Colorado-Big Thompson
Nutrient Project

Phase 1 Report

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Acknowledgement

The Colorado-Big Thompson Nutrient Project Phase 1 report culminates three years of work to develop a systematic, system-wide approach to problems associated with nutrient loading to the Colorado-Big Thompson project. At the initiation of this process, the Northern Colorado Water Conservancy District (NCWCD) invited representatives of west slope and east slope local governments and organizations, federal and state agencies, and representative stakeholder groups to participate in the C-BT Nutrient Project through a Technical Advisory Team (TAT). The TAT was asked to provide expertise and input in the entire Phase 1 process, including identifying problems, scoping studies to address those problems, reviewing the results of ongoing studies, and developing recommendations for future actions. The TAT fulfilled its technical role in Phase 1 and provided a forum for broader discussion of nutrient-related water quality problems in the C-BT system. Over the course of the three year development of the Phase 1 report, forty-seven individuals representing eighteen local, federal, state, and stakeholder interests participated in the TAT. The TAT met thirteen times between February 2005 and October 2007. The meetings were well attended. A list of individuals attending and organizations represented at TAT meetings are summarized in Appendix A.

The TAT played a valuable role in development of the C-BT Nutrient Project Phase 1 report throughout the three year period, both in bringing Phase 1 of the Nutrient Project to a successful conclusion and setting the stage for future actions to protect and enhance water quality in the C-BT system. Northern Colorado Water Conservancy District recognizes the significant contributions of the TAT and expresses sincere appreciation to TAT members.
1.0 Executive Summary

The Northern Colorado Water Conservancy District (NCWCD) initiated the Colorado Big-Thompson (C-BT) Nutrient Project in 2005 to study nutrient-related water quality issues within C-BT facilities. The Project’s geographic scope includes the C-BT and Windy Gap collection facilities in Grand County, the distribution system in Larimer and Boulder Counties, and the contributing watersheds.

Water quality sampling efforts performed in conjunction with the Nutrient Project include the major reservoirs and canals of the C-BT system.

The goals of the C-BT Nutrient Project are: 1) identify nutrient-related water quality problems, 2) determine the causes, and 3) identify feasible options for improving/eliminating those problems in the Colorado-Big Thompson Project. These goals will be accomplished via a three phase process:

- **Phase 1 – Scoping**: Identify the specific water quality problems to be assessed, create priorities for study and write the study plans,
- **Phase 2 – Conduct studies and assess results**: Collect and assess data to identify the causes and effects associated with nutrient-related water quality problems in the C-BT system;
- **Phase 3 – Develop management recommendations**: Identify feasible management actions and implementation strategies.

This report presents the results of Phase 1, including recommendations for future activities.

To guide Phase I of the Nutrient Project, NCWCD established a broad based Technical Advisory Team (TAT) that provided expertise and advice throughout the process. The TAT included representatives of federal and state agencies, east and west slope local agencies and other stakeholders. The TAT will continue its key role as a broad based technical advisory group in subsequent phases of the Nutrient Project. Subsequent phases will also include public involvement components.

The C-BT system is valued for myriad purposes including municipal, industrial and irrigation water supply, recreation, aesthetics and fisheries. Input from NCWCD staff, the TAT and stakeholder interviews have identified various concerns and their potential sources in the C-BT system related to nutrient enrichment. These include algae blooms and associated algal toxins, aquatic weeds in Shadow Mountain Reservoir, development of a sediment delta in Shadow Mountain Reservoir, sediment loading of Grand Lake, the effect of the Windy Gap project on Three Lakes water quality, algae in east slope canals, taste and odor problems in finished municipal water supplies, the effect of introducing C-BT water into east slope rivers and streams, the effects of drought on algae populations, low dissolved oxygen levels in Horsetooth Reservoir, and water quality in Boulder Reservoir. One objective of Phase 1 is to fully characterize and prioritize these nutrient-related concerns in a systematic manner.
The TAT was asked to prioritize the relevant concerns. Following this prioritization exercise, data, monitoring programs, reports and special studies that addressed the top five priority concerns were reviewed. More than 50 documents and 21 datasets were identified and summarized to document the status of current knowledge. Based on this compilation, information needs and data gaps were identified and prioritized by the TAT. During this process, the five priority concerns were reorganized into five categories for future study and action. These are:

1. Algal Growth
2. Nutrient Sources
3. Rooted Aquatic Vegetation in Shadow Mountain Reservoir and Grand Lake
4. Nutrient Load Management
5. Taste and Odor

Twenty on-going monitoring programs and three on-going special studies are addressing the high priority categories in whole or in part. It is recommended that the ongoing monitoring programs be continued in the near term. On a regular basis, the data from each program should be analyzed and findings reported, including recommendations for modifying the monitoring programs. In addition, two new special studies are recommended. Special studies both ongoing and planned include:

- NCWCD/USBR monitoring project – east slope and west slope (2005-2007),
- Shadow Mountain drawdown monitoring (ongoing),
- NCWCD canal algae control study (ongoing),
- Three Lakes Nutrient Model Update (2007-2009), and
- Assessment of nutrient loading in Horsetooth Reservoir (pending).

Overall recommendations for future activities are summarized in Table 1-1.
<table>
<thead>
<tr>
<th>Priority Activity</th>
<th>Objectives</th>
<th>Action/Time Frame</th>
</tr>
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<tbody>
<tr>
<td><strong>1A. Algae Growth - West Slope C-BT facilities</strong></td>
<td>Characterize algae trends (species, count, seasonality and frequency) in the Three Lakes and ID the limiting constituents for algal growth and seasonal variations. Identify the trends and impacts of algal toxins on the Three Lakes and recreational and drinking water uses, now and in the future. ID impacts of algae blooms on recreation and drinking water uses.</td>
<td>Complete NCWCD/USBR Nutrient Monitoring Project report in 2008. Continue ongoing monitoring programs; Data integration and reports every three years beginning in 2009 and modify/continue ongoing programs as needed. Jointly with stakeholders, identify threshold levels of algal toxins for concern in 2008. Continue ongoing monitoring programs; Data integration and reports every three years beginning in 2009 and modify/continue ongoing programs as needed.</td>
</tr>
<tr>
<td><strong>1B. Algae Growth - East Slope C-BT facilities</strong></td>
<td>Characterize algae trends (species, severity, seasonality and frequency) in the east slope C-BT System and Big Thompson watershed and identify the limiting constituents for algal growth and seasonal variations in those constituents.</td>
<td>Complete NCWCD/USBR Nutrient Monitoring Project report in 2008. Continue ongoing nutrient/algae monitoring programs. Data integration and report every three years beginning in 2009; modify/continue ongoing programs as needed.</td>
</tr>
<tr>
<td>Priority Activity</td>
<td>Objectives</td>
<td>Action/Time Frame</td>
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<td></td>
<td>Identify the trends and impacts of algal toxins on the C-BT east slope system, and recreational and drinking water uses, now and in the future.</td>
<td>Support implementation of a monitoring program.</td>
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<tr>
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<td>Jointly with stakeholders identify threshold levels of algal toxins for concern 2009.</td>
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<td></td>
<td>Support and participate in allottee-led efforts to mitigate nutrient related taste and odor problems.</td>
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<tr>
<td></td>
<td>Identify impacts of algal blooms on recreation and drinking water uses.</td>
<td>Continue ongoing monitoring programs.</td>
</tr>
<tr>
<td>2A. Nutrient Sources - West Slope</td>
<td>Characterize current nutrient loads for the Three Lakes.</td>
<td>Continue monitoring to support Hydrosphere’s Three Lakes model.</td>
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<tr>
<td></td>
<td>Update Hydrosphere’s Three Lakes model 2008-2011.</td>
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<tr>
<td></td>
<td>Identify the cost, effectiveness, and technical feasibility of various methods to reduce nutrient loading to the Three Lakes.</td>
<td>Use monitoring data and model, information on sources and effectiveness of controls to develop report, 2011-2012.</td>
</tr>
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<td></td>
<td>Identify effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrients in the Three Lakes.</td>
<td>Evaluate local controls 2011-2012 in conjunction with feasibility study.</td>
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<tr>
<td></td>
<td>Identify the effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrients in the Three Lakes.</td>
<td>Participate in CDPHE work group on nutrient standards (2007-2010) and 2010 statewide hearing; participate in basin hearings re: proposed standards for C-BT reservoirs.</td>
</tr>
<tr>
<td>2B. Nutrient Sources – East Slope</td>
<td>Characterize current nutrient loads for the East Slope C-BT system and Big Thompson watershed.</td>
<td>Review and evaluate existing monitoring programs and identify additional data needs; collect data, estimate loads; 2009-2012.</td>
</tr>
<tr>
<td></td>
<td>Develop scope of work with municipalities using Horsetooth water, 2009.</td>
<td></td>
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<tr>
<td></td>
<td>Estimate future nutrient loads to the east slope C-BT system and Big Thompson watershed.</td>
<td>This objective will be addressed as part of the characterization of nutrient loads, 2009-2012.</td>
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<tr>
<td></td>
<td>Identify cost, effectiveness, and technical feasibility of methods to reduce nutrient loading to the east slope C-BT system.</td>
<td>Following nutrient load characterization; 2013.</td>
</tr>
<tr>
<td>Priority Activity</td>
<td>Objectives</td>
<td>Action/Time Frame</td>
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<tr>
<td></td>
<td>Identify effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrient control the east slope C-BT system.</td>
<td>Following nutrient load characterization, 2013.</td>
</tr>
<tr>
<td>3. Algae Growth - East Slope C-BT canals (moved from 1B above for consistency with Table 4.3-2)</td>
<td>Identify species of attached algae in east slope canals, seasonal variations, tolerances and methods of reducing nutrient levels to reduce algal growth.</td>
<td>Data integration and reports every three years beginning in 2009; modify/continue monitoring programs as needed.</td>
</tr>
<tr>
<td></td>
<td>These objectives are being addressed by NCWCD’s current monitoring and control measures; Develop effective, sustainable and safe methods for algae control in east slope canals.</td>
<td>These objectives are being addressed by NCWCD’s current monitoring and control measures;</td>
</tr>
<tr>
<td></td>
<td>Monitoring of weed growth will occur annually, beginning in 2007. The TAT will continue to follow progress of this issue and recommend management strategies if needed.</td>
<td>Continue ongoing monitoring programs as needed.</td>
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<tr>
<td></td>
<td>Identify sources of nutrients contributing to plant growth. Identify sediment loading sources in Three Lakes system related to weed growth in new areas. Identify areas of new growth caused by sedimentation.</td>
<td>Areas of new growth will be identified as part of monitoring program; sediment inflow monitoring will be monitored and quantified as needed.</td>
</tr>
<tr>
<td></td>
<td>Reclamation conducted a survey of weed growth in August 2007. NCWCD will be monitoring growth by comparing satellite images from last September, 2006 and 2007.</td>
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2.0 Introduction

The Northern Colorado Water Conservancy District (NCWCD) initiated the Colorado Big-Thompson (C-BT) Nutrient Project in 2005 to study nutrient-related water quality issues within C-BT facilities. The Project’s geographic scope includes the C-BT and Windy Gap collection facilities in Grand County, the distribution system in Larimer and Boulder Counties, and the contributing watersheds.

Water quality sampling efforts performed in conjunction with the Nutrient Project include the major reservoirs and canals of the C-BT system (Figures 1, 2 and 3).
Figure 1
Figure 3
2.1. Project Goals

The goals of the C-BT Nutrient Project are:

1. identify nutrient-related water quality problems in the C-BT system;
2. determine the causes of those water quality problems; and
3. identify feasible options for improving/eliminating those problems in the Colorado-Big Thompson Project.

The goals of the C-BT Nutrient Project are to be accomplished via a 3-phase process:

- **Phase 1 – Scoping**: Identify the specific water quality problems to be assessed, create priorities for study and write the study plans,
- **Phase 2 – Conduct studies and assess results**: Collect and assess data to identify the causes and effects associated with nutrient-related water quality problems in the C-BT system;
- **Phase 3 – Develop management recommendations**: Identify feasible management actions and implementation strategies.

This report presents the results of Phase 1. Phase 1 commenced in March 2005 and was completed in November 2007. Phase 2 is currently underway.

2.2. Approach and Methods for Phase 1

The objectives of Phase 1 included defining:

1. the overall goals and objectives of the project,
2. water quality concerns that will be assessed,
3. studies needed to determine the cause of the concerns and prioritization of those studies, and
4. scopes of work, budgets and schedules for Phase 2.

Phase 1 activities included:

1. establishment of a broad based Technical Advisory Team;
2. defining the goals of the project;
3. identifying concerns in the C-BT system associated with nutrient loading and prioritizing those concerns;
4. reviewing relevant data, information, and studies from completed and ongoing efforts related to the identified concerns and their potential causes;
5. identifying data gaps;
6. crafting studies needed to assess the concerns and establishing priorities for study implementation;
7. developing scopes of these studies to be conducted during Phase 2, including schedules and budgets; and
8. submitting a report to NCWCD management and Board with recommended goals, scopes of studies, preliminary budgets and schedules.

The results of Phase 1 were documented in a series of Technical Reports:

1. Goals & Geographic Scope

2. Identification and Prioritization of Problems Associated with Nutrient Loading

3. Identification of relevant data, information, and studies from completed and ongoing efforts related to priority problems, and data and information gaps.

Three technical reports provide the results of these efforts:

3A. Nutrient Project Priorities and Related Studies and Datasets

3B. Nutrient Project Priority Descriptions, Known Information Summaries and Data Gap Analysis

3C. Data Gaps and Current Data Collection and Study Efforts

4. Information needs and data gap priorities.

The technical reports are summarized in this report and are available for review by contacting NCWCD at 970-532-7700.

2.3. Technical Advisory Team

Given the geographic scope of the Nutrient Project and the diversity of parties affected, NCWCD recognized the importance of broad based input throughout the study process. To provide that input on a continuous and formal basis, NCWCD established a Technical Advisory Team (TAT) for the Nutrient Project. The initial TAT included representatives of the U. S. Bureau of Reclamation, U.S. Geological Survey, Colorado Water Quality Control Division, Grand County, Big Thompson Watershed Forum, and selected NCWCD/Municipal Subdistrict allotees. Initial TAT members were invited to participate based upon their expertise as related to the goals of the Nutrient Project.

The TAT was originally envisioned as a group of technical experts who would participate in identifying problems, scoping studies to address those problems, reviewing the results of studies, and developing recommendations for future actions through all three phases of the study. The TAT fulfilled its technical role in Phase 1 and has evolved into a forum made up of representatives of federal, state, regional, and local organizations interested in or affected by water quality in the C-BT system.
The TAT actively participated in Phase 1 of the Nutrient Project. The TAT met thirteen times between February, 2005 and October 2007. The meetings were well attended. A list of individuals attending and organizations represented at TAT meetings is summarized in Appendix A.
3.0 Nutrient-Related Concerns and Priorities

Following identification of the overall goals and objectives of the project (documented in Technical Report #1: Goals & Geographic Scope), the TAT identified the water quality concerns that will be assessed in Phase I (documented in Technical Report #2: Identification and Prioritization of Problems Associated with Nutrient Loading). TAT members, NCWCD staff and other stakeholders identified numerous concerns related to nutrient enrichment, algae growth, and related impacts in the C-BT system by:

1) Compiling a complete list of concerns related to water quality in the C-BT system on both the east and west slopes through discussions with TAT members, interviewing 13 west slope and east slope stakeholders, and questioning NCWCD staff members;

2) Providing the full list of concerns to the TAT for ranking and identifying the top five priority concerns;

3) An implementation plan was developed for Phase 2 of the Nutrient Project.

3.1. Characterization of Nutrient Problems

Project participants interviewed representatives of federal, state, and local governmental agencies and private parties interested in or affected by nutrient-related issues in the C-BT system (Appendix B). As a result of the interviews and input from the TAT members, a list of concerns was compiled. Some of the concerns identified were outside the scope of the C-BT Nutrient Project. Relevant concerns are described below.

3.1.1. East Slope

Concerns identified by the TAT and through interviews with east slope stakeholders are listed below for each water body.

Carter Lake
- Algal toxins
- Ability to meet future nutrient standards
- Algae blooms
- Productivity of the lake as it impacts fisheries
- Drinking water taste and odor problems
- Ability to meet drinking water standards

Horsetooth Reservoir
- Ability to meet future nutrient standards
- Algae blooms
- Algal toxins
- Productivity of the lake as it impacts fisheries
• Drinking water taste and odor problems
• Ability to meet drinking water standards
• Levels of total organic carbon
• Algae growth on bottom of recreational boats

**Big Thompson River**
• Nutrient loading from C-BT system

**Canals**
• Algae growth and effects of algae control activities on receiving water bodies

### 3.1.2. West Slope

West slope problems identified by the TAT and through interviews with west slope stakeholders are listed below for each water body.

**Lake Granby**
• Quality of water released to Colorado River
• Algae Blooms
• Ability to meet future nutrient standards
• Productivity of the lake as it impacts fisheries
• Algal toxins

**Shadow Mountain**
• Algae blooms
• Aquatic vegetation as it relates to nutrient loading
• Productivity of the lake as it impacts fisheries
• Clarity
• Algal toxins
• Ability to meet future nutrient standards

**Grand Lake**
• Algae blooms
• Aquatic vegetation as it relates to nutrient loading
• Productivity of the lake as it impacts fisheries
• Clarity
• Algal toxins
• Ability to meet future nutrient standards
• Direct homeowner water intake taste and odor problems

### 3.2. Priorities

Once all identified issues were placed into the appropriate category (east slope, west slope or out-of-scope), the TAT was asked to rank the nutrient-related concerns. In ranking the concerns, the TAT considered the following factors: human health concerns,
the magnitude of economic impacts and the geographic extent of impacts. Each TAT member organization was asked to submit only one ranking representing their organization’s official response.

Based upon the results of the rankings, as well as a discussion at the April 28, 2005 TAT meeting, the TAT concurred on five priority problems:

1A. Free-Floating Algae Blooms in the C-BT System
1B. Attached algae in C-BT east slope canals
2. Rooted Aquatic Vegetation in Grand Lake and Shadow Mountain Reservoir
3. Potential violation of future nutrient standards in the C-BT system
4. Taste and odor problems for drinking water on the east slope
5. Nutrient loading of the Big Thompson River by C-BT

Subsequent Phase 1 efforts focused on these five priority problems.
4.0 Available Information and Data Gaps

The second objective of the Nutrient Project is to identify the studies needed to determine the cause of the five priority problems. To achieve this objective, relevant data, data collection/monitoring efforts, reports, and studies addressing nutrient-related water quality problems in the C-BT system were identified. Project staff reviewed and summarized this information with respect to the five problems prioritized by the TAT. Based on this review, project staff identified data gaps and the TAT prioritized them for future activities.

4.1. Assessment of Available Data and Information

A comprehensive list of available and anticipated reports related to the five priority problems was compiled. Lists of relevant datasets and on-going monitoring programs were also developed. This information and data was made available to the TAT (Technical Report No. 3A: Nutrient Project Priorities and Related Studies and Datasets). Over 50 historic or anticipated reports (Appendix C) and 21 monitoring programs or datasets (Appendix D) were identified.

Summaries of all reports were developed that included objectives, methodology and main conclusions. Twenty-one monitoring programs were summarized and evaluated for their ability to address the priority problems. Project staff wrote monitoring program summaries for each data collection program that included the scope and components of each program, purpose of the program, responsible entity, sampling sites, monitoring frequencies and constituents, and a map showing sampling sites.

Each monitoring program summary was compared with each priority problem to identify whether the monitoring program contributes data or information relevant to the problem. Two levels of contribution were defined: primary, meaning that addressing the nutrient problem is one of the primary objectives of the monitoring program; and secondary, meaning that the monitoring program produces data that assists in addressing the nutrient problem, but addressing the nutrient problem is not a primary objective.

Of the twenty-one monitoring programs evaluated, all contributed some amount of information to the identified nutrient problems. Each monitoring program was designed to meet specific information needs. Although some of that information needs overlap the nutrient problems identified in this process, few of the programs are designed to provide a comprehensive look at the five priority problems. Thus, there are numerous, significant gaps in data and information regarding nutrient problems within the C-BT system.

Over the last five years there has been a significant effort to establish regional monitoring programs and to coordinate existing efforts. The Big Thompson Watershed Forum, Grand County Water Information Network and NCWCD all contract with the United States Geological Survey for stream, canal and reservoir monitoring. Those sites provide a good baseline of water quality throughout the system. The recent addition of the three year comprehensive monitoring program by the U.S. Bureau of Reclamation through a contract with NCWCD on five C-BT reservoirs will enhance the ability to address data gaps.

The majority of current monitoring resources are spent in the areas of nutrient sources and algae growth. In contrast, very little focused monitoring is currently contributing to data gaps regarding a) rooted aquatic vegetation in Shadow Mountain Reservoir and Grand Lake, b)
nutrient load management, and c) taste and odor. Most on-going data collection programs are geared towards providing data to define the scope and impacts of nutrient problems rather than on implementing management actions to solve problems.

From the study and monitoring program summaries, existing information related to each of the five priority problems was compiled (Technical Report No. 3B: Nutrient Project Priority Descriptions, Known Information Summaries and Data Gap Analysis). The available information was accepted with no assumptions or evaluations regarding validity.

Based upon the available information, as well as input from the TAT, information needs and data gaps regarding each priority problem were identified (Technical Report #3C Data Gaps and Current Data Collection and Study Efforts). Information needs and data gaps were then prioritized by the TAT (Technical Report # 4A: Data Gap Prioritization).

4.2. Available Information and Data Gaps For Priority Problems

Problem descriptions, impacts, available information, current management and study efforts, and data gaps are presented below for each priority problem.

4.2.1. Priority Problem #1A: Free-Floating Algae Blooms in the C-BT System

4.2.1.a Problem Description

On the West Slope, free-floating algae occurs in the Three Lakes system and may be affecting the clarity of the Three Lakes. Algae reportedly moves among the Three Lakes system. Data from the Grand County Water Information Network in July 2005 shows cyanobacteria (blue-green algae) cell counts above 2,000 cells/ml, which is the point at which the World Health Organization recommends monitoring for the presence of algal toxins in drinking water supplies. For lakes with recreational exposure only, such as Lake Granby, the recommended guideline for increased surveillance is 20,000 cells/ml (WHO, 1999). Cell counts have not been demonstrated to be strongly correlated with the presence of cyanotoxins, and Colorado does not currently have recommended guidelines for cyanobacteria cell counts or cyanotoxins.

According to marina operators, users of Lake Granby do not report algal blooms, clarity, or odor problems. The system does not act like a ‘normal’ lake system with respect to algae blooms as the algal density increases through the summer, rather than blooming and dying off. However, TAT members disagree and point to numerous instances of lakes that behave in this manner, with algae die-offs occurring only when the system becomes limited in some fashion. Regarding Grand Lake, as relayed during Nutrient Project stakeholder interviews, there have been more blooms observed in the last five years and higher densities around the marinas, though this is anecdotal and the data does not exist to confirm this. Sampling at Grand Lake Yacht Club has resulted in more algae being sighted and reported, though this data is not available for review. In the late summer, there appears to have been a significant reduction in clarity over time. Interviewees also said that algal blooms are significant near the end of the summer and are getting progressively worse, with blooms occurring on Grand Lake nearly every day during some years.
On the East Slope, Carter Lake Marina reports no water quality problems. Boats stored for the summer rarely have algae growth on the bottom. On Horsetooth Reservoir, algae growth on the bottoms of the boats can be a problem; however algae blooms in Horsetooth do not appear to be an issue. The C-BT canal system may be transporting algae cells from one reservoir to another, though TAT members point out that their survival and reproduction capacity is not guaranteed even if they are moved through the system.

4.2.1.b  Impacts

The impacts of free-floating algae in the C-BT system include:

1. A decrease in water clarity;
2. Interference with recreation, including impacts on the food web and fisheries, in Grand Lake, Shadow Mountain Lake, and to some extent Horsetooth Reservoir;
3. Impaired aesthetics;
4. Adverse effects on recreational tourism and corresponding economic impacts on the Three Lakes area;
5. Taste and odor problems on the east slope, specifically in September and October of 2003;
6. Health concerns regarding the potential release of algal toxins into water bodies during the algal cells’ natural life cycle.

4.2.1.c  Available Information Summary

Twenty two studies relevant to Priority Problem #1A provided the following information regarding nutrient loading and algal blooms.

The Windy Gap Environmental Impact Statement (1981) provides information from a number of earlier reports from the 1950s – 1970s regarding conditions in the Three Lakes, including the following:

- A 1954 study concluded that algae originating in Shadow Mountain Reservoir had greatly increased the algal population of Grand Lake.
- Algal sampling in 1956, in response to a concern that a repeat of a severe 1953 algal bloom was imminent, found that Asterionella was the dominant algal species.
- In the early 1950s, the lakes were showing signs of eutrophy, which is often the case with newly constructed reservoirs. Over time, nutrients from the newly constructed lake beds decreased and reduced the trophic states of the lakes towards oligotrophy.
- A 1966 study attributed system-wide algal problems to the fertility of Lake Granby and Shadow Mountain Reservoir. Shadow Mountain Reservoir inundated a fertile mountain park grazing area.
- A 1968 survey by the National Park Service found the status of Lake Granby and Grand Lake to be between oligotrophic and mesotrophic, and Shadow Mountain to be mesotrophic.
- A 1971 Department of Wildlife (DOW) study found the Three Lakes to have low primary productivity, though C-BT operations and continued raw sewage input from residences around the lake had the potential to move them into a eutrophic state.

- Three Lakes Water and Sanitation District was established in 1971 to eliminate both raw sewage discharge and treated wastewater discharge into the Three Lakes.

- A 1972 study concluded that algae were not a nuisance and that annual blooms were a minor natural problem caused by nutrient increases during overturn of the lakes. It found Shadow Mountain Reservoir to be eutrophic.

- Seasonal data available from 1974 show that nutrients in the Three Lakes tend to be one-third higher in June than September, with bottom waters averaging about 10 percent higher than surface waters.

In the mid-1970s through early-1980s, several reports were completed on the potential impact of Windy Gap diversions on nutrient loading of the Three Lakes system. These studies concluded that the Three Lakes would not become eutrophic due to increased loading from Windy Gap, although there would be increases in nitrogen and phosphorus loads. Increased phosphorus loads would occur in the Fraser River as a result of development in the Fraser River basin. It was estimated that the Three Lakes could receive phosphorus loading of 4,400 kilograms per year from Windy Gap without becoming eutrophic, which translates into an equivalent loading in the Fraser River basin of 32,000 kilograms per year.

There does not appear to be a consensus regarding whether or not algae growth in the Three Lakes and throughout the C-BT System is nitrogen or phosphorus limited. It has been suggested that both nitrogen and phosphorus are limiting in a given water body depending on the time of year.

An increased number of algal blooms have been observed in Grand Lake over the last five years, according to stakeholders. Higher algae densities have been reported around the marinas. Sampling at Grand Lake Yacht Club has resulted in more algae being sighted and reported. A significant reduction in clarity has been reported in late summer. Algae blooms are significant near the end of the summer and are perceived as getting progressively worse. Blooms can occur on Grand Lake nearly every day during some years. However, data to support these observations is sparse, as sampling for algae has only been consistently conducted since 2004.

The draft EIS on the Windy Gap project provided some historical information on Horsetooth Reservoir and Carter Lake:

- Oxygen depletions in Horsetooth Reservoir and Carter Lake were identified in a 1971 report (Nelson, 1971).

- Horsetooth was the most biologically productive reservoir in the C-BT system. Oxygen depletion occurred from summer stagnation and decomposition of algae.

- Carter Lake also showed some signs of oxygen depletion, though it was the least biologically productive lake in the system. The low position of the Carter Lake inflow
could account for low productivity, as associated nutrients are conveyed to the reservoir bottom and are unavailable to surface biota.

On March 14, 2006, the Colorado Water Quality Control Commission listed Horsetooth Reservoir on the Section 303(d) list of water quality limited segments requiring total maximum daily loads (TMDLs) due to non-attainment of the dissolved oxygen standard. The Division determined that the available data demonstrated a long term exceedance of the dissolved oxygen standard, even though there is evidence of aquatic life in Horsetooth Reservoir that does not appear to be impaired. (Colorado Department of Public Health and Environment, Water Quality Control Commission, 5 CCR 1002-93, Regulation #93, Section 303(d) list, Water Quality Limited Segments Requiring TMDLs, effective April 30, 2006). The relationship of dissolved oxygen depletion and the standard violation to decomposition of algae is not clear.

On the east slope, Carter Lake Marina reports no water quality problems. Boats stored for the summer on Carter Lake rarely have algae growth on the bottom. On Horsetooth Reservoir, however, algae growth on the bottoms of boats can be a problem. Algae blooms in Horsetooth Reservoir do not appear to be an issue. Free-floating algae in the C-BT canal system may be transporting cells to non-affected water bodies.

Accurate measurement of nutrient loads to reservoirs and concentrations within reservoirs is important for management. Nutrient as well as dissolved oxygen and other significant data are limited, and sampling and analytical methods are not consistent among monitoring programs and laboratories, which makes further analysis, modeling etc. difficult.

4.2.1.d Current Management/Study Efforts

NCWCD has contracted with U.S. Bureau of Reclamation’s Technical Services Center to conduct a monitoring program (NCWCD/USBR Monitoring Program) for the C-BT system that includes Secchi disk measurements, collection of algae, zooplankton and other water quality data. Grand County Water Information Network is collecting algae samples at Grand Lake, Shadow Mountain Reservoir, and Lake Granby. The Cities of Loveland and Fort Collins continue to collect total algae counts in their respective watersheds. Ongoing monitoring programs are described in Appendix D.

4.2.1.e Data Gaps

Unknown information identified by TAT members as well as in the reviewed reports regarding free-floating algae blooms in the C-BT system includes:

1. Quantitative data on algae blooms is needed to determine whether there is a trend regarding the severity or frequency of algae blooms, and to determine whether available data can identify such trends.
2. The data needs to be analyzed, or data collected, to determine the seasonal variations in algae blooms in the Three Lakes system, and the consequences of those seasonal blooms, on both the east slope and west slope.

3. It is uncertain whether data are available to identify trends of algal toxins, and whether or not – on a consistent basis – the trends are becoming more severe. The data needs to be reviewed – or collected – to identify trends in algal toxins in the C-BT system.

4. The relationship of algal growth and decay to the release of manganese from bottom deposits in Horsetooth Reservoir is unknown. Data needs to be collected to determine whether algal growth – or the transport of algae into Horsetooth Reservoir – and subsequent deposition is a significant cause of anoxic conditions that result in the release of manganese.

5. Over time, different reports have identified – or assumed – that either nitrogen or phosphorus is limiting algal growth. Available data indicates that either or both may be true, and that either nitrogen or phosphorus limitations may come into play depending on the season. Additional data are needed to determine if nitrogen or phosphorus is limiting algal growth in the Three Lakes and throughout the C-BT system, under what circumstances, and to determine if this is variable, depending on the season.

6. Horsetooth Reservoir was listed as impaired due to low dissolved oxygen. The relationship of low dissolved oxygen to algae growth and decay is unknown.

7. Current and future impacts of algal blooms on local and regional economics, water treatment costs, recreation and drinking water uses should be studied.

8. The impact of algal transport through the Adams Tunnel on east slope reservoirs should be looked at.

4.2.2. **Priority Problem #1B: Attached Algae in East Slope C-BT Canals**

4.2.2.a **Problem Description**

Algae is growing on the sides of various east slope C-BT canals. This occurs primarily in the Charles Hansen feeder canal, the Boulder Feeder Canal and the Saint Vrain Supply Canal. Algae growth impedes the flow of water in the canals, decreasing delivery volumes and increasing delivery times. Reclamation and NCWCD rely on copper sulfate applications for the treatment of the algae in the canals. Recently, a segment of the Big Thompson River, below the Big Thompson power plant, was placed on the State WQCD 303(d) list for copper for a violation of the State’s water quality standard for copper (based on hardness values).
4.2.2.b Impacts

The impacts of attached algae in C-BT canals include:

1. Interference with water delivery and power generation on the east slope;
2. Increased levels of copper in rivers and streams as a result of current copper sulfate treatment methods and potentially harmful ecological effects;
3. Increased cost to treat/maintain canals;
4. Use of copper sulfate, which causes large kills of algal matter, can release taste and odor causing compounds into the water supply. There is also the potential release of algal toxins;
5. Attached algae in the canals causes some public perception problems.

4.2.2.c Available Information Summary

Eight studies were determined to be relevant to Priority Problem #1B.

Algae are growing on the sides of various east slope C-BT canals, primarily in the Charles Hansen feeder canal, the Boulder Feeder Canal and the Saint Vrain Supply Canal. Algae growth impedes the flow of water in the canals, decreasing delivery volumes and increasing delivery times.

The U.S. Bureau of Reclamation (USBR) and NCWCD have relied on copper sulfate applications for the treatment of the algae in the canals. Recently, a segment of the Big Thompson River, below the Hansen feeder canal discharge to the Big Thompson River was placed on the State WQCD 303(d) list for violation of the State’s copper standard.

Levels of copper are high in the canals due to copper algaecide applications to reduce phytoplankton levels. If feasible, nutrient reduction is the preferred way to minimize phytoplankton blooms.

4.2.2.d Current Management/Study Efforts

USBR and NCWCD completed a study in 2007 to determine the dissipation rate of copper sulfate in C-BT distribution facilities and to evaluate alternative treatment methods. That study and subsequent monitoring showed that copper sulfate use in the C-BT canals is best limited to only when absolutely necessary. NCWCD is currently experimenting with different types of algae control, including grass carp, hydrogen peroxide and ultrasonic devices.

4.2.2.e Data gaps

Information needs and data gaps identified by TAT members and in the reviewed reports regarding attached algae in the C-BT system include:
1. The species of attached algae that are a problem throughout the system;
2. Dissipation rates of copper sulfate applied in the system;
3. Whether or not lower application rates of algaecide will control algae;
4. Whether or not other products such as chelated coppers will control algae;
5. Whether or not algal species change during the year;
6. Whether or not some of the algae species have developed a tolerance to copper sulfate;
7. The potential for large kills of algae to release taste and odor compounds in finished drinking water supplies;
8. Effective methods of reducing nutrient loading to control algal growth in canals.

4.2.3. **Priority #2: Rooted Aquatic Vegetation in Grand Lake and Shadow Mountain Reservoir**

4.2.3.a  **Problem Description**

Rooted aquatic vegetation fill the majority of the water column in several shallow areas within Shadow Mountain Reservoir. Many people are concerned about the impacts of aquatic plants on the recreational and aesthetic values of this reservoir and about potential influences on the water quality in Grand Lake. There is a public perception that rooted aquatic vegetation growth is expanding in the Shadow Mountain Reservoir and Grand Lake. There is also the potential for the vegetation fragments to spread and become established in Grand Lake, and some homeowners there have indicated that this is indeed happening. The vegetation may also contribute to operational problems for Reclamation by obstructing trash racks at the entrance to the Adams Tunnel.

4.2.3.b  **Impacts**

Overabundant rooted and floating vascular plants create a major nuisance for most lake users. Weed growth limits access to many areas of the lake, interferes with fishing and boating, and creates an aesthetic nuisance for area residents. An abundance of aquatic vegetation causes public perception problems relating to the quality of their recreational experience, aesthetic issues for homeowners near the reservoir, and the odor of decomposing vegetation. Weed growth may also present a maintenance problem for conveyance systems. Weed fragments were reported to partially block screens at the inlet to the Adams Tunnel in August 2004.

The yearly die-off of the weeds has been theorized as a contributor to spring algal blooms in Shadow Mountain and Grand Lake, as the decomposing vegetation and the associated total organic carbon (TOC) can foster localized internal nutrient releases (USBR, 2005). Abundant aquatic weed growth may exacerbate the accumulation of sediment at the outlet of the North Fork of the Colorado River. The deposition of sediment could be contributing nutrients to Shadow Mountain Reservoir. Stands of aquatic vegetation are important habitat, however at the current density they may be impairing habitat.
Fifteen studies were determined to be relevant to Priority Problem #2. Information from these studies regarding aquatic weeds in Shadow Mountain Reservoir and Grand Lake is summarized below.

Weed growth is not an indication of eutrophication of Shadow Mountain Reservoir (Lewis, 1992). Weed growth is driven by the soil-bound nutrients in the lake bottom, not by nutrient concentrations in the water. Reducing nutrients in the water column will not impact weed growth (USBR, 2005 and USBR, 1981). The two main factors that can be expected to regulate macrophyte growth in Shadow Mountain Reservoir in the future will be water level stability and transparency of the water.

Weed growth is a natural byproduct of the original physical condition of Shadow Mountain Reservoir; however sedimentation may be increasing the littoral zone of Shadow Mountain Reservoir, which increases the amount of suitable habitat for weed growth (USFS, 1983 and Lewis, 1992). The North Fork of the Colorado River contributes 71% of the total sediment load to Shadow Mountain Reservoir and Grand Lake. Grand Lake North Inlet contributes 20% of the total sediment load, due mostly to the amount of water it contributes to the system rather than to disproportionately high sediment concentrations. The Supply Creek watershed and, minimally, a gravel pit on the North Fork also contribute sediment loading (HDR, 2003).

Core samples of the North Fork delta (Pinyon Engineering, 2000) at seven sites found:

- The delta is mostly sandy loam soil of medium sand grain size.
- Median total phosphorus = 476.5 mg/kg
- Median ammonia = 37.9 mg/kg
- Median nitrite + nitrate = non-detect
- Median total organic carbon = 1.14%

A 2005 survey by USBR shows that the north end of Shadow Mountain Reservoir is 25 – 100% covered by elodea and coontail. The middle section of the reservoir is 25 – 100% covered by elodea and coontail. The south end of the reservoir shows little weed growth, but has some elodea.

Given present substrate and light conditions, the weeds are likely at maximum growth potential. The best option appears to be harvesting and lake level drawdown. Following a drawdown, there is a likelihood of increased algae blooms in the next year (USBR, 2005).

To control sedimentation near the North Fork inlet, implementation of best management practices such as construction site controls, recreational road and trail mitigation, minimization of temporary in-stream diversion berms, etc. is the best approach. A catchment basin might also be useful (HDR, 2003).
In 2004, the U.S. Bureau of Reclamation initiated a study of the aquatic vegetation stands in Shadow Mountain Reservoir. The report issued in 2005 recommended a drawdown that would lower water levels in Shadow Mountain Reservoir by 12 feet for one month, beginning in late October or early November, followed by monitoring to determine its effectiveness. A drawdown occurred in November, 2006. While the operation appears to be successful, monitoring will occur during the summer of 2007 and the results will be known in the late summer. Reclamation conducted a survey of weed growth in August 2007. NCWCD will be monitoring growth by comparing satellite images from September 2006 and September 2007.

NCWCD added four sampling dates from July 1 through October 1, 2007 to the Reclamation sampling program. (See Attachment 1, Scope of Work.) A separate scope of work will be developed to provide a report in 2008 on this weed control project and its impacts.

Grand County zoning regulations contain several features intended to control erosion. Examples include a minimum of 30 feet and a maximum of 150 feet setback in the Three Lakes Design Review area from the high water line of streams and reservoirs, limits to agricultural practices that cause accelerated soil erosion within the Three Lakes Design Review Area, and a required soil erosion and sedimentation plan for any golf course development. Also, BMP’s apply that are recommended in the East Grand Water Quality Board “Erosion and Sediment Control for Construction Activities Guidance Manual” and Northwest Colorado Council of Governments’ (NWCCOG) water quality management documents.

4.2.3.e Data gaps

Concerns and unknowns identified by TAT members as well as in the reviewed reports regarding aquatic vegetation in Grand Lake and Shadow Mountain Reservoir include:

1. The data on sediment sources to the North Fork are not sufficient to identify sources or effective control measures;

2. The data are not sufficient to determine whether sediment loading is changing over time or if Shadow Mountain sediment is being deposited in Grand Lake;

3. The impact of plant growth and decomposition, as well as sediment import, on nutrient concentrations of the water column and sediment needs to be determined;

4. There is a need to determine whether vegetation is being established in Grand Lake and Lake Granby, and, if so, locations and causes;

5. There is a need to determine whether in-lake nutrients, through settling, are accumulating in the sediments and contributing to vegetation growth;

6. There is a need to identify effective vegetation control measures and the frequency of implementation;
4.2.4. Priority Problem #3: Potential violation of future nutrient standards in the C-BT system

4.2.4.a Problem Description

The C-BT system could be affected by future nutrient standards in two ways: in its reservoirs and in streams downstream of seventeen C-BT discharge points (thirteen on the east slope and four on the west slope). In 1998, EPA published a Clean Water Action Plan in the Federal Register calling for the development of region-specific nutrient criteria. The State of Colorado submitted its plan to EPA in 2002, and proposes to have criteria developed by 2010. It is unknown what the nutrient standards will ultimately consist of, however the TAT believes it is important to create a baseline understanding of nutrient presence and movement within the C-BT reservoirs and at its 17 discharge points and use that understanding to proactively assess the likelihood of potential violations of future nutrient standards.

4.2.4.b Impacts

The impacts of excess nitrogen and phosphorus in reservoirs and streams are well documented, and include increased primary productivity, algae blooms, low dissolved oxygen, food web changes, and increased cost of raw water treatment and impairment of water uses, including recreation. If, after the adoption of water quality standards for nutrients parts of the C-BT system and/or any of its contributing or receiving watersheds are in non-compliance, the impact will be the long and expensive development of Total Maximum Daily Loads (TMDLs). In addition, violation of future nutrient standards may contribute to the public’s perception that a reservoir is “polluted” and unsafe to drink or recreate in. Therefore, it is in NCWCD’s interest, as well as that of its allottees, to better understand nutrient loading in the C-BT system.

4.2.4.c Available Information Summary

Twenty eight studies were determined to be relevant to Priority Problem #3. Information from these studies is summarized below.

Most studies found all lakes in the C-BT system to be mesotrophic (USBR, 1981 and USGS, 1990 and NWCCOG, 1998 and USBR, 2005). The water quality of all reservoirs is generally acceptable for primary uses; however the Three Lakes have higher nutrient loads than would be expected for mountain lakes under background conditions (Lewis, 1992). While the lakes are mesotrophic, they are susceptible to additional nutrient loadings, and could cycle towards eutrophy with enough nutrient input. Modeling conducted in the 1970s found that under certain population estimates and the associated increases in the phosphorus concentration of wastewater effluent in the Fraser Basin, “…a very real potential for eutrophication of the three lakes could result.” (USBR, 1981)

A trend study found that median concentrations of dissolved nitrite plus nitrate concentrations were generally less than 0.2 mg/l, and median concentrations of total phosphorus were less than 0.05 mg/l at all sites. Trend analysis for the period of record (1970-1987) showed a significant decrease in total phosphorus (an 87 – 94% reduction) in Lake Granby, Horsetooth Reservoir
and Carter Lake. There was a 65% decrease in the Granby Pump Canal. Ammonia plus organic nitrogen was also found to have a decreasing trend. (USGS, 2002)

Algae blooms were common in Shadow Mountain Reservoir in the 1950s and 1960s. One reason could be the fact that Shadow Mountain was built on a fertile mountain park grazing area (USBR, 1981). Sediment loads from tributaries may contribute to water column nutrient concentrations. The North Fork of the Colorado supplies 71% of the total sediment load to Shadow Mountain Reservoir and Grand Lake, while the North Inlet to Grand Lake contributes 20% of the total sediment load. The majority of the sediment yield occurs during snowmelt runoff conditions (USGS, 1983).

Several studies focused on water quality within Grand County. At the water quality site on the Colorado River within Rocky Mountain National Park (RMNP) there were no exceedences of state water quality standards. On the North Fork near its inlet to Shadow Mountain, there were exceedences of the un-ionized ammonia standard (standard = .02mg/l, result = .7 mg/l), however there was only one sample. Also at the same site, there were exceedences of the iron standard (standard = 300 mg/l, result = 420 mg/l). In Shadow Mountain Reservoir near the dam, there were exceedences of boron, cadmium, lead and silver standards (HDR, 2003). Samples taken of the Town of Grand Lake’s stormwater runoff during two storm events exceeded benchmark values for TOC, BOD and NO₃+NO₅. The samples did not exceed benchmark values for ammonia, total Kjeldahl nitrogen (TKN), or total phosphorus (TP) (CDPHE, 2002)

Studies in Horsetooth Reservoir found that dissolved inorganic nitrogen is above the usual levels where nitrogen limits phytoplankton productivity or biomass; upstream sites had higher epilimnetic ammonia values (.006 – .065 mg/l) while downstream sites tended to have higher hypolimnetic values (.011 – .056 mg/l); and total Kjeldahl nitrogen levels were indicative of high organic matter (0.11 – 0.74mg/l at 1 meter and 0.11 – 0.67mg/l at bottom) (USBR, 2005 and ERA, 1998). The same studies found that Horsetooth is mostly phosphorus limited, with some seasonal nitrogen limitation and that total phosphorus levels were typically higher at the reservoir bottom than the epilimnion (0.009 – .058 mg/l @1 meter, .010 – .085 at bottom). Low dissolved oxygen (DO) levels in Horsetooth may be caused by the level of allochthonous (from outside sources) total organic carbon.

In Horsetooth Reservoir, minor improvements in TP loading could resolve water quality problems. In addition, keeping the reservoir as full as possible during the stratified season and discharging as much water as possible once surface cooling begins to facilitate re-aeration of the water column would help (ERA, 1998). It would also seem that the position of the inlets at Carter Lake and Horsetooth Reservoir is the controlling factor with respect to productivity and consequent oxygen depletion (USBR, 1981).

One problem related to nutrient concentrations in Horsetooth Reservoir and Carter Lake is low dissolved oxygen levels in the late summer. Carter Lake was identified as being the least productive lake in the system, which could be attributable to the low position of the inlet, as its nutrients would be conveyed to the reservoir bottom and so would be unavailable to biota (USBR, 1981)

In Boulder Reservoir, there is a strong relationship between reservoir operations and deep-water depleted dissolved oxygen leading to release of manganese from the sediments. If a high rate of water exchange could be sustained during June (about 3,500 acre-feet), the decline in oxygen...
concentrations that occurs in most years would likely be prevented, which would stop the release of manganese. (Lewis, 2005) High turbidity in Boulder Reservoir is probably the main factor suppressing the growth of phytoplankton, though nutrient supplies are modest, and tributary waters contribute only moderate amounts of nutrients to the reservoir. (Lewis, 2004 and Lewis, 2005)

4.2.4.d Current Management/Study Efforts

In addition to the datasets and reports identified in Technical Report #3A, there are on-going programs to study this priority problem. The State Water Quality Control Division is currently crafting language for statewide nutrient standards, which are due to be adopted in 2010. NCWCD staff is participating in a state workgroup on this issue.

All Larimer County and Grand County land use codes, stormwater management plans and development codes mentioned in other problem descriptions apply.

The Big Thompson Watershed Forum is currently drafting a Water Quality Management Plan. This process will evaluate the water quality impacts of nutrients in the Big Thompson Watershed and identify management strategies to reduce or eliminate those impacts. The Plan is scheduled to be completed in late 2007.

4.2.4.e Data gaps

Concerns and unknowns identified by TAT members as well as in the reviewed reports regarding potential violation of future nutrient standards in the C-BT system include:

1. It is unknown whether the sediments from the North Fork delta contribute to nutrient concentrations in the water column.

2. It is unknown why the nutrient concentrations and algal populations differ so significantly between Horsetooth and Carter lakes, though the depth of the inlet is speculatively a cause.

3. Nutrient loading from all sources has not been quantified.

4. Impact of a future fire, fire related timber clearing, or timber clearing related to pine beetle disease around the Three Lakes on surface runoff nutrient loads

5. Impact of new reservoirs (Windy Gap Firming Project, Northern Integrated Supply Project and others) on C-BT water quality

6. Methods to decrease nutrient loading to the reservoirs has not been examined.

7. Acceptable nutrient loads to the reservoirs have not been identified.
4.2.5. Priority Problem #4: Taste and Odor Problems in East Slope Drinking Water Supplies

4.2.5.a Problem Description

High levels of algae can occur seasonally in east slope rivers and streams supplied or partially supplied by the Colorado-Big Thompson Project. This includes the Big Thompson River and may include others as data is assessed. It is currently unknown whether high algae levels in the rivers are a result of C-BT inputs or of other practices within the respective watersheds. This issue can vary tremendously by year. For example, in September 2003, significantly higher levels of algae resulted in taste and odor problems in the city of Loveland’s water supply.

In addition, some C-BT allotees (Fort Collins and Boulder among them) have concerns about finished water problems caused by manganese which can cause staining of domestic plumbing fixtures. Manganese can be released from reservoir bottom sediments during anoxic conditions, which can be exacerbated by excess nutrient concentrations. Fort Collins has modified treatment processes over time in order to adapt to changes in Horsetooth Reservoir water quality. Fort Collins can also directly link taste and odor episodes with algal population shifts in Horsetooth Reservoir. Soldier Canyon Filter Plant has experienced some taste and odor episodes, but those episodes have not been directly related to algal populations in Horsetooth Reservoir. Drinking water taste and odor problems were identified by the TAT and through interviews with east slope stakeholders in Carter Lake and Horsetooth Reservoir.

4.2.5.b Impacts

The impacts of taste and odor problems in east slope drinking water supplies include:

1. Noticeably offensive taste and odor at certain times of certain years;
2. Concerns by customers regarding whether or not the water is safe;
3. Increased sampling costs for the water utility;
4. Increased treatment cost by the water utility in an attempt to remove the taste and odor;
5. Even infrequent occurrences of taste and odor in drinking water can cause hundreds of complaints to a utility. Fear of illness caused by the water can be prevalent. The perception that a utility is not doing a good enough job can also be caused by more frequent taste and odor occurrences;
6. Frequent taste and odor episodes have the potential to have an economic impact on a city.

4.2.5.c Available Information Summary

Seven studies were determined to be relevant to Priority Problem #4. Information from these studies regarding taste and odor within east slope drinking water supplies is summarized below.

The City of Loveland experienced nuisance taste and odor problems when the water plant withdrew water directly from the Big Thompson River and the Charles Hansen Feeder Canal in 2003 while Green Ridge Glade Reservoir was being enlarged. There were no health concerns. The problem did not occur previously when water was taken from the Green Ridge Glade Reservoir because the reservoir was treated to prevent algal blooms. The enlarged reservoir is now operational. There are possible problems with high algal counts in the Big Thompson River
that may be contributing to taste and odor problems experienced by Loveland. Loveland sampled total algae at a number of points on the east slope portion of the C-BT system between the east portal of Adams Tunnel and the city’s water treatment plant intake on the Big Thompson River. Samples were generally collected between September 2003 and January 2004. The samples taken in September and October 2003 reflected increased algal activity. Average counts were four to ten times higher than in the later, cooler months of November 2003 to January 2004.

Releases of metals, including manganese, from reservoir bottom sediments, are caused by low dissolved oxygen. Low DO can be caused by the decomposition of algae and other sources of organic carbon in reservoirs. Decomposition consumes dissolved oxygen that is normally present in the water, which creates conditions favorable to manganese release from the sediment.

The City of Fort Collins has reported taste and odor problems which appear to be the result of withdrawing water from the low oxygen/high manganese portion of Horsetooth Reservoir. Fort Collins has had to modify treatment processes over time in order to adapt to changes in Horsetooth Reservoir water quality. Fort Collins has also directly linked taste and odor problems with algal shifts in Horsetooth Reservoir. (BTWF, 2004)

The City of Boulder has experienced problems resulting from the withdrawal of water from the low oxygen zone in Boulder Reservoir where manganese is released and can accumulate. Boulder has decided to expand its options for withdrawing water from the Boulder Reservoir by installing a second outlet at the South Dam, located at a point within the water column where water quality will likely be different from that of the existing outlet.

4.2.5.d Current Management/Study Efforts

Other than the data collected by the City of Loveland in the Big Thompson River and the City of Fort Collins in Horsetooth Reservoir, there is little site-specific, historic phytoplankton data available. NCWCD’s C-BT reservoir monitoring program, begun in spring 2005, is collecting algae and phytoplankton samples in Horsetooth Reservoir and Carter Lake. A similar coordinated effort is taking place at U.S. Geological Survey and NCWCD water quality sites in C-BT canals. In addition, NCWCD will incorporate regular phytoplankton monitoring in its facilities beginning in 2008.

4.2.5.e Data gaps

Concerns and unknowns identified by TAT members as well as in the reviewed reports regarding taste and odor problems in east slope drinking water supplies include:

1. The extent to which algal blooms, or other organic matter, are contributing to the manganese taste and odor problems being experienced by the City of Fort Collins is unknown. Additional data needs to be collected to determine if the algal problem is contributing to manganese dissolution in Horsetooth Reservoir, i.e., under anoxic conditions at the bottom of the reservoir.

2. The sources and species of algae in the Big Thompson drainage are unknown, i.e., are they being imported from the west slope or being grown as a result of nutrient enrichments in the Big Thompson basin or in C-BT canals. Additional information is needed to identify the source of algal counts and the species of algae from the east slope and west slope.
3. The City of Loveland experienced nuisance taste and odor problems when withdrawing water directly from the Big Thompson River and the Charles Hansen Feeder Canal. The relative levels of algae present in the feeder canal and Big Thompson River are known only since Loveland began phytoplankton sampling in 2003. Whether or not the taste and odor problems will continue now that Green Ridge Glade Reservoir has been completed is unknown.

4. Economic impacts and potential impacts due to customer perception of problems have not been quantified.

4.2.6. Priority Problem #5: Nutrient Loading to the Big Thompson River

4.2.6.a Problem Description

The C-BT system and the Big Thompson River are connected in several places. C-BT water and native Big Thompson water are mixed in Lake Estes, the Dille Tunnel and at the trifurcation on the Hansen Feeder Canal. For that reason, excess nutrients in either system can impact the other. In addition, several Front Range cities (Estes Park, Loveland, and Greeley) take their drinking water supplies from both sources and have a vested interest in maintaining high water quality in both the river and the C-BT system.

4.2.6.b Impacts

Excess nutrients in the Big Thompson River and the C-BT system can cause problems for drinking water suppliers, as was the case for the City of Loveland in 2004. Excess nutrients can also contribute to eutrophication of the terminal reservoirs resulting in a reduction in dissolved oxygen levels and impairment of aquatic habitat. Excess nutrients can also increase drinking water treatment costs and trigger frequent algal blooms.

The presence of algae in the river or odor caused by decaying organic matter can cause the public to view the river as “polluted.”

4.2.6.c Available Information Summaries

Eight studies were determined to be relevant to Priority Problem #5.

The Environmental Protection Agency’s recommended nutrient reference condition for the southern Rockies subecoregion is 0.04 mg/l total nitrogen, and 0.0064 mg/l total phosphorous. For the upper Big Thompson watershed, median total nitrogen (TN) was reported at 0.297 mg/l and median total phosphorus (TP) values were reported at 0.019 mg/l. These measurements “indicate significant nitrogen and phosphorous enrichment in the upper watershed compared to values for pristine environments in this subecoregion” (BTWF, 2003) though TAT members are not sure how applicable EPA’s reference conditions are to Colorado.
Total phosphorous loading estimates indicate that the Estes Park Sanitation District and the Upper Thompson Sanitation District effluents affect the mass transport of phosphorus downstream. Estes Park urban runoff also provides nutrients to the system. Nitrate plus nitrite are always below the primary standards for drinking water and should not pose any health problems in these surface waters. No ammonia measurements exceeded the acute or chronic aquatic toxicity levels (BTWF, 2003).

Atmospheric sources of nitrogen on the east side of RMNP, which drains into the Big Thompson river contributed 2.28 kg N/ha at Bear Lake and 3.35 kg N/ha at Loch Vale in 2002. Some alpine ecosystems in RMNP are at an advanced stage of nitrogen saturation (USGS, 2003).

4.2.6.d Current Management/Study Efforts

The Big Thompson Watershed Forum is currently drafting a Water Quality Management Plan. This process will evaluate the water quality impacts of nutrients in the Big Thompson Watershed and identify management strategies to reduce or eliminate those impacts. The Plan is scheduled to be completed in late 2007.

The State Water Quality Control Division is developing statewide nutrient standards, which are due to be adopted in 2010.

Larimer County land use codes include provisions that relate to water quality adjacent to drinking water reservoirs (section 8.12.6), water body setbacks of a minimum of 100 feet (section 8.17.2.B), and stormwater management plans (Section 8.12.4). In addition, the Larimer County Stormwater Management Manual includes provisions on erosion and sediment control elements and stormwater plan requirements.

The Estes Valley Development Code also includes regulations on stream setbacks (Section 7.6) and erosion control during construction.

4.2.6.e Data gaps

Concerns and unknowns identified by TAT members as well as in the reviewed reports regarding Nutrient Loading to the Big Thompson River include:

1. While total nitrogen and total phosphorus values in the upper Big Thompson watershed indicate enrichments over levels found pristine environments, the significance of these levels with respect to algae and nutrient problems in the Big Thompson basin is unknown.

2. A comprehensive list of distinct nutrient sources and their loads is lacking. Variations on a seasonal basis are unknown.

3. Impact of nutrient loads in the Big Thompson watershed on C-BT water quality
4.3. Data Gap Analysis and Priorities

Once the data gaps summarized in Sections 4.2.1 through 4.2.5 were compiled, the TAT was asked to prioritize them. In compiling the data gaps for prioritization, redundancy and overlap among the data gaps became evident. To better organize the prioritization process, the data gaps were disassociated from the five priority problems and reorganized under five new, broad categories:

A. Nutrient Sources
B. Algae Growth
C. Rooted Aquatic Vegetation in Shadow Mountain Reservoir and Grand Lake
D. Nutrient Load Management
E. Taste and Odor

Appendix E relates the individual data gaps to the five categories, A through E.

4.3.1. Data Gap Prioritization

The TAT prioritized the data gaps summarized in Section 4.2.1 through 4.2.5 and their associated categories described in Appendix E. The TAT scored each category according to ten questions that ranged from the urgency to the geographic impacts of each data gap. This is documented in Technical Report 4A: Data Gap Prioritization Methods.

Nine TAT member organizations scored the data gaps. The scores were summed and averaged, and the results presented to the TAT at the September 21, 2006 meeting. Table 4.3-1 shows the results of the scoring process, with each data gap color-coded by the category under which it falls.
## Table 4.3-1: Results of Data Gap Prioritization Process

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Total Score</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1.2: Identify the trends and impacts of algal toxins on the 3 lakes, and recreational and drinking water uses, now and in the future.</td>
<td>32.45</td>
<td>3.25</td>
</tr>
<tr>
<td>B2.2: Identify the trends and impacts of algal toxins on the C-BT East Slope system, and recreational and drinking water uses, now and in the future.</td>
<td>31.34</td>
<td>3.13</td>
</tr>
<tr>
<td>A1.1: Characterize current nutrient loads for the Three Lakes</td>
<td>31.05</td>
<td>3.11</td>
</tr>
<tr>
<td>A1.2: Estimate future nutrient loads to the Three Lakes</td>
<td>30.66</td>
<td>3.07</td>
</tr>
<tr>
<td>B1.1: Characterize algae trends (species, severity, seasonality and frequency) in the 3 Lakes and identify the limiting constituents for algal growth and seasonal variations in those constituents.</td>
<td>30.41</td>
<td>3.04</td>
</tr>
<tr>
<td>D1.1: Identify the cost, effectiveness, and technical feasibility of various methods to reduce nutrient loading to the 3 lakes</td>
<td>29.90</td>
<td>2.99</td>
</tr>
<tr>
<td>B2.1: Characterize algae trends (species, severity, seasonality and frequency) in the East Slope C-BT System and Big Thompson watershed and identify the limiting constituents for algal growth and seasonal variations in those constituents.</td>
<td>29.68</td>
<td>2.97</td>
</tr>
<tr>
<td>A2.1: Characterize current nutrient loads for the East Slope C-BT system and Big Thompson watershed</td>
<td>29.04</td>
<td>2.90</td>
</tr>
<tr>
<td>B2.3: Identify economic impacts of algal blooms on local and regional economies, water treatment costs, recreation and drinking water uses.</td>
<td>29.02</td>
<td>2.90</td>
</tr>
<tr>
<td>D2.1: Identify the cost, effectiveness, and technical feasibility of various methods to reduce nutrient loading to the east slope C-BT system</td>
<td>28.91</td>
<td>2.89</td>
</tr>
<tr>
<td>A2.2: Estimate future nutrient loads to the East Slope C-BT system and Big Thompson watershed</td>
<td>28.74</td>
<td>2.87</td>
</tr>
<tr>
<td>E1.1: Identify the relationship between algal growth and taste and odor problems experienced by water users on the East Slope</td>
<td>28.66</td>
<td>2.87</td>
</tr>
<tr>
<td>B3.2: Develop effective sustainable and safe treatment methods for algal growth in East Slope canals</td>
<td>28.08</td>
<td>2.81</td>
</tr>
<tr>
<td>B3.1: Identify the species of attached algae in the East Slope canals, seasonal variations, tolerances and effective methods of reducing nutrient levels to avoid algal growth in East Slope canals.</td>
<td>27.59</td>
<td>2.76</td>
</tr>
<tr>
<td>D1.2: Identify the effectiveness of current institutional regulatory controls and achieving acceptable levels of nutrient control in the 3 Lakes</td>
<td>27.30</td>
<td>2.73</td>
</tr>
<tr>
<td>D2.2: Identify the effectiveness of current institutional regulatory controls and achieving acceptable levels of nutrient control the east slope C-BT system</td>
<td>26.80</td>
<td>2.68</td>
</tr>
<tr>
<td>C3.1: Effective treatment technologies to manage growth of rooted aquatic vegetation</td>
<td>26.27</td>
<td>2.63</td>
</tr>
<tr>
<td>C2.2: Identify sources of nutrients contributing to veg. growth</td>
<td>26.04</td>
<td>2.60</td>
</tr>
<tr>
<td>E1.2: Identify the economic impacts to utilities due to taste and odor problems caused by algal growth</td>
<td>25.43</td>
<td>2.54</td>
</tr>
<tr>
<td>C2.1: Identify sediment loading sources in Three Lakes system related to veg. growth in new areas</td>
<td>25.27</td>
<td>2.53</td>
</tr>
<tr>
<td>C1.1: Identify areas of new aquatic veg. growth caused by sedimentation</td>
<td>25.13</td>
<td>2.51</td>
</tr>
</tbody>
</table>
After discussion of the results, the TAT agreed that further synthesis of the data gaps was necessary. Based on the prioritization results, data gap priorities fell into four broad categories that can be used as the basis for developing studies and comprehensive study plans. The prioritized categories are:

1. Algae Growth and Impacts in East/West Slope C-BT facilities
2. Nutrient Load Characterization and Management in East/West Slope C-BT facilities
3. Algal Growth in East Slope C-BT Canals
4. Rooted Aquatic Vegetation West Slope C-BT facilities

The first two categories are subdivided into east and west slope activities for the purpose of defining studies and study plans. The TAT also decided that taste and odor issues are best addressed by the individual drinking water utilities. Taste and odor issues are incorporated into Category 1 re: impacts of algae growth which addressed impacts on drinking water. Table 4.3-2 shows the final study categories and study objectives.
<table>
<thead>
<tr>
<th>Study Category</th>
<th>Study Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1A. Algae Growth and Impacts in West Slope C-BT facilities</strong></td>
<td>Characterize algae trends (species, count, seasonality and frequency) in the Three Lakes and ID limiting constituents for algae growth and seasonal variations.</td>
</tr>
<tr>
<td></td>
<td>ID the trends and impacts of algal toxins on the Three Lakes and recreational and drinking water uses, now and in the future.</td>
</tr>
<tr>
<td></td>
<td>Identify impacts of algal blooms on recreation and drinking water uses.</td>
</tr>
<tr>
<td><strong>1B. Algae Growth and Impacts in East Slope C-BT facilities</strong></td>
<td>Characterize algae trends (species, severity, seasonality and frequency) in the east slope C-BT System and Big Thompson watershed and identify the limiting constituents for algal growth and seasonal variations in those constituents.</td>
</tr>
<tr>
<td></td>
<td>ID trends and impacts of algal toxins on C-BT east slope system, recreational and drinking water uses, now and in the future.</td>
</tr>
<tr>
<td></td>
<td>Identify impacts of algal blooms on recreation and drinking water uses.</td>
</tr>
<tr>
<td><strong>2A. Nutrient Load Characterization and Management in West Slope C-BT facilities</strong></td>
<td>Characterize current Three Lakes nutrient loads.</td>
</tr>
<tr>
<td></td>
<td>Estimate future Three Lakes nutrient loads.</td>
</tr>
<tr>
<td></td>
<td>Identify the cost, effectiveness, and technical feasibility of various methods to reduce nutrient loading to the Three Lakes.</td>
</tr>
<tr>
<td></td>
<td>ID effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrient control in the Three Lakes.</td>
</tr>
<tr>
<td><strong>2B. Nutrient Load Characterization and Management in East Slope C-BT facilities</strong></td>
<td>Characterize current nutrient loads for East Slope C-BT system and Big Thompson watershed.</td>
</tr>
<tr>
<td></td>
<td>Estimate future nutrient loads to the east slope C-BT system and Big Thompson watershed.</td>
</tr>
<tr>
<td></td>
<td>Identify the cost, effectiveness, and technical feasibility of various methods to reduce nutrient loading to the east slope C-BT system.</td>
</tr>
<tr>
<td></td>
<td>Identify the effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrient control the east slope C-BT system.</td>
</tr>
<tr>
<td><strong>3. Algal Growth in East Slope C-BT Canals</strong></td>
<td>ID species of attached algae in east slope canals, seasonal variations, tolerances and methods of reducing nutrient levels to control algae.</td>
</tr>
<tr>
<td></td>
<td>Develop effective, sustainable and safe treatment methods for algal growth in east slope canals.</td>
</tr>
<tr>
<td><strong>4. Rooted Aquatic Vegetation in West Slope C-BT facilities</strong></td>
<td>Identify effective treatment technologies to manage growth of rooted aquatic vegetation.</td>
</tr>
<tr>
<td></td>
<td>ID sources of nutrients contributing to plant growth.</td>
</tr>
<tr>
<td></td>
<td>Identify sediment loading sources in Three Lakes system related to weed growth in new areas.</td>
</tr>
<tr>
<td></td>
<td>ID areas of new growth caused by sedimentation.</td>
</tr>
</tbody>
</table>
5.0 Future Actions

Section 4.0 identified and prioritized studies and study objectives (Table 4.3-2) for east slope and west slope nutrient-related problems, including algae growth and impacts, nutrient load characterization and management, algae growth in east slope C-BT canals, and aquatic vegetation in west slope C-BT facilities. This section recommends future actions, including ongoing monitoring programs, special studies, the future role of the TAT, and potential funding sources for future work.

Twenty ongoing monitoring programs and seven special studies are addressing the high priority study objectives in whole or in part. This includes two new special studies: the Three Lakes Nutrient Model Update and Nutrient Load Characterization for Horsetooth Reservoir.

5.1. Ongoing monitoring programs

The ongoing monitoring programs and special studies are described in Table 5.1-1. These programs contribute data and information to the categories of priority nutrient problems. It is recommended that these ongoing monitoring programs be continued in the near term.

In addition to continuing the monitoring programs in the near term, it is recommended that data from each program be assessed every three years. The tri-ennial report on each program should include recommendations regarding whether or not the monitoring program is meeting objectives, and any modifications needed. It is recognized that the ongoing monitoring programs have multiple objectives. The three year review should serve to determine whether the programs are meeting objectives and providing recommendations for any necessary modifications for meeting the objectives of the program, including those related to the C-BT nutrient study. NCWCD will work with other parties involved in these monitoring programs to determine the needs for data integration and reporting.
<table>
<thead>
<tr>
<th>ID</th>
<th>Collector</th>
<th>Monitoring Program Name</th>
<th>Date</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BTWF</td>
<td>Volunteer Monitoring Data</td>
<td>on-going</td>
<td>Volunteer monitoring sites in the Big T. watershed</td>
</tr>
<tr>
<td>2</td>
<td>CDPHE</td>
<td>CDPHE monitoring in Grand County</td>
<td>on-going</td>
<td>Monitoring to support triennial reviews of standards</td>
</tr>
<tr>
<td>3</td>
<td>City of Boulder</td>
<td>Boulder Monitoring Program</td>
<td>on-going</td>
<td>Monitoring quality of Boulder raw water supplies</td>
</tr>
<tr>
<td>4</td>
<td>City of Fort Collins</td>
<td>Ft. Collins Monitoring Program</td>
<td>on-going</td>
<td>Monitoring quality of Ft. Collins raw water supplies</td>
</tr>
<tr>
<td>5</td>
<td>City of Loveland</td>
<td>Algae Counts in the Big Thompson Watershed</td>
<td>on-going</td>
<td>Algal cell counts for T&amp;O producing types for water supply purposes</td>
</tr>
<tr>
<td>6</td>
<td>Dr. WM Lewis, Jr.</td>
<td>Greeley Monitoring Program, Boyd Water Supply</td>
<td>on-going</td>
<td>Data and Annual Reports for Greeley’s water supply that include 2 sites in the Hansen Feeder Canal</td>
</tr>
<tr>
<td>7</td>
<td>EGWQB/USGS</td>
<td>Monitoring in Grand County</td>
<td>on-going</td>
<td>Monitoring quality of Grand County waters</td>
</tr>
<tr>
<td>8</td>
<td>Ft. Collins</td>
<td>Horsetooth Algae Speciation Data</td>
<td>on-going</td>
<td>Database of all water quality data collected in Grand County</td>
</tr>
<tr>
<td>9</td>
<td>GCWIN</td>
<td>Phytoplankton and Algal Toxin monitoring</td>
<td>on-going</td>
<td>Monitoring of Three Lakes and others for algae and toxins</td>
</tr>
<tr>
<td>10</td>
<td>GCWIN</td>
<td>NCWCD WQ Monitoring Program</td>
<td>on-going</td>
<td>Database of water quality data throughout C-BT/Windy Gap systems</td>
</tr>
<tr>
<td>11</td>
<td>Northern Water</td>
<td>Canal Algae Control monitoring</td>
<td>on-going</td>
<td>Monitoring of canal algae populations to support alternate algae control experiments</td>
</tr>
<tr>
<td>12</td>
<td>Northern Water</td>
<td>Nutrient Project Reservoir Monitoring Data</td>
<td>2005-2007</td>
<td>Data collected specifically for C-BT Nutrient Project</td>
</tr>
<tr>
<td>13</td>
<td>Northern Water/USGS</td>
<td>C-BT Reservoir/Canal monitoring</td>
<td>on-going</td>
<td>Long-term monitoring of key C-BT sites</td>
</tr>
<tr>
<td>14</td>
<td>Northern Water/USGS/State</td>
<td>Flow Records</td>
<td>on-going</td>
<td>Data collected on stream/canal flows throughout C-BT</td>
</tr>
<tr>
<td>15</td>
<td>RiverWatch</td>
<td>Stream monitoring program</td>
<td>on-going</td>
<td>Statewide volunteer monitoring program for streams</td>
</tr>
<tr>
<td>16</td>
<td>Three Lakes/USGS</td>
<td>Three Lakes Tributary monitoring</td>
<td>on-going</td>
<td>Monitor quality of water in tribus to Three Lakes</td>
</tr>
<tr>
<td>17</td>
<td>USGS</td>
<td>NWIS</td>
<td>on-going</td>
<td>WQ Data collected at several sites</td>
</tr>
<tr>
<td>18</td>
<td>USGS/BTWF</td>
<td>Big Thompson Watershed Stream, Canal and Reservoir monitoring</td>
<td>on-going</td>
<td>Monitor quality of water in Big Thompson River, tribus and C-BT system</td>
</tr>
<tr>
<td>19</td>
<td>USGS; Mike Stevens</td>
<td>Grand Ditch breach data</td>
<td>2006</td>
<td>Data collected by USGS on the impacts of the Grand Ditch breach</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Collector</th>
<th>Special Study Name</th>
<th>Date</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NCWCD</td>
<td>Three Lakes model update</td>
<td>2007-2009</td>
<td>Update Hydrosphere’s Three Lakes model to include data through 2007 for guidance on source management</td>
</tr>
<tr>
<td>2</td>
<td>NCWCD/USBR</td>
<td>Report on C-BT Nutrient Project Monitoring</td>
<td>2008</td>
<td>Track WQ from 2005-2007 in the C-BT system reservoirs and canals</td>
</tr>
<tr>
<td>3</td>
<td>USBR</td>
<td>Report on Shadow Mountain Drawdown Effectiveness</td>
<td>2007</td>
<td>Document effectiveness and impacts from 2006 SMR drawdown</td>
</tr>
<tr>
<td>4</td>
<td>NCWCD</td>
<td>Canal Algae Control Report</td>
<td>2009 (tent)</td>
<td>Document efforts to utilize alternative methods of algae control in C-BT east slope canals</td>
</tr>
<tr>
<td>5</td>
<td>Ft. Collins</td>
<td>Poudre/Big Thompson Dissolved Organic Matter Study</td>
<td>2008</td>
<td>Document nature and changes of DOM in Poudre and C-BT systems</td>
</tr>
<tr>
<td>6</td>
<td>NCWCD</td>
<td>Horsetooth Nutrient Loading study</td>
<td>TBD, after #5</td>
<td>Study nutrient loading of Horsetooth Resv. To understand sources, internal cycling</td>
</tr>
<tr>
<td>7</td>
<td>BTWF</td>
<td>Retrospective Analysis of Big Thompson Water Quality, 2000 – 2006</td>
<td>2007</td>
<td>Review of 6 years of water quality data in the Big Thompson watershed</td>
</tr>
</tbody>
</table>
5.2. Special Studies

Special studies fall in the category of both ongoing and new. Special studies include those shown in Table 5.1-1. The status of these special studies and their future role in the C-BT nutrient project are discussed below.

5.2.1. Three Lakes Nutrient Model Update

This new study is designed to update the existing Three Lakes model, which was last updated in 2002. NCWCD has contracted with Hydrosphere Resources, Inc. to update the model. The update will incorporate data through 2007.

Additional data collected in 2007 will be incorporated into the model, including the following:

- **Flow gauge on Stillwater Creek**: Stillwater is one of the largest water contributors to the Three Lakes, but it is un-gauged. Previous modeling efforts synthesized the hydrograph from three different creeks. Gauging of Stillwater will provide important inflow data for the model.

- **Water quality data on Stillwater Creek**: Stillwater appears to contribute significant nutrient loading. Samples were taken during the 2007 summer months on Stillwater Creek.

- **Roaring Fork Creek**: There was no water quality data from this tributary in the original model. Grab samples were taken monthly, Summer 2007.

- **Colorado River downstream of Windy Gap**: A site will be added immediately downstream of Windy Gap to collect water quality data. The data will be collected weekly while pumping, and monthly afterwards.

- **Internal Three Lakes phosphorus loading**: Hydrosphere will review internal phosphorus loading in the Three Lakes, currently lumped into “miscellaneous internal loading” in the model, identify discreet sources, and determine if significant nutrient loading from these sources is occurring.

Hydrosphere staff will attend meetings and advise NCWCD regarding data collection through 2007. These efforts have been funded by NCWCD for 2007.

5.2.2. NCWCD/USBR Nutrient Monitoring Project

The project includes extensive monitoring of the Three Lakes, Horsetooth Reservoir, and Carter Lake for algae species and related water quality parameters. The project was initiated in 2005, with monitoring in 2005, 2006, and 2007. A report will be produced in 2008. The report should contribute substantially to understanding algae growth and nutrient concentrations in C-BT canals and reservoirs. The TAT will have the opportunity to review a draft of the 2008 report.

Until the report is completed in 2008, no expanded activities regarding algae monitoring are anticipated. The report will provide recommendations for future monitoring, data integration, reporting, and any needed special studies after 2008.
5.2.3. Report on Shadow Mountain Drawdown Effectiveness

In October, 2006, Shadow Mountain Reservoir was drawn down in an effort to kill aquatic vegetation around its shoreline. The operation appears to have been successful. Reclamation conducted a survey of weed growth in August 2007. NCWCD will be monitoring growth by comparing satellite images from last September (2006) and 2007. A report on vegetation re-growth should be available in early 2008.

To monitor any changes in water quality as a result of the drawdown, USBR and USGS added sampling dates from June through October 2007. A total of $44,000 was contributed by Grand County, GCWIN, NCWCD and Reclamation for this effort. Reporting on the water quality data will be scoped in 2008.

5.2.4. NCWCD Canal Algae Control Report

NCWCD and Reclamation completed a draft of a study on copper sulfate use and algae control techniques in the C-BT system in 2006. NCWCD is continuing its efforts to reduce use of copper sulfate to treat algae growth in its canals. Alternative methods will be evaluated during 2007 and 2008. These efforts will include use of grass carp in canals to remove aquatic rooted plants and experiments with hydrogen peroxide to control growth of algae. NCWCD is also investigating coating the canals to prevent establishment of algae on canal walls. NCWCD and Reclamation are developing a plan for evaluating alternatives. A report is tentatively scheduled for 2009.

5.2.5. Poudre/Big Thompson Dissolved Organic Matter Study

The Tri-Districts (Soldier Canyon Filter Plant), City of Greeley, City of Fort Collins, and NCWCD have initiated a study of dissolved organic (DOM) matter entitled “Characterization of Dissolved Organic Matter in Colorado Drinking Water Sources and Treatment Plants of the Upper Cache la Poudre, Horsetooth Reservoir, and Associated Components of the C-BT Project.” The objectives of the project are 1) evaluate the changes in DOM characteristics from the inlet to outlet of Horsetooth Reservoir, 2) characterize the nature of DOM from the significant water sources of the upper Poudre and the C-BT project, and 3) evaluate the changes in DOM between water treatment plant influent and effluent at the Soldier Canyon Filter Plant, Fort Collins Water Treatment Facility, and Greeley-Belleview Water Treatment Plant. The study includes monitoring DOM and total organic carbon on the Big Thompson River, Horsetooth Reservoir, upper Poudre mainstem, North Fork of the Poudre River, Hansen feeder canal, Hansen supply canal, east portal of Adams Tunnel, Big Thompson River above influences of the C-BT project, and water treatment plant influent and post filtration effluent at the three treatment plants. The proposed study would help understand the fraction of DOM in Horsetooth Reservoir that can be managed at the watershed level to help control future increases in TOC, and identify potential impacts to water treatment from future changes in level of DOM in source water. Analyses of water samples and development of a report will take place from October 2007 through December 2008.

5.2.6. Horsetooth Reservoir Nutrient Study

Nutrient loading efforts on the east slope, when initiated, will first focus on Horsetooth Reservoir, given impacts on raw water treatment plants and the recent 303(d) listing by the State of Colorado.

Funding in 2007 and 2008 will go towards a collaborative effort with the cities of Fort Collins and Greeley and the Soldier Canyon Treatment Plant to study Dissolved Organic Matter in the reservoir. A work group of NCWCD staff and municipalities using Horsetooth water will develop a scope of work for nutrient loading analysis after completing of the DOM study in 2008.
5.2.7. **Retrospective Analysis of Big Thompson Water Quality 2001-2006**

The Big Thompson Watershed Forum has sponsored a water quality report entitled “Retrospective Analysis of Water Quality Data in the Big Thompson Watershed, 2001-2006.” The analysis included data from 48 fresh water stations plus reservoir and lake data. Water quality variables included nutrients levels, general water quality parameters, E-coli and total chloroform. The report will assess water quality and also identify problems with data quality, and recommendations for resolving data quality issues. The report will be available in November 2007.

5.3. **Summary of Recommendations**

Recommendations from the Phase 1 study are summarized in Table 5.3-1.
<table>
<thead>
<tr>
<th>Priority Activity</th>
<th>Objectives</th>
<th>Action/Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A. Algae Growth - West Slope C-BT facilities</td>
<td>Characterize algae trends (species, count, seasonality and frequency) in the Three Lakes and ID the limiting constituents for algal growth and seasonal variations.</td>
<td>Complete NCWCD/USBR Nutrient Monitoring Project report in 2008; Continue ongoing monitoring programs; Data integration and reports every three years beginning in 2009 and modify/continue ongoing programs as needed.</td>
</tr>
<tr>
<td></td>
<td>Identify the trends and impacts of algal toxins on the Three Lakes and recreational and drinking water uses, now and in the future.</td>
<td>Continue ongoing monitoring programs; Data integration and reports every three years beginning in 2009 and modify/continue ongoing programs as needed; Jointly with stakeholders, identify threshold levels of algal toxins for concern in 2008 ID impacts of algae blooms on recreation and drinking water uses.</td>
</tr>
<tr>
<td>1B. Algae Growth - East Slope C-BT facilities</td>
<td>Characterize algae trends (species, severity, seasonality and frequency) in the east slope C-BT System and Big Thompson watershed and identify the limiting constituents for algal growth and seasonal variations in those constituents.</td>
<td>Complete NCWCD/USBR Nutrient Monitoring Project report in 2008 Continue ongoing nutrient/algae monitoring programs; Data integration and report every three years beginning in 2009; modify/continue ongoing programs as needed.</td>
</tr>
</tbody>
</table>

Table 5.3-1 Summary of Recommendations – C-BT Nutrient Project
<table>
<thead>
<tr>
<th>Priority Activity</th>
<th>Objectives</th>
<th>Action/Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1B. Algae Growth - East Slope</strong></td>
<td>Identify the trends and impacts of algal toxins on the C-BT east slope system, and recreational and drinking water uses, now and in the future.</td>
<td>Support implementation of a monitoring program;</td>
</tr>
<tr>
<td><strong>Slope C-BT facilities (cont)</strong></td>
<td>Support and participate in allottee-led efforts to mitigate nutrient related taste and odor problems.</td>
<td>Jointly with stakeholders identify threshold levels of algal toxins for concern 2009.</td>
</tr>
<tr>
<td></td>
<td>Identify impacts of algal blooms on recreation and drinking water uses.</td>
<td>Continue ongoing monitoring programs;</td>
</tr>
<tr>
<td><strong>2A. Nutrient Sources - West</strong></td>
<td>Characterize current nutrient loads for the Three Lakes.</td>
<td>Continue monitoring to support Hydrosphere’s Three Lakes model 2007-2010.</td>
</tr>
<tr>
<td><strong>Slope</strong></td>
<td>Estimate future nutrient loads to the Three Lakes, including Fraser imports.</td>
<td>Following update of Three Lakes nutrient model, 2010 or 2011.</td>
</tr>
<tr>
<td></td>
<td>Identify the cost, effectiveness, and technical feasibility of various methods to reduce nutrient loading to the Three Lakes.</td>
<td>Use monitoring data and model, information on sources and effectiveness of controls to develop report, 2011-2012</td>
</tr>
<tr>
<td></td>
<td>Identify effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrients in the Three Lakes.</td>
<td>Evaluate local controls 2011-2012 in conjunction with feasibility study.</td>
</tr>
<tr>
<td></td>
<td>Evaluate nutrient load characterization; 2013.</td>
<td>Participate in CDPHE work group on nutrient standards (2007-2010) and 2010 statewide hearing; participate in basin hearings re: proposed standards for C-BT reservoirs.</td>
</tr>
<tr>
<td><strong>2B. Nutrient Sources – East</strong></td>
<td>Characterize current nutrient loads for the East Slope C-BT system and Big Thompson watershed.</td>
<td>Review and evaluate existing monitoring programs and identify additional data needs; collect data, estimate loads; 2009-2012.</td>
</tr>
<tr>
<td><strong>Slope</strong></td>
<td>Estimate future nutrient loads to the east slope C-BT system and Big Thompson watershed.</td>
<td>Develop scope of work with municipalities using Horsetooth water, 2009.</td>
</tr>
<tr>
<td></td>
<td>Identify cost, effectiveness, and technical feasibility of methods to reduce nutrient loading to the east slope C-BT system.</td>
<td>Following nutrient load characterization; 2013.</td>
</tr>
<tr>
<td>Priority Activity</td>
<td>Objectives</td>
<td>Action/Time Frame</td>
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<tr>
<td><strong>2B. Nutrient Sources – East Slope (cont)</strong></td>
<td>Identify effectiveness of current institutional regulatory controls in achieving acceptable levels of nutrient control the east slope C-BT system.</td>
<td>Following nutrient load characterization, 2013.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Participate in CDPHE work group on nutrient standards (2007-2010) and 2010 statewide hearing; participate in basin hearings re: proposed standards for C-BT reservoirs.</td>
</tr>
<tr>
<td><strong>3. Algae Growth - East Slope C-BT canals (moved from 1B above for consistency with Table 4.3-2)</strong></td>
<td>Identify species of attached algae in east slope canals, seasonal variations, tolerances and methods of reducing nutrient levels to reduce algal growth.</td>
<td>Data integration and reports every three years beginning in 2009; modify/continue monitoring programs as needed.</td>
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<td></td>
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<td>These objectives are being addressed by NCWCD’s current monitoring and control measures;</td>
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<tr>
<td></td>
<td>Develop effective, sustainable and safe methods for algae control in east slope canals.</td>
<td>These objectives are being addressed by NCWCD’s current monitoring and control measures;</td>
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<tr>
<td></td>
<td></td>
<td>Monitoring of weed growth will occur annually, beginning in 2007.</td>
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<td></td>
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<td>The TAT will continue to follow progress of this issue and recommend management strategies if needed.</td>
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<td></td>
<td>Identify sources of nutrients contributing to plant growth.</td>
<td>Continue ongoing monitoring programs as needed.</td>
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<td></td>
<td>Identify sediment loading sources in Three Lakes system related to weed growth in new areas.</td>
<td>Areas of new growth will be identified as part of monitoring program; sediment inflow monitoring will be monitored and quantified as needed.</td>
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<tr>
<td></td>
<td>Identify areas of new growth caused by sedimentation.</td>
<td>Reclamation conducted a survey of weed growth in August 2007. NCWCD will be monitoring growth by comparing satellite images from last September, 2006 and 2007.</td>
</tr>
</tbody>
</table>
6.0 Bibliography


United State Bureau of Reclamation Technical Services Center, 2005, *Physical, Chemical and Biological Characteristics of Horsetooth Reservoir, Fort Collins, CO.*


United States Forest Service, Arapahoe National Recreational Area, 1983, *Sedimentation Study of the ANRA.*


United States Geologic Survey, 1990, *Analysis of Water Quality Data and Sampling Programs at Selected Sites in North Central CO.*


## Appendix A – Technical Advisory Team (TAT) Attendees

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>REPRESENTATIVE</th>
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<tbody>
<tr>
<td>Big Thompson Watershed Forum</td>
<td>Rob Buigy</td>
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<tr>
<td></td>
<td>Jeffrey Boring</td>
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<td></td>
<td>Zack Shelly</td>
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<tr>
<td>City of Boulder</td>
<td>Jim Shelley</td>
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<td></td>
<td>Scot Gillespie</td>
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<td></td>
<td>Bret Linenfelser</td>
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<tr>
<td>Colorado Department of Public Health and Environment Water Quality Control Division</td>
<td>Joni Nuttle</td>
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<tr>
<td>Colorado State University</td>
<td>Brett Johnson</td>
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<tr>
<td>East Larimer County Water District</td>
<td>Bob Reed</td>
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<tr>
<td>Town of Estes Park</td>
<td>Tom Blaue</td>
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<td>City of Fort Collins</td>
<td>Ben Alexander</td>
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<td>Judy Billica</td>
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<td>Kevin Gertig</td>
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<td>Debra Campbell</td>
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<td>Nancy Stuart</td>
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<td>Kathleen Morris</td>
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<td>Jennifer Murray</td>
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<td>Grand County Water Information Network</td>
<td>Sarah Clements</td>
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<td>Ted Wang</td>
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<tr>
<td>Grand Lake Citizen</td>
<td>Shane Hale</td>
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<td>Greater Grand Lake Shoreline Association</td>
<td>John Brooks</td>
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<td>Steve Paul</td>
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<tr>
<td>City of Greeley</td>
<td>Sean Cronin</td>
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<td>John McCutchan</td>
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<td>Jean Marie Boyer</td>
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<td>Left Hand Water District</td>
<td>Jan Toniazzo</td>
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<td>Larry Wyeno</td>
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<td>Doug Druliner</td>
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<td></td>
<td>Kip Bassong</td>
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<tr>
<td>Water Consult, Engineering Planning Consultants</td>
<td>Tom Pitts</td>
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