Groundwater Availability Modeling

Cindy Ridgeway
Contract Manager
Yegua-Jackson Aquifer “GAM”

Texas Water Development Board
what is the gam program?

• **Purpose**: to develop tools that can be used to help Groundwater Conservation Districts, Regional Water Planning Groups, 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 a groundwater model?

- model (modˈl), n. 10. a simplified representation of a system or phenomenon..... Webster’s Dictionary
- “A model is any device that represents an approximation of a field situation” Anderson and Woessner (1992)
- “a representation of reality that attempts to explain some aspect of it and is always less complex than the system it represents” Domenico (1972)
- “representation of reality” = numerical representation of a groundwater flow system
- simplified numerical representation of a complex groundwater flow system
process to develop a model

- Gather data
- Create conceptual model
- Develop model
- Calibrate to measured data
- Make predictions
- Bonus: develop graphics to help understand resource
what is the status of the models?
17 models completed for the 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.
models completed for the minor aquifers

1. Rita Blanca  
2. Blaine  
3. Woodbine  
4. Nacatoch*  
5. Queen City  
6. Sparta  
7. Lipan  
8. Igneous  
9. Parts of West Texas Bolsons  
10. Dockum  
11. Edwards-Trinity (High Plains)*

*Under going final review
models under development for the minor aquifers

1. Yegua-Jackson
2. Presidio portion of West Texas Bolsons
3. Independent model of Bone Spring-Victorio Peak
models to be completed for the minor aquifers

1. Brazos River Alluvium
2. Llano Uplift—Marble Falls, Ellenburger-San Saba, & Hickory
3. Capitan Reef Complex
4. Blossom
5. Marathon
6. Rustler (next to be modeled)
how do we use GAM?

• The model
  - predict water levels and flows in response to pumping and drought
  - effects of well fields

• Data in the model
  - water in storage
  - recharge estimates
  - hydraulic properties

• Groundwater Management Areas, Groundwater Conservation Districts and Regional Water Planning Groups can request runs
Water Code & Texas Water Development Board rules require that Groundwater Conservation Districts use GAM information, if available, for their management plans.

TWDB rules require that Regional Water Planning Groups use managed available groundwater estimates, if developed in time for the planning cycle.
Managed available groundwater (MAG)...the amount of groundwater available for use.

The State does not directly decide how much groundwater is available for use: Groundwater Conservation Districts will through Groundwater Management Area process.

A GAM is a tool that can be used to assess groundwater availability once Groundwater Conservation Districts within Groundwater Management Areas decide on the desired future condition of the aquifer.
Groundwater Conservation Districts, Regional Water Planning Groups, Texas Water Development Board, and others collect new information on aquifer.

Texas Water Development Board plans to update GAMs every five years with new information.

Please share information and ideas with TWDB on aquifers and GAMs.
GAM are living tools...

- Working on refining structure and researching recharge for Gulf Coast Aquifer from Brazos River to Rio Grande
- Working on localized model of the Seymour Aquifer
- Updating the Edwards-Trinity (Plateau) and Pecos Valley aquifers model
- Almost done working on updating the Hill Country portion of the Trinity Aquifer model
- Completed various updates to Ogallala Aquifer models, Carrizo-Wilcox Aquifer models, and southern Gulf Coast Aquifer model
participating in the GAM process

- Stakeholder Advisory Forums (SAF)
  - hear about progress on the model
  - comment on model assumptions
  - offer information (timing is important!)
  - http://www.twdb.state.tx.us/gam/GamSH.asp

- Report review
  - Conceptual model
    http://www.twdb.state.tx.us/gam/ygjk/ygjk.htm
  - at end of project

- Contact Texas Water Development Board
  - contract manager
comments:

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Web information:
www.twdb.state.tx.us/gam
Groundwater Availability Model for the Yegua-Jackson Aquifer

Stakeholder Advisory Forum #2
San Antonio, TX

April 10, 2009

Cindy Ridgeway

Van Kelley and Neil Deeds
Outline of Presentation

- Yegua-Jackson GAM Team
- What is a Conceptual Model?
- Structure
- Water Levels and Groundwater Flow
- Hydraulic Properties
- Surface Water
- Recharge and Natural Discharge
- Pumping
- Groundwater Quality
- Summary of Conceptual Model
- Review of Project Milestones and Schedule
Yegua-Jackson GAM Team

**INTERA**
- Project management
- SAF meetings
- Heads and calibration targets
- Recharge implementation
- Surface water / groundwater interaction
- Pumping data and implementation
- Water quality
- Model construction/calibration/SA
- Project reporting/deliverables

**Baer Engineering** *(Paul Knox)*
- Geology/structure

**URS** *(Steve Young)*
- Aquifer Properties

**Graham Fogg**
- Senior Technical Review
Modeling Protocol

Today’s Discussion

Define model objectives

Data compilation and analysis

Conceptual model

Model design

Calibration

Steady State*

Transient*

Verification

Prediction

Reporting

Future Water Strategies

Comparison with field data

*Includes sensitivity analysis
Conceptual Model

- Identify relevant processes and physical elements controlling flow in the aquifer:
  - Geologic Framework
  - Hydrologic Framework
  - Hydraulic Properties
  - Heads, Sources & Sinks (Water Budget)

- Determine Data Deficiencies

- The conceptual model dictates how you translate the “real world” to a mathematical model
Study Background
Yegua-Jackson Study Area
Active Model Boundary for the Yegua-Jackson Aquifer GAM

- Y-J Aquifer is considered a minor aquifer in Texas as of the 2002 State Water Plan
- Exists primarily in the outcrop and near-outcrop regions of the Yegua Formation and Jackson Group
Major Aquifers in the Study Area

Source: Online: Texas Water Development Board, March 2007
Regional Water Planning Groups
Groundwater Conservation Districts
Groundwater Management Areas

![Groundwater Management Areas Map]

Legend:
- 13: Groundwater Management Areas
- 11: Active Boundary
- 12: County Boundaries
- 14: State Line
- 15: Gulf of Mexico

Miles Scale: 0, 20, 40
River Authorities

- Guadalupe-Blanco River Authority
- Lower Colorado River Authority
- San Jacinto River Authority
- Trinity River Authority
- Lower Neches Valley Authority
- Angelina-Neches River Authority
- Sabine River Authority
- Lavaca-Navidad River Authority
- Nueces River Authority
- North Harris County RWA
- San Antonio River Authority

Miles

River Authorities
Active Boundary
County Boundaries
State Line
Gulf of Mexico
Topography
Average Annual Precipitation
Major Structural Features

Del Rio Foldbelt
Picachos Arch
Sabine Transfer Fault
Galveston Transfer Fault
Brazos Transfer Fault
Matagorda Transfer Fault
San Marcos Arch
Rio Grande Embayment
Houston Embayment
Limit of Salt Deposition

Mayor Sediment Sources

Active Boundary
State Line
Gulf of Mexico
County Boundaries
Yegua-Jackson Aquifer

Outcrop
Downdip
## Generalized Stratigraphic Section

<table>
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<th>Series</th>
<th>Group</th>
<th>Formation</th>
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<td>Whitsett</td>
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<td>Middle</td>
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<td>Cook</td>
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<td>Mountain</td>
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After Preston, 2007
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<td>Middle</td>
<td>Cook Mountain</td>
</tr>
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</table>

Knox et al., 2007
Structural Cross-section over the San Marcos Arch
Structure
Yegua-Jackson Structure Study - 2007

- Structure completed for the TWDB by INTERA and Baer Engineering in 2007
- Divided into four units based upon a sequence stratigraphy approach
  - Upper Jackson
  - Lower Jackson
  - Upper Yegua
  - Lower Yegua
- Also mapped
  - Net sand
  - Depositional Environments
  - Faults
Stratigraphic Correlation Basemap with Cross-section Lines
Base of Yegua-Jackson Aquifer

Well Locations

Active Boundary
County Boundaries
State Line
Gulf Of Mexico

Bottom of Yegua (ft)
-8,477 - -8,000
-7,999 - -7,000
-6,999 - -6,000
-5,999 - -5,000
-4,999 - -4,000
-3,999 - -3,000
-2,999 - -2,000
-1,999 - -1,000
-999 - 0
1 - 1,000

Miles
0 20 40
Top of Lower Yegua Unit
Thickness of Lower Yegua Unit
Lower Yegua Depositional Facies Map

Legend
- State Line
- Shelf Edge
- Yegua-Jackson outcrop
- County Boundaries
- Well Locations
- Sediment Input Axis
  (Size Relative to Sed. Vol.)

Facies
- Fluvial
- Floodplain < 50'
- Deltaic/Delta Front/Strandplain
- Distal Delta
- Delta Margin < 50'
- Shelf
- Shelf Margin < 50'
- Shelf Channel
- Shelf Edge Delta
- Slope
- Shelf/Slope Sand > 50'

Miles
0 10 20 40 60
Upper Yegua depositional facies map
Upper Jackson depositional facies map
Water Levels
Water Levels

- **Data Sources**
  - TWDB well database
  - USGS Groundwater for the Nation

- **Objectives**
  - Regional groundwater flow
  - Estimate steady-state conditions in the aquifer
  - Estimate conditions in the aquifer at the beginning, middle, and end of the transient model calibration (i.e., 1980, 1990, and 1997)
  - Evaluate transient water-level conditions
  - Evaluate cross-formational flow

- **Evaluated individually for the four aquifer layers**
  - Compared completion interval or total depth to structural top and bottom of aquifer layers
  - Used only data for which a layer could be determined
Locations with Water-Level Data
Regional Groundwater Flow

- **Outcrop areas**
  - Influenced by topography
  - Flow is from topographic highs along drainage divides to topographic lows in creeks and rivers

- **Confined portion**
  - Flows horizontally along the dip of the aquifer
  - Flows vertically across formations
  - Dip of the land and the aquifer is towards the Gulf of Mexico
Steady-State Water Levels

- Some pumping for rural domestic, livestock and municipal purposes as early as 1900
  - Relatively small and likely did not result in significant drawdown
- Water-level data prior to 1950 was assumed to be representative of steady-state conditions
- Data insufficient to contour
  - Relationship between ground surface and water levels explored
  - Steady-state surface produced from this relationship
  - In the end, the calibrated model will provide the best estimate of steady-state heads
Transient Water Levels – Upper Jackson Unit

- **Trinity County**
  - Water-Level Elevation (feet): 38-62-801
  - Year range: 1930 to 2010

- **Polk County**
  - Water-Level Elevation (feet): 37-57-702
  - Year range: 1930 to 2010

- **Grimes County**
  - Water-Level Elevation (feet): 60-17-201
  - Year range: 1930 to 2010

- **Fayette County**
  - Water-Level Elevation (feet): 59-58-301
  - Year range: 1930 to 2010

- **Grimes County**
  - Water-Level Elevation (feet): 59-32-701
  - Year range: 1930 to 2010
Transient Water Levels – Upper Jackson Unit (cont’d)
Transient Water Levels – Upper Yegua Unit

Grimes County

Trinity County

Fayette County

Karnes County

Angelina County

Water-Level Elevation (feet)

Year

Water-Level Elevation (feet)

Year

Water-Level Elevation (feet)

Year

Water-Level Elevation (feet)

Year

Water-Level Elevation (feet)

Year
Transient Water Levels – Upper Yegua Unit (cont’d)
Transient Water Levels – Lower Yegua Unit

- 59-15-602
  - Grimes County

- 37-42-602
  - Angelina County

- 36-41-205
  - Sabine County

- 86-15-604
  - Zapata County

- 86-16-705
  - Zapata County
Hydraulic Properties
Information Sources for Estimating Hydraulic Properties

- Lithologic data available from Knox (2007) study of the Yegua-Jackson structure
- Aquifer descriptions from USGS and TWDB reports
- No data available from Myers (1969)
- Pumping Test Results available from Texas Commission on Environmental Quality
- Hydraulic Properties available in the Oil & Gas Literature
Results from TCEQ Public Water Supply Pumping Tests

- **75 Pumping Tests were Identify within Yegua-Jackson footprint**

- **Screening Process Eliminate about 50% of wells**
  - Well screen information missing or questionable
  - Well screen interval above the aquifer
  - Drawdown data could not be analyzed using Cooper-Jacob straight-line analysis method

- **41 of the Pumping Tests were Accepted**
  - Constant pumping rate for several hours
  - Lithological information available from driller logs
  - Cooper Jacob fit $R^2$ greater than 0.80
## Summary of Pumping Test Results

<table>
<thead>
<tr>
<th>Geologic Unit</th>
<th>Number of Tests</th>
<th>Average Depth of Test</th>
<th>Hydraulic Conductivity (ft/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arithmetic Mean</td>
</tr>
<tr>
<td>Upper Jackson</td>
<td>14</td>
<td>539</td>
<td>6.6</td>
</tr>
<tr>
<td>Lower Jackson</td>
<td>1</td>
<td>605</td>
<td>12</td>
</tr>
<tr>
<td>Upper Yegua</td>
<td>11</td>
<td>408</td>
<td>9.9</td>
</tr>
<tr>
<td>Lower Yegua</td>
<td>11</td>
<td>610</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Note: At least 60% of well screen required to intersect the geologic unit
Relationship Between Conductivity and Sand Percent

- **Lower Yegua**
  - Linear Regression: $R^2 = 0.58$

- **Upper Jackson**
  - Linear Regression: $R^2 = 0.2009$

- **Upper Yegua**
  - Linear Regression: $R^2 = 0.6161$
Approach for Generating Hydraulic Properties

- **Highlights from Pumping Tests Analysis**
  - Hydraulic conductivity values (2 to 20 ft/day) form TCEQ information consistent with limited values from other reports
  - Most information in up-dip regions, limited data from down-dip regions

- **Approach for Populating Hydraulic Conductivity Field**
  - Use guidelines and relationships between geologic properties and hydraulic properties extracted from field data and other studies
  - Use depositional facies and lithology from Knox and others (2007)
  - Consider relationships developed by oil & gas geoscientists from Yegua-Jackson and Gulf Coast deposits
  - Consider relationships developed from TWDB GAM studies
Bed Thickness and Sand Percentage – Fluvial Facies

![Diagram showing bed thickness and sand percentage for different geological formations.]

- **Bed Thickness (ft)**
  - >80
  - 60-80
  - 40-60
  - 20-40
  - 0-20

- **Percentage Sand in Geological Formation**
  - >80
  - 60-80
  - 40-60
  - 20-40
  - 0-20

- **Percentage Clay in Geological Formation**
  - >80
  - 60-80
  - 40-60
  - 20-40
  - 0-20
Bed Thickness and Sand Percentage – Deltaic Facies

- Upper Jackson
- Lower Jackson
- Upper Yegua
- Lower Yegua

Sand Percentage

<table>
<thead>
<tr>
<th>Percentage Sand in Geological Formation</th>
<th>Bed Thickness (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;80</td>
<td>&gt;80</td>
</tr>
<tr>
<td>60-80</td>
<td>60-80</td>
</tr>
<tr>
<td>40-60</td>
<td>40-60</td>
</tr>
<tr>
<td>20-40</td>
<td>20-40</td>
</tr>
<tr>
<td>0-20</td>
<td>0-20</td>
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</table>

Clay Percentage

<table>
<thead>
<tr>
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<th>Bed Thickness (ft)</th>
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<tr>
<td>&gt;80</td>
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<td>40-60</td>
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<td>20-40</td>
<td>20-40</td>
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<tr>
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Porosity and Permeability Data from Oil and Gas Studies

<table>
<thead>
<tr>
<th>Geological Formations</th>
<th>Porosity Loss per 1000 ft of depth of burial</th>
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<tbody>
<tr>
<td>Miocene</td>
<td>1.34</td>
</tr>
<tr>
<td>Frio</td>
<td></td>
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<tr>
<td>Areas 1-6</td>
<td>1.28</td>
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<td>Areas 1-3</td>
<td>1.48</td>
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<tr>
<td>Areas 4-6</td>
<td>2.05</td>
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<td>Vicksburg</td>
<td>1.32</td>
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<tr>
<td>Jackson/Yegua</td>
<td>2.28</td>
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<tr>
<td>Queen City</td>
<td>1.86</td>
</tr>
<tr>
<td>Wilcox</td>
<td>1.51</td>
</tr>
</tbody>
</table>

Transmissivity can be estimated by multiplying the total amount of sand in a geological unit by the average hydraulic conductivity of the sand in the unit.

Within a geologic unit, the hydraulic conductivity among different sand bodies will vary and one of the factors that affects this variation is the depositional facies of the sand.

Hydraulic conductivity decreases as a function of depth.
# Initial Assumptions Regarding Hydraulic Conductivity Field

## Geology Unit

<table>
<thead>
<tr>
<th>Geology Unit</th>
<th>Major Facies Groupings</th>
<th>Hydraulic Conductivity (ft/day)</th>
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<tr>
<td></td>
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<td>Sand</td>
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<tr>
<td>Upper Jackson</td>
<td>Fluvial</td>
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<tr>
<td></td>
<td>Delta</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Shelf</td>
<td>5</td>
</tr>
<tr>
<td>Lower Jackson</td>
<td>Fluvial</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Delta</td>
<td>8</td>
</tr>
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<td></td>
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<tr>
<td></td>
<td>Shelf</td>
<td>5</td>
</tr>
</tbody>
</table>

## Diagram

- **Porosity (%)**
- **Depth (ft)**
- **Hydraulic Conductivity (ft/day)**

- **Porosity (%)**
  - 0 to 40
- **Depth (ft)**
  - 0 to 7000
- **K (ft/day)**
  - 0 to 25.0
Estimated Transmissivity – Upper Jackson
Estimated Transmissivity – Lower Yegua
Vertical Conductivity

- Weighted harmonic mean

\[ Kv = \frac{B}{(bs/Kvs) + (bc/Kvc)} \]

- Initial values of 0.0003 ft/day for all clay deposits and 0.02 ft/day for all sand deposits, after Young and others (2008)

\( Kv \) = effective vertical hydraulic conductivity of deposit
\( Kvs \) = vertical hydraulic conductivity of sand
\( bs \) = total layer thickness of sand deposits
\( Kvc \) = horizontal hydraulic conductivity of clay
\( bc \) = total layer thickness of clay deposits
\( B \) = total aquifer thickness
Storage

Shestakov (2002)

\[ S_s = A / [D + z_0] \]

A and z0 are parameters, and D is depth.
Surface Water
Major Rivers

- Neches River
- Sabine River
- Colorado River
- Trinity River
- Trinity River
- Rio Grande
- Neches River
- Sabine River
- Colorado River
- Trinity River
- Trinity River
- Rio Grande

Yegua-Jackson Aquifer

- Outcrop
- Downdip
Flow Exceedance Curves

- Trinity
- Colorado
- San Antonio
- Nueces

Fraction of Time Exceeded

Daily Flow (cfs)

Study Number
- 49
- 54
- 349-350
- 140-142
- 159
- 192-193

Legend:
- Active Boundary
- County Boundaries
- Lakes and Reservoirs
- Rivers and Streams
- Yegua-Jackson Aquifer
  - Outcrop
  - Downdip
Other Gain-Loss Studies

- San Antonio River: +724 afy/mi
- Cibolo Creek: 0 afy/mi
- Colorado River: -22 cfs

represents the only estimated loss for the study
Illustration of Hydrograph Separation
Hydrograph Separation Results

![Map of hydrograph separation results with various data points and annotations. The map includes symbols for gage locations, active boundaries, county boundaries, lakes and reservoirs, and rivers and streams. The legend indicates the gain in acre-feet/year/mile and the fraction of time flowing at different locations.](image-url)
Hydrograph Separation Results

Gain (acre-feet/year/mile) Fraction of Time Flowing

- Gage Location
- Active Boundary
- County Boundaries
- Lakes and Reservoirs
- Rivers and Streams
- Yegua-Jackson Aquifer
- Outcrop
- Downdip

Legend
Springs

Spring Locations and Source
- United States Geological Survey
- Brune (2002)

- Active Boundary
- County Boundaries
- State Line
- Gulf Of Mexico

Yegua-Jackson Aquifer
- Outcrop
- Downdip
Reservoirs

- Sam Rayburn Reservoir
- Toledo Bend Reservoir
- Lake Livingston
- Gibbons Creek Reservoir
- Somerville Lake
- Choke Canyon Reservoir
- International Falcon Reservoir

Yegua-Jackson Aquifer

- Outcrop
- Downdip

Legend:
- Reservoirs
- Active Boundary
- County Boundaries
- State Line
- Gulf Of Mexico
Recharge and Natural Discharge
Recharge

Conceptualization of Shallow Recharge and Discharge
Recharge

Conceptualization of Deep Recharge and Discharge

Base of Slightly Saline Water

Older Formations

Younger Formations

Upper Jackson
Lower Jackson
Upper Yegua
Lower Yegua
**Recharge: A Conceptual Water Balance**

<table>
<thead>
<tr>
<th>Process</th>
<th>Value (in/yr)</th>
<th>Percentage</th>
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<tr>
<td>Evapotranspiration</td>
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<td>Precipitation</td>
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<td>Runoff</td>
<td>6</td>
<td>15%</td>
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<td>Shallow Recharge</td>
<td>0.55</td>
<td>1.4%</td>
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<td>Local Discharge</td>
<td>0.35</td>
<td>0.9%</td>
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<td>0.5%</td>
</tr>
</tbody>
</table>

Approximate values for central portion of the model region, e.g. Fayette County
Relating Recharge and Discharge

- Components of shallow recharge can be determined by estimating discharge components.
- Baseflow is assumed to be a major component of shallow discharge.
- Discharge through groundwater evapotranspiration is assumed to be less than that of baseflow.
- Shallow recharge estimated through baseflow should be considered a minimum value, due to the unknown impact of groundwater evapotranspiration.
Catchment Areas for Gages where Hydrograph Separation was Performed
Relationship between Precipitation and Baseflow

- Hypothesize that some long-term average relationship exists between precipitation and baseflow
- Take annual average precipitation over a given catchment area and regress versus annual basflow, with a time lag of several months
- Use general relationship to distribute recharge with precipitation
- Irrigation return flow is considered to have a minimal impact on recharge for the Yegua-Jackson
  - Only small amounts of irrigation pumping
  - Surface water use for irrigation (primarily Rio Grande) mostly outside the outcrop areas in Starr and Webb counties
Relationship between annual recharge and annual precipitation

8038500

8065800

8066100

8110000
Recharge

Recharge = \(10^{(0.032 \times \text{precipitation} - 1.78)} + \text{(deep recharge)}\)

Deep recharge estimate of 0.2 in/yr deep recharge from report for Grimes County
Estimate of Average Recharge

- Estimates may be high in southwestern portion of the region (few constraints available)
- Slade (2002) studies show some gaining streams in the southwestern area which is at odds with conventional wisdom
Variation of Recharge with Topography

- Recharge highest in upland areas and lowest in lowland areas
- This approach improves model calibration in the outcrop
Vertical soil conductivity estimated from SSURGO

- SSURGO soil horizons harmonically averaged
- Weighted geometric average taken for each spatial unit, based on existing percentage
Vertical soil conductivity estimated from SSURGO
Potential Evapotranspiration (ET)

Potential ET (in/yr):
- 72
- 51

Active Boundary:
State Line:
Gulf of Mexico:
County Boundaries:

Miles
ET: GAP Vegetation Classification

- TX-GAP program provides relatively detailed estimates of vegetation types
- Vegetation types compared between riparian buffer areas and overall outcrop area
Little difference evident between riparian and overall outcrop regions.
ET: Estimating Vegetation Coefficients and Rooting Depths

ETVmax = PET * Kc

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Kc</th>
<th>Rooting Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesquite</td>
<td>0.54</td>
<td>6 to 50</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.70</td>
<td>2</td>
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<tr>
<td>Pine</td>
<td>0.53</td>
<td>7</td>
</tr>
<tr>
<td>Post Oak</td>
<td>0.5*</td>
<td>5.*</td>
</tr>
<tr>
<td>Cropland</td>
<td>0.6*</td>
<td>1</td>
</tr>
</tbody>
</table>
Discharge through Pumping
Pumping discharge estimates developed for both the calibration period (1980-1997) and the period before calibration (1900 – 1980).

Assume that significant pumping from Yegua-Jackson comes only from outcrop portions
- Further down-dip, water quality is poor, and the more productive Gulf Coast Aquifer system is typically used
- Only counties with some part of Yegua-Jackson outcrop were selected

Calibration period has annual pumping for each county and each category
- Categories are: municipal, manufacturing, mining, agriculture, livestock, and rural-domestic

Pre-Calibration period has decadal pumping for each county and each category
Estimates of groundwater pumping throughout Texas for the transient calibration period (1980 – 1997) are provided in the TWDB pumping geodatabase (pumpamatic).

Pumpamatic has pumping estimates for municipal, manufacturing, power generation, mining, livestock, and irrigation.

Rural-Domestic pumping was estimated from county-specific rural population (obtained from TWDB census blocks shape file) and per-capita annual GW usage factors provided in the TWDB geodatabase.

- Pumpamatic does not explicitly identify Yegua-Jackson as a GW source in the pumpamatic (lumped as “Other Aquifer”)

- Proportion of ‘Other Aquifer’ pumping for Yegua-Jackson was decided on a county-by-county basis

- County reports were used to come up with a list of all minor aquifers that could potentially be part of the ‘other aquifer’ category.
  - For counties where such reports were unavailable, information from neighboring counties and spatial coverages of water-bearing outcropping formations were used
Pre-1980 Pumping

- Rough estimated of pumping history were generated using a combination of sources to account for groundwater withdrawals before 1980
  - TWDB wells database
  - Published County reports
  - 1981 TWDB Inventory of Irrigation in Texas

- Due to the poor temporal resolution of available information, average pumping was estimated over 10 year periods

- The TWDB wells database was primarily used to identify the earliest period for pumping from Yegua-Jackson Aquifer
  - In most cases rural-domestic pumping was reported as far back as the 1900s
Pumping Results - Discussion

- Period between 1900 and 1980 has a step-like pumping curve, due to the decadal estimates.
- Rural domestic and livestock are the largest pumping types in most cases.
- Irrigation is typically not a significant pumping category.
- All pre-1980 pumping ‘ramp up’ to calibration period estimates since the 1980 – 1989 decadal average is used in the interpolation of intermediate decades.
- Some representative pumping results are shown in following slides.
Representative Pumping Results

- Pumping estimates for Angelina county
  - Has the highest total pumping from Yegua-Jackson
  - Rural domestic pumping is the most significant category post 1980
  - Municipal and manufacturing are significant pre 1980
  - Steady increasing trend in pre-1980 estimates
Representative Pumping Results

- **Pumping estimates for Nacogdoches county**
  - Rural-domestic and municipal are the two major pumping categories
  - Pre-1980 pumping peaks in the 1960s
Representative Pumping Results

- **Pumping estimates for Wilson county**
  - Like many other counties, rural-domestic is the only significant pumping category
Water Quality
Water Quality

- Water quality can vary dramatically over short distances in the Yegua-Jackson Aquifer.
- Water quality is generally poor a short distance downdip of the outcrop.
- Based on measurements in the TWDB groundwater database, common constituents exceed MCLs for a significant percentage of measurements in many wells.
Water Quality: TDS

- Total dissolved solids estimate modified from Pettijohn and others (1988)
- TDS generally increases from northeast to southwest
Water Quality: TDS

- Total dissolved solids estimated from TWDB groundwater database values
- Most recent values used for a given well
- TDS generally increases from northeast to southwest
- Long term trends not assessed due to lack of multiple temporally spaced measurements
Water Quality: Yegua Salinity Hazard

- Salinity Hazard is one indicator of irrigation water quality
- For the Yegua Formation, 81 percent of measurements exhibit a high salinity hazard, and 28 percent of the wells have exhibited a very high salinity hazard.
Salinity Hazard is one indicator of irrigation water quality.

For the Jackson Group, 77 percent of the wells exhibit a high salinity hazard, and 34 percent of the wells exhibit a very high salinity hazard.
Summary of the Conceptual Model
Water input through areal recharge and losing streams or other surface water bodies

Water output through shallow discharge and cross-formational flow

Downdip flow decreases quickly with depth

A minimal amount of cross-formational flow occurs between the Lower Yegua and the older formations, but we will approximate with a no-flow boundary
No flow boundaries downdip and at the base of the Yegua

After development, pumping would be included as a discharge component.
## Schedule

<table>
<thead>
<tr>
<th>Project Task</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td></td>
<td>J</td>
<td>F</td>
<td>M</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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<tr>
<td>2.3 Stakeholder and TWDB Seminar</td>
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<td>3.0 Model Development</td>
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<tr>
<td>3.1 Data Collection and Conceptual Model</td>
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<tr>
<td>3.2 Model Design</td>
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<tr>
<td>4.0 Model Calibration</td>
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<tr>
<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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<tr>
<td>5.0 Documentation &amp; Tech. Transfer</td>
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<tr>
<td>5.1 Data Model Documentation</td>
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<tr>
<td>5.2 Reporting</td>
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### Reporting deliverables:
- **Final Model Report**: Final Model Report (1/28/10)  
- **TWDB & Stakeholder Training**: TWDB Technical Review Meeting, SAF Meeting
Thank You

Questions
Meeting Minutes for the Second Yegua-Jackson Groundwater Availability Model (GAM) Stakeholder Advisory Forum (SAF) Meeting

April 10, 2009

San Antonio River Authority Board Room
100 E. Guenther Street
San Antonio, Texas

The second Stakeholder Advisory Forum (SAF) Meeting for the Yegua-Jackson Groundwater Availability Model (GAM) was held on Friday, April 10th, 2009 at 1:30 PM at the San Antonio River Authority Board Room, 100 E. Guenther Street in San Antonio. A list of meeting participants is provided at the end of these meeting notes.

The primary purpose of the first SAF meeting was to provide an introduction to the Yegua-Jackson GAM Team and their proposed approach to developing the model and to solicit input from stakeholders including any available data that could be made public. The meeting also provided a forum for discussing the project schedule and provided an opportunity for feedback from stakeholders.

Meeting Introduction: Cindy Ridgeway, TWDB

The meeting was initiated by Ms. Cindy Ridgeway of the Texas Water Development Board (TWDB). She gave a brief introduction to the GAM Program and discussed how GAMs are used in Texas water resources planning. She then discussed GAMs and how they relate to Managed Available Groundwater as well as the importance of the stakeholder process.

SAF Presentation: Neil Deeds and Van Kelley, INTERA Inc

Neil Deeds and Van Kelley (INTERA) presented a prepared presentation structured according to the following outline:

1. Yegua-Jackson GAM Team
2. What is a Conceptual Model?
3. Structure
4. Water Levels and Groundwater Flow
5. Hydraulic Properties
6. Surface Water
7. Recharge and Natural Discharge
8. Pumping
9. Groundwater Quality
10. Summary of Conceptual Model
11. Review of Project Milestones and Schedule
The presentation is available on the GAM website:
(http://www.twdb.state.tx.us/gam/ygjk/ygjk.htm)

Questions and Answers: Cindy Ridgeway (TWDB) Presentation:

Q: Does the Queen City and Sparta Aquifer extend west past the Frio River? In the official TWDB outline, the aquifer appears to end at the Frio.
A: The analogous sediments extend past the Frio River, but the TWDB delineation terminates due to the water quality degradation. The Queen City and Sparta GAM does model the sediments west of the Frio River.

Questions and Answers: Van Kelley and Neil Deeds (INTERA) Presentation:

Q: In the Yegua-Jackson Aquifer does the water turn saline in the downdip portion?
A: Yes, the water quality degrades quickly in the Yegua-Jackson moving downdip from the outcrop. Most of the fresh to slightly-saline water is in the actual outcrop or in the near downdip (10s of miles) regions of the aquifer.

Q: Will the formation be more or less productive downdip?
A: Although we do not have well tests to prove it, our working conceptualization is that the formation will be less productive downdip. The hydraulic properties section of the conceptual model report details why this is likely the case.

Q: Is the Catahoula Formation part of the Gulf Coast Aquifer?
A: The Catahoula is considered part of the Gulf Coast Aquifer in the outcrop portion, but the water quality degrades significantly moving downdip.

Q: Is this the first time that the chronostratigraphic approach was used for delineating the aquifer structure in a Texas GAM?
A: This is the first time for a GAM. However, the same approach is being used to delineate the structure of the Gulf Coast aquifer for the entire state, to support the update of the Gulf Coast GAMs. Also, this approach was used to develop the Gulf Coast Aquifer model for the LCRA-SAWS water project.

Q: In reference to the structure map, are the wells that serve as control points predominantly oil wells?
A: Yes. Because there is so little fresh water in the downdip portion of the aquifer, logs from water wells were not available as a source. Conversely, the oil well logs often did not extend into the shallower portions, making data selection a challenge at times.
Q: In reference to the water level hydrographs, who monitors the water levels in the wells? How are these wells identified for a particular aquifer?
A: Water level measurements are either made by TWDB staff, USGS staff, or other local entities such as GCDs. The TWDB has a comprehensive database of water level information that is available on their website. Information about very early water levels can sometimes be found in county reports. The aquifer structure was used in association with information about screen depths to locate wells in particular units.

Q: In reference to the hydrograph separation results, why does the San Antonio River show flow only 77% of the time?
A: The gage on which the hydrograph separation was performed was not on the main channel of the San Antonio, but rather on a feeder creek. One of the difficulties with hydrograph separation is that the gage must be for a mostly uncontrolled catchment, a condition that is rare for the main river channels.
### Attendance

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Dub Smothers</td>
<td>Concerned Citizen</td>
</tr>
<tr>
<td>Rudy R. Farias</td>
<td>SARA</td>
</tr>
<tr>
<td>Melissa Bryant</td>
<td>SARA</td>
</tr>
<tr>
<td>Steve Raabe</td>
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<tr>
<td>Landon Yosko</td>
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<tr>
<td>Van Kelley</td>
<td>INTERA</td>
</tr>
<tr>
<td>Neil Deeds</td>
<td>INTERA</td>
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<tr>
<td>Cindy Ridgeway</td>
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