RECLAMATION

Managing Water in the West

Windy Gap Firming Project

Water Resources Technical Report

U.S. Department of the Interior
Bureau of Reclamation
Great Plains Region

December 2007

Water Resources
Technical Report

Windy Gap Firming Project

prepared by

ERO Resources Corporation
1842 Clarkson Street
Denver, Colorado 80218

and

Boyle Engineering Corporation
215 Union Blvd., Suite 500
Lakewood, Colorado 80228

Acronyms and Abbreviations

AF	acre-feet
BESTSM	Boyle Engineering Stream Simulation Model
C-BT	Colorado-Big Thompson Project
CDSS	Colorado Decision Support System
cfs	cubic feet per sect
CRWCD	Colorado River Water Conservation District
CWCB	Colorado Water Conservation Board
DW	Denver Water
EIS	Environmental Impact Statement
EOM	end-of-month
HUP	Historic User's Pool
MPWCD	Middle Park Water Conservancy District
Non-Participants	Windy Gap unit holders not participating in the Firming Project
NRCS	Natural Resources Conservation Service
NCWCD	Northern Colorado Water Conservancy District
PACSM	Platte and Colorado Simulations Model
Participants	Windy Gap Firming Project Participants
Reclamation	U.S. Bureau of Reclamation
SEO	State Engineer's Office
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WCFC	Willow Creek Feeder Canal
WGFP	Windy Gap Firming Project
WWTP	Wastewater treatment plant

Alternatives

Alternative 1 — No Action, Enlarge Ralph Price Reservoir
Alternative 2 — Proposed Action, Chimney Hollow Reservoir with Prepositioning
Alternative 3 — Chimney Hollow Reservoir and Jasper East Reservoir
Alternative 4 — Chimney Hollow Reservoir and Rockwell/Mueller Creek Reservoir
Alternative 5 — Dry Creek Reservoir and Rockwell/Mueller Creek Reservoir

CONTENTS

APPENDICES

TABLES

FIGURES

WINDY GAP FIRMING PROJECT
WATER RESOURCES TECHNICAL REPORT

1.0 INTRODUCTION

The Bureau of Reclamation (Reclamation) has received a proposal from the Municipal Subdistrict, Northern Colorado Water Conservancy District, acting by and through the Windy Gap Firming Project Water Activity Enterprise (Subdistrict) to improve the firm yield from the existing Windy Gap Project water supply by constructing the Windy Gap Firming Project (WGFP). The proposal includes a connection of WGFP facilities to the Colorado-Big Thompson Project. For more information on the background and purpose of the WGFP see the Windy Gap Firming Project Purpose and Need Report (ERO 2005a). This technical report was prepared to identify the potential environmental effects on water resources associated with the alternatives described below and will be used in the preparation of the environmental impact statement (EIS). This report includes an assessment of effects to ground water resources and ground water quality. There are separate technical reports that address other resources including, but not limited to, stream water quality (ERO and Hydrosphere 2007) and lake water quality (Hydrosphere 2007).

Section 2.0 describes the WGFP alternatives that are being evaluated in the EIS. Section 3.0 describes the streams, lakes, and reservoirs in the study area. Section 4.0 discusses the sources of data and the models used in the analysis. Windy Gap water rights are described in Section 5.0. Section 6.0 describes the existing hydrologic environment in the study area. Direct environmental effects are discussed in Section 7.0 and cumulative effects are discussed in Section 8.0.

2.0 ALTERNATIVES

The Windy Gap Firming Project Alternatives Report (ERO 2005b) identified four action alternatives in addition to the No Action alternative for evaluation in the EIS. All action alternatives include development of 90,000 AF of new storage in either a single reservoir on the East Slope or a combination of East Slope and West Slope reservoirs. The Subdistrict's Proposed Action is the construction of a 90,000 AF Chimney Hollow Reservoir with prepositioning. The alternatives are

- Alternative 1 (No Action)—Continuation of existing operations and agreements between Reclamation and the Subdistrict for conveyance of Windy Gap water through the Colorado-Big Thompson facilities, including the enlargement of Ralph Price Reservoir by the City of Longmont
- Alternative 2 (Proposed Action)—Chimney Hollow Reservoir (90,000 AF) with prepositioning
- Alternative 3—Chimney Hollow Reservoir (70,000 AF) and Jasper East Reservoir (20,000 AF)
- Alternative 4—Chimney Hollow Reservoir (70,000 AF) and Rockwell/Mueller Creek Reservoir (20,000 AF)

- Alternative 5—Dry Creek Reservoir (60,000 AF) and Rockwell/Mueller Creek Reservoir (30,000 AF)

Prepositioning, under the Proposed Action, involves the storage of Colorado-Big Thompson (C-BT) water in Chimney Hollow Reservoir. Windy Gap water pumped into Lake Granby would then be exchanged for C-BT water stored in Chimney Hollow. Windy Gap water stored in Chimney Hollow would be delivered and allocated to the WGFP Participants. This arrangement ensures temporary space in Lake Granby to introduce and store Windy Gap water. Total allowable C-BT storage would not change and the existing C-BT water rights and diversions would not be expanded. To prevent the C-BT Project from expanding their diversions through prepositioning, total modeled C-BT storage in Lake Granby and Chimney Hollow was limited to the capacity of Lake Granby, which is 539,758 AF. If this capacity limitation is reached, the model forces the C-BT Project to bypass water at Lake Granby. This water is then available for diversion at Windy Gap. Therefore, under prepositioning, C-BT diversions would not be expanded with respect to their current water rights and capacity limitations.

In addition to the action alternatives, a No Action alternative was identified based on what is reasonably likely to occur if Reclamation does not approve the connection of the new WGFP facilities to C-BT facilities. Under this alternative, the existing contractual arrangements between Reclamation and the Subdistrict for storage and transport of Windy Gap water through the C-BT system would remain in place. All Project Participants in the near term would maximize delivery of Windy Gap water according to their demand, Windy Gap water rights, and C-BT facility capacity constraints including availability of storage space in Lake Granby, and the Adams Tunnel conveyance constraints. The City of Longmont would develop storage independently for firming Windy Gap water if the WGFP is not implemented. Most Participants indicate that in the long term, they would seek other storage options, individually or jointly, to firm Windy Gap water because of their need for reliable Windy Gap deliveries and the substantial investment in existing infrastructure.

Those Participants that do not have a currently defined storage option would take delivery of Windy Gap water whenever it is available within the capacity of their existing water systems and delivery points under the terms of the existing Carriage Contract with Reclamation and the Northern Colorado Water Conservancy District (NCWCD). Participants that would operate under this scenario include Broomfield, Central Weld County Water District, Erie, Evans, Fort Lupton, Greeley, Little Thompson Water District, Louisville, Loveland, Platte River Power Authority, and Superior. The City of Lafayette anticipates that it would withdraw from participating in the WGFP and dispose of existing Windy Gap units and not pursue acquisition of future units if the Firming Project is not constructed.

Longmont indicates that it would develop storage facilities for Windy Gap water independently if Reclamation does not approve a connection of WGFP facilities to C-BT facilities. The City would evaluate the enlargement of the existing Ralph Price Reservoir (Button Rock Dam) located on North St. Vrain Creek or Union Reservoir located east of the City. The enlargement of Ralph Price by 13,000 AF would be the City's preferred option because Union Reservoir would not have sufficient capacity for Windy Gap water and conveyance and distribution would be more efficient from a higher elevation reservoir.

Middle Park Water Conservancy District (MPWCD), under No Action, would continue to use Windy Gap water to provide augmentation flows for other water diversions in a manner similar to current operations. MPWCD can store up to 3,000 AF of Windy Gap water in Lake Granby each year if Windy Gap water can be diverted and storage space is available.

Detailed descriptions of the components and operation of the alternatives are included in the Draft Windy Gap EIS Alternatives Descriptions report (Boyle and NCWCD 2005; NCWCD 2005).

3.0 STUDY AREA

The study area comprises tributaries to the South Platte River in northeast Colorado, where East Slope Participants are located (Figure 1) and the Upper Colorado River basin on the West Slope where Windy Gap water is diverted and where the MPWCD is located (Figure 2). Potential effects to water resources on the East Slope and West Slope from the alternative actions could occur from

- Reductions or increases in streamflows and stream stage;
- Alteration of stream morphology and sedimentation;
- Increases or reductions in ground water levels;
- Changes in ground water quality;
- Changes in the amount of water stored in existing reservoirs;
- The possible creation of one or more new reservoirs;
- Changes in stream water quality; and
- Changes in lake and reservoir water quality.

This report provides information on the Existing Conditions of the potentially affected streams, reservoirs, and ground water basins, with the exception of surface water quality, which is discussed in the Draft Surface Water Quality Technical Report (ERO 2007) and Draft Lake and Reservoir Water Quality Technical Report (Hydrosphere 2007). The report is divided into two study areas—the South Platte River basin (East Slope) and Upper Colorado River basin (West Slope). Specific locations where changes in hydrologic conditions are expected to occur were determined based on operational characteristics for each alternative and hydrologic modeling. Locations where potential effects have been identified are provided in Table 1. The WGFP Model, which represents the Colorado River basin on the West Slope, extends from the headwaters of the Colorado River downstream to the Colorado-Utah state line. The model was used to generate hydrologic data at various locations in the Upper Colorado River basin to illustrate hydrologic effects and to provide a basis for accessing effects to other resources (i.e., aquatics and recreation). Hydrologic data in this report is provided for locations downstream to the USGS gage on the Colorado River near Kremmling. The downstream extent for resource evaluations on the West Slope was based on an evaluation of hydrologic changes under the EIS alternatives. Flow changes, as a percentage of total streamflow, are less than 10 percent downstream of the confluence with the Blue River because flows increase due to gains from the contributing drainage basin and tributaries.

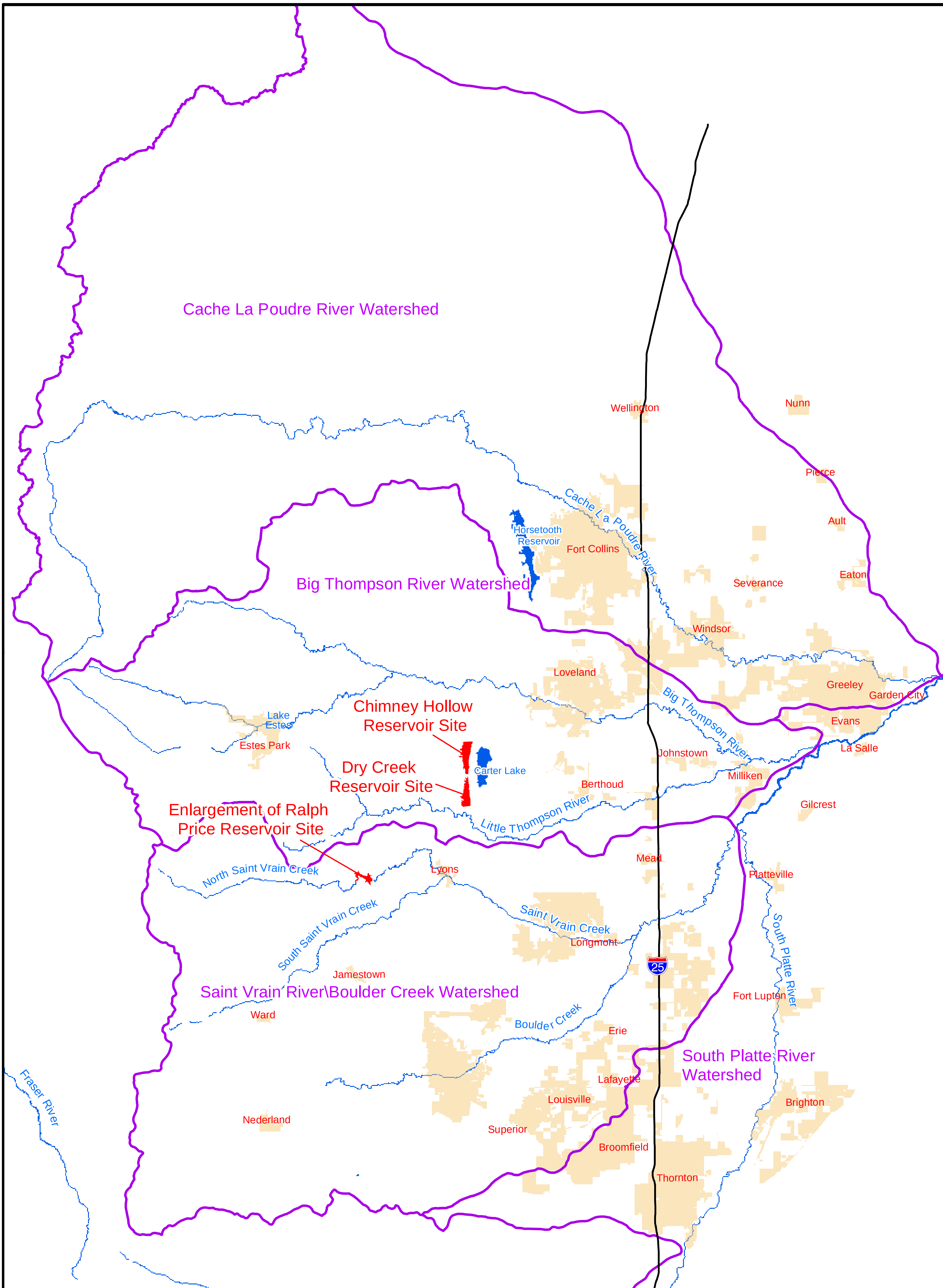
Within the study area, the hydrology for several reservoirs and stream segments would not be affected by alternative actions. Grand Lake, Shadow Mountain Reservoir, and Willow Creek Reservoir are part of C-BT's West Slope water collection and distribution system, but the storage in these reservoirs would not change from Existing Conditions for any of the alternatives under consideration. Operating criteria for Grand Lake and Shadow Mountain Reservoir (codified in Senate Document 80) require maintenance of stable water surface elevations in these reservoirs with fluctuations of less than 1 foot. Similarly, the manner in which Willow Creek Reservoir is operated would not be affected by any of the alternatives; however, there would be a change in Willow Creek Feeder Canal diversions and flows in Willow Creek below Willow Creek Reservoir. Although potential new reservoirs are located on ephemeral or intermittent streams, the existing downstream flows in these streams would be maintained by bypassing native flows. A substantial change in streamflow below new reservoirs is unlikely, although seepage below dams could result in slightly increased flows or more consistent flow. The WGFP would not affect the flows of any tributary to the Colorado River other than Willow Creek.

Table 1. Water resource locations potentially affected by the Windy Gap Firming Project.

Location	Possible Effects
West Slope	
Jasper East Reservoir basin	Surface and ground water changes due to construction of new storage reservoir
Rockwell/Mueller Creek basin	Surface and ground water changes due to construction of new storage reservoir
Lake Granby	Changes in storage/elevation
Colorado River, below Lake Granby and below Windy Gap diversion	Changes in flow/stage
Willow Creek below Willow Creek Reservoir	Changes in flow/stage
East Slope	
Chimney Hollow watershed	Surface and ground water changes due to construction of new storage reservoir
Dry Creek watershed	Surface and ground water changes due to construction of new storage reservoir
Carter Lake	Changes in storage/elevation
Horsetooth Reservoir	Changes in storage/elevation
Ralph Price Reservoir	Increase in storage
Big Dry Creek, below Broomfield's WWTP	Increase in flow/stage
Coal Creek, below Superior, Louisville, Lafayette, and Erie WWTPs	Increases in flow/stage

Location	Possible Effects
North St. Vrain Creek, below Ralph Price Reservoir	Changes in flow/stage
St. Vrain Creek from North St. Vrain Creek to Lyons and below Longmont and Little Thompson Water District WWTPs	Changes in flow/stage
Big Thompson River, between Lake Estes and Hansen Feeder Canal and below Loveland WWTP	Changes in flow/stage

On the East Slope, certain stream segments within the study area would not be affected because of the manner in which Participants intend to use their Windy Gap return flows. Windy Gap water is fully consumable; therefore, several Participants intend to reuse their Windy Gap effluent and return flows either through non-potable reuse systems, as an exchange supply, as return flow credit or as augmentation water. There would be little to no net effect on river flows for Participants that intend to use their effluent as an exchange supply or to offset depletions or meet return flow obligations. There would only be a change in flows for the reach between the point of discharge and the location of depletion. Although Windy Gap Participants Evans' and Fort Lupton's wastewater treatment plants (WWTPs) are on the South Platte River, there would be no net change in flows due to additional Windy Gap effluent discharged from their treatment plants to the river because these cities intend to use their return flows for augmentation of depletions. Thus, there would be no net change in streamflow. Similarly, the net change in Poudre River flows due to additional Windy Gap effluent discharged to the river at the City of Greeley WWTP is estimated to be zero because Greeley intends to use their Windy Gap return flows for augmentation of depletions and to offset return flow obligations.



Watersheds

0 3.25 6.5 Miles

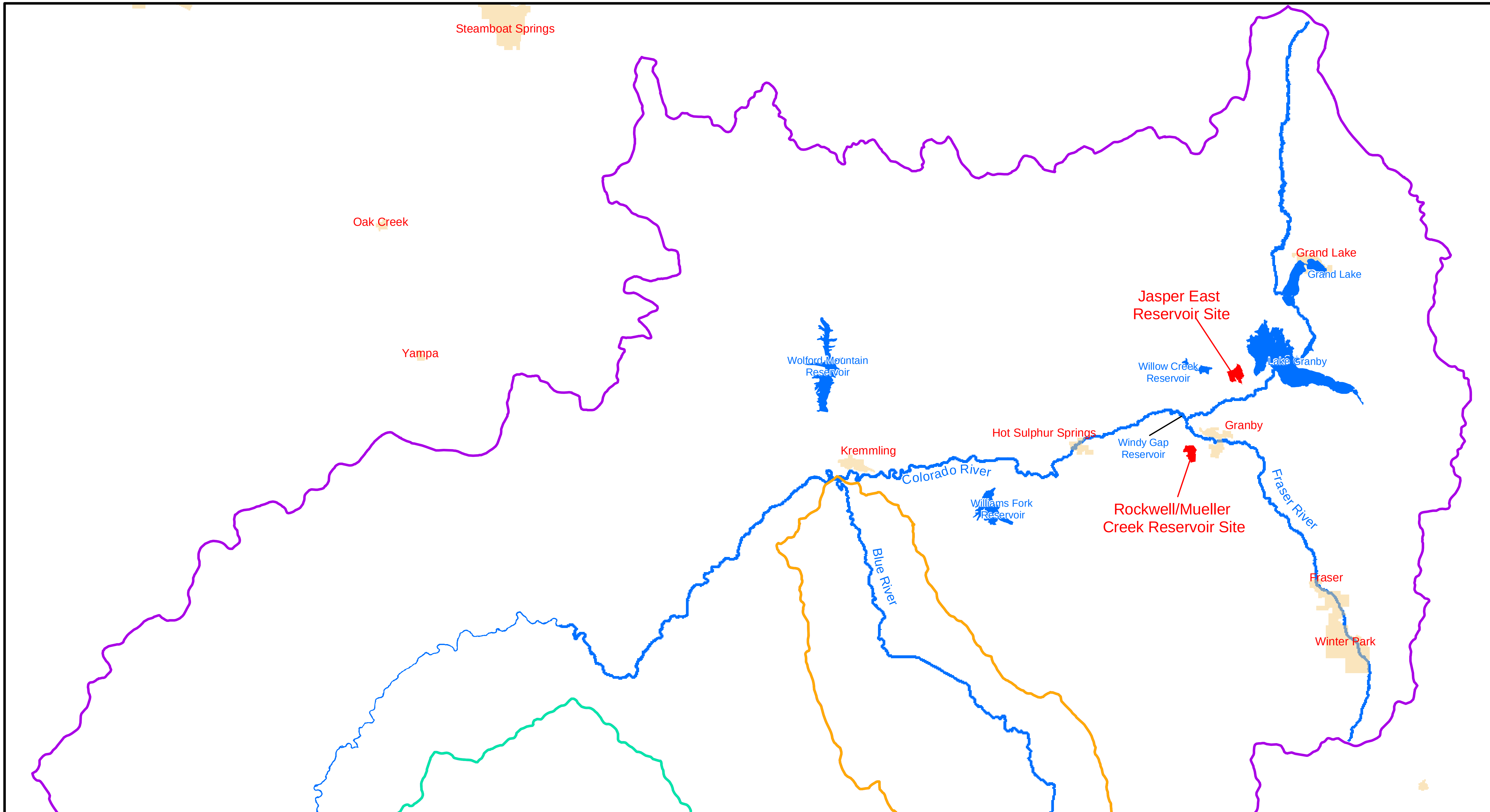
N

ERO

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Figure 1
Windy Gap Firming Project
East Slope Study Area

Prepared for: Windy Gap Firming Project
File: WGFP_East_Slpe_Project.mxd
Date: September 2007



ERO
ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Upper Colorado River Watershed
Eagle River Watershed
Blue River Watershed

0 3 6 Miles

N

Figure 2
Windy Gap Firming Project
West Slope Study Area

Prepared for: Windy Gap Firming Project
File: WGFP_West_Slope_Project.mxd
Date: September 2007

4.0 METHODS

This report provides an evaluation of the possible effects of the project alternatives to streamflows, stream stage, stream morphology and sedimentation, reservoir volumes and levels, and ground water levels and quality. It also evaluates cumulative effects of other reasonably foreseeable activities that may affect the same surface and ground water resources.

4.1. Existing Data Sources and Review

Data used in this report and in the water allocation model used to analyze the Windy Gap Firming Project alternatives and yield were obtained from the NCWCD, Reclamation, U.S. Geological Survey (USGS), WGFP Participants, the Colorado Division of Water Resources Colorado Decision Support System (CDSS) database, Denver Water Department, Colorado River Water Conservation District (CRWCD), the Upper Colorado River Basin Study and Colorado Division of Water Resources Division 1 office in Greeley. The data included

- Historical streamflows
- Historical diversions
- Historical climate data
- Water rights information (decreed rates and administration priorities)
- Windy Gap Project information (historical deliveries, unit ownership, and operations)
- C-BT Project information (historical quotas, deliveries, unit ownership, and operations)
- Reservoir data (historical inflows and releases, seepage estimates, area-capacity curves, capacities, dead storage, and operating rules)
- Bypass and instream flow requirements (rates and priorities)
- City of Longmont Ralph Price Reservoir release records
- C-BT and WGFP infrastructure information (system layout, pipeline and canal capacities, and transit losses)

4.2. Data Analysis

This report provides a summary of historical stream flows, stream morphology, and water use of the potentially affected streams, historical reservoir volumes, levels and operations of potentially affected reservoirs, and historical ground water levels and ground water use in basins that may be affected by the Windy Gap Firming Project. A computer model, as discussed below, was the principal tool used to analyze potential effects to water resources under the various alternatives and to estimate the amount of Windy Gap water that could reliably be delivered. The model generated monthly hydrologic output, including streamflows and reservoir data. The output was used to develop average, wet, and dry year data for each alternative. The model also was used to evaluate reasonably foreseeable future actions that may affect the same streams, reservoirs, and ground water basins. The model was not used to evaluate possible effects to East Slope streams where the use of Windy Gap water would increase from additional return flows that would occur primarily at Participants' WWTPs. Boyle Engineering provided a separate analysis of estimated changes in East Slope stream flows that was based on representative consumptive use and return flow patterns, individual Participant demand patterns, and identified future uses of Windy Gap return flows and reuse estimates (Boyle 2006c). ERO Resources Corporation (ERO) completed an analysis of possible effects to North St. Vrain Creek and St. Vrain Creek above the St. Vrain Supply Canal in Lyons for the No Action alternative. The analysis was based on streamflow data provided by the City of Longmont (Huson 2006) and historical diversion data. Model operations, input parameters, output, and other hydrologic analyses were verified by Reclamation hydrologists.

4.2.1. Model Description

A water allocation computer model was developed by Boyle Engineering to analyze the WGFP alternatives and to estimate the amount of Windy Gap water that could be reliably delivered, especially during periods of drought. The determination of reliable water deliveries during dry years, or "firm yield," is dependent on the amount and timing of supplies and demands, reservoir operations, physical constraints in the water conveyance system, and routes by which water can be moved from one part of the system to another. For the WGFP, firm yield is defined as the yield that can be provided each year of the study period without any shortages. A Boyle Engineering Stream Simulation Model (BESTSM) was developed that simulates these elements and their various interactions over a long time period and under changing hydrologic conditions. The BESTSM is a water allocation and accounting model that simulates river basin operations and accounts for inflows, diversions, river gains and losses, reservoir operations, and water rights using water allocation priorities. The BESTSM is used in conjunction with the Upper Colorado Water Resource Planning Model from the Colorado Decision Support System (CDSS Model) to represent the C-BT and Windy Gap Projects. The CDSS Model, which was developed by the State of Colorado, covers the Colorado River drainage from the headwaters to the Colorado-Utah state line. Therefore, the BESTSM focuses on East Slope facilities and operations, while the CDSS Model focuses on the representation of the Colorado River basin.

The purpose of using the CDSS Model was to start with a reliable, defensible assessment of West Slope base flows and take advantage of a significant effort by the state to develop demands and operating rules throughout the Upper Colorado River basin. The CDSS Model was used to evaluate the effects of water rights and operations throughout the Colorado River basin on the Windy Gap Project. These factors directly impact the amount of water physically and legally available for diversion at Windy Gap. The BESTSM extends the geographic coverage of the CDSS Model to include the major features and operations of the C-BT and Windy Gap Projects on the East Slope. In order to interface with the CDSS Model, the West Slope portion of the BESTSM extends from the headwaters of the Upper Colorado River downstream to the Windy Gap diversion dam, excluding the Fraser River. This portion of the BESTSM was adopted from and matches the CDSS Model. The CDSS Model was used specifically to determine the senior downstream demand for which Windy Gap must bypass water, and the Fraser River inflow to the Colorado River, which is used as input in the BESTSM. West Slope hydrologic information for each scenario, including streamflows and reservoir data, is obtained from the CDSS Model. The BESTSM provides information on Windy Gap and C-BT deliveries and East Slope hydrologic information for each alternative scenario.

4.2.2. Model Period

The selected model period was 1950 through 1996. Ideally, a study period should be long enough to include a variety of hydrologic conditions, including several dry years as well as wet and average years. At the same time, it should not be so long that many streamflows or reservoir end-of-month (EOM) contents must be synthesized to fill in missing data. The selected study period contains a balance of dry years, wet years, and average years. In particular, the model study period includes several drought sequences, which are followed by wet years. These types of sequences are critical for assessing hydrologic impacts since Windy Gap diversions can be substantial in wet years following dry years as evidenced by Windy Gap diversions in 2003 following 2002. For example, the model study period includes the mid-1950s drought followed by 1957 (a wet year), 1963 and 1964 (dry years) followed by 1965 (wet year), 1977 (dry year) followed by 1978 (wet year), and 1981 (dry year) followed by several wet years in the mid-1980s. These types of sequences of years allow for an evaluation of impacts associated with diverting additional Windy Gap water in wet years following dry years. Starting the model a few years prior to the mid-1950s drought period minimized the effects of initial reservoir contents on model results. The year 1950 also was chosen because most C-BT facilities, such as Lake Granby, Carter Lake, and Horsetooth Reservoir, came on-line in the early 1950s. The majority of C-BT Project facilities were in full operation by 1954. The study period ends in 1996 because of the dependence on the CDSS Model. At the time the BESTSM was developed in 2000, the available CDSS Model extended through 1996.

The need to extend the study period through 2002 (a critical dry year) was reviewed with respect to WGFP firm yield and project effects. That evaluation concluded that 2002, by itself, does not represent a more critical year for WGFP than any year in the BESTSM study period. In other words, if the model was extended through 2003, conclusions about changes in streamflow below Windy Gap and the firm yield for WGFP would remain the same. In addition, 2002 is not a key year in terms of evaluating hydrologic effects associated with each alternative. Windy Gap rights were not in priority in 2002, and the addition of a WGFP reservoir would not change that condition. Therefore, the model period from 1950 through 1996 was considered adequate for the purposes of this study because it includes dry years that are representative of the conditions on the Colorado River below Windy Gap in 2002.

4.2.3. Model Development

Three model configurations were developed, which include historical, baseline, and future conditions. The purpose of the historical model was to develop a calibrated model that accurately simulates C-BT and Windy Gap operations under historical conditions. The baseline model was configured to simulate current conditions and operations imposed on historical hydrology. The baseline model was used to analyze Existing Conditions and each of the EIS alternatives (No Action, Chimney Hollow with prepositioning, Chimney Hollow and Jasper East, Chimney Hollow and

Rockwell/Mueller Creek, and Dry Creek and Rockwell/Mueller Creek). The future conditions model reflects future development and use of existing water rights on the West Slope imposed on historical hydrology. The future conditions model was used for the cumulative effects evaluation. Each of these model configurations is described below and in the Windy Gap Firming Project Modeling Report and the Addendum to the WGFP Modeling Report (Boyle 2003, 2006a).

The historical BESTSM simulates integrated C-BT and Windy Gap Project operations under historical conditions. The historical BESTSM is driven by historical Windy Gap and C-BT diversions from the Colorado River, Willow Creek, and Big Thompson River and deliveries through the Adams Tunnel. It was calibrated and used to verify system parameters, estimated base flow hydrology, and the configuration of C-BT and Windy Gap operations in the model. The version of the State's CDSS Model that was used as the basis for the West Slope portion of the BESTSM was the Phase IIIb Model. The CDSS Model was updated based on new data, improved understanding of operations, and new features in StateMod. The version of the model that was created in this step is referred to as the CDSS historical model.

A predictive baseline BESTSM was developed next, in which C-BT and Windy Gap Project operations are rule-driven rather than defined by historical values. The baseline BESTSM is configured to simulate current C-BT and Windy Gap demands and operating policies imposed on historical hydrology. The CDSS baseline model was developed to reflect current water resources development and administration throughout the Upper Colorado River basin. In addition to updating key demands and operations, certain rules and operating parameters were relaxed, which allows the model to portray full potential use of key water rights. Changes made to the historical BESTSM and the CDSS historical model to reflect current conditions are summarized in the Windy Gap Firming Project Modeling Report (Boyle 2003) and the Addendum to the Windy Gap Firming Project Modeling Report (Boyle 2006a).

The CDSS baseline model was executed to estimate Fraser River inflows to the Colorado River and the senior downstream demand for which Windy Gap must bypass water. These values were incorporated in the baseline BESTSM input data set. The baseline BESTSM was executed for each WGFP alternative to evaluate the operations and yield of the Windy Gap Project under current conditions.

The future conditions BESTSM and CDSS Model were used for the cumulative effects analysis and reflect future, past, present, and reasonably foreseeable future actions on the West Slope imposed on historical hydrology. The CDSS future conditions model was executed to estimate Fraser River inflows and the senior downstream demand for which Windy Gap must bypass water when other reasonably foreseeable actions are incorporated in the model. These values were incorporated in the future conditions BESTSM. The future conditions BESTSM was executed for each WGFP alternative to evaluate the operations and yield of the Windy Gap Project under future conditions, as discussed in Section 8.0.

4.2.4. Model Parameters and Assumptions

Documents that are relevant to the WGFP and C-BT Project, which impose constraints and operating criteria that are reflected in the model, include Senate Document 80; the Blue River Decree; the 1980 Windy Gap-Azure Settlement Agreement; Principles to Govern the Release of Water at Granby Dam to Provide Fishery Flows Immediately Downstream in the Colorado River; Amendatory Contract for the Introduction, Storage, Carriage, and Delivery of Water for Municipal Subdistrict; the Orchard Mesa Check Case Settlement; and the temporary agreements that provide for the release of 10,825 AF annually from Williams Fork and Wolford Mountain Reservoir to the 15-Mile Reach. A detailed description of model parameters and assumptions regarding how these documents are reflected in the model is provided in the WGFP Modeling Report (Boyle 2003), the Addendum to the WGFP Modeling Report (Boyle 2006a), and the Colorado Decision Support System, Colorado River Basin Water Resources Planning Model Final Report and Appendices (Boyle and Riverside Technologies 2000).

The model was used to estimate streamflow and stream stage under Existing Conditions and all alternatives for the Colorado River, Willow Creek, and the Big Thompson River from below Lake Estes to the Hansen Feeder Canal. The model was also used to estimate reservoir volumes, surface areas, and elevations for Lake Granby, Willow Creek Reservoir, Carter Lake, and Horsetooth Reservoir under Existing Conditions and all alternatives. Similar reservoir data were generated for each potential new reservoir. The CDSS Model was relied on to provide hydrologic data for the West Slope, while the BESTSM provided similar data for the East Slope.

The model operates on a monthly time step for the entire study period. For streamflows, monthly data were disaggregated to daily data at four USGS gages that had relatively complete records during the study period. The underlying assumption was that, absent any flow changes due to the WGFP, the historical relationship between daily and total monthly flows should apply to total monthly flows estimated by the model. These flows reflect current operations and diversions associated with other existing projects (municipal, industrial, and agricultural). Current operations of existing projects are not expected to significantly change the historic pattern of flow over each month. Special attention was applied in instances where modeled operations of existing projects differ considerably from historic operations; for example, when historic and modeled spills at existing reservoirs are different or for periods prior to reservoirs coming on-line.

Daily disaggregation factors were developed at four USGS gages, including the Colorado River below Lake Granby (09019500), Colorado River near Hot Sulphur Springs (09034500), Colorado River near Kremmling (09058000), and Willow Creek below Willow Creek Reservoir (09021000). Daily disaggregation factors were developed as follows: for each day that data was available, the percentage of flow that occurred on that day (daily percentage) was calculated as the daily flow divided by the total flow that occurred in the corresponding month. The daily disaggregation factors were applied to the monthly flow data at the corresponding gage for each EIS alternative to develop daily flows, which were used for resource evaluations. For days that historical gage data were not available, average daily disaggregation factors for that day of the year were calculated as the average of all daily percentages available for that day. The average daily disaggregation factors were only applied to days that historical gage data were not available.

For locations downstream of Windy Gap on the Colorado River (gages near Hot Sulphur Springs and near Kremmling), historical flows, absent the effects of the WGFP, were developed because Windy Gap diversions with a firming project on-line would be expected to be different from historical Windy Gap diversions. To do this, historical Windy Gap pumping was added to the flow at the location of interest. Daily disaggregation factors were developed using historical flows plus historical Windy Gap pumping. The daily disaggregation factors were used to disaggregate modeled monthly flows at the location of interest, plus Windy Gap pumping. Daily Windy Gap pumping was then subtracted from the flow, which includes Windy Gap pumping, to determine daily flows along the Colorado River downstream of Windy Gap.

Because of variability in the amount, timing, and duration of Lake Granby spills, the flow of the Colorado River below Lake Granby was handled slightly differently. The disaggregation of monthly data to daily data in months that Lake Granby was modeled to spill contained a high degree of uncertainty because historical spill data show that the timing and quantity of spills in a month are highly variable. The flow below Lake Granby is a function primarily of bypass flow requirements, which are as follows:

- September through April, 20 cubic feet per second (cfs)
- May through July, 75 cfs
- August, 40 cfs

During months that Lake Granby is not spilling, the amount released from Lake Granby reflects what is needed to achieve the bypass flow requirement at the downstream gage. Therefore, the release is generally a fairly constant rate throughout the month, particularly in the winter months when there are no diversions occurring between Lake Granby and the gage. In addition, the natural inflow in this reach is small. In all months that Lake Granby did not spill in the model, the modeled monthly flows at the Colorado near Granby gage were disaggregated to daily values evenly throughout the month.

When model output showed Lake Granby spilling, the release was not constant because it is a function of the natural inflow to Lake Granby and the release to the Adams Tunnel, as opposed to the bypass flow requirement. In months that Lake Granby spilled in the model, the following approach is used to disaggregate monthly to daily flows. For each day that data was available in a month that Lake Granby spilled historically, the percentage of flow that occurred on that day (daily percentage) was calculated as the daily flow divided by the total flow that occurred in the corresponding month. Average daily disaggregation factors were then calculated as the average of all daily percentages available for each given day in corresponding months that Lake Granby spilled. Average daily disaggregation factors based on historical spill months were used to disaggregate modeled monthly flows to daily flows at the gage near Granby in months that Lake Granby was modeled to spill.

In addition to the daily data that was developed for the entire study period at the four USGS gages listed above, average monthly flows were disaggregated to daily values to develop average daily hydrographs. Average daily disaggregation factors were developed based on historical USGS gage records (Boyle 2005), and were calculated as the average of all daily percentages available for each day. The average daily disaggregation factors were applied to the average monthly flows for each EIS alternative to develop average daily flows and hydrographs (such as those shown in Figure 31, Figure 32, Figure 33, and Figure 34).

To evaluate possible effects to other East Slope streams affected by the WGFP, except for effects to North St. Vrain Creek and St. Vrain Creek under the No Action alternative, Boyle Engineering provided a separate analysis; assumptions used in that analysis are provided in the document (Boyle 2006c). The evaluation of effects to streamflows below Ralph Price Reservoir under No Action was based on the assumption that Longmont's 1999–2005 release records for Ralph Price Reservoir are representative of average flows since Longmont began releasing water from Ralph Price Reservoir. Based on historical streamflow, it was assumed that enough water would be available in the North St. Vrain above Ralph Price Reservoir throughout the year to complete the estimated exchange from the St. Vrain Supply Canal to Ralph Price Reservoir under the No Action alternative. To deliver Windy Gap water to Ralph Price Reservoir, Longmont would exchange Windy Gap water delivered to St. Vrain Creek via the St. Vrain Supply Canal upstream to Ralph Price Reservoir. Effects to Ralph Price Reservoir, North St. Vrain Creek, and St. Vrain Creek under the No Action alternative were based on estimated exchanges to and releases from Ralph Price Reservoir, which are driven by the City of Longmont's projected future Windy Gap water demands.

5.0 WINDY GAP PROJECT WATER RIGHTS

The Windy Gap Firming Project would utilize the existing water right decrees and stipulations associated with the Windy Gap Project that was constructed in 1985. The Windy Gap Project was awarded decrees for conditional water rights for a total of 600 cfs in the following actions:

- Windy Gap Pump, Pipeline, and Canal: June 22, 1967, appropriation date for a 300 cfs diversion from the Colorado River (Case No. C.A. 1768)
- Windy Gap Pump, Pipeline, and Canal, First Enlargement: July 9, 1976, appropriation date for a 100 cfs diversion from the Colorado River (Case No. W-4001)
- Windy Gap Pump, Pipeline, and Canal, Second Enlargement: April 30, 1980 appropriation date for a 200 cfs diversion from the Colorado River (Case No. 80CW108)

In addition, a conditional water storage right for 1,546.14 AF for Windy Gap Reservoir on the Colorado River was decreed in Case No. C.A. 1768 with a June 22, 1967, appropriation date.

One hundred and ninety cfs of the 300 cfs conditional water right for the Windy Gap Pump, Pipeline and Canal, and 445 AF of the 1,546.14 AF conditional water storage right for Windy Gap Reservoir were made absolute in the decree entered in Case No. 88CW169. The remaining 110 cfs of the 300 cfs, as well as the First Enlargement for 100 cfs and the Second Enlargement for 200 cfs, were made absolute in the decree entered in Case No. 89CW298. Thus, the total absolute water diversion right for the Windy Gap Project is 600 cfs and the total absolute water storage right to the Windy Gap Project at the Windy Gap Reservoir is 445 AF. The remaining 1,104.14 AF water storage right for the Windy Gap Reservoir remains conditional. The water rights decrees include the "Agreement Concerning the Windy Gap Project and the Azure Reservoir and Power Project," dated April 30, 1980, entered into by the Municipal Subdistrict, Northern Colorado Water Conservancy District, and numerous west slope parties, and the "Supplement to the Agreement of April 30, 1980" dated March 29, 1985, entered into by the Municipal Subdistrict, Northern Colorado Water Conservancy District, CRWCD, Northwest Colorado Council of Governments, Grand County Commissioners, and Middle Park Water Conservancy District. These agreements provide mitigation to West Slope entities from the transbasin diversion of water and associated impacts of the Windy Gap Project, and satisfy the Supreme Court ruling of September 14, 1979 that the conditional water right could not be granted until the Subdistrict formulated a plan to adequately mitigate any potential harm to prospective users within the upper Colorado River basin as specified in C.R.S. 37-45-118(1)(b)(IV). In return for these mitigation measures, West Slope interests agreed to withdraw objections to the Windy Gap Project conditional water right decrees and cooperate with all the necessary permitting requirements for construction of the project. The Subdistrict has fulfilled the short-term obligations under these agreements, and is continuing to operate the Windy Gap Project in accordance with the long-term obligations of these agreements and Colorado State law.

The Municipal Subdistrict, Northern Colorado Water Conservancy District entered into an "Amendatory Contract for the Introduction, Storage, Carriage and Delivery of Water for the Municipal Subdistrict, Northern Colorado Water Conservancy District, Colorado-Big Thompson Project, Colorado," Contract No. 4-07-70-W0107 (Carriage Contract) with the United States of America and the Northern Colorado Water Conservancy District on March 1, 1990. The Carriage Contract defines the rights and obligations of the Municipal Subdistrict, Northern Colorado Water Conservancy District with respect to the use of the facilities of the C-BT Project to introduce, store, carry, and deliver water diverted by the Windy Gap Project. An amendment to the Carriage Contract or an additional contract will be required to implement one or more of the action alternatives in the WGFP.

In January 2007, the Colorado State Engineer (SEO) (Simpson 2007) indicated that the Proposed Action to deliver and store water in Chimney Hollow Reservoir using prepositioning could be administered in compliance with current C-BT and Windy Gap water right decrees and within the priority system. The SEO also indicated that if Jasper East or Rockwell/Mueller Creek reservoir were selected for construction, that a change in the water right would be required.

6.0 POTENTIALLY AFFECTED ENVIRONMENT

6.1. West Slope Surface Water Hydrology

6.1.1. Colorado River from Lake Granby to Gore Canyon

6.1.1.1. Hydrologic Setting

The Colorado River study area for the hydrologic analysis starts at the outlet from Lake Granby and ends at the USGS streamflow gage below the confluence with the Blue River near Kremmling, located at the upstream end of Gore Canyon (Figure 4). The near Kremmling gage was used as the downstream end of the study area because the majority of the effects to the Colorado River are expected to occur upstream. Downstream changes in flow as a percent of total stream flow would diminish below the top of Gore Canyon due to tributary and other inflows. Potential effects to recreation, endangered fish, and other resources from hydrologic changes below Kremmling are discussed in separate technical reports.

The distance from Lake Granby to Gore Canyon is about 44 river miles; the distance from Windy Gap Reservoir to Gore Canyon is about 35 river miles. The Colorado River headwaters are defined as the continental divide on the east and north, the Williams Fork Mountains ridge to the south and west, and the Gore Range to the west and northwest. The watershed is generally defined by Grand County and encompasses an area of 1,869 square miles, with altitudes ranging from 13,400 feet along the continental divide to 7,300 feet at the upstream end of Gore Canyon. The major sub-basins of the upper Colorado River include the Colorado River, which originates in Rocky Mountain National Park, the Fraser River, Willow Creek, Williams Fork River, Troublesome Creek, Muddy Creek, and the Blue River. The major lakes and storage reservoirs in the upper Colorado River watershed include Grand Lake, Shadow Mountain Reservoir, Lake Granby, Willow Creek Reservoir, Williams Fork Reservoir, and Wolford Mountain Reservoir (Figure 4). Dillon Reservoir and Green Mountain Reservoir are located on the Blue River in Summit County. Windy Gap Reservoir is primarily a diversion forebay with about 445 AF of storage capacity.

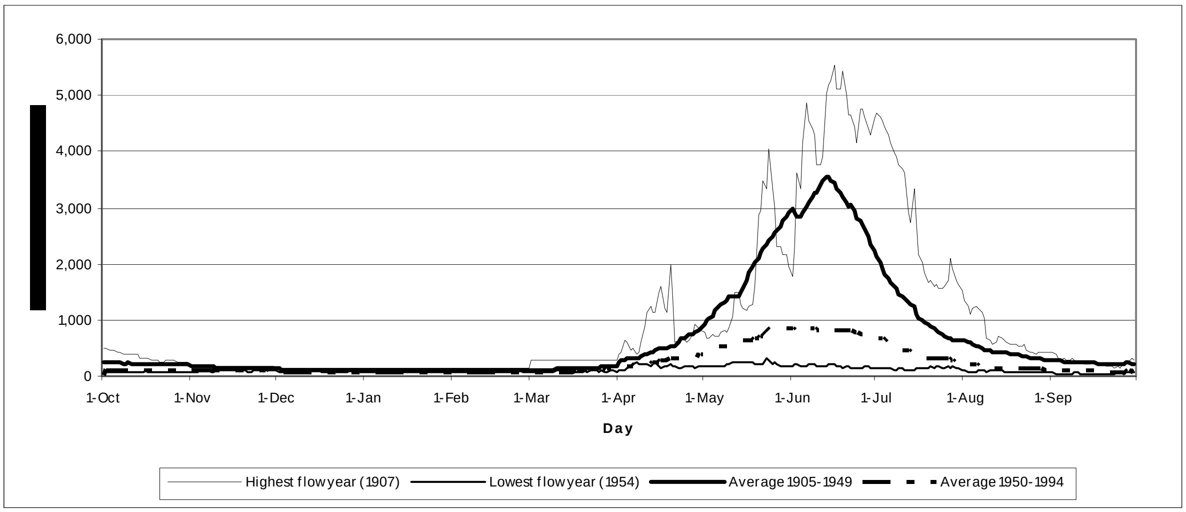
6.1.1.2. Colorado River Flows

The Colorado River and its tributaries experience widely variable seasonal fluctuations in flows, with the largest flows resulting from snowmelt. Approximately 75 percent of the total annual flow occurs during the spring and early summer runoff period of May through mid-July. There are five USGS gage stations on the Colorado River between Lake Granby and the upstream end of Gore Canyon (Figure 4), two of which are presently operated by the NCWCD. These gages are

- Colorado River below Lake Granby (09019000, 1950-present)
- Colorado River near Granby (09019500, 1908-present)
- Colorado River at Windy Gap (09034250, 1981-present)
- Colorado River at Hot Sulphur Springs (09034500, 1905-present)
- Colorado River near Kremmling (09058000, 1904-present)

The NCWCD has also operated two other gage stations on the Colorado River near the Williams Fork River and Troublesome Creek since the early 1990s (Figure 4). The streamflow gage at Hot Sulphur Springs has the longest period of record. Figure 3 presents hydrographs for the Colorado River at Hot Sulphur Springs, showing the highest (1907) and lowest (1954) flow years, as well as average daily flows for the period from 1905 to 1949 (prior to large C-BT diversions) and from 1950 to 1994. Annual flow volumes for the Colorado River at Hot Sulphur Springs from 1905 through 1994 are provided in Figure 5.

Figure 3. Colorado River at Hot Sulphur Springs, USGS (09034500) historical gage flows (1905-1994).



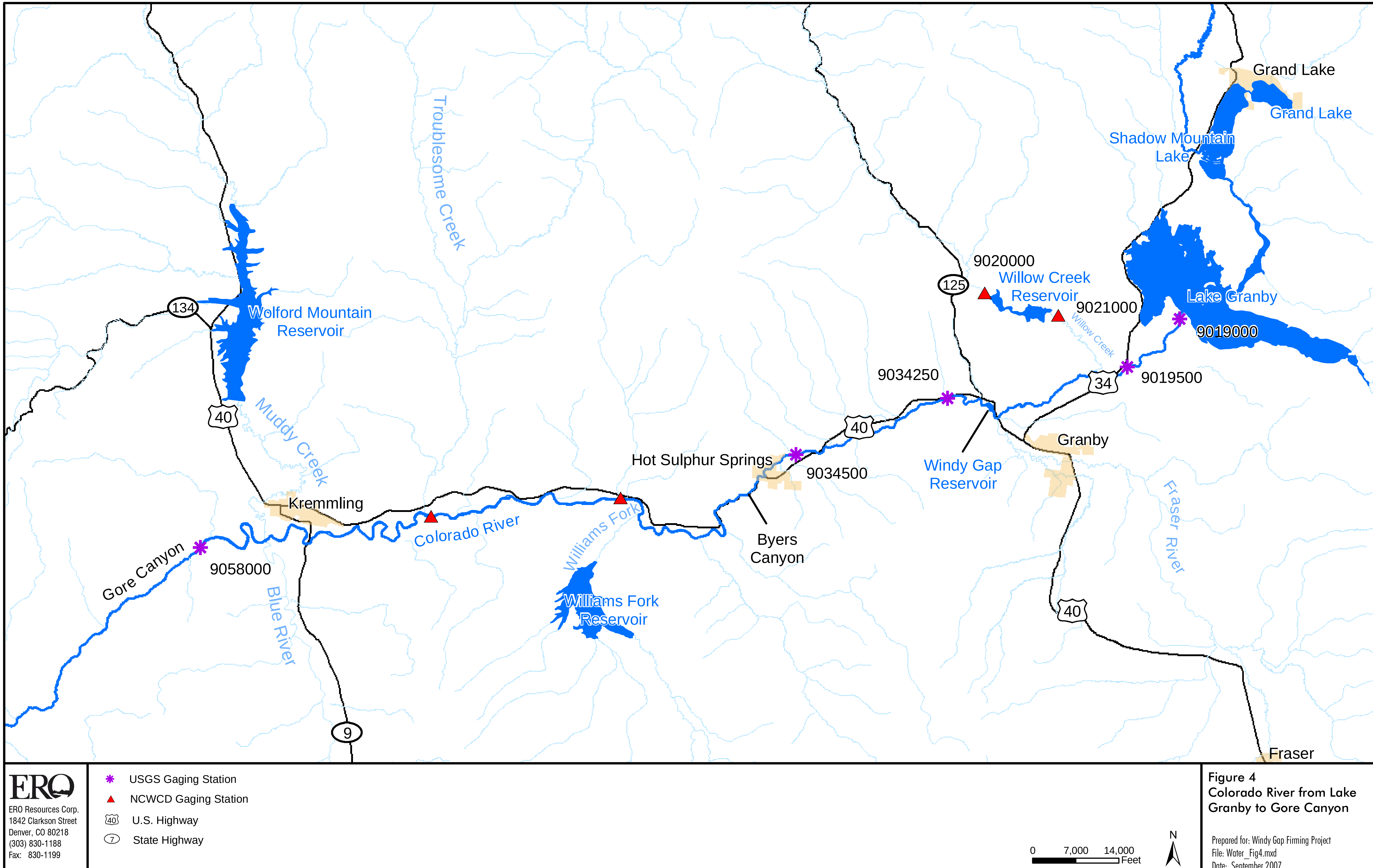
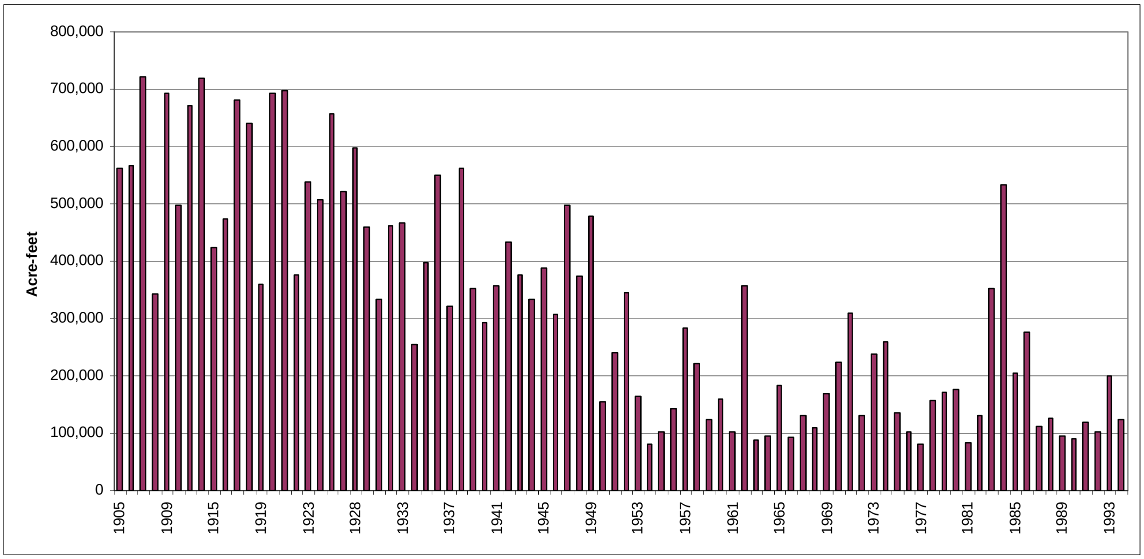


Figure 4
Colorado River from Lake Granby to Gore Canyon

Prepared for: Windy Gap Firming Project
File: Water_Fig4.mxd
Date: September 2007

Figure 5. Annual flow volumes, Colorado River at Hot Sulphur Springs.



The U.S. Department of the Interior developed the Principles to Govern the Release of Water at Lake Granby Dam to provide Fishery Flows immediately downstream in the Colorado River (Secretarial Decision Document 1961). The Principles were developed "to preserve at all times that section of the Colorado River between the reservoir to be constructed near Lake Granby and the mouth of the Fraser River as a live stream, and also to insure an adequate supply for irrigation, for sanitary purposes, for the preservation of scenic attractions, and for the preservation of fish life." The schedule of releases from Granby Reservoir is summarized as follows: 20 cubic feet per second (cfs) from September through April; 75 cfs from May through July; and 40 cfs in August. The bypass flow requirement may be reduced from May through September when the advanced forecast of inflow to the Three Lakes system and Willow Creek Reservoir is less than 230,000 AF (Boyle 2003, 2006a). Bypass flows were estimated to be reduced by 15 to 30 percent (as stipulated) for a portion of the period from May through August during the 15 years between 1950 and 1992.

During the period of record, spills from Lake Granby have occurred historically from February through October, with the largest spills occurring in May and June (Reclamation 2006). The largest average monthly spill (952 cfs) occurred in June 1984 (Table 2). The highest daily spill during this time period was 3,096 cfs, which occurred on June 17, 1996.

A Memorandum of Understanding (June 23, 1980) between the Municipal Subdistrict, NCWCD, and CDOW established instream flow requirements on the 24-mile reach of the Colorado River downstream of the WGFP to the mouth of the Blue River to support the fishery. These instream requirements include

- From the Windy Gap Diversion Point to the mouth of the Williams Fork River: 90 cfs

- From the mouth of the Williams Fork River to the mouth of Troublesome Creek: 135 cfs
- From the mouth of Troublesome Creek to the mouth of the Blue River: 150 cfs

The Subdistrict would not be required to bypass water in excess of natural inflow to the Windy Gap diversion. In addition, the MOU includes flushing flows of 450 cfs for 50 hours during the period of April 1 through June 30 are required once every 3 years if equivalent flows do not otherwise occur.

6.1.1.3. Stream Diversions

A number of tunnels, canals, and pipelines and diversions transport water from the Colorado River basin to the eastern side of the continental divide. Major transbasin diversions include the Gumlick, Vasquez, Moffat, and Roberts Tunnels owned by Denver Water (DW), and the Alva Adams Tunnel owned and operated by Reclamation.

Major direct flow diversions for water uses both on the East Slope and West Slope affect the flow of the Colorado River in the project area. Information on water diversions was taken from the Colorado Division of Water Resources CDSS database. The diversions include

- Grand Ditch, which began diverting in 1890, with a net absolute right for 524.6 cfs;
- Public Service Company's Shoshone Hydropower right, which began in 1905, with a decreed right for 1,408 cfs;
- The C-BT project, which began diverting water in 1947, water rights described in Table 5;
- Denver Water, which began diverting water from the Fraser River in 1937 via the Moffat Tunnel, with a net absolute right for 928 cfs and net conditional right for 352 cfs;
- Grand County water users, most of whom began diverting water from the Fraser River, Colorado River, and Willow Creek in the early to mid-1900s (the town of Granby's diversions began in 1890, with later appropriations in 1906 and 1963), with a net absolute right for about 527 cfs on these three streams;
- Numerous diversions and water storage on the Williams Fork River, Muddy Creek, and Blue River, most of whom began diverting water in the early to mid-1900s, with a net absolute right for about 2,400 cfs; and
- Windy Gap, which began diverting water in 1985, with an average diversion rate of 132 cfs in May and June, and much less in other months (Table 3).

Table 2. Historical spills to Colorado River from Lake Granby (cfs), 1957-2001.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	97	367	169	101	340	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	247	461	120	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	65	556	0	0
1974	0	0	0	0	0	0	0	101	583	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	808	83	0
1984	0	0	0	0	0	167	552	330	952	720	0	0
1985	0	0	0	0	0	0	0	0	37	0	0	0
1986	0	0	0	0	0	0	0	0	6	117	21	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	154	15	0
1996	0	0	0	0	0	94	395	16	595	58	0	0
1997	0	0	0	0	0	0	0	32	712	45	283	36
1998	0	0	0	0	0	0	223	71	44	182	0	0
1999	0	0	0	0	0	0	0	0	338	218	0	231
2000	205	3	0	0	0	0	0	28	127	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
Average	5	0	0	0	0	8	34	22	89	74	9	6

Source: Reclamation 2006.

Windy Gap Project water is diverted from the Colorado River at Windy Gap Reservoir (Figure 4). Once collected, it is pumped to Granby Reservoir for storage and is conveyed to the East Slope via the Adams Tunnel. The WGFP can use excess capacity in the Adams Tunnel for direct delivery of Windy Gap water to the East Slope to storage or to meet demands. Because East Slope storage capacity for Windy Gap water is limited, most Participants typically only order delivery of Windy Gap water from Granby Reservoir as needed. Windy Gap water in Lake Granby is delivered via "instantaneous delivery," which involves an exchange for C-BT water. As specified in the Carriage Contract, instantaneous delivery involves a C-BT release from Carter Lake or Horsetooth Reservoir in exchange for Windy Gap water stored in Lake Granby. Instantaneous deliveries do not require Windy Gap water to be delivered directly through the Adams Tunnel.

Table 3. Historical monthly Windy Gap diversions (AF) at Windy Gap Reservoir.

Year	April	May	June	July	Total
1985	0	488	0	2,276	2,764
1986	0	0	0	0	0
1987	0	3,730	0	0	3,730
1988	0	0	19,966	0	19,966
1989	0	0	4,036	0	4,036
1990	0	4,980	9,612	0	14,592
1991	0	0	19,303	0	19,303
1992	0	11,213	10,683	0	21,896
1993	254	11,372	10,116	0	21,742
1994	0	8,336	2,448	0	10,784
1995	0	13,620	441	0	14,061
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	58	10,300	3,892	0	14,250
2002	0	0	0	0	0
2003	6,166	27,592	30,442	0	64,200
2004	0	327	0	0	327
2005	3,697	17,326	0	0	21,023
Average	485	5,204	5,283	108	11,080
Minimum	0	0	0	0	0
Maximum	6,166	27,592	30,442	2,276	64,200

Windy Gap Reservoir is used as a regulating vessel, where water is stored until there is enough water to turn on one or more of the four pumps at 150 cfs increments. During lower river flows in the spring and summer, the pumps will be cycled on and off for ½ day to 1 day, or more, until there is no longer 150 cfs available to be pumped. At least 90 cfs is always bypassed through the reservoir. Historical Windy Gap Project monthly diversions from the Colorado River at the Windy Gap Reservoir are provided in Table 3. Since Windy Gap diversions from Windy Gap Reservoir on the Colorado River began, Windy Gap diverted no water in 1986, 1996 through 2000, and 2002 and diverted water for only two days in 2004 because either its water rights were not in priority in dry years, or there was no storage capacity in Lake Granby in wet years. Table 4 shows the number of days water was diverted at Windy Gap Reservoir and pumped to Lake Granby and the flow rate from 1985 through 2005.

Table 4. Historical daily Windy Gap diversions (cfs) at Windy Gap Reservoir (1985, 1987-1995, 2001, 2003-2005).

	# Days Water Pumped/Diverted		Diversion Rate (cfs)	
	Average	Range	Average	Range
April	8	1-17	126	29-357
May	22	2-31	208	4-600
June	21	2-31	226	19-600
July	7	Only 1985	162	72-190

The water rights of the C-BT project are provided in Table 5 and annual diversions are shown in Figure 6. The annual volumes provided in Figure 6 were calculated considering and including annual changes in storage in the Three Lakes, inflows from the Windy Gap diversion and Willow Creek Feeder Canal (WCFC), outflow to Adams Tunnel, and evaporative losses from the Three Lakes.

Existing major decreed water users with historical diversions of Colorado River water from below Lake Granby to the USGS gage at the top of Gore Canyon are provided in Table 6 (CDWR 2006). Several smaller ditches used mostly for irrigation have a combined decreed capacity of about 40 cfs. The hydrologic model incorporates all of the existing water rights and priorities shown in Table 6.

Table 5. C-BT Project storage and diversions on the Colorado River.

	Diversion Rights		
	Decreed Rate (cfs)	Average Diversion, 1975-2004 (cfs)	Average AF/yr Diverted 1975-2004
Alva Adams Tunnel	550	330	228,791
Granby Pump Canal[1]	1,100	350	188,441
Willow Creek Feeder	400	252	26,952
	Storage Rights		
	Decreed Volume (AF)	**Average Volume, 1975-2004 (AF)**	**Average Diversion, 1975-2004 (cfs)**
Granby Reservoir	543,758	161,453	407
Shadow Mtn/Grand Lake	19,669	18,067	38
Willow Creek Reservoir	10,653	8,350[2]	18

[1]The Granby Pump Canal delivers water from Lake Granby to Shadow Mountain Reservoir and Grand Lake for delivery through the Adams Tunnel.
[2]The average volume for Willow Creek Reservoir was for 1953 to 1999 (Reclamation records).

Figure 6. Annual C-BT Project diversions from the Colorado River.

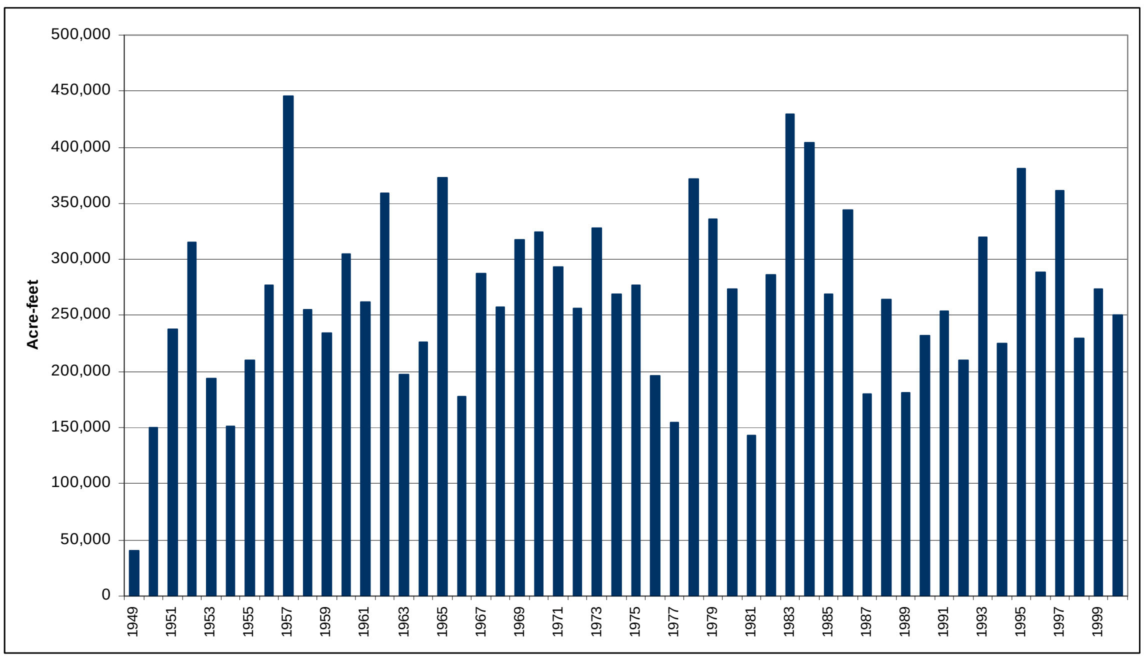


Table 6. Major water rights/users in the Colorado River from below Lake Granby to the USGS gage near Kremmling (top of Gore Canyon).

Structure Name	Location	Appropriation Date	Use	Decree Capacity (cfs)	Average Historical Diversions (AF)[1]
Coffee McQueary Ditch	S 2N 76W 15 SESWSE	1890	Irrigation / Augmentation	30.23	3,464
Selak Larrabee Ditch	S 2N 76W 20 SENWSE	1888	Irrigation	14.75	1,670
Windy Gap Pump Canal	S 2N 77W 25 SWNWNE	1967, 1976, 1980	Municipal	600	11,080[2]
Sheriff Ditch (156)	S 2N 77W 32 NWNESE	1884, 1914, 1944	Irrigation / Domestic	18.75	1,755
Ute Bill No. 2 Ditch	S 2N 78W 36 SESESW	1887, 1949	Irrigation / Domestic	14.5	1,684
Hot Sulphur Springs Water System	S 1N 78W 3 NWNWSW	1910	Municipal	3.34	115
Farris South Side Ditch	S 1N 79W 11 SWSWNW	1886, 1913, 1940	Irrigation	14.405	1,781
Sophronia Day Ditch	S 1N 79W 9 SWSENE	1890, 1891, 1907, 1908, 1909	Irrigation	24.125	4,202
Kinney Barriger Ditch	S 1N 79W 18 NWSENW	1882, 1900, 1940	Irrigation	65	7,642
Thompson Pump No 2	S 1N 80W 16 SESENW	1900	Irrigation	13.84	1,461
McElroy No. 2 Ditch	S 1N 80W 16 SENWNW	1881	Irrigation	12	792
McElroy No. 1 Ditch	S 1N 80W 17 SWNENW	1882	Irrigation	12	1,048

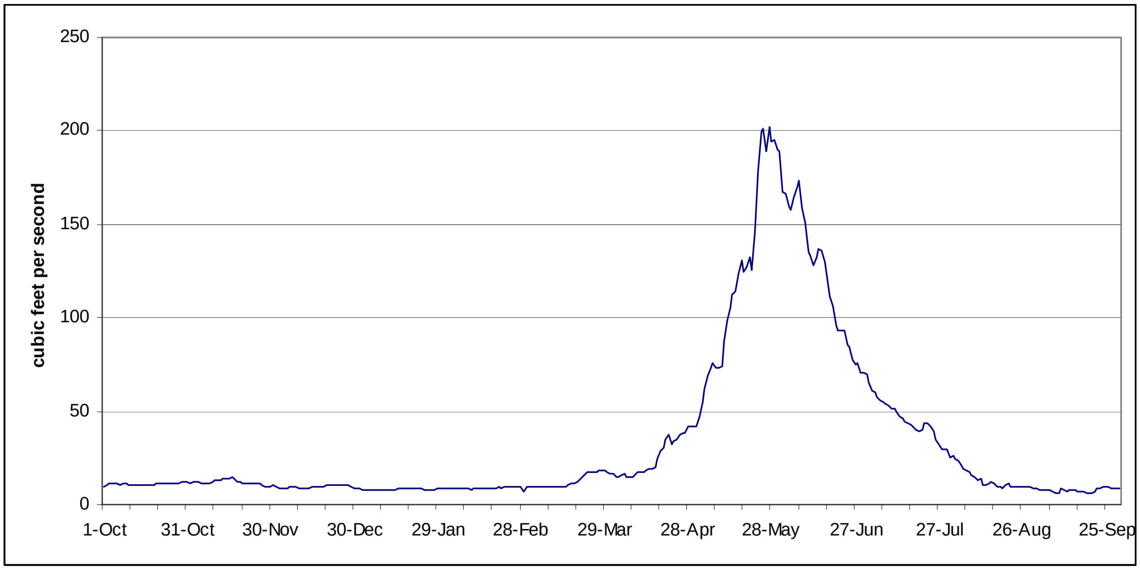
[1]Average annual diversions, 1975-2005
[2]Windy Gap diversions began 1985.

6.1.2. Willow Creek

Willow Creek is a tributary to the Colorado River whose mouth is located about 4 miles below the Colorado River outlet from Lake Granby (Figure 4). Its watershed originates within the Arapaho National Forest, with elevations ranging from 11,769 feet (Gravel Mountain) to about 7,900 feet at the Colorado River. The flow of lower Willow Creek is regulated by Willow Creek Reservoir. The drainage area above the reservoir is 134 square miles. The NCWCD diverts an annual average volume of 30,000 AF of water (1954 to 2004) from Willow Creek to Lake Granby via the Willow Creek Pump Canal as part of the C-BT Project.

A streamflow gage (09021000) is located below Willow Creek Reservoir (about 2.5 miles above the confluence with the Colorado River), where streamflow data was collected by the USGS from 1953 to 1982 and by the NCWCD since 1982. Average daily flows in Willow Creek below Willow Creek Reservoir (1953-2004) are shown in Figure 7.

Figure 7. Average daily flows, Willow Creek below Willow Creek Reservoir (Gage 9021000).

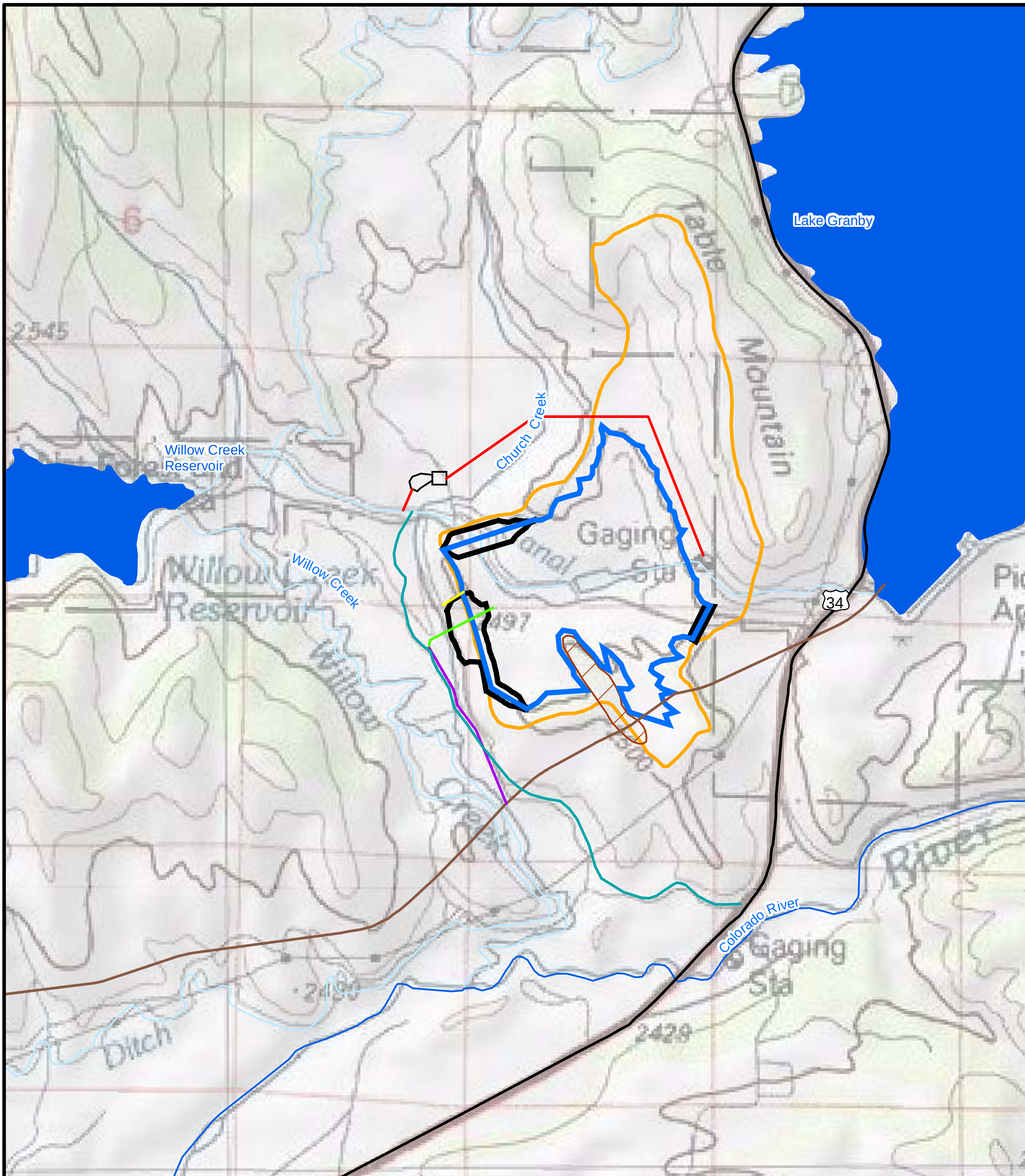


Four ditches divert water from Willow Creek below the reservoir, with adjudication dates of 1906, 1952, and 1957. The decreed diversion amounts for these ditches total about 36 cfs. There is a Colorado Water Conservation Board (CWCB) instream flow requirement of 7 cfs for Willow Creek below Willow Creek Reservoir. This is not required during the irrigation season; however, NCWCD's current operations include releasing or bypassing at least 7 cfs below the reservoir from May 1 through September 30 to maintain a "live" stream in Willow Creek.

6.1.3. Jasper East Study Area

The Jasper East study area is located in Grand County in Sections 8, 9, 16, and 17, T2N, R76W, near the southwest corner of Lake Granby (Figure 8). The study area consists mainly of flood-irrigated meadows bordered by areas of sagebrush shrublands and stands of lodgepole pine at higher elevations. The property is currently used for livestock grazing and hay meadow production. The watershed area is quite small (957 acres), with the high point at 8,830 feet on Table Mountain, located northeast of the proposed reservoir location and the low point at about 8,200 feet. An intermittent unnamed tributary to Church Creek flows from east to west through the study reservoir area before turning south to join Willow Creek.

The unnamed tributary channel is small, with little evidence of previous high flows. Precipitation and snowmelt are the main source of water supply to these creeks, but natural flows are supplemented by irrigation return flow and seepage from the Willow Creek Pump Canal and Forebay. There are no historical gage flow data for this tributary.



ERO

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

- Access Road
- Inlet - Outlet
- Spillway
- Jasper East Pipeline
- WC Pipeline
- Existing Windy Gap Pipeline
- Jasper East Reservoir
- Jasper East Dam
- Watershed Boundary

0 1,000 2,000 Feet

N

Figure 8
Jasper East Reservoir Study Area

Prepared for: Windy Gap Firming Project
File: Jasper_East_Water_Report.mxd
Date: September 2007

6.1.4. Rockwell/Mueller Creek Study Area

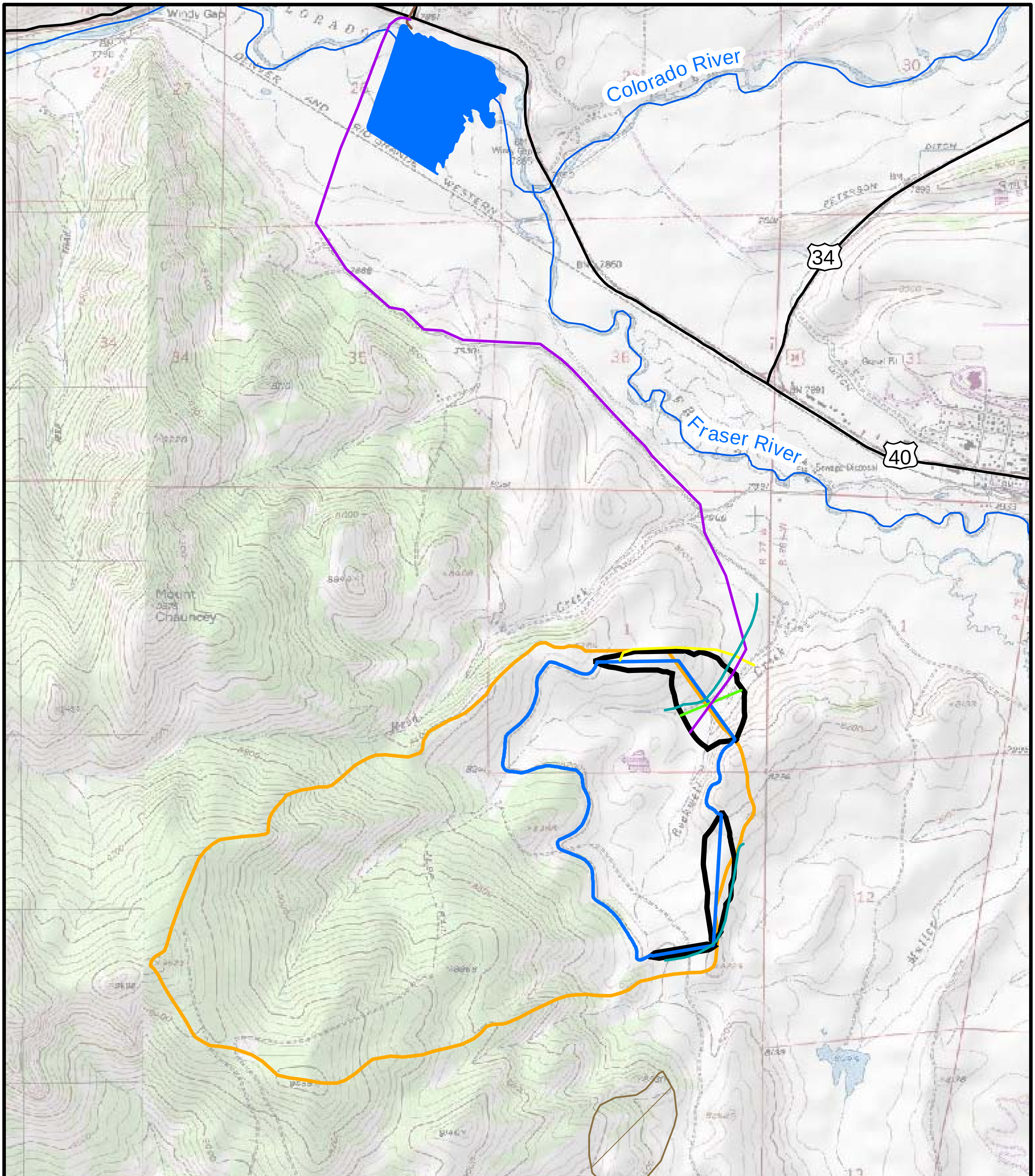
The Rockwell/Mueller Creek study area is located in Grand County in Sections 1 and 12 of T1N, R77W, about 1 mile southwest of the town of Granby (Figure 9). The study area consists mainly of big sagebrush, with some areas of lodgepole pine forest, meadow, and wetland and riparian areas. Rockwell Creek flows from south to north through the study area, and Mueller Creek flows from east to west, and joins Rockwell Creek in the northeast portion of the study area. The watershed area is 1,358 acres, most of which is located west and southwest of the proposed reservoir location. The highest elevation is 9,623 feet and the low point is at about 8,000 feet. Much of the watershed above the proposed reservoir site is fairly steep, with more than 20 percent slopes.

Rockwell and Mueller creeks flow intermittently. The creek channels are small, with little evidence of previous flood flows. Precipitation and snowmelt are the main source of water supply to these creeks. There are no historical gage flow data for Rockwell Creek or Mueller Creek.

6.2. West Slope Stream Morphology and Sedimentation

The form and structure of a stream (stream morphology), including its channel, banks, floodplain, and drainage area, can be altered by natural activities such as flooding, erosion, vegetation encroachment, or mud and debris flows. Human activity such as damming and reservoir regulation, water diversions and return flows, land use changes, and construction activities, can also alter stream morphology. Factors affecting channel dynamics include flow (i.e., frequency, magnitude, and duration), bed and bank material size and distribution, stream channel vegetation, sediment transport capacity, and sediment supply. As water flows over the channel bed and along the banks, it exerts a force in the direction of flow that, if large and frequent enough, will move the bed and bank material. This may cause the channel to become unstable and move laterally. If the force of the water is too small to move bed and bank material, or is too infrequent and causes movement only rarely, then the channel will be stable (Leopold et al. 1995).

Sediment particles are transported in flowing water by rolling or sliding along the streambed, moving above the bed with resting periods on the bed, or in suspension in the water. The first two processes help shape the bed and influence bed roughness and channel stability. The amount of material transported or deposited in a channel under a given set of conditions depends on variables that influence the quantity and type of sediment transported in the channel, and on variables that influence the capacity of the channel to transport sediment. Deposition of sediment eroded and transported from upstream can raise the streambed, which is referred to as aggradation. Lowering of the streambed, called degradation, can occur from scouring of sediments during high streamflows.



Access Road
Inlet - Outlet
Spillway
Rockwell Pipeline
Existing Windy Gap Pipeline
Rockwell Reservoir
Rockwell Dam
Rock Borrow
Watershed Boundary

0 1,250 2,500 Feet

N

ERO

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Figure 9
Rockwell/Mueller Creek Reservoir Study Area

Prepared for: Windy Gap Firming Project
File: Rockwell_Water_Report.mxd
Date: September 2007

6.2.1. Colorado River from Lake Granby to Gore Canyon

The flow of the Colorado River is affected by storage in Lake Granby, Shadow Mountain Reservoir and Grand Lake, stream diversions, return flows, and tributary inflows. Major tributaries to the Colorado River between Lake Granby and the top of Gore Canyon include

- Willow Creek, which is influenced by Willow Creek Reservoir
- Fraser River
- Williams Fork River, which is influenced by Williams Fork Reservoir
- Troublesome Creek
- Muddy Creek, which is influenced by Wolford Mountain Reservoir
- Blue River, which is influenced by Dillon and Green Mountain Reservoirs

There are also 14 minor tributaries and numerous diversions for agricultural and domestic water needs. A number of the diversions, some quite large (in particular, Grand Ditch) began prior to the installation of any gages on the Colorado River. The flow of the Colorado River has been quite variable over the period of record, in part due to diversions and storage. Sediment available for transport in the Colorado River is derived from upstream sources, tributary inflows, and channel bed and banks. The igneous and metamorphic rocks of the Colorado River headwaters are fairly resistant to weathering and, therefore, contribute little sediment to the river. A previous study showed that the Colorado River channel bed and banks are well armored and that the source of sediments in the stream is overland flow and tributary inflows (Ward and Eckhardt 1981). This study determined that the largest tributary source of sediment in the study area is Troublesome Creek; other tributaries are minor sources. The sediment supply was found to be low, so that transport capacity of the river greatly exceeded supply (Ward and Eckhardt 1981).

Ward and Eckhardt's (1981) review of historical aerial photographs determined that there was no observable change in river morphology between 1938 and 1974. To determine the type and magnitude of sediments in transport and available for transport, an intensive sampling and measurement program was completed in the spring, summer, and fall of 1980 that included samples collected on the rising and falling limbs of the hydrograph. In addition, 18 cross-sections between Granby and Gore Canyon were surveyed, and samples of surface armor and subsurface material were collected from the active streambed and banks (Ward and Eckhardt 1981). The data supported the finding that the river channel has not historically changed its position to any extent, indicating little or no disturbance and reworking of subsurface material (Ward and Eckhardt 1981). In addition, hydrologic modeling completed for the Windy Gap Project for a diversion of 54,000 AF from the Colorado River showed that deposition would not occur in any reach below Windy Gap Reservoir as a result of reduced streamflows (Ward 1981).

A recent comparison of aerial photographs of the Colorado River between Lake Granby and the top of Gore Canyon taken from 1972 to 1974, the 1990s and in 2005 show that, with the exception of the addition of Windy Gap Reservoir, there have only been minor noticeable changes in river morphology. A sample of three sets of 1970s and

2005 aerial photographs comparing the Colorado River at various locations between Lake Granby and the top of Gore Canyon are provided in Appendix A. This is apparent even in the approximately 5-mile stretch of the Colorado River from below Windy Gap Reservoir to Hot Sulphur Springs, where changes to stream morphology would most be expected due to the construction of Windy Gap Reservoir. In addition, recent cross-sectional analyses completed by aquatic ecologists for the WGFP, located 8 to 10 miles downstream of Windy Gap Reservoir, showed no evidence of recent changes to stream morphology or sediment deposition in the Colorado River near Parshall (Miller 2007).

Although there has been growth and development in the upper Colorado River watershed since 1981, there have been no major wildfires, flash floods, or alterations to the river channel that have substantially increased sediment loading to the Colorado River. Construction of Windy Gap Reservoir has likely decreased sediment loading to the river below the dam by capturing sediment.

Ward's (1981) analysis of bed materials and movement showed that the required periodic flushing flow of 450 cfs should be sufficient to transport fine sediments (2 mm or finer), thus preventing aggradation of fine sediment in the stream bottom. In addition, the analysis of stream discharge and sediment transport concluded that normal high river flows, even during Windy Gap diversions, would be adequate to transport finer sediments without the 450 cfs flushing flows (Ward 1981).

Channel maintenance flows, also known as flushing flows, maintain the physical characteristics of a stream channel critical to unimpaired flow and sediment conveyance. They provide the benefits of conveying water and eroded materials from tributaries through a stream without aggradation or degradation, scour vegetation in the channel, sustain aquatic ecosystems, temporarily store flood flows on the floodplain, and maintain healthy streambank and floodplain vegetation (Schmidt and Potyondy 2004, Coley/Forrest 2007). The lower limit of channel maintenance flows has been defined as 80 percent of the 1.5-year discharge and the upper limit is defined as the 25-year instantaneous peak flow (Schmidt and Potyondy 2004). The flow of the Colorado River at Hot Sulphur Springs was altered substantially when increased C-BT diversions began in 1947. However, as with the Colorado River below Lake Granby, in the last 6 decades, the river has remained stable and despite changes in timing and quantity, flows have continued to move water in an unimpaired manner downstream, convey sediment, and prevent sediment aggradation and degradation. It is evident that despite changes that have occurred in the Upper Colorado River basin since 1938 (especially flow changes due to C-BT diversions and the construction of Lake Granby), the form and structure of the Colorado River channel, banks, floodplain, and watershed within the study area has changed very little. The upper Colorado River is a morphologically stable stream.

The Colorado River has overflowed its banks occasionally during snowmelt events. Such events are recorded for the USGS gage near Kremmling (NOAA 2006). In recent years, the largest flows, all of which caused considerable inundation in nearby low-lying areas near Kremmling, occurred for up to a month in 1983, 1984, 1995, 1996, and 1997.

6.2.2. Willow Creek

The 2.5-mile segment of Willow Creek from Willow Creek Reservoir to the Colorado River has a sinuous channel that flows across nearly flat topography and has two small tributaries. As shown in Figure 7, the base flow of Willow Creek is about 10 cfs, which occurs during 7 months of the year. Scouring flows exceeding 1,000 cfs have occurred infrequently. Sediment supply in Willow Creek below the reservoir is limited due to the reservoir and because alluvium and soils underlying the creek and its tributaries are shallow, overlying exposed bedrock in much of the Willow Creek watershed below the reservoir.

6.3. West Slope Existing Reservoirs

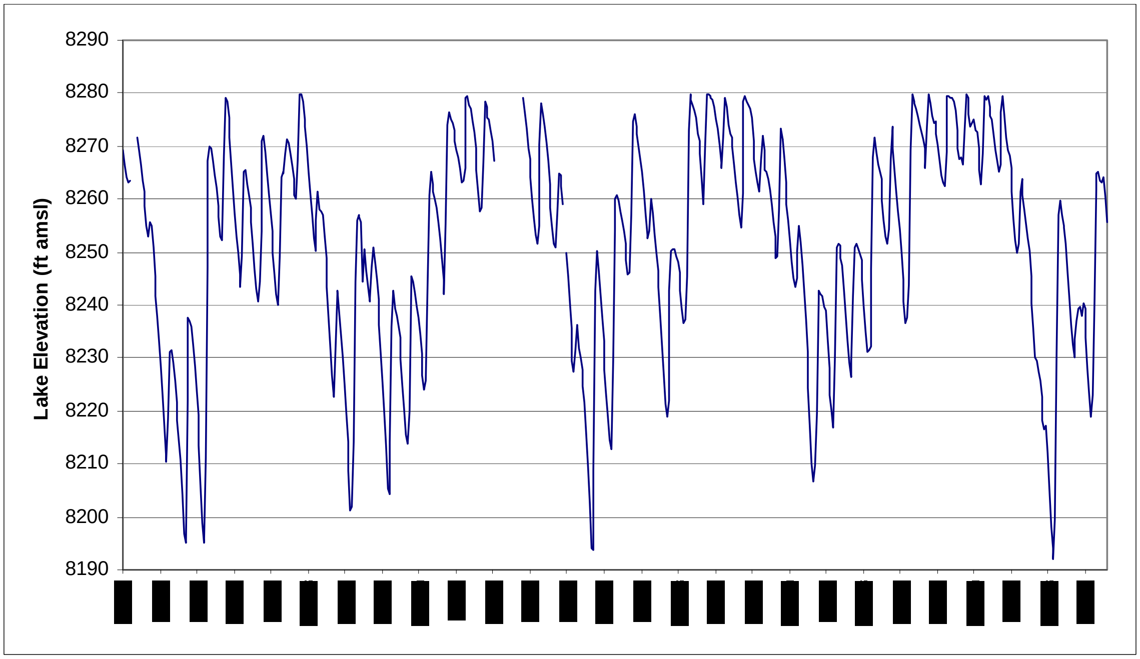
6.3.1. Lake Granby

Lake Granby, located northeast of the Town of Granby in Grand County, is the second largest reservoir in Colorado and serves as the primary storage reservoir in the C-BT system. Its surface water elevation can vary considerably depending on hydrology and operations. Major tributaries include Arapaho Creek, Stillwater Creek, Columbine Creek, and the Roaring Fork. Water is also pumped to the reservoir from Willow Creek Reservoir and Windy Gap Reservoir. Lake Granby is currently the only C-BT reservoir where Windy Gap water can be stored during the period between which it is diverted and delivered to the Participants. Outflow is either through downstream spills to the Colorado River or to Shadow Mountain Reservoir via the Farr Pumping Plant and Granby Pump Canal and eventually through the Adams Tunnel to the East Slope. Lake Granby's physical characteristics are described in Table 7. Historical lake elevations are provided in Figure 10 (Reclamation 2006). The lake elevation has varied during the past 50 years by nearly 90 feet.

Table 7. Physical characteristics of Lake Granby.

Volume	539,758 AF
Surface Area	7,256 acres
Mean Depth	74 feet
Maximum Depth	221 feet
Shoreline	40 miles

Figure 10. Historical lake elevations in Lake Granby, 1953-2006.



6.3.2. Shadow Mountain Reservoir

Although the storage in Shadow Mountain Reservoir would not change as a result of the WGFP, the reservoir's physical characteristics are provided in Table 8.

Table 8. Physical characteristics of Shadow Mountain Reservoir.

Volume	17,354 AF
Surface Area	1,852 acres
Mean Depth	9.4 ft
Maximum Depth	19.7 ft
Shoreline	8 miles

6.3.3. Grand Lake

Although the storage in Grand Lake would not change as a result of the WGFP, the lake's physical characteristics are provided in Table 9. Under Existing Conditions, as well as all alternatives, water is pumped from Lake Granby to Shadow Mountain/Grand Lake via the Granby pump canal to replace C-BT deliveries via the Adams Tunnel to the East Slope. The maximum allowable fluctuation in water surface at Shadow Mountain/Grand Lake is limited to 1 foot in accordance with Senate Document 80. Therefore, water delivered out of Grand Lake via the Adams Tunnel would be replaced with water pumped out of Lake Granby to Shadow Mountain/Grand Lake. The space created by additional WGFP storage, including prepositioning, would reside in Lake Granby. There could be some short-term fluctuations in contents in Shadow Mountain/Grand Lake under the alternatives; however, these fluctuations would be relatively small and limited to less than 1 foot of elevation change.

Table 9. Physical characteristics of Grand Lake.

Volume	68,621 AF
Surface Area	507 acres
Mean Depth	135 feet
Maximum Depth	265 feet

6.4. West Slope Ground Water Hydrology and Quality

6.4.1. Hydrogeology

6.4.1.1. Colorado River Study Area

The Colorado River study area extends approximately 44 river miles between the outlet from Lake Granby to the top of Gore Canyon, flowing in a predominantly east-west direction through Grand County (Figure 4). The area is within the Southern Rocky Mountain Geographic Province. The summary of geology of this area is based on review of several available sources (Chronic 1980; Tweto 1979; Schroeder 1995; Izett 1968; Izett and Barclay 1973), as well as geologic logs and well records obtained from the Colorado Division of Water Resources.

The geology of this segment of the Colorado River is variable and relatively complex. Units exposed at the surface include Quaternary-aged alluvium, colluvium, landslide deposits, and glacial outwash, Tertiary-aged sediments, Cretaceous-aged sedimentary rocks and volcanic rocks, and Precambrian-aged igneous and metamorphic rocks. Various faults have been mapped in the area, but the Southern Rocky Mountains are generally considered seismically inactive. In general, the width of the floodplain and the thickness of the alluvium are controlled by the bedrock geology. In reaches of the river that flow through areas of erosionally resistant bedrock units, such as the Precambrian-aged intrusives, the flood plain tends to be narrow, relatively straight, and contains little if any alluvium. In areas of less resistant bedrock geology, such as the Pierre Shale, the flood plain is relatively wide, meandering, and contains significant thicknesses of alluvium.

North and west of Granby, in the vicinity of the Colorado River's confluence with the Fraser River, alluvial sediments are mapped as approximately one mile wide on the Colorado River floodplain (Schroeder 1995). The alluvium is up to 80 to 90 feet thick in this area, but more commonly less than 50 feet thick.

Downstream of Windy Gap Reservoir, the Colorado River floodplain temporarily narrows significantly as the river bisects surficial exposures of the Windy Gap Volcanic Member. There does not appear to be continuous (or significant) alluvial deposits in this area. Beyond this point and for a distance of approximately 4 miles, the Colorado River flows generally southwesterly in an area where a floodplain up to approximately ¼ mile wide has developed, with alluvial deposits up to 65 feet thick. The alluvium is underlain by Tertiary-aged units of the Middle Park Formation.

Prior to entering the town of Hot Sulphur Springs, the Colorado River floodplain narrows significantly as it bisects volcanic rocks of the Windy Gap Volcanic Member (of Middle Park Formation). Downstream of the volcanics, the Colorado River floodplain widens considerably to about ½ mile, where the river has incised into less resistant sedimentary rocks including Pierre Shale and the upper Middle Park Formation. The floodplain in this vicinity includes terrace deposits along the edges of the floodplain and alluvium up to 60 feet thick within the modern channel.

Immediately beyond Hot Sulphur Springs, the Colorado River flows through Byers Canyon, characterized by steep valley walls composed primarily of Precambrian-aged intrusive igneous rocks. Alluvium within the canyon is discontinuous and of no significant thickness.

Between Byers Canyon and the top of Gore Canyon, the Colorado River floodplain widens, ranging in width from ¼ to ½ mile. Alluvial deposits along this segment of the river are up to 80 feet thick. In this area, alluvial deposits are underlain primarily by Tertiary-aged sediments that floor this area, including the Troublesome Formation, as well as the Cretaceous-aged Pierre Shale. West of Kremmling, the Colorado River enters Gore Canyon, where the channel cuts into Precambrian-aged metamorphic bedrock that forms steep valley walls.

Because the Colorado River drainage is the lowest area topographically, the river is most likely a discharge area for aquifers or water-bearing zones in bedrock formations that are crossed by the river. Bedrock aquifers are not expected to be affected by changes in river flow or quality and, therefore, are not discussed.

Surficial deposits along the Colorado River, such as alluvium, are usually connected hydraulically to the river. There may be areas where older alluvial terraces may no longer be directly connected to the river because of more recent erosion and downcutting by the river, isolating the older units. In addition to being connected to the river, alluvium may receive water from underlying or adjacent bedrock aquifers. In addition to alluvium, other small surficial aquifers include glacial outwash or other similar unconsolidated deposits. Within the Upper Colorado River basin, ground water production from water wells is from sedimentary formations such as the Troublesome Formation, Precambrian crystalline rocks, and unconsolidated deposits along the river.

6.4.1.2. Jasper East and Willow Creek Study Area

The geology summary of this study area is based on the review of available sources (USGS well records; Colorado Division of Water Resources well records; Tweto 1979; Izett 1974; Boyle Engineering 2005; Topper 2003). The study area is located in the Southern Rocky Mountain physiographic province. The current landforms are the result of faulting, uplift, glaciation, and erosion. The predominant geologic unit exposed at the surface in the study area is the Tertiary-aged Troublesome Formation, which consists in this area of tuffaceous mudstone and sandstone interlayered with basalt flows, and to a lesser extent, conglomerate composed of granite and volcanic rocks. The Troublesome Formation is reported to range in thickness from about 800 to 1,000 feet. Other units exposed at the surface include Tertiary-aged basalt flows, as well as Quaternary-aged terrace deposits, comprising sand and gravel along rivers and streams, and Quaternary-aged alluvium that is deposited along modern day rivers and streams, such as Willow Creek.

The primary water-yielding units in the study area include the Troublesome Formation, a bedrock aquifer, and to a lesser extent, underlying Mesozoic-age sedimentary rocks including the Dakota Sandstone, the Morrison Formation, and where significantly fractured, the Pierre Shale. Although not considered a significant water-bearing unit, alluvial deposits may yield water in useable quantities in some areas. In general, the presence of faulting, depositional environment, and geologic structure tend to play an important role concerning the occurrence of ground water in this area. Depending on the presence of a tuffaceous siltstone within it, the Troublesome Formation may be classified as either an unconfined or confined aquifer.

6.4.1.3. Rockwell/Mueller Creek Study Area

The Rockwell Creek study area is underlain by the Troublesome Formation, except in the narrow valley associated with Rockwell Creek, where limited quaternary-aged alluvium is present, and in other areas where Quaternary-aged terrace gravels and landslide deposits are present. The Troublesome Formation, about 1,000 feet thick, consists of interbedded siltstone and mudstone or shale, with less abundant arkosic sandstone and conglomerate, and minor amounts of limestone. It is the primary water-yielding unit in the study area. In addition, alluvial deposits may yield water in useable quantities, particularly downstream of the proposed dam on the south side of the Fraser River valley.

6.4.1.4. Lake Granby

Lake Granby is located within the Southern Rocky Mountain physiographic province. The general geology of the lake area is Precambrian-aged granitic and metamorphic rocks to the east side, and Tertiary-aged sedimentary rocks, primarily the Troublesome Formation, underlying the reservoir and to the west. In various areas these rocks are mantled by quaternary-aged alluvium and glacial drift.

6.4.2. Ground Water Use

6.4.2.1. Colorado River Study Area

Well records from the Colorado Division of Water Resources were reviewed for wells located within ¼ mile of the Colorado River. Based on these well records, the following observations were made:

- Most of the permitted wells appear to be used for domestic purposes or irrigation and are less than 100 feet deep.
- Approximately 70 wells are screened within alluvium or other unconsolidated materials, and are characterized as “alluvial wells.”
- An additional 17 wells are screened both in the alluvium and in underlying bedrock.

6.4.2.2. Jasper East and Willow Creek Study Area

There are less than 10 permitted wells within this study area. Existing wells are screened in unspecified sedimentary rocks that are likely the Troublesome Formation, to depths of 77 to 240 feet.

6.4.2.3. Rockwell /Mueller Creek Study Area

There are 35 permitted wells in the study area. The wells have depths ranging from 35 to 700 feet; most wells are installed to depths much greater than 100 feet. All but one well are screened in sedimentary rocks, typically sandstone and/or shale. One well is screened in volcanic rocks.

6.4.2.4. Lake Granby

There are hundreds of water supply wells located along the lake, most of which are more than 100 feet deep and are screened at a depth of 50 feet or greater.

6.4.3. Ground Water Quality

6.4.3.1. Colorado River Study Area

Within the study area, ground water recharge occurs at higher elevations and discharges in areas of low elevation; that is, into the Colorado River. Therefore, water quality in the surficial deposits along the river may be strongly influenced by bedrock water quality, particularly alluvial deposits farther from the river. The water quality of ground water in alluvial deposits adjacent to the river is more likely to be similar to that of the river. Depending on the hydraulic relationships between the river, the alluvium, and the bedrock aquifers at any given location, water quality of the alluvium is anticipated to be seasonably variable. The water quality of alluvial aquifers may also be affected by human activities, such as the use of fertilizers and pesticides and runoff from developed areas.

Water quality data results reported in two USGS studies (Apodaca and Bails 2000; Bauch and Bails 2004) and the Colorado Ground Water Atlas (Topper 2003) indicate that alluvial ground water along the Colorado River has low nutrient concentrations, low dissolved solid concentration (average of 120 mg/L), low alkalinity (less than 100 mg/L) and low hardness (average of 50 mg/L). Compared to bedrock ground water quality in this area, alluvial ground water is lower in calcium, bicarbonate, chloride, sodium and sulfate. The water quality results from a well located close to the confluence of the Blue and Colorado Rivers is typical of bedrock water quality (Apodaca and Bails 2000). The water in this well, which is 55 feet deep, has a total dissolved solids value of 513 mg/L and is a calcium-sulfate water, typical of bedrock ground water in this area. The water from this well also has much higher iron and manganese concentrations than other alluvial water in the area.

6.4.3.2. Jasper East, Rockwell/Mueller Creek and Willow Creek Study Areas

Well records indicate that ground water use in these study areas are from the Troublesome Formation. Troublesome Formation ground water is typically a calcium bicarbonate water with a total dissolved concentration of 200 mg/L and a hardness of less than 90 mg/L (Bauch and Bails 2004; Topper 2003).

6.4.3.3. Lake Granby

Water from wells located next to Lake Granby is being used for domestic purposes and is assumed to be of potable quality.

6.5. East Slope Surface Water Hydrology

6.5.1. Chimney Hollow Study Area

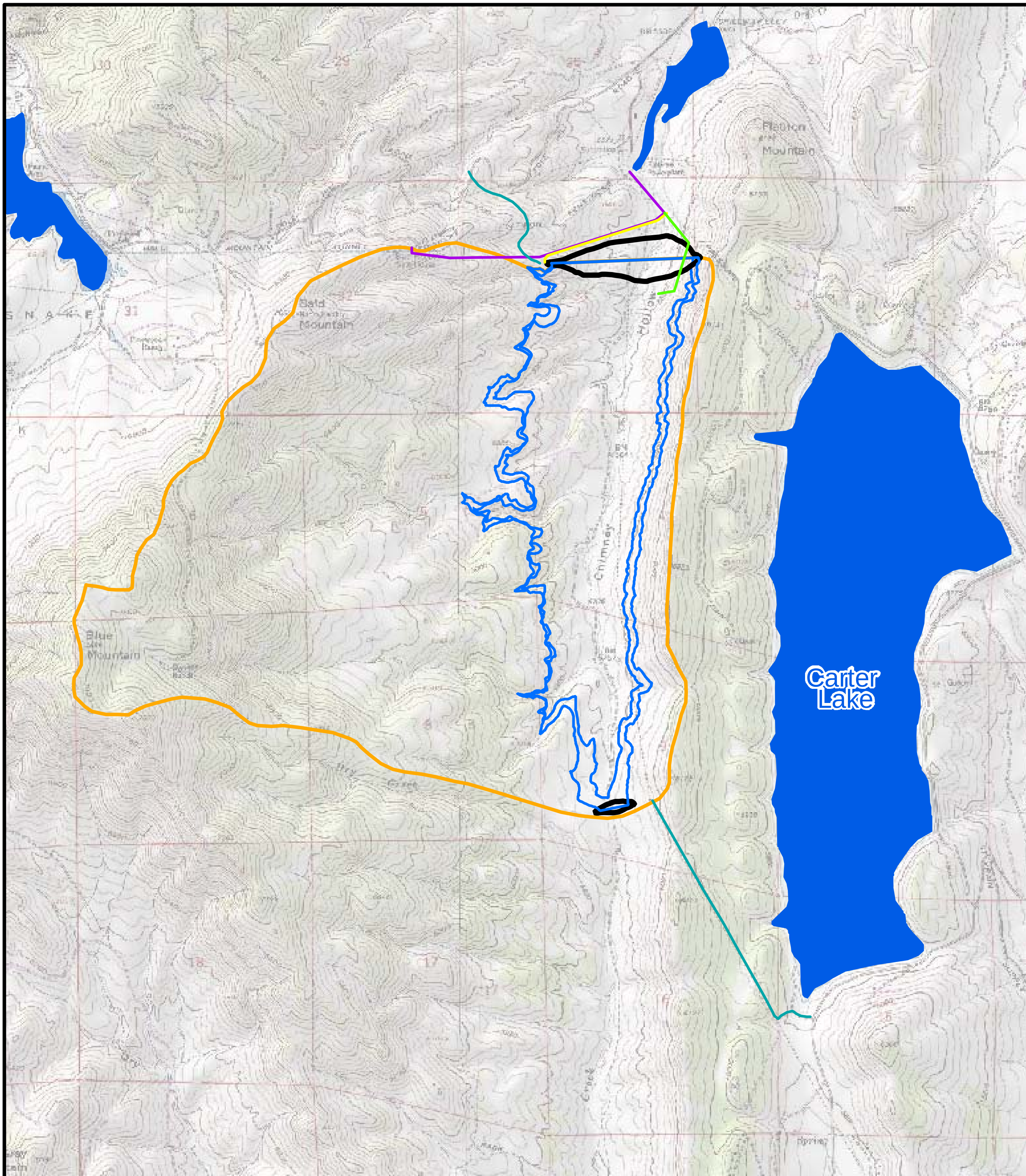
The Chimney Hollow Study Area is in Larimer County in Section 33, T5S, R70W and Sections 4, 5, and 9 of T4N, R70W in the Carter Lake Reservoir Colorado USGS Quadrangle map (Figure 11). Nearby reservoirs include Flatiron Reservoir located northeast of the site and Carter Lake directly east. The study area occurs in a long north-south trending valley between a hogback ridge to the east and foothills to the west. A small intermittent creek, Chimney Hollow, flows through the center of the valley and several ephemeral to intermittent tributaries drain from the west into the creek. Chimney Hollow drains into Flatiron Reservoir. Ponderosa pine forests cover the foothills to the west with mostly native grasslands occurring in openings within the forest. Native and non-native grasslands cover the valley floor with riparian woodlands and shrublands occurring along the drainages. Native shrublands cover the slopes on the rocky hogback to the east. The watershed covers an area of 2,986 acres, much of it to the west of the valley. The high point in the watershed is Blue Mountain (elevation 7,888 feet) to the west and the low point is about 5,520 feet. Much of the watershed is steep, with greater than 50 percent slopes on some of the eastern hogback face, 30 percent slopes to the west, and gentler slopes at the lower elevations where the reservoir would be located.

Chimney Hollow is a small, intermittent stream, with little evidence of high flows from large storm events. Precipitation and snowmelt are the main source of water supply, but there are also several springs and seeps in the Chimney Hollow watershed on both sides of the creek. There are no historical gage flow data for Chimney Hollow Creek.

6.5.2. Dry Creek Study Area

The Dry Creek Study Area occurs in the valley south of Chimney Hollow (Figure 12), separated from Chimney Hollow by a gentle saddle. The Dry Creek study area is located in Sections 16, 20, 21, and 28 in Larimer County on the Carter Lake Reservoir Colorado USGS Quadrangle map. Dry Creek, a tributary to the Little Thompson River, flows south through the valley. Several small, intermittent or ephemeral tributaries flow from the foothills to the west and a few tributaries flow from the hogback to the east to Dry Creek. The forests, shrubland, and grassland vegetation in the Dry Creek study area is similar to the Chimney Hollow Study Area. The watershed covers an area of 2,527 acres, much of it to the west and northwest of the reservoir site. The high point is 7,873 feet at the northwest corner of the watershed and the low point is at about 5,500 feet. Much of the watershed is steep (30 to 45 percent slopes), with gentler slopes at lower elevations.

Dry Creek is a small stream with intermittent flow. There is little evidence of previous flood flows. Precipitation, snowmelt, and numerous small seeps and springs are the source of water supply to the Dry Creek watershed. There are no historical gage flow data for Dry Creek.



Access Road
Inlet - Outlet
Spillway
Chimney Hollow Pipeline
Chimney Hollow Reservoir
Chimney Hollow Dam
Watershed Boundary

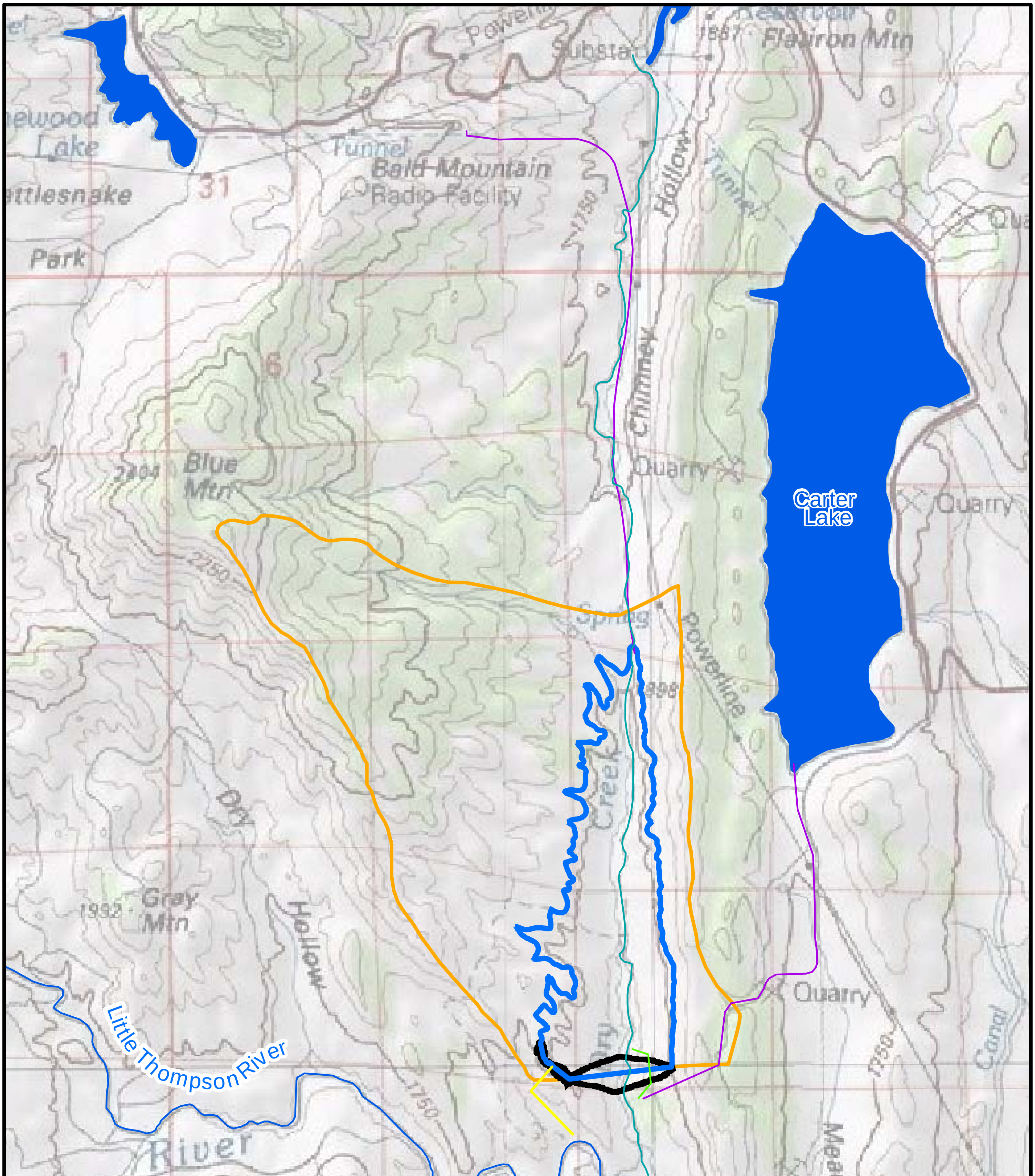
0 1,500 3,000 Feet

N

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Figure 11
Chimney Hollow Reservoir Study Area

Prepared for: Windy Gap Firming Project
File: Chimney_Hollow_Water_Report.mxd
Date: September 2007



Access Road
Inlet - Outlet
Spillway
Dry Creek Pipeline
Dry Creek Reservoir
Dry Creek Dam
Watershed Boundary

0 1,750 3,500 Feet

N

ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Figure 12
Dry Creek Reservoir Study Area

Prepared for: Windy Gap Firming Project
File: Dry_Creek_Water_Report.mxd
Date: April 2006

6.5.3. East Slope Streams

East Slope streams potentially affected by the WGFP include six streams that receive return flow discharges from 11 Project Participants (Section 6.5.3.1). In addition, the Big Thompson River would experience changes in flow with delivery of additional Windy Gap water associated with differences in C-BT diversions at Olympus and Dille Tunnels (Section 6.5.3.2), and North St. Vrain and St. Vrain creeks would also have modified flow regimes under the No Action alternative (Section 6.5.3.3). Each of these projected areas of streamflow change is discussed below.

6.5.3.1. Streams that Receive Windy Gap Return Flow

Six streams, all of which are tributary to the South Platte River, receive effluent from the Windy Gap Participants' WWTPs (Figure 13a and Figure 13b; Table 10). Central Weld County Water District serves rural domestic customers and does not have a wastewater collection system or treatment plant. Return flow is distributed over a large area in the Boulder Creek and South Platte River basins. The Platte River Power Authority reuses its Windy Gap water to extinction for power generation and does not release return flows.

Table 10. Receiving waters of Windy Gap return flows for each Participant.

Participant	Location of Receiving Water
Broomfield	Big Dry Creek
Central Weld County Water District	Boulder Creek and South Platte River basins
Erie	Coal Creek
Evans	South Platte River
Fort Lupton	South Platte River
Greeley	Cache la Poudre River
Lafayette	Coal Creek
Little Thompson Water District	St. Vrain Creek
Longmont	St. Vrain Creek
Louisville	Coal Creek
Loveland	Big Thompson River
Platte River Power Authority	None (water used to extinction)
Superior	Coal Creek

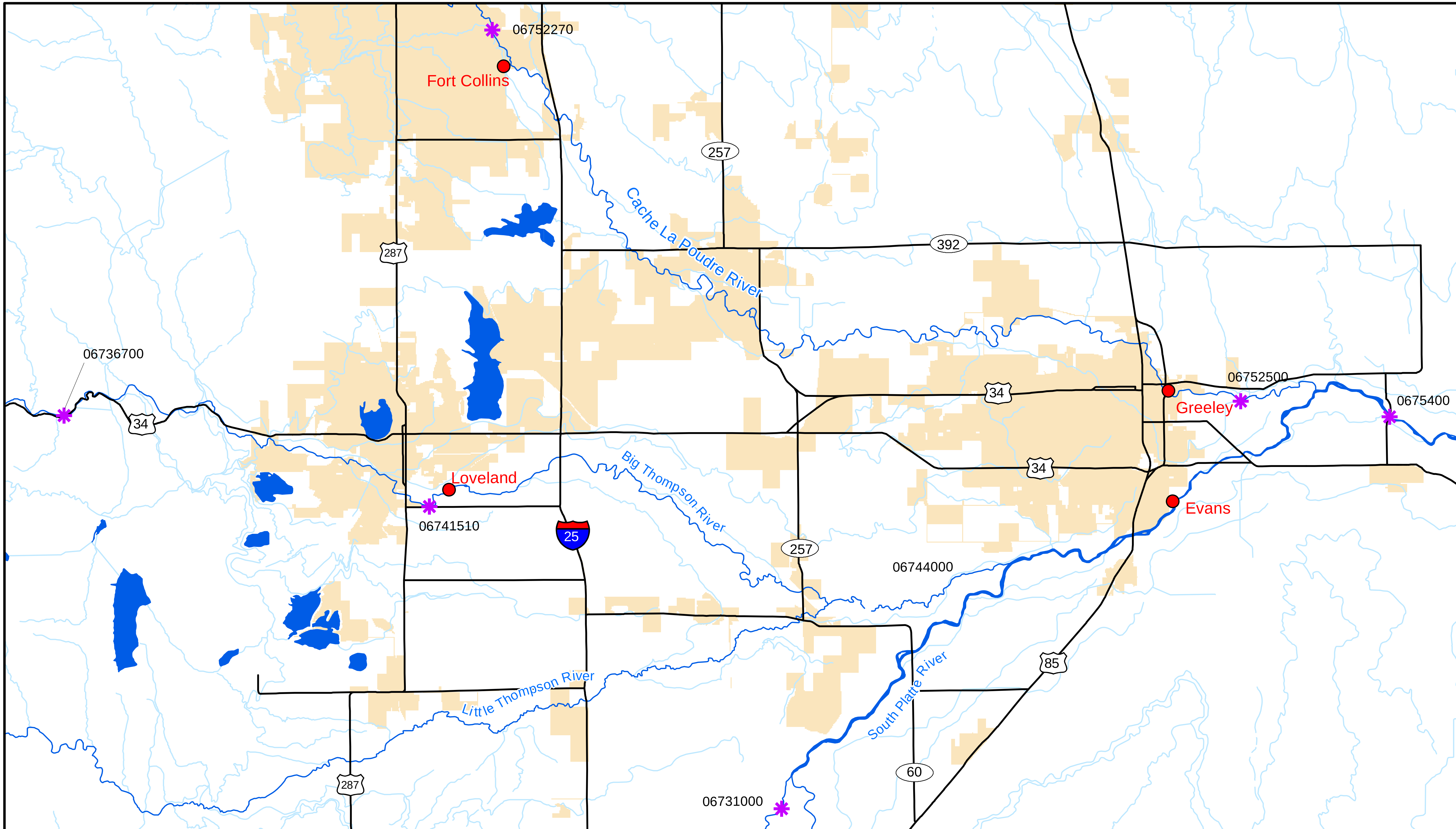
Big Dry Creek, a small perennial stream about 25 miles long with a large watershed, starts in the foothills west of Rocky Flats, flows through Standley Reservoir in Westminster, then flows northeasterly until it joins the South Platte River at Fort Lupton. The Big Thompson River is a large perennial stream about 75 miles long, with headwaters in Rocky Mountain National Park. It flows through Lake Estes in Estes Park, then east to Loveland. The Big Thompson River has its confluence with the South Platte River near La Salle. St. Vrain Creek, a large perennial stream, flows from the mountains in two main branches (North and South St. Vrain creeks) west of Lyons, where it merges into one creek, flows to Longmont, then joins Boulder Creek a few miles east of

Longmont. St. Vrain Creek flows northeasterly and joins the South Platte River south of Milliken. St. Vrain Creek is about 40 miles long between Lyons and its mouth. Coal Creek is a small perennial stream with a large watershed that flows from the continental divide near Wondervu east to Rocky Flats, then through Superior, Louisville, Lafayette and Erie. It joins Boulder Creek north of Erie close to the Weld/Boulder County line.

Figures 13a and 13b show the Participants WWTP locations in relation to the nearest USGS stream gage. These gages are

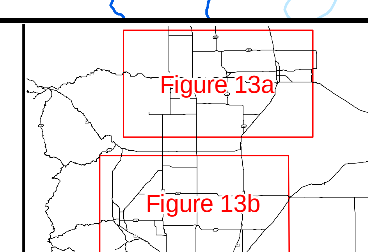
- Big Dry Creek at Westminster (06720820)
- Big Thompson River at Loveland (06741510)
- Cache la Poudre near Greeley (06752500)
- Coal Creek near Louisville (06730400)
- St. Vrain Creek below Longmont (06725450)
- St. Vrain Creek at mouth, near Platteville (06731000)
- South Platte at Fort Lupton (06721000)
- South Platte near Kersey (06754000)

Figure 14 to Figure 21 are hydrographs of the average daily historical flows recorded at these gage sites.



ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

- WWTP Locations
- USGS Gaging Station
- U.S. Highway
- U.S. Interstate
- State Highway

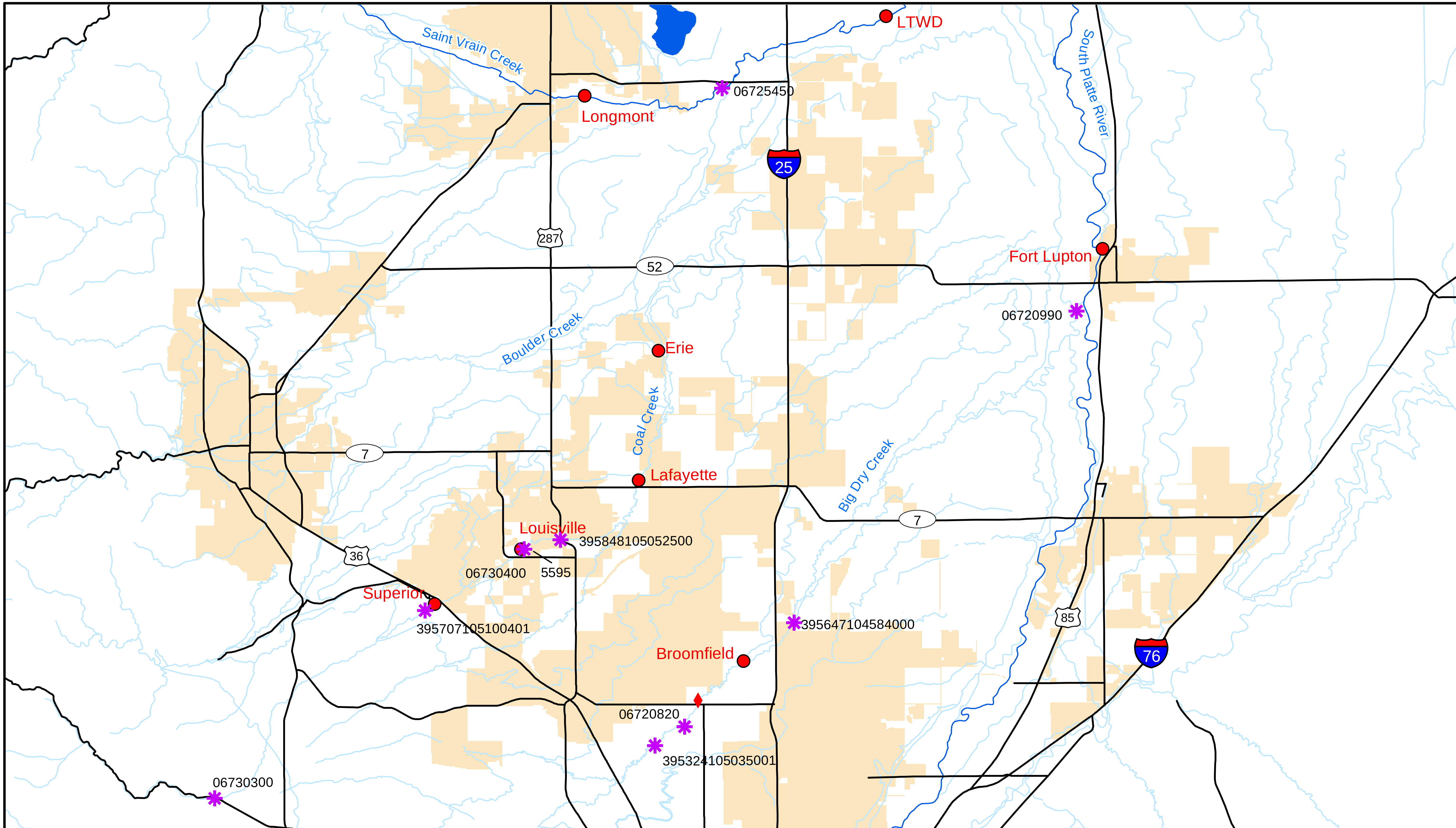


0 1.25 2.5 Miles

N

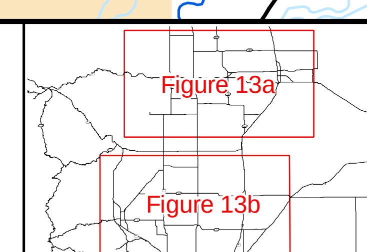
Figure 13a
East Slope Rivers and Creeks Receiving Windy Gap Return Flows

Prepared for: Windy Gap Firming Project
File: W:/2390/Mon_East_Slope_Creek_River13a.mxd
Date: March 2008



ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

WWTP Locations
USGS Gaging Station
U.S. Highway
U.S. Interstate
State Highway



0 1.25 2.5 Miles
N

Figure 13b
East Slope Rivers and Creeks Receiving Windy Gap Return Flows

Prepared for: Windy Gap Firming Project
File: W:/2390/Mon_East_Slope_Creek_River13b.mxd
Date: March 2008

Figure 14. Big Dry Creek at Westminster, USGS (06720820) historical gage flows (1987-2004).

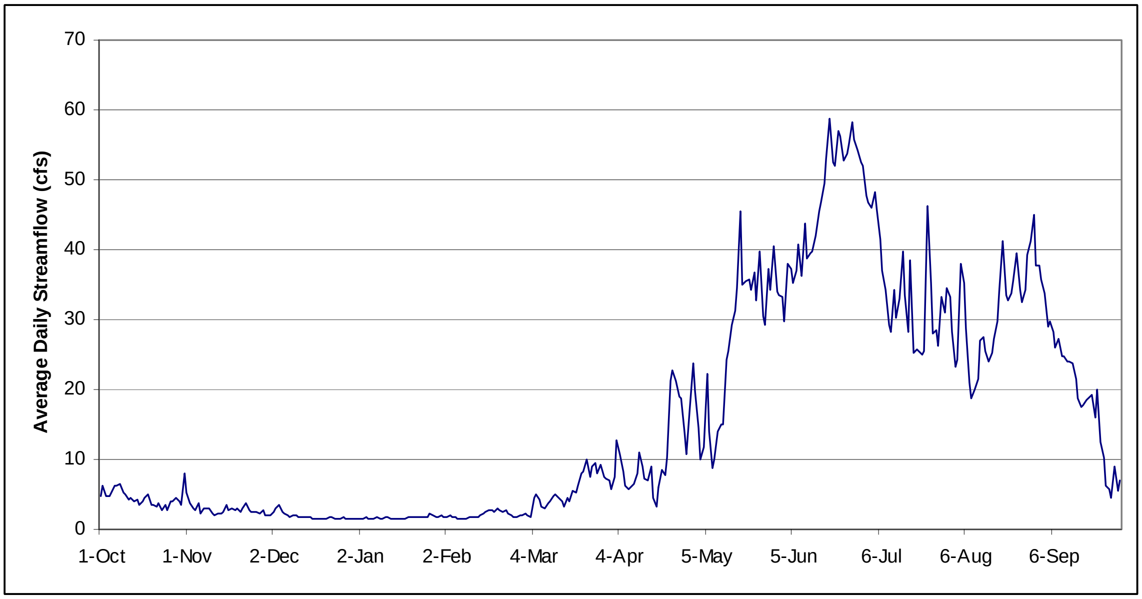


Figure 15. Big Thompson River at Loveland, USGS (06741510) historical gage flows (1979-2004).

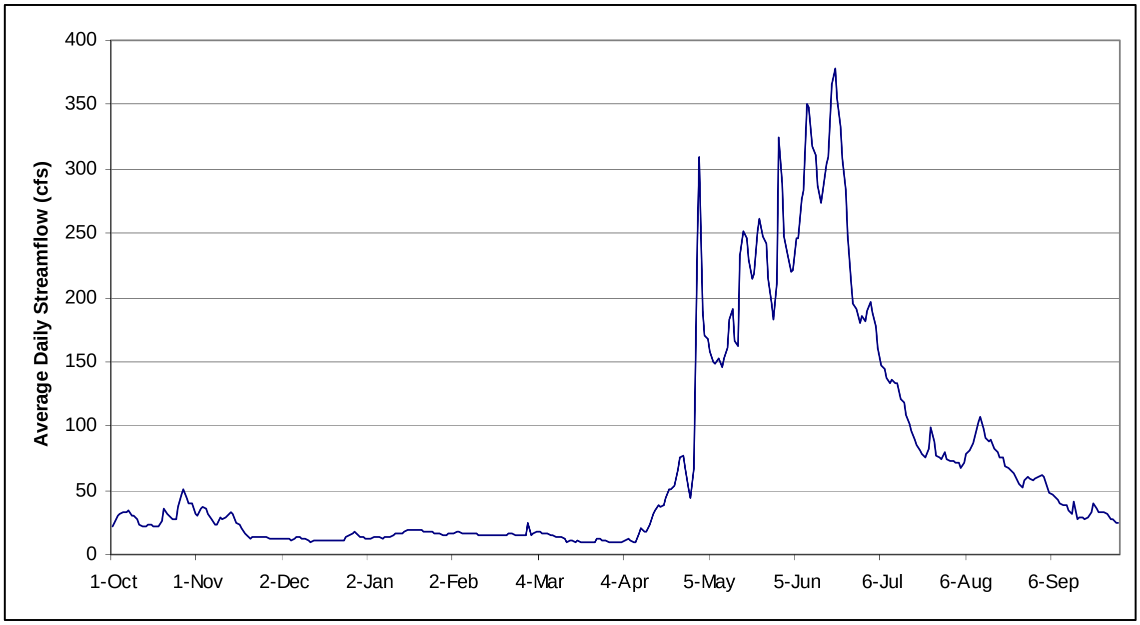


Figure 16. Cache la Poudre near Greeley, USGS (06752500) historical gage flows (1903-1998).

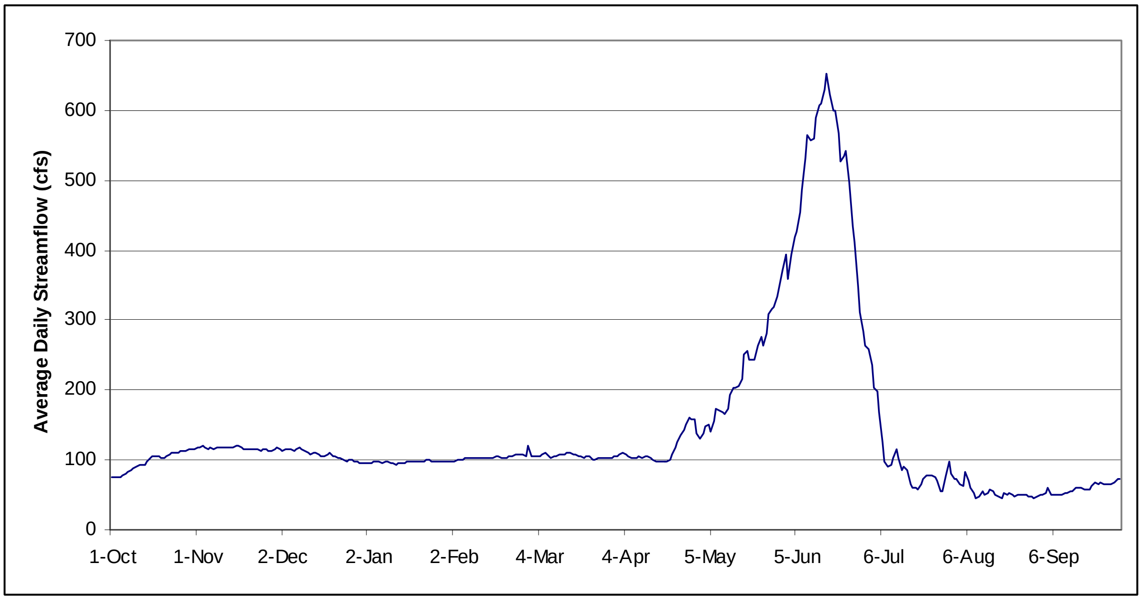


Figure 17. Coal Creek near Louisville, USGS (06730400) historical gage flows (1997-2004).

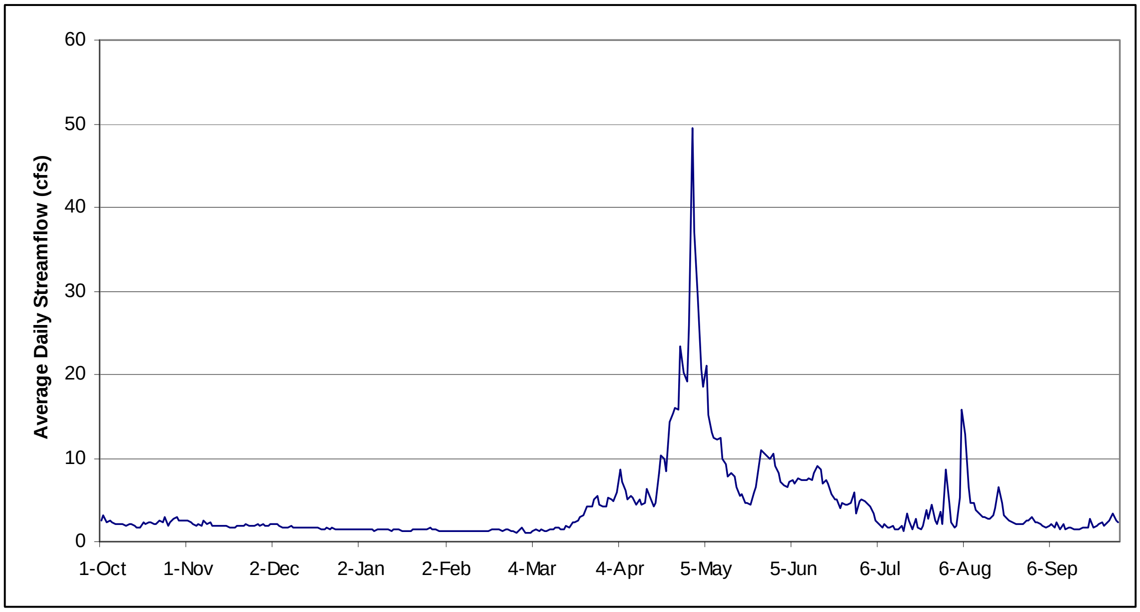


Figure 18. St. Vrain Creek below Longmont, USGS (06725450) historical gage flows (1976-2004).

Figure 19. St. Vrain Creek at mouth, near Platteville, USGS (06731000) historical gage flows (1927-1998).

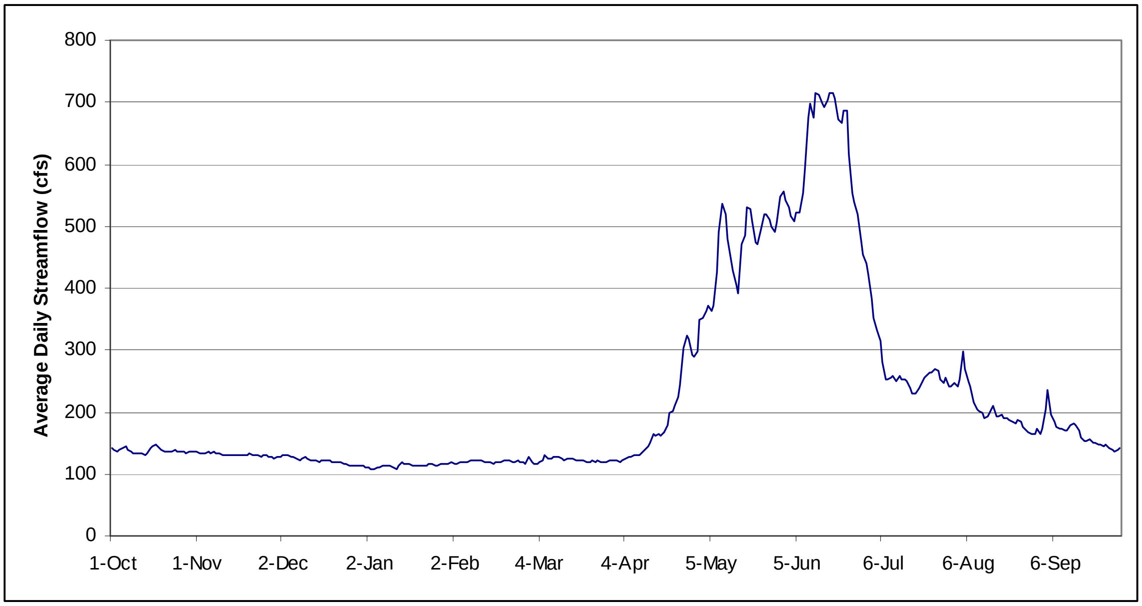


Figure 20. South Platte at Fort Lupton, USGS (06721000) historical gage flows (1909-2004).

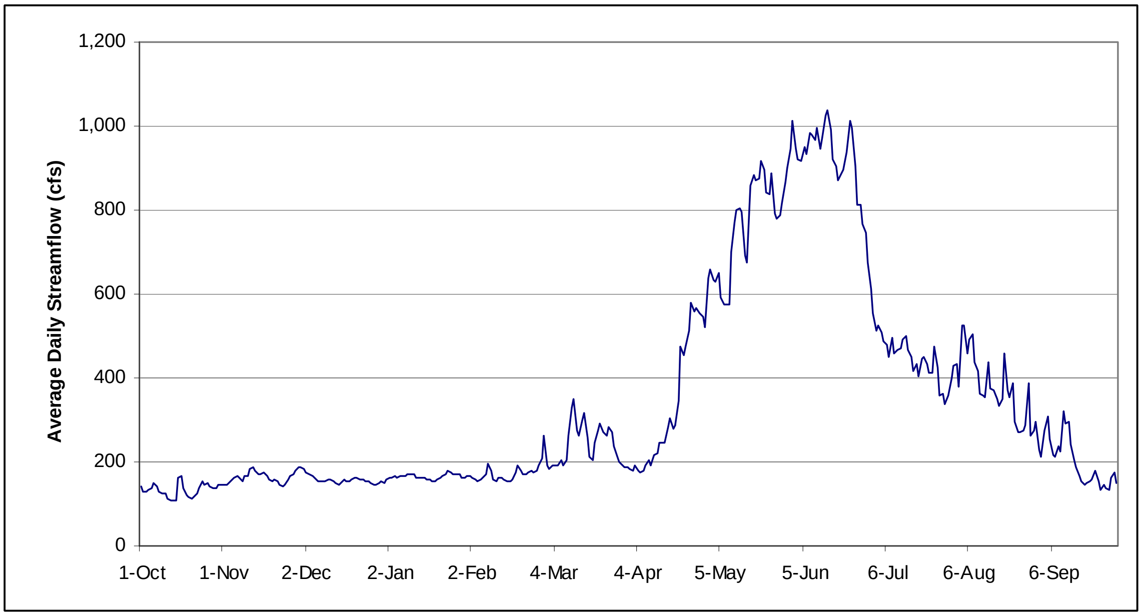
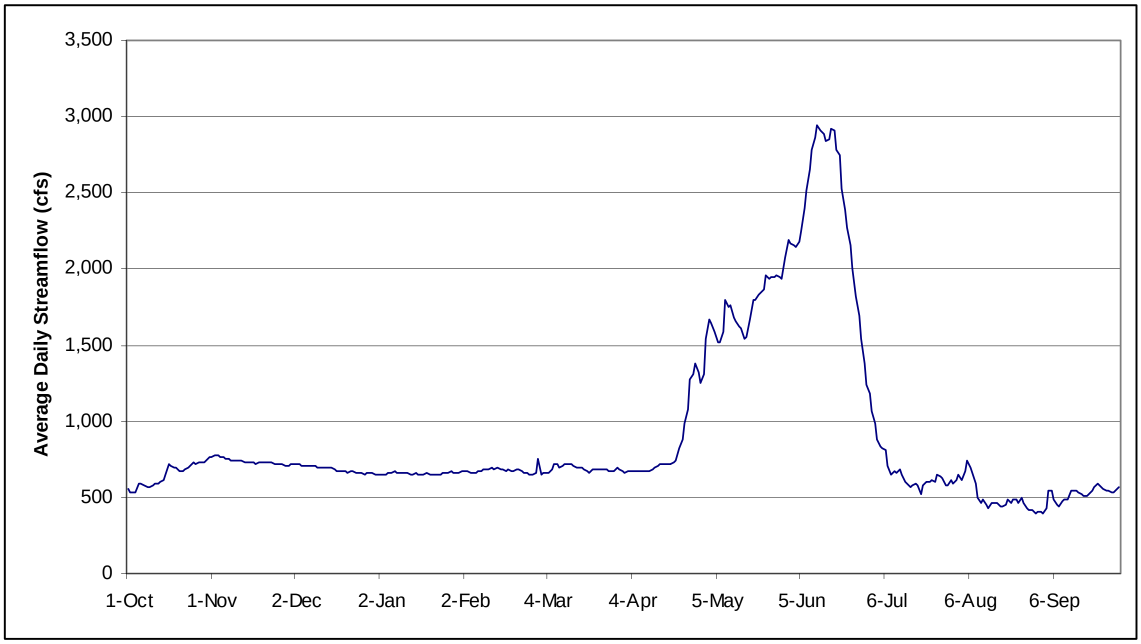


Figure 21. South Platte near Kersey, USGS (06754000) historical gage flows (1901-2004).

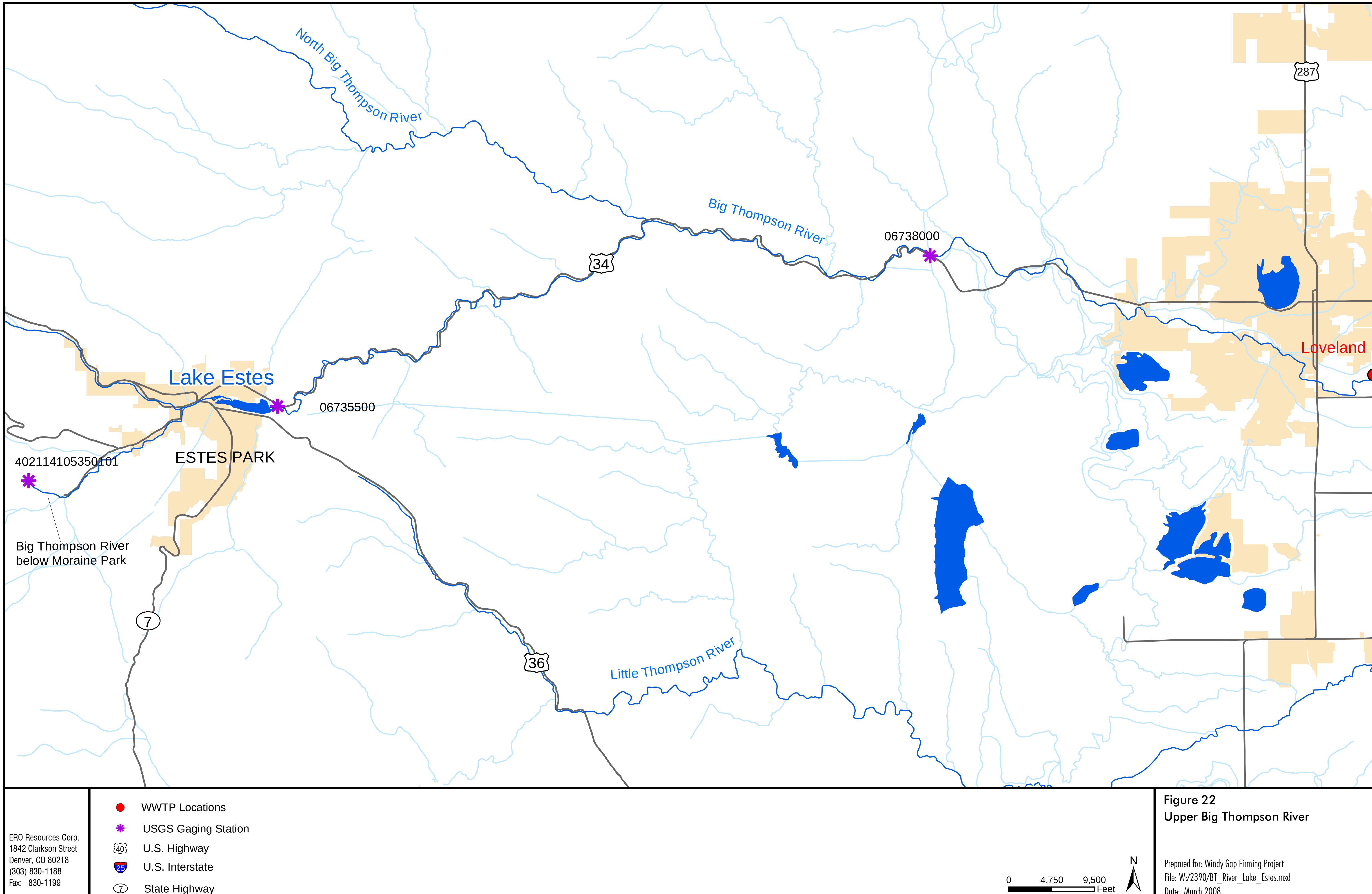


6.5.3.2. Big Thompson River from Lake Estes to Canyon Mouth

The headwaters of the Big Thompson River are at the continental divide in the northeastern part of Rocky Mountain National Park (Figure 1). The watershed ranges in elevation from about 13,150 feet (Taylor Peak) to 5,300 feet at the mouth of Big Thompson Canyon. Lake Estes, constructed in 1947 to 1948 as a component of the C-BT Project, is an in-channel reservoir just east of Estes Park. The Big Thompson River flows about 20 miles through a narrow canyon from below Lake Estes to the hogbacks at the base of the foothills (Figure 22). The C-BT Project diverts Big Thompson River water at Lake Estes via the Olympus Tunnel and at Dille Tunnel near the canyon mouth for power generation and returns the water to the Big Thompson River at the Big Thompson Power Plant. The C-BT Project can also divert Big Thompson River water under their junior direct flow water rights at Olympus and Dille Tunnels for storage in Carter Lake and Horsetooth Reservoir. Average daily Big Thompson River streamflow for the gage at the mouth of the canyon is shown in Figure 23.

6.5.3.3. North St. Vrain Creek and Upper St. Vrain Creek at Lyons

North St. Vrain Creek is used as a water supply by the City of Longmont. Its headwaters are located at the continental divide in the southeastern corner of Rocky Mountain National Park (Figure 1). The watershed ranges in elevation from about 13,300 feet (Mount Alice) to 5,300 feet in Lyons. St. Vrain Creek, a perennial stream with a large watershed, flows from the mountains in two main branches (North and South St. Vrain creeks) and merges into one creek at the base of the foothills in Lyons. The South St. Vrain splits into two main tributaries (Middle and South), both of which have their headwaters at the continental divide in the Indian Peaks Wilderness. Navajo Peak, elevation 13,409 feet, divides the southwest corner of the St. Vrain watershed from the Boulder Creek watershed to the south.

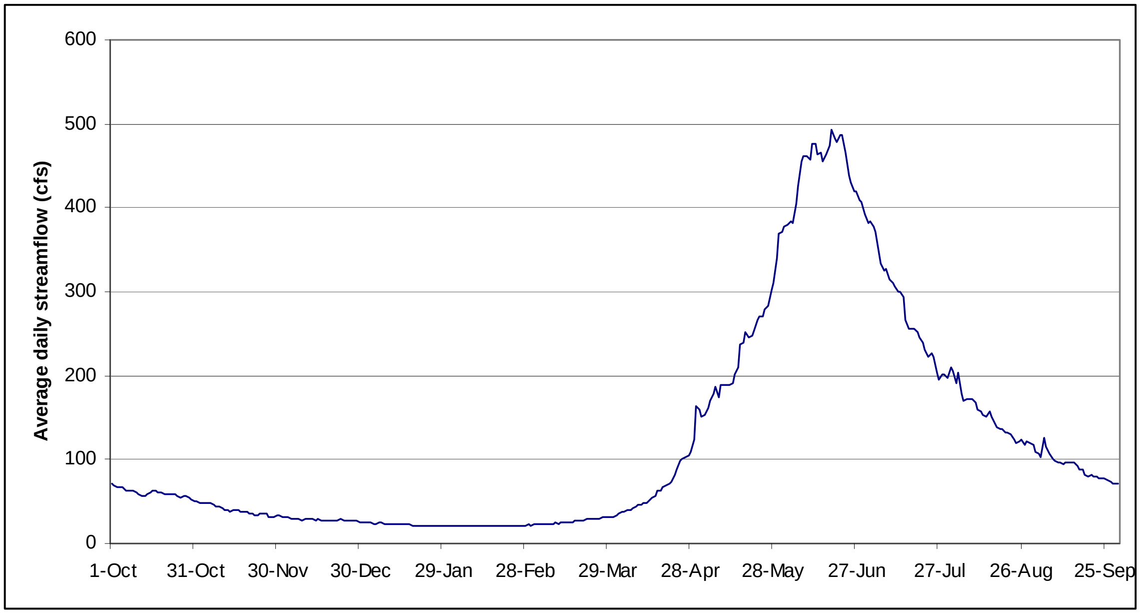


ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Figure 22
Upper Big Thompson River

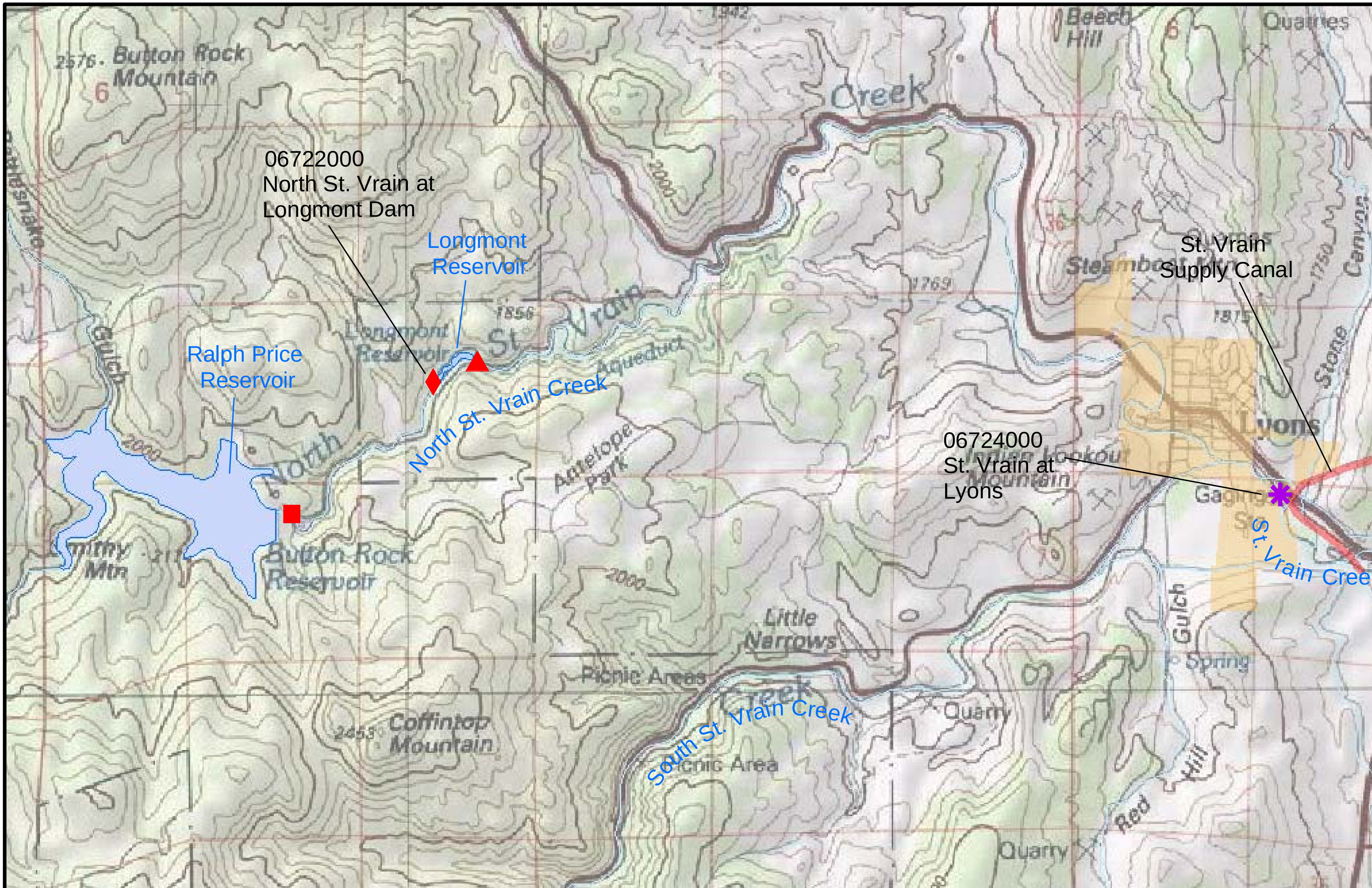
Prepared for: Windy Gap Firming Project
File: W:/2390/BT_River_Lake_Estes.mxd
Date: March 2008

Figure 23. Big Thompson River at Mouth of Canyon, USGS (0673800) historical gage flows (1927-2004).



The flow of the North St. Vrain is influenced by discharges from Ralph Price Reservoir (Button Rock Dam) and by diversions from Longmont Reservoir via the Longmont Pipeline North (about 1 mile downstream of Ralph Price Reservoir) and other diversions in or near the town of Lyons (Figure 24). Diversions from Longmont Reservoir via the Longmont Pipeline North began in 1954 and have ranged from an average of about 6 to 7 cfs during November through March and 10 to 20 cfs during the other months. Below Ralph Price Reservoir, the city voluntarily bypasses the inflow to the reservoir or 8 cfs, whichever is less, throughout the year to maintain instream flows. The City of Longmont began storing water in Ralph Price Reservoir in 1969. The City of Longmont provided records of releases from 1999 through 2005 for Ralph Price Reservoir (Figure 25). Reservoir releases reflect the flow of North St. Vrain Creek below Ralph Price Reservoir. The flow of North St. Vrain Creek below Longmont Reservoir was estimated by subtracting the average monthly diversion at Longmont's pipeline, which was obtained from Division of Water Resource records, from the flow below Ralph Price Reservoir. Other gains or losses may occur in North St. Vrain Creek below Ralph Price Reservoir; these are not represented in Figure 25. The flow of St. Vrain Creek at Lyons is gaged just above the St. Vrain Supply Canal (Figure 26).

Aside from the Ralph Price Reservoir and Longmont Pipeline North water rights, there are five ditch diversion rights with a total right to divert about 20 cfs from the approximately 10-mile reach of North St. Vrain Creek between Ralph Price Reservoir and the confluence with South St. Vrain Creek. There is also a 21 cfs minimum instream flow right for North St. Vrain Creek (CDWR 2006).



▲	City of Longmont Diversion Point
✱	USGS Gaging Stations (Flow and/or Water Quality)
♦	USGS Water Quality Monitoring Site
■	Ralph Price Reservoir Discharge Measurement Point

0 2,000 4,000 Feet

N

ERO
ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

Figure 24
North St. Vrain and St. Vrain Creek below Ralph Price Reservoir

Prepared for: Windy Gap Firming Project
File: P:/2390/ StVrain_No_Action_Impacts.mxd
Date: September 2007

Figure 25. Average monthly flows, North St. Vrain Creek below Ralph Price Reservoir and below Longmont Reservoir (1999-2005).

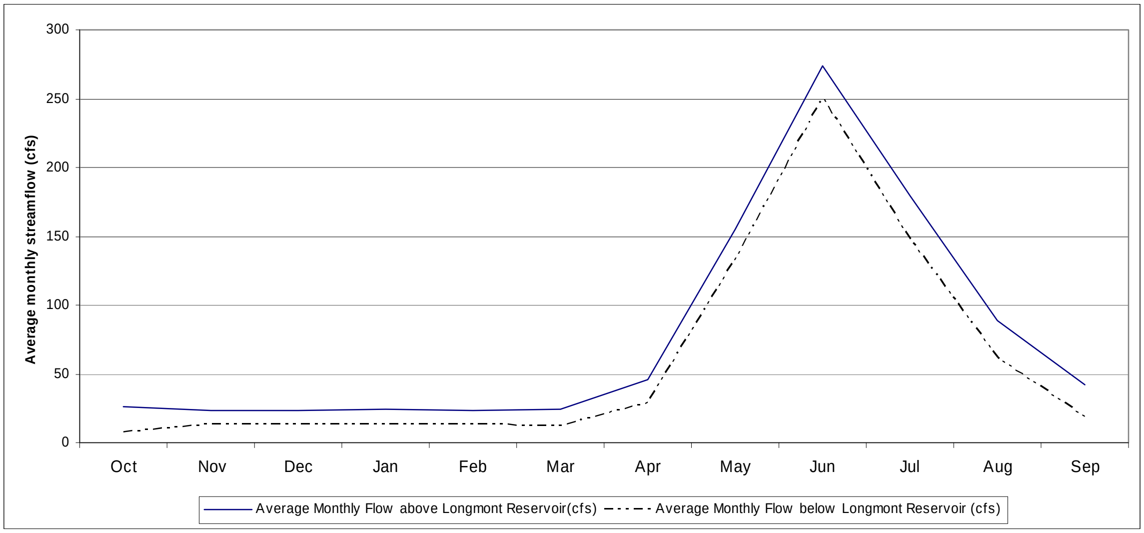
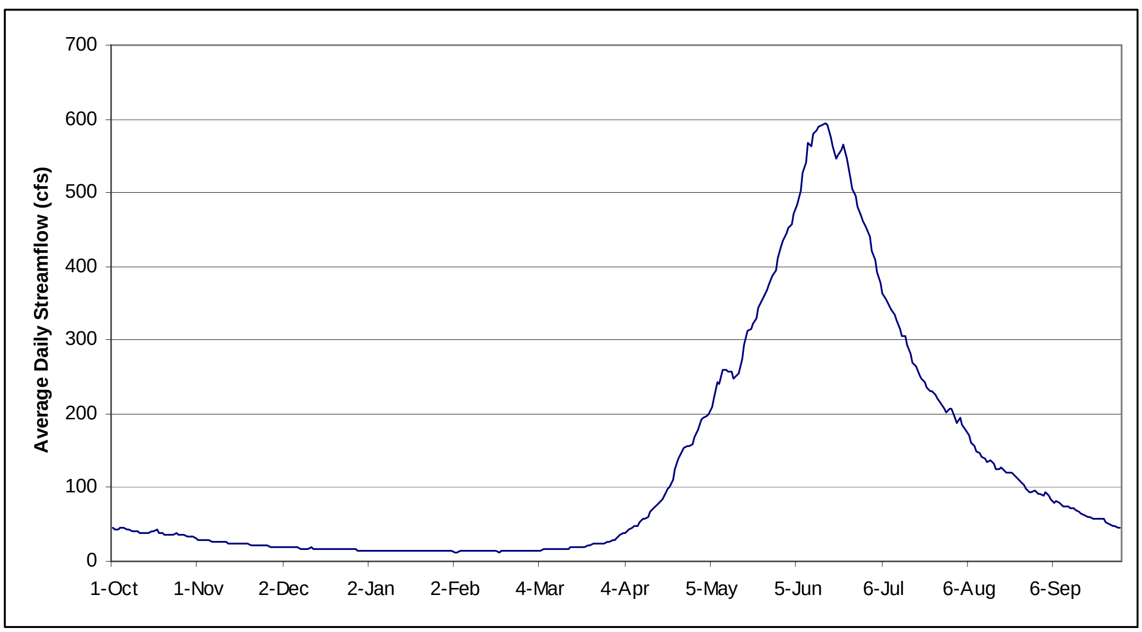


Figure 26. St. Vrain Creek at Lyons, USGS (06724000) historical gage flows (1895-1998).



6.6. East Slope Stream Morphology and Sedimentation

All of the East Slope streams in the study area (Table 1) originate in the Rocky Mountains and are dominated by the seasonal snowmelt cycle. Prior to settlement in Colorado, streams had highly variable flows during each year, with little discharge during dry times, and large floods in late spring and summer. The channels in the foothills were and still are steep and narrow, with bedrock or boulders forming the channel boundaries. Much of the channel sediment is so large that it remains stable in the channel, moving only during very large floods. Smaller sediment introduced into these streams from hill slope erosion and runoff moves rapidly downstream, with little sediment storage along the valley bottoms. As the streams enter the plains, the gradient decreases and the stream channels meander more and are less armored by boulders and cobble. Prior to settlement, plains stream channels were broad and sandy, with low banks, sparse woody vegetation and many smaller braided channels between shifting sand bars. Abundant sediment, derived from weathering and erosion of the Rocky Mountains, wind and local erosion of channels, banks, hill slopes and floodplains, was carried along these channels.

East Slope stream flows, stream morphology, and sediment loads have been thoroughly altered by land-use practices that began with the 1859 gold rush (Wohl et al. 1998). The primary influences are flow regulation and diversions, which have reduced seasonal flood peaks and increased base flows. Irrigation of agricultural fields has raised the regional water table. Reduced peak stream flows have resulted in greater sediment deposition and considerable narrowing of channels. These changes in surface and subsurface flows facilitated the growth of riparian vegetation. Damming of streams has reduced the amount of sediment carried by streams. In the foothills, other changes that have affected channels and sediment transport include a reduction in the beaver population, and placer and lode mining. Other human factors that have affected water and sediment yield to channels include forest fires, timber harvest, grazing, farming, road construction and urbanization (in particular, the increase in non-porous surfaces). Stream channels and banks along the Front Range urban corridor are generally unstable and considered by hydrologists and stream morphologists to be in a state of disequilibrium (Wohl et al. 1998). Channel patterns continue to change, channels and banks are actively eroding and scouring, and channel downcutting and excessive sediment deposition are occurring. River restoration projects completed to improve stream stability and fish habitat on some streams also have altered the dimension, pattern, and profile of streams.

6.7. East Slope Existing Reservoirs

East Slope reservoirs that may be affected by the WGFP include Carter Lake and Horsetooth Reservoir under all alternatives, and Ralph Price Reservoir, which would be enlarged under the No Action alternative. The operation of other smaller C-BT reservoirs used in the regulation of delivery of C-BT and Windy Gap water from the West Slope to the East Slope including Marys Lake, Lake Estes, Pinewood Reservoir, and Flatiron Reservoir would not change under any of the alternatives.

6.7.1. Carter Lake

Carter Lake is owned by Reclamation and operated and maintained by the NCWCD as part of the C-BT Project. Carter Lake is located between hogbacks west of Berthoud

(Figure 1). The reservoir supplies water to various Front Range and Eastern Plains cities and water districts, and the agricultural community in Boulder, Larimer, and Weld counties. Water for the reservoir is supplied from the Upper Colorado River and the Big Thompson River. C-BT and Windy Gap water is delivered to Carter Lake by pumping water up from Flatiron Reservoir through a submerged tunnel that opens into the main reservoir body. Reservoir deliveries to C-BT and Windy Gap unit holders occur via the St. Vrain Supply Canal and the Southern Water Supply Pipeline. Releases from Carter Lake can also be made via the pressure tunnel to Flatiron Reservoir; however, this occurs infrequently. Carter Lake's physical characteristics are described in Table 11.

Table 11. Physical characteristics of Carter Lake.

Volume	112,230 AF
Surface Area	1,110 acres
Mean Depth	101 feet
Maximum Depth	180 feet
Shoreline	12 miles

6.7.2. Horsetooth Reservoir

Horsetooth Reservoir is located in Larimer County and supplies water to the City of Fort Collins and the City of Greeley, as well as several rural domestic suppliers, industries, and the agricultural community in the Poudre River basin (Figure 1). Horsetooth Reservoir is owned by Reclamation and operated and maintained by the NCWCD as part of the C-BT Project. Four dams enclose this narrow reservoir, located between two hogback ridges at the base of the foothills. The main outlet is through Horsetooth Dam to the Poudre River via the Hansen Supply Canal. Water supplied from the West Slope and Big Thompson River is delivered to Horsetooth Reservoir via the Hansen Feeder Canal. Horsetooth Reservoir's physical characteristics are described in Table 12.

Table 12. Physical characteristics of Horsetooth Reservoir.

Volume	156,735 AF
Surface Area	2,143 acres
Mean Depth	73.1 feet
Maximum Depth	188 feet
Shoreline	25 miles

6.7.3. Ralph Price Reservoir

Ralph Price Reservoir (Button Rock Dam) is located within the Button Rock Preserve west of Lyons and is the primary water supply for the City of Longmont (Figure 24). Ralph Price Reservoir stores water from North St. Vrain Creek, which originates in Rocky Mountain National Park. Ralph Price Reservoir's physical characteristics are described in Table 13. The reservoir is operated such that it is full from June until

October. The storage contents then drop to about 75 percent capacity by March. The reservoir is refilled during spring runoff.

Table 13. Physical characteristics of Ralph Price Reservoir.

Volume	16,197 AF
Surface Area	227 acres
Mean Depth	71.3 feet

6.8. East Slope Ground Water Hydrology and Quality

6.8.1. Hydrogeology

6.8.1.1. Chimney Hollow and Dry Creek Study Areas

The study area hydrogeology summary is based on a review of available sources (USGS well records, Colorado Division of Water Resources well records, Tweto 1979, Braddock 1988, Boyle and NCWCD 2005). The Chimney Hollow and Dry Creek study areas are located within the Front Range near the eastern edge of the southern Rocky Mountain physiographic province. In the study areas, the southern Rocky Mountains can be physiographically subdivided into two subsections, the Lower Mountain Subsection and the Hogback Subsection.

The Lower Mountain Subsection is mostly located west of the study areas, but includes the western approximately one third to one half of the Chimney Hollow and Dry Creek study areas. It is characterized by mountain peaks, slopes, and valleys that range in elevation from approximately 5,400 to 9,400 feet above sea level.

Geology underlying the Lower Mountain Subsection is characterized by a complex series of Precambrian-aged metasedimentary and metavolcanic rocks. These rocks were subsequently intruded by younger igneous rocks. In the study area, the surface of the Precambrian rocks generally slopes downward to the east and beneath the Pennsylvanian-age sedimentary bedrock that generally comprises the Hogback Subsection. Sedimentary rocks ranging from lower Permian to upper and middle Pennsylvanian age comprise the Hogback Subsection that lies unconformably over the Precambrian rocks. The Hogback Subsection is characterized by a series of approximately north to south trending ridges and valleys. The ridges consist of tilted resistant bedrock, generally sandstone and limestone. The lower slopes and valleys consist of less resistant bedrock, generally siltstone and shale, with the lower portions of the slopes covered by a mantle of alluvium or colluvium. These sedimentary rocks dip toward the east and generally become younger in age to the east. In the project areas, the sedimentary bedrock consists of the lower Permian and middle Pennsylvanian-age Fountain Formation, as well as younger overlying bedrock formations, such as the lower Permian age Ingleside, Owl Canyon, Lyons Sandstone, and the lower Triassic and Upper Permian age Lykins Formations. The western portion of the Chimney Hollow and Dry Creek study areas are underlain by a series of Precambrian age metamorphic bedrock units. The eastern half of the study areas are underlain by lower Permian and Pennsylvanian age sedimentary rocks, primarily the Fountain Formation, which consists of arkosic conglomerate, feldspathic sandstone, siltstone, shale, and minor amounts of limestone. Within both study areas, a thin layer of Quaternary-aged alluvium and and/or colluvium mantles the Fountain Formation along the banks of Dry Creek and Chimney Hollow.

The occurrence of ground water in the study areas is limited to fractures in the well-cemented sedimentary rocks and Precambrian-age metavolcanics and metasediments. Limited quantities of ground water also may exist in the relatively thin and limited unconsolidated alluvial and colluvial deposits, but it is unlikely that the thin surficial deposits yield sufficient ground water for local use. Although generally of low hydraulic conductivity, the fractured bedrock rock units are commonly used as a source of domestic and stock water throughout the Front Range. Ground water recharge most likely occurs along the fractured bedrock outcrops or subcrops and discharges in areas of lower elevation or becomes part of larger regional flow systems.

6.8.1.2. Carter Lake

Carter Lake is located near the eastern edge of the Southern Rocky Mountain physiographic province. Similar to the Chimney Hollow and Dry Creek study areas, the Carter Lake study area can be subdivided into two subsections, the Lower Mountain Subsection and the Hogback Subsection. Carter Lake is located in an elongated north-south trending drainage in the Hogback Subsection, approximately 1 mile east of its boundary with the Lower Mountain Subsection, where Precambrian-aged metasedimentary and metavolcanic rocks are exposed and form a steep east-facing slope. Carter Lake overlies Jurassic age sedimentary rocks that have been tilted to the east from mountain building forces to the west. The tilting resulted in the formation of the north-south trending Carter Lake Anticline, located approximately 1 mile east of Carter Lake. Colluvial materials cover sedimentary rocks north and south of Carter Lake, and the Pennsylvanian-aged Fountain Formation within the Chimney Hollow Drainage.

In the Carter Lake area, useable quantities of ground water occur primarily in fractures of the Fountain Formation, other sedimentary formations, and fractured Precambrian-aged crystalline metamorphic rocks.

6.8.1.3. Horsetooth Reservoir

Horsetooth Reservoir is located within the Hogback Subsection of the Southern Rocky Mountain physiographic province. The reservoir is situated on easterly dipping sedimentary rocks comprising Cretaceous to Jurassic-aged rocks (Dakota, Morrison, and Sundance Formations) and various formations comprising the Colorado Group to the east, and Triassic through Permian-aged sedimentary rocks (Jelm, Lykins, Lyons, and Satanka Formations) to the west.

In the Horsetooth Reservoir area, useable quantities of ground water occur primarily in fractures of sedimentary units such as the Fountain and Dakota formations, and fractured Precambrian-aged crystalline metamorphic rocks west of the reservoir.

6.8.1.4. Ralph Price Reservoir

Ralph Price Reservoir is located in the Front Range foothills within the Lower Mountain Subsection of the Southern Rocky Mountain physiographic province. The geology of the area is composed of Precambrian-aged granitic rocks.

In the Ralph Price area, useable quantities of ground water occur in fractured Precambrian-aged crystalline metamorphic rocks.

6.8.2. Ground Water Use

6.8.2.1. Chimney Hollow and Dry Creek Study Areas

Well records for 10 wells within the Chimney Hollow Study Area and 24 wells within the Dry Creek study area (CDWR 2006) were reviewed. Ground water from all of the wells is used for domestic and/or livestock purposes. Nearly all of the wells within the Dry Creek study area are located above the footprint of the proposed reservoir along the hogback ridge east of the reservoir site. All of the wells were installed in sedimentary (typically the Fountain Formation) or crystalline rocks, and all are 200 to 800 feet deep except for one 77 foot deep well located at the north end of the Chimney Hollow study area.

6.8.2.2. Carter Lake

Ground water wells located near Carter Lake produce ground water from fractured sedimentary and crystalline rocks for individual homes and small commercial facilities. There are no wells located within 100 feet of Carter Lake.

6.8.2.3. Horsetooth Reservoir

Wells in this area produce limited quantities of ground water from fractured sedimentary formations. There is only one well located within 100 feet of the southeast end of Horsetooth Reservoir; it is screened at 160 to 260 feet below ground surface.

6.8.2.4. Ralph Price Reservoir

Ground water use for domestic purposes in this area is limited due to generally low water production from fractured crystalline rocks. There are no wells located near the reservoir.

6.8.3. Ground Water Quality

6.8.3.1. Chimney Hollow and Dry Creek Study Area

There is no available water quality data from ground water in this area. If water is being used for domestic purposes, it is assumed to be of potable quality.

6.8.3.2. Existing Reservoirs

Because ground water quality in the vicinity of Carter Lake, Horsetooth Reservoir and Ralph Price Reservoir is not expected to be affected by the WGFP, existing ground water quality at these locations has not been evaluated.

7.0 ENVIRONMENTAL EFFECTS

This section of the report describes the changes in hydrology and related effects for each of the alternatives. Sections 7.1 to 7.3 provide background information and summary information on surface water hydrology, ground water hydrology, and stream morphology and sedimentation. Sections 7.4 to 7.8 describe the specific effects for each alternative. Section 7.9 discusses the water yield for all of the alternatives. Cumulative effects are discussed in Section 8.0.

7.1. Surface Water Hydrology

A total of five alternatives, including four action alternatives and a No Action alternative, plus an Existing Conditions scenario were evaluated. The hydrology model output for direct effects is provided in tabular and graphic form in Appendix B (flow duration curves), Appendix D (streamflow, Windy Gap diversions and Lake Granby spills), Appendix E (stream stage), and Appendix F (lake and reservoir content, elevation and surface area).

The action alternatives include Chimney Hollow Reservoir with prepositioning (the Proposed Action), Chimney Hollow Reservoir with Jasper East Reservoir, Chimney Hollow Reservoir with Rockwell/Mueller Creek Reservoir, and Dry Creek Reservoir with Rockwell/Mueller Creek Reservoir. The baseline BESTSM and CDSS Model were executed for each of the action alternatives, Existing Conditions, and No Action. To assess whether an action alternative affects surface and ground water hydrology, each alternative was compared against Existing Conditions and the No Action alternative. The Existing Conditions scenario reflects current conditions, including demands, facilities, agreements, operations, and administration of the Colorado River. The purpose of the Existing Conditions scenario is to model current conditions as if they occurred under the same hydrologic conditions or baseflows that existed throughout the study period (1950 through 1996). For example, under the Existing Conditions scenario, the Windy Gap project is set to operate for the entire study period with the Windy Gap unit holder's current 2006 demand of approximately 21,045 AF. In addition, all reservoirs are set to operate for the entire study period, regardless of when they came on-line.

The No Action alternative is similar to Existing Conditions; however, all Participants would maximize delivery of Windy Gap water according to their demand, water rights, available storage in Lake Granby, available space in participant-owned terminal reservoirs, and existing Adams Tunnel conveyance constraints. The total annual Windy Gap demand including MPWCD, is approximately 40,765 AF. No Action reflects the estimated future full demand by all Windy Gap unit holders, including those entities not in the WGFP. The City of Longmont is the only Participant that currently has an option to develop storage independently if the WGFP is not implemented. The City of Longmont indicated that it would evaluate the enlargement of the existing Ralph Price Reservoir on North St. Vrain Creek by 13,000 AF.

Hydrologic model output associated with the action alternatives is compared against similar output generated for Existing Conditions and the No Action alternative. Hydrologic model output associated with the action alternatives is not compared with historical hydrology because of the following factors that make it difficult to isolate changes specifically attributable to each action alternative.

Demands have changed considerably over the course of the study period. For example, flows at Windy Gap are influenced to a large degree by inflow to the Colorado River from the Fraser River. DW's diversions from the Fraser River are a function of its demand and integrated system operations. Because DW's demands have increased substantially over the study period (1950 through 1996), its current diversions under similar hydrologic conditions may be considerably different than they were historically during the study period. In addition, Grand County's demands in the Fraser River basin have also increased over the study period. Therefore, differences in simulated and historical flows below the confluence with the Fraser River may be due in large part to changes in Grand County's and DW's estimated diversions from the Fraser River under their current demands.

Certain facilities and reservoirs were not in operation for the entire study period. For example, Willow Creek Reservoir and the WCFC did not come on-line until 1953. Therefore, historical flows in Willow Creek from 1950 through 1952 do not include the effects of Willow Creek Reservoir operations and WCFC diversions. However, for the EIS alternative model simulations, Willow Creek Reservoir and WCFC were made active for the entire study period. Differences in simulated and historical flows in Willow Creek prior to 1953 are due primarily to simulated Willow Creek Reservoir and WCFC diversions in those years, as opposed to WGFP diversions and operations. In addition, Wolford Mountain Reservoir did not come on-line until 1995.

River administration and project operations have changed over the study period. There have been numerous and significant changes in the operations of various projects and the administration of the Colorado River during the study period. For example, reservoir accounts and operations at Ruedi Reservoir, Williams Fork Reservoir and Wolford Mountain Reservoir have changed in response to meeting U.S. Fish and Wildlife Service (USFWS) flow recommendations in the 15-mile Reach. The Orchard Mesa Check settlement resulted in changes to the USA Grand Valley Power Plant summer call and provisions for delivering surplus Historic Users Pool water in Green Mountain Reservoir to the 15-Mile Reach. Pre-1984 versus post-1984 operating rules for Green Mountain Reservoir are different. The operations described above affect simulated streamflows and reservoir contents. However, historical flows may not reflect those operations, depending on when changes occurred.

7.1.1. Facilities and Stream Segments Affected by Windy Gap Operations

Windy Gap Project water is diverted from the Colorado River just downstream of the confluence of the Colorado and Fraser Rivers at Windy Gap Reservoir. Once diverted, it is pumped to Lake Granby for storage. Upon introduction into the C-BT system, Windy Gap diversions are subject to a 10 percent "diversion shrink" per the existing Carriage Contract between the Municipal Subdistrict and Reclamation, with the shrink amount credited to the C-BT project. Similarly, each year at the end of March, a 10 percent carryover shrink is assessed on any Windy Gap water remaining in Lake Granby, with the shrink amount being stored in the Lake Granby C-BT account[1]. C-BT may receive

---

[1] The 10 percent shrink is charged against Windy Gap diversions as follows. If the WGFP diverts 100 AF, 10 AF (10 percent diversion shrink) is allocated to the C-BT account in Lake Granby and the remaining 90 AF is allocated among the Windy Gap owners based on ownership in the WGFP. The diversion shrink paid to the C-BT Project is not accounted for separately in the C-BT account in Lake Granby. In other words, it is commingled with water stored in Lake Granby under C-BT's decreed diversion/storage rights. This is consistent with the manner in which Windy Gap diversion shrink is currently accounted for in Lake Granby. It is not necessary to account for C-BT decreed diversions/storage separately from the additional yield from shrink.

(footnote continued on next page)

additional shrink credit under the alternatives, as well as reintroduction shrink with East Slope storage alternatives; however, it may receive less carryover shrink with less storage of Windy Gap water in Lake Granby.

Windy Gap water in Lake Granby is delivered via “instantaneous delivery,” which involves an exchange for C-BT water. As specified in the Carriage Contract, instantaneous delivery involves a C-BT release from Carter Lake or Horsetooth Reservoir in exchange for Windy Gap water stored in Lake Granby. Lake Granby is currently the only long-term storage facility for Windy Gap water prior to delivery to Participants. However, under the action alternatives, Windy Gap water also would be delivered to a firming project reservoir outside the C-BT system for storage.

Windy Gap diversions and operations affect the C-BT Project because C-BT facilities are used for the storage and conveyance of Windy Gap water. For example, both C-BT and Windy Gap water are stored in Lake Granby (Figure 27). Windy Gap diversions and operations also affect flows in the Colorado River below Lake Granby, Willow Creek, St. Vrain Creek, Big Thompson River, and several East Slope rivers that receive Participants’ WWTP return flows. The effect on flows in these river segments and other locations from the WGFP is generally described below and in more detail for each of the alternatives in Sections 7.4 to 7.8.

Tables provided in Appendix D list the average monthly and annual changes in streamflow that would occur at various locations in the Colorado River from below Lake Granby to the top of Gore Canyon. Information is provided for Existing Conditions and each of the alternatives for average, dry, and wet years. Table 14 provides the range of modeled daily flow changes for the entire period of record that would occur at the three long-term USGS flow gages (near Granby, at Hot Sulphur Springs, and near Kremmling) in May through August, the months during which most Windy Gap diversions would occur. Table 14 also provides the percentage of days in May through August that various ranges of flow changes would occur. There would be some days under all of the alternatives at all three locations when flows would increase, which is due to changes in timing of spills from Lake Granby. While monthly or average daily data indicates Windy Gap diversions occurring during most days of the runoff season, a review of the daily data for the 46-year study period indicates that in a large percentage of the May to August period, there would be no change in flows from Existing Conditions for all the alternatives. A comparison of the changes in flow among alternatives indicate there would be no change in daily flows at the gage near Granby between 76 and 89 percent of the time during May through August, and between 67.5 and 71 percent of the time at Hot Sulphur Springs and at the gage near Kremmling. Flow decreases greater than 600 cfs, which is the maximum pumping capacity of the Windy Gap diversion, would be the result of changes in the timing of spills from Lake Granby and decreases in the volume of Lake Granby spills.

Total Windy Gap diversions are compared to their decreed limits. The model allows Windy Gap to divert up to 600 cfs if in priority. The limits imposed by the Azure Settlement Agreement are on the amount of Windy Gap water measured and delivered through the Adams Tunnel after diversion shrink is assessed.

Table 14. Range and percent occurrence of daily flow changes under the alternatives (compared to Existing Conditions), May through August.

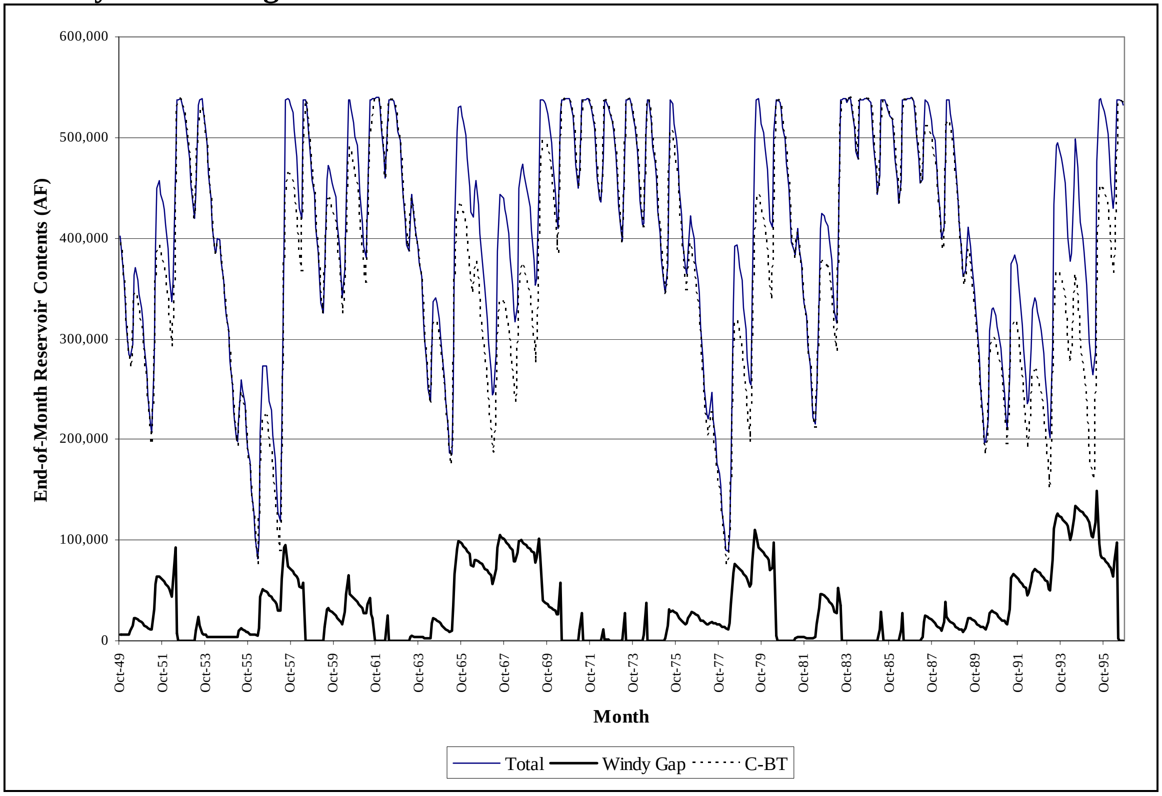
Colorado River near Granby

	Percentage of Days in May through August That Flow Changes Occur				
Daily Flow Changes (cfs)	**No Action**	**Proposed Action**	**Alternative 3**	**Alternative 4**	**Alternative 5**
+1 to + 157	-	9.7%	-	-	-
+1 to + 43	-	-	3.3%	3.3%	-
+1 to + 41	-	-	-	-	2.8%
+1 to + 15	1.7%	-	-	-	-
0 cfs	89.4%	76.1%	84.6%	84.6%	84.2%
-1 to -10	2.4%	2.1%	1.8%	1.8%	1.5%
-11 to -100	2.7%	3.85%	3.65%	3.7%	4.7%
-101 to -200	1.6%	3.15%	2.6%	2.65%	2.7%
-201 to -300	0.7%	1.55%	1.2%	1.15%	1.2%
-301 to -500	0.3%	1.35%	1.1%	1.1%	1.2%
-501 to -1,000	0.7%	1.2%	1.05%	1.05%	0.9%
-1,001 to -1,945	0.4%	-	-	-	-
-1,001 to -2,209			0.6%	0.6%	0.6%
-1,001 to -2,398	-	0.9%	-	-	-

Colorado River at Hot Sulphur Springs and Kremmling

	Percentage of Days in May through August That Flow Changes Occur				
Daily Flow Changes (cfs)	**No Action**	**Proposed Action**	**Alternative 3**	**Alternative 4**	**Alternative 5**
+1 to + 24	1.8%	-	0.55%	0.57%	0.54%
+1 to + 10	-	1.3%	-	-	-
0 cfs	71.4%	67.5%	68%	67.95%	68.5%
-1 to -10	1.1%	2%	2%	2.1%	0.7%
-11 to -100	10.85%	10.85%	8.25%	8.25%	9.4%
-101 to -200	6.8%	5.2%	7.2%	7.2%	6.7%
-201 to -300	2.2%	3.5%	4.5%	4.45%	3.8%
-301 to -500	3%	4.2%	4.9%	4.85%	5.25%
-501 to -1,000	1.7%	4%	3.4%	3.4%	3.8%
-1,001 to -1,738	0.6%	-	-	-	-
-1,001 to -1,844	-	-	-	1.2%	-
-1,001 to -1,847	-	-	1.2%	-	-
-1,001 to -1,987	-	-	-	-	1.2%
-1,001 to -2,682	-	1.4%	-	-	-

Figure 27. End-of-month storage volume of C-BT and Windy Gap water in Lake Granby for Existing Conditions.



7.1.1.1. Colorado River below Lake Granby

Flows in the Colorado River below Lake Granby are a function of bypass flow requirements and Lake Granby spills. In years that Lake Granby is not spilling, flows in the Colorado River below Lake Granby reflect the bypass flow requirements, which are generally 20 cfs from September through April, 75 cfs from May through July, and 40 cfs in August. When Lake Granby is spilling, the flow below Lake Granby equals the amount that is spilled. There would be differences in Lake Granby spills among the alternatives, which would cause variations in flows below Lake Granby (Table D-1). Storage of Windy Gap water in Lake Granby would vary for each alternative, resulting in differences in spills of Windy Gap water from Lake Granby. For example, under the Existing Conditions scenario, Windy Gap water could only be stored in Lake Granby; therefore, Windy Gap contents in Lake Granby would generally be higher than under the alternatives. In a wet year, total contents in Lake Granby would typically be higher entering the runoff season under the Existing Conditions scenario because Windy Gap contents would be higher. As a result, when Lake Granby fills, the amount of Windy Gap water spilled from Lake Granby would be higher on average than under the alternatives. In addition, Lake Granby C-BT spills would differ to a lesser degree among alternatives because of variations in Windy Gap operations, including the amount of Windy Gap shrink paid to the C-BT project due to Windy Gap diversions and carryover storage, instantaneous deliveries and prepositioning. For example, variations in the amount of shrink paid to the C-BT project would result in variations in C-BT contents in Lake Granby and consequently the timing and amount of C-BT spills.

The modeled spills from Lake Granby are higher than historical spills for several reasons:

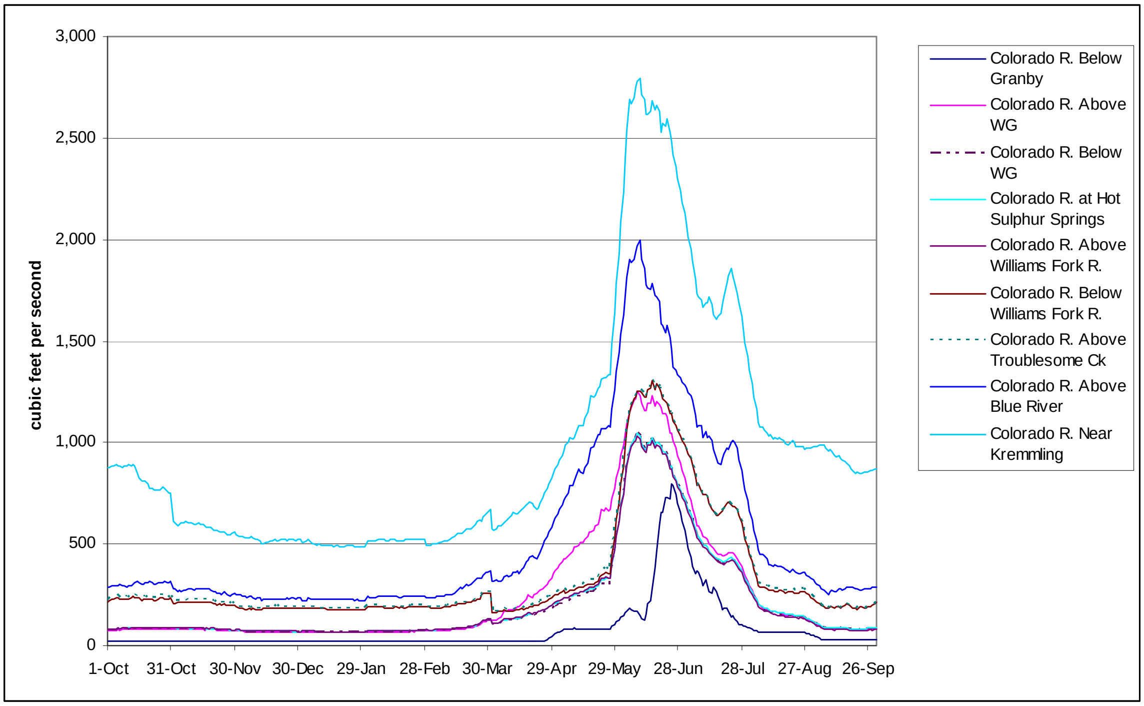
- Historically, the NCWCD made preemptive releases early in the year to avoid large spills later during spring/summer runoff. Preemptive releases have historically been made in March, April, and May in some years, in anticipation that Lake Granby would spill. These releases have typically been made when Lake Granby contents are relatively high going into the runoff season and Lake Granby is projected to spill based on forecasted inflows. Preemptive spills were not included in the model because they are discretionary and not made in every year that Lake Granby is forecasted to spill. Also, there is considerable variability in the timing and amount of these releases. The lack of a forecasting function in the model resulted in larger Windy Gap spills (see also discussion of *Lake Granby Spills* in Section 7.4.1.1);
- The Windy Gap Project was not completed until 1985 and demand for Windy Gap has increased over time and will increase in the future, thus demands are higher in the model than they were historically; therefore, Windy Gap contents in Lake Granby were often higher going into spill years in the model; and
- There is more C-BT water pumped from the Big Thompson River to storage in Carter in Horsetooth Reservoirs under Existing Conditions as a result of recent changes in Reclamation operating rules based on forecasting of anticipated Big Thompson River spring flows than has happened historically, resulting in higher C-BT spills under Existing Conditions.

Colorado River flows below Windy Gap Reservoir would also be affected by differences in Windy Gap diversions among the alternatives. With firming storage, Windy Gap diversions would primarily be higher in wet years because there would typically be capacity available for storing Windy Gap water. However, under Existing Conditions, there is no conveyance or storage capacity in the C-BT system for Windy Gap water when Lake Granby fills. Therefore, under Existing Conditions and the No Action alternative, Windy Gap diversions would be limited or curtailed in most wet years.

Because the flow of the Colorado River would be reduced in average and wet years below Lake Granby due to a decrease in spills and below the Windy Gap diversion due to increased diversions under all alternatives (Table D-12 and Table D-14), the potential for flooding would decrease. The greatest decrease in flooding potential would occur under the Proposed Action and the smallest decrease would occur under No Action.

The hydrologic model output shows that the Colorado River, within the study area, is largely a gaining stream with increasing flows downstream, even with numerous diversions for various uses (Figure 28). The largest sources are tributaries, but there are also diffuse sources, which include ground water and irrigation return flows. Small losses in stream flow (10 percent or less) were shown in the model to occur between Hot Sulphur Springs and the Williams Fork River and between the Williams Fork River and Troublesome Creek. These losses are due to the placement of estimated gains/losses in relation to modeled diversions.

Figure 28. Modeled average daily Colorado River flows for the study area for Existing Conditions.



7.1.1.2. Willow Creek

Differences in Willow Creek flows among the alternatives would be due to differences in WCFC diversions. The C-BT Project diverts water from Willow Creek for delivery to Lake Granby via the WCFC. Although WCFC diversions are a C-BT Project operation, they can be affected by Windy Gap diversions and operations. When space in Lake Granby is not a limiting factor on the amount that can be diverted from Willow Creek, there would be no difference in WCFC diversions and, consequently, no differences in Willow Creek flows among the alternatives. However, when Lake Granby fills, differences in WCFC diversions can occur. C-BT operations take precedence over Windy Gap Project operations; therefore, the first water spilled from Lake Granby is Windy Gap. Instead of pumping water from Willow Creek to force Windy Gap water to spill, Windy Gap water in Lake Granby is exchanged with C-BT water in Willow Creek Reservoir. This results in a spill of what is then considered Windy Gap water from Willow Creek Reservoir. The amount of Windy Gap water exchanged to Willow Creek Reservoir is the lesser of the amount of Windy Gap water in Lake Granby or the amount that can be physically and legally pumped from Willow Creek. The degree to which WCFC diversions would be different among the alternatives is a function of Windy Gap storage in Lake Granby and the amount of Windy Gap water exchanged to C-BT in place of WCFC diversions.

There could also be differences in WCFC diversions among the alternatives due to differences in Lake Granby C-BT contents. There would be differences in C-BT contents in Lake Granby among the alternatives due primarily to differences in Windy Gap diversions and the shrink paid to the C-BT project, prepositioning, and instantaneous deliveries. C-BT water diverted from the Colorado River for storage in Lake Granby takes priority over pumping from Willow Creek. As such, WCFC diversions depend on both C-BT and Windy Gap contents in Granby.

7.1.1.3. St. Vrain Creek

Changes in St. Vrain Creek flows due to Windy Gap operations would occur only under the No Action alternative. Under this alternative, Longmont indicates that it would evaluate the enlargement of the existing Ralph Price Reservoir located on North St. Vrain Creek. Longmont's Windy Gap water would be released to St. Vrain Creek via the St. Vrain Supply Canal and exchanged upstream to the enlarged Ralph Price Reservoir. This operation would affect flows in the North Fork St. Vrain Creek and St. Vrain Creek in the reach from Ralph Price Reservoir downstream to the intersection with the St. Vrain Supply Canal. Deliveries to Longmont would be conveyed using existing infrastructure.

7.1.1.4. Big Thompson River

The C-BT Project diverts water under junior direct flow water rights from the Big Thompson River at the Olympus and Dille Tunnels for storage in Carter Lake and Horsetooth Reservoir. The C-BT Project also diverts water from the Big Thompson River for power generation. These power diversions are typically referred to as "skim diversions" because the water is returned to the Big Thompson River at the Big Thompson Power Plant. Windy Gap operations such as prepositioning and instantaneous deliveries to meet Windy Gap demands affect the available capacity in Olympus Tunnel, Carter Lake and Horsetooth Reservoir, which in turn affects C-BT diversions from the Big Thompson River. Small changes in the flow of the Big Thompson River below Lake Estes (below the Olympus and Dille Tunnels) would occur under all of the alternatives from the import of additional Windy Gap water, resulting in differences in C-BT diversions from the Big Thompson River for storage and power generation.

7.1.1.5. Other East Slope Rivers

With a Windy Gap Firming Project on-line, use of Windy Gap water would increase, and as a result there would be additional return flows to East Slope rivers within the South Platte River watershed attributable to indoor and outdoor use of Windy Gap water. Additional Windy Gap return flows attributable to indoor use would occur primarily at Participants' WWTPs. Additional Windy Gap return flows attributable to outdoor irrigation use would occur at various locations throughout the Participants' service areas.

7.1.1.6. South Platte River

Changes in flows would occur to four tributaries to the South Platte River (Big Dry Creek, Big Thompson River, Coal Creek and St. Vrain Creek). The only decrease in flow that would occur would be to the Big Thompson River above the Canyon gage in June of wet years (Table D-10). All other changes would be flow increases. Changes in flow to the South Platte River as a result of the changes in tributary flows were not evaluated. It is expected that the small net flow increase that would occur to the South Platte River as discussed in the section on *East Slope Streams* for each of the Alternatives, would not be measurable for much distance due to stream diversions, evapotranspiration, and losses to ground water.

7.1.1.7. C-BT Deliveries

C-BT project demands and deliveries would not change as a result of implementation of any of the WGFP alternatives. C-BT deliveries would continue to meet demands without any shortages under all the alternatives and the amount of C-BT water delivered would not exceed current amounts (Table 15). The C-BT demands shown in Table 15 are an estimate of demands based on delivery of a full quota for the current C-BT unit distribution (Boyle 2003 and 2006a).

The WGFP is able to use C-BT facilities for the storage and delivery of Windy Gap water; however, Windy Gap operations cannot negatively impact the C-BT Project. The WGFP is intended to use excess capacity in the C-BT System. The Amendatory Contract for the Introduction, Storage, Carriage, and Delivery of Water for Municipal Subdistrict establishes the criteria for Windy Gap use of C-BT facilities.

Table 15. Modeled C-BT Project demand and delivery for Existing Conditions and all WGFP alternatives.

Month	Average Demand and Delivery (AF)
January	5,429
February	5,022
March	5,270
April	10,944
May	22,389
June	24,153
July	49,413
August	52,644
September	31,332
October	17,952
November	4,974
December	4,984
TOTAL	234,506

Note: Table 15 includes C-BT deliveries made via the Big Thompson River.

7.1.1.8. Loss of C-BT Water from Reservoir Evaporation

C-BT evaporative losses from the major C-BT reservoirs and Chimney Hollow Reservoir would change as a result of the Firming Project (Table 16). All evaporation in C-BT reservoirs is charged to the C-BT Project. Due to the integrated operations of the three lakes system, evaporative losses at Lake Granby, Shadow Mountain, and Grand

Lake are replaced by C-BT diversions to storage and the Windy Gap shrink paid to the C-BT Project. The 10 percent diversion shrink and 10 percent carryover shrink paid by the WGFP to the C-BT Project are intended to offset losses (i.e., evaporation and conveyance) due to the introduction, storage, and delivery of Windy Gap water. Therefore, evaporative losses in all C-BT reservoirs are charged to the C-BT Project regardless of the Windy Gap contents in that facility. Evaporation losses in Windy Gap reservoirs (Chimney Hollow, Jasper East, Dry Creek, and Rockwell) would be allocated pro rata to each account in the reservoir based on the amount stored in each account.

There would be no change in evaporative losses under any of the alternatives for Willow Creek Reservoir, Shadow Mountain Reservoir, or Grand Lake. There would be no change in the end-of-month contents or surface area at Willow Creek Reservoir, Shadow Mountain Reservoir, or Grand Lake due to the alternatives. Evaporation is a function of the surface area of the reservoir. Because there would be no differences in surface area when compared to the Existing Conditions or No Action scenarios, there would be no differences in evaporative losses at these reservoirs that are attributable to the alternatives. Long-term storage of C-BT water in Chimney Reservoir would only occur under the Proposed Action. C-BT water could reside in Chimney Hollow or Dry Creek Reservoirs under Alternatives 3, 4 or 5 for short periods due to reintroduction shrink; however, the amount stored would be small and the associated evaporative losses minimal. Differences in evaporative losses between Existing Conditions and the alternatives are due to a number of factors, including

- Storing C-BT water in Chimney Hollow Reservoir. C-BT water stored in Chimney Hollow would be charged evaporative losses pro rata based on the amount stored in that account. The same amount of C-BT water stored in Chimney Hollow would experience a different evaporative loss than if it was stored in Lake Granby. The evaporative loss rates on the East Slope at Chimney Hollow would be different than those at Lake Granby on the West Slope. In addition, the geometries and capacities of Lake Granby and Chimney Hollow are different; therefore, the surface area attributable to C-BT water stored in Chimney Hollow would be different than if that water was stored in Lake Granby;
- Changes in deliveries to and storage in Granby, Carter and Horsetooth Reservoirs;
- Changes in Windy Gap diversion shrink, carryover shrink and reintroduction shrink; and
- A decrease or elimination of Windy Gap in-lieu deliveries, which were used historically to allow borrowing of C-BT water with repayment using Windy Gap water when available.

Table 16. Modeled evaporative losses from C-BT reservoirs for Existing Conditions and WGFP alternatives.

Alternative	Lake Granby (AF/yr)	Carter Lake (AF/yr)	Horsetooth Reservoir (AF/yr)	C-BT Storage in Chimney Hollow (AF/yr)	Total (AF/yr)
Existing Conditions	8,524	2,056	3,459	---	14,039
No Action (Alt 1)	8,355	2,048	3,450	---	13,853
Proposed Action (Alt 2)	8,106	2,050	3,339	356	13,851
Alternative 3	8,289	2,050	3,422	---	13,761
Alternative 4	8,292	2,051	3,441	---	13,784
Alternative 5	8,291	2,051	3,441	---	13,783

All evaporative losses in Lake Granby are charged to the C-BT account. Because total contents in Lake Granby would be lower under the alternatives, total evaporative losses charged to C-BT would be lower because less Windy Gap water would be stored in Lake Granby under the alternatives. More Windy Gap water would be stored in the WGFP reservoirs and, therefore, less evaporation loss would be charged to C-BT in Lake Granby.

7.1.1.9. Changes in C-BT and Windy Gap Spills from Lake Granby

Spills from Lake Granby would change under the alternatives. Compared to Existing Conditions, over the long term C-BT spills from Lake Granby would be little changed under all of the alternatives; Windy Gap spills would be reduced substantially, particularly under the Proposed Action (Table 17). Windy Gap spills would include the spill of what would now be Windy Gap water from Willow Creek Reservoir (see Section 8.4.3.3 for more discussion).

Table 17. Modeled average annual C-BT and Windy Gap spills for Existing Conditions and the alternatives.

	C-BT Spills (AF)	Windy Gap Spills (AF)	Total Spills (AF)
Existing Conditions	23,712	17,331	41,042
No Action	23,083	13,471	36,554
Proposed Action	24,180	5,042	29,222
Alternative 3	22,981	8,460	31,440
Alternative 4	22,988	8,472	31,460
Alternative 5	22,832	8,529	31,361

7.1.2. Comparison of Model Simulation Output

Average monthly streamflows, stream stages, and reservoir contents for each alternative are presented in Appendices D, E, and F for key C-BT and Windy Gap Project facilities and the affected river segments described above. For each alternative, average values are presented for the 47-year study period (1950 through 1996). In addition, dry and wet year averages are presented, which are defined as the average of the five wettest and five driest years in the study period (each representing about 10 percent of the period of record). The five driest years were 1954, 1966, 1977, 1981, and 1989 and the five wettest years were 1957, 1983, 1984, 1986, and 1995, based on the estimated baseflow below Lake Granby. Baseflows at the USGS gage on the Colorado River near Kremmling, which is at the downstream extent of the study area, were also reviewed to confirm the selection of the five driest and wettest years. At the Kremmling gage, four of the five driest and wettest years are the same as at the gage below Lake Granby. In both cases, the years chosen are within the nine driest and wettest years at both gages.

A summary that compares average annual flows at key locations for Existing Conditions and all of the alternatives is provided in Table 18. Table 19 summarizes flow data for dry years; therefore, the data presented in that table is an average of the five driest years in the study period. Table 20 summarizes flow data for wet years; therefore, the data presented in that table is an average of the five wettest years in the study period.

Table 18. Comparison of <u>average</u> annual flows (1950-1996) and diversions at key locations (AF).

Location	Node	Existing Conditions	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
			No Action			Proposed Action - Chimney Hollow w/Pre-positioning			Chimney Hollow w/Jasper East			Chimney Hollow w/ Rockwell/Mueller Creek			Dry Creek w/ Rockwell/Mueller Creek		
		Avg. Annual Flow	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]
Adams Tunnel C-BT deliveries	514634	231,679	231,509	-170	<1%	231,196	-483	<1%	230,795	-884	<1%	230,800	-879	<1%	231,041	-638	<1%
Adams Tunnel Windy Gap deliveries	514634	11,500	22,410	10,910	49%	31,045	19,545	63%	30,411	18,911	62%	30,433	18,933	62%	30,782	19,282	63%
Total Adams Tunnel Deliveries	514634	243,179	253,919	10,740	4%	262,240	19,061	8%	261,206	18,027	7%	261,223	18,044	7%	261,822	18,644	8%
Colorado River below Lake Granby	09019500	59,385	55,343	-4,042	-7%	50,220	-9,165	-15%	52,071	-7,313	-12%	52,091	-7,294	-12%	51,903	-7,482	-13%
Willow Creek Feeder diversions	510958	36,172	37,544	1,372	4%	38,760	2,588	7%	38,349	2,177	6%	38,339	2,167	6%	38,438	2,266	6%
Willow Creek at the confluence with the Colorado River	510546	18,294	16,933	-1,361	-7%	15,727	-2,567	-14%	16,138	-2,156	-12%	16,148	-2,146	-12%	16,049	-2,245	-12%
Fraser River at the confluence with the Colorado River	510876	91,025	91,025	0	0%	91,027	2	0%	91,028	3	0%	91,028	3	0%	91,028	3	0%
Colorado River above the Windy Gap diversion	514700	187,889	182,487	-5,403	-3%	176,158	-11,731	-6%	178,421	-9,468	-5%	178,451	-9,438	-5%	178,164	-9,725	-5%
Windy Gap diversions	514700	36,532	43,573	7,041	19%	46,084	9,552	26%	48,052	11,520	32%	47,997	11,466	31%	48,483	11,951	33%
Colorado River below Windy Gap	514700	151,358	138,914	-12,444	-8%	130,075	-21,283	-14%	130,370	-20,988	-14%	130,453	-20,904	-14%	129,681	-21,676	-14%
Colorado River at Hot Sulphur Springs	09034500	156,475	144,023	-12,452	-8%	135,176	-21,299	-14%	135,472	-21,003	-13%	135,555	-20,920	-13%	134,783	-21,692	-14%
Colorado River above the confluence with the Williams Fork River	51_ADC008	154,031	141,579	-12,452	-8%	132,732	-21,298	-14%	133,027	-21,003	-14%	133,111	-20,920	-14%	132,339	-21,692	-14%
Williams Fork River at the confluence with the Colorado River	09038500	90,083	90,084	2	0%	90,084	2	0%	90,084	2	0%	90,084	2	0%	90,084	2	0%
Colorado River below the confluence with the Williams Fork River	512037	246,931	234,481	-12,450	-5%	225,634	-21,296	-9%	225,930	-21,001	-9%	226,013	-20,918	-8%	225,241	-21,690	-9%
Colorado River above the confluence with Troublesome Creek	51_ADC011	252,443	239,993	-12,450	-5%	231,147	-21,296	-8%	231,442	-21,001	-8%	231,526	-20,917	-8%	230,753	-21,689	-9%
Troublesome Creek at the confluence with the Colorado River	500526	52,396	52,399	3	0%	52,399	3	0%	52,399	3	0%	52,399	3	0%	52,399	3	0%
Colorado River above the confluence with the Blue River	512036	379,050	366,605	-12,445	-3%	357,760	-21,291	-6%	358,055	-20,995	-6%	358,139	-20,912	-6%	357,366	-21,684	-6%
Blue River at the confluence with the Colorado River	36_ADC019	313,612	313,613	1	0%	313,613	2	0%	313,613	1	0%	313,613	1	0%	313,613	1	0%
Colorado River near Kremmling	09058000	701,801	689,357	-12,444	-2%	680,512	-21,289	-3%	680,807	-20,994	-3%	680,890	-20,910	-3%	680,118	-21,683	-3%
Colorado River above Pumphouse	50_ADC020	696,777	684,333	-12,444	-2%	675,488	-21,289	-3%	675,783	-20,994	-3%	675,866	-20,910	-3%	675,094	-21,683	-3%

Location	Node	Existing Conditions	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
			No Action			Proposed Action - Chimney Hollow w/Pre-positioning			Chimney Hollow w/Jasper East			Chimney Hollow w/ Rockwell/Mueller Creek			Dry Creek w/ Rockwell/Mueller Creek		
		Avg. Annual Flow	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]
Muddy Creek at confluence with the Colorado River	09041500	65,522	65,524	2	0%	65,524	2	0%	65,525	3	0%	65,525	3	0%	65,525	3	0%
Lake Granby Spills	514620	38.707	34,508	-4,199	-11%	28,624	-10,083	-26%	30,671	-8,037	-21%	30,690	-8,017	-21%	30,551	-8,157	-21%
Windy Gap Spills from Willow Creek Reservoir	513710	2,335	2,045	-290	-12%	597	-1,738	-74%	770	-1,565	-67%	770	-1,565	-67%	810	-1,525	65%
C-BT Diversions from the Big Thompson River (Olympus & Dille)	NA	27,990	27,632	-358	-1%	25,048	-2,942	-11%	27,062	-928	-3%	27,062	-928	-3%	26,616	-1,374	-5%
Big Thompson River below Lake Estes	06735500	66,701	67,145	444	1%	69,884	3,183	5%	67,666	965	1%	67,667	966	1%	68,146	1,445	2%
Big Thompson River at the Canyon Gage	06738000	89,367	89,725	358	0%	92,308	2,942	3%	90,294	928	1%	90,295	928	1%	90,740	1,374	2%

[1]Differences indicate the quantitative or percent change from Existing Conditions. A positive difference denotes an increase in flows.

Table 19. Comparison of average annual dry year flows (1954, 1966, 1977, 1981, 1989) and diversions at key locations (AF).

Location	Node	Existing Conditions	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
			No Action			Proposed Action - Chimney Hollow w/Pre-positioning			Chimney Hollow w/Jasper East			Chimney Hollow w/ Rockwell/Mueller Creek			Dry Creek w/ Rockwell/Mueller Creek		
		Avg. Annual Flow	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]
Adams Tunnel C-BT deliveries	514634	304,061	304,299	238	<1%	304,863	802	<1%	303,636	-425	<1%	303,640	-421	<1%	304,219	158	<1%
Adams Tunnel Windy Gap deliveries	514634	10,126	11,858	1,732	17%	28,349	18,223	180%	15,913	29,959	296%	15,968	5,842	58%	21,766	11,640	115%
Total Adams Tunnel deliveries	514634	314,187	316,157	1,970	1%	333,210	19,024	6%	319,549	5,362	2%	319,608	5,421	2%	325,985	11,.799	4%
Colorado River below Lake Granby	09019500	21,946	21,946	0	0%	21,946	0	0%	21,946	0	0%	21,946	0	0%	21,946	0	0%
Willow Creek Feeder diversions	510958	22,200	22,200	0	0%	22,200	0	0%	22,200	0	0%	22,200	0	0%	22,200	0	0%
Willow Creek at the confluence with the Colorado River	510546	3,962	3,962	0	0%	3,962	0	0%	3,962	0	0%	3,962	0	0%	3,962	0	0%
Fraser River at the confluence with the Colorado River	510876	35,432	35,432	0	0%	35,432	0	0%	35,432	0	0%	35,432	0	0%	35,432	0	0%
Colorado River above the Windy Gap diversion	514700	74,938	74,938	0	0%	74,939	0	0%	74,938	0	0%	74,938	0	0%	74,938	0	0%
Windy Gap diversions	514700	7,804	7,804	0	0%	7,804	0	0%	7,804	0	0%	7,804	0	0%	7,804	0	0%
Colorado River below Windy Gap	514700	67,134	67,134	0	0%	67,134	0	0%	67,134	0	0%	67,134	0	0%	67,134	0	0%
Colorado River at Hot Sulphur Springs	09034500	70,656	70,656	0	0%	70,655	-1	0%	70,655	-1	0%	70,655	-1	0%	70,655	-1	0%
Colorado River above the confluence with the Williams Fork River	51_ADC008	67,380	67,380	0	0%	67,380	0	0%	67,380	0	0%	67,380	0	0%	67,380	0	0%
Williams Fork River at the confluence with the Colorado River	09038500	77,202	77,202	0	0%	77,202	0	0%	77,202	0	0%	77,202	0	0%	77,202	0	0%
Colorado River below the confluence with the Williams Fork River	512037	147,416	147,416	0	0%	147,416	0	0%	147,416	0	0%	147,416	0	0%	147,416	0	0%
Colorado River above the confluence with Troublesome Creek	51_ADC011	149,898	149,898	0	0%	149,898	0	0%	149,898	0	0%	149,898	0	0%	149,898	0	0%
Troublesome Creek at the confluence with the Colorado River	500526	27,418	27,418	0	0%	27,418	0	0%	27,418	0	0%	27,418	0	0%	27,418	0	0%
Colorado River above the confluence with the Blue River	512036	229,222	229,222	0	0%	229,222	0	0%	229,222	0	0%	229,222	0	0%	229,222	0	0%
Blue River at the confluence with the Colorado River	36_ADC019	213,141	213,141	0	0%	213,141	0	0%	213,141	0	0%	213,141	0	0%	213,141	0	0%
Colorado River near Kremmling	09058000	450,286	450,286	0	0%	450,286	0	0%	450,286	0	0%	450,286	0	0%	450,286	0	0%
Colorado River above Pumphouse	50_ADC020	445,113	445,113	0	0%	445,112	0	0%	445,112	0	0%	445,113	0	0%	445,112	0	0%
Muddy Creek at confluence with the Colorado River	09041500	42,760	42,760	0	0%	42,760	0	0%	42,760	0	0%	42,760	0	0%	42,760	0	0%

Location	Node	Existing Conditions	Alternative 1 No Action			Alternative 2 Proposed Action - Chimney Hollow w/Pre-positioning			Alternative 3 Chimney Hollow w/Jasper East			Alternative 4 Chimney Hollow w/ Rockwell/Mueller Creek			Alternative 5 Dry Creek w/ Rockwell/Mueller Creek		
		Avg. Annual Flow	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]
Lake Granby Spills	514620	0	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Windy Gap Spills from Willow Creek Reservoir	513710	0	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
C-BT Diversions from the Big Thompson River (Olympus & Dille)	NA	551	475	-76	-14%	0	-551	-100%	0	-551	-100%	0	-551	-100%	0	-551	-100%
Big Thompson River below Lake Estes	06735500	53,535	53,611	76	0%	54,086	551	1%	54,086	551	1%	54,086	551	1%	54,086	551	1%
Big Thompson River at the Canyon Gage	06738000	67,160	67,237	76	0%	67,711	551	1%	67,711	551	1%	67,711	551	1%	67,711	551	1%

[1]Differences indicate the quantitative or percent change from Existing Conditions. A positive difference denotes an increase in flows.

Table 20. Comparison of average annual wet year (1957, 1983, 1984, 1986, 1995) flows and diversions at key locations (AF).

Location	Node	Existing Conditions	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
			No Action			Proposed Action - Chimney Hollow w/Pre-positioning			Chimney Hollow w/Jasper East			Chimney Hollow w/ Rockwell/Mueller Creek			Dry Creek w/ Rockwell/Mueller Creek		
		Avg. Annual Flow	Avg. Annual Flow	Diff.[1]	Per-cent Diff.[1]	Avg. Annual Flow	Diff.[1]	Per-cent Diff.[1]	Avg. Annual Flow	Diff.[1]	Per-cent Diff.[1]	Avg. Annual Flow	Diff.[1]	Per-cent Diff.[1]	Avg. Annual Flow	Diff.[1]	Percent Diff.[1]
Adams Tunnel C-BT deliveries	514634	168,706	167,182	-1,524	1%	161,816	-6,890	4%	165,747	-2,959	2%	165,750	-2,956	2%	164,840	-3,866	2%
Adams Tunnel Windy Gap deliveries	514634	12,081	29,879	17,798	147%	30,343	18,262	151%	40,085	28,004	232%	40,103	28,022	232%	37,810	25,729	213%
Total Adams Tunnel deliveries	514634	180,787	197,062	16,274	9%	192,159	11,372	6%	205,832	25,044	14%	205,853	25,066	14%	202,650	21,863	12%
Colorado River below Lake Granby	09019500	144,383	136,621	-7,762	-5%	130,271	-14,112	-10%	132,355	-12,028	-8%	132,374	-12,009	-8%	130,886	-13,497	-9%
Willow Creek Feeder diversions	510958	33,685	39,335	5,650	17%	40,417	6,732	20%	39,953	6,268	19%	39,953	6,268	19%	39,935	6,250	19%
Willow Creek at the confluence with the Colorado River	510546	52,778	47,128	-5,650	-11%	46,046	-6,732	-13%	46,510	-6,268	-12%	46,510	-6,268	-12%	46,528	-6,250	-12%
Fraser River at the confluence with the Colorado River	510876	178,477	178,477	0	0%	178,477	0	0%	178,477	0	0%	178,477	0	0%	178,477	0	0%
Colorado River above the Windy Gap diversion	514700	403,835	390,423	-13,412	-3%	382,991	-20,844	-5%	385,539	-18,296	-5%	385,558	-18,277	-5%	384,087	-19,748	-5%
Windy Gap diversions	514700	38,512	63,870	25,357	66%	73,923	35,411	92%	78,940	40,428	105%	78,775	40,262	105%	77,543	39,031	101%
Colorado River below Windy Gap	514700	365,323	326,553	-38,769	-11%	309,068	-56,255	-15%	306,599	-58,724	-16%	306,784	-58,539	-16%	306,544	-58,779	-16%
Colorado River at Hot Sulphur Springs	09034500	369,677	330,908	-38,769	-10%	313,423	-56,254	-15%	310,954	-58,723	-16%	311,138	-58,539	-16%	310,898	-58,778	-16%
Colorado River above the confluence with the Williams Fork River	51_ADC008	369,268	330,499	-38,770	-10%	313,014	-56,254	-15%	310,544	-58,724	-16%	310,729	-58,539	-16%	310,490	-58,779	-16%
Williams Fork River at the confluence with the Colorado River	09038500	138,018	138,018	0	0%	138,018	0	0%	138,018	0	0%	138,018	0	0%	138,018	0	0%
Colorado River below the confluence with the Williams Fork River	512037	509,758	470,989	-38,769	-8%	453,505	-56,253	-11%	451,035	-58,723	-12%	451,220	-58,539	-11%	450,980	-58,778	-12%
Colorado River above the confluence with Troublesome Creek	51_ADC011	519,392	480,623	-38,770	-7%	463,138	-56,254	-11%	460,669	-58,724	-11%	460,853	-58,539	-11%	460,614	-58,778	-11%
Troublesome Creek at the confluence with the Colorado River	500526	92,324	92,324	0	0%	92,324	0	0%	92,324	0	0%	92,324	0	0%	92,324	0	0%
Colorado River above the confluence with the Blue River	512036	706,315	667,545	-38,769	-5%	650,061	-56,253	-8%	647,591	-58,723	-8%	647,776	-58,539	-8%	647,536	-58,778	-8%
Blue River at the confluence with the Colorado River	36_ADC019	493,554	493,554	0	0%	493,554	0	0%	493,554	0	0%	493,554	0	0%	493,554	0	0%
Colorado River near Kremmling	09058000	1,217,038	1,178,269	-38,769	-3%	1,160,785	-56,253	-5%	1,158,315	-58,723	-5%	1,158,500	-58,538	-5%	1,158,260	-58,778	-5%
Colorado River above Pumphouse	50_ADC020	1,212,435	1,173,666	-38,769	-3%	1,156,182	-56,253	-5%	1,153,712	-58,723	-5%	1,153,897	-58,538	-5%	1,153,657	-58,778	-5%
Muddy Creek at confluence with the Colorado River	09041500	86,980	86,980	0	0%	86,980	0	0%	86,980	0	0%	86,980	0	0%	86,980	0	0%

Location	Node	Existing Conditions	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5		
			No Action			Proposed Action - Chimney Hollow w/Pre-positioning			Chimney Hollow w/Jasper East			Chimney Hollow w/ Rockwell/Mueller Creek			Dry Creek w/ Rockwell/Mueller Creek		
		Avg. Annual Flow	Avg. Annual Flow	Diff. [1]	Per-cent Diff. [1]	Avg. Annual Flow	Diff. [1]	Per-cent Diff. [1]	Avg. Annual Flow	Diff. [1]	Per-cent Diff. [1]	Avg. Annual Flow	Diff. [1]	Per-cent Diff. [1]	Avg. Annual Flow	Diff. [1]	Percent Diff. [1]
Lake Granby Spills	514620	129,094	120,328	-8,766	-7%	112,911	-16,184	-13%	115,706	-13,389	-10%	115,725	-13,370	-10%	114,236	-14,858	-12%
Windy Gap Spills from Willow Creek Reservoir	513710	3,357	1,039	-2,318	-69%	0	-3,357	-100%	349	-3,008	-90%	349	-3,008	-90%	349	-3,008	-90%
C-BT Diversions from the Big Thompson River (Olympus & Dille)	NA	67,946	68,253	308	0%	67,386	-560	-1%	67,902	-43	0%	67,906	-40	0%	67,938	-8	0%
Big Thompson River below Lake Estes	06735500	72,849	72,874	25	0%	74,765	1,916	3%	72,874	25	0%	72,874	25	0%	72,874	25	0%
Big Thompson River at the Canyon Gage	06738000	108,593	108,285	-308	0%	109,153	560	1%	108,636	43	0%	108,633	40	0%	108,601	8	0%

[1]Differences indicate the quantitative or percent change from Existing Conditions. A positive difference denotes an increase in flows.

7.2. Ground Water Hydrology and Quality

7.2.1. Ground Water Hydrology

Ground water along streams, existing reservoirs, and potential new reservoirs may be affected by the WGFP as a result of the following:

- Changes in existing reservoir elevations
- Water storage in new reservoirs
- Changes in stream stage

Lake surface elevations in Lake Granby, Carter Lake and Horsetooth Reservoir would be lowered during some months under the alternatives. However, at all of the reservoir locations, the ground water flow direction is controlled by topography, which in general slopes toward the reservoirs. With the exception of areas below the dams, ground water is most likely moving toward the reservoirs and would, in general, be only slightly affected by changes in reservoir elevation. The occasional large decreases in reservoir elevations during a series of dry years could result in temporary changes in ground water levels near the reservoirs. Seepage from the reservoirs is mostly controlled by the nature of the geology and the engineering design of the impoundment. The anticipated small changes in reservoir elevation would not significantly change the rate of seepage below dams. The historical variation in the lake surface elevation of Lake Granby (nearly 90 feet) is larger than the expected change due to any of the alternatives.

There would be no change in water surface elevations at Willow Creek Reservoir for any of the WGFP alternatives; hence, ground water near this reservoir would not be affected.

With respect to potential new reservoirs, there would likely be no effects to ground water because the direction of ground water flow is generally towards the reservoir site and the relatively low hydraulic conductivity of the bedrock units would limit the influence of a new reservoir. The proposed new reservoirs are located in areas of relatively low elevation that are typically the discharge areas for bedrock aquifers. Therefore, they would not be affected by new water storage because ground water would be, in general, moving towards the reservoirs. Even if a new reservoir is located in a bedrock recharge area, impounding additional surface water may result in positive effects, such as reducing typical seasonal variability in recharge, thereby increasing ground water availability. However, it is possible that seepage losses through or beneath new impoundment(s) could raise ground water levels below the dams. Depending on current ground water conditions, and actual seepage losses from a reservoir, higher ground water levels could result in vegetation changes, effects to agriculture (either positive or negative), and nuisance water near existing structures, such as basements.

In the Colorado River, the largest predicted average monthly change in stream stage under the various alternatives would be a decrease of less than 3 inches in the river below Windy Gap during average years and less than 6 inches during wet years (Table E-2). Changes of this magnitude would not result in changes in water production from nearby alluvial aquifers or wells. It is unlikely that the expected changes in ground water levels due to changes in stream stage would be measurable beyond tens of feet from the river. Similar small decreases in stream stage on Willow Creek are unlikely to measurably affect nearby shallow wells. Projected increases in streamflow for several East Slope streams from additional water imports would likely not affect stream stage by more than a few inches because the water in these streams spreads out within wide alluvial channels. Therefore, ground water levels would not be expected to change more than a few inches.

Potential effects to ground water hydrology are discussed in more detail for each of the alternatives.

7.2.2. Ground Water Quality

ERO and Hydrosphere (2007) and Hydrosphere (2007) analyzed possible changes in water quality for each of the alternatives in existing reservoirs (Lake Granby, Carter Lake and Horsetooth Reservoir), proposed new reservoirs (Chimney Hollow, Dry Creek, Jasper East and Rockwell/Mueller Creek reservoirs) and East Slope and West Slope streams in the project area. The predicted change in water quality in the existing reservoirs under all of the alternatives is relatively small, and, given the small predicted changes in ground water levels adjacent to the reservoirs, it is unlikely that ground water quality will be affected by any of the alternatives.

The predicted water quality of the new reservoirs under the various alternatives is expected to be similar to that of existing reservoirs (Hydrosphere 2007). Because seepage from the new reservoirs is expected to be small, and surface water quality is generally better relative to typical background ground water quality, it is unlikely that ground water quality near the proposed reservoirs will be negatively affected.

For the Colorado River, the water quality model results for the various alternatives indicates that there may be some changes in water quality, such as specific conductance, which could increase as much as 10 percent in some parts of the Colorado River (ERO and Hydrosphere 2007). The percent change of other constituents is predicted to be less than 10 percent. Similar changes in alluvial ground water quality along the river would be expected. As discussed in Section 6.4.3.1, bedrock water quality in the Upper Colorado River basin is of much poorer water quality and flows toward the alluvium. The predicted changes in Colorado River stage during Windy Gap diversions would slightly reduce the water level in the alluvium (Section 7.2.1), thus increasing the amount of bedrock water recharging the alluvial aquifer. Ground water flow from bedrock to the alluvium is probably controlled more by the low hydraulic conductivity of the bedrock than it is by the water level in the alluvium and, therefore, it is likely that the ground water flow from the bedrock would change only slightly as a result of small water level changes in the alluvium. Also, the water level changes in the alluvium would be within the range of natural variability and the changes would attenuate farther from the river. Therefore, it is expected that any changes to alluvial water quality as a result of reduced stream levels during Windy Gap diversions would not be measurable.

Modeling of Willow Creek (ERO and Hydrosphere 2007) showed that ground water inflow is the dominant source of water to Willow Creek below Willow Creek Reservoir. Therefore, it is unlikely that changes in the water quality of Willow Creek predicted for the WGFP alternatives (ERO and Hydrosphere 2007) would affect ground water quality near the creek because the creek is not losing water to ground water.

The water quality of North St. Vrain Creek is expected to improve under the No Action alternative (it would not be affected under the other alternatives). Therefore, there would be no negative effects to ground water quality near North St. Vrain Creek. Predicted water quality changes to the Big Thompson River between Lake Estes and the Hansen Feeder Canal are predicted to be very small and are not expected to affect ground water quality near the river.

For the other East Slope streams where small water quality changes are predicted to occur under all of the alternatives due to changes in Participants' WWTP return flows (ERO and Hydrosphere 2007), there may be minor changes to alluvial ground water quality near the streams. This includes the Cache la Poudre River below Greeley's WWTP, the Big Thompson River below Loveland's WWTP, St. Vrain Creek below Longmont's and the Little Thompson Water District's WWTPs, Big Dry Creek below Broomfield's WWTP and Coal Creek below Superior's, Louisville's, Lafayette's and Erie's WWTPs.

Potential effects to ground water quality are discussed in more detail for each of the alternatives.

7.3. Stream Morphology and Sedimentation

Potential effects to stream morphology were evaluated for each of the alternatives. Significant changes in the frequency and magnitude of the channel maintenance flows could affect the morphology of a stream channel and alter sediment transport and the rate of sediment deposition in a stream. In addition, such changes may affect the growth of riparian habitat and wetland habitat located along or near streams. Decreases in streamflow could result in the reduction of the sediment transport capacity of the river and could cause aggradation and vegetation to encroach into the stream channel. Increases in streamflow could result in increased streambed and bank erosion, degradation, and increased sediment transport in the streams. Increases in streamflows could also flood and potentially diminish or scour riparian and wetland habitat along the edges of a stream. Potential effects to stream morphology are discussed for each of the alternatives in the following sections. Potential effects to riparian vegetation are discussed in the Vegetation and Wetlands Technical Report (ERO 2006b).

The WGFP would reduce the magnitude of spring/summer peak snowmelt runoff flows in the Colorado River during years when the project could divert water, resulting in a decrease in flood risk below Windy Gap Reservoir. Potential new reservoirs would capture flood flows that might occur within their watersheds. The increase in flows that would occur to streams on the East Slope could increase the flood risk; however, the estimated flow increases would be small compared to flood flows caused by snowmelt runoff or large storm events.

7.4. Alternative 1 (No Action)

Under the No Action alternative, the WGFP would not occur; therefore, all Participants would maximize delivery of Windy Gap water according to their demand, water rights, available storage in Lake Granby and existing Adams Tunnel conveyance constraints. The City of Longmont is the only Participant that currently has an option to develop storage independently if the WGFP is not implemented. The City of Longmont indicated that it would evaluate the enlargement of the existing Ralph Price Reservoir by 13,000 AF. The modeled differences between the No Action alternative and Existing Conditions are as follows:

- The total annual Windy Gap demand, which includes WGFP Participants, non-Participants, and the MPWCD, would be approximately 40,765 AF under No Action, versus 21,045 AF under Existing Conditions (Appendix C). Windy Gap demands under No Action would be higher than under Existing Conditions and the Action alternatives because Participants would try to maximize their use of Windy Gap water, when available, as their demands increase in the future. Under the Action alternatives, the Participants' demands would reflect the amount of Windy Gap water that could be delivered each year without any shortage. In other words, the Participants would operate the Windy Gap Project to provide firm yield with storage on-line. While Windy Gap demands would be higher under No Action, average Windy Gap deliveries under this scenario would be less than the action alternatives. Average deliveries would be less because C-BT storage would be unavailable for Windy Gap water in wet years; therefore, Windy Gap water would typically be spilled or would not be pumped in those years. As a result, Windy Gap deliveries would be considerably less than the demand.
- In addition to storing Windy Gap water in Lake Granby, Longmont would divert Windy Gap water by exchange to an enlarged Ralph Price Reservoir for use at a later time as long as there is space in the Adams Tunnel and St. Vrain Supply Canal. Windy Gap deliveries to Longmont would be made first from Lake Granby via instantaneous delivery. When no Windy Gap water is available in Lake Granby, Longmont would release Windy Gap water previously stored in Ralph Price Reservoir to meet Longmont's demands.

7.4.1. Surface Water Hydrology

7.4.1.1. C-BT and Windy Gap Project Operations and Diversions

Adams Tunnel Diversions. Adams Tunnel diversions include C-BT and Windy Gap water deliveries to the East Slope. Adams Tunnel diversions include C-BT deliveries to Carter Lake, Horsetooth Reservoir, C-BT deliveries to meet C-BT demands above Flatiron Reservoir and along the Big Thompson River, and instantaneous deliveries to meet Participants' Windy Gap demands (i.e., C-BT deliveries from Carter Lake and Horsetooth Reservoir to meet Windy Gap demands that are exchanged for Windy Gap supplies in Lake Granby). Windy Gap deliveries to meet demands are made via instantaneous delivery; therefore, they are reflected as C-BT deliveries through the tunnel to replace corresponding releases made from Carter Lake or Horsetooth Reservoir. Instantaneous deliveries are reflected as Windy Gap deliveries through the Adams Tunnel in Tables 18, 19, and 20. C-BT deliveries would remain about the same under No Action, so any changes in Adams Tunnel deliveries would be primarily from additional deliveries of Windy Gap water.

Average annual Adams Tunnel deliveries would be approximately 243,000 AF under Existing Conditions versus about 254,000 AF under the No Action alternative (Table 18). Deliveries through the Adams Tunnel under No Action would be about 11,000 AF higher than Existing Conditions because of additional Windy Gap diversions to Ralph Price Reservoir and deliveries to meet higher Windy Gap demands. Differences in average monthly tunnel deliveries would be greatest during the Windy Gap diversion season from May through August with the exception of June (Table D-2). Deliveries through the tunnel would be greater in May, July and August primarily due to additional Windy Gap diversions to Ralph Price Reservoir. Deliveries from September through January would be greater due to additional instantaneous Windy Gap deliveries to meet demands. Differences in tunnel deliveries would be minimal in February, March, April, and June because C-BT operations would often require the full tunnel capacity in those months.

Dry year average annual Adams tunnel deliveries would be approximately 314,000 AF under Existing Conditions versus 316,000 AF under No Action (Table 19). The difference between No Action and Existing Conditions would be minimal because there would typically be little to no Windy Gap water in Lake Granby available for delivery in dry years. There would be no difference in April, May and June because the tunnel would be operating at capacity (the modeled capacity of the tunnel was reduced in April to reflect maintenance operations) in all three of those months.

Wet year average annual Adams tunnel deliveries would be approximately 181,000 AF under Existing Conditions versus 197,000 AF under No Action (Table 20). Deliveries through the tunnel would be greater in May, July and August due primarily to additional Windy Gap diversions to Ralph Price Reservoir. This would be a factor particularly in wet years because when Lake Granby fills, Windy Gap diversions would be curtailed under Existing Conditions. However, under No Action, Longmont would be able to divert Windy Gap water directly through the Adams Tunnel and exchange water to Ralph Price Reservoir to the extent there is space in the tunnel and the reservoir. Wet year average C-BT deliveries would be about 1,500 AF less under No Action compared to Existing Conditions. The difference in wet years would be primarily because when the Adams and/or Olympus Tunnels are full, it could take several months to replace the instantaneous deliveries that were made to meet Windy Gap demands out of Carter Lake and Horsetooth Reservoir due to tunnel constraints. In some cases C-BT water delivered to East Slope reservoirs is replacing an instantaneous delivery to meet a Windy Gap demand in previous months. The difference in C-BT deliveries through the tunnel is, therefore, related to the timing of instantaneous Windy Gap deliveries versus C-BT deliveries to Carter Lake and Horsetooth to replace an instantaneous delivery. Differences in C-BT and Windy Gap deliveries due to timing are minimized when averaging over the entire study period, as shown in Table 18.

Windy Gap Diversions. Under the No Action alternative, Windy Gap would be delivered first to Lake Granby and then to Ralph Price Reservoir (for Longmont) if there is available space in Adams Tunnel. Average annual Windy Gap diversions would be approximately 36,500 AF under Existing Conditions versus 43,600 AF under No Action (Table 18). Average monthly differences between Existing Conditions and No Action would be greatest in June and July (Table D-3). There would be no differences in Windy Gap diversions between Existing Conditions and No Action in years that Lake Granby does not fill because there would be no difference in the supply available to Windy Gap and available storage capacity would not be a constraint. However, when Lake Granby fills, Windy Gap cannot divert under Existing Conditions. Under No Action, Longmont could still divert Windy Gap water to Ralph Price Reservoir when Lake Granby is full as long as there is space in the tunnel. June and July correspond with months that Lake Granby typically fills; therefore, differences in Windy Gap diversions would be, on average, greatest in those months.

In dry years, there would be no difference in Windy Gap diversions between Existing Conditions and No Action (Table D-3). In dry years, Windy Gap diversions would be limited by the physically and legally available supply in the Colorado River, which does not vary among alternatives in dry years. Available space in Lake Granby would not be a limiting factor on Windy Gap diversions in dry years. Annual Windy Gap diversions in an average dry year are estimated to be 7,804 AF for both No Action and Existing Conditions (Table 19). This is an average of the five driest years (1954, 1966, 1977, 1981, and 1989). In those years, Windy Gap diversions ranged from approximately 300 AF in 1954 to 19,430 AF in 1989. The more severe the dry year, the less Windy Gap water would be pumped.

In wet years, monthly differences between Existing Conditions and No Action would be greatest in July and August (Table D-3). In the wettest years, Lake Granby would generally fill by the end of July; therefore, Windy Gap diversions under Existing Conditions would be minimal in July. Similarly, Lake Granby is full in August in the wettest years under Existing Conditions; therefore, wet year average Windy Gap diversions are zero in August. However, under No Action, Windy Gap would still divert in July and August after Lake Granby fills to the extent there is space in the tunnel so that Windy Gap water could be delivered to St. Vrain Creek and exchanged upstream to Ralph Price Reservoir.

Willow Creek Feeder Canal Diversions. The C-BT Project diverts water from Willow Creek for delivery to Lake Granby via the WCFC. When space in Lake Granby is not a limiting factor on the amount of water that can be diverted from Willow Creek, there would be no difference in WCFC diversions among the alternatives. This is reflected in the dry year average WCFC diversions. In dry years, Lake Granby storage is generally low, in which case WCFC diversions are not limited by available capacity in Lake Granby. Therefore, dry year average WCFC diversions are a function of the physically and legally available supply in Willow Creek and would be the same for Existing Conditions and all of the alternatives.

Average annual WCFC diversions are approximately 36,200 AF under Existing Conditions and 37,500 acre-feet under No Action (Table 18). Under average and wet conditions, there would be differences in WCFC diversions between Existing Conditions and No Action, primarily during the runoff season in June, July and August. Differences occur because C-BT operations take precedence over Windy Gap Project operations; therefore, the first water spilled from Lake Granby would be Windy Gap water. When Lake Granby fills with both Windy Gap and C-BT water, Windy Gap water in Lake Granby would be exchanged with C-BT water in Willow Creek Reservoir. This eliminates the need to pump C-BT water from Willow Creek Reservoir, which would cause Windy Gap water to spill from Lake Granby. This results in a spill of Windy Gap water from Willow Creek Reservoir. The amount of Windy Gap water exchanged to Willow Creek Reservoir would be the lesser of the amount of Windy Gap water in Lake Granby or the amount that can physically and legally be pumped from Willow Creek. WCFC diversions would be least under Existing Conditions because Windy Gap exchanges with C-BT in place of WCFC diversions would be higher. Under Existing Conditions, Windy Gap water would be stored only in Lake

Granby and Windy Gap demands would be lower than they would be under No Action. As a result, Windy Gap contents in Lake Granby would generally be higher preceding spills, so more Windy Gap water in Lake Granby would be exchanged to C-BT in place of WCFC diversions.

There could also be differences in WCFC diversions among the alternatives due to differences in Lake Granby C-BT contents. Differences in C-BT contents in Lake Granby among the alternatives would be due to variations in Windy Gap operations, including the amounts of Windy Gap shrink paid to the C-BT project and instantaneous deliveries. When water is diverted from Willow Creek to fill Lake Granby, the amount diverted depends on both C-BT and Windy Gap contents in Lake Granby.

The difference in WCFC diversions among alternatives may be overestimated because the WGFP model does not forecast Lake Granby spills. The WGFP model determines the amount of Windy Gap pumping each month and does not take into account whether or not Lake Granby is nearing a spill condition. As a result, the model occasionally shows pumping of Windy Gap water into Lake Granby early in the runoff season, and the same water is spilled from Lake Granby in succeeding months. This occurs most frequently in the Existing Conditions scenario because Windy Gap demands are lower and all Windy Gap water is stored in Lake Granby prior to delivery to the Participants. This occasionally results in a larger Windy Gap pool in Lake Granby under the Existing Conditions scenario, which in turn results in a larger exchange with Willow Creek Reservoir in spill conditions than under the action alternative scenarios. As a result, under the Existing Conditions scenario, more Windy Gap water in Lake Granby would be exchanged with C-BT water, as opposed to pumping water from Willow Creek. Therefore, part of the increase in WCFC diversions under the No Action and action alternatives results from the lack of a “forecasting” mode in the WGFP model, which tends to overestimate Windy Gap diversions in wet years and consequently underestimate WCFC diversions under certain conditions in the Existing Conditions scenario.

Lake Granby Spills. For the section of the Colorado River below Lake Granby where river flows have been dominated by releases from Lake Granby since 1951, releases from Lake Granby would continue to meet the needs of water rights users as well as the bypass flow requirement. The frequency, timing and magnitude of spills from Lake Granby would change under No Action. Average annual Lake Granby spills would be approximately 38,700 AF for Existing Conditions versus 34,500 AF for No Action (Table 18). Spills occurring for a duration of 2 months in June and July would be nearly the same; those occurring in June through August would occur slightly less often and would be of a smaller magnitude, and spills occurring only during the month of July would occur slightly less frequently and would be of smaller magnitude (Table D-11). As explained further in Section 7.5.1.1, the majority of the difference in spills would be attributable to differences in Windy Gap spills in wet years, particularly in July.

It is important to note that Lake Granby spills under Existing Conditions and No Action may be overestimated because forecasting is not factored into the WGFP Model. The annual decision to pump Windy Gap water takes into account Upper Colorado River basin snowpack, Lake Granby contents, spring precipitation during runoff, Big Thompson River basin forecasts, and orders for Windy Gap water. A forecasting function that takes into account all of these variables was not incorporated in the model because of the difficulty in accurately predicting these variables. Instead, Windy Gap diversions to Lake Granby could occur as long as there is space in Lake Granby. As a result, Windy Gap water pumped to Lake Granby in April and May in wet years would often be spilled in June or July under Existing Conditions and No Action. In effect, early season Windy Gap diversions are retimed as spills later in the season in wet years. This also would occur under the Proposed Action and Alternatives 3, 4, and 5, but to a much lesser degree, because Windy Gap diversions early in the season would often be stored in West Slope firming storage or East Slope firming storage if Adams Tunnel capacity exists. If Windy Gap diversions were reduced to some degree in April and May in wet years primarily under Existing Conditions and No Action, the difference in spills and flows below Lake Granby would be less (primarily in June and July). Reductions in Windy Gap diversions in April and May would also result in greater differences in flows in the Colorado River below Windy Gap in these months between Existing Conditions and No Action versus the other alternatives. However, this would occur in wet years when flows are typically high.

C-BT Diversions from the Big Thompson River. Average annual Big Thompson River diversions would be approximately 28,000 AF for Existing Conditions versus 27,600 AF for No Action (Table 18). The small difference in Big Thompson River diversions would be due primarily to a decrease in C-BT diversions for power generation due to differences in the available capacity in the Olympus Tunnel, Carter Lake, and Horsetooth Reservoir under No Action.

7.4.1.2. West Slope Streams

Colorado River below Lake Granby. Under average and wet conditions, differences in flows below Lake Granby between Existing Conditions and No Action would be a function of differences in the timing and amount of Lake Granby spills. In dry years, when there are no spills from Lake Granby, the flow of the Colorado River below Lake Granby would not change under the No Action alternative.

Table D-11 provides the modeled Granby Reservoir spill periods, average spill and maximum spill for Existing Conditions and all of the alternatives. The model shows spills occurring for as short as a month (June, July, or August) and up to as long as 4 months (May through August), with the most frequent spills occurring for 2 months in June through July (13 percent of the 47 year model period) under Existing Conditions and No Action. The spill periods are nearly identical under Existing Conditions and No Action, but the estimated flow in the river at the gage near Granby would be reduced during some of the spill periods.

Table 14 provides the range and percent occurrence of flow increases and decreases that would occur under the alternatives during May through August, the period when most Windy Gap diversions would occur. About 90 percent of the time during those months, no changes in the flow of the Colorado River near Granby would occur. About 6 percent of the time, flow decreases of greater than 10 cfs would occur. Flow decreases exceeding about 300 cfs would be due to reduced spills from Lake Granby.

Colorado River above the Windy Gap Diversion. Flows in the Colorado River above Windy Gap (Table D-13) reflect the outflow from Lake Granby, tributary inflows from Willow Creek and the Fraser River, Colorado River mainstem irrigation diversions, and ungaged gains/losses to the river including ground water and irrigation return flows. In dry years, flows in the Colorado River above Windy Gap would be the same among all alternatives because there would be no difference in flows below Lake Granby, in Willow Creek or in the Fraser River. Differences in the average and wet year average flows above Windy Gap among alternatives coincide with the differences in flows below Lake Granby due to spills and in Willow Creek at the mouth due to differences in WCFC diversions when Lake Granby fills. Under No Action, average annual flow would decrease about 3 percent (Table D-13). The largest monthly flow reduction would be a 6 percent decrease during July in average years and a 10 percent reduction in July flows in wet years (Table D-13). Flow decreases would occur under No Action from June through October (Figure 31).

Colorado River below the Windy Gap Diversion to the Top of Gore Canyon. Flows in the Colorado River below Windy Gap, at Hot Sulphur Springs and above the confluence with the Williams Fork River reflect the outflow from Lake Granby, tributary inflows from Willow Creek and the Fraser River, Colorado River mainstem irrigation diversions, Windy Gap diversions, and ungaged gains/losses to the river. Average annual flows in the Colorado River below the Windy Gap diversion to Hot Sulphur Springs reflect about 5,000 AF of accretion because modeled ungaged gains/losses to the river exceed Colorado River mainstem diversions in this reach under Existing Conditions and the WGFP alternatives (Table 18). In addition, Colorado River average annual flow from Hot Sulphur Springs to above the confluence with the Williams Fork River would decrease by about 2,400 AF because the modeled mainstem diversions generally exceed the modeled ungaged gains/losses to the river in this reach. (Modeled flow accretions and reductions along the river are sensitive to the placement of gains and losses in relation to diversions. Actual flow accretions and reductions along the river may be more or less depending on where actual gains/losses occur in relation to diversions.)

At Hot Sulphur Springs, no changes in flow would occur about 71 percent of the time between May and August, the period when most Windy Gap diversions occur (Table 14). Flow decreases of 1 to about 300 cfs would occur about 21 percent of the time and flow decreases of about 300 cfs or greater would occur about 5 percent of the time during May through August.

Flows below the confluence with the Williams Fork River and above the confluence with Troublesome Creek reflect the inflow from the Williams Fork River (including Williams Fork Reservoir releases). Flows above the confluence with the Blue River include the tributary inflow from Troublesome Creek and Muddy Creek. Flow near Kremmling above Gore Canyon includes the tributary inflow from the Blue River (including Green Mountain Reservoir releases). The modeled average annual river flow decreases by about 5,000 AF from Kremmling to the top of Gore Canyon because the modeled mainstem diversions generally exceed the modeled ungaged gains/losses to the river in this reach (Table 18).

The average annual flow reduction under the No Action alternative in the Colorado River below the Windy Gap diversion would be 8 percent at Hot Sulphur Springs, 5 percent below the Williams Fork, and 2 percent near Kremmling (Table 18). The largest average monthly flow reduction under the No Action alternative would occur in July from below Windy Gap to Hot Sulphur Springs; this would be a 20 percent reduction in average years and a 25 percent reduction in wet years (Table D-16). Reductions in streamflow under No Action would occur primarily from May through August (Figure 32 and Figure 33). The largest monthly average stream stage changes would be an 11 percent reduction (1.5 inches) in July of average years and a 15 percent reduction (5 inches) in July of wet years below Windy Gap Reservoir (Table E-2). Farther downstream, July average flow reductions would decrease to 5 percent at the top of Gore Canyon in average years and a 9 percent reduction in wet years (Table E-3). The monthly average stage changes at this location would be less than 5 percent, or 2 inches in average years and slightly less than 5 inches in wet years. In dry years, flows in the Colorado River would be the same among all alternatives because there is no difference in flows below Lake Granby, in the tributaries to the Colorado River, or in Windy Gap diversions (Table 19). Average annual flows at the USGS gage at the top of Gore Canyon would be about 12,400 AF (17 cfs) higher under Existing Conditions than No Action (Table 18). At the USGS gage near Kremmling, no changes in flow would occur about 71 percent of the time between May and August, the period when most Windy Gap diversions occur (Table 14). Flow decreases of 1 to about 300 cfs would occur about 22 percent of the time and flow decreases of about 300 cfs or greater would occur about 5 percent of the time during May through August.

Colorado River minimum stream flow requirements below the Windy Gap diversion of 90 cfs would occur for 167 days in average years under both Existing Conditions and the No Action alternative. Dry year minimum stream flows would occur for 147 days each year under Existing Conditions and No Action.

Willow Creek. The average annual flow reduction under the No Action alternative in Willow Creek at the confluence with the Colorado River would be 7 percent (Table D-15). The largest flow reduction in Willow Creek would occur in July; this would be a 19 percent reduction (32 to 26 cfs) in average years and a 34 percent reduction (112 to 75 cfs) in wet years. Flow decreases would occur under No Action from June through August (Figure 34). There would be no changes in Willow Creek flow in dry years (Table D-15). Stage changes in Willow Creek are not available because the USGS stream gage below Willow Creek Reservoir has not been in operation for more than 20 years and a stage/discharge curve is not available.

Differences in flows in Willow Creek below Willow Creek Reservoir and the WCFC are a function of differences in WCFC diversions. Dry year average flows in Willow Creek would be the same for all alternatives because there would be no differences in WCFC diversions. However, in average and wet years, WCFC diversions would increase, primarily during the runoff season in June, July, and August under No Action; therefore, Willow Creek flows would decrease in the same months in comparison with Existing Conditions (Table 18 and Table 20). Increases in WCFC diversions occur when Lake Granby fills. Under Existing Conditions, more Windy Gap water in Lake Granby would be exchanged with C-BT water, as opposed to pumping water from Willow Creek, because Windy Gap storage contents would typically be higher under Existing Conditions than No Action. WCFC diversions versus exchanges with Windy Gap water would be higher under No Action, resulting in lower flows in Willow Creek at the mouth than would occur under Existing Conditions. The difference in WCFC diversions among alternatives may be overestimated because the WGFP model does not forecast Lake Granby spills (see Section 7.4.1.1).

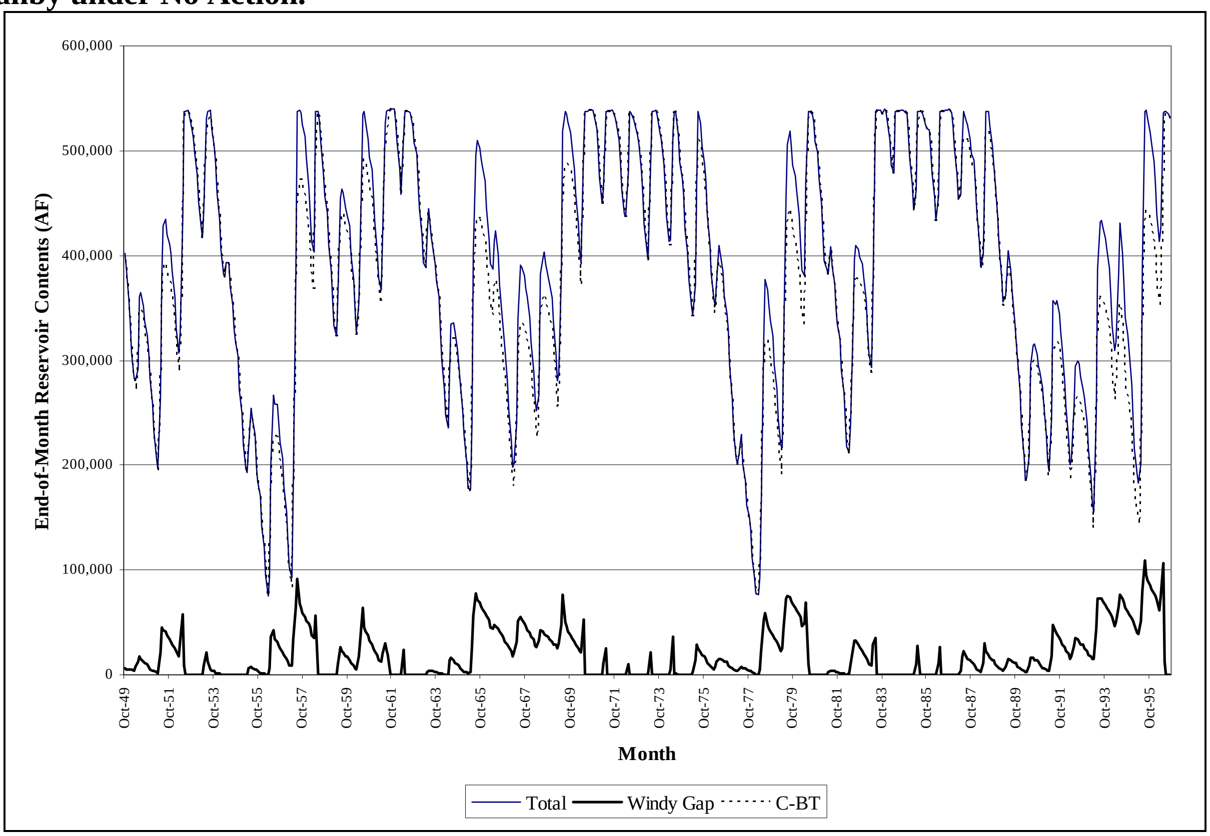
7.4.1.3. West Slope Reservoirs

Lake Granby. Average monthly contents in Lake Granby under Existing Conditions would be higher than No Action, with differences ranging from about 12,000 AF in July to about 17,000 AF in January through May (Table F-7). The largest change in the average monthly volume of Lake Granby that would occur under the No Action alternative is a 5 percent reduction in average years, a 4 percent reduction in dry years and an 8 percent reduction in wet years (Table F-7). The maximum monthly average lake elevation change would be a decrease of 3 feet in average years, 2 feet in dry years and 5 feet in wet years (Table F-8).

Differences in Lake Granby contents for Existing Conditions and No Action would be greatest during dry year sequences. During these years, Windy Gap diversions would not be limited by C-BT contents in Lake Granby; therefore, differences in Lake Granby contents would be due primarily to Windy Gap demands and instantaneous deliveries, and deliveries to Ralph Price Reservoir. Differences in Lake Granby contents and surface elevations would be greatest (up to 18 feet) during dry year sequences; the chance of a decrease in the lake level of more than 10 feet in any given year would be about 6 percent.

The amount of C-BT and Windy Gap water stored in Lake Granby would change under No Action compared to Existing Conditions (Figure 27 and Figure 29).

Figure 29. End-of-Month Storage Volume of C-BT and Windy Gap Water in Lake Granby under No Action.



7.4.1.4. East Slope Streams

Streams that Receive Windy Gap Return Flows. Under the No Action alternative, the use of Windy Gap water would be higher in comparison with Existing Conditions; as a result there would be additional return flows to East Slope streams. Additional Windy Gap return flows attributable to indoor use of Windy Gap water occur primarily at Participants' WWTPs. Additional Windy Gap return flows attributable to outdoor irrigation use occur at various locations within Participants' service areas. However, for the purpose of analyzing affects on East Slope stream flows, it was assumed that return flows attributable to outdoor irrigation use would occur at each Participant's WWTP.

The potential effects on flows in East Slope streams due to the proposed alternatives were not included in the WGFP model, but were evaluated in a separate analysis (Boyle 2006b). Maximum increases in East Slope streams due to increased return flows from Participants would be higher under No Action than Existing Conditions and other alternatives because the demand for Windy Gap water and, therefore, the maximum delivery, would be greater under No Action (Table 21). However, average return flows would be less under No Action than under Alternatives 2 through 5 because average deliveries would be less. There would be no net change in streamflow from November to March between the No Action alternative and Existing Conditions because either Participants do not intend to use their Windy Gap supplies in those months, reusable effluent is stored for use later in summer months, or return flows are used to offset depletions or augment return flow obligations. Table 21 compares the average maximum flow increases attributable to additional Windy Gap return flows under the No Action alternative to the average maximum monthly flows at the nearest USGS gage. No adjustments were made to gage flows to account for gains/losses that may occur between the gages and WWTPs. For example, Coal Creek receives effluent from Superior, Louisville, Lafayette, and Erie (Figures 13a and 13b). There is only one active USGS gage on Coal Creek. This gage is located in the vicinity of Superior's and Louisville's WWTPs, which is located approximately 4 miles upstream of Erie's WWTP and 8 miles upstream of Lafayette's WWTP. The Coal Creek gage does not account for the contribution from Rock Creek, which occurs upstream of Erie's and Lafayette's WWTPs. The Loveland WWTP is located just downstream of the USGS gage (Figure 13a). The USGS gage flows presented are the closest measured flows to the location where additional returns would occur at Participants' WWTPs. In Coal Creek and St. Vrain Creek, return flows would increase at more than one location; the return flows for these creeks have not been added together in Table 21.

Table 21. East Slope streamflow increases under No Action.

Stream Segment	Flow Condition[1]	Apr	May	Jun	Jul	Aug	Sep	Oct
		cfs						
Big Dry Creek above Broomfield WWTP (USGS gage 06720820, adjusted for average historical Broomfield WWTP effluent, 1995-2004)	Existing average flow	13.3	28.9	51.1	41.5	38.5	23.6	10.1
	Existing maximum flow	19	40.5	73.2	86.5	49	40.3	16.2
	Average flow increase	1.5	2.6	3.1	3.7	3.7	3.1	1.5
	Maximum flow increase	3.5	5.9	7.0	8.5	8.5	7.0	3.4
Coal Creek below Superior, above Louisville, Lafayette, and Erie WWTPs (USGS gage 06730400)	Existing average flow	12.3	13.1	7	2.8	4.1	2.1	2.6
	Existing maximum flow	36	35	13	4.3	15	3.1	3.8
	Average flow increases above gage	0.8	1.4	1.2	0.9	0.7	0.6	0.5
	Maximum flow increase above gage	1.7	1.7	1.7	1.7	1.7	1.7	1.7
	Average flow increases below gage	1.5	2.8	2.3	1.8	1.3	1.2	1.0
	Maximum flow increase below gage	3.3	3.3	3.4	3.3	3.3	3.4	3.2
St. Vrain Creek below Longmont WWTP (USGS gage 06725450)	Existing average flow	76	234	348	175	148	101	68
	Existing maximum flow	259	1155	1227	485	185	152	159
	Average flow increase	2.2	0.8	0.9	10.7	10.5	10.3	9.3
	Maximum flow increase	3.0	0.8	0.9	11.0	11.0	11.3	10.8
St. Vrain Creek below LTWD WWTP (USGS gage 06731000)	Existing average flow	178	472	627	313	231	184	160
	Existing maximum flow	622	2362	2316	972	653	292	398
	Average flow increase	0.3	0.7	0.8	0.9	0.9	0.7	0.3
	Maximum flow increase	0.8	1.3	1.5	1.5	1.5	1.5	0.7
Big Thompson River below Loveland WWTP (USGS gage 06741510)	Existing average flow	41	251	296	129	84	37	28
	Existing maximum flow	292	2078	1493	418	153	84	66
	Average flow increase	0	1.4	1.2	2.0	3.5	3.9	2.8
	Maximum flow increase	0	1.6	1.6	3.2	6.4	9.8	9.4

[1]Existing average and maximum flow are at stream gage locations. Average and maximum flow increases are at Participants' WWTPs and dispersed return flow locations from outdoor use.

It is important to note that Windy Gap water is reusable to extinction. The majority of Participants reuse Windy Gap effluent either through non-potable reuse systems, as an exchange supply, as return flow credit, or as augmentation water. Each Participant's anticipated first use and reuse of its Windy Gap supplies, as documented in the Draft Purpose and need Report (ERO 2005a), was taken into account when estimating Windy Gap return flows to East Slope streams.

North St. Vrain Creek and St. Vrain Creek. Under the No Action alternative, the flow of North St. Vrain Creek, as well as St. Vrain Creek in the approximately 1-mile stretch from the confluence of the North and South forks to the St. Vrain Supply would change due to exchanges of Windy Gap water to storage in Ralph Price Reservoir and Windy Gap releases from Ralph Price Reservoir to meet Longmont's demands (Figure 24). Flows in these reaches would decrease during the runoff season (except in June), when water is diverted to storage at Ralph Price Reservoir in exchange for deliveries to St. Vrain Creek at the St. Vrain Supply Canal. Releases from Ralph Price Reservoir to meet Longmont's Windy Gap demands would occur throughout the year (Table 22). Flows in these reaches would increase in September and October when releases exceed the amount exchanged to storage.

Longmont's diversions from North St. Vrain Creek would increase during most months of the year; additional diversions related to exchanging Windy Gap water upstream would occur in May, July, and August (Table 22). Longmont's average net diversions into Ralph Price Reservoir in May, July and August would increase by 15 cfs, 45 cfs, and 3 cfs, respectively. This would reduce the average flow of North St. Vrain Creek below Ralph Price Reservoir and Longmont's pipeline by about 10 percent in May, 25 percent in July and 3 percent in August. The average monthly flow in June below Ralph Price Reservoir would not change because average monthly diversions to storage at Ralph Price Reservoir would be offset by Windy Gap releases to meet Longmont's demands.

Diversions by Longmont from the North St. Vrain at the Longmont Pipeline are limited by the pipeline's physical capacity of 28.5 cfs. In July and August, Longmont typically uses most of that pipeline capacity for its existing diversions. As a result, there would be flow changes below Longmont's Pipeline if Longmont could not divert the entire Windy Gap release from Ralph Price Reservoir to Longmont Reservoir. Longmont would divert any excess Windy Gap that can not be diverted at the Longmont Pipeline farther downstream above the St. Vrain Supply Canal. The flow of St Vrain Creek would not change downstream of the St. Vrain Supply Canal because Windy Gap water would be released to St. Vrain Creek at the St. Vrain Supply Canal and exchanged upstream into Ralph Price Reservoir.

Table 22. Average monthly change in flow of North St. Vrain Creek below Ralph Price Reservoir and St. Vrain Creek above the St. Vrain Supply Canal.

Month	N. St. Vrain between Ralph Price Reservoir and Longmont Reservoir			N. St. Vrain below Longmont Reservoir			St. Vrain at Lyons (USGS gage (cfs)		
	Exist. Cond. (cfs)	No Action (cfs)	% Change	Exist. Cond. (cfs)	No Action (cfs)	% Change	Exist. Cond. (cfs)	No Action (cfs)	% Change
January	24	28	18%	13	13	0%	14	14	0%
February	23	27	18%	13	13	0%	13	13	0%
March	24	28	17%	12	12	-0%	20	20	0%
April	46	48	4%	29	29	0%	91	91	0%
May	155	140	-10%	133	118	-11%	297	282	-5%
June	274	277	1%	250	250	0%	528	528	0%
July	179	134	-25%	147	107	-27%	296	256	-13%
August	89	86	-3%	59	58	-3%	135	133	-1%
September	42	60	43%	19	32	67%	67	80	19%
October	26	43	67%	8	15	90%	39	46	18%
November	23	27	18%	13	13	0%	24	24	0%
December	23	27	19%	13	13	0%	17	17	0%

Note: North St. Vrain Creek flows below Ralph Price and Longmont Reservoirs derived using City of Longmont release records from 1999-2005 and Colorado Division of Water Resource diversion records for 1999-2004.

Flows in the North St. Vrain below Longmont Reservoir and in the approximately 1-mile segment of St. Vrain Creek above the St. Vrain Supply Canal would change minimally or not at all during November through April, June, and August. Streamflow in these segments would increase during September and October and decrease in July (Table 22).

Big Thompson River from Lake Estes to Hansen Feeder Canal. Under No Action, flows in the Big Thompson River below Lake Estes (Figure 22) would not change during most months, but would increase by 1 percent in June and July in an average year due primarily to a decrease in C-BT diversions for power generation (Table D-7). The minor increase in Big Thompson River flows at the mouth of the canyon would represent less than a 1 percent annual change to existing flows (Table D-10). There would be no change in river stage except in June during a wet year, when the stage would increase by less than one inch (Table E-1).

7.4.1.5. East Slope Reservoirs

Carter Lake. Average monthly differences in Carter Lake contents between Existing Conditions and No Action would be relatively small, with decreases in reservoir storage under No Action ranging from near zero to about 1,300 AF (Table F-1). The largest change in the monthly Carter Lake volume that would occur under the No Action alternative would be a 2 percent reduction in average years, a 1 percent reduction in dry years and a 3 percent reduction in wet years (Table F-1). The maximum monthly average lake elevation change reduction would be 1 foot in average years, less than a foot in dry years, and 2 feet in wet years (Table F-2).

In general, Carter Lake contents would be less under No Action than Existing Conditions due primarily to differences in C-BT deliveries from Carter Lake to meet Windy Gap demands (instantaneous Windy Gap deliveries). Differences in instantaneous deliveries between No Action and Existing Conditions would occur due to differences in Windy Gap supplies in Lake Granby and differences in monthly Windy Gap demands. Average monthly differences would be slightly higher in wet years and lower in dry years. The greatest difference would occur in summer months. There would be little difference in average monthly contents between Existing Conditions and No Action during winter months because differences in Windy Gap demands would be less and more often there would be no Windy Gap water in Lake Granby available for delivery. In months when there is no Windy Gap water in Granby, there would be no differences in Carter Lake operations between No Action and Existing Conditions.

Carter Lake contents under No Action would occasionally be as much as 7 feet lower than Existing Conditions. This would be due primarily to differences in Windy Gap demands and instantaneous deliveries out of Carter Lake. The chance of a decrease in the elevation of Carter Lake equal to or exceeding 5 feet in any given year would be less than 10 percent.

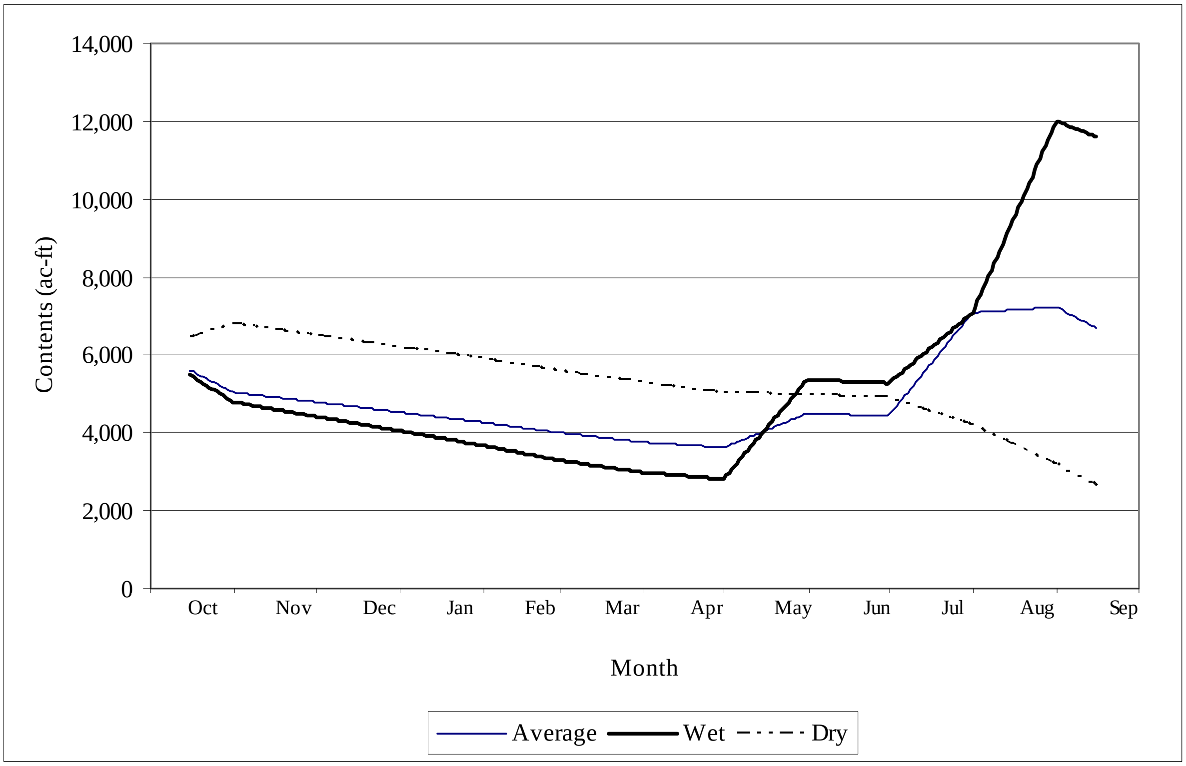
Horsetooth Reservoir. Average monthly differences in Horsetooth Reservoir contents between Existing Conditions and No Action would be minor, with differences ranging from about 100 AF to about 700 AF (Table F-4). The largest change in the average monthly volume of Horsetooth Reservoir that would occur under the No Action alternative would be a 1 percent reduction in average, dry and wet years (Table F-4). The maximum monthly average lake elevation change would be less than a 1 foot decrease in average and dry years and a 1 foot decrease in wet years (Table F-5).

In general, average monthly contents in Horsetooth Reservoir would be less under No Action than Existing Conditions due to differences in C-BT deliveries from Horsetooth Reservoir to meet Windy Gap demands as described above for Carter Lake. This is less of a factor for Horsetooth Reservoir than Carter Lake because there is less Windy Gap demand north of Horsetooth versus south of Carter Lake.

Occasionally, Horsetooth Reservoir contents under No Action would be up to 2 feet lower than Existing Conditions. This would be due to differences in instantaneous deliveries out of Horsetooth Reservoir. The chance of a decrease in Horsetooth of as much as 2 feet in any given year would be about 10 percent.

Ralph Price Reservoir. Changes to Ralph Price Reservoir storage would occur only under the No Action alternative. It was assumed that operations of the existing storage of about 16,200 AF would not change (except for evaporation losses) due to the enlargement. Fluctuations in reservoir storage associated with the 13,000 AF of additional storage would be due to evaporation, exchanges of Windy Gap water to storage and Windy Gap releases to meet Longmont’s demands (Figure 30). Figure 30 does not include the existing storage in Ralph Price Reservoir.

Figure 30. No Action Alternative-Ralph Price Reservoir average, wet, and dry year daily contents for 13,000 AF of new storage.



7.4.2. Ground Water Hydrology and Quality

7.4.2.1. West Slope Reservoirs

Existing annual variation in the level of Lake Granby of up to nearly 90 feet is much greater than the maximum 18 foot change that would occur under the No Action alternative. Water levels in some shallow wells near the lake may be connected to lake levels; however, it is probable that much of the ground water adjacent to the lake is from topographically higher areas surrounding the lake rather than from Lake Granby. As discussed in Section 7.2.2, and because water quality changes to these reservoirs as a result of the WGFP are predicted to be small, it is expected that there would be no effect to ground water quality.

7.4.2.2. West Slope Streams

Changes in flow and the resulting stage changes are considered to be minor with respect to potential effects to adjacent ground water levels. The changes in river stage under No Action would not result in measurable effects to ground water levels. As discussed in Section 7.2.2, and because predicted water quality changes to these streams as a result of the WGFP are predicted to be small, it is expected that there would be only minor effects to alluvial ground water quality along the Colorado River and no effects to ground water quality near Willow Creek.

7.4.2.3. East Slope Reservoirs

The maximum predicted decrease in the elevation of Carter Lake would be 7 feet and in Horsetooth Reservoir would be 2 feet. Potential effects to ground water levels near Carter

Lake, Horsetooth Reservoir, and Ralph Price Reservoir would be expected to be minor for the reasons discussed in Section 7.2.1. As discussed in Section 7.2.2, and because water quality changes to these reservoirs as a result of the WGFP are predicted to be small, it is expected that there would not be any effect to ground water quality.

7.4.2.4. East Slope Streams

Because the average monthly stage change in the Big Thompson River between Lake Estes and the Hansen Feeder Canal under No Action would be less than 0.01 foot (Table E-1), effects to alluvial or bedrock ground water would be negligible. For the other East Slope streams affected by changing return flows from Participants' WWTPs, because stage changes are expected to be small, increases in alluvial ground water levels would likely be unmeasurable. As discussed in Section 7.2.2, it is expected that ground water quality would not be affected near the foothill streams (North St. Vrain Creek, St. Vrain Creek at Lyons and Big Thompson River below Lake Estes to the Hansen Feeder Canal). For the other East Slope streams, there may be minor changes to alluvial ground water quality near the streams.

7.4.3. Stream Morphology and Sedimentation

7.4.3.1. West Slope Streams

Colorado River. Evaluation and modeling of the effects to the Colorado River for the 1981 Windy Gap Project EIS (USDI 1981) showed that with a proposed average withdrawal of 56,000 AF per year of water at Windy Gap Reservoir, no significant increases in sediment transport or the rate of sediment deposition would occur downstream of the diversion (Ward and Eckhardt 1981). Ward and Eckhardt's study (1981) is still relevant despite its early publication because the reductions in streamflow for the Windy Gap Project were greater than would occur under No Action and thus, the sediment transport rate of the river far exceeds the sediment supply to the river and no aggradation of the channel is likely. Although the number of pumping days and daily pumping rates evaluated in the original Windy Gap EIS were different than what was used for the present evaluation, the average annual diversion was greater in the earlier study than would occur under the No Action alternative (43,600 AF per year). The previous study concluded that the required flushing periodic flow[2] of 450 cfs below Windy Gap Reservoir for 50 hours during the period from April 1 to June 30 every three years should be sufficient to transport fine sediments (Ward 1981). The occurrence of flows equal to or greater than 450 cfs for Existing Conditions and the alternatives is shown for wet and average years (Table 23).

[2] Per June 23, 1980 MOU between the Municipal Subdistrict, Northern Colorado River Water Conservancy District, NCWCD, and the CDOW.

Table 23. Flushing flows in the Colorado River below Windy Gap Reservoir.

	Wet Year (10 % of all years)		Average Year	
	Period of flow 450 cfs or greater	Number of days of flow 450 cfs or greater	Period of flow 450 cfs or greater	Number of days of flow 450 cfs or greater
Existing Conditions	May 3-Aug 13	103	May 30-July 13	45
No Action (Alt 1)	May 3-Aug 4	94	May 30-July 6	38
Proposed Action (Alt 2)	May 5-Aug 3	93	May 31-July 5	36
Alternatives 3 to 5	May 5-Aug 3	93	May 31-July 4	35

Flow duration curves, which have been derived from daily flow changes, provide a comparison between Existing Conditions and No Action for the two USGS gages located at Hot Sulphur Springs and near Kremmling (Figure B-1 and Figure B-2). By comparing the flow duration curves, the maximum difference between Existing Conditions and No Action for a given exceedance percentage can be determined. Because many of the morphologic characteristics of a channel are formed when a stream flows at its bankfull discharge (1½- to 2-year peak flow) (Rosgen 1996), differences shown on the flow duration curves between Existing Conditions and the alternatives that are lower than the bankfull discharge would have minimal effects on channel morphology. At Hot Sulphur Springs, the 2-year peak discharge was estimated to be 923 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 3.3 percent of the time (percentage of days during the study period). At the gage near Kremmling, the 2-year peak discharge was estimated to be 2,850 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 3 percent of the time.

Under No Action, the 2-year peak discharge at the Hot Sulphur Springs gage would be exceeded about 3 percent of the time, or 1 percent less than under Existing Conditions. The 2-year peak discharge at the gage near Kremmling would be exceeded only slightly less than 3 percent of the time (less than a 1 percent difference from Existing Conditions). The slight reduction in the percentage of time that the 2-year peak discharge would be exceeded at the two gage sites below the Windy Gap diversion is unlikely to significantly affect stream morphology or change sediment transport or deposition.

As discussed in Section 6.6, another method to evaluate stream channel morphology is to compare changes in the range of channel maintenance flows (Schmidt and Potyondy 2004). This analysis has been completed using daily flows for Existing Conditions and the alternatives (Table D-19). At Hot Sulphur Springs, the lower limit of channel maintenance flows, defined as 80 percent of the 1.5-year peak flow, was calculated to be 510 cfs. Under Existing Conditions, a flow of at least 510 cfs occurred for 23 days on average (in years when such flows occurred), with a 62 percent chance of occurrence in any given year (Table D-19). Under No Action, flows of at least 510 cfs occurred for 21 days on average (in years when such flows occurred), with a 53 percent chance of occurrence in any given year. The upper limit of channel maintenance flows is defined as the 25-year peak flow; such a flow occurred only once under Existing Conditions, but not under modeling of the No Action alternative. Ten-year peak flows or greater (4,600 cfs or more) occurred under Existing Conditions for 4 days on average (in years when such flows occurred) and under No Action for 4.2 days on average (in years when such flows occurred), with a 13 percent chance of occurrence in any given year under Existing Conditions and an 11 percent chance of occurrence in any given year under No Action. In general, channel maintenance flows would occur about 1 percent less frequently under No Action than Existing Conditions, but the duration of such flows in a year when channel maintenance flows occur could be slightly longer. The differences in channel maintenance flows between Existing Conditions and No Action are minor and are not expected to alter channel morphology or sediment movement at Hot Sulphur Springs.

The magnitude, timing and frequency of channel maintenance flows in the Colorado River below Lake Granby would change as a result of changes in spills. When spills are not occurring, the flow of the river below Lake Granby is controlled by bypass flows; it is difficult, therefore, to define a range of channel maintenance flows based on peak flow events. A comparison of modeled spill events, based on changes in daily flows, is provided in Table D-4. Under No Action, there would be two less spill events, but flows of 510 cfs or more (the low range of channel maintenance flows at Hot Sulphur Springs) would continue to occur for periods of 1 to 4 months. Flows over 2,500 cfs would occur during 21 percent of all years, compared to 28 percent of all years under Existing Conditions. These differences are minor and are not expected to alter channel morphology or sediment movement in the Colorado River below Lake Granby. The range in streamflows under No Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment.

Willow Creek. The flow duration curve for Willow Creek provides a comparison between Existing Conditions and No Action for the USGS gage located below Willow Creek Reservoir (Figure B-3). The 2-year peak discharge was estimated to be 80 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 5 percent of the time. Under the No Action alternative, the 2-year peak discharge would be exceeded slightly less than under Existing Conditions (less than a 1 percent change); therefore, it is unlikely that there would be a significant affect to stream morphology or change in sediment transport or deposition.

7.4.3.2. East Slope Streams

North St. Vrain and St. Vrain Creeks. Under the No Action alternative, streamflows in the reach between Ralph Price Reservoir and the St. Vrain Supply Canal would change due to exchanges of Windy Gap water to storage in Ralph Price Reservoir and releases from Ralph Price Reservoir to meet Longmont's future Windy Gap demands. Streamflow in North St. Vrain Creek between Ralph Price Reservoir and Longmont Reservoir would change by less than 20 percent during nine months of the year, but in the low flow months of September and October flows would be expected to increase by 43 and 67 percent, respectively (Table 22). The largest flow decrease (25 percent) would occur in July when snowmelt flows typically are decreasing. In the North St. Vrain below Longmont Reservoir, there would be no flow changes or very small flow changes in 8 months of the year, but in September and November, flows would be expected to increase by 67 and 90 percent, respectively (Table 22). The largest flow decrease (27 percent) would occur in July. The larger flow changes occurring in North St. Vrain Creek are unlikely to alter the morphology of the stream and affect sediment movement because the North St. Vrain Creek channel, like many foothill creeks, has a channel that is stabilized by bedrock or boulders. The boulders and other large sediment tend to move only during flood events. In addition, the largest percent flow changes that would occur in September and October (less than 20 cfs) are much less than the high flows that typically occur during the spring and summer months each year.

Big Thompson River. Under the No Action alternative, flow increases in the Big Thompson River from Lake Estes to the Hansen Feeder Canal would occur in June and July, but would be 1 percent or less of average existing monthly flows (Table D-8 and Table D-9). This minor change in flow would be well within the historical range of flows and is unlikely to affect stream morphology or sedimentation.

Streams that Receive Windy Gap Return Flows. The predicted streamflow increases for the East Slope stream segments that receive Windy Gap return flows (Big Dry Creek, Coal Creek, St. Vrain Creek, and Big Thompson River) are unlikely to substantially alter stream morphology and sedimentation because the increased flows would be small compared to the spring and early summer flows that these channels have the capacity for. In addition, as described in Section 6.6, streams on the East Slope have not experienced natural streamflow conditions for more than 100 years, and are not in equilibrium with respect to channel forming and channel moving processes, erosion, or sediment loading, movement and deposition. Given the magnitude of the flow increases (less than 9 cfs), it would be difficult to measurably differentiate changes to stream morphology and sedimentation due to changes in Participants' WWTP return flows from the many other ongoing actions influencing East Slope streamflow conditions.

7.5. Alternative 2 (Chimney Hollow Reservoir with Prepositioning)—Proposed Action

Chimney Hollow with prepositioning includes approximately 90,000 AF of storage at the Chimney Hollow site on the East Slope. This alternative includes prepositioning, which is a method of operation intended to facilitate delivery of Windy Gap water to the East Slope. Prepositioning involves use of available Adams Tunnel capacity to deliver C-BT water to Chimney Hollow to occupy storage space that is not occupied by Windy Gap water. Delivery of C-BT water to Chimney Hollow in this manner would maintain Chimney Hollow essentially full at all times. Delivery of C-BT water from Lake Granby into Chimney Hollow would create space for Windy Gap water in Lake Granby. When Windy Gap water is diverted into Lake Granby, the C-BT water in Chimney Hollow would be exchanged for a like amount of Windy Gap water in Lake Granby. This operation would relieve the need to deliver Windy Gap water through Adams Tunnel to Chimney Hollow during the diversion season because this operation would be accomplished via an exchange instead.

The general goal for filling and releasing Windy Gap water from Chimney Hollow and Lake Granby would be to deliver Windy Gap water to Chimney Hollow by exchange as soon as possible to minimize Windy Gap spills from Lake Granby. Deliveries to Participants would be made first from Lake Granby via instantaneous delivery. When no water is available in Lake Granby, water previously delivered to Participant's accounts in Chimney Hollow would be released to meet demands.

7.5.1. Surface Water Hydrology

7.5.1.1. C-BT and Windy Gap Project Operations and Diversions

Adams Tunnel Diversions. Adams Tunnel diversions to the East Slope include C-BT deliveries to Carter Lake, Horsetooth Reservoir, and Chimney Hollow (for prepositioning), C-BT deliveries to meet C-BT demands above Flatiron Reservoir and along the Big Thompson River, and Windy Gap instantaneous deliveries to meet Participants demands (i.e., C-BT deliveries to meet Windy Gap demands exchanged for Windy Gap supplies in Lake Granby). Windy Gap deliveries from Lake Granby to meet demands are made via instantaneous delivery; therefore, in the model, they are reflected as C-BT deliveries through the tunnel to replace releases made from Carter Lake or Horsetooth Reservoir. Instantaneous deliveries are included as Windy Gap deliveries through the Adams Tunnel in Tables 18, 19, and 20.

Average annual Adams Tunnel deliveries would be approximately 243,000 AF under Existing Conditions, and 254,000 AF under No Action versus 262,000 AF under Alternative 2 (Table 18). Average monthly deliveries through the Adams Tunnel under the Proposed Action would be generally higher than Existing Conditions and No Action because of C-BT deliveries to Chimney Hollow and instantaneous deliveries to meet Windy Gap demands (Table D-2). Average annual C-BT deliveries to the East Slope under the Proposed Action would be about 500 AF less than Existing Conditions and 300 AF less than No Action. Deliveries through the tunnel would be greatest from December through June as C-BT water is delivered to Carter Lake, Horsetooth, and Chimney Hollow to refill those reservoirs and meet storage targets (Table D-2). Typically Carter Lake is filled by the end of May and Horsetooth Reservoir by the end of June, after which Adams Tunnel deliveries decrease. The Adams Tunnel is typically shut down for maintenance during the last two weeks in October, first two weeks in November, last week in March and first two weeks in April. Therefore, total Adams Tunnel deliveries in those months would typically be less than other months because of these outages. In addition, Reclamation indicated that maintenance on the Adams Tunnel may increase by about 10 percent with a firming project on-line. To reflect this additional maintenance requirement, the Adams Tunnel was modeled as being down for an additional 3.5 days in March for each of the alternatives. Therefore, the Adams Tunnel capacity in March for the Proposed Action would be approximately 3,800 AF less than Existing Conditions and No Action because of the additional tunnel outage anticipated.

The monthly amounts of C-BT water delivered to Chimney Hollow would be relatively constant and generally coincide with the amount of Windy Gap water released to meet Participant demands, which would range from about 1,000 AF to 2,400 AF per month throughout the year. Differences in deliveries to meet Windy Gap demands would occur because the monthly demand would be different or because Windy Gap contents in Lake Granby would be different. Average monthly tunnel deliveries under the Proposed Action would be approximately 1,590 AF higher than Existing Conditions and 690 AF higher than No Action; however, deliveries would be lower by about 4,600 AF on average when maintenance is occurring to the tunnel in March. Differences in tunnel deliveries would be minimal in February, April, and June because C-BT operations typically require the full tunnel capacity in those months. For example, there would be minimal difference in tunnel deliveries in June because the tunnel is typically at capacity in combination with C-BT diversions from the Big Thompson River at Olympus Tunnel. In almost every June, the Olympus Tunnel, which includes Adams Tunnel deliveries and C-BT diversions from the Big Thompson River, is full due to C-BT operations. As a result, there would be minimal capacity available for Windy Gap operations in June, and therefore, almost no difference among the alternatives in that month.

Average monthly deliveries through the tunnel would be slightly higher from September through January under the Proposed Action than other action alternatives because of C-BT deliveries from Lake Granby to Chimney Hollow for prepositioning. Under the other alternatives, Windy Gap deliveries through the tunnel during the winter months would be more sporadic and only made to meet Windy Gap demands if Windy Gap water is available in either Jasper East or Rockwell/Mueller Creek reservoirs.

Dry year average annual Adams tunnel deliveries would be approximately 314,000 AF under Existing Conditions and 316,000 AF under No Action versus 333,000 AF under the Proposed Action (Table 19). In general, Adams Tunnel deliveries would be higher in dry years than average and wet years primarily because C-BT deliveries to the East Slope would be higher. In dry years, the C-BT quota would typically be higher, and as a result deliveries from the West Slope to meet C-BT demands would be higher. Carter Lake and Horsetooth Reservoir also would be drawn upon more heavily to meet C-BT demands, so more water would be delivered to the East Slope to refill those reservoirs. In the five dry years evaluated (1954, 1966, 1977, 1981, and 1989), the average C-BT quota was 100 percent versus an average of about 75 percent for the whole period of record. Similar to average conditions, monthly differences in Adams Tunnel deliveries in dry years would be a function of C-BT deliveries to Chimney Hollow, instantaneous deliveries to meet Windy Gap demands, and maintenance operations in March. Differences in instantaneous deliveries to meet Windy Gap demands would occur because the monthly demand is different or because Windy Gap contents in Lake Granby are different. Differences in August and September would also be due to additional C-BT deliveries to Carter Lake and Horsetooth Reservoir to meet storage targets under the Proposed Action. Reservoir contents in Carter Lake and particularly Horsetooth Reservoir would be less under the Proposed Action in dry years because of additional C-BT deliveries made to Chimney Hollow in previous months. The tunnel capacity available for deliveries to Carter Lake and Horsetooth Reservoir would be more limited in dry years, primarily during the runoff season. There would generally be more tunnel capacity available in August and September; therefore, additional deliveries would be made from Lake Granby to Carter Lake and Horsetooth Reservoir to meet storage targets in those months. There would be little to no difference in February, April, May, June, July and October in dry years because the Adams Tunnel would be operating at capacity in combination with the Olympus Tunnel in all of those months. In dry years, C-BT deliveries would be about 800 AF higher under the Proposed Action than Existing Conditions, and about 500 AF higher than No Action (Table 19). In addition, Windy Gap deliveries would be approximately 18,220 AF higher under the Proposed Action than Existing Conditions, and about 16,500 AF higher than No Action (Table 19). Windy Gap deliveries through the Adams Tunnel are higher in an average dry year under the Proposed Action due to deliveries to Chimney Hollow to maintain that reservoir full. C-BT deliveries to Chimney Hollow are counted as Windy Gap deliveries through the Adams Tunnel because that water is later exchanged for Windy Gap water diverted to Lake Granby. Windy Gap does not divert any more water in a dry year under the Proposed Action compared to Existing Conditions and No Action; however, because there is less Windy Gap water available in a dry year, more water is delivered through the tunnel to maintain Chimney Hollow full.

Wet year average annual Adams Tunnel deliveries would be approximately 181,000 AF under Existing Conditions and 197,000 AF under No Action versus 192,000 AF under the Proposed Action (Table 20). In general, Adams Tunnel deliveries would be lower in wet years than average and dry years primarily because C-BT deliveries to the East Slope would be lower. In wet years, the C-BT quota would generally be lower and as a result, deliveries from the West Slope to meet C-BT demands and refill Carter Lake and Horsetooth Reservoir would be lower. C-BT deliveries to the East Slope via the Adams Tunnel also would be less because C-BT diversions from the Big Thompson River would be higher in wet years. In wet years, C-BT water would be diverted from the Big Thompson River into the Olympus Tunnel and delivered to storage in Carter Lake and/or Horsetooth Reservoir. This would reduce the need to deliver C-BT water from the West Slope to Carter Lake and Horsetooth Reservoir and is the reason Adams Tunnel deliveries would be low in June, July and August.

In wet years, tunnel deliveries would be lowest under Existing Conditions because in all five wet years evaluated, Lake Granby fills by June and all Windy Gap water is spilled, resulting in little to no instantaneous Windy Gap delivery to meet demand. From May through January, tunnel deliveries under the Proposed Action would be generally higher than Existing Conditions and No Action. Differences in those months typically coincide with C-BT diversions to Chimney Hollow and differences in instantaneous Windy Gap deliveries because the monthly demand would be different or Windy Gap contents in Lake Granby would be different. C-BT deliveries through the Adams Tunnel would be almost 7,000 AF lower under the Proposed Action than Existing Conditions and about 5,500 AF lower than No Action (Table 20).

Windy Gap Diversions. Under the Proposed Action, Windy Gap diversions would be delivered to Lake Granby and exchanged with C-BT water in Chimney Hollow Reservoir. This would relieve the need to deliver Windy Gap water through Adams Tunnel to Chimney Hollow during the diversion season because this operation would be accomplished via an exchange instead.

Windy Gap diversions would be constrained by several factors, including

- Downstream senior water right calls and instream flow requirements
- Decree limitations
- Physical supply
- Pump station and Windy Gap pipeline conveyance limitations
- Available space in Lake Granby
- Available space in the Firming Project reservoirs
- Available space in Adams Tunnel

The degree to which these constraints apply (timing and amount) would vary among the alternatives, resulting in differences in Windy Gap diversions. More details on the specific decree limitations and instream flow requirements defined by the Windy Gap water rights decrees and the Azure Settlement Agreement are provided in the WGFP Modeling Report (Boyle 2003) and the WGFP Modeling Report Addendum (Boyle 2006a).

Average annual Windy Gap diversions would be approximately 36,500 AF under Existing Conditions and 43,600 AF under No Action versus 46,100 AF under the Proposed Action (Table 18). Average monthly Windy Gap diversions would be greatest in May and then June for the Proposed Action and all alternatives (Table D-3). While physically and legally available supplies might be greater in June than May, Windy Gap diversions would more often be constrained by available capacity in Lake Granby, the Adams Tunnel, and the firming reservoirs in June than May, particularly in wet years. Differences in Windy Gap diversions among alternatives would occur only when there are differences in the amount of storage space or tunnel space available, differences in Lake Granby spills (Table D-4), or WCFC diversions, which affect the flow available for pumping at Windy Gap Reservoir. Average monthly differences between Existing Conditions and the Proposed Action would be greatest in June and July, which coincides with months that Lake Granby would typically be full in wet years. Under Existing Conditions, Windy Gap would not divert when Lake Granby is full in wet years. However, under the Proposed Action, delivery of C-BT water from Lake Granby to Chimney Hollow would create space for Windy Gap water in Lake Granby. This would enable Windy Gap to divert additional water in wet years when Lake Granby is typically full under Existing Conditions. Average Windy Gap diversions under No Action would be less than the Proposed Action in May and June because there would be only 13,000 AF available at Ralph Price Reservoir for storage of Longmont's Windy Gap water and Windy Gap water must be delivered through Adams Tunnel. In comparison, there would be about 90,000 AF of storage at Chimney Hollow and Windy Gap water would not need to be physically delivered through the tunnel. Windy Gap diversions under No Action would be higher than the Proposed Action in July and August due to differences in wet year diversions, as explained in Section 7.4.1.1.

In dry years, average monthly Windy Gap diversions would be relatively low in comparison with average and wet year diversions and there would be no difference among the alternatives (Table 19). In dry years, Windy Gap diversions would be limited by the physically and legally available supply in the Colorado River, which would not vary among alternatives. Available space in Lake Granby and the firming project reservoirs would not be limiting factors. As a result, there would be no difference in Windy Gap diversions between Existing Conditions, No Action, and the Proposed Action.

During wet years, Windy Gap diversions would be approximately 38,500 AF under Existing Conditions and 63,900 AF under No Action versus 73,900 AF under the Proposed Action (Table 20). Wet year average Windy Gap diversions under the Proposed Action would be considerably higher than both Existing Conditions and No Action in May, June, and July (Table D-3). Wet year Windy Gap diversions in May and June would often be limited by available space in Lake Granby under Existing Conditions and No Action, whereas under the Proposed Action additional Windy Gap would be diverted to Lake Granby in those months to the extent there is space in Lake Granby created by delivery of C-BT water to Chimney Hollow Reservoir. Monthly differences between Existing Conditions and the Proposed Action would be greatest in July (Table D-3). In the wet years evaluated, Lake Granby would be full or would fill by the end of July; therefore, Windy Gap diversions under

Existing Conditions would be minimal in July. Similarly, Lake Granby would be full in August in all of the wet years selected under Existing Conditions; therefore, wet year average Windy Gap diversions would be zero in August. However, with Chimney Hollow, Windy Gap could divert in July and August to the extent there is space in Lake Granby created by delivery of C-BT water to Chimney Hollow.

Willow Creek Feeder Canal Diversions. Average annual WCFC diversions would be approximately 36,200 AF under Existing Conditions and 37,500 AF under No Action versus 38,800 AF under the Proposed Action (Table 18). Under average and wet conditions, there would be differences in WCFC diversions between Existing Conditions, No Action and the Proposed Action primarily during the runoff season in June, July and August. Under the Proposed Action, WCFC diversions would increase primarily during the runoff season in June, July, and August; therefore, Willow Creek flows would decrease in the same months. Increases in WCFC diversions would occur when Lake Granby fills. Under the modeled Existing Conditions, more Windy Gap water in Lake Granby would be exchanged with C-BT water, as opposed to pumping water from Willow Creek, because Windy Gap storage contents would be typically higher under Existing Conditions than the Proposed Action. WCFC diversions versus exchanges with Windy Gap water would be higher under the Proposed Action, resulting in lower flows in Willow Creek at the mouth versus both Existing Conditions and No Action. The difference in WCFC diversions among alternatives may be overestimated because the WGFP model does not forecast Lake Granby spills (see Section 7.4.1.1).

Lake Granby Spills. C-BT storage in Lake Granby takes precedence over Windy Gap storage. When Lake Granby fills, the first water spilled is Windy Gap water in proportion to the amounts in each account; the MPWCD account spills next, and finally the C-BT account spills if necessary.

Average annual Lake Granby spills would be greatest under Existing Conditions and No Action and least under the Proposed Action. Average annual Lake Granby spills would be approximately 38,700 AF under Existing Conditions and 35,400 AF under No Action versus 28,600 AF under the Proposed Action (Table D-1). Lake Granby generally only spills in wet years; there would be no spills in dry years for the Proposed Action and other alternatives. Under the modeled Existing Conditions, Windy Gap water would only be stored in Lake Granby and Windy Gap demands would be lower than under No Action and the Proposed Action. As a result, Windy Gap contents in Lake Granby would be generally higher; consequently, more Windy Gap water would be spilled. There could also be differences in C-BT spills among alternatives to the degree that C-BT contents in Lake Granby would be different. There would be differences in C-BT contents in Lake Granby among alternatives due to variations in Windy Gap operations, including the amounts of Windy Gap shrink paid to the C-BT Project, instantaneous deliveries, and prepositioning.

Windy Gap spills under the Proposed Action would be less than Existing Conditions, No Action and the other alternatives because storage of each Participant's Windy Gap water in Lake Granby would be protected from spilling to the degree that there is C-BT water in their storage account in Chimney Hollow. Participants could store Windy Gap water in Lake Granby if their Chimney Hollow account is full of Windy Gap water; however, this water is subject to spilling by the C-BT Project. Any Participant's Windy Gap water stored in unprotected space (subject to spilling) would be reallocated among Participants that have protected space available when Lake Granby fills, as opposed to spilling Windy Gap water and pumping it back up to Lake Granby. Windy Gap water that is protected from spilling would be exchanged with C-BT storage in Chimney Hollow as soon as it is diverted to Lake Granby. Diversions of Windy Gap water to Lake Granby in this manner and reallocation of Windy Gap water in unprotected space to protected space when Granby fills would minimize Windy Gap spills. Under Alternatives 3, 4, and 5, Participants' Windy Gap water would be stored in Lake Granby when West Slope firming storage and the Adams Tunnel are full. All this Windy Gap water would be subject to spill by the C-BT Project resulting in greater spills of Windy Gap water from Lake Granby.

C-BT Diversions from the Big Thompson River. Average annual Big Thompson River diversions would be approximately 28,000 AF under Existing Conditions and 27,600 AF under No Action versus 25,000 AF under the Proposed Action (Table 18). Differences in Big Thompson River diversions would be due primarily to differences in diversions for power generation (skim diversions). Skim diversions are modeled as the last C-BT operation to occur each month; therefore, differences in skim diversions could occur when available capacity in the Olympus Tunnel is limiting. Under the Proposed Action, C-BT deliveries to Chimney Hollow would reduce the capacity in the Olympus Tunnel in comparison with Existing Conditions and No Action, which would result in lower skim diversions. C-BT diversions from Lake Granby and the Big Thompson River to storage in Carter Lake and Horsetooth Reservoir also affect the available capacity in the Olympus Tunnel. To the degree that there are differences in Carter Lake and Horsetooth contents among alternatives, C-BT deliveries to these reservoirs to meet storage targets could vary, which could cause differences in skim diversions if available capacity in Olympus Tunnel is affected and limiting. In general, monthly differences in skim diversions in average, wet and dry years would be relatively small (Table D-5).

The only difference in dry year average Big Thompson River diversions would be in July. Dry year average monthly diversions in July would be approximately 550 AF under Existing Conditions versus 0 AF under the Proposed Action (Table D-5). In those years, C-BT diversions from Lake Granby to Chimney Hollow, Carter Lake and/or Horsetooth Reservoir would fill the Adams and Olympus Tunnels under the Proposed Action. Because these C-BT operations take precedence over skim diversions, there would be no capacity remaining in the Olympus Tunnel for skim diversions in dry years under the Proposed Action.

7.5.1.2. West Slope Streams

Colorado River below Lake Granby. Under average and wet conditions, variations in flows below Lake Granby among the alternatives would be a function of differences in the timing and amount of Lake Granby spills. Differences in flows below Lake Granby measured above Windy Gap Reservoir would be greatest in June, July and August, which are months when Lake Granby typically spills. Table D-1 provides average monthly spills and Table D-12 provides average monthly river flows; however, it must be recognized that during spill periods (usually May through August, but also infrequently in September and October) the range of flows is and would be widely variable. Windy Gap spills under the Proposed Action would be less than Existing Conditions, No Action, and the other alternatives because

Participants' Windy Gap water in Lake Granby would be protected from spilling to the extent there would be C-BT water stored in Chimney Hollow Reservoir. When total C-BT contents in Lake Granby and Chimney Hollow combined reaches 539,568 AF, which is the physical capacity of Lake Granby, C-BT would have to bypass water at Lake Granby. This would prevent the C-BT Project from storing more water in Lake Granby than it could without prepositioning and spilling "protected" Windy Gap Participant water. Windy Gap water in Lake Granby would also be immediately exchanged with C-BT water in Chimney Hollow Reservoir, in which case deliveries to Chimney Hollow would not be dependent on available capacity in the Adams Tunnel. These operations would reduce Windy Gap spills; therefore, average monthly flows below Lake Granby would be lowest under the Proposed Action. Bypass flow requirements below Lake Granby would be maintained for the Proposed Action and all alternatives.

Lake Granby C-BT spills also would be slightly different among the alternatives because of variations in Windy Gap operations including the amounts of Windy Gap shrink (diversions shrink, reintroduction shrink and carryover shrink) paid to the C-BT project, instantaneous deliveries, and prepositioning. For example, Windy Gap diversions would be different among the alternatives, so the amount of diversion shrink paid to the C-BT project would also be different. For the Proposed Action, shrink would be paid when Windy Gap water is initially diverted to Lake Granby and exchanged into Chimney Hollow and again when it is reintroduced into the C-BT system (reintroduction shrink). However, shrink would not be paid on Windy Gap diversions to Jasper East or Rockwell/Mueller Creek reservoirs under Alternatives 3, 4, and 5. Shrink would only be paid once deliveries are made from these West Slope reservoirs and introduced into the C-BT system. Variations in the amount of shrink paid to the C-BT project would result in variations in C-BT contents in Lake Granby and, potentially, variations in spills. However, the differences in C-BT spills and their effect on flows below Lake Granby would be less in comparison with Windy Gap spills.

In years when Lake Granby is not spilling, the flows in the Colorado River below Lake Granby would continue to equal the bypass flow requirements. During the winter months (November through April), the average monthly flow below Lake Granby would be 20 cfs under average, wet and dry conditions (Table D-12). During dry years, the average flows below Lake Granby during the runoff season from May through August would equal the bypass flow requirements. The Windy Gap Firming Project Modeling Report (Boyle 2003) provides a discussion of reduced bypass flow requirements in dry years.

In wet years, prepositioning limits on total C-BT contents in Lake Granby and Chimney Hollow would result in slightly higher Lake Granby spills and flows below Lake Granby in June on average under the Proposed Action than under No Action and Existing Conditions (Table D-12). In the wet years evaluated, C-BT would bypass slightly more water by Lake Granby on average in June because the combined total C-BT storage in Lake Granby and Chimney Hollow would be limited. In July, the average wet year flow below Lake Granby would be about 7,800 and 10,700 AF lower under No Action and the Proposed Action, respectively, than Existing Conditions, primarily due to lower Windy Gap contents in Lake Granby in July and consequently lower Windy Gap spills in that month. In August, the wet year average flow below Lake Granby would be about 4,800 AF lower under the Proposed

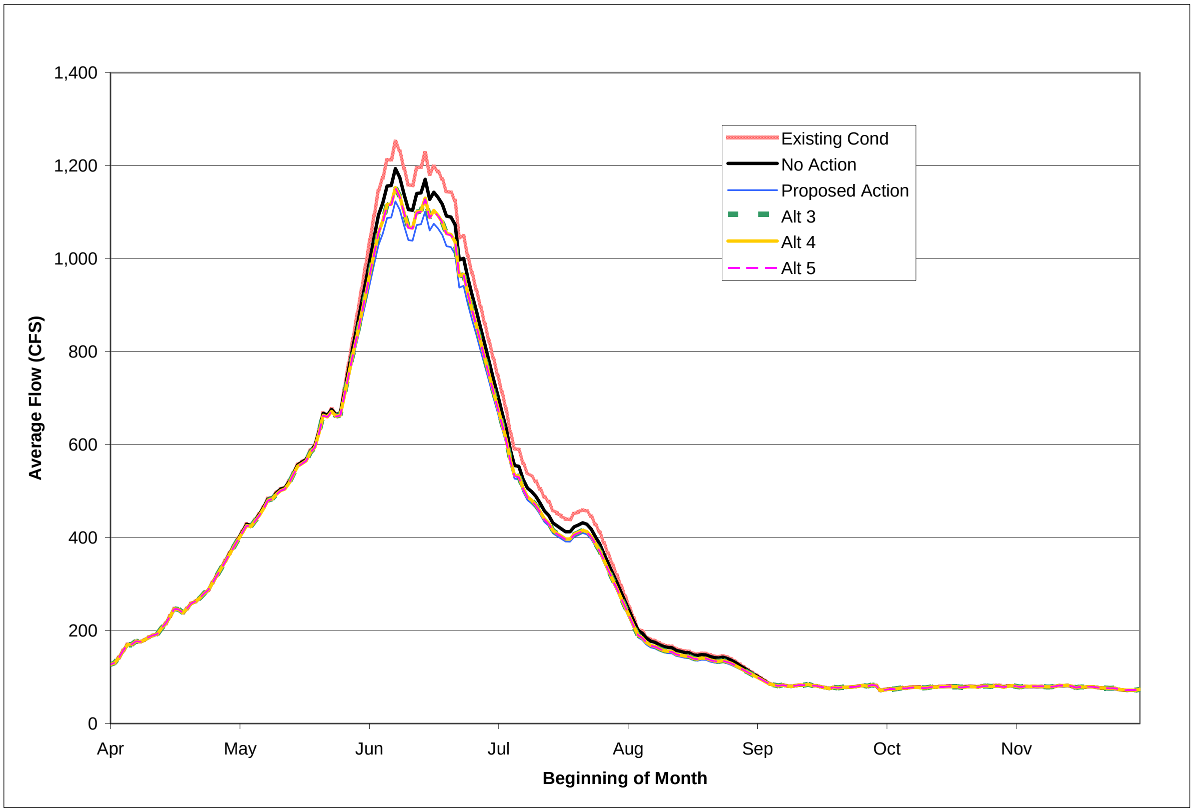
Action than both Existing Conditions and No Action primarily due to differences in Windy Gap spills.

Table D-11 provides the modeled Granby Reservoir spill periods, average spill and maximum spill for Existing Conditions and all of the alternatives. The model shows spills occurring for as short as a month (June, July or August) and up to as long as 4 months (May through August), with the most frequent spills occurring for 2 months in June through July under Existing Conditions and the Proposed Action. The spill periods and estimated flow of the river at the gage near Granby would be altered under the Proposed Action. For example, 2 month spills in June and July would be very similar to Existing Conditions, but 3 month spills from May through July would not occur under the Proposed Action.

Table 14 provides the range and percent occurrence of flow increases and decreases that would occur under the Proposed Action during May through August, the period when most Windy Gap diversions would occur. About 10 percent of the time, flow increases to the river would occur as a result of changes in the timing of spills from Lake Granby. About 76 percent of the time during those months, no changes in the flow of the Colorado River near Granby would occur. About 12 percent of the time, flow decreases of greater than 10 cfs would occur.

Colorado River above the Windy Gap Diversion. Flows in the Colorado River above Windy Gap reflect the outflow from Lake Granby, tributary inflows from Willow Creek and the Fraser River, Colorado River mainstem irrigation diversions, and ungaged gains/losses to the river including ground water irrigation return flows. Average annual Colorado River flows above Windy Gap Reservoir would be about 11,800 AF higher under Existing Conditions than the Proposed Action (Table 18). The average annual decrease in flow under the Proposed Action would be 6 percent and in a wet year would be 5 percent (Table D-13). Flow decreases would occur under the Proposed Action primarily from June to August (Figure 31). Most of the changes in streamflow result from a difference in Lake Granby spills in wet years. The largest monthly flow decrease would be 11 percent in July of an average year and 21 percent in August of a wet year. There would be no change in flow in dry years.

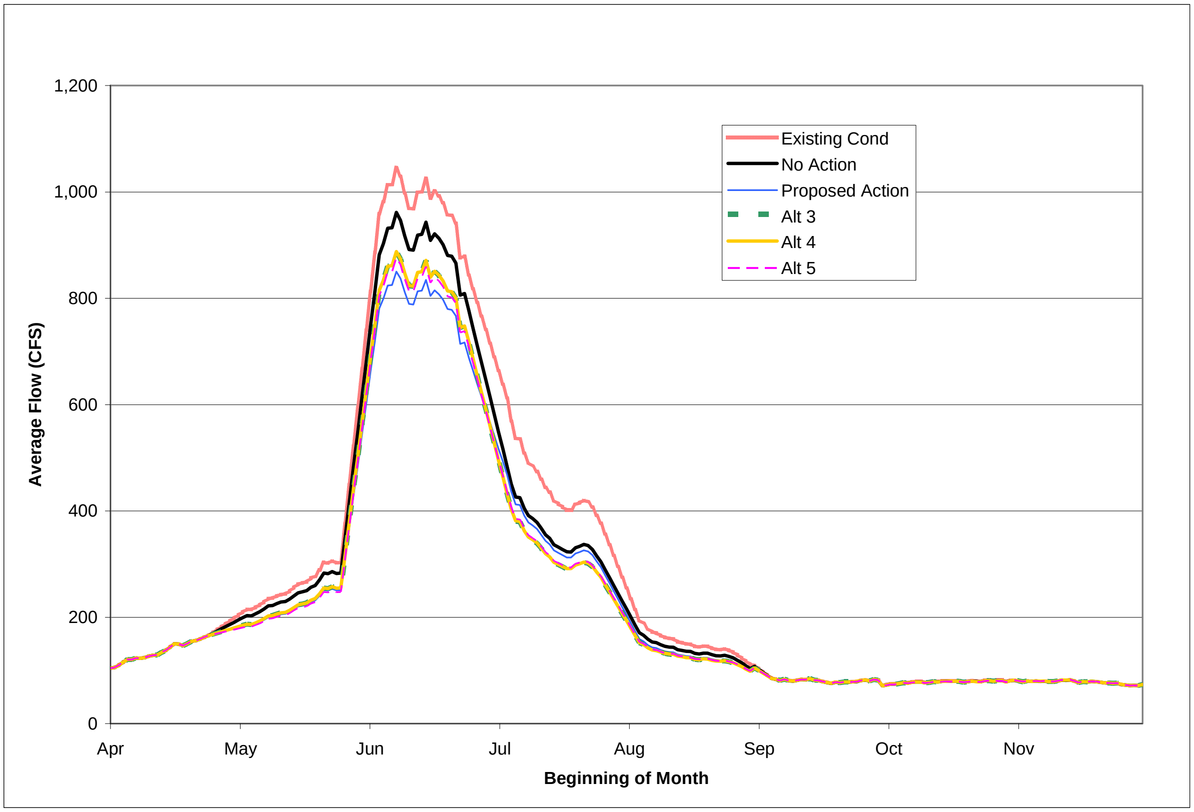
Figure 31. Average daily flows, Colorado River above Windy Gap Reservoir.



Colorado River below the Windy Gap Diversion. The largest flow reduction under the Proposed Action would occur in the Colorado River below the Windy Gap diversion to Hot Sulphur Springs. Annual average Colorado River flows below the Windy Gap diversion would be about 14 percent lower than Existing Conditions (Table 18) and about 6 percent lower than the No Action alternative. Flow decreases would occur under the Proposed Action primarily from May through August (Figure 32). The maximum monthly average flow reduction would occur in July and would be at most a 23 percent reduction in average years (Table D-14). In wet years, the greatest average percent change in flows would occur in August, with a 33 percent reduction. Similarly, there would be a 13 percent reduction (2 inches) in average river stage in July for average years and a 19 percent reduction (2.8 inches) in average river stage in wet years (Table E-2). Flow reductions for Alternatives 3, 4, and 5 would be slightly greater than the Proposed Action because of greater Windy Gap diversions.

Table 14 shows that no changes in daily flows at the Hot Sulphur Springs gage would occur 67.5 percent of the time during the May through August period when most Windy Gap diversions occur. Daily flow decreases of 1 to 100 cfs would occur about 13 percent of the time between May through August, while larger daily flow decreases would occur about 18 percent of the time during that period.

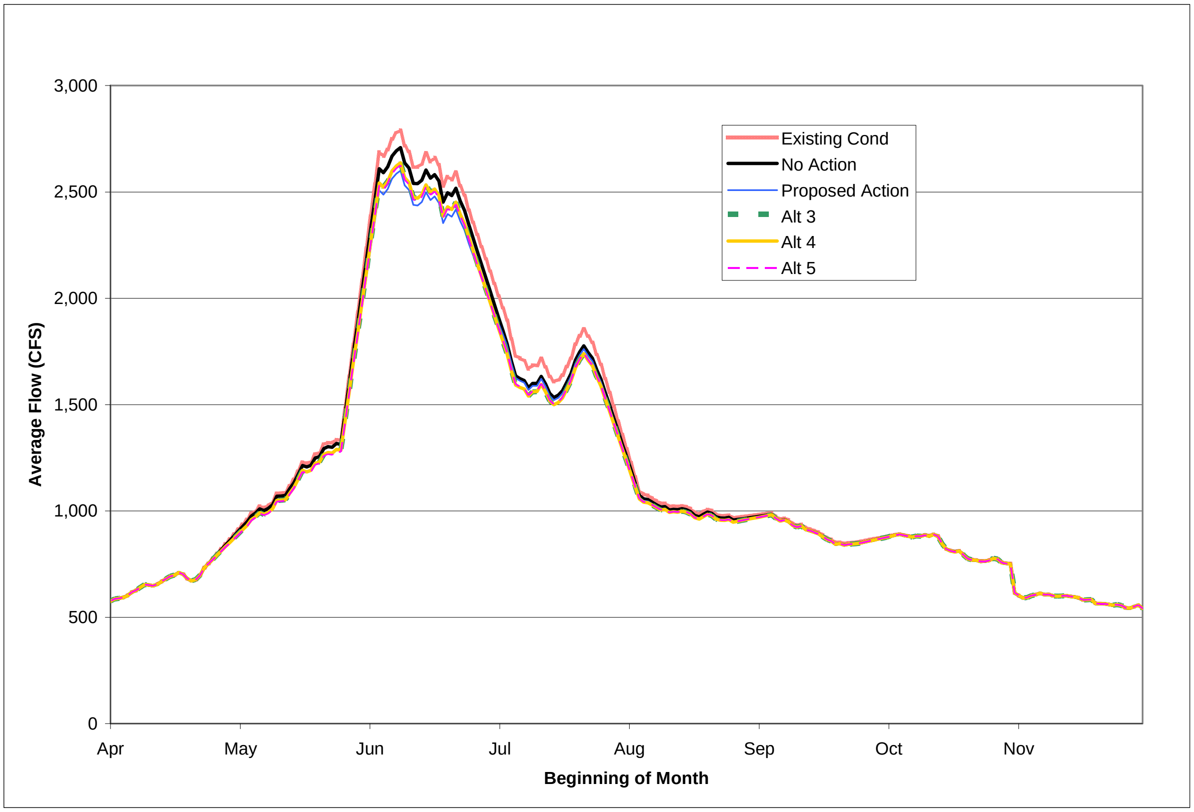
Figure 32. Average daily flows, Colorado River below Windy Gap Reservoir.



Reductions in Colorado River streamflow as a percent of total flow decrease downstream with additional inflows from Williams Fork River, Troublesome Creek, Muddy Creek, the Blue River and other smaller tributaries. Below Williams Fork River, Colorado River average annual flows would decrease by about 9 percent from Existing Conditions (Table 18) and by the top of Gore Canyon at the Kremmling gage average annual flows would decrease about 3 percent under the Proposed Action (Table 18). Average July flow reductions at the Kremmling gage would be 6 percent lower in average years and about 10 percent lower in wet years (Table D-18). Flow decreases would occur under the Proposed Action from May through September with the majority in June and July (Figure 33). The average stage changes on the Colorado River near Kremmling in July would be less than 5 percent, or 2.5 inches in average years and 5 inches in wet years (Table E-3).

At the USGS gage near Kremmling, average daily flows would not change about 68 percent of the time between May and August, the period when most Windy Gap diversions occur (Table 14). Daily flow decreases of 1 to 100 cfs would occur about 13 percent of the time during these months and daily flow decreases greater than 100 cfs would occur about 18 percent of the time between May and August.

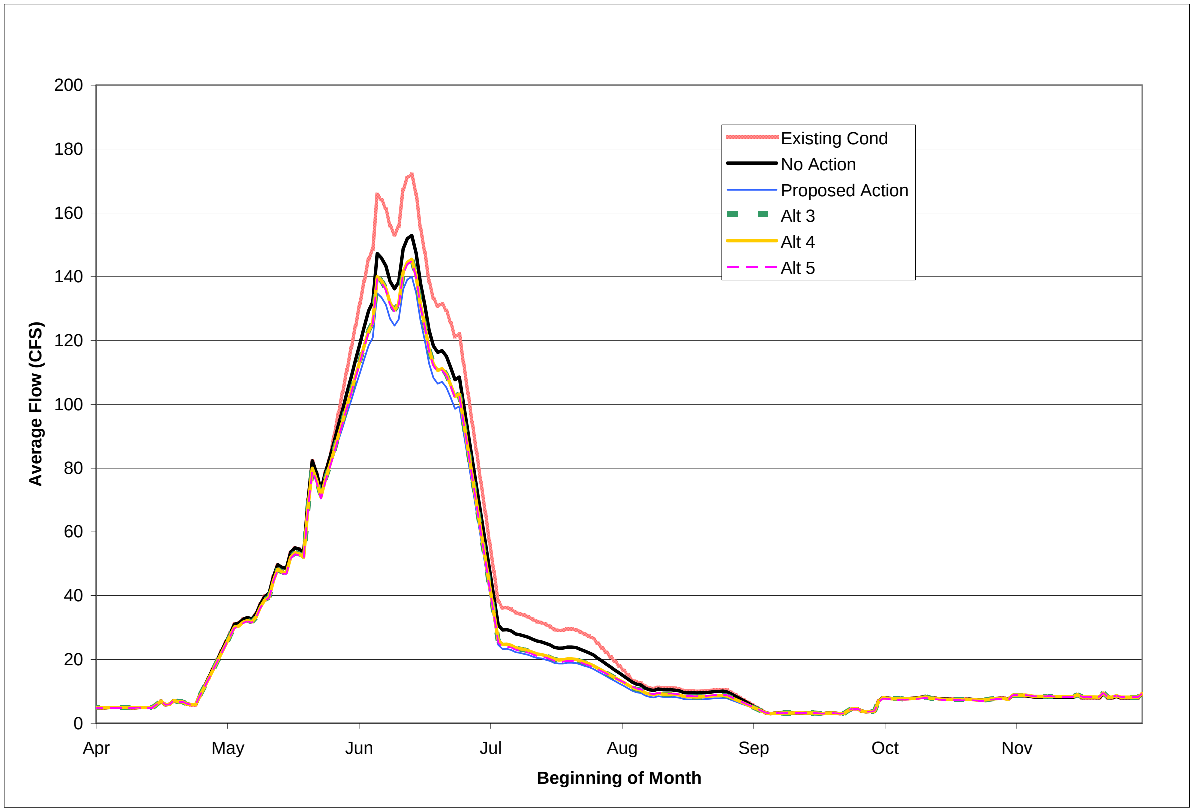
Figure 33. Average daily flows, Colorado River near Kremmling.



In dry years, flows in the Colorado River below the Windy Gap diversion would be the same among all alternatives because there would be no difference in flows below Lake Granby, in the tributaries to the Colorado River, or in Windy Gap diversions. Differences in the average and wet year average flows below the Windy Gap diversion among alternatives coincide with the differences in Windy Gap diversions and flows below Lake Granby due to spills and in Willow Creek due to differences in WCFC diversions. For example, average annual flows above Gore Canyon would be about 21,300 AF (29.4 cfs) higher under Existing Conditions than the Proposed Action, which is the sum of the average annual difference in flows below Lake Granby (9,200 AF/12.7 cfs) and in Willow Creek (2,600 AF/3.6 cfs), and in Windy Gap diversions (9,500 AF/13.1 cfs).

Willow Creek. Average annual streamflow in Willow Creek would decrease about 14 percent from Existing Condition and about a 7 percent decrease compared to the No Action alternative (Table 18). Wet year average flows for the Proposed Action would be about 3,300 AF less in June in comparison with Existing Conditions because corresponding WCFC diversions would be 3,300 AF higher than Existing Conditions (Table D-15). Section 7.4.1.2 describes in more detail why WCFC diversions would increase under the action alternatives in comparison with Existing Conditions and No Action. The largest monthly average flow reduction in Willow Creek at the confluence with the Colorado River under the Proposed Action would occur in July; this would be a 36 percent reduction in average years and a 34 percent reduction in wet years (Table D-15). Flow decreases would occur under the Proposed Action from May through August (Figure 34). The difference in Willow Creek flows among alternatives may be overestimated because the WGFP model does not forecast Lake Granby spills (see Section 7.4.1.1).

Figure 34. Average daily flows, Willow Creek at the confluence with the Colorado River.



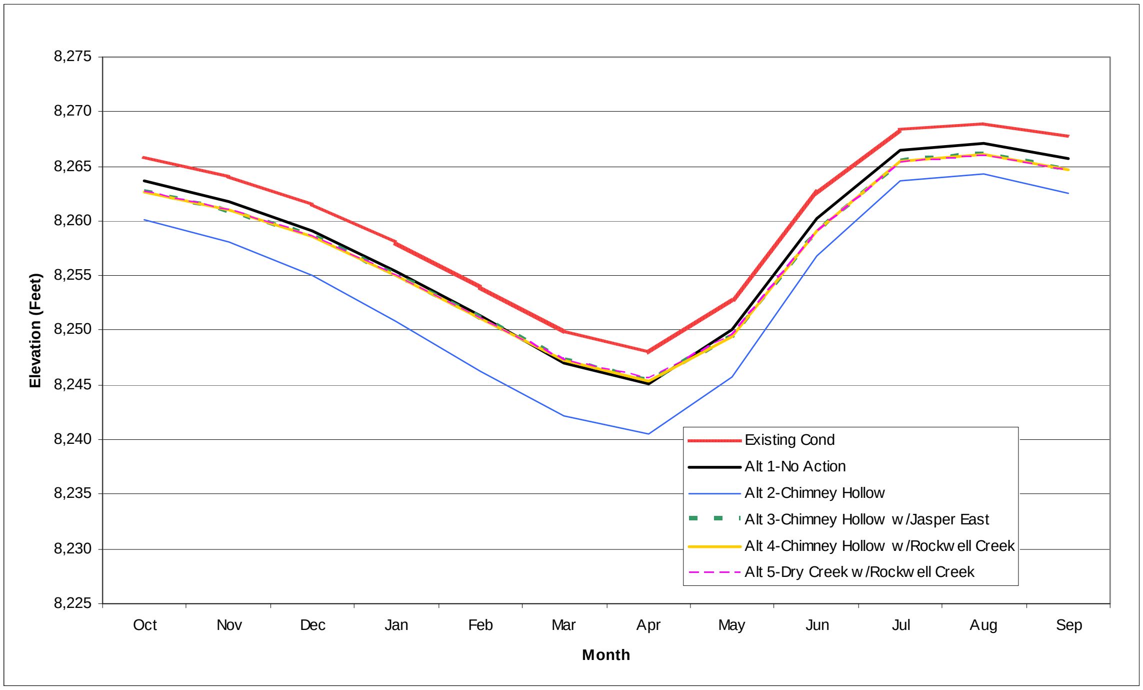
7.5.1.3. West Slope Reservoirs

Lake Granby. Average, dry and wet year average monthly contents in Lake Granby for all alternatives are provided in Table F-7. Average monthly Lake Granby elevations for all of the alternatives are shown in Figure 35. Differences in Lake Granby end of month contents between Existing Conditions, No Action, and the Proposed Action would occur primarily for the following reasons:

- *Differences in the storage of Windy Gap water in Lake Granby*. Under the modeled Existing Conditions, Windy Gap water could only be stored in Lake Granby when space is available. Under the Proposed Action, Windy Gap water diverted to Lake Granby would be exchanged with C-BT water in Chimney Hollow until Chimney Hollow is full of Windy Gap water, subject to volumetric limits in the decree. There are no decreed storage limits in Chimney Hollow Reservoir. Any additional Windy Gap water diverted above the capacity of Chimney Hollow would be stored in Lake Granby. Differences in Windy Gap storage in Lake Granby would result in differences in deliveries to meet Windy Gap demands, which would also affect Lake Granby contents.

- *Differences in Windy Gap demands*. Under Existing Conditions, total annual Windy Gap demands including MPWCD are approximately 21,045 AF. Under No Action and the Proposed Action, Windy Gap demands would be approximately 40,765 AF and 33,220 AF, respectively. Differences in the magnitude and timing of Windy Gap deliveries to meet demands would result in differences in Windy Gap contents in Lake Granby.
- Variations in the amounts of Windy Gap shrink (diversions shrink, reintroduction shrink and carryover shrink) paid to the C-BT project. Windy Gap diversions would be different among the alternatives, so the amount of diversion shrink paid to the C-BT project would be different. For the Proposed Action, shrink would be paid when Windy Gap water is initially diverted to Lake Granby and delivered to Chimney Hollow by exchange and again when it is reintroduced into the C-BT system (reintroduction shrink), whereas deliveries from Ralph Price Reservoir under No Action would not incur reintroduction shrink because these deliveries are not reintroduced into the C-BT system. Variations in the amount of shrink paid to the C-BT project would result in variations in C-BT contents in Lake Granby among alternatives.
- *Differences in Adams Tunnel maintenance*. Reclamation indicated that maintenance on the Adams Tunnel may increase by about 10 percent with a firming project on-line. Based on direction provided by Reclamation staff, it was assumed that additional maintenance would occur in March. Therefore, average Adams Tunnel deliveries in March for the Proposed Action would be less than Existing Conditions and No Action because of the additional tunnel outage anticipated in March. A reduction in deliveries from Lake Granby through the tunnel in March could affect both C-BT and Windy Gap contents in Lake Granby in that month and the following months.

Figure 35. Lake Granby estimated average year surface elevation for all alternatives.



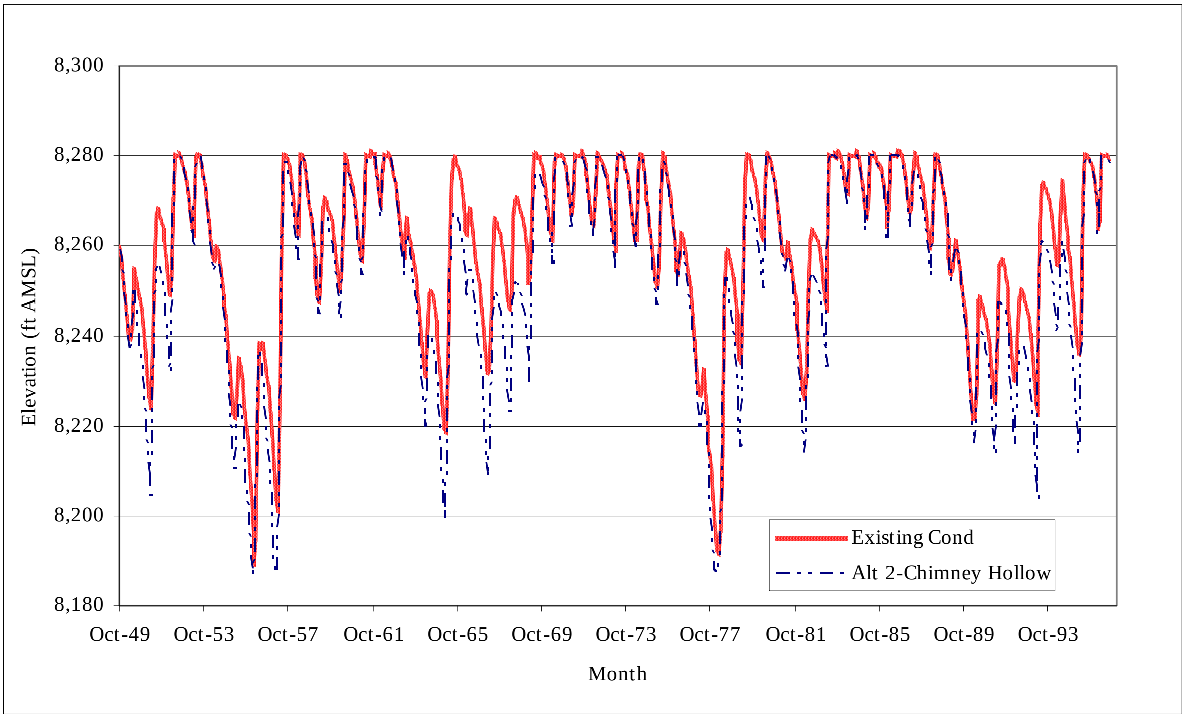
Average differences between the Proposed Action and Existing Conditions would range from about 31,000 AF in July and August to about 46,500 AF in February (Table F-7). Under No Action, the higher Windy Gap demand and storage of Windy Gap diversions in Ralph Price Reservoir would reduce Windy Gap contents in Lake Granby. As a result, there would be less difference in Lake Granby contents between No Action and the Proposed Action.

The largest change in the average monthly volume of Lake Granby that would occur under the Proposed Action would be a 13 percent reduction in February and March in average years compared to Existing Conditions (Table F-7). Average monthly reservoir content during the summer months would be about 7 to 9 percent lower than Existing Conditions. Average reservoir surface elevation would fluctuate in a pattern similar to Existing Conditions under the Proposed Action (Figure 36). In dry years, average September reservoir content drops up to 13 percent, whereas in wet years up to a 16 percent reduction would occur in February and March. The maximum monthly average lake elevation change would be 8 feet in average years, 6 feet in dry years, and 10 feet in wet years (Table F-8).

Lake Granby contents and surface elevations would be similar for Existing Conditions, No Action, and the Proposed Action during wet year sequences (two or more sequential wet years), when Lake Granby fills and spills (Table F-7 and Table F-8). When Lake Granby fills with C-BT water, there would be very little difference between the alternatives because differences in C-BT operations and contents in Lake Granby due to Windy Gap would be relatively small. Differences in Lake Granby contents and surface elevations would be greatest (up to 23 feet) during dry year sequences; the chance of a decrease in the lake level of more than 10 feet in any given year would be 32 percent). During these years, Windy

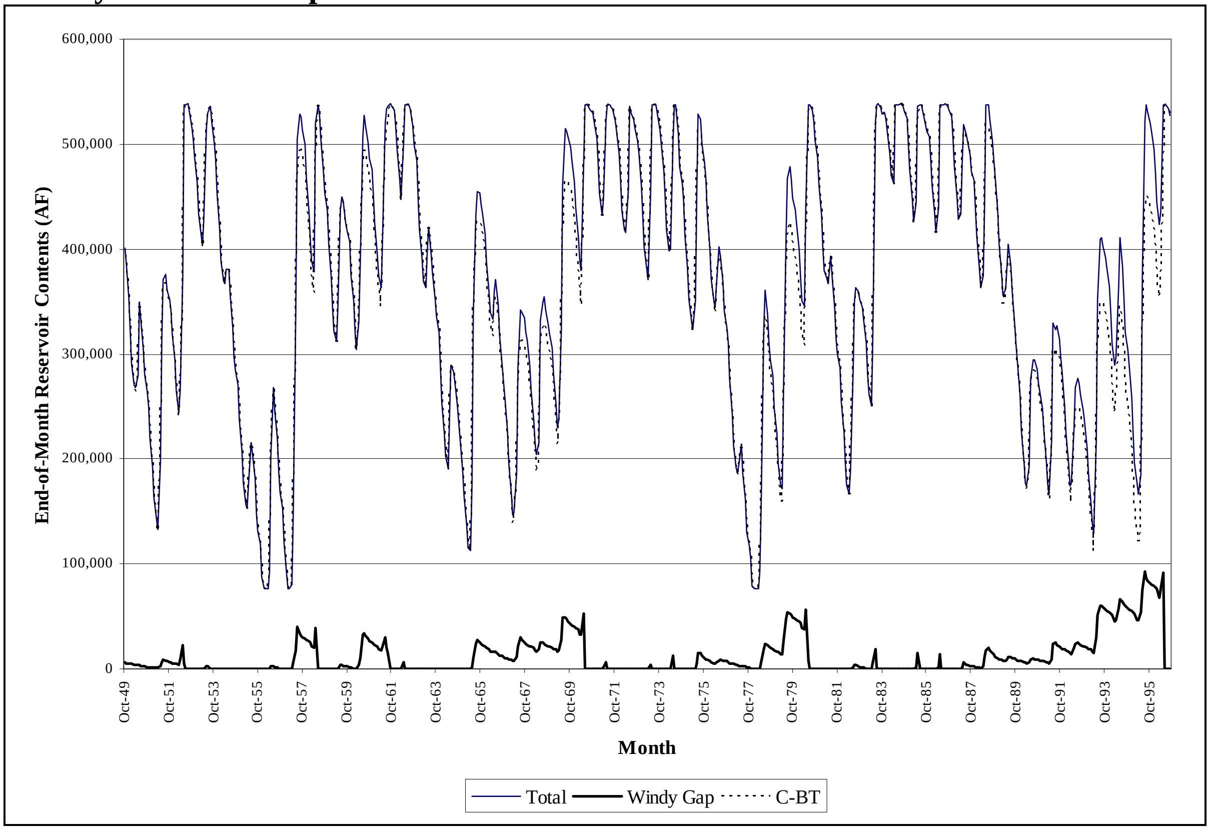
Gap diversions would not be limited by available storage capacity in Lake Granby; therefore, differences would be greater due to C-BT deliveries to Chimney Hollow, Windy Gap storage in Lake Granby, Windy Gap demands and deliveries, and shrink payments, which would have accumulated over the months since the previous Lake Granby spill.

Figure 36. Lake Granby estimated average monthly surface elevation for the Proposed Action.



The amount of C-BT and Windy Gap water stored in Lake Granby would change under the Proposed Action compared to Existing Conditions (Figure 27 and Figure 37).

Figure 37. End-of-month storage volume of C-BT and Windy Gap water in Lake Granby under the Proposed Action.



7.5.1.4. East Slope Streams

Streams that Receive Windy Gap Return Flows. Under the Proposed Action, more Windy Gap water would be delivered to the East Slope than under Existing Conditions and, as a result, there would be additional return flows to East Slope streams attributable to indoor and outdoor use of Windy Gap water. Additional Windy Gap return flows attributable to indoor use would occur primarily at Participants' WWTPs (Figures 13a and 13b). Additional Windy Gap return flows attributable to outdoor irrigation use would occur at various locations throughout the Participants' service areas.

Affects on flows in East Slope streams were not modeled in the WGFP Model. Therefore, a separate analysis was conducted to assess the potential effects on flows in East Slope streams due to the alternatives (Boyle 2006c). Without a WGFP there would be years that little or no Windy Gap water is delivered; therefore, in those years there would be no return flows attributable to the use of Windy Gap water. The analysis considered the maximum potential flow change in East Slope streams due to additional Windy Gap return flows that would occur under the Proposed Action by comparing the difference in return flows in years that no Windy Gap water is delivered under Existing Conditions.

Windy Gap water is reusable to extinction. The majority of Participants would reuse Windy Gap effluent either through non-potable reuse systems, as an exchange supply, as return flow credit, or as augmentation water. Each Participant's anticipated first use and reuse of Windy Gap supplies as documented in the Draft Purpose and Need Report (ERO 2005a) was taken into account when estimating Windy Gap return flows to East Slope streams.

The WGFP would increase streamflow in several East Slope streams during the months of April through October. There would likely be no change in streamflow from November to March because the Participants would not use their Windy Gap supplies in those months, or reusable effluent would be stored for use later in summer months, or Windy Gap reusable effluent would be used as an augmentation supply to offset depletions or meet return flow obligations. Maximum predicted changes in flows for all East Slope streams for Alternatives 2 through 5 are provided in Table 24. The maximum yield would also be equivalent to the firm yield and average yield under the Proposed Action.

Table 24. Maximum streamflow increases to East Slope streams for Windy Gap Alternatives 2 through 5.

Stream Segment[1]	cfs	Apr	May	Jun	Jul	Aug	Sep	Oct
Big Dry Creek above Broomfield WWTP (USGS gage 06720820, adjusted for average historical Broomfield WWTP effluent, 1995-2004)	Existing average flow	13.3	28.9	51.1	41.5	38.5	23.6	10.1
	Existing maximum flow	19	40.5	73.2	86.5	49	40.3	16.2
	Maximum flow increase	3.5	5.9	7	8.5	8.5	7	3.4
Coal Creek below Superior, above Louisville, Lafayette and Erie WWTPs USGS gage 06730400)	Existing average flow	12.3	13.1	7	2.8	4.1	2.1	2.6
	Existing maximum flow	36	35	13	4.3	15	3.1	3.8
	Maximum flow increase above gage	1.6	1.6	1.6	1.6	1.6	1.6	1.5
	Maximum flow increase below gage	3.5	3.7	3.9	4	4	3.9	3.3
St. Vrain Creek below Longmont WWTP (USGS gage 06725450)	Existing average flow	76	234	348	175	148	101	68
	Existing maximum flow	259	1,155	1,227	485	185	152	159
	Maximum flow increase	1.7	0.5	0.5	6.2	6.2	6.4	6.1
St. Vrain Creek below LTWD WWTP (USGS gage 06731000)	Existing average flow	177	400	535	214	164	124	103
	Existing maximum flow	856	2256	2203	852	410	592	286
	Maximum flow increase	0.8	1.3	1.5	1.8	1.8	1.5	0.7
Big Thompson River below Loveland WWTP (USGS gage 06741510)	Existing average flow	41	251	296	129	84	37	28
	Existing maximum flow	292	2,078	1,493	418	153	84	111
	Maximum flow increase	0	0.8	0.8	1.6	3.3	5.1	4.9

[1]Existing average flow and maximum flow are at stream gage locations. Maximum flow increases are at Participants' WWTPs and dispersed return flow locations from outdoor use.

Table 24 compares the average maximum flow increases attributable to additional Windy Gap return flows under Alternatives 2 to 5 to the average maximum monthly flows at the nearest USGS gage. No adjustments were made to gage flows to account for gains/losses that may occur between the gages and WWTPs. The USGS gage flows presented are the closest measured flows to the location where additional returns will occur at Participant's

WWTPs. As discussed in Section 7.4.1.4, the flow recorded at the gages may not be a good representation of the flow at a Participant's WWTP because of the distance between the gage and the point of return, and the changes in flow that occur in between, such as diversions and tributary inflow. In Coal Creek and St. Vrain Creek, return flows would increase at more than one location; the return flows for these creeks have not been added together in Table 24.

North St. Vrain Creek. There would be no change in the flow of North St. Vrain Creek under the Proposed Action because Ralph Price Reservoir would not be enlarged.

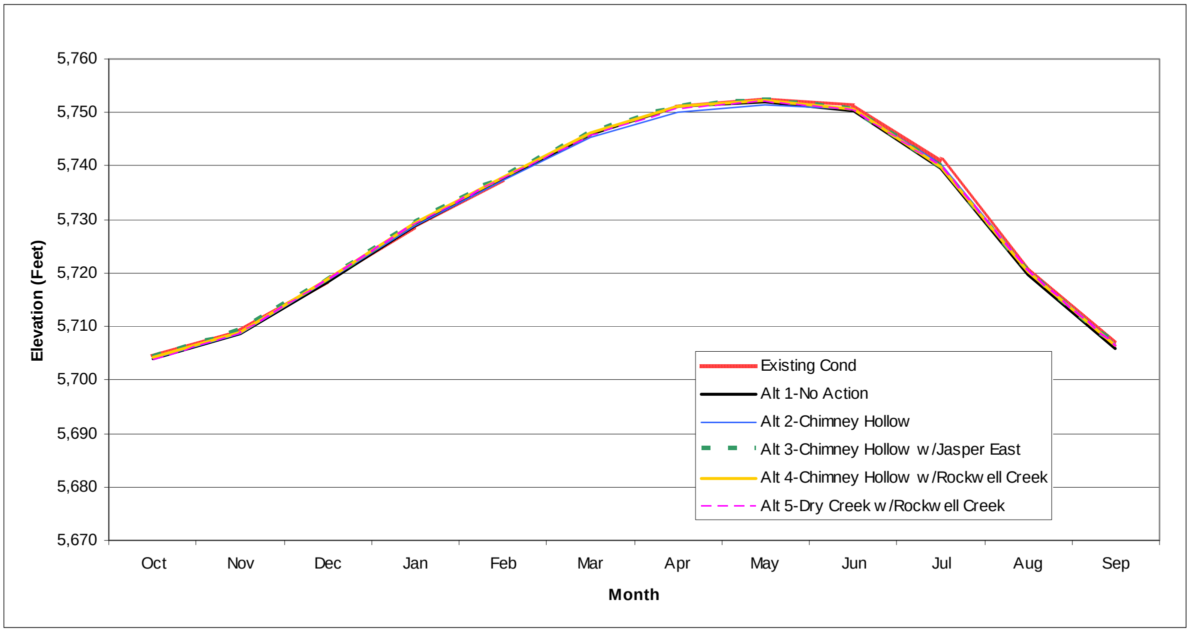
Big Thompson River from Lake Estes to Canyon Mouth. Due to lower skim diversions under the Proposed Action, average monthly flows in the Big Thompson River below Lake Estes would increase by up to 9 percent (May and July) in an average year, and would increase by as much as 5 percent (June) during wet years (Table D-8). Average Big Thompson River July flows at the mouth of the canyon would be a 7 percent increase over Existing Conditions flows with a 3 percent increase in annual flows (Table D-10). The maximum monthly average change in river stage would occur every year in July, but would be less than an inch (Table E-1).

7.5.1.5. East Slope Reservoirs

Carter Lake. Average monthly differences in Carter Lake contents between Existing Conditions, No Action and the Proposed Action would be small, ranging from essentially zero to 1,300 AF (Table F-1). Average monthly Carter Lake elevations under the Proposed Action would not vary substantially from Existing Conditions (Figure 38). The largest change in the monthly volume of Carter Lake that would occur under the Proposed Action would be a 1 percent reduction in average years, a 2 percent reduction in dry years, and a 3 percent reduction in wet years (Table F-1). The maximum monthly average lake elevation change would be a reduction of 1 foot in average and dry years and a reduction of 2 feet in wet years (Table F-2).

In general, average monthly contents in Carter Lake would be less during the summer months under the Proposed Action. This would be primarily due to greater C-BT deliveries from Carter Lake to meet Windy Gap demands via instantaneous delivery (when Windy Gap water is available for exchange in Lake Granby) and C-BT deliveries to Chimney Hollow. C-BT deliveries to Chimney Hollow Reservoir could reduce C-BT deliveries to Carter Lake if available capacity in the Adams Tunnel is limited or C-BT contents in Lake Granby are exhausted. There would be differences in instantaneous deliveries among these scenarios due to differences in the amount of Windy Gap water stored in Lake Granby and differences in monthly Windy Gap demands.

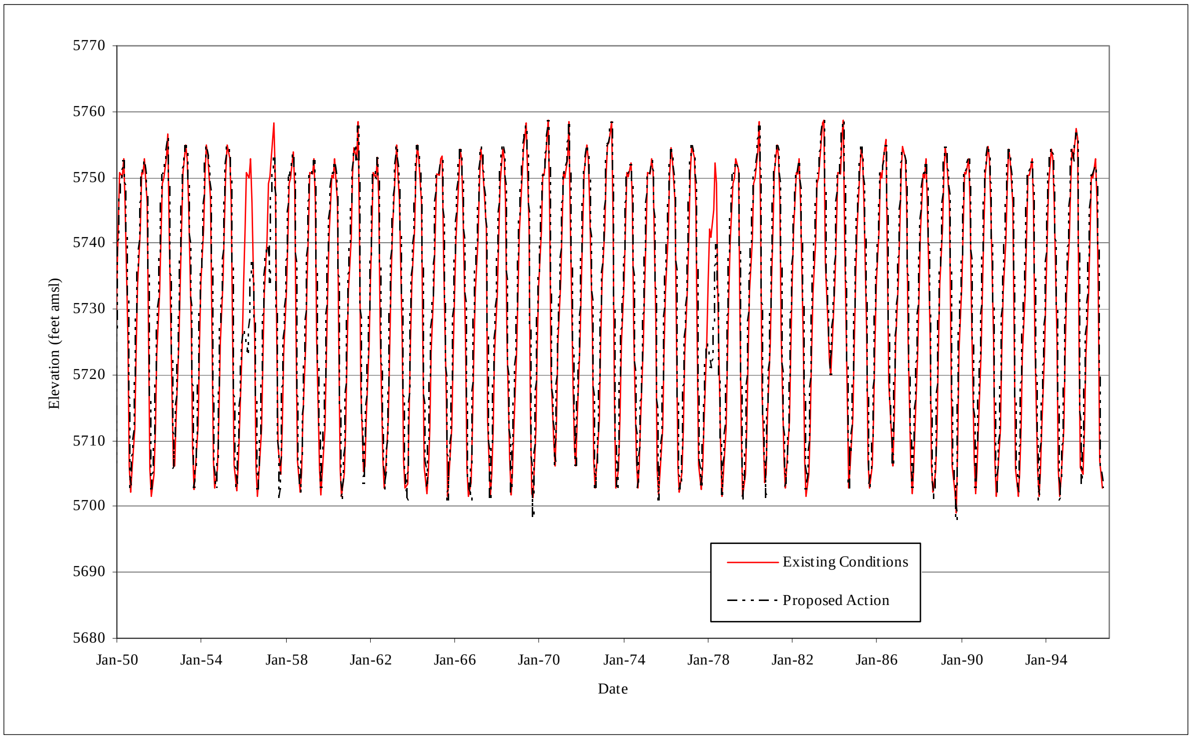
Figure 38. Carter Lake estimated average year surface elevation for all alternatives.



In the winter months, particularly in wet and dry years, average monthly Carter Lake contents under the Proposed Action would be less than 1 percent higher than both Existing Conditions and No Action (Table F-1). In wet and dry years, Windy Gap deliveries would be made almost exclusively from Chimney Hollow during the winter months, as opposed to via instantaneous delivery from Carter Lake under Existing Conditions. Because there would be less instantaneous deliveries from Carter Lake during the winter months under the Proposed Action, Carter Lake contents would be slightly greater on average.

In dry years when C-BT contents in Lake Granby are exhausted, Carter Lake contents under the Proposed Action would be much lower than Existing Conditions and No Action. The decrease is predicted to be as much as 27 feet; however, the chance of a decrease in the elevation of Carter Lake exceeding 4 feet in any given year would be only 6 percent (Figure 39). C-BT contents in Lake Granby would be exhausted earlier in dry year sequences due to C-BT deliveries to Chimney Hollow in previous years. As a result, the amount of C-BT water available for delivery to Carter Lake and Horsetooth Reservoir would be less, and consequently C-BT contents in those reservoirs would be less.

Figure 39. Carter Lake estimated average monthly surface elevation for the Proposed Action.



Horsetooth Reservoir. Average monthly Horsetooth Reservoir storage under the Proposed Action would range from about 3,000 AF to 10,600 AF lower than Existing Conditions, with slightly less changes compared to No Action (Table F-4). The largest change in the average monthly volume of Horsetooth Reservoir that would occur under the Proposed Action would be an 8 percent reduction in the spring of average years, a 12 percent reduction in July during dry years, and a 9 percent reduction in the spring of wet years (Table F-4). The surface elevation of Horsetooth Reservoir would vary from Existing Conditions for the Proposed Action and all of the alternatives (Figure 40). The estimated maximum average monthly elevation change primarily in the spring and summer (6 feet in average years, 7 feet in wet years and 9 feet in dry years) would be greater for the Proposed Action than other alternatives (Table F-5).

Differences in reservoir content would be primarily due to C-BT deliveries to Chimney Hollow Reservoir, which could reduce C-BT deliveries to Horsetooth if available capacity in the Adams Tunnel was limiting or C-BT contents in Lake Granby were exhausted in dry years. Horsetooth Reservoir contents would also be lower under the Proposed Action due to greater C-BT deliveries from Horsetooth to meet Windy Gap demands when Windy Gap water is available for exchange in Lake Granby. However, that is less of a factor for Horsetooth Reservoir than Carter Lake because there is less Windy Gap demand north of Horsetooth versus south of Carter Lake. Differences in March are also a function of Adams Tunnel maintenance operations in that month. Average Adams Tunnel deliveries in March for the Proposed Action would be approximately 4,600 AF less than Existing Conditions and No Action because of the additional tunnel outage anticipated in March. This causes a reduction in C-BT deliveries from Lake Granby to Horsetooth and consequently lower Horsetooth contents in March and the following months on average. C-BT deliveries to Carter Lake would not be affected by the additional tunnel outage in March because Carter Lake storage targets are met before deliveries are made to Horsetooth Reservoir.

Occasionally, Horsetooth Reservoir contents under the Proposed Action would be lower than Existing Conditions (35 to 40 feet) in dry years if C-BT contents in Lake Granby are exhausted earlier due to C-BT deliveries to Chimney Hollow Reservoir in previous years; however, the chance of a decrease in Horsetooth of more than 10 feet in any given year would be only 15 percent (Figure 41). This would occur due to C-BT deliveries made to Chimney Hollow in previous years. As a result, the amount of C-BT water available for delivery to Carter Lake and Horsetooth Reservoir would be less in dry years if C-BT contents in Lake Granby are exhausted, and consequently C-BT contents in those reservoirs would be less. C-BT contents in those reservoirs could also be less in a dry year if Adams Tunnel capacity is a limiting factor. Although C-BT contents in Carter Lake and Horsetooth would be lower in those years, total C-BT reservoir contents, including C-BT contents in Chimney Hollow, would be roughly the same.

Figure 40. Horsetooth Reservoir estimated average surface elevation for all alternatives.

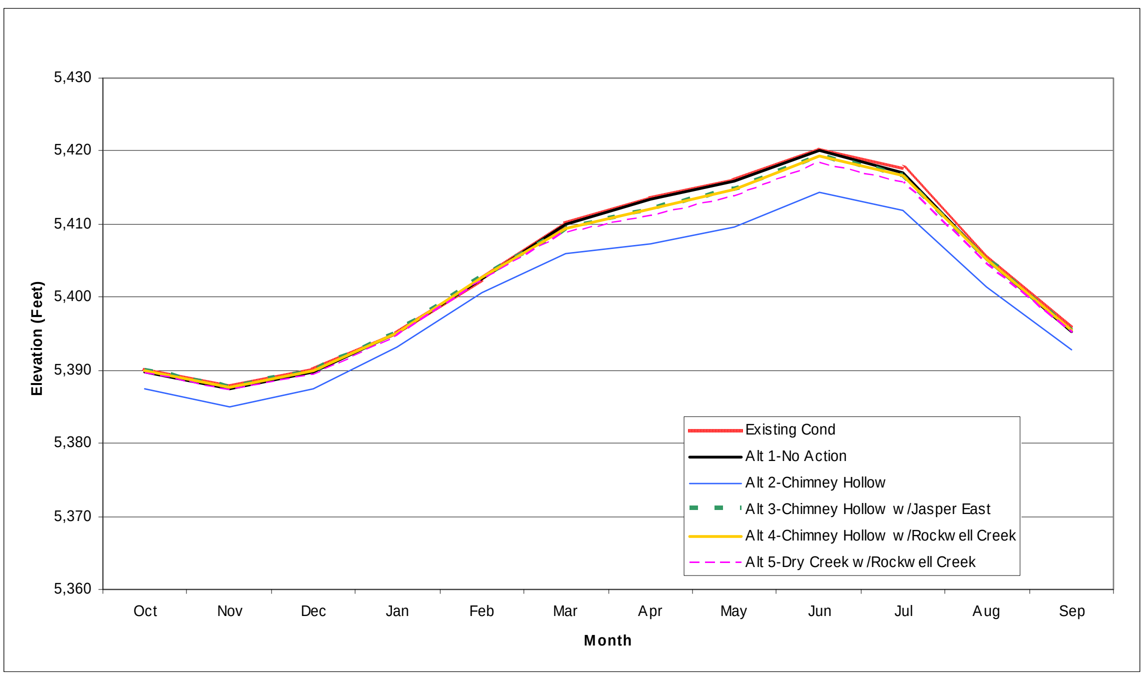
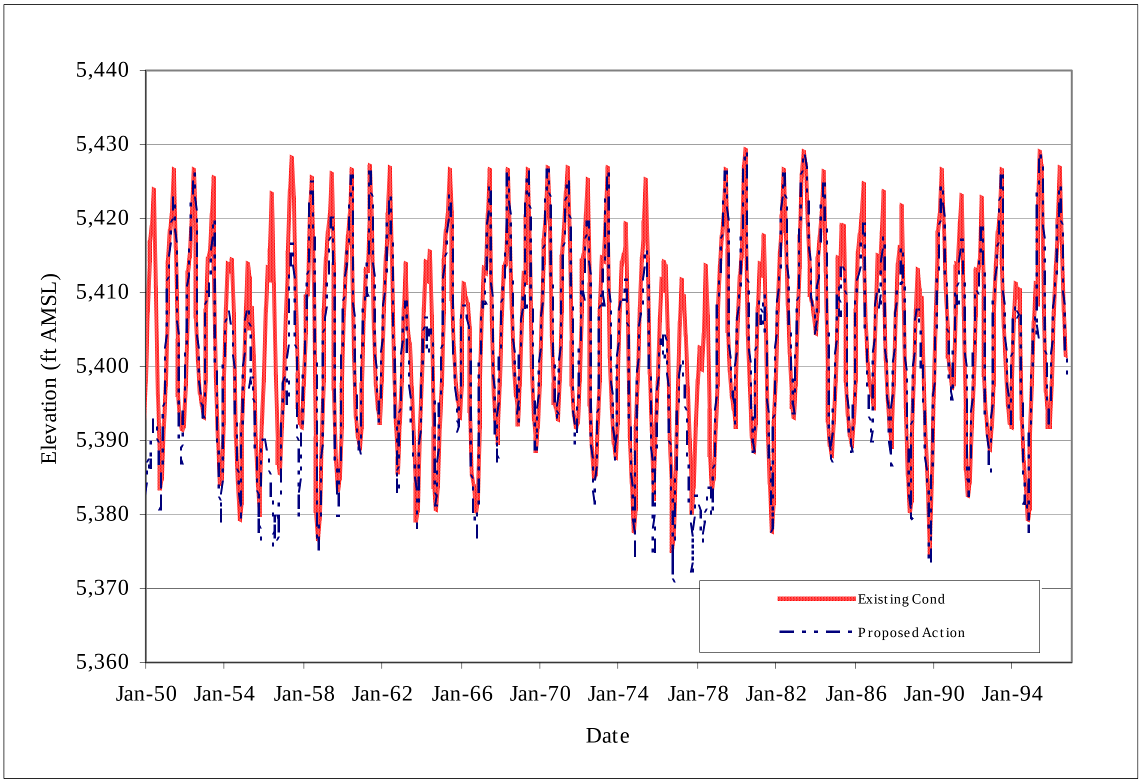


Figure 41. Horsetooth Reservoir estimated average monthly surface elevation for the Proposed Action.



Chimney Hollow Reservoir. Chimney Hollow Reservoir would remain nearly full of both C-BT and Windy Gap water (Figure 42). Fluctuations in the end of month contents from full reflect modeled evaporation losses that are assessed at the end of the month and deliveries to meet demands, which also occur at the end of the month in the model. Windy Gap contents in Chimney Hollow typically would increase during the runoff season as Chimney Hollow fills and would decrease through the remainder of the year as releases are made to meet Windy Gap demands. During dry year sequences, less Windy Gap water would be diverted and stored in Chimney Hollow; consequently, C-BT contents would be highest in those years. Figure 43 shows the modeled monthly volume of C-BT and Windy Gap water that would be stored in Chimney Hollow Reservoir under the Proposed Action.

Figure 42. Proposed Action Chimney Hollow Reservoir average, wet, and dry year daily contents.

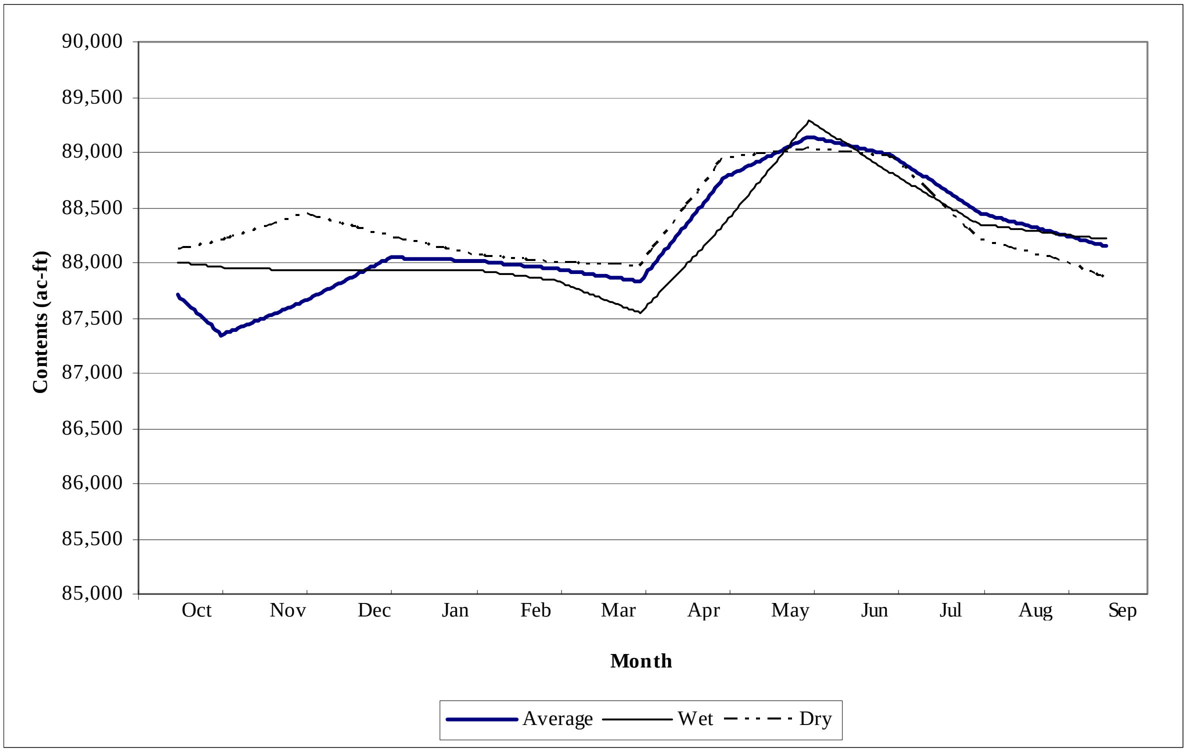
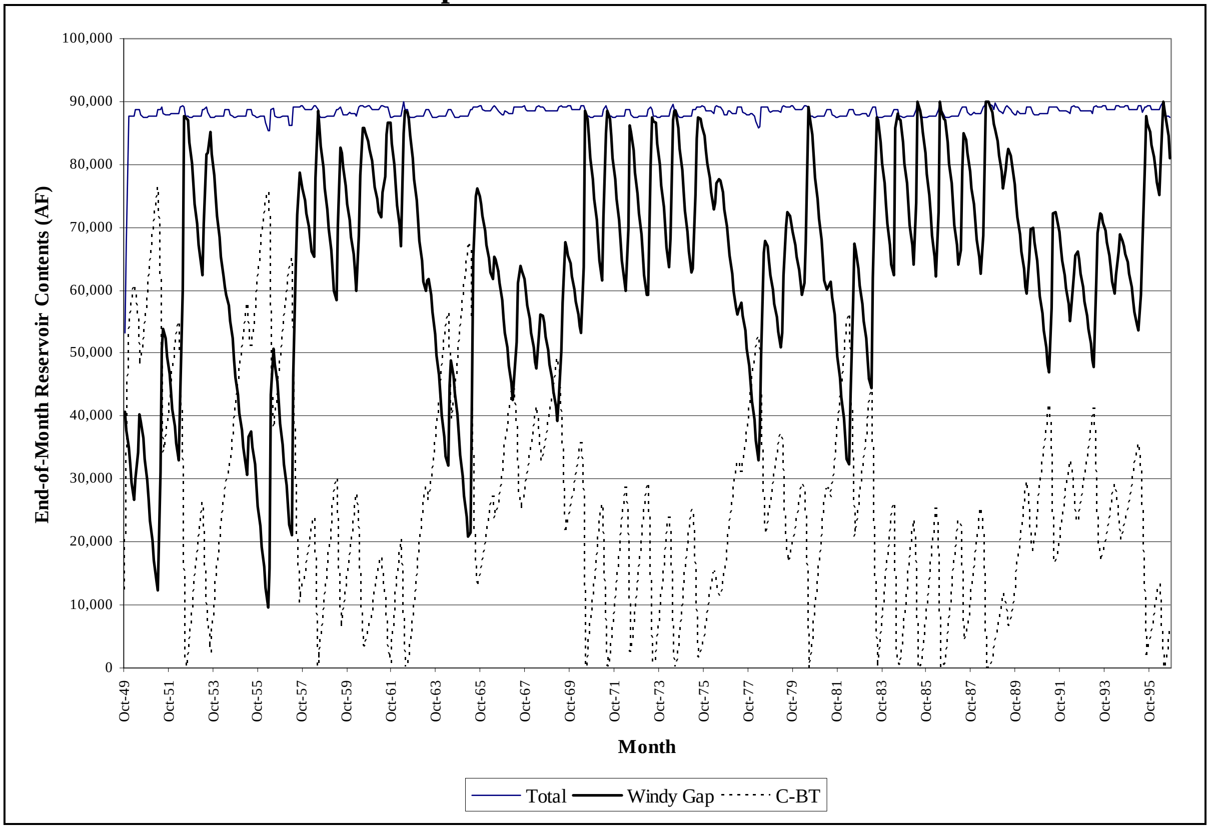


Figure 43. End-of-month storage volume of C-BT and Windy Gap water in Chimney Hollow Reservoir under the Proposed Action.



7.5.2. Ground Water Hydrology and Quality

7.5.2.1. West Slope Reservoirs

Although the Proposed Action would result in the largest reduction in the elevation of Lake Granby on average of any of the alternatives (occasionally more than 20 feet), the existing annual variation in lake level of nearly 90 feet is much greater. The source of ground water to the lake is from topographically higher areas surrounding the lake.

As discussed in Section 7.2.2, there are not expected to be any measurable effects to ground water quality for the Proposed Action or other alternatives.

7.5.2.2. West Slope Streams

Changes in flow and the resulting stage changes are considered to be minor with respect to potential effects to adjacent ground water levels. The changes in river stage under the Proposed Action would not result in measurable effects to ground water levels.

As discussed in Section 7.2.2, it is expected that there would be only minor effects to alluvial ground water quality along the Colorado River and no effects to ground water quality near Willow Creek.

7.5.2.3. East Slope Reservoirs

The impoundment of surface water in Chimney Hollow or Dry Creek would not negatively affect existing ground water and nearby ground water users. Ground water use in these areas is limited primarily to domestic wells in fractured bedrock, usually in higher areas around the project alternatives. The bedrock aquifers are recharged by infiltration in areas where the bedrock aquifers crop out, usually well above the footprint of the proposed impoundment. It is possible that the proposed impoundment could provide additional recharge to fractured aquifers, but this would likely be limited due to the relatively low hydraulic conductivity of the bedrock formations. Any changes in the surface elevation of existing reservoirs (Carter Lake and Horsetooth Reservoir) would result in minimal changes to nearby ground water levels, as discussed in Section 7.2.1.

As discussed in Section 7.2.2, there are not expected to be any effects to ground water quality at the proposed or existing reservoir locations for the Proposed Action.

7.5.2.4. East Slope Streams

Because the average monthly stage change in the Big Thompson River between Lake Estes and the Hansen Feeder Canal under No Action would be no more than 0.05 foot (Table E-1), effects to alluvial or bedrock ground water would be negligible. For the other East Slope streams affected by changing return flows from Participants' WWTPs, because stage changes are expected to be small, increases in alluvial ground water levels would likely be unmeasurable. As discussed in Section 7.2.2, it is expected that ground water quality would not be affected near the foothill streams (North St. Vrain Creek, St. Vrain Creek at Lyons, and Big Thompson River below Lake Estes to the Hansen Feeder Canal). For the other East Slope streams, there may be minor changes in alluvial ground water quality near the streams.

7.5.3. Stream Morphology and Sedimentation

7.5.3.1. West Slope Streams

Colorado River. Evaluation and modeling of the effects to the Colorado River for the 1981 Windy Gap Project EIS showed that with a proposed average withdrawal of 56,000 AF per year of water at Windy Gap Reservoir, no significant increases in sediment transport or the rate of sediment deposition would occur downstream of the diversion (Ward and Eckhardt 1981). Ward and Eckhardt's study (1981) is still relevant despite its early publication because the predicted decreases in streamflow under the Proposed Action would be less than those evaluated in the original EIS, and the sediment transport rate of the river far exceeds the sediment supply even at higher diversion rates used in the previous study. In addition, there have been no substantial changes in the watershed condition that have accelerated sediment delivery, and Windy Gap Reservoir now captures a portion of the sediment from the Upper Colorado and Fraser River basins. Although the number of pumping days and daily pumping rates evaluated in the original Windy Gap EIS were different than what was estimated for the present evaluation, the average annual diversion was greater in the earlier study than would occur under the Proposed Action (46,100 AF), the No Action alternative (43,600 AF per year), or any of the other action alternatives (48,100 AF to 48,500 AF). As discussed in Section 7.4.3.1, the previous study concluded that the required flushing flow of 450 cfs below Windy Gap would be sufficient to transport fine sediments (Ward 1981). Under the Proposed Action there would be 93 days of flushing flows greater than 450 cfs in wet years compared to 103 days under Existing Conditions and 94 days under No Action (Table 23). In an average year, flows greater than 450 cfs would occur for 36 days, compared to 45 days under Existing Conditions and 38 days under No Action.

Flow duration curves, derived from daily flow changes, provide a comparison of the percentage change in flows at different rates between Existing Conditions and the Proposed Action for the USGS gages located at Hot Sulphur Springs and near Kremmling (Figure B-1 and Figure B-2). By comparing the flow duration curves, the maximum difference between Existing Conditions and the alternatives for a given exceedance percentage can be determined. Because the average morphologic characteristics of a channel are formed when a stream flows at its bankfull discharge (1½- to 2-year peak flow) (Rosgen 1996), differences shown on the flow duration curves between Existing Conditions and the alternatives that are lower than the bankfull discharge would have minimal effects on channel morphology. At Hot Sulphur Springs, the 2-year peak discharge was estimated to be 923 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 3.3 percent of the time (percent of days in study period). At the gage near Kremmling, the 2-year peak discharge was estimated to be 2,850 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 3 percent of the time.

Under the Proposed Action, the 2-year peak discharge at the Hot Sulphur Springs gage would be exceeded about 3 percent of the time, or 1 percent less than under Existing Conditions. The 2-year peak discharge at the gage near Kremmling would be exceeded only slightly less than 3 percent of the time (less than a 1 percent change from Existing Conditions). The slight reduction in the percentage of time that 2-year peak discharge would be reached at the two gage sites below the Windy Gap diversion is unlikely to significantly affect stream morphology or change sediment transport or deposition.

As discussed in Section 6.6, another method to evaluate stream channel morphology is to compare changes in the range of channel maintenance flows (Schmidt and Potyondy 2004). This analysis has been completed using daily flows for Existing Conditions and the alternatives. At Hot Sulphur Springs, under Existing Conditions, the lower limit of channel maintenance flows (80 percent of the 1.5-year peak flow) of at least 510 cfs occurred for 23 days on average (in years when such flows occurred), with a 62 percent chance of occurrence in any given year (Table D-19). Under the Proposed Action, flows of at least 510 cfs occurred for 19 days on average (in years when such flows occurred), with a 53 percent chance of occurrence in any given year. The upper limit of channel maintenance flows is defined as the 25-year flow; such a flow (6,520 cfs) occurred once under Existing Conditions (in years when such flows occurred), but would not occur under the Proposed Action. Ten-year flows or greater (4,600 cfs or more) occurred under Existing Conditions for 4 days on average (in years when such flows occurred) and under the Proposed Action for 5.3 days on average (in years when such flows occurred), with a 13 percent chance of occurrence in any given year under Existing Conditions and a 6 percent chance of occurrence under the Proposed Action. In general, channel maintenance flows would occur about 1 percent less frequently under the Proposed Action than Existing Conditions, but the duration of such flows in a year when channel maintenance flows occur could be slightly longer. The differences in channel maintenance flows between Existing Conditions and the Proposed Action alternative are minor and are not expected to alter channel morphology or sediment movement at Hot Sulphur Springs.

For the section of the Colorado River below Lake Granby where river flows have been dominated by releases from Lake Granby, releases from Lake Granby would continue to meet the needs of water rights users as well as the bypass flow requirement. The frequency, timing and magnitude of spills from Lake Granby would change under the Proposed Action, as discussed in Section 7.5.1.1 under "Lake Granby Spills." For example, spills occurring for 3 months in May through July would not occur under the Proposed Action, but spills occurring for two months in June and July would occur more frequently (Table D-11).

The magnitude, timing and frequency of channel maintenance flows in the Colorado River below Lake Granby would change as a result of changes in spills. When spills are not occurring, the flow of the river below Lake Granby is controlled by bypass flows; it is difficult, therefore, to define a range of channel maintenance flows based on peak flow events. A comparison of modeled spill events is provided in Table D-4. Under the Proposed Action, there would be 7 less spill events compared to Existing Conditions, but flows of 510 cfs or more (within the range of channel maintenance flows at Hot Sulphur Springs) would continue to occur for periods of 1 to 4 months. Flows over 2,500 cfs would occur during 17 percent of all years, compared to 28 percent of all years under Existing Conditions. These differences are not expected to alter channel morphology or sediment movement in the Colorado River below Lake Granby. The range in streamflows under the Proposed Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment.

Willow Creek. The flow duration curve for Willow Creek provides a comparison between Existing Conditions and this alternative for the USGS gage located below Willow Creek Reservoir (Figure B-3). The 2-year peak discharge was estimated to be 80 cfs. Under Existing Conditions, this flow would be exceeded about 5 percent of the time. Under the Proposed Action, the 2-year peak discharge would be exceeded slightly less than under Existing Conditions (less than a 1 percent change); therefore, it is unlikely that there would be measurable effects to stream morphology or changes in sediment transport or deposition.

7.5.3.2. East Slope Streams

Big Thompson River. The largest estimated flow increases to the Big Thompson River below Lake Estes would occur in May through July, but would be less than 9 percent of the monthly average flow of the river (Table D-8). By the mouth of the Big Thompson Canyon streamflows reach a maximum increase of 7 percent on average (Table D-10). It is not expected that these flow increases (a maximum of 18 cfs in July) would measurably alter stream morphology or sediment transport and deposition given that spring and summer high flows in the Big Thompson River exceed 500 cfs.

Streams that Receive Windy Gap Return Flows. The predicted streamflow increases for the East Slope stream segments that receive Windy Gap return flows (Big Dry Creek, Coal Creek, St. Vrain Creek, and the Big Thompson River) are unlikely to substantially alter stream morphology and sedimentation because the increased flows would be small compared to the spring and early summer flows that these channels have the capacity for. In addition, as described in Section 6.6, streams on the East Slope have not experienced natural streamflow conditions for more than 100 years, and are not in equilibrium with respect to channel forming and channel moving processes, erosion, or sediment loading, movement and deposition. Given the magnitude of the average monthly flow increases (less than 9 cfs), it would be difficult to measurably differentiate changes to stream morphology and sedimentation due to changes in Participants' WWTP return flows from the many other ongoing actions influencing East Slope streamflow conditions.

7.6. Alternative 3 (Chimney Hollow Reservoir with Jasper East Reservoir)

This alternative is a combination of storage at the Chimney Hollow site (approximately 70,000 AF) on the East Slope and storage at the Jasper East site (approximately 20,000 AF) on the West Slope. These reservoirs would operate jointly to firm Windy Gap diversions. The general goal for filling and releasing from Chimney Hollow, Jasper East and Lake Granby would be to convey Windy Gap water to the East Slope as soon as possible. This would minimize Windy Gap spills from Lake Granby and maximize space available in Jasper East for Windy Gap diversions when Lake Granby and the Adams Tunnel are full. Windy Gap diversions would first be delivered to Chimney Hollow and would be limited by available space in Chimney Hollow and the Adams Tunnel. If Chimney Hollow Reservoir or the Adams Tunnel are full, Windy Gap diversions would be delivered to Jasper East until full and then to Lake Granby if space is available. Windy Gap deliveries to Participants would be made first from Lake Granby via instantaneous delivery, then Jasper East either directly or via instantaneous delivery, and last from Chimney Hollow Reservoir.

7.6.1. Surface Water Hydrology

7.6.1.1. C-BT and Windy Gap Project Operations and Diversions

Adams Tunnel Diversions. Average annual Adams Tunnel deliveries would be approximately 243,000 AF under Existing Conditions and 254,000 AF under No Action versus 261,000 AF under Chimney Hollow and Jasper East (Table 18). Deliveries through the Adams Tunnel under Alternative 3 would be higher than Existing Conditions and No Action because of additional Windy Gap diversions to Chimney Hollow and deliveries to meet Windy Gap demands. C-BT water delivered through the Adams Tunnel would be about 600 AF less than Existing Conditions and 400 AF less than No Action due primarily to reintroduction shrink which is allocated to East Slope C-BT reservoirs and slightly reduces the amount of C-BT water brought through the tunnel. Differences in average monthly tunnel deliveries would be greatest in March due to maintenance (described in Section 7.5.1.1) and during the Windy Gap diversion season from May through August, with the exception of June (Table D-2). Windy Gap water would be delivered to the East Slope to the extent available capacity exists in the tunnel. Under Alternative 3, deliveries through the tunnel would be greater in May, July and August primarily due to additional Windy Gap diversions to Chimney Hollow. Deliveries from September through January would be greater due to additional Windy Gap deliveries from the West Slope to meet demands. Differences in tunnel deliveries would be minimal in February, April, and June because C-BT operations typically require the full tunnel capacity in those months. For example, there would be no difference in tunnel deliveries in June because the tunnel would typically be at capacity in combination with C-BT diversions from the Big Thompson River through Olympus Tunnel. In almost every June, the Olympus Tunnel, which includes Adams Tunnel deliveries and C-BT diversions from the Big Thompson River, would be full due to C-BT operations. As a result, there would be minimal capacity available for Windy Gap operations in June and; therefore, almost no difference among the alternatives in that month.

Dry year average annual Adams tunnel deliveries would be approximately 314,000 AF under Existing Conditions and 316,000 AF under No Action versus 320,000 AF under Alternative 3 (Table 19). Similar to average conditions, monthly differences in Adams Tunnel deliveries in dry years would be a function of differences in Windy Gap deliveries to meet demands and diversions to Chimney Hollow.

Wet year average annual Adams tunnel deliveries would be approximately 181,000 AF for Existing Conditions and 197,000 AF under No Action versus 206,000 AF under Alternative 3 (Table 20). Differences in Adams Tunnel deliveries among alternatives would primarily be a function of differences in Windy Gap deliveries and diversions to East Slope firming storage. With higher Windy Gap demands, more Windy Gap water would be delivered instantaneously to meet demands, which is reflected as C-BT deliveries through the tunnel to replace releases from Carter Lake and Horsetooth Reservoir. In addition, in wet years delivery of C-BT water through the tunnel would be about 3,900 AF less than Existing Conditions (Table 20).

Windy Gap Diversions. Under Alternative 3, Windy Gap diversions would first be delivered to Chimney Hollow, limited by available space in Adams Tunnel. If the Adams Tunnel is full, Windy Gap diversions would be delivered to Jasper East and then to Lake Granby to the extent space is available. This configuration minimizes Windy Gap spills from Lake Granby and maximizes space available in Jasper East for Windy Gap diversions when Lake Granby and the Adams Tunnel are full.

Average annual Windy Gap diversions would be approximately 36,500 AF under Existing Conditions and 43,600 AF under No Action versus 48,100 AF under Chimney Hollow and Jasper East (Table 18). Average monthly differences between Existing Conditions and Alternative 3 would be greatest in June and July, which coincides with months that Lake Granby is typically full in wet years. Under Existing Conditions, Windy Gap would not divert when Lake Granby is full; however, under Alternative 3, Windy Gap would divert when Lake Granby is full as long as there is space in Jasper East Reservoir or space in the Adams Tunnel for delivery to Chimney Hollow or Jasper East reservoirs. Average annual Windy Gap diversions under Alternative 3 would be about 2,000 AF higher than the Proposed Action due primarily to differences in diversions in wet years in July and August and spills from Lake Granby. In wet years, Chimney Hollow would typically fill by the end of June or July under the Proposed Action, whereas Chimney Hollow and Jasper East would typically not fill until the end of July or August under Alternative 3, primarily due to tunnel capacity constraints.

In dry years, there would be no difference in Windy Gap diversions among the alternatives (Table 19). In dry years, Windy Gap diversions would be limited by the physically and legally available supply in the Colorado River, which does not vary among alternatives. Available space in Lake Granby and the firming project reservoirs would not be limiting factors in dry years.

During wet years, Windy Gap diversions would be about 78,900 AF under Alternative 3 compared to 38,500 AF for Existing Conditions, and 63,400 AF for the No Action Alternative (Table 20). Wet year average Windy Gap diversions under Alternative 3 would be considerably higher than both Existing Conditions and No Action in May and June. Wet year Windy Gap diversions in May and June would often be limited by available space in Lake Granby under Existing Conditions and No Action, whereas additional Windy Gap can be diverted to Jasper East under Alternative 3 in those months. In wet years, monthly differences between Existing Conditions and Alternative 3 would be greatest in July and August (Table D-3). In wet years, Lake Granby would generally fill by the end of July under Existing Conditions; therefore, Windy Gap diversions under Existing Conditions would be minimal in July. Similarly, Lake Granby would be full in August in wet years under Existing Conditions; therefore, wet year average Windy Gap diversions would be zero in August. However, with Alternative 3, Windy Gap would divert in July and August even if Lake Granby filled and if there was space in the Adams Tunnel for delivery to Chimney Hollow or water could be delivered to Jasper East Reservoir.

Willow Creek Feeder Canal Diversions. See Section 7.5.1.1 for a discussion of WCFC diversions and differences among the alternatives. The average annual WCFC diversion under Alternative 3 would be about 2,200 AF greater than Existing Conditions, about 800 AF more than No Action, and about 400 AF less than under Alternative 2 (Table 18).

Lake Granby Spills. Average annual Lake Granby spills would be approximately 30,700 AF for Alternative 3, compared to 38,700 AF under Existing Conditions, and 35,400 AF under the No Action Alternative (Table D-1). There would be no dry year spills, and wet year spills would be about 13,000 AF less than Existing Conditions and 7,000 AF less than the No Action alternative. Table D-11 shows that the frequency and magnitude of spills would differ between Existing Conditions and Alternative 3. For example, under Alternative 3, no spill of 1 month duration would occur in July or August, but 2-month spills occurring in June through July would occur more often than under Existing Conditions.

C-BT Diversions from the Big Thompson River. Average annual Big Thompson River diversions would be approximately 27,000 AF under this alternative, which is about 1,000 AF less than Existing Conditions and about 600 AF less than the No Action alternative (Table 18). There would be a slight reduction in C-BT diversions due to a reduction in available capacity in the Olympus Tunnel and differences in Carter Lake and Horsetooth Reservoir contents.

7.6.1.2. West Slope Streams

Colorado River below Lake Granby. Section 7.5.1.2 describes in detail how the flow of the Colorado River below Lake Granby would change under the alternatives due to changes in spills. Table D-1 provides average monthly spills and Table D-12 provides average monthly river flows below Lake Granby; however, it must be recognized that during spill periods (usually May through August, but also infrequently in September and October) the range of flows is and would be widely variable. Windy Gap spills from Lake Granby under Alternative 3 would be less than Existing Conditions and No Action; consequently, average monthly flows of the river below Lake Granby would be lower. Table D-11 provides the modeled Granby Reservoir spill periods, average spill and maximum spill for Existing Conditions and all of the alternatives. The model shows spills occurring for as short as a month (June, July, or August) and up to as long as 4 months (May through August), with the most frequent spills occurring for 2 months in June through July under Existing Conditions and Alternative 3. The spill periods and estimated flow of the river at the gage near Granby would be altered under Alternative 3. For example, 3 month spills from May through July and 1 month spills in July or August would not occur under Alternative 3.

Table 14 provides the range and percent occurrence of flow increases and decreases that would occur under Alternative 3 during May through August, the period when most Windy Gap diversions would occur. About 85 percent of the time during those months, no changes in the flow of the Colorado River near Granby would occur. About 10 percent of the time, flow decreases of greater than 10 cfs would occur.

Colorado River above the Windy Gap Diversion. The annual decrease in Colorado River flow above the Windy Gap Diversion under Alternative 3 would be 5 percent in average and wet years (Table D-13). There would be no change in flow in dry years. The largest monthly average flow decrease would be 10 percent in July of an average year and 14 percent decrease in August of a wet year. Flow decreases would occur under Alternative 3 from May through August and October (Figure 31).

Colorado River below the Windy Gap Diversion. Colorado River streamflow below the Windy Gap diversion would decrease annually by about 14 percent compared to Existing Conditions (Table D-14) and by about 6 percent compared to the No Action Alternative. The largest average flow reduction under Alternative 3 in the Colorado River below Windy Gap would be a 28 percent reduction in average and wet years in July (Table D-14). Flow decreases would occur under Alternative 3 from May through August and October (Figure 32). There would be no changes to streamflows in dry years. On average, there would be a 16 percent reduction (2 inches) in river stage in average years and an 18 percent reduction (5.5 inches) in river stage in wet years (Table E-2) in July. See Section 7.5.1.2 for additional discussion of flow in the Colorado River below the Windy Gap diversion and differences between the alternatives.

Table 14 shows that no changes in daily flows at the Hot Sulphur Springs gage would occur about 68 percent of the time during the May through August period when most Windy Gap diversions occur. Daily flow decreases of 1 to 100 cfs would occur about 10 percent of the time between May through August, while larger daily flow decreases would occur about 21 percent of the time during that period.

Farther downstream, average annual flow reductions would be smaller, with a 9 percent decrease in Colorado River flow below Williams Fork River (Table D-17) and a 3 percent reduction at the top of Gore Canyon at the Kremmling gage in average years (Table D-18). The largest monthly average decrease in flow at the Kremmling gage would be a 7 percent reduction in June of average years and a 10 percent reduction in July and August of wet years. Flow decreases would occur under Alternative 3 from May through September (Figure 33). The average monthly stage changes at this location would be less than 4 percent, or 3 inches in average years and 5.4 inches in wet years in July (Table E-3).

At the USGS gage near Kremmling, average daily flows would not change about 68 percent of the time between May and August, the period when most Windy Gap diversions occur (Table 14). Daily flow decreases of 1 to 100 cfs would occur about 10 percent of the time during these months and daily flow decreases greater than 100 cfs would occur about 21 percent of the time between May and August.

Willow Creek. Average annual streamflow in Willow Creek would decrease about 12 percent from Existing Conditions and about 5 percent compared to the No Action alternative (Table D-15). Section 7.5.1.2 provides details on why the flow would decrease. The largest average flow reduction in Willow Creek at the confluence with the Colorado River under this alternative would occur in July; this would be a 32 percent reduction in average years (32 to 22 cfs) and a 34 percent reduction in wet years (112 to 75 cfs) (Table D-15). Flow decreases would occur under Alternative 3 from May through August and October (Figure 34). There would be no changes in flow in dry years.

7.6.1.3. West Slope Reservoirs

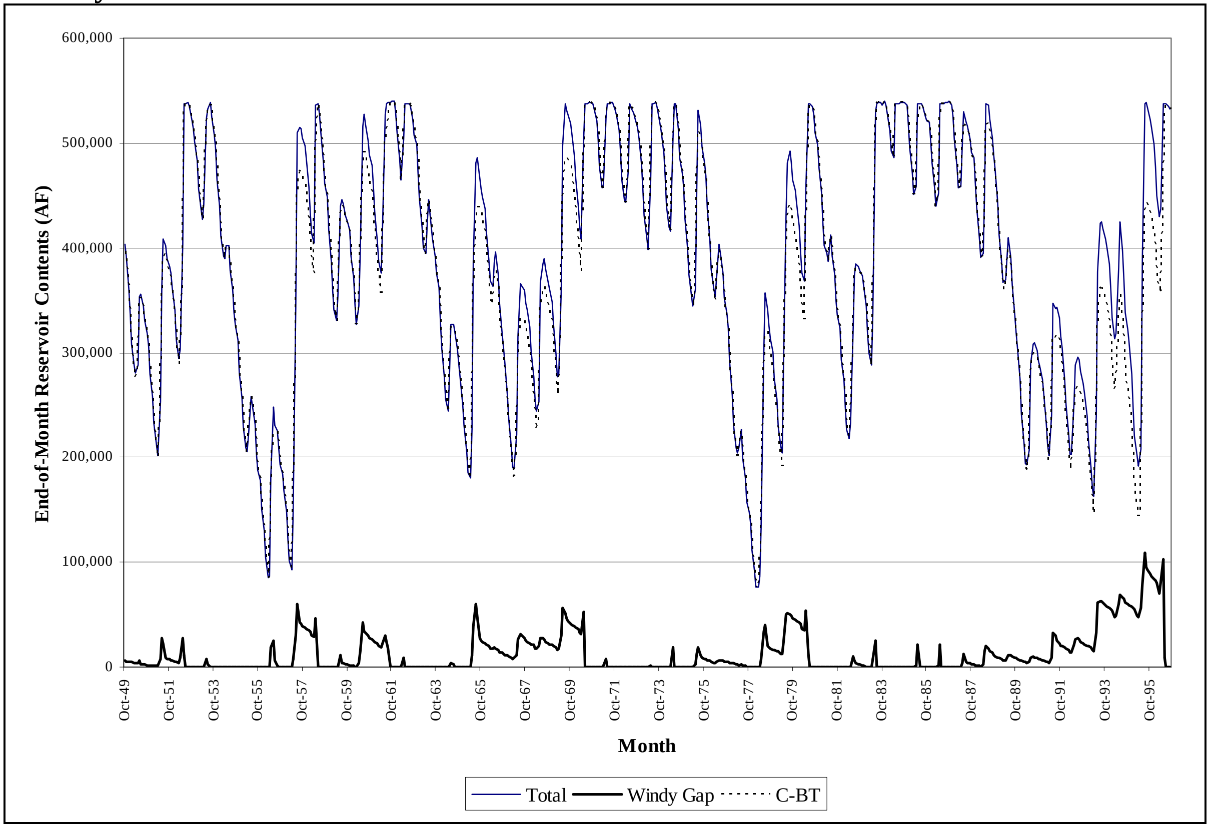
Lake Granby. Average differences in Lake Granby storage between Alternative 3 and Existing Conditions range from about 15,000 AF in March to about 23,000 AF in June (Table F-7). Lake Granby contents would be similar for Existing Conditions, No Action, and Alternative 3 during wet year sequences, when Lake Granby would fill and spill. Differences in Lake Granby contents would be greatest during average and dry year sequences. During these years, Windy Gap diversions would not be limited by C-BT contents in Lake Granby; therefore, differences among the alternatives due to Windy Gap storage in Lake Granby and Windy Gap demands, deliveries, and shrink payments would be greatest. In those years, Windy Gap water would more often be stored in Chimney Hollow and Jasper East Reservoirs rather than Lake Granby under Alternative 3. The reasons for differences in Lake Granby end of month contents between Existing Conditions, No Action, and the Proposed Action, which are described in Section 7.5.1.3, also generally apply for Alternative 3.

The largest change in the average monthly volume of Lake Granby that would occur under this alternative would be a 6 percent reduction in average years, a 5 percent reduction in dry years and a 9 percent reduction in wet years (Table F-7). The maximum monthly average lake elevation change would be a reduction of 4 feet in average years, 3 feet in dry years and 5 feet in wet years (Table F-8).

Differences in Lake Granby contents for Existing Conditions and Alternative 3 would be greatest during dry year sequences. During these years, Windy Gap diversions would not be limited by C-BT contents in Lake Granby; therefore, differences in Lake Granby contents would be due primarily to Windy Gap demands and deliveries and shrink payments. Differences in Lake Granby contents and surface elevations would be greatest (up to 5 feet) during dry year sequences; the chance of a decrease in the lake level of 3 feet or more in any given year would be only 10 percent. During these years, Windy Gap diversions would not be limited by available storage capacity in Lake Granby; therefore, differences would be greater due to Windy Gap storage in Lake Granby, Windy Gap demands and deliveries, and shrink payments.

The amount of C-BT and Windy Gap water stored in Lake Granby would change under Alternative 3 compared to Existing Conditions (Figure 27 and Figure 44).

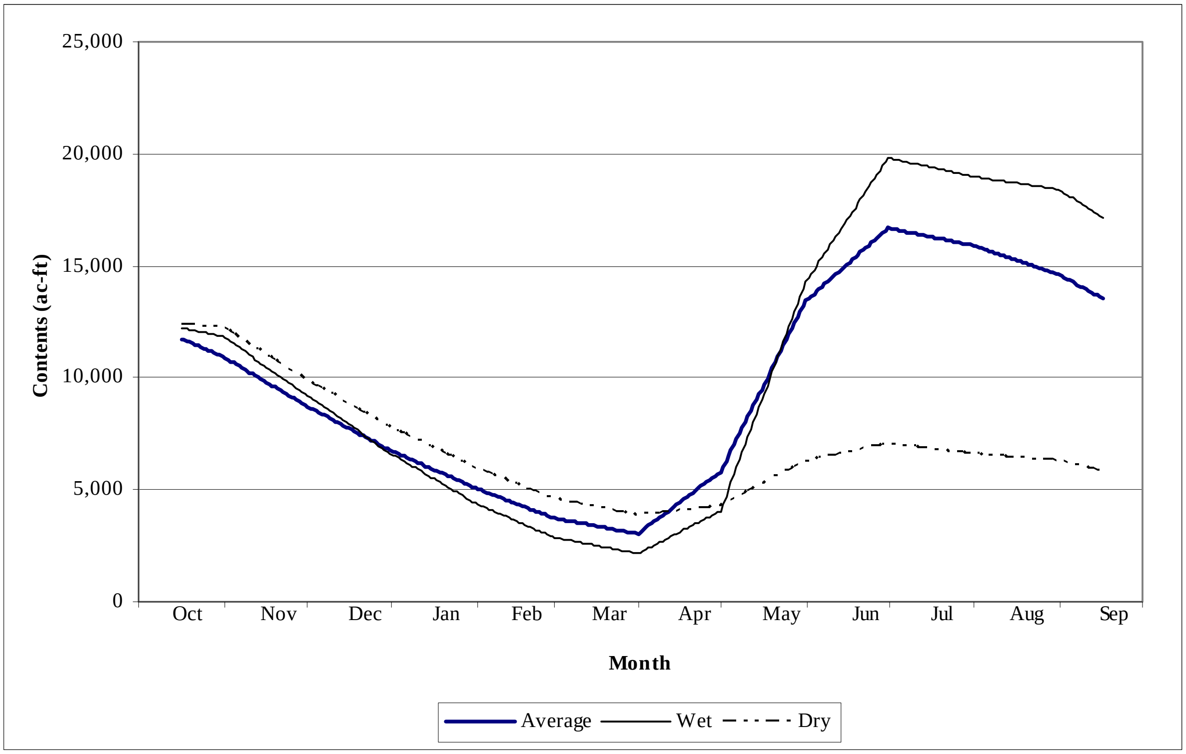
Figure 44. End-of-month storage volume of C-BT and Windy Gap water in Lake Granby under Alternative 3.



Jasper East Reservoir. There would be considerable fluctuation in Jasper East contents from year to year (Figure 45). In general, Jasper East would fill during the Windy Gap diversion season and then empty prior to the following diversion season as releases are made to meet Windy Gap demands. Releasing Windy Gap water from Jasper East to meet demands prior to releasing from Chimney Hollow would maximize the space available in Jasper East for Windy Gap diversions when Lake Granby and the Adams Tunnel are full. Operating Jasper East in this manner would maximize Windy Gap firm yield.

Jasper East Reservoir would not fill in dry year sequences because Windy Gap diversions would be limited by the physically and legally available supply. However, in most average and wet years, Jasper East would fill as long as there are sufficient supplies after Windy Gap diversions to Chimney Hollow occur.

Figure 45. Alternative 3—Jasper East Reservoir average, wet, and dry year daily contents.



7.6.1.4. East Slope Streams

Streams that Receive Windy Gap Return Flows. Under Alternative 3, more Windy Gap water would be delivered to the East Slope than under Existing Conditions and, as a result, there are additional return flows to East Slope streams attributable to indoor and outdoor use of Windy Gap water. Section 7.5.1.2 describes the potential changes to flows in various East Slope streams, which would be similar for all action alternatives.

Big Thompson River from Lake Estes to Canyon Mouth. Under Alternative 3, average monthly flows in the Big Thompson River from below Lake Estes to the Hansen Feeder Canal would increase slightly from April to July (Table D-8) due to a reduction in C-BT diversions from the Big Thompson River. The largest average change would be a 4 percent increase in May in an average year and a 6 percent increase in July during a dry year. There would be no change during wet years. The maximum monthly average change in river stage would occur during dry years in July, but would be less than an inch (Table E-1).

7.6.1.5. East Slope Reservoirs

Carter Lake. Average monthly differences in Carter Lake contents between Existing Conditions, No Action and Alternative 3 would be small, ranging from essentially 0 AF to 1,400 AF (Table F-1). Average monthly contents in Carter Lake would be generally less under No Action and Alternative 3 during the summer months. This would be due primarily to differences in C-BT deliveries from Carter Lake to meet Windy Gap demands (instantaneous deliveries). Windy Gap demands would be met first with instantaneous deliveries from Carter Lake and Horsetooth Reservoir under Existing Conditions, No Action and Alternative 3. Differences in instantaneous deliveries among these scenarios would be due to differences in the amount of Windy Gap water available in Lake Granby for exchange to C-BT and differences in monthly Windy Gap demands.

Average monthly contents under Alternative 3 would be slightly higher than both Existing Conditions and No Action during the winter months. More often there would be less Windy Gap water in Lake Granby in the winter months under Alternative 3 than under Existing Conditions and No Action; therefore, Windy Gap deliveries would more often be made from Chimney Hollow or Jasper East in these months, as opposed to via instantaneous delivery from Carter Lake or Horsetooth Reservoir. Because there are less instantaneous deliveries from Carter Lake during the winter months under Alternative 3, Carter Lake contents would be higher on average in those months.

The largest change in the average monthly volume of Carter Lake that would occur under this alternative would be a 1 percent reduction in average and dry years and a 3 percent reduction in wet years (Table F-1). The maximum monthly average lake elevation change would be 1 foot decrease in average and dry years and a 2 foot decrease in wet years (Table F-2).

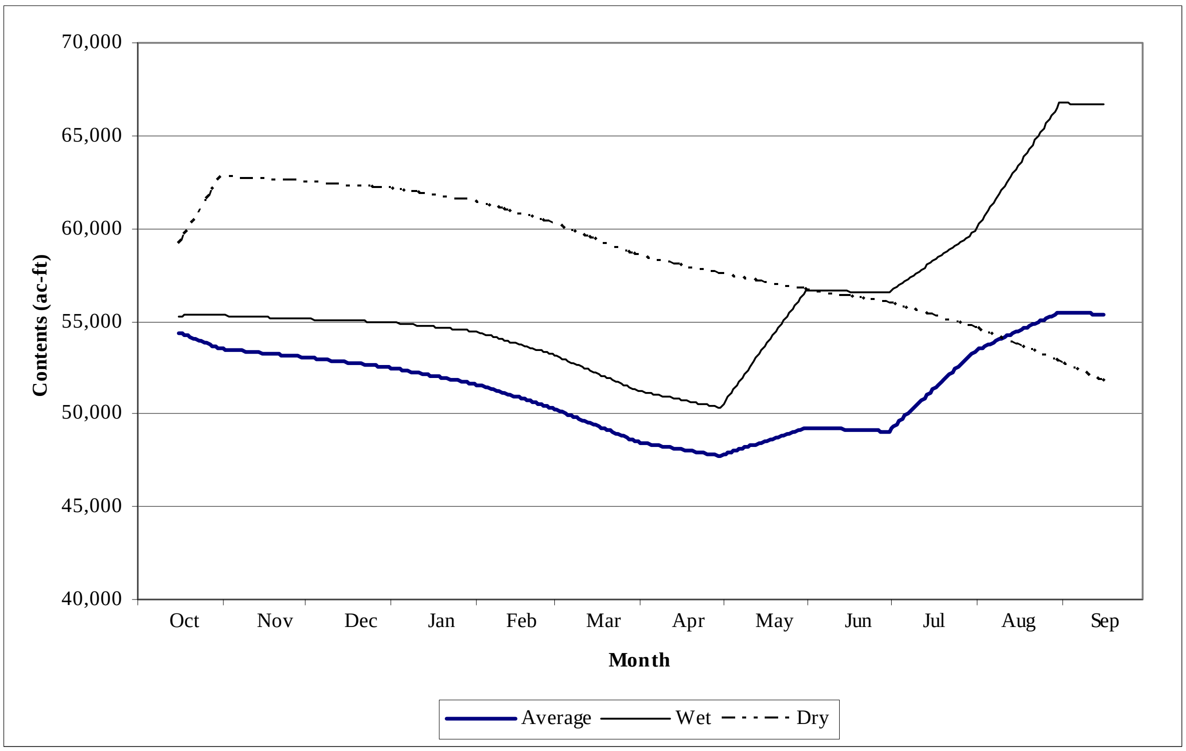
Horsetooth Reservoir. Differences in average monthly Horsetooth Reservoir contents between Existing Conditions and Alternative 3 would be up to 2,600 AF lower from March through December and up to 300 AF higher in February (Table F-4). Differences in monthly contents would be due in part to differences in instantaneous C-BT deliveries from Horsetooth Reservoir to meet Windy Gap demands, as described above for Carter Lake. Another key difference relates to Adams Tunnel maintenance operations in March. Average Adams Tunnel deliveries under Alternative 3 would be approximately 3,700 AF less than Existing Conditions in March because of the additional tunnel outage anticipated that month. This would cause a reduction in C-BT deliveries from Lake Granby to Horsetooth and consequently lower Horsetooth Reservoir contents in March and the following months. There would also be differences in Horsetooth Reservoir contents due to differences in C-BT deliveries to Horsetooth Reservoir. C-BT deliveries to Horsetooth Reservoir would vary among alternatives due to differences in available capacity in the Adams Tunnel and C-BT contents in Lake Granby.

Average monthly contents in Horsetooth Reservoir under Alternative 3 would be higher than both Existing Conditions and No Action in winter months, particularly during wet years. There would typically be less Windy Gap water in Lake Granby in the winter months under Alternative 3; therefore, Windy Gap deliveries would be made from Chimney Hollow or Jasper East in those months, as opposed to via instantaneous delivery from Horsetooth Reservoir under Existing Conditions and No Action. Because there are less instantaneous deliveries from Horsetooth Reservoir during the winter months under Alternative 3, Horsetooth Reservoir contents would be higher on average in those months.

The largest change in the monthly average volume of Horsetooth Reservoir that would occur under Alternative 3 would be a 2 percent reduction in average years, a 3 percent reduction in dry years, and a 1 percent change in wet years (Table F-4). The maximum monthly average lake elevation change would be a reduction of 2 feet in average and dry years and a 1 foot reduction in wet years (Figure 40; Table F-4). A comparison of average surface elevations in Horsetooth Reservoir for Alternative 3 and other alternatives is shown in Figure 40.

Chimney Hollow Reservoir. Chimney Hollow contents would increase during the runoff season as Chimney Hollow fills and decrease through the remainder of the year as releases are made to meet Windy Gap demands (Figure 46). Chimney Hollow would fill during periods of two or more consecutive wet years. The reservoir contents appear much higher for much of the year during dry years because, during the model period, the years preceding dry years were generally wetter that the years preceding wet or average years. Therefore, the reservoir contents would be higher carried over from a wet year, but would drop throughout the year. Chimney Hollow contents would be lowest following consecutive dry years.

Figure 46. Alternative 3—Chimney Hollow Reservoir average, wet, and dry year daily contents.



7.6.2. Ground Water Hydrology and Quality

7.6.2.1. West Slope Reservoirs

Alternative 3 would result in small decreases in Lake Granby surface water elevations. The existing variation in lake level is nearly 90 feet. It is probable that much of the ground water adjacent to the lake is from topographically higher areas surrounding the lake rather than from Lake Granby. The lake elevation change associated with Alternative 3 is considered to be minor with respect to potential effects to ground water and the existing range in reservoir levels. The changes in reservoir stage would not result in measurable effects to ground water.

Although the level of Jasper East Reservoir would vary considerably, ground water in the underlying bedrock is recharged in areas of higher elevation and would not be expected to be affected by water storage in Jasper East Reservoir.

As discussed in Section 7.2.2, it is expected that there would not be any measurable effects to ground water quality under Alternative 3.

7.6.2.2. West Slope Streams

Changes in flow and the resulting stage changes are considered to be minor with respect to potential effects to adjacent ground water levels. The changes in river stage would not result in measurable effects to ground water.

As discussed in Section 7.2.2, it is expected that there would be only minor effects to alluvial ground water quality along the Colorado River and no effects to ground water quality along Willow Creek.

7.6.2.3. East Slope Reservoirs

The impoundment of surface water at Chimney Hollow would not have negative effects to existing ground water and nearby ground water users. Ground water use in the area is limited primarily to domestic wells in fractured bedrock, usually in higher areas around the reservoir site. Currently, the bedrock aquifers are recharged by infiltration in areas where the bedrock aquifers crop out, usually well above the footprint of the proposed impoundment. It is possible that the Chimney Hollow Reservoir could provide additional recharge to fractured aquifers, but this would likely be limited due to the relatively low hydraulic conductivity of the bedrock formations.

The changes in storage and surface elevations of Carter Lake and Horsetooth Reservoir would result in minor effects to nearby ground water levels, as discussed in Section 7.2.1.

As discussed in Section 7.2.2, it is expected that there would not be any effects to ground water quality for Alternative 3.

7.6.2.4. East Slope Streams

Because the average monthly stage change in the Big Thompson River between Lake Estes and the Hansen Feeder Canal under No Action would be no more than 0.02 foot (Table E-1), effects to alluvial or bedrock ground water would be negligible. For the other East Slope streams affected by changing return flows from Participants' WWTPs, because stage changes are expected to be small, increases in alluvial ground water levels would likely be unmeasurable. As discussed in Section 7.2.2, it is expected that ground water quality would not be affected near the foothill streams. For the other East Slope streams on the plains, there may be minor changes to alluvial ground water quality near the streams.

7.6.3. Stream Morphology and Sedimentation

The effects to stream morphology and sediment transport and deposition would be very similar under all of the action alternatives because Colorado River diversions are about the same. See Sections 7.4.3 and 7.5.3 for a discussion of effects to stream morphology and sedimentation.

Channel maintenance flows in the Colorado River near Granby and at Hot Sulphur Springs for Existing Conditions and the alternatives are provided in Tables D-4 and D-19.

The differences in channel maintenance flows between Existing Conditions and Alternative 3 are minor and are not expected to alter channel morphology or sediment movement in the Colorado River.

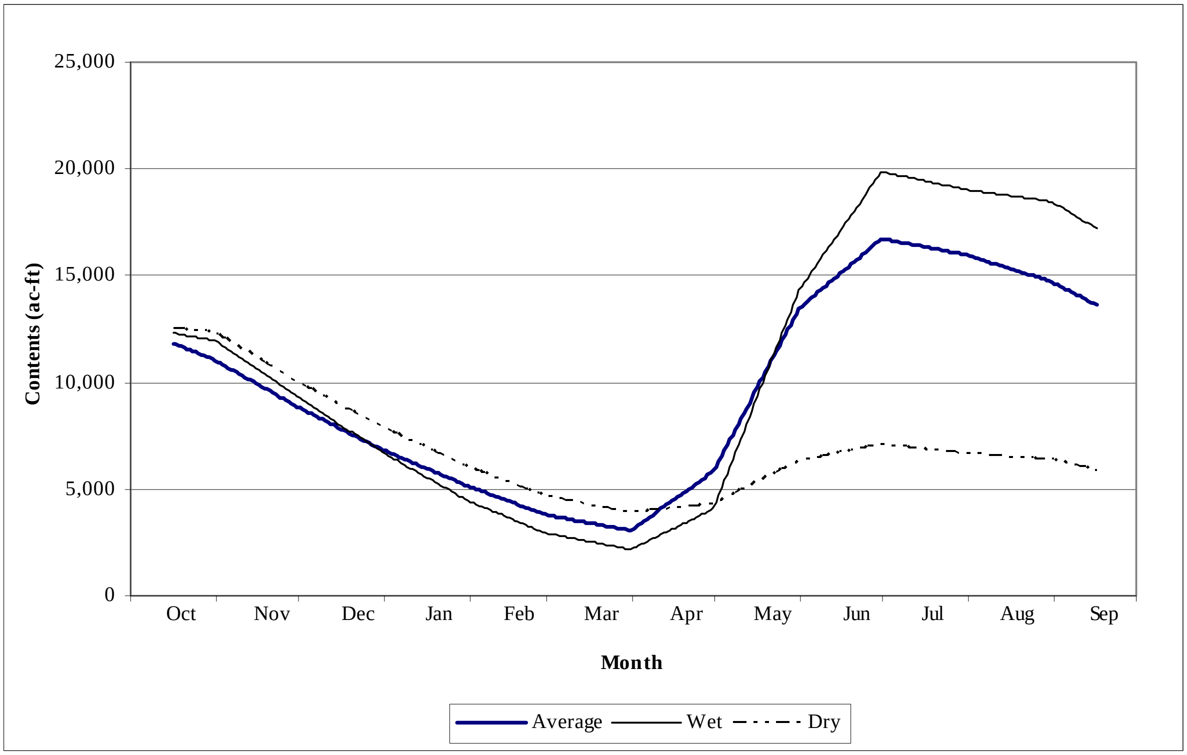
7.7. Alternative 4 (Chimney Hollow Reservoir with Rockwell/Mueller Creek Reservoir)

This alternative is a combination of storage at the Chimney Hollow site (approximately 70,000 AF) on the East Slope and storage at the Rockwell/Mueller Creek site (approximately 20,000 AF) on the West Slope. These reservoirs would operate jointly to firm Windy Gap diversions. The general goal for filling and releasing from Chimney Hollow, Rockwell/Mueller Creek and Lake Granby would be to convey Windy Gap water to the East Slope as soon as possible. This would minimize Windy Gap spills from Lake Granby and maximize space available in Rockwell/Mueller Creek for Windy Gap diversions when Lake Granby and the Adams Tunnel are full. Windy Gap diversions would first be delivered to Chimney Hollow, limited by available space in Chimney Hollow and the Adams Tunnel. If Chimney Hollow Reservoir or the Adams Tunnel were full, Windy Gap diversions would be delivered to Rockwell/Mueller Creek until full and then Lake Granby if space was available. Deliveries to Participants would be made first from Lake Granby via instantaneous delivery, then Rockwell/Mueller Creek either directly or via instantaneous delivery, and last from Chimney Hollow Reservoir.

7.7.1. Surface Water Hydrology

There would be no difference between Alternative 4 and Alternative 3 in terms of project operations, facility sizes and conveyance limitations. The only difference between these alternatives would be the evaporation losses experienced at Rockwell/Mueller Creek Reservoir versus Jasper East Reservoir. Rockwell/Mueller Creek would be a more efficient site in terms of storage versus surface area, with less evaporative losses. However, the difference in evaporative losses between these two reservoir sites would be small, resulting in almost no difference in streamflows, reservoir contents, and diversions between these alternatives. Windy Gap diversions would be slightly higher under Alternative 3 than Alternative 4 to compensate for the additional evaporative losses experienced at Jasper East. Jasper East contents would also be slightly less than Rockwell/Mueller Creek on average due to additional evaporative losses. However, these differences would typically not be carried forward from year to year because Jasper East and Rockwell/Mueller Creek would typically be filled and emptied each year (Figure 47). The model simulation output for Alternatives 3 and 4 are essentially the same. Table 18, Table 19, and Table 20 provide a summary comparison of changes in stream flow for average, dry, and wet years for Alternative 4 and the other alternatives. The reasons for differences in model output between Existing Conditions, No Action and Alternative 3, which are summarized in Section 7.6.1, also apply to Alternative 4. Effects to stream flows, stream stages and reservoir volumes and levels would be virtually identical to Alternative 3 (Table 14; Appendices D, E, and F). Average daily contents for Chimney Hollow Reservoir would be the same as for Alternative 3 (Figure 46).

Figure 47. Alternative 4—Rockwell/Mueller Creek Reservoir average, wet, and dry year daily contents.



7.7.2. Ground Water Hydrology and Quality

7.7.2.1. West Slope Reservoirs

Changes in storage in Lake Granby and the resulting stage changes are considered to be minor with respect to potential effects to ground water. The changes in reservoir stage would not result in measurable effects to ground water.

Depending on the actual seepage losses from the Rockwell/Mueller Creek Reservoir impoundment, areas downstream of the Rockwell/Mueller site could be impacted negatively by increased ground water levels. Seepage from the impoundment could raise ground water levels sufficiently to affect vegetation and existing structures. Well records from this area indicate that most, if not all, wells located in this area produce water from deeper formations rather than shallow deposits, such as alluvium. Seepage losses from the impoundment would likely not impact the deeper aquifers.

As discussed in Section 7.2.2, there would likely not be any negative effects to ground water quality at Lake Granby or the Rockwell/Mueller Creek site.

7.7.2.2. West Slope Streams

Effects to ground water near the West Slope Streams would be the same as discussed in Sections 7.2 and 7.6.2.2.

7.7.2.3. East Slope Reservoirs

The effects to ground water would be the same as discussed in Sections 7.2 and 7.6.2.3.

7.7.2.4. East Slope Streams

The effects to ground water would be the same as discussed in Sections 7.2 and 7.6.2.3.

7.7.3. Stream Morphology and Sedimentation

The effects to stream morphology and sediment transport and deposition would be very similar under all of the action alternatives. See Sections 7.4.3 and 7.5.3 for a discussion of effects to stream morphology and sedimentation.

7.8. Alternative 5 (Dry Creek Reservoir with Rockwell/Mueller Creek Reservoir)

This alternative is a combination of storage at the Dry Creek site (approximately 60,000 AF) on the East Slope and storage at the Rockwell/Mueller Creek site (approximately 30,000 AF) on the West Slope. These reservoirs would operate jointly to firm Windy Gap diversions. The general goal for filling and releasing from Dry Creek, Rockwell/Mueller Creek and Lake Granby would be to convey Windy Gap water to the East Slope as soon as possible. This would minimize Windy Gap spills from Lake Granby and maximize space available in Rockwell/Mueller Creek Reservoir for Windy Gap diversions when Lake Granby and the Adams Tunnel are full. Windy Gap diversions would first be delivered to Dry Creek, limited by available space in Adams Tunnel. If the Adams Tunnel is full, Windy Gap diversions would be delivered to Rockwell/Mueller Creek until full and then Lake Granby if space is available. Deliveries to Participants would be made first from Lake Granby via instantaneous delivery, then Rockwell/Mueller Creek either directly or via instantaneous delivery, and last from Dry Creek.

7.8.1. Surface Water Hydrology

There are no differences between Alternative 5 and Alternative 3 in terms of overall project operations and conveyance limitations. However, the capacity of Dry Creek Reservoir would be 10,000 AF less than Chimney Hollow Reservoir and the capacity of Rockwell/Mueller Creek Reservoir would be 10,000 AF more than Jasper East Reservoir. Figure 48 and Figure 49 show average daily contents for Dry Creek and Rockwell/Mueller Creek Reservoirs, respectively. As a result, there would be differences in evaporative losses experienced at the sites. Rockwell/Mueller Creek is a more efficient site in terms of storage versus surface area and as a result evaporative losses would be less at Rockwell/Mueller Creek than Jasper East at similar storage contents. Chimney Hollow and Dry Creek would have similar area-capacity relationships; therefore, differences in evaporative losses would be minimal at similar contents. However, there would be differences in evaporative losses when additional water is stored in Rockwell/Mueller Creek under Alternative 5 versus in Chimney Hollow under Alternative 3.

Annual Windy Gap diversions under Alternative 5 would be about 1 percent higher on average than Alternative 3 because there would be more West Slope firming storage available for Windy Gap diversions in situations when the Adams Tunnel and Lake Granby are full (Table 18). An additional 10,000 AF of storage at Rockwell/Mueller Creek would enable Windy Gap to divert more water when Lake Granby and the Adams Tunnel are full in comparison with Alternatives 3 and 4. When Windy Gap diversions are not limited by firming storage capacity and available capacity in the Adams Tunnel, total Windy Gap diversions would be the same for alternatives 3, 4, and 5. The only difference would be the division of Windy Gap water among East Slope and West Slope storage.

The differences in evaporative losses and Windy Gap diversions between Alternative 3 and Alternative 5 would be small, resulting in almost no difference in simulation output between these alternatives. The model simulation output for these two alternatives was essentially the same; therefore, the reasons for differences in model output between Existing Conditions, No Action and Alternative 3, which are summarized in Sections 7.4.1 and 7.6.1, also apply to Alternative 5. Table 18, Table 19, and Table 20 provide a summary comparison of changes in stream flow for average, dry, and wet years for Alternative 5 and the other alternatives. Effects to stream flows, stream stages, and reservoir volumes and levels are very similar to Alternative 3 and Alternative 4.

Dry Creek Reservoir contents would increase during the runoff season as the reservoir fills and decrease through the remainder of the year as releases are made to meet Windy Gap demands (Figure 48). Dry Creek would fill during periods of 2 or more consecutive wet years. The reservoir contents appear much higher for much of the year during dry years because, during the model period, the years preceding dry years were generally wetter than the years preceding wet or average years. Therefore, the reservoir contents would be higher carried over from a wet year, but would drop throughout the year. Dry Creek Reservoir contents would be lowest following consecutive dry years.

Figure 48. Alternative 5—Dry Creek Reservoir average, wet, and dry year daily contents.

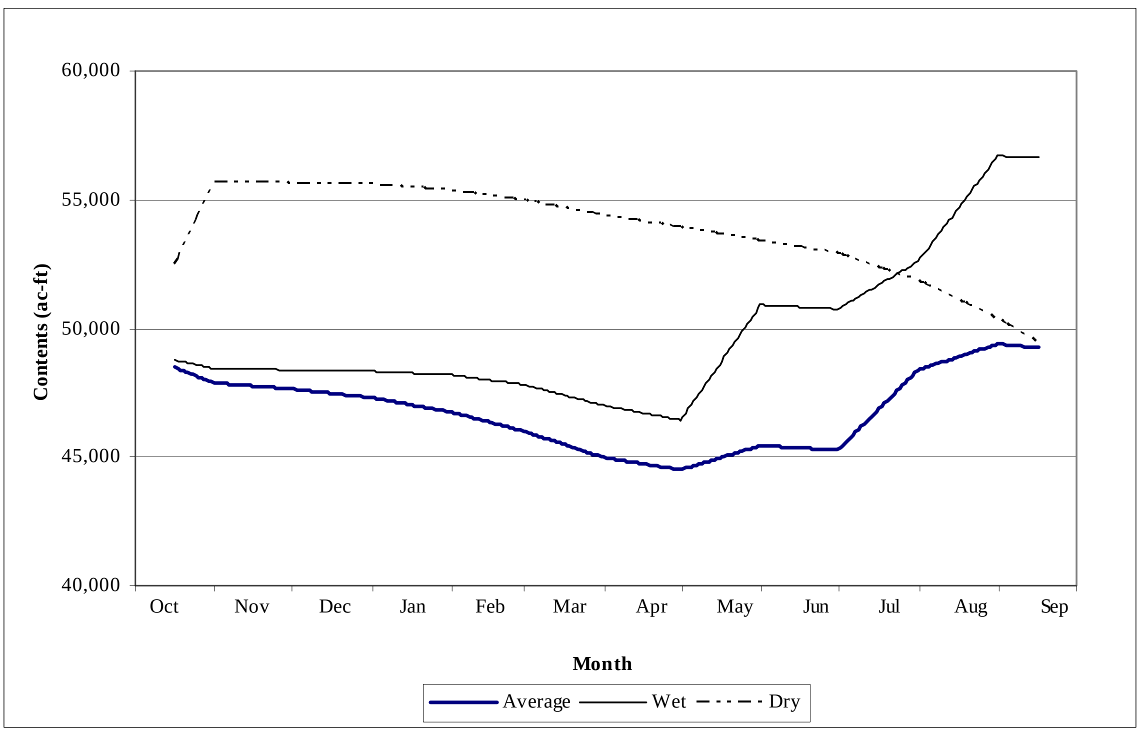
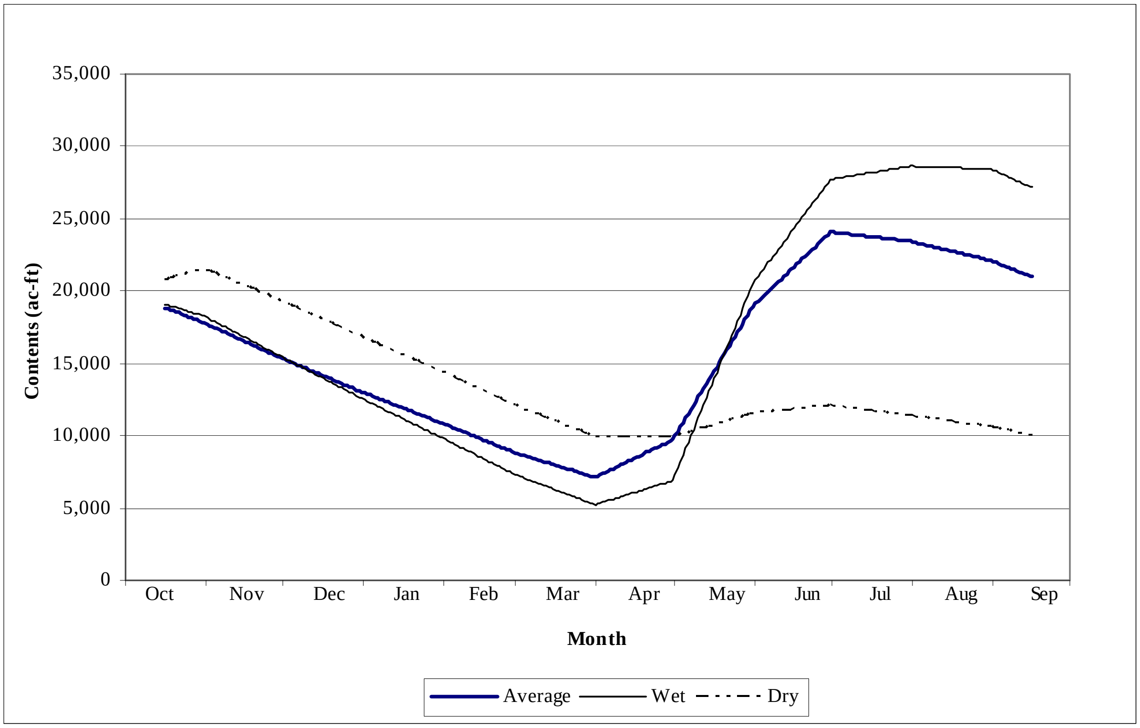


Figure 49. Alternative 5—Rockwell/Mueller Creek Reservoir average, wet, and dry year daily contents.



7.8.2. Ground Water Hydrology and Quality

7.8.2.1. East Slope and West Slope Streams

Effects to ground water would be the same as discussed in Sections 7.2 and 0.

7.8.2.2. East Slope and West Slope Reservoirs

The impoundment of surface water in Dry Creek Reservoir, Carter Lake and Horsetooth Reservoir would not have negative effects to existing ground water and nearby ground water users. Effects to ground water would be the same as discussed in Sections 7.2 and 7.7.2.1.

7.8.3. Stream Morphology and Sedimentation

The effects to stream morphology and sediment transport and deposition would be very similar under all of the action alternatives. See Section 7.6.3 for a discussion of effects to stream morphology and sedimentation.

7.9. Windy Gap Firming Project Participant and Non-Participant Demands, Firm, and Average Yields

A summary of annual Participant and non-Participant demands and yields for Existing Conditions and all alternatives are shown in Table 25 (which includes the Middle Park Water Conservancy District) and Table 26. Table 27 shows MPWCD's demands and yields. The yield for the action alternatives would be similar because the storage volumes would be the same. Firm yield is defined as the yield that can be provided by the WGFP each year of the study period without any shortages. Alternative 5 would have the highest firm yield of 26,200 AF per year for the Participants and Alternatives 3 and 4 would have the lowest firm yield at 25,420 AF per year for the Participants. The No Action alternative would have a firm yield of about 7,200 AF per year due to the additional storage at Ralph Price Reservoir. The firm yield under Existing Conditions is zero. Tables showing the monthly demand, firm yield and average yield for WGFP Participants, non-Participants and the Middle Park Conservancy District are provided in Appendix C.

Windy Gap demands under No Action are higher than under Existing Conditions and the Action alternatives because Participants would try to maximize their use of Windy Gap water when it is available as their demands increase in the future. Under the Action alternatives, the Participants' demands reflect the amount of Windy Gap water that could be delivered each year without any shortage. In other words, the Participants would operate the Windy Gap Project to provide firm yield with storage on-line. While Windy Gap demands would be higher under No Action, average Windy Gap deliveries under this scenario would be less than the Action alternatives. Average deliveries would be less because C-BT storage space would be unavailable for Windy Gap in wet years (Windy Gap water would typically be spilled in those years and deliveries would be considerably less than the demand).

The demand for Windy Gap unit holders not in the Firming Project would increase in the future for all alternatives and as a result, the average yield to non-participants would increase (Table 26). Windy Gap yield for non-participants would increase slightly compared to the No Action alternative under each of the action alternatives because more storage for non-participant water would be available in Lake Granby and non-participant water in Lake Granby would not spill as soon, so they would be able to deliver more water. The firm yield to non-participants would remain zero under all alternatives.

Table 25. Windy Gap Participant demand, average yield, and firm yield.

Condition/Alternative	Demand	Average Yield	Firm Yield
Existing Conditions	20,825	11,372	0
Alternative 1 No Action	36,665	21,936	1,229
Alternative 2 Chimney Hollow	26,130	29,010	26,559
Alternative 3 Chimney Hollow w/Jasper East	29,130	28,259	25,849
Alternative 4 Chimney Hollow and Rockwell	28,420	28,284	25,849
Alternative 5 Dry Creek and Rockwell	29,200	29,071	26,629

Table 26. Windy Gap Non-Participant demands, average yield, and firm yield.

Condition/Alternative	Demand	Average Yield	Firm Yield
Existing Conditions	220	140	0
Alternative 1 No Action	4,100	2,190	0

Condition/Alternative	Demand	Average Yield	Firm Yield
Alternative 2 Chimney Hollow	4,100	2,300	0
Alternative 3 Chimney Hollow w/Jasper East	4,100	2,320	0
Alternative 4 Chimney Hollow and Rockwell	4,100	2,320	0
Alternative 5 Dry Creek and Rockwell	4,100	2,330	0

Storage of 3,000 AF was included in Alternatives 2 through 5 for firming MPWCD's Windy Gap water. Under Existing Conditions, MPWCD can only store their Windy Gap water in Lake Granby; therefore, MPWCD's firm yield is zero. Under the No Action alternative, the firm yield for the MPWCD would remain zero, but average yield would increase because of an increase in demand. Under the action alternatives, the firm annual yield would be 429 AF, which closely reflects the minimum amount of Windy Gap water pumped during the study period less the shrink payment. The average MPWCD yield for each of the action alternatives would be close to 3,000 AF.

Table 27. MPWCD demands, average yield, and firm yield.

Condition/Alternative	Demand	Average Yield	Firm Yield
Existing Conditions	145	102	0
Alternative 1 No Action	3,000	2,026	0
Alternative 2 Chimney Hollow	3,000	2,880	429
Alternative 3 Chimney Hollow w/Jasper East	3,000	2,839	429
Alternative 4 Chimney Hollow and Rockwell	3,000	2,864	429
Alternative 5 Dry Creek and Rockwell	3,000	2,871	429

8.0 CUMULATIVE EFFECTS

8.1. Introduction

Cumulative effects result from the incremental effect of an alternative action when added to other past, present, and reasonably foreseeable future actions. Cumulative effects can result from individually minor, but collectively significant actions taking place over a time period. Potential future actions were identified through public and agency scoping, input from cooperating agencies and local agencies, and available data on known projects or actions under consideration. Actions that meet all of the following criteria were considered reasonably foreseeable and were included in the cumulative effects analysis:

- The action would occur within the same geographic area where effects from the alternative WGFP actions are expected to occur.
- The action would affect the same environmental resources as the WGFP alternatives, and measurably contribute to the total resource impact.
- There is reasonable certainty as to the likelihood of the action occurring; the action is not speculative.
- There is sufficient information available to define the action and conduct a meaningful analysis.

Several potential future actions were considered reasonably foreseeable and were not included in the hydrologic analysis. Potential future actions that did not meet the criteria for reasonably foreseeable actions included projects such as construction of Wolcott or Sulphur Gulch reservoirs for storage and release of 10,825 AF for endangered fish in the lower Colorado River. Although these actions are not currently considered reasonably foreseeable, they could occur at some point in the future; however, based on the best available information, these actions did not meet the criteria for reasonably foreseeable actions. The Windy Gap Firming Project Alternatives Report provides a discussion of the actions reviewed, but not considered reasonably foreseeable (ERO 2005b). The assumptions used for future changes in water releases from Williams Fork Reservoir and Wolford Mountain Reservoir for endangered species are discussed below under reasonably foreseeable actions.

This section of the report evaluates the potential cumulative effects to water resources associated with alternative actions in addition to identified reasonably foreseeable actions that are expected to occur in the future. Changes in surface water hydrology, ground water hydrology and water quality, and stream morphology and sedimentation are discussed for the alternatives in a similar format and sequence as the direct environmental effects in Section 7.0. The estimated firm yield to Windy Gap Firming Project Participants and non-Participants with reasonably foreseeable actions in place are also summarized.

8.2. Reasonably Foreseeable Actions

Several reasonably foreseeable actions are anticipated to occur in the future regardless of the implementation of any of the WGFP action alternatives or the No Action alternative. Reasonably foreseeable actions were divided into water-based actions that would affect portions of the Colorado River where Windy Gap diversions would occur, and land-based actions that include ground disturbances or other activities near potential WGFP facilities. Water- and land-based reasonably foreseeable actions are defined below.

8.2.1. Water-Based Reasonably Foreseeable Actions

DW Moffat Collection System Project. The Moffat Collection System Project is currently proposed by DW to develop 18,000 AF/year of new, firm annual yield to the Moffat Treatment Plant to meet future raw water demands on the East Slope. The supplies to meet Denver Water’s additional future demand of 18,000 AF/year would come from its entire integrated system, which includes Moffat System, the South Platte River, and Blue

River supplies. Denver Water would draw on their additional storage in the Moffat System to meet their demands, in combination with releases from their South System. As a result, Denver Water's Moffat Tunnel diversions would increase by approximately 9,000 to 10,000 AF/year on average, while additional diversions from South Boulder Creek, the South Platte River, and Blue River would increase by about 8,000 to 9,000 AF/year on average, depending on the alternative.

This project is anticipated to result in additional diversions from the upper Fraser River and Williams Fork River basins. DW's proposed additional Fraser River diversions would be located upstream of the Windy Gap Project diversion site on the Colorado River and would directly affect the availability of water for the WGFP. Because a Proposed Action has not been identified for the Moffat Collection System Project, a scenario for hydrologic modeling was considered that maximizes DW's future diversions from the Fraser River basin. DW provided output from its Platte and Colorado Simulations Model (PACSM) run that includes DW's total system demand at approximately 393,000 AF/year, which would be full use of its existing system, plus 18,000 AF of new firm yield generated by the Moffat Collection System Project. DW's current demand is 285,000 AF/year; therefore, an increase in demand of 108,000 AF/year was considered for the cumulative effects analysis. DW provided monthly transbasin diversion data generated from their model, PACSM, for the Roberts Tunnel, Gumlick Tunnel, and Moffat Tunnel under a demand of 393,000 AF/year. These diversions were placed as a demand (boundary condition) in the WGFP model at these structures, respectively. DW separated the Williams Fork River (via Jones Pass Tunnel) yield to the Moffat Tunnel from the Fraser River basin yield to the Moffat Tunnel. Accordingly, in the WGFP Model, the Moffat Tunnel node demand is set to DW's modeled Fraser River basin yield. This demand is "fed" by diversions at four collection sites (Jim Creek, Vasquez Creek, St. Louis Creek, and Ranch Creek). Jones Pass Tunnel is modeled as an exporting diversion structure, with demand set to DW's modeled Williams Fork River basin yield. DW's modeling period ends in 1991, so Moffat Tunnel and Jones Pass demand had to be estimated for the last 5 years of the WGFP study period (see memo, Extension of the Denver Water Diversion Data Set from 1991 through 1996, Boyle, June 2005).

Urban Growth in Grand and Summit Counties. The population in Grand and Summit Counties is expected to more than double over the next 25 years, from a year-round population of about 39,000 in 2005 to about 79,000 in 2030 (ERO 2005a). Most growth in Grand County is likely to occur in the Fraser River basin upstream of the Windy Gap Project diversion site on the Colorado River. Future increases in water use in Summit County would occur primarily in the Blue River basin, a tributary to the Colorado River downstream of Windy Gap's point of diversion. Increased water use and wastewater discharges are expected to result in changes in streamflow and water quality and contribute to cumulative effects. Urban growth in Grand and Summit Counties was based on build-out municipal and industrial demands of 16,168 AF for Grand County and 17,940 AF for Summit County as identified in the *Upper Colorado River Basin Study* (Hydrosphere 2003). Year 2000 water demand in Grand County was about 3,100 AF and in Summit County was about 7,700 AF. Table 4-1 of the WGFP Modeling Report Addendum (Boyle 2006a) summarizes the build-out demands for major water providers in Grand and Summit counties. Nodes were added to the CDSS future conditions model along the Fraser River, Blue River, and Colorado River mainstem to reflect indoor, outdoor, and snowmaking build-out diversions, depletions, and return flows. Average monthly build-out diversions were incorporated as demands at the outdoor and snowmaking use nodes. Average monthly build-out depletions (diversions less return flows) were incorporated as demands at the indoor use nodes since return flows at WWTPs were assumed to occur within the same month the diversion occurred. The monthly distributions of the build-out demands, efficiencies, and locations and timing of snow making and outdoor use return flows were based on data obtained from Denver Water for the UPCO Study. Build-out diversions were modeled as senior diversions to reflect the maximum amount of depletion that could occur as a result of this growth.

Reduction of Excel Energy's Shoshone Power Plant Call. DW and Excel Energy have negotiated an agreement to periodically invoke a relaxation of the junior Shoshone call for hydropower generation on the Colorado River.[3] The agreement to relax the call could result in a one-turbine call of 704 cfs, which would be managed in such a way to avoid a Cameo Call by the Grand Valley Water users[4]. The Shoshone call could be increased above 704 cfs as needed to keep the Cameo water rights satisfied. The Shoshone call relaxation could be invoked if, in March, DW predicts its total system storage to be at or below 80 percent on July 1 that year, and the March 1 Natural Resources Conservation Service (NRCS) forecast for Colorado River flows at Kremmling or Dotsero are at or below 85 percent of average. The Shoshone call relaxation could be invoked between March 14 and May 20. DW would make available 15 percent of the "net water" stored or diverted by DW by virtue of the call relaxation for Excel Energy. Net water is water stored less water subsequently spilled after filling. In addition, DW would make available 10 percent of the net water stored or diverted by DW by virtue of the call relaxation to West Slope entities. The West Slope beneficiaries and the timing and amount of deliveries are not specified, but would be determined by DW and the CRWCD. There is currently no requirement that others that benefit from the Shoshone reduction provide water to the West Slope and Xcel. The term of this agreement is from January 1, 2007 through February 28, 2032.

Changes in Releases from Williams Fork and Wolford Mountain Reservoirs to Meet USFWS Flow Recommendations for Endangered Fish in the 15-Mile Reach. The Programmatic Biological Opinion for the recovery of endangered fish includes a provision for East Slope and West Slope water users to split equally the delivery of 10,825 AF of permanent water to the 15-Mile Reach of the Colorado River east of Grand Junction. An agreement that extends through July 1, 2009 between the City and County of Denver, the CWCB, and the USFWS exists for the interim provision of water to the 15-Mile Reach of the Colorado River for East Slope water users. A similar agreement exists between the CRWCD, CWCB, and the USFWS for West Slope water users. These agreements provide for the total release of 10,825 AF of water annually from both Williams Fork and Wolford Mountain Reservoirs (5,412.5 AF from each reservoir) to meet USFWS flow

[3] The Shoshone Hydro Plant owned by Excel Energy, is a large senior water right on the Colorado River 8 miles east of Glenwood Springs. At flows less than 1,408 cfs, it is the most senior water right on the River and can "call" water downstream from junior water rights upstream, including the Moffat Tunnel, C-BT Project, Windy Gap, and other water rights.

[4] The Cameo Call is a senior water right owned by five entities near Grand Junction. The water is used primarily for irrigation and power.

recommendations for the 15-Mile Reach. These contracts expire in 2009 and 2010, respectively, and both DW and the CRWCD have said they do not plan to continue making these releases from Williams Fork and Wolford Mountain Reservoirs in the future. The source and location of future water releases of 10,825 AF/year has not been determined. For the purposes of this analysis, it was assumed that the releases would be made from a reservoir located downstream of Kremmling and outside the study area considered for the cumulative effects analysis.

Wolford Mountain Reservoir Contract Demand. The CRWCD projects that the demand for contract water out of Wolford Mountain Reservoir will increase in the future. Currently there is about 8,750 AF/year of available contract water in Wolford Mountain Reservoir (Colorado Springs has a lease for contract water from Wolford Mountain Reservoir which reduces the firm yield of the contract pool from 10,000 AF/year to 8,750 AF/year). The CRWCD indicates that the full 8,750 AF/year would likely be contracted for by 2030. In addition, MPWCD has 3,000 AF/year of water from Wolford Mountain Reservoir, of which 613 AF/year is owed to DW under the Clinton Reservoir Agreement. The CRWCD indicated that the remaining 2,387 AF/year would likely be contracted for by 2030. Therefore, the total additional future demand for contract water from Wolford Mountain Reservoir is assumed to be 11,137 AF/year by 2030.

Expiration of DW's Contract with Big Lake Ditch in 2013. The Big Lake Ditch is a senior irrigation right in the Williams Fork basin that diverts below DW's Williams Fork collection system and above Williams Fork Reservoir. Big Lake Ditch diversions are currently delivered for irrigation above Williams Fork Reservoir and for use in the Reeder Creek drainage, which is a tributary of the Colorado River. Return flows associated with irrigation in the Reeder Creek drainage return to the Colorado River between the confluence with the Williams Fork River and the confluence with the Blue River.

In 1963, DW entered into a contract with Bethel Hereford Ranch Inc., which owned and operated the Big Lake Ditch, whereby DW purchased the Ranch's water rights. Bethel Hereford was granted a 40-year lease to continue its operation under the condition that the Big Lake Ditch water rights are not called if needed by DW. The 1963 agreement was superseded by a 1998 agreement, which extended the operation of the Big Lake Ditch through 2013, and provided more detail on the conditions under which DW would need the water. The 1998 agreement expires November 1, 2013 and DW does not plan to extend the existing contract. After the contract expires in 2013, the Big Lake Ditch can no longer divert water under the enlargement decree for 111 cfs for irrigation in the Reeder Creek drainage. As a result, future Big Lake Ditch water right diversions to the Reeder Creek basin would be abandoned, which would allow DW to capture additional water from the Williams Fork and store the water in Williams Fork Reservoir during all years that its Williams Fork Reservoir water rights are in priority.

8.2.2. Land-Based Reasonably Foreseeable Actions

Land Development. A variety of new land developments are expected to occur in the vicinity of the potential reservoir sites in Larimer, Grand, and Boulder counties. This includes residential and commercial developments on the West Slope; on the East Slope, this includes residential development, a quarry, and a new reservoir.

Larimer County Open Space. Larimer County Parks and Open Lands acquired about 1,850 acres of land adjacent to the proposed Chimney Hollow Reservoir site. The County intends to manage this property for recreation use regardless of whether Chimney Hollow Reservoir is constructed.

Urban Growth in the Northern Front Range. Continued population growth and development is expected to occur in the Northern Front Range, Colorado communities served by many of the Firming Project Participants.

8.3. Methods for Cumulative Effects Analysis

The analysis of cumulative effects to water resources was conducted in the same manner as the direct effects analysis described in Section 7.0. The future conditions BESTSM and CDSS Model developed for the cumulative effects analysis were used to simulate the potential effects of the alternatives in combination with other past, present, and reasonably foreseeable future actions. Future conditions model parameters related to past, present, and reasonably foreseeable actions are described in the Windy Gap Firming Project Modeling Report (Boyle 2003) and Addendum (Boyle 2006a).

Hydrologic output from the model includes Existing Conditions, which reflects current demands, diversions, operations, facilities and projects and administration of the Colorado River. This includes past actions such as operation of the C-BT Project, Moffat Collection System, and other actions as described in Section 6.1. The cumulative effects model output for the No Action alternative includes the addition of the reasonably foreseeable actions to past actions as a basis for comparison with the action alternatives in the future. Because of the similarity in the effects of Alternatives 3, 4, and 5, which each include a combination of East Slope and West Slope reservoirs, the cumulative effects analysis used the results of Alternative 5 (Dry Creek Reservoir and Rockwell/Mueller Creek Reservoir) as representative of these three alternatives. Thus, the cumulative hydrologic effect of Existing Conditions and future No Action are compared to the Proposed Action and Alternative 5.

All of the reasonably foreseeable water-based actions described above are represented in the WGFP Future Conditions Model except for the reduction of Excel Energy’s Shoshone Power Plant Call and the location of future releases of 10,825 AF/year to meet the flow recommendation for endangered fish in the 15-Mile reach. The effects of a Shoshone Power Plant Call reduction are discussed in Section 8.4.2.6. The current release of the 10,825 AF/year (5,412.5 AF/year from both Williams Fork Reservoir and Wolford Mountain Reservoir) was excluded from the model, and it was assumed that this water would be released downstream on the Colorado River below the study area of the WGFP. Land-based reasonably foreseeable actions do not directly affect modeling or the analysis of water resources and are not discussed.

The year 2030 was used as the time period for the assessment of cumulative effects because it is projected that the full demand for Windy Gap Firming Project water would occur by then. In addition, the identified reasonably foreseeable actions are expected to be in place by 2030. A possible exception is the timing on the future water demand for Grand and Summit Counties. The best available information indicates a build-out water demand of 34,108 AF per year for Grand and Summit Counties, which could potentially occur before or after year 2030 (Hydrosphere 2003).

8.4. Surface Water Hydrology

8.4.1. Facilities and Stream Segments Affected by Windy Gap Operations

Streams affected by Windy Gap operation include the Colorado River below Lake Granby, Willow Creek, St. Vrain Creek, Big Thompson River, and other East Slope streams that receive Windy Gap return flows, as described in Section 7.1.1. Windy Gap operations also affect Adams Tunnel diversions, WCFC diversions, C-BT Reservoir contents, Lake Granby spills and C-BT diversions from the Big Thompson River. As with the direct effects analysis, there would be no change in C-BT Project demand or deliveries for any of the alternatives under Cumulative Effects (Table 15).

8.4.2. Facilities and Stream Segments Affected by Reasonably Foreseeable Actions

Identified reasonably foreseeable actions include those activities that potentially have overlapping or incremental effects with the WGFP. This primarily includes the Colorado River downstream of the Windy Gap diversion, which is located below the confluence with the Fraser River. However, reasonably foreseeable actions in the Fraser River basin and upper Colorado River upstream of the Windy Gap diversion affect the amount of water available for diversion by the WGFP.

The five major tributaries that discharge into the Colorado River from the confluence of Willow Creek and the Colorado River downstream to Kremmling include Fraser River, Williams Fork River, Troublesome Creek, Muddy Creek, and Blue River. While there would be no change in tributary flow as a result of the WGFP alternatives, there would be streamflow changes that would occur due to reasonably foreseeable future actions. Reasonably foreseeable actions that affect tributary flow to the Colorado River are discussed below. Future Conditions include hydrologic conditions with the implementation of all reasonably foreseeable actions.

Tables provided in Appendix I list the average monthly and annual changes in streamflow that would occur at various locations in the Colorado River from below Lake Granby to the top of Gore Canyon. Information is provided for Existing Conditions and each of the alternatives for average, dry, and wet years. Table 28 provides the range of modeled daily flow changes that would occur at the three long-term USGS flow gages (near Granby, at Hot Sulphur Springs and near Kremmling) in May through August, the months during which most Windy Gap diversions would occur. Table 28 also provides the percentage of days in May through August that various ranges of flow changes would occur. There would be some days under all of the alternatives at all three locations when flows would increase due to changes in timing of spills from Lake Granby and below Windy Gap Reservoir, and also because downstream demands would increase in the future, meaning that Windy Gap would have to bypass more water to satisfy senior downstream water rights and bypass or instream flow requirements. There would be no change in daily flows at the gage near Granby between about 77 percent and 79 percent of the time during May through August, between about 6 percent and 7 percent of the time at Hot Sulphur Springs, and about 1 percent of the time at the gage near Kremmling. Flow increases would occur at Hot Sulphur Springs about 25 percent of the time in May through August and about 13 to 14 percent of the time near Kremmling.

Table 28. Range and percent occurrence of daily flow changes under the Alternatives (compared to Existing Conditions), May through August, Cumulative Effects.

Colorado River near Granby

	Percentage of Days in May through August That Flow Changes Occur		
Daily Flow Changes (cfs)	**No Action**	**Proposed Action**	**Alternative 5**
+1 to +211	3.6%	-	-
+1 to +142	-	7.8%	-
+1 to +117	-	-	3.8%
0	78.65%	76.7%	77.3%
-1 to -10	7.2%	1.5%	4.9%
-11 to -100	4%	4.4%	5.2%
-101 to -200	3%	3.65%	3.5%
-201 to -300	1.1%	1.6%	1.4%
-301 to -500	0.85%	1.5%	1.7%
-501 to -1,000	1%	1.7%	1.25%
-1,001 to -1,966	0.6%	-	-
-1,001 to -2,453	-	-	0.95%
-1,001 to -2,884	-	1.05%	-

Colorado River at Hot Sulphur Springs

	Percentage of Days in May through August That Flow Changes Occur		
Daily Flow Changes (cfs)	**No Action**	**Proposed Action**	**Alternative 5**
+1 to +159	24.9%	24.2%	23%
0 cfs	6.6%	7.25%	7.4%
-1 to -10	20.4%	20.7%	19.9%
-11 to -100	26.4%	25.6%	24.2%
-101 to -200	7.95%	5.5%	7.2%
-201 to -300	4.4%	3.5%	4.2%
-301 to -500	4.65%	5.9%	6.3%
501 to 1,000	3%	4.3%	5%
1,001 to 2,027	1.7%	-	-
1,001 to 2,319	-	-	2.7%
1,001 to 2,977	-	3%	-

Colorado River near Kremmling

	Percentage of Days in May through August Flow That Changes Occur		
Daily Flow Changes (cfs)	**No Action**	**Proposed Action**	**Alternative 5**
+1 to +197	14.5%	13.3%	13.35%
0	1.3%	1.30%	1.3%
-1 to -10	1.8%	1.6%	1.6%
-11 to -100	25.9%	27.10%	26.7%
-101 to -200	16.6%	15.5%	14.75%
-201 to -300	7.4%	7.45%	8.45%
-301 to -500	11.2%	11.5%	11%
-501 to -1,000	14.7%	13.6%	14%
-1,001 to -2,916	6.6%	-	-
-1,001 to -3,375	-	-	8.8%
-1,001 to -3,465	-	8.6%	-

8.4.2.1. Fraser River

Average annual flows in the Fraser River at the mouth would be approximately 91,000 AF under Existing Conditions and 79,700 AF under Future Conditions for all alternatives (Table 30). The reduction in flow in the Fraser River under Future Conditions would be due primarily to DW's additional transbasin diversions through Moffat Tunnel and urban growth in Grand County. Both of these reasonably foreseeable actions result in additional diversions and depletions from the Fraser River basin[5]. DW's average annual demand for Fraser River deliveries through the Moffat Tunnel and depletions associated with urban growth in the Fraser River basin would increase by about 9,300 AF and 1,600 AF, respectively, under Future Conditions compared to Existing Conditions. Reductions in flows would be greatest in June and July in average and wet years when DW's increased diversions through the Moffat Tunnel would be greatest. Other diversions in the Fraser River basin that are affected by reasonably foreseeable actions reduce average annual flows at the mouth of the Fraser River by about 400 AF. Thus, the total reduction in average annual flows at the mouth of the Fraser River under Future Conditions would be about 11,300 AF.

5 The proposed Moffat Collection System EIS alternatives would generate an additional 18,000 AF/year of new firm yield. The supplies to meet Denver Water's additional future demand of 18,000 AF/year would come from its entire integrated system, which includes Moffat System, South Platte River and Blue River supplies. Denver Water would draw on their additional storage in the Moffat System to meet their demands, in combination with releases from their South System. As a result, Denver Water's Moffat Tunnel diversions would increase by approximately 9,000 to 10,000 AF/year on average, while additional diversions from South Boulder Creek, the South Platte River and Blue River would increase by about 8,000 to 9,000 AF/year on average depending on the alternative.

8.4.2.2. Williams Fork River

Average annual flows in the Williams Fork River at the mouth would be approximately 90,100 AF under Existing Conditions and 95,300 AF under Future Conditions for all alternatives (Table 30). Changes in the quantity and timing of flows in the Williams Fork River would be primarily due to the combined effects of the following reasonably foreseeable actions.

1) Releases of 5,412.5 AF/year would no longer be made from Williams Fork Reservoir for endangered fish in the 15-Mile Reach. These releases are typically made in the fall when flows drop below the USFWS flow recommendations. This future action would change Williams Fork Reservoir operations, including the timing and quantity of reservoir storage and releases. Flows in the Williams Fork River would be affected by these changes in reservoir operations. Because fish flow releases from Williams Fork Reservoir would not be made under Future Conditions, flows in the Williams Fork River would be less by a commensurate amount in the fall compared to Existing Conditions.

DW's additional transbasin diversions from the Fraser, Williams Fork, and Blue Rivers would result in increased exchange releases from Williams Fork Reservoir to cover DW's out of priority depletions and increased substitution releases to cover DW's out of priority storage in Dillon Reservoir when Green Mountain Reservoir does not fill. The net effect of additional exchange releases and reductions in fish flow releases would be offset by a corresponding change in the amount of water stored in Williams Fork on average. As a result, changes in Williams Fork Reservoir operations (storage and releases) would affect the timing of flows below the reservoir but there would be little change in the annual quantity of flow on average due to these future actions.

2) DW's future growth and implementation of the Moffat Collection System Project would result in additional transbasin diversions from the Williams Fork River basin. DW's average annual demand for Williams Fork River diversions through Gumlick Tunnel would increase by about 2,000 AF under Future Conditions versus Existing Conditions.

3) In the future, the Big Lake Ditch can no longer divert under the enlargement decree for 111 cfs for irrigation in the Reeder Creek drainage after the expiration of the DW's Big Lake Ditch contract. Under Existing Conditions, a significant portion of the water diverted under the Big Lake Ditch was delivered for irrigation in the Reeder Creek drainage. Big Lake Ditch return flows in the Reeder Creek drainage return to the Colorado River below the confluence with the Williams Fork River. Under Future Conditions, Big Lake Ditch diversions would decrease, deliveries to the Reeder Creek drainage would be curtailed, and all Big Lake Ditch return flows would accrue to the Williams Fork River. The change in Big Lake Ditch diversions and return flows in the future would result in approximately 8,800 AF/year less depletion and a corresponding increase in flows on average in the Williams Fork River basin versus Existing Conditions.

The combined effect of the future actions described above would increase average annual flows at the mouth of Williams Fork River by approximately 5,300 AF compared to Existing Conditions. On average, changes in flows at the mouth would be greatest from June through October when differences in Big Lake Ditch depletions and return flows, DW diversions, and Williams Fork Reservoir operations would be greatest. Changes in flow under Future

Conditions would be primarily due to the reduction in Big Lake Ditch depletions and returns flows out of the Williams Fork River basin and the increase in DW's transbasin diversions. While changes in Williams Fork Reservoir operations would affect the timing of flows in the river, there would be relatively little impact on the average annual quantity of flow. Williams Fork Reservoir operations would be affected primarily by the elimination of fish flow releases, increased exchange releases to cover DW's out of priority diversions, and increased substitution releases to cover DW's out of priority storage in Dillon Reservoir when Green Mountain Reservoir does not fill.

8.4.2.3. Troublesome Creek

Flows in Troublesome Creek at the confluence with the Colorado River would be the same for all alternatives under both Existing and Future Conditions (Table 30). Some diversions on Troublesome Creek would be affected by calls on the mainstem of the Colorado River; therefore, there would be very small changes in the flow of Troublesome Creek between Existing Conditions and the alternatives.

8.4.2.4. Muddy Creek

Flows in Muddy Creek are influenced by Wolford Mountain Reservoir operations. Wolford Mountain Reservoir's primary operations include releases to cover DW's and Colorado Springs' substitution requirements for out-of-priority diversions when Green Mountain Reservoir does not fill, releases to cover contract demands, and releases for endangered fish flow requirements. The following reasonably foreseeable actions would have the greatest affect on Wolford Mountain Reservoir operations:

1) Releases of 5,412.5 AF/year will no longer be made from Wolford Mountain Reservoir for endangered fish in the 15-Mile Reach. These releases are typically made in the fall when flows drop below the USFWS flow recommendations. This future action would change Wolford Mountain Reservoir operations, including the timing and quantity of reservoir storage and releases. Flows in Muddy Creek would be affected by these changes in reservoir operations. Because fish flow releases would be not made under Future Conditions, flows in Muddy Creek would be less by a commensurate amount in the fall. However, less water would be stored during the runoff season to replace these releases, so flows during runoff would increase on average below the reservoir due to differences in the amounts stored and the timing and quantity of spills.

2) The future demand for contract water from Wolford Mountain Reservoir is anticipated to increase to about 11,100 AF/year by 2030, as previously described (Boyle 2006a). Releases from Wolford Mountain Reservoir would be required to cover future monthly depletions if the depletions are out of priority. The specific entities that would contract for this water in the future and the locations of the depletions have not been identified. Thus, the model was configured so that Wolford Mountain Reservoir would release to cover monthly contract depletions during the winter months (September through March) and in summer months of dry years. In addition, releases would be made in several average years depending on whether the Shoshone Power Plant rights were estimated to be calling. Of the total future contract demand, the average annual modeled release from Wolford Mountain Reservoir to meet this demand would be about 7,325 AF/year. This future action would change Wolford Mountain Reservoir operations, including the timing

and quantity of reservoir storage and releases. Flows in Muddy Creek would be affected by these changes in reservoir operations under Future Conditions. Because releases for contract demands increase under Future Conditions, flows in Muddy Creek would increase on average by a commensurate amount primarily during winter months and in summer months of dry years versus Existing Conditions. However, more water would be stored during the runoff season to replace these releases, so flows during runoff decrease on average below the reservoir compared to Existing Conditions.

3) Wolford Mountain Reservoir's substitution releases for DW and Colorado Springs would be also affected by reasonably foreseeable actions that reduce flows in the Blue River and Colorado River and increase the call on the Colorado River. The amount of water diverted out of priority by DW and Colorado Springs in relation to Green Mountain Reservoir increases under Future Conditions. As a result, substitution releases from Wolford Mountain would increase in the future in dry years compared to Existing Conditions.

The future actions described above combine to have the following affect on flows in Muddy Creek. Average annual flows in Muddy Creek at the mouth would be approximately 65,500 AF under both Existing Conditions and Future Conditions for all alternatives (Table 30). Both average and wet year annual flows in Muddy Creek at the mouth would be the same under Existing Conditions and Future Conditions because increased Wolford Mountain Reservoir releases under Future Conditions would be offset by an increase in the amount of water stored and reduction in spills on average. This has the effect of changing the timing of flows below the reservoir but not the quantity of flow on an average annual basis. Under Future Conditions, flows at the mouth generally would increase on average from August through March. In these months, additional reservoir releases to meet increased contract demands and substitution requirements would exceed the reduction in releases to meet fish flow requirements on average. Flows at the mouth would generally decrease on average during the runoff season under Future Conditions when more water would be stored to replace releases and spills would be reduced.

Average annual dry year flows in Muddy Creek at the mouth increase under Future Conditions versus Existing Conditions. Reservoir releases would increase under Future Conditions because additional releases to meet contract demands and substitution requirements exceed the reduction in releases to meet fish flow requirements. There would not be a corresponding increase in the amount stored to offset additional releases because Wolford Mountain Reservoir is more often limited by the available supply in dry years and generally stores similar amounts under both Existing and Future Conditions. Therefore, in dry years, flow additions due to increased reservoir releases would not be offset by flow reductions due to additional storage under Future Conditions.

8.4.2.5. Blue River

Average annual flows in the Blue River at the mouth would be approximately 313,600 AF under Existing Conditions and 258,700 AF under Future Conditions for all alternatives (Table 30). The reduction in flow in the Blue River under Future Conditions would be due primarily to DW's additional transbasin diversions through Roberts Tunnel and increased depletions due to urban growth in the Blue River basin. DW's average annual delivery through the Roberts Tunnel and depletions associated with urban growth in Summit County increase by about 54,000 AF and 3,000 AF, respectively, under Future Conditions compared to Existing Conditions. Reductions in flow would be greatest in May, June, and July in average and wet years when DW's increased diversions through Roberts Tunnel would be greatest. Additional diversions in Summit County due to growth in outdoor and snowmaking demands results in both additional depletions and changes in return flows. For example, additional snowmaking diversions decrease flows in winter months but increase flows in the summer months due to return flows. Therefore, the change in flows at the mouth of the Blue River would be a combination of the effect of additional diversions and return flows.

There would also be effects on other diversions in the Blue River basin and Dillon Reservoir and Green Mountain Reservoir operations due to reasonably foreseeable actions. Changes in diversions affect the timing and quantity of depletions and return flows. Changes in reservoir releases, the amounts stored, and spills, also affects the timing and quantity of flows at the mouth of the Blue River. The net effect would be an average annual reduction in flow of about 55,000 AF at the mouth of the Blue River.

8.4.2.6. Colorado River

As described in Section 8.2, the Shoshone call reduction would result in hydrologic changes in the Colorado River and other locations if implemented during dry years. The following sections describe the potential frequency and magnitude of hydrologic effects when the call reduction is in place.

Frequency of the Shoshone Call Reduction

The triggers to invoke that permit a relaxation of the Shoshone call are based on forecasts of Denver Water's total system storage and the March 1 NRCS forecast for Colorado River flows at Kremmling or Dotsero. Historical Denver Water (DW) reservoir contents and streamflow forecast data were relied on to evaluate how often the call relaxation would have potentially been invoked from 1947 through 2002. Because historical forecasts of DW's July 1 reservoir contents are lacking, DW's historical July 1 reservoir contents were reviewed for the period from 1947 through 2002. Historical reservoir contents provide a reasonable indication of whether the first trigger condition would have been met. DW's total system storage was less than 80 percent on July 1 in the following eleven years: 1951, 1954, 1955, 1956, 1957, 1963, 1964, 1965, 1977, 1978, and 2002. While DW's total system storage was less than 80 percent on July 1 in 1957 and 1965, it was over 90 percent later in July and August in both of those years. Both 1957 and 1965 were relatively wet years, however, flows were above average primarily after the March through May period affected by the call relaxation. Without historical forecast data, it is difficult to predict whether the Shoshone call relaxation would have been invoked in years like 1957 through 1965.

The second trigger condition that must be met to invoke permit the call relaxation involves NRCS forecast data for Colorado River flows at Kremmling or Dotsero. Streamflow forecasts for the Colorado River at Kremmling are not yet made by the NRCS. Streamflow forecasts for the Colorado River at Dotsero exist for the period from 1969 through 2005. Since Dotsero forecast data does not exist prior to 1969, the evaluation of whether the Shoshone call would have been invoked during the period from 1947 through 1968 only considered DW's historical storage contents. From 1969 through 2005, there were only three years that Denver's total system storage on July 1 was less than 80 percent: 1977, 1978 and 2002. Of those years, only 1977 and 2002 had March forecasts that were less than

85 percent or average. Therefore, it is unlikely that the call relaxation would have been invoked in 1978.

Based on historical July 1 storage contents in DW's reservoirs and available streamflow forecast data for the Colorado River at Dotsero, the Shoshone call relaxation may have been invoked in about 8 to 10 years during the period 1947 through 2002, or roughly 1 out of every 6 to 7 years. Since 2002, the Shoshone call was relaxed from March 14 through May 20 inclusive in 2003 in accordance with a March 21, 2003 agreement between Denver and the River District. The agreement to relax the call in 2003 was not based on the triggers specified in the current potential agreement. In addition, the Shoshone Power Plant was not in a position to call for water from March 10 through July 12 inclusive in 2004 because the plant was down for maintenance.

Hydrologic Effects of the Shoshone Call Reduction

The relaxation of the Shoshone call would allow diverters that would otherwise be called out to divert water in-priority even if they are junior to the Shoshone Power Plant water rights. Because more diversions would be made in-priority, releases from reservoirs such as Green Mountain, Wolford Mountain, and Williams Fork Reservoir for exchange or substitution purposes would also be less. Increased in-priority diversions and reduced reservoir releases for exchange and/or substitution would decrease flows in the Upper Colorado River basin during the relaxation period. Colorado River flows at Dotsero would not be affected outside of the relaxation period.

The magnitude and timing of flow reductions attributable to a Shoshone call relaxation could vary widely from year to year and would depend on many factors including streamflows, storage contents, project operations, and bypass/instream flow requirements. Therefore, it is difficult to quantify potential hydrologic effects associated with a call reduction. Data from 2003 and 2004 have been relied on to characterize the magnitude of hydrologic effects that have occurred historically due to a Shoshone call relaxation. While there was no formal call relaxation in 2004, the Shoshone Power Plant was down for maintenance and therefore was not in a position to call for water from March 10 through July 12. Table 29 summarizes the gains to key upstream entities due to the relaxation of the Shoshone call in 2003 and 2004 from March 14 through May 20 inclusive, as quantified by DW and reviewed by the Bureau of Reclamation, the River District, and others.

Table 29. Historical gains from Shoshone Call Relaxation March 14 through May 20 inclusive.

Project/Water Rights	2003 Gains[1,2] (AF)	2004 Gains[1] (AF)
Continental Hoosier Project (1929 and 1948 Rights)	1	212
Green Mountain Reservoir	6,415	6,190
Wolford Mountain Reservoir	2,036	5,708
Moffat Tunnel	388	1,124
Williams Fork Reservoir (1935 Right)	1,350	5,869
Roberts Tunnel	974	6,833
Dillon Reservoir	2,027	315
Windy Gap	7,850	0

Project/Water Rights	2003 Gains[1,2] (AF)	2004 Gains[1] (AF)
Homestake	193	590
Total	**21,234**	**26,841**

[1] Gains were calculated as if the Shoshone calls were 1,300 and 1,500 cfs, respectively, as opposed to 1,250 cfs and 1,408 cfs, therefore, gains are overestimated slightly.
[2] Meadow Creek Reservoir gained 432 AF in 2003 due to the Shoshone call relaxation. Gains in 2004 were not quantified.

The key projects/water rights that benefited from a reduction of the Shoshone call in 2003 and 2004 included the Continental-Hoosier Project, Green Mountain Reservoir, Wolford Mountain Reservoir, DW (Moffat Tunnel, Williams Fork Reservoir, Roberts Tunnel, and Dillon Reservoir), Windy Gap, and the Homestake Project. An explanation of the water gains to these projects is provided below.

Continental Hoosier Project. By relaxing the Shoshone call, the Continental Hoosier Project, which diverts water from the Blue River above Dillon Reservoir, was able to divert more water under their 1929 right (Table 29). The Continental Hoosier Project also diverted more water in-priority under their 1948 right, which is junior to Green Mountain Reservoir. This water would have been diverted regardless of the Shoshone call relaxation, however, there was no need to make substitution releases from Wolford Mountain Reservoir because Green Mountain Reservoir filled. Both 2003 and 2004 would have been substitution years had it not been for the Shoshone call relaxation. The reaches of river affected by these benefits are the Blue River, in relation to the 1929 water right, and Muddy Creek below Wolford Mountain Reservoir, and the Colorado River below the confluence of Muddy Creek, in relation to reduced substitution releases.

Green Mountain Reservoir. Green Mountain Reservoir, which diverts water to storage from the Blue River, was able to divert more water to storage in March and April in both 2003 and 2004 as a result of the Shoshone call relaxation (Table 29). The reach of river affected by these additional diversions is the Blue River below Green Mountain Reservoir and the Colorado River below the confluence of the Blue River. The Shoshone call relaxation could also benefit the Green Mountain Reservoir Historic User's Pool (HUP) and contract pool by reducing releases required to cover out-of-priority depletions.

Wolford Mountain Reservoir. Wolford Mountain Reservoir, which diverts water to storage from Muddy Creek, benefited from a reduction of the Shoshone call in both 2003 and 2004 because more water was stored in priority (Table 29). In addition, 2003 and 2004 would have been substitution years had it not been for the Shoshone call reduction. DW and Colorado Springs (Continental Hoosier Project) rely on Wolford Mountain Reservoir to replace (substitute) what is owed Green Mountain Reservoir if it does not fill. See the next section, for a discussion of DW's substitution releases out of Williams Fork Reservoir. With a call reduction, Green Mountain Reservoir is in priority to store more inflow below Dillon Reservoir; therefore, the call reduction can reduce the amount owed by DW and the Continental Hoosier Project. A reduction in substitution releases would reduce flows below Wolford Mountain Reservoir primarily in the fall when these releases are typically made. Had 2003 and 2004 been substitution years the benefits to DW and the Continental Hoosier Project shown in Table 29 would have been less and substitution releases would have been required. The reaches of river affected by additional storage at Wolford Mountain Reservoir and reduced substitution releases is Muddy Creek below the reservoir and the Colorado River below the confluence with Muddy Creek. Differences in substitution releases would not change flows in the Colorado River below the confluence with the Blue River.

DW (Moffat Tunnel, Williams Fork Reservoir, Roberts Tunnel Dillon Reservoir). DW diverted more water in-priority from the Fraser River and Williams Fork River basins through the Moffat Tunnel as a result of the Shoshone call relaxation in 2003 and 2004 (Table 29). Note, that this water would have been diverted regardless of the Shoshone call, however, DW did not have to make exchange releases from Williams Fork Reservoir. In a similar manner, DW diverted more water in-priority from the Blue River at Roberts Tunnel and Dillon Reservoir. Again, this water would have been diverted regardless of the Shoshone call, however, DW did not have to made exchange releases from Williams Fork Reservoir. The reach of river affected by reduced exchange releases from Williams Fork Reservoir is the Williams Fork River below Williams Fork Reservoir and the Colorado River below the confluence with the Williams Fork River.

Williams Fork Reservoir, which diverts water to storage from the Williams Fork River, also benefited from a reduction of the Shoshone call in both 2003 and 2004 (Table 29). Williams Fork Reservoir stored more water in priority and had to release less to exchange against DW's out-of-priority diversions (described above). In addition, 2003 and 2004 would have been substitution years had it not been for the Shoshone call relaxation. DW relies on Williams Fork Reservoir to replace (substitute) what is owed Green Mountain Reservoir if it does not fill. With a call reduction, Green Mountain Reservoir is in priority to store more inflow below Dillon Reservoir; therefore, the call reduction can reduce the amount owed by DW. A reduction in substitution releases would reduce flows below Williams Fork Reservoir primarily in the fall when these releases are typically made. Had 2003 and 2004 been substitution years the benefits to DW shown in Table 29 would have been less and substitution releases would have been required. The reach of river affected by increased diversions to storage and reduced substitution releases from Williams Fork Reservoir is the Williams Fork River below Williams Fork Reservoir and the Colorado River below the confluence with the Williams Fork River. Differences in substitution releases would not change flows in the Colorado River below the confluence with the Blue River.

Windy Gap. By relaxing the Shoshone call in 2003, the Windy Gap Project diverted additional water from the Colorado River from mid-April through mid-May (Table 29). The reach of river affected by these diversions is the Colorado River below Windy Gap. The Windy Gap Project did not benefit from the call reduction in 2004 because there were other factors that constrained diversions, namely downstream instream flow requirements. It is likely that 2004 is more typical of future Windy Gap benefits during call reductions. Although March 1 forecasts for storage and runoff were low in 2003, late-season snow increased runoff significantly. This resulted in a significant quantity of water available for Windy Gap pumping and DW storage contents greater than 80 percent on July 1. The supply available to Windy Gap was higher in 2003 than it would likely be in most years the call is relaxed.

Homestake Project. The Homestake Project diverted water primarily in mid to late April due to a reduction in the Shoshone call in both 2003 and 2004 (Table 29). Additional diversions by the Homestake Project affect the Eagle River and the Colorado River below the confluence with the Eagle River.

DW Deliveries to West Slope Entities. The current agreement provides that DW will make available to West Slope entities 10 percent of the net water stored or diverted by DW as a result of the call reduction. The agreement does not specify the beneficiaries nor does it define how water will be provided by DW (i.e., reservoir releases, increased bypasses, etc.). As such, the potential hydrologic effects of these deliveries are difficult to characterize. In 2003, DW provided water to Grand County through augmentation of flows in the Fraser River, achieved by bypasses that were in addition to bypass flows required of DW. In addition, water was dedicated to the MPWCD from DW's account at Wolford Mountain Reservoir and to the Clinton Ditch and Reservoir Company from DW's account in Clinton Reservoir.

Summary

The triggers to invoke that permit a relaxation of the Shoshone call are based on forecasts of DW's total system storage and the March 1 NRCS forecast for Colorado River flows at Kremmling or Dotsero. Based on historical July 1 storage contents in DW's reservoirs and available streamflow forecast data for the Colorado River at Dotsero, the Shoshone call relaxation may have been invoked in about 8 to 10 years during the period 1947 through 2002, or roughly 1 out of every 6 to 7 years.

The key projects/water rights that would benefit from a Shoshone call relaxation include the Continental-Hoosier Project, Green Mountain Reservoir, Wolford Mountain Reservoir, DW (Moffat Tunnel, Williams Fork Reservoir, Roberts Tunnel, and Dillon Reservoir), Windy Gap, and the Homestake Project. These projects/facilities would be able to divert more water in-priority even if they are junior to the Shoshone Power Plant water rights. Because more diversions would be made in-priority, releases from reservoirs such as Green Mountain, Wolford Mountain, and Williams Fork Reservoir for exchange or substitution purposes would be less. Increased in-priority diversions and reduced reservoir releases for exchange and/or substitution would decrease flows in the Upper Colorado River basin primarily in the Williams Fork River, Muddy Creek, the Blue River, and the Colorado River mainstem below the Windy Gap diversion during the relaxation period. There would be no change in Colorado River flows at Dotsero outside of the relaxation period. The only changes in flows outside of the relaxation period would be due to differences in substitution releases from Wolford Mountain and Williams Fork Reservoirs. However, differences in substitution releases would not change flows in the Colorado River below the confluence with the Blue River. Flows in the Fraser River basin during the relaxation period would likely not be affected because DW diverts regardless of the Shoshone call and exchanges with releases from Williams Fork Reservoir to cover out-of-priority diversions. Flows in the Fraser River basin could potentially be higher outside of the relaxation period if DW increases bypasses in a manner similar to 2003 as part of the 10 percent water owed to West Slope entities.

The magnitude and timing of flow reductions attributable to a Shoshone call relaxation could vary widely from year to year. In 2003 and 2004 the flow reductions due to a relaxation of the Shoshone call totaled 21,234 AF and 26,841 AF, respectively.

8.4.3. Comparison of Model Simulation Output

A summary comparing average annual flows and diversions at key locations on the West Slope for Existing Conditions, No Action, the Proposed Action, and Dry Creek and Rockwell/Mueller Creek Reservoirs (Alternative 5), which is representative of Alternatives 3 and 4, is provided in Table 30. As with the direct effect analysis, average values for each of the alternatives were modeled for the 47-year study period (1950 to 1996). In addition, dry and wet year averages, which are defined as the average of the five wettest (1957, 1983, 1984, 1986, and 1995) and five driest years (1954, 1966, 1977, 1981, and 1989) in the study period are shown in Table 31 and Table 32, respectively.

The average monthly streamflow, stream stage, and reservoir content for each of the alternatives under cumulative effects are presented in Appendices G, H, and I for key C-BT and WGFP reservoirs and affected stream segments.

In general, the reason for the differences in streamflow, reservoir content, diversions, and operations between Existing Conditions, No Action, and the action alternatives under Future Conditions are similar to those discussed in detail for direct effects in Section 7.0. Sections 8.5 to 8.7 summarize modeling results for No Action, the Proposed Action, and Alternative 5. The primary reasons for differences in C-BT and Windy Gap Project operations and diversions and streamflow changes as a result of the reasonably foreseeable actions would be similar for all of the alternatives, as described below.

8.4.3.1. Adams Tunnel Diversions

Adams Tunnel diversions would be less for all of the alternatives under Future Conditions compared to direct effects because of the reduction in Windy Gap diversions as a result of reasonably foreseeable actions. C-BT deliveries through the Adams Tunnel in the future would be the same as Existing Conditions because C-BT storage, demands, and deliveries would be the same.

8.4.3.2. Windy Gap Diversions

Windy Gap diversions would generally be less in the future under all of the alternatives for the following reasons.

1) The amount of water available for diversion at Windy Gap would decrease under Future Conditions because the Fraser River inflow to the Colorado River would decrease (on average). DW's increased demand and the Moffat Collection System Project results in additional diversions from the upper Fraser River basin. In addition, urban growth in Grand County results in increased water use and diversions in the Fraser River basin. DW's and Grand County's increased diversions and depletions in the Fraser River basin occur upstream of the Windy Gap Project diversion site on the Colorado River and are senior in priority to Windy Gap; therefore, these future actions directly reduce the amount of water available for diversion at Windy Gap. About 82 percent of the future average annual flow reduction of 11,300 AF in Fraser River flows would be due to DW's demand for Fraser River diversions through the Moffat Tunnel. The remainder would be from additional Grand County water use and other diversions that would affect the quantity and timing of flows in the Fraser River.

Additional diversions in Grand County due to growth in outdoor and snowmaking demands would result in both additional depletions and changes in return flows. For example, additional snowmaking diversions would decrease flows in winter months but increase flows in the summer months due to return flows. Therefore, the change in flows available at Windy Gap would be a combination of the effect of additional diversions and changes in return flows.

2) The amount of water available for diversion at Windy Gap also would change due to differences in Lake Granby spills and WCFC diversions under Future Conditions. However, typically differences in spills and WCFC diversions would occur in wet years when Windy Gap diversions are often constrained by other factors (decree limitations and available space in the C-BT system and the firming project reservoirs), as opposed to the physical supply at Windy Gap.

3) The amount of water legally available for diversion at Windy Gap would decrease under Future Conditions. The flow regime in the Colorado River downstream of Windy Gap and the call on the river that controls how much is legally available for diversion at Windy Gap would be affected by the reasonably foreseeable future actions. In average and wet years, Windy Gap diversions are typically controlled by the 90-cfs minimum downstream flow requirement. In dry years, the amount Windy Gap must bypass to satisfy downstream senior rights is often controlled by the Shoshone Power Plant water rights. The reasonably foreseeable actions could at times change the call on the Colorado River downstream of Windy Gap; in this case, the amount of water legally available to Windy Gap would change. The largest effect from foreseeable actions would be DW's additional diversions through Roberts Tunnel and depletions associated with urban growth in Summit County; these actions would substantially reduce the amount of Blue River inflow to the Colorado River, which is upstream of the Shoshone Power Plant diversion. As a result, the amount of flow at the Shoshone Power Plant would decrease under Future Conditions. If changes in the flow regime affect the ability to meet the demand at Shoshone under Future Conditions, the amount of water that Windy Gap must bypass could change. The flow that Windy Gap must bypass to satisfy downstream senior rights would be higher on average because the flow available to meet the Shoshone call would decrease under Future Conditions.

4) Differences in available capacity in Lake Granby and the Adams Tunnel between Existing Conditions and Future Conditions would affect Windy Gap diversions. For example, at times when Windy Gap diversions are limited by available capacity in Lake Granby or the Adams Tunnel under Existing Conditions, Windy Gap diversions could increase under Future Conditions if available capacity is no longer a constraint and there is sufficient water available to divert.

8.4.3.3. Willow Creek Feeder Canal Diversions

The C-BT Project diverts water from Willow Creek for delivery to Lake Granby via the WCFC. When space in Lake Granby is not a limiting factor on the amount of water that can be diverted from Willow Creek, there would be no difference in WCFC diversions among the alternatives. When space in Lake Granby is a limiting factor and Lake Granby fills with both Windy Gap and C-BT water, Windy Gap water in Lake Granby would be exchanged with C-BT water, as opposed to pumping from Willow Creek to spill Windy Gap water. This is considered a "paper spill" of Windy Gap water.

WCFC diversions would be higher under Future Conditions because there can be more physical space available in Lake Granby for diversions from Willow Creek in wet years prior to spills. Windy Gap diversions would be less on average under Future Conditions; therefore, Windy Gap contents in Lake Granby would often be lower in wet years prior to spills. Under Future Conditions, there would be more opportunity to physically pump water from Willow Creek, as opposed to exchanging against Windy Gap water in wet years.

There would also be minor differences in WCFC diversions between Existing and Future Conditions due to differences in Lake Granby C-BT contents. For each alternative, there would be differences in C-BT contents in Lake Granby due to Windy Gap operations, such as shrink payments to the C-BT Project, demands and deliveries, and spills. When water is diverted from Willow Creek to fill Granby, the amount diverted depends on both C-BT and Windy Gap contents in Granby.

There would be essentially no difference in dry year WCFC diversions between Existing Conditions and Future Conditions. Average annual dry year WCFC diversions would be the same for all alternatives under both Existing and Future Conditions. The reasonably foreseeable actions do not affect the supply available to the WCFC and diversions would not be limited by available capacity in Lake Granby in dry years.

8.4.3.4. Lake Granby Spills

C-BT storage in Lake Granby takes precedence over Windy Gap storage. When Lake Granby fills, the first water spilled would be Participant and Non-Participant Windy Gap water in proportion to the amounts in each account. The MPWCD account would spill next, and finally the C-BT account would spill, if necessary. Lake Granby spills would decrease in the future primarily because less Windy Gap water would be pumped and, therefore, Windy Gap spills would be less. Lake Granby generally only spills in wet years; hence, dry year and average spills would be zero for all alternatives under both Existing and Future Conditions. There also would be a difference in C-BT spills from Lake Granby under Future Conditions due to changes in Windy Gap operations; however, the change in C-BT spills would be less than Windy Gap spills.

8.4.3.5. C-BT Diversions from the Big Thompson River

The C-BT Project diverts water under its junior direct flow water rights from the Big Thompson River at the Olympus and Dille Tunnels for storage in Carter Lake and Horsetooth Reservoir. The C-BT Project also diverts water from the Big Thompson River for power generation. These power diversions are typically referred to as "skim diversions" because the water is returned to the Big Thompson River at the Big Thompson Power Plant. C-BT diversions from the Big Thompson River to storage in Carter Lake and Horsetooth Reservoir take precedence over C-BT diversions from the West Slope to storage and skim diversions.

For each alternative, there would be differences in C-BT diversions and reservoir contents between Existing and Future Conditions due to Windy Gap operations, such as shrink payments, demands and deliveries, and spills. However, these differences would have a relatively minor impact on C-BT diversions from the Big Thompson River. Differences in Big Thompson River diversions between Existing and Future Conditions would be due primarily to differences in skim diversions. Skim diversions are modeled as the last C-BT operation to occur each month; therefore, differences in skim diversions could occur when available capacity in the Olympus Tunnel is limiting. C-BT deliveries from Lake Granby and the Big Thompson River to storage in Carter Lake and Horsetooth Reservoir also affect the available capacity in the Olympus Tunnel. To the degree that there would be differences in Carter Lake and Horsetooth contents between alternatives, C-BT deliveries to these reservoirs to meet storage targets could vary, which causes differences in skim diversions if available capacity in Olympus Tunnel is limiting.

8.4.3.6. Colorado River below Lake Granby

Flows in the Colorado River below Lake Granby are a function of bypass flow requirements and spills from Lake Granby. In years that Lake Granby is not spilling, the flows in the Colorado River below Lake Granby would equal the bypass flow requirements. Bypass flow requirements can be reduced based on forecasted inflows to Shadow Mountain/Grand Lake and Lake Granby (see Section 3.2.4.1 of the WGFP Modeling Report for more detail). However, any reduction in bypass flow requirements would be the same under Existing Conditions and Future Conditions among the alternatives. In dry years, there would be no differences in flows below Lake Granby between Existing and Future Conditions among the alternatives because Lake Granby does not spill in dry years.

Windy Gap pumping and, consequently, storage in Lake Granby, would be less under Future Conditions for all alternatives versus Existing Conditions. As a result, Windy Gap spills under Future Conditions would be reduced. C-BT spills also would change under Future Conditions because of differences in Windy Gap operations. In particular, Windy Gap shrink payments to the C-BT Project would be less under Future Conditions because Windy Gap pumping and deliveries would be less, which reduces Windy Gap diversion, carryover, and reintroduction shrink payments to the C-BT Project. However, the differences in C-BT spills and their effect on flows below Lake Granby would be less in comparison with Windy Gap spills.

8.4.3.7. Colorado River above the Windy Gap Diversion

Flows in the Colorado River above Windy Gap reflect the outflow from Lake Granby, tributary inflows from Willow Creek and the Fraser River, Colorado River mainstem irrigation diversions, and ungaged gains/losses to the river including irrigation return flows and ground water. The majority of the reduction in flow in the Colorado River above Windy Gap in the future would be due to reasonably foreseeable actions that reduce flows in the Fraser River basin (additional DW and Grand County demands).

8.4.3.8. Colorado River below Windy Gap Diversion

Flows in the Colorado River below Windy Gap at Hot Sulphur Springs and above the confluence with the Williams Fork River reflect the outflow from Lake Granby, tributary inflows from Willow Creek and the Fraser River, Colorado River irrigation diversions, Windy Gap diversions, and ungaged gains/losses to the river. Flows in the Colorado River below the confluence with the Williams Fork River reflect the additional inflow from the Williams Fork River and the associated changes in timing and quantity of due future actions described in Section 8.4.2.2. Below the confluence with the Williams Fork River to above the confluence with Troublesome Creek, streamflow would be affected by a reduction in return flows to the Colorado River from the Big Lake Ditch. Under Existing Conditions, return flows associated with Big Lake Ditch diversions into the Reeder Creek basin accrue to the Colorado River below the confluence with the Williams Fork River. In the future, these return flows would no longer occur and as a result the gain in this reach decreases under Future Conditions.

Flows in the Colorado River above the confluence with the Blue River include the tributary inflow from Troublesome Creek and Muddy Creek. Flows below Kremmling include the tributary inflow from the Blue River. Changes in the timing of streamflows in Muddy Creek would occur as a result of eliminating releases for endangered fish, changes in substitution releases and future contract releases from Wolford Mountain Reservoir (see Section 8.4.2.3). Changes in future Blue River inflow to the Colorado River as a result of increased water demand would reduce streamflow in the Colorado River.

8.4.3.9. Willow Creek

Differences in flows in Willow Creek below Willow Creek Reservoir and the WCFC would be a function of differences in WCFC diversions. Reasonably foreseeable actions do not directly affect Willow Creek flow, but changes in Windy Gap diversions as result of future actions would affect WCFC diversions, and hence, Willow Creek flows. Paper spills of Windy Gap water from Willow Creek Reservoir would decrease in the future primarily because less Windy Gap water would be pumped and, therefore, Windy Gap contents in Lake Granby would often be less when Lake Granby fills. With less Windy Gap water in Lake Granby when spills occur, paper spills of Windy Gap water from Willow Creek Reservoir would be less.

Table 30. Cumulative Effects—Comparison of average annual year flows (1950-1996) and diversions at key locations (AF).

Location	Node	Existing Conditions	Alt 1.—No Action			Alt. 2—Chimney Hollow w/ Pre-positioning			Alt .5—Dry Creek w/ Rockwell Creek		
		Avg. Annual Flow	Avg. Annual Flow	Difference	Percent Diff.	Avg. Annual Flow	Difference	Percent Diff.	Avg. Annual Flow	Difference	Percent Diff.
Adams Tunnel diversions	514634	243,179	251,943	8,764	4%	259,583	16,404	7%	258,933	15,755	6%
Lake Granby Spills	514620	38,707	31,896	-6,812	-18%	26,142	-12,566	-32%	27,890	-10,817	-28%
Colorado River below Lake Granby	09019500	59,385	52,976	-6,409	-11%	47,880	-11,505	-19%	49,403	-9,981	-17%
Willow Creek Feeder diversions	510958	36,172	37,828	1,656	5%	39,010	2,837	8%	38,586	2,414	7%
Willow Creek at the Confluence with the Colorado River	510546	18,294	16,685	-1,609	-9%	15,516	-2,777	-15%	15,939	-2,354	-13%
Fraser River at the confluence with the Colorado River	510876	91,025	79,725	-11,300	-12%	79,729	-11,296	-12%	79,714	-11,311	-12%
Colorado River above Windy Gap diversion	514700	187,889	168,544	-19,345	-10%	162,279	-25,611	-14%	164,211	-23,679	-13%
Windy Gap diversions	514700	36,532	38,973	2,441	7%	40,791	4,259	12%	42,991	6,459	18%
Colorado River below Windy Gap	514700	151,358	129,571	-21,787	-14%	121,488	-29,870	-20%	121,220	-30,138	-20%
Colorado River at Hot Sulphur Springs	09034500	156,475	134,095	-22,380	-14%	126,006	-30,469	-19%	125,738	-30,737	-20%
Colorado River above the confluence with the Williams Fork River	51_ADC008	154,031	131,649	-22,382	-15%	123,559	-30,472	-20%	123,291	-30,740	-20%
Williams Fork River at the confluence with the Colorado River	09038500	90,083	95,345	5,262	6%	95,346	5,263	6%	95,346	5,263	6%
Colorado River below the confluence with the Williams Fork River	512037	246,931	229,807	-17,124	-7%	221,718	-25,213	-10%	221,450	-25,481	-10%
Colorado River above the confluence with Troublesome Creek	51_ADC011	252,443	227,567	-24,876	-10%	219,479	-32,964	-13%	219,210	-33,233	-13%
Troublesome Creek at the confluence with the Colorado River	500526	52,396	52,425	29	0%	52,425	29	0%	52,425	29	0%
Colorado River above the confluence with the Blue River	512036	379,050	354,135	-24,915	-7%	346,048	-33,002	-9%	345,781	-33,270	-9%
Blue River at the confluence with the Colorado River	36_ADC019	313,612	258,663	-54,949	-18%	258,677	-54,935	-18%	258,678	-54,933	-18%
Colorado River near Kremmling	09058000	701,801	621,912	-79,889	-11%	613,838	-87,963	-13%	613,572	-88,229	-13%
Colorado River above Pumphouse	50_ADC020	696,777	616,888	-79,889	-11%	608,814	-87,963	-13%	608,548	-88,229	-13%
Muddy Creek at confluence with the Colorado River	09041500	65,522	65,502	-20	0%	65,503	-19	0%	65,504	-18	0%
C-BT Diversions from the Big Thompson River	NA	27,990	27,638	-352	-1%	25,154	-2,836	-10%	26,934	-1,056	-4%
Big Thompson River below Lake Estes	06735500	66,701	67,118	417	1%	69,684	2,983	4%	67,809	1,108	2%
Big Thompson River at the Canyon Gage	06738000	89,367	89,718	352	0%	92,203	2,836	3%	90,422	1,056	1%

Note: A positive difference denotes an increase in flow.

Table 31. Cumulative Effects—Comparison of average annual <u>dry</u> year flows (1954, 1966, 1977, 1981, 1989) and diversions at key locations (AF).

Location	Node	Existing Conditions	Alt. 1—No Action			Alt 2.—Chimney Hollow w/ Pre-positioning			Alt. 5—Dry Creek w/ Rockwell Creek		
		Avg. Annual Flow	Avg. Annual Flow	Difference	Percent Diff.	Avg. Annual Flow	Difference	Percent Diff.	Avg. Annual Flow	Difference	Percent Diff.
Adams Tunnel diversions	514634	314,187	314,886	699	0%	331,654	17,468	6%	324,347	10,160	3%
Lake Granby Spills	514620	0	0	0	0%	0	0	0%	0	0	0%
Colorado River below Lake Granby	09019500	21,946	21,946	0	0%	21,946	0	0%	21,946	0	0%
Willow Creek Feeder diversions	510958	22,200	22,190	-10	0%	22,190	-10	0%	22,190	-10	0%
Willow Creek at the Confluence with the Colorado River	510546	3,962	3,962	0	0%	3,962	0	0%	3,962	0	0%
Fraser River at the confluence with the Colorado River	510876	35,432	30,879	-4,553	-13%	30,787	-4,645	-13%	30,787	-4,645	-13%
Colorado River above Windy Gap diversion	514700	74,938	70,377	-4,561	-6%	70,284	-4,654	-6%	70,284	-4,654	-6%
Windy Gap diversions	514700	7,804	3,860	-3,944	-51%	3,860	-3,944	-51%	3,860	-3,944	-51%
Colorado River below Windy Gap	514700	67,134	66,517	-617	-1%	66,424	-710	-1%	66,424	-710	-1%
Colorado River at Hot Sulphur Springs	09034500	70,656	69,494	-1,162	-2%	69,402	-1,254	-2%	69,402	-1,254	-2%
Colorado River above the confluence with the Williams Fork River	51_ADC008	67,380	66,187	-1,194	-2%	66,094	-1,286	-2%	66,094	-1,286	-2%
Williams Fork River at the confluence with the Colorado River	09038500	77,202	80,600	3,398	4%	80,659	3,456	4%	80,659	3,456	4%
Colorado River below the confluence with the Williams Fork River	512037	147,416	149,639	2,223	2%	149,605	2,188	1%	149,605	2,188	1%
Colorado River above the confluence with Troublesome Creek	51_ADC011	149,898	143,765	-6,133	-4%	143,730	-6,168	-4%	143,730	-6,168	-4%
Troublesome Creek at the confluence with the Colorado River	500526	27,418	27,494	77	0%	27,494	77	0%	27,494	77	0%
Colorado River above the confluence with the Blue River	512036	229,222	226,876	-2,346	-1%	226,593	-2,629	-1%	226,593	-2,629	-1%
Blue River at the confluence with the Colorado River	36_ADC019	213,141	193,013	-20,128	-9%	192,944	-20,198	-9%	192,943	-20,198	-9%
Colorado River near Kremmling	09058000	450,286	427,728	-22,558	-5%	427,376	-22,911	-5%	427,375	-22,911	-5%
Colorado River above Pumphouse	50_ADC020	445,113	422,555	-22,558	-5%	422,202	-22,911	-5%	422,202	-22,911	-5%
Muddy Creek at confluence with the Colorado River	09041500	42,760	46,396	3,636	9%	46,147	3,387	8%	46,147	3,387	8%
C-BT Diversions from the Big Thompson River	NA	551	687	136	25%	0	-551	-100%	0	-551	-100%
Big Thompson River below Lake Estes	06735500	53,535	53,399	-136	0%	54,086	551	1%	54,086	551	1%
Big Thompson River at the Canyon Gage	06738000	67,160	67,024	-136	0%	67,711	551	1%	67,711	551	1%

Note: A positive difference denotes an increase in flow.

Table 32. Cumulative Effects—Comparison of average annual wet year flows (1957, 1983, 1984, 1986, 1995) and diversions at key locations (AF).

Location	Node	Existing Conditions	Alt 1.—No Action			Alt. 2—Chimney Hollow w/ Pre-positioning			Alt. 5—Dry Creek w/ Rockwell Creek		
		Avg. Annual Flow	Avg. Annual Flow	Difference	Percent Diff.	Avg. Annual Flow	Difference	Percent Diff.	Avg. Annual Flow	Difference	Percent Diff.
Adams Tunnel diversions	514634	180,787	195,934	15,147	8%	189,327	8,540	5%	199,666	18,879	10%
Lake Granby Spills	514620	129,094	115,508	-13,586	-11%	110,794	-18,301	-14%	111,191	-17,904	-14%
Colorado River below Lake Granby	09019500	144,383	132,303	-12,080	-8%	128,133	-16,250	-11%	128,342	-16,040	-11%
Willow Creek Feeder diversions	510958	33,685	39,707	6,022	18%	40,417	6,732	20%	40,317	6,632	20%
Willow Creek at the Confluence with the Colorado River	510546	52,778	46,756	-6,022	-11%	46,046	-6,732	-13%	46,146	-6,632	-13%
Fraser River at the confluence with the Colorado River	510876	178,477	156,645	-21,832	-12%	156,715	-21,762	-12%	156,501	-21,976	-12%
Colorado River above Windy Gap diversion	514700	403,835	363,899	-39,935	-10%	359,091	-44,744	-11%	359,185	-44,650	-11%
Windy Gap diversions	514700	38,512	62,118	23,606	61%	69,417	30,905	80%	71,699	33,186	86%
Colorado River below Windy Gap	514700	365,323	301,782	-63,541	-17%	289,674	-75,649	-21%	287,486	-77,836	-21%
Colorado River at Hot Sulphur Springs	09034500	369,677	305,471	-64,206	-17%	293,363	-76,314	-21%	291,175	-78,501	-21%
Colorado River above the confluence with the Williams Fork River	51_ADC008	369,268	305,065	-64,204	-17%	292,957	-76,311	-21%	290,769	-78,499	-21%
Williams Fork River at the confluence with the Colorado River	09038500	138,018	145,540	7,522	5%	145,541	7,522	5%	145,541	7,522	5%
Colorado River below the confluence with the Williams Fork River	512037	509,758	453,068	-56,691	-11%	440,960	-68,798	-13%	438,772	-70,986	-14%
Colorado River above the confluence with Troublesome Creek	51_ADC011	519,392	455,774	-63,618	-12%	443,667	-75,725	-15%	441,479	-77,913	-15%
Troublesome Creek at the confluence with the Colorado River	500526	92,324	92,325	1	0%	92,325	1	0%	92,325	1	0%
Colorado River above the confluence with the Blue River	512036	706,315	642,668	-63,646	-9%	630,562	-75,752	-11%	628,373	-77,941	-11%
Blue River at the confluence with the Colorado River	36_ADC019	493,554	412,397	-81,157	-16%	412,284	-81,271	-16%	412,393	-81,161	-16%
Colorado River near Kremmling	09058000	1,217,038	1,072,235	-144,803	-12%	1,060,014	-157,024	-13%	1,057,934	-159,104	-13%
Colorado River above Pumphouse	50_ADC020	1,212,435	1,067,632	-144,803	-12%	1,055,411	-157,024	-13%	1,053,331	-159,104	-13%
Muddy Creek at confluence with the Colorado River	09041500	86,980	86,999	19	0%	86,999	20	0%	86,998	19	0%
C-BT Diversions from the Big Thompson River	NA	67,946	68,058	112	0%	66,763	-1,182	-2%	67,915	-30	0%
Big Thompson River below Lake Estes	06735500	72,849	72,874	25	0%	74,701	1,851	3%	72,874	25	0%
Big Thompson River at the Canyon Gage	06738000	108,593	108,480	-112	0%	109,775	1,182	1%	108,623	30	0%

Note: A positive difference denotes an increase in flow.

8.5. Alternative 1—No Action, Enlarge Ralph Price Reservoir

Under the No Action alternative, all Participants would maximize delivery of Windy Gap water according to their demand, water rights, available storage in Lake Granby, and existing Adams Tunnel conveyance constraints. The City of Longmont would expand the storage capacity of Ralph Price Reservoir by 13,000 AF. The total annual Windy Gap demand, including Windy Gap Participants, non-Participants, and the MPWCD, would be about 40,745 AF under No Action, compared to 21,047 AF under Existing Conditions (Appendix H).

8.5.1. Surface Water Hydrology

8.5.1.1. C-BT and Windy Gap Project Operations and Diversions

Adams Tunnel Diversions. Adams Tunnel diversions of C-BT and Windy Gap water to the East Slope would be about 243,000 AF under Existing Conditions compared to about 252,000 AF under No Action (Table 30). C-BT deliveries would not change under No Action, so the changes in Adams Tunnel deliveries would be from higher Windy Gap demands and deliveries to Ralph Price Reservoir. Dry year average annual Adams Tunnel deliveries would be about 314,000 AF under Existing Conditions compared to about 315,000 AF under No Action (Table 31). The difference would be less than 1,000 AF on average because little to no Windy Gap water would be available in Lake Granby for delivery in dry years. In wet years, Adams Tunnel deliveries would be about 181,000 AF compared to 196,000 AF for No Action (Table 32).

Windy Gap Diversions. Windy Gap annual diversions would increase from about 36,500 AF on average under Existing Conditions to about 39,000 AF under No Action (Table 30). In dry years, Windy Gap diversions would be about 4,000 AF less than Existing Conditions because there would be less water available for diversion with increased diversion by the Moffat Collection System Project, additional water use in Grand County, and a decrease in the amount of water legally available for diversion in the future (Table 31). In wet years, Windy Gap diversions would increase about 24,000 AF under No Action compared to Existing Conditions (Table 32).

Willow Creek Feeder Canal Diversions. WCFC diversions would increase on average from about 36,200 AF under Exiting Conditions to about 37,800 AF under No Action (Table 30). There would be virtually no change in WCFC diversions from Existing Conditions in dry years (Table 31), and about an 18 percent increase during wet years (Table 32).

Lake Granby Spills. Average annual spills would be about 38,700 AF under Existing Conditions compared to about 31,900 AF under No Action (Table 30). There would be no difference in dry year spills between Existing Conditions and No Action (Table 31). The primary decrease in spills would occur during wet years when Lake Granby fills and spills. Spills would decrease about 11 percent under No Action compared to Existing Conditions in wet years (Table 32). The majority of the difference in spills would occur from a reduction in spills in August of wet years (Table I-1).

C-BT Diversions from Big Thompson River. C-BT annual diversions from the Big Thompson River would be 27,900 AF under Existing Conditions and would decrease less than 1 percent on average under No Action (Table 30). In dry years, there would be a small annual increase (136 AF) in diversion under No Action on average (Table 31) in comparison with Existing Conditions. There would be no change in wet years (Table 32).

8.5.1.2. West Slope Streams

Colorado River below Lake Granby. Spills from Lake Granby would decrease under Future Conditions. Colorado River streamflow below Lake Granby would decrease from about 59,385 AF under Existing Conditions to 53,000 AF on average under No Action (Table 30). In dry years, when there would be no spills from Lake Granby, the flow of the Colorado River below Lake Granby would not change under No Action (Table 31). Streamflow below Lake Granby is primarily related to wet year spills, which would decrease about 12,100 AF under No Action compared to Existing Conditions (Table 32). For the No Action alternative, the flow of the Colorado River below Lake Granby would be about 2,400 AF lower in average years and 4,300 AF lower in wet years due to the effects of reasonably foreseeable actions on Windy Gap and C-BT operations.

Table I-11 provides the modeled Granby Reservoir spill periods, average spill and maximum spill for Existing Conditions and the alternatives with Cumulative Effects. The model shows spills occurring for as short as a month (June, July or August) and up to as long as 4 months (May through August), with the most frequent spills occurring in June through July (13 percent of the 47 year model period) under Existing Conditions and No Action. The spill periods are very similar between Existing Conditions and No Action, but the estimated flow of the river at the gage near Granby would be reduced during some of the spill periods.

Table 28 provides the changes in daily flows that would occur with Cumulative Effects in the Colorado River at the USGS gage near Granby during May through August, the period when most Windy Gap diversions would occur. Under No Action, flow increases of up to 211 cfs would occur 3.5 percent of the time during these months due to changes in the timing of spills from Lake Granby. No changes in daily flow would occur about 79 percent of the time between May and August. Daily flow decreases of 1 to 100 cfs would occur about 11 percent of the time and daily flow decreases greater than 100 cfs would occur 6.2 percent of the time during May through August.

Colorado River above the Windy Gap Diversion. Average annual streamflow in the Colorado River above the Windy Gap diversion would decrease from about 187,900 AF under Existing Conditions to about 168,500 AF under No Action (Table 30). Although Colorado River streamflow would decrease in all months, the greatest decrease in average streamflow (14 to 15 percent) would occur from June to August (Table I-13, Figure 51). The majority (58 percent) of the streamflow reduction would be from additional Moffat Collection System diversions from the Fraser River basin and additional upstream Grand County water use. Changes in Lake Granby spills and Willow Creek streamflow as a result of the Windy Gap No Action alternative would account for the remainder of the change.

In dry years, reasonably foreseeable future actions would result in about a 4,600 AF decrease in Colorado River flow above Windy Gap Reservoir (Table 31). Windy Gap operations under No Action would not affect dry year streamflow at this location.

In wet years, Colorado River flows above Windy Gap decrease about 39,900 AF on average under No Action compared to Existing Conditions (Table 32). The majority of the reduced flow in wet years would be attributable to reasonably foreseeable future actions and the remainder would be from implementation of the No Action alternative. The greatest decrease in average streamflow (19 percent) would occur in August (Table I-13).

Colorado River below the Windy Gap Diversion to the Top of Gore Canyon. Colorado River flow below the Windy Gap diversion would decrease on average from about 151,400 AF under Existing Conditions to about 129,600 AF under No Action (Table 30). About 52 percent of the flow reduction would be from reasonably foreseeable actions and the remainder due to Windy Gap diversions, primarily from June through August. Streamflow decreases would occur in all months except April, with the majority of the changes from Windy Gap diversions occurring from June to August and the effect in other months primarily from reasonably foreseeable actions (Table I-14, Figure 52). In average years, the largest average monthly reduction in flow would occur in July (26 percent, a reduction of 125 cfs). In dry years, streamflow would decrease about 600 AF under No Action with all of the change attributable to reasonably foreseeable actions (Table 31). In wet years, Colorado River flow would decrease about 63,500 AF under No Action compared to Existing Conditions (Table 32). In wet years, the largest average monthly reduction in flow would occur in August (37 percent, a reduction of 170 cfs).

At Hot Sulphur Springs, the largest average monthly flow reduction would occur in July in average flow years (26 percent, a reduction of 130 cfs) and in August in wet years (37 percent, a reduction of 175 cfs) (Table I-16). Under No Action, daily flows would increase as much as 159 cfs about 26 percent of the time in May through August, the period when most Windy Gap diversions occur (Table 28). No changes in daily flows would occur about 7 percent of the time during this period under No Action, and daily flow decreases of 1 to 100 cfs would occur about 46 percent of the time in May through August. Flow decreases of greater than 100 cfs would occur about 21 percent of the time in May through August.

Average annual streamflow in the Colorado River below the confluence with the Williams Fork River would decrease from about 246,900 AF under Existing Conditions to about 229,800 AF under No Action (Table 30). About 39 percent of the decrease in flow would be from reasonable foreseeable actions and the remainder from Windy Gap diversions. The largest average monthly flow reduction would occur in July in average years (19 percent, a reduction of 140 cfs) and in August (25 percent, a reduction of 160 cfs) in wet years (Table I-17).

Colorado River average annual streamflow at the Kremmling gage downstream of the confluence with the Blue River and Muddy Creek would decrease from about 701,801 AF under Existing Conditions to about 621,900 AF under No Action (Table 30).

Average monthly streamflow reductions range from no change in February and March to a 25 percent decrease (a flow reduction of 440 cfs) in July (Table I-18; Figure 53). Reductions in Blue River streamflow primarily from DW's additional transbasin diversions, as well as increased urban growth in the Blue River basin, changes in the operation of Wolford Mountain and Williams Fork Reservoirs, and other upstream reasonably foreseeable actions, would account for about 87 percent of the reduction in flows. Windy Gap Project diversions and operations would account for the remainder of the flow change. During dry years, all of the 22,600 AF decrease in annual flows would be the result of reasonably foreseeable actions (Table 31). In wet years, average annual Colorado River streamflow would decrease from about 1,217,000 AF under Existing Conditions to about 1,072,200 AF under No Action (Table 32). The largest average monthly flow reduction in a wet year would occur in July (17 percent, a reduction of 795 cfs).

At the USGS gage near Kremmling, daily flows during May through August, when most Windy Gap diversions occur, would increase by as much as 197 cfs about 14 percent of the time under No Action (Table 28). Daily flow decreases of 1 to 100 cfs would occur about 28 percent of the time May through August, and daily flow decreases greater than 100 cfs would occur about 57 percent of the time during those months.

Willow Creek. Average annual Willow Creek streamflow would decrease 9 percent from about 18,300 AF under Existing Conditions to about 16,700 AF under No Action (Table 30). Differences in streamflow in Willow Creek are a function of changes in WCFC diversions as a result of operation of the Windy Gap Project. There would be no change in Willow Creek flows in dry years (Table 31) and a decrease of 11 percent in wet years (Table 31). The largest average monthly flow reduction in an average year would be 29 percent in July (32 cfs to 23 cfs) (Table I-15; Figure 54). The largest average monthly flow reduction in a wet year would be 34 percent in July (112 to 75 cfs).

8.5.1.3. West Slope Reservoirs

Lake Granby. Average monthly contents in Lake Granby under the No Action would range from about 19,500 AF less in August to about 23,500 AF less in May compared to Existing Conditions (Table K-7). These changes would result in lake levels about 3 to 4 feet lower than Existing Conditions (Table K-8). The largest change in storage would occur from March to May, with up to 7 percent decrease in average monthly storage in average and dry years and 10 percent in wet years. In dry years, Lake Granby elevations would be about 3 to 4 feet lower than Existing Conditions and in wet years No Action would range from 1 to 6 feet lower.

Differences in Lake Granby contents and surface elevations would be greatest (up to 23 feet) during dry year sequences; the chance of a decrease in the lake level of 10 feet or more would be 21 percent.

8.5.1.4. East Slope Streams

North St. Vrain Creek and St. Vrain Creek. Under the No Action alternative, the flow of North St. Vrain Creek, as well as St. Vrain Creek in the approximately one mile stretch from the confluence of the North and South forks to the St. Vrain Supply Canal would change due to exchanges of Windy Gap water to storage in Ralph Price Reservoir and Windy Gap releases from Ralph Price Reservoir to meet Longmont's demands (Table 33). Changes in flows in these reaches would be slightly smaller with reasonably foreseeable future actions because there would be less Windy Gap water available for the City of Longmont to divert to storage in Ralph Price Reservoir.

Table 33. Cumulative Effects—Average monthly change in flow of North St. Vrain Creek below Ralph Price Reservoir and St. Vrain Creek above St. Vrain Supply Canal.

Month	N. St. Vrain between Ralph Price Reservoir and Longmont Reservoir			N. St. Vrain below Longmont Reservoir			St. Vrain at Lyons (USGS gage)		
	Exist. Cond. (cfs)	No Action (cfs)	% Change	Exist. Cond. (cfs)	No Action (cfs)	% Change	Exist. Cond. (cfs)	No Action (cfs)	% Change
January	24	28	16%	13	13	0%	14	14	0%
February	23	27	15%	13	13	0%	13	13	0%
March	24	27	14%	12	12	0%	20	20	-0%
April	46	48	4%	29	29	0%	91	91	0%
May	155	141	-9%	133	118	-11%	297	282	-5%
June	274	275	0%	250	250	0%	528	528	0%
July	179	137	-23%	147	109	-25%	296	259	-13%
August	89	87	-2%	59	59	0%	135	135	0%
September	42	60	43%	19	32	65%	67	79	19%
October	26	43	64%	8	14	81%	39	45	16%
November	23	27	17%	13	13	0%	24	24	0%
December	23	27	17%	13	13	0%	17	17	-0%

Note: North St. Vrain Creek flows below Ralph Price and Longmont Reservoirs derived using City of Longmont release records from 1999-2005 and Colorado Division of Water Resource diversion records for 1999-2004.

Big Thompson River. Under No Action and given reasonably foreseeable future actions, flows in the Big Thompson River below Lake Estes would not change during most months, but would increase by 1 percent in June and July in average years (Table I-8) and decrease by 1 percent in April, due primarily to changes in C-BT diversions for power generation. The flow in the Big Thompson River at the mouth of the canyon would increase by 1 percent in June and July (Table I-10). There would be no change in river stage (Table J-1).

Streams that Receive Windy Gap Return Flows. Maximum increases in East Slope streams due to increased return flows from Participants' WWTPs would be higher under No Action than Existing Conditions and other alternatives because the demand for Windy Gap water and, therefore, the maximum delivery, would be greater under No Action (Boyle 2006d). However, average return flows would be less under No Action than under Alternatives 2 through 5 because average deliveries would be less. Table 34 compares the average and maximum flow increases attributable to additional Windy Gap return flows under the No Action alternative to the average and maximum monthly flows at the nearest USGS gage. No adjustments were made to gage flows to account for gains/losses that may occur between the gages and WWTPs. Except for distributed returns from rural customers, there would likely be no net change in streamflow from November to March between the No Action alternative and Existing Conditions because either Participants do not intend to use their Windy Gap supplies in those months, reusable effluent is stored for use later in summer months, or return flows are used to offset depletions or augment return flow obligations. Impacts to East Slope streams below Participants' WWTPs would be less considering reasonably foreseeable future actions because less Windy Gap water would be diverted and available to the Participants. In Coal Creek and St. Vrain Creek, return flows would increase at more than one location; the return flows for these creeks have not been added together in Table 34.

Table 34. Cumulative Effects—East Slope streamflow increases under No Action.

Stream Segment	Flow Condition[1]	Apr	May	Jun	Jul	Aug	Sep	Oct
		cfs						
Big Dry Creek above Broomfield WWTP (USGS gage 06720820, adjusted for average historical Broomfield WWTP effluent, 1995-2004)	Existing average flow	13.3	28.9	51.1	41.5	38.5	23.6	10.1
	Existing maximum flow	19	40.5	73.2	86.5	49	40.3	16.2
	Average flow increase	1.3	2.3	2.7	3.3	3.3	2.7	1.3
	Maximum flow increase	3.5	5.9	7.0	8.5	8.5	7.0	3.4
Coal Creek below Superior, above Louisville, Lafayette and Erie WWTPs (USGS gage 06730400)	Existing average flow	12.3	13.1	7	2.8	4.1	2.1	2.6
	Existing maximum flow	36	35	13	4.3	15	3.1	3.8
	Average flow increases above gage	0.7	1.4	1.1	0.8	0.6	0.5	0.4
	Maximum flow increase above gage	1.7	1.7	1.7	1.7	1.7	1.7	1.7
	Average flow increases below gage	1.4	2.8	2.1	1.6	1.1	1.0	0.7
	Maximum flow increase below gage	3.3	3.3	3.4	3.3	3.3	3.4	3.2
St. Vrain Creek below Longmont WWTP (USGS gage 06725450)	Existing average flow	76	234	348	175	148	101	68
	Existing maximum flow	259	1155	1227	485	185	152	159
	Average flow increase	2.1	0.8	0.8	10.5	10.0	9.5	8.3
	Maximum flow increase	3.0	0.8	0.9	11.0	11.0	11.3	10.8
St. Vrain Creek below LTWD WWTP (USGS gage 06731000)	Existing average flow	178	472	627	313	231	184	160
	Existing maximum flow	622	2362	2316	972	653	292	398
	Average flow increase	0.3	0.7	0.7	0.8	0.8	0.6	0.3
	Maximum flow increase	0.8	1.3	1.5	1.8	1.8	1.5	0.7

Stream Segment	Flow Condition[1]	Apr	May	Jun	Jul	Aug	Sep	Oct
		cfs						
Big Thompson River below Loveland WWTP (USGS gage 06741510)	Existing average flow	41	251	296	129	84	37	28
	Existing maximum flow	292	2078	1493	418	153	84	66
	Average flow increase	0	1.4	1.1	1.9	3.1	3.4	2.2
	Maximum flow increase	0	1.6	1.6	3.2	6.4	9.8	9.4

[1]Existing average and maximum flow are at stream gage locations. Average and maximum flow increases are at Participants' WWTPS and dispersed return flow locations from outdoor use.

8.5.1.5. East Slope Reservoirs

Carter Lake. Average monthly storage in Carter Lake would decrease less than 1 percent or 1 foot from Existing Conditions under No Action (Table K-1). The greatest change would be about a 1,200 AF decrease in storage in June and July. In dry years, the change would be close to zero and in wet years, the greatest decrease in Carter Lake elevations would be about 2 feet in August and September. In average years, under No Action there would be less than a 1 percent or 1-foot difference in Carter Lake elevations compared to Existing Conditions or No Action (Table K-2). In wet years, monthly Carter Lake elevations would be from 1 to 2 feet lower than Existing Conditions.

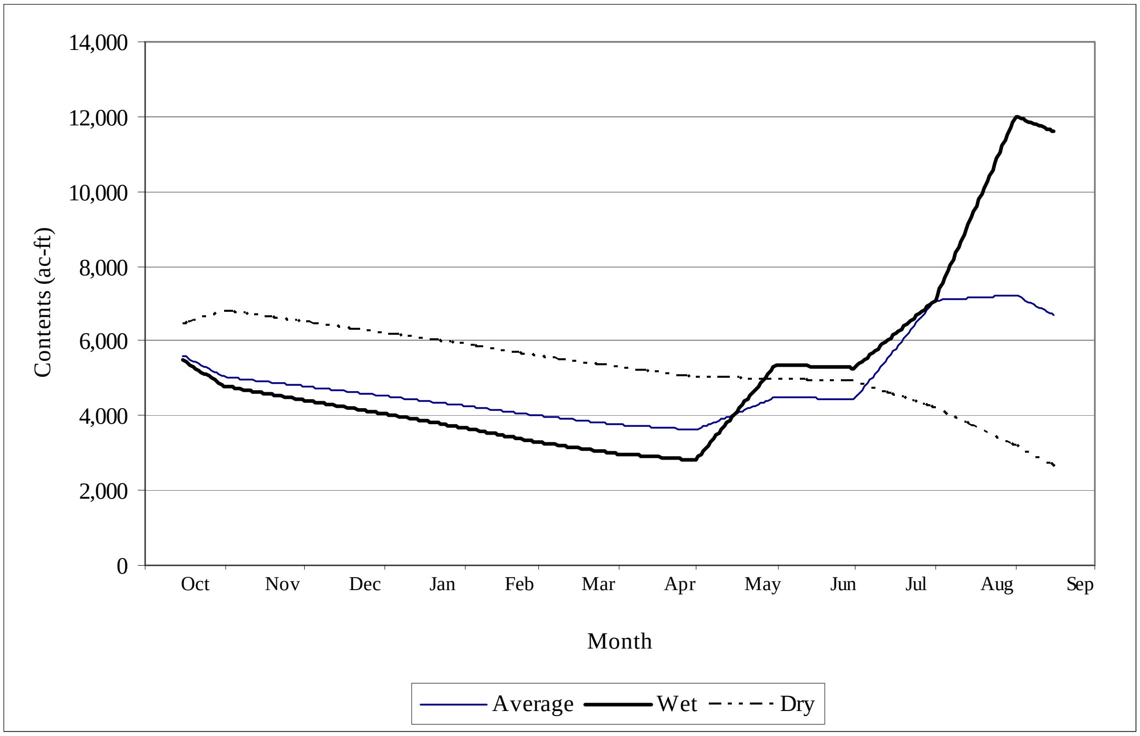
In dry years when C-BT contents in Lake Granby are exhausted, Carter Lake contents under No Action would be lower than Existing Conditions. The decrease is predicted to be as much as 8 feet; however, the chance of a decrease in the elevation of Carter Lake equal or exceeding 5 feet in any given year would be only 13 percent.

Horsetooth Reservoir. Average monthly changes in Horsetooth Reservoir content under No Action would decrease about 40 AF to 600 AF compared to Existing Conditions (Table K-4). The greatest decrease would be a 1 percent reduction in September. In dry years, Horsetooth Reservoir content would increase less than 1 percent from December to June and decrease less than 1 percent from July to November. In wet years, Horsetooth Reservoir content would decrease less than 2 percent, with the greatest percent change in November. Changes in average monthly reservoir elevation would be less than about 0.3 feet in average and wet years and less than 1 foot in wet years (Table K-5).

Occasionally, Horsetooth Reservoir contents under No Action would be lower than Existing Conditions (4 feet) in dry years; the chance of a decrease in Horsetooth of 4 feet in any given year would be 2 percent.

Ralph Price Reservoir. The additional 13,000 AF of storage available in Ralph Price Reservoir under No Action would fluctuate with exchanges of Windy Gap water storage and Windy Gap releases to meet Longmont's demands (Figure 50). Figure 50 does not include fluctuation of the existing storage account of 16,200 AF. The amount of water stored in Ralph Price Reservoir would be slightly less under future conditions because there would be less Windy Gap water available for Longmont to store in the reservoir.

Figure 50. No Action Alternative—Ralph Price Reservoir average, wet, and dry year daily contents for 13,000 AF of new storage under cumulative effects.



8.5.2. Ground Water Hydrology and Quality

8.5.2.1. West Slope Reservoirs

The existing range in annual variation in the level of Lake Granby (nearly 90 feet) is much greater than the maximum 23 foot change that would occur under the No Action alternative. Water levels in some shallow wells near the lake may be connected to lake levels; however, it is probable that much of the ground water adjacent to the lake is from topographically higher areas surrounding the lake rather than from Lake Granby. Because predicted surface water quality changes to these reservoirs as a result of the WGFP are predicted to be minor, it is expected that there would not be any effect to ground water quality.

8.5.2.2. West Slope Streams

The maximum monthly stage change in an average year in the Colorado River below Windy Gap would be a decrease of about 2 inches under No Action (Table J-2). The maximum monthly stage change in the Colorado River near Kremmling would be almost a foot (Table J-3). Stage data is not available for Willow Creek, but the maximum monthly flow change in an average year would be a decrease of 9 cfs (Table I-15). Changes in flow and the resulting stage changes are considered to be minor with respect to potential effects to adjacent ground water levels. As discussed in Section 7.2.2, and because predicted water quality changes to these streams as a result of the WGFP are predicted to be small, it is expected that there would be only minor effects to alluvial ground water quality along the Colorado River and no effects to ground water quality near Willow Creek.

8.5.2.3. East Slope Reservoirs

The maximum predicted decrease in the elevation of Carter Lake is 8 feet. The maximum predicted decrease in the elevation of Horsetooth Reservoir would be 2 feet. Potential effects to ground water levels near Carter Lake, Horsetooth Reservoir and Ralph Price Reservoir would be expected to be minor for the reasons discussed in Section 7.2.1. As discussed in Section 7.2.2, and because predicted water quality changes to these reservoirs as a result of the WGFP are predicted to be minor, it is expected that there would not be any effects to ground water quality.

8.5.2.4. East Slope Streams

Because the average monthly stage change in the Big Thompson River between Lake Estes and the Hansen Feeder Canal under No Action would be only 0.01 foot (Table J-1), effects to alluvial or bedrock ground water would be negligible. For the other East Slope streams affected by changing return flows from Participants' WWTPs, because stage changes are expected to be small, increases in alluvial ground water levels would likely be unmeasurable. As discussed in Section 7.2.2, it is expected that ground water quality would not be affected near the foothill streams (North St. Vrain Creek, St. Vrain Creek at Lyons and Big Thompson River below Lake Estes to the Hansen Feeder Canal). For the other East Slope streams, there may be minor changes to alluvial ground water quality near the streams.

8.5.3. Stream Morphology and Sedimentation

8.5.3.1. West Slope Streams

Colorado River. At Hot Sulphur Springs, the 2-year peak discharge was estimated to be 1,240 cfs under Existing Conditions (Figure G-1). Under Existing Conditions, this flow would be exceeded about 3 percent of the time (percentage of days during the study period). At the gage near Kremmling, the 2-year peak discharge was estimated to be 2,850 cfs under Existing Conditions (Figure G-2). Under Existing Conditions, this flow would be exceeded about 5 percent of the time.

Under No Action, the 2-year peak discharge at the Hot Sulphur Springs gage would be exceeded about 2.5 percent of the time, or 0.5 percent less than under Existing Conditions. The 2-year peak discharge at the gage near Kremmling would be exceeded 3 percent of the time (a 2 percent difference from Existing Conditions). The slight reduction in the percentage of time that the 2-year peak discharge would be exceeded at the two gage sites below the Windy Gap diversion is unlikely to significantly affect stream morphology or change sediment transport or deposition.

An examination of changes in channel maintenance flows is another way to look at potential effects to stream morphology. At Hot Sulphur Springs, the lower limit of channel maintenance flows, defined as 80 percent of the 1.5-year peak flow, was calculated to be 510 cfs. Under Existing Conditions, a flow of at least 510 cfs occurred for 23 days on average (in years when such flows occurred), with a 62 percent chance of occurrence in any given year (Table I-19). Under No Action, flows of at least 510 cfs occurred for 21 days on average (in years when such flows occurred), with a 49 percent chance of occurrence in any given year. The upper limit of channel maintenance flows is defined as the 25-year peak flow; such a flow occurred once in July under Existing Conditions and under the No Action alternative (in years when such flows occurred). Ten-year peak flows or greater (4,600 cfs or more) occurred under Existing Conditions for 4 days on average and under No Action for 8 days on average (in years when such flows occurred) with an 13 percent chance of occurrence in any given year under Existing Conditions and 4 percent chance of occurrence in any given year under No Action. In general, the chance of channel maintenance flows occurring in a given year would be about 1 percent less under No Action than Existing Conditions, but the duration of such flows when they occur would be slightly longer. The differences in channel maintenance flows between Existing Conditions and No Action are minor and are not expected to measurably alter channel morphology or sediment movement at Hot Sulphur Springs. The range in streamflows under No Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment

The magnitude, timing and frequency of channel maintenance flows in the Colorado River below Lake Granby would change as a result of changes in spills. When spills are not occurring, the flow of the river below Lake Granby is controlled by bypass flows; it is difficult, therefore, to define a range of channel maintenance flows based on peak flow events. A comparison of modeled spill events is provided in Table I-4. Under No Action, there would be 4 less spill events, but flows of 510 cfs or more (within the range of channel maintenance flows at Hot Sulphur Springs) would continue to occur for periods of 1 to 4 months. Flows over 2,500 cfs would occur during 13 percent of all years, compared to 19 percent of all years under Existing Conditions. These differences are not expected to alter channel morphology or sediment movement in the Colorado River below Lake Granby. The range in streamflows under No Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment.

Willow Creek. The flow duration curve for Willow Creek provides a comparison between Existing Conditions and No Action for the USGS gage located below Willow Creek Reservoir (Figure G-3). The 2-year peak discharge was estimated to be 80 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 6 percent of the time. Under the No Action alternative, the 2-year peak discharge would be exceeded about 5 percent of the time (a 1 percent change); therefore, it is unlikely that there would be a significant affect to stream morphology or change in sediment transport or deposition.

8.5.3.2. East Slope Streams

St. Vrain Creek. Under the No Action alternative, streamflows in the reach of North St. Vrain Creek and St. Vrain Creek between Ralph Price Reservoir and the St. Vrain Supply Canal would change due to exchanges of Windy Gap water to storage in Ralph Price Reservoir and releases from Ralph Price Reservoir to meet Longmont's future Windy Gap demands. The flow changes that would occur in North St. Vrain Creek are unlikely to alter the morphology of the stream and affect sediment movement because the North St. Vrain Creek channel, like many foothill creeks, has a channel that is stabilized by bedrock or boulders. The boulders and other large sediment tend to move only during flood events. In addition, the largest percent flow changes that would occur in September and October (less than 20 cfs) are much less than the high flows that typically occur during the spring and summer months each year.

Big Thompson River. Under the No Action alternative, flow increases in the Big Thompson River from Lake Estes to the Hansen Feeder Canal would occur in June and July, but would be 1 percent or less of average existing monthly flows (Table I-8 and Table I-9). This minor change in flow is well within the historical range of flows and is unlikely to affect stream morphology or sedimentation.

Streams that Receive Windy Gap Return Flows. The predicted streamflow increases for the East Slope stream segments that receive Windy Gap return flows (Big Dry Creek, Coal Creek, St. Vrain Creek, and Big Thompson River) are unlikely to substantially alter stream morphology and sedimentation because the increased flows would be small compared to the spring and early summer flows that these channels have the capacity for. In addition, as described in Section 6.6, streams on the East Slope have not experienced natural streamflow conditions for more than 100 years, and are not in equilibrium with respect to channel forming and channel moving processes, erosion, or sediment loading, movement and deposition. Given the magnitude of the flow increases (less than 9 cfs), it would be difficult to measurably differentiate changes to stream morphology and sedimentation due to changes in Participants' WWTP return flows from the many other ongoing actions influencing East Slope streamflow conditions.

8.6. Alternative 2—Chimney Hollow Reservoir with Prepositioning (Proposed Action)

Chimney Hollow with prepositioning includes approximately 90,000 AF of storage at the Chimney Hollow site on the East Slope. This alternative includes prepositioning, which is a method of operation intended to facilitate delivery of Windy Gap water to the East Slope. Prepositioning involves the use of available Adams Tunnel capacity to deliver C-BT water to Chimney Hollow to occupy storage space that is not occupied by Windy Gap water. Delivery of C-BT water to Chimney Hollow in this manner would maintain Chimney Hollow essentially full at all times. Delivery of C-BT water from Lake Granby into Chimney Hollow would create space for Windy Gap water in Lake Granby. When Windy Gap water is diverted into Lake Granby, the C-BT water in Chimney Hollow would be exchanged for a like amount of Windy Gap water in Lake Granby. This operation would relieve the need to deliver Windy Gap water through Adams Tunnel to Chimney Hollow during the diversion season because this operation would be accomplished via an exchange instead.

8.6.1. Surface Water Hydrology

8.6.1.1. C-BT and Windy Gap Project Operations and Diversions

Adams Tunnel Diversions. Adams Tunnel diversions to the East Slope under the Proposed Action would be about 259,600 AF per year on average compared to about 243,000 AF under Existing Conditions and 252,000 AF under No Action (Table 30). Thus, Adams Tunnel deliveries for the Proposed Action would be about 7 percent greater than Existing Conditions or about 3 percent greater than No Action. The increased

Adams Tunnel diversions under the Proposed Action reflect additional C-BT deliveries to Chimney Hollow Reservoir. Dry year Adams Tunnel deliveries of about 331,700 AF would be about 17,500 AF greater than under Existing Conditions and No Action (Table 31). Wet year Adams Tunnel deliveries would be about 5 percent greater (189,300 AF) under the Proposed Action, compared to Existing Conditions (180,800 AF) and 3 percent less than No Action (195,900 AF) (Table 32).

Windy Gap Diversions. Windy Gap annual diversions would increase about 12 percent (40,800 AF) on average under the Proposed Action compared to Existing Conditions (36,500 AF) and would be about 4 percent greater than No Action (39,000 AF) (Table 30). In dry years, Windy Gap diversions for the Proposed Action and No Action would be about 3,900 AF, which would be about 3,900 AF less than Existing Conditions (Table 31). In wet years, Windy diversions would be about 69,400 AF under the Proposed Action compared to 38,500 AF under Existing Conditions and 62,100 AF under No Action (Table 32).

Willow Creek Feeder Canal Diversions. Average annual WCFC diversions would be approximately 36,200 AF under Existing Conditions and 37,800 AF under No Action compared to 39,000 AF under the Proposed Action (Table 30). WCFC diversions in dry years of about 22,200 AF would be the same for all alternatives and Existing Conditions (Table 31). In wet years WCFC diversions under the Proposed Action would be about 40,400 AF compared to 33,700 AF under Existing Conditions and 39,700 AF under No Action (Table 32).

Lake Granby Spills. Average annual Lake Granby spills under Existing Conditions of 38,700 AF would decrease to 26,100 AF under the Proposed Action and 31,900 AF under No Action (Table 30). There would be no spills in dry years under Existing Conditions or for any of the alternatives (Table 31). In wet years, which are the only years when Lake Granby actually spills, the Proposed Action would result in an annual spill of 110,800 AF compared to 129,100 AF under Existing Conditions and 115,500 AF under No Action (Table 32).

C-BT Diversions from Big Thompson River. Average annual C-BT diversions from the Big Thompson River under Existing Conditions would be about 28,000 AF compared to 25,200 AF under the Proposed Action and 27,600 AF under No Action (Table 30). There would be a small decrease in Big Thompson River diversions in dry years between Existing Conditions and the Proposed Action, although they would increase slightly (136 AF) under No Action (Table 31). In wet years, Big Thompson River diversions decrease about 2 percent under the Proposed Action to 66,800 AF compared to Existing Condition diversions of 67,900 AF (Table 32). Under No Action, Big Thompson River diversions would be about the same as Existing Conditions (68,100 AF).

8.6.1.2. West Slope Streams

Colorado River below Lake Granby. Average annual Colorado River streamflow below Lake Granby would be about 47,900 AF under the Proposed Action compared to 59,400 AF under Existing Conditions and 53,000 AF under No Action (Table 30). The greatest change in spills would occur between June and September (Table I-14). There would be no change from Existing Conditions in dry year flows under the Proposed

Action or No Action because there would be no Lake Granby spills (Table 31). In wet years, annual flow on the Colorado River below Lake Granby would average about 128,100 AF under the Proposed Action compared to about 144,400 AF under Existing Conditions and 132,300 AF under No Action (Table 32).

In years when Lake Granby is not spilling, releases to the Colorado River below Lake Granby would continue to equal the bypass flow requirements. In wet years when total combined C-BT contents in Lake Granby and Chimney Hollow Reservoir reaches 539,568 AF, which is the physical capacity of Lake Granby, C-BT water would be spilled from Lake Granby. This would prevent the C-BT Project from storing more water in Lake Granby than it could without prepositioning.

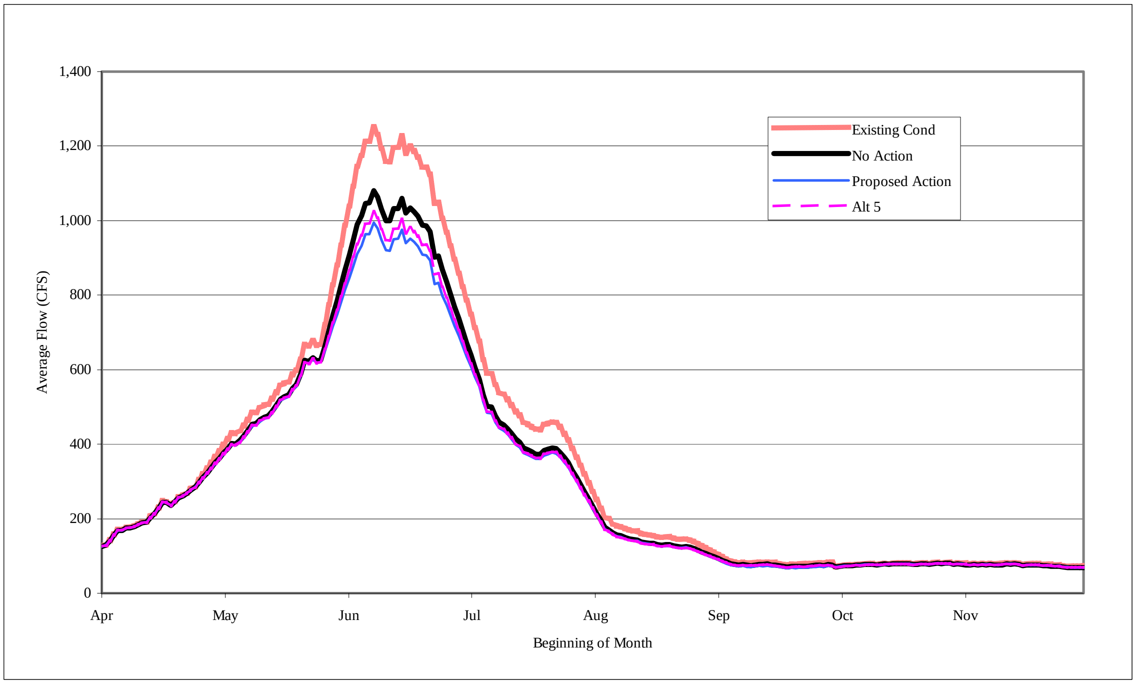
Table I-11 provides the modeled Granby Reservoir spill periods, average spill and maximum spill for Existing Conditions and the alternatives under Cumulative Effects. The model shows spills occurring for as short as a month (June, July or August) and up to as long as 4 months (May through August), with the most frequent spills occurring for 2 months in June through July under Existing Conditions and the Proposed Action. The spill periods and estimated flow of the river at the gage near Granby would be altered under the Proposed Action. For example, 2 month spills from June through July would be very similar to Existing Conditions, but 3 month spills from May through July would not occur under the Proposed Action.

Table 28 provides the changes in daily flows that would occur with Cumulative Effects in the Colorado River at the USGS gage near Granby during May through August, the period when most Windy Gap diversions would occur. Under the Proposed Action, flow increases of up to 142 cfs would occur 7.6 percent of the time during these months due to changes in the timing of spills from Lake Granby. No changes in daily flow would occur 77.5 percent of the time between May and August. Daily flow decreases of 1 to 100 cfs would occur about 6 percent of the time, and daily flow decreases greater than 100 cfs would occur about 9 percent of the time during May through August.

Colorado River above the Windy Gap Diversion. Average annual streamflow on the Colorado River above Windy Gap and below the Fraser River would be about 162,300 AF under the Proposed Action compared to about 187,900 AF under Existing Conditions and 168,500 AF under the No Action alternative (Table 30). The greatest average monthly decrease in streamflow of 21 percent would occur in June, with the greatest change in the summer months (Table I-13; Figure 51). About 44 percent of the streamflow reduction from Existing Conditions at this location would be related to reasonably foreseeable actions upstream on the Fraser River, including the Moffat Collection System Project and additional municipal Grand County water use. The remainder of the change would occur because of the change in Lake Granby spills and Willow Creek flows associated with the WGFP.

In dry years, Colorado River streamflow above the Windy Gap diversion would be about the same as No Action and would be about 6 percent less than under Existing Conditions because of reasonably foreseeable actions (Table 31). In wet years, average annual streamflow would be 359,900 AF under the Proposed Action compared to about 403,800 AF under Existing Conditions and 363,900 AF under No Action (Table 32).

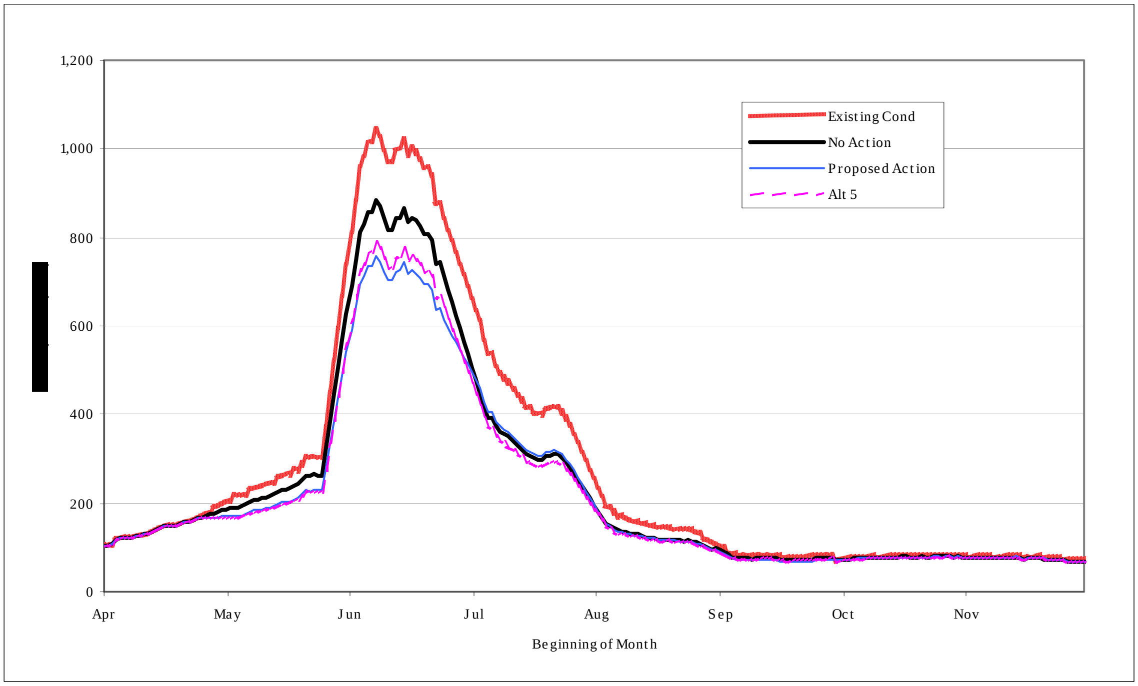
Figure 51. Average daily flows with reasonably foreseeable actions, Colorado River above Windy Gap.



Colorado River below the Windy Gap Diversion to the Top of Gore Canyon. Colorado River average annual streamflow below the Windy Gap diversion would be about 121,500 AF under the Proposed Action compared to 151,400 AF under Existing Conditions and 129,600 under No Action (Table 30). Reduced flows under the Proposed Action would occur primarily from May to August and range from an average monthly flow reduction of 20 to 27 percent from Existing Conditions (Table I-14; Figure 52). Average annual streamflow would be about 6 percent less than No Action. Reasonably foreseeable future actions would account for about 38 percent of the change in streamflow from Existing Conditions and the remainder from Windy Gap diversions. In dry years, the average annual change in flow below Windy Gap Reservoir would be about 1 percent less compared to Existing Conditions (Table 31). In wet years, Colorado River streamflow below the Windy Gap diversion would be about 289,700 AF under the Proposed Action compared to about 365,300 AF under Existing Conditions and 301,800 AF under No Action (Table 32). The greatest average percent change in flow during wet years would occur in August with a 37 percent reduction (Table I-14).

Under the Proposed Action, daily flows would increase at Hot Sulphur Springs by as much as 159 cfs about 26 percent of the time in May through August, the period when most Windy Gap diversions occur (Table 28). No changes in daily flows would occur about 8 percent of the time during this period under No Action, and daily flow decreases of 1 to 100 cfs would occur about 45 percent of the time in May through August. Flow decreases of greater than 100 cfs would occur about 22 percent of the time in May through August.

Figure 52. Average daily flows with reasonably foreseeable actions, Colorado River below Windy Gap.



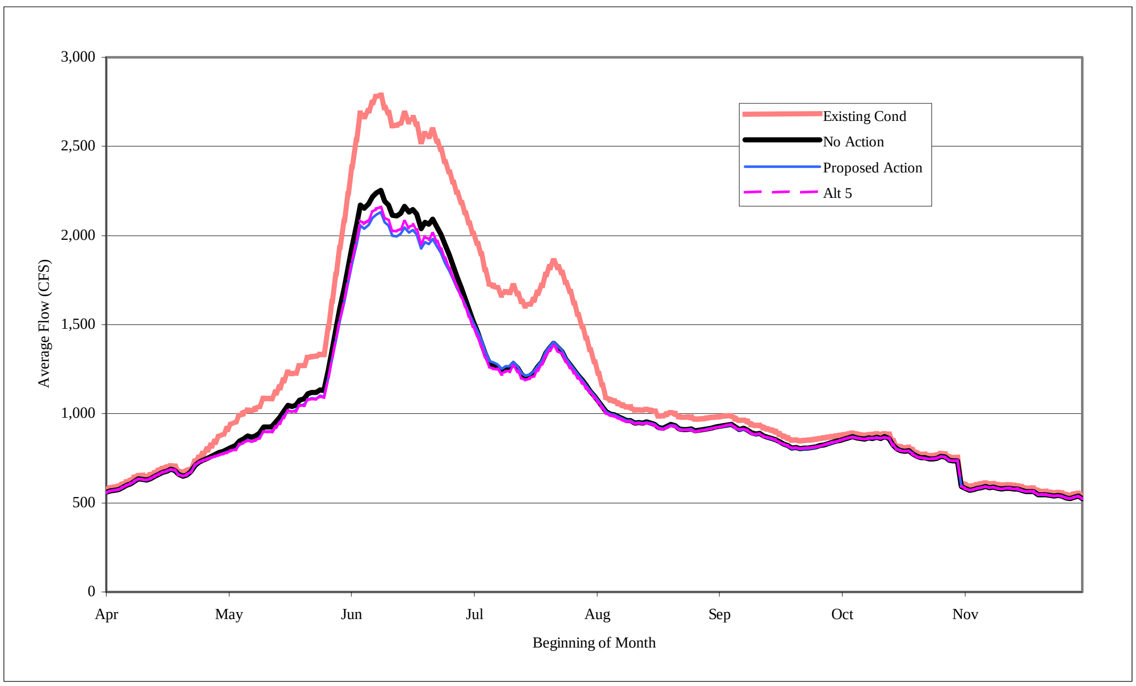
Colorado River average annual streamflow below the confluence with the Williams Fork River would be about 221,700 AF under the Proposed Action compared to 246,900 AF under Existing Conditions and 229,800 AF under Existing Conditions (Table 30). Average annual flow reductions under the Proposed Action would be about 10 percent less than Existing Conditions and about 3 percent less than No Action (Table I-17). About 26 percent of the change in Colorado River streamflow below the Williams Fork River would be the result of reasonably foreseeable actions including the elimination of endangered fish flow releases from Williams Fork Reservoir and changes in the operation of the Big Lake Ditch in the Williams Fork River basin. Windy Gap diversions would account for the remainder of the change in streamflow.

Colorado River average annual streamflow near Kremmling below the Blue River and Muddy Creek confluence would be about 613,800 AF under the Proposed Action compared to about 701,800 AF under Existing Conditions and 621,900 AF under No Action (Table 30). The average annual reduction in Colorado River streamflow near Kremmling under the Proposed Action would be about 13 percent less than Existing Conditions and about 2 percent less than No Action (Table I-18; Figure 53). The greatest change would occur from May to July with about a 17 to 25 percent reduction in average monthly flow compared to Existing Conditions. About 79 percent of the reductions in flows near Kremmling would be related to reasonably foreseeable actions, including changes in Blue River flows from DW’s future increases in demand and additional

Summit County water use and the elimination of flow releases for endangered fish and additional contract deliveries from Wolford Mountain Reservoir and other upstream reasonably foreseeable actions. In dry years, both the Proposed Action and No Action would result in annual flows about 5 percent less than Existing Conditions (Table 31). In wet years, Colorado River streamflow near Kremmling would be about 1,060,000 AF under the Proposed Action compared to about 1,217,000 AF under Existing Conditions and 1,072,000 AF under No Action (Table 32). Wet year average annual flow reductions under the Proposed Action would be about 13 percent less than Existing Conditions and about 1 percent less than No Action (Table I-18).

At the USGS gage near Kremmling, daily flows during May through August, when most Windy Gap diversions occur, would increase by as much as 197 cfs during about 13 percent of the time under the Proposed Action (Table 28). Daily flow decreases of 1 to 100 cfs would occur about 29 about of the time during May through August, and daily flow decreases greater than 100 cfs would occur about 57 percent of the time during those months.

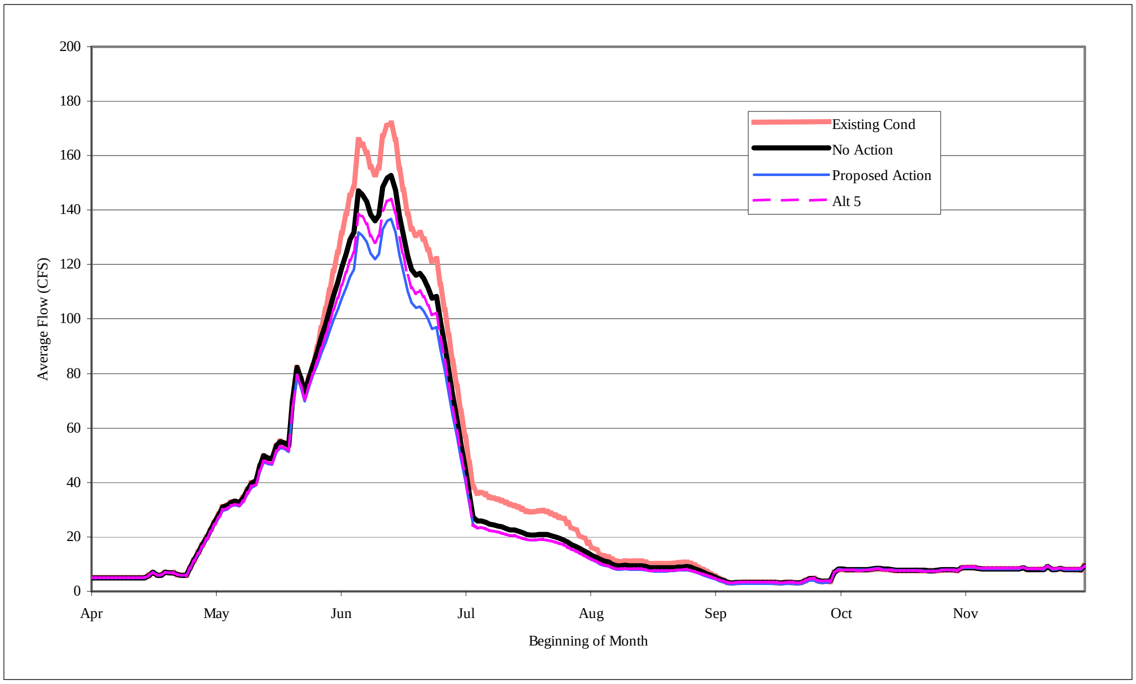
Figure 53. Average daily flows with reasonably foreseeable actions, Colorado River near Kremmling.



Willow Creek. Average annual Willow Creek streamflow would be about 15,500 AF under the Proposed Action compared to 18,300 AF under Existing Conditions and 16,700 AF under No Action (Table 30). Changes in Willow Creek flows would be related to increased WCFC diversions that reduce streamflow below Willow Creek Reservoir under the Proposed Action. In dry years, there would be no change in Willow Creek flows for the Proposed Action (Table 31). In wet years, Willow Creek streamflow would be about 46,000 AF under the Proposed Action compared to about 52,800 AF under Existing

Conditions and 46,800 AF under No Action (Table 32). The largest average monthly flow reduction in an average year would be 36 percent in July (32 cfs to 20 cfs) (Table I-15; Figure 54). The largest average monthly flow reduction in a wet year would be 34 percent in July (112 to 75 cfs).

Figure 54. Average daily flows with reasonably foreseeable actions, Willow Creek at confluence with Colorado River.



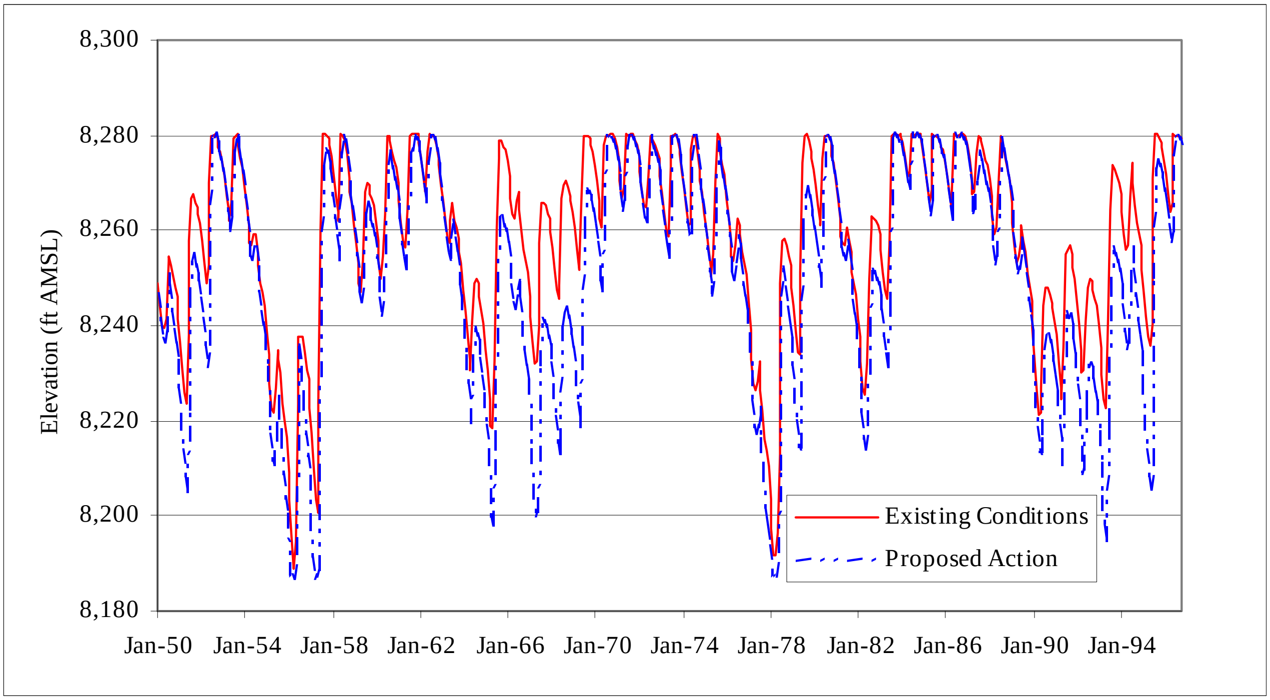
8.6.1.3. West Slope Reservoirs

Lake Granby. Average monthly contents in Lake Granby would range from about 41,100 AF to 55,300 AF lower under the Proposed Action than Existing Conditions and 21,300 AF to 32,500 AF lower than No Action (Table K-7). These changes represent a 3-to 9-foot average monthly decrease in Lake Granby elevations from Existing Conditions or about 3 to 5 feet less than lake elevations under No Action (Table K-8). The largest change from Existing Conditions occurs from January to May. In dry years, Lake Granby elevations would range from 5 to 10 feet lower than Existing Conditions and about 3 feet less than No Action (Table K-8). In wet years, the Proposed Action would result in Lake Granby elevations 2 to 11 feet less than Existing Conditions and 1 to 6 feet less than No Action. Reasonably foreseeable actions indirectly affect Lake Granby storage by reducing Windy Gap diversions. Average end-of-month contents in Lake Granby would be less under Future Conditions because Windy Gap diversions would be less, which results in lower Windy Gap contents and lower C-BT contents in Lake Granby because shrink payments would be less.

Differences in Lake Granby contents and surface elevations would be greatest under the Proposed Action (up to 33 feet during dry year sequences; the chance of a decrease in the lake level of more than 10 feet in any given year would be 40 percent (Figure 55).

During these years, Windy Gap diversions would not be limited by available storage capacity in Lake Granby; therefore, differences would be greater due to C-BT deliveries to Chimney Hollow, Windy Gap storage in Lake Granby, Windy Gap demands and deliveries, and shrink payments.

Figure 55. Lake Granby estimated average monthly surface elevation for the Proposed Action with reasonably foreseeable actions.



8.6.1.4. East Slope Streams

Big Thompson River. Under the Proposed Action and given reasonably foreseeable future actions, flows in the Big Thompson River below Lake Estes would increase in April through November (Table I-8), with the biggest increases occurring in May (8 percent) and July (9 percent), due primarily to a decrease in C-BT diversions for power generation. The flow in the Big Thompson River at the mouth of the canyon would increase in April through October, with biggest increase occurring in May (6 percent) and July (7 percent) (Table I-10). The maximum change in river stage would be 0.04 feet, occurring in May and July (Table J-1).

Streams that Receive Windy Gap Return Flows. Windy Gap return flows would increase with additional Windy Gap diversions. Table 35 provides the maximum predicted changes in flows to the affected streams compared to the average and maximum monthly flows at the nearest USGS gage. The maximum yield would also be equivalent to the firm yield and average yield under the action alternatives. No adjustments were made to gage flows to account for gains/losses that may occur between the gages and WWTPs. Except for distributed returns from rural customers, there would likely be no net change in streamflow from November to March between the No Action alternative and Existing Conditions because either Participants do not intend to use their Windy Gap supplies in those months, reusable effluent is stored for use later in summer months, or return flows are used to offset depletions or augment return flow obligations. In Coal Creek and St. Vrain Creek, return flows would increase at more than one location; the return flows for these creeks have not been added together in Table 35.

Table 35. Cumulative Effects—East Slope streamflow increases under the Proposed Action and Alternative 5.

Stream Segment	Flow Condition[1]	Apr	May	Jun	Jul	Aug	Sep	Oct
		cfs						
Big Dry Creek above Broomfield WWTP (USGS gage 06720820, adjusted for average historical Broomfield WWTP effluent, 1995-2004)	Existing average flow	13.3	28.9	51.1	41.5	38.5	23.6	10.1
	Existing maximum flow	19	40.5	73.2	86.5	49	40.3	16.2
	Maximum flow increase	3.1	5.3	6.3	7.6	7.6	6.3	3.0
Coal Creek below Superior, above Louisville, Lafayette and Erie WWTPs (USGS gage 06730400)	Existing average flow	12.3	13.1	7	2.8	4.1	2.1	2.6
	Existing maximum flow	36	35	13	4.3	15	3.1	3.8
	Maximum flow increase above gage	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	Maximum flow increase below gage	2.8	3	3.2	3.3	3.3	3.2	2.7
St. Vrain Creek below Longmont WWTP (USGS gage 06725450)	Existing average flow	76	234	348	175	148	101	68
	Existing maximum flow	259	1155	1227	485	185	152	159
	Maximum flow increase	1.6	0.5	0.5	5.9	5.9	6.1	5.8
St. Vrain Creek below LTWD WWTP (USGS gage 06731000)	Existing average flow	178	472	627	313	231	184	160
	Existing maximum flow	622	2362	2316	972	653	292	398
	Maximum flow increase	0.7	1.1	1.3	1.6	1.6	1.3	0.6
Big Thompson River below Loveland WWTP (USGS gage 06741510)	Existing average flow	41	251	296	129	84	37	28
	Existing maximum flow	292	2078	1493	418	153	84	66
	Maximum flow increase	0	0.8	0.8	1.6	3.1	4.8	4.6

[1] Existing average and maximum flow are at stream gage locations. Maximum flow increases are at Participants' WWTPS and dispersed return flow locations from outdoor use.

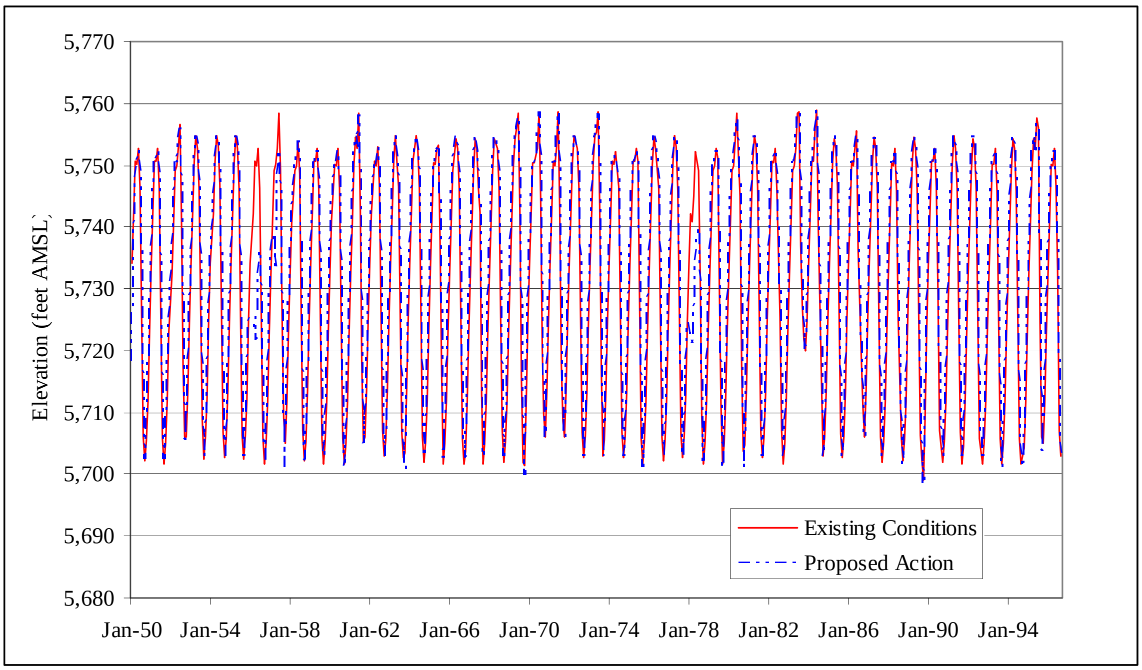
8.6.1.5. East Slope Reservoirs

Carter Lake. Carter Lake contents are a function of C-BT operations (deliveries from Lake Granby and the Big Thompson River to Carter Lake to meet storage targets and releases to meet C-BT demands) except for instantaneous C-BT deliveries to meet Windy Gap demands. Average monthly storage in Carter Lake would be about 1 percent less from March to July and in October under the Proposed Action compared to Existing Conditions (Table K-1). Changes would be less than 1 percent in other months. There would be less than a 1 percent difference between the Proposed Action and No Action.

In average or dry years, the Proposed Action would have less than a 1 percent or 1-foot difference in Carter Lake elevations compared to Existing Conditions or No Action (Table K-2). In wet years, the Proposed Action would result in monthly Carter Lake elevations from 2 feet lower to 1 foot higher than Existing Conditions and less than a 1-foot difference with No Action.

Occasionally, in dry years when C-BT contents in Lake Granby are exhausted, Carter Lake contents under the Proposed Action would be much lower than Existing Conditions and No Action. The decrease is predicted to be as much as 29 feet; however, the chance of a decrease in the elevation of Carter Lake equal or exceeding 10 feet in any given year would be less than 10 percent (Figure 56). C-BT contents in Lake Granby would be exhausted earlier in dry year sequences due to C-BT deliveries to Chimney Hollow in previous years. As a result, the amount of C-BT water available for delivery to Carter Lake and Horsetooth Reservoir would be less, and consequently C-BT contents in those reservoirs would be less. Limited Adams Tunnel capacity in dry years may also result in lower C-BT contents in those reservoirs under the Proposed Action.

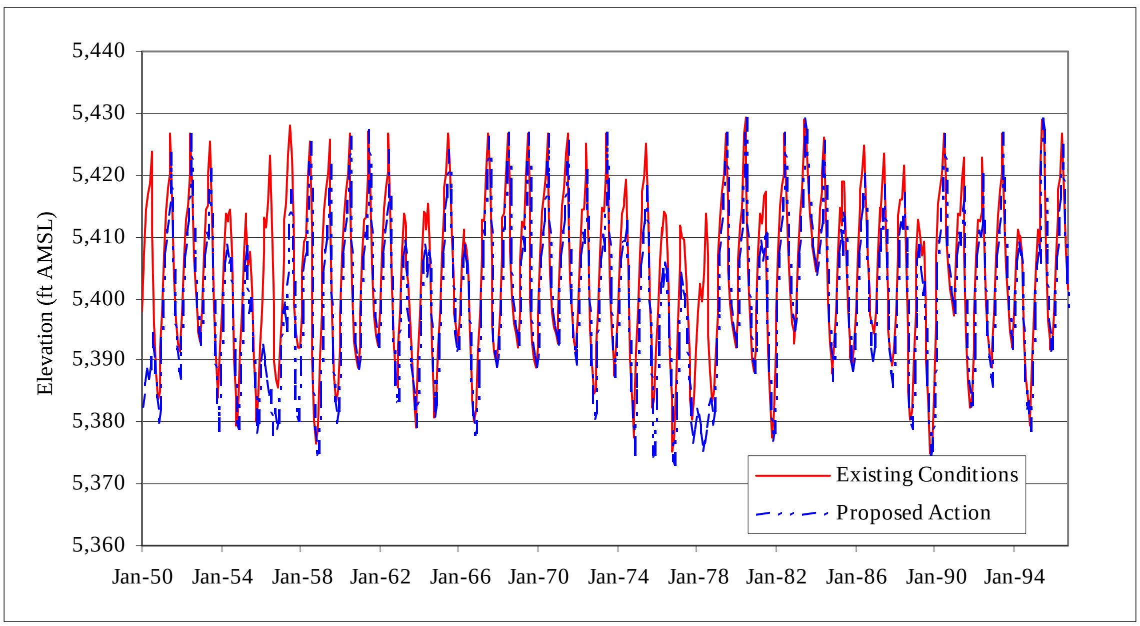
Figure 56. Carter Lake estimated average monthly surface elevation for the Proposed Alternative with reasonably foreseeable actions.



Horsetooth Reservoir. Average monthly Horsetooth Reservoir content under the Proposed Action would range from a decrease of about 2,200 AF in January to a decrease of about 9,200 AF in April compared to Existing Conditions (Table K-4). These changes represent a 1 to 6 foot decrease Horsetooth Reservoir water levels compared to both Existing Conditions and No Action (Table K-5). In dry years, the Proposed Action would result in Horsetooth Reservoir monthly average elevations about 1 to 7 feet lower than Existing Conditions and No Action. In wet years, although reservoir volume remains higher than average, the Proposed Action would result in average monthly water elevations up to about 6 feet lower in April than Existing Conditions and No Action.

Occasionally, in dry years, Horsetooth Reservoir contents under the Proposed Action would be lower than Existing Conditions (35 to 40 feet) if C-BT contents in Lake Granby are exhausted earlier due to C-BT deliveries to Chimney Hollow Reservoir in previous years; however, the chance of a decrease in Horsetooth of more than 10 feet in any given year would be less than 10 percent (Figure 57). This would occur when C-BT deliveries are made to Chimney Hollow in previous years. As a result, the amount of C-BT water in Lake Granby available for delivery to Carter Lake and Horsetooth Reservoir would be less in those years, and consequently C-BT contents in those reservoirs would be less. Limited Adams Tunnel capacity in dry years may also result in lower C-BT contents in those reservoirs under the Proposed Action. Although C-BT contents in Carter Lake and Horsetooth would be lower in those years, total C-BT reservoir contents, including C-BT contents in Chimney Hollow, would be roughly the same.

Figure 57. Horsetooth Reservoir estimated average monthly surface elevation for the Proposed Alternative with reasonably foreseeable actions.



8.6.2. Ground Water Hydrology and Quality

8.6.2.1. West Slope Streams

The existing annual variation in the level of Lake Granby of up to nearly 90 feet is much greater than the maximum 33 foot change that would occur under the Proposed Action alternative compared to Existing Conditions. Water levels in some shallow wells near the lake may be connected to lake levels; however, it is probable that much of the ground water adjacent to the lake is from topographically higher areas surrounding the lake rather than from Lake Granby. Because predicted water quality changes to these reservoirs as a result of the WGFP are predicted to be minor, it is expected that there would be no effects to ground water quality.

8.6.2.2. West Slope Streams

The maximum monthly stage change in an average year in the Colorado River below Windy Gap would be a decrease of about 4 inches under the Proposed Action (Table J-2) compared to Existing Conditions. The maximum monthly stage change in the Colorado River near Kremmling would be 1 foot (Table J-3) compared to Existing Conditions. Stage data is not available for Willow Creek, but the maximum monthly flow change in an average year would be a decrease of 11 cfs (Table I-15) compared to Existing Conditions. Changes in flow and the resulting stage changes are considered to be minor with respect to potential effects to adjacent ground water levels. The changes in river stage under the Proposed Action would not result in measurable effects to ground water levels. As discussed in Section 7.2.2, and because predicted water quality changes to these streams as a result of the WGFP are predicted to be small, it is expected that there would be only minor effects to alluvial ground water quality along the Colorado River and no effects to ground water quality near Willow Creek.

8.6.2.3. East Slope Reservoirs

The maximum predicted decrease in the elevation of Carter Lake is 29 feet compared to Existing Conditions. The maximum predicted decrease in the elevation of Horsetooth Reservoir is 35 to 40 feet compared to Existing Conditions. Potential effects to ground water levels near Carter Lake and Horsetooth Reservoir would be expected to be minor for the reasons discussed in Section 7.2.1. As discussed in Section 7.2.2, and because water quality changes to these reservoirs as a result of the WGFP are predicted to be minor, it is expected that there would not be any effects to ground water quality.

8.6.2.4. East Slope Streams

Because the average monthly stage change in the Big Thompson River between Lake Estes and the Hansen Feeder Canal under the Proposed Action would be less than an inch (Table J-1) compared to Existing Conditions, effects to alluvial or bedrock ground water would be negligible. For the other East Slope streams affected by changing return flows from Participants' WWTPs, because stage changes are expected to be small, increases in alluvial ground water levels would likely be unmeasurable. As discussed in Section 7.2.2, it is expected that ground water quality would not be affected near the foothill streams (North St. Vrain Creek, St. Vrain Creek at Lyons and Big Thompson River below Lake Estes to the Hansen Feeder Canal). For the other East Slope streams, there may be minor changes to alluvial ground water quality near the streams.

8.6.3. Stream Morphology and Sedimentation

8.6.3.1. West Slope Streams

Colorado River. Flow duration curves provide a comparison of the percentage change in flows at different rates between Existing Conditions and the Proposed Action for the USGS gages located at Hot Sulphur Springs and near Kremmling (Figure G-1 and Figure G-2). At Hot Sulphur Springs, the 2-year peak discharge was estimated to be 1,240 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 3 percent of the time (percent of days in study period). At the gage near Kremmling, the 2-year peak discharge was estimated to be 2,850 cfs under Existing

Conditions. Under Existing Conditions, this flow would be exceeded about 5 percent of the time.

Under the Proposed Action, the 2-year peak discharge at the Hot Sulphur Springs gage would be exceeded about 2.5 percent of the time, or 0.5 percent less than under Existing Conditions. The 2-year peak discharge at the gage near Kremmling would be exceeded 3 percent of the time (a 2 percent change from Existing Conditions). The slight reduction in the percentage of time that 2-year peak discharge would be reached at the two gage sites below the Windy Gap diversion is unlikely to significantly affect stream morphology or change sediment transport or deposition.

The range of channel maintenance flows would also change under the Proposed Action. At Hot Sulphur Springs, under Existing Conditions, the lower limit of channel maintenance flows (80 percent of the 1.5-year peak flow) of at least 510 cfs occurred for 23 days on average (in years when such flows occurred), with a 62 percent chance of occurrence in any given year (Table I-19). Under the Proposed Action, flows of at least 510 cfs occurred for 21 days on average (in years when such flows occurred), with a 47 percent chance of occurrence in any given year. The upper limit of channel maintenance flows is defined as the 25-year flow; such a flow (6,520 cfs) occurred once under Existing Conditions, but would not occur under the Proposed Action. Ten-year flows or greater (4,600 cfs or more) occurred under Existing Conditions for 4 days on average and under the Proposed Action for 8 days on average (in years when such flows occurred), with a 13 percent chance of occurrence in any given year under Existing Conditions and a 4 percent chance of occurrence under the Proposed Action. In general, the chance of channel maintenance flows occurring in a given year would be about 1 percent less under the Proposed Action than Existing Conditions, but the duration of such flows in a year when channel maintenance flows occur would be slightly longer. The differences in channel maintenance flows between Existing Conditions and the Proposed Action alternative are minor and are not expected to measurably alter channel morphology or sediment movement at Hot Sulphur Springs. The range in streamflows under the Proposed Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment.

For the section of the Colorado River below Lake Granby where river flows have been dominated by releases from Lake Granby, releases from Lake Granby would continue to meet the needs of water rights users as well as the bypass flow requirement. The frequency, timing and magnitude of spills from Lake Granby would change under the Proposed Action, as discussed in Section 7.5.1.1 under "Lake Granby Spills." For example, spills occurring for 3 months in May through July would not occur under the Proposed Action, and spills occurring in July would occur less frequently (Table I-11).

The magnitude, timing and frequency of channel maintenance flows in the Colorado River below Lake Granby would change as a result of changes in spills. When spills are not occurring, the flow of the river below Lake Granby is controlled by bypass flows; it is difficult, therefore, to define a range of channel maintenance flows based on peak flow events. A comparison of modeled spill events is provided in Table I-4. Under the Proposed Action, there would be 7 less spill events compared to Existing Conditions, but flows of 500 cfs or more (within the range of channel maintenance flows at Hot Sulphur

Springs) would continue to occur for periods of 1 to 4 months. Flows over 2,500 cfs would occur during 11 percent of all years, compared to 19 percent of all years under Existing Conditions. These differences are not expected to alter channel morphology or sediment movement in the Colorado River below Lake Granby. The range in streamflows under No Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment.

Willow Creek. The flow duration curve for Willow Creek provides a comparison between Existing Conditions and this alternative for the USGS gage located below Willow Creek Reservoir (Figure B-3). The 2-year peak discharge was estimated to be 80 cfs. Under Existing Conditions, this flow would be exceeded about 6 percent of the time. Under the Proposed Action, the 2-year peak discharge would be exceeded slightly less than under Existing Conditions (a 1 percent change); therefore, it is unlikely that there would be measurable effects to stream morphology or changes in sediment transport or deposition.

8.6.3.2. East Slope Streams

Big Thompson River. The largest estimated flow increases to the Big Thompson River below Lake Estes would occur in May through July, but would be less than 10 percent of the monthly average flow of the river during those months (Table I-8). By the mouth of the Big Thompson Canyon the maximum streamflow increase (7 percent) would occur in July of an average year (Table I-10). It is not expected that these flow increases (a maximum of 18 cfs in July) would measurably alter stream morphology or sediment transport and deposition given that spring and summer high flows in the Big Thompson River exceed 500 cfs.

Streams that Receive Windy Gap Return Flows. The predicted streamflow increases for the East Slope stream segments that receive Windy Gap return flows (Big Dry Creek, Coal Creek, St. Vrain Creek, and the Big Thompson River) are unlikely to substantially alter stream morphology and sedimentation because the increased flows would be small compared to the spring and early summer flows that these channels have the capacity for. In addition, as described in Section 6.6, streams on the East Slope have not experienced natural streamflow conditions for more than 100 years, and are not in equilibrium with respect to channel forming and channel moving processes, erosion, or sediment loading, movement and deposition. Given the magnitude of the average monthly flow increases (less than 9 cfs), it would be difficult to measurably differentiate changes to stream morphology and sedimentation due to changes in Participants' WWTP return flows from the many other ongoing actions influencing East Slope streamflow conditions.

8.7. Alternative 5—Dry Creek Reservoir with Rockwell/Mueller Creek Reservoir

The cumulative effects discussion for Alternatives 3, 4, and 5 were combined because of the similarity in the results for alternatives that operate with both an East Slope and West Slope storage component. The results presented in this section are for Alternative 5. Alternative 5 includes 30,000 AF storage in Rockwell/Mueller Reservoir on the West Slope, compared to 20,000 AF of storage in Jasper East under Alternative 3 or 20,000 AF of storage in Rockwell/Mueller in Alternative 4. More storage on the West Slope and less storage on the East Slope under Alternative 5 results in slightly greater Windy Gap diversions and other hydrologic changes; thus, the hydrologic effects of Alternatives 3 and 4 would generally be similar, but slightly less.

8.7.1. Surface Water Hydrology

8.7.1.1. C-BT and Windy Gap Project Operations and Diversions

Adams Tunnel Diversions. Adams Tunnel diversions under Alternative 5 would be 258,900 AF compared to about 243,200 AF under Existing Conditions and 251,900 AF under No Action (Table 30). Thus, Adams Tunnel deliveries for Alternative 5 would be about 6 percent greater than Existing Conditions or about 2 percent greater than No Action. Dry year Adams Tunnel diversions would be about 3 percent greater (324,300 AF) than Existing Conditions and No Action (314,900 AF) (Table 31). In wet years, Adams Tunnel deliveries under Alternative 5 (199,700 AF) would be about 10 percent greater than Existing Conditions (180,800 AF) and about 2 percent greater than No Action (199,900 AF) (Table 32).

Windy Gap Diversions. Windy Gap average annual diversions would increase about 18 percent (43,000 AF) under Alternative 5 compared to Existing Conditions (36,500 AF) and would be about 11 percent greater than No Action (39,000 AF) (Table 30). Dry year diversions under Alternative 5 would be about 3,900 AF, the same as No Action and less than Existing Conditions (7,800 AF) (Table 31). In wet years, Alternative 5 would divert about 71,700 AF compared to 38,500 AF under Existing Conditions and 62,100 AF under No Action (Table 32).

Willow Creek Feeder Canal Diversions. Average annual WCFC diversions under Alternative 5 would be about 38,600 AF compared to 36,200 AF under Existing Conditions and 37,800 AF under No Action (Table 30). There would be no difference in WCFC diversions in dry years between Alternative 5 or any of the alternatives and Existing Conditions (Table 31). In wet years, WCFC diversions under Alternative 5 would be about 40,300 AF compared to 33,700 AF under Existing Conditions and 39,700 AF under No Action (Table 32).

Lake Granby Spills. Although Lake Granby spills only occur in wet years, average annual Lake Granby spills decrease from 38,700 AF under Existing Conditions and 31,900 AF under No Action to 27,900 AF under Alternative 5 (Table 30). There would be no dry year spills under Alternative 5, Existing Conditions, or any on the alternatives (Table 31). In wet years, Alternative 5 would result in an average annual spill about 14 percent lower (111,200 AF) than Existing Conditions (129,100 AF) and about 3 percent less than No Action (115,500 AF) (Table 32).

C-BT Diversions from Big Thompson River. Average annual C-BT diversions from the Big Thompson River under Alternative 5 would be about 26,900 AF compared to 28,000 AF under Existing Conditions and 27,600 AF under No Action (Table 30). There would be no change in Big Thompson River diversions in dry years and less than a 1 percent change in wet years compared to Existing Conditions (Table 31 and Table 32).

8.7.1.2. West Slope Streams

Colorado River below Lake Granby. Average annual Colorado River streamflow below Lake Granby would be about 49,400 AF under Alternative 5 compared to 59,400 AF under Existing Conditions and 53,000 AF under No Action (Table 30). There would be no change from Existing Conditions in dry years (Table 31). In wet years, annual streamflow under Alternative 5 would be 128,300 AF compared to 144,400 AF under Existing Conditions and 132,300 AF under No Action (Table 32).

Table I-11 provides the modeled Granby Reservoir spill periods, average spill and maximum spill for Existing Conditions and the alternatives with cumulative effects. The model shows spills occurring for as short as a month (June, July or August) and up to as long as 4 months (May through August), with the most frequent spills occurring for 2 months in June through July under Existing Conditions and Alternative 5. The spill periods and estimated flow of the river at the gage near Granby would be altered under Alternative 5. For example, 4-month spills from May through August would be very similar to Existing Conditions, but 3-month spills from May through July and 1-month spills in July or August would not occur under Alternative 5.

Table 28 provides the changes in daily flows that would occur with Cumulative Effects in the Colorado River at the USGS gage near Granby during May through August, the period when most Windy Gap diversions would occur. Under Alternative 5, flow increases of up to 117 cfs would occur about 3.7 percent of the time during these months due to changes in the timing of spills from Lake Granby. No changes in daily flow would occur about 78 percent of the time between May and August. Daily flow decreases of 1 to 100 cfs would occur about 10 percent of the time and daily flow decreases greater than 100 cfs would occur about 9 percent of the time during May through August.

Colorado River above the Windy Gap Diversion. Colorado River average annual streamflow above the Windy Gap diversion and below the Fraser River under Alternative 5 would be about 13 percent less (164,200 AF) than Existing Conditions (187,900 AF) and 3 percent less than No Action (168,500 AF) under No Action (Table 30). About 48 percent of the streamflow reduction from Existing Conditions would be related to reasonably foreseeable actions upstream. Although Colorado River streamflow would decrease in all months, the greatest decrease in average streamflow (16 to 18 percent) would occur from June to August (Table I-13; Figure 51). In dry years, Colorado River streamflow above Windy Gap would be about 6 percent less than Existing Condition and about the same as No Action (Table 31 and Table 32). In wet years, the greatest decrease in average monthly streamflow (25 percent) would occur in August (Table I-13).

Colorado River below the Windy Gap Diversion to the Top of Gore Canyon. Average annual streamflow below the Windy Gap diversion would be about 121,200 AF under Alternative 5 compared to about 151,400 AF under Existing Conditions and 129,600 AF under No Action (Table 30). The greatest monthly changes in streamflow would occur from May to August, with up to a 30 percent decrease in July flows (Table I-14; Figure 52). About 38 percent of the change in flow from Existing Conditions would be related to reasonably foreseeable actions and the remainder from Windy Gap Project diversions.. In dry years, Alternative 5 would result in a less than 1 percent decrease in streamflow below the Windy Gap diversion compared to Existing Conditions and would be about the same as No Action (Table 31). In wet years, streamflow below Windy Gap would be about 21 percent less under Alternative 5 (287,500 AF) than Existing Conditions (365,300 AF) and 5 percent less than No Action (301,800 AF) (Table 32). The greatest average monthly change in wet years would be 34 percent decrease in August (Table I-14).

Under Alternative 5, daily flows at Hot Sulphur Springs would increase as much as 159 cfs about 24 percent of the time in May through August, the period when most Windy Gap diversions occur (Table 28). No changes in daily flows would occur about 8 percent of the time during this period under this alternative, and daily flow decreases of 1 to 100 cfs would occur about 43 percent of the time in May through August. Flow decreases of greater than 100 cfs would occur about 25 percent of the time in May through August.

The average annual Colorado River streamflow below the confluence with the Williams Fork River would be 221,450 AF under Alternative 5 compared to about 246,900 AF under Existing Conditions and 229,800 AF under No Action (Table 30). Average annual flow reductions under Alternative 5 would be about 10 percent less than Existing Conditions and about 3 percent less than No Action (Table I-17). About 26 percent of the change in Colorado River streamflow below the Williams Fork River would be the result of reasonably foreseeable actions including the elimination of endangered fish flow releases from Williams Fork Reservoir and changes in the operation of the Big Lake Ditch in the Williams Fork River basin. Windy Gap diversions would account for the remainder of the change in streamflow.

Colorado River average annual streamflow near Kremmling below the Blue River and Muddy Creek confluence would be about 613,600 AF under Alternative 5 compared to about 701,800 AF under Existing Conditions and 621,900 AF under No Action (Table 30). The average annual reduction in Colorado River streamflow near Kremmling under Alternative 5 would be about 13 percent less than Existing Conditions and about 2 percent less than No Action. The greatest change would occur from May to July with about a 17 to 26 percent reduction in average monthly flow compared to Existing Conditions (Table I-18; Figure 53). About 79 percent of the reduction in flow near Kremmling would be related to reasonably foreseeable actions and the remainder would be from the Windy Gap Project. In dry years, Alternative 5 would result in average annual flows of about 5 percent less than Existing Conditions and about the same as No Action (Table 31). In wet years, average annual Colorado River streamflow near Kremmling would be about 13 percent lower under Alternative 5 (1,057,900 AF) compared to 1,217,000 AF under Existing Conditions and about 1 percent lower than No Action (1,072,200 AF) (Table 31).

At the USGS gage near Kremmling, daily flows during May through August, when most Windy Gap diversions occur, would increase by as much as 197 cfs about 13 percent of the time under Alternative 5 (Table 28). Daily flow decreases of 1 to 100 cfs would occur 28.5 percent of the time during May through August, and daily flow decreases greater than 100 cfs would occur about 57 percent of the time during those months.

Willow Creek. Average annual Willow Creek streamflow would be about 15,900 AF under Alternative 5 compared to about 18,300 AF under Existing Conditions and 16,700 AF under No Action (Table 31). There would be no change in Willow Creek streamflow in dry years under Alternative 5 and wet year flows would be about 13 percent less than Existing Conditions and less than 2 percent lower than No Action (Table 31 and Table 32). The largest average monthly flow reduction in an average year would be 36 percent in July (32 to 20 cfs) (Table I-15; Figure 54). The largest average monthly flow reduction in a wet year would be 34 percent in July (112 to 75 cfs).

8.7.1.3. West Slope Reservoirs

Lake Granby. Average monthly content in Lake Granby would range from about 21,200 AF lower in April to 31,000 AF lower in June under Alternative 5 compared to Existing Conditions (Table K-7). Compared to No Action, Lake Granby storage under Alternative 5 would range from about 8,700 AF lower in August to about 1,700 AF higher in April. These changes under Alternative 5 represent a 4- to 5-foot average monthly decrease in reservoir elevations change from Existing Conditions or about 0 to 2 feet lower compared to No Action (Table K-8). In dry years, Lake Granby elevations would range from about 3 to 4 feet lower than Existing Conditions and 0 to 1 foot lower than No Action. In wet years, Alternative 5 would result in Lake Granby elevations from 2 to 6 feet lower than Existing Conditions and 0 to 1 foot lower than No Action.

Differences in Lake Granby contents and surface elevations would be greatest (up to 23 feet) during dry year sequences; the chance of a decrease in the lake level of 10 feet or more would be 34 percent.

8.7.1.4. East Slope Streams

Big Thompson River. Under Alternative 5 and given reasonably foreseeable future actions, flows in the Big Thompson River below Lake Estes would increase in April through August and November (Table I-8), with the biggest increases occurring in May (4 percent), due primarily to a decrease in C-BT diversions for power generation. The flow in the Big Thompson River at the mouth of the canyon would increase in April through October, with biggest increase occurring in May (3 percent) (Table I-10). The maximum change in river stage would be 0.02 feet, occurring in May (Table J-1).

Streams that Receive Windy Gap Return Flows. Windy Gap return flows would increase with additional Windy Gap diversions. Table 35 provides the maximum predicted changes in flows to the affected streams compared to the average and maximum monthly flows at the nearest USGS gage. No adjustments were made to gage flows to account for gains/losses that may occur between the gages and WWTPs. Except for distributed returns from rural customers, there would be no net change in streamflow from November to March between the No Action alternative and Existing Conditions because either Participants do not intend to use their Windy Gap supplies in those months, reusable effluent is stored for use later in summer months, or return flows are used to offset depletions or augment return flow obligations.

8.7.1.5. East Slope Reservoirs

Carter Lake. Average monthly storage in Carter Lake would be less than 1 percent or 1-foot lower under Alternative 5 than Existing Conditions and No Action, primarily from May to August (Table K-1 and Table K-2). In dry years, reservoir volume would change less than 1 percent compared to Existing Conditions and No Action. In wet years, Alternative 5 would result in average monthly Carter Lake water levels generally less than 1 percent lower than Existing Conditions except in August, which would average 2 percent lower and September, which would average 3 percent lower. Alternative 5 would not vary more than 1 percent from Carter Lake storage under No Action.

Occasionally n dry years when C-BT contents in Lake Granby are exhausted earlier or available capacity in Adams Tunnel is limited, Carter Lake contents under Alternative 5 would be lower than Existing Conditions. The decrease is predicted to be as much as 6 feet; however, the chance of a decrease in the elevation of Carter Lake equal or exceeding 5 feet in any given year would be only 13 percent.

Horsetooth Reservoir. Average monthly Horsetooth Reservoir content under Alternative 5 would range from a decrease of about 3,600 AF in April to an increase of about 100 AF in February compared to Existing Conditions and No Action (Table K-4). This is equivalent to a decrease in reservoir elevation of about 2 feet or less (Table K-5). In dry years, the greatest difference between Alternative 5 and Existing Conditions/No Action would be about a 4-foot decrease in average monthly elevations from May to July. In wet years, Alternative 5 average monthly elevations in Horsetooth would be less than 2 feet lower than Existing Conditions and No Action.

Occasionally in dry years, Horsetooth Reservoir contents under Alternative 5 would be lower than Existing Conditions (6 feet) if C-BT contents in Lake Granby are exhausted earlier or available capacity in Adams Tunnel is limited; the chance of a decrease in Horsetooth of 5 to 6 feet in any given year would be only 15 percent.

8.7.2. Ground Water Hydrology and Quality

8.7.2.1. West Slope Streams

The existing annual variation in the level of Lake Granby of up to nearly 90 feet is much greater than the maximum 23-foot change that would occur under the Alternative 5 compared with Existing Conditions. Water levels in some shallow wells near the lake may be connected to lake levels; however, it is probable that much of the ground water adjacent to the lake is from topographically higher areas surrounding the lake rather than from Lake Granby. Because water quality changes to these reservoirs as a result of the WGFP are predicted to be minor, it is expected that there would be no effects to ground water quality.

8.7.2.2. West Slope Streams

The maximum monthly stage change in an average year in the Colorado River below Windy Gap would be a decrease of about 3.5 inches under Alternative 5 (Table J-2) compared with Existing Conditions. The maximum monthly stage decrease in the Colorado River near Kremmling would be 1 foot (Table J-3) compared with Existing Conditions. Stage data is not available for Willow Creek, but the maximum monthly flow change in an average year would be a decrease of 12 cfs (Table I-15) compared with Existing Conditions. Changes in flows and stream stages in the Colorado River and in Willow Creek are considered to be negligible with respect to potential effects to ground water connected to these streams (primarily alluvial ground water) because there would not be measurable effects to ground water levels. As discussed in Section 7.2.2, and because predicted water quality changes to these streams as a result of the WGFP are predicted to be small, it is expected that there would be only minor effects to alluvial ground water quality along the Colorado River and no effects to ground water quality near Willow Creek.

8.7.2.3. East Slope Reservoirs

The maximum predicted decrease in the elevation of Carter Lake is 6 feet compared with Existing Conditions. The maximum predicted decrease in the elevation of Horsetooth Reservoir is 6 feet. Potential effects to ground water levels near Carter Lake and Horsetooth Reservoir would be expected to be minor for the reasons discussed in Section 7.2.1. As discussed in Section 7.2.2, and because water quality changes to these reservoirs as a result of the WGFP are predicted to be minor, it is expected that there would not be any effects to ground water quality.

8.7.2.4. East Slope Streams

Because the average monthly stage change in the Big Thompson River between Lake Estes and the Hansen Feeder Canal under Alternative 5 would be only 0.02 foot (Table J-1), effects to alluvial or bedrock ground water would be negligible. For the other East Slope streams affected by changing return flows from Participants' WWTPs, because stage changes are expected to be small, increases in alluvial ground water levels would likely be no more than a few inches. As discussed in Section 7.2.2, it is expected that ground water quality would not be affected near the foothill streams (North St. Vrain Creek, St. Vrain Creek at Lyons and Big Thompson River below Lake Estes to the Hansen Feeder Canal). For the other East Slope streams, there may be minor changes to alluvial ground water quality near the streams.

8.7.3. Stream Morphology and Sedimentation

8.7.3.1. West Slope Streams

Colorado River. Flow duration curves provide a comparison of the percentage change in flows at different rates between Existing Conditions and the Proposed Action for the USGS gages located at Hot Sulphur Springs and near Kremmling (Figure G-1 and Figure G-2). At Hot Sulphur Springs, the 2-year peak discharge was estimated to be 1,240 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 3 percent of the time (percent of days in study period). At the gage near Kremmling, the 2-year peak discharge was estimated to be 2,850 cfs under Existing Conditions. Under Existing Conditions, this flow would be exceeded about 5 percent of the time.

Under Alternative 5, the 2-year peak discharge at the Hot Sulphur Springs gage would be exceeded about 2.5 percent of the time, or 0.5 percent less than under Existing Conditions. The 2-year peak discharge at the gage near Kremmling would be exceeded 3 percent of the time (a 2 percent change from Existing Conditions). The slight reduction in the percentage of time that 2-year peak discharge would be reached at the two gage sites below the Windy Gap diversion is unlikely to significantly affect stream morphology or change sediment transport or deposition.

At Hot Sulphur Springs, under Existing Conditions, the lower limit of channel maintenance flows (80 percent of the 1.5-year peak flow) of at least 510 cfs occurred for 23 days on average (in years when such flows occurred), with a 62 percent chance of occurrence in any given year (Table I-19). Under Alternative 5, flows of at least 510 cfs occurred for 19 days on average (in years when such flows occurred), with a 47 percent chance of occurrence in any given year. The upper limit of channel maintenance flows is defined as the 25-year flow; such a flow (6,520 cfs) occurred once under Existing Conditions (in years when such flows occurred), but would not occur under Alternative 5. Ten-year flows or greater (4,600 cfs or more) occurred under Existing Conditions for 4 days on average and under Alternative 5 for 7.5 days on average (in years when such flows occurred), with a 13 percent chance of occurrence in any given year under Existing Conditions and a 4 percent chance of occurrence under Alternative 5. In general, the chance of channel maintenance flows occurring in a particular year would be about 1 percent less under Alternative 5 than Existing Conditions, but the duration of such flows in a year when channel maintenance flows occur could be slightly longer. The differences in channel maintenance flows between Existing Conditions and the Proposed Action alternative are minor and are not expected to alter channel morphology or sediment movement at Hot Sulphur Springs.

The magnitude, timing and frequency of channel maintenance flows in the Colorado River below Lake Granby would change as a result of changes in spills. When spills are not occurring, the flow of the river below Lake Granby is controlled by bypass flows; it is difficult, therefore, to define a range of channel maintenance flows based on peak flow events. A comparison of modeled spill events is provided in Table I-4. Under Alternative 5, there would be 7 less spill events compared to Existing Conditions, but flows of 500 cfs or more (within the range of channel maintenance flows at Hot Sulphur Springs) would continue to occur for periods of 1 to 4 months. Flows over 2,500 cfs would occur during 11 percent of all years, compared to 19 percent of all years under Existing Conditions. These differences are not expected to alter channel morphology or sediment movement in the Colorado River below Lake Granby. The range in streamflows under No Action would continue to provide flows sufficient to maintain channel capacity, provide periodic scouring, and transport sediment.

Willow Creek. The flow duration curve for Willow Creek provides a comparison between Existing Conditions and this alternative for the USGS gage located below Willow Creek Reservoir (Figure G-3). The 2-year peak discharge was estimated to be 80 cfs. Under Existing Conditions, this flow would be exceeded about 6 percent of the time. Under Alternative 5, the 2-year peak discharge would be exceeded slightly less than under Existing Conditions (a 1 percent change); therefore, it is unlikely that there would be measurable effects to stream morphology or changes in sediment transport or deposition.

8.7.3.2. East Slope Streams

Big Thompson River. The largest estimated flow increases to the Big Thompson River below Lake Estes would occur in May, but would be only a 7 cfs (4 percent) increase (Table I-8). By the mouth of the Big Thompson Canyon the maximum streamflow increase (3 percent) would occur in May of an average year (Table I-10). It is not expected that these flow increases would measurably alter stream morphology or sediment transport and deposition given that spring and summer high flows in the Big Thompson River exceed 500 cfs.

Streams that Receive Windy Gap Return Flows. The predicted streamflow increases for the East Slope stream segments that receive Windy Gap return flows (Big Dry Creek, Coal Creek, St. Vrain Creek, and the Big Thompson River) are unlikely to substantially alter stream morphology and sedimentation because the increased flows would be small compared to the spring and early summer flows that these channels have the capacity for. In addition, as described in Section 6.6, streams on the East Slope have not experienced natural streamflow conditions for more than 100 years, and are not in equilibrium with respect to channel forming and channel moving processes, erosion, or sediment loading, movement and deposition. Given the magnitude of the average monthly flow increases (less than 9 cfs), it would be difficult to measurably differentiate changes to stream morphology and sedimentation due to changes in Participants' WWTP return flows from the many other ongoing actions influencing East Slope streamflow conditions.

8.8. Windy Gap Firming Project Participant and Non-Participant Demands, Firm and Average Yields

A summary of annual Participant and non-Participant demands and yields for Existing Conditions, No Action, Proposed Action, and Alternative 5 are shown in Table 36 (which includes the Middle Park Water Conservancy District) and Table 37. The yield for the action alternatives would be similar because the storage volumes would be the same. The Proposed Action would have a slightly higher firm yield of 23,616 AF than Alternative 5 (23,583 AF). Alternatives 3 and 4 would have similar firm yields. The No Action alternative would have a firm yield of about 5,198 AF because of the additional storage at Ralph Price Reservoir and higher demand in the future. The firm yield under Existing Conditions is zero. Tables showing the monthly demand, firm yield, and average yield for WGFP Participants, non-Participants, and the Middle Park Conservancy District are provided in Appendix H.

Windy Gap demands under No Action are higher than under Existing Conditions and the Action alternatives because Participants would try to maximize their use of Windy Gap water when it is available as their demands increase in the future. Under the Action alternatives, the Participants' demands reflect the amount of Windy Gap water that could be delivered each year without any shortage. In other words, the Participants would operate the Windy Gap Project to provide firm yield with storage on line. While Windy Gap demands would be higher under No Action, average Windy Gap deliveries would be less than the action alternatives.

The demand for Windy Gap unit holders not in the Firming Project would increase in the future for all alternatives and as a result, the average yield to non-Participants would increase (Table 37). Windy Gap yield for non-Participants under the action alternatives would increase slightly compared to No Action because more storage for non-Participant water would be available in Lake Granby and non-Participant water in Lake Granby would not spill as soon, so the non-Participants would be able to deliver more water. The firm yield to non-Participants would remain zero under all alternatives.

Table 36. Cumulative Effects—Windy Gap Participant demand, average yield, and firm yield.

Condition/Alternative	Demand	Average Yield	Firm Yield
Existing Conditions	20,680	11,270	0
No Action (Alt 1)	33,645	18,149	579
Proposed Action (Alt 2)	23,616	23,616	23,616
Alternative 5 Dry Creek and Rockwell	23,583	23,583	23,583

Table 37. Cumulative Effects—Windy Gap Non-Participant demand, average yield, and firm yield.

Condition/Alternative	Demand	Average Yield	Firm Yield
Existing Conditions	220	140	0
No Action (Alt 1)	4,100	1,990	0
Proposed Action (Alt 2)	4,100	2,050	0
Alternative 5 Dry Creek and Rockwell	4,100	2,070	0

Storage of 3,000 AF was included in Alternatives 2 through 5 for firming Middle Park Water Conservancy District's (MPWCD) Windy Gap water. Under Existing Conditions, MPWCD can only store their Windy Gap water in Lake Granby; therefore, MPWCD's firm yield is zero. Under the No Action alternative, the firm yield for the MPWCD would remain zero, but average yield increases because of an increase in demand. Under the action alternatives, the firm annual yield would be 429 AF, which closely reflects the minimum amount of Windy Gap water pumped during the study period less the shrink payment (Table 38). The average yield for each of the action alternatives would be close to 3,000 AF.

Table 38. Cumulative Effects—MPWCD demands, average yield, and firm yield.

Condition/Alternative	Demand	Average Yield	Firm Yield
Existing Conditions	147	105	0
No Action (Alt 1)	3,000	1,922	0
Proposed Action (Alt 2)	3,000	2,759	429
Alternative 5 Dry Creek and Rockwell	3,000	2,757	429

9.0 REFERENCES

Apodaca, L. E. and J. B. Bails. 2000. Water Quality in Alluvial Aquifers of the Southern Rocky Mountains Physiographic Province, Upper Colorado River Basin, Colorado, 1997. U.S.G.S. Water Resources Investigation Report 99-4222.

Bauch, N. J. and J. B. Bails. 2004. Water Quality Characteristics and Ground Water Quantity of the Fraser River Watershed, Grand County, Colorado, 1998-2001. U.S. Geological Survey Water Resources Investigation Report 03-4275.

Boyle Engineering Corporation and Riverside Technologies, Inc. 2000. Colorado Decision Support System, Colorado River Basin Water Resources Planning Model, Final Report, Colorado Water Conservation Board, Colorado Division of Water Resources, July.

Boyle Engineering. 2003. Windy Gap Firming Project Draft Modeling Report. Prepared for Municipal Subdistrict, Northern Water Colorado Water Conservancy District.

Boyle Engineering. 2005. Disaggregation of WGFP Model Monthly to Daily Streamflow and Reservoir Output. Prepared for Northern Colorado Water Conservancy District. January 25.

Boyle Engineering and NCWCD (Northern Colorado Water Conservancy District). 2005. Draft Windy Gap EIS Alternatives Descriptions Report. May.

Boyle Engineering. 2006a. Addendum to the Windy Gap Firming Project Modeling Report. Prepared for Municipal Subdistrict, Northern Water Colorado Water Conservancy District.

Boyle Engineering. 2006b. No Action Alternative Return Flows to East Slope Streams. Prepared for NCWCD and ERO Resources Corporation. March 31.

Boyle Engineering. 2006c. WGFP Return Flow Impacts to East Slope Rivers. Prepared for NCWCD and ERO Resources Corporation. April 12.

Boyle Engineering. 2006d. Windy Gap Return Flow Impacts to East Slope Rivers—Cumulative Effects Analysis. July 17.

Braddock, W. A., P. Nutalaya, and R. B. Colton. 1988. Geologic Map of the Carter Lake Quadrangle, Boulder and Larimer Counties. U.S. Geological Survey.

Chronic, H. 1980. Roadside Geology of Colorado. Mountain Press Publishing Co., Missoula, MT.

Coley/Forrest. 2007 Significance of Flushing Flows. Prepared for Grand County. November 2007.

Colorado Division of Water Resources (CDWR). 2007. Surface and Ground Water Records, Office of the State Engineer.

Earthinfo, Inc. 2004. U.S. Geological Survey Ground Water Quality Data CD, West 1. Boulder, CO.

Earthinfo, Inc. 2005. U.S. Geological Survey Daily Values CD, West 1. Boulder, CO.

ERO Resources Corporation (ERO). 2005a. Windy Gap Firming Project Purpose and Need Report. Prepared for U.S. Bureau of Reclamation and Municipal Subdistrict, Northern Colorado Water Conservancy District.

ERO Resources Corporation (ERO). 2005b. Windy Gap Firming Project Alternatives Report. Prepared for U.S. Bureau of Reclamation and Municipal Subdistrict, Northern Colorado Water Conservancy District.

ERO Resources Corporation (ERO). 2006. Draft Vegetation Resources Technical Report. Prepared for U.S. Bureau of Reclamation and Municipal Subdistrict, Northern Colorado Water Conservancy District.

ERO Resources Corporation (ERO) and Hydrosphere Resource Consultants. 2007. Draft Surface Water Quality Technical Report. Prepared for U.S. Bureau of

Reclamation and Municipal Subdistrict, Northern Colorado Water Conservancy District.

Huson, K. 2006. City of Longmont 1999-2005 Button Rock Dam Release Records. Personal correspondence with ERO Resources Corporation.

Hydrosphere Resource Consultants. 2003. Upper Colorado River Basin Study, Phase II Final Report. Prepared for Grand County et al. May 29.

Hydrosphere Resource Consultants. 2007. Draft Lake and Reservoir Water Quality Technical Report. Prepared for U.S. Bureau of Reclamation and Municipal Subdistrict, Northern Colorado Water Conservancy District.

Izett, G. A. 1968. Geology of the Hot Sulphur Springs Quadrangle, Grand County, Colorado. U.S. Geological Survey Professional Paper 586.

Izett, G. A. 1974. Geologic Map of the Trail Mountain Quadrangle, Grand County, Colorado. U.S. Geological Survey Map GQ-1156.

Izett, G. A. and C. S. V. Barclay. 1973. Geologic Map of the Kremmling Quadrangle, Grand County, Colorado. U.S. Geological Survey Map GQ-1115.

Leopold, Luna B., M. Gordon Wolman and John P. Miller. 1995. Fluvial Processes in Geomorphology. Dover Publications, Inc.

Miller, W. 2007. Personal communication with Barbara Galloway at ERO Resources Corporation regarding Colorado River cross-sectional analysis near Parshall, CO.

National Oceanic and Atmospheric Administration and National Weather Service (NOAA). 2006. Advanced Hydrologic Prediction Service: Denver/Boulder: Colorado River near Kremmling. Flood stage forecast and historical river crests.

Reclamation (U.S. Bureau of Reclamation). 2006. Lake Granby Historical Spill Records and Lake Granby Surface Elevations. Personal communication with Northern Colorado Water Conservancy District and ERO Resources Corporation.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Schmidt, L. J. and J. P. Potyondy. 2004. Quantifying Channel Maintenance Instream Flows: An Approach for Gravel-Bed Streams in the Western United States. USDA, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-128. May.

Schroeder, D. A. 1995. Geologic Map of the Granby Quadrangle, Grand County, Colorado. U.S. Geological Survey.

Secretarial Decision Document, Principles to govern the Release of Water at Granby Dam to provide Fishery Flows immediately Downstream in the Colorado River, signed January 19, 1961 by Fred A. Seaton, Secretary of the Interior; D.H. Jansen, Director, Bureau of Sport Fisheries and Wildlife; F.E. Dominy, Commissioner, Bureau of Reclamation; R.L. Leffler, Assistant Secretary of the Interior for Fish and Wildlife; and F.G. Aandahl, Assistant Secretary of the Interior for Water and Power.

Simpson, H. D. 2007. Personal communication between Hal Simpson the State Engineer and Fred Ore, the Area Manager for Bureau of Reclamation Eastern Area Office. January 17.

Topper, R., K. L. Spray, W. H. Bellis, J. L. Hamilton, and P. E. Barkmann. 2003. Ground Water Atlas of Colorado; Special Publication 53. Colorado Geological Survey.

Tweto, O. 1979. Geologic Map of Colorado. U.S. Geological Survey.

USDI (U.S. Department of Interior). 1981. Colorado-Big Thompson Windy Gap Projects Colorado Final Environmental Impact Statement. Water and Power Resources Service.

Ward, T. J. 1981. Analysis of Aggradation and Degradation below Proposed Windy Gap Reservoir, Colorado. Research Institute of Colorado, Fort Collins, CO. Submitted to Northern Colorado Water Conservancy District, September.

Ward, T. J. and J. Eckhardt. 1981. Analysis of Potential Sediment Transport Impacts below the Windy Gap Reservoir, Colorado River. Aquatic Resources Management of the Colorado River Ecosystem, Edited by V. Dean Adams and Vincent A. Lamarra. Ann Arbor Science.

Wohl, E., R. Mc Connell, J. Skinner, and R. Stenzel. 1998. Inheriting Our Past: River Sediment Sources and Sediment Hazards in Colorado. Department of Earth Sciences, Colorado State University. Colorado Water Resources Research Institute.

10.0 GLOSSARY

acre-foot: A volume of water equal to one foot in depth covering an area of one acre. Also 43,560 cubic feet, or 325,851 gallons. Used to measure stored water quantities.

aggradation: The raising of stream beds or floodplains by deposition of sediment eroded and transported from upstream.

alluvial ground water: Ground water that is hydrologically part of a surface stream that is present in permeable soil material, usually small rock and gravel.

alluvium: Sediment deposited by streams.

appropriation: The right to take water from a stream, tributary, or aquifer for beneficial use at a specified rate of flow, either for immediate use or to store for later use. Usually evidenced by a water court decree. Must be adjudicated to establish seniority of right.

aquifer: An underground deposit of sand, gravel, or rock through which water can pass or is stored. Aquifers supply the water for wells and springs. In an unconfined aquifer, the upper surface of the saturated aquifer is a changing water table under atmospheric pressure. In a confined (artisan) aquifer the water is maintained under pressure by nonporous rocks surrounding it.

augmentation plan: A court-approved plan that allows a water user to divert water out of priority so long as adequate replacement is made to the affected stream system preventing injury to the water rights of senior users.

augmentation: Replacing the quantity of water depleted from the stream system caused by an out-of-priority diversion.

bedrock: Continuous solid rock that outcrops at the surface locally, but generally is overlain by unconsolidated material (such as alluvium).

call: The exercise of a senior water right holder of "calling" for his or her water rights, requiring upstream junior water right holders to allow water to flow to the senior right holder.

conservancy district: Established by decree of a court under the Water Conservancy District Act of 1937. A conservancy district can obtain rights-of-way for works; contract with the United States or otherwise provide for the construction of facilities; assume contractual or bonded indebtedness; administer, operate, and maintain physical works; have authority to conserve, control, allocate, and distribute water supplies; and have contracting and limited taxing authority to derive the revenues necessary to accomplish its purposes. There are currently 46 conservancy districts in Colorado.

conservation: Obtaining the benefits of water more efficiently.

consumptive use: Any use of water that permanently removes water from the natural stream system.

Continental Divide: An imaginary boundary line that runs north-south along the crest of the Rocky Mountains, separating river and drainages that flow into the Atlantic Ocean or Gulf of Mexico from those that flow into the Pacific Ocean.

cubic feet per second (cfs): A rate of water flow at a given point, amounting to a volume of one cubic foot for each second of time. Equal to 7.48 gallons per second, 448.8 gallons per minute, or 1.984 acre-feet per day.

decree: A court decision about a water right that is then administered by Colorado's Water Resources Department.

degradation: Any lowering of a streambed, such as from scouring of sediments.

demand management: Reduced water use, accomplished either through temporary measures such as restrictions during a drought, or through long-term conservation programs. These programs include replacement of inefficient fixtures with more efficient fixtures such as 1.6 gallon toilets, installation and maintenance of landscapes that have low water requirements, or changes in customer attitudes that lead to reduction in water use.

direct flow (also direct right): Water diverted from a river or stream for use without interruption between diversion and use except for incidental purposes, such as settling or filtration.

diversion: The removal of water from its natural course or location, or controlling water in its natural course or location by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump or other device.

domestic use water: Water used by people for personal needs, home, and business. (From an individual well.) Also may refer to water use in restrooms in commercial and business buildings.

drought: A long period of below average precipitation.

effluent: Water discharged after use, as in water leaving a wastewater treatment plant; an outflowing branch of a stream or lake.

effluent exchange: The practice of using wastewater effluent from transbasin water, non-tributary water sources, or other sources without causing injury to other water rights as a replacement source of water for diversion of water farther upstream that would otherwise have been out of priority.

ephemeral stream: An intermittent stream that flows only in direct and immediate response to precipitation, and has no prolonged flow from ground water sources.

evapotranspiration (ET): The total moisture loss from an area controlled by climatic conditions and plant processes.

exchange: A process by which water, under certain conditions, may be diverted out of priority at one point by replacing it with a like amount of water at another point.

firm annual yield: The yearly amount of water that can be dependably supplied from the raw water sources of a given water supply system.

floodplain: That portion of a stream valley, adjacent to its channel, that is built of sediments deposited by the stream and is covered with water when the stream overflows its banks during floods.

gallons per capita per day (gpcd): A term generally used to approximate the average amount of drinking or treated water used per day, per person, in a year's time.

ground water: Water found below the earth's surface. For different types of groundwater and the laws that pertain to them see

historic use: The documented diversion and consumptive use of water over a period of years.

hydraulic conductivity: The rate of flow of water through a cross-section of an aquifer under a unit hydraulic gradient (units are gpd/ft^2, ft/sec or m/sec).

hydrogeology: The study of the geology, movement and chemistry of subsurface water (ground water).

instream flows: Water flowing in its natural stream bed, such as water required for maintaining flowing streams, or for fish.

instream use: Any use of water that does not require a diversion.

intermittent stream: A stream that carries water only part of the time, generally in response to periods of heavy runoff from snowmelt or precipitation events.

perennial stream: A stream that flows from source to mouth throughout the year.

junior water right: Water rights that are more recent than older or more senior rights.

nonpoint source: Pollution discharged over a wide land area, not from one specific location. Runoff from city streets, parking lots, home lawns, agricultural land, individual septic systems and construction sites that finds its way into lakes and streams constitutes an important source of water pollutants.

Period of record: The historical period for which streamflow records exist.

point of diversion: A specifically named place where water is removed from a body of water.

potable: Water that is considered safe for domestic consumption; drinkable.

prepositioning: Under the Proposed Action, prepositioning involves the storage of Colorado-Big Thompson Project water in Chimney Hollow Reservoir. Windy Gap water pumped into Lake Granby would then be exchanged for C-BT water stored in Chimney Hollow. Windy Gap water stored in Chimney Hollow would be delivered and allocated to the WGFP Participants.

prior appropriation doctrine: A legal concept in which the first person to appropriate water and apply it to a beneficial use has the first right to use that amount of water from that source. Each successive appropriator may only take a share of the water remaining after all senior water rights are satisfied. This is the historical basis for Colorado water law and is sometimes known as the Colorado Doctrine or the principle of "first in time, first in right."

priority: The right of an earlier appropriator to divert from a natural stream in preference to a later appropriator.

priority date: The date of establishment of a water right. The rights established by application have the application date as the date of priority.

raw water: Untreated water.

recharge: The addition of water to groundwater.

reservoir: An impoundment of collected water controlled by a dam (raw water) or storage tank (potable water).

return flows: Unconsumed water that returns to its source –surface or groundwater – after use.

reuse: To use water again; to intercept for subsequent beneficial use either directly or by exchange water that would otherwise return to the stream system.

riparian: Relating to the bank of a natural watercourse (as a river) or sometimes of a lake or a tidewater.

river basin: The land area surrounding one river from its headwaters to its mouth.

runoff: Water that flows on the earth's surface to streams, rivers, lakes and oceans.

sedimentation: The act or process of depositing sediment from water.

senior water right: Water rights that are staked the earliest with the water court.

spill: Water release from a reservoir for operational reasons or because it is full.

stream morphology: The study of the form and structure of a stream, including its channel, banks, floodplain and drainage area.

supply management: Methods by which a utility maximizes use of available raw water.

surface water: Water present on the earth's surface.

sustainability: A decision-making concept describing development that meets current needs without compromising the ability of future generations to meet their needs.

system loss: An amount of water, expressed as a percentage, lost from a water storage or distribution system due to leaks, evaporation, seepage and unauthorized use.

transbasin diversion: The conveyance of water from its natural drainage basin into another basin for beneficial use.

transpiration: The process by which plants remove soil moisture by losing water vapor through their leaves.

tributary: A stream or river that flows into a larger one.

turbidity: A cloudy condition in water due to suspended silt or organic matter.

water and sanitation districts: A special taxing district formed by the residents of the district for the combined purpose of providing potable water and sanitary wastewater services.

water court: A special division of the district court with a district judge (called the water judge) that deals with water matters.

water right: A property right to make beneficial use of a particular amount of water with a specified priority date.

watershed: The area of land that catches rain and snow that drains or seeps into a marsh, stream, river, lake or ground water. The highest ground, such as mountains or ridges, forms boundaries between watersheds.

Terms taken from the Colorado Waterwise Council, Dictionary of Water Words (Great Basin Research, Natural Resources Information Group 2002) and The Dictionary of Geological Terms (Bates and Jackson 1984).