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TMDL for Selenium in the Colorado River Watershed

Utah Water Quality Board Approval Date:
EPA Approval Date:

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Water Quality Protection Section

Colorado River Selenium TMDL

EPA Approval Date:

Waterbody ID	UT14010005-001_00 Colorado River-6, UT14030001-005_00 Colorado River-5, UT14030005-004_00 Colorado River-4, UT14030005-003_00 Colorado River-3
Location	Grand & San Juan Counties, Utah
Pollutants of Concern	Selenium (Se)
Impaired Beneficial Uses	3B: Protected for warm water species of game fish and other warm water aquatic life including the necessary aquatic organisms in their food chain
Current Loading	31.06 Kg/day average during low flow conditions
Loading Allocation (TMDL)	21.375 Kg/day average during low flow conditions
Load Reduction	9.685 Kg/day during low flow conditions
Wasteload Allocation (Moab WWTP) Moab WWTP current load	Not to exceed 4.14 μg/L or 23.5 grams/day Selenium Less than 4.04 grams/day (based on detection limit of 1 μg/L)
Margin of Safety	0.46 μg/L Selenium (10% explicit) 2.375 Kg/day during low flow conditions
Defined Targets/Endpoints	1) Total maximum load as a daily average of less than 21.375 Kg/day 2) Load reduction of 9.685 Kg/day 3) Water quality target of 4.14 μg/L
Implementation Strategies	1) Colorado River Basin Salinity Control Program 2) Selenium Management Program 3) National Irrigation Water Quality Program 4) Landowner participation
This document is identified as a TMDL for waters in the Colorado River drainage and is submitted under §303d of the Clean Water Act to U.S. EPA for review and approval.	

Table of Contents

1.0 Introduction

Section 303(d) of the Clean Water Act and US Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting applicable water quality standards or designated uses under technology-based controls. TMDLs specify the maximum amount of a pollutant which a waterbody can assimilate and still meet water quality standards. Based upon calculation of the total load that can be assimilated, TMDLs allocate pollutant loads to sources and a margin of safety (MOS). This study determines allowable limits for pollutant loading to meet the water quality standard and designated uses for the Colorado River Watershed from the confluence with the Green River upstream to the Utah/Colorado state line.

This document presents a TMDL for the above mentioned section of the Colorado River which was listed on Utah's 2006 303(d) list for impairment associated with excess concentrations of selenium (Se) (UDEQ 2006). At high concentrations selenium is toxic to aquatic life and increases the risk of deformities and decreased reproduction in fish and aquatic birds.

The Colorado River will be listed on subsequent 303(d) lists for selenium until the TMDL has been approved by EPA. It is important to note that data collection in support of this TMDL is an ongoing effort and that as new data are collected the TMDL may be revised accordingly. The table below presents the 2006 303(d) list information for the Colorado River.

Table 1.1 - Impairment listing for the Colorado River above the confluence with the Green River

8-Digit HUC	Designated Uses*	Pollutants of Concern	Primary Source of Impairment
14010005	Warm water aquatic life	Selenium	Natural geologic formations, subsurface flows.

The Colorado River from the Utah/Colorado Stateline down to the confluence with the Green River is known for scenic landscapes, whitewater rafting, outdoor recreation, and multiple other uses. The State of Utah has designated the beneficial uses of the Colorado River as protected for culinary use, recreational use, aquatic life use and agricultural use (1C, 2A, 3B, 4).

2.0 Identification of Waterbody, Pollutant of Concern, Pollutant Sources

Land Use, Cover, Ownership and Topography

General land use, cover, ownership and topography data were gathered from the Automated Geographic Reference Center (AGRC) for the State of Utah.

Topography is an important factor in watershed management because stream types, precipitation, and soil types can vary drastically by elevation. Dry conditions make irrigation necessary for nearly all crops grown in the watershed. If irrigation water is applied in excess of plant requirements that excess amount will percolate below the rooting zone where it picks up TDS and Se, and returns with elevated concentrations to watershed streams either as surface runoff or groundwater base flow. Tables 2.1 & 2.2 show landownership and water related landuse respectively for the Colorado River drainage above the confluence with the Green River. Figure 2.1 shows the impaired section of the Colorado River in Utah (yellow) and the surrounding geography.

Table 2.1 Land Ownership

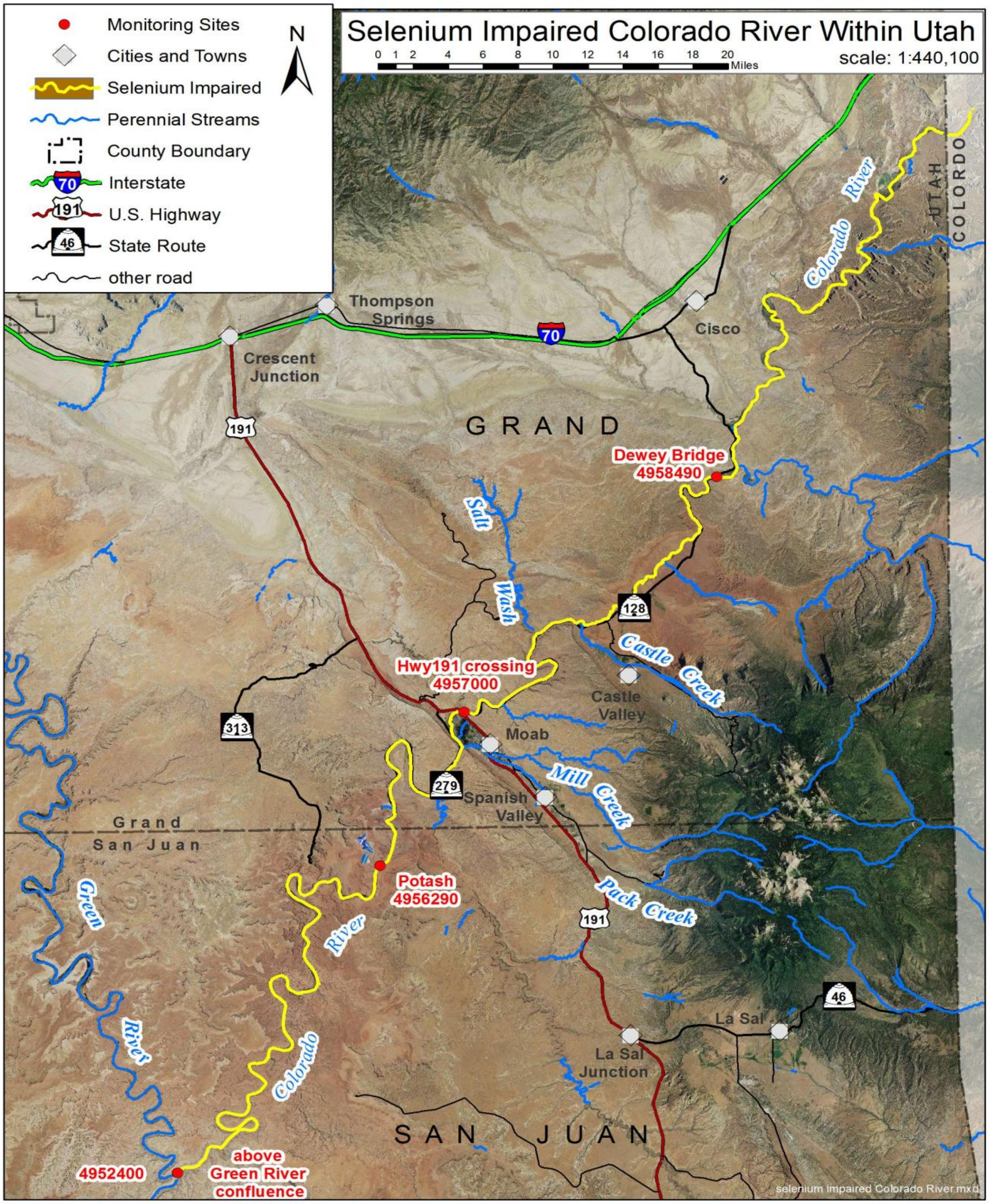
Ownership	Acres	Percent of Total Watershed Area	Detail
Bureau of Land Management	1,585,322	61.7	BLM
National Forest	231,370	9.0	Moab Ranger District and north slope of Monticello Ranger District
National Parks, Monuments & Historic Sites	217,100	8.5	Arches and Canyonlands
National Wilderness Area (near Jones Canyon)	5,101	0.2	Near Jones Canyon confluence with Westwater Canyon, Colorado River
Other State (UDOT)	139	0.0	road right-of-ways
Private	239,549	9.3	
State Parks and Recreation	4377	0.2	Utah State Parks (DNR)
State Sovereign Land	12,170	0.5	Utah Forestry, Fire, and State Lands (DNR)
State Trust Lands (SITLA)	271,146	10.6	SITLA: School and Institutional Trust Lands Administration
State Wildlife Reserve/Management Area	1,646	0.1	Utah Wildlife Resources (DNR)
Tribal Lands	177	0.0	Uintah/Ouray Reservation: headwaters of Left Hand Nash Wash
Total	2,568,097	100	

Table 2.2 Water Related Landuse

Landuse	Acres	Percent of Total Watershed Area	Detail
All Agricultural Land	66,895.6	2.60	Includes irrigated, fallow, and dry farms
Riparian	5,017.7	0.20	Stream/lake associated habitat
Urban Grass	315.5	0.01	Urban Parks and Golf Courses
Urban	8,908.3	0.35	Urban (homes, yards, roads, businesses, schools)
Water	10,058.6	0.39	Surface Water: rivers, lakes, ponds
Total	91,195.6	3.55	3.55% of total drainage area

As can be seen in Table 2.2 the irrigated lands in the watershed total less than 3% of the drainage basin. The majority of the irrigated land in Utah is located in Spanish Valley and Castle Valley where Mill Creek and Castle Creek drain to the Colorado River. These two tributaries have negligible loads of selenium to the Colorado River. Mill Creek contributes an average of 0.02 kg/day and Castle Creek contributes an average of 0.03 kg/day. Neither tributary shows concentrations that exceed the 4.6 μg/L standard at the watershed outlets. Loading averages were calculated from 9 data points on Mill Creek and 11 data points on Castle Creek collected since 2002.

Figure 2.1 Colorado River Area



Threatened & Endangered Species

The Colorado and Green Rivers are designated critical habitat for the four endangered fish species with Westwater Canyon being identified as one of the best remaining habitats for humpback chub. Several thousand bonytail have been experimentally released into the Colorado River in the last decade. Selenium is hypothesized as contributing to the decline of endangered fish species within the upper Colorado River Basin because it may inhibit reproduction and recruitment.

The BLM's program for T&E species consists of inventory and monitoring, habitat management, and compliance with the Endangered Species Act through Section 7 consultations with U.S. Fish and Wildlife Service. The Moab Field Office has active inventory and monitoring programs for listed species. Endangered fish studies are conducted by the Utah Division of Wildlife Resources and U.S. Fish and Wildlife Service. The BLM is also working with other agencies on conservation agreements to restore Colorado cutthroat trout, bluehead sucker, roundtail chub and flannel mouth sucker, all of which are Utah sensitive species.

All implementation activities associated with the TMDL will take into consideration any T&E species present.

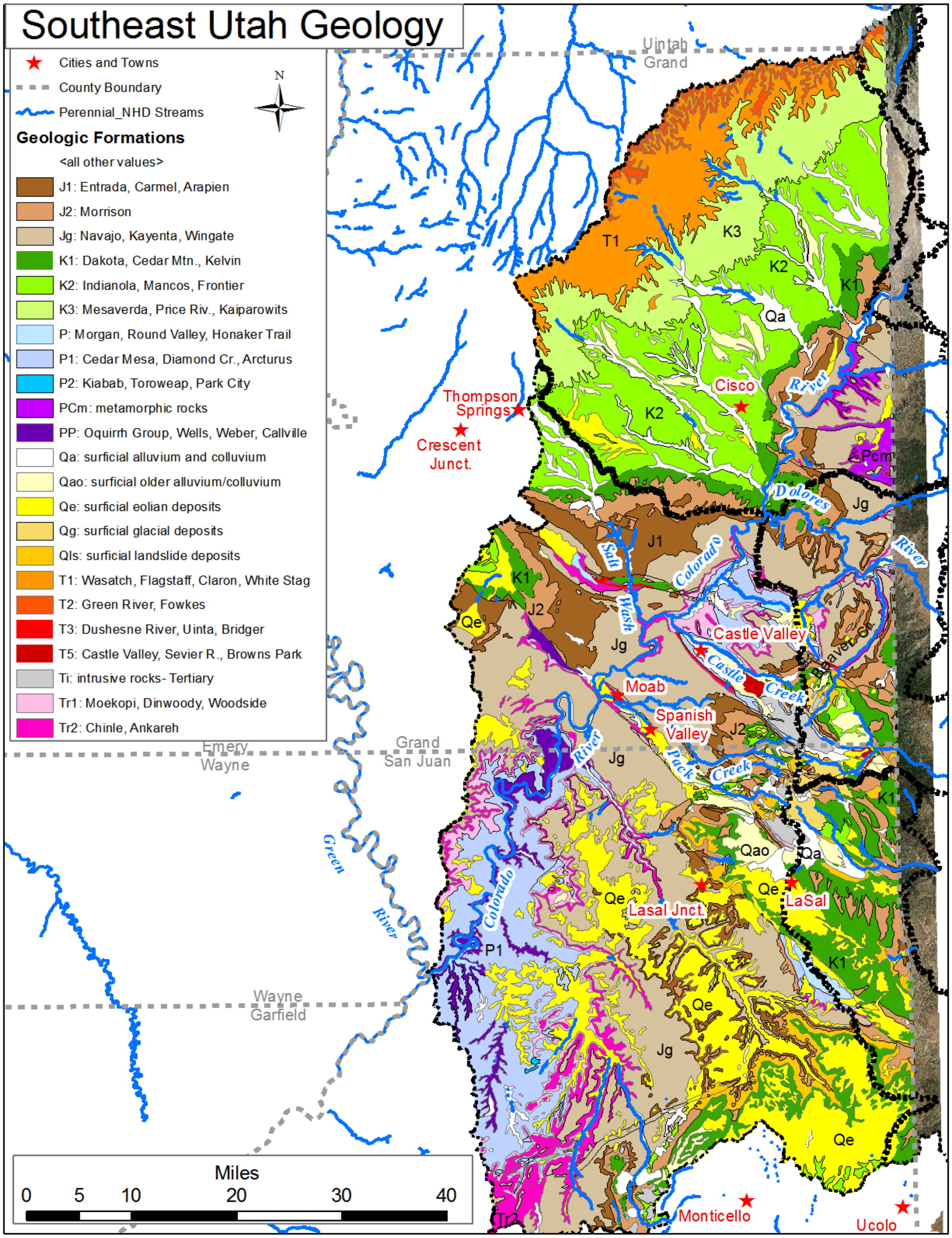
Pollutant of Concern

Selenium is an essential micro-nutrient but is toxic in high concentrations. It is relatively abundant in Mancos shale derived soils and landscapes. In elevated concentrations, selenium has been proven to cause mortality, deformity, and reproductive failure in fish and aquatic birds (USEPA 1998). The toxicity of selenium depends on its chemical form. Selenium becomes bioavailable to aquatic biota through surface and groundwater interactions with surrounding geology. In alkaline soils and in oxidizing conditions selenium uptake is increased because it is in its biologically active form.

Mancos shale is comprised of organic-rich, fine-grained sedimentary rock deposited in very low oxygen conditions (see figure 2.2, formation K2). This type of shale is also a probable source of metals found in some mineral deposits. Many shale formations are sources for pollutants such as Se (USGS 2004). In addition, soils in proximity to volcanic activity contain elevated selenium concentrations. Selenium is also found in coal.

Normal processes, enhanced by seepage from irrigated agriculture in the upper watershed, are capable of transporting the naturally-occurring Se in the sediments in the watershed to the stream system.

Figure 2.2 – Geology of the Colorado River Watershed

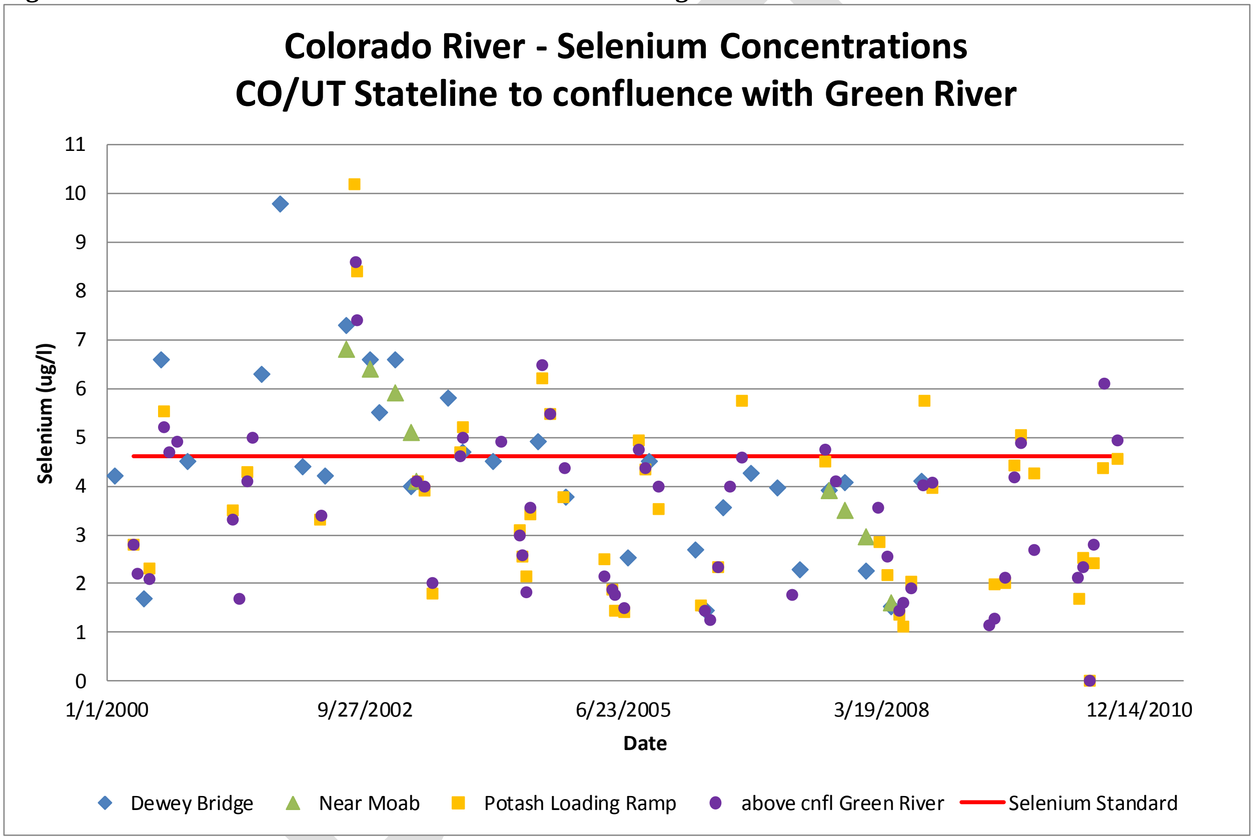


Pollutant loads of selenium in this TMDL were calculated from data collected at four monitoring locations along the Colorado River in Utah.

- 4958490 COLO R AT DEWEY BRIDGE
- 4957000 COLORADO R AT US191 XING NEAR MOAB
- 4956290 COLORADO RIVER AT POTASH BOAT RAMP
- 4952400 COLORADO R AB CNFL / GREEN R

Between 2000 and 2010 the Utah Division of Water Quality collected a total of 149 samples from these stations (see table 3.2). Of these 149 samples 40 exceeded state standards for selenium (figure 2.3). All samples were collected under the supervision of the Utah Division of Water Quality and analyzed at the Utah Public Health Lab.

Figure 2.3 – Selenium concentration data at four monitoring locations



Pollutant Sources

Selenium exists naturally in the Mancos Shale derived soils common to the Colorado River Basin. Studies suggest that selenium mobilization occurs primarily in shallow aquifers, which can be influenced by irrigation and water delivery through unlined canal networks. Water in shallow aquifers is a diffuse source of return flows to tributaries and the Colorado River, thus making it difficult to determine where specific sources of selenium loading occur. Irrigation is common in the upper basin in both agricultural and urban settings. Irrigation practices have been noted to concentrate selenium when irrigation waters evaporate and concentrate the dissolved components (GBSTF 2003). Other anthropogenic sources of selenium include the combustion of coal, petroleum fuels and smelting metals.

In the publication 'Salinity and Selenium, an Internal Report to the Colorado River Basin Salinity Control Forum' (2003) the Technical Subcommittee concluded that the majority of selenium loading to Lake Powell comes from two principle sources in Colorado, the Grand Valley and the Gunnison River Basin (30% and 31% respectively). The report further identifies 25% as coming from the Green River and 8% from the San Juan River. The majority of the remaining 6% is attributed to the Dolores River and the Colorado River above Grand Valley. The major source of loading in these areas is irrigation of Mancos shale-derived soils (Engberg, 1999).

3.0 Water Quality Standards and TMDL Target

The Clean Water Act requires every state to adopt water quality standards to protect, maintain, and improve the quality of surface waters. Water quality standards consist of three major components:

- Beneficial uses reflect how humans and wildlife can potentially use the water. Examples of beneficial uses include aquatic life support, agriculture, drinking water supply, and recreation. Every waterbody in Utah has designated uses; however, not all uses apply to all waters.
- Criteria define the condition of the water that is necessary to support the beneficial uses. Numeric criteria represent the maximum concentration of a pollutant that can be in the water and still protect the beneficial use of the waterbody. Narrative criteria state that all waters must be free from sludge, floating debris, oil/scum, color and odor producing materials, substances that are harmful to human, animal, or aquatic life, and nutrients in concentrations that may cause algal blooms.
- The Antidegradation policy establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need.

The Utah Water Quality Board (UWQB) is responsible for establishing water quality standards that are then administered by the Utah Department of Environmental Quality, Division of Water Quality. These standards are found in the Utah Administrative Code, Standards of Quality for Waters of the State R317-2 and vary based on the beneficial use assignment of the waterbody (UDWQ 2010). The table below summarizes the selenium standards pertaining to the 303(d) listed segment in the Colorado River.

Table 3.1 Colorado River Designated Uses and associated Selenium Standards

Designated Use	Description	Selenium
1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water.	50 μg/l (max)
2B	Protected for infrequent primary contact recreation. Also protected for secondary contact recreation where there is a low likelihood of ingestion of water or a low degree of bodily contact with the water. Examples include, but are not limited to, wading, hunting, and fishing.	N/A
3B	Protected for warm water species of game fish and other warm water aquatic life including the necessary aquatic organisms in their food chain.	4-day avg: 4.6 μg/L 1-hour max: 18.4 μg/L
4	Protected for agricultural uses including irrigation of crops and stock watering.	50 μg/l (max)

Utah's Listing Methodology and 303(d) Status

The beneficial use support status for streams in Utah is determined by comparing the results of analyzed samples to water quality standards. Utah has defined guidelines for assessing each beneficial use. To be in full beneficial use support for any pollutant, no more than one violation of the criterion can be observed in a three year period. For any pollutant, greater than 2 violations of the criterion in a 3-year period will cause the Beneficial Use to be assessed as Non-supporting.

Of the samples analyzed, 32% exceed the 4.6 μg/L standard at Dewey Bridge and 25% exceed the standard above the confluence with the Green River (see Table 3.2).

Table 3.2 - Percent exceedance & number of observations

Colorado River at Dewey Bridge - 4958490				
From	**To**	**# Observations**	**# Exceedances**	**% Exceedance**
2000	**2010**	**31**	**10**	**32%**
Colorado River at US 191 crossing near Moab - 4957000				
From	**To**	**# Observations**	**# Exceedances**	**% Exceedance**
2000	**2010**	**9**	**4**	**44%**
Colorado River at the Potash Boat Ramp - 4956290				
From	**To**	**# Observations**	**# Exceedances**	**% Exceedance**
2000	**2010**	**49**	**11**	**22%**
Colorado River above confluence with Green River - 4952400				
From	**To**	**# Observations**	**# Exceedances**	**% Exceedance**
2000	**2010**	**60**	**15**	**25%**

As can be seen in Figures 3.1 to 3.4 selenium concentration varies widely even within the same year although the trend at each site indicates a decrease in concentrations. Several high concentrations were observed in 2002 and 2003. This explains the high percent of exceedances at the site near Moab where 5 of the 9 samples were collected in 2002-2003. Analysis of the data using load duration curves was selected because of the high temporal variability seen in the concentration data at all sites.

Figure 3.1 - Selenium concentration at Dewey Bridge

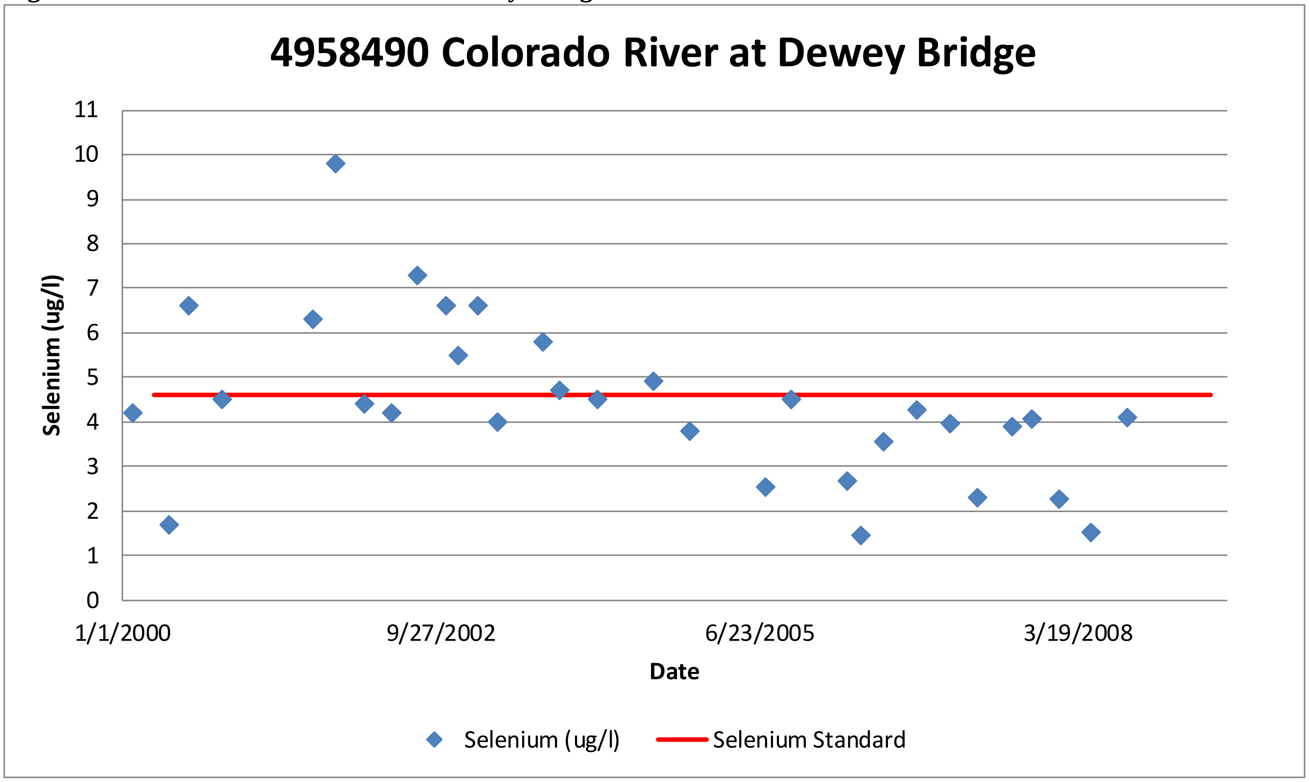


Figure 3.2 - Selenium concentration near Moab

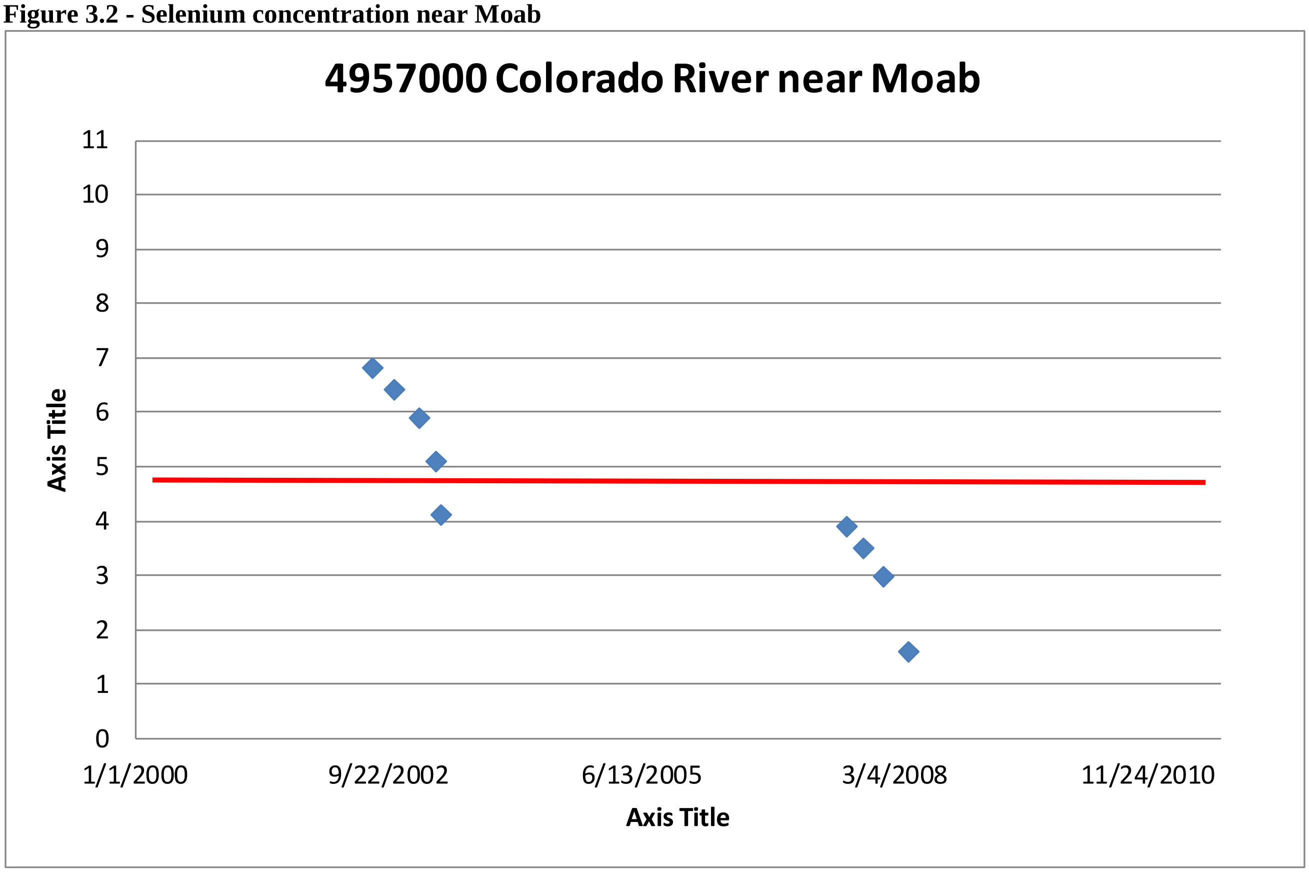


Figure 3.3 - Selenium Concentration at Potash Boat Ramp

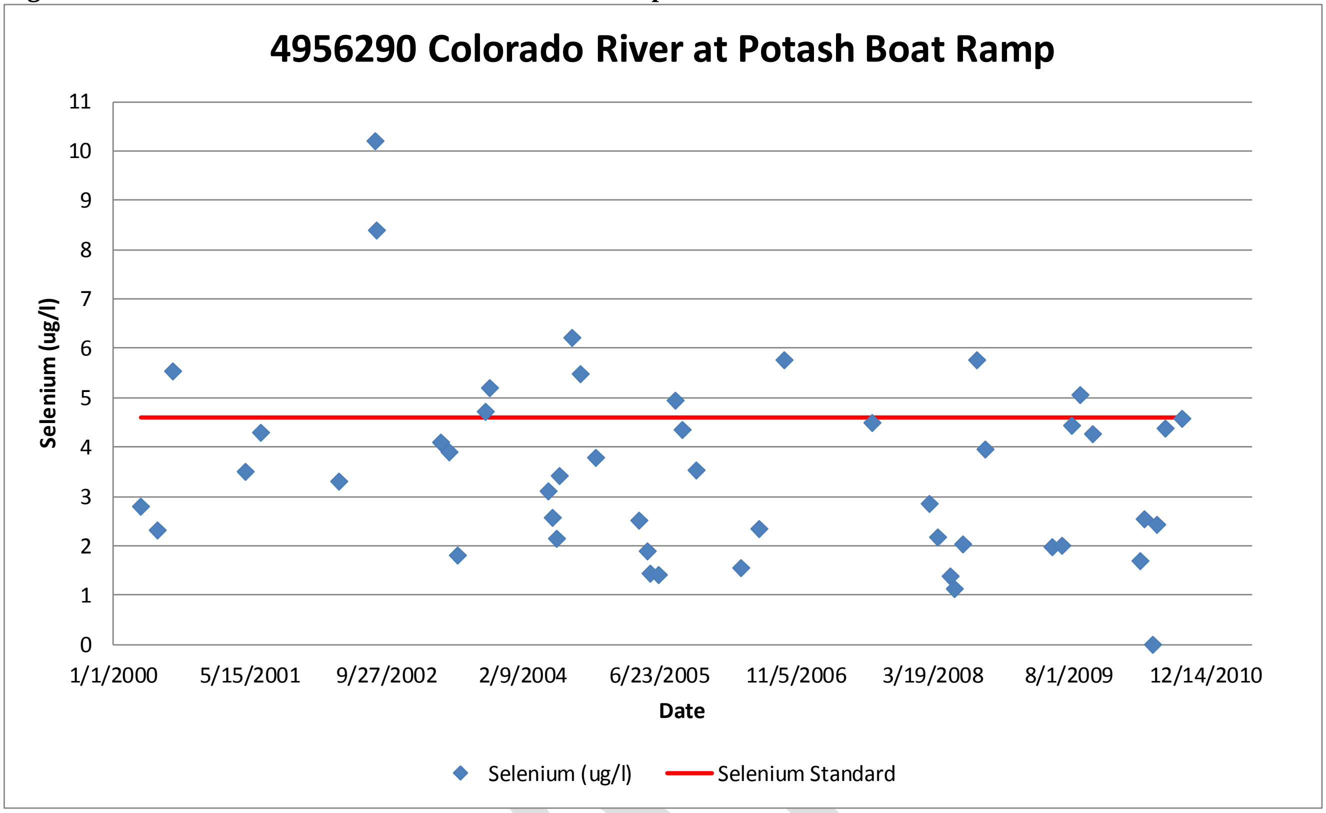
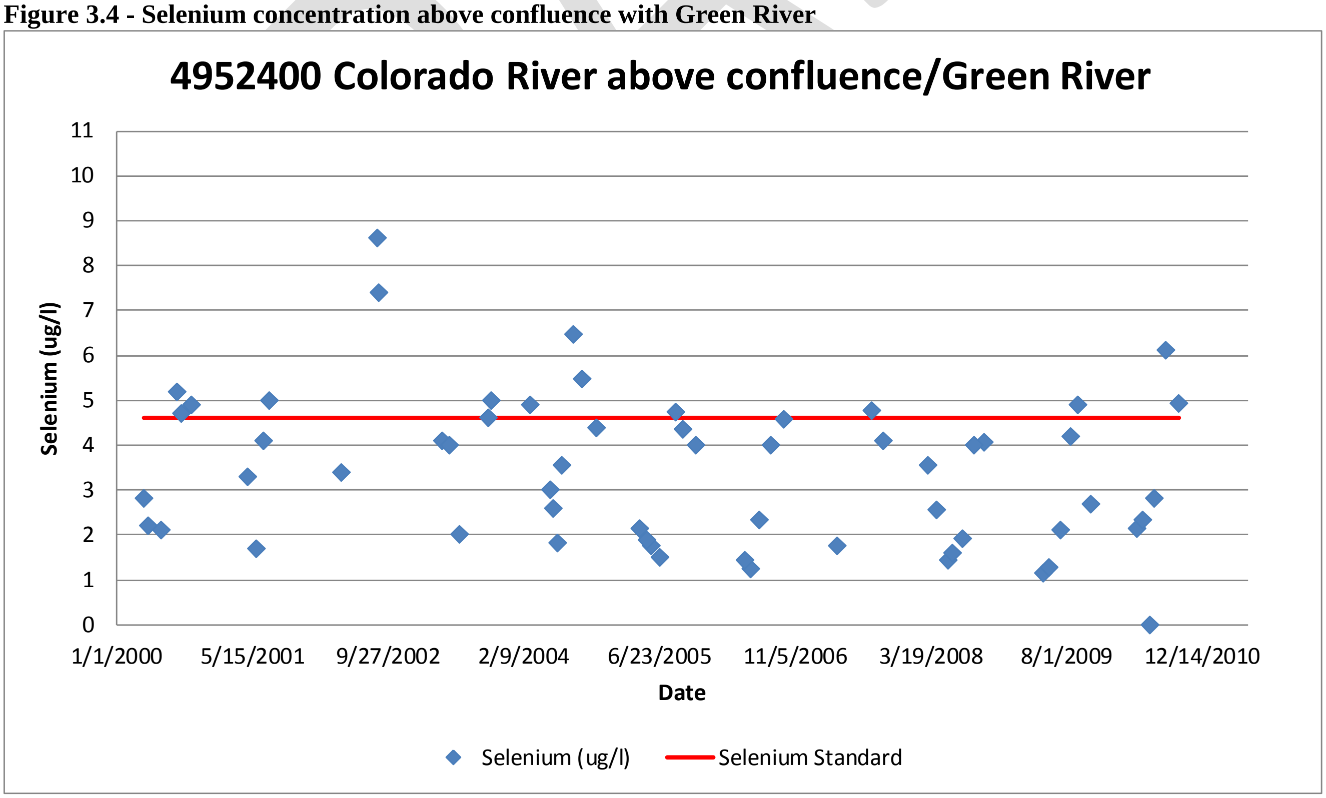


Figure 3.4 - Selenium concentration above confluence with Green River



TMDL Endpoints

A TMDL is the sum of allocated point source loads (wasteload allocation), non-point source loads (load allocation), and natural background loads. In addition, the TMDL must include a margin of safety either implicitly or explicitly, that accounts for the uncertainty in the analysis. Conceptually, this definition is denoted by the equation

$$\mathbf{TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS}$$

Where WLA = wasteload allocation
LA = load allocation
MOS = margin of safety

The TMDL establishes the total loading a stream can assimilate without violating its water quality standard. This analyses will focus on and establish the TMDL for selenium on the Colorado River from the confluence with the Green River upstream to the UT/CO Stateline based on flow. This TMDL is calculated on a daily basis to account for complex and varying hydrology and critical conditions in the river reach and is expressed as a mass loading.

Selenium

Utah’s chronic numeric water quality criteria for selenium was used to establish endpoints for TMDL development. The TMDL endpoint is the chronic Warm Water Aquatic Life and Waterfowl Criteria for selenium of 4.6 µg/L. The reductions specified in the TMDL to meet the chronic 4 day average water quality standard will ensure compliance with the acute selenium water quality standard of 18.4 µg/l based upon the current data set.

4.0 Loading Capacity

This section provides a description of available selenium data and analyses conducted to understand the current water quality conditions in the river. Water quality data has been collected by UDEQ at 4 stations on the Colorado River. Pollutant loads of selenium are presented using load duration curves. The load duration curve approach characterizes water quality concentrations at different flow regimes. The method provides a visual display of the relationship between stream flow and loading capacity, the frequency and magnitude of water quality standard exceedances, allowable loadings, and size of load reductions.

The load duration curve approach is applicable to this reach of the Colorado River because stream flow is an important factor in the determination of loading capacities, as it accounts for how stream flow patterns affect changes in water quality over the course of a year.

Table 4.1 shows the average actual load & load capacity as a function of flow regime. Site 4957000 Colorado River at US191 near Moab was omitted from the analysis because of insufficient data. The selenium loading capacity is calculated based on the State standard for selenium of 4.6 μg/L. Only during dry conditions is the load capacity exceeded at the Dewey Bridge site and only at the low conditions is the capacity exceeded downstream at the Potash and Green River sites. Similarly Table 4.2 shows that the only time of year when the load exceeds the capacity is in the month of August when the majority of the low flow regime occurs.

Figures 4.1 to 4.3 show the load duration curves for each site. At all monitoring locations the selenium loading remains fairly constant or slightly decreases which is a strong indicator that the selenium is from a constant source such as groundwater baseflow.

Figure 4.4 plots average flow at each site and average daily load at each site. As the average flow increases (by over 500 cfs) going downstream, the average daily load decreases (by about 1.5 Kg). The increased flow is serving to dilute the concentration of selenium and minimal if any selenium is being added in the Utah portion of the drainage basin.

Table 4.1 – Average Actual Load & Load Capacity as a function of Flow Regime – Kg/day

Flow Regime	Percent time flow is exceeded	Dewey Bridge		Potash Boat Ramp		Above confluence with Green River	
		Actual Load	Load Capacity	Actual Load	Load Capacity	Actual Load	Load Capacity
High	0 - 10	79.2	305.7	97.9	312.9	95.6	295.5
Moist	10 - 40	58.3	111.6	41.3	116.4	40.4	127.2
Mid Range	40 - 60	47.9	55.3	54.7	64.2	50.1	66.7
Dry	60 - 90	44.4	41.3	38.8	42.8	38.9	42.1
Low	90 - 100	23.6	26.2	35.3	24.0	31.1	23.8

Table 4.2 – Actual Load and Load Capacity by Month

Colorado River above confluence with Green River - Average Daily Selenium Loading (Kg)									
	March	April	May	June	July	August	September	October	November
Actual Load	31.3	38.3	65.9	53.9	44.1	37.7	55.1	38.8	39.1
Loading Capacity	35.7	73.0	178.9	131.5	100.7	35.1	56.7	39.5	45.1

Figure 4.1 - Dewey Bridge Load Duration Curve

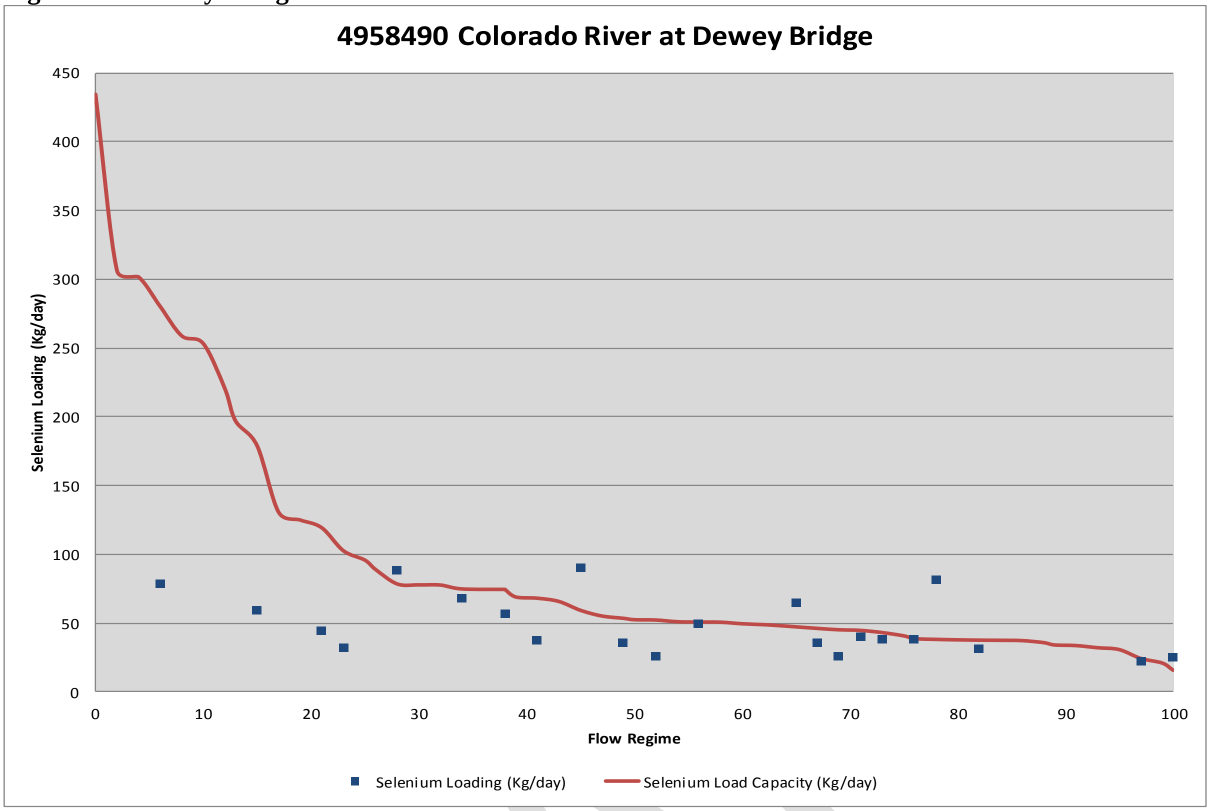


Figure 4.2 - Potash Boat Ramp Load Duration Curve

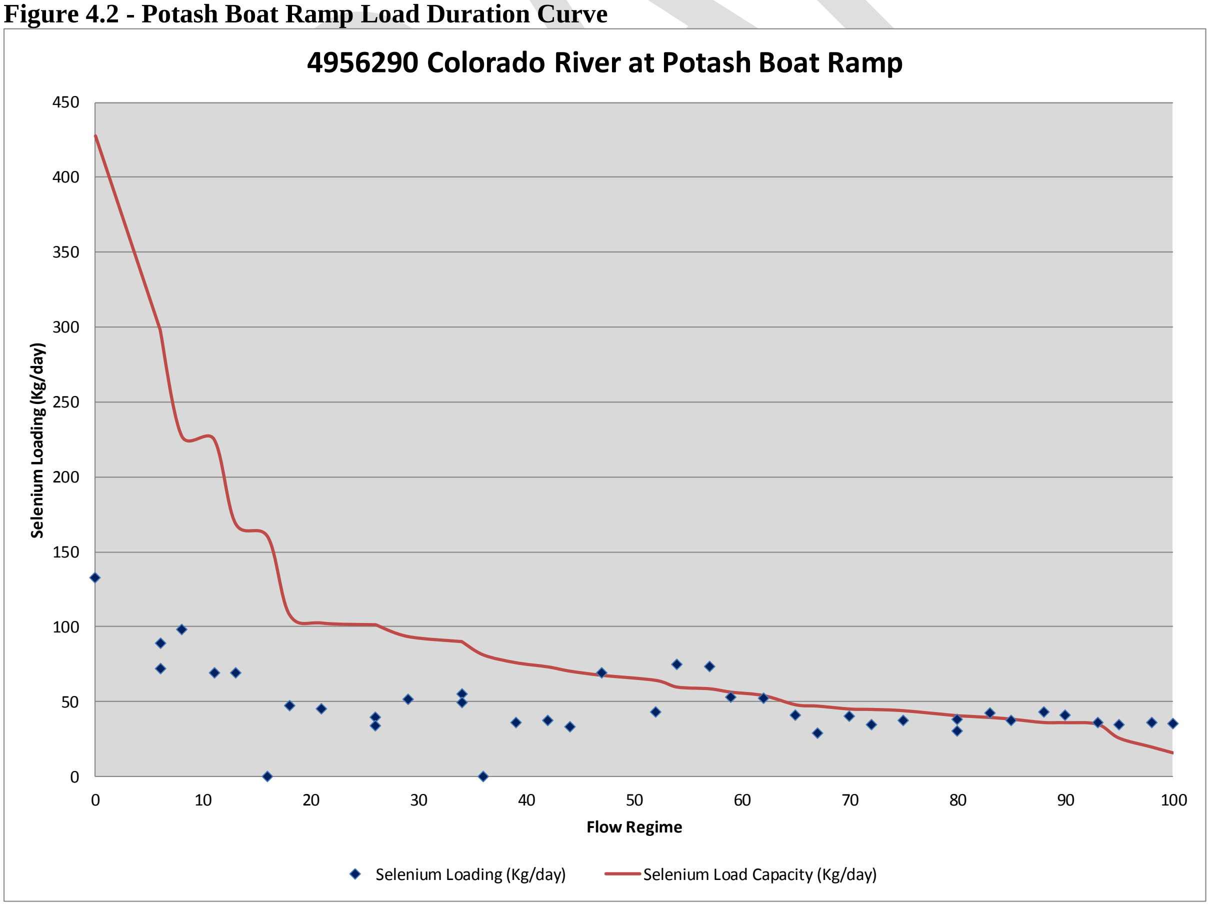


Figure 4.3 - Colorado River above confluence with Green River Load Duration Curve

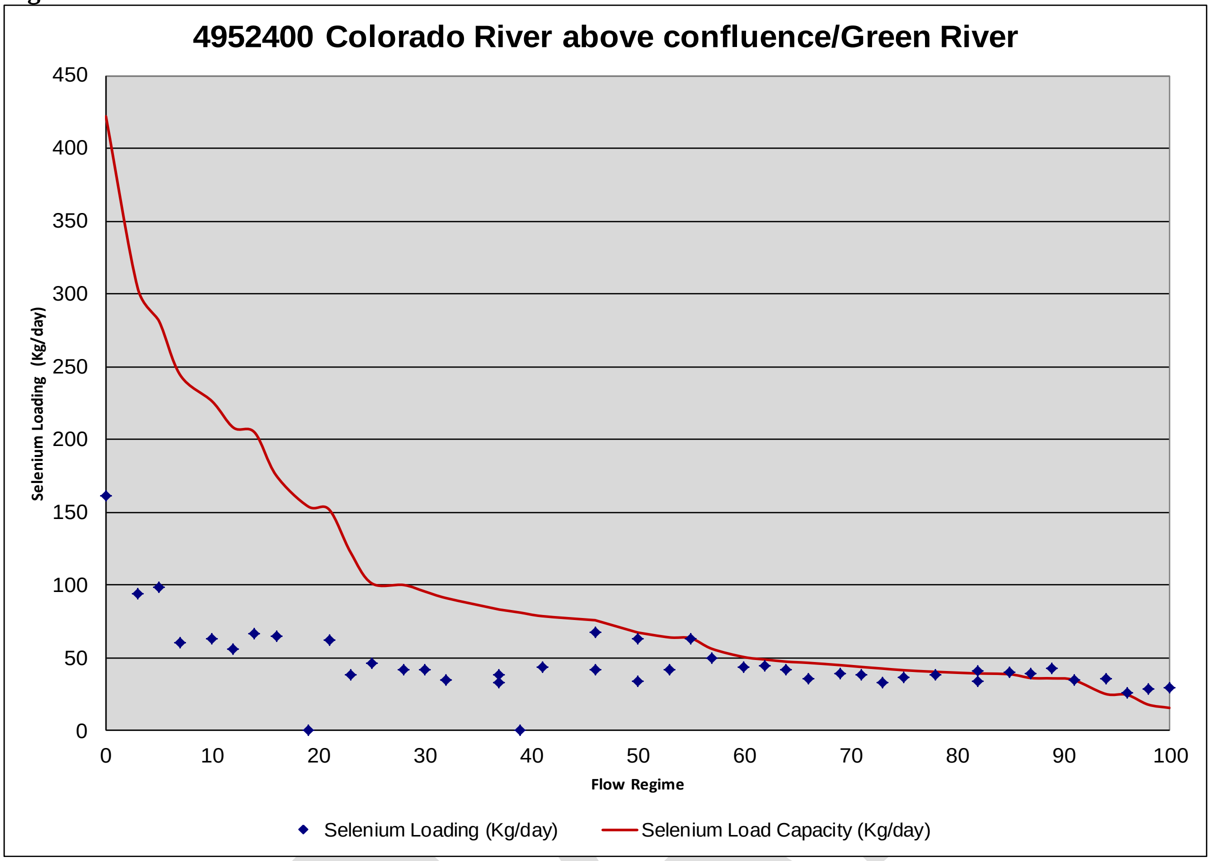
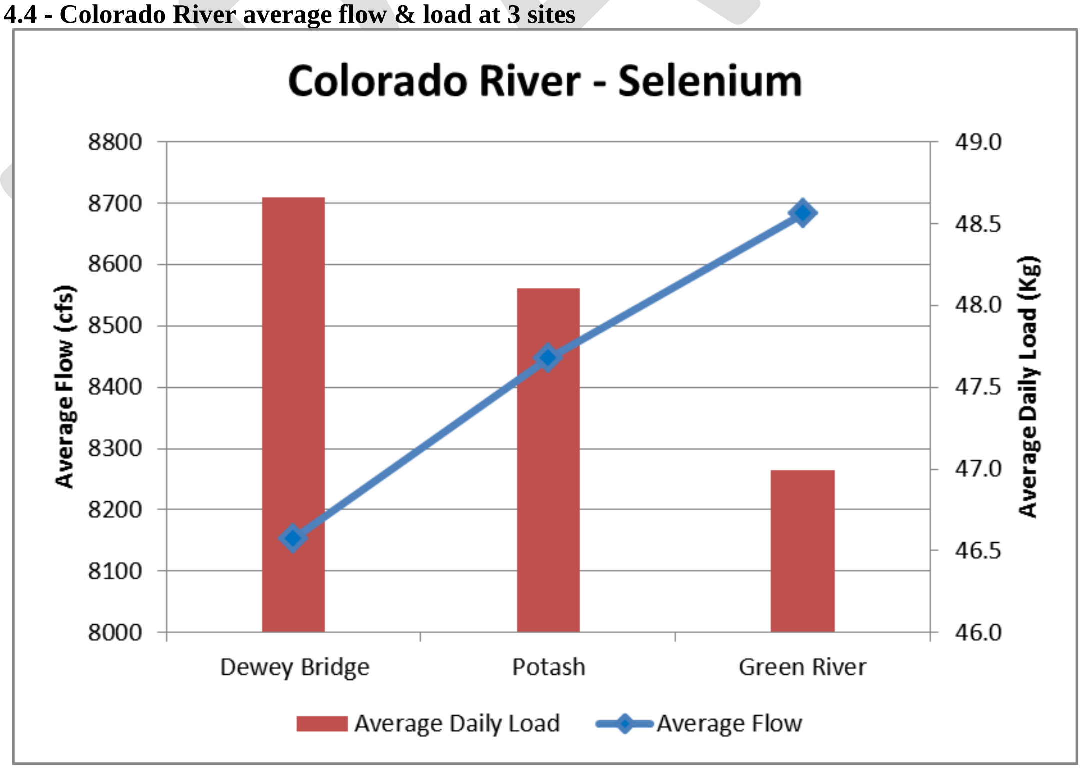


Figure 4.4 - Colorado River average flow & load at 3 sites



5.0 Load Allocations and Waste Load Allocations

Moab City Waste Water Treatment Plant
Between 2002 and 2008 nine effluent samples were collected from the Moab City wastewater treatment plant by the Division of Water Quality. All selenium samples collected had selenium levels too low to detect. The laboratory detection limit for selenium is 1 μg/L. For loading calculations in this document, one half of the detection limit is used (0.5 μg/L). Average flow from the Moab WWTP is 1.07 million gallons per day (mgd) and plant capacity is 1.5 mgd. The current load estimate for the WWTP was calculated using 1 μg/L concentration times an average flow of 1.07 mgd resulting in 4.04 grams/day loading to the Colorado River. Flow from the Moab WWTP accounts for approximately 0.02 percent of the flow in the Colorado River.

6.0 Margin of Safety

The MOS is a required part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991). Implicit methods incorporate the MOS using conservative model assumptions to develop allocations. Explicit methods specify a portion of the total TMDL as the MOS, allocating the remainder to sources.

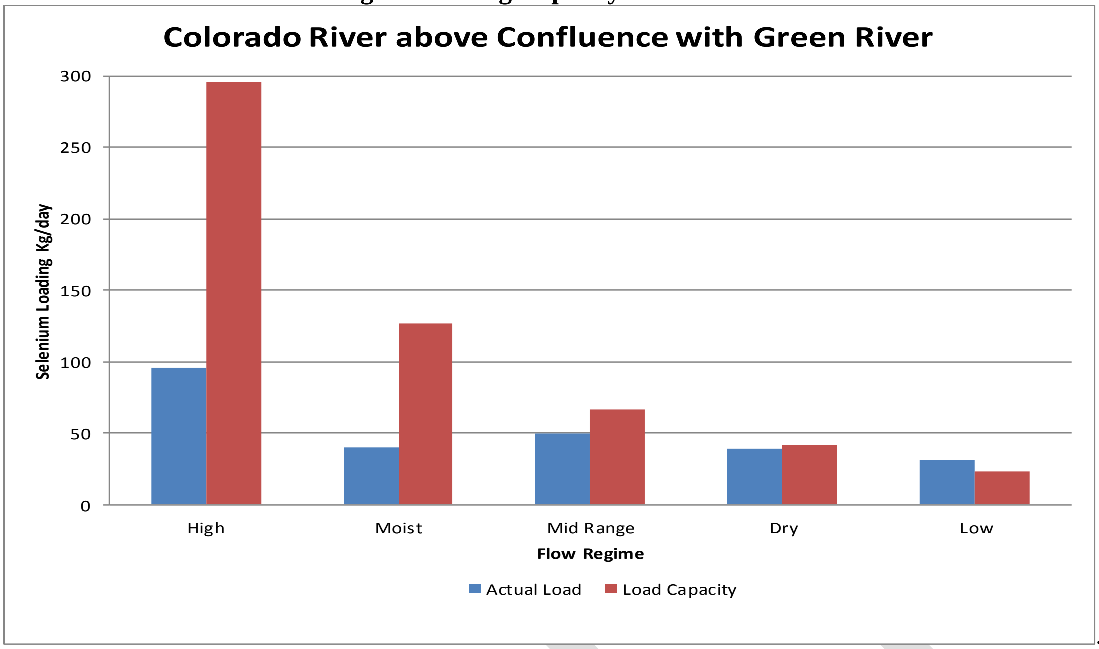
For the Colorado River TMDL, the MOS was included explicitly by allocating 10 percent of the loading capacity to the MOS due to the uncertainties regarding the proportion of natural versus anthropogenic sources and with the data gaps primarily associated with flow.

Margin of Safety = 0.46 μg/L or 2.375 Kg/day during low flow conditions.

7.0 Seasonal Variation

Tables 7.1 & 7.2 clearly show that the selenium problem in the Colorado River is seasonal and occurs in predominately low flow conditions in August.

Figure 7.1 - Selenium Current Loading vs. Loading Capacity



In Figure 7.1 the loading capacity is compared to the current load associated with each flow regime. The only category in which the current load exceeds the capacity is in the low flow regime. The only month the current load exceeds the loading capacity is in August where sixty percent of the lowest flows are observed (Figure 7.2).

Figure 7.2 – Average Selenium Loading vs. Loading Capacity by Month

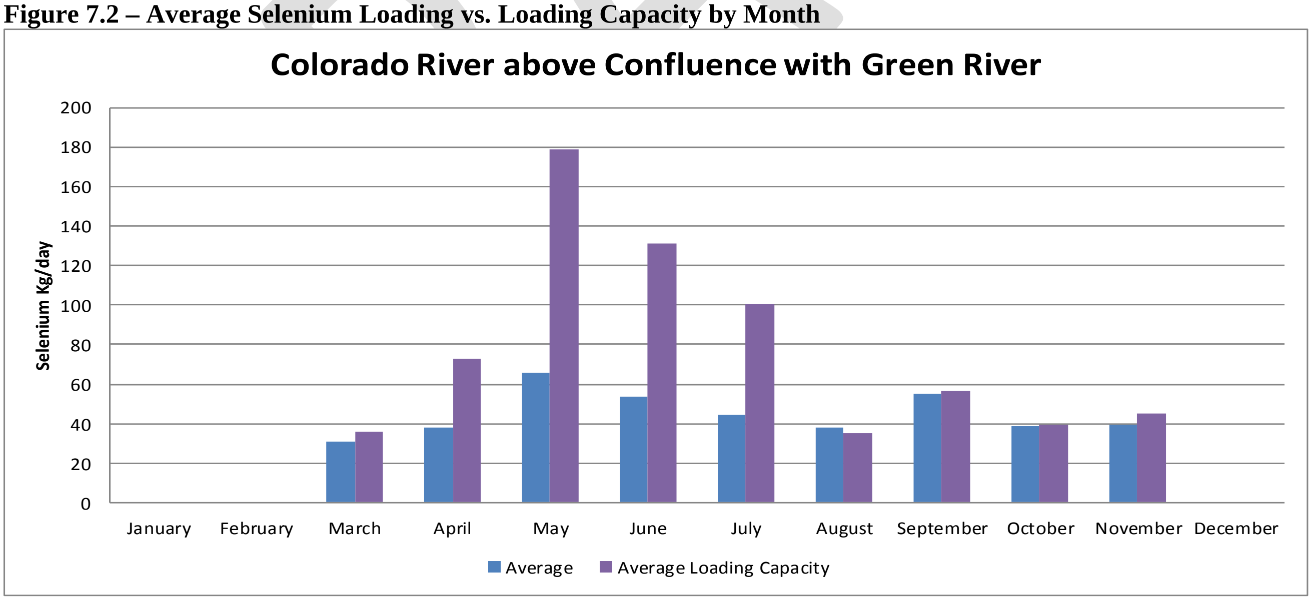
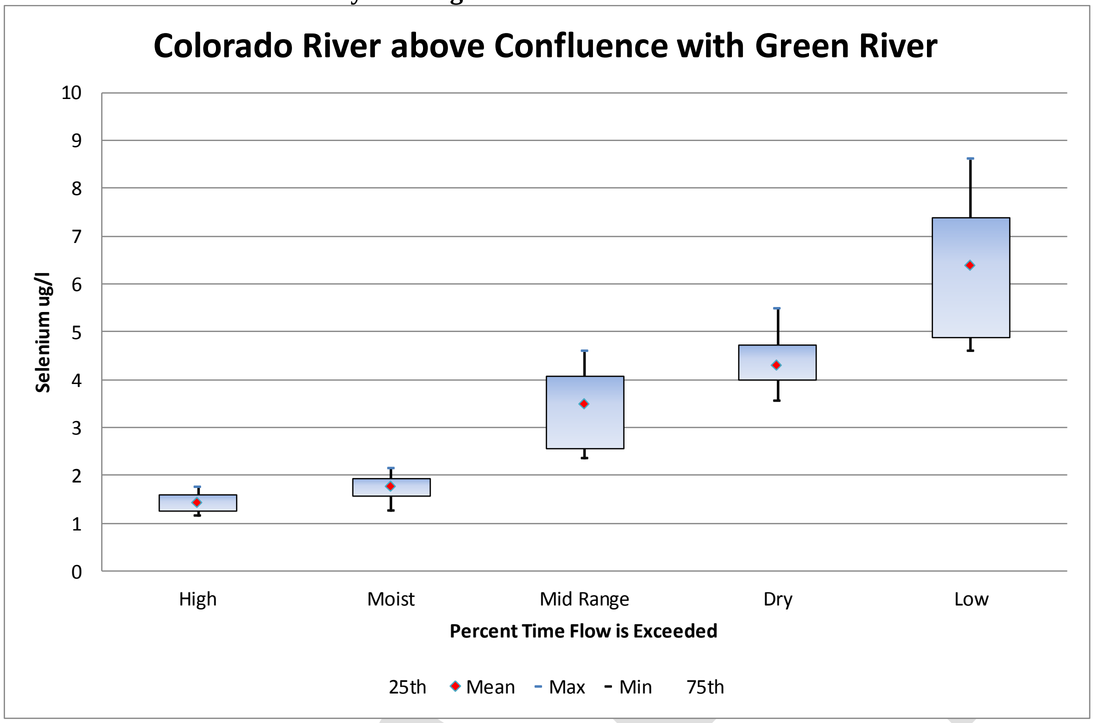


Figure 7.3 shows selenium concentration data distribution by flow regime. Only the low flow regime has an average concentration that exceeds the state standard of 4.6 µg/L. Exceedance of the standard during low flow conditions is an indication that the source of the impairment is from groundwater inflow that has seeped through Mancos shale soils.

Figure 7.3 - Selenium concentration by flow regime

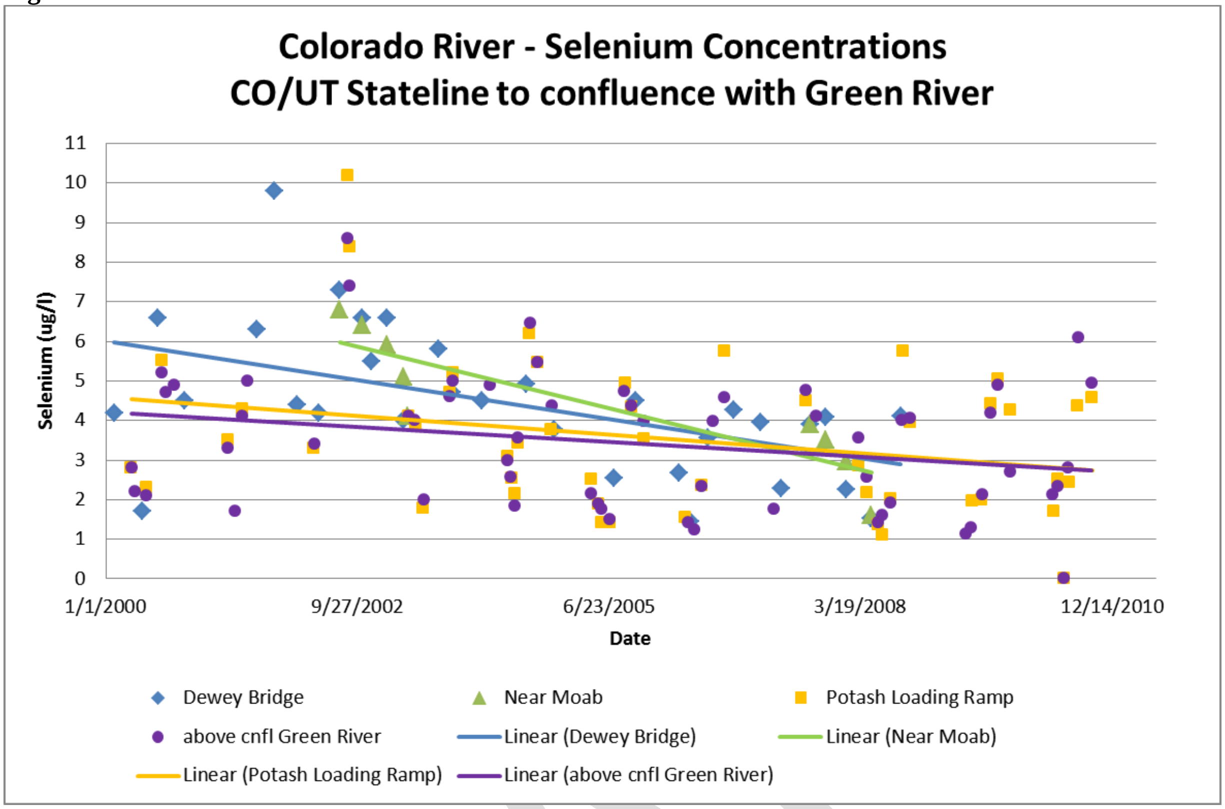


8.0 Reasonable Assurance

It is important to recognize that because the sources of pollutant loads originate primarily from natural and anthropogenic non-point sources, implementation of the best management practices (BMPs) is voluntary. The assurance that implementation activities will occur is that implementation is currently ongoing under the cooperative efforts of local agricultural producers, the Colorado River Basin Salinity Control Program, the Selenium Management Program and the National Irrigation Water Quality Program.

In figure 8.1 trend lines are added to figure 2.3 to show decreasing concentration trends at all monitoring sites. These decreasing trends are evidence that the Colorado River Basin Salinity Control Program, the Selenium Management Program, the National Irrigation Water Quality Program combined with landowners and citizen groups are having a positive impact on reducing selenium in the Colorado River. These proven programs have and will continue to help reduce selenium loading into the system.

Figure 8.1 - Selenium concentration trends



9.0 Future Monitoring

Long-term monitoring of water quality will be conducted at the four locations used in this study, and will be used to evaluate the effects of BMPs, as well as progress toward meeting water quality goals and supporting beneficial uses.

The water quality monitoring stations used in this TMDL are all located on the main stem of the Colorado River. Data from these stations may include storm flows and runoff events captured during routine monitoring visits; however storm flows are not specifically targeted. Additionally, a large portion of the watershed is drained by dry washes that only flow after storm events. Pollutant loads generated from storm events in these drainages are not captured by the current water quality monitoring strategy.

10.0 Implementation Plan

Conversion of flood irrigation to more efficient sprinkler irrigation is a common BMP in the Colorado River Watershed for reducing TDS and selenium loads. Significant irrigation upgrades have been made in the last two decades. The key to effectively reducing the anthropogenic loads in the Colorado River watershed while maintaining current water rights and irrigation use is to continue to improve and maintain water use efficiency projects and to minimize surface runoff, seepage, and deep percolation.

11.0 Public Participation

Local stakeholder participation for the draft TMDL was accomplished through stakeholder meetings with the Moab Area Watershed Partnership (MAWP). These meetings were designed to present the issues and inform stakeholders. The draft TMDL will be given to the stakeholders for comments.

Participants include:
• Grand County Water Conservancy District
• San Juan County Soil Conservation District
• Grand County Soil Conservation District
• NRCS
• UDEQ, Division of Water Quality
• USU Extension
• BLM
• SITLA
• USFWS
• UACD
• Spanish Valley Irrigation Company

It is important to have local input to affect water quality improvements and practices. The local stakeholders are actively participating in the MAWP and taking the lead in improving local water quality.

References

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