WATER QUALITY DATA REVIEW

This appendix includes review of constituents identified as being important indicators of the health of stream habitat along the Colorado and Fraser River within Grand County, Colorado. These constituents include nutrients, metals, inorganic and organic parameters. In addition, algae conditions are briefly reviewed and included as appropriate.

Nonpoint source water quality issues in the study area include increased sediment and nutrient loads from urban land uses, agriculture, winter road maintenance and recreation. The major point source discharges in the study area included municipal or domestic wastewater treatment plants. The Colorado Department of Health extensively evaluated point source problems in 1974 as part of the Colorado River Basin 303(e) Plan. A basin plan was developed and adopted to address point source problems. Since the basin plan was adopted, development of wastewater treatment facilities has generally proceeded in accordance with its recommendations. Most of the wastewater treatment and improvements to point source discharges occurred in the mid-1990s (NWCCG 2002). Thus review of water quality data focuses on data collected over the last 10 to 15 years, so as to best represent current conditions.

This study identified 14 constituents as important indicators of the health of fish habitat. These constituents include nutrients, metals, and inorganic and organic parameters. Guidelines for data review are generally based on two sources: water quality standards set by the Colorado Water Quality Control Commission (WQCC), and the Ecoregional Guidelines for nutrient criteria documents for lakes, reservoirs, rivers and streams and wetlands. A summary of the constituents, their purpose, the guidelines for review, and a synopsis of the results for each parameter are presented in the following sections and in Table C1. Within the context of this analysis, criteria or standards are derived from the noted sources and together, form the basis of guidelines used to review water quality data.

Table C1. Constituents and Criteria

Constituents	Guidelines for Review	Source
Physical and Biological:		
Dissolved Oxygen	6.0-7.0 mg/L; Flag if <6.0 mg/L	Water Quality Control Commission (WQCC) Reg 33
pH	6.5-9.0 acceptable range	WQCC Reg 33
Turbidity	1.3 NTU; Flag if >5 NTU	Ecoregional guidelines (EPA 2000)
Organic/Inorganic:		
Nitrates	10 mg/L	WQCC Reg 33
Nitrates as N	0.01 < x < 2.0 mg/L	Binns 1982
Nitrites	0.05 mg/L	WQCC Reg 33, EPA drinking water standards
Phosphorus as P	0.1 mg/L	Ecoregional guidelines (EPA 2000)
Chloride	0.011-0.019 mg/L	WQCC Reg 33
Ammonia as N	Flag if >0.1 mg/L NH_3	EPA 1986
Metals:		
Manganese	table value standard	WQCC Reg 33
Iron	1000 (total recoverable)	WQCC Reg 33
Copper	table value standard	WQCC Reg 33

AVAILABLE DATA FOR EACH REACH

Instantaneous data obtained from USGS and GCWIN databases are recorded by USGS, DWB, NCWCD, Riverwatch or CRWCD. Note that temperature and DO can vary greatly depending on time of day and collection location in the stream. Thus instantaneous values for these parameters are presented to indicate stream conditions with the caveat that the information represents one point in time measuring a diurnal variable which may not accurately represent a section of river. Table C2 summarizes available data and sources for each parameter.

Data for this analysis are sporadic and vary in frequency and timing. Data may have been collected only once per month, or once per year, or even less. Note that water quality data preceding 1995 were not included in this evaluation since many of the improvements to wastewater treatment plants, as noted in the NWCCG report, were implemented and went on line in the mid-1990s. Table C2 summarizes available data and sources for each parameter.

Table C2. Available Nutrient Data for Streams and Rivers in Grand County, by Parameter

Gage Name	Number	Entity	Parameters	Date of Record	# Records
CO River at Hot Sulpher Springs (hist)	9034500	USGS	Amm+Org N	10/19/1979-8/18/1994	74
CO River at Kremmling (bridge CO 9)	9058000	USGS	Amm+Org N	6/3/1976-10/2/2003	91
CO River at Windy Gap	9034250	USGS	Amm+Org N	12/20/1994-8/20/2003	30
CO River below Lake Granby	9019000	USGS	Amm+Org N	11/22/2000-9/25/2003	16
CO River near Granby	9019500	USGS	Amm+Org N	5/18/1976-8/24/1976	2
Fraser at Hwy 40 at Granby	400453105554200	USGS	Amm+Org N	4/7/1995-9/12/2000	2
Fraser at Tabernash at bridge on Grand County 84	9027100	USGS	Amm+Org N	4/7/1995-9/21/1998	3
Fraser River at Winter Park	9024000	USGS	Amm+Org N	4/15/1976-4/7/1995	5
Muddy Creek	9041400	USGS	Amm+Org N	7/7/1995-10/8/2003	101
Ranch Crk near Tabernash	9033100	USGS	Amm+Org N	5/17/1976-9/1/1999	13
CO River at Hot Sulpher Springs (hist)	9034500	USGS	Ammonia	12/18/1990-10/8/1992	9
CO River at Kremmling (bridge CO 9)	9058000	USGS	Ammonia	6/3/1976-11/17/1992	28
CO River near Granby	9019500	USGS	Ammonia	5/18/1976-8/24/1976	2
Fraser above conf. with CO R.	FR-4	NCWCD	Ammonia	5/30/1991-6/27/2001	27
Fraser at Tabernash at bridge on Grand County 84	9027100	USGS	Ammonia	8/8/1990-12/2/1992	31
Fraser below St. Louis at Fraser (hist)	9027010	USGS	Ammonia	8/8/1990-12/2/1992	29
Fraser River at Winter Park	9024000	USGS	Ammonia	8/23/1976-1/4/1977	3
Ranch Crk near Tabernash	395957105493900	USGS	Ammonia	5/17/1976-8/23/1976	2
Ranch Crk. near Fraser	9032000	USGS	Ammonia	9/8/2003-9/21/2004	10
Willow Creek	WC-1	NCWCD	Ammonia	5/30/1991-6/27/2001	55
Willow Creek	WC-3	NCWCD	Ammonia	5/30/1991-6/27/2001	57
Blue River near Kremmling	9057700	USGS	DO	5/27/1971-9/11/2002	12
Blue River near Kremmling	RW 251	Riverwatch	DO	12/7/1992-4/8/2003	88
Blue River near Kremmling	RW 252	Riverwatch	DO	12/4/1992-4/28/2003	89
Blue River near Kremmling	WS-BL-023	DWB	DO	8/14/2002-11/17/2005	14
CO River at Gore Trailhead	WS-CO-002	DWB	DO	11/14/2002-11/15/2004	9
CO River at Hot Sulpher Springs (hist)	9034500	USGS	DO	8/25/1970-8/18/1994	156
CO River at Hot Sulpher Springs (hist)	RW 203	Riverwatch	DO	11/18/2004-5/15/2007	6
CO River at Kremmling (bridge CO 9)	WS-CO-004	DWB	DO	8/14/2002-11/17/2005	14
CO River at Windy Gap	9034250	USGS	DO	12/20/1994-11/14/2003	31
CO River at Windy Gap	RW 543	Riverwatch	DO	12/7/1998-5/15/2007	60
CO River below Lake Granby	9019000	USGS	DO	5/21/1970-9/28/2004	45
CO River N of Parshall at Bar Lazy J Ranch Bridge	WS-CO-003	DWB	DO	8/13/2002-11/17/2005	14
CO River near Granby	9019500	USGS	DO	5/18/1976-8/24/1976	2
Fraser above conf. with CO R.	FR-4	NCWCD	DO	5/30/1991-9/24/2002	25
Fraser at Hwy 40 at Granby	400453105554200	USGS	DO	4/7/1995-9/23/2004	35
Fraser at Tabernash at bridge on Grand County 84	9027100	USGS	DO	8/8/1990-9/22/2004	336
Fraser at Tabernash at bridge on Grand County 84	WS-FR-004	DWB	DO	2/26/1999-6/25/2003	11
Fraser below St. Louis at Fraser (hist)	9027010	USGS	DO	8/8/1990-9/29/1994	197
Fraser River at Winter Park	9024000	USGS	DO	4/15/1976-4/7/1995	5
Muddy Creek	9041400	USGS	DO	7/7/1995-9/15/2004	112
Muddy Creek	RW 255	Riverwatch	DO	4/21/1993-2/3/2003	63
Muddy Creek	WS-CO-001	DWB	DO	8/14/2002-11/17/2005	6
Muddy Creek	WS-CO-005	DWB	DO	1/29/2004-11/17/2005	8
Ranch Crk near Tabernash	9033100	USGS	DO	2/26/1997-3/29/2000	37
Ranch Crk near Tabernash	395840105472700	USGS	DO	11/5/1998-9/21/2004	32
Ranch Crk near Tabernash	395957105493900	USGS	DO	5/17/1976-8/23/1976	2
Ranch Crk. near Fraser	9032000	USGS	DO	2/27/1997-9/21/2004	57
Williams Fork River below Williams Fork Reservoir	WS-WF-009	DWB	DO	5/24/2000-12/14/2005	42
Willow Creek	WC-1	NCWCD	DO	5/30/1991-7/16/2002	39
Willow Creek	WC-3	NCWCD	DO	5/30/1991-9/24/2002	39
CO River at Hot Sulpher Springs (hist)	9034500	USGS	Nitrate	10/1/1948-5/21/1957	76
CO River at Kremmling (bridge CO 9)	9058000	USGS	Nitrate	6/3/1976-11/17/1992	18
CO River near Granby	9019500	USGS	Nitrate	5/18/1976-8/24/1976	2
Fraser above conf. with CO R.	FR-4	NCWCD	Nitrate	5/30/1991-9/24/2002	57
Fraser at Tabernash at bridge on Grand County 84	9027100	USGS	Nitrate	8/8/1990-1/21/1993	36
Fraser below St. Louis at Fraser (hist)	9027010	USGS	Nitrate	8/8/1990-12/2/1992	32
Fraser River at Winter Park	9024000	USGS	Nitrate	4/15/1976-1/4/1977	3
Ranch Crk near Tabernash	395957105493900	USGS	Nitrate	5/17/1976-8/23/1976	2
Ranch Crk. near Fraser	9032000	USGS	Nitrate	9/8/2003-9/21/2004	10
Willow Creek	WC-1	NCWCD	Nitrate	5/30/1991-7/16/2002	102

Table C2. Available Nutrient Data for Streams and Rivers in Grand County, by Parameter, co*nt.*

Willow Creek	WC-3	NCWCD	Nitrate	5/30/1991-9/24/2002	104
CO River near Granby	9019500	USGS	Organic N	5/18/1976-8/24/1976	2
Fraser River at Winter Park	9024000	USGS	Organic N	4/15/1976-1/4/1977	3
Ranch Crk near Tabernash	395957105493900	USGS	Organic N	5/17/1976-8/23/1976	2
Blue River near Kremmling	9057700	USGS	P	8/8/2002-9/11/2002	2
Blue River near Kremmling	RW 252	Riverwatch	P	5/6/2002-3/3/2003	2
Blue River near Kremmling	WS-BL-023	DWB	P	8/14/2002-11/17/2005	14
CO River at Gore Trailhead	WS-CO-002	DWB	P	8/14/2002-11/15/2004	10
CO River at Hot Sulpher Springs (hist)	9034500	USGS	P	6/20/1966-8/18/1994	76
CO River at Kremmling (bridge CO 9)	WS-CO-004	DWB	P	8/14/2002-11/17/2005	14
CO River at Windy Gap	9034250	USGS	P	12/20/1994-11/14/2003	31
CO River N of Parshall at Bar Lazy J Ranch Bridge	WS-CO-004	DWB	P	8/13/2002-11/17/2005	14
CO River near Granby	9019500	USGS	P	5/18/1976-8/24/1976	4
Fraser above conf. with CO R.	FR-4	NCWCD	P	5/30/1991-9/24/2002	30
Fraser at Hwy 40 at Granby	400453105554200	USGS	P	4/7/1995-9/23/2004	34
Fraser at Tabernash at bridge on Grand County 84	9027100	USGS	P	4/7/1995-9/22/2004	74
Fraser at Tabernash at bridge on Grand County 84	WS-FR-004	DWB	P	2/26/1999-6/25/2003	11
Fraser River at Winter Park	9024000	USGS	P	4/15/1976-4/7/1995	9
Muddy Creek	9041400	USGS	P	7/7/1995-9/15/2004	112
Muddy Creek	WS-CO-001	DWB	P	8/14/2002-11/5/2003	6
Muddy Creek	WS-CO-005	DWB	P	1/29/2004-11/17/2005	8
Ranch Crk near Tabernash	9033100	USGS	P	11/5/1998-3/29/2000	14
Ranch Crk near Tabernash	395840105472700	USGS	P	11/5/1998-9/21/2004	32
Ranch Crk near Tabernash	395957105493900	USGS	P	5/17/1976-8/23/1976	4
Ranch Crk. near Fraser	9032000	USGS	P	11/5/1998-9/21/2004	33
Williams Fork River below Williams Fork Reservoir	WS-WF-009	DWB	P	1/22/2002-12/14/2005	26
Willow Creek	WC-1	NCWCD	P	5/30/1991-7/16/2002	42
Willow Creek	WC-3	NCWCD	P	5/30/1991-9/24/2002	43
Blue River near Kremmling	9057700	USGS	pH	7/9/1969-9/11/2002	26
Blue River near Kremmling	RW 251	Riverwatch	pH	12/7/1992-4/8/2003	84
Blue River near Kremmling	RW 252	Riverwatch	pH	12/4/1992-4/28/2003	79
Blue River near Kremmling	WS-BL-023	DWB	pH	8/14/2002-11/17/2005	13
CO River at Gore Trailhead	WS-CO-002	DWB	pH	8/14/2002-8/5/2004	9
CO River at Hot Sulpher Springs (hist)	9034500	USGS	pH	5/1/1947-8/18/1994	793
CO River at Hot Sulpher Springs (hist)	RW 203	Riverwatch	pH	11/18/2004-5/15/2007	6
CO River at Kremmling (bridge CO 9)	WS-CO-004	DWB	pH	8/14/2002-11/17/2005	13
CO River at Windy Gap	9034250	USGS	pH	12/20/1994-11/14/2003	57
CO River at Windy Gap	RW 543	Riverwatch	pH	12/7/1998-5/15/2007	59
CO River below Lake Granby	9019000	USGS	pH	7/9/1969-9/28/2004	86
CO River N of Parshall at Bar Lazy J Ranch Bridge	WS-CO-003	DWB	pH	8/13/2002-11/17/2005	13
CO River near Granby	9019500	USGS	pH	5/18/1976-8/24/1976	2
Fraser above conf. with CO R.	FR-4	NCWCD	pH	5/30/1991-9/24/2002	55
Fraser at Hwy 40 at Granby	400453105554200	USGS	pH	4/7/1995-9/23/2004	33
Fraser at Hwy 40 at Granby	400550105581800	USGS	pH	4/7/1995-9/21/1998	6
Fraser at Tabernash at bridge on Grand County 84	9027100	USGS	pH	8/8/1990-9/22/2004	397
Fraser at Tabernash at bridge on Grand County 84	WS-FR-004	DWB	pH	2/26/1999-6/25/2003	11
Fraser below St. Louis at Fraser (hist)	9027010	USGS	pH	8/8/1990-9/29/1994	199
Fraser River at Winter Park	9024000	USGS	pH	8/23/1976-4/7/1995	6
Muddy Creek	9041400	USGS	pH	7/7/1995-9/15/2004	212
Muddy Creek	RW 255	Riverwatch	pH	4/13/1993-3/12/2003	63
Muddy Creek	WS-CO-001	DWB	pH	8/14/2002-11/15/2003	6
Muddy Creek	WS-CO-005	DWB	pH	1/29/2004-11/17/2005	7
Ranch Crk near Tabernash	9033100	USGS	pH	2/26/1997-3/29/2000	47
Ranch Crk near Tabernash	395840105472700	USGS	pH	11/5/1998-9/21/2004	31
Ranch Crk near Tabernash	395957105493900	USGS	pH	5/17/1976-8/23/1976	2
Ranch Crk. near Fraser	9032000	USGS	pH	2/27/1997-9/21/2004	54
Williams Fork River below Williams Fork Reservoir	WS-WF-009	DWB	pH	5/24/2000-12/14/2005	40
Willow Creek	WC-1	NCWCD	pH	5/30/1991-7/16/2002	81
Willow Creek	WC-3	NCWCD	pH	5/30/1991-9/24/2002	82
CO River at Hot Sulpher Springs (hist)	9034500	USGS	Total N	10/19/1979-2/17/1983	16
CO River below Lake Granby	9019000	USGS	Total N	11/14/2003-9/28/2004	6
CO River near Granby	9019500	USGS	Total N	5/18/1976-8/24/1976	4
Fraser River at Winter Park	9024000	USGS	Total N	4/15/1976-1/4/1977	6
Muddy Creek	9041400	USGS	Total N	11/19/2003-9/15/2004	11
Ranch Crk near Tabernash	395957105493900	USGS	Total N	5/17/1976-8/23/1976	4

CONSTITUENTS-PHYSICAL AND BIOLOGICAL

Dissolved Oxygen

Dissolved oxygen (DO) is present in some amount in almost all water. It is required for many organisms that live in the river, but extremes in either direction can be harmful for aquatic organisms. The level of DO in the water depends on temperature, water velocity and turbulence, and the existing organisms in the water. An abundance of nutrients can result in algae blooms which can produce a "diurnal" effect in streams. DO levels decrease at night due to respiration of aquatic vegetation or decaying material, but then increase dramatically during sunlight hours due to photosynthesis. This is a natural process in all streams but affects the health of a stream and its' fishery when DO levels fall too low.

Expected levels in a healthy river ecosystem may range from 6.0 milligrams per liter (mg/L) to 12.0 mg/L (River Watch). Fish kills may be expected in water with DO levels of 4.0 mg/L and lower (Commissioner for the Environment, Australia). A minimum of 6.0 mg/L is used to review data for indications of DO deficiency. Review of the available DO data indicates that most readings fall within the acceptable guidelines. Exceptions occur at Williams Fork, where several readings fell below 6.0 mg/L. Figures C1 to C3 presents instantaneous DO readings along the Colorado and Fraser Rivers including their tributaries, since 1995.

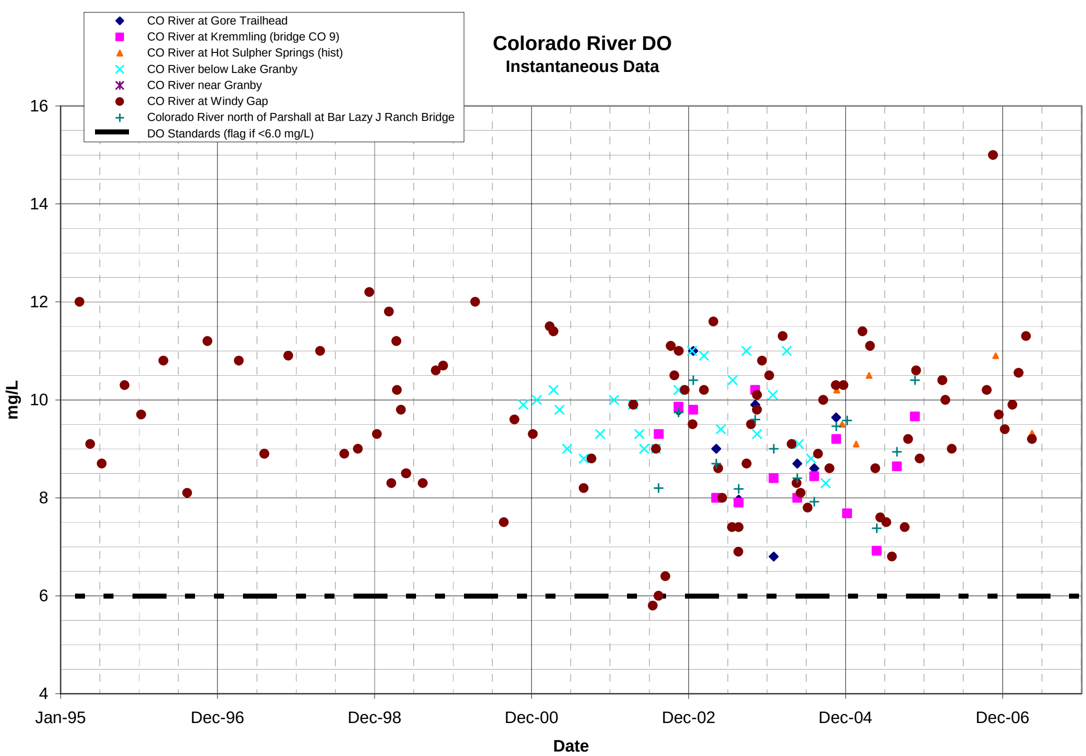

Figure C1. Dissolved Oxygen in the Colorado River

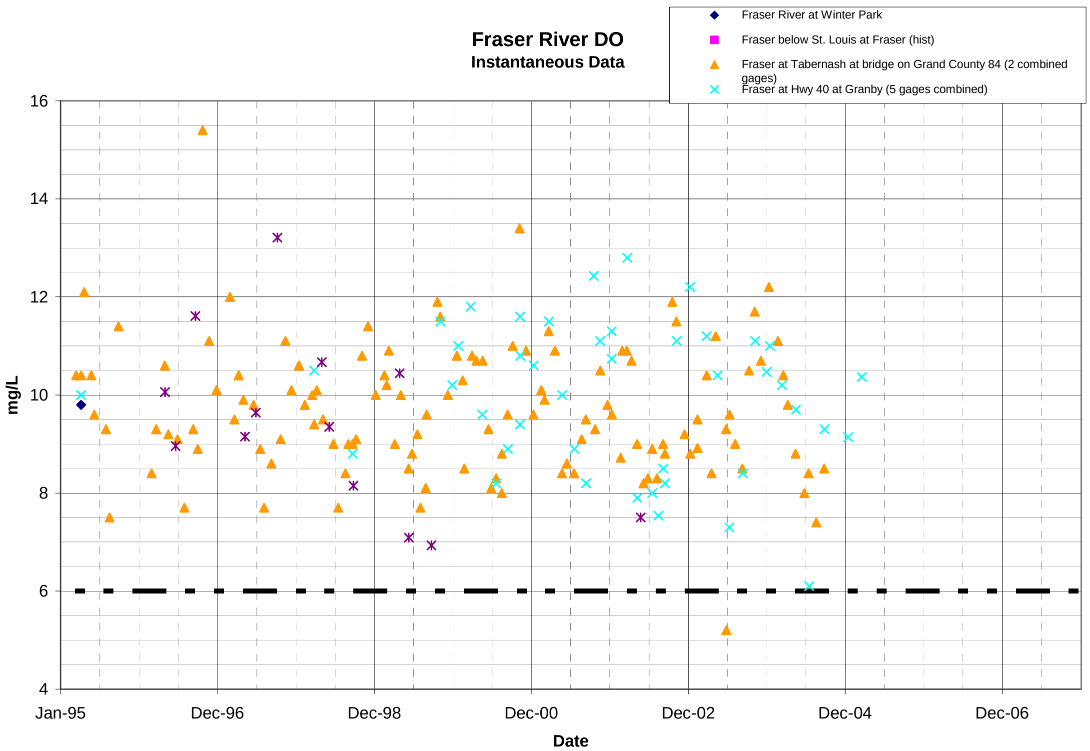

Figure C2. Dissolved Oxygen in the Fraser River

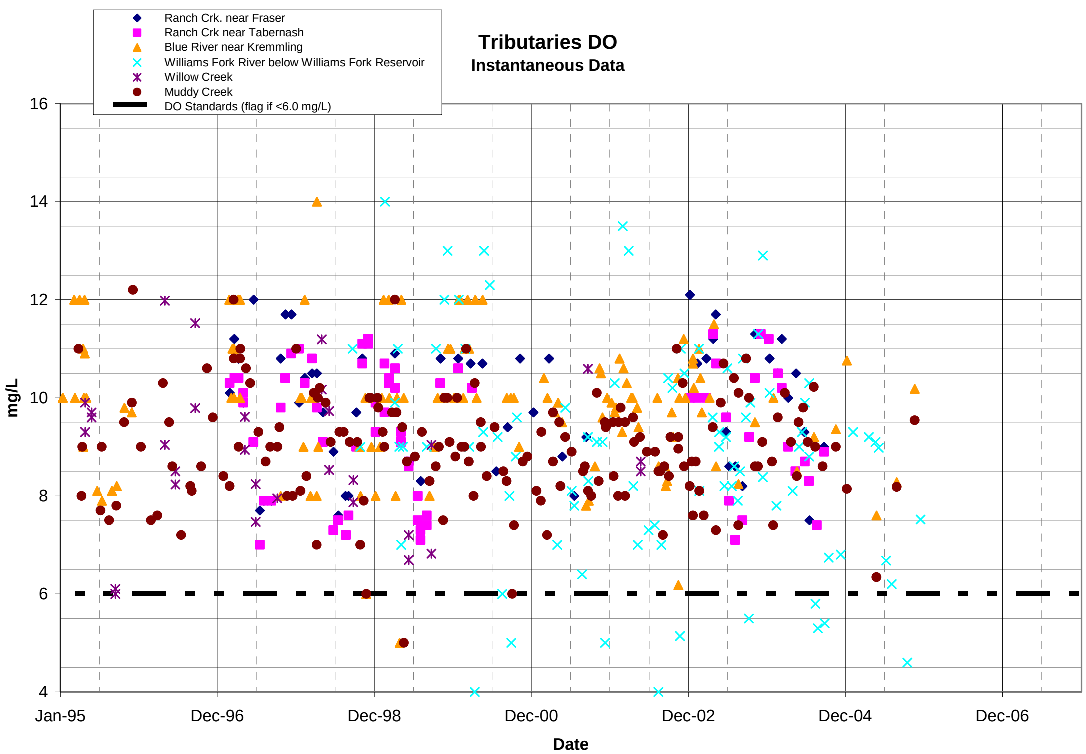

Figure C3. Dissolved Oxygen in Important Tributaries to the Colorado and Fraser Rivers

pH

Analysis of pH is used to describe the acidity or alkalinity of the river or stream. Both low and high pH values can drastically affect the sustainability of the river ecosystem. Reduced pH is especially harmful, as it can boost the toxicity of pollutants such as ammonia. Runoff from surface soils with low or high pH can directly affect the river acidity and alkalinity. Young fish and larvae are especially sensitive to low pH, although extremes on either end may affect them. Guidelines for pH of natural, healthy river systems may vary from 6.5 to 9.0 (River Watch).

Review of the available pH data indicates that most readings fall within the acceptable guidelines. Exceptions occur at gages near Tabernash on the Fraser River, where pH values routinely exceeded 9.0 between 1995 and 2004. In addition, the pH of the Colorado River at Windy Gap has exceeded 9.0 several times since 2000. Figures C4 to C6 show instantaneous pH readings along the Colorado and Fraser Rivers and their tributaries 1995 and mid 2000s. Results from water quality sampling for the years 2007-2009 indicate pH is elevated in these two reaches, however, a pattern and/or source is not easily identified based on desk-top review of this data. Further testing and monitoring is recommended.

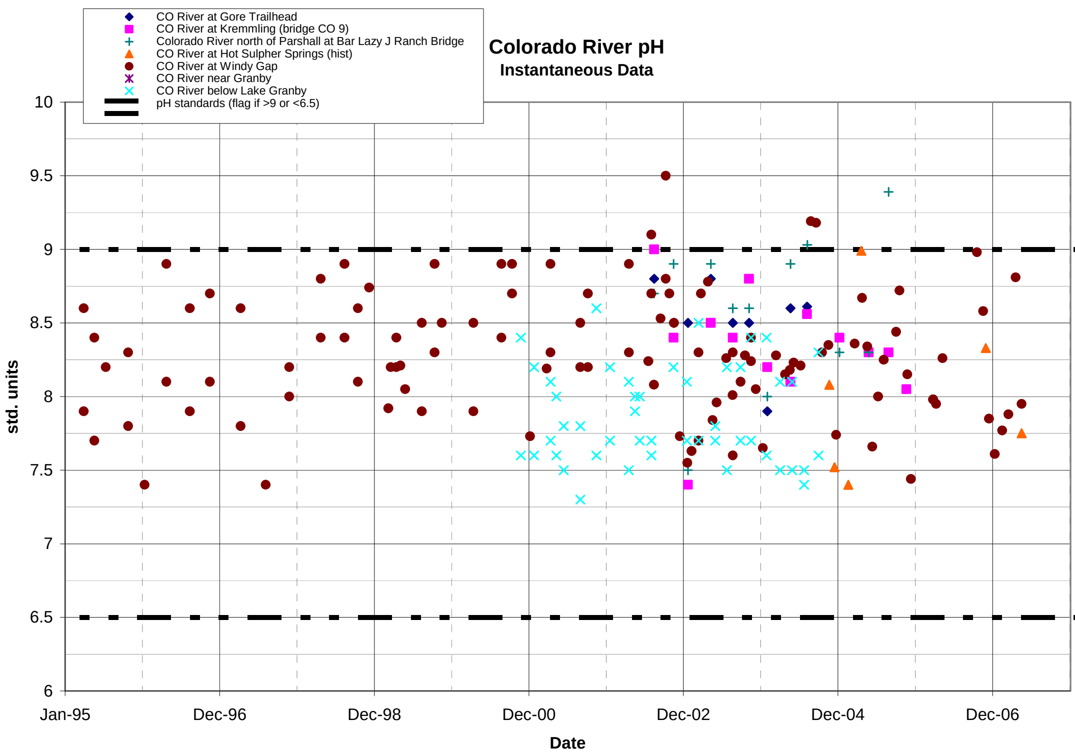

Figure C4. Colorado River pH Plot

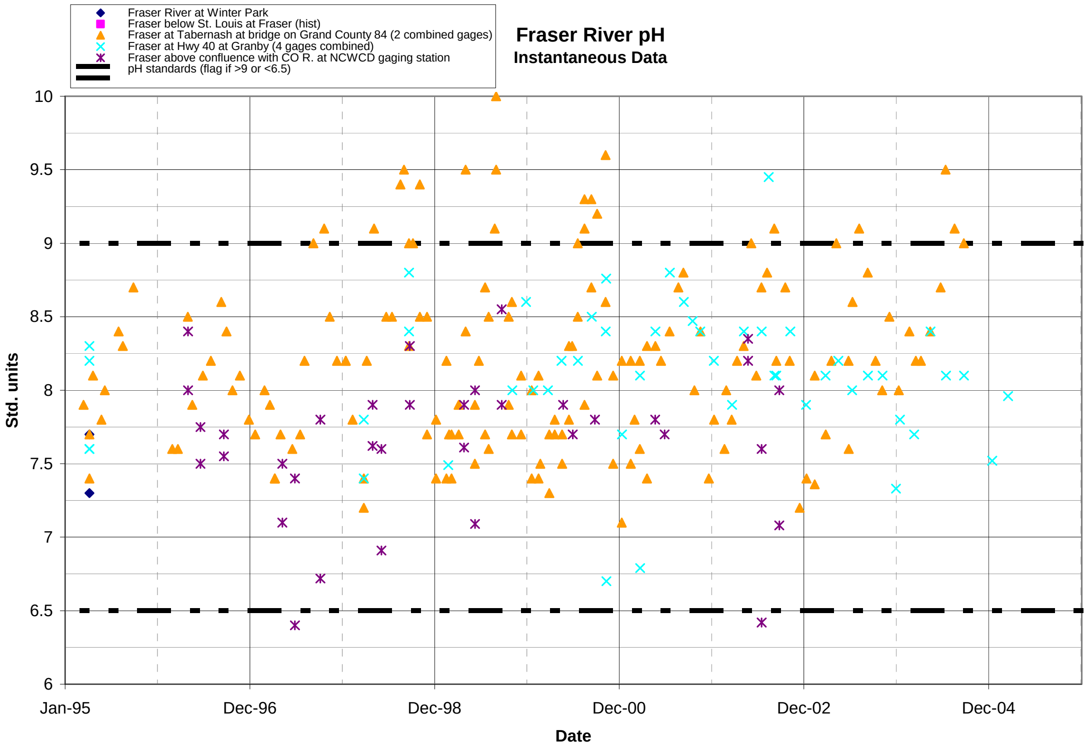

Figure C5. Fraser River pH Plot

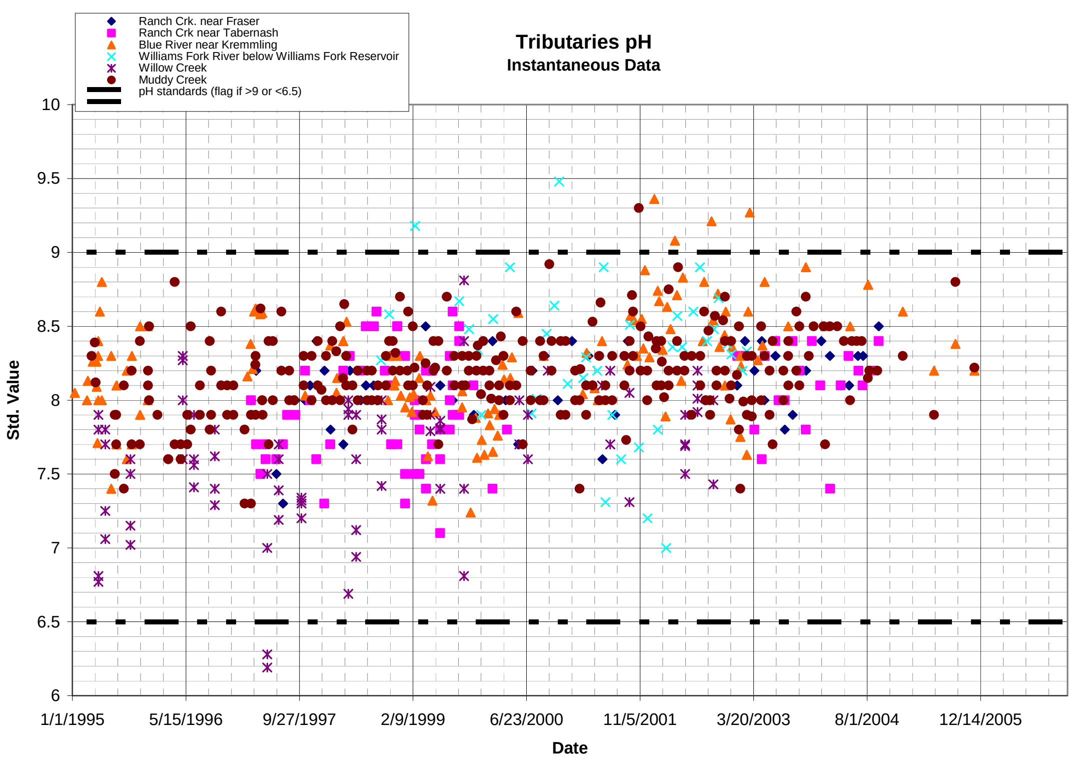

Figure C6. Tributaries pH Plot

Turbidity

In turbulent flow, the high TSS will stay in suspension and can add to the receiving stream's turbidity. While in suspension, the material could affect trout in two ways. First, as trout are sight-feeders, their ability to find food could be impaired. Second, in high enough concentrations, gill damage could occur. Once the material deposits out, which it could do in very tranquil pools, it can add to substrate embeddedness and perhaps limit habitat for quality insects such as mayflies, stoneflies and caddisflies. Also, clay beds can serve as good rooting material for rooted aquatic vegetation, which can be either good or bad, depending on the stream and circumstances. The clay deposits could also smother trout eggs deposited in the tailspill at the downstream end of the pool just as the flow breaks into the next riffle.

Union Pacific Railroad (UPRR) operates the Moffat Tunnel, which includes the discharge of groundwater seepage from the tunnel to both the east and west sides of the portal, as permitted by the Colorado Department of Public Health and Environment. Monthly monitoring data received from the state on UPRR’s Moffat discharge indicate that some of the parameters are of concern in terms of water quality guidelines for stream health. Parameters of particular concern include total suspended solids (TSS), iron, and mercury, copper and lead.

CONSTITUENTS-ORGANIC/INORGANIC

Nitrates

Nitrogen is another important nutrient in the river, essential for life and sustainability, but destructive in large quantities. If there is not enough nitrogen in a river system, macroinvertrate production is reduced resulting in less food for the fishery. In large quantities, nitrogen becomes food for masses of cyanobacteria, or blue-green algae. When overpopulated, the algae will die off, asphyxiating the river. Nitrogen may be found in several forms: ammonia, nitrate, or nitrite, to name a few, and sources may range from natural organic matter to human sewage and fertilizers. Nitrogen, in addition to phosphorus, may be used as an indicator of human impacts on the land and river ecosystem.

Review of the available Nitrogen data indicates that most readings fall within the range of guidelines for nitrates as N.

Phosphorus

Phosphorus and inorganic phosphorus in the form of phosphate play a major role in the structural framework of aquatic life forms. Phosphorus is a limiting factor in most ecosystems, controlling the rate of growth. However, excess phosphorus is problematic, allowing out-of-control growth, and is one of the major causes of excessive algae. Phosphorus can be generated from non-point surface runoff and is present in fertilizers and sometime in municipal wastewater effluent, a result of the use of detergents and soaps.

Review of the available phosphorus data indicates elevated levels on the Fraser River near Granby and Tabernash, and Willow Creek, where phosphorus values rose to more than twice the guideline in the late nineties. The gage on the Colorado River at Kremmling recorded several high phosphorus values in 2000 through 2005 as well. Figures C7 to C9 show instantaneous phosphorus readings along the Colorado and Fraser Rivers and their tributaries since 1995.

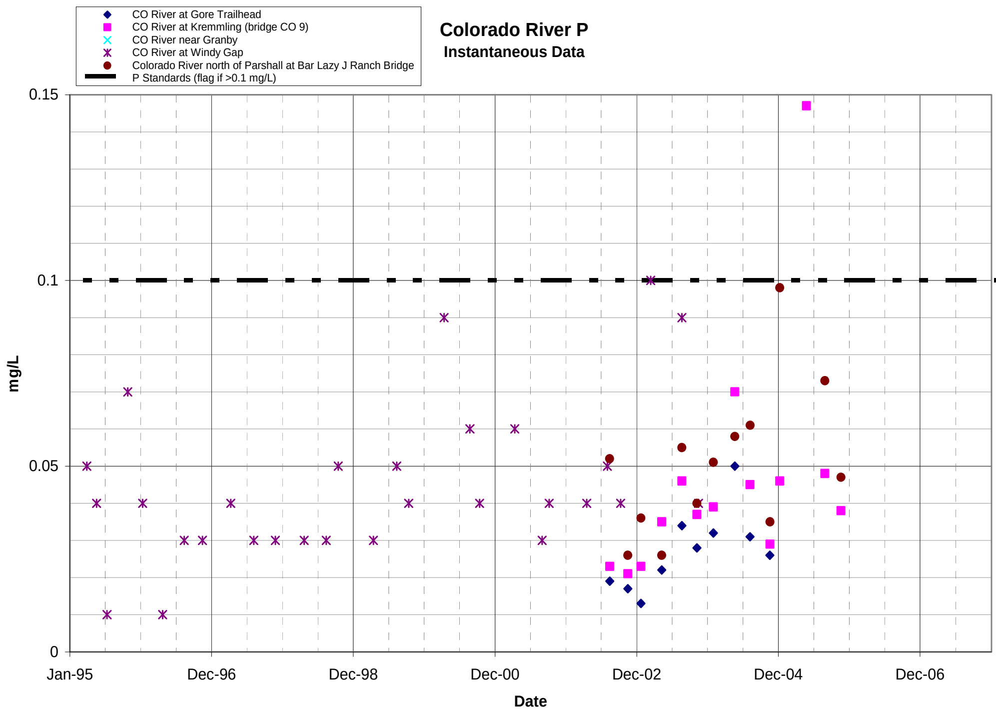

Figure C7. Phosphorus Concentrations in the Colorado River.

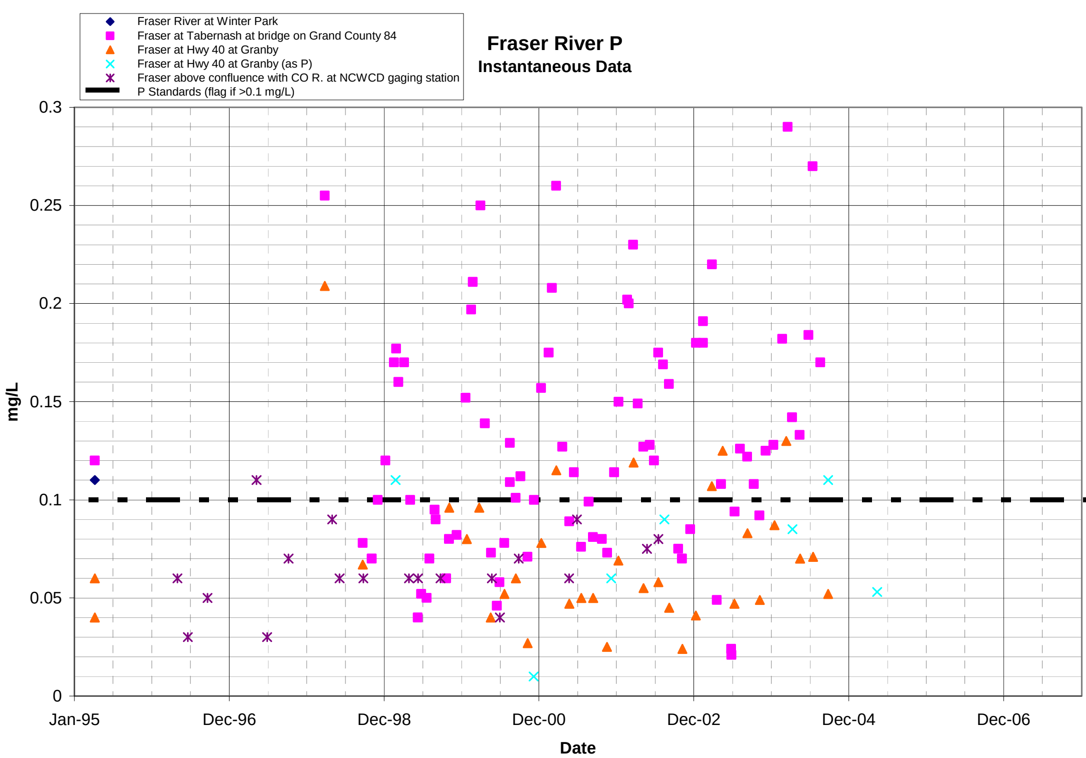

Figure C8. Phosphorus Concentrations in the Fraser River.

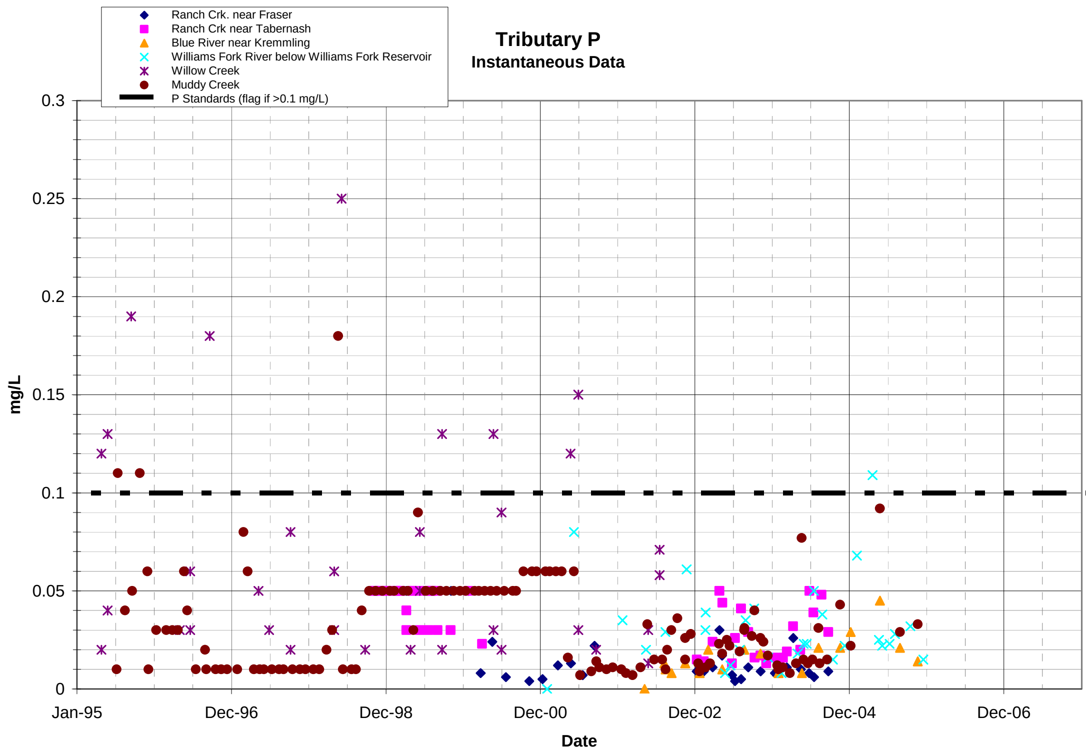

Figure C9. Phosphorus Concentrations in Tributaries.

Chloride, Ammonia as N

Review of the available data indicates that most readings for chloride and ammonia fall within the range of guidelines.

CONSTITUENTS-METALS

Metals could potentially impact the trout fishery through physiological stress, reduced condition, reproductive impairment/failure, and increased mortality. There are two none concerns related to metals. The first is the Moffat Tunnel Discharges. Union Pacific Railroad (UPRR) operates the Moffat Tunnel, which includes the discharge of groundwater seepage from the tunnel to both the east and west sides of the portal, as permitted by the Colorado Department of Public Health and Environment. Monthly monitoring data received from the state on UPRR's Moffat discharge indicate that some of the parameters are of concern in terms of water quality guidelines for stream health. Parameters of particular concern include total suspended solids (TSS), iron, and mercury, copper and lead.

Secondly as of April 2010 several reaches on the Fraser River have been placed by the State of Colorado on the 303(d) list for monitoring and evaluation for Copper. This river segment extends from Hammond Ditch to the confluence with the Colorado River.

The magnitude of the problem for TSS and metals will most likely worsen as river flows are predicted to decrease with increases in diversions The Moffat Tunnel discharge permit no. CO-0047554 was renewed on July 31, 2009 under protest from Northwest Colorado Council of Governments and Grand County. Grand County requested the west portal discharge include a sedimentation/flocculation facility designed to treat the outfall meeting the same standards as the County wastewater treatment plant operators and other dischargers to the river and its tributaries.

OTHER

Algae

Guidelines for Assessing Algae in Streams

Algae has been observed in most stream reaches within Grand County, as well as in Granby Reservoir, Shadow Mountain Reservoir and Grand Lake, referred to as the 'Three Lakes'. Algae can be a "nuisance", due to aesthetics, and clogging of pump intakes. Algae can also contribute to fish mortality as warm, still, or slow-moving water with high nutrient content (N and P) contribute to low dissolved oxygen content. As water temperature increases, the Petri dish effect magnifies the influence of N and P exasperating algae growth and continued decline in dissolved oxygen (Clements 2007).

Currently, there are no definite guidelines for assessing algae in streams, as there are for lakes. However, the State of Colorado is developing criteria for algae in streams because algae have emerged along the Colorado River and other affected waterways. The State of Colorado and the U.S. Environmental Protection Agency (EPA) suggest that soluble nutrient levels can be related to algal biomass. Establishing threshold values, however, relies on values identified from reference reaches. Use of these values must consider suitability of the reference reach when compared with each reach in question. The EPA Clean Water Act Section 304(a) criteria set levels for N, P, Chlorophyll *a*, and clarity (turbidity/transparency). The current numeric values from Section 304(a) for N and P are: 0.04 mg/L Total Kjedldahl Nitrogen (TKN) and 6.3 micrograms per liter (µg/L) TP (Southern Rockies Ecoregion). The Colorado Department of Health nutrient criteria approach will most likely vary by designated uses including aquatic life, recreation, and direct water supply. (Johnson 2007).

In Grand County, phosphorus concentrations exceed the EPA guidelines in many of the streams and rivers, while nitrates and ammonia do not, indicating that phosphorus levels may be the culprit in the observed algal blooms. Phosphorus cannot act alone, however, and further analysis indicates warmer water temperatures and lower velocities in areas where plentiful algal blooms have been observed including reaches CR4, CR5, FR9, and FR10.

Algae in Grand County

A study conducted for the Three Lakes area reports that the predominate algae species in the lake and reservoirs are golden (chrysophytes) and green (chlorophytses). Blue-green algae was also detected in the lake and reservoirs (HRC 2003b). Reports indicate that the lake and reservoirs may be either N or P limited, with much of the nutrient loading supplied by precipitation, contributing 4 percent of the total inflow, 19 percent of the total nitrogen, and 20 percent of the total phosphorus. Windy Gap Reservoir is also recognized as a source, when pumping, evidenced in 2001 when it was estimated that Windy Gap contributed 19 percent of the phosphorus load)HRC 2003b).

The Three Lakes Study does not consider algae impacts from the lake and reservoirs on the downstream receiving streams. However, it is possible that N and/or P loads are higher as a result of contributions from the lakes. Other sources tributary to streams may include point source discharges from wastewater treatment plants, overland runoff, and nutrients from Windy Gap.

Predicting Algae in Study Reaches

As previously discussed, warm, still, or slow-moving water with high nutrient content is highly conducive to algal blooms. These blooms are also associated with low dissolved oxygen content, which can cause fish kills. As water temperature increases, the Petri dish effect magnifies the influence of N and P.

Some information is available on temperature indicators for blue-green algae that may also apply to golden and green algae, which indicates that water temperatures consistently above 28 ^{o}C or 82 ^{o}F encourage algae blooms (Bluegreen Initiative). Another paper from Poland (Plinski and others 1999) studies blue-green algae in the Baltic Sea, and uses both the ratio of N to P (N:P) and temperature as indicators of potential for algae growth. These values are N:P over 2.8, and temperature indicators as follows: No growth below 10 ^{o}C, growth bursts over 18 ^{o}C, optimum growth 20 to 25 ^{o}C. Lastly, a paper titled "Effect of Temperature on Blue-Green Algae in Lake Mendota" (Konopka and others 1978) studied a lake in Madison, Wisconsin. It also indicates a strong correlation of algae growth with temperatures between 20 and 30 ^{o}C and little growth from 10 to 20 ^{o}C.

Several conclusions may be made, extrapolating information from these studies and from the nutrient analysis, and assuming the information can be applied to other forms of algae and other locations, including Grand County. First, concentrations of nitrogen and phosphorus may be a factor related to higher algae blooms. In Grand County, phosphorus concentrations exceed the guidelines in many streams and rivers, while nitrates and ammonia do not, indicating that phosphorus levels may be the culprit in algal blooms. Phosphorus cannot act alone, however, and further analysis indicates warmer water temperatures and lower velocities in areas where plentiful algal blooms have been observed including reaches CR4, CR5, FR9, and FR10. Figure C10 and C11 are included on the following this paragraph, showing the presence of algae in reach CR4 in July 2007.

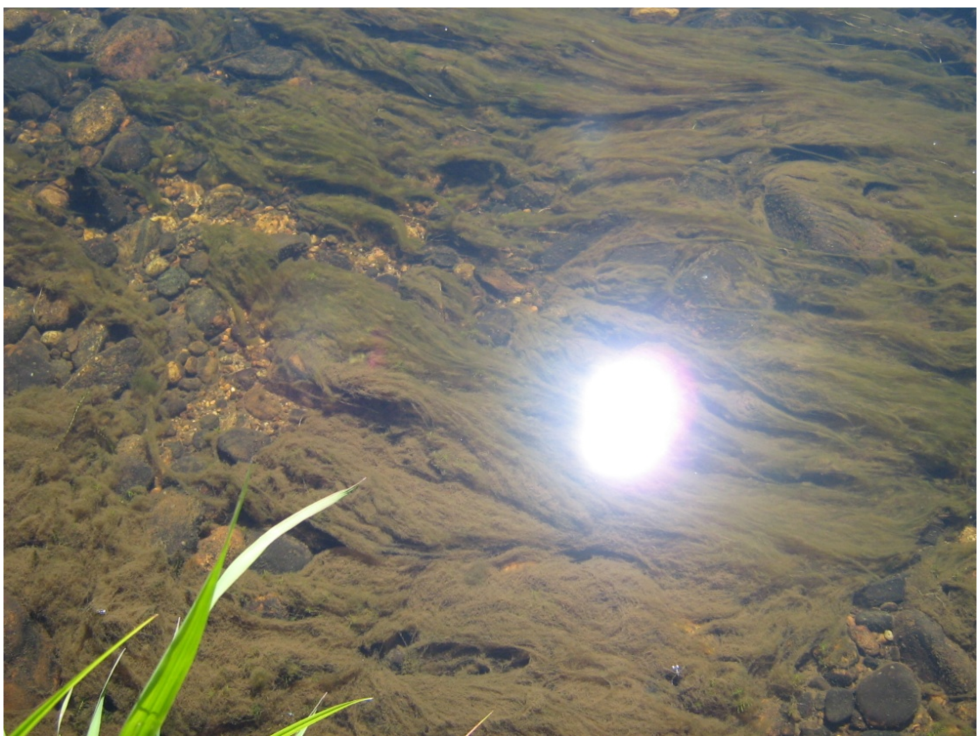

Figure C10 Colorado River between Hot Sulphur Springs and Windy Gap, July 2007.

Colorado River between Hot Sulphur Springs and Windy Gap, July 2007.

Whirling Disease

Tubifex tubifex (Tt) is as segmented worm that inhabits the sediments of lakes and rivers and is an important source of food for fish. Four strains of Tt are present in rivers. These worms host *Myxobolus cerebralis* (Mc), a parasite that can cause whirling disease, spread by the release of fish-infecting triactinomyxon (TAM) spores into the water. Recent studies indicate that, of the four strains, one (III) is the most susceptible to the parasite. This parasite was introduced into the upper Colorado River basin in the mid-1980s, causing catastrophic loss of wild rainbow trout in the drainage. Studies indicate that Windy Gap Reservoir was the major source of production of the trout-infecting (TAM) spore linked to the demise of the rainbow trout fishery (Gilbert and others 2003). Tt prefers warm murky water with temperatures ranging between 18^{o}C and 20 ^{o}C but can survive in ranges of 5 ^{o}C to 35 ^{o}C . The worm can also survive without oxygen for months and is capable of surviving in polluted water with organic matter that almost no other species can endure (Gilbert and others 2003).

A study prepared by the Colorado Division of Wildlife (TU 2001) reports efforts to quantify TAM production began at Windy Gap in 1997. Filtration studies indicate massive annual production of TAMs between 1997 and 2001 but reduced levels more recently. This drop in TAM production is linked to a drop in the lineage III worm. In 1998, approximately 38 percent of the total worm population was composed of lineage III worms compared with 2004 and 2005, when less than 15 percent of the total population was lineage III. Studies indicate that this decrease is likely due to the lineage III worm being out-competed by the other strains. At this time, ongoing monitoring will be required to see if this natural shift will reduce whirling disease within the immediate vicinity of Windy Gap. In addition, the Colorado Department of Wildlife (CDOW) is introducing a strain of rainbow trout with a resistant to whirling disease (Ewert 2008). Again, ongoing monitoring will be required to access success.

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