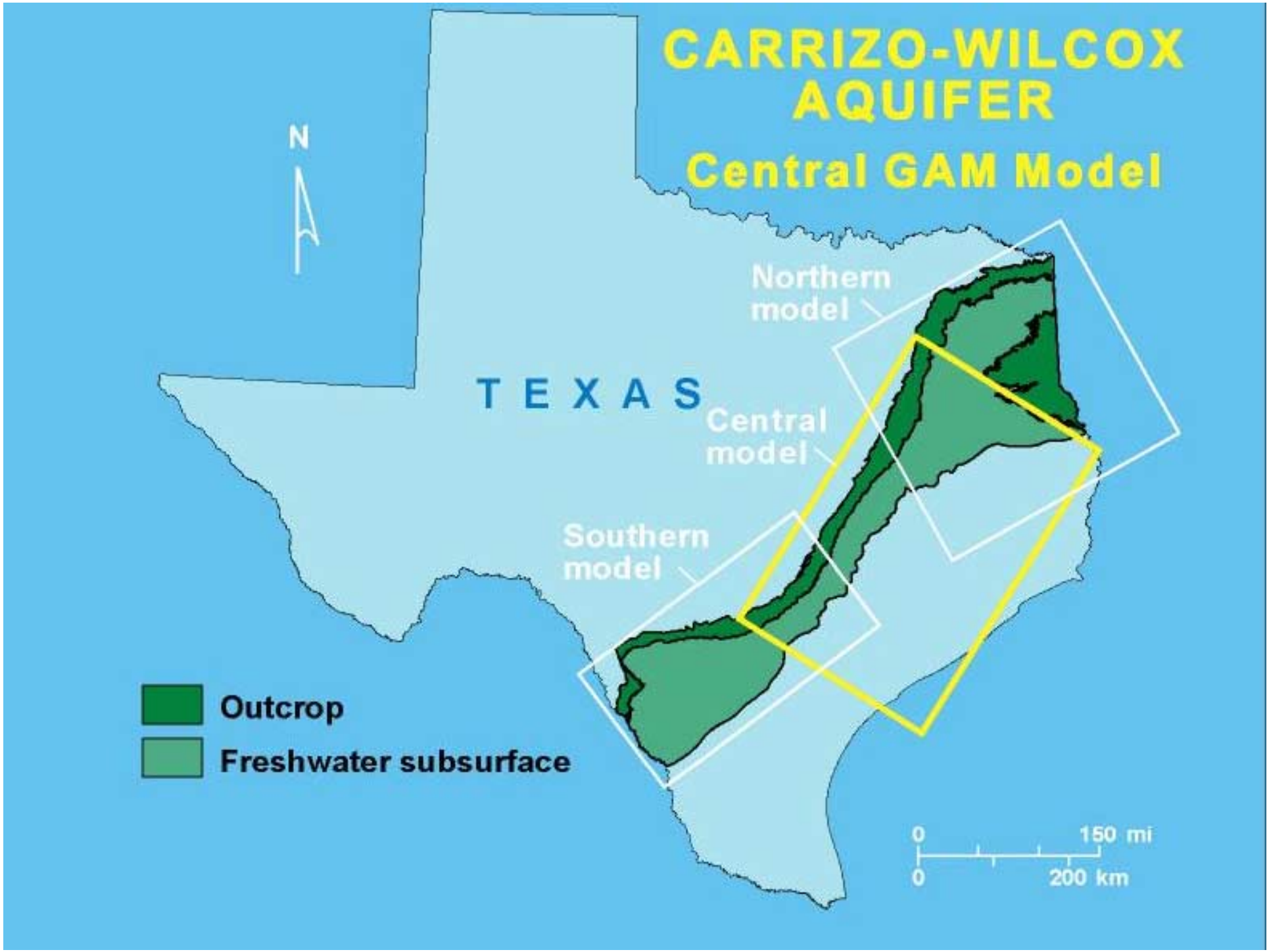

GAM
Groundwater
Availability
Modeling
texas water development board

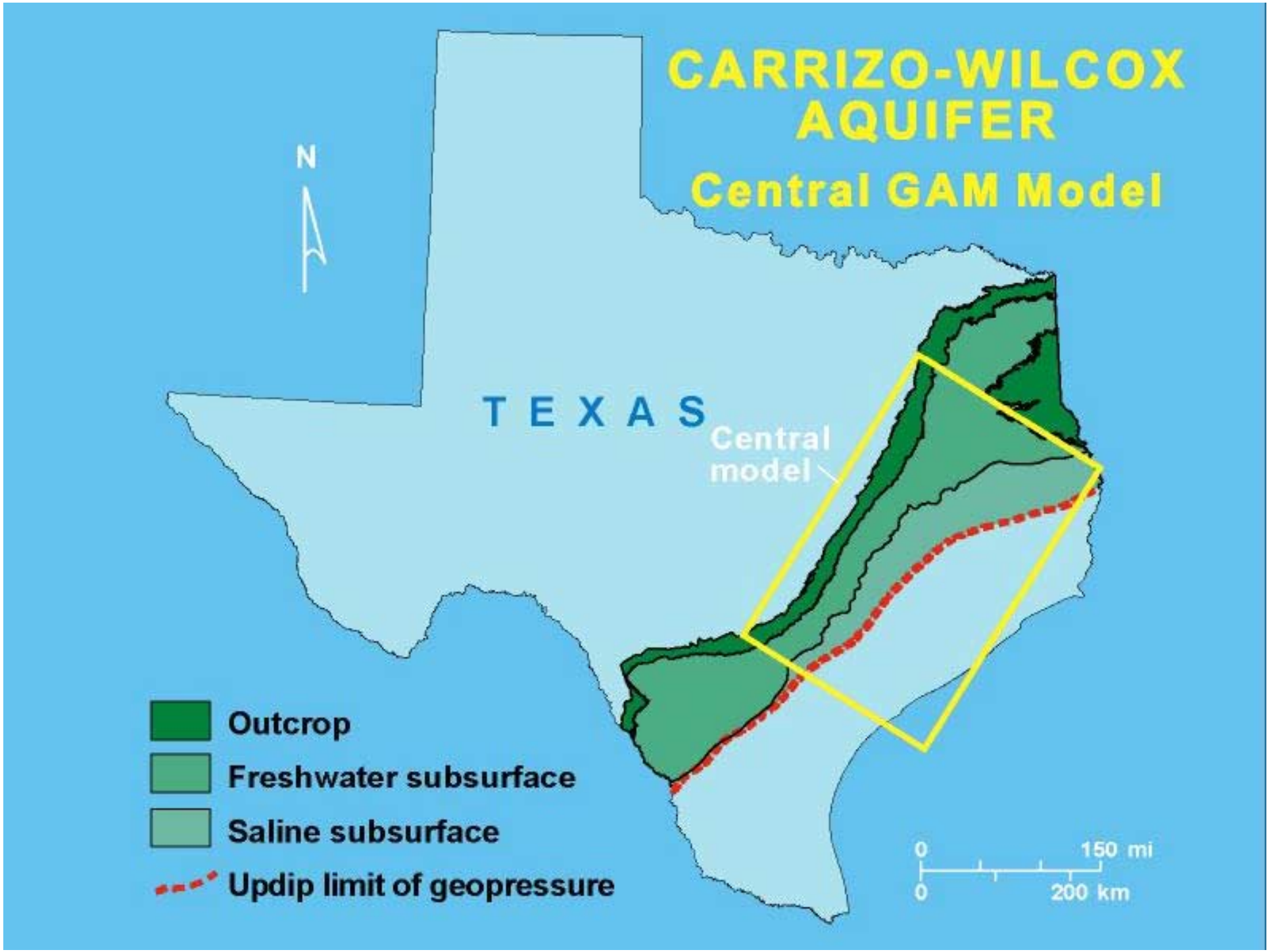

CARRIZO-WILCOX AQUIFER
Central GAM Model
N
TEXAS
Northern model
Central model
Southern model
Outcrop
Freshwater subsurface
0
150 mi
0
200 km

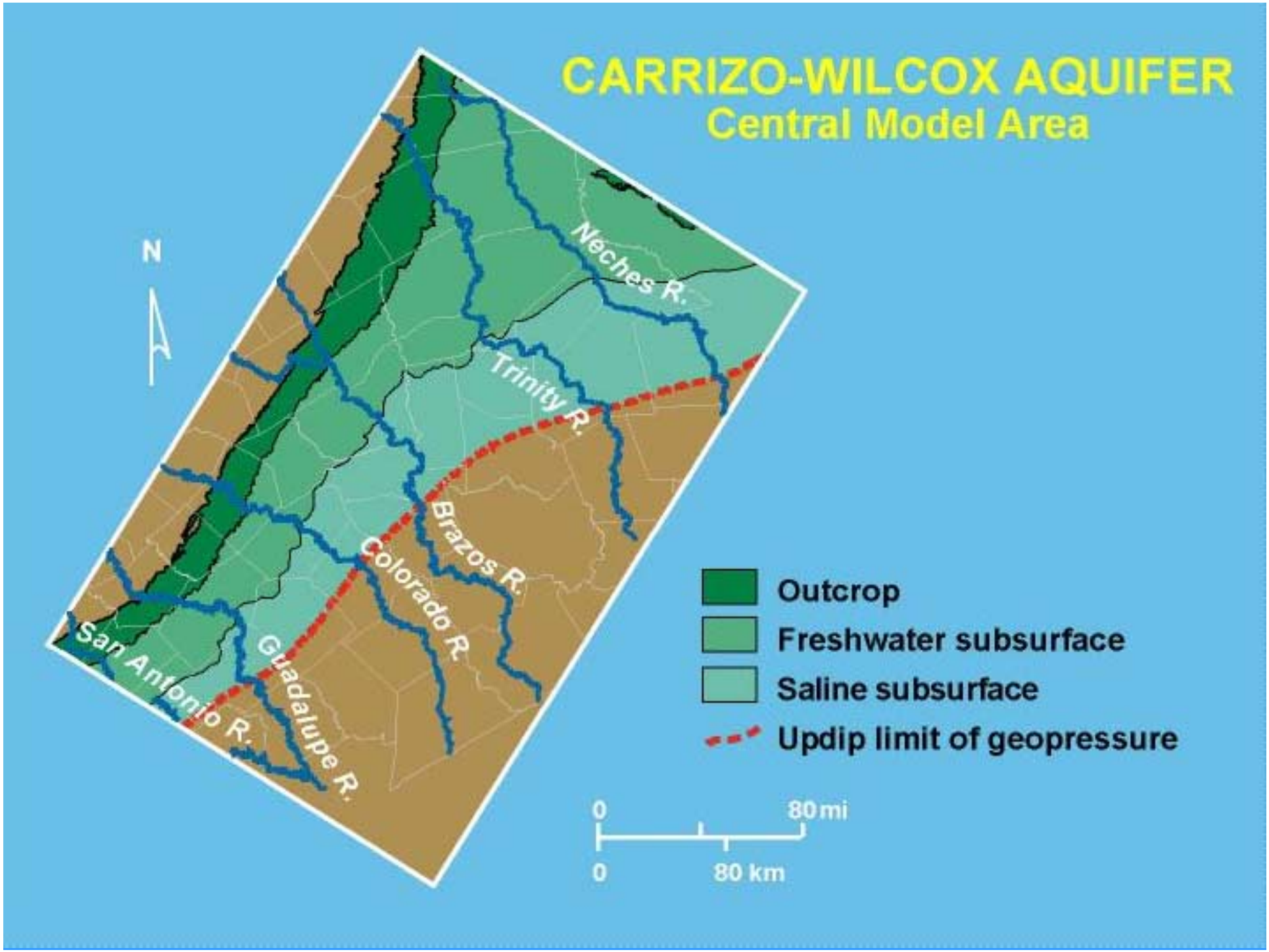
ROLE OF GAM MODEL

- Goal of GAM project is to develop a scientifically accurate and realistic computer model
- Model will represent the aquifer's water budget and groundwater processes such as recharge, discharge, and pumping
- Model will be used by groundwater conservation districts (GWCD), regional water planning groups (RWPG), TWDB, and individuals to evaluate the hydrologic effects of various water use alternatives
- Stakeholder participation is important to ensure the model is accepted as a valid representation of the aquifer
- Once the model is developed, it can be used to assess availability of groundwater

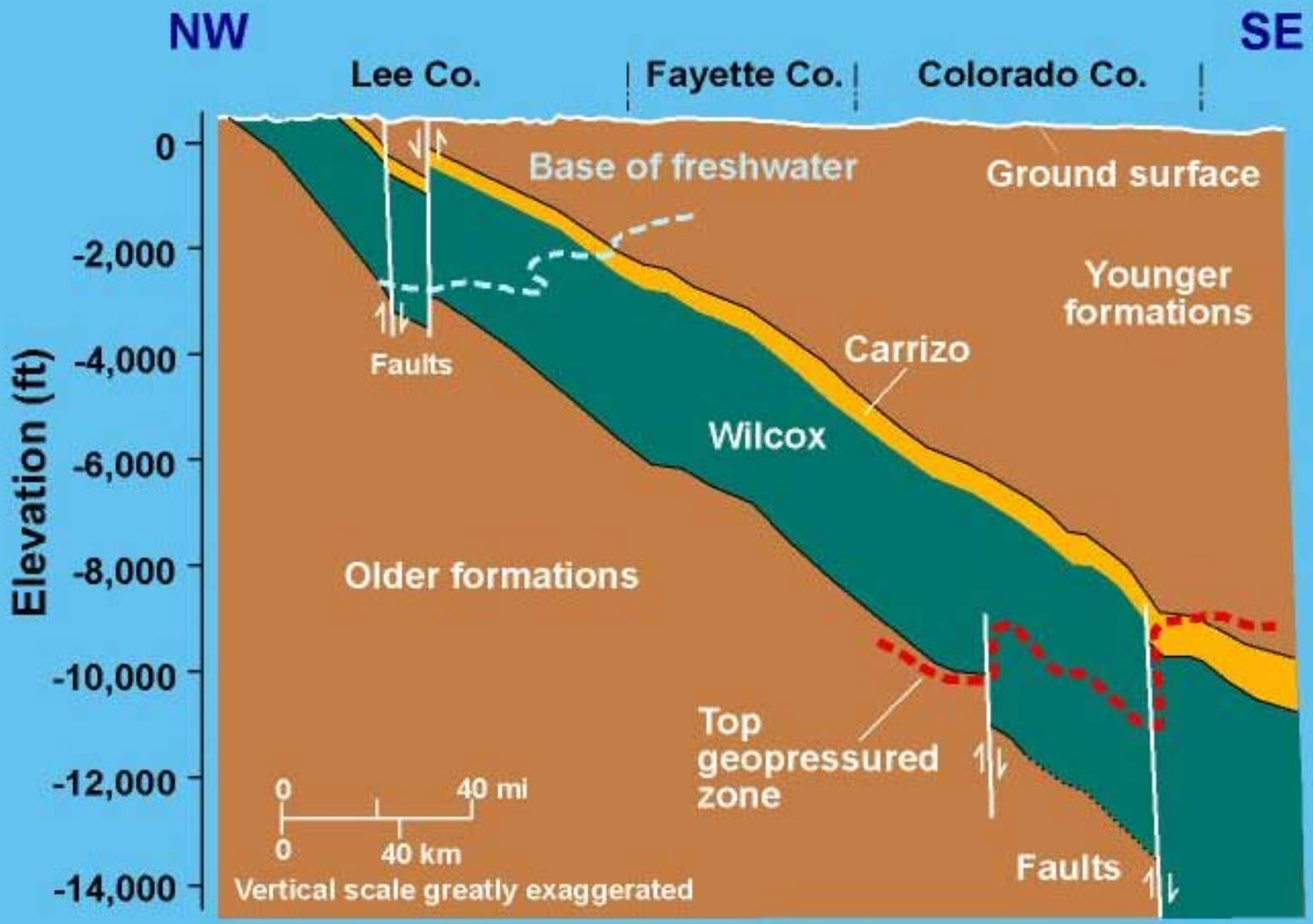
AGENDA
STAKEHOLDER ADVISORY FORUM (SAF) MEETING
October 31, 2001

- Review of aquifer hydrogeology for building the computer model
- Recharge
- Potentiometric surface
- Pumping distribution
- Model construction and initial simulations
- Schedule and status

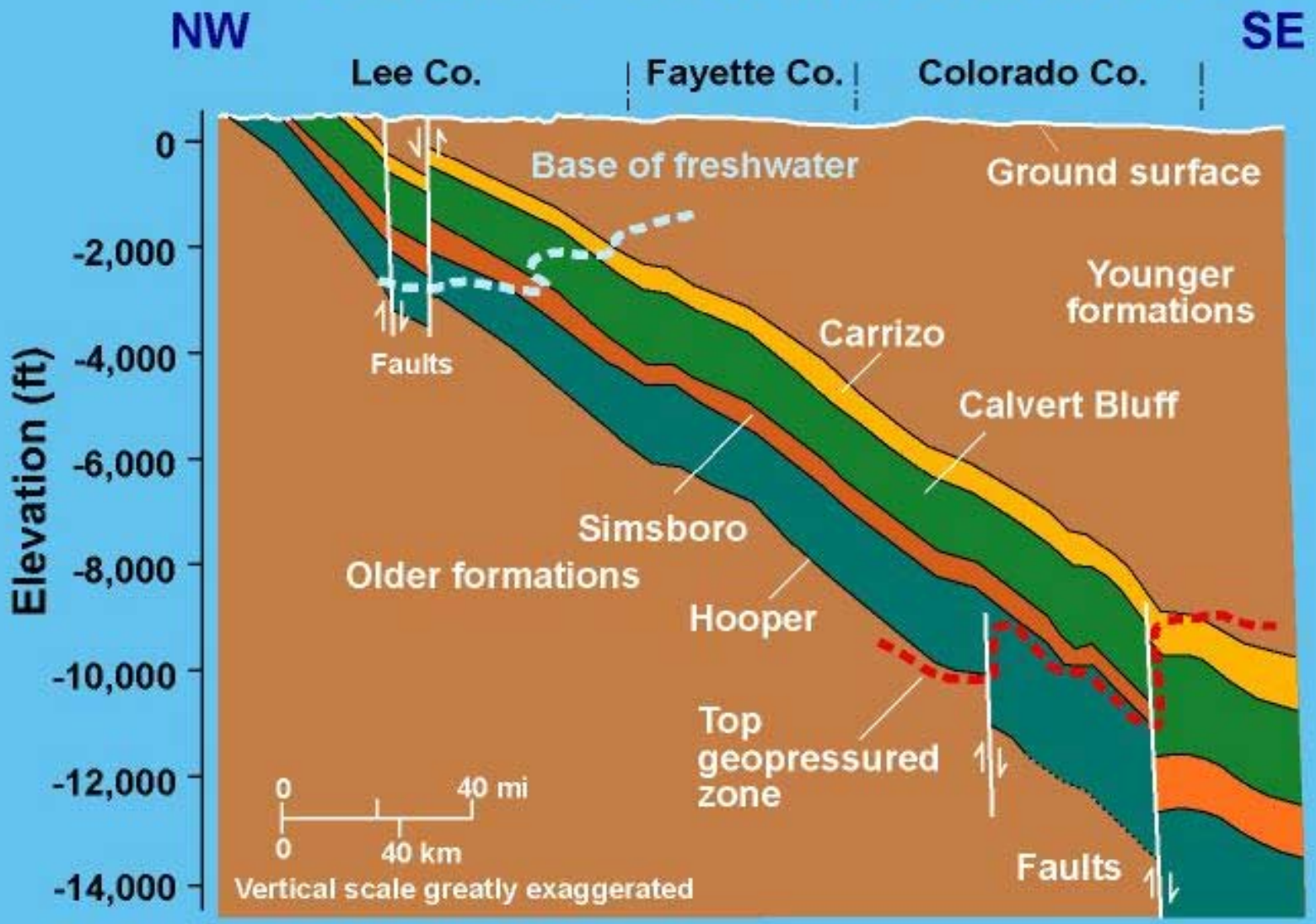

CARRIZO-WILCOX AQUIFER
Central GAM Model
N
TEXAS
Central model
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0
150 mi
0
200 km


CARRIZO-WILCOX AQUIFER
Central Model Area
N
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0
80 mi
0
80 km

CARRIZO-WILCOX HYDROGEOLOGY



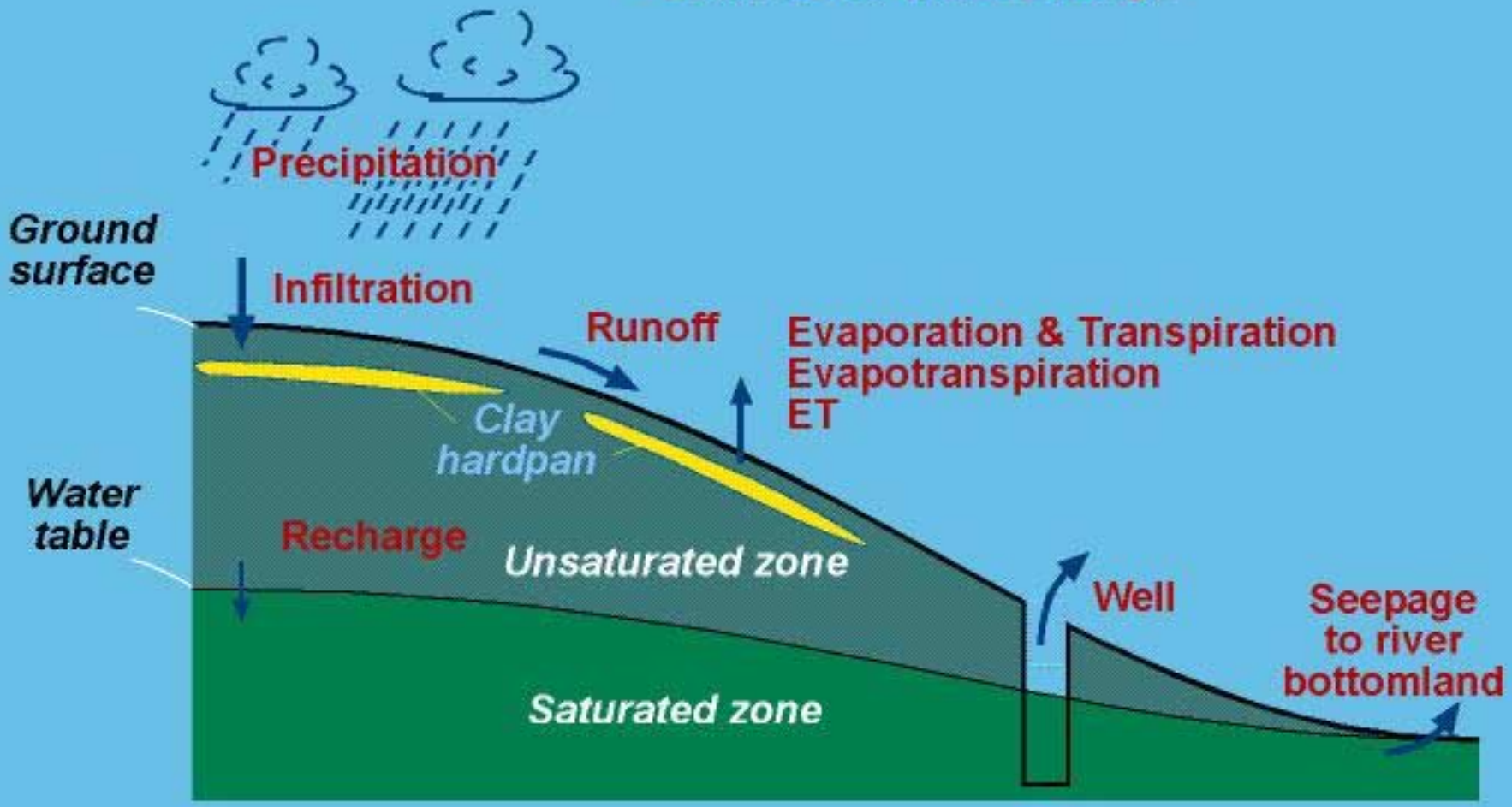
CARRIZO-WILCOX HYDROGEOLOGY
Central Part of Model Area



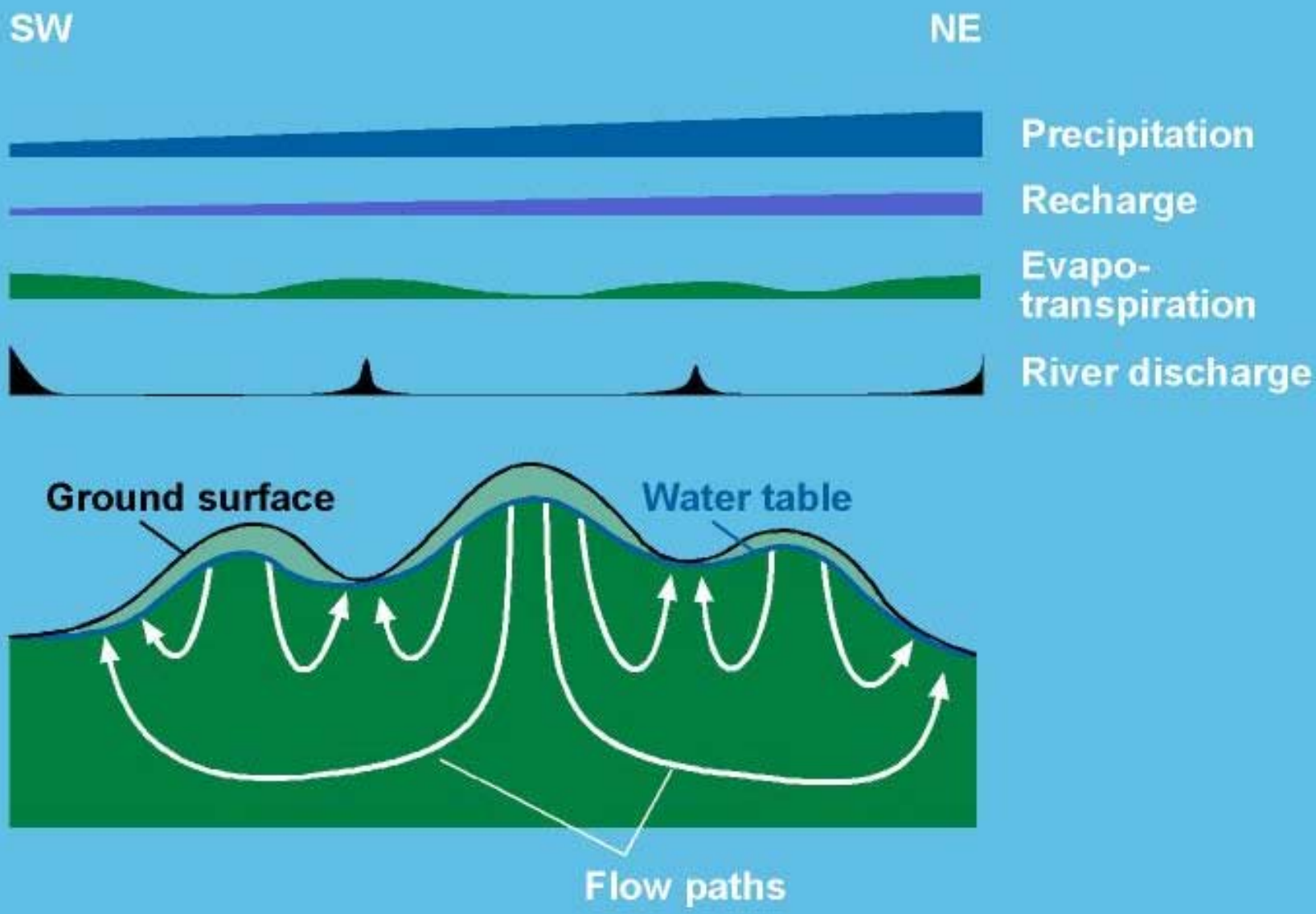
RECHARGE

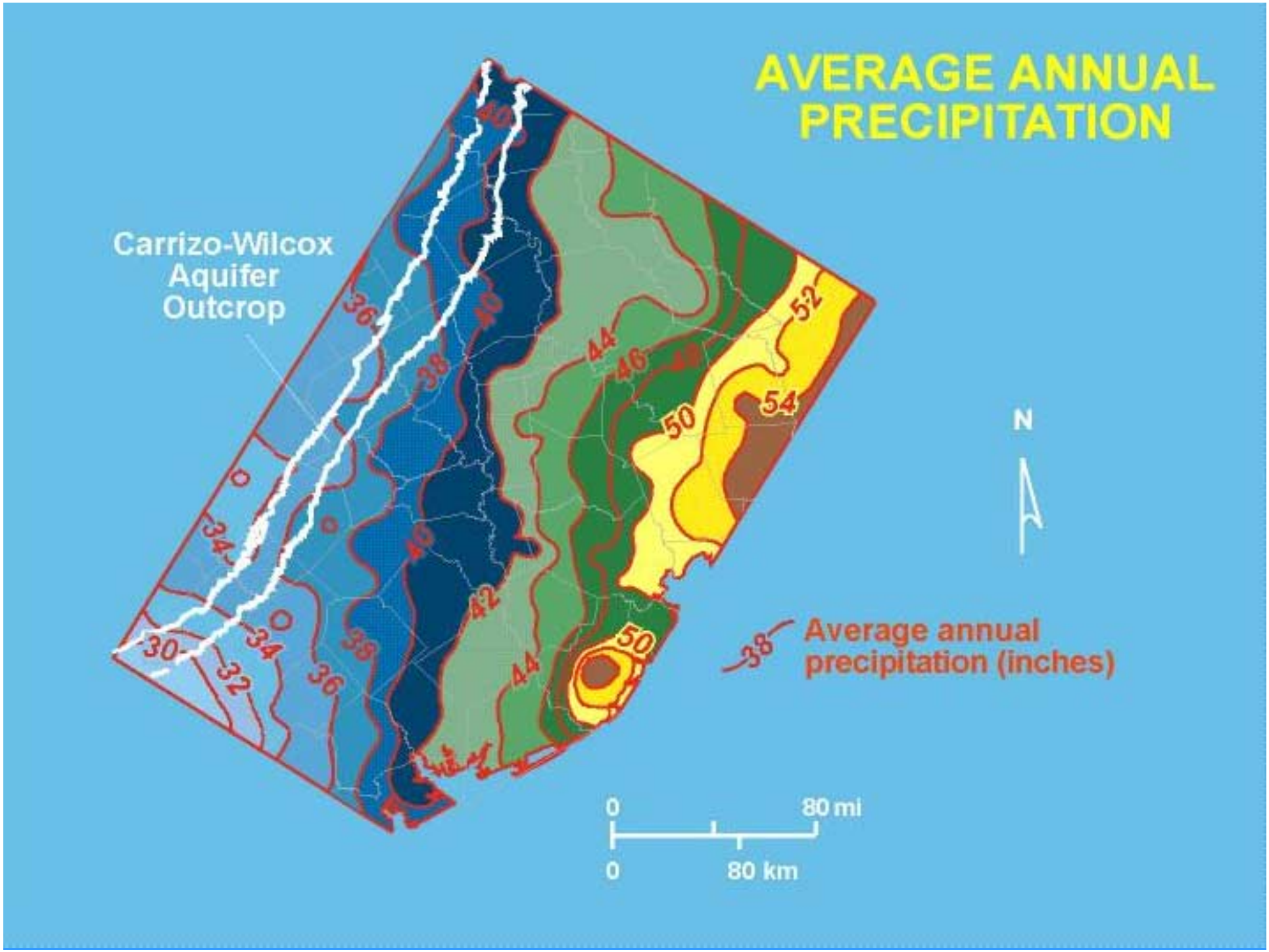
SOURCE OF CAPTURED RECHARGE

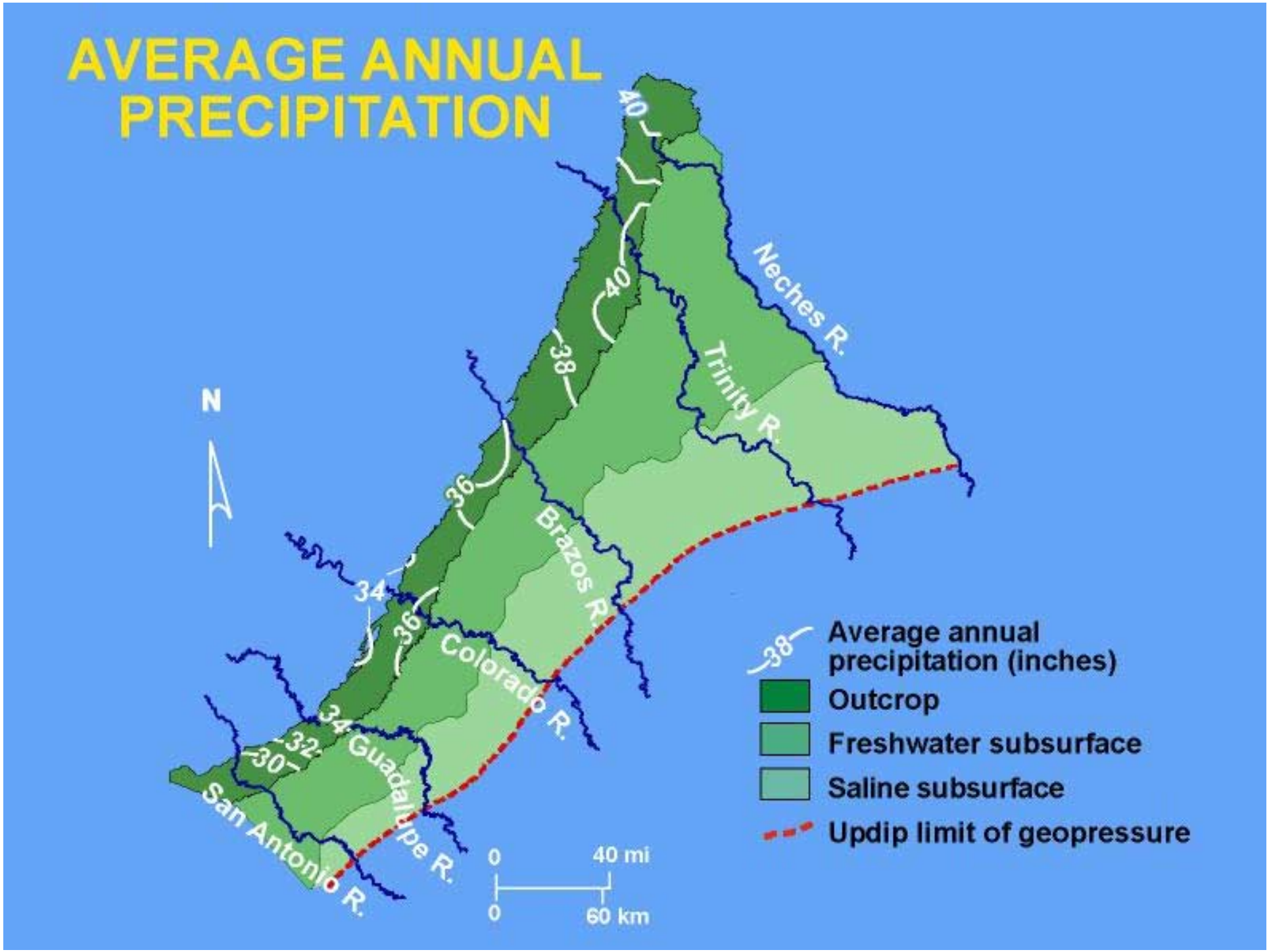
Recharge = Precipitation
- Runoff
- ET
- Gain in Soil-water Storage



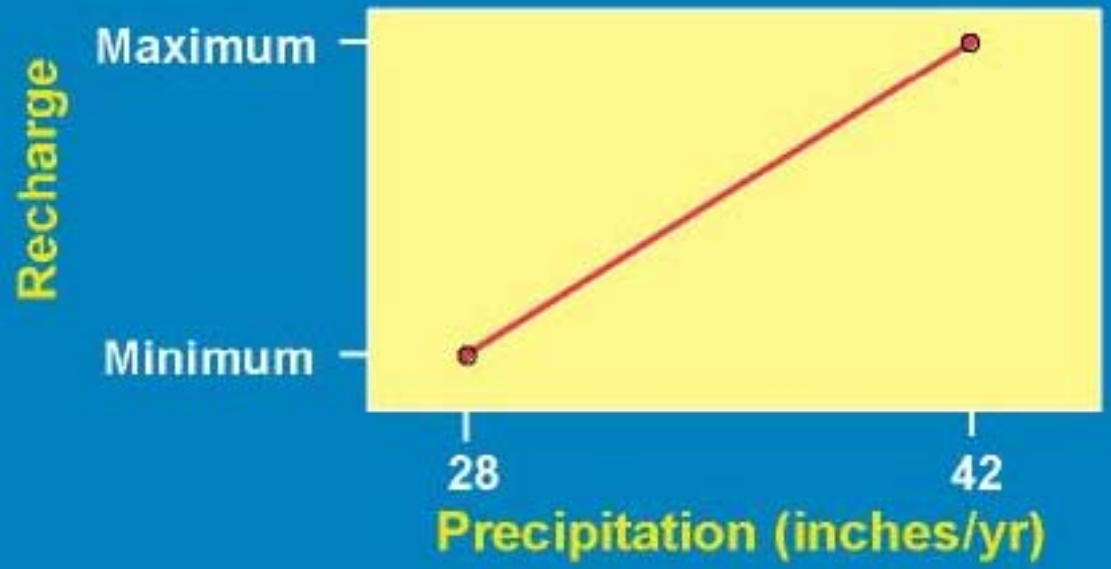
APPROACH FOR MODELING RECHARGE

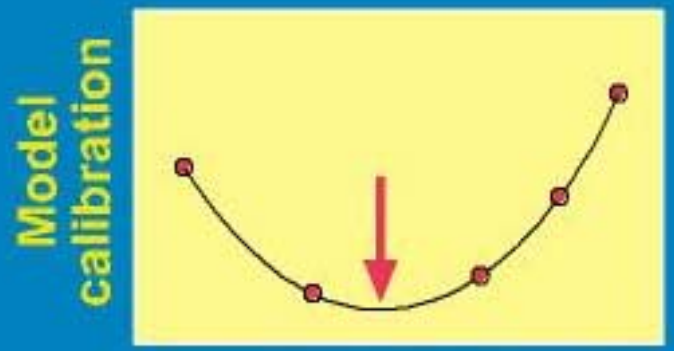



AVERAGE ANNUAL PRECIPITATION
Carrizo-Wilcox Aquifer Outcrop
30
34
38
42
44
46
50
52
54
N
38
Average annual precipitation (inches)
0
80 mi
0
80 km

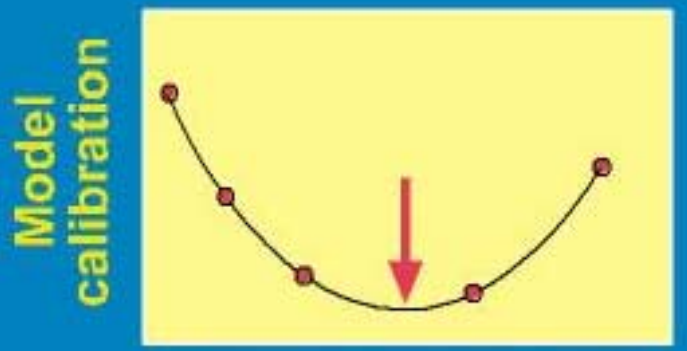

AVERAGE ANNUAL PRECIPITATION
40
40
38
36
34
32
30
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
N
0
40 mi
0
60 km
Average annual precipitation (inches)
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure

RECHARGE MODELED FROM PRECIPITATION





Minimum recharge

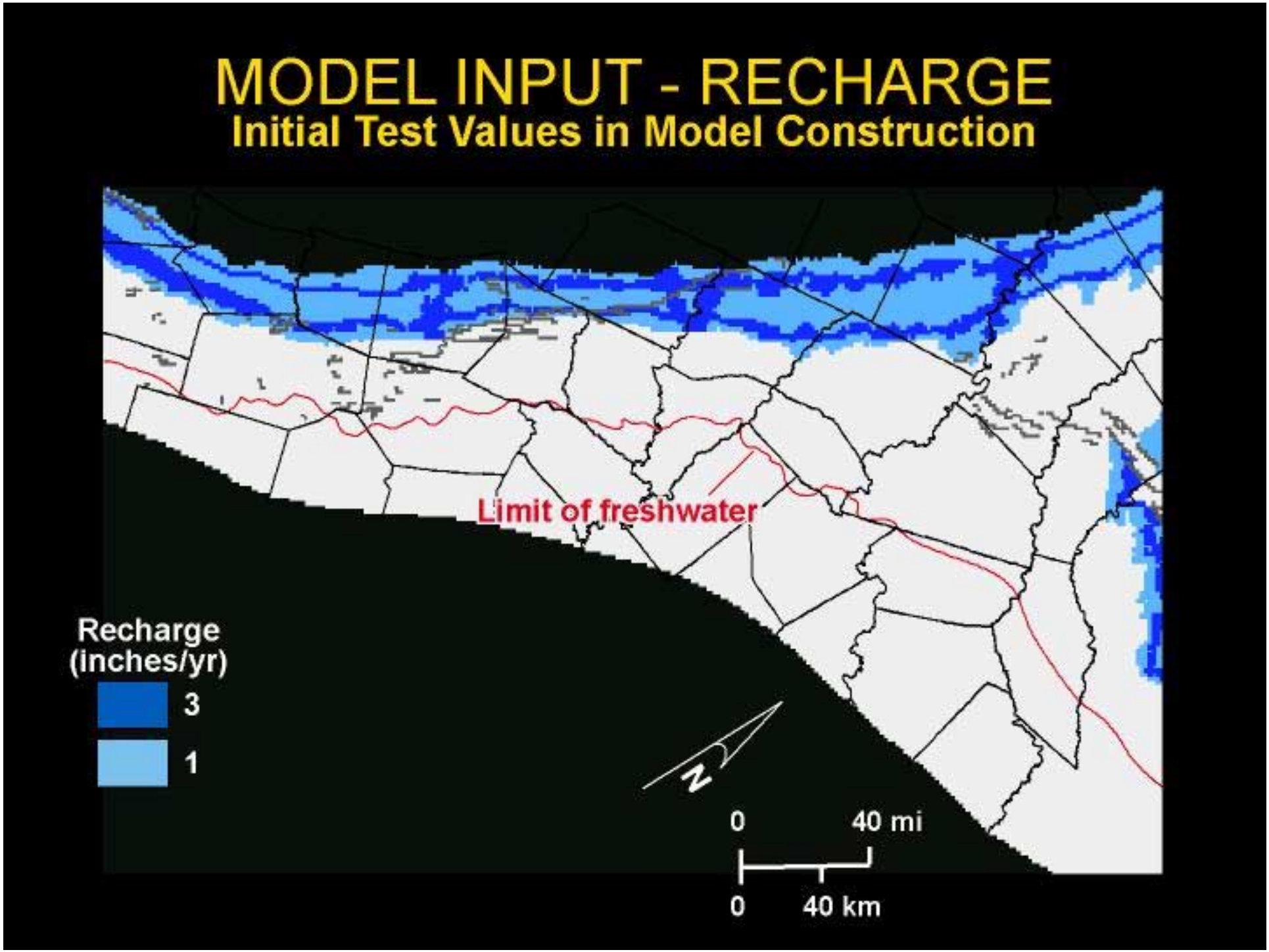


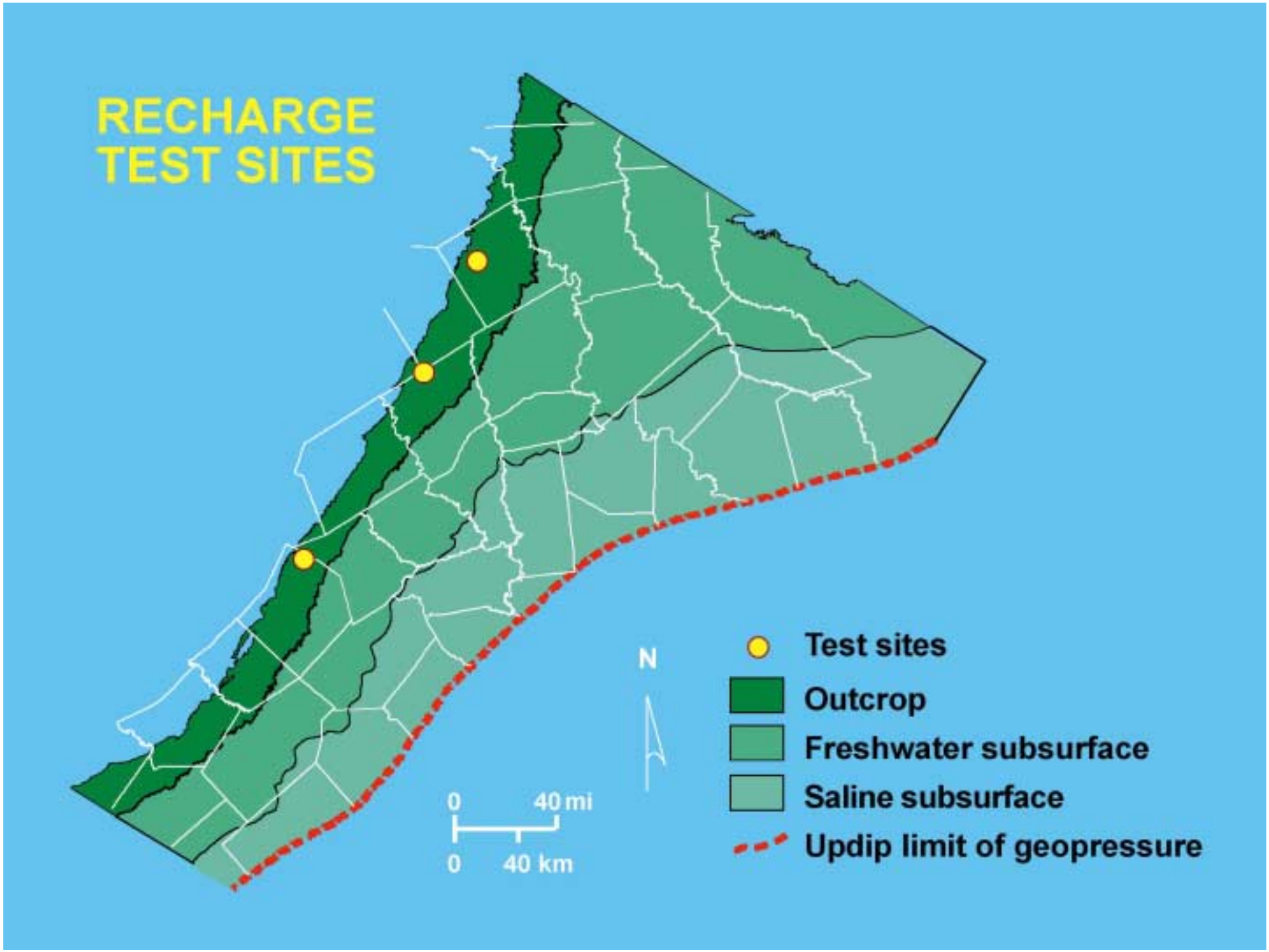
Maximum recharge

SOIL TYPES
Estimation of Recharge Factors

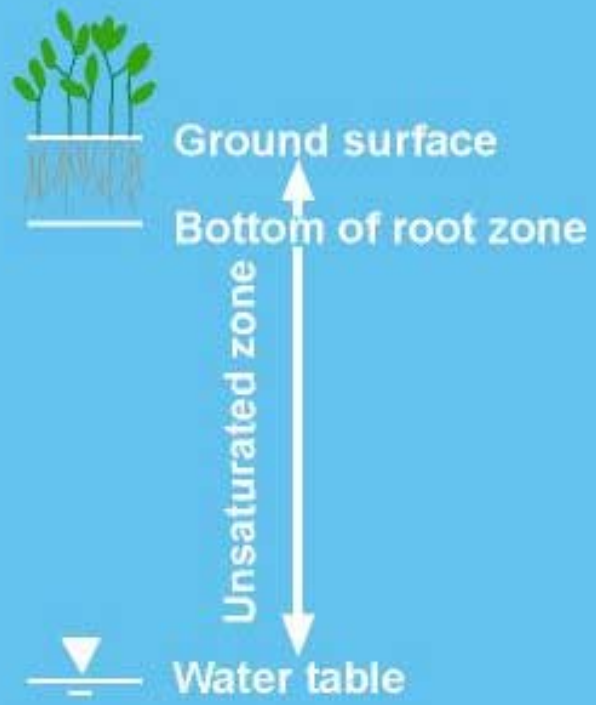
MODEL INPUT - RECHARGE

Initial Test Values in Model Construction




RECHARGE
TEST SITES
N
0 40 mi
0 40 km
Test sites
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure

CHLORIDE (Cl) MASS BALANCE METHOD FOR ESTIMATING RECHARGE



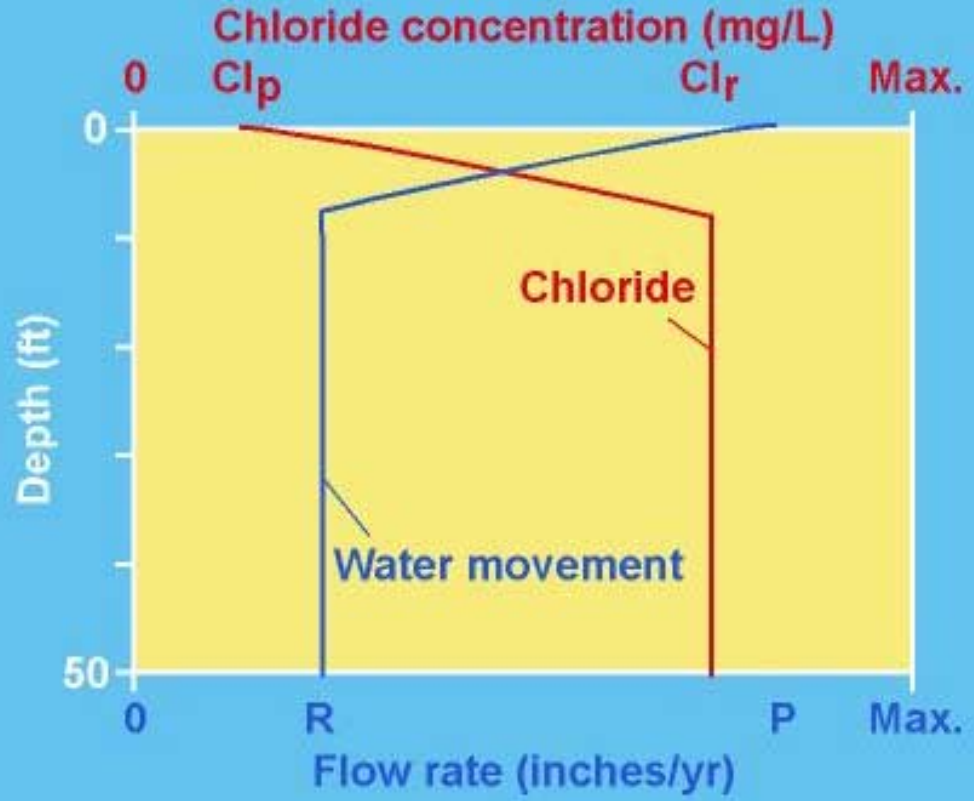
Precipitation includes water and dissolved salts including chloride

Evapotranspiration concentrates chloride in soil water

Drainage and percolation moves soil water from the root zone to the water table

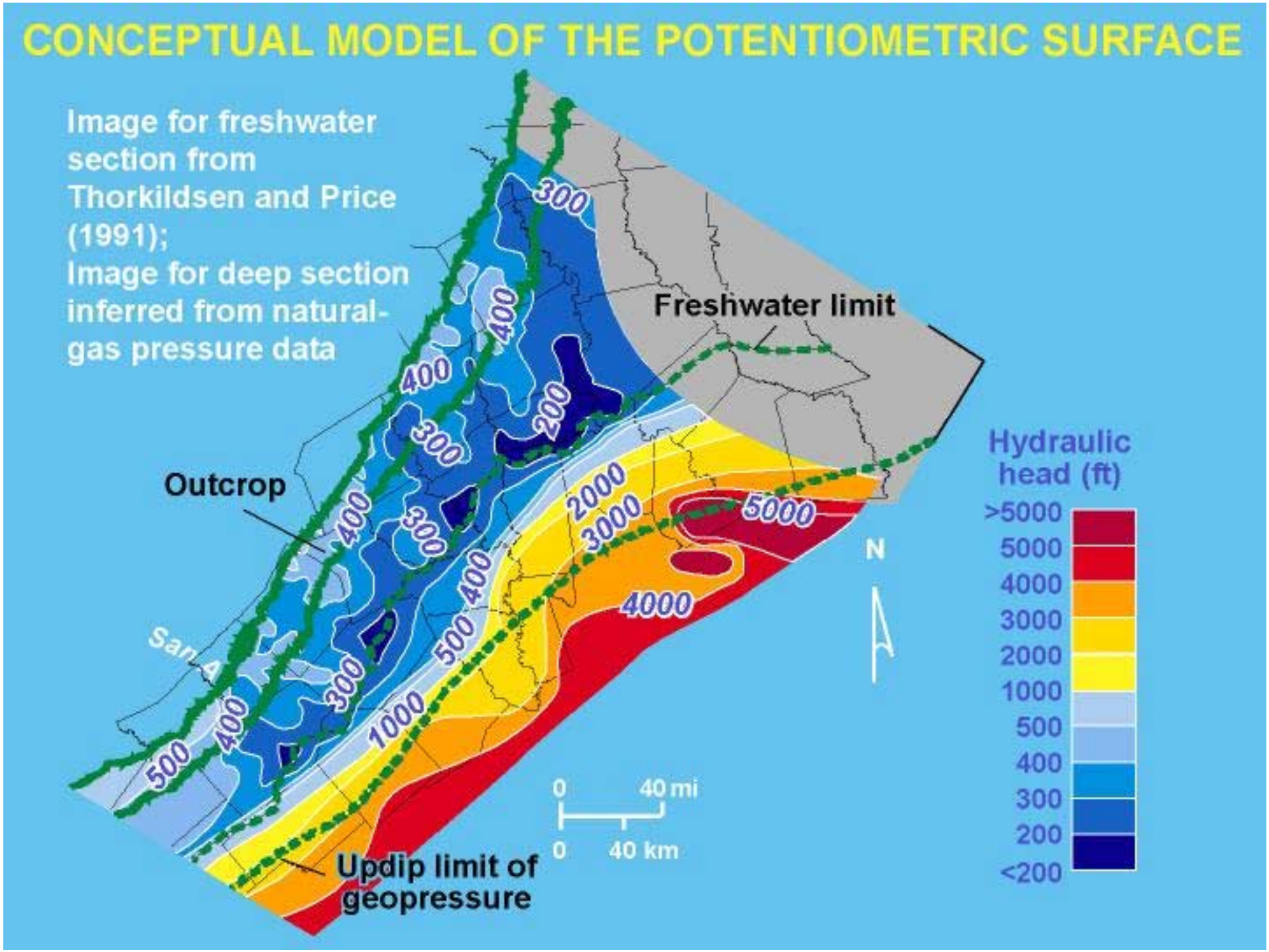
Recharge occurs when the soil water reaches the water table

CHLORIDE (Cl) MASS BALANCE METHOD FOR ESTIMATING RECHARGE

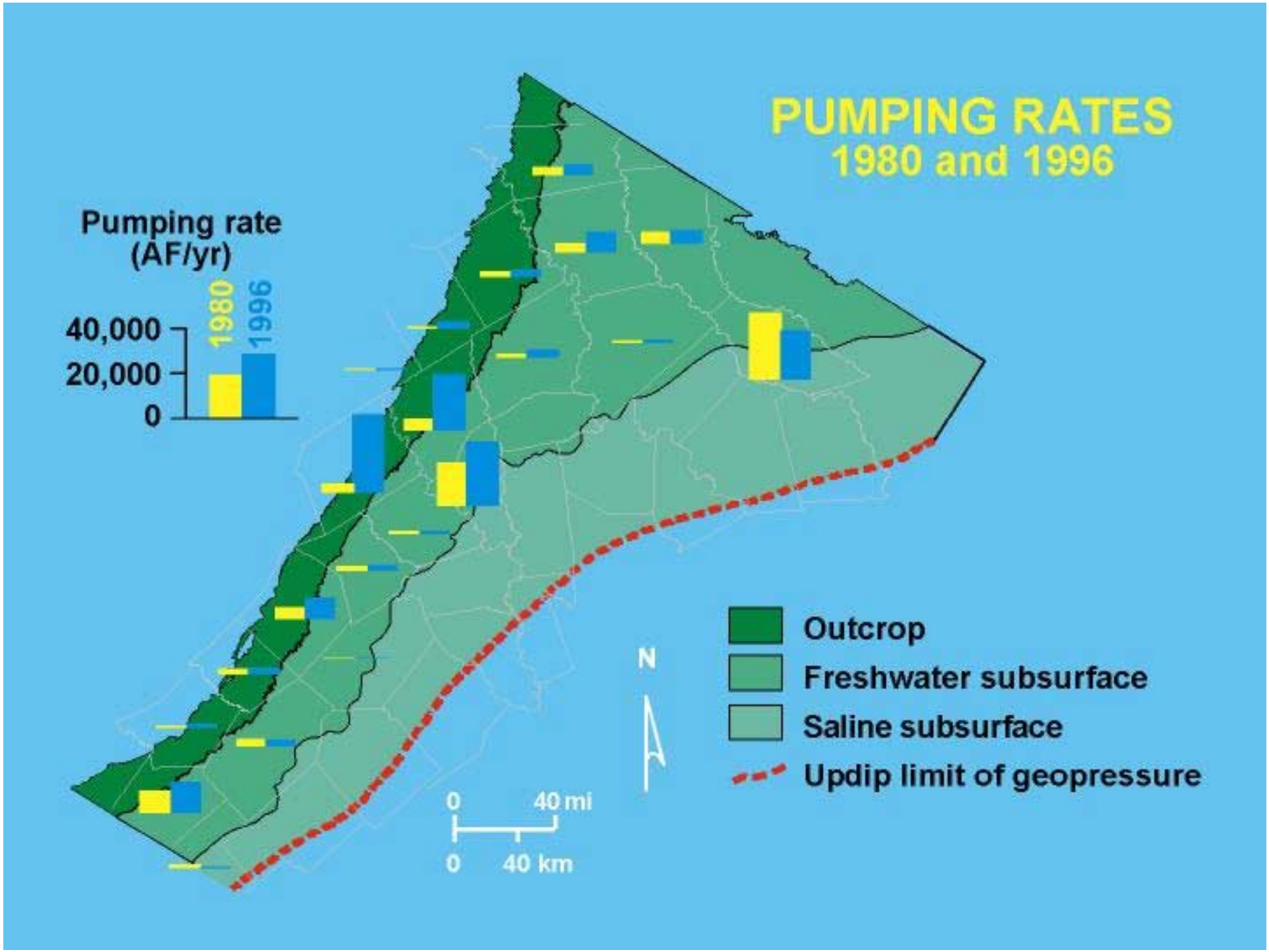


POTENTIOMETRIC SURFACE
Initial Hydraulic Head

CONCEPTUAL MODEL OF THE POTENTIOMETRIC SURFACE



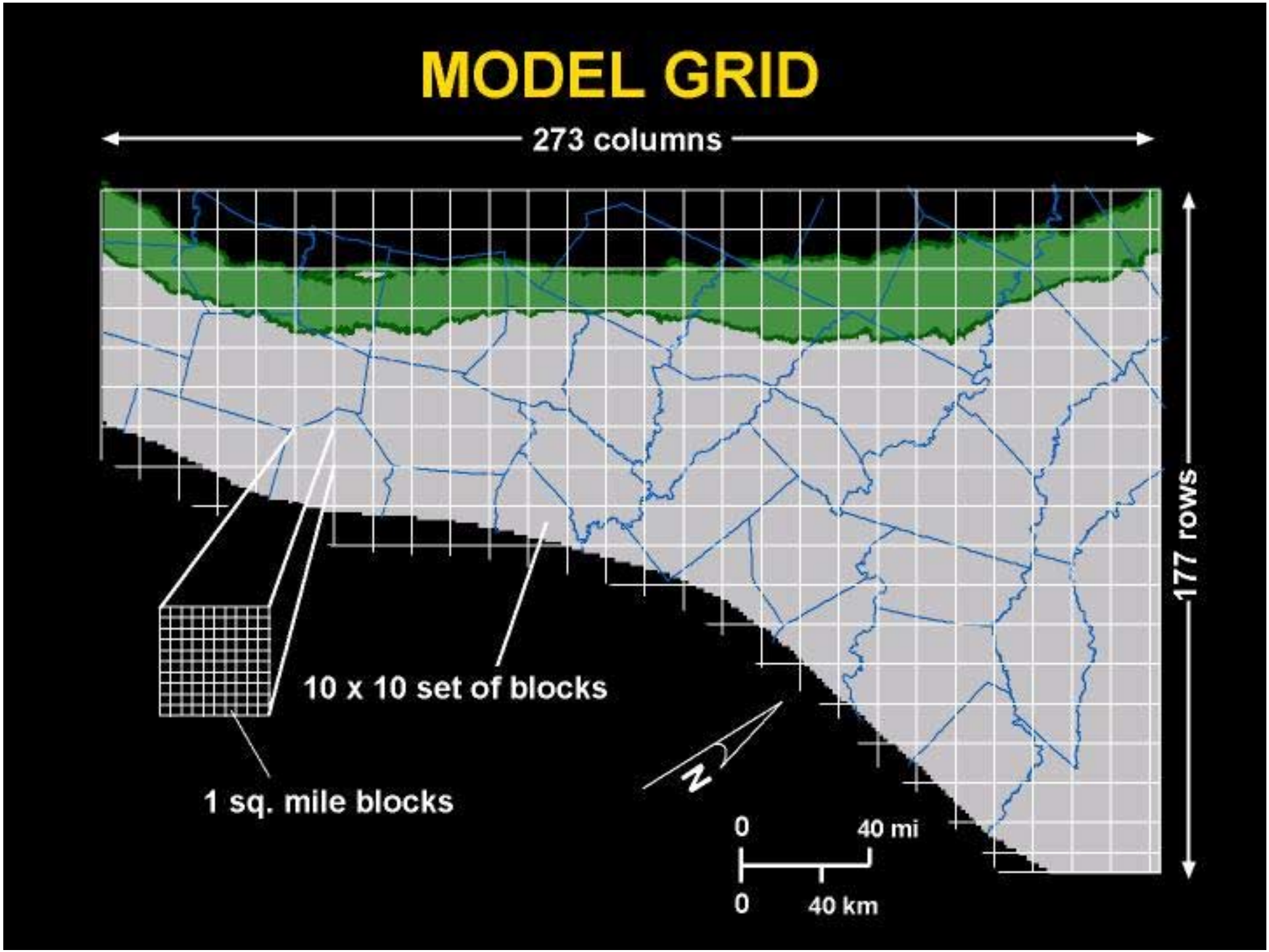
PUMPING DISTRIBUTION


PUMPING RATES
1980 and 1996
Pumping rate
(AF/yr)
1980
1996
40,000
20,000
0
N
Outcrop
Freshwater subsurface
Saline subsurface
Updip limit of geopressure
0
40 mi
0
40 km

MODEL CONSTRUCTION

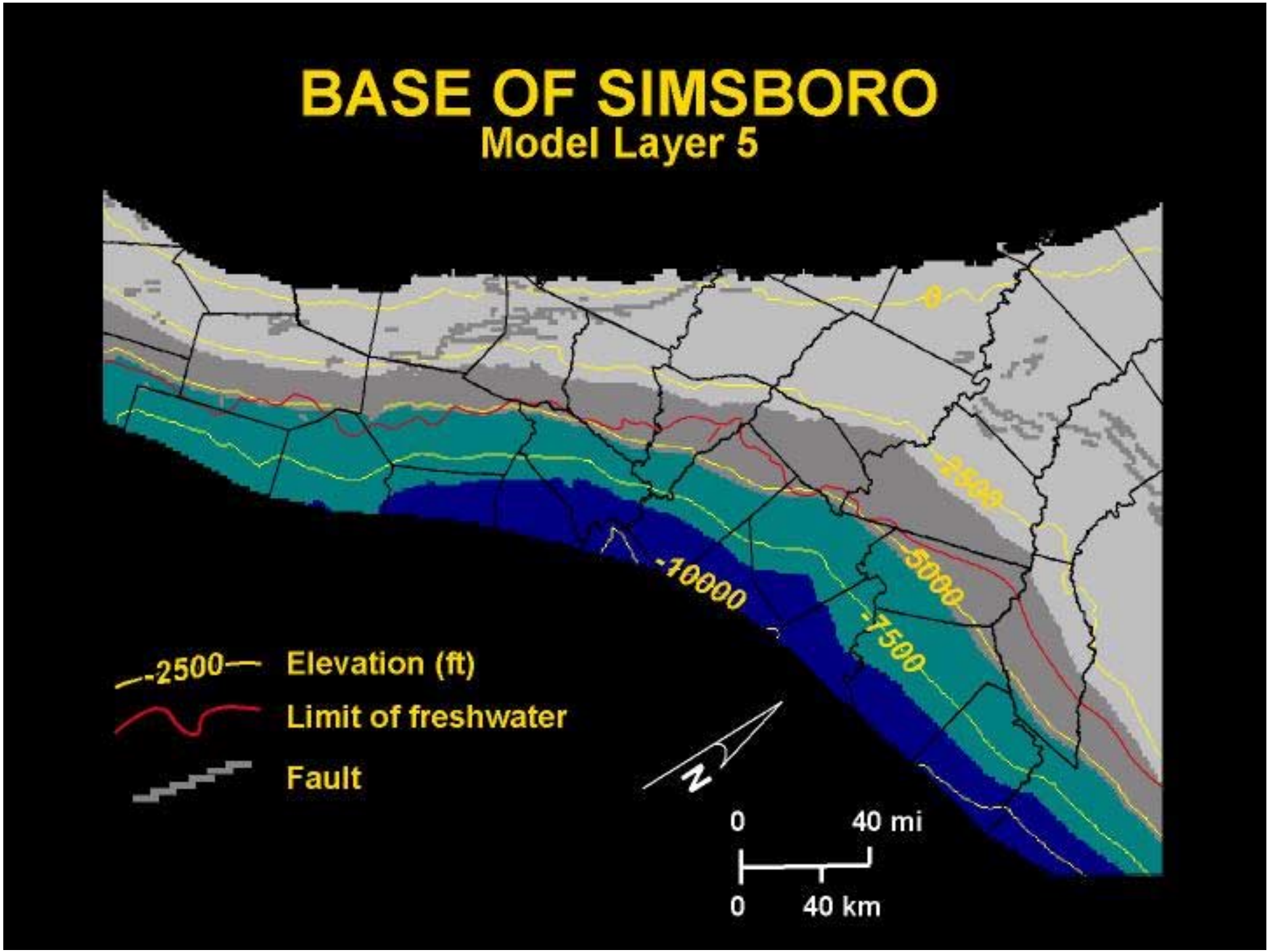
MODEL INFORMATION REQUIREMENTS

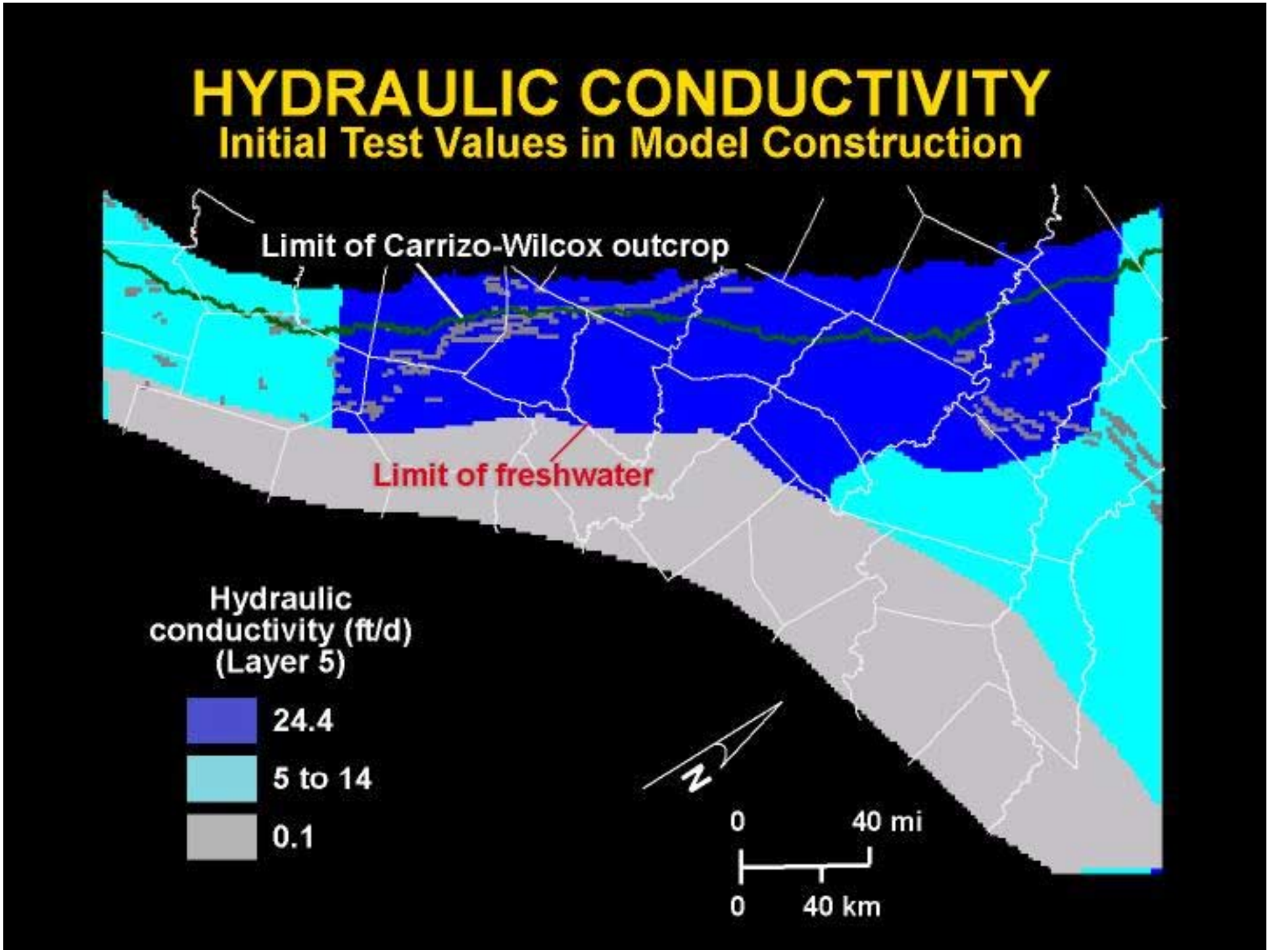
- **Aquifer geometry**
  - Model grid
  - Model perimeter and extent
  - Top elevation of layers
  - Bottom elevation of layers
  - Initial or “predevelopment” values of water levels
- **Aquifer properties**
  - Hydraulic conductivity
  - Storage coefficient
- **Boundary conditions and fluxes**
  - Surface water (rivers, creeks, and springs)
  - Recharge
  - Evapotranspiration
  - Pumping
  - Downdip and lateral boundaries

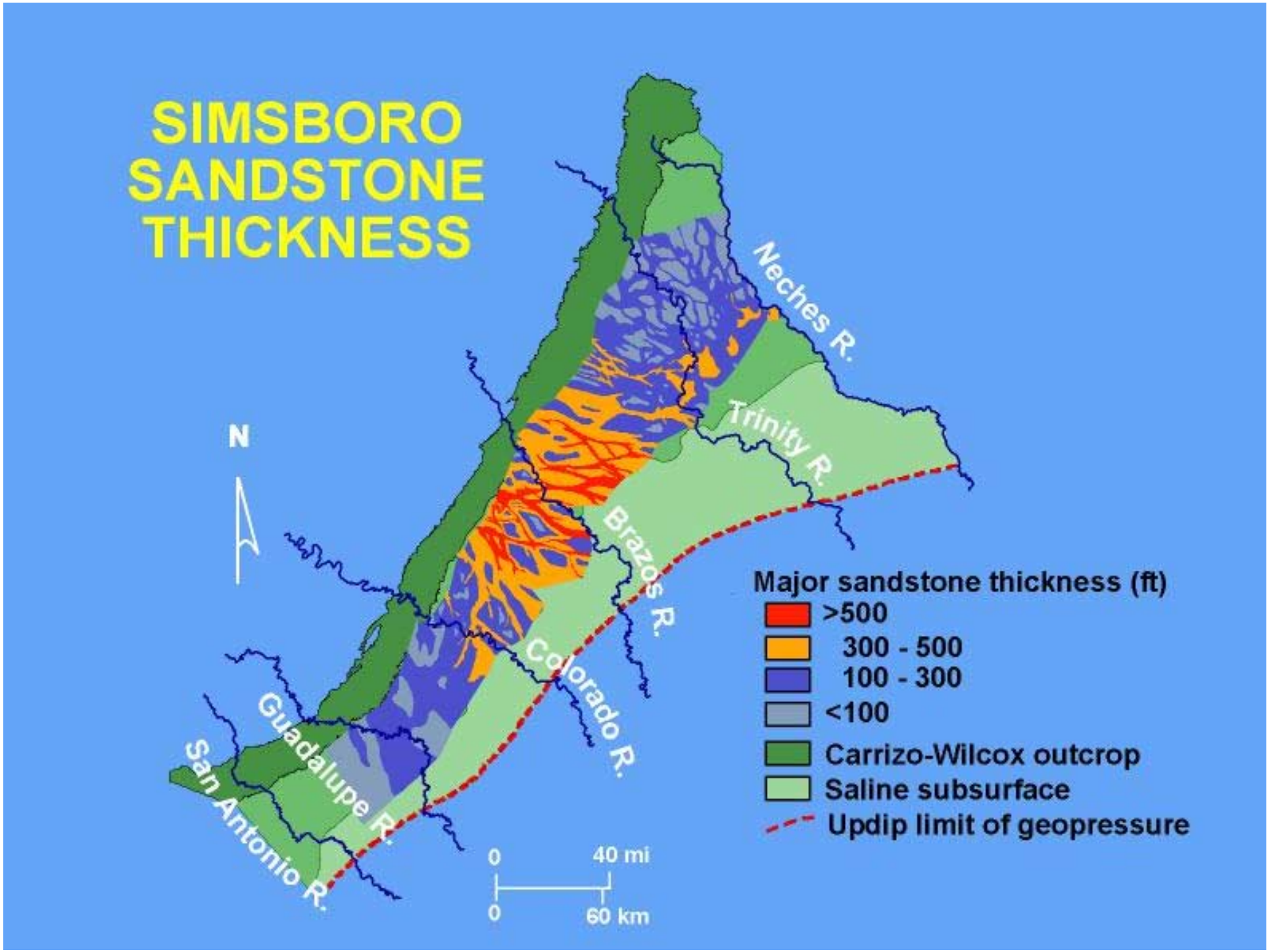

MODEL GRID
273 columns
177 rows
10 x 10 set of blocks
1 sq. mile blocks
N
0
40 mi
0
40 km

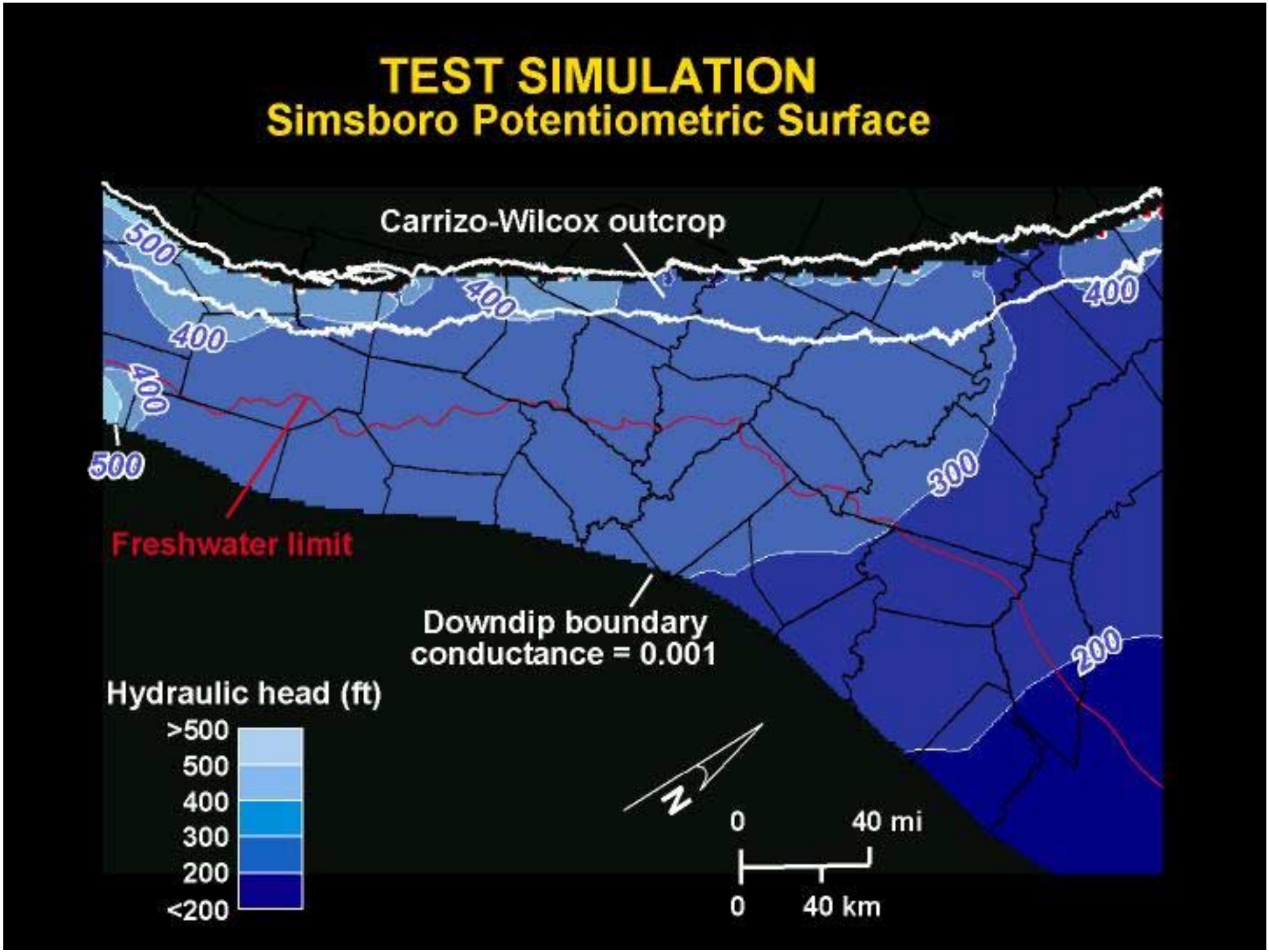
BASE OF SIMSBORO

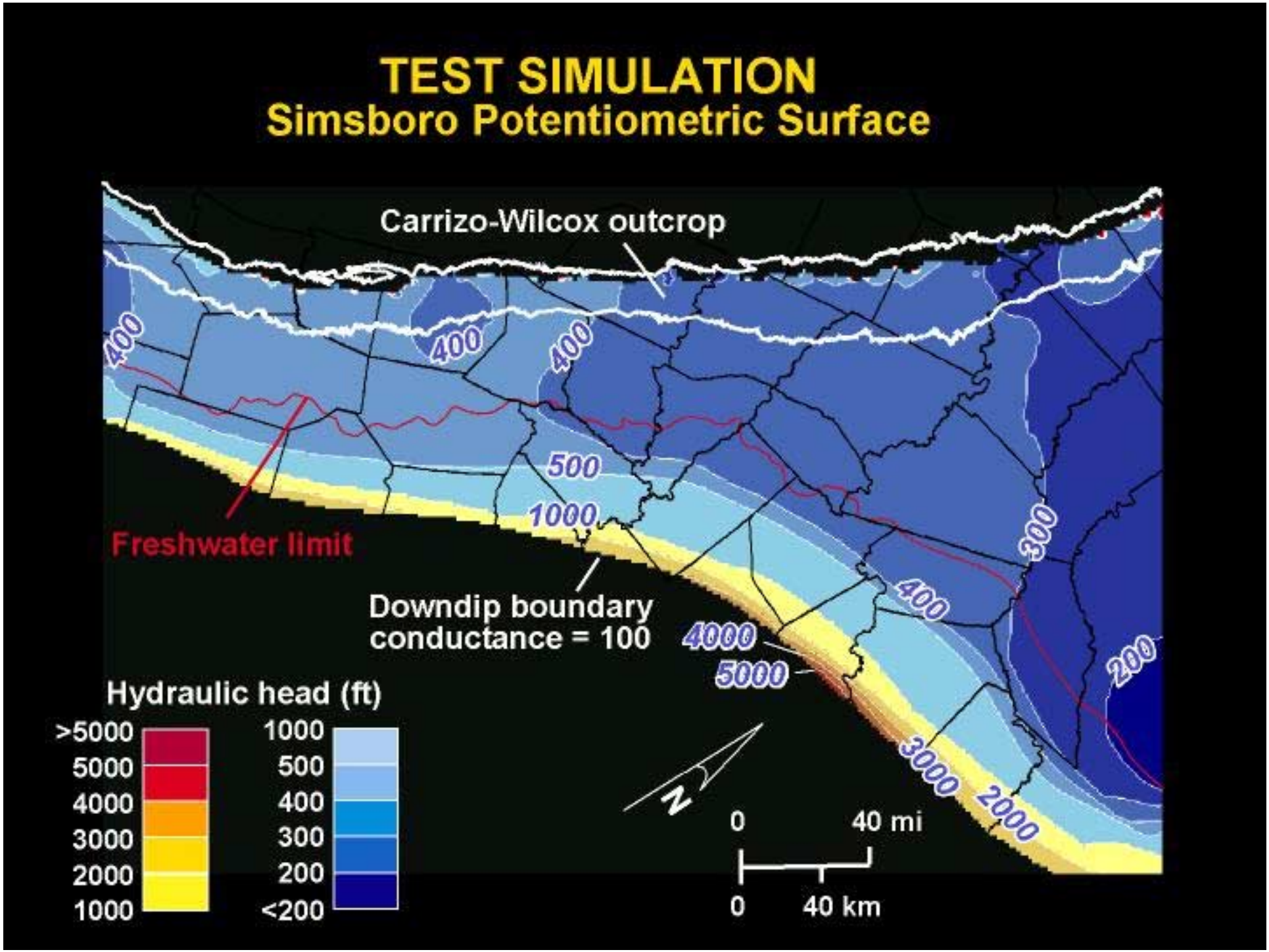
Model Layer 5




HYDRAULIC CONDUCTIVITY
Initial Test Values in Model Construction
Limit of Carrizo-Wilcox outcrop
Limit of freshwater
Hydraulic conductivity (ft/d) (Layer 5)
24.4
5 to 14
0.1
N
0
40 mi
0
40 km


SIMSBORO
SANDSTONE
THICKNESS
N
Neches R.
Trinity R.
Brazos R.
Colorado R.
Guadalupe R.
San Antonio R.
0
40 mi
0
60 km
Major sandstone thickness (ft)
>500
300 - 500
100 - 300
<100
Carrizo-Wilcox outcrop
Saline subsurface
Updip limit of geopressure


TEST SIMULATION
Simsboro Potentiometric Surface
Carrizo-Wilcox outcrop
500
400
400
400
400
500
300
200
Freshwater limit
Downdip boundary
conductance = 0.001
Hydraulic head (ft)
>500
500
400
300
200
<200
N
0
40 mi
0
40 km


TEST SIMULATION
Simsboro Potentiometric Surface
Carrizo-Wilcox outcrop
Freshwater limit
Downdip boundary
conductance = 100
400
400
400
500
1000
300
400
4000
5000
200
3000
2000
Hydraulic head (ft)
>5000
5000
4000
3000
2000
1000
1000
500
400
300
200
<200
N
0
40 mi
0
40 km

SCHEDULE AND STATUS OF MODEL CONSTRUCTION

REVISED PROJECT SCHEDULE

Construct model (Original)	Jan 2001	to	July 2001
Construct model (Revised)	Jan 2001	to	Dec 2001
Steady-state calibration	Aug 2001	to	Oct 2001
Steady-state calibration	Jan 2002	to	Apr 2002
Transient calibration & verification	Nov 2001	to	Mar 2002
Transient calibration & verification	Apr 2002	to	June 2002
Predictive simulations	Mar 2002	to	April 2002
Predictive simulations	July 2002	to	July 2002
Report preparation	May 2002	to	Sept 2002
Draft report due	Sept 2002		
Final report due	Jan 2003		

PROJECT SCHEDULE

- **First SAF meeting** — **April 2001**
  - Introduction
- **Second SAF meeting** — **July 2001**
  - Conceptual model
- **Third SAF meeting** — **Oct 2001**
  - Steady-state calibration
- **Fourth SAF meeting** — **Jan 2002**
  - Steady-state calibration
- **Fifth SAF meeting** — **April 2002**
  - Steady-state calibration complete
  - Transient calibration
- **Sixth SAF meeting** — **July 2002**
  - Transient calibration complete
  - Predictive models
- **Seventh SAF meeting** — **Oct 2002**
  - Comments on draft report
- **Final report due** — **Jan 2003**

Stakeholder Advisory Forum (SAF)
Central Carrizo-Wilcox Aquifer Groundwater Availability Model

Forum Meeting No. 3
Wednesday, October 31, 2001, at 1:30 p.m.
Bureau of Economic Geology
Austin, TX

List of Attendees

Name	Affiliation
Nathan Ausley	Post Oak Savannah GWCD
James Bene	RW Harden & Assoc
Mark Bryson	Brazos G RWPG/ ALCOA
Dick Burns	ALCOA
Susan Butler	SAWS
Andrew Chastain-Howley	WPR Consulting
Rick Conner	BUGCD
Alan Dutton	BEG
Shirley Dutton	BEG
Robert Gresham	Brazos Valley Council of Gov.
Keith Hansberger	Lost Pines GCD
Bob Harden	RW Harden & Assoc
Bob Kier	Robert S Kier Consulting
Katie Kier	BEG
Bill Klemt	LBG Guyton
James Kowis	ALCOA
Robert Mace	TWDB
Amanda Masterson	BEG
David Meesey	TWDB
Ann Mesrobian	Lost Pines GCD
Barry Miller	GCUWCD
Kevin Morison	SAWS
Steve Musick	TNRCC
Ron Naumann	Spring Hills WCD/SCRWPG Region L
Dave ORourke	HDR Engineering
Denis Qualls	BRA
George Rice	GRGH
Grant Snyder	URS Corp.
Sheril Smith	Bastrop County resident/ Sierra Club
Wayne Tschirhart	GBRA
Eddy Young	TX/NM Power Co./ Brazos Valley GCD

Stakeholder Advisory Forum (SAF)
Central Carrizo-Wilcox Aquifer Groundwater Availability Model

Forum Meeting No. 3
Wednesday, October 31, 2001, at 1:30 p.m.
UT Pickle Research Campus Commons Building
Austin, TX

Questions and Answers

QUESTION: What types of boundaries are used in the model?
ANSWER: The updip limit of geopressure is the downdip limit of the model. The base of the model is the bottom of the Hooper Formation. The top of the model includes the Reklaw Formation, which is a clay-rich unit above the Carrizo, and water levels for the Queen City, which is a minor aquifer above the Reklaw. The boundary to the north lies along the surface water divide between the Neches and the Trinity Rivers and the boundary to the south follows the surface water divide between the San Antonio and the Colorado Rivers. The lateral boundaries may be changed from no-flow boundaries to transient boundaries later in model calibration.

QUESTION: Why are the three model grids that study the Carrizo-Wilcox Aquifer not aligned?
ANSWER: Model grids are oriented so that the predominant direction of groundwater flow would be aligned with rows or columns of the model grid. To optimize results, the grids for the north, south, and central models were aligned separately.

QUESTION: What is the best way to compare the three models?
ANSWER: Model results should prove to be comparable in areas of model overlap. One would look, for example, at simulated water levels in the model cells representing the same 1 square mile area.

QUESTION: Is an average annual recharge used or historical highs and lows?
ANSWER: BEG is focusing on the long term, or historical averages for the steady-state calibration. For the historical calibration we will look at actual annual precipitation to estimate how recharge may have varied through the years. This will include the drought of record as well as local droughts in the 1980s and 1990s.

QUESTION: Can the recharge rate be influenced by when the rain comes, for example, if a heavy rain follows a dry period?
ANSWER: Runoff varies with what is called ‘antecedent moisture condition’ and rainfall intensity and other factors. In the model area we would assume that there is less recharge from storms with a higher amount of runoff than from storms with less runoff. But this is a level of detail that we will not be able to reproduce when constructing this model.

QUESTION: How does the calculated evapotranspiration (ET) affect the amount of recharge introduced into the aquifer?
ANSWER: Recharge may be estimated in the context of a water budget as precipitation minus runoff and ET. In this model, the MODFLOW ET package is not being used to represent the ET that occurs within the soil zone in the upland areas. Instead, the ET package is being used along with the 'drain' package and 'streamflow routing package' to remove water from the aquifer beneath low-lying areas in the outcrop. This represents the removal of water from the aquifer by trees and shrubs in the bottomlands along creeks and rivers. We assume that there is more groundwater discharge to streams and rivers during the winter when ET is less and water table is close to ground surface. The ET package lets us represent this part of the water cycle in a way that complements the use of other MODFLOW packages.

QUESTION: What's the source of chloride in the aquifer?
ANSWER: We will assume that dissolved chloride in the unsaturated zone in this area comes from the salt in precipitation, and that the chloride in precipitation comes from aerosols sourced in the ocean. In western parts of the United States, chloride also may comes from dust picked up by wind blowing over salt flats. So long as we know how much chloride there is in precipitation, the source is not critical for the chloride method to work for recharge estimation. As our tests are in the Simsboro sand, our assumption that there are not other sources of chloride in the unsaturated zone is reasonable. Below the water table, the main source of chloride in the aquifer is old diluted seawater that still remains in the low-permeability clay-rich deposits within the Carrizo-Wilcox aquifer.

QUESTION: How long does chloride movement take in the aquifer?
ANSWER: Our two water tests (analysis of tritium isotope) show that the uppermost part of the aquifer has water less than 50-yr old. This means that the travel time between ground surface and the water table must be less than 50 yr. The chloride concentration in the unsaturated zone represents each year's input of chloride into the system.

QUESTION: What kind of sites is BEG selecting for test wells for recharge measurement; will agricultural influences be taken into account?
ANSWER: We are focusing on areas that have been grassland for most of the past 40 to 50 years. These locations may have cattle on them, but not cultivation. We will have to consider how the cattle (and also weed spray and fertilizers) might affect chloride levels.

QUESTION: Are there other field results against which you can compare the test results?
ANSWER: Bridget Scanlon has compiled information on recharge rates from field tests and modeling studies. That information is on the GAM resources web page (http://www.twdb.state.tx.us/GAM/resources/resources.htm). Alan Dutton's dissertation work in Freestone County included one estimate of recharge rate. Since that estimate was for the Calvert Bluff, it might not be comparable to the expected Simsboro results. One of the reasons we are making these tests is that there is so little field information on recharge rates.

QUESTION: Will BEG compare results of the field testing to watershed budgeting prior to the introduction of Water Availability Modeling (WAM)?
ANSWER: That comparison is not part of this study.

QUESTION: Will the GAM project for the Carrizo-Wilcox aquifer be an ongoing project after this particular study is complete?
ANSWER: GAM work on the Carrizo-Wilcox model will not continue after the current project is complete. The model, of course, will be available for use by the public including groundwater conservation districts and regional water planning groups. The TWDB has stated an intent to look at model calibration every five years, that is, seeing how model prediction compares to actual water levels in the future, and seeing whether any aspect of the model needs revision.

QUESTION: What is the cause for increased pumping of ground water in the Lufkin area?
ANSWER: It could be the result of a change in economic activity or other factors not yet identified.

QUESTION: What's the cause of the low area in the potentiometric surface in the test simulation in the northeast part of the model area?
ANSWER: Low elevation of land surface and how the boundary was assigned in this test version of the model might be the explanation. BEG is working closely with Duke Engineering to resolve any discrepancy because the area in question is an area of model overlap.

QUESTION: Why doesn't the test run of potentiometric surface reflect the previous work of Thorkildsen and Price (1991)?
ANSWER: The Thorkildsen and Price publication (Ground-water Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region) is a composite look at all of the aquifer layers in one map. The test simulation shown here is for the Simsboro Formation, one layer of the model. The result shown here also from a test version of the model set up to check for model input consistency and errors in our conceptual model. The calibrated model obviously needs to more closely resemble and match water-level data.