Conceptual Model for the High Plains Aquifer GAM

Stakeholder Advisory Forum #2
Lubbock, TX

Presented By:

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

Texas Water Development Board
May 14, 2014
Todays Topics

- Introduction to the Groundwater Availability Modeling program (Cindy Ridgeway, TWDB)
- Conceptual Model for the High Plains Aquifer System
- Demonstration of the High Plains Aquifer System conceptual model viewer (in beta)
Groundwater Availability Modeling

Rohit Goswami, Hydrologist
Cindy Ridgeway, Contract Manager

High Plains Aquifer System Groundwater Availability Model (GAM)

Texas Water Development Board
Disclaimer

The statements contained in this presentation are my current views and opinions and are not intended to reflect the positions of, or information from, the Texas Water Development Board, nor is it an indication of any official policy position of the Board.
GAM Program

* Purpose: to develop tools that can be used to help GCDs, RWPGs, and others understand and manage their groundwater resources.
* Public process: you get to see how the model is put together.
* Freely available: models are standardized, thoroughly documented. Reports available over the internet.
* Living tools: periodically updated.
What is Groundwater Availability?

Policy + Science = Groundwater Availability

Desired Future Conditions + GAM or other tool = Modeled Available Groundwater

Goal: informed decision-making
Groundwater Model
Major Aquifers

Note:
The Edwards-Trinity (Plateau) and Pecos Valley aquifers are included in the same model.
These boundaries are approximate and do not show overlaps between models.
Minor Aquifers

(Updated 4/1/2013)
How we use Groundwater Models

* Texas Water Code, § 36.1071 (h)

Inform groundwater districts about historical conditions in the aquifer

<table>
<thead>
<tr>
<th>Management Plan requirement</th>
<th>Aquifer or confining unit</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>Estimated annual amount of recharge from precipitation to the district</td>
<td>Edwards-Trinity (Plateau) Aquifer</td>
<td>140,509</td>
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<tr>
<td></td>
<td>Pecos Valley Aquifer</td>
<td>14,115</td>
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<tr>
<td></td>
<td>Dockum Aquifer</td>
<td>0</td>
</tr>
<tr>
<td>Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers</td>
<td>Edwards-Trinity (Plateau) Aquifer</td>
<td>31,222</td>
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<tr>
<td></td>
<td>Pecos Valley Aquifer</td>
<td>9,804</td>
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<td>Dockum Aquifer</td>
<td>0</td>
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<tr>
<td>Estimated annual volume of flow into the district within each aquifer in the district</td>
<td>Edwards-Trinity (Plateau) Aquifer</td>
<td>32,993</td>
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<td></td>
<td>Pecos Valley Aquifer</td>
<td>3,441</td>
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<td>Dockum Aquifer</td>
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</table>
How we use Groundwater Models

* Texas Water Code, § 36.108 (d): Assist districts and management areas in determining desired future conditions
How we use Groundwater Models

* Texas Water Code, § 36.1084 (b): Develop modeled available groundwater based on desired future conditions

<table>
<thead>
<tr>
<th>County</th>
<th>Regional Water Planning Area</th>
<th>Basin</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>2060</th>
</tr>
</thead>
</table>

How we use Groundwater Models

* Texas Water Code, § 36.108 (d) (3)

Estimating total recoverable storage for explanatory reports
Stakeholder Advisory Forums

* Keep updated about progress of the model
* Understand how the groundwater model can, should, and should not be used
* Provide input and data to assist with model development
Contact Information

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Web information:

http://www.twdb.texas.gov/groundwater/models/gam/hpas/hpas.asp#saf
http://www.twdb.texas.gov/groundwater/index.asp
Key Aspects of Conceptualization

The **Conceptual Model** is a simplified description of the various hydrogeologic and structural components of an aquifer system and their interactions.

- Extent and hydrostratigraphy
- Structure*
- Hydraulic/storage properties
- Recharge/discharge*
- Groundwater production*
- Cross-formational flow
- Water quality

*Additional financial support from HPWD, NPGCD, and PGCD allowed increased analyses in these areas of the conceptual model, in addition to enhanced data visualization and additional stakeholder meetings
Study Area
### Extent and Hydrostratigraphy

#### Table

<table>
<thead>
<tr>
<th>System</th>
<th>Formation</th>
<th>Aquifer</th>
<th>Model Layer</th>
<th>North</th>
<th>Central</th>
<th>South</th>
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<td>Quaternary</td>
<td>Pecos Valley Alluvium</td>
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<tr>
<td>Tertiary</td>
<td>Ogallala</td>
<td>Ogallala</td>
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<td>Cretaceous</td>
<td>Duck Creek&lt;sup&gt;†&lt;/sup&gt;</td>
<td>Boracho&lt;sup&gt;‡&lt;/sup&gt;</td>
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<td>Kiamichi&lt;sup&gt;©&lt;/sup&gt;</td>
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<td>Antlers</td>
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<td>Jurassic</td>
<td>Morrison</td>
<td>Rita Blanca</td>
<td></td>
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<td>Exeter</td>
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<tr>
<td>Triassic</td>
<td>Cooper Canyon</td>
<td>Upper Dockum</td>
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<td>3</td>
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<td></td>
<td>Trujillo</td>
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<td></td>
<td>Santa Rosa</td>
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<td>Permian</td>
<td>Dewey Lake</td>
<td>Rustler</td>
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<td>Rustler</td>
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</tbody>
</table>

<sup>†</sup> Edwards-Trinity (High Plains) Aquifer represented by layer 2 in the central portion of the domain.

<sup>‡</sup> Edwards-Trinity (Plateau) Aquifer represented by layer 2 in the southern portion of the domain.
Structure

- Correlation based on 2,050 geophysical logs retrieved from:
  - BRACS database
  - BEG Geophysical Log Facility
  - commercial suppliers
  - Railroad Commission
  - UT Lands Office
  - NM Oil Conservation Division
  - City of Amarillo
  - City of Canyon

- Secondary information from driller’s logs, cores, and previous studies
  - Use for “infilling”
  - Added detail in inter-geophysical log areas

- Lithology based on calibrated gamma ray logs.

- Additional District funding allowed significant increase in geophysical log resolution and improved detail in surface creation.
Lithology Estimates

Sand thickness/fractions from geophysical logs compared favorably to previous studies
City of Canyon has productive Dockum wellfield in Randall County.
Total HPAS Thickness

- Highest where the Dockum is thickest in the South
- Generally corresponds with area of poor water quality in the Dockum
Water Levels

- Water-level data from 21,645 wells were retrieved from
  
  - TWDB groundwater database
  - Groundwater Conservation Districts
  - USGS groundwater database

- Wells were assigned to aquifers based on the current study’s new structural surfaces

- When no well screen information was known, total depth and professional judgment was used (e.g. other information, such as water level trends, nearby well completions)

- Predevelopment estimates utilized known spring and other surface discharge locations to infill areas with lack of data
Pre-development Water Levels

Steep gradient will be difficult to simulate in single unconfined layer (no good alternative)

Contour Interval = 200 ft
Pre-development Water Levels
Transient Water Levels

N. Ogallala: **1288** hydrographs

Areas with small initial saturated thickness or unsuitable topography (for ag) show steadier levels
Transient Water Levels

S. Ogallala: 1721 hydrographs

Believed to be due to urban runoff to playas
Transient Water Levels

Rita Blanca: 19 hydrographs

Edwards-Trinity (High Plains): 10 hydrographs
Transient Water Levels

Upper Dockum: 26 hydrographs
Transient Water Levels

Lower Dockum: 165 hydrographs

Most hydrographs in areas near outcrop where water quality is best. Currently lack hydrographs showing potential effects of O&G water use on Santa Rosa water levels.
Water Level Decline

Map showing contour intervals of water level decline across different regions.
# Hydraulic Parameters

<table>
<thead>
<tr>
<th>Initial values</th>
<th>OGALLALA</th>
<th>ETHP</th>
<th>DOCKUM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage</strong></td>
<td>Sy: Blandford and others (2003) + Dutton and others (2001) + McGuire (2012)</td>
<td>Sy : 0.05 for limestone, 0.15 for sand, 0.1 for shale</td>
<td>Ss and Sy : Ewing and others (2008)</td>
</tr>
</tbody>
</table>
Hydraulic Parameters

Kh (ft/day) in Ogallala Aquifer
- < 5
- 5-20
- 20-30
- 30-50
- 50-100
- 100-500
- 500-1000

Kh (ft/day) in Edwards-Trinity (High Plains)
- 0-2
- 2-4
- 4-6
- 6-8
- 8-10
- 10-12
Hydraulic Parameters

**Kh (ft/day) in Upper Dockum**
- Green: 0 - 0.1
- Yellow: 0.1 - 0.3
- Light brown: 0.3 - 1
- Dark brown: 1 - 3
- Purple: 3 - 10
- Pink: 10 - 30
- Upper Dockum Aquifer
- Active Model Boundary
- County Boundary
- State Boundary

**Kh (ft/day) in Lower Dockum**
- Green: 0 - 0.1
- Yellow: 0.1 - 0.3
- Light brown: 0.3 - 1
- Dark brown: 1 - 3
- Purple: 3 - 10
- Pink: 10 - 30
- Lower Dockum Boundary
- Active Model Boundary
- County Boundary
- State Boundary
## Recharge

<table>
<thead>
<tr>
<th></th>
<th>N. OGALLALA</th>
<th>S. OGALLALA</th>
<th>DOCKUM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-development</strong></td>
<td>Based on chloride mass balance + soil type</td>
<td>Based on playa density</td>
<td>From previous GAM (Ewing and others, 2008)</td>
</tr>
<tr>
<td><strong>Post-development</strong></td>
<td>Unchanged from pre-development</td>
<td>Based on land use distribution</td>
<td>From previous GAM (Ewing and others, 2008)</td>
</tr>
</tbody>
</table>

Additional district funding allowed new analyses from the Scanlon and Reedy at the BEG, especially in the area of irrigation return flow.
**Recharge**

Nitrate breakthrough indicative of irrigation return flow.

Nitrate follows irrigated/cultivated land.

No 1950’s breakthrough to support “immediate” return flow.
No breakthrough with deep water table, less cultivated land.
Recharge Estimates: Dockum
Natural Discharge

- Discharge to surface water from Ogallala not a large portion of post-development water balance

- Used spring locations to tie water levels to surface in Predevelopment

- Saline lakes typically denote areas of former or current discharge.
Natural Discharge: Springs and Saline Lakes
Groundwater Production

- Pumping is the dominant discharge mechanism.

- Pumping data taken from:
  - TWDB Water Use Survey
  - Amosson and others (2003)
  - INTERA, Inc. & Dutton (2010)
  - Blandford et al. (2003)
  - TWDB Irrigation Survey
  - North Plains GCD
  - Ewing et al. (2008)
  - Blandford et al. (2008)

- Demand-based pumping estimates prior to 1980 (from irrigation survey) will likely be revised where they are significantly different from storage changes calculated from water levels.

Additional district funding allowed development of a GIS-based tool for efficiently calculating storage change.
Groundwater Production

Southern Ogallala Pumping in Texas

Pumping (AFY)

- Irrigation
- Manufacturing
- Mining
- Municipal
- Power
- Rural Domestic
- Livestock
- Total

Year

2010

Groundwater Production

Pumping from Ogallala Aquifer (AFY)

- South of 500 mg/L Contour
- North of the 500 mg/L Contour

Predevelopment Saturated Thickness (ft)

Water Table Change (ft)
Groundwater Production: Using Storage Change

Technique requires high density monitoring network, and high production, otherwise storage change estimate is swamped by “noise” in data.

For some counties, clear differences exist between storage change estimates and demand-based estimates.
Cross-formational Flow

- Some evidence of cross-formational flow found in literature review based on lithology, heads and hydrochemistry
Water Quality

- Groundwater water quality analysis included 5,897 wells retrieved from
  TWDB Groundwater Database (TX)
  USGS NWIS Database (non-TX)

- Wells were assigned to aquifers based on the current study’s new structural surfaces.

- Only the most recent sampling event for a given parameter was chosen from each well.
Water Quality
Conceptual Model

- **During Pre-development:** recharge balances discharge, no net change in groundwater storage
- **During Post-development:** increased discharge from pumping, locally increased recharge from irrigation, overall reduction in natural discharge and GW storage
- **Northern and Southern sections** have different hydrostratigraphy and recharge patterns.
Conceptual Model

- Recharge/Discharge
- Rita Blanca Outcrop
- Interplaya Recharge
- Recharge in Playa
- Discharge to Spring/Salt Lake
- Stream-Aquifer Interaction

L1
- Ogallala

L2
- Rita Blanca
- L2 (Pass Through)

L3
- Upper Dockum

L4
- Lower Dockum

Legend:
- Recharge
- Stream-Aquifer Interaction
- Discharge to Spring
- Down-dip Flow
- Cross-formational Flow
- Model Layer Number
- No-flow Boundary
Conceptual Model
### Schedule

<table>
<thead>
<tr>
<th>Project Task</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td>1.0 Project Management</td>
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<tr>
<td>1.1 Monthly Status Report</td>
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<td>1.2 TWDB Review Meetings</td>
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<td>1.3 Senior Technical Review</td>
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<td>2.0 Stakeholder Communication</td>
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<td>2.1 Stakeholder Interaction</td>
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<td>2.2 SAF Meeting</td>
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<td>2.3 Stakeholder and TWDB Seminar</td>
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<td>3.0 Model Development</td>
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<td>3.1 Data Collection and Conceptual Model</td>
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<td>3.2 Model Design</td>
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<td>4.0 Model Calibration</td>
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<td>4.1 Steady State Calibration</td>
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<td>4.2 Transient Calibration</td>
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<td>4.3 Sensitivity Analysis</td>
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<td>5.0 Documentation &amp; Tech. Transfer</td>
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<td>5.1 Data Model Documentation</td>
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<tr>
<td>5.2 Reporting</td>
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</table>

- **Monthly Report**
- **CM** Conceptual Model Report
- **FM** Final Model Report
- **TWDB & Stakeholder Training**
- **TWDB Technical Review Meeting**
- **SAF Meeting**
- **Draft Model Report**
- **CM** Conceptual Model Report
- **FM** Final Model Report
- **TWDB & Stakeholder Training**
High Plains Aquifer System Conceptual Model Viewer

- Link: hpasgam.intera.com
- Web-based, works through browser
- Road and satellite basemaps
- Address finder
- Layer selector
- Aquifer Boundaries
- Surfaces
- Surface query tool
- Water level monitoring wells
  - Marker clustering (“drill down” to individual wells)
  - Time series water level plots
  - Time series saturated thickness (Ogallala only)

The application is in beta, and we need your feedback to make it better.
1. Q: What TDS concentration is used for the Dockum Aquifer boundary
   A: 5,000 mg/L. 3,000 mg/L typically defines other aquifers in Texas
2. Q: What are the restrictions to the types of geophysical logs that were used? CRMWA has logs
   that do not appear to have been considered in this study
   A: INTERA will follow up with CRMWA.
3. Q: In the conceptual model report, “downdip” appears to be used interchangeably with
   “confined” or “subcrop”. Suggest using “downdip” to describe direction following the actual
   dip.
   A: Nomenclature will be reviewed for consistency in the structure section.
4. Q: Is there recharge along the Canadian River in the Dockum? The Canadian is thought to be
   source of discharge.
   A: We do conceptualize recharge as occurring in the Dockum outcrop in that area, although
   some of that recharge likely discharges locally to the Canadian
5. Q: How many geophysical logs were used to define the Rita Blanca?
   A: Looking at the slide, it appears to be 15-20.
6. Q: Did the pump test data from the CRMWA wells affect the estimate of hydraulic conductivity
   in Roberts County?
   A: It affects the estimate locally, but the values were not significantly outside the range that
   had estimated in previous studies.
7. Q: Follow up. It appears that several of the more recent pump tests were not considered in the
   conceptual model.
   A: INTERA will follow up with CRMWA.
8. Q: Will the data from the CRMWA wellfield be used to estimate specific yield?
   A: Single well pump tests cannot be used to estimate specific yield
9. General discussion of recharge in Lynn County. Pumping in the 1950s drew down water levels,
   wells ran dry. Some of those wells have since recovered.
10. Please adjust pre-development and post-development legends so that the bins are the same
    color.
11. Comment on springs: In Dallam County, Buffalo Springs may emanate from the Rita Blanca
    instead of Ogallala/Dockum.
12. Q: Pumping in Roberts County appears low for 2010. CRMWA has meter data for their wellfield
    use for the past several years.
    A: INTERA will follow up with CRMWA.
13. Comment: Demand based pumping estimates are often 10-20% higher than metered (or
    reported) data
14. Q: What is the source of recharge in the Dockum that creates east-southeast gradient in the
    northwest portion of the model (there is no outcrop evident there).
A: Either lateral flow from outcrop areas in New Mexico, or crossformational flow from overlying units (Rita Blanca or Ogallala).

15. Comment: Instead of “playa recharge” it may be more accurate to say “recharge around playas” since studies have shown that the clay fill in the playas does not allow significant infiltration.

16. Q: When will 2010 water-in-storage numbers be available for the new model?
   A: They could be available early in 2015, when the transient model is completed in draft form.

17. Q: Does the conceptual model viewer show all wells with water level measurements?
   A: No, the wells that are shown are from the TWDB groundwater database, and contain at least five historical measurements.

18. Q: Will the model be able to estimate impacts of water level change on springs?
   A: We can calibrate to springs, only when they consist of a discrete feature and have good historical measurements. Otherwise they are treated more as potential sources for discharge, but are not a focus of calibration. So in most cases, the answer is no.

19. Q: Can this model be used at a local scale for particular well fields? Will the size of the model make it difficult to run?
   A: The model will be too coarse for simulating day-to-day wellfield operations. That would require either a submodel, or a refined version of the model. We don’t anticipate excessively long run times for the regional model, but the ability to run it will be dependent on the experience of the user.
<table>
<thead>
<tr>
<th>NAME</th>
<th>AFFILIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neil Deeds</td>
<td>INTERA</td>
</tr>
<tr>
<td>Steve Shumate</td>
<td>Panhandle Groundwater Conservation District</td>
</tr>
<tr>
<td>Ray Brady</td>
<td>Hemphill County Underground Water Conservation District</td>
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<td>C. E. Williams</td>
<td>Panhandle Groundwater Conservation District</td>
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<tr>
<td>Dale Hallmark</td>
<td>North Plains Groundwater Conservation District</td>
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<td>Steve Walthour</td>
<td>North Plains Groundwater Conservation District</td>
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<td>Bob Harden</td>
<td>R. W. Harden &amp; Associates</td>
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<td>Ben Weinheimer</td>
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<td>John Williams</td>
<td>Canadian River Municipal Water Authority/ Region A</td>
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