Monitoring Long-Term Relationships Among Surface Flow, Groundwater, and Vegetation on the Gila River

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Martha Cooper has worked for The Nature Conservancy in Southwest New Mexico since 2006. Working with a diverse group of conservation partners in the region, she manages science, stewardship and restoration projects on the Conservancy's Gila and Mimbres River Preserves and watersheds. Martha received an MS in 1999 in forest ecosystem science from the University of Maine. She received her BA in 1995 in biology from Amherst College.

Ellen Soles works with the Southern Colorado Plateau Network of the National Park Service and Northern Arizona University in long-term monitoring of riparian sites at parks in the southwestern U.S. Most of her research and monitoring work since 1999 has focused on interactions between alluvial groundwater and surface water systems in the southwestern U.S., with the Gila River in New Mexico an ecosystem of special interest. She received an MA in rural geography from Northern Arizona University in 2001.

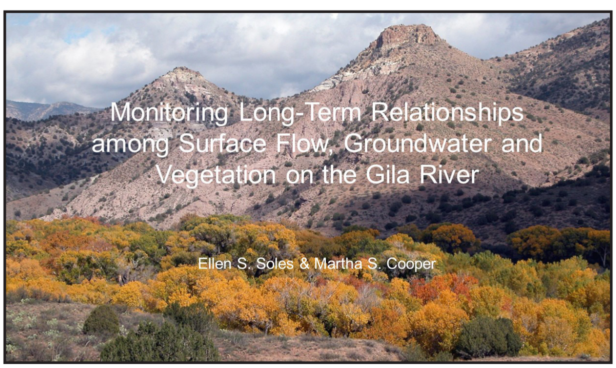


Figure 1. The Gila River in the Cliff-Gila Valley of New Mexico is a rare example of a riverine system in the semi-arid southwestern U.S. whose flow regime remains relatively intact. The river provides the opportunity to examine how unaltered patterns of streamflow and inundation shape the composition and diversity of alluvial floodplain habitats in such regions. We illustrate these dynamics with hydrologic, vegetation, and topographic data from long-term study transects in the Cliff-Gila Valley.

Figure 2. Researchers' canine companions appreciate opportunities to explore the Gila River.

Figure 3. Despite low flows that typically drop to 20 cfs during the dry months of May through July, native riparian vegetation on the Gila is robust, diverse, and broadly distributed across floodplains.

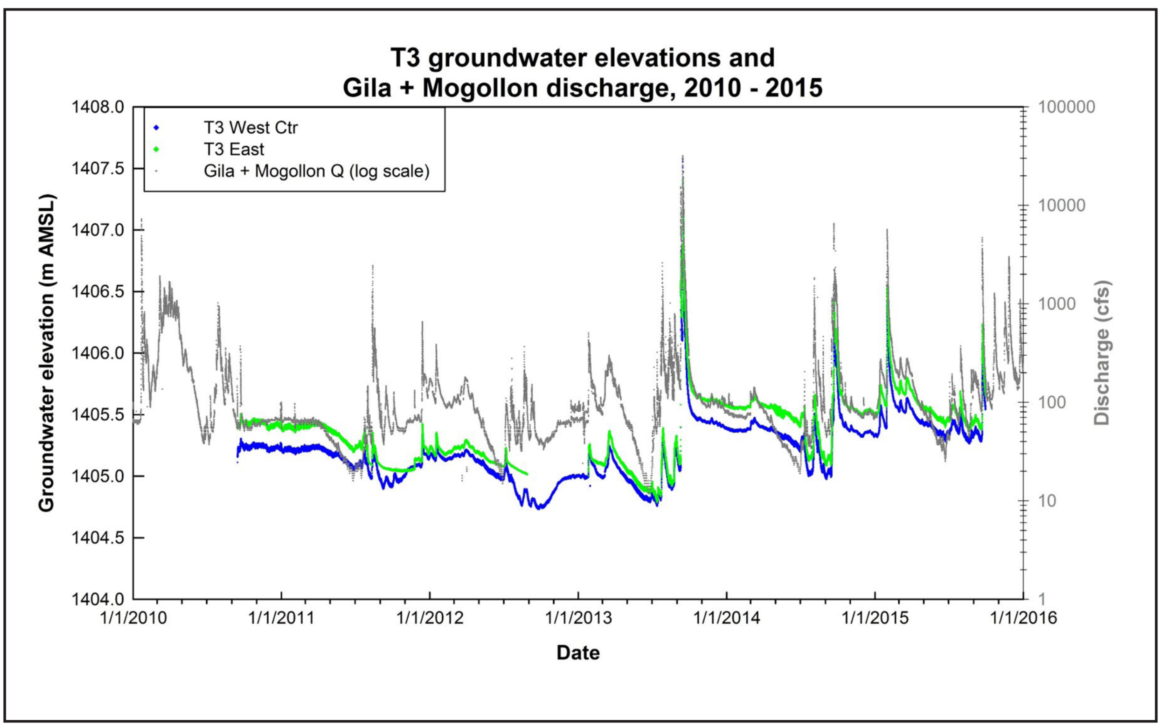


Figure 4. Total streamflow at the head of the Cliff-Gila Valley (gray line plotted on log scale), calculated from the USGS Gila near Gila (09430500) and Mogollon Creek (09430600) gauges for 2010-2016. Blue and green lines plot corresponding groundwater elevations in two wells immediately below the Mogollon Creek-Gila River confluence. Rapid groundwater response to changes in surface flow is typical throughout the valley. Surface flow is highly variable, both intra- and inter-annually; and although perennial, often drops to < 20 cfs during the driest months of early summer.

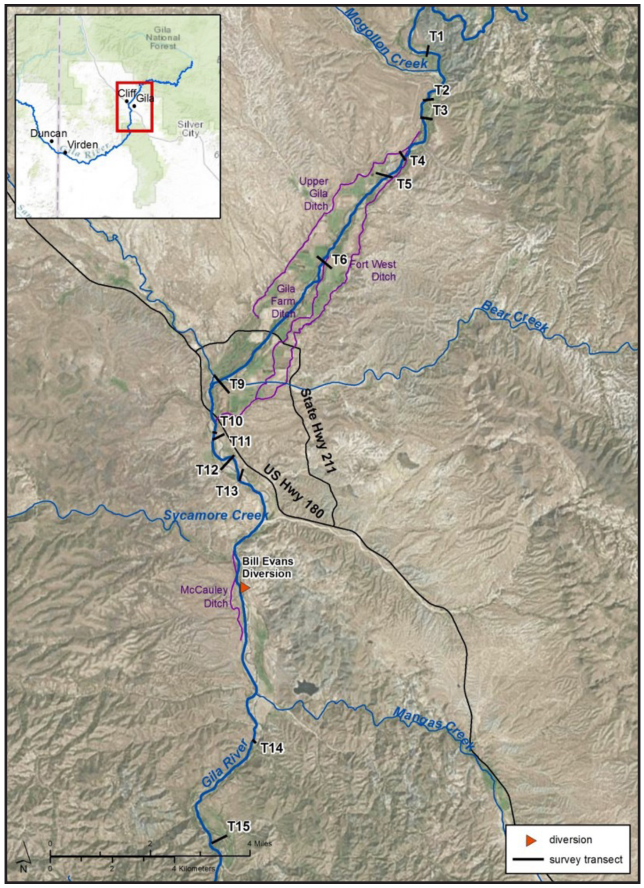


Figure 5. Small-scale agricultural diversion of water from the Gila River in the Cliff-Gila Valley began more than a century ago over time, becoming a substantial component of the valley's hydrology (increasing residence time of water in the valley) even while leaving the river's flow regime nearly intact. The river and its broad floodplains – and irrigated agriculture - sustain biologically diverse, robust, and essential habitat.

Figure 6. Sandhill cranes seasonally utilize irrigated agricultural fields throughout the valley.

Figure 7. Native riparian forest provides crucial habitat for threatened and endangered species like the yellow-billed cuckoo (upper left) and southwestern willow flycatcher (lower right).

Figure 8. Segment of the upstream study area, near the head of the Cliff-Gila Valley, in 2014. Active floodplain widths in the valley vary from around 400 m to more than 600 m. Much of the floodplain vegetation is distant from water in the river's main channel(s) (blue), often > 100 m distant.

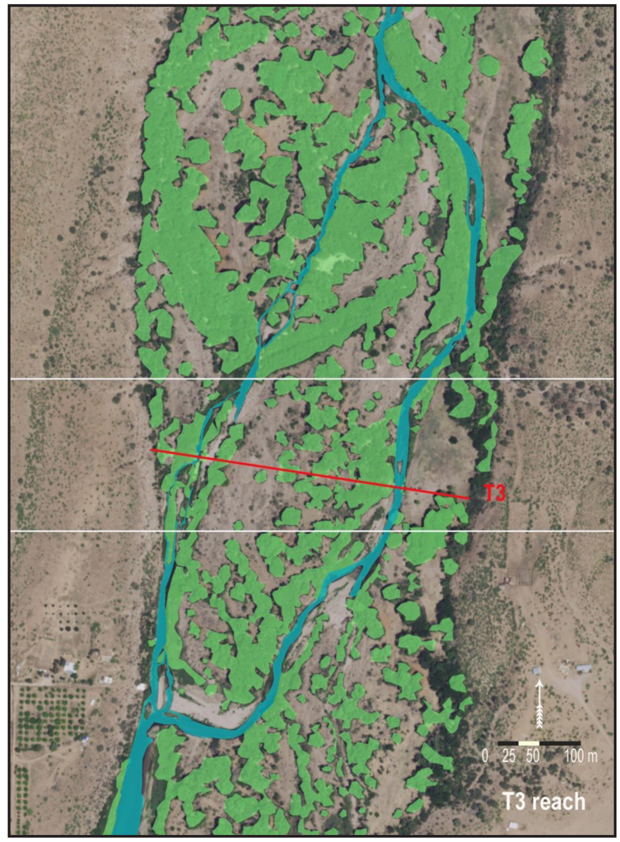


Figure 9. Riparian vegetation highlighted in segent of the upstream study area, near the head of the Cliff-Gila Valley, in 2014.

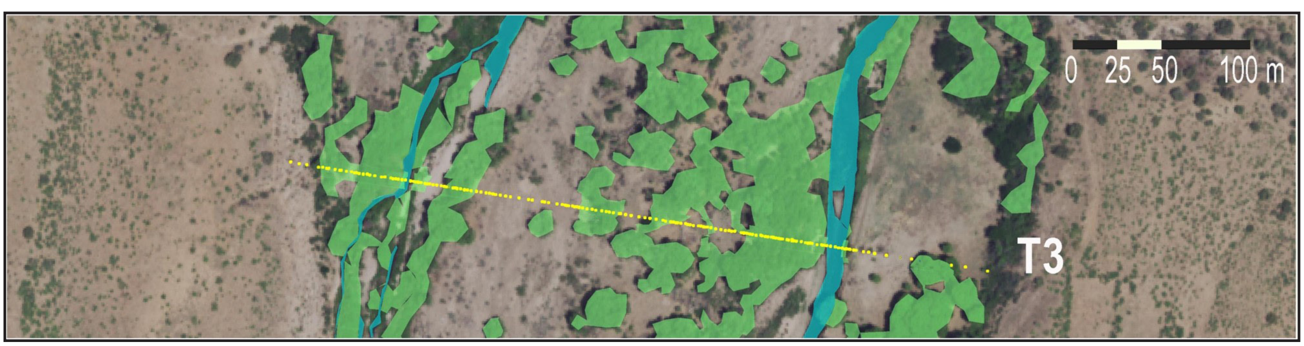


Figure 10. Close-up view of the area outlined in white in Figure 9, bracketing study transect T3. Topographic, hydrologic, and vegetation data have been collected on T3 (yellow dots) since 2010.

Figure 11. Downstream segment of the study area near the lower end of the Cliff-Gila Valley, in 2014. Blue shading indicates the main channel.

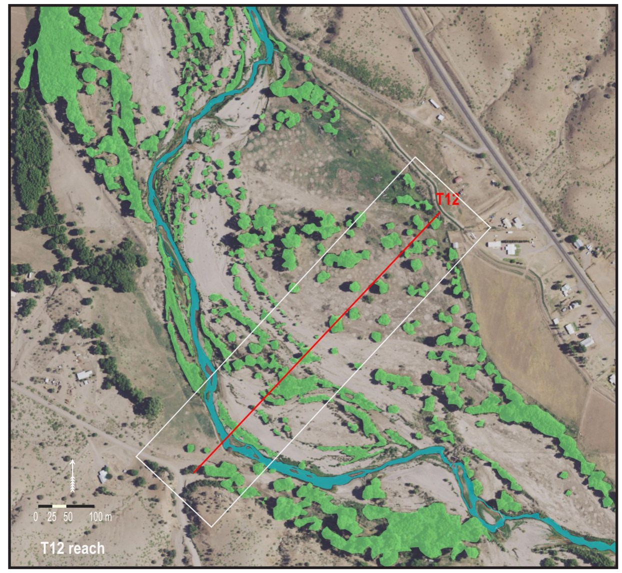


Figure 12. Floodplain vegetation highlighted in downstream segment of the study area near the lower end of the Cliff-Gila Valley, in 2014. Diverse habitats created by distinctive, parallel "stringers" of vegetation characterize the Gila River's broad floodplains throughout the Cliff-Gila Valley.

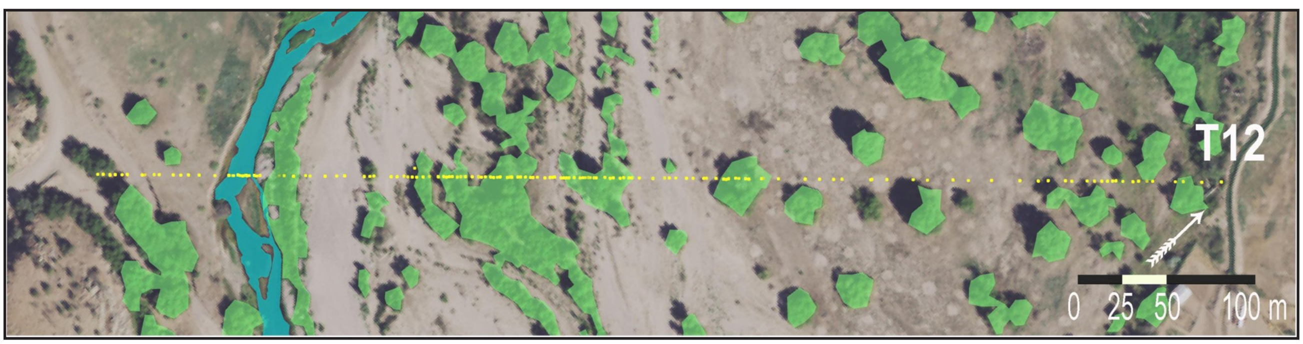


Figure 13. Close-up view of the area outlined in white in Figure 12, bracketing study transect T12. Topographic, hydrologic, and vegetation data have been collected on T12 (yellow dots) since 2010.

Figure 14 and Figure 15. The view across the T12 transect in 2010 and 2016. Floodplain vegetation expansion after scouring floods through 2005 was slower in this downstream reach, but rapid growth has occurred since 2010.

Figure 16. The width of each cover type or vegetation community that crosses a transect (e.g., the span of each highlighted green area in Figure 13 where it crosses the yellow dotted line) is calculated from mapping data collected during each survey. Twelve cover types are mapped, including five riparian or wetland types.

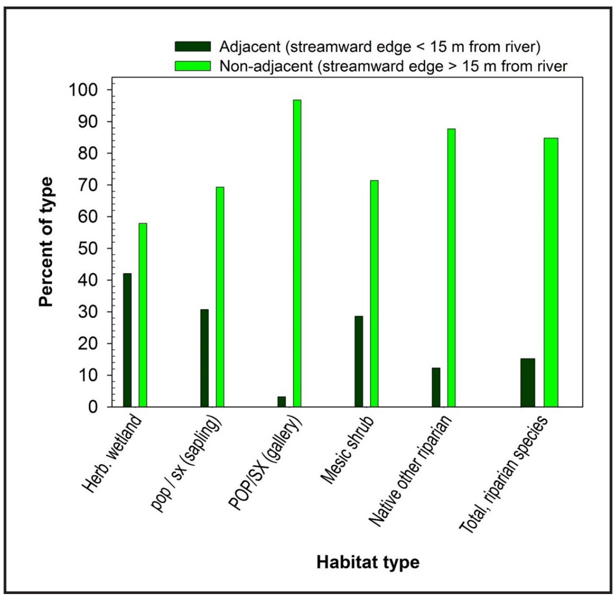


Figure 18. Percents of floodplain riparian and wetland vegetation communities located distant from the main river channel (> 15 m) versus adjacent to the river. Results were calculated from data collected on 13 study transects in 2012. Riparian habitat was five times more likely to occupy areas distant from the main channel than adjacent to it, demonstrating the broad distribution of these vegetation types across floodplains.

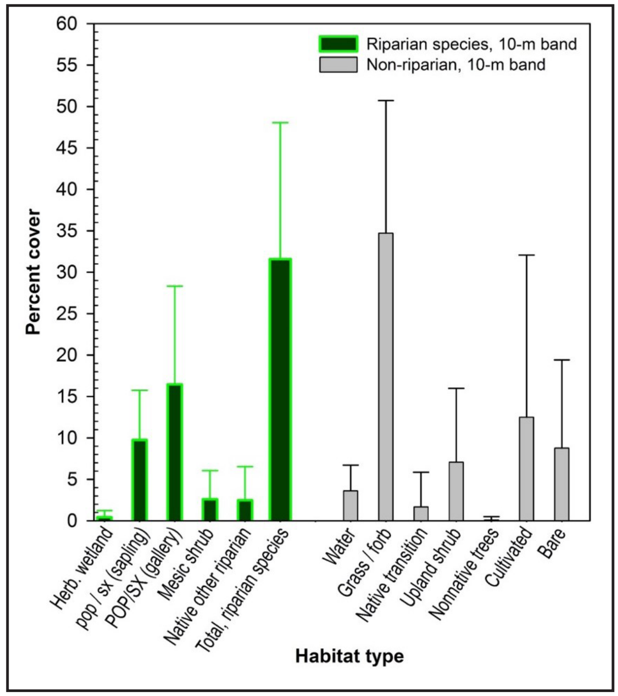


Figure 17. Total percent cover of each of 12 habitat types, mapped photogrametrically within 10-m bands spanning each of 13 study transects. Data are from 2011 aerial photography. Green columns are riparian vegetation types; gray bars are non-riparian. In total, wetland and riparian species occupy about 1/3 of the floodplain width, about the same as grass/forb cover. Young cottonwood/willow stands (po/sx) are mapped separately from gallery stands (PO/SX) to track establishment and growth over time.

Figure 19. Mosaic of vegetation on the floodplain. Left, cottonwood seedling; right, off-channel wetland with cattails, rush, and willows.

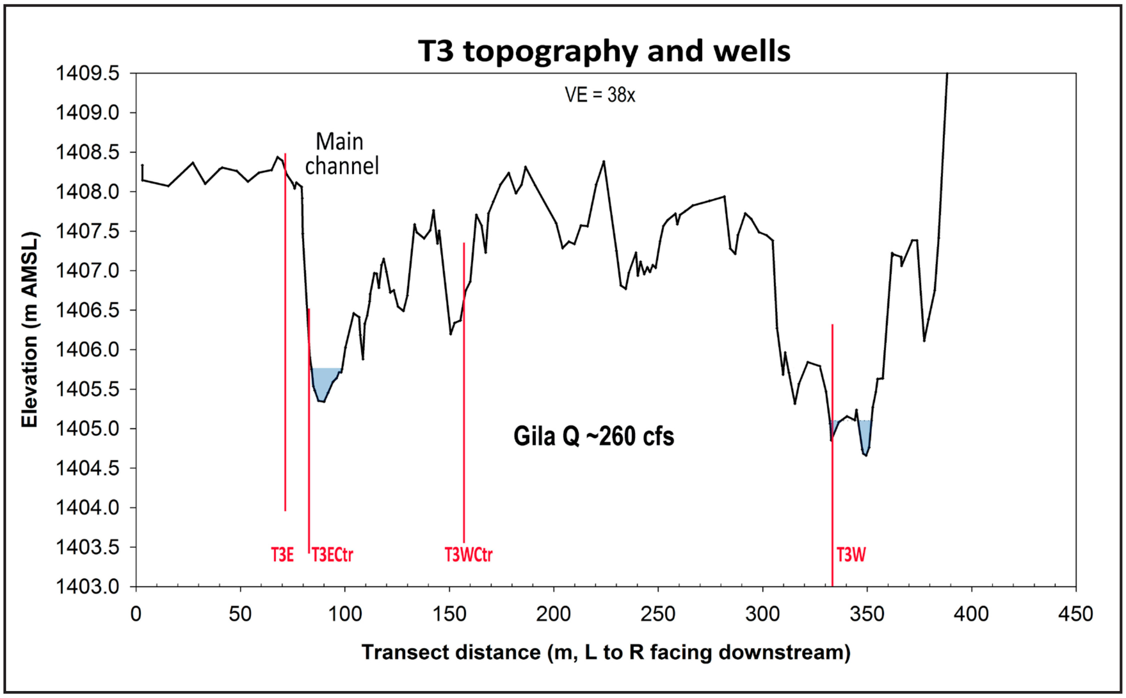


Figure 20. Depicts floodplain and channel topography on study transect T3 in 2012. Blue shading in channel represents river stage during the survey; discharge was 260 cfs. Multiple secondary channels cross the transect. T3 well positions (T3E, T3ECtr, T3WCtr, and T3W) are also shown. Continuous groundwater level data were used to calculate groundwater slopes and depths to water across the transect. Note exaggeration of vertical scale relative to horizontal scale (VE=38x).

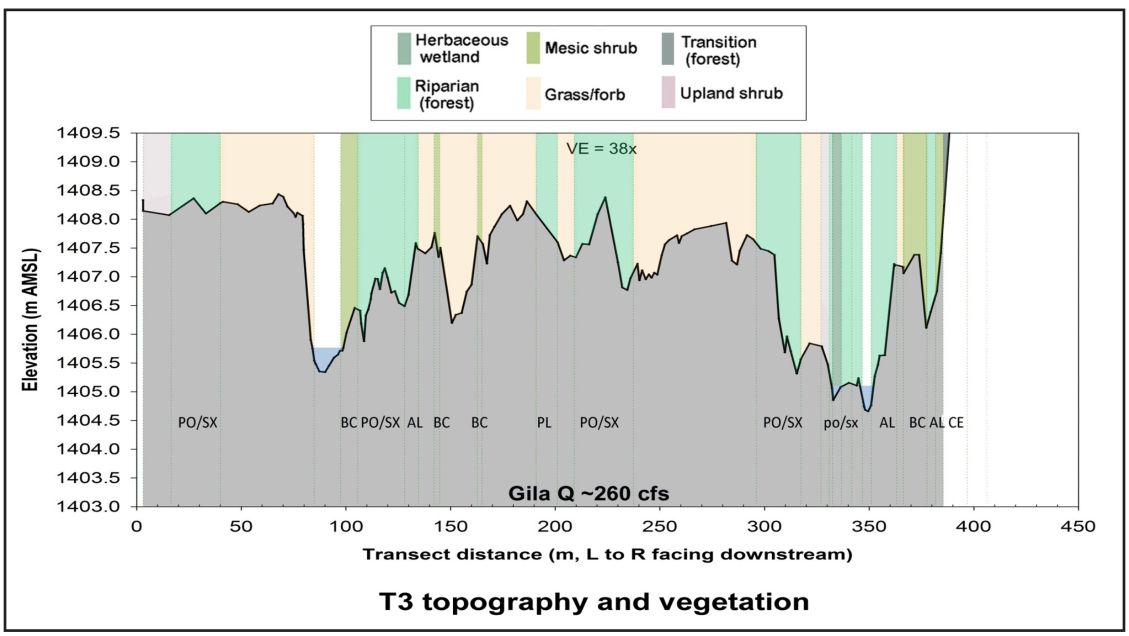


Figure 21. Left to right: PO/SX, mature cottonwood/willow; BC, Baccharis salicifolia; AL, Alder; PL, Sycamore; po/sx, young cottonwood/willow; CE, hackberry. Grass/forb (yellow) and barren (white) areas are unlabeled. Color bands representing the position of each vegetation community mapped during the survey are superimposed on T3 topography. Riparian vegetation types are labeled across the bottom of graph. Bands of riparian vegetation, dependent on relatively shallow depths to groundwater, are typically found along the margins of secondary channels across the full floodplain extent on this transect. Young cottonwood/willow (po/sx) establish on some of the lowest-elevation zones on the transect.

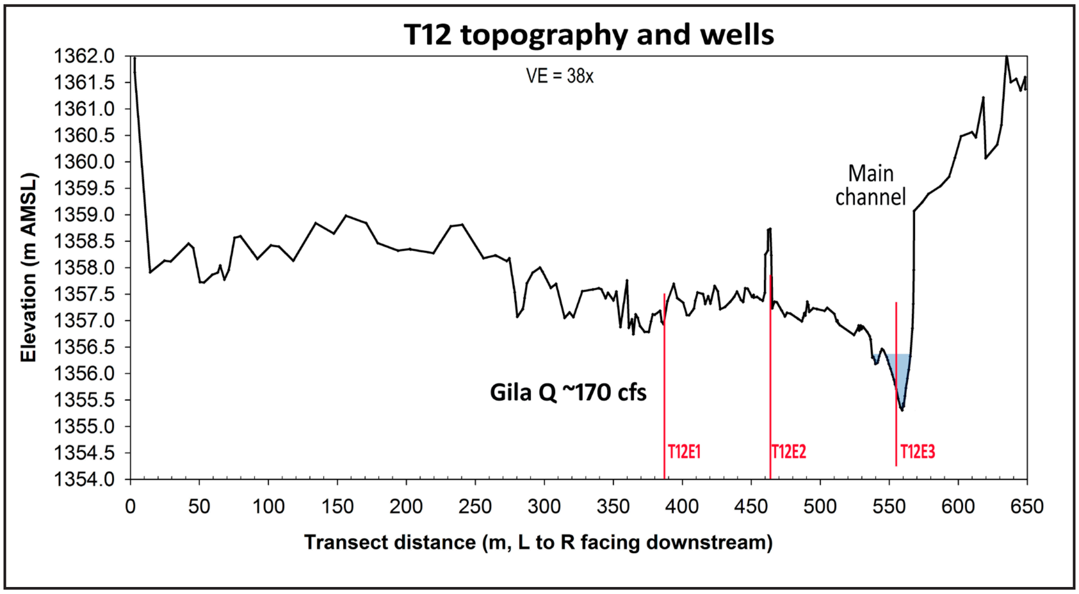


Figure 22. Floodplain and channel topography on study transect T12 in 2012. Blue shading in channel represents river stage during the survey; discharge was approximately 170 cfs. Secondary channel features are generally limited to the right half of the floodplain. T12 well positions (T12E1, T12E2, and T12E3) are also shown. Continuous groundwater level data were used to calculate groundwater slopes and depths to water across the transect. Note exaggeration of vertical scale relative to horizontal scale (VE=38x).

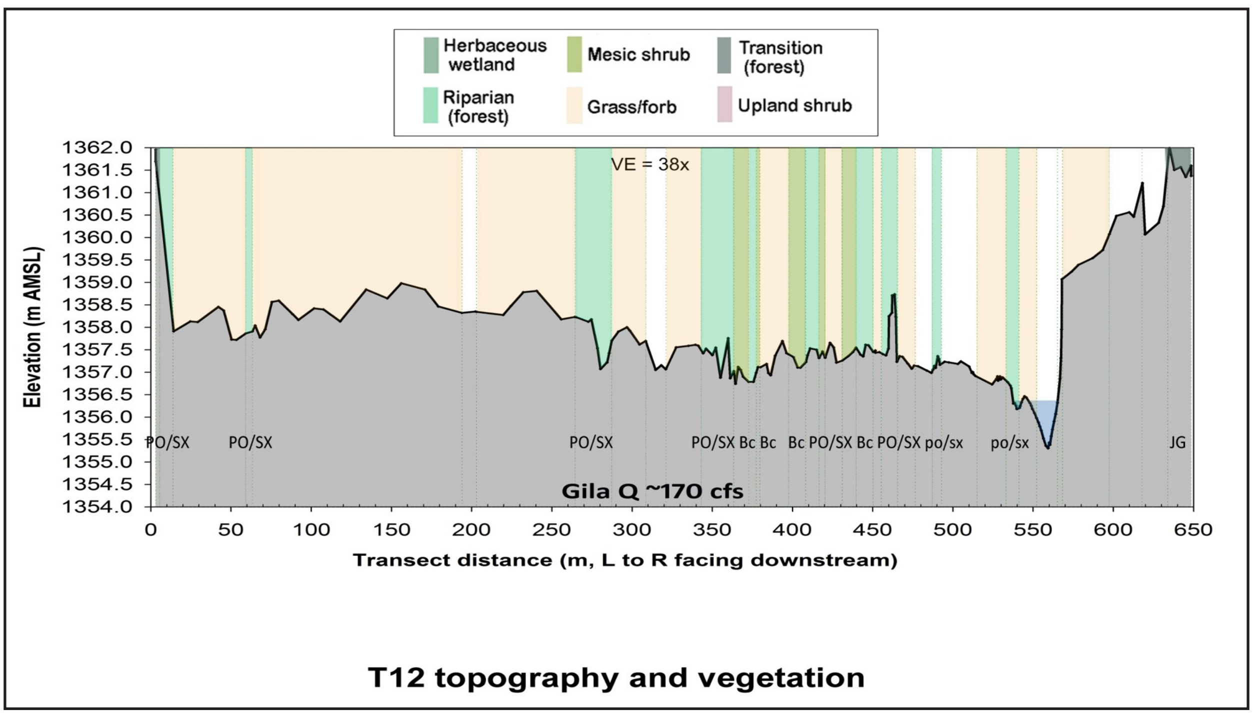
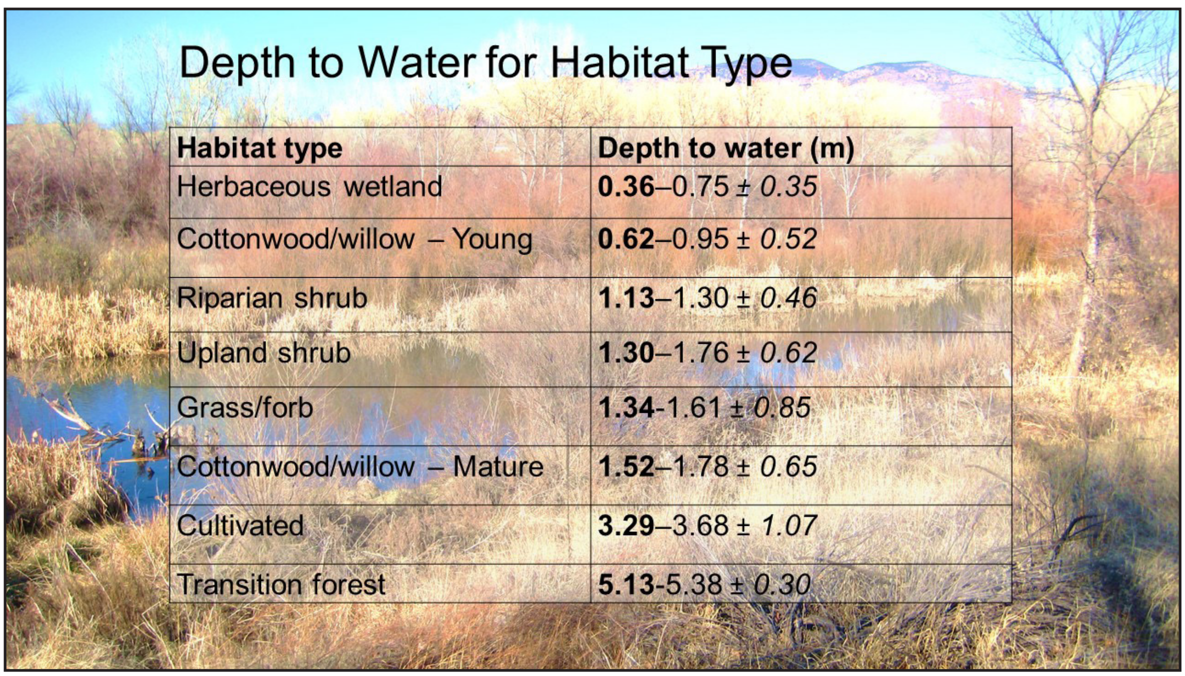


Figure 23. Left to right: PO/SX, mature cottonwood/willow; BC, Baccharis salicifolia; po/sx, young cottonwood/willow; JG, walnut. Grass/forb (yellow) and barren (white) areas are unlabeled. Riparian vegetation types are labeled across the bottom of graph. Color bands representing the position of each vegetation community mapped during the survey are superimposed on T12 topography. On this transect, grass and forb species dominate the higher-elevation left half of the transect. Nearly all bands of riparian vegetation are found along secondary channels in the lower-elevation right half of the transect. Young cottonwood/willow (po/sx) have established in some of the lowest-elevation zones near the main channel.

Figure 24. Monitoring well data collection at well T12E1.



Depth to Water for Habitat Type

Habitat type	Depth to water (m)
Herbaceous wetland	**0.36**–0.75 ± *0.35*
Cottonwood/willow – Young	**0.62**–0.95 ± *0.52*
Riparian shrub	**1.13**–1.30 ± *0.46*
Upland shrub	**1.30**–1.76 ± *0.62*
Grass/forb	**1.34**-1.61 ± *0.85*
Cottonwood/willow – Mature	**1.52**–1.78 ± *0.65*
Cultivated	**3.29**–3.68 ± *1.07*
Transition forest	**5.13**-5.38 ± *0.30*

Figure 25. We used depths to groundwater across each transect to calculate the range of median depths to groundwater by vegetation community (habitat type). The range of depths for each type reflects seasonal variation in median depths; +/- values = 1 SD. As suggested by transect mapping results, herbaceous wetland and young cottonwood/willow establish where depths to water are shallowest. Depths to water in mature cottonwood/willow stands are typically about 1 m greater than in young stands, a consequence of long-term floodplain aggradation due to sediment capture among these species. Depths to water for grass/forb and upland shrub communities are similar. Transition forest types (e.g., walnut; hackberry) are found almost exclusively on higher terrace features.

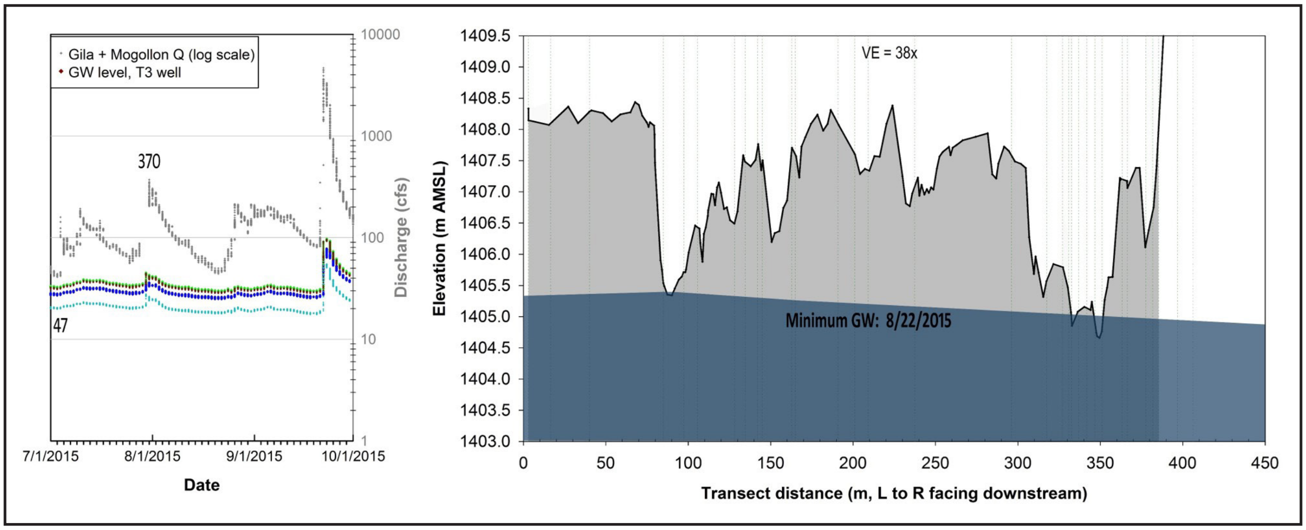


Figure 26. River discharge and corresponding groundwater level changes (left panel) on transect T3, during the summer of 2015. Minimum surface flow was 47 cfs in early July. Maximum depth to groundwater on T3 during the period occurred on August 22, when groundwater was 1.5 - 2 m below the secondary channel features on the floodplain (left panel).

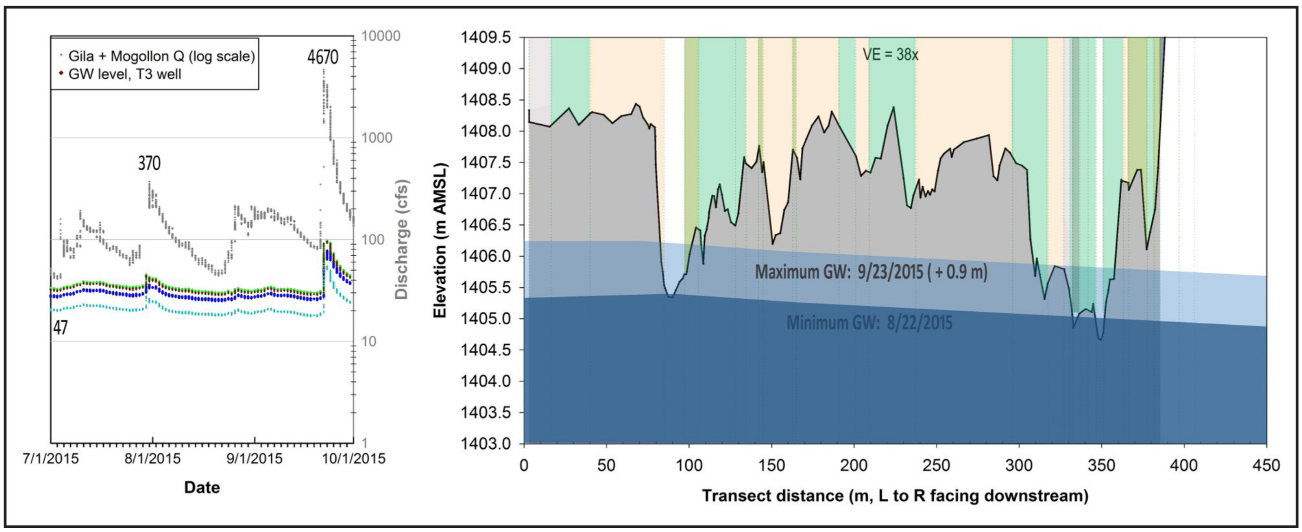


Figure 27. Effects of moderate flood pulse on summer depths to groundwater on transect T3, summer 2015. Surface stage briefly peaked at 4670 cfs on September 22 (left panel). Groundwater levels rose rapidly in response, peaking nearly 1 m above their previous minimum. Low surfaces occupied by young cottonwood/willow (dark green bands near right transect end) were re-wetted; groundwater rose to within 0.5-1 m of ground surface among older, deeper-rooted riparian trees (pale and olive green bands). Small floods (1500-5000 cfs) are typical during the summer monsoon months, helping to replenish near-surface groundwater crucial to riparian species across the floodplain extent.

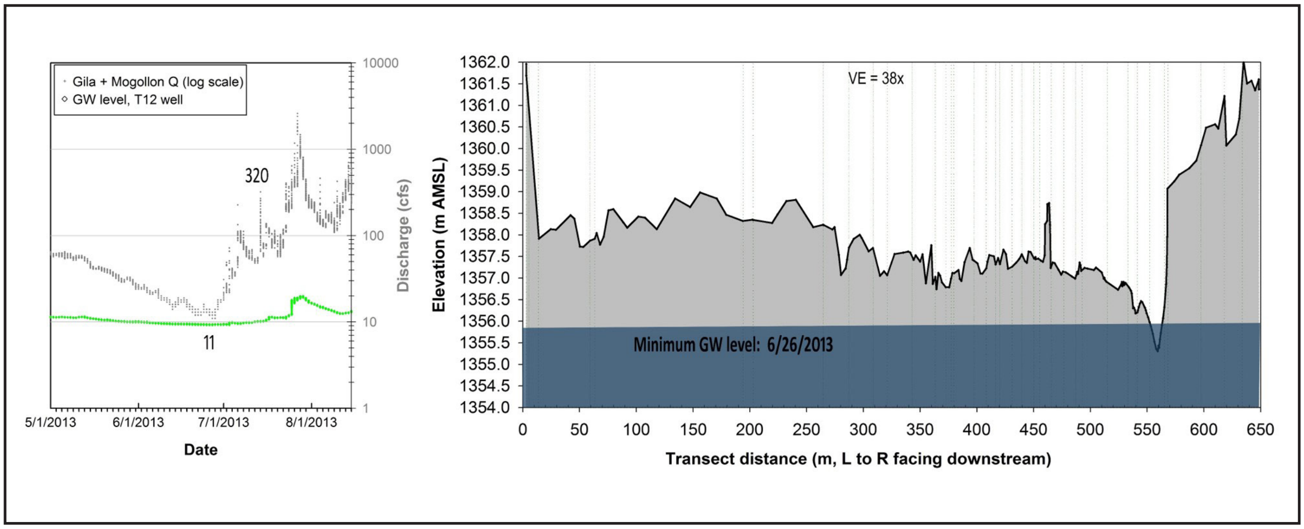


Figure 28. A similar example from the summer of 2013 on transect T12: river discharge and corresponding groundwater level changes (left panel) reflect a minimum surface flow of 11 cfs that year, in late June. Depths to groundwater on T12 during the period were greatest on June 26, 1 - 1.5 m below the secondary channels crossing the right floodplain.

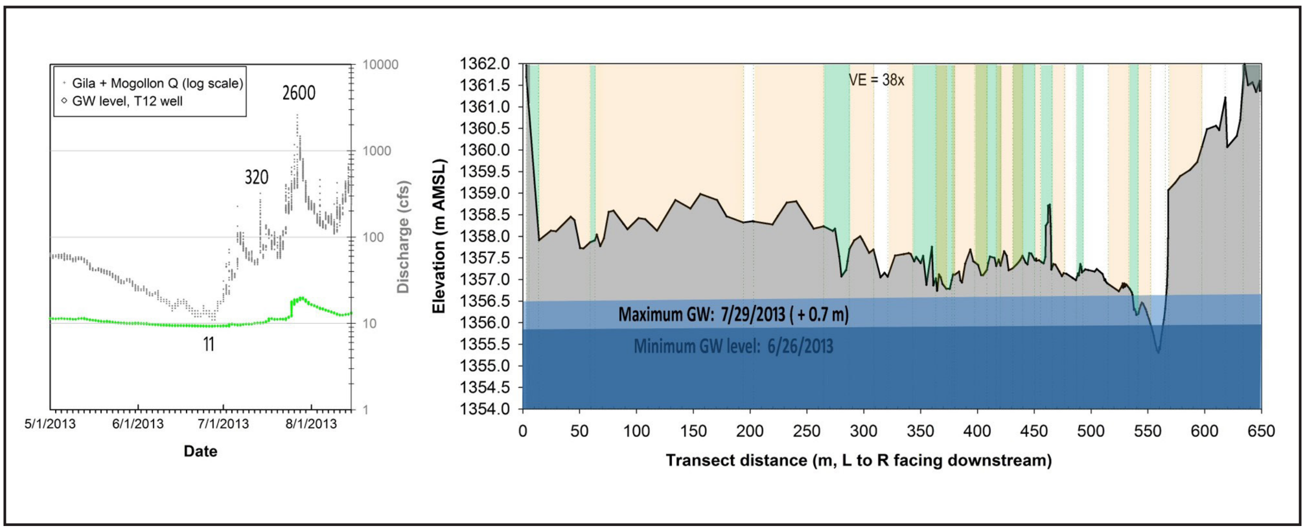


Figure 29. Monsoon peak flow in 2013 was 2600 cfs, on July 27. Groundwater on transect T12 rose by 0.7 m within two days (left panel), to a level < 0.5 m below riparian vegetation established among the secondary channels on the right floodplain and on low surfaces adjacent to the main channel. On this transect, grasses and annual forbs dominate the higher-elevation left end of the transect, where depths to groundwater are always greatest.

Figure 30. Clockwise from upper left: cottonwood, alder, and diverse native understory line a perennial secondary floodplain channel ~200 m distant from main channel at low flow; partial floodplain inundation during 30,000 cfs peak flow September, 2013; surface flow diverges into a floodplain channel at ~1200 cfs flow (left); the same channel transports flow far downstream along the floodplain margin (right); cottonwood, willow, sycamore, and other native trees occupy floodplain adjacent to irrigated pasture. Some of the distinctive microhabitats created by interactions between complex floodplain topography and the Gila River's highy variable flow regime. This diversity of ecotypes provides the foundation for the robust, prolific ecosystem created by the Gila River corridor in southwest New Mexico.

Figure 31. The authors thank New Mexico Department of Game & Fish and the U.S. Bureau of Reclamation for project funding and support.