Bushy Lake 2022 Summary Report

California Wildlife Conservation Board Grant Agreement for Bushy Lake Conceptual Restoration Plan WC-1943CA
Data Contributing to Critical Elements for Western Pond Turtle Habitat

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Objective 1: Conduct Studies and Designs for Pond Turtle Conservation and Fire Resilient Habitat Restoration – Collect Western Pond Turtle Baseline Data

Task 1.1, 1.2, and 1.3 - Collect Western Pond Turtle Baseline Data and Task 1.2 Identify Invasive Aquatic Species and Threats (Non-Native Turtles)

The Western pond turtle (WPT) (*Actinemys marmorata*) is California's only native freshwater turtle species. In 2015, the U.S. Fish and Wildlife Service (USFWS) initiated a status review for listing the WPT under the U.S. Endangered Species Act (USFWS 2015). WPT is listed as a "species of special concern" by the state of California, "endangered" by the state of Washington, and "sensitive/critical" by the state of Oregon (CBD, 2022). Furthermore, WPT recovery plans have been developed in Washington (Hays et al. 1999), and WPT conservation priorities have been established in Oregon (Rosenberg et al. 2009).

In 2014, the taxonomy was revised based on genetic research, and there are currently two recognized pond turtle populations in California: Northwestern (*Actinemys marmorata marmorata*) and Southwestern (*Actinemys marmorata pallida*) pond turtles (collectively referred to as "pond turtles") (Alvarez et al. 2021, CDFW 2022, Iverson et al. 2017, Spinks and Shaffer 2005, Spinks et al. 2010, 2014, 2016). Both species are recognized as "species of special concern" in California and have been in steady decline (Alvarez 2021, Bury et al. 2012, Spinks et al. 2016). The WPT is a Priority 1 Species of Special Concern in the southern part of the range (roughly corresponding to the range of the Southwestern pond turtle), and a Priority 3 Species of Special Concern elsewhere in California (roughly corresponding to the range of the Northwestern pond turtle) (Spinks et al. 2016). Factors such as loss and degradation of aquatic habitat; habitat alteration, fragmentation, and destruction; urbanization and agricultural conversion; shell disease (Lambert et al. 2021); competition with non-native turtle species (NNT); and predation of nests have resulted in the decline and local extirpation of pond turtles throughout much of the historic range (Bury et al. 2012, Cayan et al. 2008, Spinks et al. 2016, Purcell et al. 2017). Changing climate conditions, especially ongoing drought and wildfires, magnify threats to WPT populations (Purcell et al. 2017).

Western Pond Turtle Life History

Pond turtles are known to mate throughout the spring, summer, and fall. Turtle brumation, a form of hibernation, occurs from approximately October through late February to early March, with periodic active periods throughout the winter months (Alvarez, Pers. Comm, 2021). From mid-April through the end of July, female turtles travel to upland habitat to construct nests (CBD 2022, USFWS 2015). Turtles (both native and non-native) travel an average of 100m away from the water to nest. However, females have been observed traveling as far as 500m to nest (Davidson and Alvarez 2020, Holland 1994, Holte

1998, Lovich and Meyer 2002, Reese and Welsh 1997, Storer 1930). During the nesting process, turtles will dig "phantom" or "exploratory" nests, which are shallow, incomplete nests without eggs or plugs (a clump of soil, vegetation, and turtle urine utilized to cover the nest) (Alvarez and Davidson 2018).

WPTs usually construct one nest, however, there are records of double-clutching (Bury et al. 2012, Germano and Rathbun 2008). Clutch sizes range from 1 to 11 eggs (Germano and Rathbun 2008, Holland 1994, Lovich and Meyer 2002). The eggs hatch in August and the hatchlings remain in their nests. The hatchlings' movements slowly displace soil until there is an opening for them to emerge from, between late February and early March (Davidson and Alvarez 2020, Germano and Bury 2001, Goodman 1997, Spinks et al. 2003).

Literature reviews on pond turtles illustrate a high degree of variability in the life history between site differences; species differences, and inter-annual climate variability of precipitation, temperature, flooding, drought, and aquatic habitat quality (Davidson and Alvarez 2020, Ernst and Lovich 2009, Bury et al. 2012.). Given the variation and uncertainty evident in published literature, our field research at Bushy Lake appears increasingly important.

Methods

The Bushy Lake Conceptual Restoration Plan (CRP) Project monitored a resident WPT population to document and understand their abundance, size classes, nesting and basking habitat, and reproductive success, as well as to identify significant habitat elements for pond turtles. Baseline surveys for WPTs were conducted by collecting data using the following methods: a) visual basking surveys; b) mark-recapture sampling; and c) nesting surveys. Sampling followed USGS WPT trapping and visual survey protocols (USGS 2006a, 2006b). Bushy Lake training, sampling, and data collection methodology was overseen by Jeff Alvarez, a turtle expert with extensive experience in WPT and other reptile and amphibian conservation and restoration practices. We initiated visual surveys in 2020; data was not up to the quality assurance standards of this project and was not included in this report. Turtle nest survey training took place on May 21 and 23, 2021. *In-situ* nest surveys and mark-recapture training took place at Moorhen Marsh on June 23, 2021.

Turtle populations were impacted by a June 6, 2021, fire that burned roughly 130 acres of the lower American River, roughly 60% of the Bushy Lake site. The fire burned to the edge of the aquatic habitat at Bushy Lake.

Visual Basking Survey Methods

Visual basking surveys were initiated on February 21, 2021, to document when the turtles first began to emerge from brumation (USGS 2006). Weekly surveys were conducted in 2021 on February 21 and 27; March 20 and 26; April 2, 16, and 23; and May 14. Surveys were calibrated by having an experienced biologist, Gunner Michaelson, participate in all surveys to provide consistency. Metrics recorded include location and species type, size, and age. If a species determination cannot be confidently made, turtles are listed as "unknown." The turtle count approximates the number of individual turtles that can be found basking at Bushy Lake on a given day. It can be expected that there are 2-3 times more turtles present than what is observed in visual surveys (Alvarez, Pers. Comm., 2021). Visual basking surveys were stopped after May 14 and were superseded by detailed mark-recapture data.

Recapture Survey Methods

Monthly live turtle mark-recapture studies began in July of 2020 (USGS, 2006a). Trapping dates in 2020 included March 21, 22; June 14, 20, 21, 23, 25, 26, and 28; August 8 and 9; September 20; October 4; November 8; and December 14. Trapping dates in 2021 occurred monthly, with an exception to February due to Covid concerns (January 3; March 7; April 4: May 2; June 6; July 7; August 1; September 5; October 10; November 7; and December 5). Monthly trapping dates will be initiated in March 2022. Newly captured NNTs were marked by filing one notch in the 80th scute. Each WPT was marked with a unique pair of scute marks to differentiate individuals and was photographed. Turtles were returned to the point of capture in Bushy Lake as soon as data was collected.

Visual Nesting Survey Methods

Jeff Alvarez provided nesting survey training on May 21 and 23, 2021 which coordinated with USGS protocols (USGS 2006a). Turtle nesting surveys were conducted daily from May 20 to July 1, 2021, excluding June 6-9 due to the June 6 fire. The 2022 monitoring schedule will be informed by the 2021 visual surveys, mark-recapture, and nesting survey data.

Results

Visual Basking Survey Results

The maximum number of turtles observed in a single day was on March 26, 2021, with 133 turtles (Figure 1). We observed WPTs basking during multiple surveys: two on February 27, one on March 20, one on March 26, and one on May 14, 2021. Most of the turtles observed in basking surveys were non-native sliders (*Trachemys* species) Species data from visual observations correlated with the mark-recapture surveys (Figure 2). It can be expected that there are 2-3 times more turtles present than what is observed in visual basking surveys (Alvarez, Pers. Comm, 2021).

In 2021, we observed turtles emerging from brumation on February 27 during visual surveys. In 2022, we observed turtles emerging two weeks earlier than in 2021, corresponding to higher temperatures. Visual survey data includes total turtles observed, without distinguishing between NNT and WPT. We did not feel we could adequately distinguish between turtle species with our spotting scopes, so lumped together in our observations.

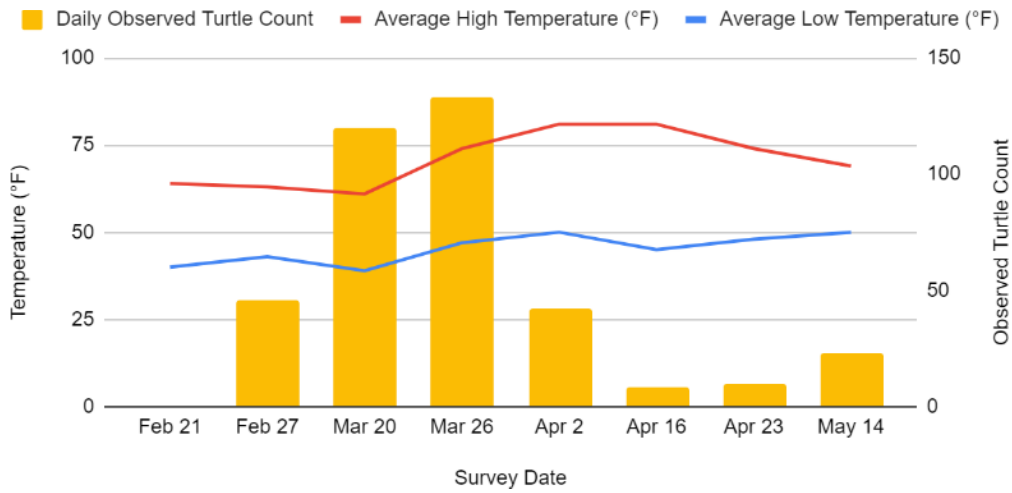


Figure 1. Daily Observed Turtle Count from 2021 Visual Basking Surveys with High and Low Temperatures(°F).

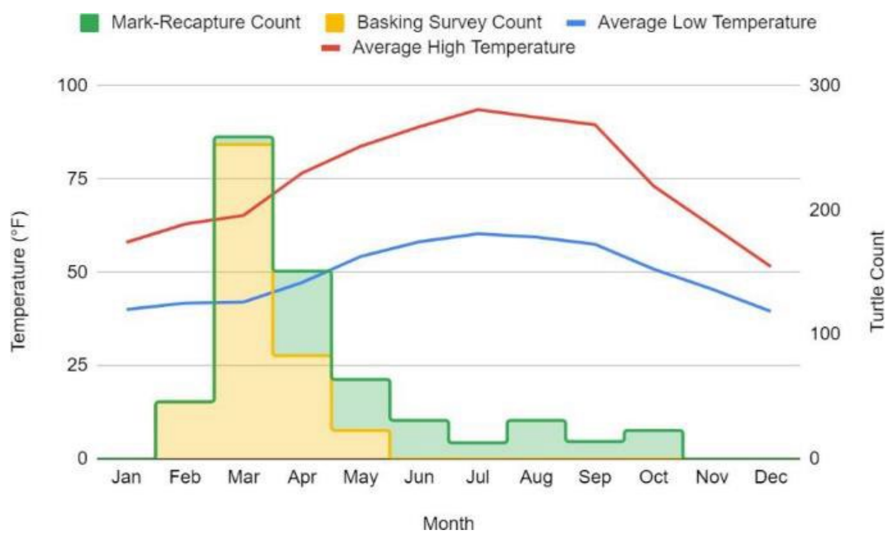


Figure 2. Mark-Recapture and Basking Survey Turtle Count with the Average High and Low Temperatures (2021).

Mark-Recapture Survey Results

In 2021, a total of 227 turtle captures were recorded; of these, 73 were recaptures and 154 were unique individuals (Table 1). During mark-recapture surveys, we captured six WPTs. In the history of the Bushy Lake restoration project, four individual WPTs have been identified, three adult males and one adult female. Pond turtle #1 (male) has been captured five times since March 2020; #2 (unknown sex) once in March 2020; #3 (male) four times since September 2020; and #4 (female) once in April 2021 (Table 2). The resident WPT population has the potential to reproduce; we have found two WPT nests (predated). Visual basking and nesting survey data are consistent with the mark-recapture data (Figure 2).

WPTs are significantly smaller in size and weight than the Bushy Lake NNTs (the average WPT weight is 723g and the average NNT weight is 1,026g). The average physical characteristics of the WPT included the following: 722.75 g weight; 17.48 cm carapace length; 13.73 cm carapace width; 5.98 cm maximum height; 13.63 cm plastron length; and 10.63 cm plastron width (Table 3).

Table 1. Live mark-recapture data summary for 2020 – 2021.

Species Group	2020	2021
Non-native Turtles	147 (9)	221 (68)
Western Pond Turtles	5 (4)	6 (5)
Total	152 (13)	227 (73)

[Total Count (Recapture Count)]

Table 2. Capture and release of each Western pond turtle (*Actinemys marmorata*) at Bushy Lake 2020 – 2021.

Trapping Date	Turtle Identification	Life Stage, Sex	Age
3/22/2020	1	Adult Male	9
3/22/2020	2	UK	UK
6/14/2020	1	Adult Male	9
9/20/2020	1	Adult Male	9
9/20/2020	3	Adult Male	9
4/4/2021	1	Adult Male	9
4/4/2021	4	Adult Female	6
5/2/2021	3	Adult Male	9
6/6/2021	1	Adult Male	9
7/6/2021	3	Adult Male	9
10/10/2021	3	Adult Male	9

Each pond turtle individual is identified with a unique color (blue, green, red, or yellow) (UK = Unknown).

Table 3. Average (2020-2021) size of all turtles captured at Bushy Lake.

	Weight (g)	Carapace Length (cm)	Carapace width (cm)	Max Height (cm)	Plastron Length (cm)	Plastron Width (cm)
Northwestern Pond Turtle Average (2020-2021)	722.75	17.48	13.73	5.98	10.63	13.63
Slider Average (2020-2021)	1026.09	17.69	13.85	6.96	11.68	13.30
Peninsula Cooter	3340.00	30.00	23.00	10.70	28.00	15.00
Painted Turtle	375.00	15.00	11.00	5.00	6.50	13.50

Western pond turtle (*Actinemys marmorata*); slider species [red-eared slider (*Trachemys scripta elegans*), melanistic red-eared slider, yellow-bellied slider (*Trachemys scripta scripta*)]; peninsula cooter (*Pseudemys peninsularis*); painted turtle (*Chrysemys picta*)

NNTs observed at Bushy Lake dominantly consist of slider species, including red-eared sliders (*Trachemys scripta elegans*); melanistic red-eared sliders; and yellow-bellied sliders (*Trachemys scripta scripta*). One painted turtle (*Chrysemys picta*) and one Peninsula cooter (*Pseudemys peninsularis*) have additionally been observed at Bushy Lake. The sampled slider population consisted of 227 adults and 64 juveniles, with 135 females and 65 males. We were unable to determine the sex of 91 turtles, a majority of which were juveniles. The mean physical characteristics of the dominant slider species included the following: 1,026.09 g weight; 17.69 cm carapace length; 13.85 cm carapace width; 6.96 cm maximum height; 13.30cm plastron length; and 11.68 cm plastron width (Table 4). Female sliders are heavier than male sliders (the female average weight is 1406.05g and the male average weight is 871.13g). Turtle abundance peaked in April and June; there are more males in April, which correlates with the mating season, and more females in June, which correlates with the nesting season (Figure 3).

Table 4. The count of non-native turtles by age class and sex at Bushy Lake (2020-2021).

Sex	Adult	Juvenile	Total
Male	60	7	67
Female	133	2	135
Unknown Sex	36	55	91
Total	229	64	293

Slider species [red-eared slider *(Trachemys scripta elegans)*, melanistic red-eared slider, yellow-bellied slider *(Trachemys scripta scripta)];* peninsula cooter *(Pseudemys peninsularis);* painted turtle *(Chrysemys picta)*

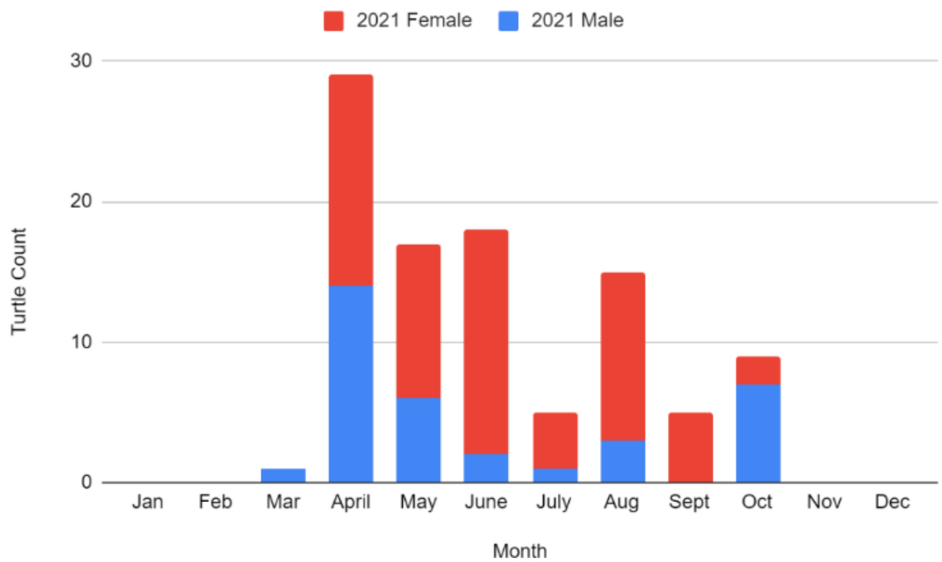


Figure 3. Count of slider species per month in 2021 by adult male and adult female individuals. Note: no mark-recapture studies were conducted in February. [Red-eared slider (*Trachemys scripta elegans*), melanistic Red-eared slider, Yellow-Bellied slider (*Trachemys scripta scripta*)].

Nesting Survey Pre-fire Results

Turtle mating began in late April 2021 and nesting activity peaked in May and June. A total of 55 nests were observed at Bushy Lake from May 20 to June 30, 2021 (Table 5). All turtle nests we located were burned and destroyed in the June 6 wildfire in 2021; active turtle nesting nearly stopped at the peak of nesting season. We found 2 predated WPT nests. Over a 2-year time frame (2020–2021), 3 WPT nests were identified, and all were predated by skunks. For the NNTs, we observed 41 skunk-predated turtle nests; 3 intact nests; and 9 live turtles exhibiting nesting behavior (8 pre-fire). We observed on NNT nesting post-fire in an unburned location. The test was predated by a skunk. Turtle nests are typically very difficult to locate; we are sure we missed some nests, and the charred site conditions enhanced our ability to locate predated nests. Figure 4 illustrates the total nests and nesting areas located throughout the Bushy Lake site. This map will enable us to prioritize nesting surveys in 2022.

Table 4. Nesting Surveys at Bushy Lake from May 20 – June 30, 2021.

Nest Discovery	Western Pond Turtle Predated Nest	Non-native Turtle Predated Nest	Live Turtles (nesting behavior)	Total
Pre-Fire	1	13	8	22
Post-Fire	1	31	1	33
Total	2	44	9	55

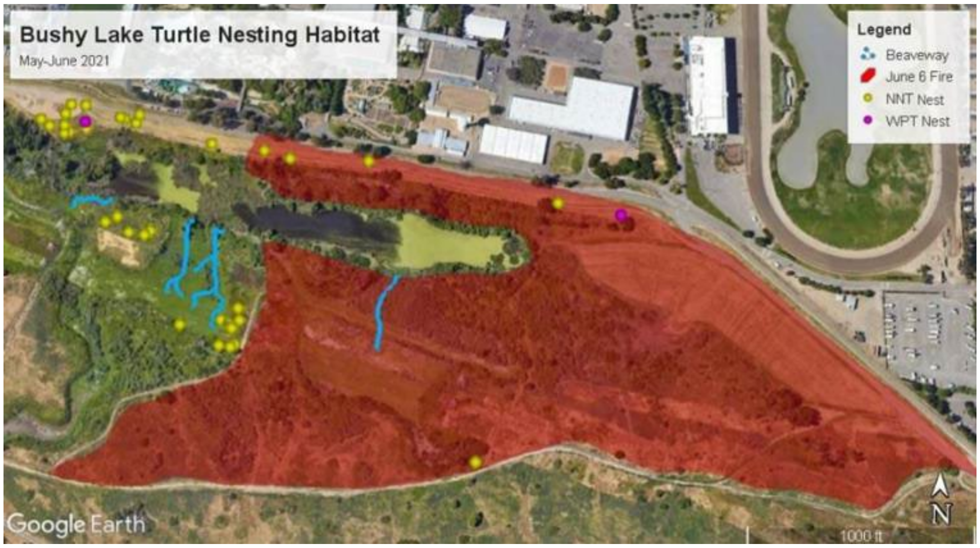


Figure 4. Turtle nests identified during 2021 nesting surveys, the approximate June 6, 2021, fire footprint, and beaveways.

The June 6, 2021, fire occurred during peak turtle nesting activity. The majority of the potential nesting areas were burned, leaving small and fragmented potential nesting habitat areas. The ash-covered areas do not provide successful potential nesting habitat; neither the viable eggs nor hatchlings survive these conditions (Alvarez, Pers. Comm, 2021). After the wildfire, all observations were atypical. Daily surveys continued in the unburned areas through the end of June 2021. Burned and predated turtles' nests were easy to locate in the burned area, enabling us to map these potential nesting areas for 2022. (Figure 5). We will resume nesting surveys in spring 2022. Post-fire nesting surveys are anticipated to provide valuable information for the CRP and designing meaningful habitat restoration.

Figure 5. Key resources at Bushy Lake, including key turtle nesting habitat, active wildlife areas, and the in-situ pilot restoration site.

Beaver Activities

North American beaver (*Castor canadensis*) surveys and monitoring are not part of the original grant scope. However, monitoring observations at Bushy Lake indicates that beaver activities are positively impacting the ecosystem. The scientific literature demonstrates that beavers are keystone species and ecosystem engineers. Our hypothesis is that beaver activities enhance biodiversity at Bushy Lake as well as contributing to fire resiliency.

Beaver activities at Bushy Lake include felled trees, 2 beaver lodges, the construction of beaveways (i.e., beaver-constructed canals), a beaver impoundment at the inlet, and images of beavers captured in wildlife cameras (Figure 6a). Beaver activities expand the wetted perimeter of surface water; expand aquatic habitat; provide ecosystem complexity and habitat interspersion; and increase vegetative, aquatic, and avian biodiversity (Baker and Hill 2003, Cooke and Zach 2008, Metts et al. 2001). The increase of water resources and expansion of the wetted perimeter additionally contributes to fire resiliency (Cooke and Zach 2008, Dittenbrenner et al. 2018, Fairfax and Whittle 2020, Longcore et al. 2007).

Beaver dams and impoundments are positively correlated with improved water quality (Lundquist and Dolman, 2018). The literature suggests that beaver dams may provide improved water quality through decreased pollutant phosphorus (Baker and Hill, 2003). Preliminary water quality studies at Bushy Lake indicated elevated phosphorus levels at the inlet. Although there is no clear correlation between the

Bushy Lake beaver impoundment and phosphorus levels, beaver activities and water quality will continue to be monitored.

The wildfire on June 6, 2021, laid down at the edge of the wetted perimeter of Bushy Lake and in the dendritic patterning formed by beaveways on the southern edge of Bushy Lake. These beaveways created a fire break that protected a significant amount of aquatic and riparian habitat surrounding Bushy Lake. The beaveways additionally link terrestrial and aquatic habitats, providing access to upland nesting habitat for female turtles (Figure 6b, 6c). Lastly, beaver impoundments and lodges appear to provide protected juvenile turtle habitat and basking habitat to pond turtles (Alvarez 2006).

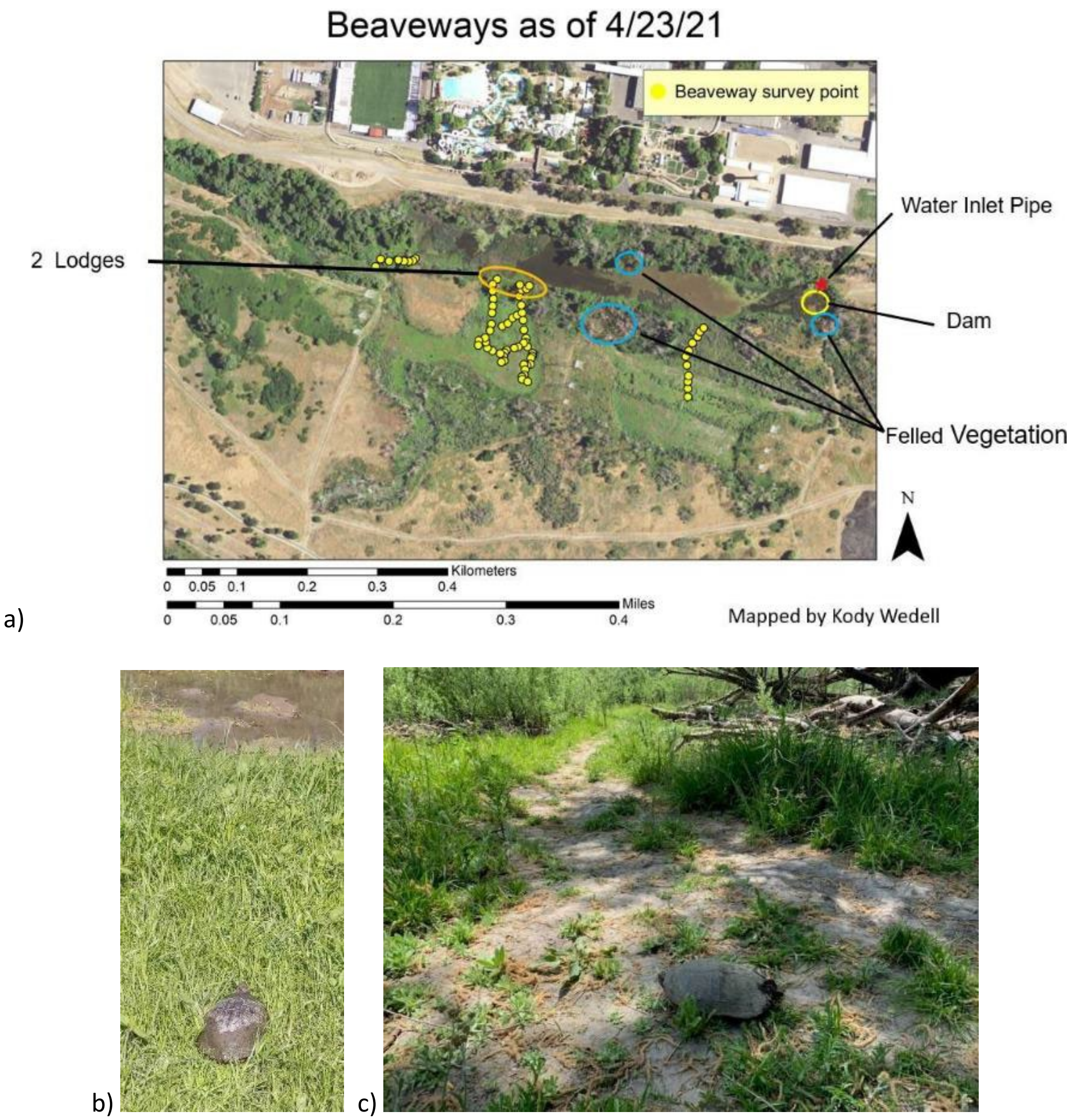


Figure 6. a) Beaver activity at Bushy Lake (Mapping of the beaveways conducted by Wedell, 2021). b, c) Red-eared sliders traveling near beaveways that have attempted nesting, respectfully June 7, 2020, and April 24, 2021

Beavers remain in Bushy Lake after the June 6, 2021, fire. Although in other areas, wildfires have shown to negatively impact beaver habitat and have resulted in declining beaver occupancy (Hood, et al. 2007), The Bushy Lake beaver population has remained stable. Two individual beavers were photographed in our wildlife cameras near the beaver lodges (Figure 7). Beavers were observed carrying vegetation to and from the lodges, indicating they are still active post-fire. Beaver activity observed by the wildlife cameras was nocturnal. We will continue to observe beavers at Bushy Lake to determine their contributions to restoration goals. We believe they contribute to adding habitat complexity and interspersion; improving turtle habitat; and increasing the wetted perimeter of aquatic habitat to increase fire resiliency. The presence of beavers at Bushy Lake is a valuable opportunity for natural habitat improvements and public and scientific education.

Figure 7. Two beavers pictured near beaver lodges at Bushy Lake, September 21, 2021, ©Bushy Lake Restoration Project, 2021

Identification of Key Stressors to Site Conditions

Western Pond Turtles

Currently, there is a small resident population of WPT at Bushy Lake. We have recaptured the same turtles over the past two years. The presence of WPT nests indicates the potential for a reproducing population. Habitat complexity and plentiful basking sites indicate that good turtle habitat occurs at Bushy Lake.

Competition from Non-Native Turtles

The large NNT population, primarily slider subspecies due to their abundance (red-eared, melanistic red-eared, and yellow-bellied sliders), out-number the WPT and compete for nesting and basking sites. Sliders are larger, more aggressive, and have higher reproductive potential than WPTs. Furthermore, there are more female than male sliders at Bushy Lake; more adult females indicate a higher reproductive ability. A large reproductive NNT population increases stress on native turtles. It will be essential to reduce the number of NNTs, especially adult females, to achieve the goal of WPT population conservation in the CRP.

Lastly, it is unknown how the Bushy Lake turtles interact with habitats or turtles in the adjacent lower American River or the transitional upland habitat. Several predated and exploratory nests have been observed between the American River and Bushy Lake, however, it is unclear if the nests were made by turtles coming from the river or the lake. Turtle movement patterns between riverine and lacustrine aquatic habitats are unknown. It is important to identify how different turtle species are utilizing this transitional habitat for nesting, whether they are moving back and forth between the two habitats, and if Bushy Lake is a sink or source for WPTs.

Turtle Nest Predation

Nesting surveys conducted in 2021 indicated a high number of predated nests, primarily by skunks (Alvarez, Pers. Comm, 2021). Turtle nests are most at risk of predation in the first 1-2 weeks after eggs are laid (Ibid). In 2022, we plan to utilize wire mesh cages to cover and protect eggs in nests. The wire mesh will be removed after 2 months to allow the emergence of hatchlings. Protecting nests is one strategy to increase survival and support native turtle population growth.

Bicycle Collisions

Pond turtles face significant risks from human activities adjacent to Bushy Lake. Between March 2020 and December 2021, 76 turtles displayed shell damage indicative of strikes with bicycles (Table 6) (Alvarez, Pers. Comm, 2021). One adult female WPT had shell striations indicative of bicycle strikes (Figure 8). The shell damage indicative of bicycle strikes consists of multiple circular indentations with chipped "rings," showing the different layers of keratin, on both the plastron and carapace (Figure 8) (Alvarez, Pers. Comm, 2021).

Table 5. Count and proportion of native and non-native turtles with shell pitting attributed to bicycle strikes at Bushy Lake from March 2020 - December 2021.

	Total Turtles Captured	Native and Non-native Turtles with Pitting	Adult Females with Pitting	Adult Males with Pitting	Adult Unknown Sex with Pitting	Juvenile Males with Pitting
Count	294	76	50	19	4	3
Proportion (%)	-	25.9%	65.8%	25%	5.3%	3.9%

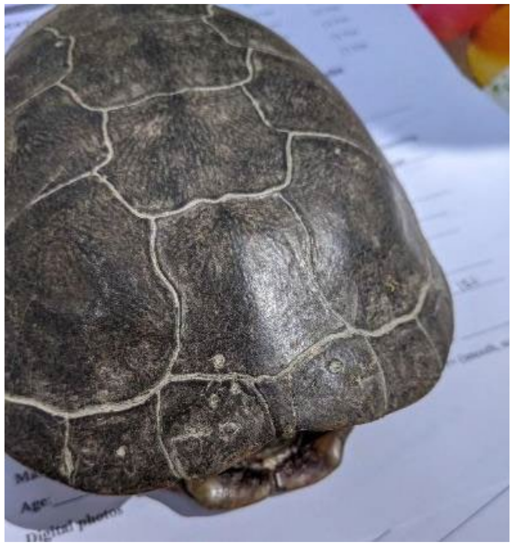


Figure 8. Pitting on the plastron of a female Western pond turtle, which is associated with bicycle strikes (*Actinemys marmorata*) at Bushy Lake, April 4, 2021

Furthermore, Bushy Lake has several adjacent trails that have been opened to off-road bicyclists and are additionally utilized by homeless individuals on bicycles. The risk of turtle-bicycle collisions increases during nesting season in late spring and summer when females are moving between the aquatic and terrestrial nesting habitats. In the summer of 2021, Sacramento County Parks placed signs to inform bicyclists of potential turtle crossings during nesting season.

Wildfire

The wildfire on June 6, 2021, occurred at the peak of turtle nesting season. The fire burned to the lake's edge and disrupted turtle nesting activities. With 60% of Bushy Lake burned, much of the upland habitat with nesting potential burned. All nests we located were burned. Even if a turtle did successfully nest in the burned area, neither the eggs nor hatchlings would likely survive (Alvarez, Pers. Comm, 2021)). No nesting activity was observed after the fire.

The fire burned most of the understory terrestrial vegetation surrounding Bushy Lake. Continued nesting surveys in 2022 will allow for the comparison of nesting activities pre-and post-fire, as well as enhance our understanding of the key turtle nesting habitats at Bushy Lake.

Identification of Critical Habitat Elements

In order to inform the CRP, we are preparing a map of key habitat areas including the following: 1) mapping aquatic habitat in and around Bushy Lake, 2) quantifying woody debris that could be used as potential basking sites, and 3) measuring the depth and substrate of the lake. This data will result in a map of existing habitat, allowing the CRP to include habitat improvements and providing a baseline map to measure changes in habitat types over time. We will add the wetland edge and ecotonal plant community types and habitats in 2022. We will additionally map vegetation types, map the wetland-upland boundary, and utilize the California Rapid Assessment Method (CRAM) on the site.

The fire on June 6, 2021, provided an excellent opportunity to test the site's fire resiliency, survey the post-fire regeneration, and study the impacts on turtle nesting and fitness. It's possible that the burning of the dense weedy thatch and standing vegetation may result in better nesting habitat in 2022. We are extending the data collection period through the next May to June nesting season in 2022 to determine the impacts of fire on turtle habitat, survival, and nesting success. Additional turtle surveys will include continued nesting surveys and conducting mark-recapture surveys along the adjacent lower American River. We were awarded a small grant from the Sacramento Zoo to allow us to continue our turtle research.

Preliminary Restoration Recommendations

Protecting habitat from further degradation and fragmentation is the highest priority for pond turtle conservation (CDFWS 2022). In addition to this, the CRP's goal of habitat restoration is an important management priority, particularly that which 1) increases connectivity between currently isolated habitats, and 2) increases the extent of setback or buffer habitat around wetlands that is suitable for nesting. We plan to protect nests using wire mesh screens to prevent predation. At this time, we plan to investigate the potential of protected *in-situ* nursery areas in our CRP to increase reproduction, and the survival and fitness of WPT hatchlings and juveniles. We are unlikely to recommend a formal head-starting program due to the potential for shell-wasting disease, a challenge that is currently impacting Washington's pond turtles (Hayes 1999). We plan to optimize habitat and remove large female NNTs so pond turtle populations can survive with little intervention. We will explore alternatives for the removal of NNT. One encouraging observation is that pond turtles can live near human disturbance if they have suitable basking and nesting sites (Lambert et al. 2013, Lambert et al. 2019, Spinks et al. 2003, Thomson and Schaffer 2010).

Multiple options for WPT conservation are currently in the brainstorming process; any solution must be within the confines of the regulatory framework and permitting in collaboration with California Fish and Wildlife (CDFW). Current options include:

a) <u>protect and restore</u> habitat for Western pond turtles (a potential restoration option includes the removal of cattails and bulrushes to maintain open water and basking habitat);
b) <u>provide an *in-situ* "nursery"</u> to maximize habitat for successful nesting and hatchling survival and recruitment;
c) remove or sterilize 50-70% of NNTs;
d) create a closed pond on private land to remove and manage NNTs;
e) <u>protect turtle nests</u> from predators and other disturbances;
f) optimize aquatic and terrestrial habitats for nesting females and hatchlings;
g) <u>manage open terrestrial vegetation</u> in the uplands to facilitate nesting;
h) <u>monitor trail and bicycle use</u> during nesting season, put up signage;
i) <u>monitor beaver activity</u> and beaveways to determine synergistic relationships with turtles and other wildlife; and/or
j) <u>provide signage and education</u> to protect nesting turtles and hatchlings' movement between terrestrial and aquatic habitats during nesting season.

Task 1.4 - Maintain Pilot Restoration Project as in *In-Situ* Reference Area

Background of *In-Situ* Restoration Project

The Bushy Lake Eco-Cultural Restoration Project began in 2015. The goals for the ongoing project include enhancing habitat for fire-resiliency and showcasing the Parkway's tribal and cultural uses. The pilot restoration project utilizes experimental design, monitoring, and adaptive restoration and management. Hundreds of CSU Sacramento students have been involved in setting up experiments and applying adaptive management. Dr. Michelle Stevens teaches ENVS 151 Restoration Ecology, and the class is participating in the Expanded Sustainable Interdisciplinary Research to Inspire Undergraduate Success Project; there are 67 courses at 5 institutions in the Sacramento Region participating. The Bushy Lake *In-Situ* Restoration Project allows Dr. Stevens to provide students with authentic interdisciplinary learning experiences. Furthermore, it appears that ENVS 151 is the only class directly participating in a community engagement project at the same time.

June 6 Wildfire at Bushy Lake

On June 6, 2021, a fire swept through Bushy Lake, burning a total of 130 acres. The entire 6-acre pilot *in-situ* restoration area was burned to the water's edge. The Bushy Lake Restoration Project was awarded a grant of $10,000 through Sacramento State University's President's Circle Restoration Fund to monitor post-fire natural recruitment and replant the restoration project. Data collected on the demonstration project between the 2015 and 2021 will be used to redesign the pilot restoration, implement native revegetation, and monitor natural revegetation and the recruitment of native vegetation.

The project hypothesis is that restoring culturally significant plants will build fire resiliency into the project due to thousands of years of Traditional Fire Management by the Nisenan, Maidu, and Miwok Native Californians. We are observing that culturally significant vegetation adapted to Traditional Fire Management is recovering and coming back naturally, supporting the fire resiliency hypothesis. We are monitoring the site for this data to inform the CRP.

The fire severely damaged biotic structures throughout the site, which presented an opportunity for monitoring and adaptive management. The Bushy Lake Restoration Team is performing fire-resiliency monitoring of post-fire vegetation within the pilot restoration area. Post-burn dominant plant species recovering at Bushy Lake include walnut (*Juglans californica*), sandbar willow (*Salix exigua*), arroyo willow (*Salix lasiolepis*), Goodding's willow (*Salix gooddingii*), box elder (*Acer negundo*), Oregon ash (*Fraxinus latifolia*), Fremont's cottonwood (*Populus fremontii*), and non-native elm (*Ulmu species*). Shrubs that are revegetating include elderberry (*Sambucus mexicana*), coyote brush (*Baccharis pilularis*), California blackberry (*Rubus ursinus*), and California grape (*Vitis californica*). The elderberry *(Sambucus mexicana*) is especially important as part of the area is designated for the Valley Elderberry Longhorn beetle (*Desmocerus californicus dimorphus*) species. Dominant understory species colonizing the site include creeping wild rye (*Elymus triticoides*), white root (*Carex barbarae*), and mugwort (*Artemisia douglasiana*). This data was used to inform the selection of a fire resilient native plant pallet.

The WCB grant did not provide funding for post-fire revegetation, and the in-situ restoration site was burned to ashes. Using additional funding sources, we have replanted burned areas that are not revegetating. Replanting occurred in January and February 2022 (See Appendix A - Photographs). We plan to plant narrowleaf (*Asclepias fascicularis*) and showy (*Asclepias speciosa*) milkweeds in May 2022. Plant species were selected based on their cultural significance, fire-resiliency, and benefit to native pollinator species. Now, at the end of February, over 94 community volunteers have helped with site preparation and replanting in the *in-situ* restoration site.

Monitoring for Natural Recruitment and Fire-Resiliency

In the Fall semester of 2021, we monitored the resiliency of the *in-situ* restoration site. We found that the Mugwort-dominated area is revegetating with both mugwort and creeping wild rye. The mugwort has increased from 37% cover to 55% cover since the fire. Visual observations showed that not only did the proportion of plants increase, but vegetation height across the restoration area increased as well (Figure 9). The white root (*Carex barbarae*) section of the project is one of the largest extents on the lower American River. The area has recovered from the fire, and we have expanded the area through replanting (Figure 10).

September 20, 2021 December 1, 2021

Figure 9. Illustrates changes in the proportion of vegetated vs. unvegetated ground across randomized transects between September 20 and December 1 (Photo Lexi von Ehrenkrook).

September 20, 2021 December 1, 2021

Figure 10. Illustrates changes in the proportion of *Carex barbarae* vegetated vs. unvegetated ground at permanent photo stations September 20 and December 1 (Photo Lexi von Ehrenkrook).

The restored areas adjacent to the east trail experienced the most prolonged burn damage due to the fire's slow approach from the east. Post-fire plant species occurring right after the fire within the monitoring quadrats include Great Valley gumweed (*Grindelia camporum*), California poppy (*Eschscholzia californica*), and common yarrow (*Achillea millefolium*). Senescent vegetation was deadheaded on November 29. The south quadrats and planted areas in the southeast portion of the project area experienced the most significant burning in the June fire. Very little native vegetation was observed emerging immediately post-fire. At this time, some native revegetation is occurring from the pollinator seed mix and we will continue to monitor the area.

Replanting Areas Destroyed by June 6 Fire

The Bushy Lake Restoration Team has revegetated the pilot restoration area with fire-resilient, culturally significant native plant species. Revegetation efforts focus on enhancing the linear habitat connectivity between Bushy Lake's aquatic and terrestrial ecosystems and creating thermal refugia for wildlife. The revegetation of native fire-resistant and drought-tolerant species will contribute to a more resilient landscape.

Plants selected for revegetation were chosen based on the five years of data collected at Bushy Lake between 2015 and 2021 (Table 7). Michele Ranieri and Patrick Reynolds (Sacramento River Partners), and Dan Meier (California Native Plant Society) provided professional input on native plants and seeds (Table 7). We placed an order with River Partners for a plant pallet with 600 native California plants. Funding for plants was donated by the Sierra Club and Green, Inc. Selected plant species were chosen due to their potential for fire resiliency, benefits to native pollinators, and cultural significance. White root (*Carex barbarae)*, for example, holds significant cultural use for California Indian basket weavers as it provides long rhizomes utilized in the weaving of coiled baskets. The site was prepared for planting, and seedlings were planted in February. Milkweed planting will be delayed until May of 2022, to ensure the best chance of survival.

Table 6. Plant pallet order placed with River Partners listing plant species, ecotype, and pick-up status.

Scientific Name	Common Name	Ecotype, County	Qty of Plants	Price/ Plant	Subtotal	Container Size	Notes
Achillea millefolium	yarrow	Cache Creek Watershed, Lake Co.	40	$0.98	$39.20	Plug	Ready
Asclepias fascicularis	narrow leaf milkweed	N. of Winters, Yolo Co.	52	$0.98	$50.96	Plug	dormant not available till May
Asclepias speciosa	showy milkweed	South of Colusa, Colusa Co.	52	$0.98	$50.96	Plug	dormant not available till May
Carex barbarae	Santa Barbara sedge	Yolo Bypass, Yolo Co.	256	$0.98	$250.88	Plug	Ready
Elymus triticoides	creeping wildrye	Yolo Bypass, Yolo Co.	100	$0.81	$81.00	Plug	Ready
Grindelia camporum	gumplant	Yolo Bypass, Yolo Co.	40	$0.98	$39.20	Plug	Ready
Muhlenbergia rigens	deer grass	Lincoln, Placer Co.	10	$0.81	$8.10	Plug	Ready
Solidago velutina spp. Californica	California goldenrod	California Source	20	$0.98	$19.60	Plug	Ready
Stipa pulchra	purple needlegrass	Fiske Creek, Yolo co.	10	$0.81	$8.10	Plug	Ready
Symphyotrichum chilense (Aster chilensis)	California aster	Willow Slough, Yolo Co.	20	$0.98	$19.60	Plug	Sold out

A pollinator seed mix was purchased from Hedgerow Farms. California native nectar plants provide a significant benefit to native pollinator species at the site. Many of these plants are also important culturally. For example, pinole is a seed mixture that is utilized to create porridge or dried cakes for storage. Showy and narrowleaf milkweed are included within the planting pallet to provide the additional benefit of a breeding resource for monarch butterflies (*Danaus plexippus*) (Table 8).

Table 7. Pollinator Seed Mix provided by Hedgerow Farms and Planted in 2021 and 2022.

Great Valley Gumweed	*Grindelia camporum*
Common Yarrow	*Achillea millefolium*
Narrowleaf Soap plant	*Chlorogalum angustifolium*
California Poppy	*Eschscholzia california*
Woodland Clarkia	*Clarkia unguiculata*
Fort William Clarkia	*Clarkia williamsonii*
Bolander's Sunflower	*Helianthus bolanderi*
Chick Lupine	*Lupinus microcarpus var. densiflorus*
Rock Phacelia	*Phacelia californica*
Great Valley Phacelia	*Phacelia ciliata*
Narrowleaf Milkweed	*Asclepias fascicularis*
Showy Milkweed	*Asclepias speciosa*

Monitoring and Adaptive Management

It will be vitally important to provide water and mulch to keep the revegetated area alive. Weeding will also be essential. Adaptive management will be achieved by reaching out to community volunteers through our website and social media sites (Facebook and Instagram).

The restoration team hopes to secure a steady form of irrigation for the pilot restoration area to more readily water the revegetated areas and to allow plants to establish during the dry season. Currently, we are watering every week with buckets. Ultimately, a combination of irrigating via a water pump and manual watering will be the best solution to the limitations at the site.

Conclusion and Further Actions to Support draft CRP

Native plant species are crucial to the success of restoring riparian vegetation around the lake because of the possibility of a higher frequency of fires. To ensure that the lake and riparian habitat provide resources for wildlife, the area needs to be able to rejuvenate after future disturbances. Planting and encouraging the presence of native, fire-resistant, and drought-tolerant plant species, such as white root (*Carex barbarae*) and creeping wildrye (*Elymus triticoides*), in the Bushy Lake area, while limiting the presence of invasive species has proved beneficial to these fire-prone areas. The natural recruitment and ecological succession of these native plant species after the burn demonstrates their resiliency and tolerance to fire, which helps determine the plants most suitable for restoration.

It is important to prevent the devastating wildfires that have occurred for 3 out of 5 years at Bushy Lake. CSU Sacramento's Nathan Dietrich (Associate Vice President, Public Affairs and Advocacy at California State University, Sacramento) and Rita Gallardo Good (Director of Civic Affairs) met with Sacramento City Fire Department and have reached an agreement to promote fire safety at Bushy Lake. The Red Hawk Casino Fire Crew is planning to develop a hand line fire break on the east side of Bushy Lake. A map of key resources, based on both avian and turtle nesting habitats, was provided to Sacramento City Fire Department to protect key natural resources from fire crews. We are also participating in the Parkway Fire Safe Council.

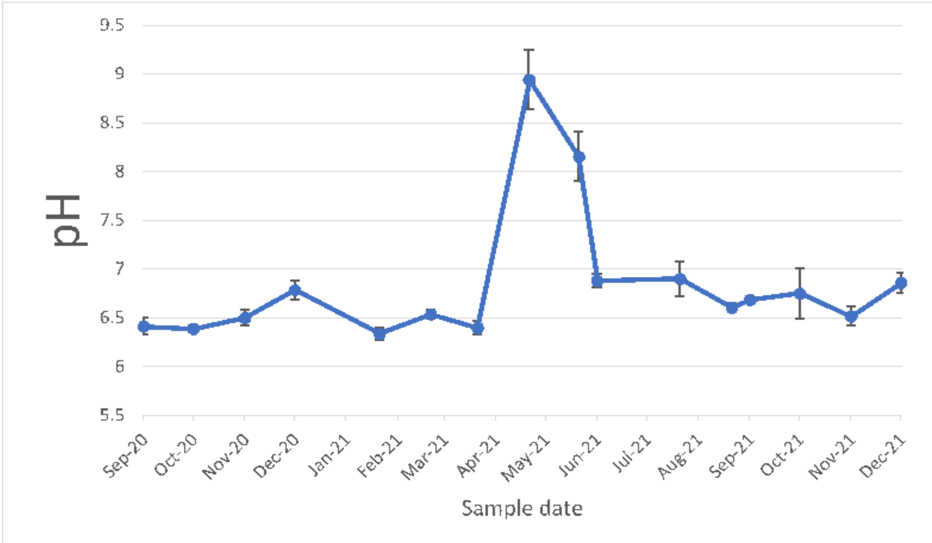
We are using our webpage and social media sites to conduct community outreach for community involvement and education. We plan to have an Earth Day event on April 16, 2022, to weed, dance to live music and embrace the Bushy Lake site.

Task 1.5 - Aquatic Habitat and Water Quality Summary Report

Water Quality

The Aquatic Habitat team sampled water quality and aquatic invertebrates monthly from September 2020 until December 2021 (6 locations for 16 months). Sampling has revealed an average conductivity of 410.21, average pH of 6.85, average turbidity measure of 7.14, and an average chlorophyll-a measure of

1.32 µg/L. The average level of phosphates was 0.92 mg/L and the average level of nitrates was 0.181 mg/L. The pH remained relatively stable over time except in April and May 2021 when it substantially increased (Figure 11). All other measures of water quality varied by month with no obvious pattern except conductivity and turbidity (Figures 11-13). Conductivity decreased during the winter of 2021 (and 2022) and increased again in April 2021, coinciding with the rainy season. Turbidity peaked in January and again in May 2021, but subsequent months had low turbidity levels. Conductivity was negatively correlated with turbidity ($r=-0.56$, $P=0.03$) but no other water quality measures were correlated with each other. Preliminary tests suggest *E. coli* was present at low levels (sampling dates: 8/16 and 9/17/2021). Average levels were only 0.286 and 0.429 CFUs per ml respectively. Overall, the water quality results suggest that Bushy Lake is indicative of an oligotrophic lake or pond (Smith et al. 1999).



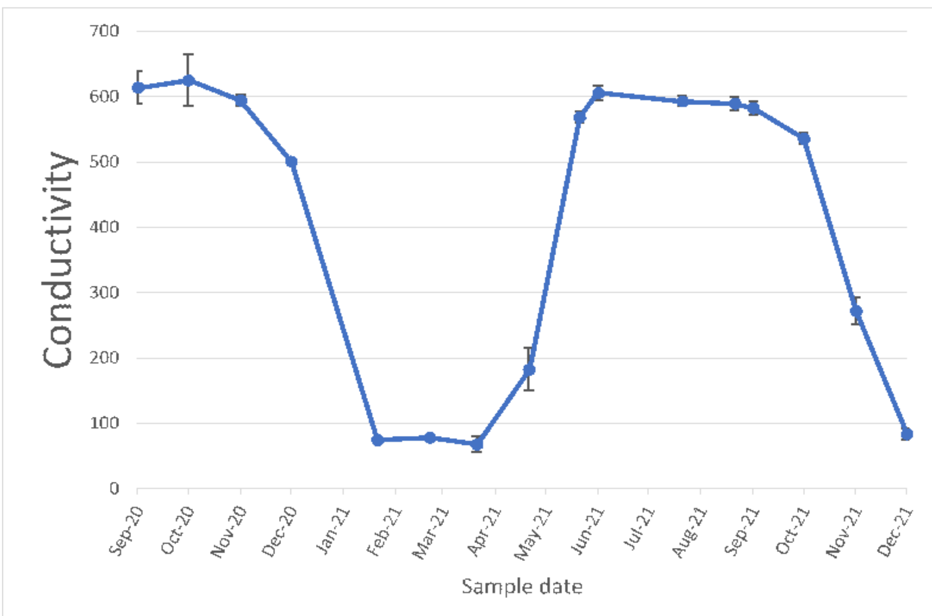
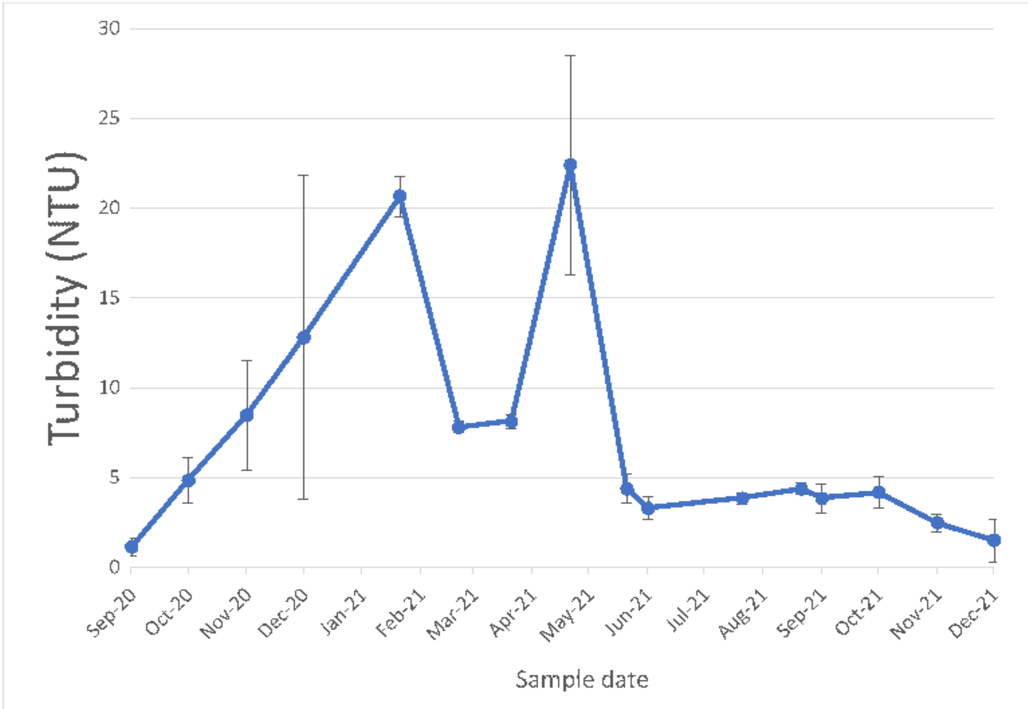


Figure 11. Monthly measurements of pH and conductivity in Bushy Lake from Sept 2020 until December 2021. Values represent the mean (±SE) of six sites sampled per month.



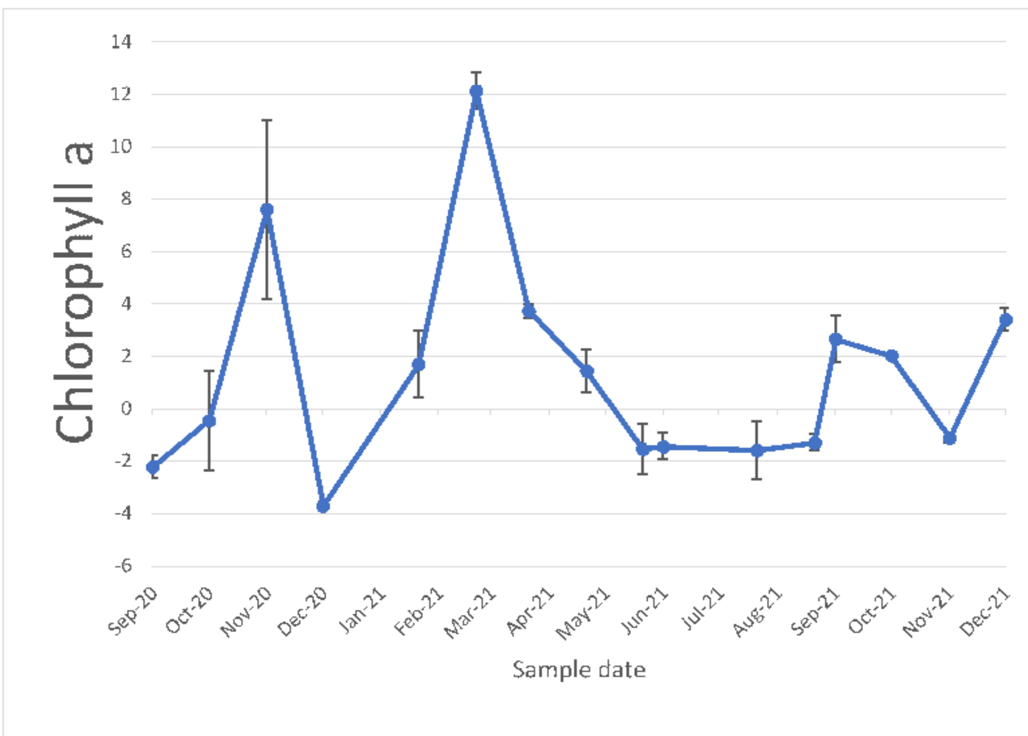
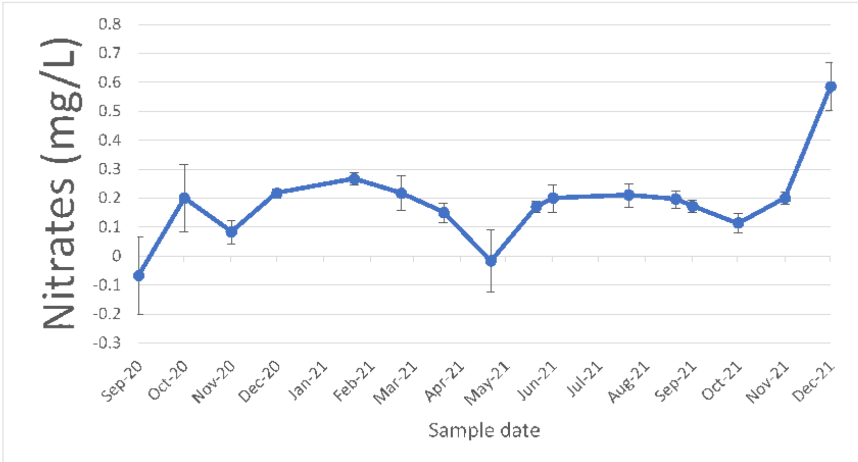


Figure 12. Monthly measurements of turbidity and chlorophyll-a in Bushy Lake from Sept 2020 until December 2021. Values represent the mean (±SE) of six sites sampled per month.



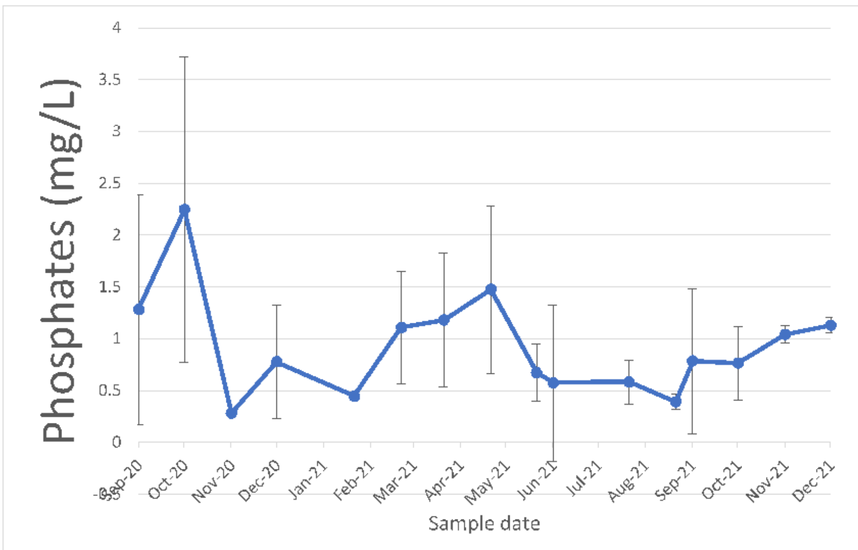


Figure 13. Monthly measurements of nitrates and phosphates in Bushy Lake from Sept 2020 until December 2021. Values represent the mean (±SE) of six sites sampled per month.

Aquatic Community

We used sweep nets (n = 3 sweeps) in six locations to measure the abundance, richness, and composition of the macroinvertebrate community. Aquatic sampling revealed an average of 66.4 individual organisms encountered per month. A total of 21 different taxa have been encountered over the 16 months with an average of 4.75 taxa per month (7.56 total richness). These values were highly variable during the 16-month sampling period but appear to have been declining since July 2021 (Figure 14). Some of the most frequently encountered invertebrates included crustaceans (Cladocera, Copepoda, Ostracoda) and insects (Corixidae, Odonata, Chironomidae), which are important prey items for Western pond turtles (especially juveniles). An invasive freshwater shrimp, whose identification has yet to be confirmed (although it is likely *Palaemonetes kadiakensis*, Mississippi glass shrimp), was regularly sampled (12/14 sampling sessions) in low abundances. We found positive correlations between taxa abundances and mean richness ($r=0.72$, $P=0.002$) and total richness ($r=0.61$, $P=0.01$). Phosphate and abundance exhibited a positive non-significant ($r=0.49$, $P = 0.06$) trend, but no water quality measurements were correlated with taxa abundances or richness.

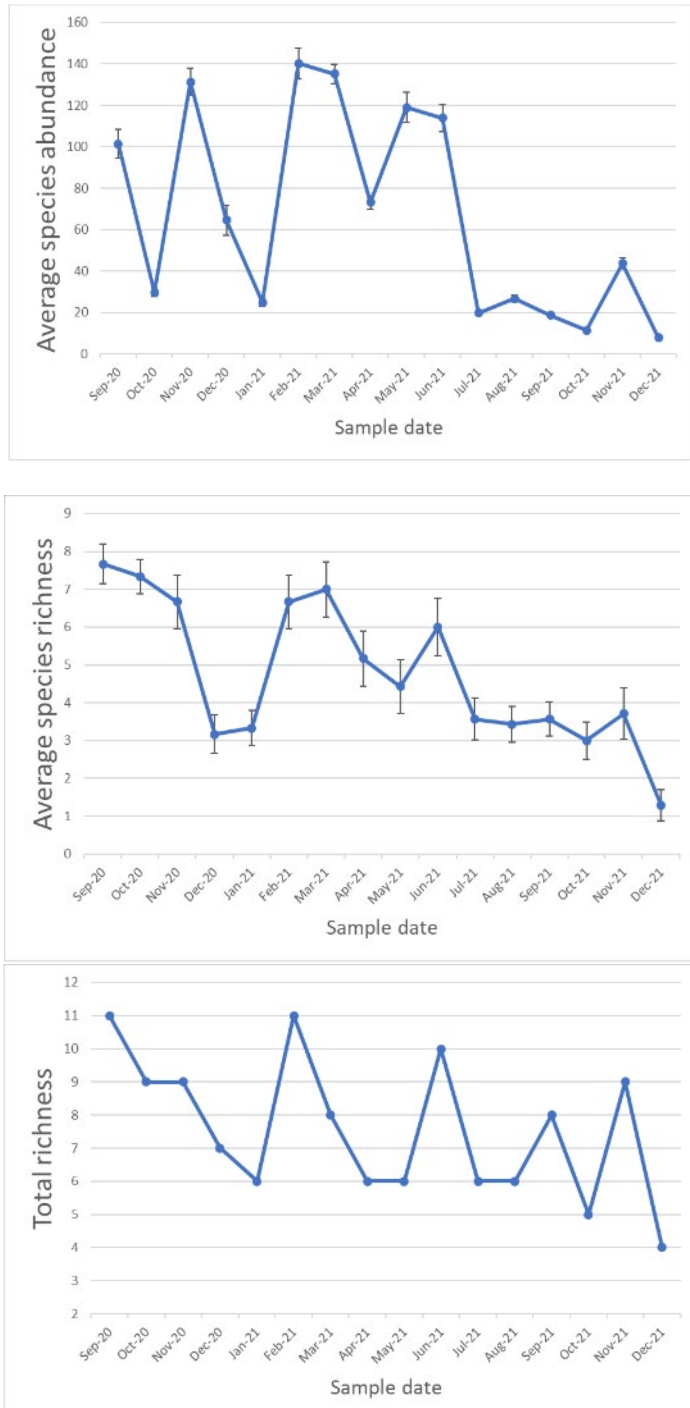


Figure 14. Mean (±SE) abundance, richness, and total richness of macroinvertebrates sampled monthly in Bushy Lake.

To supplement net sampling, baited minnow traps were deployed in ten locations in the lake to sample invasive crayfish and larger mobile fauna from September 2020 until Dec 2021 (16 months). We detected the invasive red swamp crayfish (*Procambarus clarkii*) (native to the Southeastern United States) during all 16 sampling sessions and in 51.5% of all deployed traps. Crayfish abundances were highly variable over time (Figure 15) with an overall mean (±SE) of 0.84±0.16 crayfish per trap. The sex ratio was slightly biased towards males but not significantly so (1.21:1; P=0.41), which is consistent with other studies of red swamp crayfish. This invasive burrowing crayfish is widely recognized for its bio-erosive activities that can disturb the shoreline stability of lakes, rivers, and even levees. These crayfish outcompete native crayfish and prey on native snails, crustaceans, and insects. However, they are also an important member of the lake food web and are preyed on by turtles, bullfrogs, and fish, among others. Indeed, crayfish are an important source of protein for adult Western pond turtles (Bury 1986). We also captured invasive American bullfrog tadpoles (*Lithobates catesbeinus*) in 12 out of 16 sampling sessions and in 9% of all deployed traps. While frequently observed during sampling, the abundances of bullfrogs were relatively low (0.12±0.4 frogs per trap; Figure 15). Regardless, invasive bullfrogs can be voracious predators and are highly aggressive; they can potentially prey on small turtles and compete for prey. Western pond turtle hatchlings have been found in the stomach contents of bullfrogs in southern California (Nicholson et al. 2020). Finally, we rarely observed invasive catfish in 2 out of 16 sampling sessions and in 3.8% of traps. Catfish are typically opportunistic predators feeding on crustaceans, insects, fish, and plants, among other organisms; thus, they likely compete for prey with Western pond turtles. However, they have been known to rarely prey on turtles (Haubrock et al. 2018).

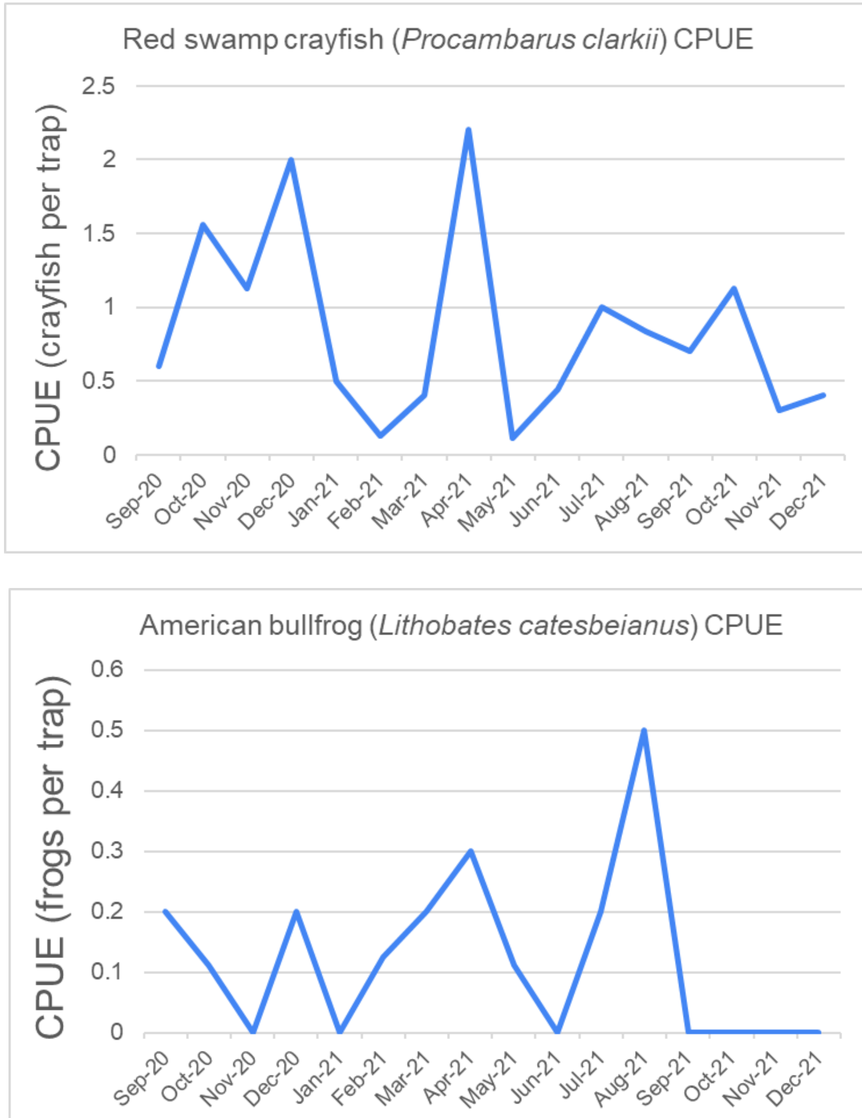


Figure 15. Relative abundances (mean catch per unit effort, CPUE) of invasive red swamp crayfish (top) and American bullfrogs (bottom).

Overall, aquatic sampling revealed a diverse community of macroinvertebrates including several taxa that are likely important prey species for Western pond turtles. In addition, our sampling revealed the presence of invasive species likely to compete with or prey on Western pond turtles. Invertebrate abundances varied dramatically across months, but the driving factors affecting these patterns are presently unknown. Furthermore, it is unclear how these may affect Western pond turtles or even whether turtle predation affects these patterns. Since Western pond turtles can also consume plant material (Bury 1986), a precise assessment of Western pond turtles' diet feeding behavior, and consumption levels is recommended.

Habitat Mapping

We conducted a preliminary survey to assess potential turtle basking sites during September 2021. We found 19 potential turtle basking sites (largely pieces of woody debris), although fluctuating water levels in the lake will likely expose new sites and submerge existing sites. A more in-depth examination of the below water aquatic habitats is currently underway.

Task 1.6 - Hydrology Objectives

Determine the land surface drainage conditions that contribute to surface water flow and storage at Bushy Lake

The focus of this effort was to construct a detailed map of how water transits the Bushy Lake area to better understand how water enters or leaves the small Bushy Lake watershed. This section breaks down that effort into a discussion about surveying and mapping the surface, plotting the survey data in ArcGIS software, using ArcGIS tools to assess surface flow conditions, and assessing the role of pumping groundwater from Cal Expo to Bushy Lake (via a discharge pipe) has on the Lake.

Setting

Bushy Lake resides in a roughly 0.5 mi^2 (1.29 km^2) terrace remnant of the American River floodplain that abuts up to the western side of the Cal Expo site in Sacramento, California (UTM – 10S 637138 m E; 4271383 m N) (Figure 16). Construction and management of the Folsom Reservoir in the mid-1950s have resulted in lower flows in this portion of the American River which has limited the frequency of flood inundation onto this terrace surface.

Figure 16. General location map of the Bushy Lake area. Bushy lake is bordered by Cal Expo facilities near the top of the image and the American River near the bottom of the image. The green zone represents the proposed restoration area on the floodplain remnant that contains Bushy Lake.

This area has been an ongoing ecological restoration area. In 1976, the lake, along with 86 acres, was designated a State Nature Preserve Area and is protected under the Bushy Lake Preservation Act.

The Lake was artificially created in the 1960s as part of a water storage structure to facilitate the proposed development of a golf course. The development of the golf course was halted by efforts from the Save the American River Association (SARA) and in 1976, the Bushy Lake Preservation Act was enacted which designated the area as a State Nature Preserve Area. Once designated as a nature preserve, further development in that area ceased. More recently, a plan is being developed to ecologically restore the area around Bushy Lake. The hydrologic connection between the lake and the American River is a necessary aspect of developing such a restoration plan.

The property is currently owned by Cal Expo and managed by the Sacramento County Parks. Recreational activities and the American River bicycle trail traverse the floodplain in this area.

Surveying

over many months (Spring of 2020 to Fall of 2021), survey data was collected by hand using a Trimble GEO-7x field survey instrument at the Bushy Lake site. Specifically, latitude, longitude, and elevation data were collected at over 2000 locations within the Bushy Lake study area which exists on a small terrace remnant within the levees that bracket the American River. Initially, drone-collected aerial photographs were considered for building the three-dimensional model but high voltage overhead power lines that traverse the site substantially impacted the navigation and geo-locational abilities of the drones resulting in the switch to hand surveying of the study site.

Surveys were conducted on foot with data being collected approximately every 10 feet. The terrain was challenging in many places as overgrown vegetation, homeless encampments, and swampy areas produced obstacles to data collection. Figure 17 shows the location of the collected survey data.

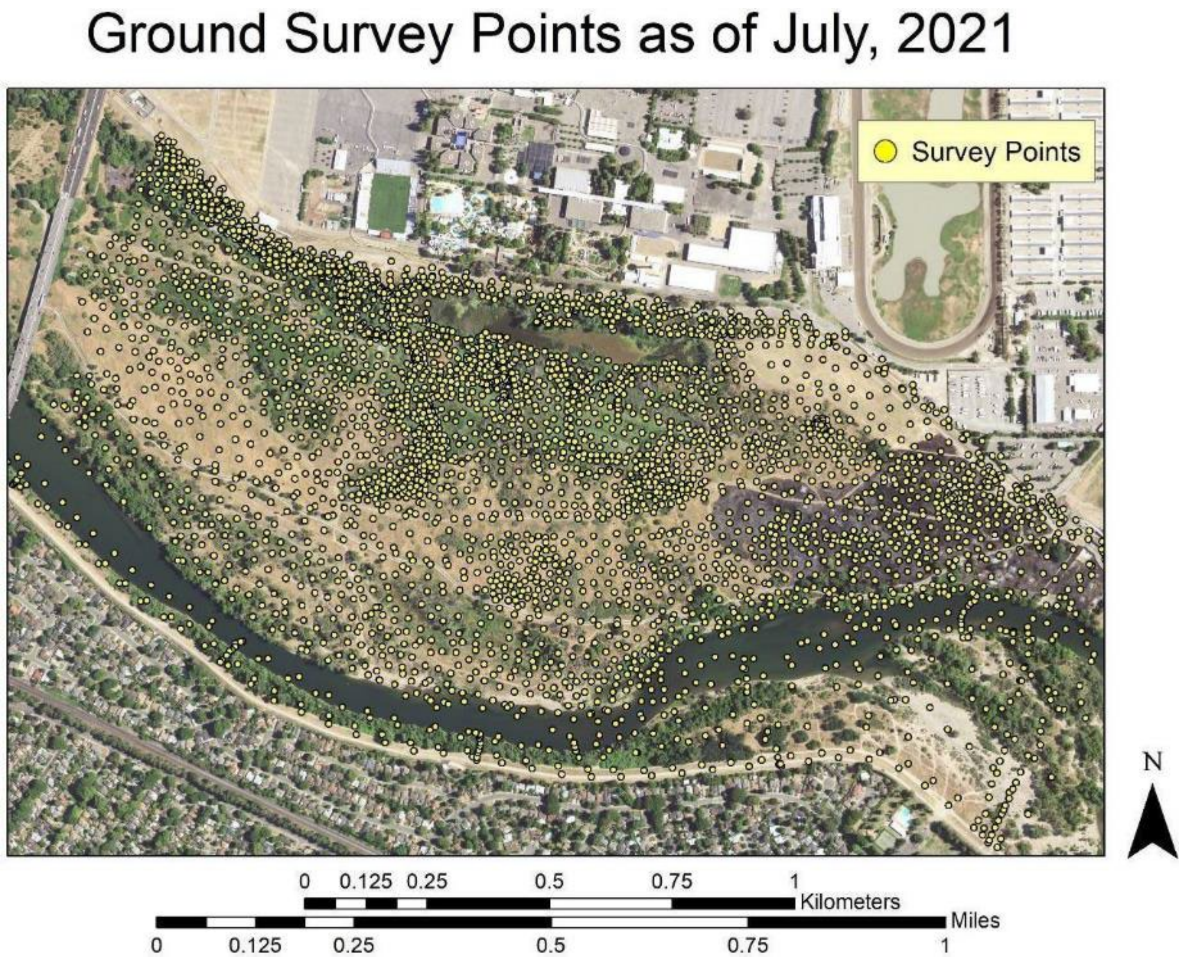


Figure 17. General map of the Bushy Lake study area showing the location of over 2000 survey points used to build the surface topography map.

Making the site flow map

The survey data was incorporated into ArcGIS software to manage the voluminous data set and produce a digital elevation model of the surface to better characterize site-specific flow conditions. Survey data was plotted in the appropriate geographic coordinate system, incorporated into the construction of a triangular irregular network (TIN), statistically managed to account for data irregularities, and converted to a raster formatted digital elevation model (DEM) (Figure 18).

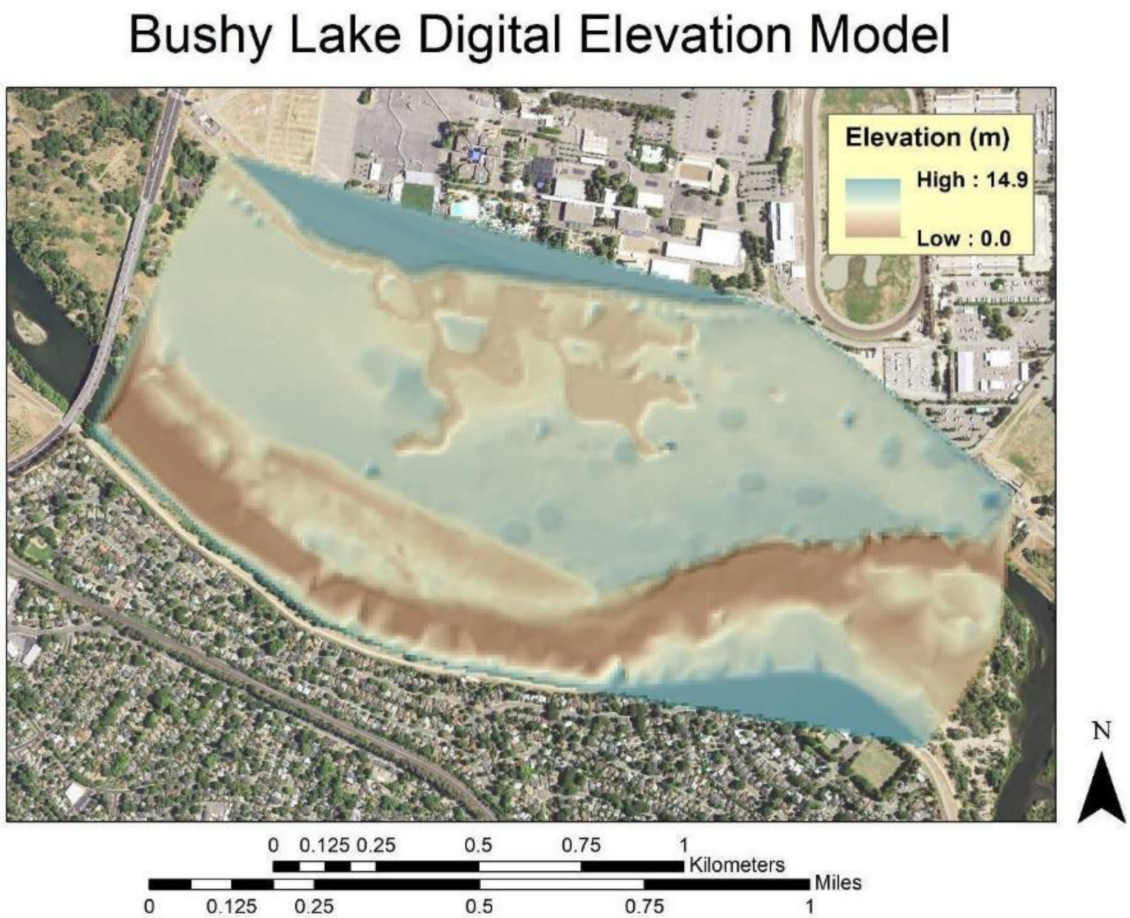


Figure 18. Digital elevation model of the floodplain remnant including Bushy Lake (light brown terrain in the middle of the map just south of CalEXPO).

Once converted to a digital elevation model format, ArcGIS hydrology tools were used to fill in any anomalous pockets or pits in the DEM, to create a raster of flow direction from each cell to its steepest downslope neighbor, and to create a raster of accumulated flow into each cell of the raster. This process then produces a flow map of surface waters on the floodplain remnant which includes Bushy Lake. Figure 19 shows the surface flow conditions and accumulation spots resulting from this analysis. Mapping out the flow patterns and the area that water then accumulates produced Figure 20 which details these conditions. Specifically, the surface area (light blue area) of the surrounding terrain that contributes to surface flow to the Lake (under appropriate conditions – enough rainfall to produce surface flow) is around 0.9 square kilometers. In this Figure, blue and red arrows outline the relative direction that surface waters would flow on this surface. The blue arrows represent flow into Bushy Lake while the red arrows represent flow away from Bushy Lake. It's important to note that on the north side of the floodplain remnant (between Bushy Lake and CalEXPO) there is a substantial levee that has been constructed to protect CalEXPO from potential American River floodwaters. This levee controls all flow onto the site from the CalEXPO site. Essentially no surface waters can directly transit across this barrier unless pumped through some sort of underground pipeline (Cal Expo) or through a stormwater culvert (located on the west end of the floodplain remnant.

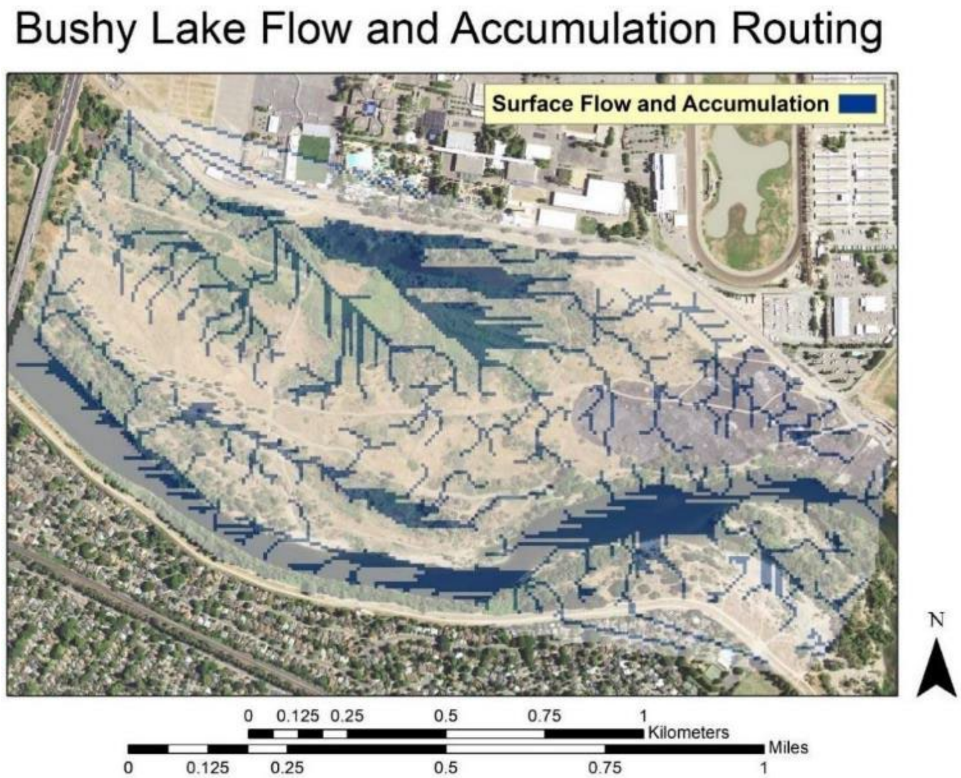


Figure 19. Surface water flow and accumulation areas as determined from hydrologic modeling of the ground surface elevational conditions.

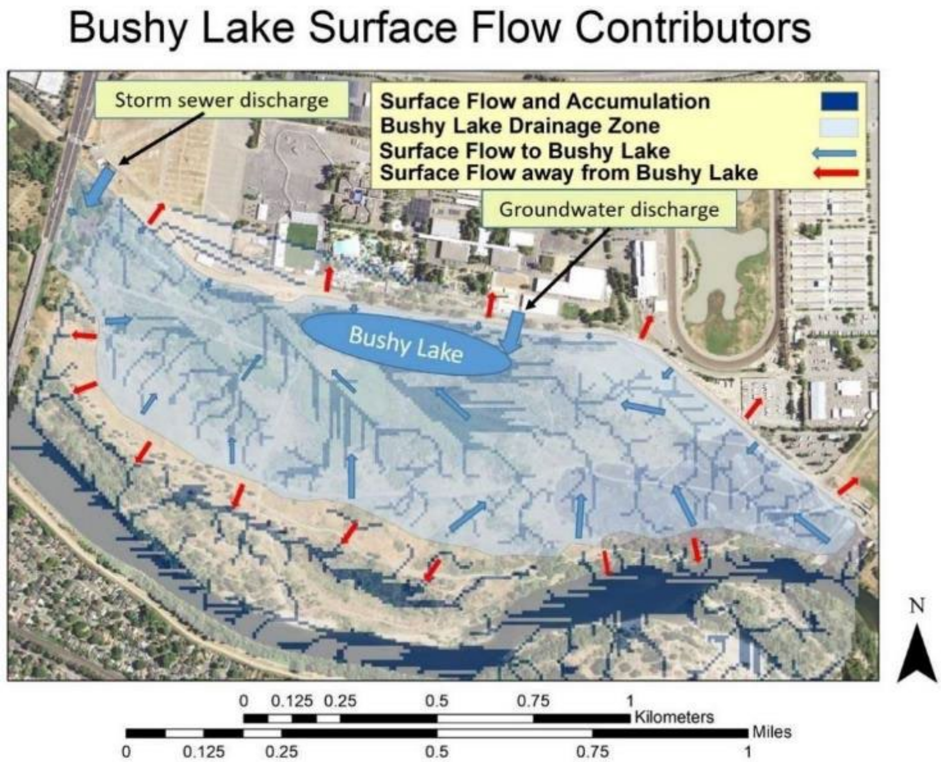


Figure 20. Bushy Lake terrain flow map outlining (in light blue) the area that contributes to surface drainage into the Lake under appropriate conditions.

Assess the hydrologic relationship between Bushy Lake and the nearby channel of the American River (ongoing)

General Geology and the connection between Bushy Lake and the America River

Bushy Lake exists on an elevated terrace feature along the American River. This landscape feature is within the existing levees that were constructed along the eastern and western sides of the American River, just east of Bushy Lake and just west of the American River channel.

No subsurface exploratory work (drilling or pump testing) was conducted for this study but other studies (Schlemon 1972, Helley and Harwood 1985) detail the Modesto Formation and Holocene age alluvium comprising the valley fill along this lower reach of the American River (Figure 21). Two distinct fills of the Modesto Formation have been identified, a basal gravel component and a younger coarse- to medium-grained granitic sand deposit. Holocene age alluvial fills consist of un-weathered gravel, sand, and silt from the Sierra Nevada deposited by the present-day American River from various alluvial processes. Dredge tailings from in-channel mining from the late 1800s and forward are likely preserved within these deposits and more modern channel modifications have impacted the surface of the terrace (a golf course planned on this feature in the early 1960s actually created Bushy Lake) as well.

For the above reasons, the infiltration rate at Bushy Lake is interpreted to be quite large due to the high hydraulic conductivity of river sediments the lake lies above, however, quantitative infiltration rates have not been measured for this study.

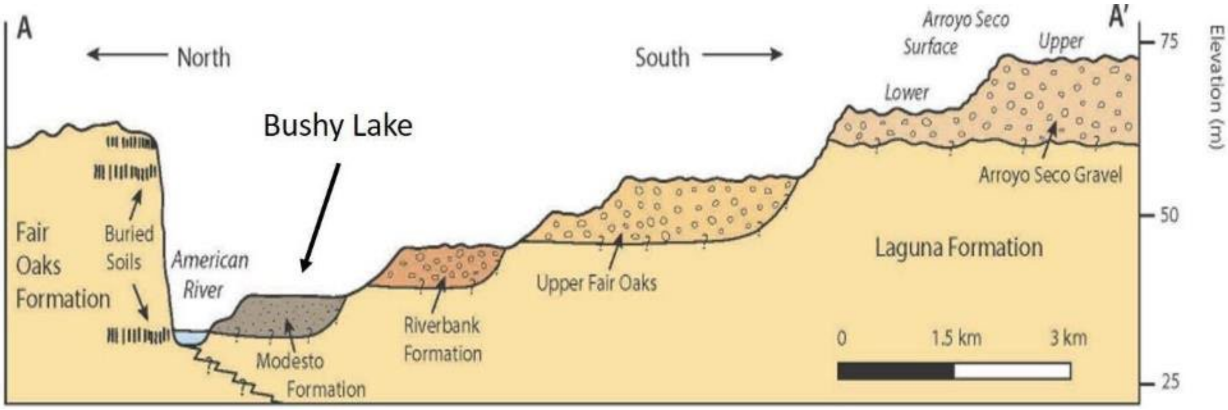


Figure 21. Stratigraphic sequence of river deposits. Age of deposition becomes younger closest to the modern channel in opposition to the law of superposition. Bushy Lake resides in Modesto Formation and Holocene-aged alluvial sediment (Bond et al., 2018).

Surface water elevation data was collected along the shoreline of Bushy Lake, along the terrace edge where it meets the eastern levee, and along the water's edge of the American River channel in Spring – 2021, Fall – 2021, and Winter – 2022 to assess the general direction of flow between the Lake and the nearby American River channel throughout the calendar year. Since Bushy Lake exists approximately 4 meters above the east bank of the American River in this vicinity, it was generally assumed that subsurface water flow would move from Bushy Lake to the American River. The results of the water level measurements confirm this assumption as water flow during each of the measurement time periods had flow gradients to the American River varying from 0.004 to 0.008 (Figures (22, 23, and 24)). Since flow in the American River along this reach is managed through releases from Folsom Reservoir, the only possible way surface water flow could course from the American River to Bushy Lake would be through a substantial discharge from the Reservoir (perhaps during a large precipitation event or other potential flooding events) that inundated the Bushy Lake terrace feature.

Considering the relatively consistent flow gradients between Bushy Lake and the American River as well as the likely high permeability conditions of the subsurface sediments, Bushy Lake would be expected to continually lose surface water to the local groundwater system as groundwater flows toward,s the American River.

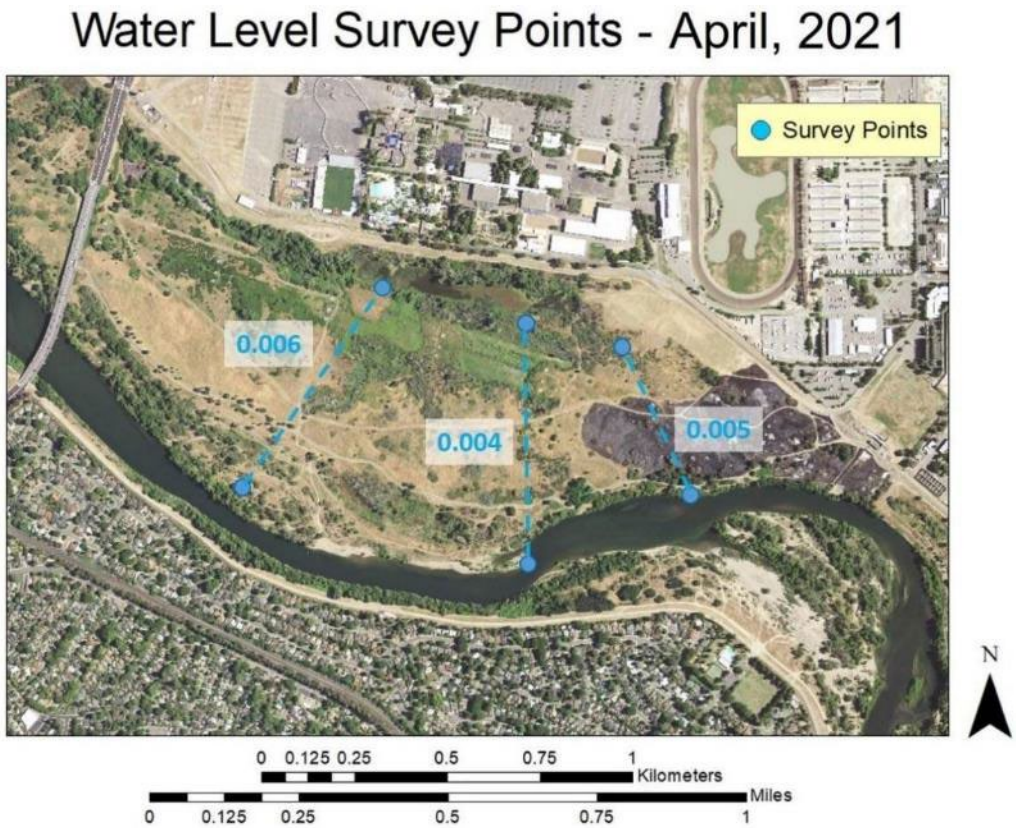


Figure 22. Measured groundwater flow gradients as measured on 4/20/21. Flow is from Bushy Lake to the American River channel.

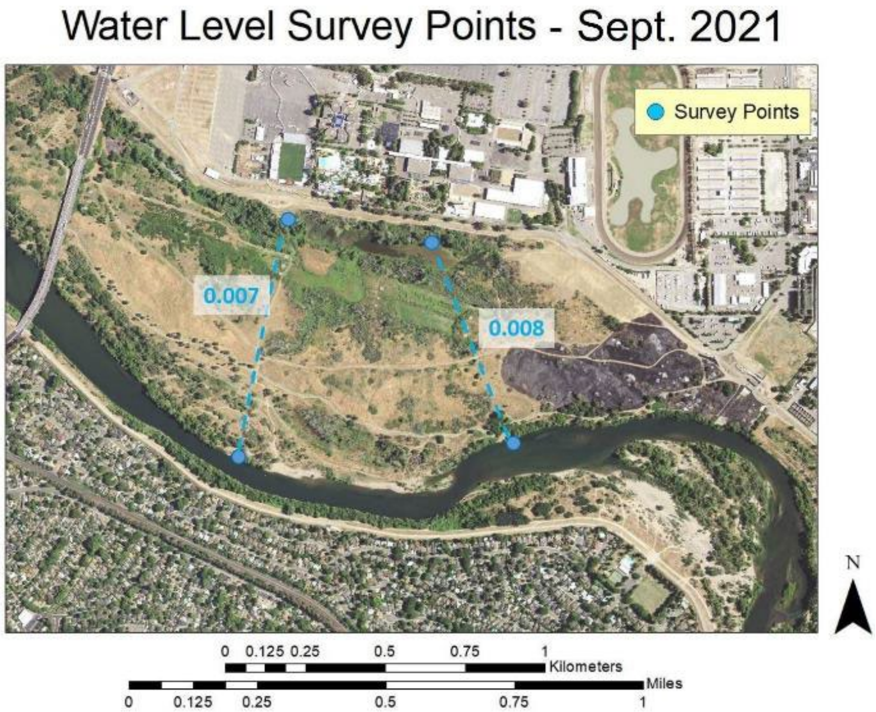


Figure 23. Measured groundwater flow gradients as measured on 9/1/21. Flow is from Bushy Lake to the American River channel.

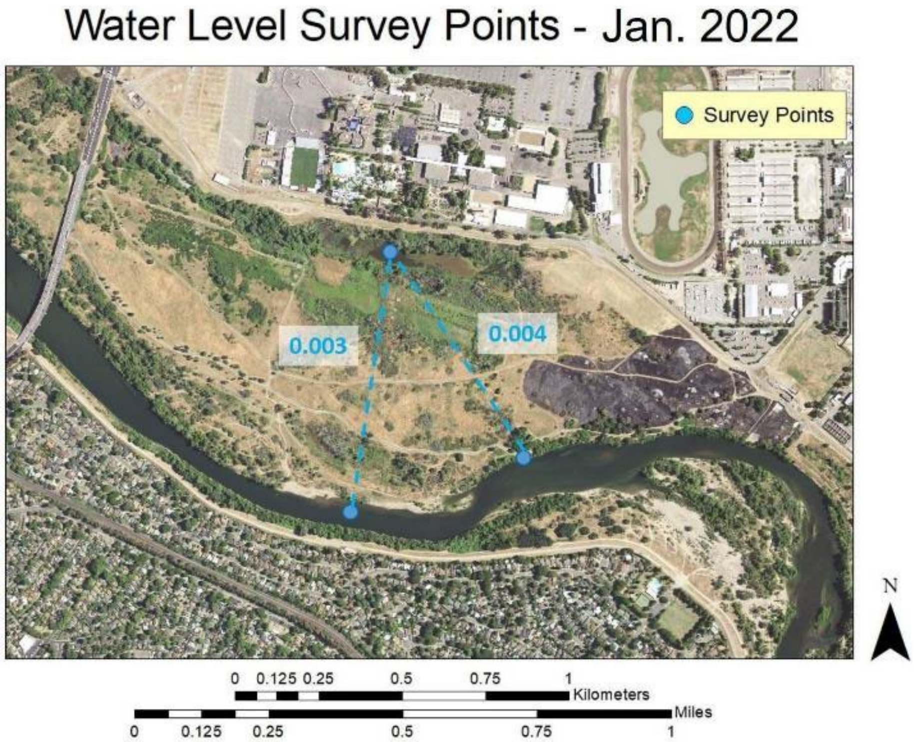


Figure 24. Measured groundwater flow gradients as measured on 1/13/2022. Flow is from Bushy Lake to the American River channel.

Groundwater augmentation to Bushy Lake

Cal Expo reports an unusually high volume of groundwater (50,000,000 gallons = 95 gallons/minute) is pumped into Bushy Lake each year. Since there is no surface water discharge from Bushy Lake to the nearby American River, this groundwater volume maintains lake level throughout the year, infiltrates to the subsurface through the Lake floor, and evaporates away during the warm summer months.

Based on these numbers, pumped groundwater would permeate through the soils at the base of the Lake at a low to moderate rate (~0.1 gal/ft2/day) for fine-grained mixes of sands, silts, and clays.

There is also evapotranspiration (eT) that will remove surface waters from this system as well – although this study didn't measure those parameters, Drexler et al., (2008) measured an eT rate of 6 mm/day in the Twitchell Island area in the nearby Delta region in the Central Valley and considering that both of these sites are wetlands and have similar climatic conditions and elevations), this value seems reasonable. Considering the volume of groundwater augmentation to the Lake, likely filtration rates into the subsurface, probable eT losses to the atmosphere, and the fact that no surface water discharges from the Lake to the American River, the waters in the Lake would be expected to cycle through this system at a rate of 1.5 to about 6X per year at a 95-GPM rate.

Assess how Bushy Lake responds to upstream dam releases and what impact high discharge flow events may have on Bushy Lake

In this portion of the study, the Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling software is used to model flood discharges along the American River Parkway in the vicinity of the Bushy Lake Nature Preserve.

The United States Army Corps of Engineers developed HEC-RAS to model surface hydraulic flow for the management of rivers, harbors, and other public works. HEC-RAS is capable of performing one-dimensional steady flow, one/two-dimensional unsteady flow, sediment transport, and water temperature/quality modeling. It is equipped to model river channels from simple single-reach rivers to braided networked river systems. The advantages of HEC-RAS lie in its versatility, widespread use, and ease of use. Although certain limitations exist, HEC-RAS can have instability problems when working in especially steep/flat river systems (Brunner, 2021). With the adjustment, these limitations can usually be overcome.

Hydrogeologic Setting

Channel gradient is gentle along the lower American River with an elevation change of about 0.55m per kilometer (Shulter, 1982). Due to the fluvial setting, the geology of the American River Parkway consists of loose poorly sorted cobbles, pebbles, and sand. In modern times the deposition of river sediments is confined between large levees on either side of the floodplain. These levees provide flood protection to Sacramento and extend about 20m above the riverbed. The levees are composed of a rock core with a low hydraulic conductivity sediment layer to prevent leakage. The current channel overlies a series of six Pleistocene paleochannels. River deposits found in the area have been identified as the Modesto Formation, Riverbank Formation, Upper Fair Oaks, Arroyo Seco Sequence, Fair Oaks Formation, and Laguna Formation (Bond et al., 2018). In general, the American River has migrated northward through time with the oldest sediment deposition occurring in the town of Elk Grove (Figure 21).

Surface Hydrology

Water flow along the Lower American River is controlled and originates from Folsom Lake Reservoir. The lake was created in 1955 with the creation of the Folsom Dam by the Army Corps of Engineers. The dam provides flood control along with hydropower and water storage. Flows of Folsom Dam can change very rapidly to meet changing water needs. Nimbus Dam, seven miles below Folsom stores and regulates the flows out of Folsom Dam. As a result of the dams, all water flowing through the American River Parkway has been regulated by the Bureau of Reclamation at Folsom Dam. Folsom has a max discharge capacity of 130,000 CFS but flows as low as 600 CFS have been observed during water scarce seasons. The USGS operates a gauge below Nimbus Dam at Fair Oaks and has collected discharge data since 1987.

Methods

The basic data needed for creating a HEC-RAS hydrologic model are discharge, the channel geometry, channel roughness, and water elevation at a control location. Each subsequent section addresses the application of basic data requirements.

HEC-RAS - Setup

The parkway is modeled using HEC-RAS version 6.1.0. The first step in any HEC-RAS model is to set up an organized folder system and set a geographic projection. The projection used for the American River Parkway is (NAD83 UTM, UTM Zone 10N, European Petroleum Survey Group: 26910). The projection file was obtained from spatialreference.org.

Before modeling can begin, the user must decide which model type is most suitable, whether that be a HEC-RAS 1D or 2D model. This is defined by the desired model run times, outputs, availability of data, the complexity of the river system, and computation equations. In general, a 1D model may be preferred when streams/channels have unidirectional flow and defined over-banks, have limited access to good terrain data, or have time restraints. A 2D model may be preferred when there is a complex river system, shallow water flow areas, unclear flow direction, where detailed flood mapping is required, or in dam-break studies. Recent software developments and increases in hardware computation speed have made HEC-RAS 2D modeling faster, easier, and more versatile than ever. For this project, a 2D model was developed to accurately model shallow water flow along the floodplain.

Building the Terrain (Channel Geometry)

The foundation of any HEC-RAS model begins with good terrain data. Initially, the model was going to use a digital elevation model that was created from survey data collected in early 2021. Upon further investigation, the USGS has LIDAR available for the area which has larger extents than what was surveyed. The “USGS Wildfire B5a” LIDAR data set is used and has a resolution of 1m. One complication when using LIDAR is its inability to accurately penetrate water. Because of this, the LIDAR data has flat and noisy data along water surfaces. This caused problems in three distinct areas, the American River main channel, a bay along a bend in the river called Paradise Beach, and the extent of Bushy Lake. To correct problems with elevation data, HEC-RAS allows for layering different terrain datasets together.

To add bathymetric data to the American River, survey data was incorporated into the digital elevation model. Survey data was collected using a Trimble Geo 7x. Survey points were manually taken by walking and placing the Trimble unit. The Trimble unit is capable of recording location to an accuracy of 2 cm. Using ArcMap, the interpolated river bathymetry was cut from the survey data. Within HEC-RAS, the bathymetry was layered over the LIDAR data set. This led to a data set that was a good estimation of river bathymetry in some areas of the river reach but was missing data where we were unable to physically reach/wade while surveying. To obtain a complete terrain model with bathymetry, a 1D geometry can be used to edit 2D terrains within HEC-RAS. Editing 2D terrains with 1D geometries require the creation of two distinct objects. These consist of cross-sections and bank lines. The first step in the process is to create multiple cross-sections across the river surface in RAS Mapper from left to right downstream (see figure 2). Then bank lines are drawn to define where the river surface meets the ground of the elevation model. To edit the 2D terrain the cross-sections were manually adjusted to conform to the observed bathymetry from surveying. The new cross-sections are then essentially used to “carve” out the 2D terrain. The bank lines are used to determine the extents to which the channel is carved.

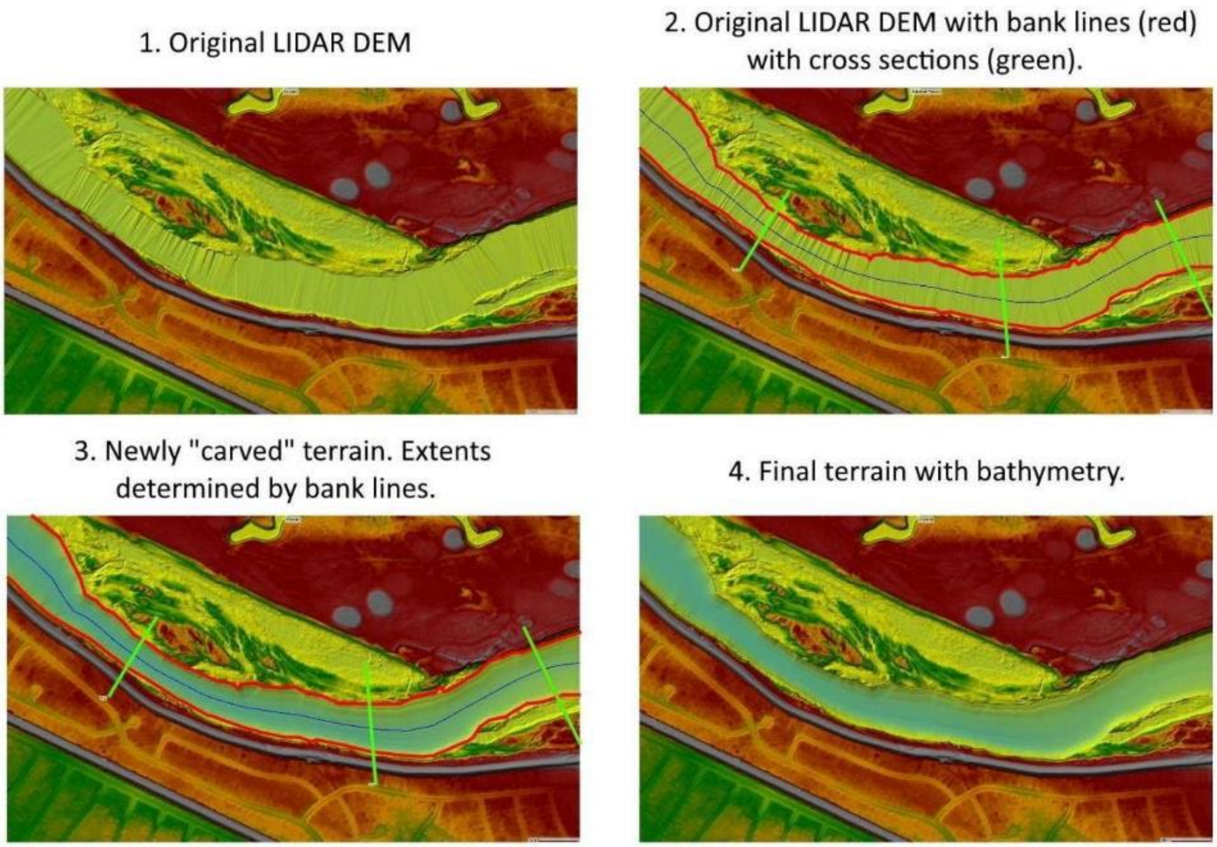


Figure 25. Adding bathymetry to LIDAR DEM within HEC-RAS using a 1D geometry to edit a 2D terrain.

Using the same method, the terrain was modified to add bathymetry for Bushy Lake and the Paradise Beach area (Figure 25). Bushy Lake bathymetry was estimated at 1.5 at the deepest. When editing the Paradise beach area, the American River bathymetry was layered on top to maintain a smooth channel transition.

Discretizing the Model

Once the physical terrain of the model is complete, the computational mesh must be generated. To do this a geometry is created to define the boundaries of the 2D flow area to be calculated. This boundary was set to cover the parkway surrounding Bushy Lake. Additional coverage of the parkway outside the area of Bushy Lake would increase model run times significantly. A cell resolution of 10m x 10m was chosen to give sufficient resolution/maintain model efficiency. Each cell in the computational mesh has a center where the water surface is computed for that cell and boundary faces where flow across is calculated. Once the cell size and 2D flow area are determined the computational mesh is automatically generated and consists of cells with individual computation points. Automation of this process is fast but can generate errors in areas with complicated geometry. Errors usually consist of cells being created with too many faces. HEC-RAS calculations require a cell to have 8 faces maximum. To remedy errors additional computation points can be added to reduce cell faces.

An important step in creating the computational mesh is to add “break lines”. Break lines are manually added to force the computational mesh to align (Figure 26). This was done in river channels to align cells along flow direction to increase the accuracy of flow calculations.

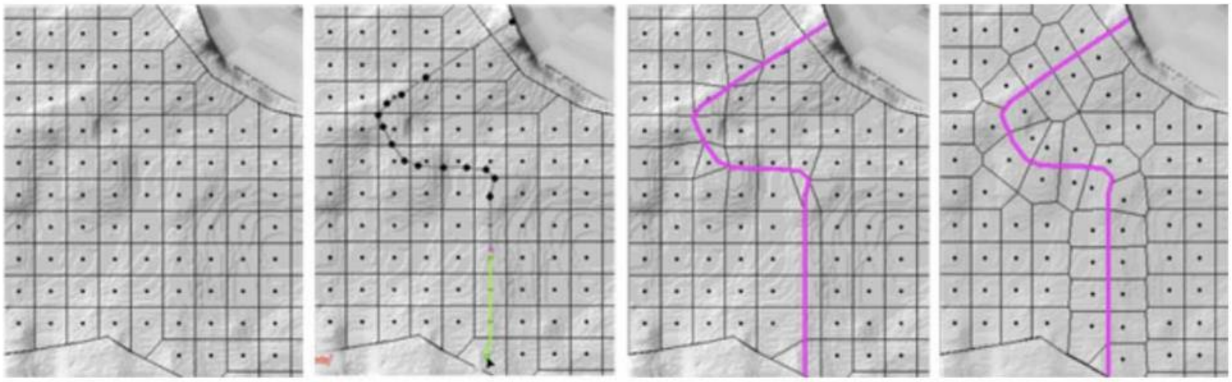


Figure 26. Example of break line enforcement. This creates new computation points on each side of the line and forces cell faces to align along it.

Break lines should also be added along high ridges to prevent what is called “leakage”. This is when a cell encompasses both sides of a feature and during computation, water can essentially pass through that feature without going over. Break lines were added along the levees of the parkway to combat leakage.

Boundary Conditions (Water Elevation at a Control Location)

A boundary condition defines the locations at which water is applied and removed from the model. They can be applied externally to the model boundaries or internally within the defined 2D flow area. For this modeling exercise, only external boundary conditions were used as there are no significant sources/sinks of water within the model area. At the downstream side of the model, a “Normal Depth” boundary is applied. This boundary condition used Manning’s equation to estimate a stage height for each computed flow (Brunner, 2021) (Corvallis Forest Research Community, 2006).

In HEC-RAS when using a normal depth boundary condition, the variable that has to be defined by the user is that for slope at the boundary condition. To do this a profile was cut from the terrain model and then directly measured for slope across the boundary. A 0.0004 friction slope was applied to the downstream boundary. At the upstream end of the model, a “Flow Hydrograph” boundary condition was used. A flow hydrograph boundary allows for discharges over time from gauge data to be added to the model. Flow data is user-defined and explained in the Flow Hydrographs section. This boundary condition also requires a slope and was measured the same way as the downstream component. A friction slope of 0.00085 was applied to the upstream boundary condition.

Land Cover (Channel Roughness)

When computing flow over a 2D flow area, a Manning’s *n* value must be defined. This is a roughness coefficient that is used to account for energy loss due to friction in overland/channel flow. In HEC-RAS it is common to associate land cover classifications with manning n values. For this model, the 2019 National

Land Cover Database was used. The land cover classification areas were imported to HEC-RAS and then a manning's n value was applied to each NLCD classification. The manning' n values used were referenced from (Army Corps Engineers, 2021). These numbers were then altered slightly to better match field observations.

Flow Hydrographs (Discharge)

Two distinct observations were seen when looking at discharge rates from the Fair Oaks gauge. Firstly, peak discharges do not necessarily correspond with the largest storms. This is a result of how reservoir capacity at Folsom Lake before a storm can affect downstream discharge rates. Low water storage levels will not change discharge rates as filling the reservoir is favored. If the reservoir is near capacity then large amounts of water begin to discharge to prepare for increased water levels. The second observation is that when there is an increase in discharge, rates generally increase and fall rapidly. For large discharges (>50,000 CFS) the flows generally rise and fall over a period between 1 and 3 days and these discharges are a direct result of the flood control measures.

From the patterns observed at the Fair Oaks gauge, a series of hydrographs were fabricated to represent different max discharges. Hydrographs were designed in excel as a bell curve that rises and falls over a 3-day time period in 1-hour intervals (Figure 27). The standard deviation of the bell curve was set to the mean of the time series divided by 2.5. This led to the discharge hydrographs that were similar to what was observed at the gauge. Max discharges chosen to model were 130k CFS, 80k CFS, 70k CFS, 60k CFS, 50k CFS, and 40k CFS. 130,000 CFS was modeled to serve as a worst-case scenario in discharge.

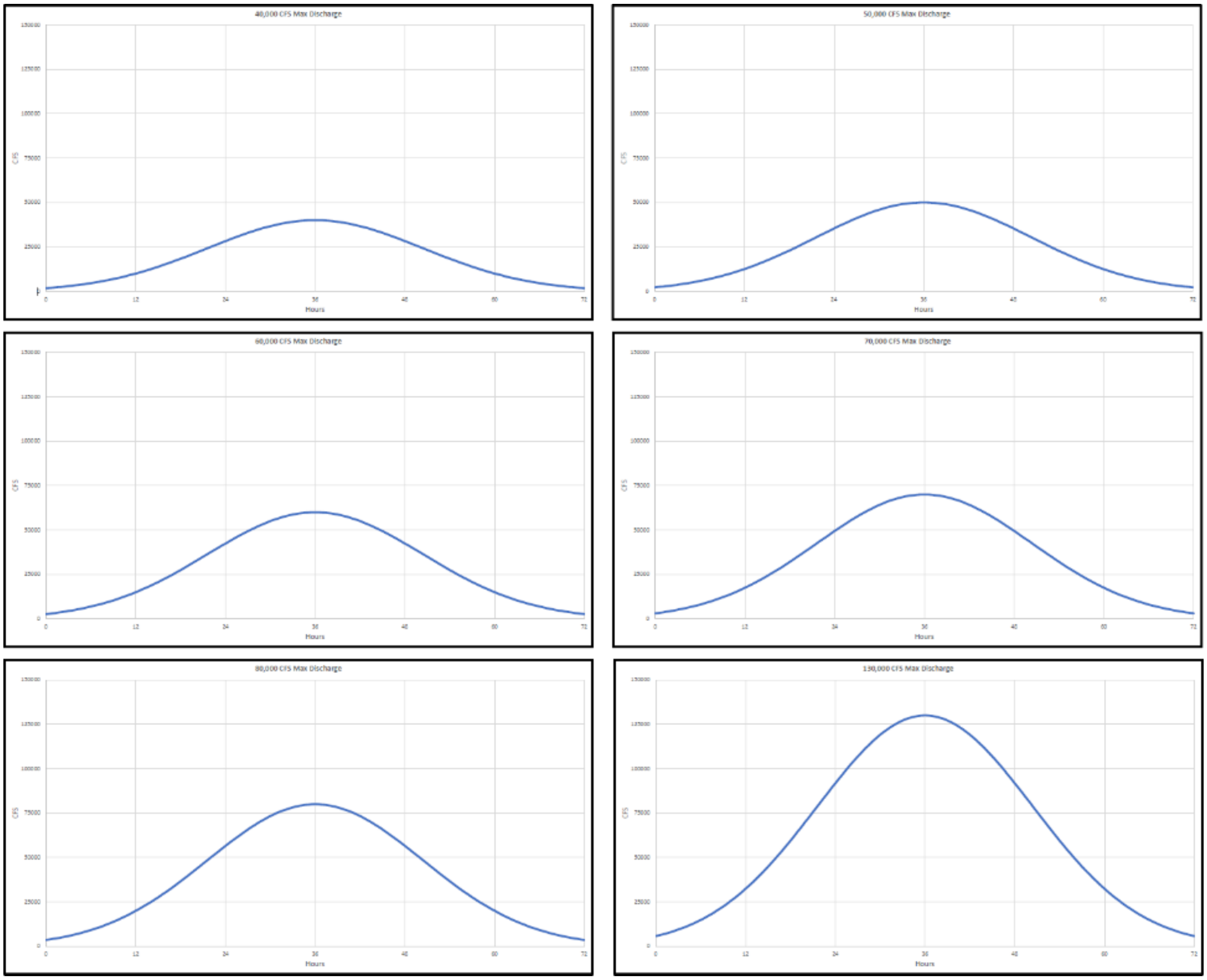


Figure 27. Hydrographs used in generating flow data for the model. Hydrographs are bell curves with flows occurring over a 3-day interval.

Computations

When running a HEC-RAS model special consideration must be taken to apply the correct computation tolerances. The simulation time window was set to three days to match hydrographs. A computation interval must also be specified and tells the model how often to calculate water elevations. A rule when choosing a computation interval is to make sure that a courant number below 1 is achieved.

Eq 2: $C = v\frac{\Delta t}{\quad}$

Where: C = Courant Number
V = Water Velocity (ft/s)
Δt = Computation Interval (s)
Δx = Length between mesh elements (ft)

This ensures that water particles in the model do not propagate beyond the next cell between computations. Essentially it is to prevent water from “skipping” cells. Courant numbers greater than 1 can lead to computation inaccuracies and model instability. For this model, a variable time step is used, and computation intervals occur between a range of defined courant numbers. The lower courant limit is set to 0.25 and the maximum is 0.8.

HEC-RAS allows the user to choose the equation set that is used to calculate flow. The default is “Diffusion Wave”. In general, the diffusion wave runs the fastest and has the greatest stability, however, it does not accurately model shallow water flow. For this model, the Shallow Water Equations – Eulerian Method (SWE-EM) set was used. This computation method uses the St. Venant equations to conserve momentum when calculating flow. Along with the equation set, theta was adjusted. Theta is a weighting factor for the special derivative used to solve the St. Venant equations and can be adjusted between 1.0 to 0.6. A higher value improves model stability but is less accurate in solution. For this model, a theta value of 0.8 was achieved before instability occurred.

Results

Floodplain Extent

When observing what discharges connect to the overlying floodplain, we are concerned with what max water depth is achieved with each flow. Looking at the modeled depths, a few observations are similar across each computation. Firstly, the areas to first become inundated with water on the floodplain are the same in each model. The time series below conveys the general water movement around Bushy Lake (figures 28 – 34). The time series is for 80,000 CFS peak discharge.

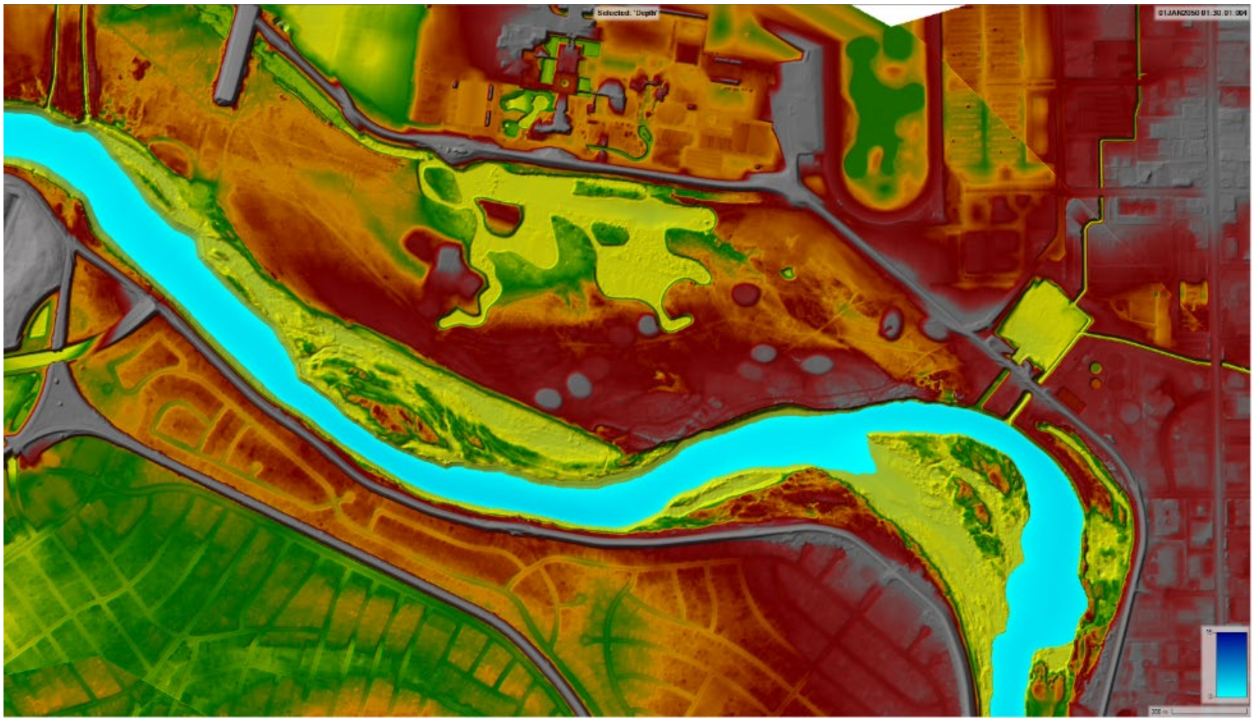


Figure 28. Initial water depth when starting computations.

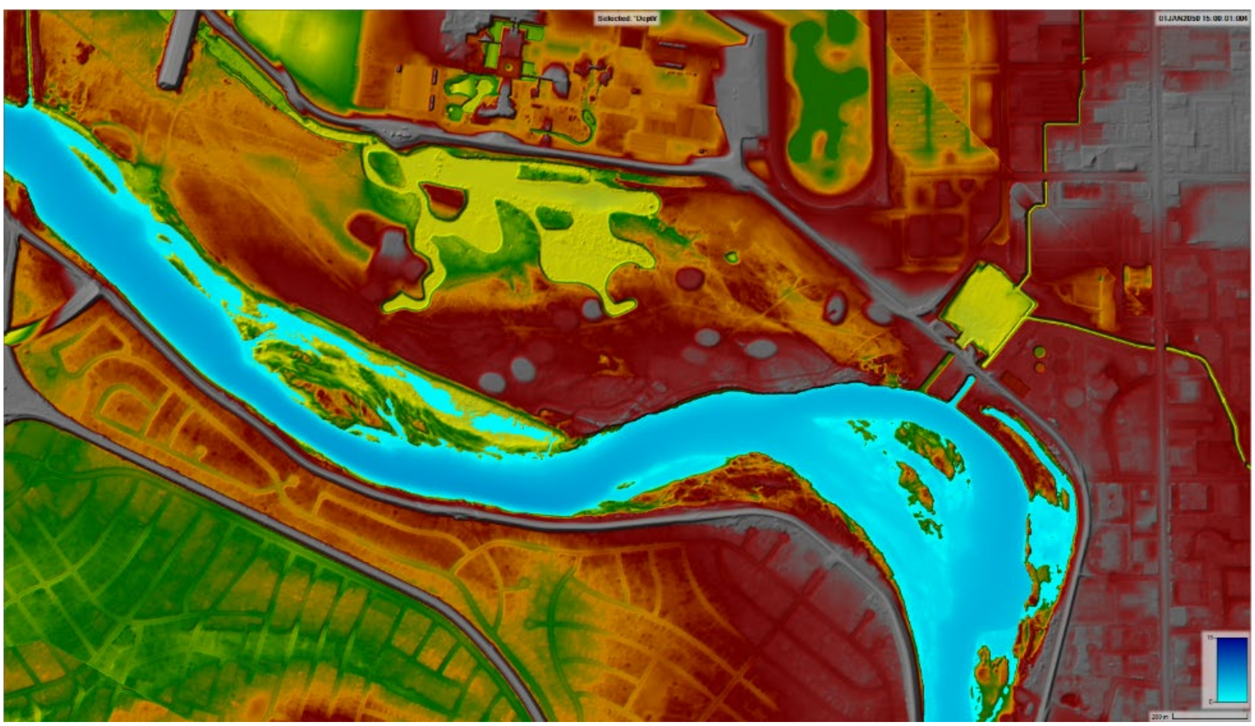


Figure 29. At 15 hours the channel has filled previously dry areas and is beginning to reach capacity.

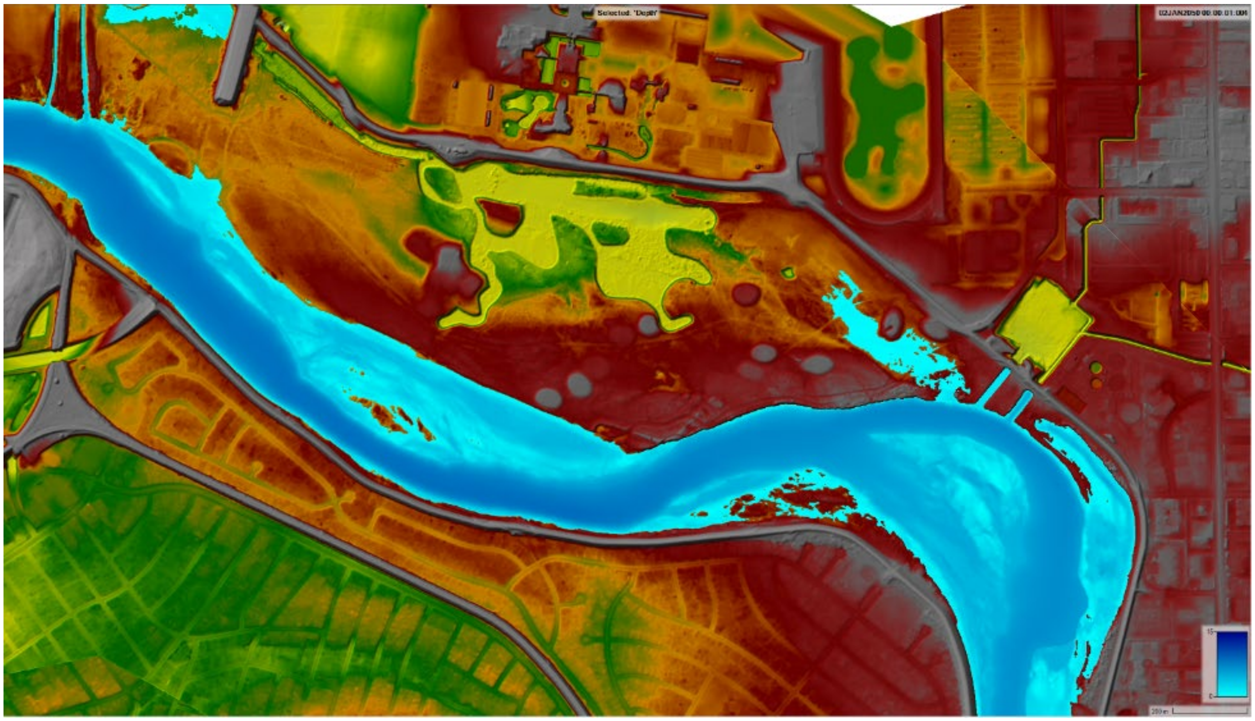


Figure 30. At 24 hours the channel has reached capacity. Connection to the floodplain has begun to the east of Bushy Lake.

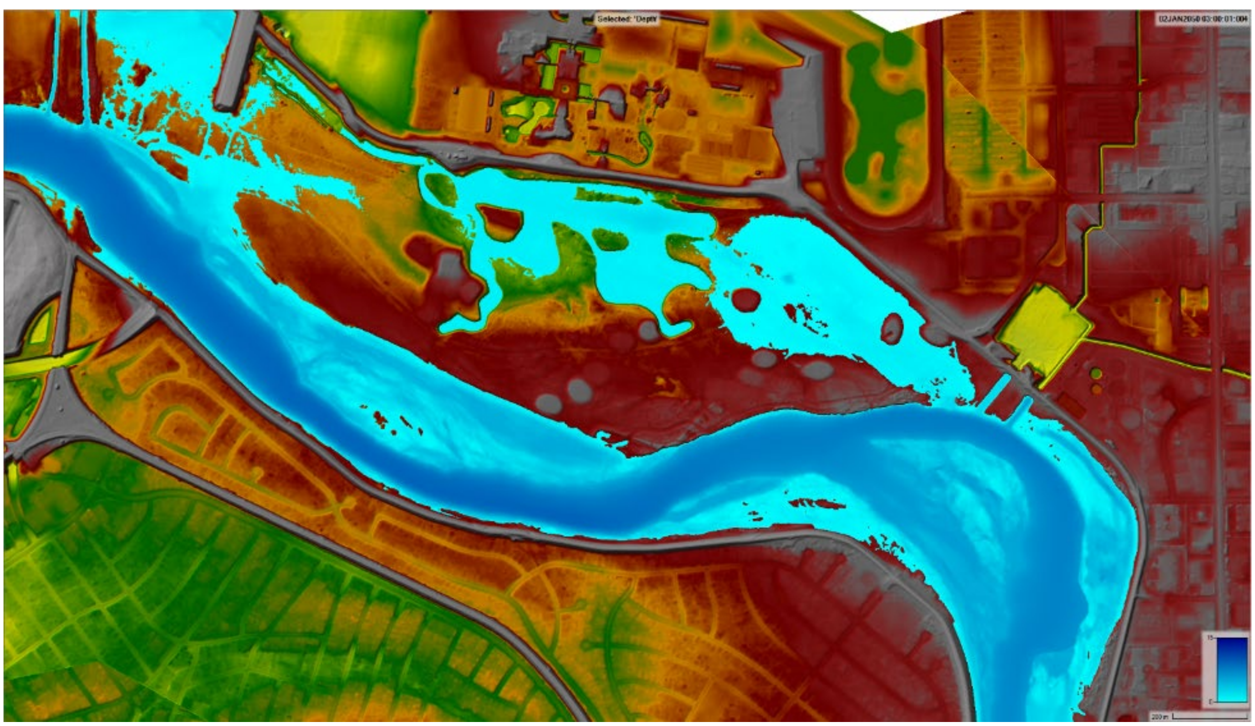


Figure 31. At 27 hours the waters have reached Bushy Lake from the east and are starting to inundate the floodplain to the west of Bushy Lake

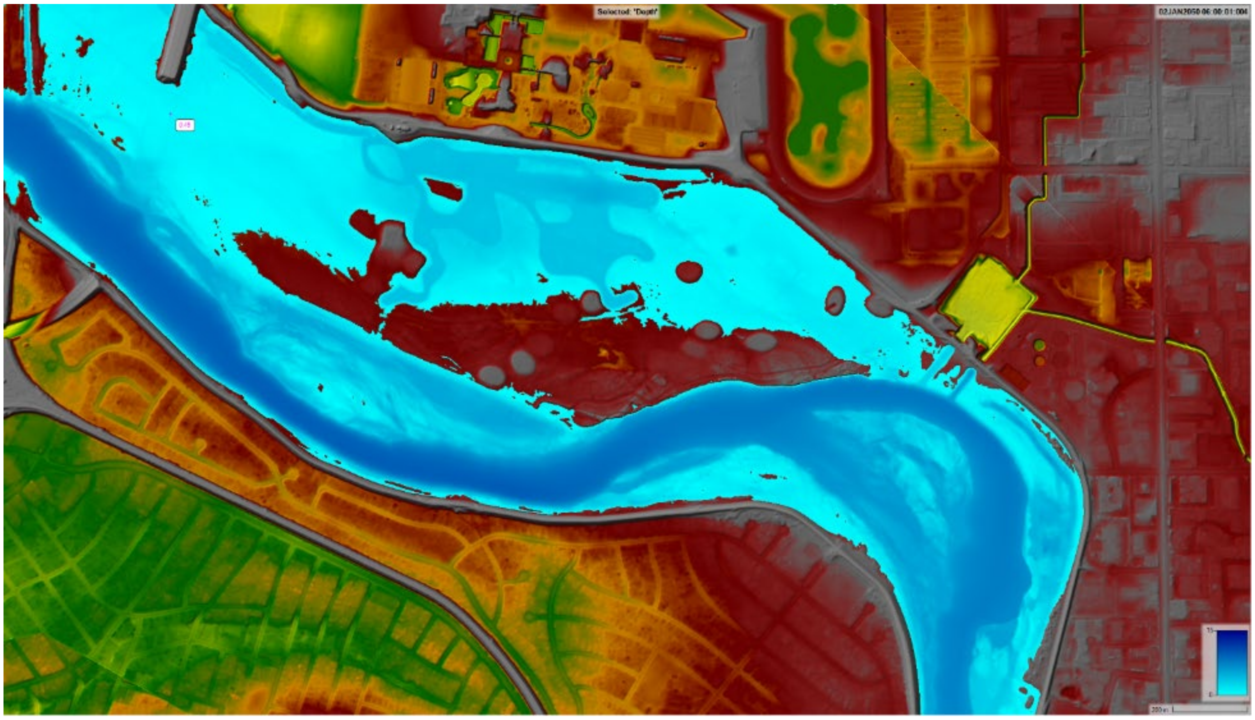


Figure 32. At 30 hours the floodplain has connected on either side and the area surrounding Bushy Lake is under a significant amount of water.

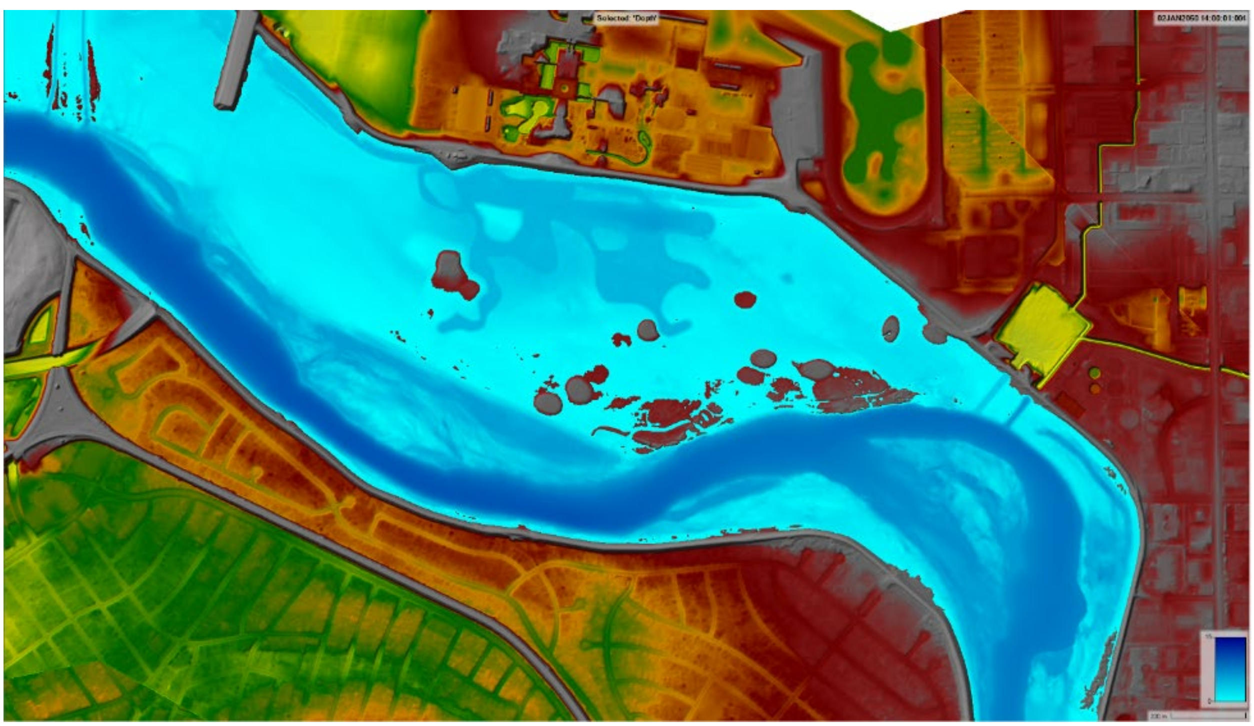


Figure 33. At 38 hours discharge has reached its peak and the area of Bushy Lake is almost completely under water.

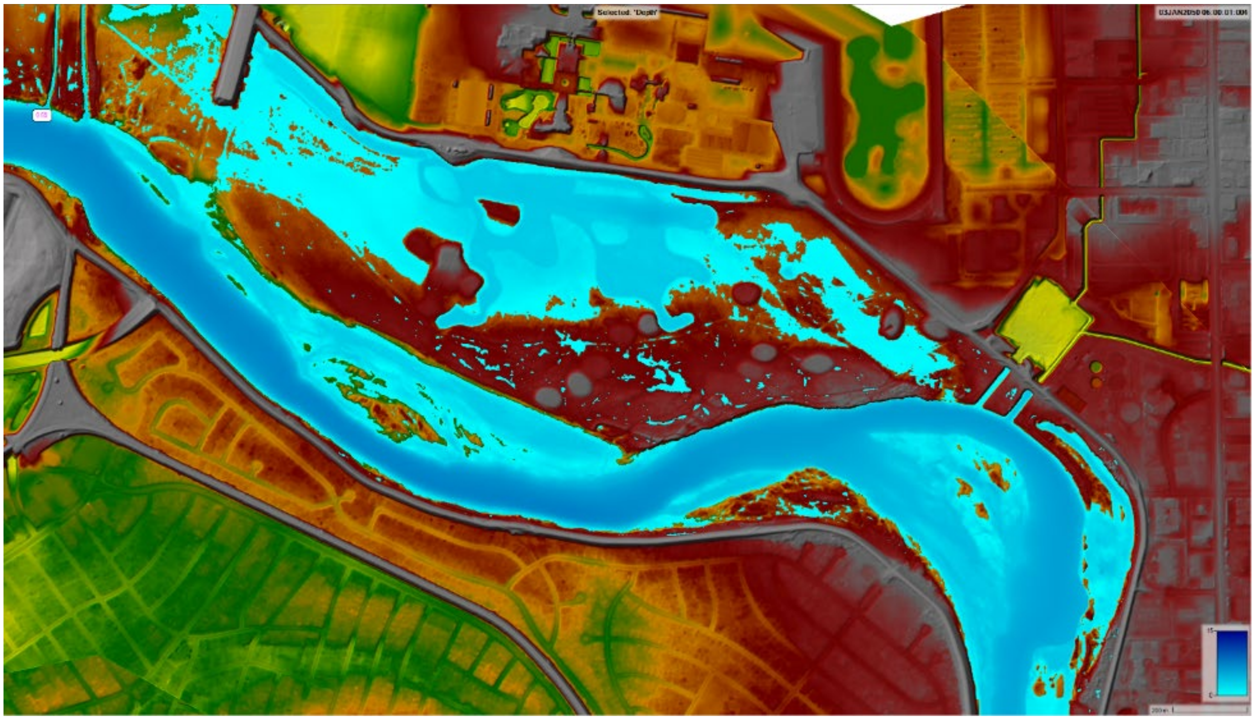


Figure 34. At 54 hours the waters have receded as discharge lessens and the area of Bushy Lake remains inundated with water.

When viewing the time series, the movement of water is the same in each model run. Firstly, the east side of Bushy Lake is the first to become inundated, shortly after the western floodplain becomes connected to the river. The southern side of Bushy Lake is at a higher elevation than the surrounding floodplain. Due to this, it is the last area to be underwater. Any water that does overtop the river bank eventually flows towards the low spot that is Bushy Lake. When floods recede, the water is residually stuck around Bushy Lake.

When observing the effects of varying peak discharges the differences observed are the extent to which Bushy Lake becomes flooded. Smaller discharges only slightly flood Bushy Lake or do not reach the floodplain at all. Modeling outputs show the max water depth achieved for each peak discharge (Figures 35 – 40).

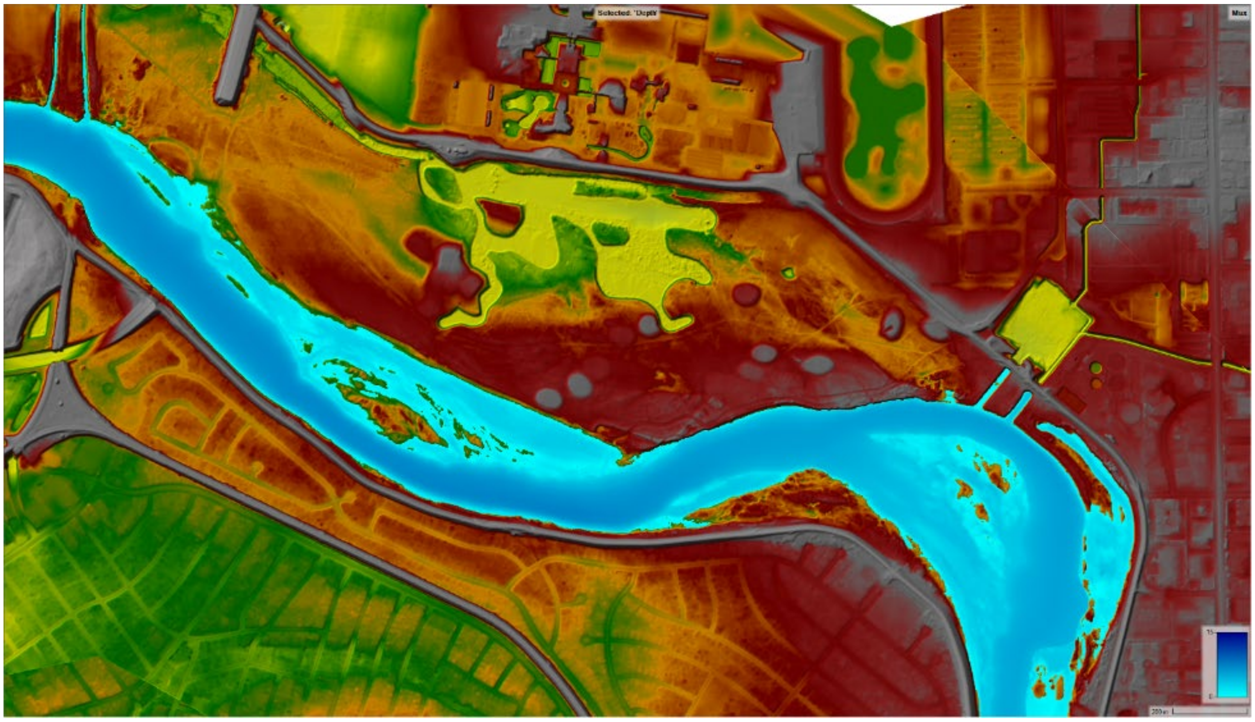


Figure 35. 40,000 CFS Max Water Depth

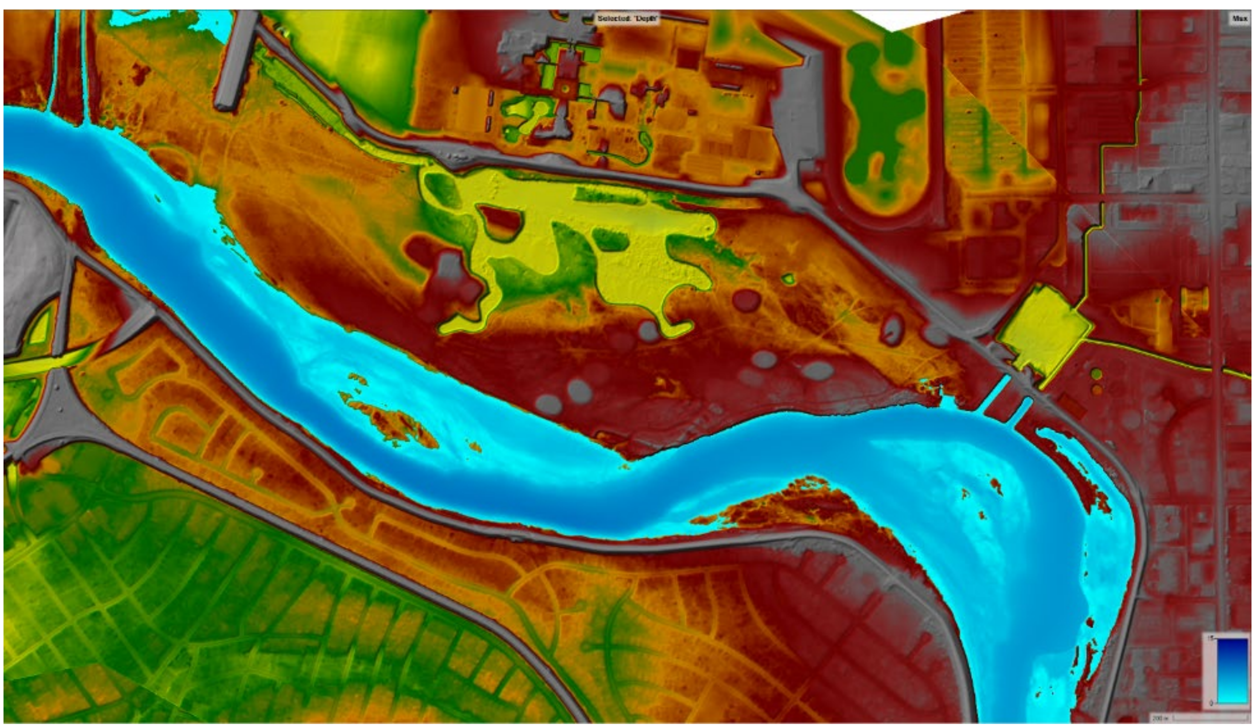


Figure 36. 50,000 CFS Max Water Depth

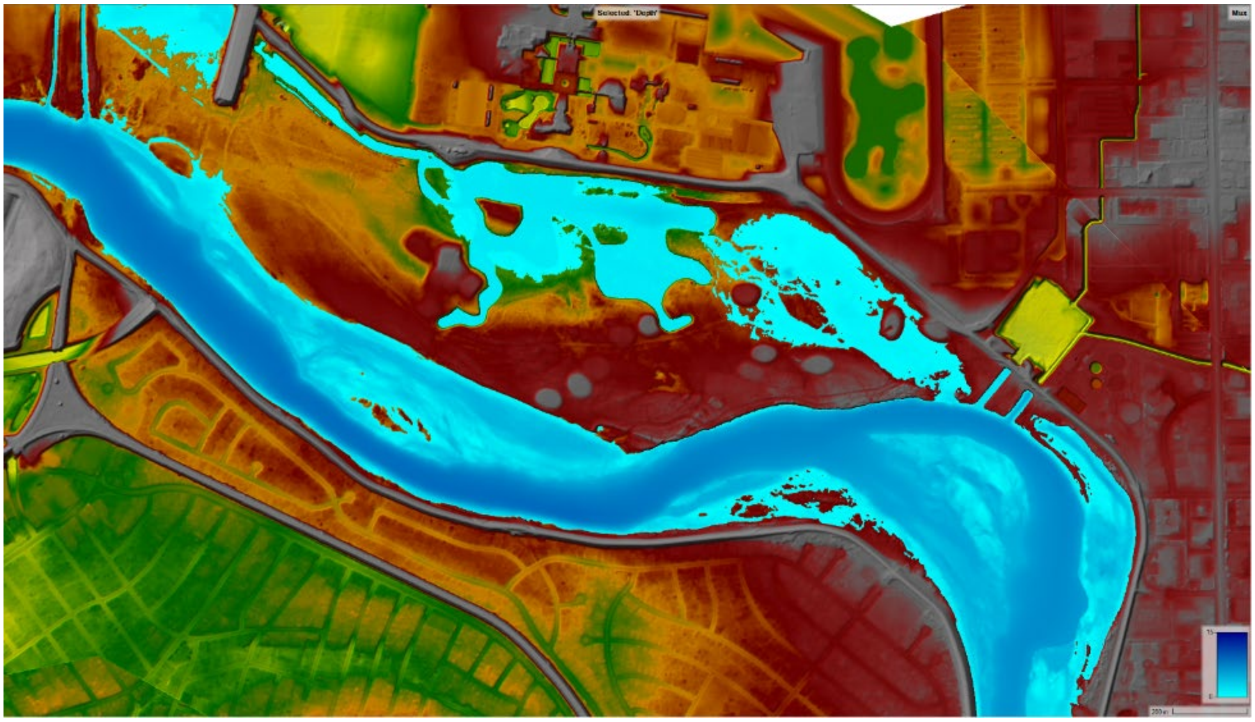


Figure 37. 60,000 CFS Max Water Depth

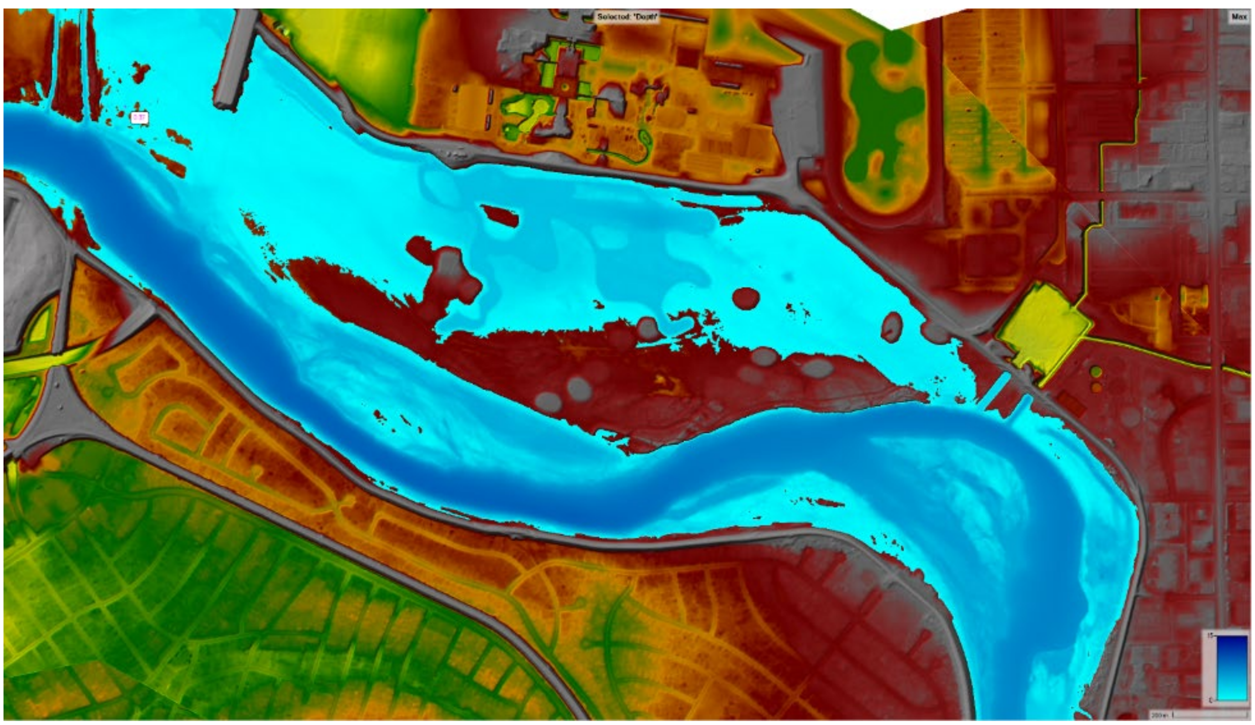


Figure 38. 70,000 CFS Max Water Depth

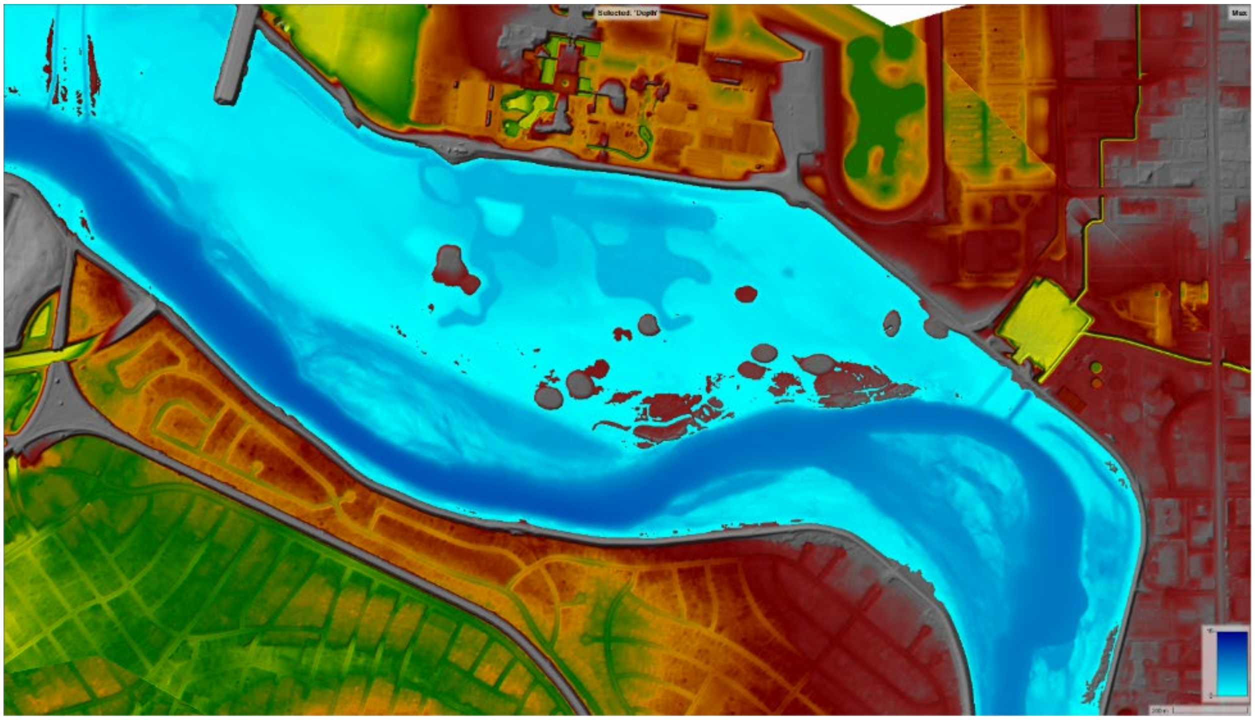


Figure 39. 80,000 CFS Max Water Depth

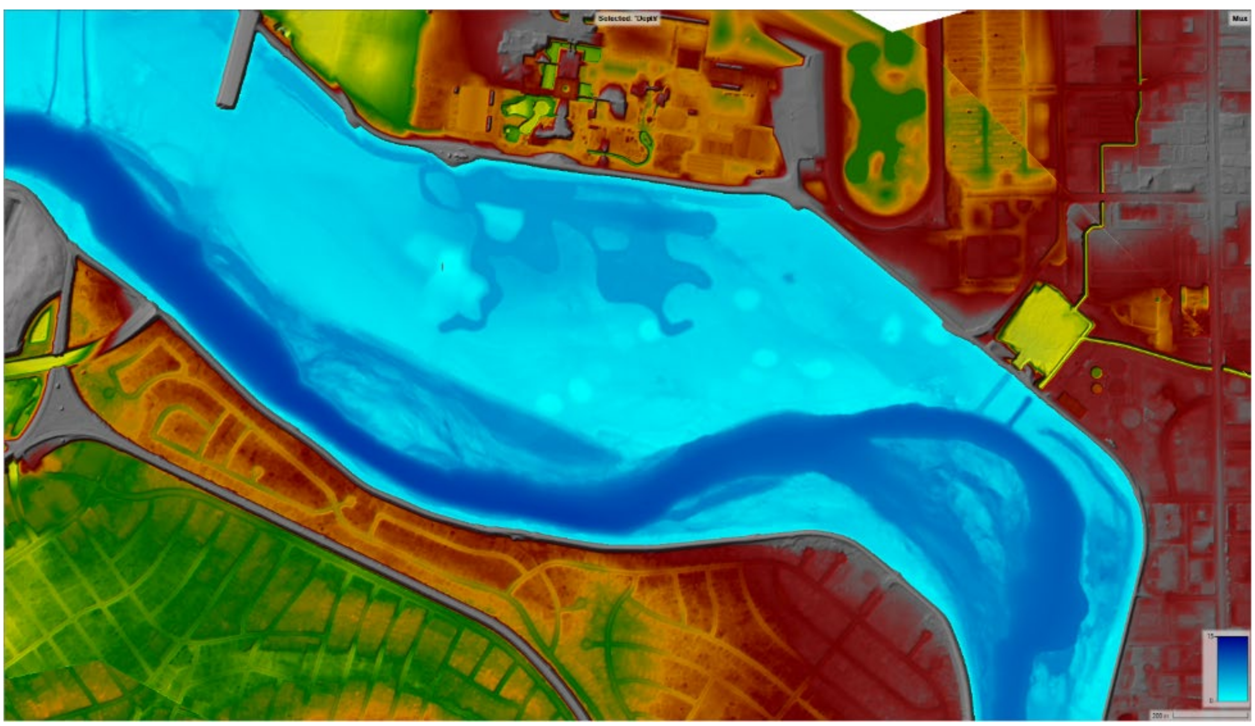


Figure 40. 130,000 CFS Max Water Depth

The model outputs are very straightforward and show the range/extent of floodplain inundation for each discharge. Looking at the wax water depth maps we can see that flows under 60,000 CFS do not connect with the floodplains and are confined to the channel. Flows above this do spill onto the floodplain, but the extent of inundation varies. Major flooding of Bushy Lake does not occur until about 80,000 CFS (Water depths around Bushy Lake on the floodplain at 70,000 CFs are less than 3 ft). Flows around 60,000 would most likely not flood Bushy Lake and instead would infiltrate into the ground. This model does not include infiltration in its calculations and as such is just a hypothesis. When viewing water depths at 130,000 CFS the area is completely flooded from levee to levee. This model does show that 130,000 CFS would not overtop the levees and is in agreement with the Army Corps of Engineers' estimated max discharge of ~135,000 CFS.

Uncertainty

This model is an approximation of the conditions at the Bushy Lake nature preserve and such contains inherent errors that may not convey conditions completely accurately. Firstly, flows are calculated from the bell curve hydrographs. A typical flood hydrograph contains a tailing end after floods where flows remain heightened which is not reflected in the hydrographs used. Also, a typical flood would coincide with mass sediment movement. HEC-RAS has the capability for sediment transport modeling; however, it is not used in this analysis. Manning's n values in the model were applied using a land cover map. A better estimation could be achieved by physically measuring an n value at a location. The absence of an accurate bathymetry map meant that bathymetry in the model had to be “created” and estimated from observations.

Conclusions

From the time series (Figures 35 – 40) flows upon the floodplain follow a predictable pattern. Flows most easily reach the floodplain at the east and west side of Bushy Lake. This southern side of Bushy Lake is a high point created from the construction of the American River Parkway bicycle path. This bicycle path has inhibited flows that contribute to Bushy Lake lessening its recharge potential. It is significant that flows under 60,000 CFS do not connect with the overlying floodplain. Looking at the Fair Oaks gauge (Figure 41) we can see that only two events over 60,000 CFS have occurred since 1980. The likelihood of Bushy Lake filling from the American River flows on a regular basis is extremely unlikely. A restoration plan would need to implement other means of maintaining water levels in the Lake.

In all this is an estimation of what flood discharges may look like at Bushy Lake. Due to the inherent simplification of the model, the main conclusions should remain broad in scope. The main observation is that flows under 60,000 will not contribute to the floodplain and that flows that do contribute, will come from the east and west side of Bushy Lake

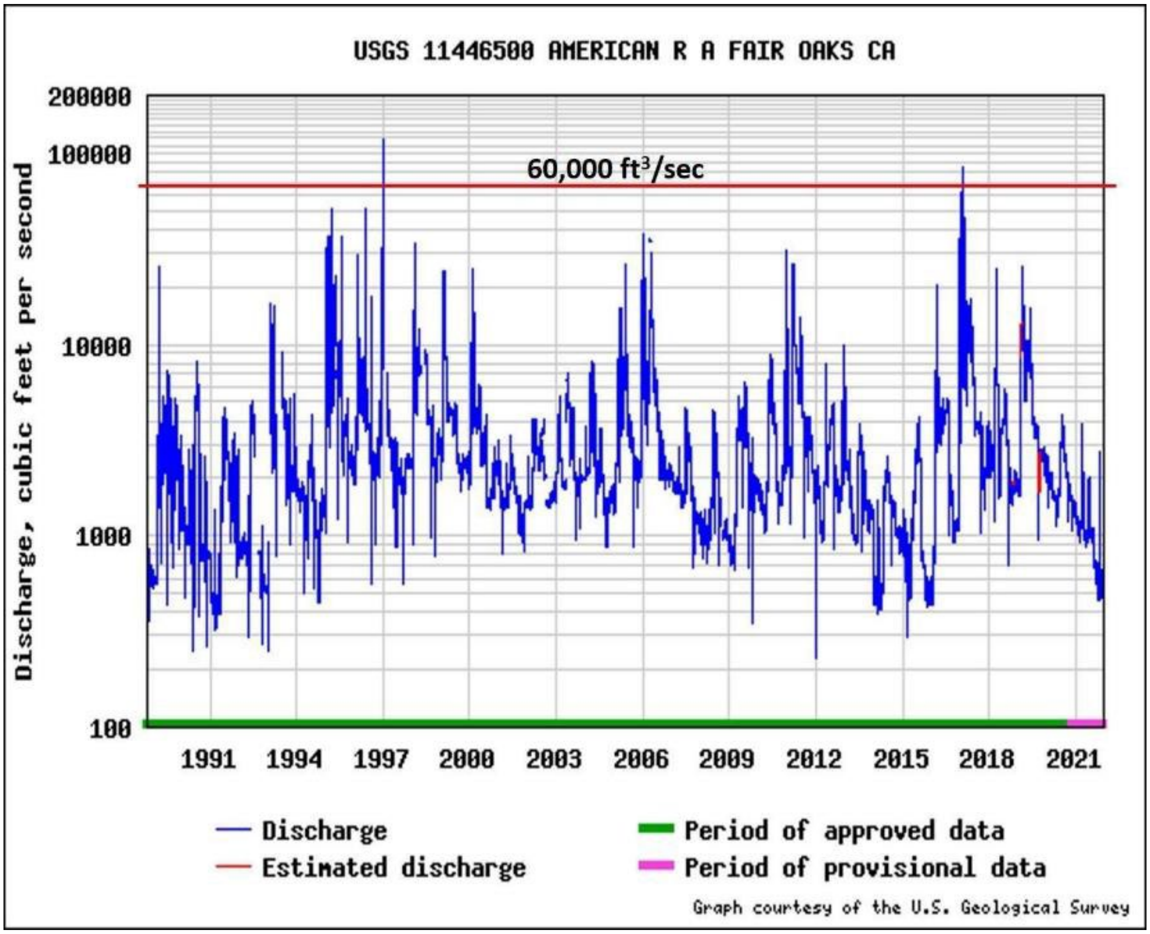


Figure 41. Fair Oaks gauge reading for discharge (1989-2021). In 1997 and 2017 flows of over 60,000 CFS occurred (red horizontal line) and likely flooded the area of Bushy Lake. Numerous events on the order of 20,000-30,000 CFS occur, but would be confined to the river channel.

Assess the role that groundwater pumping from Cal Expo and stormwater flow near Cal Expo has on surface inflow into Bushy Lake (ongoing)

Conclusions

Detailed ground surface mapping suggests that approximately 0.9 km^2 (0.35 mi^2) of the terrain surrounding Bushy Lake would drain into the Lake under precipitation conditions that produced surface water runoff. Likely subsurface sediments in this area would be expected to be generally porous and permeable and waters in the Lake could easily drain from the Lake to the nearby American River Channel. Organic matter (leaf and vegetation litter) or that produced by aquatic life in the Lake that gets deposited on the bottom of the Lake would likely reduce the infiltration rate of Lake waters to the underlying groundwater system. The degree that which this may occur has not been studied.

Subsurface water flow drains from Bushy Lake to the American River at gradients that range from 0.003 to 0.008. The subsurface sediments that underlie Bushy Lake are likely coarse-grained sands and gravels from the Modesto Formation. These conditions present along the entire reach of the American River where this terrace feature occurs suggests that Bushy Lake continuously loses lake waters to the local groundwater system that eventually discharges into the nearby American River channel.

HEC-RAS software was used to route potential floodwaters down the American River through the Bushy Lake reach to assess the discharge values that might inundate the Bushy Lake terrain. By simulating channel and surrounding landscape conditions, floodwaters of varying discharge rates were routed down the channel and showed that discharge rates near 60,000 CFS place floodwaters on the terrace feature that holds Bushy Lake. Under this scenario, the lower elevations of the terrace surface and Bushy Lake are underwater from this hypothetical flood event. If discharges were to reach about 80,000 CFS, complete inundation of the terrace feature (and Bushy Lake) would occur.

Conclusions / Recommendations

In its natural state, Bushy Lake is maintained by groundwater pumping from Cal Expo, as mandated by the Bushy Lake Preservation Act. The Bushy Lake Preservation Act requires “CalExpo to preserve, for public day use and enjoyment, the CalExpo floodplain in a manner consistent with the definition of a state park”. The riparian habitat at Bushy Lake is deemed “of vital importance and an integral part of the American River”. “Bushy Lake'' means a body of water in the Bushy Lake area with approximately 11 acres of water surface in the summer and approximately 80 acres in the winter" (Public Resources Code Section 5830-5835) (Justia 2022).

The Bushy Lake CRP will need to develop alternative scenarios of water allocation from groundwater pumping by Cal Expo, based on drier and warmer climate conditions leading to more frequent and severe drought conditions. Without groundwater inputs from Cal Expo, Bushy Lake does not support an adequate volume of surface water necessary to maintain a perennial open water system supporting existing aquatic and riparian ecosystems. If the reported groundwater pumping volumes are accurate, Bushy Lake loses anywhere from 1.5 to 6 times the volume of water that the Lake holds each year. Considering the size of the drainage area that contributes surface water to the Lake from precipitation events, the rate of water loss through the floor of the Lake, and the likely evapotranspiration rate during the warmer and drier parts of the year, any ceasing of groundwater pumping would be detrimental to the local ecology that depends on a wet lake under present conditions and mandates.

We will consider restoration alternatives that consider potential impacts to the groundwater augmentation to the Lake as a result of climatic variations or unforeseen groundwater issues (contamination, severe drought, etc.) and plan for these potential uncertainties and disruptions to the water supply.

Restoration alternatives will be evaluated in the draft CRP that includes variable lake levels that rely less on groundwater to augment the lake and achieve the restoration planning goals and objectives. The alternative lake level/ groundwater investigation will include the following alternatives: 1) continued pumping at existing levels mandated by the Bushy Lake Preservation Act; 2) no pumping and allowing the lake to dry with natural precipitation and overland flows; and 3) modified pumping and drawdown rates that maximize a sustainable and biodiverse ecosystem at Bushy Lake. In summary, the Bushy Lake restoration team (with input from stakeholders) will consider alternative lake levels with variable groundwater contributions from Cal Expo.

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Appendix A - Photographs

Visual images of restoration at Bushy Lake pre-and post- June 6, 2021, fire

Dr. Michelle Stevens and CSU Sacramento students planting native vegetation, Spring 2021 (Kathleen Colima).

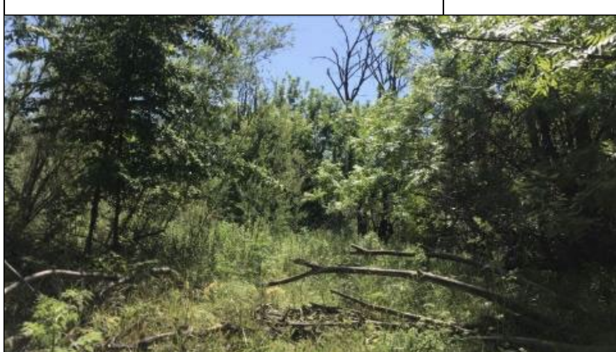
Same plots post fire (Kathleen Colima).

Same plots January 2022 (Alexandra von Ehrenkrook).

Dr. Michelle Stevens observing native plant plots, Spring 2020 (Jake Kincaid).

Same plots post fire (Michelle Stevens).

Same area of site January 2022 (Alexandra von Ehrenkrook).

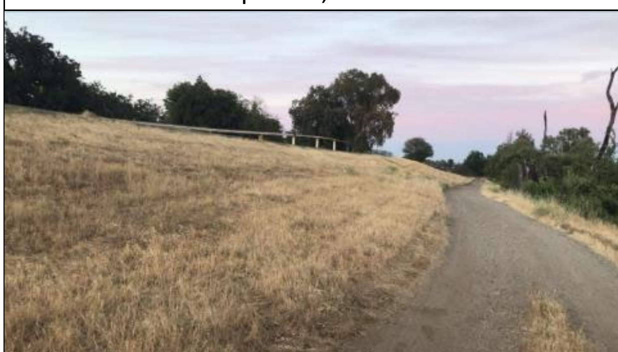


Basking turtle observation site 1 on May 1st, 2021.

Turtle observation site 1 post fire, pictured on June 8th, 2021 (Kathleen Colima).

Entrance to basking turtle observation site 2 on April 2nd, 2021.

Entrance to turtle observation site 2 to post fire, pictured June 8th, 2021 (Kathleen Colima).



The unburned levee, a critical turtle nesting area.

Burned levee post fire (Kathleen Colima).