U.S. Geological Survey

Using an Integrated Geophysical and Hydrogeologic Approach to Characterize the Hydrostratigraphy of the Edwards Aquifer, Bexar County, Texas

By

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Introduction

- The Edwards aquifer is a productive karst aquifer in south-central Texas.
  - Primary source of public water for Bexar County (San Antonio)
  - Supplies large quantities of water to agriculture, industry, and major springs in adjacent Comal and Hays Counties
  - Springs flowing from the aquifer support recreational and business activities and provide water to downstream users
- Aquifer recharge is from:
  - Streamflow loss
  - Direct infiltration of rainfall in the recharge zone (outcrop of aquifer along northwestern margin)
  - Cross-formational flow from the adjacent and underlying Trinity aquifer

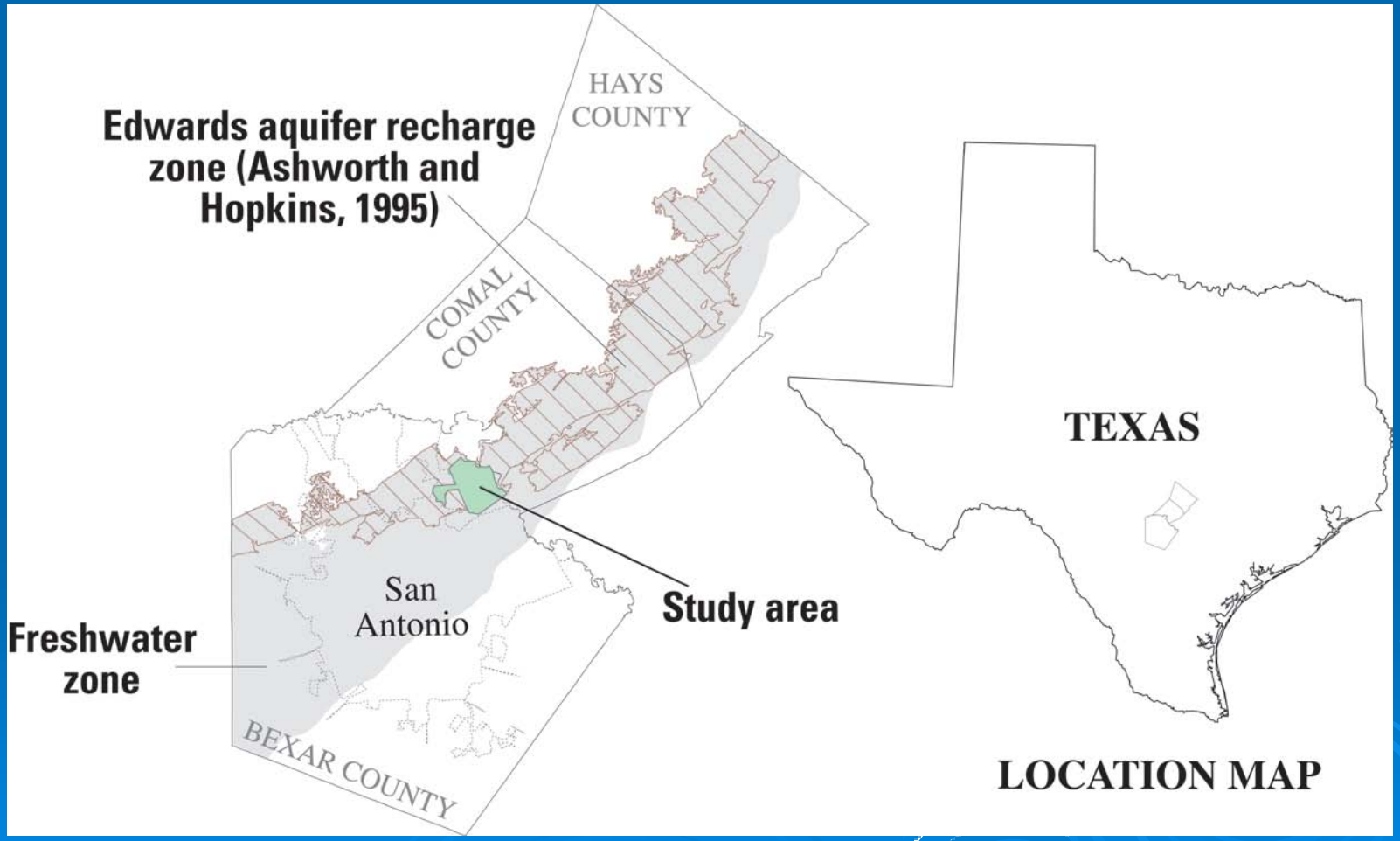
Problem:

- Increasing development in the recharge zone of the Edwards aquifer:
  - Currently (began in 2007), a 16-square-kilometer (km2) area of mainly rangeland in Bexar County northeast of San Antonio is undergoing urban development.
- Possible aquifer contamination sources due to urbanization:
  - Leakage of hazardous materials, or runoff containing:
    - Fertilizers
    - Pesticides
    - Herbicides
    - Automobile fluids
    - Other commonly used chemicals

Project Scope

- Characterize the hydrostratigraphy of the Edwards aquifer in the study area
  - Using an integrated hydrogeologic and geophysical approach
- Associate ranges of resistivity to each of seven hydrostratigraphic zones of the Edwards aquifer
  - Use existing information, along with local-scale geologic mapping and surface geophysics
- Identify, to extent possible, the vertical and lateral extent of the hydrostratigraphic zones throughout the study site
  - Using variations in electrical resisitivty
- Knowledge of the hydrostratigraphy can lead to
  - Better understanding of the potential of vertical and lateral groundwater flow.
  - Decision support for placement of monitoring wells for detecting contamination associated with urbanization.

Study Site


HAYS COUNTY
Edwards aquifer recharge zone (Ashworth and Hopkins, 1995)
COMAL COUNTY
TEXAS
San Antonio
Study area
Freshwater zone
BEXAR COUNTY
LOCATION MAP

Hydrostratigraphy of the area

Period, group, formation, or member				Aquifer	Hydrostratigraphic zone	Thickness (feet)	Lithology	Hydrogeologic function[1]	Cavern development[2]	Relative permeability
Lower Cretaceous	Edwards Group	Person Formation	Cyclic and marine members, undivided (Kpcm)	Edwards aquifer	II	80-90	Mudstone to packstone; *miliolid* grainstone; chert	Aquifer	Many subsurface; might be associated with paleokarst development	High permeability
			Leached and collapsed members, undivided (Kplc)		III	70-90	Crystalline limestone; mudstone to grainstone; chert	Aquifer	Extensive lateral development; large rooms	High permeability
			Regional dense member (Kprd)		IV	20-24	Dense, argillaceous mudstone	Confining unit	Very few; only vertical fracture enlargement	Low permeability; vertical barrier to flow
		Kainer Formation	Grainstone member (Kkg)		V	50-60	*Miliolid* grainstone; mudstone to wackestone; chert	Aquifer	Few	Generally low permeability except in conduits
			Kirschberg Evaporite member (Kkk)		VI	50-60	Highly altered crystalline limestone; chalky mudstone; chert	Aquifer	Few	Moderate permeability
			Dolomitic member (Kkd)		VII	110-130	Mudstone to grainstone; crystalline limestone; chert	Aquifer	Abundant caves associated with fracture solution and bedding planes	High permeability associated with fractures and caves
			Basal nodular member (Kkb)		VIII	50-60	Shaly, nodular limestone; mudstone and *miliolid* grainstone	Confining unit or aquifer	Extensive lateral development; abundant springs	Not-fabric selective; conduit, generally low permeability except in conduits
	Glen Rose Limestone		Upper member Kgr(u) (cavernous zone 3)	Trinity aquifer	A[4]	120+	Alternating and interfingering medium-bedded mudstone, wackestone, and packstone with local solution zones	Confining unit or aquifer	Caves associated with fractures and bedding planes, springs associated with bedding planes, terraced topography interbedded limestone forming ledges	Probably very permeable near contact with Edwards Group; permeability decreases with depth

- Hydrostratigraphy refers to seven hydrostratigraphic zones of the Edwards aquifer throughout the study site.
  - The hydrostratigraphic zones were initially identified by Maclay and Smalls (1976).
  - Identified on the basis of test-hole cores and borehole geophysical logs.
  - Each zone has distinct lithology, fracture characteristics, and porosity.

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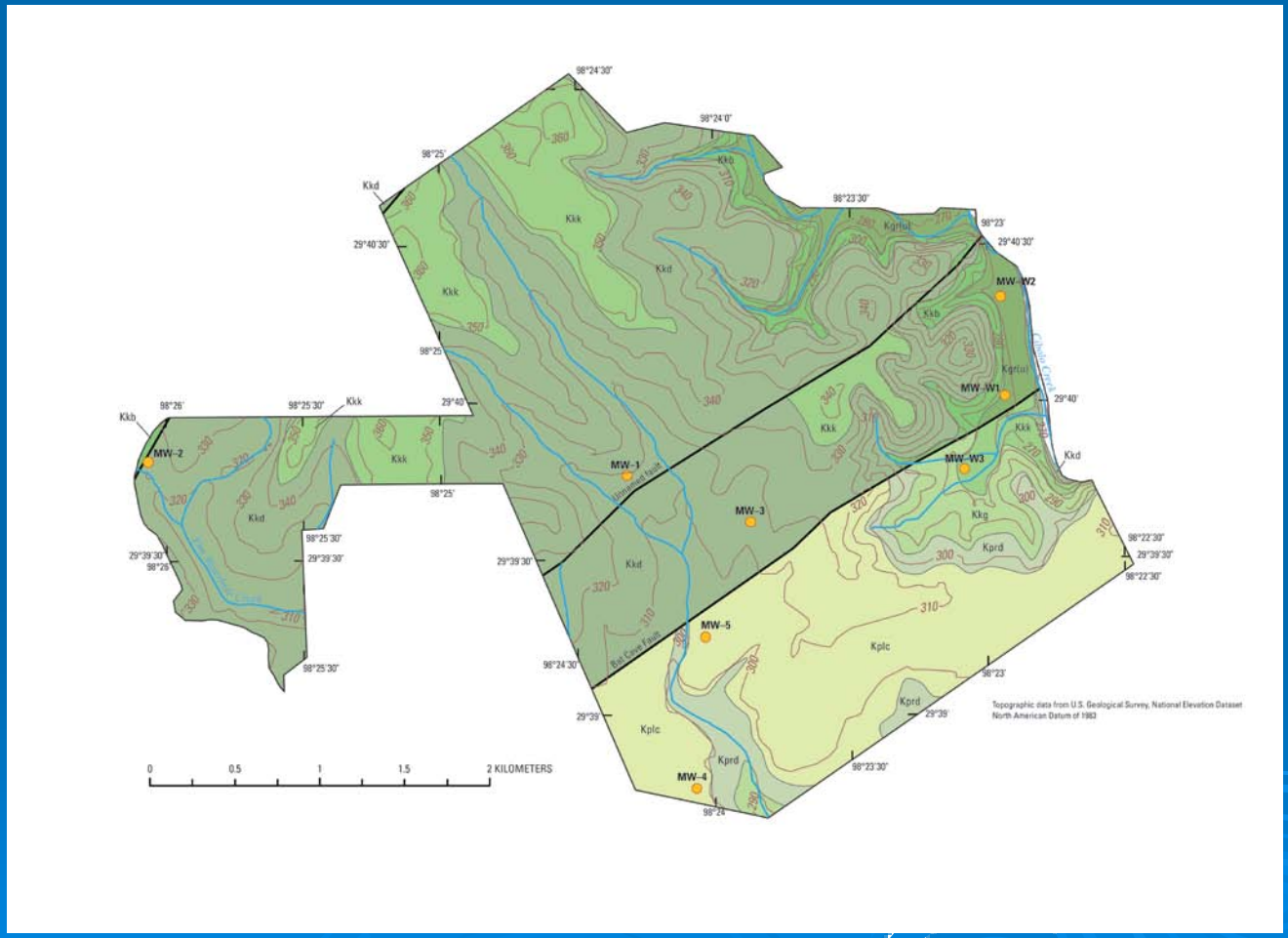
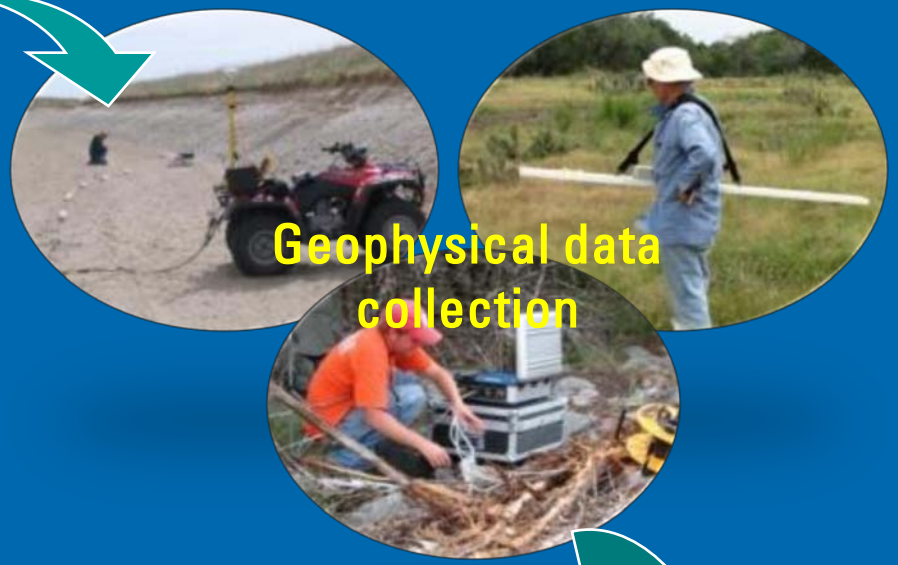
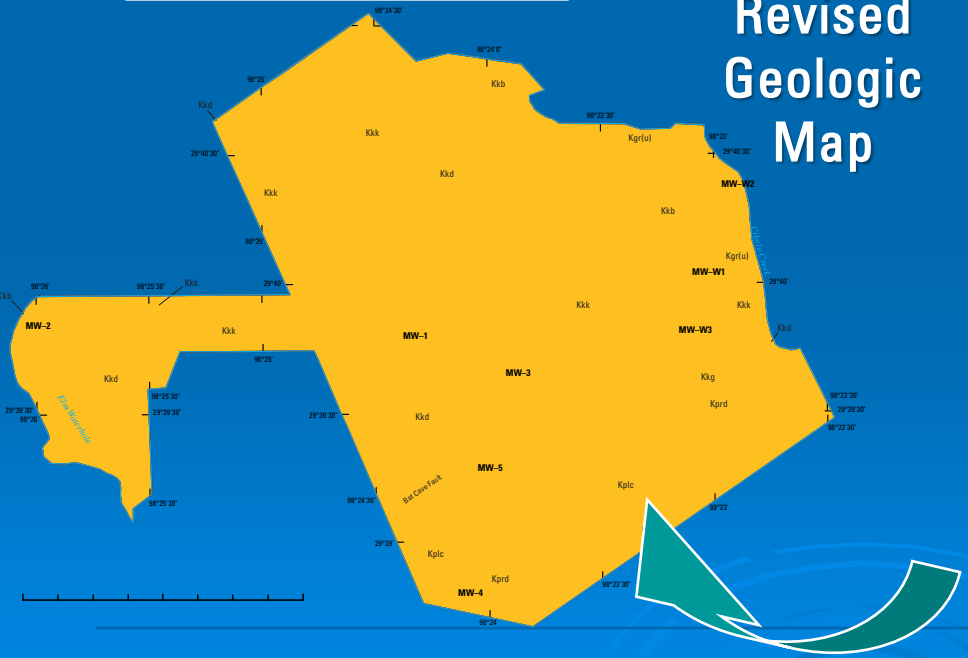
Geologic Map
(Stein and Ozuna 1995)

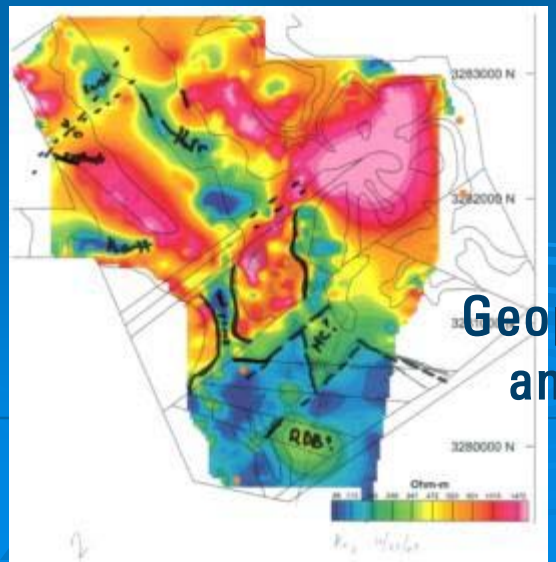


Methods used for integrated study



Revised
Geologic
Map





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Hydrogeologic Mapping

- Surficial geologic mapping:
  - Local-scale field mapping
  - Existing regional-scale geologic maps
    - Stein and Ozuna (1995)
    - Clark (2003)
    - Hanson and Small (1995)
- Lithologic descriptions are based on Dunham's classification
- Thickness of the various formations and members were determined on the basis of field observations, geophysical logs, and data from the aforementioned reports.

Geophysical Resistivity Methods

- Why would resistivity methods be useful to establish a better understanding of the subsurface hydrogeology?
  - No other physical property of naturally occurring rocks or soils display such a wide range of values.
  - In most rocks, electricity is conducted electrolytically by the interstitial fluid, and resistivity is controlled more by porosity, water content, and water quality than by the resistivity of the rock matrix.

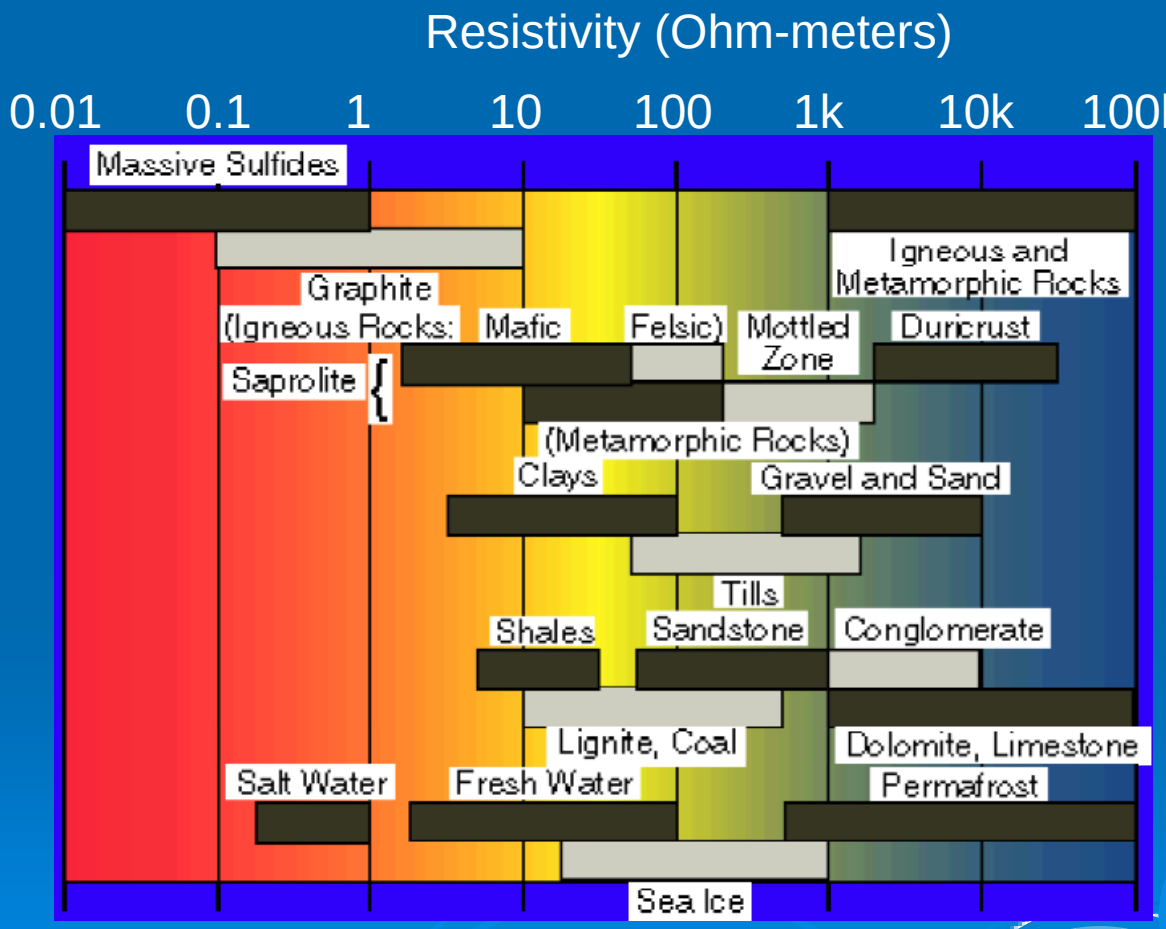
Zohdy, 1974

What Influences Resistivity?

- Water Content
  - An increase in water content of a formation will decrease the resistivity (dry vs. wet).
- Water Quality
  - An increase in total dissolved solids (TDS) of the formation water will decrease the resistivity (fresh vs. saline).
- Clay Minerals
  - Finer grained sediments typically have a lower resistivity than coarser grained sediments.
- Rock Matrix
  - Consolidated rocks typically have higher resistivities.

Fitterman, 2000

Resistivities of Geologic Materials



Fitterman, 2000

Goal of Resistivity Surveys

- Obtaining information about subsurface geology and hydrology of use in:
  - Formulating geologic and hydrologic models
  - Guiding, reducing, or eliminating drilling
  - Delineating aquifer boundaries
  - Estimating water quality
  - Estimating ground-water model parameters

Fitterman, 2000

How do we achieve this goal?

- Mapping variations in apparent electrical resistivity
- Modeling resistivity data to obtain subsurface resistivity distribution
- Interpreting geology/hydrology based on model resistivities

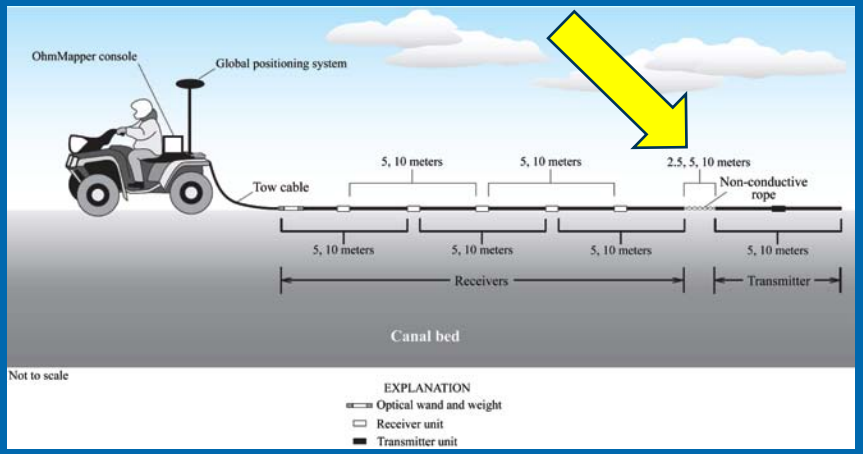
Fitterman, 2000

Resistivity Data Collection Methods

- Method
  - Shallow subsurface (0 – 15m)
    - Capacitively Coupled Resistivity (CC Resistivity)
    - Frequency Domain Electromagnetics (FDEM)
  - Deep subsurface (5 – 75m)
    - Time-Domain Electromagnetics (TDEM)
    - Direct Current Resistivity (DC Resistivity)
- Ground Truthing
    - Surficial Geologic Mapping
    - Geologic borings from testholes

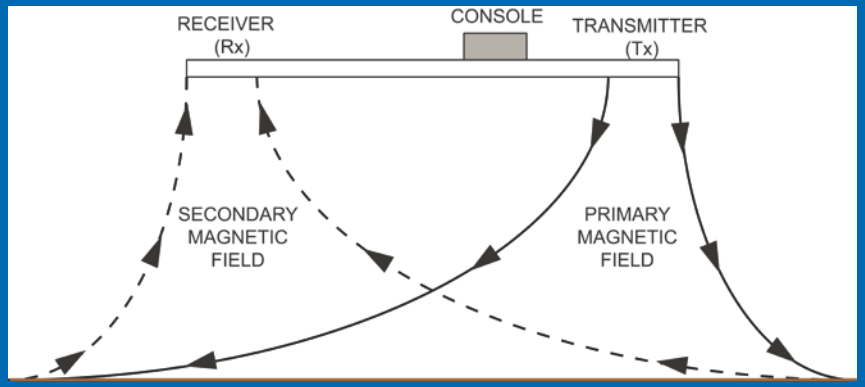
Capacitively-Coupled Resistivity

- OhmMapper (Geometrics)
  - Towed array system (ATV)
  - Integrated with GPS
  - Continuous data collection
  - Used to generate 2D depth profiles of near surface.
  - To increase depth the distance between transmitter and receiver are increased.



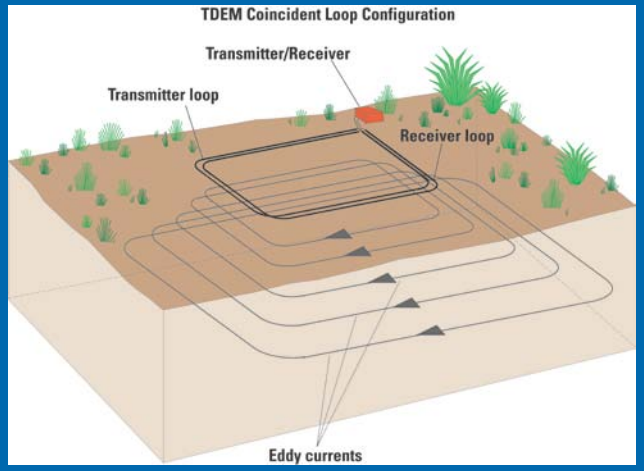
Frequency-Domain Electromagnetics

- GEM-2 (Geophex)
  - Handheld portable device
  - Integrates with GPS
  - Continuous data collection
  - Used to generate 2D depth profiles of near surface
  - Uses lower transmit frequencies to increase investigation depth



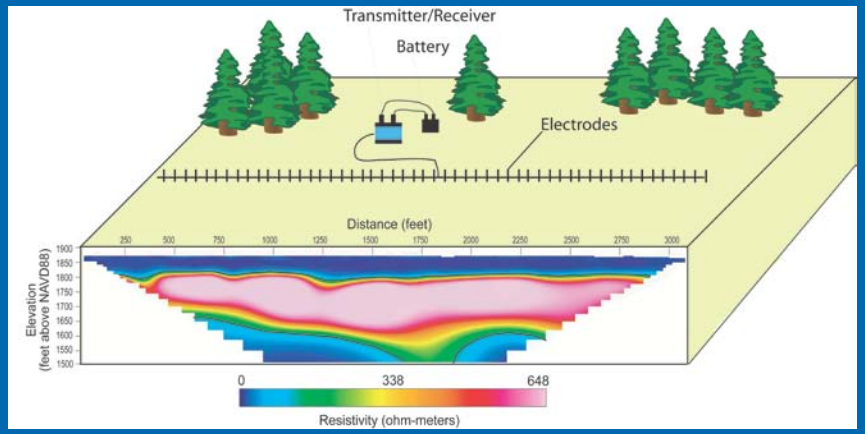
Time-Domain Electromagnetics

- TerraTEM (Alpha Geo Science)
  - Coincident coil setup
  - Uses integrated GPS
  - Gives vertical 1D electrical stratigraphy profiles
  - Uses larger transmit and receive coils to increase depth

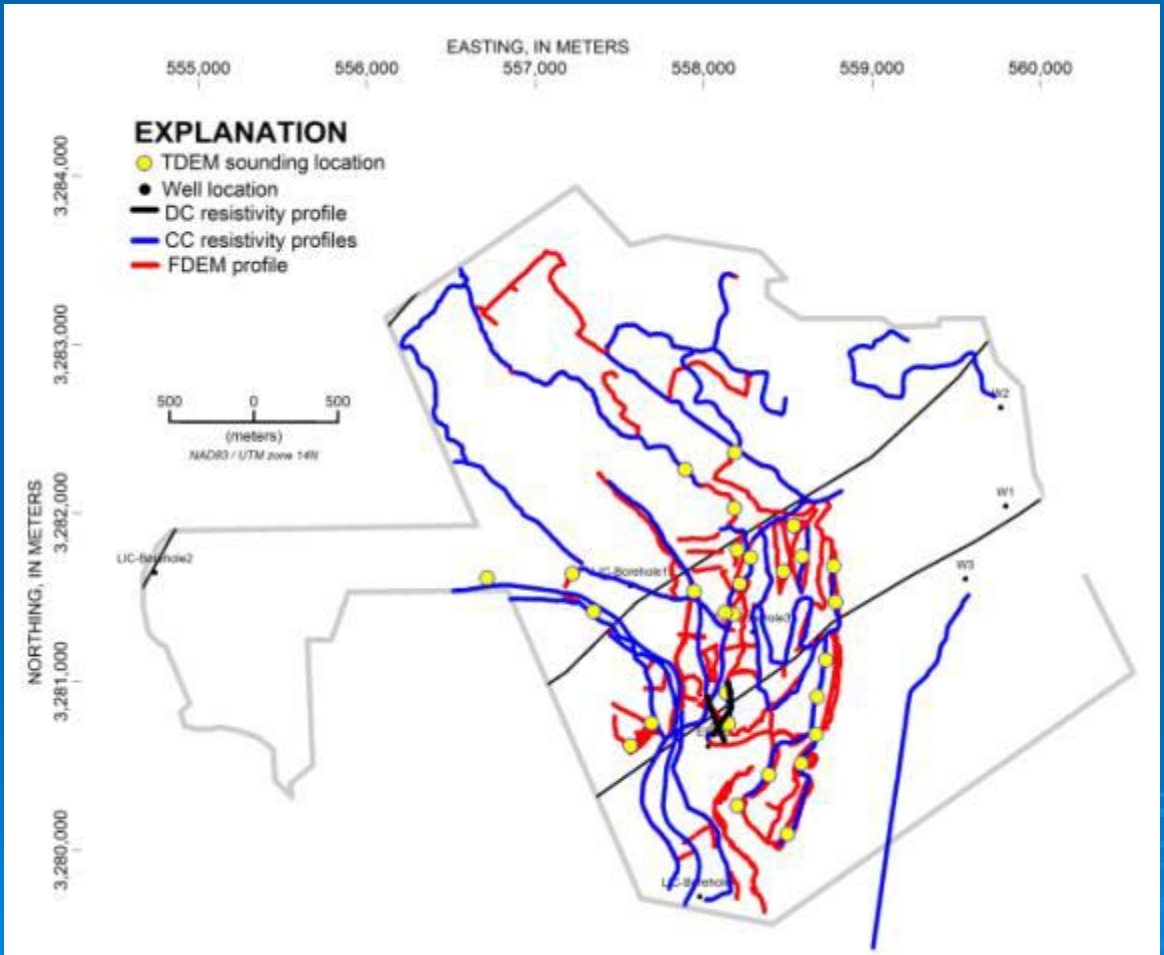


Direct-Current Resistivity

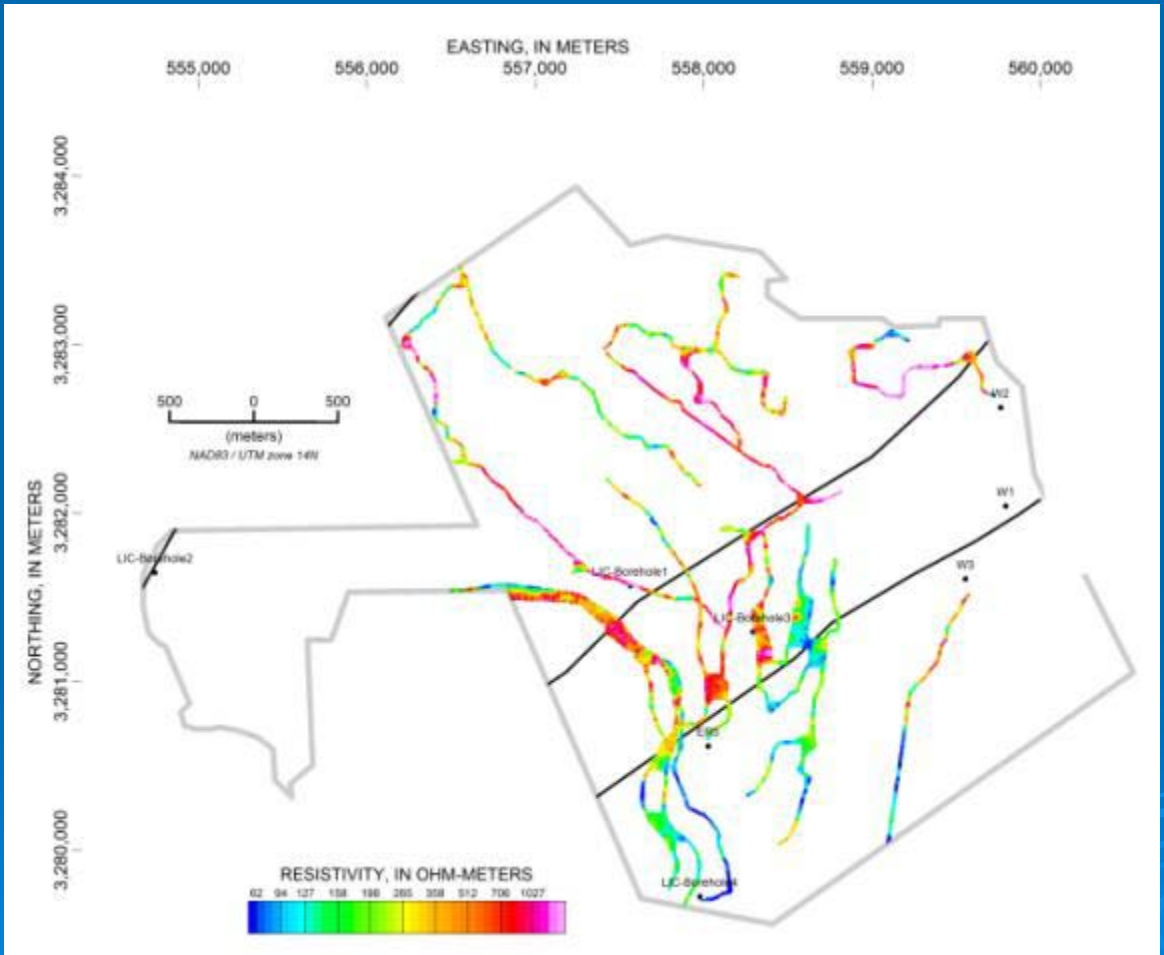
- Syscal Pro (Iris Instruments)
  - Grounded electrode system
  - Not integrated with GPS
  - Provides 2D depth profiles of resistivity
  - Electrode spacing is increased to increase depth



Geophysical Data Coverage



CC Resistivity Grid



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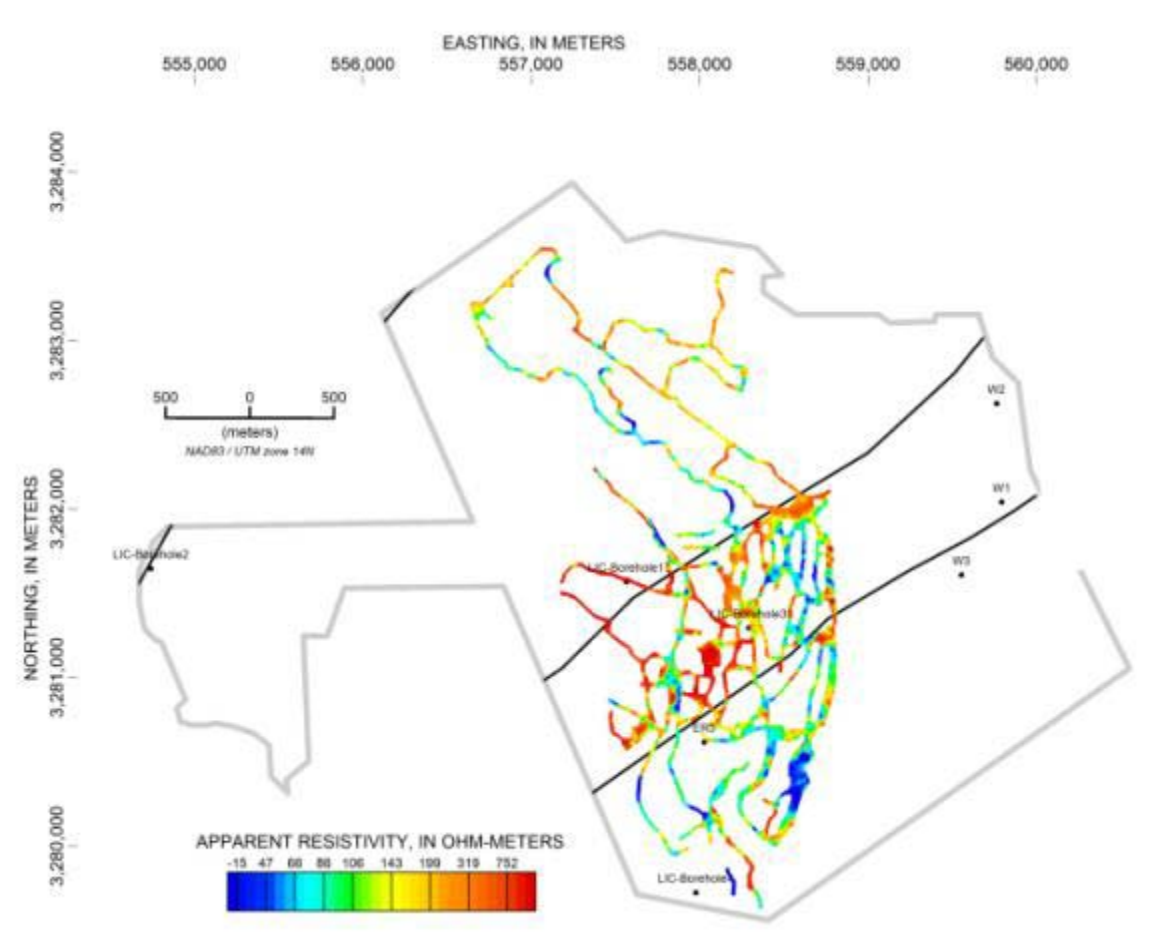
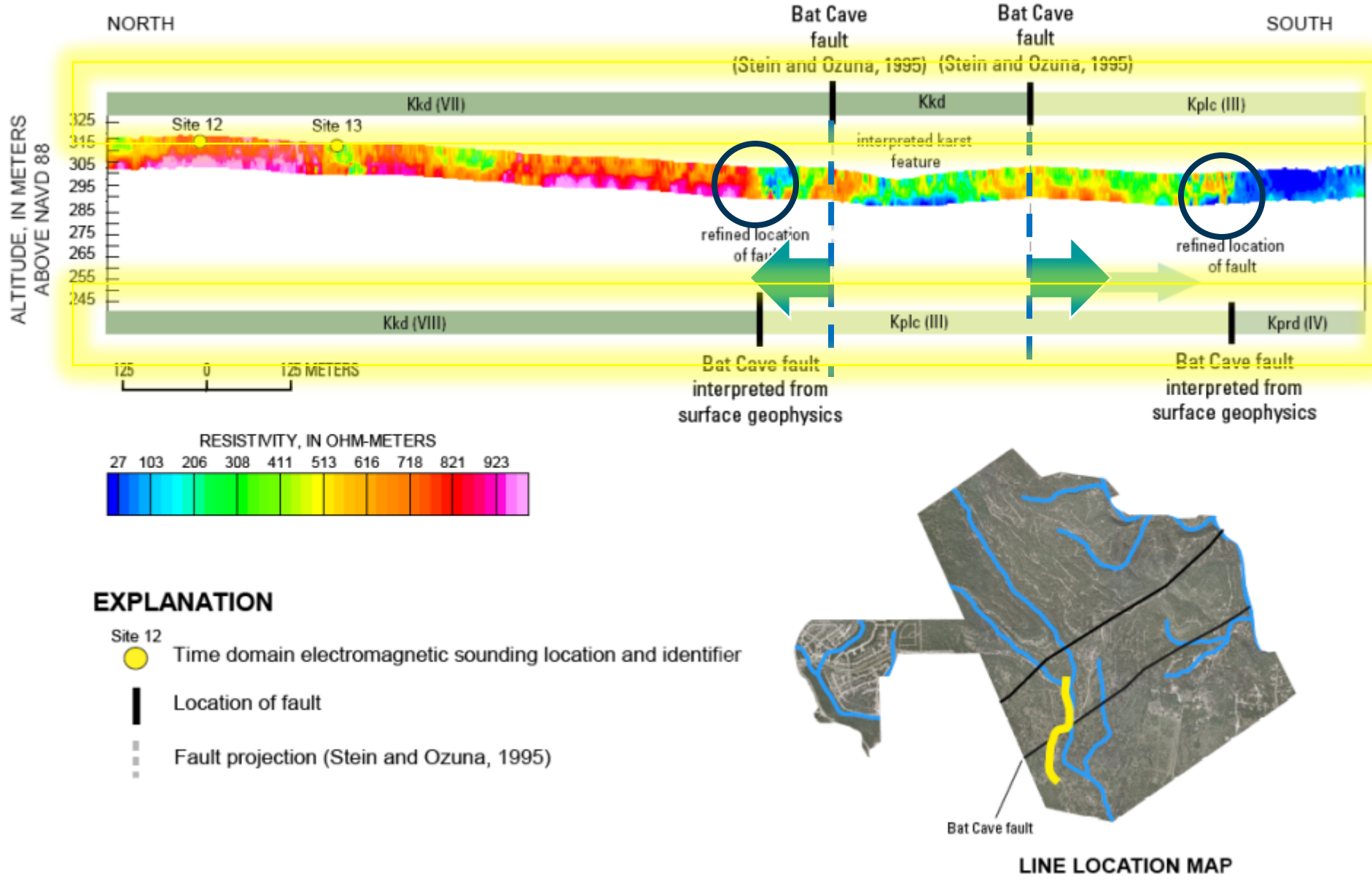
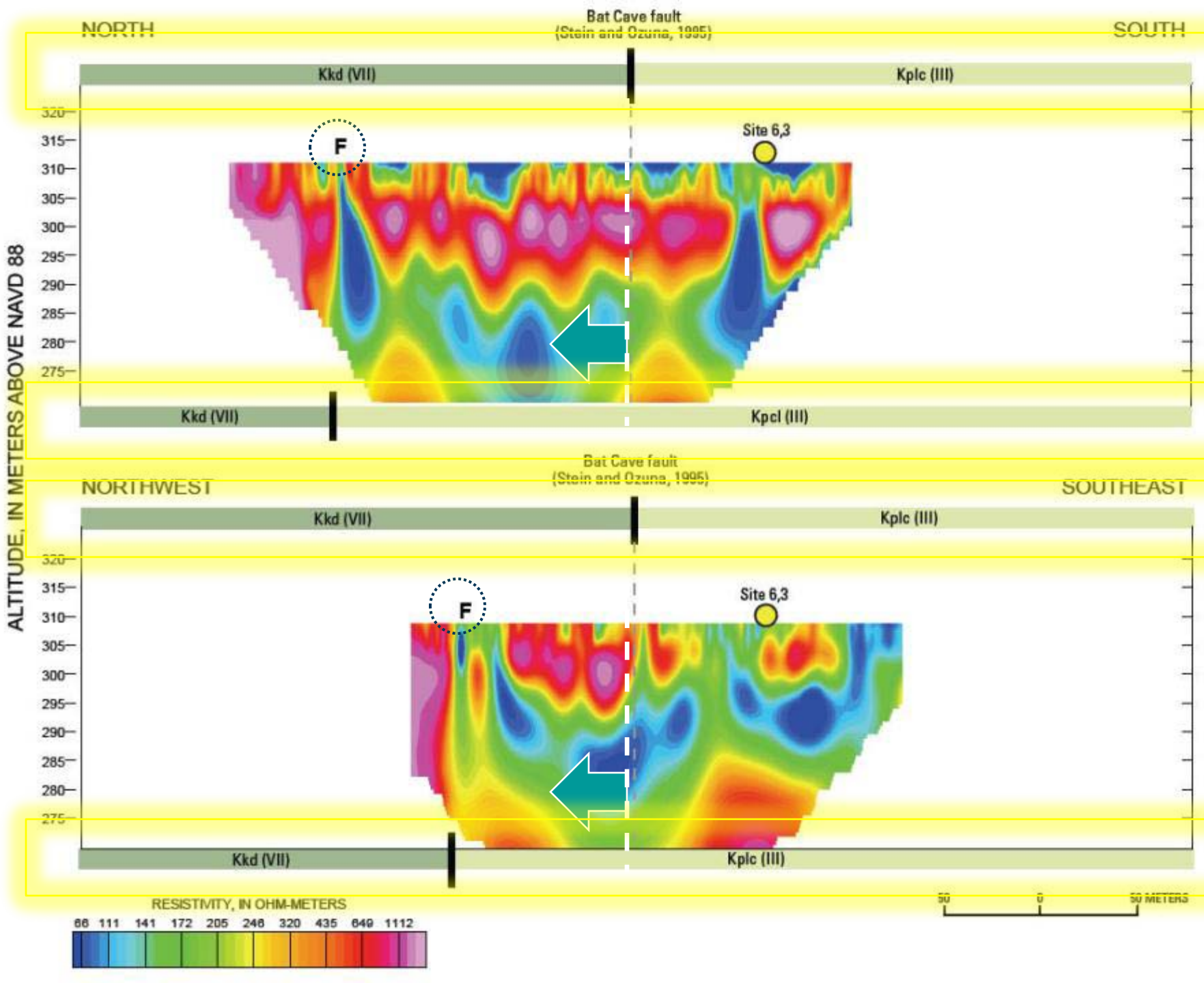
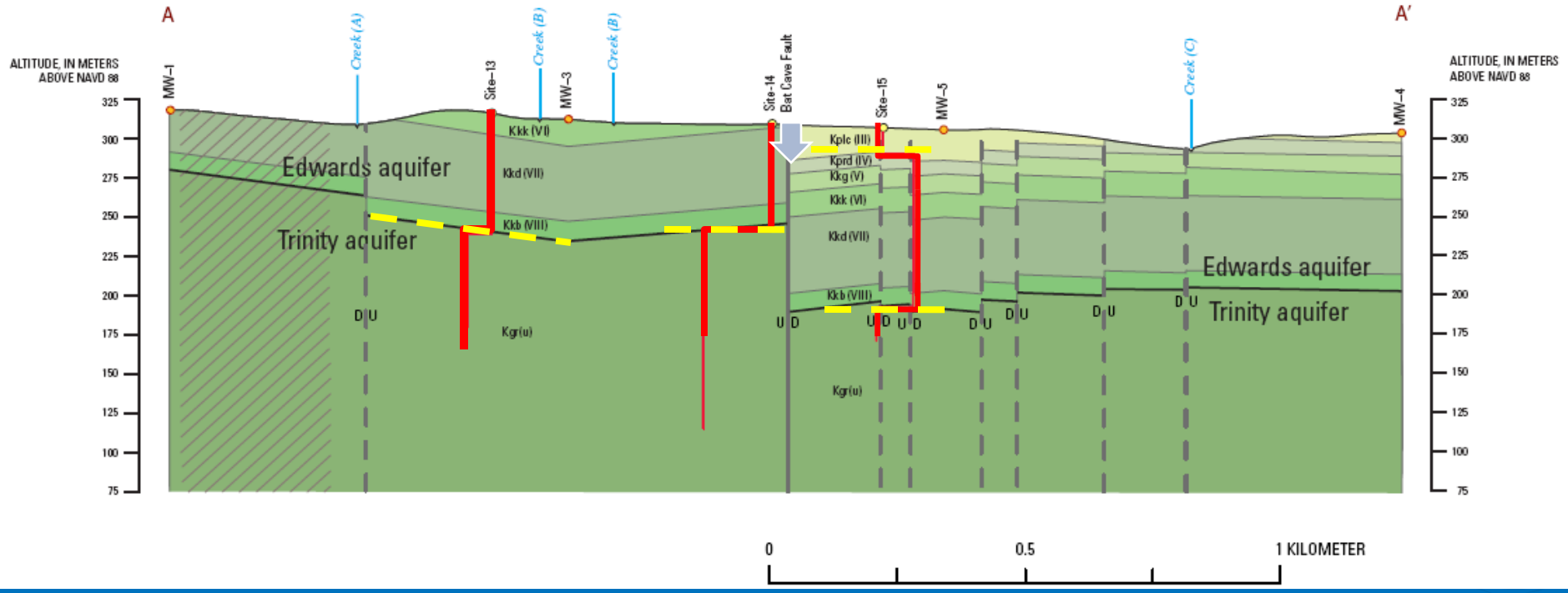
FDEM Apparent Resistivity Grid




NORTH
SOUTH
Bat Cave fault
(Stein and Ozuna, 1995)
Bat Cave fault
(Stein and Ozuna, 1995)
ALTITUDE, IN METERS ABOVE NAVD 88
325
315
305
295
285
275
265
255
245
Site 12
Site 13
Kkd (VII)
Kkd
Kplc (III)
interpreted karst feature
refined location of fault
refined location of fault
Kkd (VIII)
Kplc (III)
Kprd (IV)
125
0
125 METERS
Bat Cave fault interpreted from surface geophysics
Bat Cave fault interpreted from surface geophysics
RESISTIVITY, IN OHM-METERS
27 103 206 308 411 513 616 718 821 923
EXPLANATION
Site 12
Time domain electromagnetic sounding location and identifier
Location of fault
Fault projection (Stein and Ozuna, 1995)
Bat Cave fault
LINE LOCATION MAP


NORTH
Bat Cave fault
(Stein and Ozuna, 1995)
SOUTH
Kkd (VII)
Kplc (III)
320
315
310
305
300
295
290
285
280
275
F
Site 6,3
Kkd (VII)
Kpcl (III)
ALTITUDE, IN METERS ABOVE NAVD 88
NORTHWEST
Bat Cave fault
(Stein and Ozuna, 1995)
SOUTHEAST
Kkd (VII)
Kplc (III)
320
315
310
305
300
295
290
285
280
275
F
Site 6,3
Kkd (VII)
Kplc (III)
RESISTIVITY, IN OHM-METERS
66 111 141 172 205 246 320 435 649 1112
50
0
50 METERS

TDEM Section



Hydrostratigraphic Model

Edwards aquifer unit	Hydrologic characterization	Generalized resistivity range
Cyclic and Marine	high permeability, local low permeability mudstone	Moderate 100-300
Leached and collapsed	high permeability	High 300-500
Regional dense	low permeability, barrier to vertical flow	Low Below 100
Grainstone	generally low permeability, local high permeability in conduits and fractures	Moderate 100-300
Kirschberg evaporite	moderate permeability	High 300-500
Dolomitic	high permeability associated with fractures and caves	Very high Above 500
Basal nodular	generally low permeability, local high permeability in conduits and fractures	Low Below 100

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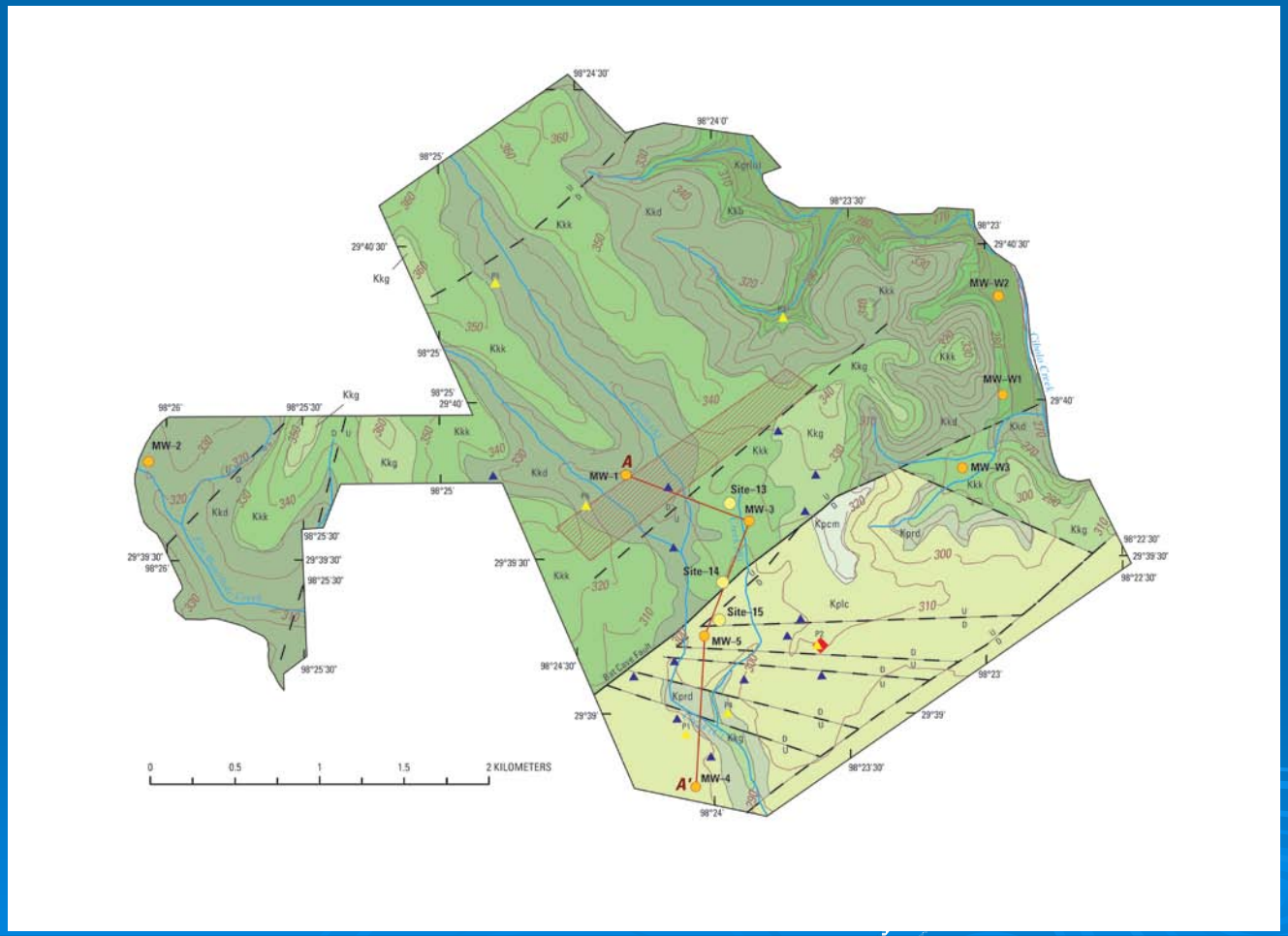
Modified Site Map



References

- Fitterman, David, 2000, Presentation on Electrical Properties of Rocks, accessed June 1, 2006, at *http://water.usgs.gov/usgs/ogw/bgas/2D_resistivity/electrical_resistivity.pdf*

- Shah, S.D., Smith, B.D., Clark, A.K., and Payne, J.D., 2008, An integrated hydrogeologic and geophysical investigation to characterize the hydrostratigraphy of the Edwards aquifer in an area of northeastern Bexar County, Texas: U.S. Geological Survey Scientific Investigations Report 2008–5181 *http://pubs.usgs.gov/*

- This and other Texas Water Science Center Publications can be downloaded at the following URL:

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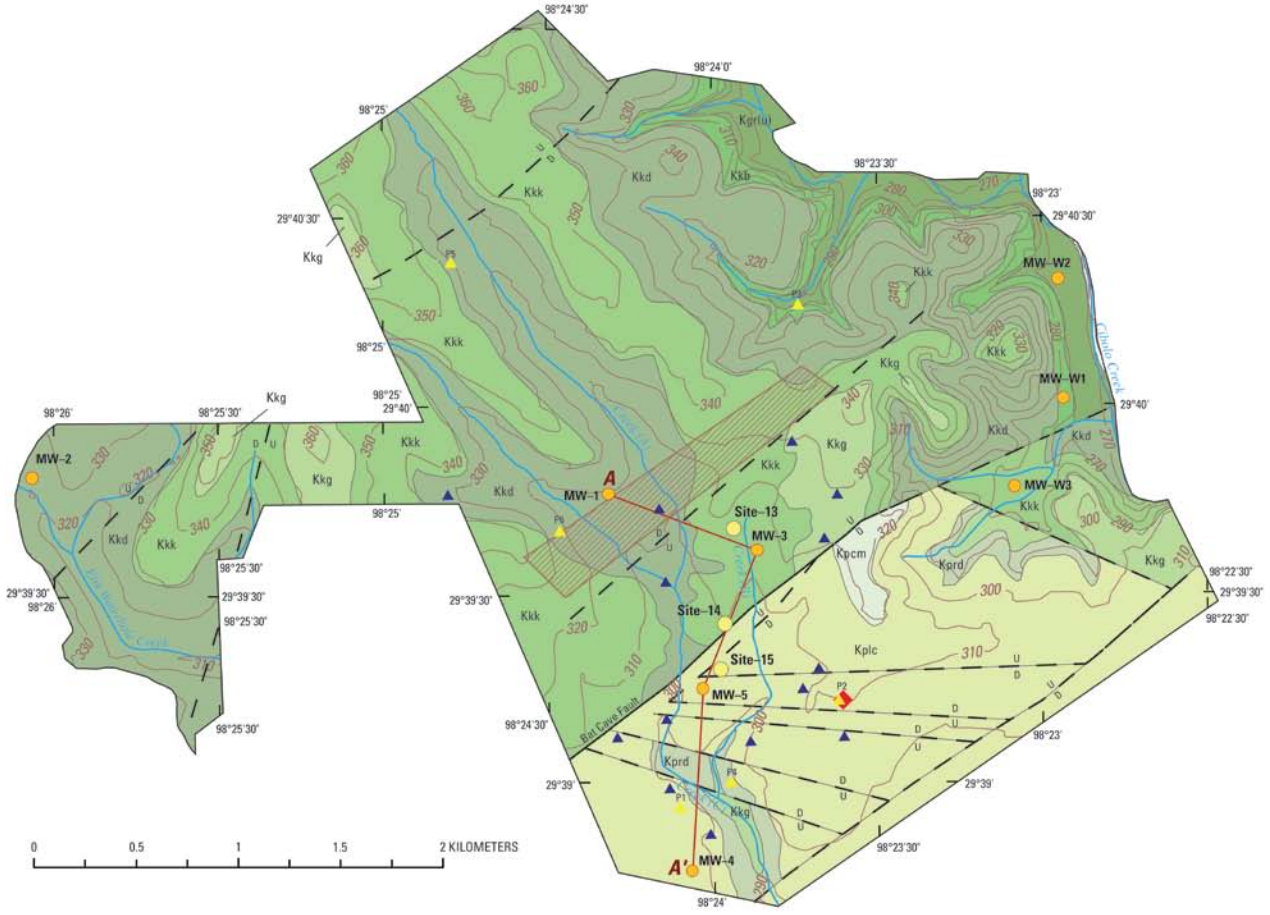
Questions?


MW-1
MW-2
MW-3
MW-4
MW-5
MW-W1
MW-W2
MW-W3
Site-13
Site-14
Site-15
A
A'
Kkg
Kkd
Kkk
Kkb
Kprd
Kpcm
Kplc
Bat Cave Fault
0
0.5
1
1.5
2 KILOMETERS

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