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Prospects for Managed Aquifer Recharge Using Stormwater:

Harris County and Beyond

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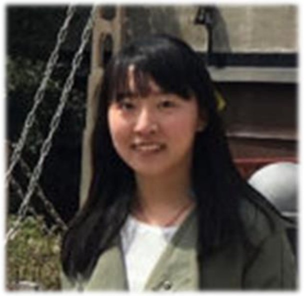
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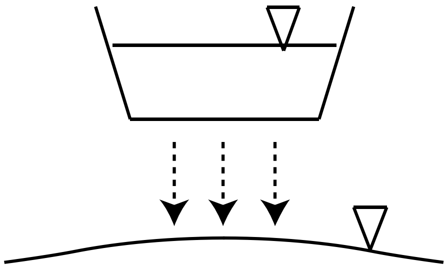
HARRIS COUNTY FLOOD CONTROL DISTRICT

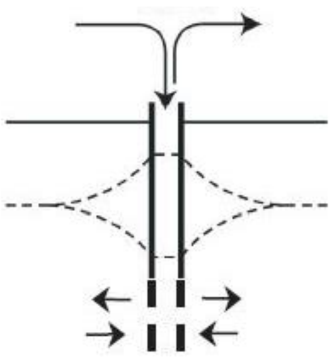
HARRIS COUNTY PRECINCT 4 COMMISSIONER R. JACK CAGLE

What is Managed Aquifer Recharge (MAR)?

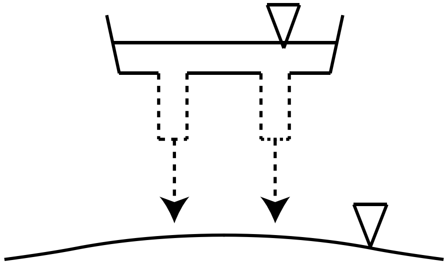
Infiltration Basins



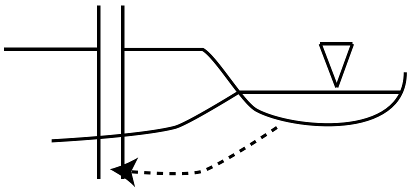
Aquifer Storage and Recovery (ASR)



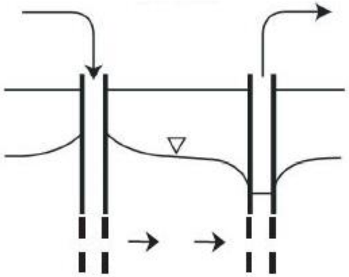
Dry Wells



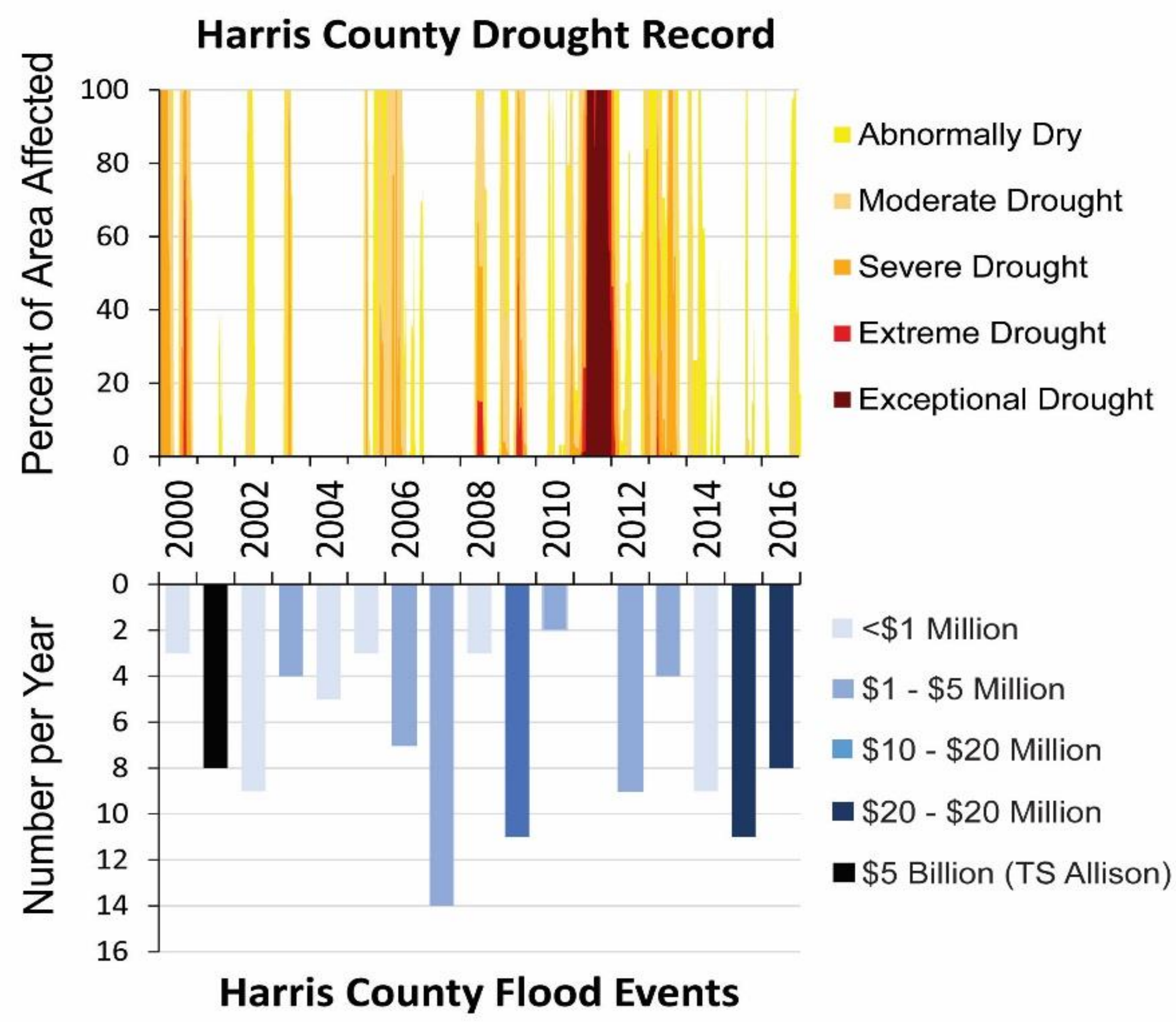
Bank Filtration



Aquifer Storage, Transfer and Recovery (ASTR)



Why does Harris County need MAR?



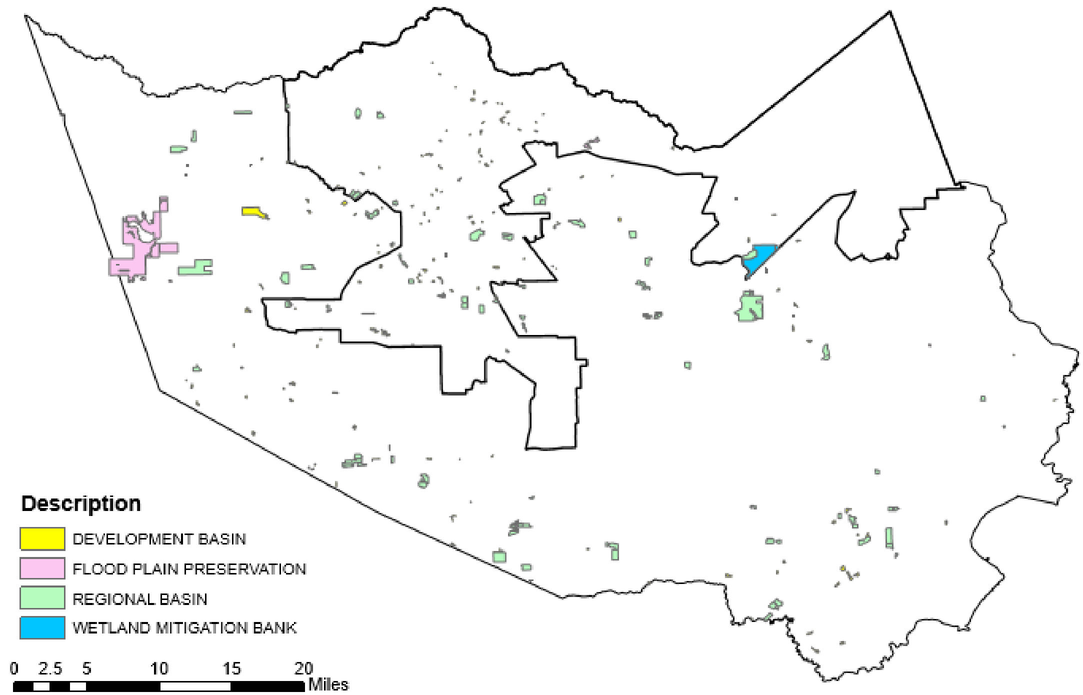
MAR for Stormwater & Flood Control?

Research Question: Can MAR be used as a flood control tool in Harris County?

Methods: Feasibility study followed by pilot

Table 3.1.1 – List of Selected Harris County Detention Basins and

Basin Number[1]	Watershed[1]	Design Volume[1] (acre-ft)	Estimated Area[1] (acres)	Surface Soil Conductivity[2] (mm/d)	Depth First V (ft)
K500-05-00	Cypress Creek	160	38.8	230	4
K500-01-00	Cypress Creek	426	137	470	24
P500-02-00	Greens Bayou	1957	260.7	29	8.5
P545-01-00	Greens Bayou	2015	279.6	2300	3
P500-03-00	Greens Bayou	2349	185	780	2
E515-01-00	White Oak Bayou	111	14	780	12
E500-12-00	White Oak Bayou	241	25.3	780	16
E500-04-00	White Oak Bayou	283	28.4	470	2
E500-11-00	White Oak Bayou	296	25.7	780	3
E535-01-00	White Oak Bayou	400	43.5	780	6



Quantity Challenge: Mismatch in Scale between Surface and Subsurface

- Excellent for promoting groundwater storage
- Good for stormwater management
- Inadequate for flood control

Percent Volume of Standard Basin Emptied (400 acre-ft)	Flow Rate (MGD) Needed			
	1 day	2 days	3 days	7 days
25%	33	16	11	5
50%	65	33	22	9
75%	98	49	33	14
100%	130	65	43	19

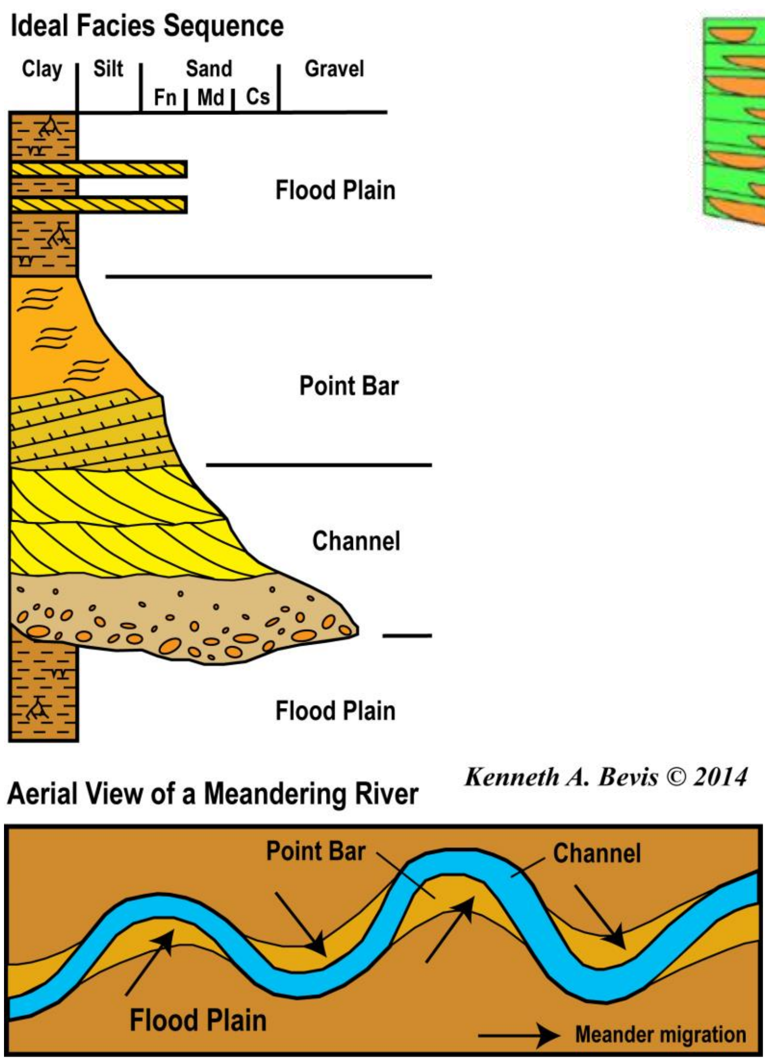
Quality Challenge: Treatment Needed

Pretreatment needed for stormwater pollutants, as shown in White Oak Bayou example

Type	Constituent	Units	Median	Maximum
Metals	Cadmium	µg/L	0.3	2.5
	Copper	µg/L	8.33	20.5
	Lead	µg/L	5	31.5
	Manganese	mg/L	1.51	3.14
	Zinc	µg/L	37.4	110
Nutrients	Orthophosphate	mg/L	0.1	0.1
	Phosphorus as P	mg/L	0.213	1.12
	Nitrogen, Nitrate (NO3) as N	mg/L	0.504	3.92
	Nitrogen, Nitrite (NO2) as N	mg/L	0.088	0.332
Microbial	Escherichia coli	MPN/100mL	15531	90900
	Fecal Coliform	CFU/100mL	16000	76000
Other	Oil and Grease, Total Recoverable	mg/L	2.5	5.35
	Suspended Sediment Concentration	mg/L	97	1820
	Total dissolved solids	mg/L	107	134
	Total suspended solids	mg/L	64	1450

Red = exceeds primary standards, **Orange** = exceeds secondary standards, **Yellow** = potentially problematic

Geology Challenge: Sedimentary Layers



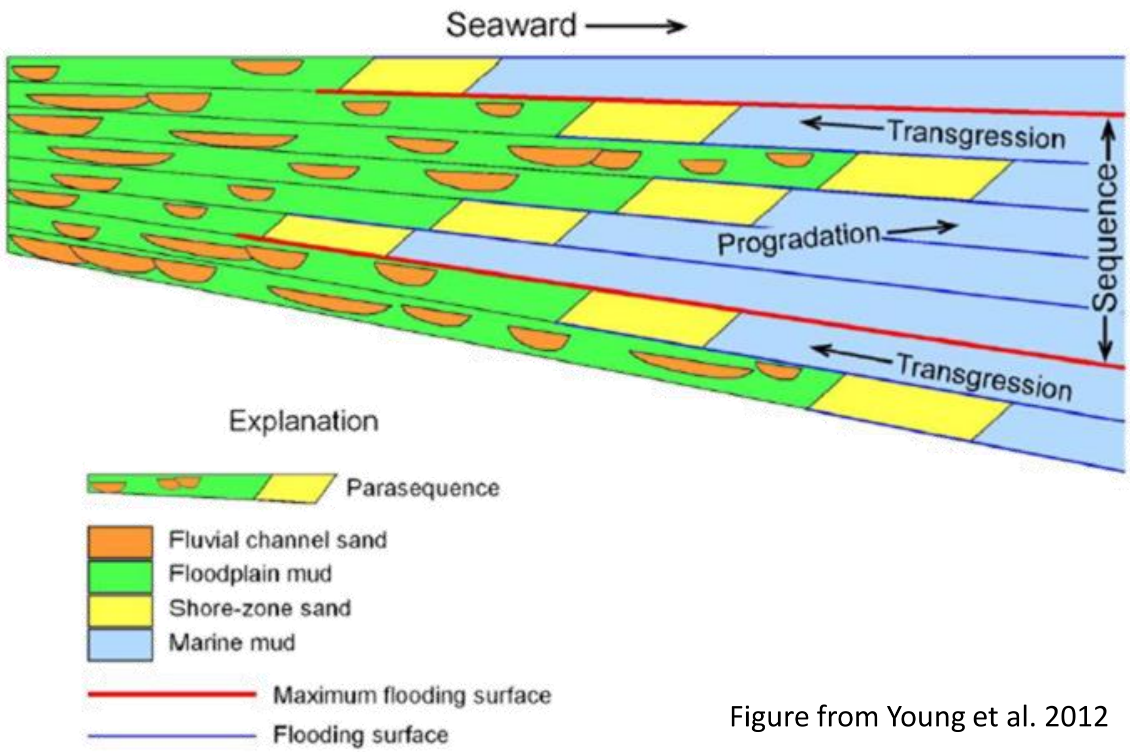
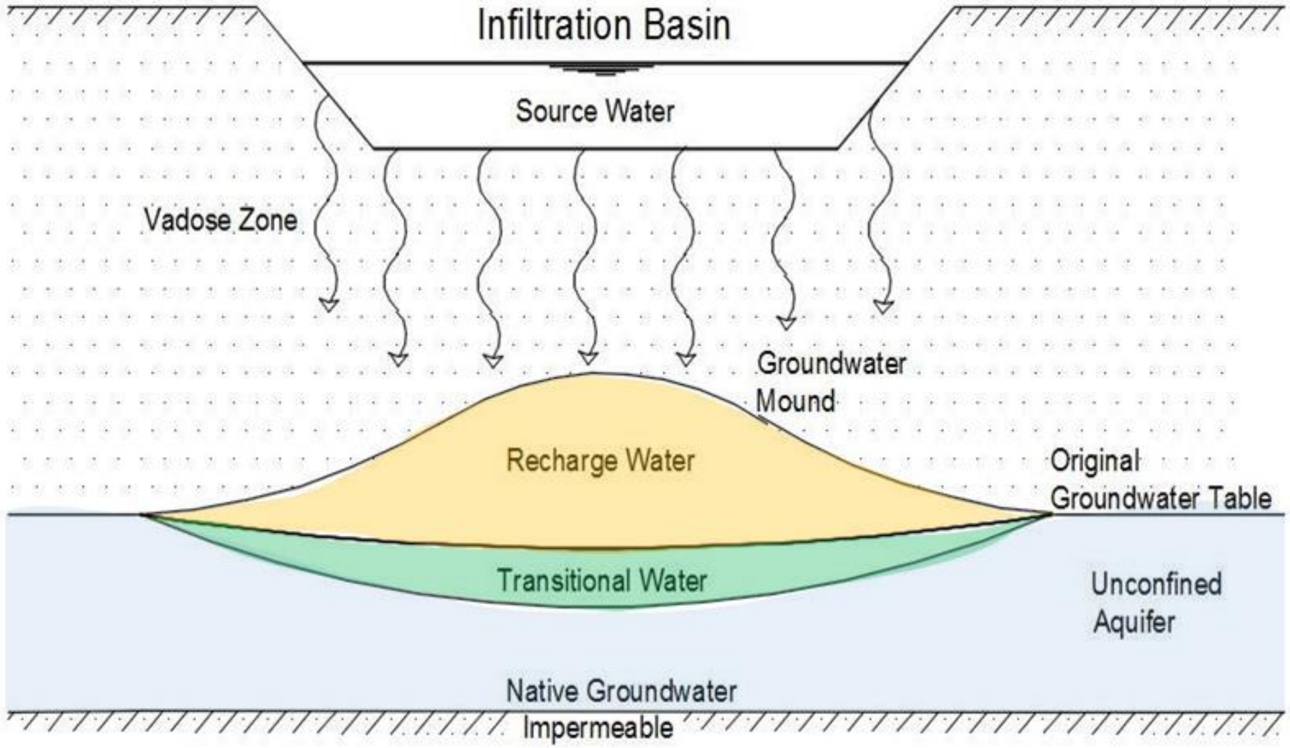


Figure from Young et al. 2012

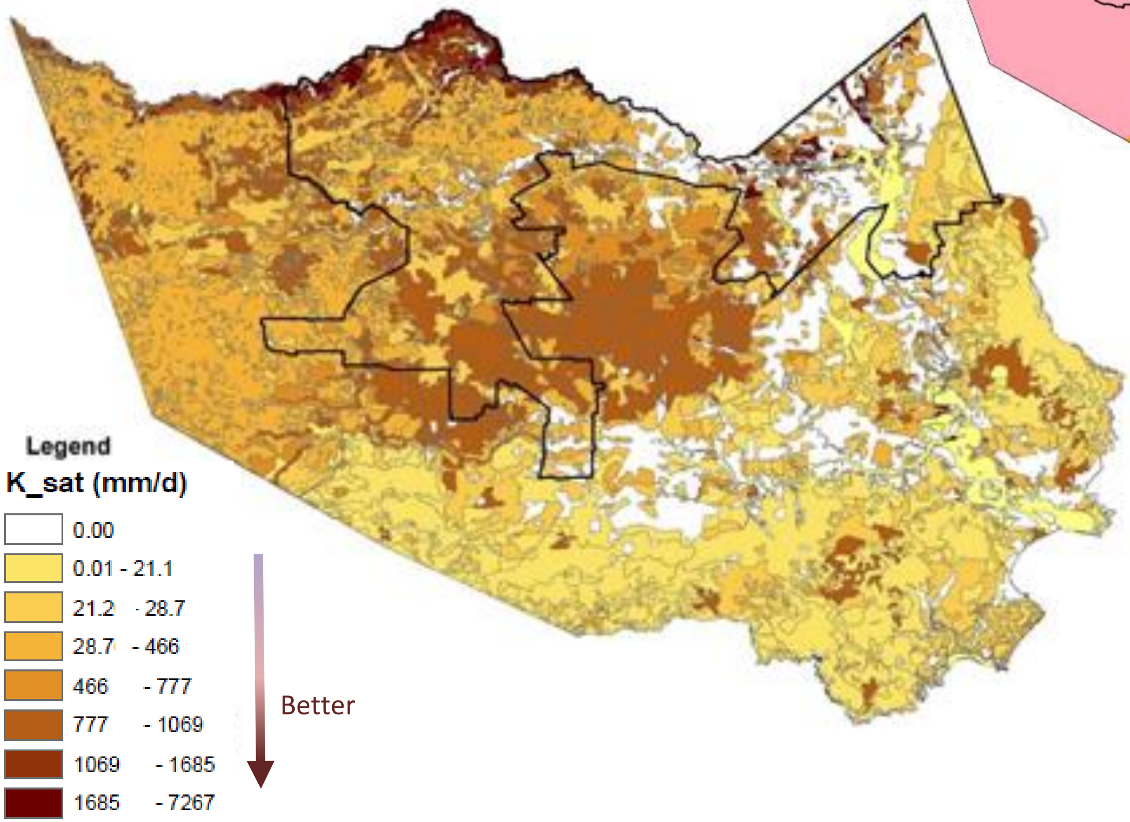
Method 1: Enhanced Infiltration

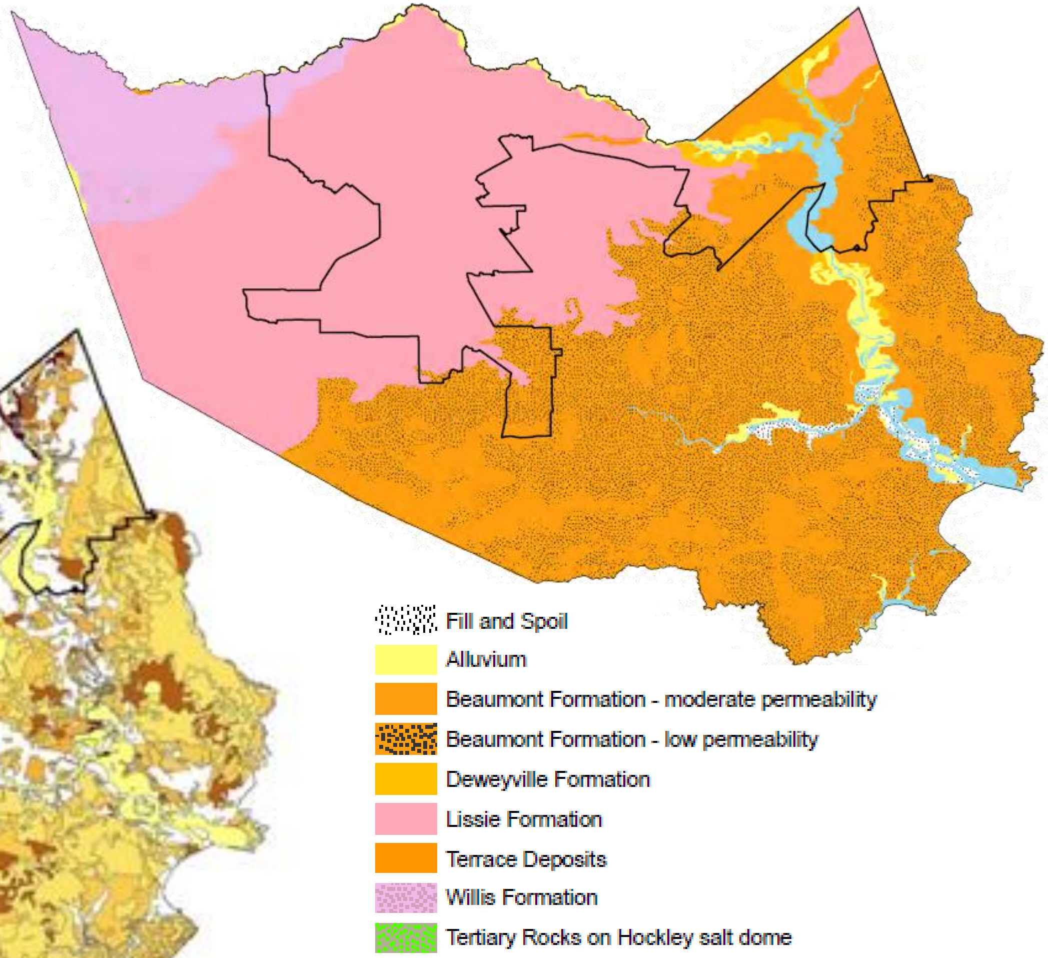
Approach: Alter existing basins to promote infiltration. Could include soil amendments, trenches, proprietary systems



Method 1: Enhanced Infiltration

Findings: Target Lissie or Willis Formations





Data source: USDA Web Soil Survey (2017)

Method 1: Enhanced Infiltration

Findings: Under a unit head gradient, a reasonable fraction of stormwater should infiltrate northern soils

Percent Volume of Standard Basin Emptied (400 acre-ft)	Infiltration Rate (mm/d) Needed			
	1 day	2 days	3 days	7 days
25%	625	313	208	89
50%	1250	625	417	179
75%	1875	938	625	268
100%	2500	1250	833	358

$$I = \frac{f * H_{basin}}{t} = \frac{0.25 * 8.2\ ft}{1\ day} = 2\ \ ft/d = 610\ mm/d$$

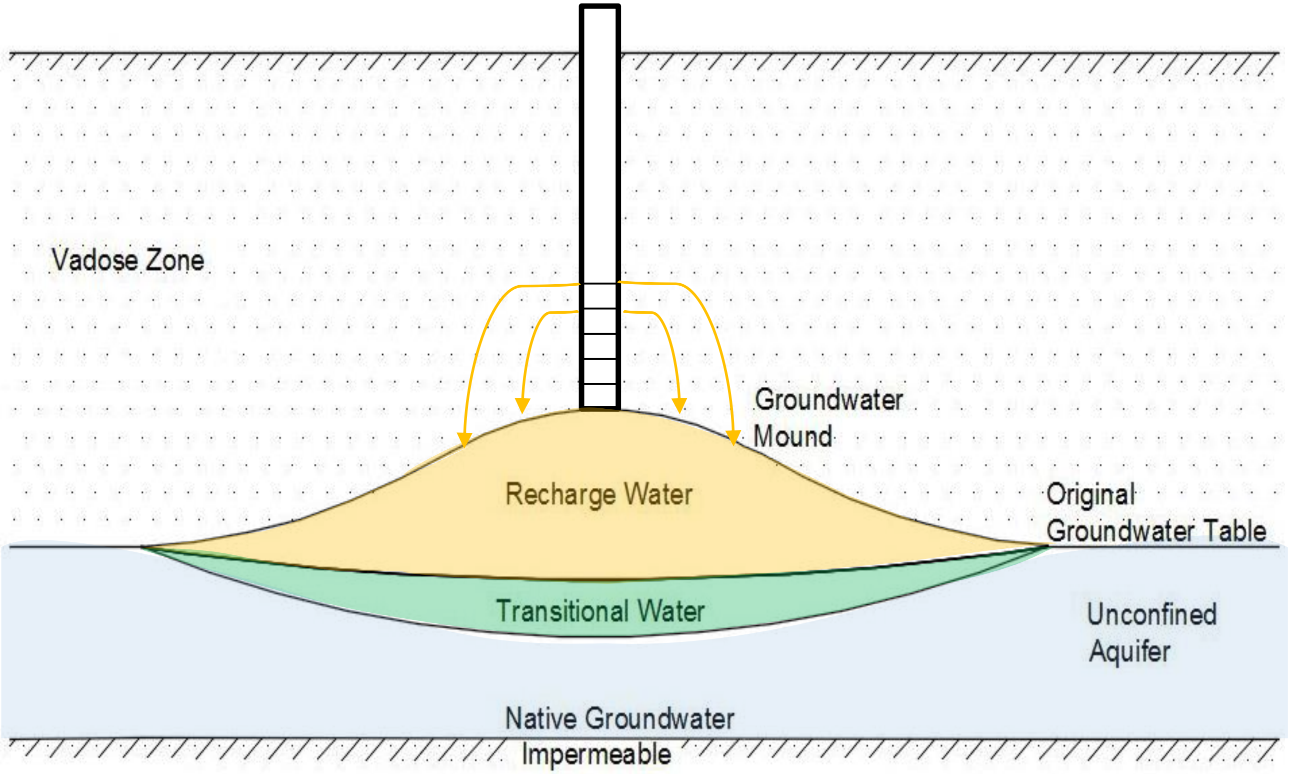
Method 1: Enhanced Infiltration

Findings: Conversion of existing and future detention ponds to enhanced infiltration basins may be easiest alternative

Project Brays, HCFCD, 2017

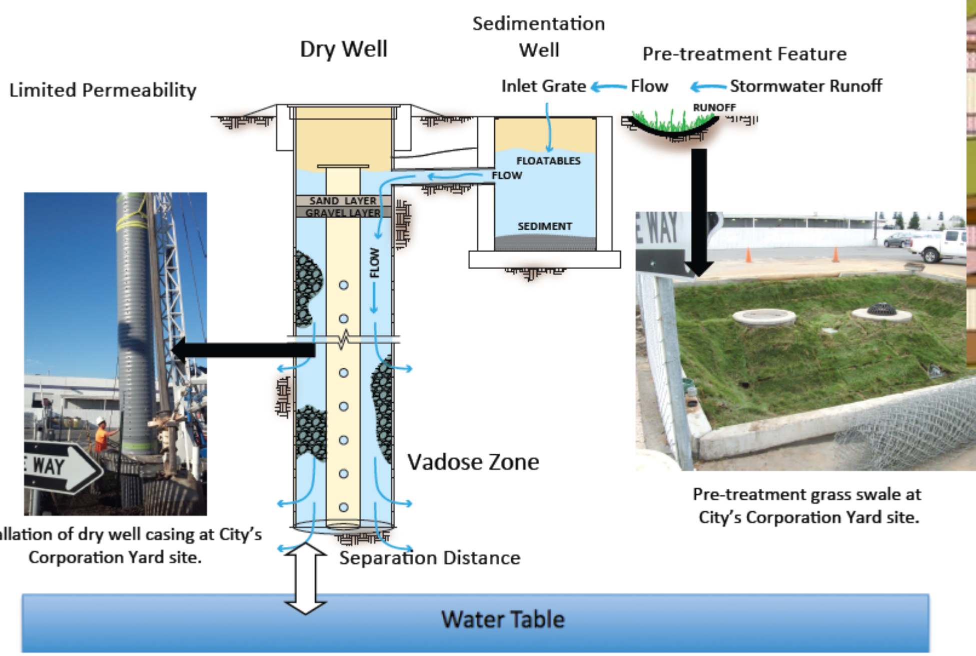
Method 2: Dry/Unsaturated Zone Wells

Approach: Infiltration wells into unsaturated layers of aquifer, near basins or distributed (e.g., low-impact development)



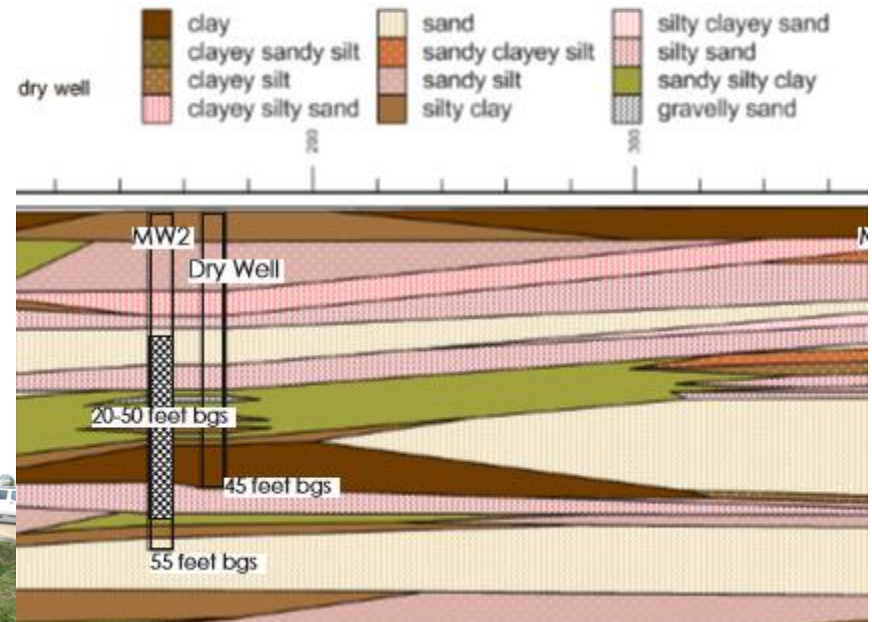
Method 2: Dry/Unsaturated Zone Wells

Findings: Works well in highly layered sediments, can be coupled with passive pretreatment



Installation of dry well casing at City's Corporation Yard site.

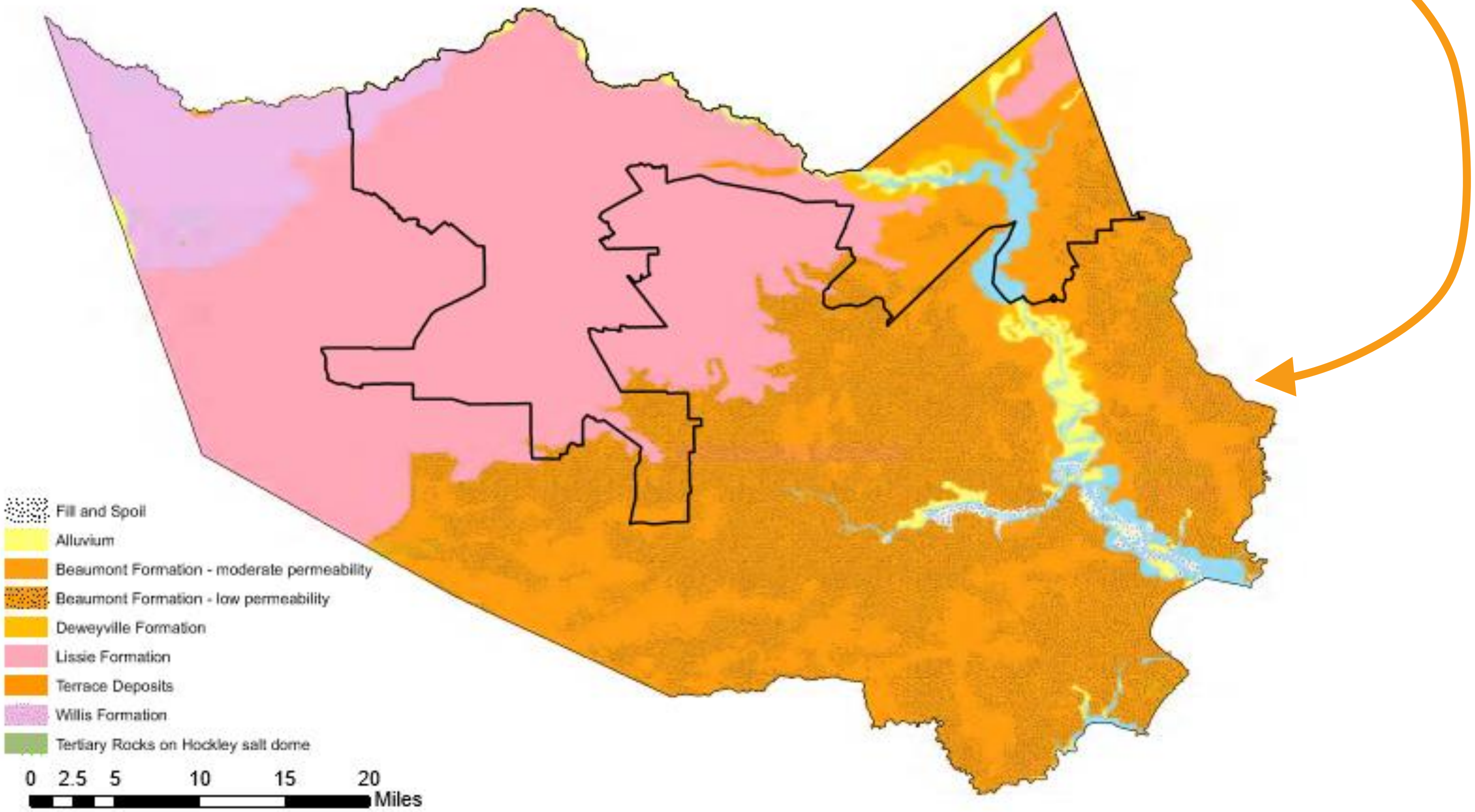
Pre-treatment grass swale at City's Corporation Yard site.



Images from City of Elk Grove, CA

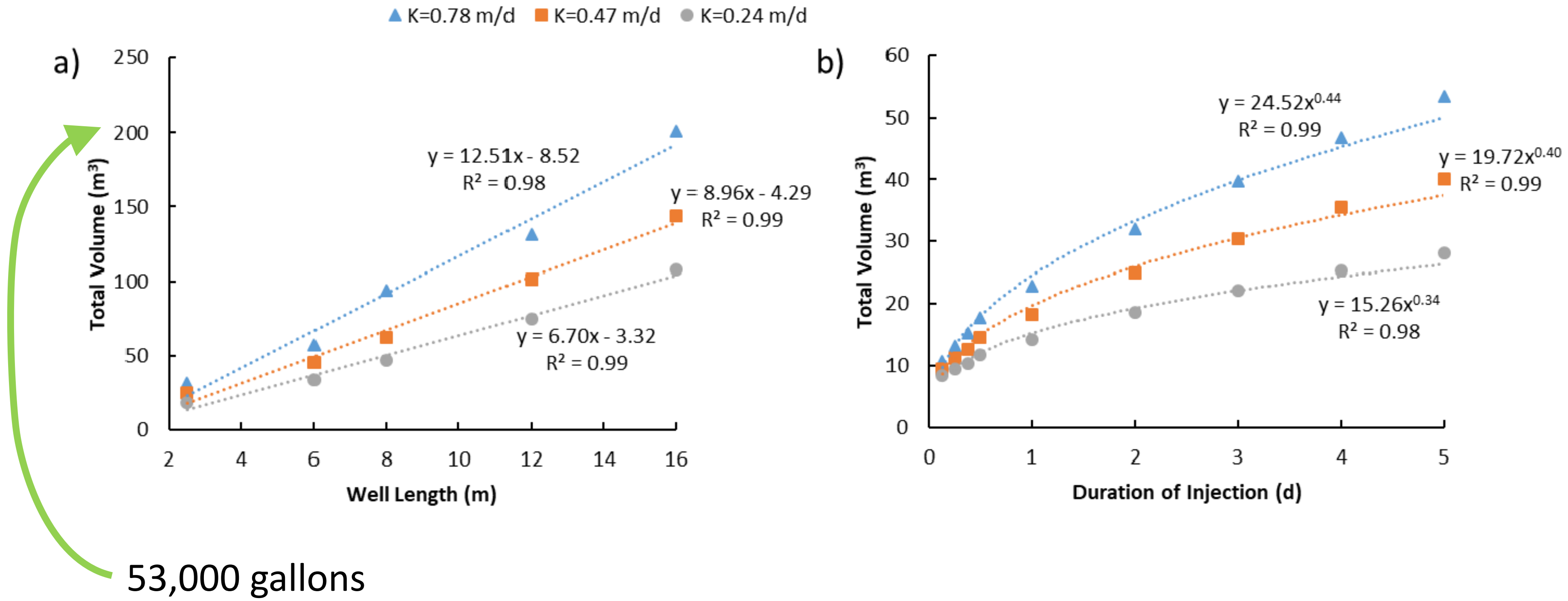
Method 2: Dry/Unsaturated Zone Wells

Findings: In areas with low permeability clays, dry wells into Chicot better than infiltration basins



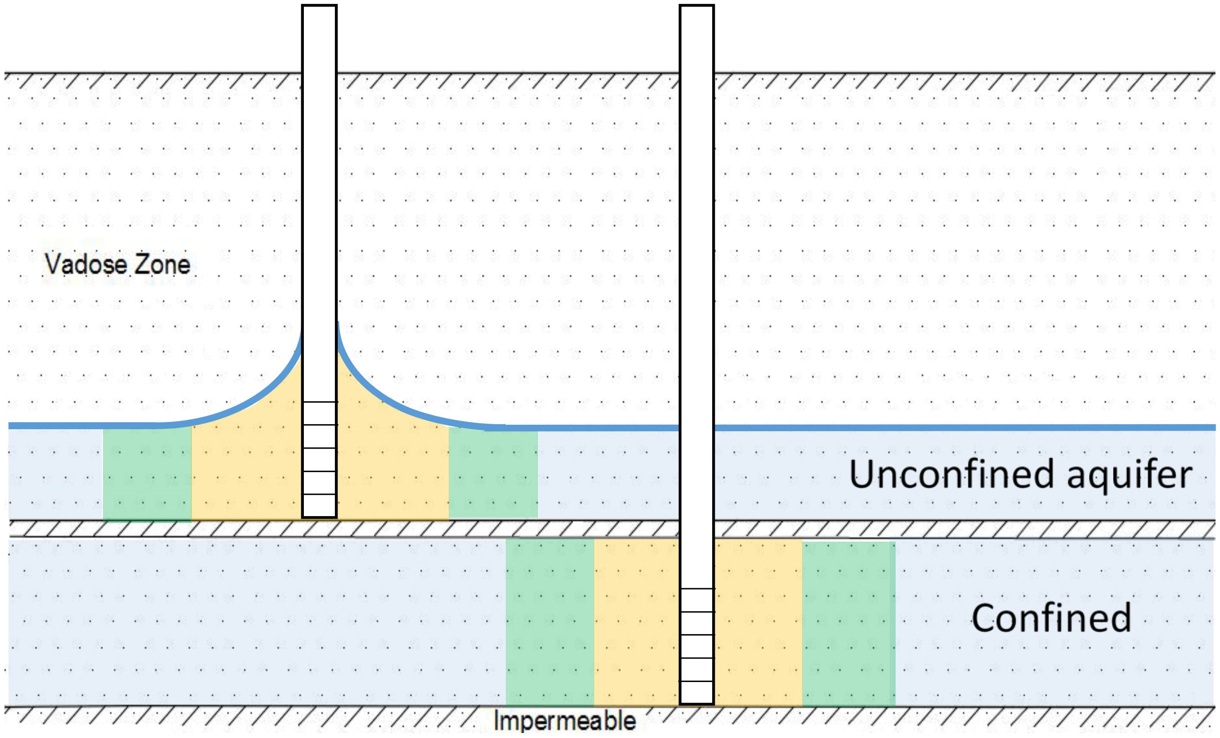
Method 2: Dry/Unsaturated Zone Wells

Findings: Would need large, distributed system to achieve target volumes



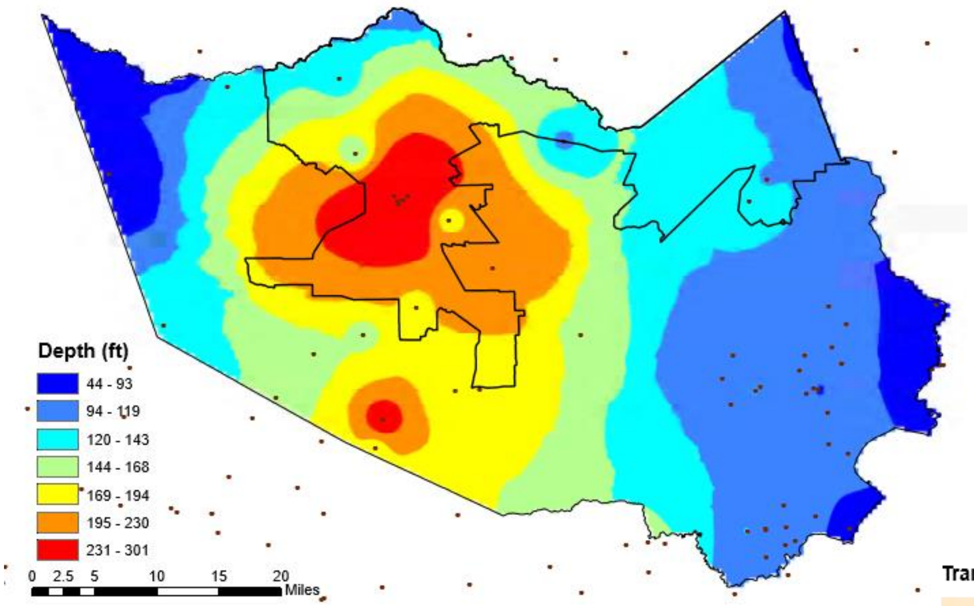
Method 3: Traditional ASR/ASTR

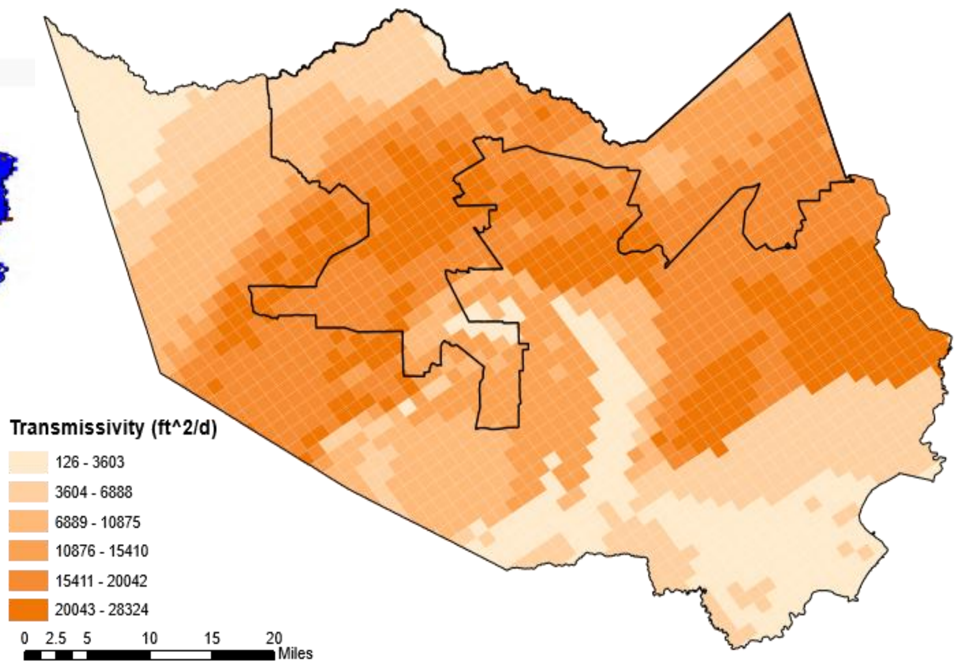
Approach: Inject water from basins or treatment plants into aquifer at high surface water flows. Possibly allow neighboring municipalities to recover from own wells.



Method 3: Traditional ASR/ASTR

Findings: Chicot portion of the Gulf Coast aquifer most amenable to ASR

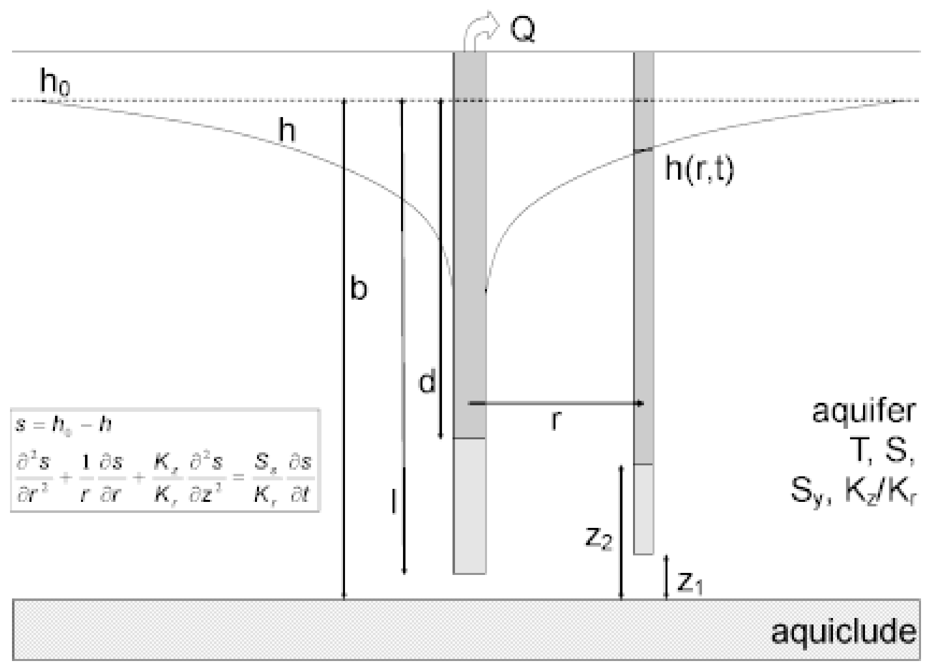




Method 3: Traditional ASR/ASTR

Findings:

- One well can passively flow at up to 13 MGD
  - Empties “standard basin” in 13 days
- Pumping can increase flow rate
  - Uncertain as to safe limits to applied pressure
  - Best guess is <190 psi
  - Standard pumps sufficient



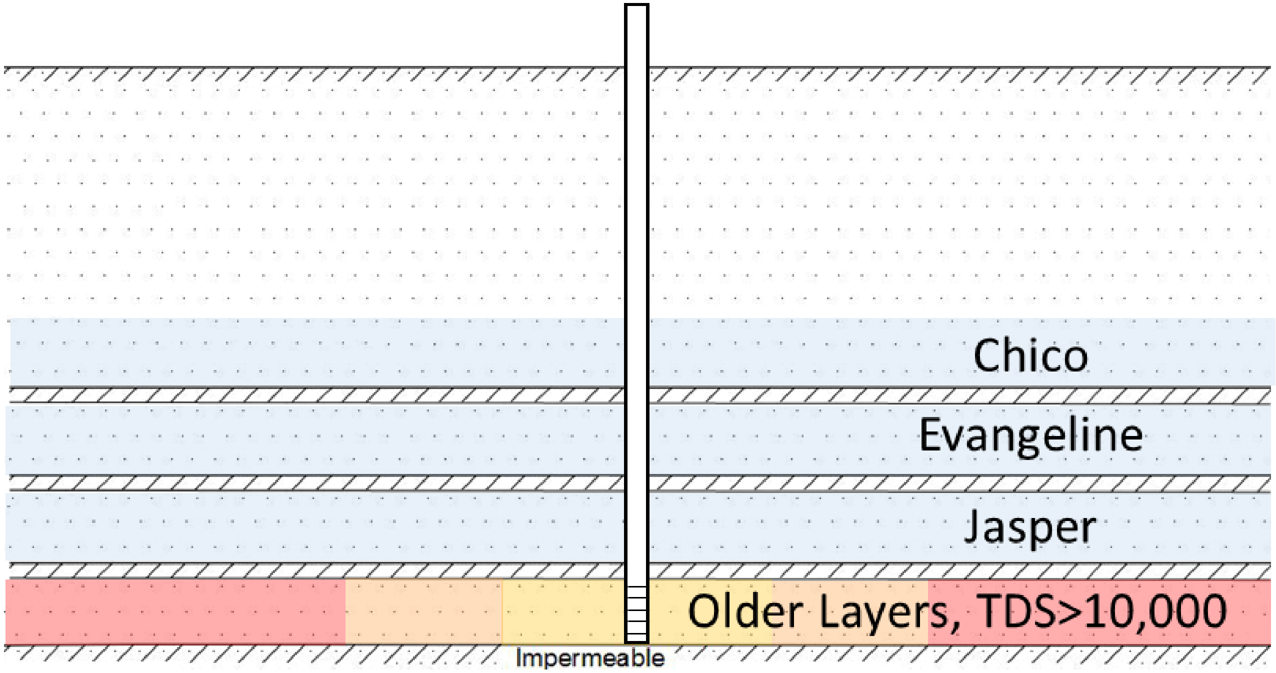
Method 3: Traditional ASR/ASTR

Findings: However, one injection well at 13 MGD would take 13 days to empty standard basin, need multiple

<table>
<tr><th colspan="2" rowspan="2">Spacing Required (ft)</th><th colspan="12">Injection Period (days)</th></tr>
<tr><th colspan="3">1</th><th colspan="3">2</th><th colspan="3">3</th><th colspan="3">7</th></tr>
<tr><th colspan="2">Number of Wells</th><th>4</th><th>8</th><th>16</th><th>4</th><th>8</th><th>16</th><th>4</th><th>8</th><th>16</th><th>4</th><th>8</th><th>16</th></tr>
<tr><td rowspan="4">% of basin to inject</td><td>25%</td><td>130</td><td><100</td><td><100</td><td colspan="3"><100</td><td colspan="3"><100</td><td colspan="3"><100</td></tr>
<tr><td>50%</td><td>x</td><td>360</td><td>270</td><td>170</td><td><100</td><td><100</td><td colspan="3"><100</td><td colspan="3"><100</td></tr>
<tr><td>75%</td><td>x</td><td>2500</td><td>470</td><td>1600</td><td>320</td><td>180</td><td>220</td><td><100</td><td><100</td><td colspan="3"><100</td></tr>
<tr><td>100%</td><td>x</td><td>x</td><td>940</td><td>x</td><td>600</td><td>390</td><td>980</td><td>260</td><td>170</td><td colspan="3"><100</td></tr>
</table>

Method 4: Deep Formation Injection

Approach: Inject water from basins into non-aquifer layers (TDS>10,000) or abandoned salt domes.



Method 4: Deep Aquifer Injection

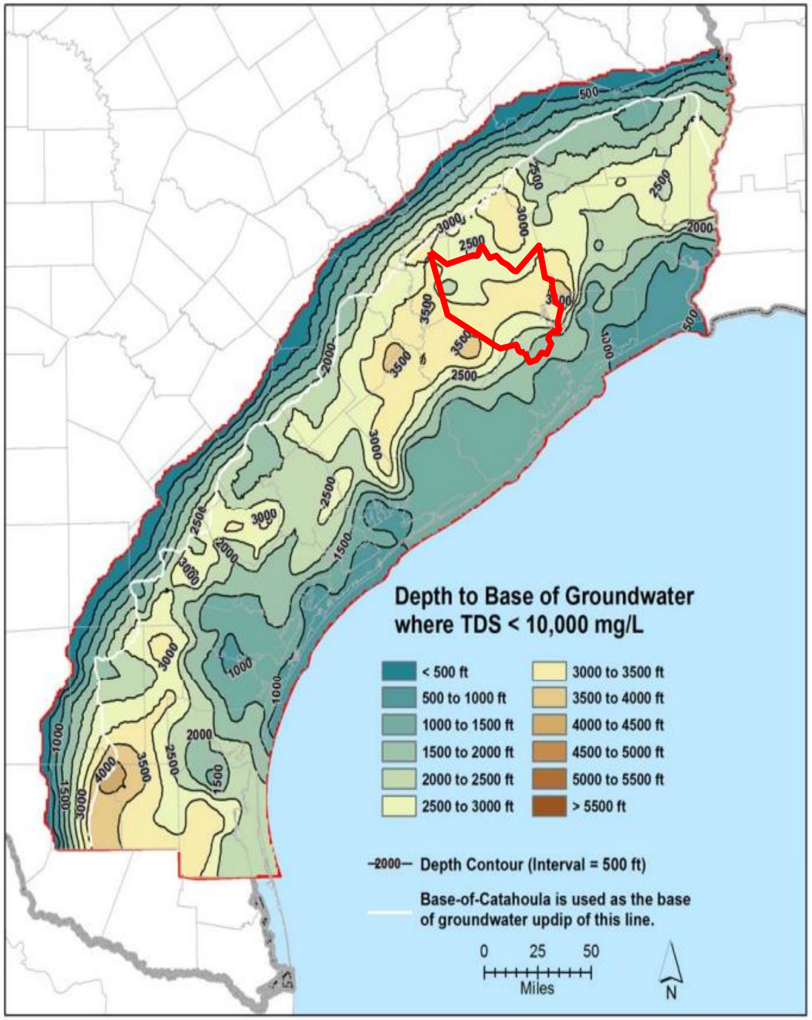


Figure modified TWDB report, INTERA (2016)

Findings:

- Frio or Yegua formations
- Injection rates between approximately 600-700 gpm at 800 – 1000 ft spacing
- Massive construction costs, ~$5M per well

Regulatory Challenge: Evolving Laws

Findings: Current regulatory environment limits some technologically feasible solutions

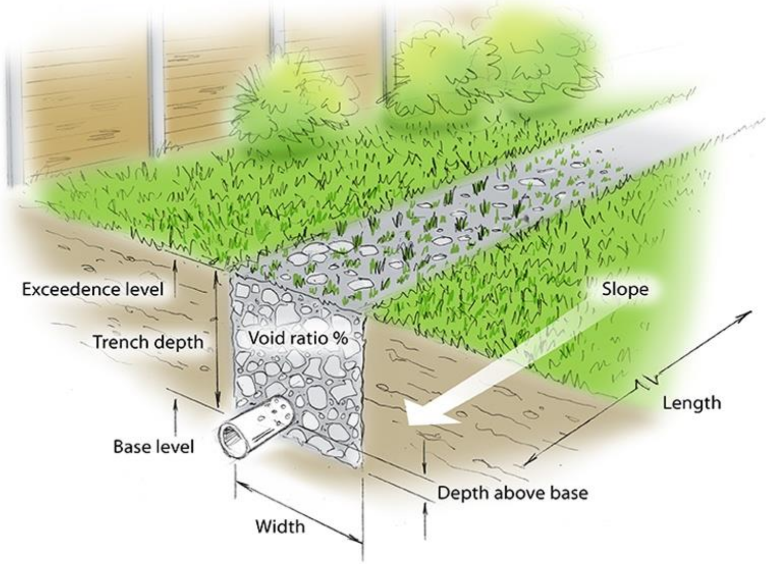
MAR/ASR Options	Surface Water Permit	Injection Permit
1. Natural Infiltration	None	None
2. Dry Well Infiltration	Possible	**Yes, Class V TCEQ permit**
3. ASR Injection	**Yes**	**Yes, Class V TCEQ permit**
4. Deep Aquifer Injection	**Yes/Beneficial Use?**	**Yes, Class I –** above 10,000 mg/L TCEQ permit ?

DRI Phase II: Pilot Enhanced Infiltration

Approach: Test three systems, control area, and outlet structure changes in detention basin in N. Harris County

DRI Phase II: Pilot Enhanced Infiltration

Infiltration Trenches



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Soil Amendments

Takeaways

- ASR/MAR typically not fast enough for flood control, but can be an important part of a stormwater management portfolio.
- Techniques should be matched to geology – layering and sand content key considerations.
- Stormwater quality and pretreatment needs/logistics still an open question.
- Pilot aimed at showing non-degredation of groundwater during enhanced infiltration.
- Regulatory environment may need some clarifications.

Questions?

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Geology Challenge: Sedimentary Layers

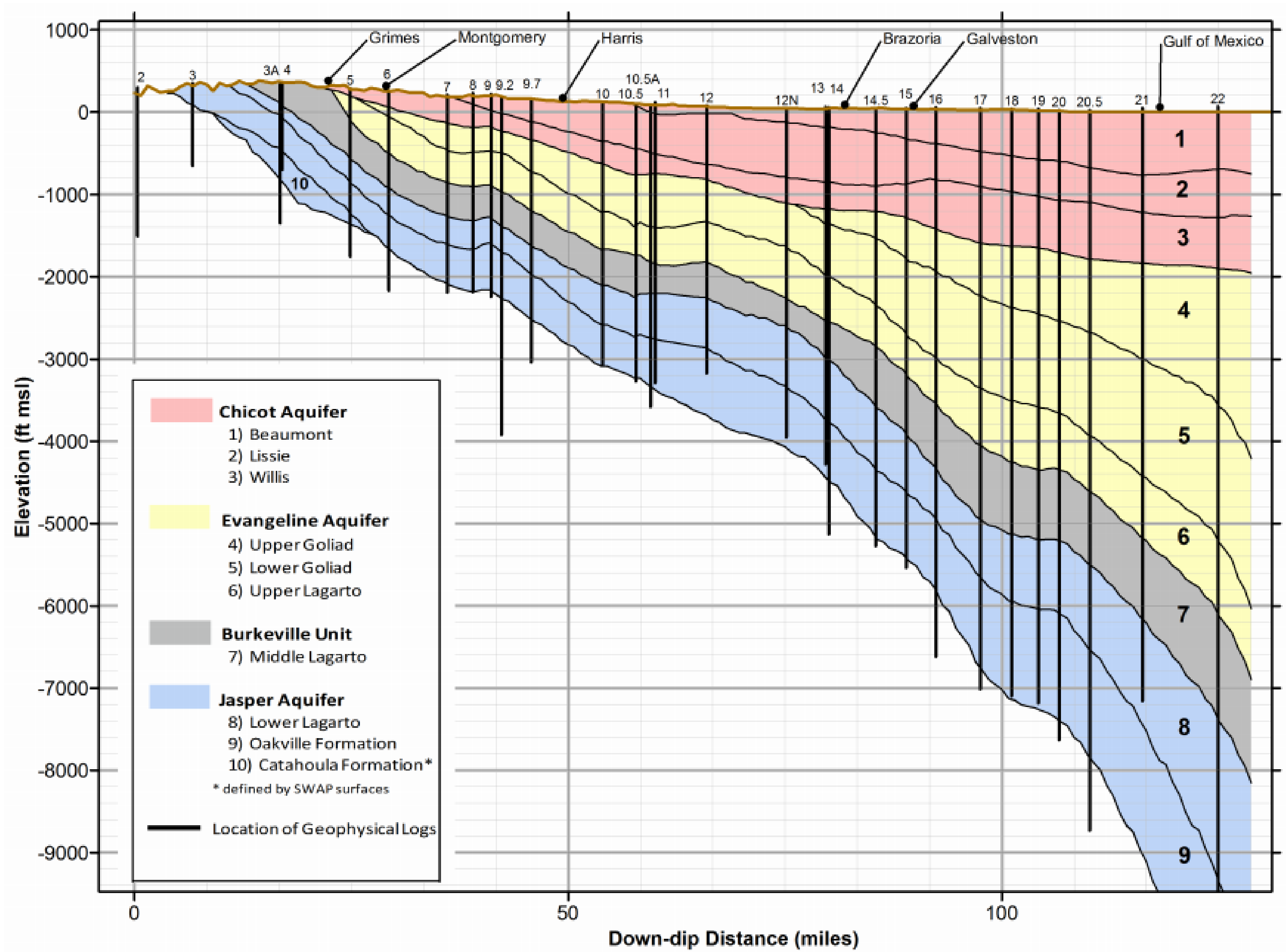
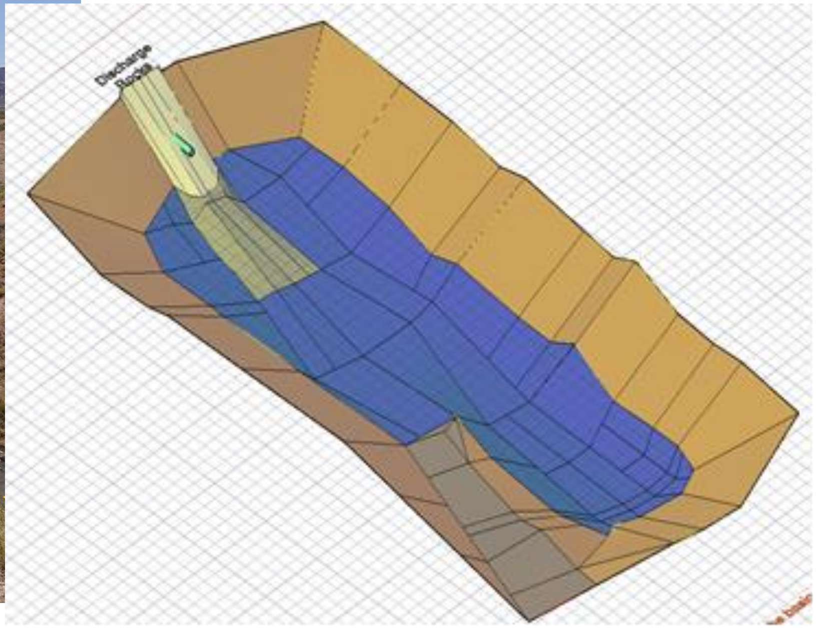


Figure 6-4 **Vertical cross-section of the geological units near dip section 7 in Figure 1-1.**

Method 1: Enhanced Infiltration

Background: El Paso infiltration systems have rates between 6 – 32 ft/d, depending on clogging and perched layers



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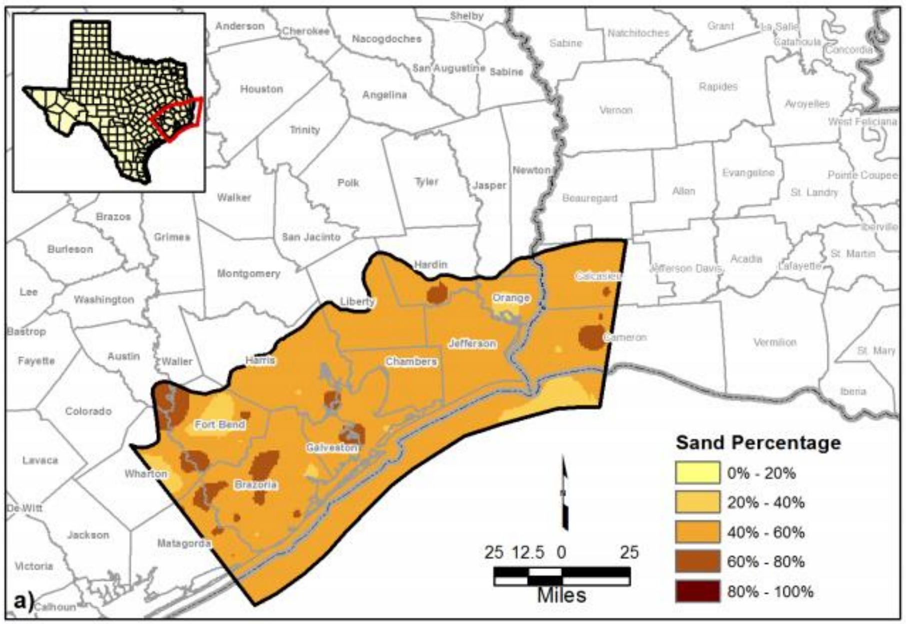
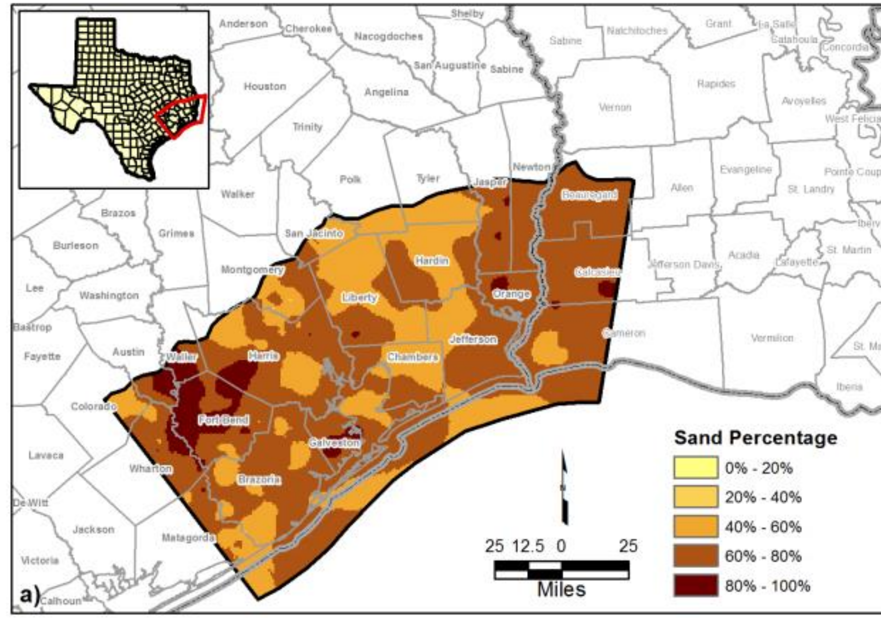
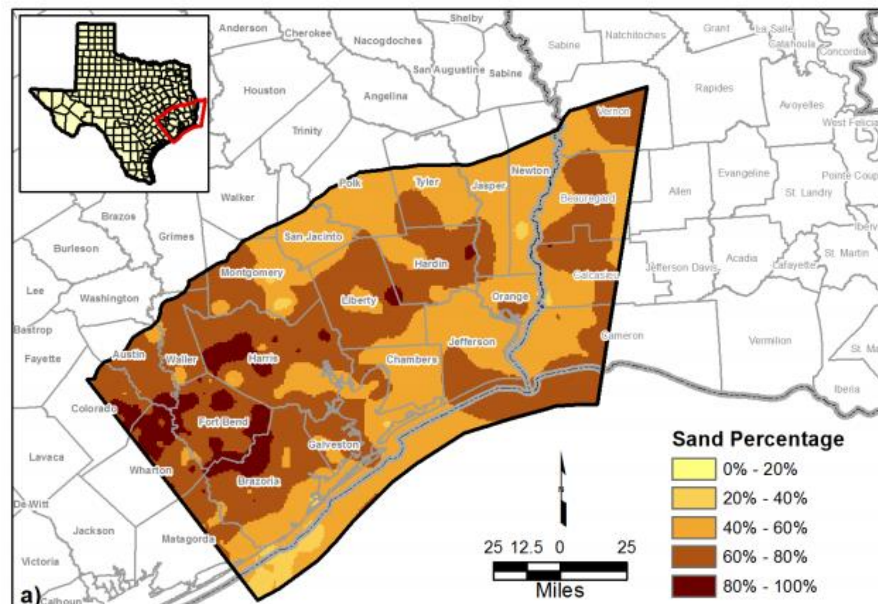
Findings: Target Lissie or Willis Formations



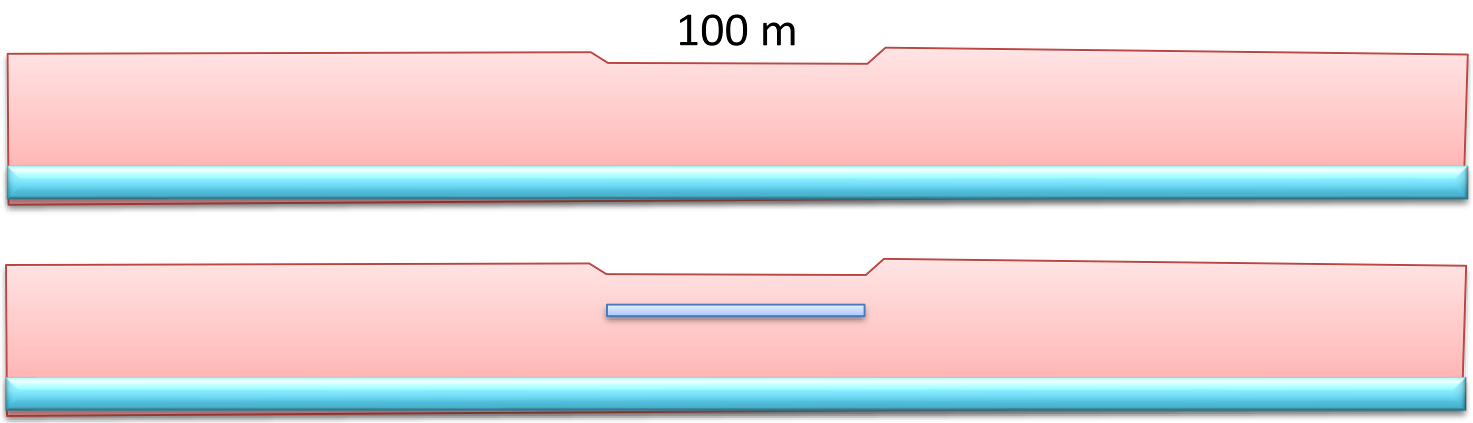


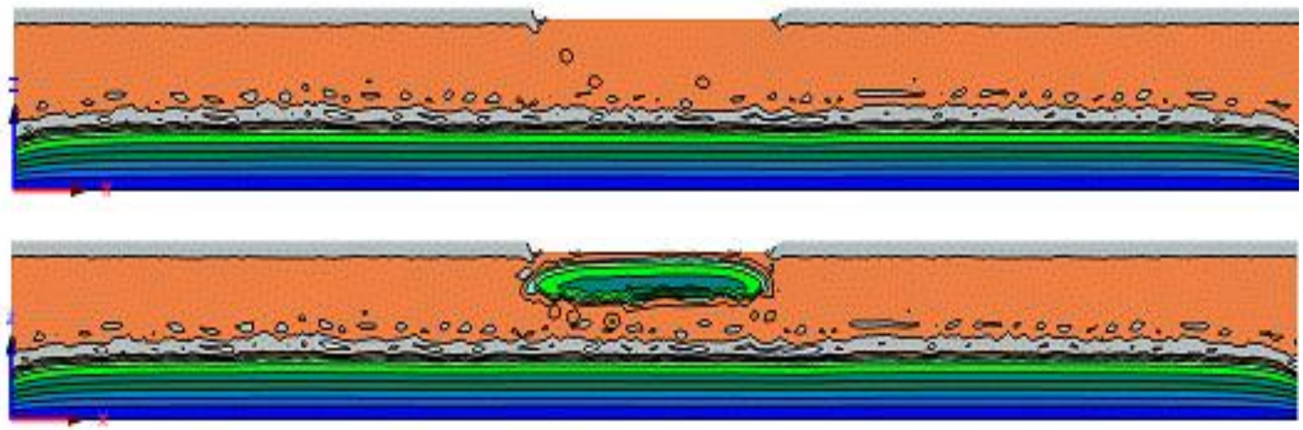


Sand percentages in Beaumont (left), Lissie (top right), and Willis (bottom right) Formations. Figures from Young et al. 2012

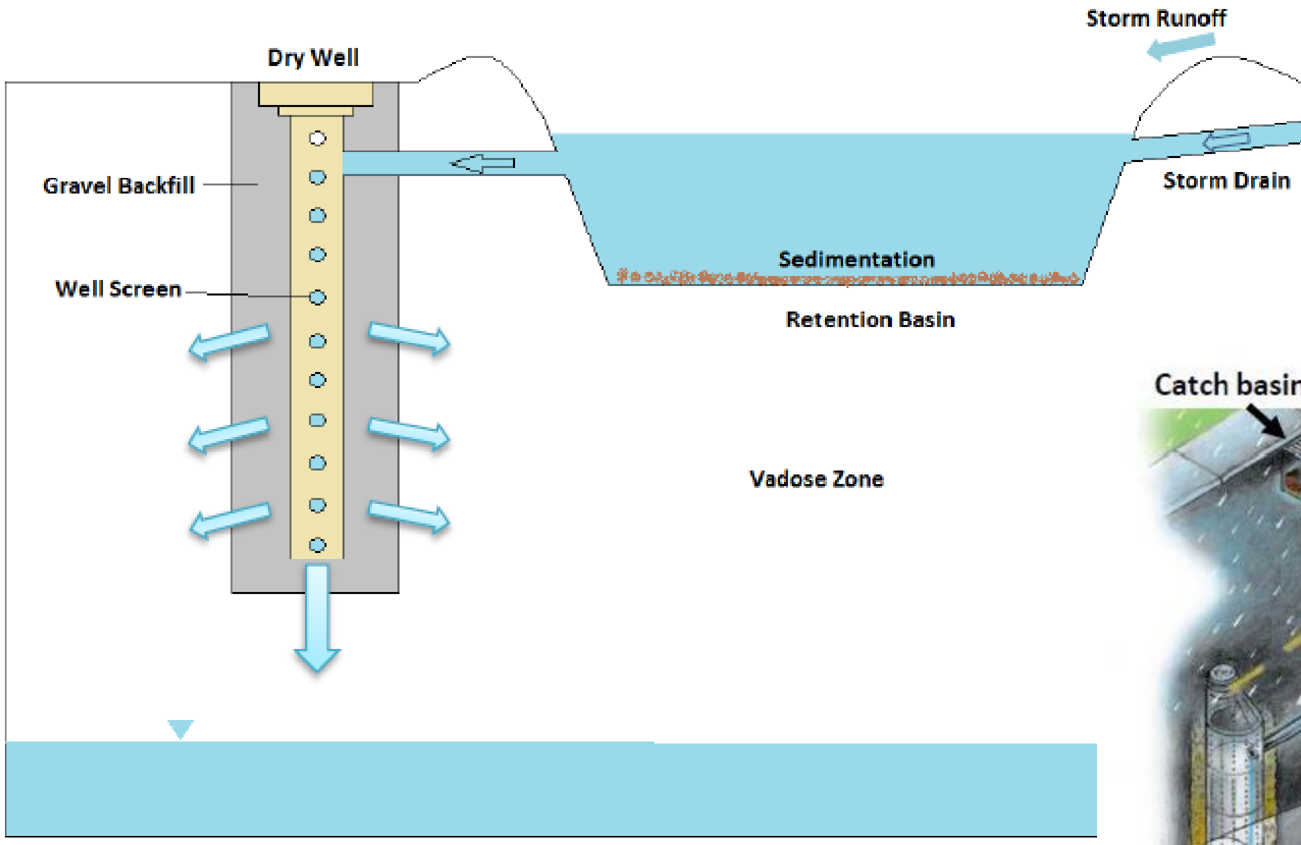
Method 1: Enhanced Infiltration

Findings: HYDRUS modeling helps estimate infiltration





Method 2: Dry/Unsaturated Zone Wells



Method 3: Traditional ASR/ASTR

Findings: Large scale feasibility study (Smith et al., 2018) suggested Chicot