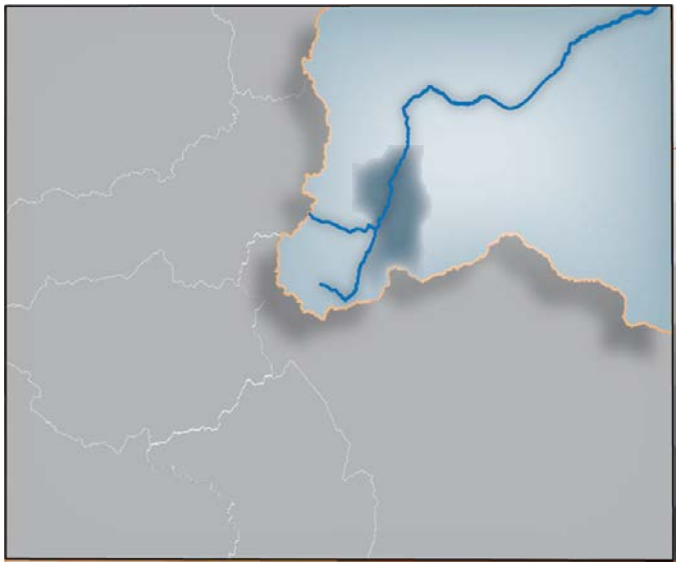

Appendix E – Water Quality

South Platte Basin Implementation Plan

South Platte Basin Roundtable/Metro Basin Roundtable

Prepared by TDS Consulting, Inc.

April 17, 2015

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South Platte River Basin Implementation Plan Water Quality and Watershed-Health Aspects Executive Summary

A bibliographic review was conducted provide information on water quality and watershed "health", based upon past and recent investigations completed in various watersheds of the South Platte River Basin or for the Basin in its entirety. A brief water quality overview is included for the Republican River Basin. This report summarizes study results and information available from a number of sources, including numerous websites and makes specific recommendations regarding information gaps and future water quality and water-related environmental issues facing the Basin's stakeholders in the future.

Watershed resources management includes stormwater and flood control. Innovative projects are being developed in the Basin that provide water quality and flood control benefits. In addition, numerous studies have dealt with water quality characterization and/or management for large parts of the South Platte River Basin or for the entire Basin. One primary example is the U.S. Geological Survey's study of the Basin's water resources under the auspices of its National Water quality Assessment (NAWQA) Program. The Basin has been delineated into a total of 18 eight digit hydrologic unit codes (so-called HUCs). Only subareas approximately covering the first 12 HUCs are included this review, with descriptions of available information and data provided generally in an upstream-to-downstream order.

This review identifies the range of water quality monitoring data and related information available for the various subareas of the South Platte Basin. A number of the subareas surrounding the Denver metropolitan area, including plains and mountain tributaries, have watershed plans, monitoring reports, source water protection plans, and other investigation reports describing specific issues of concern in water quality or watershed health. The intent of this review was to highlight, subarea by subarea (watershed by watershed) conditions of concern for these attributes and, in some cases, remedial projects or mitigation measures for maintaining or improving these conditions. The concept of sustainable watershed water resources management underlies many of the watershed or subarea based studies cited in this review.

Sustainable management for environmental and recreational attributes is interrelated with water supply complexities and land use changes affecting water quality and land cover, the latter factor being especially critical in the forested, mountain tributary streams flowing into the South Platte River. In this respect, institutional consideration (e.g., Federal vs. private land ownership) plays a role. The role of land management Federal and State agencies, as well as the water resources and environmental protection agencies requiring compliance with the NEPA, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Clean Water Act (CWA) regulations is critical to the goal of sustainable water- resources management. In

addition, the Colorado Department of Health and Environment (CDPHE) monitors water quality throughout the State.

From a water quality perspective in the South Platte Basin, the following examples demonstrate the diversity of concerns relative to current and future Statewide planning:

1. Wastewater treatment and reuse are important facets of the Basin's water supplies. Innovative systems are being developed in the Basin to increase water availability for various beneficial uses.
2. Water quality changes, generally beneficial, due to West Slope transfers of water into the Basin.
3. The occurrence and areal extent of agricultural related chemicals (nitrogen or phosphorus compounds, herbicides and insecticides) affecting shallow groundwater resources and eventually downstream streamflow quality.
4. Mountain communities relying upon bedrock wells, providing limited supplies and impacting in some areas by cross-contamination from individual wastewater treatment systems.
5. The threat of emerging contaminants (including pharmaceuticals and personal care products) being only partially removed by current state-of-the-art wastewater technologies and potentially being introduced into water bodies downstream of wastewater treatment facility discharges and septic systems. To date, these types of contaminants remain unregulated, due to low detection limits. However, water supply providers in the Basin are beginning to gather baseline information on these substances.
6. Forested areas of mountain tributaries of the South Platte Basin are being impacted by climate variability, diseases and disturbances affecting trees. This degradation of forested lands is resulting in increased wildfire potential, contribution of organic decomposition and nonpoint source nutrients, and challenges in tree-kill diseases and control of wildfires and increased nutrients.
7. A few of the mountain tributaries have been impacted by historical mining and mine-related activities. These cases (primarily involving the North Fork of the South Platte River, Clear Creek, Boulder Creek, and St. Vrain Creek watersheds), along with the presence of a mineralized zone transecting these watersheds, result in concerns of trace metals concentrations and controls to reduce these through various forms of remedial actions.
8. Cherry Creek and other plains streams move great quantities of sand through their respective watershed each year, increasing sediment and releasing phosphorus.
9. Water supplies provided by municipal water utility entities are regulated by the U.S. Environmental Protection Agency (EPA) and in recent years, these entities have been required to document the water quality of these supplies in annual reports. These reports are important, in that, from year to year, supply sources may well vary, depending on both surface water and groundwater sources.
10. Water resources management includes groundwater resources in the Basin, both alluvial systems interactive with streams and deeper groundwater systems. Bedrock

aquifers of the Denver Basin Aquifer system are a key part of overall supplies in the Denver metropolitan area. Bedrock aquifers in mountainous areas of the Basin provide sufficient supplies for individual wells. Water quality concerns with these groundwater sources may exist and should be taken into account.

11. There are salinity concerns related to wastewater treatment plant discharges and salted roads. These salinity issues can impact both surface water and groundwater supplies.
12. Changing regulatory temperature standards can create additional consumptive use for the additional cooling water needed to meet these standards.
13. Stormwater controls, the need to integrate Clean Water Act (CWA) and Safe Drinking Water Act (SDWA) requirements, and impacts from individual sewage disposal systems (septic systems) are also concerns that merit future consideration.

This report review attempts to cover many, but not all, of the examples provided above. It is hoped that the information contained herein is sufficient to promote deliberations involving these topics, to help to prioritize future investments in maintaining or improving the water quality and watershed health of the South Platte Basin, and to contribute to the overall Statewide water planning process.

1 Introduction

1.1 Background and Purpose

This report, to be appended to the South Platte BIP, is intended to provide information on water quality and watershed "health", based upon past and recent investigations completed in various watersheds of the South Platte River Basin or for the Basin in its entirety. This report summarizes study results and information available from a number of sources, including several websites. The report's last section summarizes the general present conditions involving water quality and watershed health and makes specific recommendations regarding information gaps and future water quality and water related environmental issues facing the Basin's stakeholders in the future.

1.2 General Physical Setting

The South Platte River Basin (Basin) comprises approximately 24,000 square miles (mi^2) and is located principally in the northeastern quadrant of the State of Colorado. Relative small parts of the Basin are located in states of Nebraska and Wyoming. These minor areas impact the lower stream reaches of the South Platte River and are not included within the scope of this assessment. Also, the western part of the Republican River Basin is included in the areal extent of water quailty/watershed health characterization effort documented herein.

2 Approaches

Through his professional experience and personal contacts, the principal investigator (PI) of this study is generally familiar with water quality conditions as well as watershed health issues facing many parts of the Basin. Information regarding these attributes has been supplemented through fairly intensive web-based searches for watershed- or subarea-based entities, data, and information dealing with the issues addressed in this study. The intent is to provide some indication of the range of water quality data, information, and studies providing a comprehensive water quailty/watershed health depiction of the Basin's areal extent.

Numerous studies have dealt with water quality characterization and/or management for large parts of the South Platte River Basin or for the entire Basin. One primary example is the U.S. Geological Survey's study of the Basin's water resources under the auspices of its National Water quality Assessment (NAWQA) Program. Example highlights of several investigations are given later.

Also, the Basin has been delineated into a total of 18 eight digit hydrologic unit codes (HUCs); this delineation is used by the U.S. Geological Survey and other organizations for dealing with the various subareas of the major river basins of the U.S. Of these 18 HUCs, only subareas associated with the first 14 HUCs are considered within the scope of this study. In particular, relatively more interest and information is available for the first seven HUCs (for this Basin, identified as 10190001 through 10190014), located in the upstream (southern) and western (mountain tributaries) areas of the Basin. The

descriptions of available information and data for 12 of these HUCs are provided generally in an upstream-to-downstream order. No information was found for the downstream-most tributary HUCs 10190013 (Beaver Creek) and 10190014 (Pawnee Creek). The HUC-delineated methodology is a logical way to discuss water quailty/watershed health conditions or issues; however, various water quality oriented stakeholder entities do not follow these delineations exactly. Accordingly, the details provided in this assessment generally follow the upstream-to-downstream sequence offered by the 12 HUCs of the Basin but are modified to include information for the various watershed or subarea based organizations dealing with conditions and issues for smaller subareas of the Basin.

3 Discussion

3.1 Basinwide Characterization

An overview of historical water quality conditions was provided in a broader South Platte River Basin assessment study for the Colorado Water Conservation Board by Woodward-Clyde Consultants (1982, pp. 35-40). A USGS bibliography (Dennehy and Ortiz-Zayas, 1993) provides a more extensive list of study reports. As noted above, a primary, more-recent source for the topic of this study is provided by the USGS' NAWQA Program. Many of the USGS studies under this program were completed in the 1990s; therefore, some of the topics addressed in several technical reports are proposed for updating. Nonetheless, water quality issues identified during these investigations are judged largely relevant today and in the future. Four examples of water quality issues were identified and warrant some consideration herein:

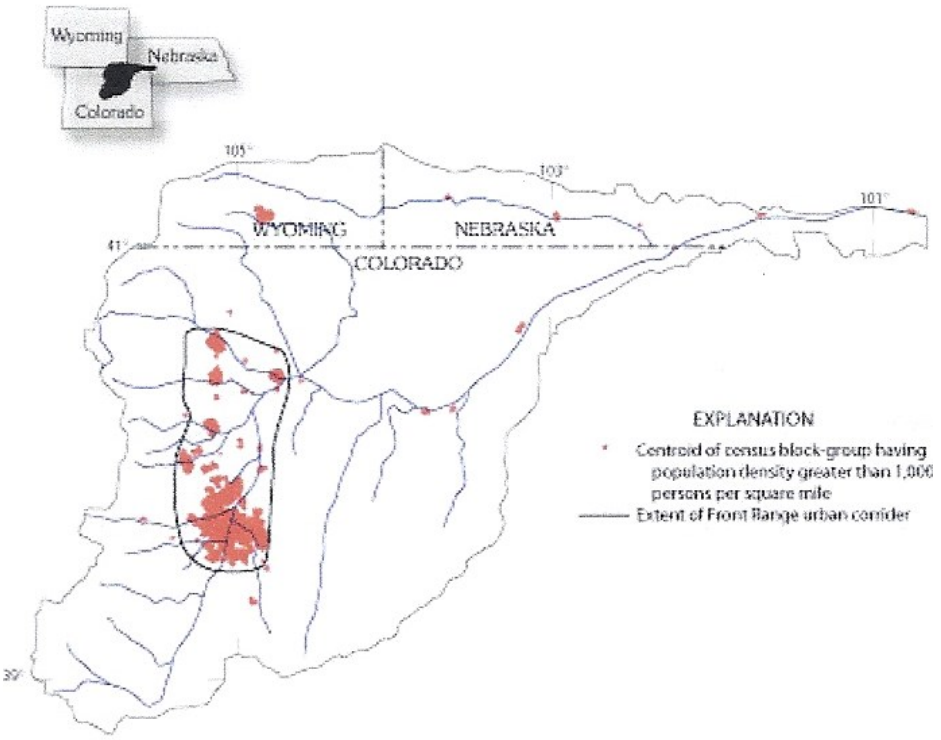
1. Water development and water quality.—Water development began in 1870 in the Basin (Dennehy and others, 1998, p. 8), when the first irrigation ditches were constructed. Over the past 140+ years, irrigated agriculture in the Basin and trans-basin water conveyance into the Basin has significantly altered the "natural" (historical) hydrologic system. These alterations, in addition to increased population growth with needs for water supply and wastewater treatment, have affected the quantity and quality of water in the South Platte River. Besides direct water quality impacts, changes have resulted in a substantial decrease in channel width of the South Platte River, to a greater degree prior to 1938. Considering ground water/surface water interactions is critical to effective water management, especially in the upper and lower stream reaches of the South Platte River.

2. Because agriculture accounts for about 37 percent of the land use in the Basin, impacts of agricultural chemicals (herbicides and pesticides) are of increasing concern. In the NAWQA study, it was estimated that 2 million pounds of active pesticide ingredients have been applied annual in the Basin (Dennehy and others, 1998, p. 16). This trend is due to greater water demands in populated zones (primarily the Denver metropolitan area), requiring innovative water exchange systems in alluvial recharge/withdrawal areas downgradient of these zones in which water is pumped, conveyed by pipeline, and treated for municipal water supplies. Addressing levels of agricultural chemicals, as well as other chemicals of concern,

will be of increasing importance to assure good water quality for potable water supplies.

3. Municipal wastewater treatment plants (WWTPs) are permitted to discharge limited amounts of nutrients. Over the recent two decades, largely due to the total maximum daily load (TMDL) assessment process by the CDPHE, nutrient discharge limits are becoming more stringent. In the basin in the 1990s, 25 WWTPs along the Front Range urban corridor discharged approximately 275 million gallons per day (gpd) of effluent, constituting about 95 percent of the total daily effluent discharge in the Basin (Dennehy and others, 1998, p. 18). About 7,000 tons of nitrogen and 1,200 tons of phosphorus were discharged by WWTPs into the Basin (Litke, 1996). These estimates have decreased in recent years, due to increased WWTP treatment through denitrification and phosphorus removal technologies (www.lewwtp.org/our-process/denitrification).

Figure 1 - Distribution of Population Centers, South Platte River Basin (Dennehy and others, 1998)



4. A NAWQA study examined the effects of different land uses (agriculture, forested, urban, and mixed urban/agriculture) on water quality, using a combination of physical, chemical, and biological information on streams and aquifers (Dennehy and others, 1998, p. 20). Customized ranking schemes and indices were used with each land use classification for assessing land use/water quality interactions impacting different categories of chemical constituents or physical/biological characteristics.

A recent Ph.D. dissertation completed at CSU (Haby, 2011) included an extensive use of available streamflow and water quality (dissolved solids) to assess areal variability and

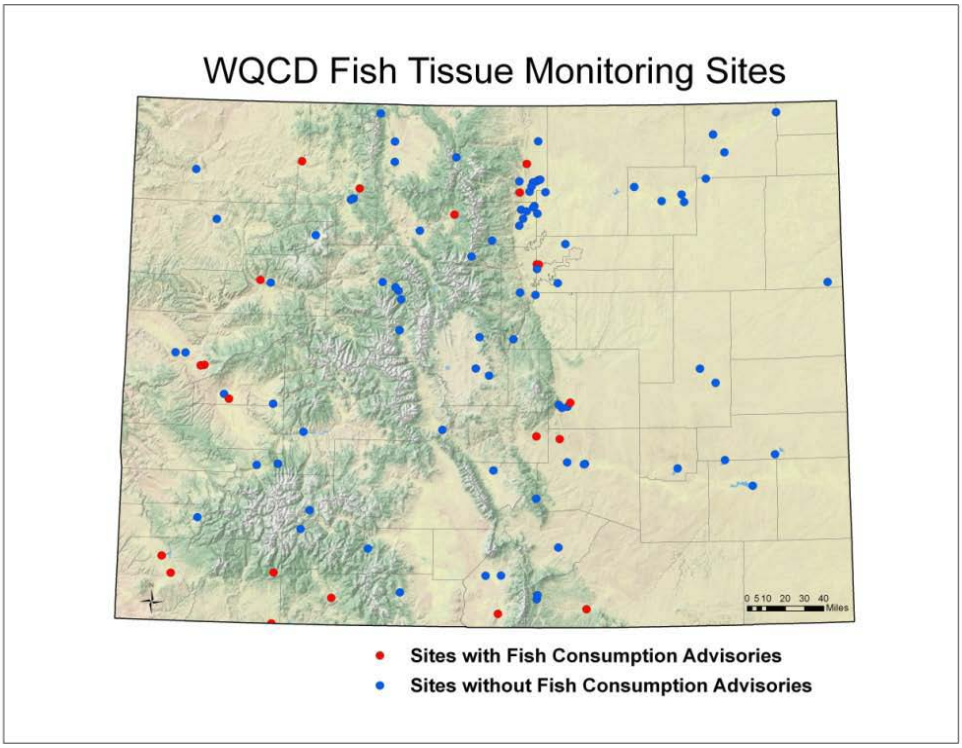
time trends in concentrations and loads of this indicator variable. Another, quite innovative CSU study evaluated the use of fauna species as indicators of groundwater quality (Ward and others, 1989), as applied to the South Platte River system.

A statewide water quality management plan (SWQMP) was developed (CDPHE, 2011) to provide a forum for water quality planning using a watershed based framework. This "living" document (presuming periodic updates are forthcoming as proposed by CDPHE-WQCD) is to assist water policymakers, managers, and others (stakeholders) in setting priorities, developing strategies, and evaluating progress in water quality protection and restoration efforts. Chapter 11 of this initial SWQMP document deals with the Platte River Basin (including the part of the North Platte River in Colorado). This is a useful compendium of information on water quality information as well as ecology, stream standards, and completed total maximum daily loads (TMDLs) assessment studies and plans for implementation. *[Note: These are separate phases in the TMDL process; few implementation plans are known to have been developed to date.]*

Many municipalities and water districts conduct their own water quality assessments. Some of those entities include Denver Water, Aurora Water, Northern Water, and Greelwy.

One means of tracking progress of the goal of the SWQMP is through the Integrated Water quality Monitoring & Assessment Report – the most recent of a series of State of CO (305(b) reports in fulfillment of this section of the Clear Water Act (CDPHE, 2012). This document provides a broad range of water quality related information, including key topics such as impacts on wetlands, funded 319 grants for nonpoint source projects, approved TMDLs, and aquatic species. CDPHE fish tissue monitoring sites are indicated in the following map of Colorado:

Figure 2 - CDPHE Fish-Tissue Monitoring Sites



Finally, a section of this report summarizes assessment results for the South Platte River Basin (CDPHE, 2012, Appendix D, pp. 134-135), in terms of use support according to USEPA's system of five integrated report (IR) categories (CDPHE, 2012, pp. 5-8) for fully supporting water bodies in the state by basin:

Table 1 - EPA Integrated Report Categories

Table 25: Individual Use Summary for the South Platte River Basin.

EPA IR Category	River Miles	Lake Acres
1 - Fully Supporting	7,042	19,248
2 - Some Uses Supporting	1,582	13,375
3 - Insufficient Data, including waters on the M&E list	10,214	68,410
4a – TMDL Completed and Approved	123	0
4b – Impaired no TMDL Necessary	0	0
4c - Impaired Naturally, Placed on the M&E list	0	0
5 - Impaired and TMDL Necessary	3,139	13,047

For example, category (IR) 1 means a stream reach is attaining water quality standards; for category 2, only some classified uses are attained, etc. Category 5 triggers the need for a TMDL.

A statewide strategic plan for the protection of wetlands and riparian areas has been developed by the Colorado Parks and Wildlife (CPW, 2011). An early South Platte conference (Woodring, 1993) focused on the theme of defining ecological and sociological integrity of the Basin. Institutional aspects of water quality management (Nichols and others, 1972) focused on the South Platte River Basin.

This information overview document now will describe a range of examples of water quality and watershed health study results on a watershed- or subarea-delineated basis, in a general upstream-to-downstream order. In the summary and conclusions section of this report, a tabulation of watershed/subarea based organizations and contact information is provided.

3.2 Upper South Platte River Basin

For water quality and watershed health purposes, the Coalition for the Upper South Platte (CUSP) was organized in 1998. Its areal extent covers a land area of 2,600 square miles (mi^2) from the Continental Divide to Strontia Springs Reservoir southwest of the Denver metropolitan area. This area encompasses all of HUC 10190001 and part of HUC 10190002 *(water-usgs.gov/GIS/huc-name.html#Region10)*. This upper Basin watershed is heavily used for recreation (fishing, camping, hiking, etc.) and supplies municipal water for about $3/4^{th}$ of the State's residents *(www.uppersouthplatte.org/watershed.html)*, including the Centennial Water & Sanitation District serving the Highlands Ranch (TDS Consulting Inc., 2001). The South Park area within this sub-basin has recently been the focus of oil and gas development (Johnson, 2012). A source water protection plan study is being developed for water supplies for downstream municipalities (Beth Nielsen, CUSP, *written communication*, March 24, 2014). A Water Quality Assessment of the Upper South Platte was conducted by consultants for Denver Water in September 2013. The study identified potential impacts to water quality from mine discharges, fires, and recreation (Denver Water, September 2013).

3.3 Chatfield (Reservoir) Basin

The Chatfield Watershed Authority (CWA) was created in 1984. A draft watershed plan for this area encompassing Chatfield Reservoir, the Plum Creek tributary subwatershed, and the reservoir South Platte inflow/outflow points has been prepared for the Chatfield Watershed Authority (CWA) (Tetra Tech, Inc., 2013). A related watershed planning process brochure outlines priority projects for this watershed. Historically, a long term monitoring program (since 1983) has collected data on surface water quality (in-Reservoir, inflows/outflow), as well as groundwater quality for some Plum Creek alluvial wells) (ASI, 1994). Annual water quality reports (CWA, 2013a) and a "roadmap" for attaining water quality goals (CWA, 2013b) are examples of watershed management. Also, a nonpoint source investigation has been completed for the Plum Creek subwatershed, and a water quality model application was done for Chatfield Reservoir. A

more recently completed environmental impact statement (EIS) involving evaluating impacts of designating a part of the Reservoir's volume for water supply (storage reallocation for its primary designation for flood control) was completed by the U.S. Army Corps of Engineers (2013); ambient water quality conditions as well as changes due to Reservoir operations by this reallocation were included in this NEPA impacts assessment. Two example of an upstream Plum Creek phosphorus study is given by Kunkel and Steele (1993) and TDS Consulting Inc. (2000). A summary of historical data is given in DRCOG (1997). Comparisons of total phosphorus-chlorophyll-*a* relationships for several Denver Metropolitan area reservoirs (Chatfield, Bear Creek, Cherry Creek, and Standley Lake) are reported in Steele and others (1991) and updated in Lorenz and others (1995). As part of the RCRA Part B regulations, groundwater quality conditions were evaluated at the Martin-Lockheed facility located southwest of Chatfield Reservoir (WCC, 1983).

Figure 3 - Chatfield (Reservoir) Basin (Source: Tetra Tech, Inc., 2013)

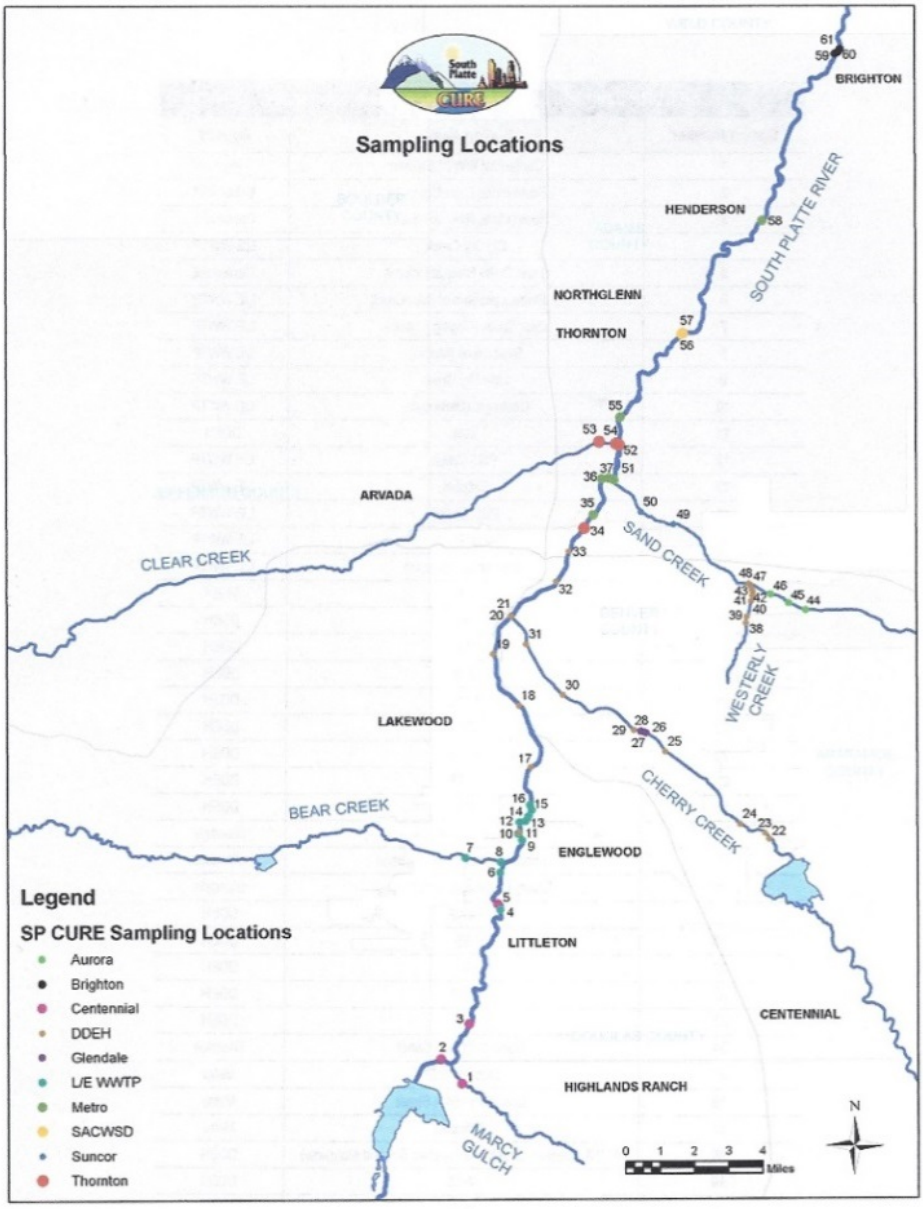
3.4 South Platte in the Denver Metropolitan Area

The primary water quality planning agency for this region/subarea is the South Platte Coalition for Urban River Education (SPCURE). Technical issues overseen by SPCURE

include water quality monitoring, modeling, TMDLs, load allocations (LAs), and wasteload allocations (WLAs). It works through coordination with other local governmental entities.

Figure 4 - Sampling along the South Platte River in the Denver Metropolitan Area (Source: SPCURE website)

Figure 5 - SPCURE Water quality Monitoring Sites (www.spcur.org)



Beginning in this subarea and downstream along the South Platte River, nitrates in both streamflow and groundwater have been investigated by the USGS (Litke, 1996; McMahon and others, 1996). Pesticides also have been of concern (Kimbrough and Litke, 1996; 1998). Focus included assessing conditions in the South Platte River alluvial aquifer between Denver and Greeley, covering an area of about 75 mi^2. This critical resource is impacted by both WWTF discharges upstream and use of fertilizers on adjacent agricultural lands. The USGS study objective was to assess the extent to which naturally occurring processes in the aquifer might reduce nitrate concentrations, thereby decreasing the effects of irrigated agriculture on water quality of the South Platte River. Water-sediment chemistry along the South Platte River in the Denver Metropolitan Area has been characterized (Steele and Doerfer, 1983). Farther downstream along the South

Platte River, municipal water-supply pumpback schemes (Aurora Water, *undated;* CO District Court, 2011) have been developed or are being expanded).

Figure 6 - South Platte River, Northern Denver Metropolitan Area (Source: CDPHE-WQCD, 2012, p. D-13)

The USGS has conducted a recent, extensive evaluation of the Denver Basin aquifer system (Paschke, 2011), which includes a large middle part of the South Platte River Basin. This aquifer system is a key component of water management and water use activities in the Basin. Although the focus of this document is on water availability and management, the USGS NAWQA program for the South Platte Basin listed two studies for assessing groundwater quality in Denver Basin domestic and public supply wells *(http//co.water.usgs.gov/projects/CO255/ index.html)*. A series of USGS hydrologic atlases (Robson and Romero, 1981a; 1981b; Robson and others, 1981a; 1981b; Robson and Banta, 1995) include water quality data assessment of the four aquifer units comprising the Denver Basin bedrock system. Management of groundwater use from these units continues to be a challenge to water resources decision makers. More recently, conjunctive surface water/groundwater uses through recharge and subsequent withdrawals are being considered by several water providers.

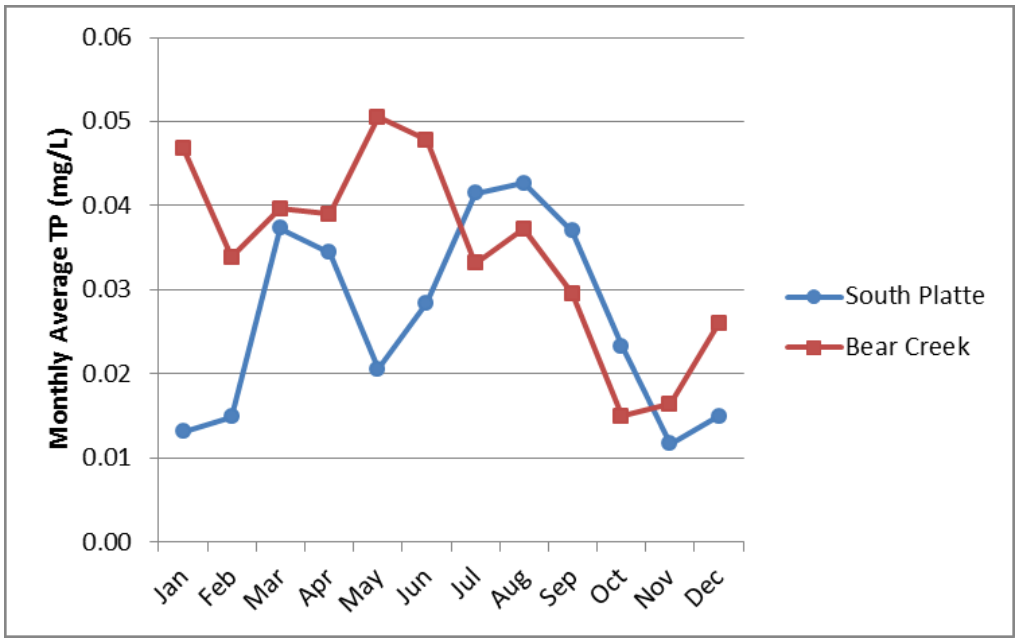
3.5 Bear Creek Watershed

The Bear Creek Watershed Authority (BCWA), established in 1981, “protects and restores water and environmental quality within the Bear Creek watershed …” Its primary focus is on dealing with water quality upstream from Bear Creek Reservoir. The BCWA has conducted a long term monitoring program of inflow streams as well as in-Reservoir water quality conditions for areal characterization and evaluation of time trends. CDPHE-WQCD Control Regulation #74 designates the BWCA as the “water quality management” agency” and specified phosphorus targets (both concentration limits and loads) for

WWTF dischargers in the watershed. In addition, the BWCA submits annual reports to describe the watershed's water quality status.

Evergreen Lake was dredged in the 1980s (WCC, 1980). Hydros Consulting, Inc. (2011) conducted a water quality assessment and water treatment alternatives cost analysis of the Bear Creek/Turkey Creek watershed of behalf of the Denver Water Department (DWD). Two technical memoranda document their study findings. An example of seasonal (monthly) variations in total-phosphorus (TP) concentrations from the second report is given as follows:

Figure 7 - Seasonal variations of Total-Phosphorus Concentrations, South Platte River (Strontia Springs) vs. Bear Creek (above Harriman Ditch), Averages of 2000-2010 Data (Source: Hydros Consulting, Inc., 2011, p. 9)



Seasonal variations of Total Phosphorus Concentrations, South Platte River (Strontia Springs) vs. Bear Creek (above Harriman Ditch), Averages of 2000-2010 Data *(Source: Hydros Consulting, Inc., 2011, p. 9)*

A watershed plan is in progress for the lower reach of Bear Creek, downstream from Bear Creek Reservoir to the confluence with the South Platte River *(groundworkcolorado.org website)*.

The Turkey/Bear Creek watershed, as well as several other mountain stream watersheds flowing into the South Platte River, has critical groundwater resources used primarily by mountain homes and small communities. A multiyear water quality monitoring program was conducted for CDOT for assessing during construction impacts of U.S. Highway 285 improvements along Turkey Creek (TDS Consulting Inc., 2003). An assessment was for the Turkey Creek watershed was completed for Jefferson County by its zoning department and the U.S. Geological Survey, comparing historical versus current (2001) water quality conditions (USGS and JeffCo, 2001, Table 1). Earlier studies investigated interactions between domestic wells and septic fields, indicating cases of *e-Coli* and nutrient contamination. An example of one study done in the Kinney Park area is given

by In-Situ (1986). These studies have resulted in recommended spacing between wells and septic systems to minimize the possibility of well contamination in fractured bedrock. A mountain area aquifer sustainability study (CDM, 2010) was conducted for the CWCB.

3.6 Cherry Creek Basin

The Cherry Creek Basin Water Quality Authority (CCBWQA) goals include achieving and maintaining a chlorophyll-a standard (18 ug/L) for Cherry Creek Reservoir, reducing sediment loads from the watershed, and maintaining and enhancing the overall diversity of habitat in the watershed (www.cherrycreekbasin.org/cc_goals.aspx). Its 2012 watershed plan (Leonard Rice Engineers, Inc., 2012) is in the process of being updated. Its monitoring program, begun in the early 1980s (Steele and others, 1989), has evolved over time, and data results and interpretation, along with other watershed protection and restoration activities, are incorporated in a series of annual reports (Advanced Sciences, Inc., 1994; Leonard Rice Engineers, Inc. and others, 2012). Examples of stormwater runoff projects and effectiveness are given by Mulhern and Steele, 1988; Kunkel and others, 1992; and Kunkel and Steele, 1992). Later reports on effectiveness of sediment detention basins are available.

3.7 Upper Clear Creek Watershed/Standley Lake

The Upper Clear Creek Watershed Association (UCCWA) was created in 1993; a primary function of this organization is to represent the watershed's "upper basin" stakeholders as well as to provide a forum for addressing water quality issues and concerns for downstream ("tributary basin" and "Standley Lake") entities. The framework for this coordination is through the Clear Creek/Standley Lake Watershed Agreement (Hydros Consulting, Inc., 2012, Appendix A). A watershed wide monitoring program began in February 1994; a monitoring plan was developed for describing monitoring sites, sample scheduling, and variables to be measured in the field or analyzed in the laboratory. The monitoring plan has been dynamic, with the most recent status comprising two components: one focusing on nutrients/sediment related/physical variables (Hydros Consulting, Inc., 2012, Appendix B); the second involving trace metals and supported by the USEPA. This separation into two monitoring components began in 2005. As with most watersheds, other water quality data are being collected in this watershed by other entities (Steele, 2012). Watershed agreement annual reports to the CDPHE's Water Quality Control Commission have included basic data appendices for both monitoring program components; however, recent reports have not included the trace metals data.

A useful "state-of-the-watershed" report on the upper Clear Creek watershed was prepared by Norbeck and Flineau (1997). Funded by the USEPA, a watershed advisory group (WAG) dealing with mine impacts existing in the late 1990s; the group's findings are given in a final report (Board of Upper Clear Creek Watershed Advisory Group, 2001). The original upper Clear Creek watershed plan (TDS Consulting Inc., 2006), which focused upon trace metals and associated stream standards and prioritization of mining related remediation projects, has been updated and enhanced by Clear Creek Consultants and Matrix Design Group (2014).

The Clear Creek Watershed Foundation (CCWF) was created to develop and implement projects in the watershed for the protection and restoration of water quality and watershed health. A watershed sustainability report outlined various management techniques applicable to the watershed (CCWF, 2007). Over the past two decades, a number of USEPA and 319 grants have been managed by the CCWF for improving conditions, primarily involving historical mine impacted areas.

Numerous study reports completed over the past two decades document a wide range of the watershed's water quality and watershed health conditions. Examples include the following:

- Advanced Sciences, Inc. (1993)–watershed/Standley Lake water quality data assessment
- Steele and Clayschulte (1997) – water quality assessment summary for the watershed
- Huyck and others (1999) – metals and fauna studies for mine site remediation
- Bell (1999) – collation of physical, chemical, and biological watershed data
- Herron and others (2001) – reclamation feasibility, Virginia Canyon
- Abel and Steele (2002) – seasonal variability in trace metals concentrations
- Woodling and Ketterlin (2002) – CDOW biological monitoring program update
- TDS Consulting Inc. (2002) – trace metals data assessment for CDPHE-HMWMD
- Szewczyk and Emerick (2002) – CSM study of stream habitat quality
- Wildeman and others (2003) – CSM mine waste-pile/sediment characterization study
- Medine (2004) – USEPA-funded model development and application, WASP4-Meta4
- Butler (2005) – CSM trace metals study of the North Fork Clear Creek
- Matrix Design Group (2013) – CDOT-funded sediment control action plan (SCAP)
- JW Associates, Inc. (2013) – watershed/wildfire assessment and prioritization study
- TDS Consulting Inc. (2013) – latest addendum, trace metals data/loads assessment

The remedial investigation/feasibility study project managed by CDPHE-HMWMD (Tetra Tech-RMC, 2004a; 2004b) addressed the final remediation work to be completed for Operable Unit 4 for the watershed as a Superfund site. There have been several iterations of QUAL2E model applications for the watershed. Other reports focus on issues associated with water quality and ecology of Standley Lake (Tetra Tech, Inc., 1994; Horn and others, 1996; Hydros Consulting, Inc., 2012). A source water protection plan for water users of Standley Lake was conducted by Buirgy (2010). Historical impacts of Rocky Flats on Woman Creek, which previously flowed into Standley Lake, are of interest (Advanced Sciences, Inc., 1992; Steele and others, 1993a; 1993b). A watershed restoration environmental assessment was conducted by the USDA (2013) for selected sites in the upper Clear Creek watershed. The mountain tributary aquifer sustainability study (CDM, 2010) was noted previously and applies to this watershed as

well. Other recent, relevant water quality presentations include Pierce and others (2010) and Steele and others (2012).

3.8 Barr Lake/Milton Reservoir

The Barr Lake-Milton Reservoir Watershed Association (BMWA) is a "consensus driven group dedicated to improving water quality through collaborative efforts" (Patten, 2009). A water quality assessment for Barr Lake was completed by AMEC Earth and Environmental (2008). A watershed plan for the entire Barr-Milton subarea has been completed (BMWA, 2008). This subarea is undergoing change, due to increased interest in a recharge/pumping project in the Beebe Draw area downgradient from Barr Lake by the United Water & Sanitation District on behalf of southeast Denver metropolitan area water providers. For water quality protection with an earlier water rights application involving this subarea, the settlement document is of interest (CO District Court, 2011). An amendment to this for a follow-on water rights case is pending.

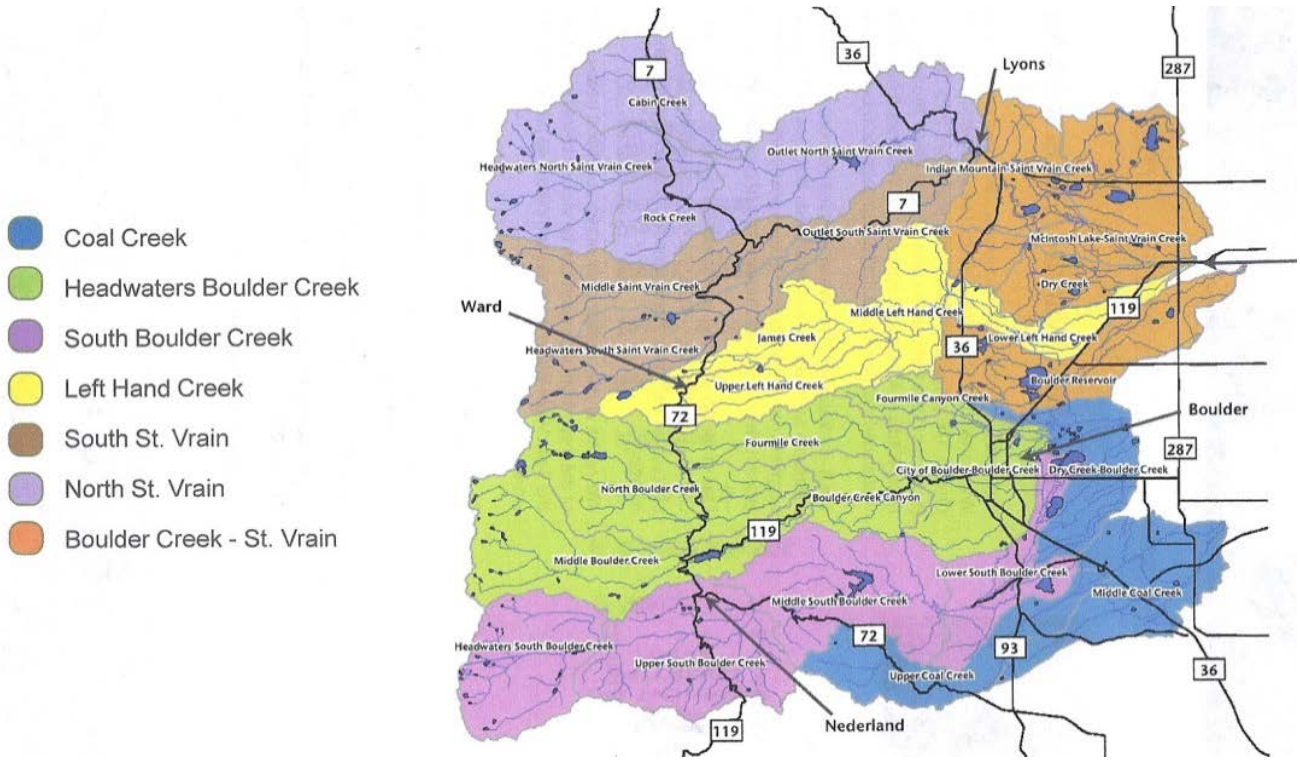
Figure 8 - Barr Lake/Milton Reservoir Subarea (AMEC Earth & Environmental, 2008)

Water development in this subarea demonstrates the challenge of integrated management of surface water/groundwater resources for various beneficial uses and users. The benefits of the water quality monitoring efforts through SPCURE transfer to current and possible future impacts on water development in this subarea. Maintaining recreational and wildlife aspects of these impoundments also is a critical factor, benefitting the entire mid-South Platte River basin area.

3.9 St. Vrain Creek Watershed

The St. Vrain Creek watershed also encompasses several smaller mountain streams (north-to-south): Left Hand Creek, Boulder Creek, and Coal Creek. St. Vrain Creek then flows northeast into the Big Thompson River. An USEPA website provides a water quality assessment on a stream segment basis (www.iaspub.epa.gov/tmdl_waters10/...). One of the more critical subwatersheds is for Boulder Creek; a water quality assessment was made by the USGS in a state-of-the-watershed report (Murphy, 2006). JW Associates also include the St. Vrain Creek watershed in his series of watershed/wildfire assessments (www.jw-associates.org/ saintvrain.html). The Colorado State Forest Service (CSFS, 2013) forest health status report included this as well as other mountain watersheds in the eastern part of the South Platte Basin. Mountain Pine Beetle and Spruce Beetle progression maps are provided and can be compared with previous years' (1996-2013) areal depictions of affected forest areas.

Figure 9 - Saint Vrain Watershed Catchments (Source: JW Associates)



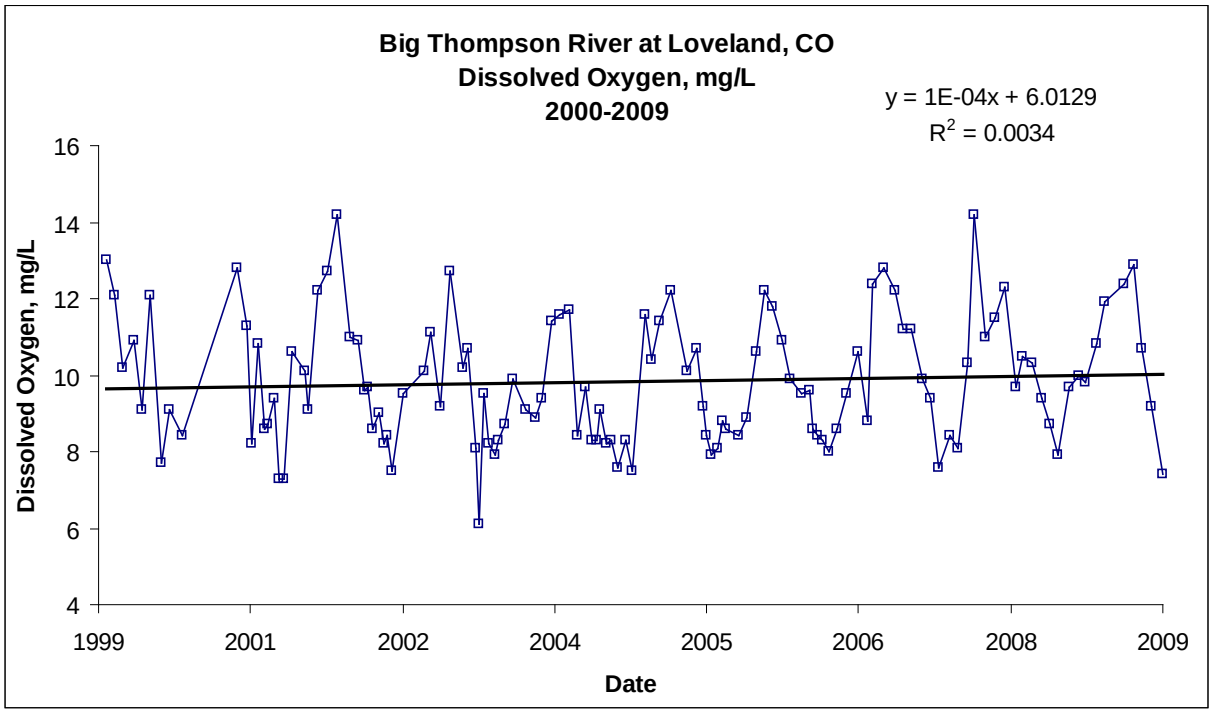
3.10 Big Thompson River Watershed

The Big Thompson Watershed Forum (BTWF) is the organization overseeing water quality and watershed health investigations for this watershed. A watershed management plan was completed by Buirgy (2007). JW Associates and JG Management System Inc. (2010) conducted a watershed assessment, focusing upon prioritization of watershed based hazards to water supplies. In 2013, the BTWF sponsored a nutrient pilot project involving the Sylvan Dale Guest Ranch (www.btwatershed.org).

Walsh and others (1978) assessed water quality recreational benefits, using Rocky Mountain National Park as a case study and based upon interviews with Park visitors. This study indicated a statistical relationship between benefits from water quality and patterns of participation in outdoor recreation activities, attitudes, and other socioeconomic variables.

CSU has collaborated with the BTWF on compiling and analyzing water quality data for this watershed (Haby and Loftis, 2007).

Figure 10 - Seasonal Variations in Dissolved-Oxygen Concentrations, Big Thompson River at Loveland, CO (Source: J.D. Stednick, Colorado State University, written communication, July 30, 2010)



3.11 Cache la Poudre River Watershed

The NRCS (2009) completed a “rapid assessment” of this watershed, focusing upon irrigated agriculture. Conservation system improvements included issues of nutrient and pest management. Impaired water quality stream segments were identified for E. coli and selenium, as well as low dissolved oxygen concentrations in Horsetooth Reservoir

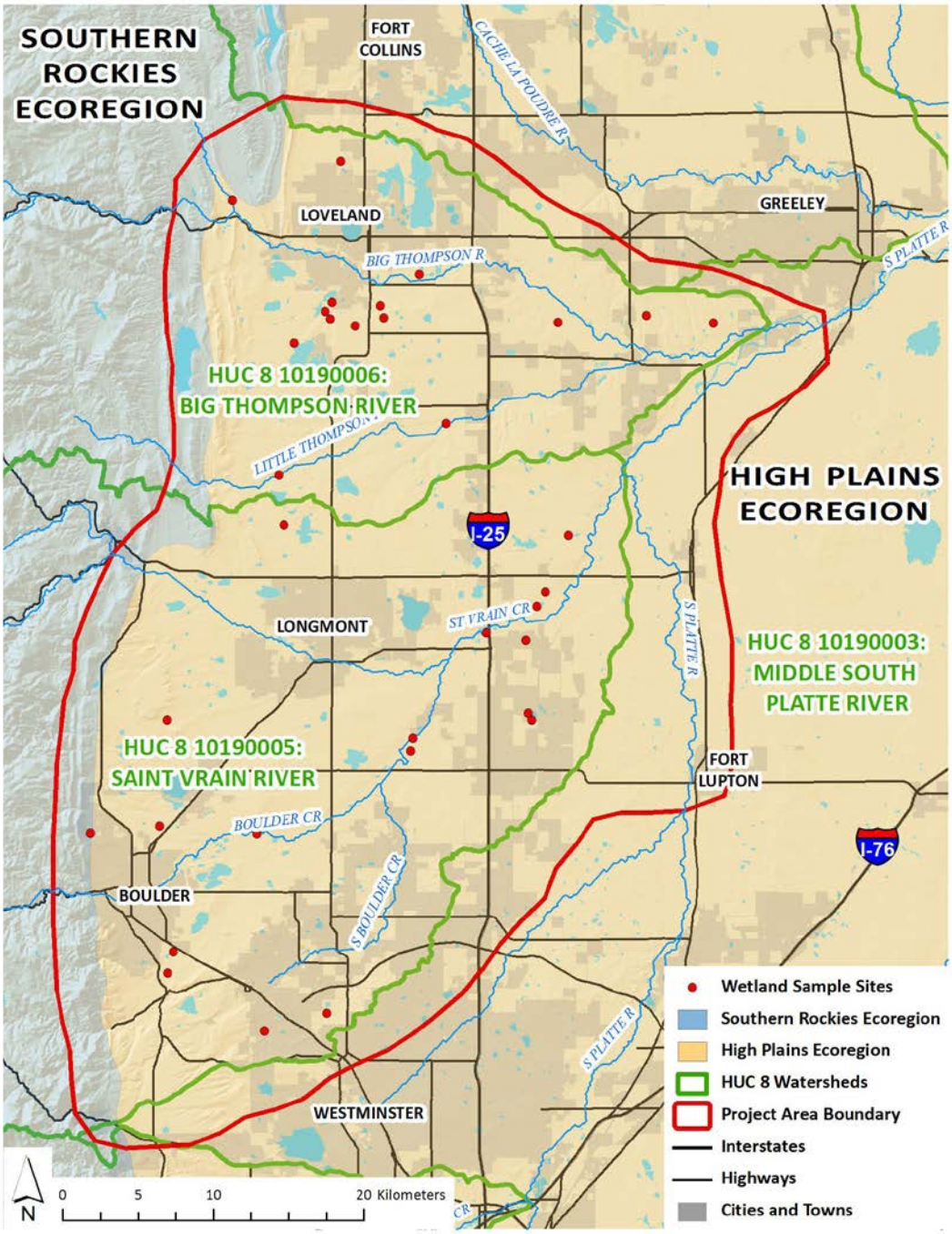
(NRCS, 2009, p. 12). Additional water quality descriptions are included in CDPHE (2012) and WQCD (2013).

This watershed plays a major role in the Colorado-Big Thompson trans-basin diversion project and the more recent proposed Windy Gap Firming project (USBOR, 2011). Another proposed project currently undergoing review is the Northern Integrated Supply Project (NIPS) (USEPA, undated). All of these water development projects have water quality and watershed health implications. A baseline water quality monitoring program started in 1991 under the auspices of the Northern Colorado Water Conservancy District. The program component, as an example, for "flowing sites" (streams, rivers, and canals) is described in a summary fact sheet by NCWCD (2010). Basic data and numerous water quality data analysis reports are available from NCWCD. With the domestic/municipal water use of NCWCD's system, emerging contaminants also are being analyzed (NCWCD, 2013). A "rapid assessment" was made by the NRCS (2009). The Cache la Poudre watershed has also been doing water quality mitigation after the fire.

A couple of CSU studies are relevant to this watershed relative to nutrient characterization:

- Goodwin (2011) – phosphorus transport/eutrophication in the Cache la Poudre watershed
- Son (2013) – nutrient load inputs to the Cache la Poudre watershed

Figure 11 – Big Thompson – St. Vrain Watersheds Showing Wetland Sample Sites (Source: CDPHE-WQCD, 2012, p. 122)



3.12 Northern Plains Basin Tributaries (Lone Tree Creek & Crow Creek)

Wylie and others (1993) studied nitrate conditions in the alluvial aquifer of Lone Tree Creek. Lone Tree Creek is susceptible to flooding. This subarea is part of the Pawnee

National Grasslands (USDA, 2014; ARNF, 2009), protected as part of the Arapaho-Roosevelt National Forest. No other water quality data sources or related issues were found in this cursory assessment effort.

3.13 Southern Plains Basin Tributaries (Box Elder Creek, Kiowa Creek, and Bijou Creek)

The Boxelder Stormwater Authority was created in August 2008. Although its 2006 Master Plan dealt primarily with flooding issues, it included components addressing water pollution control and watershed protection (PBSJ, 2006). Recent concerns of hydraulic fracking in Box Elder Creek (Jaffe, 2014) are indicative of the increasing public awareness of this energy development alternative in many parts of the South Platte Basin.

3.14 Lower South Platte River Basin

The Lower South Platte Water Conservancy District (LSPWC) was founded in 1964 and deals primarily with water resources management of the Basin's interactive surface water/groundwater system within the State of Colorado. A number of CSU-based studies have been conducted for evaluating ambient quantity/quality characteristics as well as model-predicted changes for improved water resources management.

Figure 12 - Irrigation-Diversion Ditch, Lower South Platte River (Source: LSPWCD website)

3.15 Republican River Basin

The part of the Republican River Basin in Colorado is bordered on the east by the State of Kansas. The Republican River Water Conservation District was created in 2004 to promote compliance with the tri-state Republican River Compact, principally involving farmers and ranchers in the Basin. Water use in Colorado involves surface waters of the

Republican River system as well as the west-central part of the critical Ogallala Aquifer (American Ground Water Trust, 2002). No surface water investigations were found through the internet web research. However, the Ogallala Aquifer was studied intensively by the U.S. Geological Survey. Water quality baseline studies were conducted in earlier USGS reports. A recent New York Times article (Bair, 2011) summarized several water quality issues impacting the Ogallala Aquifer:

- 14 percent of all Ogallala irrigation wells tested contained on or more pesticides
- The most common detected herbicide was Atrazine
- Five percent of testes Ogallala irrigation wells indicated nitrate concentrations equal to or in excess of the safe drinking water standard (<10 mg/L NO^3-N) set by the USEPA.

4 Impaired and Threatened Waters

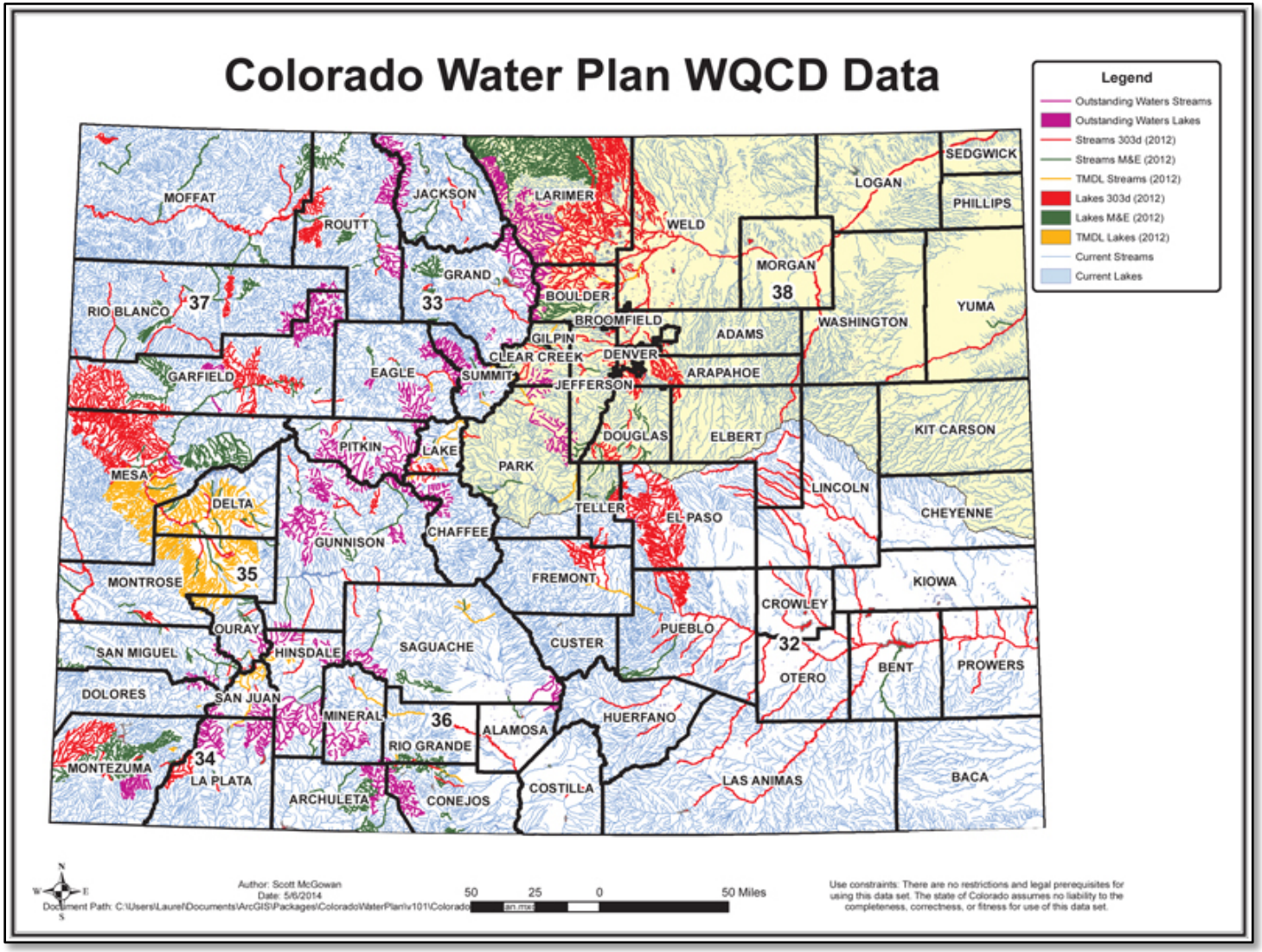
The term "303(d)" indicates those waters on the list of impaired and threatened waters (stream/river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval. States are required to assess the condition of surface waters and submit lists of those that are too polluted to meet water quality standards (called impaired waters). The Act requires that states establish priorities to address these impaired waters by developing water restoration plans (also known as Total Maximum Daily Loads or TMDLs). TMDLs identify pollutant load limits necessary to clean up the water to meet water quality standards and then quantify a pollutant "budget" for different sources of pollutants. The water restoration plans are then implemented via permit requirements and through a variety of other local, state or federal water protection programs.

The Colorado Department of Health and Environment maintains an ongoing monitoring plan to assess the water quality of the State's streams and lakes. The objective of the monitoring plan is to gather, assess and report data regarding the chemical, physical and biological integrity and quality of state surface waters for the Federal Clean Water Act (CWA) 303d list of impaired waters and the 305b report of status of water quality in Colorado as the EPA Integrated Report.[1]

The 303d listed lakes and streams found throughout the Basin are shown in Figure 13, highlighting waterways where water quality may be of concern in the South Platte Basin.

[1] Sources: Colorado Department of Health and Environment (CDPHE), Environmental Protection Agency (EPA)

Figure 13 - South Platte 303d Listed Waterways



Source: CDPHE

5 Summary and Conclusions

A tabulation of various watershed based water quality management entities (a few water conservancy districts are included) was judged to be useful for the users of this document, where only selective references can be given to indicate the diversity and magnitude of useful investigations and reports available for addressing water quality and watershed health:

Table 2 - Summary of Watershed/Regional/Subbasin Organizations, South Platte River Basin

SP Organization	*Website*	*Contact*	*Description/Notes*
Coalition for the Upper South Platte (CUSP)	www.uppersouthplatte.org	Beth Nielsen, Program Assistant	Water quality, forest health, wildlife mitigation, and education; South Park (oil & gas development)
Chatfield (Reservoir) Watershed Authority	www.chatfieldwatershedauthority.org	Larry Moore & Kevin Urie, Co-Chairs	Water quality protection for drinking-water supplies, recreation, fisheries, and other beneficial uses, small WWTPs
South Platte Coalition for Urban River Evaluation (SPCURE)	www.spcure.org	Sarah Reeves, Coordinator	Water quality monitoring, USGS data/model studies, TMDLs, sediment impacts; WWTP discharges
Bear Creek Watershed Authority (BCWA)	www.bearcreekwatershedauthority.org	Russ Clayschulte, Executive Director	Established 1981, monitoring program, includes Turkey Creek, GW-WQ studies, TMDLs, small WWTPs
(Lower) Bear Creek Watershed Planning and Assessment	groundworkscolorado.org	Rachael Hansen, Program Manager	319 Grant (awarded in 2011); website information; watershed plan in process
Cherry Creek Basin Water Quality Authority (CCBWQA)	www.cherrycreekbasin.org	Chuck Reid, Manager	Watershed plan (2012); long term water quality monitoring (annual reports); reservoir controls (TP/chlorophyll-a); WWTPs
Upper Clear Creek Watershed Association (UCCWA); Clear Creek Watershed Foundation (CCWF)	www.clearcreekwatershed.com	Katie Fendel, UCCWA Chair; J. David Holm, CCWF Executive Director	Water quality monitoring, USGS data/model studies, TMDLs, I-70 sediment-control impacts; WWTP discharges; watershed plan update (2013); management agreement (Standley Lake Cities)
St. Vrain River	www.svlhwcd.org	Sean Cronin,	Organized in 1971; levy

SP Organization	Website	Contact	Description/Notes
Watershed Stakeholders		Executive Director	taxes; providing augmentation water to members; water education
Big Thompson Watershed Forum (BTWF); also NCWCD, see below	www.btwatershed.org	Zach Shelley, Program Director	WQ monitoring and assessments; watershed management plan (2007); watershed protection volunteers; CO-BT Project
Big Thompson River Restoration Coalition			Restore river corridor, fisheries and natural areas, and make watershed resilient to future flooding.
Cache la Poudre River Basin - Northern Colorado Water Conservancy District(NCWCD)	www.northernwater.org (also see STP below)	Eric Wilkinson, General Manager	Providing water to northeastern CO via the trans-basin CO-BT P and the Windy Gap projects (above) and the proposed NIPS/Glade Project
Lone Tree Creek/Crow Creek tributaries (Pawnee Natl. Grasslands)	www.fs.fed.us/r2/arnf/	T.J. Williams, USFS	Arapaho-Roosevelt National Forest/Pawnee National Grasslands
Box Elder Creek/Kiowa Creek/Bijou Creek	www.hoaonlineresource.com/boxelder/news.php?category=4		Boxelder Stormwater Authority; stormwater master plan (2006)
Lower South Platte Conservancy District	www.lspwcd.org	Jo Frank, General Manager	Created in 1964; 406,000 acres of agricultural lands; water management and technical services
South Platte River Urban Waters Partnership	www.urbanwaters.gov	Devon Buckels, AICP, Coordinator	Non-regulatory partnership of over 40 organizations focusing on water quality, water protection, and water awareness in the South Platte River watershed.
South Platte Forum	www.southplatteforum.org	Jennifer Brown	Annual conferences since 1989
Republican River Water Conservation District (RRWCD)	www.rrwcd.org	Deb Daniel, General Manager	Created in 2004, self-governed, promotes local involvement in Republican River Compact; Ogallala Aquifer conservation
Colorado Department of Parks and Wildlife (CDPW) - RiverWatch	www.coloradowater.org	Michaela Taylor, Program Manager	Started in 1989; primarily volunteers with training; lab in Ft. Collins (CDPW)
Save the Poudre (STP)–Poudre Waterkeeper	www.savethepoudre.org	Gina Janett	Advocacy group, against proposed NIPS/Glade Project
Centennial Water & Sanitation District	www.centennialwater.org	John Hendrick, General	Water/wastewater provides in Highlands Ranch

SP Organization	Website	Contact	Description/Notes
		Manager	
Evergreen Metro District	www.evergreenmetrodistrict.com	David Lighthart, General Manager	Supplies water and wastewater treatment for the Evergreen community area
Aurora Water	aurorawater.org		Supplies water to its service area
Golden Utilities	www.cityofgolden.net/departments-divisions/water/		Water & wastewater treatment for the Golden service area
Littleton Water & Light	www.littletonwaterandlight.org		
Lakewood Utilities	www.lakewood.org/Utilities/		
Englewood Utilities	www.englewoodgov.org		
Denver Water Department	www.denverwater.org		Supplies water to its service area
Standley Lake Cities	Cities of Westminster, Northglenn, Thornton, and Arvada		Stakeholders in the upper Clear Creek watershed
Greeley	www.greeleygov.com/water		
Longmont	www.ci.longmont.co.us/pwwu/water/		
Fort Collins	www.fcgov.com/utilities/		
Fort Collins-Loveland Water District	www.fclwd.com/		
Boulder	https://bouldercolorado.gov/water		
United Water and Sanitation District	www.unitedwaterdistrict.com	Bob Lembke, President	Client districts: ACWWA and ECCV (SE Denver metro area)
Northern Colorado Water and Sanitation District	www.northernwater.org/		

Municipal water supply utilities and providers require development and submittal of annual water quality reports to be available to the public. Examples are those by Centennial (2013), Aurora Water (2012) and the Denver Water Department (2013).

Long term human-health epidemiological studies are recommended to assess the potential long term adverse impacts of the presence of minute concentrations of chemicals introduced into water supplies – namely, herbicides and insecticides, and pharmaceuticals and personal care products (PPCPs, or emerging contaminants) (Battaglin and others, 2013; Daughton and Ternes, 1999; Sprague and Battaglin, 2005; NCWCD, 2013; Stephenson, 2013). These substances currently are unregulated by the USEPA and CDPHE; however, low detection analytical methods have been developed, and this regulatory situation may change in the near future.

Finally, review of water management strategies proposed in the past (Nichols and others, 1972; CCRI South Platte Team, 1980) might be beneficial with regard to future planning in the South Platte River Basin as well as Statewide planning from the standpoints of

water quality and watershed health. The benefits of dealing with these issues on a watershed/subarea scale are demonstrated by the bibliographic overview provided by this document. Also, we may learn from *post audit* analysis of water development projects that were not authorized (USEPA, 1996). The review of reasons why these past efforts did not move forward can assist in future planning, particularly as similar projects will likely be needed in the future.

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