Association of Environmental and Engineering Geologists

CAVE AND KARST GEOLOGY AT

CAVE WITHOUT A NAME

BOERNE, TEXAS

September 21, 2021

Sponsored by:

Duane Kreuger

Cave Without a Name

National Speleological Society

National Cave and Karst Research Institute

Trip Leaders:

Geary Schindel, P.G.
President, National Speleological Society
President, Karst Works, Inc.

Graham Schindel, G.I.T
SAK Construction LLC

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President, National Speleological Society
President, Karst Works, Inc.

Graham M. Schindel, GIT
Engineering Geologist
SAK Construction LLC

Introduction

Cave Without a Name is located in the Cretaceous Lower Glen Rose Limestone and has been a commercial (show) cave for more than 70 years. The highly decorated cave has more than three miles of mapped passage and includes an active stream passage. This field trip will discuss both surface and subsurface karst processes. We will view sinkholes, discuss the hydrogeology of the region, and the unique problems of caves and karst related to environmental and engineering geology.

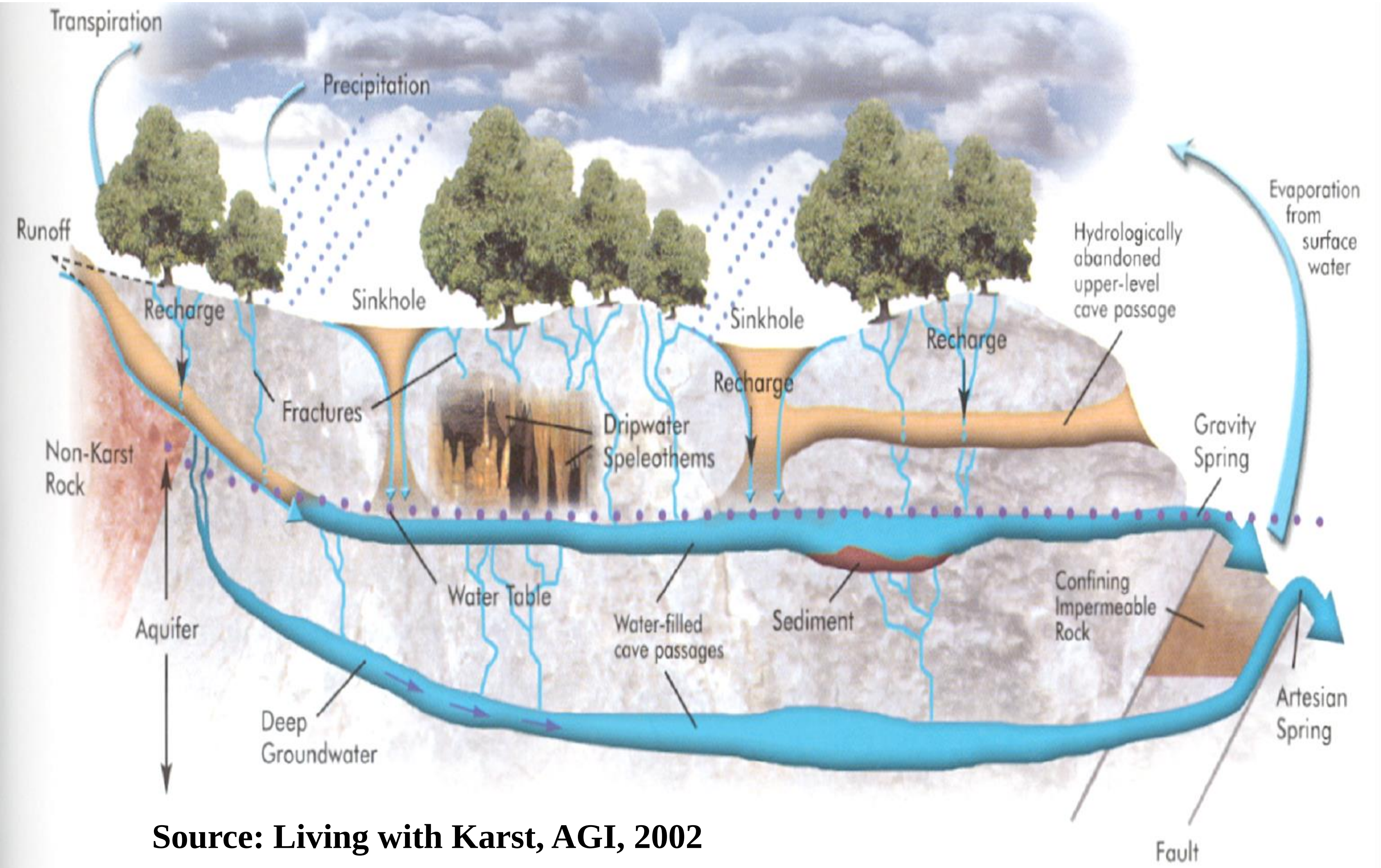
Field Trip Safety

Some hazards of concern during the field trip are venomous snakes and fire ants. This is one of the few regions in the country that contains all four types of venomous snakes: rattlesnake, copperhead, water moccasin, and coral. The wildlife and plants of Texas are noted for bites, stings, and stickers - they are usually fairly apparent. Fire ants are common in the field. While not large, they are well named. Their sting feels much like touching a hot poker and can ruin your day. If you have a bad reaction to their sting, they may ruin the rest of your stay in Texas. Please watch where you are standing, observe your feet often. Anything that looks like an ant mound is a fire ant mound—please give them plenty of room. Please bring any health and safety issues to the attention of the trip leaders.

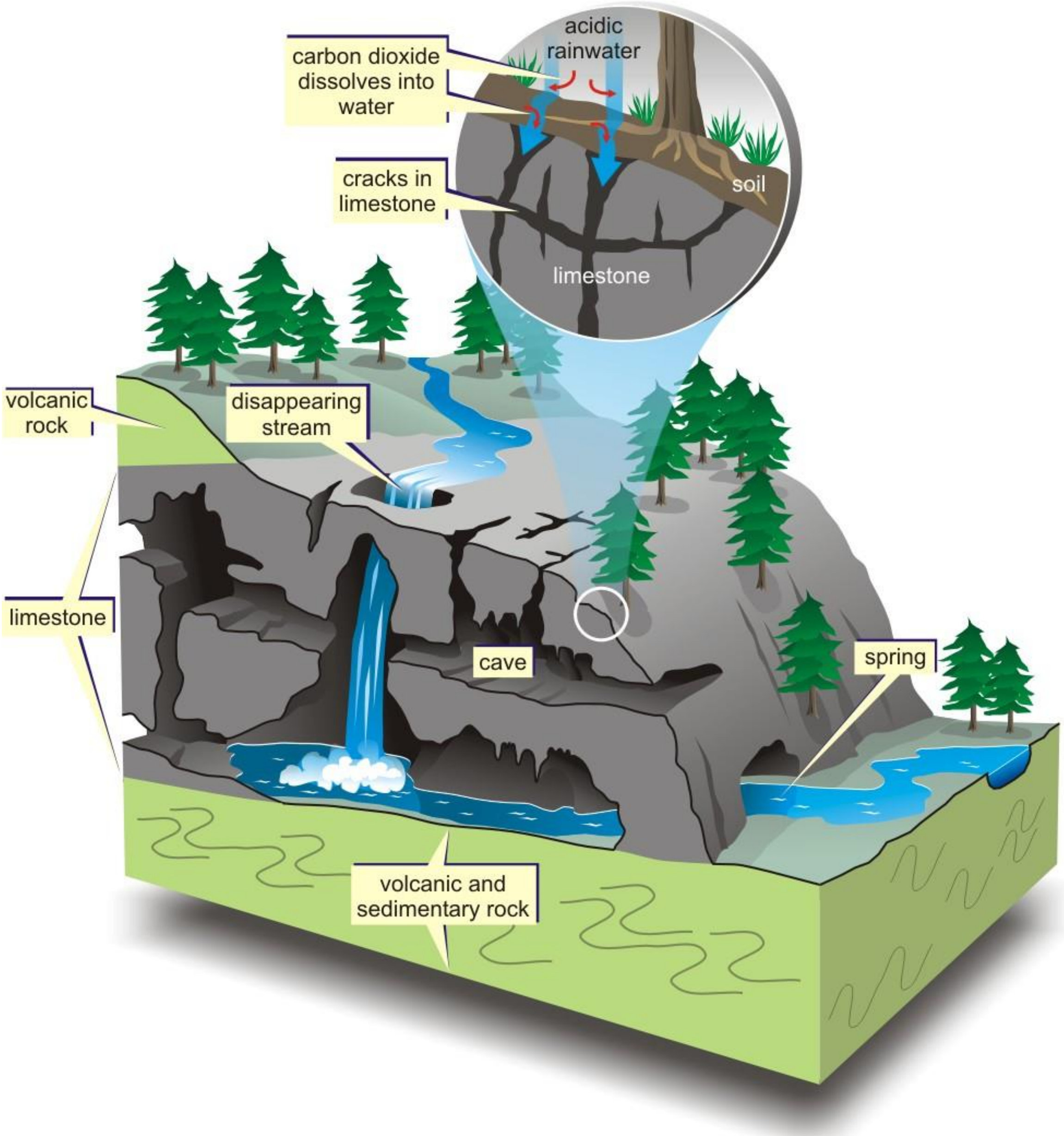
Field Trip Leader Biographies

Geary M. Schindel, PG has 40 years of experience as a karst hydrogeologist and is a professional geoscientist in Texas. He has a BS from West Virginia University and MS from Western Kentucky University where his graduate study was on point and non-point bacterial contamination in a karst groundwater system. He has worked on UST, CERCLA, RCRA, and Source Water Protection projects across the US and numerous foreign countries. He has performed more than 500 groundwater tracer tests in the US. Geary is President and a fellow of the National Speleological Society and a fellow of the Geological Society of America. He has served as Chief Technical Officer, Director, and Senior Hydrogeologist with the Edwards Aquifer Authority and is also President of Karst Works, Inc. a firm specializing in cave and karst environmental and engineering issues.

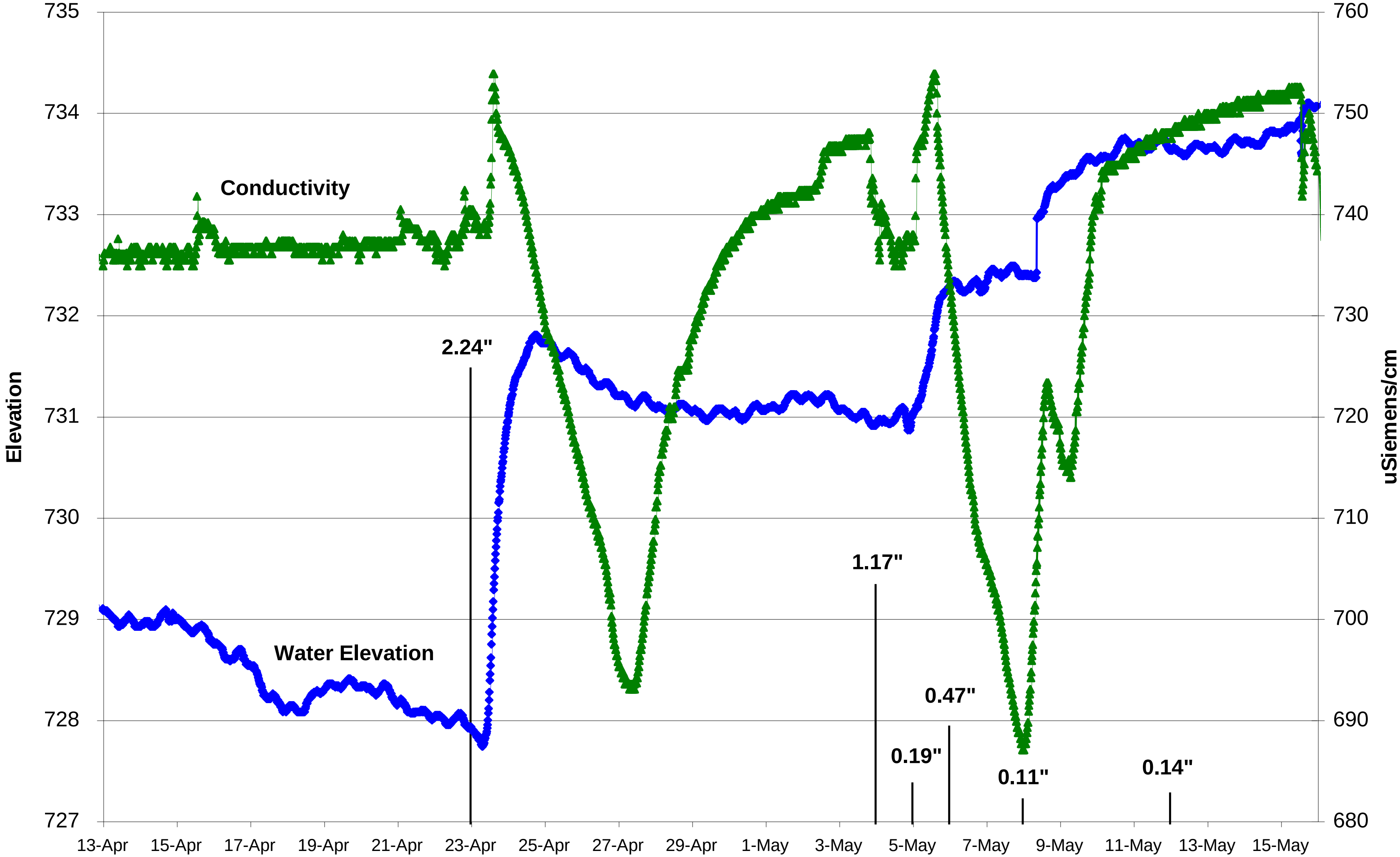
Graham M. Schindel, GIT has more than 10 years of experience as an geotechnical engineer and hydrogeologist. He holds a BS and MS from Northern Arizona University where he worked on the hydrogeology of the North Rim, Grand Canyon National Park. He has worked for GeoConcepts/TerraCon Consultants, Black and Veatch, and SAK Construction on pipeline, tunneling, to mitigate karst related hazards to infrastructure and meet environmental regulations. He is a fellow of the National Speleological Society and Project Manager at Karst Works, Inc.



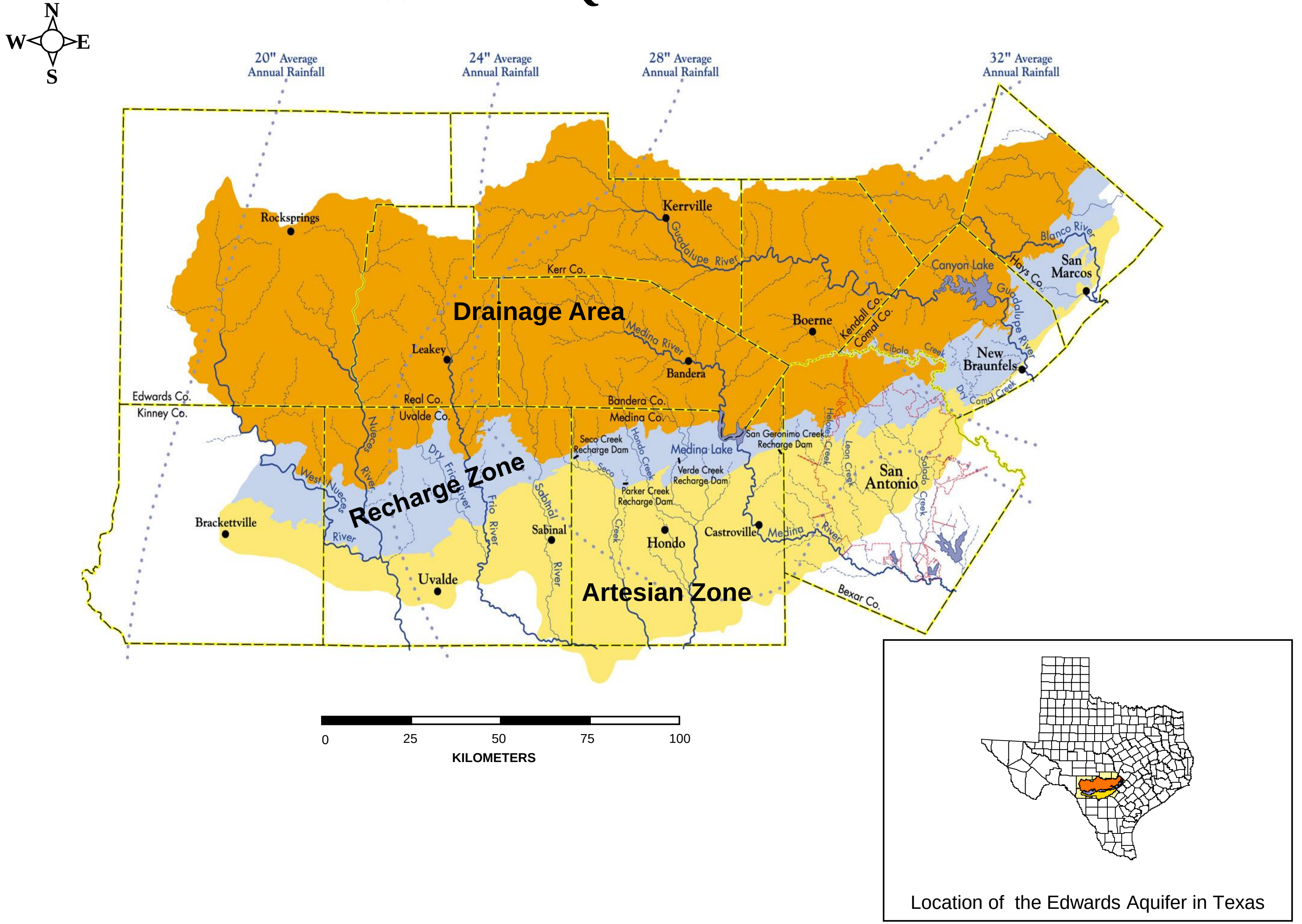
Source: Living with Karst, AGI, 2002


acidic
rainwater
carbon dioxide
dissolves into
water
cracks in
limestone
soil
limestone
volcanic
rock
disappearing
stream
limestone
cave
spring
volcanic and
sedimentary rock

Graph of conductivity, rainfall and groundwater elevation for the Blanco Well, Edwards Aquifer, South Central Texas



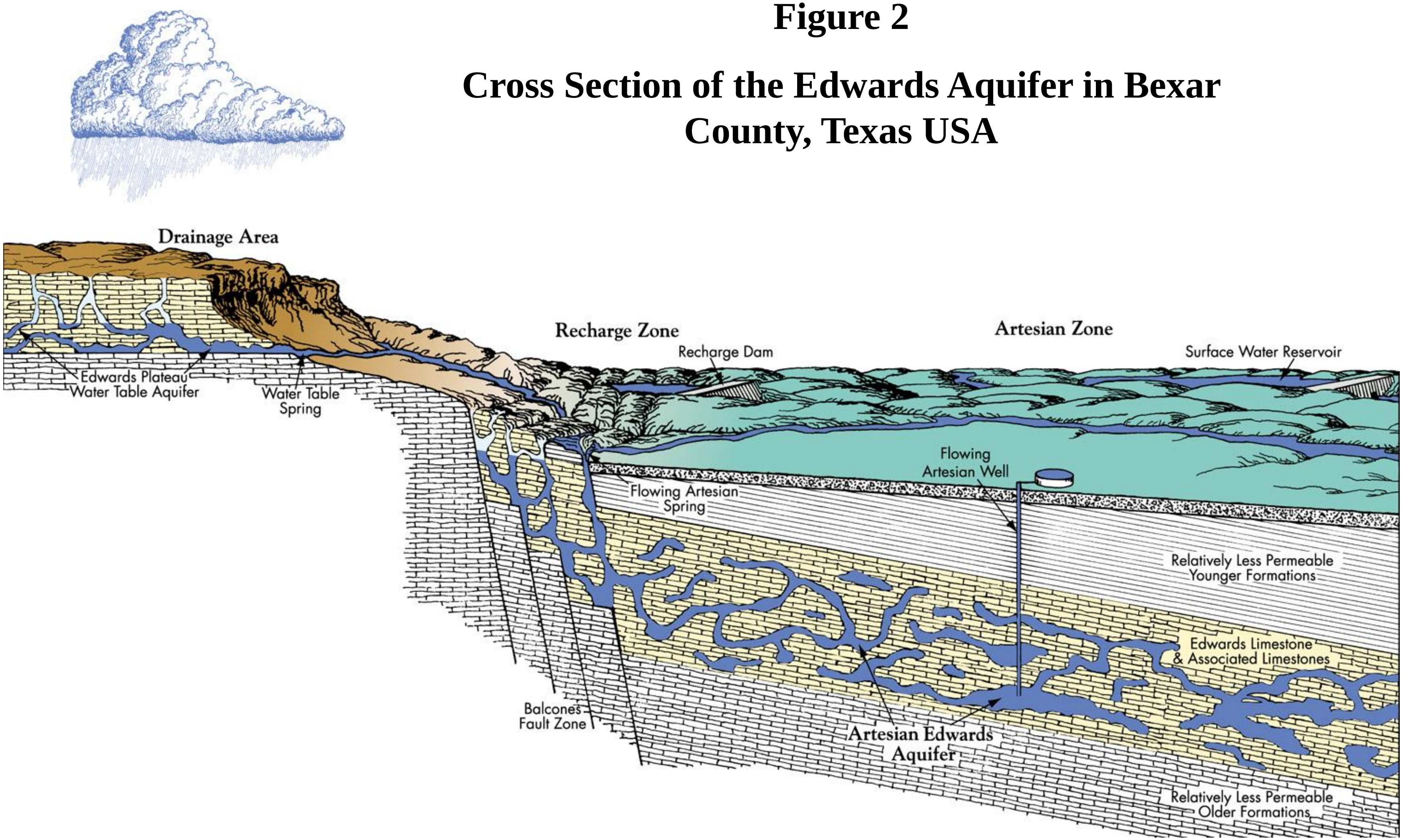
EDWARDS AQUIFER REGION

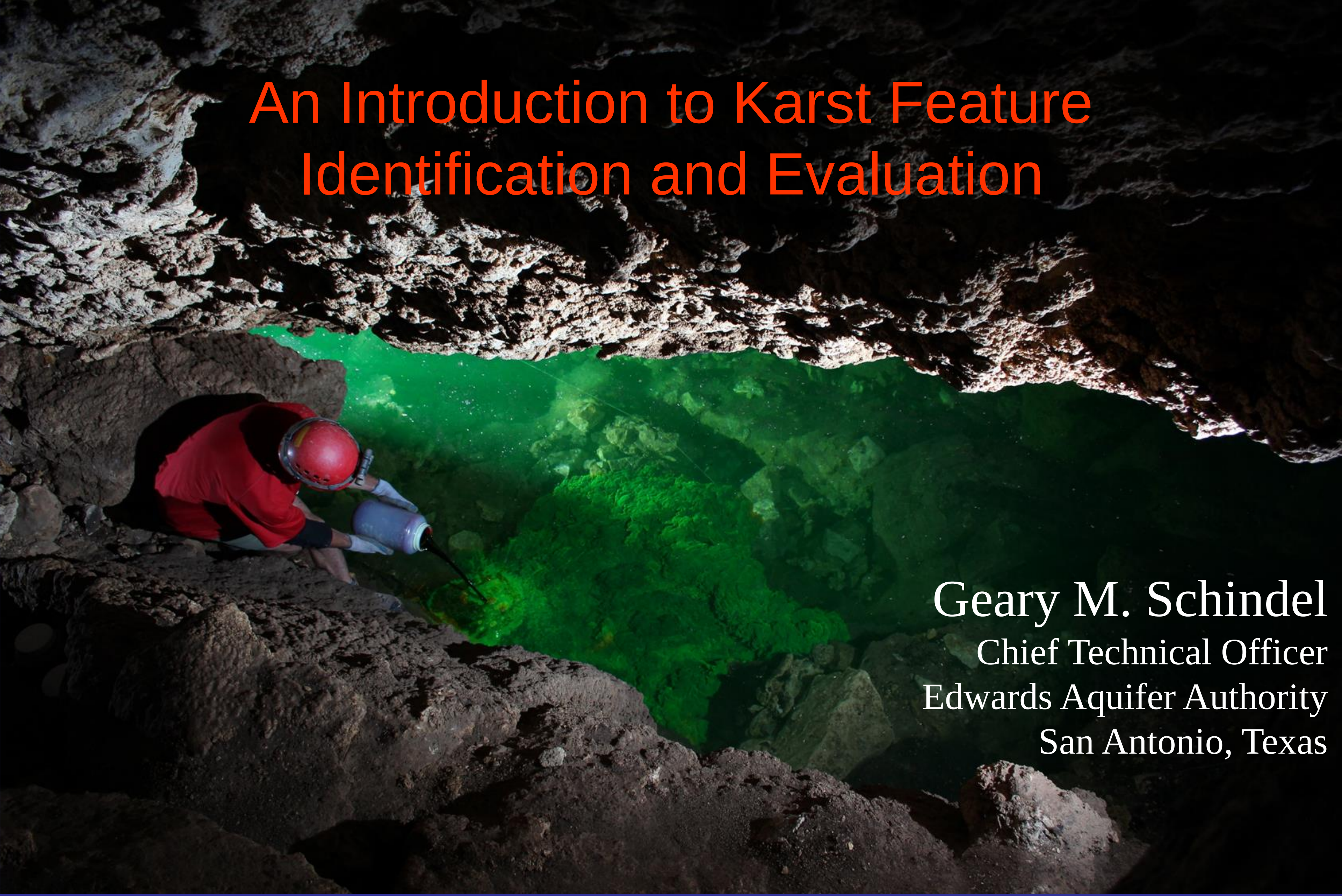


Location of the Edwards Aquifer in Texas

Figure 2

Cross Section of the Edwards Aquifer in Bexar County, Texas USA





An Introduction to Karst Feature Identification and Evaluation

Geary M. Schindel
Chief Technical Officer
Edwards Aquifer Authority
San Antonio, Texas

December 2019

Purpose of this Talk

- Define karst

Definition:

Karst is "an hydrogeologic mass-transfer system in soluble rocks with a permeability structure dominated by conduits dissolved from the rock and organized to facilitate the circulation of fluids"

(Huntoon, 1995, Klimchouk and Ford, 2000)

- Karst may or may not be expressed at the surface.
- A karst system can operate in the subsurface without any apparent relationship to the surface.

Karst is characterized by the presence of one or more of the following:

- Soluble rocks
- Enlarged fractures, faults, and bedding planes
- Dissolution on rock outcrops (karren)
- Sinkholes (dolines)
- Sinking and losing streams
- Caves and pits

Karst is characterized by the presence of one or more of the following:

- Well integrated subsurface drainage system
- Rapid groundwater velocities
- Springs
- Unique biology within the aquifer (depending upon aquifer age)

So, Which Rocks become Karstified?

Soluble Rocks

I. Salt – so soluble that it doesn’t last long at Earth’s surface.
II. Gypsum – not as soluble as salt, but still rapidly removed by solution.
III. Carbonates – limestone and dolostone, the most prevalent and familiar karst aquifers.
IV. Quartz – sandstone and quartzites.
V. Alluvium, grus, granites.

Aquifers

Idealized

Single Permeability
Isotropic

Homogeneous

Mathematically
Tractable

Real

Multiple Permeabilities

Anisotropic

Hetrogeneous

Mathematically
Challenging

Real Aquifer Characteristics

- Real aquifers have multiple, two or more, interacting sets of permeability in the same volume.
- The most transmissive permeability feature is organized into a channel system.
- The high transmissivity channel system is self organized by solution of the aquifer (and coupled mechanical erosion).

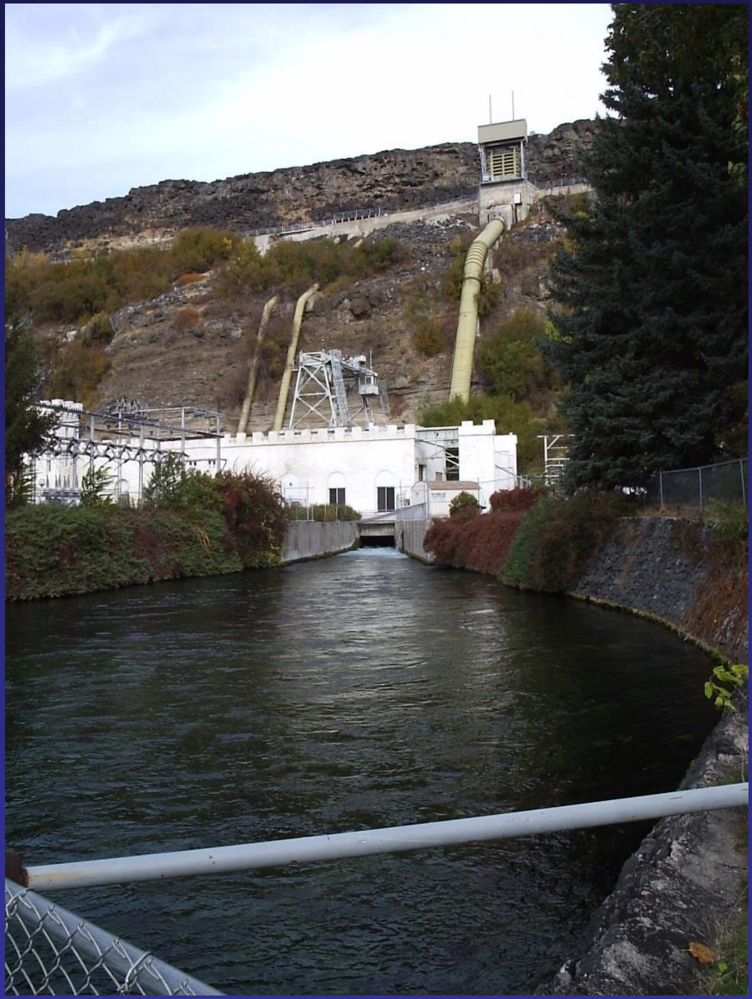
Real Aquifer Characteristics (cont.)

- Real aquifers can exhibit both rapid, long-distance, often turbulent water flow coupled with substantial longer-term storage of water in the same aquifer.

Conduits and Heterogeneities

- Produced during formation of aquifer
  - Igneous rock aquifers
  - Sedimentary rock aquifers
  - Unconsolidated aquifers
    - Fluvial processes
    - Glacial/fluvial processes
- Produced after formation of aquifer
  - Faulting
  - Lithification/jointing
  - Solution – karst aquifers

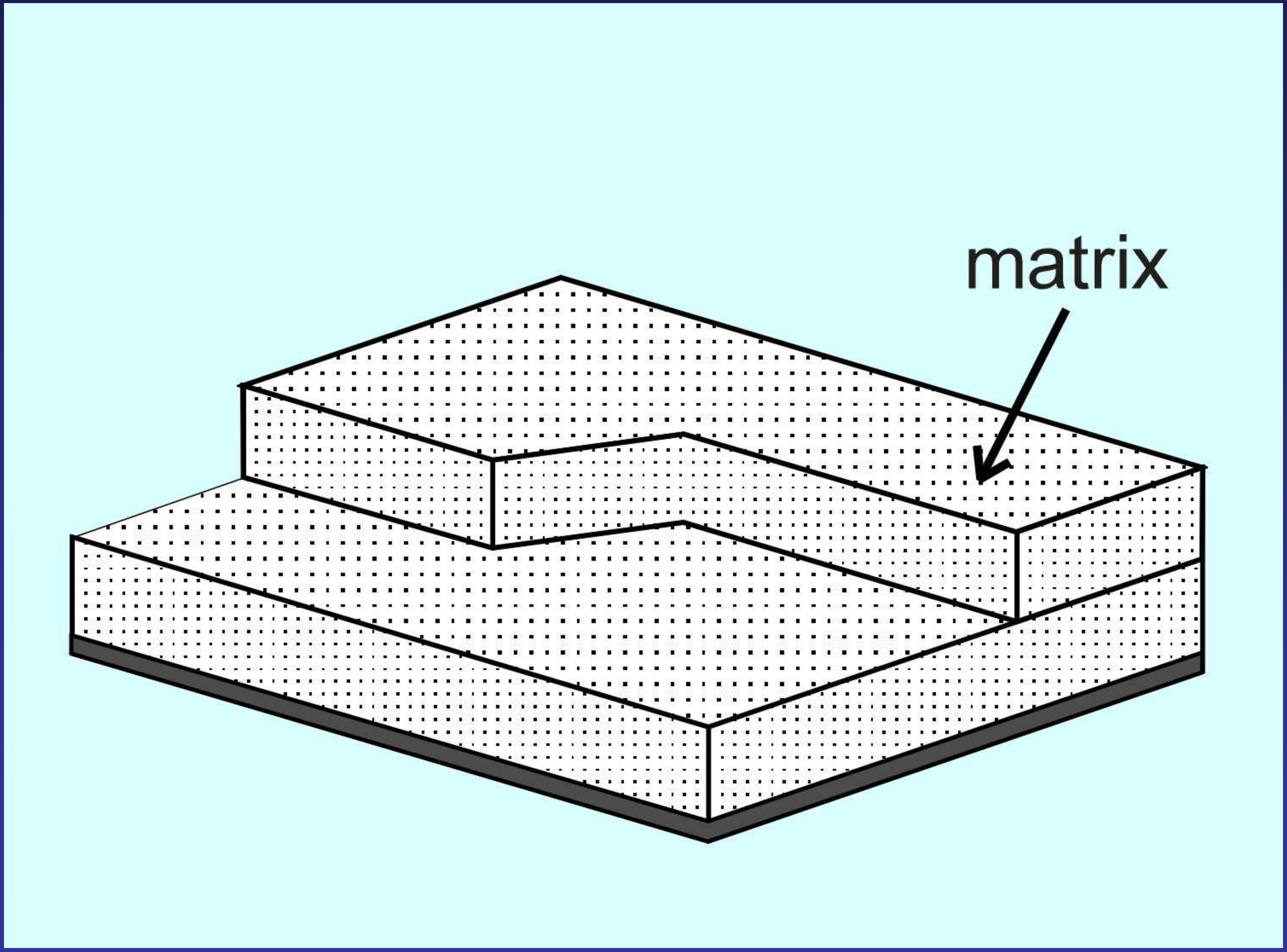
(Some of the) "Thousand Springs", Snake River, Idaho



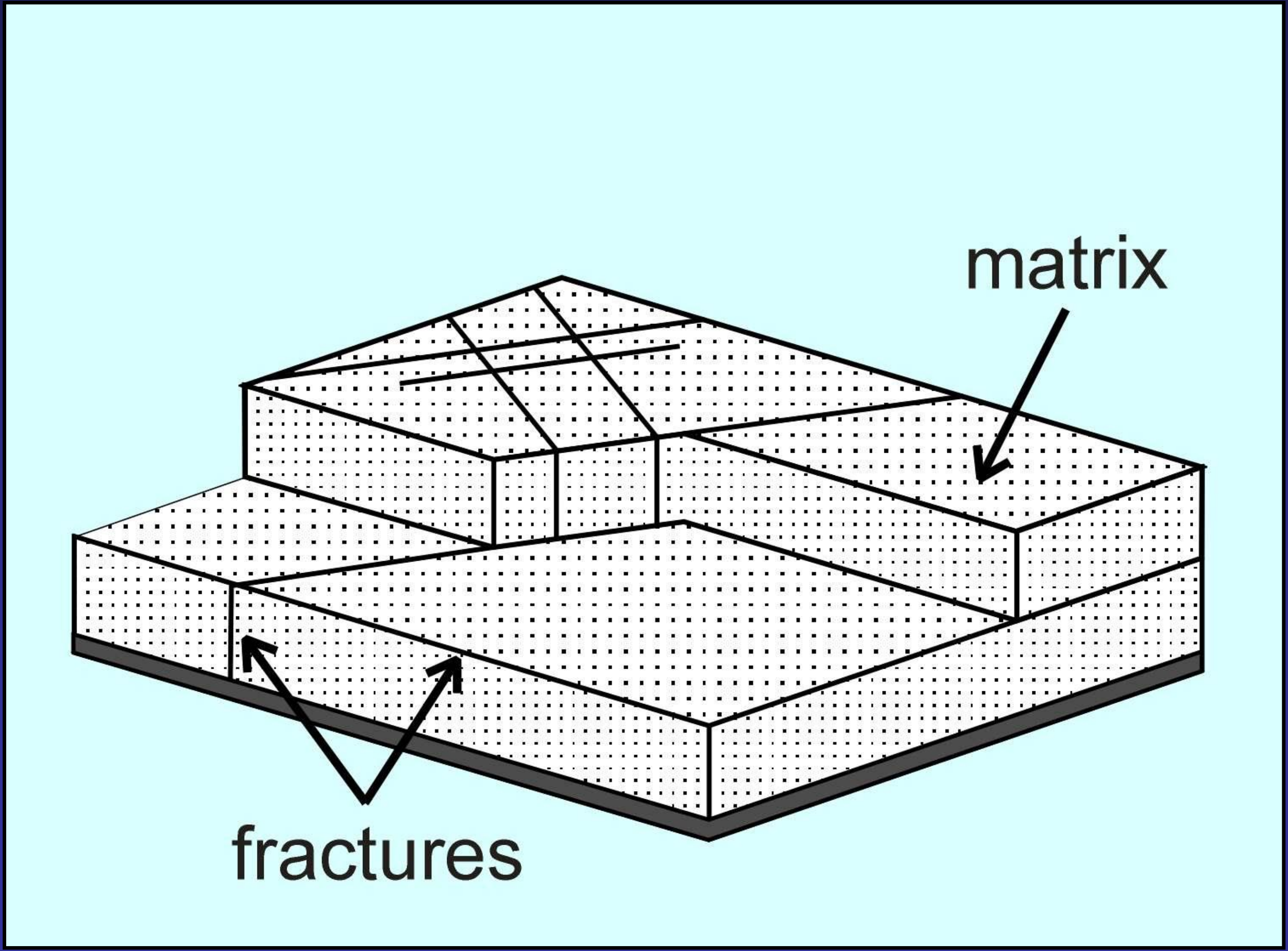
Columbia River Basalts

Largest spring in United States –

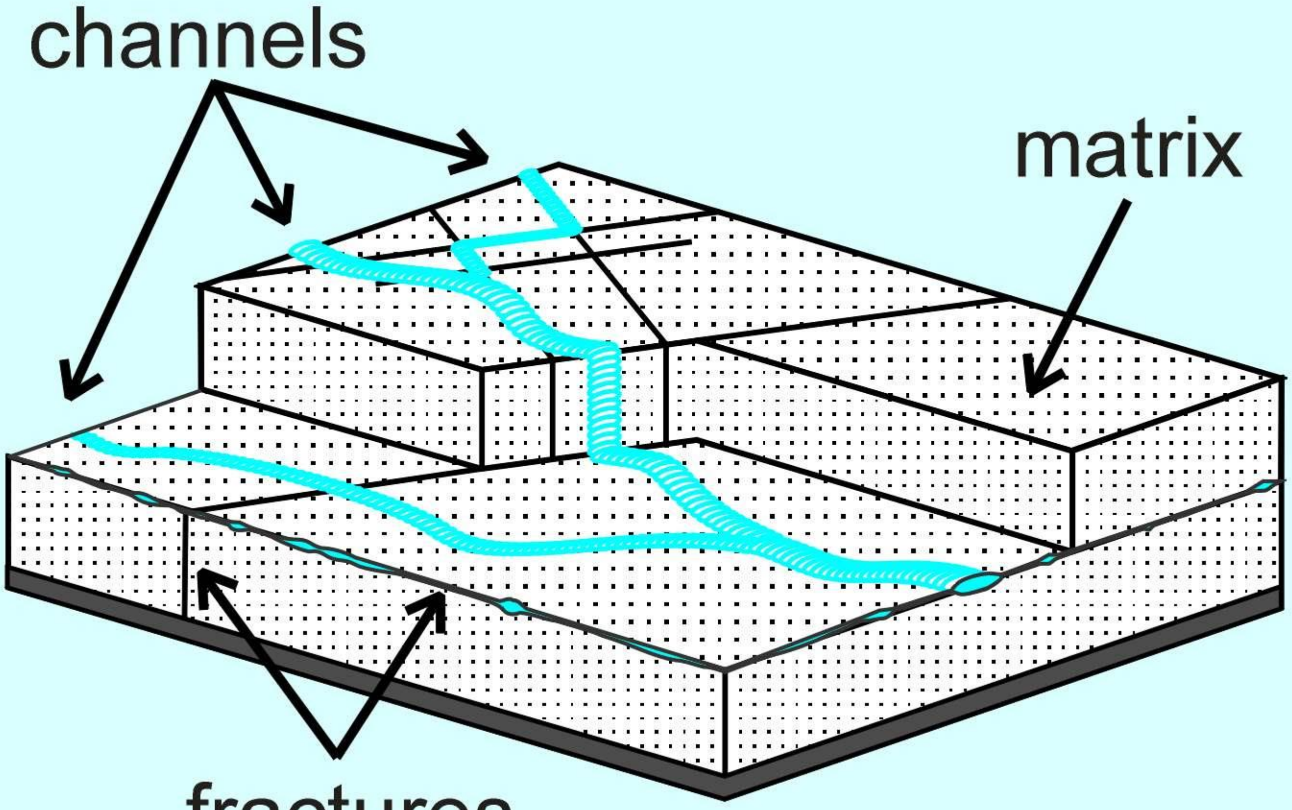
Permeability structure
- 3D component



Permeability structure - 3D + 2D components



Permeability structure
- 3D + 2D +1D components

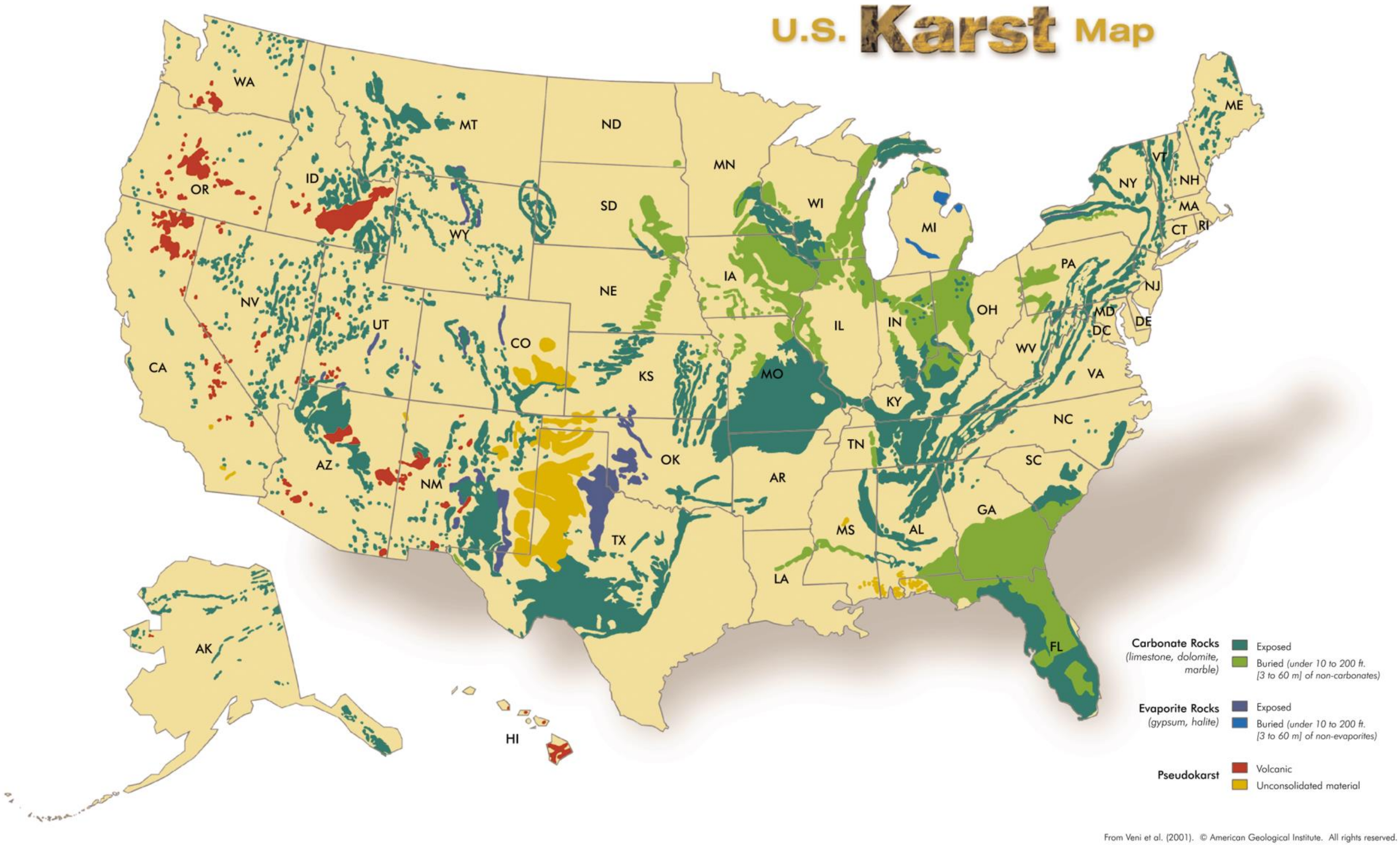


Worthington, 1999

Carbonate aquifers have triple porosity - matrix, fractures and channels

Area	K (m s^{-1})		
	Matrix	Fracture	Channel
Smithville, Ontario	1×10^{-10}	1×10^{-5}	3×10^{-4}
Mammoth Cave, Kentucky	2×10^{-11}	1×10^{-5}	3×10^{-3}
Chalk, England	1×10^{-8}	4×10^{-6}	6×10^{-5}
Yucatan, Mexico	7×10^{-5}	1×10^{-3}	4×10^{-1}

How common is karst ?

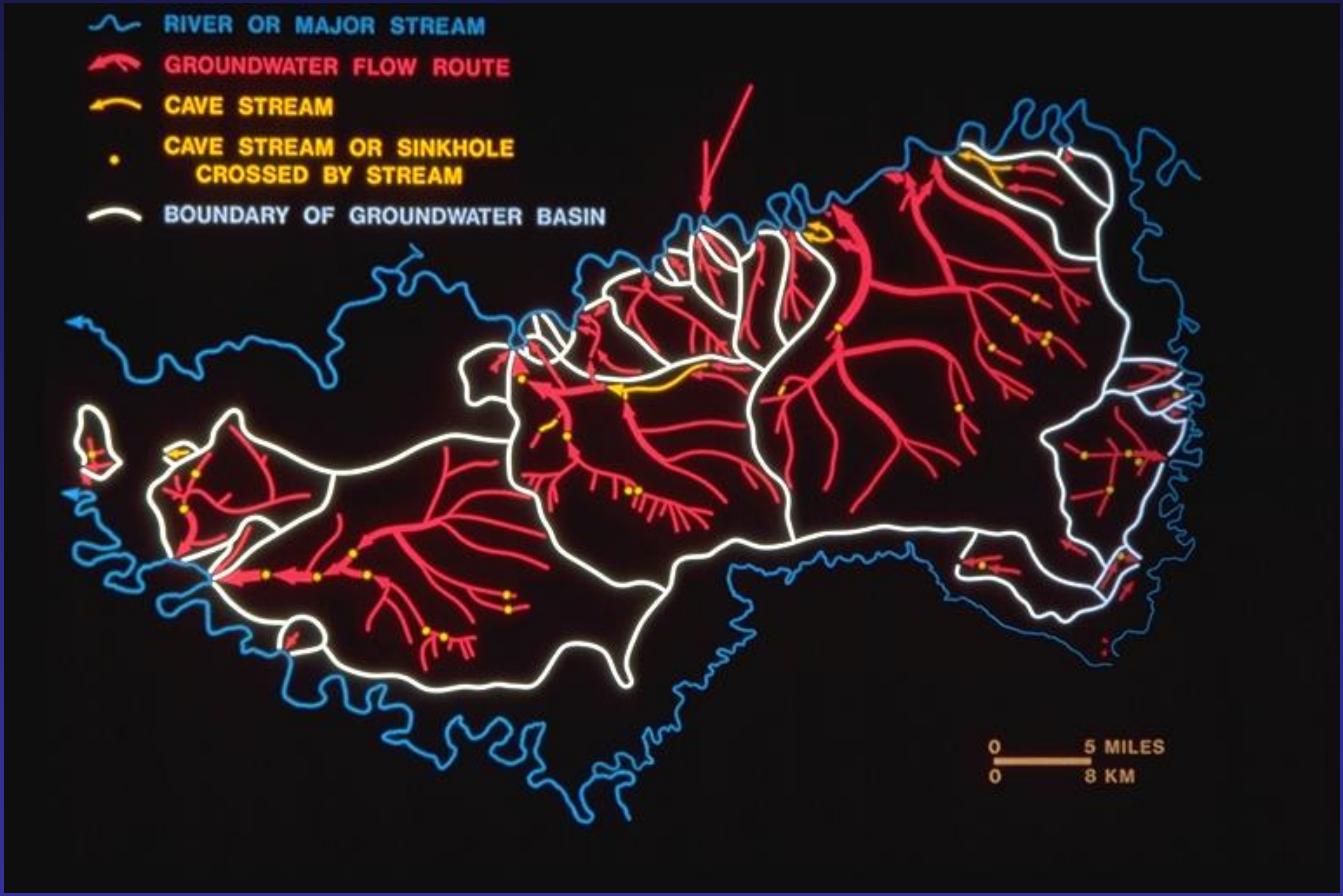


From Veni et al 2001

Karst aquifers often exist under landscapes with few, if any, visible surface karst features

- The Artesian portion of the Balcones Fault Zone Edwards Aquifer

Mammoth Cave Area, Kentucky



If soluble rocks are present, the surface and related groundwater system is karst and a FP aquifer is present. It should be treated as a PFP rather than a EPM until shown to be otherwise.

This point is critical in designing monitoring systems, responding to hazardous materials spills, land use planning, and groundwater resource management

Surface Stream Crossing Recharge Zone

Recharge Feature - 60 foot deep natural shaft

Storm Water Entering Recharge Feature

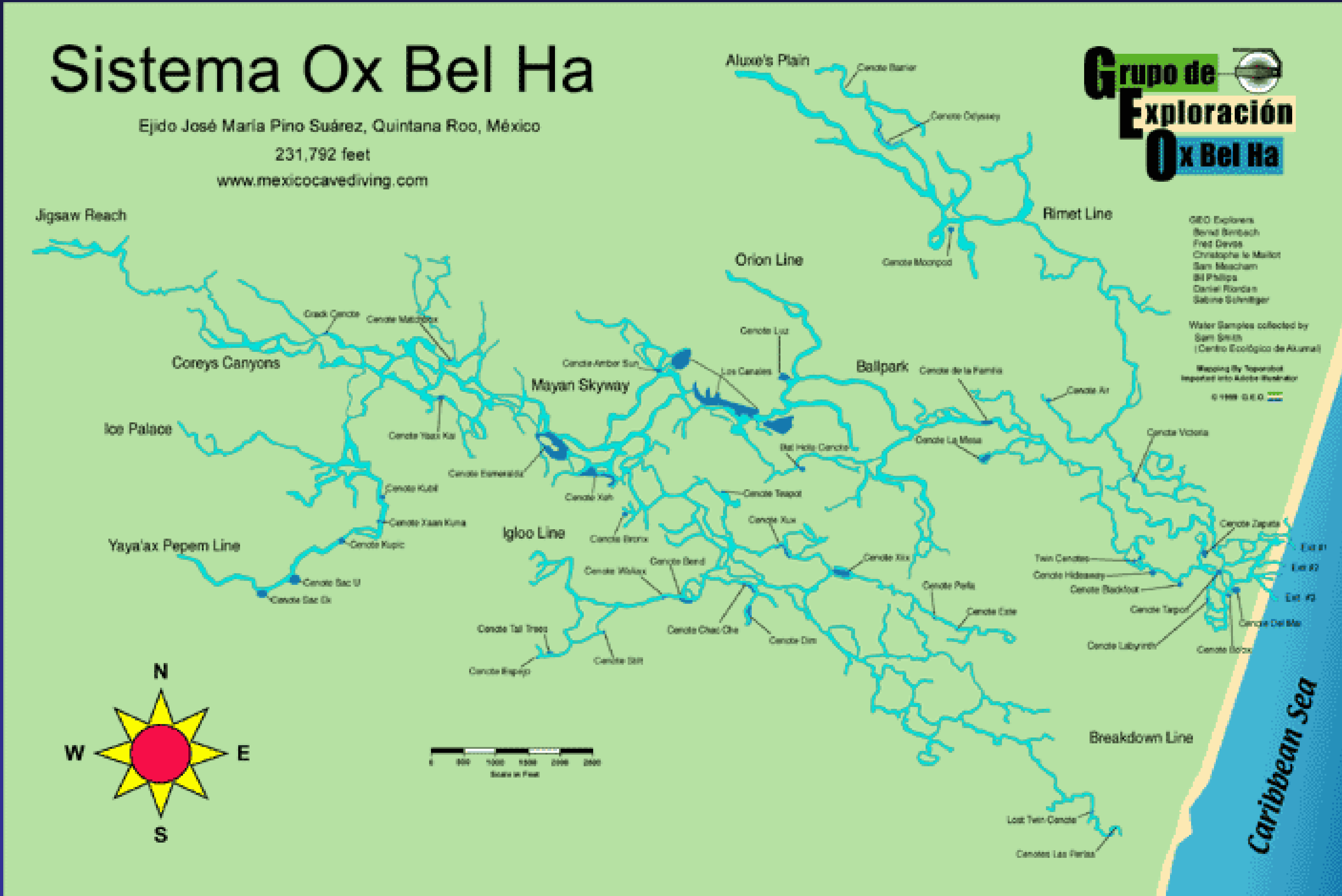
Texas Blind Salamander


SOUTHERN BIOLOGICAL SUPPLY COMPANY
McKENZIE, TENN. 38201

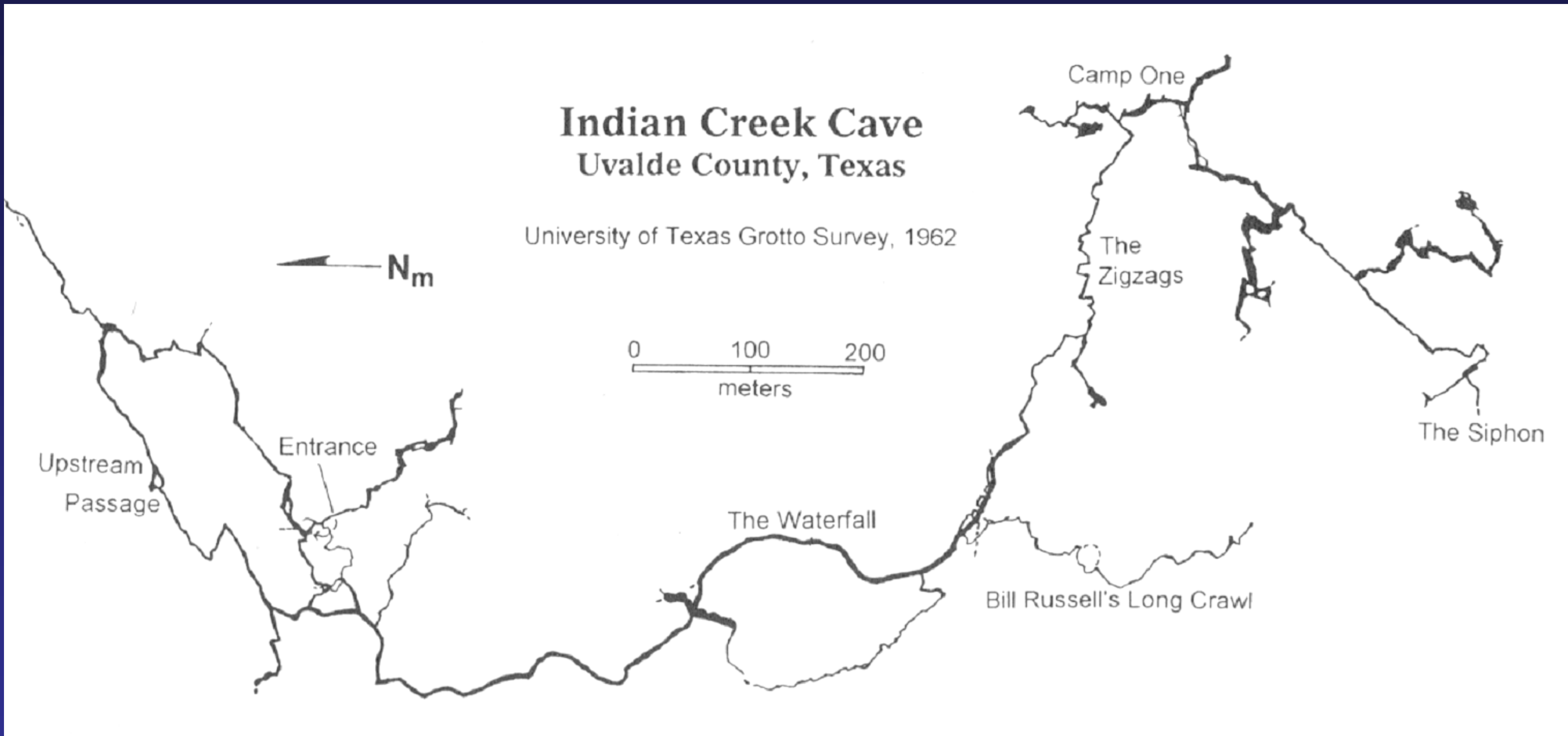
Sally Ward Cave in Oligocene Limestone in Northern Florida

Over 100 miles of underwater cave passage has been mapped in Florida

Photo by Barry Miller, Global Underwater Explorers
Woodville Karst Plain Project, Northern Florida



Mapped underwater cave system in the Yucatan of Mexico in Miocene-Pliocene limestones. Current mapped length is 133 kilometers

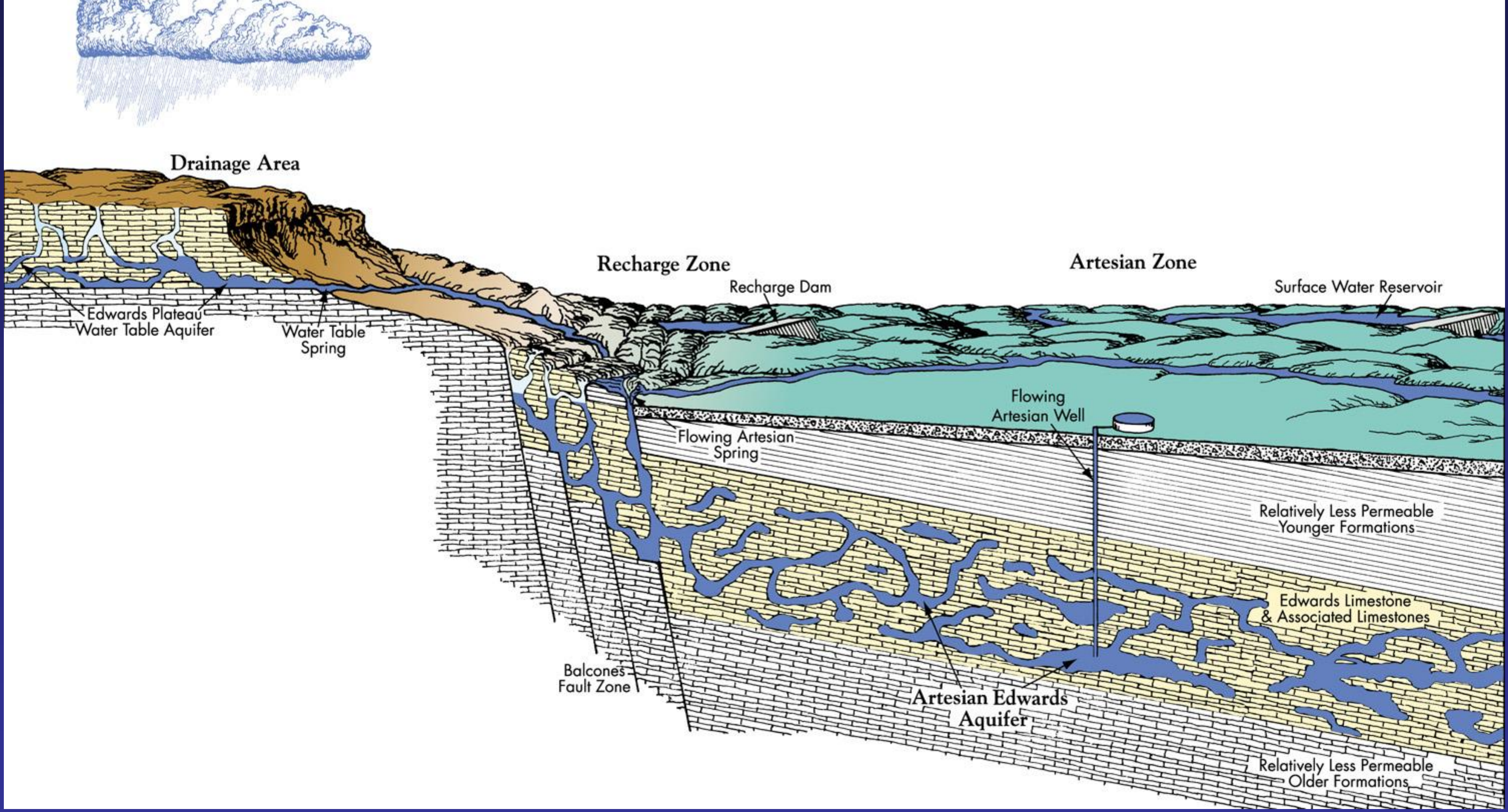


Mapped length is 6.7 kilometers

4th longest cave in Texas

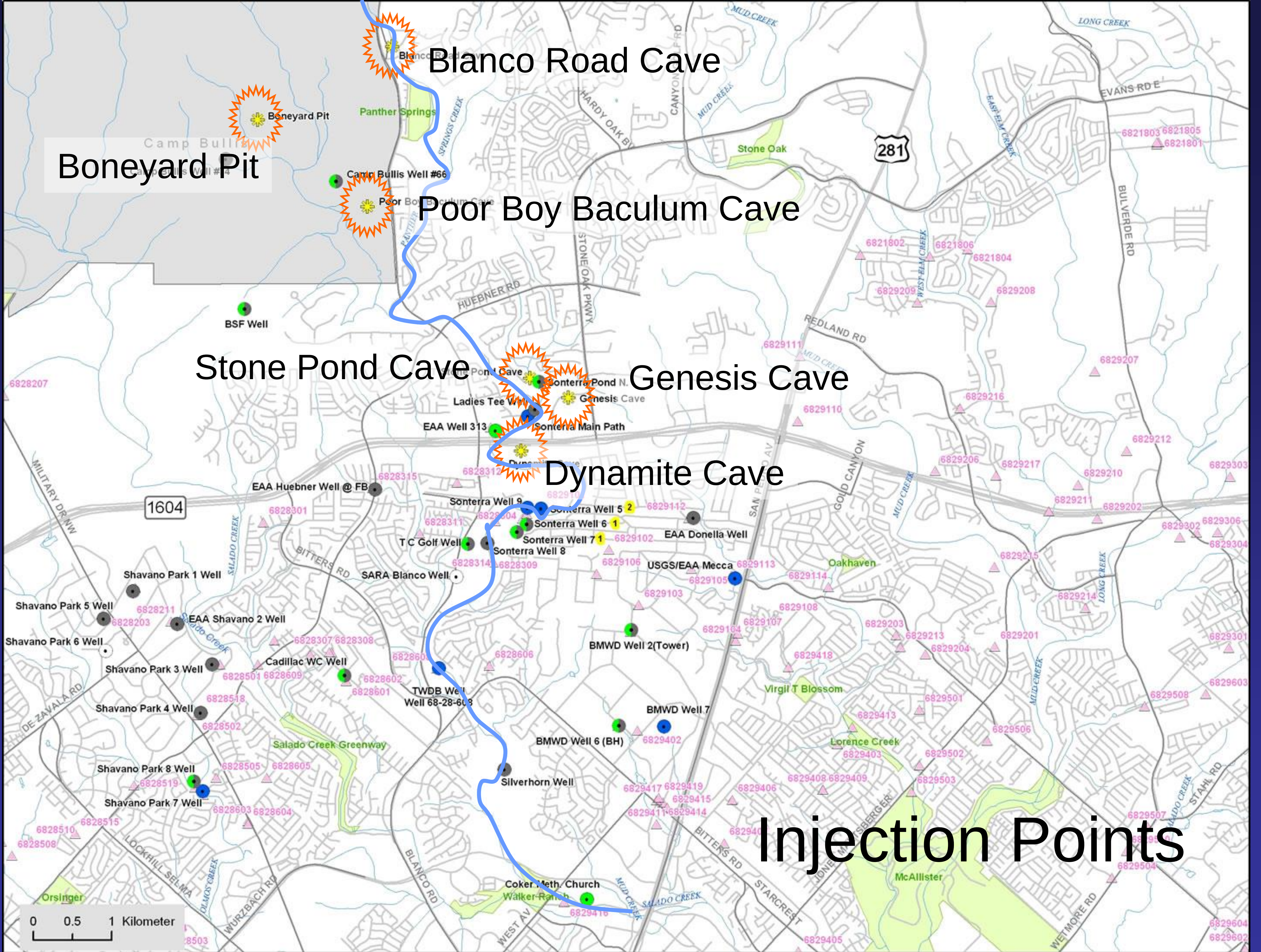
Source: Elliott and Veni, 1994

Cross Section of the Edwards Aquifer in Bexar County, Texas USA



Fluorescent Tracers

- Soluble in water
- Non toxic
- Used in food and drugs
- Low detection limits (= 10 ppt)
- Low cost of dye ($20 - $40 per kg)
- Low cost of analysis ($4 - $20 per analysis)

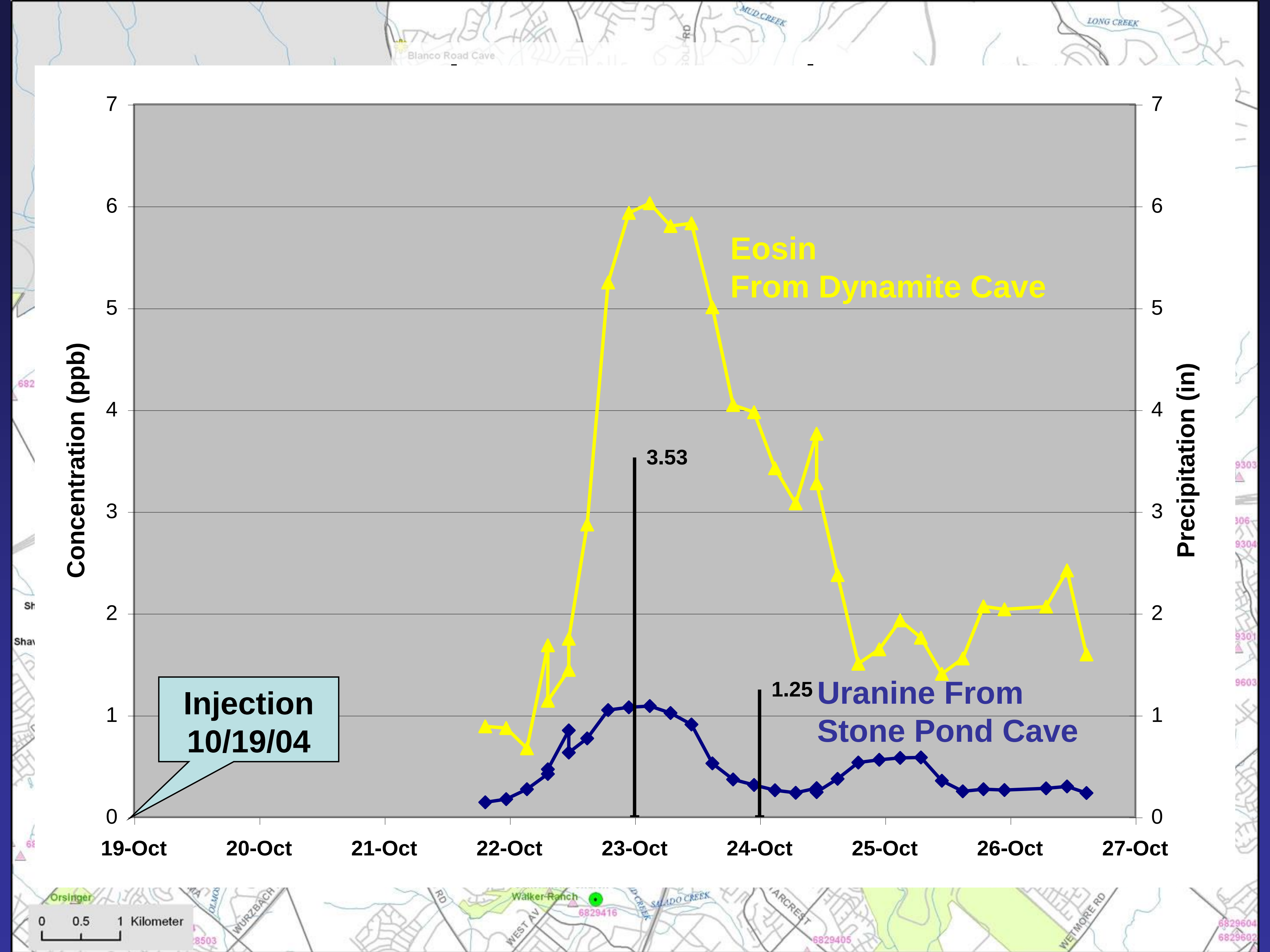


Blanco Road Cave
Boneyard Pit
Poor Boy Baculum Cave
Stone Pond Cave
Genesis Cave
Dynamite Cave
Injection Points
Camp Bullis
Boneyard Pit
Panther Springs
Camp Bullis Well #66
Stone Oak
281
BSF Well
Ladies Tee Well
EAA Well 313
Sonterra Main Path
Sonterra Pond
Genesis Cave
1604
EAA Huebner Well @ FB
Sonterra Well 9
Sonterra Well 5
Sonterra Well 6
Sonterra Well 7
Sonterra Well 8
T C Golf Well
EAA Donella Well
USGS/EAA Mecca
SARA Blanco Well
Shavano Park 1 Well
Shavano Park 5 Well
EAA Shavano 2 Well
Shavano Park 6 Well
Shavano Park 3 Well
Cadillac WC Well
Shavano Park 4 Well
TWDB Well
BMWD Well 2(Tower)
BMWD Well 7
BMWD Well 6 (BH)
Silverhorn Well
Shavano Park 8 Well
Shavano Park 7 Well
Salado Creek Greenway
Virgil T Blossom
Lorence Creek
Oakhaven
McAllister
Orsinger
Coker Meth. Church
Walker Ranch
HUEBNER RD
REDLAND RD
EVANS RD E
BULVERDE RD
STONE OAK PKWY
HARDY OAK BLVD
MILITARY DR NW
BITTERS RD
BLANCO RD
WEST AV
LOCKHILL SELMA
WURZBACH RD
DE ZAVALA RD
WETMORE RD
STARCREST
STAHL RD
0 0.5 1 Kilometer

Dye Injections

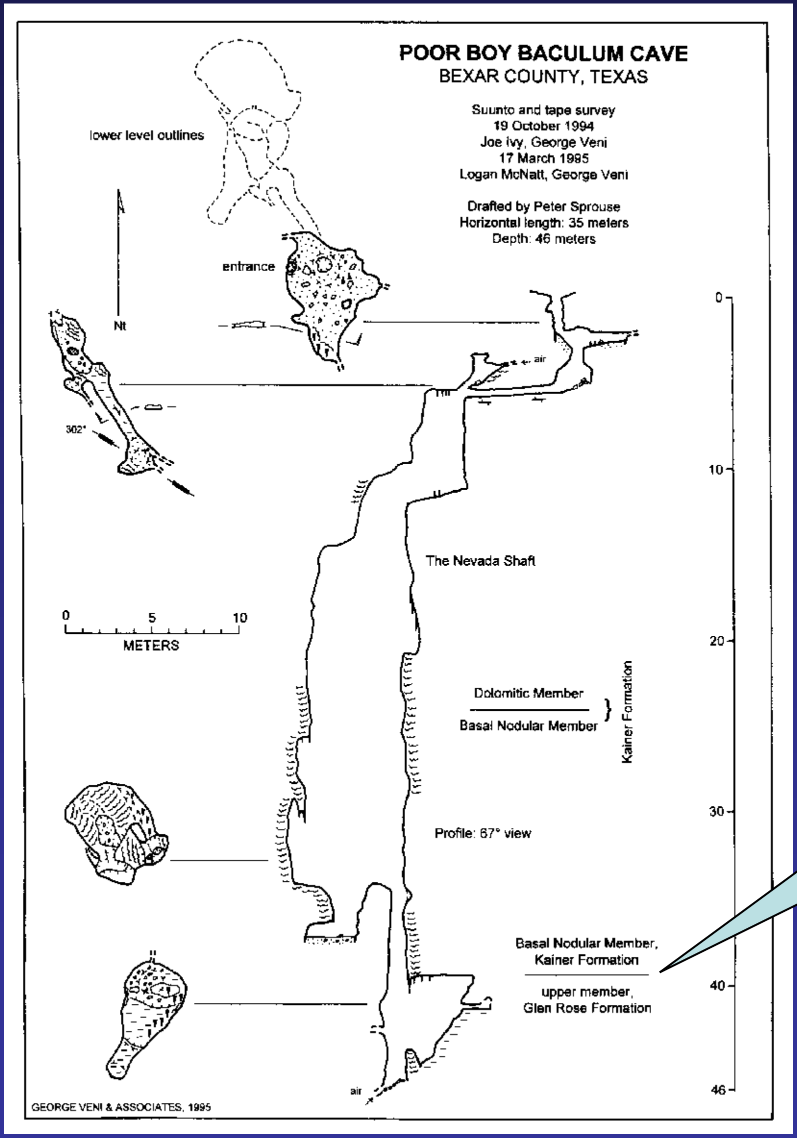
Dynamite Cave

Stone Pond Cave

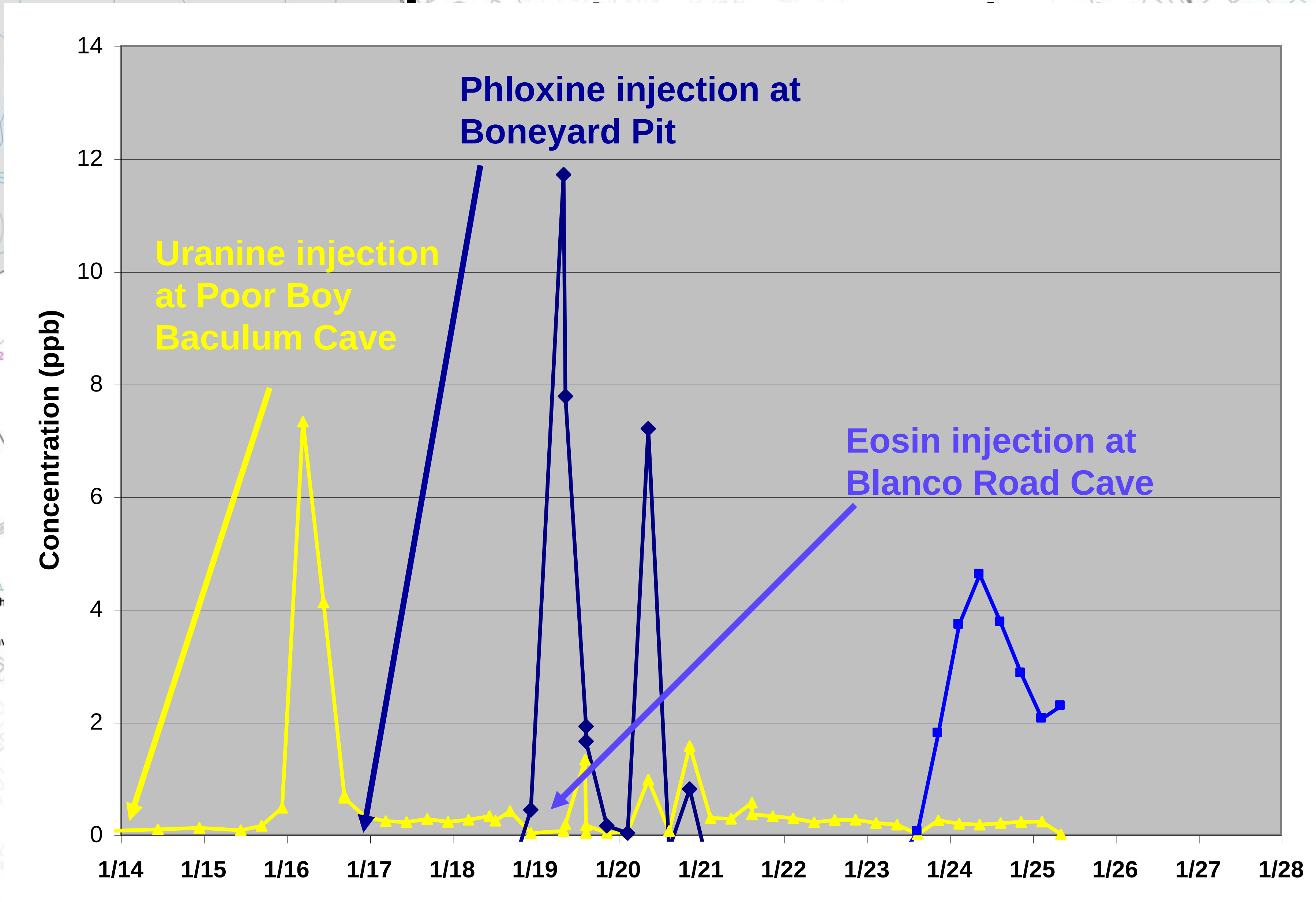


Eosin
From Dynamite Cave
Uranine From
Stone Pond Cave
Injection
10/19/04
3.53
1.25
Concentration (ppb)
Precipitation (in)
0
1
2
3
4
5
6
7
19-Oct
20-Oct
21-Oct
22-Oct
23-Oct
24-Oct
25-Oct
26-Oct
27-Oct

Poor Boy Baculum Cave

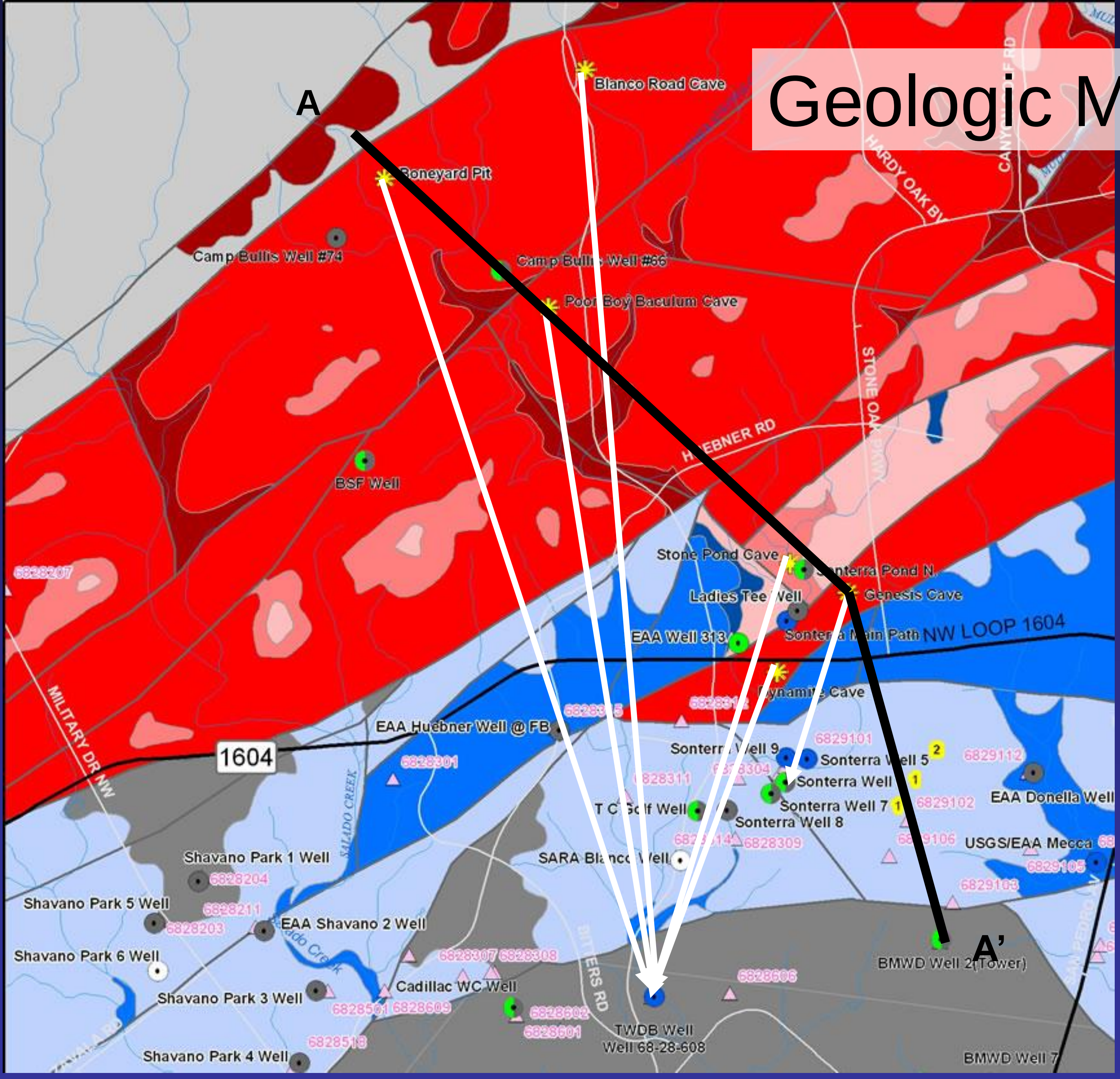


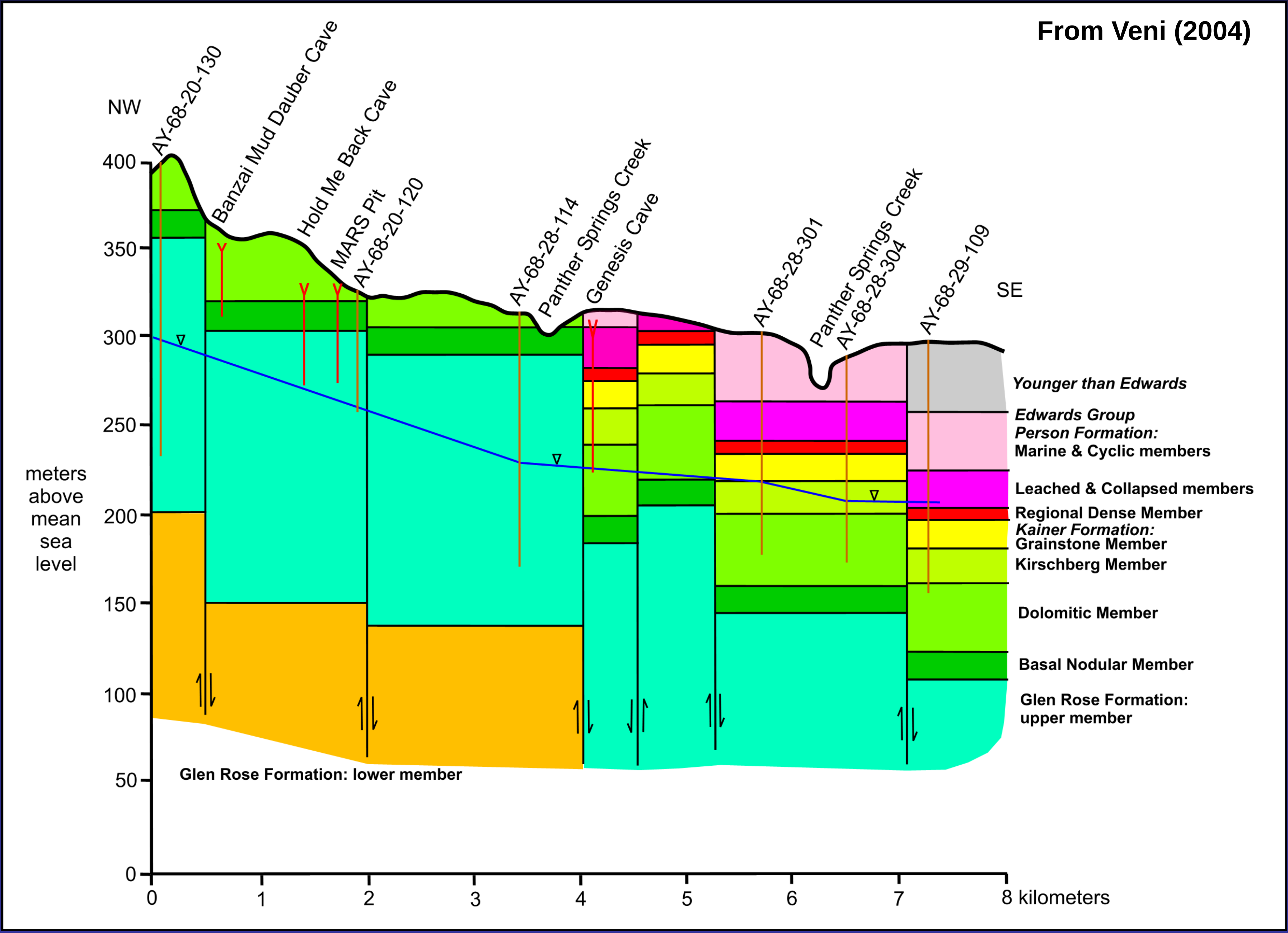
Depth to the base of the Edwards at 130 ft



Velocity: 11,600 ft/day

Geologic Map





From Veni (2004)
NW
SE
AY-68-20-130
Banzai Mud Dauber Cave
Hold Me Back Cave
MARS Pit
AY-68-20-120
AY-68-28-114
Panther Springs Creek
Genesis Cave
AY-68-28-301
Panther Springs Creek
AY-68-28-304
AY-68-29-109
meters
above
mean
sea
level
400
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
7
8 kilometers
Younger than Edwards
Edwards Group
Person Formation:
Marine & Cyclic members
Leached & Collapsed members
Regional Dense Member
Kainer Formation:
Grainstone Member
Kirschberg Member
Dolomitic Member
Basal Nodular Member
Glen Rose Formation:
upper member
Glen Rose Formation: lower member

Conclusions

- Preferential flowpath associated with Panther Springs Creek
  - Dyes bypassed most pumping wells and monitoring wells
  - Flowpaths do not appear to be controlled by structure
  - Flowpaths do not appear to be controlled by stratigraphy
- Apparent groundwater velocities ranged from 80 to 13,300 ft/day
- Groundwater flows freely between the Upper Member of the Glen Rose Formation and the Edwards Aquifer in the Panther Springs Creek basin

Walkerton, Ontario, Canada

E coli 0157 H7 Outbreak in 2000

- Municipal water supply wells contaminated by pathogenic bacteria.
- Town of 5,000
- Chlorination of water supply inadequate
- Seven deaths
- 2300 illnesses
- 150 people awaiting organ transplants

George Veni & Associates

Hydrogeologists and Biologists
Environmental Management Consulting
Cave and Karst Specialists

EVALUATION OF THE ELIGIBILITY OF CAVE WITHOUT A NAME, KENDALL COUNTY, TEXAS, AS A NATIONAL NATURAL LANDMARK

Prepared for:

U.S. National Park Service
IMR – Western Archeological & Conservation Center
1415 N. 6th Avenue
Tucson, Arizona 85705-6643

4 February 2003

507 E. Chapman, Carlsbad, New Mexico 88220-9283
505-234-1409 • gveni@warpdriveonline.com • 410-383-2276 (fax)

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EVALUATION OF THE ELIGIBILITY OF CAVE WITHOUT A NAME, KENDALL COUNTY, TEXAS, AS A NATIONAL NATURAL LANDMARK

by
George Veni Ph.D.

Introduction

Cave Without A Name is a show cave located in central Texas within Kendall County. Discovered in the 1920s, it opened to the public for tours in 1939. Veni (1994) provided an overview of the cave, generally recognized as one of the more significant caves in Texas. The purpose of this report is to evaluate the cave's eligibility for designation as a National Natural Landmark. The report follows the format recommended by the National Registry of Natural Landmarks. As a supplement to that format, Appendix A provides a glossary of cave, karst, and other specialized terms used in this report. Appendix B provides conversions from standard international metric units used in this report to English units.

My qualifications in conducting this evaluation are that I am a hydrogeologist specializing in caves and karst terrains. I received my Master's degree from Western Kentucky University in 1985 and Ph.D. from the Pennsylvania State University in 1994. Cave Without A Name was an important part of my doctoral dissertation (Veni, 1997). Since 1987, I've owned and served as principal investigator of George Veni and Associates, providing karst hydrogeological, biological, and environmental research and consultation services. I hold U.S. Fish and Wildlife Service Permit TE026436-0 to collect and study federally listed endangered Texas karst species. I also serve as the President of the Texas Speleological Survey, a non-profit corporation that serves as the database for Texas cave information, Executive Secretary of the National Speleological Society's Section of Cave Geology and Geography, and Adjoin Secretary to the Governing Bureau of the International Union of Speleology. Thus, I have detailed knowledge of caves locally and around the world.

Given my 27 years of familiarity with and research involving Cave Without A Name and its surroundings, I had little need to conduct additional fieldwork for this evaluation. I have compiled and reviewed all available technical and non-technical information on the cave; most of the unpublished material was contained in the files of the Texas Speleological Survey, my personal files, or derived from personal communications over the years with people knowledgeable about the cave. Information on the current status of the cave came through personal observation or communication with Mike Burrell, the cave's manager. Photographs of the cave that accompany this report were taken in January 2003.

Part A. Description of the Natural Feature

1) Geological Features

Characteristics: Caves predominantly occur in karst terrains, landscapes that form primarily by dissolution of the bedrock. Karst is characterized by features that include caves, sinkholes, sinking streams, and underground streams and covers about 20-25% of the United States. One the largest contiguous karst regions in the country is the Edwards Plateau in central Texas (Veni, 2002). Despite their size, karst areas are among the least studied, most poorly understood, and most adversely impacted landscapes, because many of the features that define them and the resources they contain are "hidden" underground.

Many of the world's most productive groundwater supplies are karst aquifers that release record high volumes of water from wells and springs. Old and hydrologically inactive caves can serve as highly important paleontological and archeological sites. Protected from the elements on the surface, materials left in such caves can be preserved for thousands of years.

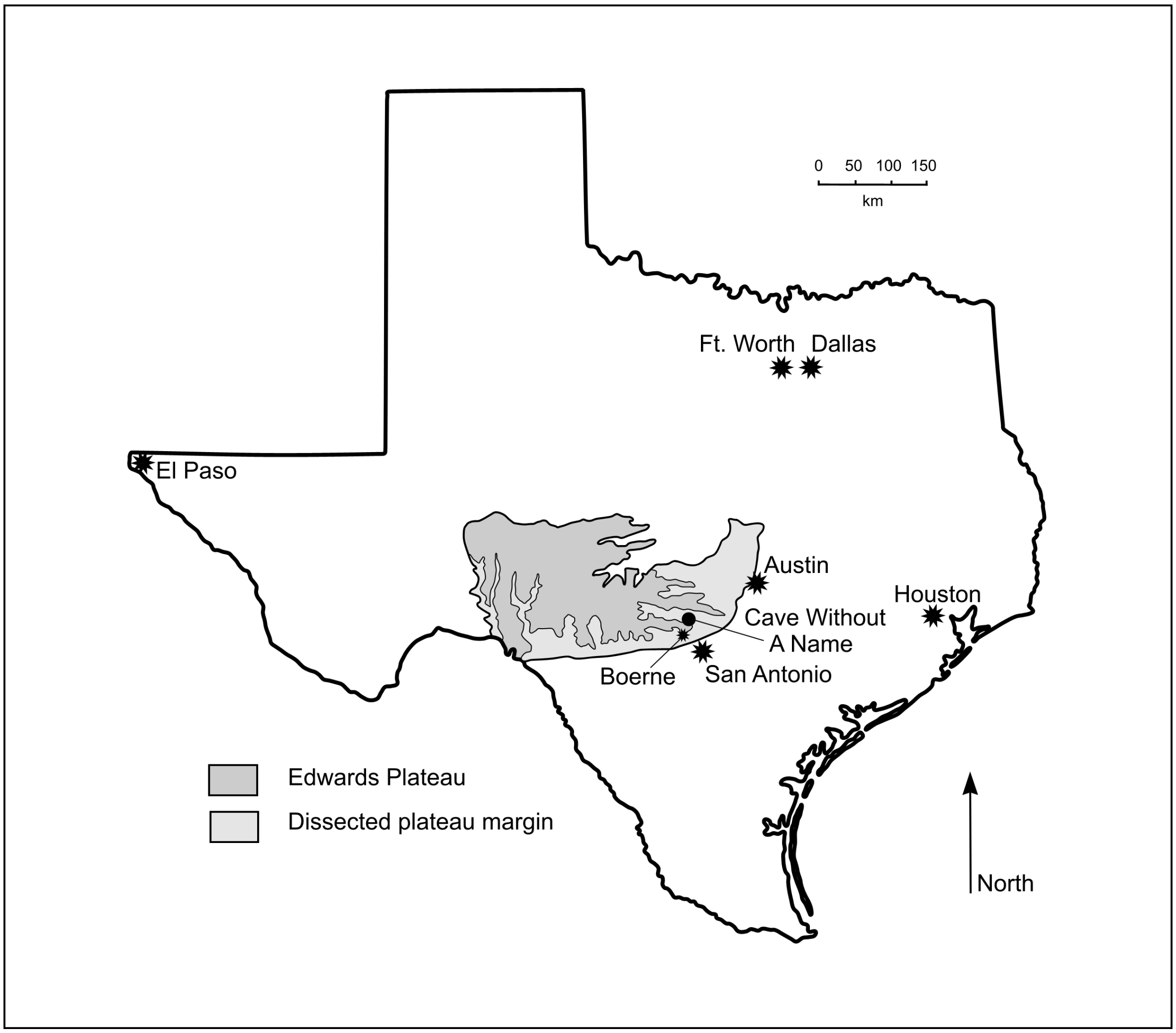
The karst of central Texas is well known but not as well studied as other karst regions. Quinlan (1978) and White (1988) recognized it as a major but less typical karst region. It has topographically subdued surface features, such as sinkholes on the scale of a few meters and often much smaller, and caves that can seldom be followed by people from sinkholes where water enters the ground to where it discharges from a spring. Cave Without A Name is one of the region's few examples of a karst hydrologic system that is accessible from points of recharge to discharge. While it has no single outstanding characteristic that demands recognition as a National Natural Landmark, its combination of features that are rare and/or outstanding examples on a regional to national scale warrant consideration for that status. Further, the cave's use as a show cave makes it extremely valuable as an educational resource.

Distribution: Figure 1 provides the location of the cave at the southeastern corner of the Edward Plateau physiographic region, in what is locally known as the "Hill Country," where streams cut into the plateau's margin. Figure 2 shows a map of the downstream end of the cave, which includes the area open to tourists. Figure 3 is a map of the surveyed extent of the cave on a topographic map. It includes nearby Spring Creek Cave which might have been related to Cave Without A Name early in its development. Figure 4 expands the scope of Figure 3 to include the results of a tracer test that delimit the furthest exactly known hydrologic extent of the cave. The estimated extent of the cave's drainage basin is explained and illustrated later in this report.

Physical Description: Cave Without A Name is a show cave with two natural entrances: a spring entrance known as Dead Man's Cave (Figures 2 and 5) and a pit located next to an excavated walk-in entrance for the tour trail (Figures 2 and 6). The artificial entrance intersects the natural pit, and its trail spirals down the pit's walls to a depth of 22 m. A short but low passage leads into a large chamber, 185 m long by 13-20 m wide by up to 10 m high, identified in Figure 2 as the "Commercial Section." Large speleothems divide it into several rooms.

A large underground stream passage lies at the south end of the chamber. Downstream, it extends 770 m and emerges as a spring near the cave's Dead Man's entrance. Discharge from the spring has been measured between 2-29 L/s. During flood events, water also flows from the Dead Man's entrance, the older, original spring before the water diverted to a lower elevation spring outlet. Upstream from the large chamber, the cave has been surveyed nearly 3 km. Additional exploration in that direction will require scuba equipment. The stream has relatively few tributaries, but those present are not all fully explored (Figure 3). Cave Without A Name is the sixth longest cave in Texas with a currently surveyed length of 4,332 m; it has a vertical extent of 27.1 m (Veni, 1994).

Figure 1
Location map of Texas, Edwards Plateau, and Cave Without A Name



The cave is developed in the Cretaceous age lower member of the Glen Rose Formation within the Middle Trinity Aquifer, listed as a critical water supply area by the state of Texas (Groundwater Protection Unit, 1989). Unlike most caves that form by water recharging the aquifer through many fractures and sinkholes, converging into a main stream discharging at a spring, Cave Without A Name has a less common origin. It captures part of the flow of the Guadalupe River and returns it several kilometers downstream via the Dead Man's entrance, which flows into Spring Creek, a tributary to the Guadalupe. The creek may be formed by collapse of the downstream continuation of

Cave Without A Name, and nearby Spring Creek Cave (Figure 3) may have been a tributary to that collapsed passage. The cave's recharge point along the Guadalupe River is not well defined and probably occurs mostly through solutionally enlarged fractures along a particular reach of the river about 3.4 km northwest of the cave's upstream end. Additional research is needed to better identify the zone of capture. By dating the rate of the river's incision, the time when the cave first began to form is approximated at 850,000 year B.P. (Veni, 1997). Dye tracing by Harden (1985) found the cave's stream extends at least another 2.6 km northwest to where it flows through Alzafar Water Cave (Figure 4).

Figure 2
Downstream and show cave sections of Cave Without A Name
(Fieseler, Jasek, and Jasek, 1978)

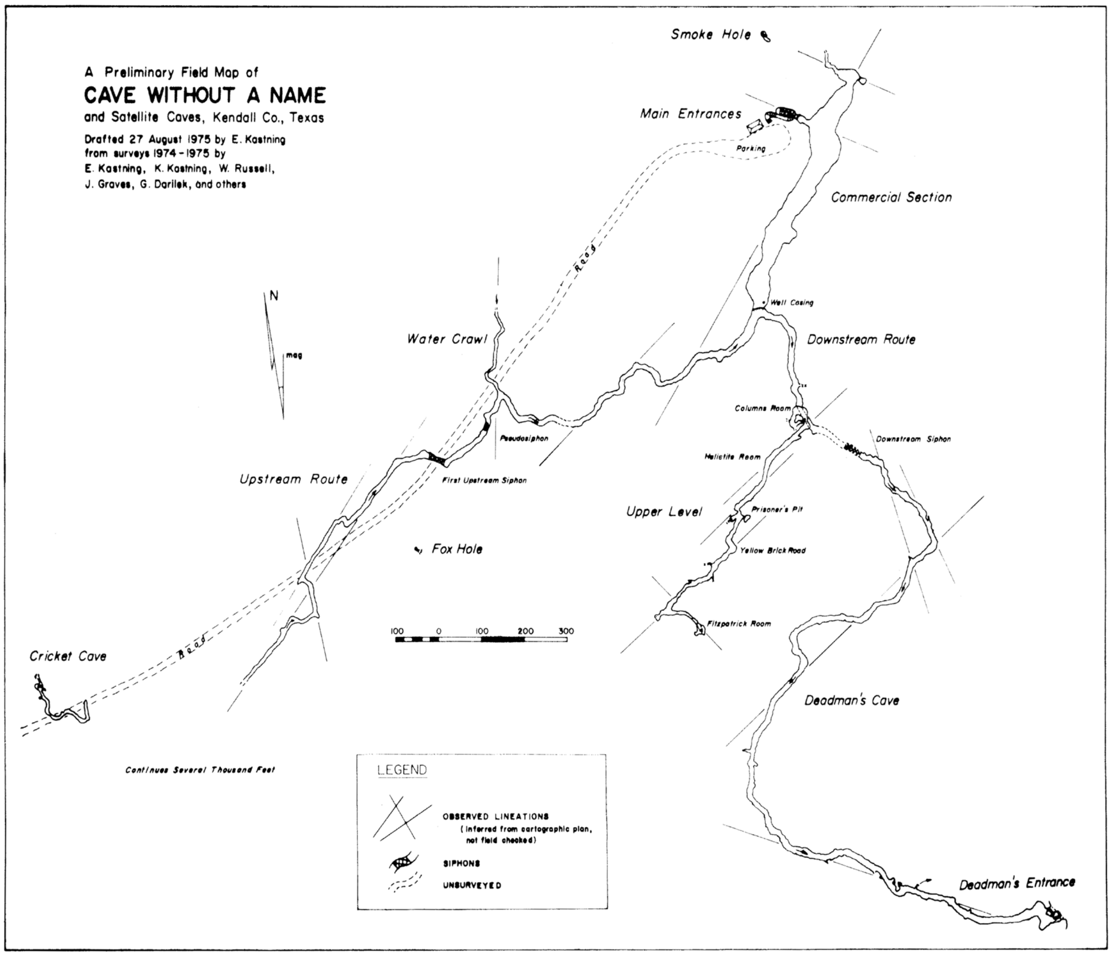


Figure 3
Map of Cave Without A Name and Spring Creek Cave
(Veni, 1994)

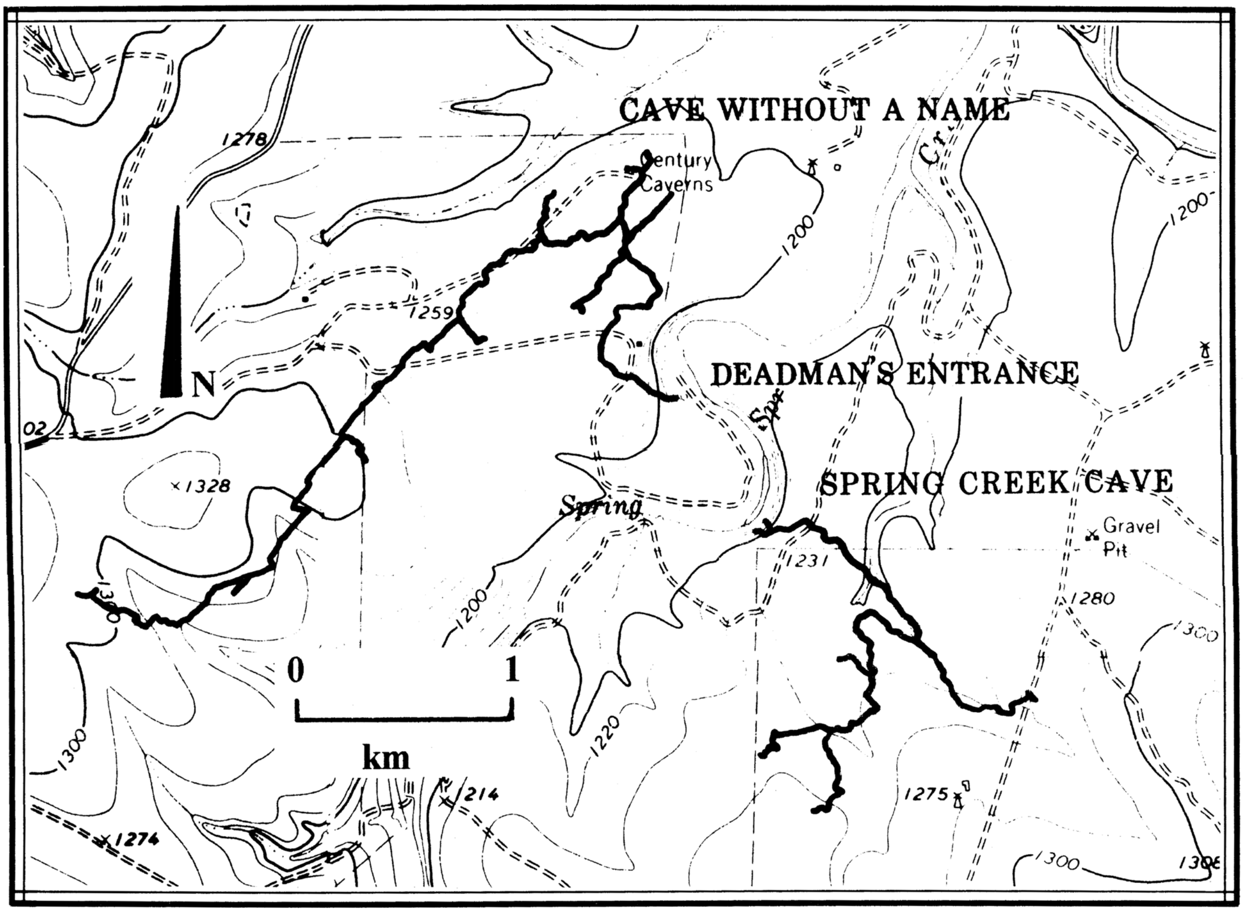


Figure 4
Map of tracer test conducted by Harden (1985) from
Alzafar Water Cave to Cave Without A Name (Veni, 1997)

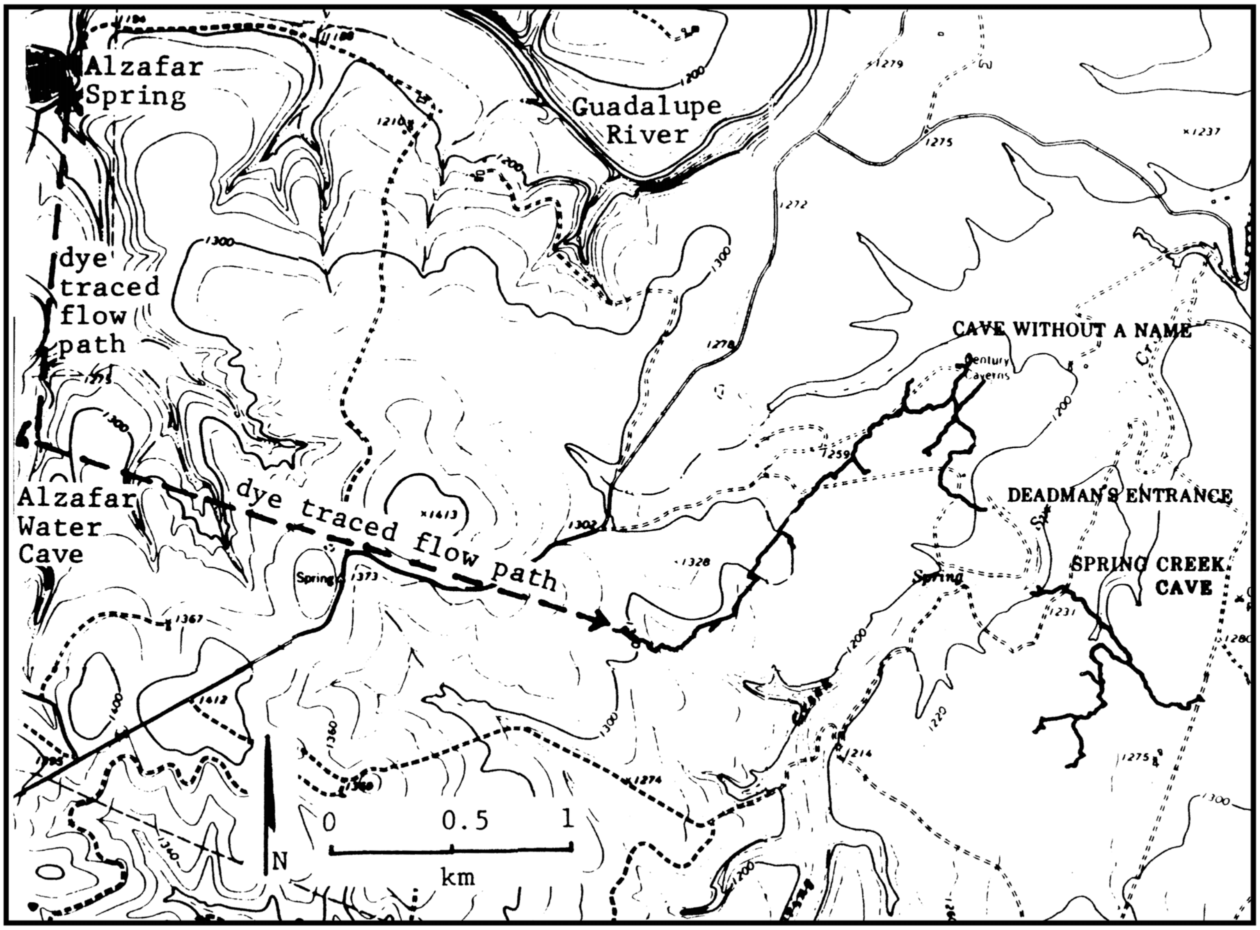


Figure 5
Dead Man's (spring) entrance to Cave Without A Name
partially obscured by rockfall

Figure 6
Cave Without A Name artificial tourist entrance building slopes down toward natural pit entrance surrounded by stone wall

Many speleothems in the cave are common types but include some of the more outstanding examples in the region, such as stalactites, stalagmites, and columns. Some are the largest or best examples of their types in the State of Texas such as the cave bacon which is not only large, but beautifully developed (Figure 7). The rimstone dams are the longest in the state, spanning the 13 to 20-m-wide passage; they form the largest single rimstone series in the state with a length of over 20 m (Figure 8). Several large and strangely re-shaped stalagmites and columns are excellent examples of the effects of Pleistocene Epoch flooding of the cave, features seldom seen in other caves in the region (Figure 9). Other uncommon features are the botryoidal stalactites, referred to as the "White Grapes" along the tour trail (Figure 10).

Figure 7
Cave bacon in Cave Without A Name,
the largest and best developed in the region

Figure 8
Partial view of rimstone dams in Cave Without A Name, the longest and most extensive in the region

Figure 9
The Queen's Throne in Cave Without A Name,
a speleothem reshaped as a canopy by Pleistocene flooding

Figure 10
Unusual botryoidal "White Grapes" stalactites in Cave Without A Name

The cave's most unique and spectacular features are blue speleothems. While some faint blue tint occurs in speleothems along the tour trail, most and the best examples occur far from the trail in a large side passage called the New Room (identified in Figure 2 as "Upper Level"). These include all varieties of dripstone plus subaqueously formed dogtooth spar. The color ranges from a faint baby blue to a steel blue-gray. These are the only blue speleothems reported in Texas and among the few blue speleothems known in the United States. The cause of the color is unknown; samples have not been analyzed. Based on White's (1997) review, Co^{2+}, Cr^{2+}, and Cu^{2+} produce blue color in speleothems. The color is rare because these elements are rare in cave environments and unstable in oxygen-rich groundwater. Analyses of the cave's stream water and of dripwater elsewhere in the cave included tests for Co^{2+} and Cr^{2+}, but only trace amounts were detected (Veni, 1997) and are probably insufficient to account for the color. Co^{2+} currently seems the most likely cause of the color since Cr^{2+} is only known to color silicate minerals. Cu^{2+} is only known to color aragonite (White, 1997) but is the next most likely coloring agent since aragonite is a high-pressure form of calcite; Cave Without A Name's blue speleothems are calcite. Photographs of in situ blue speleothems could not be taken for this report due to high water levels, flooding the passage leading to the New Room where those speleothems are located. Figure 11 is a photograph of a naturally broken blue-gray sample that was removed from the New Room prior to this study for analysis.

Figure 11
Thin layer of nationally rare blue-gray flowstone in Cave Without A Name

The cave has had few and limited paleontological excavations, but the results suggest that Cave Without A Name potentially has some of the more important paleontological deposits in the state and perhaps for that part of the country. The cave's pit entrance has trapped many animals in the cave. The excavations were conducted at the base of the pit and included several taxa no longer present in central Texas: ermine (*Mustela erminea*), bog lemming (*Synptomys cooperi*), meadow vole (*Microtus pennsylvanicus*), masked shrew (*Sorex cinereus*), eastern chipmunk (*Tamias striatus*), short-tailed shrew (*Blarina brevicauda*), prairie king-snake (*Lampropeltis calligaster*), and four-lined snake (*Eumeces tetragrammus*) (Lundelius, 1967; Holman, 1969). Toomey (1994) summarized the results to suggest deposition during the early Holocene, probably around 9,000 B.P., and the presence of a cooler, moister climate at the time.

Since Toomey's (1994) summary, several bones encased in calcite have been found in rimstone dams and other locations more than 100 m from the pit (Figure 12). This indicates that animals which survived the fall moved through the cave in search of water and escape, and the paleontological deposit is much larger than previously recognized. Based on limited exposures, the sediments in the cave are at least 4-5 m thick. Only the uppermost layers have been sampled for bone; older significant deposits almost certainly lay deeper. Very few caves in Texas contain bone-bearing deposits older than 20,000 years, but Cave Without A Name certainly has that potential.

Figure 12
Bones in rimstone dam in Cave Without A Name,
tentatively identified as Pleistocene-age Scimitar Cat (*Homotherium serum*)

Associated biota: See the following section on Biotic Communities.

2) Biotic Communities

Characteristics: Cave ecosystems are generally nutrient-poor environments. Most available food energy comes from material washed or brought into the cave and may be decomposed, or of other decreased nutritional value. Trogloxenes, like bats and cave crickets that must return regularly to the surface, serve vital roles in the ecosystems by providing many of the nutrients needed by the troglobites, the obligate cave-dwelling species. Fewer nutrients have two primary effects on cave ecosystems. First, species evolve characteristics that allow them to survive under those conditions, such as smaller body sizes and reduction or loss of unneeded features that consume energy, such as pigment and eyes. Second, the population and diversity of species tend to be low when compared to surface environments.

Troglobites in central Texas are generally believed to have developed as a result of climatic changes in the Pleistocene Epoch. This resulted in at least the local extinction of surface populations, whereas those species inhabiting caves as trogloxenes and troglophiles became genetically isolated and evolved into troglophiles and troglobites. In some cases, the surface ancestor no longer inhabits the surface; in other cases, the surface ancestor may have re-invaded the area when climate changes occurred but have become genetically isolated from the cavernicole populations (Barr, 1968; Mitchell and Reddell, 1971; Elliott and Reddell, 1989).

Where a single species occupied caves over a broad area, canyon downcutting and faulting led to isolation of different populations and subsequent speciation. In some respects, this resembles the concept of speciation in islands in that a single ancestor may have given rise to species in isolated "islands" of karst. The evolution of *Eurycea* salamanders has apparently resulted in the isolation of different spring populations as surface streams dried and salamanders retreated into caves and survived in isolation, such as those in Cave Without A Name and the surrounding area (Chippendale et al. 2000). To the east and south, where species isolation is more extreme and those karst areas are being urbanized by the cities of Austin and San Antonio, three salamanders and several invertebrate troglobites have been federally listed as endangered (USFWS, 1994, 2000).

Troglobites require high and mostly stable humidity, although some species are more dependent on higher humidity than others. Delicate, highly evolved troglobites are usually found only in the deepest parts of caves where humidity is essentially 100%. Less cave-adapted species may be found closer to the entrance where humidity may be significantly lower. Dry caves or dry parts of caves typically contain few species, and troglobites are essentially absent. Under unusually wet conditions, troglobites may venture closer to entrances where food is more abundant but they can be expected to retreat deep into crevices or into the soil when drying occurs. Most troglobites require stable temperatures. When cold air settles into a cave, some species normally found roaming on cave floors might retreat to ceiling pockets where the air temperature is higher. Other species will move into the soil, loose rocks, or interstitial spaces during hot, dry conditions.

Distribution: Information on the distribution of cavernicole species in Cave Without A Name and throughout the karst of central Texas is contained primarily in the unpublished biospeleology database maintained by James Reddell, Curator of Invertebrate Entomology at the Texas Memorial

Museum. In general, the suite of species found in the cave is limited to the Edwards Plateau physiographic region (Figure 1), although many of the cave's species have much smaller and incompletely mapped distribution. The most pertinent published information is Reddell's (1994) overview of Texas cave fauna. Chippindale et al. (2000) examined the distribution of *Eurycea* salamanders in central Texas. A general evaluation of the species known in Cave Without A Name indicates a mix of animals that are relatively broadly distributed throughout the central Texas karst (e.g., the spider *Eidmannella rostrata* and millipede *Speodesmus echinourus*) with species restricted to a roughly 20-km radius within the lower member of the Glen Rose Formation in the Cibolo Creek and Guadalupe River watersheds (e.g. the beetle *Rhadine speca speca* and salamander *Eurycea latitans*). Biological collections and observations in Cave Without A Name are presently insufficient to describe species distribution within the cave except in generalizations. The aquatic species are possibly the most widely distributed within the cave. Terrestrial species are more abundant in the tourist part of the cave due to greater nutrient inflow and more abundant habitat; the stream passage has relatively few areas with dry floors. Troglophiles, trogloxenes, and accidentals are found mostly in the pit entrance. They are probably abundant in the Dead Man's entrance, but that area has not been biologically surveyed and will likely yield several new records for the cave.

Native vegetation: While plants do not occur in caves, the maintenance of healthy plant communities on the surface above and in the vicinity of caves is essential to the maintenance of healthy cave ecosystems. Plants provide food for foraging cave crickets and other trogloxene species, and buffer caves from extreme changes in temperature and humidity. A natural plant community also reduces the number of exotic species that may adversely impact cave ecosystems. Historically, the area around Cave Without A Name was a mixed oak-juniper-grassland upland, with the Ashe juniper occurring mostly in the canyons. Since the settlement of Europeans in the region and the control of natural grassfires that restricted juniper distribution, much of the upland area is now dominated by juniper. Thurow and Taylor (1995), among other studies, have demonstrated that dense juniper growth reduces the infiltration of water into the subsurface. The owners of Cave Without A Name have initiated a program to selectively cut and remove some of the invasive juniper to maintain natural flow into the cave. Some of the surrounding properties within the cave's drainage basin also have juniper control programs of clearing or prescribed burns.

Wildlife: Several biological collections and observations have been conducted in Cave Without A Name but probably do not fully represent the richness of the cave's fauna. Studies of the cave stream and at the Dead Man's entrance are particularly limited and will likely produce the most new records. Below is a list of species recorded at Cave Without A Name (provided by James Reddell, Texas Memorial Museum, personal communication, 1995). This list is current since more recent collections have not been conducted, although more additional biological studies are planned for 2003 (Reddell, personal communication, 2002). Most of the species lack common names but are provided below if assigned:

Snails: *"Horatia" nugax* (Pilsbry and Ferriss) (troglobite)
Gastrocopta contracta (Say)
Bulimulus dealbatus mooreanus (Pfeiffer)
Helicodiscus eigenmanni Pilsbry (troglophile)
Euglandina singleyana (W.G. Binney)
Polygyra sp.
Succinea sp.

Glyphyalinia roemeri (Pilsbry and Ferriss)
Zonitoides arboreus (Say)
Ostracods: *Ankylocythere sinuosa* (Rioja)
Amphipods: *Stygobromus bifurcatus* (Holsinger) (troglobite)
Stygobromus longipes (Holsinger) (troglobite)
Crayfish: *Procambarus* (*Scapulicambarus*) *clarkii* (Girard) (troglophile)
Spiders: *Cicurina varians* Gertsch and Mulaik (troglophile)
Eidmannella rostrata Gertsch (troglobite)
Harvestmen: *Hoplobunus madla* Goodnight and Goodnight (troglobite)
Millipedes: *Speodesmus echinourus* Loomis (troglobite)
Hot house millipedes: *Oxidus gracilus* (Koch) (troglophile)
Cave crickets: *Ceuthophilus* (*Ceuthophilus*) sp. (trogloxene)
Ceuthophilus (*Ceuthophilus*) *secretus* Scudder (trogloxene)
Ceuthophilus (*Geotettix*) *cunicularis* Hubbell (trogloxene)
Ground beetles: *Rhadine speca speca* (Barr) (troglobite)
Scarab beetles: *Onthophogus cavernicollis* Howden and Cartwright
Rove beetles: *Paederinae* genus and species
Eustilicus condei (Jarrige) (troglophile)
Flies: *Woodiphora magnipalpis* (Aldrich)
Cascade Caverns salamander: *Eurycea latitans* Mitchell and Reddell (troglobite)
Slimy salamander: *Plethodon albagula* Grobman (trogloxene)
Gulf Coast toad: *Bufo valliceps* Wiegmann (trogloxene)
Barking frogs: *Hylactophryne augusti latrans* (Cope)
Rio Grande leopard frogs: *Rana berlandieri* Baird (accidental)
Bullfrogs: *Rana catesbeiana* Shaw
Eastern pipistrelle bats: *Pipistrellus subflavus subflavus* (Cuvier) (trogloxene) (Figure 13)

Several of the snail records (*Gastrocopta, Bulimulus, Euglandina, Polygyra, Succinea* and *Glyphyalinia*) were collected during paleontological excavations in the cave. The faunal list shows a maturely developed habitat of both terrestrial and aquatic cavernicoles with a wide array of troglobites and troglophiles. One species of note is the rare Cascade Caverns salamander (*Eurycea latitans*), which is on the State of Texas list of threatened species (Campbell, 1995); photographs of this species are not available.

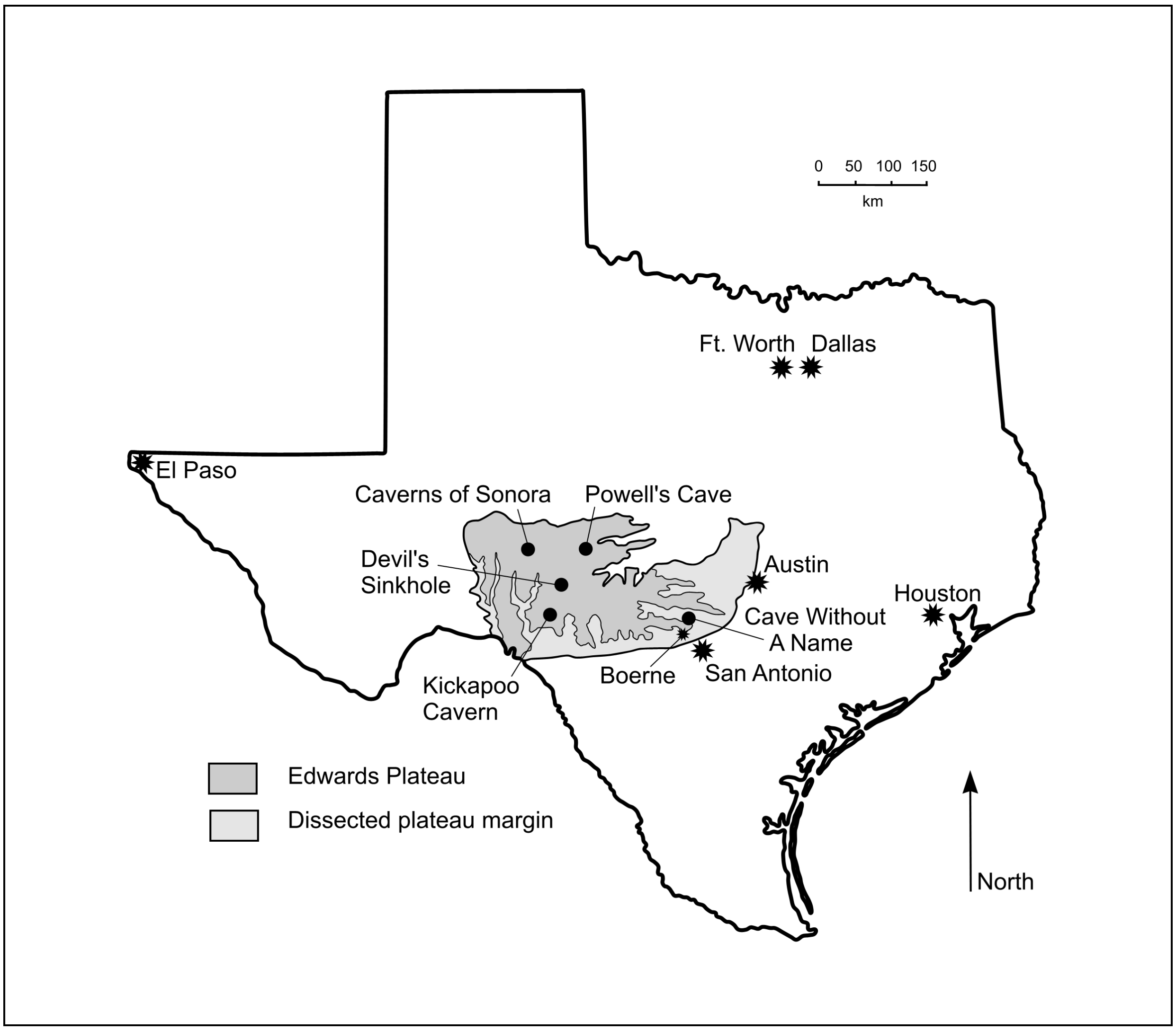
Physical Environment/Geological Context: See the above section on Geological Features.

Figure 13
Eastern pipistrelle bat (*Pipistrellus subflavus subflavus*) in Cave Without A Name

Part B. Comparison of Sites Considered

No information was provided to me on other cave sites currently considered for National Natural Landmark recognition. Powell (1970) listed significant caves of the United States for consideration in the National Natural Landmark Program and included four from Texas, with their locations shown on Figure 14: Caverns of Sonora, Devil's Sinkhole, Kickapoo Cavern, and Powell's Cave. Caverns of Sonora has since been designated a National Natural Landmark and is not used for comparison. The remaining three caves are used for comparison in this evaluation, since they represent significant caves in geological and biological settings most comparable to Cave Without A Name. It is possible that one or more of the caves has already been designated a National Natural Landmark.

Figure 14
Locations of significant Texas caves



#1 Devil's Sinkhole

This cave is located in Edwards County, Texas, near the town of Rocksprings and within Devil's Sinkhole State Natural Area. The State of Texas purchased this historically important cave in 1985 to protect its large colony of Mexican free-tailed bats (*Tadarida brasiliensis mexicana*), an endemic species of troglobitic amphipod, and the physical integrity of this outstanding natural geologic feature. The cave is the largest known chamber in Texas and one of the largest chambers in the country, measuring 138 m long by 76 m wide by up to 25 m high. Entry is gained through a 20 to 30-m-diameter pit that drops 42 m into the center of the room. Veni (1994) provided the most recent comprehensive summary description of the cave.

#2 Powell's Cave

This cave is located on private property in Menard County, Texas, near the town of Menard. Since Powell's (1970) report (Powell's name is only coincidentally the same as the cave; he had no relationship to the cave or its owners), the cave's name was modified to the "Powell's Cave System" following connection to Neel's Cave via a common stream passage. The cave is currently the 29th longest in the U.S. at a surveyed length of more than 27 km (Gulden, 2002). Its incompletely explored stream passage is surveyed at more than 6.5 km long, has a proven length of at least 8.6 km when explored sections are included, and may potentially be one of the world's longest passages. Veni (1994) provided the most recent comprehensive summary description of the cave.

#3 Kickapoo Cavern

This cave is located in Kinney County, Texas, near the town of Brackettville and within Kickapoo Caverns State Natural Area. The State of Texas purchased this historically important cave in 1986 to protect its physical integrity, which includes the largest passage and speleothems in Texas, as well as other nearby caves and important surface and subsurface habitats. The cave is relatively short, with a total length of 428 m and a vertical extent of 39.7 m, but its main passage averages 28 m wide by 10 m high. The cave's large columns fill much of the passage in two locations. Veni (1994) provided the most recent comprehensive summary description of the cave.

List of Other Sites Considered. Except for Powell's (1970) list, information on other sites currently considered was not provided. Discussion of the 67 listed caves is beyond the scope of this evaluation. If specific caves pertinent to this evaluation are identified, I will include them in a revision of this report.

Recommendation: The above three sites are significant primarily for their physical attributes, such as size and length, and the hydrogeologic conditions that created them. The Devil's Sinkhole alone was considered worthy of purchase and protection as a Texas state natural area, as was Kickapoo Caverns along with other features on that property. Both caves also contain rich histories of local importance. Devil's Sinkhole has a significant fauna, but no notable fauna is known from Kickapoo Cavern or Powell's Cave. No significant paleontological materials have been recovered from these three caves. The size of Devil's Sinkhole and the length of Powell's Cave are among the largest and longest in the country. All three caves occur in relatively undisturbed environments; the ongoing ranching at Powell's Cave and former ranching at Devil's Sinkhole and Kickapoo Cavern show no evidence of direct adverse impacts on the caves.

At first review, Cave Without A Name may not seem as significant as the above three caves.

While it is large and extensive for its area, its passages and rooms are smaller than those of Kickapoo Cavern and Devil's Sinkhole, and it is less than one-fifth the length of Powell's Cave. However, closer study shows that Cave Without A Name surpasses those caves in significance due to the following combination of factors:

- The cave is a good example of a less common mode of cave development.
- Some of its speleothems are the largest and/or best examples of their type in the region.
- Blue speleothems found in the cave are the only ones known in Texas and are exceedingly rare nationally.
- The cave contains a rich fauna including a rare salamander on the state list of threatened species.
- Paleontological deposits in the cave are regionally significant and, with further study, have a good chance of proving nationally significant.

Regional Superlative Statement: Cave Without A Name is a significant cave that warrants National Natural Landmark designation for its variety of notable to outstanding attributes. It contains one of the more important faunas in the Hill Country area and includes one species of state-wide significance. Some the largest and best examples of various types in speleothems in the Edwards Plateau physiographic region are present. Its paleontological deposits are notable in the Edwards Plateau region and are potentially of state or national importance. The cave's blue speleothems are rare and outstanding examples on a national scale.

Part C. Description of Recommended Site

Introduction: Cave Without A Name was not included in Powell's (1970) list of potential National Natural Landmark caves but has since come to the attention of the National Natural Landmark Program. I do not have information on who first suggested the cave for landmark designation. Approximately 6% of its total 4.3 km length is open to the public for guided tours. Most of the cave's extent is within a long stream passage that captures its flow from the Guadalupe River. A rare species of salamander on the Texas list of threatened species lives in the stream passage. The stream flows through a small section of the tour portion of the cave and does not flow through another section known as the New Room. These areas are respectively noted for important paleontological deposits and rare blue speleothems. The cave was also known as Century Caverns in 1970s.

Location: Cave Without A Name is located in Kendall County, Texas, 16 km northeast of the town of Boerne, along the southeastern edge of the Edwards Plateau. The city of San Antonio is located about 50 km to the south (Figures 1 and 14). The most common means of reaching the cave is by following Interstate Highway 10 to Boerne, exiting on Highway 87 and taking it into the middle of town to County Road 474, which leads 10 km northeast to Kreutzberg Road. Signs along Kreutzberg Road direct the way for 8.5 km east to the cave.

The cave's entrances are on the Kendalia 7.5' U.S. Geological Survey topographic quadrangle, and its upstream end extends into the Sisterdale 7.5' quadrangle. The boundary for the proposed Cave Without A Name National Natural Landmark encompasses the estimated drainage basin for the cave as shown in Figure 15.

Description:

Geology: Cave Without A Name and its proposed boundaries on Figure 15 are entirely within the lower member of the Glen Rose Formation of the Cretaceous Trinity Group. The boundaries are hydrologically defined based on the cave's likely groundwater drainage basin. The basin is delineated per Harden's (1985) tracer test and a detailed hydrogeologic study of the cave and area (Veni, 1997). Since the cave is a hydrogeologic system, protection of its groundwater drainage basin is critical to protecting the cave, its contents, and features. However, the groundwater basin is fed in large part by the Guadalupe River. The river extends 95 km west, upstream of the cave's boundaries, and captures water from an area of about 2,700 km^2, but not all of the water in the river or in this area reaches the cave. Some is captured by other caves, karst features, and fractures. The effect of surface drainage on the cave from any particular area is also dynamic, varying with dilution from rainfall, changes in evapotranspiration rates, and according to the parts of the surface drainage basin in which the rainfall fell. Hydrologic models of flow in the river and through the cave have not been developed to meaningfully include portions of the surface drainage basin within the cave's boundaries; such models should be considered, if available, in future reviews and revisions of the boundaries.

Associated biota: All common and rare species listed previously in this report for the cave are by definition included within the cave's groundwater drainage basin boundaries. If activities within those boundaries are appropriately managed, the health of the cave's ecosystem would be assured (barring adverse hydrologic impacts from the Guadalupe River). None of the species currently known in Cave Without A Name are endemic to the cave. The populations of ostracods, amphipods, crayfish, and the threatened Cascade Caverns Salamander are restricted to the cave's stream and all other species are known from the terrestrial habitat in the tourist portion of the cave (Figures 2 and 3). No photographs are known of the less common species.

Ownership: The main entrance to Cave Without A Name is owned by Mr. Tom Summers. The cave is managed by Mr. Mike Burrell. Mr. Summers and Mr. Burrell support the proposal to designate Cave Without A Name as a National Natural Landmark. The property owned by Mr. Summers measures 0.21 km^2 and is outlined in Figure 15; an adjacent 0.21 km^2 is under contract for purchase by Mr. Summers and is also outlined in Figure 15. Most of the cave extends under adjacent properties, and the boundaries encompass some properties at greater distances. The Dead Man's entrance to the cave is owned by Mr. Anthony Faldyn, who supports National Natural Landmark designation for the cave (Mike Burrell, personal communication, 2003). For management purposes, practical access into 82% of the known cave is controlled by Mr. Summers since part of the passage connecting the Dead Man's entrance to the rest of the cave is permanently flooded.

Land Use and Site Condition: The Cave Without A Name property and surrounding properties have historically served as low-density cattle ranches. Ranching has been discontinued at Cave Without A Name since it was opened as a show cave in 1939. Some traditional ranches in the area surrounding the cave have been sold for low-density rural housing. The primary potential ill effect of the rural housing development is the deterioration of the cave's water quality due to septic systems and household and yard chemical use. Aquatic species are more likely to be adversely affected than the terrestrial species. The undeveloped area around the cave's main entrance should protect the terrestrial species from predatory or competitive species associated with urbanization, per the standards of the U.S. Fish and Wildlife Service (2002).

The cave is not showing adverse impacts from the change in land use thus far, and county officials have enacted measures to help protect the local groundwater from contamination by septic effluent. Such measures benefit the cave but their effectiveness has not been proven and no monitoring is being conducted to assess them. Most of the cave extends away from the area of current development, reducing the potential for impact and its severity. Accurately estimating impacts is not possible due to unknown effectiveness of the protection measures, unquantified and unregulated activities such as application of lawn chemicals, and insufficient details on groundwater flow paths leading to the cave. My best estimate is one of little to no risk to the cave's geological features and probably low risk to its ecosystem.

Use of Cave Without A Name for tourism has resulted in no notable degradation of geological features and probably low impact to its ecosystem. Baseline data prior to development are not available for comparison. The primary impact of tourist development are the broad trails throughout the cave which replace natural floor sediments with compacted gravel and clay that are less favorable to cave species. Trampling of species is also likely, but probably has little impact since the species are less common on the trails. The trails were first built in 1939 and modified in later years before their potential impacts were understood. Mr. Summers, the owner, is considering reducing the trail size and restoring as much of the floor as possible to a natural state. Volunteers have spent considerable effort restoring one section of floor (Figure 16) and cleaning speleothems that were sullied during the early years of commercialization. Continued use as a show cave under current management and proposed management should continue to improve conditions and restore natural features.

Boundaries: The proposed boundaries for Cave Without A Name in Figure 15 are defined based on hydrogeologic factors and cannot be precisely described in terms of physiographic or cultural features; the base maps for Figure 15 are the Bergheim, Boerne, Kendalia, and Sisterdale 7.5' U.S.G.S. topographic quadrangles. The boundaries are generally described below along with the justification for their position.

Figure 16
Portion of natural floor in Cave Without A Name restored by volunteers

Since protection of the cave primarily requires protection of its drainage basin, the boundaries proposed in this report delineate the cave's approximate groundwater drainage basin as best as can be defined with the currently available information. As noted previously in this report, additional tracer studies, exploration, and hydrogeologic investigation are needed to better define this area. Surface water flowing into the groundwater basin certainly contributes to the cave, especially the Guadalupe River, but until the groundwater basin is better delineated the significance of some surface water flowing into the groundwater basin cannot be accurately determined. The Guadalupe River is certainly highly significant to the cave, but it is well beyond the scope of this report to determine which portion of its 2,700-km^2 watershed should be considered for protection and/or management relative to Cave Without A Name.

The downstream or eastern end of the cave's groundwater drainage basin is the most accurately defined. Spring Creek truncates the cave and drainage into it. An east-flowing tributary to Spring Creek 200 m north of Cave Without A Name also cuts deeply into the limestone to truncate any extensions of the cave in that direction. Side passages in that part of the cave were probably formed by water flowing into the cave from that tributary to Spring Creek.

The southern groundwater basin boundary is approximated on the surveyed position of the cave and the theoretical straight-line flow path from Alzafar Water Cave that was established by tracer testing (Harden, 1985). Groundwater in karst seldom flows in a straight line, but at the scale of Figure 15 the straight line is probably an adequate approximation for four primary reasons:

1) The upstream end of Cave Without A Name is aligned along a strong structural lineament that guides part of the Guadalupe River, tributaries to the Guadalupe River, and tributaries to Spring Creek.
2) The approximated straight-line flow path from Alzafar Water Cave to Cave Without A Name closely follows the structural lineament. While the location of Alzafar Water Cave is not precisely known, the most likely changes in its position will improve its alignment with the lineament.
3) Cave Without A Name formed by capturing water from the Guadalupe River that probably flowed along fractures associated with the structural lineament. This route represents the steepest hydrologic gradient in the area between the river and Spring Creek, and caves tend to develop linearly where gradients are steep.
4) Potentiometric mapping by Veni (1997) demonstrated a steep gradient along the lineament.

The southern boundary encompasses some nearby small, surface water drainage areas but generally extends only 240-440 m south of the cave or tracer flow path, unlike the northern boundary which averages about 700 m from the flow path in the central part of the groundwater drainage basin. The reason for this difference is that the area to the north is upgradient and up the gentle dip of limestone where areas further away are more likely to drain into the cave than from the southern, downgradient and downdip areas. However, compared to most caves which have groundwater basins that dramatically widen in upgradient areas, the basin for Cave Without A Name is relatively narrow. This reflects the cave's less common mode of development by capturing flow from the Guadalupe River, resulting in relatively rapid development of the main passage but much slower development of tributary passages needed to widen its drainage basin boundaries (Veni, 1997).

The upstream or western end of the drainage basin boundary is established mostly along the Guadalupe River and a deeply incised tributary that would truncate the cave in that direction while feeding water into it from the river. The basin extends 1.5 km north of Alzafar Water Cave based on dye tracing by Harden (1985), who found that water in that cave flows to both Cave Without A Name to the east and Alzafar Spring to the north. Veni (1997) described possible models for this bifurcation of flow, which has been observed in other caves in the area. Since the flow path leading to Alzafar Spring is physically a part of the same conduit system as Cave Without A Name, it is included within the cave's groundwater basin boundaries.

Effect of Publicity: Cave Without A Name is already publicized. The effect of National Natural Landmark designation will result in some increase in publicity, but the impact should be favorable. The current and proposed management of Cave Without A Name provides the public with technically accurate information and promotes recognition of the need to carefully develop and manage caves and karst landscapes. National Natural Landmark designation will help validate that sound advice and the importance of caves to the region's state-designated critical groundwater supplies (Figures 17 and 18).

Figure 17
Well pipe into Cave Without A Name extending into underground stream

Figure 18
Underground stream in Cave Without A Name

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U.S. Department of the Interior
National Park Service
National Natural Landmarks Program

Name: Cave Without A Name (Century Caverns)

Location: Kendall County, Texas

Description: Cave Without A Name is the 6th longest cave in Texas with more than 4.3 km surveyed. It contains a large room and an extensive underground river that well represent a less common mode of cave development. Some of the cave's speleothems are the largest and/or best examples of their type in the region. Blue speleothems found in the cave are the only ones known in Texas and are exceedingly rare nationally. The cave's rich fauna includes a rare salamander on the state list of threatened species. Paleontological deposits are regionally significant and, with further study, may prove nationally significant. Its owners support continued sound management. Designation of the cave as a National Natural Landmark will enhance their ability to educate the public about the importance of caves and karst resources. The cave is located 10 miles (16 km) northeast of Boerne.

Significance: Cave Without A Name contains one of the more important faunas in the Hill Country area, one species of state-wide significance, rare and nationally outstanding examples of speleothems, and regionally important paleontological deposits that are potentially of state or national importance.

Ownership: Mr. Tom Summers

Evaluator: Dr. George Veni
George Veni and Associates

National Natural Landmark Brief February 2003

APPENDIX A
Glossary of Geologic, Karst, and Biological Terminology

This glossary is broad in scope to assist nonspecialists reviewing this report, but is not meant to cover all possible terms. Additional karst definitions and geologic terms can be found in the geologic dictionary of Jackson (1997); for biospeleological terms see Culver (1982).

Aquifer: Rocks or sediments, such as cavernous limestone and unconsolidated sand, which store, conduct, and yield water in significant quantities for human use.

Base level: The level to which drainage gradients (surface and subsurface) are adjusted, usually a surface stream, relatively impermeable bedrock, or water table. Sea level is the ultimate base level.

Baseflow: The "normal" discharge of stream when unaffected by surface runoff; derived from groundwater flowing into the stream channel.

Beds: See strata.

Breakdown: Rubble and boulders in a cave resulting from collapse of the cave ceiling.

Calcite: The predominant mineral in limestone. It is relatively soluble compared to other common minerals, and allows for the dissolution of limestone and the precipitation of calcite speleothems.

Cave: A naturally occurring, humanly enterable cavity in the earth, at least 5 m in length and/or depth, in which no dimension of the entrance exceeds the length or depth of the cavity (definition of the Texas Speleological Survey).

Cave raft: A calcite speleothem that may precipitate as thin sheets or flakes on the surface of ponded water in caves, if the water is sufficiently saturated with respect to calcite; often called "cave ice."

Cavernicole: A species of animal that spends at least part of its life cycle in the subterranean environment.

Chamber: See room.

Conduit: A subsurface bedrock channel formed by groundwater solution to transmit groundwater; often synonymous with cave and passage, but generally refers to channels either too small for human entry, or of explorable size but inaccessible. When used to describe a type of cave, it refers to base level passages that were formed to transmit groundwater from the influent, upgradient end of the aquifer to the effluent, downgradient end.

Conduit flow: Groundwater movement along conduits; usually rapid and turbulent.

Conduit groundwater divide: Where the baseflow of a cave passage splits to flow downstream in two different conduits, and often to two different destinations. Divides can occur both above and below the water table.

Cretaceous: A period of the geologic time scale that began 135 million years ago and ended 65 million years ago.

Depth: In relation to the dimensions of a cave or karst feature, it refers to the vertical distance from the elevation of the entrance of the cave or feature to the elevation of its lowest point. See vertical extent for comparison.

Dip: The angle that joints, faults or beds of rock make with the horizontal; colloquially described as the "slope" of the fractures or beds. "Updip" and "downdip" refer to direction or movement relative to that slope.

Diffuse flow: Laminar and very slow groundwater movement within small voids of primary and secondary porosity, excluding conduit and fissure flow; "intergranular" flow.

Discharge: The water exiting an aquifer, usually through springs or wells; also the amount of water flowing in a stream.

Downdip: See dip.

Drainage basin: A watershed; the area from which a stream, spring, or conduit derives its water.

Drainage divide: Location where water diverges into different streams or watersheds. On the surface they usually occur along ridges or elevated areas. In aquifers, they occur along highs in the potentiometric surface between groundwater basins.

Endemic: Biologically, refers to an organism that only occurs within a particular locale.

Fault: Fracture in bedrock along which one side has moved with respect to the other.

Footprint: The outline of a structure or cave in plan view; generally refers to defining the horizontal limits as they relate to the land surface.

Fracture: A break in bedrock that is not distinguished as to the type of break (usually a fault or joint).

Geomorphology: The branch of geology that studies the shape and origin of landforms.

Grade: The continuous descending profile of a stream; graded streams are stable and at equilibrium, allowing transport of sediments while providing relatively equal erosion and sedimentation. A graded profile generally has a steep slope in its upper reaches and a low slope in its lower reaches.

Head: The difference in water level elevations that creates the pressure for water movement down a gradient.

Headward: In the direction of greater elevation; typically refers to upstream or up a hydraulic gradient.

Helictite: A curving, often branching calcite speleothem that may protrude into a cave at any angle;

formed by capillary groundwater flow.

Historic: One of four temporal/technological periods recognized by archeologists for the central Texas region. It is generally recognized as the beginning of permanent European and/or American contact and settlement up to the mid-20th century.

Holocene: An epoch of the Quaternary Period of the geologic time scale that began about 10,000 years ago and continues to the present.

Hydrogeology: The study of water movement through the earth, and the geologic factors that affect it.

Hydrograph: A graph illustrating changes in water level or discharge over time.

Hydrology: The study of water and its origin and movement in atmosphere, surface, and subsurface.

Impermeable: Does not allow the significant transmission of fluids.

Joint: Fracture in bedrock exhibiting little or no relative movement of the two sides.

Karst: A terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock. Karst areas commonly have few surface streams; most water moves through cavities underground.

Karst feature: Generally, a geologic feature formed directly or indirectly by solution, including caves; often used to describe features that are not large enough to be considered caves, but have some probable relation to subsurface drainage or groundwater movement. These features typically include but are not limited to sinkholes, enlarged fractures, noncavernous springs and seeps, soil pipes, and epikarstic solution cavities.

Length: In relation to the dimensions of a cave or karst feature, it refers to the summed true horizontal extent of the cave's passages or the feature's extent.

Lineament: A linear feature, usually observed in aerial photographs, which likely represents a geologic feature such as a fault, joint, or lithologic contact.

Lithology: The description or physical characteristics of a rock.

Passage: An elongate, roofed portion of a cave or karst feature; usually a conduit for groundwater flow.

Perched groundwater: Relatively small body of groundwater at a level above the water table; downward flow is impeded within the area, usually by impermeable strata.

Permeable: Allows the significant transmission of fluids.
Permeability: Measure of the ability of rocks or sediments to transmit fluids.

Phreatic: The area below the water table, where all voids are normally filled with water.

Piracy: The natural capture of water from a watershed, stream, aquifer, or cave stream, and its transmission to a different watershed, stream, aquifer, or cave stream.

Pit: A vertical cavity extending down into the bedrock; usually a site for recharge, but sometimes associated with collapse.

Pleistocene: An epoch of the Quaternary Period of the geologic time scale that began 2 million years ago and ended about 10,000 years ago. Colloquially called the "Ice Age" due to its episodes of continental glaciation.

Porosity: Measure of the volume of pore space in rocks or sediments as a percentage of the total rock or sediment volume.

Potentiometric surface: A surface representing the level to which underground water confined in pores and conduits would rise if intersected by a borehole. See water table.

Quaternary: A period of the geologic time scale that began 2 million years ago and continues to the present.

Reach: The length of a stream or stream segment; often used to denote similar physical characteristics.

Recharge: Natural or artificially induced flow of surface water to an aquifer.

Resolution: The dissolving or solution of speleothems, usually due to their submergence by or changes in their source flow to chemically undersaturated groundwater. Sometimes called redissolving.

Resurgence: See spring.

Rimstone dam: A hard, dense, crystalline calcite deposit that forms along the edge of a cave pool or stream, commonly maintaining the water it contains at a higher elevation than the adjacent floor. See travertine dam.

Room: An exceptionally wide portion of a cave, often at the junction of passages; commonly indicative of either the confluence of groundwater flowpaths or of slow, nearly ponded, groundwater flow. Generally synonymous with chamber, except that chamber is usually reserved for relatively large rooms.

Shaft: See pit.

Sink: See sinkhole.

Sinkhole: A natural indentation in the earth's surface related to solutional processes, including features formed by concave solution of the bedrock, and/or by collapse or subsidence of bedrock or soil into underlying solutionally formed cavities.

Solution: The process of dissolving; dissolution.

sp.: Taxonomic abbreviation for "species;" when following a genus name, it indicates lack of identification to species level. Plural is spp.

Speleogenesis: The process of cave origin and development.

Speleothem: A chemically precipitated secondary mineral deposit (e.g., stalactites and stalagmites) in a cave; usually calcite but can form from gypsum and other minerals.

Spring: Discrete point or opening from which groundwater flows to the surface; strictly speaking, a return to the surface of water that had gone underground.

Stage: The water level elevation or height measured in a stream or a well.

Strata: Layers of sedimentary rocks; usually visually distinguishable. Often called beds. The plural of stratum.

Stratigraphic: Pertaining to the characteristics of a unit of rock or sediment.

Stratigraphy: Pertaining to or the study of rock and sediment strata, their composition and sequence of deposition.

Strike: The direction of a horizontal line on a fracture surface or on a bed of rock; perpendicular to dip.

Structure: The study of and pertaining to the attitude and deformation of rock masses. Attitude is commonly measured by strike and dip; deformational features commonly include folds, joints, and faults.

Sump: A cave passage that descends below the surface of flowing or standing water.

Tracer test: The injection of a non-toxic, traceable substance, often a fluorescent dye, into a groundwater system, and its recovery at a downgradient location (usually a spring). This technique is commonly used in karst areas to define groundwater flow paths and travel times.

Travertine dam: A hard, dense, crystalline calcite deposit, often synonymous with rimstone dam. Recent usage associates it with surface streams where its development may in part be affected by plants and organic materials. Its soft, spongy and porous variety is called tufa.

Trend: The azimuthal direction of a linear geologic feature, such as the axis of a fold or the orientation of a fracture; commonly used to denote average or general orientations rather than specific orientations.

Troglobite: A species of animal that is restricted to the subterranean environment and which typically exhibits morphological adaptations to that environment, such as elongated appendages and loss or reduction of eyes and pigment.

Troglophile: A species of animal that may complete its life cycle in the subterranean environment but which may also be found on the surface.

Trogloxene: A species of animal that inhabits caves but which must return to the surface for food or other necessities.

Type locality: The location or area from which a species is first found and described, or where a section or unit of bedrock is described as the typical example; more commonly called type area or type section when used in a geologic context.

Unconfined: Pertaining to aquifers having no significant impermeable strata between the water table and the land surface.

Updip: See dip.

Vadose: Pertaining to the zone above the water table where all cavities are generally air-filled, except during temporary flooding.

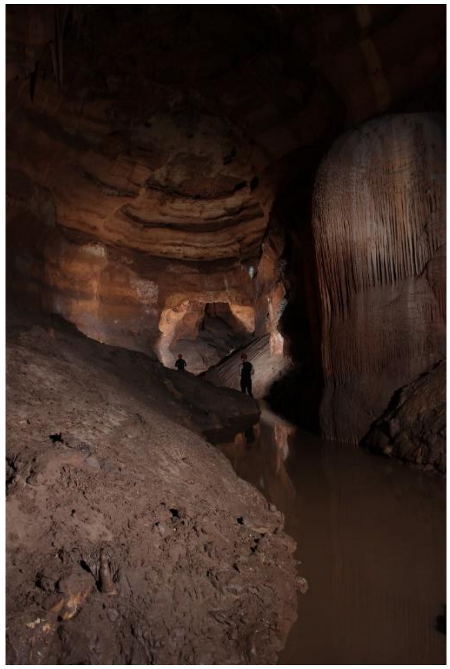
Vertical extent: In relation to the dimensions of a cave, refers to the vertical distance from the highest elevation to the lowest elevation of the cave. Generally used when a portion of a cave extends above its entrance. See depth for comparison.

Water table: The boundary of the phreatic and vadose zones. A potentiometric surface but the term is used only in unconfined aquifers.

APPENDIX B

Conversions:
International System of Units to English Units

MULTIPLY	BY	TO GET
	Length	
centimeters (cm)	0.3937	inches (in)
meters (m)	3.281	feet (ft)
kilometers (km)	0.621	miles (mi)
	Area	
square meters (m^2)	10.76	square feet (ft^2)
square kilometers (km^2)	0.3861	square miles (mi^2)
square kilometers (km^2)	247.1	acres (ac)
	Volume	
liters (L)	0.264	gallons (gal)
cubic meters (m^3)	264.17	gallons (gal)
cubic meters (m^3)	0.00081	acre-feet (a-f)
	Flow	
liters per second (L/s)	0.0353	cubic feet per second (cfs)
liters per second (L/s)	15.85	gallons per minute (gpm)
cubic meters per second (m^3/s)	35.31	cubic feet per minute (cfm)
cubic meters per second (m^3/s)	0.000158	gallons per minute (gpm)
cubic meters per second (m^3/s)	70.05	acre-feet per day (a-f/d)
	Temperature	
degrees Celsius	multiply by 1.8 then add 32	degrees Fahrenheit



Stream Passage In Cave Without a Name

Well Used as Toilet