UPPER COLORADO RIVER BASIN STUDY
Phase II

FINAL REPORT

May 29, 2003

Prepared for

Grand County
Summit County
Colorado River Water Conservation District
Denver Water
Colorado Springs Utilities
Middle Park Water Conservancy District
Northern Colorado Water Conservancy District
NWCCOG's Water Quality/Quantity Committee

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PHASE II UPPER COLORADO RIVER STUDY
EXECUTIVE SUMMARY

I. Introduction

The Upper Colorado River Basin Study (UPCO) was initiated in 1998 to identify and investigate water quantity and quality issues in the Study Area consisting of Grand and Summit Counties[1]. The primary goal of Phase II of UPCO was to develop the information and analytical tools necessary to understand existing hydrology and water quality conditions in the study area and how increased water diversions may impact those conditions. This information was meant to support discussions and negotiations between the stakeholders as they seek solutions to current and future water supply, reservoir level, instream flow, and water quality issues. Participants in the study were Grand and Summit Counties, Colorado River Water Conservation District (River District), Middle Park Water Conservancy District (Middle Park), Northwest Colorado Council of Government's Water Quality and Quantity Committee (QQ), Northern Colorado Water Conservancy District (Northern), Denver Water (Denver) and Colorado Springs.

The principal components of the Phase II study were: 1) compilation and analysis of water resources and water supply data for Summit and Grand Counties; 2) expansion of Denver's hydrologic and water rights model (Platte and Colorado Simulation Model, PACSM) to represent individual West Slope water supply systems; 3) development of a data management and display tool to support the analysis of impacts associated with existing and future water supply and demand scenarios; and, 4) identification of issues to be addressed in Phase III, the solutions phase, of the study.

The study analyzed existing and future conditions based on the 1947-1991 hydrologic record. That is, the model used natural or "undepleted" stream flows for those years and accounted for the operation of water rights and demands to predict quantity and timing of water supplies, the depleted stream flows, and reservoir levels under various assumptions for the demands. The 1947-1991 period includes wet, dry and average years but does not include any years that are comparable to drought conditions as severe as what occurred during 2002 when streamflows in certain areas were the lowest ever recorded. Impacts created by the 2002 drought are discussed in more detail on page viii of this Executive Summary.

The UPCO evaluations indicate a need for additional water supplies in Grand and Summit Counties for existing and future municipal demands as well as instream flows to support the area's recreational uses and maintain low-flow levels used to determine waste load allocations for wastewater treatment plants. The key to developing solutions and

[1] Phase I of UPCO was the development of the Scope of Work for Phase II. Phase III, to be initiated in mid-2003, involves a collaborative effort by the participating parties to seek solutions to the issues identified in the Phase II study report.

addressing impacts is cooperation among the UPCO partners as future water projects are planned.

II. Water Needs

Upper Colorado River In-Basin Water Needs

Water demands in Grand and Summit Counties will grow as the area continues to be a destination resort and important recreation and tourism center for Colorado. Likewise, Denver Water and the Northern Water Colorado Conservancy District are also planning to further develop their existing water supplies, which are diverted from the study area for use on the Front Range, as their populations continue to grow. The UPCO study quantified current and future water demands. The following provides an overview:

Water Provider (1)	Current Demands(acre-feet per year) (2)	Future Demands (acre-feet per year) (3)	Comments (4)
Grand County	3,100	14,200	Approximately 70% of future demands are in the Fraser River Basin.
Summit County	8,000	17,900	Approximately 25% of future demands are in the Upper Blue River area above Dillon. The remaining future demands are primarily in the Silverthorne, Eagles Nest, and Mesa Cortina areas.
Denver Water	285,000	386,000	Please see below for more detail.
Northern	247,800	Up to 271,700	Additional diversions by the Windy Gap project.

Notes:

1) For Summit and Grand Counties, the amounts shown in this table include all of the major water providers but do not include dispersed domestic usage in unincorporated areas not served by major providers.

2) Current demands are based upon the year 2000. Approximately one-half of Denver's current water supply is derived from East Slope sources in the South Platte River Basin.

3) Future demands for Grand and Summit Counties are based upon estimated buildout conditions. Denver's future demand is for their near-term (future baseline) planning horizon (2030) and their estimated buildout demand is 450,000 acre-feet per year.

4) Water Demands for Colorado Springs are not included because no increases in water diversions from the Study Area are planned.

In-basin Instream and Recreational Water Needs

The UPCO study also compiled information regarding instream flow water rights, water levels necessary for water-based-recreational activities, and wastewater treatment plant discharges. This information was used to evaluate the impact on stream flow and lake

levels, and goes beyond just the municipal and domestic water demands of the study area. The study incorporated the following types of information for purposes of evaluation of impacts:

- Colorado Water Conservation Board (CWCB) instream-flow water rights
- Minimum and optimum fish flows
- Low, high and optimum kayaking flows
- Low, high and optimum rafting flows
- Reservoir levels necessary for boat ramps and marinas
- Wastewater treatment plant 1-day and 30-day, 3-year low flows

The CWCB instream-flow rights are of interest because they limit junior water diversions and represent the minimum flows necessary to protect the environment to a reasonable degree subject to water availability. The modeling explicitly accounted for these instream-flow water rights.

The fish, kayaking, and rafting flows and reservoir levels are guidelines that the study established based on information from CDOW and local, established guides and businesses. The flows and reservoir levels represent what the recreation and in-basin communities believe is important to sustain a quality recreational experience.

The wastewater treatment plant information provides an indication of potential water quality impacts in streams below wastewater treatment plants. Wastewater treatment facilities' discharge permits depend on certain minimum stream flows for determining the quality and quantity of the wastewater that can be discharged to the stream. If stream flows drop too low, then wastewater treatment plants may be required to provide additional treatment, forcing expensive treatment plant modifications.

Denver Water Needs

Under the PACSM scenarios evaluated in Phase II, at full use of the existing system the average annual Roberts Tunnel diversions will increase by about 64% from 70,500 acre-feet of existing demand to 115,400 acre-feet. This increase will occur as demand in the Denver Water service area grows without building new facilities. In addition to the 64%, if the next project on line were a North System supply with a firm yield of 15,000 acre-feet, diversions from Summit County would increase by 3% to 118,600 acre-feet. If the next project on line were a South System supply, the diversions from Summit County would increase by an additional 7% to 123,400 acre-feet.

Similarly, at full use of the existing system the average Moffat Tunnel diversions will increase by about 6% from 63,600 acre-feet of existing demand to 67,400 acre-feet. Again, this increase will occur as demand increases without building any new facilities. If the next project on line is a North System supply with a firm yield of 15,000 acre-feet, diversions would increase from Grand County by 9% to 73,600 acre-feet, while a South System supply would increase diversions by 8% to 72,600 acre-feet.

Northern Colorado Water Conservancy District Water Needs

The Colorado-Big Thompson/Windy Gap system is designed to collect up to an average of 310,000 acre-feet of water from the Upper Colorado River for conveyance through the Alva B. Adams Tunnel to the East Slope for supplemental irrigation and municipal water supply purposes. Under existing demands CB-T and Windy Gap diversions from the West Slope average about 247,800 acre-feet per year. Under future demands, average annual diversions are expected to increase by about 10% up to 271,700 acre-feet.

III. Study Results

Phase II of the UPCO study represents the most comprehensive water planning and hydrologic evaluation to-date for the headwaters of the Colorado River. The primary results of this phase of the UPCO study are detailed quantifications of water supplies, stream flows, and reservoir levels for various locations in Grand and Summit Counties. The results of the modeling are voluminous, containing daily data for 45 years at nearly 40 locations for several separate model "runs."

The data display tool provides a means to compare various water supply and planning options. Four water supply and demand "scenarios" were modeled:

1. Existing Demand with Existing Supply
2. Full Use Demand of Existing Supply
3. Full Use with 15,000 acre-feet of New North System Supply including full use of Windy Gap
4. Full Use with 15,000 acre-feet of New South System Supply including full use of Windy Gap

The evaluation entailed reviewing the model output for locations of interest and comparing the current conditions with future conditions to discern where and when water shortages are likely to occur. The table below summarizes the estimated water supply shortages for water providers in Grand and Summit Counties.

Study Area Water Demands and Shortages

	Average Annual Water Demand (AF)		Average Annual Shortages Under Modeled Scenarios (AF)				
Water Provider	Existing (yr. 2000)	Future Buildout	Existing Demand with Existing Supply	Full Use Demand of Existing Supply	Full Use with New N. System Supply	Full Use with New S. System Supply	Maximum Annual Shortage (AF)
GRAND COUNTY							
Columbine Lake WD	157	303	0	0	0	0	0
Town of Grand Lake	199	1,262	0	0	0	0	7
Hot Sulphur Springs[1]	116	1,667	0	41	41	41	44
Town of Kremmling[2]	441	888	0	18	18	18	18
Winter Park Rec. and W&S District (Indoor)	151	500	2	52	55	50	204
Winter Park Rec. (Snowmaking)	199	477	0	10	8	8	70[3]
Grand County W&SD	687	3,711	1	977	996	973	1,903
Winter Park West W&SD	454	618	0	2	2	2	23
Town of Fraser[3]	309	1,326	0	8	8	8	27
Silver Creek Resort[4]	189	2,950	0	19	19	19	68
Town of Granby	230	465	0	0	0	0	5
Grand County Totals	**3,132**	**14,167**	**3**	**1,127**	**1,147**	**1,119**	**2,369**
SUMMIT COUNTY							
Arapahoe Basin Snowmaking[5]	0	351	0	133	133	133	330
Keystone-Montezuma Domestic	0	30	0	2	2	2	11
Keystone Snake River Snowmaking[6]	485	1,157	27	207	207	207	668[7]
Keystone Gulch	0	78	0	11	11	11	2
Keystone Golf Course[7]	170	170	0	0	0	0	2
Keystone Ranch[8]	268	274	0	0	0	0	6
Snake River WD	555	1,903	1	35	35	35	239
East Dillon WD	290	623	1	11	11	11	106
Town of Breckenridge	2,062	3,355	0	0	0	0	0
Breckenridge Golf Course	176	365	7	12	12	6	88
Breckenridge Ski Resort	546	685	0	4	4	4	24
Copper Mountain W&SD	381	876	46	101	100	96	282
Copper Mountain Inc (outdoor and snowmaking)	500	689	6	13	12	12	99
Town of Frisco[9]	846	1,976	0	0	0	0	0
Dillon Valley Metro District	333	406	0	0	0	0	7
Town of Dillon	327	878	0	0	0	0	0
Buffalo Mountain / Mesa Cortina	296	755	0	0	0	0	0
Town of Silverthorne	465	2,298	0	0	0	0	0
Eagle's Nest	327	1,002	0	0	0	0	3
Summit Totals	**8,027**	**17,871**	**88**	**529**	**527**	**517**	**1,900**
Totals of Both Counties	**11,159**	**32,038**	**91**	**1,656**	**1,674**	**1,636**	**4,269**

1) Hot Sulphur will experience July shortages when 4 cfs demand exceeds 3.3 cfs right.
2) Shortages exist in some months when demand exceeds 1 cfs right. Based on Colorado River supplies.
3) December shortages.
4) December shortages.
5) Demands include domestic and snowmaking. Future snowmaking demand is 350 af/year.
6) This shortage can be eliminated by operation of the existing Montezuma shaft pumps
7) PASCM develops historical flows ending in 1991 - golf course irrigation began 1999.
8) Demands for domestic, commercial, golf course and greenbelt.
9) Shortage when the junior right using Dillon exchange cannot operate because Dillon has reached its minimum content in dry years.

As shown on the table, most water providers have sufficient water supplies to cover the current levels of demand (see page viii of this Executive Summary for discussion of 2002 drought impacts). However, under future conditions, nearly two-thirds of the providers are expected to have demands that exceed their current water rights and/or water availability. The largest shortages are predicted for the Fraser River upstream of Tabernash, the Blue River upstream of Dillon Reservoir, Snake River upstream of Dillon Reservoir and Tenmile Creek upstream of Dillon Reservoir.

Even though the hydrologic model calculates volumes down to the acre-foot and flow rates to a fraction of a cubic foot per second, the numbers provided on the table above, and in the full report, should be considered as guidelines and not the exact value of the shortage or supply. It is most useful to consider the reported values as relatively "large" or "small" and use comparisons and common sense to get a feel for the size and likelihood of future supplies and shortages.

IV. PACSM Analysis Results

Grand County

The analysis of PACSM results was divided into sub-basins.

Fraser River Basin above and below the Town of Fraser: Under the PACSM model, municipal and domestic water supplies were adequate for existing levels of water demand, but most water providers would experience shortages under future demand scenarios. Shortages would be most severe for the Grand County Water & Sanitation District, ranging from an annual minimum of 616 acre-feet to a maximum of 1,903 acre-feet and averaging 996 acre-feet. These shortages would occur primarily in the fall and winter months as a result of lack of physical supply and Denver's upstream diversions and would coincide with periods when streamflow would be below the CWCB instream flows, fish minimum flows and wastewater treatment plant low-flows.

Water quality impacts related to Berthoud Pass, though not specifically examined in this study, emerged as issues. This includes water quality impacts related to winter sanding operations on Berthoud Pass and the potential for an accident of a truck carrying hazardous materials on Berthoud Pass. The latter could significantly affect water supply in the upper part of the Fraser River, as most providers divert directly from the Fraser with no alternative sources of supply.

Colorado River Basin above the Fraser River confluence: Municipal and domestic water supplies were adequate under both existing and future demands. Though Northern is required to bypass flows below Lake Granby to maintain minimum instream flow requirements, instream flows below Lake Granby will be below CWCB, fish minimum and fish optimum levels. However, due to data inadequacies, it is not clear exactly how often this would occur. The only time flows will be below CWCB levels is when inflows are less than the minimum flow. Lake levels in Lake Granby were not fully evaluated in the study but should be before entering the solutions phase as lake levels relate to marina operations.

Colorado River below the Fraser River confluence: The water supply systems for the Towns of Hot Sulphur Springs and Kremmling were adequate for existing demands but would experience shortages under all of the future demand scenarios. In addition, instream flows below Windy Gap were below CWCB, fish minimum, and kayak minimum levels under all scenarios. Low flows in the Colorado River below Windy Gap in the late summer and early fall often result in high water temperatures that adversely impact the trout fishery.

Summit County

The PACSM results were divided into the following sub-basins:

Blue River above Dillon Reservoir: Municipal and domestic water supplies were adequate for existing and future water demand scenarios, but the Breckenridge Golf Course would experience shortages under all demand scenarios in most years during the spring and fall months. The potential for a collaborative arrangement involving in-basin water providers, Summit County and the City of Colorado Springs to develop additional storage in the Upper Blue River Basin emerges as a potential solution for further evaluation in Phase III.

Tenmile Creek above Dillon Reservoir: Copper Mountain Water & Sanitation District and the Copper Mountain Golf Course will experience frequent small water supply shortages under existing demands and occasional large shortages under future demands. Instream flows in Tenmile Creek below West Tenmile Creek were frequently below CWCB levels and occasionally below wastewater treatment plant low-flow levels under all demand scenarios.

Snake River above Dillon Reservoir: A-Basin and Keystone snowmaking, Keystone-domestic uses below Peru Creek, Keystone Gulch and the East Dillon Water District will experience water supply shortages under future demands. The water supply shortages in the Snake River Basin are due primarily to lack of adequate physical supply during the fall and winter months. At times, Keystone snowmaking shortages can be eliminated by pumping water from Denver's Montezuma shaft into the Snake River. Due to Robert's Tunnel maintenance and operational constraints, this water is not always available. An additional issue relating to reduced streamflows concerns levels of zinc, cadmium and copper in excess of aquatic life water quality standards and levels of manganese in excess of the domestic water supply standards due to acid mine drainage from the Peru Creek drainage.

Dillon Reservoir and the Blue River below Dillon: Under future demand conditions, PACSM results indicate significant increases in the frequency and duration of periods when Dillon reservoir would be below levels needed for normal operation of the Dillon and Frisco marinas. Streamflows in the Blue River below Dillon Reservoir under future demands would be at or above the 50 cfs CWCB instream flow that was determined using PHABSIM analysis, but frequently below the 55 cfs seasonal flow (10/1 – 4/30) identified by CDOW using the R-2 Cross Method. Streamflows in the Blue River below Dillon Reservoir under future demands would also frequently be below the rafting low-flow levels and kayak low-flow levels. Reservoir levels during the summer recreation

season and flows in the Blue River below Dillon are influenced primarily by water demands on the Denver System.

Green Mountain Reservoir and the Blue River Below Green Mountain: PACSM results indicated that flows in the Blue River below Green Mountain are usually above the CWCB and fish minimum levels under all scenarios. However, kayaking flows were below the minimum and optimum levels under current demands in all months except June and July and under future demands in all months except July.

V. Impacts of 2002-2003 Drought

As previously discussed, the 1947-1991 study period for the UPCO model includes a number of wet, average and dry years. The study period includes the 1954-56 and 1977 droughts, which have historically been used by water planners for estimating the "firm" yield of their water supplies. The participants of the study realize that the current 2002-2003 drought may present conditions even more severe than the past droughts. The participants also recognize that a number of conditions have occurred to-date during the 2002-2003 drought that may present unique new challenges which need to be considered in the future. These specific conditions include the following:

- Streamflows in certain areas of the Colorado River Basin and its tributaries were lower than in previous droughts.
- Problems occurred with Green Mountain Reservoir including exhausting the historic users pool (HUP) and the impact of the Heeney slide, which prevented full use of the reservoir's available storage.
- Denver Water reduced its by-pass flows past their Moffat Collection System, significantly reducing streamflows in the Fraser River Basin.
- Due to agreements between water users and Excel Energy, there were changes in the administration of the Shoshone Call.
- Clinton Reservoir may fail to fill for a fourth consecutive year, causing shortages in the planned 3-year supply for certain shareholders.
- Denver Water has nearly exhausted its Williams Fork Reservoir supply and resorted to use of Dillon Reservoir to augment its Fraser River diversions.

The degree to which these problems affect the published yields and shortages in the UPCO study are not certain. However, the participants agree that these issues should be considered during the next phase (Phase III) of the study and evaluated for potential impacts on the future shortages and water requirements of the water users in the basin.

VI. Next Steps

Phase II of the UPCO Study has identified a number of issues and problems that warrant further study. The objectives for the next phase need to be identified and the role and organization of UPCO needs to be defined. This may involve formation of one of more subgroups to address specific issues and problems. Tasks that could be addressed in Phase III of UPCO include the following activities:

- Providing a forum to develop possible solutions to some of the problems identified in the study.
- Providing information to in-basin water users and communities in their own planning efforts.
- Providing a forum to coordinate the review of water supply projects proposed by Denver and Northern.

Both Denver and Northern are in different stages of considering projects in the Study Area or that would affect the Study Area. Denver is currently involved in two projects. The South Metro Study is evaluating conjunctive use options in the South Metro area using Blue River water. This study will look to UPCO to assist in resolving issues and impacts as the study participants evaluate alternatives. Denver will initiate a National Environmental Policy Act (NEPA) review of a project for its North System. Denver has identified the need for the project but not a preferred alternative. Denver is working through the UPCO process with Grand County to include and address some of the impacts identified in UPCO. Denver's permitting agency will most likely be the Corps of Engineers. Northern is studying alternatives for a Windy Gap firming project. Northern will most likely initiate the NEPA process in the summer of 2003. The permitting agency will be the U.S. Bureau of Reclamation. Northern will continue to work through UPCO to get public input from Grand County during the NEPA process.

Some of the issues identified in UPCO are being addressed through the ongoing efforts of groups other than the UPCO Management Committee. Examples of these efforts include the Three Lakes Water Quality Study, the Snake River Task Force, two Blue River restoration projects – above and below Dillon Reservoir, and the French Gulch Remediation Opportunities Group. UPCO will work with and through existing groups where such efforts already exist.

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1. INTRODUCTION AND BACKGROUND

The Upper Colorado River Basin Study (UPCO) was initiated in early 1998 to identify and investigate water quantity and quality issues related to expected increases in Front Range and Colorado River headwater demands associated with continuing growth and economic development. The purpose of the study was to develop the information base and analytical tools needed to identify potential headwater water supply problems as well as impacts to water quality, instream recreation and the environment and to investigate potential solutions in the Study Area. The study process also provides a forum for discussions between interested stakeholders.

The UPCO Study Area includes the Colorado River Basin above the Kremmling gage within Grand and Summit Counties. The primary sponsoring parties and management committee members are Grand County, Summit County, the Colorado River Water Conservation District (River District), the Middle Park Water Conservancy District (Middle Park), Denver Water, the Northern Colorado Water Conservancy District (Northern), the Northwest Colorado Council of Government's Water Quality/Quantity (QQ) Committee, and Colorado Springs Utilities. The ski areas in the Study Area, Climax Mines, Colorado Department of Local Affairs and the Colorado Water Conservation Board (CWCB) also contributed financially.

The issues addressed in this study are directly related to competing needs for the limited water resources originating in the Upper Colorado River Basin. These issues include:

- Existing and future municipal and industrial water demands within the Upper Colorado River Basin and parts of the Front Range.

- Instream flow needs for fisheries and recreation and reservoir levels necessary to support recreation and tourism within the Upper Colorado River Basin.

- Water quality within the Upper Colorado River Basin including wastewater treatment plant needs, abandoned mine sites (as reflected by existing data), and nonpoint source pollution.

The UPCO analysis of impacts is based upon the 1947-1991 hydrologic record represented in Denver Water's Platte and Colorado Simulation Model (PACSM). This period includes representative wet, dry and average years but does not include any years that are comparable to drought conditions as severe as what occurred during 2002, when streamflows were the lowest ever recorded. Most water providers have used historic droughts, such as those that occurred in 1954-1956 or 1977, as the standard against which to design their systems, and have employed demand restrictions and measures to supplement their supplies during more severe droughts. The analysis results presented in this report and summarized below represent the range of dry, average and wet conditions that, based on historical observations, are expected to normally prevail. However, this study was not designed or intended to address unusually severe or sustained drought conditions. In many cases the water shortage issues identified in this report were much

more severe during the drought of 2002 and additional shortages occurred that were not apparent in the PACSM results. The goal of UPCO is to develop solutions to problems identified in the study. Additional study will be needed in Phase III to identify issues associated with the 2002 drought and possible remedies.

2. STUDY SCOPE AND METHODOLOGY

The UPCO study is being implemented in three sequential phases. Phase I, completed in October of 1998, involved the preparation of a detailed scope of work for the development of information and analytical tools and the preliminary analysis of water quantity and quality issues. Phase II consisted of the implementation of the Scope of Work developed in Phase I, the results of which are included in this report. Phase III, to be initiated in mid-2003, involves a collaborative effort among the parties to seek solutions to the issues identified in Phase II. The information and analytical tools developed in Phase II of the study will be used to support the Phase III efforts and to provide technical information as needed to evaluate proposed solutions.

2.1 Geographic Orientation

The primary UPCO Study Area encompasses the Upper Colorado River Basin, including the Blue and Fraser Rivers in Grand and Summit Counties, above the USGS gaging station located about 3 miles below the Town of Kremmling on the Colorado River (Study Area). The study examines existing and future water diversions by Northern, Denver Water, and Colorado Springs from the Study Area to the East Slope. The map in Figure 2.1 shows the Study Area and study data reporting locations. Approximately, 42% of native flows are currently diverted to the Front Range in Grand County and approximately 22% of native flows diverted from Summit County. Both Counties expect additional diversions and the participants believe that UPCO will help the project proponents choose the best alternative based on the UPCO study.

Specific locations of interest were identified for which hydrologic and water quality information is needed to compare and evaluate potential impacts associated with increases in water diversions. These locations reflect major points of diversion, storage, return flow, stream confluences, significant instream flow reaches, whitewater rafting reaches and stream segments with water quality implications. The study process identified the following locations of interest:

- Blue River North of Breckenridge, just below French Gulch to evaluate water quality from the Breckenridge area and the French Gulch mining district;
- Hoosier Tunnel diversions;
- Blue River Near Dillon, above Dillon Reservoir for hydrologic conditions and impacts to fisheries;
- Snake River near Montezuma, which is the USGS gage nearest the mouth of the Snake River to provide hydrologic conditions and may be used for water quality evaluations and impacts to fisheries;
- Tenmile Creek below West Tenmile confluence for basic hydrologic conditions and impacts to fisheries;
- Dillon Reservoir lake levels and operation including releases to the Blue River and Robert's Tunnel;

- Straight Creek for water quality and hydrology;
- Blue River below Rock Creek confluence to evaluate fisheries and whitewater rafting;
- Green Mountain Reservoir levels and operation including releases to the Blue River;
- Blue River at the confluence with the Colorado for hydrologic conditions;
- Fraser River at Upper Station for background water quality and general hydrologic conditions (not a PACSM node);
- Moffat Tunnel diversions;
- Fraser River near Winter Park for water quality in the Winter Park area and flows below the Moffat diversion tunnel;
- Fraser River below Vasquez Creek for water quality effects from upstream point source discharges;
- Fraser River below St. Louis Creek confluence for hydrologic conditions and water quality below the Town of Fraser;
- Fraser River at Colorado River confluence for hydrologic conditions and water quality effects from the Granby area;
- Lake Granby including reservoir levels, operations and releases;
- Adams Tunnel diversions;
- Colorado River below Windy Gap diversion dam for hydrologic conditions;
- Windy Gap diversions;
- Williams Fork Reservoir operations including reservoir levels and releases for fishery considerations;
- Willow Creek reservoir operation;
- Colorado River below Williams Fork River for hydrologic conditions;
- Colorado River below Troublesome Creek for hydrologic conditions;
- Wolford Mountain Reservoir for reservoir levels and releases;
- Colorado River at Kremmling for hydrologic conditions and water quality;
- Denver's unused reusable effluent;
- Denver's North System reservoir contents; and
- Denver's South Platte reservoir contents.

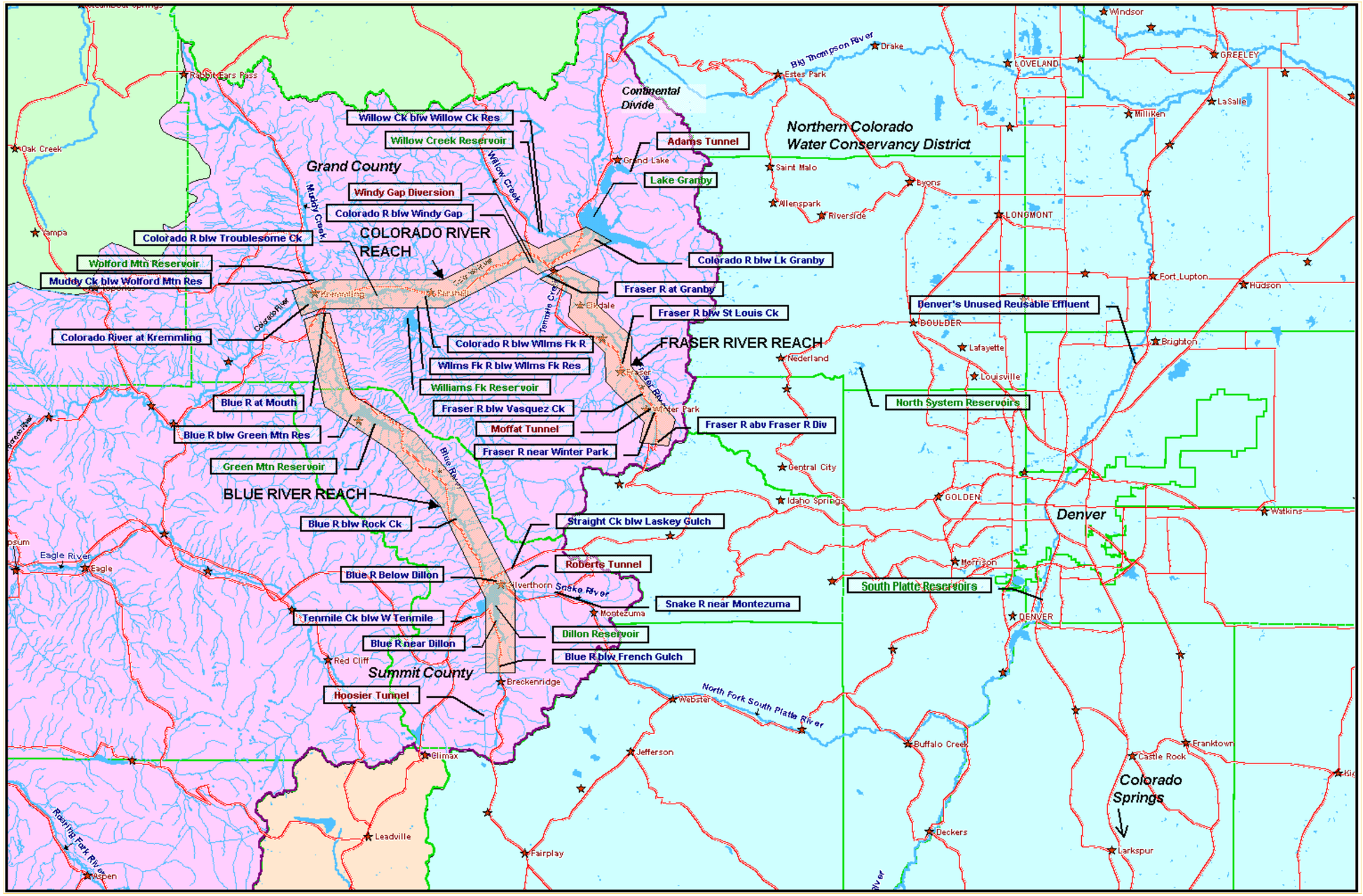


Figure 2.1 UPCO Study Area and Locations of Interest

Additional reporting items were added during the study process to provide information on Denver's South Platte Reservoir contents, Gross Reservoir contents and unused reusable effluent. This information is useful for understanding the relationships between East and West Slope water supply systems.

2.2 Study Approach and Methodology

The primary goal of Phase II of the UPCO study process was to develop the information and analytical tools necessary to understand currently existing hydrology and water quality conditions in the Study Area and how those conditions would be impacted by growing East and Study Area water demands. Phase II therefore included four major components: 1) development of additional water resources data for Summit and Grand Counties; 2) expansion of Denver's PACSM to more fully represent Study Area water supply systems; 3) development of a data management and display tool to support the analysis of impacts associated with existing and future water supply and demand scenarios; and 4) identification of issues to be addressed in Phase III, the solutions phase, of the study. The approach to each study component is described below.

2.2.1 The Study Process

In 1997, Denver Water released its Integrated Resource Plan that outlined how it would meet its future water needs. Denver expected to meet some of its future demand with expanded use of water rights for the Moffat Tunnel and Roberts Tunnel Collection Systems in Grand and Summit Counties. Northern was also beginning to discuss its plans for a project on either the West or East Slope that would firm up its Windy Gap yield. Firming up the Windy Gap yield would mean more diversions from the Grand County. Summit and Grand Counties, however, had no comprehensive plan for how to meet their future needs or if they would have enough water to meet their future growth. The West Slope entities involved recognized that they needed to quantify cumulative impacts in the Study Area associated with East and West Slope demands and how those demands would affect water resources in the Study Area. Additionally, the study aimed to identify "red flags" where impacts from future diversions would arise so that local governments in the Study Area could plan accordingly.

The study was directed by a Management Committee, which consisted of representatives from Summit and Grand Counties, Middle Park, River District, the QQ Committee, Denver Water and Northern. Colorado Springs Utilities joined the Management Committee in 2001 after it became clear that Colorado Springs intended to change its operations in the Upper Blue River Basin.

Two Advisory Committees (one for each County), comprised of interested stakeholders in the basins, were created to ensure the impact criteria were accurately represented in the Project. The impact criteria included fishing flows, kayaking flows, rafting flows, and reservoir levels. Once the impact criteria were developed, it was circulated for review among the Advisory Committee for confirmation. The Advisory Committees will also be consulted in the Phase III examination of alternative solutions.

The Management Committee agreed to ground rules and a Participation Agreement to facilitate cooperation. The Management Committee also used the process as a forum for discussing political issues affecting the parties as the study progressed.

2.2.2 Data Development

The water resources data needed for Summit and Grand Counties included historical streamflows, natural flows (for some locations), current water demands, projected future water demands, water diversions, return flows, water rights, and water quality. It was also necessary to develop geographic information regarding service areas for in-basin water providers, points of diversion and return flows, and stream segments with instream flow criteria for aquatic life and recreation.

A variety of water resources data was compiled for all of the major in-basin water supply systems in Summit and Grand Counties. This information included existing and projected future water demands (including average monthly and daily demands), water rights/water supply portfolios, diversion, storage and return flow facilities. This effort involved the review of previous studies and engineering reports and a series of meetings with QQ staff, individual water providers, and State Engineer's Office District Water Commissioners. This information was synthesized into memoranda describing each in-basin water supply system, the applicable water rights, return flows and the method used for modeling the system. These memoranda are included in a sub-directory with the UPCO Data Display Tool. It is important to note that this data gathering effort focused upon major in-basin water supply systems and did not include dispersed uses within Summit and Grand Counties. Many of these uses in Summit County are included in the County's pending augmentation plan or are otherwise served under agreements with the County.

Water quality data for the Blue and Upper Colorado River Basins was compiled from various sources including the EPA STORET database, the USGS, and various monitoring programs conducted by the Colorado Water Quality Control Divisions and others. This effort was originally intended to focus primarily on water quality data paired with streamflow data collected within the last 10 years in the vicinity of the Study Area locations of interest. Unfortunately, much of the available sampling data did not include streamflow measurements and many of the sampling locations were not well documented. Water quality data compiled through this effort were incorporated into an Access database that is included in a sub-directory with the UPCO Data Display Tool.

For some stream locations of interest where gage data were not available, natural flows for the 1947-1991 period of record were developed. Natural flows at these intermediate locations were interpolated using a "flow-splitting" process based on work previously done by Hydrosphere in the Summit County Small Reservoir Feasibility Study (Hydrosphere 1989). Natural flows were developed on a daily time step and provided to Denver Water for use in the expansion of PACSM to represent Summit and Grand County water supply systems. The methodology used for development of the natural flows for the relevant locations of interest and bypass flow requirements for several

points of diversion for in-basin water users were documented in PACSM Node documents which have been incorporated into the PACSM data display tool.

Information on instream flow water rights and recreational water needs was compiled to provide criteria for evaluation of the impacts of current and future water demand scenarios at key stream and reservoir locations of interest. These evaluation criteria included Colorado Water Conservation Board (CWCB) instream flow water rights, biological and recreational fish flows, kayaking flows, rafting flows, and reservoir levels necessary for operation of boat ramps and marinas. Reservoir levels and reservoir operations can also impact air quality, access, water quality, water temperature and general aesthetics. Instream water needs were based upon data compiled by the QQ Committee from technical documents and reports from the CDOW related to the Metro Denver Water Supply EIS (U.S. Army Corps of Engineers 1988), meetings with local anglers, rafting companies, kayak shops and marina operators. For the instream demands, a high flow, optimum flow and minimum flow (e.g., "fish minimum") were determined for each activity on each stream segment where that activity occurred. In addition, information on 1-day and 30-day, 3-year low flows used for the calculation of effluent permit limits for wastewater treatment plants were compiled for applicable locations of interest for use as an indicator of potential water quality impacts.

2.2.3 PACSM Expansion

Denver Water has developed an integrated system of computer programs to simulate streamflows, reservoir operations and water supply availability. This model, known as the Platte and Colorado Simulation Model (PACSM), simulates operation of the Denver Water system and the systems of other related water collection systems within portions of the Platte, Colorado and Arkansas River Basins. During Phase I of the UPCO study process, the Management Committee agreed that expansion of Denver's PACSM would be the most efficient approach to the analyses needed to accomplish the study objectives.

Early in the Phase II study process, a PACSM Review Committee was convened to determine whether PACSM adequately and correctly depicted the hydrology, water rights, and operations within the Colorado River Basin, and to provide suggestions for any necessary PACSM refinements. The Committee conducted a detailed review of PACSM's Study Area operations including PACSM operating information memoranda and an extensive set of PACSM output data that reflected the operation of Denver's system and the major water projects within the Colorado River Basin under existing conditions. An 'existing conditions' PACSM run was used for this verification effort because PACSM assumptions and output data could be compared directly to actual current operating practices and observed data.

2.2.4 Data Management and Display Tool Development

The issues addressed in the UPCO process required that changes in streamflows and reservoir levels resulting from various water demand and development scenarios be estimated with reasonable accuracy at the specified locations of interest in the Study Area. Specific effects on future water supplies for individual in-basin water users and

impacts on instream flows and water quality at these locations under various scenarios were of particular interest. The results in Phase II of the UPCO study process must be easily viewable and comparable in order to facilitate discussion and the design and evaluation of additional scenarios anticipated in Phase III.

The information needs of the Study required the simplicity and flexibility of a tool to display detailed and summary data from PACSM so that various scenarios could be compared with each other and with the streamflow and reservoir level evaluation criteria. The UPCO Data Display Tool was developed using Microsoft Excel and Visual Basic. A Study Area map-based interface allows the user to select locations of interest or stream reaches, choose various PACSM water demand scenarios, and view the resulting hydrologic implications graphically or in tabular form. The user may also select available streamflow and reservoir level evaluation criteria for comparison with the results of the PACSM scenarios.

2.3 Relationship to Other Studies and Planning Processes

There have been several other studies and planning processes that are directly related to the UPCO study that were completed prior to UPCO or were underway during the UPCO study process. The purposes of these studies and their relationships to UPCO are summarized below.

The Metropolitan Water Supply Investigation (MWSI): The MWSI study was completed in 1999 by the Colorado Water Conservation Board in cooperation with 47 Front Range water suppliers. The study included a survey of current and projected water demands, existing and future sources of supply, and an assessment of potential supply sources that involved cooperative actions between water users. The cooperative supply options investigated included conjunctive use of surface water and nontributary ground water systems to the south of Metro Denver, systems integration and coordinated operations of water supply facilities, and interruptible supply agreements between municipal and agricultural water users. The MWSI report provides a comprehensive overview of Front Range water use, future water needs and the planning and development efforts underway to meet those needs. The study process spawned several follow-up studies to further investigate cooperative actions applicable to specific subregional areas including the South Metro Water Supply Investigation, the Northeast Quadrant Study, and the Northwest Cooperative Investigation. These studies are described separately below. The need for the UPCO study became apparent during the MWSI process because many of the cooperative actions identified in the MWSI would impact Study Area water diversion and storage facilities (Hydrosphere 1999).

Metro Denver subregional water supply planning efforts:

> **South Metro Water Supply Investigation:** The Arapahoe County Water Resource Authority, the Douglas County Water Resource Authority, Denver Water, and the River District have been involved in studies of nontributary groundwater resources that included investigations of recharge potential and potential interconnection with surface water facilities in order to facilitate

conjunctive use of surface and groundwater resources. Conjunctive use could result in an increase in the amount of water withdrawn from the South Platte as well as Dillon Reservoir through the Roberts Tunnel from the Blue River in Summit County to meet water demands in areas to the south of Denver that are not currently served by the Denver system. These investigations are ongoing.

Northeast Quadrant Investigation: The Northeast Provider Group included Aurora, Brighton, Denver Water, FRICO, South Adams County Water & Sanitation District and Thornton. This study focused on the hydrology, water rights, operations, water quality and raw water storage aspects of effluent management and systems integration concepts identified in the MWSI project. The study identified the need for additional storage below the Metro Wastewater Treatment Plant for regulation of reusable effluent for non-potable reuse. Most of Denver Water's reusable effluent is return flows from water imported to the South Platte from the Blue River Basin. Reuse is one means of maximizing utilization and consumptive use of water imported from the Blue River Basin.

Northwest Cooperative Investigation: The Northwest Provider Group focused on interested water providers in the Clear Creek/Big Dry Creek Basins including the cities of Arvada, Broomfield, the Consolidated Mutual Water Company, Denver Water, and Westminster. This study provided additional analysis of system integration concepts previously identified in the MWSI project, with emphasis on the potential benefits of system interconnections and cooperative use of storage facilities. The specific purpose of the study effort was to define the potential additional yield that could be cooperatively developed using water rights, storage, conveyance and delivery facilities currently or potentially available to the Northwest Provider Group in conjunction with Denver's existing water supply system and some of its water rights. The study was completed in February 1999 and identified several options for more effective utilization of existing facilities and development of new or enlarged facilities to increase dry-year water supply availability. Discussions between Denver Water and several of the northwest providers are ongoing. Several of the storage options considered in the Northwest Cooperative Investigation are directly related to the UPCO study because they would increase the amount of water delivered to the Front Range via Denver's Moffat Tunnel Collection System (Hydrosphere 1999).

Denver Water update of Integrated Resource Plan (IRP): In 1997, Denver Water completed an IRP to update water demand projections and evaluate alternative water supply planning strategies. In conjunction with this effort a new raw water supply planning model for the Denver system (PACSM) was developed as a tool for evaluation of new water supply sources and system management alternatives. In February 2002, Denver Water revised the IRP report to provide a progress check on work toward implementing the tasks set forth in the 1997 report and an update to reflect the changes resulting from those initiatives and other changing conditions. The IRP includes a "Board Resource Statement" that emphasizes the importance of working cooperatively with other utilities and non-water utility interests outside the Denver Metropolitan Area. With regard to Western Slope interests the Board Resource Statement states that "any

future structural projects located on the Western Slope should be developed cooperatively with Western Slope entities for the benefit of all parties" (Denver Water 2002).

SB 74 – Denver Basin and South Platte River Basin Technical Study: The Colorado Division of Water Resources and the Colorado Water Conservation Board, in response to direction from the General Assembly (Senate Bill 96-74), conducted the Denver Basin and South Platte River Basin Technical Study, which was completed in 1998. The primary purposes of this investigation were to investigate the adequacy of existing replacement/relinquishment requirements for Denver Basin wells and the impacts of conservation, water reuse, conjunctive use and runoff from impervious surfaces on water rights and water supplies. These investigations focused primarily on potential impacts to water rights and water users in the South Platte River Basin below Denver, but also identified the need for further investigation of West Slope impacts (Hydrosphere 1998). In addition, the SB 74 study included investigations to estimate the economic life of the Denver Basin Aquifers (Hydrosphere 1997).

Division 5 Water Availability Study for Endangered Fish (a.k.a. the Colorado River Coordinated Facilities Operations Program (CFOP): This study effort was initiated in 1999 by the Colorado Water Conservation Board and is funded primarily by the Upper Colorado River Endangered Fish Recovery Program. The primary purpose of this investigation is to identify mechanisms for delivery of 20,000 acre-feet of water to augment peak flows in the 15-Mile Reach of the Colorado River through coordinated operations of existing facilities and possible new facilities. This study is scheduled to be completed in early 2003. Implementation of the study recommendations could affect the operation of reservoirs and diversion facilities in the UPCO Study Area including Green Mountain, Dillon, and Williams Fork Reservoirs.

Chatfield Storage Reallocation Study: In early 1998, the U.S. Army Corps of Engineers in cooperation with the Colorado Water Conservation Board initiated investigation of the feasibility of allocation or reallocation of Chatfield Reservoir storage for water supply purposes. The allocation of additional capacity at Chatfield to municipal water supply storage could have some effect on the operation of the Roberts Tunnel Collection system and Dillon Reservoir. This study is currently underway and expected to be completed in late 2003.

3. STUDY RESULTS

This section of the UPCO report provides a summary overview of in-basin water needs for water supply systems, environmental and recreational instream flows, and water levels for reservoir recreational facilities. It also describes water collection and storage systems that divert water from the Study Area to the Front Range and the current and projected demands associated with those systems. The PACSM Results section of the report summarizes the potential impacts on in-basin water needs associated with current and future water demands under four PACSM scenarios. The output data from the PACSM model runs is available on the UPCO Data Display Tool CD. Possible solutions to the water shortage, instream flow and reservoir level issues identified in the Study Results section of this report are discussed in the Conclusions and Possible Solutions section.

3.1 Upper Colorado River In-Basin Water Needs

The information on in-basin water supply systems compiled during the study process was summarized in a series of memoranda describing each individual water supply system, its operations, service area, existing and future water demands, water rights portfolio and the modeling approach implemented in PACSM. These memoranda (known as Operating Information and Node Documents) were distributed in draft form to the water providers for their review, and corrections and refinements to the memoranda were made in response to comments. Final versions of the Operating Information and Node Documents are included in this report by reference and available on the UPCO Data Display Tool CD. The following discussion provides an overview of in-basin water supply systems including the current and projected future buildout water demands.

3.1.1 In-Basin Water Supply Systems

3.1.1.1 Grand County

Table 3.1 summarizes the existing and future projected water needs of Grand County water suppliers and provides general descriptions of their service areas and water sources. Under existing conditions (year 2000), water demands for providers in Grand County totaled 3,132 acre-feet per year. Grand County water providers expect a more than 450% increase in demands to 14,167 acre-feet per year. The timing of these future demands depends upon economic development trends in the respective service areas of the individual water providers. Some areas are expected to grow more rapidly due to their proximity to the Winter Park and Sol Vista ski areas and other recreational attractions such as Grand Lake.

Approximately 70% of the total existing and future water demands in Grand County are for water providers in the Fraser River Basin with supply sources derived from alluvial wells and surface water diversions from the Fraser River and its tributaries. The largest growth in water demands in the Fraser Basin is expected to occur in areas served by the Grand County Water & Sanitation District No. 1, the Town of Fraser and Silver Creek Resort. The Grand County Water & Sanitation District No. 1, which serves areas along the Fraser River to the north of Winter Park, is the single largest water provider in Grand County with total existing demands of about 687 acre-feet and estimated future demands of 3,711 acre-feet per year.

The Town of Grand Lake projects a more than 600% increase in water demands for its service area located to the northwest of Grand Lake. Hot Sulphur Springs, located on the Colorado River 8 miles below the mouth of the Fraser River, projects a more than 1,400% increase in demand.

Table 3.1. Summary of Grand County water suppliers existing and future demands and water sources

Water Supplier (Types of Use)	* Water Demands (acre-feet/year)		Service Area Location	Water Sources
	Existing	Projected Buildout		
Columbine Lake WD (domestic)	157	303	Northwest of Grand Lake	Three surface water diversions and one well on Tonahutu Creek above Grand Lake
Town of Grand Lake (municipal)	199	1,262	Northwest shore of Grand and Shadow Mountain Lakes	One well tributary to Grand Lake and one surface water diversion from Tonahutu Creek
Hot Sulphur Springs (municipal)	116	1,667	On the Colorado River about 15 miles above Kremmling	Surface water diversion from the Colorado River just below Heinbaugh Creek
Town of Kremmling (municipal)	441	888	On the Colorado River just above the Blue River confluence	Surface water diversion from Sheep Creek and water right for future diversion from the Colorado River at the Sheep Creek confluence
Winter Park Rec. and W&S District (Indoor) (domestic, commercial)	151	500	Winter Park and Mary Jane Ski Areas, Town of Winter Park and surrounding areas south of Town of Fraser	Fraser River surface water diversion and alluvial wells with augmentation from Crooked Creek rights, Clinton Reservoir and Middle Park Windy Gap exchange water
Winter Park Rec. (Snowmaking)	199	477	Winter Park and Mary Jane Ski Area snowmaking	Diversion by exchange from Denver's Vasquez Canal with Clinton Reservoir augmentation
Grand County W&SD #1 (municipal)	687	3,711	Along Fraser River north of Winter Park (formerly Hideaway Park)	Surface water diversions from Little Vasquez Creek and Vasquez Creek with augmentation from Crooked Creek rights, Clinton Reservoir and the Middle Park Windy Gap pool
Winter Park West W&SD (municipal)	454	618	Residential development northeast of Fraser	Seven alluvial wells along the Fraser River

Water Supplier (Types of Use)	* Water Demands (acre-feet/year)		Service Area Location	Water Sources
	Existing	Projected Buildout		
Town of Fraser (municipal)	309	1,326	Along Fraser River just above St. Louis Creek	Seven alluvial wells along the Fraser River and a surface water diversion on St. Louis Creek with augmentation from Middle Park Windy Gap pool and Clinton Reservoir
Town of Granby (municipal)	230	465	On the Fraser River just above the confluence with the Colorado River	Surface water diversion from the Fraser River with augmentation from Middle Park Windy Gap pool and Clinton Reservoir
Silver Creek Resort (domestic, commercial, snowmaking)	189	2,950	West of the Fraser River to the south of Granby	Alluvial wells along the Fraser River to the south of Granby with augmentation from ditch rights, Green Mountain HUP and Wolford Mountain pools
Grand County Totals	**3,132**	**14,167**		

* Water demands are those modeled in PACSM and may be slightly different than those reported by water providers due to rounding.

3.1.1.2 Summit County

Table 3.2 summarizes the existing and future projected water needs of Summit County water providers and provides general descriptions of their service areas and water supply sources. Under existing conditions (year 2000), demands for water providers in Summit County totaled 8,027 acre-feet per year. Summit County water providers expect a 220% increase in demands to 17,871 acre-feet per year. The timing of future buildout demands is uncertain and will depend upon economic development trends in the respective service areas of the individual water providers.

Approximately 35% of the total existing and 25% of the future buildout water demands in Summit County are for water providers in the Upper Blue River above Dillon Reservoir. The primary supply sources for these water providers are alluvial wells and surface water diversions from the Blue River and its tributaries. The Town of Breckenridge, located on the Blue River above French Gulch, is the largest water provider in Summit County with total existing demands of about 2,062 acre-feet and estimated future demands of 3,355 acre-feet per year.

The largest growth in water demands in the basin is expected to occur in areas below Dillon Reservoir including the Town of Silverthorne, Eagles Nest and Mesa Cortina. Water demands in these areas are expected to grow from the existing level of about 1,088 acre-feet to 4,055 acre-feet under future buildout demands. Water supply sources for these areas are Blue River surface water diversions and alluvial wells.

About 19% of the current demands in Summit County are for water providers in the Snake River Basin. Under existing conditions, these providers serve demands totaling about 1,478 acre-feet per year. These providers expect their demands under future buildout conditions to increase by about 268% to 3,963 acre-feet per year.

Approximately 20% of current and future demands in Summit County are for areas within the Tenmile Creek Basin including Copper Mountain and the Town of Frisco. Under existing conditions, demands in the Tenmile Creek total about 1,727 acre-feet per year and are expected to increase by 200% to 3,541 acre-feet per year under buildout conditions.

The East Dillon Water District derives its water supplies from alluvial wells in the Soda Creek drainage and serves current demands of about 290 acre-feet per year. Under future buildout conditions demands are expected to increase by about 214% to 623 acre-feet per year. The Town of Dillon and the Dillon Water & Sanitation District systems use surface water from a diversion on Straight Creek to meet total current demands of about 660 acre-feet per year and project future demands to increase by about 200% to 1,284 acre-feet per year.

Table 3.2. Summary of Summit County water suppliers existing and future annual demands and water sources

Water Supplier (type of use)	* Water Demands (acre-feet/year)		Service area Location	Water Sources
	Existing	Projected Buildout		
Arapahoe Basin (snowmaking and commercial)	0	351	On the North Fork of the Snake River south of Loveland Pass	Surface water diversions from the North Fork of the Snake River at the base of the ski area and below Porcupine Gulch with augmentation from Clinton Reservoir and Green Mountain
Keystone-Montezuma (domestic)	0	30	Future development along the Snake River below Peru Creek and above the North Fork	Anticipated development of four alluvial wells and two surface water diversions from the Snake River above the North Fork with augmentation from Clinton Reservoir and Green Mountain
Keystone Mountain (snowmaking)	485	1,157	South of the Snake River about 3 miles above Dillon Reservoir	Surface water diversion from the Snake River 0.5 mile below the North Fork with Clinton Reservoir augmentation
Keystone Gulch (on-mountain commercial)	0	78	Keystone Mountain and base area facilities	Alluvial wells on Keystone Gulch with augmentation from Clinton Reservoir and Green Mountain
Keystone Golf Course (domestic and irrigation)	170	170	Along the Snake River above Soda Creek	Surface water diversion from the Snake River with augmentation from transferred ditch rights and Clinton Reservoir
Keystone Ranch (domestic and irrigation)	268	274	Within the Soda Creek Basin south of the Snake River arm of Dillon Reservoir	Four alluvial wells and Reynolds Reservoir on Soda Creek with augmentation from transferred irrigation rights on Soda Creek and Keystone Gulch
Snake River Water District (domestic and commercial)	555	1,903	Keystone Resort and surrounding area excluding Keystone Ranch	Alluvial wells on the Snake River 3 miles above Dillon Reservoir with augmentation from Vidler Tunnel Water Company, ditch transfers, Windy Gap and the Summit County Agreement
East Dillon Water District (domestic and commercial)	290	623	Southeast of the Town of Dillon in Soda Creek Basin	Seven alluvial wells along Soda Creek with augmentation from Vidler Tunnel rights, Columbus Ditch and Green Mountain HUP

Water Supplier (type of use)	* Water Demands (acre-feet/year)		Service area Location	Water Sources
	Existing	Projected Buildout		
Town of Breckenridge (municipal)	2,062	3,355	Along the Blue River above French Gulch	Surface water diversions from Goose Pasture Tarn on the Blue River and Barton Gulch with augmentation from Green Mountain Reservoir, Windy Gap, Summit County, and Clinton Reservoir agreements
Town of Breckenridge Golf Course (irrigation)	176	365	Along the Blue River north of Breckenridge	Surface water diversion from the Swan River with augmentation from Green Mountain HUP and Clinton Reservoir
Breckenridge Ski Resort (snowmaking and commercial)	546	685	West of the Town of Breckenridge	Surface water diversion from the Blue River at Maggie Pond for snowmaking and individual wells for domestic and commercial uses with augmentation from Green Mountain Reservoir, Windy Gap, Clinton Reservoir, Lusher Ditch and Goose Pasture Tarn
Copper Mountain Water & Sanitation District (domestic and commercial)	381	876	Copper Village area east of Vail Pass at the confluence of Tenmile and West Tenmile Creek	Three alluvial wells and one surface diversion from West Tenmile Creek for domestic and commercial uses, open space and golf course irrigation with augmentation from Green Mountain Reservoir and Windy Gap
Copper Mountain Inc (irrigation and snowmaking)	500	689	Copper Mountain Ski Area and Golf Course east of Vail Pass at the confluence of Tenmile and West Tenmile Creek	Surface diversions and wells that divert water for snowmaking, ski area restaurants and golf course irrigation from Tenmile and West Tenmile Creeks with augmentation from Clinton Reservoir and Dillon Reservoir
Town of Frisco (municipal)	846	1,976	Southwest shore of Dillon Reservoir	Surface water diversion from North Tenmile Creek and 5 alluvial wells on Tenmile Creek and one on Meadow Creek with augmentation from Green Mountain HUP and contract, Windy Gap, the Summit County Agreement and Clinton Reservoir

Water Supplier (type of use)	* Water Demands (acre-feet/year)		Service area Location	Water Sources
	Existing	Projected Buildout		
Dillon Valley Metro District (domestic)	333	406	North of the Town of Dillon and south of I-70 along Straight Creek	Surface water diversion from Straight Creek below Laskey Gulch, water rights senior to Shoshone and Green Mountain Reservoir
Town of Dillon (municipal)	327	878	East shore of Dillon Reservoir	Surface diversions from Straight Creek near confluence with Laskey Gulch with augmentation from Green Mountain HUP and supplemental supply from Old Dillon Reservoir, the Summit County Agreement and Clinton Reservoir
Buffalo Mountain / Mesa Cortina (domestic)	296	755	Residential development to the southwest of Silverthorne	Four alluvial wells along the Blue River below Salt Lick Gulch with augmentation from the Green Mountain HUP, Windy Gap
Town of Silverthorne (municipal)	465	2,298	Along Blue River north of Dillon Dam	Blue River surface water diversion and six alluvial wells below Straight Creek with Graff, Ruth and Valaer ditch rights with augmentation from Windy Gap, Green Mountain HUP, Clinton Reservoir, Old Dillon Reservoir, and Dillon Reservoir
Eagle's Nest (domestic)	327	1,002	North of and adjacent to the Town of Dillon	Receives water from the Town of Silverthorne and two alluvial wells along Blue River below Willow Creek with augmentation from transferred Willow Creek irrigation rights
Summit County Totals	**8,027**	**17,865**		

* Water demands are those modeled in PACSM and may be slightly different than those reported by water providers due to rounding.

3.1.2 In-Basin Instream and Recreational Water Needs

For purposes of evaluating impacts on streamflows and reservoir levels within Summit and Grand Counties, information was compiled on instream flow water rights and water levels for water based recreational activities. In addition, for indication of potential water quality impacts for stream reaches below wastewater treatment plants, the 1-day and 30-day, 3-year low flows used for determining waste load allocations were compiled from CPDES permits. These evaluation criteria were incorporated into the PACSM data display tool for the applicable stream and reservoir locations of interest:

- Colorado Water Conservation Board instream flow water rights
- Minimum and optimum fish flows
- Low, high and optimum kayaking flows
- Low, high and optimum rafting flows
- Reservoir levels for normal operations of boat ramps and marinas (as well as attendant benefits to the community)
- Wastewater treatment plant 1-day and 30-day, 3-year low flows

To develop the in-basin instream water needs, the QQ Committee met with local anglers, extrapolated data from various technical reports such as the Metro Denver Water Supply EIS, CDOW, rafting companies, kayak shops and marina operators. From those discussions, the impact criteria were determined. For the instream uses, a high flow, optimum flow and minimum flow were determined for each activity on each stream segment where that activity occurred. Instream flow evaluation criteria developed through this process for Grand and Summit Counties are shown in Table 3.3 and Table 3.4 respectively. These flows and reservoir levels represent what the recreation and in-basin communities believe is important to sustain a quality recreational experience.

Marina operators provided information on optimum and minimum reservoir levels for normal operation of their facilities. Information also included the boating season for each reservoir and potential mitigation for future operations under lower reservoir levels. The instream flow and reservoir level criteria were documented in memoranda prepared by QQ Staff and are included in the Flow Criteria sub-directory on the UPCO Data Display Tool CD.

Discharge limits for wastewater treatment plants are based on the dilution flows in the rivers and lakes. Therefore, flows necessary for dilution of wastewater plant discharges came from either the operators of the plants or from Colorado Pollution Elimination Discharge permits for each discharger.

Table 3.3 Grand County Flow Criteria Table

Stream Reach	Locations of Interest	Fish Flows (cfs) and (dates)			Kayak Flows (cfs) and (dates)			Raft Flows (cfs) and (dates)			Waste Water Treatment Plant (Annual Low) (cfs)	
		CWCB	Min	Opt	Low	High	Opt	Low	High	Opt	1E3	30E3
Fraser R. above Fraser	Fraser R. near Winter Park	8 cfs (5/15-9/15); 3.5 cfs (9/16-5/14)									2.6	3.2
	Fraser R. below Vasquez Creek	11 cfs (5/15-9/15); 5 cfs (9/16-5/14)	9 (year-round)	12.5 (year-round)	250 (season: late May to early June)	1,000	550				4.9	6.2
Fraser R. below Fraser	Fraser R. below St Louis Creek	17 cfs (5/15-9/15); 11 cfs (9/16-5/14)			250	1,000	400-700				12	13
	Fraser R. at Granby Gage	Upper Seg: 17 cfs (5/15-9/15) 11 cfs (9/16-5/14) Lower Seg: 30 cfs (5/15-9/15); 19 cfs (9/16-5/14)									15	23
Colorado R. above Fraser R. confl.	Colorado R. below Lake Granby	40 cfs (5/01-8/31); 20 cfs (9/01-4/30)	30	45 (year-round)								

Stream Reach	Locations of Interest	Fish Flows (cfs) and (dates)			Kayak Flows (cfs) and (dates)			Raft Flows (cfs) and (dates)			Waste Water Treatment Plant (Annual Low) (cfs)	
		CWCB	Min	Opt	Low	High	Opt	Low	High	Opt	1E3	30E3
Colorado R. below Fraser R. and above Kremmling	Colorado R. below Windy Gap	90 cfs	125 (year-round)	200 (year-round)	300 (season: June)	1,000 – 2,000+	400 – 1,000					
	Colorado R. below Williams Fork	135 cfs										
	Williams Fork below Reservoir		50	200								
	Colorado R below Trouble-some	150 cfs										
Colorado R. below Kremmling	Co. R. at Kremmling				400	1,100	1,100	400	>11,000	2,000 – 3,000		
	Muddy Ck below Wolford										2.8	2.8

Table 3.4 Summit County Flow Criteria Table

Stream Reach	Locations of Interest	Fish Flows (cfs) and (dates)			Kayak Flows (cfs) and (dates)			Raft Flows (cfs) and (dates)			Waste Water Treatment Plant (Annual Low) (cfs)	
		CWCB	Min	Opt	Low	High	Opt	Low	High	Opt	1E3	30E3
Blue River above Dillon Reservoir	Blue R. below French Gulch				100		500				18	20
	Blue R. near Dillon	32 cfs (5/01-10/31); 16 cfs (11/01-4/30)										
Tenmile Creek above Dillon Reservoir	Tenmile Creek below West Tenmile Creek	10 cfs (4/01-9/30); 7 cfs (10/01-3/31)									4.2	5.1
Snake River above Dillon Reservoir	Snake River near Montezuma Gage	12 cfs (5/01-10/31); 6 cfs (11/01-4/30)									7.7	10

Stream Reach	Locations of Interest	Fish Flows (cfs) and (dates)			Kayak Flows (cfs) and (dates)			Raft Flows (cfs) and (dates)			Waste Water Treatment Plant (Annual Low) (cfs)	
		CWCB	Min	Opt	Low	High	Opt	Low	High	Opt	1E3	30E3
Blue River below Dillon Reservoir	Blue River below Dillon Reservoir	50	75 (5/1-9/30); 55 (10/1-4/30)	100	300	1,200 (season: 6/1-7/4)	600 – 1,100				44	57
	Blue River below Rock Creek	90 cfs (04/01-4/30) 115 cfs (05/01-8/31) 90 cfs (09/01-9/30) 78 cfs (10/01-10/31) 67 cfs (11/01-3/31)			300	1,200 (season: 6-7/4)	600-1,100	550	2,000	700-1,400		
Green Mountain Reservoir and Blue River below Green Mountain	Blue R. below Green Mountain Reservoir	60 cfs (5/01-7/15); 85 cfs (7/16-4/30)	60 (5-7/15); 140 (7/16-9/30); 100 (10/1-4/30)		<600	>600	500 (season: late summer)					

3.1.3 Denver Water System

Denver Water, as part of the recent IRP update, has recently completed a detailed review of existing and future water supply and demand. Current demand on the Denver Water system is estimated at 285,000 acre-feet per year and build-out demands, expected to occur in the middle of the 21st century, are projected to reach approximately 450,000 acre-feet. Denver Water's 450,000 acre-feet build-out demand includes 30,000 acre-feet as a safety factor against unexpected events that could impact the available supply or projected demands (Denver Water 2002). Table 3.5 shows modeled Denver Water diversions from the Study Area under existing and future demand scenarios.

The Denver Water System currently serves a population of about 1.1 million people in the City and County of Denver and surrounding areas within Jefferson, Adams, Broomfield, Arapahoe, and Douglas Counties. The population served in these areas is projected to grow to approximately 1.9 million in the mid-21st century.

Table 3.5. Denver Water System Average Annual Diversions Under UPCO Scenarios (acre-feet)

PACSM Scenario	Total Demand	Roberts Tunnel	Moffat Tunnel
1. Existing conditions	285,000	70,500	63,600
2. Future baseline	371,000	115,400	67,400
3. Future baseline with north project	386,000	118,700	73,600
4. Future baseline with south project	386,000	123,500	72,600

3.1.4 Continental-Hoosier Diversion System

The Continental-Hoosier Diversion System (a.k.a. the Blue River Project) is located southwest of Breckenridge, Colorado, and is owned by the City of Colorado Springs. Water is diverted from the Blue River and its tributaries on the West Slope to the Middle Fork of the South Platte River on the East Slope. The collection system for the Hoosier Tunnel includes 2,120 acre-feet of storage in Upper Blue Lakes on Monte Cristo Creek. Diversions to the East Slope through the Hoosier Tunnel average about 12,000 acre-feet per year under current and future PACSM demand scenarios.

3.1.5 Colorado-Big Thompson/Windy Gap

The Colorado-Big Thompson Project (CB-T) is a complex system of reservoirs, pipelines, tunnels, canals and pipelines that diverts water from the headwaters of the Colorado River to the Big Thompson River, a tributary of the South Platte River. CB-T was authorized by Congress in 1937 and developed by the U.S. Department of Interior, Bureau of Reclamation under a repayment contract with the Northern. Major Study Area

components of the CB-T Project include Lake Granby with a storage capacity of 539,800 acre-feet, Shadow Mountain Reservoir and Grand Lake with a combined capacity of 18,400 acre-feet, and Willow Creek Reservoir with a capacity of 10,600 acre-feet (U.S. Dept. of Interior 1981).

The Windy Gap Project was completed in 1985 by the Municipal Subdistrict of Northern and consists of a dam and pumping station located on the Colorado River below the confluence of the Fraser River. The CB-T/Windy Gap system is designed to collect up to an average of 310,000 acre-feet of water for conveyance through the Alva B. Adams Tunnel to the East Slope for supplemental irrigation and municipal water supply purposes. Historically, the amount of water available to the CB-T West Slope collection system has been less than the 310,000 acre-feet design capacity. Windy Gap has a 600 cfs water right and under the Azure agreement diversions are limited to 90,000 acre-feet in any one year and 650,000 acre-feet over any 10 year period. The estimated long-term yield of Windy Gap is 54,000 acre-feet per year. Table 3.6 shows modeled CB-T and Windy Gap diversions under existing and future demand scenarios. Not all of the water diverted at Windy Gap is delivered to the East Slope through the Adams Tunnel due to evaporation losses, a 10% bookover of delivered water to the CB-T pool, bookover to the 3,000 acre-feet West Slope pool, and bumping of Windy Gap water when the CB-T pool fills (Northern 2003).

Table 3.6. Colorado-Big Thompson/Windy Gap Average Annual Diversions Under UPCO Scenarios (acre-feet)

PACSM Scenario	Adams Tunnel	CB-T Supply	Windy Gap Diversion
1. Existing conditions	247,838	236,005	21,191
2. Future baseline	271,716	235,553	46,289
3. Future baseline with north project	270,080	235,545	44,430
4. Future baseline with south project	270,780	235,560	45,137

3.2 Use of PACSM in Phase II

Denver Water has developed an integrated system of computer programs to simulate streamflows, reservoir operations and water supply availability. This model, known as the Platte and Colorado Simulation Model (PACSM), simulates operation of the Denver Water system and the systems of other related water collection systems within portions of the Platte, Colorado and Arkansas River Basins.

In PACSM, the rivers and water supply systems are represented as a system of "linked nodes," or measurement points, representing diversions, stream gages, reservoirs, points requiring a minimum instream flow, or any location where information is needed. The nodes – of which there are more than 450 – are linked by rivers, canals, pipelines or

tunnels. The model allocates water to a diversion or reservoir based upon available flow, water rights, diversion or storage capacity, and water demand. At each node, numerous types of information are available on a daily basis throughout a 45-year hydrologic period (1947 – 1991). For example, at a reservoir, the available information includes inflow, evaporation, seepage, exchanges, reservoir releases and hydroelectric power generation (Denver Water 2002).

3.2.1 PACSM Verification Process

The results of the UPCO Study are based upon Denver's PACSM depiction of the hydrologic and water supply aspects of various scenarios representing existing and future water demands in the Upper Colorado River Basin. A PACSM Review Committee was formed to determine whether PACSM adequately and correctly depicted the hydrology, water rights and projects operations of the Colorado River Basin for the purposes of this Study, and to provide suggestions for PACSM refinements if necessary.

The Committee conducted a detailed review of PACSM's West Slope operations including PACSM operating information memoranda and an extensive set of PACSM output data that reflected the operation of Denver's system and the major water projects within the Colorado River Basin under existing conditions. An 'existing conditions' PACSM run was used for this verification effort because PACSM assumptions and output data could be compared directly to actual current operating practices and observed data.

The Committee provided Denver with extensive comments on PACSM's representation of several projects, principally regarding the Colorado-Big Thompson and Windy Gap Projects, Green Mountain Reservoir, Wolford Mountain Reservoir, and the Grand Valley Project. Denver Water staff made corrections and refinements to PACSM in response to these comments. This process involved the review of six iterations of PACSM output data production, Committee meetings, and subsequent PACSM modifications and refinements by Denver Water staff.

The PACSM Review Committee concluded that PACSM adequately simulates the hydrology, major water rights and the operations of major water storage and diversion projects within the Colorado River Basin under existing conditions for the purposes of this UPCO Study. It was also determined that PACSM was ready to undergo further modifications as necessary to represent the individual M&I water supply systems within the Study Area. The output data from PACSM Run No. SSUM0640, dated 5/21/99, serves as a benchmark for these conclusions.

It was recognized that additional PACSM refinements may be needed to adequately represent future operations of Colorado River Basin water projects such as contract water deliveries from Green Mountain Reservoir, Wolford Mountain Reservoir and the Middle Park Water Conservancy District's Windy Gap supplies. The Committee also understood that Denver Water would continue to refine PACSM, both to represent Study Area water systems as part of the UPCO study and for purposes unrelated to the UPCO study.

Upon completion of the PACSM modifications necessary to simulate the alternative "futures' specified in the UPCO scope of work, the "existing conditions" scenario was rerun to produce a benchmark for comparison to the alternative futures. The results of this comparison are discussed under the PACSM Results section of this report.

3.2.2 PACSM Scenarios

This study evaluates the results of four water supply and demand scenarios representing existing conditions and alternative future conditions. Each of the scenarios was evaluated for wet, dry and average years based on the 1947-1991 hydrologic record represented in PACSM. The assumptions defining the existing and future hydrologic scenarios are summarized below. Table 3.7 provides a summary of the supply and demands assumptions for each of the Study Area water supply systems represented in PACSM. The study participants have two remaining PACSM model runs left for Phase III, the solutions phase.

- **PACSM 1 – Existing Supply and Demand (current conditions)**. PACSM 1 represents current water supply and demand conditions and serves as a baseline for the evaluation of modeling results associated with the future supply and demand scenarios. Under this scenario, Denver's average annual demand is modeled at 285,000 acre-feet and demands for in-basin water users are those shown in the "Existing" column of Table 1.

- **PACSM 2 – Existing Supply and Full Use Demand**. PACSM 2 represents existing water supply systems, including approved system additions, under future projected full use demand conditions. Under this scenario, Denver's average annual demand is 375,000 AF and in-basin demands reflect the "Projected Buildout" water demands listed in Table 1. This scenario includes 17,000 acre-feet of reuse, 5,000 acre-feet of gravel pit exchange and 8,000 of system refinements.

- **PACSM 3 – New 15 KAF North System Supply and Full Demand**. PACSM 3 represents the same water supply and demand conditions described above for PACSM 2 with an additional 15,000 acre-feet of new supply developed primarily from Denver Water's northern collection system and an additional 15,000 acre-feet of Denver system-wide demand.

- **PACSM 4 – New 15 KAF South System Supply and Full Demand**. PACSM 4 represents the same water supply and demand conditions described above for PACSM 2 with an additional 15,000 acre-feet of new supply developed primarily from Denver Water's southern collection system and an additional 15,000 acre-feet of Denver system-wide demand.

Table 3.7 Water Supply and Demand Assumptions for PACSM Scenarios

Denver Water	**Existing** Supply & **Existing** Demand	**Existing** Supply & **Full Use** Demand	New **15 kaf North System** Supply	New **15 kaf South System** Supply
Northern/CBT				
CBT Operations	Current = Full	Current = Full	Current = Full	Current = Full
Windy Gap Supply	Existing Demand	Full Demand	Full Demand	Full Demand
West Slope				
Colorado River Demands				
Columbine Lake Water District	existing	buildout	buildout	buildout
Town of Grand Lake	existing	buildout	buildout	buildout
Town of Hot Sulphur Springs	existing	buildout	buildout	buildout
Town of Kremmling	existing	buildout	buildout	buildout
Fraser River Basin Demands				
Winter Park Rec. and W&S Dist. Indoor	existing	buildout	buildout	buildout
Winter Park Rec. Snowmaking	existing	buildout	buildout	buildout
Grand County W&S	existing	buildout	buildout	buildout
Winter Park West	existing	buildout	buildout	buildout
Town of Fraser	existing	buildout	buildout	buildout
Silver Creek Resort	existing	buildout	buildout	buildout
Town of Granby	existing	buildout	buildout	buildout
Blue River Basin Demands				
Arapahoe Basin Snowmaking	existing	buildout	buildout	buildout
Keystone-Montezuma Domestic	existing	buildout	buildout	buildout
Keystone Snake River Snowmaking	existing	buildout	buildout	buildout
Keystone Gulch	existing	buildout	buildout	buildout
Keystone Golf Course	existing	buildout	buildout	buildout
Keystone Ranch	existing	buildout	buildout	buildout
Snake River WD	existing	buildout	buildout	buildout
East Dillon WD	existing	buildout	buildout	buildout
Town of Breckenridge (indoor and ou	existing	buildout	buildout	buildout
Town of Breckenridge Golf Course	existing	buildout	buildout	buildout
Breckenridge Ski Resort	existing	buildout	buildout	buildout
Copper Mountain W&SD	existing	buildout	buildout	buildout
Copper Mountain Inc (outdoor and sr	existing	buildout	buildout	buildout
Town of Frisco	existing	buildout	buildout	buildout
Dillon Valley Metro District	existing	buildout	buildout	buildout
Town of Dillon	existing	buildout	buildout	buildout
Buffalo Mountain / Mesa Cortina	existing	buildout	buildout	buildout
Town of Silverthorne	existing	buildout	buildout	buildout
Eagle's Nest	existing	buildout	buildout	buildout

3.3 PACSM Results

The results presented below have been organized by geographic stream reaches or sub-basins within Summit and Grand Counties. Many of these stream reaches include multiple locations of interest where PACSM results are available. However, because of the complexity of reporting results for each of the more than 35 location of interest, this report will focus on the overall impacts and concerns associated each geographic sub-basin. Modeling results are described in terms of impacts or changes related to the applicable streamflow and reservoir level evaluation criteria, previously described in Section "In-basin Environmental & Recreational", associated with the various PACSM

scenarios. This discussion of results focuses primarily on potential problem areas and issues and does not provide detailed descriptions of all of the impacts and changes that may occur under the future demand scenarios.

An important caveat regarding modeling results: PACSM simulates streamflows, water diversions, return flows and reservoir functions operating under water laws, agreements and other assumptions that often, by necessity, simplify what may actually occur on the ground and in natural systems. Issues and concerns presented below may therefore require further detailed analyses to verify their accuracy and fully understand their causal factors. This report deals with regional water management issues and is not a substitute for local water supply planning.

3.3.1 Grand County

3.3.1.1 Overview of Physical Setting and Issues

Grand County is located about 90 miles northwest of Denver to the west of the Continental Divide. The County encompasses all of the Fraser River Basin, the Williams Fork River Basin and the headwaters of the Colorado River above the Town of Kremmling. Grand Counties' primary population centers are located along the Fraser River to the northwest of the Winter Park Ski Area, the Granby area near the confluence of the Fraser and Colorado Rivers, the Grand Lake area to the north of Granby, and the towns of Hot Sulphur Springs and Kremmling.

The current population of Grand County is about 12,500 people. During the last decade, Grand County has experienced an average population growth rate of over 4% per year making it one of the fastest growing counties in Colorado.

Historically, the economy of Grand County was based primarily on agriculture and mining. More recently, the economy of the county has shifted to summer and winter recreation along with associated development activity. Approximately 65% of the land area is public land, which is primarily National Forest System land administered by the USDA Forest Service. The Winter Park and Silver Creek ski areas are popular destination for skiers and snowboarders.

Based upon the Grand County population centers and the locations of water storage reservoirs and diversion systems, PACSM results are presented below for the following sub-basins: the Fraser River above Fraser, the Fraser River below Fraser, the Colorado River above the Fraser River Confluence, the Colorado River below the Fraser and above Kremmling, and the Colorado River below Kremmling. Table 3.8 below provides a summary overview of the issues identified for each sub-basin and a more detailed discussion of the issues.

Table 3.8 Grand County Issues Summary

Stream Reach or Sub-basin	In-basin Water Suppliers	Out-of-basin Water Diversions	Locations of Interest	Issues
Fraser River above Fraser	Winter Park Snowmaking Winter Park Rec. Winter Park W&S Dist. Grand County W&S Dist.	Denver/Moffat Collection System	Fraser R above Denver div. Fraser R near Winter Park Fraser R below Vasquez Creek Moffat Tunnel	❑ Small occasional shortages for Grand County W&S for PACSM 1 and large shortages for PACSM 2,3&4 ❑ Occasional small shortages for Winter Park W&S for PACSM 1 and potential large shortages under PACSM 2,3&4 ❑ Flow below Vasquez Ck under CWCB ISF and fish minimum for PACSM 1,2,3&4 ❑ Flows often below Wastewater Treatment Plant 1-day, 3-year low flow (1E3) in Sep – Apr for PACSM 1,2,3&4 ❑ Emergency water supply sources needed in case of contamination of upper Fraser River
Fraser River below Fraser	Town of Fraser (wells located in Fraser) Winter Park West W & S Town of Granby Silver Creek Resort	Denver/Moffat Collection System	Fraser R. below St Louis Creek Fraser River at Granby Gage	❑ Small shortages for Town of Fraser and Silver Creek Resort, mostly in December ❑ Possible occasional small shortages for Winter Park West W&S ❑ Flows below St Louis Ck below CWCB ISF and fish minimum in fall under PACSM 1, and below CWCB ISF and fish minimum in fall and winter under PACSM 2,3&4 ❑ Flows below St Louis Ck often below WWTP 1E3 and 30E3 in July through February under PACSM 1,2,3&4 ❑ Flows below Granby below WWTP 1E3 during September and October

Stream Reach or Sub-basin	In-basin Water Suppliers	Out-of-basin Water Diversions	Locations of Interest	Issues
Colorado River above Fraser River Confluence	Columbine Lake Water District Town of Grand Lake	Northern/CB-T	Lake Granby Colorado R below Lake Granby Willow Creek Reservoir Willow Creek	❑ Higher water levels in Lake Granby due to increases in Windy Gap pumping under PACSM 2,3,&4. Possible nutrient loading increase could impact trophic status of reservoir ❑ Flows below Lake Granby frequently below CWCB instream flow, fish minimum and optimum in August through March under all scenarios when inflows are less than criteria levels
Colorado River below Fraser River and above Kremmling	Hot Sulphur Springs	Denver/Moffat Collection System Denver/Williams Fork Collection System Northern/CB-T Northern/Windy Gap	Windy Gap diversions Colorado R below Windy Gap Colorado R below Williams Fork Williams Fork Reservoir Williams Fork below Reservoir Colorado R below Troublesome	❑ Hot Sulphur Springs shortages in July (4 cfs demand exceeds 3.3 cfs right) under PACSM 2,3&4 ❑ Flows below Windy Gap frequently below CWCB instream flow (90 cfs) in August – March under PACSM 1,2,3&4 ❑ Flow below Windy Gap usually below Fish minimum (125 cfs) in July – April under PACSM 1,2,3&4 ❑ Flows below Windy Gap usually below Kayak minimum (300 cfs) in June under PACSM 1,2,3,&4 ❑ Flow below Williams Fork below CWCB instream flow (135 cfs) summer and fall under PACSM 1,2,3&4 ❑ Low flow / high temperature below Windy Gap

Stream Reach or Sub-basin	In-basin Water Suppliers	Out-of-basin Water Diversions	Locations of Interest	Issues
Colorado River below Kremmling	Kremmling	Denver/Moffat Collection System Denver/Williams Fork Collection System Northern/CB-T Northern/Windy Gap Denver/Roberts Tunnel Golden/Vidler Tunnel Colorado Springs/ Hoosier Tunnel	Wolford Mountain. Reservoir Muddy Creek below Wolford Mountain. Reservoir Colorado River at Kremmling	❑ Town of Kremmling demand exceeds 1 cfs water right during March and April under PACSM 2,3,&4 ❑ Duration of period in May – July when Colorado River at Kremmling is at or above the Kayak and Raft optimum flow (1,100 cfs). This period would be shorter under PACSM 2,3,&4

Fraser River above Fraser

Streamflows in the Fraser River above the Town of Fraser are impacted by Denver Water's Moffat Tunnel Collection System, Berthoud Pass Tunnel diversions and in-basin diversions for the Town of Winter Park, the Winter Park Ski Area, and surrounding commercial and residential development. Wastewater return flows accrue to the Fraser River in the Town of Winter Park. The primary locations of interest in this sub-basin area are the Moffat Tunnel, the Fraser River above Denver's diversion, the Fraser near Winter Park, and the Fraser River below Vasquez Creek. PACSM results indicate the following issues:

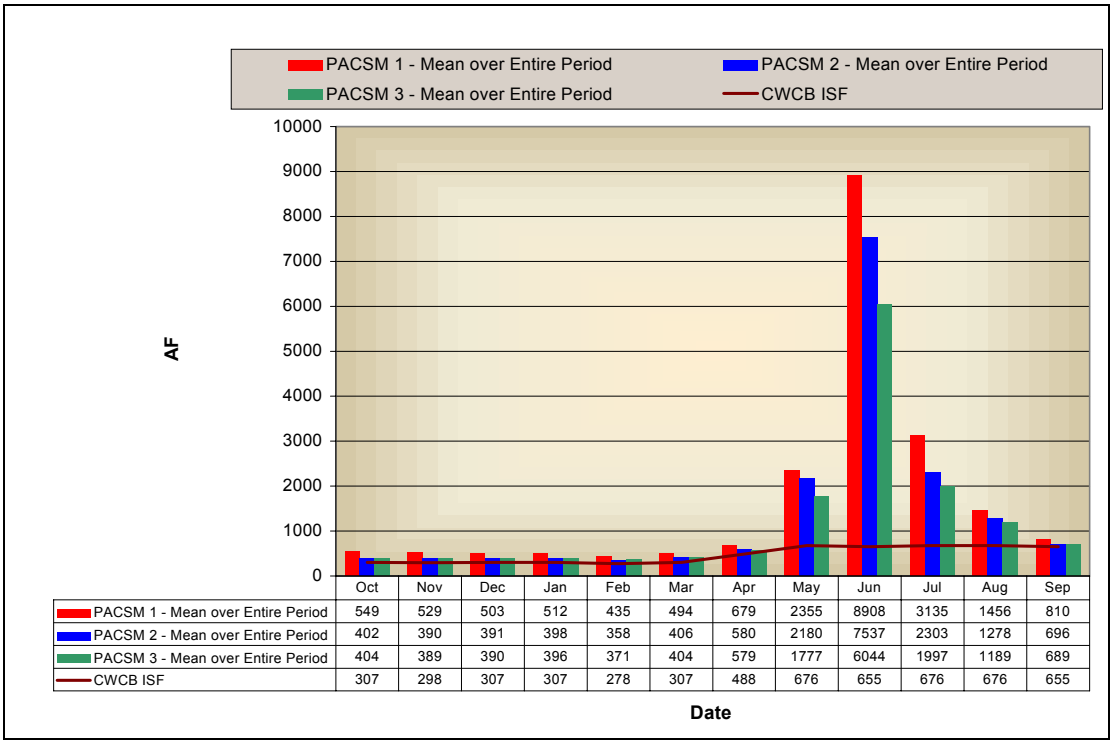
In-basin water supply issues: Water supplies for the Grand County Water & Sanitation District, the largest water user in this sub-basin area, appear to be adequate under existing demand conditions. However, modeling results do indicate occasional small shortages during fall, winter and early spring months. Under all PACSM future demand scenarios, shortages range from an annual minimum of 616 acre-feet to 1,903 acre-feet per year and occur in all years.

The model indicates occasional shortages for the Winter Park Recreation Association and the Winter Park Water & Sanitation District under existing demand conditions that occur primarily during the months of July, August, and September. Under existing conditions, these shortages are rare and range from 1 to 23 acre-feet per year. Under future scenarios there would be a significant increase in the frequency and amount of water shortages occurring in late summer and winter months with annual shortfalls ranging from 6 to 204 acre-feet.

Water supplies for Winter Park snowmaking appear to be adequate under existing water demand conditions. Model results indicate possible shortages under future demands occurring primarily during the month of February and, in dry years like 1987 during the months of October and November. It is unlikely that these shortages are significant because snowmaking operations are typically minimal during October and are usually concluded by the end of January.

An additional water supply issue in the upper Fraser River Basin is needed for emergency water supply sources in case of contamination of the river due to an accident on Berthoud Pass resulting in the discharge of hazardous materials.

In-stream flow issues: Flows in the Fraser River above Fraser would be reduced during the fall and winter by about 2 cfs under future demand scenarios due primarily to increases in diversions for snowmaking, domestic and commercial uses at the Winter Park Ski Area, the Town of Winter Park and surrounding areas. During the spring and early summer months, peak flows would be reduced substantially due primarily to increases in diversions to the Front Range by the Moffat Tunnel Collection System, as illustrated in Figure 3.1.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PACSM 1 - Mean over Entire Period	549	529	503	512	435	494	679	2355	8908	3135	1456	810
PACSM 2 - Mean over Entire Period	402	390	391	398	358	406	580	2180	7537	2303	1278	696
PACSM 3 - Mean over Entire Period	404	389	390	396	371	404	579	1777	6044	1997	1189	689
CWCB ISF	307	298	307	307	278	307	488	676	655	676	676	655

Figure 3.1 Fraser River below Vasquez Creek, average monthly flow volumes.

Stream flows under all scenarios would be equal to and occasionally below the CWCB instream flow levels during the winter (5 cfs) and frequently below the summer season (4/15 – 9/15) CWCB instream flow (11 cfs) for one or two weeks during the October and April shoulder months. Fraser River flows below Vasquez Creek would usually be well below the minimum and optimum fish flow levels, 9 cfs and 12.5 cfs respectively, during the months of October through March under all PACSM scenarios.

Water quality issues: Under current water demands, flows in the Fraser River below Vasquez Creek are occasionally below the wastewater treatment plant 1-day, 3-year low flow levels used for determining the wasteload allocations for the Grand County Water & Sanitation District treatment plant. Under future demand scenarios, flows would often be below the 1-day, 3-year low flow levels, particularly during the months of October through December (Figure 3.2).

Water quality impacts related to Berthoud Pass, though not specifically examined in this study, emerged as issues. This includes water quality impacts related to winter sanding operations on Berthoud Pass and the potential for an accident of a truck carrying hazardous materials on Berthoud Pass. The latter could significantly affect water supply in the upper part of the Fraser River.

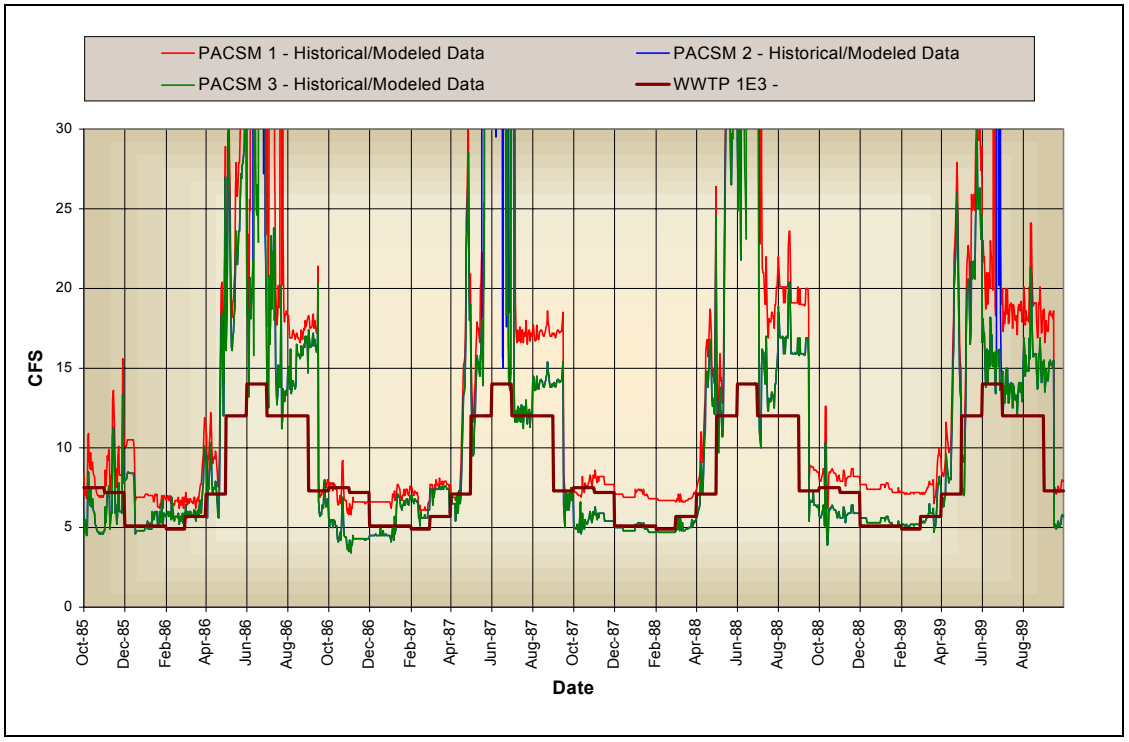


Figure 3.2 Fraser River below Vasquez Creek, average daily flows

Fraser River below Fraser

Streamflows in the Fraser River below the Town of Fraser are impacted by Denver Water's Moffat Tunnel Collection System, in-basin diversions for areas above Fraser, the Town of Fraser, the Winter Park West Water & Sanitation District, the Town of Granby and the Silver Creek Resort. Wastewater return flows accrue to the Fraser River below the Town of Fraser, below the Town of Tabernash, and below Granby. The primary locations of interest in this sub-basin area are the Fraser River St Louis Creek, and the Fraser at Granby (USGS gaging station). PACSM results indicate the following issues:

In-basin water supply issues: Water supplies for the Town of Fraser, the Winter Park West Water & Sanitation District, the Town of Granby and the Silver Creek Resort appear to be adequate under existing demand (PACSM 1) conditions. Under all PACSM future demand scenarios (PACSM 2, 3, and 4), water supplies for the Town of Granby appear to be adequate, while shortages ranging from an annual minimum of 7 acre-feet to 68 acre-feet per year are indicated for the Town of Fraser and the Silver Creek Resort. These shortages would occur in every year during the month of December and in years like 1984 during March and November. The model also indicates some small infrequent shortages could occur for the Winter Park West Water & Sanitation District under future demand scenarios.

Instream flow issues: Under current demand conditions, streamflows in the Fraser River below St. Louis Creek were usually well above the CWCB instream flow level (5 cfs 9/16-45/14, 17 cfs 5/15-9/15) except during late September. Under future demand scenarios, streamflows during the months of October through January would frequently

be 1 to 3 cfs below the CWCB instream flow level. These flow reductions were due primarily to in-basin diversions to meet buildout demands (Figure 3.3).

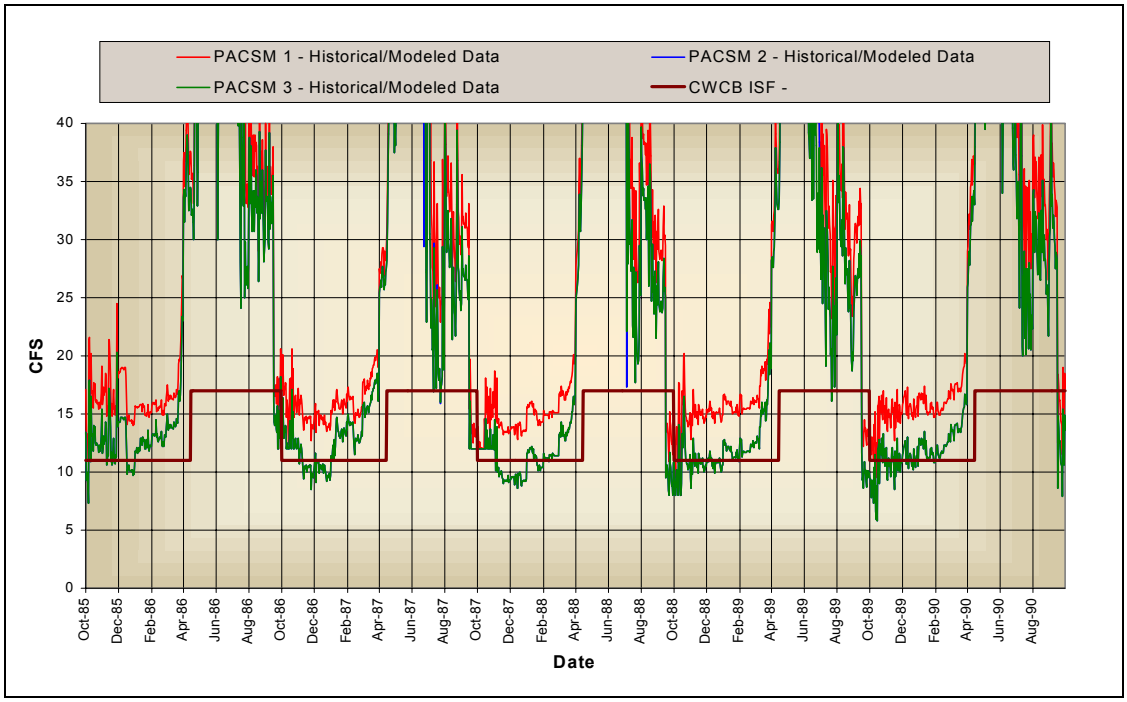


Figure 3.3 Fraser River below St Louis Creek

Streamflows in the Fraser River at Granby, under all PACSM scenarios, during the fall and winter months were generally more than double the flows at the upstream location of interest below St. Louis Creek due to irrigation and wastewater return flows. Flows were usually well above the CWCB instream flow levels (19 cfs 10/1-4/14 and 30 cfs 4/15-9/30) except during late September for one or two weeks leading up to October 1st when the CWCB instream flow water right is reduced from 30 cfs to 19 cfs.

Water quality issues: Under current water demands, flows in the Fraser River below St. Louis Creek were occasionally below the wastewater treatment plant 1-day and 30-day, 3-year low flow levels used for determining the wasteload allocations for the Fraser Water & Sanitation District wastewater treatment plant. Under future demand scenarios, flows would often be below the 1-day and 30-day, 3-year low flow levels, during the months of July through February.

Under current and all of the future demand scenarios, flows in the Fraser River at Granby during September and October would be below the wastewater treatment plant 1-day, 3-year low flow levels used for determining the wasteload allocations for the Granby Water & Sanitation District wastewater treatment plant.

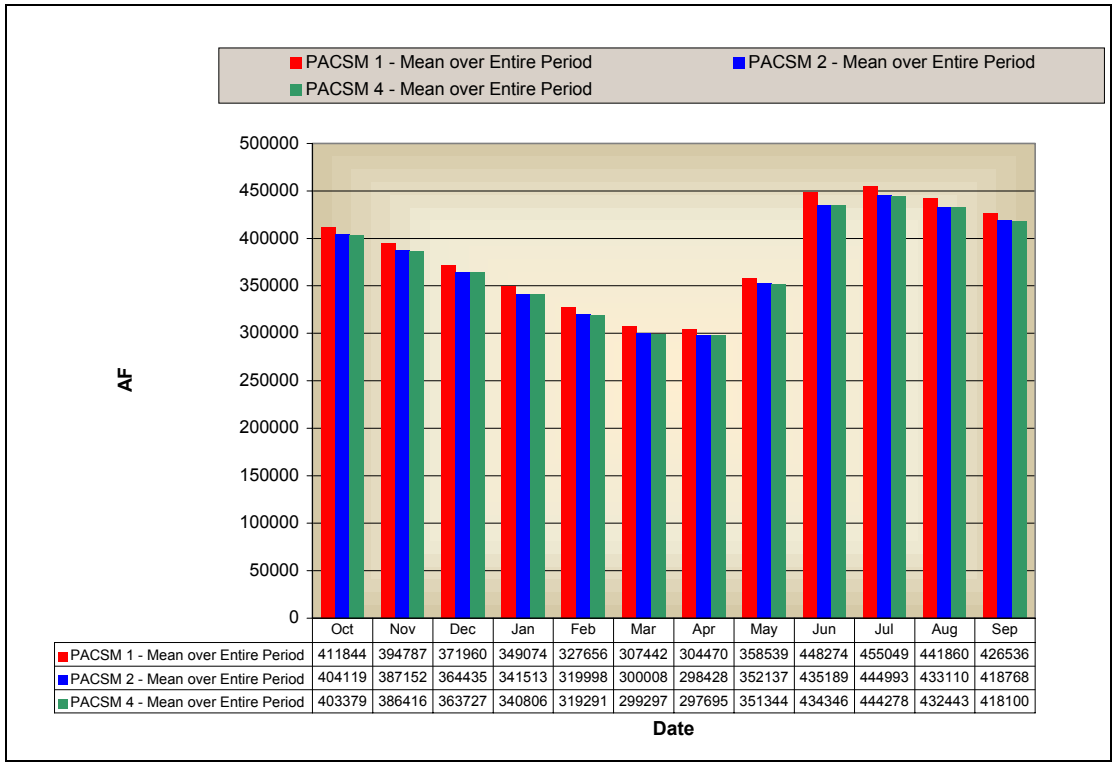
Colorado River above the Fraser River Confluence

Streamflows in the Colorado River above the Fraser River are impacted by CB-T operations and in-basin diversions for the Columbine Lake Water District and the Town

of Grand Lake. Wastewater and return flows accrue to Willow Creek below Willow Creek Reservoir. The primary locations of interest in this sub-basin area are Lake Granby, the Colorado River below Lake Granby, Willow Creek Reservoir and Willow Creek below Willow Creek Reservoir. PACSM results indicate the following issues:

In-basin water supply issues: Water supplies for the Columbine Lake Water District and the Town of Grand Lake appear to be adequate under all current and future demand scenarios.

Lake Granby Reservoir level issues: End of month storage contents in Lake Granby would be slightly lower under future PACSM scenarios due to increases in Windy Gap deliveries, as shown in Figure 3.4. No reservoir level criteria have been established for evaluation of this impact.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PACSM 1 - Mean over Entire Period	411844	394787	371960	349074	327656	307442	304470	358539	448274	455049	441860	426536
PACSM 2 - Mean over Entire Period	404119	387152	364435	341513	319998	300008	298428	352137	435189	444993	433110	418768
PACSM 4 - Mean over Entire Period	403379	386416	363727	340806	319291	299297	297695	351344	434346	444278	432443	418100

Figure 3.4 Lake Granby end of month contents.

Instream flow issues: In PACSM, the minimum of either the CWCB instream flow levels (20 cfs 9/1-4/30 and 40 cfs 5/1-8/31) or the natural inflow to Lake Granby is bypassed. Historical gage data indicates flows have usually been at or slightly below the CWCB instream flow during September through April and above the CWCB flow in May through August. Historically, flows have been below the Fish minimum (30 cfs) and optimum (45 cfs) during the months of August through April, as shown in Figure 3.5. Outflows from Granby will not change significantly under future demand scenarios.

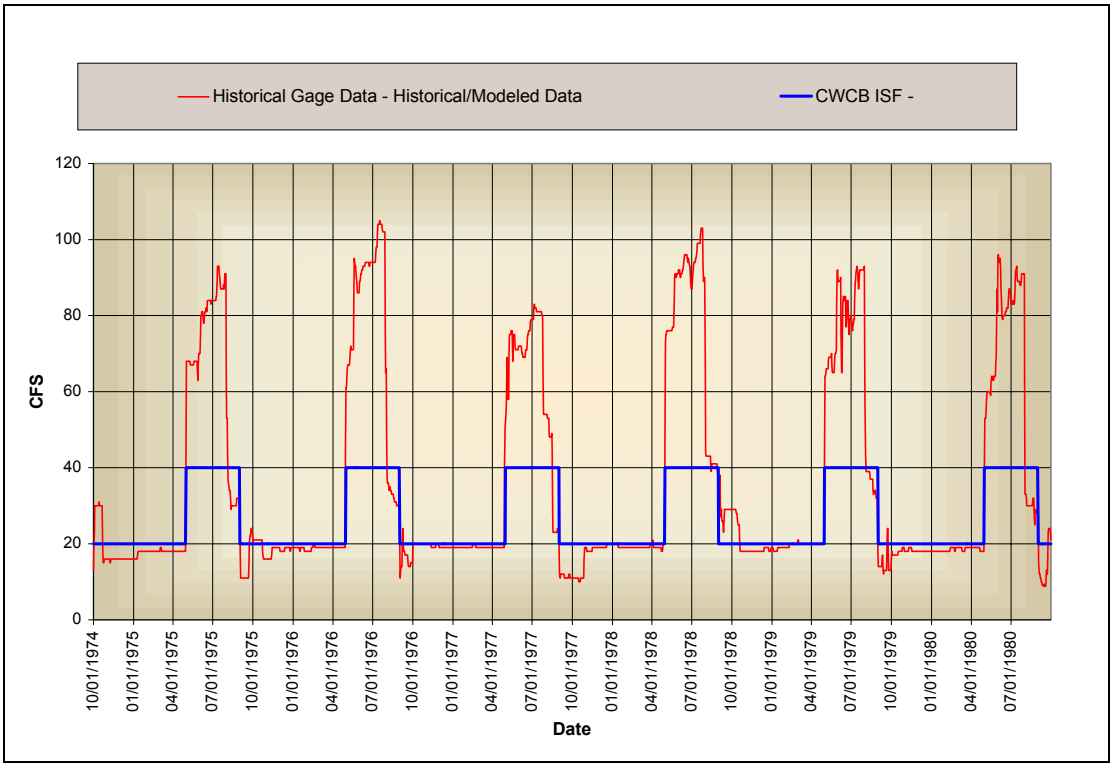


Figure 3.5 Colorado River below Lake Granby

Water quality issues: Increased pumping of water from the Colorado River at Windy Gap would result in an increase in nutrient loading to Lake Granby. Lake Granby water quality issues are being addressed in a separate investigation, the Three Lakes Clean Lakes Study.

Colorado River below the Fraser and above Kremmling

Streamflows in the Colorado River below the Fraser River confluence and above Kremmling are impacted by CB-T operations, Windy Gap diversions, the Moffat Tunnel Collection System (including the Williams Fork Collection System), upstream in-basin water users and the Town of Hot Sulphur Springs. Wastewater return flows from Hot Sulphur Springs are discharged to the Colorado River to the west of the town. The primary locations of interest in this sub-basin area are Windy Gap diversions, the Colorado River below Windy Gap, the Colorado River below the Williams Fork, Williams Fork Reservoir, the Williams Fork River below the reservoir, and the Colorado River below Troublesome Creek. PACSM results indicate the following issues:

In-basin water supply issues: Water supplies for the Town of Hot Sulphur Springs appear to be adequate under current demands. Under the future demand scenarios, the model indicated a shortage of 41 acre-feet during the month of July when the Town's 3.3 cfs water right would not be sufficient to meet the projected demand of 4.0 cfs. The development area that would generate this future level of demand is currently outside of the Hot Sulphur Springs town boundary, and there seems to be some uncertainty as to the likelihood of this future development.

Instream flow issues: Under all PACSM scenarios for current and future water demands, streamflows in the Colorado River below Windy Gap would be below the CWCB instream flow (90 cfs) during the months of August through March, as shown in Figure 3.6. Flows below Windy Gap under all PACSM scenarios would also be below the Fish Minimum flow level (125 cfs) during the months of July through April in most years and below the Kayak Minimum level (300 cfs) through most of the month of June in most years.

It is important to note that the Windy Gap pumping is limited primarily to the May through June timeframe and therefore does not affect the river during periods when flows are below the CWCB instream flow and Fish Minimum flow levels. Windy Gap operations under future demands, however, could result in Colorado River flows that would be below the Kayak Minimum level more frequently in June than has occurred historically.

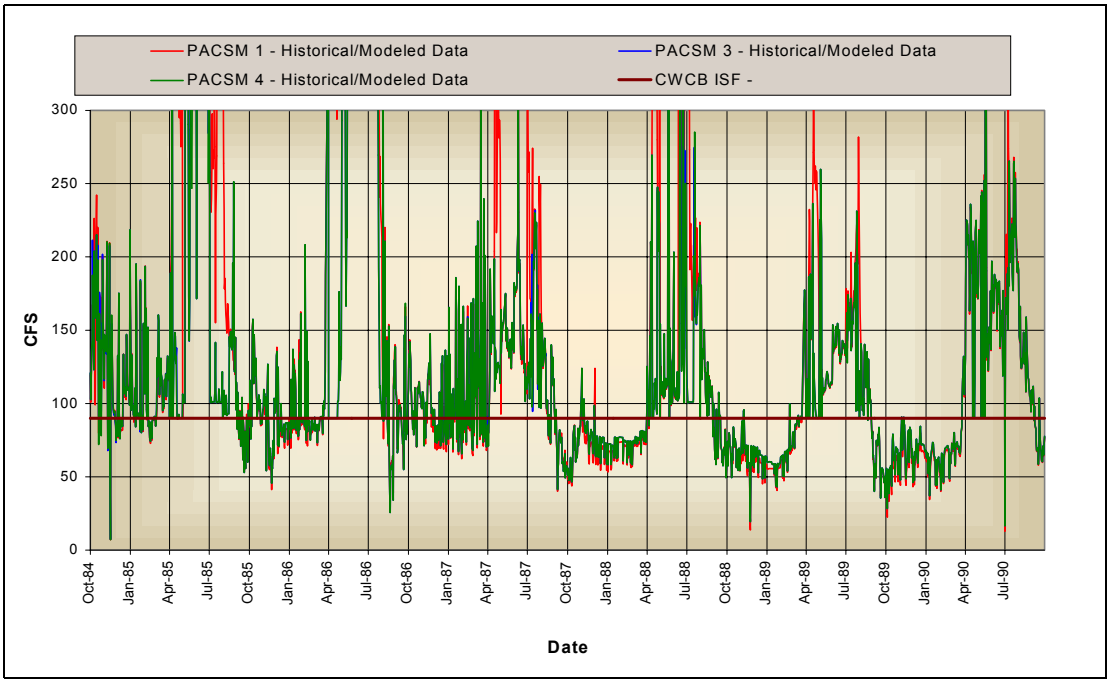


Figure 3.6 Colorado River below Windy Gap, average daily flow.

Flows in the Colorado River above Williams Fork, under all PACSM scenarios, would usually be below the CWCB instream flow level (135 cfs) during the winter low flow months of December through February and occasionally during the late summer and fall. The duration of these shortages would be less than the shortages shown above in Figure 3.6 due to releases from William Fork Reservoir during the winter.

As shown in Figure 3.7, streamflows in the Williams Fork below Williams Fork Reservoir under current and future demand conditions were often below the fish minimum flow of 50 cfs during the summer and fall months and occasionally in the early spring. Under all of the current and future demand PACSM scenarios, streamflows below Williams Fork Reservoir would tend to be higher than under historical conditions

during the months of June through October and lower during November through May. As demands on the Denver system increase, more replacement water would be released from Williams Fork Reservoir for exchanges up the Blue River and replacement of Moffat Tunnel Collection System diversions. Streamflows would often be above the Fish Optimum level (200 cfs) in the late summer and early fall due to reservoir releases. Flow levels above the Fish Maximum (450 cfs) would occur only during reservoir spills which usually occur in June. The frequency and duration of spills would be reduced under future demand scenarios.

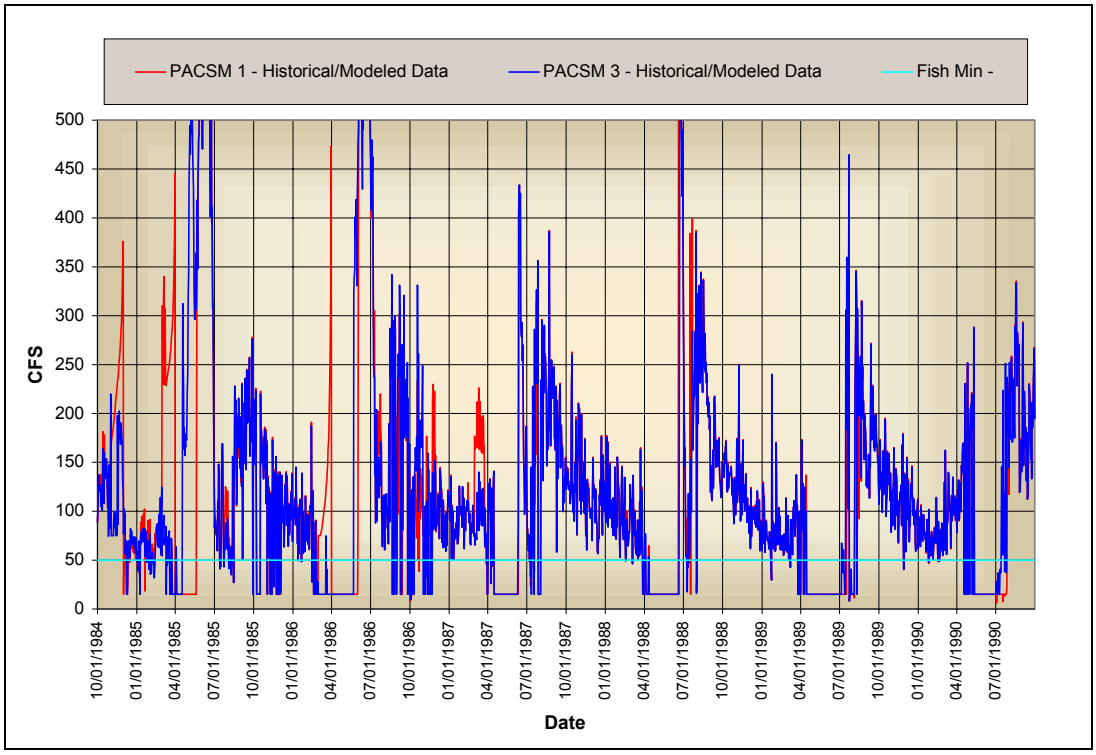


Figure 3.7 Williams Fork River below Williams Fork Reservoir, average daily flows.

Under all demand scenarios, streamflows in the Colorado River below Troublesome Creek would be generally well above the CWCB instream flow (150 cfs), with the exception of some occasional one or two day events during winter low flows in some years.

Water quality issues: Available data indicates that water quality in the Colorado River below the Fraser River and above Kremmling meets all applicable stream standards. However, during low flow conditions in the stream segment below Windy Gap and above the Williams Fork, water temperatures in the late summer and early fall often exceed 70° F, which is above the maximum temperature level that can be tolerated by trout. Low streamflows and elevated temperatures may contribute to the whirling disease problem found in this section of the Colorado River.

Colorado River below Kremmling

Streamflows in the Colorado River below Kremmling are impacted by all of the out-of-basin and in-basin water supply facilities previously described for the Blue River, Fraser River and Upper Colorado River basins. The Town of Kremmling diverts water from Sheep Creek and the Colorado River at the confluence of Sheep Creek. Wastewater return flows from the Town of Kremmling are discharged to Muddy Creek southwest of Kremmling. The primary locations of interest in this sub-basin area are Wolford Mountain Reservoir, Muddy Creek below Wolford Mountain Reservoir, and the Colorado River at Kremmling (USGS gaging station).

In-basin water supply issues: Water supplies for the Town of Kremmling appear to be adequate under current demands. Under the future demand scenarios, the model indicates a total shortage of 18 acre-feet during the months of March and April when the Town's demand exceeds its 1.0 cfs water right.

Instream flow issues: Streamflows in the Colorado River below Kremmling were typically well above the Kayak and Raft Minimum levels (400 cfs). This condition would continue under future demand scenarios, but the duration of periods in the May through July time frame when flows would be at or above the Kayak and Raft Optimum level (1,100 cfs) would be reduced (Figure 3.8).

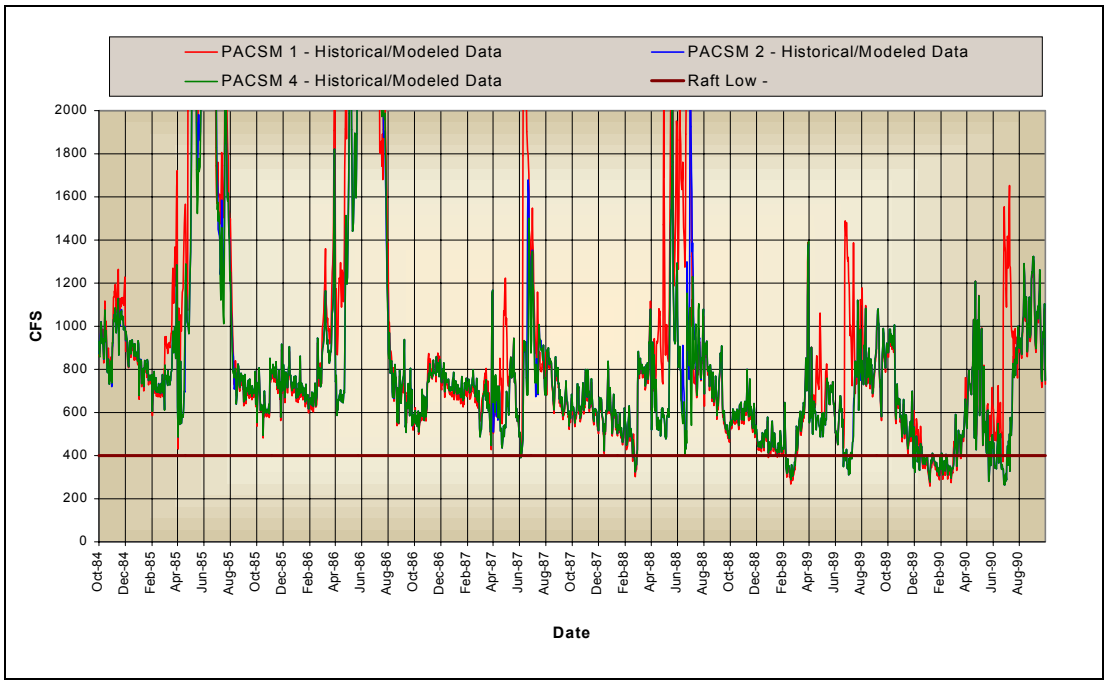


Figure 3.8 Colorado River below Kremmling, average daily flows.

Under future demand scenarios (PACSM 2, 3, and 4), streamflows in Muddy Creek below Wolford Mountain Reservoir would be higher than under current demands (PACSM 1) by an average of about 18 cfs during the months of July through March. This increase was due to releases from Wolford Mountain Reservoir for Denver Water's substitution for water diverted at Dillon Reservoir and for augmentation requirements

associated with demand increases on in-basin water supply systems. No instream flow or reservoir level criteria have been established for Muddy Creek and Wolford Mountain Reservoir.

3.3.2 Summit County

3.3.2.1 Overview of Physical Setting and Issues

Summit County is entirely within the Blue River Basin to the west of the Continental Divide and is easily accessible from the Front Range metro Denver area via I-70 which enters the County from the east at the Eisenhower Tunnel and leaves the county to the west at Vail Pass. Summit County has four primary population centers at the towns of Breckenridge, Dillon, Frisco and Silverthorne, with most of its 24,000 residents living in surrounding unincorporated areas. During the 1970 through 1980 period, Summit County was the fastest growing county in the United States, and it has been one of he fastest growing counties in Colorado for the last 20 years. During the peaks of the winter skiing/snowboarding season, which occur during weekends and holidays in December and March, the peak population is estimated to reach over 110,000 people (Summit County 2002).

The natural setting of Summit County is ideal for many summer and winter recreational pursuits including skiing, hiking, fishing, boating, river rafting and kayaking, and golf. Approximately 73% of Summit County is public land, most of which is National Forest System land administered by the USDA Forest Service. Four major ski areas are located in Summit County: Arapahoe Basin, Breckenridge, Copper Mountain, and Keystone. During the summer months, Dillon and Green Mountain Reservoirs provide extensive boating and fishing opportunities and the Blue River is a major attraction for fishing, rafting and kayaking, though its Gold Medal fishery status is currently in jeopardy. The Eagle Nest Wilderness and other areas in the Arapaho National Forest are heavily used for hiking, backpacking and site seeing.

Based upon the Summit County population centers and the locations of water storage reservoirs and diversion systems, PACSM results are presented below for the following sub-basins: the Blue River above Dillon Reservoir; Tenmile Creek; the Snake River; Dillon Reservoir; the Blue River below Dillon; and Green Mountain Reservoir and the Blue River below Green Mountain. Table 3.9 below provides a summary overview of the issues identified for each Summit County sub-basin, followed by a more detailed discussion of the issues.

Table 3.9 Summit County Issues Summary

Stream Reach or Sub-Basin	In-Basin Water Suppliers	Out-of-Basin Water Diversions	Locations of Interest	Issues
Blue River above Dillon Reservoir	Town of Breckenridge Breckenridge Ski Area Breckenridge Golf Course	Colorado Springs/Hoosier Tunnel	Blue River Below French Gulch Blue River near Dillon	❑ Breckenridge Golf Course shortages under PACSM 1,2,3&4 ❑ Blue River below French Gulch winter flows 1 to 2 cfs lower in PACSM 2,3,&4 than PACSM 1 due to in-basin diversion increases ❑ Potential water supply shortages for dispersed usage above Dillon ❑ Flows below wastewater treatment plant 1E3 and 30E3 under PACSM 1,2,3&4 ❑ Potential impacts to Breckenridge Kayak Course ❑ Persistent exceedences of aquatic life standards for cadmium, copper, lead, and zinc and elevated total dissolved solids in Blue River below French Gulch, some exceedence of standards for zinc in Blue Rive below Swan River

Stream Reach or Sub-Basin	In-Basin Water Suppliers	Out-of-Basin Water Diversions	Locations of Interest	Issues
Tenmile Creek above Dillon Reservoir	Copper Mountain Village Copper Mountain. Golf Course Copper Mountain. Ski Area Town of Frisco	None	Tenmile Creek below West Tenmile Creek	❑ PACSM 1 frequent small shortages in Apr/May and Jul/Sep for Golf Course and frequent shortages for Copper Mountain Water & Sanitation District ❑ PACSM 2,3&4 frequent small shortages and occasional large shortages for all uses ❑ Fall, winter and early spring flows frequently below CWCB instream flow for all PACSM scenarios ❑ Fall and winter flows occasionally below 1E3 and 30E3
Snake River above Dillon Reservoir	A-Basin Snowmaking Keystone-Montezuma Domestic Keystone Mountain Snowmaking Keystone Gulch Keystone Golf Course Keystone Ranch Snake River Water District East Dillon Water District	Golden/Vidler Tunnel	Snake River near Montezuma Gage below North Fork confluence	❑ PACSM 2,3,&4 water supply shortages for A-Basin snowmaking, Keystone-Montezuma Domestic, Keystone Snowmaking, Keystone Gulch and East Dillon Water District ❑ Persistent exceedences of aquatic life standard for zinc and occasional exceedences of standards for cadmium and copper

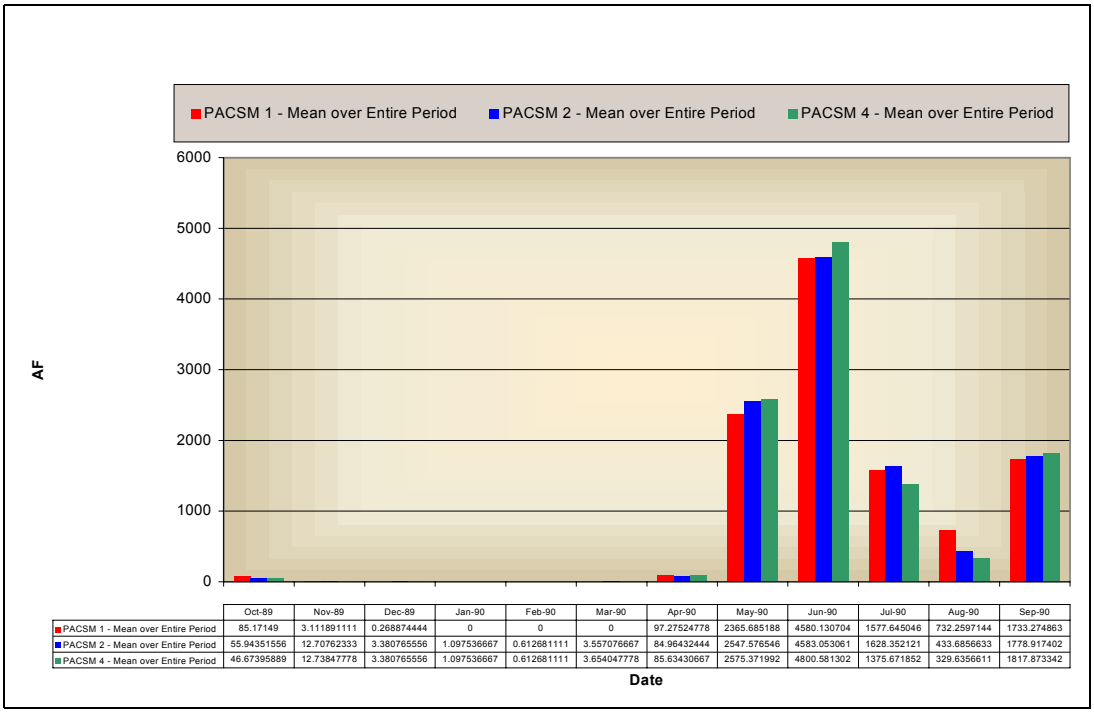
Stream Reach or Sub-Basin	In-Basin Water Suppliers	Out-of-Basin Water Diversions	Locations of Interest	Issues
Dillon Reservoir		Denver/Roberts Tunnel Colorado Springs/ Hoosier Tunnel Golden/Vidler Tunnel	Dillon Reservoir Roberts Tunnel	❑ Historically, reservoir below Frisco marina minimum in 11 out of 26 years ❑ Under PACSM 1, reservoir below Frisco marina minimum 19 out of 26 years ❑ Under PACSM 2, reservoir below Frisco marina minimum 21 out of 26 years ❑ Under PACSM 3, reservoir below Frisco marina minimum in 21 out of 26 years ❑ Under PACSM 4, reservoir below Frisco marina minimum in 24 out of 26 years
Blue River below Dillon Reservoir	Town of Frisco Town of Silverthorne Town of Dillon Buffalo Mountain/ Mesa Cortina Eagles Nest	Denver/Roberts Tunnel Colorado Springs/ Hoosier Tunnel Golden/Vidler Tunnel	Blue River below Dillon Reservoir Straight Creek below Laskey Gulch Blue River below Rock Creek	Blue River below Dillon: ❑ PACSM 2,3&4, increased frequency and duration of flows at 50 cfs (CWCB instream flow) and below Fish minimum (55 cfs) below Dillon Reservoir ❑ PACSM 2,3&4 flows often below Kayak low flow Blue River below Rock Creek: ❑ PACSM 2,3&4 flows often below CWCB instream flow in fall winter and early spring ❑ PACSM 3&4 flows often below Kayak low and Raft low flows

Stream Reach or Sub-Basin	In-Basin Water Suppliers	Out-of-Basin Water Diversions	Locations of Interest	Issues
Green Mountain Reservoir and Blue River below Green Mountain	None	Denver/Roberts Tunnel Colorado Springs / Hoosier Tunnel Golden/Vidler Tunnel	Green Mountain Reservoir Blue River below Green Mountain Reservoir Blue River at mouth	❑ Flows usually meet CWCB instream flow and Fish minimum for all PACSM scenarios ❑ Flows during August and September often 250 to 300 cfs below Kayak optimum (500 cfs) under PACSM 1,2,3,&4

Blue River above Dillon Reservoir

Streamflows in the Blue River above Dillon Reservoir are currently impacted by the Hoosier Tunnel transmountain diversion (Colorado Springs) and in-basin diversions for the Town of Breckenridge, the Breckenridge Golf Course, and Breckenridge Ski Area snowmaking, domestic and commercial uses. Wastewater and return flows accrue to the Blue River above Dillon Reservoir. The primary locations of interest in this sub-basin area are the Hoosier Tunnel, the Blue River below French Gulch and the Blue River just above Dillon Reservoir. PACSM results indicate the following issues:

In-basin water supply issues: Water supplies for the Town of Breckenridge and the Breckenridge Ski Area, the largest water users in this sub-basin area, appear to be adequate under all PACSM scenarios. The model indicated shortages for the Breckenridge Golf Course under all four scenarios, primarily during the months of May, June, September and October. Under existing conditions, these shortages would occur to some extent in most years and vary from 1 to 50 acre-feet per year. Under future scenarios, shortages vary from 1 to 88 acre-feet per year. Under future conditions, there would be a small reduction in Hoosier diversions during the months of April, July, August and October and a small increase in diversions during May, June and September as shown below in Figure 3.9.



	Oct-89	Nov-89	Dec-89	Jan-90	Feb-90	Mar-90	Apr-90	May-90	Jun-90	Jul-90	Aug-90	Sep-90
PACSM 1 - Mean over Entire Period	85.17149	3.111891111	0.268874444	0	0	0	97.27524778	2365.685188	4580.130704	1577.645046	732.2597144	1733.274863
PACSM 2 - Mean over Entire Period	55.94351556	12.70762333	3.380765556	1.097536667	0.612681111	3.557076667	84.96432444	2547.576546	4583.053061	1628.352121	433.6856633	1778.917402
PACSM 4 - Mean over Entire Period	46.67395889	12.73847778	3.380765556	1.097536667	0.612681111	3.654047778	85.63430667	2575.371992	4800.581302	1375.671852	329.6356611	1817.873342

Figure 3.9 Hoosier Tunnel Mean Monthly Flow Volumes (1947-91).

Under current and future scenarios there could be water supply shortages for dispersed domestic usage above Dillon in areas that are outside of the service area for the Town of Breckenridge. Summit County has recently developed an augmentation plan for these

water users, but the adequacy of their physical and legal supplies has not been evaluated in the context of UPCO.

In-stream flow issues: Flows in the Blue River below French Gulch (Figure 3.10) would be reduced during the fall and winter by 1 to 2 cfs under future scenarios due to increases in diversions for snowmaking at the Breckenridge Ski Area and increased diversions for domestic use by the Town of Breckenridge. The only instream flow criteria applicable to this reach of the Blue River were kayaking flows and wastewater treatment plant low flows.

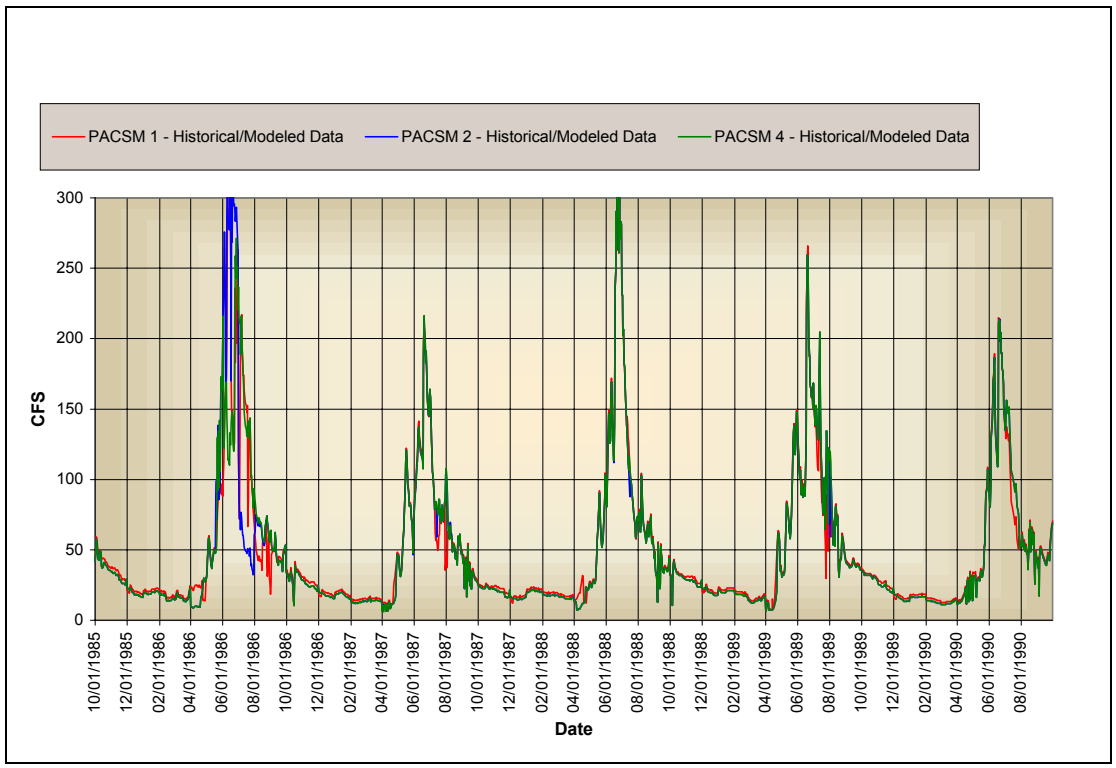


Figure 3.10 Blue River below French Gulch average daily flows.

Under all PACSM scenarios, streamflow for the Breckenridge kayak course during the months of June and July were usually be at or above the 100 cfs level that is considered the minimum amount needed for satisfactory recreational features at the white water park. However, the peak flows were usually 100 to 300 cfs less than the 500 cfs or higher flows that are considered to be the optimum design flows for the white water park.

Water Quality: Existing water quality conditions in the Blue River below French Gulch indicate persistent exceedences of aquatic life Table Value Standards (TVS) for trace metals including cadmium, copper, lead and zinc. Concentrations of total dissolved solids (TDS) were also elevated. The primary source of this contamination is acid drainage from abandoned mines in the French Creek drainage. The Blue River above French Gulch and other tributary inflows provide dilution water that reduces

concentrations at locations downstream. Below the confluence of the Swan River metals concentrations met TVS except for occasional exceedences for dissolved zinc.

Under current and future water demands, flows in the Blue River below French Gulch were usually well below the 1-day 3-year (18 cfs) and 30-day 3-year (20 cfs) low flow level used for determining the wasteload allocations for the Breckenridge Sanitation District wastewater treatment plant.

Metals and TDS concentrations tend to be highest during periods of low streamflow and early spring runoff and lowest during high runoff flows that occur in May and June. Increases in water diversions for domestic and snowmaking purposes during the low flow winter months would reduce the amount of dilution water in the stream reach below French Gulch and may result in somewhat higher metals and TDS concentrations under future demand scenarios.

Tenmile Creek

Streamflows in the Tenmile Creek above Dillon Reservoir are currently impacted by in-basin diversions for Copper Mountain including the village, the Golf Course, and Ski Area snowmaking, domestic and commercial uses. Streamflows in Tenmile Creek are also affected by water storage and augmentation releases from Clinton Reservoir located on Clinton Creek near Climax. Wastewater and return flows from the Copper Mountain area accrue to Tenmile Creek below the confluence of West Tenmile Creek, and wastewater return flows from Frisco accrue to Dillon Reservoir. The primary location of interest in this sub-basin area is Tenmile Creek below West Tenmile Creek approximately two miles above Dillon Reservoir. PACSM results indicate the following issues:

In-basin water supply issues: Water supplies for the Town of Frisco, the largest water user in this sub-basin area, appeared to be adequate under all PACSM scenarios. The model indicated shortages for Copper Mountain outdoor and snowmaking uses under all four scenarios, primarily during the months of March, April, May, July, August and September. Under existing conditions, these shortages would occur to some extent in most years in April and September and vary from 1 to 39 acre-feet per year. Under future scenarios the pattern and amount of shortages during the March through September period would be about the same as under existing conditions but the maximum annual shortage increases to 99 acre-feet due primarily to occasional shortages for snowmaking during the months of December and January. The snowmaking shortages indicated by the model were rare and usually small with the exception of December 1955 (86 acre-feet) and January 1964 (24 acre-feet).

In-stream flow issues: Flows in Tenmile Creek below West Tenmile Creek (Figure 3.11) would be reduced during the fall and winter by 1 to 1.5 cfs under future scenarios due to increases in diversions for snowmaking at the Copper Mountain Ski Area and increased diversions for domestic and commercial uses. During the spring and summer months flows would be reduced up to 5 cfs due to increases in demands for domestic and commercial uses. The model indicates that during the fall and winter months in average and wet years, streamflows would occasionally drop below the CWCB instream flow and

during dry years flows would frequently be below the CWCB instream flow and the 1-day and 30-day, 3-year low flow for the Copper Mountain Wastewater Treatment Plant.

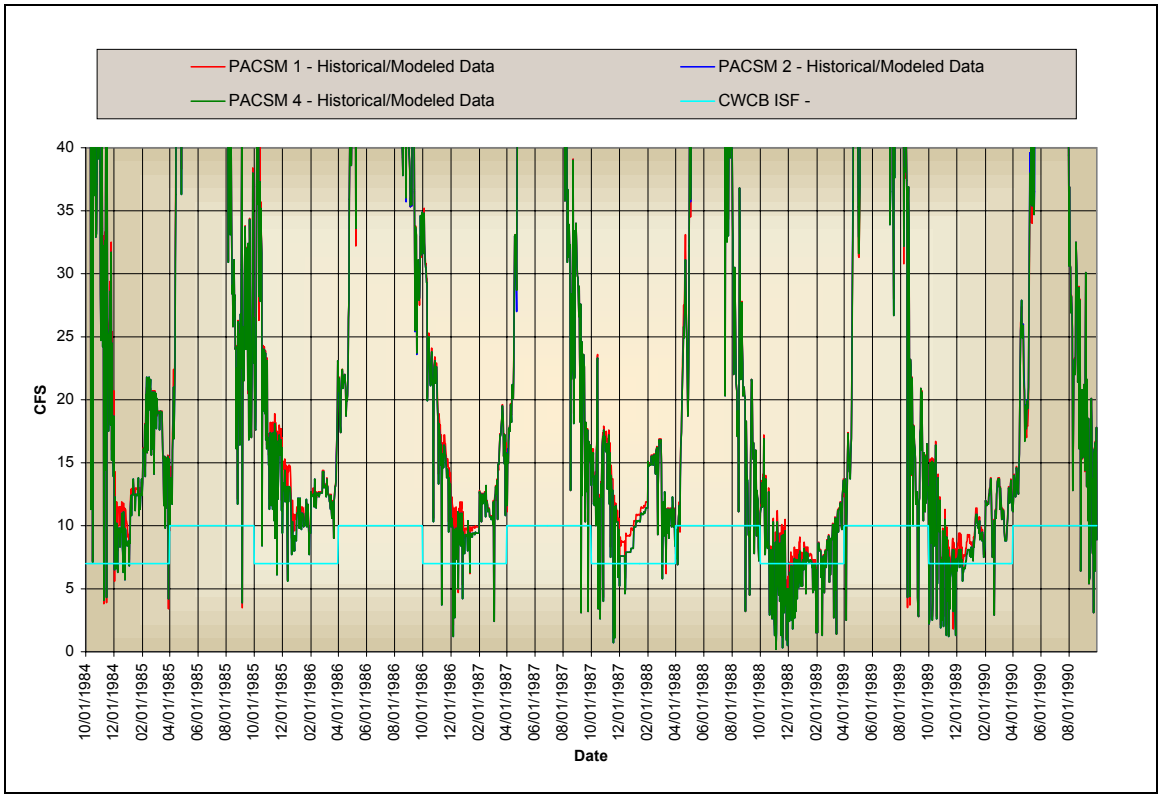


Figure 3.11 Tenmile Creek below West Tenmile Creek average daily flows.

Snake River

Streamflows in the Snake River above Dillon Reservoir are currently impacted by in-basin diversions including: Arapahoe Basin snowmaking and domestic uses; Keystone Resort snowmaking domestic, commercial, greenbelt and golf course uses; and Snake River Water District domestic, commercial and park irrigation uses; and Montezuma area domestic and commercial uses. Streamflows in the Keystone Gulch and Soda Creek tributaries of the Snake River are affected by diversions for Keystone Ranch domestic, commercial and golf course uses, and East Dillon Water District domestic and commercial uses. Streamflows in the Snake River are also impacted by the Vidler Tunnel diversions from the Peru Creek basin to the East Slope. Wastewater and return flows for most of the in-basin uses are returned to the Snake River and to Dillon Reservoir. The primary location of interest in this sub-basin area is the Snake River at the USGS gaging station located just below the confluence of the North Fork. PACSM results indicate the following issues:

In-basin water supply issues: Water supplies for the Arapahoe Basin, Keystone–Montezuma domestic (below Peru Creek confluence), Keystone Golf Course and Keystone Ranch appear to be adequate under existing conditions (PACSM 1). The model indicated potential shortages under existing conditions for Keystone Ski Area

snowmaking that averaged 27 acre-feet per year and could be as high as 142 acre-feet per year. These shortages were relatively small but frequent during the months of October, November, January and February and tend to be larger and more frequent during December. The model also indicated occasional small shortages under current demands for the Snake River Water District and the East Dillon Water District.

Under future demand scenarios, water supplies for the Keystone Golf Course and the Snake River Water District appear to be adequate. The model indicated shortages for Arapahoe Basin under future demand scenarios during the months of September through March. These shortages occurred in every year and range from 29 acre-feet to 330 acre-feet per year. Occasional shortages of 2 to 11 acre-feet per year for Keystone-Montezuma Domestic uses occurred under future demands during the months of December through March. For Keystone Snake River snowmaking, shortages in the October through February timeframe occurred to some degree in all years under future demands. These shortages range from 5 to 668 acre-feet per year and average 207 acre-feet per year. Water shortages for Keystone Gulch (Keystone Ranch), ranging from 1 to 35 acre-feet per year under future demands, would occur to some degree in all years. Water shortages for the East Dillon Water District would occur in most years, averaging 11 acre-feet per year and ranging from 0 to 106 acre-feet per year.

Most of the shortages for the Snake River Basin occur during low flow fall and winter months due to lack of physical supply or senior CWCB instream flow water rights. In-basin sources of augmentation may be needed to address these shortages.

In-stream flow issues: Flows in the Snake River below the North Fork (Figure 3.12) would be reduced during the fall and winter by about 1 cfs under future scenarios due to increases in diversions for snowmaking at the Arapahoe Basin and Keystone Ski Areas and increased diversions for domestic and commercial uses. Winter streamflows appeared to be above the CWCB instream flow in all years because the State's instream flow water rights are senior to water rights for snowmaking.

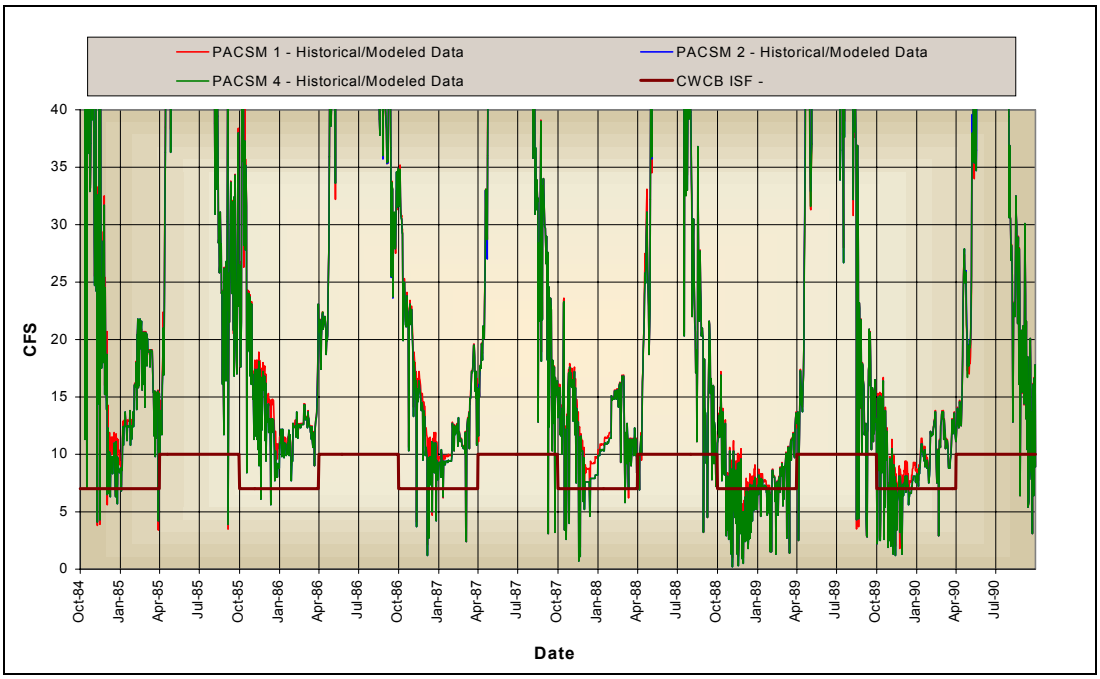


Figure 3.12 Snake River below North Fork average daily flows.

Water Quality: Existing water quality conditions in the Snake River are impacted by acid drainage from numerous abandoned mines, located mostly in the Peru Creek drainage, and the weathering of disseminated pyrite, which is a natural source of acidity in the Snake River above the confluence of Deer Creek. Water quality in Peru Creek and the Snake River below Peru Creek is impaired by elevated concentrations of cadmium, copper, lead and zinc that persistently exceed aquatic life TVS and concentrations of iron and manganese that frequently exceed domestic water supply standards. In the Snake River above Deer Creek, concentrations of aluminum, cadmium, copper, lead and zinc exceed aquatic life TVS and concentrations of iron and manganese exceed domestic water supply standards.

Metals concentrations in the Snake River tend to decrease through the stream reach below Deer Creek and above Peru Creek due primarily to dilution from Deer Creek and other tributary inflows. Metals concentrations in the Snake River increase significantly due to loadings from Peru Creek, but then tend to decrease again as clean tributary inflows, most notably from the North Fork, contribute dilution water. Below the confluence with the North Fork of the Snake River, concentrations of zinc remain persistently elevated above the aquatic life standard, while cadmium and copper occasionally exceed the standards. Concentrations of dissolved manganese persistently exceed the domestic water supply standard. Hardness and TDS concentration in the Snake River above and below the confluence of the North Fork tend to be very low.

For most of the sampling sites along the Snake River, the pattern of metals concentrations follows stream discharge with the lowest concentrations occurring during spring runoff. At the point of diversion for Keystone snowmaking, located approximately 0.6 mile below the confluence of the North Fork, during the snowmaking season (October through

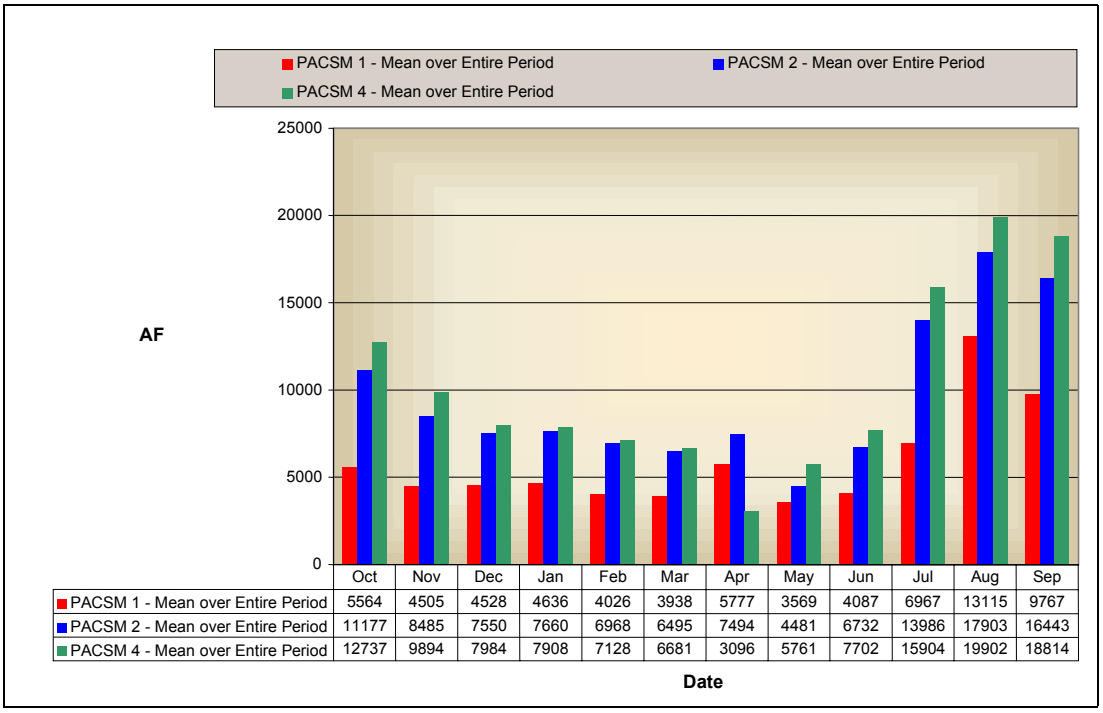
February), concentrations of total zinc and total manganese average about 350 μg/L and 230 μg/L, respectively (Hydrosphere 2001).

Water diversions from the Snake River for domestic, irrigation and snowmaking uses do not result in any measurable changes in metals concentrations below the points of diversion because the primary sources of metals contamination are upstream. Water diversions do, however, result in some reduction in the metals load in the Snake River that is directly proportionate to the amount of water diverted. With this reduction in streamflows and metals loading, there is also some reduction in metals concentrations in the Snake River downstream due to dilution from tributary inflows below the North Fork including Keystone Gulch and Frey Creek. A portion of the metals load removed with diversions is returned to the Snake River with return flows. Water diversions from the North Fork of the Snake River for snowmaking at A-Basin, however, remove dilution water from the system, resulting in higher metals concentrations in the Snake River below the North Fork (USDA Forest Service 1999).

Dillon Reservoir

Dillon Reservoir, located on the Blue River above the Town of Silverthorne, is owned and operated by Denver Water. The dam was completed in 1963 with an active storage capacity of approximately 254,000 acre-feet and is the largest reservoir in the Denver Water system (Denver Water 1976). Water from the Blue River and its tributaries above Straight Creek is stored in Dillon Reservoir and diverted directly into the Roberts Tunnel under the Continental Divide to the North Fork of the South Platte River. Dillon Reservoir, with a surface area of up to 3,233 acres and 26.8 miles of shoreline, provides a major recreational facility that is heavily used for boating and fishing. Recreational facilities around Dillon Reservoir include camping and picnic areas, hiking and biking trails, and marinas. Lower reservoir levels can also affect air quality due to exposed shorelines, water quality, public access, tourism, fisheries, and aesthetics. UPCO locations of interest associated with Dillon are Dillon Reservoir and the Roberts Tunnel.

Under current demand conditions (PACSM 1) an average of about 70,500 acre-feet per year is diverted through the Robert Tunnel to Denver. Under future baseline and buildout demands, average annual diversions would increase to approximately 115,400 acre-feet per year and 123,500 acre-feet per year with a south system project (PACSM 2 and 4 respectively), as shown in Figure 3.13.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PACSM 1 - Mean over Entire Period	5564	4505	4528	4636	4026	3938	5777	3569	4087	6967	13115	9767
PACSM 2 - Mean over Entire Period	11177	8485	7550	7660	6968	6495	7494	4481	6732	13986	17903	16443
PACSM 4 - Mean over Entire Period	12737	9894	7984	7908	7128	6681	3096	5761	7702	15904	19902	18814

Figure 3.13 Roberts Tunnel mean monthly flow volumes (WY 1947-1991).

As demands on the Denver Water system increase, Dillon Reservoir will experience more fluctuation in water levels than has occurred historically. Figure 3.14 provides a comparison of historical Dillon Reservoir content compared to modeled conditions and minimum levels necessary for normal operations at the Frisco Marina during the summer boating season (June through September). Under historical conditions, the reservoir content was less than the minimum (238,415 acre-feet, 9,012 surface elevation) during part or all of the boating season in 11 out of 26 years. Under modeled current demand conditions (PACSM 1), reservoir levels would be less than the Frisco Marina minimum in 19 out of 26 years.

However, under the current demand scenario, in dry years such as 1977 and 1991 the amount of reservoir drawdown is less than what occurred historically, primarily because of East Slope exchange operations that were not used historically. The existing system includes 5,000 acre-feet of yield from gravel pit storage exchange, the use of Bi-City effluent, and reusable water derived from the Englewood Ranch Creek System. The existing system also includes about 8,000 acre-feet of yield from East Slope refinements assumed to be in place since 1991. Denver's ability to use Wolford Mountain Reservoir for substitution also allows more water to be retained in Dillon Reservoirs during dry years.

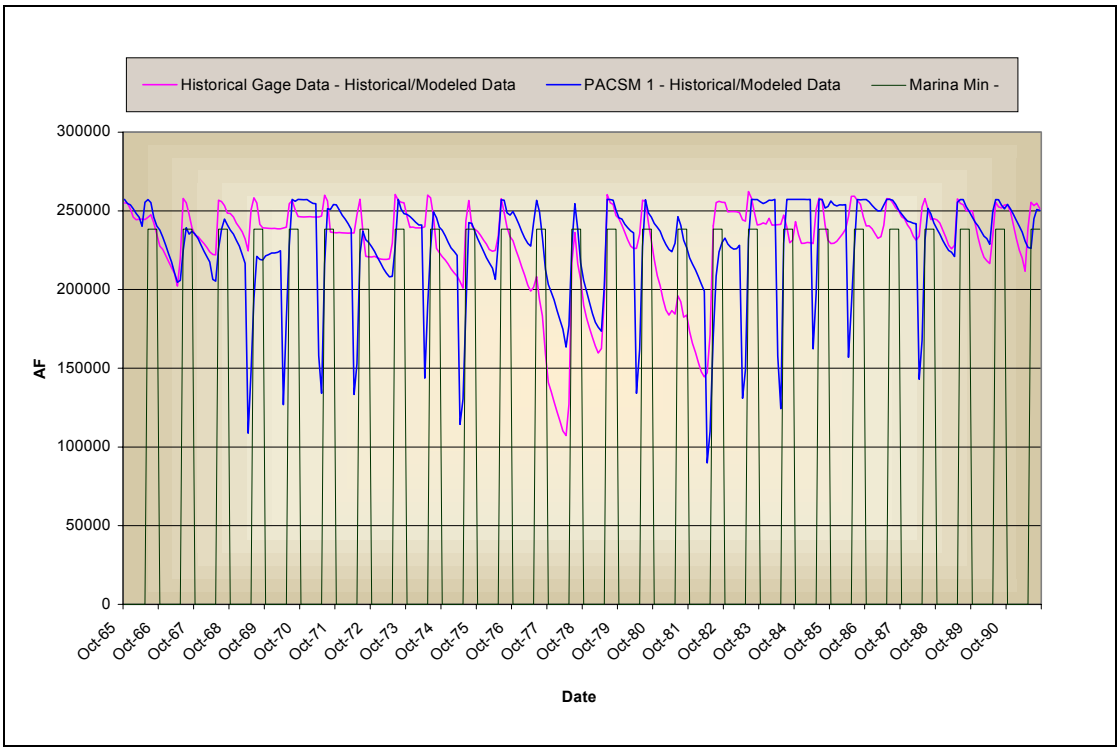


Figure 3.14 Dillon Reservoir end of month contents under historical and current demand conditions (WY 1965-1991).

Under future demand scenarios, as shown in Figure 3.15 and 3.16, the frequency and magnitude of reservoir draw downs at Dillon would be substantially increased. Under future baseline demands (PACSM 2), the modeled reservoir content was less than the minimum for a portion of or all of the boating season at the Frisco Marina in 21 out of 26 years. Under future buildout demand conditions (PACSM 4), modeled reservoir levels were less than the Frisco Marina minimum in 24 out of 26 years. The Frisco Marina is the worst-case scenario in that it is impacted first but there are also impacts to Dillon Marina as well as to air quality, tourism, and aesthetics as reservoir levels are drawn down.

Dillon Reservoir contents under future buildout demands with a north system supply project (PACSM 3) and a south system supply (PACSM 4) are shown in Figure 3.16. For PACSM 3, the modeled reservoir content was less than the minimum for part or all of the boating season in 21 out of 26 years. The buildout demand scenario with a south system supply project would result in larger reservoir drawdowns in dry years when levels would be below the marina minimum for all of the boating season, but would not substantially increase the frequency or amount of drawdown in wet and average years.

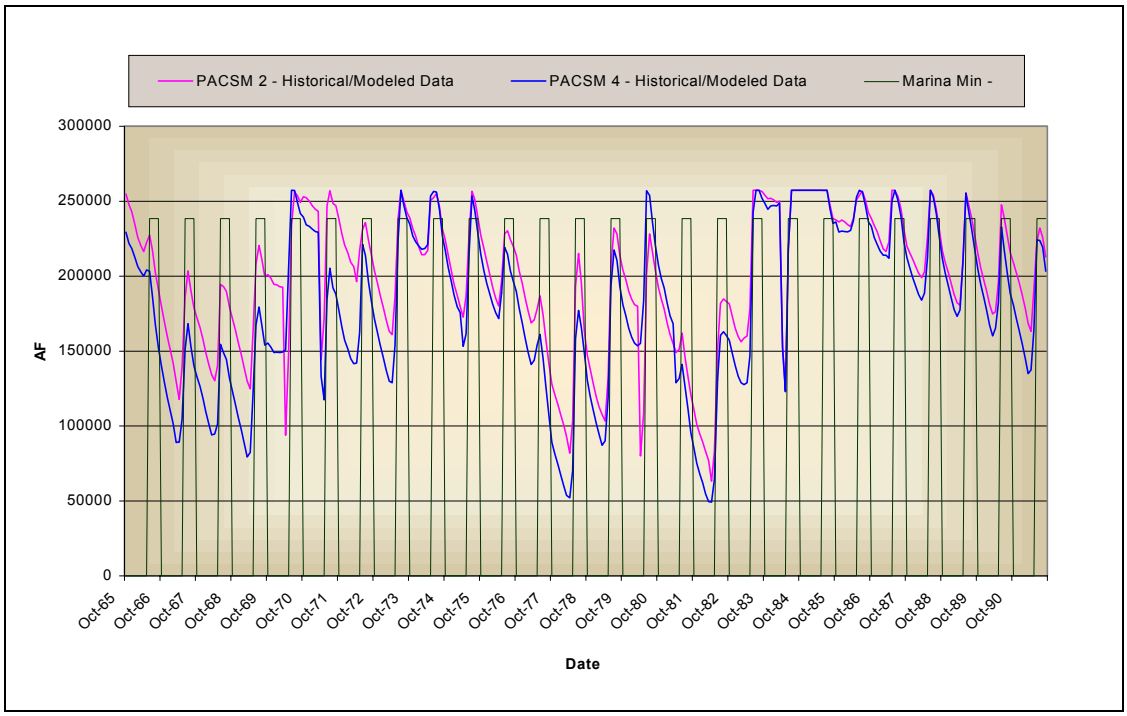


Figure 3.15 Dillon Reservoir end of month contents under future baseline and buildout demand conditions (WY 1965-1991).

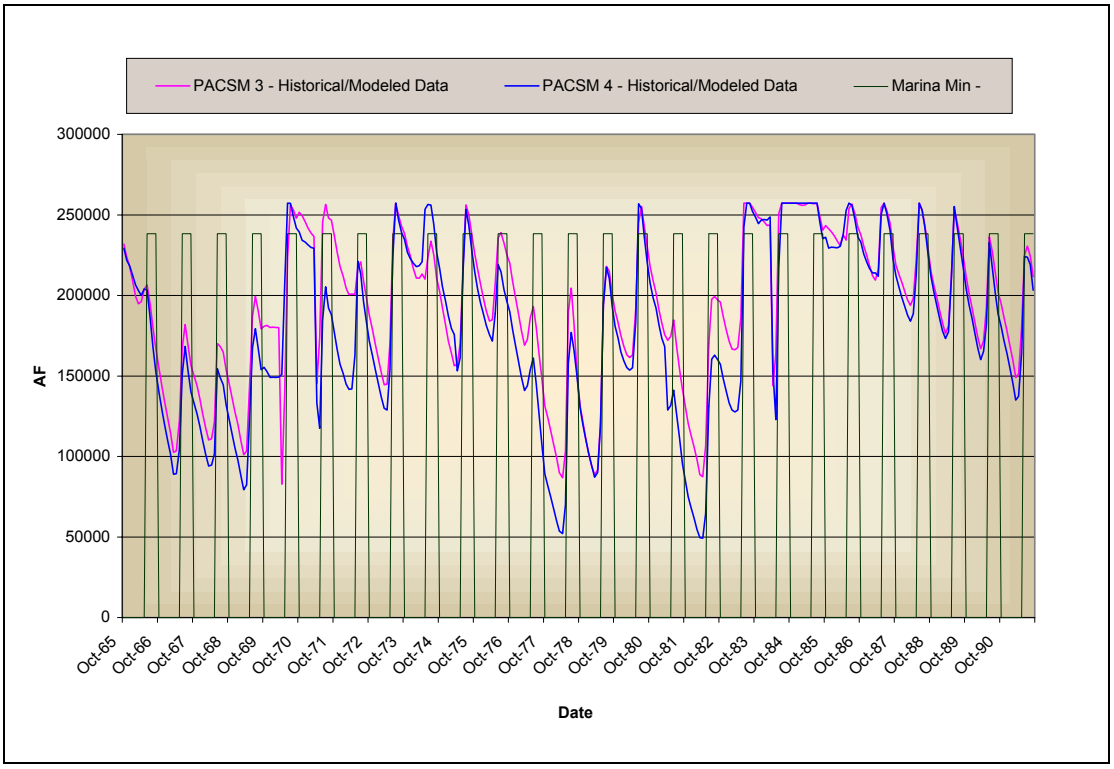


Figure 3.16 Dillon Reservoir end of month contents under buildout demand conditions (PACSM 3 and 4, WY 1965-1991).

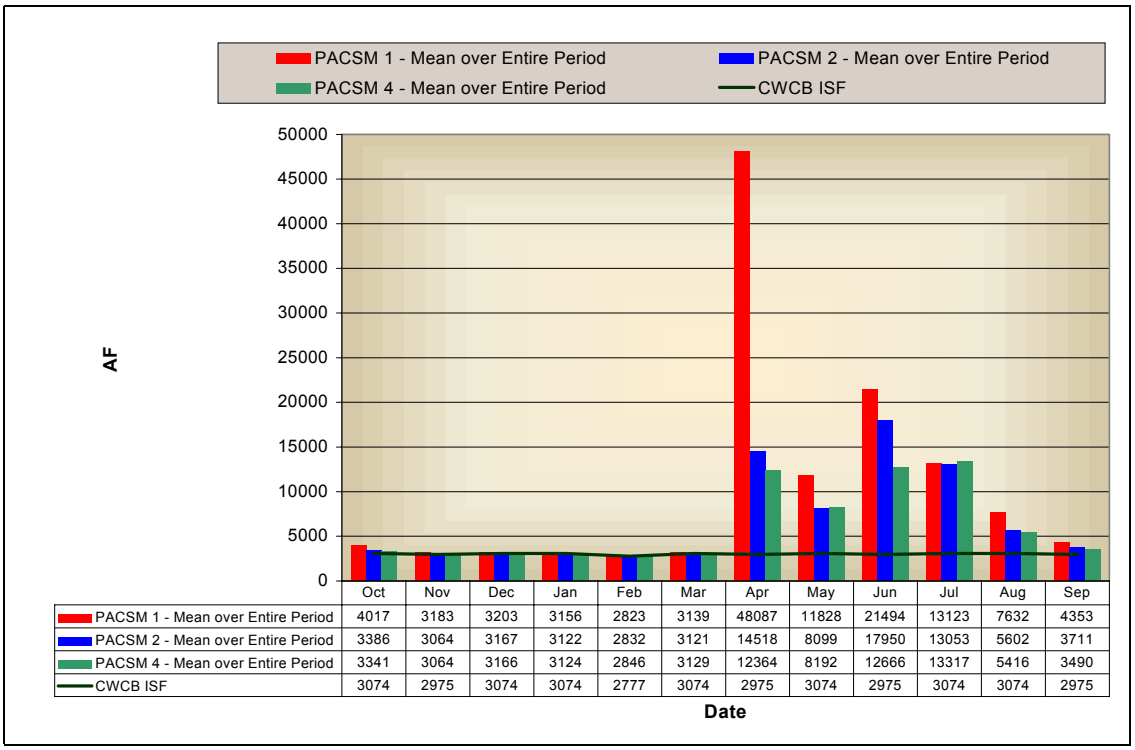
Blue River below Dillon Reservoir

Streamflows in the Blue River below Dillon Reservoir are currently impacted by Dillon Reservoir operations which includes diversions to Denver through the Roberts Tunnel, in-basin diversions above Dillon Reservoir and in-basin diversions for the Towns of Silverthorne and Dillon, the Buffalo Mountain and Mesa Cortina subdivisions, the Eagles Nest subdivision and golf course, and diversions above Dillon Reservoir. The Town of Dillon and the Dillon Valley Metro District divert water from Straight Creek, which is included in this sub-basin area because it flows into the Blue River just below Dillon Dam. This stream reach is also affected by wastewater return flows from the Silverthorne/Dillon Wastewater Treatment Plant located about 3.5 miles below Dillon Dam. The primary locations of interest in this stream reach are the Blue River below Dillon Reservoir (USGS gage), Straight Creek below Laskey Gulch, and the Blue River below Rock Creek. PACSM results indicate the following issues:

In-basin water supply issues: Modeling results indicated that water supplies for the Towns of Dillon and Silverthorne and the Buffalo Mountain/Mesa Cortina subdivisions were adequate under all PACSM scenarios. The model indicated small shortages for Eagles Nest and the Dillon Valley Metro District, but these shortages were so small and infrequent that they were less than the margin of error to be expected in this kind of analysis and do not indicate any significant water supply problems. In extremely dry years, the Towns of Dillon, Silverthorne, Frisco, and the Buffalo Mountain/Mesa Cortina subdivisions could experiences shortages if the Green Mountain Reservoir Historic Users Pool fails to fill.

In-stream flow issues: Model results show that average monthly flows in the Blue River below Dillon (Figure 3.17) would be reduced below historical conditions for all PACSM scenarios in all months of the year. The only exception to this was the month of April under the current demand scenario (PACSM 1) where an operational rule in the model is in place to release up to 1,800 cfs to minimize or prevent reservoir spills that could cause flooding. These releases were then recaptured downstream in Green Mountain Reservoir. This effect was not as pronounced in the future demand scenarios (PACSM 2, 3, and 4) because there was more space available in Dillon to store spring runoff inflows and the potential for reservoir spills was therefore significantly reduced.

Under all scenarios, flows in the Blue River below Dillon were at or above the CWCB instream flow of 50 cfs, with the exception of occasions in unusually dry years when inflows to Dillon Reservoir were less than 50 cfs. Under future demand scenarios there would be substantial increases in diversions through the Roberts Tunnel Collection System, which reduce the frequency and volume of Dillon spills. Flows in the Blue River below Dillon were thus maintained at or close to the CWCB instream flow level throughout much of the year and were often below the Fish Minimum flow level of 55 cfs as reported by the fishing community in Summit County. Under all future demand scenarios (PACSM 2, 3, and 4), flows in Blue River below Dillon would frequently be below the Kayak low flow criteria level of 300 cfs from June 1 to July 4.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PACSM 1 - Mean over Entire Period	4017	3183	3203	3156	2823	3139	48087	11828	21494	13123	7632	4353
PACSM 2 - Mean over Entire Period	3386	3064	3167	3122	2832	3121	14518	8099	17950	13053	5602	3711
PACSM 4 - Mean over Entire Period	3341	3064	3166	3124	2846	3129	12364	8192	12666	13317	5416	3490
CWCB ISF	3074	2975	3074	3074	2777	3074	2975	3074	2975	3074	3074	2975

Figure 3.17 Blue River below Dillon average monthly flows under historical, current and future baseline demands.

Under PACSM scenarios 2, 3, and 4, flows in the Blue River below Rock Creek would often be below the CWCB levels in fall, winter and early spring as shown in Figure 3.18. Flows under PACSM 3 and 4 would often be below the Kayak low flow (300 cfs 6/1 – 7/4) and Raft low flow levels (550 cfs 6/1 – 7/4).

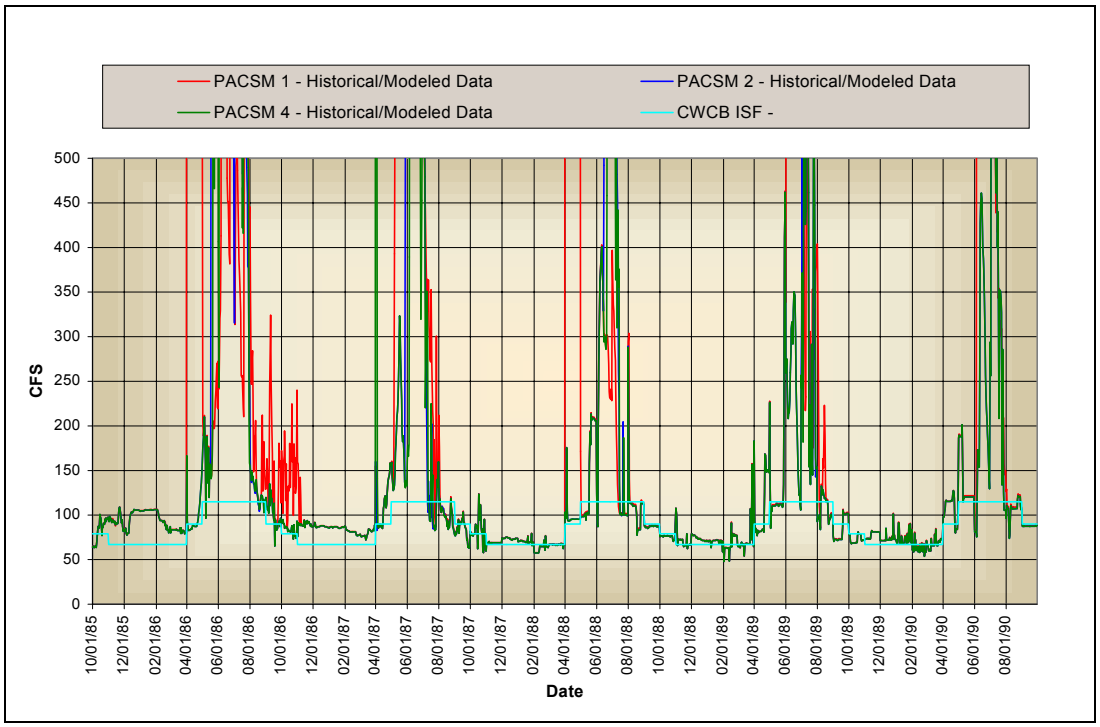


Figure 3.18 Blue River Below Rock Creek

Water quality issues: Water quality data for the Blue River below Dillon indicated that all stream standards were being met and that ambient conditions are generally better than standards.

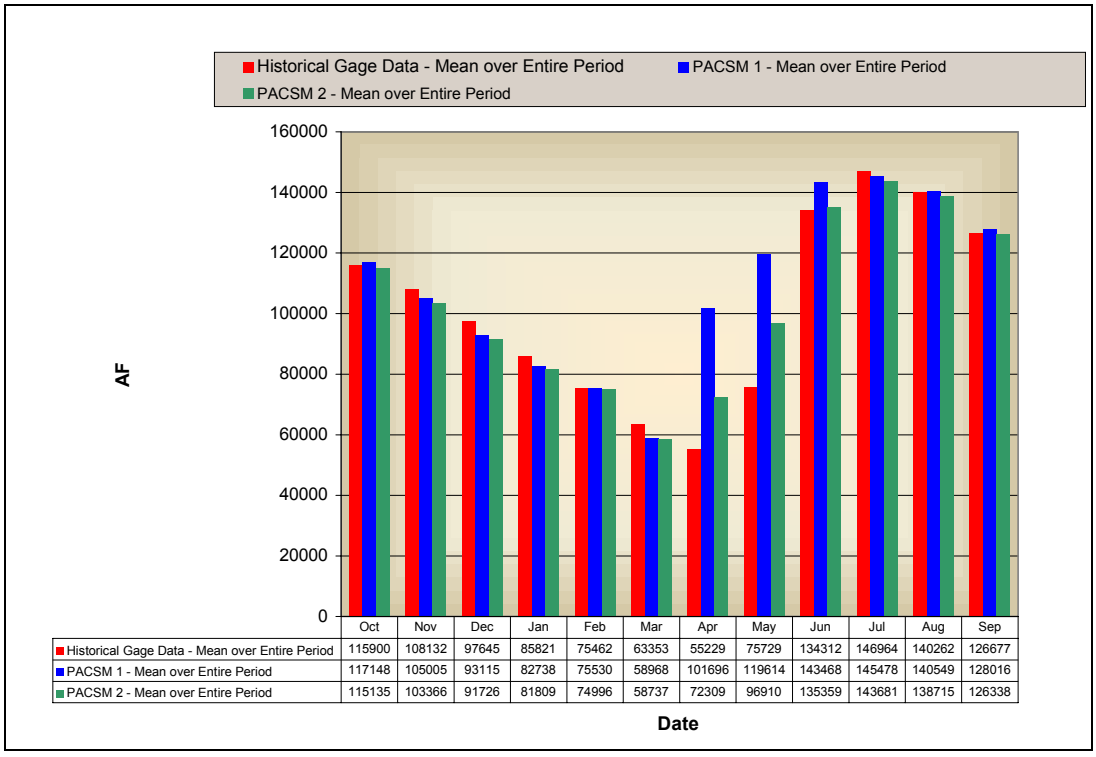
Green Mountain Reservoir and the Blue River below Green Mountain

Green Mountain Dam, located on the Blue River thirteen miles above its confluence with the Colorado River, was completed in 1943 by the U.S. Bureau of Reclamation as part of the Colorado-Big Thompson Project (CB-T). Green Mountain Reservoir has a total storage capacity of about 154,600 acre-feet, of which 52,000 acre-feet are available for replacement of out of priority CB-T diversions to the East Slope and about 100,000 acre-feet for power generation and beneficial consumptive uses in western Colorado (U.S. Dept. of Interior 1981). Green Mountain Reservoir operates pursuant to Senate Document 80 and subsequent agreements.

Green Mountain Reservoir and streamflows in the Blue River below Green Mountain are affected primarily by reservoir operations and by the amount of water flowing into the reservoir after upstream depletions associated with water uses and diversions previously described. In 2002, low reservoir levels created a landslide due to loss of pressure in the soils forcing the Bureau of Reclamation to change its operations of Green Mountain Reservoir. This impacted in-basin users relying on the contract pool as their supply was not available and they were forced to find additional sources.

In-basin water supply issues: Many of the in-basin water suppliers rely upon Green Mountain Reservoir augmentation water, particularly during the late summer and winter

months. Modeling results indicated that the average end-of-month contents in Green Mountain Reservoir would be slightly lower under future scenarios than has occurred historically in the months of July through March (Figure 3.19). These increases in reservoir drawdown were due to the combined impacts of increases in diversions through the Roberts Tunnel Collection System and increases in augmentation needs for water providers in the Study Area. However, during the months of April, May and June, reservoir levels could be higher than historical levels under PACSM scenarios 1 and 2 due to April flood control releases from Dillon that are recaptured in Green Mountain. Reservoir contents under PACSM scenarios 3 and 4 would be only slightly lower than scenario 2 during the months of March through June.

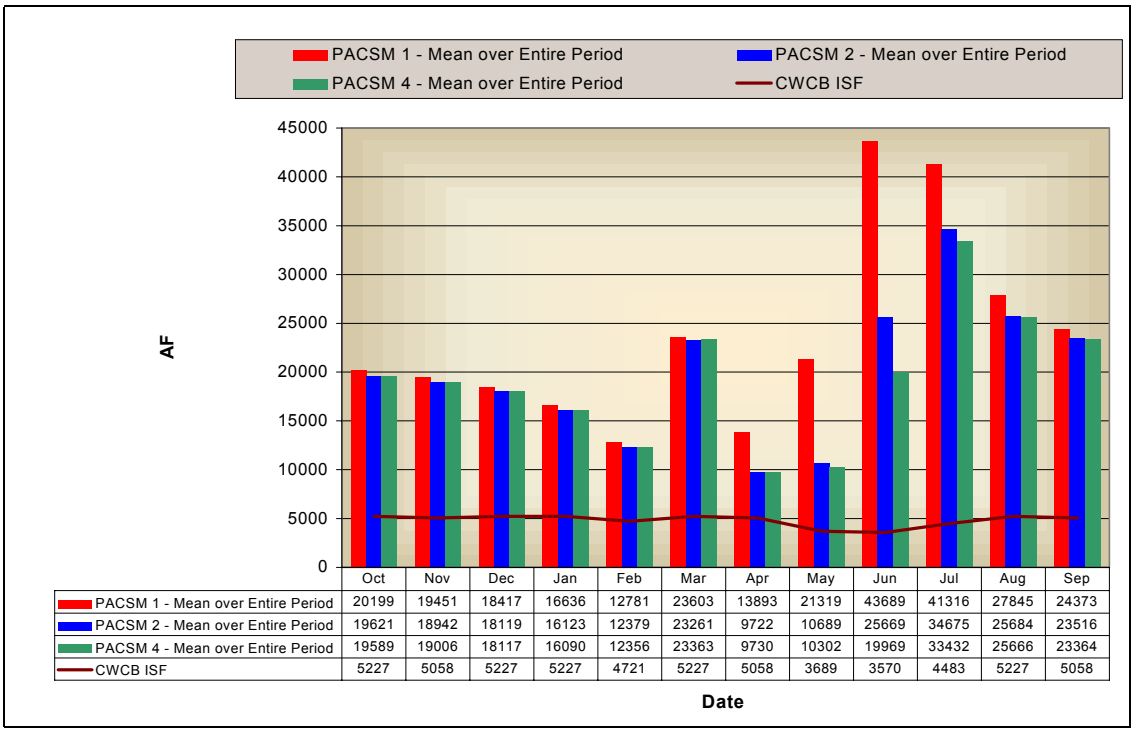


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Historical Gage Data - Mean over Entire Period	115900	108132	97645	85821	75462	63353	55229	75729	134312	146964	140262	126677
PACSM 1 - Mean over Entire Period	117148	105005	93115	82738	75530	58968	101696	119614	143468	145478	140549	128016
PACSM 2 - Mean over Entire Period	115135	103366	91726	81809	74996	58737	72309	96910	135359	143681	138715	126338

Figure 3.19 Green Mountain Reservoir End of Month Contents

There are no major in-basin domestic water supply systems in the Study Area that divert water directly from the Blue River below Green Mountain Reservoir.

In-stream flow issues: Model results for all PACSM scenarios indicated that flows in the Blue River below Green Mountain Reservoir would usually be at or above CWCB levels (60 cfs 5/1 – 7/15, and 85 cfs 7/16-4/30) and Fish Minimum levels (60 cfs 5/01 – 7/15, 140 cfs 7/16-9/30, and 100 cfs 10//1-4/30). Under future demand scenarios (PACSM 2, 3, and 4), streamflows below Green Mountain would be reduced below current conditions in all months of the year. The largest reductions would occur in the spring and summer due primarily to reductions in the amount of reservoir spills, as shown in Figure 3.20.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PACSM 1 - Mean over Entire Period	20199	19451	18417	16636	12781	23603	13893	21319	43689	41316	27845	24373
PACSM 2 - Mean over Entire Period	19621	18942	18119	16123	12379	23261	9722	10689	25669	34675	25684	23516
PACSM 4 - Mean over Entire Period	19589	19006	18117	16090	12356	23363	9730	10302	19969	33432	25666	23364
CWCB ISF	5227	5058	5227	5227	4721	5227	5058	3689	3570	4483	5227	5058

Figure 3.20 Blue River below Green Mountain Reservoir monthly flow volumes.

Instream flow issues: Kayaking is popular in the Blue River below Green Mountain Reservoir in the late summer and early fall as releases are being made to satisfy downstream calls. PACSM results indicated that under all scenarios, flows in the Blue River below Green Mountain in August and September would usually be below the optimum level for Kayaking (500 cfs) by 250 to 300 cfs.

4. CONCLUSIONS AND POSSIBLE SOLUTIONS

The Phase II UPCO Study Report and the supporting documentation provided with the UPCO Data Display Tool have identified a number of significant issues associated with in-basin water supply needs, instream flows, and reservoir levels. This section of the report presents possible solutions and mitigating measures that have been identified during the Phase II study process for further review and consideration by stakeholders in Phase III. These issues, as previously described in the Study Results section of this report, are summarized below, and for each sub-basin area, possible solutions and measures that could potentially mitigate the impacts are identified.

Potential solutions that would be most feasible are those that benefit multiple stream reaches and water providers, utilize existing infrastructure, and could be cooperatively implemented without significant controversy over environmental, legal and institutional issues.

4.1 Grand County:

Table 4.1 provides a summary of the issues and impacts identified for each of the sub-basins and stream reaches in Grand County and a preliminary list of possible solutions to the impacts and issues associated with current and future water demands. In some cases, potential solutions apply to issues that have been identified for several stream reaches or sub-basins. For example, in the Fraser River Basin, the potential solutions identified in Table 10 could serve to benefit stream reaches above and below the Town of Fraser and the Colorado River below the Fraser confluence.

Table 4.1 Grand County Issues and Solutions Summary

Stream Reach	Issues	Possible Solution
Fraser River above Fraser	❑ Small occasional shortages for Grand County Water & Sanitation District for PACSM 1 and large shortages for PACSM 2,3&4 ❑ Occasional small shortages for Winter Park Water & Sanitation for PACSM 1 and potential large shortages under PACSM 2,3&4 ❑ Flow below Vasquez Creek under CWCB instream flow and fish minimum for PACSM 1,2,3&4, primarily in late September ❑ Flows often below Wastewater Treatment Plant 1-day, 3-year low flow (1E3) in Sep – Apr for PACSM 1,2,3&4	Physical supply shortages can be addressed through bypass arrangements with Denver Water, extension of the Williams Fork Collection System, or additional in-basin storage that may require pumping from downstream locations. ❑ Bypass options could include: Denver Water could reduce diversions and use Fraser and Williams Fork collections systems to supplement Fraser River flows during fall and winter. Denver recovers lost yield through additional East Slope storage for Moffat System, new or acquired (such as Meadow Creek Reservoir, Vail Ditch) storage reservoir in Ranch Creek Basin with pumpback to Moffat collection system. (This potential solution by itself would not be sufficient to meet all of the Winter Park demands ❑ Use of Windy Gap to recover bypass flows via the CB-T System with East Slope interconnection to Denver's north end service area. (Bureau of Reclamation approval would be required.) ❑ Additional in-basin storage reservoir(s) in conjunction with pumpback to store runoff. Use pumpback and Denver's collection system to move water back up to mainstem or tributaries during low flow periods. ❑ Reduce CWCB instream flow below Vasquez Creek from 11 cfs to 5 cfs for Sept 15 – 30 so that the instream flow time frame is consistent with the stream reach above Vasquez Creek. ❑ Increase conservation measures in Grand County. ❑ Dry-year water supply, such as non-tributary groundwater, to maintain higher flows in the Fraser.

Stream Reach	Issues	Possible Solution
Fraser River below Fraser	❑ Small shortages for Town of Fraser and Silver Creek Resort, mostly in December ❑ Possible occasional small shortages for Winter Park West Water &Sanitation District ❑ Flows below St Louis Creek below CWCB instream flow and fish minimum in fall under PACSM 1, and below CWCB instream flow and fish minimum in fall and winter under PACSM 2,3&4 ❑ Flows below St Louis Ck often below Wastewater Treatment Plant 1E3 and 30E3 in July through February under PACSM 1,2,3&4 □ Flows below Granby below Wastewater treatment Plant 1E3 during September and October	❑ Same as for Fraser River above Fraser. ❑ Wastewater treatment consolidation with pumpback (little straw).
Colorado River above Fraser River Confluence	❑ Higher water levels in Lake Granby due to increases in Windy Gap pumping under PACSM 2,3,&4. Possible nutrient loading increase could impact trophic status of reservoir ❑ Flows below Lake Granby frequently below CWCB instream flow, fish minimum and optimum in August through March under all scenarios	❑ Possible Lake Granby water quality issues being addressed in separate study (Three Lakes Clean Lakes Assessment) ❑ Fall and winter flow below Lake Granby could be supplemented through reservoir releases that could be recovered at Windy Gap (with installation of low-volume pumping capability).

Stream Reach	Issues	Possible Solution
Colorado River below Fraser River and above Kremmling	❑ Hot Sulphur Springs shortages in July (4 cfs demand exceeds 3.3 cfs right) under PACSM 2,3&4 ❑ Flows below Windy Gap frequently below CWCB instream flow (90 cfs) in August – March under PACSM 1,2,3&4 ❑ Flow below Windy Gap usually below Fish minimum (125 cfs) in July – April under PACSM 1,2,3&4 ❑ Flows below Windy Gap usually below Kayak minimum (300 cfs) in June under PACSM 1,2,3,&4 ❑ Flow below Williams Fork below CWCB instream flow (135 cfs) summer and fall under PACSM 1,2,3&4 ❑ Low flow/high temperature below Windy Gap	❑ Use Williams Fork Reservoir for replacement releases during low flow periods instead of Green Mountain and/or Wolford. ❑ In-basin water conservation to reduce demands. ❑ There is considerable debate whether additional reuse on the Front Range is a solution. Some believe that installing potable reuse on the Front Range will reduce demands on the Moffat Tunnel and Northern's System. Others believe installing potable reuse will not reduce demands on the Moffat Tunnel and Northern's System. Resolution of this issue must be left for another study. ❑ Jasper Reservoir or other Study Area storage. ❑ Windy Gap bypass channel could help to reduce water temperatures and Whirling disease. (Colorado Division of Wildlife is currently working on these issues.) ❑ Pumpback from the Colorado River at Kremmling to Windy Gap (another little straw).
Colorado River below Kremmling	❑ Town of Kremmling demand exceeds 1 cfs water right during March and April under PACSM 2,3,&4 ❑ Duration of period in May – July when Colorado River at Kremmling is at or above the Kayak and Raft optimum flow (1,100 cfs) reduced under PACSM 2,3,&4	❑ Reservoir releases for endangered fishes could enhance late summer/fall flows below Kremmling. ❑ Same as for Colorado River above Kremmling. ❑ Town of Kremmling plans to develop new intake facility on the Colorado River below Sheep Creek.

In Grand County, the primary solutions to the issues identified for the Fraser River Basin center on the need for additional physical supplies of water during the mid-summer, fall and winter to meet instream flow objectives and the current and future demands of in-basin water supply systems. For the Colorado River above and below the Fraser River confluence, potential solutions would most likely involve modification of the operations of the CB-T and Windy Gap Projects. The possible solutions and mitigating measures that emerge as the most promising options for further consideration in Phase III of the UPCO study are discussed below.

Fraser River above and below Fraser: The Moffat Tunnel Collection System diverts 12 to 15 cfs during the winter to the East Slope. Delivery to the Upper Fraser River of a portion of the flows that are currently diverted through the Moffat Tunnel during the fall and winter would enhance instream flows and water quality but would reduce the yield of the Moffat Tunnel Collection System. For example, a bypass of 4 to 6 cfs to the Upper Fraser River over a 120 day period in the fall and winter would increase flows sufficiently in most years to maintain CWCB instream flows and wastewater treatment plant low flows. This would reduce Denver Water's yield by about 1,200 acre-feet, and it would enhance flows in the Fraser River and the Colorado River downstream to the confluence of the Williams Fork. Recovery of this loss in yield could be achieved through the development of additional storage capacity on the East Slope, such as the Gross Reservoir enlargement or the proposed reservoir on Leyden Gulch. Another option would be acquisition of storage on the West Slope such as Meadow Creek Reservoir or development of a new storage facility in the Ranch Creek drainage with pumpback to the Moffat Tunnel Collection System.

Under an expanded variation of the 1,200 acre-feet Moffat Tunnel Collection System delivery idea, Denver would shut down the Moffat Tunnel during November through March of each year and divert its Moffat system water into Granby Reservoir via the Windy Gap project. (Denver's Moffat system diversions average about 5,000 acre-feet per year during this 5-month period.) This water would be delivered to Broomfield via the Carter Lake pipeline in trade for Broomfield assigning its 5,000 acre-feet treated water contract with Denver to Arvada. Arvada would, in turn, reduce its raw water delivery entitlement from Denver's North Side system by 5,000 acre-feet.

The purpose of this admittedly complex arrangement would be to restore the entire Fraser River Basin to an essentially natural streamflow regime during the low flow months of November through March without the loss of yield to any party. This would provide major benefits to fisheries and water supplies within the basin. Denver's yield could be made whole without having to build additional capacity into Denver's contemplated North Side system project, although it would not eliminate the need for such a project. This arrangement could exacerbate Denver's North System supply problem, depending upon the timing of deliveries to Arvada.

There are obviously a large number of institutional, technical and economic issues associated with this idea, including but not limited to the following:

- Agreements would be needed with Northern and U.S. Bureau of Reclamation, along with all the usual NEPA compliance and Endangered Species Act requirements.

- Denver would have to change its Moffat system rights to add a downstream alternate point of diversion. This could entail significant legal expense and the risk of some loss in yield associated with use of the alternate point of diversion.

- The Windy Gap pumping plant would have to be modified to be able to pump at low and varying flow rates during the winter season. The cost of such a modification would not be trivial.

- Granby Reservoir would experience increased seasonal pollutant loading from 5,000 acre-feet of water pumped from the Colorado River at times when Fraser Basin wastewater discharges would comprise a relatively high percentage of the streamflow. This could result in the paradoxical situation where Fraser Basin dischargers would have to upgrade their wastewater treatment plants as a result of having more base flow in the river.

- There would be a significant energy requirement associated with pumping Moffat water into Granby. However, the hydropower generated on the east side of the CB-T system would more than offset this energy requirement, but the arrangements needed to credit the energy gain against the energy cost would not be trivial.

- It is unclear whether there is seasonally unused capacity in the Carter pipeline, who actually owns this capacity and what they would charge for its use.

- This idea would entail significant operational changes to Broomfield's water supply system, and Broomfield would probably not be willing to trade firm treated water for not-quite-as-firm raw water without compensation.

- This idea would entail significant operational changes to Arvada's water supply system, and Arvada would probably not be willing to trade not-quite-as-firm raw water for firm treated water without compensation.

- This arrangement could exacerbate Denver's north system supply problem.

- This entire arrangement would enormously complicate the lives of numerous Denver Water operational staff, and would make Denver wonder why it spent all that money winterizing its Moffat Collection System.

Colorado River above and below the Fraser River: Solutions for the Colorado River mainstem are limited and would likely require changes in the operation of the CB-T and Windy Gap systems. For example, releases from Lake Granby could enhance streamflows in the Colorado River downstream to Windy Gap and then pumped back up to Granby. This would require modification of the Windy Gap pumps. Operation of this type of water recirculation system would be expensive and would result in an increase in nutrient loading to Lake Granby. Enhancement of flows below Windy Gap would result in a loss of yield to the CB-T system.

4.2 Summit County

Table 4.2 provides a summary of the issues and impacts identified for each of the sub-basins and stream reaches in Summit County. The table also includes a preliminary list of possible solutions that could potentially help to offset or mitigate the impacts and issues associated with current and future water demands.

In the Summit County portion of the UPCO Study Area, separate solutions will be needed to effectively address issues in the sub-basin areas that are tributary to Dillon Reservoir: the Blue River above Dillon Reservoir; Tenmile Creek above Dillon Reservoir; and the Snake River above Dillon Reservoir. The primary solutions to the issues identified for these sub-basins center on the need for additional physical supplies of water during certain times of the year to meet instream flow objectives and future demands of in-basin water supply systems (and in some cases current demands). The possible solutions and mitigating measures for each of these sub-basins that emerge as the most promising options for further consideration in Phase III of the UPCO study are discussed below.

Table 4.2 Summit County Issues and Solutions Summary

Stream Reach	Issues	Possible Solution
Blue River above Dillon Reservoir	❑ Breckenridge Golf Course shortages under PACSM 1,2,3&4 ❑ Blue River below French Gulch winter flows 1 to 2 cfs lower in PACSM 2,3,& 4 than PACSM 1 due to in-basin diversion increases ❑ Potential water supply shortages for dispersed usage above Dillon ❑ Potential impacts to Breckenridge Kayak Course ❑ Persistent exceedences of aquatic life standards for cadmium, copper, lead, and zinc and elevated total dissolved solids in Blue River below French Gulch, some exceedence of standards for zinc in Blue Rive below the Swan River	❑ New storage or enlarge storage above French Gulch. Possible joint project with Colorado Springs to expand some of their storage on Hoosier Pass. ❑ Wellington Oro Mine pool storage in French Gulch ❑ Cleanup measures planned for French Gulch mine drainage ❑ A permanent Colorado Springs substitution agreement, under which 250 acre feet of water from Upper Blue Reservoir would be available for use within Summit County and up to 1,850 acre feet would be released from Upper Blue to Dillon in substitution years.
Tenmile Creek above Dillon Reservoir	❑ PACSM 1 frequent small shortages in Apr/May and Jul/Sep for Golf Course and frequent shortages for Copper Mountain Water & Sanitation District ❑ PACSM 2,3&4 frequent small shortages and occasional large shortages for all uses. ❑ Fall, winter and early spring flows frequently below CWCB instream flow for all PACSM scenarios □ Fall and winter flows occasionally below 1E3 and 30E3	❑ Possible purchase of Tenmile Creek water rights from Climax or use of water from the Clinton Reservoir dead pool. ❑ Non-potable reuse on golf courses in Summit County. ❑ Eagle Park Reservoir.

Stream Reach	Issues	Possible Solution
Snake River above Dillon Reservoir	❑ PACSM 2,3,&4 water supply shortages for A-Basin snowmaking, Keystone-Montezuma Domestic, Keystone Snowmaking, Keystone Gulch and East Dillon Water District ❑ Persistent exceedences of aquatic life standard for zinc and occasional exceedences of standards for cadmium and copper	❑ Montezuma shaft pumping during snowmaking season to supplement fall and winter flows through Keystone (Subject to Denver's operations and maintenance activities on the Roberts tunnel) ❑ Possible purchase of Tenmile Creek water rights from Climax or use of water from the Clinton Reservoir dead pool ❑ Reservoir sites located in Peru Creek drainage ❑ Mine site remediation
Dillon Reservoir	❑ Historically, reservoir below marina minimum in 11 out of 26 years ❑ Under PACSM 1, reservoir below Frisco marina minimum (9,011 ft.) 19 out of 26 years ❑ Under PACSM 2, reservoir below Frisco marina minimum 21 out of 26 years ❑ Under PACSM 3, reservoir below Frisco marina minimum in 21 out of 26 years ❑ Under PACSM 4, reservoir marina minimum in 24 out of 26 years	❑ Movable floating marina for Frisco ❑ New Boat ramps (Improvements are currently underway.) ❑ Dredging or excavation of the marina areas ❑ There is considerable debate whether additional reuse on the Front Range is a solution. Some believe that installing potable reuse on the Front Range will reduce demands on the Roberts Tunnel System. Others believe installing potable reuse will not reduce demands on the Roberts Tunnel System. Resolution of this issue must be left for another study. ❑ Dry-year water supply, such as non-tributary groundwater, to maintain higher water levels in Dillon by reducing demand on Roberts Tunnel System and/or increasing operational flexibility. There is also considerable debate about whether this possible solution would actually improve conditions at Dillon Reservoir.

Stream Reach	Issues	Possible Solution
Blue River below Dillon Reservoir	Blue River below Dillon: ❑ PACSM 2,3&4, increased frequency and duration of flows at 50 cfs (CWCB ISF) and below Fish Min (55 cfs) below Dillon Reservoir ❑ PACSM 2,3&4 flows often below Kayak low Blue River below Rock Creek: ❑ PACSM 2,3&4 flows often below CWCB levels in fall winter and early spring ❑ PACSM 3&4 flows often below Kayak low and Raft low	❑ Same as above for Dillon Reservoir. ❑ Operational changes to provide ramping releases from reservoirs to simulate natural hydrology for the benefit of the fisheries and releasing less water during spring run-off for longer periods of time to stretch the rafting and kayaking season. ❑ Creation of a low flow channel below the dam and fish habitat improvements ("Blue River Restoration Project" is already underway but needs financial assistance.) ❑ There is considerable debate whether additional reuse on the Front Range is a solution. Some believe that installing potable reuse on the Front Range will reduce demands on the Roberts Tunnel System. Others believe installing potable reuse will not reduce demands on the Roberts Tunnel System. Resolution of this issue must be left for another study. ❑ Increase dry year conservation measures in the Metro area and Summit County. ❑ Dry-year water supply, such as non-tributary groundwater, to maintain higher water levels in Dillon by reducing demand on Roberts Tunnel System. ❑ Develop boat chutes on Blue River. ❑ Develop Green Mountain pumpback project for instream flow and water supply purposes.
Green Mountain Reservoir and Blue River below Green Mountain	❑ Flows usually meet CWCB levels and Fish Minimum for all scenarios.	❑ None required.

Blue above Dillon Reservoir: Previous studies have identified the need for additional storage in the Blue River Basin above Dillon Reservoir for augmentation of flows during the winter. Storage sites above French Gulch would be the most desirable because releases would benefit all of the critical stream reaches on the Upper Blue River. The City of Colorado Springs could also benefit from additional storage that would enhance the yield and operational flexibility of the Hoosier Tunnel system. The potential for a collaborative arrangement involving in-basin water providers, Summit County, and the City of Colorado Springs to develop additional storage in the Upper Blue River Basin emerges as a potential solution for further evaluation in Phase III.

A substitution agreement involving Colorado Springs, Denver, the River District and Summit County has been the subject of recent discussions. Under such an arrangement, up to 250 acre-feet of water would be available for release from the Upper Blue Reservoir for use within Summit County.

Another possible, but more ambitious and complex, arrangement would involve a reduction or elimination of diversions through the Continental-Hoosier Diversion System. This would enhance streamflows in the Blue River downstream to Dillon Reservoir in April through August, and Upper Blue Reservoir would be used primarily for in-basin water supply purposes. Colorado Springs would recover its lost yield through an arrangement in which the City of Aurora would trade its share of Homestake Collection System water to Colorado Springs for Hoosier System water conveyed to Aurora via Dillon Reservoir and the Roberts Tunnel.

A possible storage location is the Wellington Oro Mine site located on French Creek about 1.2 miles upstream from the confluence with the Blue River. It has received considerable attention recently due to a Superfund remedial action. The mine works contain over 12 miles of tunnels and stopes that fill with water during snowmelt runoff. Previous attempts to clear water from the mine works to provide access required pumping for extended periods (months) at rates rumored to be near 900 gallons per minute. The volume in the mine pool may provide an opportunity for storage to augment late season flows in the Blue River below Breckenridge. Similar opportunities have been utilized near Park City Utah.

Tenmile Creek above Dillon Reservoir: Additional storage capacity and water rights may be available from the Climax Mine that could serve to augment streamflows in Tenmile Creek during the fall, winter and early spring. Specific details regarding this option have not been investigated but should be considered for further investigation and discussion in Phase III. Denver Water has been exploring options for participation in ongoing negotiations regarding potential development of Eagle River, Arkansas River and Tenmile Creek water resources through a joint use project involving Aurora, Colorado Springs, Climax, water users in the Eagle River Basin, and the River District. One of the options under discussion would allow Denver Water to receive a firm yield of 5,000 acre-feet that would be conveyed to Dillon Reservoir via Tenmile Creek. It may be possible to convey this water, or a portion of it, during low-flow periods to enhance instream flows.

Snake River above Dillon Reservoir: Several possible reservoir sites have been identified in the Upper Snake River, but the economic and environmental feasibility of these options are questionable. Keystone Resort has entered into an agreement with Denver Water that allows it to pump up to 4.5 cfs from the Roberts Tunnel, via the Montezuma Shaft, into the Snake River for augmentation of streamflows, subject to Denver's operations and maintenance activities on the Roberts Tunnel. The Montezuma Shaft pump station discharges to the Snake River approximately 3.5 miles above the confluence of the North Fork. Operation of this facility could possibly be expanded to enhance instream flows and provide dilution water that would reduce downstream metals concentrations. Additional augmentation water may be needed, however, for the consumptive uses associated with future demands.

Dillon Reservoir and the Blue River below Dillon: Reservoir levels during the summer recreation season and flows in the Blue River below Dillon are influenced primarily by water demands on the Denver System and the need to operate the system to optimize its firm annual yield. Potential solutions to the reservoir level and instream flow issues identified center on measures that could reduce demands for Roberts Tunnel Collection System water or increase operational flexibility.

Measures that could reduce or delay the need for diversions to the East Slope include increased utilization of reusable return flows and additional efficiency measures, beyond those already planned. Long-term water supply options identified by Denver Water include measures to increase utilization of reusable effluent through possible pumpback of reusable effluent, effluent storage, and indirect potable reuse. These possibilities are identified in Denver Water's 2002 IRP as options that may be needed to meet new water demands beyond 2030 for potential build-out the Combined Service Area.

In 1996, Denver Water set a goal of saving 16,000 acre-feet of water per year through additional conservation efforts by the year 2030 and a total of 29,000 acre-feet by 2045. The 2002 IRP update included an assessment of the performance of Denver Water's conservation program that concluded that the current program would not produce the 29,000 acre-feet goal. Denver Water staff is currently evaluating conservation options involving new incentive measures, effective conservation mandates and rate incentives. Aggressive implementation of conservation measures could reduce the overall rate of demand growth resulting in less demand for West Slope water.

Denver Water, the River District and a group of South Metro Denver water providers are conducting a collaborative study of water supply options involving the conjunctive use of surface and non-tributary groundwater supply systems. This type of project would involve a physical connection between Denver's surface water system and South Metro area groundwater systems. Wet year spills from Denver's South Platte system reservoirs and Dillon Reservoir would then be used to meet water demands of South Metro water users and to recharge the Denver Basin groundwater aquifers. Water from the Denver Basin would be available to meet demands on the Denver system during dry years and to pay back the water from the Denver System used by South Metro. The primary goal of this arrangement is to develop a sustainable system for long-term utilization of Denver Basin groundwater.

This type of conjunctive use arrangement, however, would result in a substantial reduction in spills from Dillon Reservoir and lower reservoir levels during the summer season. As mitigation to the West Slope, South Metro could deliver more water in dry years to Denver than required in order to reduce impacts on Dillon Reservoir. While detailed operational studies of conjunctive use are not yet complete, it is possible that Denver's operational flexibility could be enhanced such that higher levels in Dillon Reservoir could be maintained during certain years.

4.3 Impacts of 2002-2003 Drought

As previously discussed, the 1947-1991 study period for the UPCO model includes a number of wet, average and dry years. The study period includes the 1954-56 and 1977 droughts, which have historically been used by water planners for estimating the "firm" yield of their water supplies. The participants of the study realize that the current 2002-2003 drought may present conditions even more severe than the past droughts. The participants also recognize that a number of conditions have occurred to-date during the 2002-2003 drought that may present unique new challenges which need to be considered in the future. These specific conditions include the following:

- Streamflows in certain areas of the Colorado River Basin and its tributaries were lower than in previous droughts.
- Problems occurred with Green Mountain Reservoir including exhausting the historic users pool (HUP) and the impact of the Heeney slide, which prevented full use of the reservoir's available storage.
- Denver Water reduced its by-pass flows past their Moffat Collection System, significantly reducing streamflows in the Fraser River Basin.
- Due to agreements between water users and Excel Energy, there were changes in the administration of the Shoshone Call.
- Clinton Reservoir may fail to fill for a fourth consecutive year, causing shortages in the planned 3-year supply for certain shareholders.
- Denver Water has nearly exhausted its Williams Fork Reservoir supply and resorted to use of Dillon Reservoir to augment its Fraser River diversions.

The degree to which these problems affect the published yields and shortages in the UPCO study are not certain. However, the participants agree that these issues should be considered during the next phase (Phase III) of the study and evaluated for potential impacts on the future shortages and water requirements of the water users in the basin.

4.4 Next Steps

Phase II of the UPCO Study has identified a number of issues and problems that warrant further study. The objectives for the next phase need to be identified and the role and organization of UPCO needs to be defined. This may involve formation of one of more subgroups to address specific issues and problems. Tasks that could be addressed in Phase III of UPCO include the following activities:

- Providing a forum to develop possible solutions to some of the problems identified in the study.
- Providing information to in-basin water users and communities in their own planning efforts.
- Providing a forum to coordinate the review of water supply projects proposed by Denver and Northern.

Both Denver and Northern are in different stages of considering projects in the Study Area or that would affect the Study Area. Denver is currently involved in two projects. The South Metro Study is evaluating conjunctive use options in the South Metro area using Blue River water. This study will look to UPCO to assist in resolving issues and impacts as the study participants evaluate alternatives. Denver will initiate a National Environmental Policy Act (NEPA) review of a project for its North System. Denver has identified the need for the project but not a preferred alternative. Denver is working through the UPCO process with Grand County to include and address some of the impacts identified in UPCO. Denver's permitting agency will most likely be the Corps of Engineers. Northern is studying alternatives for a Windy Gap firming project. Northern will most likely initiate the NEPA process in the summer of 2003. The permitting agency will be the U.S. Bureau of Reclamation. Northern will continue to work through UPCO to get public input from Grand County during the NEPA process.

Some of the issues identified in UPCO are being addressed through the ongoing efforts of groups other than the UPCO Management Committee. Examples of these efforts include the Three Lakes Water Quality Study, the Snake River Task Force, two Blue River restoration projects – above and below Dillon Reservoir, and the French Gulch Remediation Opportunities Group. UPCO will work with and through existing groups where such efforts already exist.

5. LIST OF REFERENCES

Colorado Water Conservation Board. 2002. Instream Flow Summary List.

Denver Board of Water Commissioners. July 1997. Water for Tomorrow: The History, Results and Projections of the Integrated Resource Plan.

Denver Board of Water Commissioners. February 2002. Water for Tomorrow: The History, Results, Projections and Update of the Integrated Resource Plan.

Denver Board of Water Commissioners. February 2002. Water For Tomorrow: An Integrated Resource Plan, Water Resources Appendix.

Denver Board of Water Commissioners. December 1976. Features of the Denver Water System.

Hydrosphere. February 1999. Northwest Cooperative Investigation Final Reports for Task 1: Mutual Education; Task 2: Future Baseline Representation; Task 3: Estimate of Future Unused Supply.

Hydrosphere. June 2001. Keystone Ski Area Water Quality Study. Prepared for Keystone Resort and the USDA Forest Service, White River National Forest.

Hydrosphere and others. January 1999. Metropolitan Water Supply Investigation Final Report to the Colorado Water Conservation Board.

Hydrosphere and others. October 1997. Denver Basin and South Platte River Basin Technical Study.

U.S. Army Corps of Engineers. March 1988. Metropolitan Denver Water Supply Environmental Impact Statement.

USDA Forest Service, White River National Forest. September 1999. Arapahoe Basin Master Development Plan Final Environmental Impact Statement.

U.S. Department of the Interior. 1981. Water and Power Resources Service Project Data. A water Resources Technical Publication.