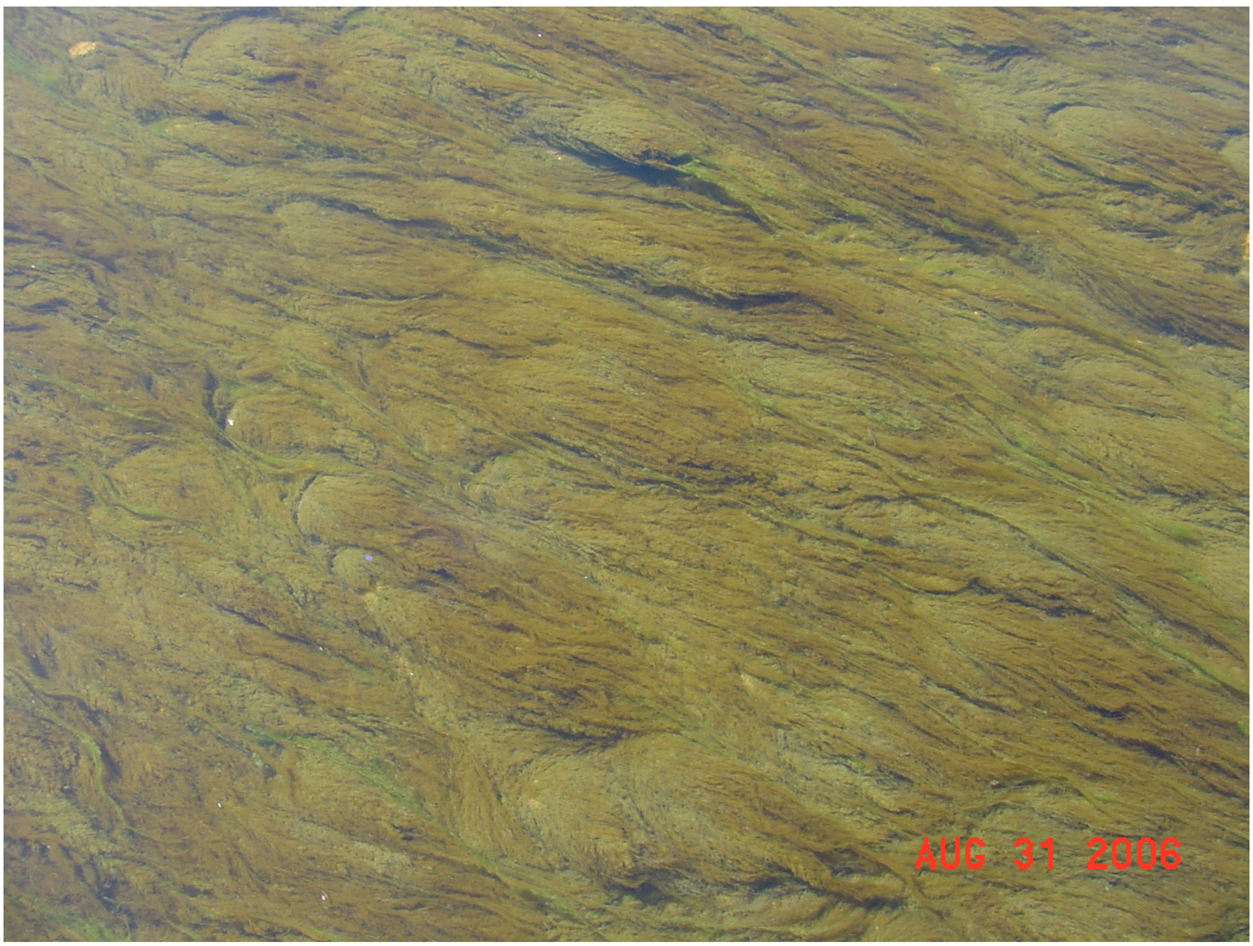
A Review of Nutrient Conditions and Associated Water Quality Standards for the Carson River

A supporting document for the Carson River Report Card

November 2007



Algae in EF Carson River between Highway 88 and Muller Lane

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Introduction

In support of its Clean Water Act responsibilities, the Nevada Division of Environmental Protection (NDEP) – Bureau of Water Quality Planning (BWQP) is developing a Carson River Watershed Assessment or Report Card. Drawing upon numerous studies and monitoring efforts, the Report Card will provide a compilation of current knowledge about the chemical, physical and biological health of the Carson River watershed with a focus on aquatic life uses from the Nevada/California stateline to Lahontan Reservoir. It is hoped that the Report Card will be a valuable tool for educating the public, agencies and decisionmakers on the state of the river (from a Clean Water Act perspective), thereby providing direction for their future actions and decisions. The Report Card will also be a key planning tool for BWQP in possible future steps, such as standards revisions, comprehensive Total Maximum Daily Loads (TMDLs), watershed plan development and restoration projects.

The purpose of this report is to summarize nutrient and dissolved oxygen conditions in the Carson River system (Figure 1), and review the existing associated water quality standards set to control nutrient-related problems. Also, recommendations on additional work and water quality standard revisions are provided.

Background

Nutrients and Impairment

TetraTech (2005) and others have concluded that the use of nutrient concentrations alone are poor predictors of eutrophication impacts. In an examination of data for over 600 streams, Dodds et al. (2002) found relationships that nutrient concentrations accounted for less than half of the variance in the benthic algae biomass. It was speculated that other factors such as flow, temperature, light availability, substrate conditions, macroinvertebrate grazing, etc. were responsible to the remaining variability. Following is a brief discussion of these other factors that impact algal growth.

Flow: Stream algal biomass varies with time with peak levels usually occurring the summer when flows are lower. Also, biomass levels can vary from year to year depending upon the flow conditions and other factors. Additionally, the time since the stream experienced a scouring-flow event can be a factor. Biggs (2000) found that 62 percent of the variance in peak biomass was explained by the time since the last flood event.

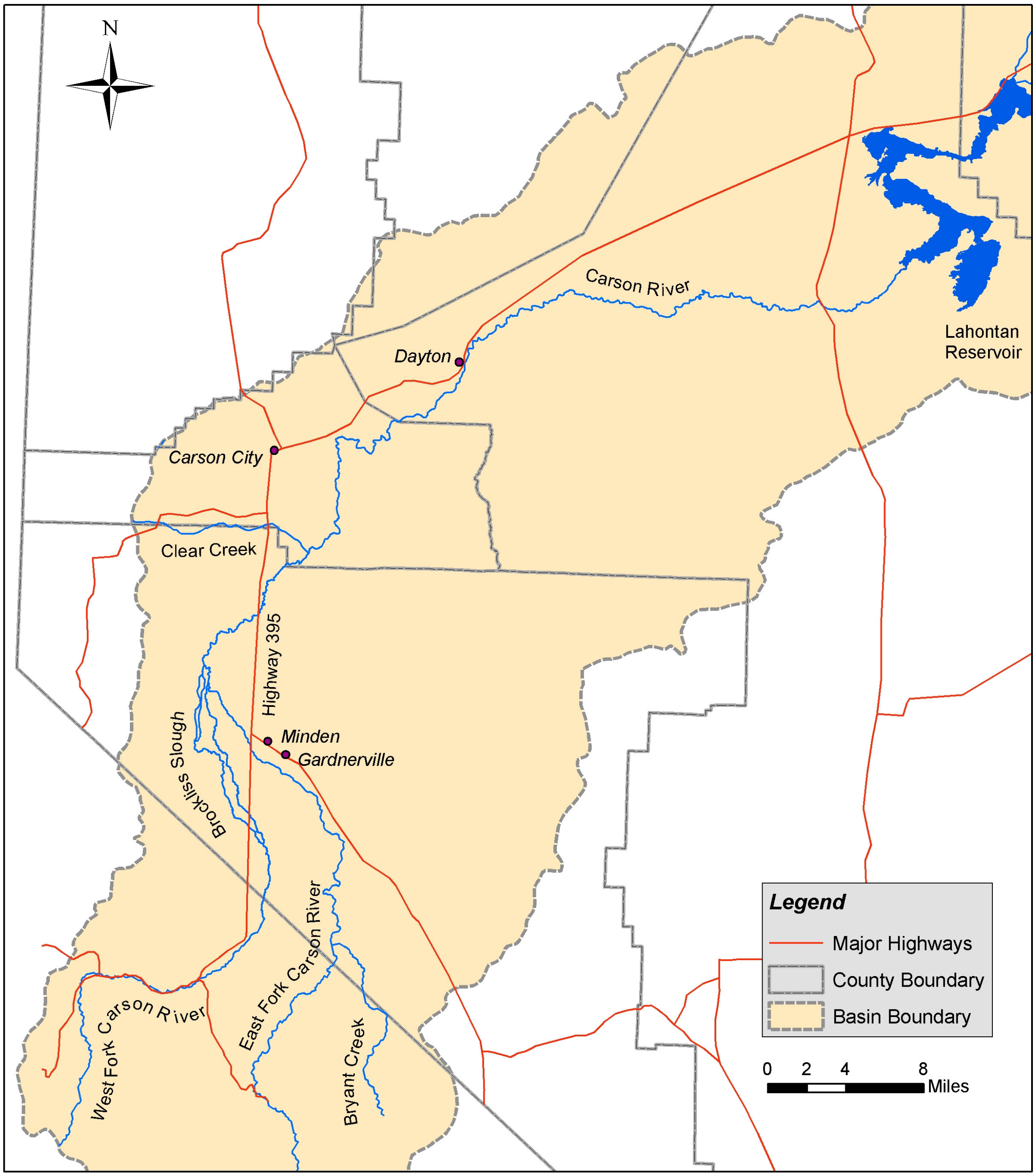


Figure 1. Carson River Study Area

Temperature: Increased temperatures can lead to increased biological activity, including algae. However, cladophora algae has been found to die-off at temperatures over 23.5° C (Dodds and Gudder, 1992).

Shading/light: Welch and others (1992) have found that shading can substantially reduce algal production. Water column turbidity can also inhibit periphyton growth, even at relatively low levels (<10 NTU) (Quinn et al., 1992). Another shading source to consider is the topography of the surrounding landscape.

Substrate conditions: Large, rough substrates are the best habitat for periphyton due to its need to attach to objects. Sedimentation on top of rocky substrate can decrease periphyton biomass (Welch et al., 1992).

Biological community structure: Steinman (1996) has found that dense populations of algae consuming grazers can lead to negligible algal biomass, even with high nutrient levels. Also, there is some evidence that bacteria may outcompete algae for nutrients and secrete allelopathic substances that inhibit algal growth (EPA N-Steps Website, 2007).

Dissolved oxygen levels: While some algae are a necessary component of the ecosystem, excessive algae can lead to depressed DO levels in the early morning. Algae photosynthesis during the daylight periods can lead to supersaturated DO conditions with peak DO levels typically around mid-afternoon. During the night, algae decay and other processes cause unsaturated DO conditions with minimum DO levels occurring around sunrise (EPA, 2000).

Existing Water Quality Standards

Nevada's water quality standards for the East and West Forks, and the Carson River are contained in Nevada Administrative Code (NAC) 445A.146 through 445A.158. The associated nutrient and dissolved oxygen numeric criteria are provided in Table 1. Two different types of numeric criteria exist: 1) Requirements to Maintain Existing Higher Quality (RMHQ), and 2) beneficial use standards (BUS). RMHQs are based upon existing quality (typically set at the 95th percentile of the available data) and have been set as part of Nevada's antidegradation approach for its waters. By definition, RMHQs are more restrictive than BUSs. BUSs are set at levels needed to protect the beneficial uses. Typically, BUS values are based upon either EPA recommendation, site specific criteria, or other information.

In the Carson River, both RMHQs and BUSs have been set for total phosphorus. The current TP BUSs were added to the NAC in 1984 (Pahl, 2004) and set as annual averages. It appears that the 0.1 mg/l TP BUS was taken from EPA's 1976 *Quality Criteria for Water* (Red Book). According to the EPA guidance, a TP level of 0.1 mg/l is a desired goal for the prevention of plant nuisances in streams not discharging directly to lakes. This same guidance did not provide any recommendations for nitrogen species levels desired for the control of algae, etc. This is probably the reason the nitrate standard was set at the high value of 10 mg/l for the protection of drinking water uses, with no recognition of nitrate impacts upon eutrophication.

The current DO standards were also set in 1984 based in part on EPA guidance. The higher value (6 mg/l) was set to assure sufficient intergravel DO levels for the protection of incubating salmonid eggs and fry (Pahl, 2004).

Table 1. Summary of Nutrients and Dissolved Oxygen Water Quality Standards in the Carson River above Lahontan Reservoir

NAC	Water body	Reach	Total Phosphorus (as P)		Total Nitrogen (as N)	Nitrate (as NO3)	Dissolved Oxygen
			RMHQ	BUS	RMHQ	BUS	
445A.147	West Fork Carson	Stateline	0.016 (AA) 0.033 (SV)	0.10 (AA)	0.4 (AA) 0.5 (SV)	10.0 (SV)	5.0 (Nov-May) 6.0 (Jun-Oct)
445A.148	Bryant Creek	Stateline	0.036 (AA) 0.05 (SV)		0.6 (AA) 1.0 (SV)		
445A.149	East Fork Carson	Stateline	0.03 (AA) 0.065 (SV)		0.5 (AA) 1.1 (SV)		
445A.150		Stateline to Hwy 395	None		0.4 (AA) 0.5 (SV)		
445A.151		Hwy 395 to Muller Lane			0.5 (AA) 0.8 (SV)		
445A.152	West Fork Carson	Stateline to confluence			0.8 (AA) 1.3 (SV)		5.0 (Nov-Apr) 6.0 (May-Oct)
	East Fork Carson	Muller Lane to confluence					
	Carson River	Confluence to Genoa Lane					
445A.153	Carson River	Genoa Lane to Cradlebaugh Bridge (Hwy 395)			0.85 (AA) 1.2 (SV)		
445A.154	Carson River	Cradlebaugh (Hwy 395) Bridge to Mexican Ditch Gage			0.8 (AA) 1.3 (SV)		
445A.155	Carson River	Mexican Ditch Gage to New Empire			1.3 (AA) 1.7 (SV)		5.0 (Jan-Dec)
445A.156	Carson River	New Empire to Dayton Bridge			1.2 (AA) 1.6 (SV)		
445A.157	Carson River	Dayton Bridge to Weeks (Hwy 95)			0.6 (AA) 1.1 (SV)		

Values are single value criteria unless otherwise noted.
AA = Annual Average
SV = Single Value

Nevada's 303(d) List

Every two years, Nevada is required under the federal Clean Water Act to produce a list (303(d) List) of waters not meeting applicable water quality standards (BUSs only). Since 1992, the Carson River and forks from Muller Lane to Lahontan Reservoir have been on the 303(d) list for exceedances of the TP standards. Until recently, insufficient data have existed to evaluate compliance with the DO standards. While much of the Carson River in on the 303(d) list for TP, it is uncertain the extent to which eutrophication problems (excess algae, depressed DO) exist.

Nevada's Nutrient Criteria Strategy

The development of more appropriate nutrient criteria has become a major focus throughout the United States. Since 1998, Nevada has been participating with California, Arizona and EPA Region IX in a regional technical advisory group aimed at developing more appropriate nutrient criteria. With impetus provided by this regional effort, Nevada has developed a statewide nutrient criteria strategy (NDEP, 2007). In part, the strategy is driven by the fact that the use of phosphorus and nitrogen concentrations alone have been found to be poor predictors of eutrophication conditions (TetraTech 2005). Other factors such as flow, water temperature, light availability, substrate conditions, macroinvertebrate grazing, etc. also impact observed algae levels. For nutrient impairment to be determined requires a multiple line-of-evidence approach, considering (at a minimum) nutrient levels, algae levels and dissolved oxygen concentrations. In fact in a recent memorandum (Grumbles, 2007), EPA states that nutrient criteria should address causal (nitrogen and phosphorus) and response (chlorophyll-a, transparency) variables to be effective.

Based upon this information, key components of the Strategy were developed:

- For existing standards: Treat TP standards as indicators of potential eutrophication problems. For waters exceeding the TP standards, perform followup evaluations (such as algae and DO sampling) to determine the beneficial use support status.

- For new waters to be added to NAC: Consider not incorporating N or P criteria into the NAC, but include DO criteria. Establish preliminary P and N indicators (non-regulatory) of potential eutrophication problems. For waters exceeding the N or P indicators, perform followup evaluations (such as algae and DO sampling) to determine the beneficial use support status. Consideration should be given to the setting of benthic algae chlorophyll-a standards.

- In the long term, NDEP hopes to implement a program consisting of detailed nutrient sampling, algae sampling, physical condition measurements for a range of waterbody types with varying use support/impairment conditions. Analyses would be done in an attempt to develop a matrix of appropriate indicators (N, P, DO, algae levels, etc.) useful for determining water condition. After a significant level of testing, these indicators could ultimately be incorporated into the NAC. Overall, it is hoped that nutrient criteria of the future incorporate a more robust approach for considering the various conditions and factors leading to eutrophication-related impairment.

Major Past Studies

Quantification of Non-point Source Nutrient Pollution, Impacts Along the Carson River, Nevada (Horvath and Warwick, 1996)

This project sought to quantify the impacts of nonpoint source pollution on the water quality of the Carson River from Genoa Lane to Cradlebaugh Bridge (Highway 395). Following a Lagrangian scheme, water quality samples were collected for 3 separate seasons during 1994. Using the WASP5 (Water Quality Analysis Program) model, the system was simulated.

Key Findings/Conclusions:

- During the summer sampling (June 28, 1994), OP levels ranged from 0.17 to 0.30 mg/l and TP levels ranged from 0.25 to 0.39 mg/l, all well in excess of the water quality standard (0.1 mg/l). However, nitrate levels in the river were low ranging from 0.02 to 0.03 mg/l.

  Comment: These conditions are consistent with other studies and an analysis of the long-term data.

- During a one-day (July 11, 1994) hourly DO monitoring effort at Cradlebaugh Bridge (Highway 395), DO levels were found to drop below the 5 mg/l standard for approximately 6 hours with a minimum of 4.1 mg/l. Additionally, hand readings taken in the early morning on June 28, 1994 at Genoa Bridge indicated DO levels between 4.15 and 5.0 mg/l for at least 2 hours.

  Comment: This period of 1994 experienced extremely low flows. During the late June to mid-July period studied by Horvath and Warwick, the flows were at the 5^{th} percentile level (for the period of record, only 5% of the days experienced lower flows). Water quality standards are thought not to apply during such low flow conditions.[1]

- Based upon the modeling results, Horvath and Warwick concluded that "*nutrient loadings from groundwater flow allow a prolific algal population*" in the Carson River even if all nutrient loads from surface returns were eliminated. However, they also concluded that a more accurate quantification of the quantity and quality of the groundwater would be valuable.

  Comment: The modeling showed these results due to the fact that rather high nutrient loadings were assumed to be coming from groundwater in the area. This assumption may or may not be appropriate. Groundwater quality levels were assumed based upon USGS data from one shallow well in the general area. Though not well documented by Horvath and Warwick, it appears that these data were taken from Thodal (1988) for Well Number 32. This well is actually closer to Minden than it is to Genoa and may not be

[1] Nevada Administrative Code 445A.121(8) states "The specified standards are not considered violated when the natural conditions of the receiving water are outside the established limits, including periods of extreme high or low flow." While "low flow" is not defined in the regulations, a threshold of 10^{th} percentile flows may be appropriate.

representative of groundwater quality entering the river. Based upon these data, Horvath and Warwick assumed groundwater inflow nitrate levels of 0.93 mg/l (nitrate as N) which is significantly higher than levels measured in the river and in other surface inflows. As Horvath and Warwick stated, additional work is needed to better quantify groundwater loads to the river.

Estimating Non-Point-Source Loads and Associated Water Quality Impacts (Warwick, et al., 1997)

This project was a water quality modeling (WASP5) effort undertaken to estimate non-point source loading and associated water quality impacts to the Carson River. The scope of the project was limited to modeling only 1 day (July 31, 1990) using grab sample data collected by NDEP. No diel dissolved oxygen or algae monitoring data were available.

Key Findings/Conclusions:

- Modeling showed that a 48% reduction in total phosphorus loads would be required to meet the water quality standard (annual average of 0.1 mg/l). However, model simulations predicted that high algal levels and large diel DO fluctuations would still occur downstream of the loads at this reduction level as nitrogen is the limiting nutrient. A reduction of 97% in TP was needed to attain real improvement DO levels, at which point TP becomes the limiting nutrient.

  Comment: When reviewing these findings, it must be kept in mind that the WASP5 model was calibrated for only 1 day of water quality data, which did not include any diel DO data. There was no effort to validate with additional datasets. Nonetheless, it is believed that the general conclusion of nitrogen-limitation is valid.

Water-Quality Assessment of the Las Vegas Valley Area and the Carson and Truckee River Basins, Nevada and California – Nutrients, Pesticides, and Suspended Sediment, October 1969 – April 1990 (Kilroy et al., 1997, WRIR 97-4106)

This report was produced as part the USGS's NAWQA (National Water-Quality Assessment Program) activities. Data up through April 1990 were included in the analyses.

Key Findings/Conclusions:

- Nitrogen and phosphorus concentrations in the headwater areas were generally low during the study period (median OP = 0.03 mg/l, median nitrate <0.10 mg/l).

- As of 1990, orthophosphates and total phosphorus levels at Ft. Churchill (near Weeks) have decreased compared to 1970s and 1980s. No trends with total nitrogen and nitrate were identified at Ft. Churchill over the 20-year study period (1970-90). However, ammonia levels decreased since the 1970s.

- For water years 1970-89 at Ft. Churchill, the mean annual total nitrogen load was estimated to be 370 tons and the mean annual total phosphorus load was estimated at 90 tons.

Physical Data and Biological Data for Algae, Aquatic Invertebrates, and Fish from Selected Reaches on the Carson and Truckee River, Nevada and California, 1993-97 (Lawrence and Seiler, 2002)

This report presents biological data for algae collected in the Carson River system between 1993 and 1996.

Key Algae Data Presented:

- Algal density in riffle areas, pool areas for various algal taxon (in cells per cm^2). Diatoms and blue-green algae were found to dominate.

- Algal ash-free dry weight and chlorophyll-a and chlorophyll-b concentrations were provided.

Data from Lawrence and Seiler (2002) are summarized in subsequent sections of this report.

Carson River Special DO and Temperature Monitoring Report – 2001 (Pahl, 2002)

As part of a special investigation during the summer of 2001, NDEP collected water quality information at a number of sites on the East Fork Carson, Brockliss Slough and Carson River. During the study period, flows at 10311000 Carson River at Carson City were rather low, near the 10th percentile level.

Key Findings/Conclusions:

- Based upon early morning spot readings:
    - DO levels at EF Carson River at Muller Lane frequently fell well below the 5 mg/l water quality standard, with values down to 1 mg/l.
    - DO levels at EF Carson River at Lutheran Bridge and Highway 88, and Carson River at Genoa Lane ranged from 4.5 to more than 8 mg/l throughout July-August 2001.
    - DO levels at West Branch Brockliss at Muller Lane and Genoa Lane were frequently well below 5 mg/l standard, with values as low as 2.5 mg/l.
    - DO levels at East Branch Brockliss at Genoa Lane remained near or above the 5 mg/l water quality standard.

- During July/August, reported nitrate concentrations were 0.04 mg/l or less, orthophosphates ranged from 0.10 to 0.28 mg/l, and total phosphorus ranged from 0.16 to 0.33 mg/l at Carson River at Genoa Lakes Golf Course.

Trends in Nitrate and Dissolved-Solids Concentrations in Ground Water, Carson Valley, Douglas County, Nevada, 1985-2001 (Rosen, 2003)

Rosen analyzed nitrate levels in 27 monitoring wells in the Carson Valley and found that 56% showed increasing trends, with 11% showing decreases, and 33% showing no change. Nitrate levels between 1 to 5 mg/l (as nitrogen) were measured in several of the wells, with values above 15 mg/l in two wells.

Sources of Phosphorus to the Carson River Upstream from Lahontan Reservoir, Nevada and California, Water Years 2001-02 (Alvarez and Seiler, 2004)

Two specific goals of this investigation were: 1) to identify those reaches of the Carson River upstream from Lahontan Reservoir where the greatest increases in phosphorus and suspended-sediment concentrations and loading occur; and 2) to identify the most important sources of phosphorus. Towards these goals, USGS collected numerous water quality samples during the Water Years 2001 and 2002. Other historic data were also included in the analysis.

Key Findings/Conclusions:

- ❑ For the West Fork Carson above Carson Valley, most of the phosphorus levels were below the water quality standard (0.1 mg/l). For the East Fork Carson above Carson Valley, there were significant exceedances of the standard, with most occurring during spring runoff (March-May). Downstream of Carson Valley nearly all of the samples exceeded the water quality standards, with the highest levels occurring during the spring and summer.

- ❑ During the summer, the composition of the phosphorus changes from particulate phosphorus entering Carson Valley to orthophosphate leaving Carson Valley. The authors state that "*This change could indicate that particulate phosphorus entering Carson Valley is settling out…and is being replaced by orthophosphate from other sources. Alternatively, the particulate phosphorus could be converted to orthophosphate as it travels across Carson Valley.*" The authors also concluded that the source is likely agricultural.

- ❑ The authors concluded that during the 2-year study period (2001-02) a majority (~80%) of the phosphorus load leaving the Carson Valley during the October to March period was generated within the Carson Valley area. They also concluded that the headwater reaches of the East and West Forks contributed up to 58 percent of the annual phosphorus load leaving Carson Valley during the study period 2001-02.

  Comment: The authors do state that the calculations of this percentage does not account for phosphorus loads that have been removed from the river due to irrigation diversions. If the loads removed due to irrigation diversions are taken into account, it is estimated that the 58 percent value would be closer to 50 percent.

- During the period 2001-02, the estimated total phosphorus loads entering Eagle Valley and Dayton-Churchill Valleys were greater than the amount leaving these valleys. They concluded that these valleys may be acting as phosphorus sinks. However, they further state that the phosphorus may be mobilized during flood events.

  Comment: Some of the reduction in loads is likely due to phosphorus losses from the river due to irrigation diversions.

- For those reaches in Carson Valley, the largest increases in phosphorus loadings are associated with agricultural activities.

- The authors identified the need to better assess groundwater discharge quantity/quality to the Carson River.

- Potential sources of phosphorus in the study area were identified as natural inputs from undisturbed soils, erosion of soils and streambanks, construction of low-head dams and their destruction during floods, manure production and grazing by cattle along streamsides, drainage from fields irrigated with streamwater and treated effluent, groundwater seepage, and urban runoff including inputs from golf courses.

Carson River: Phase I – Total Maximum Daily Loads for Total Phosphorus (NDEP, 2005)

Several segments of the Carson River have been included on the State's 303(d) list for exceedances of the total phosphorus standard. This TMDL document was produced to address these listings as required by federal regulations.

Key Findings/Conclusions:

- Point source discharges of treated effluent were removed from the system in 1987. A comparison of pre-1987 to post-1987 data show that both OP and TP concentrations decreased at Deer Run Road and Weeks Bridge (Highway 95) apparently due to the removal of the effluent discharges.

- OP and TP concentrations on the East and West Forks above Carson Valley are generally below the water quality standard. OP and TP concentrations generally increase downstream from that point with the highest average OP and TP concentrations occurring at Mexican Gage and New Empire (Deer Run Road) with lesser levels at Weeks Bridge (Highway 95). Most of the post-1987 OP and TP levels at Mexican Gage and Deer Run Road show exceedances of the phosphorus standard. The highest average concentrations OP and TP at Mexican Gage and Deer Run occur during the July-September period, with highest average loads occurring during the spring runoff period (April-June).

- Degraded physical conditions of the river have contributed to exceedance of the phosphorus standards, with inputs from watershed runoff, agricultural return flows, grazing livestock, streambank erosion, urban runoff all potential sources. Mitigation efforts should focus on reaches upstream of Deer Run Road in Carson City.

- Significant positive correlations between flow and TP were identified for the East Fork at Riverview Mobile Home Park site, indicating that erosion and particulate transport are affecting the TP concentrations. Significant negative correlations between flow and TP at Mexican Gage suggest that dilution at high flows may be the dominant process. Of the 5 sites evaluated, flow is thought to have least influence on TP at the New Empire site (Deer Run Road) and at the West Fork Carson River at Paynesville site

- Significant load reductions are needed to meet the existing TP water quality standards. For example at Mexican Gage, TP loads need to be reduced by 36 to 68% depending upon flow conditions.

Dissolved Oxygen Dynamics in the Carson River (Latham, 2005); Dissolved Oxygen Dynamics in the Carson River, Nevada: Results from Field Programs during the Summers of 2003 and 2004 (Fritsen et al., 2006); NDEP Carson River Water Quality Modeling Report (Warwick, 2006)

The purpose of this project was to monitor and assess nutrient/dissolved oxygen/algae conditions in the Carson River between Genoa Lane and Deer Run Road. Water quality modeling (WASP) was performed to support the evaluation.

Key Findings/Conclusions:

- Continuous DO monitoring sondes indicated that minimum DO levels were mostly near or above the 5 mg/l standard at Genoa Lane, Cradlebaugh Bridge and Foerschler Ranch (upstream of Mexican Dam) in both 2003 and 2004. Diel changes ranged from 3 to 5 mg/l. However, the Riverview Park site (Carson City) experienced minimum DO levels above 5 mg/l in 2003 and extremely low DO levels (near zero) during 2004. In 2004, macroscopic filamentous growths were prevalent downstream of Mexican Dam. Also, flows at this time were low, near the 10^{th} percentile level. The low DO at Riverview Park in 2004 was thought to be due in part to the die off of the significant Cladophora algal bed that had become established.

- Algal biomass in some locations were in excess of threshold suggested for the protection of aquatic life and recreational uses in other systems (Nordin, 1985). Benthic chlorophyll-a levels were in excess of 70 mg/m^2 at some locations placing the river in the eutrophic category based upon biomass.

- Low N:P ratios in the algae suggest that nitrogen is the limiting nutrient. Water column nitrate levels were very low throughout the study area with most values than 0.02 mg/l, while OP values were frequently >0.1 mg/l and TP values were frequently >0.2 mg/l. The water column N:P ratios also suggest that N may be a limiting nutrient.

- Water quality modeling indicated that a diel fluctuation in nitrates may be occurring within the study area, with utilization by periphyton during daylight hours lowering levels near zero. No diel water chemistry data were collected to confirm.

- Throughout 2003, the cyanobacteria genera were the most abundant filamentous periphyton at most sonde locations. Cladophora was the most abundant filamentous algae in early 2004.

- The WASP modeling effort was not successful at simulating the low DO levels measured at the Riverview Park site. Several potential causes are offered: 1) unmonitored source of pollution entered the river upstream; 2) algal material may have collected on the DO probe; 3) problems with the model such as inaccurate simulation of cladophora die off at high temperatures.

Carson River Special Dissolved Oxygen and Temperature Monitoring Report – 2005 (Pahl, 2006)

During a 6-week period beginning in early August 2005, NDEP monitored early morning and late afternoon DO levels at 10 sites on the East and West forks of the Carson River and Brockliss Slough. Streamflows during this period were near or above the median flows.

Key Findings/Conclusions:

- The most frequent DO standard violations occurred at: EF Carson River at Muller Lane, WF Carson River from Highway 88 to Muller Lane, and Brockliss Slough (both branches) from Muller to Genoa Lane.
    - EF Carson River at Muller Lane experienced DO levels down to 3.7 mg/l, consistent with earlier findings during the 2001 NDEP special study (Pahl, 2002). The likely cause of the low DO levels were thick algae mats found in the river between Highway 88 and Muller Lane.
    - WF Carson River is largely dewatered (Pugsley, 2004) with all to most of its flow directed into Brockliss Slough above Highway 88. Between Highway 88 and Muller Lane, WF Carson flows consistent primarily of irrigation return flows and EF Carson River water conveyed in the irrigation delivery system. The lowest overall DO levels were measured at Centerville Lane ranging from 1.4 to 2.3 mg/l. Little flow existed at this location.
    - DO readings at many of the Brockliss Slough locations were typically in the 4 to 5 mg/l range. The most severe conditions were found at the West Branch Brockliss Slough at Genoa Lane with morning DO levels consistently around 1 mg/l. Though little flow movement was visible for both Brockliss branches at Genoa Lane, the East Branch experienced higher DO levels (3.4 to 4.9 mg/l).

2004 Nutrient Levels in Carson Valley Groundwater based upon Discharge Monitoring Reports (Pahl, 2006)

This report summarizes 2004 groundwater nutrient data submitted to NDEP as part of groundwater permit conditions for the Carson Valley.

Key Findings/Conclusions:

- A majority of the compiled groundwater data consists of total nitrogen and nitrate concentrations, with little data for phosphorus. Nitrate/total nitrogen levels are highly variable ranging from less than detection limits to 11 mg/l. Of greatest concerns are levels near the river:
  - In the area around the Sunridge Golf Course and Nevada State Prison, nitrate levels ranged from less than detection limits to 3.3 mg/l, and nitrogen levels ranged from 0.3 to 3.5 mg/l.
  - In the area of the East Fork Carson River near Muller Lane, nitrate levels in the groundwater ranged from less than detection limits to 3.0 mg/l, and nitrogen levels ranged from less than detection limits to 3.3 mg/l.

DISCUSSION

Observed Eutrophication Problem Areas

A number of sites have been identified which experience eutrophication problems, i.e. excessive algae growth and/or depressed dissolved oxygen levels:

West Fork Carson River between Highway 88 and Centerville Lane: NDEP (Pahl, 2006) measured low DO levels in this reach of the West Fork Carson River with the lowest levels at Centerville Lane (as low as 1.4 mg/l). Figure 2 shows the stagnant flow conditions that typically exist at Centerville Lane. As discussed earlier, the West Fork is largely redirected to Brockliss Slough leaving little flow in the West Fork at this location.

West Fork Carson River below Muller Lane: As part of a Thermal Infrared Survey on August 8, 2006, Watershed Sciences (2006) collected a series of photographic images of the East Fork, West Fork and mainstem Carson River upstream of Carson City. These photographs showed considerable algae and/or macrophyte growth along the lower reach of the West Fork Carson River (Figure 3).

East Fork Carson River between Highway 88 and Muller Lane: NDEP (Pahl, 2002; Pahl 2006) measured low DO levels in the East Fork Carson River at Muller lane in 2001 (as low as 1 mg/l) and in 2006 (around 4 mg/l). During 2001, a thick algae mat developed in this reach and has been observed in subsequent years (Figure 4). In 2006, higher flows were experienced and thick algae mat still developed. This stretch of the river has very little shading providing much light for algal use.

Brockliss Slough: At several locations throughout the Brockliss Slough, NDEP (Pahl, 2006) measured DO levels frequently less than the 5 mg/l water quality standard. The worst conditions were in the West Branch Brockliss Slough at Genoa Lane with minimum DO levels below 2 mg/l. Figure 5 shows the stagnant conditions typical for this location. A downstream diversion dam for the Genoa Lake Golf Course has caused flow to backup at Genoa Lane on both branches of the Brockliss Slough. However, minimum DO conditions on the East Branch Brockliss Slough appear to be somewhat better (ranging from 3.4 to 5 mg/l).

Figure 2. West Fork Carson River at Centerville Lane, 2005

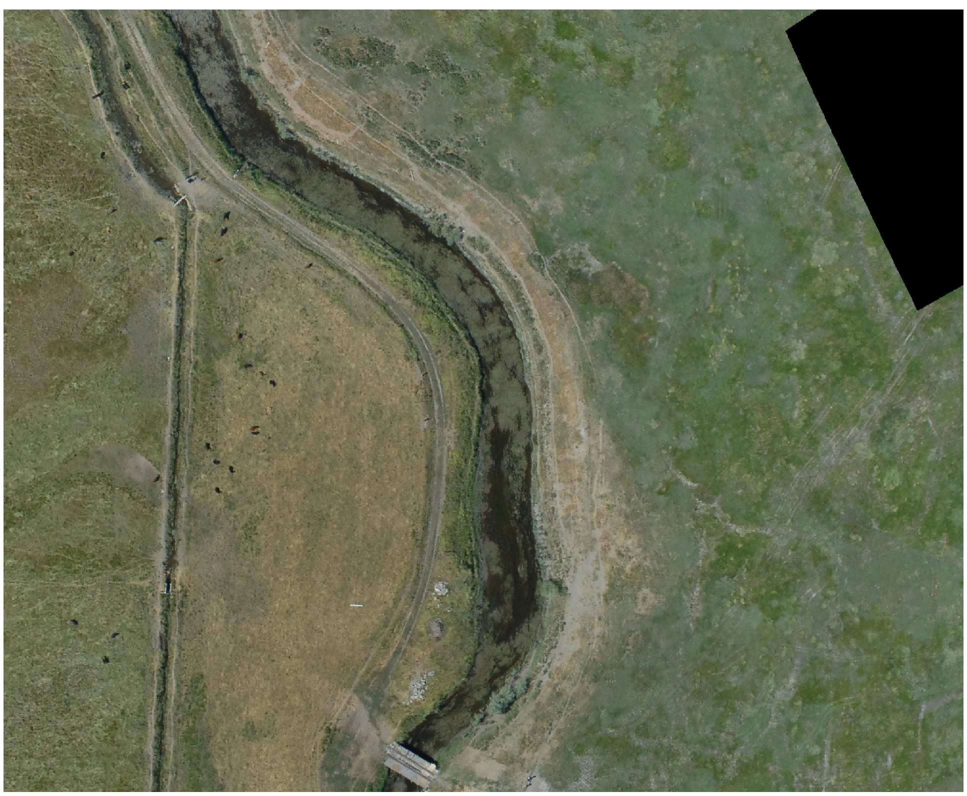


Figure 3. West Fork Carson River below Muller Lane, 2006

Figure 4. Algae Mat in East Fork Carson River between Highway 88 and Muller Lane, 2004

Figure 5. West Branch Brockliss Slough at Genoa Lane, 2005

Carson River at Riverview Park: DRI (Latham, 2005; Fritsen et al., 2006) measured extremely low dissolved oxygen levels (Figure 6) in the Carson River at Riverview Park during the summer of 2004, with below average flows. Thick algal mats were also observed in the area (Figure 7). As noted by Latham (2005) and Fritsen et al. (2006), excessive algae and depressed DO problems were not observed in 2003 at Riverview Park, which experienced near average flows. In subsequent visits to the site by NDEP staff, excessive algae levels have not been observed during the summers of 2005 and 2006 which experienced higher flows than 2004. Even in 2007, when flows were lower than 2004 flows, no excessive algae were observed. Flow may not be a good indicator of when eutrophication problems are expected to occur at this site.

Figure 6. Dissolved Oxygen at Riverview Park - 2004

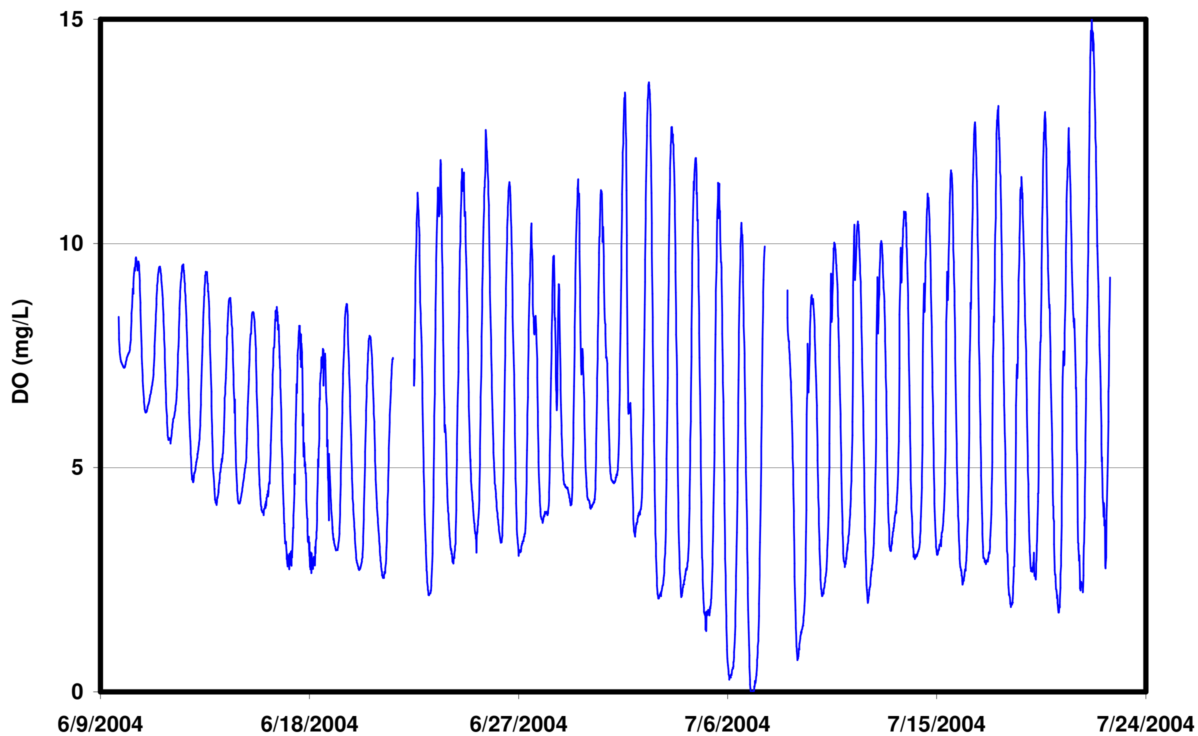


Figure 7. Algae Mats in Carson River near Riverview Park, 2004

Summary of Algae Screening Surveys

During the summers of 2006 and 2007, NDEP performed a number of qualitative algae screening surveys which included estimations of percent cover of stream bottom by algae. Biggs (2000) suggests that algae cover >30% may be an indicator of impairment of recreation and aquatic uses. During 2006, excessive algae levels (50% or more) were observed at only 2 locations (Table 2). In 2007, daily flows were at or below the 10^{th} percentile levels (in some cases, flow were at near record low levels) which resulted in high algae cover at each of the seven sites. According to the Nevada Administrative Code 445A.121(8), water quality standards are not considered violated during violations occur during these periods of extreme low flow, such as occurred in 2007.

Table 2. Maximum Percent Cover by Algae in 2006 & 2007

Site	2006	2007
EF Carson River upstream of Lutheran Bridge	0 - 25%	50 – 75%
EF Carson River upstream of Highway 88	50 – 75%	75 – 100%
EF Carson River between Highway 88 and Muller Lane	100%	100%
Carson River near south end of Silver Saddle Ranch	0 - 25%	50 – 75%
Carson River upstream of main Brunswick Reservoir seep	n/a	50 – 75%
Carson River downstream of main Brunswick Reservoir seep	0 - 25%	50 – 75%
Carson River south of Moundhouse	0 - 25%	50 - 75%

Algae Characteristics

Lawrence and Seiler (2002) presented algal densities (cell counts per cm^2) for riffle and pool areas at several sites throughout the Carson system. According to their data, cyanobacteria (blue-green algae) were the dominant taxa in the riffle areas, while diatoms were the dominant taxa in the pool areas. In most instances, green algae made up than 10% of the total cell counts.

Lawrence and Seiler (2002) also presented algae biomass data throughout the system during 1993 through 1996, with chlorophyll-a levels ranging from 1 to 130 mg/m^2, the highest values typically occurring between Minden/Gardnerville and Dayton State Park. Most recently, DRI (Fritsen et al., 2006) collected some algae data for a portion of the system. In both 2003 and 2004, DRI observed felts and filamentous algae throughout their study area (from Genoa Lane to Riverview Park). Measured algal biomass chlorophyll-a in the Carson River ranging from 131 to 592 mg/m^2 during 2003 (near Genoa Lane, Cradlebaugh Bridge, upstream of Mexican Dam, and Riverview Park), and ranging from 17 to 351 mg/m^2 during 2004 (Cradlebaugh Bridge and Riverview Park). A variety of studies suggest that chlorophyll-a levels above 100 to 200 mg/m^2 impair a variety of beneficial uses (NDEP, 2007). It must be realized that algal biomass can be highly variable throughout a given stream reach and it becomes difficult to accurately quantify the overall density. Much more algae sampling using agreed upon protocols is needed to better understand biomass dynamics in the Carson River.

DRI found that throughout 2003 the cyanobacteria genera were the most abundant filamentous periphyton at most sonde locations, though levels in 2003 were quite a bit lower than in 2004 and did not cause substandard DO conditions. Cladophora was the most abundant filamentous algae in early 2004. USGS data at various sites on the East Fork, West Fork and Carson River indicate that cyanobacteria are not uncommon and can represent a significant portion of the algae cells for a given site (Lawrence and Seiler, 2002). Cyanobacteria are capable of utilizing nitrogen gas dissolved in the water, and typically occur in waters with low nitrogen concentrations.

Nutrient Levels in the Water

NDEP and others have been collecting water chemistry data throughout the Carson River for several years. The intent of this section is to provide a quick overview of nutrient levels in the Carson River system from stateline to Lahontan Reservoir based upon data collected at some of the key monitoring locations. For more detailed information, the reader can refer to the numerous reports mentioned in the ***Major Past Studies*** section. Figure 8 and Table 3 show the 11 monitoring sites used in the following discussions.

Figures 9 and 10 present boxplots of TP and OP concentrations for the period 1988-2006[2] for 11 locations on the Carson system. As previous studies have discussed, TP and OP levels coming into Carson Valley are typically low. The highest median TP and OP values have occurred at CR-2: Carson River at Cradlebaugh Bridge. From that point downstream, the median values tend to decrease. The West Fork at Muller Lane (WF-2) also experiences some high TP and OP levels (median of about 0.2 mg/l). At this point, the West Fork River is primarily conveying return flows and East Fork water.

Figures 11 and 12 present boxplots of TP and OP levels for July through September for the period 1988-2006. The July-September period was chosen in an attempt to capture nutrient conditions during the peak growing season for algae. Again, the highest median values are identified at Carson River at Cradlebaugh Bridge. Compared to the year-round data, the summer TP and OP medians are generally higher.

Boxplots of TN and Nitrate+Nitrite concentrations (1988-2006) are provided in Figures 13 and 14. Somewhat similar to the TP plots, the highest TN median occurs at CR-2: Carson River at Cradlebaugh and at WF-2: West Fork at Muller Lane. The nitrate+nitrite plot shows little difference in levels between the 11 sites with all median levels <0.1 mg/l.

July-September TN and Nitrate+Nitrite boxplots are presented in Figures 15 and 16. The summer TN medians are similar to the year-round TN medians with higher levels at CR-2 and WF-2. However, the summer Nitrate+Nitrite plot shows elevated levels at EF-2 (East Fork at Highway 88) as compared to the other 10 sites. It is possible that high Nitrate+Nitrite concentrations at EF-2 have contributed to the high algae growth in the East Fork between Highway 88 and Muller Lane (Figure). Additional study is needed to better understand this stretch of the East Fork.

[2] Permitted wastewater treatment facility discharges ceased to exist in 1987. The period 1988-2006 was selected as a period more representative of current conditions.

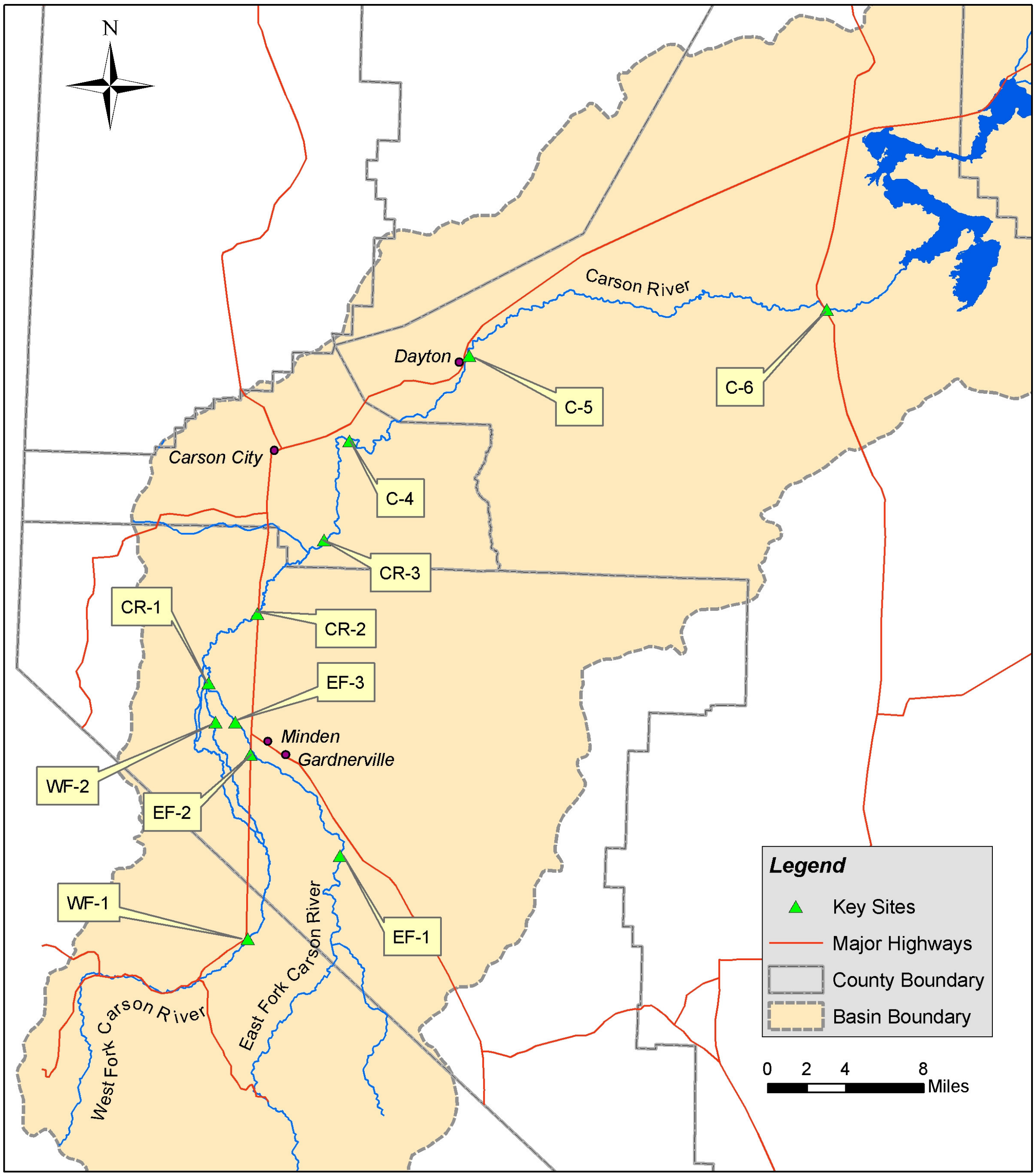


Figure 8. Selected Nutrient Monitoring Sites

Table 3. Selected Sampling Locations on the Carson River System

ID	Description	Agency ID	Agency
WF-1	West Fork Carson River at Paynesville	C-8	NDEP
		SW-05	STPUD
WF-2	West Fork Carson River at Muller Lane	C-14	NDEP
		CVWF	CVCD
EF-1	East Fork Carson River at Riverview Mobile Home Park	C-9	NDEP
		CVWB	CVCD
		10309010	USGS
EF-2	East Fork Carson River at Highway 88	C-16	NDEP
		CV88	CVCD
EF-3	East Fork Carson River at Muller Lane	C-15	NDEP
CR-1	Carson River at Genoa Lane	C-3	NDEP
CR-2	Carson River at Cradlebaugh Bridge	C-2	NDEP
CR-3	Carson River at Mexican Gage	C-13	NDEP
		CVMG	CVCD
		10311000	USGS
CR-4	Carson River at Deer Run Road (New Empire)	C-1	NDEP
		CVDR	CVCD
		10311400	USGS
CR-5	Carson River at Dayton Bridge	C-11	NDEP
		DVD	DVCD
CR-6	Carson River at Weeks	C-10	NDEP
		DVW	DVCD
		10312000	USGS
		10312020	USGS

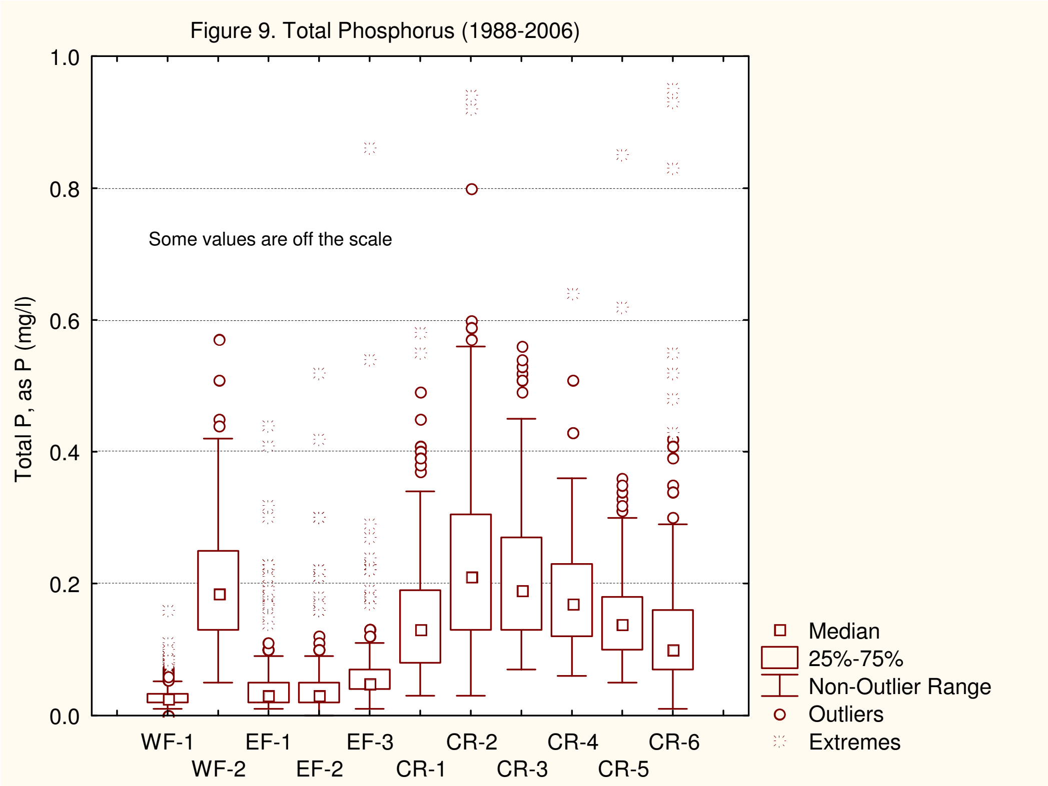


Figure 9. Total Phosphorus (1988-2006)
Total P, as P (mg/l)
1.0
0.8
0.6
0.4
0.2
0.0
Some values are off the scale
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

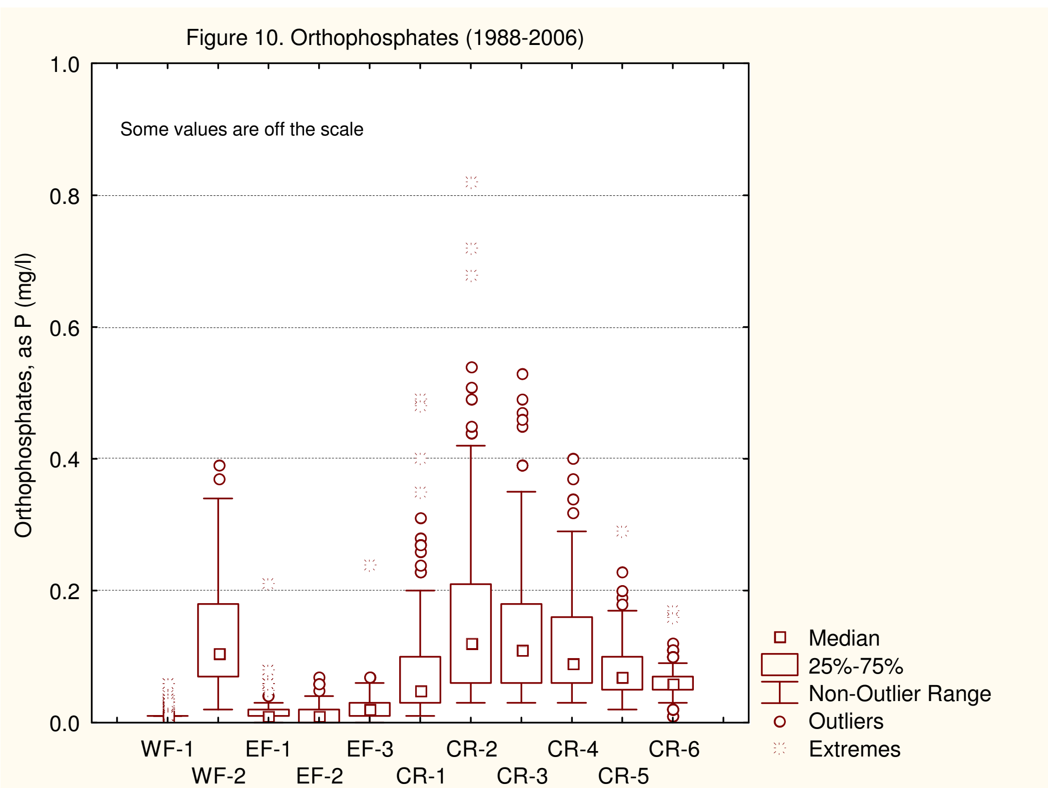


Figure 10. Orthophosphates (1988-2006)
Orthophosphates, as P (mg/l)
1.0
0.8
0.6
0.4
0.2
0.0
Some values are off the scale
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

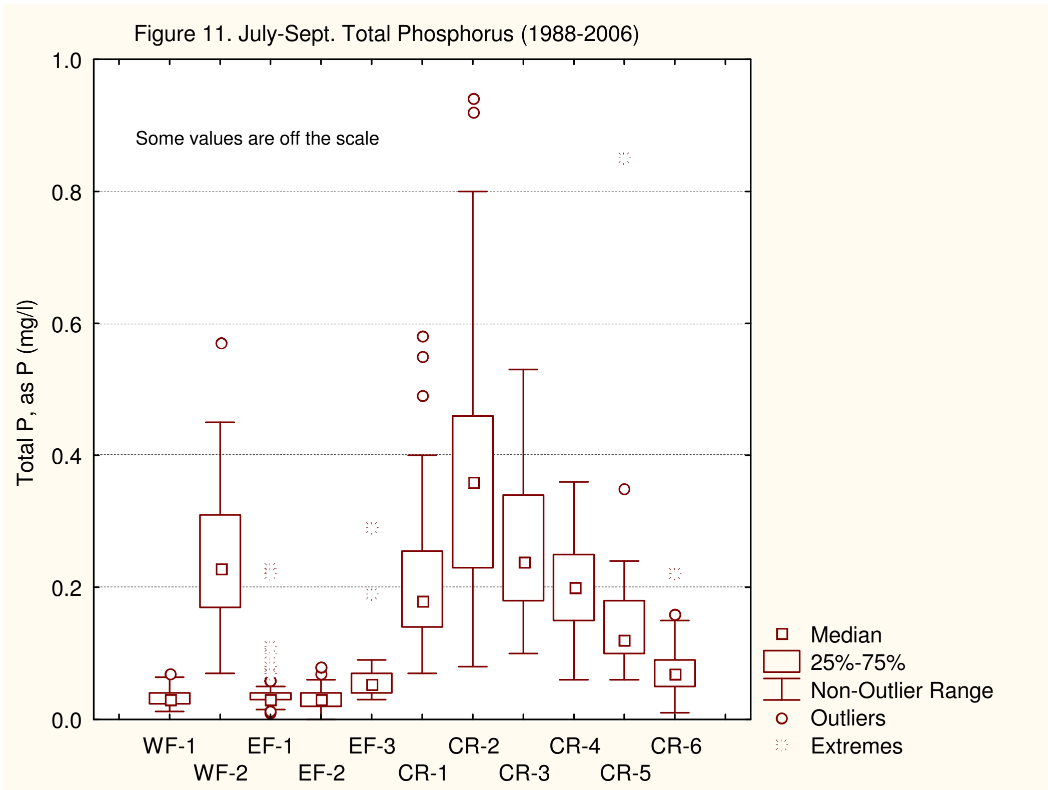


Figure 11. July-Sept. Total Phosphorus (1988-2006)
Some values are off the scale
Total P, as P (mg/l)
1.0
0.8
0.6
0.4
0.2
0.0
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

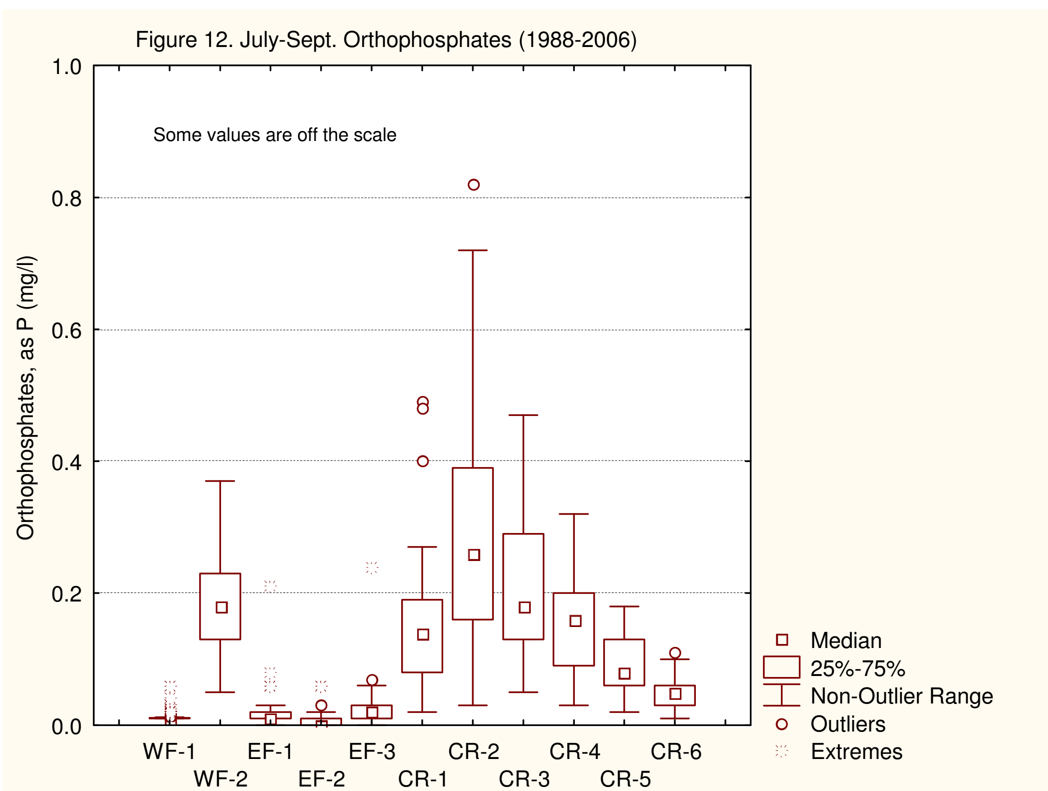


Figure 12. July-Sept. Orthophosphates (1988-2006)
Some values are off the scale
Orthophosphates, as P (mg/l)
1.0
0.8
0.6
0.4
0.2
0.0
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

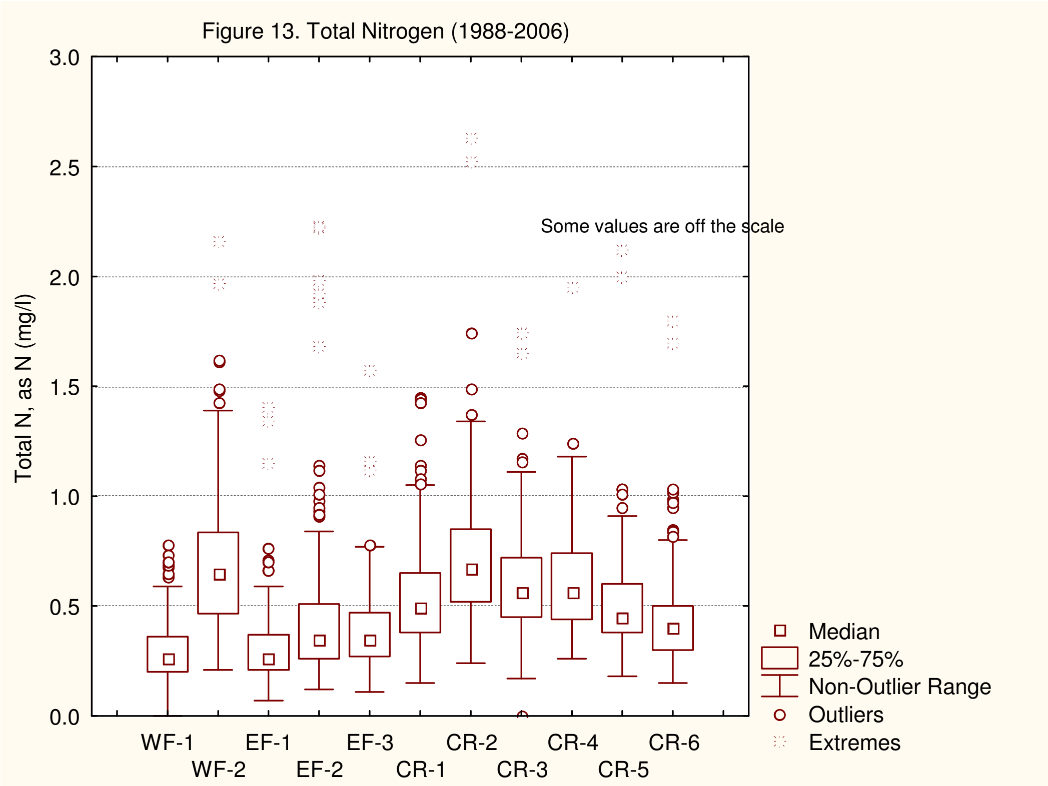


Figure 13. Total Nitrogen (1988-2006)
Total N, as N (mg/l)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Some values are off the scale
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

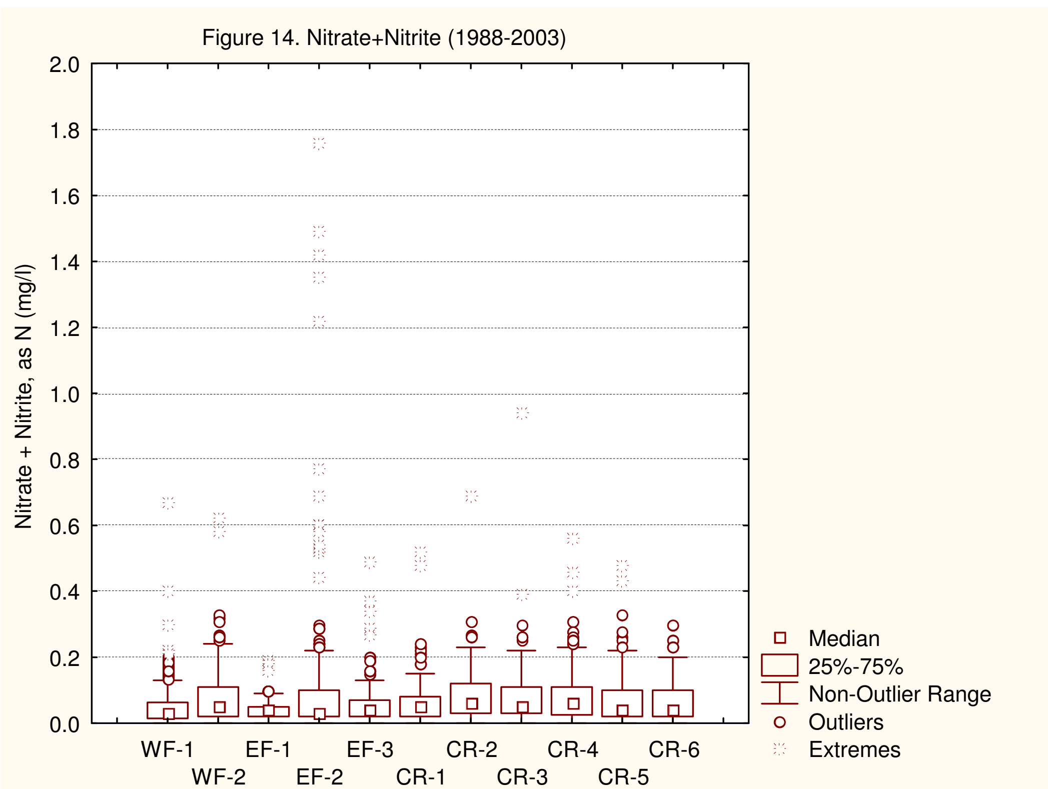


Figure 14. Nitrate+Nitrite (1988-2003)
Nitrate + Nitrite, as N (mg/l)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

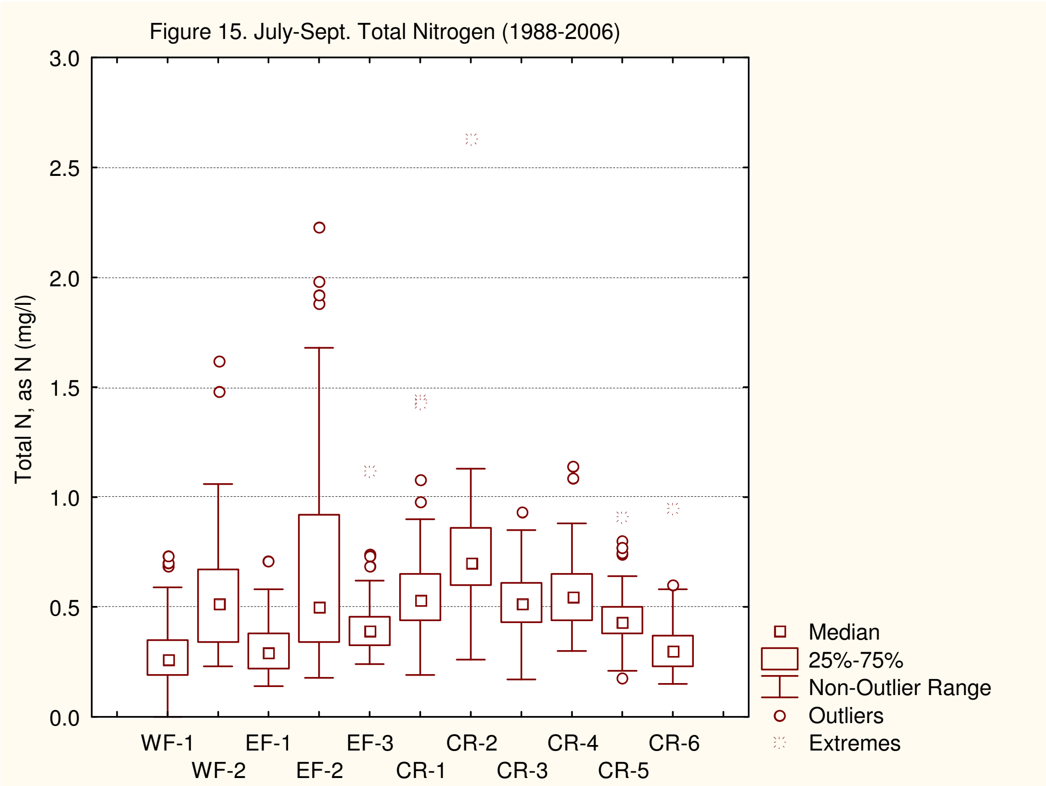


Figure 15. July-Sept. Total Nitrogen (1988-2006)
Total N, as N (mg/l)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

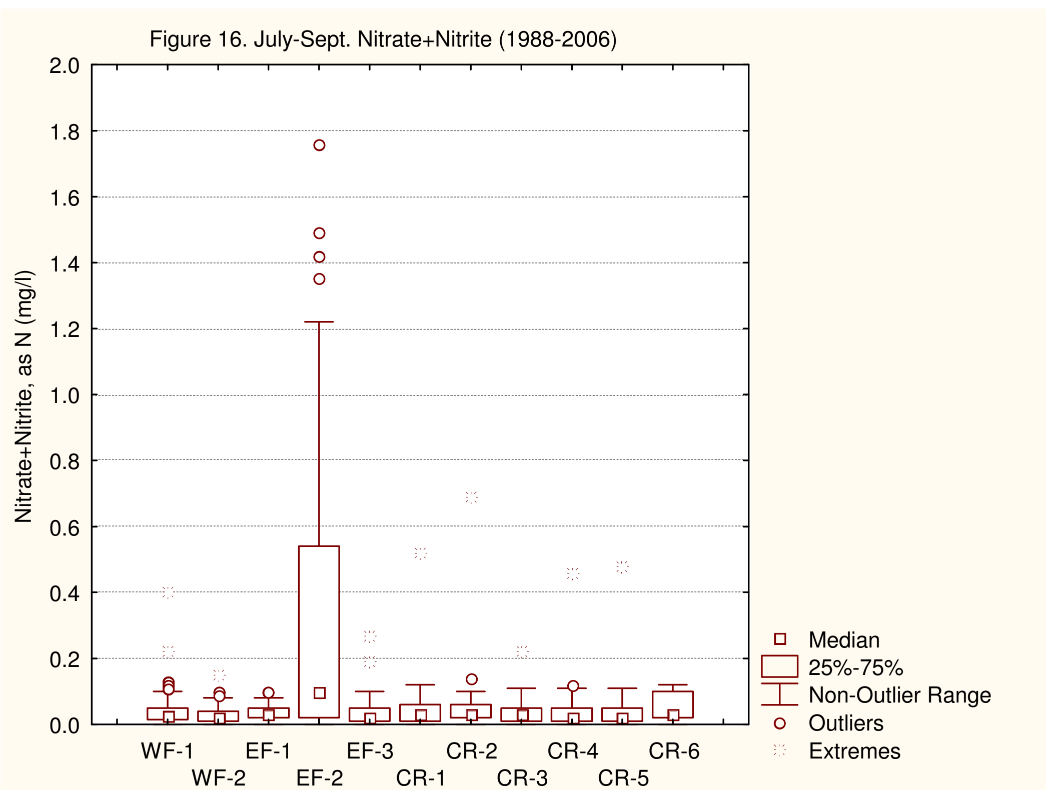


Figure 16. July-Sept. Nitrate+Nitrite (1988-2006)
Nitrate+Nitrite, as N (mg/l)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
WF-1
WF-2
EF-1
EF-2
EF-3
CR-1
CR-2
CR-3
CR-4
CR-5
CR-6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

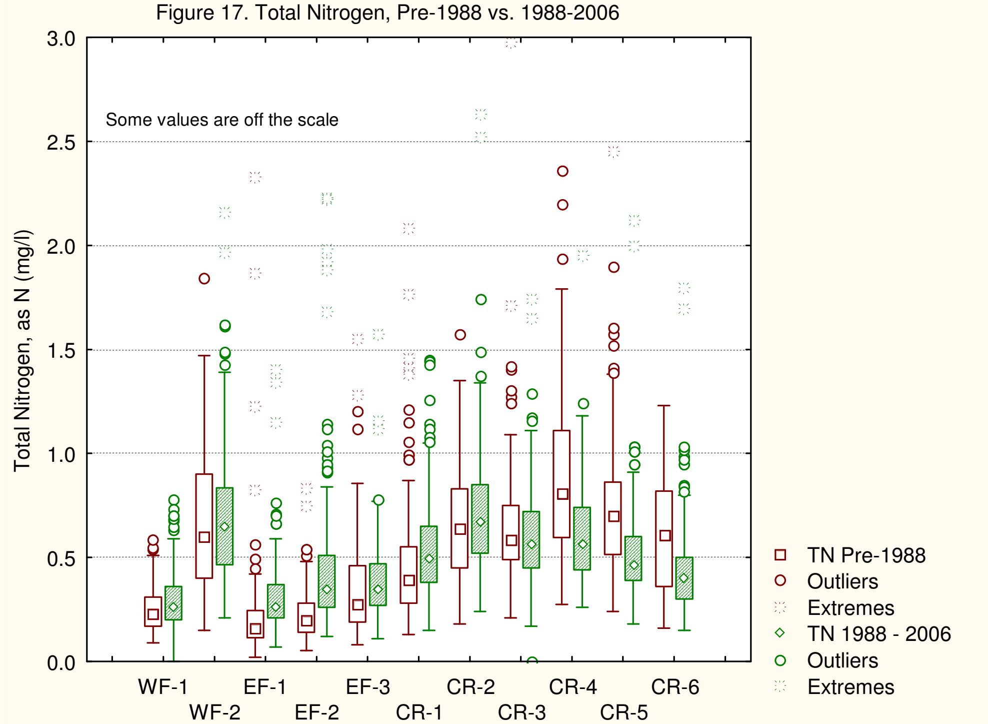
Trends

Overall, nutrient levels in the Carson River system have decreased throughout much of the lower stretches. Much of the decrease is thought to be primarily due to the removal of permitted treated wastewater treatment discharges (in Carson Valley and Carson City) by 1987 (Figures 17 through 20). Mann-Whitney tests were performed to determine the statistical significance of differences between the median values for "Pre-1988" and for "1988-on" (Table 4).

Figure 17 presents boxplots of total nitrogen levels for the Pre-1988 Period versus 1988-2006. The median values at the upper sites (above CR-3: Carson River at Mexican Gage) show an increase for the 1988-2006 period. However, the cause of these increases is unknown. The largest decreases in median TN values occurred at CR-4: Carson River at Deer Run Road and below. Figure 18 shows that median nitrate+nitrite values have decreased at sites in the Genoa area and lower. Much like TN, some of the largest decreases in median nitrate+nitrite values occurred at CR-4: Carson River at Deer Run Road and below. These decreases are likely due to changes in upstream wastewater effluent management.

Figure 19 shows little change in total phosphorus median values at many of the sites. Median values decreased at CR-4: Carson River at Deer Run Road and below. Changes in Carson City's wastewater effluent management are likely the major cause of these decreases. Figure 20 also shows little change in orthophosphates in the upper sites[3]. However, the large median values decreased occurred at CR-4: Carson River at Deer Run Road and below, again due to Carson City's effluent management changes.

Figure 17. Total Nitrogen, Pre-1988 vs. 1988-2006



[3] While the Mann-Whitney test (Table 4) show that OP decreases were statistically significant for the upper sites, the relative OP concentrations were rather low.

Figure 18. Nitrate+Nitrite, Pre-1988 vs. 1988-Present

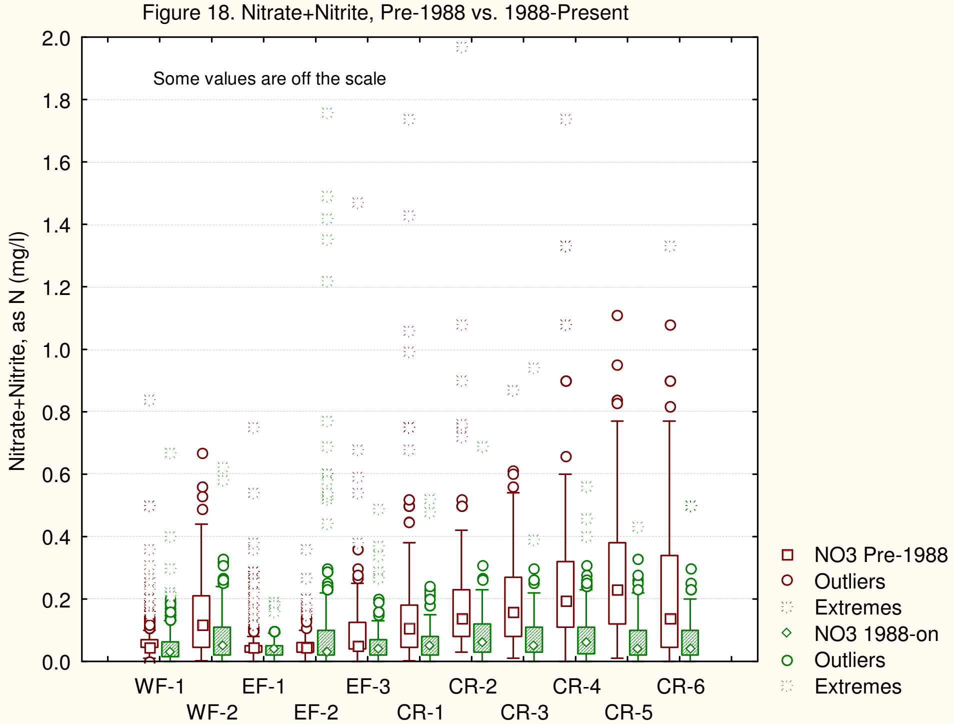
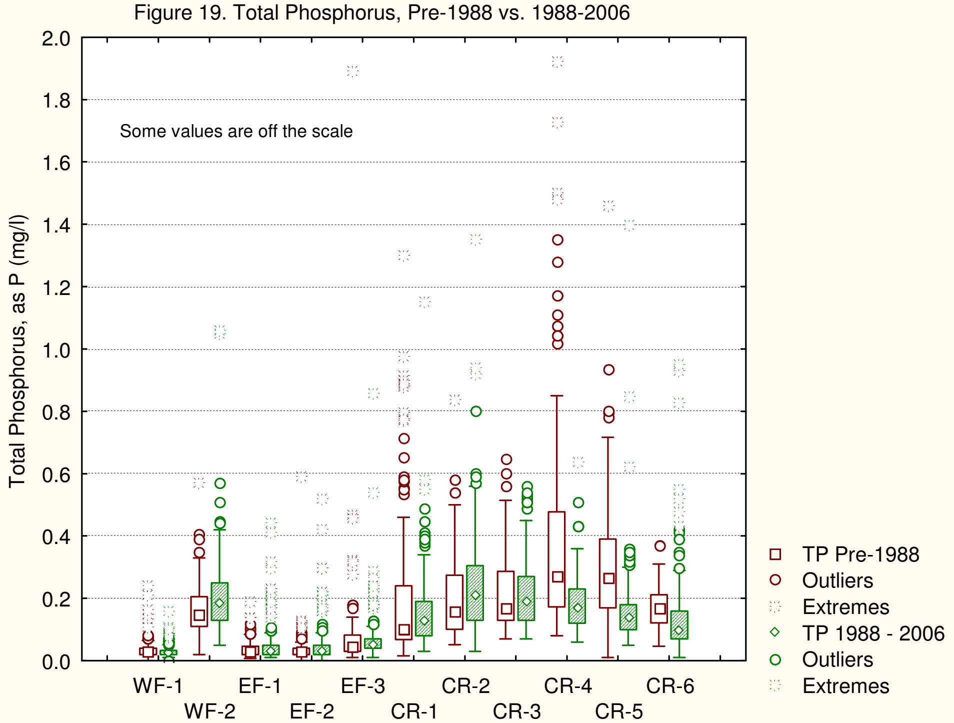


Figure 19. Total Phosphorus, Pre-1988 vs. 1988-2006



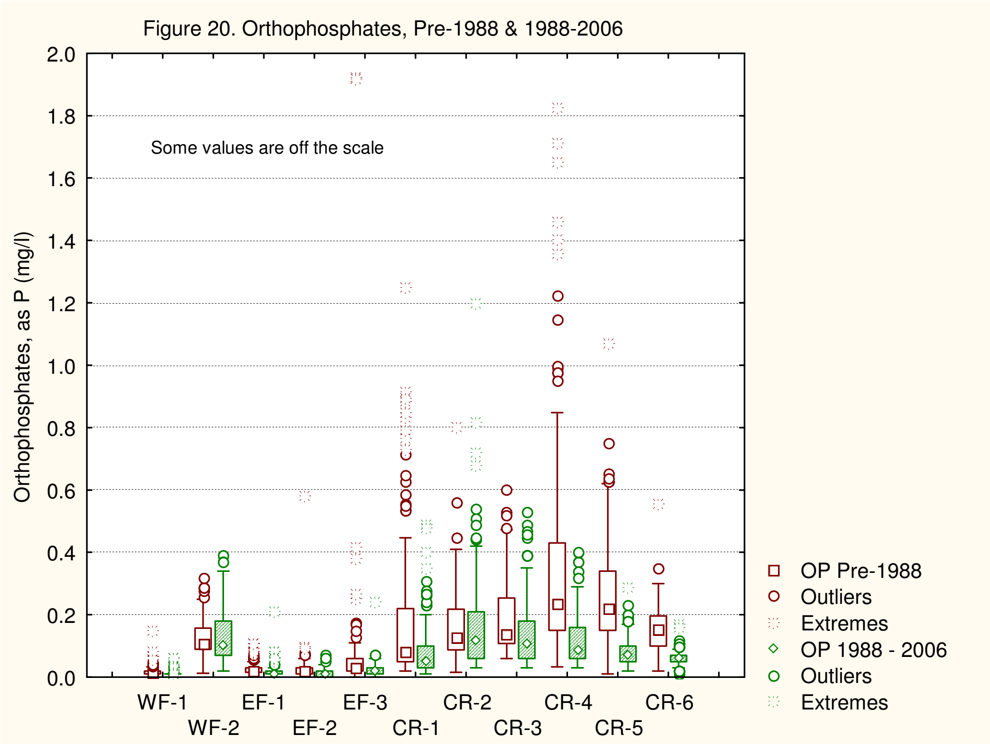


Table 4. Mann-Whitney Test Results – Pre-1988 Medians vs. 1988-on Medians

ID	Description	Change in Median/p-value[1]			
		TN	Nitrate+Nitrite	TP	OP
WF-1	WF at Paynesville	Increase	Not determined[2]	No Change	Decrease
		0.005		0.162	0.000
WF-2	WF at Muller Lane	No Change	Decrease	Increase	No Change
		0.646	0.000	0.001	0.771
EF-1	EF at Riverview	Increase	Not determined[2]	No Change	Decrease
		0.000		0.778	0.000
EF-2	EF at Hwy 88	Increase	Not determined[2]	No Change	Decrease
		0.000		0.723	0.000
EF-3	EF at Muller Lane	Increase	Not determined[2]	No Change	Decrease
		0.000		0.893	0.000
CR-1	CR at Genoa Lane	Increase	Decrease	No Change	Decrease
		0.000	0.000	0.272	0.000
CR-2	CR at Cradlebaugh	No Change	Decrease	Increase	Decrease
		0.262	0.000	0.004	0.038
CR-3	CR at Mexican Gage	No Change	Decrease	No Change	Decrease
		0.175	0.000	0.808	0.000
CR-4	CR at Deer Run Road	Decrease	Decrease	Decrease	Decrease
		0.000	0.000	0.000	0.000
CR-5	CR at Dayton	Decrease	Decrease	Decrease	Decrease
		0.000	0.000	0.000	0.000
CR-6	CR at Weeks	Decrease	Decrease	Decrease	Decrease
		0.000	0.000	0.000	0.000

[1] Differences in the medians were considered statistically significant where p-value <0.05

[2] High detection limits during the pre-1988 precluded the determination of differences between the medians. The results were sensitive to the values assumed for the "<detection limit" values.

Limiting Conditions

Liebig's Law of the Minimum states that the growth of an organism (algae in this case) is limited by the substance or other conditions which is available in the least quantity relative to the needs of the growth/reproduction needs of the organism Lee (1998). A number of factors can limit the growth of algae, such as nutrient concentrations, substrate, flow, shading, temperature, etc. According to Lee (1998, 199), it is inappropriate to conclude that either N or P are limiting based solely on N:P ratios of water column concentrations. This tends to be an over simplification. OP and DIN are only limiting algae growth when they occur in low concentrations (< 5 ug/l for OP; < 20 ug/l for DIN) (Lee, 1999). However, even growth rate-limiting concentrations can support some algal biomass given sufficient time to grow.

The available data suggests that nitrogen levels are one of the algae limiting factors in the Carson River system. Fritsen and others (2006) reported that the N:P ratios of the algae in their Carson River study area (Genoa Lane to Deer Run Road) were extremely low ranging from 0.31 to 3.0 and that DIN concentrations are frequently very low (<10 ug/l). However, Fritsen and others conclude that the algae sampling method may have impacted these results. Many of the algae samples contained sediments and sedimentary organic matter which may have skewed the results.

Within the Carson River system, stream substrate may be another factor which could limit algae growth in some locations. NDEP investigations show that much of the East Fork Carson and Carson River streambottom between Muller Lane and Carson City is dominated by sand (Pahl, 2006). Large, rough substrates are the best habitat for periphyton due to its need to attach to objects (Welch et al., 1992).

Nutrient Sources

Following is a brief discussion of nutrient sources in the watershed. The reader is referred to the many previous reports for more detailed information.

Phosphorus: As discussed by Alvarez and Seiler (2004), and NDEP (2005), potential sources of phosphorus to the West Fork, East Fork and main Carson Rivers include:

- Watershed and channel erosion
- Irrigation
- Livestock
- Urban runoff
- Irrigation with treated effluent
- Fertilizer
- Septic tank leach fields

From a river eutrophication perspective, the level of bioavailable nutrients during the summer are of the most concern. It is during this time that flows drop (with decreased scouring velocities, and higher light levels reaching the stream bottom) and temperatures increase (increasing biological activity) leading to maximum benthic algae growth. Alavarez and Seiler (2004) found large increases in TP loads (predominately due to OP) entering the rivers in the Carson Valley during the summer. They concluded that agriculture is the likely source of the OP loads.

Nitrogen: Rosen (2003) identified several nitrate sources to the groundwater in Carson Valley:

- Livestock
- Fertilizer
- Irrigation using treated effluent
- Septic tanks

Based upon 2000 data, Rosen estimated general nitrate levels in the groundwater (Figure 21). He found that nitrate levels generally exceeded 2 mg/l in septic tank areas. Pahl (2006) also documented some elevated nitrate groundwater levels in Carson Valley. While the nitrate levels found by Rosen and Pahl were mostly less than the drinking water standard (10 mg/l), much lower levels are a concern for the Carson River. Given the low nitrate concentrations in the river and the low flow typical in the late summer, groundwater loading could be a concern. Unfortunately, the actual nitrate loading from the groundwater to the river is unknown and additional work is needed.

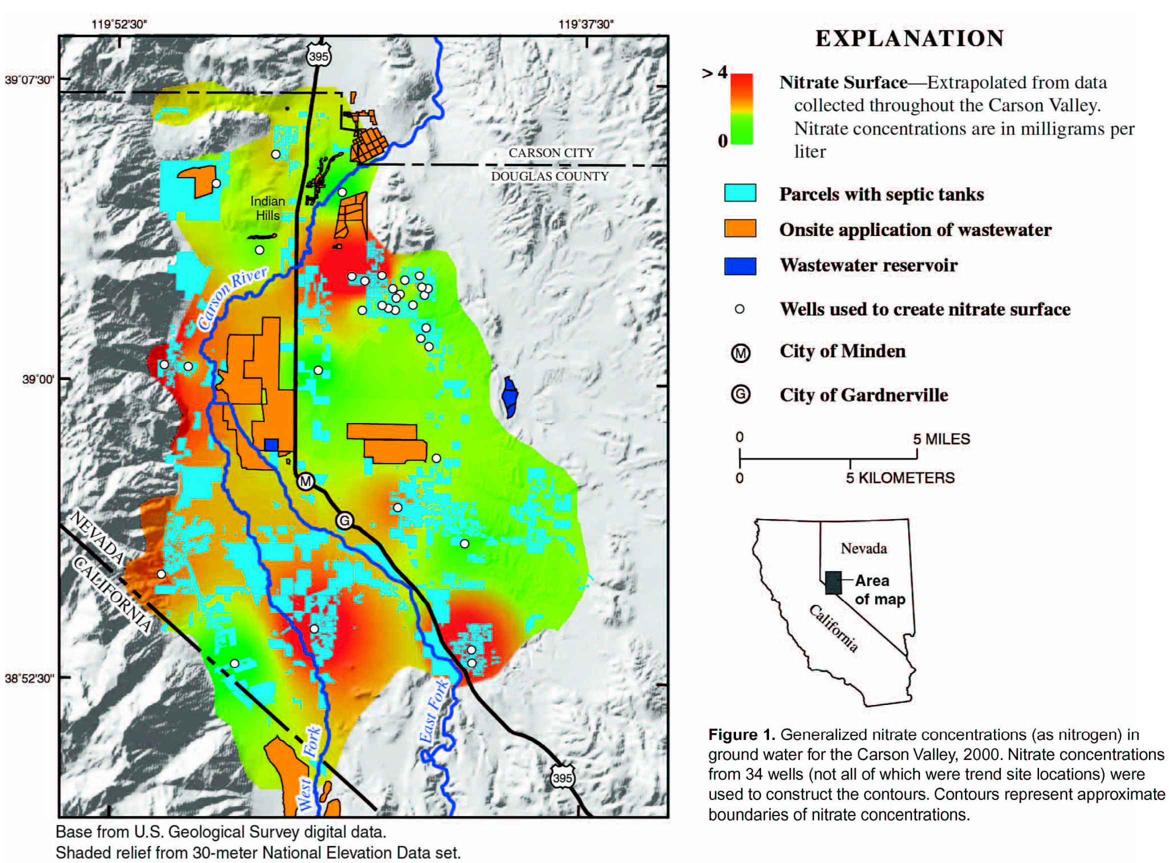


Figure 1. Generalized nitrate concentrations (as nitrogen) in ground water for the Carson Valley, 2000. Nitrate concentrations from 34 wells (not all of which were trend site locations) were used to construct the contours. Contours represent approximate boundaries of nitrate concentrations.

Figure 21. Nitrate Levels in Groundwater for Carson Valley, 2000 (Rosen, 2003)

Brunswick Reservoir Seep

Carson City utilizes Brunswick Reservoir to store treated effluent for later irrigation reuse. However, the reservoir is on top of fractured bedrock allowing seepage. It is estimated that an average of approximately 2,000 acre-feet per year seeps from the reservoir to the Carson River (BHC Consultants, 2006) from 2 major seep areas, one is located about 0.5 miles west of the reservoir and the other enters the river about 0.7 miles to the north of the reservoir. The seep to the west of the reservoir is by far the largest averaging about 1.9 cfs (2004-2006), and the other seep averaging about 0.4 cfs (2004-2006). However the combined flow from these 2 areas was found to vary considerably during 2004-2006, from a low of 0.4 cfs to a high of 6.7 cfs.

Data collected by Carson City demonstrates that some nutrient removal is occurring from the time the effluent enters Brunswick Reservoir to when the effluent seeps to the Carson River. The treatment plant effluent typically has total nitrogen and total phosphorus levels of about 27 mg/l and about 6 mg/l, respectively (Harper, 2006). TN and TP levels in the seeps average about 1.8 mg/l and about 0.04 mg/l, respectively. Further work would be needed to understand the causes of these reductions.

Most of the time, the seep flow is small in comparison to the Carson River flow and the nutrient loads coming from the seeps are largely diluted by the river water. However during extreme low flow periods (such as occurred in 1994, 2001, 2007 for example), the seep has been the only flow in this part of the river. As discussed above, elevated algae levels were observed in the Carson River both upstream and downstream of the main seep during the summer of 2007. It is uncertain the extent to which the seep water contributed to the elevated algae levels in the river below the main seep. Later that summer when the river went dry upstream, high algae levels continued through late summer 2007 due to the seep water. However, it is believed to be more beneficial to the ecosystem to have "wet" water, with elevated algae levels, than to have no water at all.

Diel Fluctuations in Nutrient Concentrations

As discussed in **Major Past Studies**, Latham's (2006) modeling efforts suggest that nitrate levels within his study reach experienced a diel fluctuation in concentrations, ranging from near zero (during peak photosynthesis) to 0.2 mg/l (at night) at one location. While no data have yet to be collected to confirm this fluctuation, other studies have measured diel nitrate fluctuations in other systems. In a northern California stream, Nolan et al. (1995) found nitrate levels fluctuating from about 0.028 mg/l in the afternoon to 0.042 mg/l in the evening. In an effluent dominated concrete lined stream, Kent et al. (2005) measured total nitrogen levels fluctuating from about 3 mg/l (as N) during the daytime to up to 8 mg/l at night. For fifth order streams in Oregon, Gregory (1979) found a greater than 80% decrease in nitrate levels from midnight to midday. These studies suggest that mid-day samples may under predict available nutrients in streams.

Review of Nutrient and Dissolved Oxygen Standards

As discussed earlier, the Carson River section of the NAC contains TP standards (0.1 mg/l, annual average) for the control of nuisance plants/algae based upon 20-year old EPA guidance. It must be noted that the EPA guidance in question recommended 0.1 mg/l as a single value. For reasons unknown, the State adopted this value as an annual average. It is believed that an annual average value is likely not protective of aquatic life uses within the stream. Of more interest is the phosphorus levels during the peak algal growing season (summer). Future revisions of the phosphorus standards should include single value criteria, with consideration given to the summer when most of the algal biomass generally occurs. Also, it may be more appropriate focus on dissolved forms of P which are believed to be more bioavailable.

Though annual average TP standard may not be appropriate to protect the river, it may be important for protection of Lahontan Reservoir. According to federal regulations, downstream waters need to be considered when establishing upstream standards:

> 40 CFR 131.10(b) – In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters.

Much more work is needed to determine more appropriate river nutrient levels needed to protect Lahontan Reservoir.

Currently, the nitrate beneficial use standard (10 mg/l) is set for the protection of drinking water use, not for aquatic life protection. Much lower levels are thought to be needed for the control of excess algal biomass. Future regulation revisions need to be set while considering nitrates as a nutrient. Unfortunately, significant resources would need to be expended to better define appropriate nitrate limits.

As stated earlier, nutrient impairment needs to be determined using a multiple line-of-evidence approach, considering (at a minimum) nutrient levels, algae levels and dissolved oxygen concentrations. Therefore the future nutrient criteria should include a suite of values for these factors. This idea is supported by a recent EPA memorandum (Grumbles, 2007) which states that nutrient criteria should address causal (nitrogen and phosphorus) and response (chlorophyll-a, transparency) variables to be effective. Until more appropriate nutrient criteria are developed, NDEP plans on relying on the multiple line-of-evidence approach when determining nutrient impairment.

Currently, the DO standards for the main forks and the Carson River above Mexican Gage are seasonally variable set at 5 mg/l during the late spring, summer and early fall, and at 6 mg/l for the remainder of the year. The rest of the river below Mexican Gage has a year-round DO standard of 5 mg/l. According to the NDEP Standards Revision Rationale (1984), these values were based upon EPA guidance (1976) available at the time. The Rationale goes on to state that the 6 mg/l value "…is intended to assure sufficient intragravel DO for protection of incubating salmonid eggs and fry." Since that time, EPA has issued somewhat different DO recommendations than that in previous guidance documents (Table 5). Of particular interest is the high minimum DO (8.0) needed to maintain an acceptable intergravel level (5.0) for early life stages of trout in coldwater systems.

Table 5. EPA Guidance – Dissolved Oxygen Concentrations (1986)

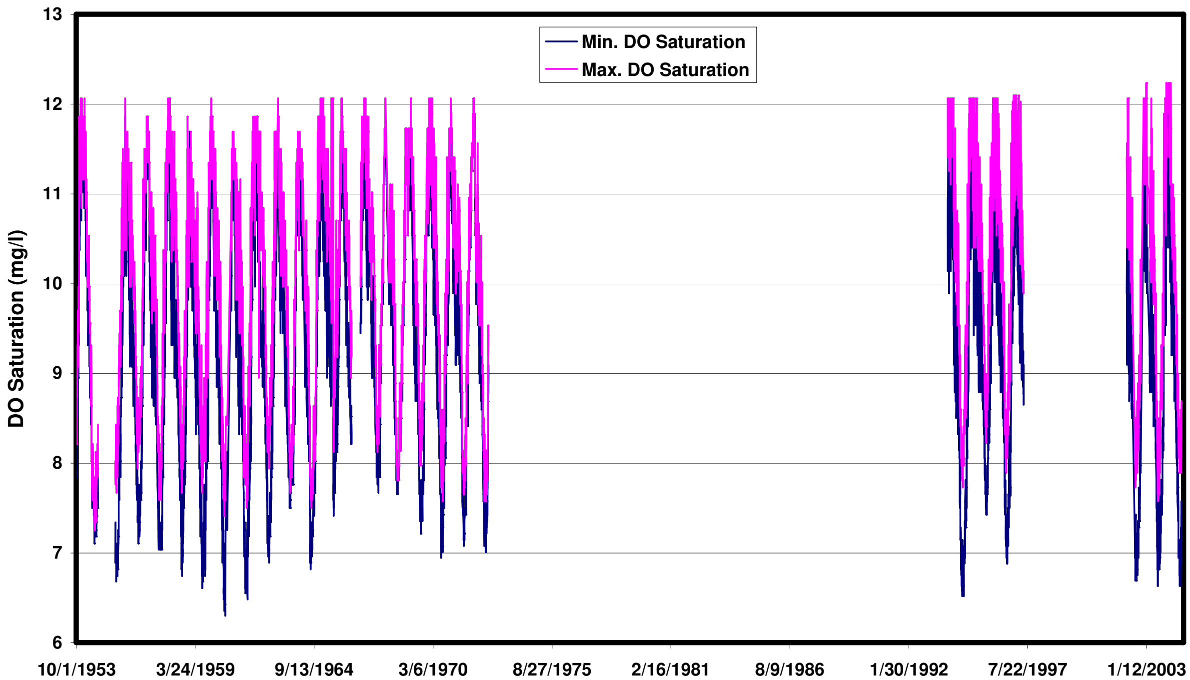
Metric	Coldwater Criteria		Warmwater Criteria	
	Early Life Stages[1,2]	Other Life Stages	Early Life Stages	Other Life Stages
30-day Mean		6.5		5.5
7-day Mean	9.5 (6.5)		6.0	
7-day Mean Minimum		5.0		4.0
1-day Minimum	8.0 (5.0)	4.0	5.0	3.0

[1] These are water column concentrations recommended to achieve the required intergravel dissolved oxygen concentrations shown in parentheses. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.
[2] Includes all embryonic and larval stages and all juvenile forms to 30-days following hatching.

Achieving minimum DO levels above 8.0 mg/l in the coldwater portion Carson River and its forks (upstream of Deer Run Road) may not be realistic especially in the lower stretches. Without the influence of biological processes, stream dissolved oxygen levels would tend to follow the DO saturation levels, which are affected by water temperature and elevation[4]. A plot (Figure 22) of the minimum and maximum DO saturation levels at Site EF-1 (USGS Sta. 10309000) based upon maximum and minimum water temperatures shows that DO saturation levels below the 8 mg/l threshold are common during the summer (July through September). When the influence of algal activity are overlaid on the DO saturation levels in Figure 22, the mid-afternoon DO levels will be higher due to photosynthesis and the early morning DO levels will be lower due to respiration. In the lower reaches of the Carson coldwater system, stream temperatures are even higher resulting in even lower DO saturation levels, and lower early morning DO levels. It does not appear realistic to adopt the 8 mg/l 1-day minimum DO standard at this time. However, there may be value in incorporating some of the other values into the regulations.

[4] DO saturation levels decrease with increases in temperature and increases in elevation.

Figure 22. Minimum and Maximum DO Saturation Levels - USGS Sta. 10309000 - EF Carson River nr. Gardnerville



Conclusions and Recommendations

1. While much of the Carson River is included on Nevada's 303(d) List due exceedances of phosphorus standards, excess algae and depressed DO levels have only been identified in a few locations during average flows (West Fork at various locations; East Fork between Hwy 88 and Muller Lane; Brockliss Slough at Genoa Lane. During low flow periods, eutrophication problems typically become more prevalent. Additional sampling/monitoring may be appropriate to determine nutrient impairment status on the river between Dayton and Lahontan Reservoir, depending upon resources and agency priorities.

2. Very excessive algae have been observed every year on the East Fork Carson between Highway 88 and Muller. Additional work should be done to understand the source of this problem.

3. Until more appropriate nutrient criteria can be incorporated into the regulations, NDEP should utilize a multiple line-of-evidence approach (including nutrients, algae biomass, and dissolved oxygen) when assessing nutrient impairment conditions. As always, flow needs to be considered when examining impairment status. It is recommended that the current DO standards be retained at this time.

4. The existing nitrate standard (10 mg/l) needs to be lowered to a value more applicable to the Carson River. This current standard has led potential dischargers (to surface and nearby groundwater) and others believe that effluent nitrate levels of 10 mg/l are acceptable. Even the current Total Nitrogen RMHQs may be too high to adequately control eutrophication problems in the system. However at this time, there may not be insufficient data upon which to set a more appropriate nitrate standard.

5. Additional water quality and algae sampling is needed throughout the river in order to better quantify biomass and species (such as cyanobacteria), and improve our understanding of the nutrient-algae dynamics. A better understanding of the occurrence of cyanobacteria may be valuable in the future. Efforts to reduce nitrogen contributions to the river could promote cyanobacteria growth.
    a. As part of this effort, diel sampling should take place to characterize the fluctuations of nutrients over a 24-hour period.

6. Sand has been identified as the dominant substrate material for the Carson River within the lower Carson Valley. As such, these sandy conditions may be limiting the ability for algae to grow. If future restoration efforts improve substrate conditions (larger material such as gravel, cobble, etc.) in this reach, increased algae growth may be an unintended consequence. Additional investigations should be undertaken to determine the algal growth potential in this reach of the Carson River prior to significant restoration activities that lead to increased substrate size. However given the upstream sediment load, it may not be realistic to achieve a gravel/cobble substrate in this stretch of the Carson River.
7. More work is needed to better characterize ground discharge to the river, along with the associated nutrient loads, and the source of these loads.

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