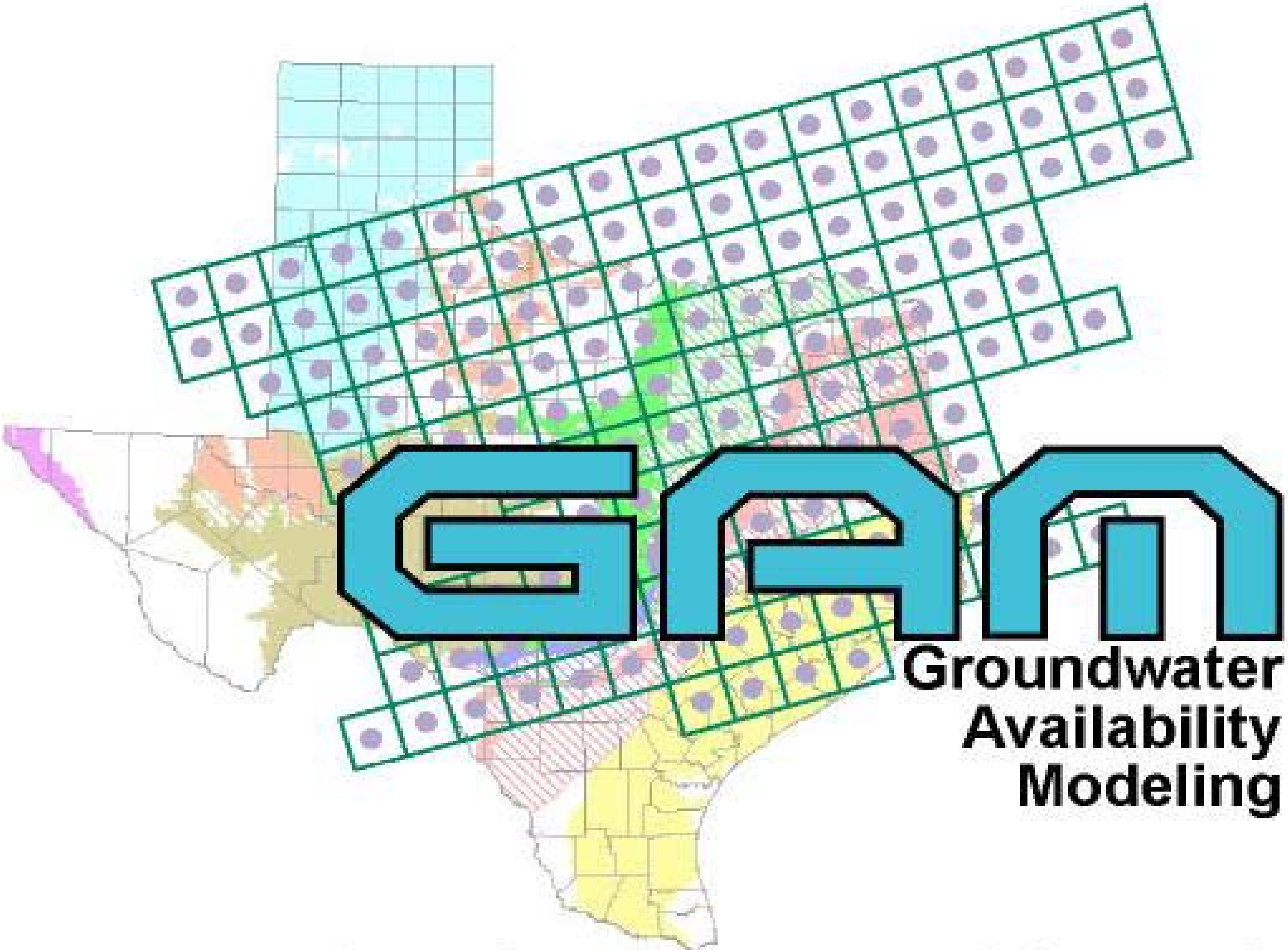
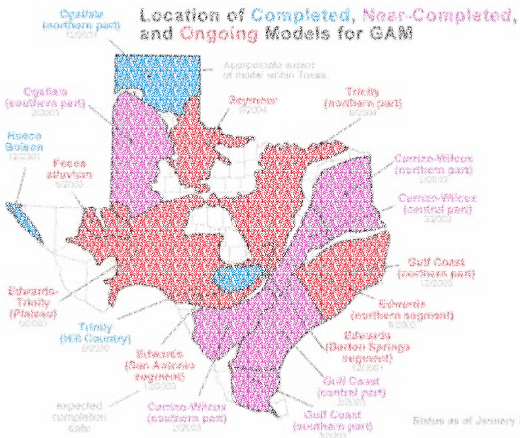
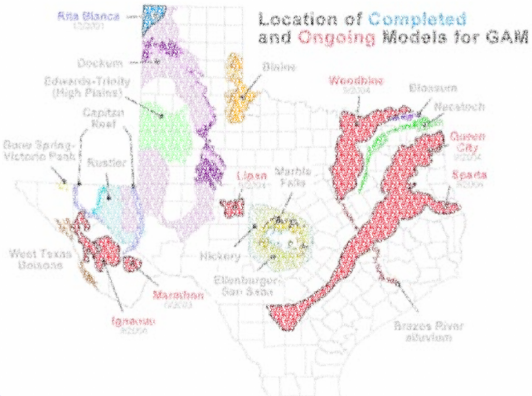


Groundwater
Availability
Modeling

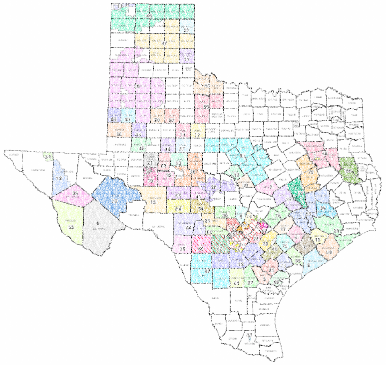
texas water development board

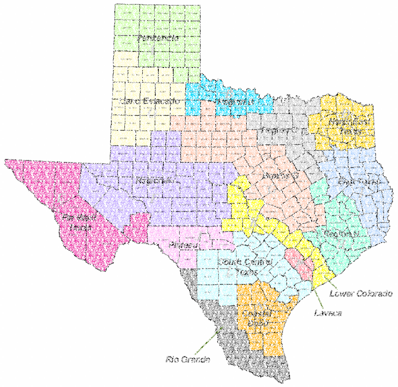
Groundwater Availability Modeling



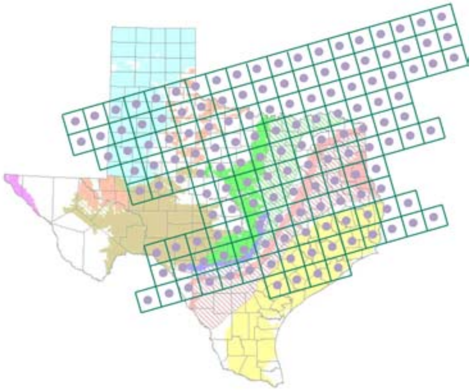


Cindy Ridgeway
Contract Manager





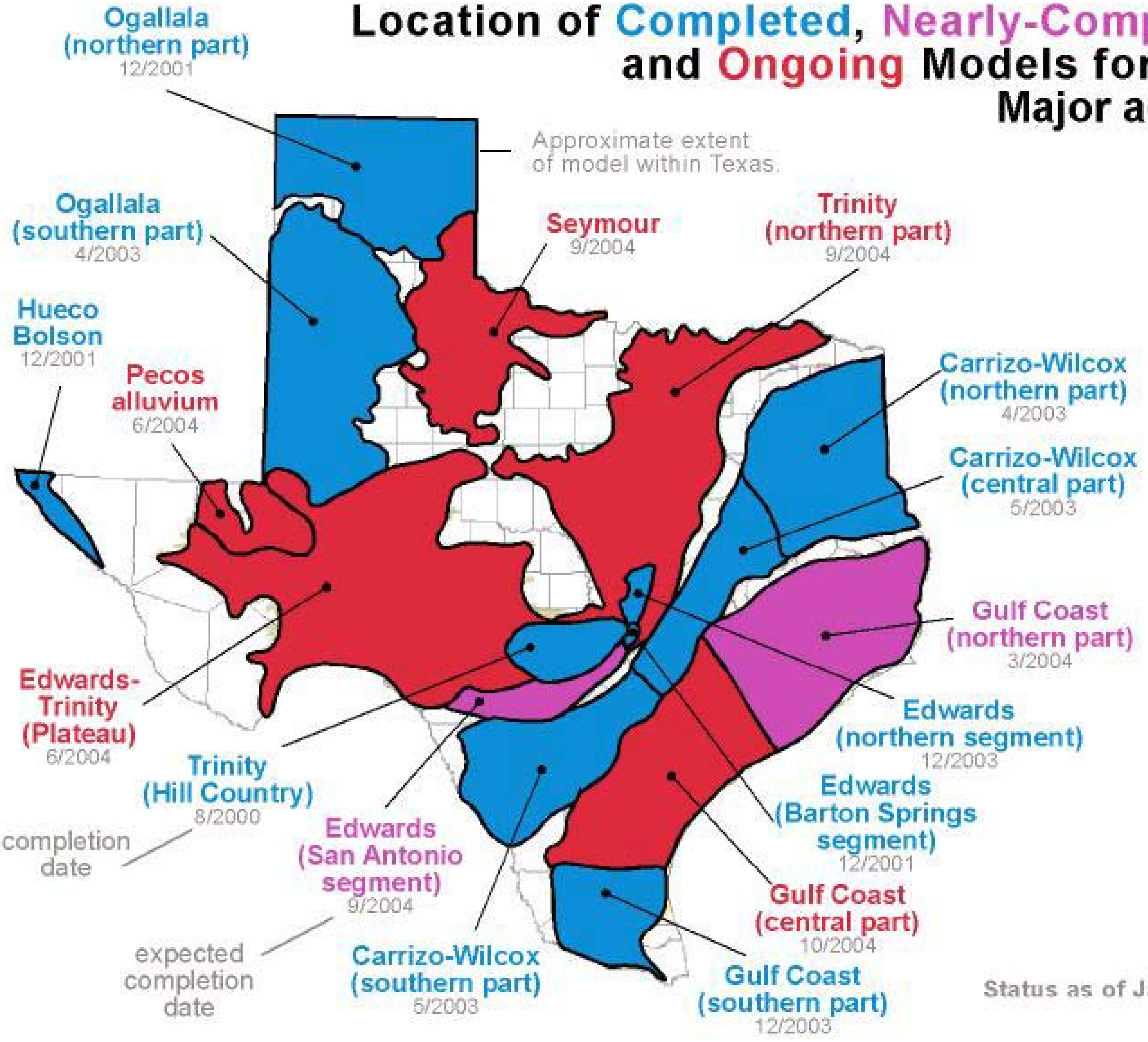
Texas Water Development Board



GAM

- Purpose: to develop the best possible groundwater availability model with the available time and money.
- Public process: you get to see how the model is put together.
- Freely available: standardized, thoroughly documented, and available over the internet.
- Living tools: periodically updated.

Location of Completed, Nearly-Completed, and Ongoing Models for GAM: Major aquifers



Approximate extent of model within Texas.

Ogallala (northern part)
12/2001

Ogallala (southern part)
4/2003

Hueco Bolson
12/2001

Pecos alluvium
6/2004

Seymour
9/2004

Trinity (northern part)
9/2004

Carrizo-Wilcox (northern part)
4/2003

Carrizo-Wilcox (central part)
5/2003

Gulf Coast (northern part)
3/2004

Edwards (northern segment)
12/2003

Edwards (Barton Springs segment)
12/2001

Gulf Coast (central part)
10/2004

Gulf Coast (southern part)
12/2003

Carrizo-Wilcox (southern part)
5/2003

Edwards (San Antonio segment)
9/2004

Trinity (Hill Country)
8/2000

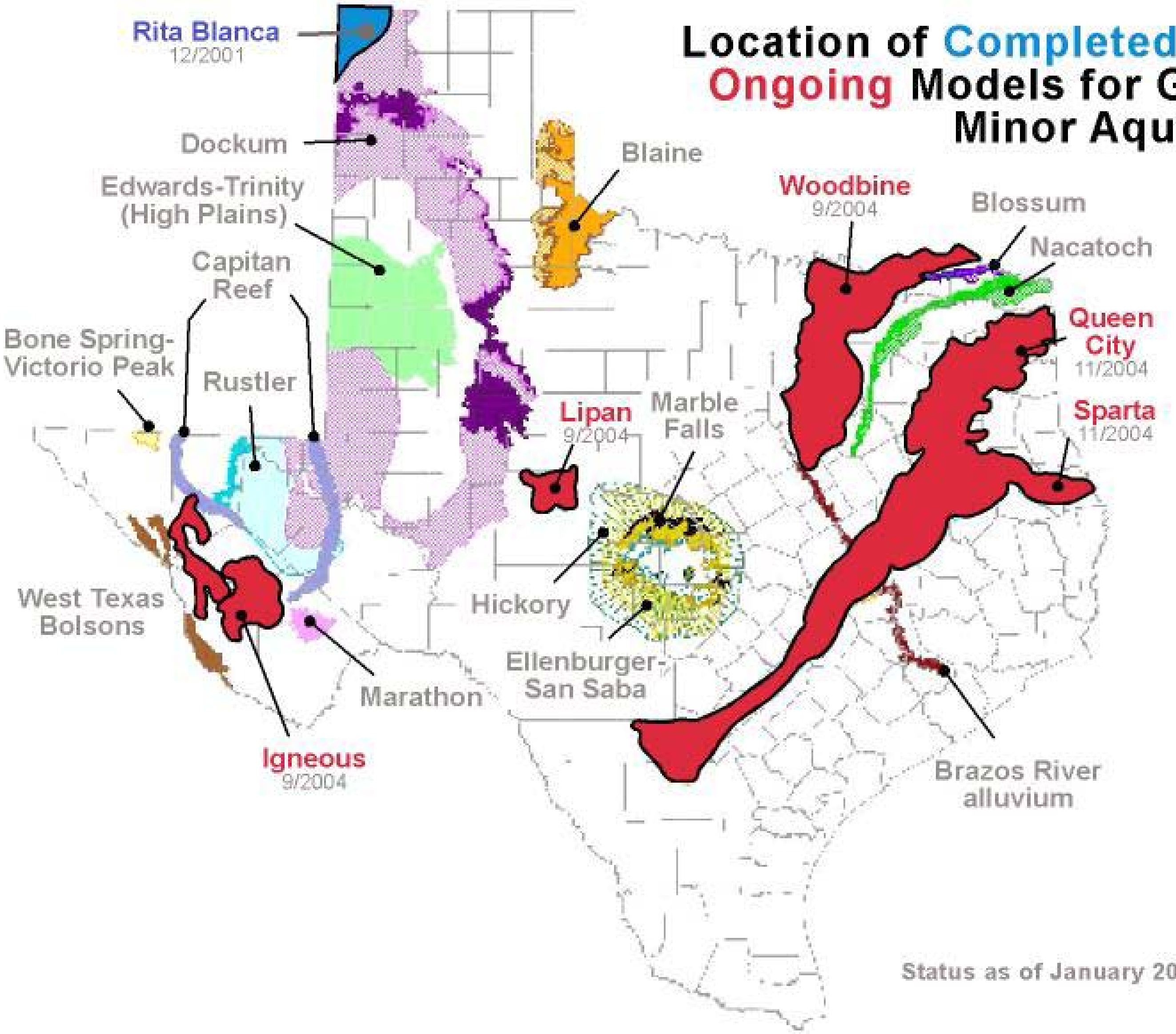
Edwards-Trinity (Plateau)
6/2004

completion date

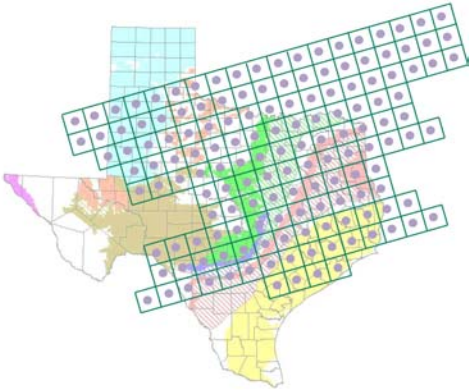
expected completion date

Status as of January 2004

Location of Completed and Ongoing Models for GAM: Minor Aquifers

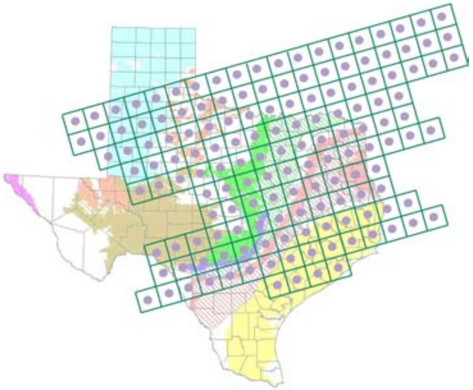


Status as of January 2004



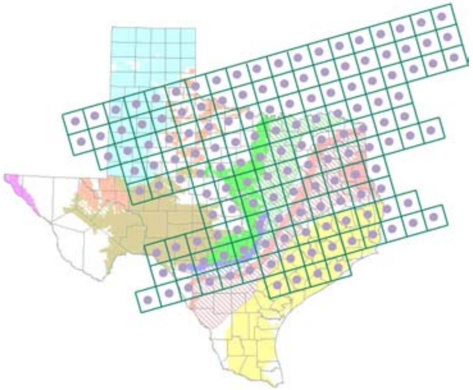
What is groundwater availability?

- …the amount of groundwater available for use.
- The State does not decide how much groundwater is available for use: GCDs and RWPGs decide.
- A GAM is a <u>tool</u> that can be used to assess groundwater availability once GCDs and RWPGs decide how to define groundwater availability.



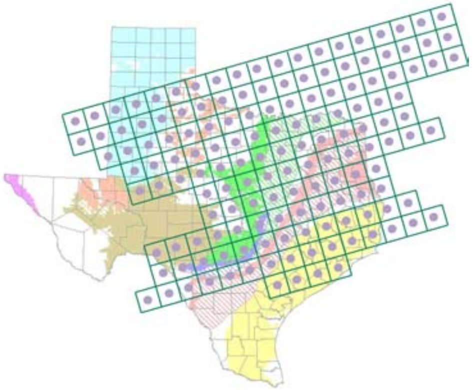
How do we use GAM?

- The model
  - predict water levels and flows in response to
  - effects of well fields
- Data in the model
  - water in storage
  - recharge estimates
  - hydraulic properties
- GCDs and RWPGs can request runs



Do we have to use GAM?

- Water Code & TWDB rules require that GCDs
- TWDB rules require that RWPGs use GAM

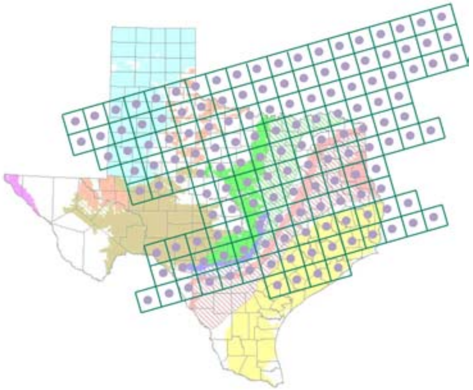


Living

Tools

- GCDs, RWPGs, TWDB, and others collect new
- This information can enhance the current
- TWDB plans to update GAMs every five years
- Please share information and ideas with TWDB

Participating in the GAM Process



- SAF meetings
  - hear about progress on the model
  - comment on model assumptions
- Report review
  - Happening now! Final Draft Report posted on TWDB website.
  - http://www.twdb.state.tx.us/gam/symr/symr.htm
  - Please read it and feel free to offer suggestions, comments, or
- Contact TWDB
  - Cindy Ridgeway (512) 936-2386 or Robert Mace (512) 936-

Contract Manager
cindy.ridgeway@twdb.state.tx.us
(512)936-2386
www.twdb.state.tx.us/gam

Groundwater Availability Modeling (GAM) for the Seymour Aquifer

Fourth Stakeholder Advisory Forum

April 1, 2004

Groundwater Availability Modeling
texas water development board

INTERA

WPRC

ENPROTEC
Engineering solutions with a view for tomorrow.

PARSONS

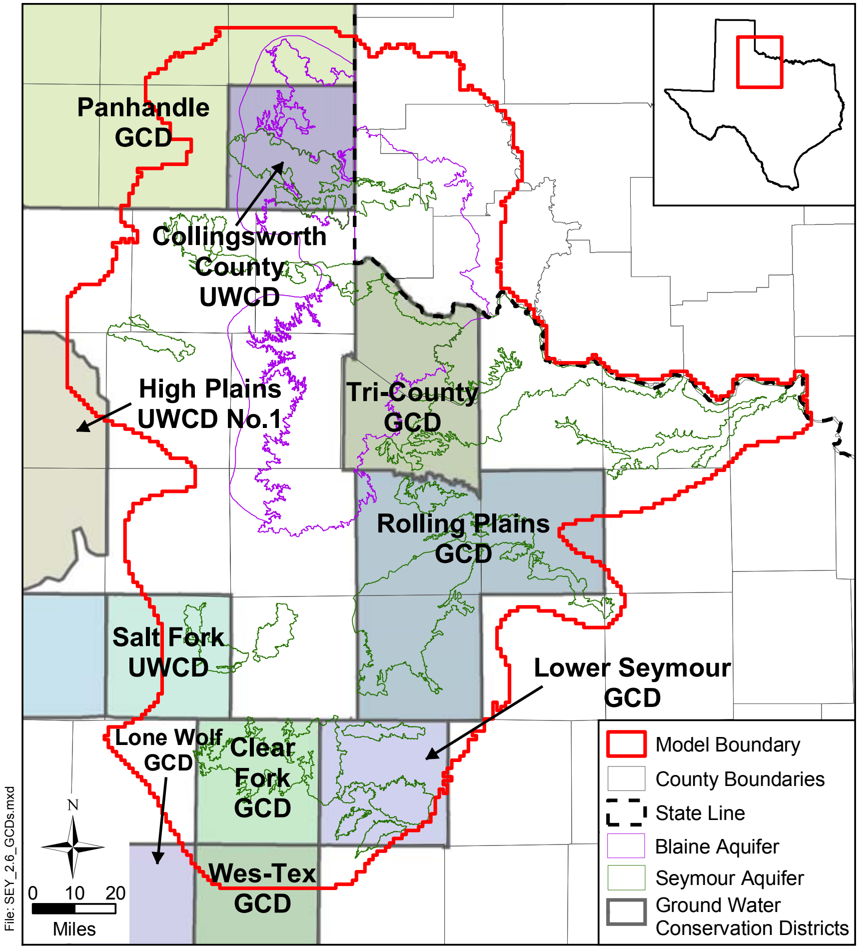
Outline of Presentation

- Aquifer Review
- Draft Report Overview
- Model Design
- Conceptual Model
- Model Implementation
- Steady-State Model
- Transient Model Results
- Drought of Record
- Predictive Model Results
- Conclusions
- Model Limitations and Future Improvements
- GAM Schedule

Aquifer Review

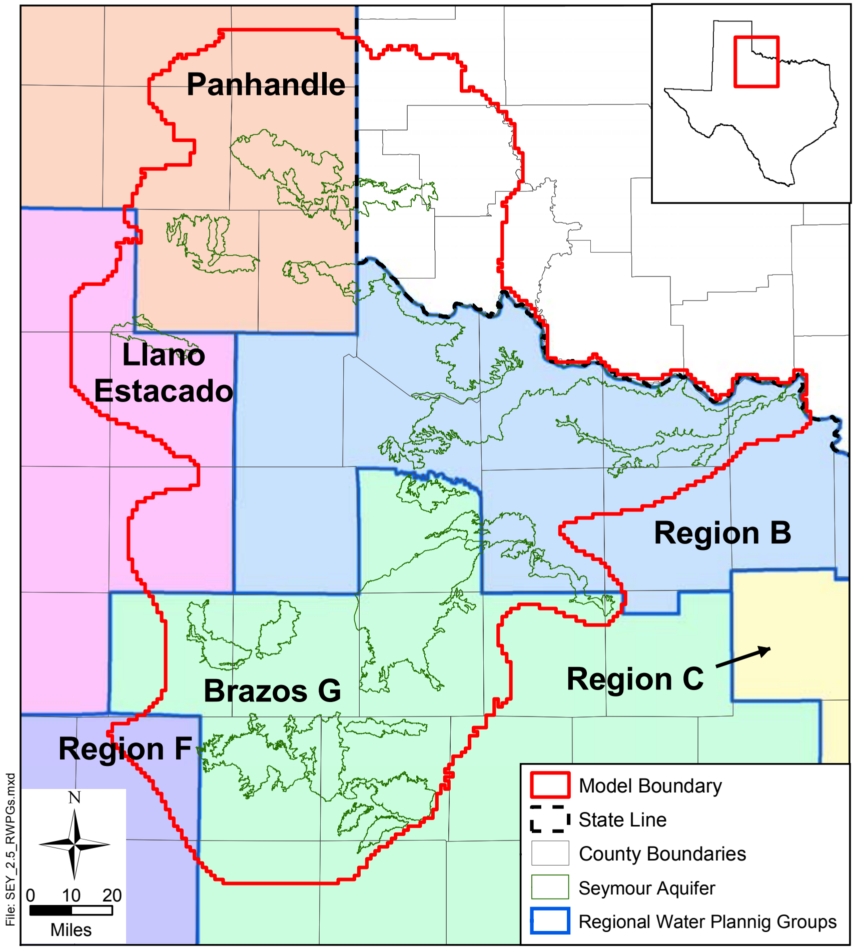
Aquifer Location

GCDs and UWCDs



Source: Online: Texas Water Development Board, August 2003

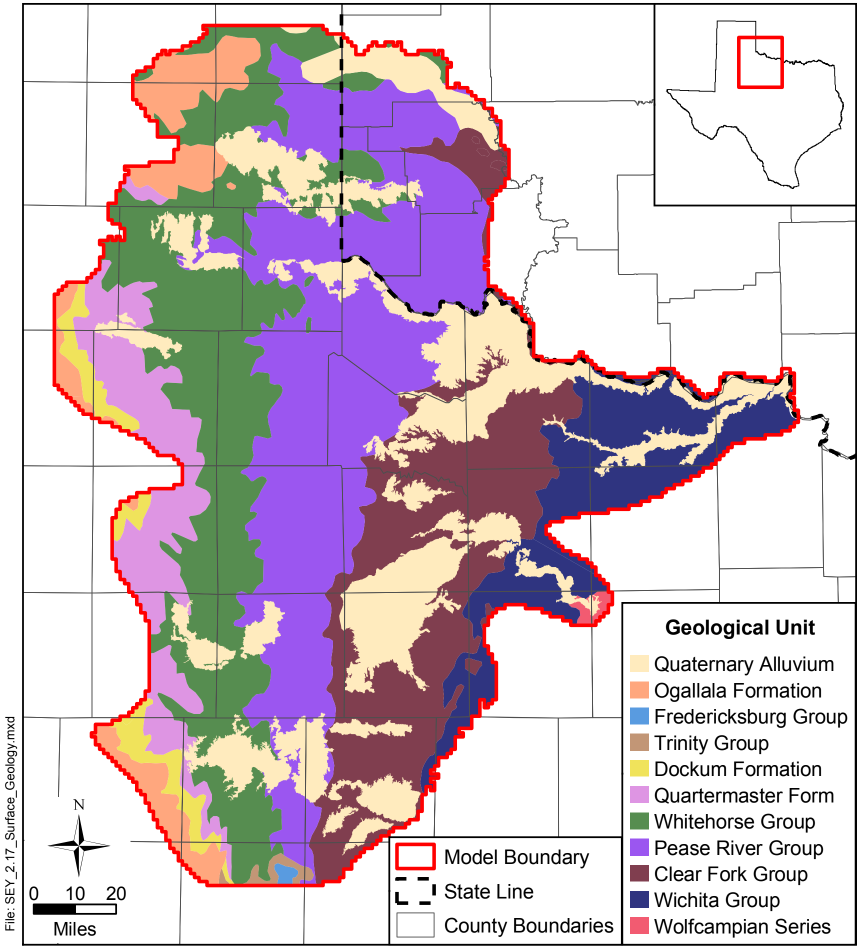
RWPGs



Source: Online: Texas Water Development Board, September 2002

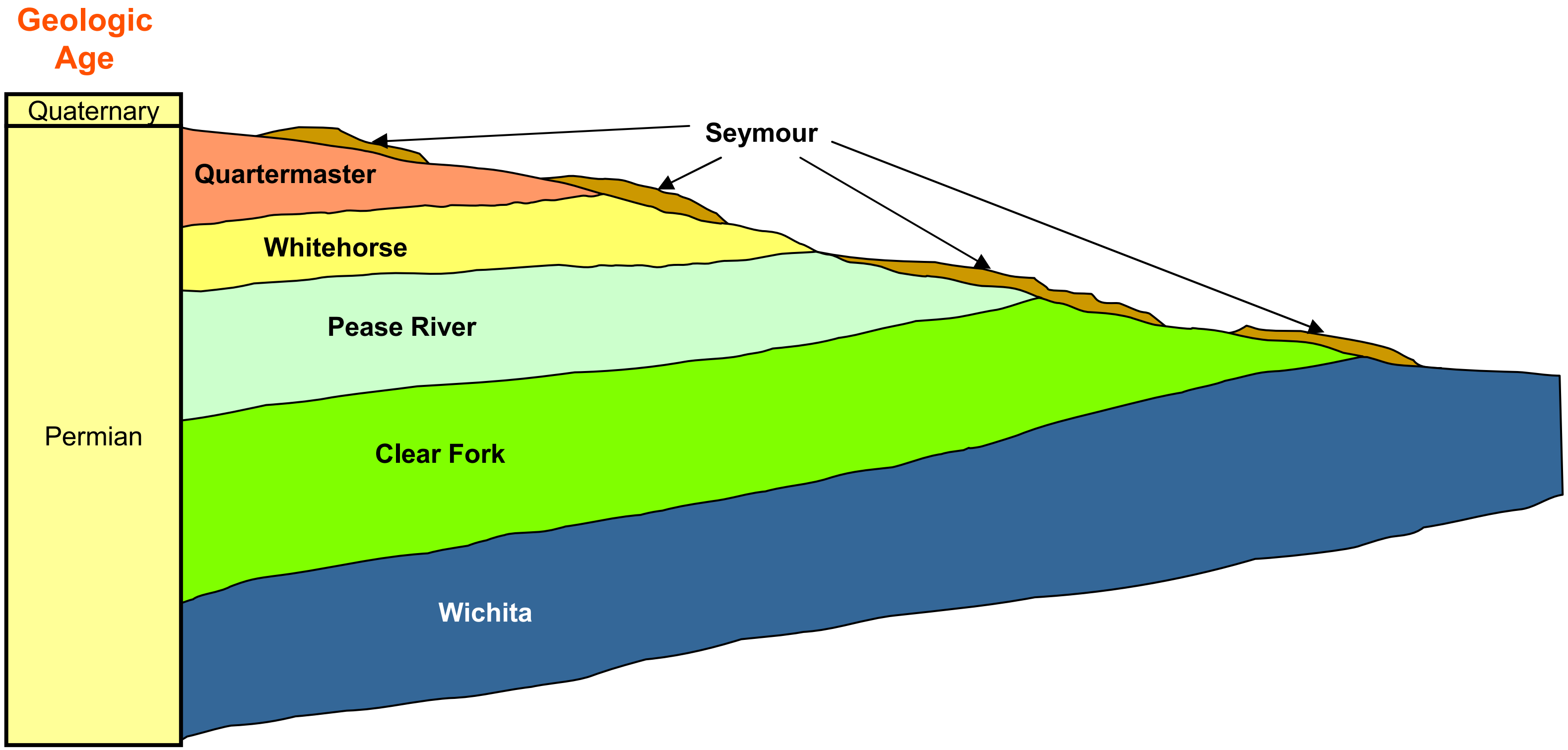
General Stratigraphy & Surface Geology

Seymour/Alluvium	
Quartermaster – Ochoa Group	
Whitehorse – Artesia Group	
Pease River Group	Dog Creek Shale Blaine Formation Flowerpot Shale San Angelo Sandstone
Clear Fork Group	Choza Formation Vale Formation Arroyo Formation
Wichita Group	

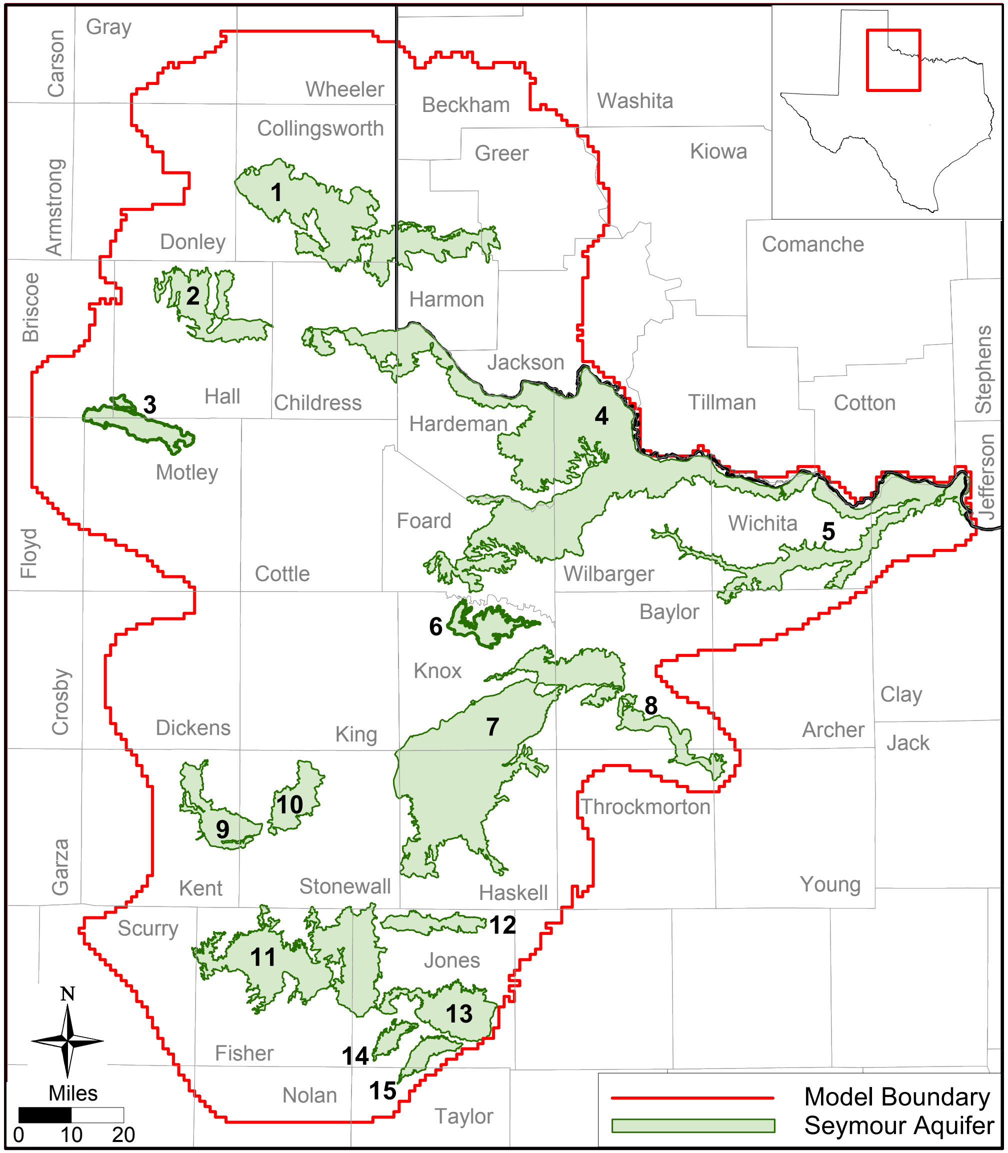


Source: Online: United States Geological Survey

Generalized Cross Section



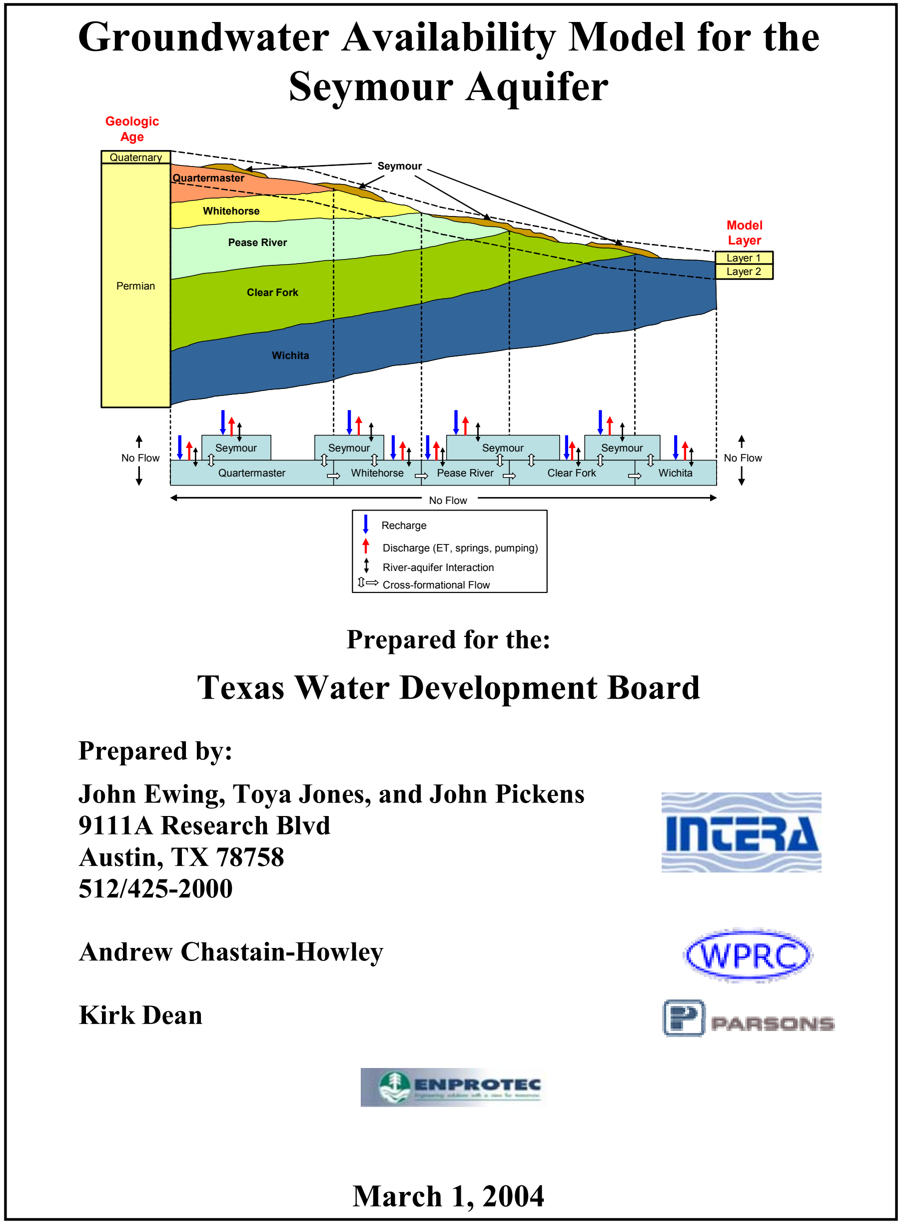
Seymour Pods



Draft Report Overview

Report Status

- Delivered to TWDB on March 1, 2004
- In public review period until April 9, 2004
- Submit comments in writing to Cindy Ridgeway at the TWDB
  - cindy.ridgeway@twdb.state.tx.us
  - 1700 North Congress Avenue
    P.O. Box 13231
    Austin, Texas 78711-3231
- Can download report at: http://www.twdb.state.tx.us/gam/symr/symr.htm
- Several CDs with report available here at meeting



Groundwater Availability Model for the Seymour Aquifer

Prepared for the:

Texas Water Development Board

Prepared by:

John Ewing, Toya Jones, and John Pickens
9111A Research Blvd
Austin, TX 78758
512/425-2000

Andrew Chastain-Howley

Kirk Dean

March 1, 2004

Report Overview

- Section 1 - Introduction
- Section 2 – Study Area
  - Study area
  - Physiography and climate
  - Geology
- Section 3 - Previous Investigations
- Section 4 – Hydrogeologic Setting
  - Hydrostratigraphy
  - Structure
  - Water levels and regional groundwater flow
  - Recharge
  - Natural aquifer discharge
- Section 4 (continued)
  - Hydraulic properties
  - Aquifer discharge through pumping
  - Water quality
- Section 5 - Conceptual Model of Groundwater Flow for the Seymour GAM
- Section 6 – Model Design
  - Code and processor
  - Boundary condition implementation
  - Model hydraulic parameters

Report Overview (continued)

- Section 7 – Modeling Approach
  - Calibration
  - Calibration target uncertainty
  - Sensitivity analysis
  - Predictions
- Section 8 – Steady-State Model
  - Calibration
  - Simulation results
  - Sensitivity analysis
- Section 9 – Transient Model
  - Calibration
- Section 9 (continued)
  - Simulation results
  - Sensitivity analysis
- Section 10 – Model Predictive Simulations
  - Drought of record
  - Predictive simulation results
  - Predictive simulation water budget
- Section 11 – Limitations of the Model
  - Limitations of supporting data
  - Assessment of assumptions

Report Overview (continued)

- Section 11 (continued)
  - Limits for model applicability
- Section 12 – Future Improvements
  - Additional supporting data
  - Future model implementation improvements
- Section 13 – Conclusions
- Section 14 – Acknowledgements
- Section 15 - References
- Appendices
  - A – Brief summary of historical development of the Seymour and Blaine aquifers on a county by county basis
  - B – Compilation of structure data from TCEQ well log records
  - C – Standard operating procedures (SOPs) for processing historical pumpage data TWDB Seymour GAM project

Report Overview (continued)

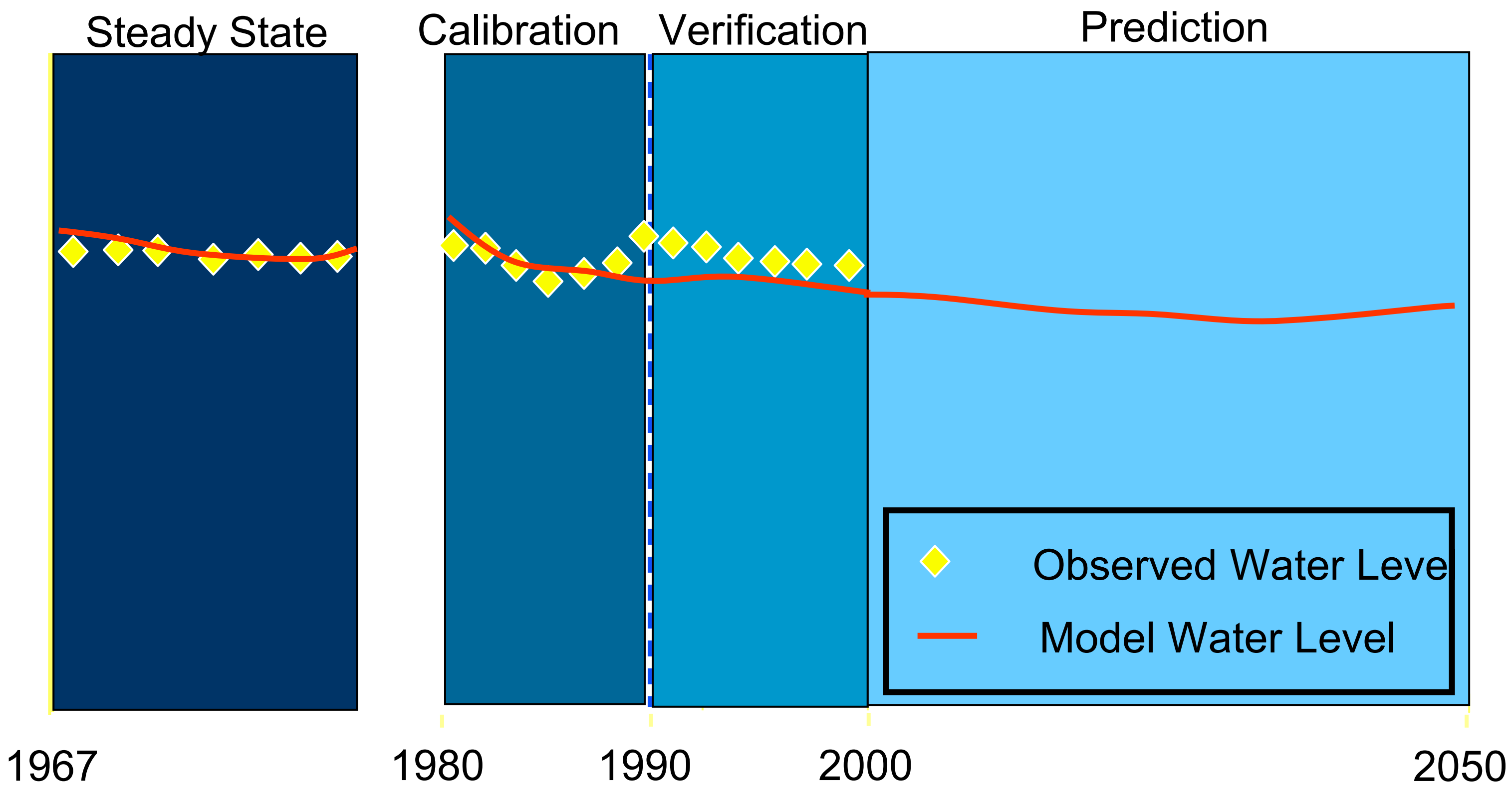
- Appendices (continued)
  - D – Standard operating procedures (SOPs) for processing predictive pumpage data TWDB Seymour GAM project
  - E – All transient hydrographs for the Seymour aquifer
  - F – All transient hydrographs for the Blaine aquifer

Model Design

Modeling Protocol

- Compile and Analyze Field and Literature Data
- Develop a Conceptual Model
- Model Design
- Calibrate the Model
- Verify the Model
- Use the Model for Predictive Purposes

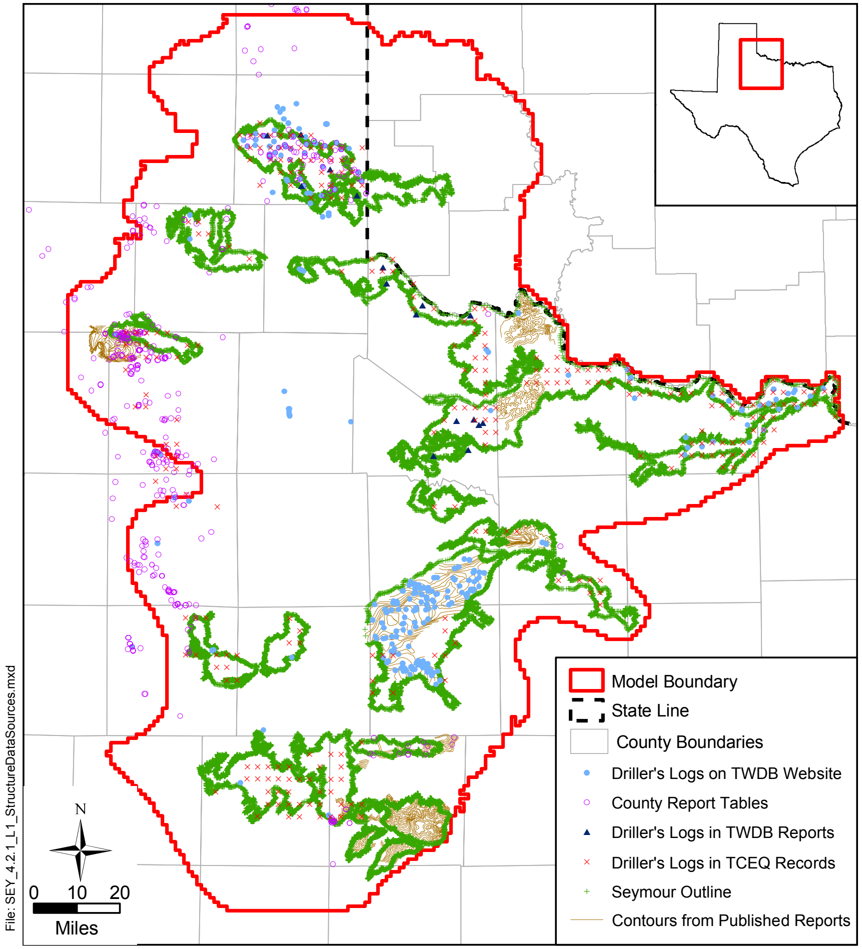
Schematic of Modeling Periods



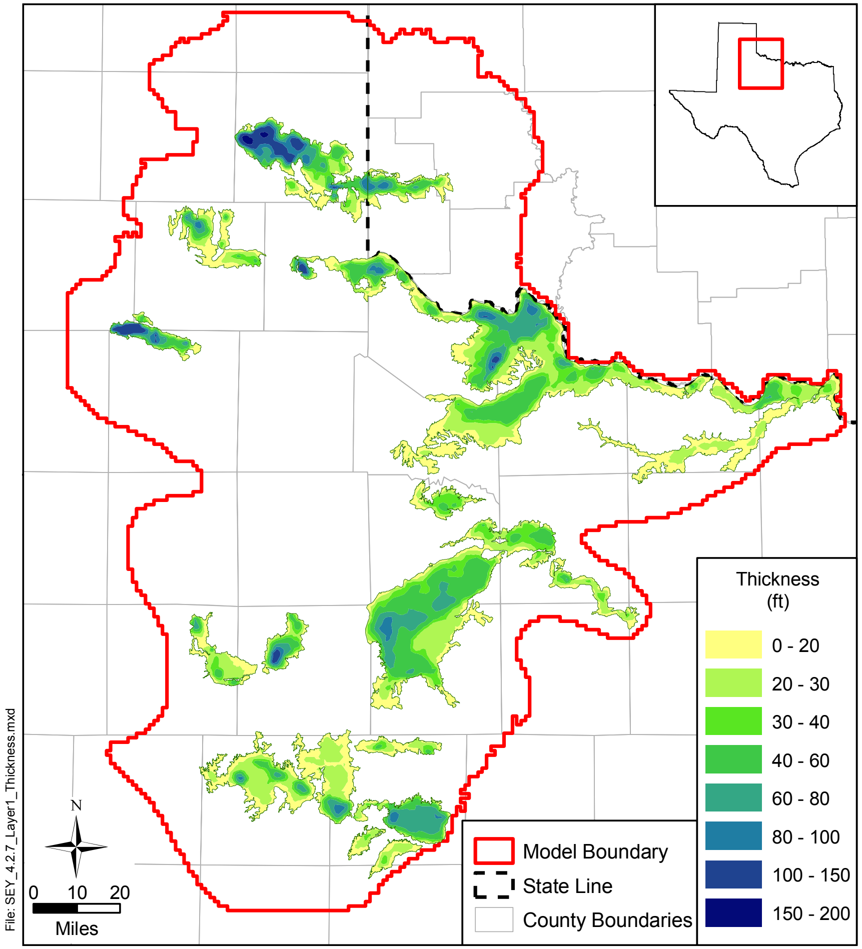
Conceptual Model

Structure - Seymour

Data Sources

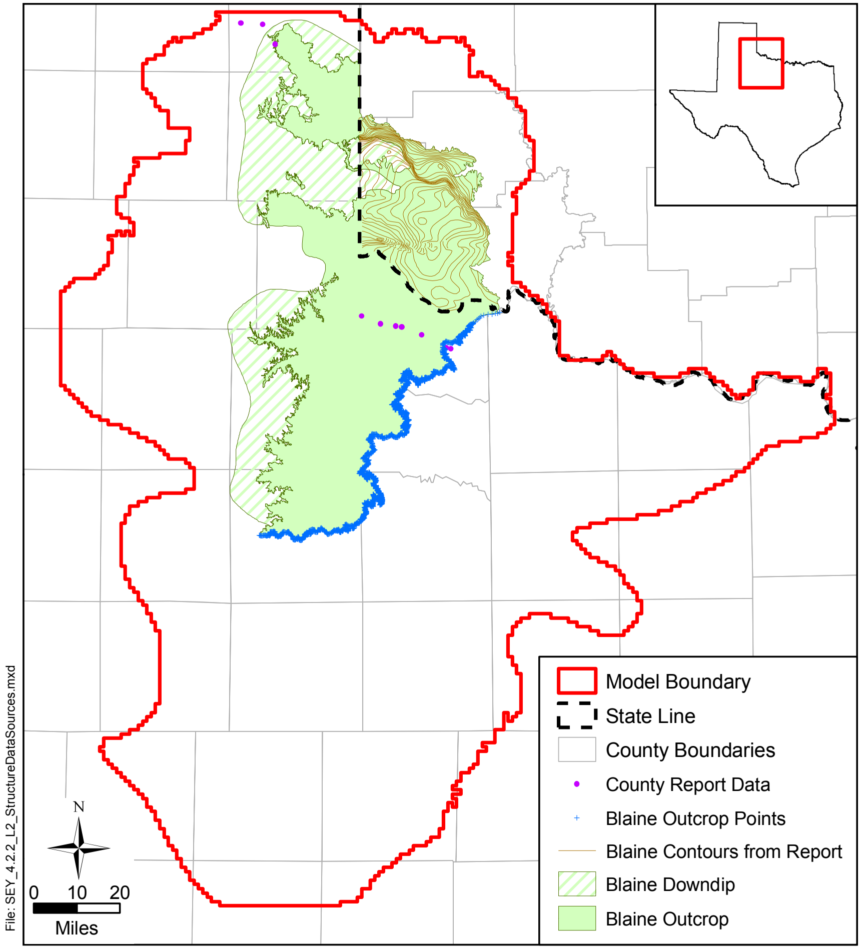


Thickness Map

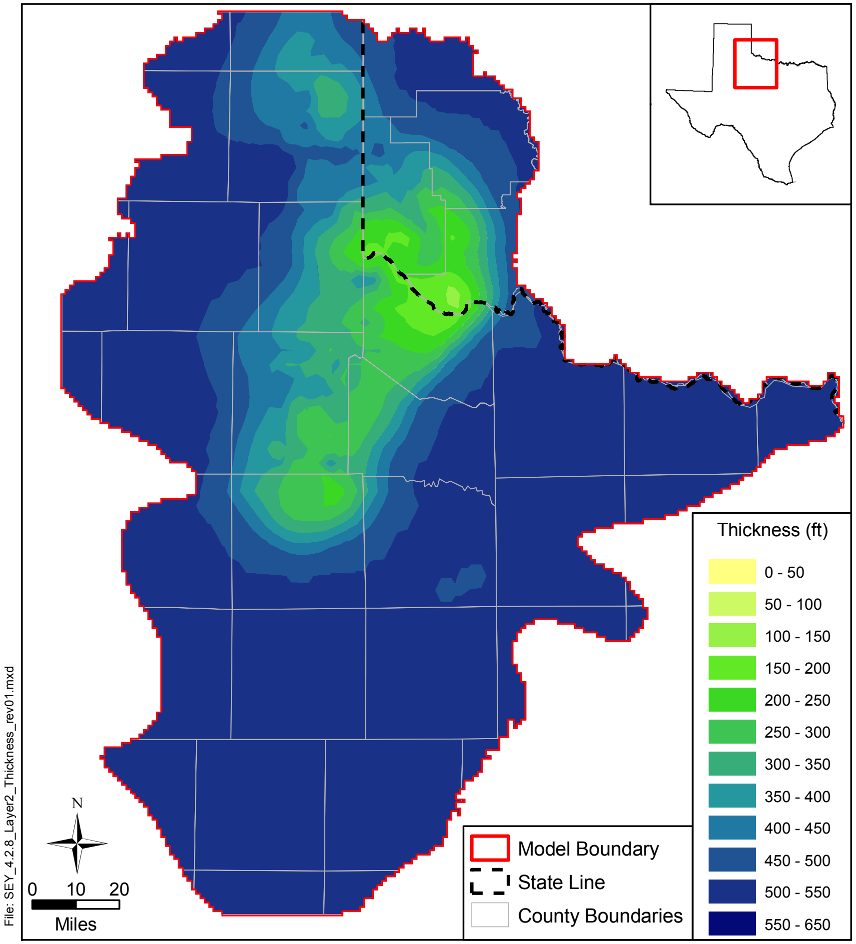


Structure - Blaine

Data Sources

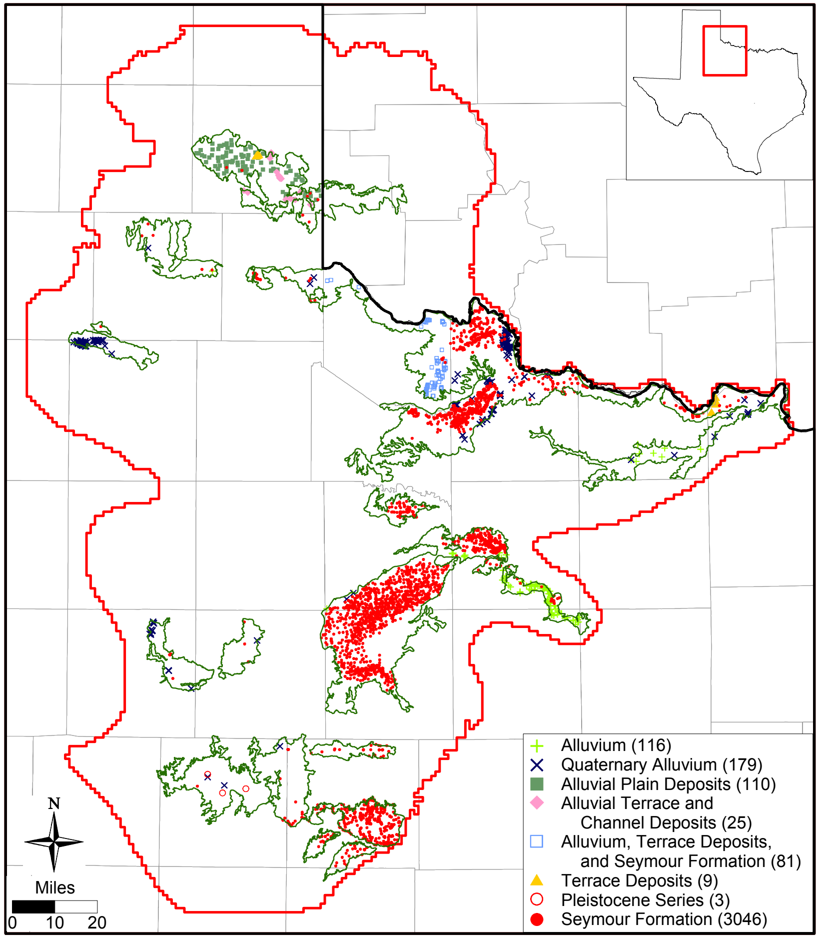


Thickness Map



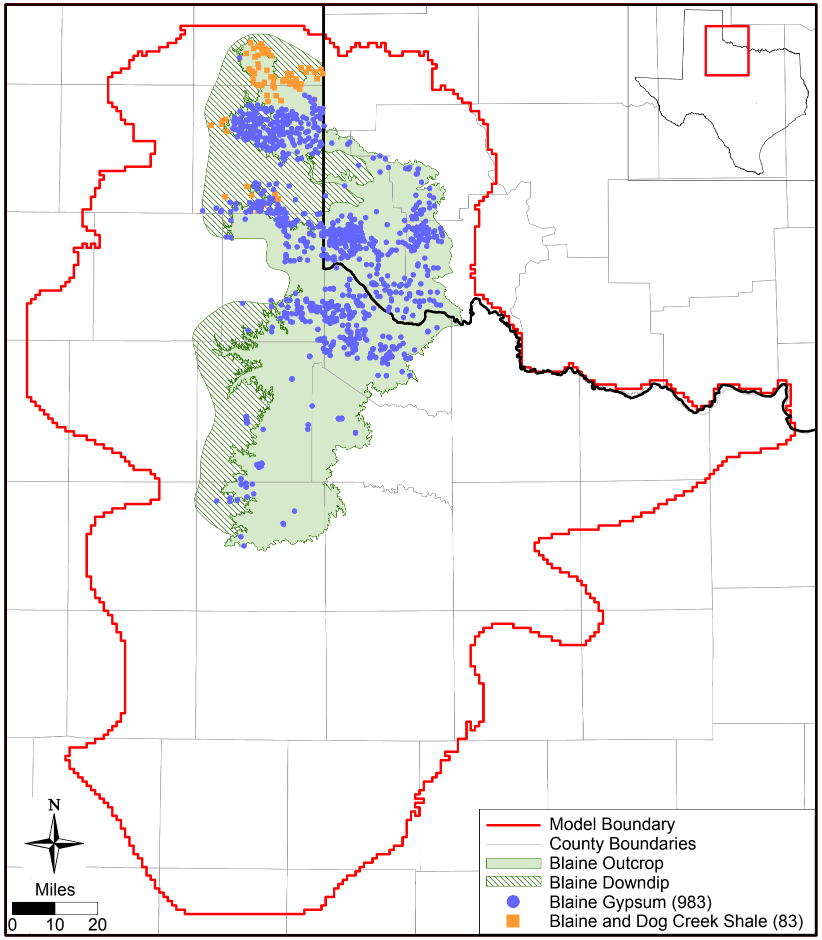
Water-Level Measurement Locations

Seymour



11,855 water-level measurements
in 3,569 wells

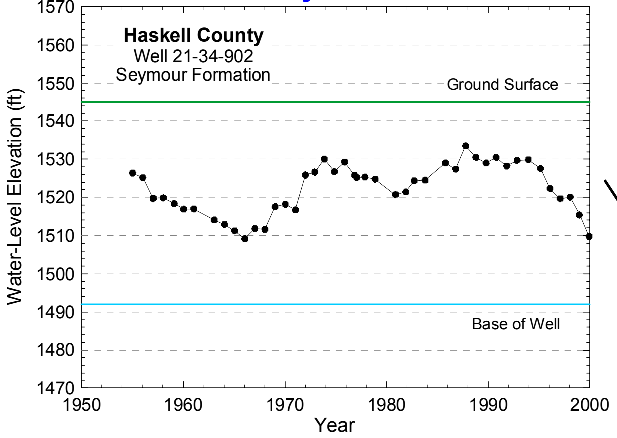
Blaine



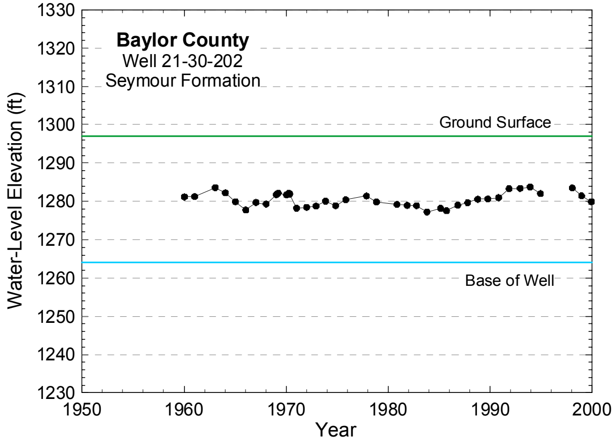
2,941 water-level measurements
in 782 wells

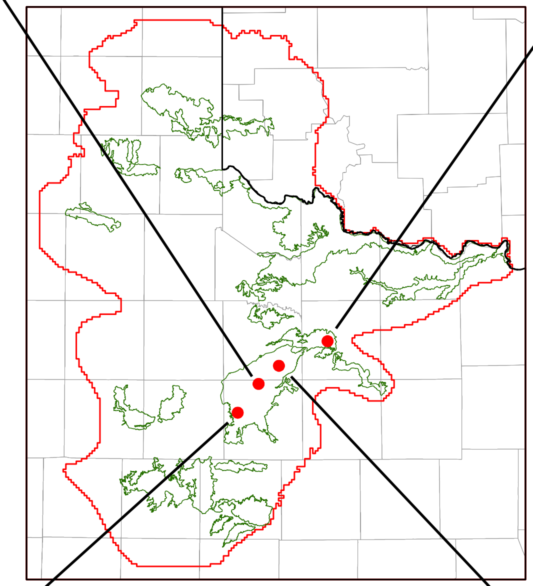
Example Hydrographs – Seymour

Cyclic

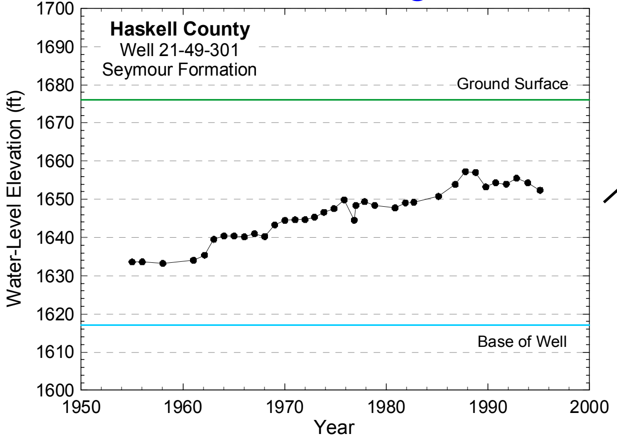


Stable

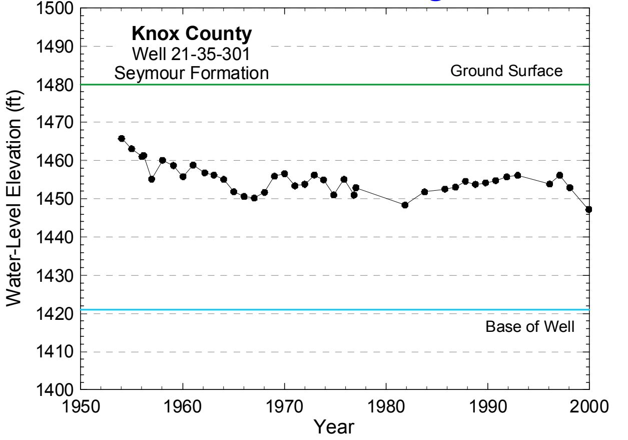




Increasing

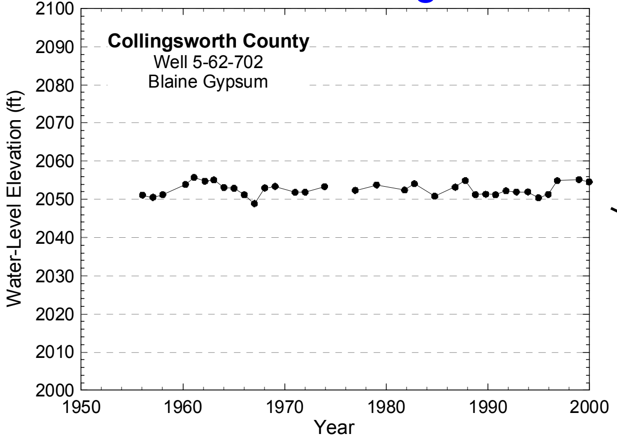


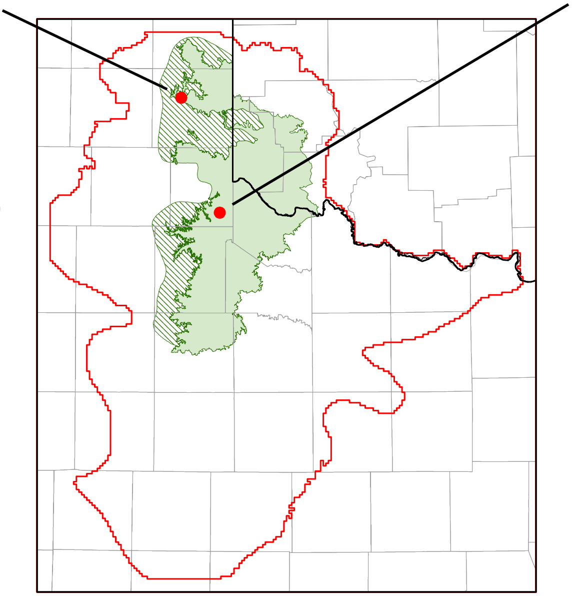
Decreasing



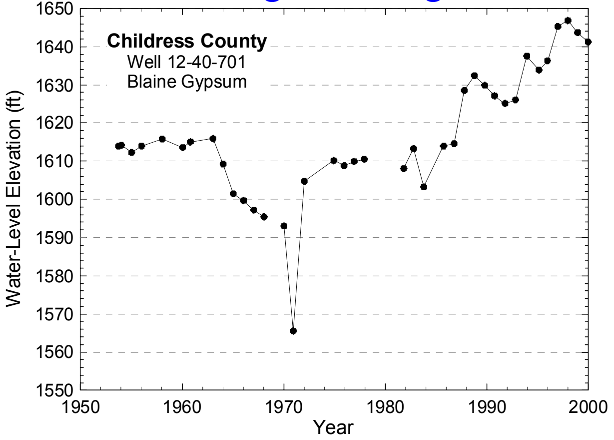
Example Hydrographs - Blaine

Small Change



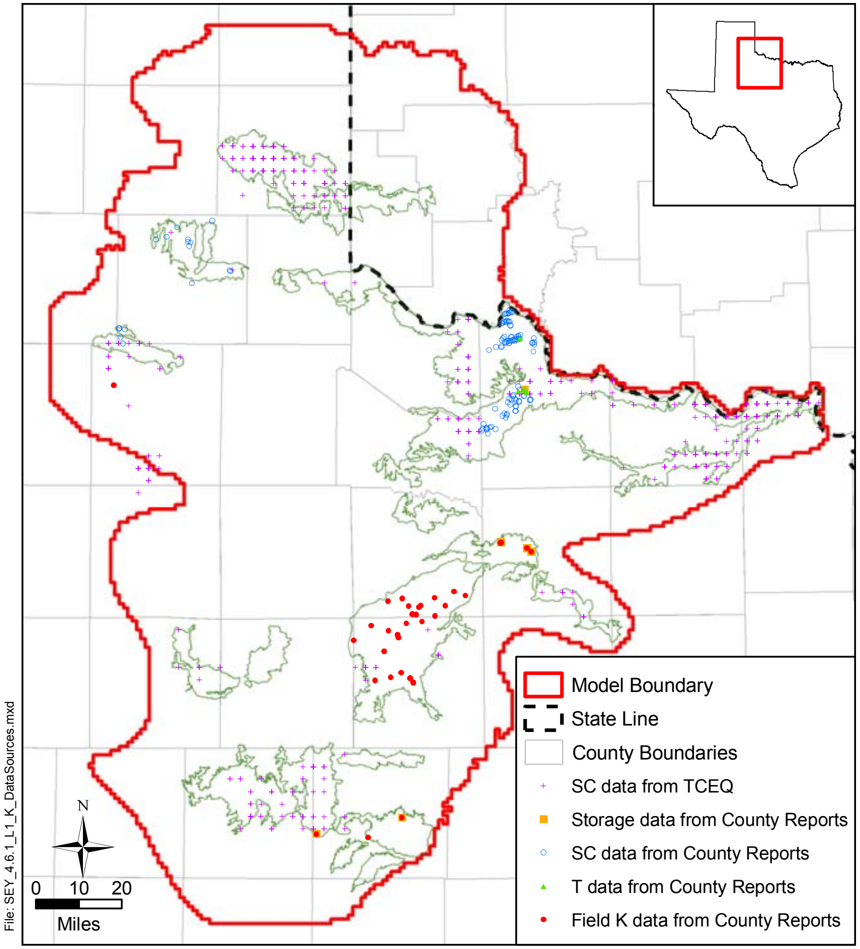


Large Change

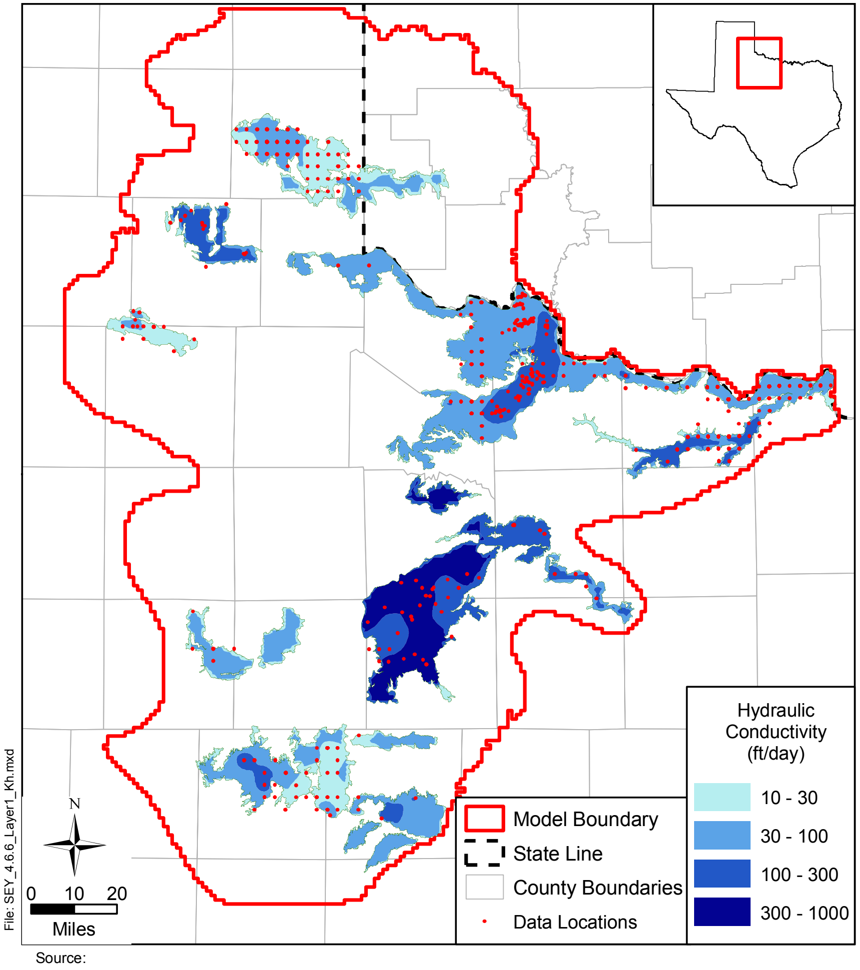


Hydraulic Conductivity - Seymour

Data Sources

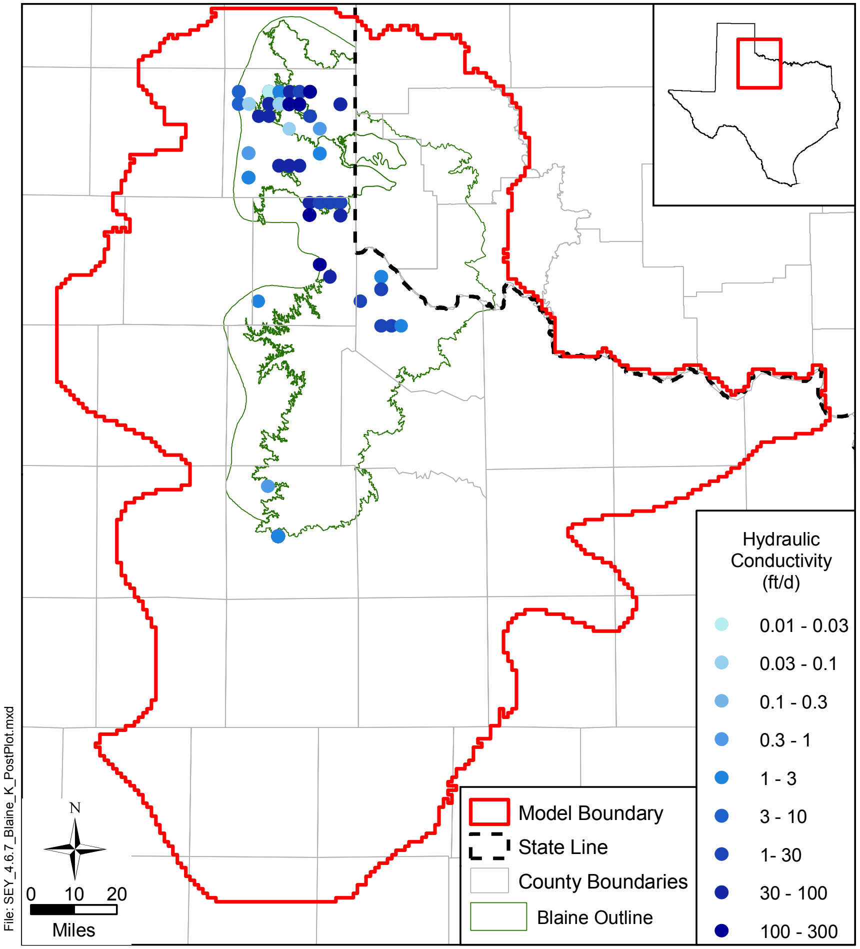


Hydraulic Conductivity Values

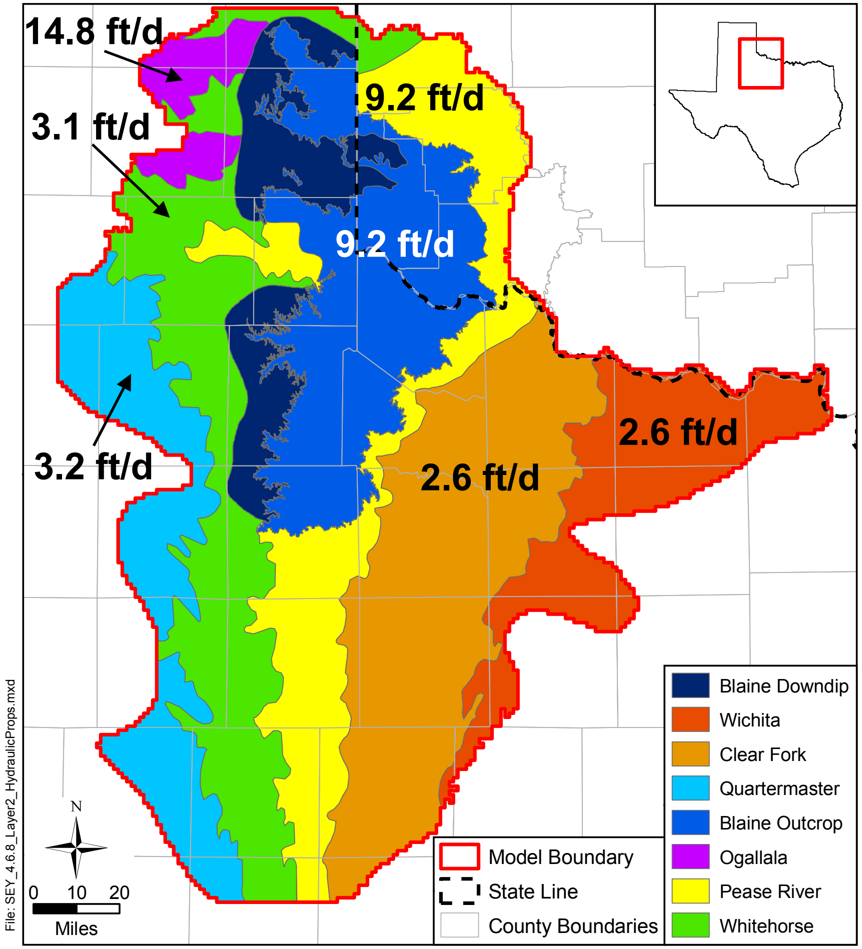


Hydraulic Conductivity - Permian

Blaine Data Sources & Values



Hydraulic Conductivity Values



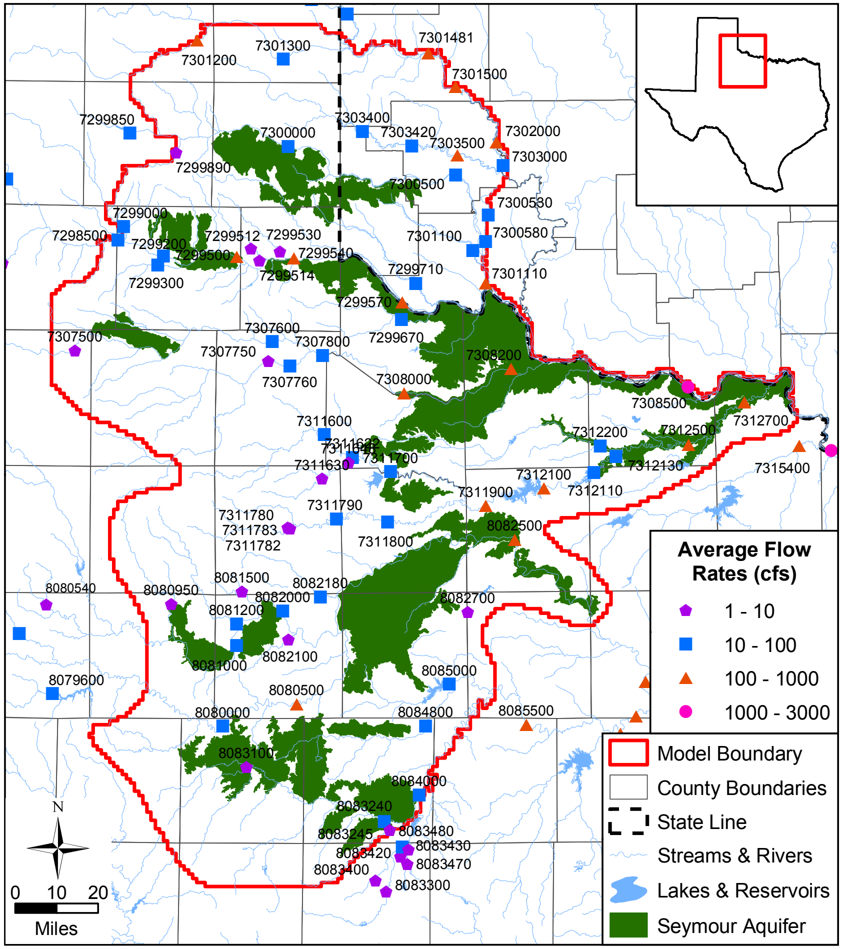
Source:

Recharge Estimates

County/Area	Aquifer	Recharge (in/yr)	Reference	Technique
Haskell and Knox Counties	Seymour	2.2	R.W. Harden & Associates (1978)	Water budget
Hardeman County	Seymour	1.0	Maderak (1972)	Darcy's Law
Baylor County	Seymour	2.6	Preston (1978)	Baseflow discharge
Jones County	Seymour	1.8	Price (1978)	Baseflow discharge
Wilbarger County	Seymour	2.5	Willis and Knowles (1953)	Baseflow discharge
Haskell County	Seymour	0.20 to 1.18	Scanlon et al. (2003)	Field study
Fisher/Jones counites	Seymour	0.28	Scanlon et al. (2003)	Unsaturated flow modelin
Greer and Jackson counties, OK	Blaine	1.1 to 1.5*	Muller and Price (1979)	Water budget
Greer, Harmon, Jackson counties, OK and Childress, Collingsworth, Hardeman counties, TX	Blaine	1.5	Runkle and McLean (1995)	Numerical model calibration parameter

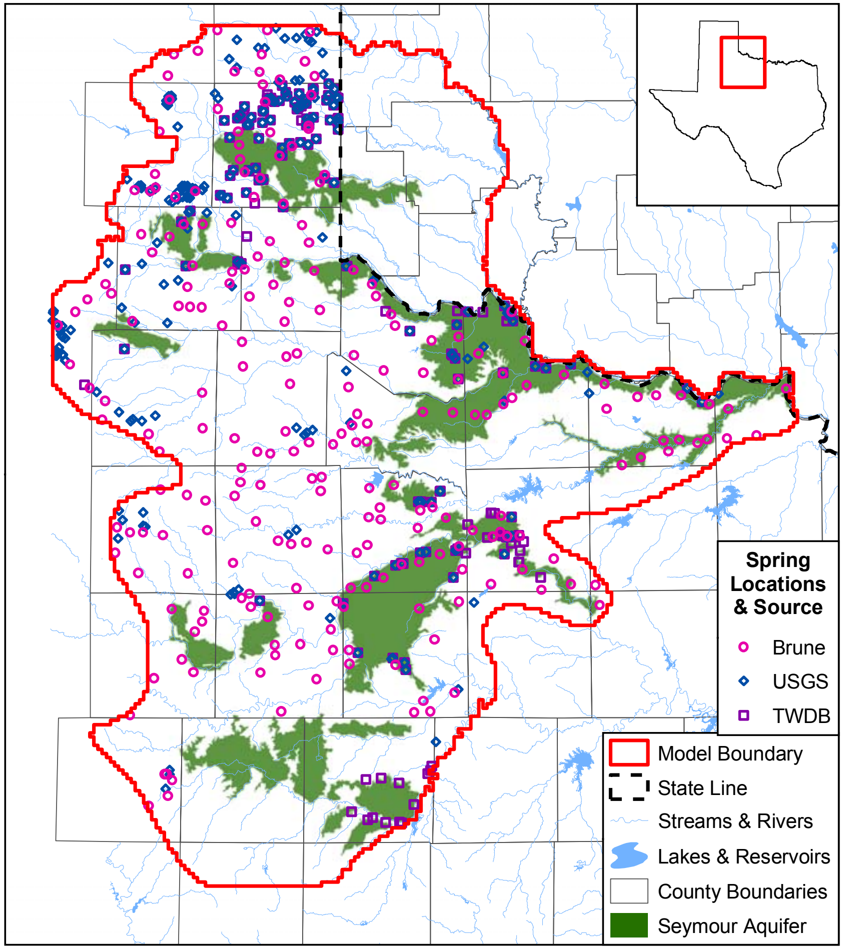
Natural Aquifer Discharge

Streams



Source: USGS website: March, 2003

Springs



Source:

Aquifer Discharge Through Pumping

- Point Source Data
  - Municipal, power, mining, manufacturing
- Non-Point Source Data
  - Irrigation, livestock, county-other (domestic)
- Steady State (approx. 1967-1970)
  - Literature sources or assumed to be the same as 1980 historical pumpage
- Historical (1980-1997)
  - TWDB water use survey database
- Predictive (2000-2050)
  - TWDB estimates based on projected water demand reported by RWPGs

Total Pumpage - Seymour

County	SS	1980	1990	2000	2010	2020	2030	2040	2050
Archer	1	1	1	0	0	0	0	0	0
Baylor	4,385	6,947	2,514	1,806	1,695	1,536	1,440	1,392	1,353
Briscoe	2	2	2	4,063	4,063	4,063	1,821	1,821	1,821
Childress	41	10,041	5,876	64	65	70	71	72	73
Clay	424	462	580	803	745	722	714	721	723
Collingsworth	10,650	3,057	16,950	14,135	14,124	14,125	14,120	14,112	14,110
Fisher	1,076	2,151	2,203	3,325	3,195	3,228	3,139	3,074	3,028
Foard	2,573	5,103	3,663	5,025	4,875	4,730	4,590	4,455	4,321
Hall	9,734	21,690	12,755	8,317	8,302	8,288	8,276	8,269	8,266
Hardeman	4,640	3,416	2,481	401	395	392	388	385	383
Haskell	21,911	39,297	22,210	21,972	21,281	20,647	20,032	19,437	18,870
Jones	1,767	2,212	2,257	4,045	3,888	3,767	3,658	3,560	3,470
Kent	687	527	770	1,625	1,212	999	875	786	725
Knox	18,384	50,235	32,547	26,247	26,242	26,285	26,289	25,650	25,035
Motley	1,598	3,454	3,776	2,065	2,003	1,943	1,885	1,828	1,774
Stonewall	322	363	353	1,258	1,189	1,109	1,035	967	935
Taylor	17	17	12	0	0	0	0	0	0
Throckmorton	3	3	3	0	0	0	0	0	0
Wichita	1,755	1,756	1,716	1,873	2,058	2,070	2,085	2,099	2,096
Wilbarger	6,192	26,589	19,543	23,349	22,806	22,281	21,823	21,374	20,989
Young	1	1	1	0	0	0	0	0	0
Total	**86,164**	**177,324**	**130,213**	**120,373**	**118,138**	**116,255**	**112,241**	**110,002**	**107,972**

All withdrawals rounded to the nearest 1 AFY.

Total Pumpage - Blaine

County	SS	1980	1990	2000	2010	2020	2030	2040	2050
Childress	7,858	108	92	3,755	3,743	3,740	3,737	3,735	3,734
Collingsworth	9,332	2,906	4,126	4,532	4,524	4,511	4,505	4,499	4,494
Cottle	5,550	86	60	4,782	4,630	4,477	4,334	4,188	4,047
Foard	120	10	18	25	24	24	23	22	22
Hall	21	21	12	28	25	22	19	17	15
Hardeman	6,014	6,582	4,896	4,841	4,696	4,559	4,423	4,292	4,165
King	528	528	79	344	341	339	337	336	335
Knox	2	2	0	1,333	1,333	1,333	1,333	1,300	1,268
Wheeler	1,478	1,478	749	50	48	48	48	47	49
Total	**30,903**	**11,721**	**10,032**	**19,690**	**19,364**	**19,053**	**18,759**	**18,436**	**18,129**

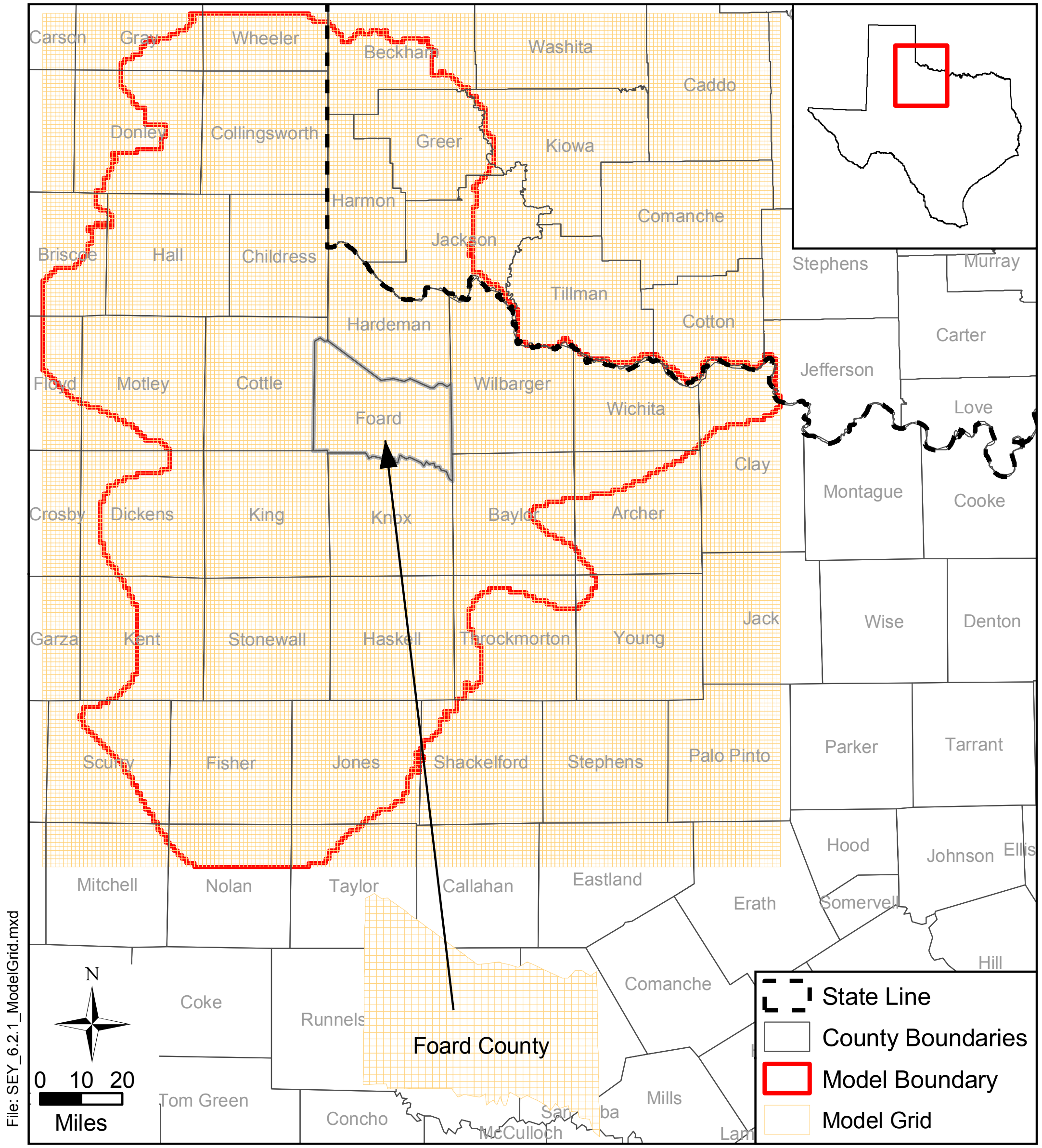
All withdrawals rounded to the nearest 1 AFY.

Uses of Water (%) – 1980-1999 Average

Water Use Category	Seymour	Blaine
Irrigation	93 %	95 %
Municipal	5 %	0
Manufacturing	0	0
Mining	0	0
Power	0	0
Livestock	0.4 %	1 %
Rural Domestic	1.6 %	4 %

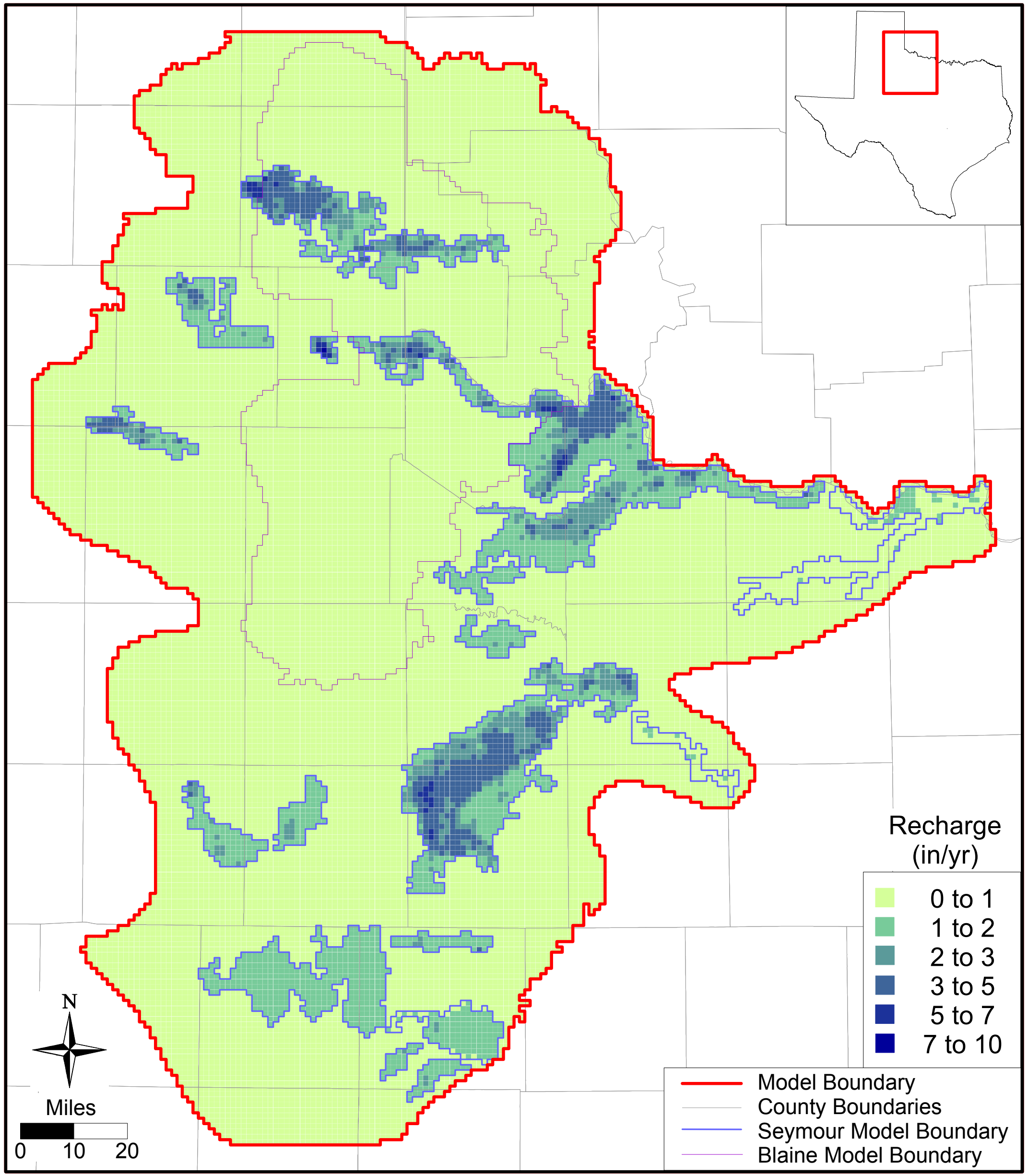
Model Implementation

Model Grid



1 square mile grid blocks
180 columns and 208 rows
3,436 active cells in layer 1
20,001 active cells in layer 2

Recharge


Recharge (in/yr)
0 to 1
1 to 2
2 to 3
3 to 5
5 to 7
7 to 10
Model Boundary
County Boundaries
Seymour Model Boundary
Blaine Model Boundary
N
Miles
0
10
20

Model Input

- Hydrostratigraphic Surfaces for Each Layer
- Hydraulic Properties
  - Hydraulic Conductivity
  - Storativity (transient model only)
- Recharge
- Stream Flow
- Pumpage
- Reservoir Stages

Model Evaluation

- Model results compared to observed data
  - Observed water levels
  - Stream flow
- Model results evaluated against literature data
  - Recharge
- Model results evaluated against conceptual model

Steady-State Model

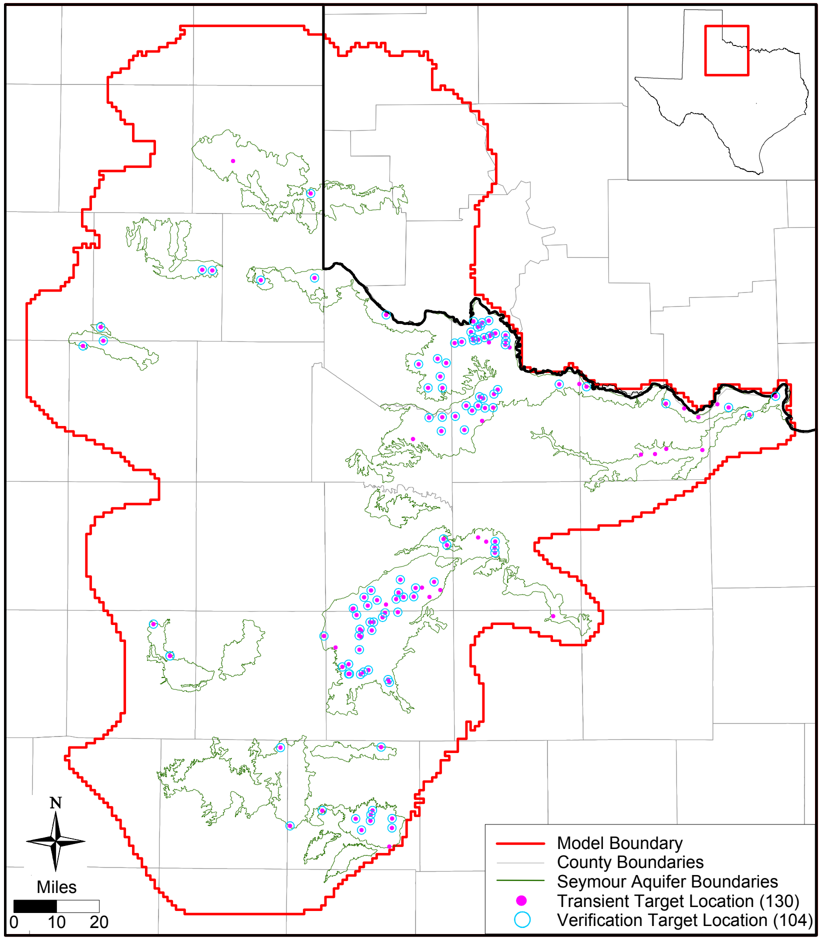
Steady-State Model

- The model was calibrated to a time period during which the aquifer was at near steady-state conditions.
- Simulated water levels were compared to observed water levels during the steady-state period.
- The residuals between observed and simulated water levels were calculated.
- Parameters were modified to minimize residuals.
- Represents a first estimate of aquifer parameters.

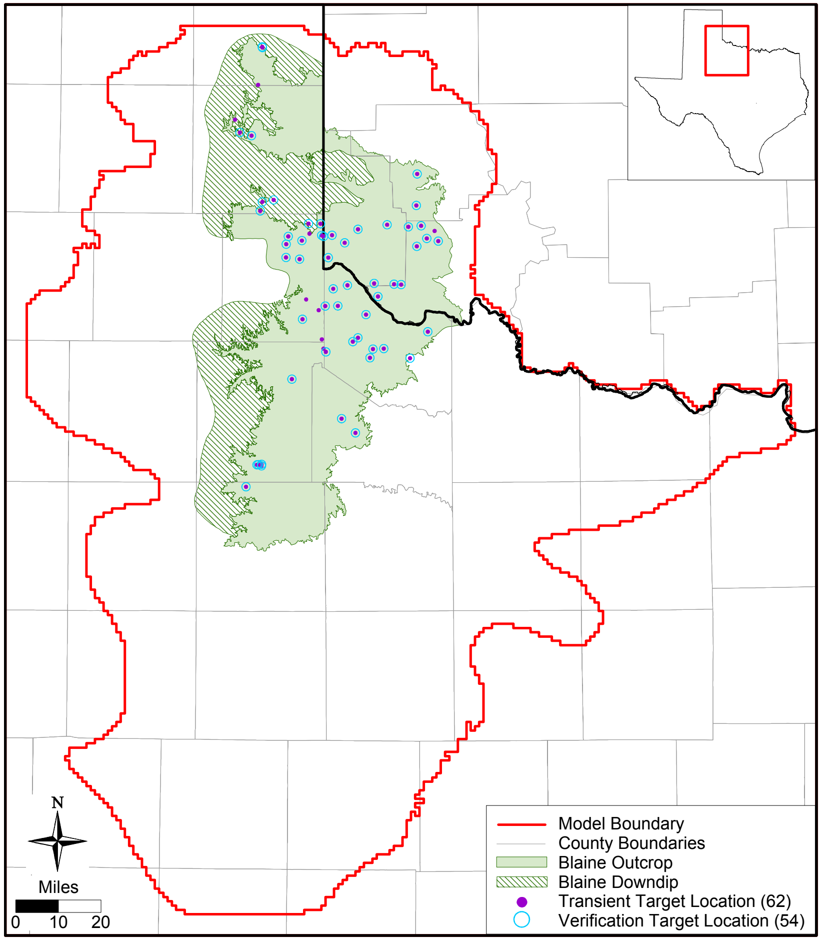
Transient Model Results

Transient Target Locations

Seymour

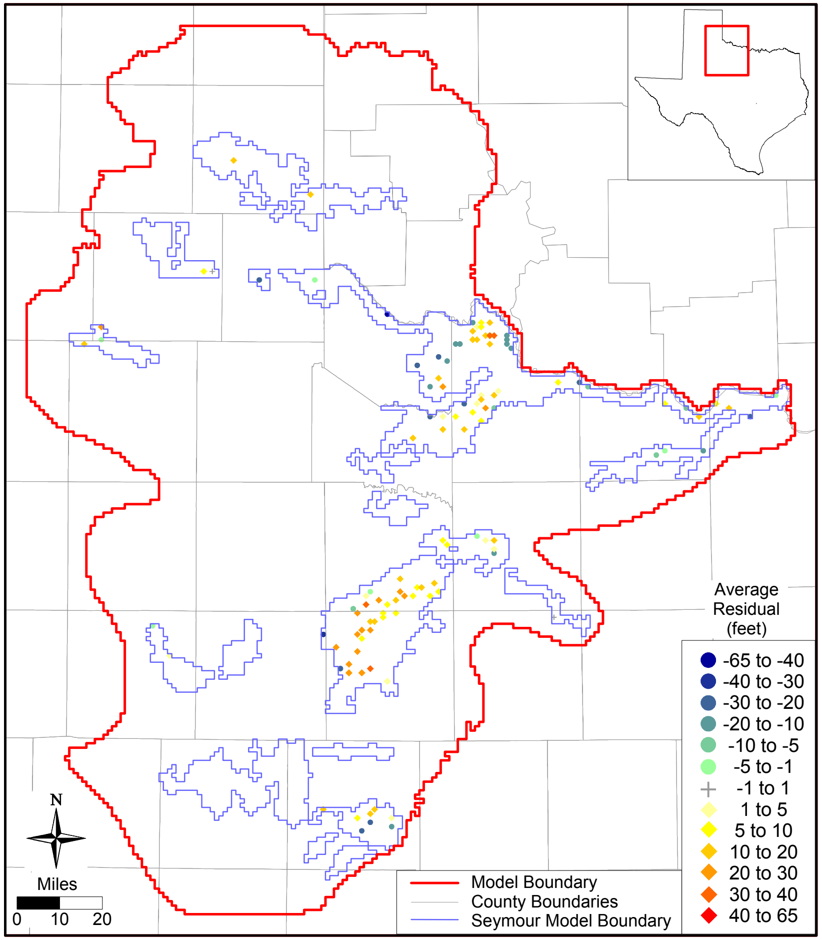


Blaine

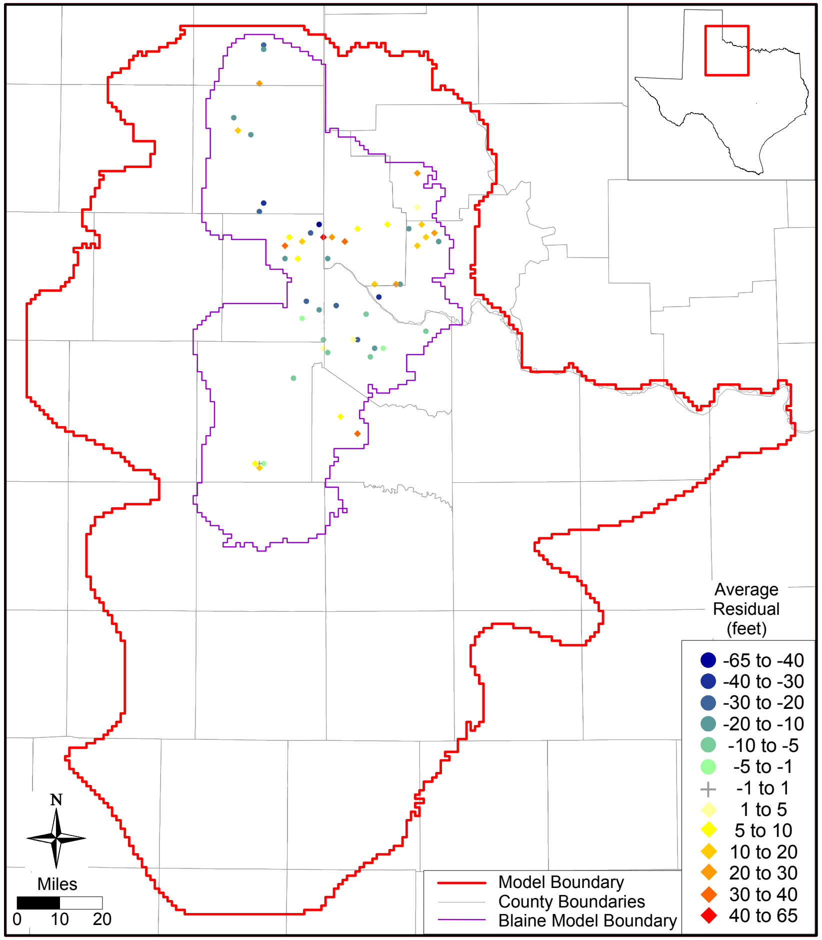


Average Residuals - Calibration

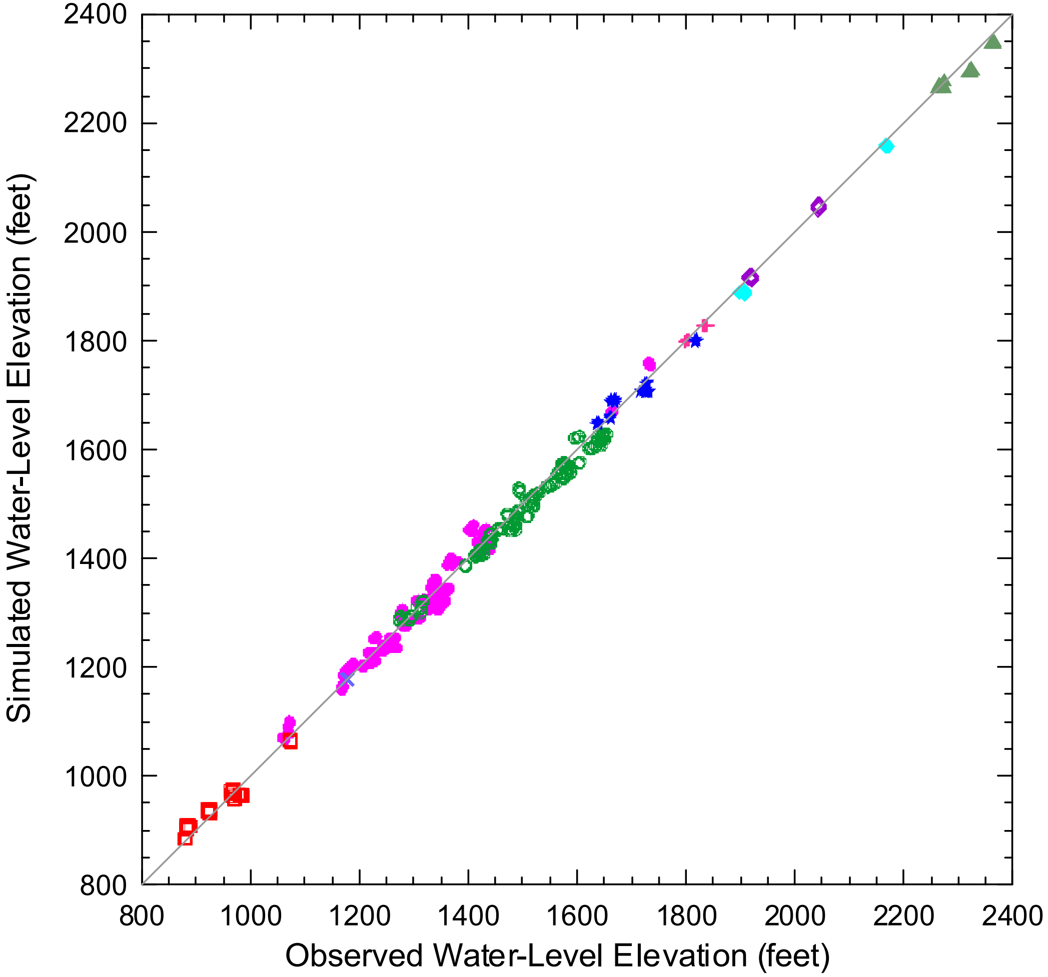
Seymour



Blaine

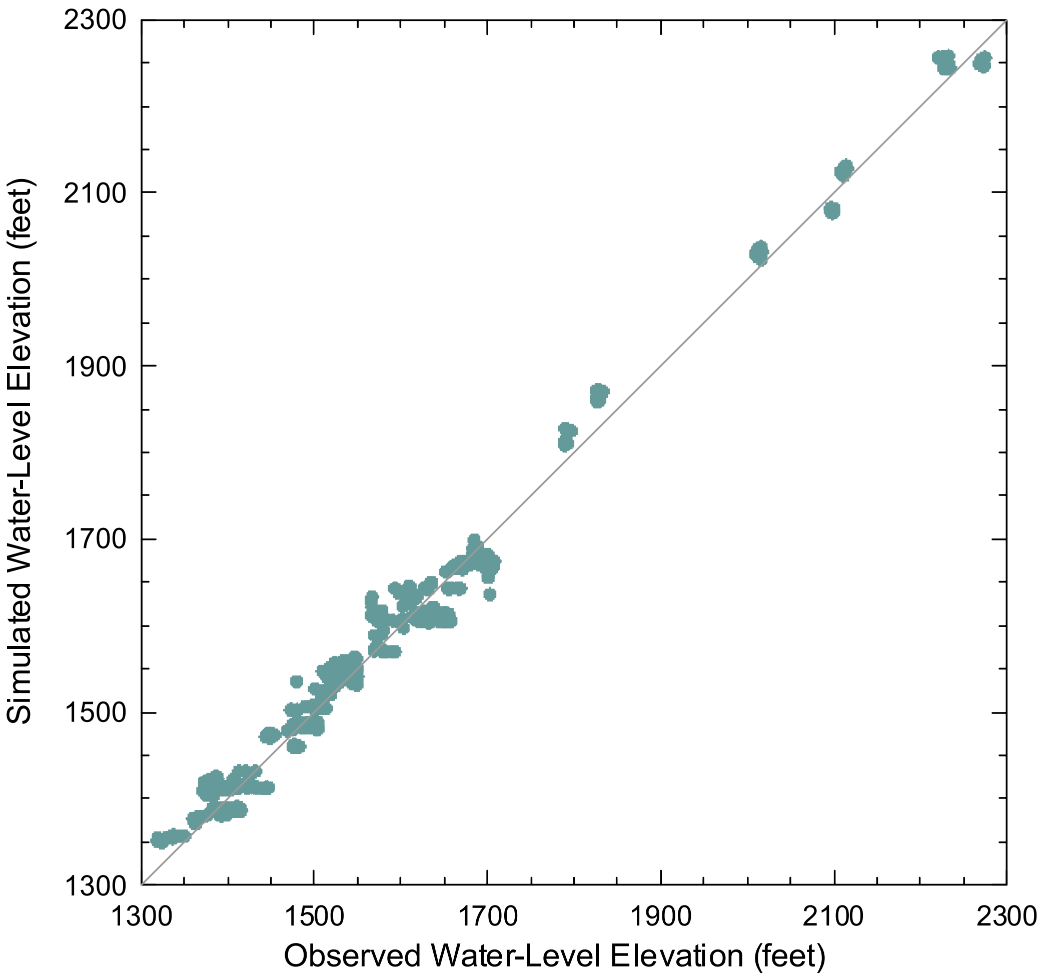


Calibration Water-Level Comparison - Seymour



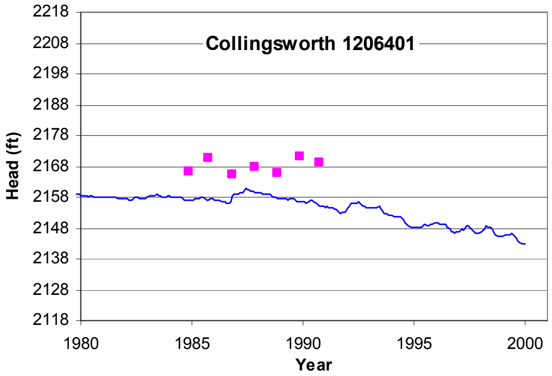
Number of Targets	**1004**
Minimum Residual	**-52.5 ft**
Maximum Residual	**41.2 ft**
Residual Mean	**4.8 ft**
Absolute Residual Mean	**13.3 ft**
Total RMS	**16.2 ft**
Observed Head Range	**1486 ft**
Adjusted RMS	**0.01 ft**

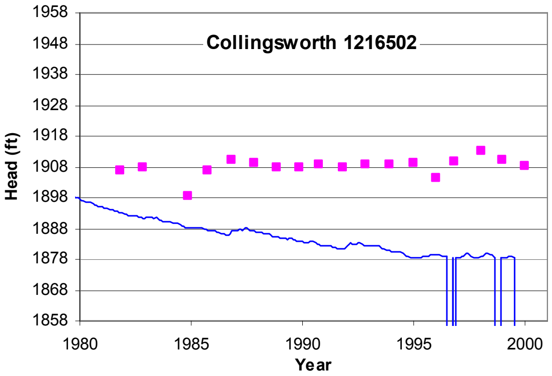
Calibration Water-Level Comparison - Blaine



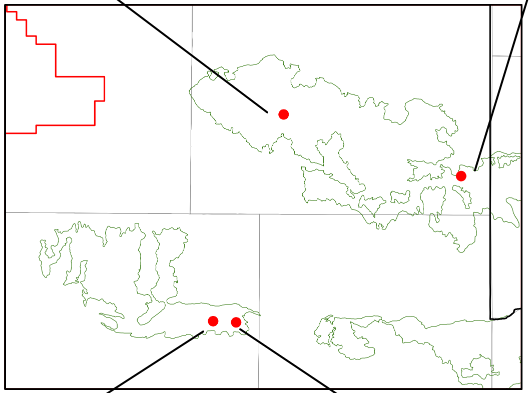
Number of Targets	**737**
Minimum Residual	**-66.4 ft**
Maximum Residual	**66.8 ft**
Residual Mean	**5.5 ft**
Absolute Residual Mean	**19.1 ft**
Total RMS	**22.7 ft**
Observed Head Range	**956 ft**
Adjusted RMS	**0.02 ft**

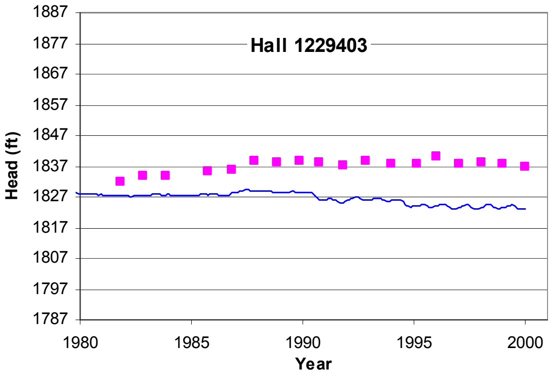
Selected Hydrographs - Seymour

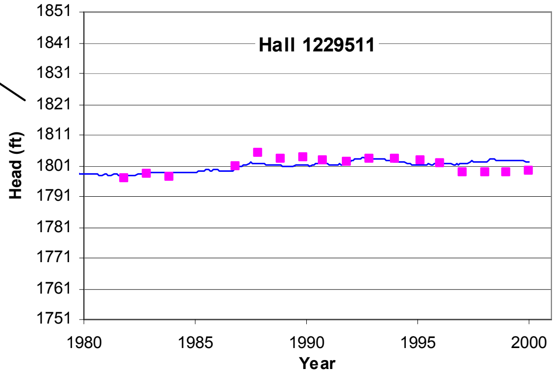




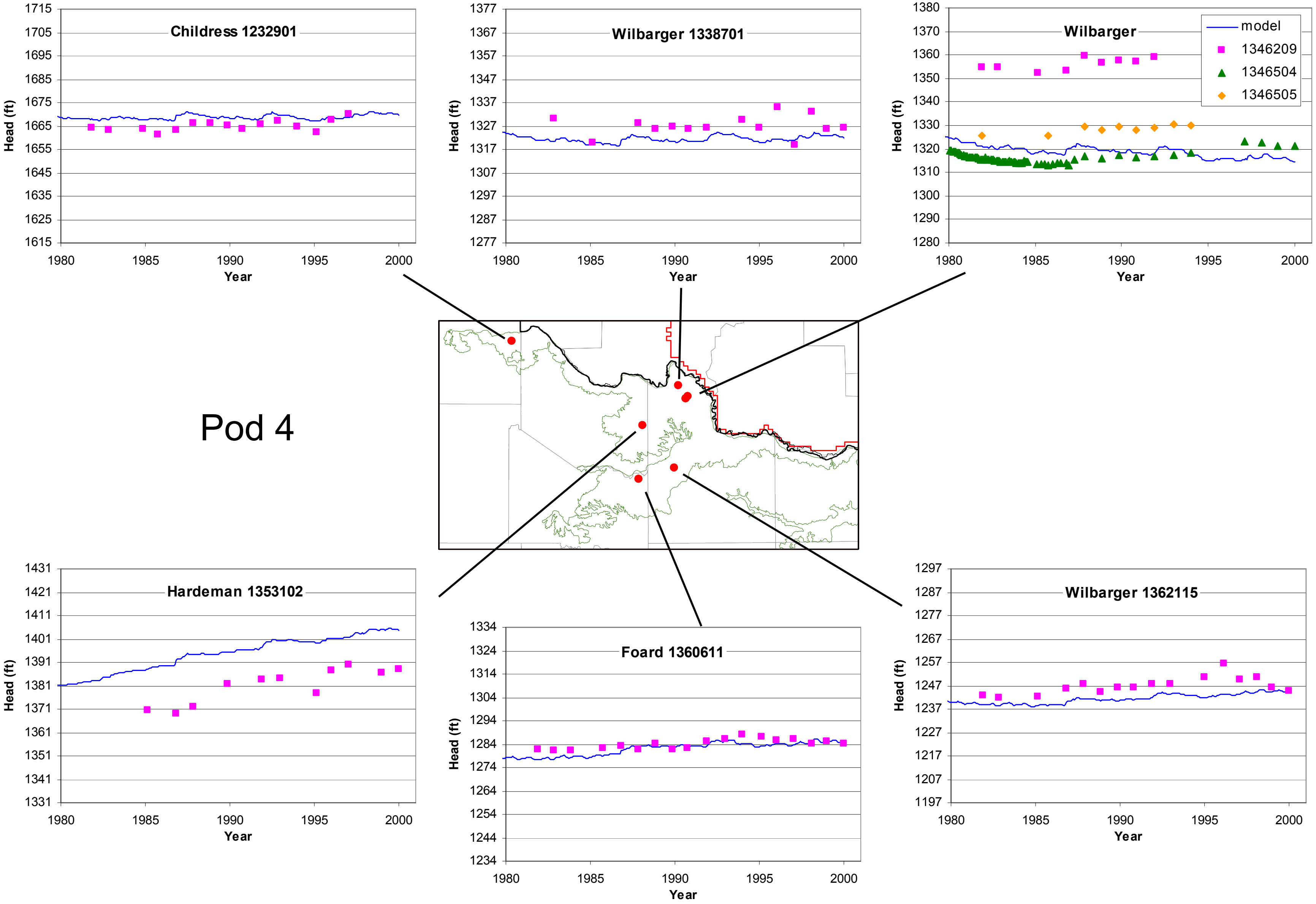
Pods 1 and 2





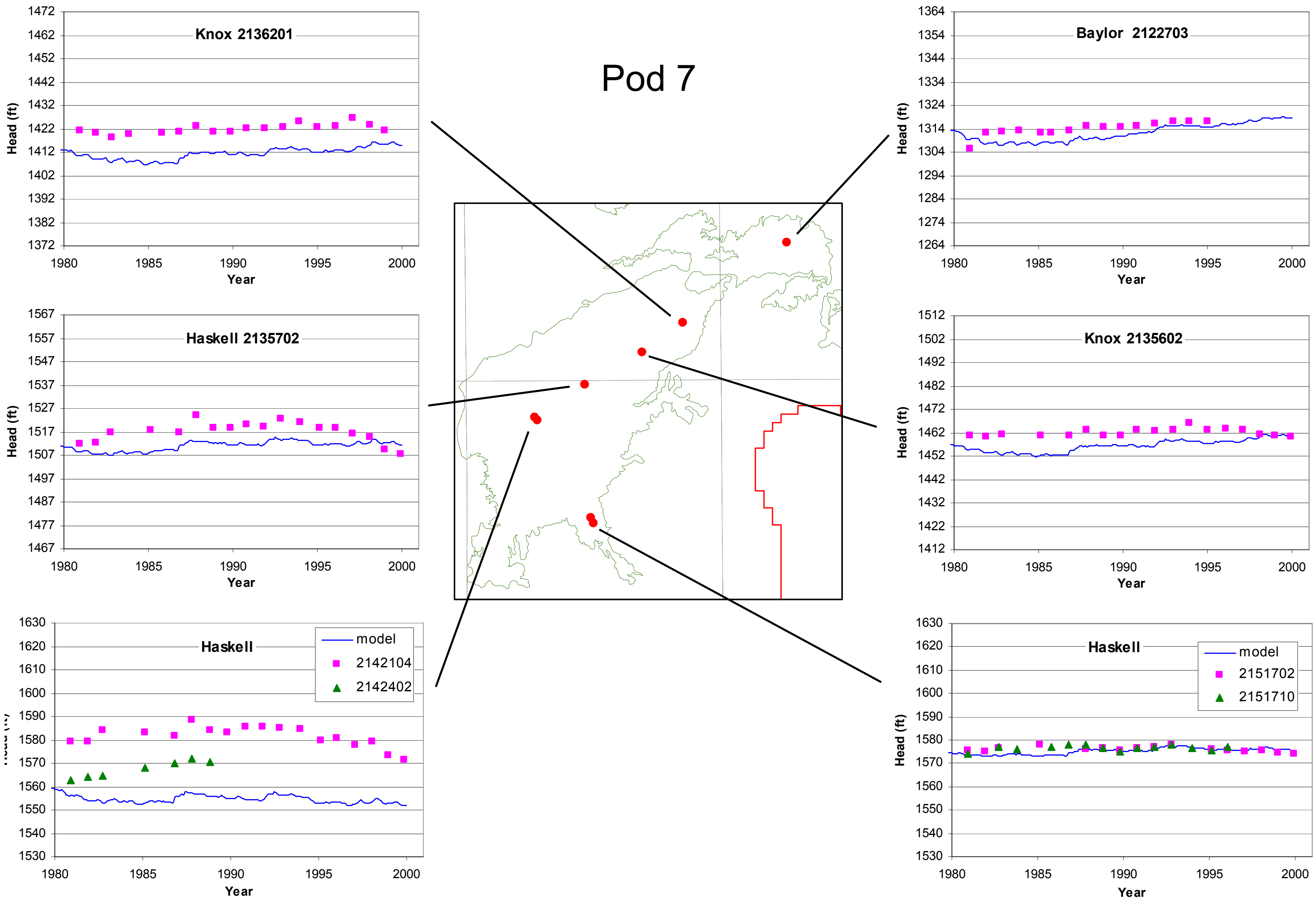


Selected Hydrographs - Seymour

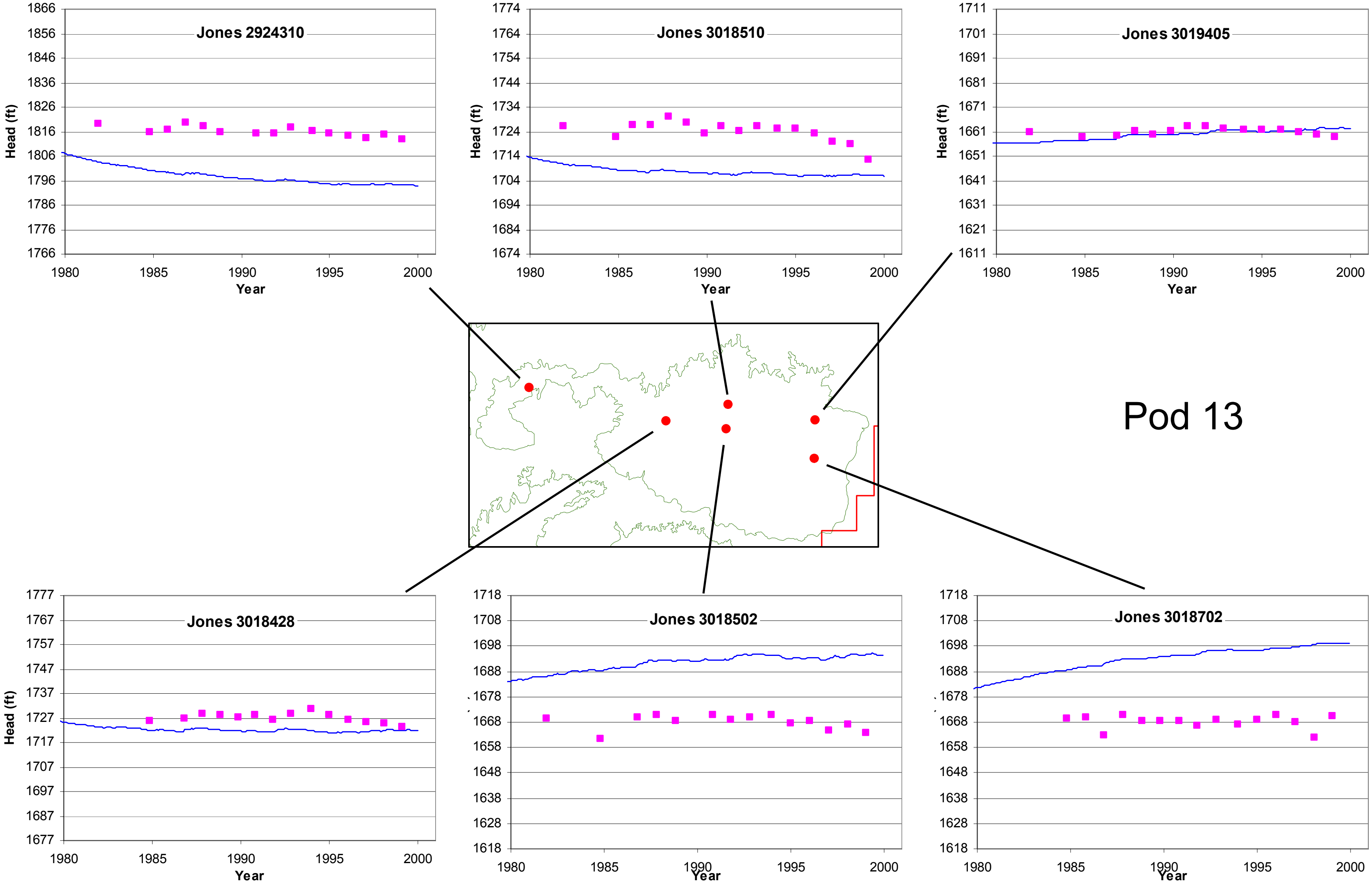


Pod 4

Selected Hydrographs - Seymour

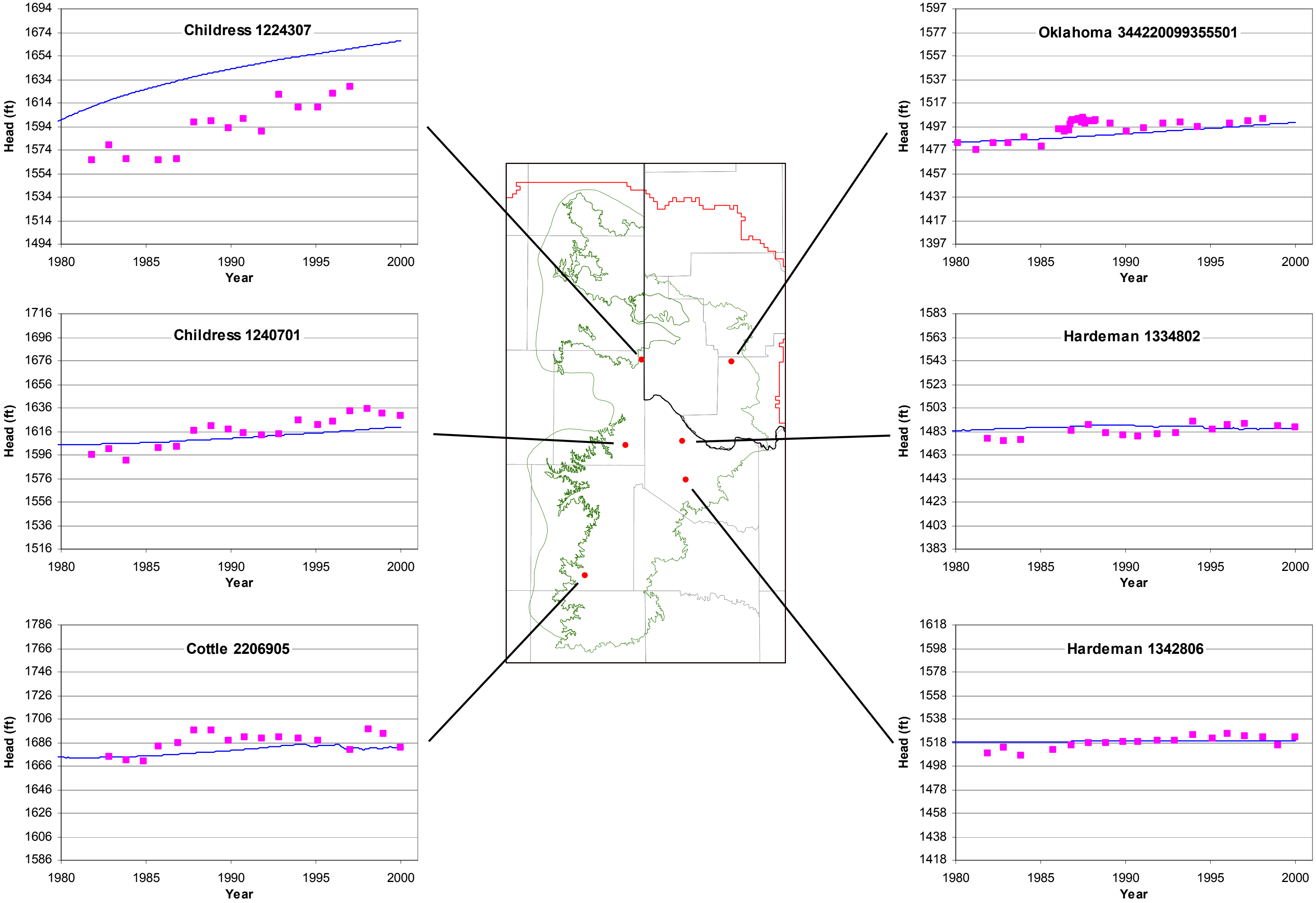


Selected Hydrographs - Seymour



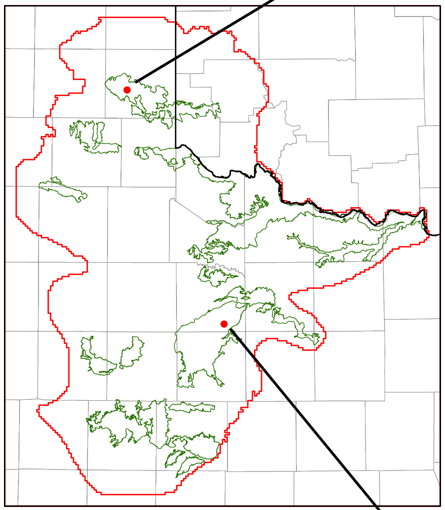
Pod 13

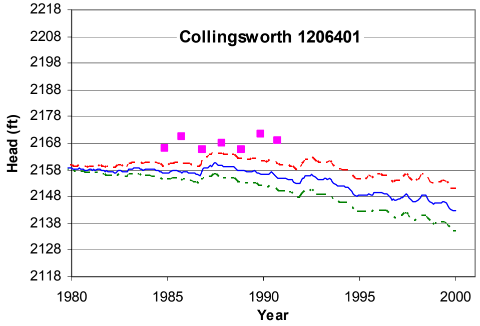
Selected Hydrographs - Blaine

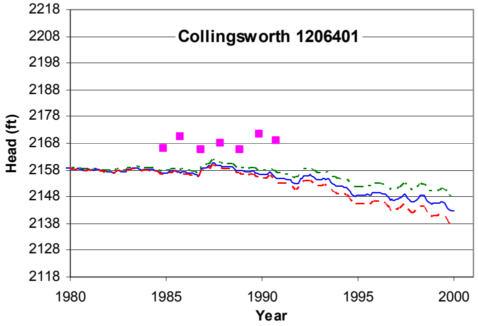


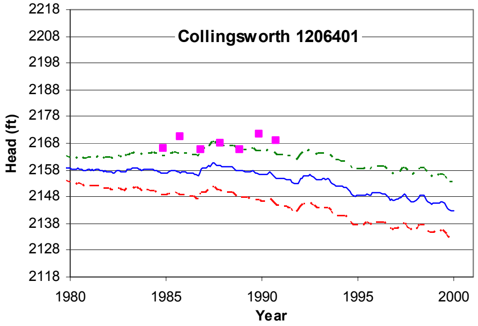
Hydrograph Sensitivities - Seymour

■ measured
-·-·- factor = 0.8
—— factor – 1.0
- - - - factor = 1.2





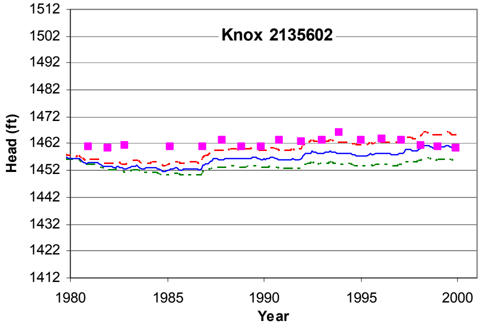


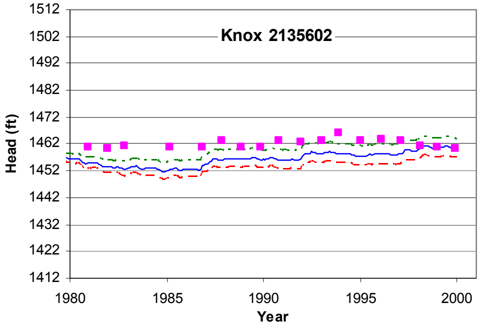


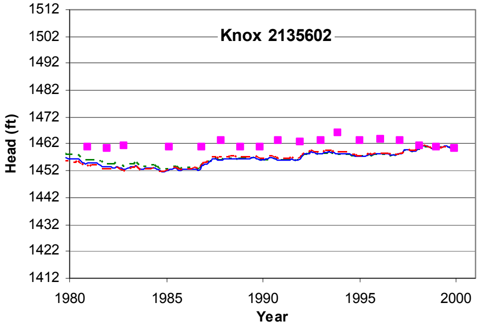
Sensitivity to Recharge

Sensitivity to Pumping

Sensitivity to Kh

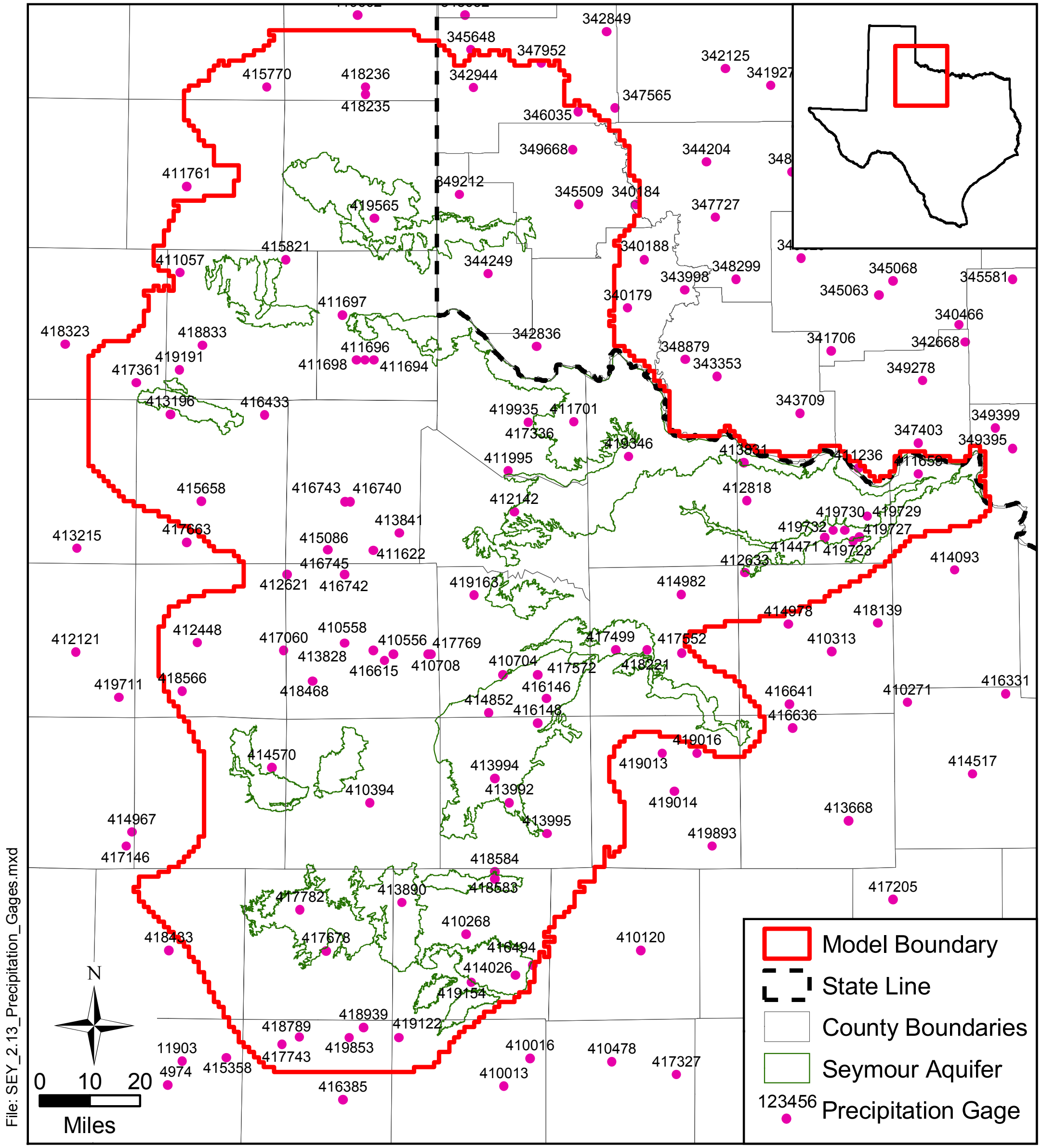






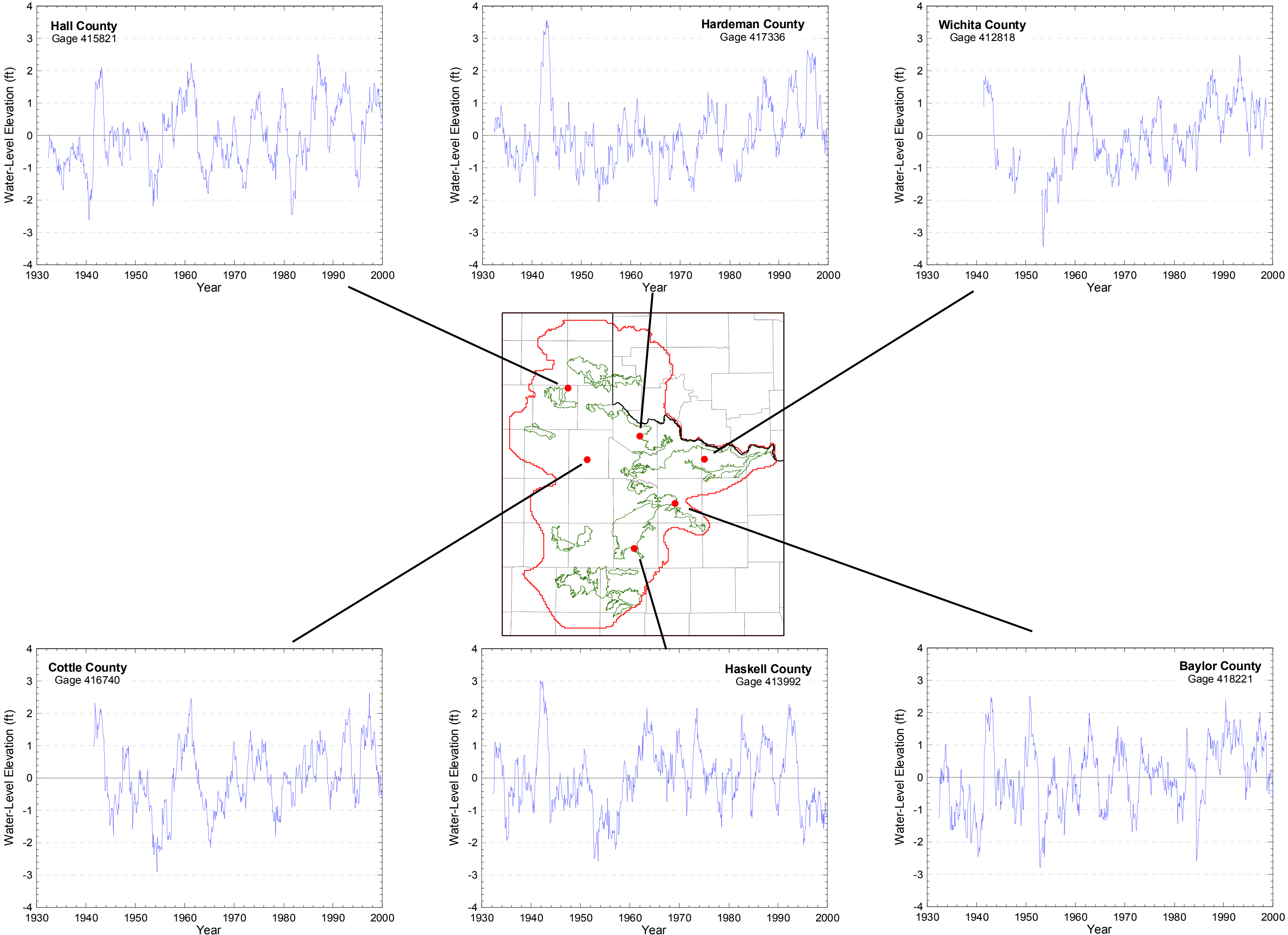
Drought of Record

Precipitation Gage Locations



Source: Online: National Climatic Data Center

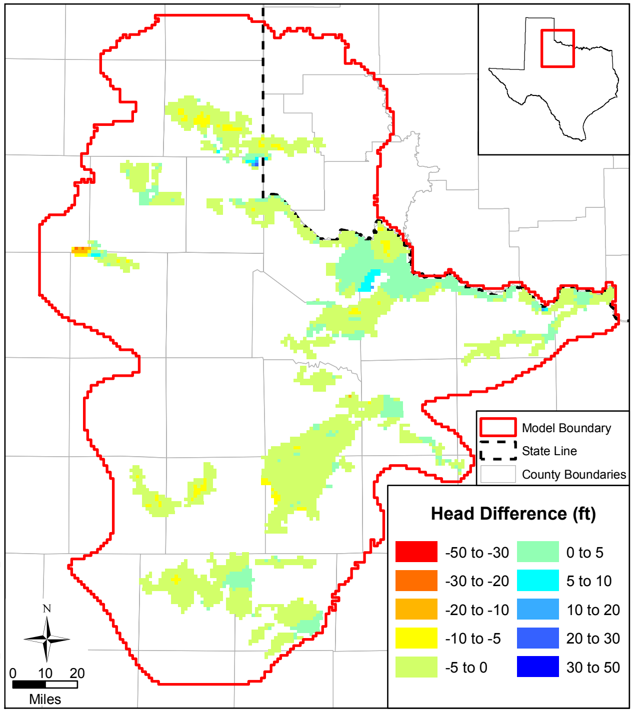
Standardized Precipitation Index – Individual Gages



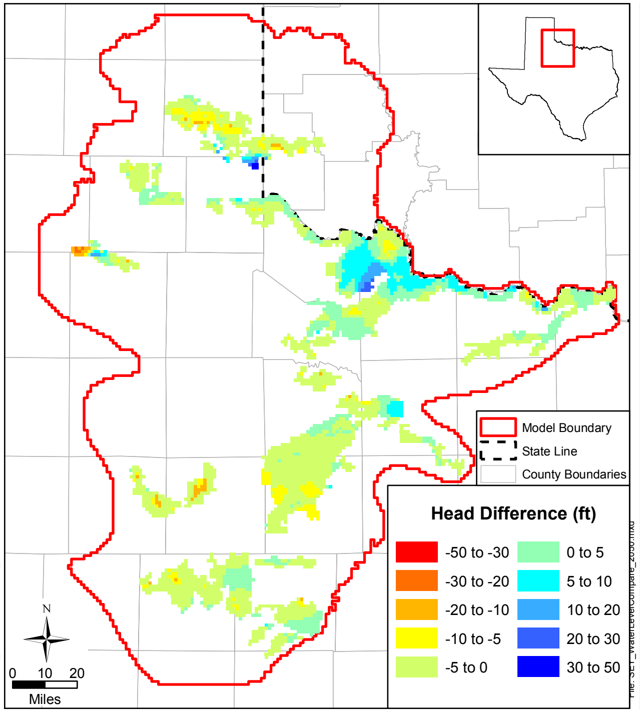
Predictive Model Results

Predicted Water-Level Differences - Seymour

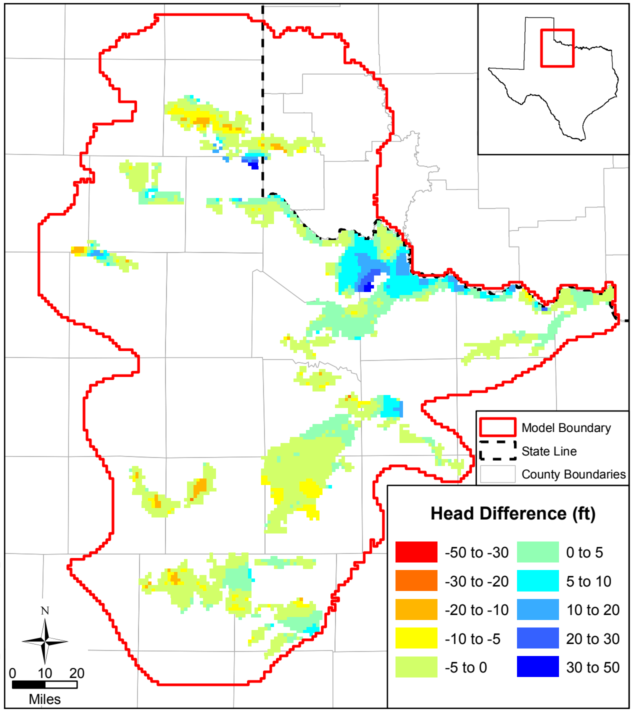
2000 and 2010



2000 and 2030



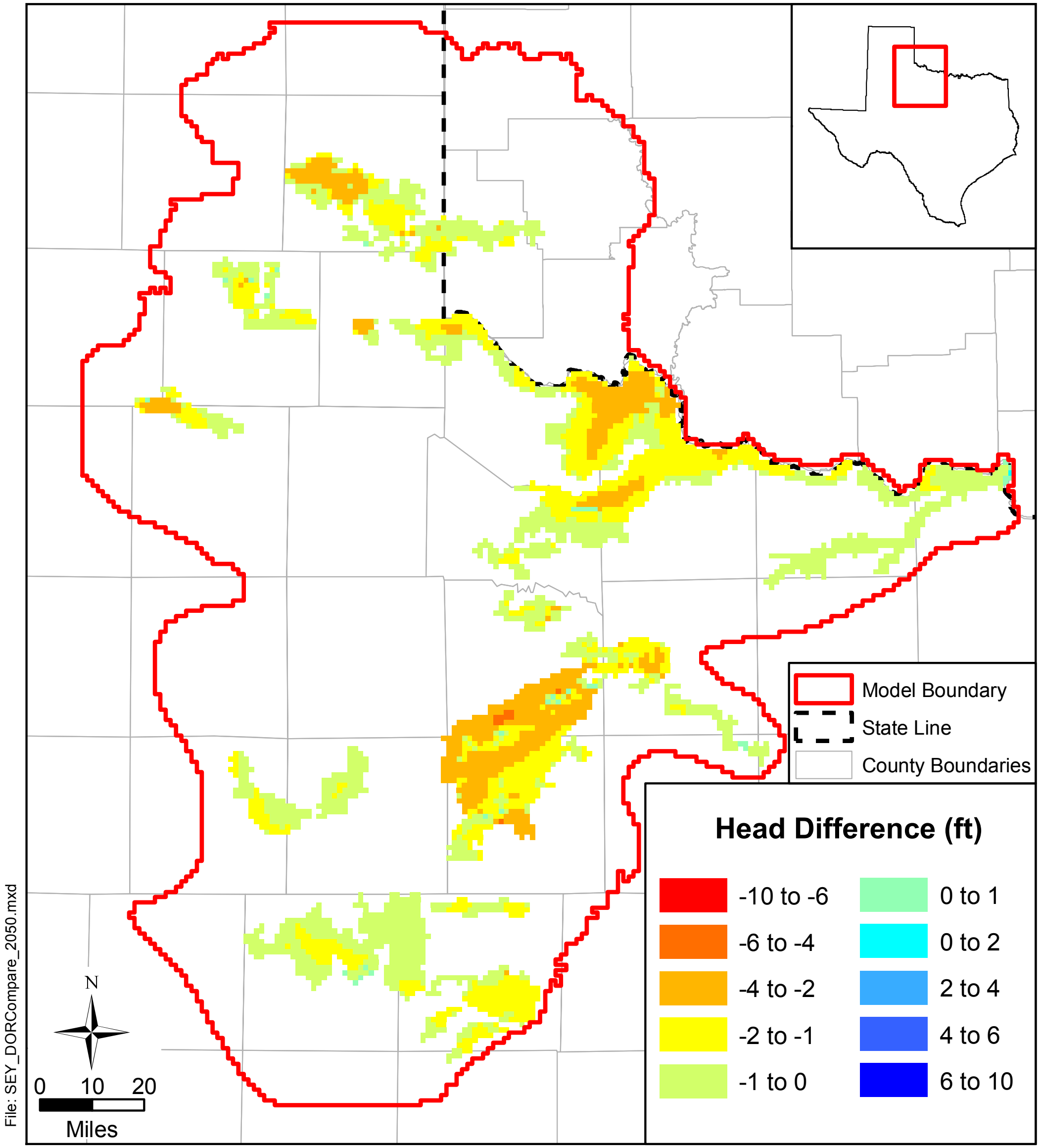
2000 and 2050



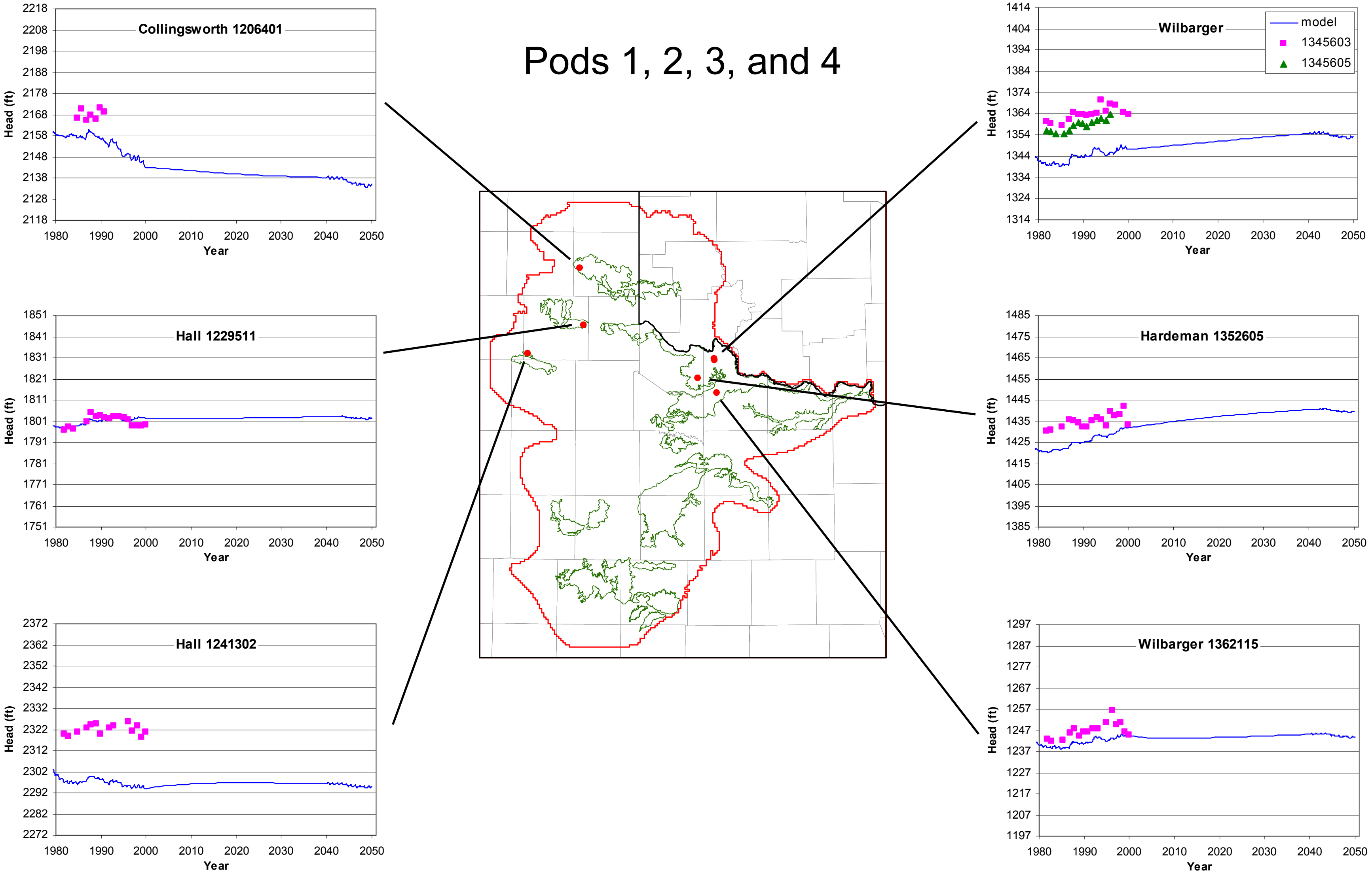
Head Difference (ft)

🟥 -10 to -6
🟧 -6 to -4
🟧 -4 to -2
🟨 -2 to -1
🟩 -1 to 0
🟩 0 to 1
🟦 0 to 2
🟦 2 to 4
🟦 4 to 6
🟦 6 to 10

Drought and Average Differences 2050

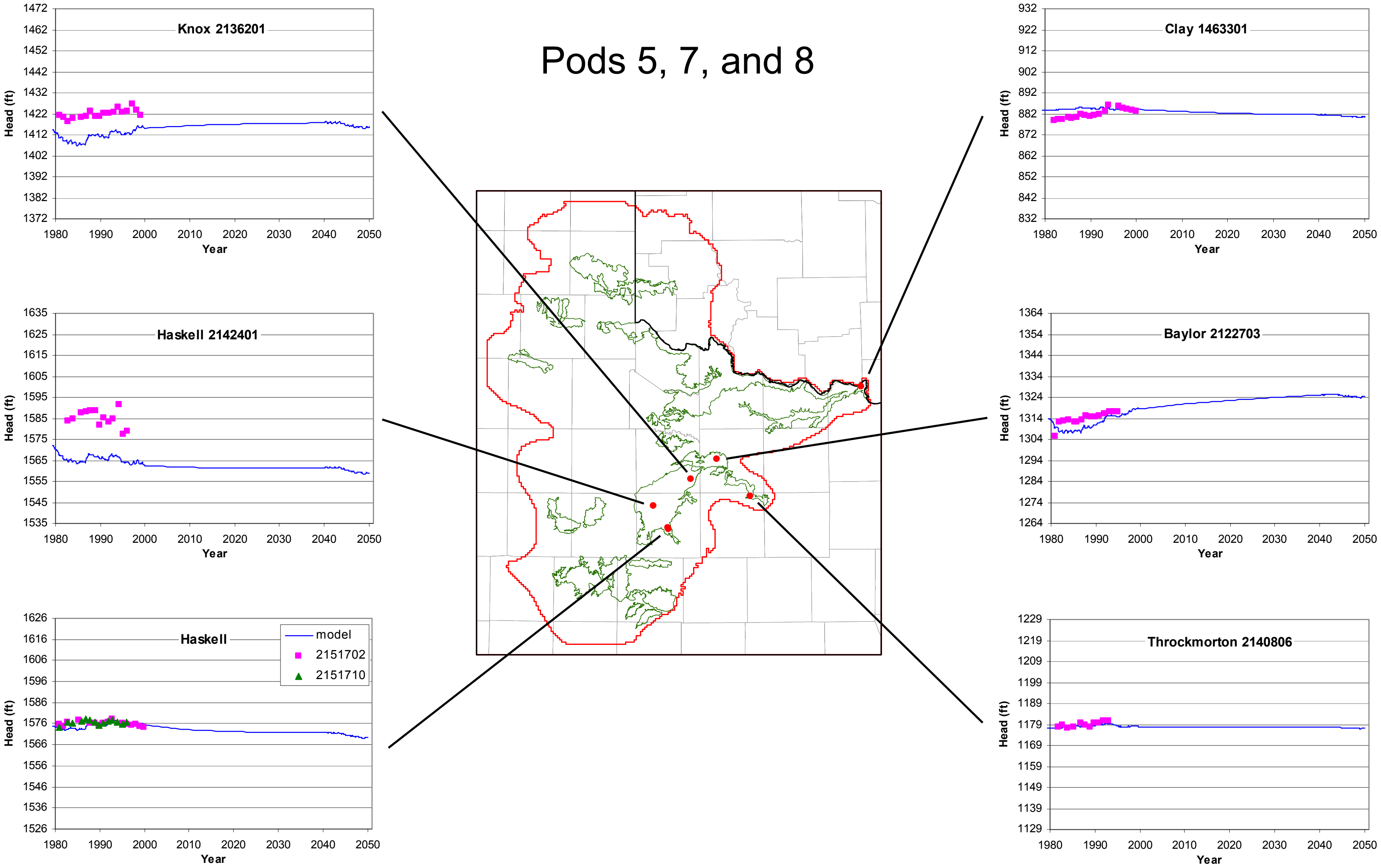


Predicted Hydrographs – Seymour



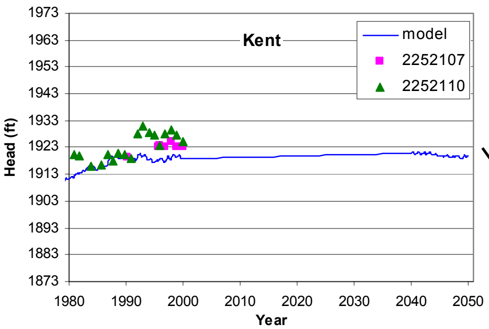
Predicted Hydrographs – Seymour

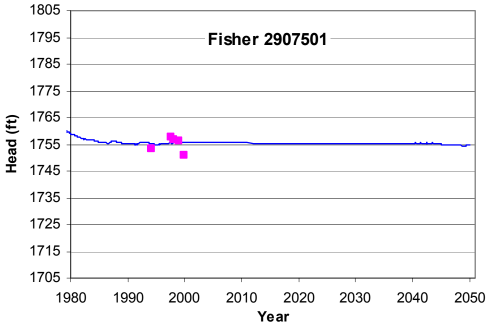
Pods 5, 7, and 8

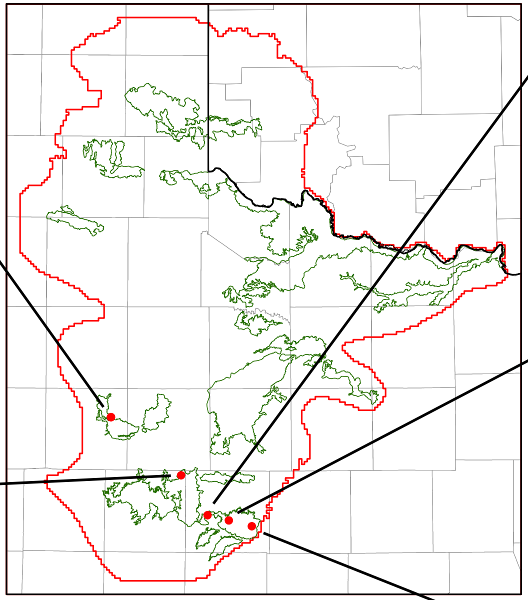


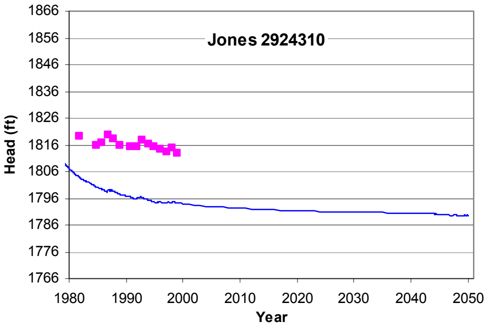
Predicted Hydrographs – Seymour

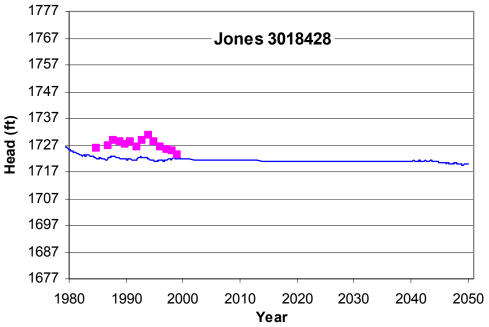
Pods 9, 11 and 13

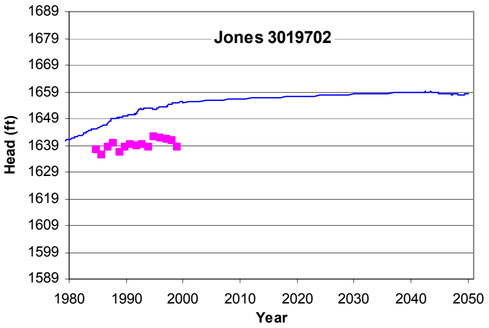




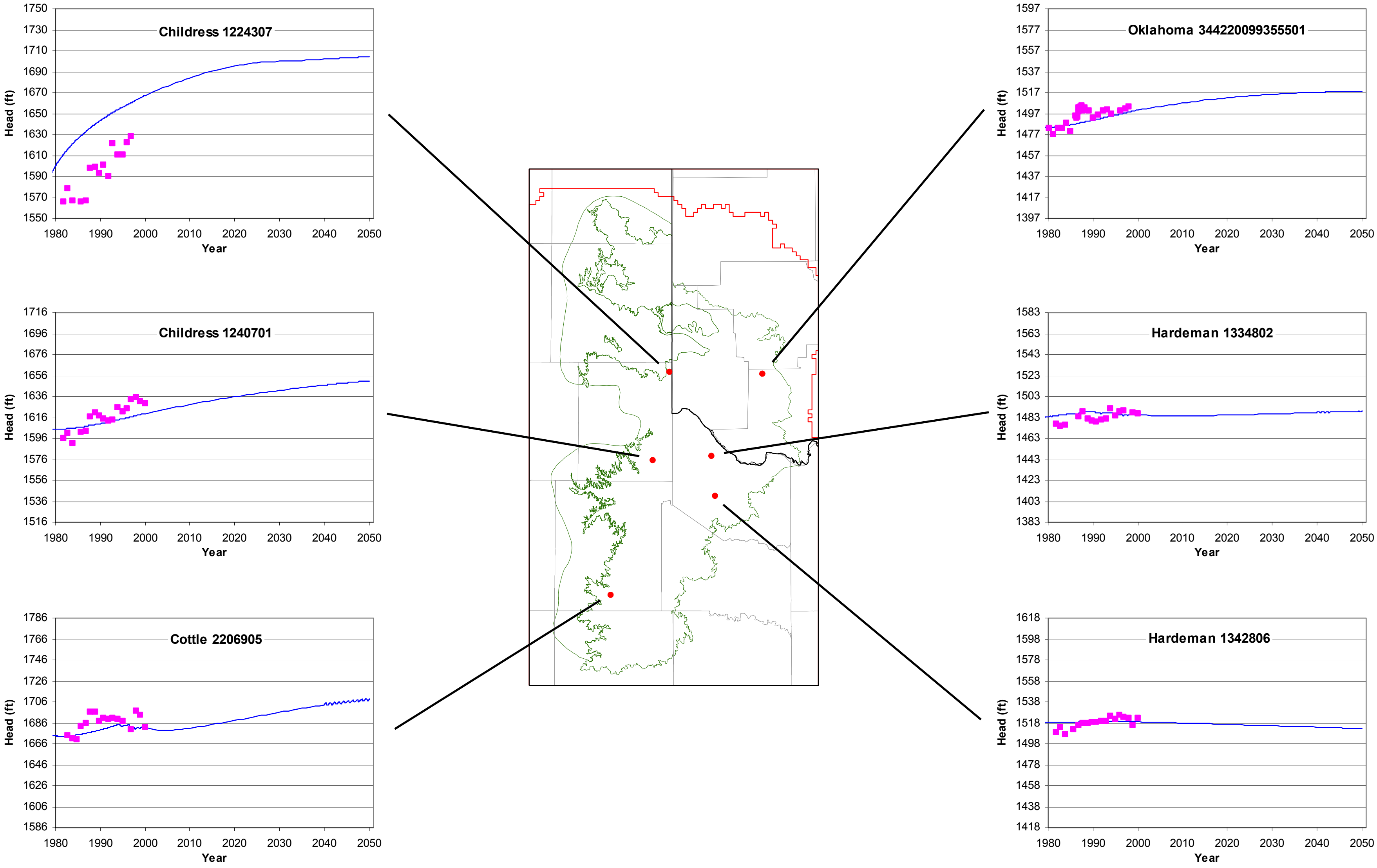








Predicted Hydrographs – Blaine



Conclusions

Conclusions

- Steady-state model
  - Reproduces steady-state heads within GAM criteria and uncertainty of head estimates
  - Average recharge rate of 0.6 in/yr, with an average rate of 2 in/yr applied to the Seymour
  - Aquifer inflow - 94% from recharge
  - Aquifer outflow – 48% to streams, 31% to ET, and 19% to pumping
  - Most sensitive parameters are recharge, stream conductance, and horizontal hydraulic conductivity in the Permian (layer 2)

Conclusions (continued)

- Transient model
  - Reproduces transient heads within GAM criteria and uncertainty of head estimates
  - Aquifer inflow - 94% from recharge
  - Aquifer outflow – 35% to streams, 20% to ET, and 20% to pumping
  - Most sensitive parameters are recharge and pumping

Conclusions (continued)

- Predictions
  - Average increase of 1.6 feet in the Seymour aquifer between 2000 and 2050
  - Average decline of 0.6 feet in the Permian between 2000 and 2050
  - DOR heads an average of 1.1 feet lower than average-condition heads in Seymour
  - DOR heads an average of 1.7 feet lower than average-condition heads in the Permian

Model Limitations and Future Improvements

Model Limitations

- Limitations of supporting data
  - Hydraulic head in select Seymour pods
  - Stream/aquifer gain loss estimates
  - Blaine structural data
  - Hydraulic property data for the Permian
- Assumptions
  - No-flow boundaries in layer 2
  - Spatial variation in recharge
  - Temporal variation in recharge
  - Maximum ET and extinction depth

Model Limitations (continued)

- Model applicability
  - Regional scale
    - The Seymour aquifer is not regionally connected but rather consists of small isolated pods.
  - Grid-block size
    - The size of the pods is small relative to the grid-block size of 1 square mile.
  - Structure
    - Thin nature of aquifer results in significant impact on simulated water level with small errors in structure (1-mile averaging) and /or observed water levels.

Model Limitations (continued)

- Model applicability
  - Pumping for steady-state
    - Small errors in pumping in the steady-state model will impact the steady-state solution.
  - Surface water/groundwater coupling
    - The model does not provide a rigorous solution to surface water modeling.
  - Water-quality issues
    - Only a preliminary assessment of water quality is conducted for the GAMs.

Future Improvements

- Additional supporting data
  - Water-level monitoring in pods with sparse measurements
  - Recharge studies
  - Surface water/groundwater studies
  - Stream gaging data
  - Horizontal hydraulic conductivity in Seymour and Permian
  - Accurate location of base of Seymour

Future Implementation Improvements

- Consider each pod individually
  - this would result in more accurate simulation of aquifer dynamics at the pod scale
- Refine gridding based on
  - the size of the pod being modeled
  - hydraulic stresses in the pod being modeled
  - the ultimate goal of the model

GAM Schedule

- Project start – November 2002
- Draft conceptual model – August 15, 2003*
- Draft conceptual model report – August 31, 2003
- Steady-state model calibration – November 25, 2003*
- Transient calibration & verification – January 30, 2004*
- Predictions – February 13, 2004*
- Draft Model Report to TWDB – March 1, 2004
- Public feedback on Draft Report – April 9, 2004
- TWDB feedback on Draft Report – April 30, 2004*
- Model Training Seminar – May 2004
- Final Model Report to TWDB – June 30, 2004

Note: * means technical review meeting scheduled with the TWDB

Seymour GAM SAF 4 – April 1, 2004
Attendance List

Name	Affiliation
H. L. Ayers	Tri Co GWD
Johnny Kaja	Tri Co GWD
Nancy Johnson	WPRC
Curtis W. Campbell	Red River Authority
Ray Brady	Panhandle GWCD
Thomas L. Powell	Collingsworth County UWCD
Cindy Ridgeway	TWDB
Don A. Butler	NRCS Board Member
Mike McGuire	RPGCD
Larry Lundstrom	City of Electra
David Meesey	TWDB
Andrew Chastain-Howley	WRPC
John Ewing	Intera

Summary Memorandum Report
Seymour Aquifer GAM
Stakeholders Advisory Forum #4, Seymour, Texas
April 1, 2004

PRESENTATION

The fourth Stakeholder Advisory Forum was held on Thursday, April 1, 2004 at 1.30 p.m. at the Portwood Arts and Civic Center, 800 Morris Street in Seymour, Texas.

The presentation topics for this forum included:
1) Aquifer Review
2) Draft Report Overview
3) Model Design
4) Conceptual Model
5) Model Implementation
6) Steady-State Model
7) Transient Model Results
8) Drought of Record
9) Predictive Model Results
10) Conclusions
11) Model Limitations and Future Improvements
12) GAM Schedule

A summary of questions, answers and other discussion is listed below.

QUESTIONS AND ANSWERS

Q: Tommy Powell: Why is the projected total pumping reducing over time? We have noticed that pumping has increased between 2000 and 2004 and so it is likely to continue this upward trend.
A: John Ewing and Cindy Ridgeway: The data is taken from the Regional water planning Group reports from 2002. Either the assumption is that there is less water available, or the demand is projected to be less.

Info: Tri-County GCD: I have the same question. I think it’s going to be higher, not lower.

Q: City of Electra: Does it relate to population? Or because we don’t have it, so we can’t use it because it’s not there.
A: Cindy Ridgeway: It relates to demand. All factors are combined into the projection, including the water not being available.

Info: David Meesey: Also, in this area of Texas and other parts of the state, irrigation has been reduced because in some cases it’s not cost-effective to grow certain crops.

Info: Andrew Chastain-Howley and Cindy Ridgeway: Explained that the model can take changing factors into account; the parameters can be changed. This is especially true of pumping to take into account local variations and scenarios for different development plans.

Info: Tommy Powell: Collingsworth County UWCD will be sending the TWDB some more recent information on pumping in the County.

Info: Tri-County GCD: In the past 2 years we have added a third more wells in Hardeman and Wilbarger Counties. Some of this [increased pumping] is due to the drought.
Info: Tommy Powell: In some counties there's more land in CRP [therefore there is reduced water usage] this is often cyclical due to farm economics.

Info: David Meesey: The pumping projections are based on a lot of external factors. You would want to put in a lot of different scenarios so you can see what would happen and get answers for different scenarios. It's good to know several different solutions.

Info: Tri-County GCD: If gas prices keep going up you could see crops grown for fuels and pumping would go up.

Q: Curtis Campbell: Can this [the modeling] be done for the different pods separately? Some of the hydrographs are way off.
A: John Ewing: Some of it has to do with it being a one-mile grid. It's hard to predict for one mile due to the topographic and water level variations over this mile. In some cases where there are multiple wells in a grid cell some of the predicted water levels match very closely and others follow a similar trend but are offset from the prediction.

Info: John Ewing, Cindy Ridgeway, Andrew Chastain-Howley: There will be a workshop (probably in May) for stakeholders to teach them how to use the model. It should be noted that this will be a fairly detailed hands-on workshop.

Q: Ray Brady: Can this workshop be done through a weblink at the agricultural extension facility in Lockhart?
A: Cindy Ridgeway: I'll check into it. You need a computer and will need to have the software installed and the model too. If you have the capability for doing it, that can be done. We may have the workshop in Austin so everyone will have a computer.

Q: Curtis Campbell: Will this workshop be open to consultants?
A: Cindy Ridgeway: Yes.

Info: Mike McGuire: Most of the regional water planning groups have already set their groundwater availability projections. It may be best to use this as a tool for the next round of planning, and to make sure there are no major problems.

Info: Curtis Campbell: If you're looking at a specific water problem, this would work.

Q: Mike McGuire: The modeling will probably need to be done on a pod-by-pod basis sooner or later.
A: Cindy Ridgeway: It can be run now on a pod-by-pod basis. You can refine the grid as needed. If you have the data, the grid can be refined. Another factor is the size of the pod. However, more detailed data will probably be necessary to significantly refine the grid. The better the data, the better the model will be.

Q: Tri-County GCD: The groundwater availability is very different within areas of pod 4, is this shown in the model?
A. John Ewing: It is shown on the hydraulic conductivity graphics and by the number of wells found in the different areas

Info: Cindy Ridgeway: The model should be run by pod and not less than a pod. Whatever is going on in one part will affect the whole pod.

Q: Tri-County GCD: We had a period of high recharge this year and no rain. Where did the water come from? How long does it take for the water to move through the aquifer?
A: Cindy Ridgeway and John Ewing: Possibly the water is flowing from upslope. There's a lag in the recharge to water level rise. An isotope analysis would tell you where your water came from.

Q: Tri-County GCD: Do you do any geophysical work [to determine the structure]?
A: Cindy Ridgeway: No, but we've used other techniques such as air photos and airborne geophysics for other applications.

Info: Mike McGuire: Talk to Andrew Chastain-Howley about geophysical work and studies.

Prepared by: Andrew Chastain-Howley and Nancy Johnson
Date: April 5, 2004