Water Quality Along the Middle Rio Grande of New Mexico
Final Technical Report for New Mexico Water Resources Research Institute

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Research Summary:

The Middle Rio Grande valley in New Mexico supports the largest and fastest-growing center of population in the state. Over the past century, the river has been highly modified to accommodate downstream water delivery requirements and to protect inhabitants of the valley from flood danger. Dams and reservoirs, jetty jacks, levees and other physical alterations of the river channel change the seasonality and variability of river flow (hydrograph) from the historic pattern, which in turn causes shifts in habitat availability and life history timing of aquatic and riparian organisms (Molles et al., 1998). Associated decreases in groundwater levels may encourage the survival of non-native over native riparian plants (Dahm et al., 2002). Also, the potential deficit of water in the alluvial aquifer for human consumption has prompted the City of Albuquerque to reserve a volume of surface water, delivered by the Rio Grande through the San Juan-Chama diversion, for treatment and distribution as city drinking water. Water quality in modified rivers can be negatively affected by both physical alteration, i.e. decreases in the biological complexity needed to remove excess nutrients, and by urbanization, i.e. increases in nutrient delivery to the river via impervious surface runoff and/or wastewater effluent (Paul and Meyer, 2001). This research was initiated to monitor water quality along the Middle Rio Grande of New Mexico and identify sources and sinks of nutrients to the river.

The study reach stretches approximately 300 km from the Otowi gauge, above Cochiti Dam, to the uppermost extent of Elephant Butte Reservoir. Surface water samples were collected from all significant tributaries to the Rio Grande and from the main channel at a well-mixed point below each tributary (Figure 1, sample sites). These samples were analyzed for temperature, pH, salinity (as specific conductivity), concentrations of dissolved oxygen, major cations and anions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, Br^-, SO_4^{2-}), dissolved organic carbon (DOC), the inorganic nitrogen (N) species ammonium (NH4-N) and nitrate (NO3-N), total dissolved phosphorus as phosphate (PO4-P), dissolved inorganic carbon (DIC), and chlorophyll-a. This sampling occurred quarterly, with associated data collected on monthly and hourly time scales (see "Related Projects" section). Discharge values were obtained from the U. S. Geological Survey gauges located along the reach. Data presented in this report are from the August 2005 and February 2006 sampling periods, and this report will focus on specific water quality parameters: salinity (as specific conductivity) and nutrients (DOC, NO3-N, and PO4-P).

River discharge is lower during the summer sampling period, and is strongly affected during this season by large depletions for agricultural irrigation, especially below the Isleta and San Acacia diversion dams (Figure 2). Surface water salinity increases downstream (presumably due to evapoconcentration), more markedly during summer, with highly saline tributary inputs apparent within the urban reaches and at the range of sampling sites from river kilometer 160-180 (Figure 3). Nutrient (DOC, NO3-N and PO4-P) loads carried by the river reach similar maximum magnitudes during the winter (Figure 4) and summer (Figure 5) seasons. The amount of DOC in surface water is relatively stable throughout the reach during both seasons, but the loads of nitrate and phosphate differ spatially and temporally. Along the reach, NO3-N and PO4-P loads increase below three point sources: the wastewater treatment outflows at Bernalillo, Rio Rancho and Albuquerque. These loads decrease during both seasons below the San Acacia diversion dam, which is due to the large decrease in discharge in the river channel below that point. Finally, during the summer sampling period, nitrate and phosphate carried by the river decreases below the point source inputs, whereas during the winter these nutrients are exported downstream. Ammonium loads showed a similar pattern to nitrate and phosphate but are not reported due to many samples containing concentrations below the detectable limit.

Three temporal and spatial patterns of water quality are apparent in these results: a relatively invariant distribution of DOC load, a moderately variable distribution of salinity, and a highly variable distribution of N and P load. DOC load in the Middle Rio Grande appears relatively unaffected by urbanization and channel modification. Maximum DOC concentrations in this reach are approximately 3 mg/L during the summer and 4 mg/L during the winter, low in comparison to other modified rivers in more mesic regions. High-salinity inputs in the urban reach correspond with wastewater outflows; the tributaries that may significantly affect river salinity, though, are located at the boundary between the Albuquerque and Socorro physiographic provinces where highly saline, deep groundwater connectivity may be important in explaining salinity levels (Mills, 2004). Overall, surface water salinity in the Middle Rio Grande seems to be primarily affected by natural processes of evapoconcentration and groundwater input. Nitrate and phosphate loads in the river appear significantly augmented by effluent from wastewater treatment facilities in the urban reach of the Middle Rio Grande. The downstream decrease in these nutrients during the summer months could be due to in-channel retention (Haggard et al., 2005) or terrestrial uptake during the diversion of water for irrigation (Oelsner et al., 2007). In-channel retention is more likely during the summer than winter/spring because 1) lower discharge brings a higher volume of water in contact with littoral macrophytes and benthos for increased amounts of time, 2) increases in the effectiveness of the nutrient supply for biological uptake and processing, and 3) higher temperatures prompt higher biological uptake rates. The retention of nutrients in the terrestrial (agricultural) portion of the river floodplain due to irrigation diversions from the river is also possible. For example, river water entering the irrigation canal system can carry nutrient concentrations as high as ~1.65 mg/L NO3-N at Isleta in September 2005, while concentrations of nitrate, ammonium, and phosphate re-entering the river from these tributary return flows are consistently low (Figure 6).

Results from this project suggest that urbanization provides the most significant inputs of nutrients that affect Middle Rio Grande water quality, specifically in the form of treated effluent. If the seasonal patterns seen here hold from year to year, potential mediation of these inputs within the river channel and irrigation systems will be highest during the low-flow summer months and lowest during the high-flow winter/spring months. Delivery of low quality, high nutrient water to Elephant Butte Reservoir will be highest during colder, high-flow periods of time.

References Cited:

Dahm, C.N., Cleverly, J.R., Coonrod, J.A.A., Thibault, J.R., McDonnell, D.E., and Gilroy, D.J. (2002) Evapotranspiration at the land/water interface in a semi-arid drainage basin. *Freshwater Biology* **47**: 831-843.

Haggard, B.E., Stanley, E.H., and Storm, D.E. (2005) Nutrient retention in a point-source-enriched stream. *Journal of the North American Benthological Society* **24**: 29-47.

Mills, S. (2004) Quantifying salinization of the Rio Grande using environmental tracers. M.S. Thesis, Department of Earth and Environmental Science. Socorro, NM: New Mexico Tech.

Molles, M.C.J., Crawford, C.S., Ellis, L.M., Valett, H.M., and Dahm, C.N. (1998) Managed flooding for riparian ecosystem restoration. *BioScience* **48**: 749-756.

Oelsner, G.P., Brooks, P.D., and Hogan, J.F. (2007) Nitrogen sources and sinks in the Middle Rio Grande, NM. *Journal of the American Water Resources Association* **in press**.

Paul, M.J., and Meyer, J.L. (2001) Streams in the Urban Landscape. *Annual Review of Ecology and Systematics* **32**: 333-365.

Related projects:
Long-term data collection using this sampling approach, and with the addition of sampling on different scales (monthly main-stem and tributary sampling, and continuous sampling of DO, temperature, pH, conductivity and turbidity with a data SONDE at four points within the urban reach) was recently provided to Dr. Cliff Dahm and is implemented by Ph.D. student David Van Horn. Data is available at http://sev.lternet.edu/data/search/riogrande/index.php.

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Figure 1. Sampling points along the Middle Rio Grande (MRG) used in this study.

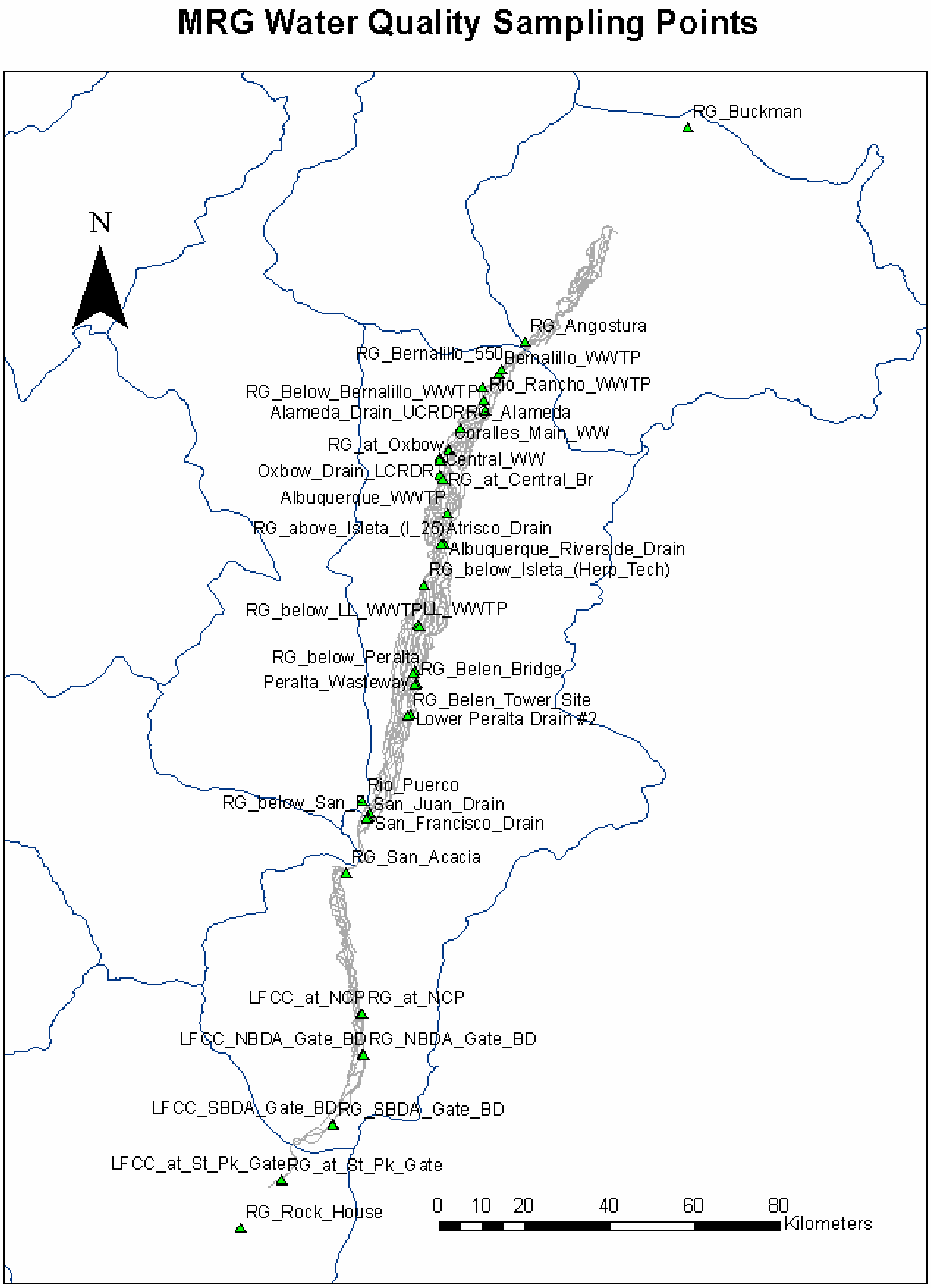
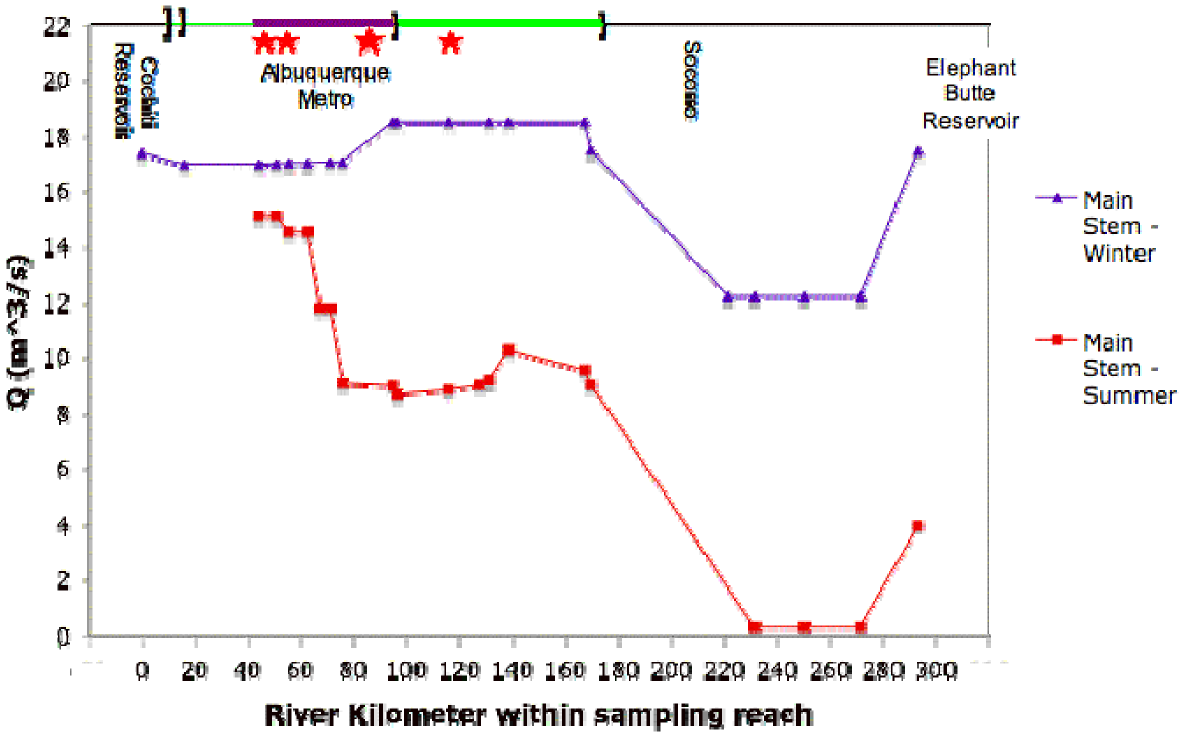


Figure 2. Discharge, in m^3 s^{-1}, from USGS gauges through the Rio Grande sampling reach in August 2005 and February 2006. Location reference along top of figure: brackets represent dams/diversions (from left = upstream: Cochiti, Angostura, Isleta and San Acacia), the purple bar represents primarily urban and green primarily agricultural land use along the river, red stars represent locations of wastewater treatment outflows directly into the Rio Grande.



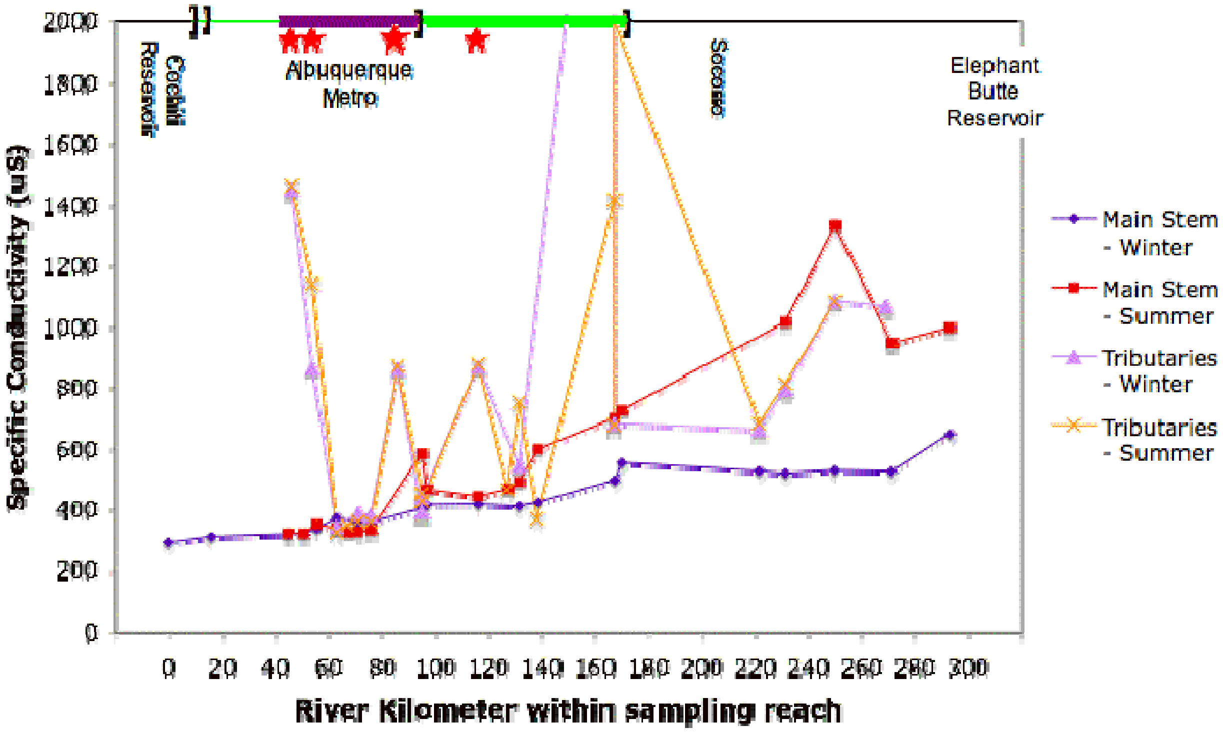


Figure 3. Salinity as specific conductivity, in µS, for both Rio Grande main channel and tributaries through the sampling reach in August 2005 and February 2006. Location reference along top of figure: brackets represent dams/diversions (from left = upstream: Cochiti, Angostura, Isleta and San Acacia), the purple bar represents primarily urban and green primarily agricultural land use along the river, red stars represent locations of wastewater treatment outflows directly into the Rio Grande.

Figure 4. Nutrient load, in g s^{-1}, of nitrate (NO3-N), phosphate (PO4-P) and dissolved organic carbon (DOC) through the Rio Grande sampling reach in February 2006. Location reference along top of figure: brackets represent dams/diversions (from left = upstream: Cochiti, Angostura, Isleta and San Acacia), the purple bar represents primarily urban and green primarily agricultural land use along the river, red stars represent locations of wastewater treatment outflows directly into the Rio Grande.

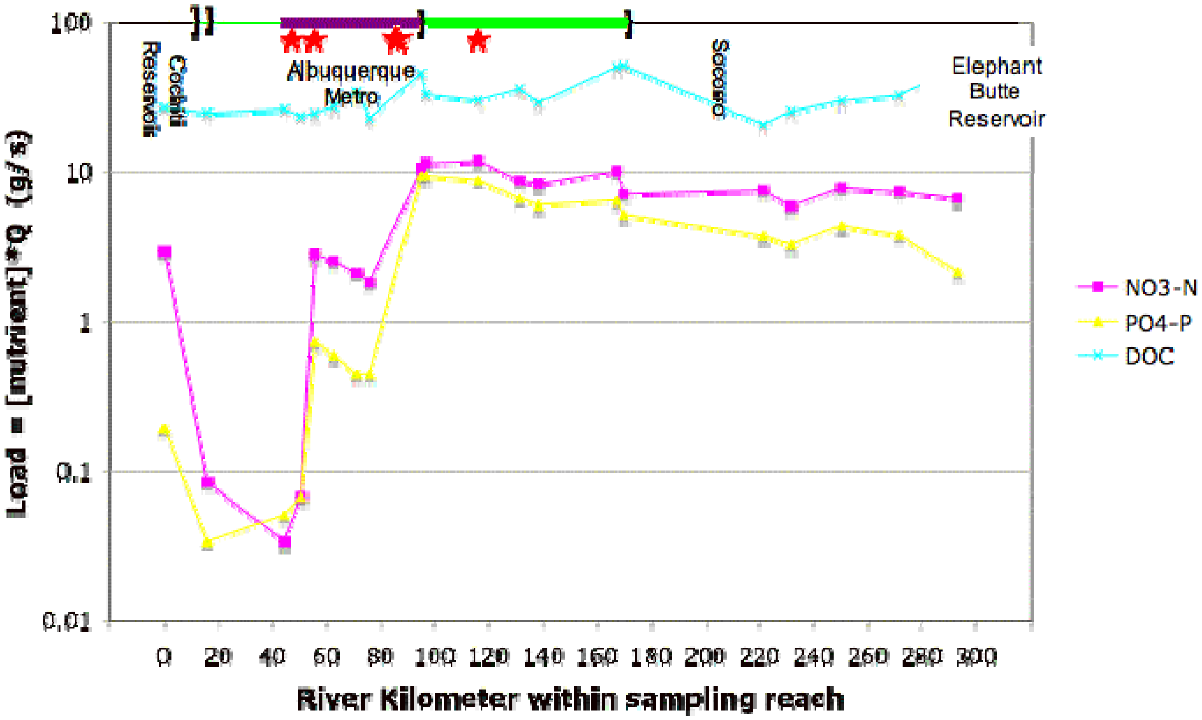


Figure 5. Nutrient load, in g s^{-1}, of nitrate (NO3-N), phosphate (PO4-P) and dissolved organic carbon (DOC) through the Rio Grande sampling reach in August 2005. Location reference along top of figure: brackets represent dams/diversions (from left = upstream: Cochiti, Angostura, Isleta and San Acacia), the purple bar represents primarily urban and green primarily agricultural land use along the river, red stars represent locations of wastewater treatment outflows directly into the Rio Grande.

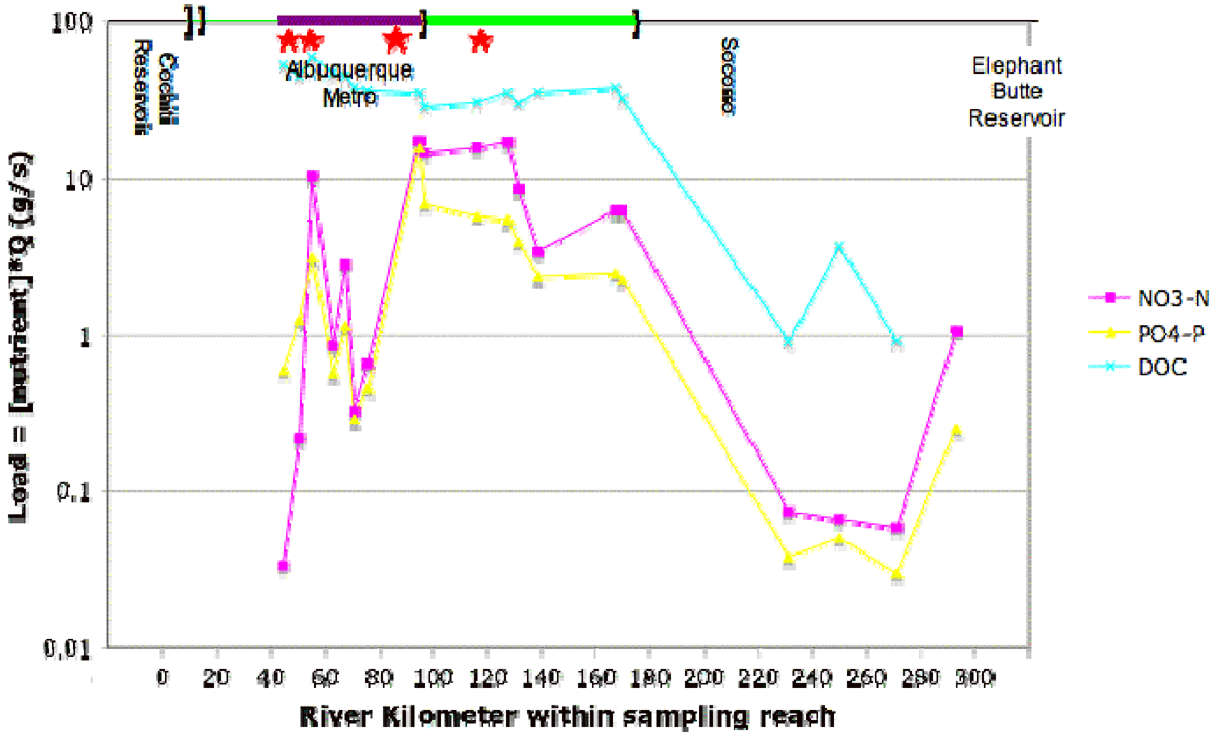


Figure 6. Box plots of all data from inputs for both seasons from Rio Grande tributaries of different land use type: AG=agricultural, URB=urban, WTP=wastewater treatment plant effluent. Conductivity is shown in μS; DOC, NO3-N and PO4-P in mg/L, NH4-N in μg/L. Mean agricultural tributary input concentrations of NO3-N and PO4-P are 0.66 and 0.26 mg/L, respectively.