

Riparian Restoration Planning for Long-term Success: an Example from the Upper Gila River, Arizona

Riparian Restoration & Tamarisk Beetle Workshop

Coachella Valley Water District

Palm Desert, California

23 October 2019

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Stillwater Sciences

Restoration Framework Process

- Restoration Goals and Objectives with Community Support
- Suitable Restoration Sites and Strategies
- Monitoring Objectives and Protocols
- Environmental Permits
- Implement Active Restoration

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Desert Riparian Ecosystems

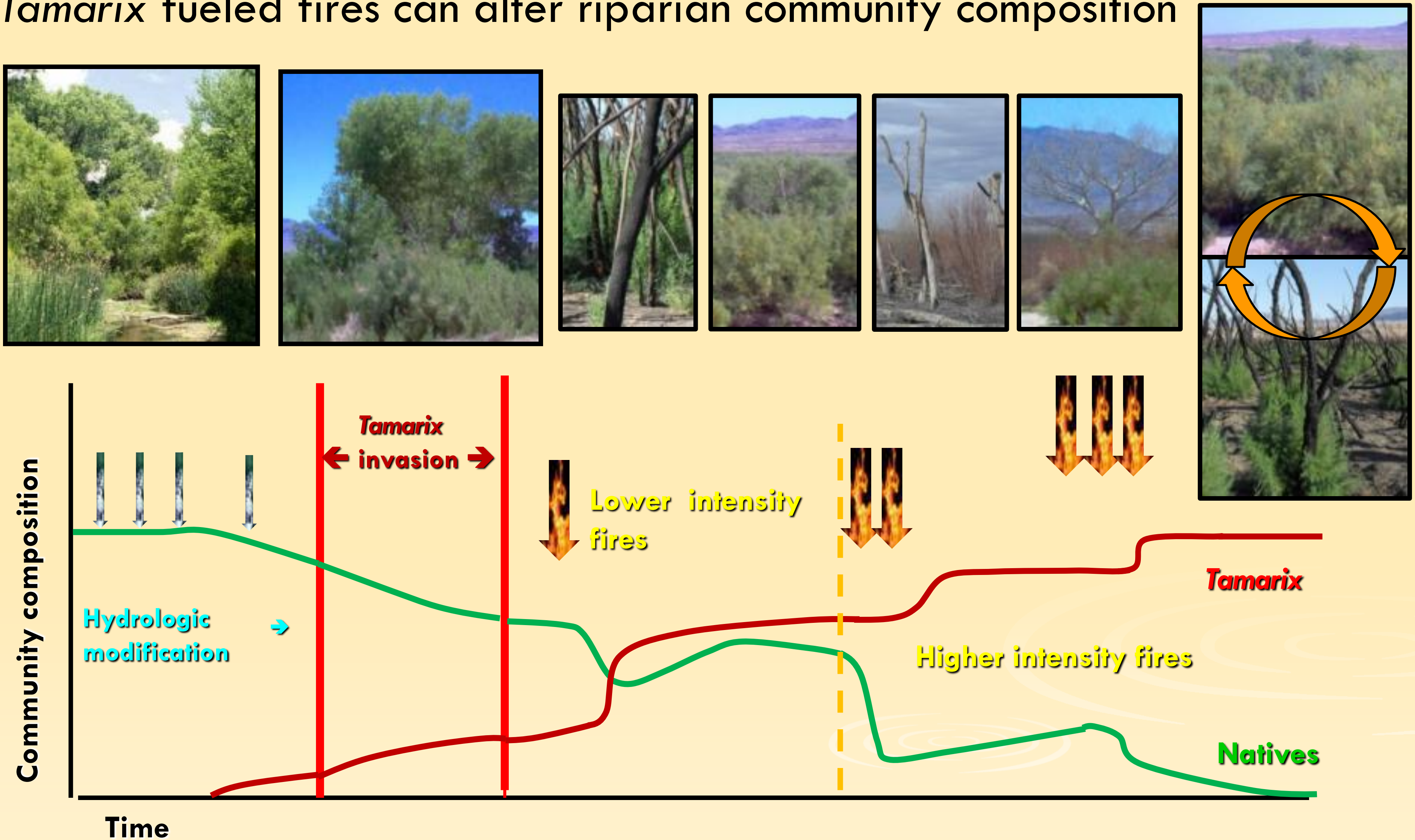
- **Ecologically and economically valuable**
  - **High diversity and productivity**
  - **Wildlife habitat**
  - **Water resources**
  - **Recreational use**
  - **Other ecosystem services**

Impacts of *Tamarix* invasion are well documented

- Displaces native riparian plant species
- Alteration and simplification of habitat structure
- Soil degradation and groundwater depletion
- Disrupts mycorrhizal growth and persistence
- Alters erosion and sedimentation (flood management)
- Increases wildfire risk

The *Tamarix* fire cycle

Tamarix fueled fires can alter riparian community composition



Courtesy of Gail Drus

Need for Riparian Restoration

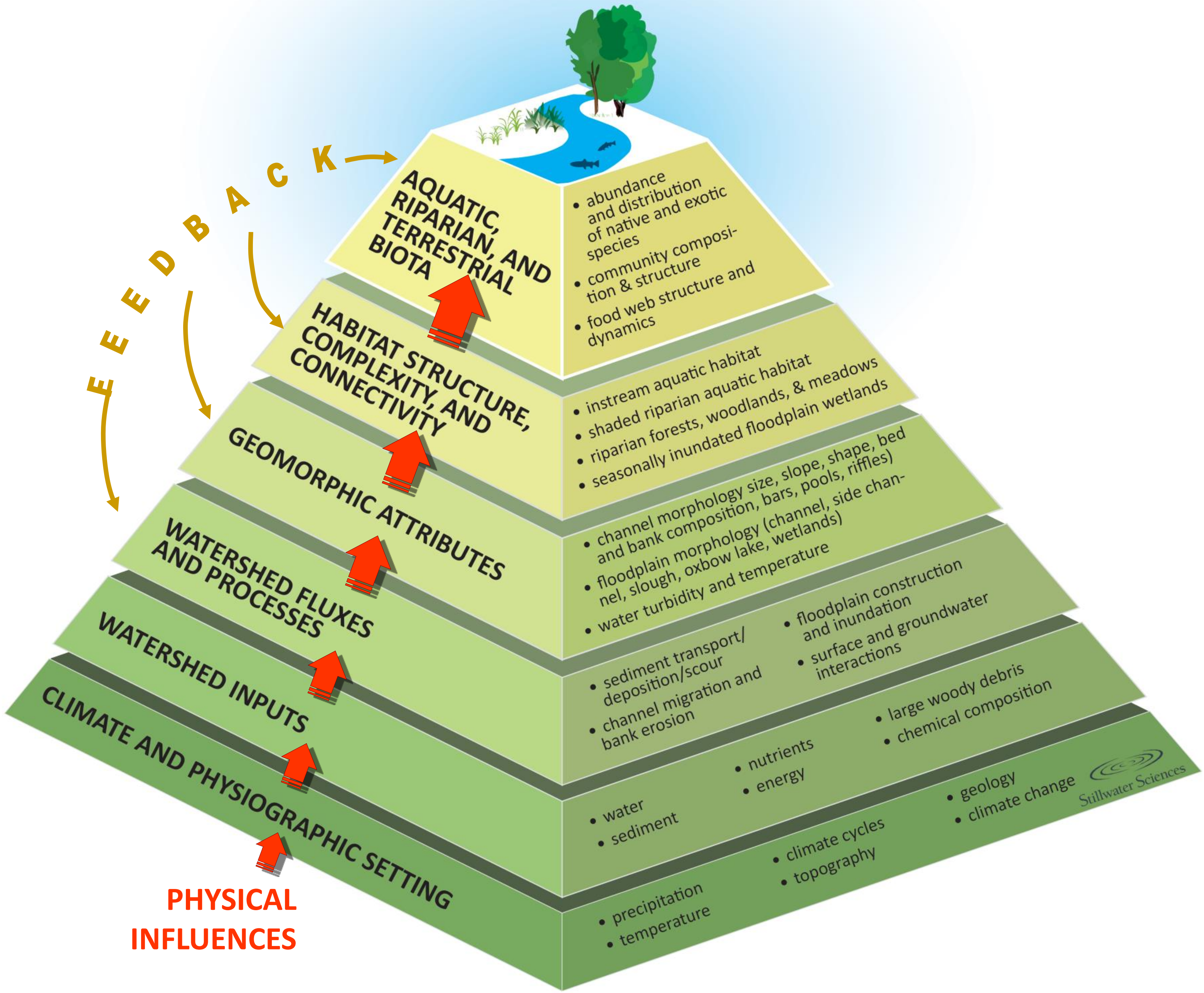
- Tamarisk/Saltcedar infestation
  - Has replaced native vegetation
  - Increases fire risk
  - Changes river morphology
  - Uses deeper water resources
  - Can increase soil surface salinity
- Important habitat for Southwestern Willow Flycatcher (SWFL)

Need for Riparian Restoration

- Expected arrival of tamarisk beetle within a few years

- Anticipated impacts to SWFL habitat

ECOLOGICAL LINKAGES CONCEPTUAL MODEL



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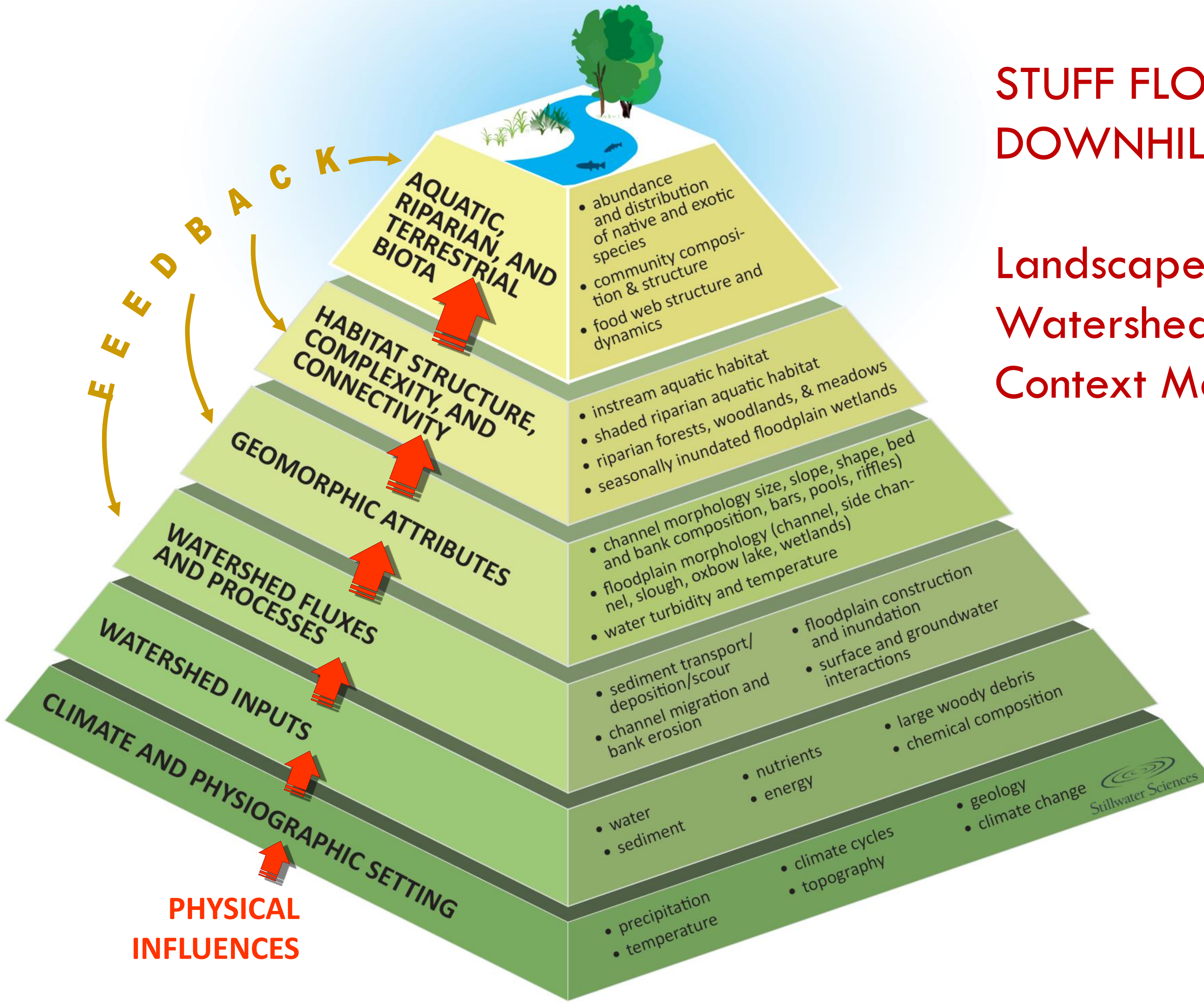
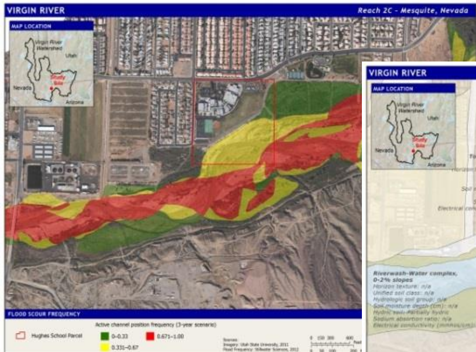


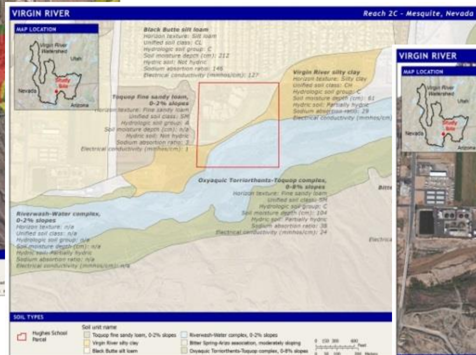
STUFF FLOWS DOWNHILL!

Landscape and Watershed Context Matters

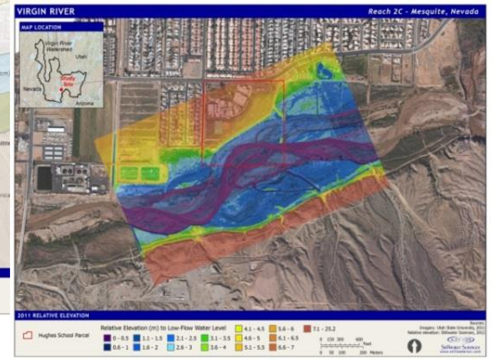
Use Ecohydrological Assessment to Determine Biophysical Template for Restoration



Flood Reset Zone



Soils
(texture & salinity)



Depth to Groundwater (Relative Elevation)

Physical Elements

BIOPHYSICAL TEMPLATE

Vegetation Types

Vegetation Structure
(canopy height)

+

Focal Species Habitat

Biological Elements

Next: Use Biophysical Template to Define Management Units & Priorities

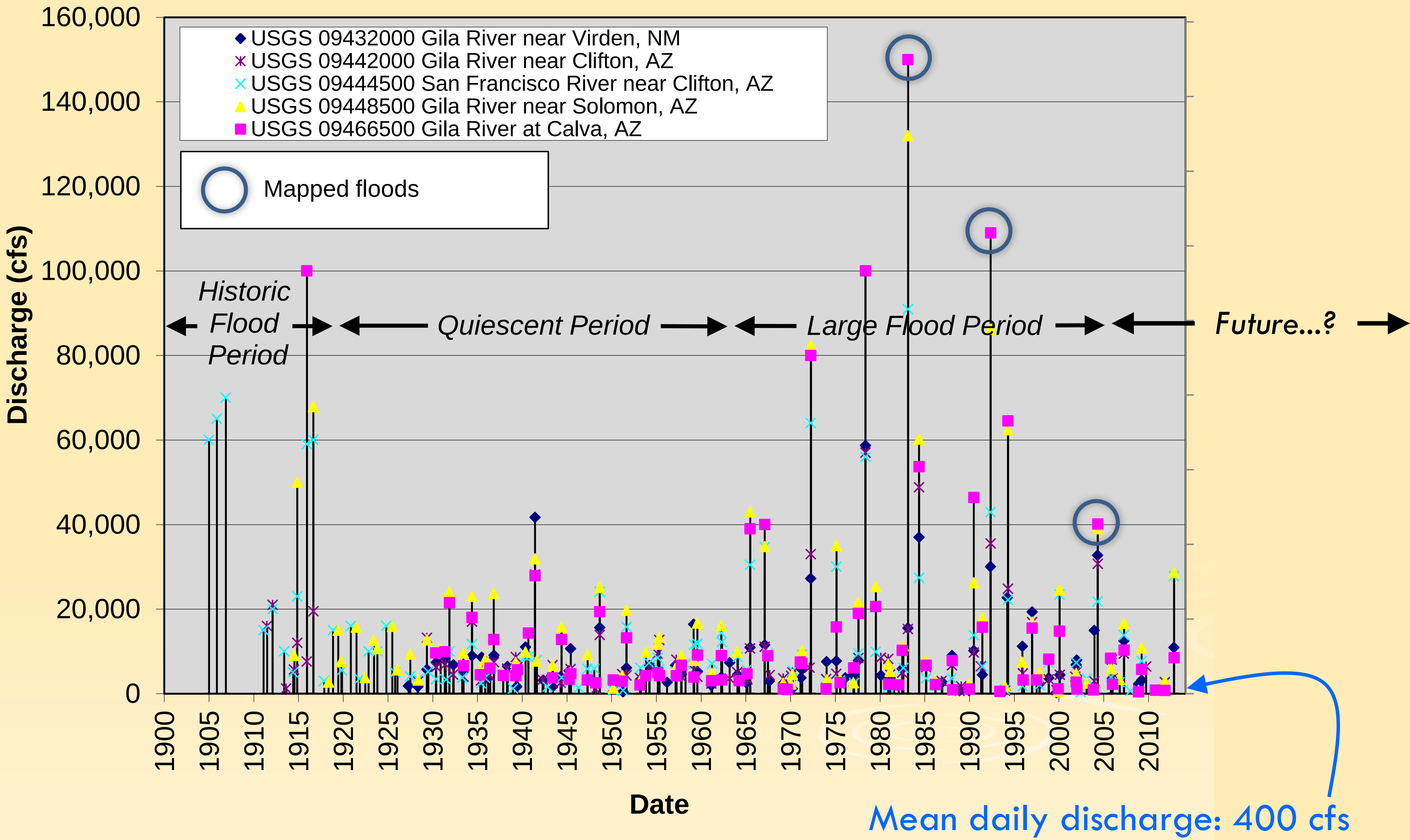
Key Elements of the Upper Gila River Riparian Restoration Framework Project

- Remote sensing data collection (USU RS/GIS)
- Ecohydrology Assessment (Stillwater)
- SWFL habitat modeling (USGS and NAU)
- Site surveys and pre-biocontrol baseline monitoring (Stillwater/UCSB/DBG/NAU)
- Technical input to GWP on restoration plan, monitoring protocols, plant propagation (Stillwater/UCSB/DBG/NAU)
- Community outreach, landowner coordination (GWP)
- Agency coordination and permitting application (GWP/Stillwater/NAU)

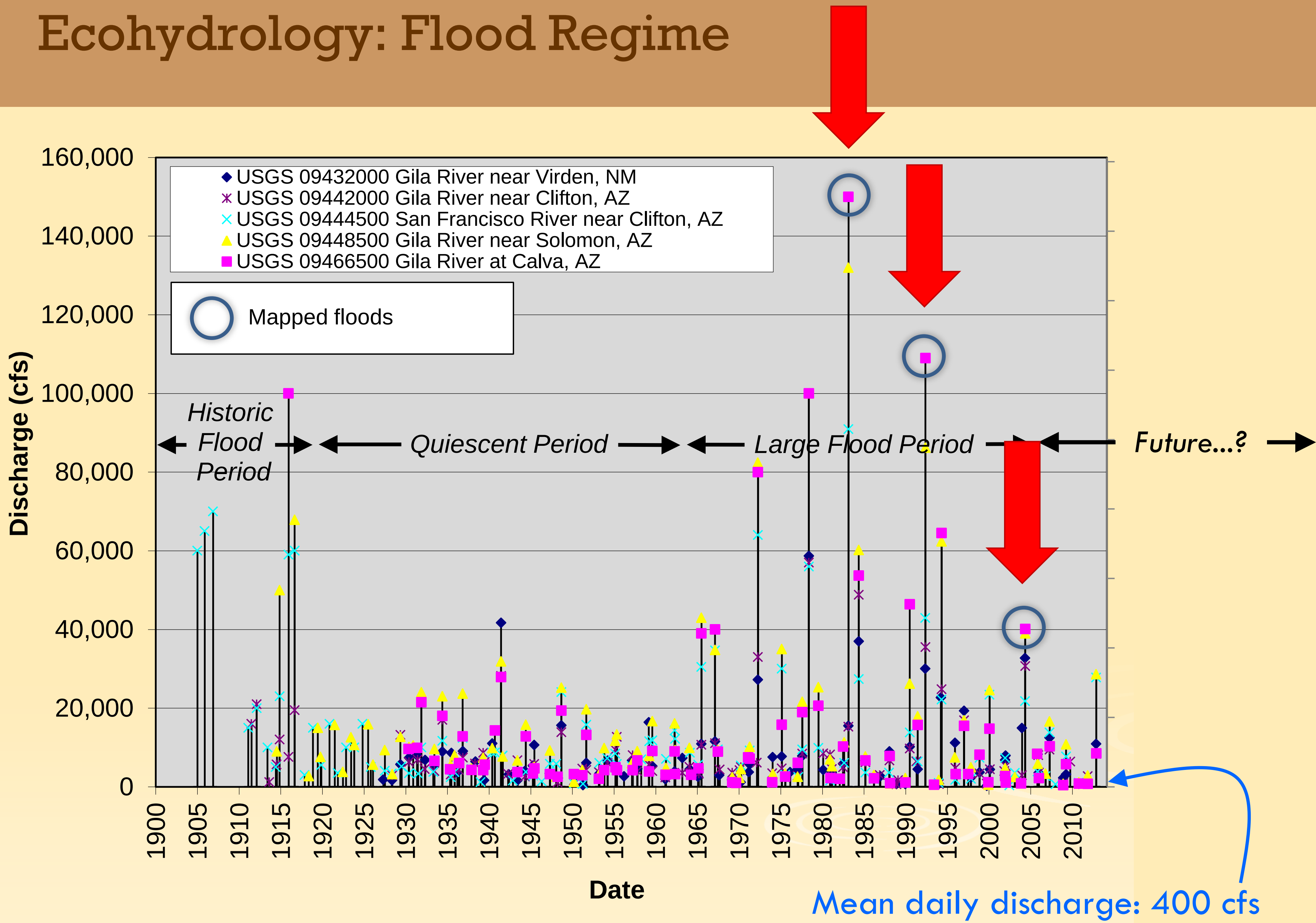
Ecohydrological Approach – Restoration Suitability

Ecohydrology: Physical Setting

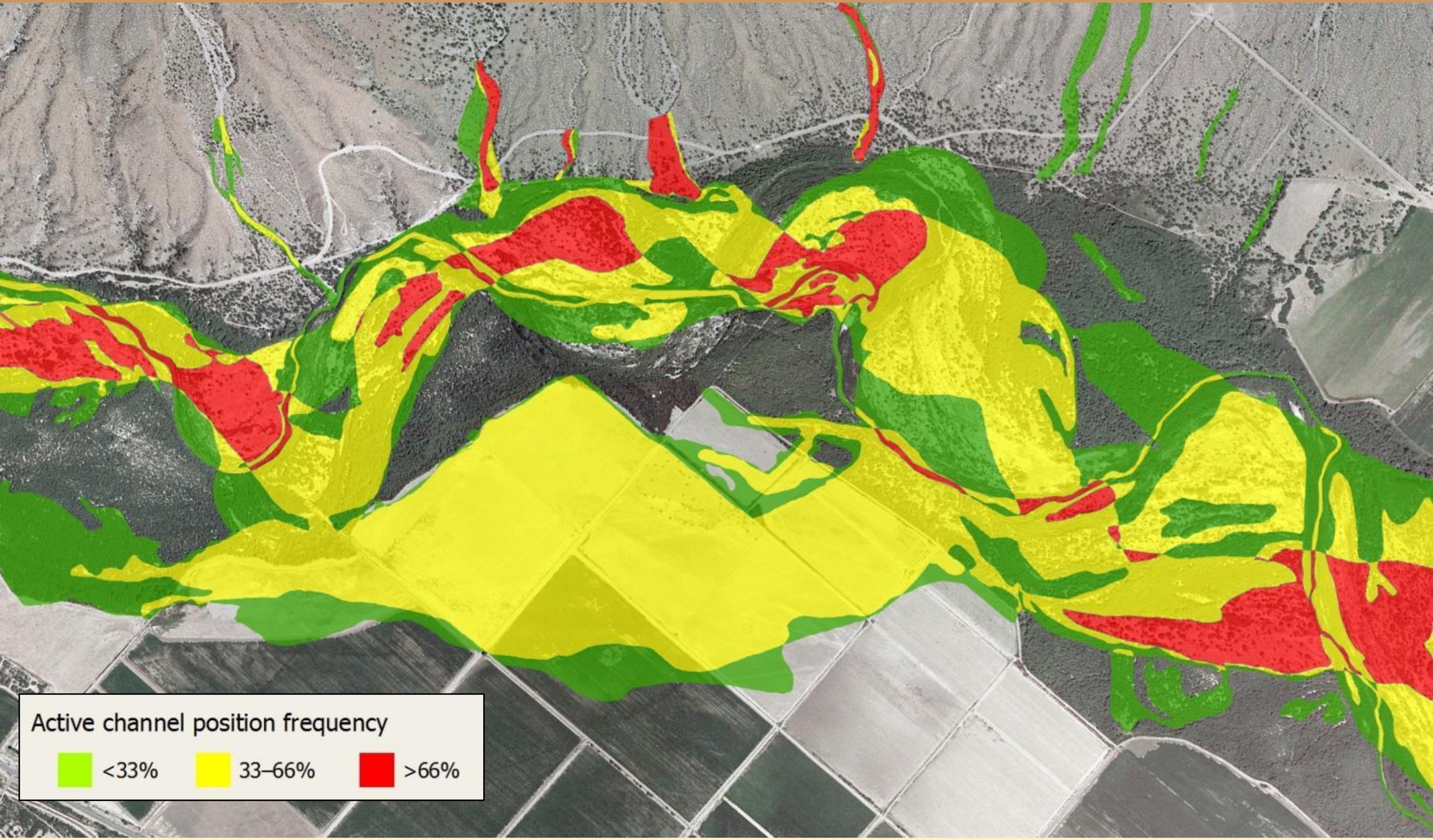
Ecohydrology: Flood Regime



Ecohydrology: Flood Regime

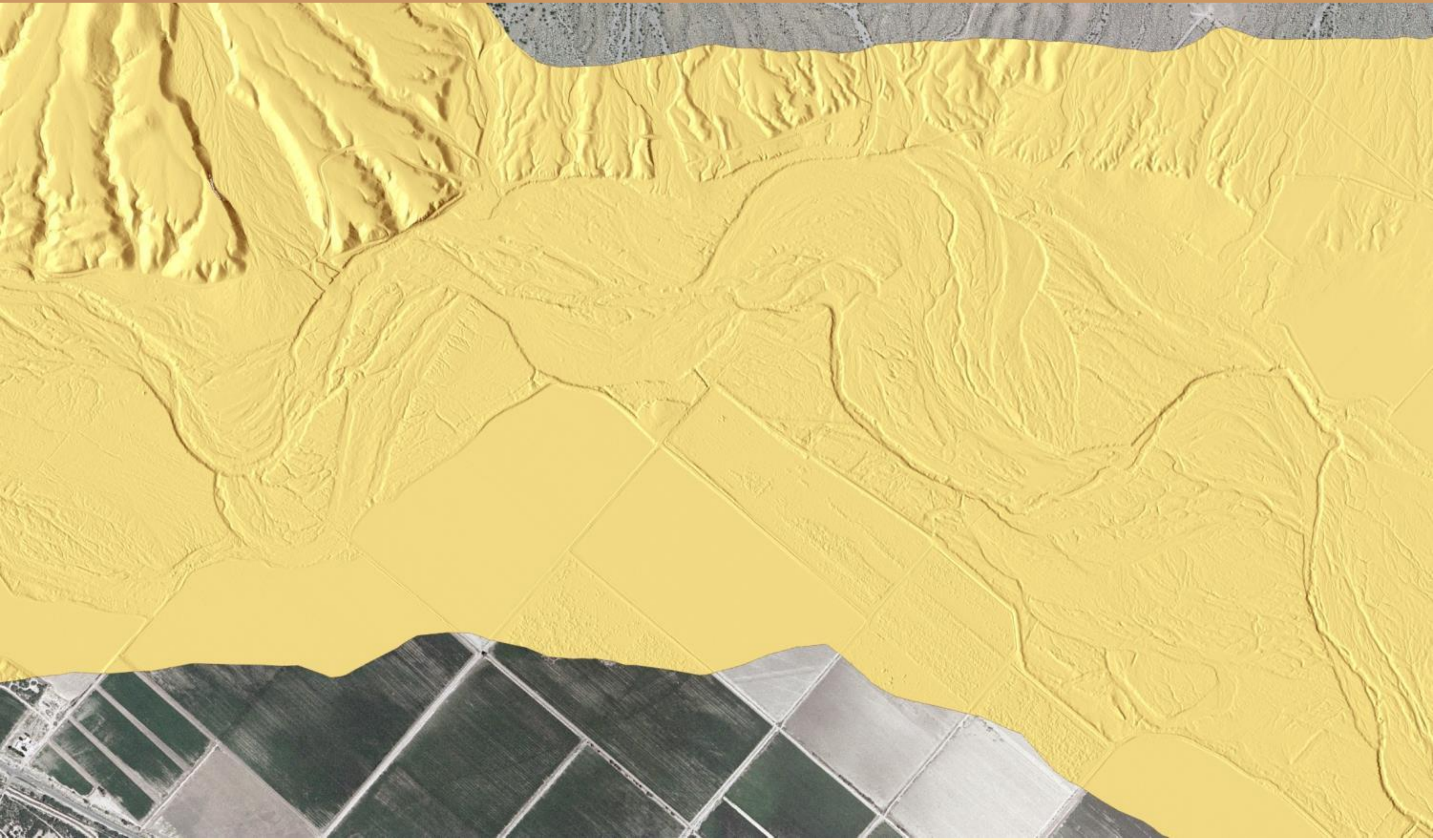


Ecohydrology: Flood-Scour Frequency



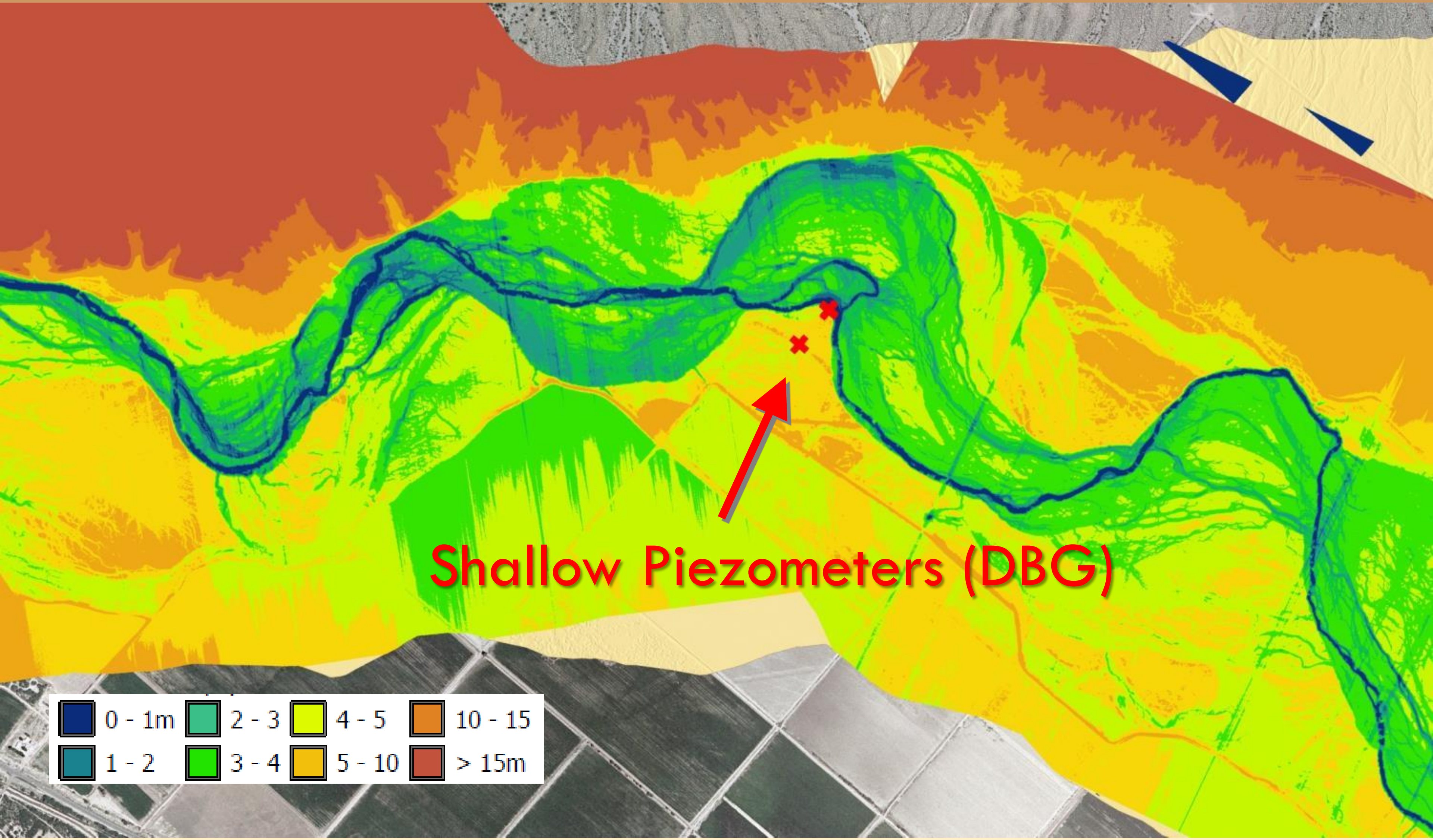
Flood-scour Frequency and "Flood Reset Zone" (Stillwater)

Ecohydrology: Topography



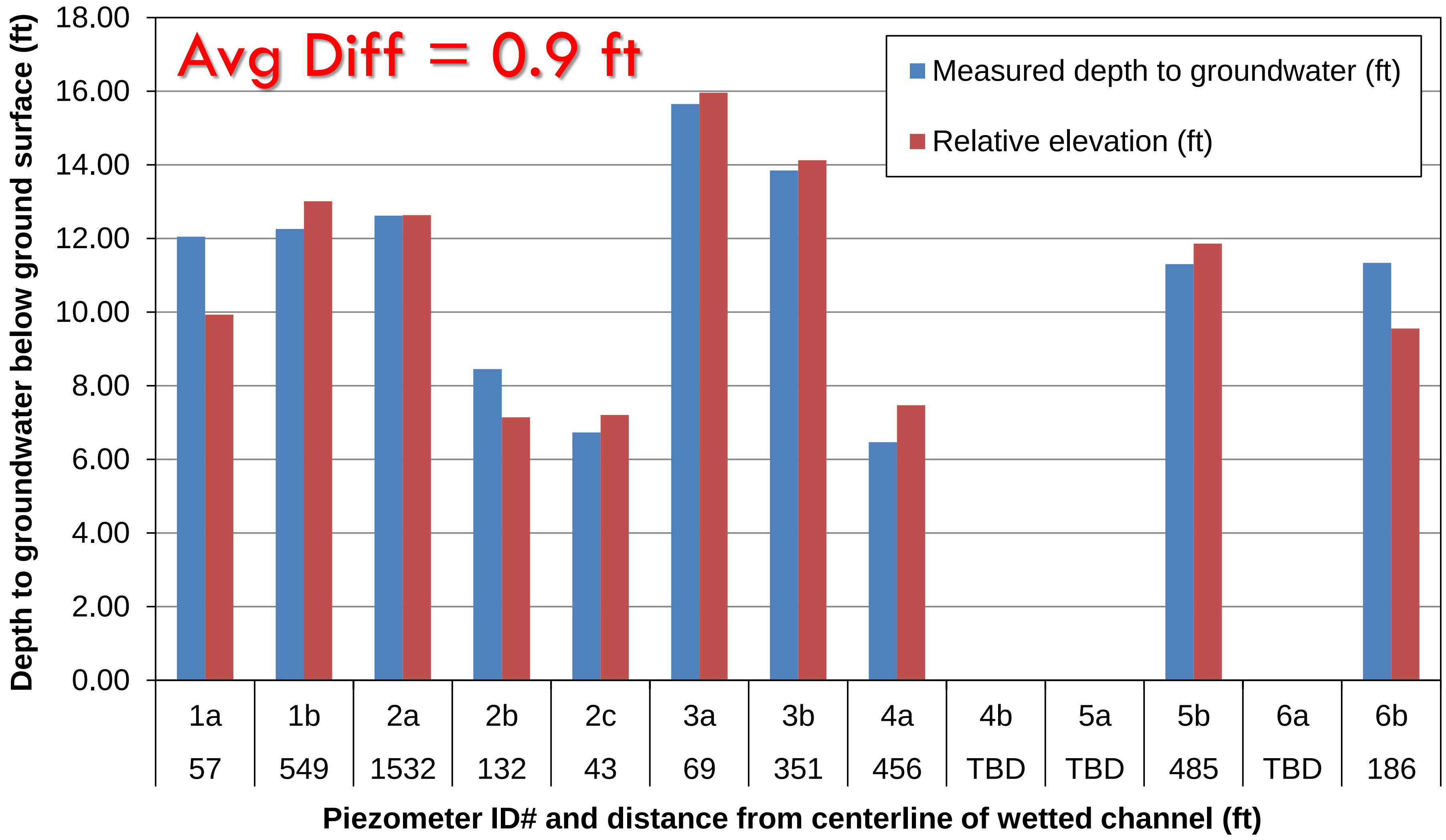
LiDAR Topography (USU RS/GIS)

Ecohydrology: Water Availability (Relative Elevation)



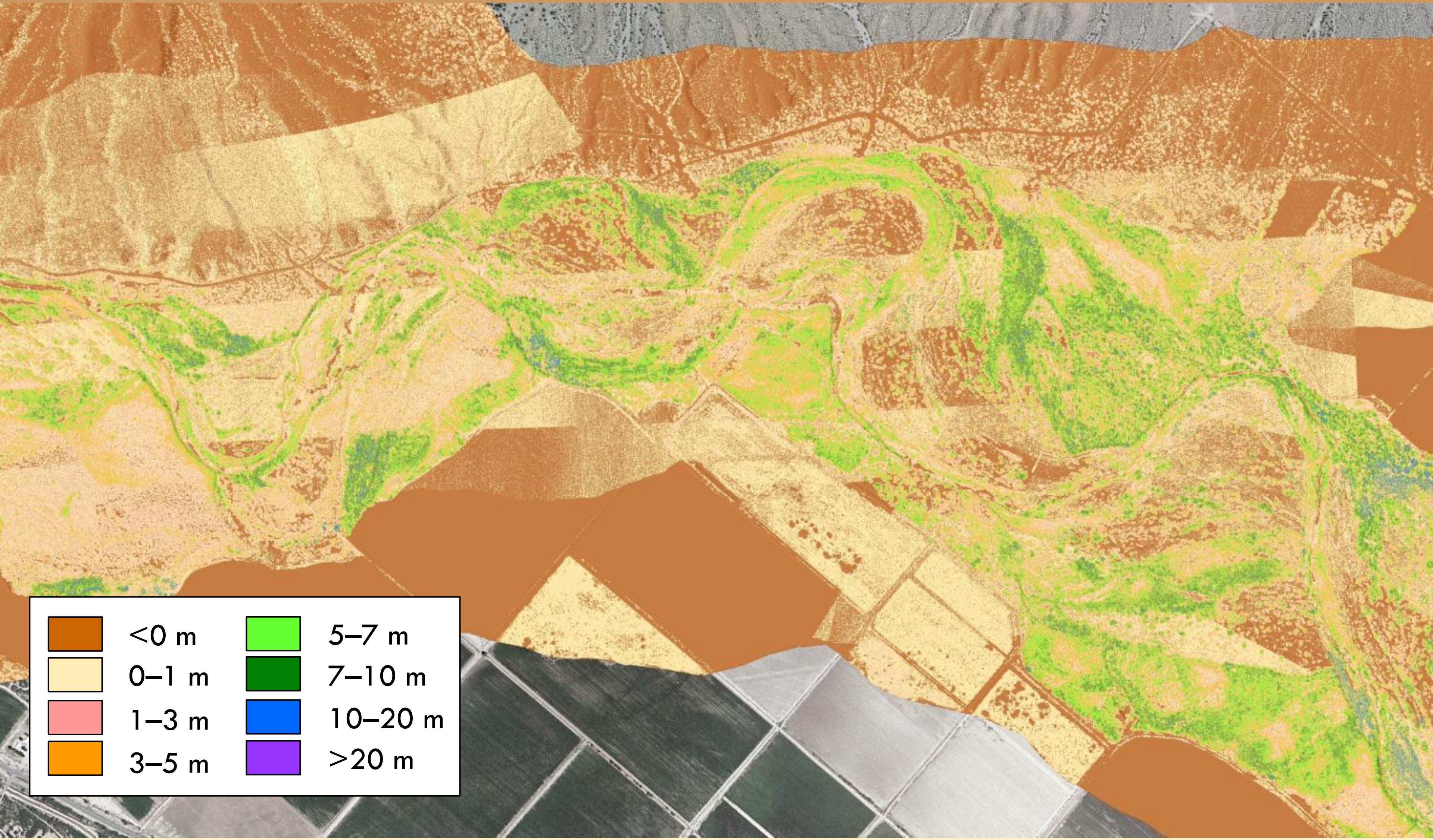
Relative Elevation above low-flow channel from LiDAR (USU/Stillwater)

Ecohydrology: Groundwater (Direct Measurement)



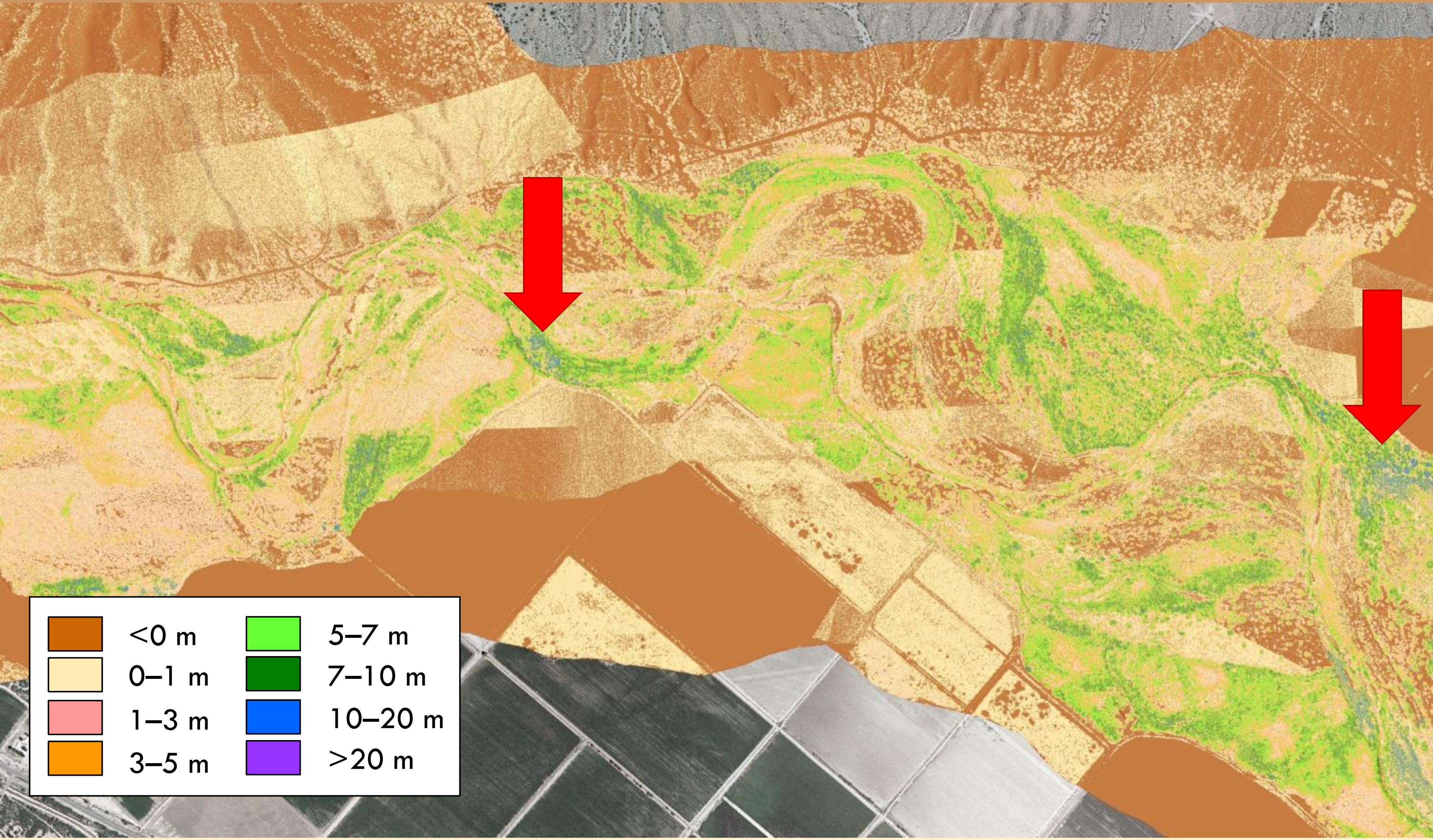
10 of 13 GW Monitoring Stations [3 forthcoming] (DBG/Stillwater)

Ecohydrology: Vegetation Characterization



Canopy Heights derived from LiDAR 1st returns (USU/Stillwater)

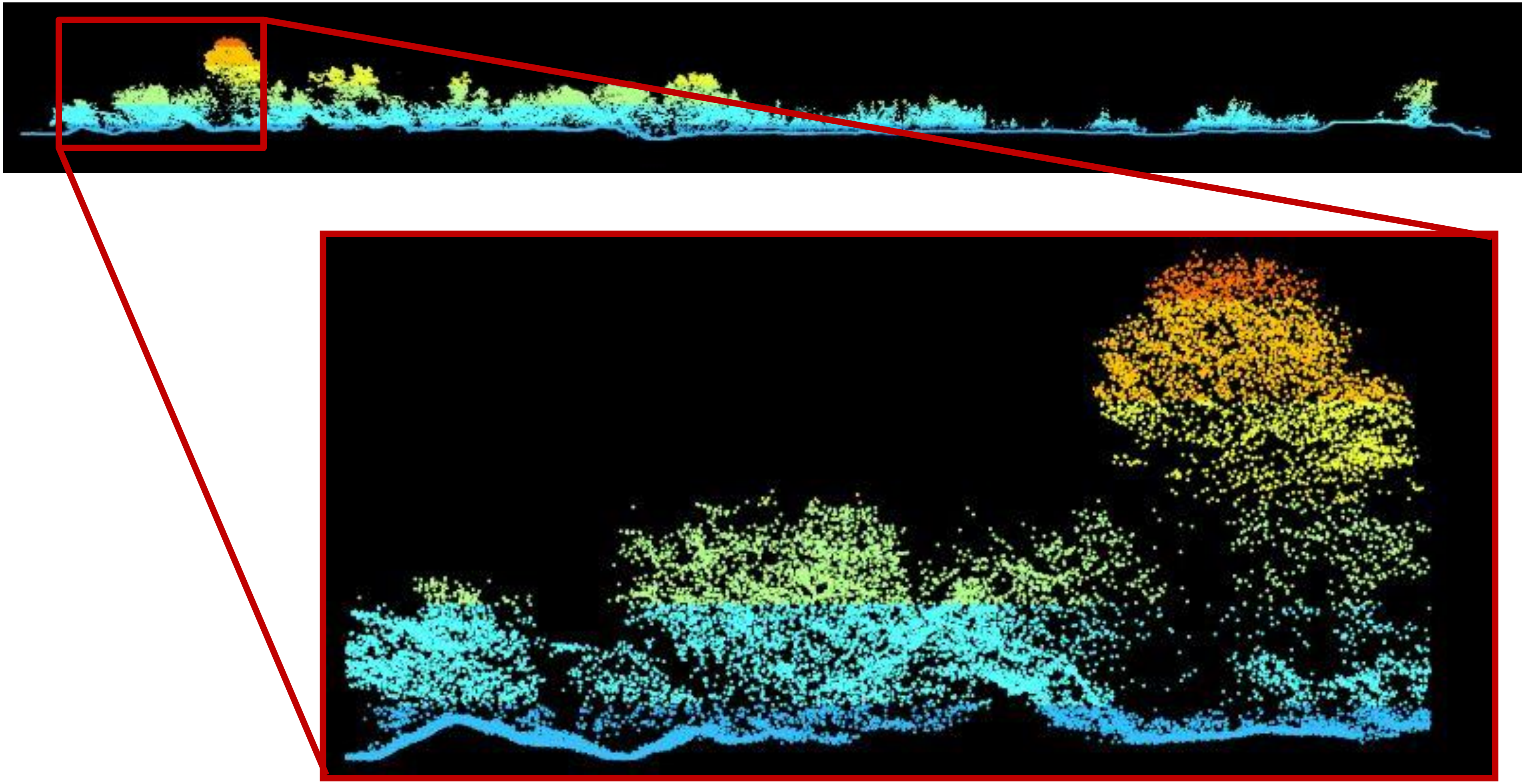
Ecohydrology: Vegetation Characterization



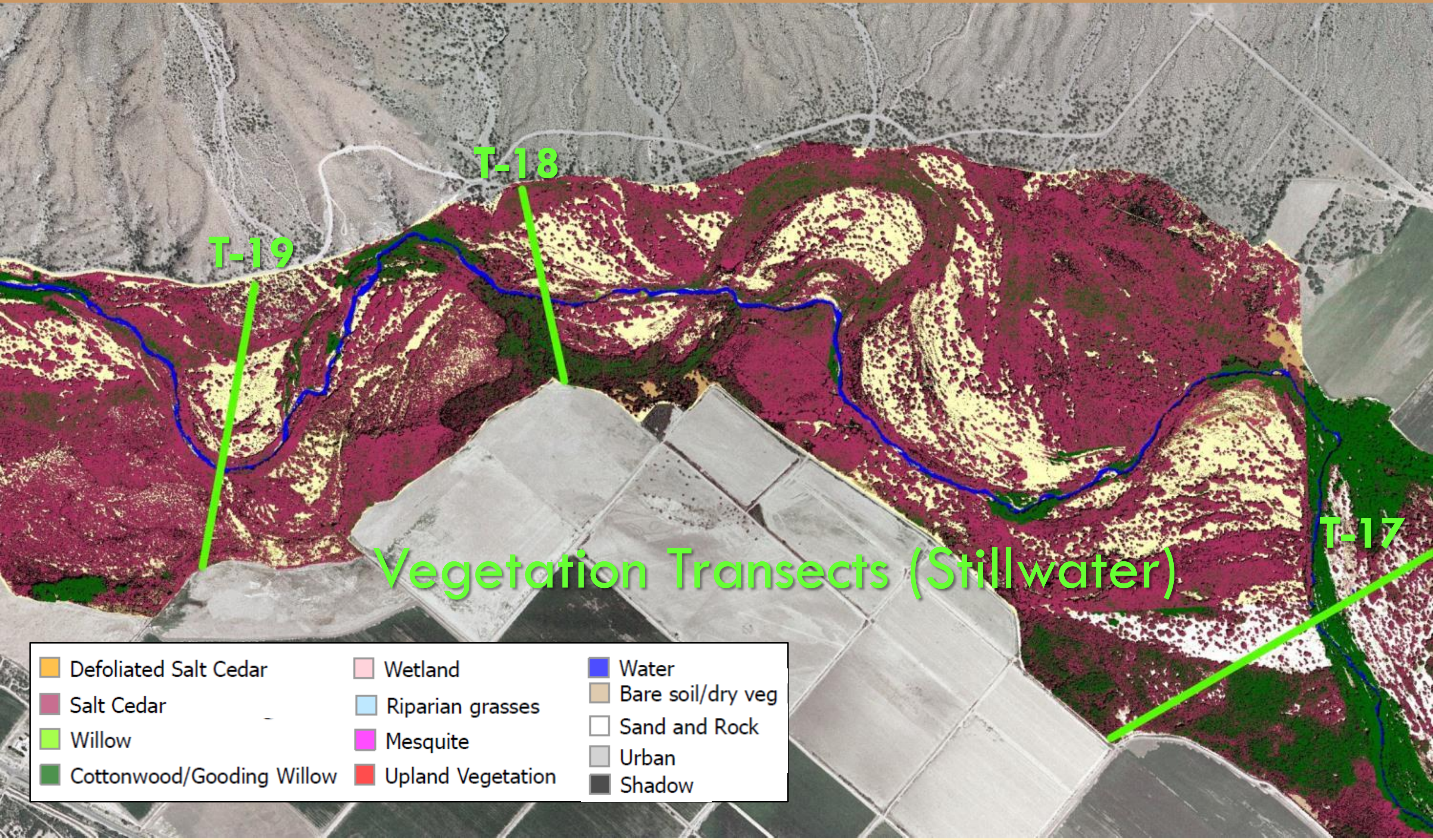
Canopy Heights derived from LiDAR 1st returns (USU/Stillwater)

VEGETATION & HABITAT STRUCTURE

- High density LiDAR to assess vegetation structure
- Habitat Suitability Modeling for Southwestern Willow Flycatcher, Western Yellow-billed Cuckoo, and Least Bell's Vireo



Ecohydrology: Vegetation Characterization



Vegetation Classification from Remote Sensing (USU RS/GIS)

Ecohydrology: Vegetation Characterization

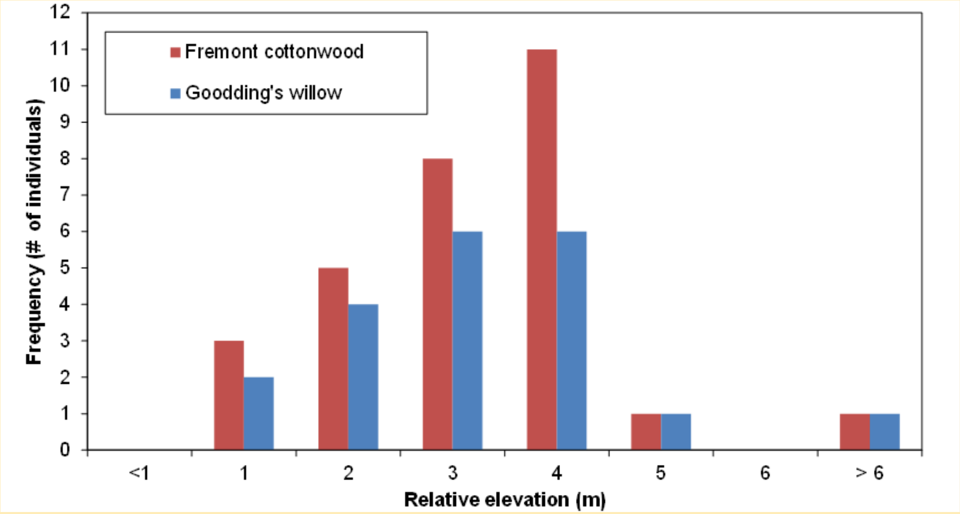
<u>Transect-Plot Surveys</u>

Estimated time since last flooded: <1, 1–2, 3–5, 6–10, or >10 years
Soil texture: gravel, silt, loam, clay, sand
Topography: convex, flat, concave, undulating
Percent ground cover of: water, vegetation, organic debris, cobble/boulder, gravel, and fine sediments
Evidence of: flooding, fire, soil moisture, and agricultural return flows
Types and intensities of unnatural disturbances: competition from nonnative invasive species, off-road vehicle use, and bulldozing/earth moving
Vegetation-type dominance: trees, shrubs, or forbs
Tree, shrub, and herb phenology: early, peak, or late
Species: name, age (e.g., seedling, mature, decadent), and percent cover of all prevalent plants
Vegetation type: name and vegetation type name of any adjacent, un-sampled vegetation

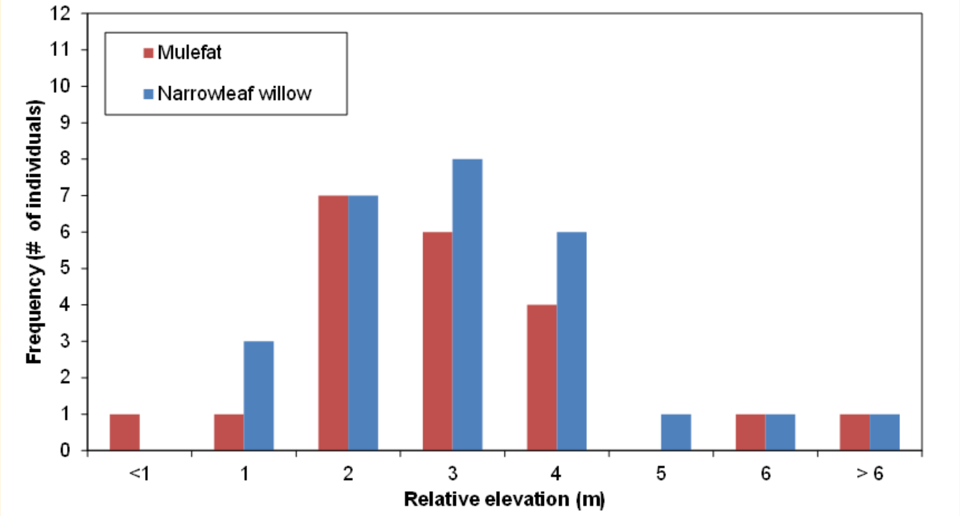
Vegetation Transects (Stillwater)

Ecohydrology: Vegetation Characterization

Fremont cottonwood-
Gooding's willow woodland

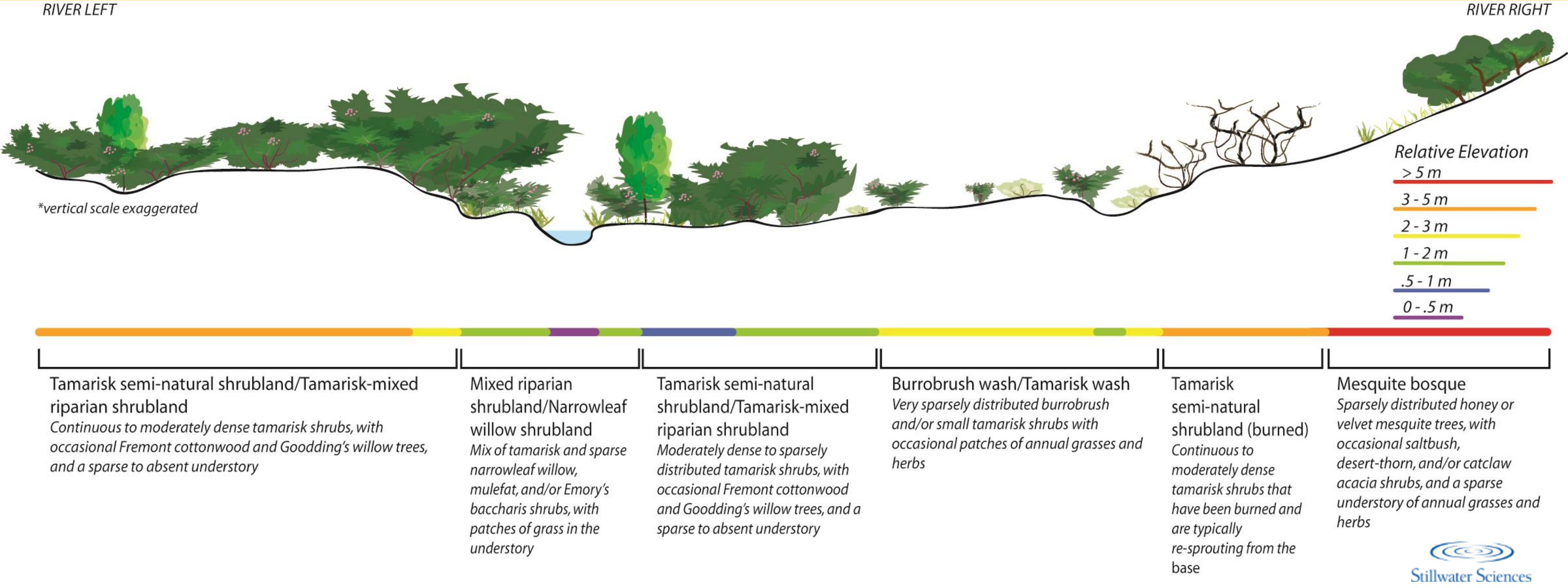


Mixed riparian shrubland



Group or alliance level of the U.S. National Vegetation Classification (NVC) system

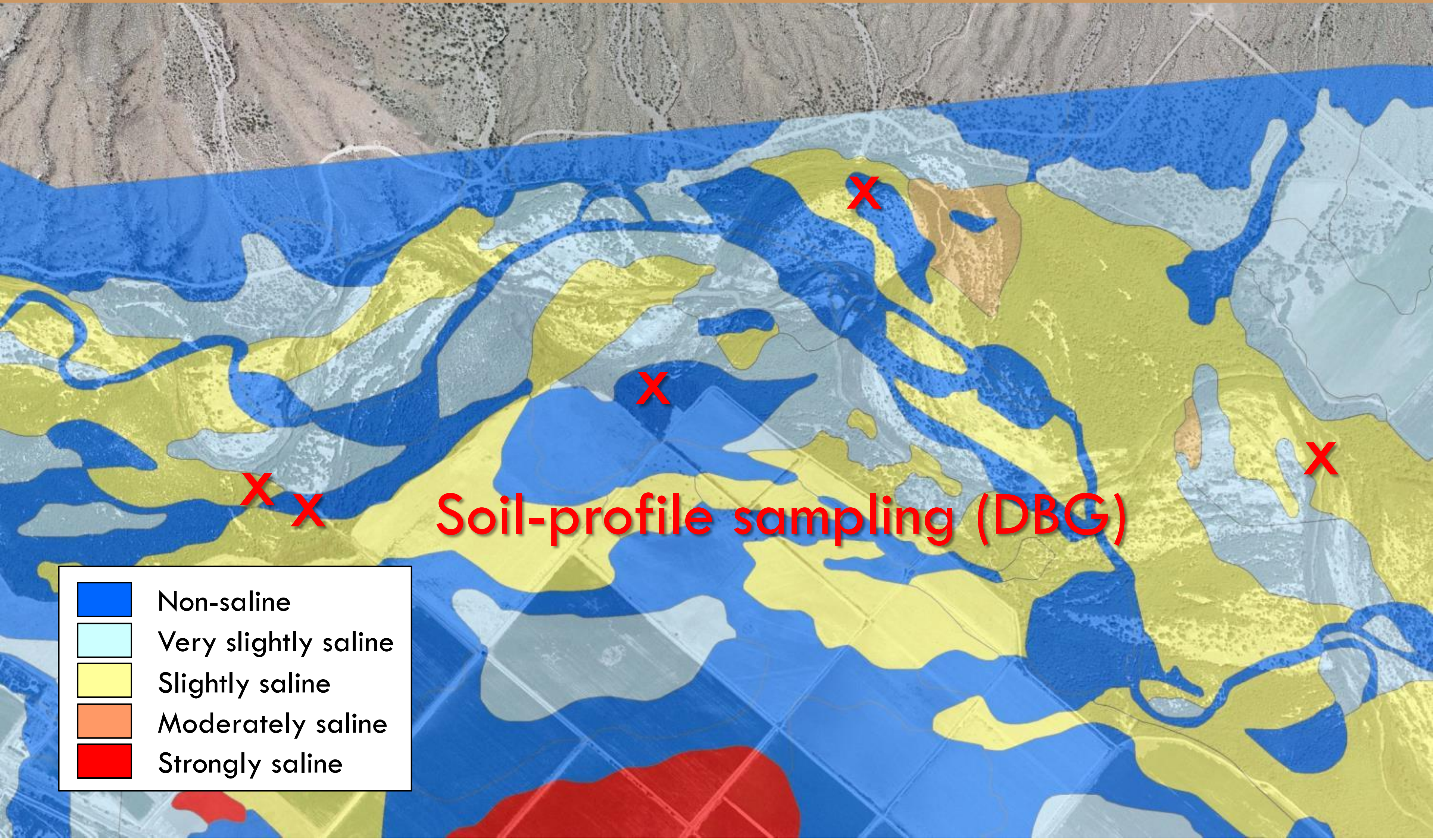
Ecohydrology: Vegetation Characterization



Findings

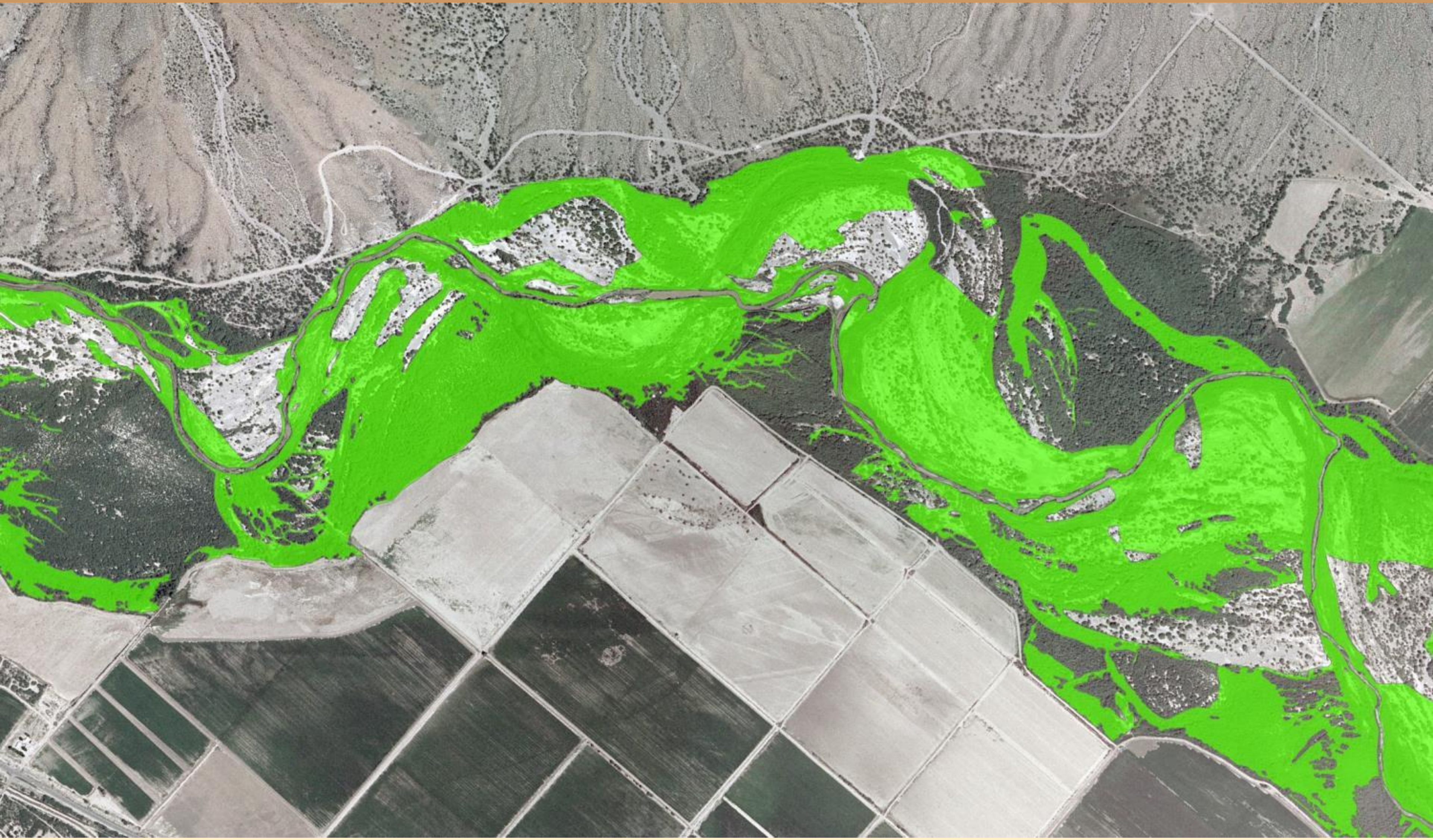
- **Variation along river length and across width; density (growth potential) greatest downstream (ag return flows) and closest to river (surface water/shallow groundwater)**
- **Limited natural recruitment of native woody vegetation; most stands aged to 1993 flood**
- **Natural recruitment potential greatest in and near the Flood Reset Zone (active scour in Sept 2013: 28600 cfs=6 yr RI, 8500 cfs=3 yr RI)**
- **Propagule islands at existing native stands; new islands implemented almost anywhere else**
- **Take advantage of recent burned areas**

Ecohydrology: Soil Characterization (Salinity)



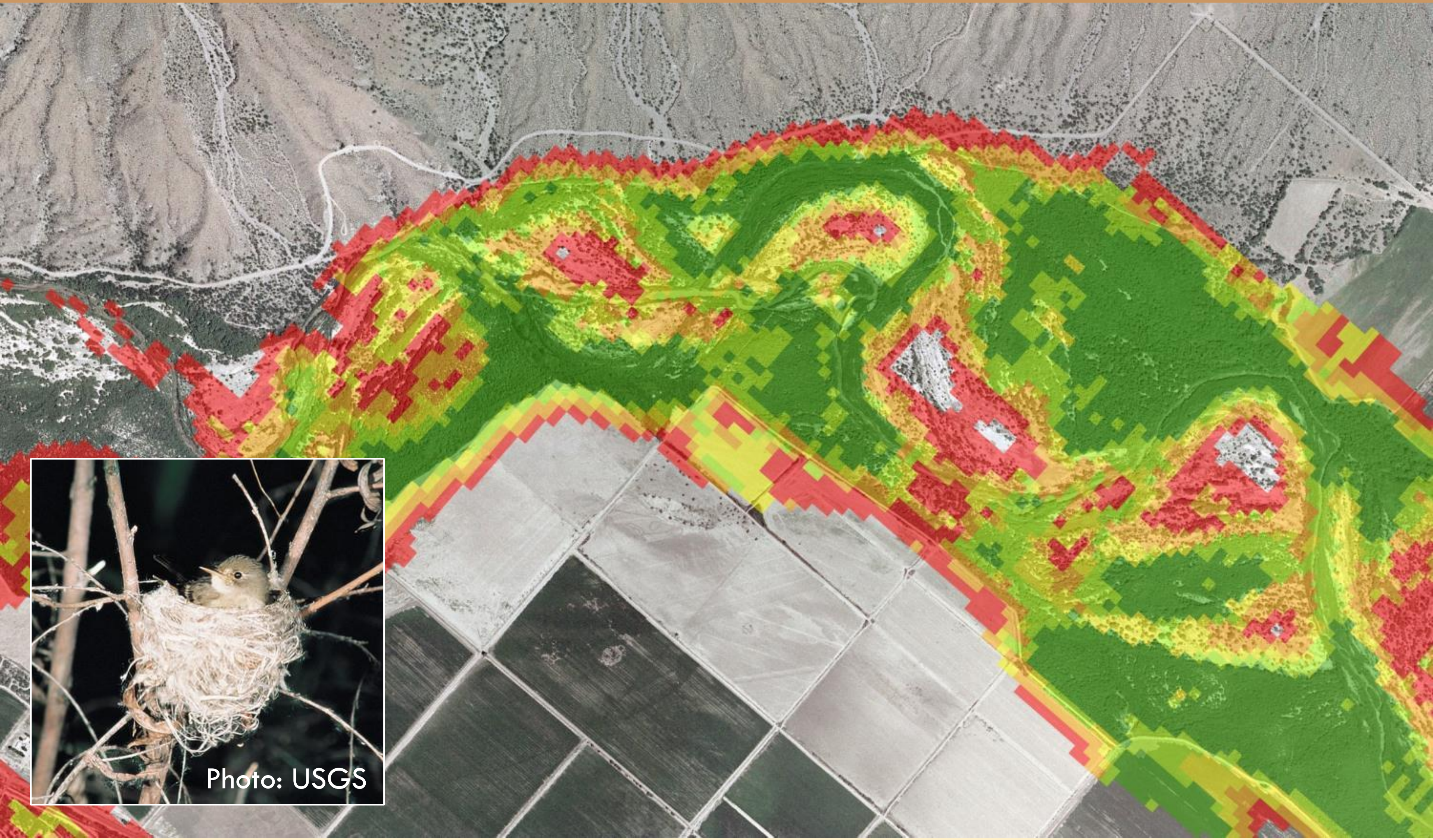
Soil Salinity from SSURGO Database (NRCS/Stillwater)

Ecohydrology: Potentially Suitable Restoration Areas



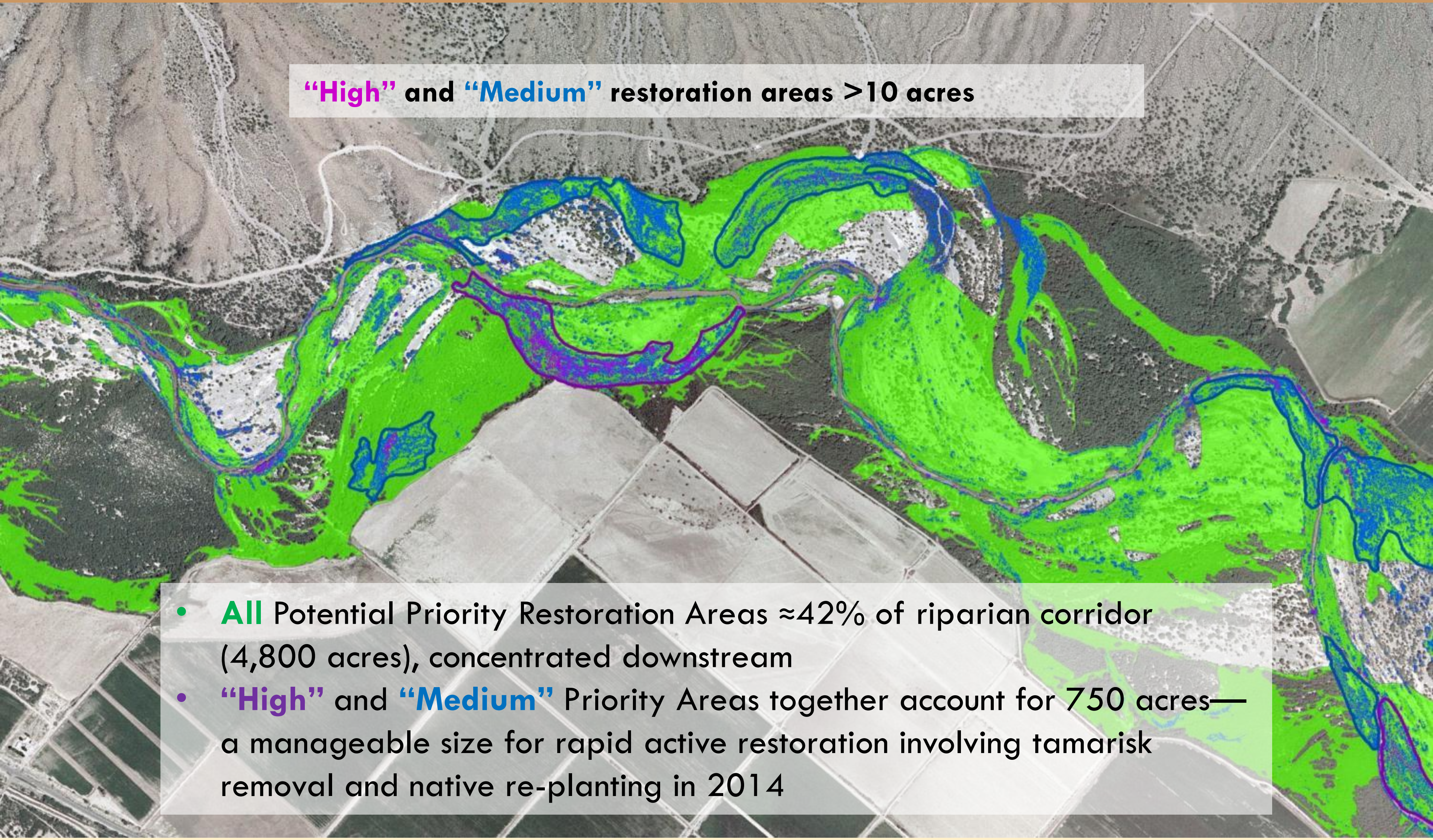
All Potentially Suitable Restoration Areas (Stillwater)

SWFL Breeding Habitat Suitability



SWFL Breeding Habitat Suitability (LANDSAT) from J. Hatten (USGS)

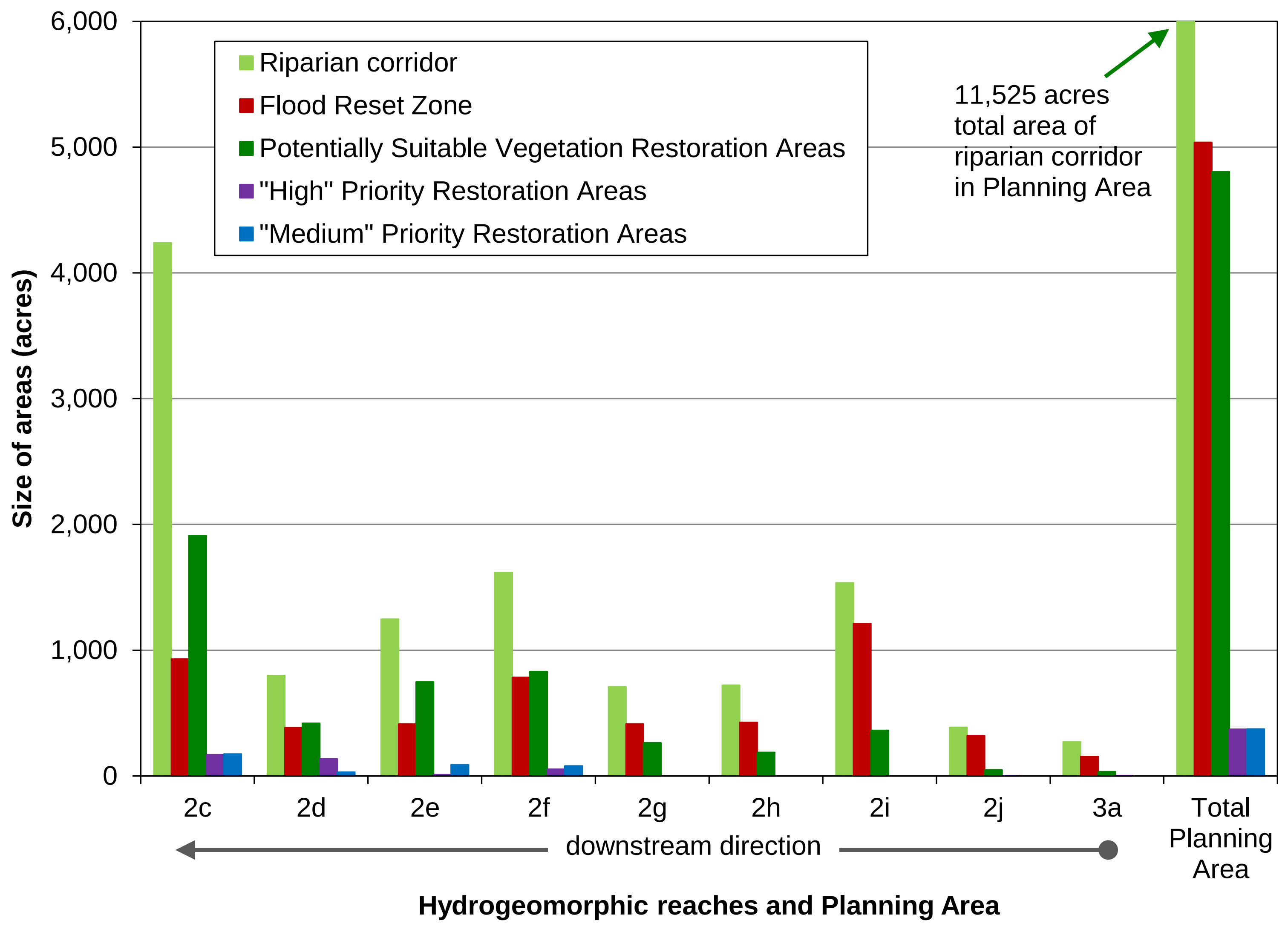
Ecohydrology: Potentially Suitable Restoration Areas



- **All** Potential Priority Restoration Areas ≈42% of riparian corridor (4,800 acres), concentrated downstream
- **"High"** and **"Medium"** Priority Areas together account for 750 acres—a manageable size for rapid active restoration involving tamarisk removal and native re-planting in 2014

"High" and "Medium" Priority Restoration Areas (Stillwater)

Ecohydrology: Potentially Suitable Restoration Areas



Histogram of sizes of the riparian corridor, Flood Reset Zone, and Potentially Suitable Vegetation Restoration Areas within the Planning Area and each of the hydrogeomorphic reaches.

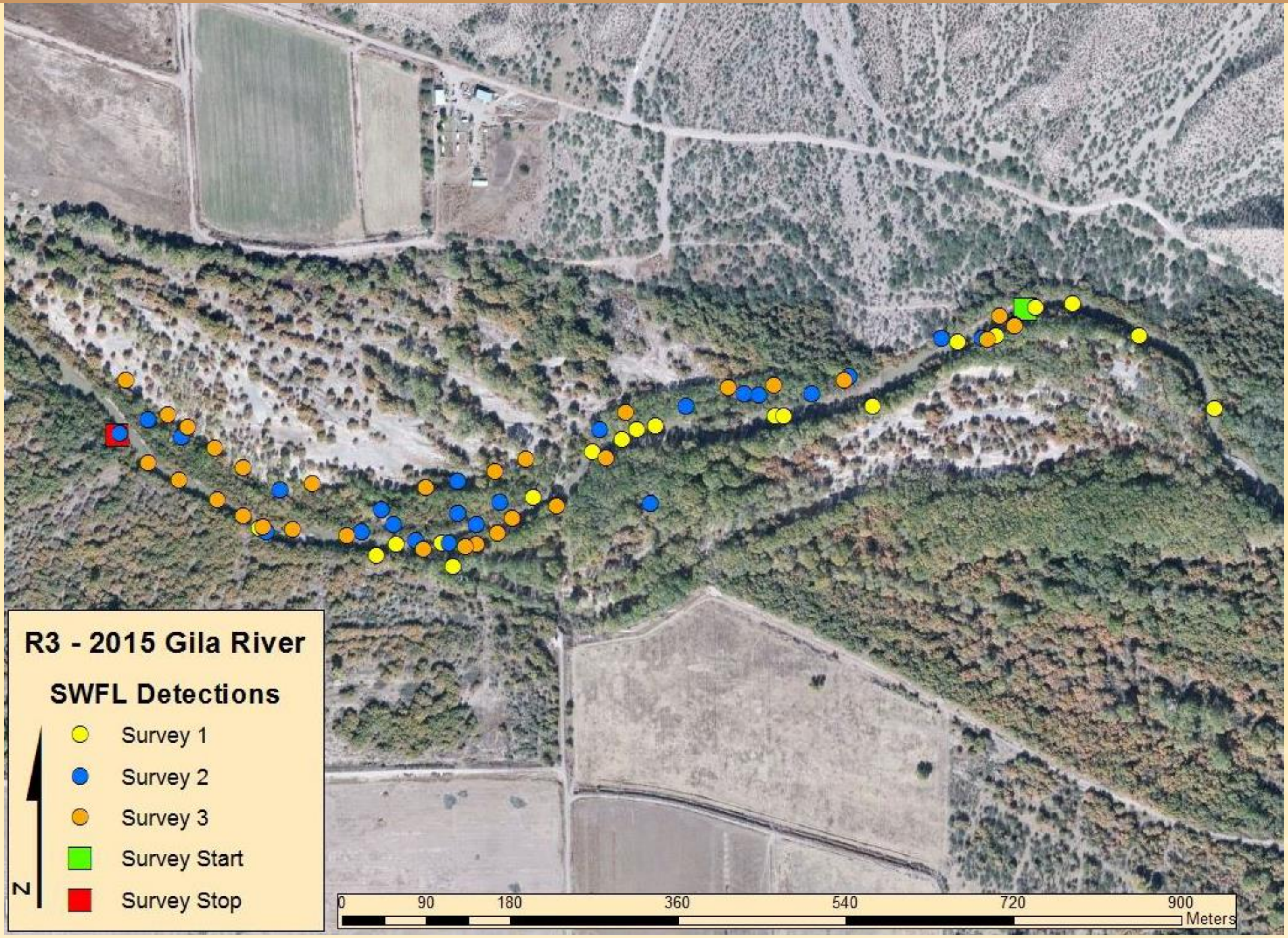
Restoration Approach

1. Restore native riparian vegetation suitable for SWFL nesting habitat
    - Remove and treat tamarisk to create space for natives
    - Facilitate natural recruitment of natives
    - Plant natives
    - Use a phased, patchwork approach to minimize short-term impacts
    - Risk management and the flood reset zone
2. Strategic active restoration of native habitat patches or “propagule islands” in occupied habitat
3. Passive restoration in areas disturbed by fires or floods

Road to Implementation

- Stakeholder and Landowner Outreach
- Refine Priority Sites
- Planting Design and Nursery
- Agency Coordination
- Permit Applications
- Refine and Implement Monitoring Plan
- Implement restoration in phases

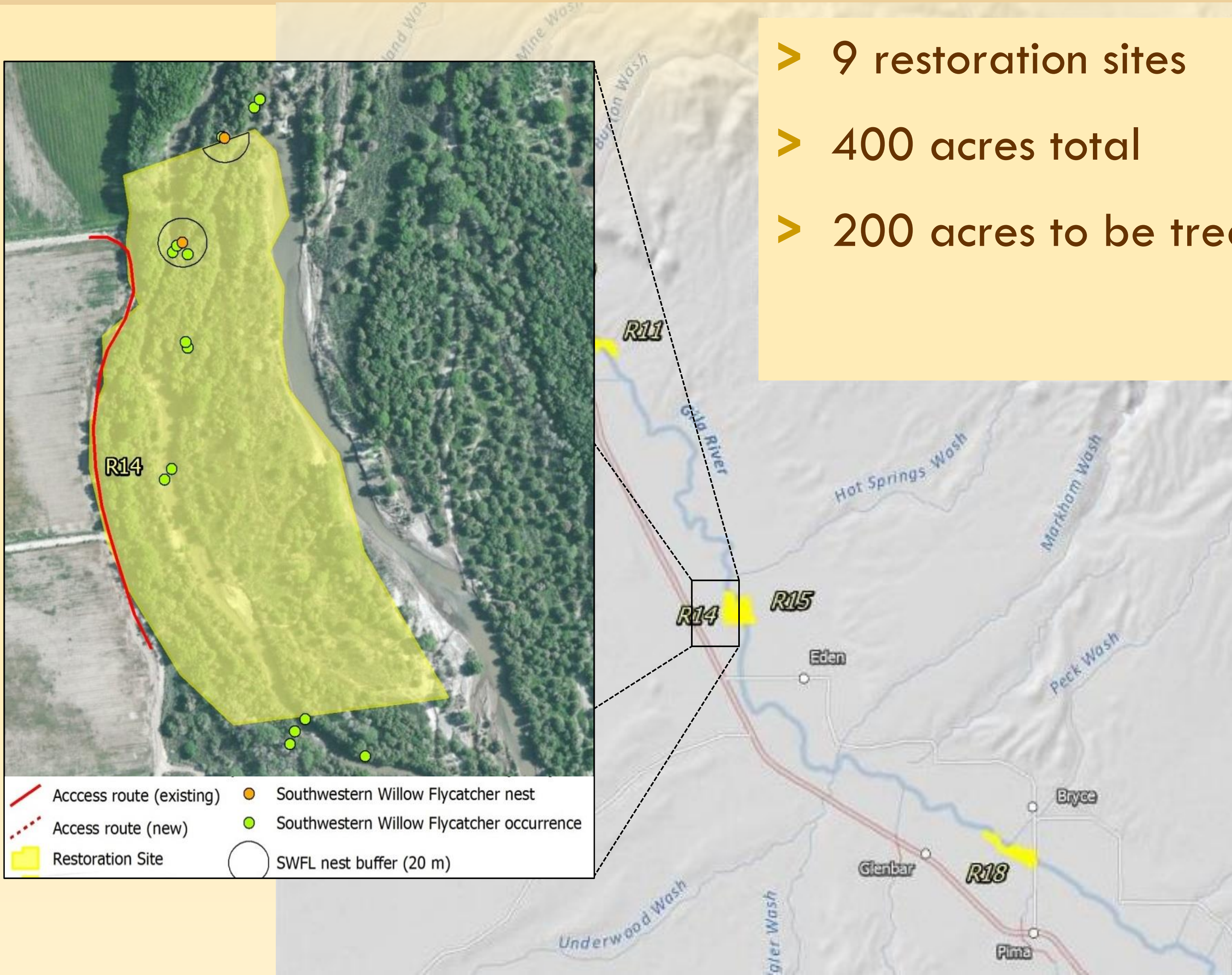
SWFL and WYBC Presence



SWFL and WYBC Protocol-Level Surveys

Restoration Sites

- 9 restoration sites
- 400 acres total
- 200 acres to be treated



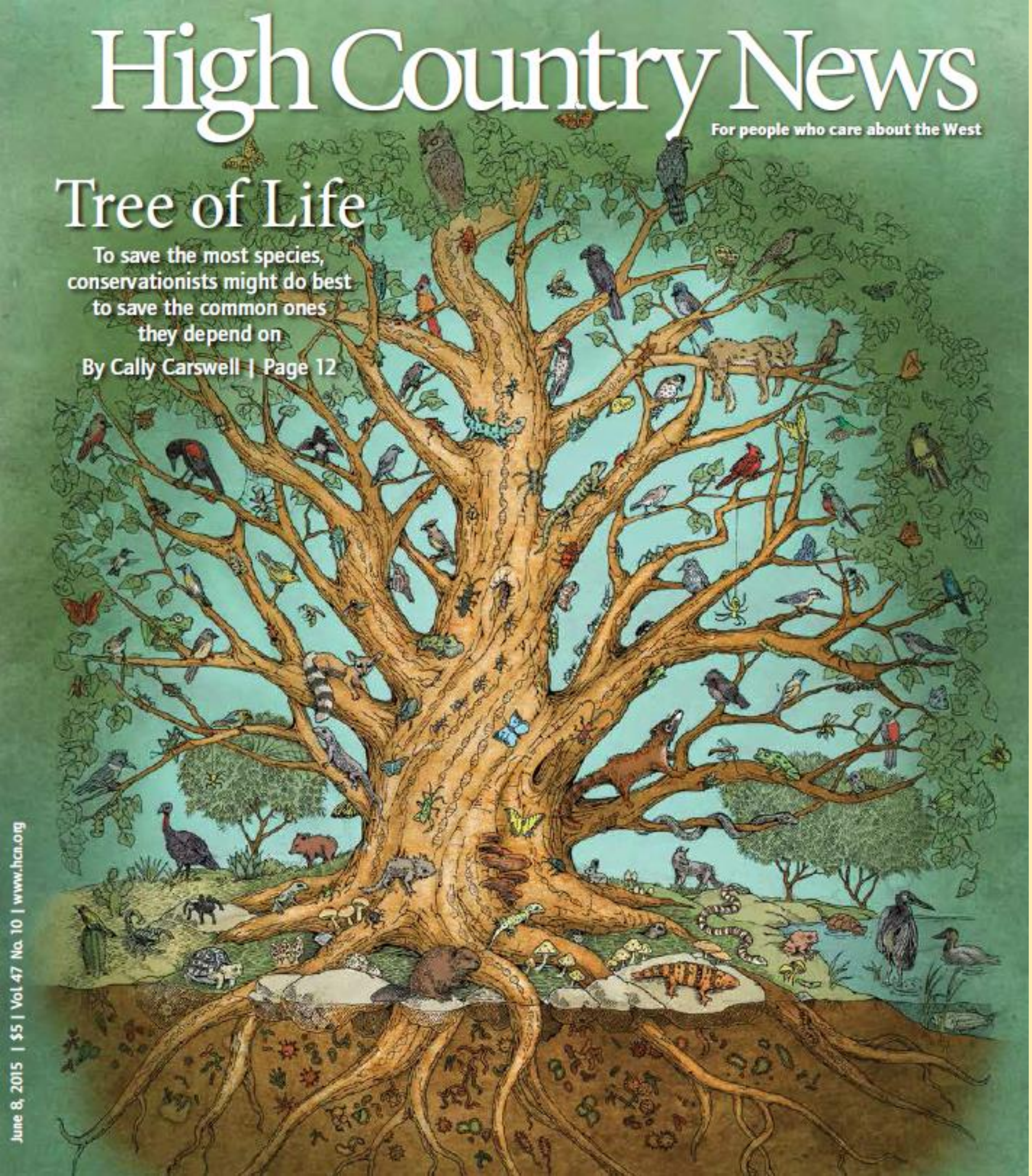
Agency Coordination & Permitting Process

- Pre-application discussions with USFWS to introduce project and consider permitting alternatives
- CWA Section 404 Nationwide Permit 27 for Aquatic Habitat Restoration, Establishment, and Enhancement Activities from USACE
- Federal nexus for USFWS consultation under Section 7 of the ESA
- CWA Section 401 Certification with ADEQ
- NHPA Section 106 Review with SHPO

Implementation

Monitoring

- Monitor vegetation recruitment, planting success, size and density
- Wildlife monitoring: SWFL and WYBC
- Experimental plots to test planting methods
- Monitoring of beetle colonization and habitat changes vs pre-beetle conditions (have restoration and the beetle put the ecosystem on a desired trajectory?)
- Consider common garden plots to compare response of different ecotypes (with Tom Whitham and colleagues at NAU)



The Reality of Climate Change and the Need for Genetics Approaches in Riparian, River and Watershed Restoration to Maintain Biodiversity in Changing Environments

Tom Whitham, Northern Arizona University

NORTHERN ARIZONA UNIVERSITY

Extensive genetic variation in natural populations, especially for foundation, keystone, dominant, and other species of large effect can define communities.

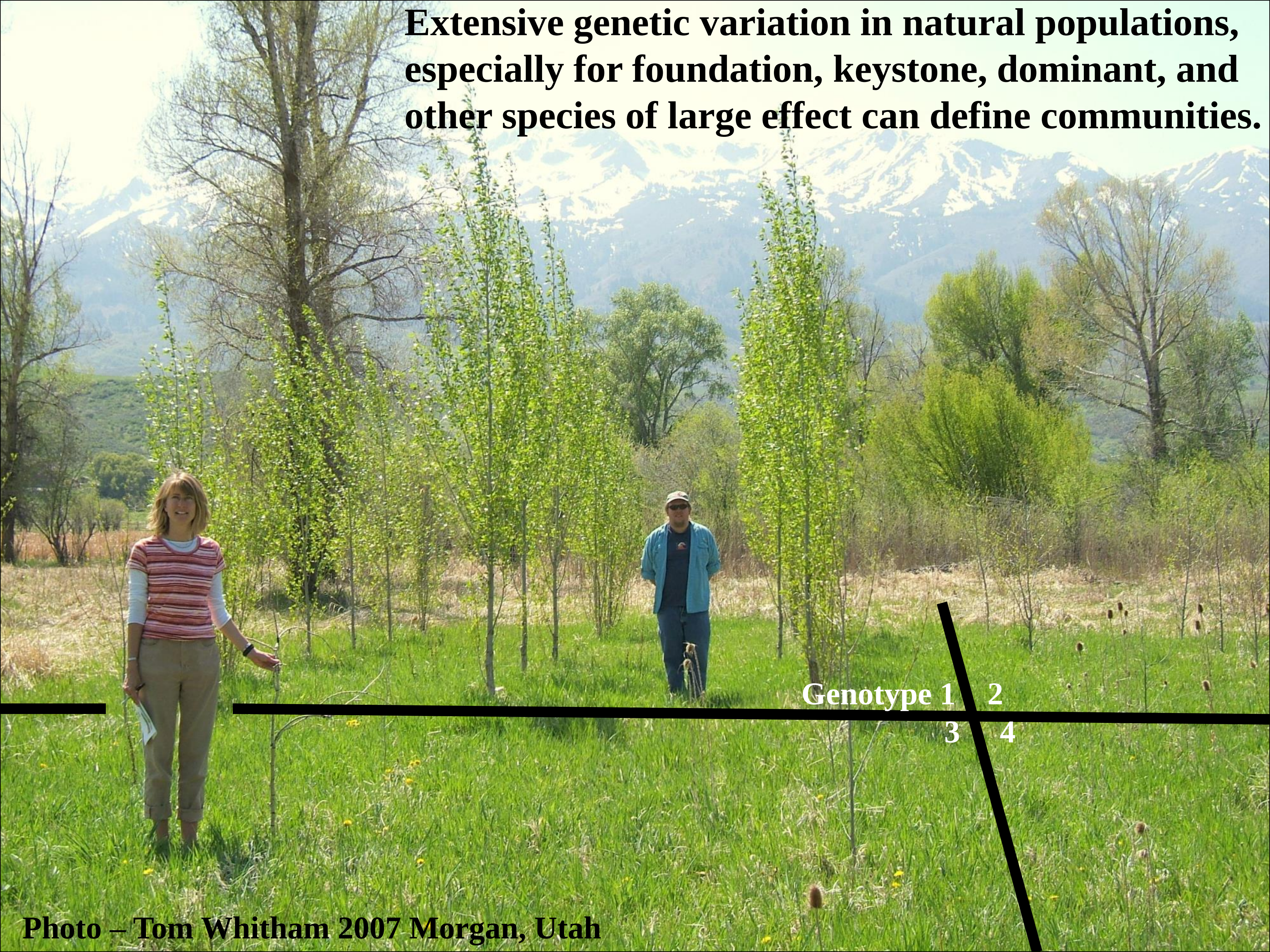


Photo – Tom Whitham 2007 Morgan, Utah

Genetics-Based Community and Ecosystem Structure

Plant Growth 25-72%

(architecture) Bailey et al. 2004 Evolution, (productivity) Lojewski et al. 2009 Tree Physiology, Grady et al. 2011 Global Change Biology, (sink-source) Compson et al. 2011 Oecologia, (leaf economic traits) Grady et al. 2013 Functional Ecology, Kaluthota et al. 2015 Tree Physiology

Trophic Structure & Networks 80%

(tree-insects-birds) Bailey et al. 2006 Ecology Letters, Smith et al. 2011 J of Evolutionary Biology, (aquatic) Marks et al. 2009 Freshwater Biology, Compson et al. 2014 Ecosystems, (terrestrial) Lamit et al. 2015 J of Ecology, Smith et al. 2015 Acta Oecologica, Lau et al. 2015 Ecology

Nutrient Cycles 34-65%

Schweitzer et al. 2004 Ecology Letters, 2005 Ecology, 2005 Oikos, 2011 Population Ecology, Classen et al. 2007 J of Ecology, Fischer et al. 2010 Plant & Soil, Schweitzer et al. 2011 Pop. Ecology, Classen et al. 2013 Ecosphere

Soil Feedbacks 20%

Pregitzer et al. 2010 Evolutionary Ecology, Smith et al. 2011 Plant & Soil, Gehring et al. 2014 Botany, Schweitzer et al. 2012

Community Stability 32%

Keith et al. 2010 Ecology

GMO Effects on Communities 25-33%

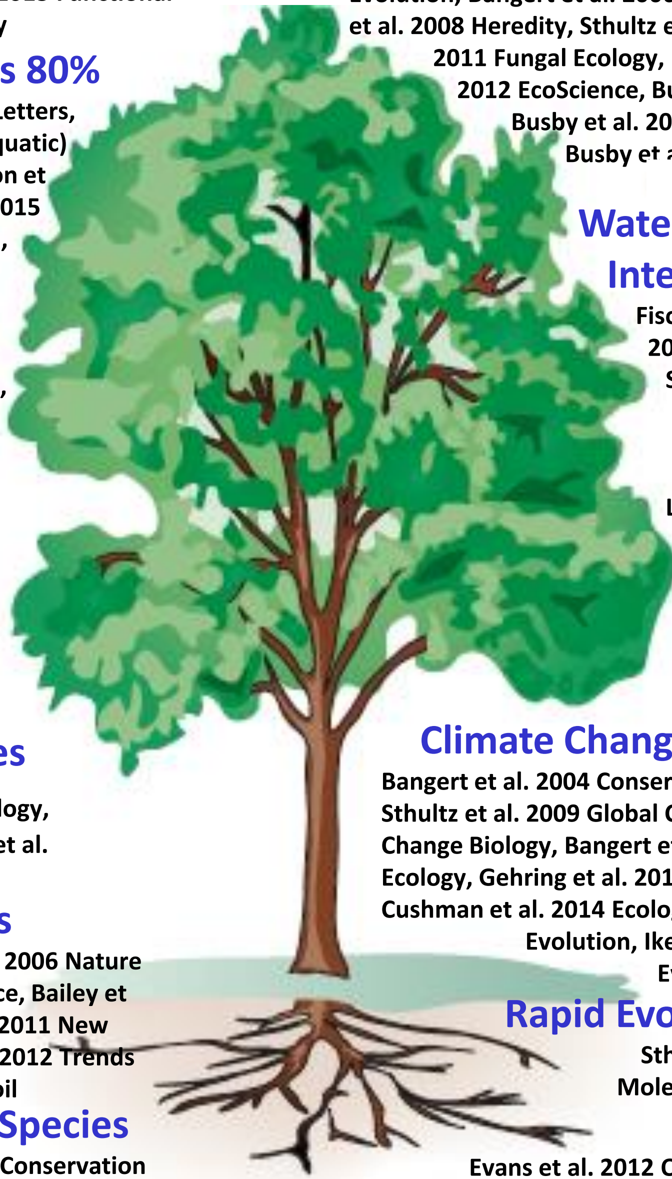
Axelsson et al. 2011 J. Appl. Ecology, Axelsson et al. 2011 Chemoecology, Hjältén et al. 2012 PLoS One

Review and Meta-Analysis

Whitham et al. 2003 Ecology, Whitham et al. 2006 Nature Reviews Genetics, Whitham et al. 2008 Science, Bailey et al. 2009 Phil. Trans. R. Soc. B., Wymore et al. 2011 New Phytologist, Allan et al. 2012, Whitham et al. 2012 Trends in Plant Science, Fischer et al. 2014 Plant & Soil

Evolution of Associated Species

Evans et al. 2008 Evolution, Evans et al. 2012 Conservation Genetics, Evans et al. 2013 Evolutionary Ecology



Biodiversity 39-78%

(Bacteria, Insects, Spiders, Birds, Mammals, Lichens, Endophytes, Pathogens, Mycorrhizae) Wimp et al. 2004 Ecology Letters, Wimp et al. 2007 Molecular Ecology, Shuster et al. 2006 Evolution, Bangert et al. 2006a,b Molecular Ecology, Schweitzer et al. 2008 Ecology, Bangert et al. 2008 Heredity, Sthultz et al. 2009 New Phytologist, Barbour et al. 2009, Lamit et al. 2011 Fungal Ecology, Ferrier et al. 2012 Arthropod-Plant Interactions, Meneses et al. 2012 EcoScience, Busby et al. 2013 J of Ecology, Lamit et al. 2014 Am J Botany, Busby et al. 2014 J of Ecology, Gehring et al. 2014 Frontiers in Microbiology, Busby et al. 2015 Ecology, Compson et al. 2015 Ecosphere, Floate et al. 2015 New Phytologist

Water Cycles & the Terrestrial-Aquatic Interface 35-40%

fluxes from soil to plant to atmosphere – Fischer et al. 2004 Oecologia; aquatic relationships – LeRoy et al. 2006 Ecology, LeRoy et al. 2007 J. N. American Benthological Soc., Wymore et al. 2015 Freshwater Science

Understory Plant Community Composition & Biomass 14-20%

Lamit et al. 2011 Botany, Adams et al. 2011 American Journal of Botany, Michalet et al. 2011 Ecology Letters

Belowground Carbon Storage & Root Production 77%

Fischer et al. 2006 Oecologia, Fischer et al. 2007 New Phytologist, Lojewski et al. 2012 New Phytologist

Climate Change, Exotics, Conservation & Modeling

Bangert et al. 2004 Conservation Biology, Bangert & Whitham 2007 Evolutionary Ecology, Sthultz et al. 2009 Global Change Biology, Whitham et al. 2010, Grady et al. 2011 Global Change Biology, Bangert et al. 2013 Restoration Ecology, Grady et al. 2013 Functional Ecology, Gehring et al. 2014 Molecular Ecology, Ikeda et al. 2014 Functional Ecology, Cushman et al. 2014 Ecological Applications, Woolbright et al. 2014 Trends in Ecology & Evolution, Ikeda et al. 2014 PLoS One, Grady et al. 2015 Restoration Ecology, Evans et al. 2015 Heredity

Rapid Evolution in Plants Redefines Communities

Sthultz et al. 2009 Global Change Biology, Gehring et al. 2014 Molecular Ecology, Smith et al. 2015 Oecologia

G x E Interactions & Gene Discovery

Evans et al. 2012 Oecologia, Busby et al. 2014 J of Ecology, Lamit et al. 2015 Ecology, Zinkgraf et al. 2015 J Insect Physiology, Evans et al. 2015 J of Ecology

Fremont cottonwood, West Clear Creek, AZ, © Photo by Tom Whitham

Genetic solutions from reciprocal common gardens that identify genotypes and populations that can survive future environments

Concerns about genetic pollution are minor relative to the impacts of global change.

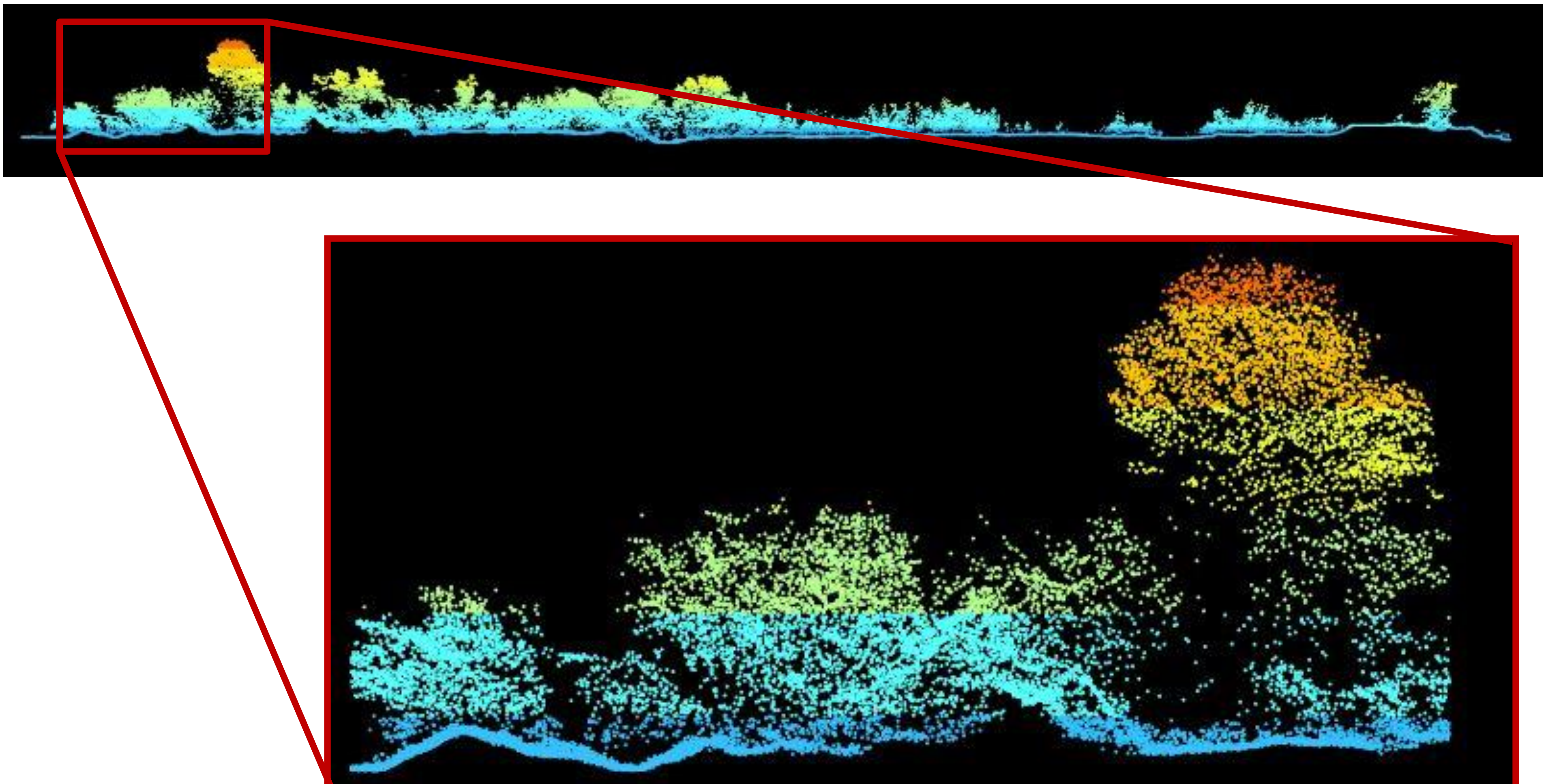
1. Restoration often occurs at sites like the Little Colorado River, where few natives still exist and there is nothing left to pollute.

2. Local maladaptation to a changing environment renders genetic pollution a moot issue as the local stock looses its homesite advantage.

3. Reliance on local evolution only works if the genetic variance in local population is greater than the predicted environmental changes and if plants can migrate faster than the predicted climate changes.

VEGETATION & HABITAT STRUCTURE

- High density LiDAR to assess vegetation structure
- Habitat Suitability Modeling for Southwestern Willow Flycatcher, Western Yellow-billed Cuckoo, and Least Bell's Vireo



CONCLUDING COMMENTS

- Riparian ecosystems are **naturally dynamic**
- Human alterations, including ***Tamarix*** introduction, have created **novel riparian ecosystems**
- Introduction of the **Tamarisk Beetle** is **shifting trajectory** of these novel ecosystems
- **Management interventions** will often be required to shift systems to a **more desirable trajectory**
  - ***Active Restoration***: Removal of *Tamarix* and active planting of native riparian species to promote more rapid recovery
  - ***Reduce other stressors***: surface flow and groundwater management, grazing, floodplain development

SWFL (Photo by USGS)

Acknowledgements

Stillwater Sciences

Funding: Gila Watershed Partnership of Arizona; The Walton Family Foundation

Science Team: Desert Botanical Garden (1939–2014); Northern Arizona University; University of California, Santa Barbara; USGS – science for a changing world; RS/GIS Laboratory

GIS Staff: Karley Rodriguez, Rafael Real de Asua

Field Support: Devyn Orr and Dan Koepke

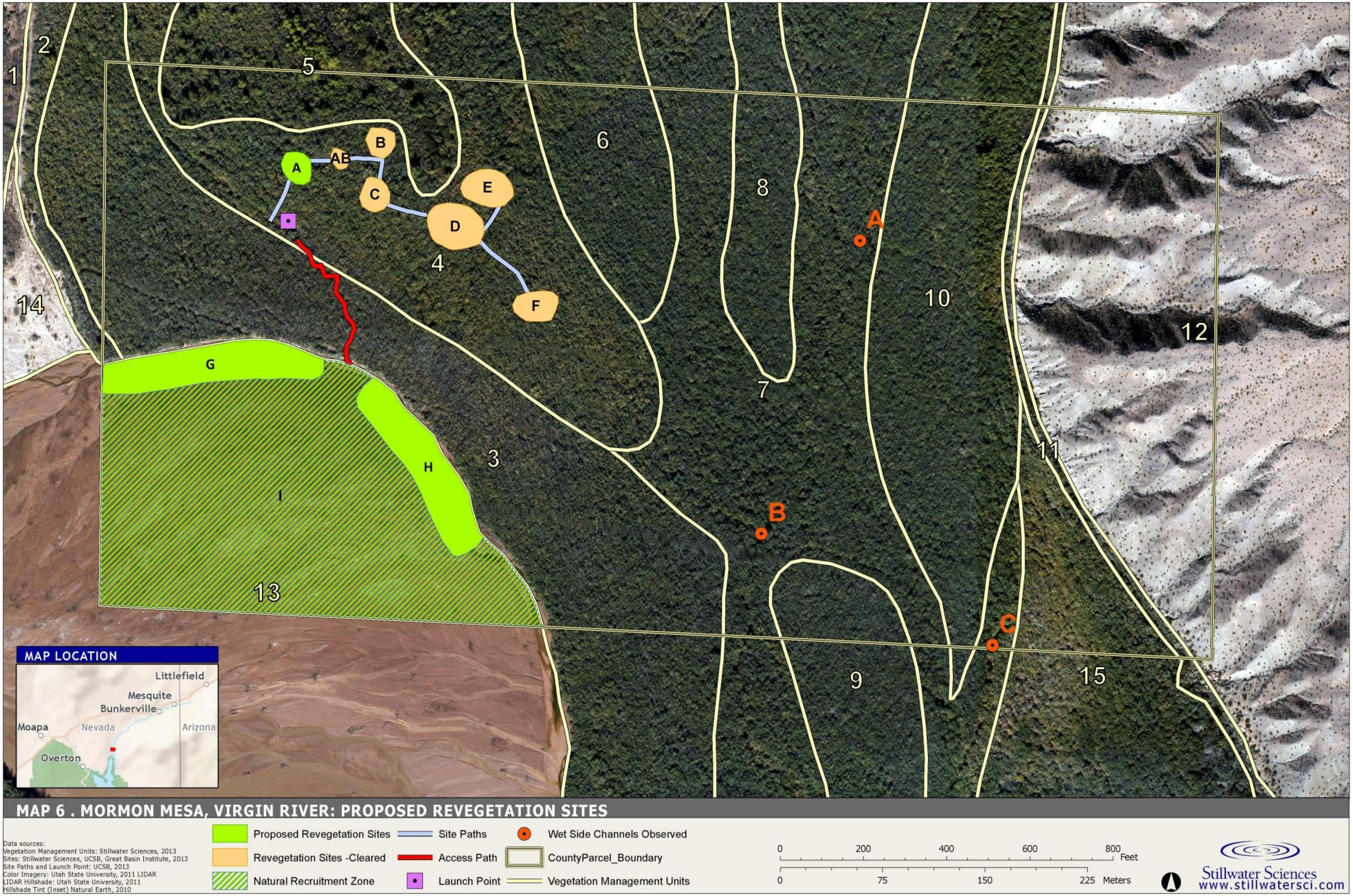
Additional Support: Tamarisk Coalition (Restore Connect Innovate); Cross-Watershed Network —XWN—; Southwest Decision Resources

Restoration Implementation Concepts: Clark County Virgin River Reserve Unit 1

- Goal: Develop a restoration plan to enhance and expand existing habitat for the SWFL and other riparian birds
- 80 acre parcel
  - Existing Vegetation: Dense Tamarisk, scattered Goodding's willow and a few other natives

- Clark County Desert Conservation Program
- Great Basin Institute
- Partners in Conservation
- Stillwater Sciences
- UC Santa Barbara
- Walton Family Foundation

Initial Planting Areas



Patch F: 13 Feb 2014

Patch E: 31 October 2014

Patch D: October 2013

Patch D: June 2019

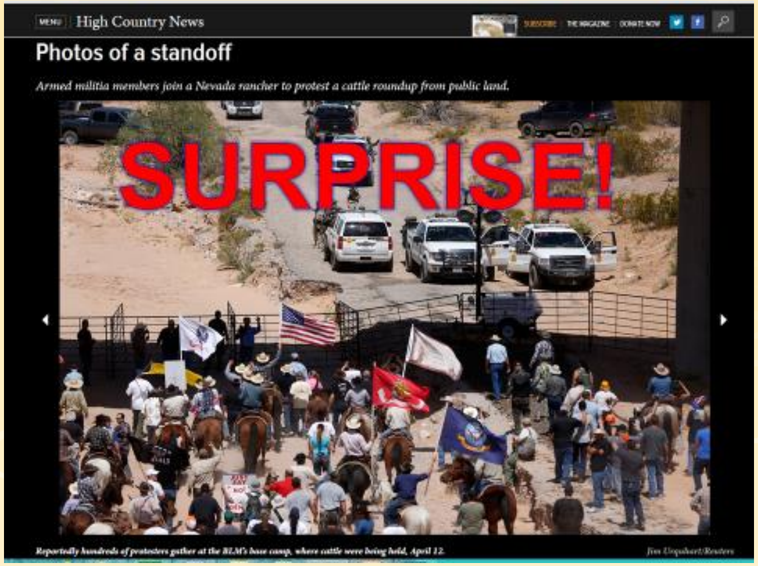
Lessons Learned

- ***Don't bite off more than you can chew!***
- ***Focused monitoring and adaptive management will be critical in designing and implementing effective riparian management.***
- ***Assessing ecological restoration potential is essential for identifying areas most likely to benefit from active restoration, and greatly reduce the risk of failure.***
- ***The Multi-Scale Ecohydrological Approach is Effective for:***
    - *Initial Restoration Feasibility Planning*
    - *Prioritization*
    - *Site Design*
    - *Guiding Monitoring*
- *Th*

SWFL (Photo by USGS)

Lessons Learned

- *In designing adaptive management and monitoring programs, we typically focus on measures to* ***increase resiliency to natural disturbances****. However,* ***unexpected human actions*** *in or near the restoration area can also create substantial challenges and surprises.*
- ***Careful oversight during implementation is critical*** *– the best laid plans can go astray if the plan is not properly implemented.*
- ***Ecohydrological Framework Useful in Decision Support Tool Context for Rangewide SWFL Recovery Planning***



SUMMARY

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- Introduction of the **Tamarisk Beetle** is **shifting trajectory** of these novel ecosystems
- **Management interventions** will often be required to shift systems to a **more desirable trajectory**
  - ***Active Restoration***: Removal of *Tamarix* and active planting of native riparian species to promote more rapid recovery
  - ***Reduce other stressors (passive restoration)***: *surface flow* and *groundwater* management, *grazing*, floodplain development

SWFL (Photo by USGS)

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- Orr, B., M. Johnson, G. Leverich, , T. Dudley, J. Hatten, Z. Diggory, K. Hultine, D. Orr, and S. Stone. 2017. **Multi-scale riparian restoration planning and implementation on the Virgin and Gila Rivers.** In: B.E. Ralston and D.A. Sarr (eds.), *Case Studies of Riparian and Watershed Restoration Areas in the Southwestern United States—Principles, Challenges, and Successes.* U.S. Geological Open File Report 2017-1091, 116 p., https://doi.org/10.3133/ofr20171091.
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ADDITIONAL INFORMATION

- CASE STUDY ON DESERT LCC WEBSITE: https://desertlcc.org/resources/CCAST
    - Gila Watershed Partnership: Restoration to Mitigate Tamarisk Beetle Impacts: A Case Study on Habitat Restoration
    - Applied science focus examples are under development
        - Ecohydrological Restoration Framework
        - Use of LIDAR and other Remote Sensing in Restoration Planning & Design

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