Water Quality in the Middle Rio Grande
Rio Grande Seminar, May 2nd, 2008

David Van Horn, Graduate Student, Biology Department, University of New Mexico
Outline

• Introduction – who wants this data

• Monthly Synoptic Sampling:
  – Methods
  – Nutrients in the Middle Rio Grande (MRG)
  – Salts in the MRG

• Continuous Monitoring:
  – Methods / site selection
  – Results
URGWOM Program Interests

- Upper Rio Grande Water Operations Model
- Based on RiverWare modeling software
- This software can be used to model:
  - Water balance budgeting for reservoirs
  - River Reach Routing
  - Diversions
  - Water Quality
Collaborative Program Interests

• How does water quality in the MRG impact the RGS Minnow?

• Parameters of Interest Include: temperature, dissolved oxygen, conductivity, turbidity, dissolved salts, nutrients, pesticides and toxic chemicals.

• How do these parameters vary spatially and temporally?

• Relative contribution of point versus non-point sources?
Academic Interests

• LINX I and LINX II identified the MRG river network as unique – it violated all of the assumptions of a nitrogen removal model based on the river network.

• How does this unique network structure impact nutrient cycling?
Research Questions

• What are the sources and sinks of nutrients to the MRG and how do these vary spatially and temporally?

• Are these nutrient sources/sinks similar to those found in other systems?

• What are the major sources of dissolved salts to the MRG and how do these sources vary spatially and temporally?

• How do episodic events impact water quality in the MRG?
Synoptic Sampling Methods

- Collect water samples from approx. 30 sites from above Cochiti to Elephant Butte.

- Samples collected 29 times approximately monthly starting September 2005 during periods of stable flow.

- Mainstem samples on all dates.

- Tributary inputs on 15 dates.

- Samples analyzed for: pH, temp., cond, major nutrients, anions, cations, DOC, DIC.
Nutrients in the MRG

• Excess nutrients in river ecosystems affect in-stream conditions and downstream aquatic ecosystems in a variety of ways including:
  • Algal blooms – some of which are toxic
  • Simplification of aquatic communities
  • Oxygen sags and semi – permanent zones of hypoxia
## Nutrients in the MRG:

<table>
<thead>
<tr>
<th>Site</th>
<th>NO$_3$ Load</th>
<th>NO$_3$ Conc.</th>
<th>PO$_4$ Load</th>
<th>PO$_4$ Conc.</th>
<th>NH$_4$ Load</th>
<th>NH$_4$ Conc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Entering MRG</td>
<td>60.3</td>
<td>0.02</td>
<td>28.7</td>
<td>0.01</td>
<td>7.6</td>
<td>0.00</td>
</tr>
<tr>
<td>Bernalillo WWTP</td>
<td>1.7</td>
<td>0.71</td>
<td>2.7</td>
<td>1.00</td>
<td>29.2</td>
<td>10.65</td>
</tr>
<tr>
<td>Albuquerque WWTP</td>
<td>915.6</td>
<td>4.49</td>
<td>601.5</td>
<td>2.95</td>
<td>73.6</td>
<td>0.36</td>
</tr>
<tr>
<td>Rio Rancho WWTP</td>
<td>126.6</td>
<td>10.23</td>
<td>37.9</td>
<td>3.09</td>
<td>2.2</td>
<td>0.16</td>
</tr>
<tr>
<td>Los Lunas WWTP</td>
<td>53.4</td>
<td>13.89</td>
<td>14.3</td>
<td>3.67</td>
<td>7.3</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Units: Loads – kg solute day$^{-1}$, Concentrations – mg l$^{-1}$
Nutrients in the MRG: Spatial and Temporal Variability - SRP
Nutrients in the MRG: Spatial and Temporal Variability – Nitrate
Nutrients in the MRG:

- **Diagram 1:**
  - Title: Percent Nitrate Removed vs. Percent Water Diverted
  - Equation: $R^2 = 0.798$
  - Description: A positive correlation between percent nitrate removed and percent water diverted.

- **Diagram 2:**
  - Title: Percent Nitrate Removed vs. Percent Water Remaining
  - Equation: $R^2 = 0.717$
  - Description: A negative correlation between percent nitrate removed and percent water remaining.
Nutrients in the MRG:

- Percent SRP Removed vs. Percent Water Diverted ($R^2 = 0.717$)
- Percent SRP Removed vs. Percent Water Remaining ($R^2 = 0.901$)
Nutrients in the MRG:

- Nitrate Removed Within River
- Nitrate Removed/Added by Agricultural System

Percentage of Nitrate Load Removed/Added

Sampling Month


Nitrate Load Removed: 0-120%
Nitrate Load Added: 0-120%
Nutrients in the MRG:

![Bar chart showing the percentage of SRP load removed or added by different months and systems.](image-url)
Nutrients in the MRG:

• 250 km² of cropland are irrigated in the MRG each month during the irrigation season – most of which do not require intensive fertilization.

• Flood irrigation conditions may promote nutrient removal.

• The network of irrigation ditches and drains contains ~ 2,100 km of channel, approximately 7 times the length of the MRG – small streams effectively process nutrients.
Nutrients in the MRG:

![Graph showing the relationship between nitrate-N export and population density in various river systems. The x-axis represents population density (people km\(^{-2}\)) on a logarithmic scale, ranging from 0.1 to 1000, and the y-axis represents nitrate-N export (kg N km\(^{-2}\) year\(^{-1}\)) also on a logarithmic scale, ranging from 0.1 to 1000. The graph includes data points for Yukon, Mississippi, Rhine, Murray-Darling, Nile, Orange, Zambezi, and Rio Grande. Each river system is represented by a different marker, and the data points show a trend of increasing nitrate-N export with increasing population density.](image-url)
Model of Nutrient Retention in the MRG:

- Model Includes:
  - Mean monthly diversions
  - Mean river Q for historically wet, dry, and average flow years
  - Nutrient loading data

- Model was run under several scenarios including:
  - Present conditions
  - Albuquerque metropolitan area uses ~ 4.25 m³/sec of treated river water
  - A 25% population increase
  - A minimum river flow requirement of 8.5 m³/sec
Model of Nutrient Retention in the MRG:

Current Conditions
Current Nut. Loading Minus 4.25 m3/sec
25% Population Increase
8.5 m3/sec Minimum Flow Requirement
Model of Nutrient Retention in the MRG:

- Current Conditions
- Current Nut. Loading Minus 4.25 m3/sec
- 25% Population Increase
- 8.5 m3/sec Minimum Flow Requirement
Nutrients in the MRG: Model Summary

- Under current conditions ~ 125 and 50 metric tons or nitrate and SRP respectively are exported from the MRG.

- If the Abq Metro area drew all of its water from the MRG, export of nitrate and SRP from the MRG would decline.

- A 25% population increase in the Abq Metro area that depended entirely on MRG water for municipal use would return export levels to current conditions.

- A minimum instream flow requirement of 8.5 m³/sec would dramatically increase downstream delivery of nitrate and SRP.
Nutrients in the MRG: Summary

• NO$_3^-$, NH$_4^+$, and SRP are added to the MRG primarily by WWTPs.

• During months with minimal diversion the flux of NO$_3^-$ and SRP from the MRG to downstream systems is ~ 50% of inputs.

• During months with significant diversions the delivery of NO$_3^-$ and SRP from the MRG to downstream systems is ~ 5% of inputs.

• There is a strong positive relationship between the water removed from the system for irrigation and the nitrate and SRP removed from the system.

• In stream removal of nitrate and SRP is relatively constant while removal by the agricultural system varies.

• Similar patterns are seen in other arid land rivers where significant portions of flow are diverted for irrigation.
Dissolved Salts in the MRG

- Salinization can impact aquatic ecosystems and the humans that depend on them in several ways including:
  - Direct toxicity for aquatic organisms
  - Shifts in community structure
  - Water potability for human consumption and use for irrigation
Salts in the MRG: Spatial and Temporal Variability – Specific Conductance

Specific Conductance (μS), May 2007

Specific Conductance (μS), June 2007

Discharge (cfs)
## Salts in the MRG

<table>
<thead>
<tr>
<th>Site</th>
<th>Na Ratio</th>
<th>K Ratio</th>
<th>Mg Ratio</th>
<th>Ca Ratio</th>
<th>SO$_4$ Ratio</th>
<th>Br Ratio</th>
<th>Cl Ratio</th>
<th>Cl/Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG Angostura</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Rio Rancho WWTP</td>
<td>9.0</td>
<td>9.3</td>
<td>0.7</td>
<td>1.0</td>
<td>2.2</td>
<td>7.0</td>
<td>21.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Albuquerque WWTP</td>
<td>5.4</td>
<td>7.0</td>
<td>1.1</td>
<td>1.1</td>
<td>2.0</td>
<td>11.1</td>
<td>14.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Abq Rvsd Drn</td>
<td>1.8</td>
<td>1.7</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
<td>3.2</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Atrisco Drn</td>
<td>1.6</td>
<td>1.4</td>
<td>1.2</td>
<td>1.3</td>
<td>1.6</td>
<td>2.4</td>
<td>2.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Lower SJ Drn</td>
<td>3.0</td>
<td>2.0</td>
<td>1.8</td>
<td>1.7</td>
<td>2.6</td>
<td>4.9</td>
<td>5.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Rio Puerco</td>
<td>24.7</td>
<td>3.2</td>
<td>7.6</td>
<td>5.3</td>
<td>20.7</td>
<td>28.7</td>
<td>57.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Elmendorf Drn</td>
<td>6.7</td>
<td>2.5</td>
<td>2.8</td>
<td>2.2</td>
<td>3.3</td>
<td>6.9</td>
<td>13.7</td>
<td>2.0</td>
</tr>
<tr>
<td>LFCC at State Park</td>
<td>6.7</td>
<td>2.4</td>
<td>2.4</td>
<td>2.1</td>
<td>3.0</td>
<td>7.2</td>
<td>12.0</td>
<td>1.7</td>
</tr>
<tr>
<td>RG at Rock House</td>
<td>4.7</td>
<td>2.1</td>
<td>1.9</td>
<td>1.8</td>
<td>2.8</td>
<td>5.4</td>
<td>8.9</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Salts in the MRG: Spatial and Temporal Variability - Chloride

**Graphs:**

1. Chloride Concentration (mg/l), May 2007
   - Concentration vs. River Kilometer
   - Discharge vs. River Kilometer

2. Chloride Concentration (mg/l), June 2007
   - Concentration vs. River Kilometer
   - Discharge vs. River Kilometer
Salts in the MRG: Spatial and Temporal Variability - Sulfate

Sulfate Concentration vs. River Kilometer for May 2007

Sulfate Concentration vs. River Kilometer for June 2007

Discharge (cfs) vs. River Kilometer

Sulfate Concentration (mg/l), May 2007

Sulfate Concentration (mg/l), June 2007
Salts in the MRG: Spatial and Temporal Variability - Sodium

Graph shows the Sodium Concentration (mg/l) versus Discharge (cfs) for two different months: May 2007 and June 2007. The graphs illustrate the variability in sodium concentration along the river, with markers indicating different points of interest such as WTP and Dm locations.
Salts in the MRG: Spatial and Temporal Variability - Potassium

- May 2007
  - Potassium Concentration vs. Discharge
  - Discharge (cfs)
  - Potassium Concentration (mg/l)

- June 2007
  - Potassium Concentration vs. Discharge
  - Discharge (cfs)
  - Potassium Concentration (mg/l)
Salts in the MRG: Spatial and Temporal Variability - Magnesium

![Graph showing magnesium concentration and discharge over river kilometers in May and June 2007.](graph.png)

- **Magnesium Conc:** May 2007
- **Magnesium Conc:** June 2007
- **Discharge (cfs)**

River Kilometer:
- Bern WWTP
- Rio R. WWTP
- Axt WWTP
- Axt/Abt Dm
- Los L. WWTP
- Lwr Perf Dm 1
- Lwr Si Dm
- Rio Puerco/Salado
- Low F CC

**Notes:**
- The graphs illustrate the spatial and temporal variability of magnesium concentrations and discharge along the river.
- May 2007 data shows a relatively stable magnesium concentration with slight variations along the river.
- June 2007 data indicates a slight increase in magnesium concentration, especially in the middle river kilometers.

**Legend:**
- Red dots represent magnesium concentration.
- Black dots represent discharge.

**Scale:**
- Magnesium Conc. (mg/l):
  - May 2007: 6 to 12 mg/l
  - June 2007: 6 to 20 mg/l
- Discharge (cfs):
  - May 2007: -500 to 3500 cfs
  - June 2007: 0 to 3500 cfs

**Conclusion:**
- Magnesium concentrations show variation along the river, with potentially greater concentrations in June 2007 compared to May 2007.
- Discharge patterns also vary, with some segments showing increased discharge in June.
Salts in the MRG: Summary

• Salinity increases in the downstream direction during all months.

• The various types of inputs to the river have distinct ion signatures.

• WWTPs contain high concentrations of Na, K, Br and Cl.

• Irrigation return flows are elevated in Br and Cl.

• Saline tributary inputs contain high levels of all ions except K.
Continuous Monitoring in the MRG

- Four YSI 6920 sondes located in the Albuquerque reach of the MRG.


- Began collecting data in June 2006.

- Measure pH, conductivity, dissolved oxygen, temperature and turbidity at 15 minute intervals.
Continuous Monitoring in the MRG
Continuous Monitoring in the MRG

Rio Grande at the Bernalillo 550 Bridge, July 2007 through February 2008

Rio Grande at the Alameda Bridge, July 2007 through February 2008
Continuous Monitoring in the MRG
Continuous Monitoring in the MRG

Rio Grande at the Alameda Bridge, June 2006 through March 2008

$DO, \text{ mg/L}$

$\text{Temp., C}$
Episodic Events in the MRG

Discharge (cfs)

- Rio Grande Discharge
- NDvsn Channel Discharge

Dissolved Oxygen (mg/l)

Date/Time

29-Apr-07 00:00 30-Apr-07 12:00 02-May-07 00:00 03-May-07 12:00 05-May-07 00:00
Episodic Events in the MRG

**Discharge**
- Rio Grande Discharge
- N Dvsn Channel Discharge

**Dissolved Oxygen**

Date/ Time

05-Jul-07 12:00 07-Jul-07 00:00 08-Jul-07 12:00 10-Jul-07 00:00 11-Jul-07 12:00
Episodic Events in the MRG

Discharge
- Rio Grande Discharge
- NDvsn Channel Discharge

DO (mg/l)
- Dissolved Oxygen Alameda
- Dissolved Oxygen Rio Bravo

Date/ Time
Alameda Bridge and Rio Bravo Bridge DO Sags as a Function of Upstream Discharge

Size of DO Sag at the Downstream Sonde

Maximum of North Diversion Channel Discharge Peak, cfs
Episodic Events in the MRG: Summary

- Episodic events frequently increase turbidity in the MRG.

- Some events cause DO sags in the river – these events appear to be closely linked to discharge from the north diversion channel.

- A cursory investigation of the data shows a decreasing trend in primary production from the 550 bridge to the I-25 bridge.
Overall Summary

- Waste water treatment plants increase nutrient loads in the MRG by ~ 2000 %, however, agricultural irrigation removes most of these inputs during some months.

- Salinity in the MRG increases substantially by the end of the reach as a result of waste water, irrigation returns and natural inputs.

- Episodic events, particularly those associated with Abq., negatively impact water quality.
Acknowledgments

• Field/Lab Work: Nick Engquist, Evan Bussanich, Becky Engquist, Casey Seaman, Jen VanHorn

• Sample Analysis: John Craig, Mehdi Ali

• Funding: Mark Horner, Lesley McWhirter, Michael Fies – US Army Corps of Engineers, Cyndie Abeyta – US Fish and Wildlife Service, Sevilleta LTER

• Data Analysis and Management: Jen Tichy, Kristin Vanderbilt

• Discharge Data: USGS, MRGCD

• Site Selection: Lydia Zeglin, Chelsea Crenshaw