased metals concentrations in Red Dog Creek (compared with concentrations measured before mining), the water flows through naturally mineralized areas and remains high in metals, especially Cd, Pb, and Zn (Appendices 5 and 12).

Water Quality at Station 140 is acidic with pH levels as low as 5.2.

Water samples collected between 1992 and 1995 exceed the reported chronic/acute toxicity limits for Cd in 75% of the samples, for Pb in 85% of the samples, and for Zn in 86% of the samples (Table 14). Given the high metals concentrations, it is unlikely that this waterway would support fish, aquatic invertebrates, or aquatic plants.

Table 14. Middle Fork Red Dog Creek, Station 140. Percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	20		70
Cadmium	75	100	101
Copper	0	0	72
Lead	42	85	101
Zinc	86/68*	100	101

*86% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 68% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Shelly Creek

Few water samples were collected in Shelly Creek (Appendix 12). Shelly Creek has moderately hard water (Appendix 12) and in 1995, water contained concentrations of Al and Cd that were elevated above the reported chronic/acute toxicity levels (79% samples for Al and 36% of samples for Cd) (Table 15). Seventy nine percent of the water samples contained concentrations of Cd that were above the Maximum Allowable Concentration and 93% of the samples exceeded the Maximum Allowable Concentration for Zn. Concentrations of Fe ranged from 0.19 to 1.22 mg Fe/L.

Water in Shelly Creek is naturally high in metals. It is likely that high concentrations of Al, Cd, Fe, and Zn limit the aquatic life use of this creek.

Table 15. Shelly Creek. Percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	79		14
Cadmium	36	79	14
Copper	0	31	13
Lead	7	14	14
Zinc	43/14*	93	14

*43% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 14% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Connie Creek

Few water samples were collected in Connie Creek (Appendix 12). Connie Creek has moderately hard water and in 1995, metals concentrations were generally lower than reported chronic/acute toxicity levels for Cd, Cu, Pb, and Zn (Table 16).

Connie Creek contains the best water quality of any of the tributaries to Middle Fork Red Dog Creek. If fish were not excluded from this tributary by the poor water quality in Middle Fork Red Dog Creek, it is possible they could inhabit this creek.

Table 16. Connie Creek, percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	33		12
Cadmium	8	25	12
Copper	0	8	12
Lead	17	17	12
Zinc	8/8*	50	12

*8% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 8% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Sulfur Creek

Sulfur Creek is a small, intermittent tributary with an estimated summer flow of less than 3 cfs. The creek contains small step pools. Flows are too low to allow fish to swim upstream between step pools. Sulfur Creek typically stops flowing in mid-summer. In 1995, flows stopped in late July.

Only two water samples were collected in Sulfur Creek (Appendix 12), both in 1995. Sulfur Creek has moderately hard water (133 and 140 mg/L) and in 1995, water contained concentrations of Cd, Pb, and Zn that were elevated above the Maximum Allowable Concentrations (Table 17).

High metals concentrations and the poor water quality in Middle Fork Red Dog Creek, along with the small size of Sulfur Creek, its steep step pools, and intermittent flows, probably exclude fish from using this tributary.

Table 17. Sulfur Creek, percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	17		6
Cadmium	0	37	6
Copper	0	0	6
Lead	33	67	6
Zinc	0/0*	100	6

*0% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 0% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Rachael Creek

Rachael Creek has moderately hard water and in 1995, water contained very high concentrations of Al (from 1.17 to 1.81 mg/L) and Cu (from 0.04 to 0.06 mg/L) and low pH (from 4.7 to 5.9) (Appendix 12). According to the Canadian Water Quality Guidelines (CWQG), at pH below 6.5, Al is extremely toxic to aquatic life. The CWQG suggests a maximum Al concentration of 0.005 mg/L to protect aquatic life when the pH is less than 6.5. The median concentration of Al measured in Rachael Creek during 1995 was 340 times the toxic level and the maximum concentration measured in 1995 was more than 650 times the toxic level; pH was below the State Water Quality Criteria for protection of aquatic life. The combination of high concentrations of Al and low pH would exclude most, if not all, aquatic species from Rachael Creek. Concentrations of Cu and Zn also were elevated above the Maximum Allowable Concentrations in 100% of the samples (Table 18).

Table 18. Rachael Creek, percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	100		10
Cadmium	0	0	11
Copper	0	100	11
Lead	0	0	11
Zinc	0/0*	100	11

*0% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 0% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Hilltop Creek

Hilltop Creek is a small tributary to Red Dog Creek that flows from the southeast edge of the currently developed deposit. Flows in the creek are low and may be intermittent. Metals concentrations are high (Table 19 and Appendix 12); water in this tributary contains some of the highest metals concentrations found in any tributaries to Red Dog Creek. Cominco Alaska Inc. sampled three sections of Hilltop Creek in 1995: the headwaters, the middle section, and the lower section near Red Dog Creek. Metals were not as high at the headwaters near the mine pit as in the middle section (Appendix 12).

This creek was not sampled for fish, aquatic invertebrates, or aquatic plants during this study. High concentrations of Al (average 5.97 mg/L, range 0.26 - 9.59 mg/L), Cd (average 6.43 mg/L, range 3.2 to 7.8 mg/L), Pb (average 3.4 mg/L, range 0.39 to 4.22 mg/L) and zinc (average 1197 mg/L, range 147 to 1580 mg/L) combined with low pH (range 4.2 to 6.1) would exclude aquatic communities from this creek.

Table 19. Hilltop Creek, percent of water samples exceeding chronic/acute levels.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	100		11
Cadmium	100	100	11
Copper	no data available		
Lead	100	100	11
Zinc	100	100	10

*100% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 100% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

North Fork Red Dog Creek

Only 14 samples were collected from Station 12 during 1995 and 2 in 1992 (Appendix 12). Most of the metals samples were below the limit of detection; 1 sample in 1995 had Cd and Zn concentrations above the reported chronic/acute toxic levels (Table 20). This sample also had concentrations above the Maximum Allowable Concentration for Cd, Pb, and Zn. Except for the one water sample with slightly elevated metals concentrations, the water in North Fork Red Dog Creek is of high quality for aquatic life.

Table 20. North Fork Red Dog Creek, percent of water samples exceeding chronic/acute criteria.

Metal	% Samples exceeding chronic/acute toxicity to adult salmonid fish	% Samples exceeding Maximum Allowable Concentration	Total number of samples
Aluminum	0		10
Cadmium	6	6	16
Copper	0	0	16
Lead	0	6	16
Zinc	6/0*	6	16

*6% of the samples exceeded the reported chronic toxic level of 2 mg Zn/L, 0% of the samples exceeded the higher reported chronic toxic level of 4 mg Zn/L.

Conclusions

Mainstem Red Dog Creek

Although water quality periodically exceeds toxic limits and Maximum Allowable Concentrations, exceedences are not sufficient to exclude fish and other aquatic species. Water quality has been improved from background by the mine sump collection system and, probably, by high effluent discharges.

Middle Fork Red Dog Creek

Concentrations of metals, especially Cd and Zn, are sufficiently high to preclude use by fish, aquatic plants, and aquatic invertebrates.

Sulfur Creek

Fish use of Sulfur Creek is limited by poor water quality in Middle Fork Red Dog Creek as well as the small size, low and intermittent flows, and step pool configurations found in Sulfur Creek. Water quality is poor.

Rachael Creek

High concentrations of Al and low pH would eliminate most, if not all, aquatic species from this tributary.

Shelly Creek

Water in Shelly Creek is degraded by elevated concentrations of Al, Cd, Cu, and Zn. It is likely that poor water quality combined with low flows and high gradient limit use of this waterway by fish and other species of aquatic life.

Connie Creek

Poor water quality in Middle Fork Red Dog Creek limits upstream movement of fish. Connie Creek supports a community of aquatic invertebrates and algae.

Hilltop Creek

Extremely poor water quality due to elevated concentrations of Al, Cd, Pb, and Zn would eliminate most classes of organisms from Hilltop Creek.

North Fork Red Dog Creek

Water quality in this tributary is excellent and rarely exceeds limits reported to cause acute or chronic toxicity to aquatic species.

Biological Evaluations

Benthic Macroinvertebrates: Baseline Studies

Aquatic invertebrate communities were sampled by EVS and Ott Water Engineers (1983) and Dames and Moore (1983) as part of the baseline studies conducted for Red Dog Creek. Taxonomy for Oligichaeta and Chironomidae has been revised substantially since these reports were completed. Therefore, in the present report Chironomidae and Oligichaeta from baseline data are not identified below family level for Chironomidae or class for Oligichaeta.

Ikalukrok Creek, Station 73

Aquatic invertebrate samples were collected in Ikalukrok Creek at Station 73, about 5 km (3 miles) downstream from Station 8 (Table 21, Appendix 6, EVS and Ott Water Engineers 1983). There are no significant inflows of water to Ikalukrok Creek between Stations 8 and 73; therefore, water quality conditions are similar and the invertebrate data are believed to represent populations in Ikalukrok Creek at Station 8.

Among the creeks influenced by mineralization from Red Dog Creek, Ikalukrok Creek contained the greatest abundance of aquatic invertebrates. Taxonomic richness was similar to communities in Mainstem Red Dog Creek and Middle Fork Red Dog Creek.

Mainstem Red Dog Creek, Station 10

Few invertebrates were collected in Mainstem Red Dog Creek (Table 21, Appendix 6). There was an average of 3.1 invertebrates collected during each sampling time, with only 5.5 taxonomic groups represented.

Middle Fork Red Dog Creek, Station 20 and Station 140

Dames and Moore (1981) describe the macroinvertebrate communities in Middle Fork Red Dog Creek:

> There is little or no macroscopic life in the Main Fork Red Dog Creek from Station 43 below where the first major drainage from the ore body enters the creek to Station 20 above the confluence of the North Fork. Tributaries entering this reach from the ore body significantly degrade the water quality and the suitability of the aquatic habitat. Other tributaries entering this reach support rich and diverse invertebrate life but are of insufficient volume to dilute the stream to the point where long-term residency is possible.

EVS and Ott Water Engineers collected about the same number of invertebrates from Station 21 (an average of 15 per sample time) and Station 140 (an average of 13.9 per sample time) (Table 21, Appendix 6). Taxonomic richness also was similar at the two stations: EVS and Ott Water Engineers reported an average of 5 taxonomic groups from Station 21 and 4.7 taxonomic groups from Station 140. At both stations the majority of invertebrates were Plecoptera.

Shelly Creek, Connie Creek, Sulfur Creek, and Rachael Creek, Hilltop Creek

No baseline data on aquatic invertebrate populations are available for any of these tributaries.

North Fork Red Dog Creek

North Fork Red Dog Creek contained both the greatest abundance and the highest taxonomic richness of any of the sites sampled during baseline studies. In the limited sampling done by EVS and Ott Water Engineers (Table 21 and Appendix 6), 8 different taxonomic groups were found. Ephemeroptera and Plecoptera dominated the aquatic invertebrate community. Dames and Moore (1983) reported similar populations of aquatic invertebrates in their baseline studies (Appendix 6).

Table 21. Aquatic invertebrates collected during baseline studies by EVS (1983).

Creek	Invertebrate Abundance average #/sample	Invertebrate Abundance maximum #/sample	Taxonomic Richness average #/sample	Taxonomic Richness maximum #/sample
Ikalukrok C. (Sta. 73)	16.3	41.8	5.4	7
Mainstem Red Dog Creek	4.8	1.4	5	6
Middle Fork Red Dog Creek				
Station 21	15	24.7	5	5
Station 140	13.9	33.1	4.7	5
North Fork Red Dog Creek	63.5	100.2	7	8

No data were found for Shelly, Connie, Sulfur, or Rachael Creek
Data from EVS and Ott Water Engineers (1983)

Macroinvertebrates: Current Study

Aquatic invertebrate communities were sampled in 1995 to detect any changes in either abundance or taxonomic richness that may have occurred since development of the Red Dog Mine. Communities were sampled once in July. Because different methods were used to collect invertebrates and because invertebrate taxonomy has changed since the baseline sampling, only general comparisons between pre- and post mining are made.

Methods

Five semi-quantitative samples were collected at each sample site with a "D" net in July 1995. Samples were washed through a plankton bucket into whirl-pack bags, preserved in 70% ETOH, and labeled.

Samples were sorted from rocks and organic debris, identified to lowest practical taxonomic level, and counted. All invertebrate samples were permanently preserved in homeopathic vials with neoprene stoppers and stored at Alaska Department of Fish and Game, Fairbanks. Hilltop Creek was not sampled.

Results and Discussion

Results of the invertebrate sampling are summarized in Table 22. Data from each sample on numbers of invertebrates by family are presented in Appendix 7.

Table 22. Aquatic invertebrate communities, 1995.

Creek	Invertebrate Abundance		Taxonomic Richness	
	average #/sample	maximum #/sample	average #/sample	maximum #/sample
Ikalukrok Creek				
Station 8	7.4	24	1.4	4
Mainstem Red Dog Creek				
Station 10	4	13	1	2
Station 11	0.4	1	0.4	1
Middle Fork Red Dog Creek				
Station 140	0.2	1	0.2	1
Station 20	1	3	0.6	1
Tributary Streams				
Sulfur Creek	36.6	74	1.8	3
Shelly Creek	4.2	7	1.6	2
Connie Creek	40.6	47	2.6	3
Rachael Creek	0.2	1	0.2	1
North Fork Red Dog Creek	26	40	5.4	7

Ikalukrok Creek

Station 8

Samples collected in Ikalukrok Creek had an average of 7.4 invertebrates and 1.4 taxa per sample, with a maximum of 24 invertebrates and a total of 4 taxa (Table 22, Appendix 7). Invertebrates were primarily Nematodes (from 60% to 100% of the total). Only one Plecoptera and no Ephemeroptera or Trichoptera were found.

Mainstem Red Dog Creek

Station 10

An average of 4 invertebrates and 1 taxon were collected in Mainstem Red Dog Creek at Station 10. Three invertebrate families were represented: Nematoda, Diptera: Tipulidae, and Diptera: Chironomidae. Nearly 100% of the invertebrates were Nematoda.

Station 11

Invertebrate communities in Mainstem Red Dog Creek at Station 11 were even more depauperate than at Station 10. Only 1 taxon was found: Diptera: Chironomidae; the average number of invertebrates per sample was less than 1 because 60% of the samples had no invertebrates.

Middle Fork Red Dog Creek

Station 20

Only five Nematoda were found in the aquatic invertebrate samples collected at Station 20. The lack of taxonomic richness and invertebrate abundance suggests that this section of Red Dog Creek does not support a viable invertebrate community.

Station 140.

Only one Chironomidae larvae was found in the five aquatic invertebrate samples collected at Station 140; it could not be determined if this one invertebrate drifted from upstream areas or was produced locally. The lack of taxonomic richness and invertebrate abundance suggests that this section of Red Dog Creek does not support a viable invertebrate community and that invertebrate production is low to non-existent.

Shelly Creek

Few invertebrates were found in Shelly Creek (Appendix 7). The aquatic benthic community included a small leach (Hirudinea), Nematoda, the Dipteran Chironomidae, and the Plecoptera: Nemouridae. The average number of invertebrates per sample was 4.2 and the maximum number was 7.

Connie Creek

Connie Creek supports an abundant, however not diverse, invertebrate community. Invertebrate abundance was similar to that found in the North Fork Red Dog Creek; however, the community had lower taxonomic richness than found in the North Fork Red Dog Creek. In order of abundance, taxa found were Diptera: Chironomidae, Ephemeroptera: Heptagenidae, Diptera: Tipulidae, and Plectoptera: Nemouridae.

Sulfur Creek

Sulfur Creek supports a fairly abundant invertebrate community with low taxonomic richness. In order of abundance, the invertebrate groups found were Nematoda and Chironomidae. Exuvia from Plecoptera: Nemouridae were found; they did not appear to be pre-emergent.

Rachael Creek

The invertebrate community in Rachael Creek was virtually non-existent: only two Chironomidae adults were found. It is unlikely these insects were produced in Rachael Creek.

North Fork Red Dog Creek

North Fork Red Dog Creek had an invertebrate community that was both diverse and abundant. Ten different taxonomic groups were found; more than at any other site. Tipulidae, Trichoptera, and Ephemeroptera were too immature to identify beyond family (or order for Trichoptera). Chironomidae were primarily case-builders, probably primarily Orthocladinae. Identification of Chironomidae larvae was beyond the scope of this project.

Conclusions

Invertebrate communities, as demonstrated by both taxonomic richness (more than 2 orders represented) and abundance (more than 1 invertebrate per sample) were documented in the following streams:

North Fork Red Dog Creek
Sulfur Creek
Connie Creek

When compared to baseline studies, aquatic invertebrate densities were lower in Station 73 in 1995 than in Station 73 or Station 8 during baseline studies (Table 23). EVS reported more invertebrates from Station 21 during baseline (average of 15 organisms per approximately 0.1 m^2 sample) than during post mining sampling at Station 20 in 1995 (average of 1 organism per approximately 0.1 m^2 sample). Ikalukrok Creek upstream of Red Dog Creek was sampled by Dames and Moore during baseline studies. At that time, this site had the highest invertebrate density measured anywhere in the drainage: there was an average of 245 organisms per approximately 0.1 m^2 sample).

Table 23. Average invertebrate density reported by Dames and Moore (1983), EVS (1983) and ADF&G (1995) at various sampling locations in the Wulik River drainage.

Station	average number of organisms/sample
Dames and Moore Baseline Data	
Station 10	3
Station 8	71
Station 9	245
EVS Baseline Data	
Station 73	16.3
Middle Fork Red Dog Creek	3.1
Station 21	15.0
Station 140	13.9
North Fork Red Dog Creek	63.5
ADF&G	
Station 8	7.4
Station 10	4
Station 11	0.4
Station 20	1
Station 140	0.2
Sulfur Creek	36.6
Shelly Creek	4.2
Connie Creek	40.6
Rachael Creek	0.6
North Fork Red Dog Creek	26

Microinvertebrates

Baseline Studies

No data were found on microinvertebrate communities during baseline studies.

Current Study

Streams in the Red Dog area were sampled in July 1995 for the presence of microinvertebrate communities. This component of the aquatic community was examined to determine its importance in each stream.

Methods

Five rocks were collected from each sample site and packed in individual plastic, sealed bags. Rocks were examined within 6 hours of collection with a dissection microscope at 10 to 60 x. Scrapings of the rocks were mounted on a microscope slide with water and examined with a compound microscope. Photographs were taken of the organisms.

Results and Discussion

Ikalukrok Creek

Station 8

Examination of all surfaces of five rocks from Station 8 showed few microinvertebrates and no visible algae. One small (<1 mm Chironomidae) and one small (<1 mm) mite were found. No other microinvertebrates were found on the rocks.

Mainstem Red Dog Creek

Station 10

No plant or invertebrate life was observed on any of the rocks, with the exception of one empty Simulidae pupal case.

Station 11

One of the five rocks supported sub-microscopic Simulidae larvae, nothing was observed on the other four rocks.

Middle Fork Red Dog Creek

Station 20

A small (<1 mm) Chironomidae larvae was found on one of the rocks. No microinvertebrates were found on any of the other rocks, nor was algae, moss, or blue-green bacteria visible with microscopic examination.

Station 140

Five rocks were examined, no plants or invertebrates were observed.

Shelly Creek

Rocks from Shelly Creek were covered with a thick mineral precipitate; no signs of plant or animal life were detected with microscopic examination.

Connie Creek

Rocks from Connie Creek supported from 20 to 100 sub-microscopic Chironomidae. No other invertebrates were observed on the rocks. Abundant mosses were observed along the stream margin; no invertebrates were observed in the mosses (at 50 to 250 x).

Sulfur Creek

Rocks from Sulfur Creek contained no visible aquatic vegetation. Two small invertebrates were observed; they appeared to be tiny aquatic leeches.

Rachael Creek

Rocks were coated with a thick precipitate that probably was aluminum; no invertebrates or plants were observed.

North Fork Red Dog Creek

Each rock was covered with diatoms and blue-green bacteria, probably Nostoc. Chironomidae larvae were associated with the blue-green bacteria. Rocks had from 25 to hundreds of Chironomidae. Also observed on the rocks were filamentous green algae, pupal cases from Simulidae, sub-microscopic Ephemeroptera and Plecoptera nymphs, and Trichoptera larvae. Clusters of unidentified insect eggs were found on some of the rocks.

Conclusions

Microscopic and sub-microscopic communities were found on rocks from the following streams:

Ikalukrok Creek (only a sparse community)
Connie Creek
North Fork Red Dog Creek

Periphyton: Baseline Studies

EVS and Ott Water Engineers (1983) conducted limited sampling of periphyton communities in Middle Fork Red Dog Creek by measuring concentrations of chlorophyll-a. Their methods were similar to those used by ADF&G in this study. EVS and Ott Water Engineers (1983) reported concentrations of chlorophyll-a ranging from 0.01 to 0.10 mg/cm^2 in flowing water upstream of the South Fork Red Dog Creek and chlorophyll-a concentrations ranging from 0.04 to 0.20 mg/cm^2 in seeps adjacent to

Middle Fork Red Dog Creek. Periphyton was not sampled in Red Dog Creek downstream of the South Fork or in Ikalukrok Creek.

Periphyton: Current Study

Methods

Five rocks were collected at each sample site within a riffle section. A 5 cm x 5 cm square of high density foam was placed on the rock. Using a small tooth brush, all material around the foam square was removed and rinsed away with clean water. The foam was removed from the rock and the rock was brushed with a clean tooth brush and rinsed onto a 0.45 *u*m glass fiber filter, held by a magnetic filter holder connected to a hand vacuum pump. Excess water was pumped through the filter, and approximately 1 ml saturated $MgCO_3$ was added to the filter to prevent acidification. The dry filter was wrapped in a large filter (to absorb any additional water, labeled, and placed in a zip-lock bag and packed over desiccant. Filters were frozen in a light-proof container with desiccant.

Filters were cut into small pieces and placed in an extraction tube with 10 ml of 90% buffered acetone. Extraction tubes were covered with aluminum foil and were held in a dark refrigerator for 24 hours. After extraction, samples were read on a Shimadzu UV-1601 Spectrophotometer and a Turner Model 10 Fluorometer. Trichromatic equations (according to Standard Methods, APHA 1992) were used to convert spectrophotometric optical densities to total chlorophyll-a. The Turner Fluorometer was calibrated with US EPA standards according to Standard Methods. A calibration curve was developed, using known standards, standard dilutions, and chlorophyll-a concentrations determined with a spectrophotometer. Hilltop Creek was not sampled.

Results and Discussion

Periphyton communities (i.e., detecting chlorophyll-a in at least 3 of the 5 samples) were documented in North Fork Red Dog Creek, Sulfur Creek, Shelly Creek, and Connie Creek (Appendix 8). Station 11 contained one sample with measurable amounts of chlorophyll-a, and Ikalukrok Creek contained two samples with measurable amounts of chlorophyll-a.

Conclusions

Based on samples examined for the presence of chlorophyll-a (a measure of periphyton standing crop), periphyton communities were documented in the following sites:

North Fork Red Dog Creek	Sulfur Creek
Connie Creek	Shelly Creek

Limited algal productivity was indicated in Ikalukrok Creek and Mainstem Red Dog Creek.

Macrophytes: Baseline Studies

No previous studies were found that documented the presence of aquatic macrophytes in Ikalukrok Creek or Red Dog Creek and its tributaries.

Macrophytes: Current Study

Streams in the Red Dog area were examined and photographed in July 1995 for the presence of macrophytic plants. Aquatic plants may be an important component of an aquatic community and an indicator of good water quality. Hilltop Creek was not sampled.

Methods

Our intention was to collect any visible macrophyte algae along the stream and place it in a labeled plastic bag for later identification. Because few macrophytes were observed and those were generally limited to mosses, we noted their presence only. The following is a description of macrophyte communities observed at each sample site.

Results and Discussion

Ikalukrok Creek

Station 8

The edges of the stream bank at Station 8 in Ikalukrok Creek were gravel, with no aquatic plants along the stream margins. Mosses grew in seeps adjacent to the stream, but there were no aquatic plants found in the stream.

Mainstem Red Dog Creek

Station 10

The edges of the stream bank at Station 10, Mainstem Red Dog Creek contained wide gravel bars and shrub vegetation. No aquatic plants were found in the stream.

Station 11

The Mainstem Red Dog Creek at Station 11, just below the confluence with the North Fork, contained wide gravel bars and the banks supported shrub vegetation. No aquatic plants were found in the stream.

Middle Fork Red Dog Creek

Station 20

The edges of the stream bank at Station 20 in Middle Fork Red Dog Creek were gravel, with few grasses and shrubs. No aquatic plants were found in the stream.

Station 140

This section of the Middle Fork of Red Dog Creek is a man-made channel with steep, graveled sides. No vegetation has established along the stream margins. There were no aquatic plants found in the water.

Shelly Creek

The banks of Shelly Creek were covered with shrub willows. No aquatic plants were evident on the stream bottom; however, mosses grew abundantly along the stream margins.

Connie Creek

The edges of Connie Creek were primarily gravel, with shrubs growing on the stream banks. A few mosses were observed on the stream bottom.

Sulfur Creek

The banks of Sulfur Creek contained grasses and sedges. No aquatic plants were found in this darkly stained creek.

Rachael Creek

The stream banks along Rachael Creek were covered with grasses, sedges, and other terrestrial plants. No aquatic plants were evident in the stream.

North Fork Red Dog Creek

North Fork Red Dog Creek contained abundant aquatic mosses and filamentous algae on the stream bed. The edges of the creek were filled with various aquatic plants. The mosses and filamentous algae in the stream appeared to provide an important substrate for aquatic invertebrates.

Conclusions

Aquatic macrophytes were an important part of the aquatic ecosystem in North Fork Red Dog Creek, and to a lesser extent, in Connie Creek and Shelly Creek. They were not found in the other sites. We believe that high metals concentrations in Middle Fork Red Dog Creek contributed to the absence of aquatic macrophytes in downstream areas.

Fish: Baseline Studies

Baseline studies conducted by Dames and Moore (1983) reported fish use in Ikalukrok Creek, Mainstem Red Dog Creek, and North Fork Red Dog Creek (Table 24). Fish species present in the Wulik River are listed to illustrate the importance of this river for fish. Common and scientific names of fish are listed in Appendix 9.

Table 24. Fish species collected during baseline studies.

Water body	Use (fish species)	Notes
Ikalukrok Creek	Migration (AG) Spawning (AG, ChumS) Rearing (AG, DV, SSc)	few present
Mainstem Red Dog Creek	Migration (AG)	migration limited to spring high flows
Middle Fork Red Dog Creek	no fish found	
North Fork Red Dog Creek	Migration (AG) Spawning (AG) Rearing (AG)	
Wulik River	Arctic grayling slimy sculpin chum salmon Dolly Varden humpback whitefish round whitefish least cisco Bering cisco Alaska blackfish pink salmon sockeye salmon coho salmon chinook salmon ninespine stickleback	

DV = Dolly Varden, AG = Arctic grayling, SSc = slimy sculpin, ChumS = chum salmon
Shelly, Rachael, Connie, and Sulfur Creeks were not sampled.

Natural Fish Kills

EVS and Ott Water Engineers (1983) observed natural fish kills in 1982 while collecting baseline data for the Wulik River drainage. Arctic grayling moralities ranged from underyearling juveniles (20 to 40.9 mm) to sub-adults (75 to 220 mm); Dolly Varden mortalities were juveniles (53 to 113 mm). Thirty six dead Dolly Varden and 171 dead Arctic grayling were found in Red Dog Creek between Station 12 and the mouth in July and August 1982. One juvenile Dolly Varden and one juvenile Arctic grayling were found dead in Ikalukrok Creek above the confluence of Red Dog Creek. EVS and Ott Water Engineers reported that fish found dead in Red Dog Creek had considerable amounts of brown precipitate and mucus on their gills and occasionally had hemorrhaged gills and opaque eyes.

Fish: Current Study

Methods

ADF&G flew aerial surveys using fixed-wing aircraft in fall 1979 through 1995, with the exception of 1983, 1985, 1986, and 1990. The fall surveys covered the Wulik River from its mouth near the village of Kivalina to a point approximately five river miles above its confluence with Ikalukrok Creek.

ADF&G trapped Dolly Varden and other fish species (e.g., Arctic grayling, slimy sculpin) in Ikalukrok Creek, North Fork Red Dog Creek, and Mainstem Red Dog Creek from 1991 through 1995. Sampling was done with minnow traps baited with salmon roe contained in perforated plastic containers. Minnow traps fished from about 20 to 80 hours each sample period.

ADF&G conducted visual stream surveys for Arctic grayling and other fish in North Fork Red Dog Creek, Mainstem Red Dog Creek, and Middle Fork Red Dog Creek from 1991 through 1995 and in Shelly, Sulfur, Connie, and Rachael Creeks in 1995. Arctic grayling were sampled by angling in North Fork Red Dog Creek, Mainstem Red Dog Creek, and Ikalukrok Creek.

Results and Discussion

The number of overwintering Dolly Varden in the Wulik River ranged from 30,853 in 1984 to a high of 144,138 fish in 1993 (Appendix 10, Weber Scannell and Ott 1995). Surveys showed the Wulik River to be one of the most important drainages for overwintering Dolly Varden in northwest Alaska.

Fish were found to inhabit Ikalukrok Creek, Mainstem Red Dog Creek, and North Fork Red Dog Creek. Slimy sculpin were not found in Mainstem Red Dog Creek or North Fork Red Dog Creek before 1995. They are believed to migrate into these creeks in spring after breakup, then use the waterways for summer rearing. Most likely, they migrate downstream in fall, before freeze-up. The uses of streams by fish after development of the Red Dog mine are listed in Table 25. The data on catch per unit effort and actual numbers of fish are given in Weber Scannell and Ott (1995).

Table 25. Post-mining use of Wulik River drainage streams by fish.

Stream	Use (Fish Species)	
Ikalukrok Creek Station 8	Migration (AG, DV, SSc) Rearing (AG, DV, SSc)	
Ikalukrok Creek[1] upstream of Red Dog Creek	Migration (AG) Rearing (AG)	
Mainstem Red Dog Creek Station 10	Migration (AG, DV, SSc) Rearing (AG, DV, SSc)	
Station 11	Migration (AG, DV, SSc) Rearing (AG, DV, SSc)	
Middle Fork Red Dog Creek		
Station 20	no fish found	
Station 140	no fish found	
Shelly Creek	no fish found	
Connie Creek	no fish found	
Sulfur Creek	no fish found	
Rachael Creek	no fish found	
North Fork Red Dog Creek	Migration (AG, DV, SSc) Spawning (AG) Rearing (AG, DV, SSc)	
Wulik River[2]	Arctic grayling	pink salmon
	slimy sculpin	sockeye salmon
	chum salmon	coho salmon
	Dolly Varden	chinook salmon
	humpback whitefish	ninespine stickleback
	round whitefish	burbot
	least cisco	
	Bering cisco	
	Alaska blackfish	

DV = Dolly Varden, AG = Arctic grayling, SSc = slimy sculpin.

[1]Incomplete surveys have been conducted in Ikalukrok Creek above Red Dog Creek. Species other than Arctic grayling may be using this portion of the creek.

[2]Fish use was not documented in the Wulik River.

Point Source Evaluation

Comparisons of water quality and metals concentrations data before and after development of the Red Dog Mine (Table 26) indicate the following changes related to the point source discharge from the mine and to diversion and collection of the mine seepage water. It is not possible to separate the effects of effluent from mine seepage collection. Refer to summaries of water quality data presented in Appendices 1 through 5 and to the complete listing of water quality and metals data from sampling stations in Appendices 11 and 12, and water quality and metals data from mine effluent in 1995 in Appendix 13.

In summer 1995 the wastewater treatment plant discharged maximum amounts of treated water. The volume of mine discharge during 1995 is representative of the amount of discharge requested by Cominco Alaska Inc. in the NPDES permit.

Table 26. Comparisons of water quality and metals before and after mine development.

Analyte or Factor	Ikalukrok Creek	Mainstem Red Dog Creek	Middle Fork Red Dog Creek
Temperature	NMC[1]	NMC	NMC
pH	>[1]	>	>
Flow	>	>	>
Hardness	>	>	>
TSS	NMC	NMC	NMC
Dissolved Oxygen	NMC	NMC	NMC
Turbidity	NMC	NMC	NMC
Conductivity	>	>	>
TDS	>	>	>
Sulfate	>	>	>
Al	not related[2]	not related	not related
Cd	<[1]	<	<
Cu	<	<	<
Pb	<	<	<
Zn	<	<	<

[1]NMC = no measurable change, < = decrease, > = increase over background conditions.
[2] Concentrations of Al appear to be related to high rainfall and increased erosion.

Non-Point Source Evaluation: Whole Effluent Toxicity

Whole effluent toxicity (WET) tests were conducted on water taken from Middle Fork Red Dog Creek at Station 140 during summer 1995 (Parametrix 1995 a, b, c, d, e, and f) and from Ikalukrok Creek at Station 9 above Red Dog Creek (Parametrix 1995f). WET tests were conducted at other stations that are influenced by the mine discharge effluent. Because it is not possible to separate effects between natural mineralization and mine effluent, those test results are not presented.

Tests on water taken from Station 140 (Table 27) showed significant toxicity for both *Ceriodaphnia dubia and Pimephales promelas.* The no observed effects concentration (NOEC) was <1% Station 140 water mixed with 99% laboratory water. The concentration of Station 140 water resulting in 50% mortality was <1%.

Table 27. Whole Effluent Toxicity at Station 140.

		Ceriodaphnia dubia		*Pimephales promelas*	
Date Water Collected		survival	reproduction	survival	growth mg
June 11-14 1995	NOEC[1]	1%	<1%	1%	1%
	LOEC[2]	6%	1%	6%	>1%
	LC50[3]	2%		5%	
June 19,21,23 1995	NOEC	1%	1%	1%	1%
	LOEC	6%	1%	6%	>1%
	LC50	2%		3%	
July 5,7,10 1995	NOEC	<1%	<1%	1%	1%
	LOEC	1%	1%	6%	>1%
	LC50	<1%		2%	
July 17,19,21	NOEC	<1%		1%	1%
	LOEC	1%		6%	>1%
	LC50	<1%		2%	

[1]NOEC = No Observed Effects Concentration.
[2]LOEC = Lowest Concentrations at which adverse effects were observed.
[3]LC50 = Concentration at which 50% of the test population died.

Station 9, Ikalukrok Creek above Red Dog Creek

Whole effluent toxicity tests conducted on water from Ikalukrok Creek at Station 9 (above Red Dog Creek) did not show significant toxicity for *Ceriodaphnia dubia* or *Pimephales promelas* survival in August 1995 (Table 28). The NOEC for *C. dubia* survival was 100%. Tests did show significant detrimental effects of Station 9 water on *C. dubia* reproduction, with a NOEC of 1% Station 9 water.

Whole effluent toxicity tests using Station 9 water collected in September 1995 showed somewhat higher toxicity for *C. dubia* than in August, the NOEC was 73% and the LC50 was 84%. Survival and growth of *P. promelas* remained at 100% in September samples.

Table 28. Whole Effluent Toxicity at Ikalukrok Creek, Station 9.

		Ceriodaphnia dubia		*Pimephales promelas*	
Date Water Collected		survival	reproduction	survival	growth mg
August 6 1995	NOEC[1]	100%	1%	100%	100%
	LOEC[2]	>100%	<1%	>100%	>100%
	LC50[3]	>100%	N/A	>100%	N/A
Sept. 9 1995	NOEC	73%		100%	100%
	LOEC	100%		>100	>100%
	LC50	84%		>100	

[1]NOEC = No Observed Effects Concentration.
[2]LOEC = Lowest Concentrations at which adverse effects were observed.
[3]LC50 = Concentration at which 50% of the test population died.

Conclusions and Recommendations

Information from baseline studies and from post-mining studies were used to determine the ability of each waterway to support a viable aquatic community (Table 29 for fish, Table 30 for invertebrates, Table 31 for periphyton). Aquatic communities include any combination of fish, aquatic macroinvertebrates, aquatic microinvertebrates, periphyton, and macrophytes. Incidental occurrence of a few organisms is not considered to constitute a community.

Table 29. Summary of fish use of streams in the upper Wulik River drainage.

Stream	Pre-mining	Post-mining	Attainable
Ikalukrok Creek	Yes	Yes	Yes
Mainstem Red Dog Creek	Yes	Yes	Yes
Middle Fork Red Dog Creek	No	No	No
Sulfur Creek	No	No	No
Shelly Creek	? (No)	No	No
Connie Creek	? (No)	No	No
Rachael Creek	? (No)	No	No
Hilltop Creek	?(No)	No	No
North Fork Red Dog Creek	Yes	Yes	Yes

? = no data were available.

Table 30. Summary of aquatic micro and macroinvertebrate use of streams in the upper Wulik River drainage.

Stream	Pre-mining	Post-mining	Attainable
Ikalukrok Creek	Yes	Low	Yes
Mainstem Red Dog Creek	Low	Low	Yes
Middle Fork Red Dog Creek	No	No	No
Sulfur Creek	?	No	No
Shelly Creek	?	Very Low	No
Connie Creek	?	Yes	Yes
Rachael Creek	?	No	No
Hilltop Creek	?	No	No
North Fork Red Dog Creek	Yes	Yes	Yes

? = no data were available.

Table 31. Summary of macrophyte and periphyton use of streams in the upper Wulik River drainage.

Stream	Pre-mining	Post-mining	Attainable
Ikalukrok Creek	Low	Low	Limited
Mainstem Red Dog	Low	Low	Limited
Middle Fork Red Dog	No	No	No
Sulfur Creek	?	Yes	Limited
Shelly Creek	?	Low	Limited
Connie Creek	?	Yes	Yes
Rachael Creek	?	No	No
Hilltop Creek	?(No)	No	No
North Fork Red Dog Creek	Yes	Yes	Yes

? = no data were available.

Based upon information presented in this Use Attainability Analysis, the Alaska Department of Fish and Game recommends retaining the stream classification for Aquatic Life in the following streams:

Connie Creek
Ikalukrok Creek
North Fork Red Dog Creek
Mainstem Red Dog Creek

The Alaska Department of Fish and Game recommends elimination of the stream classification for Aquatic Life in the following waterbodies:

Middle Fork Red Dog
Shelly Creek
Hilltop Creek
Sulfur Creek
Rachael Creek

References Cited

Cominco Engineering Services Ltd. 1983. Wastewater collection and management: Red Dog Project. File No. RDS .012. 65 pp.

Alabaster, J.S. and R. Lloyd. 1982. Water Quality Criteria for Freshwater Fish. Butterworth Scientific. Second Edition. 361 pp.

American Public Health Association (APHA), American Water Works Association, and Water Environment Federation. 1992. Standard Methods for the Examination of Water and Wastewater. 18th Edition. A.E. Greenberg, L.S. Clesceri, and A.D. Eaton, eds. American Public Health Assoc. Washington, D.C.

Dames and Moore. 1981. Surface water and aquatic biological investigations of the Red Dog Area, Alaska. Prepared for Cominco American, Inc. 123 pp. + Append.

Dames and Moore. 1983. Environmental Baseline Studies, Red Dog Project. Prepared for Cominco Alaska Inc.

EBA Engineering Inc. 1991. Red Dog Mine Design of Mine Water Diversion Dam, Supporting Design Report.

EVS Consultants Ltd. and Ott Water Engineers, Inc. 1983. Toxicological, Biophysical, and Chemical Assessment of Red Dog Creek, DeLong Mountains, Alaska, 1982. for Alaska Department of Environmental Conservation. October 1983. Project 143-1.

Ontario Ministry of the Environment. 1984. Water Management, Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, Revised. Toronto, Ontario. 70 pp. Reviewed in Canadian Water Quality Guidelines 1995.

Parametrix, Inc. 1995a. Toxicity Evaluation of Stations 10, 73, and 140 to *Ceriodaphnia dubia* and *Pimephales promelas*. Prepared for Cominco Alaska Inc. Kotzebue, AK 99752. Project No. 55-2833-01 (01). July 1995.

Parametrix, Inc. 1995b. Toxicity Evaluation of Station 140 to *Ceriodaphnia dubia* and *Pimephales promelas*. Prepared for Cominco Alaska Inc. Kotzebue, AK 99752. Project No. 55-2833-01 (01). June 1995.

Parametrix, Inc. 1995c. Toxicity Evaluation of Station 140 to *Ceriodaphnia dubia* and *Pimephales promelas*. Prepared for Cominco Alaska Inc. Kotzebue, AK 99752. Project No. 55-2833-01 (01). July 1995.

Parametrix, Inc. 1995d. Toxicity Evaluation of Station 140 to *Ceriodaphnia dubia* and *Pimephales promelas*. Prepared for Cominco Alaska Inc. Kotzebue, AK 99752. Project No. 55-2833-01 (01). August 1995.

Parametrix, Inc. 1995e. Toxicity Evaluation of Station 140 to *Ceriodaphnia dubia* and *Pimephales promelas*. Prepared for Cominco Alaska Inc. Kotzebue, AK 99752. Project No. 55-2833-01 (01). September 1995.

Parametrix, Inc. 1995f. Toxicity Evaluation of Stations 9, 10, 73, and 140 to *Ceriodaphnia dubia* and *Pimephales promelas*. Prepared for Cominco Alaska Inc. Kotzebue, AK 99752. Project No. 55-2833-01 (01). September 1995.

US EPA. 1985. Ambient Water Quality Criteria for Lead - 1984 Criteria and Standards Division, US Environmental Protection Agency, Washington, D.C. EPA-440/5-84-027.

Weber Scannell, P.K. and A. G. Ott. 1995. Fishery Resources below the Red Dog Mine, Northwest Alaska. ADF&G Tech. Report No. 95-5. Juneau, AK.

Appendix 1. Summary of water quality data, 1979-1983.

Station		Hardness mg/L	TDS mg/L	Sulfate mg/L	pH	Temperature °C
Station 20	median	93		108	6.6	5.0
	maximum	145		149	6.9	14.3
	minimum	58.5		66	5.7	0.0
	count	16		3	5	5
Station 30	median	92.1	216	174	5.85	6.3
Station 30	maximum	201	287	324	6.5	12.8
Station 30	minimum	67.5	131	95	5.3	0.0
Station 30	count	12	4	5	8	7
Station 12	median	96.15	187	87.5	7.5	6.3
North Fork	maximum	217	210	98	7.8	8.7
	minimum	39	183	50	6.0	0.0
	count	16	3	3	8	7
Station 140						
	median	89			6.4	
	maximum	155			6.7	
	minimum	68			5.8	
	count	10			10	
Station 09	median	116	143	60	7.5	4.1
Station 09	maximum	290	284	76	7.9	14.7
Station 09	minimum	34	115	30		-0.1
Station 09	count	24	4	3	9	8

TDS = total dissolved solids

Appendix 2. Summary of water quality data, 1979-1983.

Station		Dissolved Oxygen mg/L	Conductivity *u*mho/cm	Flow cfs	Alkalinity mg/L
Station 140	median				
Station 140	maximum	13.2	230		13
Station 140	minimum	10.4	140		2.2
Station 140	count	5	8		10
Station 73	median				68.4
Station 73	maximum	13.4	220		87.8
Station 73	minimum	10.2	110		47.4
Station 73	count	48	50		15
Station 30	median	11.3	276	8.55	4.95
Station 30	maximum	14.2	650	27	16
Station 30	minimum	10.4	63	1.3	1
Station 30	count	8	7	8	8
Station 20	median	11.6	265	13.5	23
Station 20	maximum	14.2	525	76	44
Station 20	minimum	9.7	28	1.6	1.7
Station 20	count	5	5	18	5
Station 12	median	7.7	352	19	90.5
Station 12	maximum	7.9	591	92	115.4
Station 12	minimum	7.2	44	12	48.8
Station 12	count	14	7	15	15
Station 10	median	10.9	328	32.0	70
Station 10	maximum	13.5	1090	126.0	245
Station 10	minimum	0.3	154	3.2	5.2
Station 10	count	9.0	8	25	9
Station 08	median	11.6	289	102.5	75
Station 08	maximum	13.7	940	310.0	388
Station 08	minimum	2.3	179	15.0	12
Station 08	count	9	8	14	10.

Appendix 2, continued.

Station		D.O. mg/L	Conduct. *u*mho/cm	Flow cfs	Alkalinity mg/L
Station 12	median	11.25	352	20	99
Station 12	maximum	14.4	591	92	138
Station 12	minimum	9.5	44	8.1	8.4
Station 12	count	8	7	19	8
Station 09	median	11.7	282.5	132	73.5
Station 09	maximum	13.9	480	1260	176
Station 09	minimum	0.2			16
Station 09	count	9	8	31	26

Appendix 3. Summary metals data, 1979-1983.

Station		Al mg/L	Cd mg/L	Cu mg/L	Pb mg/L	Zn mg/L
Station 140	median	0.73	0.12		0.33	15.70
Station 140	maximum	2.31	0.21		1.11	28.50
Station 140	minimum	0.15	0.07		<0.08	9.06
Station 140	count	20	20		20	20
Station 73	median		0.0115		0.029	0.98
Station 73	maximum		<0.025		<0.08	1.8
Station 73	minimum		<0.006		0.0003	0.349
Station 73	count		12		12	12
Station 30	median	0.665	0.1335	0.013	0.274	15.85
Station 30	maximum	2.31	0.94	0.028	1.11	49.8
Station 30	minimum	0.15	0.071	0.007	0.0026	9.06
Station 30	count	24	32	4	32	32
Station 20	median	0.325	0.078	0.009	0.11	9.865
Station 20	maximum	0.91	0.14	0.025	0.36	16.5
Station 20	minimum	0.05	<0.02	<0.005	0.0015	2.63
Station 20	count	28	34	4	34	34
Station 12	median	<0.15	0.03	<0.01	<0.08	0.02
Station 12	maximum	0.55	0.03	<0.01	<0.08	0.37
Station 12	minimum	<0.02	<0.0002	<0.002	<0.004	0.01
Station 12	count	25	29	5	29	29
Station 10	median	<0.15	0.03	<0.001	<0.08	3.70
Station 10	maximum	1.19	0.10	<0.02	0.10	13.00
Station 10	minimum	<0.02	<0.002	<0.002	<0.001	0.57
Station 10	count	38	43	15	43	43
Station 08	median	0.04	<0.01	<0.001	<0.004	0.74
Station 08	maximum	0.17	0.04	<0.02	0.028	4.20
Station 08	minimum	<0.02	<0.001	<0.001	<0.001	0.17
Station 08	count	10.00	18	10	18	18

Appendix 3, continued.

Station		Al mg/L	Cd mg/L	Cu mg/L	Pb mg/L	Zn mg/L
Station 12	median	<0.15	<0.025	<0.005	<0.08	0.023
Station 12	maximum	0.55	<0.025	0.013	<0.08	0.37
Station 12	minimum	<0.02	<0.0002	<0.002	<0.0001	0.005
Station 12	count	25	29	5	29	29
Station 09	median	0.045	0.002	0.0045	0.0012	0.0255
Station 09	maximum	0.23	0.025	0.012	<0.08	2.3
Station 09	minimum	<0.02	<0.0002	<0.001	<0.0001	0.006
Station 09	count	10	24	10	24	24

Appendix 4. Summary of Water Quality Data, 1991-1995.

Ikalukrok Creek, Station 8.
Hardness, total dissolved solids, and pH.

Year		Hardness mg/L	TDS mg/L	pH
1991	median	179	261	7.1
	maximum	270	406	7.5
	minimum	143	174	6.8
	count	11	11	11
1992	median	237	312	7.44
	maximum	798	1040	8.2
	minimum	53.1	64	5.7
	count	29	29	29
1993	median	131	181	7.7
	maximum	191	229	8.2
	minimum	55.9	68	6.7
	count	12	17	17
1994	median	132.5	159.5	7.7
	maximum	498	658	8.2
	minimum	43.2	57	7.2
	count	22	22	22
1995	median	156	209	7.7
	maximum	666	906	7.9
	minimum	82.5	118	7.1
	count	12	15	14

Appendix 4, continued.

Station 8. Temperature, dissolved oxygen, conductivity, and flow.

Date		Temperature °C	Dissolved Oxygen mg/L	Conductivity *u*mho/cm	Flow cfs
1991	median	5.8	12.8	348	
	maximum	11.5	13.6	576	
	minimum	-0.2	10.3	215	
	count	11	10	8	
1992	median	7.6	9.2	465	
	maximum	13.6	13.2	135	
	minimum	-0.5	4	11	
	count	29	25	22	
1993	median	6.7	11.15	268	189.9
	maximum	15	20	420	248.3
	minimum	2	8.1	50	131.5
	count	17	12	14	2
1994	median	4	11.55	248	
	maximum	8.4	13.2	790	
	minimum	0	7.5	143	
	count	22	22	20	
1995	median	5.8	13	330	
	maximum	10.6	14.5	442	
	minimum	1	12.7	261	
	count	14	5	6	

Appendix 4, continued.

Mainstem Red Dog Creek, Station 10

Year		Hardness mg/L	Total Dissolved Solids mg/L	pH
1991	median	244	349	7.0
	maximum	563	831	7.5
	minimum	179	207	6.7
	count	12	12	12
1992	median	369	519	7.4
	maximum	1540	1850	8.1
	minimum	52.7	67	6.12
	count	30	30	30
1993	median		214.5	7.55
	maximum		369	8.2
	minimum		50	6.6
	count		18	18
1994	median	177	228	7.7
	maximum	1100	1610	7.9
	minimum	99.3	127	7.2
	count	18	18	18
1995	median	580	824	7.6
	maximum	1070	1610	7.8
	minimum	247	171	7.1
	count	9	19	14

Appendix 4, continued.

Mainstem Red Dog Creek, Station 10

Date		Temperature °C	Dissolved Oxygen mg/L	Conductivity umho/cm	Flow cfs
1991	median	6.1	11.8	481	
	maximum	14.1	14.0	665	
	minimum	-0.2	9.5	270	
	count	11	11	8	
1992	median	5.35	9.8	680	
	maximum	13.9	13.4	2090	
	minimum	-0.5	4.9	114	
	count	30	28	27	
1993	median	7			182.6
	maximum	17			400
	minimum	1			32.7
	count	18			6
1994	no samples were collected.				
1995	median	9.5		1029	
	maximum	13		1790	
	minimum	3		97	
	count	14		14	

Appendix 4, continued.

Middle Fork Red Dog Creek, Station 20.
Hardness, total dissolved solids, sulfate, and pH.

Year		Hardness mg/L	TDS mg/L	Sulfate mg/L	pH
1991	median	354	568		7
	maximum	763	1310		7.6
	minimum	210	346		6
	count	13	13		13
1992	median	561	810		6.8
	maximum	1560	2230		8
	minimum	28	50		6.1
	count	32	32		32
1993	median	53.5	198		7.1
	maximum	74	961		7.7
	minimum	32.9	57		6.3
	count	2	19		18
1994	median	319	509	300	7
	maximum	1580	2440	1500	9
	minimum	71.5	97	55	6
	count	18	18	18	17
1995	median	597	1680	1000	7.3
	maximum	1170	2190	1500	7.8
	minimum	138	135	57	6.6
	count	5	28	10	25

Appendix 4, continued.

Middle Fork Red Dog Creek, Station 10.

Temperature, dissolved oxygen, conductivity, and flow.

Year		Temperature. °C	Dissolved Oxygen mg/L	Conductivity *u*mho/cm	Flow cfs
1991	median	5.5	11.9	1.3	577
	maximum	16.1	16	6.1	1570
	minimum	-0.2	8.8	0.4	440
	count	12	12	13	11
1992	median	6.7	9	0.435	0.96
	maximum	19.4	13.4	11	2.56
	minimum	0	1.8	0.12	0.08
	count	32	29	30	32
1993	median	5.5	12.3	3.35	
	maximum	13	12.5	3.7	
	minimum	0	12.1	3	
	count	18	2	2	
1994	median	4			
	maximum	13			
	minimum	0			
	count	17			
1995	median	12		1580.5	7.6
	maximum	15.2		2390	28.9
	minimum	7		94	26.7
	count	24		26	9

Appendix 4, continued.

Middle Fork Red Dog Creek, Station 140.
Hardness, total dissolved solids, and pH.

Date		Hardness mg/L	TDS mg/L	pH
1991	median	155	345	7
	maximum	267	717	8.2
	minimum	108	210	5.2
	count	19	13	52
1992	median	127.5	204	6.5
	maximum	242	456	8.2
	minimum	25.2	16.6	5.7
	count	36	36	36
1993	no samples were collected.			
1994	no samples were collected.			
1995	median	412.5		
	maximum	624		
	minimum	105		
	count	32		

Appendix 4, concluded.

Station 140. Temperature, dissolved oxygen, conductivity, and flow.

Date		Temperature °C	Dissolved Oxygen mg/L	Conductivity *u*mho/cm	Flow cfs
1991	median	4.3	11.5	305	
	maximum	11.6	15	490	
	minimum	-0.2	7.7	178	
	count	13	13	10	
1992	median	8.25	7.5	274	
	maximum	15.4	12.5	58	
	minimum	-0.1	3.3	27	
	count	36	33	28	
1994	median			680	
	maximum			70	
	minimum			63	
	count			7	
1995	median				4.65
	maximum				24.2
	minimum				2.1
	count				20

Appendix 5. Summary of Metals Data, 1991-1995.

Ikalukrok Creek, Station 8 and 73.

Year		Al mg/L	Cd mg/L	Cu mg/L	Pb mg/L	Zn mg/L
1991	median	<0.05	0.012	<0.01	0.008	1.62
	maximum	<0.05	0.040	<0.01	0.023	3.61
	minimum	<0.05	0.007	<0.01	<0.001	1.07
	count	12	12	12	12	12
1992	median	<0.05	0.007	<0.01	<0.002	0.865
	maximum	0.73	0.024	<0.01	0.094	3.120
	minimum	<0.05	<0.003	<0.01	<0.002	0.305
	count	28	28	28	28	28
1993	median	<0.05	<0.003		<0.002	0.203
	maximum	0.28	<0.003		0.009	0.389
	minimum	<0.05	<0.003		<0.002	0.143
	count	17	17		17	17
1994	median	0.085	0.003		0.006	0.282
	maximum	1.02	0.02		0.078	2.62
	minimum	0.05	0.003		0.002	0.098
	count	23	23		23	23
1995	median	0.145	0.00483	0.00322	0.00565	0.619
	maximum	1.06	0.0198	0.01	0.106	2.01
	minimum	0.05	0.00069	0.0016	0.00058	0.138
	count	13	17	17	17	17

Appendix 5, continued.

Mainstem Red Dog Creek, Station 10

Date		Al mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Zn mg/L
1991	median	<0.05	0.036	<0.01	0.02	0.026	5.85
	maximum	<0.05	0.047	<0.01	0.06	0.028	6.54
	minimum	<0.05	0.010	<0.01	0.02	0.010	1.58
	count	12	12	12	12	12	12
1992	median	<0.05	0.02	<0.01	0.045	0.007	2.515
	maximum	0.892	0.06	<0.01	2.98	0.386	5.92
	minimum	<0.05	<0.003	<0.01	0.02	<0.002	0.699
	count	30	30	30	30	29	30
1993	median	<0.05	0.008			0.014	0.939
	maximum	0.69	0.013			0.136	1.31
	minimum	<0.05	<0.003			0.004	0.463
	count	18	18			18	17
1994	median	0.108	0.014			0.023	1.59
	maximum	0.403	0.031			0.07	3.38
	minimum	<0.05	0.006			0.004	0.533
	count	17	18			18	18
1995	median	0.05	0.02	0.0034	0.083	0.0187	2.55
	maximum	0.105	0.237	0.0047	0.237	0.0393	3.67
	minimum	0.05	0.012	0.0014	0.057	0.0131	1.39
	count	9	18	18	8	18	18

Appendix 5, continued.

Middle Fork Red Dog Creek, Station 20.

Year		Al mg/L	Cd mg/L	Cu mg/L	Pb mg/L	Zn mg/L
1991	median	<0.05	0.13	<0.01	0.161	21.75
	maximum	0.48	0.19	<0.01	0.295	32.40
	minimum	<0.05	0.06	<0.01	0.044	8.28
	count	12	12	12	12	12
1992	median	<0.05	0.045	<0.01	0.0405	6.38
	maximum	0.226	0.147	0.012	0.23	18.7
	minimum	<0.05	0.013	<0.01	0.015	1.6
	count	30	30	30	30	30
1993	median	<0.05	0.026		0.049	3.29
	maximum	0.38	0.032		0.348	3.83
	minimum	<0.05	0.013		0.016	1.64
	count	17	17		17	17
1994	median	0.086	0.029		0.095	3.57
	maximum	1.25	0.52		0.345	11.3
	minimum	0.05	0.016		0.01	2.1
	count	23	23		23	23
1995	median	0.091	0.0428	0.00589	0.046	4.91
	maximum	0.197	0.0559	0.109	0.142	8.06
	minimum	0.05	<0.00005	0.00023	0.00039	0.0008
	count	9	28	28	28	28

Appendix 5, continued.

Middle Fork Red Dog Creek, Station 140

Year	Al mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Zn mg/L
1991 median	0.1	0.08	0.04	0.215	0.108	13.8
maximum	0.44	0.758	0.05	2.9	0.856	157
minimum	0.05	0.003	0.01	0.04	0.01	1.4
count	56	56	56	54	56	56
1992 median	0.05	0.054	0.01	0.023	0.181	9.99
maximum	1.61	0.216	0.07	3.69	1.94	138
minimum	0.05	0.012	0.01	0.02	0.046	1.47
count	36	36	36	36	36	36
1993 median	0.08	0.02	0.01	0.58	0.10	1.93
maximum	0.46	0.15	0.02	1.68	0.58	16.30
minimum	0.05	0.01	0.01	0.17	0.05	1.10
count	20	20	3	3	20	20
1994 median	0.103	0.035	0.058	0.101	0.207	4.11
maximum	1.47	0.15	0.058	0.101	0.542	29.5
minimum	0.05	0.012	0.058	0.101	0.126	1.57
count	13	13	1	1	13	13
1995 median	0.196	0.1045	0.0128	0.236	0.1815	22.1
maximum	0.196	0.262	0.0197	0.236	0.345	33.6
minimum	0.196	0.0317	0.0056	0.236	0.131	4.78
count	1	32	32	1	32	32

Appendix 5, continued.

Shelly Creek, 1995

	Hardness mg/L	Al mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Zn mg/L	pH
median	62	0.271	0.0137	0.0140	0.403	0.0496	1.62	6.8
maximum	116	0.549	0.0447	0.0235	1.220	0.6040	5.10	7.3
minimum	33	0.077	0.0006	0.0016	0.190	0.0052	0.09	6.4
count	5	14	14	13	13	14	14	6

Connie Creek, 1995

	Hardness mg/L	Al mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Zn mg/L	pH
median	79	0.09	0.00	<0.005	0.09	0.01	0.12	6.85
maximum	148	0.37	0.19	0.06	1.22	0.27	36.80	7.40
minimum	51	0.05	0.00	<0.005	0.05	<0.002	<0.01	6.60
count	5	12	12	12	11	12	12	6

Rachael Creek, 1995

	Hard mg/L	Al mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Zn mg/L	pH
median	256	1.70	0.00300	0.0610	2.80	0.0008	0.707	5.45
maximum	491	3.27	0.00381	0.0840	4.28	0.0480	0.838	5.90
minimum	164	1.17	0.00214	0.0427	0.25	0.0003	0.202	4.70
count	5	10	11	11	9	11	11	4

Appendix 5, continued.

Sulfur Creek, 1995

	Hardness mg/L	Al mg/L	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Zn mg/L	pH
median	132	0.05	0.0070	0.0064	0.058	0.0913	0.971	7.0
maximum	140	5.97	0.0118	0.0200	20.100	2.1200	1.900	7.4
minimum	87	0.05	0.0030	0.0012	0.036	0.0658	0.399	6.5
count	4	6	6	6	5	6	6	4

Hilltop Creek

Date	Al mg/L	Cd mg/L	Fe mg/L	Pb mg/L	Zn mg/L	pH
Middle of Hilltop						
7/31/95	17.10	10.1	20.6	2.64	2130	3.55
8/1/95	27.60	10.5	22	2.33	2080	3.5
Mouth of Hilltop						
7/31/95	7.87	6.2	3.45	4.69	1510	4.25
8/1/95	12.20	6.9	4.11	4.55	1600	4.1
Headwaters of Hilltop						
7/31/95	15.40	3.78	85.5	1.63	530	2.71
8/1/95	12.20	6.9	4.11	4.55	1600	4.1
Hilltop Monitoring						
8/16/95	9.39	7.8	3.68	4.12	1580	4.2
8/21/95	8.19	7.6	1.96	4.22	1550	4.8
8/25/95	9.59	7	3.88	3.90	147	4.2
8/29/95	8.47	5	2.39	3.78	1430	4.6
9/3/95	7.75	6.7	2.17	3.49	1460	5
9/6/95	4.09	6.5	0.37	3.39	1260	
9/13/95	3.65	7	0.21	0.39	1380	5.7
9/21/95	2.97	6.9	0.11	3.94	1250	5.7
9/28/95	8.29	6.8	0.8	3.09	1250	5
10/6/95	3.05	6.2	0.16	3.35	1150	5.8
10/17/95	0.26	3.2	0.03	3.75	710	6.1

Appendix 6. Invertebrates found in Wulik River Drainage Before Mining.

Baseline Studies Conducted by EVS (1983).

	Oligichaeta		Chironomidae		Plecoptera		Ephcmeroptera	
Station	Taxa	N	Taxa	N	Taxa	N	Taxa	N
Ikalukrok Creek								
Station 73	3	2.5	9	6.5	2	3.2	1	2.3
(sampled at	3	0.2	9	1.2	1	0.2	1	0.1
4 locations)	2	7.9	11	14.1	2	12.3	1	5.5
July	1	0.7	10	4.2	2	1.5	1	1.2
August	3	2	9	3	2	3.8	3	1.9
	2	0.2	6	1.5	2	1.7	2	1.0
	2	10.3	7	22.1	2	6.5	3	2.9
	3	1.2	7	14.6	1	0.7	2	0.6
Station 9								
July	2	0.4	12	6.4	2	2.2	1	0.4
Mainstem Red Dog Creek								
Station 10								
July	1	<0.1	9	3.9	2	0.3	1	0.5
August	1	<0.1	5	0.7	2	0.2	2	0.4
Middle Fork Red Dog Creek								
Station 21								
July	2	0.8	6	2.4	2	0.9	1	1.1
August	2	4.8	9	2.8	2	9.8	1	7.3
Station 140								
July	1	1.5	8	1.4	2	0.1	1	0.4
August	0	0	6	2	2	0.3	1	3
August	2	12	10	5.5	0	9.3	3	6.3
North Fork Red Dog Creek								
July	3	10.3	11	50.3	2	15.6	2	24.0
August	3	9.2	13	6.1	3	4	3	7.5

Appendix 6, continued.

Baseline Studies Conducted by Dames and Moore (1983).

Station	Non-Insect Invertebrates	Chironomidae	Plecoptera	Ephemeroptera	Total
Station 10	1	1	0	1	3
Station 8	11	76	14	55	156
Station 8	1	22	2	11	36
Station 8	2	14	2	4	22
Station 9	17	52	71	105	245

Appendix 7. Invertebrate data, 1995.

		Ikalukrok Creek, Station 8						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		1	24	1	11	0	7.4	24
Total number of taxa		1	1	1	4	0	1.4	4
	Acarina							
	Nematoda	1	24	1	6			
	Tipulidae							
Diptera	Chironomidae larvae				3			
	Chironomidae pupae		1 exuvia					
	Simulidae							
Ephemeroptera	Heptagenidae				1			
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae				1			
	Capniidae							
Trichoptera								
		Connie Creek						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		42	38	37	39	47	40.6	47
Total number of taxa		3	1	3	3	3	2.6	3
	Acarina							
	Nematoda							
	Tipulidae			1		1		
Diptera	Chironomidae larvae	35	37	33	37	44		
	Chironomidae pupae	2	1	2		1		
	Simulidae				1	1		
Ephemeroptera	Heptagenidae	4		1	1			
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae	1 + 1exuvia						
	Capniidae							
Trichoptera								

Appendix 7, continued.

		Sulfur Creek						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		74	12	57	20	20	36.6	74
Total number of taxa		2	2	2	1	1	1.6	2
	Acarina							
	Nematoda	70	7	56	20	20		
	Tipulidae							
Diptera	Chironomidae larvae	3	5	1				
	Chironomidae pupae	1						
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae	1	exuvia	exuvia				
	Capniidae							
Trichoptera								

		Rachael Creek					average	maximum
Sample number		1	2	3	4	5		
Total number of organisms		1	1	1	0	0	0.6	1
Total number of taxa		1	1	1	0	0	0.6	1
	Acarina							
	Nematoda							
	Tipulidae							
Diptera	Chironomidae larvae							
	Chironomidae pupae		1 adul	1 adult				
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae	1		1 exuvia				
	Capniidae							
Trichoptera								

Appendix 7, continued.

		Red Dog Creek, Station 11						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		0	1	0	1	0	0.4	1
Total number of taxa		0	1	0	1	0	0.4	1
	Acarina							
	Nematoda							
	Tipulidae							
Diptera	Chironomidae larvae				1			
	Chironomidae pupae		1pupa					
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae							
	Capniidae							
Trichoptera								

		North Fork Red Dog Creek						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		14	40	24	26	26	26	40
Total number of taxa		6	5	7	6	3	5.4	7
	Acarina	1	3	1		2		
	Nematoda	3						
	Tipulidae	1		1				
Diptera	Chironomidae larvae	1	30	12	4	12		
	Chironomidae pupae		2	2	2	2		
	Simulidae	2		1p	1p			
Ephemeroptera	Heptagenidae	6	3	4	14	10		
	Baetidae		2	2	2			
	Siphloneuridae				1			
Plecoptera	Nemouridae							
	Capniidae		1		2			
Trichoptera				1				

Appendix 7, continued.

		Red Dog Creek, Station 140						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		0	1	0	0	0	0.2	1
Total number of taxa		0	0	0	0	0	0	0
	Acarina							
	Nematoda							
	Tipulidae							
Diptera	Chironomidae larvae		1					
	Chironomidae pupae							
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae	1 exuvia						
	Capniidae							
Trichoptera								

		Red Dog Creek, Station 20						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		1	1	3	0	0	1	3
Total number of taxa		1	1	1	0	0	0.6	1
	Acarina							
	Nematoda	1	1	3				
	Tipulidae							
Diptera	Chironomidae larvae							
	Chironomidae pupae							
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae							
	Capniidae							
Trichoptera								

Appendix 7, concluded.

		Red Dog Creek, Station 10						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		2	5	13	0	0	4	13
Total number of taxa		1	3	1	0	0	1	3
	Acarina							
	Nematoda	2	3	12				
	Tipulidae		1 Tipula					
Diptera	Chironomidae larvae			1				
	Chironomidae pupae		1					
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae		1 exuvia					
	Capniidae							
Trichoptera								
		Shelley Creek						
Sample number		1	2	3	4	5	average	maximum
Total number of organisms		4	3	4	7	3	4.2	7
Total number of taxa		1	1	2	2	1	1.4	2
	Acarina							
	Nematoda	4			5	3		
	Tipulidae							
Diptera	Chironomidae larvae		2	2	2			
	Chironomidae pupae	1 exuvia		1a				
	Simulidae							
Ephemeroptera	Heptagenidae							
	Baetidae							
	Siphloneuridae							
Plecoptera	Nemouridae		1	1	2 exuvia			
	Capniidae							
Trichoptera								

Appendix 8. Estimates of Chlorophyll-a, 1995.

Periphyton samples were collected and analyzed by ADF&G according to methods presented in the text.

Creek	Station Number	ug/cm^2 chlorophyll-a
Ikalukrok Creek	Station 8	0.155
Ikalukrok Creek	Station 8	<LOD
Ikalukrok Creek	Station 8	<LOD
Ikalukrok Creek	Station 8	<LOD
Ikalukrok Creek	Station 8	0.215
Mainstem Red Dog Creek	Station 10	<LOD
Mainstem Red Dog Creek	Station 10	<LOD
Mainstem Red Dog Creek	Station 10	<LOD
Mainstem Red Dog Creek	Station 10	<LOD
Mainstem Red Dog Creek	Station 10	<LOD
Mainstem Red Dog Creek	Station 11	<LOD
Mainstem Red Dog Creek	Station 11	<LOD
Mainstem Red Dog Creek	Station 11	0.567
Mainstem Red Dog Creek	Station 11	<LOD
Mainstem Red Dog Creek	Station 11	<LOD
Middle Fork Red Dog Creek	Station 20	<LOD
Middle Fork Red Dog Creek	Station 20	<LOD
Middle Fork Red Dog Creek	Station 20	<LOD
Middle Fork Red Dog Creek	Station 20	<LOD
Middle Fork Red Dog Creek	Station 20	<LOD
Middle Fork Red Dog Creek	Station 140	<LOD
Middle Fork Red Dog Creek	Station 140	<LOD
Middle Fork Red Dog Creek	Station 140	<LOD
Middle Fork Red Dog Creek	Station 140	0.11
Middle Fork Red Dog Creek	Station 140	<LOD
Sulfur Creek		0.56
Sulfur Creek		0.49
Sulfur Creek		0.62
Sulfur Creek		0.80
Sulfur Creek		0.32

Appendix 8, concluded.

Creek	Station Number	ug/cm^2 chlorophyll-a
Shelly Creek		0.041
Shelly Creek		0.136
Shelly Creek		0.064
Shelly Creek		0.078
Shelly Creek		<LOD
Connie Creek		0.12
Connie Creek		0.11
Connie Creek		0.13
Connie Creek		0.14
Connie Creek		0.07
Rachael Creek		<LOD
Rachael Creek		<LOD
Rachael Creek		<LOD
Rachael Creek		<LOD
Rachael Creek		<LOD
North Fork Red Dog Creek	Station 12	0.896
North Fork Red Dog Creek	Station 12	1.273
North Fork Red Dog Creek	Station 12	0.558
North Fork Red Dog Creek	Station 12	0.337
North Fork Red Dog Creek	Station 12	0.273

Appendix 9. Common and Scientific Names of Fish from Wulik River Drainage

Arctic grayling	*Thymallus arcticus*
slimy sculpin	*Cottus cognatus*
Dolly Varden	*Salvelinus malma*
humpback whitefish	*Coregonus pidschian*
round whitefish	*Prosopium cylindraceum*
least cisco	*Coregonus sardinella*
Bering cisco	*Coregonus laurettae*
Alaska blackfish	*Dallia pectoralis*
chum salmon	*Oncorhynchus keta*
pink salmon	*O. gorbuscha*
sockeye salmon	*O. nerka*
coho salmon	*O. kisutch*
chinook salmon	*O. tshawytscha*
ninespine stickleback	*Pungitius pungitius*

Appendix 10. Overwintering Adult Dolly Varden in the Wulik River.

Fish were aerial surveyed by ADF&G before freeze up. Data on fish surveys are presented in Weber Scannell and Ott (1995). All surveys were conducted by A. DeCicco, ADF&G.

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1987	893	60,397	61,290	99
1988	1500	78,644	80,144	98
1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994	415	66,337	66,752	99

Appendix 11. Water quality and metals data, 1979-1983.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Wulik River									
Station 02	6/19/81	D&M	113	147					800.0
Station 02	7/16/81	D&M	118	166		7.7	11.7	237	1700.0
Station 02	8/14/81	D&M	103	174		7.4	12.0		2100.0
Station 02	9/6/81	D&M	183			7.6	11.5	291	650.0
Station 02	3/17/82	D&M	200			6.7	9.9	320	
Station 02	6/1/82	D&M				7.1	12.9	111	2700.0
Station 02	7/9/82	D&M				7.8	10.3	219	800.0
Station 02	8/10/82	D&M				8.0	11.2	264	500.0
Station 02	9/12/82	D&M				7.9	12.7	275	600.0
Station 02	10/16/82	D&M				7.9	13.9	230	190.0
Ikalukrok Creek at Dudd Creek									
Station 07	6/18/81	D&M	96	128					
Station 07	9/7/81	D&M	179			7.5	11.3	300	110.0
Station 07	7/9/82	D&M				7.7	9.3	216	175.0
Station 07	8/11/82	D&M				7.8	11.8	268	118.0
Station 07	9/12/82	D&M				7.9	12.8	293	135.0
Station 07	10/17/82	D&M				7.7	12.6	320	45.0
Ikalukrok Creek									
Station 73	3/19/82	D&M				7.9	0.6	1050	
Station 73	7/6/82	EVS							
Station 73	7/6/82	EVS							
Station 73	7/10/82	D&M				7.5	9.6	189	1550.0
Station 73	7/23/82	EVS							
Station 73	7/23/82	EVS							
Station 73	7/31/82	EVS							
Station 73	7/31/82	EVS							
Station 73	8/11/82	D&M				7.7	11.4	264	108.0
Station 73	8/14/82	EVS							
Station 73	8/14/82	EVS							
Station 73	9/13/82	D&M				7.1	13.2	282	100.0
Station 73	10/19/82	D&M				7.7	12.4	230	28.0
Ikalukrok Creek below Red Dog Creek									
Station 08	8/11/81	D&M	146	174		6.9	11.2		140.0
Station 08	9/4/81	D&M	167			7.7	11.0	292	110.0
Station 08	3/21/82	D&M	720	635		7.3	2.3	940	

Appendix 11, continued.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Station 08	5/30/82	D&M	28			6.1	13.7	233	300.0
Station 08	7/8/82	D&M	96		62	7.5	10.0	200	162.0
Station 08	7/8/82	D&M			36				
Station 08	8/12/82	D&M	155			7.6	11.6	499	105.0
Station 08	9/13/82	D&M			72	7.6	13.5	286	100.0
Station 08	9/13/82	D&M	145						100.0
Station 08	10/19/82	D&M	194		114	7.3	11.8	440	15.0
Station 08	10/19/82	D&M							
Station 08	5/28/83	P&N							280.0
Station 08	6/15/83	P&N							89.0
Station 08	6/15/83	P&N							
Station 08	7/10/83	P&N							75.0
Station 08	8/3/83	P&N							80.0
Station 08	9/3/83	P&N							80.0
Station 08	7/18/81	D&M	79	124		7.1	12.1	179	310.0
Ikalukrok Creek above Red Dog Creek									
Station 09	6/17/81	D&M	90	115					110.0
Station 09	7/16/81	D&M	93	123		7.5	11.7	192	230.0
Station 09	8/11/81	D&M	142	163		7.2	11.3		98.0
Station 09	9/4/81	D&M	163			7.5	11.7	285	82.0
Station 09	3/19/82	D&M	290	284		7.1	0.2	430	
Station 09	5/30/82	D&M	34			6.0	13.9	243	170.0
Station 09	7/6/82	EVS	85						245.0
Station 09	7/6/82	EVS	85						245.0
Station 09	7/8/82				30	7.8	9.8	188	132.0
Station 09	7/8/82	EVS	92						132.0
Station 09	7/14/82	EVS							100.0
Station 09	7/21/82	EVS	123						70.0
Station 09	7/22/82	EVS	127						100.0
Station 09	7/23/82	EVS	121						190.0
Station 09	7/23/82	EVS	121						190.0
Station 09	7/24/82	EVS	109						250.0
Station 09	7/26/82	EVS	87						1260.0
Station 09	7/29/82	EVS	105						360.0
Station 09	7/31/82	EVS	106						460.0
Station 09	7/31/82	EVS							
Station 09	8/1/82	EVS	111						365.0
Station 09	8/7/82	EVS	133						135.0
Station 09	8/12/82	D&M				7.8	11.5	480	78.0

Appendix 11, continued.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Station 09	8/12/82	EVS	123						100.0
Station 09	8/12/82	CL	152						78.0
Station 09	8/14/82	EVS	110						770.0
Station 09	8/14/82	EVS							
Station 09	9/13/82	D&M	143		60	7.9	13.5	280	73.0
Station 09	10/19/82	D&M	176		76	7.8	12.9	370	11.0
Station 09	5/28/83	P&N							200.0
Station 09	6/15/83	P&N							67.0
Station 09	7/10/83	P&N							50.0
Station 09	8/3/83	P&N							60.0
Station 09	9/3/83	P&N							60.0
Mainstem Red Dog Creek									
Station 10	6/17/81	D&M	86	159	69.6	6.6			32.0
Station 10	7/17/81	D&M	99	175	66.6	6.5	11.7	233	76.0
Station 10	8/11/81	D&M	156	198	46.0	6.6	10.7		35.0
Station 10	9/4/81	D&M	184	232	87.0	6.4	10.9	341	28.0
Station 10	3/19/82	D&M				6.7	0.3	1090	
Station 10	3/21/82	D&M		876	440.0				
Station 10	5/30/82	D&M	21	24	7.9	6.1	13.5	154	123.0
Station 10	5/30/82	D&M		9	8.8				
Station 10	7/6/82	EVS	93						50.0
Station 10	7/6/82	EVS							
Station 10	7/8/82	D&M	107	158	68.0	7.0	9.2	236	30.0
Station 10	7/8/82	D&M							
Station 10	7/14/82	EVS							25.0
Station 10	7/14/82	EVS							
Station 10	7/21/82	EVS	147						20.0
Station 10	7/21/82	EVS							
Station 10	7/22/82	EVS	137						22.0
Station 10	7/22/82	EVS							
Station 10	7/23/82	EVS	155						26.0
Station 10	7/23/82	EVS							
Station 10	7/23/82	EVS							
Station 10	7/23/82	EVS	140						27.0
Station 10	7/24/82	EVS	151						32.0
Station 10	7/24/82	EVS							
Station 10	7/26/82	EVS							126.0
Station 10	7/29/82	EVS	119						58.0
Station 10	7/29/82	EVS							

Appendix 11, continued.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Station 10	7/30/82	EVS	117						66.0
Station 10	7/30/82	EVS							
Station 10	7/31/82	EVS	98						108.0
Station 10	7/31/82	EVS							
Station 10	8/1/82	EVS	107						80.0
Station 10	8/1/82	EVS							
Station 10	8/7/82	EVS	127						36.0
Station 10	8/12/82	D&M		207	75.0	7.3	11.5	492	27.0
Station 10	8/12/82	EVS	142						32.0
Station 10	8/12/82	EVS							
Station 10	8/14/82	EVS	107						80.0
Station 10	8/14/82	EVS							
Station 10	9/13/82	D&M	144	210	102.0	7.3	13.0	315	27.0
Station 10	9/13/82	D&M							
Station 10	10/19/82	D&M		286	124.0	7.0	10.6	450	3.2
Station 10	10/19/82	D&M	227						3.2
Middle Fork Red Dog Creek				(upstream of North Fork Red D					
Station 20	6/15/78	W&O							
Station 20	5/31/82					5.7	14.2	28	55.0
Station 20	7/6/82	EVS	59						
Station 20	7/6/82	EVS							
Station 20	7/8/82	D&M	64		66	6.6	9.7	181	14.0
Station 20	7/8/82	D&M							
Station 20	7/14/82	EVS							15.0
Station 20	7/14/82	EVS							
Station 20	7/21/82	EVS	109						8.0
Station 20	7/23/82	EVS	110						10.0
Station 20	7/23/82	EVS	103						11.0
Station 20	7/23/82	EVS							
Station 20	7/23/82	EVS							
Station 20	7/24/82	EVS	105						13.0
Station 20	7/24/82	EVS							
Station 20	7/26/82	EVS	107						54.0
Station 20	7/29/82	EVS	81						20.0
Station 20	7/29/82	EVS							
Station 20	7/30/82	EVS	75						22.0
Station 20	7/30/82	EVS							
Station 20	7/31/82	EVS	70						36.0
Station 20	7/31/82	EVS							

Appendix 11, continued.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Station 20	8/1/82	EVS	75						29.0
Station 20	8/1/82	EVS							
Station 20	8/7/82	EVS	90						11.0
Station 20	8/12/82	D&M				6.9	11.0	525	12.0
Station 20	8/12/82	D&M							
Station 20	8/12/82	EVS	93						11.0
Station 20	8/12/82	EVS							
Station 20	8/14/82	EVS	93						76.0
Station 20	8/14/82	EVS							
Station 20	9/13/82	D&M	96		108	6.6	12.1	265	12.0
Station 20	9/13/82	D&M							
Station 20	10/19/82	D&M	145		149	6.8	11.6	390	1.6
Station 20	10/19/82	D&M							
Middle Fork Red Dog Creek									
Station 30	6/17/81	D&M		131					
Station 30	7/17/81	D&M		170		5.9	11.4	237	27.0
Station 30	8/12/81	D&M	129	262	120	5.8	11.6		8.2
Station 30	9/5/81	D&M		287	174	5.8	13.3	374	6.1
Station 30	5/31/82	D&M				5.3	14.2	63	22.0
Station 30	7/6/82	EVS	68						
Station 30	7/6/82	EVS							
Station 30	7/8/82	D&M			95	6.5	10.4	220	8.9
Station 30	7/8/82	D&M							
Station 30	7/23/82	EVS	134						
Station 30	7/23/82	EVS							
Station 30	7/23/82	EVS	134						
Station 30	7/23/82	EVS							
Station 30	7/24/82	EVS	155						
Station 30	7/24/82	EVS							
Station 30	7/26/82	EVS							
Station 30	7/26/82	EVS	85						
Station 30	7/29/82	EVS	84						
Station 30	7/29/82	EVS							
Station 30	7/30/82	EVS	94						
Station 30	7/30/82	EVS							
Station 30	7/31/82	EVS	88						
Station 30	7/31/82	EVS							
Station 30	8/1/82	EVS	77						
Station 30	8/1/82	EVS							

Appendix 11, continued.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Station 30	8/13/82	D&M				6.2	11.1	276	14.0
Station 30	8/13/82	D&M							
Station 30	8/14/82	EVS	90						
Station 30	8/14/82	EVS							
Station 30	9/13/82	D&M			196	6.5	11.2	383	5.6
Station 30	9/13/82	D&M							
Station 30	10/19/82	D&M	201		324	5.8	11.2	650	1.3
Station 30	10/19/82	D&M							
Middle Fork Red Dog Creek									
Station 140	7/6/82	EVS	68			6.7			
Station 140	7/6/82	EVS							
Station 140	7/23/82	EVS	134			6.1			
Station 140	7/23/82	EVS							
Station 140	7/23/82	EVS	134			5.9			
Station 140	7/23/82	EVS							
Station 140	7/24/82	EVS	155			5.8			
Station 140	7/24/82	EVS							
Station 140	7/26/82	EVS	85			6.1			
Station 140	7/26/82	EVS							
Station 140	7/29/82	EVS	84			6.6			
Station 140	7/29/82	EVS							
Station 140	7/30/82	EVS	94			6.5			
Station 140	7/30/82	EVS							
Station 140	7/31/82	EVS	88			6.7			
Station 140	7/31/82	EVS							
Station 140	8/1/82	EVS	77			6.5			
Station 140	8/1/82	EVS							
Station 140	8/14/82	EVS	90			6.3			
Station 140	8/14/82	EVS							
North Fork Red Dog Creek									
Station 12	6/17/81	D&M		187					
Station 12	7/17/81	D&M		183		7.0	11.9	275	54.0
Station 12	8/12/81	D&M	94	210		7.0	11.2		34.0
Station 12	9/4/81	D&M				7.7	10.9	373	17.0
Station 12	5/31/82	D&M	39			6.0	14.4	44	66.0
Station 12	7/7/82	D&M			50.0	7.5	11.3	255	20.0
Station 12	7/23/82	EVS	188						16.0

Appendix 11, continued.

Water Quality Data, before mining.									
Station	DATE	Source	hard.	TDS	SO4	pH	D.O.	Cond.	Flow
			mg/L	mg/L			mg/L		cfs
Station 12	7/23/82	EVS							
Station 12	7/23/82	EVS	180						16.0
Station 12	7/23/82	EVS							
Station 12	7/24/82	EVS	180						18.0
Station 12	7/24/82	EVS							
Station 12	7/26/82	EVS	70						74.0
Station 12	7/29/82	EVS	98						34.0
Station 12	7/29/82	EVS							
Station 12	7/30/82	EVS	49						54.0
Station 12	7/30/82	EVS							
Station 12	7/31/82	EVS	58						76.0
Station 12	7/31/82	EVS							
Station 12	8/1/82	EVS	65						53.0
Station 12	8/1/82	EVS							
Station 12	8/7/82	EVS	94						19.0
Station 12	8/12/82	D&M	201			7.8	11.2	591	15.0
Station 12	8/12/82	EVS	155						16.0
Station 12	8/12/82	EVS							
Station 12	8/14/82	EVS	85						92.0
Station 12	8/14/82	EVS							
Station 12	9/13/82	D&M	179		87.5	7.8	12.6	352	14.0
Station 12	10/19/82	D&M	217		98.0	7.5	9.5	450	8.1

Appendix 11, continued.

Metals Concentrations before Mine Development													
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Wulik River													
Station 02	6/19/81	D&M	D				0.002			<	0.000		0.02
Station 02	7/16/81	D&M	D				0.004				0.000		0.00
Station 02	8/14/81	D&M	D			<	0.002				0.000		0.00
Station 02	9/6/81	D&M	D				0.008				0.012		0.13
Station 02	3/17/82	D&M	D				0.006				0.001		0.02
Station 02	6/1/82	D&M	T				0.000				0.001		0.00
Station 02	7/9/82	D&M	T				0.009				0.001		0.01
Station 02	8/10/82	D&M	T				0.002				0.001		0.01
Station 02	9/12/82	D&M	T				0.002				0.001		0.01
Station 02	10/16/82	D&M	T				0.002				0.001		0.01
Ikalukrok Creek at Dudd Creek													
Station 07	6/18/81	D&M	D				0.007				0.001		0.34
Station 07	9/7/81	D&M	D				0.012				0.004		0.29
Station 07	7/9/82	D&M	T				0.010				0.001		0.21
Station 07	8/11/82	D&M	T				0.004				0.001		0.34
Station 07	9/12/82	D&M	T				0.008				0.001		0.48
Station 07	10/17/82	D&M	T			<	0.002				0.001		0.28
Ikalukrok Creek													
Station 73	3/19/82	D&M	D				0.004				0.009		3.00
Station 73	7/6/82	EVS	T				0.006				0.017		0.86
Station 73	7/6/82	EVS	D				0.006				0.007		0.71
Station 73	7/10/82	D&M	T				0.012				0.000		0.35
Station 73	7/23/82	EVS	T			<	0.025			<	0.080		1.18
Station 73	7/23/82	EVS	D			<	0.025			<	0.080		1.10
Station 73	7/31/82	EVS	T			<	0.025			<	0.080		1.44
Station 73	7/31/82	EVS	D				0.025			<	0.080		1.42
Station 73	8/11/82	D&M	T				0.007				0.001		0.68
Station 73	8/14/82	EVS	T				0.012				0.045		1.80
Station 73	8/14/82	EVS	D				0.011				0.041		1.74
Station 73	9/13/82	D&M	T				0.011				0.002		0.86
Station 73	10/19/82	D&M	T				0.006				0.001		0.70
D = dissolved metals, T = total metals, TR = total recoverable metals.													

Appendix 11, continued.

Metals Concentrations before Mine Development													
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Ikalukrok Creek below Red Dog Creek													
Station 08	8/11/81	D&M	D				0.007				0.000		0.77
Station 08	9/4/81	D&M	D				0.008				0.010		0.76
Station 08	3/21/82	D&M	D				0.034				0.001		0.48
Station 08	5/30/82	D&M	T		0.02		0.001	<	0.002		0.009		0.17
Station 08	7/8/82	D&M	T		0.02		0.016	<	0.002		0.002		0.71
Station 08	7/8/82	D&M	D				0.014				0.001		0.72
Station 08	8/12/82	D&M	T		0.14		0.025		0.022		0.004		1.66
Station 08	9/13/82	D&M	D.				0.019				0.001		2.25
Station 08	9/13/82	D&M	T		0.17		0.020		0.005		0.028		1.74
Station 08	10/19/82	D&M	T		0.02		0.038		0.003		0.002		4.20
Station 08	10/19/82	D&M	D				0.034				0.002		4.10
Station 08	5/28/83	P&N	T		0.14		0.004		0.003		0.006		0.38
Station 08	6/15/83	P&N	D				0.002				0.005		0.41
Station 08	6/15/83	P&N	T		0.03		0.004		0.005		0.014		0.44
Station 08	7/10/83	P&N	T		0.03		0.007		0.002		0.002		0.30
Station 08	8/3/83	P&N	T		0.04		0.004		0.001		0.010		0.26
Station 08	9/3/83	P&N	T		0.08		0.014		0.005		0.026		0.94
Station 08	7/18/81	D&M	D				0.010				0.013		0.97
Ikalukrok Creek above Red Dog Creek													
Station 09	6/17/81	D&M	D			<	0.002				0.002		0.095
Station 09	7/16/81	D&M	D				0.004			<	0.000		0.014
Station 09	8/11/81	D&M	D				0.005			<	0.000		0.018
Station 09	9/4/81	D&M	D				0.007				0.001		0.006
Station 09	3/19/82	D&M	D				0.002				0.001		0.143
Station 09	5/30/82	D&M	T		0.02	<	0.000		0.002		0.001		0.026
Station 09	7/6/82	EVS	T				0.001				0.004		2.300
Station 09	7/6/82	EVS	D			<	0.001				0.001	<	0.015
Station 09	7/8/82												
Station 09	7/8/82	EVS	T		0.02		0.003		0.004	<	0.000		0.013
Station 09	7/14/82	EVS											
Station 09	7/21/82	EVS											
Station 09	7/22/82	EVS											
Station 09	7/23/82	EVS	T			<	0.025			<	0.080		0.023
Station 09	7/23/82	EVS	D			<	0.025			<	0.080		0.029
Station 09	7/24/82	EVS											
Station 09	7/26/82	EVS											
Station 09	7/29/82	EVS											
Station 09	7/31/82	EVS	T			<	0.025			<	0.080		0.028

Appendix 11, continued.

Metals Concentrations before Mine Development													
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Station 09	7/31/82	EVS	D			<	0.025			<	0.080		0.023
Station 09	8/1/82	EVS											
Station 09	8/7/82	EVS											
Station 09	8/12/82	D&M	D				0.020				0.002		1.660
Station 09	8/12/82	EVS											
Station 09	8/12/82	CL	T		0.13		0.002		0.008		0.000		0.023
Station 09	8/14/82	EVS	T			<	0.001				0.008		0.075
Station 09	8/14/82	EVS	D			<	0.001			<	0.080		0.054
Station 09	9/13/82	D&M	T		0.23		0.002		0.004	<	0.000		0.025
Station 09	10/19/82	D&M	T		0.02		0.002		0.009		0.001		0.032
Station 09	5/28/83	P&N	T		0.06		0.000		0.012		0.002		0.032
Station 09	6/15/83	P&N	T		0.03		0.001		0.002		0.001		0.031
Station 09	7/10/83	P&N	T		0.03	<	0.001		0.005		0.000		0.017
Station 09	8/3/83	P&N	T		0.08	<	0.001		0.001		0.001		0.012
Station 09	9/3/83	P&N	T		0.06		0.006		0.008		0.002		0.020
Mainstem Red Dog Creek													
Station 10	6/17/81	D&M	D				0.022		0.004		0.001		3.90
Station 10	7/17/81	D&M	D				0.025		0.005		0.007		3.44
Station 10	8/11/81	D&M	D				0.026		0.005		0.001		3.47
Station 10	9/4/81	D&M	D				0.038		0.004		0.001		4.03
Station 10	3/19/82	D&M	T	<	0.02		0.095		0.009		0.004		13.00
Station 10	3/21/82	D&M	D	<	0.02		0.098		0.002		0.001		9.20
Station 10	5/30/82	D&M	T				0.002		0.005		0.028		0.66
Station 10	5/30/82	D&M	D	<	0.02		0.002		0.003		0.012		0.57
Station 10	7/6/82	EVS	T		1.19		0.026				0.065		3.00
Station 10	7/6/82	EVS	D		0.05		0.025				0.065		2.65
Station 10	7/8/82	D&M	T	<	0.02		0.024	<	0.002		0.008		3.32
Station 10	7/8/82	D&M	D	<	0.02		0.023	<	0.002		0.002		3.23
Station 10	7/14/82	EVS	T		0.37		0.029			<	0.080		3.71
Station 10	7/14/82	EVS	D	<	0.15		0.027			<	0.080		3.70
Station 10	7/21/82	EVS	T	<	0.15		0.031			<	0.080		4.18
Station 10	7/21/82	EVS	D.	<	0.15		0.032			<	0.080		4.11
Station 10	7/22/82	EVS	T		0.50		0.035			<	0.080		4.68
Station 10	7/22/82	EVS	D		0.62		0.035			<	0.080		4.50
Station 10	7/23/82	EVS	T	<	0.15		0.034			<	0.080		4.28
Station 10	7/23/82	EVS	D	<	0.15		0.034			<	0.080		4.04
Station 10	7/23/82	EVS	D	<	0.15		0.040			<	0.080		4.54
Station 10	7/23/82	EVS	T		0.54		0.038			<	0.080		4.80
Station 10	7/24/82	EVS	T		0.19		0.035			<	0.080		4.73

Appendix 11, continued.

Metals Concentrations before Mine Development													
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Station 10	7/24/82	EVS	D	<	0.15		0.036			<	0.080		4.76
Station 10	7/26/82	EVS	D		0.38	<	0.025			<	0.080		2.45
Station 10	7/29/82	EVS	T		0.42		0.028			<	0.080		3.68
Station 10	7/29/82	EVS	D	<	0.15		0.027			<	0.080		3.50
Station 10	7/30/82	EVS	T		0.63	<	0.025				0.100		2.87
Station 10	7/30/82	EVS	D		0.48	<	0.025			<	0.080		2.59
Station 10	7/31/82	EVS	T		0.64	<	0.025			<	0.080		2.81
Station 10	7/31/82	EVS	D	<	0.15	<	0.025			<	0.080		2.73
Station 10	8/1/82	EVS	T		0.55		0.026			<	0.080		3.29
Station 10	8/1/82	EVS	D	<	0.15		0.026			<	0.080		3.29
Station 10	8/7/82	EVS	T		0.32		0.036			<	0.080		4.29
Station 10	8/12/82	D&M	D		0.05		0.034		0.019		0.002		4.23
Station 10	8/12/82	EVS	T	<	0.15		0.041			<	0.080		5.06
Station 10	8/12/82	EVS	D	<	0.15	<	0.025			<	0.080		2.06
Station 10	8/14/82	EVS	T		0.61		0.020				0.060		2.67
Station 10	8/14/82	EVS	D		0.18		0.017				0.056		2.50
Station 10	9/13/82	D&M	T		1.01		0.038		0.002		0.083		3.81
Station 10	9/13/82	D&M	D		0.21		0.034		0.002		0.002		3.46
Station 10	10/19/82	D&M	D	<	0.02		0.041		0.007		0.001		4.30
Station 10	10/19/82	D&M	T		0.04		0.044		0.016		0.002		4.58
Middle Fork Red Dog Creek													
Station 20	6/15/78	W&O	T				0.020				0.084		2.63
Station 20	5/31/82												
Station 20	7/6/82	EVS	T		0.91		0.055				0.130		8.33
Station 20	7/6/82	EVS	D		0.08		0.050				0.053		7.54
Station 20	7/8/82	D&M	T		0.07		0.078		0.010		0.074		9.40
Station 20	7/8/82	D&M	D				0.077				0.007		8.90
Station 20	7/14/82	EVS	T		0.67		0.099				0.150		15.00
Station 20	7/14/82	EVS	D		0.23		0.110				0.110		13.70
Station 20	7/21/82	EVS	D	<	0.15		0.110			<	0.080		16.20
Station 20	7/23/82	EVS	T		0.83		0.110				0.360		15.60
Station 20	7/23/82	EVS	D	<	0.15		0.100			<	0.080		15.10
Station 20	7/23/82	EVS	T		0.86		0.099				0.350		13.40
Station 20	7/23/82	EVS	D	<	0.15		0.095			<	0.080		12.70
Station 20	7/24/82	EVS	T		0.86		0.094				0.360		13.40
Station 20	7/24/82	EVS	D	<	0.15		0.092				0.099		12.90
Station 20	7/26/82	EVS	D		0.24		0.046				0.093		5.88
Station 20	7/29/82	EVS	T		0.68		0.078				0.200		10.40
Station 20	7/29/82	EVS	D	<	0.15		0.078			<	0.080		10.20

Appendix 11, continued.

Metals Concentrations before Mine Development												
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Station 20	7/30/82	EVS	T		0.63		0.064				0.290		8.36
Station 20	7/30/82	EVS	D		0.16		0.062				0.110		8.34
Station 20	7/31/82	EVS	T		0.41		0.060				0.180		8.12
Station 20	7/31/82	EVS	D	<	0.15		0.059			<	0.080		8.00
Station 20	8/1/82	EVS	T		0.48		0.068				0.170		8.79
Station 20	8/1/82	EVS	D	<	0.15		0.069			<	0.080		8.67
Station 20	8/7/82	EVS	T		0.62		0.120				0.220		14.50
Station 20	8/12/82	D&M	T				0.119		0.025		0.266		13.70
Station 20	8/12/82	D&M	T				0.064				0.188		7.25
Station 20	8/12/82	EVS	T		0.54		0.120				0.310		15.20
Station 20	8/12/82	EVS	D		0.51		0.057				0.180		7.51
Station 20	8/14/82	EVS	T		0.59		0.043				0.170		5.93
Station 20	8/14/82	EVS	D		0.21		0.047				0.140		5.90
Station 20	9/13/82	D&M	T		0.52		0.107		0.008		0.097		9.91
Station 20	9/13/82	D&M	D				0.104				0.002		9.82
Station 20	10/19/82	D&M	T		0.05		0.140		0.005		0.021		16.50
Station 20	10/19/82	D&M	D				0.137				0.017		16.40
Middle Fork Red Dog Creek													
Station 30	6/17/81	D&M	D				0.088				0.005		12.40
Station 30	7/17/81	D&M	D				0.110				0.248		12.60
Station 30	8/12/81	D&M	D				0.184				0.009		23.60
Station 30	9/5/81	D&M	D				0.182		0.007		0.003		12.90
Station 30	5/31/82	D&M											
Station 30	7/6/82	EVS	T		1.60		0.091				0.240		13.40
Station 30	7/6/82	EVS	D		0.44		0.084				0.230		12.40
Station 30	7/8/82	D&M	T		0.30		0.115		0..0130		0.257		15.90
Station 30	7/8/82	D&M	D				0.114				0.169		15.50
Station 30	7/23/82	EVS	T		2.31		0.210				1.110		28.50
Station 30	7/23/82	EVS	D		1.50		0.190				0.870		27.40
Station 30	7/23/82	EVS	T		1.27		0.190				0.650		26.70
Station 30	7/23/82	EVS	D		0.31		0.190				0.640		26.10
Station 30	7/24/82	EVS	T		1.34		0.180				0.990		25.80
Station 30	7/24/82	EVS	D		0.94		0.940				0.880		24.30
Station 30	7/26/82	EVS	T		0.17		0.078				0.110		10.50
Station 30	7/26/82	EVS	D	<	0.15		0.075			<	0.080		10.40
Station 30	7/29/82	EVS	T		1.02		0.140				0.350		18.60
Station 30	7/29/82	EVS	D		0.60		0.140				0.350		17.90
Station 30	7/30/82	EVS	T		0.64		0.120				0.400		16.70
Station 30	7/30/82	EVS	D		0.50		0.130				0.190		16.60

Appendix 11, continued.

Metals Concentrations before Mine Development													
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Station 30	7/31/82	EVS	T		0.76		0.110				0.320		14.20
Station 30	7/31/82	EVS	D		0.53		0.110				0.340		14.00
Station 30	8/1/82	EVS	T		0.69		0.110				0.310		14.80
Station 30	8/1/82	EVS	D		0.48		0.110				0.310		14.60
Station 30	8/13/82	D&M	T		0.40		0.141		0.028		0.253		15.80
Station 30	8/13/82	D&M	D				0.137				0.007		15.10
Station 30	8/14/82	EVS	T		0.95		0.075				0.270		9.12
Station 30	8/14/82	EVS	D		0.24		0.071				0.190		9.06
Station 30	9/13/82	D&M	T		1.25		0.213		0.019		0.278		22.40
Station 30	9/13/82	D&M	D				0.210				0.014		22.20
Station 30	10/19/82	D&M	T		0.72		0.481		0.007		0.462		49.80
Station 30	10/19/82	D&M	D				0.445				0.412		49.20
Middle Fork Red Dog Creek													
Station 140	7/6/82	EVS	T		1.60		0.091				0.240		13.40
Station 140	7/6/82	EVS	D		0.44		0.084				0.230		12.40
Station 140	7/23/82	EVS	T		2.31		0.210				1.110		28.50
Station 140	7/23/82	EVS	D		1.50		0.190				0.870		27.40
Station 140	7/23/82	EVS	T		1.27		0.190				0.650		26.70
Station 140	7/23/82	EVS	D		0.81		0.190				0.640		26.10
Station 140	7/24/82	EVS	T		1.34		0.180				0.990		25.80
Station 140	7/24/82	EVS	D		0.94		0.170				0.880		24.30
Station 140	7/26/82	EVS	T		0.17		0.078				0.110		10.50
Station 140	7/26/82	EVS	D	<	0.15		0.075			<	0.080		10.40
Station 140	7/29/82	EVS	T		1.02		0.140				0.350		18.60
Station 140	7/29/82	EVS	D		0.60		0.140				0.350		17.90
Station 140	7/30/82	EVS	T		0.64		0.120				0.400		16.70
Station 140	7/30/82	EVS	D		0.50		0.130				0.190		16.60
Station 140	7/31/82	EVS	T		0.76		0.110				0.320		14.20
Station 140	7/31/82	EVS	D		0.53		0.110				0.340		14.00
Station 140	8/1/82	EVS	T		0.69		0.110				0.310		14.80
Station 140	8/1/82	EVS	D		0.48		0.110				0.310		14.60
Station 140	8/14/82	EVS	T		0.95		0.075				0.270		9.12
Station 140	8/14/82	EVS	D		0.24		0.071				0.190		9.06
North Fork Red Dog Creek													
Station 12	6/17/81	D&M	D				0.005			<	0.000		0.02
Station 12	7/17/81	D&M	D				0.003			<	0.000		0.04
Station 12	8/12/81	D&M	D				0.009			<	0.000		0.05
Station 12	9/4/81	D&M	D				0.002				0.000		0.01

Appendix 11, continued.

Metals Concentrations before Mine Development													
Station	DATE	Source	Report*		Al		Cd		Cu		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L
Station 12	5/31/82	D&M	T	<	0.02	<	0.000		0.003		0.001		0.08
Station 12	7/7/82	D&M	T	<	0.02		0.002		0.002		0.001		0.01
Station 12	7/23/82	EVS	T		0.21	<	0.025			<	0.080		0.07
Station 12	7/23/82	EVS	D	<	0.15	<	0.025			<	0.080		0.02
Station 12	7/23/82	EVS	T		0.35	<	0.025			<	0.080		0.37
Station 12	7/23/82	EVS	D	<	0.15	<	0.025			<	0.080		0.15
Station 12	7/24/82	EVS	T		0.29	<	0.025			<	0.080		0.05
Station 12	7/24/82	EVS	D	<	0.15	<	0.025			<	0.080	<	0.02
Station 12	7/26/82	EVS	D	<	0.15	<	0.025			<	0.080		0.05
Station 12	7/29/82	EVS	T		0.32	<	0.025			<	0.080		0.02
Station 12	7/29/82	EVS	D	<	0.15	<	0.025			<	0.080	<	0.02
Station 12	7/30/82	EVS	T		0.55	<	0.025			<	0.080		0.02
Station 12	7/30/82	EVS	D		0.16	<	0.025			<	0.080	<	0.02
Station 12	7/31/82	EVS	T		0.26	<	0.025			<	0.080	<	0.02
Station 12	7/31/82	EVS	D	<	0.15	<	0.025			<	0.080		0.02
Station 12	8/1/82	EVS	T	<	0.15	<	0.025			<	0.080		0.02
Station 12	8/1/82	EVS	D	<	0.15	<	0.025			<	0.080	<	0.02
Station 12	8/7/82	EVS	T		0.41	<	0.025			<	0.080	<	0.02
Station 12	8/12/82	D&M	T		0.13	<	0.002		0.013		0.002		0.02
Station 12	8/12/82	EVS	T	<	0.15	<	0.025			<	0.080		0.13
Station 12	8/12/82	EVS	D	<	0.15	<	0.025			<	0.080		0.03
Station 12	8/14/82	EVS	T		0.34	<	0.001			<	0.008		0.11
Station 12	8/14/82	EVS	D	<	0.15	<	0.001			<	0.001		0.06
Station 12	9/13/82	D&M	T		0.31		0.002		0.005		0.001		0.01
Station 12	10/19/82	D&M	T	<	0.02		0.002		0.006		0.001		0.02

Appendix 11, continued.

DATE	REF.		Report		Cd		Pb		Zn
					mg/L		mg/L		mg/L
Sulfur Creek, Station 34									
7/15/81	D&M		D		0.008		0.0719		0.188
8/11/81	D&M		D		0.005		0.2650		0.970
9/4/82	D&M		D		0.007		0.0481		1.167
Shelly Creek, Station 38									
9/4/81	D&M		D		0.013		0.0037		0.694
7/7/82	D&M		T		0.019		0.0220		0.613
8/13/82	D&M		T		0.006		0.0099		0.340
9/13/82	D&M		T		0.021		0.0256		0.910
10/20/82	D&M		T		0.028		0.0801		2.310
Connie Creek, Station 40									
9/4/81	D&M		D.		0.013		0.0041		0.222
3/23/82	D&M		D		0.002		0.0021		0.002
7/7/82	D&M		T		0.012		0.0181		0.201
8/13/82	D&M		T		0.011		0.0213		0.761
9/13/82	D&M		T		0.005		0.0158		0.756
10/20/82	D&M		T		0.021		0.0267		2.420
Rachael Creek, Station 47									
7/7/82	D&M		T		0.008		0.0006		0.061
8/13/82	D&M		T		0.002		0.0034		0.079
9/13/82	D&M		T		0.002		0.0005		0.142
10/20/82	D&M		T		0.002		0.0010		0.100
Middle Fork Red Dog Creek, Station 45									
6/15/81	D&M		D		0.011		0.0010		1.700
8/11/81	D&M		D		0.008		0.0032		0.284
9/4/81	D&M		D		0.006		0.0010		0.213
7/6/82	EVS		T	<	0.001		0.0020		0.053
7/6/82	EVS		D	<	0.001		0.0020		0.039
7/7/82	D&M		T		0.010		0.0006		0.045
7/23/82	EVS		T	<	0.025	<	0.0800		0.370
7/23/82	EVS		D	<	0.025	<	0.0800		0.089
7/23/82	EVS		T	<	0.025	<	0.0800		0.069
7/23/82	EVS		D	<	0.025	<	0.0800		0.036
7/24/82	EVS		T	<	0.025	<	0.0800		0.051

Appendix 11, concluded.

DATE	REF.		Report		Cd		Pb		Zn
					mg/L		mg/L		mg/L
Middle Fork Red Dog Creek, Station 45, continued									
7/24/82	EVS		D	<	0.025	<	0.0800		0.049
7/26/82	EVS		D	<	0.025	<	0.0800		0.120
7/29/82	EVS		T	<	0.025	<	0.0800		0.088
7/29/82	EVS		D	<	0.025	<	0.0800		0.058
7/30/82	EVS		T	<	0.025	<	0.0800		0.088
7/30/82	EVS		D	<	0.025	<	0.0800		0.055
7/31/82	EVS		T	<	0.025	<	0.0800		0.078
7/31/82	EVS		D	<	0.025	<	0.0800		0.055
8/1/82	EVS		T	<	0.025	<	0.0800		0.086
8/1/82	EVS		D	<	0.025	<	0.0800		0.066
8/13/82	D&M		T		0.004		0.0008		0.028
8/14/82	EVS		T	<	0.001		0.0040		0.200
8/14/82	EVS		D	<	0.001	<	0.0010		0.150
9/13/82	D&M		T		0.002		0.0009		0.075
10/20/82	D&M		T		0.002		0.0004		0.034
9/4/81	D&M		D		0.021		0.0152		0.682

Appendix 12. Water quality and metals data, 1991-1995.

Ikalukrok Creek: Station 8 and Station 73													
Water Quality													
Station	Date	Reference	Hard	TDS	SO4		TSS	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
			mg/L	mg/L	mg/L		mg/L		°C	mg/L	NTU		
Station 08	8/3/91	Cominco	143	174		<	5	6.8	11.2	10.6	0.6	576	
Station 08	8/8/91	Cominco	252	384		<	5	7.0	6.6	11.1	0.9	320	
Station 08	8/9/91	Cominco	269	406			5	7.0	5.7	12.9	1.3	497	
Station 08	8/13/91	Cominco	179	257			6	7.5	10.0	13.6	1.4		
Station 08	8/16/91	Cominco	164	299		<	5	7.4	11.5	10.3			
Station 08	8/19/91	Cominco	200	280		<	5	7.1	10.7	12.8			
Station 08	8/24/91	Cominco	270	369		<	5	7.4	5.8	13.1	0.4	310	
Station 08	8/27/91	Cominco	174	221		<	5	7.2	5.1	13.2	0.7	215	
Station 08	8/29/91	Cominco	179	232		<	5	7.0	4.3	12.0	1.3	215	
Station 08	10/2/91	Cominco	174	261		<	5	7.1	2	13	0.4	440	
Station 08	10/5/91	Cominco	181	251		<	5	7.3	-0.2	15**	0.7	376	
Station 08	5/27/92	Cominco	277	429		<	5	5.7	2.6	4	0.9	0.844	
Station 08	6/10/92	Cominco	53.1	64			26	7.4	0.2	7.9	2.9	0.110	
Station 08	6/16/92	Cominco	54.3	73			56	6.2	2.4	10.6	20	0.118	
Station 08	6/24/92	Cominco	77	95		<	5	7.5	7.6	16.2**	2.7	0.163	
Station 08	7/2/92	Cominco	107	134		<	5	7.2	9.6	8.9	1.30	0.202	
Station 08	7/2/92	Cominco	107	134		<	5	7.2	9.6	8.9			1.30
Station 08	7/8/92	Cominco	126	165		<	5	7.4	12.3	10.2	0.45	0.268	
Station 08	7/8/92	Cominco	126	165		<	5	7.4	12.3	10.2			0.45
Station 08	7/15/92	Cominco	168	209		<	5	7.4	8.7	8.3	0.34	0.351	
Station 08	7/15/92	Cominco	168	209		<	5	7.4	8.7	8.3			0.34
Station 08	7/18/92	Cominco	154	201		<	5	7.9	11.2	7.6	0.47	0.331	
Station 08	7/18/92	Cominco	154	201		<	5	7.9	11.2	7.6			0.47
Station 08	7/22/92	Cominco	224	311		<	5	7.8	9.3	8.6	0.35	0.440	
Station 08	7/22/92	Cominco	224	311		<	5	7.8	9.3	8.6			0.35
Station 08	7/25/92	Cominco	241	337		<	5	7.2	11.2	12.1	---	0.485	
Station 08	7/25/92	Cominco	241	337		<	5	7.2	11.2	12.1			---
Station 08	7/29/92	Cominco	392	548		<	5	7.4	13.6	9.2			0.60
Station 08	7/29/92	Cominco	392	548		<	5	7.4	13.6	9.2	0.60	0.783	
Station 08	9/2/92	Cominco	162	201		<	5	7.0	5.2	13.2	0.53	0.330	
Station 08	9/5/92	Cominco	237	312		<	5	8.2	4.7	7.3	0.35	0.446	
Station 08	9/9/92	Cominco	333	431		<	5	7.6	1.4	6.5	0.27	0.555	
Station 08	9/12/92	Cominco	273	376		<	5	8.2	0.6		0.3	0.584	
Station 08	9/16/92	Cominco	344	461		<	5	8.2	0.3		0.5	0.667	
Station 08	9/22/92	Cominco	389	540		<	5	8.1	0	12.8	0.25	0.630	
Station 08	9/26/92	Cominco	356	500		<	5	7.5	0	14.8**	0.46	0.330	
Station 08	9/30/92	Cominco	476	699		<	5	7.6	0	10.8	0.3	0.980	
Station 08	10/3/92	Cominco	798	1040		<	5	7.5	-0.5	12.0	0.24	1.350	
Station 08	10/10/92	Cominco	472	623		<	5	7.7	0	11.5	0.38	0.890	
Station 08	10/15/92	Cominco	262	328		<	5	7.4	0.1	10.4	0.33	0.510	
Station 73	6/3/93	Cominco	55.9	68			18	7.4	3	20	9.2	50	
Station 73	6/10/93	Cominco	78.3	101		<	5	7.7	7	16	16	127	
Station 73	6/20/93	Cominco	92.5	98		<	5	7.8	11	8.4	0.9	178	
Station 73	6/24/93	Cominco	126	161		<	5	7.1	11	9.6	0.8	250	

Appendix 12, continued.

Ikalukrok Creek: Station 8 and Station 73													
Water Quality													
Station	Date	Reference	Hard	TDS	SO4		TSS	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
			mg/L	mg/L	mg/L		mg/L		°C	mg/L	NTU		
Station 73	6/29/93	Cominco	135	144		<	5	6.7	10	9.5	0.5	267	
Station 73	7/9/93	Cominco	101	125			8	7.5	6	13.4	2	223	
Station 73	7/18/93	Cominco	127	176		<	5	7.7	15	11.8	0.4	270	
Station 73	7/24/93	Cominco	159	182		<	5	8.2	13.5	10.2	0.2	295	
Station 73	8/1/93	Cominco		187		<	5	7.8	6.7	11.2	0.56	420	
Station 73	8/12/93	Cominco		181		<	5	7.4	5		0.24	285	
Station 73	8/21/93	Cominco		171		<	5	8.1	11		0.64	262	
Station 73	8/28/93	Cominco		229		<	5	8	7				
Station 73	9/4/93	Cominco	191	205		<	5	7.9	4				
Station 73	9/8/93	Cominco	168	200		<	5	8	4				
Station 73	9/12/93	Cominco	172	213		<	5	7.7	5.5	11.1	0.38	366	131.5
Station 73	9/20/93	Cominco		188		<	5	7.4	4.5	12.5	0.3	327	248.3
Station 73	10/10/93	Cominco	183	204		<	5	7.8	2	8.1	1.1	361	
Station 73	5/18/94	Cominco	43.2	57	19		16	7.4	2	12.3	5.4		1083
Station 73	5/22/94	Cominco	54.3	72	21		22	7.4	1	12.8	8.7		1145
Station 73	6/2/94	Cominco	98.6	136	50	<	5	7.7	4	12.4	1.1	286	218
Station 73	6/9/94	Cominco	83.2	96	34	<	5	7.2	7.3	11.5	1.5	177	571
Station 73	6/22/94	Cominco	148	181	68	<	5	8.2	6.5	9.1	0.5	143	106
Station 73	6/26/94	Cominco	131	153	53	<	5	7.9	8.4	9.5	0.7	247	135
Station 73	6/28/94	Cominco	135	168	59	<	5	8.1	2.9	7.5	0.9	280	120
Station 73	7/3/94	Cominco	117	133	40	<	5	8	3.9	9.5	1.1	220	179
Station 73	7/13/94	Cominco	111	143	40	<	5	7.2	4	10.4	3	197	575
Station 73	7/19/94	Cominco	116	142	34	<	5	7.9	7.9	9.4	0.8	222	348
Station 73	7/27/94	Cominco	223	144	42	<	5	7.9	7.7	9.9	1.3	241	361
Station 73	8/5/94	Cominco	134	166	58	<	5	7.8	7.4	9.9	9.9	210	
Station 73	8/11/94	Cominco	98.1	109	27		41	7.7	4.3	12.2	15	197	
Station 73	8/15/94	Cominco	103	123	41		17	7.6	2.5	12.2	0.6	209	
Station 73	8/23/94	Cominco	121	166	57		6	7.4	4	12.4	4.3	253	
Station 73	9/1/94	Cominco	175	252	110		8	7.7	4	11.8	2.4	250	
Station 73	9/9/94	Cominco	216	307	140	<	5	7.7	4	11.1	2.3	431	
Station 73	9/13/94	Cominco	274	377	200	<	5	7.6	3.9	8.6	2.6	518	
Station 73	9/22/94	Cominco	304	386	190	<	5	7.7	1	11.6	1.5	548	
Station 73	9/25/94	Cominco	430	557	180	<	5	7.7	1	12.6	1	642	
Station 73	10/2/94	Cominco	498	658	400	<	5	7.7	1	13.2	1	690	
Station 73	10/17/94	Cominco	391	627	290	<	5	7.6	0	12.8	0.8	790	
Station 08	5/20/95	Cominco	121	159	93			7.2	2				
Station 08	5/25/95	Cominco	82.5	122	60			7.1	3				
Station 08	5/30/95	Cominco	100	130	64			7.3					
Station 73	6/3/95	Cominco	120	157	79		7	7.6	4		2.2	261	
Station 73	6/4/95	Cominco	183	260	130		5	7.2	1	12.7	2.7	372	
Station 73	6/11/95	Cominco		164	96	<	5		3	13	1.85	267	
Station 73	6/13/95	Cominco		254		<	5						
Station 73	6/18/95	Cominco		190		<	5	7.7	4	14.5	2.48	289	

Appendix 12, continued.

Ikalukrok Creek: Station 8 and Station 73													
Water Quality													
Station	Date	Reference	Hard	TDS	SO4		TSS	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
			mg/L	mg/L	mg/L		mg/L		°C	mg/L	NTU		
Station 73	6/25/95	Cominco	196	264				7.9	5.5	14.5	1.18	420	
Station 73	6/27/95	Cominco						7.8	6.1	12.9	1.21	442	
Station 73	6/29/95	Cominco											
Station 8	7/2/95	Cominco	99.2	118	42	<	5	7.8	7				
Station 8	7/10/95	Cominco	292	414	250			7.7	7				
Station 8	7/16/95	Cominco	129	681	400			7.7	10				
Station 8	8/6/95	Cominco	666	906	590			7.7	9.6				
Station 8	8/16/95	Cominco	184	209	100			7.9	8.7				
Station 8	8/22/95	Cominco	609	877	560			7.9	10.6				

Appendix 12, continued.

Ikalukrok Creek: Station 8 and Station 73

Station	Date	Reference	matrix		Al		Cd		Cu		Fe		Pb		Zn
					mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
Station 08	8/3/91	Cominco	TR	<	0.05		0.011	<	0.01	<	0.020		0.009		1.900
Station 08	8/8/91	Cominco	TR	<	0.05		0.022	<	0.01		0.04		0.015		3.610
Station 08	8/9/91	Cominco	TR	<	0.05		0.018	<	0.01		0.02		0.011		2.700
Station 08	8/13/91	Cominco	TR	<	0.05		0.040	<	0.01		0.04		0.006		1.420
Station 08	8/16/91	Cominco	TR	<	0.05		0.007	<	0.01		0.08	<	0.002		1.070
Station 08	8/19/91	Cominco	TR	<	0.05		0.012	<	0.01		0.06		0.001		1.540
Station 08	8/24/91	Cominco	TR	<	0.05		0.014	<	0.01		0.04		0.009		1.920
Station 08	8/27/91	Cominco	TR	<	0.05		0.010	<	0.01		0.09		0.008		1.610
Station 08	8/29/91	Cominco	TR	<	0.05		0.009	<	0.01		0.06		0.005		1.630
Station 08	10/2/91	Cominco	TR	<	0.05		0.012	<	0.01		0.06		0.007		1.570
Station 08	10/5/91	Cominco	TR	<	0.05		0.018	<	0.01		0.09		0.023		2.850
Station 08	5/27/92	Cominco	TR	<	0.05		0.018	<	0.01		0.06		0.088		2.660
Station 08	6/10/92	Cominco	TR		0.45	<	0.003	<	0.01		1.04		0.005		1.100
Station 08	6/16/92	Cominco	TR		0.73		0.006	<	0.01		2.38		0.094		0.721
Station 08	6/24/92	Cominco	TR	<	0.05	<	0.003	<	0.01		0.164		0.006		0.305
Station 08	7/2/92	Cominco	TR	<	0.05		0.005	<	0.01		0.079		0.003		0.484
Station 08	7/2/92	Cominco	TR	<	0.05		0.005	<	0.01		0.079		0.003		0.484
Station 08	7/8/92	Cominco	TR	<	0.05		0.004	<	0.01		0.023	<	0.002		0.370
Station 08	7/8/92	Cominco	TR	<	0.05		0.004	<	0.01		0.023	<	0.002		0.370
Station 08	7/15/92	Cominco	TR	<	0.05	<	0.003	<	0.01		0.049	<	0.002		0.362
Station 08	7/15/92	Cominco	TR	<	0.05	<	0.003	<	0.01		0.049	<	0.002		0.362
Station 08	7/18/92	Cominco	TR	<	0.05	<	0.003	<	0.01		0.047	<	0.002		0.344
Station 08	7/18/92	Cominco	TR	<	0.05	<	0.003	<	0.01		0.047	<	0.002		0.344
Station 08	7/22/92	Cominco	TR		0.07		0.008	<	0.01		0.118	<	0.002		0.903
Station 08	7/22/92	Cominco	TR		0.07		0.008	<	0.01		0.118		0.002		0.903
Station 08	7/25/92	Cominco	TR		0.06		0.009	<	0.01		0.046	<	0.002		0.826
Station 08	7/25/92	Cominco	TR		0.06		0.009	<	0.01		0.046	<	0.002		0.826
Station 08	7/29/92	Cominco	TR	<	0.05		0.022	<	0.01		0.064	<	0.002		1.950
Station 08	7/29/92	Cominco	TR	<	0.05		0.022	<	0.01		0.064	<	0.002		1.950
Station 08	9/2/92	Cominco	TR	<	0.05		0.006	<	0.01		0.06		0.012		0.771
Station 08	9/5/92	Cominco	TR	<	0.05		0.007	<	0.01		0.06		0.007		0.914
Station 08	9/9/92	Cominco	TR	<	0.05		0.01		0.011		0.05		0.006		1.310
Station 08	9/12/92	Cominco	TR	<	0.05		0.007	<	0.01		0.07	<	0.002		1.010
Station 08	9/16/92	Cominco	TR	<	0.05		0.011	<	0.01		0.10		0.003		1.240
Station 08	9/22/92	Cominco	TR	<	0.05		0.01	<	0.01		0.10	<	0.002		1.390
Station 08	9/26/92	Cominco	TR	<	0.05		0.011	<	0.01		0.06	<	0.002		1.440
Station 08	9/30/92	Cominco	TR	<	0.05		0.019	<	0.01		0.06	<	0.002		2.230
Station 08	10/3/92	Cominco	TR	<	0.05		0.024	<	0.01		0.069		0.002		3.120
Station 08	10/10/92	Cominco	TR	<	0.05		0.014	<	0.01		0.05	<	0.002		1.900
Station 08	10/15/92	Cominco	TR	<	0.05		0.005	<	0.01		0.046		0.003		0.790
Station 73	6/3/93	Cominco	TR		0.28	<	0.003						0.009		0.164
Station 73	6/10/93	Cominco	TR		0.06	<	0.003						0.004		0.16
Station 73	6/20/93	Cominco	TR	<	0.05	<	0.003						0.003		0.143
Station 73	6/24/93	Cominco	TR		0.05	<	0.003					<	0.002		0.389

Appendix 12, continued.

Ikalukrok Creek: Station 8 and Station 73									
Station	Date	Reference	matrix	Al	Cd	Cu	Fe	Pb	Zn
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Station 73	6/29/93	Cominco	TR	< 0.05	< 0.003			< 0.002	0.233
Station 73	7/9/93	Cominco	TR	0.1	< 0.003		0.179	0.004	0.151
Station 73	7/18/93	Cominco	TR	< 0.05	< 0.003		0.052	0.002	0.15
Station 73	7/24/93	Cominco	TR	< 0.05	< 0.003		< 0.02	< 0.002	0.156
Station 73	8/1/93	Cominco	TR	< 0.05	< 0.003			0.003	0.154
Station 73	8/12/93	Cominco	TR	< 0.05	< 0.003			< 0.002	0.216
Station 73	8/21/93	Cominco	TR	< 0.05	< 0.003			0.004	0.169
Station 73	8/28/93	Cominco	TR	< 0.05	< 0.003			< 0.002	0.239
Station 73	9/4/93	Cominco	TR	< 0.05	< 0.003		0.054	< 0.002	0.23
Station 73	9/8/93	Cominco	TR	< 0.05	< 0.003		0.06	< 0.002	0.203
Station 73	9/12/93	Cominco	TR	< 0.05	< 0.003		0.056	0.003	0.279
Station 73	9/20/93	Cominco	TR	< 0.05	< 0.003		0.081	0.003	0.208
Station 73	10/10/93	Cominco	TR	< 0.05	< 0.003		0.096	< 0.002	0.282
Station 73	5/18/94	Cominco	TR	0.427	0.004		0.954	0.05	0.416
Station 73	5/22/94	Cominco	TR	0.423	< 0.003		0.978	0.022	0.275
Station 73	6/2/94	Cominco	TR	0.056	0.004		0.138	0.003	0.212
Station 73	6/9/94	Cominco	TR	0.059	< 0.003		0.148	0.004	0.153
Station 73	6/22/94	Cominco	TR	< 0.05	< 0.003		0.049	< 0.002	0.206
Station 73	6/26/94	Cominco	TR	< 0.05	< 0.003		0.035	< 0.002	0.168
Station 73	6/28/94	Cominco	TR	< 0.05	< 0.003		0.073	0.05	0.183
Station 73	7/3/94	Cominco	TR	< 0.05	< 0.003		0.099	0.022	0.134
Station 73	7/13/94	Cominco	TR	0.094	0.004		0.263	0.01	0.467
Station 73	7/19/94	Cominco	TR	< 0.05	< 0.003		0.085	< 0.002	0.135
Station 73	7/27/94	Cominco	TR	< 0.05	0.005		0.225	0.006	0.338
Station 73	8/5/94	Cominco	TR	0.058	< 0.003		0.107	0.005	0.232
Station 73	8/11/94	Cominco	TR	1.02	< 0.003		1.5	0.033	0.282
Station 73	8/15/94	Cominco	TR	0.563	< 0.003		0.872	0.017	0.31
Station 73	8/23/94	Cominco	TR	0.334	0.01		0.86	0.016	1.19
Station 73	9/1/94	Cominco	TR	0.343	0.006		0.812	0.016	0.672
Station 73	9/9/94	Cominco	TR	0.354	0.007	< 0.01	0.617	0.008	0.841
Station 73	9/13/94	Cominco	TR	0.295	0.007		0.643	0.006	0.788
Station 73	9/22/94	Cominco	TR	0.3	0.004		0.359	< 0.002	0.432
Station 73	9/25/94	Cominco	TR	0.153	0.007		0.303	< 0.002	0.791
Station 73	10/2/94	Cominco	TR	0.134	0.007		0.387	0.003	0.865
Station 73	10/17/94	Cominco	TR	< 0.05	0.006		0.098	< 0.002	0.577
Station 08	5/20/95	Cominco	TR	0.967	0.01	< 0.01		0.095	1.71
Station 08	5/25/95	Cominco	TR	1.06	0.009	< 0.01		0.106	1.29
Station 08	5/30/95	Cominco	TR	0.299	0.008	< 0.01		0.03	1.11
Station 73	6/3/95	Cominco	TR	0.208	0.00332	0.00442	0.661	0.0081	0.434
Station 73	6/4/95	Cominco	TR	0.19	0.00483	0.0045	0.67	0.00565	0.619
Station 73	6/11/95	Cominco	TR	0.145	0.00303	0.00322		0.00267	0.39
Station 73	6/13/95	Cominco	TR		0.00398	0.0029		0.00487	0.537
Station 73	6/18/95	Cominco	TR		0.00379	0.0034		0.00555	0.46

Appendix 12, continued.

Ikalukrok Creek: Station 8 and Station 73										
Station	Date	Reference	matrix		Al	Cd	Cu	Fe	Pb	Zn
					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Station 73	6/25/95	Cominco	TR		0.112	0.00433	0.0029	0.286	0.00367	0.593
Station 73	6/27/95	Cominco	TR			0.0055	0.004		0.00377	0.648
Station 73	6/29/95	Cominco	TR			0.00377	0.003		0.00354	0.509
Station 8	7/2/95	Cominco	TR		0.152	0.00078	0.0024		0.00135	0.138
Station 8	7/10/95	Cominco	TR		0.105	0.0125	0.0035		0.0115	1.73
Station 8	7/16/95	Cominco	TR	<	0.05	0.0152	0.0031		0.00881	1.56
Station 8	8/6/95	Cominco	TR	<	0.057	0.0185	0.0021		0.00718	1.95
Station 8	8/16/95	Cominco	TR		0.145	0.00069	0.003		0.00058	0.14
Station 8	8/22/95	Cominco	TR		0.067	0.0198	0.0016		0.00831	2.01

Appendix 12, continued.

Station 10, Mainstem Red Dog Creek										
Water Quality										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
8/3/91	Cominco	179	237		6.7	12.7	10.9	0.5	665	
8/8/91	Cominco	347	546		6.9	7.0	10.7	1.7	420	
8/9/91	Cominco	398	621		7.1	6.1	11.8	0.7	575	
8/13/91	Cominco	344	552		7.1	11.7	9.9	1.3		
8/16/91	Cominco	269	352		6.8	14.1	9.5			
8/19/91	Cominco	190	610		7.0	13.4	12.2			
8/24/91	Cominco	563	831		7.1	6.0	11.5	0.5	600	
8/26/91	Cominco				7.0	4.2	13.0	1.0	285	
8/27/91	Cominco	242	346							
8/29/91	Cominco	233	329		6.8	3.0	12.8	3.5	270	
10/2/91	Cominco	221	207		7.0	2	14	0.2	542	
10/5/91	Cominco	181	235		7.3	-0.2	14	0.6	389	
10/8/91	Cominco	245	331		7.5			0.5		
5/27/92	Cominco	227	331		6.2	1.9	4.9	1.5	0.547	
6/10/92	Cominco	64.7	91		7.4	0	9.8	3.4	0.136	
6/16/92	Cominco	52.7	67		6.1	2	10.2	20	0.114	
6/24/92	Cominco	97.4	123		7.6	7.9	13.4	3.7	0.202	
7/2/92	Cominco	130	173		7.2	10.5	9.0	2.50	0.244	
7/8/92	Cominco	162	205		7.3	12.4	9.9			0.84
7/15/92	Cominco	293	431		7.4	9.7	6.8	0.27	0.635	
7/18/92	Cominco	219	302		8.0	12.3	7.1	0.36	0.470	
7/22/92	Cominco	394	564		7.8	10.3	8.0			0.17
7/25/92	Cominco	472	675		7.9	11.9	10.9			---
7/29/92	Cominco	619	937		7.1	13.9	8.7	0.21	1.150	
8/1/92	Cominco	709	1060		7.5	13.2	11.0	0.2	1.220	
8/5/92	Cominco	828	1230		7.4	12.4	8.7	0.2	1.420	
8/8/92	Cominco	742	994		7.7	10.1	9.2	0.5	1.200	
8/12/92	Cominco	240	346		7.9	5.4	7.3	0.5	0.483	
8/15/92	Cominco	329	438		7.0	4.4	7.8	0.3	0.512	
8/17/92	Cominco	342	195		7.4	6.7	9.8	0.4	0.651	
8/22/92	Cominco	199	232		8.0	6.5	9.7	1.9	0.369	
8/29/92	Cominco	344	505		7.6	8.2	7.7	0.3	0.680	
9/2/92	Cominco	192	237		7.0	5.3	12.5	0.65	0.304	
9/5/92	Cominco	331	447		8.1	5	11.3	0.45	0.624	
9/9/92	Cominco	446	618		7.5	1.3	8.4	0.39	0.767	
9/12/92	Cominco	489	689		8.1	1.1		0.3	0.914	
9/16/92	Cominco	749	1100		8.0	0.1		0.44	1.330	
9/22/92	Cominco	761	1140		7.8	0	12	0.22	1.400	
9/26/92	Cominco	713	1070		7.2	0	12.3	0.46	1.001	

Appendix 12, continued.

Station 10, Mainstem Red Dog Creek										
Water Quality										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
9/30/92	Cominco	893	1311		7.3	0	10.4	0.25	1.460	
10/3/92	Cominco	1540	1850		7.2	-0.5	10.3	0.37	2.090	
10/10/92	Cominco	900	1290		7.4	0	11	0.76	1.470	
10/15/92	Cominco	421	533		7.4	0.1	11.6	0.22	0.736	
5/28/93	Cominco		50		7.2	1	11.2	3.4	77	400
6/5/93	Cominco		74		7.6	6				
6/13/93	Cominco		103		7.2	7				
6/19/93	Cominco		120		8.2	12				
6/24/93	Cominco		242		6.8	10				
6/29/93	Cominco		369		7.2	12				
7/10/93	Cominco		177		7	10				
7/14/93	Cominco		202		7.9	13				
7/21/93	Cominco		227		7.9	17				
8/6/93	Cominco		176		7.3	5				
8/14/93	Cominco		269		6.9	7				
8/20/93	Cominco		256		7.9	7				
8/29/93	Cominco		330		7.9	7				
9/2/93	Cominco		365		7.8	3				32.7
9/10/93	Cominco		233		7.7	3				80.2
9/14/93	Cominco		157		7.5	5.5				285
9/25/93	Cominco		244		7.8	1				40.6
6/11/94	Cominco	101	131	58	7.8	5				
6/15/94	Cominco	136	166	84	7.8	7.8				
6/25/94	Cominco	150	190	85	7.9	10.1				
6/30/94	Cominco	191	253	120	7.9	3.8				135.1
7/13/94	Cominco	132	168	59	7.5	5				95.8
7/22/94	Cominco	157	195	72	7.8	7.5				42.8
7/24/94	Cominco	99.3	127	43	7.7	7.5				240
8/3/94	Cominco	163	203	93	7.7	6.3				
8/9/94	Cominco	233	320	140	7.7	8.6				
8/21/94	Cominco	119	168	63	7.3	4				
8/23/94	Cominco	131	182	64	7.3	4				
9/1/94	Cominco	307	447	240	7.6	4				143
9/8/94	Cominco	416	583	320	7.7	4				120
9/11/94	Cominco	454	659	400	7.6	4				97
9/18/94	Cominco	773	1100	680	7.8	3				55
9/25/94	Cominco	1100	1510	1600	7.6	1				36
10/2/94	Cominco	1060	1520	800	7.7	1				

Appendix 12, continued.

Station 10, Mainstem Red Dog Creek										
Water Quality										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
10/14/94	Cominco	1040	1610	1000	7.2	0				
6/3/95	Cominco	247	171	210	7.2	3.0		2	507	
6/8/95	Cominco	336	459		7.1	3.0		3	97	
6/11/95	Cominco		525	350	7.5	8.0		1	638	
6/13/95	Cominco		688					1		
6/18/95	Cominco		588		7.6	6.4		1	666	
6/25/95	Cominco		745		7.6	8		0	958	
6/27/95	Cominco		824		7.6	8			1029	
6/29/95	Cominco	580	885	550						
6/29/95	Cominco		824							
7/2/95	Cominco	443	664	410	7.7	10			812	
7/10/95	Cominco	406	610	400						
7/12/95	Cominco		830	650						
7/16/95	Cominco	675	1060		7.8	10			1206	
7/23/95	Cominco		1240		7.6	10.9			1499	
8/2/95	Cominco		1610		7.5	13			1775	
8/6/95	Cominco	965	1470	1000	7.6	10.5			1719	
8/16/95	Cominco	1070	1510	940	7.7	12.8			1790	
8/20/95	Cominco	975	1380	970	7.7	9.5			1769	
8/27/95	Cominco		1400		7.8	10.5			656	

Appendix 12, continued.

Station 10, Mainstem Red Dog Creek														
Metals Concentrations														
Date	Reference	matrix		Al		Cd		Cu		Fe		Pb		Zn
				mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
8/3/91	Cominco	TR	<	0.05		0.034	<	0.01	<	0.020		0.027		5.740
8/8/91	Cominco	TR	<	0.05		0.039	<	0.01	<	0.020		0.026		6.080
8/9/91	Cominco	TR	<	0.05		0.040	<	0.01	<	0.020		0.026		6.360
8/13/91	Cominco	TR	<	0.05		0.040	<	0.01	<	0.020		0.026		5.800
8/16/91	Cominco	TR	<	0.05		0.035	<	0.01	<	0.020		0.014		5.090
8/19/91	Cominco	TR	<	0.05		0.047	<	0.01	<	0.020		0.028		6.540
8/24/91	Cominco	TR	<	0.05		0.042	<	0.01	<	0.020		0.028		6.210
8/26/91	Cominco	TR												
8/27/91	Cominco	TR	<	0.05		0.035	<	0.01		0.02		0.026		5.890
8/29/91	Cominco	TR	<	0.05		0.036	<	0.01	<	0.020		0.022		6.050
10/2/91	Cominco	TR	<	0.05		0.028	<	0.01		0.03		0.015		3.890
10/5/91	Cominco	TR	<	0.05		0.010	<	0.01		0.06		0.013		1.580
10/8/91	Cominco	TR	<	0.05		0.024	<	0.01		0.03		0.010		3.460
5/27/92	Cominco	TR	<	0.05		0.017	<	0.01		0.074		0.386		2.380
6/10/92	Cominco	TR		0.15	<	0.003	<	0.01		0.581		0.028		0.699
6/16/92	Cominco	TR		0.89		0.008	<	0.01		2.98		0.108		0.822
6/24/92	Cominco	TR		0.07		0.006	<	0.01		0.271		0.015		0.884
7/2/92	Cominco	TR		0.09		0.009	<	0.01		0.199		0.007		1.210
7/8/92	Cominco	TR	<	0.05		0.010	<	0.01	<	0.020		0.002		1.060
7/15/92	Cominco	TR	<	0.05		0.020	<	0.01	<	0.020	<	0.002		2.450
7/18/92	Cominco	TR	<	0.05		0.013	<	0.01	<	0.020	<	0.002		1.350
7/22/92	Cominco	TR	<	0.05		0.028	<	0.01		0.032	<	0.002		3.110
7/25/92	Cominco	TR	<	0.05		0.032	<	0.01		0.023	<	0.002		3.130
7/29/92	Cominco	TR	<	0.05		0.045	<	0.01		0.031	<	0.002		4.290
8/1/92	Cominco	TR	<	0.05		0.047	<	0.01		0.048		0.004		4.770
8/5/92	Cominco	TR	<	0.05		0.060	<	0.01		0.047		0.004		5.920
8/8/92	Cominco	TR	<	0.05		0.050	<	0.01		0.040		0.004		5.130
8/12/92	Cominco	TR	<	0.05		0.019	<	0.01		0.064		0.009		2.270
8/15/92	Cominco	TR	<	0.05		0.020	<	0.01		0.056		0.007		2.580
8/17/92	Cominco	TR	<	0.05		0.014	<	0.01		0.037		0.022		1.760
8/22/92	Cominco	TR		0.10		0.010	<	0.01		0.289		0.084		1.420
8/29/92	Cominco	TR	<	0.05		0.016	<	0.01		0.032		0.017		2.000
9/2/92	Cominco	TR	<	0.05		0.012	<	0.01		0.05		0.026		1.710
9/5/92	Cominco	TR	<	0.05		0.016	<	0.01		0.03		0.016		1.890
9/9/92	Cominco	TR	<	0.05		0.015	<	0.01		0.04		0.012		2.070
9/12/92	Cominco	TR	<	0.05		0.023	<	0.01		0.04		0.008		2.580
9/16/92	Cominco	TR	<	0.05		0.034	<	0.01		0.06		0.010		4.060
9/22/92	Cominco	TR	<	0.05		0.037	<	0.01		0.05	<	0.002		4.380
9/26/92	Cominco	TR	<	0.05		0.037	<	0.01		0.04				4.650

Appendix 12, continued.

Station 10, Mainstem Red Dog Creek														
Metals Concentrations														
Date	Reference	matrix		Al		Cd		Cu		Fe		Pb		Zn
				mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
9/30/92	Cominco	TR	<	0.05		0.049	<	0.01		0.04		0.004		5.830
10/3/92	Cominco	TR	<	0.05		0.047	<	0.01		0.055		0.005		5.840
10/10/92	Cominco	TR	<	0.05		0.043	<	0.01		0.054	<	0.002		5.050
10/15/92	Cominco	TR	<	0.05		0.023	<	0.01		0.039		0.005		2.660
5/28/93	Cominco	TR		0.31		0.004						0.034		
6/5/93	Cominco	TR		0.24	<	0.003						0.027		0.463
6/13/93	Cominco	TR		0.14		0.005						0.017		0.61
6/19/93	Cominco	TR	<	0.05		0.003						0.016		0.618
6/24/93	Cominco	TR		0.05		0.008						0.009		1.06
6/29/93	Cominco	TR	<	0.05		0.013						0.008		1.31
7/10/93	Cominco	TR		0.06		0.006						0.021		0.939
7/14/93	Cominco	TR	<	0.05		0.009						0.016		0.896
7/21/93	Cominco	TR	<	0.05		0.007						0.004		0.719
8/6/93	Cominco	TR		0.09		0.010						0.027		1.1
8/14/93	Cominco	TR	<	0.05		0.007						0.004		1.02
8/20/93	Cominco	TR	<	0.05		0.008						0.010		1.02
8/29/93	Cominco	TR	<	0.05		0.008						0.007		1.02
9/2/93	Cominco	TR	<	0.05		0.010						0.006		1.09
9/10/93	Cominco	TR		0.061		0.009						0.012		1.05
9/14/93	Cominco	TR		0.69		0.008						0.136		0.919
9/25/93	Cominco	TR	<	0.05		0.007						0.010		0.791
6/11/94	Cominco	TR		0.108		0.006						0.028		0.533
6/15/94	Cominco	TR		0.066		0.006						0.014		0.669
6/25/94	Cominco	TR	<	0.05		0.007						0.009		0.779
6/30/94	Cominco	TR				0.011						0.01		0.958
7/13/94	Cominco	TR		0.175		0.009						0.026		1.11
7/22/94	Cominco	TR	<	0.05		0.008						0.01		0.746
7/24/94	Cominco	TR		0.21		0.012						0.07		1.14
8/3/94	Cominco	TR		0.232		0.008						0.045		1.11
8/9/94	Cominco	TR		0.064		0.009						0.02		1.05
8/21/94	Cominco	TR		0.403		0.026						0.045		2.99
8/23/94	Cominco	TR		0.263		0.016						0.03		2.04
9/1/94	Cominco	TR		0.259		0.019						0.058		2.16
9/8/94	Cominco	TR		0.298		0.025						0.045		3.38
9/11/94	Cominco	TR		0.19		0.026						0.026		3.17
9/18/94	Cominco	TR		0.067		0.026						0.012		2.78
9/25/94	Cominco	TR		0.05		0.031						0.005		3.05
10/2/94	Cominco	TR	<	0.05		0.023						0.008		2.42

Appendix 12, continued.

Station 10, Mainstem Red Dog Creek									
Metals Concentrations									
Date	Reference	matrix		Al	Cd	Cu	Fe	Pb	Zn
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10/14/94	Cominco	TR	<	0.05	0.029			0.004	2.55
6/3/95	Cominco			0.073	0.12	0.0047	0.184	0.0337	1.39
6/8/95	Cominco			0.105	0.0124	0.0042	0.237	0.0393	1.54
6/11/95	Cominco				0.0139	0.0034		0.0226	1.43
6/13/95	Cominco				0.0141	0.0027		0.0181	1.62
6/18/95	Cominco				0.019	0.0036		0.027	1.83
6/25/95	Cominco				0.0196	0.0034		0.0202	2.34
6/27/95	Cominco								
6/29/95	Cominco			0.05	0.0176	0.0033	0.1	0.0254	2.27
6/29/95	Cominco				0.237	0.0037		0.0189	2.58
7/2/95	Cominco			0.072	0.0176	0.0036		0.0249	2.05
7/10/95	Cominco			0.092	0.0195	0.0043	0.136	0.0187	2.669
7/12/95	Cominco				0.0202	0.0043		0.0134	2.72
7/16/95	Cominco		<	0.05	0.0249	0.0031	0.066	0.0165	2.55
7/23/95	Cominco				0.0254	0.002		0.0139	3.14
8/2/95	Cominco				0.0315	0.0026		0.016	3.08
8/6/95	Cominco		<	0.05	0.0308	0.0023	0.059	0.0143	3
8/16/95	Cominco		<	0.05	0.0349	0.0016	0.06	0.0162	3.67
8/20/95	Cominco		<	0.05	0.0328	0.0016	0.057	0.0131	3.31
8/27/95	Cominco				0.0353	0.0014		0.0204	3.56

Appendix 12, continued.

Station 20: Middle Fork of Red Dog Creek										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
8/5/91	Cominco	688	1020		6.5			2.1	910	
8/6/91	Cominco	210	346		6.8	13.6	10.5	1.3	447	
8/15/91	Cominco	763	1310		6.0	16.0	9.1	6.1		
8/18/91	Cominco	751	1240		6.4	16.1	8.8	0.8		
8/23/91	Cominco	623	987		6.6	13.3	9.1	0.4	1570	
8/26/91	Cominco	355	631		7.2	5.3	11.7	1.3	455	
8/28/91	Cominco	298	560		7.6	5.7	12.1	1.3	440	
8/29/91	Cominco	315	527		7.4	12.1	9.8	1.3	490	
10/1/91	Cominco	547	986		6.0	3	12	0.5	1239	
10/4/91	Cominco	354	564		7.0	3	14	3	779	
10/7/91	Cominco	246	404		7.5	-0.2	16	1.3	577	
10/10/91	Cominco	215	370		7.3	0	16	0.5	553	
10/16/91	Cominco	333	568		7.0	0	14	0.5	785	
5/27/92	Cominco	349	410		7.1	2.4	4.1	1.3	0.701	
6/9/92	Cominco	28	50		6.4	0.3	7.1	2	0.076	
6/16/92	Cominco	36.1	54		6.5	6.1	10.2	4.5	0.928	
6/23/92	Cominco	44.8	72		6.1	7.3	15.9*	2.4	0.105	
7/2/92	Cominco	95	143		6.7	13.0	8.6	0.90	0.178	
7/9/92	Cominco	145	208		7.2	13.0	8.7		0.301	
7/11/92	Cominco	145	230		7.0	11.7	8.8		0.334	
7/15/92	Cominco	538	787		6.7	10.7		0.43	0.907	
7/18/92	Cominco	411	642		6.9	12.6	6.2	0.85	0.833	
7/22/92	Cominco	662	1010		7.0	15.5	8.3	0.12	1.200	
7/25/92	Cominco	791	1250		6.9	15.3	8.5	0.19	1.430	
7/29/92	Cominco	918	1400		6.7	19.4	7.6	0.24	1.600	
7/31/92	Cominco	983	1470		6.6	15.6	9.3	0.30	1.570	
8/3/92	Cominco	781	1170		6.4	12.8	11.0	0.2	1.300	
8/6/92	Cominco	1230	1940		6.4	14.2	12.0	0.4	1.790	
8/12/92	Cominco	372	566		7.1	8.2	6.6	0.6	0.184	
8/15/92	Cominco	532	762		6.8	5.5	6.9	0.2	0.958	
8/18/92	Cominco	562	828		6.2	4.8	24**	0.2	0.954	
8/22/92	Cominco	267	383		7.7	7.4	1.8	11.0	0.090	
8/28/92	Cominco	287	447		6.5	8.6	9.0	0.5	0.607	
8/30/92	Cominco	481	791		6.9	10.6	8.3	0.9	0.100	
9/3/92	Cominco	174	250		7.5	4.2	7.3	0.45	0.375	
9/4/92	Cominco	579	815		7.5	6.1	9	0.4	1.014	
9/7/92	Cominco	672	958		7.7	5.1	9.9	0.17	1.157	
9/10/92	Cominco	560	805		6.7	4.5	12.8	0.38	0.973	
9/18/92	Cominco	1240	1860		8.0	5	11	0.45	1.260	
9/24/92	Cominco	1290	1890		6.8	0	11.2	0.15	2.060	
9/26/92	Cominco	1240	1980		7.2	0	12.7	0.45	2.230	
9/29/92	Cominco	1410	2060		6.9	0	13.4	0.15	2.480	
10/1/92	Cominco	1510	2230		6.8	0	13.3	0.18	2.560	
10/10/92	Cominco	1560	2210		7	1.2	10	0.73	2.300	
10/15/92	Cominco	1110	1740		6.3	0.3	12.2	0.28	2.040	
5/18/93	Cominco	32.9	71		6.4	1.5	12.5	3.7		
5/27/93	Cominco		58		6.9	2	12.1	3		
6/4/93	Cominco		57		7.4					
6/12/93	Cominco		74		7.7	3				
6/17/93	ADEC-Nome	74	111		7.19	5.0				
6/17/93	Cominco		100		6.6	5				

Appendix 12, continued.

Station 20: Middle Fork of Red Dog Creek										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
6/23/93	Cominco		407		7.2	12				
6/30/93	Cominco		751							
7/8/93	Cominco		290		6.6	9				
7/15/93	Cominco		194		6.8	12				
7/25/93	Cominco		235		7	13				
8/3/93	Cominco		190		6.8	7				
8/11/93	Cominco		198		6.3	7				
8/19/93	Cominco		362		7.3	9				
8/27/93	Cominco		497			9				
9/5/93	Cominco		961		7.2	6				
9/10/93	Cominco		278		7.1	3				
9/15/93	Cominco		160		6.7	3				
9/25/93	Cominco		244		7.4	0				
9/29/93	Cominco				7.2	0				
1/1/94	Cominco	218	355	210	7.2	2				
1/9/94	Cominco	160	230	140	7.4	5				
1/17/94	Cominco	271	391	250	7.3	13				
1/24/94	Cominco	245	361	220	7.4	13				
1/30/94	Cominco	273	404	250	6.9	6				
5/6/94	Cominco	1960	2930	1900	7.4	1				35.9
5/10/94	Cominco	406	637	410	6.4	1				37.2
5/19/94	Cominco	67.2	110	63	6.8	1				
5/25/94	Cominco	71.5	97	55	6.8	4				
7/9/94	Cominco	94	144	68	7.2	5				
7/13/94	Cominco	100	141	73	7.3	8				
7/21/94	Cominco	132	183	96	7.3	9				
7/29/94	Cominco	203	206	160						
8/6/94	Cominco	324	508	300	7.3	13				
8/13/94	Cominco	89	128	69	7	8				
8/20/94	Cominco	90.6	156	82	6.3	5				
8/23/94	Cominco	123	198	100	6.3	4				
8/25/94	Cominco									
9/1/94	Cominco	444	693	410	7.2	6				
9/10/94	Cominco	714	1080	730	7.3	6				
9/10/94	Cominco									
9/15/94	Cominco	313	510	300	7.3	4				
9/21/94	Cominco	1280	1780	1100	7.2	3				
9/29/94	Cominco	1520	1970	1300	8	4				
10/8/94	Cominco	1440	2210	1300	6.9	1				
10/15/94	Cominco	1440	2150	1300	8	0				
10/22/94	Cominco	1450	2280	1400	8.3	1				
10/26/94	Cominco	1580	2440	1500	8.7	1				
6/1/95	Cominco	356	525	360	7.1	7			660	
6/7/95	Cominco		1270		6.8	10			94	
6/9/95	Cominco	597	823	590	7.4	9.5			931	
6/12/95	Cominco		1210	800	7.6	8			1264	
6/15/95	Cominco		135		7.7	7			233	
6/18/95	Cominco		1210		6.8	7.9			1382	
6/24/95	Cominco		392		7				566	
6/25/95	Cominco		1450							
6/27/95	Cominco		1460	1200	7.4	8			167	

Appendix 12, continued.

Station 20: Middle Fork of Red Dog Creek										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
7/1/95	Cominco	138	168	57	7.1	9		1.78	1268	
7/4/95	Cominco		1490		7.4	9		0.27	1691	
7/7/95	Cominco		1250		7.3	10		1.06	1470	
7/10/95	Cominco	736	1090	750	7.3	7		0.96	1323	
7/14/95	Cominco		1640		7.4	14		0.23	1764	
7/19/95	Cominco	1170	1720	1200	6.6	12		0.49	1880	
7/22/95	Cominco		1880		7.3	15.2		0.18	2110	
7/25/95	Cominco		2010		7.4	14.8		0.16	2110	
7/28/95	Cominco		2100			13.2				
7/30/95	Cominco		2090		7.2			0.16	1330	
8/4/95	Cominco		2190						2380	27.1
8/8/95	Cominco		2090	1500	7.2	12			2340	26.7
8/11/95	Cominco		2060		7.7	13.8			1990	27.6
8/13/95	Cominco		2100		7.8	13.1			2310	26.7
8/17/95	Cominco		2090	1400	7	12.5			2390	27.4
8/23/95	Cominco		2060	1500	7.6	13			2360	28
8/25/95	Cominco		2140		7.3	13.4			2270	28.9
8/27/95	Cominco		2040		7.6	12.5			226	28.8
8/31/95	Cominco		2090		7	12.4			2340	27.6

Appendix 12, continued.

Station 20: Middle Fork of Red Dog Creek

Date	Reference	matrix		Al		Cd		Cu		Fe	Pb	Zn
				mg/L		mg/L		mg/L		mg/L	mg/L	mg/L
8/5/91	Cominco	TR		0.06		0.071	<	0.01	<	0.020	0.098	12.30
8/6/91	Cominco	TR	<	0.05		0.132	<	0.01	<	0.020	0.168	23.70
8/15/91	Cominco	TR		0.48		0.177	<	0.01		5.07	0.295	29.20
8/18/91	Cominco	TR		0.13		0.126	<	0.01		0.48	0.272	19.80
8/23/91	Cominco	TR	<	0.05		0.164	<	0.01		0.02	0.153	26.00
8/26/91	Cominco	TR	<	0.05		0.192	<	0.01		0.07	0.234	32.40
8/28/91	Cominco	TR	<	0.05		0.178	<	0.01		0.08	0.184	31.00
8/29/91	Cominco	TR	<	0.05		0.174	<	0.01		0.07	0.171	29.80
10/1/91	Cominco	TR	<	0.05		0.088	<	0.01		0.06	0.072	11.30
10/4/91	Cominco	TR		0.19		0.059	<	0.01		0.80	0.154	8.28
10/7/91	Cominco	TR		0.05		0.084	<	0.01		0.16	0.076	13.40
10/10/91	Cominco	TR	<	0.05		0.076	<	0.01		0.11	0.044	12.90
10/16/91	Cominco	TR	<	0.05		0.097	<	0.01		0.04	0.053	16.10
5/27/92	Cominco	TR	<	0.05	<	0.003	<	0.01		0.12	0.050	0.09
6/9/92	Cominco	TR		0.23		0.015	<	0.01		0.87	0.092	2.23
6/16/92	Cominco	TR		0.14		0.013	<	0.01		0.36	0.056	1.60
6/23/92	Cominco	TR		0.13		0.014	<	0.01		0.553	0.086	1.94
7/2/92	Cominco	TR	<	0.05		0.028	<	0.01		0.078	0.025	4.45
7/9/92	Cominco	TR	<	0.05		0.040	<	0.01	<	0.020	0.019	5.97
7/11/92	Cominco	TR	<	0.05		0.043	<	0.01	<	0.020	0.015	6.39
7/15/92	Cominco	TR	<	0.05		0.068	<	0.01		0.026	0.029	9.46
7/18/92	Cominco	TR	<	0.05		0.076	<	0.01		0.070	0.021	10.60
7/22/92	Cominco	TR		0.06		0.101	<	0.01		0.041	12.200	10.60
7/25/92	Cominco	TR		0.05		0.098	<	0.01		0.040	0.032	11.10
7/29/92	Cominco	TR		0.06		0.079	<	0.01		0.128	0.041	8.20
7/31/92	Cominco	TR		0.08		0.081	<	0.01		0.099	0.050	9.06
8/3/92	Cominco	TR	<	0.05		0.111	<	0.01		0.080	0.020	12.10
8/6/92	Cominco	TR	<	0.05		0.089	<	0.01		0.080	0.052	9.93
8/12/92	Cominco	TR		0.06		0.034	<	0.01		0.118	0.039	4.60
8/15/92	Cominco	TR	<	0.05		0.040	<	0.01		0.062	0.028	5.52
8/18/92	Cominco	TR	<	0.05		0.029	<	0.01		0.060	0.036	4.31
8/22/92	Cominco	TR		0.10		0.024		0.012		0.292	0.222	3.28
8/28/92	Cominco	TR	<	0.05		0.047	<	0.01		0.036	0.094	6.37
8/30/92	Cominco	TR		0.07		0.034	<	0.01		0.176	0.130	4.54
9/3/92	Cominco	TR		0.06		0.04	<	0.01		0.08	0.105	5.64
9/4/92	Cominco	TR	<	0.05		0.035	<	0.01		0.11	0.106	4.55
9/7/92	Cominco	TR	<	0.05		0.038	<	0.01		0.05	0.059	4.88
9/10/92	Cominco	TR	<	0.05		0.047	<	0.01		0.06	0.052	6.57
9/18/92	Cominco	TR	<	0.05		0.033	<	0.01		0.11	0.041	4.61
9/24/92	Cominco	TR										
9/26/92	Cominco	TR	<	0.05		0.06	<	0.01		0.13	0.040	7.39
9/29/92	Cominco	TR	<	0.05		0.071	<	0.01		0.06	0.033	8.44
10/1/92	Cominco	TR	<	0.05		0.074	<	0.01		0.061	0.028	8.47
10/10/92	Cominco	TR	<	0.05		0.059	<	0.01		0.078	0.037	6.73
10/15/92	Cominco	TR	<	0.05		0.147	<	0.01		0.05	0.030	18.70
5/18/93	Cominco	TR		0.16		0.026	<	0.01		0.672	0.142	3.21
5/27/93	Cominco	TR		0.28		0.014					0.152	1.64
6/4/93	Cominco	TR		0.12		0.014					0.104	1.78
6/12/93	Cominco	TR		0.13		0.013					0.112	1.64
6/17/93	ADEC-Nome	TR		0.053		0.015	<	0.01		0.118	0.057	2.06
6/17/93	Cominco	TR		0.06		0.017					0.066	2.21

Appendix 12, continued.

Station 20: Middle Fork of Red Dog Creek												
Date	Reference	matrix		Al mg/L		Cd mg/L		Cu mg/L		Fe mg/L	Pb mg/L	Zn mg/L
6/23/93	Cominco	TR		0.07		0.021					0.049	2.59
6/30/93	Cominco	TR	<	0.05		0.026					0.041	3.09
7/8/93	Cominco	TR	<	0.05		0.029					0.050	3.51
7/15/93	Cominco	TR	<	0.05		0.026					0.045	3.13
7/25/93	Cominco	TR	<	0.05		0.026					0.016	3.29
8/3/93	Cominco	TR		0.21		0.024					0.177	3.11
8/11/93	Cominco	TR	<	0.05		0.026					0.034	3.60
8/19/93	Cominco	TR	<	0.05		0.028					0.049	3.53
8/27/93	Cominco	TR	<	0.05		0.027					0.036	3.61
9/5/93	Cominco	TR	<	0.05		0.032					0.029	3.83
9/10/93	Cominco	TR		0.06		0.024					0.044	3.30
9/15/93	Cominco	TR		0.38		0.029					0.348	3.50
9/25/93	Cominco	TR	<	0.05		0.028					0.064	3.50
9/29/93	Cominco	TR										
1/1/94	Cominco	TR	<	0.05		0.025					0.01	3.14
1/9/94	Cominco	TR		0.068		0.016					0.095	2.10
1/17/94	Cominco	TR	<	0.05		0.022					0.062	2.61
1/24/94	Cominco	TR	<	0.05		0.024					0.046	2.96
1/30/94	Cominco	TR	<	0.05		0.025					0.022	2.84
5/6/94	Cominco	TR	<	0.05		0.52					0.094	5.39
5/10/94	Cominco	TR		0.086		0.072					0.322	9.27
5/19/94	Cominco	TR		0.414		0.026					0.26	3.37
5/25/94	Cominco	TR		0.208		0.022					0.137	2.68
7/9/94	Cominco	TR		0.065		0.027					0.115	3.64
7/13/94	Cominco	TR		0.087		0.029					0.1	3.57
7/21/94	Cominco	TR	<	0.05	<	0.025					0.038	3.09
7/29/94	Cominco	TR		0.056		0.027					0.093	3.39
8/6/94	Cominco	TR	<	0.05		0.028					0.078	3.26
8/13/94	Cominco	TR		0.489		0.031					0.341	3.78
8/20/94	Cominco	TR		0.766		0.086					0.232	10.10
8/23/94	Cominco	TR		0.539		0.062					0.12	8.77
8/25/94	Cominco	TR		0.673		0.067		0.03			0.165	8.86
9/1/94	Cominco	TR		0.581		0.053					0.132	6.12
9/10/94	Cominco	TR		0.624		0.059					0.084	8.05
9/10/94	Cominco											
9/15/94	Cominco	TR		1.25		0.08		0.049			0.345	11.30
9/21/94	Cominco	TR		0.174		0.046					0.08	5.53
9/29/94	Cominco	TR	<	0.05		0.033					0.012	3.13
10/8/94	Cominco	TR	<	0.05		0.034					0.013	2.92
10/15/94	Cominco	TR	<	0.05		0.036					0.017	3.21
10/22/94	Cominco	TR	<	0.05		0.051					0.022	4.13
10/26/94	Cominco	TR	<	0.05		0.033					0.027	2.68
6/1/95	Cominco			0.118		0.034	<	0.01	<	0.193	0.142	4.39
6/7/95	Cominco			0.079		0.0327		0.0084			0.0676	4.14
6/9/95	Cominco					0.0287		0.0075			0.0914	3.07
6/12/95	Cominco					0.0296		0.0058			0.0651	3.14
6/15/95	Cominco					7E-05		0.0012			0.0004	0.00
6/18/95	Cominco					0.0418		0.0091			0.0946	3.71
6/24/95	Cominco					0.0462		0.0069			0.109	8.06
6/25/95	Cominco					0.0394		0.0071			0.0632	4.43
6/27/95	Cominco			0.091		0.0458		0.0075			0.0704	4.90

Appendix 12, continued.

Station 20: Middle Fork of Red Dog Creek														
Date	Reference	matrix		Al mg/L		Cd mg/L		Cu mg/L		Fe mg/L		Pb mg/L		Zn mg/L
7/1/95	Cominco			0.197		5E-05		0.0008		0.308		0.0009		0.01
7/4/95	Cominco					0.0352		0.006				0.0476		4.53
7/7/95	Cominco					0.0386		0.0078				0.061		5.29
7/10/95	Cominco			0.106		0.0431		0.109				0.0586		5.96
7/14/95	Cominco					0.0395		0.0062		0.124		0.0501		4.68
7/19/95	Cominco					0.0463		0.0073				0.0617		5.25
7/22/95	Cominco			0.112		0.0456		0.0038				0.0429		4.96
7/25/95	Cominco					0.0487		0.0042				0.0402		4.89
7/28/95	Cominco					0.0458		0.0038				0.0363		4.93
7/30/95	Cominco					0.0406		0.0042				0.0352		4.41
8/4/95	Cominco					0.0398		0.003				0.0301		5.11
8/8/95	Cominco		<	0.05		0.0425		0.0062		0.088		0.0368		4.38
8/11/95	Cominco					0.0432		0.0078				0.0374		4.92
8/13/95	Cominco					0.0537		0.0021				0.0391		4.92
8/17/95	Cominco		<	0.05		0.0496		0.002		0.077		0.0377		5.19
8/23/95	Cominco		<	0.05		0.0536		0.0018		0.071		0.0412		5.68
8/25/95	Cominco					0.0538		0.0023				0.0444		6.39
8/27/95	Cominco					0.0559		0.0002				0.0481		5.55
8/31/95	Cominco					0.0475		0.0022				0.0329		5.11

Appendix 12, continued.

Station 140: Bypass Channel around Ore Body										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
6/13/92	Cominco	242	40		6.6	4	10.2	5	0.066	
6/15/92	Cominco	25.2	47		6.1	4.2	9.7	3.7	0.065	
6/28/92	Cominco	49.1	79		6.3	6.2	6.9	1.8	0.077	
7/4/92	Cominco	75	111		6.0	10.0	8.5	2.10	0.177	
7/4/92	Cominco	75	111		6.0	10.0	8.5			2.10
7/11/92	Cominco	109	153		6.7	12.2	6.6	---	0.254	
7/11/92	Cominco	109	153		6.7	12.2	6.6			---
7/15/92	Cominco	118	197		6.5	8.4		1.00	0.285	
7/15/92	Cominco	118	197		6.5	8.4				1.00
7/18/92	Cominco	127	219		6.3	11.7	3.3	1.10	0.343	
7/18/92	Cominco	127	219		6.3	11.7	3.3			1.10
7/22/92	Cominco	146	266		6.6	12.4	5.2	0.17	0.370	
7/22/92	Cominco	146	266		6.6	12.4	5.2			0.17
7/25/92	Cominco	159	324		6.2	12.6	7.4	0.25	0.426	
7/25/92	Cominco	159	324		6.2	12.6	7.4			0.25
7/29/92	Cominco	173	323		6.6	15.4	4.8			0.35
7/29/92	Cominco	173	323		6.6	15.4	4.8	0.35	0.487	
7/31/92	Cominco	190	321		5.9	13.5	10.0	0.15	0.455	
7/31/92	Cominco	190	321		5.9	13.5	10.0			0.15
8/3/92	Cominco	209	394		5.7	13.6	9.8	0.2	0.500	
8/6/92	Cominco	214	412		6.6	10.6	6.8	0.4	0.515	
8/12/92	Cominco	109	166		6.4	5.9	6.4	1.0	0.055	
8/15/92	Cominco	126	180		6.2	3.5	6.4	0.4	0.213	
8/17/92	Cominco	120	165		7.4	4.8	16**	0.5	0.255	
8/21/92	Cominco	106	150		8.2	6.6	10.0	0.7	0.213	
8/28/92	Cominco	123	184		7.6	7.0	8.0	0.7	0.287	
8/30/92	Cominco	110	159		6.1	8.1	8.3	1.7	0.027	
9/3/92	Cominco	116	16.6		8.1	3.6	6	0.54	0.238	
9/5/92	Cominco	122	181		6.7	3.6	7.5	0.4	0.260	
9/8/92	Cominco	130	196		7.0	3.3	10.1	0.22	0.263	
9/10/92	Cominco	128	211		7.5	3.3	7.7	0.7	0.290	
9/18/92	Cominco	155	248		7.3	1.2	12.5	0.2	0.202	
9/24/92	Cominco	195	303		6.8	0	11.9	0.29	0.484	
9/25/92	Cominco	197	351		6.6	0	10.1	0.4	0.480	
9/29/92	Cominco	217	416		6.0	0	7.6	0.22	0.480	
10/1/92	Cominco	232	456		6.2	-0.1	5.4	0.16	0.580	
5/16/93	Cominco				6					
5/19/93	Cominco				6.2	2	13.2			

Appendix 12, continued.

Station 140: Bypass Channel around Ore Body										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
5/25/93	Cominco									
6/4/93	Cominco									
6/9/93	Cominco				7	5				
6/10/93	Cominco									
6/17/93	Cominco									
6/26/93	Cominco									
6/30/93	Cominco									
7/6/93	Cominco									
7/16/93	Cominco									
7/25/93	Cominco									
8/2/93	Cominco				7	5				
8/11/93	Cominco				6.6	5				
8/18/93	Cominco				7	6				
8/24/93	Cominco				7.2	5				
9/1/93	Cominco				7.5	3		0.5	300	315.3
9/9/93	Cominco				7.9					
9/14/93	Cominco									6.2
9/24/93	Cominco				7	0				17.4
5/19/94	Cominco						6.8	1		66.4
5/27/94	Cominco						6.3			33.7
6/8/94	Cominco						7	6		26
6/16/94	Cominco						6.9	5		16
7/12/94	Cominco									33.7
7/21/94	Cominco									10.6
7/29/94	Cominco									25
8/13/94	Cominco									
8/23/94	Cominco									
9/6/94	Cominco						6.7	5		
9/23/94	Cominco						6.9	1		
10/8/94	Cominco									
10/27/94	Cominco						6.7	1		
6/4/95	Cominco		190							11.6
6/8/95	Cominco		105							24.2
6/8/95	Cominco		112							20.3
6/11/95	Cominco		109	71						20.3
6/14/95	Cominco		120							17.4
6/19/95	Cominco		131							12.6
6/21/95	Cominco		152							20.3
6/23/95	Cominco		163							6.9

Appendix 12, continued.

Station 140: Bypass Channel around Ore Body										
Date	Reference	Hard	TDS	SO4	pH	Temp.	D.O.	Turb	Cond	Flow, cfs
		mg/L	mg/L	mg/L		°C	mg/L	NTU		
6/26/95	Cominco		273							
7/5/95	Cominco		230							
7/7/95	Cominco		232							
7/10/95	Cominco		210							
7/13/95	Cominco		298							
7/17/95	Cominco		327							
7/19/95	Cominco		327							
7/21/95	Cominco		397							
7/24/95	Cominco		428							
7/26/95	Cominco		447							
7/28/95	Cominco		490							
7/31/95	Cominco		561							
8/2/95	Cominco		566							2.3
8/4/95	Cominco		615							2.1
8/6/95	Cominco		624							2.3
8/9/95	Cominco		593							2.6
8/11/95	Cominco		587							3.4
8/13/95	Cominco		574							4.1
8/17/95	Cominco		557							3.2
8/20/95	Cominco		535							3.2
8/23/95	Cominco		535							4.4
8/25/95	Cominco		521							4.9
8/27/95	Cominco		542							4.9
8/30/95	Cominco		515							4.1

Appendix 12, continued.

Station 140: Bypass Channel around Ore Body														
Date	Reference	matrix		Al		Cd		Cu		Fe		Pb		Zn
				mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
6/13/92	Cominco	TR		0.14		0.012	<	0.01		0.396		0.111		1.47
6/15/92	Cominco	TR		0.14		0.012	<	0.01		0.354		0.071		2.07
6/28/92	Cominco	TR		0.06		0.017	<	0.01		0.169		0.057		2.25
7/4/92	Cominco	TR	<	0.05		0.025	<	0.01		0.083		0.046		3.99
7/4/92	Cominco	TR	<	0.05		0.025	<	0.01		0.083		0.046		3.99
7/11/92	Cominco	TR	<	0.05		0.035	<	0.01	<	0.020		0.072		5.76
7/11/92	Cominco	TR	<	0.05		0.035	<	0.01	<	0.020		0.072		5.76
7/15/92	Cominco	TR	<	0.05		0.054	<	0.01	<	0.020		0.117		9.99
7/15/92	Cominco	TR	<	0.05		0.054	<	0.01	<	0.020		0.117		9.99
7/18/92	Cominco	TR	<	0.05		0.074	<	0.01	<	0.020		0.182		138.00
7/18/92	Cominco	TR	<	0.05		0.074	<	0.01	<	0.020		0.182		138.00
7/22/92	Cominco	TR		0.07		0.117	<	0.01		0.023		0.181		21.60
7/22/92	Cominco	TR		0.07		0.117	<	0.01		0.023		0.181		21.60
7/25/92	Cominco	TR		0.06		0.129	<	0.01	<	0.020		0.242		23.10
7/25/92	Cominco	TR		0.06		0.129	<	0.01	<	0.020		0.242		23.10
7/29/92	Cominco	TR	<	0.05		0.165	<	0.01	<	0.020		0.352		28.60
7/29/92	Cominco	TR	<	0.05		0.165	<	0.01	<	0.020		0.352		28.60
7/31/92	Cominco	TR		0.07		0.187	<	0.01	<	0.020		0.394		33.80
7/31/92	Cominco	TR		0.07		0.187	<	0.01	<	0.020		0.394		33.80
8/3/92	Cominco	TR		0.05		0.192	<	0.01	<	0.020		0.438		34.60
8/6/92	Cominco	TR	<	0.05		0.199	<	0.01		0.047		0.504		36.20
8/12/92	Cominco	TR		0.08		0.024	<	0.01		0.134		0.057		3.51
8/15/92	Cominco	TR		0.07		0.030	<	0.01		0.063		0.050		5.00
8/17/92	Cominco	TR	<	0.05		0.028	<	0.01		0.055		0.052		4.41
8/21/92	Cominco	TR		1.61		0.032		0.07		3.690		1.940		3.75
8/28/92	Cominco	TR	<	0.05		0.038	<	0.01		0.055		0.206		5.43
8/30/92	Cominco	TR		0.10		0.037	<	0.01		0.111		0.306		4.65
9/3/92	Cominco	TR		0.06		0.032	<	0.01		0.13		0.170		4.44
9/5/92	Cominco	TR	<	0.05		0.034	<	0.01		0.05		0.148		4.94
9/8/92	Cominco	TR	<	0.05		0.037	<	0.01		0.03		0.117		5.87
9/10/92	Cominco	TR	<	0.05		0.042		0.01		0.04		0.110		7.04
9/18/92	Cominco	TR	<	0.05		0.078	<	0.01		0.02		0.170		14.10
9/24/92	Cominco	TR	<	0.05		0.112		0.01		0.02		0.204		20.70
9/25/92	Cominco	TR	<	0.05		0.145	<	0.01		0.02		0.266		26.40
9/29/92	Cominco	TR	<	0.05		0.194		0.01	<	0.020		0.400		34.80
10/1/92	Cominco	TR	<	0.05		0.216	<	0.01	<	0.020		0.408		39.90
5/16/93	Cominco			0.27		0.146		0.02		1.68		0.424		16.30
5/19/93	Cominco			0.17		0.029	<	0.01		0.584		0.326		3.14
5/25/93	Cominco			0.08		0.016						0.158		1.80

Appendix 12, continued.

Station 140: Bypass Channel around Ore Body												
Date	Reference	matrix		Al		Cd		Cu		Fe		Pb		Zn
				mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
6/4/93	Cominco	TR		0.15		0.012						0.208		1.63
6/9/93	Cominco	TR		0.1		0.016						0.141		1.62
6/10/93	Cominco	TR		0.09		0.011	<	0.01		0.17		0.101		1.13
6/17/93	Cominco	TR		0.07		0.010						0.112		1.10
6/26/93	Cominco	TR		0.07		0.012						0.089		1.34
6/30/93	Cominco	TR	<	0.05		0.014						0.080		1.27
7/6/93	Cominco	TR	<	0.05		0.012						0.064		1.32
7/16/93	Cominco	TR	<	0.05		0.019						0.084		1.97
7/25/93	Cominco	TR	<	0.05		0.020						0.051		1.89
8/2/93	Cominco	TR		0.21		0.030						0.580		2.92
8/11/93	Cominco	TR	<	0.05		0.025						0.093		3.08
8/18/93	Cominco	TR	<	0.05		0.025						0.059		2.69
8/24/93	Cominco	TR		0.08		0.024						0.074		2.60
9/1/93	Cominco	TR	<	0.05		0.025						0.050		2.77
9/9/93	Cominco	TR		0.06		0.023						0.096		2.63
9/14/93	Cominco	TR		0.46		0.017						0.366		1.89
9/24/93	Cominco	TR		0.08		0.032						0.299		3.53
5/19/94	Cominco	TR		0.392		0.035						0.54		4.11
5/27/94	Cominco	TR		0.105		0.024						0.23		2.62
6/8/94	Cominco	TR		0.103		0.012						0.22		1.57
6/16/94	Cominco	TR	<	0.05	<	0.015				0.101		0.2		1.81
7/12/94	Cominco	TR		0.088		0.029						0.16		2.57
7/21/94	Cominco	TR		0.055		0.032						0.13		3.88
7/29/94	Cominco	TR		0.072		0.031						0.14		3.23
8/13/94	Cominco	TR		0.263		0.039						0.21		4.37
8/23/94	Cominco	TR		1.05		0.1		0.058				0.21		13.20
9/6/94	Cominco	TR		1.47		0.114						0.21		15.70
9/23/94	Cominco	TR		0.699		0.137						0.49		18.50
10/8/94	Cominco	TR	<	0.05		0.148						0.15		20.00
10/27/94	Cominco	TR		0.077		0.15						0.21		29.50
6/4/95	Cominco	TR				0.058		0.015				0.24		8.69
6/8/95	Cominco	TR		0.196		0.033		0.01		0.236		0.18		5.03
6/8/95	Cominco	TR				0.034		0.011				0.18		5.74
6/11/95	Cominco	TR				0.032		0.01				0.16		4.78
6/14/95	Cominco	TR				0.032		0.012				0.2		5.59
6/19/95	Cominco	TR				0.033		0.013				0.18		5.87
6/21/95	Cominco	TR				0.037		0.011				0.25		6.60
6/23/95	Cominco	TR				0.039		0.013				0.21		7.50

Appendix 12, continued.

Station 140: Bypass Channel around Ore Body								
Date	Reference	matrix	Al	Cd	Cu	Fe	Pb	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/26/95	Cominco	TR		0.074	0.015		0.24	13.40
7/5/95	Cominco	TR		0.063	0.017		0.17	11.50
7/7/95	Cominco	TR		0.058	0.017		0.14	11.40
7/10/95	Cominco	TR		0.063	0.02		0.13	11.80
7/13/95	Cominco	TR		0.071	0.016		0.16	14.70
7/17/95	Cominco	TR		0.085	0.019		0.19	15.70
7/19/95	Cominco	TR		0.089	0.016		0.17	18.40
7/21/95	Cominco	TR		0.106	0.016		0.15	21.00
7/24/95	Cominco	TR		0.103	0.008		0.16	23.20
7/26/95	Cominco	TR		0.112	0.007		0.15	25.30
7/28/95	Cominco	TR		0.262	0.014		0.35	25.50
7/31/95	Cominco	TR		0.115	0.006		0.17	29.10
8/2/95	Cominco	TR		0.148	0.006		0.19	30.30
8/4/95	Cominco	TR		0.15	0.006		0.19	32.80
8/6/95	Cominco	TR		0.17	0.019		0.21	33.60
8/9/95	Cominco	TR		0.168	0.017		0.22	33.20
8/11/95	Cominco	TR		0.156	0.015		0.23	31.20
8/13/95	Cominco	TR		0.15	0.014		0.2	25.80
8/17/95	Cominco	TR		0.141	0.008		0.16	30.30
8/20/95	Cominco	TR		0.143	0.011		0.17	29.20
8/23/95	Cominco	TR		0.145	0.012		0.22	28.20
8/25/95	Cominco	TR		0.138	0.012		0.18	28.40
8/27/95	Cominco	TR		0.136	0.013		0.22	24.10
8/30/95	Cominco	TR		0.135	0.01		0.16	26.90

Appendix 12, continued.

North Fork of Red Dog Creek											
Water Quality											
Station	Date	Reference	Hard	TDS	SO4		TSS	pH	Temp.	Turb	Cond
			mg/L	mg/L	mg/L		mg/L		°C	NTU	
Station 12	9/7/92	Cominco	208	248		<	5	7.7	3	0.44	0.363
Station 12	9/12/92	Cominco	218	273			5	7.8	2.8	0.6	0.357
Station 12	6/1/95	Cominco		101				7.5	7		
Station 12	6/7/95	Cominco		152		<	5	7.7	7		
Station 12	6/12/95	Cominco		155	55	<	5	8.1	5.2		
Station 12	6/18/95	Cominco		148		<	5	8		2	229
Station 12	6/27/95	Cominco		225		<	5				
Station 12	7/1/95	Cominco		1030		<	5				
Station 12	7/7/95	Cominco		201		<	5				
Station 12	7/10/95	Cominco		178		<	5				
Station 12	7/19/95	Cominco		223		<	5				
Station 12	7/25/95	Cominco		256		<	5				
Station 12	7/30/95	Cominco		290		<	5				
Station 12	8/8/95	Cominco		317		<	5				
Station 12	8/13/95	Cominco		297		<	5				
Station 12	8/23/95	Cominco		279		<	5		10		
Station 12	8/27/95	Cominco		310		<	5				

Appendix 12, continued.

North Fork of Red Dog Creek											
Metals Concentrations											
Station	Date		Al		Cd		Cu		Pb		Zn
			mg/L		mg/L		mg/L		mg/L		mg/L
Station 12	9/7/92	<	0.05	<	0.003	<	0.01	<	0.002	<	0.01
Station 12	9/12/92	<	0.05	<	0.003	<	0.01	<	0.002	<	0.01
Station 12	6/1/95		0.156	<	0.003	<	0.01	<	0.002		0.1
Station 12	6/7/95				0.00009		0.0013		0.00036		0.008
Station 12	6/12/95			<	0.00004		0.0012		0.00012		0.008
Station 12	6/18/95				0.00004		0.0008		0.0002		0.01
Station 12	6/27/95				0.00008		0.0025		0.00015		0.013
Station 12	7/1/95				0.032		0.0107		0.165		3.94
Station 12	7/7/95			<	0.00004		0.0012		0.00014	<	0.01
Station 12	7/10/95		0.131								
Station 12	7/19/95				0.00006		0.0011		0.00029		0.013
Station 12	7/25/95			<	0.00004		0.0011		0.00009		0.018
Station 12	7/30/95				0.00004		0.0009		0.00011		0.008
Station 12	8/8/95				0.0002		0.0009		0.00009		0.009
Station 12	8/13/95				0.0008		0.0009		0.0001		0.009
Station 12	8/23/95				0.00025		0.0005		0.00039		0.011
Station 12	8/27/95				0.00012		0.0004		0.00012		0.008

Appendix 12, continued.

All data collected by Cominco Alaska Inc.														
Date	Hard		Al		Cd		Cu		Fe		Pb		Zn	pH
	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Connie Creek														
5/12/95			0.37		0.005	<	0.01		1.22		0.196		0.615	6.60
5/31/95	51		0.11	<	0.003	<	0.01		0.17		0.016		0.088	6.70
6/7/95			0.17		0.003		0.0023		0.12		0.002		0.006	7.00
6/8/95			0.09		0.004		0.0021		0.12		0.009		0.065	6.60
6/26/95	79		0.08		0.007		0.0021		0.05		0.004		0.107	7.40
7/4/95	76.2		0.087		0.0006		0.0020		0.08		0.013		0.1	7.3
7/24/95	132	<	0.05		0.0011		0.002		0.06		0.005		0.16	
7/31/95	148	<	0.05		0.0009		0.002		0.06		0.005		0.14	
8/15/95			0.347		0.186		0.056				0.273		36.8	
9/3/95			0.073		0.0008		0.003		0.09		0.005		0.14	
9/21/95			0.05		0.0007		0.002		0.06		0.003		0.11	
10/7/95			0.101		0.0011		0.003		0.26		0.014		0.17	
Rachael Creek														
5/12/95			1.59	<	0.0030		0.06		0.25		0.048		0.202	4.70
5/31/95	164		2.19	<	0.0030		0.06		1.79		0.007		0.357	5.10
5/26/95	256		1.59		0.0023		0.05		1.57		0.002		0.506	5.80
7/4/95	252		1.81		0.0021		0.064		1.61		8E-04		0.51	5.9
			1.99	<	0.003		0.084			<	0.001		0.62	
7/19/95	413		1.57		0.003		0.06		3.3		5E-04		0.71	
7/31/95	491		1.17		0.0031		0.043		2.8		0.002		0.78	
8/15/95			1.53		0.0038		0.047		4.22		8E-04		0.84	
9/3/95			1.97		0.0033		0.073		4.28		3E-04		0.8	
9/21/95					0.0037		0.072				4E-04		0.83	
10/7/95			3.27		0.0031		0.073		3.77		8E-04		0.78	

Appendix 12, concluded.

All data collected by Cominco Alaska Inc.														
Date	Hard		Al		Cd		Cu		Fe		Pb		Zn	pH
	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Shelly Creek														
5/12/95			0.238		0.005	<	0.01		0.4		0.154		0.29	6.4
5/31/95	33.1		0.077	<	0.003	<	0.01		0.27		0.011		0.4	6.8
6/7/95			0.175		0.0006		0.003		0.4		0.028		0.47	6.7
6/7/95			0.108		0.0006		0.002		0.19		0.005		0.09	6.7
6/26/95	61.9		0.125		0.0104		0.006		0.2		0.018		1.35	7.1
7/4/95	61.1		0.137		0.01		0.006		0.19		0.02		1.28	7.3
7/12/95			0.304		0.017		0.014				0.049		1.89	
7/24/95	102		0.436		0.0237		0.015		0.55		0.05		3.23	
7/29/94		<	0.1		0.01				0.3		0.04		0.86	
7/31/95	116		0.549		0.0322		0.021		0.82		0.071		4.2	
8/15/95			0.461		0.0316		0.019		0.7		0.065		3.59	
9/3/95			0.472		0.0297		0.02		0.89		0.604		3.55	
9/21/95			0.504		0.0447		0.024		1.06		0.083		5.1	
10/7/95			0.511		0.0367		0.021		1.22		0.079		4.13	
Sulfur Creek														
5/12/95			5.97		0.009		0.02		20.10		2.120		1.240	6.50
5/31/95	87.3	<	0.05		0.004	<	0.01		0.153		0.193		0.494	7.00
6/26/95	130.0	<	0.05		0.012		0.0022		0.036		0.094		1.900	7.00
7/4/95	133		0.053		0.0049		0.001		0.06		0.089		0.7	7.4
7/12/95			0.061		0.003	<	0.01				0.069		0.4	
7/24/95	140	<	0.05		0.0096		0.003		0.05		0.066		1.68	
August	no flow													

Appendix 13. Water quality and metals concentrations in mine effluent, 1995.

Red Dog Mine Discharge, Water Quality												
Date	Hardness mg/L	TDS mg/L	SO4 mg/L		TSS mg/L		Cn\Tot mg/L		Cn/WAD mg/L	pH	Temp. °C	Flow, cfs
5/9/95	1400		1200				0.04		0.05	9.5	4	7.33
5/10/95		1800		<	5					9.9	4	10.79
5/11/95										9.5	4	10.49
5/12/95		1300	750	<	5		0.06		0.06	9.5	4	10.49
5/13/95										9.7	4	10.73
5/14/95										9.5	3	10.63
5/15/95		1040	690	<	5		0.02		0.03	9.5	3	10.55
5/16/95										9.6	2	10.63
5/17/95										9.6	2	10.46
5/18/95		1370	890	<	5		0.01		0.01	9.7	2	11.31
5/19/95										9.7	3	10.78
5/20/95										10	3	10.55
5/21/95										10	3	3.45
5/22/95			1400	<	5		0.01		0.01	11	4	7.77
5/23/95		2060								10	4	10.94
5/24/95										10	4	11.12
5/25/95		2000	1200	<	5		0.01		0.01	10	4	11.1
5/26/95										10	5	11.65
5/27/95										10	4	5.24
5/28/95										10	4	11.04
5/29/95		1820	1200	<	5		0.01		0.01	10	5	10.7
5/30/95										10	6	10.02
5/31/95										10	6	6.62
6/1/95	1310	1780	1300	<	5		0.01		0.01	10	6	2.2
6/2/95												
6/3/95		2200		<	5					10	6	17.3
6/4/95	1550	1210	1600	<	5				0.02	10	5	17.1
6/4/95	1580						0.02					
6/4/95												
6/5/95							0.01		0.02	10	6	18.2
6/6/95		2240		<	5					10	6	15.4
6/7/95		2260		<	5		0.01		0.01	10	7	19.1
6/7/95							0.01					
6/8/95		2190		<	5		0.01			10	8	19.6
6/9/95	1540	2300	1200	<	5	<	0.01	<	0.01	10	9	19.6
6/10/95		2270		<	5	<	0.01	<	0.01	10	10	19.9

Appendix 13, continued.

Red Dog Mine Discharge, Water Quality												
Date	Hardness	TDS	SO4		TSS		Cn\Tot		Cn/WAD	pH	Temp.	Flow, cfs
	mg/L	mg/L	mg/L		mg/L		mg/L		mg/L		°C	
6/11/95		2230	1600	<	5					10	10	19.8
6/12/95	1530	2340	1600	<	5	<	0.01	<	0.01	10	10	20.1
6/13/95		2370	1600	<	5					10	9	20.5
6/14/95		2370	1600	<	5					10	9	20.7
6/14/95		2400		<	5							
6/15/95		2350	1800	<	5	<	0.01			9.9	10	21
6/16/95		2370		<	5					9.9	10	21.1
6/17/95		2420		<	5					9.9	9	21.4
6/18/95		2310		<	5					9.4	10	20.9
6/19/95		2430		<	5	<	0.01	<	0.01	9.4	11	21
6/20/95		2390		<	5					9.4	11	20
6/21/95	1590	2440	1700	<	5	<	0.01	<	0.01	9.5	11	20.4
6/22/95		2300		<	5					9.4	11	16.3
6/23/95	1590	2440		<	5	<	0.01	<	0.01	9.7	11	15.7
6/24/95		2310		<	5					9.6	11	13
6/25/95	1600	2410	1700	<	5					9.2	10	19.1
6/26/95	1630	1920	1700	<	5	<	0.01	<	0.01	9.4	10	19
6/27/95		2380		<	5					9.7	11	18.2
6/28/95		2340	1700	<	5					9.6	11	14.1
6/28/95		2450		<	5							
6/29/95	1630					<	0.01	<	0.01	9.6	12	25
6/30/95		2440		<	5					9.5	12	25.4
7/1/95		2384		<	5	<	0.01			9.7	12	25.5
7/2/95	1610	2290	1700	<	5					9.6	12	25.6
7/3/95		2330		<	5	<	0.01			9.7	13	25.6
7/4/95		2350		<	5					9.8	12	25.5
7/5/95		2350		<	5					9.7	11	25.2
7/6/95	1580	2300	1700	<	5	<	0.01			9.7	11	24.8
7/7/95	1600	2450	1700	<	5					9.7	11	25.4
7/8/95		2490		<	5					9.7	11	25.6
7/9/95		2450		<	5					9.7	11	25.7
7/10/95	1620	2410		<	5	<	0.01			9.7	11	22.6
7/11/95		2460	1700	<	5					9.6	12	25.3
7/12/95		2470		<	5					9.6	13	24.5
7/13/95	1660	2520	1700	<	5	<	0.01			9.6	14	24.7
7/14/95		2500		<	5					9.6	16	24.8
7/15/95		2540		<	5					9.5	15	24.5

Appendix 13, continued.

Red Dog Mine Discharge, Water Quality												
Date	Hardness	TDS	SO4		TSS		Cn\Tot		Cn/WAD	pH	Temp.	Flow, cfs
	mg/L	mg/L	mg/L		mg/L		mg/L		mg/L		°C	
7/16/95		2540		<	5					9.5	16	24.4
7/17/95		2500		<	5					9.5	15	24.4
7/18/95		2300		<	5					9.5	15	24.9
7/19/95	1640	2420	1600	<	5	<	0.01			9.4	14	24.8
7/20/95	1560	2370		<	5					9.4	13	24.7
7/21/95		2400	1600	<	5	<	0.01			9.6	13	24.6
7/22/95	1710	2540		<	5					9.4	14	17.4
7/23/95	1730	2470	1700	<	5	<	0.01			9.4	13	24.5
7/24/95		2470		<	5					9.4	13	24.5
7/25/95		2470		<	5					9.4	13	24.5
7/26/95		2470	1700	<	5	<	0.01			9.4	13	24.5
7/27/95		2500		<	5					9.5	14	24.2
7/28/95		2430		<	5	<	0.01			9.5	15	23.2
7/29/95		2430		<	5					9.4	15	24.7
7/30/95		2450		<	5					9.7	15	24.9
7/31/95		2400		<	5	<	0.01			9.5	14	24.9
8/1/95		2450		<	5					9.8	14	25.4
8/2/95		2420		<	5					9.8	14	25.1
8/3/95	1760	2530	1700	<	5					9.8	14	25.1
8/4/95	1880	2610	1700	<	5	<	0.01			9.8	15	25
8/5/95		2440		<	5					9.8	14	25.2
8/6/95	1640	2450		<	5	<	0.01			9.8	13	24.8
8/7/95		2560	1700	<	5					9.8	13	24.8
8/8/95		2510		<	5					9.8	13	24.6
8/9/95	1680	2470		<	5	<	0.01			9.8	13	24.5
8/10/95		2460	1700	<	5					9.8	13	24.3
8/11/95	1670	2460	1800	<	5	<	0.01			9.8	14	24.2
8/12/95		2490		<	5					9.8	14	24.3
8/13/95		2570		<	5					9.8	14	22.6
8/14/95	1650	2490	1700	<	5	<	0.01			9.8	14	24.2
8/15/95		2560		<	5					9.8	13	24
8/16/95		2550		<	5					9.7	13	24
8/17/95		2590		<	5					9.7	13	24.1
8/18/95	1790	2460	1700	<	5		0.02			9.7	13	24.3
8/19/95		2510	1800	<	5					9.7	13	21.9
8/20/95	1710	2510		<	5	<	0.01			9.7	13	23.8
8/21/95		2480		<	5					9.7	13	24.1

Appendix 13, continued.

Red Dog Mine Discharge, Water Quality												
Date	Hardness	TDS	SO4		TSS		Cn\Tot		Cn/WAD	pH	Temp.	Flow, cfs
	mg/L	mg/L	mg/L		mg/L		mg/L		mg/L		°C	
8/22/95		2500		<	5					9.4	13	24.3
8/23/95	1720	2460	1800	<	5	<	0.01			9.6	13	23.7
8/24/95		2510		<	5					9.5	13	24.2
8/25/95		2490		<	5	<	0.01			9.4	13	24
8/26/95		2570		<	5					9.5	13	24
8/27/95		2620		<	5					9.5	13	23.9
8/28/95	1580	2490	1800	<	5	<	0.01			9.8	13	23.9
8/29/95		2550		<	5					9.5	13	23.9
8/30/95		2590		<	5					9.5	13	23.9
8/31/95		2620		<	5					9.5	13	23.7

Appendix 13, continued.

Red Dog Mine Discharge, metals concentrations														
All metals are as total recoverable, sampled from the mine effluent.														
Date		Al		Cd		Cu		Hg		Pb		AG		Zn
		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
5/9/95	<	0.05		0.014		0.041		0.0005		0.004		0.003		0.13
5/10/95														
5/11/95														
5/12/95	<	0.05		0.01		0.071		0.0005	<	0.002		0.01		0.04
5/13/95														
5/14/95														
5/15/95	<	0.05		0.006		0.03		0.0005	<	0.002		0.01		0.05
5/16/95														
5/17/95														
5/18/95	<	0.05		0.007	<	0.01		0.0005		0.012		0.01		0.13
5/19/95														
5/20/95														
5/21/95														
5/22/95	<	0.05		0.009	<	0.01		0.0005		0.004		0.01		0.06
5/23/95														
5/24/95														
5/25/95	<	0.05		0.008	<	0.01		0.0005		0.005		0.01		0.1
5/26/95														
5/27/95														
5/28/95														
5/29/95	<	0.05		0.008	<	0.01		0.0005		0.005		0.01		0.12
5/30/95														
5/31/95														
6/1/95	<	0.05		0.009	<	0.01				0.003		0.01		0.08
6/2/95														
6/3/95				0.0083		0.0149		0.0005		0.00125				0.04
6/4/95	<	0.05		0.0087		0.015		0.0005		0.00157		7E-05		0.04
6/4/95	<	0.05		0.0095		0.0178		0.0005		0.00269		5E-05		0.08
6/4/95				0.007		0.015		0.0005	<	0.002				0.03
6/5/95				0.0091		0.0149				0.00094				
6/6/95				0.0078		0.0139		0.0001		0.00099				0.04
6/7/95		0.08		0.0077		0.0127		0.0001		0.00094				0.04
6/7/95				0.0081		0.0124		0.0001		0.0021		5E-05		0.17
6/8/95				0.0074		0.0111		0.0001		0.00096				0.04
6/9/95	<	0.05		0.0089		0.0108		0.0001		0.00133		0.01		0.05
6/10/95				0.0093		0.0079		0.0001		0.001				0.04
6/11/95				0.0096		0.0069		0.0001		0.0009				0.04
6/12/95	<	0.05		0.0095		0.0069		0.0001		0.0009		0.01		0.05

Appendix 13, continued.

Red Dog Mine Discharge, metals concentrations								
All metals are as total recoverable, sampled from the mine effluent.								
Date		Al	Cd	Cu	Hg	Pb	AG	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/13/95			0.0092	0.0054	0.0001	0.0009		0.05
6/14/95			0.0084	0.0067	0.0005	0.001		0.04
6/14/95								
6/15/95	<	0.05	0.0079	0.0069	0.0005	0.00073	0.01	0.04
6/16/95			0.0086	0.0073	0.0005	0.00079		0.04
6/17/95			0.0079	0.0071	0.0005	0.00073		0.05
6/18/95			0.0278	0.0076	0.0002	0.00052		0.05
6/19/95			0.0338	0.0081	0.0002	0.00036		0.05
6/20/95			0.0159	0.0063	0.0005	0.0007		0.03
6/21/95	<	0.05	0.0136	0.0058	0.0005	0.00076	0.1	0.06
6/22/95			0.0136	0.0058	0.0005	0.00045		0.04
6/23/95	<	0.05	0.0137	0.006	0.0005	0.00074	0.01	0.05
6/24/95			0.0134	0.0054	0.0005	0.00102		0.06
6/25/95	<	0.05	0.0163	0.0066	0.0001	0.0011	0.01	0.09
6/26/95			0.0155	0.0058	0.0001	0.00054	0.01	0.04
6/27/95			0.0143	0.0055	0.0001	0.00045		0.04
6/28/95			0.0148	0.0068	0.0001	0.0005		0.04
6/28/95								
6/29/95	<	0.05		0.0039	0.0001	0.00047	0.01	0.04
6/30/95				0.0053	0.0001	0.00057		0.04
7/1/95			0.0135	0.0044	0.0001	0.00042		0.03
7/2/95	<	0.05	0.0137	0.004	0.0001	0.00036	0.01	0.03
7/3/95			0.0135	0.0044	0.0001	0.00042		0.03
7/4/95			0.0121	0.0046	0.0001	0.00035		0.03
7/5/95			0.0113	0.0048	0.0001	0.0003		
7/6/95	<	0.05	0.0126	0.004	0.0001	0.00035	0.01	0.03
7/7/95	<	0.05	0.0125	0.0049	0.0001	0.00037	0.01	0.03
7/8/95			0.0122	0.0047	0.0001	0.00041		0.03
7/9/95			0.0123	0.0048	0.0001	0.00041		0.03
7/10/95	<	0.05	0.0122	0.0053	0.0001	0.00035	0.01	0.03
7/11/95			0.0116	0.0046	0.0001	0.00214		0.04
7/12/95			0.0108	0.0039	0.0001	0.0005		0.03
7/13/95			0.011	0.0043	0.0001	0.00046		0.03
7/14/95			0.0112	0.0029	0.0001	0.00068		0.04
7/15/95			0.0111	0.0025	0.0001	0.00079		0.05
7/16/95			0.0125	0.0026	0.0001	0.00076		0.04
7/17/95			0.0162	0.0027	0.0001	0.00052		0.04
7/18/95			0.0188	0.0035	0.0001	0.00048		0.04

Appendix 13, continued.

Red Dog Mine Discharge, metals concentrations

All metals are as total recoverable, sampled from the mine effluent.

Date		Al	Cd	Cu	Hg	Pb	AG	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7/19/95	<	0.05	0.0181	0.0033	0.0001	0.00053	0.01	0.04
7/20/95			0.0199	0.003	0.0001	0.00046		0.03
7/21/95	<	0.05	0.0203	0.0029	0.0001	0.0004	0.01	0.03
7/22/95	<	0.05	0.0126	0.0023	0.0001	0.00036	0.01	0.03
7/23/95	<	0.05	0.0111	0.002	0.0001	0.00031	0.01	0.03
7/24/95	<	0.05	0.0203	0.0021	0.0001	0.00026	0.01	0.03
7/25/95	<	0.05	0.0152	0.0023	0.0001	0.00033		0.03
7/26/95			0.0172	0.0031	0.0001	0.00044		0.04
7/27/95			0.0159	0.0027	0.0001	0.00042		0.03
7/28/95			0.0144	0.0033	0.0001	0.00058		0.04
7/29/95			0.0188	0.0028	0.0001	0.0005		0.03
7/30/95			0.0162	0.0039	0.0001	0.00048		0.03
7/31/95			0.0157	0.0035	0.0001	0.00063		0.03
8/1/95			0.0125	0.004	0.0001	0.00066		0.03
8/2/95			0.0139	0.0026	0.0001	0.00114		0.04
8/3/95			0.0145	0.0029	0.0001	0.00093	0.01	0.04
8/4/95	<	0.05	0.0125	0.0029	0.0001	0.00087	0.01	0.04
8/5/95			0.0138	0.0034	0.0003	0.0012		0.04
8/6/95	<	0.05	0.0147	0.0061	0.0002	0.00107	0.01	0.04
8/7/95			0.0144	0.0056	0.0003	0.00109		0.04
8/8/95			0.0142	0.0055	0.0002	0.00107		0.03
8/9/95	<	0.05	0.014	0.0053	0.0002	0.0009	0.01	0.34
8/10/95			0.0142	0.0079	0.0001	0.00099		0.03
8/11/95	<	0.05	0.0142	0.008	0.0001	0.00088	0.01	0.04
8/12/95			0.0149	0.0079	0.0001	0.00098		0.04
8/13/95			0.0193	0.0011	0.0001	0.00199		0.05
8/14/95	<	0.05	0.0179	0.0008	0.0001	0.0012	0.01	0.05
8/15/95			0.0154	0.0008	0.0001	0.00086		0.04
8/16/95			0.0161	0.001	0.0001	0.00077		0.04
8/17/95			0.017	0.0025	0.0001	0.00082		0.03
8/18/95	<	0.05	0.0166	0.0011	0.0001	0.00092	0.01	0.03
8/19/95			0.0157	0.001	0.0001	0.00123		0.03
8/20/95	<	0.05	0.032	0.0014	0.0001	0.00222	0.01	0.03
8/21/95			0.0307	0.0016	0.0001	0.00169		0.03
8/22/95			0.0308	0.0011	0.0001	0.0018		0.03
8/23/95	<	0.05	0.0172	0.0005	0.0001	0.00119	0.01	0.03
8/24/95			0.0184	0.0005	0.0001	0.00094		0.03
8/25/95			0.018	0.0005	0.0001	0.00114		0.03

Appendix 13, concluded.

Red Dog Mine Discharge, metals concentrations															
All metals are as total recoverable, sampled from the mine effluent.															
Date		Al		Cd		Cu		Hg		Pb		AG		Zn
		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L
8/26/95				0.0175		0.0004		0.0001		0.0008				0.03
8/27/95				0.0201		0.0005		0.0001		0.00079				0.03
8/28/95	<	0.05		0.0187		0.0004		0.0001		0.00108		0.01		0.04
8/29/95				0.0175		0.0009		0.0001		0.00126				0.03
8/30/95				0.0159		0.0007		0.0002		0.00128				0.04
8/31/95				0.015		0.0008		0.0002		0.00117				0.04

Appendix F:
Chesapeake Bay UAAs

UAA for Tidal Waters of the Chesapeake Bay Mainstem and its Tidal Tributaries in the State of Maryland

Use Attainability Analysis for tidal waters of the Chesapeake Bay Mainstem and its tidal tributaries located in the State of Maryland.

Preamble

In April 2003, the U.S. Environmental Protection Agency (EPA) Region III issued guidance entitled *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll* a *for the Chesapeake Bay and Its Tidal Tributaries* (*Regional Criteria Guidance*). The development of the *Regional Criteria Guidance* was the realization of a key commitment in the *Chesapeake 2000* agreement. In that agreement, the signatories (the states of Pennsylvania, Maryland and Virginia; the District of Columbia; the Chesapeake Bay Commission and the EPA) committed to, "by 2001, define the water quality conditions necessary to protect aquatic living resources." New York Delaware and West Virginia agreed to the same commitment through a separate six-state memorandum of understanding with the EPA.

The EPA, in the *Regional Criteria Guidance*, defined the water quality conditions called for in the *Chesapeake 2000* agreement through the development of Chesapeake Bay-specific water quality criteria for dissolved oxygen, water clarity and chlorophyll *a*. The EPA also identified and described five habitats, or designated uses, that provide the context in which the EPA Region III derived adequately protective Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll *a.* Collectively, the three water quality conditions provide the best and most direct measures of the effects of too much nutrient and sediment pollution on the Bay's aquatic living resources—fish, crabs, oysters, their prey species and underwater bay grasses. These criteria were developed as part of a larger effort to restore Chesapeake Bay water quality.

The Maryland Department of the Environment, as a partner working in good faith to fulfill the goals of the *Chesapeake 2000* agreement, is currently in the process of promulgating the new Chesapeake Bay water quality standards to protect the Bay's aquatic living resources within the State of Maryland. This Use Attainability Analysis was developed by the Department to be a companion to the new Chesapeake Bay water quality standards (COMAR 26.08.01.01, 26.08.02.02, 26.08.02.03-3, and 26.08.08.08). This analysis describes the development and geographical extent of the designated uses to which the water quality criteria may apply, and as such serves as a resource to the State and its citizens to assist them in the monitoring, assessment, and protection of the Bays' resources.

The Use Attainability Analysis is not law or regulation; it is an assessment of the attainability of the current Bay water quality standards as well as the newly proposed water quality standards.

EXECUTIVE SUMMARY

In May 2003, the U.S. Environmental Protection Agency (EPA) Region III issued guidance entitled *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll* a *for the Chesapeake Bay and Its Tidal Tributaries (Regional Criteria Guidance)*. The EPA developed this guidance to achieve and maintain the water quality conditions necessary to protect aquatic living resources of the Chesapeake Bay and its tidal tributaries. The *Regional Criteria Guidance* is intended to assist the Chesapeake Bay jurisdictions—Maryland, Virginia, Delaware and the District of Columbia—in adopting revised water quality standards to address nutrient and sediment-based pollution in the Chesapeake Bay and its tidal tributaries. Part of the jurisdictions' water quality standards development process may be to conduct use attainability analyses (UAAs). The EPA also developed the *Technical Support Document for Identifying Chesapeake Bay Designated Uses and Attainability* (*Technical Support Document*) to assist states in developing their individual UAAs.

The UAA process is traditionally conducted by individual states. This UAA document provides the technical background information for the Maryland UAA. This UAA documents why the current designated uses for aquatic life protection cannot be attained in all parts of Maryland's Chesapeake Bay and the associated tidal tributaries. It provides scientific data showing that natural and human-caused conditions that cannot be remedied are the basis for the non-attainment and proposes refined designated uses that Maryland has considered for the current water quality standards development and adoption processes. The document also provides scientific data indicating that the refined designated uses are attainable in most of Maryland's Chesapeake Bay segments and documents that the refined designated uses protect existing aquatic life uses. Finally, this UAA briefly summarizes economic analyses based on implementation of Maryland's Tributary Strategies, including estimates of the cost of implementation of the appropriate control scenarios.

INTRODUCTION TO USE ATTAINABILITY ANALYSIS

The Water Quality Standards Regulation (40 CFR 131.3) defines a UAA as "…a structured scientific assessment of the factors affecting the attainment of a use which may include physical, chemical, biological, and economic factors…" (40 CFR 131.10[g]). The Water Quality Standards Regulation requires a state to conduct a UAA when it designates uses that do not include those specified in Section 101(1)(2) of the Federal Water Pollution Control Act.[1] A state must also conduct a UAA when it wishes to remove a specified designated use of the Federal Water Pollution Control Act or adopt subcategories of those specified uses that require less stringent criteria.

When conducting a UAA, a state must demonstrate that attaining the designated use is not feasible due to one or more of six factors specified in Section 131.10(g) of the Water Quality Standards Regulation. These factors are:

1. Naturally occurring pollutant concentrations prevent the attainment of the use;
2. Natural, ephemeral, intermittent, or low-flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of a sufficient volume of effluent without violating state water conservation requirements to enable uses to be met;
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modifications in a way that would result in the attainment of the use;
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles and the like, unrelated to chemical water quality, preclude attainment of aquatic life protection uses; and
6. Controls more stringent than those required by sections 301(b)(1)(A) and (B) and 306 of the Act would result in substantial and widespread economic and social impacts.

The Water Quality Standards Regulation also specifies that any change in designated uses must show that the existing uses are still being protected. The EPA's 1983 *Water Quality Standards Handbook* provides two definitions for an existing use. First, an existing use can be defined as fishing, swimming or other uses that have actually occurred since November 28, 1975. The second definition of an existing use is that the water quality of a water body is suitable to allow the use to be attained—unless there are physical problems, such as substrate or flow, that prevent use attainment. The Water Quality Standards Regulation, in turn, requires state anti-degradation policies to protect existing water quality. Therefore, any recommendations regarding refined designated uses for Maryland portions of the Chesapeake Bay and its tidal tributaries must ensure that existing aquatic life uses continue to be protected.

ATTAINABILITY OF MARYLAND'S CURRENT WATER QUALITY STANDARDS

Maryland's current water quality standards for the Chesapeake Bay include aquatic life use, commercial shellfish harvest, and water contact recreation uses. To protect the aquatic life uses in the Bay and its tidal tributaries, Maryland adopted a dissolved oxygen criteria of 5 mg/L applied year-round throughout all tidally influenced waters. In 1987, the Bay Program partners set a 40 percent loading reduction goal for "controllable" nitrogen and phosphorus to improve low oxygen conditions in the deep trench of the mainstem Bay. This translated into an actual basinwide nitrogen goal of 20 percent reduction of the controllable nitrogen load, while the basinwide phosphorus goal was about a 31 percent reduction from a 1985 baseline. Caps on nitrogen and phosphorus loads were established through the 1992 Amendments to the Chesapeake Bay Agreement and were allocated to each of the 10 major tributary basins in Maryland. The State developed tributary strategies that laid out schedules for taking the specific reduction actions needed to achieve these loading goals. In 1996, Maryland listed all portions of the Chesapeake Bay and most of its tidal tributaries were listed as impaired by nutrients or sediment on the States' 303(d) list. With the signing of the Chesapeake 2000 Agreement, Maryland and the other Chesapeake Bay Program partners have committed to go beyond setting new loading caps for nutrient and sediment and developing local stakeholder-based implementation plans. They have committed to "correct the nutrient- and sediment-related problems in the Chesapeake Bay and its tidal tributaries sufficiently to remove the Bay and the tidal portions of its tributaries from the list of impaired waters (303(d) list) under the Clean Water Act."

To avoid potential negative impacts that a regulatory TMDL process might have on the successful, cooperative efforts being used by the states' tributary strategy programs, the Chesapeake 2000 Agreement lays out a series of commitments directed towards seeking a cooperative solution to restoring Bay water quality. An important initial commitment was defining the water quality conditions necessary to support Bay living resources–fish, crabs, oyster, Bay grasses in 2003 (EPA, 2003). Also, the Bay State partners (DE, MD, VA, and the District of Columbia) agreed to adopt the new water quality standards by 2005.

As part of the new Bay water quality standards adoption process, an analysis of the feasibility of attainment of the current water quality standards must be performed. This is the first step in the UAA process. The determination of non-attainability of the current water quality standards in the Chesapeake Bay and its tidal tributaries is based on three of the six 40 CFR 131 (10)(g) factors noted above— (1) natural factors, (2) human-caused conditions that cannot be remedied, and (3) hydrologic modification (Patapsco River Navigation channels). Output from model-simulated attainment scenarios, TMDL model scenarios for the Patapsco River, and the paleoecological record of the Chesapeake Bay ecosystem provide evidence that these conditions prevent attainment of current designated uses.

To understand the overall feasibility of attaining **current** designated uses in the Chesapeake Bay and its tidal tributaries, the Chesapeake Bay Program analyzed three scenarios: 'all-forest,' 'pristine' and 'everything, everywhere by everyone,' or the E3 scenario. The first two scenarios are the best representations of pre- European settlement conditions (to capture natural pollutant levels). The third scenario (E3) represents the boundary of what is considered physically implausible by Maryland and other State partners for reducing nutrient and sediment pollution. The results of these modeling scenarios demonstrate that even under pristine conditions, the 5 mg/L dissolved oxygen criteria is not attained in the deep channel and deep water (approximately 3% and 1% Baywide, respectively) during the summer months. For the E3 scenario, 59 percent, 23 percent and 2 percent non-attainment are exhibited in the deep-channel, deep-water and open-water areas, respectively, even after implementation of nutrient reduction measures that represent limits of technology.

During the past decade, paleoecological studies of the Chesapeake Bay's late Holocene dissolved oxygen record have been carried out using several proxies of past dissolved oxygen conditions, which are preserved in sediment cores that have been dated using the most advanced geochronological methods. These studies, using various indicators of past dissolved oxygen conditions, are reviewed in Cronin and Vann (2003) and provide information that puts the monitoring record of the modern Chesapeake Bay into a long-term perspective and permits an evaluation of natural variability in the context of restoration targets. Several major themes emerge from the time period studied.

The 20th century sedimentary record confirms the limited monitoring record of dissolved oxygen, documenting that there has been a progressive decrease in dissolved oxygen levels, including the periods of extensive anoxia in the deep-channel region of the Chesapeake Bay that have been prominent during the past 40 years. Most studies provide strong evidence that there was a greater frequency or duration of seasonal anoxia beginning in the late 1930s and 1940s and again around 1970, reaching unprecedented frequencies or duration in the past few decades in the mesohaline Chesapeake Bay and the lower reaches of several tidal tributaries (Zimmerman and Canuel 2000; Hagy 2002).

Extensive late 18th and 19th century land clearance also led to oxygen reduction and hypoxia, which exceeded levels characteristic of the previous 2,000 years. Best estimates for deep-channel mid-bay seasonal oxygen minima from 1750 to around 1950 are 0.3 to 1.4-2.8 mg/l and are based on a shift to dinoflagellate cyst assemblages of species tolerant of low dissolved oxygen conditions. These patterns are likely the result of increased sediment influx and nitrogen and phosphorous runoff due to extensive land clearance and agriculture.

Before the 17th century (pre-settlement), dissolved oxygen proxy data suggest that dissolved oxygen levels in the deep channel of the Chesapeake Bay varied over decadal and inter-annual time scales. These paleo-dissolved oxygen reconstructions are consistent with the Chesapeake Bay's natural tendency to experience seasonal oxygen reductions due to its bathymetry, freshwater-driven salinity stratification, high primary productivity and organic matter and nutrient regeneration (Boicourt 1992; Malone 1992; Boynton et al. 1995).

The combined results of the E3, all-forest and pristine scenarios along with the scientific conclusions from the paleoecological record, strongly indicate that current Maryland aquatic life designated uses cannot be achieved in the Chesapeake Bay's and tidal tributaries' deep-water and deep-channel habitats where natural physical processes and bottom bathymetry-related barriers prevent oxygen replenishment. Natural conditions, as well as human-caused conditions that cannot be remedied have caused the trend towards hypoxia and most recently (especially after the 1960s) anoxia in the main channel of the Chesapeake Bay and some of its larger tidal tributaries. The impact of these patterns has been observed in large-scale changes in benthos and phytoplankton communities, which are manifestations of habitat loss and degradation.

DEVELOPMENT OF THE REFINED DESIGNATED USES

Current designated uses for the Chesapeake Bay and its tidal tributaries do not fully reflect natural conditions and are too broad in their definition of use to support the adoption of more habitat-specific aquatic life water quality criteria. The current uses also change across jurisdictional borders within the same water body. Therefore, the first step in this process was to derive attainable designated uses that protect current and existing uses and propose criteria to protect those uses Baywide. In refining the tidal-water designated uses, the six Bay watershed states and the District of Columbia considered five principal factors:

- Habitats used in common by sets of species and during particular life stages should be delineated as separate designated uses;
- Natural variations in water quality should be accounted for by the designated uses;
- Seasonal uses of different habitats should be factored into the designated uses;
- The Chesapeake Bay criteria for dissolved oxygen, water clarity and chlorophyll *a* should be tailored to support each designated use; and
- The refined designated uses applied to the Chesapeake Bay and its tidal tributary waters will support the federal Clean Water Act goals and state goals for aquatic life uses existing in these waters since 1975.

The five refined designated uses reflect the habitats of an array of recreationally, commercially and ecologically important species and biological communities. The vertical and horizontal extent of the designated use boundaries are based on a combination of natural factors, historical records, physical features, hydrology, bathymetry and other scientific considerations.

> The *migratory fish spawning and nursery designated use* protects migratory and resident tidal freshwater fish during the late winter to late spring spawning and nursery season in tidal freshwater to low-salinity habitats. Located primarily in the upper reaches of many Bay tidal rivers and creeks and the upper mainstem Chesapeake Bay, this use will benefit several species including striped bass, perch, shad, herring, sturgeon and largemouth bass.
>
> The *shallow-water bay grass designated use* protects underwater bay grasses and the many fish and crab species that depend on the vegetated shallow-water habitat provided by underwater grass beds.

The *open-water fish and shellfish designated use* focuses on surface water habitats in tidal creeks, rivers, embayments and the mainstem Chesapeake Bay and protects diverse populations of sport fish, including striped bass, bluefish, mackerel and sea trout, as well as important bait fish such as menhaden and silversides.

The *deep-water seasonal fish and shellfish designated use* protects animals inhabiting the deeper transitional water-column and bottom habitats between the well-mixed surface waters and the very deep channels. This use protects many bottom-feeding fish, crabs and oysters, and other important species such as the bay anchovy.

The *deep-channel seasonal refuge designated use* protects bottom sediment-dwelling worms and small clams that bottom-feeding fish and crabs consume. It also protects the meiofaunal community important to biogeochemical cycling processes in the bottom sediments. Low to occasional no dissolved oxygen conditions occur in this habitat zone during the summer.

ATTAINABILITY OF REFINED DESIGNATED USES

The Chesapeake Bay Program assessed attainability for the refined designated uses based on dissolved oxygen for the migratory and spawning, open-water, deep-water and deep-channel designated uses. Attainability for the shallow-water designated use was assessed based on historic and recent data on the existence of underwater bay grass acreage. The Chesapeake Bay Program did not assess attainability for the chlorophyll *a* criteria, which applies to the open-water designated use, because this criteria is expressed in narrative terms and does not provide a numeric value around which to perform attainability analyses.

For the refined designated uses to which the dissolved oxygen criteria apply, the Chesapeake Bay Program evaluated attainability by comparing the modeled water quality response to a series of technology-based nutrient reduction scenarios. This series of scenarios was developed to represent the watershed's nutrient and sediment reduction potential in terms of the types, extent of implementation and performance of best management practices (BMPs), wastewater treatment technologies and storm water controls. These scenarios range from Tier 1, which represents the current level of implementation plus regulatory requirements implemented through 2010, to a theoretical limit-of-technology scenario referred to previously as the "E3" scenario ("everything, everywhere by everybody"). Tier 2 and Tier 3 are intermediate scenarios between Tier 1 and the E3 scenario. These tiers are artificial constructs of technological levels of effort and do not represent the actual programs that jurisdictions will eventually implement to meet the water quality standards. Rather, the state is using the tiers developed by the Chesapeake Bay Program as an assessment tool to determine potential load reductions achievable by various levels of technological effort, and to model water quality responses to controls. Tier 3 level of effort scenarios have been adopted as the starting point for the implementation of Maryland's Tributary Strategies. More recent and precise work has indicated that a level of effort beyond Tier 3 will be necessary to achieve water quality standards.

The Chesapeake Bay Program used the Chesapeake Bay Watershed and Water Quality Models to determine the water quality response to the pollutant reductions in each scenario (Appendix 1) and then compared these modeled water quality observations within the five refined designated uses to determine the spatial and temporal extent of non-attainment with the respective dissolved oxygen criteria. Specifically, comparison of model results for dissolved oxygen were made to a monthly average dissolved oxygen concentration of 6 mg/l for the migratory and spawning use, 5 mg/l for the open-water use, 3 mg/l for the deep-water use and 1 mg/l for the deep-channel use.

ATTAINMENT OF PROPOSED DISSOLVED OXYGEN CRITERIA

<u>Migratory Spawning & Nursery Designated Use:</u> Current monitoring data and Chesapeake Bay Water Quality Model outputs indicate that the migratory and spawning designated use is essentially being attained in the Chesapeake Bay and its tidal tributaries for dissolved oxygen. The few segments that are not fully attaining the dissolved oxygen criterion would fully attain this use in the Tier 1 scenario (lowest level of control technologies).

<u>Open Water Designated Use:</u> Appendix 1 provides the results of the attainability analysis for dissolved oxygen for the open-water (including shallow-water), deep-water and deep-channel designated uses, by Chesapeake Bay Program segment. As Appendix 1 illustrates, current monitoring data (presented under the ‘observed’ column) indicate that the open-water designated use (OW under the DU column) is frequently not fully attained. However, under the “New Confirm” column attainment is more frequent and non-attainment achieves a much smaller magnitude. Non-attainment of 1 percent or less is considered attainable due to natural variability, anticipation of reduced phosphorus flux as a result of greater oxygenation and reduced pollution inputs, and various uncertainties in the models and current load measurements.

<u>Deep Water, & Deep Channel Designated Uses:</u> For the deep-water designated use for dissolved oxygen criteria, very little attainment is achieved based on current monitoring data and existing implementation, and only some degree of attainment is seen at reduction levels equivalent to Tier 2. At the reduction levels represented by the E3 scenario, attainment is achieved for all segments of the Chesapeake Bay except for two: the Patapsco River mesohaline (PATMH), and the middle central Chesapeake Bay (CB4MH). Appendix 1 also illustrates that under observed conditions, the proposed dissolved oxygen criteria are not attained for the deep-channel designated use. With increasing load reductions, represented by Tier 3, percent non-attainment is primarily less than 2 percent, except in the man-made navigation channels serving the Port of Baltimore in PATMH. Due to significant non-attainment (77% when point sources are at E3) resulting from Federally-authorized hydrologic modification (see Appendix 3) and complex circulation patterns that move hypoxic and anoxic waters from the Bay’s main channel into the Patapsco through advection, the State has determined that further refinement of the designated use to preclude aquatic life use during the seasonal application period of June 1 to September 30 was necessary. Therefore, the State has proposed a “Navigation Channel” designated use subcategory with the applicable D.O. criteria being 0 mg/L from June 1 to September 30 inclusive.

ATTAINMENT OF PROPOSED WATER CLARITY CRITERIA

Shallow Water Bay Grass Designated Use: Attainability for the shallow-water bay grass designated use is based on historic and recent data on the distribution of underwater bay grasses. Detailed analyses using this data—including historical aerial photographs—were undertaken to map the distribution and depth of historical underwater bay grass beds in the Chesapeake Bay and its tidal tributaries. These analyses led to the adoption of the single best year method that considers historical underwater bay grass distributions from the 1930s through the early 1970s as well as more recent distributions since 1978 to present. Using this method, the Chesapeake Bay Program and its watershed partners established a baywide underwater bay grass restoration goal of 185,000 acres. Because of limitations associated with mapping underwater bay grasses using historical photography, the estimate of past underwater bay grass distributions is conservative. Therefore, the restoration goals for the Bay and its tidal tributaries (See Appendix) is conservative as well and considered attainable.

CONFIRMATION THAT EXISTING USES ARE MET

In establishing the refined designated uses, Maryland and the state partners in collaboration with the Chesapeake Bay Program, took explicit steps in developing the requirements and boundaries to ensure that existing aquatic life uses would continue to be protected as the EPA water quality standards regulation require. For some refined designated uses—the migratory fish spawning and nursery, the deep-water and the deep-channel—the application of new dissolved oxygen criteria will result in improvements to existing water quality conditions. The refined open-water fish and shellfish designated use dissolved oxygen criteria will continue to provide an equal level of protection as the current state water quality standards afford to the same tidal waters. The refined shallow-water bay grass designated use ensures protection of existing underwater bay grass-related uses because the single best year method is based on historical (1930s through the early 1970s) and more recent (1978–present) underwater bay grass distributions. This method goes beyond the requirements of the federal clean water act that states that existing uses are those uses that actually occurred on or after November 28, 1975.

ECONOMIC ANALYSES

The *Technical Support Document* summarizes three types of economic analyses that the Chesapeake Bay Program performed in conjunction with developing revised water quality criteria, designated uses and boundaries for those uses in the Chesapeake Bay and its tidal waters. An analysis was undertaken to estimate the costs of implementing the hypothetical control scenarios (represented by the Tier 1-3 scenarios). Maryland has performed the same types of economic analyses on the Maryland Tributary Strategies Program, the “Tier 3” implementation plan for meeting the new Bay water quality standards. The Bay program also conducted screening-level analyses to rule out areas that would not experience substantial and widespread economic and social impacts if states implemented controls more stringent than those required by sections 301 and 306 of the Clean Water Act. The results of analyses to model regional economic impacts are also summarized in the *Technical Support Document.*

Cost

The projected total (capital and operating) costs are approximately $10 billion through 2010. This is predicated on a statewide evaluation of the sewage treatment upgrades and best management practice implementation levels necessary to attain the water quality standards in the Bay and tidal tributaries. Implementation measures were used to achieve water quality standards with consideration of cost, cost effectiveness, feasibility, and minimization of undesired impacts such as sprawl. The costs can be broken out into the broad categories of agricultural best management practices, urban best management practices, sprawl and septic systems, and point sources. There is considerable uncertainty about the cost estimates in each category, particularly for urban best management practices and sprawl and septic systems; consequently there is considerable uncertainty about the total cost. There is additional uncertainty about the effectiveness of the BMPs and therefore the level of implementation that will actually be needed. Nevertheless, after considerable review by State program staff, EPA and contractors, this is the best estimate possible at the current time. It is anticipated that as innovative and more effective management practices are developed, the implementation will evolve and change the costs.

A reevaluation of the water quality benefits that can be achieved is scheduled for 2007 and will incorporate a revised watershed model, a refined water quality model, better estimates of best management practice efficiency, and the incorporation of best management practices not currently included in the watershed model. This will likely modify the required implementation levels and therefore the costs.

Economic impact

The relevance of the economic impact of achieving water quality standards to the Use Attainability Analysis is dependent on several factors:

- Whether the costs that will be incurred to meet water quality standards are mandatory or can be incurred as funds become available,

- Whether the costs result from an administrative decision such as a permit or result from legislative action such as the Bay Restoration Fund, and
- As a corollary, whether the costs result from the regulatory promulgation of these water quality standards or would be incurred even if this action didn't take place.

Costs are mandatory for only two components: point sources and urban best management practices. If the costs are not mandatory, e.g., because there are no direct regulatory controls, then economic impact is not relevant to the UAA because the costs and therefore the impact are only incurred on a cooperative basis. It has generally been accepted among the local governments and tributary teams, that where no regulatory requirement exists, implementation will be dependent on providing funding and other incentives. However, without a requirement, the economic impact will be only that which is accepted by the public or provided by funding agencies. Those costs will be spread nationally in the case of federal funding, resulting in a minimal impact or one absorbed into existing programs. In the case of State funding, they will be legislatively directed as a general policy decision, absorbed within existing programs, or will not occur. In any of these cases, the impact will either be acceptable or not result immediately from the implementation of the water quality standards.

For point sources, the Maryland General Assembly has acted prior to the promulgation of the water quality standards, thus promulgation of the standards cannot be the direct cause of any costs incurred for the Bay Restoration Fund. Further, the General Assembly has effectively determined that the costs are not prohibitive by passing Governor Ehrlich's legislation. This provides the funds necessary to leverage bond issuance that will cover the full costs of enhanced nutrient removal at major wastewater treatment plants. The Fund also provides for a significant amount of cover crops, a very cost effective agricultural best management practice, as well as installation of denitrifying septic systems in the critical area, where the benefit of such systems to the Bay will be greatest.

Although implementation of urban best management practices is required, it is required under the NPDES permit system and costs would be incurred regardless of this change in water quality standards. Further, at this time the permits are technology-based, not water quality-based, and therefore not dependent on this regulatory action. The costs of implementation of the National Pollutant Discharge Elimination Systems (NPDES) municipal separate storm sewer system (MS4) permits vary from jurisdiction to jurisdiction, as does the economic impact, because economic factors (i.e., number of households and median household income) and costs vary from jurisdiction to jurisdiction. If there are significant and widespread impacts for stormwater permits they need to be addressed as part of the permit conditions, not at the water quality standards level since the standards will still have general applicability, even if this creates a problem in a particular jurisdiction. In such a case, the issue will be handled at the jurisdiction level.

Finally, the costs for agricultural best management practices cannot be compelled under existing regulations or permit requirements, and it has been generally agreed that implementation will occur as funds are made available. If the funds are actually available, then it is implicit that the economic hardship was not significant and widespread. Further, the Water Quality Improvement Act of 1998 in combination with the Bay Restoration Act funding for cover crops, were both passed prior to this promulgation, and therefore the water quality standards promulgation can be the cause of the costs.

ECONOMIC BENEFITS OF IMPROVED WATER QUALITY

As stated previously, when evaluating use attainability, states may consider whether controls more stringent than those required by sections 30l(b)(l)(A) and (B) and 306 of the Clean Water Act would result in substantial and widespread economic and social impacts. Estimating potential economic benefits also is integral to understanding the economic impacts of improving water quality in the Chesapeake Bay and its tidal tributaries To estimate the potential economic benefits of restoring Chesapeake Bay water quality, a regional forecasting model developed by Regional Economic Modeling, Inc. (REMI), and an economic impact model (IMPLAN) from the Minnesota IMPLAN Group was used. The IMPLAN model indicates that the Tier 3 scenario would result in a net increase in output, employment, and value-added in the six Chesapeake Bay watershed states and the District of Columbia. In addition, the REMI model forecasts that gross regional product in the State of Maryland will grow by 37 percent by 2010, corresponding to 19 percent growth in employment and 17 percent growth in real disposable personal income. This estimated growth is not accounted for in the IMPLAN results (which are based on current economic conditions). The economic stimulus from Tier 3 results from increased spending in high-wage industries (e.g., wastewater treatment technologies) as well as an influx of funds for pollution controls (e.g., federal cost shares for agricultural BMPs); additional market benefits likely to result from improved water quality (e.g., commercial and recreational fishing industries) are not included. Therefore, the regional economy should expand as a result of the tier scenarios.

Although no comprehensive estimate of the benefits from nutrient and sediment reduction actions in the Chesapeake Bay watershed is available, data suggest that the Chesapeake Bay affects industries that generate approximately $20 billion and 340,000 jobs (including commercial fishing, boat building and repair and tourism). Tourism, as a composite industry, represents the 14th largest source of output, and the 8th largest source of employment, in the Chesapeake Bay watershed. It is not clear the extent to which each of these sectors relies on Chesapeake Bay water quality; however, participation rates and expenditures on recreational fishing suggest that a significant percentage of tourism output is likely linked to the quality of water bodies such as the Chesapeake Bay. For example, the U.S. Fish and Wildlife Service’s 2001 National Survey of Fishing, Hunting and Wildlife-Associated Recreation reports annual expenditures by fishermen of $1,261 million, and 1,859,000 fishing participants, in the states of Maryland, Virginia and Delaware.

Available studies of benefits include Bockstael et al. (1989), which estimate the total value of 20 percent improvement in nitrogen and phosphorous concentrations in the Chesapeake Bay to be $17 million to $76 million in 1996 dollars. Similarly, Krupnick (1988) estimated the total value of a 40 percent improvement in nitrogen and phosphorus concentrations at $43 million to $123 million (in 1996 dollars).

REFERENCES

Boicourt, WC. 1992. Influences of circulation processes on dissolved oxygen in Chesapeake Bay. In: Smith, D., M. Leffler and G. Mackiernana (eds.). *Oxygen Dynamics in Chesapeake Bay: A Synthesis of Research.* University of Maryland Sea Grant College Publications, College Park, Maryland. Pp 7-59.

Boynton, WR, JH Garber, R. Summers and WM Kemp. 1995. Inputs, transformations, and transport of nitrogen and phosphorus in Chesapeake Bay and selected tributaries. Estuaries 18:285-314.

Cronin, TM and C. Vann. 2003. The sedimentary record of anthropogenic and climatic influence on the Patuxent Estuary and Chesapeake Bay ecosystems. Estuaries 26(2A).

EPA. 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. April 2003, 231 pp and Appendices. EPA 903-R-03-002.

Hagy, JD. 2002. Eutrophication, hypoxia and trophic transfer efficiency in Chesapeake Bay. Ph.D. Dissertation. University of Maryland, College Park, MD.

Malone, TC. 1992. Effects of water column processes on dissolved oxygen: Nutrients, plankton and zooplankton. In: Smith, D., M. Leffler and G. Mackiernana (eds.). *Oxygen Dynamics in Chesapeake Bay: A Synthesis of Research.* University of Maryland Sea Grant College Publications, College Park, Maryland. Pp 61-112.

Zimmerman and Canuel, 2002. Sediment geochemical records of eutrophication in the mesohaline Chesapeake Bay. *Limnol. Oceanogr.*, 47(4), 2002, 1084–1093

Appendix 1: Chesapeake Bay Program Attainment Table. MIG=Migratory and Spawning Use, OW=Open Water Use, DW=Deep Water Use, DC=Deep Channel Use. New confirmation run results are used to make attainment estimate. A=fully attained at nutrient allocation. Proportion = proportion of time and volume not in attainment. Less than 0.01 (1%) within margin of error and not considered significant, greater than 1% treated by variance in the designated uses section.

Table 1- Key Scenarios- Summary of Dissolved Oxygen Criteria Attainment*

Segment	Segment		DU	Observed	New Confirm
Mainstem Upper Bay (CB1TF)	CB1TF	CB1TF	MIG	A	A
	CB1TF	CB1TF	OW	A	A
Mainstem Upper Bay (CB2OH)	CB2OH	CB2OH	MIG	A	A
	CB2OH	CB2OH	OW	1.92	0.09
Mainstem Upper Bay (CB3MH)	CB3MH	CB3MH	MIG	0.19	A
	CB3MH	CB3MH	OW	A	A
		CB3MH	DW	4.18	0.46
		CB3MH	DC	13.52	0.40
Mainstem Mid-Bay (CB4MH)	CB4MH	CB4MH	OW	0.05	A
		CB4MH	DW	19.64	6.99
		CB4MH	DC	45.19	1.75
Mainstem Mid-Bay (CB5MH)	CB5MH	CB5MH	OW	A	A
		CB5MH	DW	6.16	0.86
		CB5MH	DC	13.79	0.08
Patuxent Tidal Fresh (PAXTF)	PAXTF	PAXTF	MIG	A	A
	PAXTF	PAXTF	OW	A	A
Patuxent Mid-Estuary (PAXOH)	PAXOH	PAXOH	MIG	A	A
	PAXOH	PAXOH	OW	9.79	0.10
Patuxent Lower Estuary (PAXMH)	PAXMH	PAXMH	MIG	A	A
	PAXMH	PAXMH	OW	7.40	A
		PAXMH	DW	5.52	A
Potomac Tidal Fresh (POTTF)	POTTF	POTTF	MIG	A	A
	POTTF	POTTF	OW	A	A
Potomac Mid-Estuary (POTOH)	POTOH	POTOH	MIG	A	A
	POTOH	POTOH	OW	2.10	0.20
Potomac Lower Estuary (POTMH)	POTMH	POTMH	MIG	A	A
	POTMH	POTMH	OW	0.78	A
		POTMH	DW	6.90	0.58
		POTMH	DC	18.89	0.17
	JMSOH	JMSOH	OW	A	A
Eastern Bay (EASMH)	EASMH	EASMH	MIG	A	A
	EASMH	EASMH	OW	A	A
		EASMH	DW	3.26	0.27
		EASMH	DC	20.23	0.10
Choptank Mid-Estuary (CHOOH)	CHOOH	CHOOH	MIG	A	A
	CHOOH	CHOOH	OW	0.11	A
Choptank Lower Estuary (CHOMH1)	CHOMH1	CHOMH1	MIG	A	A
	CHOMH1	CHOMH1	OW	2.27	0.92
Choptank Lower Estuary (CHOMH2)	CHOMH2	CHOMH2	MIG	A	A

	CHOMH2	CHOMH2	OW	0.33	A
Tangier Sound (TANMH)	TANMH	TANMH	OW	0.15	0.33
Pocomoke (POCMH)	POCMH	POCMH	OW	A	A
Chester Lower (CHSMH)**	CHSMH	CHSMH	MIG	A	A
	CHSMH	CHSMH	OW	5.67	1.98
	CHSMH	CHSMH	DW	0.85	A
	CHSMH	CHSMH	DC	11.80	A

* 4/1/03, Version 15 -- Changes since version 12: SAV Re-calibration, Wetlands Oxygen Demand, No Seasonal Anoxic Zone

** for information purposes only, model not sufficiently calibrated for these areas

UAA for the Federal Navigation Channels in Tidal Portions of the Patapsco River

Use Attainability Analysis for the federal navigation channels located in tidal portions of the Patapsco River.

Use Attainability Analysis For Patapsco River Mesohaline (PATMH):

Preamble

In April 2003, the U.S. Environmental Protection Agency (EPA) Region III issued guidance entitled *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll* a *for the Chesapeake Bay and Its Tidal Tributaries* (*Regional Criteria Guidance*). The development of the *Regional Criteria Guidance* was the realization of a key commitment in the *Chesapeake 2000* agreement. In that agreement, the signatories (the states of Pennsylvania, Maryland and Virginia; the District of Columbia; the Chesapeake Bay Commission and the EPA) committed to, "by 2001, define the water quality conditions necessary to protect aquatic living resources." New York Delaware and West Virginia agreed to the same commitment through a separate six-state memorandum of understanding with the EPA.

The EPA, in the *Regional Criteria Guidance*, defined the water quality conditions called for in the *Chesapeake 2000* agreement through the development of Chesapeake Bay-specific water quality criteria for dissolved oxygen, water clarity and chlorophyll *a*. The EPA also identified and described five habitats, or designated uses, that provide the context in which the EPA Region III derived adequately protective Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll *a.* Collectively, the three water quality conditions provide the best and most direct measures of the effects of too much nutrient and sediment pollution on the Bay's aquatic living resources—fish, crabs, oysters, their prey species and underwater bay grasses. These criteria were developed as part of a larger effort to restore Chesapeake Bay water quality.

The Maryland Department of the Environment, as a partner working in good faith to fulfill the goals of the *Chesapeake 2000* agreement, is currently in the process of promulgating the new Chesapeake Bay water quality standards to protect the Bay's aquatic living resources within the State of Maryland. This Use Attainability Analysis was developed by the Department to be a companion to the new Chesapeake Bay water quality standards (COMAR 26.08.01.01, 26.08.02.02, 26.08.02.03-3, and 26.08.08.08). This analysis describes the development and geographical extent of the designated uses to which the water quality criteria may apply, and as such serves as a resource to the State and its citizens to assist them in the monitoring, assessment, and protection of the Bays' resources.

The Use Attainability Analysis is not law or regulation; it is an assessment of the attainability of the current Bay water quality standards as well as the newly proposed water quality standards.

Purpose:
This use attainability analysis is provided to support the proposed water quality regulation at COMAR 26.08.02.03-3 §C (7)(f)

Executive Summary:
The current designated use for the Patapsco River (including Baltimore Harbor) is Use I, meaning that the water quality should be expected to support aquatic life and provide for recreation in and on the water. The Chesapeake Bay Program in collaboration with the Bay

Watershed States (MD, VA, PA , NY, DE, and Washington D.C.) have recently developed new water quality standards for the Bay mainstem and its tidal tributaries, including the Patapsco River. The new standards proposes up to 4 designated uses for the Patapsco River applied spatially and temporally based on the needs of living resources and the hydrology and bathymetry of the Patapsco River.

An analysis of the existing water quality data indicates that the dissolved oxygen criteria for the deep channel seasonal refuge use (instantaneous minimum of 1.0 mg/L, applied June 1 to September 30) cannot be met, even after projected nutrient reductions from point sources (based on implementation of ENR to achieve 3 mg/L TN) and the application of the Tributary Strategies reductions for nonpoint sources. The current best projections of the water quality model indicate a minimum 70% exceedence rate in the deep channel seasonal refuge designated use. The dissolved oxygen criteria for the open water designated use, which applies from October 1 to May 31, is projected to be attained within the accepted biologic reference curve.

The application of 40CFR§131.10(g) use attainability factors 1, 3, and 4 are necessary based on the analyses of existing water quality data and the Chesapeake Bay water quality model's calculations of expected conditions following nutrient reductions projected by the implementation of the Tributary Strategies. Further, this analysis is supported by examining the historical background of Army COE activities conducted in the Patapsco River pursuant to the Federal Rivers and Harbors Act of 1852 and its subsequent reauthorizations. Therefore, the Department of the Environment is proposing a modification of the designated uses and criteria within the Chesapeake Bay Segment "Patapsco River Mesohaline (PATMH)". The proposed modification is to the dissolved oxygen criteria for the deep channel seasonal refuge designated use from an instantaneous minimum of 1.0 mg/L to an instantaneous minimum of 0.0 mg/L applied temporally and spatially from June 1 to September 30. The proposed modification will result in a further subcategorization from the designated use subcategory of "Deep Channel Seasonal Refuge" to a limited use subcategory of "Navigation Channel", thus removing the support of aquatic life use normally required by water quality standards.

Introduction to Use Attainability Analysis:
The Water Quality Standards Regulation (40 CFR 131.3) defines a UAA as "…a structured scientific assessment of the factors affecting the attainment of a use which may include physical, chemical, biological, and economic factors…" (40 CFR 131.10[g]). The Water Quality Standards Regulation requires a state to conduct a UAA when it designates uses that D.O. not include those specified in Section 101(1)(2) of the Federal Water Pollution Control Act. The regulation at 131.10(j) provide that a state must conduct a use attainability analysis (UAA) whenever:

> the State designates or has designated uses that D.O. not include those specified in CWA Section 101(a)(2); or
>
> the State wishes to remove a CWA Section 101(a)(2) use, or to aD.O.pt subcategories of uses specified in CWA Section 101(a)(2) which require less stringent criteria.

States may remove a designated use which is not an existing use, as defined in Sec. 131.3, or establish sub-categories of a designated use, if the State can demonstrate that attaining the designated use is not feasible because:

(1) Naturally occurring pollutant concentrations prevent the attainment of the use; or
(2) Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or
(3) Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
(4) Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
(5) Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
(6) Controls more stringent than those required by 33 USC 1301 §§ 301(b)(1)(A) and (B) and 306 of the Act would result in substantial and widespread economic and social impacts.

The Water Quality Standards Regulation also specifies that any change in designated uses must show that the existing uses are still being protected. "Existing uses" means those uses *actually attained in the water body on or after November 28, 1975*, whether or not they are included in the water quality standards. Existing uses can include those uses (i.e. fishing, swimming, navigation) people make or have made sometime since November 1975, whether or not the water quality supports that use; and/or uses that the water quality is good enough to support, unless there are physical problems, such as substrate or flow, that prevent use attainment.

Patapsco River Existing Use (Navigation Channel) - Historical Background:

In 1830, the Patapsco River was surveyed and it was determined that the controlling depth was 17 ft from the Chesapeake Bay to Fort McHenry. By 1836, Congress appropriated funds to dredge the entrance channels for the Baltimore Harbor, although no channel dimensions were specified in the law. Dredging was completed in 1838. This was the initiation of dredging activity in the Patapsco River to enable Baltimore Harbor to remain a productive commercial port. The following table is a summary of major activities under the Federal Rivers and Harbors Act.

Table 1. Timeline of major ACOE activities pursuant to Federal Rivers and Harbors Act

1852	Rivers & Harbors Act of 1852 authorized a channel 22 ft deep by 150 ft wide from Fort McHenry to the Chesapeake Bay off Swan Point.
1892	A 27-ft-deep Federal channel to Curtis Bay was authorized and completed
1903	The main Patapsco River channel was deepened to a 30-ft depth.
1917	The Act authorized the branch channels to 35 ft deep and 250 ft wide to the head of Curtis Bay, 35 ft deep by 400 ft wide from Fort McHenry to the Ferry Bar, then 27 ft deep by 50 ft wide to the Western Maryland Railway Bridge. The Act also authorized

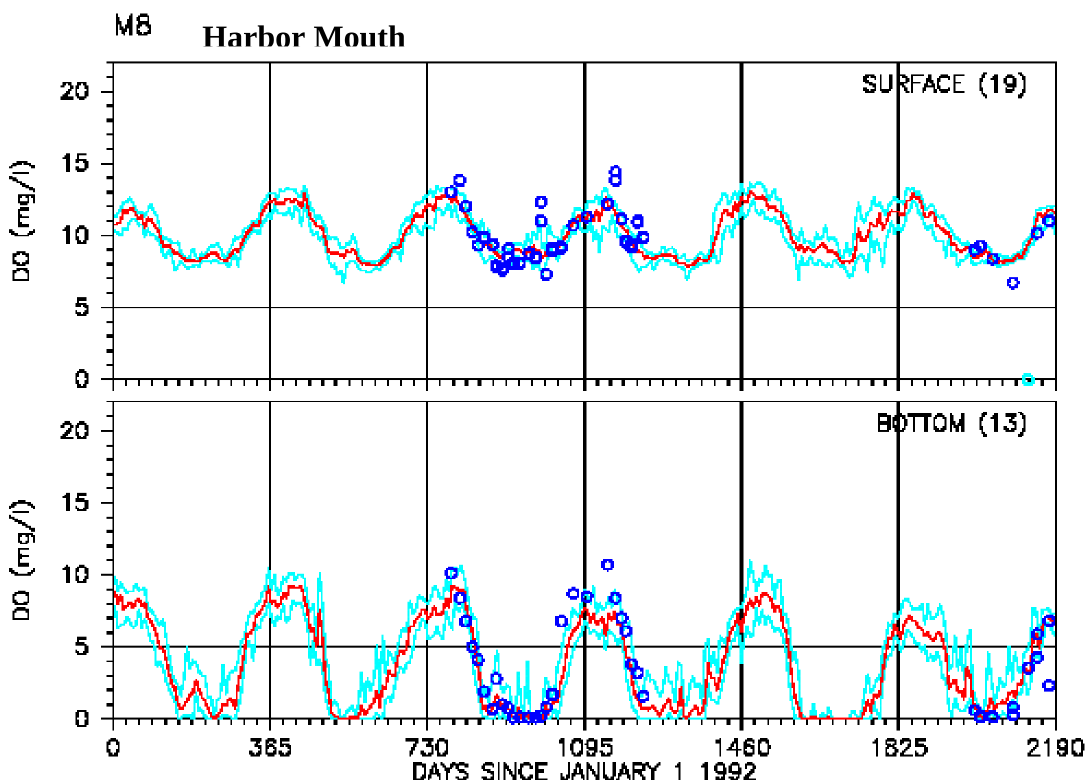
	Federal maintenance of a 35-ft channel in the Northwest Branch .
1930	The Act authorized the deepening of the Baltimore Harbor channel depth to 37 ft for the York Spit Channel in Virginia and channels from the Baltimore Light to the Sparrows Point entrance. The Act also authorized widening the channel angles between Fort McHenry and the Ferry Bar Section and increasing the channel width to 400 ft for the Curtis Bay Section.
1945	The Act authorized increasing the channel depth to 39 ft deep and 1,000 ft wide in the Cape Henry and York Spit Channels in Virginia, and to 39 ft deep and 600 ft wide from the Craighill Entrance to Fort McHenry. The 1945 Act also authorized the dredging of Curtis Creek to 35 ft deep and 200 ft wide from the head of Curtis Bay to the Pennington Avenue Bridge.
1958	The Act authorized the deepening of the main channel to 42 ft and widening the channels from the Craighill Entrance to Fort McHenry from 600 to 800 ft and the deepening and widening of the Curtis Bay and Ferry Bar Channels of the Harbor to 42 ft deep and 600 ft wide.
1970	The Act authorized deepening the main channel from Cape Henry to Fort McHenry, and the Curtis Bay Channel to 50 ft, and deepening the Northwest Branch East and West Channels to 49 and 40 ft, respectively.

Source: http://www.nab.usace.army.mil/projects/Maryland/DMMP/history.html

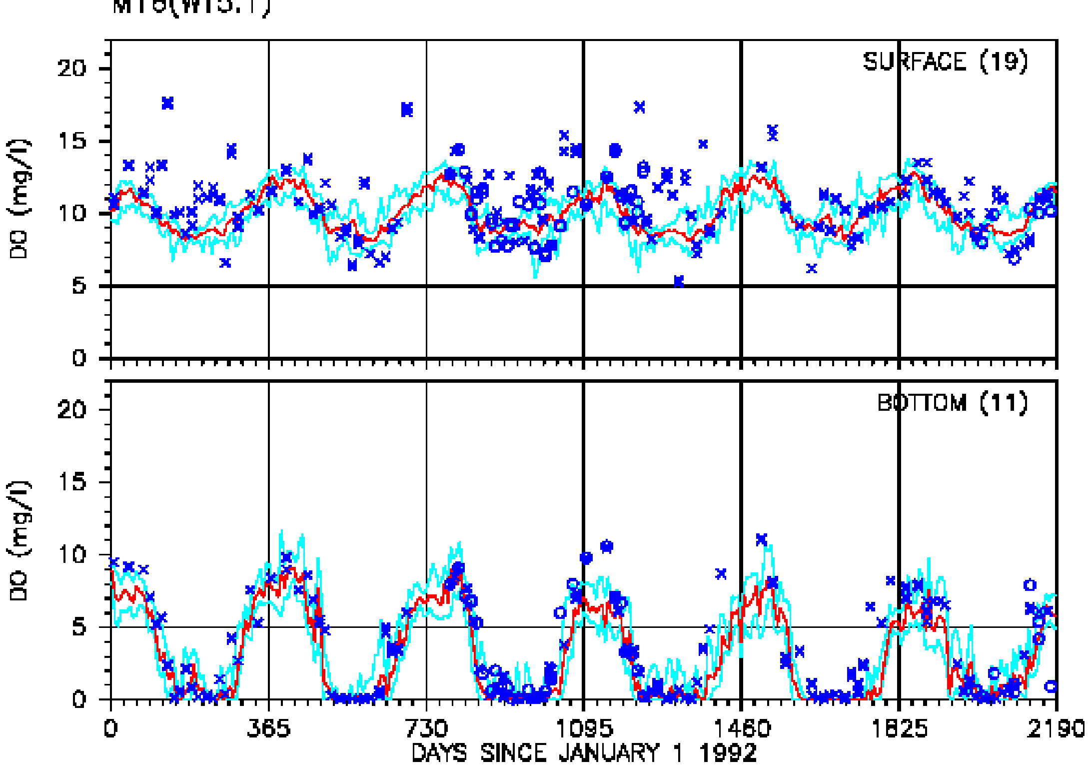
Existing Conditions (Water Quality):

Dissolved Oxygen

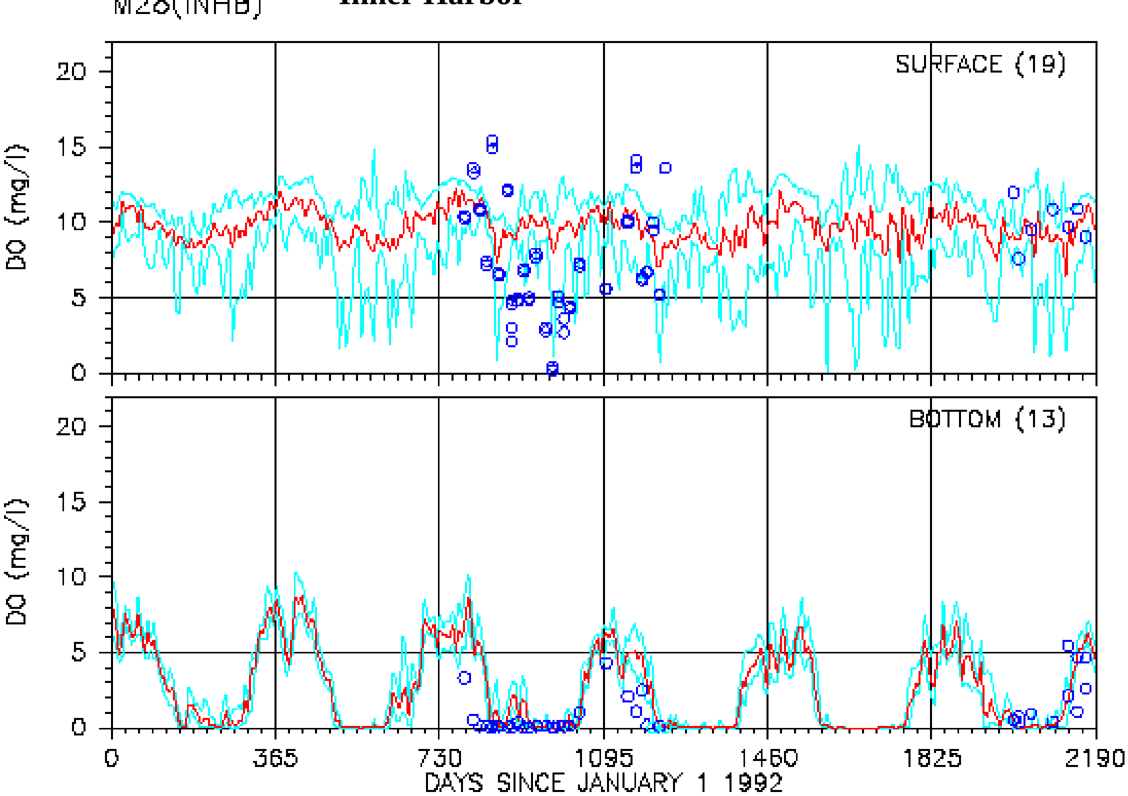
The following plots show the calibration of the Baltimore Harbor D.O. against observed data from 1992 to 1997. Note the anoxic conditions of the Harbor in the bottom layer at each station during the summer months. Anoxic conditions may start as early as as March in the Inner Harbor and May in the Middle of the Harbor Channel.



Channel



Inner Harbor



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Note: For the graphs above, the light gray lines represent the Chesapeake Bay Model Release 4.3, the dark gray lines represent the MDE adaptation of the Chesapeake Bay Model 4.3, and the open circles represent the data collected by the Department.

A number of sensitivity scenarios were run using MDE adaptation (MDE had finer resolution grid for the Patapsco River) of the Chesapeake Bay Model Release 4.3. The following sensitivity scenarios were run using the calibrated model to estimate the influence of the different loadings sources and to estimate the extend of impairments due to natural conditions and/or man-made conditions.

1) Chesapeake Bay Program (CBP) Load Allocation;
2) CBP Allocation with MDE nonpoint source (NPS) reductions;
3) CBP Allocation with MDE NPS and CBP- “E3” (Everything, everywhere, by everybody) point source (PS) reductions;
4) CBP Allocation with MDE NPS and current permits for PS;
5) CBP Allocation with MDE NPS and “Enhanced Nutrient Removal Strategy” (ENR) PS; and
6) **Tributary Strategy (MDE proposed total maximum daily load scenario – results shown in table below):**

- Baltimore Harbor Loads
  - Point Source
    - Flow: Maximum permit flow, and
    - Major Municipal PS – ENR: total nitrogen(TN): 4 milligrams/liter annual average: (3 milligrams/liter from May – October; 5 milligrams/liter from November - April), and total phosporus (TP): 0.3 milligrams/liter
    - Minor Municipal PS – ENR: TN: 18 mg/L; TP: 3 mg/L
    - Industrial PS – CBP Tier III Scenario loads
  - Nonpoint Source
    - MDE’s “Hydrodynamic Simulation Program – Fortran” model outputs x Pass Through Efficiency
    - Pass Through Efficiency = CBP allocation/CBP calibration

      TN=0.33 TP = 0.33

Scenario Results
D.O. attainment check for the proposed “Deep Channel Seasonal Refuge” use:

MDE Calibration, CBP Allocation and Possible TMDL Scenarios	**Patapsco River Mesohaline D.O. Percent non-attainment**				
	Deep Water June to September	Deep Channel June to September	Open Water June to September	Migratory Fish February to May	Open Water October to January
[1]CBP allocation with MDE projected NPS and ENR-PS	7 (3 mg/L)	**79**	0	0	0

1. This scenario represents the current Tributary Strategies reduction based on N and P allocations produced by the Chesapeake Bay Program (Model Release 4.3). The D.O. attainment check was run against the proposed criteria for each applicable designated use subcategory. A restoration variance of 7% applied temporally and spatially has been proposed for the "Deep Water Seasonal Fish and Shellfish" use, based on those same model runs.

Benthic Characterization:

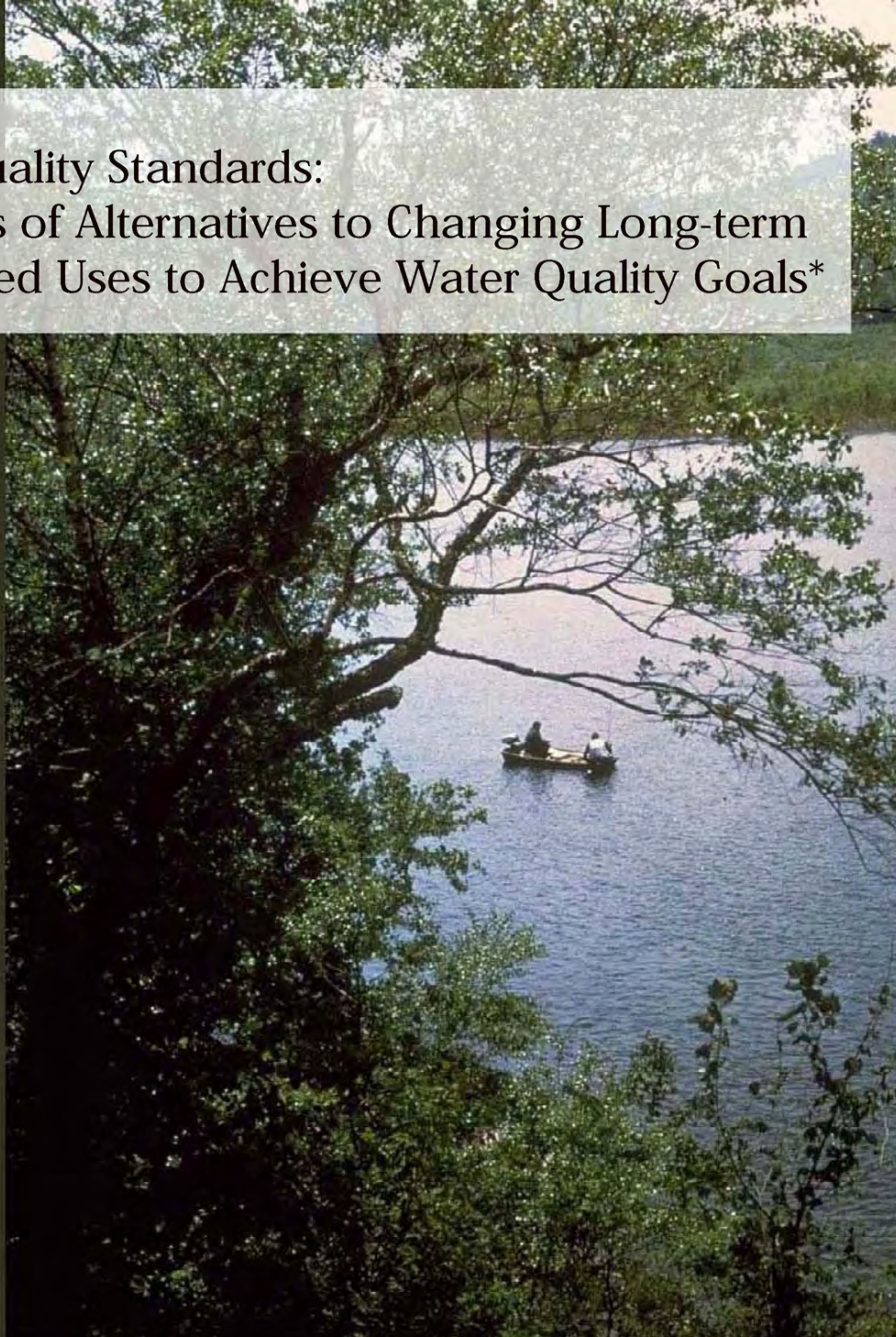
The existing benthic community in the Outer and Inner Harbor deep-dredged channels can be characterized as unstable due to frequent disturbances, such as the 42-foot dredging project, annual maintenance dredging and prop-washes associated with ship movements, and is thought to consist primarily of opportunistic species. The community likely to recolonize in the deep dredged channels would be similar in nature to the existing benthic community, since the existing benthic community is unstable and frequently disturbed, and recolonization may occur within a relatively short time.

Conclusions:

Due to significant non-attainment (77% when point sources are at E3) resulting from Federally-authorized hydrologic modification under the Rivers and Harbors Act and a complex pattern of tidal circulation that move hypoxic and anoxic waters from the Bay's main channel into the Patapsco through advection, the State has determined that further refinement of the designated use to support only benthic species that are tolerant to periods of hypoxia and/or anoxia during the seasonal application period of June 1 to September 30 is the highest attainable use in this water body segment during this period. Therefore, the State has proposed a "Navigation Channel" designated use subcategory with the applicable D.O. criteria being 0 mg/L from June 1 to September 30 inclusive. The geographic extent of this narrowly structured use is confined to the dredged channels that begin at the mouth of the Patapsco River (confluence with the Chesapeake Bay), and continuing in to the Curtis Bay and Creek, and the Middle and Northwest Branchs.

Appendix G:
Case Studies—March 2005

Water Quality Standards: Examples of Alternatives to Changing Long-term Designated Uses to Achieve Water Quality Goals*



*Case study examples developed by States and EPA

Water Quality Standards:
Examples of Alternatives to
Changing Long-term Designated Uses
To Achieve Water Quality Goals*

March 2005

* Case study examples developed by States and EPA

FOREWORD

States, Tribes, and Regions need to share information about regulatory tools for facilitating progress towards meeting Clean Water Act goals, particularly in impaired waterbodies. Attainment of water quality standards may, in some instances, require relatively long time frames (e.g., greater than five years) to achieve the State's designated use. For example, this situation may occur with the following types of sources throughout the United States:

- Combined sewer overflows (CSOs)
- Pollution by legacy contaminants (e.g., PCBs, dioxins, some metals)
- Abandoned mines
- Urban and agricultural land use impacts (e.g., nonpoint sources)
- Nutrient enrichment
- Some industrial and POTW discharges of toxic pollutants

Some of these types of sources, such as periodic discharges from CSOs or nonpoint sources, may cause temporary non-attainment of specified designated uses. For some pollutants, a relatively long time frame may be required to alleviate the impairments, such as PCB contamination or nutrient enrichment in bays, estuaries, lakes, and reservoirs. In some cases, there may not be sufficient scientific basis for determining what uses can be attained. There also may be cases where there is a common desire to improve conditions in the near term, even though the achievability, or time frame of achievability, of the water quality standards in the longer term is unknown or in question. In all of these cases, short-term mechanisms may provide a useful incentive to make environmental improvements over current conditions. When stakeholders believe they cannot achieve a long-term goal, some may resist the initiation of any improvements.

Water quality standards must include designated uses consistent with the Clean Water Act goal of "protection and propagation of fish, shellfish, and wildlife and recreation in and on the water" unless there is an analysis supporting the assertion that it is not feasible to attain such a use. Water quality standards must also include specific criteria to protect the designated uses. Implementation of these water quality standards, through establishing permit limits on point source dischargers or developing "Total Maximum Daily Loads" (TMDLs) for point and nonpoint sources, must be aimed at the applicable water quality standard. TMDLs are plans to achieve the applicable water quality standard and cannot authorize a delay in meeting otherwise applicable regulatory requirements in and of themselves. However, mechanisms that do modify the regulatory requirements can be used in conjunction with a TMDL.

There are several ways of adjusting aspects of a water quality-based program to facilitate implementation of water quality standards without removing the long-term designated use. Sometimes, these mechanisms are used in conjunction with one another to tailor a specific approach. First, States may revise their criteria to better reflect specific protection needs. States may also adjust the wasteload and load allocation portions of their TMDL to obtain an achievable balance among sources. The next level is to examine use of schedules of compliance. These are addressed in the Clean Water Act and in U.S. EPA's permitting regulations. They can apply to individual dischargers and, in more recent examples, to multiple sources. Ideally, schedules of compliance are authorized within the applicable water quality standards. States have also used authorizing state legislation and general permits to help establish and implement schedules of compliance. Finally, States can establish short-term goals, or variances, within their applicable water quality standards. These are facilitated by the same water quality standards regulatory requirements that allow removal of the long-term designated use, but are typically of reduced scope in terms of pollutants addressed, affected sources, and time of applicability.

The tools presented here for use in attaining water quality standards can serve as alternatives to changing long-term underlying designated uses and criteria. The following case studies, developed by the States and EPA, provide initial examples of some approaches and tools that have been used or are proposed for use. These particular examples focus on approaches that combine schedules of compliance with adjustments to criteria. EPA will continue to work with States to prepare case studies that illuminate the spectrum of approaches that utilize the flexibility built into the water program to achieve important objectives.

Santa Monica Bay Bacteria

Background Information

Santa Monica Bay lies offshore of Los Angeles County, California. The Los Angeles Regional Water Quality Control Board developed a TMDL to address documented bacterial water quality impairments at 44 beaches located along the coast from just south of Palos Verdes Peninsula north to the Los Angeles/Ventura County line. The Santa Monica Bay Beaches Wet-weather Bacteria TMDL was designed to preserve and enhance the water quality at Santa Monica Bay beaches during wet-weather conditions, which are defined as days with 0.1 inch or greater rainfall and the three days following the rainfall event. A separate TMDL was developed for dry weather conditions.

An estimated 55 million people visit the Santa Monica Bay beaches each year. The primary issues associated with bacterial contamination of the beaches include the health of swimmers and surfers who use the beaches for recreation, the cost of health care associated with illness originating from use of the water, and economic impacts to local economies when beachgoers go elsewhere. For example, visitors to the beaches spent an estimated $1.7 billion locally in 2002.

Many of the beaches along Santa Monica Bay were listed on California's 1998 section 303(d) list because elevated levels of coliform or beach closures associated with bacteria prevented the full support of the beaches' designated use for water contact recreation. A consent decree between the U.S. Environmental Protection Agency (EPA), Heal the Bay, Inc., and BayKeeper, Inc. was approved on March 22, 1999. As a part of the court order, EPA established a schedule to complete a TMDL to reduce bacteria at Santa Monica Bay beaches. Water quality standards, which are the basis for the targeted reduction in bacteria from dischargers identified in the TMDL, are set at a level to ensure that the risk of illness to the public from swimming at Santa Monica Bay beaches will be less than 19 illnesses per 1000 swimmers. This level of risk is consistent with EPA recommended acceptable health risk levels for marine waters.

Runoff from storm drain systems was determined to be the primary source of bacterial contamination leading to bacterial water quality impairments at the Santa Monica beaches. Elevated levels of bacterial indicators in stormwater runoff from the storm drain system has been linked to sanitary sewer leaks and spills, runoff from homeless encampments, pet waste, illegal discharges from recreational vehicle holding tanks, and malfunctioning septic tanks and urban runoff. Additional sources of elevated bacteria to marine waters could also include direct illegal discharges from boats, malfunctioning septic tanks, illicit discharges from private drains, and swimmer wash-off. It is also important to note that the bacteria indicators that are used to assess water quality are not specific to human sewage. Other possible sources that can contribute to the elevated bacterial indicator levels are fecal matter from animals and birds, vegetation, and food waste.

Treating elevated bacteria concentrations in stormwater runoff from semi-arid urban areas poses significant challenges because of the ubiquitous nature of bacteria in the urban environment coupled with the nature of storms and stormwater runoff in the semi-arid Los Angeles Region. Local wet weather characterizations have shown elevated concentrations of bacteria from every type of land use, making it difficult to prioritize and focus implementation measures in specific geographic areas. Additionally, short, intense storms that create large peak flows and volumes characterize the semi-arid Los Angeles Region. These large flows and volumes are difficult to capture and treat at one point. The Los Angeles Regional Board recognized this challenge and the need to implement stormwater capture-and-treat measures at multiple points throughout the watershed to meet TMDL requirements. Given the lengthy and complex planning process that would be required to implement a multi-benefit, watershed approach, the Regional Board proposed a unique "reference system/antidegradation" (using their terminology) approach combined with a relatively long implementation schedule, described below.

Approach

California establishes water quality standards, in part, through amendments to Regional Board "Basin Plans". In this case, two amendments served as the water quality standards mechanisms that facilitated this approach: one was a general authorizing provision for schedules of compliance and the other was a specific procedure to adjust an aspect of a water quality criterion. On February 10, 2004, EPA approved an amendment to the "Basin Plan" for the coastal watersheds of Los Angeles and Ventura Counties, which authorized inclusion of compliance schedules in NPDES permits. Although adoption of such policies is optional for a state, such implementation policies are subject to EPA review and approval under Clean Water Act (CWA) section 303(c). The amendment specifies that where the Regional Board determines it is infeasible for an existing discharger to achieve immediate compliance with an effluent limit specified to implement a new, revised or newly interpreted water quality standard, the Regional Board may establish a compliance schedule to implement a TMDL. An authorized compliance schedule must include a time schedule for completing specific actions and be based on the shortest time possible to achieve compliance.

For the Santa Monica beaches, the Regional Board proposed a wet weather TMDL to be implemented over a period of 10 to 18 years. The relatively long implementation schedule allows the use of an integrated water resources approach that takes a holistic view of regional water resources management by integrating planning for future wastewater, storm water, recycled water, and potable water needs and systems; focuses on beneficial re-use of storm water, including groundwater infiltration, at multiple points throughout a watershed; and addresses multiple pollutants that impair the Santa Monica Bay or its watershed. Although the general authorizing provision for schedules of compliance is an approved water quality standard, the specific implementation schedule for this TMDL was not subject to a specific water quality standards review action.

A unique aspect of the wet-weather TMDL is the "reference system/antidegradation approach" adopted as a water quality standard. On June 19, 2003, EPA approved the "reference system/antidegradation approach" and "natural sources exclusion approach," included as amendments to the Basin Plan, as implementation procedures for the single sample bacteriological objectives. A certain number of daily exceedances of the single sample bacteria objectives is allowed based on historical exceedance levels at existing shoreline monitoring locations, including a local reference beach within Santa Monica Bay. This approach recognizes natural sources of bacteria that may cause or contribute to exceedances of the single sample bacteria objectives. The Regional Board did not intend to require treatment or diversion of natural creeks or treatment of natural sources of bacteria from undeveloped areas. This reference system/anti-degradation approach is designed to ensure that human-generated sources of bacteria and natural bacteria conveyed by human activities (e.g., storm water conveyances) do not cause or contribute to an exceedance of water quality standards. Additional data collection will allow the Regional Board to better understand the contribution of naturally occurring bacteria and refine the numeric target to address the natural sources or to adjust the objectives to recognize naturally occurring exceedances. Arroyo Sequit Canyon, which drains to Leo Carrillo Beach was proposed as the initial reference system. Arroyo Sequit Canyon is largely undeveloped with about 98% open space and little evidence of human impact. The reference beach approach ensures that water quality is at least as good as that of the reference beach.

Although not subject to formal EPA review under CWA Sections 303(c) or 303(d), the Regional Board formally adopted a TMDL implementation schedule within a package of amendments to their "Basin Plan". The implementation schedule contains the following flexibility:

- The use of the reference approach that allows a number of exceedance days based on exceedances in an undeveloped reference watershed
- A re-opener in 4 years that allows for additional science to modify the implementation plan
- Allowance for a longer implementation plan (up to 18 years) if the cities utilize an integrated resource approach that involves watershed-wide storage and re-use and onsite treatments instead of traditional engineering approaches of capture, treatment, and discharge

Boundaries of Application

The California approach relies on the use of reference conditions to distinguish between natural and human-caused bacterial contamination of Santa Monica Beaches. Long-term implementation is required to allow time for the incorporation of changes using a multi-benefit watershed based approach. The watershed approach will strive to incorporate groundwater recharge, water re-use throughout the watershed, and integrate wastewater, storm water, recycled water, and potable water needs throughout the basin feeding Santa Monica Bay.

This application required multiple levels of approval since it was adopted as a water quality standards action. This entails multiple reviews, citizen and stakeholder input, public meetings, and formal Regional and State Board meetings. It is important to note that the "reference system/antidegradation approach" was formally adopted in the California Water Quality Standards. In this case, the adoption of the approach mostly occurred prior and/or concurrently with the adoption of the TMDL. The selection of the reference locations is critical and should reflect waters with no or virtually no anthropogenic impact. In using this approach, care must be taken in selecting the reference location. They should not be selected solely because they are the best, but degraded, conditions present in human-influenced systems.

Resources/References

California Regional Water Quality Control Board, Los Angeles Region. 2002. Santa Monica Bay Beaches Wet-weather Bacteria TMDL, California Regional Water Quality Control Board, Los Angeles Region, California Environmental Protection Agency, Los Angeles California.

California Regional Water Quality Control Board, Los Angeles Region. 2002. Amendment to the Water Quality Control Plan (Basin Plan) for the Los Angeles Region to Incorporate Implementation Provisions for the Region's Bacteria Objectives and to Incorporate a Wet-weather Total Maximum Daily Load for Bacteria at Santa Monica Bay Beaches, Resolution No. 2002-022, California Regional Water Quality Control Board, Los Angeles Region, California Environmental Protection Agency, Los Angeles California.

Long Island Sound Dissolved Oxygen

Background Information

The Connecticut Department of Environmental Protection (CTDEP), the New York State Department of Environmental Conservation, and the U.S. Environmental Protection Agency (EPA) have identified nitrogen as the primary pollutant leading to summertime hypoxia (low dissolved oxygen) in Long Island Sound bottom waters. While nitrogen is essential to a productive ecosystem, too much nitrogen fuels the excessive growth of algae. When the algae die, they sink to the bottom, where they are consumed by bacteria. The microbial decay of algae and the respiration of oxygen-breathing organisms use up the available oxygen in the lower water column and in the bottom sediments, gradually reducing the dissolved oxygen concentration to unhealthy levels. Dense algal blooms also can inhibit light penetration, preventing sufficient light from reaching the bottom in shallow areas to support the growth of submerged aquatic vegetation, an important habitat for shellfish and juvenile fish. Consequently, excessive nitrogen impairs the function and health of Long Island Sound.

Dissolved oxygen levels in the deep waters of Long Island Sound below the seasonal pycnocline routinely fall below 2 mg/L in the summer months. These levels are too low to sustain important fish and shellfish populations in the sound. State water quality standards for dissolved oxygen were 6.0 mg/L for Connecticut waters and 5.0 mg/L in the New York portion. Connecticut and New York developed the Long Island Sound nitrogen TMDL to address the hypoxia problem.

The baseline nitrogen load delivered to Long Island Sound from New York and Connecticut was estimated to be about 48,000 tons of nitrogen per year. The TMDL, which was jointly established by Connecticut and New York in December 2000 and approved by the EPA in April 2001, specifies that almost 24,000 tons of the nitrogen originating in New York and Connecticut from human sources and delivered to the sound in the baseline year be reduced by 2014. This translates into a reduction of 58.5% from the human-caused sources of nitrogen from New York and Connecticut.

The TMDL specifies that point and non-point source discharges in New York must remove about 17,150 tons per year by 2014. In Connecticut, point source dischargers will be required to remove about 6,670 tons of nitrogen annually from their effluent streams prior to discharge to Long Island Sound or its tributaries. About 400 tons of nitrogen are targeted to be removed from non-point sources, primarily urban stormwater runoff. To meet the Wasteload Allocation established in the TMDL for Publicly Owned Treatment Works (POTWs) in Connecticut, 79 POTWs will have to upgrade facilities such that the group will collectively meet the nitrogen reduction requirements.

Approach

Connecticut used a three-pronged approach to improve the hypoxic conditions in Long Island

Sound to meet water quality standards for aquatic life support uses:

- Adopting appropriate dissolved oxygen criteria for bottom waters
- Establishing a TMDL that incorporates a phased implementation plan
- Implementing a nitrogen trading program to facilitate load reductions

Connecticut recognized that their existing general water quality criteria for dissolved oxygen, which was 6.0 mg/L at any time, was not appropriate for application to deep waters of the sound below the seasonal pycnocline during the summer months. Due to natural circulation patterns and the large (>16,000 sq. mi.) watershed draining into the sound, dissolved oxygen levels below 6 mg/L in bottom waters are an expected natural occurrence when the sound stratifies during the summer months. This condition would exist even in the total absence of human derived nitrogen. Federal guidance (*Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras* (USEPA, 2000) provided a comprehensive evaluation of the effects of dissolved oxygen on aquatic life along the Atlantic coast that was necessary to support the State's adoption of a dissolved oxygen criteria that more closely reflects natural conditions and protects the biological integrity of the sound. Connecticut's criteria was approved by EPA in May 2001.

Both New York and Connecticut have committed to a phased implementation of the TMDL that will be accomplished in three steps with 5-year incremental reduction targets. Beginning in 1999, the two states are required to reduce their annual nitrogen discharges to the Sound toward a goal of 58.5% of baseline or about 24,000 tons at the end of 15 years. The phased implementation requires implementing controls to achieve:

- 23.4% reduction (40% of goal or about 9,534 tons) by August 2004
- 43.9% reduction (75% of goal or about 17,876 tons) by August 2009
- 58.5% reduction (100% of goal or about 23,834 tons) by August 2014

Recognizing that the total nitrogen load entering the Sound from human sources is dominated by point source discharges and that point sources also hold the greatest management potential, Connecticut set a goal to meet the overall reduction by implementing technologies and strategies to sewage treatment facilities with an aggressive cumulative goal of 64% nitrogen reduction from municipal POTWs. Connecticut evaluated traditional approaches to facilitating the nitrogen reductions at POTWs that require specific waste load allocations to be applied to individual facilities. The traditional approach would require facility upgrades at all POTWs to meet the reduced nitrogen loads specified in the waste load allocation in accordance with the NPDES regulations governing issuance of individual permits to each facility. Connecticut's assessment found that regulatory costs would be significant (due primarily to the need to negotiate and reissue 79 individual permits to include nitrogen reduction requirements and compliance schedules), overall capital improvement costs would be prohibitive (since the cost-effectiveness of individual upgrades and local concerns regarding financing could not be considered), and that there is not sufficient building capacity to make the simultaneous improvements across all 79 plants in time to meet the TMDL schedule.

The CTDEP asked the state legislature to approve a unique Nitrogen Credit Exchange Program. Nitrogen trading was proposed as an innovative and cost effective method to meet the necessary reductions identified in the TMDL. Public Act 01-180 was passed in 2001 and codified in the Connecticut General Statutes, Sections 22a-521 through 527. These statutes authorized DEP to issue a General Permit for Nitrogen Discharges and establish a Nitrogen Credit Exchange. The statute also established authority to convene a Nitrogen Credit Advisory Board composed of State Agency representatives (Treasury, Policy and Management, DEP) and appointed members representing municipalities involved in the program.

The Nitrogen Credit Exchange provides DEP with the flexibility it needs to minimize the costs associated with implementing the TMDL and meeting the water quality goals for Long Island Sound. The credit exchange program encourages municipal dischargers to maximize nitrogen removal using their existing facilities and provides an incentive for municipalities to implement cost-effective "retrofits" or design and build complete facility upgrades to enhance nitrogen removal. Under the terms of the General Permit for Nitrogen Discharges that regulates the 79 municipal facilities covered by the Exchange Program, each facility is assigned an annual allocation based on a percentage reduction from their baseline load. The annual allocation decreases each year reflecting anticipated cumulative progress towards meeting the 2014 TMDL goal expected as new facilities for nitrogen removal come on-line at various locations around the state. Each facility's annual allocation is thereby linked to the performance of all other plants in the State. Facilities that remove more than their annual allocation receive credits that are sold to the State. Facilities that discharge more nitrogen than their allocation must purchase credits from the State to remain in compliance with the General Permit.

The value of a credit is established each year based on the capital and operation and maintenance costs for nitrogen treatment at facilities that have completed nitrogen removal projects financed by the State Clean Water Fund relative to the load of nitrogen removed by those projects. Because the annual allocations to each facility decreases each year and the value of a credit increases (as more expensive projects are completed and more facilities incur operational expenses) the incentive to implement additional projects grows with the need to implement more costly projects to achieve the TMDL goal. The exchange program also accounts for geographical differences in the impact of nitrogen discharged by POTWs within the watershed (e.g., nitrogen discharged in New London in the eastern sound has about 18% of the impact to dissolved oxygen that nitrogen from Norwalk which is located near to the area of hypoxia). The end-of-pipe nitrogen loads at each facility is equalized using trading rations that reflect the relative impact on dissolved oxygen noted above to produce "equivalent nitrogen credits." All trades are based on equivalent credits to ensure progress is measured against improvements in Long Island Sound. Potential local impacts from nitrogen are evaluated when the individual NPDES permits are reissued and compliance with limits to protect local water quality cannot be met through trading.

The EPA Approval Process and State Implementation included the following steps:

- CTDEP and NYDEC jointly established the TMDL in December 2000
- CTDEP adopted dissolved oxygen criteria for offshore coastal waters on February 21, 2001
- EPA approved Connecticut's dissolved oxygen criteria for offshore coastal waters on May 10, 2001
- EPA approved the TMDL approved in May 2001.
- The Connecticut legislature adopted Legislation authorizing the General Permit and Nitrogen Exchange Program on July 6, 2001
- CTDEP issued the General Permit for Nitrogen Discharges in January 2002

The Nitrogen Credit Exchanges have been successfully executed for 2002 and 2003 trading years.

Boundaries of Application

Connecticut's approach, which centers on the Nitrogen Credit Exchange Program, required considerable public, municipal government and legislative buy-in prior to implementation. Frequent consultation and close coordination with EPA Region 1 was also critical to implementing the approach. The key to the program was the State legislation that authorized the creation of the Nitrogen Credit Exchange and creation of the Nitrogen Credit Advisory Board.

The operation of the credit exchange also requires the state to provide funds to purchase excess credits if Connecticut facilities collectively reduce greater amounts of nitrogen than the General Permit requires in a given year. For example, in the first year of trading, statewide facility structural and operational improvements resulted in removal of greater than 400 tons of nitrogen (equalized credits to the hypoxic area) less than projected when the annual allocations for 2002 were established in the General Permit. As a result, the State was required to disburse nearly 1.3 million dollars to purchase the excess credits generated. In 2003, loads were closer to projected expectations and approximately $300,000 was expended to purchase excess credits. In the event that the annual target is not met, funds from the sale of credits will exceed funds disbursed to buy credits and the Nitrogen Credit Advisory Board is empowered to use this money to fund research or other activities to promote nitrogen reduction efforts.

Changes to the Connecticut water quality criteria were possible because sound scientific studies were available to support this effort. State and federal partnerships that supported the scientific research on dissolved oxygen needs to support aquatic life in salt water led to EPA issuing the revised aquatic life criteria guidance upon which Connecticut's criteria are based. Studies, such as the National Estuary Program's Long Island Sound Study, contributed to a better understanding of the impacts of continuous and cyclic changes in dissolved oxygen to salt water aquatic life. Without this scientific support, the TMDL assumptions would change dramatically.

The CTDEP is experiencing faster than anticipated implementation of changes by facilities. Municipalities often appear motivated as much by the stigma attached to credit purchases as by the financial incentives incorporated into the program. This has resulted in more staff time to review design plans and process applications for facility modifications to improve nitrogen removal efficiency. Connecticut is also experiencing difficulties securing sufficient funding to meet the needs of all the facilities requesting capital through the State Revolving Fund to improve their processes to remove nitrogen. Although trading encourages implementing the most cost-effective measures first, achieving the TMDL goal will still require a significant public investment in treatment infrastructure. Nitrogen removal upgrade projects must compete with CSO remediation projects and other wastewater treatment infrastructure needs for a limited annual allocation of State Revolving Fund financing. The continued success of the program will depend in large part on maintaining a steady supply of financial support to municipalities to upgrade nitrogen treatment.

Resources/References

New York State Department of Environmental Conservation and Connecticut Department of Environmental Protection. 2000. *A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound*, New York State Department of Environmental Conservation, Albany, NY and Connecticut Department of Environmental Protection, Hartford, CT.

United States Environmental Protection Agency. 2000. *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*, EPA-822-R-00-012, United States Environmental Protection Agency, and Office of Water, Washington, DC.

Connecticut Department of Environmental Protection. 2001. *Waste Load Allocation Plan: Nitrogen Reductions Necessary to Control Hypoxia in Long Island Sound through Waste Load Allocations*, Connecticut Department of Environmental Protection, Hartford, CT.

Connecticut Department of Environmental Protection. 2001. *Nitrogen Credit Exchange: Facilitating Hypoxia Control in Long Island Sound through a Nitrogen Credit Exchange Program,* Connecticut Department of Environmental Protection, Hartford, CT.

Connecticut Department of Environmental Protection. 2001. *The Long Island Sound TMDL Frequently Asked Questions*, Connecticut Department of Environmental Protection, Hartford, CT.

Connecticut Department of Environmental Protection. 2003. *Report of the Nitrogen Credit Advisory Board to the Joint Standing Environmental Committee of the General Assembly,* Connecticut Department of Environmental Protection, Hartford, CT.

For additional information on Connecticut's Water Quality Standards, Total Maximum Daily Load, and Nitrogen Credit Exchange Program, visit the DEP web site at http://www.dep.state.ct.us/wtr or contact us at (860) 424-3704.