Assessment and Remediation of Petroleum-Impacted sites within Karst Environments –

Addressing Potential Complications With Positive Solutions

Presented by Polk County Local Program

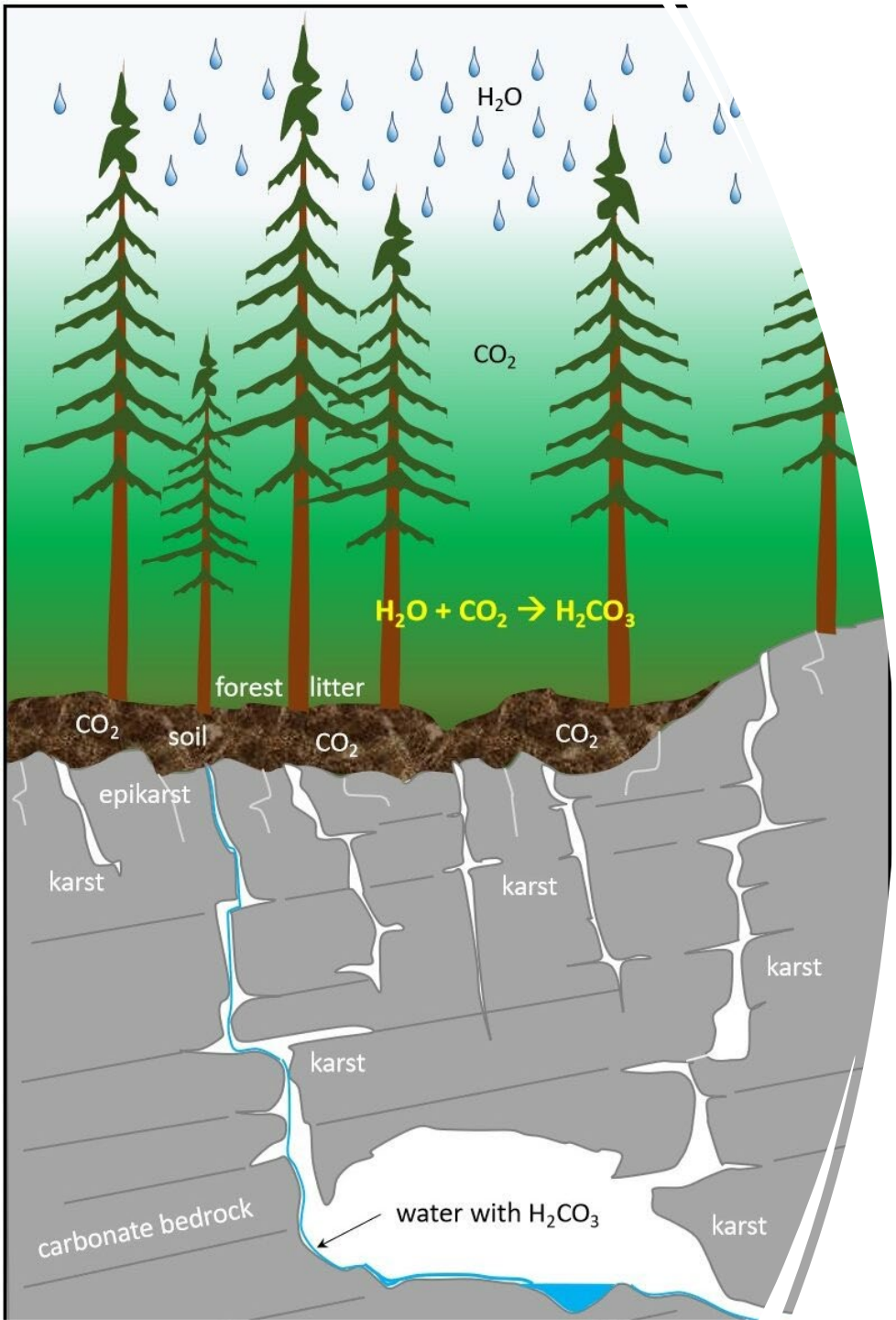
What Is a Karst Environment?

- Karst is a topography formed from the dissolution of soluble carbonate rocks such as limestone, dolomite, and gypsum(-western U.S.). It is characterized by features like drainage systems with sinkholes and caves underground.

- Karst is also most strongly developed where the water table is relatively low, such as in uplands with entrenched valleys, and where rainfall is moderate to heavy. This contributes to rapid downward movement of groundwater, which promotes dissolution of the bedrock.

How is the limestone bedrock dissolved?

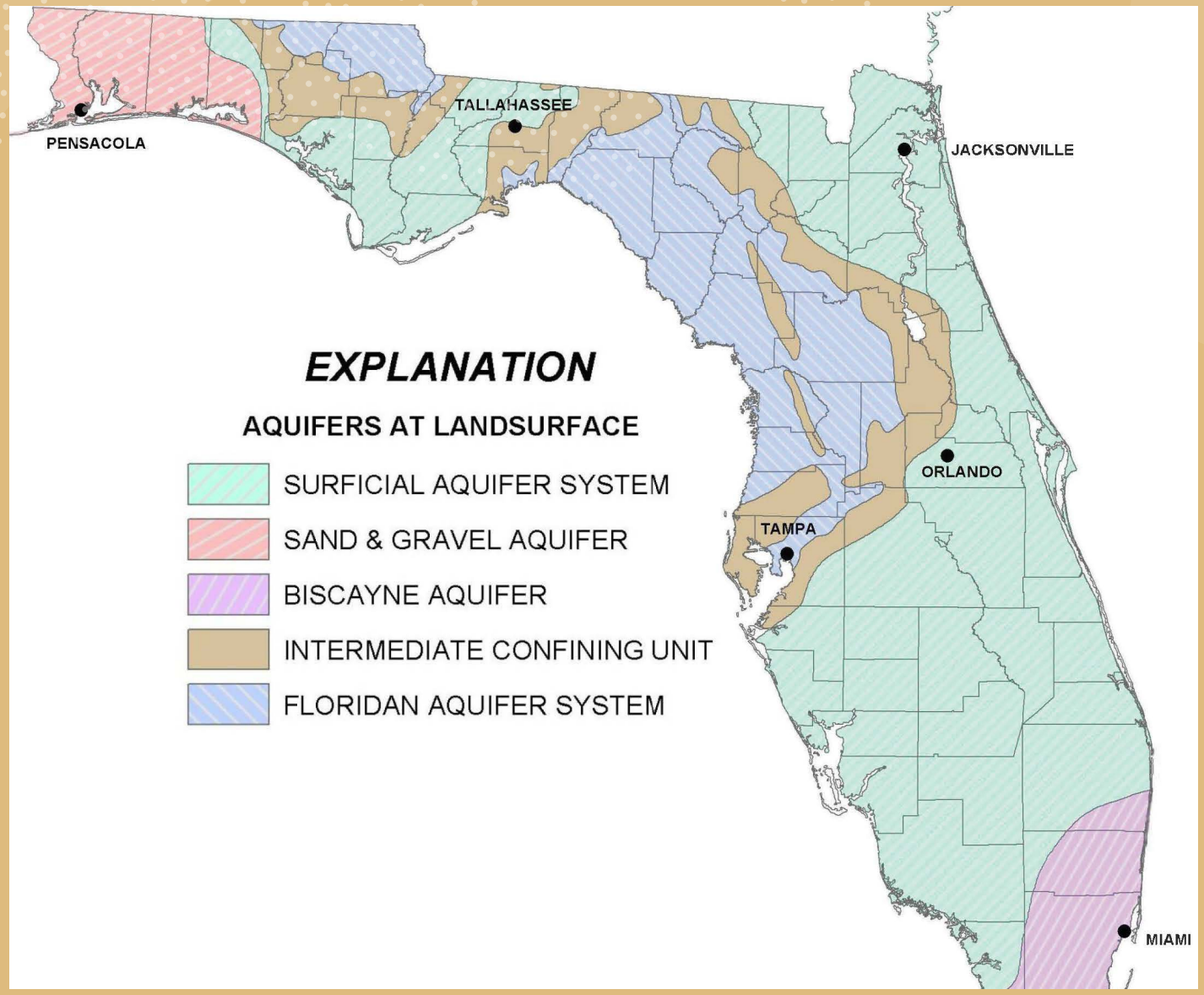
What processes occur?



Chemistry of Dissolution

- The carbonic acid that causes karstic features is formed as rain passes through Earth's atmosphere picking up carbon dioxide (CO2), which readily dissolves in the water.
- Once the rain reaches the ground, it may pass through soil that provides additional CO2 produced by soil respiration. Some of the dissolved carbon dioxide reacts with the water to form a weak carbonic acid solution, which dissolves calcium carbonate.
- The primary reaction sequence in limestone dissolution is the following:

Aquifers in Florida



Sand and Gravel Aquifer

- The **Sand and Gravel Aquifer** in the far western panhandle is the main source of water for Santa Rosa and Escambia Counties.
- It is made up of sand and gravel interbedded with layers of silt and clay.

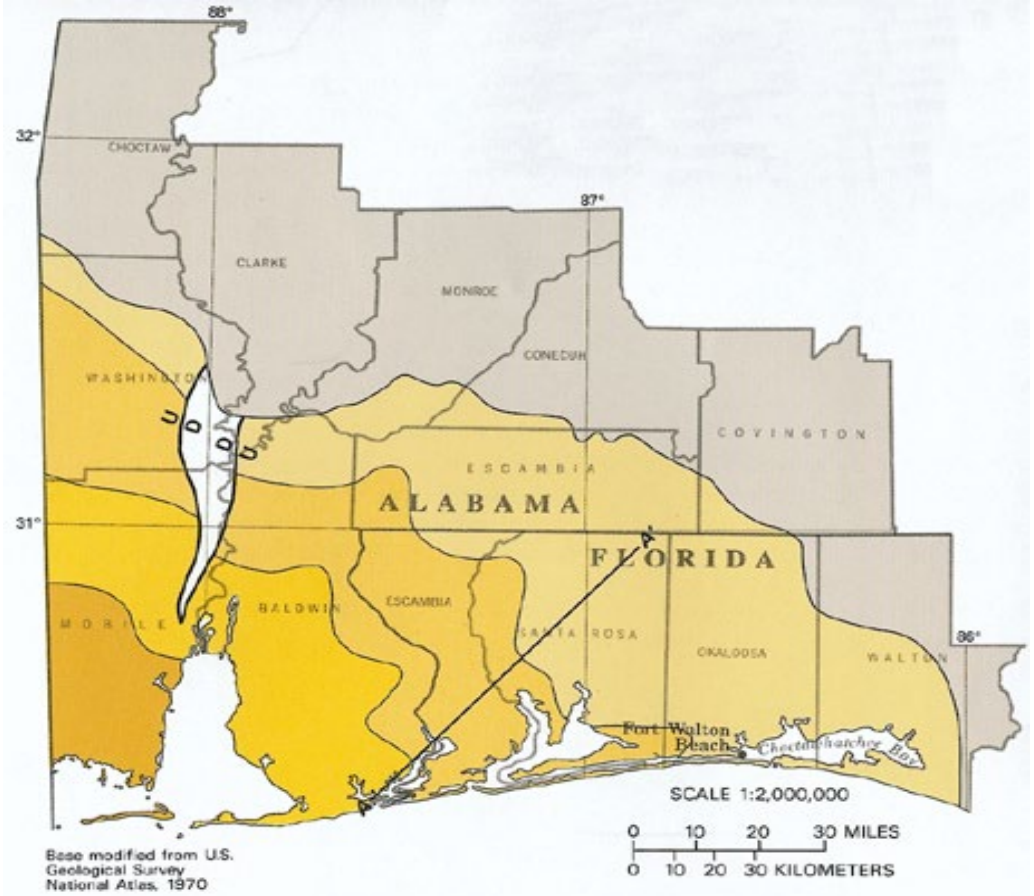
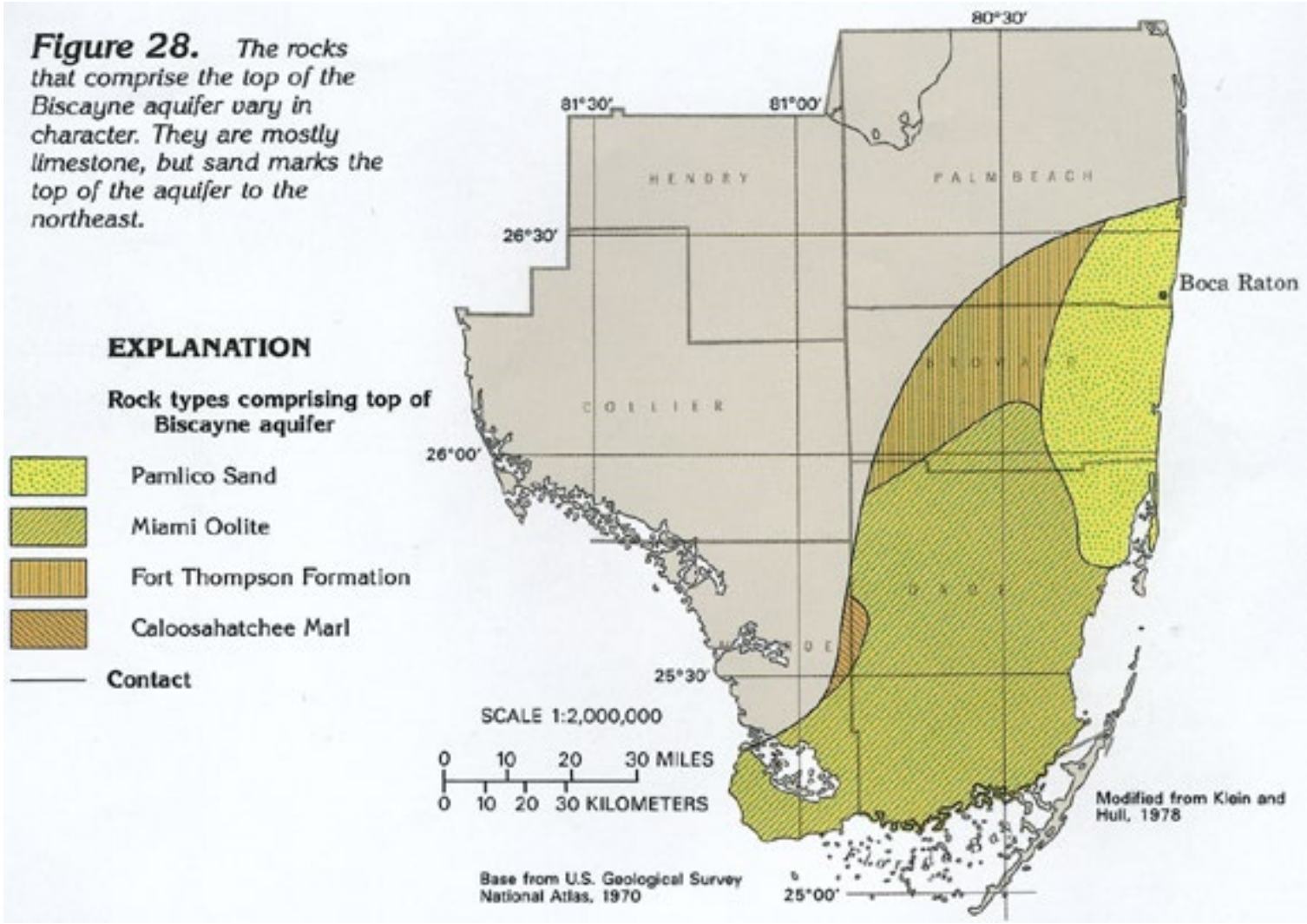


Figure 22. *The sand and gravel aquifer thickens to the southwest. In western Alabama, the aquifer is offset by a down-dropped fault block called the Mobile graben.*

Biscayne Aquifer

- The **Biscayne Aquifer** supplies water to Dade and Broward Counties and southern Palm Beach County.
- A pipeline also transports water from this aquifer to the Florida Keys.
- The aquifer is made of permeable limestone and less permeable sand and sandstone.



Surficial Aquifer System

- The **Surficial Aquifer System** is the major source of drinking water in St. Johns, Flagler and Indian River counties, as well as Titusville and Palm Bay.
- It is typically shallow (less than 50 ft. thick) and is often referred to as a ‘water table’ aquifer, but in Indian River and St. Lucie Counties, it can be up to 400 ft. thick.

The Surficial aquifer system extends throughout large areas in the Coastal Plain of Florida, Georgia and South Carolina. The Surficial aquifer is the uppermost aquifer in the Northern Atlantic Coastal Plains aquifer system. The surficial aquifer extends over large parts of the Delmarva Penninsula and the eastern coastal plain of North Carolina.

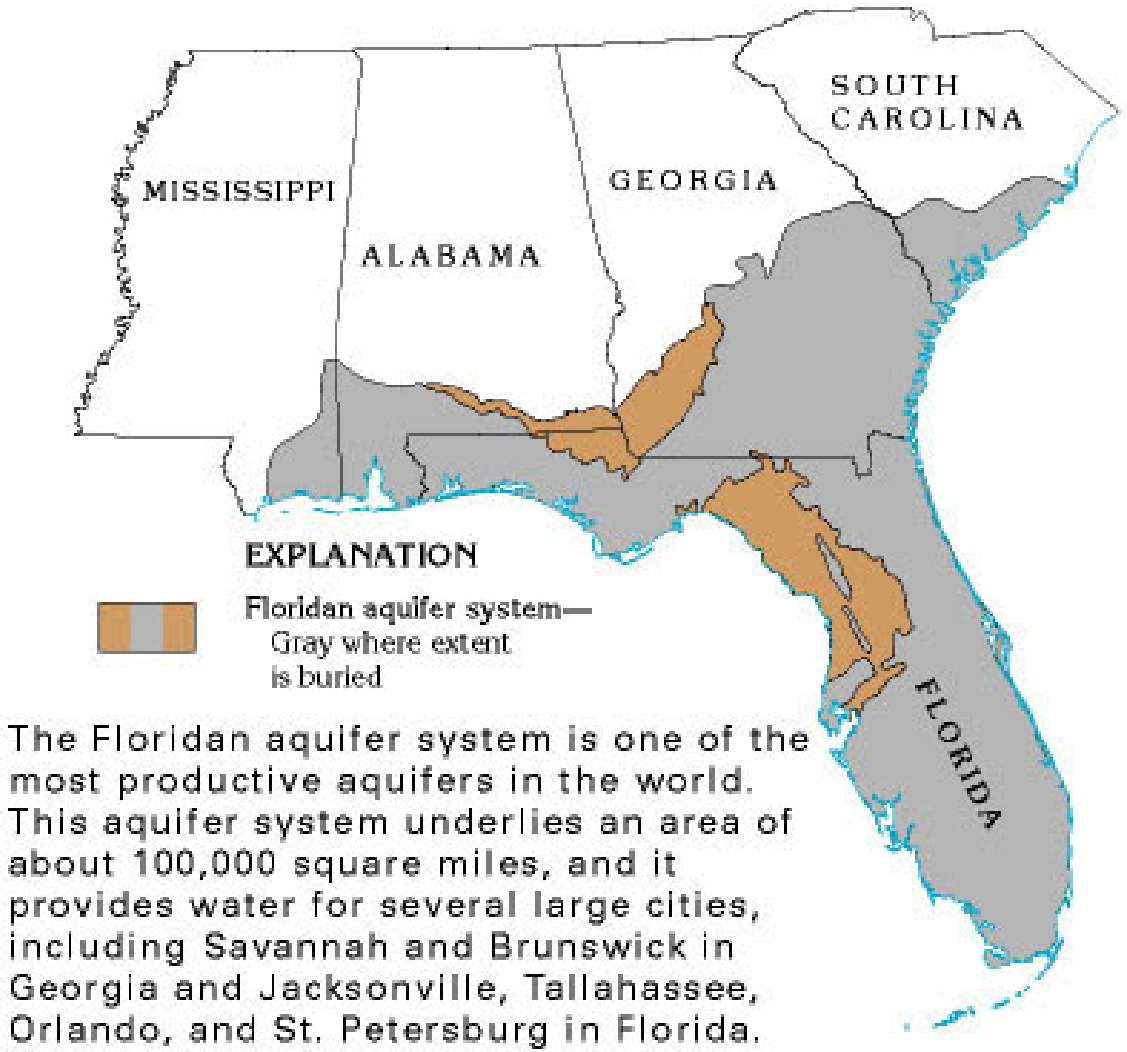
Intermediate Aquifer system

- A fourth aquifer, the **Intermediate Aquifer System** in southwest Florida lies at a depth between the Surficial Aquifer System and the Floridan Aquifer.
- It is found south and east of Tampa, in Hillsborough and Polk counties and extends south through Collier County.
- It is the main source of water supply for Sarasota, Charlotte and Lee counties, where the underlying Floridan Aquifer is too salty to be potable.

Figure 42. The intermediate aquifer system is present in southwestern Florida.

Floridan Aquifer System

- The **Floridan Aquifer System** is a principal productive artesian aquifer covering almost 100,000 sq. miles including all of Florida and parts of Georgia, Alabama, Mississippi (not used due to high salinity and depth), and South Carolina.
- It behaves as one aquifer over much of its extent, although rocks of lower permeability create hydrologic separation between the Upper Floridan Aquifer (UFA) and Lower Floridan Aquifer (LFA) sub-regionally.

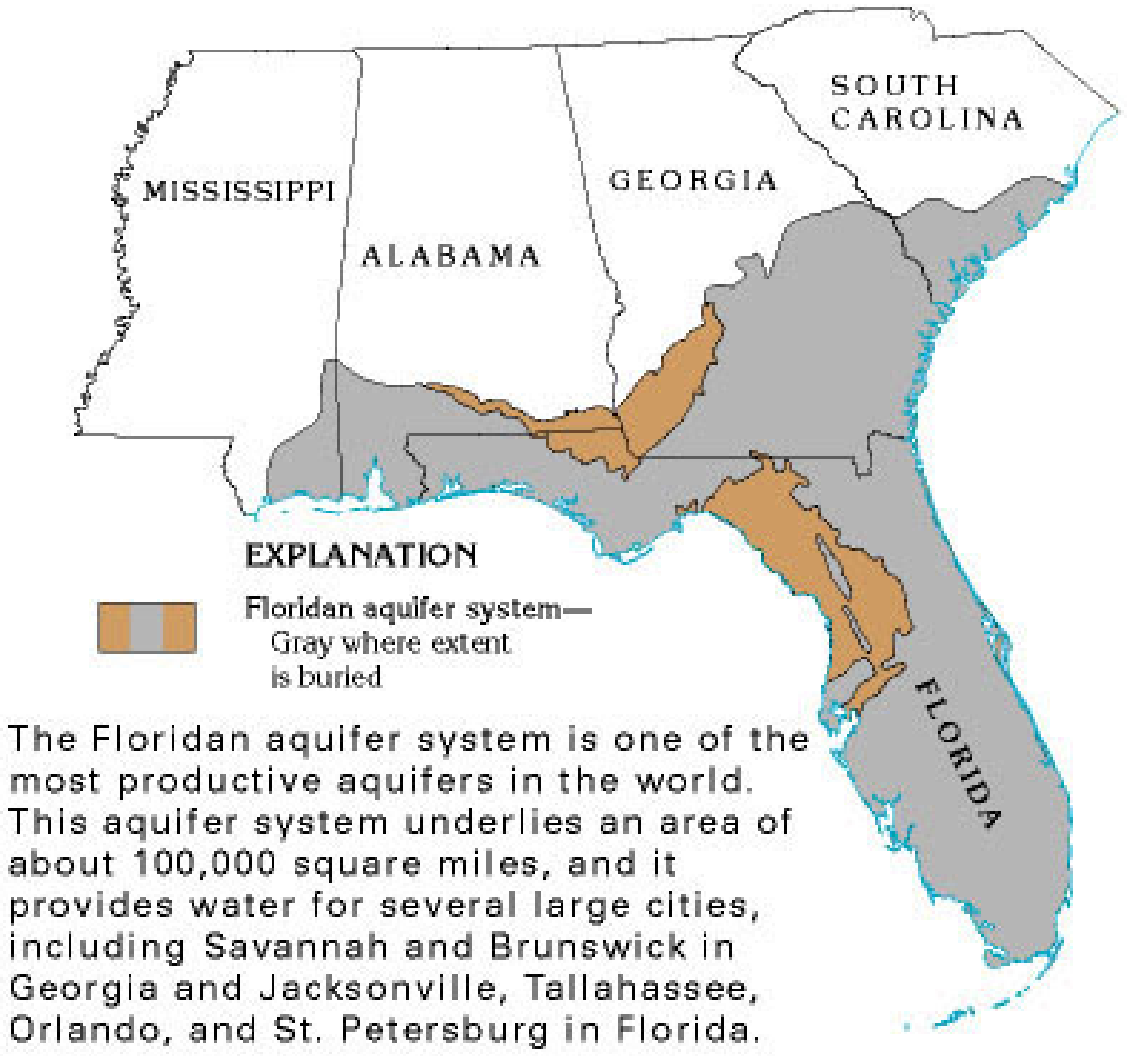


The Floridan aquifer system is one of the most productive aquifers in the world. This aquifer system underlies an area of about 100,000 square miles, and it provides water for several large cities, including Savannah and Brunswick in Georgia and Jacksonville, Tallahassee, Orlando, and St. Petersburg in Florida.

Source: *http://sr6capp.er.usgs.gov/aquiferBasics/ext_floridan.html*

Floridan Aquifer System

- The majority of freshwater is contained in the UFA and is used for water supply and is the main source of groundwater in the Kissimmee Basin.
- In south Florida, the UFA is brackish and used as reverse osmosis water, blending with shallower fresh Biscayne groundwater, and aquifer storage/recovery.
- The LFA has fresh to brackish water in northeastern Florida and Georgia, while in south Florida it is saline and used to dispose of effluent from wastewater treatment processes.



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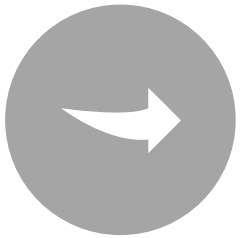
Effects of Karst Hydrogeology

Poses Potential Complications for Assessment and Remediation of **Petroleum-Impacted** Groundwater.



Change in Depth and Groundwater Flow Direction.

Change in Petroleum Plume Delineation.

Potential Contamination of Potable/Public Wells.

Now What?

Sinkholes, Underground Drainage Systems, Springs, and Caverns

- Most rainwater is slightly acidic and becomes more acidic as it moves through decaying plant debris.
- Limestone strata in Florida is porous, allowing this water to percolate and dissolve the limestone and carry it in solution.

Sinkholes, Underground Drainage Systems, Springs, and Caverns

- Over time, this process creates underground voids, drainage systems and cavities in the limestone bedrock.
- When a large cavity enlarges to the point that its ceiling can no longer support the weight of overlying sediments, the earth collapses into the cavity, creating a sinkhole.

Sinkholes, Underground Drainage Systems, Springs, and Caverns

- When groundwater discharges from an underground drainage system, it is a spring, such as Wakulla Springs, Silver Springs or Rainbow Springs.
- Sinkholes can occur in the beds of streams, sometimes taking all the stream's flow, creating a disappearing stream.

Sinkholes, Underground Drainage Systems, Springs, and Caverns

- Leon County, (county seat of Tallahassee) in the eastern panhandle, is the location of geologically active Lake Jackson, which undergoes periodic disappearances through underlying sinkholes!
- This 4,000-acre lake has a history of virtually draining about every 25 years, most recently in 2006.
- Dry caves are parts of karst drainage systems that are above the water table, such as the Florida Caverns in Marianna.

Sediment-Filled Sinkholes

- Over a considerable period of time, typical erosional and depositional processes cause sinkhole structures to fill with sediments including sand, silt, gravel and clay.
- Since most sedimentary formations are originally deposited horizontally, the presence and extent of these filled-in sinkholes may be determined through review of boring logs and noting the depth of contact with the limestone bedrock.
- This determination can be complicated due to the horizontal extent of certain lithologies, surface drainage structures and limited by depth constraints of assessment investigation activities.

Non-Karst Subsidence Incidents

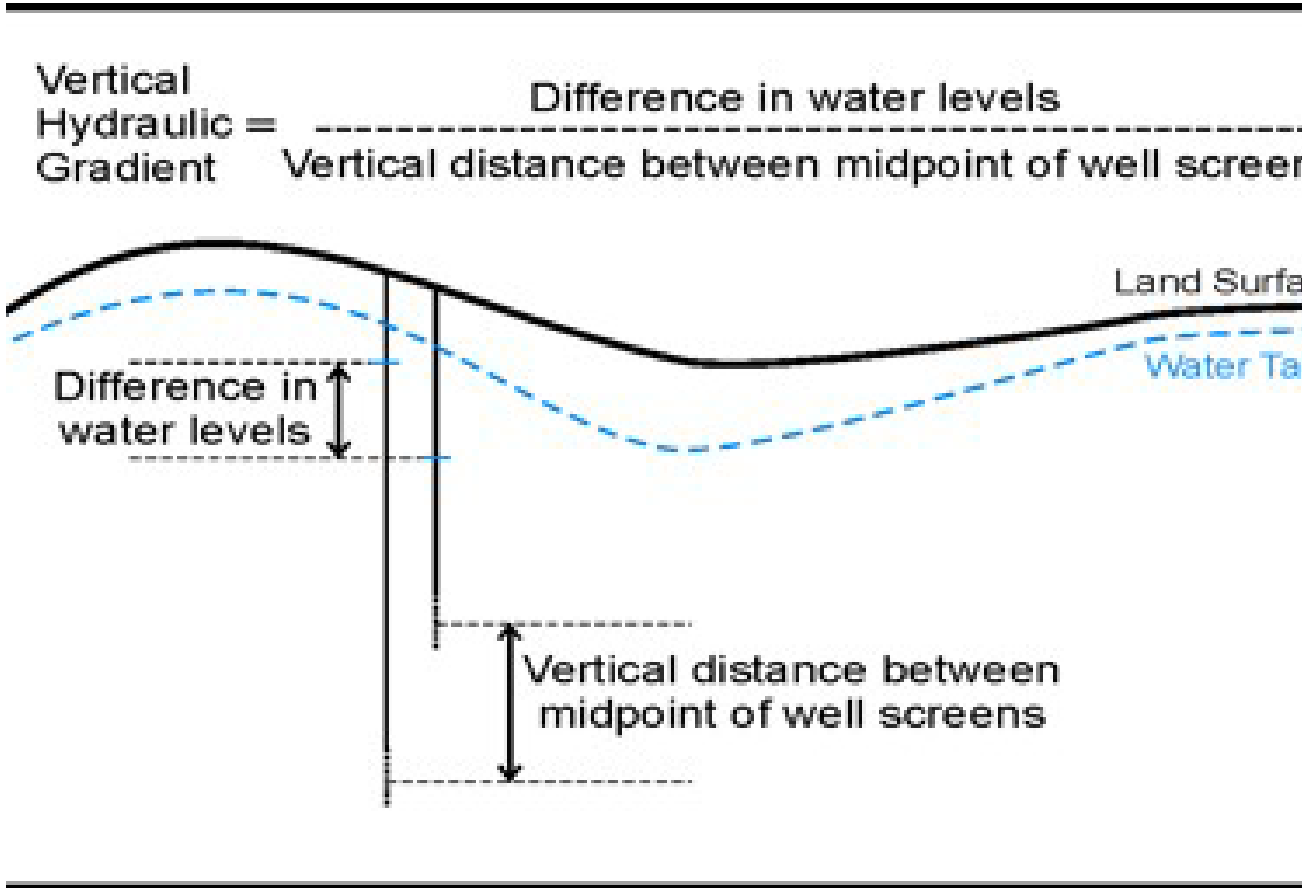
- Other subterranean events can cause holes, depressions or subsidence of the land surface that may mimic sinkhole activity.
- These include subsurface expansive clay or organic layers which compress as water is removed, collapsed or broken sewer and drainpipes or broken septic tanks, improperly compacted soil after excavation work, and even buried trash, logs and other debris… Such an event is called a **“subsidence incident.**”
- Unfortunately, at many sites where karst features may be present, these other subterranean situations exist as well, adding to the difficulty in properly assessing and remediating petroleum impacts.

Local Program 53 and PRP Sites with Karst Hydrogeology in Northwest Florida

- Local Program 53 (Polk) oversees Petroleum Restoration Program (PRP) work primarily in central Polk County, Florida. Based on a predominant sand, minor clay, and shallow limestone lithology, Polk County exhibits the most evidence of Karst Hydrogeology and its effects on Petroleum Contaminated Site Assessment and Cleanup.
- While **Karst Hydrogeology effects** are very evident in PRP sites located throughout the County in towns such as Lakeland, Winter Haven and Lake Wales, the number of sites and the difficulties encountered are **most evident in the town of Lakeland**, located in the Central and Eastern portion of Polk County, between Interstate 4 East-West and Interstate 27 North-South corridors.

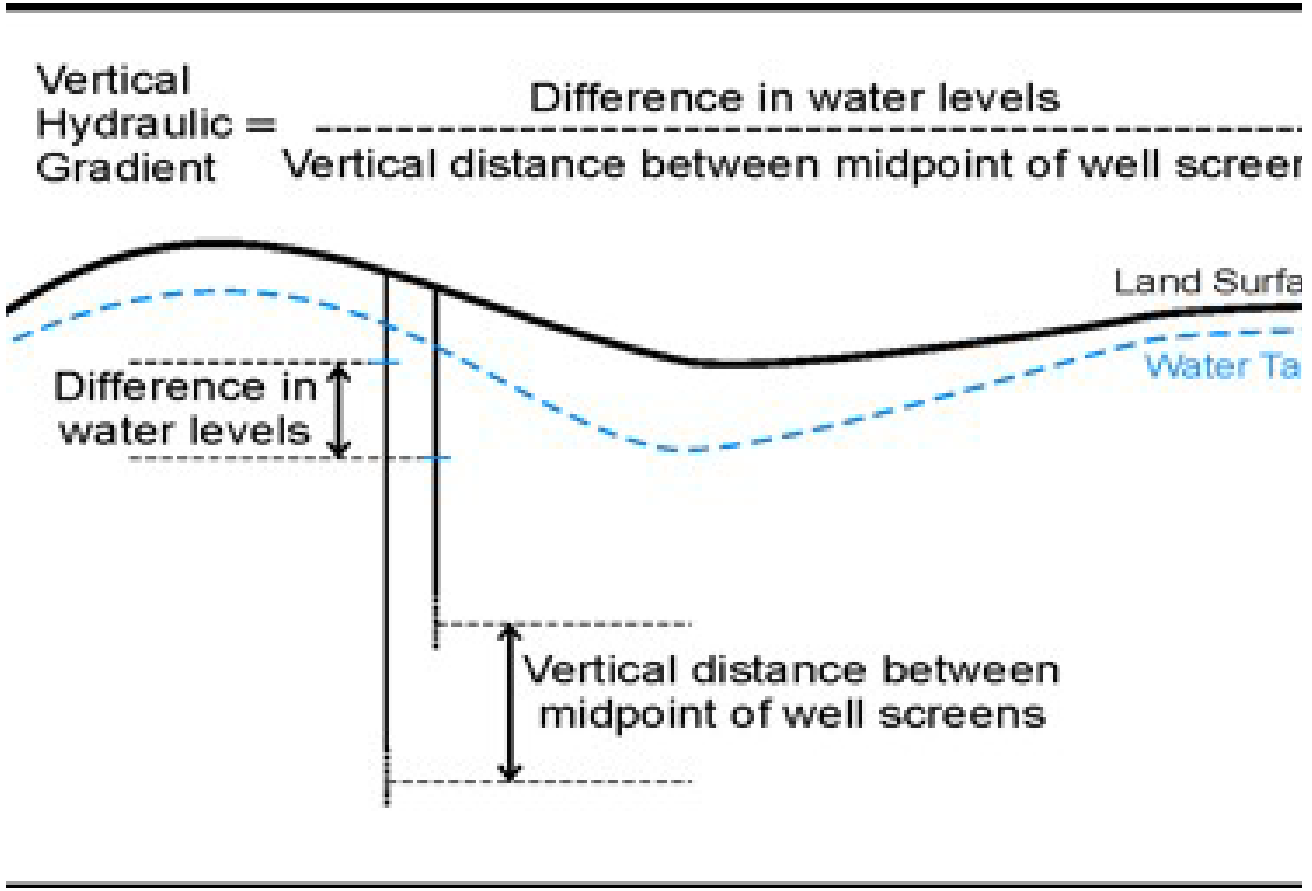
Vertical Hydraulic Gradient

- At many sites, the vertical hydraulic gradient is small in comparison to the horizontal hydraulic gradient.
- At karst sites with shallow Limestone, vertical hydraulic gradients may be very significant, leading to downward migration of contaminant plumes.
- Subtract the hydraulic head value of the deeper well from the shallower well value and divide by the vertical distance between the midpoints of the well screens.



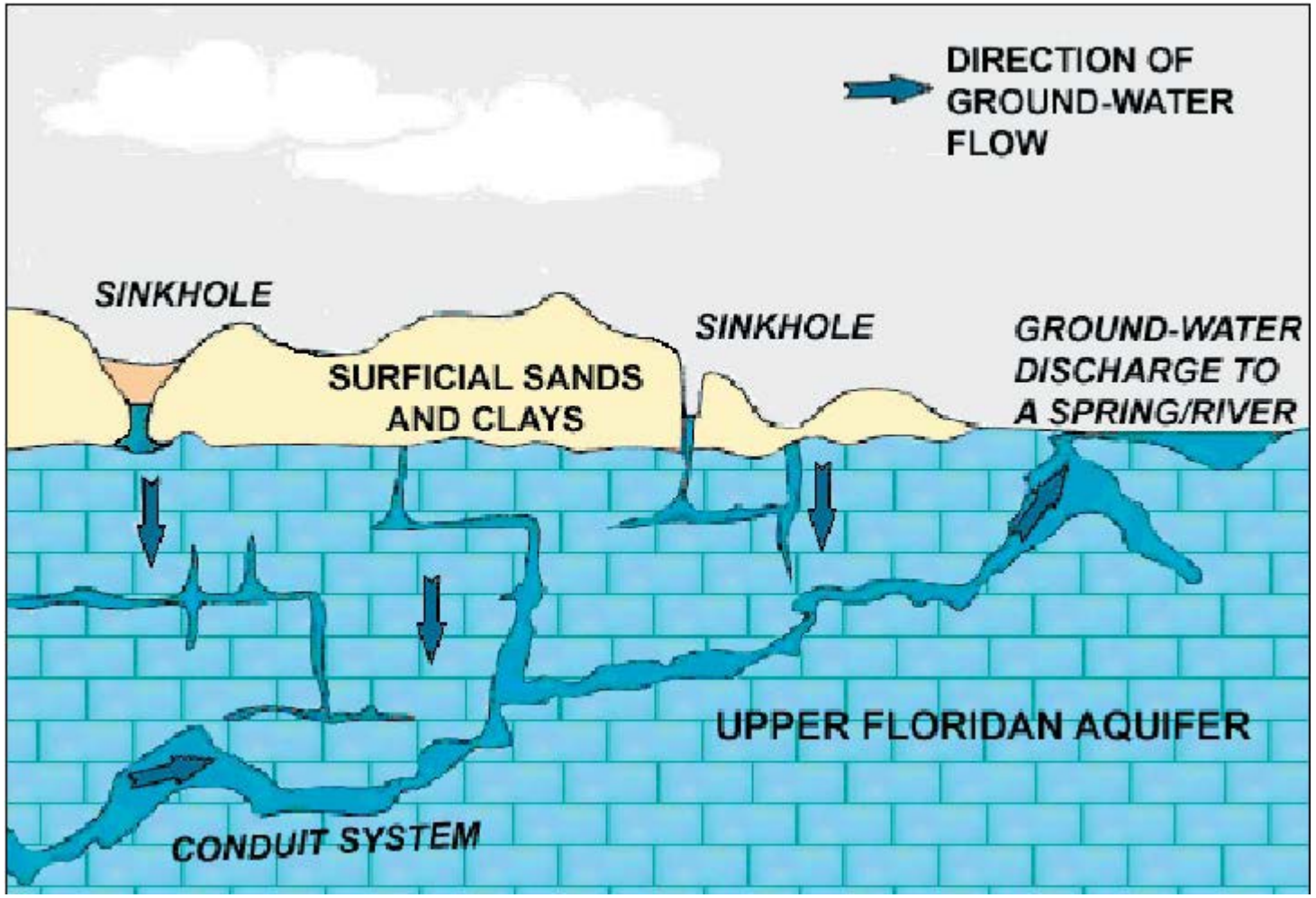
Vertical Hydraulic Gradient

- A quick look at the groundwater (GW) elevations of nearby-clustered wells (shallow, intermediate, deep, etc.), should provide evidence if a vertical hydraulic gradient is present with GW elevations dropping in feet as the wells get deeper.
- This assumes no confining layers are present.



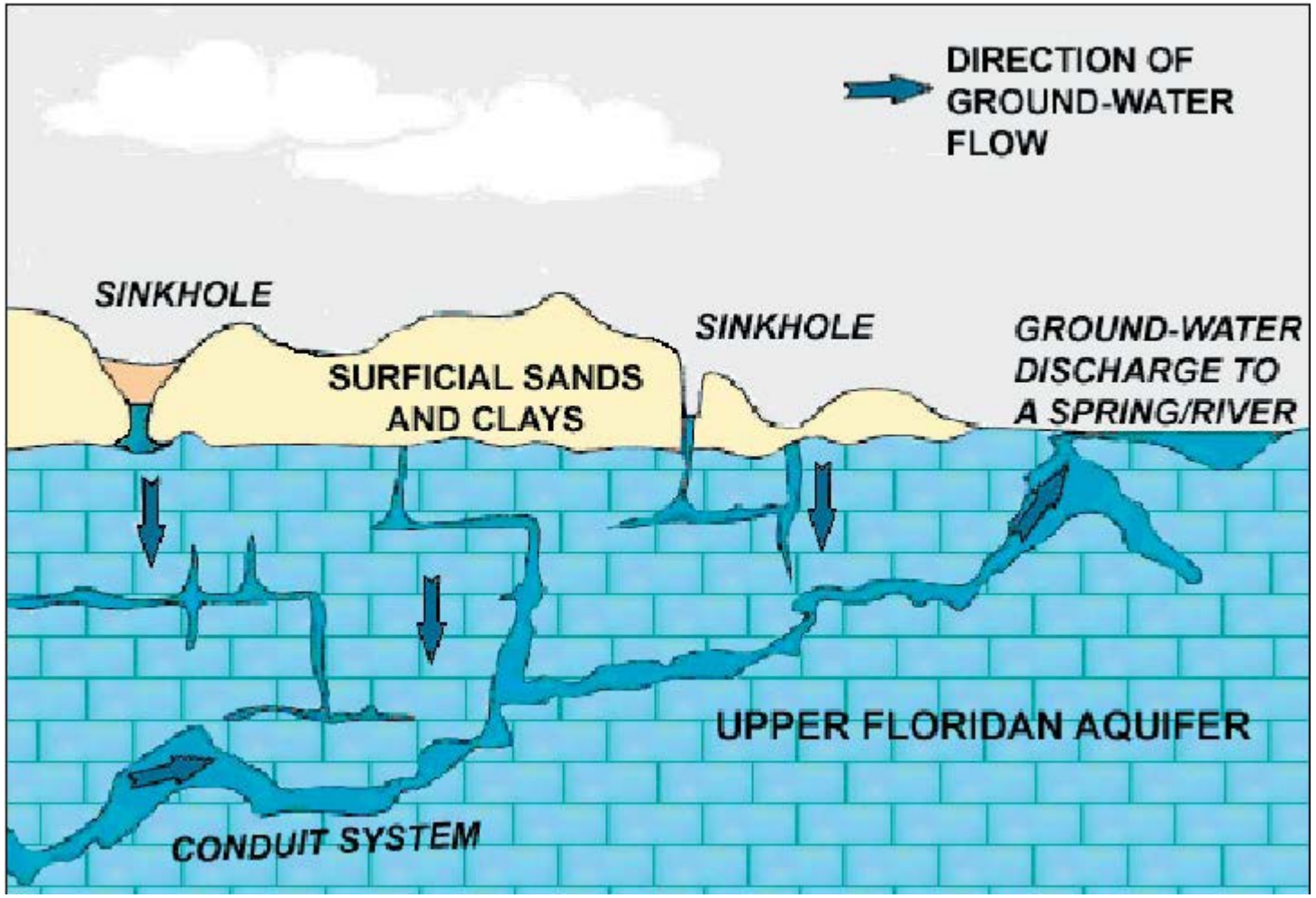
Vertical Hydraulic Gradient

- The most important mechanism that causes vertical migration of a plume is the presence of a downward vertical gradient beneath the site.
- A trend of increasing hydraulic conductivity with depth could induce a downward vertical potential beneath the site. A more permeable horizon may be situated below, and be hydraulically connected to, the shallower unit in which the discharge occurred.



Vertical Hydraulic Gradient

- A downward hydraulic potential would develop causing the groundwater and contaminant plume to migrate towards the deeper more permeable layer.



Lakeland, Polk County, Florida

- Lakeland is located in the Lakeland Ridge where limestone is near the ground surface and consequently, the area is one of karst development with many sinkholes.
- A typical lithology encountered in Lakeland is comprised of poorly-sorted quartz sands slightly clayey sands from surface to approximately 50-feet below land surface (BLS), followed by various interbedded layers of sand, silt and clay of poor to high permeability persist until a thin marl (<5-feet thick mix of clay & limestone), is encountered immediately above a chalky Limestone at approximately 55-60 feet bls.
- This typical soil column varies locally based on re-worked mining materials (phosphate).

Adcock Petroleum: FAC# 538628342

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- The Adcock Petroleum site is located at the corner of US 98 S and St. Rd. 540 in Lakeland, Polk County, FL is a former automobile service and gasoline service station. The site is currently a popular restaurant (Catfish Country).
- The site has had an EDI discharge in 1984.
- The site had multiple assessment over the years and now is currently on year 4 Operation and Maintenance with 2 systems.
- System 1 located in Catfish Country (Mult-phase extraction)- source property
- System 2 located south on Sorrel's Property (AS/SVE) – heading south towards elementary school

Adcock Petroleum: FAC# 538628342

Adcock Petroleum - Takeaways

- The current data and historic data indicate that complicated lithology is present due to shallow limestone and potential paleo-karst activities.
- High permeability sand stringers are a primary path of contaminant and that even in locations where low-permeability clays are present, contamination is present in the deep zones, most likely corresponding with the limestone aquifer.
- Furthermore, based on results from both systems, Contaminants of Concern (COC) have dropped and now appear to be shrinking into three individual plumes. A Remedial Action Plan Modification (RAPMOD) is being developed by the Agency Term Contractor (ATC) to address the central plume with continuing remediation on Sorrel's Property and Catfish Country.

Questions?

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