AQUIFER STORAGE AND RESTORATION PROJECT REVIEW

Glenn Dostal, Project Manager
Marty Stange, Hastings Utilities

Annual Forum of the Groundwater Protection Council
Orlando Florida – September 2016
01 Hastings Water System Overview
02 Modeling History
03 Water Quality Issues
04 ASR Components
05 Current Status
01

HASTINGS WATER SYSTEM OVERVIEW
OVERVIEW

- Wells pump directly into the Water Distribution System - no Treatment or Storage
- Regional Supply to Trumbull, Clay County SID #1, Hastings East Industrial Park and the Central Community College
- Possible Future Service due to Nitrates - Juniata, Glenvil, Inland, Schools and several rural subdivisions
02 MODELING HISTORY
GROUNDWATER MODELING UPDATE

- Initial Modeling – 1997 COHYST Model
- Groundwater Modeling - Updated in 2009
- Model updated by HDR Engineering – Current COHYST information was used to update the model
- Little Blue, Upper Big Blue NRD’s, Hastings’, and Adams County involved in development
- Good correlation between 1997 and 2009 results
REGIONAL GROUNDWATER FLOW

- Travel Time from Platte River – 50 years
- Estimated Time thru Vadose Zone – 30 – 50 years
20 YEAR TIME OF TRAVEL
REGIONAL GROUNDWATER RECHARGE

- Platter River provides approx. 50% of municipal well recharge
- Recharge from rain fall is approximately 25%
- Recharge from irrigation return is approximately 25%
- 50% of the recharge passes through the root zone

With the increased use of center pivots the amount of irrigation return is decreasing – critical to nitrate management
03 WATER QUALITY ISSUES
HASTINGS WATER ISSUES

- Nitrate, Uranium, Gross Alpha, Selenium, pH, Hardness and Inorganic Levels Increasing
- Atrazine Detected at low levels
- Several Wells Taken Off Line due to Nitrates
- Projection to have Insufficient Capacity in 2016 Without Additional Water Supplies or Blending
WATER SUPPLY CAPACITY PROJECTION

Median Nitrate Capacity Trend vs Max-day Demand

Typical Max-Day

Decrease in well pump capacity due to Median

Insufficient Capacity in 2016 without additional water supplies or
WATER SAMPLING

- **2010 Sampling**
  - 576 water samples collected for nitrates over 76 square mile area
  - 87.5% sampling of all known wells in the HWPA

- **2011 Sampling**
  - 200 water samples collected in an area exceeding 200 square miles
  - 42 samples analyzed for uranium

- **Results from 2010 and 2011**
  - 25% of samples exceeded nitrate up to 50 mg/l (MCL 10 mg/L) Uranium levels ranged from 1.2 to >200 µg/L (MCL 30 µg/L)

- **Currently resampling all 576 wells in 2015 / 2016**
  - 2015 results show some changes but not yet well defined
2011 Nitrate Sampling Plume

Groundwater Flow

All results in mg/l (PPM)
2015 Nitrate Sampling Plume

All results in mg/l (PPM)

New WHPA Boundary
NRD Divided Boundary
Groundwater Flow
2011/2015 Nitrate Change

-10
-10-2
-2-0
0-5
5-8
8-10
10-20

New WHPA Boundary
NRD Divided Boundary
Groundwater Flow

All results in mg/l (PPM)
Uranium 2012

Groundwater Flow

Uranium Concentrations in pp5 or ug/l
Uranium 2015

Groundwater Flow

Uranium Concentrations in pp5 or ug/l
2011/2015 Uranium Change

-20
-20 - -8
-8 - -2
-2 - 0
0 - 5
5 - 8
8 - 10
10 - 15
15 - 20
20 - 30

New WHPA Boundary
NRD Divided Boundary

Groundwater Flow

Uranium Concentrations in ppb or ug/l
VADOSE ZONE STUDY

UNL Vadose Zone Study – 2010 & 2016

- 2010 Vadose Zone sampling indicates 500 to 2000 lbs of Nitrogen per acre is located below the Root Zone and above the Aquifer – Future Contamination Source
- Isotope sampling indicates the source of Nitrates is Commercial Fertilizer – Anhydrous Ammonia
- 2016 Sampling – Define movement and time of travel to aquifer
ISOTOPE TESTING

18O vs 15N Sampling RY2010 Hastings WHP Area

• &15N Values Less Than +5 are due to Commercial

• Denitrification is not occurring

• &15N Values Greater Than +10 are due to Animal Wastes and/or Septic Tanks
## Pawnee Creek Sampling 7/10 - 7/11/98

### Isotope Ratio Analysis Summary - N15IRMS.002

<table>
<thead>
<tr>
<th>Date</th>
<th>Lab ID</th>
<th>$&amp;^{15}$N-NO$_3$</th>
<th>$&amp;^{15}$N-NH$_4$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/10/1998</td>
<td>071098-2</td>
<td>10.10</td>
<td></td>
<td>Indicates NO$_3$ is from Animal waste</td>
</tr>
<tr>
<td>7/10/1998</td>
<td>071098-6</td>
<td>17.30</td>
<td></td>
<td>Indicates NO$_3$ is from Animal waste</td>
</tr>
<tr>
<td>7/10/1998</td>
<td>071098-10</td>
<td>17.30</td>
<td></td>
<td>Indicates NO$_3$ is from Animal waste</td>
</tr>
<tr>
<td>7/12/1998</td>
<td>071298-1</td>
<td></td>
<td>9.81</td>
<td>Source of NH$_4$ may not be animal waste</td>
</tr>
<tr>
<td>7/12/1998</td>
<td>071298-2</td>
<td>21.20</td>
<td></td>
<td>Indicates NO$_3$ is from Animal waste</td>
</tr>
<tr>
<td>7/10/1998</td>
<td>071098-3</td>
<td></td>
<td>23.90</td>
<td>Indicates NH$_4$ is from Animal waste</td>
</tr>
<tr>
<td>7/10/1998</td>
<td>071098-7</td>
<td></td>
<td>23.10</td>
<td>Indicates NH$_4$ is from Animal waste</td>
</tr>
<tr>
<td>7/10/1998</td>
<td>071098-11</td>
<td></td>
<td>23.70</td>
<td>Indicates NH$_4$ is from Animal waste</td>
</tr>
<tr>
<td>7/11/1998</td>
<td>071198-2</td>
<td></td>
<td>24.70</td>
<td>Indicates NH$_4$ is from Animal waste</td>
</tr>
<tr>
<td>7/11/1998</td>
<td>071198-1</td>
<td></td>
<td>23.70</td>
<td>Indicates NO$_3$ is from Animal waste</td>
</tr>
</tbody>
</table>

Note: $\&^{15}$N values greater than 10 generally source of NO$_3$ and NH$_4$ is from animal waste
# MUNICIPAL WELL NITRATE ISOTOPE SAMPLING

## Nitrate Isotope Testing 08/01/2008

<table>
<thead>
<tr>
<th>Well #</th>
<th>NO3-N (mg/l)</th>
<th>N15N-NO3 (%)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>8.5</td>
<td>8.42</td>
<td>Indicates Commercial Fertilizer</td>
</tr>
<tr>
<td>28</td>
<td>3.1</td>
<td>5.69</td>
<td>Indicates Commercial Fertilizer</td>
</tr>
<tr>
<td>26</td>
<td>5.2</td>
<td>4.7</td>
<td>Indicates Commercial Fertilizer</td>
</tr>
<tr>
<td>16</td>
<td>7.0</td>
<td>5.88</td>
<td>Indicates Commercial Fertilizer</td>
</tr>
</tbody>
</table>

15N-NO3 Results of -5 to +5 indicate commercial fertilizer (NH4)  
15N-NO3 Results of +10 to +30 indicate animal wastes
NITRATE MANAGEMENT

- Nitrates are from both urban and rural use of fertilizer and moving through the vadose zone due to precipitation excess irrigation

- Nitrate and Water Management
  - Nitrate Management (Reduce wasting - 30%)
  - Water Conservation (Limit movement of N)

Best Management Practice must include both the proper use of Fertilizer and Irrigation. Overuse of irrigation drives the Nitrogen below the root zone thus requiring more fertilizer.
WELLHEAD MANAGEMENT AREA MAP

- Upper Big Blue NRD
- Little Blue NRD
- City of Hastings
NITRATE MANAGEMENT PLAN

Best Management Practice - Urban

- Training for all lawn care companies
- Training for all residential owners with more than 2 acres
- Promotes Soil Sampling – HU provides rebates
- Promotes rate and timing of fertilizer application
- Promotes Water Conservation (Limit movement of N)
URANIUM SOURCE

- Uranium is naturally occurring in the geologic formation
- Uranium is not normally mobile in the Hastings Area
- UNL Determined Uranium release correlated with nitrates
  - Chemical-Oxidation of Uranium
  - Microbial action
Several studies have been completed to address treatment and disposal of nitrates and uranium

Nitrate disposal via stream is a concern due to passing it on to neighbors and discharge limits on the stream

Uranium removal requires Hastings to be responsible for disposal and all future costs – Cradle to Grave Liability

Concentrate Disposal Study – 2008

Nitrate Treatment Evaluation – 2010

Uranium and Nitrate Management Plan - 2013
## CONVENTIONAL TREATMENT – EST. 2010

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>Project</th>
<th>Description</th>
<th>RO Only Treatment</th>
<th>IX Only Treatment</th>
<th>Annual O&amp;M Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2011</td>
<td>1a</td>
<td>Westbrook Water Treatment Plant Phase 1</td>
<td>$3,700,000</td>
<td>$3,700,000</td>
<td>$280,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1b</td>
<td>Westbrook Water Treatment Plant Phase 2</td>
<td>$1,700,000</td>
<td>$1,700,000</td>
<td>$280,000</td>
</tr>
<tr>
<td>2</td>
<td>2011-2014</td>
<td>2</td>
<td>Storage and Pump Station(^2) at Future North Baltimore WTP</td>
<td>$14,300,000</td>
<td>$14,300,000</td>
<td>$230,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Chemical Treatment Building(^3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Piping Network Phase 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2013-2018</td>
<td>5</td>
<td>Piping Network Phase 2 and 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>North Baltimore Water Treatment Plant Phase 1</td>
<td>$31,800,000</td>
<td>$23,800,000</td>
<td>$650,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Treatment Facility(^1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Evaporation Pond (2 Cells)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pipe to WPCC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2019-2025</td>
<td>7</td>
<td>North Baltimore Water Treatment Plant Phase 2</td>
<td>$18,300,000</td>
<td>$10,600,000</td>
<td>$650,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Treatment Facility(^1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Evaporation Pond (2 Cells)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pipe for Agricultural/Irrigation Blending</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2026-2030</td>
<td>8</td>
<td>Elevated Storage Tank at South Location</td>
<td>$2,500,000</td>
<td>$2,500,000</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Estimated Total:** $72,300,000 \(\) $56,600,000

$100,000,000 could be spent over the next 20 years for Capital and Operating Expenses
WATER MANAGEMENT GOALS

- Nitrates and Uranium are a 50 year problem (or more)
- Minimize Financial Impact to Utility and Customers
- Protect Long Term Viability of Aquifer
- Extend Useful Life of Existing Wells and Delay/Minimize Treatment
- Think outside the box - $72,300,000 is Unsustainable
04 ASR COMPONENTS
AQUIFER STORAGE AND RESTORATION PROJECT

5 Prong Solution

- Dual Pumping
- Focused Water Treatment
- Aquifer Storage and Restoration
- Irrigation Management
- Blending and Storage

COMBINATION OF ALL APPROACHES
Potential to Substantially Reduce Capital Investments in Infrastructure and Operating Costs
North Baltimore – Phase 1

Extraction Well/Dual Pumping

RO Treatment

Concentrate Storage

Injection Wells and Piping

Irrigation

Concentrate Storage

Legend:
- Sprinkler
- Reinjection Well
- Municipal Extraction Well
- Extraction System
- Treatment and Re injection System
- Agricultural Reuse System

For Conceptual Use Only

HASTINGS UTILITIES
AQUIFER STORAGE AND RESTORATION AT NORTH BALTIMORE SITE

DATE
AUGUST 2013
DUAL PUMPING

- Extend useful life of existing wells & delay/minimize treatment
- 2-3 pumps in close proximity withdraw water from top and bottom of aquifer, thus separating these two water layers
- Highest nitrate concentrations appear to be near the top of the aquifer based upon Well 33 and Well 16 Dual Pump Projects
WELL 16 DUAL PUMPING

Well 16 Dual Pump Study

Nitrate, mg/l

Deep and Shallow Wells at 450 gpm each
Deep Well - 450 gpm, Shallow Well - 300 gpm
Deep Well - 450 gpm, Shallow Well - 150 gpm
Deep and Shallow Wells at 450 gpm each
Deep Well - 250 gpm, Shallow Well - 450 gpm

Nitrate MCL 10 mg/l

Deep Well (Well 16-1) (South)  Shallow Well (Well 16-2) (North)  Blended Nitrate Level, mg/l (Pt 16-3)
FOCUSED WATER TREATMENT
REVERSE OSMOSIS

- Reverse Osmosis (RO) will be used to remove Nitrates to provide clean water for injection
- Absorbent media will be used to remove Uranium, as needed

RO Equipment is purchased and building construction starts Fall 2016
AQUIFER STORAGE AND RESTORATION

- Clean water will be injected into the aquifer to reduce nitrate and uranium contamination
- Goal: Develop a supply of clean water up gradient of the existing municipal wells

ASR5 completed and tested
# AQUIFER STORAGE AND RESTORATION PROJECT - COST

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Phase I Estimated Cost</th>
<th>Phase II &amp; III Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>ASR and Dual Pumping System Pilots</td>
<td>$ 2,132,000</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>North Baltimore SAR System</td>
<td>$ 20,636,000</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Westbrook ASR System</td>
<td></td>
<td>$ 16,415,000</td>
</tr>
<tr>
<td>III</td>
<td>Storage Blending at North Baltimore Site</td>
<td></td>
<td>$ 6,728,000</td>
</tr>
<tr>
<td></td>
<td>Total Estimated Construction Cost</td>
<td>$22,768,000</td>
<td>$ 23,143,000</td>
</tr>
</tbody>
</table>

Operation and Maintenance Cost - $1,335,400 per year
CURRENT STATUS
AQUIFER STORAGE

- Inject clean water and recover in down gradient municipal wells
- ASR No. 5 is complete
- Drawdown, Injection, and Tracer Testing completed
  - Geochemical and hydraulic modeling complete
  - Injection Well construction ASR 1-4 early 2017
  - Collector, injection, and concentrate piping is under construction
# 2016 Modeling - Most Efficient Scenario

<table>
<thead>
<tr>
<th>Pumping Condition</th>
<th>Scenario (Model Run)</th>
<th>ASR Injection Rates (gpm)</th>
<th>ASR Pumping Rates (gpm)</th>
<th>Total Municipal Pumping&lt;sup&gt;a&lt;/sup&gt; (gpm)</th>
<th>Average Percent of ASR Injected Water Pumped&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Year</td>
<td>J</td>
<td>R1, R4 = 500; R2 = 680; R3 = 100; R5 = 650</td>
<td>26 = 900; 27 = 530; 30 = 1000</td>
<td>4,535</td>
<td>ASR Extraction Wells 49</td>
</tr>
</tbody>
</table>

<sup>a</sup> Excluded any pumping wells used in ASR system

<sup>b</sup> Simulated values 20 years after injection of water into ASR recharge wells begins

<sup>c</sup> Includes wells 1, 2, 4, 8, 21, 22, 25, 28, 29, and 36
2016 MODEL RESULTS – RECHARGE BUBBLE – 1 YEAR
2016 MODEL RESULTS – RECHARGE BUBBLE – 5 YEAR
## WATER QUALITY CHARACTERISTICS

<table>
<thead>
<tr>
<th>Species</th>
<th>Current Water (mg/l)</th>
<th>Permeate Water (mg/l)</th>
<th>Injected Water (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.0</td>
<td>5.5 – 6.0</td>
<td>7 – 7.3</td>
</tr>
<tr>
<td>Alkalinity (as CaCO$_3$)</td>
<td>270</td>
<td>10 – 30</td>
<td>65</td>
</tr>
<tr>
<td>Nitrate</td>
<td>15</td>
<td>1 – 2</td>
<td>5</td>
</tr>
<tr>
<td>Arsenic</td>
<td>&lt;0.002</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Iron</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Uranium</td>
<td>0.02</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
GEOCHEMICAL MODELING IMPACT ON INORGANIC SPECIES DUE TO CHANGING AQUIFER CONDITIONS

- Contaminates Evaluate All SDWA Inorganics and Fe, Mn, Mg.
  - Eh changes - ORP
  - pH changes
  - TDS decreases
  - Dissolved oxygen addition
- Primary/secondary mineral phases
- Desorption/adsorption
- RO permeate response to pH modification (NaOH)

Pourbait Diagram

Simulated Absorption Curve

pH Response to NaOH Addition
KEY GEOCHEMICAL FINDINGS

- A decrease in TDS of injection water may cause a minor increase in adsorption of primary contaminants due to new in-situ equilibrium.

- Decreased bicarbonate alkalinity may impact Cd, Mn, and Mg. These changes are small (less than an order of magnitude) and only when bicarbonate is below 120mg/L as HCO3-.
KEY GEOCHEMICAL FINDINGS

- With lower redox (<200mV), a pH below 6 has the potential to cause iron(II) dissolution potentially releasing adsorbed or incorporated species such as from solid phase iron(III) minerals. i.e. A higher pH is good.

- pH of 6.6 – 7.5 is recommended based on redox to maximize adsorption to sediment, while keeping pH in range to enhance adsorption of U. Dissolved U levels up to one order of magnitude from the current groundwater levels could result from a lower pH.
CONCENTRATE MANAGEMENT

- The high nitrate water from the RO treatment will be used to irrigate farm ground lying over the ASR Injection field.
- This replaces irrigation use of the potable water stored in the aquifer.
- The crop will benefit from the higher nitrates in the water.
- Limit amount sent to WWTF.
- The Storage Lagoon and Pump Station have been bid. Construction starts fall 2016
- Expect to have storage facility completed by June 2017 to allow for testing of Triplex pumps
- Water available for 2017 growing season
BLENDING AND STORAGE

- If required blending of waters from high nitrate wells with low nitrate wells will be used to provide potable water
- If needed, above ground storage of potable water will be developed to meet peak day demands

Goal: Use the storage of water in the aquifer to the greatest extent possible