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Restoring Watershed Function and Recharging the Local Aquifer

Ricardo Aguirre, PE, D.WRE, CFM, AP

Director of Land Management and Water Security

Overview

- Background
- Problems We Face
- Watershed Moments
- First Principles
- Projects

Background

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Pipes, Channels, and Holes in the Ground

Problems We Face

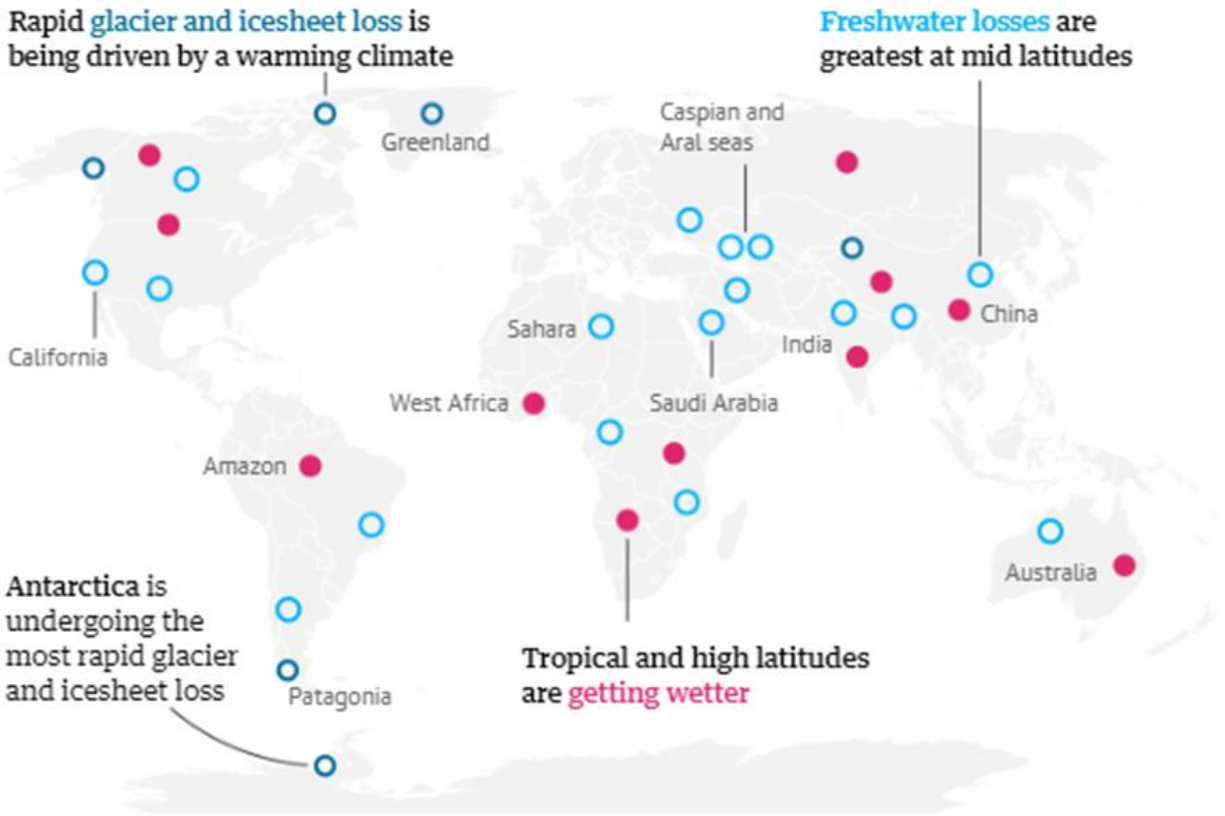
Water shortages to be key environmental challenge of the century, Nasa warns

Freshwater supplies have already seriously declined in 19 global hotspots - from China to the Caspian Sea - due to overuse, groundbreaking study shows

▲ The Theewaterskloof Dam, a key source of water supply to Cape Town, South Africa ahead of the current water crisis. Photograph: Halden Krog/AP

Water shortages are likely to be the key environmental challenge of this century, scientists from Nasa have warned, as new data has revealed a drying-out of swaths of the globe between the tropics and the high latitudes, with 19 hotspots where water depletion has been dramatic.

Nasa has identified more than 30 hotspots where freshwater is in particular danger



Guardian graphic. Source: Nasa

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Watershed Moments

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Watershed Moments

Soil Organic Matter 1.7%
Next Day - Practically no infiltration

Soil Organic Matter 5%
Next Day - Practically total infiltration

North Dakota - Courtesy: Gabe Brown

- **Soil Organic Matter (SOM) and Soil Water Holding Capacity**
- **Every 1% increase of SOM land can retain an additional 20,000 to 60,000 gallons of water/acre**

Principle 1: The Lindy Effect

The Future Life Expectancy of a Thing is Proportional to its Age

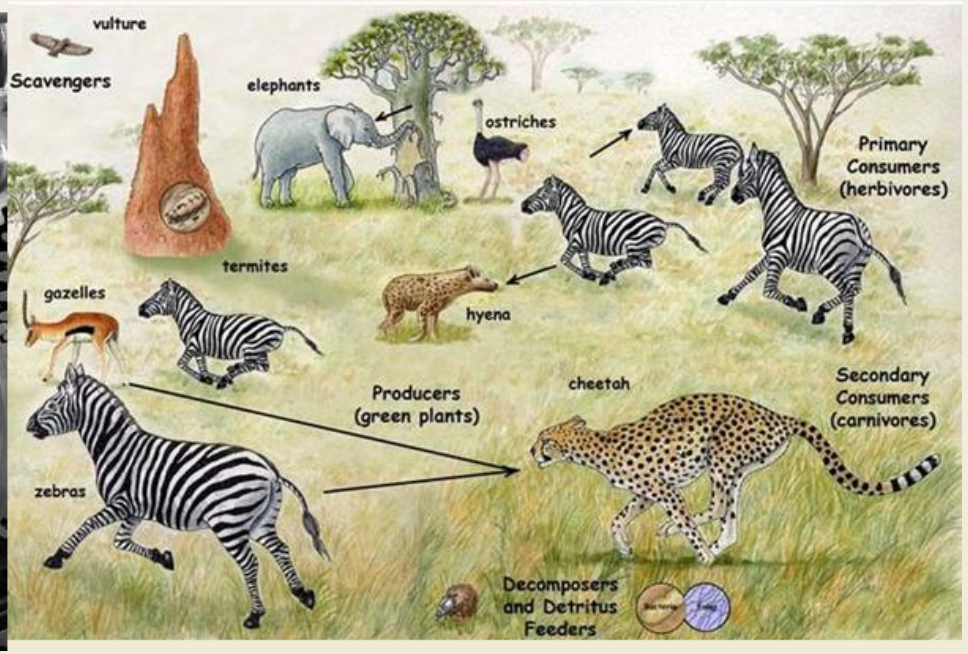
Principle 1: The Lindy Effect

The Future Life Expectancy of a Thing is Proportional to its Age

Complicated

Science and Technology
(about 150 years)

Complex



Life on Planet Earth
(about 4 billions years)

Principle 1: The Lindy Effect

Complicated

Mechanical	Nonmechanical
Development of	*Management of*
Transport: air, land, water	Agriculture
Communication: radio, television, telephone, satellite	Rangelands
Weapons: conventional, nuclear, laser	Forests
Space exploration	Air quality
Computer technology: artificial intelligence, robotics	Fisheries
Home building and home appliance technology	Water supplies and quality
Energy plants: nuclear, hydroelectric, etc.	Erosion
Medical technology: brain scanners, eyeglasses/ contact lenses, medicines, etc.	Economies
Genetic engineering	Wildlife (including insects)
Chemical technology: synthetic fertilizers	Human relationships
	Human health
(Ever-increasing success story testifying to the marvels of science)	*(Ever-increasing problems testifying to our lack of understanding*

Complex

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The Lindy Effect

Complicated

You know what you don't know.

Mechanical	Nonmechanical
Development of	*Management of*
Transport: air, land, water	Agriculture
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The Lindy Effect

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(Ever-increasing success story testifying to the marvels of science)	*(Ever-increasing problems testifying to our lack of understanding*

Complex

You don't know what you don't know..

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Overlaying Complicated Treatments on Complex Systems

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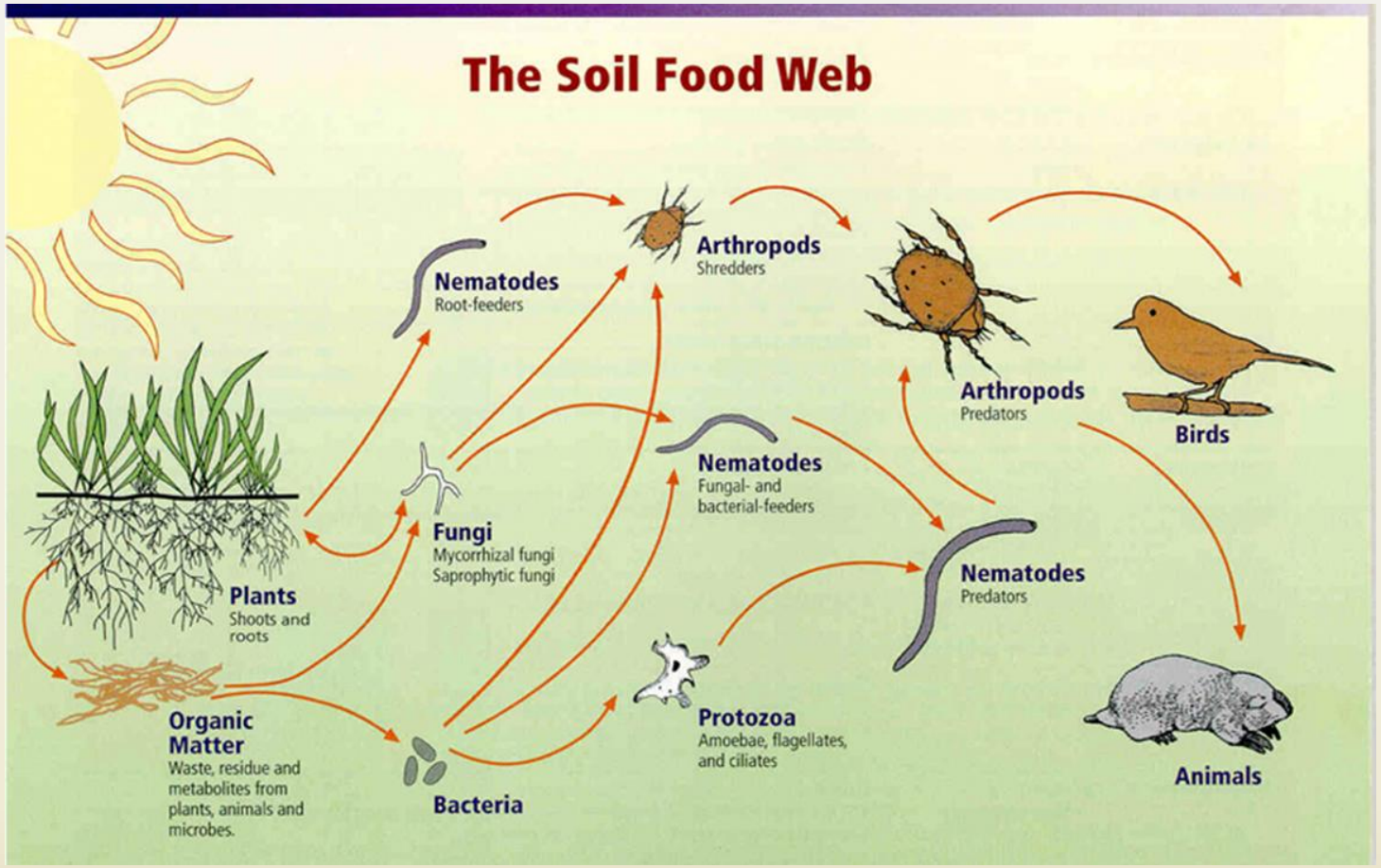
Pipes, Channels, and Holes in the Ground

Principle 2: The Plant-Microbiological Relationship

The Basis for Life on Earth

Principle 2: The Plant-Microbiological Relationship

The Basis for Life on Earth

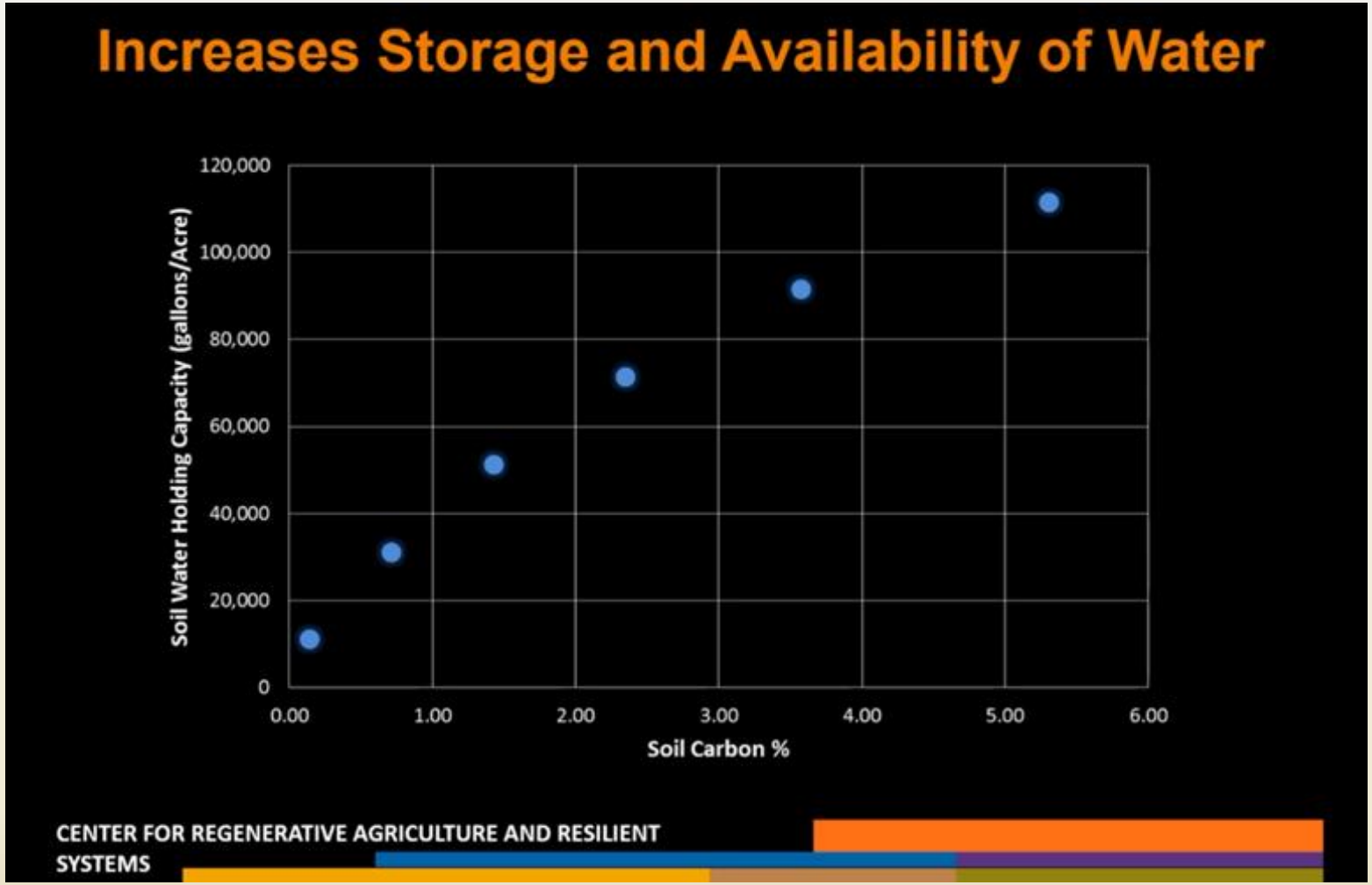


Principle 2: The Plant-Microbiological Relationship

Extracellular Polymeric Substances

- Glomalin
- Soil Carbon Sponge

Principle 2: The Plant-Microbiological Relationship



Extracellular Polymeric Substances

- Glomalin
- Soil Carbon Sponge

Courtesy: Dr. David Johnson NMSU

Principle 3: Megafauna Are Necessary

to Manage the Landforms of the Planet

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SOUTH
AFRICA

Holistic Land Management

Conventional Grazing

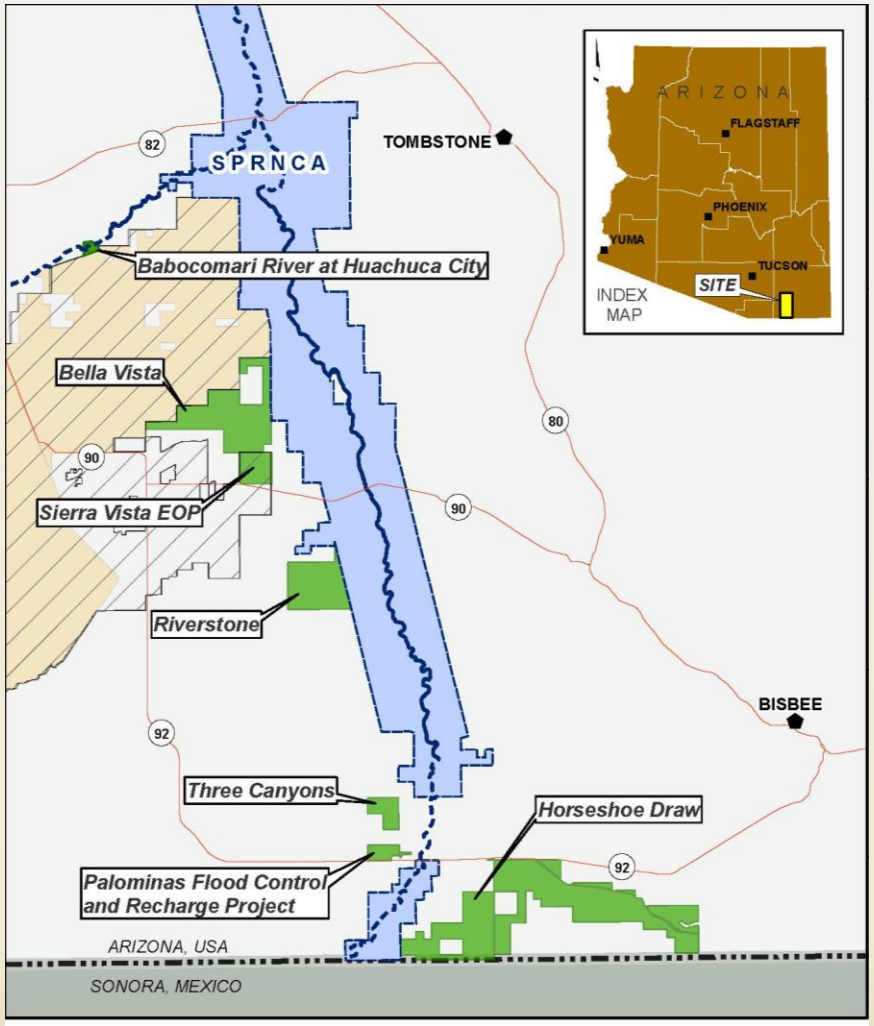
- Few animals
- Large area
- Long time (months-yrs)

Holistic Planned Grazing

- Many animals
- Small area
- Little time (hours-days)

Northern Arizona

3 Canyons Flood Control/Recharge Project



"...a regenerative grazing operation for enhancing...stormwater recharge"

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Cochise County

3 Canyons Flood Control/Recharge Project

Existing Conditions – Conventional Grazing

Proposed Conditions – Planned Grazing

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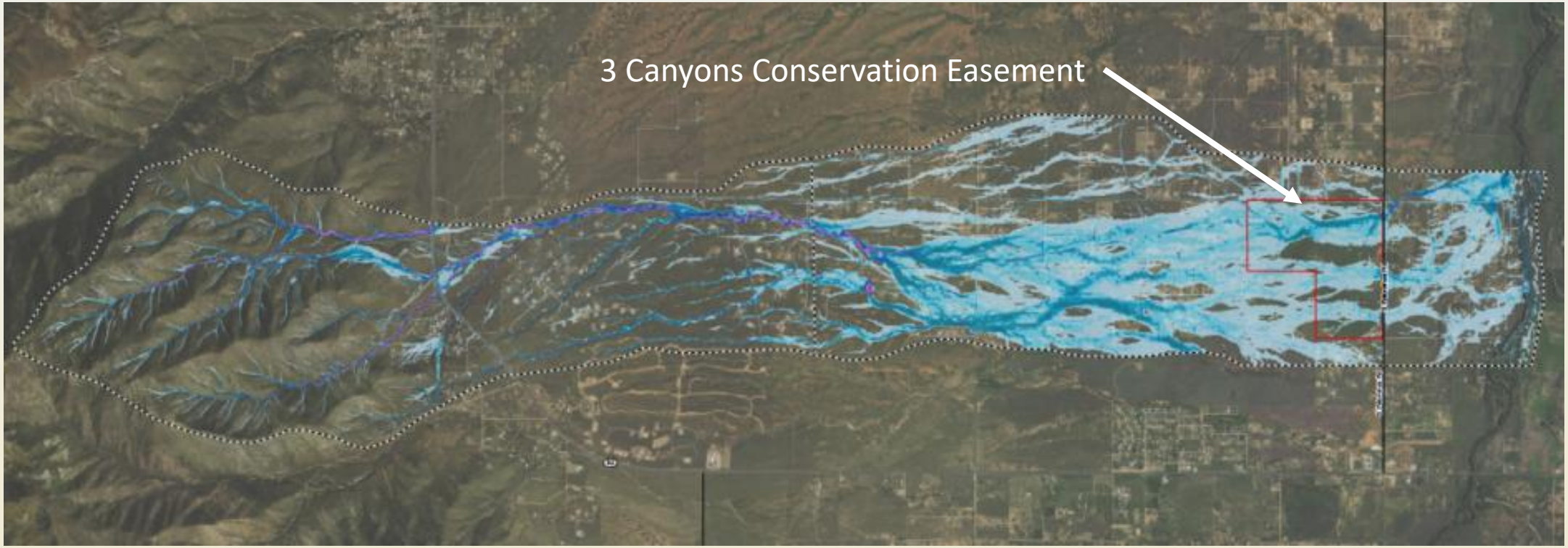
Cochise County

3 Canyons Flood Control/Recharge Project



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Cochise County

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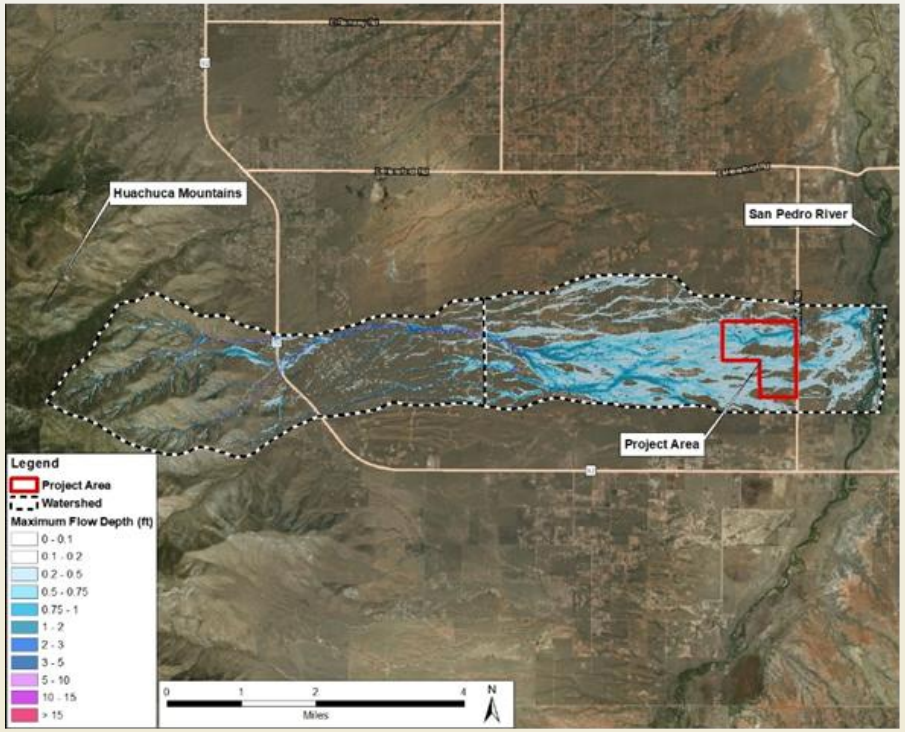
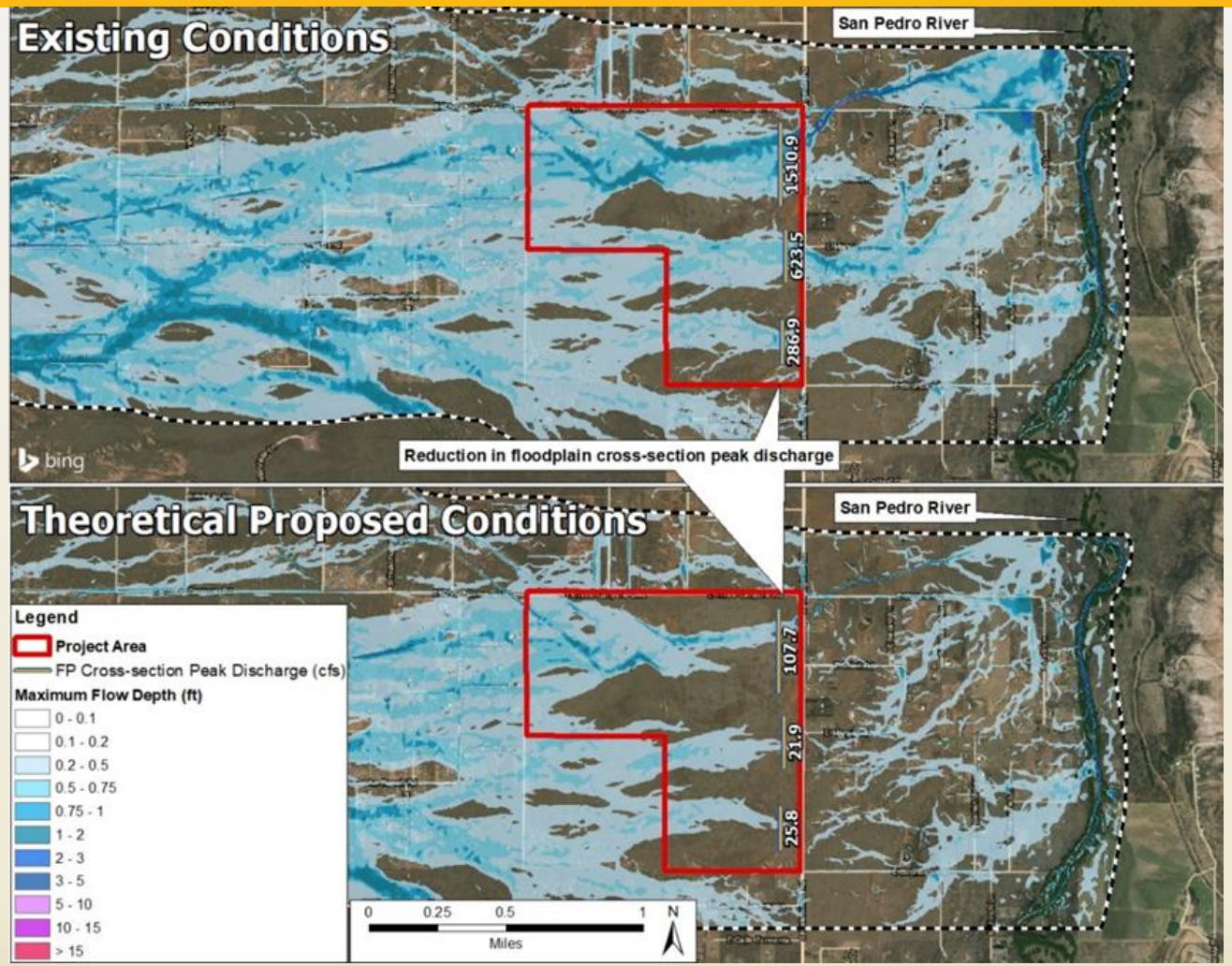


Flood reduction is 1510.9 – 107.7 = 1403.2 cfs



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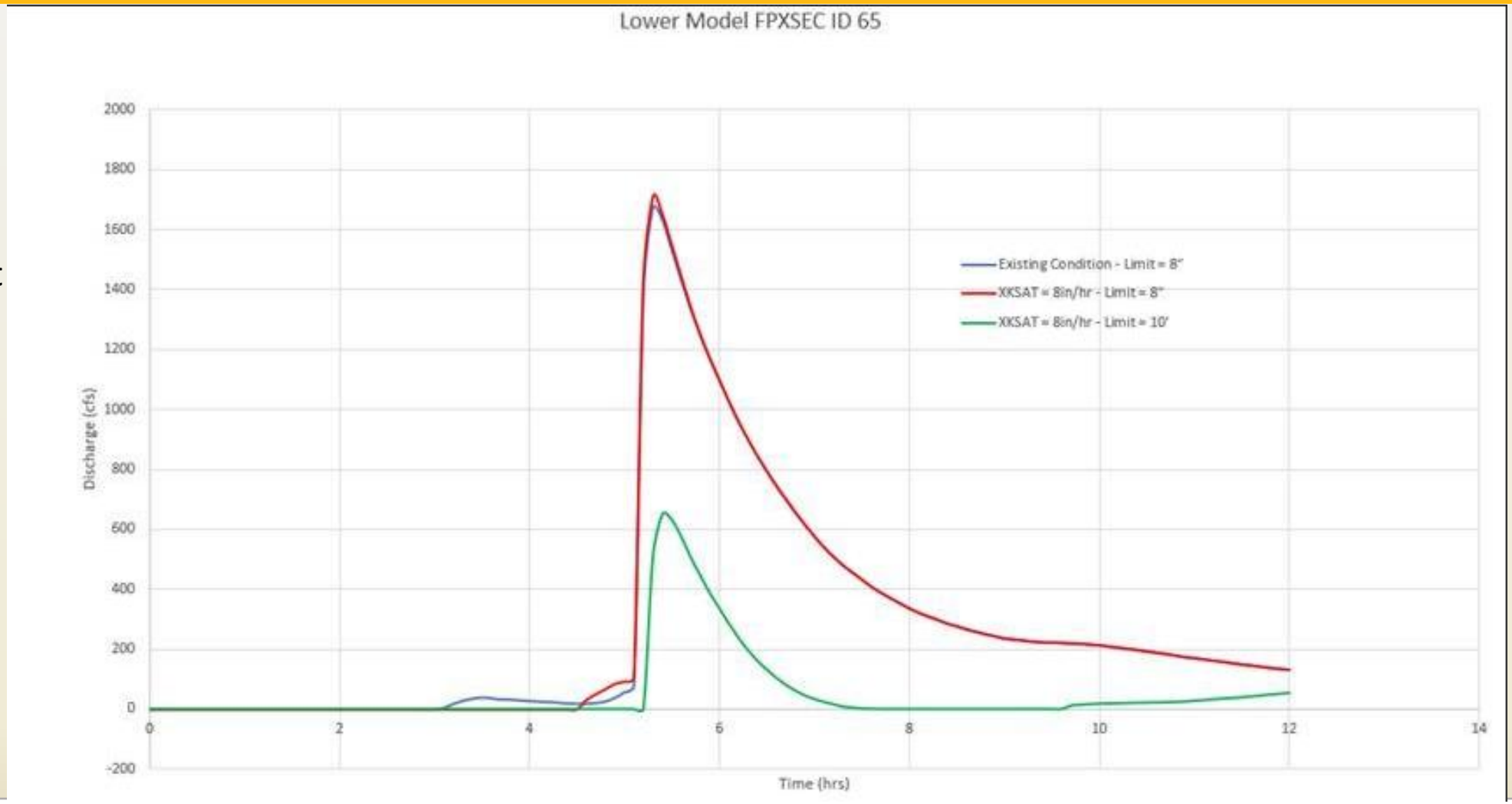
COUNTY OF COCHISE ARIZONA 1881

Cochise County

3 Canyons Flood Control Recharge Project

- 1403.2 cfs >> 227 ac-ft of potential water getting in the ground.
- Avoids much of the threat due to evaporation.



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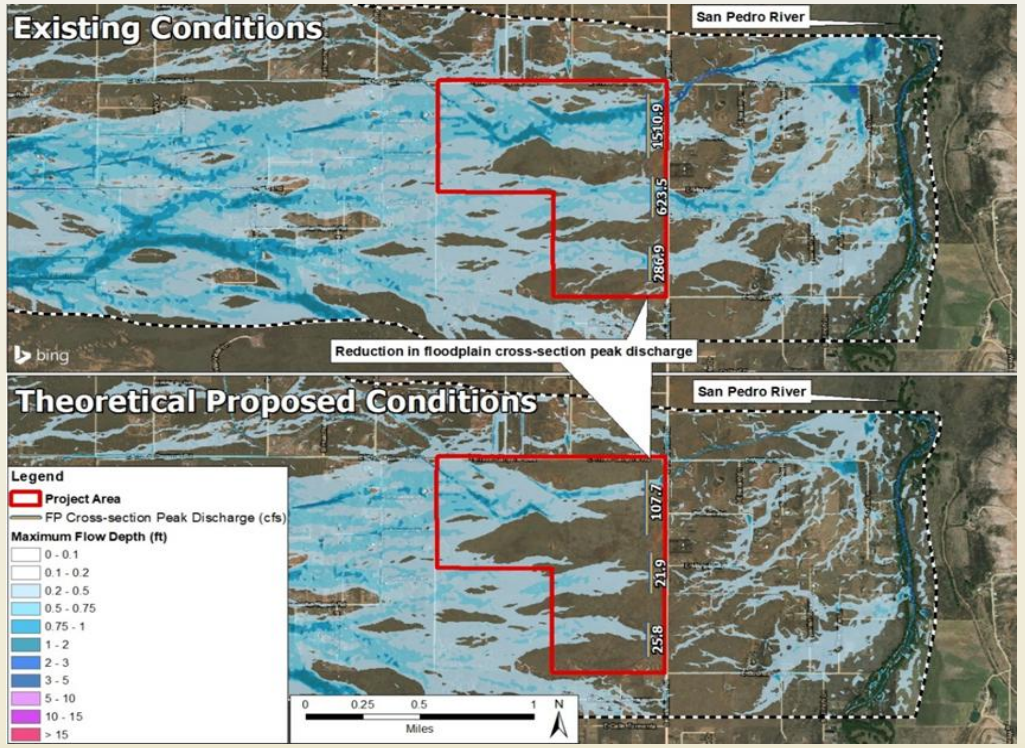
Cochise County

3 Canyons Flood Control/Recharge Project

From this

To this



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3 Canyons Flood Control Project – Cochise County

3 Canyons Flood Control Recharge Project

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Cochise County

3 Canyons Flood Control/Recharge Project

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Cochise County

3 Canyons Flood Control/Recharge Project

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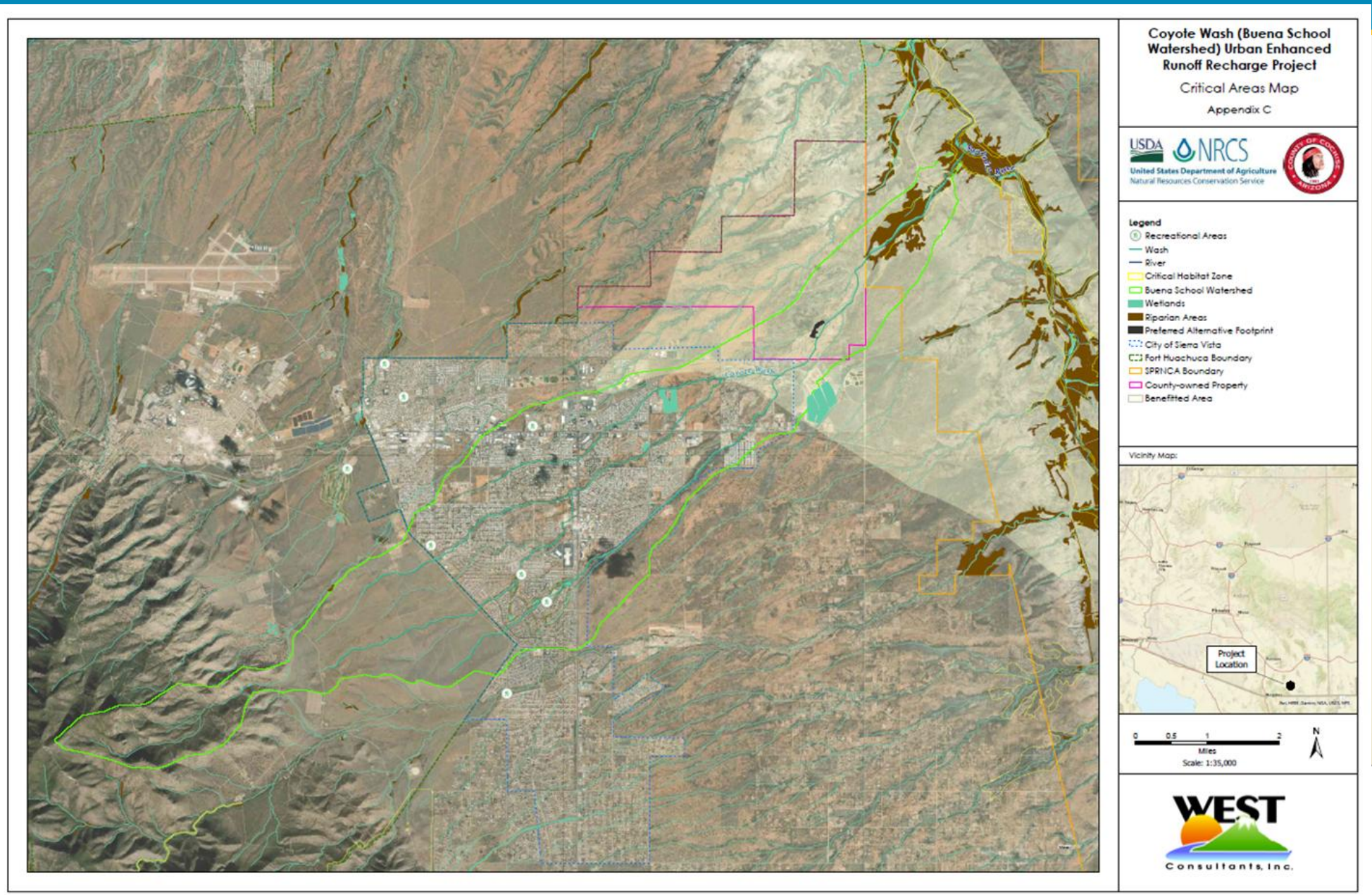
Cochise County

Coyote Wash Urban Enhanced Runoff Recharge Project



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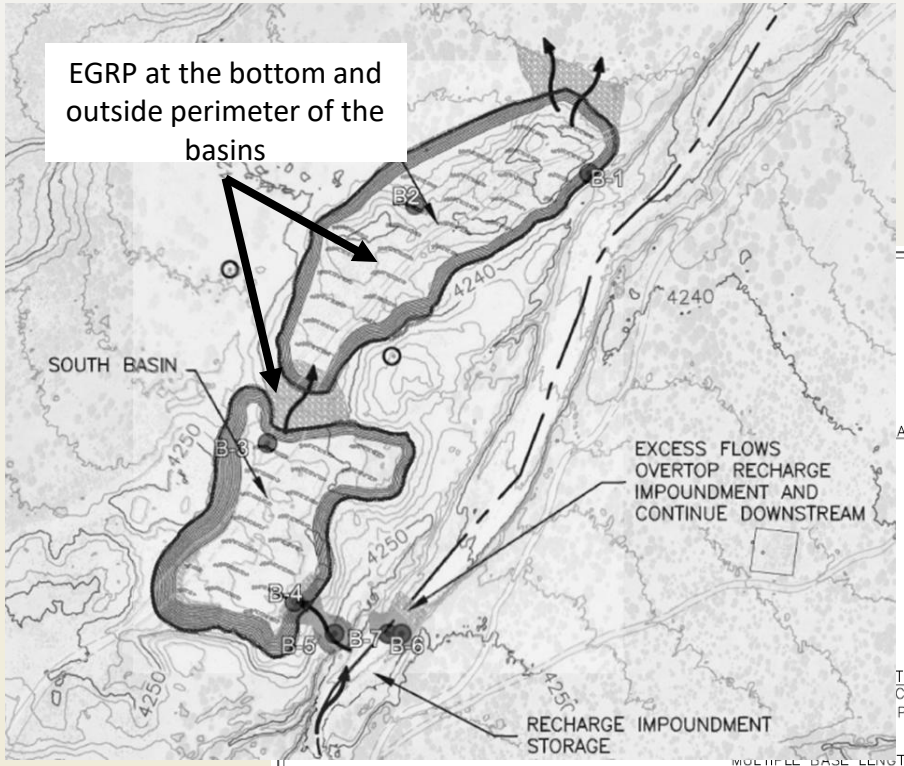
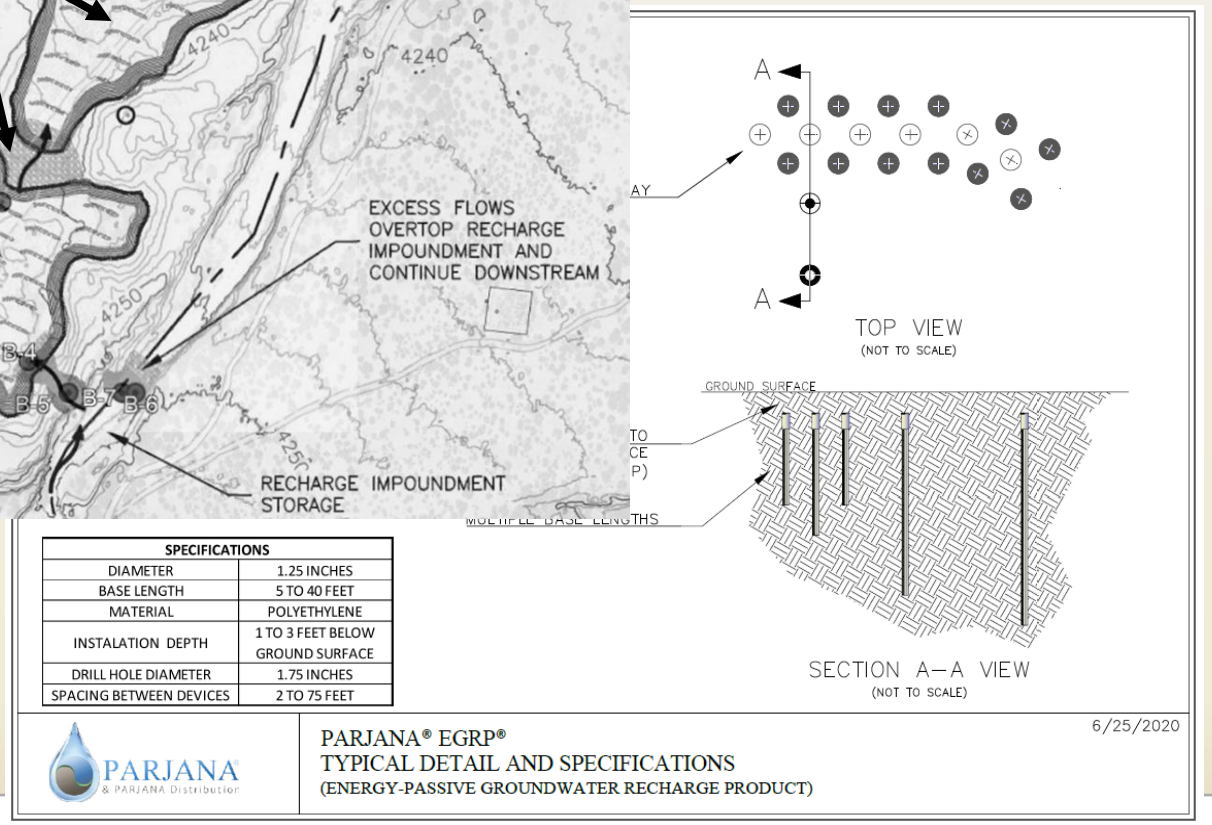
Coyote Wash Urban Enhanced Runoff Recharge Project



*Proposed EGRP lengths at the site:
5', 10', 20', 40', 60'



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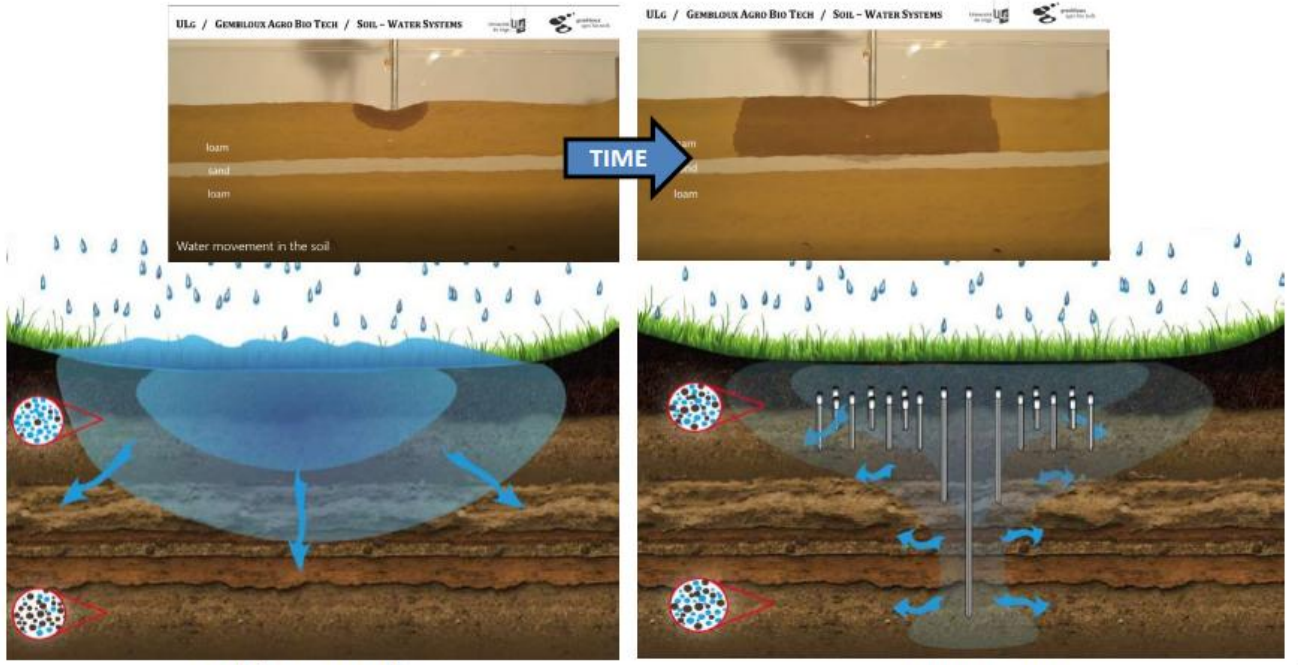
Cochise County

How it Works

- EGRP® **improve infiltration** rates up to 10X faster
- Enhances **horizontal and vertical** water distribution
- Connects soil layers
- Reduces surface tension between layers,



Without EGRP®

With EGRP®

PARJANA®

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Mechanical Enhancements and Evaporation

Modeling and Analysis – SeepW Software (GeoStudio)

- **Numerical Method**: Finite Element Method (FEM), 2D domain.
- **Mesh Size**: ~18,000 triangular and quadrilateral elements
- **Time steps**: 1,000
- **Governing Equation**: Richards' equation for **variably saturated flow**.
- **Boundary Conditions**:
  - **Evaporation from surface** (time-dependent, climate-driven).
  - **Infiltration** (from basin ponding or rainfall).
  - **Groundwater interaction** at base and sides of the domain.

$$\frac{\partial}{\partial z}\left[K\left(1+\frac{\partial h}{\partial z}\right)\right]=\frac{\partial \theta}{\partial t}$$

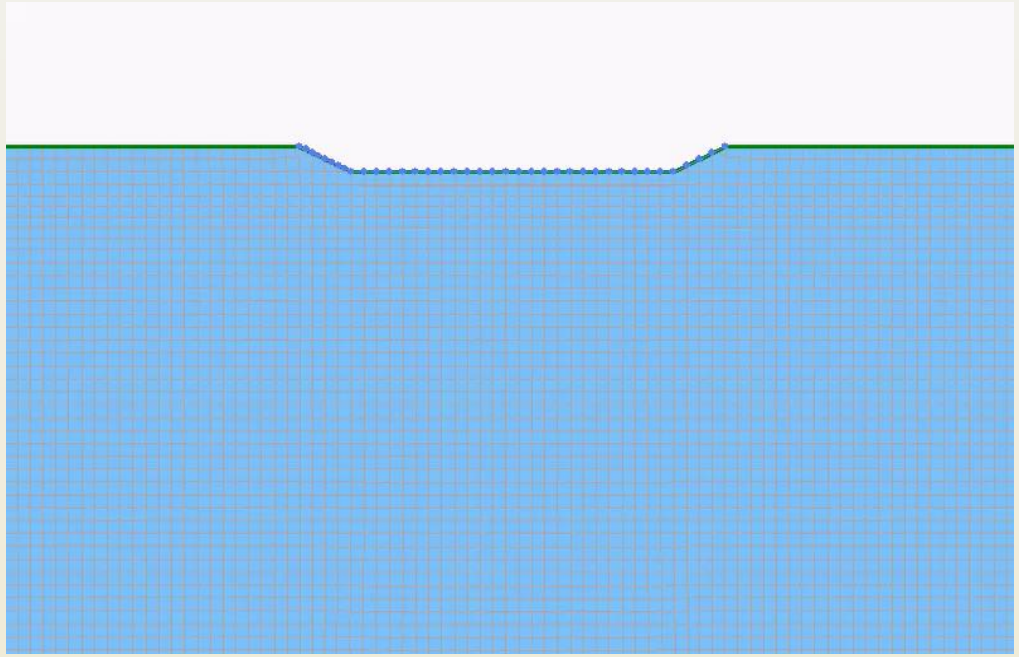
Mechanical Enhancements and Evaporation

Soil Properties and SWCC Parameters

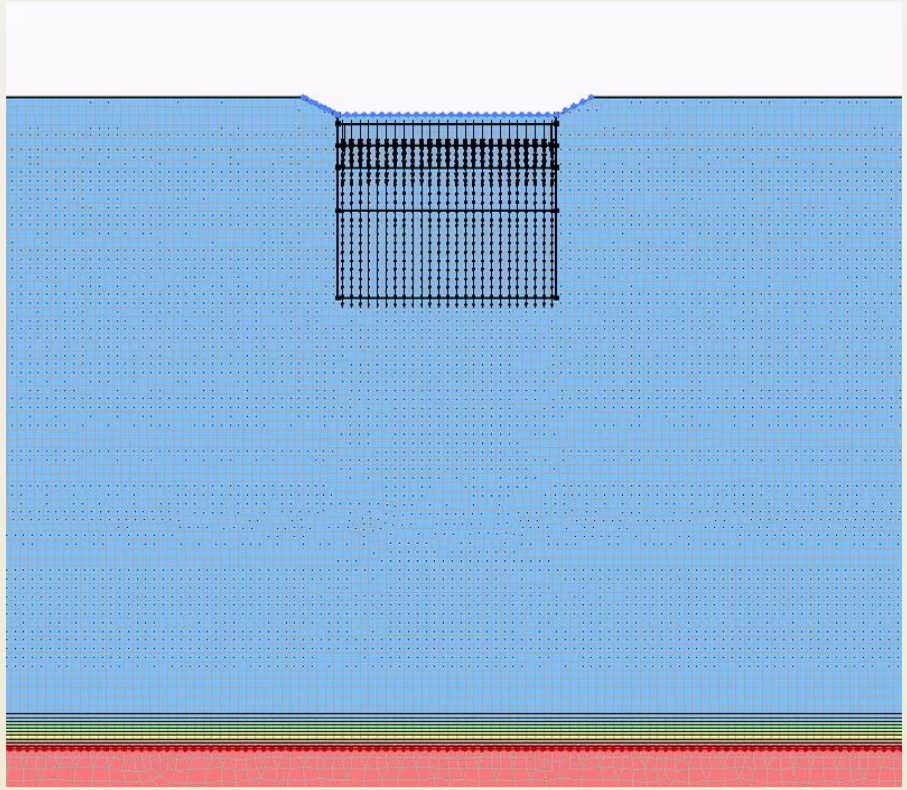
- Native soil: **Sandy Clay** (typical of Red Rock site).
- Saturated Hydraulic Conductivity: **8.3×10^{-6} ft/s**.
- Soil is **anisotropic** (horizontal K is 10× vertical K).
- Unsaturated behavior modeled using **van Genuchten Soil-Water Characteristic Curve (SWCC)**:
  - Important for simulating retention and flow in partially saturated zones.
  - Captures capillary action and moisture retention crucial to infiltration depth prediction.

Mechanical Enhancements and Evaporation

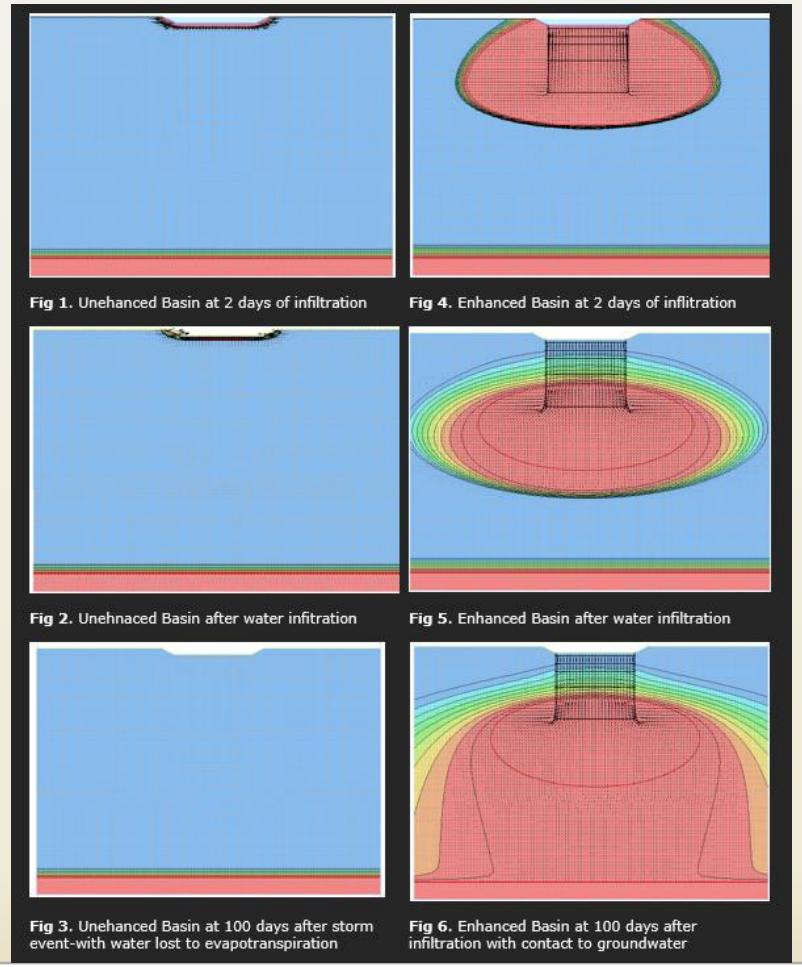
Conventional Basin



Enhanced Basin



Parjana Field Trials



- Conventional Basin
  - Surface water infiltrates 10 ft
  - Infiltrated water volume ~108,000 gallons
  - **All water is lost to evaporation**
- Enhanced Basin
  - Continuously infiltrates surface water
  - Infiltrated water volume > 1,000,000 gallons
  - **Virtually no losses to evaporation**
  - **Reaches 150 GW table in 30 days**

Mechanical Enhancements and Evaporation

Advantages of Mechanical Enhancements

- Promotes **vertical water movement** through soil via engineered means
- Enhanced **hydraulic head** at deeper depths supports the advancement of the wetting front.
- Deeper infiltration reduces the **evapotranspiration loss** and facilitates groundwater recharge.

Groundwater Recharge Field Trials

- Water Infrastructure Finance Authority (WIFA) Water Conservation Grant Fund (WCGF)
- DAAWN and Central Arizona Irrigation and Drainage District (CAIDD) Partnership for Groundwater Recharge Education and Demonstration Project

Conclusion

- Effective Land Management can Solve Water Scarcity and Flooding
- Nuisance floodwaters due to development can be used for recharge
- Mechanical enhancements may be needed to avoid evaporation

QUESTIONS

Contact Information

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www.drylandsalliance.org

US Army Corps of Engineers

USACOE EWN Regenerative Land Management Podcast

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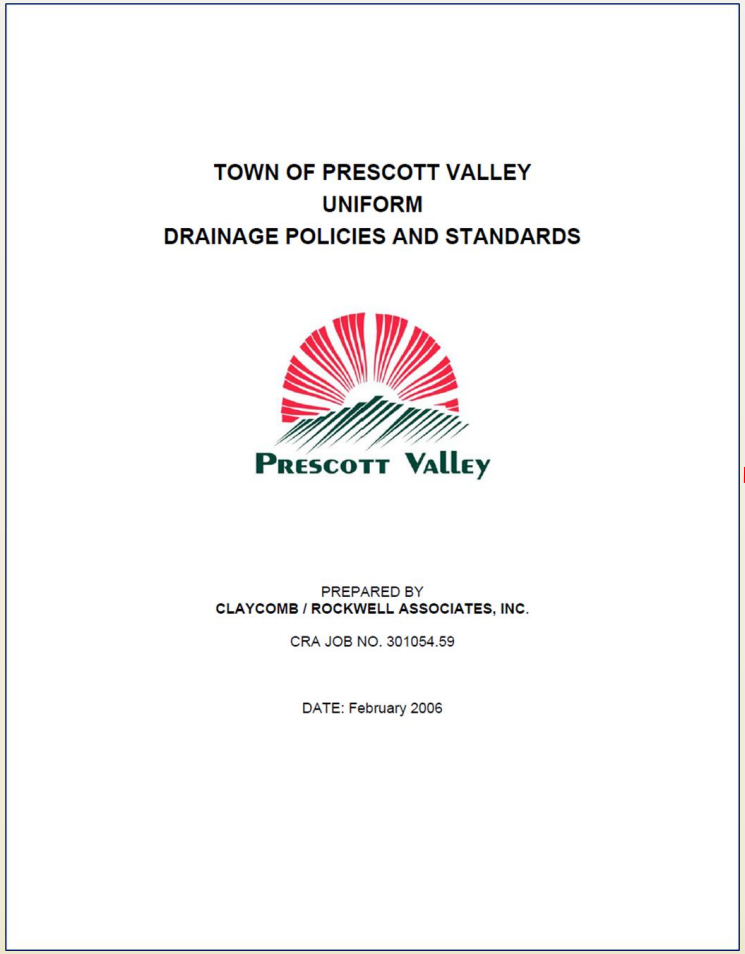
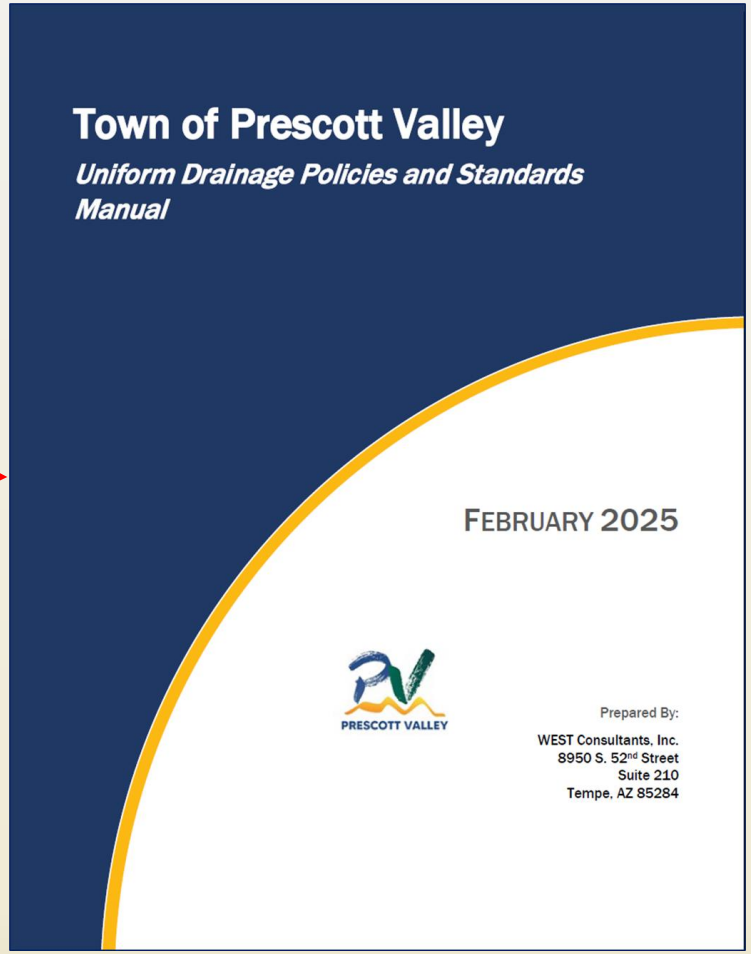
DAAWN
DRYLANDS ALLIANCE FOR ADDRESSING WATER NEEDS

First Principles

- “It ain’t what you don’t know that gets you into trouble. It’s what you know for sure that just ain’t so.” – Mark Twain
- “The gap between what you know and what you think you know are where extreme events in your life will occur.”– Nassim Taleb
- “One of the great challenges in life is knowing enough about a subject to think you’re right, but not enough about the subject to know you are wrong.”– Neil deGrasse Tyson
- “Once we realize that imperfect understanding is the human condition, there is no shame in being wrong, only in failing to correct our mistakes.” – George Soros

Prescott Valley Drainage Manual Update





Updates include:

- Best Management Practices
- Updated referenced documents
- strong, clear language
- Added green stormwater infrastructure

Prescott Valley Drainage Manual Update

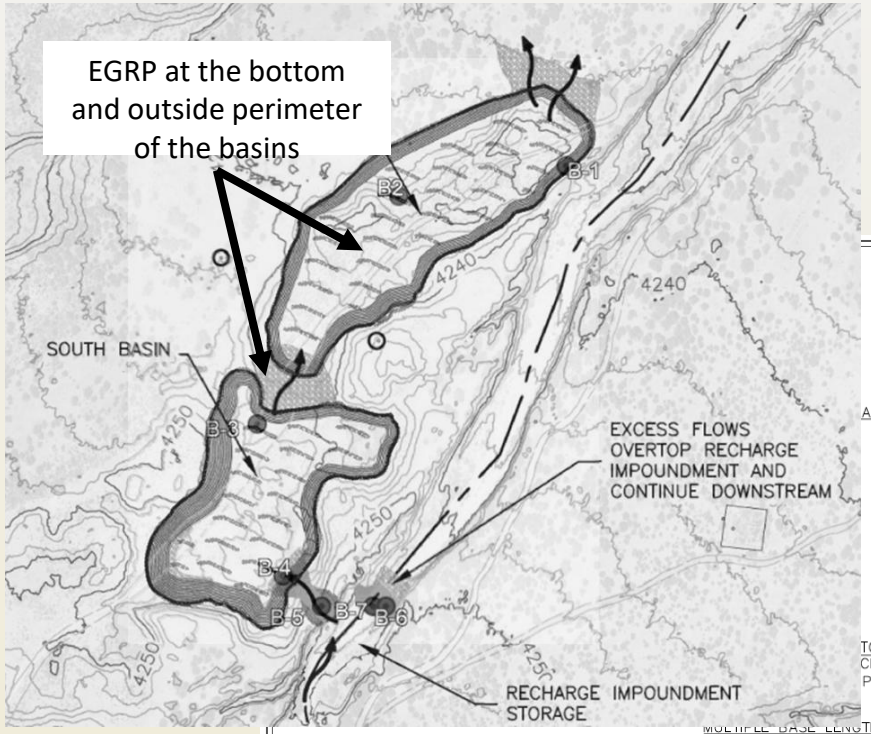
Figure 2-28. Saint Mary's Road Concrete Check Dam

Coyote Wash Urban Enhanced Runoff Recharge Project

Table 4-1 – UER Summary at Coyote Wash

Event	Existing Conditions		Pre-Developed Conditions		UER	
	Qpk (cfs)	Volume (ac-ft)	Qpk (cfs)	Volume (ac-ft)	Qpk (cfs)	Volume (ac-ft)
100-Yr, 3-hr	3902.56	860.26	2903.67	557.68	998.89	302.58
50-Yr, 3-hr	2929.04	659.16	1890.8	382.81	1038.24	276.35
25-Yr, 3-hr	2006.69	474.31	1067.34	232.51	939.35	241.8
10-Yr, 3-hr	1038.68	264.86	325.83	79.5	712.85	185.36
5-Yr, 3-hr	494.17	144.85	35.43	14.27	458.74	130.58
2-Yr, 3-hr	90.2	38.94	0.31	0	89.89	38.94
100-Yr, 6-hr	4325.25	1041.48	3333.22	670.93	992.03	370.55
50-Yr, 6-hr	3284.7	799.12	2232.97	462.63	1051.73	336.49
25-Yr, 6-hr	2344.54	585.3	1325.85	294.67	1018.69	290.63
10-Yr, 6-hr	1244.53	340.44	448.29	116.82	796.24	223.62
5-Yr, 6-hr	630.67	196.29	89.39	32.06	541.28	164.23
2-Yr, 6-hr	144.17	68.24	0.42	0.01	143.75	68.23
100-Yr, 24-hr	4837.65	1301.34	3891.11	824.48	946.54	476.86
50-Yr, 24-hr	3887.43	1048.37	2772.18	596.22	1115.25	452.15
25-Yr, 24-hr	2870.99	806.63	1717.73	397.69	1153.26	408.94
10-Yr, 24-hr	1625.48	513.26	697.86	189.07	927.62	324.19
5-Yr, 24-hr	933.88	328.12	246.72	75.73	687.16	252.39
2-Yr, 24-hr	283.63	144.98	4.02	0.64	279.61	144.34

Coyote Wash Urban Enhanced Runoff Recharge Project



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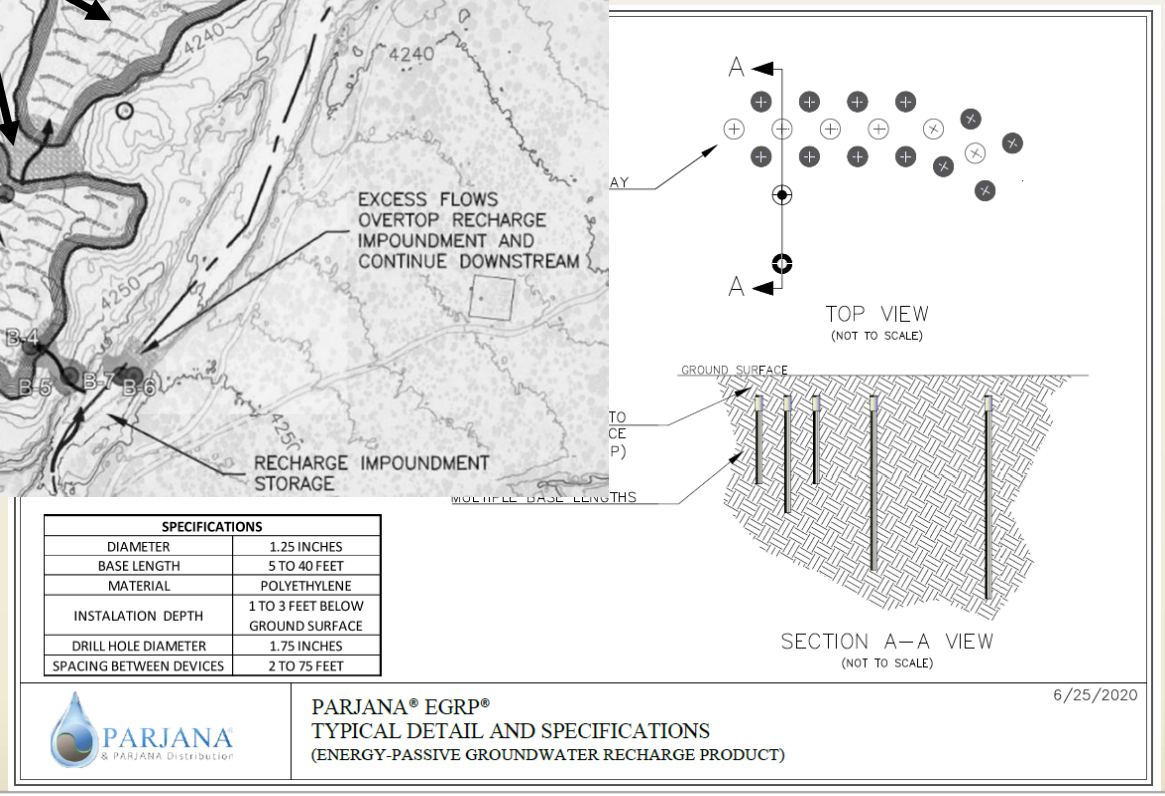

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Cochise County

Prescott Valley Drainage Manual Update

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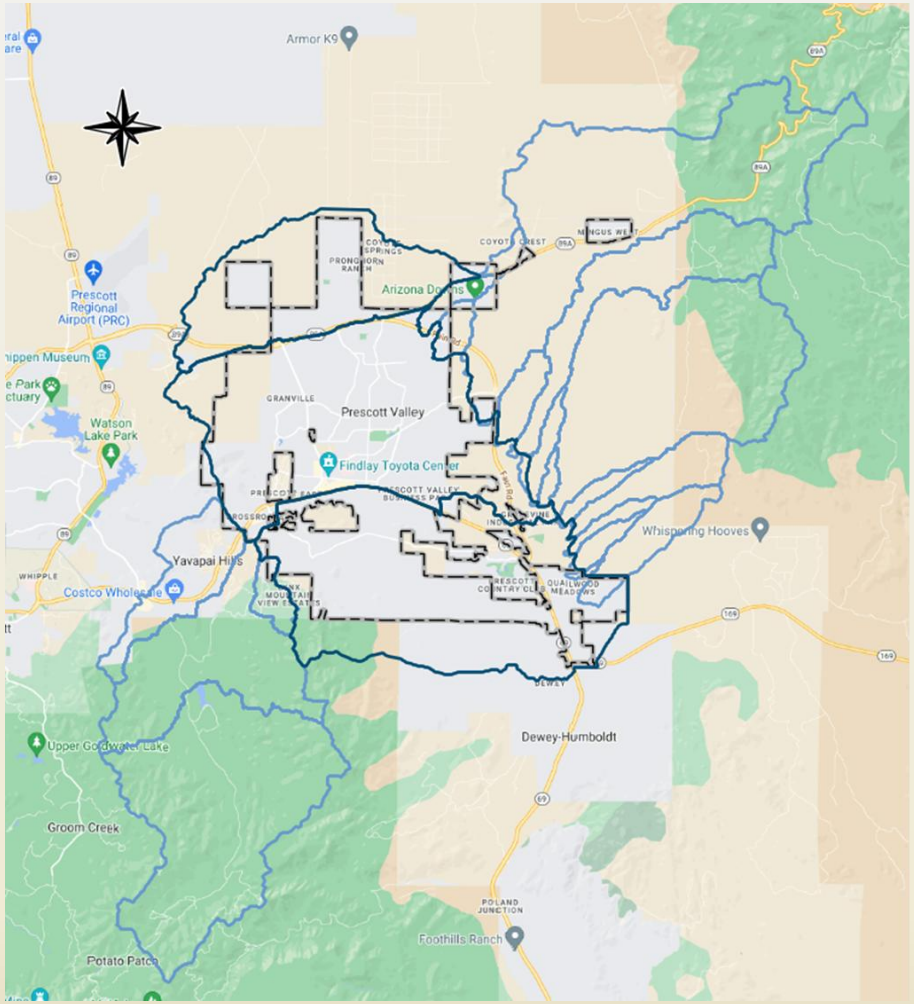
PRESCOTT VALLEY

Prescott Valley Area Drainage Master Study: Phase 1



Study Area

Detailed:	62.8 sq. miles
Limited Detail:	93.4 sq. miles
Total:	156.2 sq. miles

Detailed Area

Total number of cells:	7,783,241
Cell size:	15-feet

Data Obtained and Developed

Elevation
Land Use
Soils
Rainfall
Watershed roughness
23,387 Building Footprints
400 Culverts

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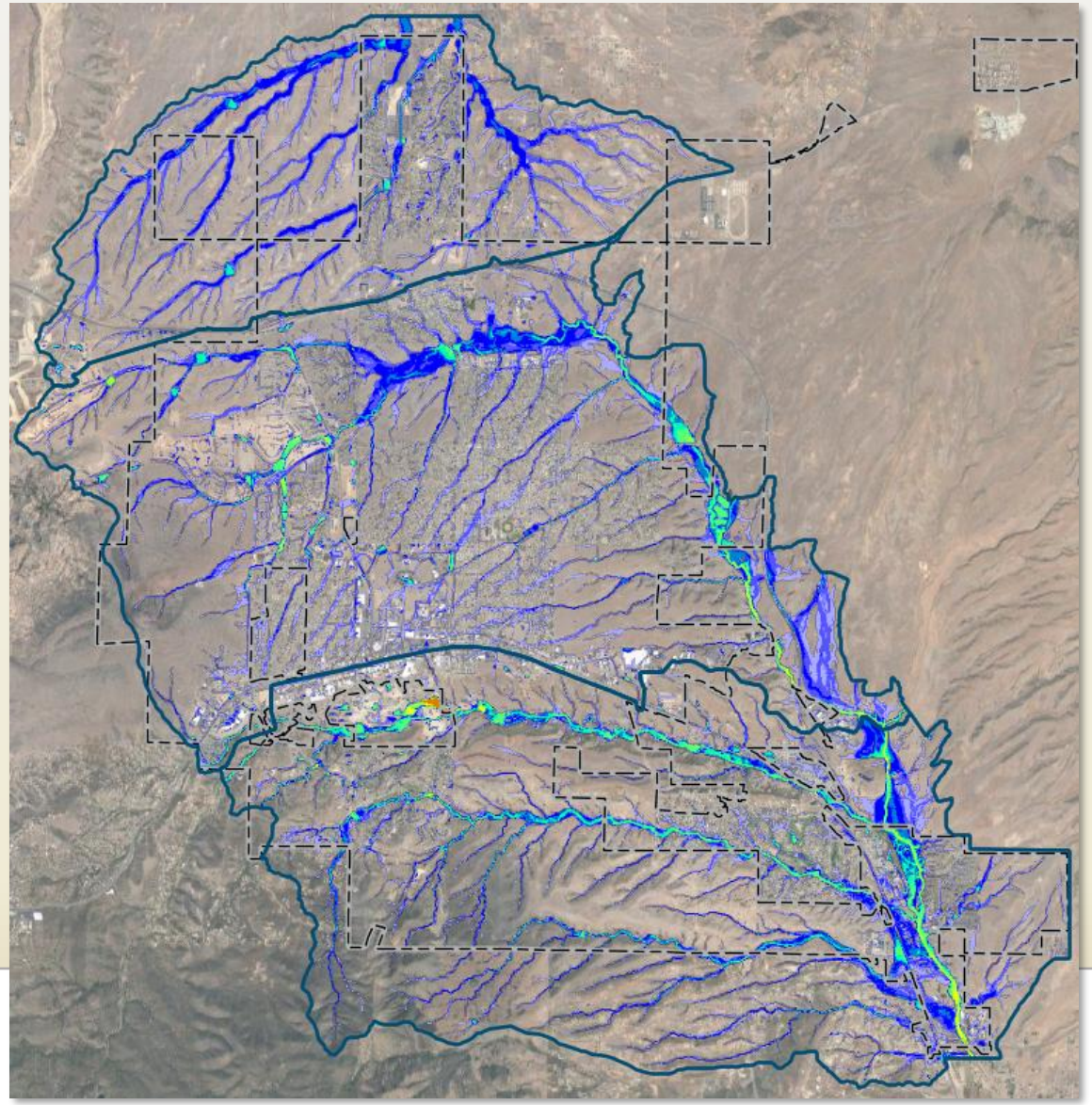
PRESCOTT VALLEY

Prescott Valley Area Drainage Master Study: Phase 2



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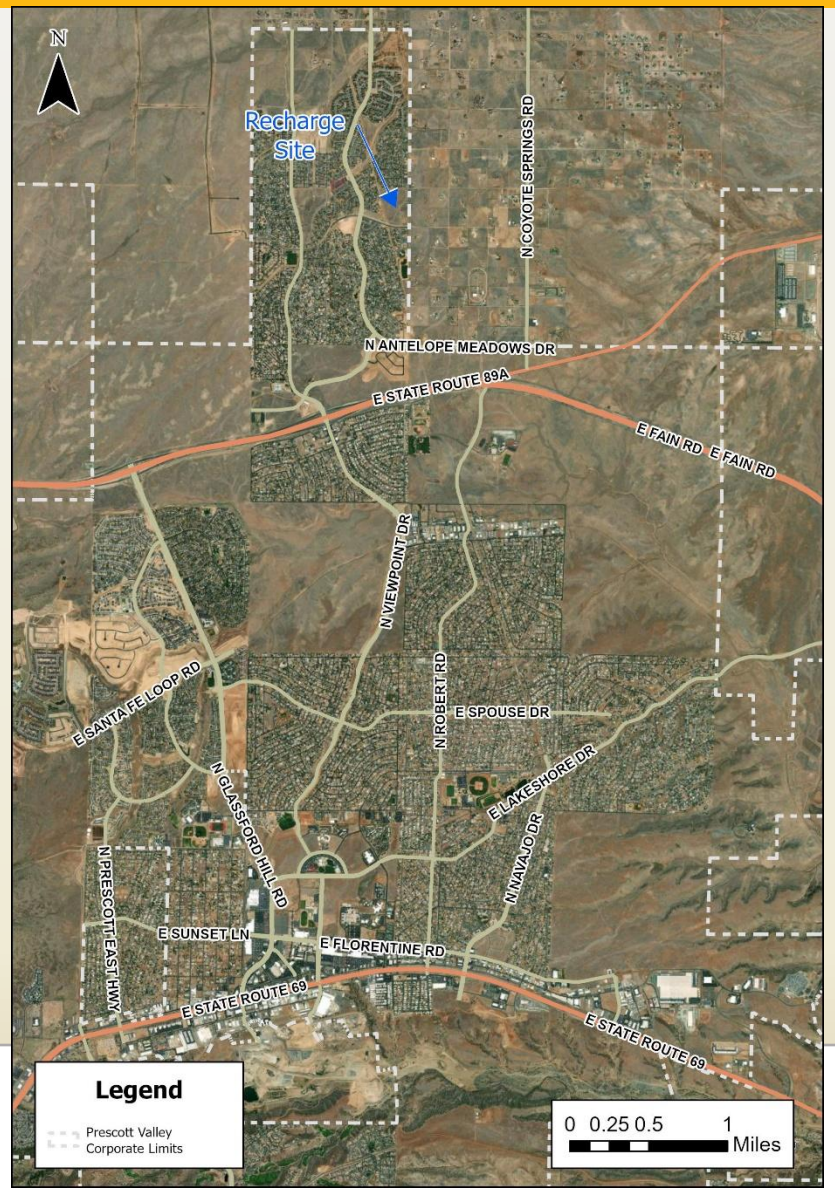
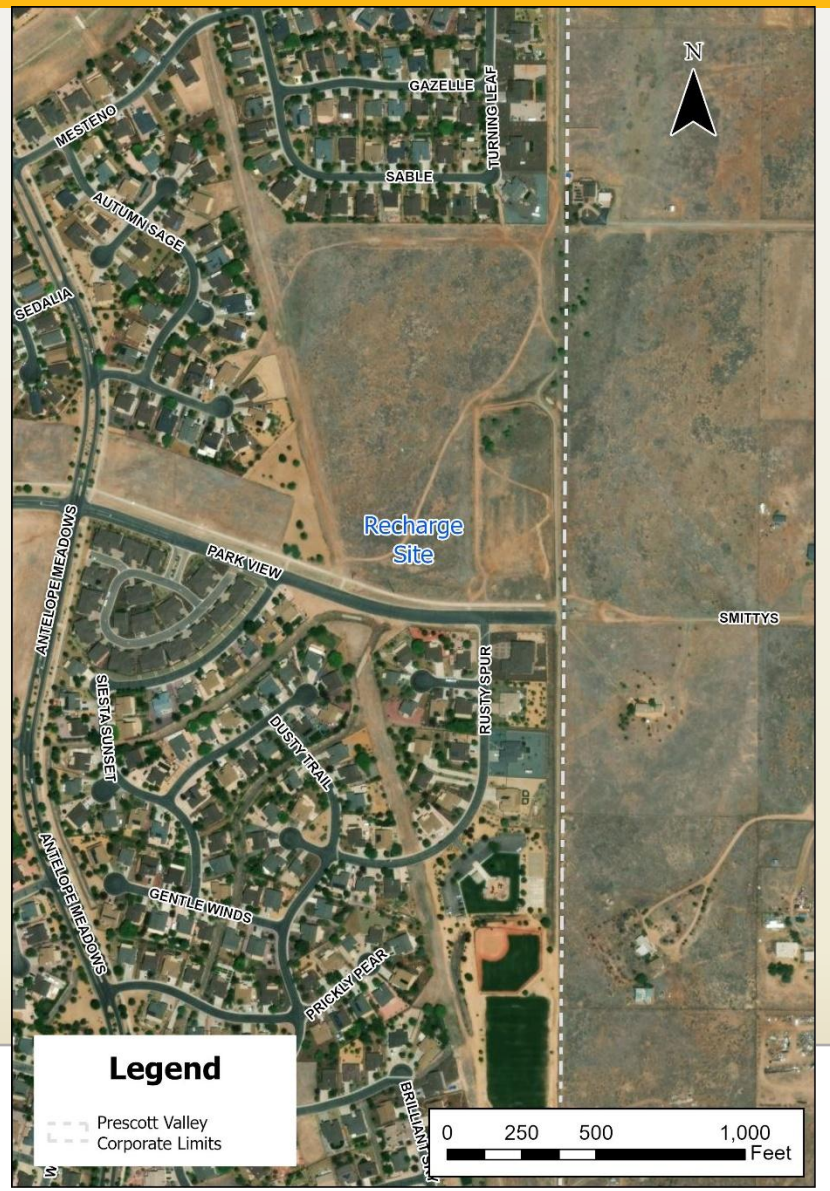
PRESCOTT VALLEY

Prescott Valley Area Drainage Master Study: Phase 2





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PRESCOTT VALLEY

Coyote Wash Urban Enhanced Runoff Recharge Project

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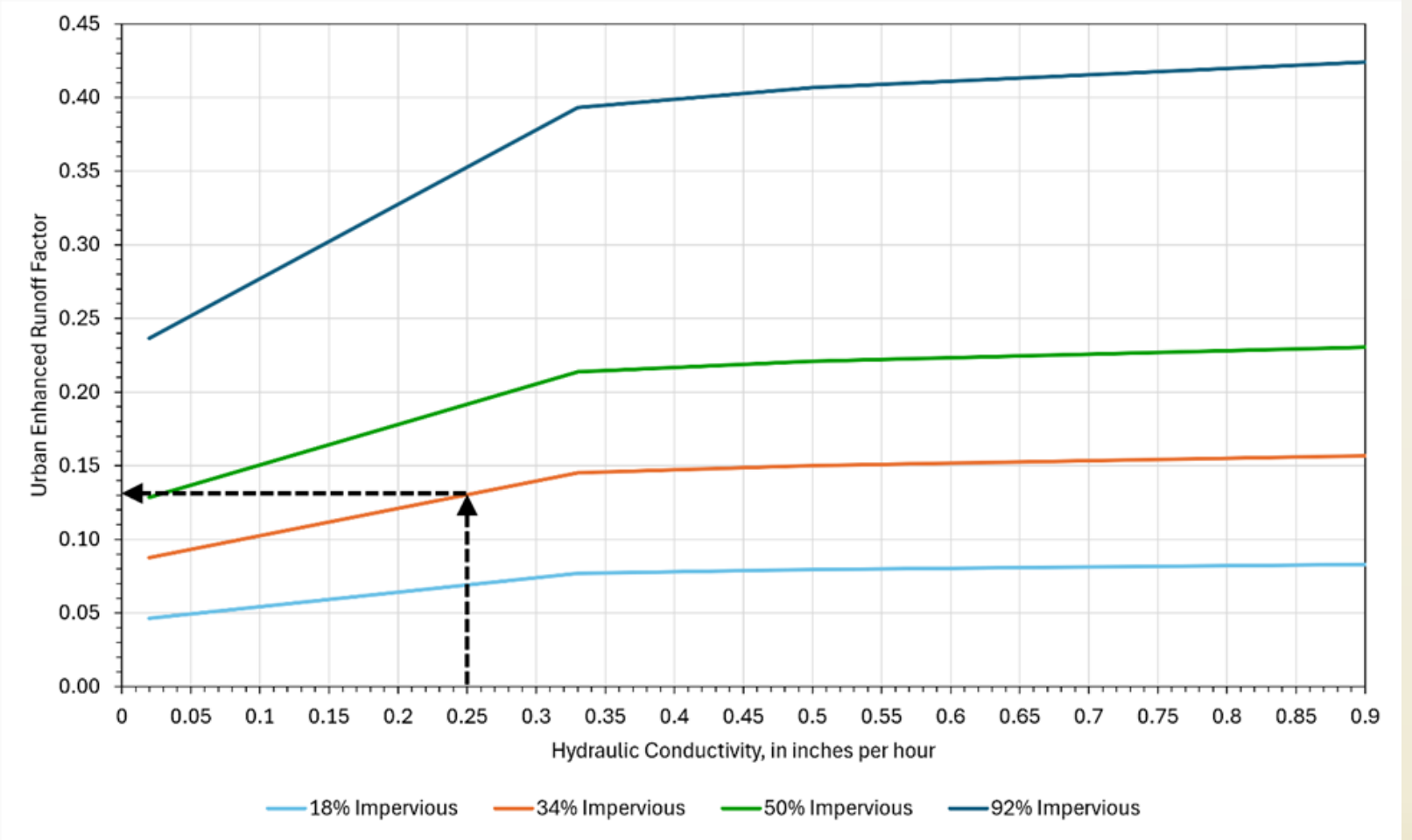
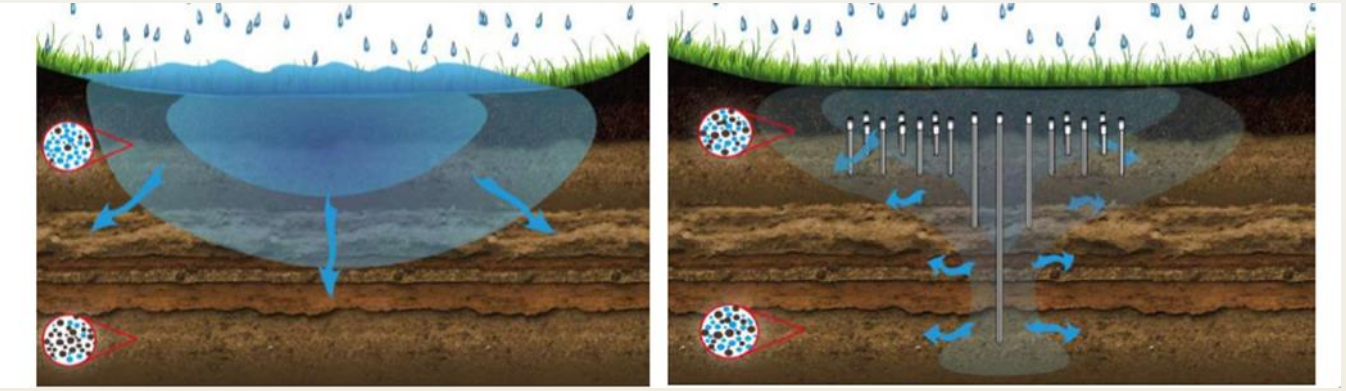
25-Yr, 3-hr	2006.69	474.31	1067.34	232.51	939.35	241.8
10-Yr, 3-hr	1038.68	264.86	325.83	79.5	712.85	185.36
5-Yr, 3-hr	494.17	144.85	35.43	14.27	458.74	130.58
2-Yr, 3-hr	90.2	38.94	0.31	0	89.89	38.94
100-Yr, 6-hr	4325.25	1041.48	3333.22	670.93	992.03	370.55
50-Yr, 6-hr	3284.7	799.12	2232.97	462.63	1051.73	336.49
25-Yr, 6-hr	2344.54	585.3	1325.85	294.67	1018.69	290.63
10-Yr, 6-hr	1244.53	340.44	448.29	116.82	796.24	223.62
5-Yr, 6-hr	630.67	196.29	89.39	32.06	541.28	164.23
2-Yr, 6-hr	144.17	68.24	0.42	0.01	143.75	68.23
100-Yr, 24-hr	4837.65	1301.34	3891.11	824.48	946.54	476.86
50-Yr, 24-hr	3887.43	1048.37	2772.18	596.22	1115.25	452.15
25-Yr, 24-hr	2870.99	806.63	1717.73	397.69	1153.26	408.94
10-Yr, 24-hr	1625.48	513.26	697.86	189.07	927.62	324.19
5-Yr, 24-hr	933.88	328.12	246.72	75.73	687.16	252.39
2-Yr, 24-hr	283.63	144.98	4.02	0.64	279.61	144.34

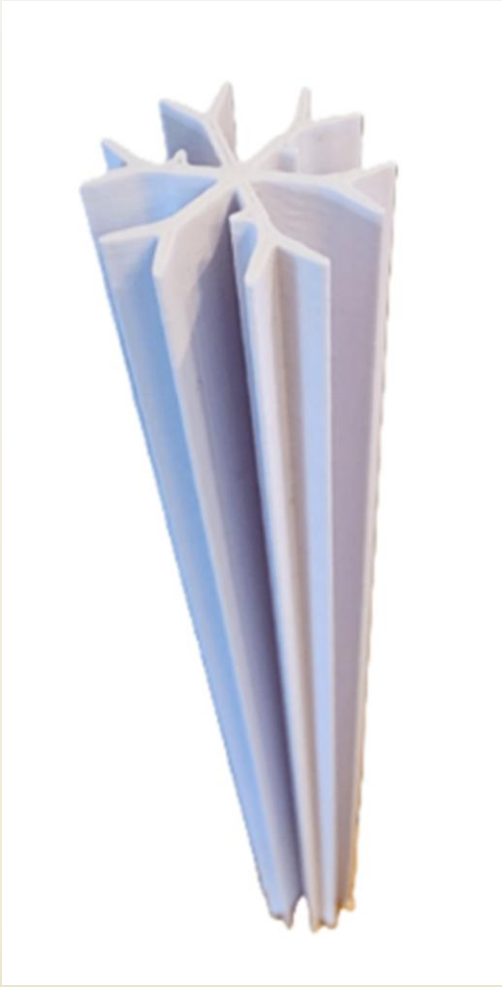
Policy Work and Urban Enhanced Runoff



UER Volume = UER Factor x Development Area x Average Annual Precipitation

Parjana Field Trials





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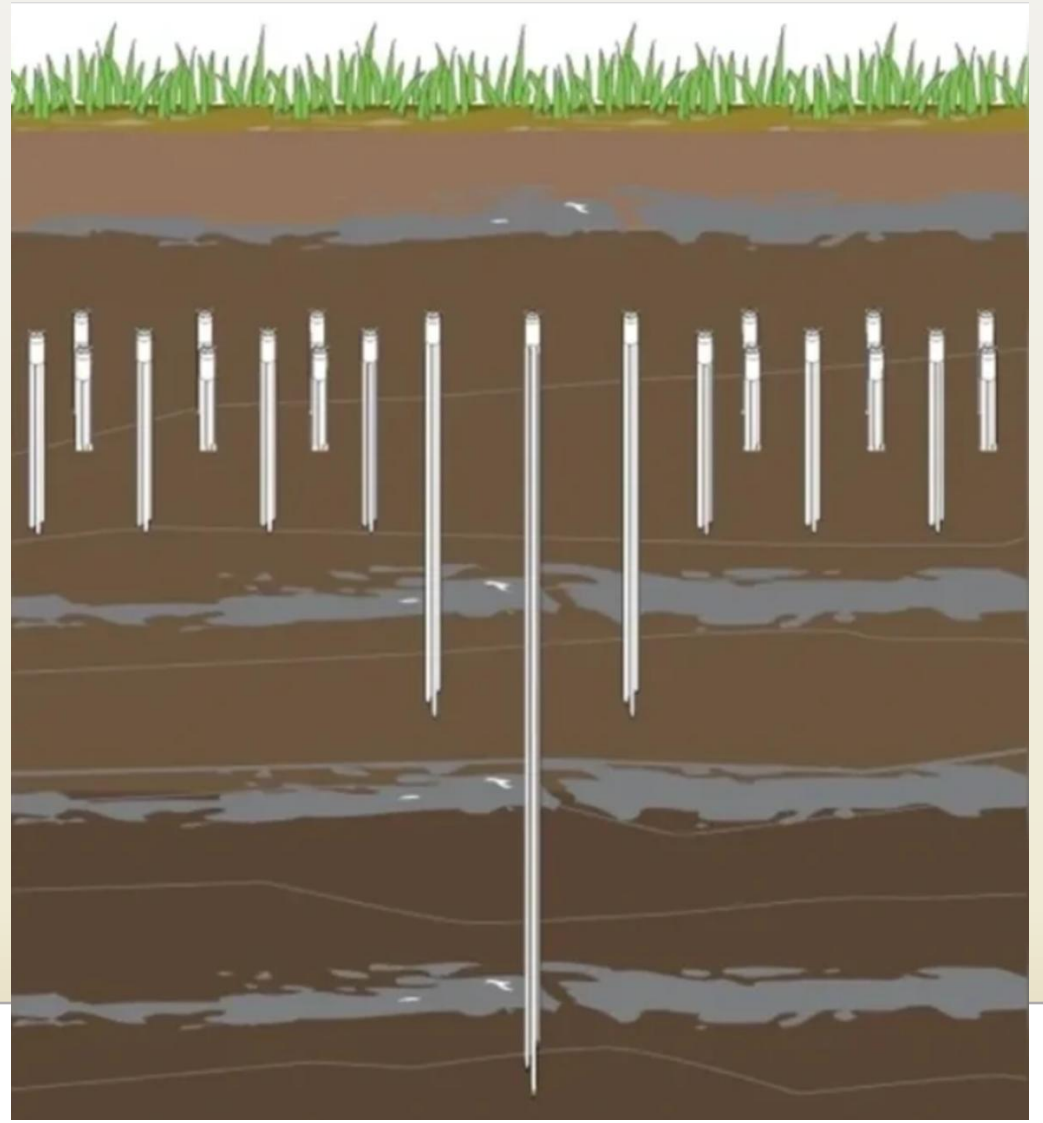
PRESCOTT VALLEY

Net Positive Water Development



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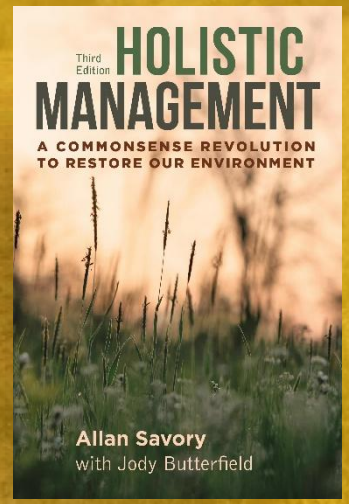
PLANNED GRAZING

Getting animals to the right place at the right time with the right behavior for the right reason.

LAND PLANNING

Thinking before you act. Planning long-term infrastructure needs that meet ecological, financial, & social goals.



FINANCIAL PLANNING

New behaviors persist only if financially feasible. Farm finances planned to ensure maximum marginal reaction.

ECO MONITORING

Rapid feedback loops that assist farmers in making the best management decisions for their land base.