Stormwater Runoff from Urbanized Areas as a Groundwater Recharge Source

Michael Milczarek, Robert C. Rice, Jason Keller, Laurel Lacher

GSA GeoSystems Analysis, Inc.
Innovative Solutions

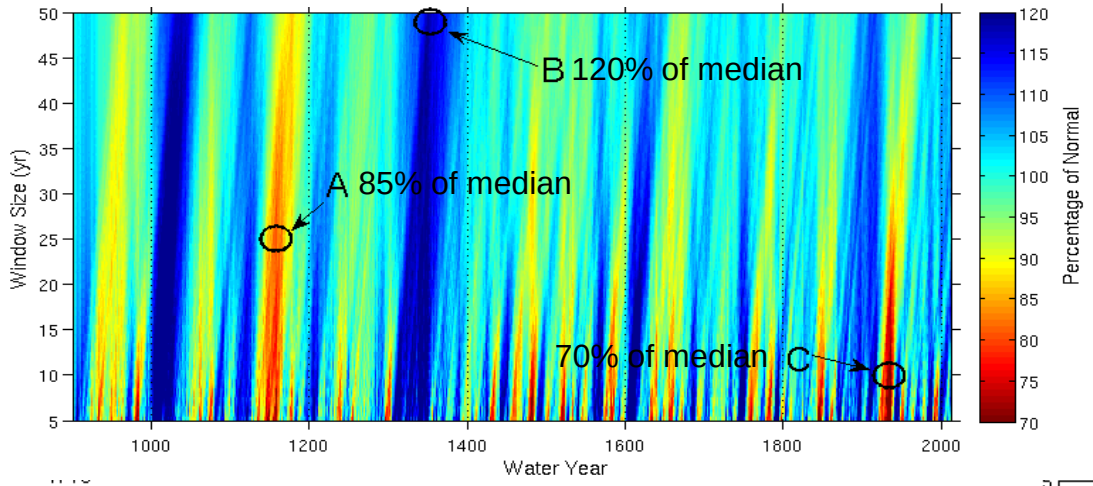
Stormwater Capture and Recharge

- Opportunities
  - Increase groundwater recharge/replenish storage
  - Reduce flooding/peak flows
  - Sediment reduction/improve water quality
- Challenges
  - How much runoff and when?
  - How much can be captured?
  - Sediment control and contamination?
  - Site hydrogeology?
  - Defining water rights/instream flow requirement/allocations

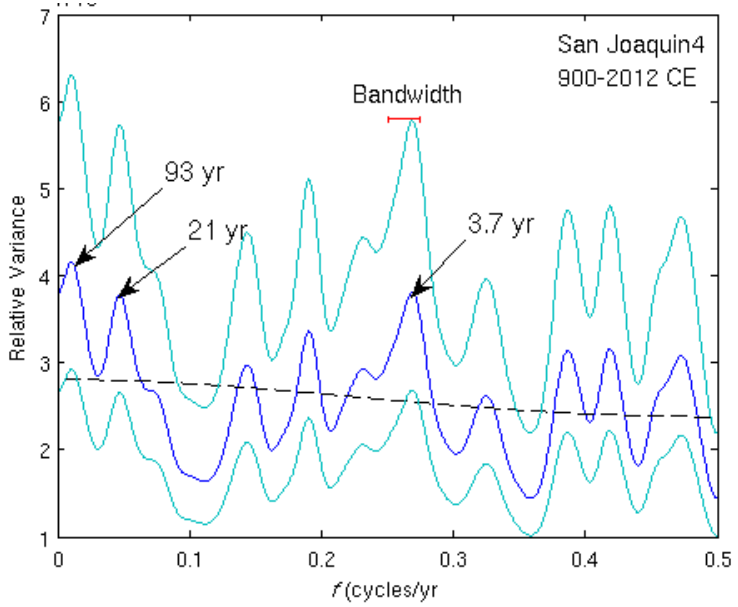
GSA GeoSystems Analysis, Inc.
Innovative Solutions

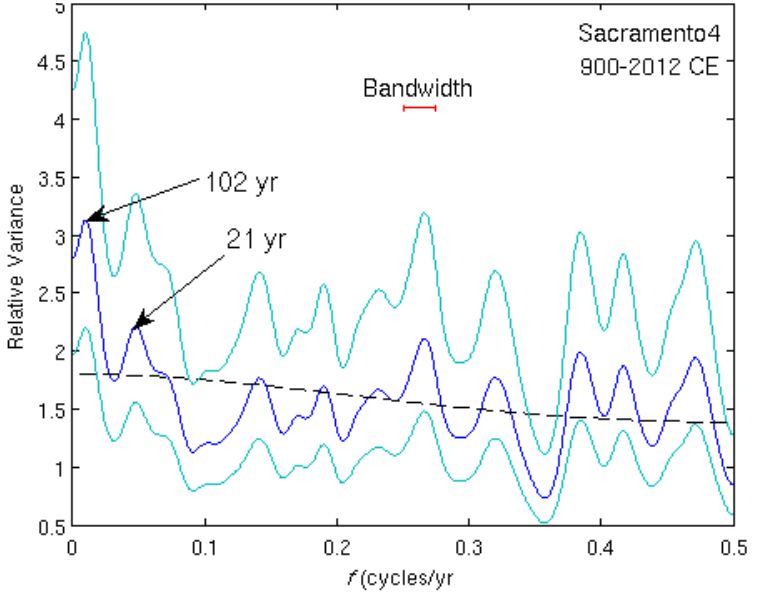
How Much and When?
Climate Reconstruction/Anomalies

Sacramento River Reconstruction

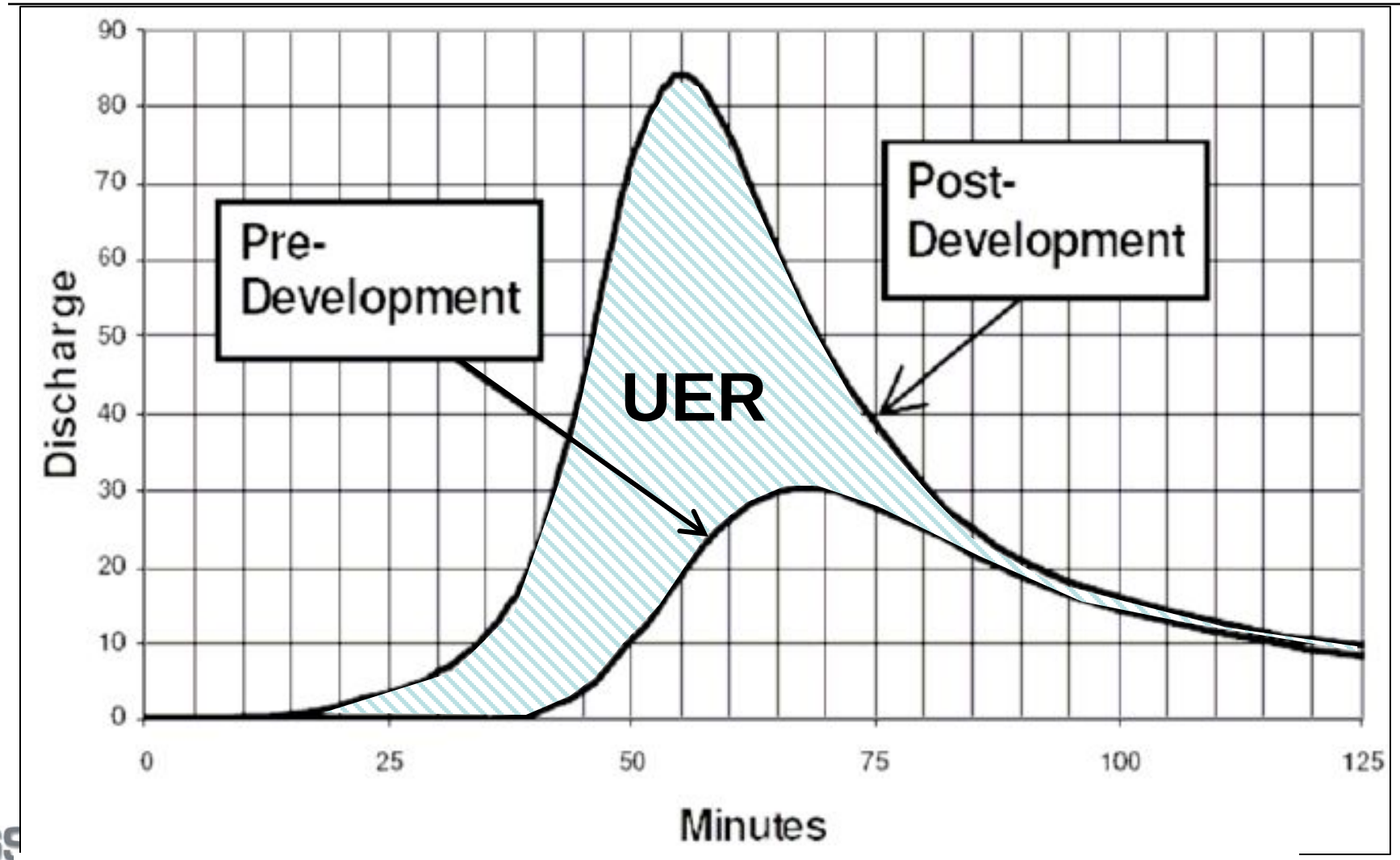


From: Meko et al., 2014. Klamath/San Joaquin/Sacramento Hydroclimatic Reconstructions from Tree Rings





How Much Can Be Captured? Urban Enhanced Runoff (UER)



Example of runoff hydrograph under pre-and post-development conditions in Bangalore, India (Adapted from Fig. 12-2 in Ramachandra and Mujumdar, 2009)

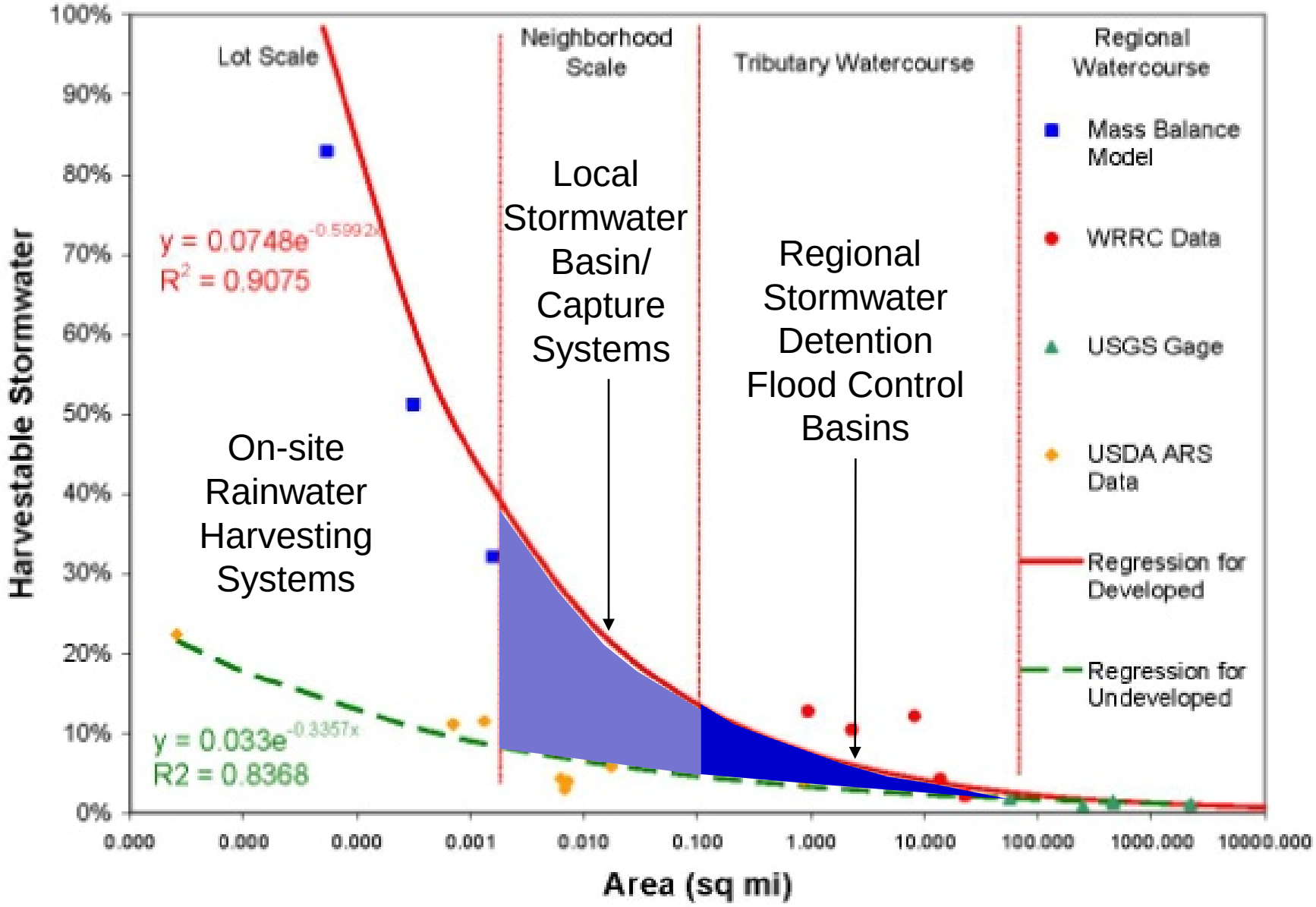


Figure 1 – Percent of Total Rainfall Available as Harvestable Rainwater and Stormwater

From: Pima County Stormwater Harvesting and Management as a Supplemental Water Source Technical Paper, 2009.

Stormwater Capture and Recharge Options

- Off-channel basins
  - Delivered by flood detention/reservoirs
- In-channel structures
  - Increase retention time and storage
- Enhancement methods
  - Conduits into the vadose zone

GSA GeoSystems Analysis, Inc.
Innovative Solutions

Off-channel Basins
Groundwater Banks/Dedicated Fields

- Just in Kern County
  - AVEK WSSP
  - AVWB
  - Kern Water Bank
  - Pioneer Water Bank
  - Berrenda Mesa WD Water Bank
  - Kern Delta WD Water Bank
  - North Kern WSD Water Bank
  - Shafter Wasco ID Water Bank
  - Semitropic WSD Water Bank
  - Buena Vista WSD Water Bank
  - Rosedale Rio Bravo WSD Water Bank
- Growers Recharging
  - Sun World
  - Wonderful (Paramount)
  - Pacific Resources & Pacific Ag
  - JG Boswell
  - Marvin Meyers
  - Maricopa Orchards

GSA GeoSystems Analysis, Inc.
Innovative Solutions


Friant Kern Canal
Woods Central Canal


North Kern WSD Water Bank


Shafter Wasco ID Water Bank


Fernandes Water Bank


Images provided by Dave Dorrance, RRG
Burns 1 Water Bank

In-channel Designs
Rock Ford

Image provided by Frank Postillion – PCFCD

In-channel Designs
Rock Ford

Upstream

Downstream

Images provided by Frank Postillion, PCFCD

GSA GeoSystems Analysis, Inc.
Innovative Solutions

In-channel Designs
Deflection Dike

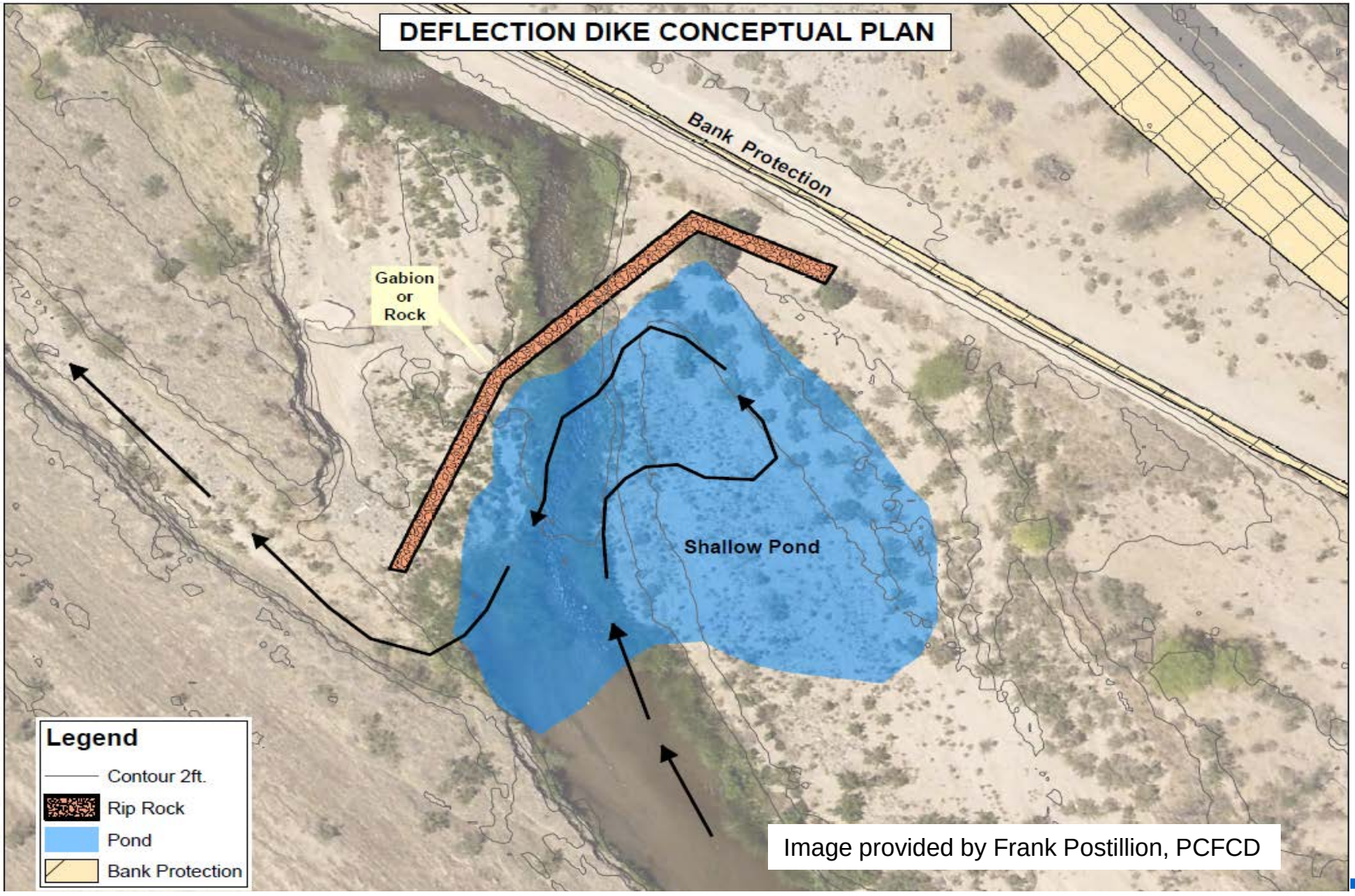
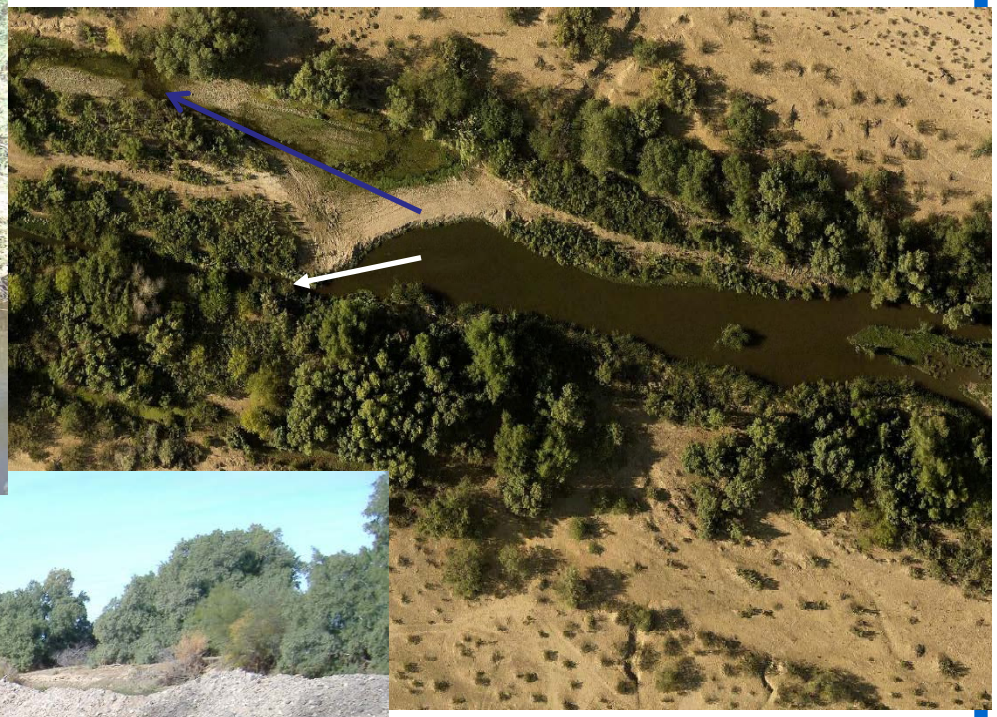


Image provided by Frank Postillion, PCFCD

In-Channel Design
Oxbow Diversion



Images provided by Frank Postillion, PCFCD

In-Channel Designs
Check Dams

Image provided by Frank Postillion, PCFCD

In-channel Designs
T and L Levees

Recharge Enhancement Methods

Drywell Installation

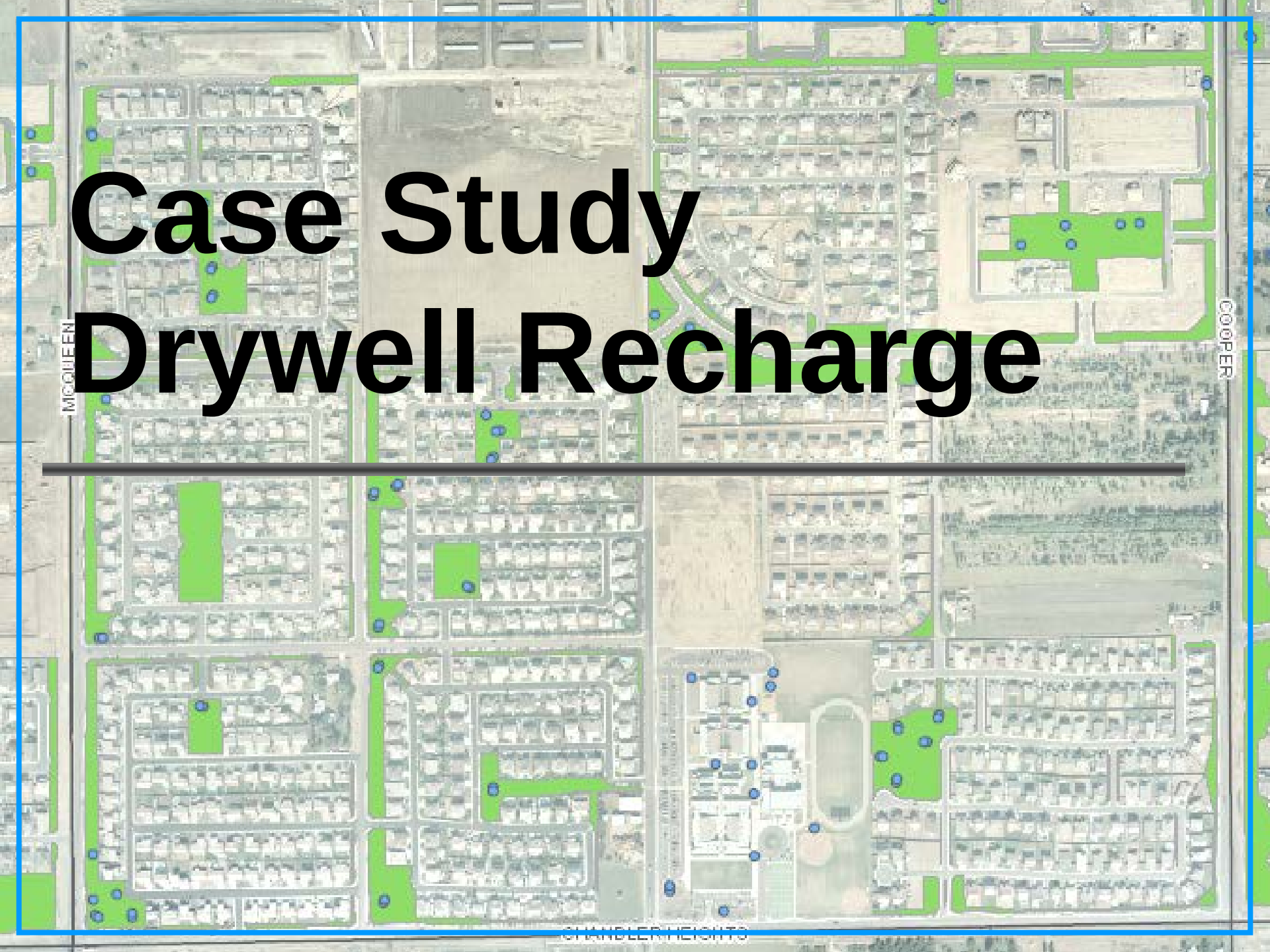

Infiltration Gallery

GSA GeoSystems Analysis, Inc.
Innovative Solutions

Recharge Enhancement Methods

Underground Storage/Recharge Systems

GSA GeoSystems Analysis, Inc.
Innovative Solutions



Case Study
Drywell Recharge

Drywell/Rockwell Case Study

- Determine the amount of groundwater recharge resulting from existing stormwater capture systems
- City of Chandler
  - approximately 39,000 acres
  - Up to 100 yr storm must be contained on site
- Impervious surface estimates: 8100 to 11,300 acres
- Neighborhood and lot scale detention basins
  - Approximately 3800 registered drywells (more now)

GSA GeoSystems Analysis, Inc.
Innovative Solutions

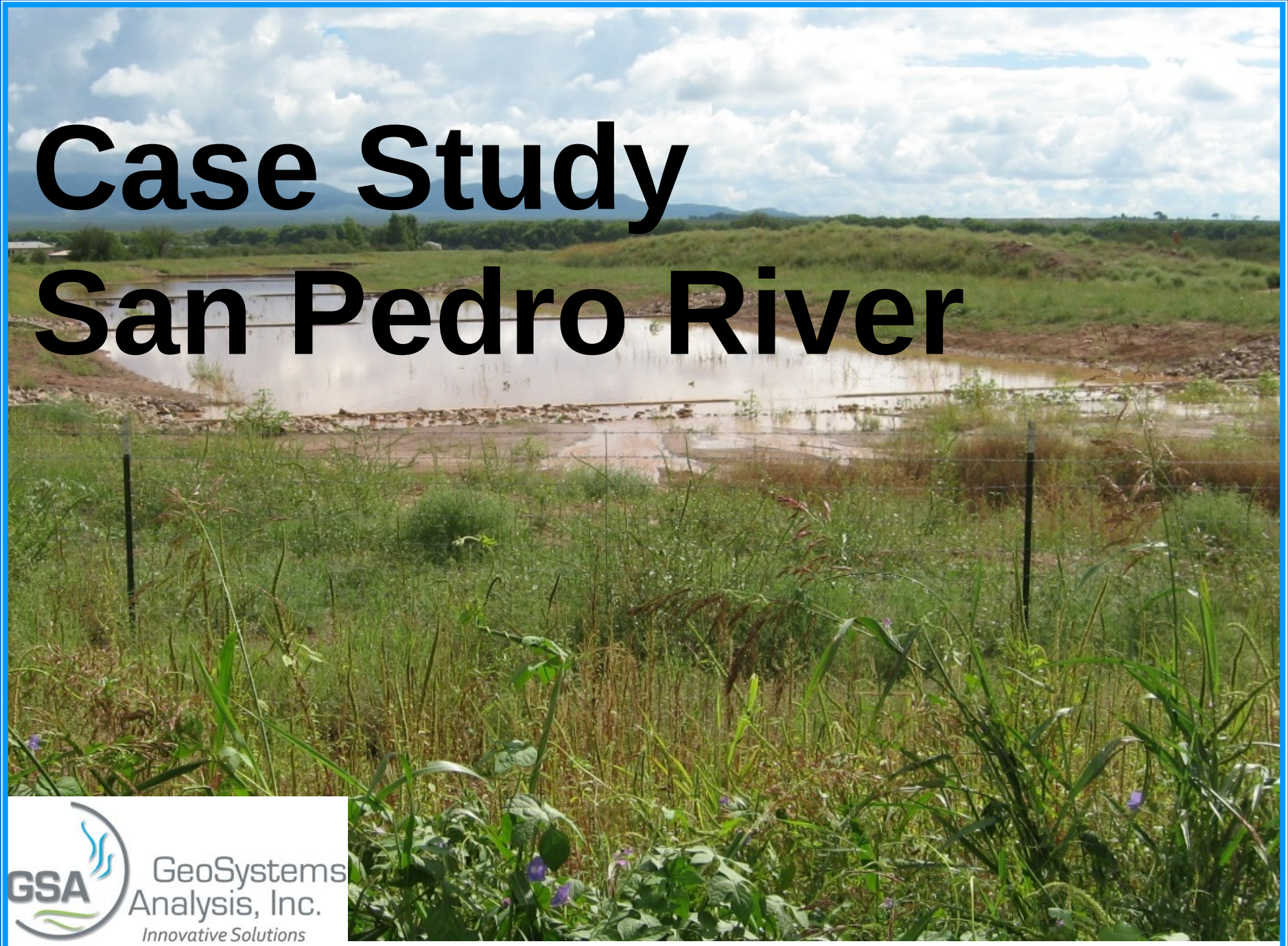
Project Approach/Results

- Average precipitation = 8.3 inches/year
  - multiple stations (108 yr record)
- GIS evaluation of land cover and land use types to develop SCS runoff model
- Estimate stormwater runoff for individual events (108 yrs)
- RESULTS:
  - Predicted UER is 5X greater than pre-development runoff
  - > 2400 afa estimated groundwater recharge

  (> 10X increase in recharge, 10% of annual precipitation)

GSA GeoSystems Analysis, Inc.
Innovative Solutions

Case Study
San Pedro River

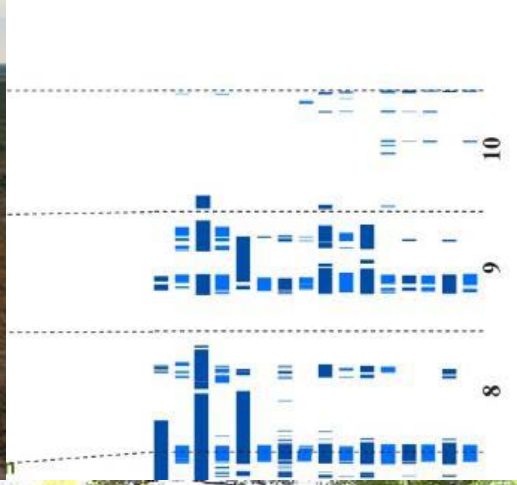


GSA GeoSystems Analysis, Inc.
Innovative Solutions

Case Study - San Pedro River

- CONCEPT: Stormwater capture and recharge basins to augment base flows in San Pedro River
  - Groundwater modeling to identify best places to help base flow
  - GIS screening and data evaluation to identify potential recharge sites
  - Surface water modeling to estimate surface water flow rates and urban enhanced runoff volumes
  - Field investigations
  - Detention/recharge basin(s) design
- Multiple drainages/sites evaluated, one facility built, one in design

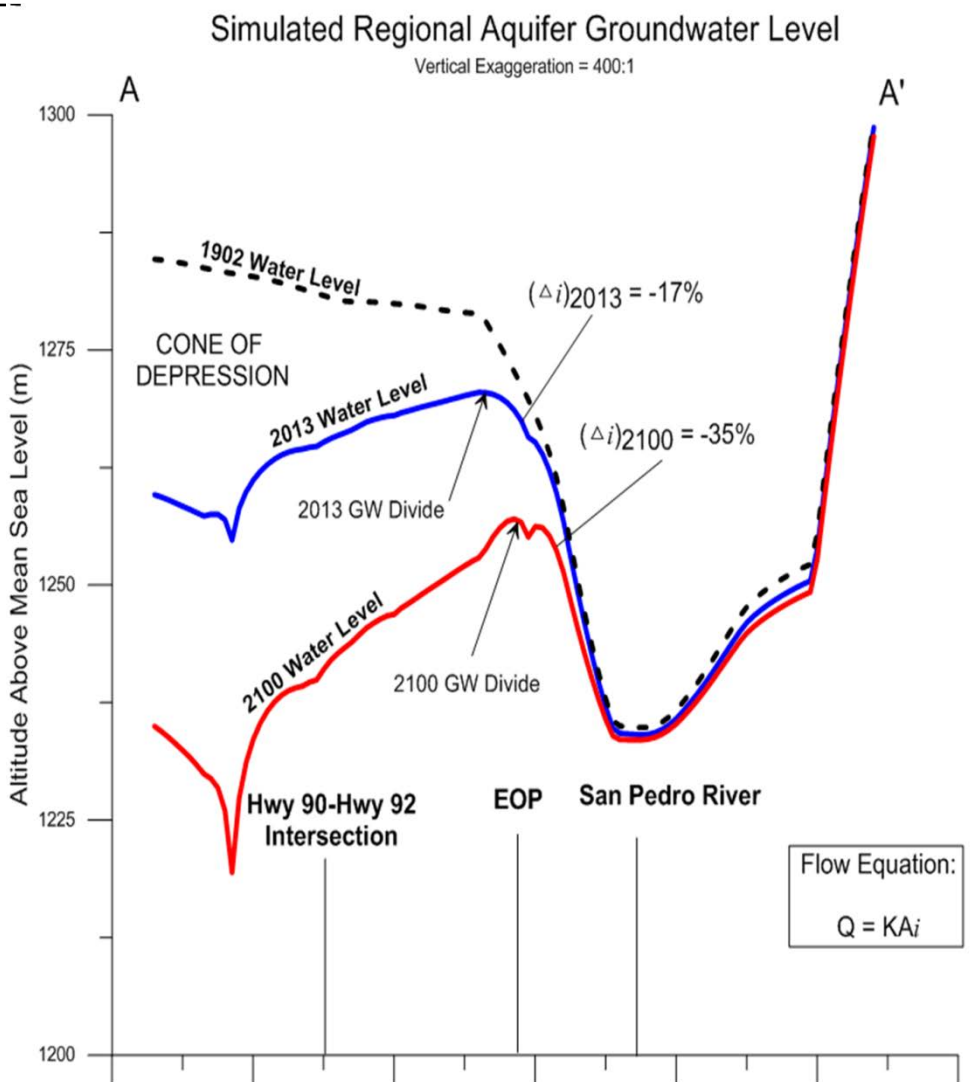
GSA GeoSystems Analysis, Inc.
Innovative Solutions



From Lacher et al, 2014. Application of Hy
Making in the Upper San Pedro River, Ariz

Groundwater Modeling

- Evaluate effect of MAR on river base flow for 100 yrs
  - USGS Upper San Pedro Basin MODFLOW model w/ River Package
- Modeling indicates:
  - MAR into cone of depression has no effect on river flows
  - Recharging along the SPRNCA boundary maintains base flows for approximately 100 yrs



From Lacher et al, 2014. Application of Hydrologic Tools and Monitoring to Support Managed Aquifer Recharge Decision Making in the Upper San Pedro River, Arizona, USA, Journal of Water

GSA GeoSystems Analysis, Inc.
Innovative Solutions

Surface Water Modeling

- How much stormwater runoff, how much UER?
- AGWA/KINEROS Model
  - Highly detailed model for greatest urbanized watershed
  - Predicts runoff, infiltration in channels and basins
  - Model events from 57 year precipitation record
    - Average = 14.5 inches/year
  - Use of regression relationships for other watersheds (13)
- Model runs to predict stormwater runoff and infiltration:
  - UER ranges from 200 to almost 700 afa depending on watershed
  - Design storm events using HEC-1
  - Estimate potential UER capture volumes (varies)

GSA GeoSystems Analysis, Inc.
Innovative Solutions

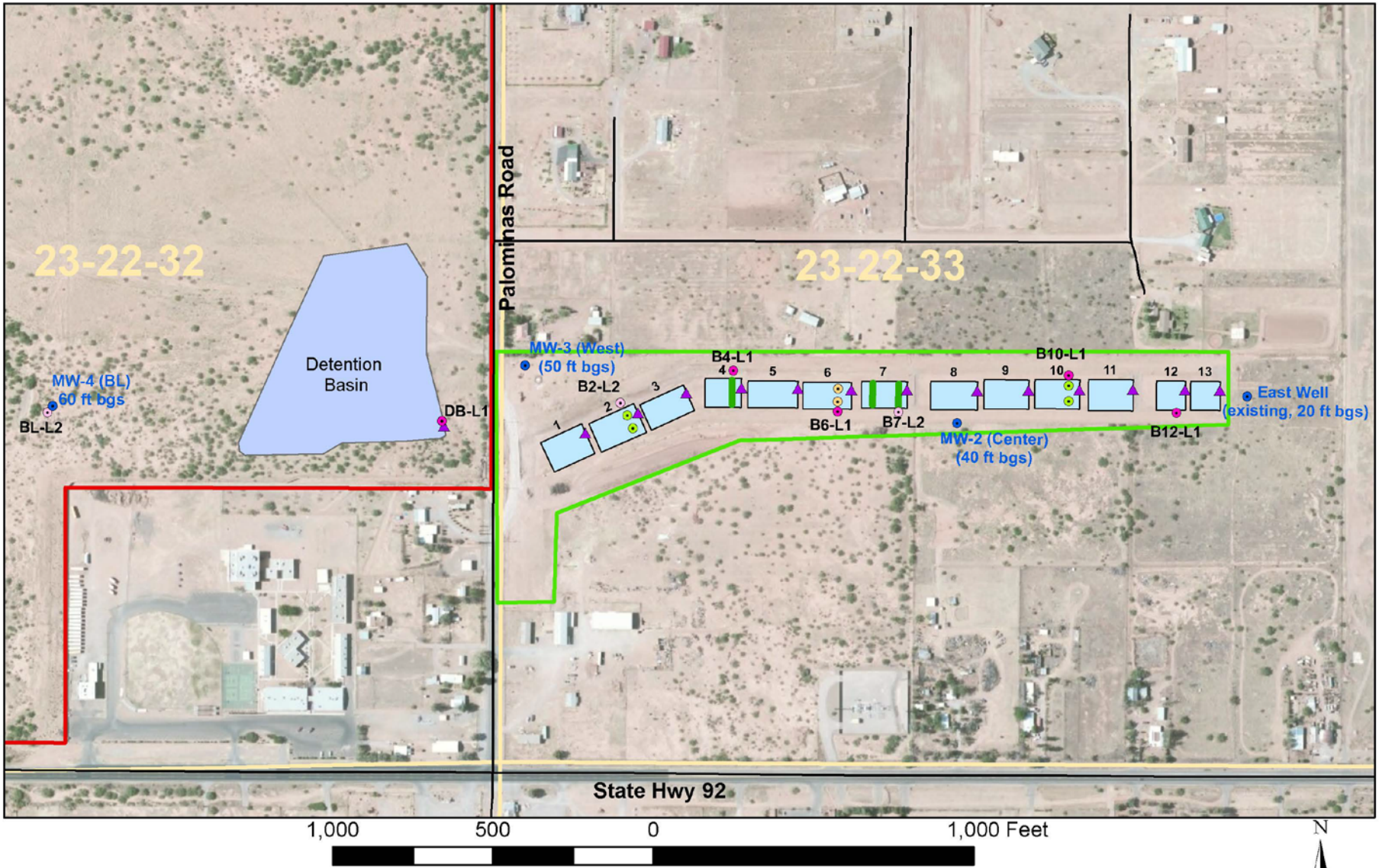
Recharge Site Investigations

Near surface back-hoe test pits and cylinder infiltrometer testing (Bouwer et al., 1998)

Borehole drilling and geologic logging

GeoSystems Analysis, Inc.
Innovative Solutions

Palominas Detention/Recharge Basin Design



Palominas Detention/Recharge Basin Design

Ephemeral Streamflow Monitoring

- In-stream monitoring network
  - Stilling wells
  - Precipitation Gauges
  - Flowtography
- Depth Data Analyzed Using:
  - Continuous Slope-Area (CSA) Method
  - HEC-RAS, HY-8
  - Stage-Storage
- Baseline stormflow data to inform facility design

GSA GeoSystems Analysis, Inc.
Innovative Solutions

What we know and what we don't

- Small is good….
  - High capture efficiency – more is better
  - Generally limited to upper parts of watershed
  - Drywells/Rockwells need design parameters
- Larger watershed capture and recharge facilities
  - How big to design? - need modeling AND monitoring
  - Need to find appropriate hydrogeology
  - Design for sediment control
- Maintenance and monitoring
  - All systems need maintenance for sedimentation
  - Need to monitor – BEFORE and AFTER

GSA GeoSystems Analysis, Inc.
Innovative Solutions

Thank you!

mike@gsanalysis.com

- Acknowledgments:
  - Cochise County
  - City of Chandler
  - The Nature Conservancy
  - Orange County Water District
  - Pima County Flood Control District
  - Renewable Resources Group
  - The Walton Foundation

GSA GeoSystems Analysis, Inc.
Innovative Solutions