



Project Summary
Quitobaquito Pond – Cottonwood Sealing
October 18 - 28, 2010

From October 18 through 28, 2010, Organ Pipe Cactus National Monument (ORPI) attempted a partial, temporary sealing of an area of Quitobaquito Pond. This was the latest phase in continuing efforts to analyze and correct an acute water-loss situation that has existed since 2006. Previous efforts included renovating the northeast spring (2007), installing a diaphragm wall inside the pond's retaining berm (2008), thinning of encroaching bulrush (2006-2010), supplementing the pond with trucked-in water (2008-2009), and renovating the southeast corner (2009). The latter project, in August 2009, proved effective at resolving the most acute loss of water from the pond (Figure 1). Following that project, the pond level rose from minus 27" to 28" (pond largely gone, Figure 12b) to minus 12", an increase of 15". In early 2010, the pond surface leveled off at minus 12", suggesting additional leakage was taking place, at or near that level, somewhere other than in the southeast corner. In late January, heavy rains over several days quickly raised the pond to nearly minus 7" (Figure 1). However, the pond surface quickly fell back to about minus 12", indicating that a high-volume leak (>10 gpm) remained, at or near that level. The often-photographed leaning cottonwood tree rooted on the retaining berm was a top candidate for the location of the leak. Both physical and circumstantial evidence implicated this tree. Multiple trials using nontoxic tracer dye in the pond, in 2009-2010, suggested water movement toward the tree. Photographs of the tree over nearly 100 years document its gradual lean toward, then over, then into the pond. Photographs and physical inspection revealed the scar of a large broken-off branch of the tree approximately 12" in diameter, which has been underwater since about 1969. These circumstances suggested that the gradual leaning of the tree may have compromised the retaining berm, and/or the underside of the tree trunk including the large branch scar may be rotting and opening conduits to allow water to flow from the pond, through the tree trunk, and then down into the earth below the retaining berm. The fact that the tree has begun to die over the past 6 to 8 years added to this speculation, because that timeframe coincides with increasingly low water levels at the pond. With evidence pointing to the cottonwood, the National Park Service set out to attempt to seal the tree off hydrologically from the pond, at least sufficiently to reduce or eliminate large water leakage. The plan was to use a combination of compacted bentonite (3/8" dry granular) and compacted fill dirt to build a water-resistant jacket up against the underside and sides of the tree, and along the inner face of the retaining berm adjacent to the tree. The project took place in these major phases:

- 1) During the spring and summer of 2010, a large peninsula of bulrush extending from the cottonwood into the pond was removed manually (Figure 2). During low-water periods since 2008, this peninsula had grown almost all the way across the pond, and had set the stage for the entire northwest end of the pond to fill in with bulrush (Compare Figure 2 with 12b, which predates the bulrush encroachment). Approximately 1200 ft² of this bulrush was removed manually, because it was beyond the reach of a backhoe operating on shore. Bulrush

was cut free, rafted to shore, then placed on the retaining berm for 1 to 2 weeks, to allow it to dry and to allow Sonoyta mud turtles to escape. The dried bulrush was then removed from the site.

2) October 18, a backhoe was used to carefully remove the remaining, extensive dense bulrush stands alongside the cottonwood, and along the inner face of the berm for about 50 feet on either side of the tree (Figure 3). Great care was taken to avoid disturbing the pond bottom or retaining berm with the backhoe. As bulrush was removed from the pond and placed on the retaining berm, workers examined the root masses to locate and remove Sonoyta mud turtles. Nine were found in the removed bulrush. Another 19 mud turtles were trapped in the pond. All 28 mud turtles were taken to monument HQ to be held for the duration of the project. The bulrush was then removed from the site.

3) October 19, an area of about 1,250 square feet around the cottonwood tree was sealed off from the remainder of the pond, using a 112-foot long temporary coffer dam consisting of vinyl pond liner material draped over a PVC-pipe frame, stabilized and sealed by sandbags (Figure 4). This was the same coffer dam used successfully in the southeast corner renovation in August 2009.

4) October 20, the pond surface had raised 0.4" overnight, which was 3 times the rate of normal seasonal rise observed in the week or more before the project (see Discussion). With the coffer dam in place, workers removed as many Quitobaquito pupfish and Sonoyta mud turtles as possible from the project area (Figure 5). Approximately 1,000 pupfish were removed, relocated immediately into the main part of the pond. Two powered pumps (with pupfish-excluding screens) and bailing buckets were used to move the water inside the coffer dam, surrounding the cottonwood, over into the main pond body. After the water level in the project area had been lowered about 6", one side of the coffer dam failed. That side was taken apart, and rebuilt with additional interior and exterior reinforcement. The other side of the dam was reinforced with additional exterior sandbags, without taking it apart. By day's end, the dam was again sealed in place but water pumping had not resumed.

5) October 21, the pond surface had again raised 0.4" overnight (see Discussion). Water pumping resumed. When the pond project area water had been lowered about 7", the other side of the coffer dam failed (Figure 6). That side was taken apart, and rebuilt with interior and exterior reinforcement. Water pumping resumed, and the dam failed a third time, when the interior water level had been lowered about 8". With proof that the temporary dam was not capable of holding back the newly-restored water column in the pond, on-site activities were concluded for the week.

Minutes before the dam began to fail the 3rd time, a preliminary inspection of the underside of the cottonwood was begun. In the center of the old branch scar, a 1.5" to 2" diameter hole was located. A shovel handle was inserted into the hole for a distance of 3 ft or more, with little resistance. The hole is at about the "minus 12 inches" level where a large remaining leak is suspected. Approximately a half-bag (25 lbs) of bentonite was pushed down the hole just as the dam collapsed, again inundating the area.

6) October 22 – 25, Project review and revision took place. A decision was made to attempt to temporarily seal off the cottonwood, without dewatering the area surrounding it. This would be done by surrounding the tree with pond liner, sealed against the pond bottom and retaining berm with sandbags, and extending up onto the cottonwood tree to a level equal to or greater than the outflow pipe. The pond liner would effectively serve as a coffer dam, supported by the tree itself and earthen fill material placed around it (wet) in 2008. October 22-25, the pond continued to rise approximately 0.3” per day

7) October 25, the pond stood at minus 9”. This yielded an average rise in the pond level Oct 22-25 of 0.3” per 24 hours, despite the coffer dam being collapsed. However, the bentonite placed in the hole October 21 remained in place. No project work was carried out on-site October 25.

October 26, the pond level had fallen back to minus 9.2”. The bentonite placed in the tree hole October 21 appeared to have been partly washed farther down into the hole, creating several funnel-shaped holes in the bentonite. Approximately 25 lbs more bentonite was forced into the hole in the tree.

The temporary coffer dam was disassembled and removed from Quitobaquito. A 72-foot long and 15-foot wide piece of pond liner was then draped around the cottonwood, and against the inner face of the retaining berm for about 8 feet to either side of the tree. The pond liner was sealed in place with sandbags, and rope holding it to the underside of the tree’s curve (Figure 7). On this day additional bulrush was removed from the west end of the pond, using a backhoe working from shore.

8) October 27, the pond surface had again raised 0.25” overnight (18 hrs). On this date, general project clean-up and routine Quitobaquito maintenance took place. Vegetation was cleared from the northeast and southwest springheads, and stream channel. All 28 Sonoyta mud turtles removed from Quitobaquito on earlier days of the project were returned and released (Figure 8). At the project area, another hole was inspected that had drawn interest earlier in the year. The hole was about 4” in diameter, and was located in the middle of the tree trunk, on the retaining berm, at the point where the tree trunk bifurcates and flares out into the root system (Figure 9). The hole appeared to be used, though not created by, a ground squirrel (no excavated material was outside the hole). The hole was probed with an iron bar and found to extend nearly 4 feet down, slanting slightly toward the pond. It suggested a large void, in the area between and among the tree’s roots and the interior of the berm. On this day, about 30 pounds of dry bentonite were poured down the hole.

9) October 28, the pond surface had raised 0.2” overnight, to minus 8.8 inches. The hole at the base of the tree was probed again, and found to extend at least 5 feet down into the berm interior, within the inside face of the berm and among cottonwood roots. Another 145 lbs of bentonite were pushed into the hole, using a tamping rod and water. This brought the quantity of bentonite in the hole to about 175 pounds, or 3 ½ bags. Although the hole might have nothing to do with water loss from the pond, it was also consistent with conceptual models of a large-volume leak, given the circumstances of the tree. It was decided that filling it with bentonite could do no harm.

Discussion

This project did not achieve its original goal, of dewatering the area surrounding the cottonwood tree and building a bentonite jacket around the tree and against the adjacent inner face of the berm. The project was re-designed, due to multiple failures of the coffer dam. Ultimately, the project succeeded in meeting several important objectives, and in its re-designed form, may partly or fully meet the original functional goal.

Bulrush Removal

This project included removing approximately 3,000 ft² of bulrush, all of which had encroached into the pond since 2008 during extreme low-water periods. Some amount of bulrush is an important component of pupfish and mud turtle habitat, and site aesthetics. However, Quitobaquito lacks a natural disturbance regime. Left unchecked by disturbance, bulrush incrementally fills in the pond. During low-water periods since 2006, dense bulrush stands have advanced 30 feet or more into the pond, building dry land as it traps sediment and accumulates organic debris.

The bulrush was removed from around the cottonwood tree, along the adjacent retaining berm, and at the bench at the northwest corner of the pond. Approximately 1,200 ft² was removed manually in spring-summer 2010, and about 1,800 ft² removed by a backhoe, positioned on the retaining berm, during this project. Removing this quantity of bulrush amounted to reclaiming about 10% of the pond's pre-2007 surface area of approximately 30,000 ft². Given the extent of bulrush encroachment since 2008 (which has reduced the surface area of the pond), removing this 3,000 ft² of bulrush probably enlarged the current pond area by more than 15%. This alone constituted important conservation and maintenance of the pond.

The Cottonwood Tree

The temporary coffer dam yielded strong evidence, perhaps final proof, that the cottonwood tree and/or the immediately-adjacent retaining berm, are the source of a large remaining leak from Quitobaquito Pond. On two consecutive nights (18 hrs each) that the dam was sealed in place, the main pond area rose about 0.4" each, whereas the rate of rise in preceding weeks was 0.11" to 0.15" *per 24 hrs* (Figure 10). This tripling (or more) of the rate of rise strongly indicated that the coffer dam had sealed, and isolated the cottonwood area from the rest of the pond, demonstrating that leakage had been taking place from within the project area inside the coffer dam. The observed rate of rise equated to a net gain in the pond of 8 gallons per minute - on the same scale as the estimated leakage rate. The only possible alternate explanation is that during these days (October 20-21) temperatures were slightly cooler than the previous week, resulting in reduced evaporation. This factor is not likely to have been sufficient to account for tripling the rate of increase in pond surface elevation.

Providing additional strong evidence of leakage through the tree was an important outcome of this project. The cottonwood tree is a famous subject of landscape and nature photographers, and is revered by Native American tribes and the public overall. If water leakage from

Quitobaquito is to be solved for the long-term, the tree must be dealt with. If removing the tree and repairing that part of the berm is to be an option under consideration, the NPS would need strong evidence the tree is in fact the problem. The NPS now has such evidence. If the tree is to be left in place until it dies naturally, the NPS now has sufficient information to construct temporary sealant around the tree, to reduce or eliminate leakage in the near term (1 to 5 years). The sealing materials placed in this project may be adequate for those purposes.

This project also provided the opportunity for limited inspection of areas of the cottonwood tree suspected as having a role in possible leakage. Extensive live bulrush, old bulrush remains, dead waterlogged branches, and soil were removed from around the tree, allowing limited visual inspection before the final failure of the coffer dam. In this process, 2 holes were located in the tree that could be significant. It was also confirmed that a man-made prop, consisting of two 8" x 8" timbers (possibly railroad ties) is wedged under the tree near the point where the trunk curves up from the horizontal. This prop was probably placed in 1962 or 1969, the two previous times the pond was drained. The prop may be relevant to the water loss problem. If it is decaying and failing, accelerated settling of the tree into the pond may result, with consequent damage to the berm. Alternately, the tree may be pushing the prop into the clay pond bottom, resulting in damage to the pond bottom and its water-holding capacity.

Pond Surface Elevation: Status and Trend

The trend in the surface elevation of Quitobaquito pond from late September to early November was somewhat unexpected, and complicates reaching firm conclusions regarding this project. Up until the first week of October 2010, it appeared that the pond was not capable of rising above the minus 12" level. This belief resulted from the trend following the August 2009 renovation of the southeast corner of the pond (Figure 1). Following that project, the pond level rose steadily from minus 27". As the level approached minus 12" in January 2010, the rate of rise diminished, even though cool temperatures and short day length would have reduced evaporative loss to near the annual minimum. In late January, heavy rains over several consecutive days resulted in the pond rising rapidly to about 8". Immediately after, the pond elevation fell quickly back to minus 12", indicating a large-volume leak controlling the pond at that level. In the warm months of 2010, the pond level fell back to almost minus 17", then began a slow rise as summer heat abated. A recovery back to minus 12" was expected. However, in early October the pond slowly rose above minus 12". On the first day of this project, it stood at minus 10.75". No apparent physical changes in the system had occurred since the southeast corner renovation. Poor summer rains had contributed little or no supplement to the pond.

The accelerated rate of the increasing pond level observed during this recent project strongly indicates substantial water loss via the cottonwood tree (Figure 10). As noted above, the rate of vertical rise approximately tripled, during the period that the cottonwood was separated from the pond by the coffer dam, and after bentonite had been inserted into a hole in the tree. The loss of 0.2" observed between October 25 and 26 may suggest that sufficient water pressure had built up to re-activate a leak in the cottonwood tree. October 26, funnel-shaped holes were seen in the bentonite that had been packed into the tree, suggesting water had forced bentonite farther into the hole. That hole is now separated from the pond by pond liner, and has had

additional bentonite inserted into it. The rate of increase has diminished, from 0.4" per 18 hours when the coffer dam was in place, to 0.15" per 24 hours Oct 28-Nov 1, after the tree had been wrapped with pond liner. This diminished rate may mean that the pond liner seal around the cottonwood is not as complete a seal as the coffer dam was. The rate observed Oct 28-Nov 1 is essentially the same as that observed in the week prior to the project. However, an important distinction exists. As the pond's water column rises, the surface area increases. Particularly along the north and northeast shorelines, the pond edge is a gentle slope – unlike the vertical bank of the retaining berm. As the water level rises, new areas are saturated along the north and east shores; much of that area consists of new land built by bulrush encroachment since 1962. And much of that land has not been saturated at current levels since 2006. In short, on November 1, the pond was rising 0.15" per day, nearing the minus 8" level. This may indicate an even greater daily net gain of pond volume than on October 13, when the pond was rising at 0.13" per day but was 3.5" lower, nearing 11.5".

Conclusion and Options

As of November 1, the pond was at minus 8.2". This was the highest, most stable pond level since early 2006 (Figures 11 and 12), and was nearly 4" higher than a maximum capacity of minus 12" that was believed to exist through most of 2010. It is not possible to conclude how much temporarily sealing the cottonwood tree is contributing to the current increase in pond level, or the pond's ability to continue rising above the minus 12" level. It is possible that the positive trend in late 2010 would have persisted even without temporarily sealing the cottonwood. It is possible the positive trend in late 2010 is a delayed effect of the August 2009 southeast corner renovation. That project had immediate positive effect (Figure 1), but a full year may have been required for its full effects to develop. It is also possible that some unknown leak (e.g. rodent burrow or tree root cavity) that opened naturally 3 to 4 years ago has now closed naturally. Regardless of the reason, Quitobaquito Pond has been restored to approximately 80% of its normal post-1962 depth, and may continue to rise. The increasing water pressure may re-activate leakage, but that remains to be seen. Considerable pond area (possibly 25%) has been displaced by bulrush encroachment during the low-water period of 2006-2010. However, the deeper water should now inhibit further rapid bulrush encroachment.

At this point, the low-water crisis at Quitobaquito of 2006-2010 appears to be largely past. However, final management actions are necessary to assure this important site persists into future years. Fortunately the National Park Service now has the opportunity to use upcoming months to monitor Quitobaquito and evaluate options for future management, without the pressure of managing an acute crisis.

Management issues and options for the near term (1 to 5 years) include:

1. Increasing water depth and pressure may trigger another rapid loss of water from the pond. The NPS may need to respond quickly again, evacuating Quitobaquito pupfish and Sonoyta mud turtles, and attempting to locate a leak.
2. If the currently positive status and trend in the pond continues, the NPS must still prepare to deal with the inevitable death and collapse of the cottonwood tree. Even if the tree

were not a leak source now (it has proved to be), it will be when it begins to fall apart and decompose. This is likely to occur over the next 1 to 5 years.

2a. The NPS could wait for the leaning cottonwood to die and fall apart, and then repair the area of the retaining berm where it once stood. In the interim, maintaining a fairly watertight seal around the tree would likely require a low to moderate level of effort. When the tree does ultimately fail, there is some chance it would fall over or break apart near the base in one catastrophic event. Such an event could tear open the retaining berm, allowing large loss of pond water and Quitobaquito pupfish. While the diaphragm wall should provide some level of protection to the berm, the half of the berm inside the diaphragm wall could be severely damaged. It is fairly clear now that the water that was escaping the pond via a leak did so by going straight down, or at least under the diaphragm wall. The NPS currently has on hand sufficient bentonite and fill material to repair/rebuild the berm immediately in the tree area, in the event the tree fails and does significant damage.

2b. A more pro-active alternative would be to remove the tree soon, under controlled circumstances, before additional problems ensue. The tree could be taken down in small pieces, to reduce impacts in the pond, and to increase worker safety. Eventually, the root mass would need to be removed from the berm edge. This would cause some damage to the berm, requiring some extent of rebuilding and repair as in option 2a, above. At current water levels, such work would require building a coffer dam to allow dewatering of the pond adjacent to where the tree is rooted in the berm. This option of removing the tree soon would relieve future managers of having to deal with a problem, possibly in crisis mode, which we understand to exist now. This option may be controversial to members of the public who value the tree. However, sufficient time is now available to communicate with the public on the issue.

3. The original plan for this project could be carried out; placing a coffer dam around the tree, dewatering the area, and building a bentonite and fill-material seal around the tree. This would now require a commercially-available temporary coffer dam, because the monument's home-made dam is not capable of holding back a >32" water column. If this original project plan is carried out, it should be recognized that even that solution would be temporary, that additional, possibly extensive work would be needed when the tree dies and disintegrates. If this option is pursued, it should be done between April and mid-September, to avoid requiring workers to work in cool water during potentially cool weather.

4. As of November 2010, up to 25% of the former pond area (pre-2006) has been displaced by bulrush encroachment. Without extensive efforts at bulrush control over the past 4 years, the pond would likely now be more than half filled in with bulrush. Even if water levels now remain high, the NPS must confront the issue of long-term pond maintenance. Much more of the 2006-2010 bulrush encroachment could be removed. Most of it is now too dense for manual removal. However, mechanical means could be employed, without using heavy equipment in the pond. For example, a dragline system could be used to tear out bulrush and drag it to shore using chains and grapples. Use of herbicide has been considered, and this option should remain on the table. While herbicide may kill or suppress bulrush, it does not remove the dense root masses and built-up new land, which would still require physical removal.

5. Optimistically, some combination of the above management actions may very well result in water again flowing out of Quitobaquito Pond via the outflow pipe. This excess of water will allow the NPS to resume better caretaking of the historic pomegranate trees just

downslope of the retaining berm. Additional options will exist, for planting a new generation of cottonwood trees at the pond. Virtually all the existing trees are contemporaries of the leaning tree, and are dead or dying. One remains fairly healthy. A replacement for the famous leaning tree could be planted near the retaining berm, but on the outside/downslope side of the berm. In such a location it could provide shade and a windbreak for the pond, reducing evaporation. It (and additional trees on that side) could also provide important aesthetic values, if not as unique and graceful as the existing tree.

This project was carried out in 6 workdays on the site. Eight to 16 workers were involved each day. There were no on-the-job injuries. No mortalities of Quitobaquito pupfish or Sonoyta mud turtles were observed.

Acknowledgements

This project, and the preparation work earlier in 2010, were carried out &/or made possible by the people listed below. Personnel are ORPI staff except where otherwise noted.

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Thanks also to Bob Bryant, Kenny Richardson, and Shawn MacGill, for their great skill, surgical precision, and hard work with heavy equipment and related operations.

Finally, special recognition is due to Ami Pate and Matt Thornton. By early November 2010, there were 42 work visits to Quitobaquito in 2010. Ami &/or Matt were present for virtually all these, always jumping in to take on the hardest tasks. Their sustained dedication and hard work made the success of 2010 possible.

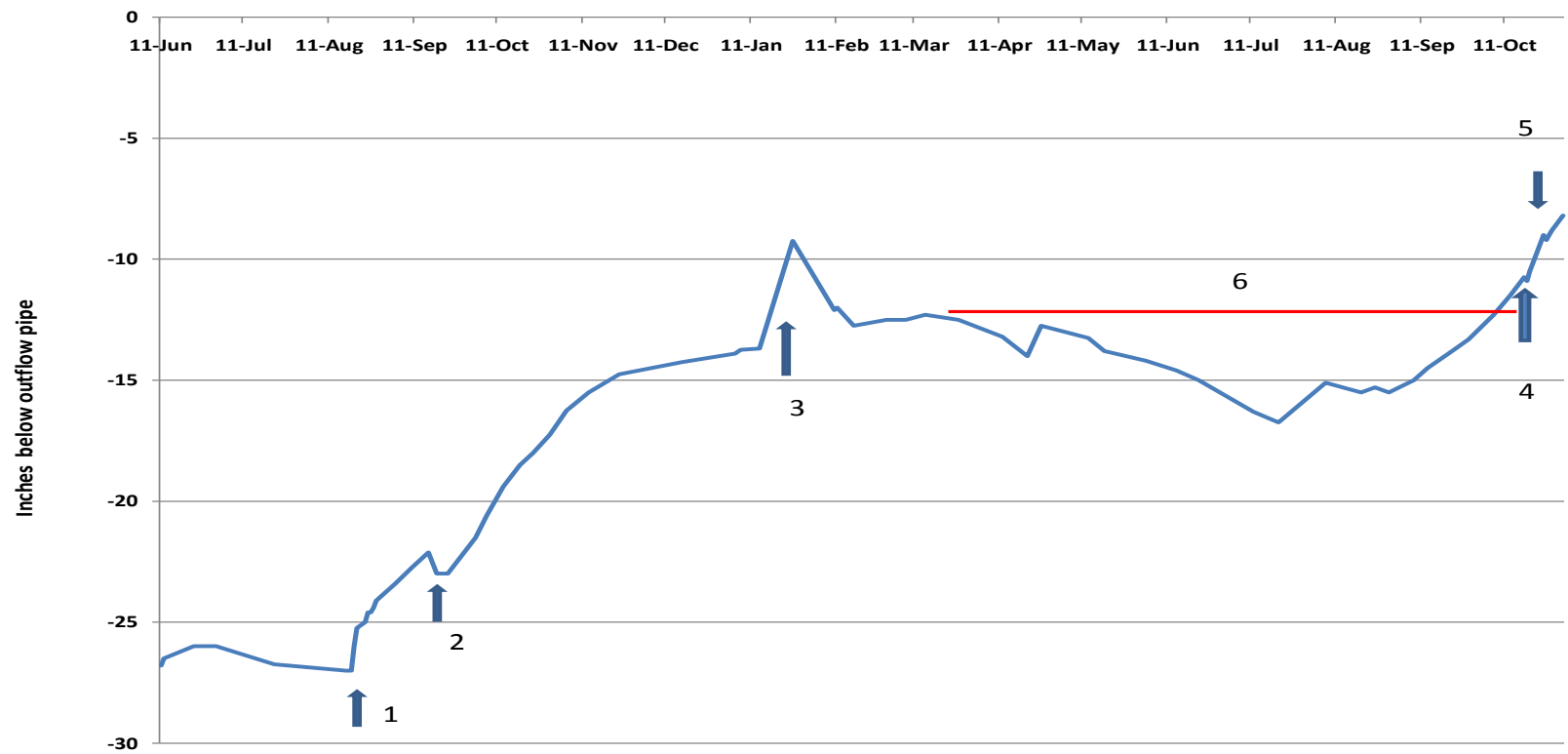


Figure 1. Trend in surface elevation of Quitobaquito Pond, June 2009 – November 2010. 1) Southeast corner renovation initiated; 2) SE corner re-filled, using water from main pond; 3) Large rains of Jan '10, followed by rapid water loss 4) Cottonwood sealing project initiated; 5) Cottonwood sealing project ended; 6) Apparent maximum possible pond level (minus 12") following loss of January rain input.



Figure 2. New bulrush stands surrounding the cottonwood, established since 2008. Upper view is from north shore to the south, lower view is from northwest shore bench to east, with workers removing bulrush.



Figure 3. Removing bulrush encroachment and inspecting for Sonoyta mud turtles. The near side of the tree has been stripped of bulrush; bulrush remains on the far side. October 18, 2010.



Figure 4. Cofferdam in place. October 19, 2010.



Figure 5. Netting for Quitobaquito pupfish and Sonoyta mud turtles. October 21, 2010.



Figure 6. Cofferd dam failure. October 21, 2009.



Figure 7. Sealing tree with pond liner. October 26, 2010.



Figure 8. Releasing Sonoyta mud turtles (*Kinosternon longifemorale sonoriensis*) back into Quitobaquito pond after project activities. October 27, 2010.



Figure 9. Holes at base of cottonwood, among roots and extending into berm. Eventually found to extend 5 feet down and toward pond. October 20, 2010.

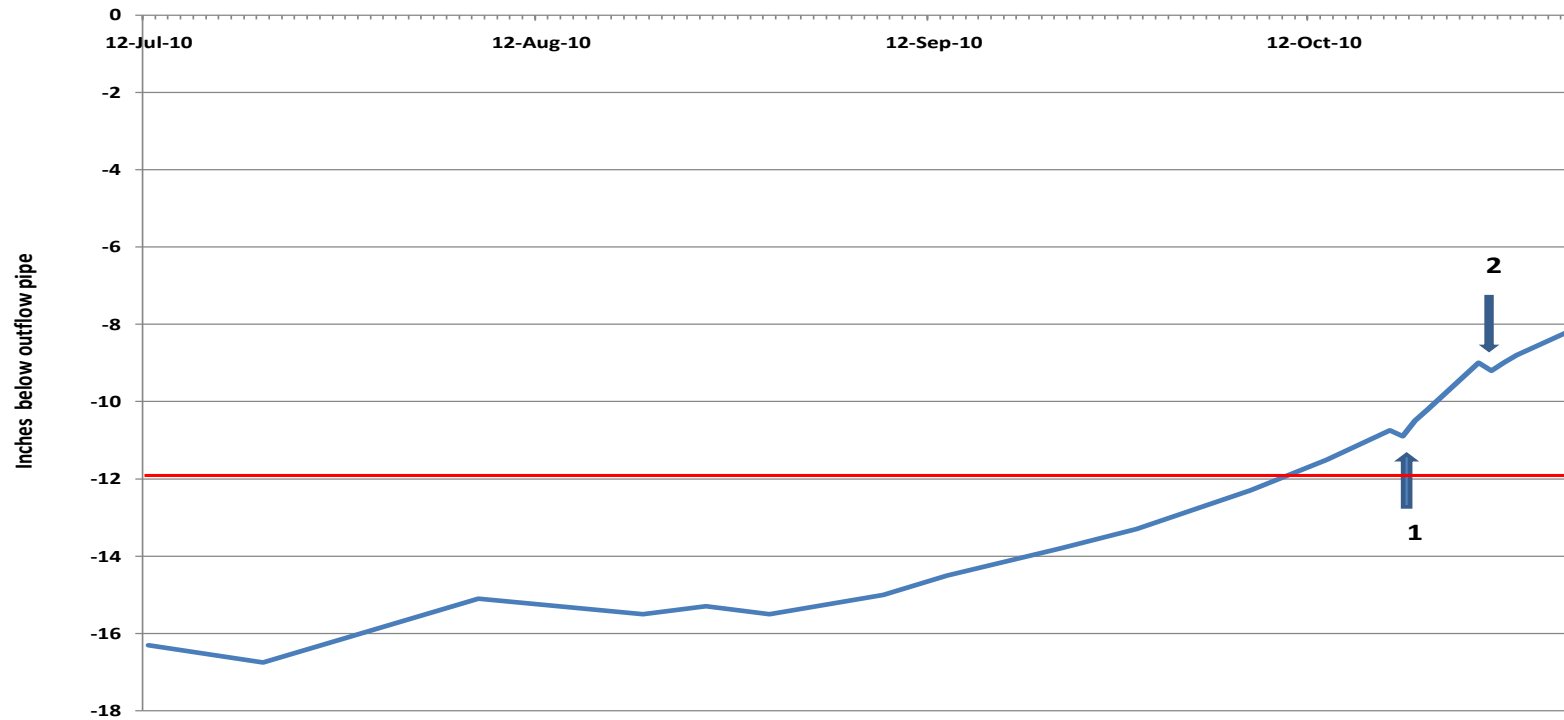


Figure 10. Trend in surface elevation of Quitobaquito Pond, 12 July – 1 November 2010. 1) Cottonwood sealing project initiated, with initial 0.25" loss due to bulrush removal; 2) Cottonwood sealing project ended, with 0.25" loss due to actual loss, bulrush removal, &/or observer variation. Note steeper curve between points 1 and 2, indicating faster increase in water level. Red line indicates apparent maximum possible pond level (minus 12") observed just prior to and after loss of large January 2010 rain input (Figure 1.).

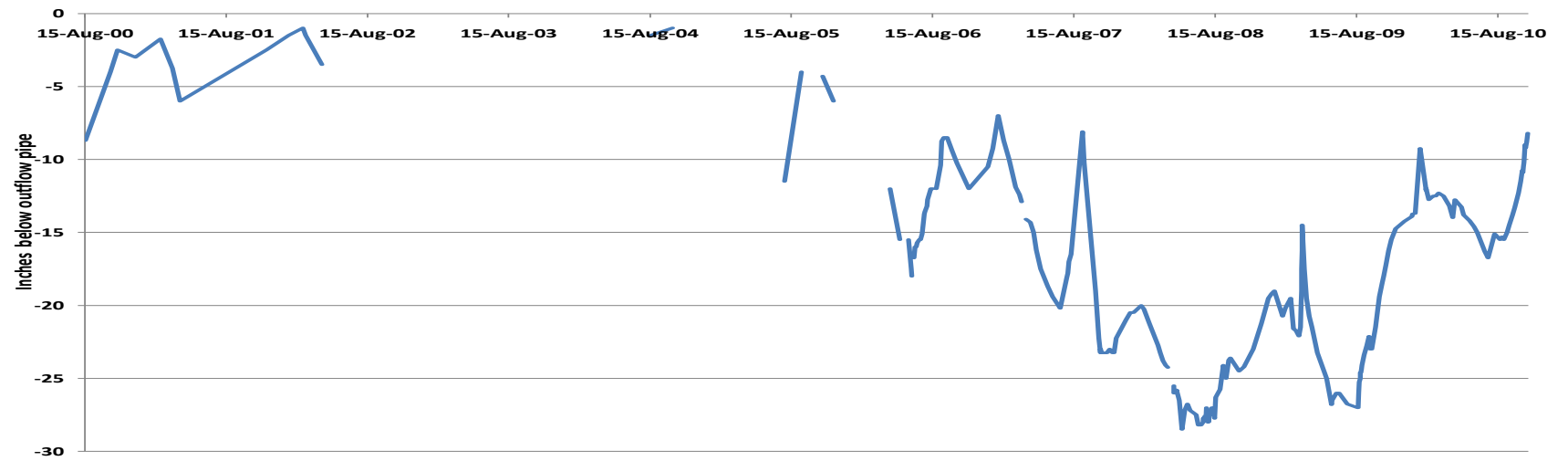


Figure 11. Surface elevation of Quitobaquito Pond, Organ Pipe Cactus National Monument, August 2000 to November 2010.



Figure 12a. Quitobaquito Pond, Organ Pipe Cactus National Monument, after the project. October 28, 2010. Pond level: minus 8.8 inches.



Figure 12b. Quitobaquito Pond, Organ Pipe Cactus National Monument. July 26, 2008. Pond level: minus 28 inches.