Overview

• Purpose of modeling evaluation
• Method of evaluation
• Model versions
• Overview of scenarios evaluated
• Model results
  – Basin-wide curtailment/reductions
  – Targeted curtailments
• Observations and discussion
Purpose of modeling evaluation

• To calculate the benefits of pumping reductions to streamflow [i.e. baseflow] and impacts on evapotranspiration and groundwater storage

• To help inform management decisions
To evaluate pumping impacts:

• Calculate water budget differences between two model runs:
  – baseline (historical pumping)
  – alternative pumping scenario

• Baseline: historical conditions for 1940-2007.
Model versions

• 7-layer model developed by Balleau:
  – Ran for baseline and scenario 11 to compare with 1-layer model (runtime: 5-12 hours)

• 1-layer model developed by SSPA from 7-layer model:
  – Functionally equivalent for calculating pumping impacts
  – Shorter runtimes allow exploring more alternatives (runtime: 30-60 minutes)
  – More detailed output allows calculating basin water budget
  – Used for initial evaluations presented here

• 1-layer model with alternative calibration with low evapotranspiration and recharge (SSPA)
Rattlesnake Creek Basin
Groundwater Points of Diversion

Senior and Junior groundwater rights with respect to File 7571 (August 15, 1957).

Kansas Department of Agriculture
Division of Water Resources
November 3, 2014
Scenario development

• DWR evaluated a wide range of pumping reduction scenarios including:
  – Basin-wide water use reductions [2.5 and 2.75]
  – Targeted curtailments near the stream [3-11]
    • Balleau response zones [7-9]
    • 1 and 2 mile corridors [10,11]
• All scenarios restrict only junior rights above Quivira intake
• All start restrictions in 1990 (except scenario 1)
Rattlesnake Creek Basin Stream Fraction, 10 year

10-year Streamflow fraction response from Balieau shapefiles

Macksville Station
Zenith Station
efr10y2
Response Fraction
0 - 0.2
0.2 - 0.4
0.4 - 0.7
0.7 - 1

Kansas Department of Agriculture
Division of Water Resources
November 3, 2014
Rattlesnake Creek Basin
Scenarios 7, 8 and 9

Shut off all RS basin junior groundwater rights based on the ten-year stream depletion fraction
Scenario 7: 70%-100%
Scenario 8: 40%-100%
Scenario 9: 20%-100%

Based on Balleau Final GMD 5 Model Files\Yr2020buff\sfr10y2 beginning in 1990

Kansas Department of Agriculture
Division of Water Resources
November 3, 2014
Shut off all Rattlesnake basin junior groundwater rights from Quivira to the Macksville station beginning in 1990
Scenario 10: Within 1 mile of RS
Scenario 11: Within 2 miles of RS
Additional scenarios examined

• 11-ML: 2-mi corridor with multi-layer model
• Delay pumping reductions to 2000
• Alternative 1-layer model calibration with lower ET and recharge

• 3: 1 mile corridor entire length
• 4: alluvial extent
• 5-6: Balleau response zones (from map; not coverage); replaced by 7-9
Streamflow response statistics evaluated

- Average baseflow increase for years 1998-2007
- Ratio of baseflow increase to pumping reduction
- Response time: lag between pumping reduction and baseflow increase
Presented scenarios
Rattlesnake C Basin impacts 1998-2007
acre-feet/yr

<table>
<thead>
<tr>
<th>scenario</th>
<th>Scenario definition</th>
<th>Δpumping</th>
<th>Δbaseflow</th>
<th>ΔB cfs</th>
<th>ΔB/ΔP</th>
<th>Δstorage</th>
<th>Δ et</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>basinwide shutoff from 1958 on</td>
<td>(143,529)</td>
<td>42,053</td>
<td>58.0</td>
<td>29.3%</td>
<td>70,505</td>
<td>22,387</td>
</tr>
<tr>
<td>2</td>
<td>basinwide shutoff from 1990 on</td>
<td>(143,529)</td>
<td>34,420</td>
<td>47.5</td>
<td>24.0%</td>
<td>76,837</td>
<td>18,007</td>
</tr>
<tr>
<td>2.5</td>
<td>basinwide 50% pumping</td>
<td>(71,765)</td>
<td>13,366</td>
<td>18.4</td>
<td>18.6%</td>
<td>34,019</td>
<td>8,662</td>
</tr>
<tr>
<td>2.75</td>
<td>basinwide 75% pumping</td>
<td>(35,882)</td>
<td>5,475</td>
<td>7.6</td>
<td>15.3%</td>
<td>18,200</td>
<td>4,265</td>
</tr>
<tr>
<td>7</td>
<td>response zone &gt;70%</td>
<td>(1,059)</td>
<td>661</td>
<td>0.9</td>
<td>62.4%</td>
<td>77</td>
<td>253</td>
</tr>
<tr>
<td>8</td>
<td>response zone &gt;40%</td>
<td>(9,701)</td>
<td>4,646</td>
<td>6.4</td>
<td>47.9%</td>
<td>1,442</td>
<td>2,597</td>
</tr>
<tr>
<td>9</td>
<td>response zone &gt;20%</td>
<td>(19,604)</td>
<td>8,326</td>
<td>11.5</td>
<td>42.5%</td>
<td>3,350</td>
<td>4,975</td>
</tr>
<tr>
<td>10</td>
<td>RSC 1-mi corridor to Macksville</td>
<td>(3,932)</td>
<td>2,115</td>
<td>2.9</td>
<td>53.8%</td>
<td>410</td>
<td>1,094</td>
</tr>
<tr>
<td>11</td>
<td>RSC 2-mi corridor to Macksville</td>
<td>(11,230)</td>
<td>5,560</td>
<td>7.7</td>
<td>49.5%</td>
<td>1,396</td>
<td>3,086</td>
</tr>
</tbody>
</table>

Notes:
[2] Scenario 1 selection begins Jan 1958 (str per 218); others begin Jan 1990 (str per 602).
[3] Scenarios are specified as input to preprocessor by scenario id and pump scaling factor.
Pumping Impact on global water budget
Scenario 2: basin-wide shutoff beginning 1990

Average annual flow rate (cfs)

-250 -200 -150 -100 -50 0 50 100 150 200 250

delta storage  delta pumping  delta et  delta baseflow (cfs)
Pumping Impact on RS Basin water budget
Scenario 2: basin-wide shutoff beginning 1990

Average annual flow rate (cfs)


(50) (100) (150) (200) (250)

delta storage  delta pumping  delta et  delta baseflow (cfs)
Scenario 2 variations: scale pumping basin-wide by 50% and 75%

- Rattlesnake Creek Basin impacts:

<table>
<thead>
<tr>
<th>scenario</th>
<th>Scenario definition</th>
<th>Δpumping</th>
<th>Δbaseflow</th>
<th>ΔB cfs</th>
<th>ΔB/ΔP</th>
<th>Δstorage</th>
<th>Δ et</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>basinwide shutoff from 1990 on</td>
<td>(143,529)</td>
<td>34,420</td>
<td>47.5</td>
<td>24.0%</td>
<td>76,837</td>
<td>18,007</td>
</tr>
<tr>
<td>2.5</td>
<td>basinwide 50% pumping</td>
<td>(71,765)</td>
<td>13,366</td>
<td>18.4</td>
<td>18.6%</td>
<td>34,019</td>
<td>8,662</td>
</tr>
<tr>
<td>2.75</td>
<td>basinwide 75% pumping</td>
<td>(35,882)</td>
<td>5,475</td>
<td>7.6</td>
<td>15.3%</td>
<td>18,200</td>
<td>4,265</td>
</tr>
</tbody>
</table>

Average impacts 1998-2007 acre-feet/yr unless otherwise noted
Scenarios 7, 8 and 9: Streamflow response zones

- **Rattlesnake Creek Basin impacts**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario definition</th>
<th>Δpumping</th>
<th>Δbaseflow</th>
<th>ΔB cfs</th>
<th>ΔB/ΔP</th>
<th>Δstorage</th>
<th>Δ et</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>response zone &gt;70%</td>
<td>(1,059)</td>
<td>661</td>
<td>0.9</td>
<td>62.4%</td>
<td>77</td>
<td>253</td>
</tr>
<tr>
<td>8</td>
<td>response zone &gt;40%</td>
<td>(9,701)</td>
<td>4,646</td>
<td>6.4</td>
<td>47.9%</td>
<td>1,442</td>
<td>2,597</td>
</tr>
<tr>
<td>9</td>
<td>response zone &gt;20%</td>
<td>(19,604)</td>
<td>8,326</td>
<td>11.5</td>
<td>42.5%</td>
<td>3,350</td>
<td>4,975</td>
</tr>
</tbody>
</table>

Average impacts 1998-2007 acre-feet/yr unless otherwise noted
Pumping Impact on global water budget
Scenario 9: 20%-100% response zone shutoff

Average annual flow rate (cfs)

-40 -30 -20 -10 0 10 20 30


delta storage  delta pumping  delta et  delta baseflow (cfs)
Scenarios 10 and 11: 1- and 2-mi corridors

- **Rattlesnake Creek Basin impacts:**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario definition</th>
<th>Δpumping</th>
<th>Δbaseflow</th>
<th>ΔB cfs</th>
<th>ΔB/ΔP</th>
<th>Δstorage</th>
<th>Δ et</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>RSC 1-mi corridor to Macksville</td>
<td>(3,932)</td>
<td>2,115</td>
<td>2.9</td>
<td>53.8%</td>
<td>410</td>
<td>1,094</td>
</tr>
<tr>
<td>11</td>
<td>RSC 2-mi corridor to Macksville</td>
<td>(11,230)</td>
<td>5,560</td>
<td>7.7</td>
<td>49.5%</td>
<td>1,396</td>
<td>3,086</td>
</tr>
</tbody>
</table>

Average impacts 1998-2007 acre-feet/yr unless otherwise noted
Comparison of results of single and multi-layer models

- Scenario 11

- Global budget impacts:

<table>
<thead>
<tr>
<th>Scenario id</th>
<th>Scenario definition [1,2,3]</th>
<th>Δpumping ac-ft/yr</th>
<th>Δbaseflow ac-ft/yr</th>
<th>Δbaseflow cfs</th>
<th>ΔB/ΔP pct</th>
<th>Δstorage ac-ft/yr</th>
<th>Δ ET ac-ft/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>RSC 2-mi corridor to Macksville (11,230)</td>
<td>5,729</td>
<td>7.9</td>
<td></td>
<td>51.0%</td>
<td>2,253</td>
<td>3,275</td>
</tr>
<tr>
<td>difference</td>
<td>[multi - single] layer versions</td>
<td>0</td>
<td>(265)</td>
<td>(0)</td>
<td>-2.4%</td>
<td>150</td>
<td>104</td>
</tr>
</tbody>
</table>

Average impacts 1998-2007 acre-feet/yr unless otherwise noted
Pumping Impact on global water budget
Scenario 11: 2-mi corridor shutdown to Macksville

Average annual flow rate (cfs)

-25 -20 -15 -10 -5 0 5 10 15 20


delta storage  delta pumping  delta et  delta baseflow (cfs)
Pumping Impact on global water budget
Scen. 11-ML: 2-mi corridor shutdown to Macksville

Average annual flow rate (cfs)

Delta storage
Delta pumping
Delta ET
Delta baseflow (cfs)
Observations

• The single and multi-layer models are functionally equivalent for determining pumping impacts on streamflow.

• The GMD5 model shows that baseflow reductions due to junior pumping are significant.

• Pumping reductions near the stream provides more effective streamflows benefits.

• Pumping shutoff scenarios take two to three years to produce a significant baseflow response.
Augmentation Scenarios
January 29, 2015

• DWR evaluated two augmentation scenarios:
  – Four augmentation wells were placed northeast of St. John; pipe outflow was placed below Wildhorse Creek on Rattlesnake Creek.
Locations of streamflow and groundwater level response hydrographs

- **Streamflow** at 5 locations along Rattlesnake creek
  - Macksville gage, augmentation outflow, sw of Quivira and Zenith gage

- **Groundwater level** at 14 locations along stream
  - At stream hydrograph locations and 1-2 mi either side
  - All four augmentation wells
Scenario 1

- 1,200 AF April-June, years 1988-1993, flow at 6.7 cfs

- Conditions suggested by Dave Romero, Balleau and Associates
Scenario 1 response plots

- Plots are differences in streamflow or groundwater level between augmentation scenario and baseline model runs. Figures:
  - 1. Both streamflow and water level response.
  - 2. Augmentation pumping and streamflow
  - 3. Cumulative streamflow
  - Single- and multilayer versions are compared.
Scenario 2

• 1,460 AF August-September, years of January flow less than 25 cfs and without severe drought as determined in July, flow at 12.1 cfs

• Conditions are based on Kansas Water Office report.
Scenario 2 response plots

- Plots are same format as Scenario 1. Figures:
  - 4. Both streamflow and water level response.
  - 5. Augmentation pumping and streamflow
  - 6. Cumulative streamflow
- Only single-layer model versions are shown (multilayer versions are similar and available).
Computed streamflow and head response to augmentation pumping (single-layer model scenario 2: Aug-Sep for years with January flow < 25 cfs at Zenith except for extreme drought years)
Augmentation pumping and computed streamflow response in nearby segment 1555, sw corner of refuge (seg. 1983) and at Zenith gage (seg. 1997) [single-layer scenario 2: Aug-Sep in selected years]
[single-layer augmentation scenario 2] Cumulative streamflow response as fraction of augmentation pumping at nearby segment (1955), sw corner of refuge (seg. 1983) and at Zenith gage (seg. 1997)
Augmentation impact hydrographs show:

• Differences in impacts between 1- and 7-layer versions are negligible.
• Scenarios 1 and 2 show similar effects.
• Cumulative impact on streamflow over time is reduced significantly by depletion effect of pumping.
• Streamflow losses due to augmentation pumping occur both during and following pumping cycles.
Yearly gaged flow at Zenith and QNWR reported diversions

- Zenith Flow
- QNWR Diversions
- Precip at Hudson (right axis)
Augmentation Scenario 2 variation
May 20, 2015

• DWR evaluated a variation on augmentation scenario 2:
  – Pump augmentation wells from layer 2 instead of layer 1 as suggested by Dave Romero.
Scenario 2 variation

• Compare multilayer version of original Scenario 2 with this variation:
  • A) Scenario 2, multilayer version, but pumping from layer 1 (Figs. 4-ML, 5-ML and 6-ML)
  • B) same as (A) but pumping from layer 2 (Figs. 4-ML-L2, 5-ML-L2 and 6-ML-L2)
Scenario 2-ML response plots (multilayer model, pump from layer 1)

- Figures:
- 4-ML. Both streamflow and water level response.
- 5-ML. Augmentation pumping and streamflow
- 6-ML. Cumulative streamflow
Computed streamflow and head response to augmentation pumping [multilayer model scenario 2: Aug-Sep for years with January flow < 25 cfs at Zenith except for extreme drought years]
Scenario 2-ML-L2 response plots (multilayer model, pump from layer 2)

• Figures:
• 4-ML-L2. Streamflow and water level response.
• 5-ML-L2. Augmentation pumping and streamflow
• 6-ML-L2. Cumulative streamflow
Computed streamflow and head response to augmentation pumping (multi-layer model scenario 2-L2 (pump from layer 2)). Aug-Sep for years with January flow < 25 cfs at Zenith except for extreme drought years.
Augmentation pumping and computed streamflow response in nearby segment 1555, sw corner of refuge (seg. 1983) and at Zenith gage (seg. 1997) [multilayer scenario 2-L2 (pump from layer 2): Aug-Sep in selected years]
[multiyear augmentation scenario 2-42 (pump from layer 2)] Cumulative streamflow response as fraction of augmentation pumping at nearby segment (1955), aw corner of refuge (1983) and at Zenith gage (1997)
Effect of pumping from Layer 2 instead of layer 1

• Streamflow response shows negligible difference (Figs. 4-ML-L2 and 6-ML-L2);

• Maximum drawdown in layer 1 is approx. 5 ft for pumping from layer 2 (Fig. 4-ML-L2, right axis), and approx. 8 ft for pumping from layer 1 (Fig. 4-ML, right axis).
Thanks!