

# KARST DISSOLUTION OF EXPOSED BEDROCK

- Basic concept: acidic water dissolves rock
- Reactions are rate limited
- Water quickly enters ground
- Irregularities exploited: fractures, faults, bedding planes



San Geronimo Creek, Northwest Bexar County

# RESULTS OF KARST DISSOLUTION

- ‘Aggressive water’ continues to dissolve once underground
- Water passages enlarged until conduit formation
- Rapid, subsurface flow via conduits

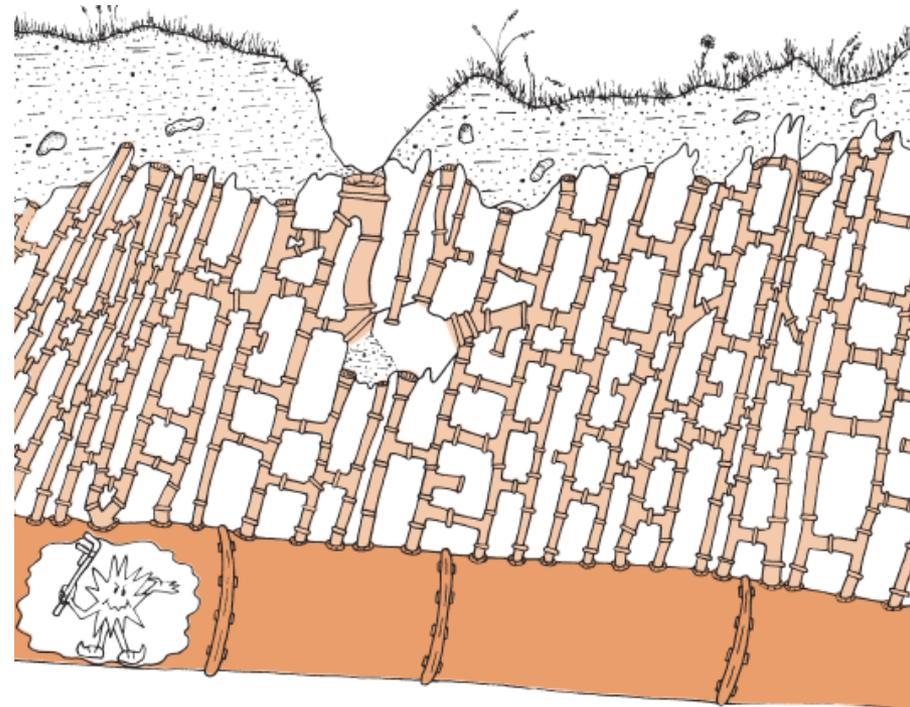
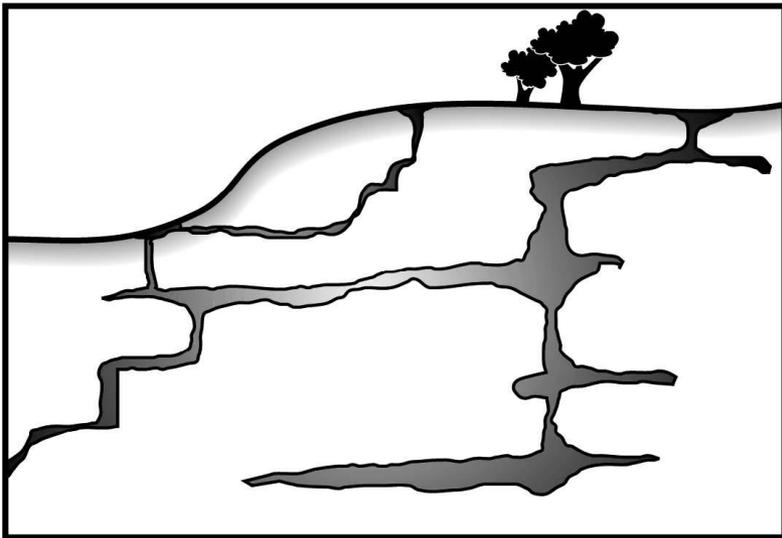
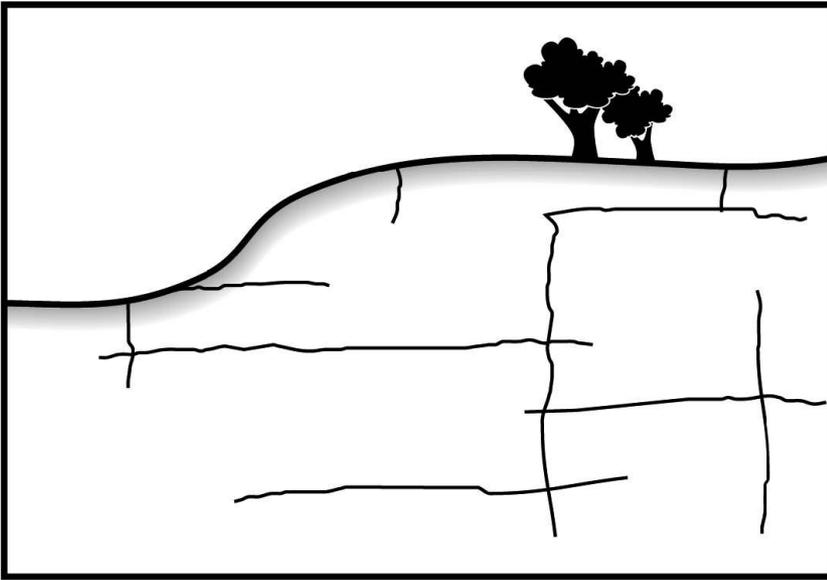


# KARST OVERVIEW

- In the subsurface these conduits feed into each other; dendritic patterns common
- Larger conduits formed
- Large volumes of water transmitted with high flow velocities

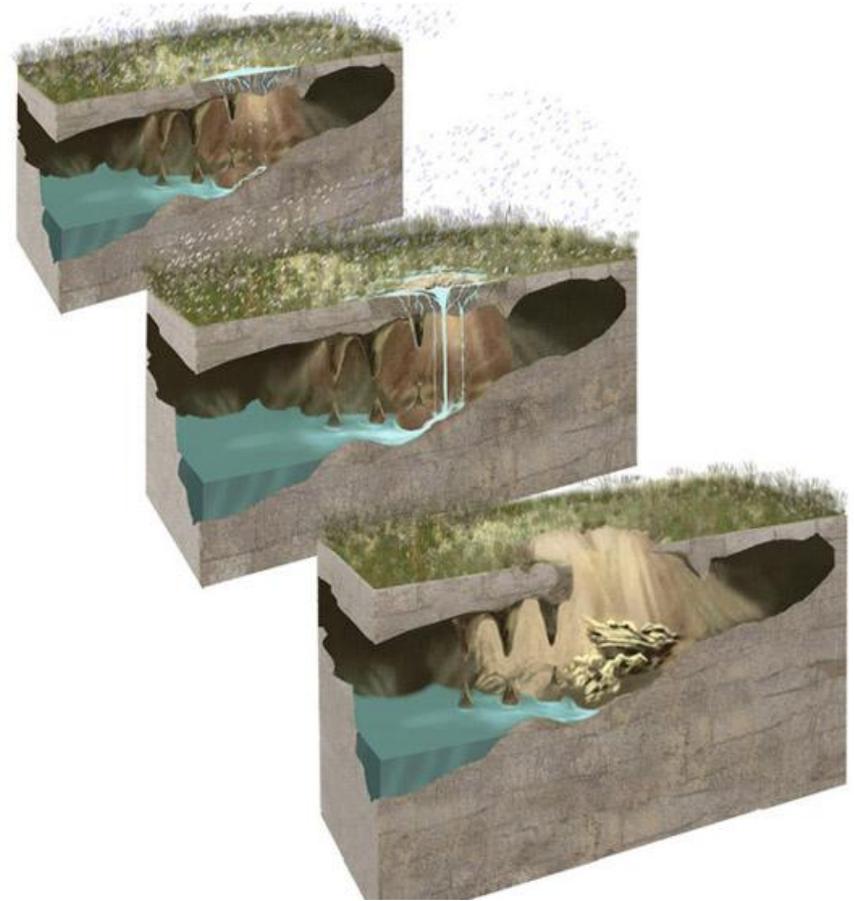


# FRACTURE CONVERGENCE



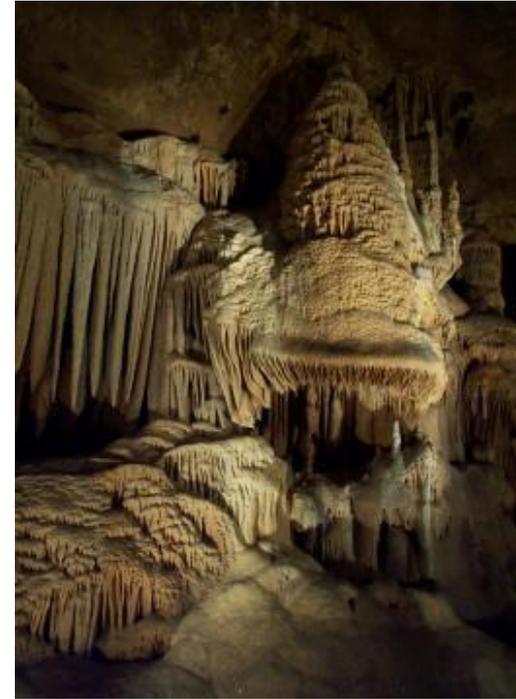
# SINKHOLE

- Void dissolved in bedrock
- Soil/rock collapses into underlying void
- Depression formed on surface.
  - Drain may or may not be visible
- Sinkholes indicate void space below



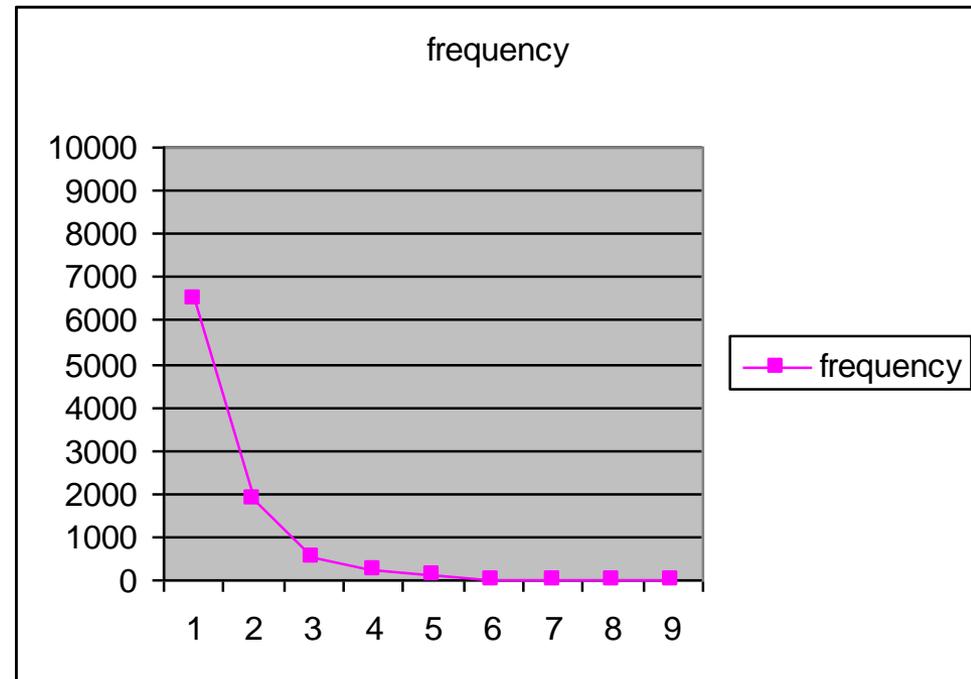
# WHAT IS A CAVE?

- Solutioned void that humans can fit into
- Conduit or passage
- Entrance is where passage intersects surface
- **How many passages *do not* intersect the surface?**



# CAVES WITHOUT ENTRANCES

- Art Palmer did a semi-log regression
- Plotted number of entrances versus frequency
- If you follow the trend you see that the number of caves without entrances is very high
- AL had <7k known caves; **Palmer's regression predicted ~100,000 caves**



# WHAT DO THESE KARST FEATURES SHOW US?

- That there are many, many interconnected water carrying passages in karst aquifers
- Only a small portion of them are enterable
  - Enterable passages are caves
- Non-enterable passages are conduits, vugs, cavities or other solutional voids smaller than people
- ***Non-enterable solution features greatly outnumber enterable features***

# AQUIFER COMPARISON

## SAND AND GRAVEL

- Small pore size mechanically filters
- Torturous flow paths slow water
- Contaminants don't travel far
- Remediation possible

## KARST

- No filtration takes place
- Fractures and conduits yield fast water velocities
- Contaminants are broadcasted over large distances
- Contaminants gone

# WHAT MAKES THE EDWARDS UNIQUE?

- Incredibly high porosity in the Edwards Limestone
  - Holey rocks
- Highly fractured and faulted rock
  - Permeability increased
- Results in incredibly fast flow rates
- Long, complex flow paths
- Geochemical complexities; bad water line
- Large springs; multiple other springs
- Unique biota



# EDWARDS AQUIFER

- Limestone; interbedded marls, clay layers
- Wikipedia describes it as “one of the most prolific artesian aquifers in the world”
- San Antonio owes its existence to the Edwards—without the aquifer the city might not exist
  - No surface water

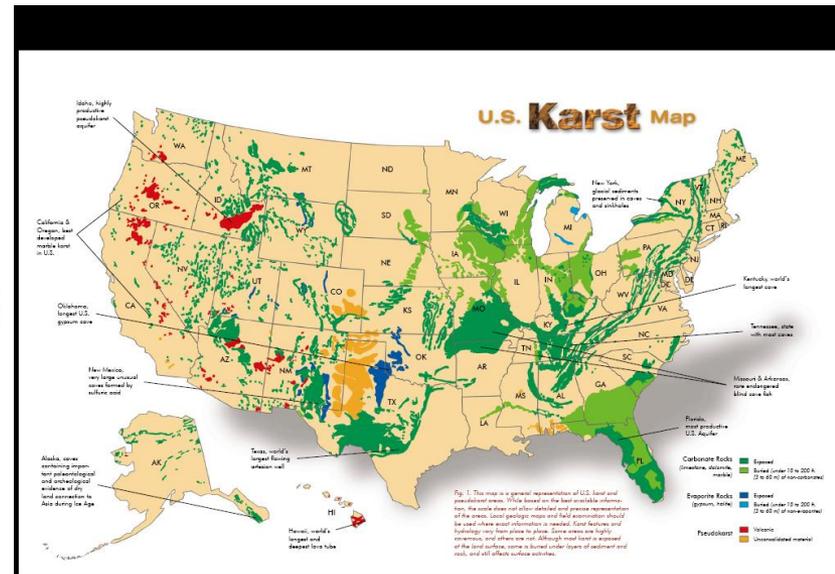
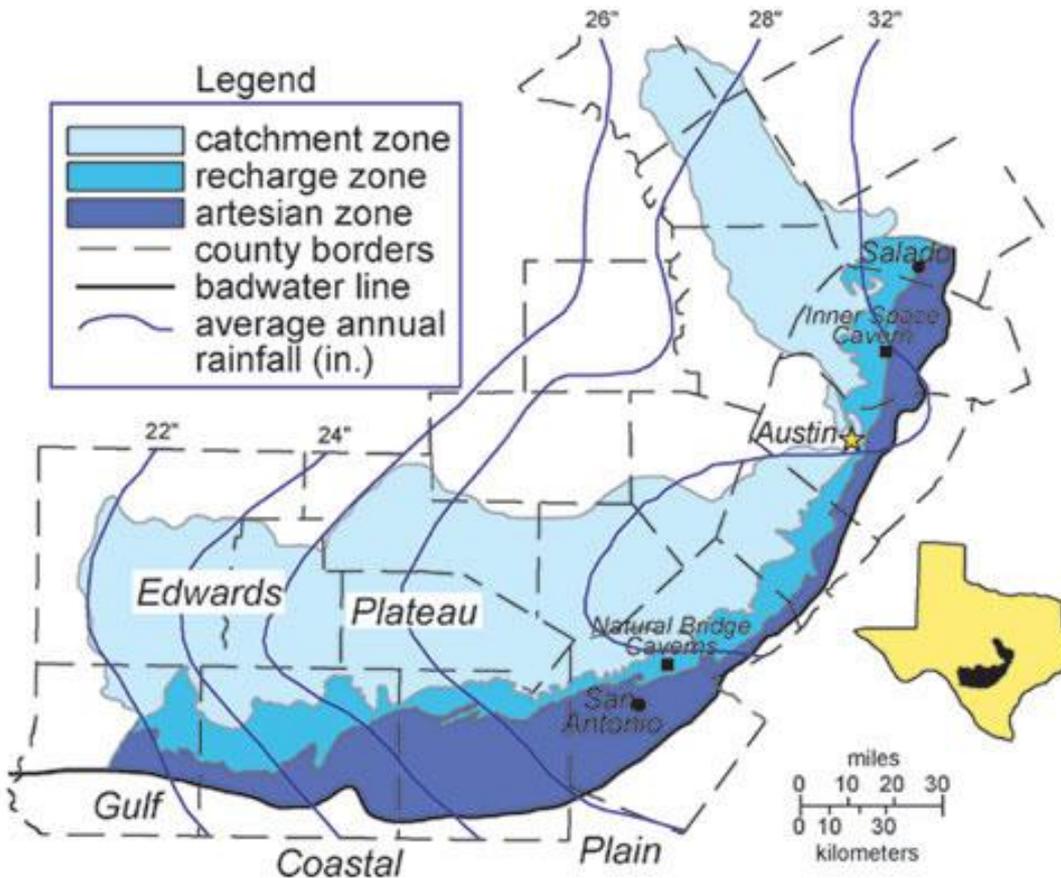


# OUTWARD APPEARANCE

- The Edwards is characterized by vugs, large pores, rocks with holes, more
  - We show off the rock's uniqueness
- *No karst in Guatemala, Canada, Mexico, the U.S. looks or behaves like the Edwards*
- *The Edwards Aquifer is an anomaly*

# EDWARDS IS A LARGE, COMPLEX SYSTEM

Regional Extent of the Edwards Aquifer



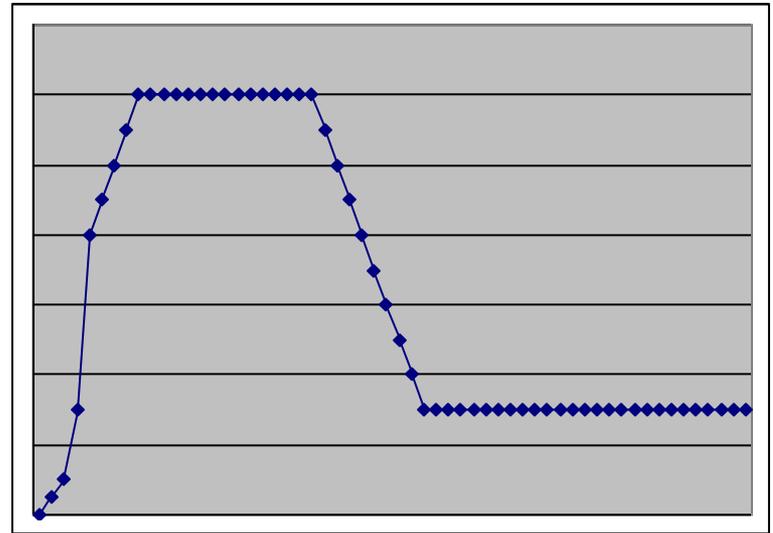
## RECHARGE ZONE VS BASIN

- Basin: water in basin to spring
- Edwards: structurally complex; different zones

(Musgrove, (2000). Regional aquifer map after Burchett et al. (1986) and Brown et al. (1992); precipitation contours from Larkin and Bomar (1983). The down-dip limit of potable water in the aquifer is defined by the bad water line (1000 mg/l)).

# FRACTURE VS. MATRIX FLOW

- Fracture flow is rapid
- Matrix flow is slow
- Contaminants have initial pulse and then bleed out over long period of time



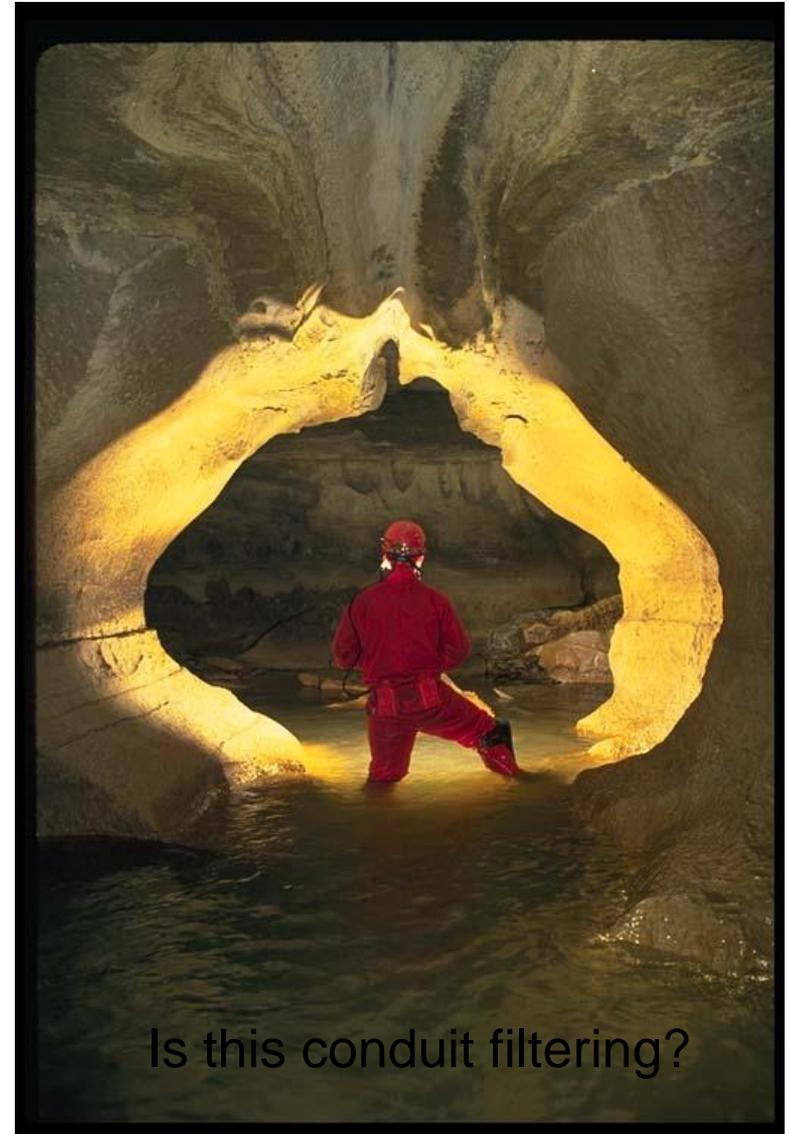
Chemical as detected at a spring

# HOW THE EDWARDS IS SPECIAL

- Very vuggy rock; extremely high porosity
- Fractured/faulted rock concentrates flow
- Very high flow velocities are the result
- Unique organisms

# KARST AQUIFER AS A FILTER

- Does the Aquifer filter?  
NO!
- Suspended solids DO SETTLE OUT, but they are NOT filtered out!
  - No size exclusion/mechanical filtration occurs
  - Garden hose analogy
- It does NOT filter microorganisms, chemical pollutants



Is this conduit filtering?

# KARST AQUIFER AS A FILTER

- Things spilled on recharge/contributing zones jeopardize the entire aquifer
  - Contaminants spilled on them have the potential to contaminate our sole water supply
- Human activity on the these areas puts the water supply of a million people at risk
  - Once contaminated: Where do we go for water?

# SINKING STREAMS

- Water directly recharges aquifer
- Represent points that are very susceptible to rapid contamination of large aquifers
- Sewage infrastructure is typically installed in stream beds.



Seco Creek

**Given that 75% to 80% of recharge occurs within streams and rivers that traverse the Edwards Aquifer Recharge Zone, the event of a spill of could have serious consequences to nearby wells.**

**The Edwards Aquifer Authority staff recently reported extremely elevated levels of fecal coliform bacteria in water wells as far as four miles away from the site of a spill that occurred on the Recharge Zone on October 15, 2012.**

**The cost of compliance with TCEQ requirements for camera testing wastewater lines on the Edwards Aquifer Recharge Zone every five years is estimated at \$37,000/mile. Currently, this cost is borne by all SAWS rate payers.**

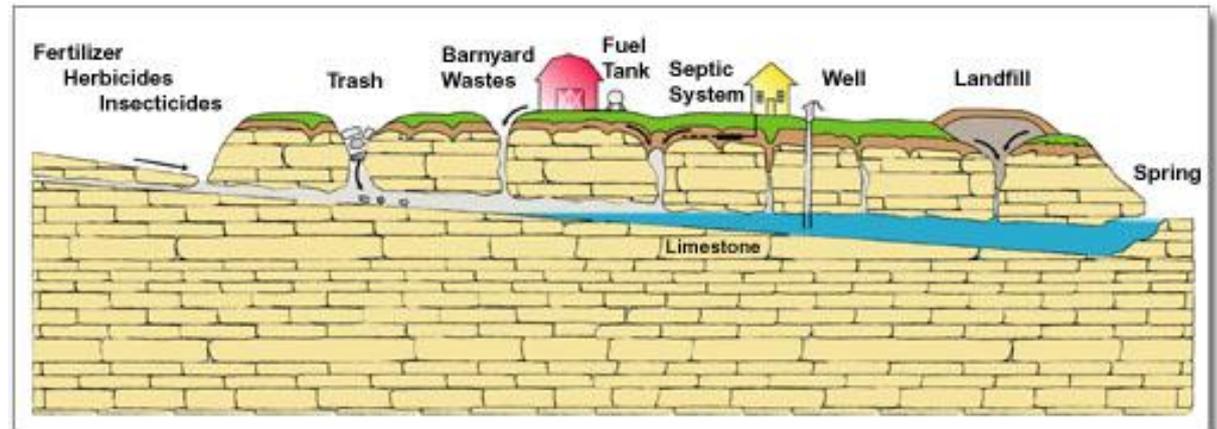
# EDWARDS MTYH #2: “Protecting caves and karst features protects the aquifer”

The law requires me to identify and protect caves and karst features on my site that is on the recharge zone. Protecting point features is enough to protect the aquifer.

# EDWARDS MTYH #2:

“Protecting features protects the aquifer”

- Protecting features is important
- *Where does water enter a karst aquifer?*
  - *Everywhere!*
  - *Not just at identifiable points*

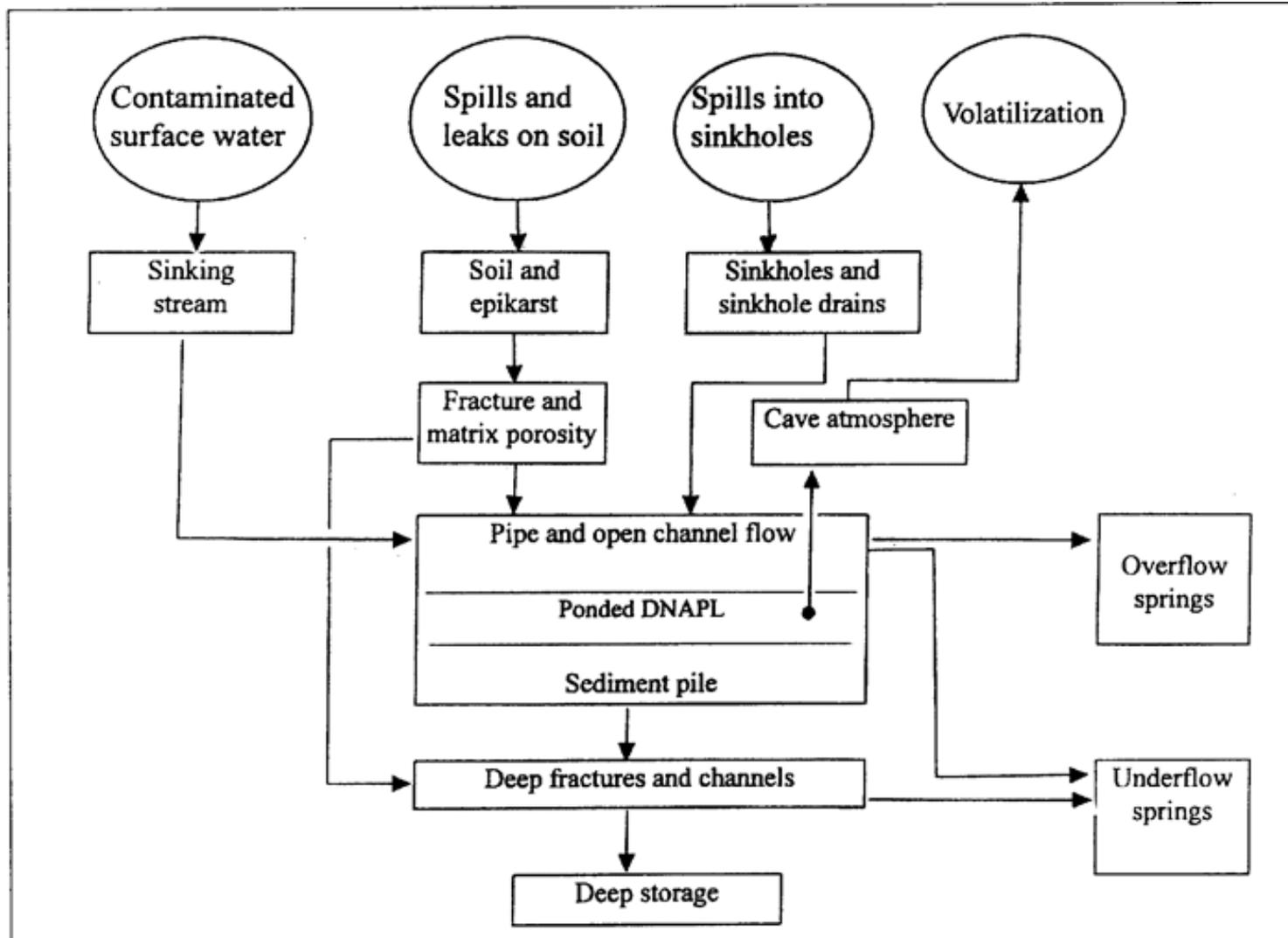


# EDWARDS MYTH #2

- How can we claim our aquifer to be protected if a handful of point features are protected?
- Do all the protected point features account for the volume of water coming out of the springs?  
NO.
- A great majority of karst features are mantled by soil and go unnoticed
  - Soil mantled fracture
- And they go unprotected



# KARST FLOW CHART



Karst-Contaminant Flow Chart

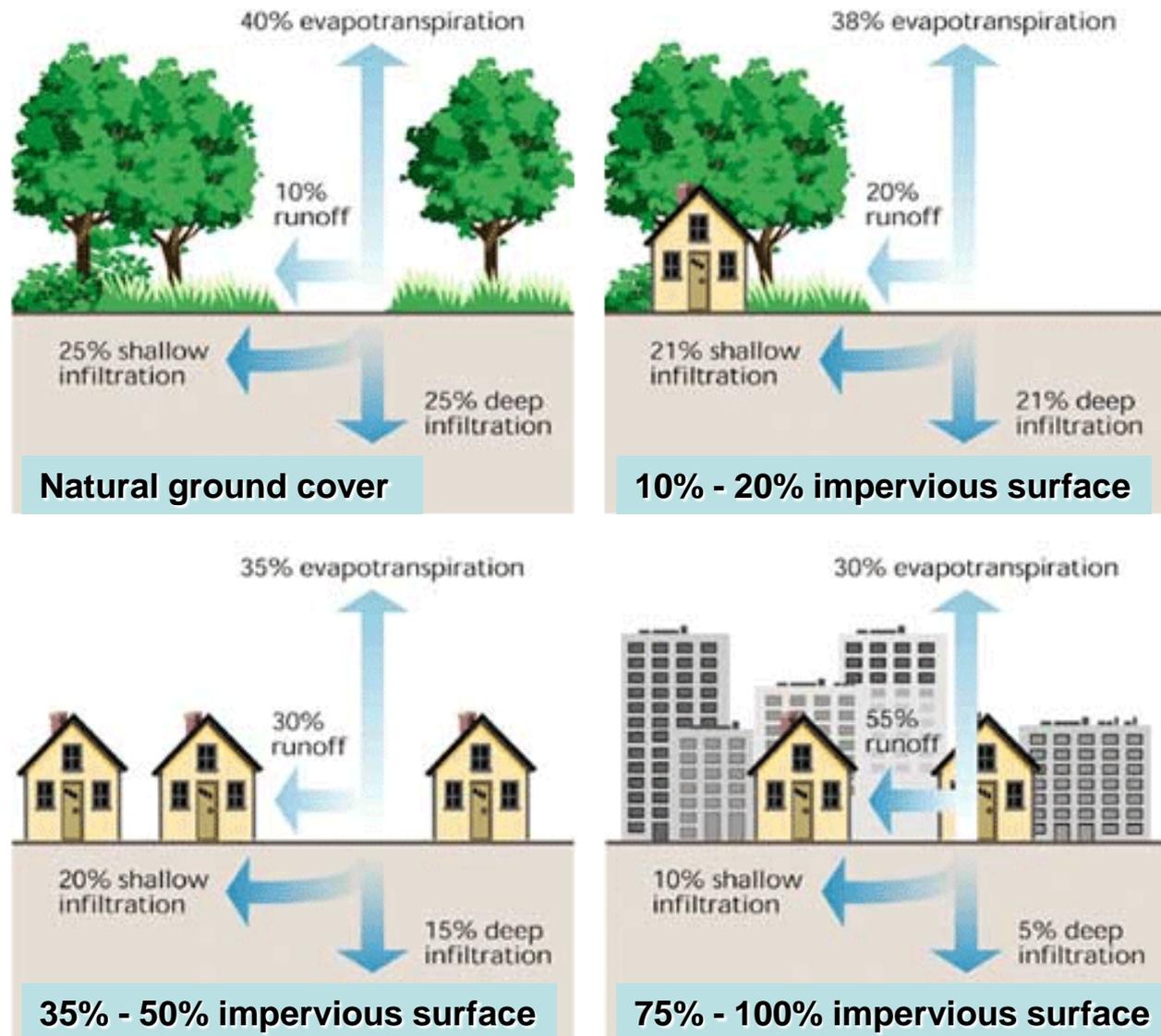
# CONCERNS

- *We need to protect large areas, NOT point features*
- How many local geologists received karst training? Regulators? Policy makers?

# CONCERNS

- The karst here is treated as discrete points in need of protection
  - *The entire area is susceptible and unique.*
- *We shouldn't be identifying point features to protect; we should be identifying large areas to protect.*
  - *Klimchouk*

# Effects of urbanization on runoff and recharge



Values shown are for comparative purposes—actual values vary geographically

**The extension of waste water service additional developments on the Edwards Aquifer Recharge Zone would serve to encourage additional high density development in this extremely sensitive area.**

# Urban Construction

Construction typically involves removal of vegetation for work access roads and for building of structures, parking lots, and utility lines. Vegetation attenuates much of the contaminants in overland flow, thus its removal causes water-quality degradation of receiving streams. Also, many tons of loose sediment are created during this process—sediment which washes into receiving streams, reservoirs, and aquifers, often prohibiting the use of such water and causing loss of biological life.

**Construction sediment can represent the greatest urban threat to aquatic resources.**



Runoff from Crownridge Heights entering Crownridge Park.

# Construction Sediment

Many studies Nationwide and in Texas document sediment loads in runoff to increase several orders of magnitude from construction areas that cover even much less than 1 percent of the drainage area for the basin. Degradation of water quality from construction sediment is often severe enough to limit or even prohibit water use and often requires expensive remedial action to correct.



**Sediment in Barton Creek flood**



**Sediment in water sample from Barton Springs**

# Other Construction pollutants

Typical construction site pollutants include fluids from construction equipment, adhesives, paints, cleaners, masonry, cement, fertilizers, pesticides, and wastes from plumbing, heating, and air conditioning installations. Below is an example of pesticides in runoff from Bee Cave Galleria development in the Barton Creek basin.



Bee Cave Galleria in Barton Creek basin



Pesticide washed into creek from improperly stored bags



Dead fish in receiving stream

6. 6. 2002

# Point Sources of Pollution

- The Edwards Aquifer Authority and TCEQ address many point sources in their rules.
- Point source pollution from sewage spills remains a serious problem.
- Karst scientists tell us that the fewer people producing sewage on the Edwards Aquifer Recharge Zone, the better.
- OSSF under Bexar County spacing requirements comes in at about 15% impervious cover.

# Non-Point Sources of urban runoff

- **Urban development** — construction, sewage, autos, parking-lots, pesticides, fertilizers, industry, animals



## Impervious ground cover

### Increased storm runoff and decreased infiltration

Increase in flooding damages and frequency

Erosion of channels and banks causing loss of property and additional stream sediment

Decrease in recharge volumes to aquifers



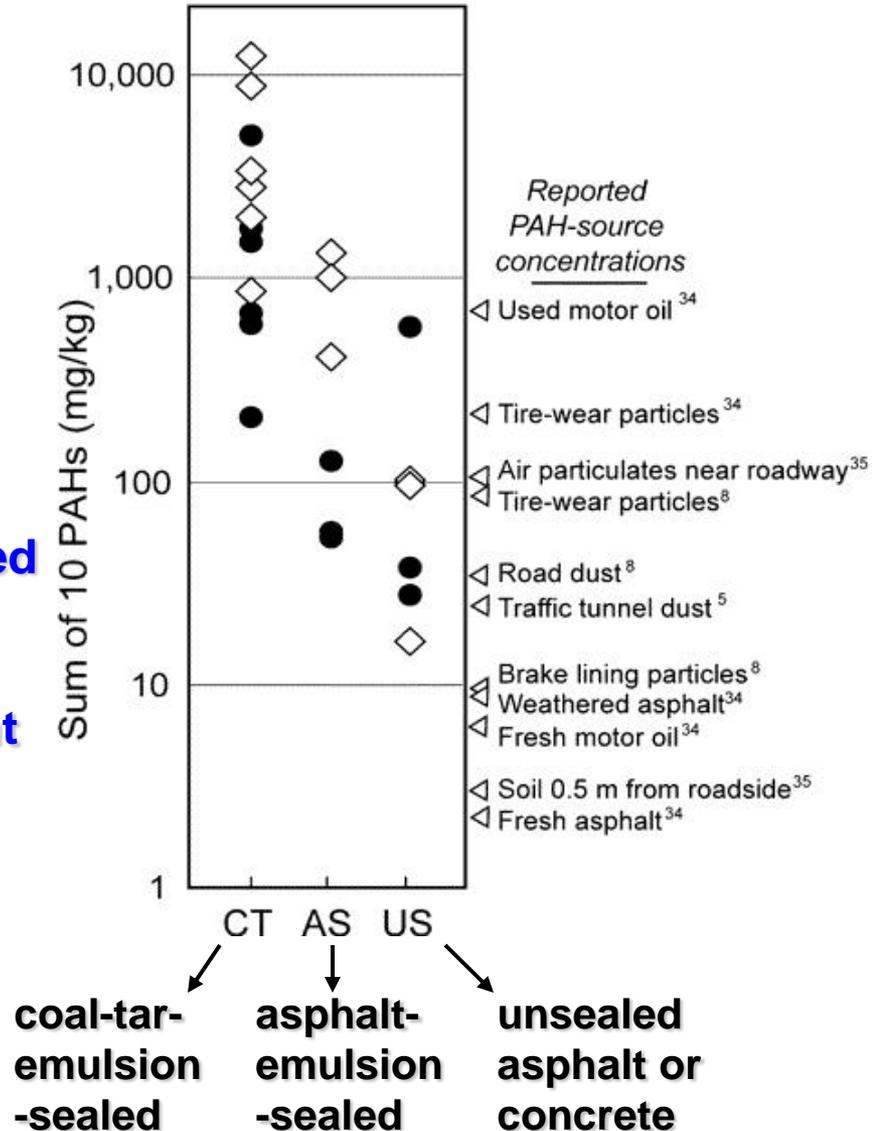
# Examples of non-point source contamination

**PAH from Parking lot sealants** represent a newly discovered major source of urban contamination. PAH (polycyclic aromatic hydrocarbons), a group member of organic compounds formed during incomplete combustion of organic matter, are in fuels such as gasoline, coal, and fuel oil. As the graph shows, PAH levels in runoff from parking lots have been much greater than levels in used motor oil.



**Sealants reapplied every few years. About 600,000 gallons of sealant are applied annually in San Antonio.**

**Levels of PAH sampled from parking lots**



# Sprawling Development



## Urban Construction

**Creation of construction sediment, exposure to construction materials and waste, loss of vegetation**

**Degradation of water quality and loss of biological life in streams, reservoirs, and aquifers due to sediment and runoff contaminated by construction materials and waste**

**Degradation of water quality due to loss of vegetation to attenuate contaminants in runoff**

## Inappropriate and Poorly-Regulated Land Use

# Heavily Irrigated and Chemically-Treated Turf



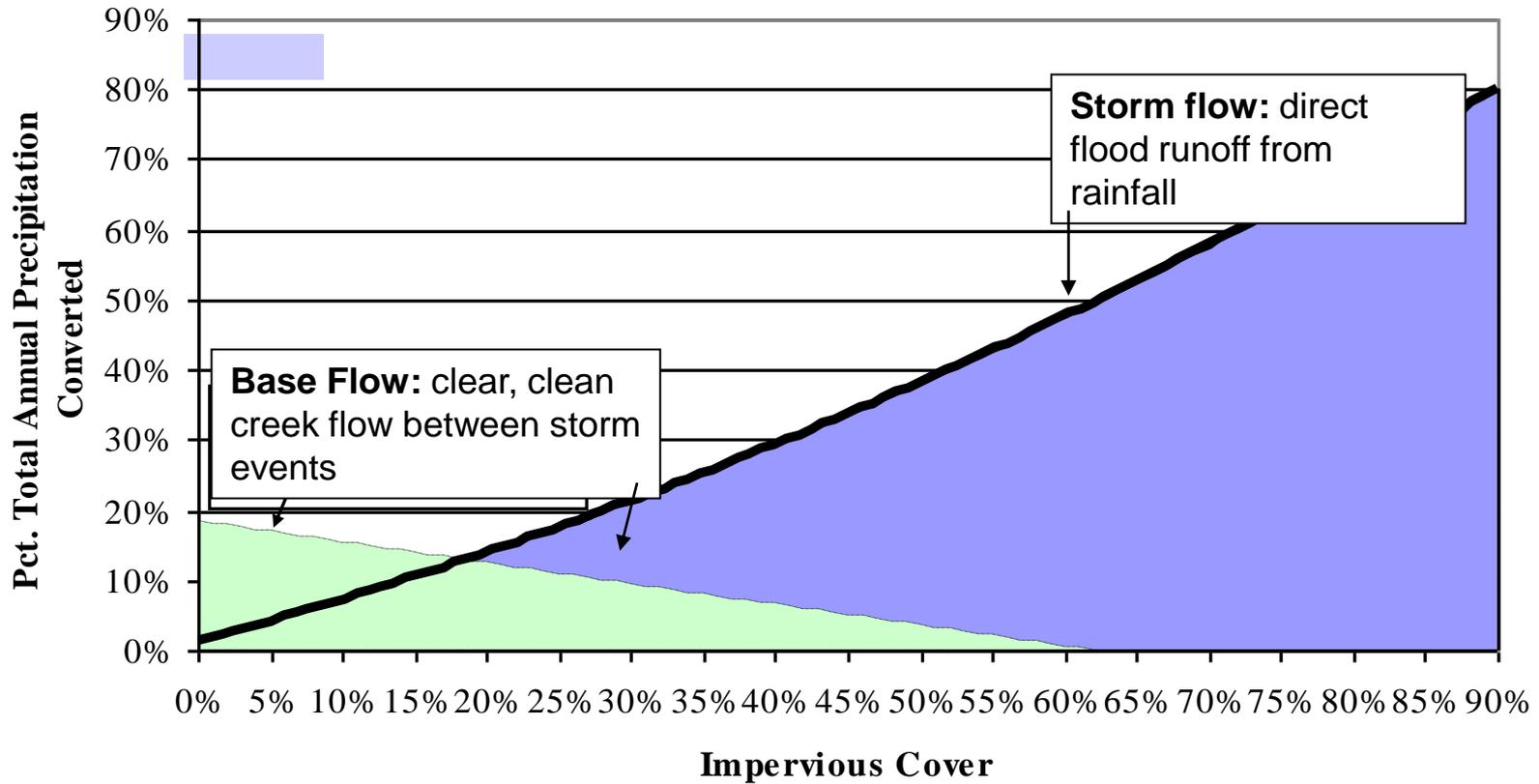
Effects of Development on Our Water:

# Decreased Base Flow in Streams Decreases Aquifer Recharge



Effects of Development on Our Water:

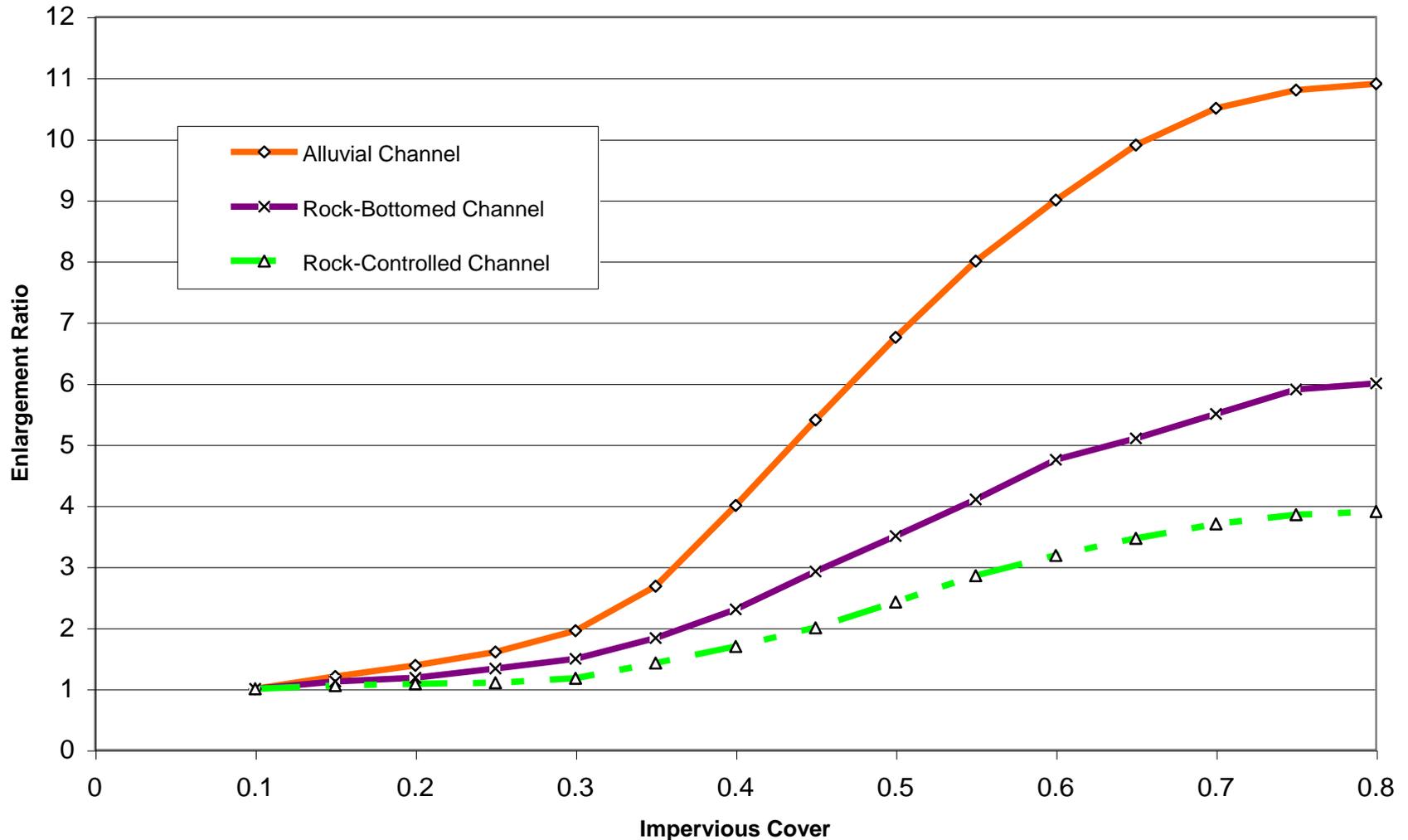
# Decreased Base Flow in Streams Decreases Aquifer Recharge



# Stream Bank Erosion



# Stream Bank Erosion



Source: Raymond Chan & Associates, Technical Procedures for the Watershed Erosion Assessments, September, 1997.

# Sewage Spills and Increased Water Use



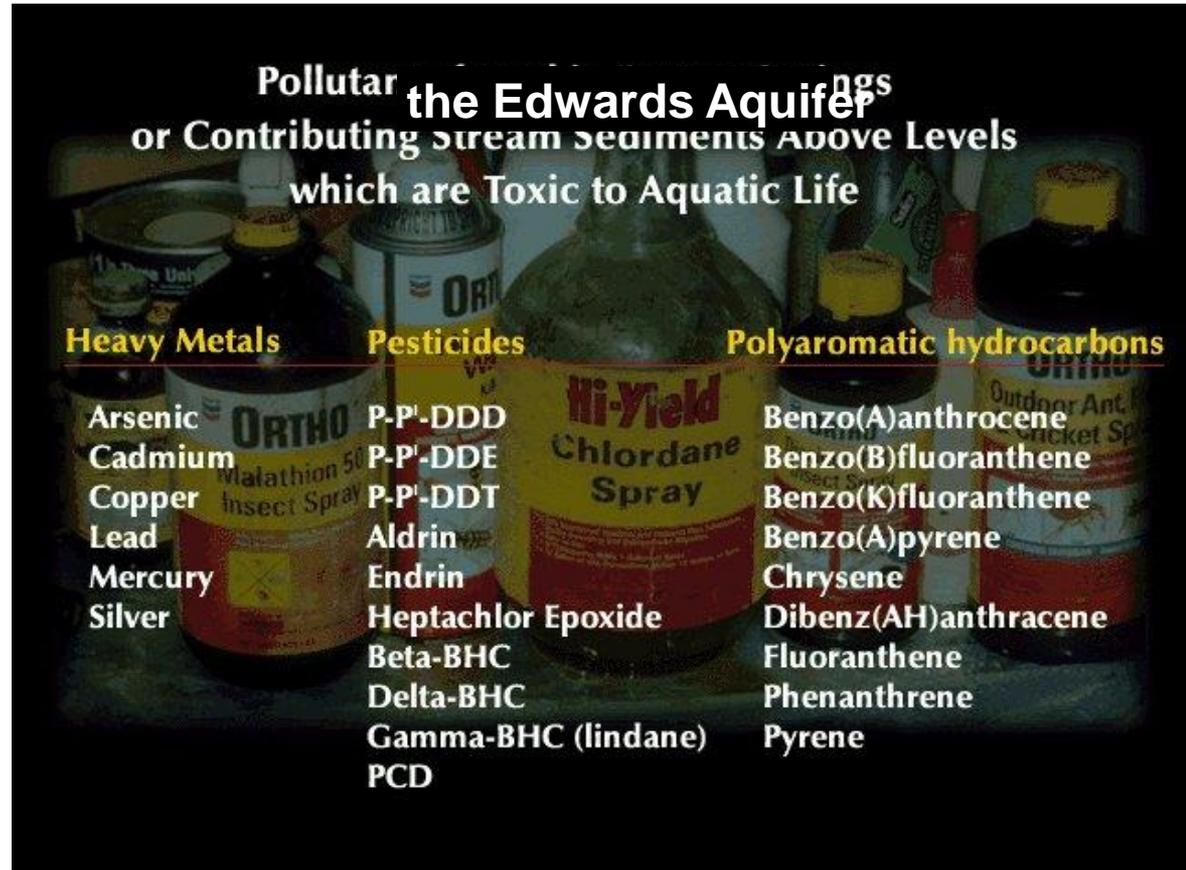
**Dense population**

**Increased water use, sewage, and waste disposal**

**Decrease in surface water and groundwater availability due to increased water use**  
***Folks on the ERZ are trying to grow grass on rocks!***

**Degradation of water quality due to sewage leaks and waste-contaminated runoff**

# Effects of Development on Our Water: **Storm Runoff Pollution**



**Urban land use**

**Industry, automobiles, lawn fertilizers and pesticides, pets, parking lot sealants**  
**Degradation of water quality for receiving streams, reservoirs, and ground water**

# **Engineered Controls Fail**

Engineered Controls Fail  
**Filtration Control Basin**



# Greater Edwards Aquifer Alliance

and thanks to Karst Waters Institute

GEAA opposes  
extending SAWS  
CCN for water and  
sewer service into the  
Edwards and Trinity  
aquifer Recharge and  
Contributing Zones.



Cave off Hwy. 281 – no longer exists