Joseph D. Grant Park
Enhancement Viability of 13 Study Ponds
Hydrology and Habitat Assessment

Rattlesnake Pond, Courtesy of Balance Hydrologics

March 2020

Prepared for:
Santa Clara County Parks Department

Prepared by:
MIG, Inc.
San Jose, California
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Balance Hydrologics
Berkeley, California
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Santa Clara County, California

March 2020

Prepared for:
Santa Clara County Parks Department
298 Garden Hill Drive

Prepared by:

MIG, Inc.
2055 Junction Avenue, Suite 205
San Jose, California 95134
www.migcom.com
Project Manager: Taylor Peterson
(tpeterson@migcom.com)

Report Authors:
Taylor Peterson
Melinda Mohamed, M.S.
Jonathan Campbell, Ph.D

Balance Hydrologics
800 Bancroft Way, Suite 101
Berkeley, California 94710
www.balancehydro.com
Project Manager: Zan Rubin
(zrubin@balancehydro.com)

Report Authors:
Zan Rubin, PhD
Kealie Pretzlav, PhD
Eric Donaldson, P.G
Barry Hecht, C.E.G., C.Hg

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LIST OF ABBREVIATED TERMS

AVMA	American Veterinary Medical Association
Bd	*Batrachochytrium dendrobatidis*; Chytrid fungus
bullfrog	*Lithobates catesbeianus*; American bullfrog
CA LCP	California Landscape Conservation Partnership
Cal IPC	California Invasive Plant Council
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFGC	California Fish and Game Code
CNDDB	California Natural Diversity Database
CRLF	California red-legged frog
CTS	California tiger salamander
DPS	Distinct Population Segment
eDNA	environmental DNA
ET	Evapotranspiration
FESA	Federal Endangered Species Act
HWB	Hydroperiod Water Balance
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
Parks	Santa Clara County Parks and Recreation Department
Pond-IT	Pond Inundation and Timing
RES	red-eared slider
RWQCB	Regional Water Quality Control Board
SSC	Species of Special Concern
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WPT	western pond turtle

1. EXECUTIVE SUMMARY

The Santa Clara County Parks and Recreation Department's mission is to provide, protect and preserve regional parklands for the enjoyment, education and inspiration of this and future generations. As such, it is the intention of the Parks Department (Parks) to enhance or restore habitat for special-status species.

Parks has identified 13 ponds in Joseph D. Grant Park that appear suitable for restoration or modification to improve the habitat for target special-status species. While there are numerous named and unnamed aquatic features within the park, the primary focus of this report is the 13 identified "study ponds" that are the target of restoration and conservation efforts for California red-legged frog (*Rana draytonii*; CRLF) and California tiger salamander (*Ambystoma californiense*; CTS), although western pond turtle (*Actinemys marmorata*; WPT) is also considered. The ponds currently or previously have been occupied by CRLF and may also provide habitat for WPT, California newt (*Taricha torosa*), Pacific chorus frog (*Pseudacris regilla*), bullfrog (*Lithobates catesbeianus*), and western toad (*Anaxyrus boreas*). CTS has been documented in some of study ponds and has been documented often in other park ponds outside of the study pond network. Modifications recommended at the ponds could potentially be implemented by Parks staff with existing equipment.

The objectives of this study are to:

- Improve the understanding of the geologic and hydrologic characteristics of the 13 study ponds.
- Characterize the current and potential benefit of the study ponds to special-status species, specifically CRLF, CTS, and WPT.
- Recommend cost-efficient and effective pond modifications, including preliminary design recommendations, to improve habitat conditions for special-status species, including:
    - Methods to promote pond inundation long enough to support CRLF and CTS larval growth and metamorphosis;
    - Methods to make study ponds inhospitable habitat for non-native predators, including bullfrog and centrarchid fish; and
    - Pond management needs for CRLF, CTS, and WPT conservation.

This report includes the following:

- A year of hydrologic data collected at each of the 13 study ponds[1];
- An assessment of existing pond habitat;
- A compilation of existing target species location data;
- An assessment of historical pond hydrology and inferred projected impacts to pond hydrology as a result of anticipated climate change through the year 2100;
- Recommended pond modifications to improve habitat;

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[1] Hydrologic modeling results for individual ponds are incorporated throughout the body of this report, but are also available along with references in Appendix A, "Pond Hydrology Monitoring and Hydroperiod Modeling, Joseph D. Grant Park, Santa Clara County, CA" by Balance Hydrologics, 2020.

- An assessment of future modeled pond hydrology in response to the recommended modifications; and
- A summary of study limitations and next steps.

The report includes the following sections:

1.0 Executive Summary – a summary of the results

2.0 Project Location and Land Uses – a description of the project setting and park use

3.0 California Red-legged Frog, California Tiger Salamander and Western Pond Turtle – a summary of the life history, habitat requirements, and legal status of the target species

4.0 Threats – a description of the management concerns for the target species

5.0 Methods – a description of field data collection and analysis methods

6.0 Existing Conditions, Projected Future Conditions, and Recommended Actions for Each Study Pond – the study results for each pond

7.0 Study Limitations and Next Steps – important caveats to consider

8.0 References – a bibliography of the citations noted in the text

The study ponds have been ranked by modification priority, though not all study ponds are recommended for modification at this time. The priorities for pond modification are summarized in the table below, and full justification is described in the Results Section, 6.3 and in Table 6-1. Ponds rated in the ‘Critical’ category are recommended to be modified by 2030, ponds rated in the ‘High’ category to be modified by 2040, and ponds rated in the ‘Low’ category to be modified by 2050, dependent on funding and other logistical support. The focus species in Table 1-1 identifies the species that will most benefit from the recommended pond modification. CTS and CRLF can and do co-exist in park ponds, but overgrown vegetation can be detrimental to CTS, while it may sometimes benefit CRLF. The exception is that all species will benefit from bullfrog control and methods to control bullfrogs are identified for many ponds.

Table 1-1. Study Pond Priority for Modification

Pond	Priority	Justification for Modification	Potential Target Species and/or Life Stage Benefitted from Modification	Recommended Modification Action
Eagle Lake	Critical	• Pond has been a source of bullfrog in the past • In the past, the pond had dried for two years and bullfrog were eradicated, allowing CRLF to re-establish • Future ability to manage water levels to protect CRLF breeding success and continue to control bullfrog habitat availability is critical	CRLF	• Adaptive drain
Bass Lake	Critical	• Perennial source of bullfrog and centrarchid fish due to constant inundation • Potential instability of berm • High potential to provide habitat for target species if modified	CTS breeding; may provide refugia for CRLF	• Spillway lowering and/or adaptive drain, depending on final design refinements • Eventual restoration of creek once pond is inundated with sediment
Hotel	High	• Potential to eliminate nonnative species effects as CTS and bullfrog have both been documented to occur in this pond • Hydrology is projected to remain suitable for CTS to 2100	CTS, CRLF	• Predator management • Pond deepening to improve habitat for CRLF
Edwards	High	• CRLF and CTS have been documented in the past	CTS, CRLF	• Spillway lowering • Livestock management
Valentine	High	• Supports bullfrog breeding due to near constant inundation • Good chance of supporting target species with predator management primarily due to location	CTS	• Predator management • Spillway lowering

Pond	Priority	Justification for Modification	Potential Target Species and/or Life Stage Benefitted from Modification	Recommended Modification Action
Kamera	High	• One of the two ponds documented to support WPT • WPT would benefit from a basking substrate in the pond. • Also has supported CTS in the past • Requires bullfrog control	CTS, WPT	• Adaptive drain or flashboard weir • Predator management • Livestock management • Installation of WPT basking substrate
Deer Valley	High, with Additional Study	• Natural pond that has provided habitat for CRLF and CTS in the past, but is losing suitability for CRLF • However, modification to improve CRLF habitat may adversely affect the pond and remove CTS habitat	CTS, CRLF	• Pond deepening, pending further investigation of current species use in Deer Valley and nearby ponds, and a better understanding of the pond hydrology
Rattlesnake	High, with Additional Study	• Supports CRLF and CTS, but bullfrog has also been documented • Has the target hydroperiod to support CRLF and CTS breeding, and is projected to remain that way well into the future, therefore there is time to collect hydrologic data from existing data loggers and re-model the pond before re-designing it.	CRLF, CTS	• Predator management • Spillway lowering pending additional years of hydrologic monitoring and documentation of continued bullfrog use
Dairy	Low	• CTS and CRLF last recorded in 2010 • Not high-quality habitat due to short and shallow hydroperiods • Berm appears to have seepage and may require significant overhaul to achieve habitat targets	CTS or CRLF	• Berm modification

Pond	Priority	Justification for Modification	Potential Target Species and/or Life Stage Benefitted from Modification	Recommended Modification Action
Brush	Low	• CTS larvae were observed in 2006, though the pond's hydroperiods is not long enough for metamorphosis, therefore the pond may be a population sink • Pond may also provide winter refugia for some species and has a strategic location that benefits species dispersal to other ponds	CTS	• Additional species surveys • Possible complete pond removal, or modification to prevent inundation during target species' breeding season
Woodland	None	• None recommended due to high confidence in lack of sufficient water supply to enhance habitat for target species	--	--
Smith	None	• None recommended due to high confidence in lack of sufficient water supply to enhance habitat for target species	--	--
Valley Oak	None	• None recommended due to high confidence in lack of sufficient water supply to enhance habitat for target species	--	--

Recommended modification actions denoted in Table 1-1 are described below:

Adaptive Drain: This method allows opening of a drain annually at a target date (e.g. April 1 to 2050; then May 1 past 2050) to allow a natural, late-summer drying that would support CRLF but restrict bullfrog breeding success by drying before larval metamorphosis.

Pond Deepening: This method would provide late summer refugia in a deepened pool where it is currently lacking. Deepening can extend the duration of ponding by reducing pond surface area and therefore the volume of evaporation.

Spillway Lowering: Similar to the adaptive drain method, this would allow the pond to dry down in the fall and restrict bullfrog breeding success, though with less control and adaptability by managers.

Predator Management: In addition to controlling the water levels in the pond with the adaptive drain, spillway lowering, and flashboard weir methods to break the life cycle of non-native predators, predator management also includes CDFW approved methods of removing individual bullfrogs. These are described in more detail in section 6.3.1 of the report.

Livestock Management: Livestock includes cattle and pigs. Cattle are used to control vegetation cover in the park and are managed by ranchers across several pastures; the pigs are feral and are not controlled. Livestock management includes pond-specific measures such as seasonal fencing to protect CRLF and CTS eggs and metamorphs from being trampled where cattle use is high, and possibly exclusion fencing to ensure not all vegetation is removed in CRLF ponds. Livestock management also includes installing troughs where necessary once currently perennial ponds are modified to dry in fall (Eagle Lake and Bass Lake in particular).

Berm Modifications: Berm modification generally entails either adding or removing soil from the berm or rebuilding the berm with low-permeability soil (and filling any wildlife burrows) to reduce leakiness.

Acknowledgements

Balance Hydrologics and MIG staff kindly acknowledge Santa Clara County Parks staff, particularly Karen Cotter, Mason Hyland, Michael Rhoades, Jared Bond, and Jeremy Farr for their guidance and assistance with this project; as well as the Grant Park rangers and maintenance staff who offered critical support during the hydrology monitoring efforts.

We also kindly acknowledge each of the scientists that have contributed to the understanding of pond dynamics, and to the understanding of the life history and ecology of the target species, as this study relies on many decades of prior scientific work.

2. PROJECT LOCATION AND LAND USES

Joseph D. Grant County Park (park) is the largest Santa Clara County regional park, spanning 10,882 acres of the eastern foothills of Santa Clara Valley, west of the base of Mt. Hamilton (Figure 1. Project Location and Figure 2. Park Boundary). The park is characterized generally by sloping grasslands and oak woodland, interspersed with portions of dense, shrub habitat. Elevations within the park range from approximately 1,400 feet in the western portion closest to the San Francisco Bay, to 2,800 along the park's easternmost border.

Santa Clara County has a Mediterranean-type climate known for warm-to-hot and dry summers with cool-to-cold wet winters. In calendar year 2019, the Mount Hamilton area had approximately 38.6 inches of rain with 70 days of rain greater than or equal to 0.1 inch. The average annual temperature in 2017 was 54.1˚F, with an extreme high of 89.0˚F in August and an extreme low of 22.0˚F in February (NOAA 2019).

The park is located within the largely undeveloped and remote eastern section of Santa Clara County and is designated as "Regional Parks Existing" on the County's Land Use and Area Designations Map (Santa Clara County 2013). It is surrounded by open space as follows: land designated as Open Space Reserve for approximately 7.4 miles to the northern border of Santa Clara County, Other Public Open Lands and Open Space for approximately 13.5 miles to the eastern County border, Open Space Reserve for approximately 24.5 miles to the southern County border, and Other Public Open Lands to the west within Santa Clara County. The park is located approximately 1.6 miles east of the City of San Jose Urban Service Area Boundary at its nearest point.

The primary waterways connecting aquatic habitat within the park flow approximately southeast to northwest towards the San Francisco Bay (Figure 2. Park Boundary). Smith Creek flows along the eastern border, bisecting the small southeastern leg of the park. The Arroyo Aguague drains the northwestern portion of the park. Finally, San Felipe Creek drains the western and southwestern portion of the park. While there are numerous named and unnamed aquatic features within the park, the primary focus of this report is a group of 13 "study ponds" that are the target of restoration and conservation efforts for CRLF, CTS, and WPT (Figure 3. Study Ponds, Figure 4. Greater Park Pond Network). At times, the term "lake" is utilized to refer to an aquatic feature, although none of the waterbodies within the park are large.

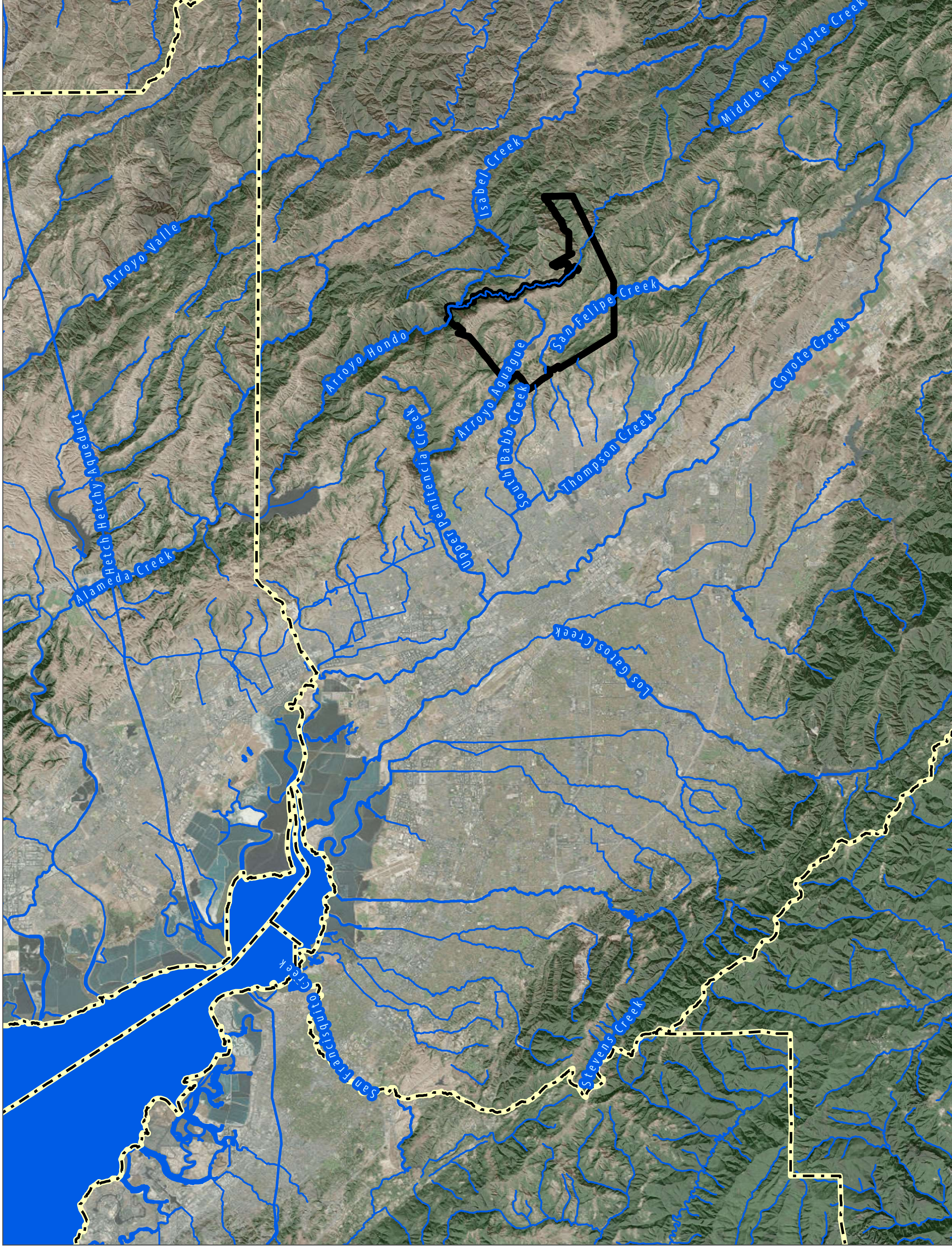
The study ponds are listed below in the order of discussion in the document and generally in the order of priority for management (see Figure 3):

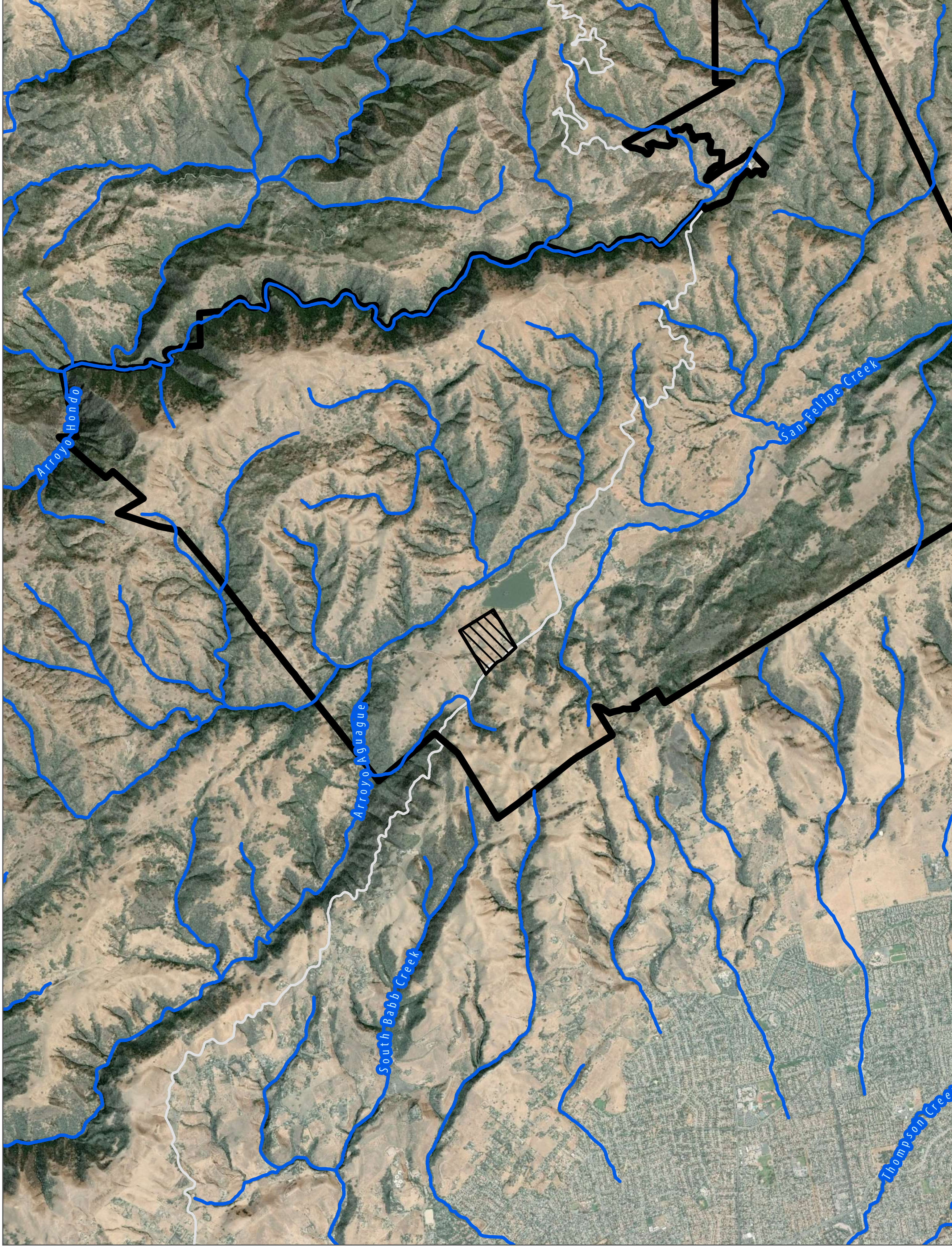
1. Eagle Lake
2. Bass Lake
3. Hotel Pond
4. Edwards Pond
5. Valentine Pond
6. Kamera Pond
7. Deer Valley Pond
8. Rattlesnake Pond

9. Dairy Pond
10. Brush Pond
11. Woodland Pond
12. Smith Pond
13. Valley Oak/Vernal Pond

The unnamed ponds and other water features shown in Figure 4 are numbered sequentially from 1 through 10, except for a water feature called an “unnamed plunge pool” within the California Natural Diversity Database (CNDDB) occurrence data and labeled accordingly “UPP1.” Other ponds on Figure 4 are named according to information listed in CNDDB occurrence data. The names given may not necessarily be official or even used by parks staff. Naming and location data (coordinates) are available from the CNDDB.

Grant Park is mapped as Critical Habitat for both CRLF and CTS. There are many ponds and water features in the park besides the 13 study ponds; those where the species have been documented to occur are shown on Figure 4. This report and associated site visits did not include a comprehensive survey of overall habitat quality for CRLF, CTS, or WPT within the entire park. However, based on pond availability, documented occurrence data, and the designation of the majority of the park as Critical Habitat for both CRLF and CTS, it is evident that Grant Park is crucial to the long term conservation of CRLF and CTS, and plays an important role in conservation of WPT as well. At the date of this report publication, WPT is not listed under the Federal Endangered Species Act (FESA) or the California Endangered Species Act (CESA) and therefore Critical Habitat has not been established for this species.


Middle Fork Coyote Creek
Isabel Creek
Arroyo Valle
San Felipe Creek
Arroyo Hondo
Coyote Creek
Arroyo Aguague
Hetch Hetchy Aqueduct
Upper Penitencia Creek
South Babb Creek
Thompson Creek
Alameda Creek
Los Gatos Creek
San Francisquito Creek
Stevens Creek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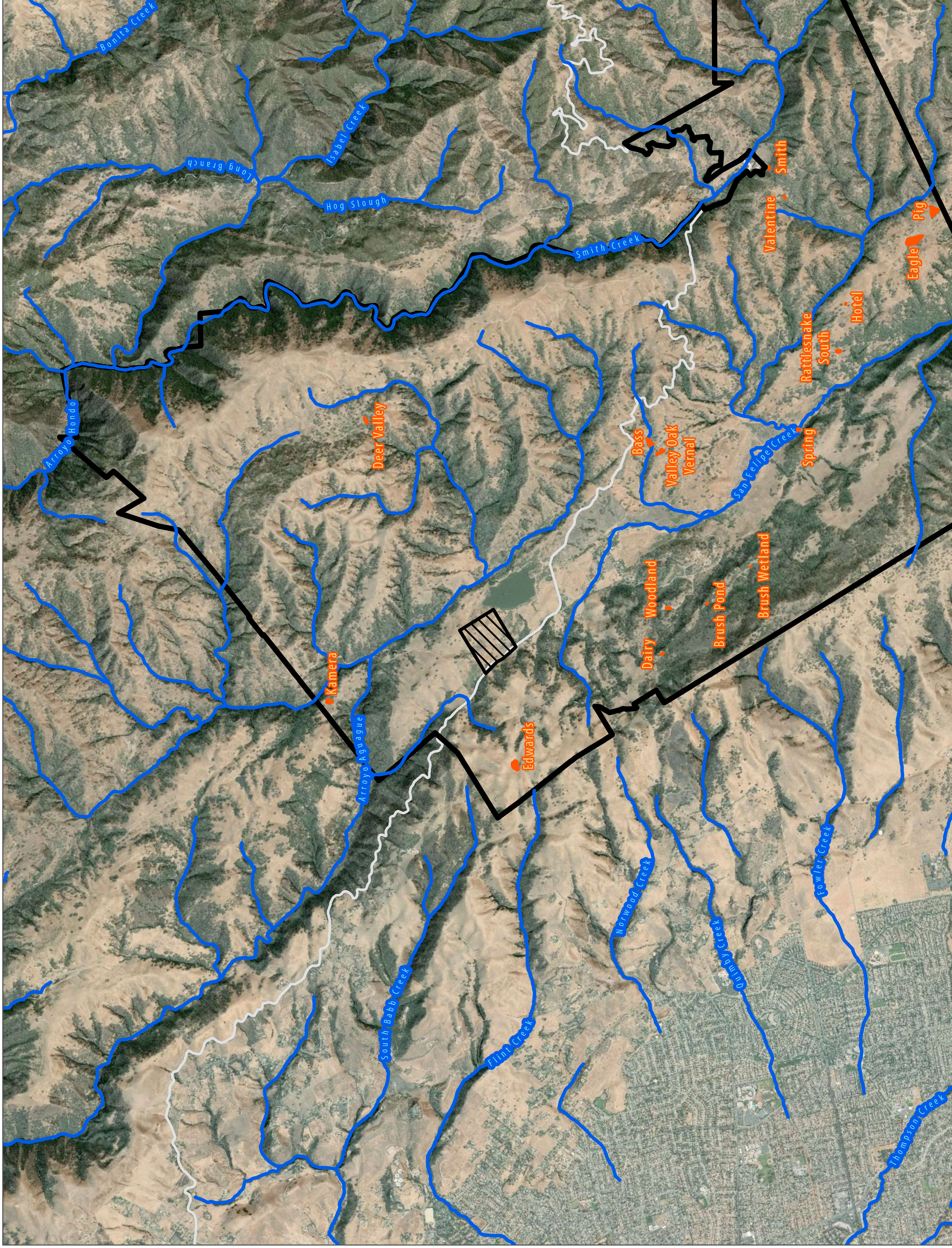
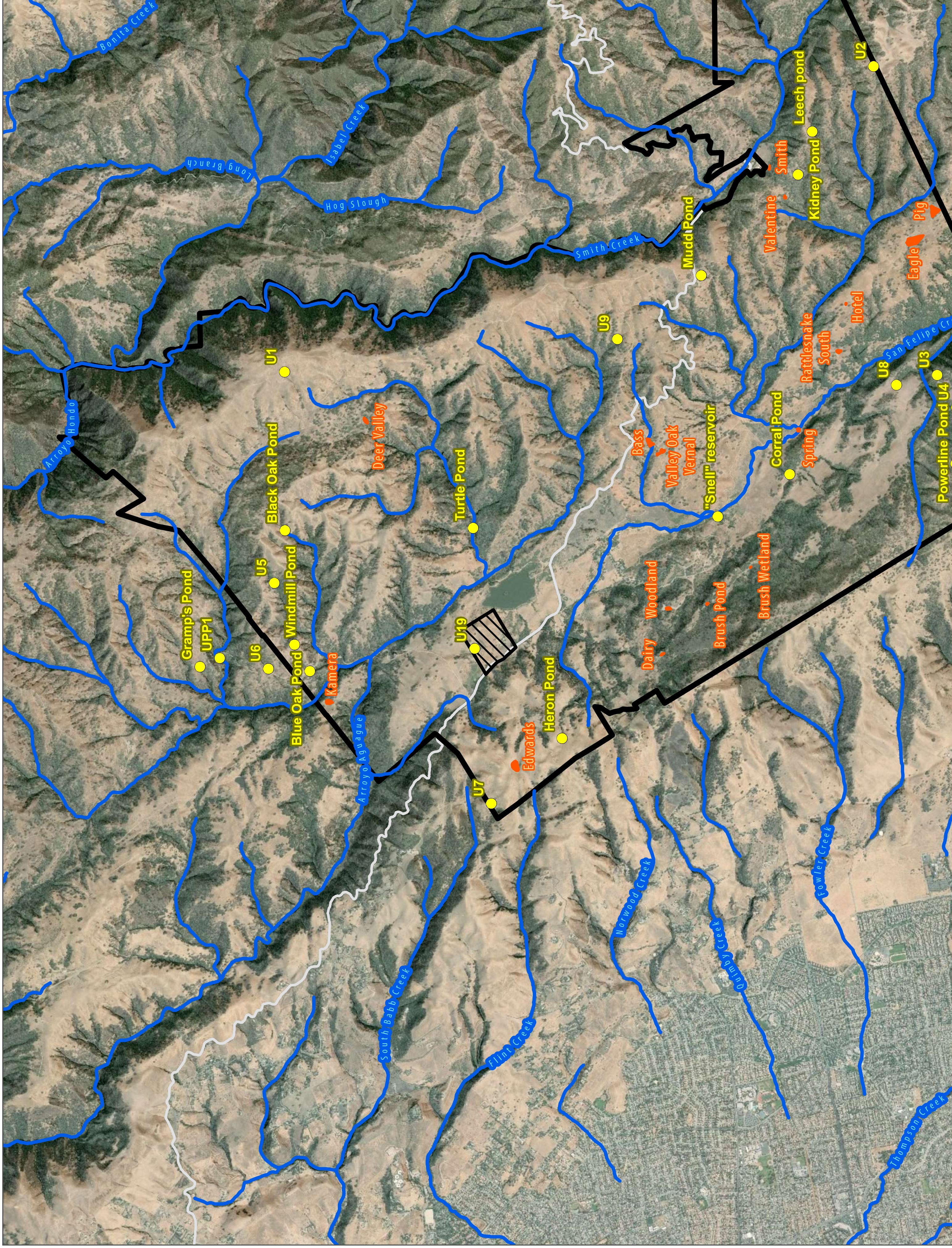
San Felipe Creek
Arroyo Aguague
South Babb Creek
Thompson Cree


Bonita Creek
Isabel Creek
Long Branch
Hog Slough
Smith Creek
Smith
Valentine
Pig
Eagle
Hotel
Rattlesnake
South
Arroyo Hondo
Deer Valley
Bass
Valley Oak
Vernal
Spring
San Felipe Creek
Woodland
Brush Wetland
Brush Pond
Dairy
Kamera
Edwards
Arroyo Aguague
Norwood Creek
Quimby Creek
Fowler Creek
South Babb Creek
Flint Creek
Thompson Creek


Bonita Creek
Isabel Creek
Long Branch
Hog Slough
Smith Creek
Arroyo Hondo
Arroyo Aguague
South Babb Creek
Flint Creek
Norwood Creek
Quimby Creek
Fowler Creek
Thompson Creek
San Felipe Cr
U1
U2
U3
U5
U6
U7
U8
U9
U19
Leech pond
Smith
Kidney Pond
Valentine
Pig
Eagle
Mudd Pond
Hotel
Rattlesnake
South
Deer Valley
Turtle Pond
Black Oak Pond
Bass
Valley Oak
Vernal
"Snell" reservoir
Corral Pond
Spring
Powerline Pond U4
Gramp's Pond
UPP1
Windmill Pond
Blue Oak Pond
Kamera
Woodland
Dairy
Brush Pond
Brush Wetland
Heron Pond
Edwards

3. CALIFORNIA RED-LEGGED FROG, CALIFORNIA TIGER SALAMANDER, AND WESTERN POND TURTLE

3.1 California Red-Legged Frog Life History and Legal Status

CRLF is the California state amphibian and is endemic to California and northern Baja California. Adults range from 1.75-5.25 inches long and have an identifying “dorsolateral” ridge (along each side of the body, striking through the eye). A precursor dorsolateral “line” is also used to identify CRLF larvae before metamorphosis. Despite the name, CRLF can range in color from a charismatic brick red to drab dark browns and grays, depending on location and prey consumed. In adult individuals without obvious red coloring, the lower abdomen and legs are often red on the frog’s underside, thus the moniker “red-legged.”

Unlike other ranids (frogs of the genus *Rana*), the larger CRLF is not a strong swimmer in waterbodies with higher currents. Consequently, CRLF frequent ponds, lakes, reservoirs, marshes, bogs, swamps, and slower-moving reaches of streams (i.e. intermittent streams that dry down in warmer months). CRLF have also been known to utilize artificially created waterbodies that mimic natural conditions, including stock ponds. CRLF are more likely to be found in waterbodies that dry seasonally, though this is believed to be due to the fact that a major predator, the American bullfrog, requires year-round inundation for extended larval growth periods and potential overwintering. CRLF are therefore not limited by physiology and behavior necessarily, and instead occur more often where their predators and predator-spread pathogens are absent (see Section 4).

CRLF breeding takes place from November-April, depending on the local climate, and lasts for approximately two weeks. Adult males arrive first to breeding sites to vocalize to potential mates. Following amplexus (physical joining of males and females that physically initiates hormonal breeding cycles), males externally fertilize a female’s egg mass. Females can lay from 300-4,000 eggs (with an average of 2,000) near the water’s surface and attached to aquatic plants. Eggs hatch into larvae in approximately four weeks. Larvae eat and mature for 4-7 months, however some populations have been known to overwinter (in the absence of limiting predators and/or other anthropogenic factors) before metamorphosing into juveniles. Tadpoles that metamorphose into larger juveniles are more likely to survive as adults and be reproductively successful, however overwintering is not a physiological necessity as it is often with bullfrog. CRLF larvae may be induced into early metamorphosis into very small metamorphs (juveniles) by pond shrinkage during a dry-down, whereas bullfrog larvae often cannot gain body mass needed for metamorphosis before ephemeral ponds dry.

Historically, the CRLF range extended from coastal areas in Mendocino County through Baja California, as well as east to the foothills of the Sierra Nevada near the Sacramento Valley and south, possibly into Kern County. While the CRLF range has shrunk in recent decades due to habitat loss, invasive predators, disease, and other anthropogenic factors, CRLF still exist in pockets throughout much of their historic range. CRLF was listed as “threatened” by the United States Fish and Wildlife Service (USFWS) under FESA in 1996, citing extirpation of CRLF from approximately 70% of its historic range. The USFWS published a recovery plan for CRLF (under former species name: *Rana aurora draytonii*) in 2002 with a goal to "reduce threats and improve the population status of the California red-legged frog sufficiently to warrant delisting" (USFWS 2002). In addition to the plan's goal of protecting occupied habitat, ensuring populations maintained and/or improved reproduction, and protecting California's metapopulation connectivity, the plan also calls for reintroduction of the species into areas where CRLF were previously extirpated and management of occupied watersheds, among other directives. CRLF are also categorized as a California Department of Fish and Wildlife (CDFW) Species of Special Concern (SSC). CRLF is a Covered Species under the Santa Clara County Habitat Conservation Plan (see section 3.4).

USFWS also designated Critical Habitat under FESA for CRLF, subsequently revising it in 2010. The Critical Habitat covers approximately 1,636,609 acres over 27 California counties. It extends throughout the majority of Joseph D. Grant County Park except for the easternmost portion (Figure 5. CRLF Critical Habitat) on the approximate boundary of the regional watershed. CRLF Critical Habitat within the park is drained by the Arroyo Aguague and San Felipe Creek, along with their tributaries. CRLF may disperse within these waterways during times of low flow or through residual pools after intermittent streams have stopped flowing. "Spill" events during times of high precipitation and/or flooding throughout the park may also disperse tadpoles and/or juveniles into more ephemeral waterbodies. Currently CRLF have been documented at Edwards, Deer Valley, Valley Oak, and Rattlesnake study ponds within the park, though CRLF have also been documented at many other waterbodies within the park that support the park's entire CRLF metapopulation (Table 6-1 and Figure 9).

Research has shown that there are three main components to viable CRLF habitat: 1) aquatic breeding habitat, 2) non-breeding aquatic habitat, and 3) available migration corridors (Fellers and Kleeman 2007). In a study of CRLF movement throughout the year at a site with similar variable habitat characteristics to the park (artificial and natural ponding habitat, with some permanent water sources and some ephemeral, interspersed with oak/woodland/riparian vegetation, etc.), Fellers and Kleeman (2007) found that adult CRLF stayed in and/or near their breeding habitat all year long. Other findings of the study included (from Fellers and Kleeman 2007):

- CRLF migration of >100 ft coincided with winter rains, although some frogs did not move until their breeding habitat was on the verge of drying
- In general, CRLF migrated toward breeding habitat at the beginning of heavy winter precipitation
- CRLF departed from their breeding habitat at varying times during the wet season, though some CRLF remained at permanent aquatic habitat all year long
- Some CRLF made small migrations during the dry season as their breeding sites dried up
- Females are more likely to leave breeding ponds than males, and are more likely to leave soon after breeding
- CRLF rely on wet conditions to migrate (rains during the wet season, fog and/or small precipitation events during the dry season)
- Vegetation and/or other habitat features that can contain moisture are preferred stopovers along migration routes between aquatic habitat (i.e. blackberry thickets [*Rubus* spp.], log jams, and root tangles were all documented in the Fellers and

Kleeman [2007] study), however CRLF have been known to cross grassland habitat as well, even at significant distances

- Riparian corridors may be used as migration corridors in times or areas of low flow
- CRLF seem to move in almost entirely linear paths when travelling from one aquatic habitat to another
- Most CRLF will not move beyond the nearest non-breeding aquatic habitat *if* they migrate from their breeding aquatic habitat at all

Aquatic habitat within the park includes a spectrum of breeding habitat from poor to favorable for CRLF breeding success. For example, aquatic habitat that is inundated year-round (e.g. Bass Lake) is characterized as poor breeding habitat for CRLF. This is due to a combination of factors: 1) aquatic habitat is inundated year-round, allowing bullfrog to complete its full life cycle and thereby increasing the population of bullfrog park-wide due to adult migration out to other aquatic habitat post-metamorphosis; 2) aquatic habitat that is inundated year-round also provides suitable breeding habitat for CRLF; however 3) both larval and adult bullfrog prey on larval and adult CRLF. In summary, this type of habitat is a “population sink” for CRLF because adults are drawn to expend reproductive energy and deposit egg masses in inundated habitat, however bullfrog predation will lead their population numbers to remain stagnate, if not decrease the total number. In contrast, high quality breeding habitat for CRLF would be suitable aquatic habitat (emergent vegetation, food resources, etc.) that is not colonized by bullfrog and is inundated at a depth and amount of time long enough to allow larval CRLF to complete their metamorphosis, potentially leading to metapopulation increases that would allow CRLF colonization of nearby unoccupied, but suitable aquatic habitat.

Due to the high availability of both breeding and non-breeding aquatic habitat as well as availability of low-flow stream channels at various times of year, much of the park provides suitable migration habitat for CRLF. Tall, dense, woody, and/or shrubby vegetation, such as the chamise-redshank chaparral and mixed chaparral, may impede CRLF migration, especially when the understory is particularly dense. Anthropogenic barriers may also impede CRLF migration, including heavily trafficked roads/trails, both by automobiles and pedestrians.

3.2 California Tiger Salamander Life History and Legal Status

CTS is an amphibian within the “mole salamander” group of burrow-dwelling salamanders, all belonging to the genus *Ambystoma*. CTS are endemic to California, with a historic range from the central California Coast into the Central Valley and north through Yolo County. Currently the species is limited to the northern Central Valley and the greater San Francisco Bay Area, with isolated pockets in Santa Barbara and Ventura counties. Within these geographic areas, CTS are separated into three genetically and geographically Distinct Population Segments (DPS). The CTS Sonoma County DPS and CTS Santa Barbara County DPS are both listed as “endangered” under FESA and are not discussed further within this report. CTS within the park are within the state and federal threatened Central California DPS. Adults can range from 5.9-8.5 inches long, have a short and round head with a blunt snout, and eyes that protrude from the sides of the head. When wet or shortly after emerging from water, adult CTS appear mostly shiny black and/or very dark brown with large yellow spots/segments. However, when observed during the dry season and/or following ground disturbance in their burrows, CTS may appear dusty in color under a thin layer of soil. Larval CTS are yellowish-gray, have short, rounded heads, a broad caudal fin, and large bushy gills.

CTS spends most of its life history on land, returning to vernal pools and other seasonal pools and ponds for breeding during the wet season. However, with human encroachment and related habitat destruction, CTS are now known to opportunistically use human-made stock ponds and other constructed impoundments that seasonally dry as breeding habitat, and that will also rarely use slower portions of streams. Rangeland that is grazed by cattle has become an important source of CTS habitat in recent decades and is a conservation “high priority” in many population areas (USFWS 2017).

This species uses mammal burrows in upland habitat when not breeding. It uses the burrows of California ground squirrels (*Otospermophilus beecheyi*) most often, but also other species’ burrows and/or deep soil crevices when available. Access to dark and cool soil at and/or near the water table is essential to CTS survival during the particularly hot summer months in many portions of the species range. During precipitation or other wet periods, adult CTS may emerge from burrows or crevices and feed in the surrounding grasslands. Like CRLF, CTS larvae are threatened by the invasive bullfrog larvae, bullfrog adults, and predatory fish (see Section 4).

Most CTS breeding takes place from December through January, depending on local climate, and may occur in one short burst or over the course of months, depending on local rainfall. In years without substantive rainfall and/or moisture, CTS breeding may not occur at all. Adult CTS reach sexual maturity after 4 or 5 years, though sub-adults may participate in the breeding migration as soon as their first year. Male CTS arrive at breeding ponds first and stay much longer than females. Following internal fertilization, females may lay up to 1,300 eggs either singly or in small groups attached to submerged vegetation, including leaf litter. Eggs hatch into larvae in approximately 10-14 days. Larvae metamorphose into juveniles in late spring to leave their natal ponds in search of upland burrow habitat.

The Central California DPS of CTS was listed as “threatened” by the USFWS under FESA in 2004 and Critical Habitat was designated in 2005. The most recent USFWS recovery plan was published in 2017 and states that the Central California DPS “faces a moderate degree of threat, has a high potential for recovery, and is in conflict with development projects, such as conversion to agriculture or urban development” (USFWS 2017). Recovery plan priorities include preventing further habitat loss and/or fragmentation to ensure a robust metapopulation that is resilient and can recover from threats including predators, disease, and climate change. CTS are also listed as threatened by CDFW under CESA. CTS is a covered species under the Santa Clara Valley Habitat Conservation Plan (see section 3.4 below).

USFWS designated Critical Habitat under FESA for the Central California DPS in 2005. The Critical Habitat covers approximately 199,109 acres over 19 California counties. CTS Central California DPS Critical Habitat, Unit 6, extends throughout much of Joseph D. Grant County park, apart from the northeastern corner, the southwestern corner, and a thin strip along the southern border of the park (Figure 6. CTS Critical Habitat). Critical Habitat within the park is drained by San Felipe Creek, Smith Creek, and possibly the Arroyo Aguague. While CTS rarely utilize flowing waters, adults may disperse through these watersheds following precipitation events and/or times of low-flow. Currently CTS have been documented at Kamera, Deer Valley, Brush Wetland, Rattlesnake, and Hotel study ponds within the park, though CTS have also been documented at many other waterbodies within the park. Based on pond availability, documented occurrence data, and the designation of the majority of the park as Critical Habitat for CTS, it is evident that Grant Park is crucial to the long term conservation of CTS.

Aquatic habitat within the park includes a spectrum of breeding habitat from poor to favorable for CTS breeding success. For example, aquatic habitat that is inundated year-round (e.g. Bass Lake) is characterized as poor breeding habitat for CTS. This is due to a combination of factors: 1) aquatic habitat is inundated year-round, allowing bullfrog to complete its full life cycle and thereby increasing the population of bullfrog park-wide due to adult migration out to other aquatic habitat post-metamorphosis; 2) aquatic habitat that is inundated year-round also provides suitable breeding habitat for CTS; however 3) both larval and adult bullfrog prey on larval and adult CTS. In summary, this type of habitat is a “population sink” for CTS because adults are drawn to expend reproductive energy and deposit egg masses in inundated habitat, however bullfrog predation will lead their population numbers to remain stagnate, if not decrease the total number. In contrast, high quality breeding habitat for CTS would be suitable aquatic habitat (suitable substrate for egg masses, suitable nearby burrows for adults in the non-breeding season, food resources, etc.) that is not colonized by bullfrog and is inundated at a depth and amount of time long enough to allow larval CTS to complete their metamorphosis, potentially leading to metapopulation increases that would allow CTS colonization of nearby unoccupied, but suitable aquatic habitat.

Salamanders in general are known as clumsy walkers, with migration impeded by minor barriers (i.e. height and density of vegetation, pitfalls, logs, curbs, etc.). While CTS migration patterns through vegetation have not been well-studied, their relatively large size would indicate that unimpeded grassland landscape with interspersed standing water is their preferred migration corridor habitat. Due to the proximity of aquatic habitat and upland habitat suitable for CTS, much of the park provides suitable migration habitat for CTS. Dense, woody, and/or shrubby vegetation such as red shank-chamise chaparral and mixed chaparral may impede CTS migration. Anthropogenic barriers may also impede CTS migration, including heavily trafficked roads/trails, both by automobiles and pedestrians.

3.3 Western Pond Turtle Life History and Legal Status

Western pond turtle (*Actinemys marmorata*; also *Emys marmorata*; WPT[2] ; also known as the Pacific pond turtle or northwestern pond turtle) is a small to medium-sized freshwater turtle and the only freshwater turtle native to California. WPT originally ranged from British Columbia south, through Washington, Oregon, California, parts of Nevada, and Baja California. The species is now presumed extirpated in British Columbia, and is locally extirpated, rare, or uncommon in states outside of California. Within California, the species can be locally common,

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but has experienced overall population declines due to habitat loss and competition from nonnative and invasive competitors, most frequently the red-eared slider (*Trachemys scripta elegans*; RES; See Section 4.3).

Adults WPT can range from 3.5-8.5 inches in shell length, with a plastron (underside of the shell) lacking hinges, and containing six pairs of cream or yellowish shields. Shields may either have large dark markings or be unmarked completely. Adults' legs and heads have black "freckling" and may appear cream or yellow overall. Adults are also sexually dimorphic, with males having a lighter throat typically with no markings, a flatter overall shell, and a concave plastron. In contrast, females typically show markings on their throats, have a taller relative shell, and have a flat or convex plastron compared with males. Hatchlings are approximately one (1) inch in shell length and have tails much longer relative to their overall size, often measuring almost as long as the shell itself.

WPT are diurnal (active during daylight) and primarily aquatic, though turtles leave waterbodies for breeding and migration due to changing water and/or food conditions. Though not consistent throughout their range, WPT are also known to hibernate and/or estivate during different times of the year. In colder portions of their range, they may hibernate by clustering into shallow areas of waterbodies (most often ponds), and slow their metabolic processes significantly, surviving from cloacal respiration instead of typical breathing above water. Other WPT may instead migrate into upland habitat near a waterbody, such as a ground squirrel burrow, and bury themselves for the winter. Hibernating WPT emerge in late winter and spring, as temperatures warm. In warmer portions of their range, WPT may also "hibernate" during times of extreme heat or drought by burying themselves in mud and again surviving through cloacal respiration, emerging when conditions improve. WPT require and are frequently observed basking on above-water portions of rocks or logs within waterbodies, though they quickly "slide" into the water if disturbed. WPT are omnivorous and most commonly inhabit lakes, ponds, marshes, rivers, streams, and irrigation ditches within woodland, grassland, and open forest complexes. Hatchling and juvenile WPT may be predated by certain fish, bullfrog, garter snakes, wading birds, and some mammals.

WPT mating occurs in April and May, though adults are not sexually mature until 8-10 years of age. Between April and August, female turtles climb out of waterbodies in search of nesting habitat near water margins, though individuals have been known to travel over 300 feet from water edges in search of suitable nesting substrate (Stebbins 2003). Nests are in small openings and nesting substrate can vary widely, though most notably the soil at a nesting site must be friable to about 4 inches in depth. Females typically lay clutches of 2-11 eggs, sometimes laying two clutches per year. Hatchlings emerge approximately 70-84 days after deposition, though they overwinter in their nests and emerge in search of aquatic habitat in March or April of the following year.

In 2004 the then California Department of Fish and Game (CDFG; now CDFW) Statewide Habitat Conservation Team identified WPT as a priority species, with directive for collection of more information and increasing conservation and management actions. The species is currently listed as a California SSC, with special consideration under the California Environmental Quality Act (CEQA), due to population declines that could qualify the species for future listing under FESA or CESA. The Center of Biological Diversity petitioned USFWS to list WPT under FESA in 2012. Following review, the USFWS found that the petition presented “substantial scientific or commercial information indicating that the petition action may be warranted for the western pond turtle (*Actinemys marmorata*) based on Factor A” and requested “information on the five listing factors under section 4(a)(1) of the Act [FESA] [3]” (USFWS 2015). State and Federal agencies are currently working with researchers, conservationists, and other stakeholders to understand the true extent of the species’ status within its current range. WPT is a Covered Species in the Santa Clara Valley Habitat Conservation Plan (see section 3.4).

The current status of breeding habitat available for WPT in the park is not well understood due to the lack of data regarding WPT and RES (see Section 4.4) distribution throughout the park. In general, year-round inundation of aquatic habitat with suitable basking substrate, availability of upland nesting habitat, and the absence of RES is preferable for WPT, though they are adaptive to changing environmental conditions. Currently WPT have been documented at Kamera and an unnamed and unmapped stock pond approximately 0.45 mile north of Bass Lake.

WPT are highly mobile and may easily disperse throughout the park in search of suitable aquatic and/or nesting habitat, though individuals will most likely remain permanently in certain waterbodies if conditions remain suitable. WPT are also omnivorous and therefore availability of specific food resources may not be a limiting factor. WPT can migrate up to 5 km (3.1 miles), but more often than not they migrate less than 3 km (1.9 miles; Holland 1994). WPT most often remains in a suitable network of aquatic habitat (e.g. a drainage and/or watershed) and only leave if conditions become highly unsuitable (e.g. in times of drought). WPT migration along creek corridors or other aquatic habitat is preferred. Due to the vast pond network suitable for WPT and the available creek courses, much of the park provides suitable breeding and migration habitat for WPT. Anthropogenic barriers are most likely to impede any WPT migration, including roads or trails that are heavily trafficked by both automobiles and pedestrians.

3.4 Target Species’ Coverage Under the Valley Plan

Grant Park is within the plan area of the Santa Clara Valley Habitat Conservation Plan and Natural Communities Conservation Plan (the Valley Plan). The USFWS and CDFW have issued permits to the signatories of the Valley Plan for take of certain species (called Covered Species), because the Valley Plan includes regional conservation measures that are designed to protect the species in perpetuity. Santa Clara County Parks is a signatory to the Valley Plan, and is both subject to the measures required in the plan to protect Covered Species (including all of the target species in this study) for its own projects, and owns and manages many of the lands that contribute to the reserve system that is the backbone of conservation for the Covered Species. The Valley Plan identifies specific measures to protect CRLF, CTS, and WPT and to mitigate for project impacts to these species. Therefore, the Parks Department has a permit to

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impact CRLF, CTS, and WPT with the implementation of specific measures identified in detail in the Valley Plan. Pond enhancement actions that benefit the species will further the Valley Plan conservation goal to “protect, enhance, and restore ecosystem integrity and functionality for threatened and endangered species.”

Table 3-1 CRLF, CTS, and WPT Habitat Requirements

Habitat Requirements or Features	California Red-Legged Frog	California Tiger Salamander	Western Pond Turtle
Pond Hydroperiod	• Inundation from December to September is optimal • Inundation from December to July would allow some successful breeding	• Inundation from December to July or August is optimal • Inundation from December through May would allow some successful breeding	• Inundation is preferred, especially in the breeding period in April or May, though shallow and drying habitat may also be utilized because eggs are laid in upland habitat
Pond Features	• Requires deeper water for escape and cover (at least 3 feet deep), as well as shallow water benches (10-20 inches) • Prefers dense emergent vegetation or shoreline riparian vegetation • An ideal pond would support 10-50 percent cover of woody vegetation along its margins, 25-75 percent cover of dense emergent vegetation, and at least 20 percent cover of relatively open shallow water benches. • Prefers above 60˚F, but common in temperatures roughly 50˚F. Summer temperatures above 80˚F.	• Prefers to have deep and shallow areas, although deep areas are not essential • Minimum depth to initiate breeding ranges from 2-4 feet • Ideally, ponds would mostly have 0-5 percent cover of emergent vegetation and typically have no more than 35 percent cover of emergent vegetation. • Can tolerate moderate to high turbidity (Median NTU of 35.5; range from 1.6 to 1,000 NTU)	• Basking sites on protruding woody debris, etc. • Deep water areas for escape cover • Shallow water areas for potential wintering and cover is optimal
Refugia	• Prefers ground squirrel and gopher burrows, vegetated seeps, overhanging banks, boulders, shrubs within 100 yards of breeding sites.	• Typically utilizes ground squirrel and pocket gopher burrows, but may also utilize leaf litter and deep soil cracks • Has been documented to migrate up to 1.5 miles between ponds and refugia	• May utilize adjacent ground squirrel burrows, muddy pond bottoms • Requires nearby bank vegetation "openings" with friable soil for nesting
Migration Barriers	• Can migrate relatively unhindered through grassland and oak savannah	• Can migrate relatively unhindered through grassland and oak savannahs.	• Roads, curbs, and other structures may prevent migration between ponds

	• Large expanses of closed-canopy forests and some shrubland may pose a barrier to migration • Roads, curbs, structures may prevent migration between ponds.	• Large expanses of closed-canopy forests and some shrubland may pose a barrier to migration • Roads, curbs, structures may prevent migration between ponds and between ponds and upland burrows.	and between ponds and upland burrows.
Dispersal Distance	• Maximum practical dispersal distance between ponds is less than 1.6 kilometers (1 mile) though they have been documented to travel up to 3.2 kilometers (2 miles).	• Exact distance is unknown, but CTS have been documented to move 1.5 miles between pond and upland refugia.	• Maximum practical dispersal distance between ponds is less than 1.6 kilometers (1 mile) though they have been documented to travel up to 3.2 kilometers (2 miles).
Prey	• Pacific tree frog, California mice, invertebrates	• Zooplankton, amphibian tadpoles, invertebrates	• Omnivorous
Predators	• Crayfish, skunks, raccoons, birds, bullfrogs, mosquitofish, and centrarchid fish (e.g., bass, perch, sunfish)	• Herons, garter snakes, predatory aquatic insects, large tadpoles, gamefish, crayfish, mosquitofish, bullfrogs	• Large wading birds, skunks, raccoons, snakes, bullfrogs, and centrarchid fish (e.g., bass, perch, sunfish)

4. THREATS

4.1 Bullfrog

The American bullfrog (*Lithobates catesbeianus*; bullfrog) is the largest North American frog with adults reaching 3.5-8 inches in length and identified by their characteristic large, noticeable tympanum (earlike membrane). Bullfrog is native to the central and eastern United States. It was first accidentally introduced to the western United States in the early 20th century via stocking lakes with fish. Further introductions of the species took place via the exotic pet trade and other unmanaged imports for a variety of purposes. They are now widespread throughout California but are notably absent from the Sierra Nevada.

Bullfrogs utilize a variety of both natural and artificial habitat, including, but not limited to, stormwater drains, lakes, ditches, ponds, marshes, streams, canals, and swamps. The breeding season lasts two to three months during the wet season, with males seeking mates throughout by their “chorus”. Females are highly selective, sometimes only mating one night throughout the entire season. Following amplexus, females may lay up to 20,000 eggs to await external fertilization in shallow waters near vegetation. This high number of eggs and subsequent tadpoles in addition to the size and voracious appetite of bullfrogs have extremely negative impacts on native amphibians. The required time for bullfrog metamorphosis is highly variable and sensitive to local climate—it may take only months in warmer climates while tadpoles have been documented to overwinter up to three years in colder climates (CDFW 2019).

Bullfrogs are notorious for eating “anything they can fit into their mouths” (CDFW 2019). For this reason, they are an enormous conservation issue to endemic Californian wildlife. Adult bullfrogs are a predator of CRLF, CTS, and WPT at various points of both species’ life histories. Larval bullfrogs eat algae, aquatic vegetation, and invertebrates, but also consume larvae and hatchlings of other herptiles, including CRLF, CTS, and WPT.

Bullfrog management is paramount to the conservation of CRLF, CTS, and WPT. Although there is some difference in opinion about which portion of the life cycle to target in eradication efforts, most conservationists agree that water draw-downs in the hotter summer months in artificially-created aquatic habitat are beneficial to keeping bullfrog numbers low while allowing higher numbers of CRLF and CTS to complete their metamorphosis.

Of the 13 study ponds, bullfrogs have been documented at Kamera Pond, Bass Lake, Rattlesnake Pond, Hotel Pond, Eagle Lake, and Valentine Pond. Bullfrog presence at these ponds indicates they are likely present in many other waterbodies within the park. Physical removal, water drawn-downs, and/or strict management of bullfrog within the entire park is an important component of restoration and conservation of CRLF and CTS breeding habitat, and to protect turtle hatchlings.

Bass Lake and the largest body of water within the park, Grant Lake, both provide recreational fishing for park visitors. While fish themselves are predators of CRLF, CTS, and WPT hatchlings, Bass Lake and Grant Lake also provide permanent sources of aquatic habitat that are ideal for bullfrog. Without management, Bass and Grant lakes will continue to provide a source of bullfrogs that can migrate out toward other habitat within the park.

4.2 Chytrid Fungus

The widespread use of bullfrog in the exotic wildlife trade as well as intentional and unintentional release of bullfrogs into naïve habitats has also led to the spread of the chytrid fungus (*Batrachochytrium dendrobatidis*; Bd). Bullfrogs are frequently carriers of the Bd, often survive the fungus's colonization of their semi-permeable skin, and they can spread Bd to other populations of amphibians. In contrast, California native amphibians including CRLF and CTS are highly susceptible to the fungus and have higher mortality rates after fungus colonization. Chytrid fungus is considered by many to be ubiquitously present in California south of the San Francisco Bay (Jeff Wilcox, Managing Ecologist of Sonoma Mountain Ranch, pers. comm.). However, some research indicates native amphibian populations may persist in the long-term if enough individuals survive initial fungus colonization (Briggs Lab 2019). Samples from a 2011 study of waterbodies at the park resulted in a positive Bd result at Kammerer and Toad ponds. While not within the group of study ponds, this positive chytrid result is assumed at all ponds within the park due to the inter-migration of amphibians. However, natural or managed seasonal dry-downs may also be an effective tool in fighting chytrid infection as the fungus requires water to survive and infect other individuals.

4.3 Centrarchid Fish

Bass Lake and Grant Lake both provide recreational fishing for park visitors and creeks through the Park provide fish habitat. However, fish of the family Centrarchidae (centrarchids; sunfishes) are predators of CRLF and CTS larvae, as well as WPT hatchlings.

Redear sunfish (*Lepomis microlophus*) are native to the Atlantic and Gulf of Mexico drainages from near the Savannah River in South Carolina south to the Nueces River in Texas (USFWS 2017). Through stocking of waterbodies for sportfishing and subsequent escapes into streams, redear sunfish are now known to occur throughout much of the western U.S. and throughout California. Smallmouth bass (*Micropterus dolomieu*) are native to the St Lawrence and Great Lake, Hudson Bay (Red River), and Mississippi River drainages, and Atlantic and Gulf of Mexico drainages from Virginia south to central Texas (USGS 2019). As with the redear sunfish, sportfish stocking and subsequent escapes have introduced the highly ecologically successful smallmouth bass to much of the western U.S. and it is widespread through California waterways. Both the redear sunfish and the smallmouth bass are known to occur within the San Felipe and Smith Creeks within the Park (UC Davis 2019) and are likely present within Bass and Grant lakes as well. Due to their predatory nature and the size of native amphibian larvae, waterbodies where these fish are present will likely continue to be population sinks for both CRLF and CTS without predator management.

4.4 Red-Eared Slider

RES are medium-sized turtles that are native in the Mississippi Valley, from Illinois south to the Gulf of Mexico, and from New Mexico east to West Virginia. Adults range in size from 3.5-14.5 inches in length and are typically identified by their red "ear," a short red stripe extending behind their eyes, although this may be less apparent in older individuals. Their shells are olive to brown in color with yellow stripes and their plastrons are typically yellow or brownish orange, with dark spots in the center of each scute (shell plate). RES have been and continuously are introduced globally primarily through the domestic pet trade. CDFW reports that "52 million individual sliders were exported from the United States to international markets between 1989 and 1997 (2020)." RES are introduced locally in California primarily through escape or owner release. They are now widespread throughout California and the western U.S., utilizing freshwater habitat including: streams, rivers, ponds, lakes, swamps, and marshes. They have also been documented at manmade aquatic habitats, including ditches, canals, and park lake and ponds. RES females become sexually mature at 2-5 years of age (much younger than WPT), and typically mate during the months of March through June. Females dig nests in small openings in friable soil from April to July, laying 1-3 clutches per year of 2-25 eggs. Hatchlings emerge approximately 75 days later, but will occasionally overwinter within nests and emerge in the spring.

Quicker sexual maturity, more frequent and larger clutch sizes, larger adult size (and subsequent larger caloric demand and space occupied at basking sites), and very general habitat preference leads RES to typically outcompete the native WPT within its range. This out-competition further exacerbates the already steady loss of WPT's native habitat along the west coast of the U.S. RES are also disease vectors, spreading bacteria including *Salmonella* spp. to native wildlife, including WPT.

RES are not currently well-managed outside of their native range. Within California, a valid sportfishing license is required to "take" RES, though there is no limit on individuals taken. CDFW generally advises those that wish to take RES for domestic purposes either keep individuals in captivity for the entirety of their lifetime, or "give it to a friend or contact your local shelter or reptile rescue organization" (2020). According to the California Fish and Game Code (CFGC) Section 6400, "it is unlawful to place, plant, or cause to be placed or planted, in any waters of this State, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the State, without first submitting it for inspection to, and securing the written permission of, the department." CDFW encourages observers of RES to report sightings to the CDFW Invasive Species Program. Removal efforts are encouraged by CDFW to adhere to the American Veterinary Medical Association's (AVMA) Guidelines for Euthanasia of Animals.

In some studies where RES were trapped and euthanized from WPT co-occupied waterbodies, average size of remaining WPT increased, potentially increasing the turtles reproductive and survival success as well (Lambert et al 2019).

There are several documented iNaturalist occurrences of RES within Grant County Park, most clustered around Bass Lake (2020).

4.5 Water Quality

Studies of water quality impacts on CRLF and CTS indicates that both species have a generally wide tolerance of water quality impacts, however CTS is slightly more adapted to lowered water quality, particularly elevated turbidity (Bobzien and DiDonato 2007). Livestock presence can increase pond turbidity, damage vegetation that stabilizes pond banks, and increase nitrogen. Cattle grazing as a form of vegetation management takes place in the vicinity of several study ponds within the park. In addition, feral pigs or wild boar (*Sus scrofa*) have been observed at the park, based on several documented occurrences in iNaturalist (2020). However, although cattle and feral pig presence may impact water quality their presence does not exclude the presence of CRLF, CTS, or WPT at any particular pond.

In general, the science of water quality impacts of domestic (cattle) and feral livestock (pigs) on both habitat and water quality is not well quantified. Cattle have been found to be beneficial in some Californian ecosystems, perhaps even aiding in recovering endangered native crustaceans (Marty 2004). In contrast, a study by Schmutzer et al found that cattle grazing led to harmful nitrogen loads and an overall decrease in water quality that resulted in decreased abundance and biodiversity in wetlands grazed by cattle (2008).

The ecology of feral pigs on a landscape is generally more destructive than that of domestic cattle. Defecation, wallowing, and rooting behaviors can decrease water quality via lowered dissolved oxygen, increased nitrogen, and increased phosphorus, far beyond typical effects of domestic cattle.

In the park, evidence of livestock impacts were observed at Edwards Pond, Kamera Pond, Bass Lake, Rattlesnake Pond, Eagle Lake and Valentine Pond during the field survey.

For better conservation and restoration results, cattle grazing and feral pigs may need to be managed during the CRLF, CTS, and WPT breeding seasons, perhaps with temporary fencing. Nests of WPT in late spring and early summer may be particularly vulnerable to physical impacts of cattle grazing and feral pig rooting. These issues would need to be regularly assessed on a pond-specific basis and recommended measures may change annually.

4.6 Climate Change

Climate change is generally expected to have a negative impact on endangered and threatened species' conservation efforts due to the relatively short amount of time species have to adapt to rapidly changing environmental conditions. Climate change is likely to lead to increasingly erratic precipitation and temperature patterns throughout the state and region. Years of low rain and/or drought may prevent multiple study ponds from inundating to depths required by CRLF, CTS, and WPT to complete their life cycles or drying some waterbodies completely. Or, flooding in seasons of higher-than-average rainfall may create inundation periods in some ponds that are suitable for bullfrog and/or other invasive species that prey on the target species. Increased flows and/or flooding through ephemeral drainages may also significantly alter migratory patterns and restrict movement between sub-populations. Increasing accessibility to migration corridors and strict predator control will become increasingly important conservation measures as climate change progresses. With regard to the study ponds, the most significant climate change impact will be increasing evapotranspiration, since they hold relatively little water, with large area-to-depth ratios. The evapotranspiration in summer months has the most drastic effect on pond hydroperiods.

The California Landscape Conservation Partnership (CA LCP) conducted species climate change vulnerability assessment for CRLF, CTS, and general "wetland dependent reptiles" (among other species) and published them in 2017. Key climate factors cited as heavily impacting the species' status included precipitation timing, precipitation amount, drought, air and water temperature, and storms. CRLF was determined to have a low-moderate vulnerability score, with precipitation changes relating to climate change influencing its success the most. Non-climate factors including invasive predators (bullfrog and centrarchids, see section 3.4) probably more heavily influence the conservation status of CRLF (CA LCP 2017). CTS was determined to have a moderate-high vulnerability score, with climate factors including precipitation timing and amount, drought, air and water temperature, and storms heavily impacting their conservation status. However, non-climate factors including development, rangeland practices (see section 3.4.5), invasive species, general land use change, and roads and highways were also cited as influencing CTS conservation. Wetland-dependent reptiles (including western pond turtles) were determined to have a moderate vulnerability score, with precipitation and disturbance via disease and flooding influencing their adaptability most. Non-climate factors including agricultural and rangeland practices and invasive species (see Section 3.4) influenced their conservation as well.

5. METHODS

5.1 Pond Field Assessment

MIG biologists Laura Moran and Melinda Mohamed, accompanied by Karen Cotter of parks staff, conducted an assessment of study ponds on December 13, 2018. Temperature at the park ranged from 40-64˚F during the day, skies were clear, and winds were generally calm, ranging from approximately 0-15 miles per hour (mph).

Pond parameters recorded included:

- Turbidity: Turbidity measurements were taken using a Hach® 2100Q Portable Turbidimeter. Three (3) 10mL water samples were taken from a single study pond, processed using the turbidimeter, recorded, and averaged to determine the final turbidity measurements, recorded in Nephelometric Turbidity Units (NTU). Glass vials were cleaned between pond measurements using a 60% ethanol solution and were dried using Kimwipes (available from Kimberly-Clark Professional) to prevent measurable lint on the inside of the vials[4].
- Water Temperature: Water temperature was recorded using a Hanna® Instruments HI98127 Waterproof pH Tester[5].
- Water pH: Water pH was recorded using a Hanna® Instruments HI98127 Waterproof pH Tester.
- Emergent Vegetative Cover: measured in approximate percentage of total inundated surface area of the pond.
- Open Water: measured in reference to approximate full-inundation levels (high water)
- Pond Structure: a general characterization of the shape of the water feature and bank slope
- Riparian/Woody Vegetation Present: a general characterization of woody vegetation present along pond banks
- Upland Dispersal Habitat: a general characterization of habitat immediately surrounding a pond, including habitat type (e.g. nonnative annual grassland, oak woodland, etc.)
- Type of Upland Dispersal Habitat: a general characterization of positive or negative attributes of the habitat surrounding a pond, in relation to CRLF and CTS dispersal (e.g. small mammal burrows for CTS, leaf litter for CRLF upland aestivation, etc.)
- Barrier to Movement: a general characterization of any major physical impediments to either CRLF or CTS dispersal between park ponds, including, but not limited to, topography surrounding the pond, spillway issues, and dense vegetation

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[4] Turbidity was too high to be measured via the meter (using light penetration) at Valley Oak or Rattlesnake ponds. No turbidity measurement was taken at Edwards, Kamera, Dairy, Brush, Woodland, or Smith ponds due to either lack of access or dry conditions

[5] No pH was recorded in Edwards, Kamera, Dairy, Brush, Woodland, or Smith ponds due to either lack of access or dry conditions

5.2 Hydrologic Study

The following describes Balance Hydrologics, Inc. (Balance) technical approach used to characterize the hydroperiod, and climate change response across the 13 study ponds within the park. The hydrology report prepared after one year of hydrologic pond monitoring and water balance monitoring is attached as Appendix A. All 13 ponds were instrumented with water-level recorders and a topographic survey was performed at each to develop stage-storage relationships. Each pond was grouped into a geomorphic genetic classification based on existing literature and reconnaissance site survey visits. The monitoring calibration data collected from December 2016 to May 2018 were supplemented with measurements of pond extent using historical aerial imagery in Google Earth®. A custom-developed and batch-run hydroperiod water balance model was constructed for each study pond to characterize the relative contributions of various hydrologic fluxes which generates monthly estimates of pond water-surface elevations throughout the historical record. The model was then extended into the future using climate projections and each pond hydroperiod was evaluated for climate resiliency. The modeling at Joseph D. Grant ponds follows the approach developed by Balance for other parks in Santa Clara County.

5.3 Water Balance Modeling

The Pond Inundation and Timing (Pond-IT) model was developed by Balance to evaluate the historical water-surface elevation of each pond. The main purpose of the Pond-IT model is to infer the dry-down timing across a range of hydrologic years and extend the model into the future using climate projections. To meet this objective, a monthly timestep was used as opposed to a daily timestep, which required more data and more computation time. In addition, more climate projection datasets are available at the monthly timestep. For the model to be integrated seamlessly between historical and projected time periods, we used of the same (monthly) timestep for both datasets. The model was constructed in Python, which is an interpreted high-level programming language with many general-purpose programming tools. Open-source Python libraries are used for this model (e.g., numpy, pandas) to take advantage of data analysis tools which can easily manipulate numerical tables and time series dataset. All Python packages used in this model are open source and free to use.

Specific methods regarding the model input data and the model calibration data are available in the attached Pond Hydrology Monitoring and Hydroperiod Modeling Report (Balance 2018; Appendix A).

In general, the following parameters were included in the model input modules:

1. Direct Rainfall
2. Watershed Runoff
3. Groundwater Input
    a. Pond Fringe Groundwater Input
    b. Shallow Bedrock Fracture Groundwater Input
    c. Deep Fault Groundwater Input

The following parameters were included in the model output modules:

1. Evapotranspiration (ET)
2. Spillway (tracking particularly wet months where pond elevation exceeded pond spillway elevation)
3. Groundwater Outputs
   a. Soil Moisture or ET Groundwater Output
   b. Leaky Pond Groundwater Output

5.4 Species Occurrence Data

CRLF, CTS, and WPT occurrence information for the park was compiled using CDFW's CNDDB. CNDDB search results for both CRLF and CTS were used to map and locate occupied aquatic features with the entirety of the park, providing a baseline understanding of both species' metapopulation within the park (Figure 4. Greater Park Pond Network, Figure 9. CRLF Pond Status, and Figure 10, CTS Pond Status). Due to the park's public access and size, scientists have been able to conduct studies relating to the health and ecological status of both CRLF and CTS. The following is a brief description of the researchers who contributed the most CRLF and CTS species information within the park to CNDDB and their research goals. Pond-specific occurrence information relating to their studies can be viewed via CNDDB.

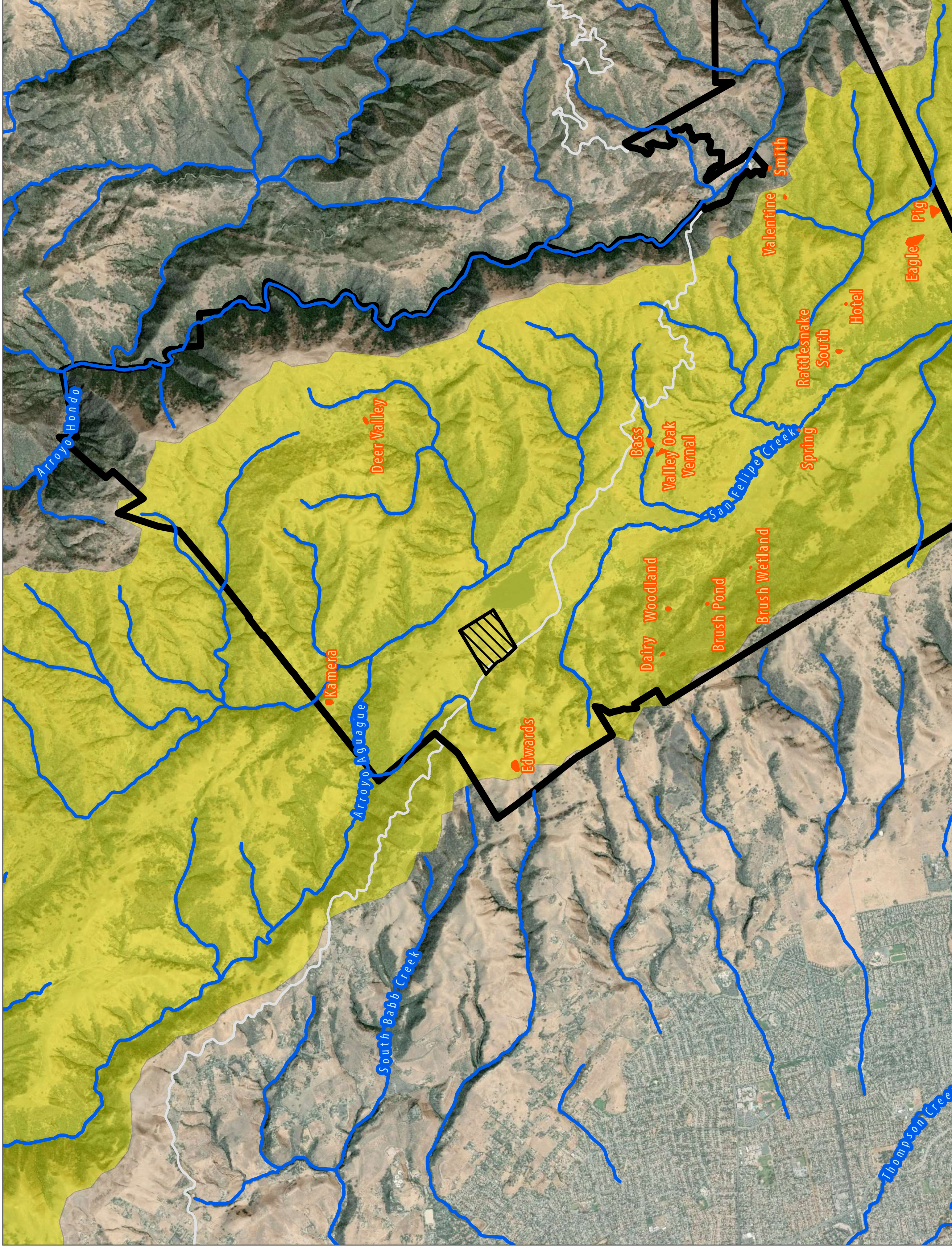
> Dr. Brad Shaffer studied hybridization between CTS and the nonnative barred tiger salamander (*Ambystoma mavortium*) and has surveyed multiple park ponds, including some study ponds, during his time at UC Davis.
>
> Dr. Gretchen Padgett-Flohr studies Bd (see section 4.2) infection in both CRLF and CTS and has collected both species from multiple park ponds.
>
> Dr. Pieter Johnson studies amphibian invasive and disease ecology and has surveyed multiple park ponds while working at the University of Colorado.

These studies all provide incidental reports of CTS and CRLF presence, and do not represent a systematic study of species presence in the park.

Data on WPT presence was compiled only from the CNDDB.

5.5 Critical Habitat

In addition to collecting species occurrence data, methods included researching Critical Habitat designated by the USFWS for CRLF and CTS. Significant portions of the park are designated as Critical Habitat for CRLF (Figure 5) and CTS (Figure 6). Of the study ponds, all but Smith Pond is within CRLF Critical Habitat, and four of the 13 study ponds are in CTS Critical Habitat.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Brush Wetland
Kamera
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Edwards
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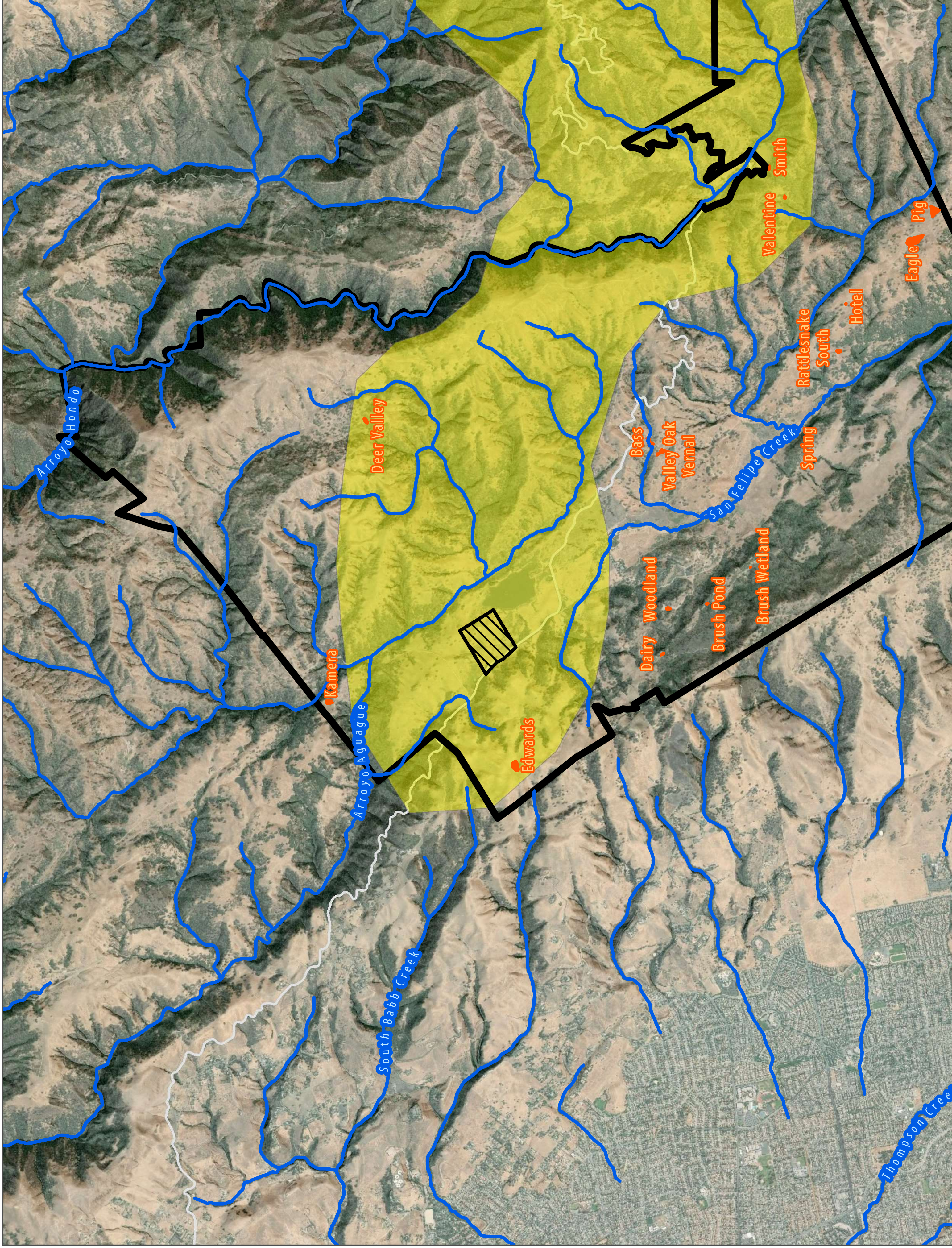
Thompson Cree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Arroyo Aguague
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6. EXISTING CONDITIONS, PROJECTED FUTURE CONDITIONS, AND RECOMMENDED ACTIONS FOR EACH STUDY POND

6.1 Setting

This report focuses on 13 ponds in a network of ponds that support CRLF and/or CTS across the park (Figure 3. Study Ponds). It assesses current conditions and recommends actions for improving the habitat for the target species, as appropriate. Not every pond is recommended to be modified, usually because of existing physical conditions or because there is not sufficient surface and groundwater flow to support target ponding duration. Alterations to the hydroperiod are focused on improving resiliency to climate change and controlling non-native bullfrog and fish predation. Photographs of each pond are provided in Appendix B.

The park contains a mosaic of vegetation types, as shown on Figure 7 (Pond Complexes). The primary drainages are San Felipe Creek that drains to the south and Arroyo Aguague that flows to the north (Figure 3). Smith Creek and Arroyo Hondo are located on the east side of the park. Most of the ponds have annual grassland/oak woodland settings, with the exception of Dairy, Woodland, and Brush that are set in denser woody vegetation such as chamise and coyote brush.

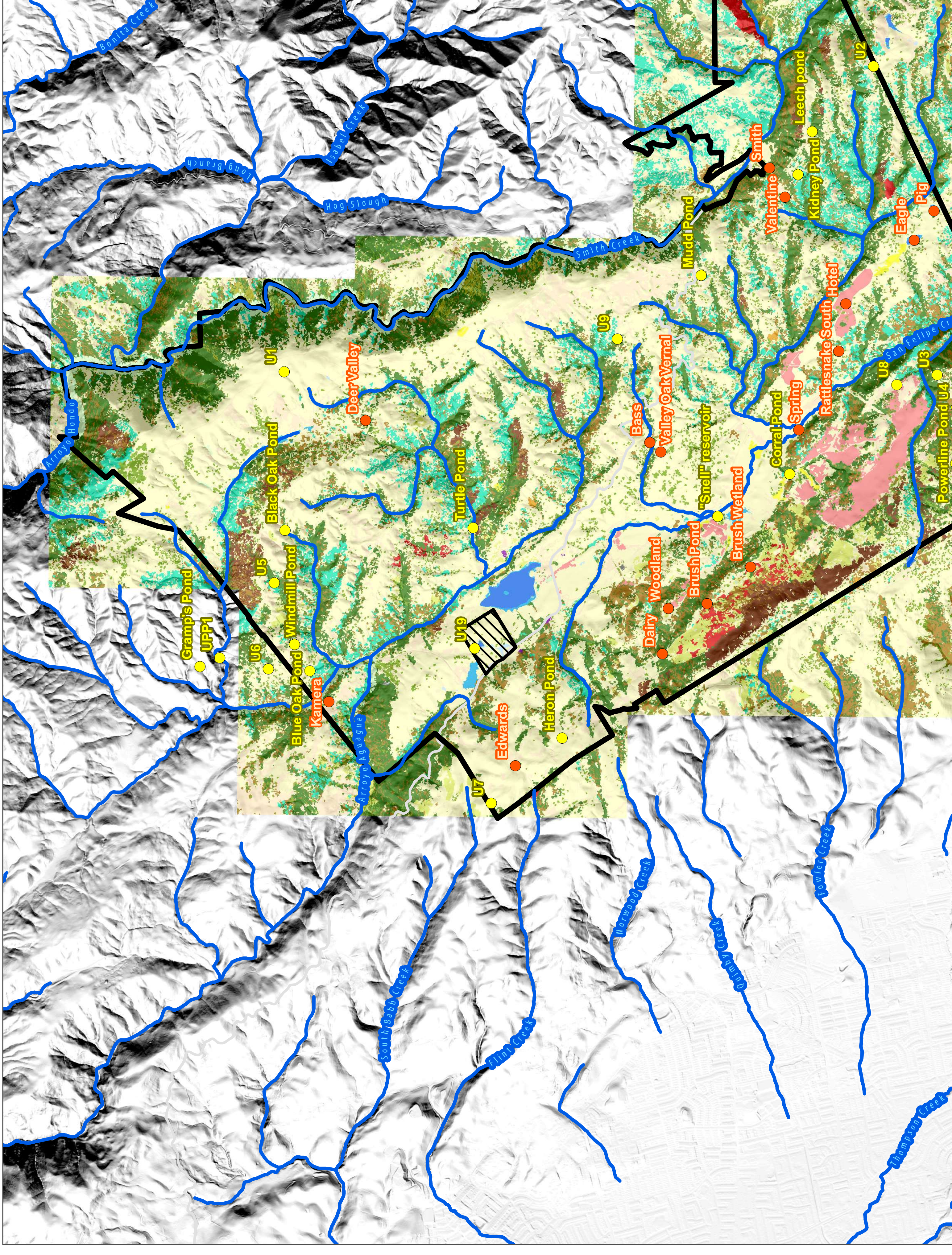
Activities in the park include public recreation and land management actions such as road and trail maintenance, brush mowing, invasive weed control, and prescribed burns. The Parks Department manages vegetation in Grant Park with a combination of cattle grazing, prescribed burning, and mowing. For reference, pastures and troughs are shown on Figure 8. Areas slated for prescribed burns (Figure 11) do not overlap the study ponds. Bass Pond may be used for fishing, and Woodland is adjacent to a campground. Otherwise the ponds are generally not associated with active recreational use, although most are near a road or trail and contribute to the passive enjoyment of the park and may be used by equestrians to water their horses.

6.2 Pond Hydrology-Existing Pond Configurations 1980-2100

Balance Hydrologics modeled pond inundation based on data collected for each pond and factoring in climate change projections. Graphs show the percent of the time each pond holds water each decade between 1980 and 2100, and what percent of the time each pond holds at least two feet of water. Results are provided for each pond in section 6.3.2.

The anticipated warming effects of climate change reduce the probability of inundation in all study ponds into the future, though some ponds are more heavily impacted than others. Additional pond dynamics such as sedimentation are not considered in the pond modelling, though changes are considered to be modest in all ponds except for Bass Lake and Smith Pond (which are actively filling with sediment, but at unknown rates). If needed, topographic surveys conducted as part of this survey can be compared to future surveys to assess sedimentation rates.

The target species do not successfully breed without enough water for a long enough period. While there are other important habitat considerations, such as vegetative cover, availability of refugia, and non-native species management, this analysis first examines the hydrologic regimes of the ponds. The basic hydrologic parameters used to determine whether a pond can provide breeding habitat for both CRLF and CTS is that it fills to a 2-foot depth from December through August at least 50% of the years over the next 80 years (to 2100), since both species are adapted to periods of drought. Although CTS can tolerate shallower depths, the two-foot parameter is used as a benchmark because it provides adequate breeding habitat for both species. Drying out in the fall helps with non-native species management.



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Smith Creek
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San Felipe Cr
Arroyo Aguague
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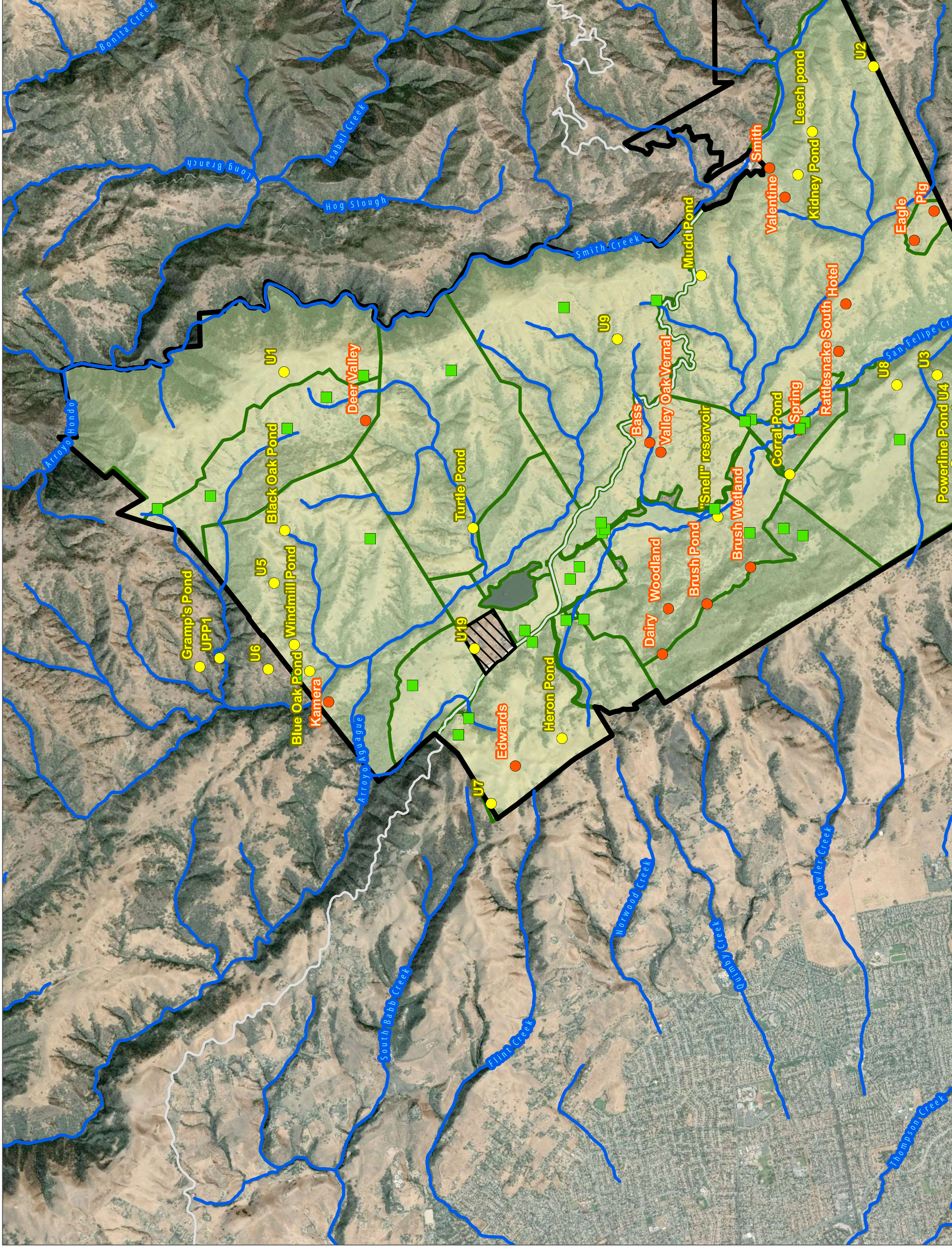
Kidney Pond
Valentine
Mudd Pond
Eagle
Pig
Hotel
Rattlesnake South
U9
U1
Deer Valley
Bass
Valley Oak Vernal
"Snell" reservoir
Corral Pond
Spring
U8
U3
Powerline Pond U4
Turtle Pond
Black Oak Pond
U5
Windmill Pond
Gramp's Pond
UPP1
U6
Blue Oak Pond
Kamera
U19
Heron Pond
Edwards
U7
Dairy
Woodland
BrushPond
Brush Wetland
Norwood Creek
Quimby Creek
Fowler Creek
South Babb Creek
Flint Creek
Thompson Creek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Powerline Pond U4
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Corral Pond
Spring
"Snell" reservoir
Brush Wetland
Black Oak Pond
Turtle Pond
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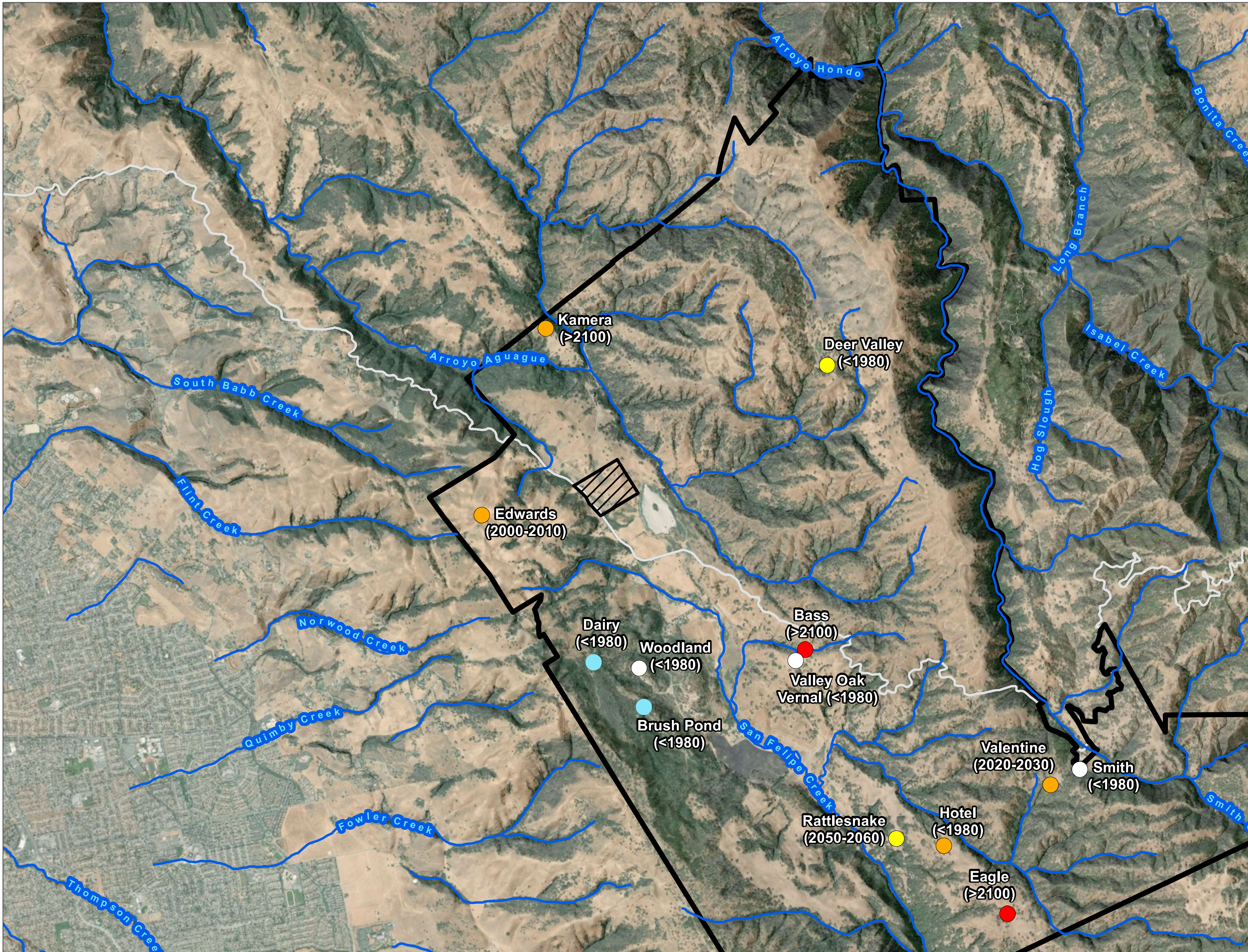
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Arroyo Aguague
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Woodland
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Bass
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Valley Oak
Vernal (<1980)
Brush Pond
(<1980)
Quimby Creek
San Felipe Creek
Valentine
(2020-2030)
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Rattlesnake
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Hotel
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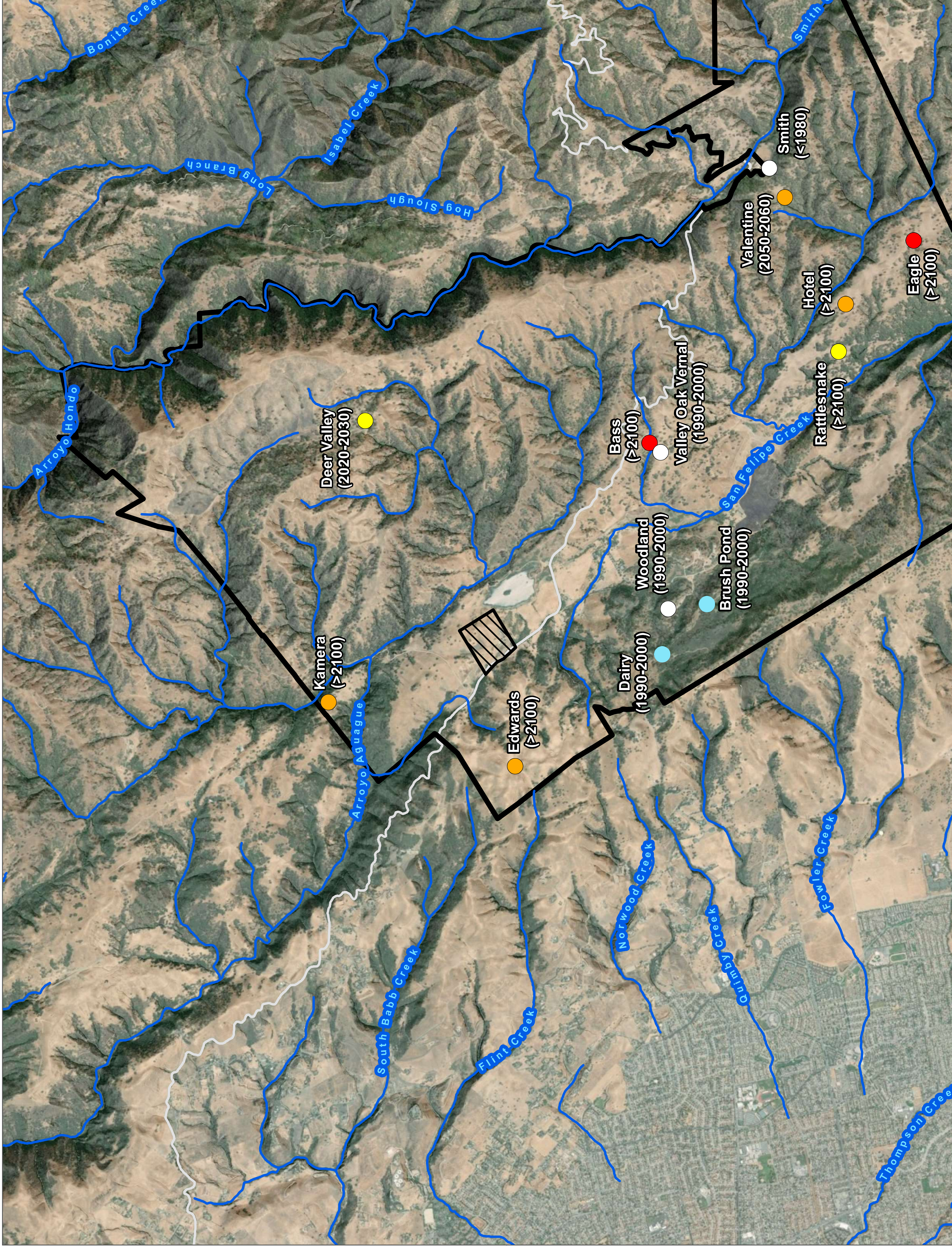
Eagle
(>2100)
Thompson Creek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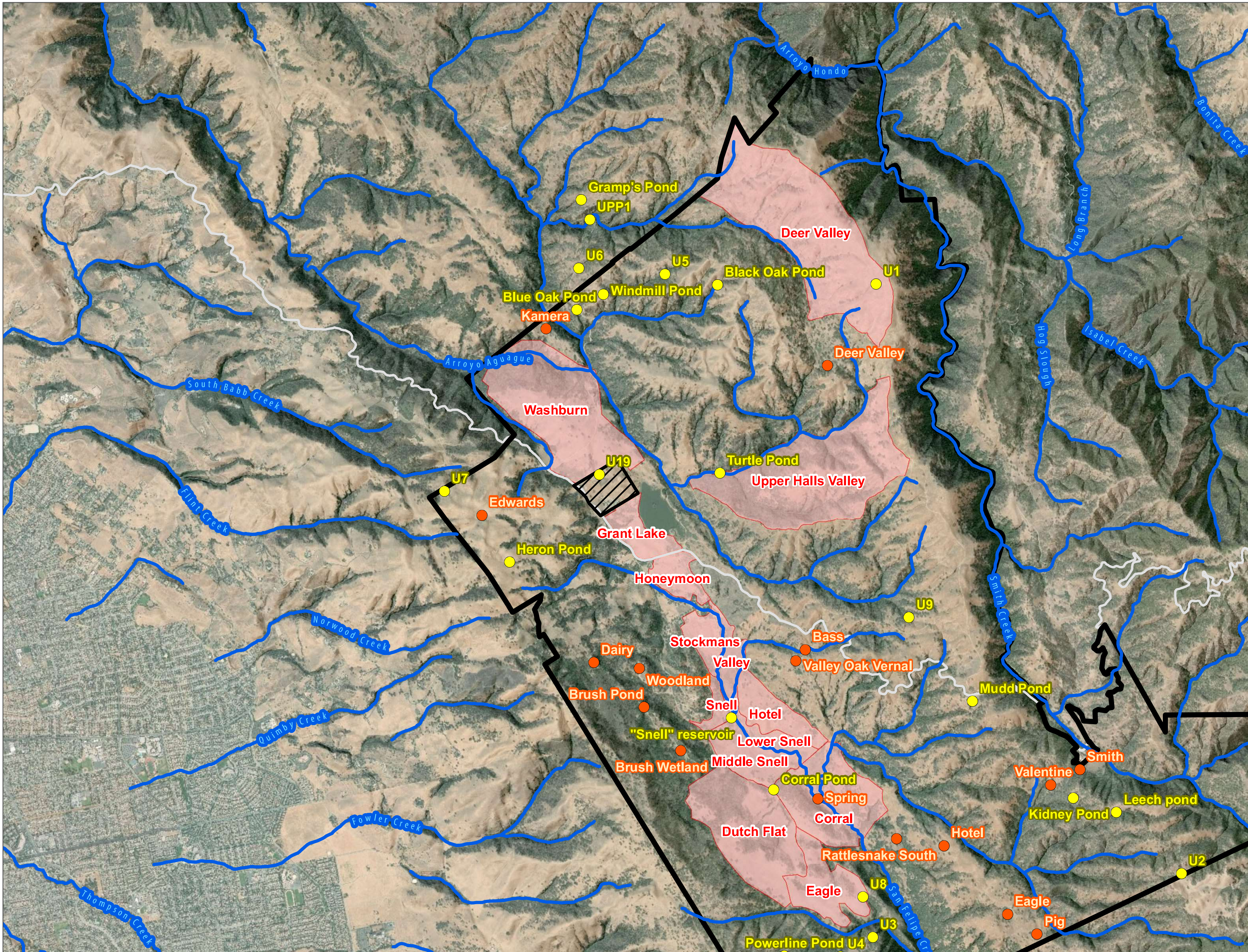
Eagle (>2100)
Rattlesnake (>2100)
Valley Oak Vernal (1990-2000)
Bass (>2100)
Deer Valley (2020-2030)
Woodland (1990-2000)
Brush Pond (1990-2000)
Dairy (1990-2000)
Kamera (>2100)
Edwards (>2100)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Windmill Pond
Kamera
Deer Valley
Arroyo Aguague
South Babb Creek
Washburn
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Turtle Pond
Upper Halls Valley
U7
Edwards
Flint Creek
Grant Lake
Heron Pond
Honeymoon
U9
Smith Creek
Norwood Creek
Bass
Dairy
Stockmans
Valley
Valley Oak Vernal
Woodland
Brush Pond
Mudd Pond
Snell
Hotel
"Snell" reservoir
Lower Snell
Quimby Creek
Brush Wetland
Middle Snell
Smith
Valentine
Corral Pond
Spring
Leech pond
Kidney Pond
Corral
Dutch Flat
Hotel
Fowler Creek
Rattlesnake South
U2
U8
Eagle
Eagle
San Felipe Cr
Thompson Creek
U3
Pig
Powerline Pond U4

6.3 Results

A summary of the results and recommendations for each pond is provided in Table 6-1 at the end of Section 6.3. Pond modification methods are described in section 6.3.1, and the results for each pond are provided in section 6.3.2. Ponds are organized in order of priority for modification: critical priority, high priority, high priority (with additional study), low priority, and no priority due to high confidence that there is a lack of sufficient water supply to enhance the habitat for the target species.

Critical Priority. These ponds either currently or recently have supported predators of the target species that can spread to other ponds, including non-study ponds, and warrant the highest priority for modification. They also have a high benefit for the target species.

- *Eagle Lake* – CRLF have recently been observed at Eagle Lake, while bullfrogs have not been observed there in two years (M. Hyland, pers. comm. 2/2020). This trend is not guaranteed under natural conditions, so it is important to be able to control the hydrology in the future. An adaptive drain is recommended.
- *Bass Lake* – erosion along the spillway at Bass Lake may affect the stability of the berm. It is a priority to prevent failure of the berm which could disperse bullfrog downstream. Additionally, modification of Bass Lake can provide habitat for all three target species. Spillway lowering is recommended to create a seasonal pond. However, eventually the pond will fill with sediment. Berm removal and creek restoration is also considered.

High Priority. These ponds provide suitable habitat for the target species, support bullfrog, and represent different geographic areas of the park. Some of the modifications are relatively simple to implement.

- *Hotel* – CTS and bullfrog have been detected at Hotel. Predator management is recommended through direct removal of bullfrog. Habitat quality for CRLF (which occurs nearby at Eagle Lake and Rattlesnake Pond), could be improved by deepening a portion of the pond to provide CRLF refugia. This would also modestly increase the hydroperiod by limiting evapotranspiration and would also provide refugia for CTS.
- *Edwards* – CTS and CRLF have both been found at Edwards Pond. Measures to improve the pond include livestock management, and spillway lowering to remove bullfrog habitat.
- *Valentine* – This pond is currently only known to support bullfrogs.It will dry in the fall in the wettest years if the spillway is lowered by 2 feet, helping with bullfrog control. It is near Eagle Lake, Hotel Pond, and Smith Pond, and has a high potential to provide suitable breeding habitat for CTS and CRLF.
- *Kamera* – This is the only study pond that is known to support WPT, and CTS has also been documented here. It supports bullfrog, so an adaptive drain or spillway modification (flashboard weir) is recommended to allow the pond to consistently dry in the fall. Livestock management is recommended to protect egg and metamorph life stages, and installation of a basking log or other substrate is recommended for WPT.

High Priority with Additional Study. These ponds are important to the species, but additional review is warranted to improve our knowledge of hydrology and species use.

- *Deer Valley* – this pond may no longer be used by CRLF, and it is not understood if CRLF could recolonize it if it is modified. Modification of the pond for CRLF may compromise it's suitability for CTS. Additional study of species use is recommended. Continued monitoring of hydrology is also recommended to increase the data and improve modeling for this pond.
- *Rattlesnake* – this pond is modeled to remain stable for the species for several years. It is recommended that hydrology data be collected for several more water years before determining the course of action.

Low Priority. The low priority ponds are modifiable, but modification does not have a clear benefit for the target species.

- *Dairy* – although CRLF and CTS have been detected at this pond, the hydrology and watershed appear to be insufficient to support breeding. The berm leaks water, but replacement or improvement of the berm may not increase the length of time enough water is in the pond for breeding. Continued hydrologic monitoring, and additional species surveys are recommended before the berm is redesigned. This may serve as a refugial pond for sub-adults or migrating CRLF and CTS.
- *Brush* – although larval CTS were detected in Brush Pond in 2006, this pond does not hold water long enough for metamorphosis, and it may be a population sink (enticing CTS to lay eggs that never reach maturity). However, it may also provide winter refugia and may have a strategic location that benefits species dispersal. Modifications to the pond to substantially increase the amount of water it can hold are likely impractical, but additional observation of species use is warranted to determine whether this pond should be removed or modified.

None. Modifications are not recommended due to a lack of sufficient water supply to achieve the ponding needed by the species.

- *Woodland* – this pond does not currently support target species, is adjacent to a campground, and does not receive sufficient surface and groundwater to produce the desired hydroperiod for successful breeding now and into the future.
- *Smith* – this pond does not currently support the species and is currently usually dry.
- *Valley Oak* – CTS was observed in Valley Oak in 2004, although this pond does not hold two-foot depths past April. It does not receive sufficient surface and groundwater inflow to sustain the desired hydroperiod to warrant increasing pond depths or making other modifications.

Table 6-1. Pond Summary, Recommended Management, and Hydrological Measures

Pond	Year CRLF Last Documented	Year CTS Last Documented	Year WPT Last Documented	Non-native Wildlife Documented	Projected Hydrology	Summary of Recommend
Eagle Lake	2019	--	--	bullfrog	Contains water deeper than 2 feet all year	• Institute a predator management p • Install adaptive drain and drain por depth each year on April 1 to allow naturally by fall • Primary focal species is CRLF
Bass Lake	--	--	--	bullfrog, centrarchid fish	Contains water deeper than 2 feet all year	• Lower spillway 8.5 feet to aid in pre by creating a seasonal pool. Will e sediment and return to creek habit • Institute predator management (fis RES) • Primary focal species is CTS, there management is recommended
Hotel	--	2010	--	bullfrog	Consistently holds water Dec through July; contains 2 ft or more at least 50% of the time Dec through Jun to 2050 and Jan through June 2050-2100	• Institute a predator management p • Deepen pond by 2 feet in a small a refuge • Primary focal species is CTS with for refuge
Edwards	2003	2010	--	--	Contains water all year most years; has a 2-ft depth Jan through June to 2100	• Lower spillway 3 feet to encourage drying in wet years (when pond fills • Collect more data on local populati conducting surveys for CRLF and Edwards, U7 Pond, and Heron Pon
Valentine	--	--	--	bullfrog	Holds water most of the year, mainly Dec through July; 2 ft depth Jan through July 50% or more of the time to 2050, then shortens to Feb through May or Jun	• Institute a predator management p • Lower spillway 2 feet to support dr wettest years • Primary focus is bullfrog control an habitat for CTS or CRLF
Kamera	--	2010	2017	bullfrog	2-ft depth all year most years with no modification	• Install an adaptive drain or spillway (flashboard weir) to facilitate fall dr • Institute a livestock and predator m program • Install WPT basking substrate • Primary focal species are CTS and
Deer Valley	2010	2018 (eggs)	--	--	Has a 2-ft depth Jan-June 50% of the time to 2030 then gets progressively drier	• Investigate status of CRLF breedin population in nearby ponds • Investigate underlying soil conditio • Gather more hydrologic data to imp results and inform design • Focal species depends on results

Pond	Year CRLF Last Documented	Year CTS Last Documented	Year WPT Last Documented	Non-native Wildlife Documented	Projected Hydrology	Summary of Recommend
Rattlesnake	2011	2011	--	bullfrog	Holds water all year; 2 ft depth expected to be consistent Jan through July	• Institute a predator management p • Lower spillway by 3 feet and recon a 2-ft deep lower central pool for re • Continue hydrology monitoring and prior to design. • Heavily utilized by cattle, exclude c small portion of the pond so vegeta CRLF can develop.
Dairy	2010	2010	--	--	Contains water Jan through June most years; has 2 ft depth 50% of the time Mar-Apr until 2040 and then again in the 2090's	• Continue monitoring both species a for at minimum 5 years to inform ar designs. Hydrology appears insuffi species' breeding, however this ma refugia pond for sub-adults that is i maintain. • Possibly rebuild berm to limit seepa • Possibly direct water from dirt road increase water supply; may require control
Brush	--	2006 (larvae)	--	--	Contains water from Dec-May most years; holds 2-ft depth in March 50% of the time to 2100	• None recommended; hydroperiod i physical modifications are unlikely extend it. • Investigate species use to determi population sink that should be rem refuge important to dispersal.
Woodland	--	--	--	--	Contains water Nov/Dec through June; 2 ft depth projected to occur Feb-Mar 50% of the time sporadically	• None recommended; high confider sufficient water supply to enhance target species.
Smith	--	--	--	--	Usually dry	• None recommended; high confider sufficient water supply to enhance target species.
Valley Oak	--	2004	--	--	Contains water greater than 50% of the time Dec through May to 2100; 2-ft depth less than 50% of the time Jan through Apr	• None recommended; high confider sufficient water supply to enhance target species.

6.3.1. Pond Modification Methods

The purpose of changing the hydrology of the study ponds is to improve target species habitat either by increasing the length of time that enough water is present and thereby improving breeding habitat, and/or by causing an annual dry down that the target species are adapted to, but predator bullfrogs and centrachid fish are not. The following methods are appropriate for the study ponds in the park.

Adaptive Drain:

For ponds which are perennially wetted (e.g. Eagle Lake, Kamera Pond, Bass Lake), a typical solution would be to lower the spillway and reduce the overall capacity of the pond so it dries out for at least a brief period in the fall each year. However, selecting a fixed spillway elevation does not allow flexibility to manage or adapt to increasing evapotranspiration (ET) projected under changing climates and inter-annual variability. That is, an adaptive drain will allow managers to adaptively modify the timing of partial drawdown as changes in climate influence pond hydrology. Similarly, installing a drain in the bottom of the pond would drain the pond quickly and require biological monitoring to both dispatch bullfrogs and protect target species, reducing flexibility and contributing to financial cost. Partially draining the pond and then allowing evaporation and seepage to slowly dry the pond mimics environmental conditions that CRLF and CTS have adapted to (e.g. water temperature will warm as the pond dries, providing life cycle cues and thus triggering behaviors and metabolic processes) that allow target species to survive; but bullfrog and fish are not adapted to ponds that dry.

Therefore, an adaptive drain is recommended to manage ponds that are perennially wetted. The drain would be installed at a specific pond depth (either in the berm or in the pond) and opened on a specific date, in most cases, April 1st. The intake can be fitted with a screen to protect target species. A small outlet pipe is recommended so that the pond drains slowly over several days or weeks to give the target species adequate time to adjust to the new pond elevation. Once the pond is drained to the target depth, anticipated ET and infiltration will continue to drain the pond so that it naturally dries by the target month, giving more natural cues to the target species about timing of pond drying.

The main benefit of an adaptive drain is that the pond can be partially drained on different days each year and as the climate changes or as management objectives evolve. In many cases, beginning around 2050, the drain may need to be opened later in the year so that increased ET does not dry the pond too early in the season for CRLF to complete a breeding cycle. The pond drain dates can be adaptively managed based on year-by-year observations of pond drying rates and can be re-evaluated as climate change projections are updated for future decades. Once bullfrog control is sufficiently achieved, it may not be necessary to drain the pond every year, potentially providing target species improved habitat of fuller ponds without threat of bullfrog predation.

The adaptive drain method is recommended for Eagle Lake and may also be considered for Kamera Pond, as described in greater detail in Section 6.3.2. See Figures 12, 13, and 14 for examples of components of adaptive drains.

Figure 12. An example of a flashboard-controlled outlet (flashboard not pictured). Water outlet elevation can be controlled via a drain pipe constructed through a berm (NC State 2020).

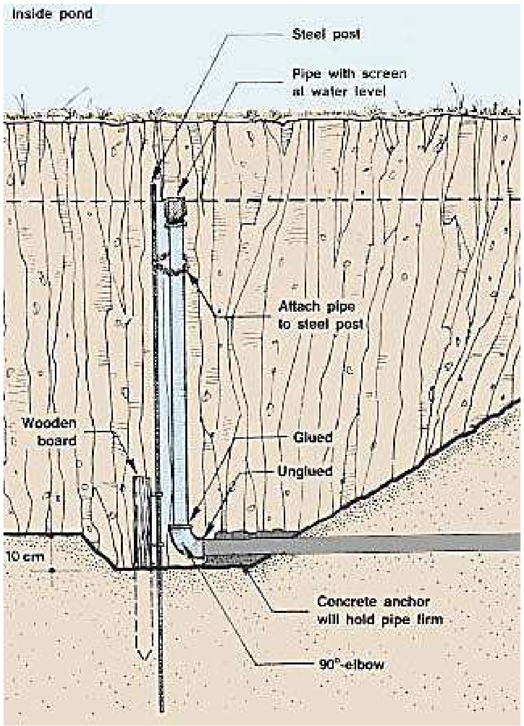

Figure 13. An example of a flashboard-controlled outlet continued, pipe outlet leading from inside pond toward potential outlet on outside of berm (flashboard not pictured; FAO 2020).

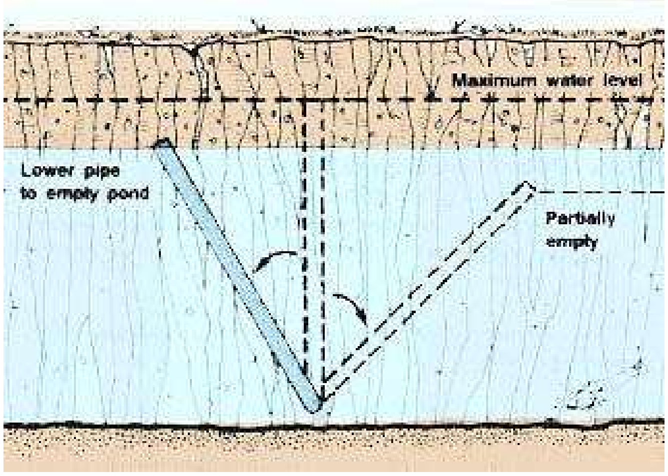

Figure 14. An example of a rotating pipe within pond to control outlet pond elevation within the pond (FAO 2020).

Pond Deepening:

In a few cases, model results and monitoring observations indicate that the existing pond hydrology and geometry produces a hydroperiod which is slightly too dry for the CRLF breeding cycle. If a pond has a wide, flat bottom, ET rates can be very high over the surface of the pond and a larger overall volume is required to maintain the desired 2 feet of water depth for CRLF refuge. Therefore, excavating a small and deep area has several benefits, which in certain cases can increase the improve expected hydroperiod for CRLF. These benefits include: 1) maintaining deeper inundation with a smaller volume of water, and 2) decreasing the summer water surface area and thus total ET. If pond deepening is recommended, the newly graded portion of the pond should likely also be lined with low-permeability sediments and the project should minimize impacts to the existing pond bottom. Rattlesnake and Hotel ponds have been identified as potentially suitable for deepening.

Change Spillway Elevation:

In some cases, model results suggest simply changing the spillway elevation. This is typically the case in ponds that are expected to have considerable surface and groundwater inputs that support perennially wet ponds and reduce the effects of increasing ET over time. Many ponds do not have significant multi-year storage, which means that spillway lowering will only affect the wettest years (when the high spillway is activated). Kamera Pond, Edwards Pond, Bass Lake, Rattlesnake Pond, and Valentine Pond have been identified as potentially suitable for an alteration of spillway elevation.

Clay Lining and/or Berm Reconstruction:

In some cases, lining the pond with less permeable clays may make a pond less susceptible to draining. However, this can be difficult to practically achieve over the scale of a pond. In some cases, re-grading a pond may increase infiltration rates as existing claypans disturbed or destroyed. However, it is possible that reconstruction of rocky and therefore leaky berms may assist with increasing pond hydroperiod. Following continued monitoring of species and hydrology, Dairy Pond may be suitable for berm reconstruction or potential clay lining.

Management:

- **Livestock (Cattle and/or Feral Pigs):** As noted in section 4.5, there is no clear connection between cattle or feral pig impacts and target species survival. However, where pond vegetation that provides substrate for egg attachment and cover for all life stages of CTS and CRLF, as well as bank vegetation potentially used for WPT nests, is being heavily impacted, it is recommended that cattle and feral pig use be managed in some way to protect vegetation in sensitive life history stages of target species (i.e. breeding). This may mean providing a trough, fencing a portion of the pond, and/or replanting. However, using cattle for vegetation control may benefit the target species in certain ponds, and the amount of impact and benefit depends on the number of head and the amount of vegetation growth. Therefore, the management program or plan will need to be adaptive and will need to be considered on a case by case basis each year.

- **Bullfrog and Non-native fish:** Non-native bullfrogs and fish are predators on juvenile CRLF, CTS, and WPT. Bullfrog and fish species cannot survive in water features that dry annually. Like RES, bullfrog requires a valid CDFW sportfishing license for “take,” although there is no bag limit on individuals. Any large-scale eradication plan enacted will need to be approved by CDFW, likely with strict methods due to the co-occurrence of native species in some of the ponds. Some potential management of bullfrog and fish species may include capture/kill as well as altering the hydroperiod of the ponds. Similar public park large-scale eradication of bullfrog for the purpose of CRLF reintroduction included targeted eradication after eDNA and audio species detections at discrete locations. Adult and subadult bullfrogs were captured in a variety of methods including spearing, seining, and hand capture and were then humanely euthanized (Kamoroff et al 2019).

- **Red-eared Slider:** RES has been detected informally, but frequently, within the park (iNaturalist 2020), but has there is no quantitative formal data available on distribution or RES use within the study pond network. RES frequently out-compete WPT for food resources and basking sites and will likely need to be eradicated to ensure WPT conservation. Due to their generalist habitat requirements, water drawdowns may not be sufficient to eradicate this species from occupied habitat. As stated in Section 4.4, a valid CDFW sportfishing license is required to “take” RES within California, though there is no limit on individuals taken. Removal efforts are encouraged by CDFW to adhere to the AVMA’s Guidelines for Euthanasia of Animals.

- **Invasive Plants:** Invasive plant species can have two significant impacts on the target species. One is to outcompete native vegetation, thereby creating a monoculture that does not provide adequate forage for the species. The other is to disrupt habitat by physically clogging it or actively removing water. Teasel is an example that may be reducing water availability in the Brush Wetland (near Brush Pond). Systematic survey and monitoring of invasive plant species is the first step to preparing an effective eradication plan and is recommended in the Next Steps noted in Section 7.0 below. Invasive plant control advice is available on the California Invasive Plant Council’s (Cal-IPC) website (2020). A native planting palette is recommended for enhanced ponds.

- **Revegetation:** Two of the target species, CRLF and WPT, benefit from vegetative cover around the pond edge; conversely, CTS benefits from a lack of vegetative cover. It is difficult to limit vegetation to one area of a pond unless the pond is heavily used by cattle. In that case it is possible to exclude cattle from a portion of the pond to allow pond vegetation cover to increase in a portion of the pond to benefit CRLF/WPT, while cattle control the vegetation in other portions of the pond to benefit CTS. This is a recommendation for Rattlesnake Pond. In some cases both CTS and CRLF or WPT occur at a pond. In those cases, such as Kamera Pond, no revegetation recommendation has been made because the pond appears to provide the appropriate habitat for both species. Revegetation and livestock management go hand-in-hand, and should be re-evaluated at each pond that supports the target species on a regular basis.

6.3.2 Pond-Specific Results and Recommendations

Each of the 13 study ponds are discussed below. Following the discussion is a representative photo of the pond and graphs showing the inundation probability for each pond under current conditions and after modification. An explanation of how to read the graphs is provided here.

Column 1, or “0-foot Inundation Probability” indicates the likelihood for each month and decade that a particular study pond will contain any water for a given month (x-axis) and decade (y-axis). Column 2, or “2-foot Inundation Probability” indicates the likelihood that a particular study pond will be inundated deeper than 2 feet for a given month and decade, an important marker for both CRLF and CTS suitability. The probability of inundation is represented in percentages, with higher percentages marked with darker colors. As an example, Kamera Pond has a 50% or higher probability of being inundated two feet or more from December through August into the 2090s, whereas Deer Valley pond has a 50% chance of containing at least two feet of water from January to June in the 2020s, shifting to February to June in the 2030s.

Eagle Lake:

Location and Watershed:

Eagle Lake lies near the southern border of the park, near a primary tributary to San Felipe Creek.

Physical Characteristics and Hydrology:

Eagle Lake is classified as a tectogenic[8] pond with Los Gatos-Gaviota complex and gravelly loam soils with an underlying geology of Franciscan mélange and metamorphic complex. There are no faults associated with the pond. Eagle Lake has a watershed area of 12.9 acres and a surface area of 1.83 acres. Modeled inundation has reached a maximum of approximately 12 feet. Generally, the lake is a bowl shape with a berm at the north end. Eagle Lake typically holds water from October through September (all year).

Eagle Lake currently has a ≥50% probability of holding water year-round in excess of 2-foot depths and is modeled to continue this way into the future.

Biological Setting:

Eagle Lake is surrounded by a mosaic of annual grassland and coast live oak woodland, with ample small mammal burrows surrounding the pond. Eagle Lake has an approximate 30% coverage of tule (*Schoenoplectus acutus*) with the remaining 70% open water during the December 2018 survey. Cattle have access to Eagle Lake approximately 2-3 weeks per year. Amphibians documented at the pond include bullfrog, Pacific chorus frog, western toad, and California newt. In 2019, park staff documented adult and metamorph CRLF at Eagle Lake (M.

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[8] A pond formed by tectonic activity that has directly or indirectly created local sediment-filled depressions over thousands of years. The water source is primarily steeper slopes with thin soils higher in the watershed rather than the slopes immediately adjacent to the basin.

Hyland, pers. comm.). Eagle Lake dried completely from 2014-2015 and subsequently, bullfrog were not observed at the pond in 2018 or 2019 during amphibian surveys conducted by Pieter Johnson (M. Hyland, pers. comm.). However, bullfrog has been documented at Eagle Lake in the past, as well as at nearby ponds including Hotel Pond and Rattlesnake Pond.

Both CRLF and CTS have been documented at other ponds near Eagle Lake, and therefore previous colonization is not an isolated occurrence and instead likely indicates genetic interchange at a larger scale between the nearby ponds. CRLF have been documented at Pig Pond approximately 0.2 mile southeast of Eagle Lake and Rattlesnake Pond approximately 0.9 mile to the northwest. CTS have been documented at unnamed pond U8 0.9 mile west of Eagle Lake, an unnamed pond (U4, Figure 4) 1.1 miles west of Eagle Lake, at Hotel Pond 0.75 mile northwest of Eagle Lake, at Rattlesnake Pond 0.9 mile northwest of Eagle Lake, at Kidney Pond 0.8 mile to the northeast, and at Leech Pond 0.95 mile to the northeast.

Threats and Issues:

The lake is typically perennial and has supported bullfrog in the past.

Recommended Modifications and/or Actions:

1. Install an adaptive drain to lower water level to allow the pond to dry by fall of each year.
2. If by April 1st the lake depth is greater than 4 feet, open the valve to slowly drain the lake to 4 feet at maximum to allow the pond to dry out by the end of the summer in order to disrupt the bullfrog life cycle.
3. In 2050, the valve likely should be opened on May 1 rather than April 1, to keep inundation suitable to target species and to account for increased evaporation expected from climate change.

Post-Modification Hydrologic Assessment:

Up until 2070, the pond will likely be inundated year-round. Beginning in 2070, the pond would most likely be dry in October of each year. Water would be present all year in most years until 2070; from 2070 on the lake would be mostly dry in October. The lake would hold at least two feet of water 50% of the time from January through July, and sometimes through August to 2100.

Recommendation:

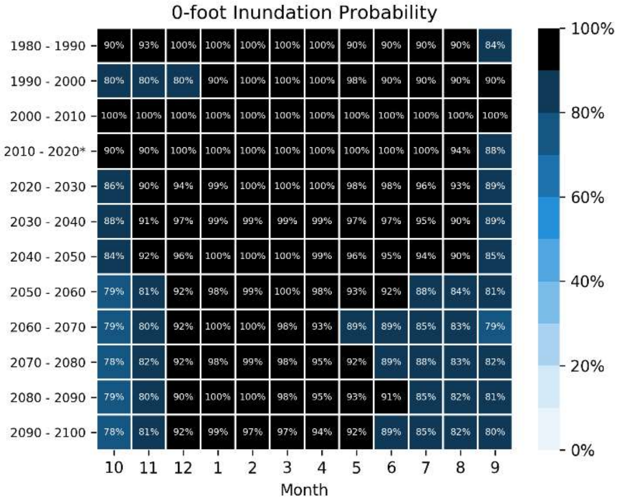
Eagle Lake has supported bullfrogs in the past, and recent observations indicate that it is possible to control the bullfrog population with periodic drying. It is recommended that a bullfrog management program be implemented at Eagle Lake to prevent it from supporting bullfrogs in the future. This would be accomplished most efficiently by installing an adaptive drain to draw down the pond to the point that it will dry naturally by the fall. The valve allows more control of the dry down period because the opening can be timed. Spillway lowering was also considered, but it would provide a fixed result and would not result in the flexibility to keep the pond full for improved habitat once bullfrogs are eradicated, or to adjust drawdown to account for changes in climate. Bullfrog control efforts should be completed in concert with similar efforts at Hotel Pond and Rattlesnake pond for greatest impact.

A representative photo and the modeled hydrology for Eagle Lake are illustrated in Figure 15.

Figure 15. Representative Photo and Modeled Hydrology for Eagle Lake

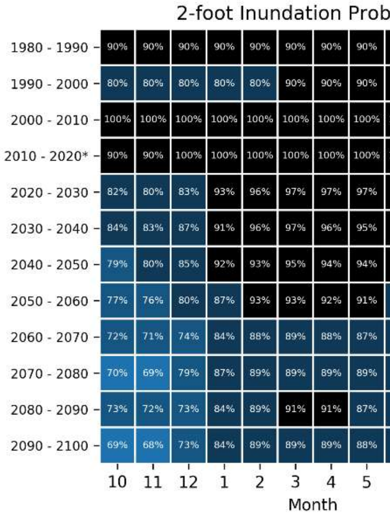
Eagle Lake, July 2, 2018 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



0-foot Inundation Probability

	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	90%	93%	100%	100%	100%	100%	100%	90%	90%	90%	90%	84%
1990 - 2000	80%	80%	80%	90%	100%	100%	100%	98%	90%	90%	90%	90%
2000 - 2010	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2010 - 2020*	90%	90%	100%	100%	100%	100%	100%	100%	100%	100%	94%	88%
2020 - 2030	86%	90%	94%	99%	100%	100%	100%	98%	98%	96%	93%	89%
2030 - 2040	88%	91%	97%	99%	99%	99%	99%	97%	97%	95%	90%	89%
2040 - 2050	84%	92%	96%	100%	100%	100%	99%	96%	95%	94%	90%	85%
2050 - 2060	79%	81%	92%	98%	99%	100%	98%	93%	92%	88%	84%	81%
2060 - 2070	79%	80%	92%	100%	100%	98%	93%	89%	89%	85%	83%	79%
2070 - 2080	78%	82%	92%	98%	99%	98%	95%	92%	89%	88%	83%	82%
2080 - 2090	79%	80%	90%	100%	100%	98%	95%	93%	91%	85%	82%	81%
2090 - 2100	78%	81%	92%	99%	97%	97%	94%	92%	89%	85%	82%	80%



2-foot Inundation Prob

	10	11	12	1	2	3	4	5
1980 - 1990	90%	90%	90%	90%	90%	90%	90%	90%
1990 - 2000	80%	80%	80%	80%	80%	90%	90%	90%
2000 - 2010	100%	100%	100%	100%	100%	100%	100%	100%
2010 - 2020*	90%	90%	100%	100%	100%	100%	100%	100%
2020 - 2030	82%	80%	83%	93%	96%	97%	97%	97%
2030 - 2040	84%	83%	87%	91%	96%	97%	96%	95%
2040 - 2050	79%	80%	85%	92%	93%	95%	94%	94%
2050 - 2060	77%	76%	80%	87%	93%	93%	92%	91%
2060 - 2070	72%	71%	74%	84%	88%	89%	88%	87%
2070 - 2080	70%	69%	79%	87%	89%	89%	89%	89%
2080 - 2090	73%	72%	73%	84%	89%	91%	91%	87%
2090 - 2100	69%	68%	73%	84%	89%	89%	89%	88%

Bass Lake:

Location and Watershed:

Bass Lake lies within the center of the park, along a primary tributary to San Felipe Creek (Figure 3).

Physical Characteristics and Hydrology:

Bass Lake is classified as an instream pond with Los Gatos-Gaviota Complex soils and gravelly loam with an underlying geology of Franciscan mélange and metamorphic complex rock. There are no faults associated with the lake. Bass Lake has a watershed area of 111 acres and a surface area of 0.65 acres. The downstream channel is undermining the spillway. Modeled inundation depths have reached a maximum of approximately 14 feet, but the average depth is approximately 9 feet. Generally, the pond is steep-sided, particularly at the berm. The pond holds water year-round. Future pond sedimentation will shorten the hydroperiod of Bass Lake.

Bass Lake currently has a 100% probability of being at least 2 feet deep all year, and modeling anticipates this will remain the case to 2100.

Biological Setting:

Bass Lake is surrounded by a mosaic of annual grassland and oak woodland. It supports emergent vegetation unless cattle are present; during the 2018 survey there was no emergent vegetation and there was evidence of heavy cattle use (trampling), however in subsequent years emergent vegetation has been observed, including both tule and cattail (M. Hyland, pers. comm.). Amphibians documented at the lake include western toad and bullfrog. Bass Lake may also contain non-native fish that prey on CRLF and CTS eggs, tadpoles, and metamorphs. Neither CRLF nor CTS have been detected at Bass Lake, although CTS has been detected at Valley Oak/Vernal within several hundred feet of Bass Lake.

CRLF has been documented at an unnamed pond (U9; Figure 3) 0.68 mile northeast of Bass Lake, at Grant Lake approximately 1.0 mile northwest of Bass Lake, and at Snell Reservoir 0.62 mile southwest of Bass Lake. CTS has been documented at Valley Oak/Vernal 0.08 mile southwest of Bass Lake, at Corral Pond 0.87 mile southwest of Bass Lake, at Brush Wetland 1.0 mile southwest of Bass Lake, and at Brush Pond 1.1 mile west of Bass Lake.

Threats and Issues:

Predator control is an important component of restoration for CRLF and CTS, and Bass provides a node from which bullfrogs can disperse to other ponds in the park. The berm is at risk of continued damage and eventual failure due to erosion, and it is unclear what the effects of berm failure will be on the lake, the creek, predator habitat and CRLF/CTS/WPT habitat. Continued sedimentation will shorten the hydroperiod of the lake and the chance of CRLF/CTS reproductive success may improve, but bullfrog will persist unless the lake completely dries at least during some years. Unless dredged, Bass Lake will fill with sediment and revert to creek habitat over time. Sedimentation rates are unknown at this time, though the topographic survey conducted during this study can be used to assess these rates in the future if needed.

Modifications:

Bass Lake presents a complicated situation, and several actions and modifications were considered, including the following:

1. Pump dry in late summer in successive years and catch non-native species to reduce their population; or
2. Rebuild and lower the spillway elevation by 8.5 feet to promote annual drying, or lower the spillway less than 8.5 feet and install an adaptive drain (though results were not modeled); or
3. Remove the berm and spillway and restore the lake to a creek and step pool environment for CRLF refuge (it would not provide breeding habitat). To provide habitat for CTS the design would need to incorporate an off-stream pond that dries out in late summer.

Although restoring the creek with step pools is an attractive idea, the pools would dry out quickly and would not provide breeding habitat for target species, which could be provided by keeping a smaller pond. Pumping the pond dry for species management requires equipment mobilization, and it is inefficient. The following modification was determined to be the best option, but even it only buys time for a pond that is destined to fill with sediment and revert to creek habitat:

1. Lower the spillway 8.5 feet to promote annual drying.

Post-Modification Hydrologic Assessment:

If the spillway is lowered by 8.5 feet the pond is modeled to be dry in the months of September and October until 2100, in addition to being dry in most Novembers. With modification, the pond will begin to inundate in December and will be inundated more than two feet from the months of January through July. The model does not include the effects of sedimentation, which is likely to shorten the hydroperiod of the pond over time.

Recommendations:

Bass Lake is a perennial source of bullfrogs that may radiate out to inhabit other ponds. Spillway lowering and vegetation management are recommended for Bass Lake to alter the hydrology so the pond dries out in the fall and breaks non-native predator (bullfrog and fish) life cycles, and to improve habitat for CTS which has been detected at Valley Oak Pond within a few hundred feet of Bass Lake in the past. Livestock grazing (cattle) can be used to manage the vegetation. Due to sedimentation it is expected that Bass Lake will eventually revert to creek habitat. Maintaining a pond in this location would require periodic dredging. At this time the recommendation is to allow the pond to revert to creek habitat over time, which will still provide a migration corridor and refugia for CTS.

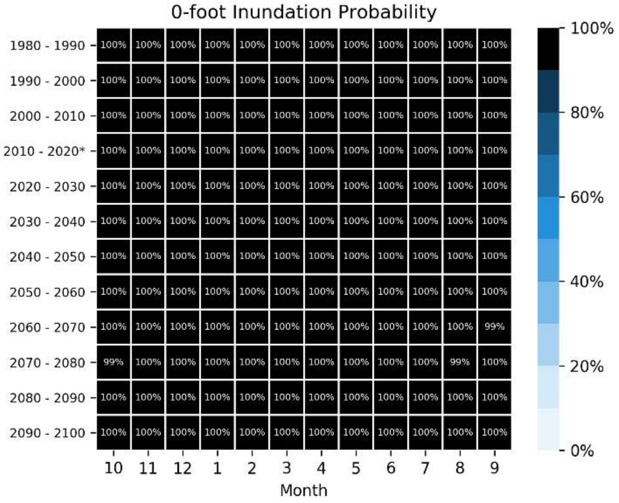
In addition, RES have been informally documented at Bass Lake (see Section 4.4). Formal surveys for RES to understand the extent of their ecology within the park, as well as park guest education and an eradication plan are recommended to improve habitat for WPT.

A representative photo and the modeled hydrology for Bass Lake is illustrated in Figure 16.

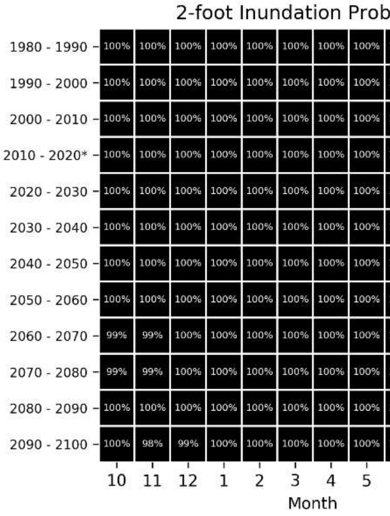
Figure 16. Representative Photo and Modeled Hydrology for Bass Lake

Bass Lake, January 30, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1990 - 2000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2000 - 2010	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2010 - 2020*	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2020 - 2030	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2030 - 2040	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2040 - 2050	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2050 - 2060	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2060 - 2070	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%
2070 - 2080	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%	100%
2080 - 2090	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2090 - 2100	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%



	10	11	12	1	2	3	4	5
1980 - 1990	100%	100%	100%	100%	100%	100%	100%	100%
1990 - 2000	100%	100%	100%	100%	100%	100%	100%	100%
2000 - 2010	100%	100%	100%	100%	100%	100%	100%	100%
2010 - 2020*	100%	100%	100%	100%	100%	100%	100%	100%
2020 - 2030	100%	100%	100%	100%	100%	100%	100%	100%
2030 - 2040	100%	100%	100%	100%	100%	100%	100%	100%
2040 - 2050	100%	100%	100%	100%	100%	100%	100%	100%
2050 - 2060	100%	100%	100%	100%	100%	100%	100%	100%
2060 - 2070	99%	99%	100%	100%	100%	100%	100%	100%
2070 - 2080	99%	99%	100%	100%	100%	100%	100%	100%
2080 - 2090	100%	100%	100%	100%	100%	100%	100%	100%
2090 - 2100	100%	98%	99%	100%	100%	100%	100%	100%

1980 - 1990	96%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

1980 - 1990	37%	63%	85%	100%	100%	100%	100%	100%

Hotel:

Location and Watershed:

Hotel pond lies in the southern section of the park, in the San Felipe Creek watershed (Figure 3).

Physical Characteristics and Hydrology:

Hotel pond is classified as a tectogenic/instream pond with Los Gatos-Gaviota complex and gravelly loam soils with an underlying geology of Franciscan mélange and metamorphic complex. There are no faults associated with the pond. Hotel Pond has a watershed area of 3.9 acres and a surface area of 0.41 acres. Modeled inundation has reached a maximum of approximately 8 feet. Generally, the pond is a shallow bowl that is steep on its north side. Hotel Pond typically holds water from December through July.

Hotel Pond has a ≥50% probability of being inundated from December through July. Ponding depths of 2 feet or more have a ≥50% probability in the months of December through June. The future trend for the pond is to hold two feet of water from December through July to 2030, and from January through June after 2030.

Biological Setting:

Hotel Pond is surrounded by a mosaic of annual grassland and coast live oak woodland, with ample small mammal burrows surrounding the pond. Although there was no emergent vegetation at the time of the December 2018 survey, the pond supports a significant stand of emergent wetland in the spring and summer. Amphibians at the pond include bullfrog, Pacific chorus frog, western toad, California newt, and CTS. Bullfrog was detected in four of seven surveys of the pond.

CRLF have been documented at Pig Pond approximately 0.8 mile southeast of Hotel Pond and an unnamed Pond (U8; Figure 4) 0.6 mile southwest of Hotel Pond. CTS have been documented at Mudd Pond 1.0 mile north of Hotel, Kidney Pond 0.9 mile east of Hotel, an unnamed pond (U3; Figure 4) 0.7 mile southwest of Hotel, and an unnamed pond (U4; Figure 4) 1 mile southwest of Hotel.

Threats and Issues:

The pond contains water year-round in some years, providing habitat for bullfrog, which has also been documented to occur in Hotel Pond and nearby at Eagle Lake and Rattlesnake Pond. To provide CRLF habitat the pond would need to be modified to increase the hydroperiod and improve refugia. Emergent vegetation may needed control to protect CTS habitat.

Modifications:

Hotel Pond is currently providing suitable habitat for CTS, and no modifications are recommended. CRLF occurs at Eagle Lake and Rattlesnake Pond, and Hotel Pond lies between these. If habitat for CRLF was to be improved, Hotel Pond would need to be modified to include an area of deeper water refuge. This would require investigation of bedrock limitations. Adding an area of deeper water would modestly increase the hydroperiod by limiting evapotranspiration. For CRLF it may also be necessary to manage cattle access to protect vegetation cover in a portion of the pond.

Post-Modification Hydrologic Assessment:

Following Hotel Pond being modified to provide an area of deeper water habitat, it will likely continue to be inundated most of the year, with dry periods in October and November. The probability of 2-foot inundation will exceed 50% from January through July.

Recommendation:

Hotel Pond’s hydroperiod is currently suitable for CTS, and its natural conditions are expected to facilitate bullfrog control, because the pond is modeled to start completely drying out in the fall this decade (2020-2030). No modifications are recommended at this time.

If in the future there is a need to provide additional CRLF habitat at Hotel Pond, it would need to provide areas of deeper refuge habitat, and vegetative cover would need to be protected from cattle.

A representative photo and the modeled hydrology for Hotel Pond is illustrated in Figure 17.

Figure 17. Representative Photo and Modeled Hydrology for Hotel Ponc

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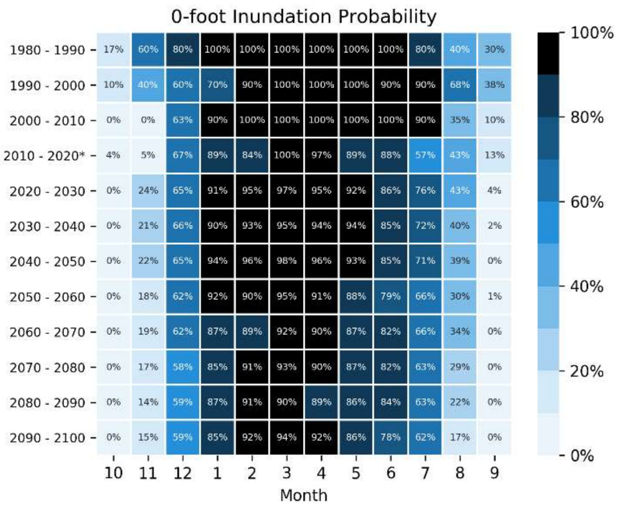
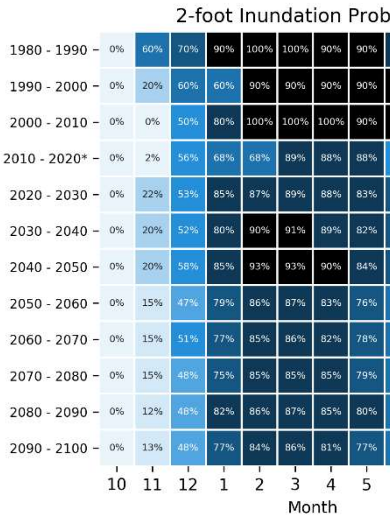
Hotel Pond, May 10, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



0-foot Inundation Probability

	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	17%	60%	80%	100%	100%	100%	100%	100%	100%	80%	40%	30%
1990 - 2000	10%	40%	60%	70%	90%	100%	100%	100%	90%	90%	68%	38%
2000 - 2010	0%	0%	63%	90%	100%	100%	100%	100%	100%	90%	35%	10%
2010 - 2020*	4%	5%	67%	89%	84%	100%	97%	89%	88%	57%	43%	13%
2020 - 2030	0%	24%	65%	91%	95%	97%	95%	92%	86%	76%	43%	4%
2030 - 2040	0%	21%	66%	90%	93%	95%	94%	94%	85%	72%	40%	2%
2040 - 2050	0%	22%	65%	94%	96%	98%	96%	93%	85%	71%	39%	0%
2050 - 2060	0%	18%	62%	92%	90%	95%	91%	88%	79%	66%	30%	1%
2060 - 2070	0%	19%	62%	87%	89%	92%	90%	87%	82%	66%	34%	0%
2070 - 2080	0%	17%	58%	85%	91%	93%	90%	87%	82%	63%	29%	0%
2080 - 2090	0%	14%	59%	87%	91%	90%	89%	86%	84%	63%	22%	0%
2090 - 2100	0%	15%	59%	85%	92%	94%	92%	86%	78%	62%	17%	0%



2-foot Inundation Prob

	10	11	12	1	2	3	4	5
1980 - 1990	0%	60%	70%	90%	100%	100%	90%	90%
1990 - 2000	0%	20%	60%	60%	90%	90%	90%	90%
2000 - 2010	0%	0%	50%	80%	100%	100%	100%	90%
2010 - 2020*	0%	2%	56%	68%	68%	89%	88%	88%
2020 - 2030	0%	22%	53%	85%	87%	89%	88%	83%
2030 - 2040	0%	20%	52%	80%	90%	91%	89%	82%
2040 - 2050	0%	20%	58%	85%	93%	93%	90%	84%
2050 - 2060	0%	15%	47%	79%	86%	87%	83%	76%
2060 - 2070	0%	15%	51%	77%	85%	86%	82%	78%
2070 - 2080	0%	15%	48%	75%	85%	85%	85%	79%
2080 - 2090	0%	12%	48%	82%	86%	87%	85%	80%
2090 - 2100	0%	13%	48%	77%	84%	86%	81%	77%

0-foot Inundation Probability

1980 - 1990	32%	70%	84%	100%	100%	100%	100%	100%	100%	90%	71%	46%

2-foot Inundation Prob

1980 - 1990	0%	60%	70%	90%	100%	100%	100%	90%

Edwards Pond:

Location and Watershed:

Edwards Pond lies along the western edge of the park and is near the headwaters of a tributary of the Arroyo Aguague, of South Babb Creek, and of Flint Creek (Figure 3).

Physical Characteristics and Hydrology:

Edwards Pond is classified as a tectogenic pond with Los Gatos-Gaviota Complex soils and gravelly loam with an underlying geology of Miocene sedimentary rocks. There are no faults associated with the pond. Edwards Pond has a watershed area of 12.6 acres and a surface area of 1.07 acres. There is a manmade berm controlling the pond outlet, and the berm appeared to be in good condition during 2017 and 2018 surveys—no significant erosion was observed. The spillway is 10 feet above the deepest portion of the pond. Modeled inundation depths have reached approximately 9 feet, but more typically the pond is inundated 2-5 feet. Generally, the pond is bowl-shaped with gradually sloping sides.

Edwards Pond is modeled to hold water during the winter months most years to 2100. It is expected to hold two feet of water 50% or more of the time from January through July.

Biological Setting:

Edwards Pond is surrounded by annual grassland and does not support emergent wetland vegetation. Amphibians documented to occur there include pacific chorus frog, western toad, CRLF, and CTS.

CTS and CRLF have been recorded to occur at Heron Pond, 0.3 miles southeast of Edwards Pond (2010 CNDDB records), and at pond U10, 0.76 mile northeast of Edwards Pond (2005 CNDDB records). CTS also has been recorded at pond U7, 0.27 mile northwest of Edwards Lake (2003 record).

Threat and Issues:

While Edwards Pond has suitable geometry and bathymetry to provide habitat for both CTS and CRLF, however they have not been documented at the pond since 2003 (CNDDB 2018). Park staff have observed that Edwards Pond did not retain water through May during drought years.

Modifications:

1. Edwards has a suitable bathymetry and no bathymetric modifications are currently recommended.
2. More robust data for target species (gathered through formal surveys) use of Edwards and nearby ponds is recommended to determine if any habitat enhancement is warranted.

Post-Modification Hydrologic Assessment:

Modeling indicates that spillway lowering would likely result in pond dry down that would prevent bullfrog from completing their life cycles (if present), but would also reduce habitat availability for CTS and CRLF over existing conditions.

Recommendations:

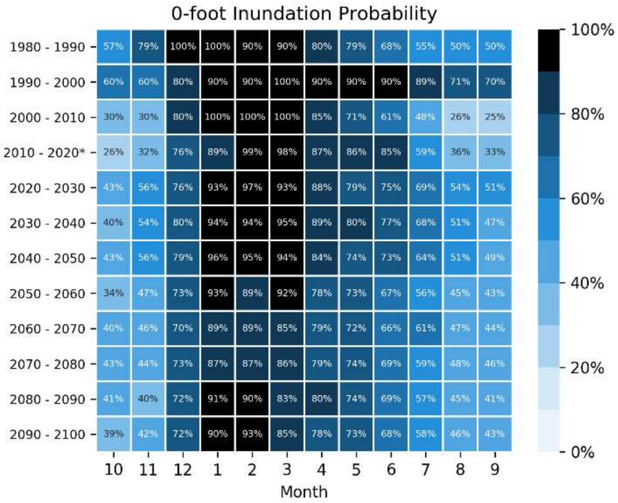
Conduct formal surveys for CRLF and CTS at Edwards Pond, U7 Pond, and Heron Pond (located within one mile of Edwards) to better understand the species use of ponds in this portion of the park. If CRLF and CTS do not currently inhabit these ponds, restoration efforts in areas of the park inhabited by the species may be a higher priority than modifying Edwards Pond.

A representative photo and the modeled hydrology for Edwards Pond are illustrated in Figure 18.

Figure 18. Representative Photo and Modeled Hydrology for Edwards P

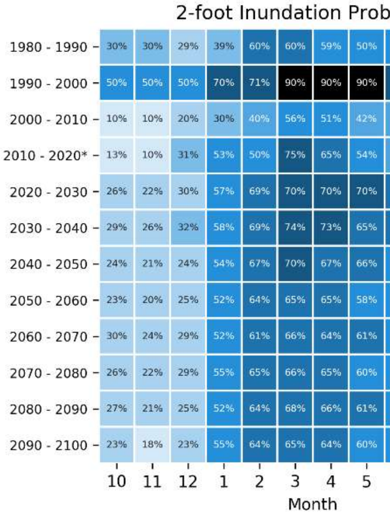
Edwards Pond, June 27, 2018 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



0-foot Inundation Probability

	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	57%	79%	100%	100%	90%	90%	80%	79%	68%	55%	50%	50%
1990 - 2000	60%	60%	80%	90%	90%	100%	90%	90%	90%	89%	71%	70%
2000 - 2010	30%	30%	80%	100%	100%	100%	85%	71%	61%	48%	26%	25%
2010 - 2020*	26%	32%	76%	89%	99%	98%	87%	86%	85%	59%	36%	33%
2020 - 2030	43%	56%	76%	93%	97%	93%	88%	79%	75%	69%	54%	51%
2030 - 2040	40%	54%	80%	94%	94%	95%	89%	80%	77%	68%	51%	47%
2040 - 2050	43%	56%	79%	96%	95%	94%	84%	74%	73%	64%	51%	49%
2050 - 2060	34%	47%	73%	93%	89%	92%	78%	73%	67%	56%	45%	43%
2060 - 2070	40%	46%	70%	89%	89%	85%	79%	72%	66%	61%	47%	44%
2070 - 2080	43%	44%	73%	87%	87%	86%	79%	74%	69%	59%	48%	46%
2080 - 2090	41%	40%	72%	91%	90%	83%	80%	74%	69%	57%	45%	41%
2090 - 2100	39%	42%	72%	90%	93%	85%	78%	73%	68%	58%	46%	43%



2-foot Inundation Prob

	10	11	12	1	2	3	4	5
1980 - 1990	30%	30%	29%	39%	60%	60%	59%	50%
1990 - 2000	50%	50%	50%	70%	71%	90%	90%	90%
2000 - 2010	10%	10%	20%	30%	40%	56%	51%	42%
2010 - 2020*	13%	10%	31%	53%	50%	75%	65%	54%
2020 - 2030	26%	22%	30%	57%	69%	70%	70%	70%
2030 - 2040	29%	26%	32%	58%	69%	74%	73%	65%
2040 - 2050	24%	21%	24%	54%	67%	70%	67%	66%
2050 - 2060	23%	20%	25%	52%	64%	65%	65%	58%
2060 - 2070	30%	24%	29%	52%	61%	66%	64%	61%
2070 - 2080	26%	22%	29%	55%	65%	66%	65%	60%
2080 - 2090	27%	21%	25%	52%	64%	68%	66%	61%
2090 - 2100	23%	18%	23%	55%	64%	65%	64%	60%

0-foot Inundation Probability

2-foot Inundation Prob

Valentine Pond:

Location and Watershed:

Valentine pond is located in the southeast portion of the park, near a primary tributary of San Felipe Creek.

Physical Characteristics and Hydrology:

Valentine Pond is classified as an instream pond in Los Gatos-Gaviota complex and gravelly loam soils with an underlying geology of Franciscan metamorphic complex. There are no faults associated with the pond. Valentine Pond has a watershed area of 9.7 acres and a surface area of 0.13 acres. Modeled inundation has reached a maximum of approximately 11 feet. Generally, the pond is bowl-shaped with both steep and more gradual banks. Valentine Pond typically holds water December through July.

Valentine Pond currently has a ≥50% probability of holding water all year. By the end of the century it will be drier, but may still hold water all year. The pond currently has a ≥50% probability of holding at least two feet of water from December through August, but this is expected to shorten in the future to as short as February through May.

Biological Setting:

Valentine Pond is surrounded by a mosaic of non-native annual grassland and oak woodland, with multiple small mammal burrows, downed wood, and leaf litter suitable for upland amphibian dispersal surrounding its banks. There was no emergent vegetation at the time of the August 2017 or December 2018 surveys. Bullfrog is the only amphibian that has been documented at Valentine Pond.

CRLF have been documented along Smith Creek, approximately 0.38 mile north of Valentine Pond, at an unnamed pond (U2; Figure 4) 1.0 mile southeast of Valentine, at Pig Pond 0.99 mile south of Valentine, and at Rattlesnake Pond 1.0 mile west of Valentine. CTS have been documented at Mudd Pond 0.72 mile northwest of Valentine, near Smith Creek approximately 0.50 mile north of Valentine, at Kidney Pond 0.16 mile southeast of Valentine, at Leech Pond 0.45 mile southeast of Valentine, at an unnamed pond (U2; Figure 4) 1.0 mile southeast of Valentine, and at Hotel Pond 0.82 mile southwest of Valentine.

Threats and Issues:

This is a steep sided pond that is currently heavily affected by cattle use. It is not known to contain the target species, but they occur nearby. If they become established in this pond it may eventually become a population sink without improvements. Because it will dry by August in future decades, resulting in natural bullfrog control, it could be a successful CRLF and CTS breeding pond except that it will have a less than 50% probability of holding 2 feet of water into August after 2020. There are potential issues with groundwater availability.

Modifications:

1. Lower the spillway two feet to support drying in the wettest years for bullfrog management.

Post-Modifications Hydrologic Assessment:

Lowering the spillway by two feet would result in the pond drying fully in October in most years from to 2020 to 2080 and every year after 2080. The pond would hold two feet of water 50% or more of the time from February through May to 2100 and would not support CRLF or CTS breeding, but could provide refugia.

Recommendations:

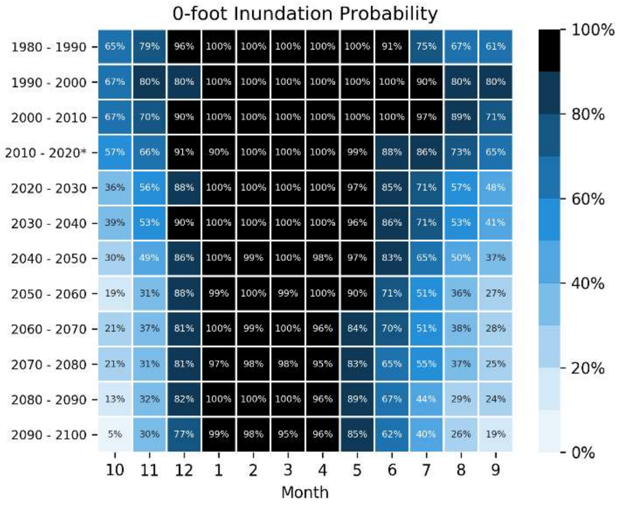
There are multiple occurrences of both CTS and CRLF within a mile of this pond, but not at this pond. Bullfrog management could protect other breeding ponds. Bullfrog control will happen naturally by the end of the century when this pond is expected to dry out in fall most of the time. Lowering the spillway by two feet so that the pond cannot be utilized for bullfrog breeding in the wettest years is recommended to assure bullfrog control occurs sooner.

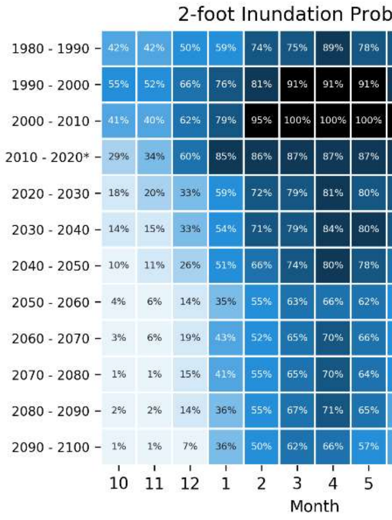
A representative photo and the modeled hydrology for Valentine Pond is illustrated in Figure 19.

Figure 19. Representative Photo and Modeled Hydrology for Valentine

Valentine Pond, October 20, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions





Kamera Pond:

Location and Watershed:

Kamera Pond lies in the northwest portion of the park (Figure 3), near a primary tributary to the Arroyo Aguague.

Physical Characteristics and Hydrology:

Kamera is a tectogenic pond in Los Gatos-Gaviota Complex gravelly loam soils with underlying Franciscan mélange geology. The pond has a watershed of 8.9 acres, and a surface area of 0.37 acre. It is a bowl-shaped, bermed pond, with depths up to 10.5 feet. The berm appears to be in good condition, and in most years the pond is wet all year, although in some years it dries early in the summer. There are no faults associated with the pond. Modeled inundation reaches a maximum of approximately 10.5 feet. Kamera pond holds some amount of water all year, including a minimum two-foot depth from December through September more than 50% of the time.

Biological Setting:

Kamera Pond is set in annual grassland at the edge of oak woodland. There is sparse vegetative cover at the pond edges. Species documented to occur in Kamera Pond include CTS, bullfrog, pacific chorus frog, western toad, California newt, and WPT. CTS was documented to have occurred in the pond in two out of seven annual surveys. Despite periodic drying (modeled to be about 23% of years), bullfrogs were detected in six out of seven annual surveys.

CRLF have been documented at an unnamed plunge pool (UPP1; Figure 4) 0.74 mile northeast of Kamera Pond, and at an unnamed reservoir (U10; Figure 4) 1.0 mile south of Kamera Pond. CTS have been documented at Gramp's Pond 0.83 mile north of Kamera Pond, at an unnamed pond (U6; Figure 4) 0.42 mile northeast of Kamera Pond, at Windmill Pond 0.41 mile northeast of Kamera Pond, at Blue Oak Pond 0.22 mile northeast of Kamera Pond, and at an unnamed pond (U5; Figure 4) 0.87 mile east of Kamera Pond.

Threats and Issues:

Bullfrogs are present and are likely to remain a threat into the future. The pond is accessed by cattle, which may cause direct mortality through trampling and indirect mortality by reducing vegetative cover which is already sparse. Kamera Pond currently meets the inundation parameters for the species and will continue to into the future. Although it will become drier over time, it will not dry completely to break the bullfrog cycle.

Modifications:

1. Install an adaptive drain four feet above the pond's deepest point, or a notch and flashboard weir at the spillway to periodically dry the pond and prevent bullfrog from completing its life cycle. The adaptive drain would be installed to at a 4 ft depth and be opened in April through 2050 and in May after 2050.

2. Cattle management may include closing the pond to cattle use during CTS and WPT breeding season, and/or fencing off a portion to increase vegetative cover for WPT.
3. WPT would benefit from placement of basking substrate in the middle of the pond, such as a tree trunk or large limb.

Post-modification Assessment

After modification with an adaptive drain, Kamera is modeled to consistently hold two feet of water during the breeding season and dry August through November, although this could be modified with drain design. In years when no bullfrog are present the drain could remain closed to maintain inundation depths for a longer period of time.

Recommendations:

The primary concern for Kamera Pond is the presence of bullfrog and therefore restoration efforts should be focused on eradication and control, both short-term and long-term. This may include identifying and controlling sources of bullfrog in neighboring ponds.

The current and future modeled inundation timeframes are suitable for the target species, however, it is recommended that an adaptive drain or flashboard weir on the spillway be installed to drain the pond annually or as-needed for bullfrog control.

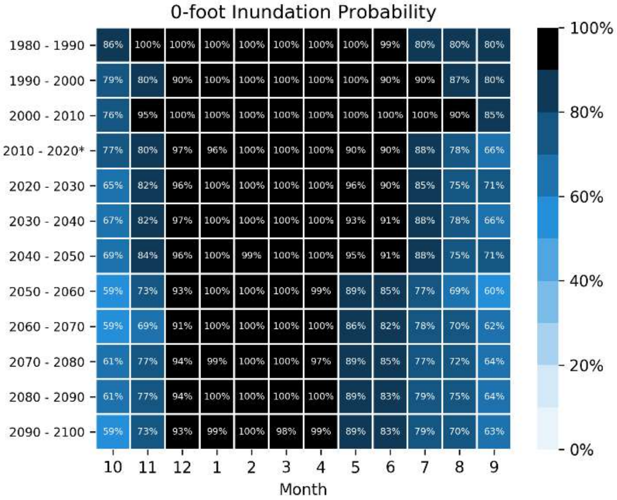
Increasing vegetative cover for WPT in a section of the pond by at least partially excluding cattle, especially during WPT nesting season, is also recommended.

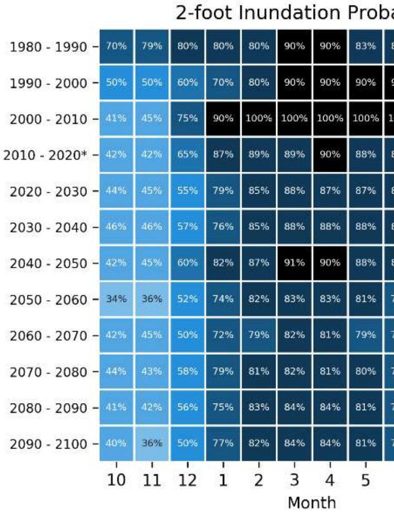
A representative photo and the modeled hydrology for Kamera Pond are illustrated in Figure 20.

Figure 20. Representative Photo and Modeled Hydrology for Kamera Po

Kamera Pond, October 20, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions





Deer Valley Pond:

Location and Watershed:

Deer Valley Pond is in the northeast portion of the park (Figure 3), near a tributary to Arroyo Aguague.

Physical Characteristics and Hydrology:

Deer Valley Pond is an instream/tectogenic pond in Los Gatos-Gaviota Complex gravelly loam soils with underlying Franciscan metamorphic complex. It has a watershed of 7.7 acres and a surface area of 0.79 acre.

Most years the pond is wet, but not full, from December to June. It is normally dry by the end of July. It is a natural pond with pond depths of 0 to 5.5 feet. It may have a groundwater source.

It currently has a ≥50% probability of holding water from December through June, and water depths of 2 feet or more have a ≥50% probability of occurring January through May. In the future the pond is expected to be drier. While it will likely hold two feet of water for six months (January through June) in the decade 2020-2030, after that the period will likely shorten to February through May in mid-century and eventually to March and April by 2100.

Biological Setting:

Deer Valley Pond is surrounded by a mosaic of nonnative annual grassland and oak woodland, with small mammal burrows, leaf litter, and shrubby vegetation to provide upland dispersal habitat for amphibians. There was no emergent vegetation at the time of the December 2018 MIG survey. Both CTS and CRLF have been documented at Deer Valley, in addition to Pacific chorus frog, western toad, and California newt.

CTS was positively identified to occur in Deer Valley Pond in five out of seven years of surveys and CRLF was found in four out of seven years of surveys. Deer Valley Pond is within a mile of several ponds that support CTS, including Black Oak Pond (0.83 mile), U1 Pond (0.62 mile), and Turtle Pond (0.95 mile; Figure 4). CRLF have not been documented in the CNDDB at any other ponds within 1 mile of Deer Valley Pond, though formal surveys may not have been conducted.

Threats and Issues:

Deer Valley Pond dries annually and does not support bullfrogs, which is beneficial for both CRLF and CTS. Climate change projections indicate that the hydroperiod will shorten over time. The pond already dries too quickly than desired to support CRLF; if CRLF are laying eggs here the pond is likely to be a population sink for CRLF. It may continue to contain enough water for CTS metamorphosis, but may become marginal for CTS breeding by 2030 due to lower water depths.

There is evidence that the pond is used as a feral pig wallow, which may directly impact amphibian eggs or larvae.

If the pond is restored to CRLF habitat it will need to be deepened and have increased vegetative or woody cover.

Deer Valley is remote, and equipment access may be difficult.

Modifications:

1. A portion of Deer Valley Pond could be deepened and lined to restore breeding habitat for CRLF, and improve habitat over the long term for CTS. Excavated soil could be used to provide an island for habitat diversity. However, model results suggest that deepening the pond by two feet does not increase the inundation period significantly and risks making the pond leakier. That would risk the loss of habitat for CTS which the pond already supports.
2. If improved for CRLF, then emergent vegetation or downed wood should be added in a portion of the pond.
3. Provide protection from pigs, if pig damage continues.

Post-Modification Hydrologic Assessment:

Modeling indicates that deepening a portion of the pond by two feet would extend the time it holds two feet of water from January through June to 2050 (currently it is 2030), and after that the two-foot depth would be consistently present February through May.

Recommendations:

Based on hydrologic modeling, Deer Valley Pond is not likely to support breeding CRLF currently, and will eventually be marginal for breeding CTS, possibly as early at 2030. If further surveys for CRLF observe breeding at Deer Valley Pond, this species would benefit from a deeper basin that will remain inundated for longer periods, and that would also provide refugia for both species. However, study of the pond substrate is warranted to determine if grading it will make it leakier and adversely impact CTS.

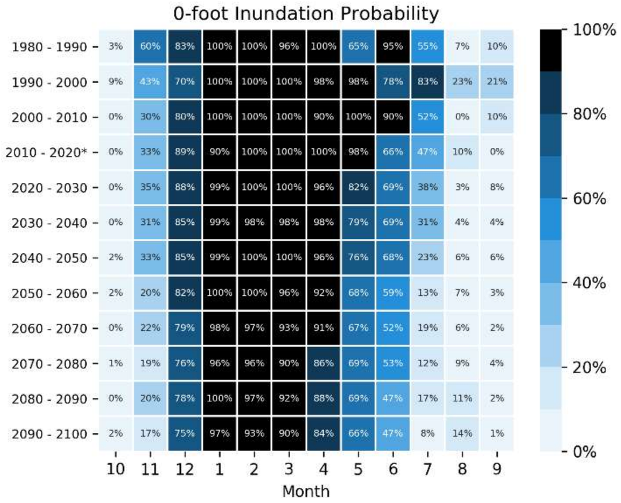
Therefore, it is recommended that pond hydrology and target species use continue to be monitored at Deer Valley and surrounding ponds, that data on pond substrate be collected, and that hydrologic data continue to be collected to update the model. Pond modification should be reassessed by 2025 to incorporate new and ongoing data collection for implementation by 2050.

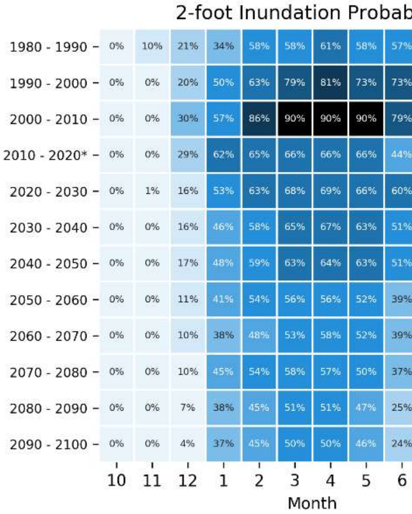
A representative photo and the modeled hydrology for Deer Valley Pond is illustrated in Figure 21.

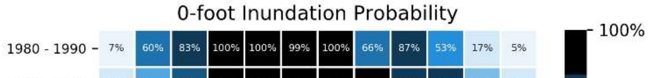
Figure 21. Representative Photo and Modeled Hydrology for Deer Valle

Deer Valley Pond, December 29, 2016 (Balance Hydrologics)

Modeled Inundation under Existing Conditions







Rattlesnake:

Location and Watershed:

Rattlesnake Pond lies in the southern section of the park, near San Felipe Creek (Figure 3).

Physical Characteristics and Hydrology:

Rattlesnake Pond is classified as a tectogenic pond with Los Gatos-Gaviota complex and gravelly loam soils with an underlying geology of Franciscan mélange and metamorphic complex. There are no faults associated with the pond. Rattlesnake has a watershed area of 8.9 acres and a surface area of 0.49 acres. Modeled inundation has reached a maximum of approximately 7 feet. Generally, the pond is flat and steep-sided. Rattlesnake typically holds water from November through September.

Rattlesnake Pond currently has a ≥50% probability of holding water all year, and a ≥50% probability of having water depths of at least 2 feet from December through August. The future trend for the pond is to hold two feet of water from December to September to 2030 and from January to August from 2030 to 2100.

Biological Setting:

Rattlesnake Pond is surrounded by a mosaic of annual grassland and coast live oak woodland, with ample small mammal burrows nearby. There was no emergent vegetation at the time of the 2018 survey. Rattlesnake pond is heavily utilized by cattle. Amphibians at the pond include bullfrog, Pacific chorus frog, western toad, California newt, rough-skinned newt, CRLF, and CTS.

CRLF have been documented at Pig Pond 1.1 miles southeast of Rattlesnake and an unnamed pond (U8; Figure 4) 0.4 mile southwest of Rattlesnake. CTS have been documented at Mudd Pond 1.0 mile northeast of Rattlesnake, Kidney Pond 1.1 mile east of Rattlesnake, an unnamed pond (U3; Figure 4) 0.6 mile southwest of Rattlesnake, an unnamed pond (U4; Figure 4) 0.8 mile southwest of Rattlesnake, and Powerline Pond approximately 1 mile southwest of Rattlesnake.

Threats and Issues:

The pond is impacted by both cattle use and bullfrog. Additionally, dense and/or shrubby vegetation surrounding the pond may impede species dispersal. Emergent vegetation is lacking in this steep-sided pond. The hydroperiod will shorten, but this may help with bullfrog eradication in the case of this pond.

Modifications:

1. Control bullfrogs by lowering the spillway by 3 feet, but also re-grade the pond to include a 2-foot lower central pool with a small surface area to improve refugia for both CRLF and not increase ET.
2. Exclude cattle from a portion of the pond to allow emergent vegetation to grow for improved CRLF cover.

Post-Modifications Hydrologic Assessment:

After modification Rattlesnake will dry out more often from September through November, will start to fill in December, and will hold at least two feet of water from January through July or August most years from now until 2100.

Recommendations:

Rattlesnake Pond is currently functioning well for CRLF and CTS, although it also supports bullfrog. Because the hydrology is near target levels and not expected to be impacted by climate change in the near future, it is recommended that additional years of hydrology data be collected to better inform any modifications in spillway elevation or deepening a section of the pond. It is recommended that manual methods of bullfrog control be implemented at this pond in the interim, particularly due to the bullfrog metapopulation impacts at nearby Hotel Pond and Eagle Lake.

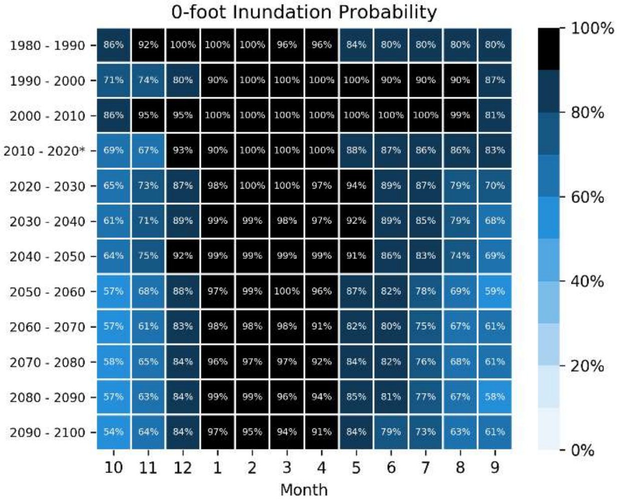
In addition, it is recommended that cattle be excluded from a portion of Rattlesnake Pond to allow vegetative cover to increase for CRLF refugia and juvenile life stages (egg masses and larvae).

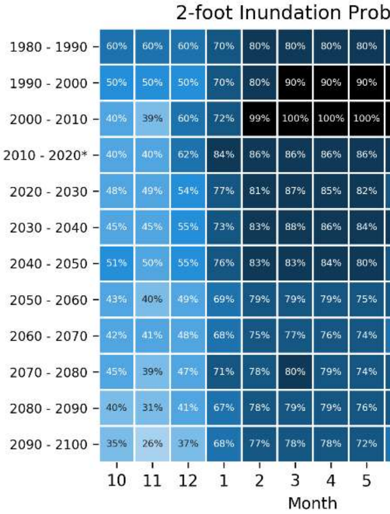
A representative photo and the modeled hydrology for Rattlesnake Pond is illustrated in Figure 22.

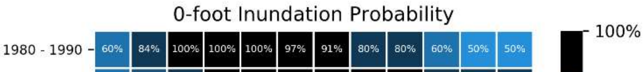
Figure 22. Representative Photo and Modeled Hydrology for Rattlesnak

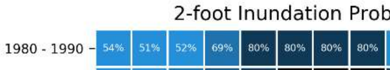
Rattlesnake Pond, May 10, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions









Dairy Pond:

Location and Watershed:

Dairy Pond lies along the southwestern edge of the park and is within the San Felipe Creek watershed (Figure 3).

Physical Characteristics and Hydrology:

Dairy Pond is classified as tectogenic. The soils are Los Gatos-Gaviota Complex, gravelly loam with an underlying geology of Miocene sedimentary rocks and Quaternary hillslope deposits. No fault is associated with this pond. It has a watershed of 3.1 acres and a surface area of 0.09 acre. Dairy Pond has a flat bowl shape with a man-made berm that was found to be in good condition during field surveys in 2017 and 2018.

Modeling over a 37-year period shows that this pond likely does not spill, that it dries annually, and that it ponds every year for at least a month, usually December or January.

Dairy Pond currently has a ≥50% probability of holding water from November through May. The probability of ponding depths reaching 2 feet or more do not exceed 44% throughout the entire year. The future trend for the pond to hold two feet of water is limited to a couple of months in winter-spring.

Biological Setting:

Dairy Pond is surrounded by dense coyote brush scrub, and emergent vegetation occurs along the edges. CRLF, CTS, and Pacific chorus frog have previously been documented at Dairy Pond.

CRLF have been documented at Heron Pond 0.82 mile northwest of Dairy, at Grant Lake 0.91 mile northeast of Dairy, and at Snell Reservoir 0.95 mile southeast of Dairy. CTS have been documented at Brush Pond 0.46 mile southeast of Dairy and at Brush Wetland 0.79 mile southeast of Dairy.

Threats and Issues:

Dairy Pond currently holds water from Nov-June but is usually dry by July and has a depth of two feet only for a couple of months. It may provide refugia but is not reliable as breeding habitat. Climate change projections indicate that Dairy will still hold water to the end of June in 2100, but that depths of two feet will rarely be achieved after 2030. Based on the gage records and modeling, it is inferred that the pond is leaky when water depths exceed 1-2 feet.

Dairy Pond is set in dense vegetation which may pose a barrier to movement between it and other ponds with CRLF and CTS. It's role for CTS and CRLF is unclear.

Modifications:

Increasing the hydroperiod could potentially be achieved by lining the berm, however this is not practical. It has a shallow soil layer, making recontouring difficult, and because it is constrained by local topography it will be difficult to increase the pond area. It may be possible to route water from the nearby road toward the pond to increase water supply, but this would also introduce sediment.

Modifications are not recommended at this time.

Post-Modification Hydrologic Assessment:

Not applicable.

Recommendation:

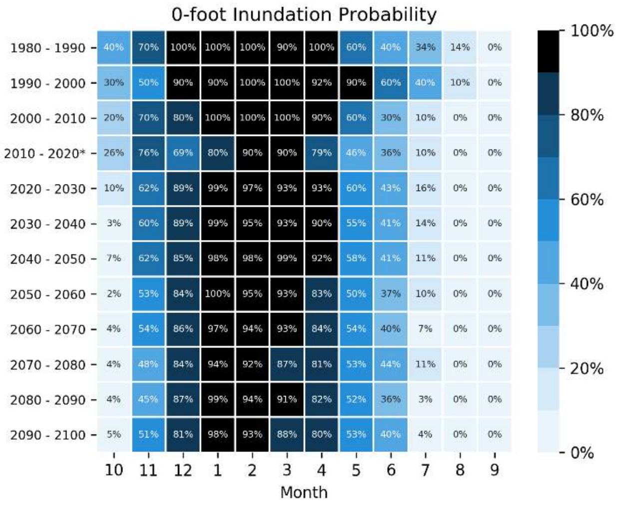
Continue monitoring species use and hydrology of Dairy Pond for up to five years to better understand the value of this pond to the species. The hydrology appears to be insufficient for target species breeding, however, this pond may serve as refugia for migrants, warranting its maintenance.

A representative photo and the modeled hydrology for Dairy Pond is illustrated in Figure 23.

Figure 23. Representative Photo and Modeled Hydrology for Dairy Pon

Dairy Pond, May 10, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



Brush Pond:

Location and Watershed:

Brush Pond is located on the west side of the park between Dairy Pond and Brush Wetland. It is in the watershed of San Felipe Creek. Brush Pond has a watershed area of 1.1 acres.

Physical Characteristics and Hydrology:

Brush Pond is a shallow depression that is classified as tectogenic and is sourced by a tributary to San Felipe Creek. The soils are Los Gatos-Gaviota Complex, gravelly loam. There is no associated fault. Brush Pond typically holds water from December through May. Between now and 2100 it is projected to be two feet deep in February and March about 50% of the time.

Biological Setting:

Brush Pond is set in annual grassland at the edge of oak woodland and chaparral habitat. There is semi-dense vegetation surrounding the pond that may hinder CRLF and/or CTS movement. CTS and Pacific chorus frog are the only amphibian species that have been documented to occur at Brush Pond. CTS larvae were last documented at the pond in 2006 during Dr. Padgett-Flohr's Bd research. Unless 2006 was an unusually wet year the pond may not have supported water long enough for those larvae to metamorphose.

CRLF have been documented at Snell Reservoir, approximately 0.53 mile east of Brush Pond and at Dairy Pond 0.44 mile northwest of Brush Pond. CTS have been documented at Valley Oak 1.0 mile northeast of Brush Pond, at Brush Wetland 0.32 mile southeast of Brush Pond, at Dairy Pond 0.44 mile northwest of Brush Pond, and at Corral Pond 0.96 mile southeast of Brush Pond (Figure 4).

Threat and Issues:

Brush Pond provides a marginal hydroperiod for successful CTS breeding, but may be important geographically for CTS movement between Dairy Pond, Brush Pond, and Brush Wetland, assuming CTS can negotiate the surrounding vegetation.

Brush Pond is in a location that topographically limits the ability to increase its size or depth and improve the hydroperiod.

Modifications:

1. This pond has a small watershed and there is not a sufficient amount of water to support the target species. No re-grading or hydrologic modifications are recommended.

Post-Modification Hydrologic Assessment:

No modifications are recommended, so post-modification was not modeled.

Recommendation:

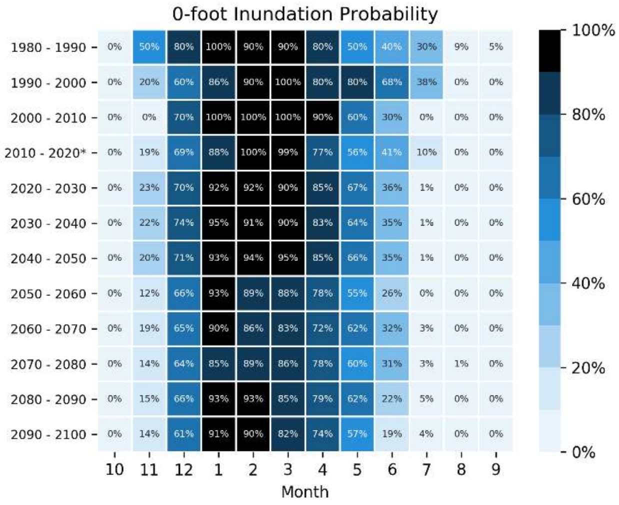
Further investigation of target species' use of Brush Pond is needed to better understand if it is important for population viability by providing non-breeding aquatic habitat and facilitating dispersal to other aquatic habitat, or if it acts as a population sink by being inundated during the egg-laying period, but drying before larvae can complete their metamorphosis. It is recommended that species use be investigated for a minimum of two, but preferably three more years. If egg masses are observed with any regularity, it is recommended that Brush Pond be decommissioned or otherwise modified to prevent inundation during CRLF's breeding season.

A representative photo and the modeled hydrology for Brush Pond is illustrated in Figure 24.

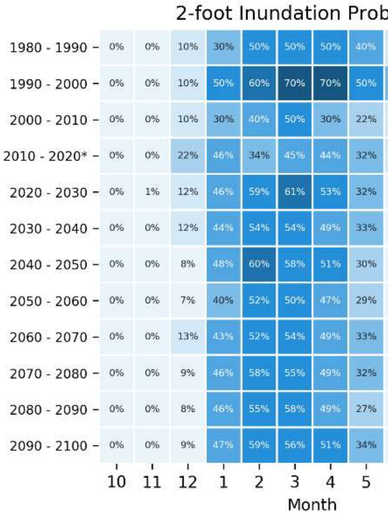
Figure 24. Representative Photo and Modeled Hydrology for Brush Pon

Brush Pond, January 30, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	0%	50%	80%	100%	90%	90%	80%	50%	40%	30%	9%	5%
1990 - 2000	0%	20%	60%	86%	90%	100%	80%	80%	68%	38%	0%	0%
2000 - 2010	0%	0%	70%	100%	100%	100%	90%	60%	30%	0%	0%	0%
2010 - 2020*	0%	19%	69%	88%	100%	99%	77%	56%	41%	10%	0%	0%
2020 - 2030	0%	23%	70%	92%	92%	90%	85%	67%	36%	1%	0%	0%
2030 - 2040	0%	22%	74%	95%	91%	90%	83%	64%	35%	1%	0%	0%
2040 - 2050	0%	20%	71%	93%	94%	95%	85%	66%	35%	1%	0%	0%
2050 - 2060	0%	12%	66%	93%	89%	88%	78%	55%	26%	0%	0%	0%
2060 - 2070	0%	19%	65%	90%	86%	83%	72%	62%	32%	3%	0%	0%
2070 - 2080	0%	14%	64%	85%	89%	86%	78%	60%	31%	3%	1%	0%
2080 - 2090	0%	15%	66%	93%	93%	85%	79%	62%	22%	5%	0%	0%
2090 - 2100	0%	14%	61%	91%	90%	82%	74%	57%	19%	4%	0%	0%



	10	11	12	1	2	3	4	5
1980 - 1990	0%	0%	10%	30%	50%	50%	50%	40%
1990 - 2000	0%	0%	10%	50%	60%	70%	70%	50%
2000 - 2010	0%	0%	10%	30%	40%	50%	30%	22%
2010 - 2020*	0%	0%	22%	46%	34%	45%	44%	32%
2020 - 2030	0%	1%	12%	46%	59%	61%	53%	32%
2030 - 2040	0%	0%	12%	44%	54%	54%	49%	33%
2040 - 2050	0%	0%	8%	48%	60%	58%	51%	30%
2050 - 2060	0%	0%	7%	40%	52%	50%	47%	29%
2060 - 2070	0%	0%	13%	43%	52%	54%	49%	33%
2070 - 2080	0%	0%	9%	46%	58%	55%	49%	32%
2080 - 2090	0%	0%	8%	46%	55%	58%	49%	27%
2090 - 2100	0%	0%	9%	47%	59%	56%	51%	34%

Woodland Pond:

Location and Watershed:

Woodland Pond is located on the west side of the park (Figure 3), in the watershed of San Felipe Creek. It is adjacent to a road and a campground.

Physical Characteristics and Hydrology:

Woodland Pond is a shallow, flat bowl that is classified as tectogenic. The soils are Los Gatos-Gaviota Complex, gravelly loam, and the underlying geology is Miocene sedimentary rocks and Quaternary hillslope deposits. The watershed is 4.6 acres, and the pond has a surface area of 0.27 acre. Bedrock was encountered at about 2.5 feet under the pond when the monitoring wells were installed. There is no fault, and no berm. Woodland Pond typically holds water from December through April.

Woodland Pond spills only occasionally. Modeling indicates that it is typically wet December through May and sometimes holds two feet of water in February and March. This pattern is not expected to change significantly through the century.

Biological Setting:

Woodland Pond is fenced with split-rails (which would not hinder amphibian dispersal), is adjacent to a campsite, and is surrounded by a mosaic of nonnative annual grassland, coyote brush, and oak woodland. Pacific chorus frog and unidentified newts (*Taricha* spp.) are the only amphibians that have previously been documented at Woodland Pond.

CRLF have been documented at Heron Pond 1.0 mile northwest of Woodland, at Grant Lake 0.86 mile north of Woodland, at Dairy Pond 0.28 mile west of Woodland, and at Snell Reservoir 0.66 mile southeast of Woodland. CTS have been documented at Dairy Pond 0.28 mile west of Woodland, at Valley Oak Vernal 1.0 mile east of Woodland, at Brush Wetland 0.57 mile southeast of Woodland, and at Brush Pond 0.26 mile south of Woodland.

Threats and Issues:

Woodland Pond is adjacent to two roads that may be directing overland flow away from the pond. One of the roads leads to a campsite, and the pond is currently fenced to discourage public access. There are slopes around the pond, and the natural direction for expansion if the pond is recontoured is across the access road to the campsite. Therefore, pond improvements may conflict with existing uses. There is also a question whether special-status species should be attracted to areas of regular human use. The pond may be difficult to deepen into bedrock.

Modifications:

The watershed of this pond is small and there is not a sufficient amount of surface water, or groundwater upwelling to fill the pond and support the target species. No re-grading or hydrologic modifications are recommended.

Post-Modification Hydrologic Assessment:

No modifications are recommended, so post-modification was not modeled.

Recommendations:

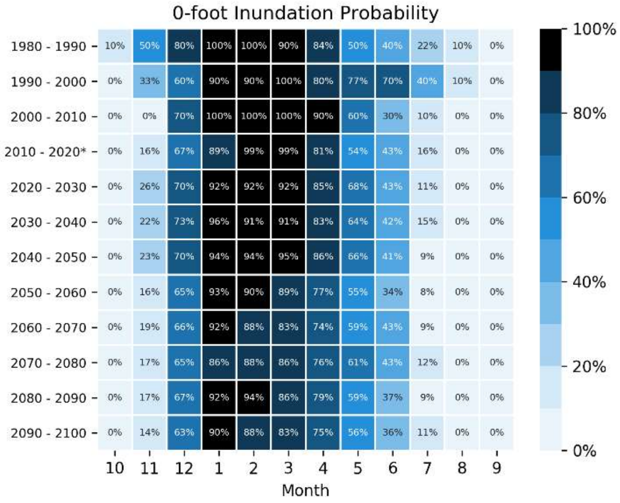
Woodland Pond is not recommended for modification or further study.

A representative photo and the modeled hydrology for Woodland Pond are illustrated in Figure 25.

Figure 25. Representative Photo and Modeled Hydrology for Woodland

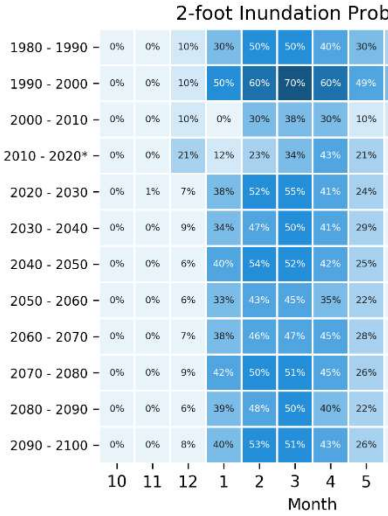
Woodland Pond, January 30, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



0-foot Inundation Probability

	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	10%	50%	80%	100%	100%	90%	84%	50%	40%	22%	10%	0%
1990 - 2000	0%	33%	60%	90%	90%	100%	80%	77%	70%	40%	10%	0%
2000 - 2010	0%	0%	70%	100%	100%	100%	90%	60%	30%	10%	0%	0%
2010 - 2020*	0%	16%	67%	89%	99%	99%	81%	54%	43%	16%	0%	0%
2020 - 2030	0%	26%	70%	92%	92%	92%	85%	68%	43%	11%	0%	0%
2030 - 2040	0%	22%	73%	96%	91%	91%	83%	64%	42%	15%	0%	0%
2040 - 2050	0%	23%	70%	94%	94%	95%	86%	66%	41%	9%	0%	0%
2050 - 2060	0%	16%	65%	93%	90%	89%	77%	55%	34%	8%	0%	0%
2060 - 2070	0%	19%	66%	92%	88%	83%	74%	59%	43%	9%	0%	0%
2070 - 2080	0%	17%	65%	86%	88%	86%	76%	61%	43%	12%	0%	0%
2080 - 2090	0%	17%	67%	92%	94%	86%	79%	59%	37%	9%	0%	0%
2090 - 2100	0%	14%	63%	90%	88%	83%	75%	56%	36%	11%	0%	0%



2-foot Inundation Prob

	10	11	12	1	2	3	4	5
1980 - 1990	0%	0%	10%	30%	50%	50%	40%	30%
1990 - 2000	0%	0%	10%	50%	60%	70%	60%	49%
2000 - 2010	0%	0%	10%	0%	30%	38%	30%	10%
2010 - 2020*	0%	0%	21%	12%	23%	34%	43%	21%
2020 - 2030	0%	1%	7%	38%	52%	55%	41%	24%
2030 - 2040	0%	0%	9%	34%	47%	50%	41%	29%
2040 - 2050	0%	0%	6%	40%	54%	52%	42%	25%
2050 - 2060	0%	0%	6%	33%	43%	45%	35%	22%
2060 - 2070	0%	0%	7%	38%	46%	47%	45%	28%
2070 - 2080	0%	0%	9%	42%	50%	51%	45%	26%
2080 - 2090	0%	0%	6%	39%	48%	50%	40%	22%
2090 - 2100	0%	0%	8%	40%	53%	51%	43%	26%

Smith Pond:

Location and Watershed:

Smith Pond lies within the southeasternmost portion of the park near Smith Creek.

Physical Characteristics and Hydrology:

Smith Pond is classified as an instream pond with Los Gatos-Gaviota complex and gravelly loam soils with an underlying geology of Franciscan metamorphic complex. There are no faults associated with the pond. Smith Pond has a watershed area of 12.2 acres and a surface area of 0.19 acres. Modeled inundation has reached a maximum of approximately 4.5 feet. Generally, the pond is shallow and flat. Smith Pond typically holds water January through March.

Smith Pond is very dry. It rarely contains water and may never reach two foot in depth in some years. It is not a dependable breeding or refuge for CRLF or CTS.

Biological Setting:

Smith Pond is surrounded by dense vegetation, including gray pine (*Pinus sabiniana*), willow (*Salix spp.*), yellow star thistle (*Centaurea solstitialis*), *Juncus* spp., *Rumex* spp., coyote brush (*Baccharis pilularis*), and Italian thistle (*Carduus pycnocephalus*). There was no emergent vegetation at the time of the December 2018 survey. There is no documentation of any amphibian species at Smith Pond.

CRLF have been documented to occur along Smith Creek, approximately 0.32 mile northwest of Smith Pond and at an unnamed pond (U2; Figure 4) 0.93 mile southeast of Smith Pond. CTS have been documented at Mudd Pond 0.80 mile northwest of Smith Pond, near Smith Creek approximately 0.44 mile north of Smith Pond, at Kidney Pond 0.19 mile south of Smith Pond, at Leech Pond 0.37 mile southeast of Smith Pond, at an unnamed pond (U2; Figure 4) 0.93 mile southeast of Smith Pond, and at Hotel Pond 1 mile southwest of Smith Pond.

Threats and Issues:

Climate change will likely impact the already short hydroperiod of this pond. There is not enough water in the pond for a long enough period to support CTS or CRLF, which have not been found to be present. The pond apparently leaks and is heavily vegetated.

Modifications:

There is not a sufficient amount of water feeding this pond to support the target species. No re-grading or hydrologic modifications recommended.

Post-Modification Hydrologic Assessment:

No modifications are recommended, so post-modification was not modeled.

Recommendation:

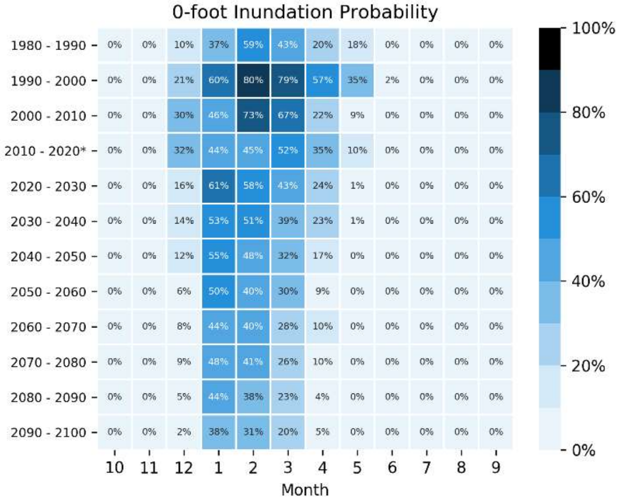
Smith Pond is not recommended for modification or further study at this time.

A representative photo and the modeled hydrology for Smith Pond are illustrated in Figure 26.

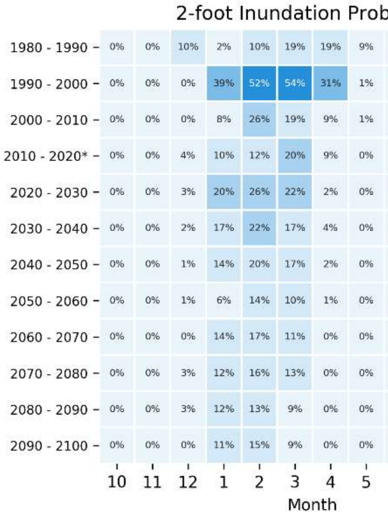
Figure 26. Representative Photo and Modeled Hydrology for Smith Pon

Smith Pond, January 30, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	0%	0%	10%	37%	59%	43%	20%	18%	0%	0%	0%	0%
1990 - 2000	0%	0%	21%	60%	80%	79%	57%	35%	2%	0%	0%	0%
2000 - 2010	0%	0%	30%	46%	73%	67%	22%	9%	0%	0%	0%	0%
2010 - 2020*	0%	0%	32%	44%	45%	52%	35%	10%	0%	0%	0%	0%
2020 - 2030	0%	0%	16%	61%	58%	43%	24%	1%	0%	0%	0%	0%
2030 - 2040	0%	0%	14%	53%	51%	39%	23%	1%	0%	0%	0%	0%
2040 - 2050	0%	0%	12%	55%	48%	32%	17%	0%	0%	0%	0%	0%
2050 - 2060	0%	0%	6%	50%	40%	30%	9%	0%	0%	0%	0%	0%
2060 - 2070	0%	0%	8%	44%	40%	28%	10%	0%	0%	0%	0%	0%
2070 - 2080	0%	0%	9%	48%	41%	26%	10%	0%	0%	0%	0%	0%
2080 - 2090	0%	0%	5%	44%	38%	23%	4%	0%	0%	0%	0%	0%
2090 - 2100	0%	0%	2%	38%	31%	20%	5%	0%	0%	0%	0%	0%



	10	11	12	1	2	3	4	5
1980 - 1990	0%	0%	10%	2%	10%	19%	19%	9%
1990 - 2000	0%	0%	0%	39%	52%	54%	31%	1%
2000 - 2010	0%	0%	0%	8%	26%	19%	9%	1%
2010 - 2020*	0%	0%	4%	10%	12%	20%	9%	0%
2020 - 2030	0%	0%	3%	20%	26%	22%	2%	0%
2030 - 2040	0%	0%	2%	17%	22%	17%	4%	0%
2040 - 2050	0%	0%	1%	14%	20%	17%	2%	0%
2050 - 2060	0%	0%	1%	6%	14%	10%	1%	0%
2060 - 2070	0%	0%	0%	14%	17%	11%	0%	0%
2070 - 2080	0%	0%	3%	12%	16%	13%	0%	0%
2080 - 2090	0%	0%	3%	12%	13%	9%	0%	0%
2090 - 2100	0%	0%	0%	11%	15%	9%	0%	0%

Valley Oak[9]:

Location and Watershed:

Valley Oak Pond is near the center of the park close to Bass Lake and near a primary tributary to San Felipe Creek (Figure 3).

Physical Characteristics and Hydrology:

Valley Oak Pond is classified as a landslide headscarp/instream pond with Los Gatos-Gaviota Complex and gravelly loam with an underlying geology of Quarternary hillslope deposits. There are no faults associated with the pond. Valley Oak Pond has a watershed area of 4.8 acres and a surface area of 0.61 acres. Modeled inundation has reached a maximum of approximately 4.4 feet deep. The pond is generally flat, shallow, and bowl-shaped and lies at the base of a gentle slope. Valley Oak is typically inundated December through April, but the hydroperiod may shorten significantly in future years due to sedimentation and climate-related impacts.

Valley Oak Pond currently has a ≥50% probability of containing water from December through June, but the probability of ponding depths reaching 2 feet are limited to February and March. The future trend for the pond to hold two feet is shortened to February.

Biological Setting:

Valley Oak Pond is surrounded by annual grassland. There was approximately 20% emergent vegetation at the time of the 2018 survey. Amphibians at the pond include CTS, western toad and California newt.

CRLF have been recorded at an unnamed pond (U9; Figure 4), 0.8 mile northeast of Valley Oak and Snell Reservoir 0.5 mile southwest of Valley Oak. CTS have been documented at Corral Pond 0.8 mile south of Valley Oak Pond; Brush Wetland, 0.9 mile southwest of Valley Oak Pond; and Brush Pond 1 mile west of Valley Oak Pond.

Threats and Issues:

Valley Oak Pond is very shallow and has a short hydroperiod that will become shorter over time. It provides minimally suitable breeding habitat for CTS at present. It is a shallow bowl with a limited watershed.

The pond is currently heavily impacted by cattle that use it as a water source.

Modifications:

Due to the small watershed and limited surface and groundwater inflows, modifications are not expected to substantially extend its hydroperiod. No re-grading or hydrologic modifications are recommended.

Post-Modifications Hydrologic Assessment:

No modifications are recommended, so post-modification was not modeled.

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[9] Also referred to as "Vernal Pond."

Recommendation:

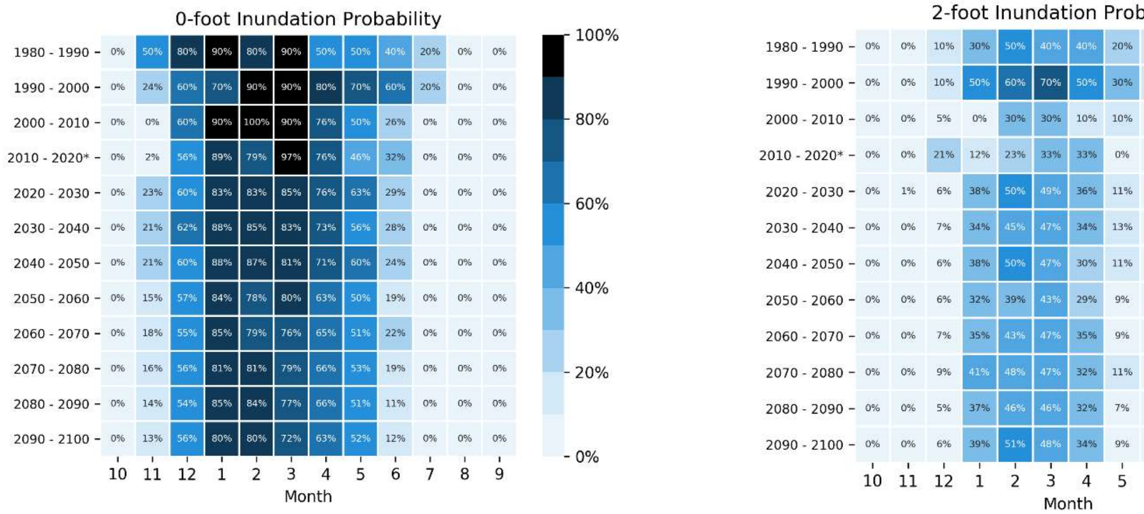
No modifications or further study are recommended for Valley Oak Pond at this time.

A representative photo and the modeled hydrology for Valley Oak Pond is illustrated in Figure 27.

Figure 27. Representative Photo and Modeled Hydrology for Valley Oak

Valley Oak Pond, May 10, 2017 (Balance Hydrologics)

Modeled Inundation under Existing Conditions



0-foot Inundation Probability

	10	11	12	1	2	3	4	5	6	7	8	9
1980 - 1990	0%	50%	80%	90%	80%	90%	50%	50%	40%	20%	0%	0%
1990 - 2000	0%	24%	60%	70%	90%	90%	80%	70%	60%	20%	0%	0%
2000 - 2010	0%	0%	60%	90%	100%	90%	76%	50%	26%	0%	0%	0%
2010 - 2020*	0%	2%	56%	89%	79%	97%	76%	46%	32%	0%	0%	0%
2020 - 2030	0%	23%	60%	83%	83%	85%	76%	63%	29%	0%	0%	0%
2030 - 2040	0%	21%	62%	88%	85%	83%	73%	56%	28%	0%	0%	0%
2040 - 2050	0%	21%	60%	88%	87%	81%	71%	60%	24%	0%	0%	0%
2050 - 2060	0%	15%	57%	84%	78%	80%	63%	50%	19%	0%	0%	0%
2060 - 2070	0%	18%	55%	85%	79%	76%	65%	51%	22%	0%	0%	0%
2070 - 2080	0%	16%	56%	81%	81%	79%	66%	53%	19%	0%	0%	0%
2080 - 2090	0%	14%	54%	85%	84%	77%	66%	51%	11%	0%	0%	0%
2090 - 2100	0%	13%	56%	80%	80%	72%	63%	52%	12%	0%	0%	0%

Month

2-foot Inundation Prob

	10	11	12	1	2	3	4	5
1980 - 1990	0%	0%	10%	30%	50%	40%	40%	20%
1990 - 2000	0%	0%	10%	50%	60%	70%	50%	30%
2000 - 2010	0%	0%	5%	0%	30%	30%	10%	10%
2010 - 2020*	0%	0%	21%	12%	23%	33%	33%	0%
2020 - 2030	0%	1%	6%	38%	50%	49%	36%	11%
2030 - 2040	0%	0%	7%	34%	45%	47%	34%	13%
2040 - 2050	0%	0%	6%	38%	50%	47%	30%	11%
2050 - 2060	0%	0%	6%	32%	39%	43%	29%	9%
2060 - 2070	0%	0%	7%	35%	43%	47%	35%	9%
2070 - 2080	0%	0%	9%	41%	48%	47%	32%	11%
2080 - 2090	0%	0%	5%	37%	46%	46%	32%	7%
2090 - 2100	0%	0%	6%	39%	51%	48%	34%	9%

Month

7. STUDY LIMITATIONS AND NEXT STEPS

7.1 Limitations

A systematic survey of species use of ponds in the park was not conducted, so this report relies on previous scientific studies, the authors' published and unpublished experience, and CNDDB records. While there are numerous named and unnamed aquatic features within the park, the primary focus of this report is a group of 13 "study ponds" that are the target of restoration and conservation efforts for CRLF, CTS, and WPT (Figure 3. Study Ponds, Figure 9. CRLF Pond Status, and Figure 10, CTS Pond Status). Each of the scientific studies report CRLF or CTS presence incidental to other data collection. Therefore, this report is necessarily based on incomplete data regarding species use of the park. We have used the available data to infer which ponds have been used for breeding, although it is not always possible to determine if breeding was successful. Consistent protocol-level surveys for CTS, CRLF, and WPT in all study ponds (and preferably within all park ponds) would provide more robust data to inform restoration plans within the park. Environmental DNA (eDNA) and other survey methods (e.g. auditory recordings for bullfrog vocalizations and/or camera traps for feral pig activity) and subsequent analysis may provide an alternative, cost-effective, and efficient method to investigate species' use of the park with limited resources.

All final restorative plans would require formal evaluation for environmental impacts or to identify actions that would require consultation and potential permits from CDFW, the Regional Water Quality Control Board (RWQCB), the United States Army Corps of Engineers (USACE), and/or the USFWS. Actions would also need to comply with the Valley Plan (see Section 3.4). This report's recommendations are suitable for a feasibility study, and do not conform to formal standards (engineering or otherwise) that are required as a basis for design.

Modifications to structures or hydrologic controls, such as lowering crest elevations or abutment configurations are conceptual only; These may require assessment of channel stability downstream or reconfiguration of emergency spillways and other protective measures, in addition to professional assessment of foundation stability and conformance with contemporary drainage regulations.

This work reflects conditions observed leading up to and including late 2018. While we conducted both field and simulative work to project needed modifications well into the future, it is the client's responsibility to assess whether conditions, populations, and climate remain reasonably as predicted, and to modify them accordingly. The possibility of regulatory changes (including specific new listings and de-listings) are not considered in this report. Conditions may change substantially following episodic events affecting this landscape, including but not limited to wildfire, extreme weather events, sustained droughts, seismic events, or establishment of new predators or pestilence; the client is responsible for timely inspections and modifications to this plan following first knowledge of such changes.

The report conforms with standard practice in the coastal counties of northern California. No further warranty, expressed or implied, is made.

7.2 Next Steps

7.2.1 Species Surveys

There are only two recorded CNDDB occurrences of WPT within the park. Currently WPT have been documented in the CNDDB at Kamera and an unnamed and unmapped stock pond approximately 0.45 mile north of Bass Lake. A systematic qualitative and quantitative assessment of this species throughout the park is needed to better understand WPT population numbers and dynamics. This will prove increasingly important as WPT is further considered for listing under either the state or federal Endangered Species Act.

Systematic survey and monitoring of invasive plant species in the ponds, and an eradication and management plan will also provide further aid to conservation and restoration efforts throughout the park.

Species use of Deer Valley, Dairy, and Brush ponds are also recommended as a priority to better understand the ecology of these ponds before modifications are finalized. Continued monitoring and species observations are also recommended for Rattlesnake Pond to better inform modification design.

7.2.2 Hydrologic Monitoring

Continuing hydrologic monitoring program for all ponds is recommended, except for Smith, Woodland, and Valley Oak where there is high confidence that the hydroperiod is not sufficient to support the target species. In particular, it is strongly recommended that monitoring in Deer Valley and Rattlesnake Ponds continue because it will enable Parks to observe the hydroperiod in a greater number of years of varying rainfall and to then further refine the models if modifications are considered. In the high-priority ponds, the hydrologic monitoring program will provide a valuable baseline when pond modifications are implemented. In the low-priority ponds, continued hydrologic monitoring is still recommended (though as a lower priority and perhaps with less calibration visits) to provide a control for the modified ponds and to assess the overall impact of climate change and other factors on pond hydrology.

7.2.3 Adaptive Management Planning

The study ponds are likely to be affected by episodic events, such as wildfire, extreme weather events (as opposed to climatic), sustained droughts, seismic, or other similar events. These can fundamentally shift or permanently alter key processes or conditions, including hydroperiod, that were used as a basis for the analysis in this report. Planning for the future of special-status species requires knowledge of what changes may be expected as a result of these events so that emergency measures may be implemented quickly following the event, and whether longer-term changes in species viability and presence should be re-assessed.

8. REFERENCES

Bobzien, S. and DiDonato, J.E., 2007. The Status of the California Tiger Salamander (*Ambystoma californiense*), California Red-Legged Frog (*Rana draytonii*), Foothill Yellow-Legged Frog (*Rana boylii*), and Other Aquatic Herpetofauna in the East Bay Regional Park District, California. Available at: https://www.ebparks.org/civicax/filebank/blobdload.aspx?blobid=30501 [Accessed March 2020].

Briggs Lab, 2019. Frog-killing chytrid fungus in California. Available at: https://labs.eemb.ucsb.edu/briggs/cherie/research/frog-killing-chytrid-fungus-california [Accessed April 2019].

California Invasive Plant Council (CAL-IPC), 2020. The Cal-IPC Inventory. Available at: https://www.cal-ipc.org/plants/inventory/ [Accessed March 2020].

California Landscape Conservation Partnership, 2017. Central Valley LCP: Priority Natural Resources and Vulnerability Assessments. Available at: http://climate.calcommons.org/cvlcp/vulnerability-assessments [Accessed July 2019].

CaliforniaHerps, 2019. Species Descriptions. Available at: http://www.californiaherps.com/index.html [Accessed April 2019].

CDFW, 2018. California Department of Fish and Wildlife, California Natural Diversity Database (CNDDB): Special Animals List, November 2018. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=109406 [Accessed April 2019].

CDFW, 2019. California’s Invaders: American Bullfrog. Available at: https://www.wildlife.ca.gov/Conservation/Invasives/Species/Bullfrog [Accessed April 2019].

CDFW, 2020. California’s Invaders: Red-Eared Slider. Available at: https://wildlife.ca.gov/Conservation/Invasives/Species/Redeared-Slider [Accessed January 2020].

CDFW, ND. Species Accounts-Amphibians. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84006&inline [Accessed April 2019].

Fellers, G. M. and Kleeman, P. M., 2007. California red-legged frog (*Rana draytonii*) Movement and Habitat Use: Implications for Conservation. Journal of Herpetology, Vol. 41, No. 2, pp. 276-286.

Food and Agriculture Organization of the United Nations (FAO), 2020. 10. Pond Outlet Structures. Available at: http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e10.htm [Accessed March 2020].

Fuller, P., Cannister, M., and Neilson, M., (USGS) 2019. *Micropterus dolomieu* Lacepède, 1802: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL. Available at: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=396 [Accessed July 2019].

iNaturalist, 2020. Explore: Observations: Common Slider. Available at: https://www.inaturalist.org/observations?place_id=any&taxon_id=39782 [Accessed March 2020].

Jennings, M. R. and Hayes, M. P. 1994. CDFG: Amphibian and Reptile Species of Special Concern in California. Available at: https://static1.squarespace.com/static/55c805dce4b0672c6263dc0d/t/55d77aeee4b0c669907e978e/1440185070298/herp_ssc1994.pdf [Accessed April 2019].

Kamoroff, C., Daniele, N, Grasso, R.L., Rising, R., Espinoza, T., and Goldberg, C.S., 2019. Effective removal of the American bullfrog (*Lithobates catesbeianus*) on a landscape level: long term monitoring and removal efforts in Yosemite Valley, Yosemite National Park. Biol Invasions (2020) 22:617-626.

Lambert, M.R., Mckenzie, J.M., Screen, R.M., Clause, A.G., Johnson, B.B., Mount, G.G., Shaffer, H.B., and Pauly, G.B., 2019. Experimental removal of introduced slider turtles offers new insight into competition with native, threatened turtle. PeerJ 7:e7444 https://doi.org/10.7717/peerj.7444

Marty, J.T., 2005. Effects of Cattle Grazing on Diversity in Ephemeral Wetlands. Conservation Biology 1626-1632, Society for Conservation Biology, DOI: 10.1111/j.1523-1739.2005.00198.x

NOAA, 2019. Global Summary of the Year Station Details: Mount Hamilton Station. Available at: https://www.ncdc.noaa.gov/cdo-web/datasets/GSOY/stations/GHCND:USC00045933/detail [Accessed April 2019].

North Carolina State University (NC State), 2020. Stormwater Wetland Construction Guidance: Urban Waterways. Available at: https://content.ces.ncsu.edu/stormwater-wetland-construction-guidance [Accessed March 2020].

Roche, L.M., Latimer, A. M., Eastburn, D. J., and Tate, K. W. 2012. Cattle Grazing and Conservation of a Meadow-Dependent Amphibian Species in the Sierra Nevada. PLoS ONE 7(4): e35734. doi:10.1371/journal.pone.0035734

Santa Clara County, 2013. Land Use Plan: June 2013. Available at: https://www.sccgov.org/sites/dpd/DocsForms/Documents/LandusePlan_map_2013.pdf [Accessed May 2019].

Schmutzer, A.C., Gray, M.J., Burton, E.C., and Miller, D.L. 2008. Impacts of cattle on amphibian larvae and the aquatic environment. Freshwater Biology, doi:10.1111/j.1365-2427.2008.0202.x

Spratt, A. 2018. “Where cattle graze and salamanders roam: Sparling Ranch Conservation Bank a win-win for ranchers, developers, wildlife.” Available at: https://www.fws.gov/natures-good-neighbors/stories/where-cattle-graze-and-salamanders-roam/ [Accessed July 2019].

UC Davis, 2019. Fish Species Data: Interactive Map. Available at: https://pisces.ucdavis.edu/map [Accessed July 2019].

USFWS, 2002. Recovery Plan for the California Red-legged Frog (*Rana aurora draytonii*). USFWS, Portland, Oregon. Viii+173 pp.

USFWS, 2017. Recovery Plan for the Central California Distinct Population Segment of the California Tiger Salamander (*Ambystoma californiense*). USFWS, Pacific Southwest Region, Sacramento, California. V+69 pp.

USFWS, 2017. Redear sunfish (*Lepomis microlophus*) Ecological Risk Screening Summary. Available at: https://www.fws.gov/fisheries/ANS/erss/highrisk/ERSS-Lepomis-microlophus_Final.pdf [Accessed July 2019].

USFWS, 2019. Species Information: California Tiger Salamander. Available at: https://www.fws.gov/sacramento/es_species/Accounts/Amphibians-Reptiles/ca_tiger_salamander/ [Accessed April 2019].

Appendix A. Balance Hydrologics Report

POND HYDROLOGY MONITORING AND HYDROPERIOD MODELING, JOSEPH D. GRANT PARK, SANTA CLARA COUNTY, CA

Report prepared for:
Santa Clara County Parks Department

Prepared by:
Zan Rubin, PhD
Kealie Pretzlav, PhD
Eric Donaldson, P.G
Barry Hecht, C.E.G., C.Hg

Balance Hydrologics, Inc.

February 2020

A draft report prepared for:

Santa Clara County Parks Department
298 Garden Hill Drive
Los Gatos, California 95032
(408) 355-2200
Karen.cotter@prk.sccgov.org

Pond Hydrology Monitoring and Hydroperiod Modeling, Joseph D. Grant Park, Santa Clara County, CA

© 2020 Balance Hydrologics, Inc. Project Assignment: 218158
by

Zan Rubin, PhD
Geomorphologist/Hydrologist

Kealie Pretzlav, PhD
Geomorphologist/Hydrologist

Eric Donaldson, P.G.
Geomorphologist/Hydrologist

Barry Hecht, C.E.G., C.Hg, Senior Principal
Geomorphologist/Hydrologist

Balance
Hydrologics

800 Bancroft Way, Suite 101
Berkeley, California 94710
(510) 704-1000
office@balancehydro.com

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1. INTRODUCTION

1.1 Problem Statement

Santa Clara County Parks asked Balance Hydrologics (Balance) and MIG/TRA to evaluate 13 ponds in Joseph D. Grant Park for existing and potential habitat value for the California red-legged frog (*Rana draytonii*, CRLF), and California tiger salamander (*Ambystoma californiense*). In the Mediterranean climate of the Bay Area, the persistence of pools in streams, ponds, and artificial impoundments through the long dry season is a key determinant of habitat availability and can be difficult to determine based on sporadic or short-term observations (Skidds and Golet, 2005). Future climate change threatens to change the annual duration of ponding, or hydroperiod, increase the intensity of storms and magnitude and duration of droughts, which may reduce and fragment available habitat through the reduction or elimination of key individual breeding and rearing pools and ponds.

1.2 Technical Goals

The primary foci of this project are to:

a) Monitor pond depth and duration from December 2016 to June 2018 and synthesize results.

b) Assemble record of historical pond extent and duration through interpretation of historical air photos.

c) Develop and calibrate pond hydroperiod models to assess pond duration under average, wet, and dry climate conditions.

d) Use downscaled global climate models to anticipate potential hydroperiod changes under long-term climate scenarios (results to be presented later, along with conceptual design recommendations).

1.3 Report Goals

This report summarizes the findings of the hydrologic monitoring and modelling of 13 ponds in Joseph D. Grant Park. Understanding the hydrology of each pond will form the basis of ecological enhancement strategies for each pond. Opportunities, constraints, and conceptual enhancement recommendations will be presented in subsequent reports.

1.4 Limitations

Analyses and information included in this report are intended for planning purposes described above. Analyses of channels and other water bodies, rocks, earth properties, topography and/or environmental processes are generalized to be useful at the scale of the watershed, both spatially and temporally. We have made efforts to incorporate sound science developed by prior workers, and evaluations completed as part of this project. However, recommendations or modeling results may need to be refined or modified as a result of discoveries made during planned subsequent habitat connectivity and prioritization evaluations, or as other relevant future studies are conducted, and results shared.

2. TECHNICAL APPROACH

The following section presents our technical approach used to characterize the hydroperiod, and climate change response across 13 ponds in Joseph D. Grant County Park. All 13 ponds were instrumented with water-level recorders and a topographic survey was performed at each to develop stage-storage relationships. Each pond was grouped into genetic classification based on existing literature and our reconnaissance site survey visits. The monitoring calibration data collected from December 2016 to May 2018 were supplemented with measurements of pond extent using historical aerial imagery in Google Earth®. A custom-developed and batch-run hydroperiod water balance model was constructed to characterize the relative contributions of various hydrologic fluxes which generates monthly estimates of pond water-surface elevations throughout the historical record. The model will be extended into the future using climate projections and each pond hydroperiod will be evaluated for climate resiliency. The modeling at Joseph D. Grant ponds follows the approach developed by Balance for other parks in Santa Clara County.

2.1 Genetic Classification

2.1.1 Genetic Classification

Ponds in watersheds with similar geology, soils, and topography often have similar hydrologic responses and groundwater patterns. Parameters such as watershed size, pond stage-storage relationship, and spillway elevation may account for many of the differences between the hydrologic responses of different ponds. The 13 ponds were genetically classified via a desktop analysis using publicly available datasets. Several sets of geologic maps were used for this study, including Wentworth and others (1999), and Graymer and others (2006). Ponds were classified into one of nine types, described in **Table 1** (adapted from Bauder et al., 2009). Not all of these classifications are present in the study area. As is the case with ponds in many urban areas, most of the ponds would not exist without anthropogenic intervention, which typically involved construction, stabilization, or supplementation of pond berms or spillways. The genetic classification here is not used to classify the processes of pond construction; otherwise all ponds except for Deer Valley would be anthropogenic. Instead, the classification is focused on the geologic, geomorphic, and soil processes that would either create a topographic low in an existing drainage channel, a seep or spring, or a combination of both, and where conditions were favorable for construction or enhancement of a pond feature. The classification may also serve to identify ponds which may have longer year-to-year hydroperiods due to persistence of saturated horizons beneath individual ponds.

The 13 ponds modeled for this report were grouped into only three of the nine classifications: Instream, Tectogenic, and Landslide Headscarp.

2.2 Pond Monitoring

2.2.1 Stage-storage Relationship Development

Balance field-surveyed each pond in August and September 2017 to develop an empirical relationship between water level, pond storage, and pond area at each water level. We surveyed all ponds using a Total Station. We surveyed key points that enabled us to define the bathymetry of each pond, including the spillway, berm, high-water marks, and current water surface elevation. We established bench-marks at each pond, so surveys could be repeated and to relate water surface elevations during future site visits. Contour lines were constructed based on the elevation relative to the deepest point recorded during the survey to create a stage-storage relationship (depth-capacity curve) for each pond.

2.2.2 Hydrologic Gaging

We installed a Solinst Levelogger© in each of the 13 ponds, which measured water depth hourly. We also installed two shallow piezometers at Dairy, Rattlesnake, and Woodlands ponds, and three piezometers at Edwards and Kamera. Each piezometer was equipped with a Solinst Levelogger© and measured water depth hourly. We installed the pond gages and piezometers in December 2016. The dataloggers were last downloaded in June and July 2018 and remain in operation. Each pond was visited at least six times during the monitoring period. During the site visits we measured the water surface elevation, downloaded the loggers, and measured the specific conductance.

2.3 Conditions in WY2017 and WY2018 Relative to Historical Norms

Pond monitoring and field surveys were carried out during water year[1] (WY) 2017 and WY2018. WY2017 was considerably wetter than most historical years. WY2017 was the wettest year in the calibration period, which begins in 2003. WY2018 was close to the historical average, though ponds and soils may have remained fuller than average from WY2017.

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[1] A water year is a period of 365 or 366 days beginning on October 1 in the prior calendar year and extending through September 30 of the named year.

2.4 Pond Modeling

2.4.1 Model Framework

A Pond Inundation and Timing (Pond-IT) model was developed to evaluate the historical water-surface elevation of each pond. The main purpose of the Pond-IT model is to infer the dry-down timing across a range of hydrologic years and extend the model into the future using climate projections (results of the climate change modeling are not yet complete). To meet this objective, a monthly timestep is sufficient compared to a daily timestep, which required more data and more computation time. In addition, many climate projection datasets are available at the monthly timestep. For the model to be integrated seamlessly between historical and projected time periods, we used of the same (monthly) timestep for both datasets. The model was constructed in Python, which is an interpreted high-level programming language with many general-purpose programming tools. Open-source Python libraries are used for this model (e.g., numpy, pandas) to take advantage of data analysis tools which can easily manipulate numerical tables and time series dataset. All Python packages used in this model are open source and free to use.

2.4.2 Model input Data

The primary time-dependent input variables used in the model are air temperature, used to calculate evapotranspiration (ET), and total monthly precipitation. Historical air temperature and monthly precipitation are sourced from PRISM Climate Group (PRISM)[2]. PRISM historical data are available annually, monthly, or daily. Air temperature and precipitation is interpolated for each 4-km grid cell through a DEM-based interpolation between publicly available gaging datasets (e.g., sourced from California Irrigation Management Information System, US Geological Survey, California Department of Water Resources, etc.). The historical data were downloaded from the PRISM website on July 25, 2018. Downloaded historical data begin in WY 1975[3] (WY1975). Because each pond model begins with an empty pond at the beginning of WY1975, results are presented beginning in water 1980 to allow 5 years of model spin-up.

Soil data for contributing watershed is sourced from the National Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO). A depth-

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[2] http://prism.oregonstate.edu/ accessed on July 25th, 2018.

[3] A water year runs from October 1 of the preceding year to September 30, of the year for which it is named. For example, water year 1975 extends from October 1, 1974 to September 30, 1975.

weighted water capacity is calculated across the soil profile thickness. If multiple soil types are located in a single watershed, the water capacity is spatially averaged in addition to depth-averaged.

The watersheds were initially delineated using the 2006 Santa Clara County LiDAR dataset, using an automatic routine in ArcGIS and then refined based on field observations of flow paths around roads, berms and other structures. Watershed size was used to calculate soil moisture storage and runoff, further explained below. For six of the thirteen ponds[4], watershed size was reduced to produce model results more consistent with inferred hydrologic response to storm events. We believe this is an acceptable adjustment in these highly fractured watersheds, where subsurface runoff pathways may differ from surface topography.

2.4.3 Model Calibration Data

The 13 ponds were calibrated using Balance's WY2017 and WY2018 hydrologic gaging data and historical aerial imagery available in Google Earth®. Google Earth® historical imagery was available starting in the mid-2000s (2004 – 2009, pond dependent), with images sourced from various planes and satellites. Ponded area was measured in each aerial image where the wetted boundary is clearly defined and observable. When drawing pond boundaries, some judgment is used to define pond water surface through stands of cattail or tule, or with interpretations of floating aquatic vegetation or algae around the pond edges. The stage-storage relationship was then used to convert pond area to a water surface elevation for use in the model calibration. The use of Google Earth® historical imagery proved to be a powerful and cost-effective approach to calibrate and validate modeled long-term historical pond hydroperiod records. Images were available up to several times per year from 2004 to present, providing calibration data for a wide range of hydrologic years and sequences of years, such as extended droughts or very wet years.

2.4.4 Pond Inundation and Timing (Pond-IT) Model

The POND-IT model was constructed using the above input and calibration data using twelve model-fit parameters (named and underlined below). Model parameters were

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[4] Models with adjusted watershed sizes are Hotel, Kamera, Rattlesnake, Smith, Valentine, Valley Oak, and Woodland

optimized using a numerical solver[5] to minimize the sum of the mean squared error between the model results and calibration data.

Model input modules are:

1. **Direct Rainfall.** Precipitation that falls directly on the pond surface plus an additional pond fringe area that directly contributes water to the pond. Pond fringe area was suggested to be approximately 2 to 4 times the pond surface area by Napolitano and Hecht (1991), who demonstrated that bank-exchange zones in surrounding hollows and swales contribute directly to runoff into the ponds. The area of the pond fringe is specified by the rainfall fringe area[6] parameter and is represented as a percentage of total pond area. Fringe area depends largely on local topography and soil properties.
2. **Watershed Runoff.** A soil-moisture accounting routine calculates the monthly soil moisture. Maximum soil water capacity is calculated using soil properties of the contributing watershed. When precipitation exceeds available soil water capacity plus ET, the excess precipitation is routed into the pond as runoff. To adjust for local variation in the ability of a soil to store water, regional soil properties can be adjusted as needed to account for local soil properties based on field observations and expertise.
3. **Groundwater Inputs.** Groundwater input delivery mechanism and timing varies widely based on soil types, underlying geology, and pond construction and so three types of groundwater inputs have been implemented in the POND-IT model. They are listed below in increasing order of precipitation lag.
    a. **Pond Fringe Groundwater Input.** Ponds are typically in local topographic depressions, so soil moisture from the surrounding area can infiltrate into the pond fringe area over short timescales. To model this, the direct rainfall (module 1, above) is lagged 1 month, and scaled by the model parameter, pond fringe groundwater. Modeling results tended to over-predict pond water surface elevations in years following very wet years and under-predict pond water surface elevations following very dry years. To address this long-

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[5] Solver used is Scipy.minimize, using method SLSQP, https://docs.scipy.org/doc/scipy/reference/optimize.minimize-slsqp.html#optimize-minimize-slsqp

[6] Underlined terms highlight the model parameter. Model parameters are discussed in Section 2.6.6 below.

term effect of precipitation, a memory scaling factor was applied to this variable, represented by the ratio between the previous year's annual precipitation and the historical average annual precipitation. For example, after WY2014, which was very dry, the memory scaling factor would reduce the pond fringe groundwater input during WY2015, because the dry conditions of WY2014 over-taxed shallow aquifers, which needed to be re-filled prior to resuming contributing groundwater into a pond.

b. **Shallow Bedrock Fracture Groundwater Input.** In watersheds with shallow, fractured bedrock, additional groundwater discharge can be sourced from these fractures with a medium-term time lag. For the pond models presented here, this shallow fracture time lag ranges from two to five months. Model results and calibration data have shown that this medium-term groundwater discharge is typically only active in wet years, when precipitation is above a certain shallow fracture threshold, which is specified in the model using the annual precipitation. The amount of water that discharges into the pond is based on the total volume of water stored in the soil column below the root zone, which is assumed to be18-inches for this study. This volume of water is released more quickly when the soil column is saturated, and more slowly when the soil is drier. The total volume of water is calculated over a shallow fracture contributing watershed area, which can sometimes be different than the contributing surface watershed area, depending on topography, deep weathering and geology.

   Shallow bedrock fracture groundwater seeps are modeled so that either the seep is active and contributing water to the pond, or the seep has run dry. The threshold for when the seep is active and contributing varies by pond, with some seeps active every year and other active during only the wettest years.

c. **Deep Fault Groundwater Input.** Groundwater that flows through deeper bedrock fracture and faults is often slower than the shallow bedrock fracture groundwater discharges. The total amount of deep fault groundwater input is the deep fault percentage of precipitation over the contributing watershed. The deep fault time lag is parameterized at seven to eight months. The lag may not represent actual groundwater flow velocities through the inferred faults, but instead may represent the timescale at which groundwater elevations in the basin have adjusted for discharge into the pond to be numerically significant. Ultimately, deep fault groundwater input is best monitored rather than estimated based on soil properties, as water levels beneath the pools can (a) also originate from delayed drainage of landslide scarps, and (b) may be largest during the second or third year of above-average rainfall, based on our experience elsewhere. A very similar effect is observed following a fire, especially where plant roots are shallow relative to the depth to water in the deeply-weathered zone (Hecht and Richmond, 2011). However, for this application, groundwater inputs characterized as sourced from a deep fault is inferred based on model calibration results, pond classification, and knowledge of the geology, soils, and topography.

Model output modules are:

1. **Evapotranspiration (ET).** ET is calculated using the Blaney-Criddle Equation, represented by

$$\boldsymbol{ET_o = p\,(a\,T_{mean} + b)}$$

where ET_o is the ET of the reference crop, irrigated turf, which published by CIMIS as a function of CIMIS zones (CIMIS 1999), T_{mean} is the mean monthly temperature, and p is the mean daily percentage of annual daytime hours as a function of site latitude, and a and b are fitting parameters estimated using least squares fit to the historical mean monthly air temperature.

While the Blaney-Criddle Equation is considered to be a more simplistic method for deriving ET, only using air temperature and zonal reference ET as input parameters. Our choice to implement a monthly model timestep reduces the likelihood that the more complex Penman-Monteith equation would improve model results. At a minimum, the Penman-Monteith formula requires daily timeseries data for solar radiation, wind speed, relative humidity, in addition to air temperature, which can vary significantly between pond locations and even with a single watershed.

Use of the Blaney-Criddle Equation assumes that ET_o for the reference crop, is approximately equal to ET from a standing body of water (Allen et al., 1998).

2. **Spillway.** In wet months, the pond elevation may exceed the pond spillway elevation. In these cases, water surface elevations are capped at the spillway elevation. Pond elevations may slightly exceed the spillway elevation during the time when the pond is spilling, but do not need to be explicitly modeled for the purposes of hydroperiod modeling and are therefore removed.

3. **Groundwater Outputs.** Groundwater discharge varies as a function of pond soil permeability and connectivity, and water use on the pond fringe and so two types of groundwater outputs have been used in the POND-IT mode. There are:

    a. **Soil Moisture or ET Groundwater Output.** As seasonally increasing air temperatures places more demand on water supplies in the pond fringe, ponded water is lost through additional vegetation uptake or the wicking of dry soils not captured in the calculated ET from the water surface. Active grazing in the pond area may also increase this type of groundwater loss as cattle are likely to drink more water in summer months compared with cooler, wetter months. Water lost in this way is parameterized as a <u>percent of ET to groundwater</u> over the pond fringe area. The magnitude of this parameter set the shape of the draw-down curve in the summer months when ET is high; the higher the percentage loss, the steeper the draw-down curve.

    b. **Leaky Pond Groundwater Output.** The soils underlying each pond have a range of soil permeability and connectivity. Clayey soils will prevent water from infiltrating into the shallow subsurface as quickly as loamy or sandy soils. Except for some Pedogenic ponds, we would expect most ponds to consistently loose some amount of water to the shallow subsurface, as a function of the volume of water in the pond. A fuller pond loses a larger volume of water over the larger wetted pond bottom area and with higher head pressure exerted on the underlying soils, compared with pond that is less full. Therefore, groundwater output is specified as a function of total pond volume as a <u>percent pond volume to groundwater</u>. Each month, the pond loses the specified volume of water to the shallow subsurface, which typically ranges from 2 to 40 percent. The higher the value, the "leakier" the pond, which may relate to the composition of the underlying soils, the proximity to faults and fractures, or the construction of the berm. The rate at which a pond loses water because it is "leaky" (i.e. <u>the percent pond volume to groundwater</u> is larger) defines the shape and slope of the draw-down curve.

3. RESULTS

Model results are presented in **Figures 1a-1m** and **Figure 2** and include three plots. The first is a timeseries (top of Figure 1) plotted from WY2000 to WY2018 and includes the monthly modeled pond water surface elevation for the historical period (blue). Monthly precipitation is plotted using the right y-axis. Calibration data collected by Balance (orange lines) and calibration data collected using aerial imagery (blue dots) are also plotted. It should be noted that POND-IT modeled at the monthly timestep (see Section 2.6.1) does not represent the daily variability associated with individual storm events and instead represents the monthly averages in water-surface elevations associated with monthly-averaged air temperatures and total precipitation. The gridded plots (center right of Figure 1a-m) present a visual representation of the hydroperiod of each pond over historical time periods for each water year. The darker color represents months when the pond is full, the lighter shading depicts months when the pond is wetted, but not full, and months with no shading indicate when the pond is empty. Third, is a histogram for each pond (bottom right of Figure 1a-m) showing the frequency of the first dry month of the year over the modeled period (1980-2018).

A table is included in each of the **Figures 1a-1m** which summarizes general watershed characteristics including size, geology, soil types, pond classification, and key findings and model limitations.

4. NEXT STEPS

- Model climate change projections to assess potential changes in pond hydroperiods.
- Develop conceptual design recommendations to enhance each pond: What ponds can be modified to meet the target hydroperiod in most years? What ponds can be enhanced to support California red-legged frog under existing conditions.

5. REFERENCES

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., (1998). "Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements." Irrig. and Drain. Paper No. 56, United Nations Food and Agriculture Organization, Rome, Italy, 300 pp.

Bauder, E. T., Bohonak, A. J., Hecht, B., Simovich, M. A., Shaw, D., Jenkins, D. G., and Rains, M., 2009, A Draft of Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Vernal Pool Depressional Wetlands in Southern California, 117p.

California Irrigation Management Information Systems (CIMIS), 1999, reference evaporation map.

Donaldson, E., Pretzlav, K., and Hecht, B., 2018, A new framework for modeling pond habitat in a changing climate: Observed and modeled pond hydroperiods in central Santa Clara County. Balance Hydrologics Inc. consulting report prepared for Guadalupe-Coyote Resource Conservation District, 79p.

Graymer, R. W., Moring B. C., Saucedo, C. M., Wentworth, C. M., Brabb, E. E., Knudsen, K. L., 2006, Geologic map of the San Francisco Bay region, 2006, Scientific Investigations Map 2918, published by US Geological Survey.

Hecht, B. and Richmond, S.,2011, Post-fire flow premium: Increased summer flows promoting salmonid survival following large wildfires in Monterey County. Salmonid Restoration Federation 45th annual conference, San Luis Obispo, California. 24 p.

Hecht, B., and Napolitano, M.B., 1991, Hydrologic processes affecting vernal pools at Ellwood Beach, California, and suggested approaches to mitigation, Balance Hydrologics Inc. consulting report prepared for LSA Associates, 67p.

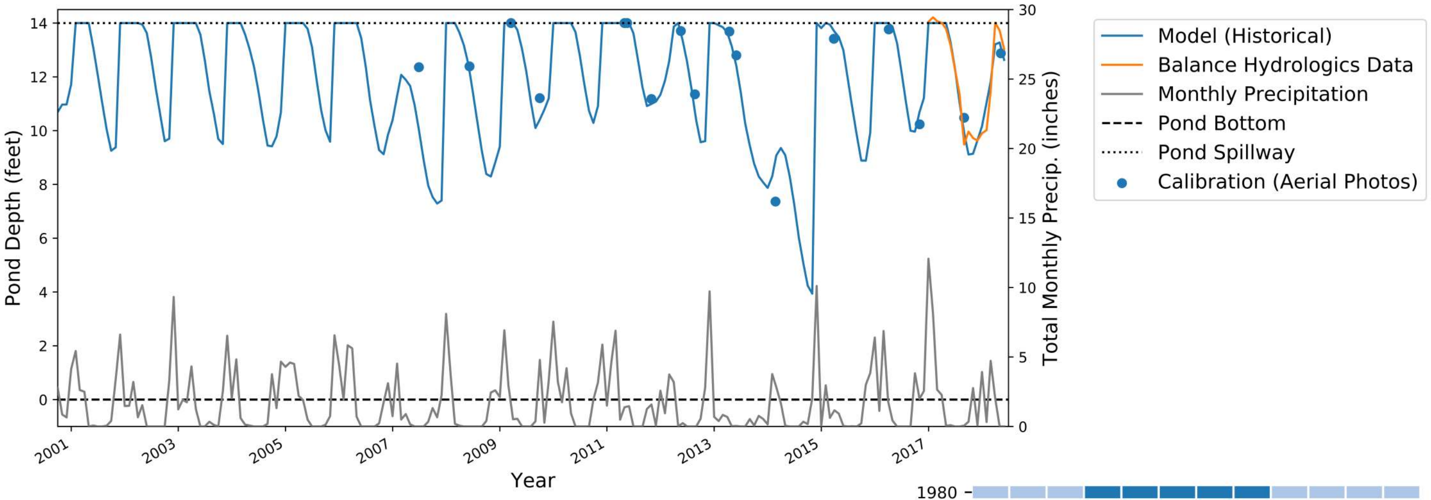
Skidds D. E., and Golet, F. C., 2005, Estimating hydroperiod suitability for breeding amphibians in southern Rhode Island seasonal forest ponds.

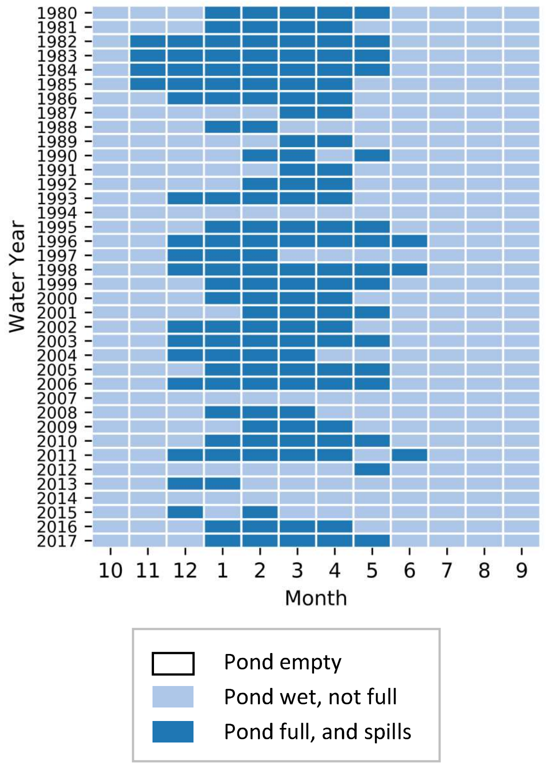
Wentworth, C.M., Blake, M.C., McLaughlin, R.J., and Graymer, R.W., 1999, Preliminary geologic map of the San Jose 30 X 60-minute quadrangle, California: a digital database. U.S. Geological Survey, Open-File Report OF-98-795

Genetic Classification	Description
Pedogenic	Vernal pools formed on old or very old terraces or deeply weathered crystalline bedrock by pedogenic processes are the most numerous and widespread. Several types of pedogenic pools are known from Southern California. In all cases, they have developed over restrictive layers created as the soils matured and which perch winter water near the soil surface.
Tectogenic	Tectonic activity has directly or indirectly created local sediment-filled depressions, which sustain vernal pools along active faults. The restrictive, or “perching” horizon supporting seasonal ponding is formed from lake sediments or ponded clays deposited in the tectonogenic depression, commonly over periods of thousands or tens of thousands of years. These pools tend to be among the largest and deepest, and are supported watersheds of (typically) 20 to 200 acres; they are distinguished by drawing much of their inflow from the steeper slopes with thinner soils near the edged of their watersheds rather than those surrounding the basin.
Landslide Head Scarp	A number of vernal pools have developed in depressions within or at the heads of landslides. As with the tectonogenic pools, inflow may originate from steeper areas at the edges of the contributing watershed, and are generally most vulnerable to changes and disturbance at the edges of their contributing areas.
Landslide Dammed	Existing drainage basins in steep to moderate landscapes are vulnerable to both large- and small-scale landslides which can dam existing channels creating a vernal pool. Inflows typically follow the existing overland pathways into channels. With no anthropogenic interference, new channels are often incised into landslide dams until normal channel processes are restored.
Mining or Quarry Depressions	Vernal pools will form inside anthropogenically created topographic lows if hydrologic conditions are favorable. Common anthropogenic depressions are quarries or surface mines.
Alluviated	Alluviated pools are formed when floodplain or natural-levee deposits left by floods on nearby streams or alluvial fans/aprons dam their outlets.
Dune Dammed	Dunes advancing over old terraces or floodplain can obstruct drainage and form dune-dammed pools. Some vernal pools are sharply elongated in the direction of the prevailing wind, presumably by waves. In many cases, the obstructing dunes or the eroding winds were formed under mid-Holocene or Pleistocene conditions, with soil-forming processes augmenting the pool-forming effects.
Bedrock (Tenaja)	A few pools are not sedimentary –for example the tenajas of Riverside County or the tanques of the Santa Rosa Plateau, but these seem to be relatively rare both in Southern California and in the Santa Clara Valley.
Instream	Stock ponds are commonly constructed in stream channels or headwater swales. The location of stock ponds in stream channels were often selected by ranchers where conditions were favorable either due to the location of seeps, or where canyon walls were close together or the stream long profile was gentler due to geology, faulting, or debris flows and landslides.

Balance Hydrologics

Table 1. Genetic Classification Descriptions, adapted from Bauder et al., 2009.



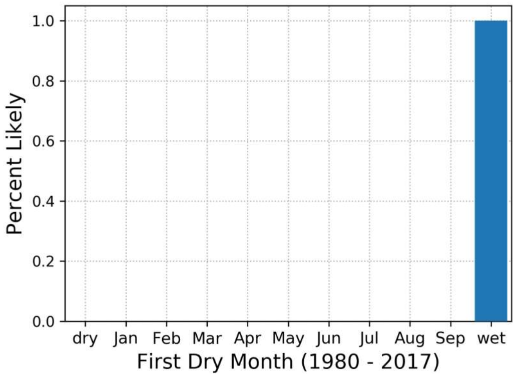


Water Year	10	11	12	1	2	3	4	5	6	7	8	9
1980	░	░	░	█	█	█	█	█	░	░	░	░
1981	░	░	░	█	█	█	█	░	░	░	░	░
1982	░	█	█	█	█	█	█	█	░	░	░	░
1983	░	█	█	█	█	█	█	█	░	░	░	░
1984	░	█	█	█	█	█	█	█	░	░	░	░
1985	░	█	█	█	█	█	█	░	░	░	░	░
1986	░	░	█	█	█	█	█	░	░	░	░	░
1987	░	░	░	░	░	█	█	░	░	░	░	░
1988	░	░	░	█	█	░	░	░	░	░	░	░
1989	░	░	░	░	░	█	█	░	░	░	░	░
1990	░	░	░	░	█	█	░	█	░	░	░	░
1991	░	░	░	░	░	█	█	░	░	░	░	░
1992	░	░	░	░	█	█	█	░	░	░	░	░
1993	░	░	█	█	█	█	█	░	░	░	░	░
1994	░	░	░	░	░	░	░	░	░	░	░	░
1995	░	░	░	█	█	█	█	█	░	░	░	░
1996	░	░	█	█	█	█	█	█	█	░	░	░
1997	░	░	█	█	█	░	░	░	░	░	░	░
1998	░	░	█	█	█	█	█	█	█	░	░	░
1999	░	░	░	█	█	█	█	█	░	░	░	░
2000	░	░	░	█	█	█	█	░	░	░	░	░
2001	░	░	░	░	█	█	█	█	░	░	░	░
2002	░	░	█	█	█	█	█	░	░	░	░	░
2003	░	░	█	█	█	█	█	█	░	░	░	░
2004	░	░	█	█	█	█	░	░	░	░	░	░
2005	░	░	░	█	█	█	█	█	░	░	░	░
2006	░	░	█	█	█	█	█	█	░	░	░	░
2007	░	░	░	░	░	░	░	░	░	░	░	░
2008	░	░	░	█	█	█	░	░	░	░	░	░
2009	░	░	░	░	█	█	█	░	░	░	░	░
2010	░	░	░	█	█	█	█	█	░	░	░	░
2011	░	░	█	█	█	█	█	░	█	░	░	░
2012	░	░	░	░	░	░	░	█	░	░	░	░
2013	░	░	█	█	░	░	░	░	░	░	░	░
2014	░	░	░	░	░	░	░	░	░	░	░	░
2015	░	░	█	░	█	░	░	░	░	░	░	░
2016	░	░	░	█	█	█	█	░	░	░	░	░
2017	░	░	░	█	█	█	█	█	░	░	░	░

☐ Pond empty
░ Pond wet, not full
█ Pond full, and spills

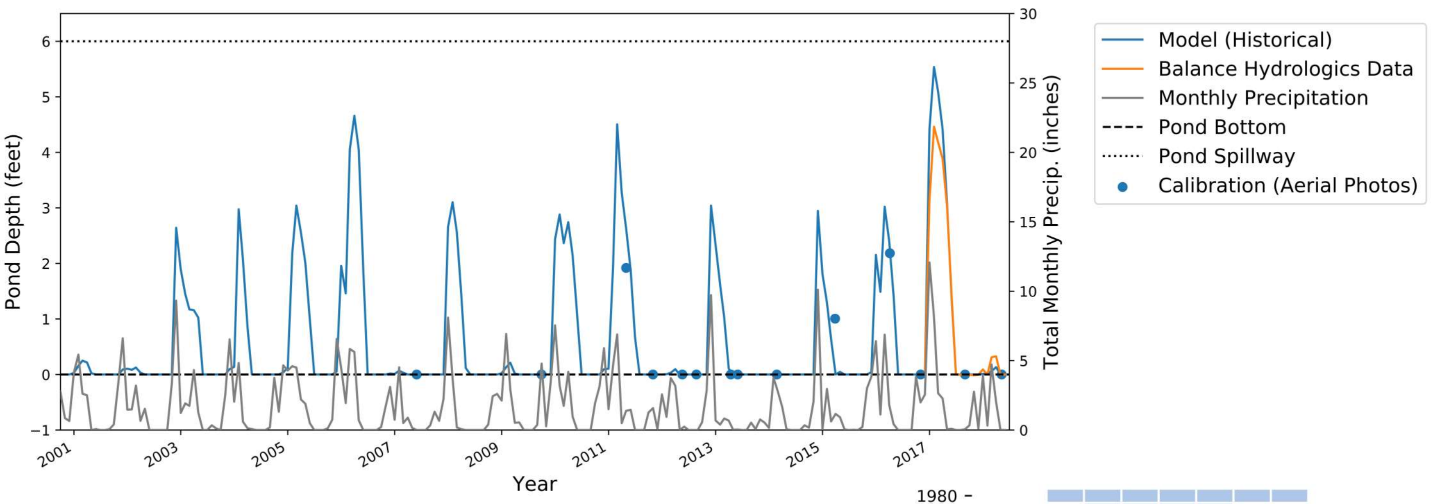
Bass Watershed Characteristics

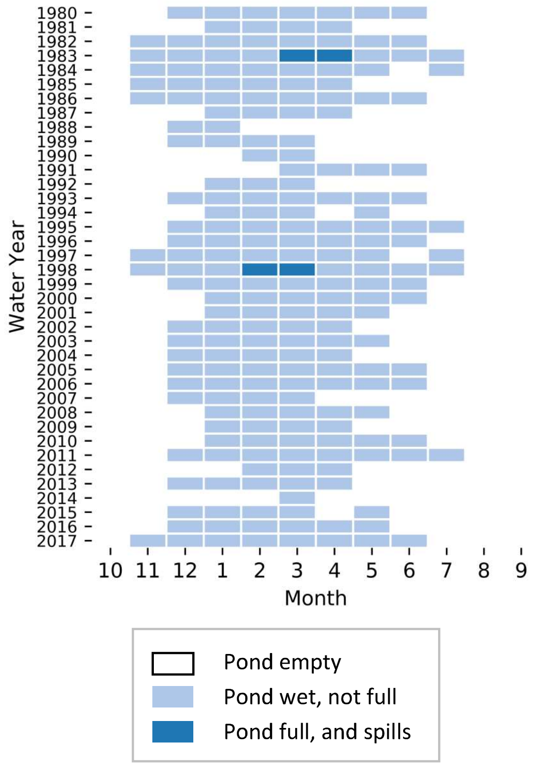
Size	111 acres
Geology	Franciscan melange and metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Channel downstream undermining spillway
Fault	None
Pond Classification	Instream
Preliminary Findings	Never empty, spills most years
Model Limitations	



Balance Hydrologics

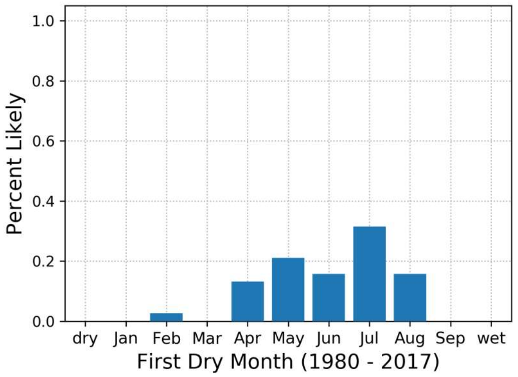
Figure 1a. **Bass Lake.** Lake characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.





Brush Watershed Characteristics

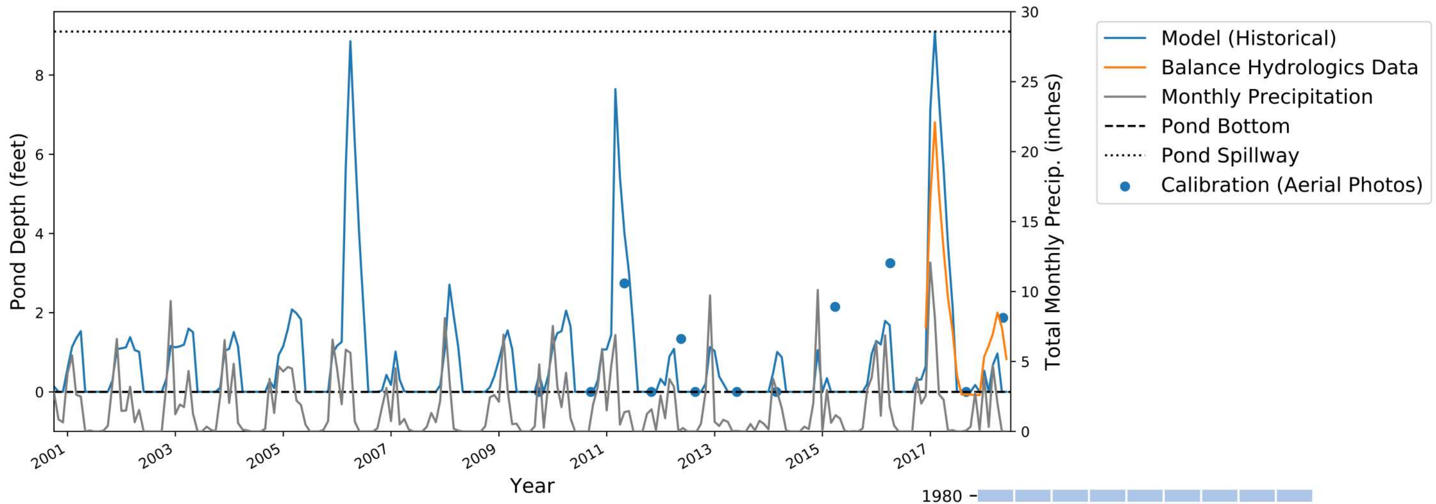
Size	1.1 acres
Geology	Miocene sedimentary rocks, Quaternary hillslope deposits
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	No Berm
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Dries up annually, frequently dry year-round
Model Limitations	Model may over-predict peaks



Balance Hydrologics

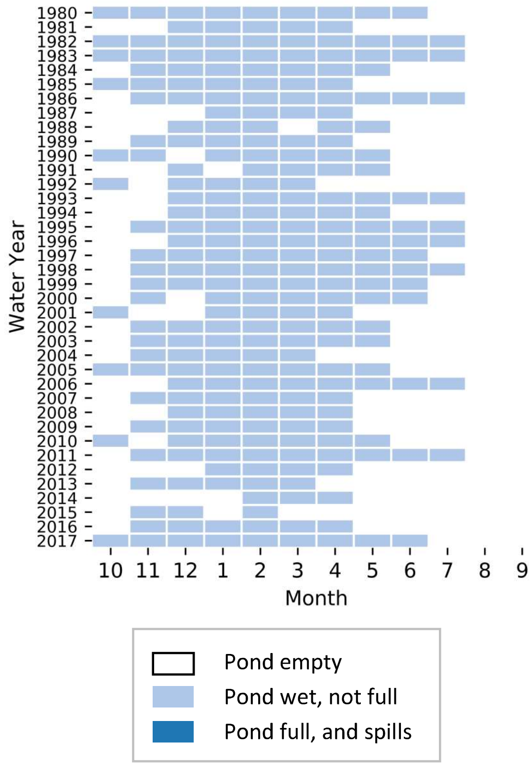
Figure 1b.

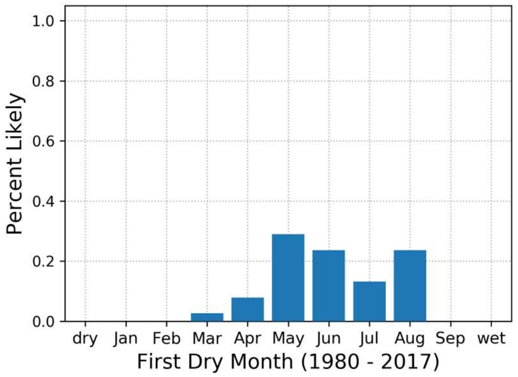
Brush Pond. Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



Dairy Watershed Characteristics

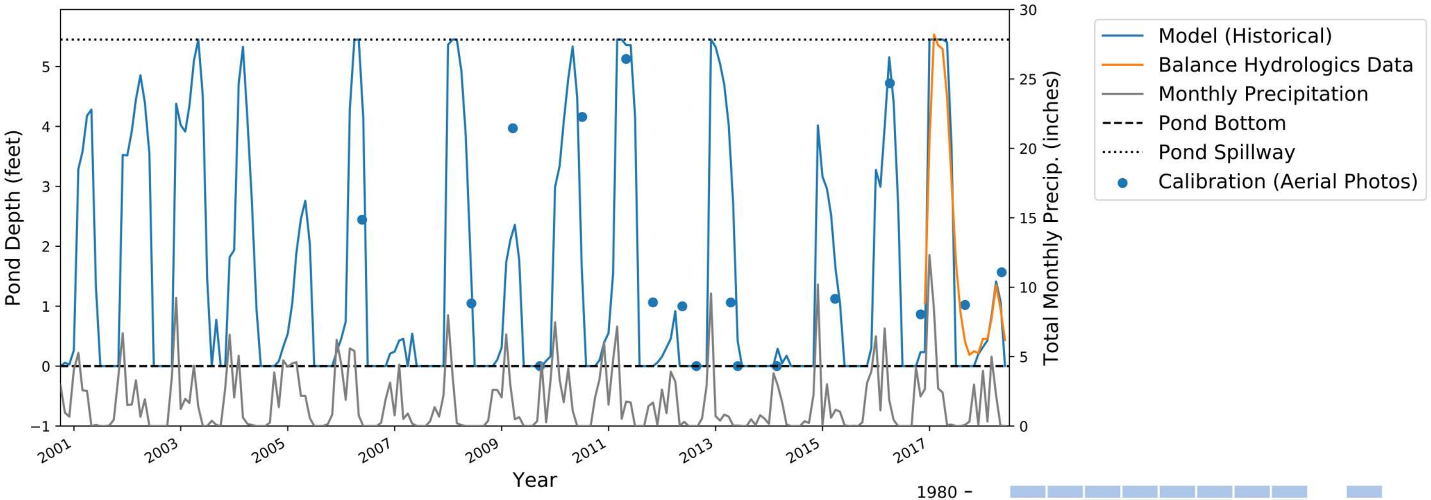
Size	3.1 acres
Geology	Miocene sedimentary rocks, Quaternary hillslope deposits
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Dries up annually, ponding every year for at least one month
Model Limitations	Model may over-predict largest peaks, and under-predict smaller peaks (existing clay layer in bottom 1-foot of pond not explicitly modeled)





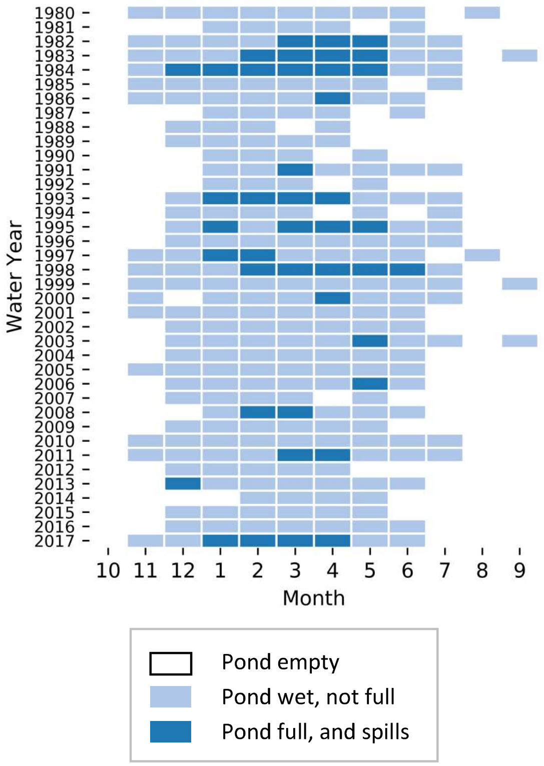
Balance Hydrologics

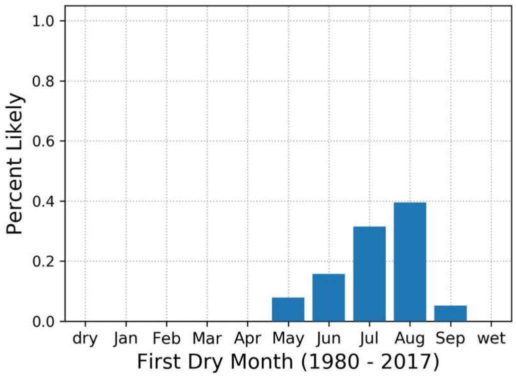
Figure 1c. **Dairy Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



Deer Valley Watershed Characteristics

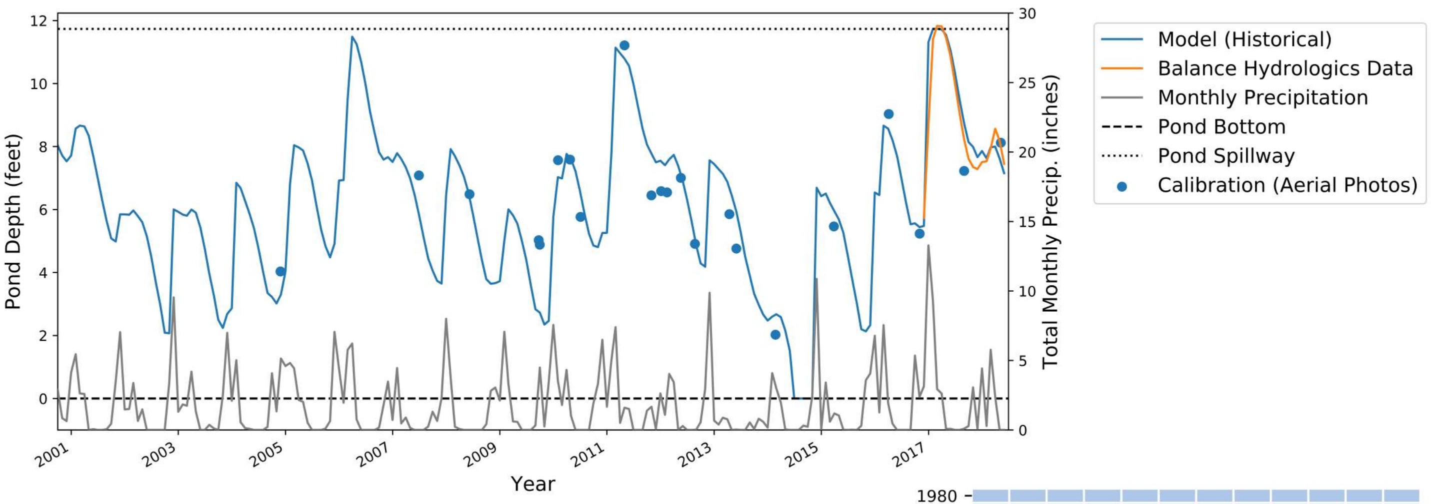
Size	7.7 acres
Geology	Franciscan metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	No Berm
Fault	None
Pond Classification	Instream/Tectogenic
Preliminary Findings	Dries up annually, spills during wet years
Model Limitations	Model may predict more rapid dry down in wet years





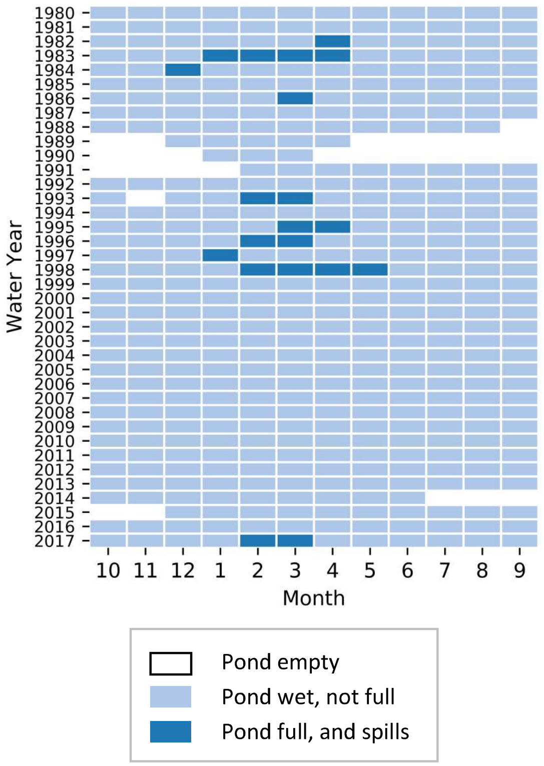
Balance Hydrologics

Figure 1d. **Deer Valley Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



Eagle Watershed Characteristics

Size	12.9 acres
Geology	Franciscan melange and metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Dries up only in extreme droughts, rarely spilling
Model Limitations	

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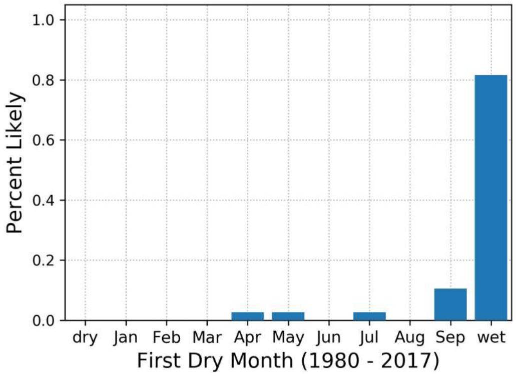
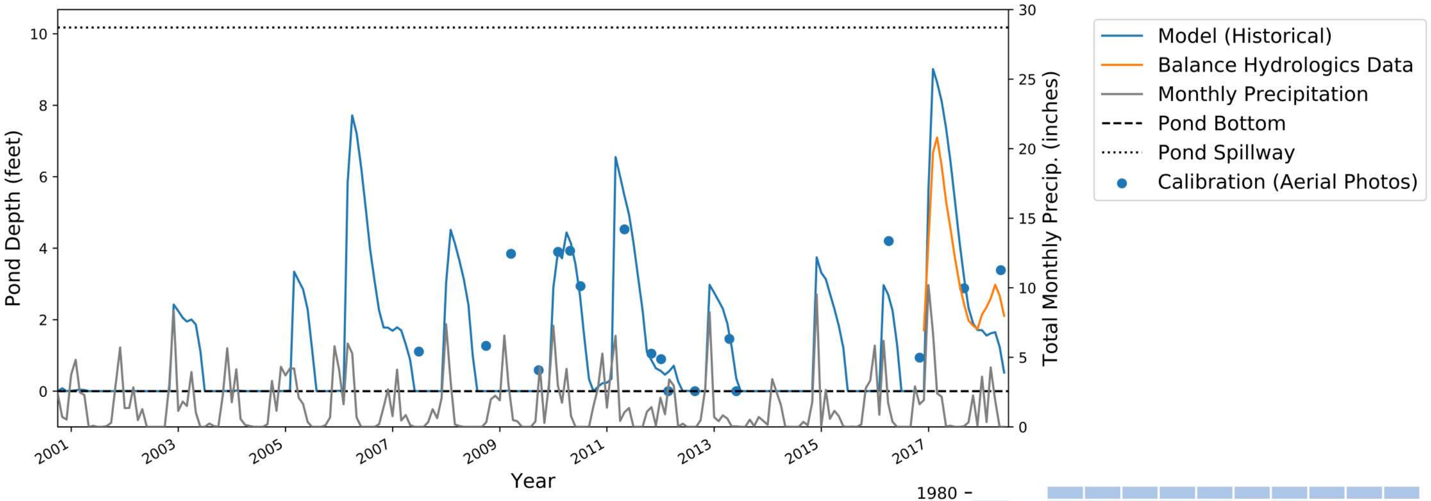
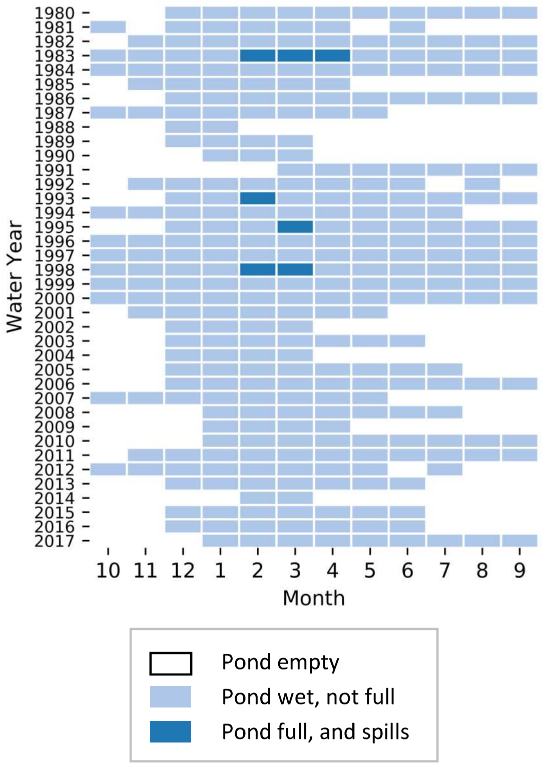


Balance Hydrologics

Figure 1e. **Eagle Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.





Edwards Watershed Characteristics

Size	12.6 acres
Geology	Miocene sedimentary rocks
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Ponding sensitive to droughts and wet periods, pond rarely spills
Model Limitations	Model may over-predict peaks

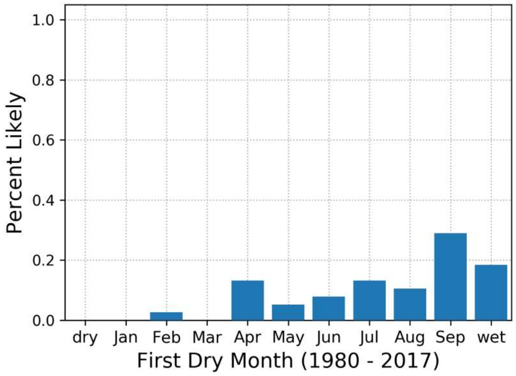
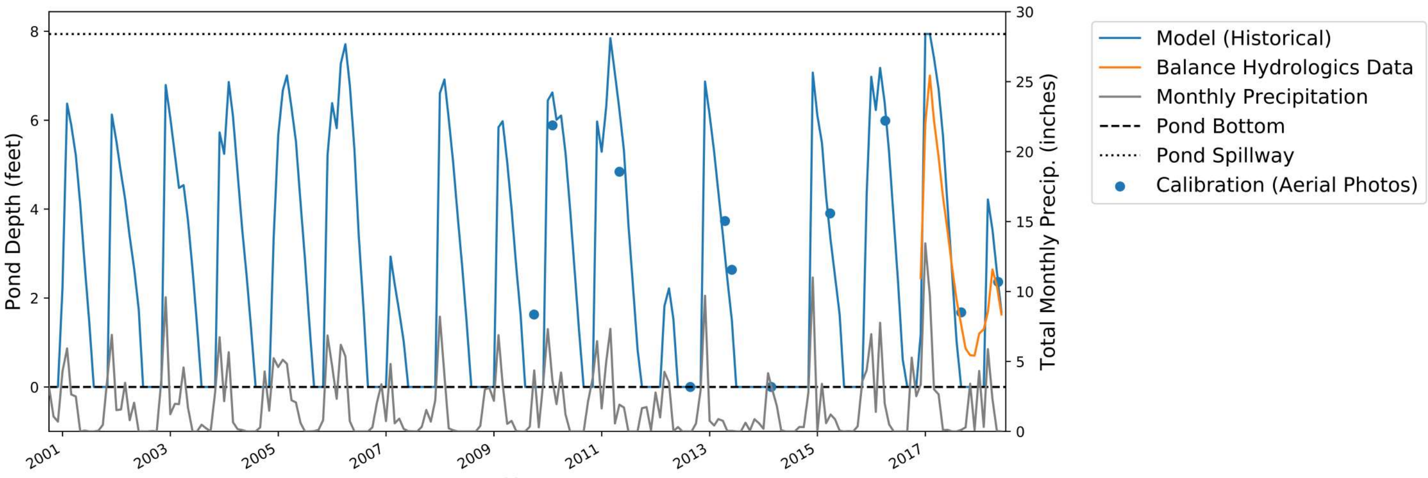
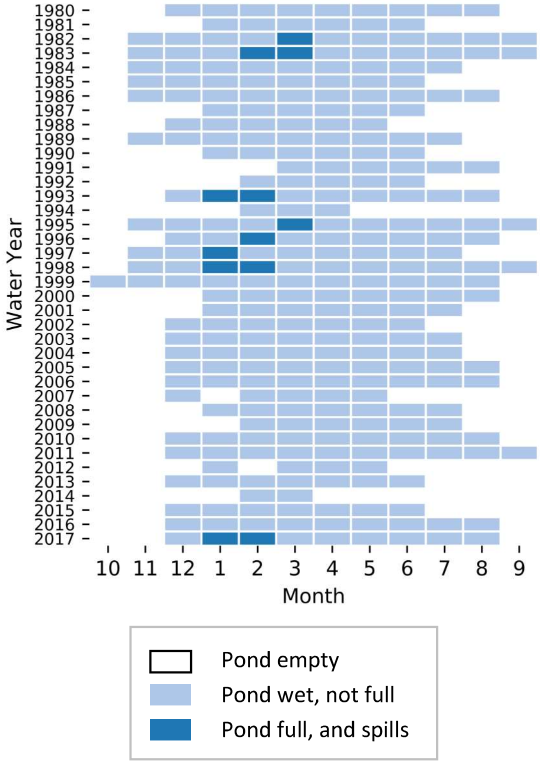


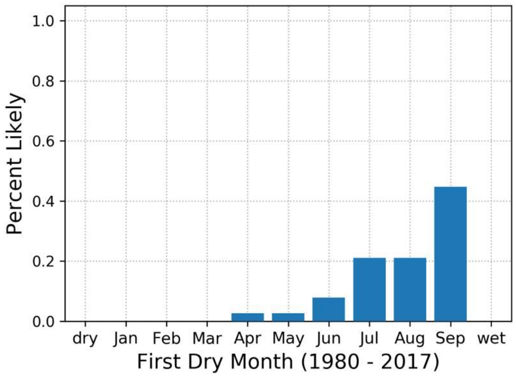
Figure 1f. **Edwards Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.





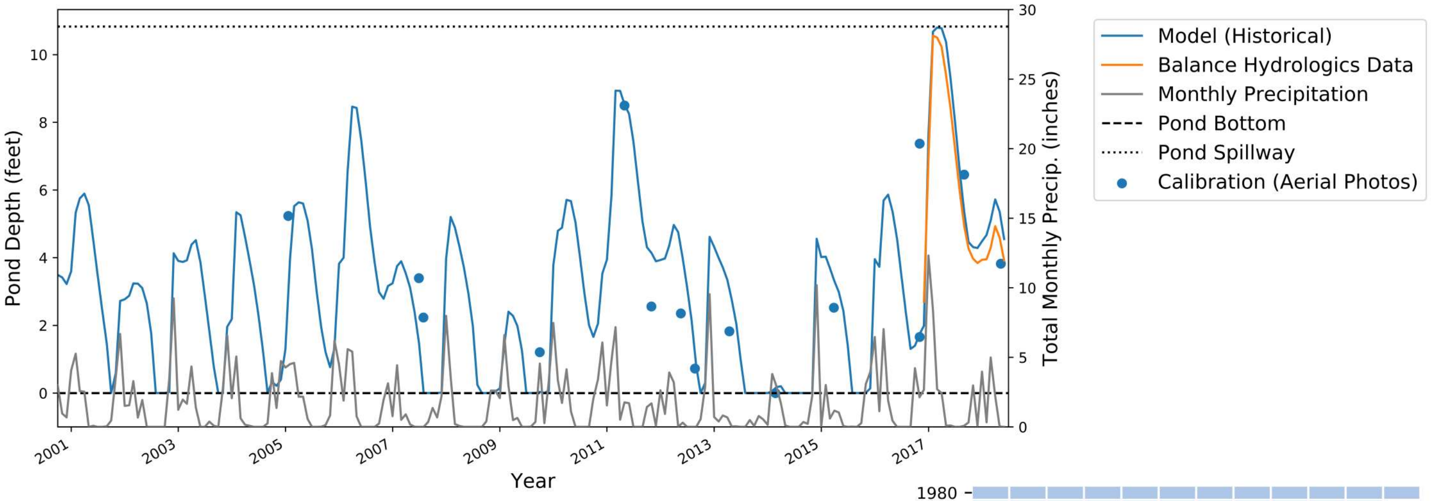
Hotel Watershed Characteristics

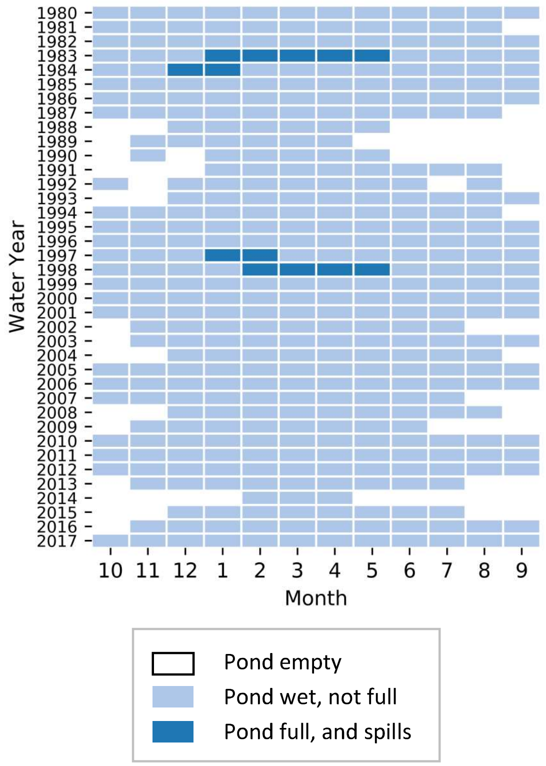
Size	3.9 acres
Geology	Franciscan melange and metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	No Berm
Fault	None
Pond Classification	Tectogenic/Instream
Preliminary Findings	Dries up each year, rarely spills
Model Limitations	Model may over-predict peaks



Balance Hydrologics

Figure 1g. **Hotel Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.





Kamera Watershed Characteristics

Size	8.9 acres
Geology	Franciscan melange
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Dries up in about half the years, rarely spills
Model Limitations	Model may over-predict lower water-surface elevations


10-20-2017

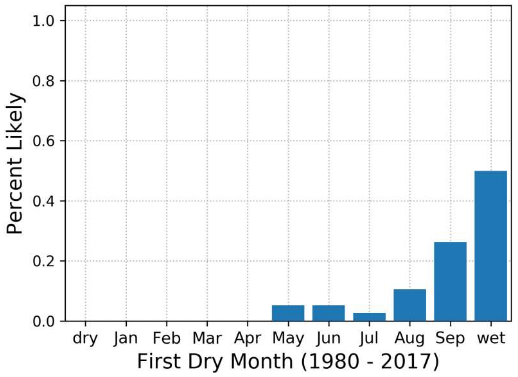
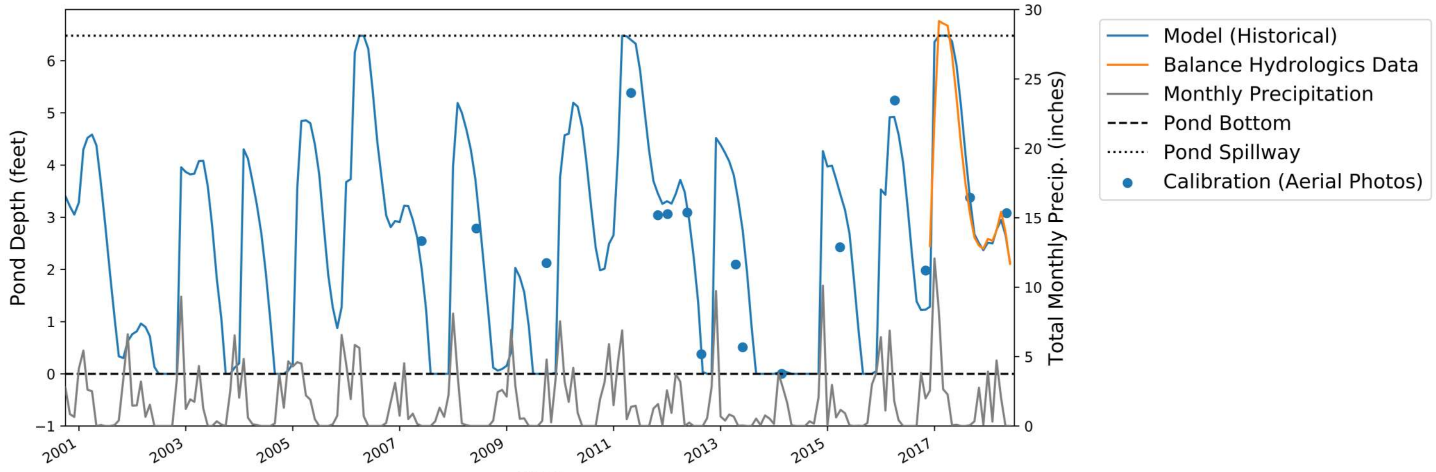
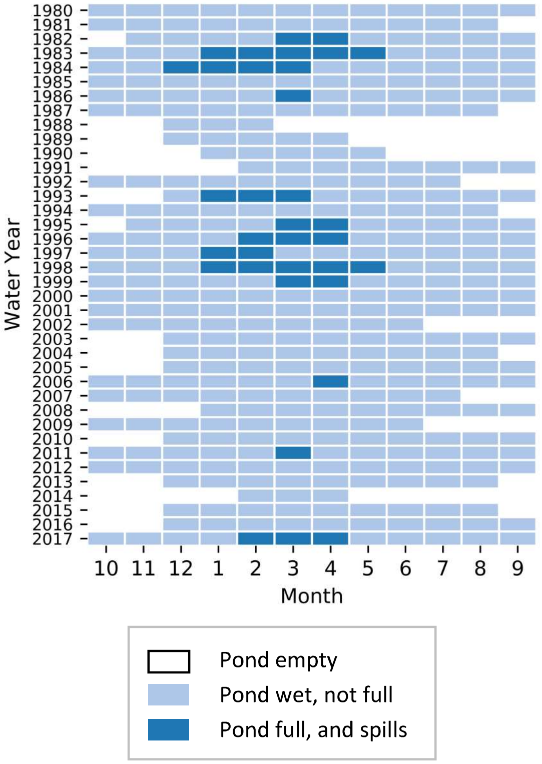


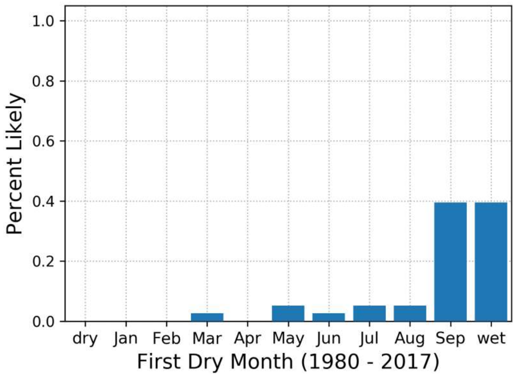
Figure 1h. **Kamera Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.





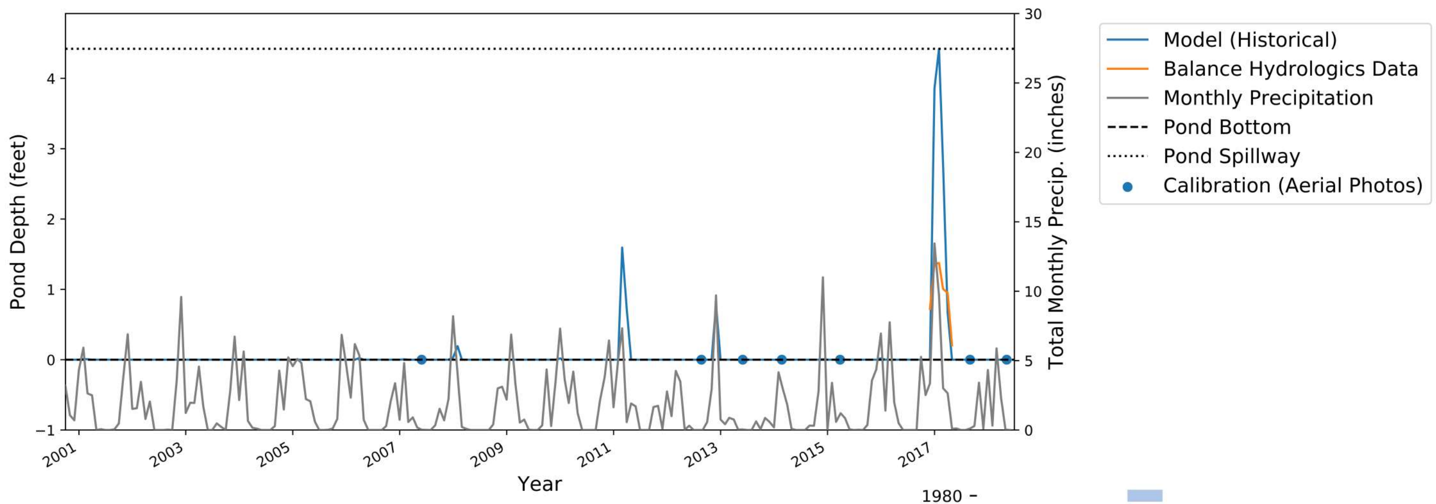
Rattlesnake Watershed Characteristics

Size	8.9 acres
Geology	Franciscan melange and metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	No Berm
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Dries up in about half the years, rarely spills
Model Limitations	Model may over-predict peaks



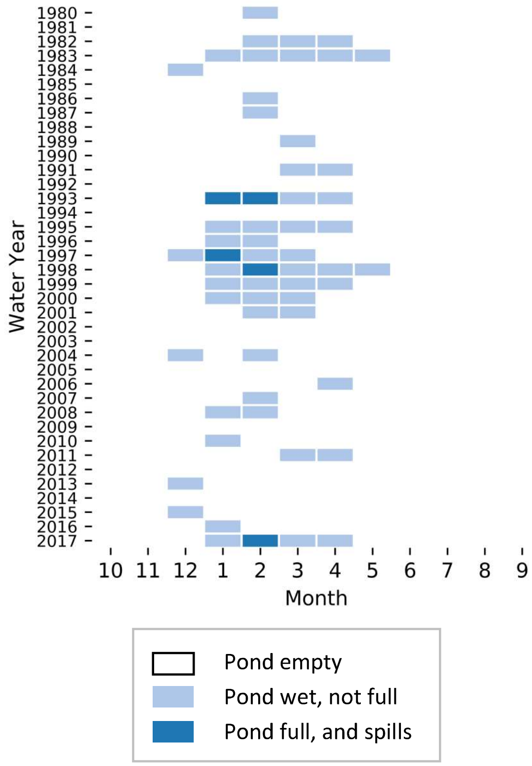
Balance Hydrologics

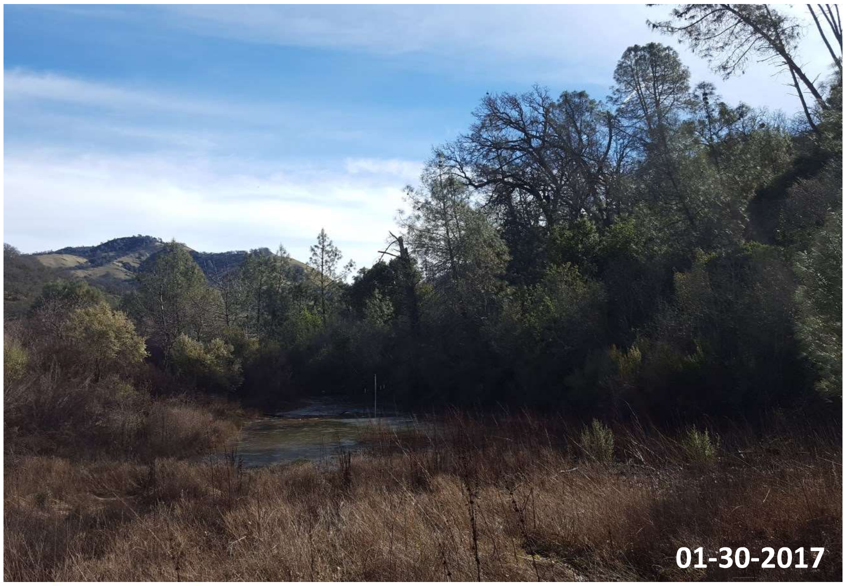
Figure 1i. **Rattlesnake Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



Smith Watershed Characteristics

Size	12.2 acres
Geology	Franciscan metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Instream
Preliminary Findings	Dries up early each year, drains quickly
Model Limitations	**Model not properly calibrated due to small size and shallow ponding**




01-30-2017

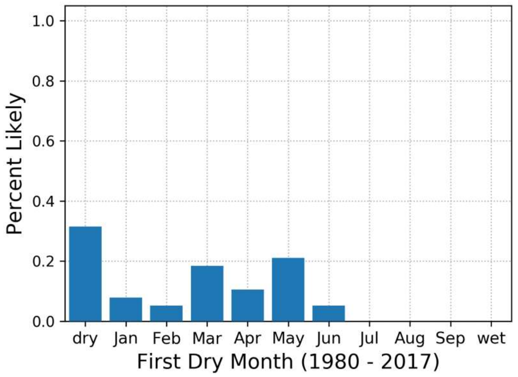
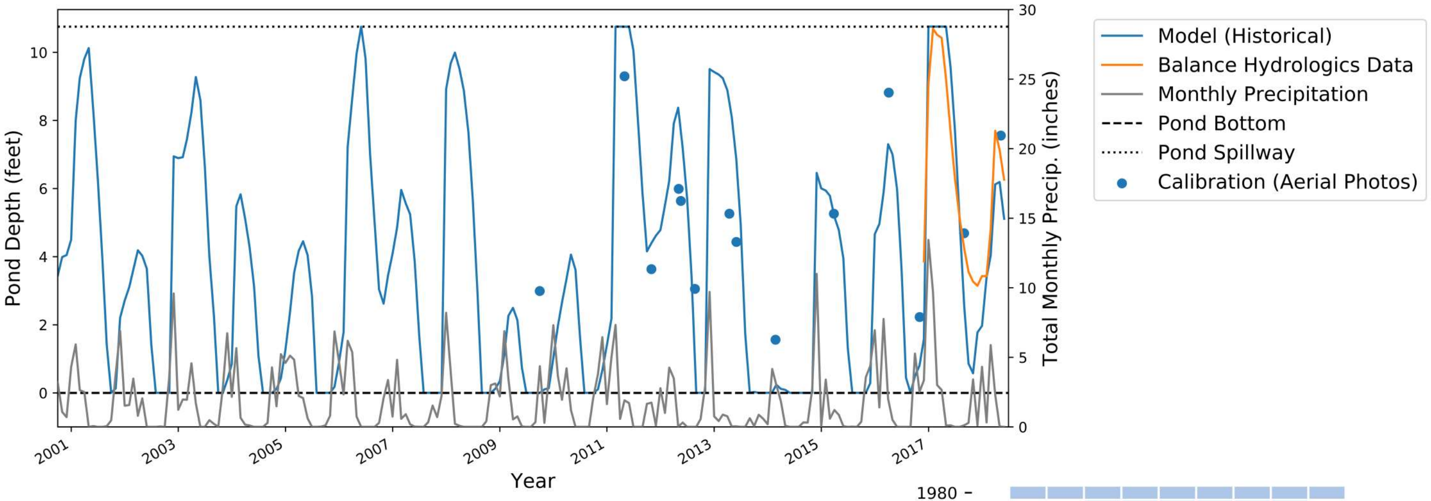
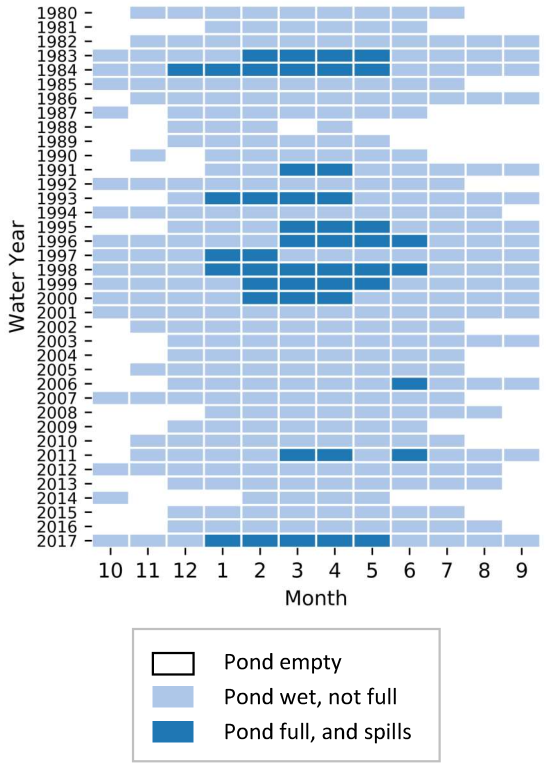


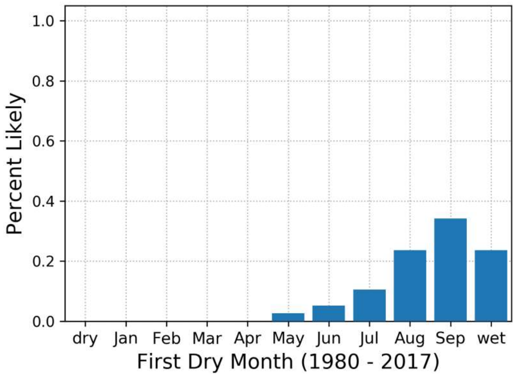
Figure 1j. **Smith Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.





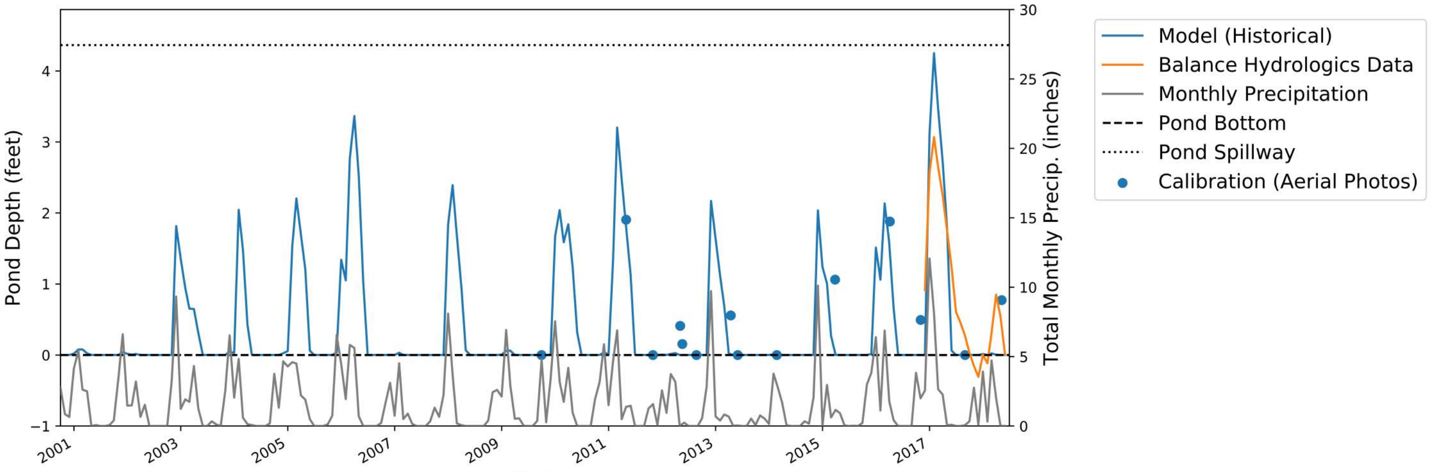
Valentine Watershed Characteristics

Size	9.7 acres
Geology	Franciscan metamorphic complex
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Instream
Preliminary Findings	Dries up in most years, rarely spills
Model Limitations	Model may under-estimate groundwater inputs during very wet years



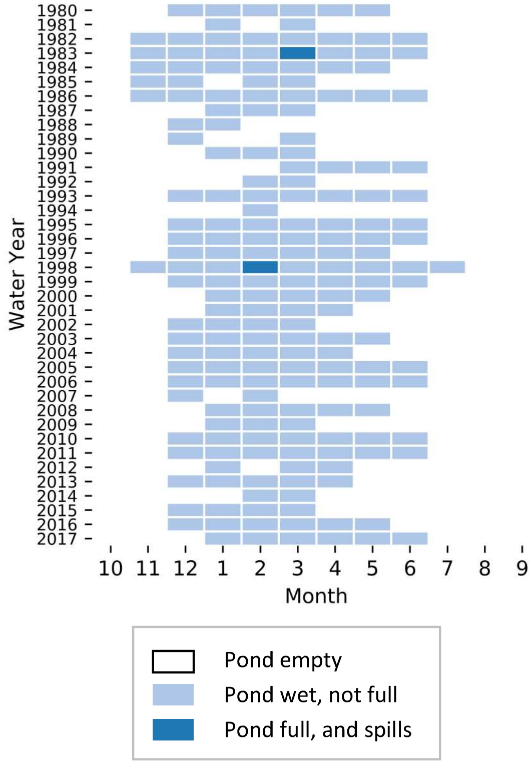
Balance Hydrologics

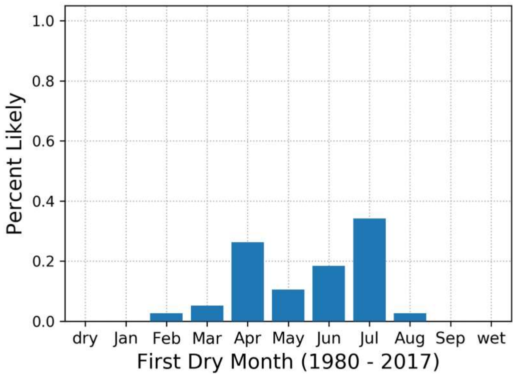
Figure 1k. **Valentine Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



Valley Oak Watershed Characteristics

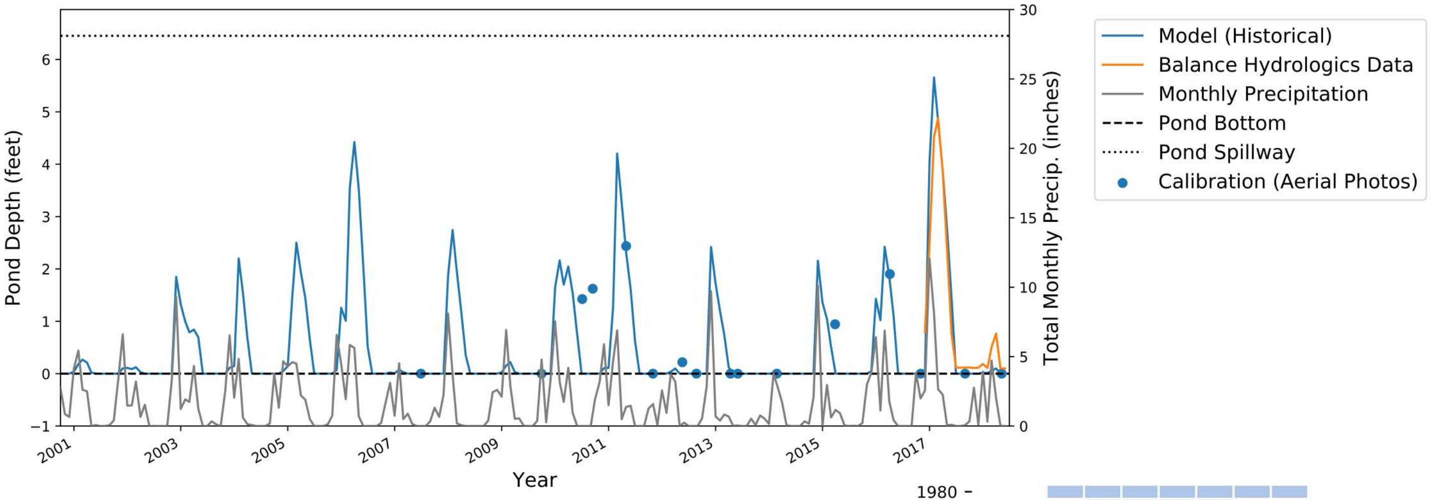
Size	4.8 acres
Geology	Quaternary hillslope deposits
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	Appears to be in good condition, no incision observed
Fault	None
Pond Classification	Landslide Headscarp/Instream
Preliminary Findings	Dries up annually, rarely spills, if ever
Model Limitations	Model may over-predict peaks

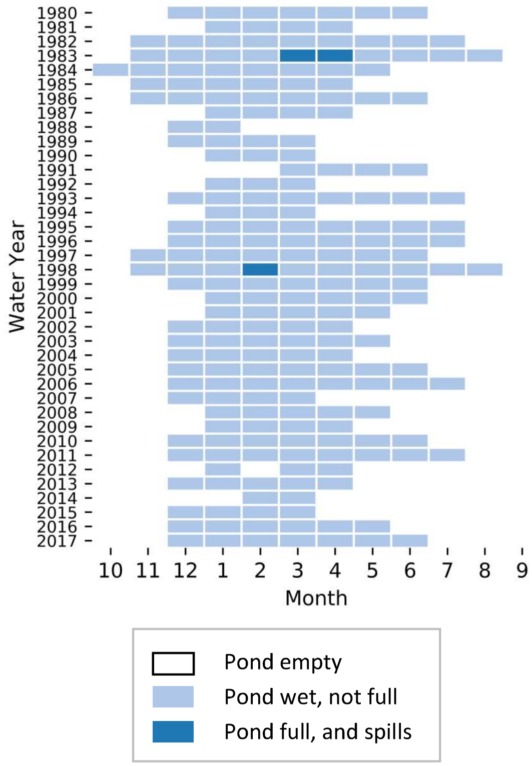




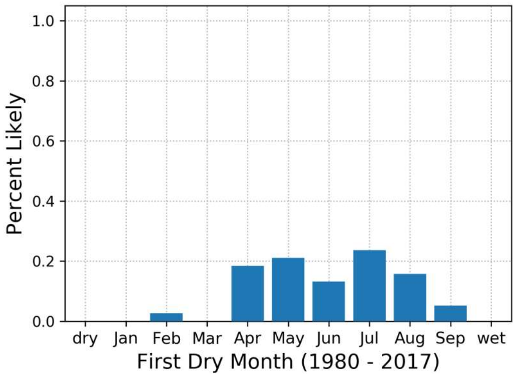
Balance Hydrologics

Figure 1l. **Valley Oak Vernal Pool.** Vernal pool characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



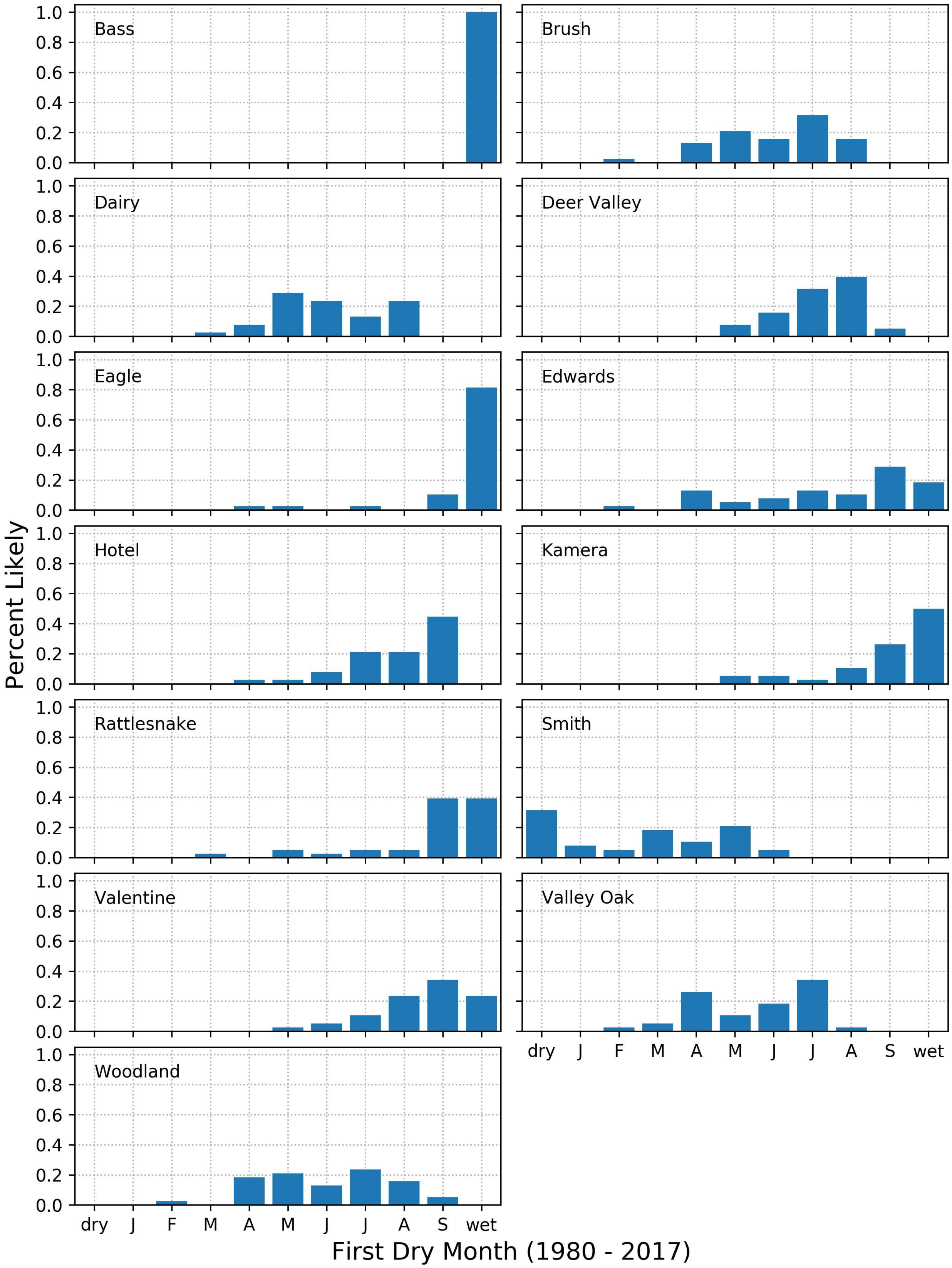


Woodland Watershed Characteristics	
Size	4.6 acres
Geology	Miocene sedimentary rocks, Quaternary hillslope deposits
Soils	Los Gatos-Gaviota Complex, gravelly loam
Berm Observations	No Berm
Fault	None
Pond Classification	Tectogenic
Preliminary Findings	Dries up annually, rarely spills, if ever
Model Limitations	Model may over-predict peaks



Balance Hydrologics

Figure 1m. **Woodland Pond.** Pond characteristics and hydroperiod model results, Joseph D. Grant County Park, Santa Clara County, CA.



Balance Hydrologics

Figure 2. **Summary of pond hydroperiods.** Histograms display the first dry month of the year.