Salinity Management for Floodplain Riparian Restoration

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Introduction

Restoring native riparian plant communities on historic floodplains is a major objective of management agencies. For example, the Lower Colorado River Multi-species Conservation Program (MSCP), implemented by the Bureau of Reclamation, includes re-vegetation of over 2,900 ha of historic floodplain with salt-intolerant native riparian species[1].

Like most large rivers, the Colorado River flow is highly regulated. Therefore, riparian habitat creation must be implemented on disconnected floodplains where salinity is often elevated due to a lack of overbank flooding, evapoconcentration of salts in upstream reservoirs, and addition of fertilizer salts on adjacent agricultural land. As a result, groundwater and soil salinity exceed the tolerance of native vegetation in many areas. Furthermore, because hydrology is likely insufficient to support planted vegetation, irrigation is required for habitat restoration. Application of irrigation over shallow groundwater can result in upward salinity migration, exacerbating salinity problems. Alternatively, irrigation and drainage might be managed to mitigate salinity.

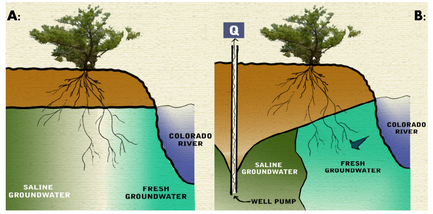
This effort aimed to identify salinity management options for riparian habitat restoration, characterize soil and groundwater conditions at current MSCP habitat creation sites, and develop potential salinity management strategies.

Background

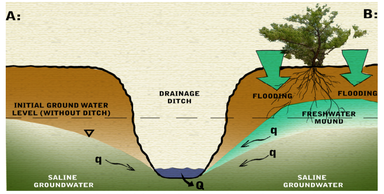
Native riparian trees require abundant, low salinity water[2]. Therefore, revegetation is typically reliant on shallow groundwater and/or high irrigation rates.

- Shallow groundwater →
  - High evaporation rates can lead to soil salinity accumulation.
  - Limited unsaturated zone for leaching salts from soil—root zone typically penetrates to groundwater.
  - Leached salts can accumulate in near-surface groundwater, depending on groundwater flow.
- Irrigation →
  - Addition of salts to soil profile and groundwater.
  - More near-surface soil evaporation.

Disconnected Floodplain—Conceptual Models



River/aquifer interactions—no management (A) and inducing groundwater freshening by groundwater pumping (B).



Saline groundwater draining (A) and saline groundwater draining with freshwater mounding due to flooding (B).

Study Locations

Three Lower Colorado River Multi-species Conservation Program Habitat Creation Areas:

Beal Lake Conservation Area (BLCA):
A 107-acre site comprised of dredge spoil material. Divided into 30 fields (1-6.2 acres) for research and development of riparian restoration methods, with each field watered independently.

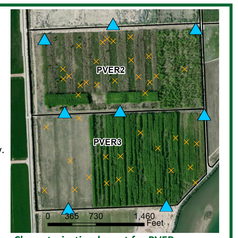
Palo Verde Ecological Reserve (PVER):
A 1,352-acre riparian habitat creation site comprised of 8 phases (36-226 acres). Former agricultural land.

Cibola National Wildlife Refuge Unit 1 Conservation Area (CNU1):
A 900-acre riparian habitat creation site comprised of five "areas". Mix of research fields and habitat creation plots.

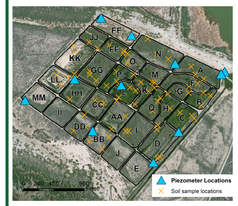
Project overview map.

Site Characterization

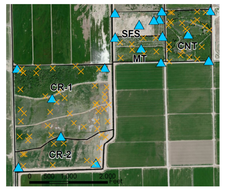
- Soils:
  - Sampled to 6' or until groundwater, composited on 2-foot intervals.
  - Measured: Texture, salinity, nutrients.
- Groundwater:
  - Grid of piezometers installed, instrumented, and sampled .
  - Measured: Groundwater depth, elevation/gradient, groundwater salinity.
- Aquifer:
  - Slug testing.
  - Measured: Hydraulic conductivity.



Characterization layout for PVER.



Characterization layout for BLCA.



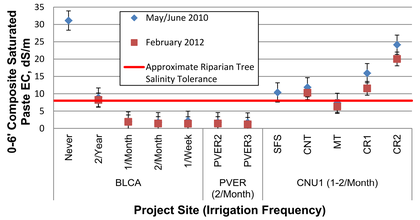
Characterization layout for CNU1.

Site Conditions

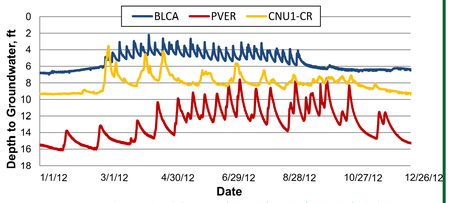
SUMMARY:

Site	Soil texture	Groundwater depth	Groundwater salinity	Frequency/Amount of percolation following irrigation events
BLCA	Sandy	Shallow	Intermediate	High/Moderate
PVER	Sandy with some loamy areas	Deep	Low	Intermediate/High
CNU1	Fine-grained (silty loam)	Intermediate	High	Low/Moderate

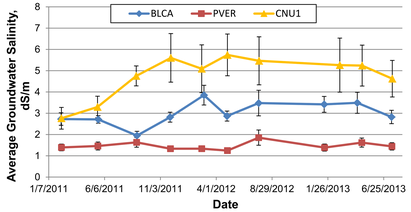
Vigorous Goodding's willows at PVER2 (left), and salt crusted soils with marginally-successful Fremont cottonwood at CNU1 CR1 (right).



Average composite soil salinity by site and sub-site. Error bars encompass one standard error.



Representative groundwater depth for BLCA (PZ-2-BL), PVER (PZ2PVER), and CNU1 (PZ5C). Peaks indicate percolation due to irrigation events.

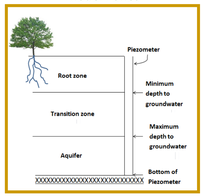


Average groundwater salinity by site . Error bars encompass one standard error.

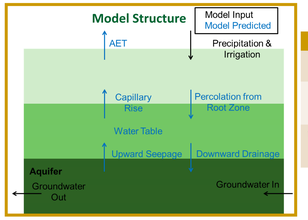
Salinity Modeling

1-D Salt-Balance Model: SaltMod—http://www.waterlog.info/saltmod.htm

Model Zones



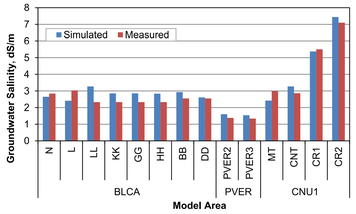
Model Structure

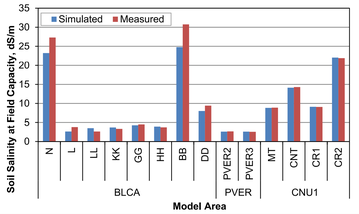


Calibration Parameters

Parameter	Description
Storage Efficiency	Ratio of soil water stored to porosity.
Root Zone Leaching Efficiency	Ratio of percolating soil water salinity to water salinity in the root zone.
Transition Zone Leaching Efficiency	The ratio of percolating soil water salinity to that in the transition zone.

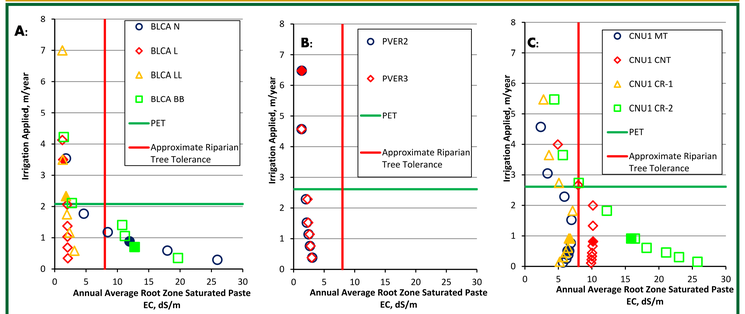
Model Calibration Results





Modeling of Irrigation Management Scenarios

Irrigation Management Scenarios:
Assess a range of irrigation volumes to determine minimum amount of water needed during the growing season to maintain acceptable soil salinity.



Model-predicted soil salinity for a subset of Beal Lake Conservation Area model areas (A), Palo Verde Ecological Reserve model areas (B), and Cibola NWR Unit 1 Conservation Area model areas. Hollow points indicate model results, and solid points indicate current irrigation amounts and salinity conditions.

Conclusions

Soil and Groundwater Salinity Governed by:

1. Soil texture: Salinity decreased with higher percent sand (enhanced drainage).
2. Irrigation application: Greater irrigation depth resulted in decreased soil salinity (higher leaching fraction).
3. Groundwater depth: Shallower water=more capillary rise and evapoconcentration in root zone.
4. Groundwater flow rates: slower flow=longer residence time, greater salinity concentration.
5. Incoming groundwater salinity: up-gradient groundwater EC dictates groundwater EC at each site.

Potential Site-specific Management Actions can Include:

1. Soil texture: Select sites with intermediate soil textures—sufficient drainage and moisture retention for vegetation.
2. Irrigation: Optimize irrigation depth to provide sufficient salt leaching (minimum application to provide acceptable salinity).
3. Groundwater depth: Drainage or groundwater pumping.
4. Incoming groundwater salinity: Avoid leaching high salt loads from up-gradient sites.

Recommendations

Sites with acceptable salinity:

1. Test soil and groundwater salinity conditions periodically to detect changes.
2. Monitor vegetation for salinity stress.

Sites with unacceptable salinity—Adaptive Management:

1. Identify site-specific tools for remediation.
2. Implement demonstration project.
3. Monitor for favorable results, and revise remediation tools as needed.

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Acknowledgements

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