FINAL REPORT | JUNE 2024

Annual Report of the Prado Basin Habitat Sustainability Program Water Year 2023

PREPARED FOR

Chino Basin Watermaster and
Inland Empire Utilities Agency

PREPARED BY

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Annual Report of the Prado Basin Habitat Sustainability Committee
Water Year 2023

Prepared for

Chino Basin Watermaster and Inland Empire Utilities Agency

Project No. 941-80-23-17

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LIST OF ACRONYMS AND ABBREVIATIONS

ACOE	Army Corps of Engineers
af	acre-feet
afy	acre-feet per year
AMP	Adaptive Management Plan
Annual Report	Annual Report of The Prado Basin Habitat Sustainability Committee
CAL FIRE	California Department of Forestry and Fire Protection
CBMWD	Chino Basin Municipal Water District
CBWM	Chino Basin Watermaster
CCWF	Chino Creek Well Field
CDA	Chino Basin Desalter Authority
CDFM	cumulative departure from the mean
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
Chino Basin	Chino Groundwater Basin
DBH	diameter at breast height
EC	electrical conductivity
EIR	Environmental Impact Report
EROS	Earth Resources Observation and Science
ESPA	Center Science Processing Architecture
FD	Fusarium Dieback
ft-amsl	feet above mean sea level
ft-bgs	feet below ground surface
FRAP	Fire And Resource Assessment Program
GIS	Geographic Information System
GMP	Groundwater Monitoring Program
GMZ	Groundwater Management Zone
HCMP	Hydraulic Control Monitoring Program
IEUA	Inland Empire Utilities Agency
In/yr	inches per year
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
mi^2	square miles
MWD	Metropolitan Water District of Southern California
NDVI	Normalized Difference Vegetation Index
NASA	National Aeronautics and Space Administration
NEXRAD	Next Generation Radar
OBMP	Optimum Basin Management Program
OC-59	The OCWD’s Imported Water Turnout Tributary to Prado Basin
OCWD	Orange County Water District
Parties	Parties to The Chino Basin Judgment
PBHSC	Prado Basin Habitat Sustainability Committee
PBHSP	Prado Basin Habitat Sustainability Program

PBMZ	Prado Basin Management Zone
POTWs	Publicly Owned Treatment Works
ppm	parts per million
Prado Basin	Prado Basin Management Zone
PSHB	Polyphagous Shot Hole Borer - *Euwallacea Fornicates*
QA/QC	Quality Assurance and Quality Control
RHMP	Riparian Habitat Monitoring Program
SAWA	Santa Ana Watershed Association
SAR	Santa Ana River
SARWM	Santa Ana River Watermaster
SEIR	Subsequent Environmental Impact Report
SWMP	Surface-Water Monitoring Program
TDS	total dissolved solids
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
USDA	United State Department of Agriculture
USFWS	United States Fish and Wildlife Service
VOCs	volatile organic compounds
Watermaster	Chino Basin Watermaster
WEI	Wildermuth Environmental Inc.
WRCRWA	Western Riverside County Regional Wastewater Authority
WY	water year

2023 Annual Report of the Prado Basin Habitat Sustainability Program

1.0 BACKGROUND AND OBJECTIVES

This *Annual Report of the Prado Basin Habitat Sustainability Program for Water Year 2023* (Annual Report) was prepared on behalf of the Prado Basin Habitat Sustainability Committee (PBHSC), convened by the Inland Empire Utilities Agency (IEUA) and the Chino Basin Watermaster (Watermaster) pursuant to the mitigation monitoring and reporting requirements of the Peace II Subsequent Environmental Impact Report (SEIR) (Tom Dodson, 2010).

This introductory section provides background on the general hydrologic setting of the Prado Basin Management Zone (Prado Basin); the Chino Basin Judgment; the Optimum Basin Management Program (OBMP), its Programmatic Environmental Impact Report (EIR) and the Peace Agreement; the Peace II Agreement and its SEIR; and the formation of the PBHSC and the development of the adaptive management plan (AMP) for the Prado Basin Habitat Sustainability Program (PBHSP).

1.1 Prado Basin

The Prado Basin is the flood control area behind Prado Dam, which was constructed in 1941 as the major flood-control facility within the Santa Ana River (SAR) Watershed. The U.S. Army Corps of Engineers (ACOE) regulates releases of water from Prado Dam for both purposes of flood control and groundwater recharge in Orange County Groundwater Management Zone (GMZ). Releases of water temporarily held in storage in the Prado Basin for groundwater recharge in Orange County is coordinated with the Orange County Water District (OCWD). Figure 1-1 shows the location of the Prado Basin in the southern portion of the Chino Groundwater Basin (Chino Basin). The Prado Basin boundary shown on Figure 1-1 is the Prado Basin Management Zone (PBMZ) boundary as defined in the Santa Ana Region Basin Plan (Santa Ana Regional Water Quality Control Board [Santa Ana Water Board], 2016), which approximately follows the 566 feet above mean sea level (ft-amsl) elevation contour behind Prado Dam.

Approximately 4,300 acres of riparian habitat have developed within the Prado Basin, creating the largest riparian habitat in Southern California. Portions of the riparian habitat have been designated as critical habitat to several endangered or threatened species. Figure 1-2 shows the locations of the critical habitat, as defined by the U.S. Fish and Wildlife Service (USFWS). Most of the riparian habitat in Prado Basin is designated as critical habitat for one or multiple species, including the Santa Ana Sucker, the Southwestern Willow Flycatcher, and Least Bell's Vireo.

The SAR flows through the Prado Basin from east to west. The tributaries of the SAR that flow into the Prado Basin include San Antonio/Chino, Cucamonga/Mill, and Temescal Creeks. The major components of flow within the SAR and its tributaries are runoff from precipitation, discharge of tertiary-treated effluent from wastewater treatment plants, rising groundwater, discharge of untreated imported water from the OC-59 turnout conveyed through the Prado Basin for groundwater recharge in Orange County GMZ, and dry-weather runoff.[1]

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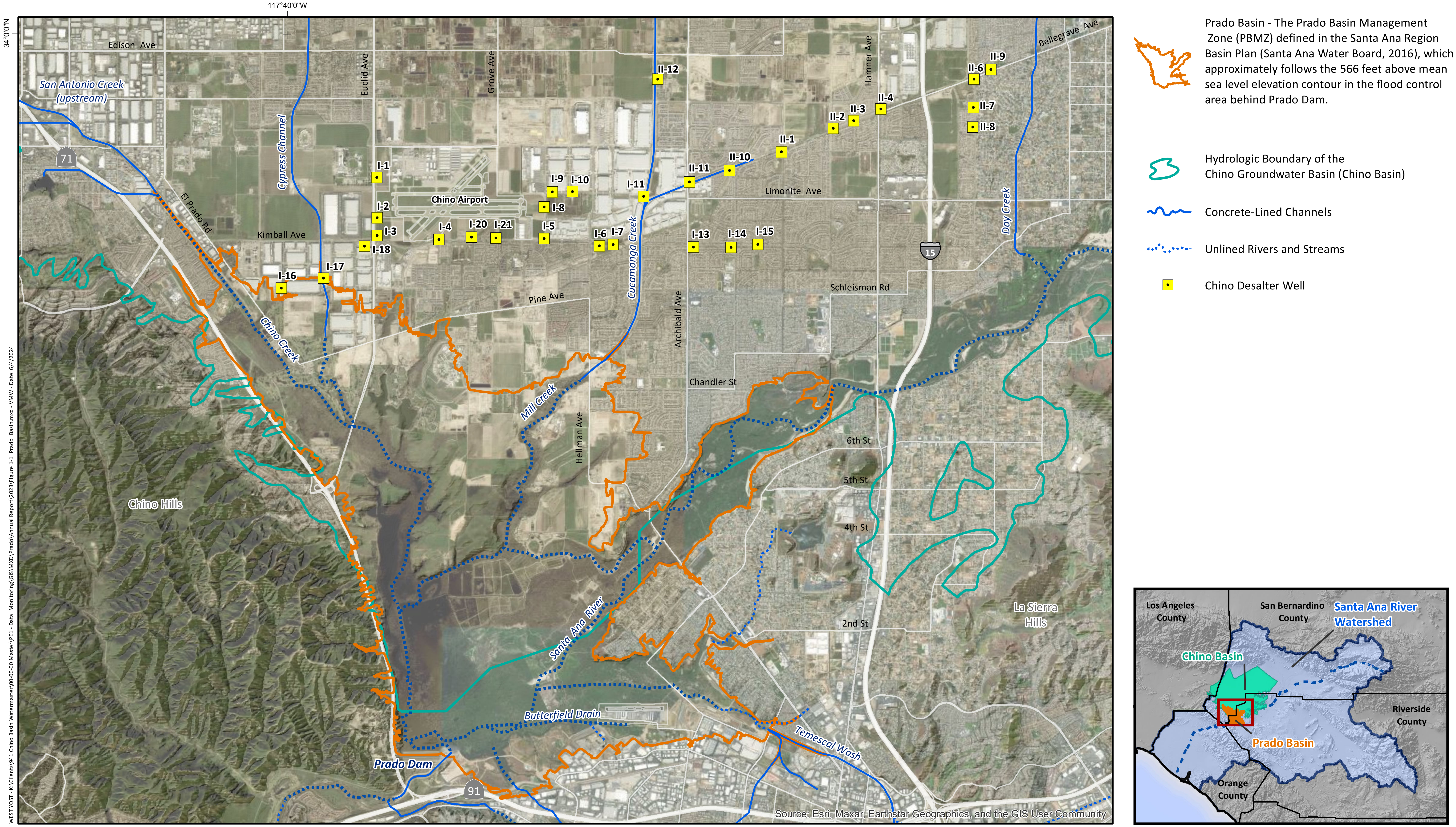
[1] Dry-weather runoff consists of excess irrigation runoff, purging of wells, dewatering discharges, etc.



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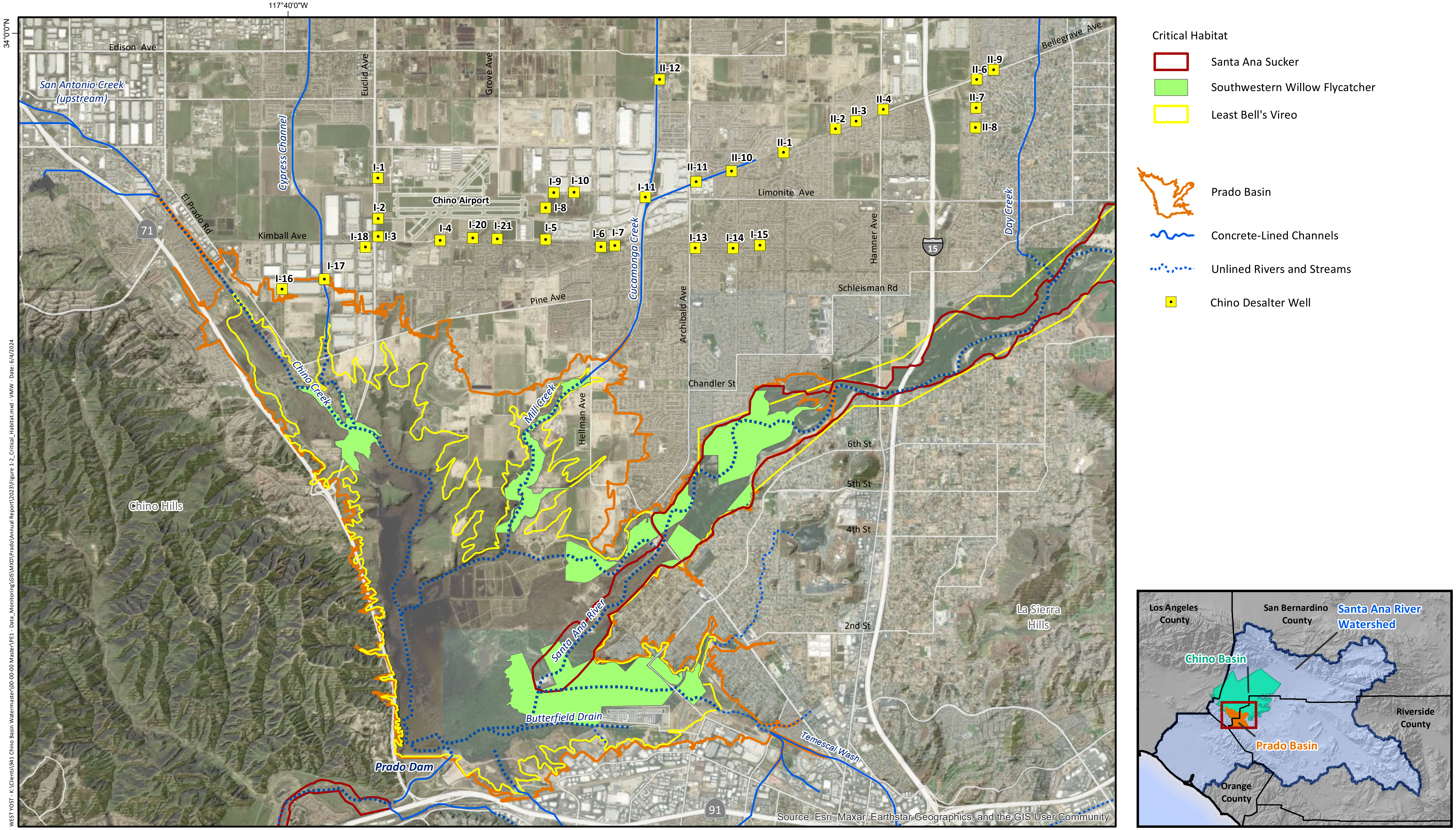
Prado Basin Area

Figure 1-1



WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\2023\Figure 1-2_Critical_Habitat.mxd - VMW - Date: 6/4/2024

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Critical Habitat for Endangered or Threatened Species in the Prado Basin Area

Figure 1-2

The Prado Basin is a hydrologically complex region of the lower Chino Basin. Groundwater in the Chino Basin generally flows from the forebay regions in the north towards the Prado Basin in the south. Depth to groundwater is relatively shallow in the Prado Basin area, and the SAR and its tributaries are unlined across the Prado Basin, which allows for groundwater/surface-water interaction. Groundwater outflows in the Prado Basin occur via evapotranspiration by riparian vegetation and rising-groundwater discharge to the SAR and its tributaries.

To the north of the Prado Basin, the Chino Basin Desalter Authority (CDA) owns and operates the Chino Desalter well field. Figure 1-1 shows the locations of Chino Desalter wells. The well field pumps groundwater with high concentrations of total dissolved solids (TDS) and nitrate. The CDA treats the groundwater at two regional facilities using reverse osmosis, ion exchange, and blending to produce a potable water supply for the region. CDA operations are fundamental to achieving many of the management goals outlined in the OBMP and both Peace Agreements, which are discussed below. The CDA facilities were expanded in 2021 and 2023 with additional treatment processes of air stripping and granulated activated carbon to treat for volatile organic compounds (VOCs) associated with the South Archibald plume, and Chino Airport plume, respectively.

1.2 Chino Basin Judgment, OBMP, and Peace Agreement

A 1978 Judgment entered in the Superior Court of the State of California for the County of San Bernardino (Chino Basin Municipal Water District vs. City of Chino et al.) established pumping and storage rights in the Chino Basin. The Judgment established Watermaster to oversee the implementation of the Judgment and provided Watermaster with the discretionary authority to develop an OBMP to maximize the beneficial use of the Chino Basin. The OBMP was developed by Watermaster and the parties to the Judgment (Parties) in the late 1990s (WEI, 1999). The OBMP maps a strategy to enhance the yield of the Chino Basin and provide reliable high-quality water supplies for the development expected to occur in the region. The goals of the OBMP are to enhance basin water supplies, to protect and enhance water quality, to enhance the management of the Basin, and to equitably finance the OBMP.

In 2000, the Parties executed the Peace Agreement (Watermaster, 2000), which documented their intent to implement the OBMP. The Peace Agreement included an OBMP Implementation Plan which outlined the time frame for implementing tasks and projects in accordance with the Peace Agreement and the OBMP. The OBMP Implementation Plan is a comprehensive, long-range water-management plan for the Chino Basin and includes: the use of recycled water for direct reuse and artificial recharge, the capture of increased quantities of high-quality storm-water runoff, the recharge of imported water when TDS concentrations are low, the desalting of poor-quality groundwater in impaired areas of the basin via the Chino Basin Desalters, the support of regulatory efforts to improve water quality in the basin, subsidence management, storage management, and the implementation of management activities to reduce the discharge of high-TDS/high-nitrate groundwater to the SAR, thus ensuring the protection of downstream beneficial uses in the Orange County GMZ.

The Chino Basin Municipal Water District (CBMWD) was the plaintiff in the legal action that resulted in the Judgment. The CBMWD was formed in 1950 to supply supplemental, imported water purchased from the Metropolitan Water District of Southern California (MWD) to the Chino Basin. On July 1, 1998, the CBMWD changed its name to the IEUA and expanded its role to become the regional supplier of recycled water for most of the Chino Basin. For OBMP implementation, the IEUA has served as the lead agency for compliance with the California Environmental Quality Act (CEQA). A Program Environmental Impact Report for the OBMP (SCH#2000041047) was certified by the IEUA in July 2000 (Tom Dodson, 2000).

1.3 The Peace II Agreement and its Subsequent EIR

To further implement the goals and objectives of the OBMP, the Parties executed the Peace II Agreement in 2007, which modified the OBMP Implementation Plan (Watermaster, 2007). The two main activities of the Peace II Agreement are: (i) increasing the controlled overdraft of the Chino Basin, as defined in the Judgment,[2] by 400,000 acre-feet (af) through 2030 (re-operation), and (ii) refining the planned expansion facilities of the Chino Basin Desalters from about 30,000 to 40,000 acre-feet per year (afy) of groundwater production. Re-operation is allocated specifically to offset the production of the Chino Basin Desalters. Both re-operation and desalter expansion contribute to the attainment of "hydraulic control" of groundwater outflow from the Chino Basin to the SAR. The attainment and maintenance of hydraulic control is a requirement of Watermaster and the IEUA, as defined in the Water Quality Control Plan for the Santa Ana River Basin (California Regional Water Quality Control Board, Santa Ana Region, 2008). Hydraulic control ensures that the water management activities in the Chino Basin will not impair the beneficial uses designated for SAR water quality downstream of Prado Dam.

The expansion of the Chino Basin Desalters, described in the Peace II Agreement, was accomplished, in part, by the construction and operation of the Chino Creek Well Field (CCWF) in the southwest portion of Chino Basin (see Figure 1-3). During Peace II Agreement planning, the estimated capacity of the CCWF was about 5,000 to 7,700 afy (WEI, 2007). The CCWF wells were constructed in 2011-2012, and their actual capacity is about 1,500 afy.

In 2010, the IEUA certified the Peace II SEIR (Tom Dodson, 2010) to evaluate the environmental impacts that could result from implementing the Peace II Agreement. One of the potential impacts evaluated was the possible lowering of groundwater levels (drawdown) in the Prado Basin area, which could impact riparian vegetation that is dependent upon shallow groundwater. In order to assess this potential impact, Watermaster's groundwater model was used in 2007 for the Peace II SEIR analysis to predict the extent and magnitude of the drawdown associated with the implementation of the Peace II Agreement, using the planned capacity of 7,700 afy[3] of the CCWF (WEI, 2007). Figure 1-3 (modified from Figure 4.4-10 from the Peace II SEIR) shows the 2007 model-predicted drawdown in the Prado Basin area for the period of 2005 to 2030. The 2007 model predictions showed some drawdown of less than five feet by 2030 throughout the riparian habitat areas along the northern portion of Prado Basin near the northern reaches of Chino Creek, Mill Creek, and the SAR.[4]

Although this modeling work indicated that implementing the Peace II Agreement would not cause significant adverse effects on Prado Basin riparian habitat, a contingency measure to address the potential for drawdown of groundwater levels and its impact on riparian vegetation was included in the Peace II SEIR as Mitigation Measure 4.4-3 (Biological Resources/Land Use & Planning section of the Mitigation Monitoring and Reporting Program).

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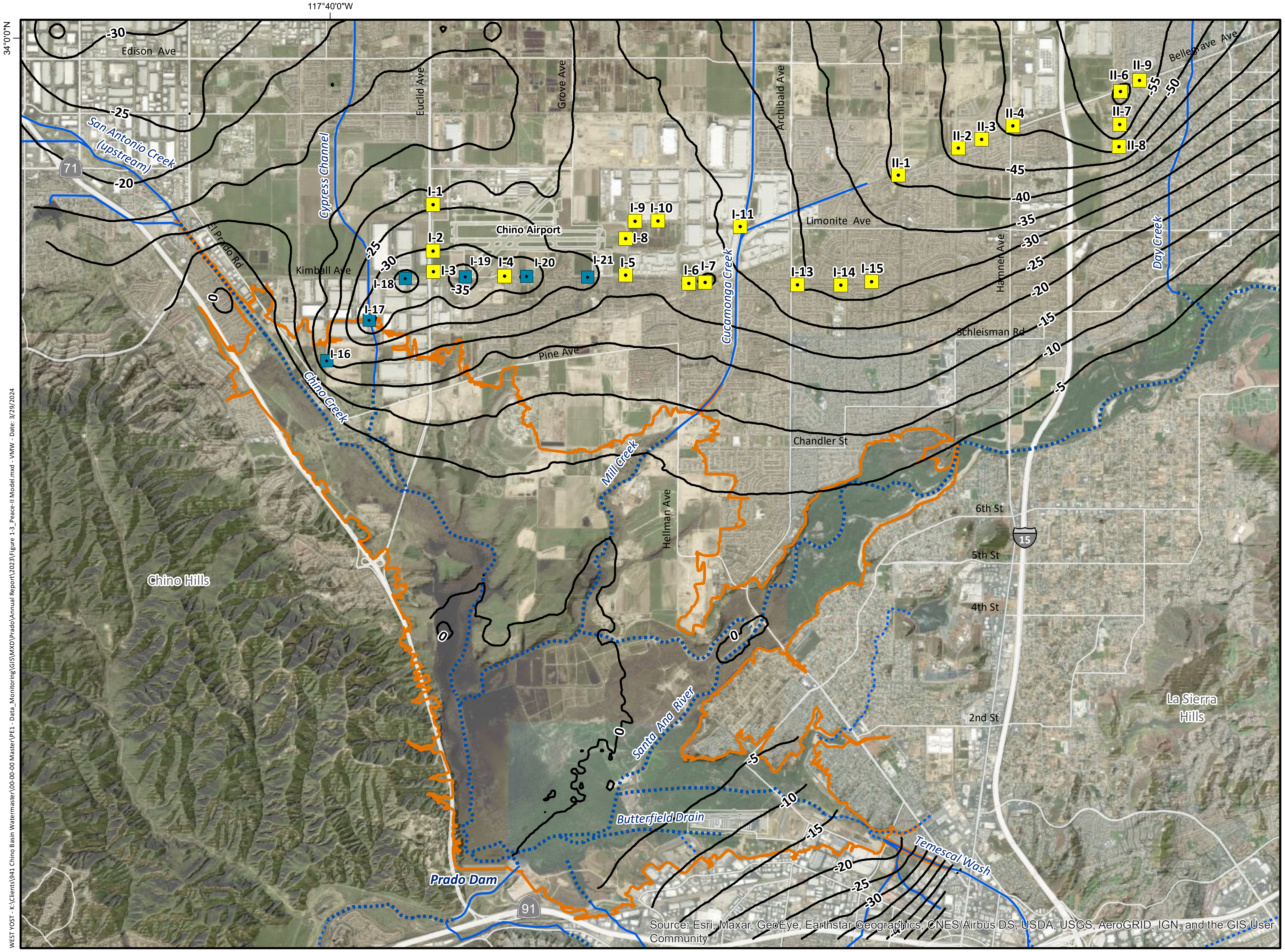
[2] The Judgment established 200,000 af of controlled overdraft over the period of 1978 to 2017. Re-operation increases the controlled overdraft to 600,000 af through 2030.

[3] The CCWF wells were constructed in 2011-2012 and their actual capacity is about 1,500 afy, not the 7,700 afy used as the planning assumption for this modeling work in 2007 for the Peace II SEIR. The PBHSP includes the use of Watermaster's most recent groundwater model update, and planning data (including actual capacity of the CCWF), are used to evaluate potential impacts to groundwater levels from the implementation of the Peace II Agreement and identify areas of prospective loss of riparian habitat. This updated modeling work is described in Section 3.7.

[4] The primary area that would be influenced by the Peace II Agreement implementation is the upper portion of Prado Basin. The Temescal Wash area is outside of the Chino Basin hydrologic boundary and is not an area of influence of potential impacts of groundwater levels from pumping at the Chino Desalter well field and implementation of the Peace II Agreement.



-10— Projected Change in Groundwater Levels *FY 2005 to FY 2030, feet*

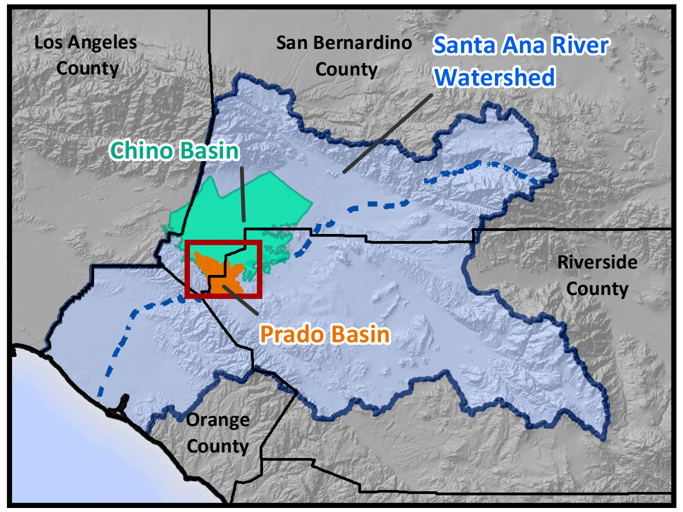
🟨 Chino Desalter Well - Location of Exsisting wells in 2007 modeled for the Peace II SEIR

🟦 Chino Desalter Well – Planned Location of the Chino Creek Well Field (CCWF) in 2007 as modeled for the Peace II SEIR with a Planned Capacity of 7,700 afy. Actual Location of the CCWF Constructed in 2011-2012 Shown in Figure 1-1 with an Actual Capacity 1,500 afy

Prado Basin

Concrete-Lined Channels

Unlined Rivers and Streams



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Projected Change in Groundwater Levels
FY 2005 to 2030 - Peace II Alternative

Figure 1-3

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Mitigation Measure 4.4-3 was developed to ensure that the riparian habitat will not incur unforeseeable significant adverse effects from the Peace II implementation and to contribute to the long-term sustainability of the riparian habitat. Mitigation Measure 4.4-3 calls for:

- Watermaster, the IEUA, the OCWD, and other stakeholders that choose to participate to jointly fund the development of an adaptive management program to monitor the extent and quality of the Prado Basin riparian habitat and investigate and identify essential factors to its long-term sustainability.
- Watermaster and the IEUA to convene the PBHSC, comprised of representatives from all interested parties to implement the adaptive management program.
- The PBHSC to prepare annual reports pursuant the adaptive management program. Annual reports are to include recommendations for ongoing monitoring and any adaptive management actions required to mitigate any measured or prospective loss of riparian habitat resulting from Peace II activities.

1.4 Adaptive Management Plan for the PBHSP

Pursuant to Mitigation Measure 4.4-3 in the SEIR, Watermaster and the IEUA convened four meetings of the PBHSC, starting in late-2012, to develop the adaptive management plan for the PBHSP and facilitate its implementation. Watermaster and the IEUA adopted the final 2016 Adaptive Management Plan for the Prado Basin Habitat Sustainability Program (AMP) in August 2016 (WEI, 2016). The AMP was designed to answer the following questions to satisfy the monitoring and mitigation requirements of the Peace II SEIR:

1. What are the factors that potentially can affect the extent and quality of the riparian habitat?
2. What is a consistent, quantifiable definition of “riparian habitat quality,” including metrics and measurement criteria?
3. What has been the historical extent and quality of the riparian habitat in the Prado Basin?
4. How has the extent and quality of the riparian habitat changed during implementation of Peace II?
5. How have groundwater levels and quality, surface-water discharge, weather, and climate changed over time? What were the causes of the changes? And, did those changes result in an adverse impact to riparian habitat in the Prado Basin?
6. Are there other factors besides groundwater levels, surface-water discharge, weather, and climate that affect riparian habitat in the Prado Basin? What are those factors? And, did they (or do they) result in an adverse impact to riparian habitat in the Prado Basin?
7. Are the factors that result in an adverse impact to riparian habitat in the Prado Basin related to Peace II implementation?
8. Are there areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement?
9. What are the potential mitigation actions that can be implemented if Peace II implementation results in an adverse impact to the riparian habitat?

The AMP outlines a process for monitoring, modeling, and annual reporting to answer and address the questions listed above. Appendix A to the AMP is the initial monitoring program: *2016 Monitoring Program for the Prado Basin Habitat Sustainability Program*. Annual reports are intended to document monitoring and modeling activities, the analysis and interpretation of the monitoring and modeling results, and recommendations for changes to the PBHSP, which may include monitoring, modeling, and/or mitigation, if deemed necessary. Any future mitigation measures that are deemed necessary will be developed jointly by Watermaster and the IEUA.

1.5 Annual Report Organization

This Annual Report for water year (WY) 2023 is the eighth annual report of the PBHSC; it documents the collection, analysis, and interpretations of the data and information generated by the PSHSP through September 30, 2023. The remainder of this report is organized as follows:

Section 2.0 – Monitoring, Data Collection, and Methods. This section describes the collection of historical information and recent monitoring data and describes the groundwater-modeling activities performed during WY 2023 for the PBHSP.

Section 3.0 – Results and Interpretations. This section describes the results and interpretations that were derived from the information, data, and groundwater-modeling.

Section 4.0 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the PBHSP through the WY 2023 and describes the recommended activities for the subsequent fiscal year as a proposed scope-of-work, schedule, and budget.

Section 5.0 – References. This section lists the publications cited in the report.

2.0 MONITORING, DATA COLLECTION, AND METHODS

The PBHSP was designed, in part, to answer Question 1 from the AMP:

- What are the factors that potentially can affect the extent and quality of the riparian habitat?

The main hydrologic factors that can potentially affect the extent and quality of the riparian habitat in the Prado Basin include, but are not limited to, groundwater levels, surface-water discharge, weather events, and long-term climate. As such, the PBHSP includes integrated monitoring and analysis programs for riparian habitat, groundwater, surface water, climate, and other potential factors (e.g., wildfire, pests, etc.).

Since the implementation of the AMP in WY 2016, data collection efforts included the compilation of historical data through present. The period of data available for each data type varies, but all span both pre- and post-Peace II Agreement implementation. Data collection efforts for all historical data were described in the first two annual reports for WY 2016 and WY 2017. Data collection efforts for subsequent water years have focused on recent water year monitoring data. All data collected and compiled for this effort were uploaded to Watermaster's centralized relational database, HydroDaVE^{SM}, and used in the analyses.

This section describes the collection of recent monitoring data and the groundwater-modeling activities performed for the PBHSP during WY 2023.

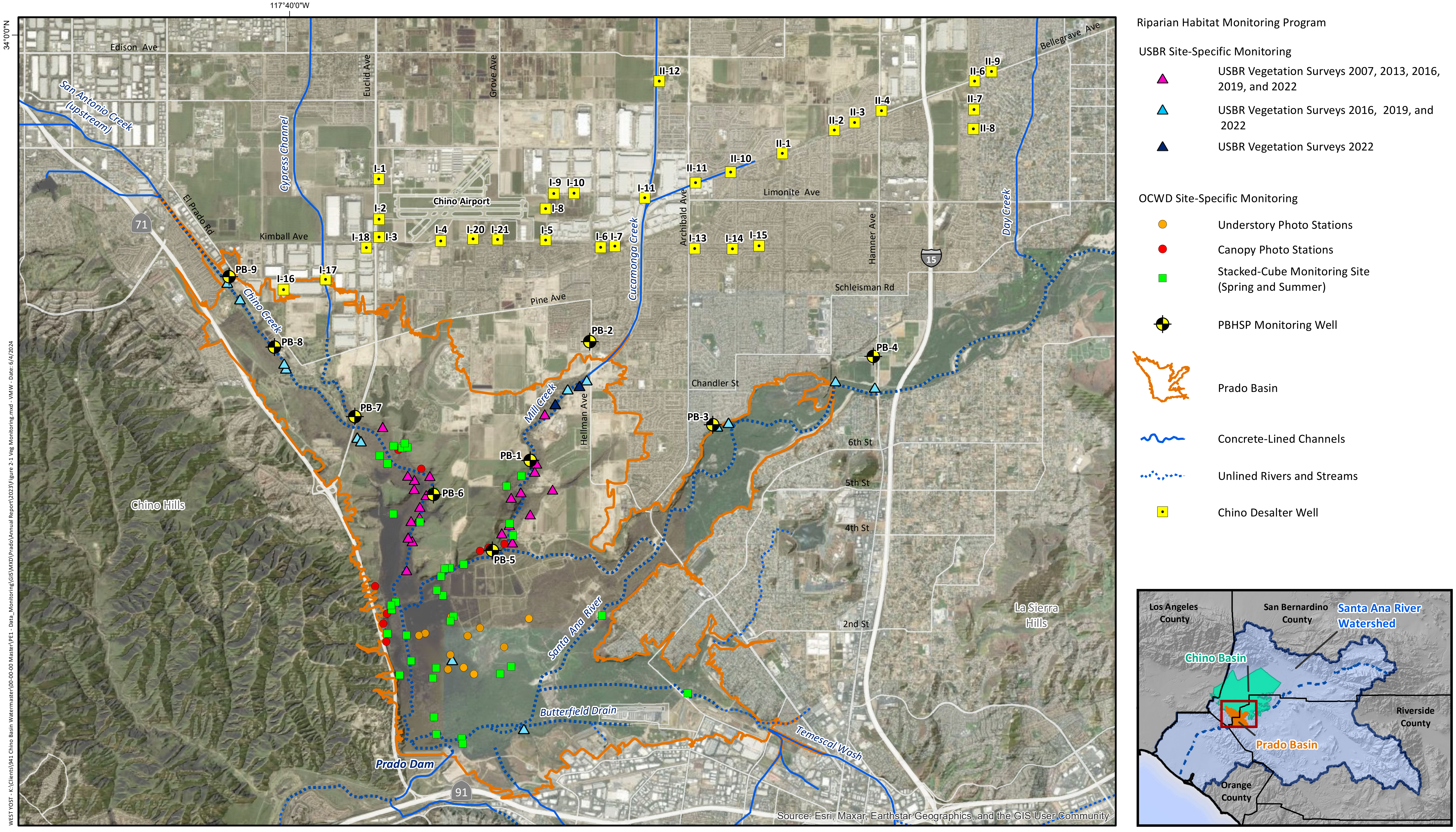
2.1 Riparian Habitat Monitoring

The objective of the Riparian Habitat Monitoring Program (RHMP) is to collect data to help answer questions 2, 3, and 4 from the AMP:

1. What is a consistent quantifiable definition of "riparian habitat quality," including metrics and measurement criteria?
2. What has been the historical extent and quality of the riparian habitat in the Prado Basin?
3. How has the extent and quality of the riparian habitat changed during the implementation of Peace II?

To answer these questions, the RHMP includes time series data and information on the extent and quality of riparian habitat in the Prado Basin over a historical period, including both pre- and post-Peace II implementation.

Figure 2-1 displays the features of the RHMP. Two types of monitoring and assessment are performed: regional and site-specific. Regional monitoring and assessment are appropriate because the main potential stress to the riparian habitat associated with Peace II activities is the regional drawdown of groundwater levels. The intent of site-specific monitoring and assessment is to verify and complement the results of regional monitoring.



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Riparian Habitat Monitoring Program

Figure 2-1

2.1.1 Regional Monitoring of Riparian Habitat

Regional monitoring and assessment of the riparian habitat is performed by mapping the extent and quality of riparian habitat over time using: 1) multi-spectral remote-sensing data and 2) air photos.

2.1.1.1 Multi-Spectral Remote Sensing Data

The Normalized Difference Vegetation Index (NDVI), derived from remote sensing measurements by Landsat Program satellites, is used to assess the extent and quality of the riparian vegetation in the Prado Basin over a long-term historical period. NDVI is a commonly used numerical indicator of vegetation health that can be calculated from satellite remote-sensing measurements (Ke et al., 2015; Xue, J. and Su, B., 2017). NDVI is calculated from visible and near-infrared radiation reflected by vegetation and is an index of greenness correlated with photosynthesis that can be used to assess spatial and temporal changes in the distribution and productivity of vegetation (Pettorelli, 2013). Areas where the NDVI is higher have greener vegetation than areas where NDVI is lower, indicating areas where the overall vegetation is healthy. Although NDVI does not provide species-specific vegetation information, the regional scale of NDVI makes it an appropriate "first indicator" of regional changes in the extent and quality of riparian vegetation. Additionally, there is NDVI data for the entire extent of the Prado Basin dating from the early 1980s to present, which allow us to characterize the history of the spatial extent and quality of the riparian vegetation prior to and after the implementation of Peace II activities (2007). A limitation of NDVI data is that it is a composite view of plant species diversity, form, structure, density, and vigor. As such, changes in NDVI may be caused by various changes in riparian habitat (Markon et al., 1995; Markon and Peterson, 2002). In other words, NDVI does not provide a complete picture of how and why vegetative changes are occurring; it simply indicates a change in vegetation. These changes can then be ground-truthed using other types of monitoring. Appendix A provides background information on NDVI, further explains why NDVI was chosen as an analytical tool for the PBHSP, discusses additional advantages and limitations of NDVI, and describes how NDVI estimates were used for the PBHSP.

For the current reporting period, NDVI estimates were collected from the United States Geological Survey (USGS) using the Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface[5] (USGS, 2017b) over the period of November 2022 through October 2023 to span the entire growing-season period (March-October 2023). To obtain complete spatial coverage of the Prado Basin area, NDVI estimates were requested for all Landsat scenes for Path 040, Rows 036 and 037 from the Landsat 7, Landsat 8, and Landsat 9 satellites. The NDVI were processed and uploaded to Watermaster's centralized relational database, HydroDaVE^{SM}, which includes tools to manage, review, and extract NDVI estimates. The frequency of NDVI estimates from the Landsat 7, 8 and 9 satellites is every one to eight days. However, not all NDVI estimates are useable due to disturbances that can be caused by cloud cover, unfavorable atmospheric conditions, or satellite equipment malfunction. NDVI estimates were reviewed for these disturbances and excluded from analysis if they were determined erroneous due to these disturbances. Appendix A describes how the NDVI estimates were collected, reviewed, and assembled for the PBHSP.

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[5] ESPA USGS

2.1.1.2 Collection and Analysis of Air Photos

Georeferenced air photos are used to visually characterize the spatial extent and quality of the riparian habitat in the Prado Basin. The air photos also serve as an independent check on interpretations of NDVI, which involves visual comparison of the extent and density of the riparian habitat (as shown in the air photos) to the NDVI maps. For ongoing monitoring, a high-resolution (3-inch pixel) image of the visible spectrum for the entire Prado Basin is acquired during the middle of the growing season, typically in July.

For the current reporting period, the acquisition of the 2023 air photo included a custom flight that was performed by Tetra Tech on July 7, 2023. The cost to acquire the 2023 air photo was shared with the OCWD. This was the seventh annual high-resolution air photo acquired for the PBHSP and cost-shared with the OCWD.

2.1.2 Site-Specific Monitoring of Riparian Habitat

The objective of the site-specific monitoring of riparian habitat is to collect data that can be used to ground-truth the interpretations derived from the regional monitoring and assessment of the riparian habitat (Pettorelli, 2013). Prior to the implementation of the AMP, site-specific monitoring performed in the Prado Basin included vegetation surveys performed by the United States Bureau of Reclamation (USBR) in 2007 and 2013 (USBR, 2008b; 2015). Since the implementation of the AMP, the USBR conducted vegetation surveys for the PBHSP in 2016, 2019, and 2022. The USBR vegetation surveys performed in 2016 and 2019 consist of 37 sites: 23 previously established USBR sites during the 2007 and 2013 sampling and 14 new sites established in 2016 that are primarily located near the PBHSP monitoring wells. The USBR vegetation surveys performed in 2022 consist of 39 sites: the 37 previously established sites surveyed in 2016 and 2019, and two additional sites in the upper portion of Mill Creek to increase the monitoring is an area where there has been some observed drawdown of groundwater levels since the PBHSP monitoring began. The OCWD performs site-specific monitoring in the southern portion of Prado Basin to monitor for effects of the operation of Prado Dam on riparian habitat. OCWD site-specific monitoring includes: seasonal monitoring at nine canopy photo stations located along the edge of Prado Basin, seasonal monitoring at 11 understory photo stations within different surface elevations of the inundation zone behind the dam, 40 stacked-cube monitoring sites monitored in the spring and summer throughout different surface elevation ranges of the inundation zone, and 40 stacked-cube monitoring sites in Least Bell’s Vireo nesting and territory locations in the riparian habitat. The most recent annual report prepared by OCWD on the results of this monitoring is the *Prado Basin Water Conservation and Habitat Assessment 2021-2022* report (OCWD, 2023).

Figure 2-1 shows the locations of the USBR vegetation surveys and the OCWD photo and stacked-cube monitoring sites.

2.2 Factors that Potentially Affect the Riparian Habitat

The main factors that can potentially affect riparian habitat in Prado Basin include but are not limited to groundwater levels, surface-water discharge, weather/climate, wildfires, and pests. This section describes the methods employed to collect and analyze information on these factors to help answer questions 5, 6, and 7 from the AMP:

1. How have groundwater levels and quality, surface-water discharge, weather, and climate changed over time? What were the causes of the changes? And did those changes result in an adverse impact to riparian habitat in the Prado Basin?

2. Are there other factors besides groundwater levels, surface-water discharge, weather, and climate that affect riparian habitat in the Prado Basin? What are those factors? And did they (or do they) result in an adverse impact to riparian habitat in the Prado Basin?
3. Are the factors that result in an adverse impact to riparian habitat in the Prado Basin related to Peace II implementation?

2.2.1 Groundwater Monitoring Program

A primary result of implementation of the Peace II Agreement is the lowering of groundwater levels (drawdown) in the southern portion of Chino Basin. Hence, drawdown is a factor that is potentially related to Peace II implementation and could adversely impact riparian habitat.

The Groundwater Monitoring Program (GMP) includes the collection of three types of data: groundwater production, groundwater level, and groundwater quality. Watermaster has been implementing a groundwater monitoring program across the entire Chino Basin to support various basin management initiatives and activities, and all data within Watermaster's centralized relational database are available to the GMP.

Watermaster's groundwater monitoring network was expanded in 2015 specifically for the PBHSP, with the construction of 16 new monitoring wells at nine sites located along the fringes of the riparian habitat and between the riparian habitat and the CDA well field. These wells, along with two existing monitoring wells, HCMP-5/1 and RP2-MW3, are specifically monitored for the PBHSP and are called the "PBHSP monitoring wells."

Figure 2-2 shows the extent of the study area for which the GMP data are compiled and used for the PBHSP. The area covers the Prado Basin and the upgradient areas to the north that encompass the Chino Desalter well field. Figure 2-2 also shows the wells in the study area where groundwater data were available in WY 2023.

2.2.1.1 Groundwater Production

Groundwater production influences groundwater levels and groundwater-flow patterns. Groundwater-production data are analyzed together with groundwater-level data to characterize the influence of groundwater production on groundwater levels. Groundwater-production data are also used as an input to the Chino Basin groundwater-flow model to evaluate past and future conditions in the Chino Basin, which, for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3).

Watermaster collects quarterly groundwater-production data for all active production wells within the Chino Basin. The data are checked for quality assurance and quality control (QA/QC) and uploaded to Watermaster's centralized relational database. The active production wells within the study area include CDA wells and privately owned wells used for agricultural, dairy, or domestic purposes.

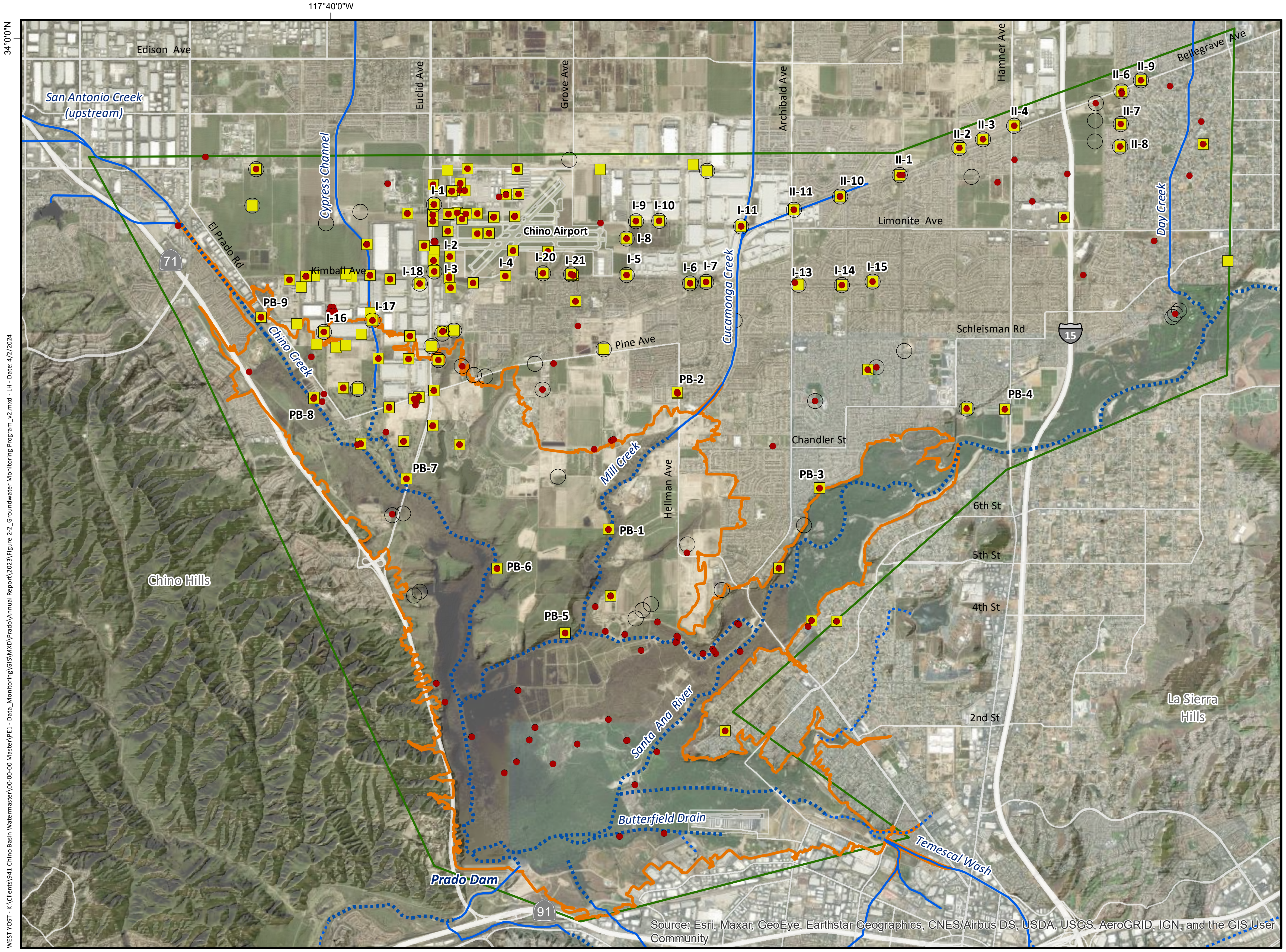
During WY 2023, Watermaster collected groundwater-production data at about 70 wells in the GMP study area.

2.2.1.2 Groundwater Level

Monitoring groundwater levels in the Prado Basin is a key component of the PBHSP, as the potential for declining groundwater levels related to Peace II implementation could be a factor that adversely impacts riparian habitat. Groundwater-level data are analyzed together with production data to characterize how groundwater levels have changed over time in the GMP study area and to explore the relationship(s) to any observed changes that occurred in the extent and quality of the riparian habitat. Groundwater-level and production data are also used as input to the Chino Basin groundwater flow model to evaluate past and future conditions in the Chino Basin, which, for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3).

Watermaster collects groundwater-level data at various frequencies at wells in the GMP study area to support various groundwater-management initiatives. The data are checked for QA/QC and uploaded to Watermaster's centralized relational database.

During WY 2023, Watermaster collected groundwater-level data from 268 wells in the study area (see Figure 2-2). Approximately 108 wells are CDA wells, dedicated monitoring wells, or private wells that are monitored by Watermaster using manual methods once per month or with pressure transducers that record water levels once every 15 minutes. At the remaining 160 wells, water levels were measured by well owners at varying frequencies and provided to Watermaster. Groundwater-levels at the 18 PBHSP monitoring wells have been measured with pressure transducers since May 2015.



Wells with Groundwater Data - Water Year 2023

○ Wells with Production Data

● Wells with Water Level Data

🟨 Wells with Water Quality Data

Wells Labeld on the Map

Chino Basin Desalter Well - Labled with **"I-" or "II-"**

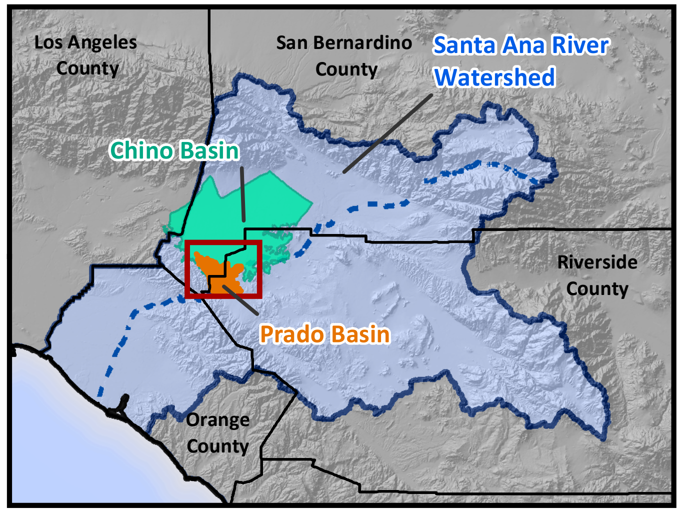
PBHSP Monitoring Well - Labled with **"PB-"**

🟩 Groundwater Monitoring Program (GMP) Study Area

Prado Basin

Concrete-Lined Channels

Unlined Rivers and Streams



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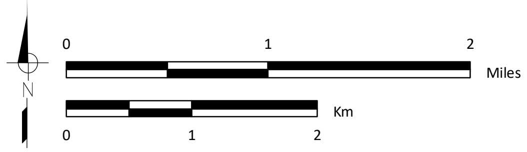

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Groundwater Monitoring Program

Figure 2-2

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2.2.1.3 Groundwater Quality

Water-quality data can be used to understand the various potential sources of shallow groundwater in the Prado Basin. Groundwater-quality data are compared to surface-water-quality data to characterize groundwater/surface-water interactions in the Prado Basin and assess the importance of those interactions to the extent and quality of the riparian habitat.

Watermaster collects groundwater-quality data from wells in the GMP study area to support various groundwater-management initiatives. These data are checked for QA/QC and uploaded to Watermaster's centralized relational database. During WY 2023, groundwater-quality data were collected from 186 wells in the study area (see Figure 2-2). Of these wells, 52 wells are dedicated monitoring wells or private wells sampled by Watermaster either using transducers that record high-frequency data, or grab samples collected quarterly, annually, or triennially (every three years). The remaining 134 were sampled by the well owners at varying frequencies.

Watermaster has performed groundwater-quality sampling at the PBHSP monitoring wells since they were constructed in 2015. The groundwater-quality monitoring has been tailored to discern the groundwater/surface-water interactions important to the sustainability of the riparian habitat. Currently Watermaster conducts triennial water quality sampling at the 18 PBHSP monitoring wells as part of their basin-wide water quality monitoring to support various groundwater-management initiatives, and the next triennial monitoring event will occur in summer of 2024.

In FY 2023/24 Watermaster began to collect and analyze high-frequency (15 minute) temperature and specific conductance (EC) readings using the transducers at all the PBHSP monitoring wells. This high-frequency temperature and EC monitoring at all the PBHSP monitoring wells is a recommendation in the WY 2022 Annual Report and a replacement of a pilot monitoring program that was conducted at four of the wells from FY 2018/19 to FY 2022/23 to study groundwater/surface-water interactions (see section 4.1 of 2022 Annual Report, West Yost, 2023). The high-frequency temperature data was already being measured by the transducers installed in the 18 PBHSP monitoring wells to measure water levels and downloaded by the Watermaster quarterly; and four of the wells have transducers that also measure high-frequency EC. As transducers are replaced, they are replaced with a transducer that measures and records high-frequency EC data in addition to the temperature and groundwater levels. In FY 2023/24 six transducers were replaced and there are now ten PBHSP monitoring wells with transducers that have probes that measure EC in addition to temperature and water level.

During FY 2023/24, the high-frequency temperature and EC data at the PBHSP monitoring sites were downloaded, processed, checked for QA/QC, and uploaded to Watermaster's relational database on a quarterly basis. During FY 2023/24, the high-frequency temperature data for the entire historical period (2015-present) were also processed, checked for QA/QC, and uploaded to the database.

2.2.1.4 Surface-Water Monitoring Program

Surface-water discharge in the Prado Basin is another factor that can influence the extent and quality of riparian habitat and can influence groundwater levels. Surface-water discharge data are evaluated for the PBHSP to characterize historical and current trends in the discharge of the SAR and its tributaries in the Prado Basin, and to explore the relationship(s) to any observed changes that occur in the extent and quality of the riparian habitat. Surface-water discharge data are also used as input to the Chino Basin groundwater-flow model to evaluate past and future conditions in the Chino Basin, which for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3). Surface-water quality is compared to groundwater-quality data to characterize groundwater/surface-water interactions in the Prado Basin and the importance of those interactions to the extent and quality of the riparian habitat.

The surface-water monitoring program for the PBHSP involves collecting existing, publicly available surface-water discharge and quality data from sites within or tributary to the Prado Basin. Figure 2-3 shows the location of the surface-water monitoring sites used in the PBHSP. These sites include discharge locations for publicly owned treatment works (POTWs), USGS stream gaging stations, Watermaster and the IEUA Maximum-Benefit Monitoring Program surface-water-quality monitoring sites, ACOE's storage levels and inflow to Prado Dam, and the OCWD's discharge of untreated imported water from the OC-59 turnout tributary to Prado Basin. All surface-water discharge and quality data were collected for WY 2023, checked for QA/QC, and uploaded to Watermaster's relational database.

In FY 2023/24 Watermaster set up and began manually collecting surface water measurements of temperature and EC at four surface-water sites located near PBHSP monitoring wells along Chino Creek and Mill Creek in coordination with high-frequency groundwater measurements of temperature and EC described above Groundwater Quality Section. The manual measurements were recommended in the WY 2022 Annual Report and part of a replacement of a pilot monitoring program performed from FY 2018/19 to FY 2022/23 to study groundwater/surface-water interactions. Data were checked for QA/QC and uploaded to Watermaster's relational database.

2.2.2 Climatic Monitoring Program

Climatic data are used to characterize how the climate has changed over time in the study area and to explore the relationship(s) to any observed changes that occurred in the extent and quality of the riparian habitat. Climatic data are also used for the Chino Basin groundwater-flow model to evaluate past and future conditions in the Chino Basin, which for the PBHSP, supports the analysis of prospective losses of riparian habitat (see Section 2.3).

The climatic monitoring program for the PBHSP involves collecting existing, publicly available spatially gridded climate datasets for precipitation and temperature in the vicinity of the Prado Basin. These climate datasets include Next-Generation Radar (NEXRAD) and the PRISM Climate Group. Figure 2-3 shows the location of the areas where the grided climate data is extracted from PRISM and NEXRAD to estimate a spatial average precipitation and temperature for the PBHSP analysis. The Chino Basin boundary is used to extract the spatially gridded data for precipitation, and the Prado Basin boundary is used to extract the spatially gridded data for maximum and minimum temperature. Climatic data are collected annually and uploaded to Watermaster's relational database.

2.2.3 Other Factors That Can Affect Riparian Habitat

The AMP recognizes that there are potential factors other than groundwater, surface water, and climate that can affect riparian habitat in the Prado Basin. These factors include, but are not limited to, wildfire, disease, pests, and invasive species. To the extent necessary, data and information on these factors are collected and analyzed to explore for relationships to changes in the extent and quality of the riparian habitat.

In WY 2016, during the analysis for the first Annual Report, two specific factors were identified as potential impacts to the riparian habitat in the Prado Basin: wildfires and an invasive pest known as the Polyphagous Shot-Hole Borer (Euwallacea fornicates; PSHB hereafter). In WY 2018, the removal of the non-native invasive weed Arundo donax (Arundo) was identified as another factor as a potential impact to riparian habitat in the Prado Basin. The following describes the information that was collected for these three factors and how they are used to explore for relationships to changes that have occurred in the extent and quality of riparian habitat.

2.2.3.1 Wildfires

Wildfires occur periodically in the Prado Basin and can reduce the extent and quality of riparian habitat. For the PBHSP, the occurrence and locations of wildfires are used to help understand and explain the trends observed in the extent and quality of the riparian vegetation.

To map the extent of any wildfires that have occurred in the study area, fire-perimeter data were collected from the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection (CAL FIRE).[6]

For the current reporting period, wildfire data were obtained from the FRAP database for the Prado Basin region for calendar year 2022.[7]

2.2.3.2 Polyphagous Shot-Hole Borer (PSHB)

The PSHB is a beetle that burrows into trees, introducing a fungus (*Fusarium euwallacea*) into the tree bark that spreads the disease Fusarium Dieback (FD).[8,9] FD destroys the food and water conducting systems of the tree, eventually causing stress and tree mortality. The PSHB was first discovered in Southern California in 2003 and has been recorded to have caused branch die-back and tree mortality for various tree specimens throughout the Southern California region (USDA, 2013). Since 2016, the PSHB is an identified pest within the Prado Basin that has the potential to negatively impact riparian habitat vegetation (USBR, 2016; Palenscar, K., personal communication, 2016; McPherson, D., personal communication, 2016).

Information on PSHB occurrence in the Prado Basin has been obtained during the USBR vegetation surveys of riparian habitat in the Prado Basin for the PBHSP during 2016, 2019, and 2022, and from the University of California, United States Department of Agriculture (USDA) and Natural Resources' online PSHB/FD Distribution Map[10], and the OCWD's PSHB trap deployment and monitoring. For the PBHSP, the occurrences of the PSHB in the Prado Basin are used to help understand and explain the trends observed in the extent and quality of the riparian vegetation.

2.2.3.3 Arundo Removal

Non-native Arundo is prominent throughout riparian habitat in the Prado Basin. Arundo consumes significantly more water than native plants, can out-compete native vegetation, and is flammable in nature, increasing the risk of wildfire. There are several SAR watershed stakeholders that remove Arundo in the riparian habitat to restore native habitat and aid in the recovery of the threatened and endangered species, such as the Least Bell's Vireo and Santa Ana Sucker. For the PBHSP, the occurrence and locations of habitat restoration activities that include the removal of Arundo can help understand and explain trends in the extent and quality of the riparian habitat. The OCWD and Santa Ana Watershed Association (SAWA), in coordination with others, are the main entities in the watershed that implement habitat restoration programs that include removing Arundo.

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[6] Frap.fire.ca.gov

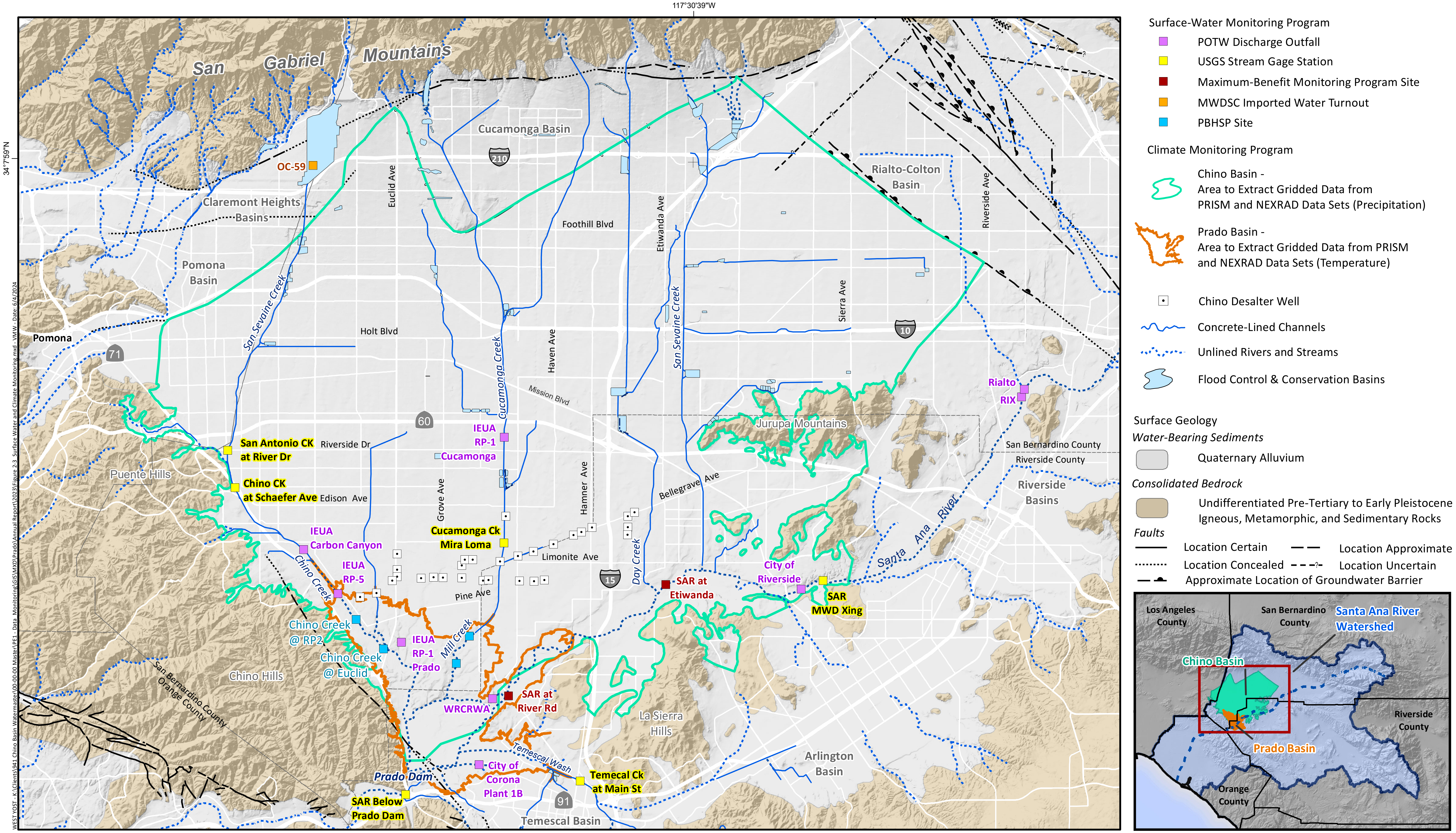
[7] Data for the previous year is available each year in April.

[8] UCANR.edu

[9] Cisr.Ucr.Edu

[10] Ucanr.edu

In WY 2023, information on Arundo removal and management activities that have occurred recently in the Prado Basin were obtained to track these programs and explore if there is a connection between these activities and trends observed in the extent and quality of riparian habitat. This effort involved coordinating with the OCWD and SAWA to obtain information on the location and timing of these programs.



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Surface Water and Climate
Monitoring Programs

Figure 2-3

2.3 Prospective Loss of Riparian Habitat

Monitoring and mitigation requirement 4.4-3 in the Peace II SEIR calls for annual reporting for the PBHSP, that will include recommendations for ongoing monitoring and any adaptive management actions required to mitigate any measured loss or **prospective loss** of riparian habitat that may be attributable to the Peace II Agreement (emphasis added). The meaning of “prospective loss” in this context is “future potential losses” of riparian habitat. Predictive modeling of groundwater levels can be used to answer question 8 from the AMP:

1. Are there areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement?

Watermaster’s most recent groundwater-modeling results can be used to evaluate forecasted groundwater-level changes within the Prado Basin under current and projected future conditions in the Basin, including, but not limited to, plans for pumping, storm-water recharge, and supplemental water recharge. To perform this evaluation, the predictive model results are mapped and analyzed to identify areas (if any) where groundwater levels are projected to decline to depths that may negatively impact riparian habitat in the Prado Basin.

For this Annual Report, Watermaster’s most recent groundwater model projections were used to characterize future groundwater-level conditions in the PBHSP study area. The most recent model projection was the simulation of planning scenario “2020 SYR1” for the 2020 recalculation of Safe Yield using the updated Chino Basin groundwater-flow model (WEI, 2020). See Section 3.7.

3.0 RESULTS AND INTERPRETATIONS

3.1 Trends in Riparian Habitat Extent and Quality

This section describes the analysis and interpretation of the monitoring data and groundwater-modeling results for the PBHSP. Analyzed data span various historical periods, based on data availability, and include both pre- and post-Peace II Agreement implementation (2007).

More specifically, this section describes the trends in the extent and quality of the riparian habitat, describes the trends in factors that can impact the riparian habitat, and evaluates potential cause-and-effect relationships—particularly any cause-and-effect relationships that may be associated with Peace II implementation. The factors that can potentially impact the extent and quality of the riparian habitat include changes in groundwater levels, surface-water discharge, climate, and other factors, such as pests, wildfires, and habitat management activities. Declining groundwater levels is the primary factor that is potentially related to Peace II implementation and could adversely impact the riparian habitat.

This section also includes a review of Watermaster's most recent predictive Chino Basin groundwater modeling results to identify areas of potential future declines in groundwater levels that could impact the riparian habitat.

3.1.1 Extent of the Riparian Habitat

Previous annual reports include an analysis of the riparian vegetation using historical air photos to map the density and extent of the vegetation in the Prado Basin (WEI, 2017; 2018; 2019; 2020). In general, these analyses concluded that from 1960 to 1999 the mapped extent of the riparian habitat increased from about 1.8 to 6.7 square miles (mi^2) and its vegetated density increased. The 1999 mapped extent is considered the maximum extent of the riparian habitat in the Prado Basin, and since has remained relatively constant in the Prado Basin along the Chino Creek, Mill Creek, and SAR reaches in the Prado Basin[11]. The maximum extent of the riparian vegetation in Prado Basin is shown on Figure 3-1a which compares the air photos that were acquired for the PBHSP in June 2022 and July 2023. Both air photos are high resolution (3-inch pixels) which allow for a side-by-side visual comparison of riparian vegetation extent and quality in 2022 and 2023. There are no significant differences in these air photos that show a change to the extent of the riparian habitat in the Prado Basin along the Chino Creek, Mill Creek, and SAR reaches in the Prado Basin. The maximum extent of the riparian habitat in the Prado Basin will be used to evaluate the NDVI data spatially and temporally to characterize changes in the quality of entire riparian habitat extent over the last year and over the 1984 to 2023 period (Sections 3.1.2.1 and 3.1.2.2).

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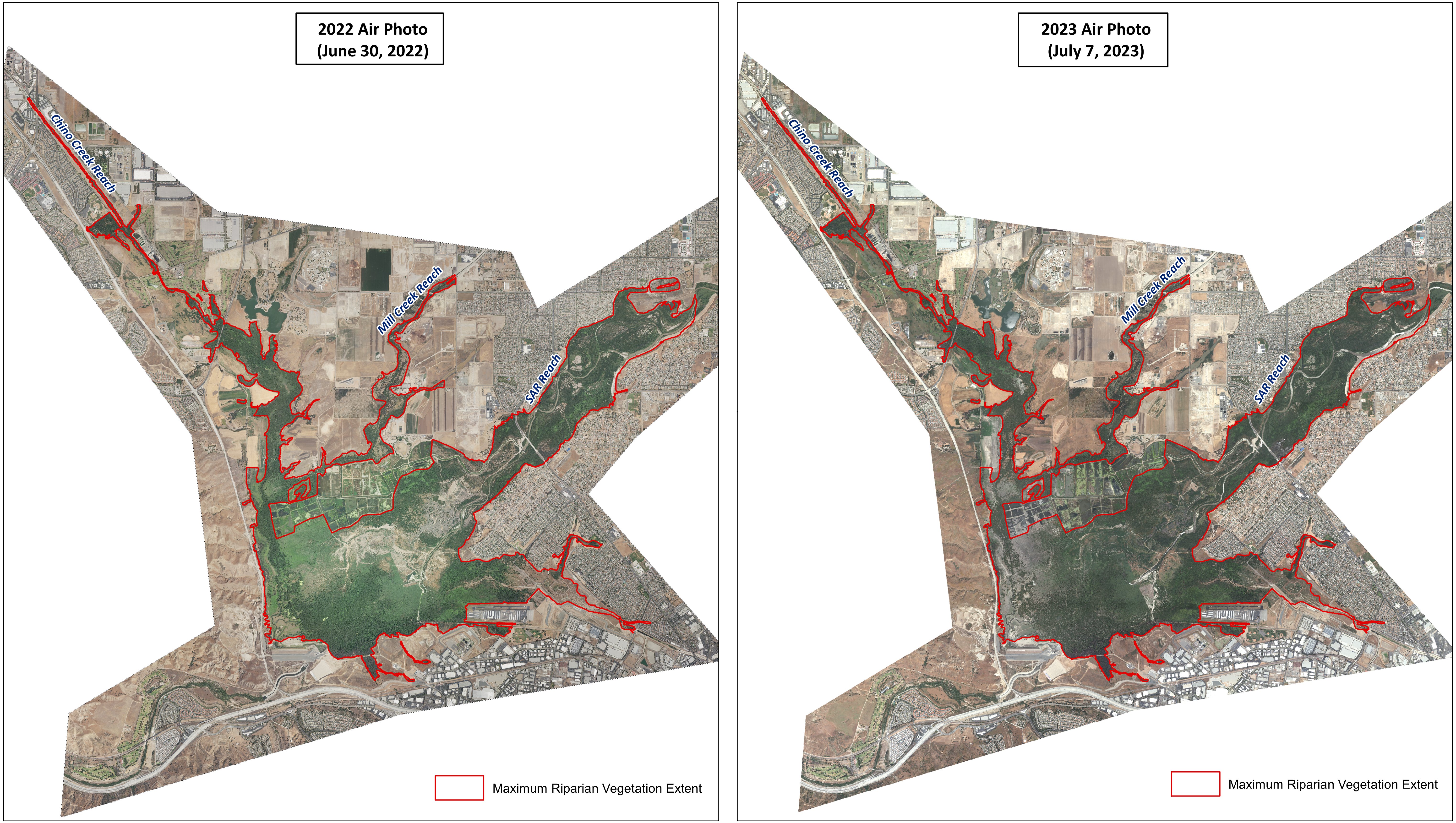
[11] Since 1999 there has been a decrease to the extent and density of the riparian vegetation along the Temescal Wash in the southeastern portion of Prado Basin. This area is outside the Chino Basin hydrologic boundary and is not an area of influence of potential impacts of Peace II implementation on groundwater levels.



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Air Photos and Extent of the Riparian Vegetation
2022 and 2023

Figure 3-1a

Figure 3-1b compares the 2023 air photo and the mapped extent of the riparian habitat to the NDVI estimates for the Prado Basin area on a date that corresponds to the maximum of the spatial average of NDVI during the growing season for 2023.[12] Generally, the following ranges in NDVI during the growing season correspond to these land cover types:

- < 0: Water
- 0 - 0.2: Non-vegetated surfaces, such as urbanized land cover and barren land
- 0.3 - 1.0: Vegetated land cover: higher NDVI values indicate greater photosynthetic activity

Three main observations and interpretations are derived from this figure:

- Prado Basin riparian vegetation areas have NDVI estimates of about 0.3 to 0.9 during the growing season. Active agricultural lands in the Prado Basin region can also have NDVI values of a similar range during the growing season.
- The NDVI estimates support the delineation of the extent of the riparian habitat as drawn from the air photos.
- The consistency of NDVI values to land cover observed in the air photo indicates that the processing of NDVI estimates for this study were performed accurately, which supports subsequent analyses and interpretations.

3.1.2 Quality of the Riparian Habitat

As discussed, and referenced in Section 2.0, NDVI is an indicator of the photosynthetic activity of vegetation and therefore can be used to interpret the health or "quality" of the riparian vegetation. In this section, NDVI is spatially and temporally analyzed in maps and time-series charts for defined areas throughout Prado Basin to characterize changes in the quality of riparian habitat over the period 1984 to 2023.

3.1.2.1 Spatial Analysis of NDVI

Figure 3-2 compares maps of NDVI across the entire Prado Basin area for 2022 and 2023 on the dates that correspond to the maximum growing-season NDVI for the year as a spatial average across the entire extent of the riparian vegetation. Figure 3-3 is a map of change in NDVI from 2022 to 2023 that was prepared by subtracting the 2022 NDVI map from the 2023 NDVI map on Figure 3-2. These figures identify areas that may have experienced a change in the quality of riparian habitat from 2022 to 2023:

- About half of the riparian vegetation extent area showed no change in NDVI from 2022 to 2023.
- NDVI decreased and increased in scattered small and large patches in the riparian vegetation throughout the Prado Basin.
- The notable patches of increase in NDVI are scattered along the SAR and below the OCWD wetlands.
- The notable patches of decrease in NDVI are located in the lower portion of Chino Creek northwest of OCWD wetlands, just behind Prado Dam, and in the lower area of Prado Basin near the SAR.

These spatial changes in NDVI will be analyzed along with the factors that can impact riparian habitat in Sections 3.2 through 3.6 of this report.

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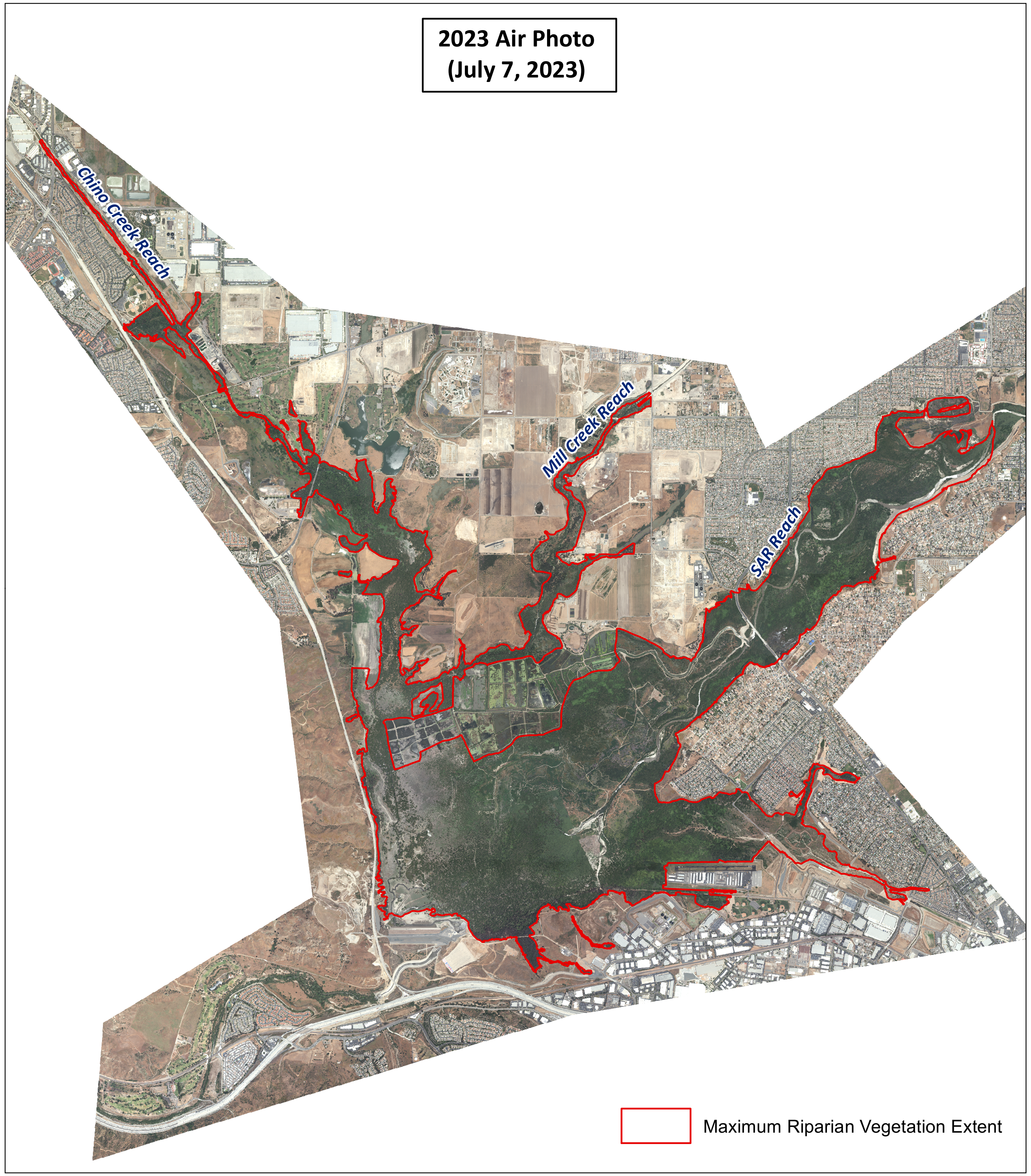
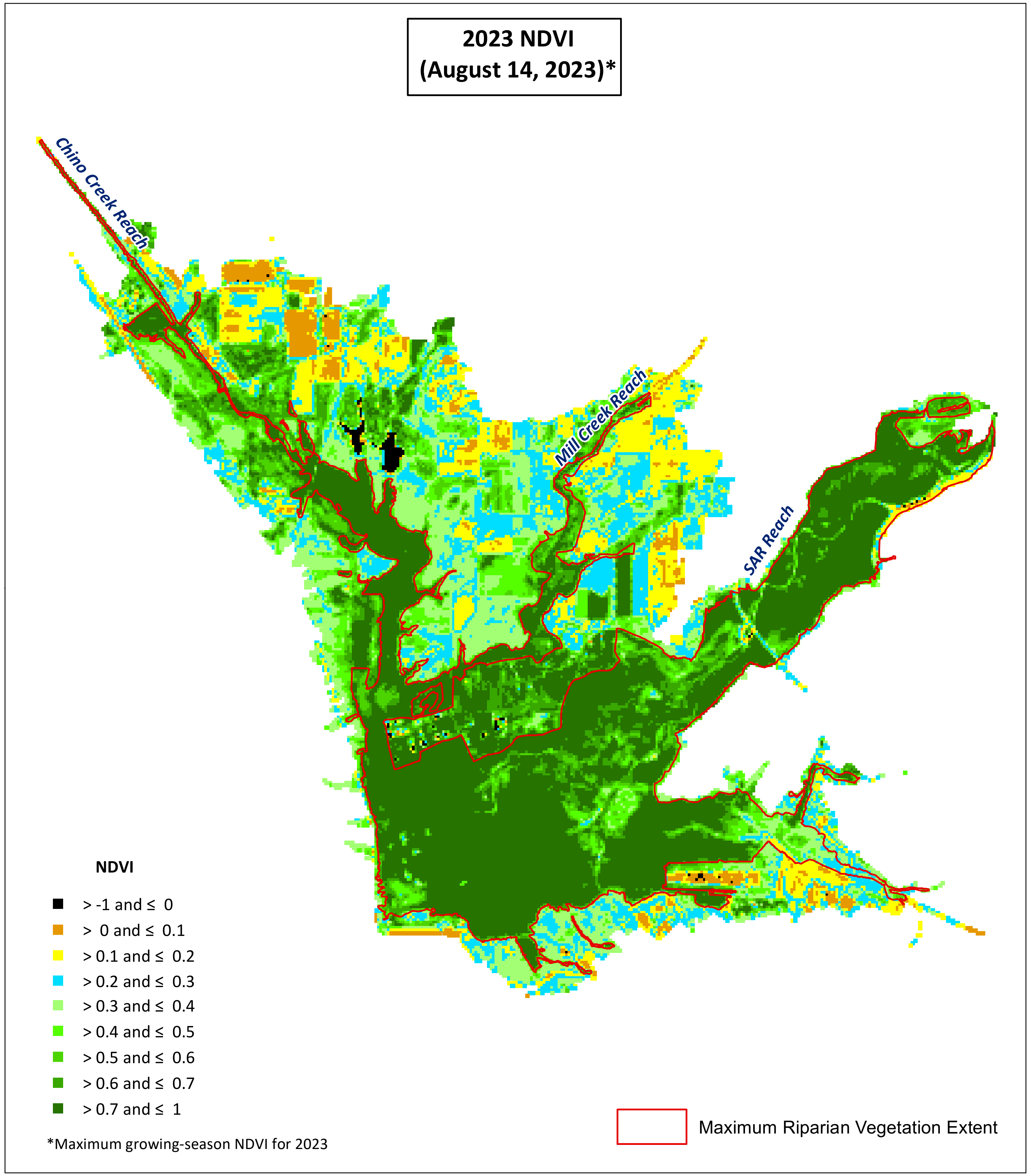
[12] The growing season for the Prado Basin riparian vegetation is from March through October (Merkel, 2007; USBR, 2008). The maximum NDVI for the 2023 growing season occurred on August 14, 2023.





*Maximum growing-season NDVI for 2023

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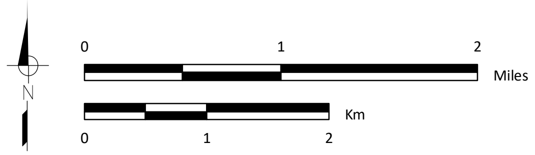

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Air Photo and Spatial NDVI for the Prado Basin
2023

Figure 3-1b

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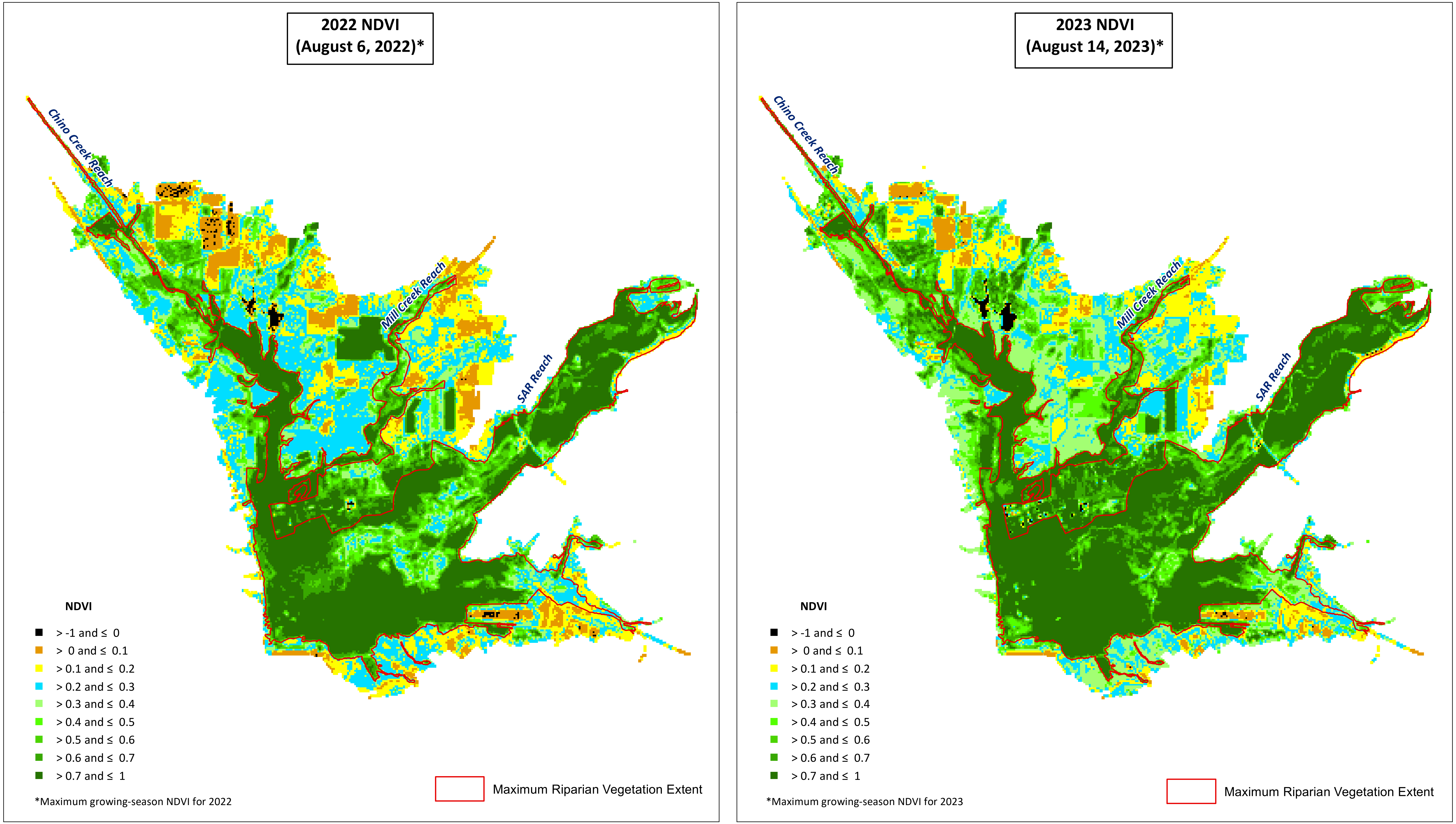

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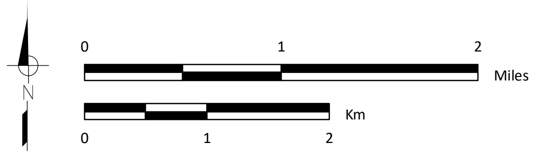

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Spatial NDVI for the Prado Basin
2022 and 2023

Figure 3-2

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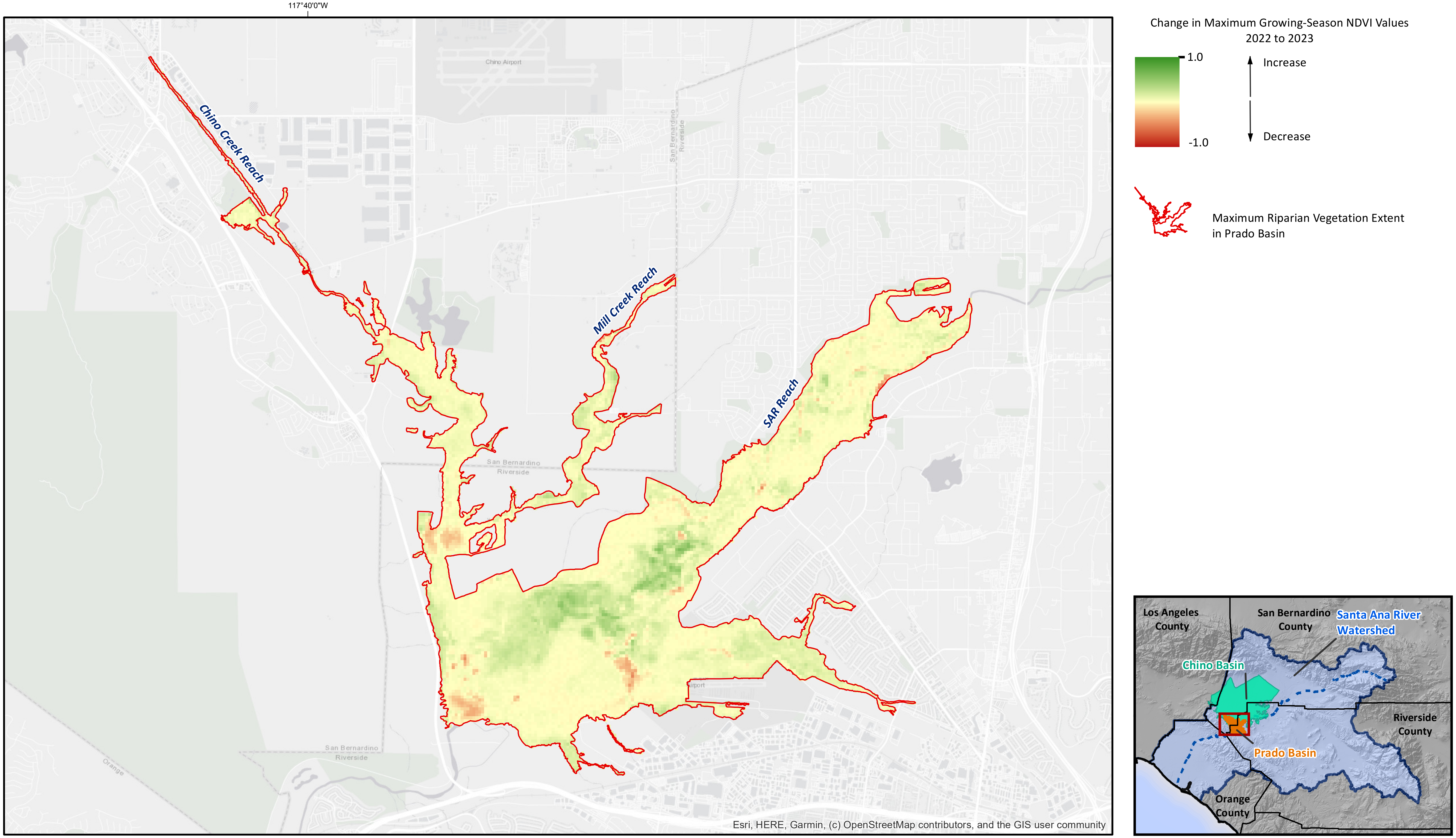

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Spatial Change in NDVI for the Prado Basin
2022 and 2023

Figure 3-3

3.1.2.2 Temporal Analysis of NDVI

NDVI pixels[13] within defined areas throughout the Prado Basin were spatially averaged and temporally analyzed in time-series charts. The defined areas include four large and 14 small areas within Prado Basin and are shown in Figure 3-4. The large areas include the extent of the riparian habitat in the entire Prado Basin (6.8 mi^2 - 19,520 NDVI pixels), the upper portion of Chino Creek (0.74 mi^2 - 2,134 NDVI pixels), the entire Mill Creek reach (0.26 mi^2 - 759 NDVI pixels), and the upper portion of Mill Creek (0.03 mi^2 – 92 NDVI pixels). The small areas are located along the northern reaches of the Prado Basin riparian habitat near the PBHSP monitoring wells and a location of a USBR vegetation survey site (10-meter radius plot). All the small areas are one NDVI pixel (30 x 30-meter pixel – 900 square meters).[14]

Figures 3-5, 3-6, 3-7a, 3-7b, and 3-8a through 3-8n are time-series charts of the NDVI for each of the defined areas that indicate changes in the quality of riparian habitat over time. These figures are used to characterize long- and short-term changes in NDVI in specific areas, which provide context for interpreting the trends and changes in NDVI that have been occurring during Peace II implementation. Each figure shows two datasets that illustrate trends in the NDVI estimates:

Spatial Average NDVI (green dots). Spatial Average NDVI are the spatial average of the NDVI pixels within the defined area. These data characterize the seasonal and long-term trends in NDVI for each defined area. The NDVI exhibits an oscillatory pattern caused by seasonal changes in the riparian habitat. The NDVI time-series are typical for a deciduous forest, where NDVI values are higher in the growing season from March through October and lower in the dormant season from November through February when plants and trees shed their leaves.

Average Growing-Season NDVI (black dots and black curve). The Average Growing-Season NDVI is the annual average of the Spatial Average NDVI for each growing season from March through October. This curve shows the annual changes and long-term trends in the NDVI for the growing season. This metric is used to analyze year-to-year changes and long-term trends in NDVI.

NDVI maps or air photos are included on the time-series charts for spatial reference and as a visual check on the interpretations derived from the time-series charts. The air photos are for 2020, 2021, 2022, and 2023, showing the last four years using the high-resolution air photos collected for the PBHSP.

To statistically characterize long-term trends in NDVI, the Mann-Kendall statistical trend test (Mann-Kendall test) was performed on the Average Growing-Season NDVI for all defined areas over the following three periods:

- 1984 to 2023: the entire period of record
- 1984 to 2006: period prior to Peace II Agreement implementation
- 2007 to 2023: period subsequent to Peace II Agreement implementation

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[13] Each NDVI pixel is 30 x 30 meters.

[14] In previous annual reports, these small areas were four NDVI pixels in this same general area. During WY 2020, these areas were modified to one NDVI pixel that aligned with the USBR vegetation survey so that the field vegetation survey data can better correlate with the NDVI time-series data.

The Mann-Kendall test utilizes a ranking formula to statistically analyze if there is an increasing trend, decreasing trend, or no trend in the NDVI time-series. Appendix B describes the Mann-Kendall test methods and results. The final Mann-Kendall test results for the Average Growing-Season NDVI are shown on each time-series chart and are summarized in Table 3-1.

Table 3-1. Mann-Kendall Test Results of the Average-Growing Season NDVI Trends for Defined Areas in the Prado Basin

		Mann Kendal Test Result[a]		
Defined Area	Figure Number	Period of Record 1984-2023	Prior to Peace II 1984-2006	Post Peace II 2007-2023
Riparian Vegetation Extent	3-5	No Trend	No Trend	No Trend
Chino Creek	3-6	Increasing	Increasing	Increasing
Mill Creek	3-7a	No Trend	Decreasing	Increasing
Upper Mill Creek	3-7b	Increasing	No Trend	Increasing
CC-1	3-8a	Increasing	Increasing	Increasing
CC-2	3-8b	Increasing	Increasing	Increasing
CC-3	3-8c	Increasing	Increasing	Increasing
CC-4	3-8d	Increasing	No Trend	Increasing
MC-1	3-8e	Increasing	Increasing	Increasing
MC-2	3-8f	No Trend	No Trend	Increasing
MC-3	3-8g	Increasing	No Trend	Increasing
MC-4	3-8h	No Trend	No Trend	No Trend
MC-5	3-8i	No Trend	No Trend	Increasing
MC-6	3-8j	Increasing	No Trend	Increasing
SAR-1	3-8k	No Trend	No Trend	Increasing
SAR-2	3-8l	Increasing	Decreasing	Increasing
SAR-3	3-8m	Increasing	No Trend	Increasing
LP	3-8n	No Trend	Increasing	No Trend

(a) See Appendix B for a description of the Mann-Kendall statistical trend test and results.

To characterize the short-term trends in NDVI, Table 3-2 summarizes the one-year change in the Average Growing-Season NDVI from 2022 to 2023 at the 18 defined areas and compares to the changes and variability in Average Growing-Season NDVI over the historical period of 1984 to 2022 at each area. During WY 2023, there were slight increasing trends in the NDVI from 2022 to 2023 at most of the areas: 15 areas increased; one area showed no trend; and two areas decreased. These one-year changes in the Average Growing-Season NDVI are all minor and within the range of long-term annual variability of the NDVI at each area.

Table 3-2. Characterization of Variability in the Average-Growing Season NDVI for Defined Areas in the Prado Basin

Defined Area	Figure Number	Historical NDVI Statistics 1984-2022		One-Year Change in NDVI from 2022-2023
		Average One-Year Change in NDVI (Absolute Value)	Maximum One-Year Change in NDVI (Absolute Value)	
Riparian Vegetation Extent	3-5	0.03	0.08	0.04
Chino Creek	3-6	0.02	0.09	0.02
Mill Creek	3-7a	0.04	0.11	0.07
Upper Mill Creek	3-7b	0.03	0.12	0.04
CC-1	3-8a	0.03	0.08	0.02
CC-2	3-8b	0.03	0.11	0.02
CC-3	3-8c	0.03	0.12	0.00
CC-4	3-8d	0.03	0.09	-0.01
MC-1	3-8e	0.04	0.12	0.03
MC-2	3-8f	0.06	0.18	0.08
MC-3	3-8g	0.03	0.13	0.02
MC-4	3-8h	0.03	0.12	0.02
MC-5	3-8i	0.04	0.12	0.08
MC-6	3-8j	0.06	0.22	0.04
SAR-1	3-8k	0.06	0.48	0.03
SAR-2	3-8l	0.04	0.13	0.03
SAR-3	3-8m	0.02	0.10	0.01
LP	3-8n	0.06	0.21	-0.03

3.1.2.3 Temporal Analysis of NDVI in Prado Basin

Figure 3-5 is a time-series chart from 1984 to 2023 of the spatial average of all 19,520 NDVI pixels that are within the maximum delineated extent of the riparian habitat in the Prado Basin.[15] The intent of the time series is to characterize the trends in NDVI for the Prado Basin as a whole, which is used as a basis of comparison to the trends in the NDVI for each of the smaller defined areas shown in subsequent figures. Instead of air photos like the time-series chart in Figures 3-6 through 3-7 and Figures 3-8a through 3-8n, Figure 3-5 includes NDVI maps from 2020, 2021, 2022, and 2023, to visually compare to the NDVI time-series.

Figure 3-5 and Tables 3-1 and 3-2 show that the Average Growing-Season NDVI varies from year-to-year by no more than 0.08 with no apparent long-term trends. The Mann-Kendall test result on the Average Growing-Season NDVI indicates “no trend” over the 1984 to 2023 period, “no trend” over the 1984 to 2006 period, and “no trend” over the 2007 to 2023 period.

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[15] The maximum extent of the riparian habitat in the Prado Basin is based on 1999 conditions and has been relatively stable since in the Chino Creek, Mill Creek, and SAR reaches, and has been verified by inspection of the 2017 to 2023 high-resolution air photos.

From 2022 to 2023, the Average Growing-Season NDVI increased by 0.04. This recent one-year increase in Average Growing-Season NDVI is within the historical range of the annual Average Growing-Season NDVI variability for the extent of the riparian vegetation and is slightly greater than the average one-year change in NDVI observed over the historical period.

This time-series analysis of NDVI suggests that the riparian habitat in Prado Basin, analyzed as a whole, has not experienced statistically significant declines in NDVI in the recent water year, nor during the post-Peace II Agreement period from 2007 to 2023.

3.1.2.4 Temporal Analysis of NDVI within Large Areas along Chino Creek and Mill Creek

Figure 3-6, Figure 3-7a, and Figure 3-7b are time-series charts from 1984 to 2023 of the spatial average for NDVI pixels within large areas of riparian habitat located along the reaches of Chino Creek, Mill Creek, and Upper Mill Creek, respectively. These charts characterize trends and changes in NDVI for these northern reaches of the riparian habitat in the Prado Basin and provide a basis for comparison to the NDVI trends and changes for each of the smaller defined areas.

Chino Creek

Figure 3-6 is an NDVI time-series chart for 1984 to 2023 of the spatial average of all 2,134 NDVI pixels along the northern reach of Chino Creek in the Prado Basin. This reach of Chino Creek is susceptible to impacts from declining groundwater levels associated with Peace II implementation.

Figure 3-6 and Tables 3-1 and 3-2 show that over the period of record, the Average Growing-Season NDVI varied from year-to-year by no more than 0.09 with a long-term increasing trend. The Mann-Kendall test result on the Average Growing-Season NDVI indicates an “increasing trend” over the 1984 to 2023 period, an “increasing trend” over the 1984 to 2006 period, and an “increasing trend” over the 2007 to 2023 period.

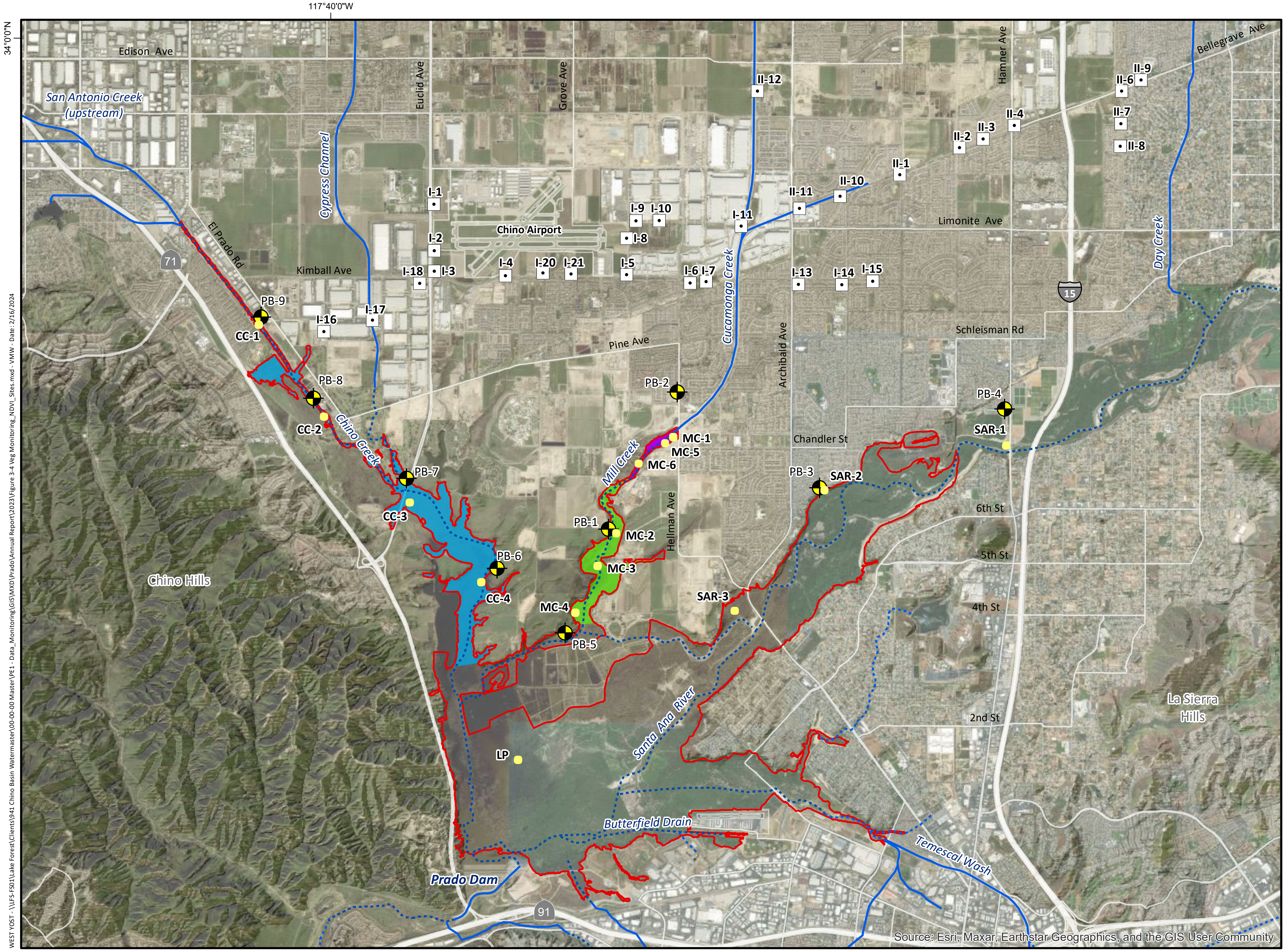
From 2022 to 2023, the Average Growing-Season NDVI increased by 0.02, which is within the historical range of variability for the annual Average Growing-Season NDVI.

Mill Creek

Figure 3-7a and Figure 3-7b are NDVI time-series charts for 1984-2023 of the spatial average for two reaches of Mill Creek: the entire reach of Mill Creek in the Prado Basin (759 NDVI pixels) and the upper portion of Mill Creek (92 NDVI pixels). This Upper Mill Creek area is susceptible to impacts from declining groundwater levels associated with Peace II implementation and was added for the analysis of NDVI time-series charts area in the Prado Basin for the 2022 Annual Report.

Figure 3-7a and Tables 3-1 and 3-2 show that over the period of record, the Average Growing-Season NDVI varied from year-to-year by no more than 0.11 for the entire Mill Creek extent. The Mann-Kendall test result on the Average Growing-Season NDVI indicates “no trend” over the 1984 to 2023 period, “decreasing trend” over the 1984 to 2006 period, and “increasing” over the 2007 to 2023 period. From 2022 to 2023, the Average Growing-Season NDVI increased by 0.07 which is within the historical range of the annual Average Growing-Season NDVI variability for the entire Mill Creek but is higher than the average one-year change in NDVI observed over the historical period. Review of the 2022 and 2023 air photos of Mill Creek area show an increase in vegetation in the middle and lower reach of the creek from 2022 to 2023.

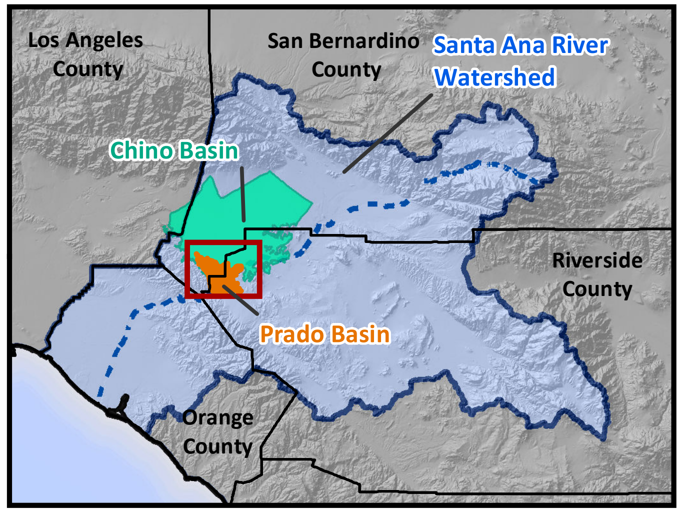
Figure 3-7b and Tables 3-1 and 3-2 show that over the period of record, the Average Growing-Season NDVI varied from year-to-year by no more than 0.12 for the upper Mill Creek reach, similar to the entire reach. The Mann-Kendall test result on the Average Growing-Season NDVI indicates an "increasing trend" over the 1984 to 2023 period, "no trend" over the 1984 to 2006 period, and an "increasing trend" over the 2007 to 2023 period. From 2022 to 2023, the Average Growing-Season NDVI increased by 0.04 which is within the historical range of the annual Average Growing-Season NDVI variability for the Upper Mill Creek area and, similar to the entire Mill Creek extent, is slightly greater than the average one-year change in NDVI observed over the historical period. Comparison of the 2022 and 2023 air photos show an increase in vegetation in the upper portion of the area from 2022 to 2023.

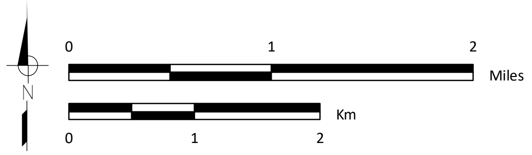


WEST YOST - \\LFS-FS01\Lake Forest\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\2023\Figure 3-4 Veg Monitoring_NDVI_Sites.mxd - VMW - Date: 2/16/2024

Defined Area Analyzed for NDVI Temporally in Time-Series Chart

- 6.8 square-mile area (19,520 pixels) Riparian Vegetation Extent (Figure 3-5)
- 0.74 square-mile area (2,134 NDVI pixels) in Chino Creek (Figure 3-6)
- 0.26 square-mile area (759 NDVI pixels) in Mill Creek, inclusive of 0.03 square-mile area (92 NDVI pixels) Upper Mill Creek area in purple (Figures 3-7a and 3-7b)
- 🟨 30 x 30-meter area (one NDVI pixel) (Figures 3-8a through 3-8n)
- ⊕ PBHSP Monitoring Well Site
- ⊡ Chino Desalter Well
- Concrete-Lined Channels
- Unlined Rivers and Streams





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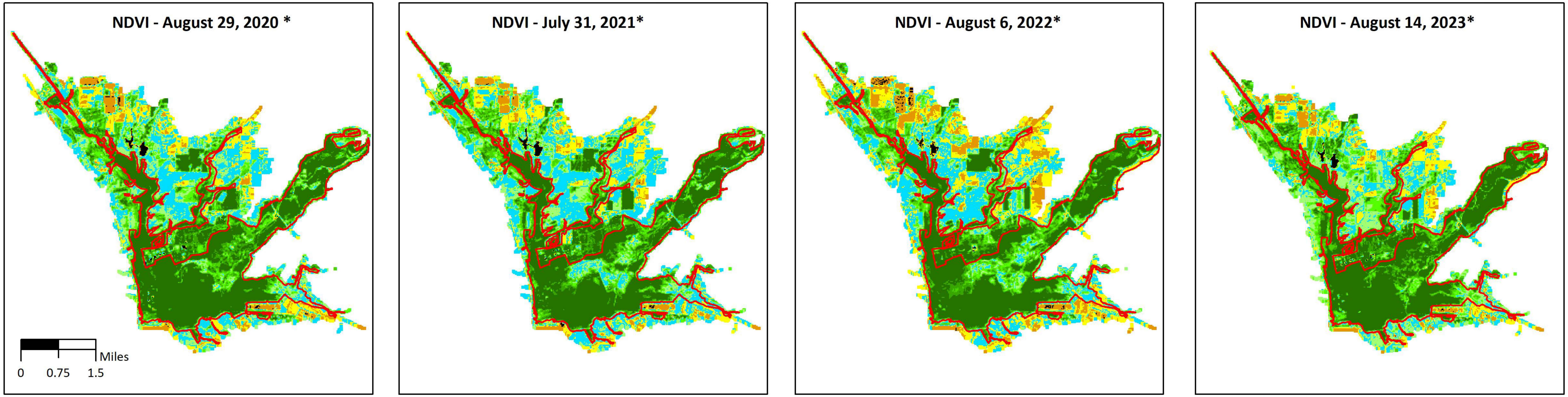
Chino Basin Watermaster and Inland Empire Utilities Agency
2023 Annual Report of the
Prado Basin Habitat Sustainability Committee

Areas for Analysis of NDVI Time Series

Figure 3-4

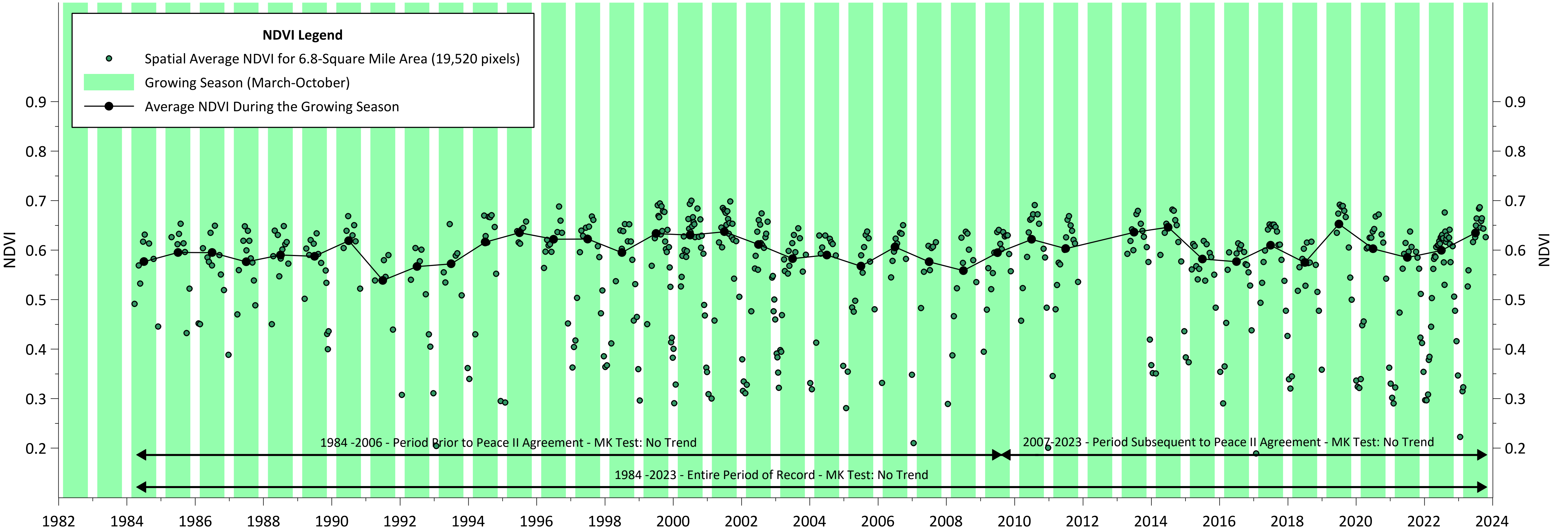


* Maximum Growing-Season NDVI

Map Legend:

NDVI

- ⬛ > -1 and ≤ 0
- 🟧 > 0 and ≤ 0.1
- 🟨 > 0.1 and ≤ 0.2
- 🟦 > 0.2 and ≤ 0.3
- 🟩 > 0.3 and ≤ 0.4
- 🟩 > 0.4 and ≤ 0.5
- 🟩 > 0.5 and ≤ 0.6
- 🟩 > 0.6 and ≤ 0.7
- 🟩 > 0.7 and ≤ 1
- 🟥 Maximum Riparian Vegetation Extent



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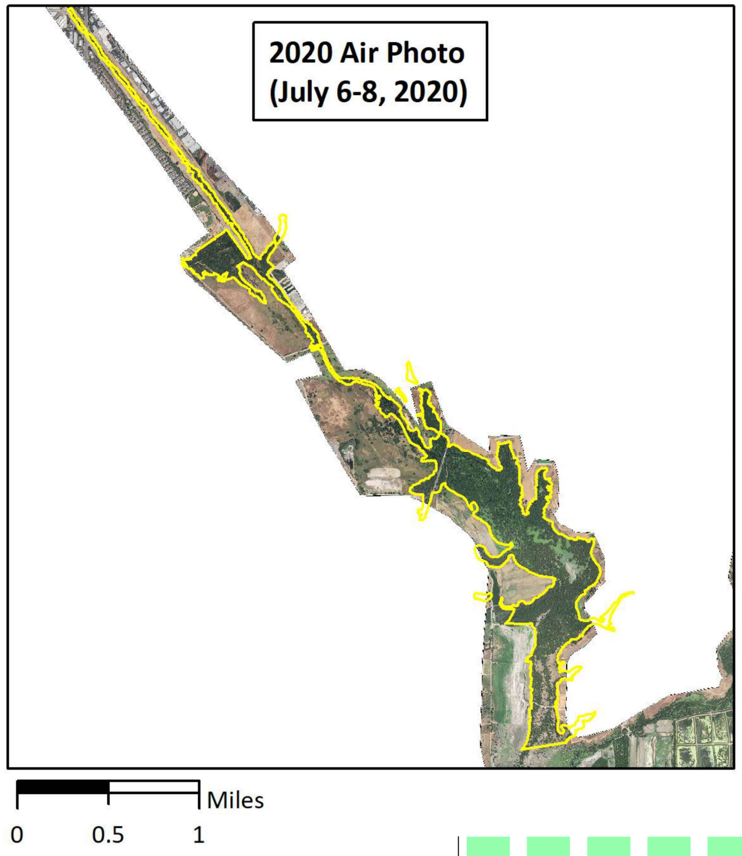
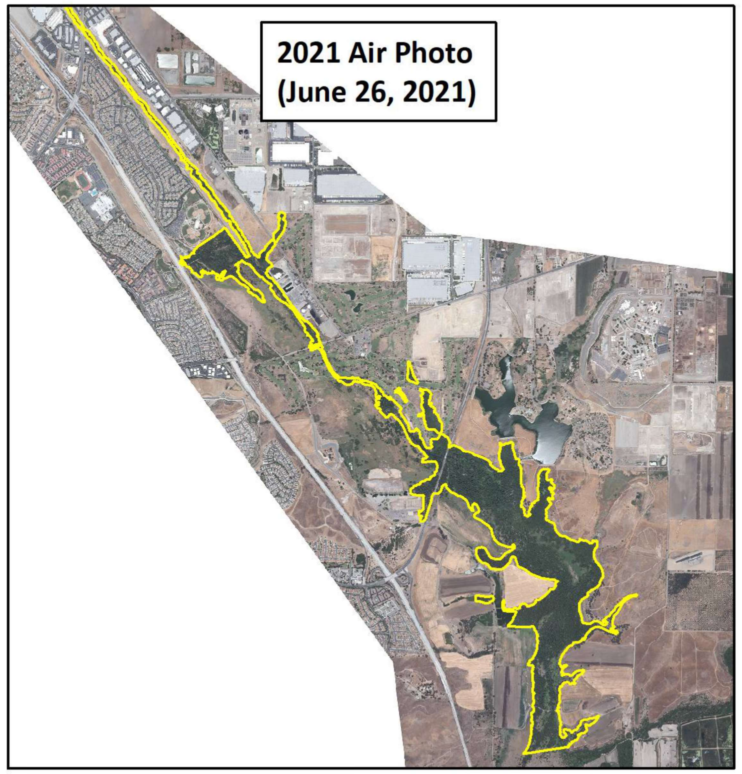
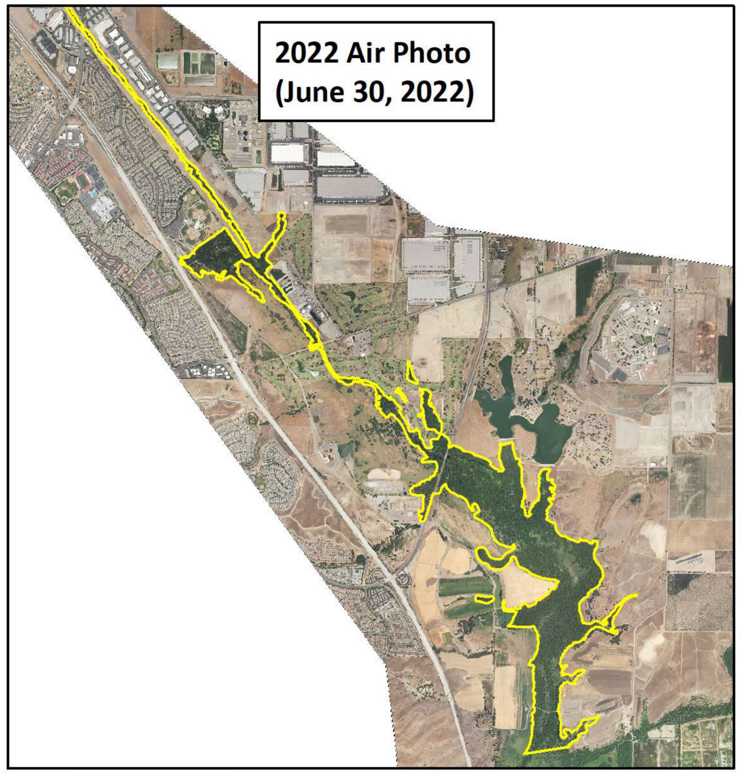
2023 Annual Report

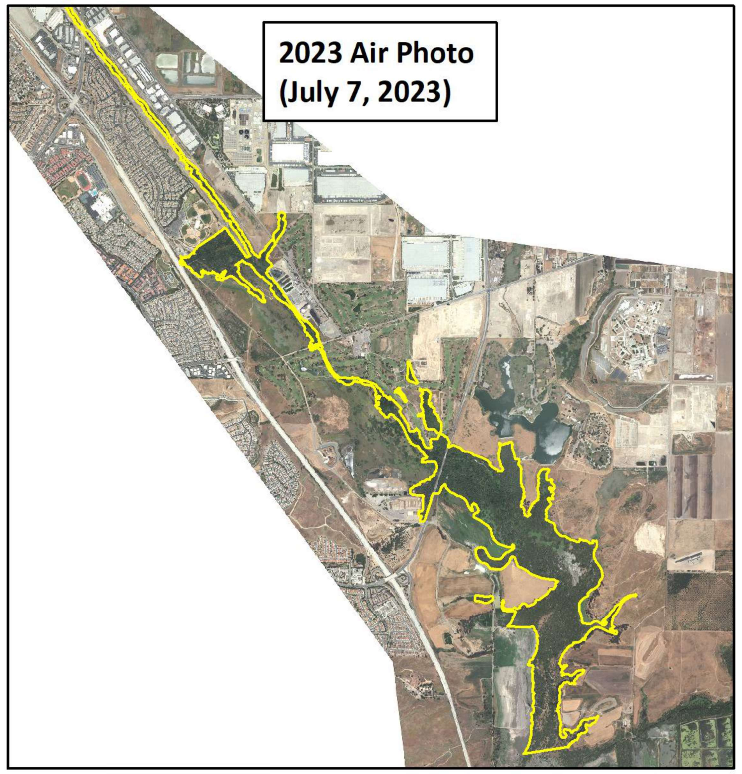
Time Series of NDVI for the Riparian Vegetation Extent - *1984 to 2023*

Figure 3-5



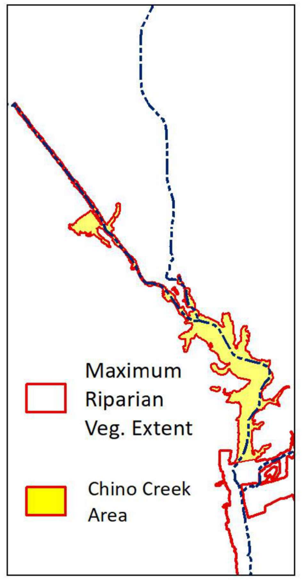


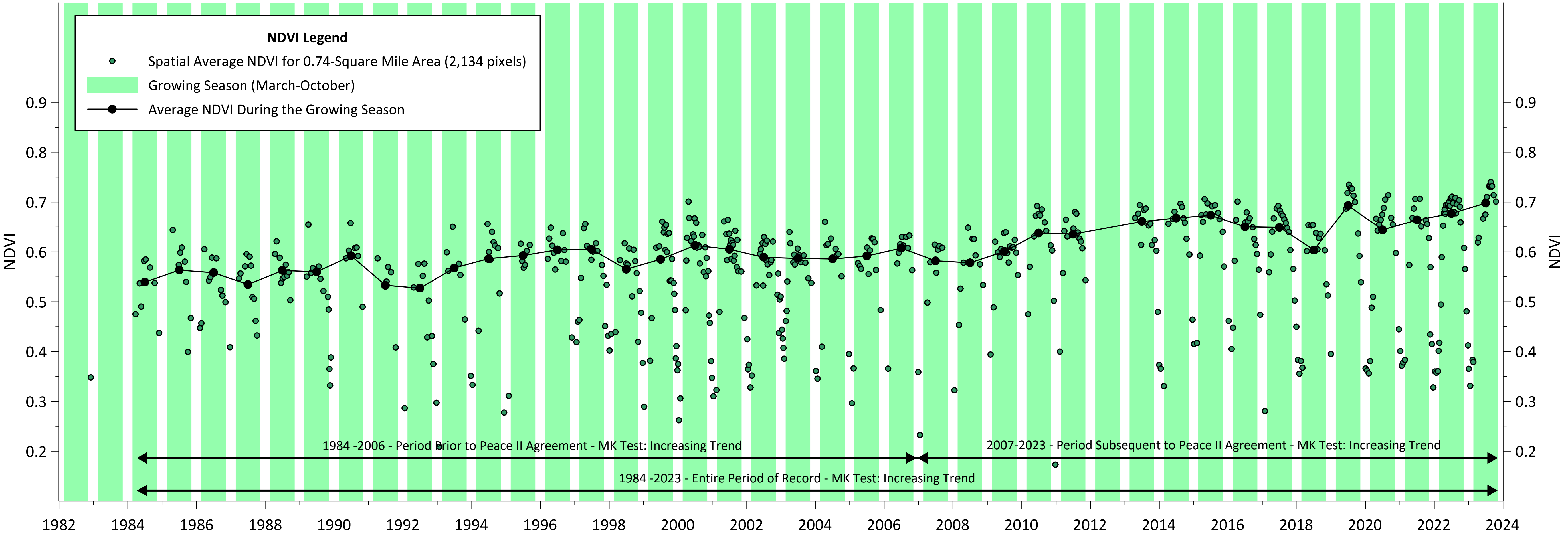




0.74 Square Mile Area (2,134 30 x 30-meter pixels)

Location of Chino Creek Area





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2023 Annual Report

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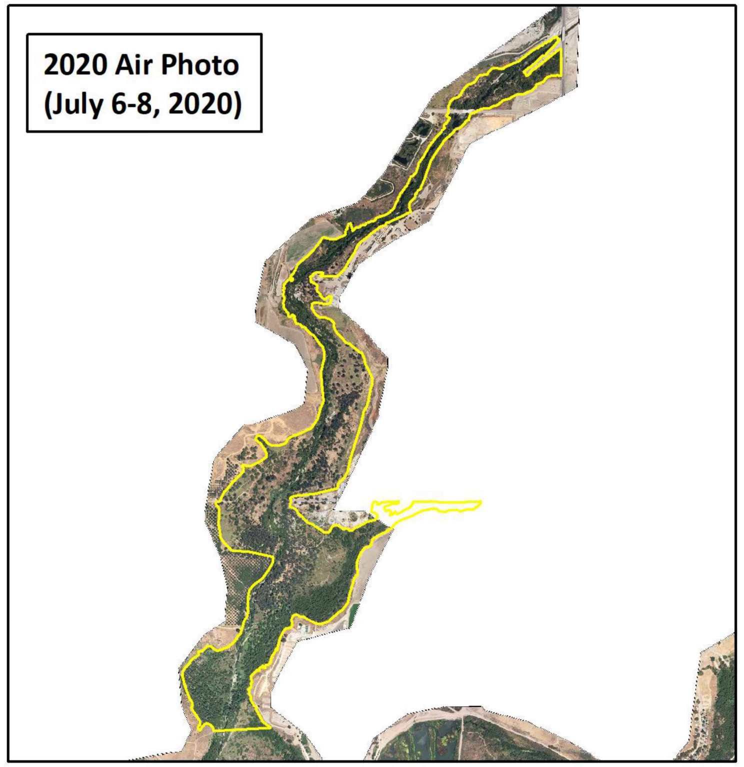
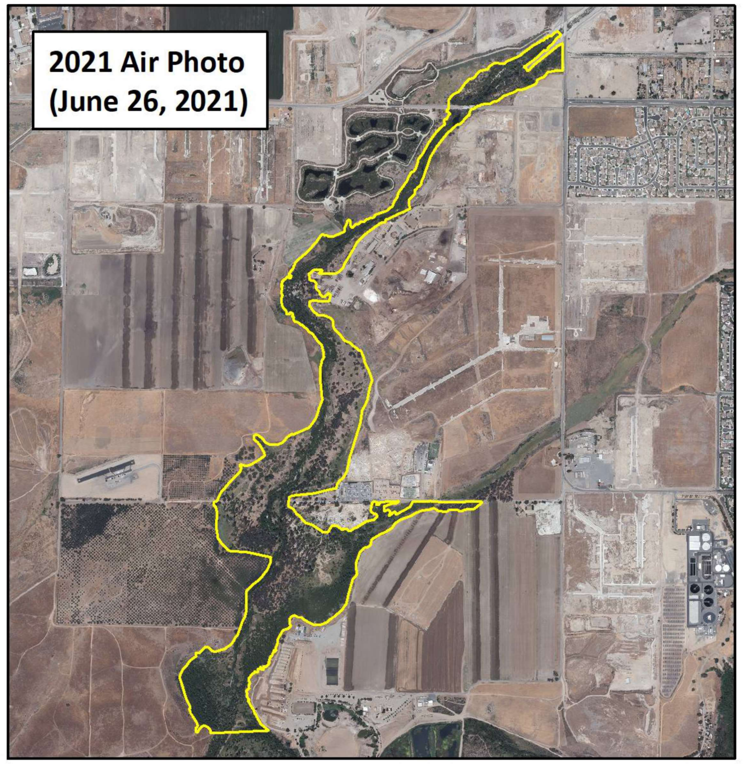
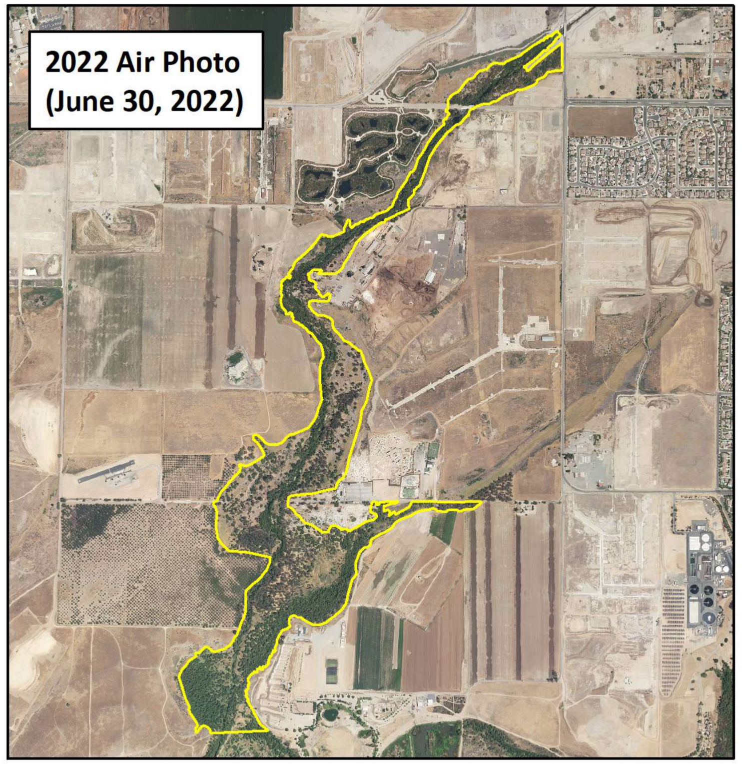
Partners in Basin Management

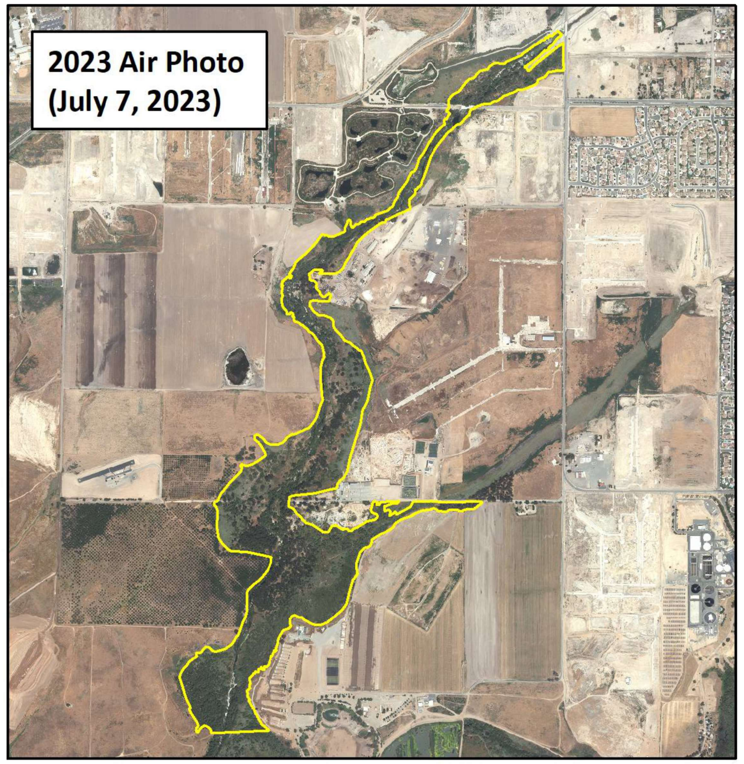
Time Series of NDVI and Air Photos
Along Chino Creek Area for 1984 to 2023

Figure 3-6





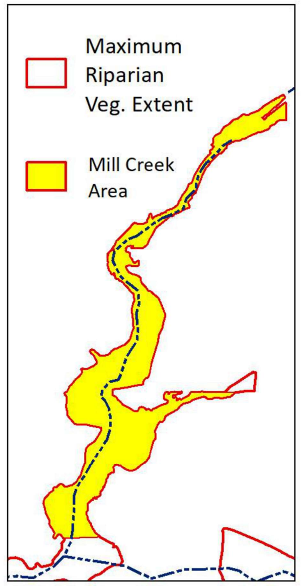


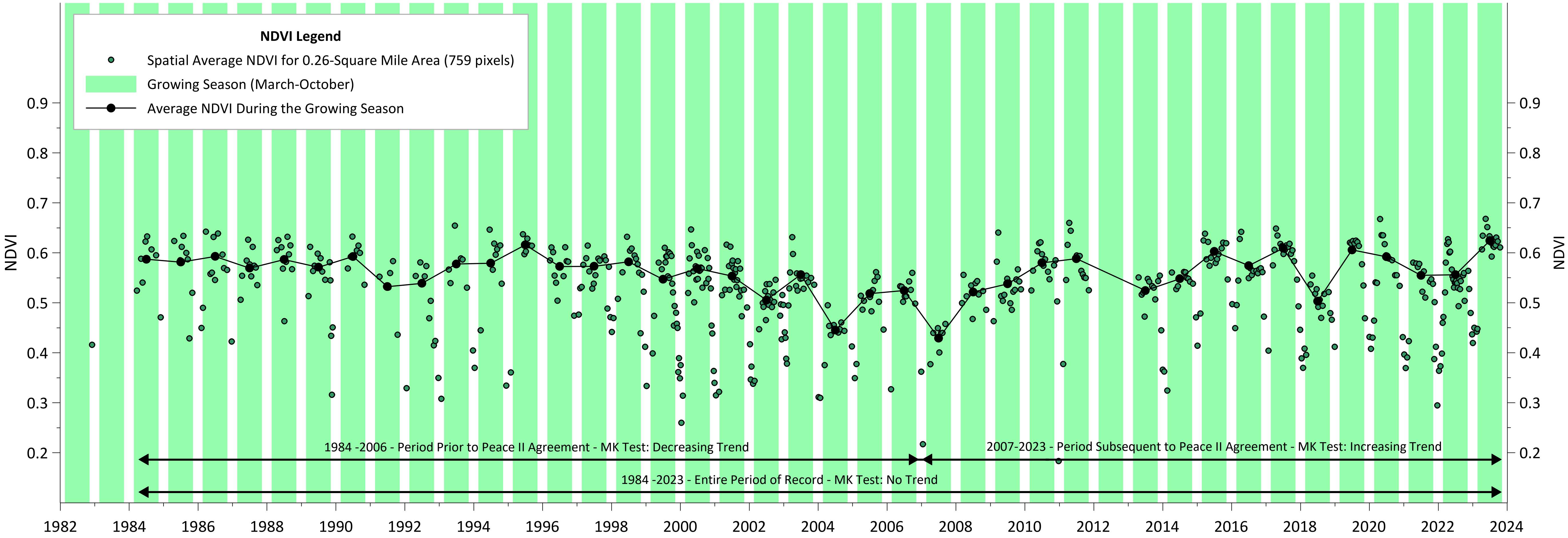


0 0.5 1 Miles

🟨 0.26 Square Mile Area (759 30 x 30-meter pixels)

Location of Mill Creek Area





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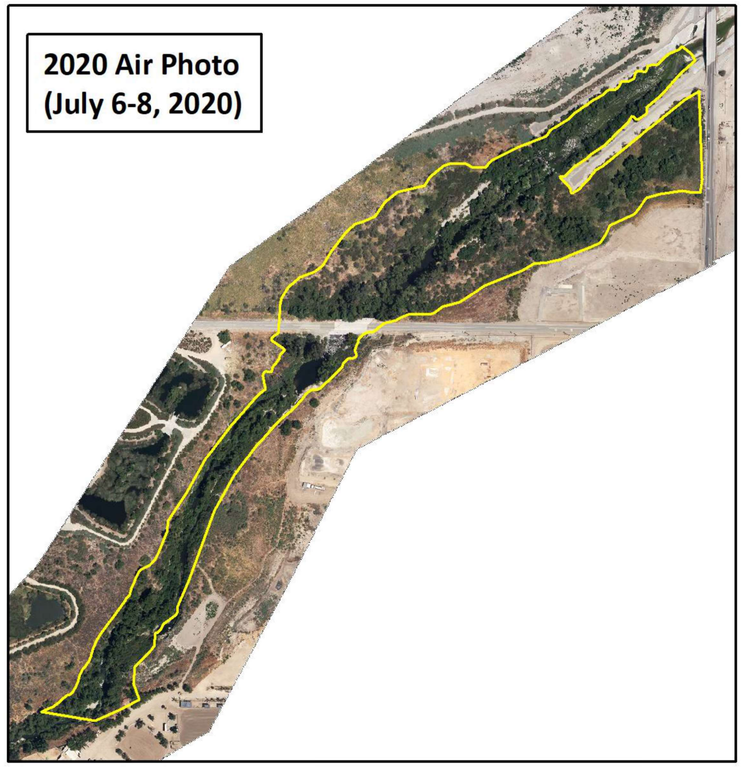
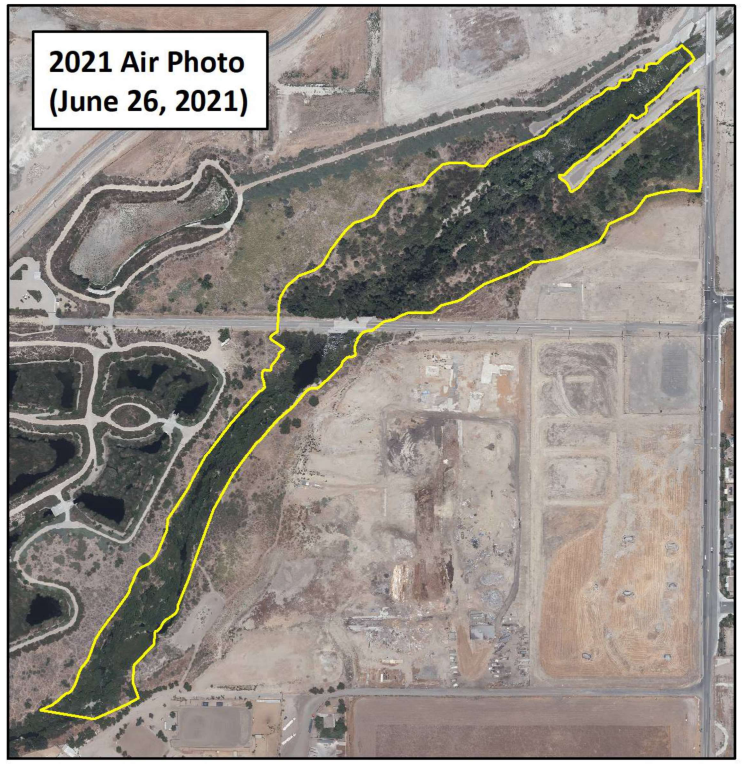
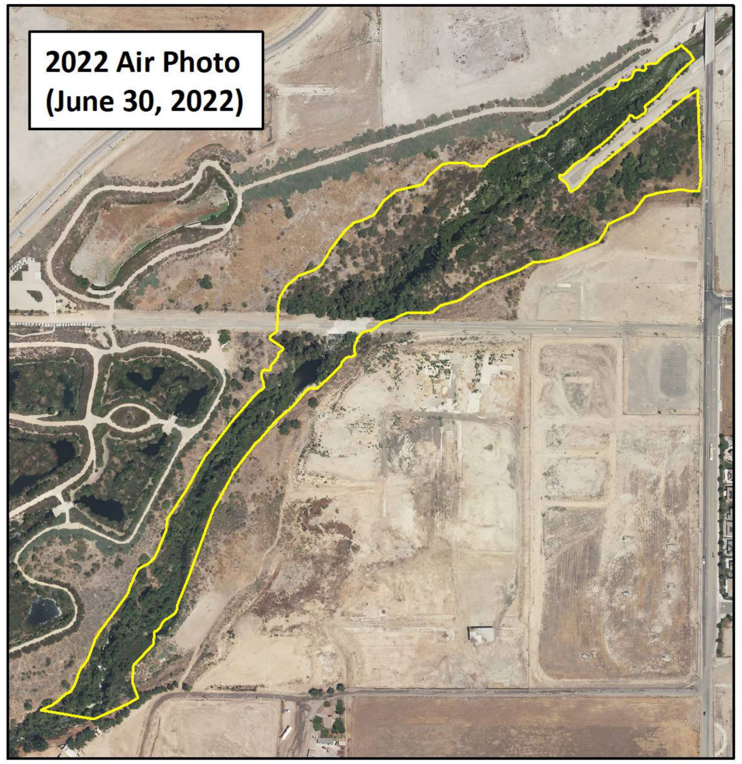
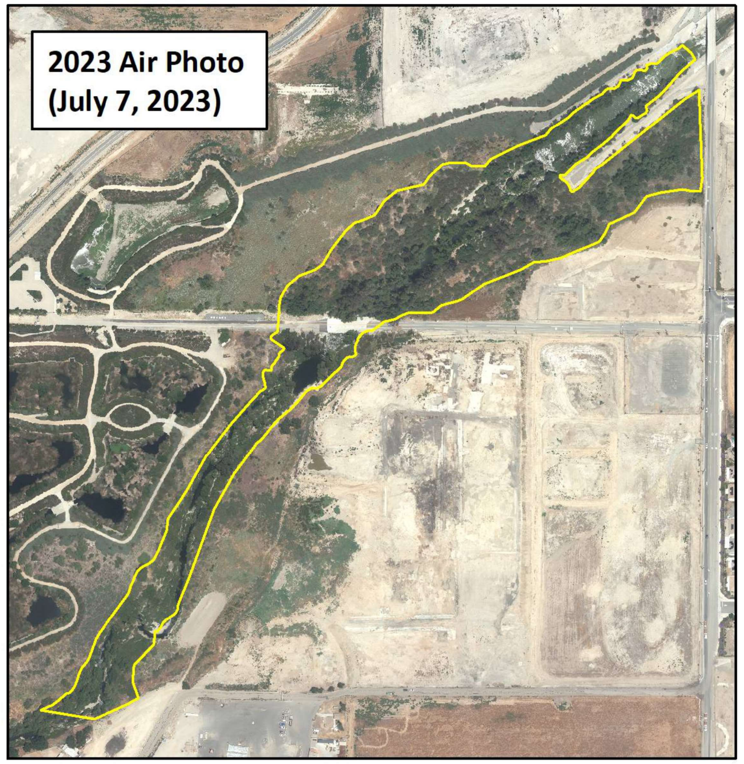
Time Series of NDVI and Air Photos
Along Mill Creek Area for 1984 to 2023

Figure 3-7a


2020 Air Photo
(July 6-8, 2020)


2021 Air Photo
(June 26, 2021)

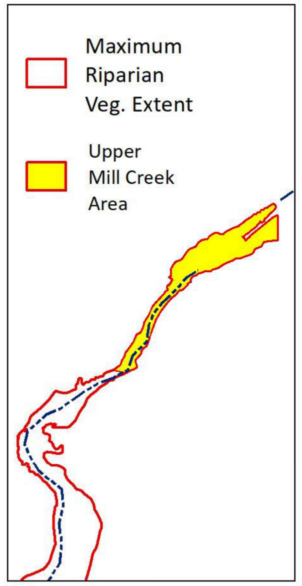

2022 Air Photo
(June 30, 2022)

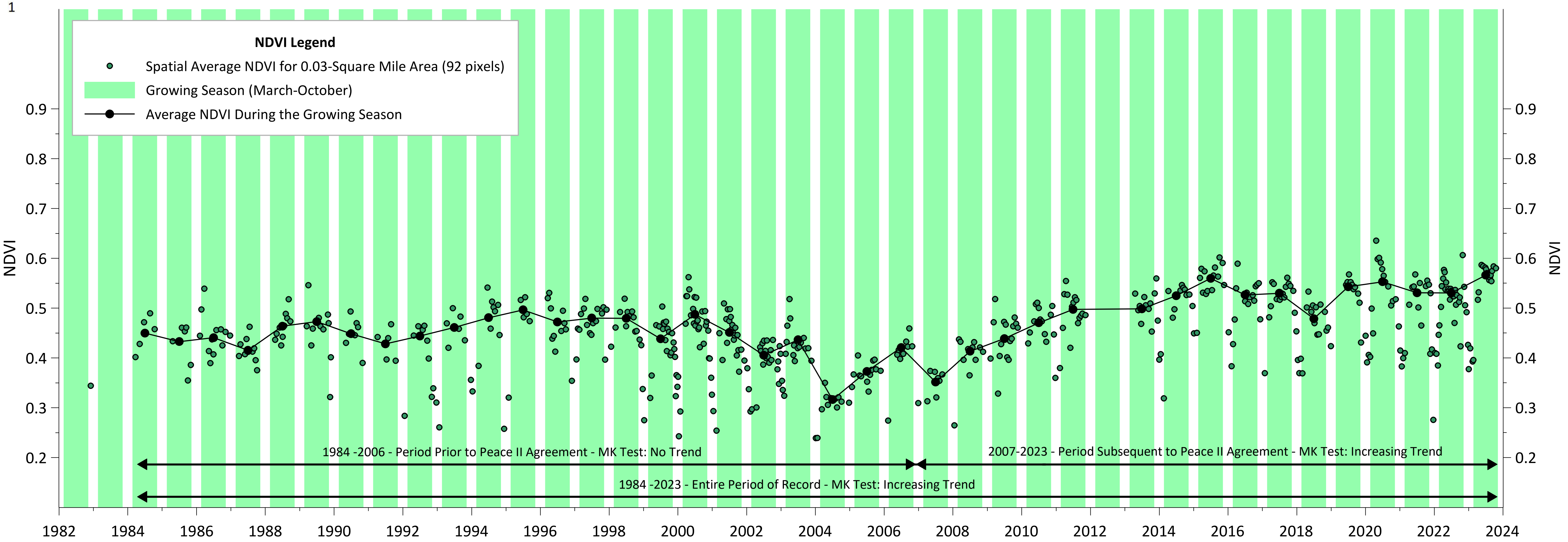

2023 Air Photo
(July 7, 2023)

0 0.5 1 Miles

0.03 Square Mile Area (92 30 x 30-meter pixels)

Location of Upper Mill Creek Area





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Time Series of NDVI and Air Photos
Along Upper Mill Creek Area for 1984 to 2023

Figure 3-7b

3.1.2.4.1 Temporal Analysis of NDVI within Small Areas along Chino Creek, Mill Creek, and the Santa Ana River

Figures 3-8a through 3-8n are time-series charts of the NDVI for one NDVI pixel for small defined areas located along Chino Creek, Mill Creek, and the SAR near the PBHSP monitoring wells from 1984 to 2023. These areas are located near a PBHSP monitoring well to facilitate the comparison of changes in groundwater levels versus changes in the riparian habitat. These small areas also align with a location of a 10-meter radius plot where vegetation surveys are conducted by the USBR every three years so that the field measurements from the surveys can be compared to the NDVI.

The purpose of these charts is to characterize long-term trends and short-term changes in NDVI for smaller areas primarily located along the northern stream reaches of the Prado Basin riparian habitat—areas that are most susceptible to potential impacts from declining groundwater levels associated with Peace II implementation, and provide a basis for comparison to the NDVI trends and changes for each of the larger defined areas.

Chino Creek **(Figures 3-8a to 3-8d)**. Four vegetated areas were analyzed along Chino Creek: CC-1, CC-2, CC-3, and CC-4 (see Figure 3-4 for locations). These figures, and Tables 3-1 and 3-2, show that over the period of record the Average Growing-Season NDVI varied from year-to-year by up to 0.12 with no long-term declining trends. For all four areas, the Mann-Kendall test result on the Average Growing-Season NDVI indicates an “increasing trend” over the 1984 to 2023 period, “no trend” or “increasing trend” over the 1984 to 2006 period, and an “increasing trend” over the 2007 to 2023 period.

For these four areas along Chino Creek, the Average Growing-Season NDVI from 2022 to 2023 increased for the two areas in the upper reach, stayed the same for one area in the middle of the reach, and decreased for one area in the lower Chino Creek reach. At all of the areas, these one-year changes in the Average Growing-Season NDVI are relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). Visual inspection of the 2022 and 2023 air photos do not show significant changes in the riparian vegetation at these four areas.

Mill Creek **(Figures 3-8e to 3-8j).** Six vegetated areas were analyzed along Mill Creek just south of the CDA well field: MC-1, MC-2, MC-3, MC-4, MC-5, and MC-6 (see Figure 3-4 for locations). The MC-5 and MC-6 were new defined areas for the analysis of NDVI time series in Prado Basin for the 2022 Annual Report. MC-5 and MC-6 align with the two new sites added for the 2022 site specific surveys performed by the USBR to increase monitoring in an area where there has been observed drawdown of groundwater levels since the PBHSP monitoring began. These figures, and Tables 3-1 and 3-2, show that over the period of record the Average Growing-Season NDVI varied year-to-year by up to 0.22 with no long-term declining trends. For all six areas, the Mann-Kendall test result on the Average Growing-Season NDVI indicates an “increasing trend” or “no trend” for the 1984 to 2023 period, an “increasing trend” or “no trend” for the 1984 to 2006 period, and an “increasing trend” or “no trend” for the 2007 to 2023 period.

The Average Growing-Season NDVI from 2022 to 2023 increased at all six areas. At all of the areas, the 2022 to 2023 one-year increases in the Average Growing-Season NDVI are within the historical ranges of one-year NDVI variability (see Table 3-2); however, the increases in NDVI at MC-2 and MC-5 are greater than the average one-year change in NDVI observed over the historical period. Visual inspection of the 2022 and 2023 air photos do not show significant changes in the riparian vegetation at these six areas, although there is a noticeable increase in vegetation from 2022 to 2023 in several of the photos, especially at MC-2 and MC-5.

Santa Ana River **(Figures 3-8k to 3-8n).** Four vegetated areas were analyzed along the floodplain of the SAR: SAR-1, SAR-2, SAR-3, and LP (see Figure 3-4 for locations). These figures, and Tables 3-1 and 3-2, show that over the period of record the Average Growing-Season NDVI varied by up to 0.48 from year-to-year. For all four areas, the Mann-Kendall test result on the Average Growing-Season NDVI indicates an “increasing trend” or “no trend” for the 1984 to 2023 period, an “increasing trend”, “no trend” or “decreasing trend” for the 1984 to 2006 period, and an “increasing trend” or “no trend” for the 2007 to 2023 period.

The Average Growing-Season NDVI from 2022 to 2023 increased at three of the sites and decreased at one of the sites. These one-year changes in the Average Growing-Season NDVI are relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). Visual inspection of the 2022 and 2023 air photos do not show significant changes in the riparian vegetation at the SAR-1, SAR-2, SAR-3, and LP areas.

The trend in the Average Growing-Season NDVI compared to the trend in the percent canopy cover measurements from the USBR surveys in 2022 do not align for two areas along the SAR (SAR-2 and LP):

- At the X13 plot within SAR-2, the USBR noted multiple dead trees in 2022 due to grapevine competition (reduced canopy cover to 46%). The NDVI did not show a related decrease, likely due to the greenness of the grapevines.
- At the X1 plot within LP, the USBR noted an increase in dead trees in 2022 due to a fire in December 2020 (reduced canopy cover to 19%). The NDVI decreased in 2021 as a result of the fire and began to rebound in 2022. The NDVI increase in 2022 is likely from the rebound in the green perennial ground cover and not from the regrowth of trees.

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

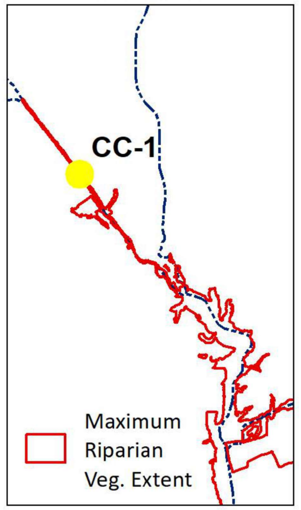
2023 Air Photo (July 7, 2023)

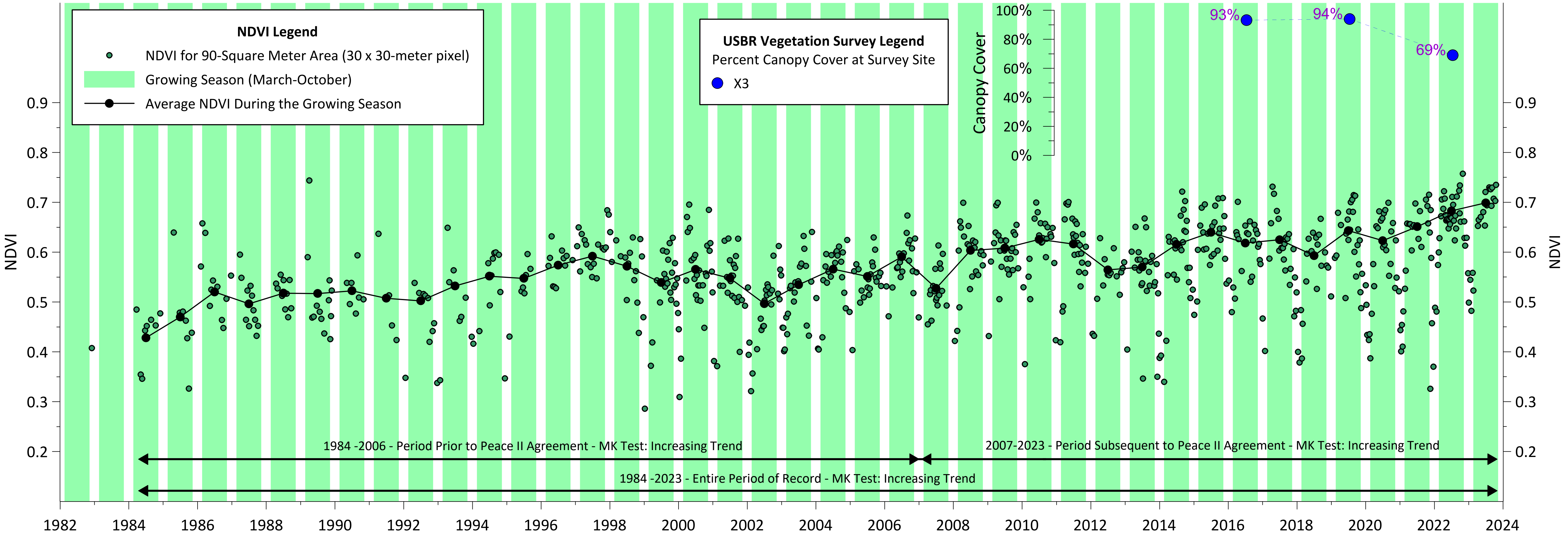
Meters
0 5 10

🟨 CC-1 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Chino Creek





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2023 Annual Report

Prepared for:

Time Series of NDVI and Air Photos

CC-1 Area for 1984 to 2023

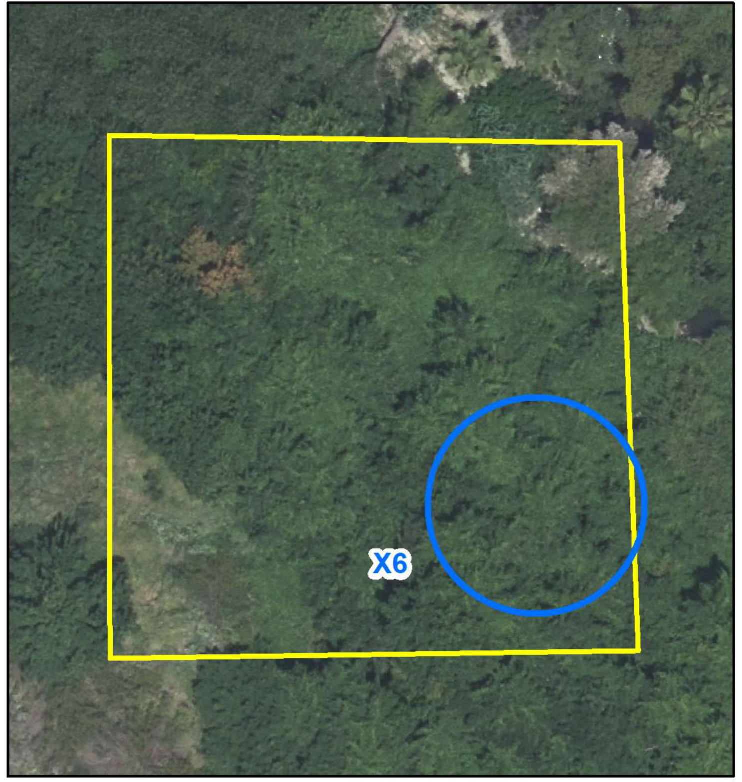
Figure 3-8a

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

2023 Air Photo (July 7, 2023)

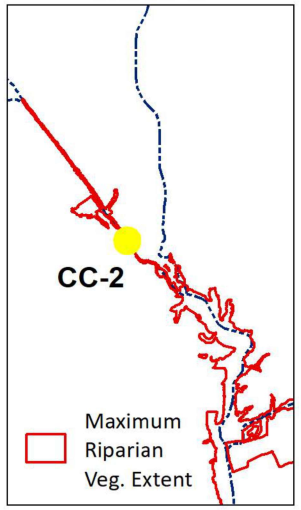


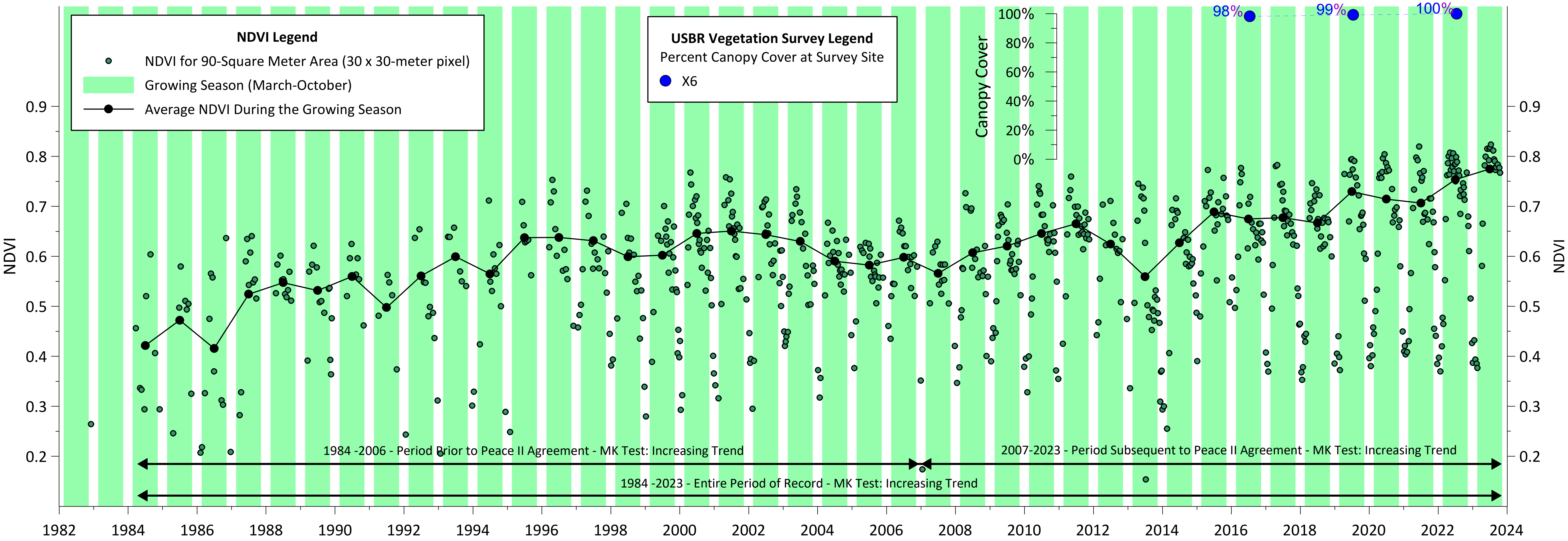
Meters
0 5 10

🟨 CC-2 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Chino Creek





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Time Series of NDVI and Air Photos
CC-2 Area for 1984 to 2023

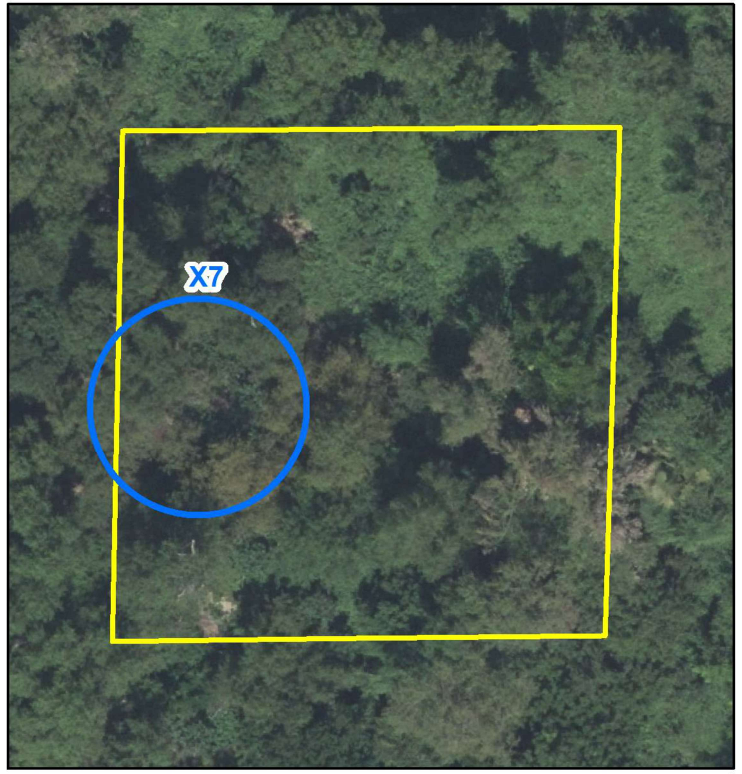
Figure 3-8b

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

2023 Air Photo (July 7, 2023)

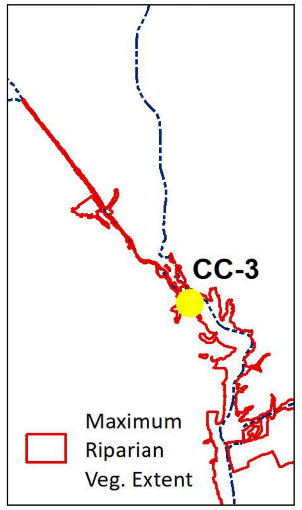


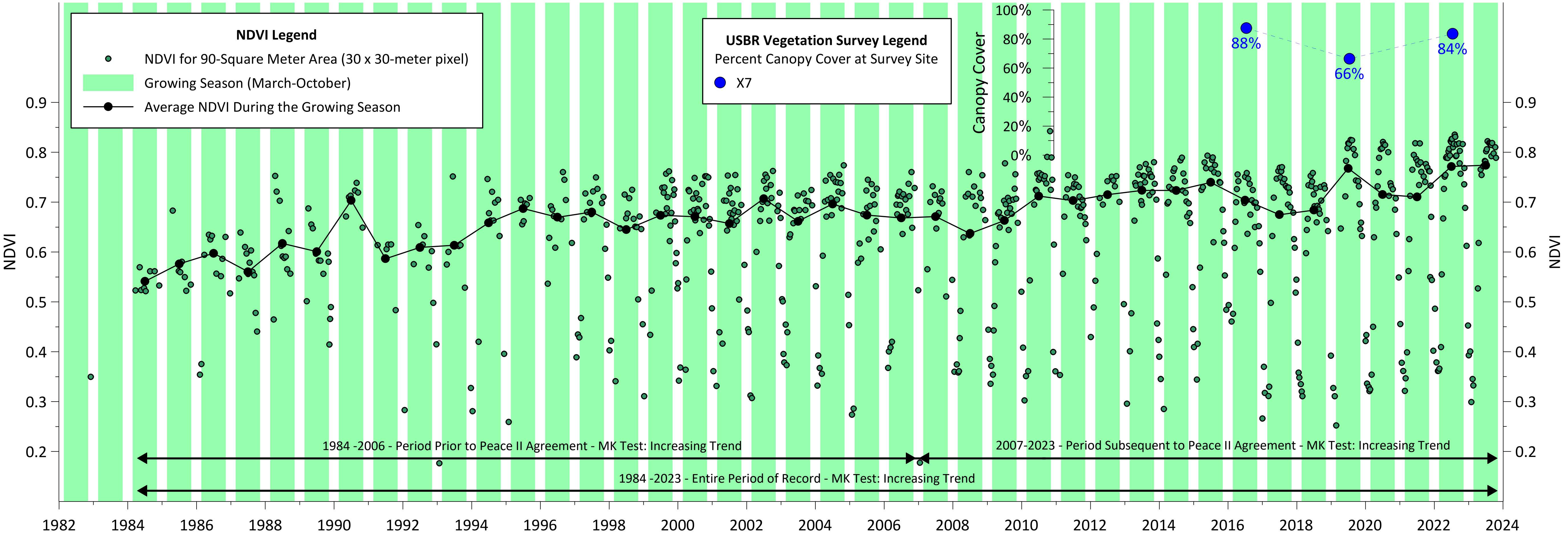
Meters
0 5 10

🟨 CC-3 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Chino Creek





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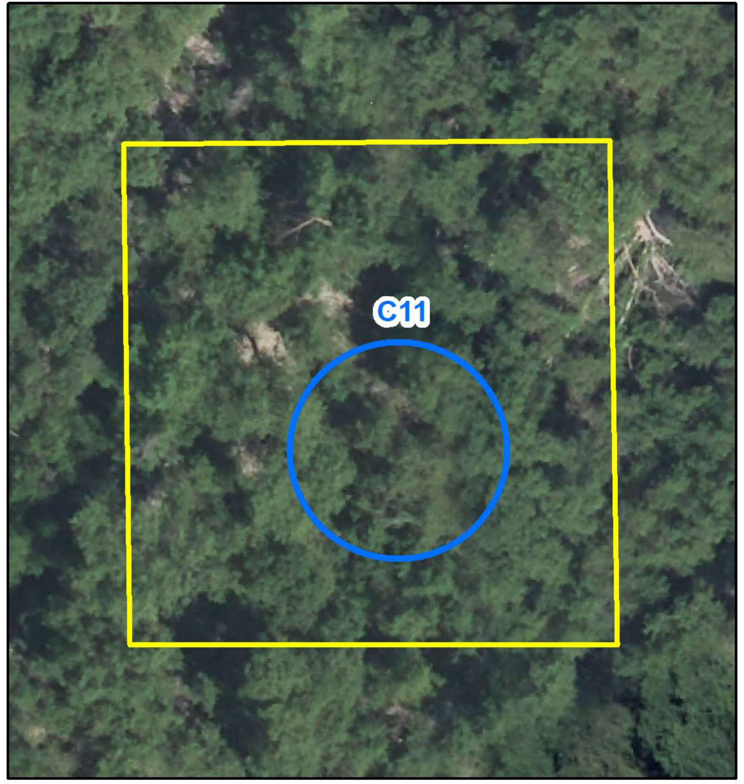
CC-3 Area for 1984 to 2023

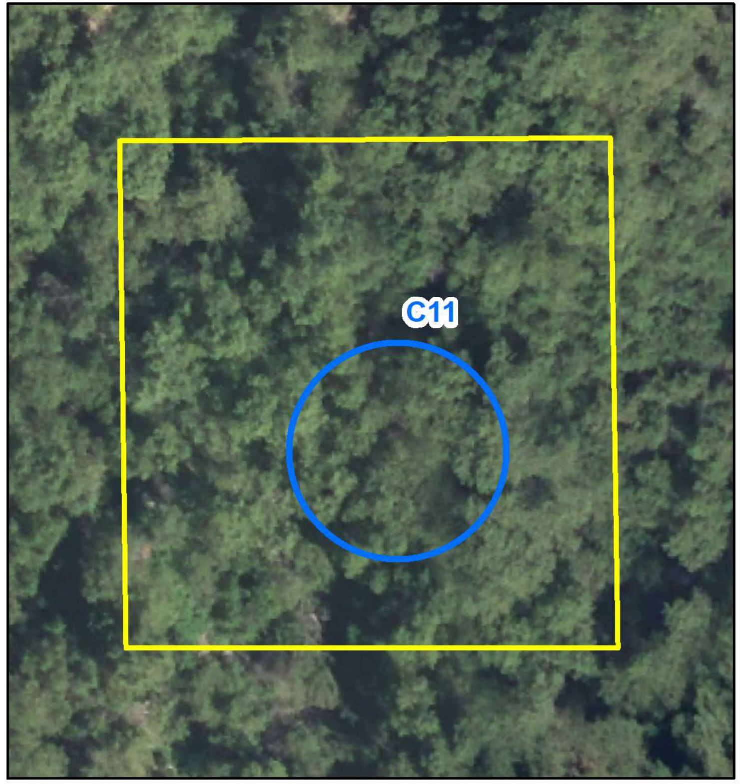
Figure 3-8c

2020 Air Photo (July 6-8, 2020)



2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

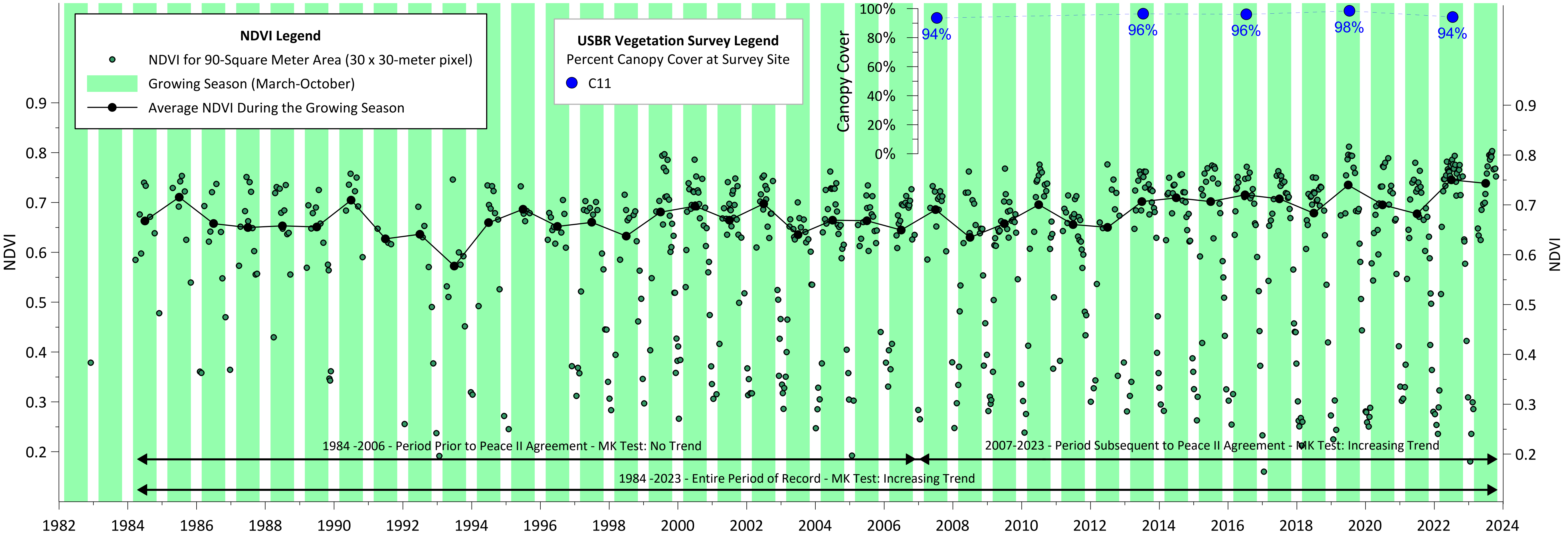


2023 Air Photo (July 7, 2023)

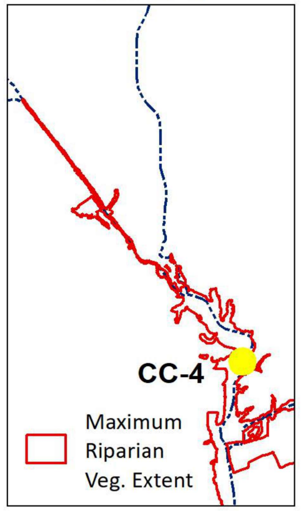
Meters
0 5 10

🟨 CC-4 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius



Location Along Chino Creek



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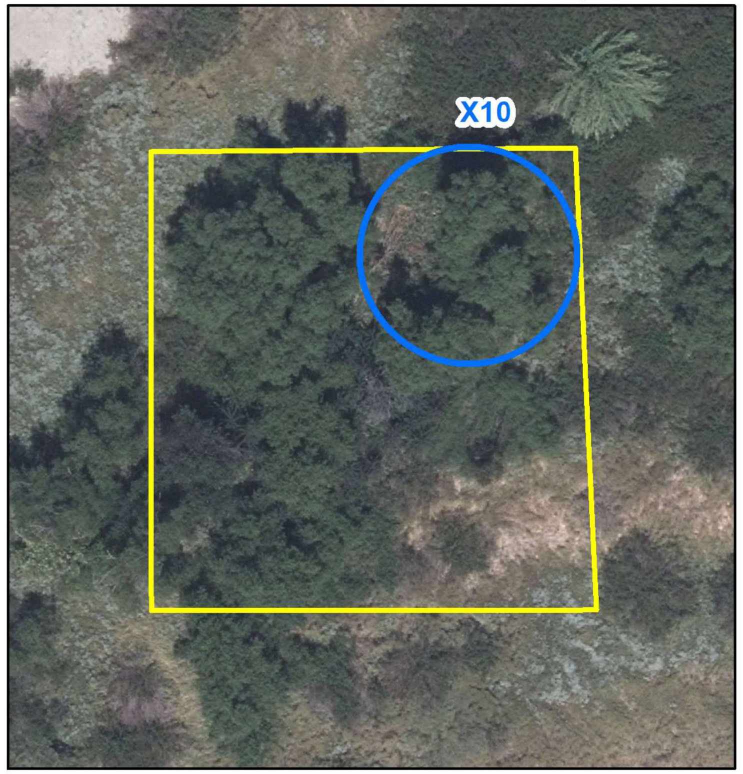
CC-4 Area for 1984 to 2023

Figure 3-8d

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)



2022 Air Photo (June 30, 2022)

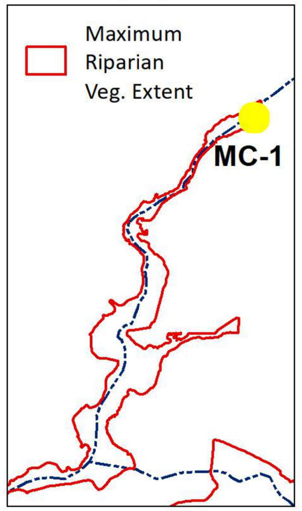
2023 Air Photo (July 7, 2023)

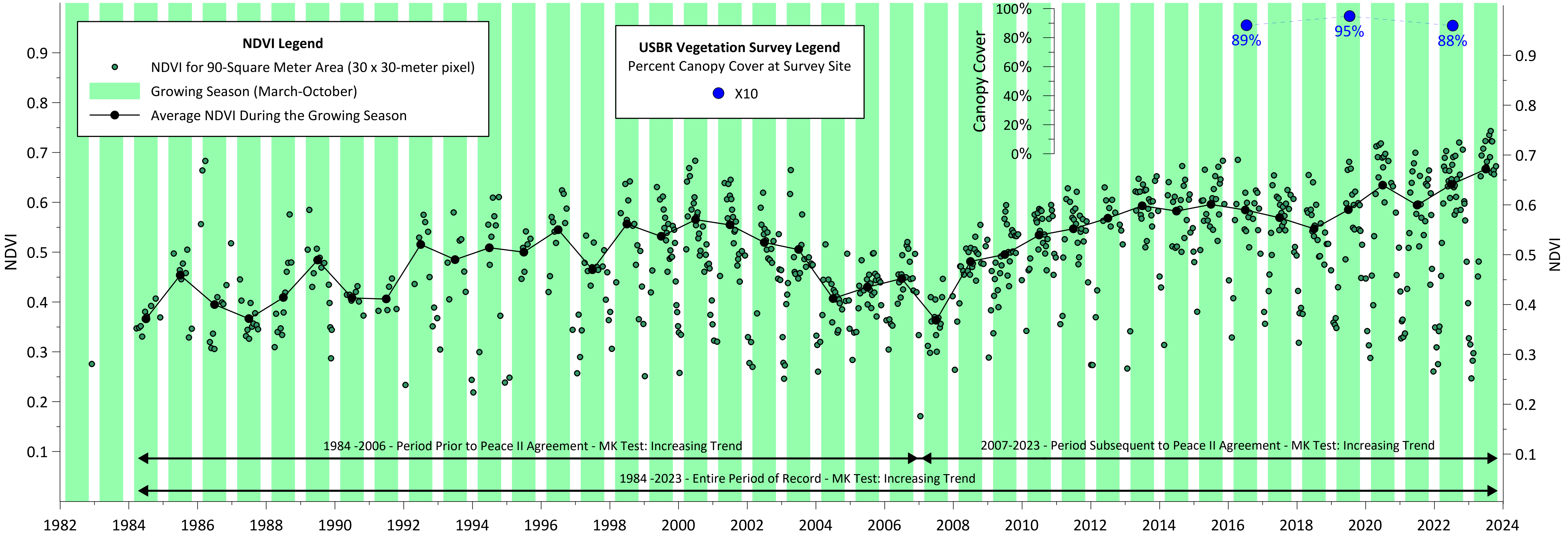
Meters
0 5 10

🟨 MC-1 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Mill Creek





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MC-1 Area for 1984 to 2023

Figure 3-8e

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

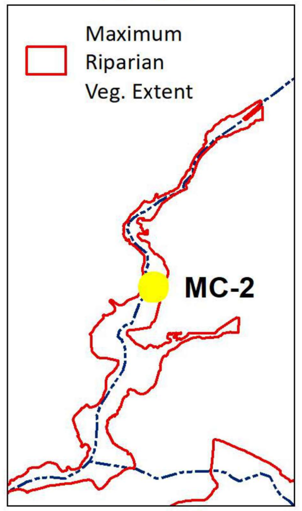
2023 Air Photo (July 7, 2023)

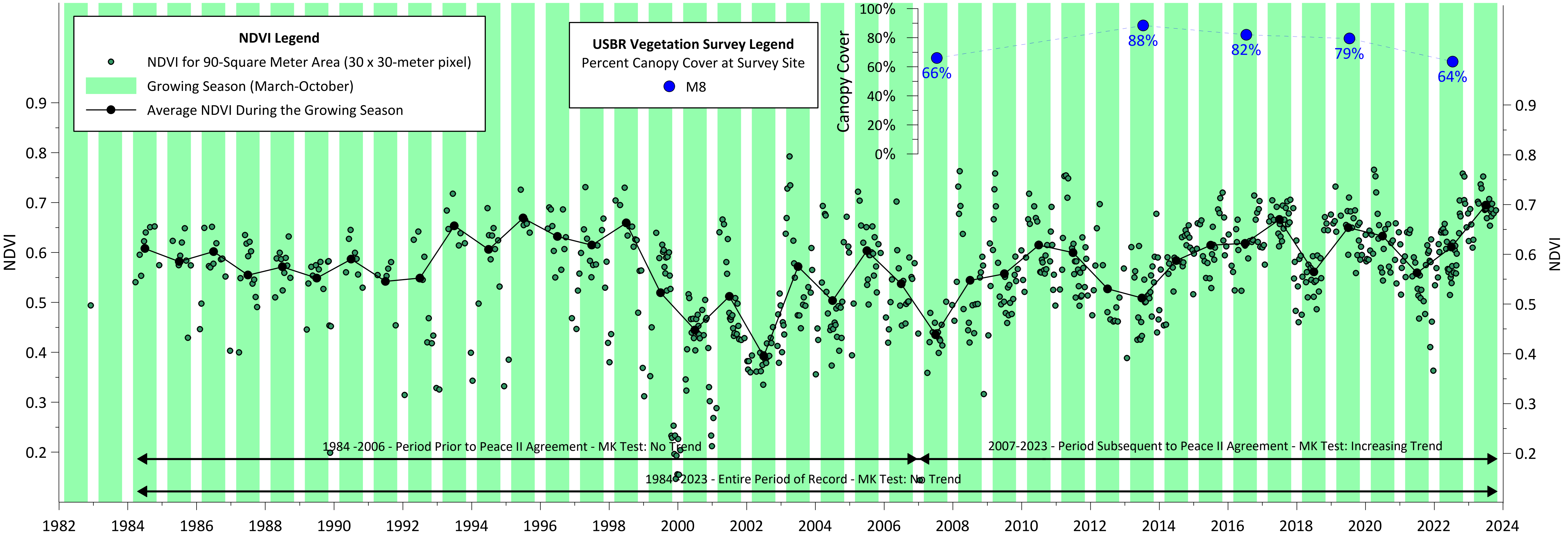
Meters
0 5 10

🟨 MC-2 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Mill Creek





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Time Series of NDVI and Air Photos
MC-2 Area for 1984 to 2023

Figure 3-8f

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

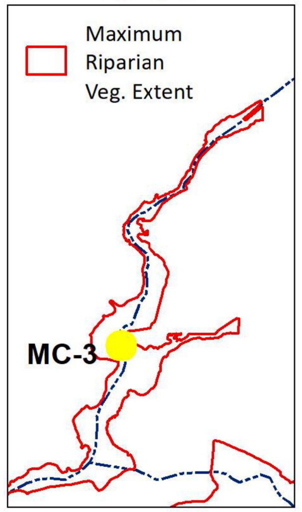
2023 Air Photo (July 7, 2023)

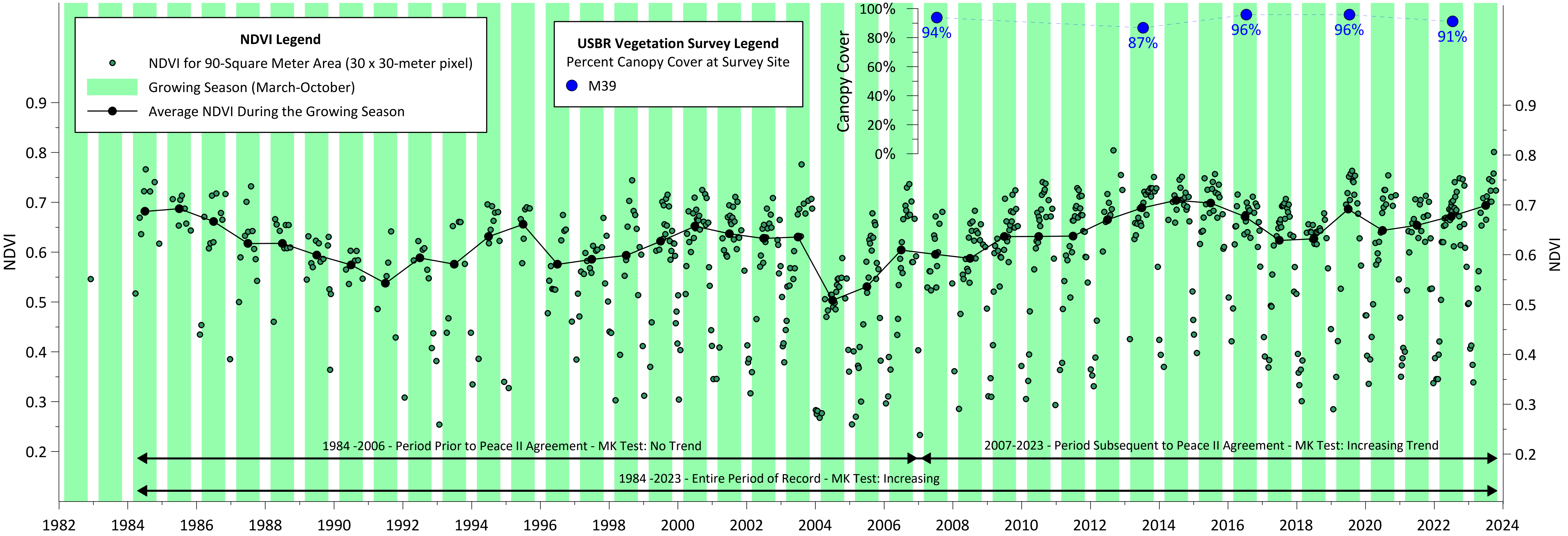
Meters
0 5 10

🟨 MC-3 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Mill Creek





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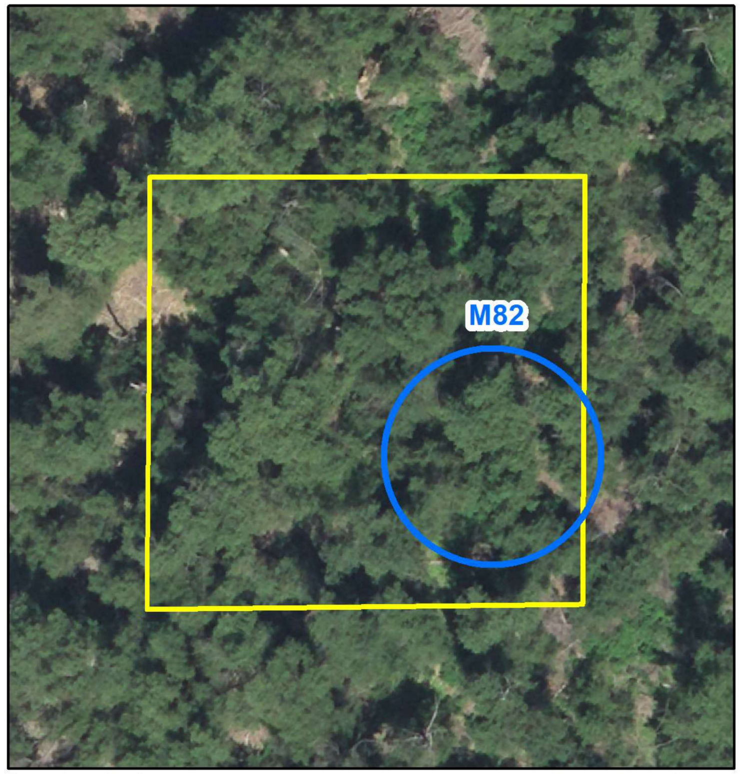
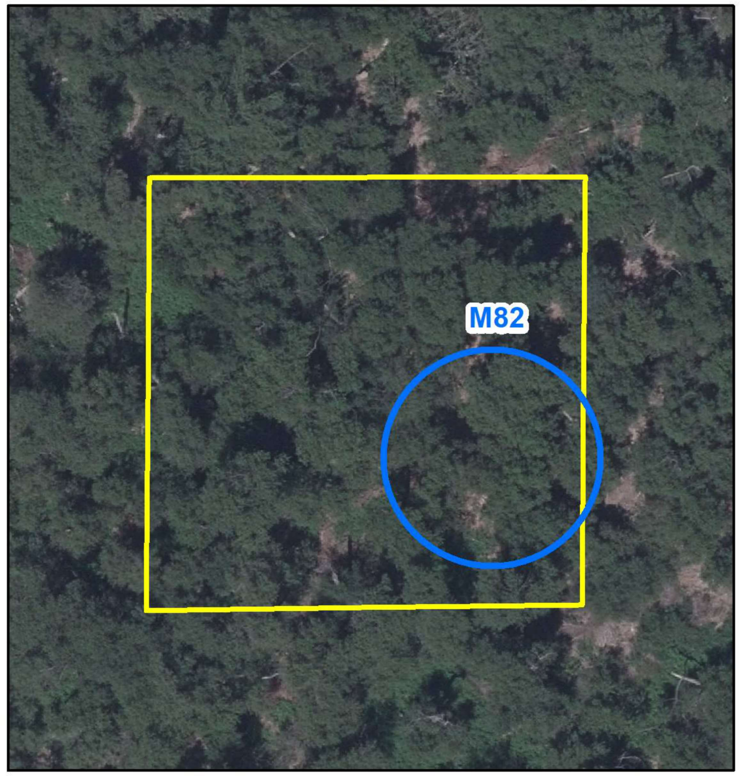
Time Series of NDVI and Air Photos
MC-3 Area for 1984 to 2023

Figure 3-8g

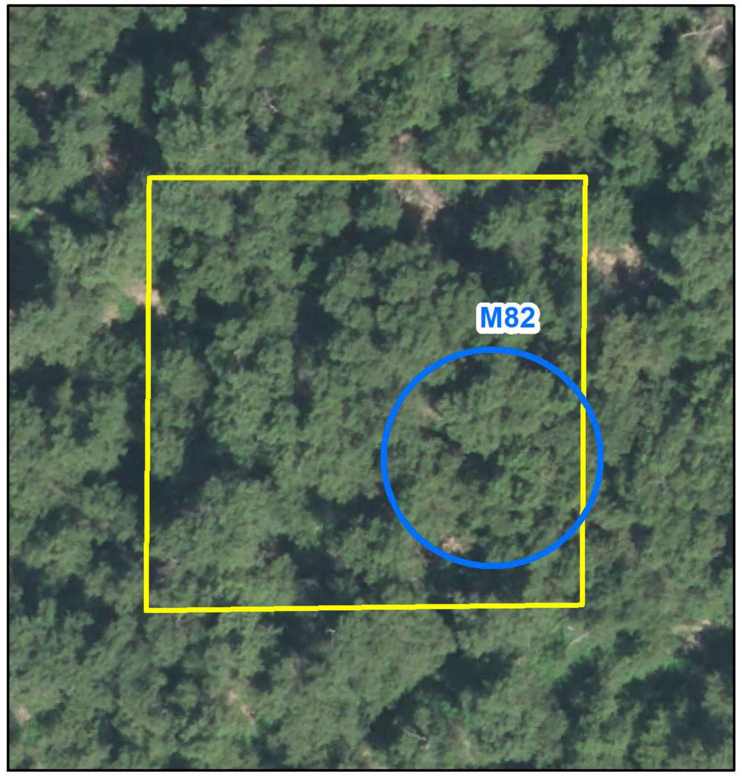
2020 Air Photo (July 6-8, 2020)



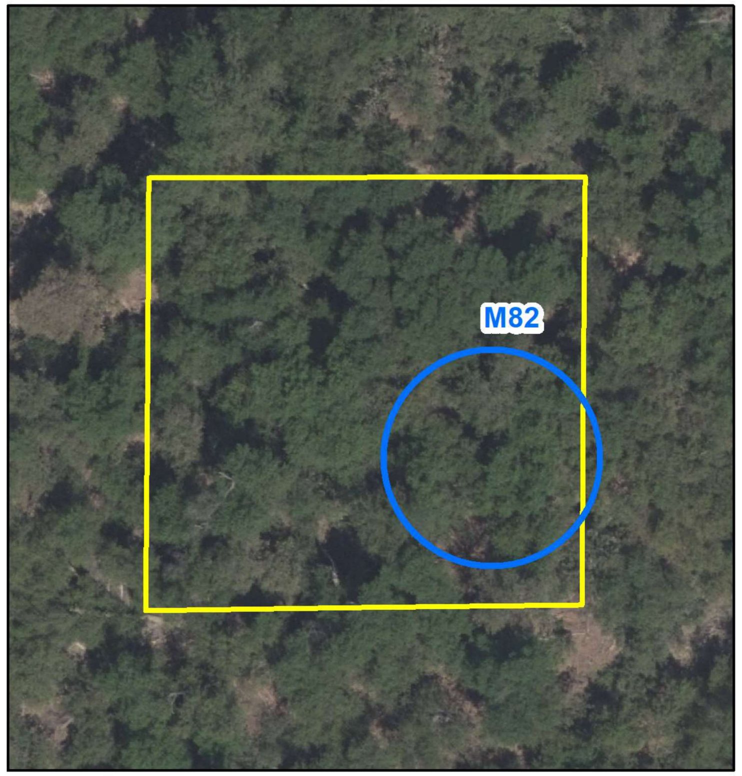
2021 Air Photo (June 26, 2021)



2022 Air Photo (June 30, 2022)



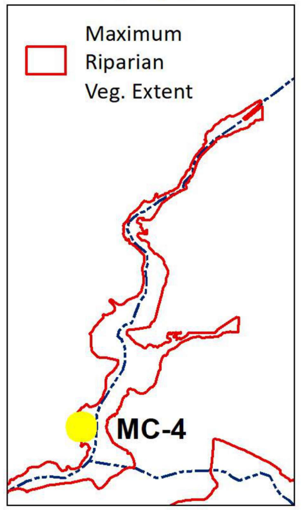
2023 Air Photo (July 7, 2023)

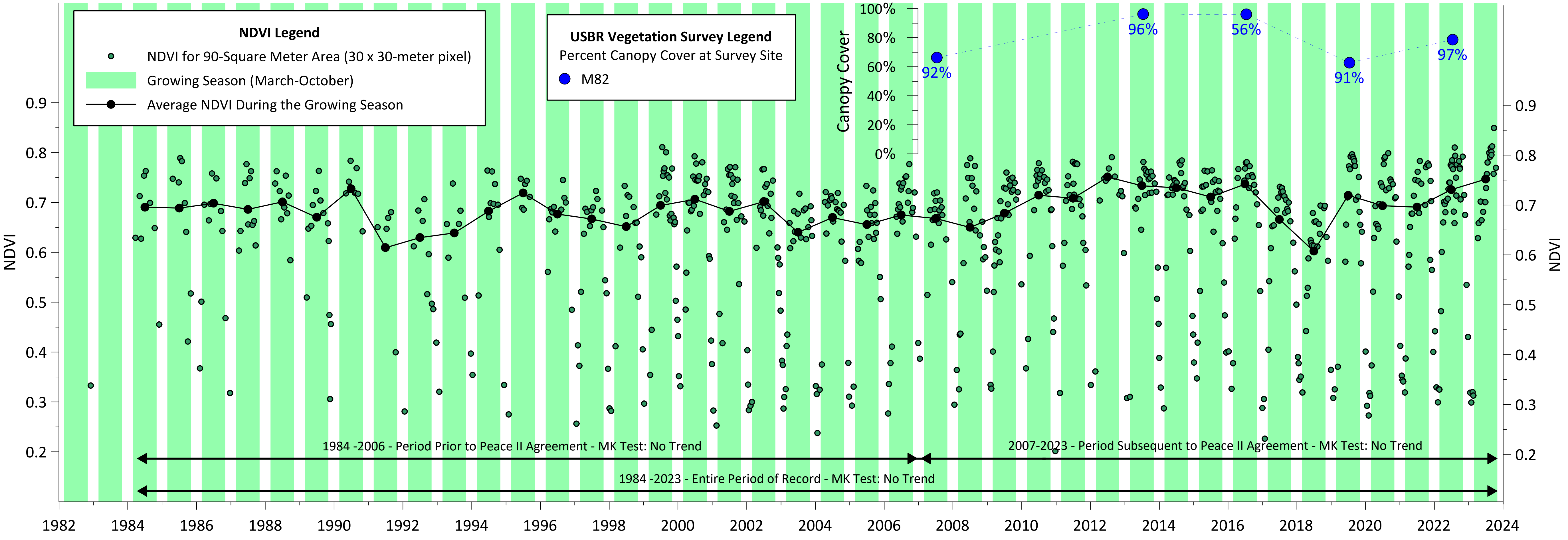


Meters
0 5 10

🟨	MC-4 Area for NDVI Analysis 30x30 meter pixel
○	Vegetation Survey Plot Location 10-meter radius

Location Along Mill Creek





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Time Series of NDVI and Air Photos
MC-4 Area for 1984 to 2023

Figure 3-8h

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

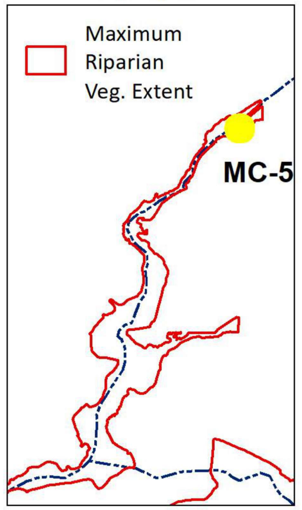
2023 Air Photo (July 7, 2023)

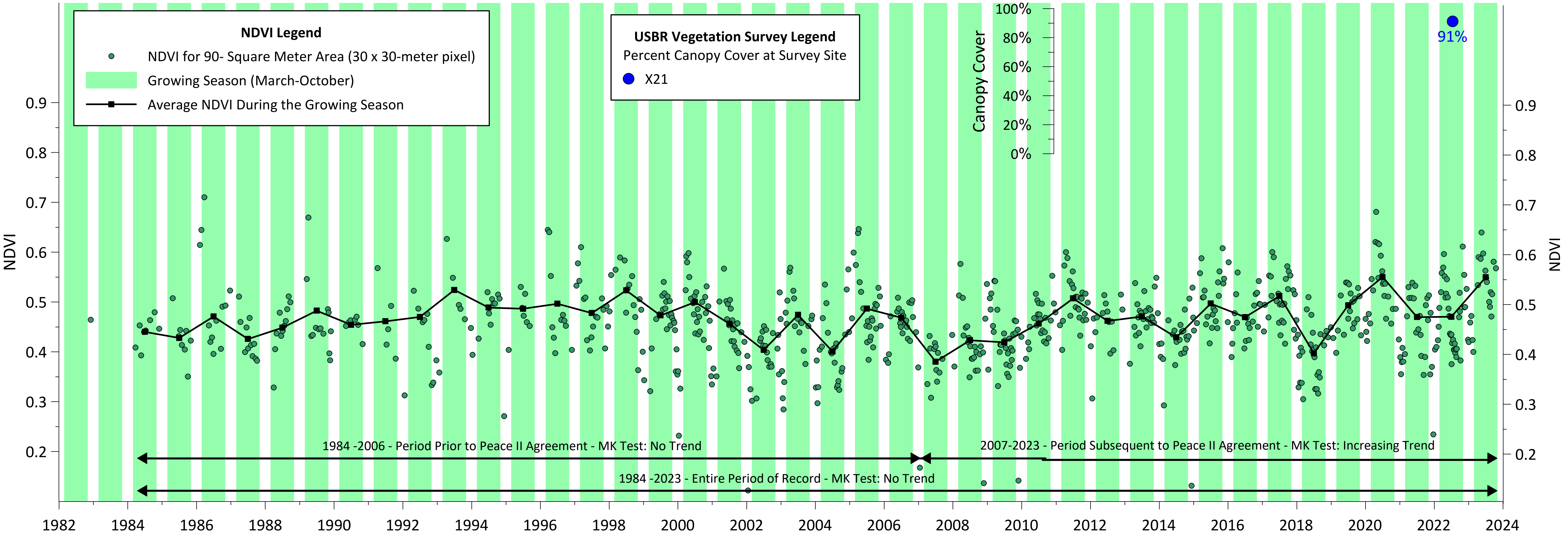
Meters
0 5 10

🟨 MC-5 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Mill Creek





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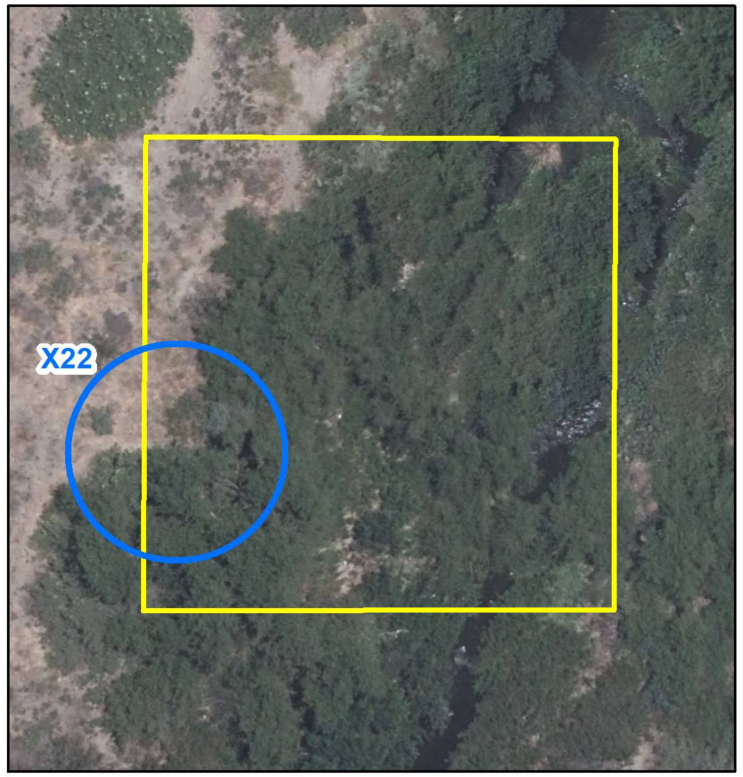
Time Series of NDVI and Air Photos
MC-5 Area for 1984 to 2023

Figure 3-8i

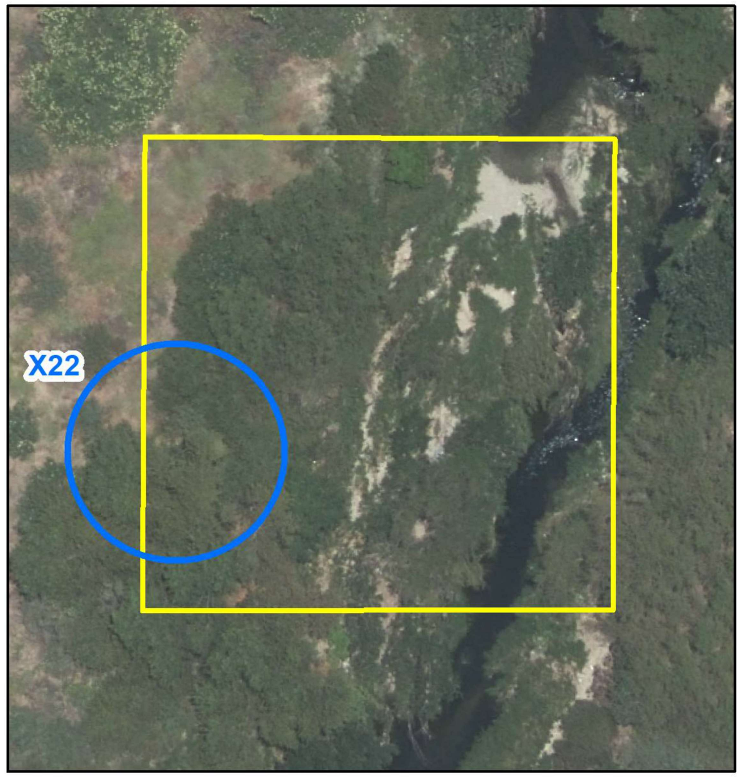
2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)



2022 Air Photo (June 30, 2022)

2023 Air Photo (July 7, 2023)

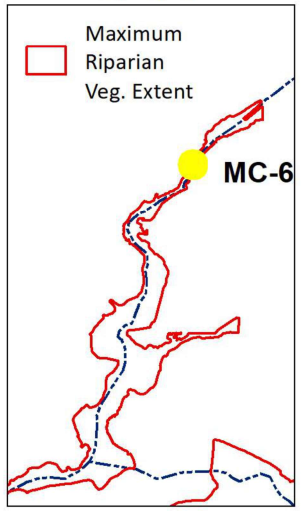


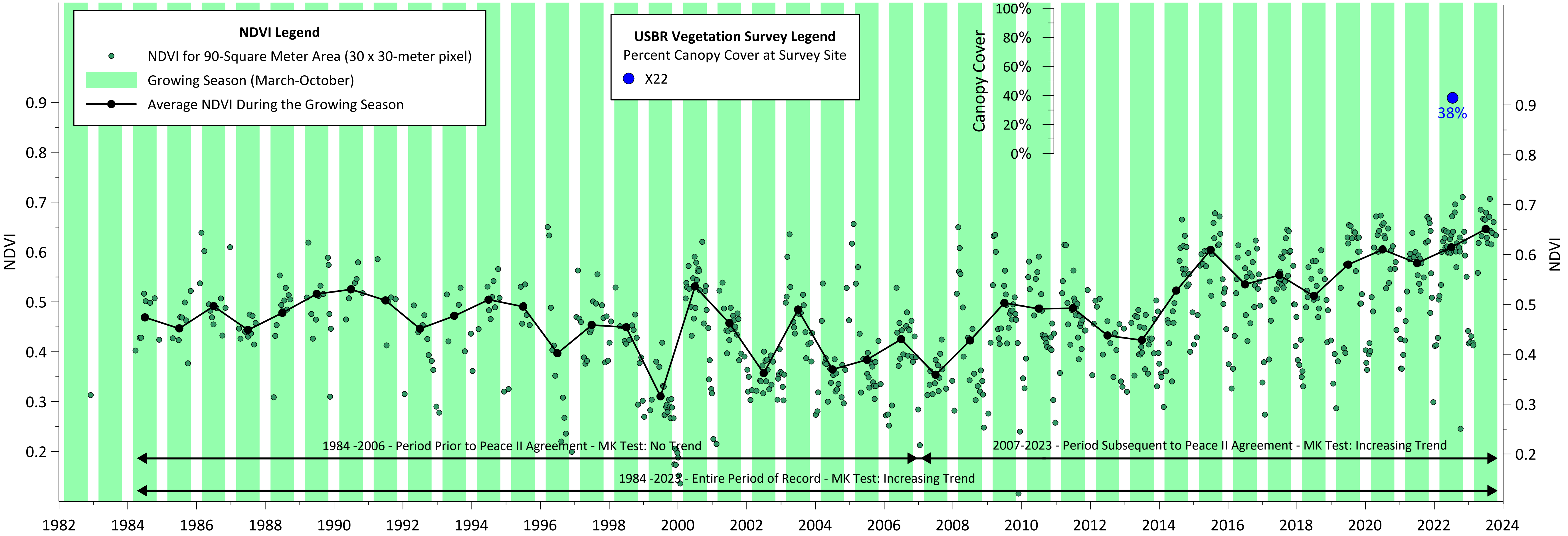
Meters
0 5 10

🟨 MC-6 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Mill Creek





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Time Series of NDVI and Air Photos
MC-6 Area for 1984 to 2023

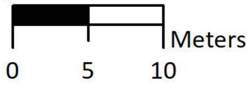
Figure 3-8j

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

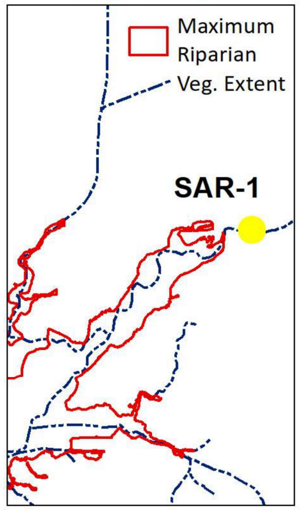
2023 Air Photo (July 7, 2023)

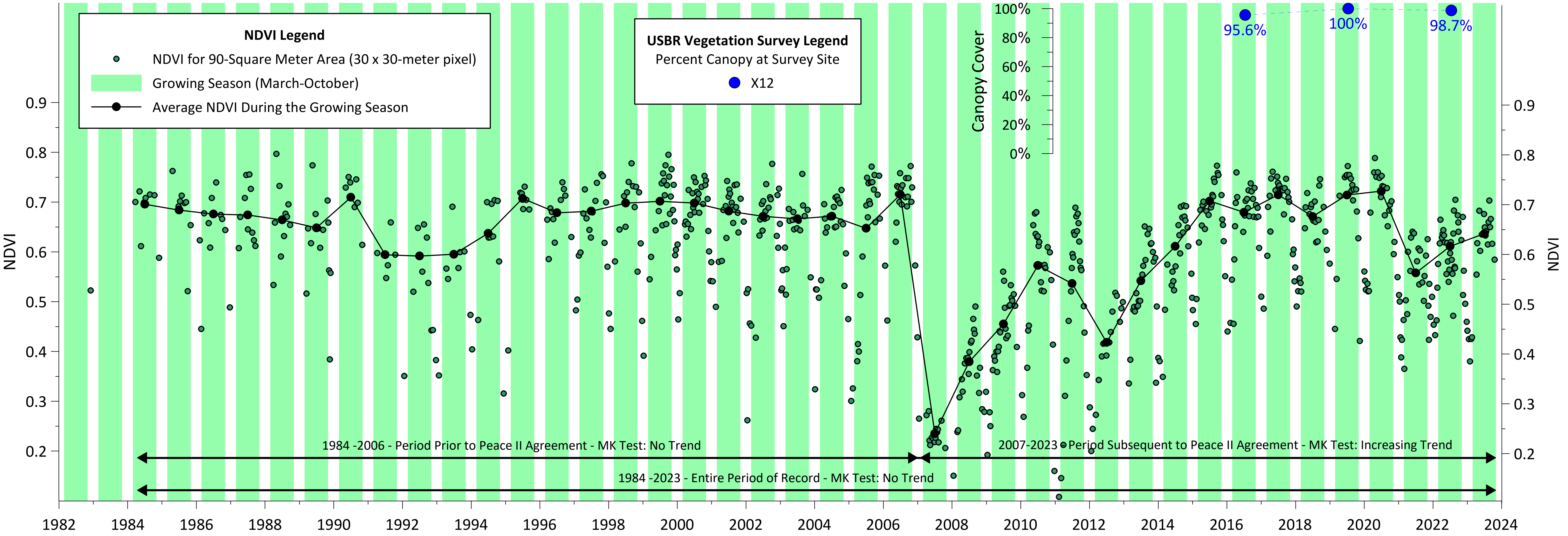


🟨 SAR-1 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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Time Series of NDVI and Air Photos

SAR-1 Area for 1984 to 2023

Figure 3-8k

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

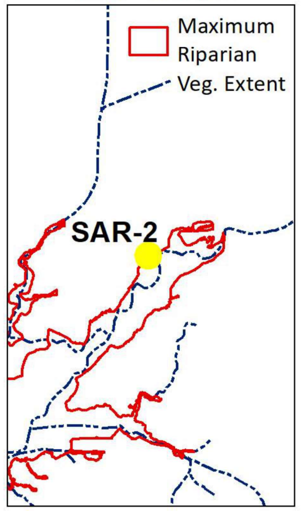
2023 Air Photo (July 7, 2023)

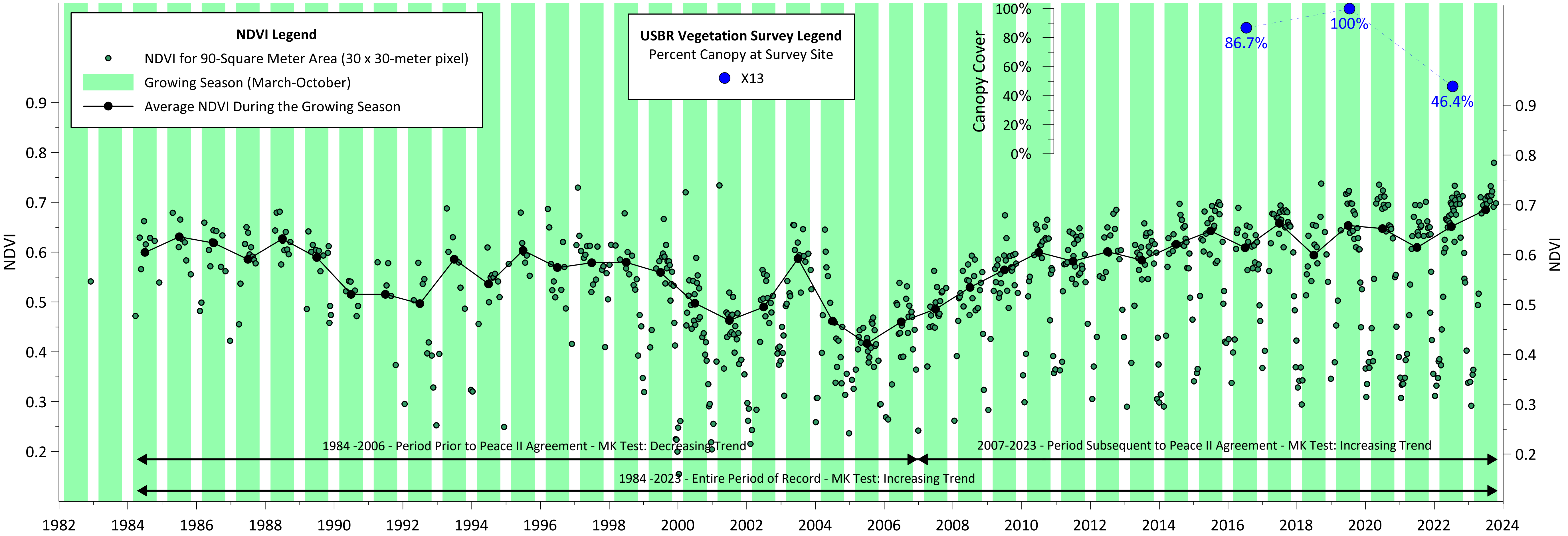
Meters
0 5 10

🟨 SAR-2 Area for NDVI Analysis 30x30 meter pixel

○ Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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SAR-2 Area for 1984 to 2023

Figure 3-8l

2020 Air Photo (July 6-8, 2020)

2021 Air Photo (June 26, 2021)

2022 Air Photo (June 30, 2022)

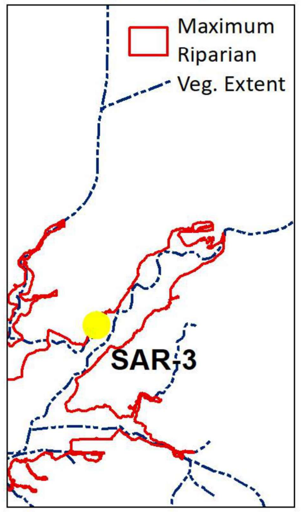
2023 Air Photo (July 7, 2023)

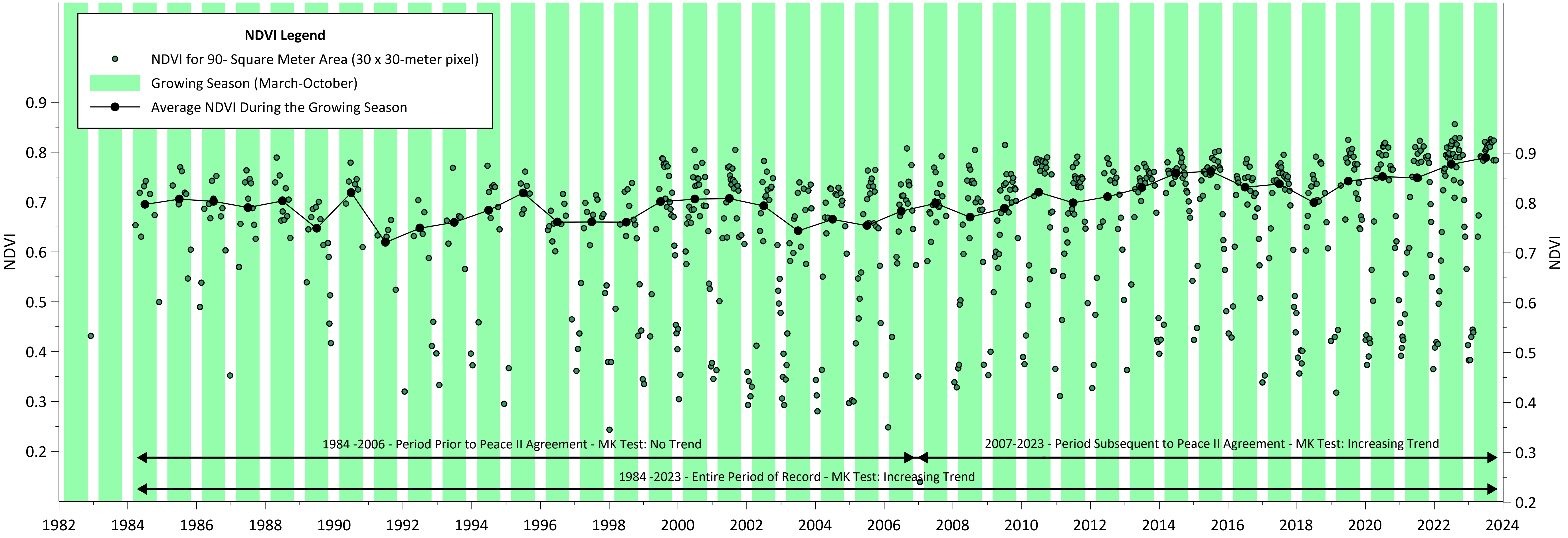
Meters
0 5 10

SAR-3 Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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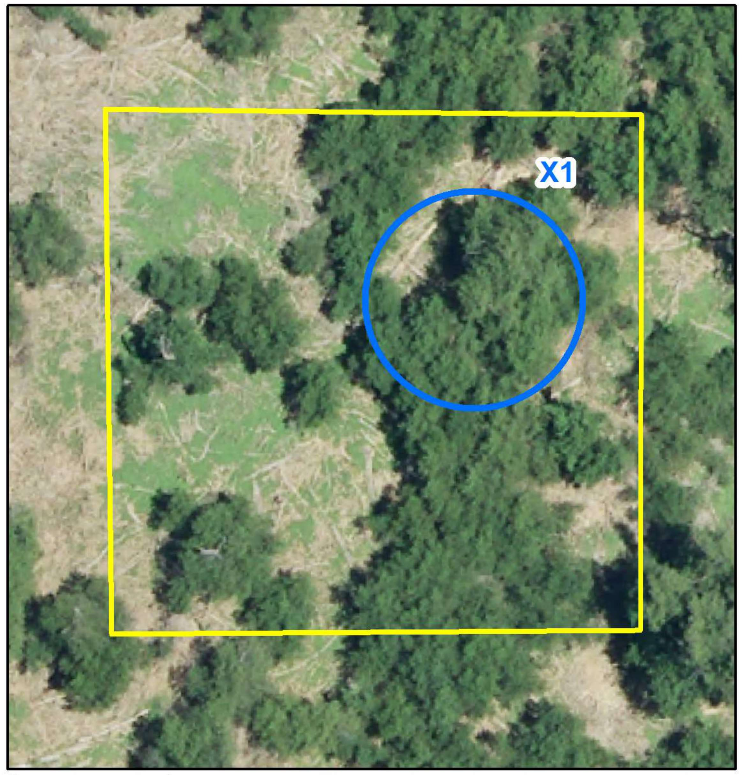
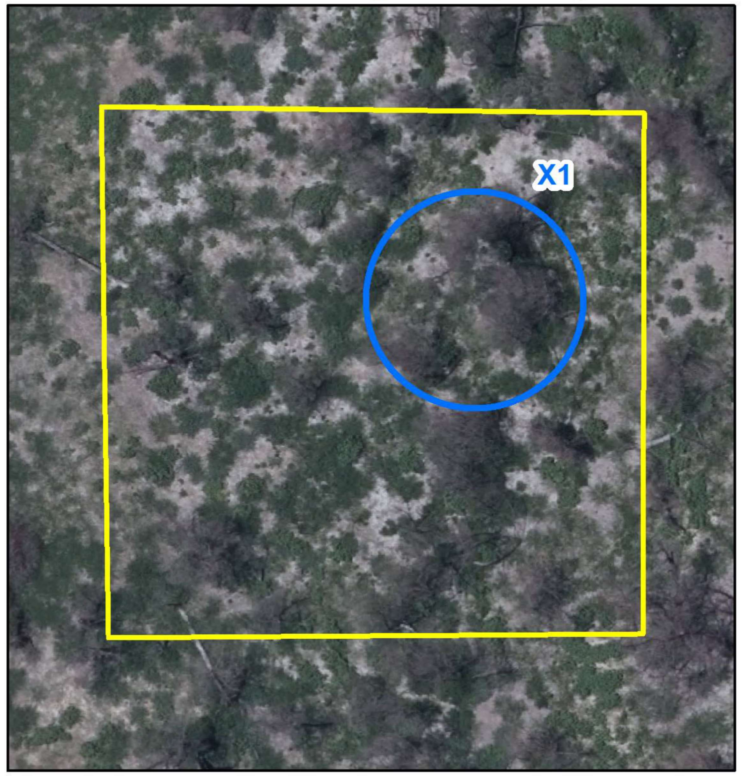
Time Series of NDVI and Air Photos
SAR-3 Area for 1984 to 2023

Figure 3-8m

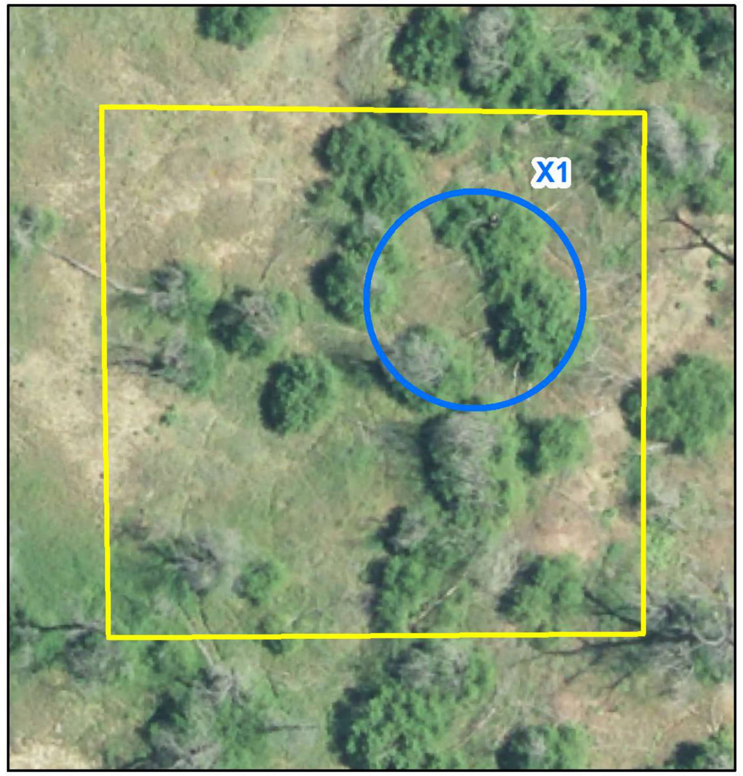
2020 Air Photo (July 6-8, 2020)



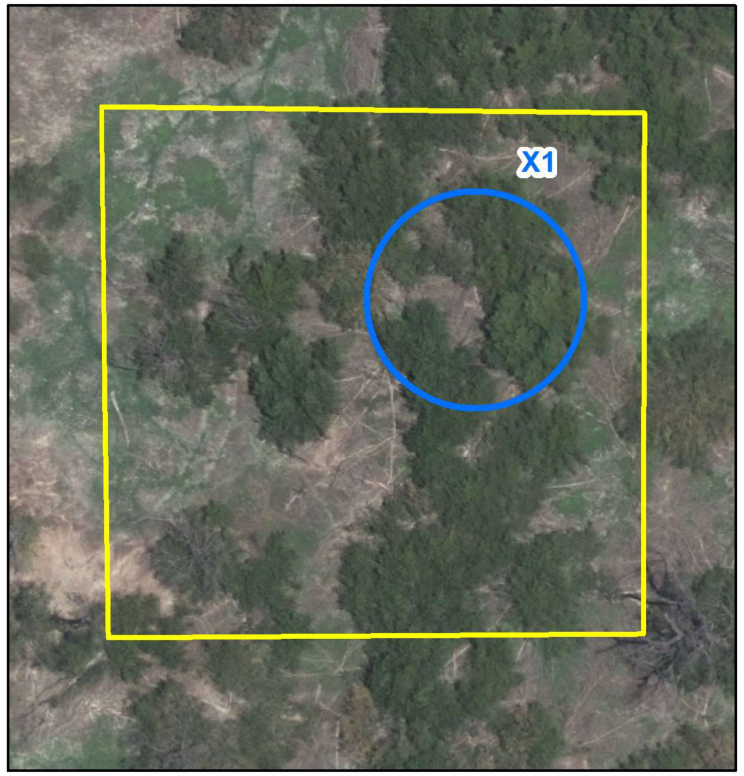
2021 Air Photo (June 26, 2021)



2022 Air Photo (June 30, 2022)



2023 Air Photo (July 7, 2023)

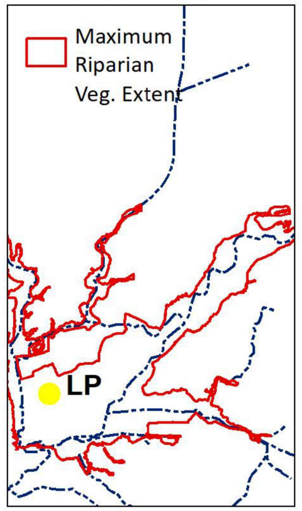


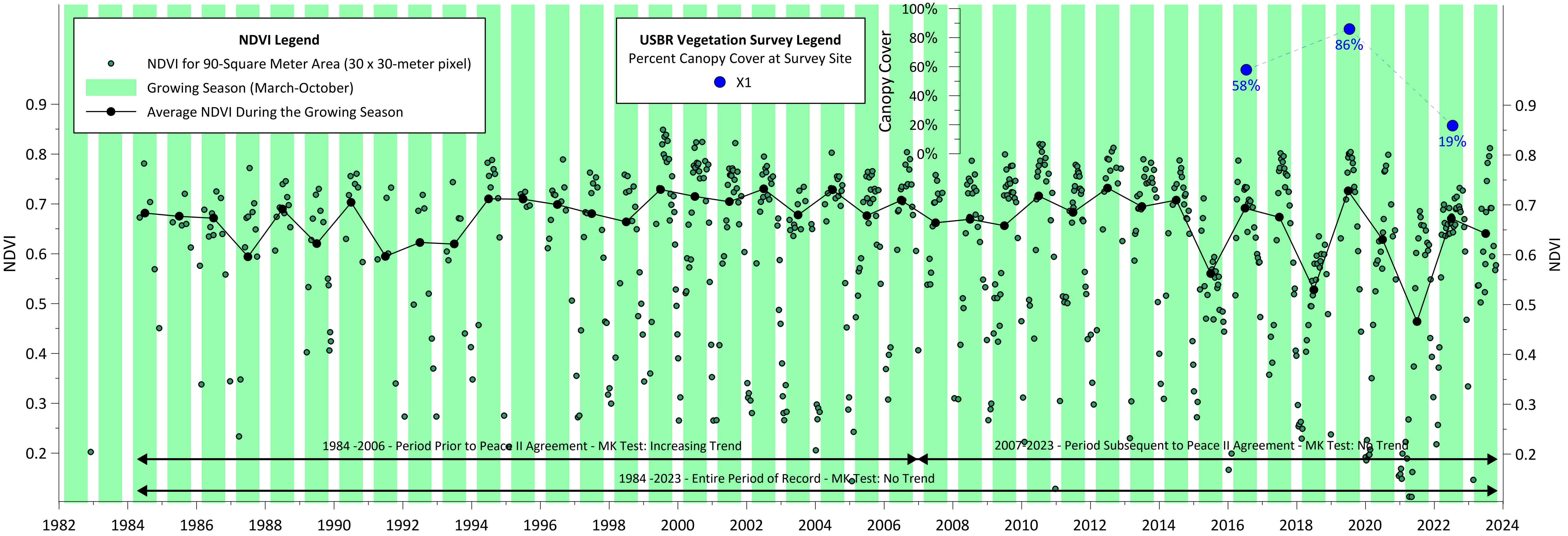
0 5 10 Meters

LP Area for NDVI Analysis 30x30 meter pixel

Vegetation Survey Plot Location 10-meter radius

Location Along Santa Ana River





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LP Area for 1984 to 2023

Figure 3-8n

3.1.3 Analysis of Vegetation Surveys

Vegetation surveys are performed for the PBHSP once every three years. The most recent vegetation survey was performed in 2022 by the USBR, which was a continuation of the surveys performed in 2007, 2013, 2016, and 2019. During the 2022 vegetation surveys 39 sites were monitored, including two new sites in the northern portion of Mill Creek. Preliminary findings and results from the 2022 vegetation surveys were published in a final report in June 2023, which is included as Appendix C to this Annual Report.

Table 3-3 summarizes the following for all sites surveyed in 2007, 2013, 2016, 2019, and 2022: the percent canopy cover; percent live, dead, and stressed trees; and percent trees with the presence of the invasive pest PSHB observed. The measurements of percent canopy cover from the USBR vegetation surveys are the most appropriate measured data for ground-truthing the NDVI. The USBR indicates that ’the observed canopy cover can be compared to NDVI data for each plot to provide a measure of ground truthing’ (USBR, 2023). Percent canopy cover is a measurement of the percentage of the ground surface area that is directly covered by the vertical projections of tree crowns (USDA, 1999). Although there is no direct quantitative relationship between percent canopy cover and NDVI, percent canopy cover is a metric of the areal density of the vegetation that is reflecting visible and near-infrared light and therefore can be used for comparison with the NDVI analysis. The percent canopy cover at the survey location (10-meter radius plot) within the small areas of NDVI analysis (30x30-meter pixel) in Figures 3-8a through 3-8n are charted with the NDVI time-series data. For the areas on Figures 3-8a through 3-8n, the percent canopy cover measurements show variability over the years and no clear increasing or decreasing trends. For most of the areas the trends in the NDVI time-series data align with the percent canopy cover measurements. There are a few notable exceptions for the areas along the SAR which are described in Section 3.1.2.1.4.

Table 3-3 shows that in 2022 the mean percent canopy cover was 81 percent along Chino Creek, 76 percent along Mill Creek, and 73 percent along the SAR; this was a slight increase along Mill Creek from 2019, and slight decrease along Chino Creek and SAR from 2019.

As shown in Table 3-3, the USBR vegetation surveys in 2016, 2019, and 2022 included the documentation of the presence of the invasive pest—the PSHB. Overall, the number of sites with the presence of the PSHB noted in 2016 (30) decreased in 2019 (7) and 2022 (11). In 2022, the percentage of tress with the PSHB observed along each stream reach was 3 percent along Chino Creek sites, 9 percent along Mill Creek, and 2 percent along the SAR. The vegetation surveys provide a measurement of the change in riparian habitat health from 2016 to 2022 for those survey locations impacted by the PSHB. This is discussed in further detail in Section 3.6.2.

Table 3-3. Summary of USBR Vegetation Surveys in 2007, 2013, 2016, 2019, and 2022 in the Prado Basin - Canopy Cover, Tree Condition, and Occurrence of Polyphagous Shot-Hole Borer

	Canopy Cover (%) [1]						Tree Condition (% trees surveyed per plot) [2]																		Polyphagous Shot-Hole Borer [3]						
							Not Stressed (Live)						Stressed						Dead												
Site	2007	2013	2016	2019	2022	Change 2019- 2022	2007	2013	2016	2019	2022	Change 2019- 2022	2007	2013	2016	2019	2022	Change 2019- 2022	2007	2013	2016	2019	2022	Change 2019- 2022	Present in 2016	% of Trees in 2016	Present in 2019	% of Trees in 2019	Present in 2022	% of Trees in 2022	% Change from 2019 to 2022
Chino Creek Sites																															
Chino 3	59%	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Chino 3B	NM	97%	96%	96%	100%	4%	NM	100%	0%	33%	43%	10%	NM	0%	100%	44%	43%	-1%	NM	0%	0%	22%	14%	-8%	no	0%	no	0%	no	0%	0%
Chino 4	80%	94%	98%	84%	86%	2%	NM	100%	7%	55%	63%	8%	NM	0%	80%	40%	5%	-35%	NM	0%	13%	5%	32%	27%	no	0%	no	0%	no	0%	0%
Chino 9	92%	96%	95%	96%	99%	3%	NM	100%	0%	23%	50%	27%	NM	0%	100%	59%	33%	-26%	NM	0%	0%	18%	17%	-1%	no	0%	no	0%	no	0%	0%
Chino 11	94%	96%	96%	98%	94%	-4%	NM	100%	50%	69%	73%	4%	NM	0%	42%	0%	9%	9%	NM	0%	8%	31%	18%	-13%	no	0%	no	0%	no	0%	0%
Chino 16	46%	61%	81%	52%	27%	-25%	NM	NM	27%	50%	50%	0%	NM	NM	64%	50%	29%	-21%	NM	NM	9%	0%	21%	21%	no	0%	no	0%	no	0%	0%
Chino 18	38%	87%	90%	77%	81%	4%	NM	100%	7%	15%	100%	85%	NM	0%	67%	69%	0%	-69%	NM	0%	27%	15%	0%	-15%	yes	40%	no	0%	no	0%	0%
Chino 21	98%	94%	88%	17%	4%	-13%	NM	100%	0%	73%	75%	2%	NM	0%	100%	0%	0%	0%	NM	0%	0%	27%	25%	-2%	yes	17%	no	0%	no	0%	0%
Chino 24	93%	93%	98%	94%	99%	5%	NM	100%	6%	32%	64%	32%	NM	0%	94%	56%	27%	-29%	NM	0%	0%	12%	9%	-3%	yes	6%	no	0%	no	0%	0%
Chino 30	79%	88%	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Chino 30B	NM	NM	89%	74%	98%	24%	NM		0%	20%	50%	30%	NM	NM	89%	50%	25%	-25%	NM	NM	11%	30%	25%	-5%	yes	100%	no	0%	no	0%	0%
Chino 31	82%	93%	97%	91%	98%	7%	NM	100%	7%	4%	68%	64%	NM	0%	93%	72%	16%	-56%	NM	0%	0%	24%	16%	-8%	yes	7%	no	0%	yes	11%	11%
Chino 34	96%	97%	89%	75%	91%	16%	NM	100%	0%	33%	0%	-33%	NM	0%	67%	33%	100%	67%	NM	0%	33%	33%	0%	-33%	no	0%	no	0%	no	0%	0%
Chino 78	95%	98%	87%	98%	95%	-3%	NM	100%	0%	45%	33%	-12%	NM	0%	80%	55%	42%	-13%	NM	0%	20%	0%	25%	25%	yes	80%	no	0%	no	0%	0%
Chino 81	92%	0%	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Chino 85	89%	0%	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Chino X3	NM	NM	93%	94%	69%	-25%	NM	NM	25%	83%	100%	17%	NM	NM	75%	17%	0%	-17%	NM	NM	0%	0%	0%	0%	no	0%	no	0%	no	0%	0%
Chino X4	NM	NM	92%	94%	45%	-49%	NM	NM	0%	43%	40%	-3%	NM	NM	100%	14%	60%	46%	NM	NM	0%	43%	0%	-43%	yes	100%	yes	71%	yes	40%	-31%
Chino X5	NM	NM	96%	95%	96%	1%	NM	NM	75%	89%	78%	-11%	NM	NM	25%	11%	22%	11%	NM	NM	0%	0%	0%	0%	yes	25%	no	0%	no	0%	0%
Chino X6	NM	NM	98%	99%	100%	1%	NM	NM	87%	47%	50%	3%	NM	NM	13%	47%	29%	-18%	NM	NM	0%	7%	21%	14%	yes	13%	no	0%	no	0%	0%
Chino X7	NM	NM	88%	66%	84%	18%	NM	NM	0%	43%	33%	-10%	NM	NM	70%	43%	67%	24%	NM	NM	30%	14%	0%	-14%	yes	70%	no	0%	yes	33%	33%
Chino X8	NM	NM	85%	99%	100%	1%	NM	NM	0%	71%	39%	-32%	NM	NM	62%	24%	33%	9%	NM	NM	38%	6%	28%	22%	yes	46%	yes	6%	yes	6%	0%
Average	**81%**	**78%**	**92%**	**83%**	**81%**	**-2%**	**--**	**100%**	**16%**	**46%**	**56%**	**10%**	**--**	**0%**	**73%**	**38%**	**30%**	**-8%**	**--**	**0%**	**11%**	**16%**	**14%**	**-2%**	**--**	**28%**	**--**	**4%**	**--**	**5%**	**1%**
Mill Creek Sites																															
Mill 1	40%	0%	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Mill 3	8%	13%	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Mill 4	38%	6%	0%	0%	0%	0%	NM	0%	0%	100%	0%	-100%	NM	63%	50%	0%	50%	50%	NM	37%	50%	0%	50%	50%	yes	50%	no	0%	YES	50%	50%
Mill 8	66%	88%	82%	79%	64%	-15%	NM	33%	33%	0%	0%	0%	NM	67%	0%	50%	100%	50%	NM	0%	67%	50%	0%	-50%	yes	33%	no	0%	NO	0%	0%
Mill 11	75%	80%	NM	NM	NM	--	NM	90%	NM	NM	NM	--	NM	0%	NM	NM	NM	--	NM	10%	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Mill 18	62%	68%	78%	90%	98%	8%	NM	100%	38%	10%	40%	30%	NM	0%	38%	80%	30%	-50%	NM	0%	25%	10%	30%	20%	yes	38%	no	0%	YES	10%	10%
Mill 22	89%	93%	96%	93%	94%	1%	NM	86%	0%	43%	0%	-43%	NM	0%	79%	43%	67%	24%	NM	14%	21%	14%	33%	19%	yes	64%	no	0%	YES	50%	50%
Mill 30	63%	63%	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Mill 35	81%	95%	NM	NM	NM	--	NM	100%	NM	NM	NM	--	NM	0%	NM	NM	NM	--	NM	0%	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Mill 39	94%	87%	96%	96%	91%	-5%	NM	92%	0%	13%	33%	20%	NM	0%	67%	63%	33%	-30%	NM	8%	33%	25%	33%	8%	yes	44%	yes	38%	NO	0%	-38%
Mill 60	76%	90%	83%	51%	45%	-6%	NM	86%	0%	0%	11%	11%	NM	0%	93%	69%	67%	-2%	NM	14%	7%	31%	22%	-9%	yes	29%	no	0%	NO	0%	0%
Mill 62	66%	96%	96%	63%	79%	16%	NM	100%	0%	6%	40%	34%	NM	0%	94%	25%	20%	-5%	NM	0%	6%	69%	40%	-29%	yes	94%	yes	25%	YES	20%	-5%
Mill 63	70%	97%	78%	43%	100%	57%	NM	100%	0%	15%	0%	-15%	NM	0%	68%	23%	0%	-23%	NM	0%	32%	62%	100%	38%	yes	41%	yes	23%	NO	0%	-23%
Mill 67	75%	95%	NM	NM	NM	--	NM	100%	NM	NM	NM	--	NM	0%	NM	NM	NM	--	NM	0%	NM	NM	NM	--	NM	NM	NM	NM	NM	NM	--
Mill 69	92%	84%	75%	98%	70%	-28%	NM	90%	0%	67%	83%	16%	NM	0%	64%	0%	17%	17%	NM	10%	36%	33%	0%	-33%	yes	64%	yes	22%	NO	0%	-22%
Mill 82	92%	96%	56%	91%	97%	6%	NM	100%	0%	69%	55%	-14%	NM	0%	75%	15%	27%	12%	NM	0%	25%	15%	18%	3%	yes	25%	yes	8%	NO	0%	-8%
Mill 101	90%	94%	83%	88%	94%	6%	NM	96%	0%	26%	57%	31%	NM	0%	87%	48%	30%	-18%	NM	4%	13%	26%	13%	-13%	yes	83%	no	0%	YES	4%	4%
Mill X9	NM	NM	94%	94%	94%	0%	NM	NM	70%	42%	50%	8%	NM	NM	30%	58%	50%	-8%	NM	NM	0%	0%	0%	0%	yes	10%	no	0%	YES	8%	8%
Mill X10	NM	NM	89%	95%	88%	-7%	NM	NM	0%	70%	73%	3%	NM	NM	50%	30%	18%	-12%	NM	NM	50%	0%	9%	9%	yes	50%	no	0%	YES	18%	18%
Mill X21	NM	NM	NM	NM	91%	--	NM	NM	NM	NM	80%	--	NM	NM	NM	NM	20%	--	NM	NM	NM	NM	0%	--	NM	NM	NM	NM	NO	0%	--
Mill X22	NM	NM	NM	NM	38%	--	NM	NM	NM	NM	78%	--	NM	NM	NM	NM	22%	--	NM	NM	NM	NM	0%	--	NM	NM	NM	NM	NO	0%	--
Average	**69%**	**73%**	**77%**	**75%**	**76%**	**1%**	**--**	**84%**	**11%**	**35%**	**40%**	**4%**	**--**	**9%**	**61%**	**39%**	**37%**	**-2%**	**--**	**7%**	**28%**	**26%**	**23%**	**-2%**	**--**	**48%**	**--**	**9%**	**--**	**11%**	**2%**
Santa Ana River Sites																															
SAR X1	NM	NM	58%	86%	19%	-67%	NM	NM	76%	75%	44%	-31%	NM	NM	5%	13%	0%	-13%	NM	NM	19%	13%	56%	43%	yes	3%	no	0%	NO	0%	0%
SAR X2	NM	NM	93%	79%	79%	0%	NM	NM	11%	60%	33%	-27%	NM	NM	89%	30%	61%	31%	NM	NM	0%	10%	6%	-4%	yes	17%	no	0%	YES	11%	11%
SAR X11	NM	NM	88%	94%	95%	1%	NM	NM	27%	44%	67%	23%	NM	NM	64%	11%	17%	6%	NM	NM	9%	44%	17%	-27%	yes	82%	no	0%	NO	0%	0%
SAR X12	NM	NM	96%	100%	99%	-1%	NM	NM	9%	44%	53%	9%	NM	NM	91%	44%	0%	-44%	NM	NM	0%	13%	47%	34%	yes	91%	no	0%	NO	0%	0%
SAR X13	NM	NM	87%	100%	46%	-54%	NM	NM	0%	17%	20%	3%	NM	NM	67%	67%	0%	-67%	NM	NM	33%	17%	80%	63%	yes	67%	no	0%	NO	0%	0%
SAR X14	NM	NM	88%	97%	97%	0%	NM	NM	0%	75%	50%	-25%	NM	NM	100%	25%	0%	-25%	NM	NM	0%	0%	50%	50%	yes	100%	no	0%	NO	0%	0%
Average	**-**	**-**	**85%**	**93%**	**73%**	**-20%**	**-**	**-**	**21%**	**53%**	**45%**	**-8%**	**-**	**-**	**69%**	**32%**	**13%**	**-19%**	**-**	**-**	**10%**	**16%**	**42%**	**26%**	**-**	**60%**	**-**	**0%**	**-**	**2%**	2%
Average all Sites	**75%**	**76%**	**86%**	**82%**	**78%**	**-4%**	**-**	**91%**	**15%**	**43%**	**48%**	**5%**	**-**	**5%**	**68%**	**37%**	**30%**	**-7%**	**-**	**4%**	**17%**	**19%**	**22%**	**4%**	**-**	**40%**	**-**	**5%**	**-**	**7%**	**1%**

Notes:

NM - Not Measured

1- Canopy cover is a measurement of the percentage of a ground area directly covered by vertical projections of tree crowns. In the field, canopy cover is measured using a spherical densiometer standing five meters from the center of the plot in the four cardinal directions (north, south, east, west). Canopy Cover percent herein is the average of the four measurements.

2- Tree condition is a qualitative measurement of the health of the tree. Trees were assessed and classified as "live," "stressed," or "dead". The percentage of each classification per plot is shown here.

3- In 2016 and 2019 trees were assessed for the presence of polyphagous shot-hole borers (PSHB). If a tree showed signs of the beetle it was noted. The percent of trees in each plot that showed signs of beetle infestation was then calculated.

3.1.4 Summary

The extent of the riparian habitat in the Prado Basin has been delineated from air photos and maps of NDVI. The extent increased from about 1.85 mi^2 in 1960 to about 6.7 mi^2 by 1999 and has remained relatively constant through 2023 along the Chino Creek, Mill Creek, and SAR reaches.

The quality of riparian habitat has been characterized through the analysis of air photos, maps of NDVI, and time-series charts of NDVI for large and small areas located throughout the Prado Basin:

- The NDVI change map shows mostly no change with large and small patches of NDVI increases and decreases throughout the riparian vegetation in the Prado Basin. Notable increases in the NDVI spatially are observed in large patches along the SAR and below the OCWD wetlands. Notable decreases in the NDVI spatially are observed in large patches along the lower portion Chino Creek northwest of the OCWD wetlands, just above Prado Dam, and in the lower area of the Prado Basin.
- The analyses of NDVI time series indicate that from 2022 to 2023 there was a slight increase in the greenness of the riparian vegetation across the Prado Basin when analyzed as a whole, as well as along the Chino Creek and Mill Creek reaches when analyzed as a whole. These increases were within the historical ranges of one-year NDVI variability observed for these areas and some were greater than the average of the one-year changes observed historically. The NDVI time series at the 14 small defined areas throughout the Prado Basin indicate that from 2022 to 2023 there was an increase in the greenness of the riparian vegetation at most of the areas, and a slight decrease or stable trend at three of the areas. At all areas, these one-year changes in the Average Growing-Season NDVI are within the historical ranges of one-year NDVI variability. At the MC-2 and MC-5 areas, where NDVI increased the most from 2022 to 2023, the increases in NDVI are greater than the average one-year change in NDVI observed over the historical period.
- The Mann-Kendall test result on the Average Growing-Season NDVI for the post Peace II Agreement period from 2007 to 2023 indicates an “increasing trend” or “no trend” for the Prado Basin riparian vegetation as whole and all the other areas analyzed through the Prado Basin.

The remainder of Section 3.0 describes the factors that can affect the riparian habitat, how these factors have changed over time, and how the changes in these factors may explain the changes that are being observed in the riparian habitat described above.

3.2 Groundwater and Its Relationship to Riparian Habitat

Peace II Agreement implementation was projected to change groundwater pumping patterns and reduce groundwater replenishment through 2030, both of which would change groundwater levels in the Chino Basin. These groundwater level changes caused by Peace II Agreement implementation and other unrelated water management activities[16] have the potential to impact the extent and quality of Prado Basin riparian habitat.

This section characterizes the history of groundwater pumping and changes in groundwater-levels in the GMP study area and compares this history to the trends in the extent and quality of the riparian habitat described in Section 3.1.

3.2.1 Groundwater Pumping

Table 3-4 lists the groundwater pumping estimates for the GMP study area for WY 1961 to 2023.[17] Figure 3-9 is a map that illustrates the spatial distribution of groundwater pumping from wells within the GMP study area for WY 2023. This figure includes a bar chart of the annual groundwater pumping in the GMP study area (from Table 3-4 below). Figure 3-9 illustrates the following history of groundwater pumping within the GMP study area:

- From 1961 to 1990, groundwater pumping averaged about 45,900 afy. Pumping mainly occurred at private domestic and agricultural wells distributed throughout the area.
- From 1991 to 1999, groundwater pumping steadily declined, primarily due to conversions of agricultural land uses to urban. By WY 1999, groundwater pumping was estimated to be about 23,600 afy, about 49 percent less than average annual pumping from 1961 to 1990.
- From 2000 to 2023, CDA pumping commenced and increased to replace the declining agricultural groundwater pumping, as envisioned in the OBMP/Peace Agreement and Peace II Agreement. In WY 2023, total groundwater pumping was about 41,150 afy—an increase of about 75 percent from 1999.
- Since WY 2019, the annual CDA pumping increased by about 8,000 afy and in mid-2020 the CDA pumping reached its intended pumping rate of 40,000 afy to maintain hydraulic control of the Chino Basin.
- In WY 2023, the CDA pumping maintained its intended pumping rate of 40,000 afy. The total CDA pumping in the GMP study area was 36,688 af because the CDA well II-12 that came online in August 2021 is outside of the GMP study area. Total CDA pumping in WY 2023 was 39,814 af.

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[16] Other water management activities unrelated to Peace II Agreement implementation include changes in wastewater discharge to the SAR due to conservation, recycling, and drought response; increases in storm water diverted and recharged; increases in recycled water recharge; management of groundwater in storage; and the implementation of the Dry-Year Yield Program with MWD.

[17] Production for years prior to WY 2001 were estimated in the calibration of the 2013 Chino Basin groundwater model (WEI, 2015). Production estimates for WY 2001 and thereafter are based on metered production data and water-duty estimates compiled by Watermaster.

Table 3-4. Annual Groundwater Pumping in the Groundwater Monitoring Program Study Area

Water Year	Non-CDA Pumping, afy[(a)]	CDA Pumping, afy	Total Pumping, afy[(a)]
1961	48,577	0	48,577
1962	43,811	0	43,811
1963	43,293	0	43,293
1964	45,170	0	45,170
1965	43,294	0	43,294
1966	46,891	0	46,891
1967	42,709	0	42,709
1968	47,180	0	47,180
1969	37,754	0	37,754
1970	45,849	0	45,849
1971	45,492	0	45,492
1972	47,541	0	47,541
1973	38,427	0	38,427
1974	47,014	0	47,014
1975	44,606	0	44,606
1976	44,847	0	44,847
1977	45,710	0	45,710
1978	46,881	0	46,881
1979	48,829	0	48,829
1980	46,402	0	46,402
1981	53,326	0	53,326
1982	41,719	0	41,719
1983	42,200	0	42,200
1984	52,877	0	52,877
1985	46,876	0	46,876
1986	54,501	0	54,501
1987	46,875	0	46,875
1988	46,277	0	46,277
1989	46,835	0	46,835
1990	45,732	0	45,732
1991	42,266	0	42,266
1992	44,617	0	44,617
1993	43,186	0	43,186
1994	37,390	0	37,390
1995	32,604	0	32,604
1996	35,200	0	35,200
1997	33,340	0	33,340
1998	22,366	0	22,366
1999	23,632	0	23,632

Table 3-4. Annual Groundwater Pumping in the Groundwater Monitoring Program Study Area

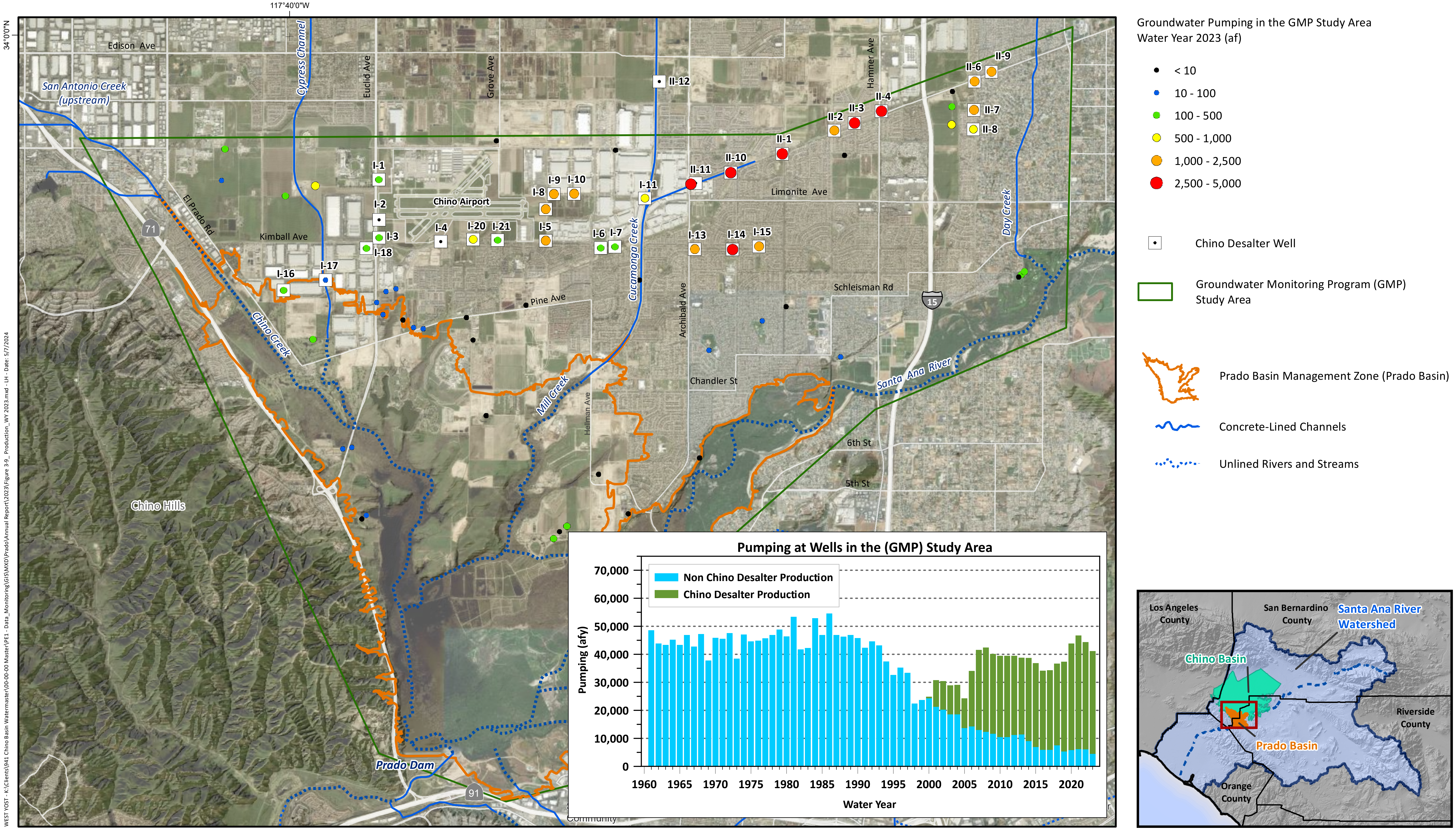
Water Year	Non-CDA Pumping, afy[(a)]	CDA Pumping, afy	Total Pumping, afy[(a)]
2000	24,299	523	24,822
2001	21,249	9,470	30,719
2002	20,271	10,173	30,445
2003	18,600	10,322	28,922
2004	18,606	10,480	29,086
2005	13,695	10,595	24,290
2006	14,261	19,819	34,079
2007	12,988	28,529	41,517
2008	12,293	30,116	42,409
2009	11,694	28,456	40,150
2010	10,452	28,964	39,416
2011	10,460	28,941	39,401
2012	11,193	28,230	39,423
2013	11,433	27,380	38,813
2014	9,059	29,626	38,685
2015	6,985	29,877	36,862
2016	5,900	28,249	34,148
2017	5,899	28,351	34,250
2018	7,504	29,191	36,695
2019	5,348	32,004	37,352
2020	5,875	37,973	43,848
2021	6,155	40,501(b)	46,656
2022	6,066	38,277(c)	44,342
2023	4,462	36,687	41,149
Average: 1961-1990	45,917	0	45,917
Average: 1991-1999	34,956	0	34,956
Average: 2000-2023	11,448	25,114	36,562

(a) Prior to WY 2001 production is estimated with the calibrated 2013 Chino Basin groundwater model (WEI, 2015).

(b) Total CDA production in WY 2021 was 40,649 af; active CDA well II-12 is outside of the GMP study area and not included in the total annual pumping for the GMP study area.

(c) Total CDA production in WY 2022 was 40,684 af; active CDA well II-12 is outside of the GMP study area and not included in the total annual pumping for the GMP study area.

(d) Total CDA production in WY 2023 was 39,814 af; active CDA well II-12 is outside of the GMP study area and not included in the total annual pumping for the GMP study area.



Prepared by:

WEST YOST
Water. Engineered.

Prepared for:

Chino Basin Watermaster and Inland Empire Utilities Agency
2023 Annual Report of the
Prado Basin Habitat Sustainability Committee

Groundwater Pumping
Water Year 2023

Figure 3-9

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3.2.2 Groundwater Levels

Figures 3-10a and 3-10b are groundwater-elevation contour maps of the GMP study area for the shallow aquifer system in September 2016 (first Annual Report condition) and September 2023 (current condition).[18] The contours were created from rasterized surfaces of groundwater elevations that were created based on measured groundwater elevations at wells. The raster of groundwater elevation for September 2016 was subtracted from the raster of groundwater elevation for September 2023 to create a raster of change in groundwater elevation from 2016 to 2023 (Figure 3-11). Figure 3-11 shows that groundwater levels changed by about +/- 10 feet across most of the GMP study area from 2016 to 2023. The greatest areas of change in groundwater elevation occurred in the northern portion of the GMP study area near the Chino Desalter well field. Groundwater levels declined by 10 feet near the central portion of Chino Desalter well field north of Mill Creek (Wells I-5, I-8, I-9, I-10,) and near Well II-2. Groundwater levels increased by about 15 feet near the northern reach of Chino Creek at the Chino Desalter well field Wells I-16 and I-17.

Within the extent of the riparian vegetation, groundwater elevations changed less than +/- 5 feet from 2016-2023, with the greatest declines occurring in the northern reach of Mill Creek. Along the riparian vegetation area in the northern reach of Mill Creek (just south of PB-2), groundwater levels declined about four feet since 2016. At well PB-2 just to the north of Mill Creek, groundwater levels have declined by five feet since 2016. This north portion of Mill Creek is where previous Annual Reports have observed the most declines in groundwater levels in the riparian vegetation area (West Yost 2022; 2023) and is part of the regional pumping depression expanding around the Chino Desalter well field to the north. Over this last year groundwater levels have increased about four feet from the historical lower groundwater levels observed in this area and reported in last year’s Annual Report (West Yost 2022; 2023). Another area of groundwater level declines within the extent of the riparian vegetation since 2016 is along the SAR near well PB-3 where levels have declined 1.5 feet.

Within the extent of the riparian vegetation in the northern reach of Chino Creek, groundwater levels have increased the most since 2016 by about 10 feet. Section 3.2.3 describes a decrease in pumping in the Chino Creek area.

Figure 3-12 is a map of depth-to-groundwater in September 2023. It was created by subtracting a one-meter horizontal resolution 2020 digital-elevation model (DEM)[19] of the ground surface from the raster of groundwater elevation for September 2023. An outline of the Prado Basin riparian habitat extent is superimposed on the 2023 depth-to-groundwater raster. With few exceptions, the riparian habitat generally overlies areas where the depth-to-groundwater is less than 15 feet below the ground surface (ft-bgs). The shallow groundwater could exit the Prado Basin via rising groundwater discharge to the SAR and its tributaries and/or evapotranspiration by the riparian vegetation.

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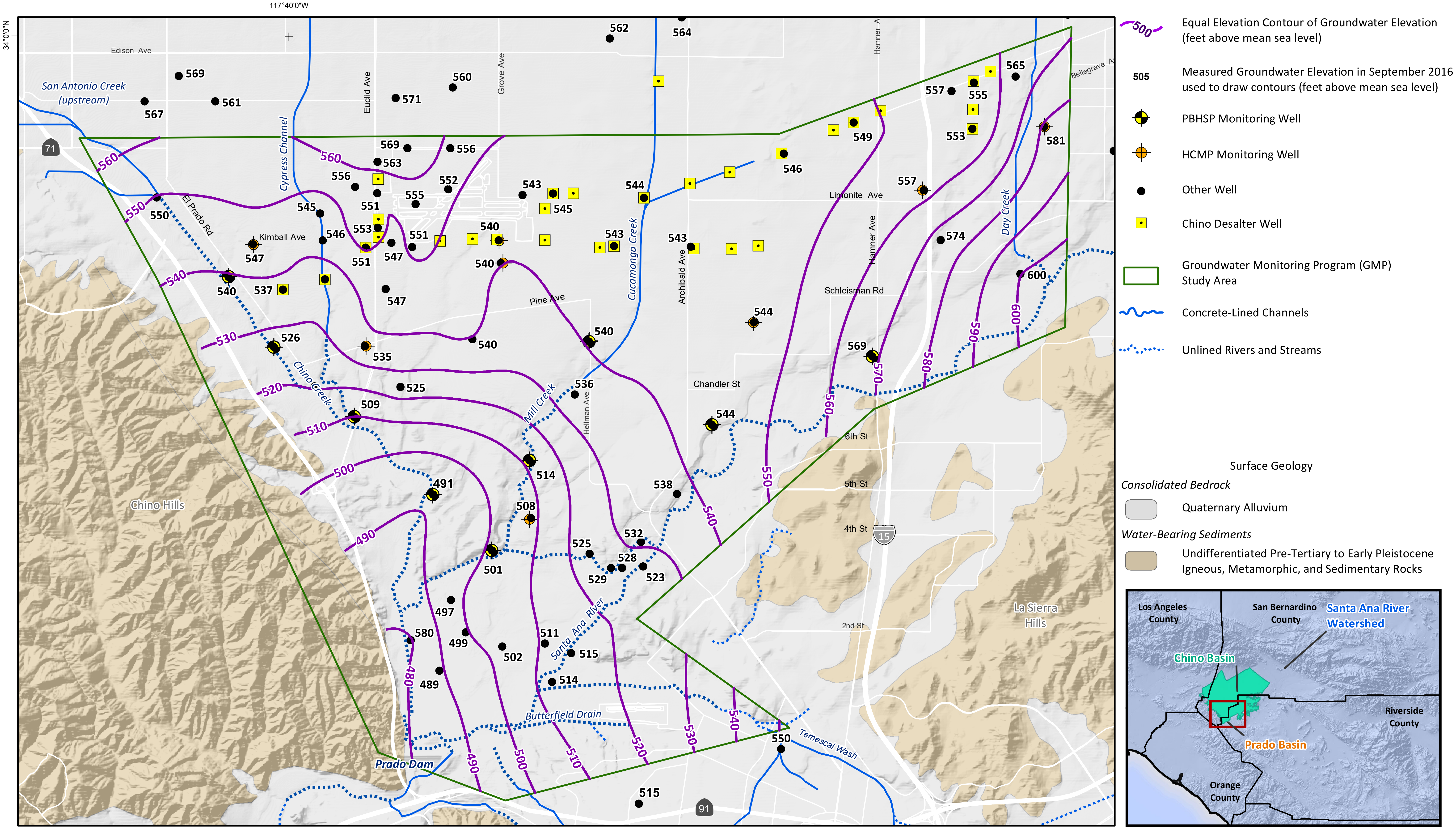
[18] Historical groundwater elevation data for the Prado Basin are scarce due to a lack of wells and/or monitoring. As such, the discussion and interpretation of measured groundwater elevations focuses on the GMP’s period of record.

[19] The 2020 DEM is from LiDAR data collected of the Prado Basin and along the SAR during July 2020 when Watermaster, IEUA, OCWD, and San Bernadino Valley Water District collaborated and cost-shared the collection of the 2022 air photo of the Prado Basin.



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Date: 6/5/2024

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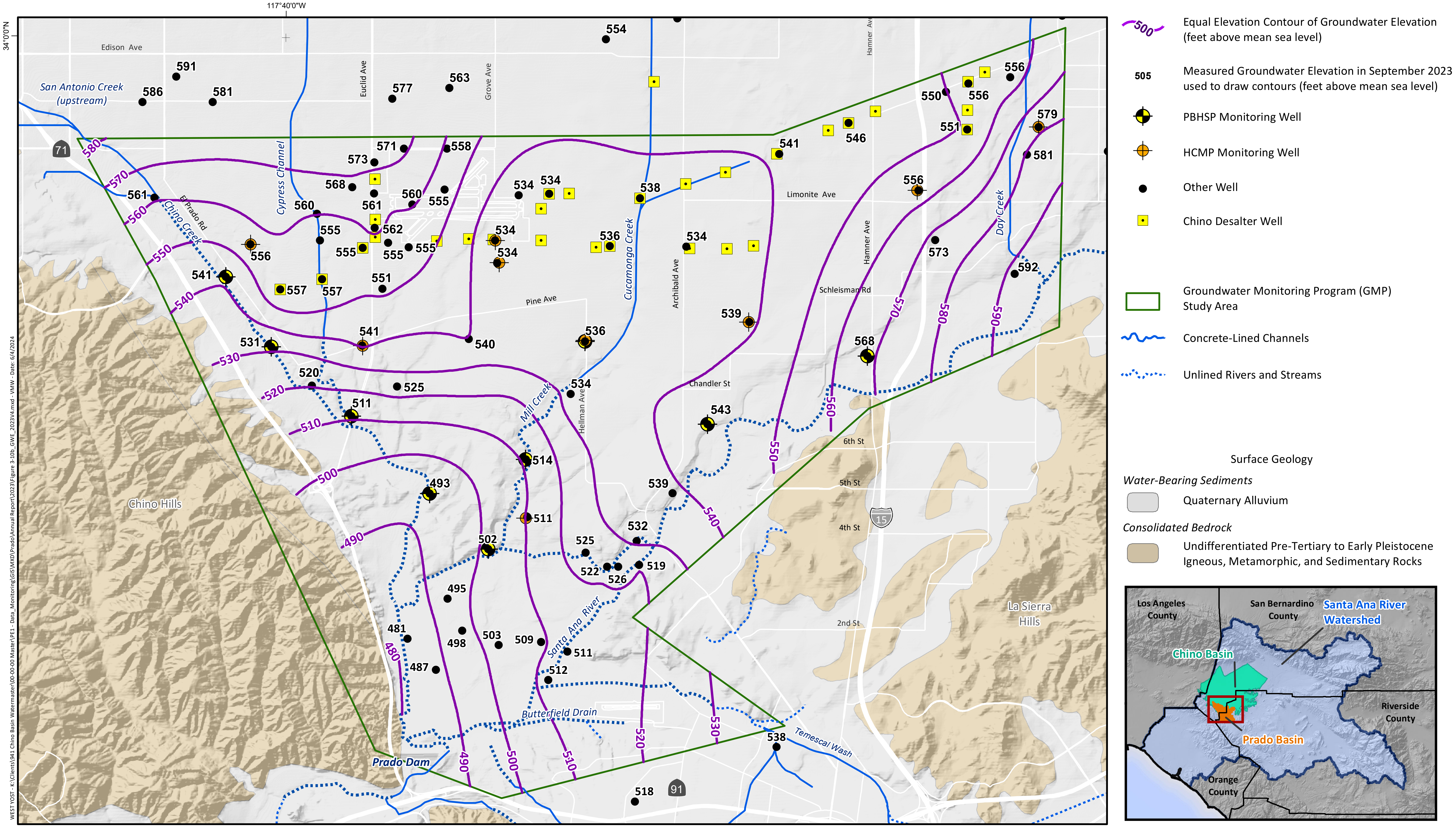
Map of Groundwater Elevation
September 2016 - Shallow Aquifer System

Figure 3-10a



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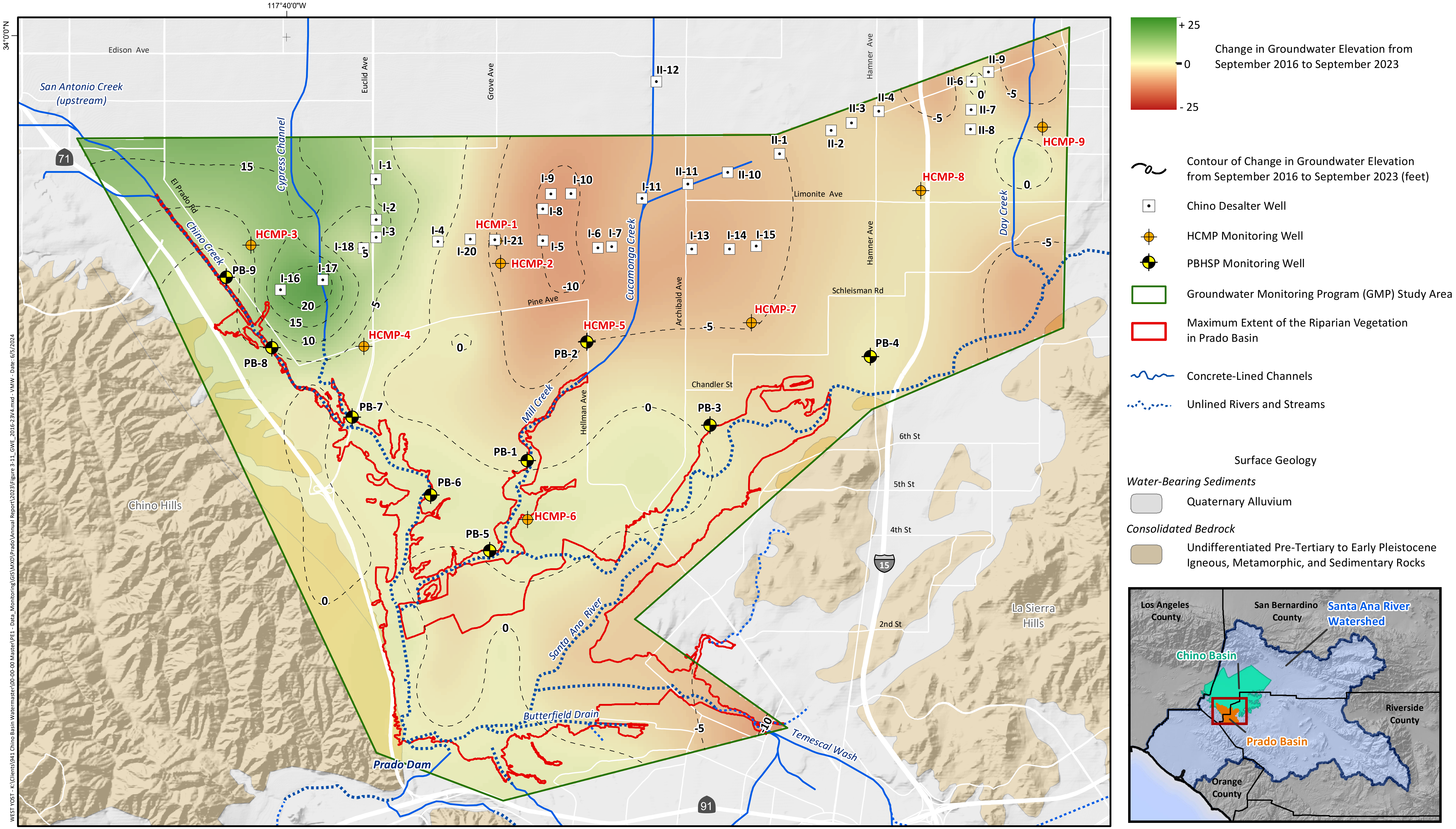
Map of Groundwater Elevation
September 2023 - Shallow Aquifer System

Figure 3-10b



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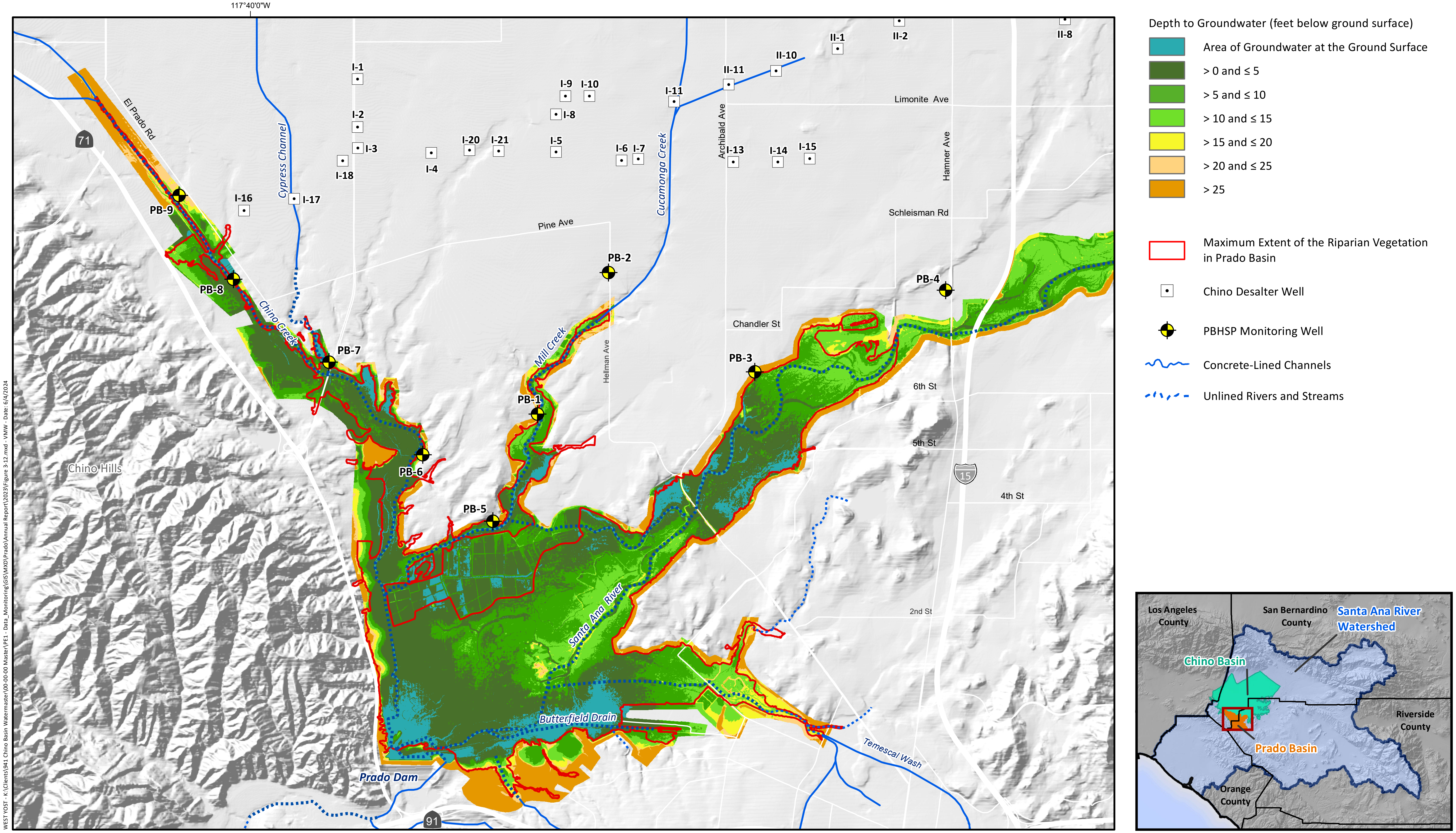
Change in Groundwater Elevation
September 2016 to September 2023

Figure 3-11



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Depth to Groundwater
September 2023

Figure 3-12

3.2.3 Groundwater Levels Compared to NDVI

Figures 3-13a through 3-13c are time-series charts that compare long-term trends in groundwater pumping and groundwater elevations to the trends in the quality of the riparian vegetation as indicated by the NDVI for three reaches in the Prado Basin: Chino Creek, Mill Creek, and the SAR. The period of analysis for these charts is 1984 to 2023—the period of NDVI availability. The upper chart in these figures compares changes in groundwater levels for each respective area to long-term trends in groundwater pumping within the respective regions of the GMP study area (Chino Creek, Mill Creek, and SAR regions). The annual groundwater pumping for wells within the respective regions is a stacked bar chart for the Chino Desalter wells and non-Chino Desalter wells. Groundwater-elevation estimates for the period of 1984 to 2018 were extracted from Watermaster's 2020 calibration of its groundwater-flow model at the monitoring well locations (WEI, 2020). The more recent groundwater-elevation data shown on these charts were measured at monitoring wells constructed by Watermaster and the IEUA to support the Hydraulic Control Monitoring Program (HCMP) (beginning in 2005) and the PBHSP (beginning in 2015). Where the measured and model-estimated groundwater elevations overlap in time, the model-estimated elevations mimic the seasonal fluctuations and longer-term trends of the measured elevations and are typically no more than 10 feet different. This supports the use of these model-estimated groundwater elevations in this analysis to evaluate general historic trends prior to when there were actual water level measurements.

The lower chart in Figures 3-13a through 3-13c displays the time series of the Average Growing-Season NDVI for the defined areas (discussed in Section 3.1) along Chino Creek, Mill Creek, and the SAR. For reference, the Mann-Kendall test results for trends in the Average Growing-Season NDVI for 1984 to 2023, 1984 to 2006, and 2007 to 2023 are shown in the legend.

The NDVI observations and interpretations below focus on recent changes in Average Growing-Season NDVI (Section 3.1) and whether observed groundwater level trends may be contributing to recent NDVI changes.

Chino Creek (Figure 3-13a). During the late 1990s, groundwater levels along Chino Creek increased, particularly along the north reach of Chino Creek, where groundwater levels increased by over 30 feet. The increase in groundwater levels was most likely due to reduced pumping in the area. Since 2000, groundwater levels have remained relatively stable, even as Chino Basin Desalter pumping commenced and increased at CDA wells I-I, I-2, I-3, I-4, I-16, I-17, I-18, I-20, and I-21 to the north of Chino Creek (see inset map on Figure 3-13a). Since 2017, total pumping at these Chino Desalter wells in the Chino Creek area has been at historically low volumes, contributing to a decrease in pumping in this area.

From 2015-2023, the measured groundwater levels at the PBHSP monitoring wells along Chino Creek show an increasing trend along the northern portion of Chino Creek (PB-9/1, PB-8, and RP2-MW3) and stable trend along the central and southern reach, (PB-7/1 and PB-6/1). Groundwater levels fluctuate seasonally, in some cases by more than 15 feet, under the seasonal stresses of pumping and recharge. During the winter months of WY 2017, 2019, and 2023, groundwater levels at the PBHSP monitoring wells increased to their highest recorded levels, likely in response to the recharge of stormwater discharge in unlined creeks and the associated surface-water reservoir that ponds behind Prado Dam. Over the last year (September 2022 to September 2023) groundwater levels increased about 1 foot along the upper northern reach of Chino Creek (PB-9/1), increased by up to 2 feet along lower northern reach (PB-8, and RP3-MW3), and increased by up to 3 feet along the southern reach of Chino Creek (PB-7/1 and PB-6/1).

The Average Growing-Season NDVI and the air photo analyses along Chino Creek show that changes in the vegetation were relatively minor during 2022 to 2023 (discussed in Section 3.1), and the NDVI increased at two of the areas, stayed the same at one area, and decreased at one area. Hence, the main observations and conclusions for the period of 2022 to 2023 for the Chino Creek reach are that groundwater levels increased, and the riparian vegetation did not change significantly.

Mill Creek. ***(Figure 3-13b).*** During the 1990s, groundwater levels along Mill Creek increased, particularly along the north reach of Mill Creek where groundwater levels increased by about 10 feet, most likely due to reduced agricultural pumping in the area. Since 2000, groundwater levels have declined, particularly along the north reach of Mill Creek where groundwater levels have declined by up to 15 feet. The decline in groundwater levels was most likely due to the onset and progressive increase in Chino Basin Desalter pumping at CDA wells I-5, I-6, I-7, I-8, I-9, I-10, I-11, I-20, I-21 to the north of Mill Creek (see inset map on Figure 3-13b). Since 2017, total pumping at these Chino Desalter wells in the Mill Creek area have progressively increased, reaching a historically high volume in 2021 and slightly declining after, contributing to the overall increase in the total pumping observed in this area.

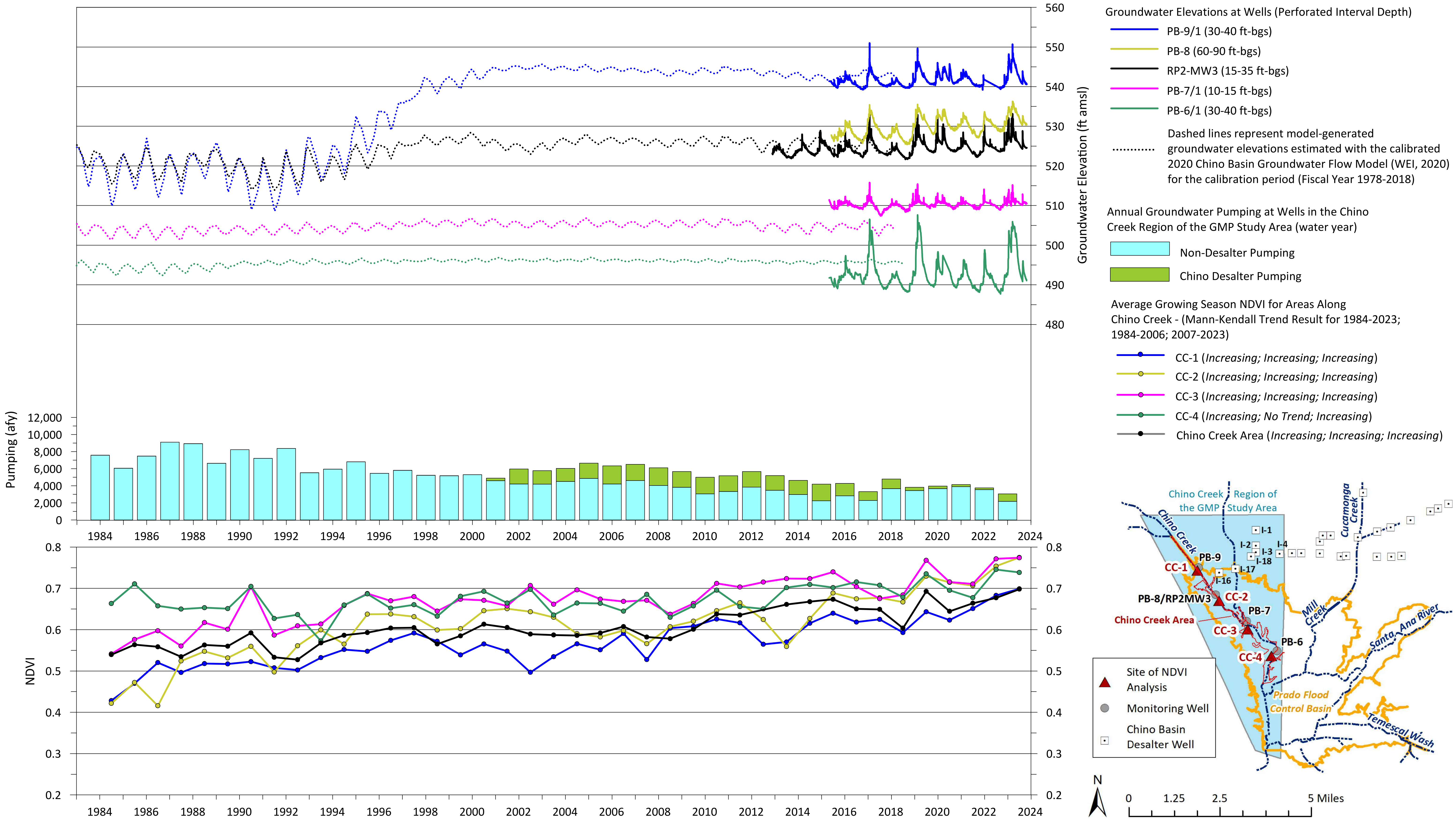
From 2015 to 2023, the measured groundwater levels at the PBHSP monitoring wells along Mill Creek show a decreasing trend in the northern portion of Mill Creek (PB-2 and HCMP-5/1) and a slight decreasing trend in the central reach (PB-1/2), and a stable trend in the southern reach (PB-5/1 and HCMP-6/1). The decreases in groundwater levels in the northern Mill Creek area are likely due to the increase in pumping observed in this area. Groundwater levels fluctuate seasonally, in some cases by more than 10 feet, under the seasonal stresses of pumping and recharge. During the winter months in WY 2017, WY 2019, and WY 2023, groundwater levels at most of the PBHSP monitoring wells increased to their highest recorded levels, likely in response to the recharge of stormwater discharge in unlined creeks and the associated surface-water reservoir that ponds behind Prado Dam. Over the last year (September 2022 to September 2023) groundwater levels increased at all the monitoring wells along Mill Creek by 3 to 4 feet. This increase follows a year of decreasing trends and historically low groundwater levels in this area.

The Average Growing-Season NDVI and air photo analyses along Mill Creek show that changes in the vegetation were relatively minor during 2022 to 2023 (discussed in Section 3.1), and the NDVI increased at all of the areas. Hence, the main observations and conclusions for the period of 2022 to 2023 for the Mill Creek reach are that groundwater levels increased and the riparian vegetation did not change significantly. The NDVI for the Upper Mill Creek, MC-1, MC-5, and MC-6 areas in the northern portion of Mill Creek where groundwater levels have declined the most since 2016 continued to show an increasing trend over this past year.

Santa Ana River (***Figure 3-13c***). During the 1990s, the groundwater levels along SAR increased in response to a decline in pumping from 1990 to 2000. These responses were greatest along the eastern portion of SAR where they increased up to five feet. Since 2000, groundwater levels have declined by a similar magnitude along the eastern portion of the SAR due to the onset and progressive increase in Chino Basin Desalter pumping at CDA wells I-13, I-14, I-15, and II-1 through II-11 to the north of the SAR (see inset map on Figure 3-13c), while groundwater levels slightly increased along the western portion of the SAR near the Archibald well. Since 2018, total pumping at these Chino Desalter wells in the SAR area have progressively increased to a historically high volume in 2021, declining only slightly since, contributing to the increase in the total pumping observed in this area.

From 2015 to 2023, the measured groundwater levels at the PBHSP monitoring wells show a slight decreasing trend along the northeastern portion near PB-4, a stable trend along the northern portion near PB-3/1, and a slight increasing trend along the southwestern portion near the Archibald 1. The decreases in groundwater levels in the northeastern portion of the SAR area (near PB-4) are likely due to the increase in pumping observed in this area. Groundwater levels fluctuate seasonally, in some cases by up to three feet under the seasonal stresses of pumping and recharge. Over the last year, from September 2022 to September 2023, groundwater levels at the monitoring wells along the SAR increased by about 1.5 feet along the northeastern and northern portions (PB-4/1 and PB-3/1) and increased by about 1 foot along the western portion (Archibald 1).

The Average Growing-Season NDVI and air photo analyses along the SAR show that changes in the vegetation were relatively minor during 2022-2023 (discussed in Section 3.1) and the NDVI increased at all of the areas except for LP. Hence, the main observations and conclusions for the period of 2022 to 2023 for the SAR reach are that groundwater levels increased and the riparian vegetation did not change significantly.



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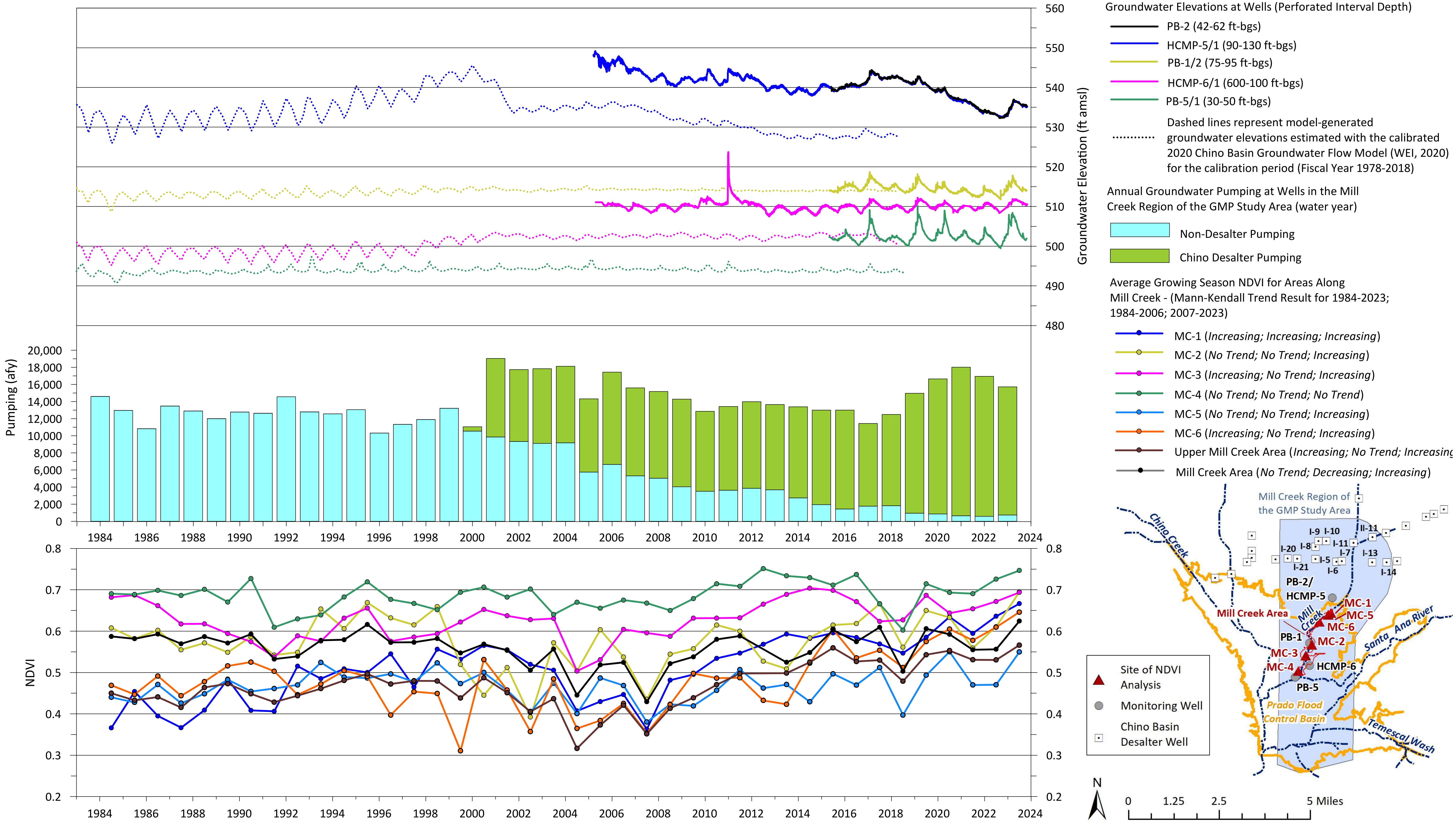
Groundwater Levels and Production versus NDVI
Chino Creek Area for 1984-2023

Figure 3-13a



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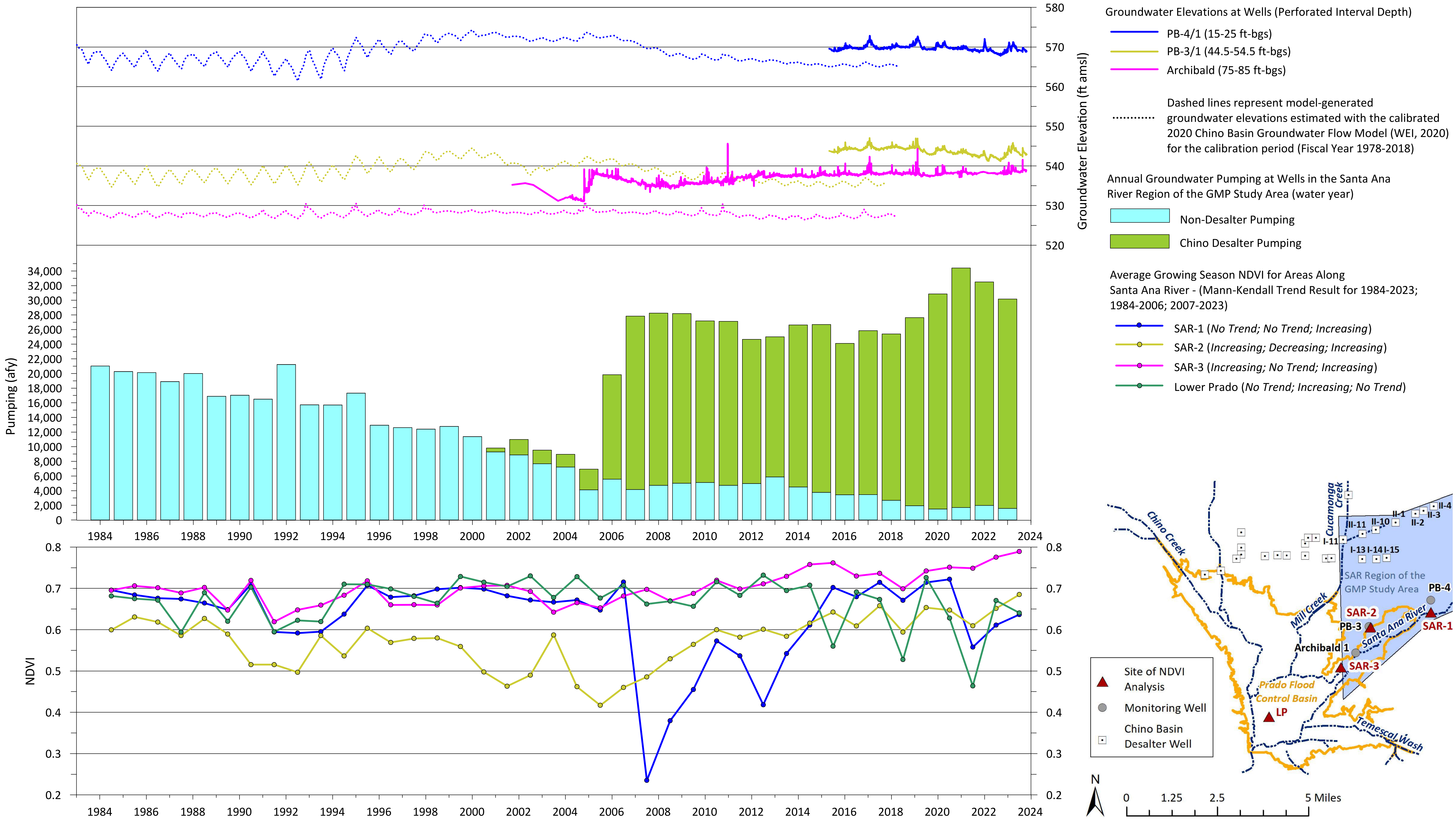
Groundwater Levels and Production versus NDVI
Mill Creek Area for 1984-2023

Figure 3-13b



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Groundwater Levels and Production versus NDVI
Santa Ana River Area for 1984-2023

Figure 3-13c

3.2.4 Summary

The following observations and interpretations were derived from the analysis of groundwater pumping, groundwater levels, and NDVI:

- From 1961 to 1990, groundwater pumping from private domestic and agricultural wells in the study area averaged about 45,900 afy. From 1991 to 1999, groundwater pumping steadily declined to about 23,600 afy primarily due to conversions from agricultural to urban land uses. In 2000, CDA pumping commenced to replace the declining agricultural production, and by 2018, groundwater pumping in the study area was about 37,000 afy. Since WY 2019, total groundwater pumping in the study area increased almost 10,000 afy due to increased CDA pumping, to reach its intended pumping rate of 40,000 afy. In WY 2023, there was 41,149 af total groundwater pumping in the GMP study area; 36,687 af of this was CDA pumping.
- Since groundwater-level measurements commenced at the PBHSP monitoring wells in 2015, there have been some increasing and decreasing trends in groundwater levels observed in the riparian vegetation area along the reaches of Chino Creek, Mill Creek, and SAR. From September 2016 to September 2023, groundwater levels have changed less than +/-5 feet throughout most of the extent. Groundwater levels have declined the most along the northern portion of Mill Creek, just south of the PB-2 monitoring well, where levels decreased by five feet likely due to increased pumping at the Chino Desalter wells to the north. Groundwater levels increased the most over this period in the northern reach of Chino Creek by about 15 feet where pumping has decreased.
- Over the past year from 2022 to 2023 groundwater levels generally increased or remained stable in the Prado Basin near the riparian vegetation areas along the reaches of the SAR, Mill Creek, and southern portion of Chino Creek. From 2022 to 2023 groundwater levels increased in areas where they were at historical lows the previous year as measured for the PBHSP. Of note is the northern portion of Mill Creek, where groundwater levels declined by about eight feet just south of PB-2 through 2022 and have now increased three feet over this last year. In Section 3.1, the analysis of air photos and NDVI for the riparian habitat in indicates that the riparian vegetation did not change significantly in any of the areas, and there was a general increase in NDVI.

3.3 Analysis of Groundwater/Surface Water Interactions

One of the objectives of the PBHSP is to identify factors that contribute to the long-term sustainability of Prado Basin riparian habitat. The depth to groundwater analysis shown in Figure 3-12 indicates that the riparian vegetation exists in areas of shallow groundwater, where groundwater levels are typically 15 ft-bgs or less, and that the riparian vegetation is likely dependent, at least in part, upon the shallow groundwater. There have been multiple studies for the PBHSP on the groundwater/surface-water interactions in the Prado Basin to determine the source of shallow groundwater that is available for consumptive use by the riparian vegetation, and that may be important to the long-term sustainability of the riparian habitat.

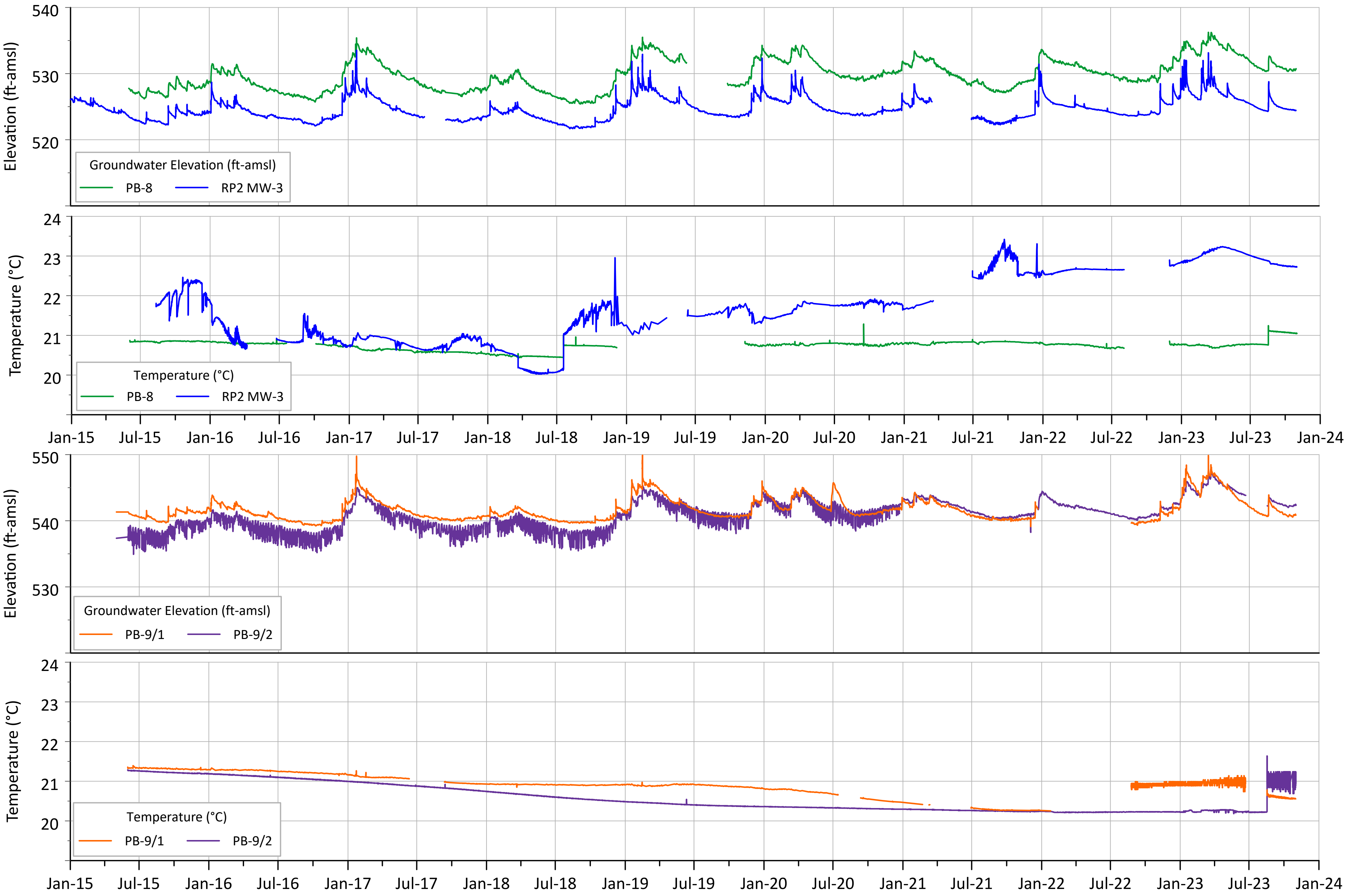
3.3.1 Past Monitoring of Groundwater/Surface Water Interactions:

Historical monitoring of groundwater/surface water interactions for the PBHSP include:

- From FY 2015 to FY 2018 quarterly groundwater samples were collected from the 18 PBHSP monitoring wells and analyzed at a minimum for general minerals. The general mineral chemistry data collected was analyzed along with groundwater-level data, model-generated groundwater-flow directions, and surface-water quality and flow data to help characterize groundwater/surface-water interactions in the Prado Basin and determine the source of the shallow groundwater.
- The Annual Reports for WY 2017 and WY 2018 (Section 3.3) included a comprehensive analysis to understand the sources of the shallow groundwater in the Prado Basin (WEI, 2018; 2019). The analysis included using surface-water discharge and quality, groundwater quality, groundwater levels, and groundwater modeling as multiple lines of evidence to analyze the groundwater/surface water interactions at the nine PBHSP well locations—along the fringes of the riparian habitat and adjacent to Chino Creek, Mill Creek, and the SAR. In general, the analysis concluded that the SAR and northern portion of Mill Creek are losing reaches, characterized by streambed recharge. Most other areas along Chino and Mill Creeks are gaining reaches, characterized by groundwater discharge. That said, at most locations in the Prado Basin, there appear to be multiple and transient sources that feed the shallow groundwater, and the groundwater/surface-water interactions are complex. Additional monitoring was recommended to better characterize the sources of shallow groundwater and groundwater/surface-water interactions.
- From FY 2018 to FY 2023 a pilot monitoring program was conducted to determine if the high-frequency data enhances and better reveals the interpretation of groundwater/surface-water interactions previously studied for the PBHSP. The pilot monitoring program included the installation of transducers that record EC, temperature, and water levels at 15-minute intervals at two locations in Chino Creek and the same high-frequency monitoring at four nearby monitoring wells (PB-7 and PB-8 clusters). Additionally, during the first two years of the pilot monitoring program, surface water and groundwater-quality samples were collected to support the high-frequency data.
- The Annual Report for WY 2022 included an analysis of the pilot monitoring program data (West Yost, 2023). The analysis concluded that that the high-frequency monitoring of EC and temperature at shallow monitoring wells can reveal the source waters that recharge shallow groundwater. Additionally, the high-frequency monitoring of groundwater-level elevations, surface water stage, and thalweg elevations can also reveal the source waters that recharge shallow groundwater. We also learned from the pilot monitoring program that it is difficult to collect high-frequency data in the surface water because the transducers are oftentimes lost during large storm events and the transducers become clogged with mud which compromises the accuracy of the data. The WY 2022 report included recommendations to discontinue the pilot monitoring program and, in its place, use the high-frequency monitoring of EC, temperature, and water level for each pair of PBHSP monitoring wells, most of which was already being collected, and collect quarterly field measurements for EC and temperature of the surface water flowing in the streams adjacent to the monitoring wells.

3.3.2 Current Monitoring for Groundwater/Surface Water Interactions

In 2023 the monitoring of groundwater/surface water interactions per the recommendations in the WY 2022 Annual Report from the analysis of the pilot monitoring program (described above) included: (i) processing and compiling the high-frequency temperature data which was already being collected at all the PBSHP monitoring wells since 2015; (ii) establishing the locations of surface water sites near the PBHSP monitoring wells to collect field measurements of EC and temperature, and initiating quarterly measurements; and (iii) replacing transducers at the PBHSP monitoring wells as needed with transducers that measure EC in addition to temperature and level readings (now ten wells have transducer that measure EC). Later in 2024 professional elevation surveys of the stream thalweg elevation next to all PBHSP monitoring wells will be conducted. Figures 3-14a through 3-14e are time series charts that display the high-frequency temperature and water level data that have been collected at the PBHSP monitoring wells. Each figure includes the shallow and deeper well at two well locations adjacent to the Chino Creek, Mill Creek, or SAR. Subsequent Annual Reports will show these charts with the addition of the other data that began to be collected in 2023 (high-frequency EC, surface water field measurements of EC/temperature, and stream thalweg elevations), and will be used to analyze the groundwater/surface water interactions at these locations.



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High-Frequency Monitoring to Characterize Groundwater/Surface-Water Interactions

Chino Creek Near PB-8 and PB-9

Figure 3-14a

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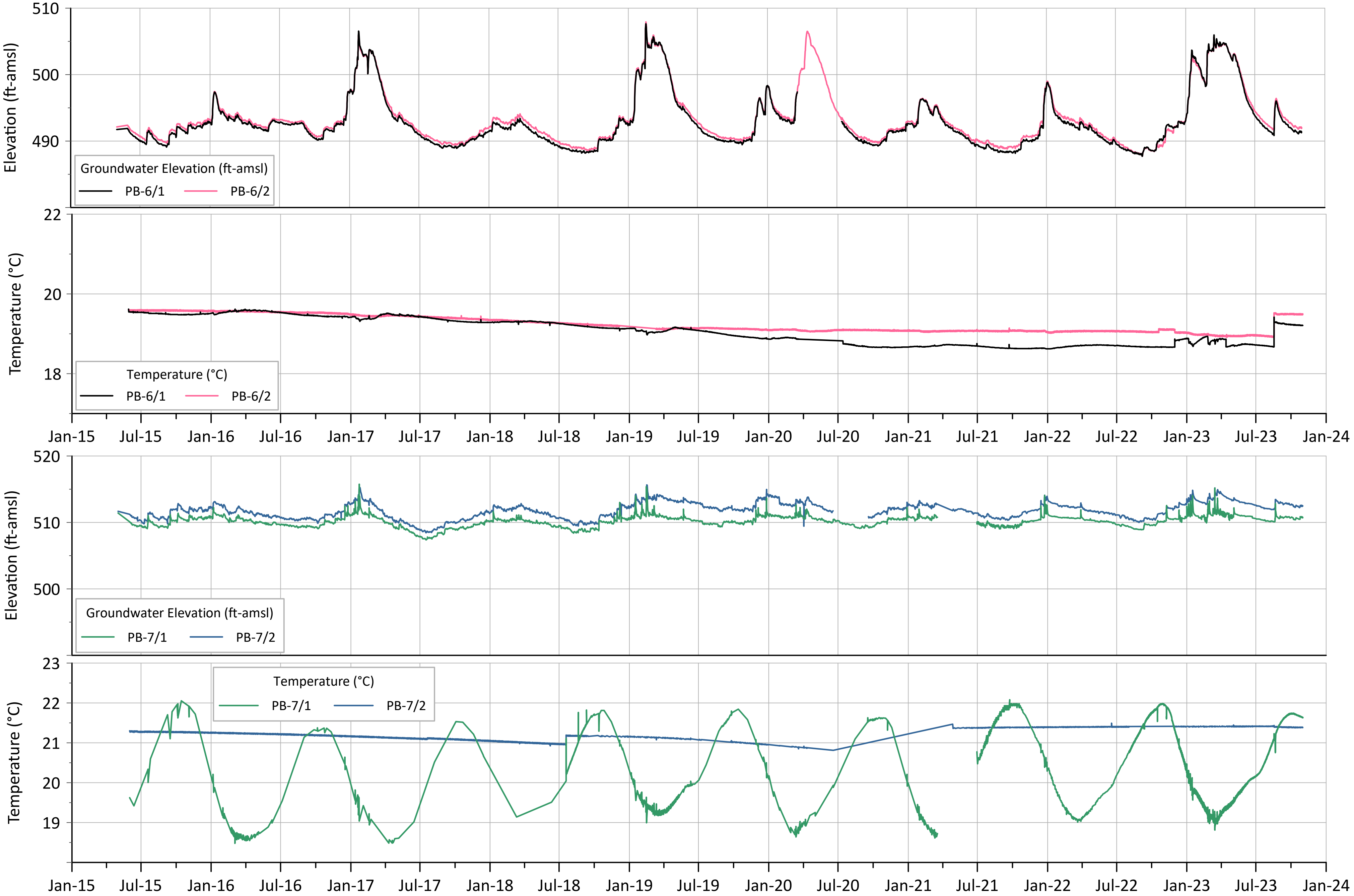

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High-Frequency Monitoring to Characterize Groundwater/Surface-Water Interactions
Chino Creek Near PB-6 and PB-7

Figure 3-14b

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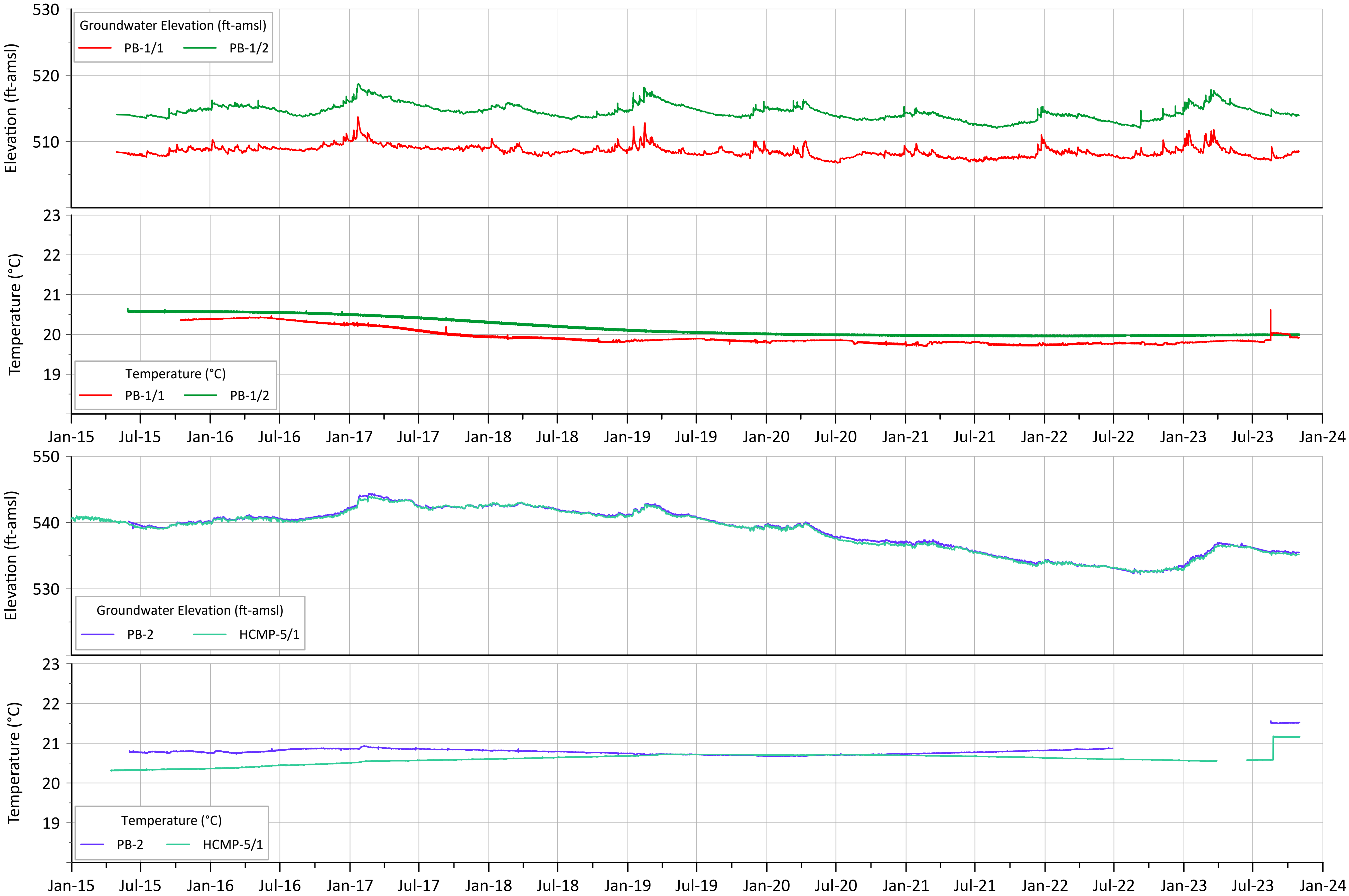

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Mill Creek Near PB-1 and PB-2

Figure 3-14c

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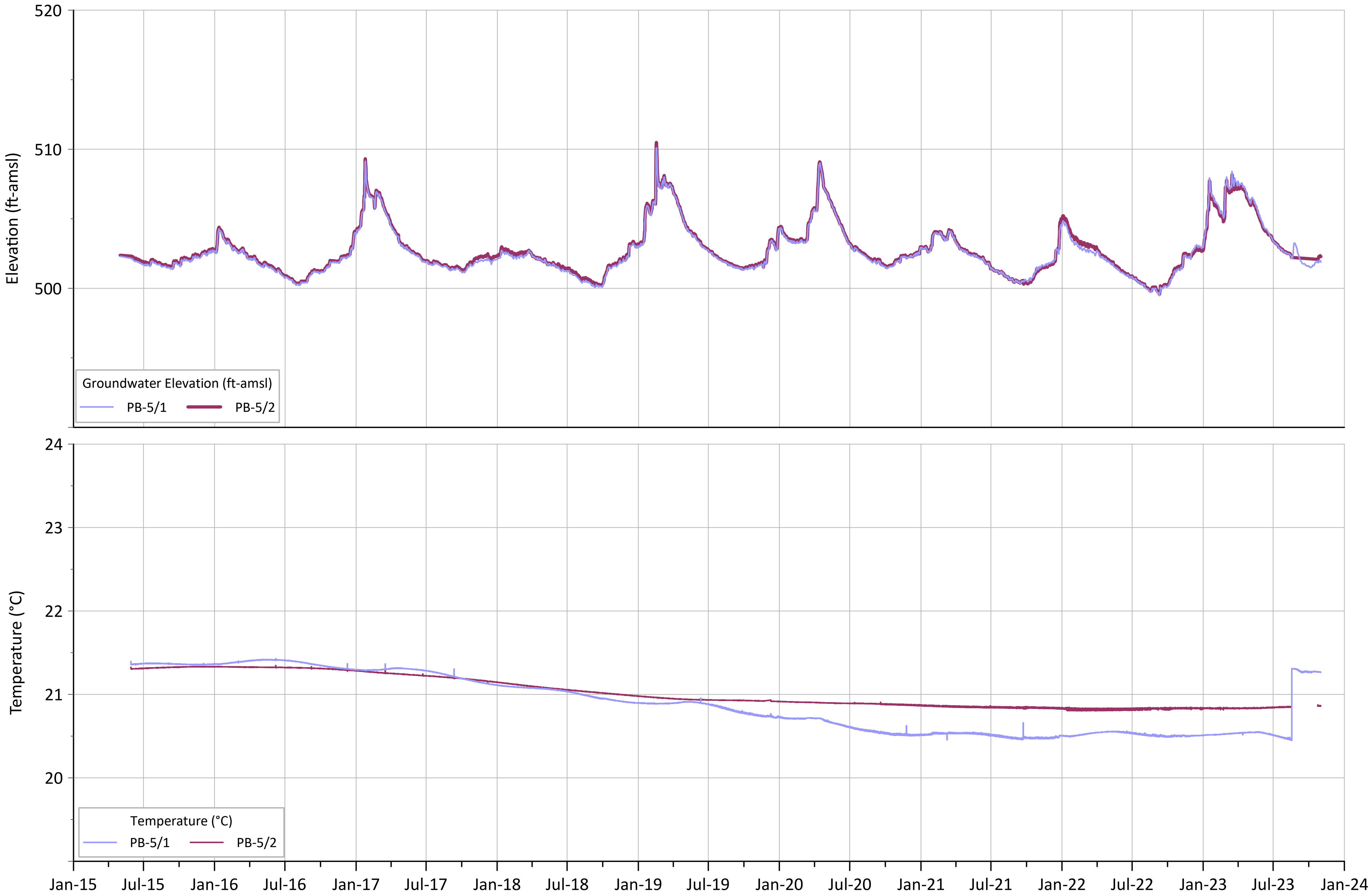

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Mill Creek Near PB-5

Figure 3-14d

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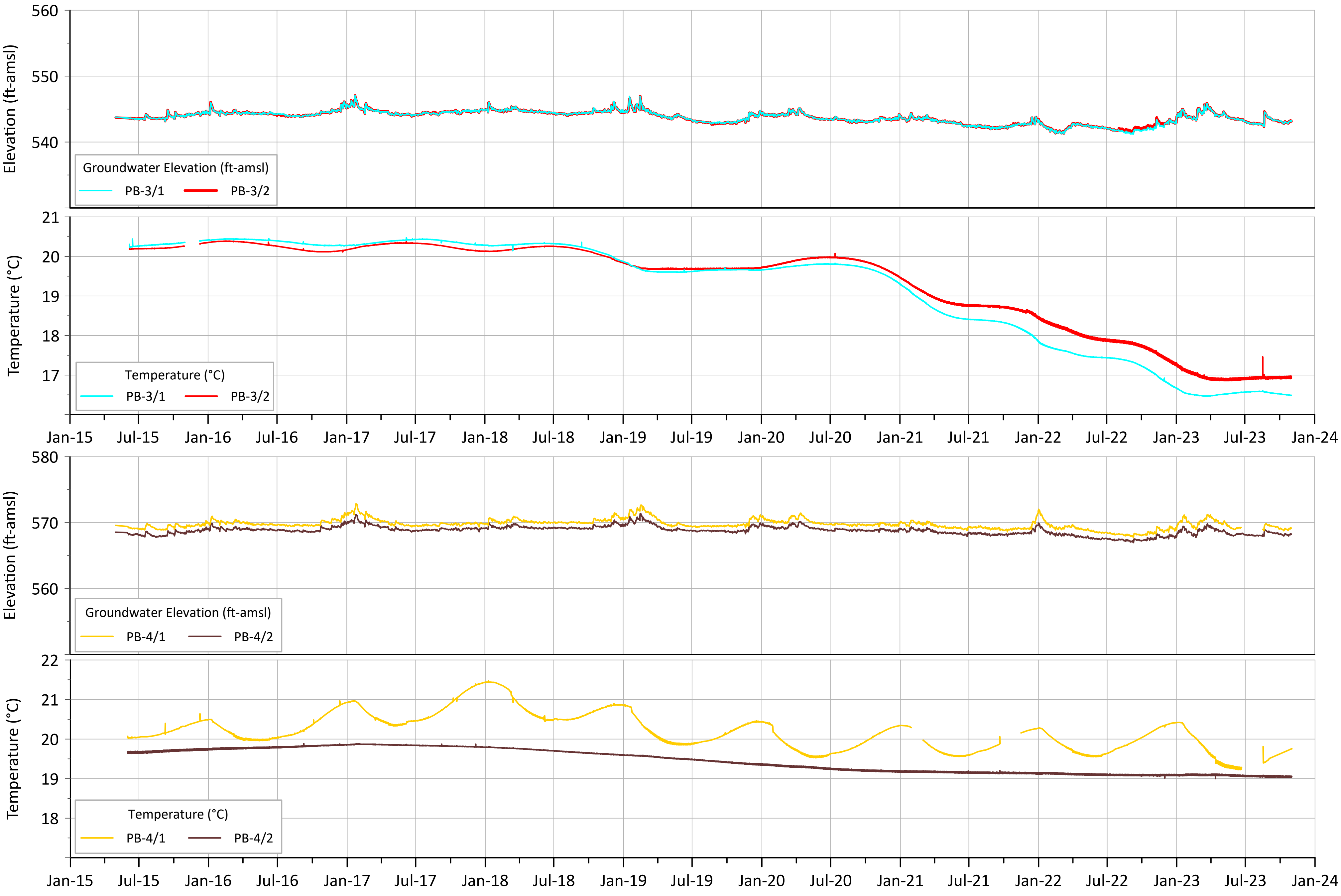

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High-Frequency Monitoring to Characterize Groundwater/Surface-Water Interactions

SAR Near PB-3 and PB-4

Figure 3-14e

3.4 Climate and Its Relationship to the Riparian Habitat

Precipitation and temperature are climatic factors that can affect the extent and quality of riparian habitat. Precipitation can provide a source of water for consumptive use by the riparian vegetation via the direct infiltration of precipitation and runoff, which increases soil moisture that can be directly used by the vegetation, or by maintaining groundwater levels underlying the vegetation for its subsequent use. Temperatures affect the rate of plant growth and productivity. Both factors are unrelated to the implementation of the Peace II Agreement. This section characterizes the time series of precipitation and temperature in the Prado Basin area and compares that time series to trends in the quality of the riparian habitat, as indicated by NDVI, to help determine if these factors have influenced the riparian habitat in the Prado Basin.

3.4.1 Precipitation

Figure 3-15 is a time-series chart that shows annual precipitation estimates within the Chino Basin for WY 1896 to 2023. These estimates were computed as a spatial average across the Chino Basin using rasterized data from the PRISM Climatic Group (an 800-meter by 800-meter grid). The long-term average annual precipitation in the Chino Basin is 16.3 inches per year (in/yr). The chart includes a cumulative departure from mean (CDFM) precipitation curve, which characterizes the occurrence and magnitude of wet and dry periods: positive sloping segments (trending upward to the right) indicate wet periods, and negative sloping segments (trending downward to the right) indicate dry periods.

Review of the CDFM precipitation curve indicates that the Chino Basin experienced several prolonged wet and dry periods from WY 1896 to 2023. Typically, dry periods are longer in duration than wet periods. The longest dry period occurred between 1946 through 1977 (32 years). The current dry period is a 25-year period, starting in WY 1999, and includes the Peace/Peace II Agreement period (2001 through 2023). Over the 128-year record, about 40 percent of the years had precipitation greater than the average, and 60 percent had below average precipitation. In the 23-year period since the Peace Agreement was implemented, about 30 percent of the years had precipitation greater than the average, and 70 percent had below average precipitation. Precipitation in WY 2023 was 29.85 inches, which is:

- 13.55 inches above the long-term average
- about 3.5 times as much as the previous WY 2022 (8.73 inches)
- the highest annual precipitation since WY 2005 (37.91 inches)
- the ninth highest annual precipitation over the 128-year record

3.4.2 Temperature

Maximum and minimum temperatures during the growing season are the temperature metrics used in this analysis because plant growth and development are dependent upon the temperatures surrounding the plant (Hatfield and Prueger, 2015). Maximum temperatures during the growing season directly influence photosynthesis, evapotranspiration, and breaking of the dormancy of vegetation (Pettorelli, 2015). Minimum temperatures affect nighttime plant respiration rates and can potentially have an effect on plant growth that occurs during the day (Hatfiled et al., 2011). Hence, both temperature metrics can influence NDVI. All species of plants have a range of maximum and minimum temperatures necessary for growth (Hatfield and Prueger, 2015). Climate change is more likely to increase minimum temperatures while maximum temperatures are affected more by local conditions (Knowles et al., 2006; Alfaro et al., 2006).

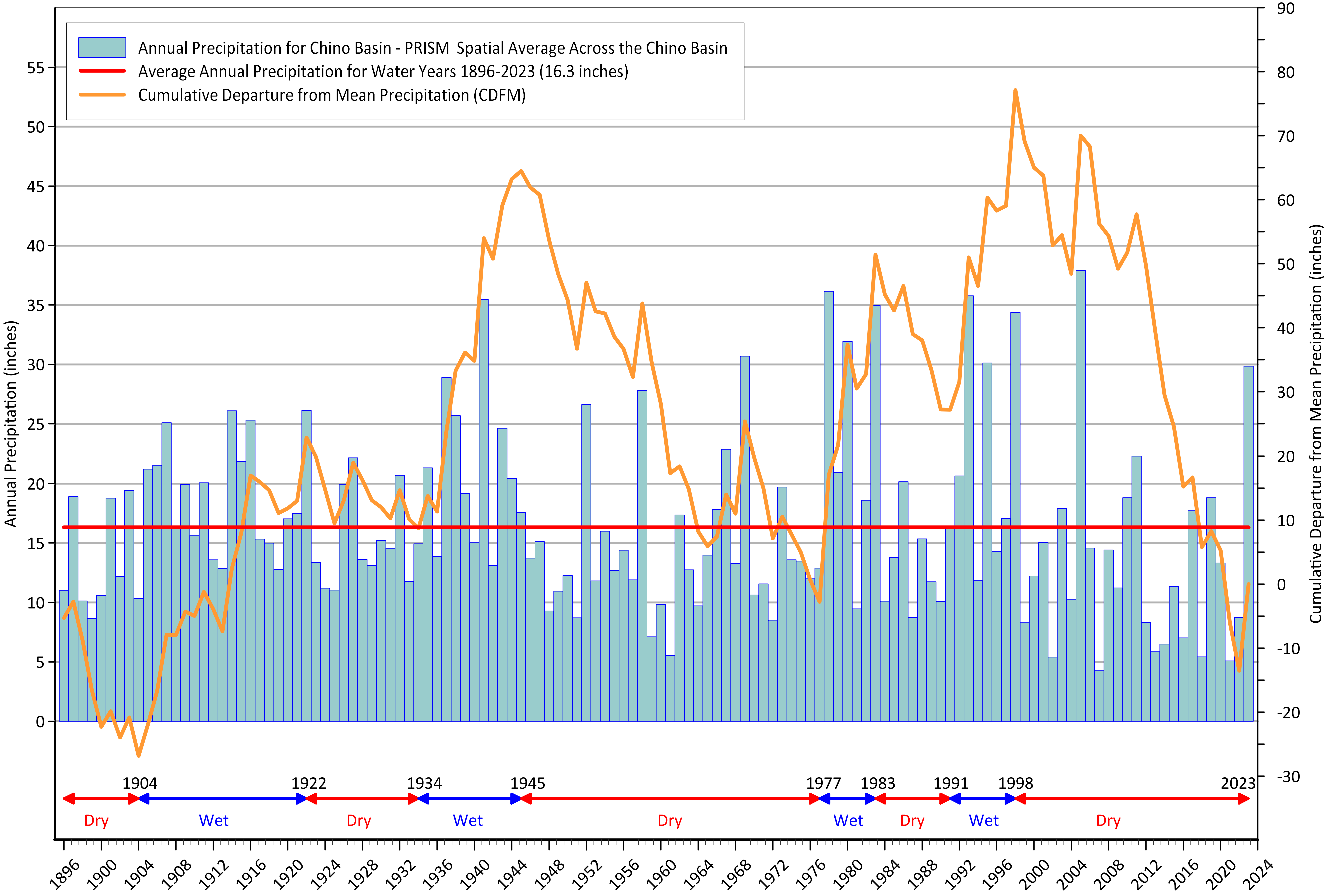
Figure 3-16 is a time-series chart that shows the average maximum and minimum Prado Basin temperatures for the growing-season months of March through October from 1896 to 2023 (growing-season maximum and minimum temperatures). These temperature estimates were computed as a spatial average across the Prado Basin using rasterized data from the PRISM Climatic Group (an 800-meter by 800-meter grid) of monthly maximum and minimum temperature estimates. This chart also shows the five-year moving average of the growing-season maximum and minimum temperatures for the Prado Basin. The five-year moving average is a smoothing technique used to reveal trends over time.

This chart also shows a complete record of atmospheric carbon dioxide (CO_2) concentrations assembled from multiple sources:

- Values prior to 1959 were estimated from an analysis of the Law Dome DE08 and DE08-2 ice cores in Antarctica. (Acquired from the Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov/trends/co2/lawdome.html. Accessed on June 6, 2017).
- Values after 1959 are from measured CO2 concentration data at the Mauna Loa Observatory in Hawaii. (Acquired from the National Oceanic and Atmospheric Association's Earth Systems Research Laboratory, https://www.esrl.noaa.gov/gmd/ ccgg/trends/full.html. Accessed on February 4, 2024.

The time history of atmospheric CO_2 concentrations shows a slight increasing trend from about 290 parts per million (ppm) in the late 1890s to about 310 ppm in 1950. After 1950, the CO_2 concentration shows an amplified increasing trend and exceeds 400 ppm by 2015.

From 1896 to 2023, the growing-season maximum temperature fluctuates between 80 degrees Fahrenheit (°F) to 87°F and has a slight increasing trend. From 1896 to 2023, the growing-season minimum temperature fluctuates between 49°F to 59°F and has a prominent increasing trend starting in 1950 of about 5°F through 2023. This increasing trend in the growing-season minimum temperature beginning 1950 appears to correlate with the increase in atmospheric CO_2 concentrations. The five-year moving averages of both the growing-season minimum and maximum temperatures display a decreasing trend over the recent five-year period since 2018 when it had the highest values over the entire period of record. In 2023, the growing-season minimum and maximum temperatures and the five-year moving averages all decreased from the previous period. The average growing-season minimum temperature was 57°F and the average growing-season maximum temperature was 82°F.



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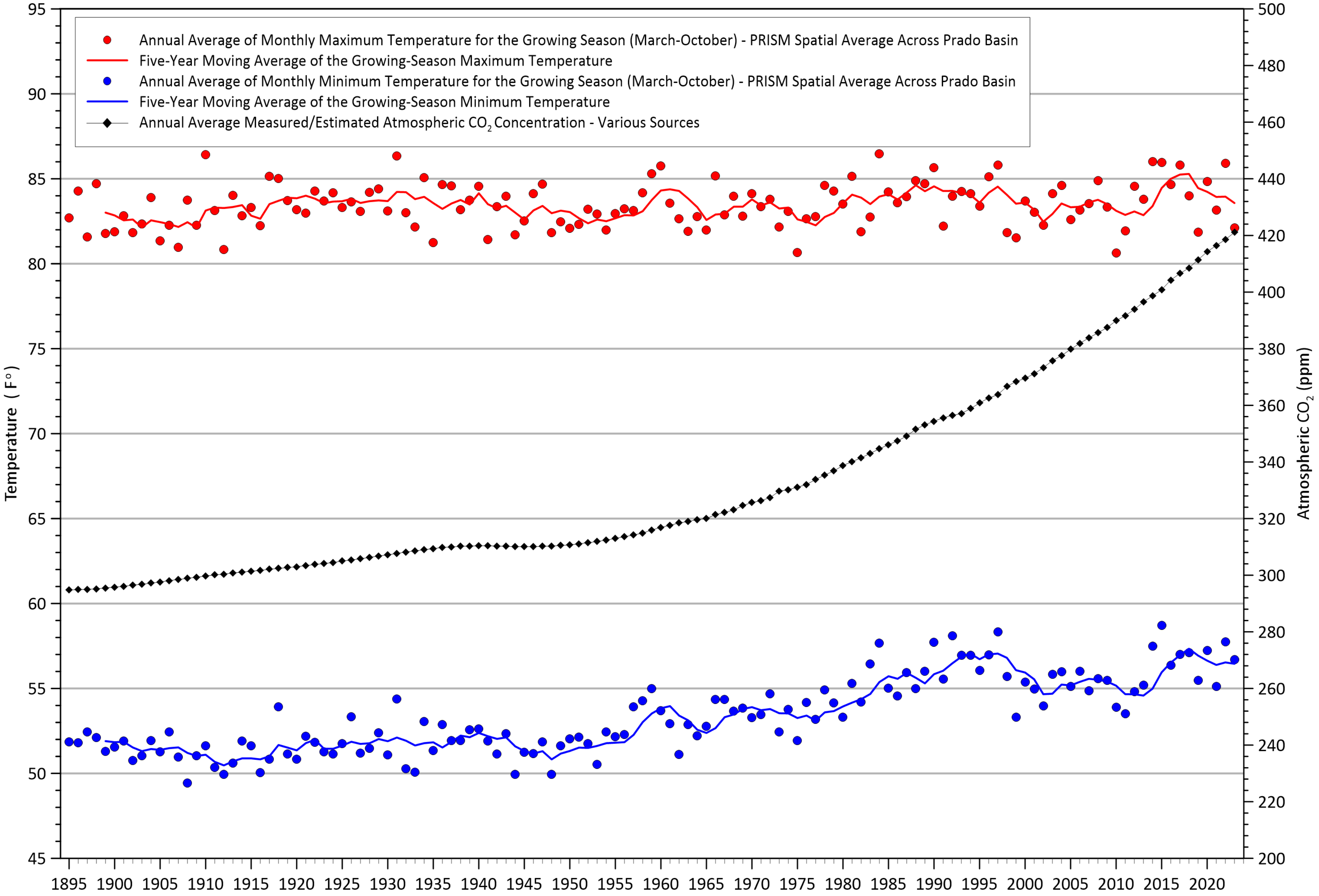
Annual Precipitation in the Chino Basin
Water Year 1986 - 2023

Figure 3-15



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Maximum and Minimum Temperature in Prado Basin

1895-2023

Figure 3-16

WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GRAPHER\GRF\Prado\AnnualR\Figure 3-16_Prado_Max_Min_Temp.grf - lhedley - 2/4/2024

3.4.3 Climate Compared to NDVI

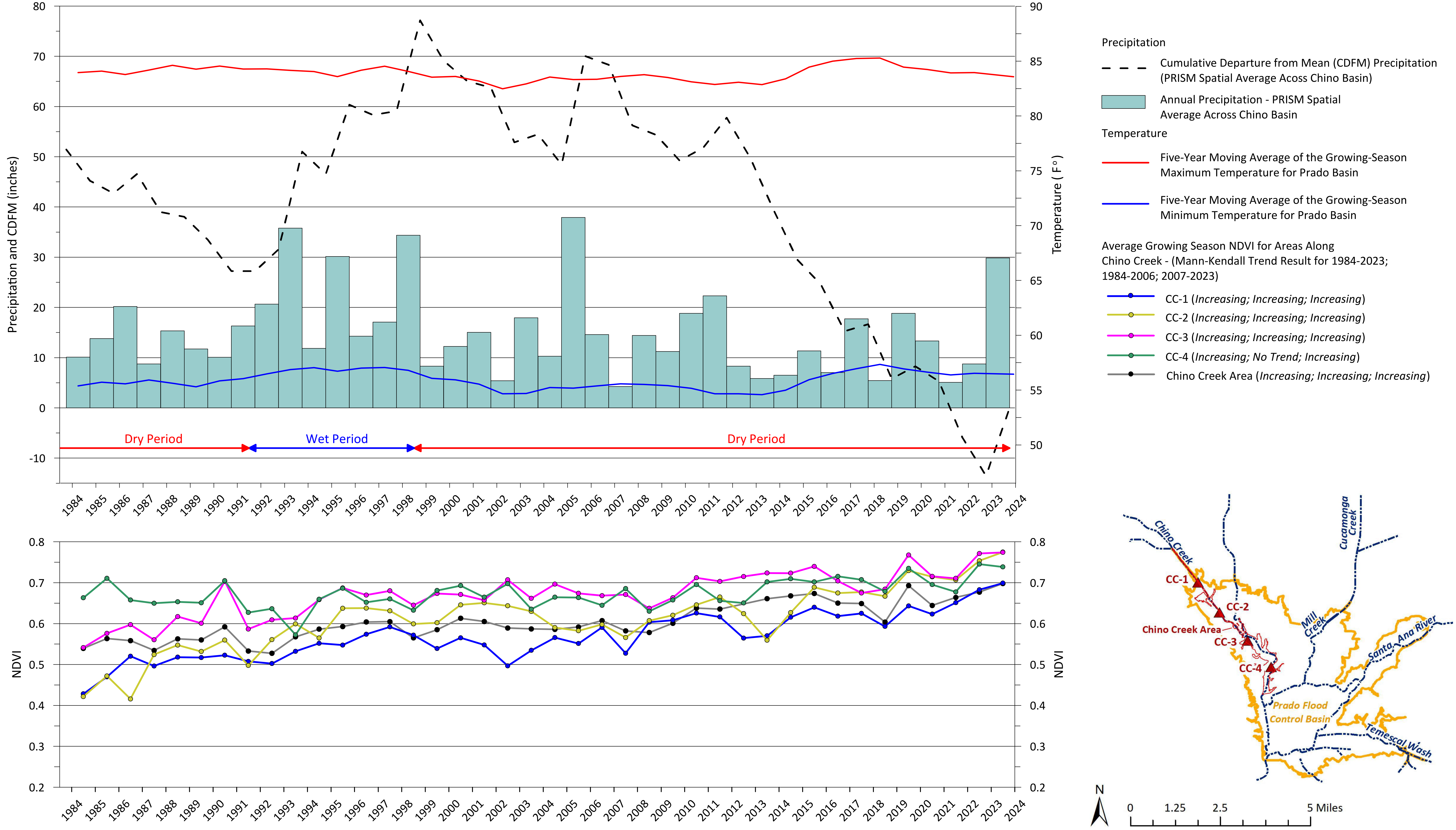
Figures 3-17a through 3-17c are time-series charts that compare long-term trends in precipitation and temperature to trends in the quality of the riparian vegetation, as indicated by NDVI, for three reaches in the Prado Basin: Chino Creek, Mill Creek, and the SAR. The period of analysis is 1984-2023—the period of NDVI availability. The upper chart on the figures displays the time series of annual precipitation in Chino Basin, the CDFM precipitation curve, and the five-year moving average for the growing-season maximum and minimum temperatures in the Prado Basin. The lower chart displays the time series of the Average Growing-Season NDVI for the defined areas discussed in Section 3.1 along Chino Creek, Mill Creek, and the SAR. For reference, the Mann-Kendall test results for trends in the Average Growing-Season NDVI for 1984-2023, 1984-2006, and 2007-2023 are shown in the legend.

The observations and interpretations below are focused on recent changes in Average Growing-Season NDVI during 2023 described in Section 3.1 and whether observed trends in temperature and precipitation may be contributing to recent increases in NDVI.

Chino Creek (Figure 3-17a). From 2022 to 2023, the Average Growing-Season NDVI for the whole Chino Creek area increased. Average Growing-Season NDVI increased for the two northern-most areas along Chino Creek (CC-1 and CC-2), stayed the same for the central area (CC-3), and decreased for the southern-most area (CC-4). For all these areas, the one-year increases in NDVI were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI and vegetation occurred during a year in which precipitation was well above average and significantly greater than the prior year. The wetter conditions are likely a contributing cause of the various changes in the NDVI along Chino Creek. Increases in precipitation likely caused more green plant growth in the northern reach of Chino Creek causing the increases in the NDVI. Flooding in the southern areas of Chino Creek and water held behind the dam may have caused a slight decrease in NDVI during the early part of the growing season. Previous annual reports have observed overall similar trends with NDVI increases throughout the Prado Basin in years with increased precipitation (WEI, 2019). Hence, the main observations and conclusions for the 2022 to 2023 period are that there were much wetter conditions and the riparian vegetation did not change significantly along Chino Creek.

Mill Creek (Figure 3-17b). From 2022 to 2023, the Average Growing-Season NDVI increased for the whole Mill Creek and Upper Mill Creek areas, and the six areas along Mill Creek. At all the areas, the one-year NDVI changes are within their historical ranges of the one-year NDVI variability, however, the increase in NDVI for MC-2 and MC-5, as well as for the entire Mill Creek area was greater than the average annual change in NDVI over the historical period of record (see Table 3-2). These recent changes in NDVI and vegetation occurred during a year in which precipitation was well above average and significantly greater than the prior year. The wetter conditions are likely a contributing cause of the increases in the NDVI observed along Mill Creek. Previous annual reports have observed similar trends with NDVI increases throughout the Prado Basin in years with increased precipitation (WEI, 2019). Hence, the main observations and conclusions for the 2022 to 2023 period are that there were much wetter conditions and the riparian vegetation increased but did not change significantly along Mill Creek.

Santa Ana River (Figure 3-17c). From 2022 to 2023, the Average Growing-Season NDVI increased at three of the areas along the SAR and decreased at one of the areas (LP). For all of these areas, the one-year NDVI changes were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI and vegetation occurred during a year in which precipitation was well above average and significantly greater than the prior year. The wetter conditions are likely a contributing cause of the increases in the NDVI observed along the SAR. Previous annual reports have observed similar trends with NDVI increases throughout the Prado Basin in years with increased precipitation (WEI, 2019). The slight decrease in NDVI for the LP area is likely because the area was flooded during the early part of the growing season. Hence, the main observations and conclusions for the 2022 to 2023 period are that there were wetter conditions and the riparian vegetation did not change significantly along the SAR.



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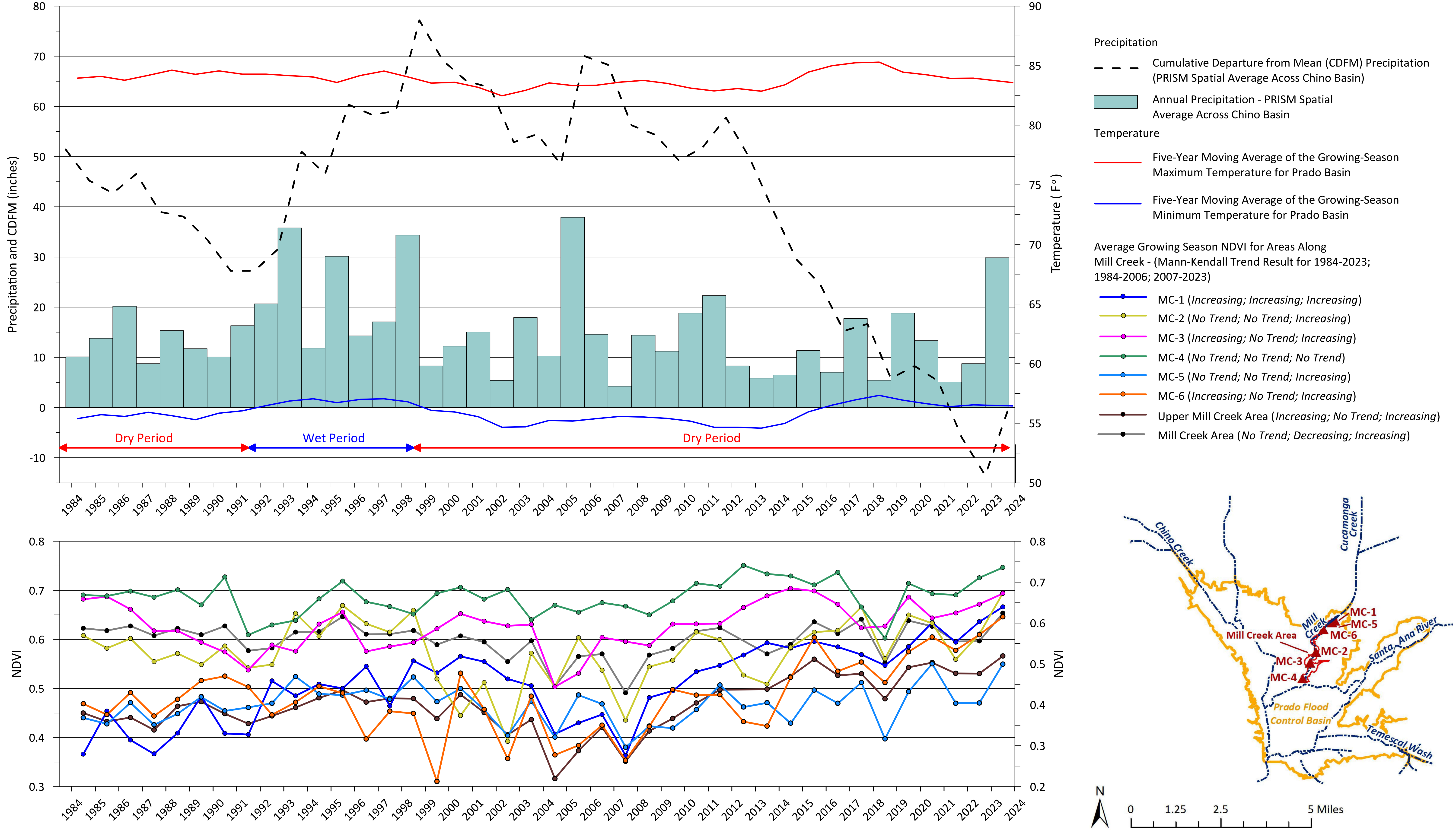
Climate verus NDVI
Chino Creek Area for 1984-2023

Figure 3-17a



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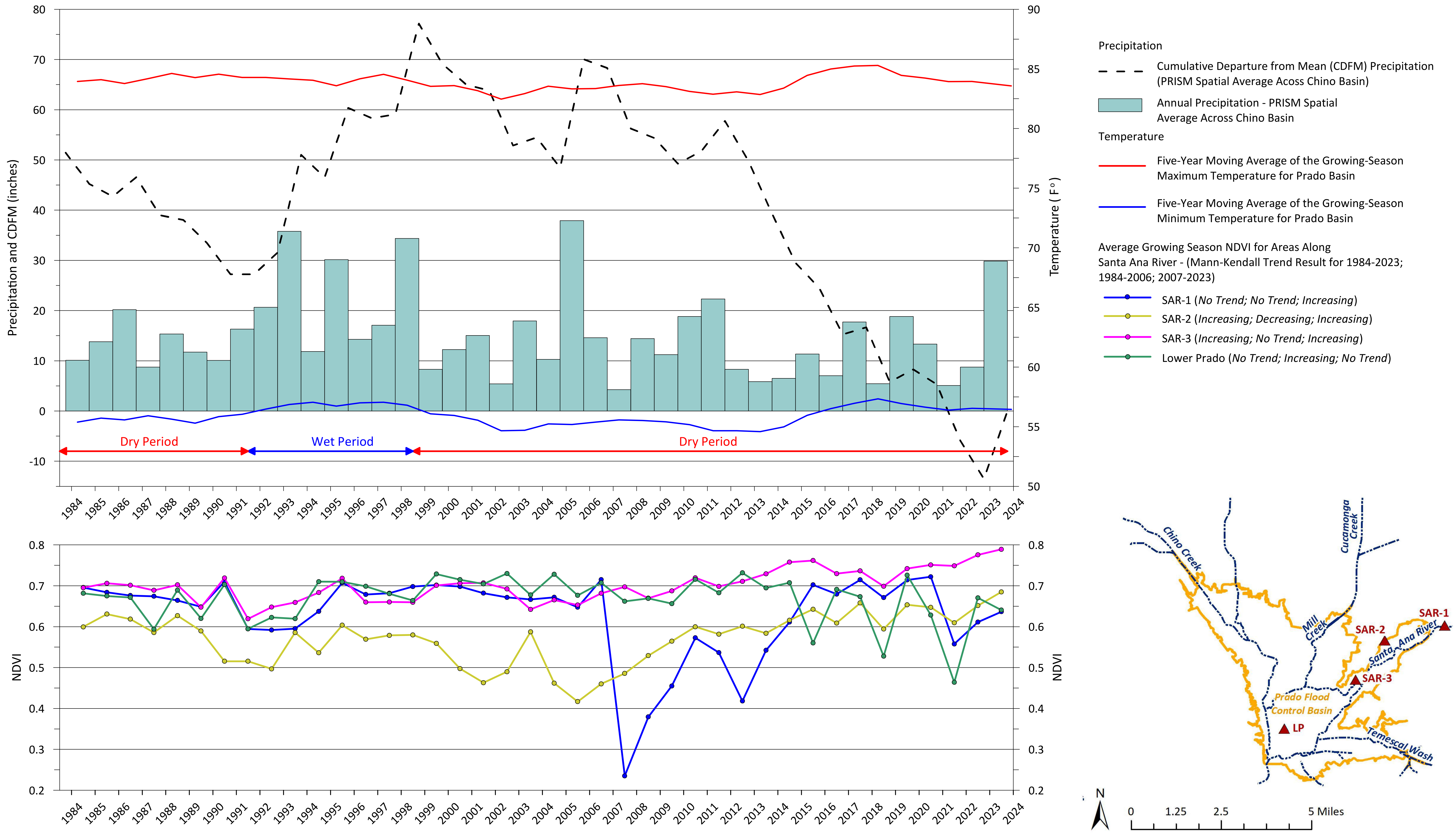
Climate verus NDVI
Mill Creek Area for 1984-2023

Figure 3-17b



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Climate verus NDVI

Santa Ana River and Lower Prado Area for 1984-2023

Figure 3-17c

3.5 Stream Discharge and Its Relationship to the Riparian Habitat

Stream discharge in the SAR and its tributaries that flow through the Prado Basin is a factor that can affect the extent and quality of Prado Basin riparian habitat. Stream discharge can recharge the groundwater system along losing stream reaches and supply water through the groundwater system to riparian vegetation. Stream discharge is also important to fauna living within the stream system. Flooding events and flood-control/water-conservation operations at Prado Dam can scour and inundate areas of the riparian habitat and potentially cause adverse impacts.

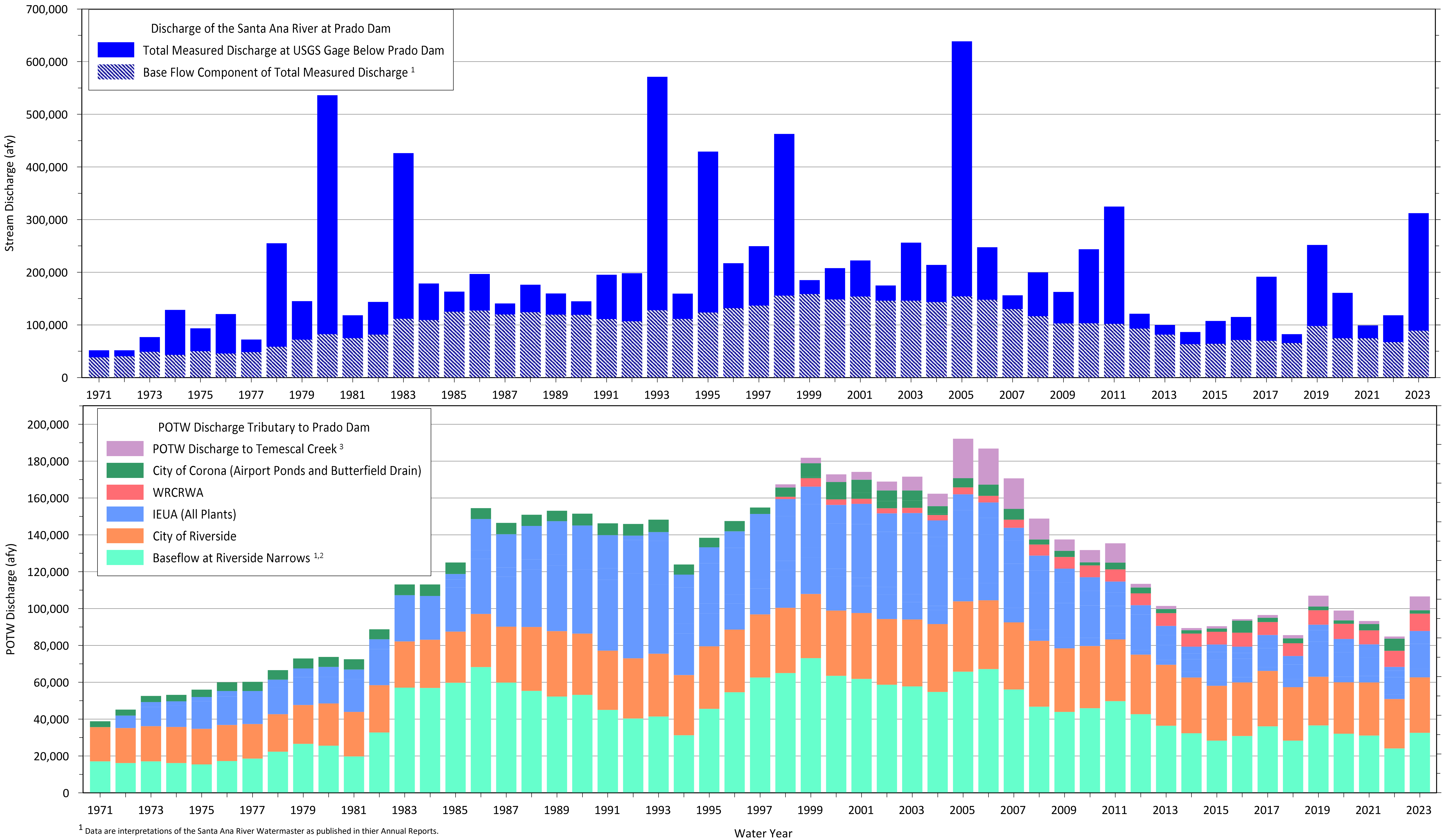
This section characterizes the time series of stream discharge within the Prado Basin and compares that time series to trends in the extent and quality of the riparian habitat, as indicated by NDVI, to help determine whether changes in stream discharge have influenced the riparian habitat in the Prado Basin.

3.5.1 Stream Discharge

There are three primary components of stream discharge in the SAR and its tributaries: storm discharge, non-tributary discharge, and base-flow discharge. Storm discharge is rainfall runoff. Non-tributary discharge typically originates from outside the watershed, such as imported water discharged from the OC-59 turnout on San Antonio Creek. Base-flow discharge, as used herein and by the Santa Ana River Watermaster (SARWM), includes tertiary-treated wastewater discharge from POTWs, rising groundwater, and dry-weather runoff. Figure 3-18 includes time-series charts that summarize important annual discharges within the upper SAR watershed that are tributary to Prado Dam from water years 1971 to 2023 (SARWM, 2023). The upper chart on Figure 3-18 characterizes the annual outflow from the Prado Basin as total measured SAR discharge at USGS gage *SAR at below Prado Dam* and shows the base-flow component of the total measured discharge as estimated by the SARWM. This chart shows that base-flow discharge declined from about 154,000 afy in 2005 to an average of about 81,000 afy over the recent five-year period 2019-2023. The decline in base-flow discharge is primarily related to declines in POTW effluent discharges that are tributary to Prado Basin. In WY 2023, the total discharge at below Prado Dam and baseflow discharge increased from the previous year:

- **Total Discharge at below Prado Dam in WY 2023**. Total discharge in WY 2023 was about 312,300 af, which is about 180,900 afy more than the average total discharge over the previous ten years (2013 to 2022), and a 193,900 afy increase from total discharge in WY 2022. It is the highest total discharge since 2011, when discharge was about 324,900 afy and the eighth highest total discharge over the entire time period of record from 1971 to 2023.
- **Base-Flow Discharge at below Prado Dam in WY 2023**. Base-flow discharge was about 89,200 afy, which is about 16,200 afy more than the average base-flow discharge over the previous ten years (2013 to 2022), and about 22,000 afy more than base-flow discharge in WY 2022.

The lower chart on Figure 3-18 shows the combined POTW discharges that are tributary, at least in part, to Prado Dam. The POTW discharges are the primary component of the baseflow discharge. The POTW discharges declined from a high of about 192,000 afy in 2005 to an average of about 98,000 afy for the last five years (2019-2023). This decrease is mostly attributed to decreases in effluent discharge from the IEUA and the POTWs that discharge to Temescal Creek. The post-2005 decrease in POTW effluent discharge was caused by increased recycled-water reuse, decreased water use due to the economic recession that began in 2008, and the implementation of emergency water-conservation measures during the 2012 drought and since. In WY 2023, POTW discharge was about 106,600 afy, which is about 12,400 afy more than the average POTW discharge over the previous ten years (2013-2022), and about 21,800 afy more than POTW discharge in WY 2022.



[1] Data are interpretations of the Santa Ana River Watermaster as published in thier Annual Reports.

[2] Baseflow at Riverside Narrows includes POTW discharge from RIX and Rialto plants, rising groundwater, and dry weather runoff

[3] Includes discharge from EVMWD, EMWD, and LLWD plants

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Discharge Tributary to Prado Dam
Water Year 1960-2023

Figure 3-18

3.5.2 Stream Discharge Compared to NDVI

Figures 3-19a through 3-19c are time-series charts that compare long-term trends in stream discharge to trends in the quality of the riparian vegetation, as indicated by NDVI, for three reaches in Prado Basin: Chino Creek, Mill Creek, and the SAR. The period of analysis for these charts is 1984 to 2023, the period of NDVI availability. The upper chart on the figures displays the annual volumes of measured discharge to each stream during the growing season (March to October), including measurements at USGS gaging stations located upstream of the Prado Basin, and POTW discharges.[20] The lower chart displays the time series of the Average Growing-Season NDVI for defined areas, as discussed in Section 3.1, along Chino Creek, Mill Creek, and the SAR. For reference, the Mann-Kendall test results for trends in the Average Growing-Season NDVI for 1984 to 2023, 1984 to 2006, and 2007 to 2023 are shown in the legend.

The observations and interpretations below are focused on the recent (2023) changes in Average Growing-Season NDVI, as described in Section 3.1, and whether observed trends in surface-water discharge may be contributing to recent changes in NDVI.

Chino Creek (Figure 3-19a). Chino Creek is a concrete-lined, flood-control channel that transitions into an unlined stream channel at the Prado Basin boundary and flows south to merge with Mill Creek and the SAR behind Prado Dam (see Figure 2-3). The upper chart on Figure 3-19a shows discharge in Chino Creek during the growing season, including: measured discharge at USGS gage *Chino Creek at Schaefer* and the POTW discharges downstream of the USGS gage, including discharges from the IEUA Carbon Canyon, RP-2, RP-5, and RP-1 plants. Measured discharge at *Chino Creek at Schaefer* includes storm-water and dry-weather runoff in the concrete-lined channel upstream of the IEUA discharge locations and imported water discharge from the OC-59 turnout. Discharges not characterized in this figure are storm-water runoff, dry-weather runoff, and rising-groundwater discharge downstream of the *Chino Creek at Schaefer* gage. From 1984 to 2023, discharge in Chino Creek during the growing season progressively increased through 1999 and then decreased. The decreasing trend in growing-season discharge since about 1999 was caused by dry climatic conditions, water conservation in response to drought, and decreases in effluent discharge from the IEUA plants. During the previous ten-year period from 2013 to 2022, growing-season discharge in Chino Creek averaged about 7,500 afy. In 2023, growing-season discharge was about 13,200 afy, which is about 5,700 af more than the average growing-season discharge for the previous ten years and about 8,500 af more than growing-season discharge in 2022. This increase in growing-season discharge in Chino Creek during 2023 is attributed to the significant increase in precipitation and a slight increase in the IEUA RP-5 and IEUA RP-1 effluent. The discharge measured at the USGS *Chino Creek at Schaefer* gage increased by about 5,600 af from WY 2022 to WY 2023 largely as a result of increased stormflow from increased precipitation.

From 2022 to 2023, the Average Growing-Season NDVI for the whole Chino Creek area increased. Average Growing-Season NDVI increased for the two northern-most areas along Chino Creek (CC-1 and CC-2), stayed the same for the central area (CC-3), and decreased for the southern-most area (CC-4). For all these areas, the one-year changes in NDVI were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These recent changes in NDVI occurred during a year of above average discharge — the highest since 2011. Hence, the main observations and conclusions for the 2023 period are that there were higher discharge conditions in Chino Creek and the riparian vegetation did not change significantly along Chino Creek.

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[20] These charts do not describe other hydrologic processes that affect surface-water discharge within the Prado Basin, including evaporation, evapotranspiration, the infiltration of water along unlined stream segments, and rising groundwater discharge.

Mill Creek (Figure 3-19b). Cucamonga Creek is a concrete-lined flood-control channel and transitions into an unlined stream channel at the Prado Basin boundary, and at that point, its name changes to Mill Creek (see Figure 2-3). The upper chart on Figure 3-19b shows discharge in Mill Creek during the growing season, including: POTW effluent discharge from the IEUA RP-1 plant to Cucamonga Creek, and measured discharge downstream at the USGS gage *Cucamonga Creek near Mira Loma* (less the RP-1 discharge). The measured discharge at *Cucamonga Creek near Mira Loma* (less the RP-1 discharge) is representative of storm-water and dry-weather runoff in Cucamonga Creek upstream of this gaging station. Discharges not characterized on this figure are storm-water runoff, dry-weather runoff, and rising-groundwater discharge downstream of the *Cucamonga Creek near Mira Loma* gage.

Also shown on upper chart is the volume of flow during the growing season that is estimated to be in the upper portion of Mill Creek less the surface water that is diverted to the Mill Creek Wetlands in this area. The Mill Creek Wetlands began diverting water from Mill Creek just north of where Mill Creek begins (see inset map for location of Mill Creek Wetlands). Water from the Mill Creek Wetlands re-enters Mill Creek just downstream of the MC-6 area; hence the volume of water in the upper portion of Mill Creek near the MC-1, MC-5, and MC-6 areas is less than the flow represented in this bar chart. Since 2016, water diverted to the Mill Creek Wetlands during the growing-season has ranged from 13 percent to 42 percent of the total flow. Therefore, the growing-season discharge in the northernmost region of Mill Creek near the MC-1, MC-5, and MC-6 areas is on average about 24 percent less than the discharge in Mill Creek south of the Mill Creek Wetlands.

From 1984 to 2023, growing-season discharge in Mill Creek progressively increased through 2004 and then decreased. The decreasing trend in growing-season discharge since about 2004 was caused by dry climatic conditions, water conservation in response to drought conditions after 2012, and the decrease in effluent discharge from the IEUA RP-1 plant. During the previous ten-year period from 2013 to 2022, total growing-season discharge averaged about 8,700 afy. In 2023, the growing-season discharge was about 31,800 afy in Mill Creek, which is about 23,900 af more than the previous year and 3.5 times the average growing-season discharge over the previous ten years (2013 to 2022). The increase in growing-season discharge is largely attributed to increased stormwater flow from the high amount of precipitation in WY 2023, which is accounted for in the discharge measurements at the USGS gage *Cucamonga Creek near Mira Loma* (less the RP-1 discharge). From WY 2022 to WY 2023, discharge measurements at the USGS gage *Cucamonga Creek near Mira Loma* (less the RP-1 discharge) increased by about 20,500 afy, while discharge from RP-1 increased by about 3,400 afy. In 2023 the growing-season discharge in the Upper portion of Mill Creek downstream of the diversion to the Mill Creek Wetlands was about 28,900 afy[21], which is about is about 19,300 afy more than the average flow estimated for this area since the Mill Creek Wetlands began operation in 2016 and about 22,900 af higher than 2022.

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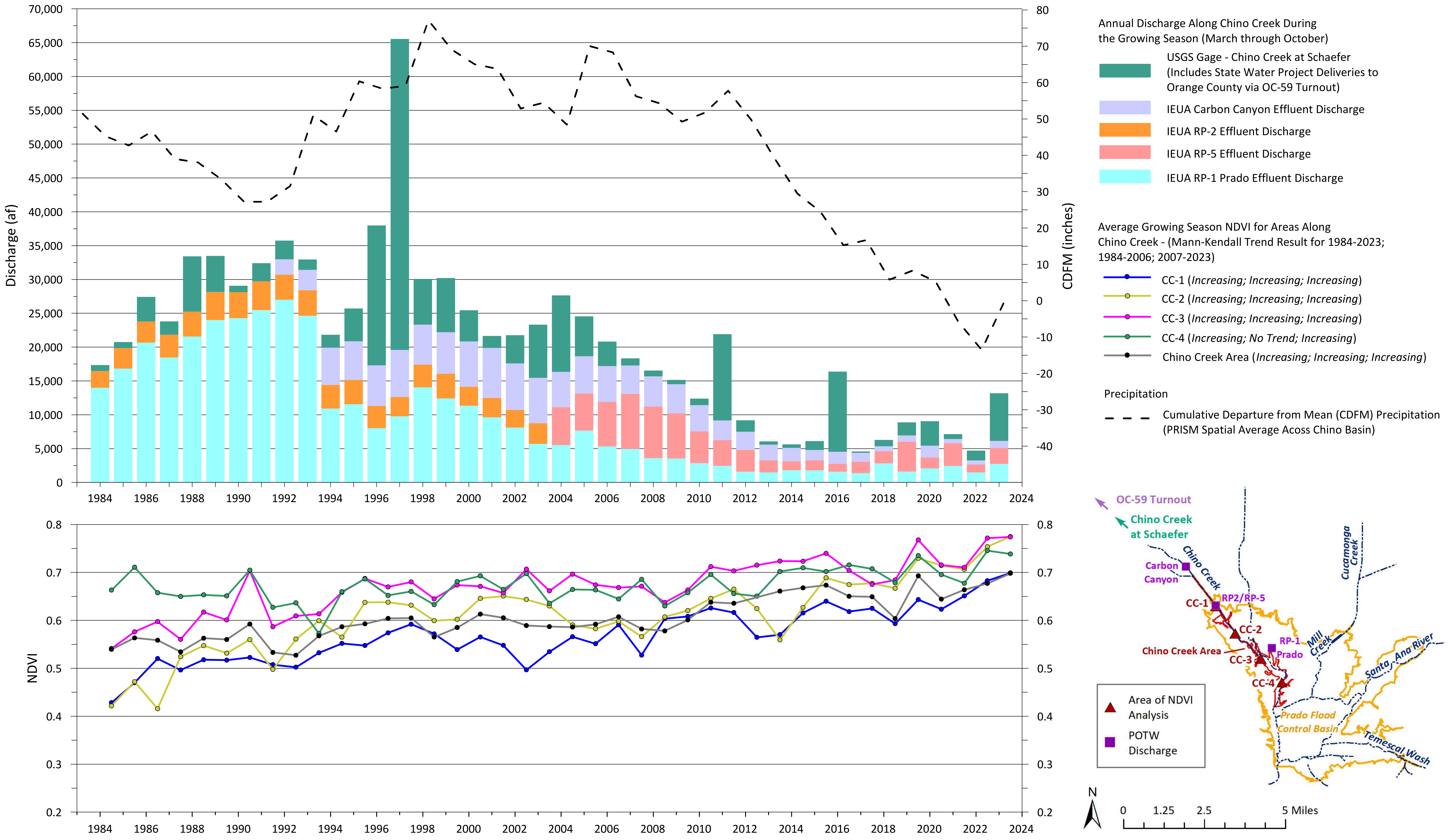
[21] The City of Ontario measures the water diverted to the Mill Creek Wetlands every month using flow meters located at the two culverts where water is diverted. Due to equipment malfunction no monthly flow data was available from July to October 2023. During these months, flow was estimated as 39% (average historical percentage) of the total monthly discharge measured at the USGS gage *Cucamonga Creek near Mira Loma*.

From 2022 to 2023, Average Growing-Season NDVI increased for the whole Mill Creek and Upper Mill Creek areas, and the six areas along Mill Creek. At all the areas, these one-year changes in NDVI are within their historical ranges of the one-year NDVI variability (see Table 3-2). However, the MC-2 and MC-5 areas had an increase in Average Growing-Season NDVI that was greater than the average annual change historically and the air photo for the entire Mill Creek area shows an increase in green vegetation from 2022 to 2023. These recent changes in NDVI occurred during a year of historically high discharge in Mill Creek. Hence, the main observations and conclusions for the 2023 period are that there were above average discharge conditions in Mill Creek and although NDVI increased all along Mill Creek reach, the increase was not significant in comparison to other year-to-year changes in NDVI.

Santa Ana River (Figure 3-19c). The SAR is an unlined stream channel from the Riverside Narrows to Prado Dam—its entire reach across the Chino Basin (see Figure 2-3). The upper chart on Figure 3-19c shows the annual growing-season discharge at the USGS gage *SAR at MWD Crossing* (Riverside Narrows) and the annual growing-season discharges to the SAR downstream of the Riverside Narrows, including POTW effluent from the City of Riverside's Regional Water Quality Control Plant and the Western Riverside County Regional Wastewater Authority (WRCRWA) plant that is conveyed in an unlined channel (along with a portion of SAR discharge) to the OCWD Wetlands. The measured discharge at the *SAR at MWD Crossing* gage represents storm-water runoff and base-flow discharge in the SAR upstream of the gaging station at the Riverside Narrows. The base-flow discharge includes POTW discharge from the RIX and Rialto treatment plants, dry-weather runoff, and rising groundwater. Discharges not characterized on this figure are storm-water runoff, dry-weather runoff, and rising-groundwater discharge downstream of the *SAR at MWD Crossing* gage.

From 1984 to 2005, growing-season discharge in the SAR averaged about 81,900 afy with episodic increases in storm-water discharge during wet years. Since 2012, growing-season discharge in the SAR gradually declined and averaged about 46,500 afy from 2013 to 2022. The decreasing trend in growing-season discharge was caused by dry climatic conditions, water conservation in response to drought, and decreasing base flow at the Riverside Narrows. In 2023, the growing-season discharge in the SAR was about 97,300 af, which is about 50,900 af more than the average growing-season discharge during the previous ten years (2013 to 2022) and more than 2 times the growing-season discharge in 2022. The increase in growing-season discharge is largely attributed to increased stormwater flow from the high amount of precipitation in WY 2023, which is accounted for in the discharge measurements at the USGS gage *SAR at MWD Crossing*. From WY 2022 to WY 2023, discharge measurements at the USGS gage *SAR at MWD Crossing* increased by about 57,800 afy, while the City of Riverside's effluent discharge increased by about 2,800 afy and WRCRWA effluent discharged increased by about 300 afy.

From 2022 to 2023, the Average Growing-Season NDVI increased at three areas along the SAR and decreased at the LP area. For all of these areas, the one-year NDVI changes were relatively minor and within the historical ranges of one-year NDVI variability (see Table 3-2). These changes occurred during a year of historically high discharge conditions in the SAR. Hence, the main observations and conclusions for the 2022 to 2023 period are that there were significantly higher discharge conditions in the SAR and the riparian vegetation did not change significantly along the SAR. The decrease in the Average Growing-Season NDVI for the LP area is likely related to pooling of surface water in the area behind Prado Dam and inundation as a result of increased precipitation.



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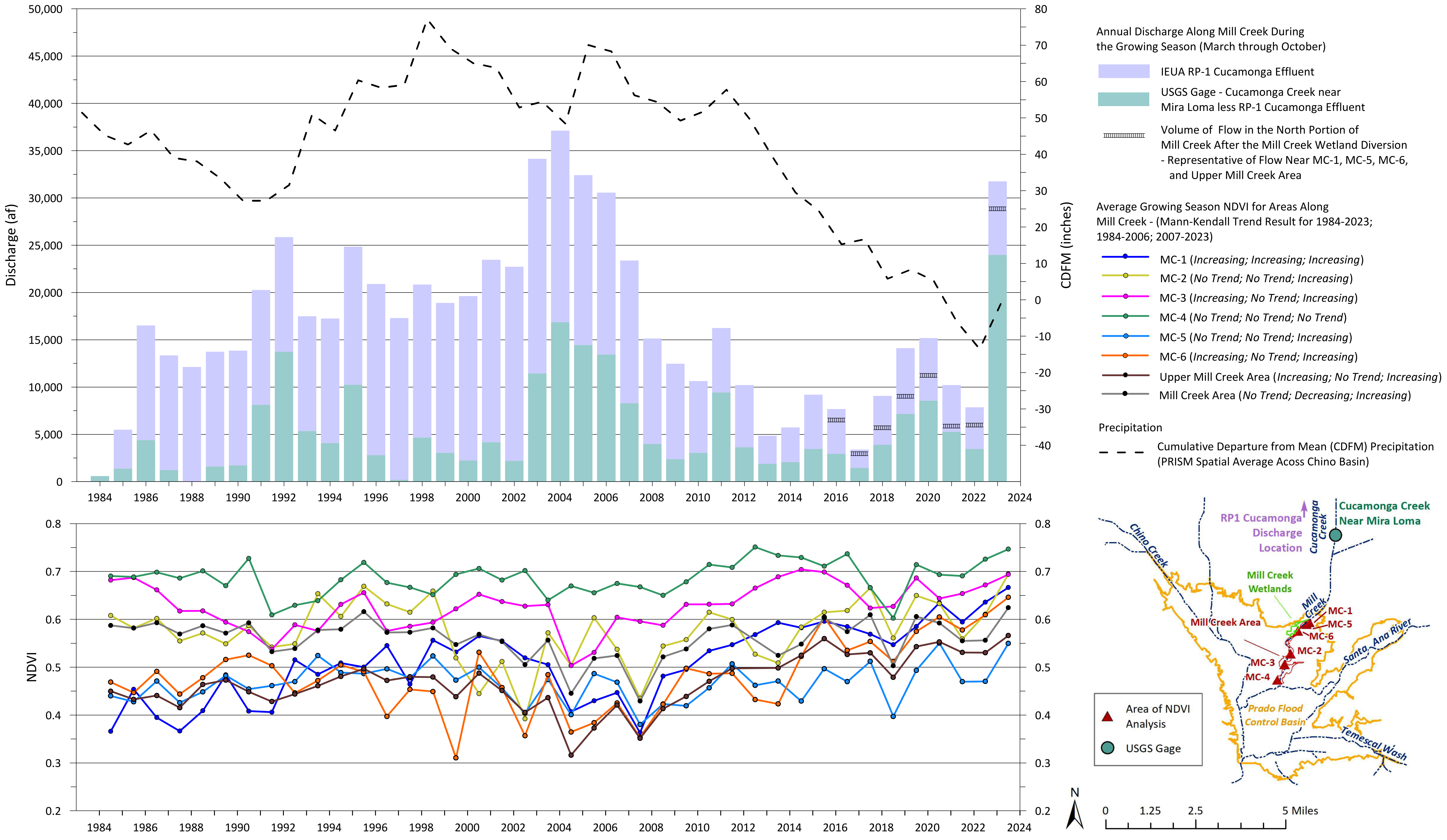
Surface-Water Discharge versus NDVI
Chino Creek Area for 1984-2023

Figure 3-19a



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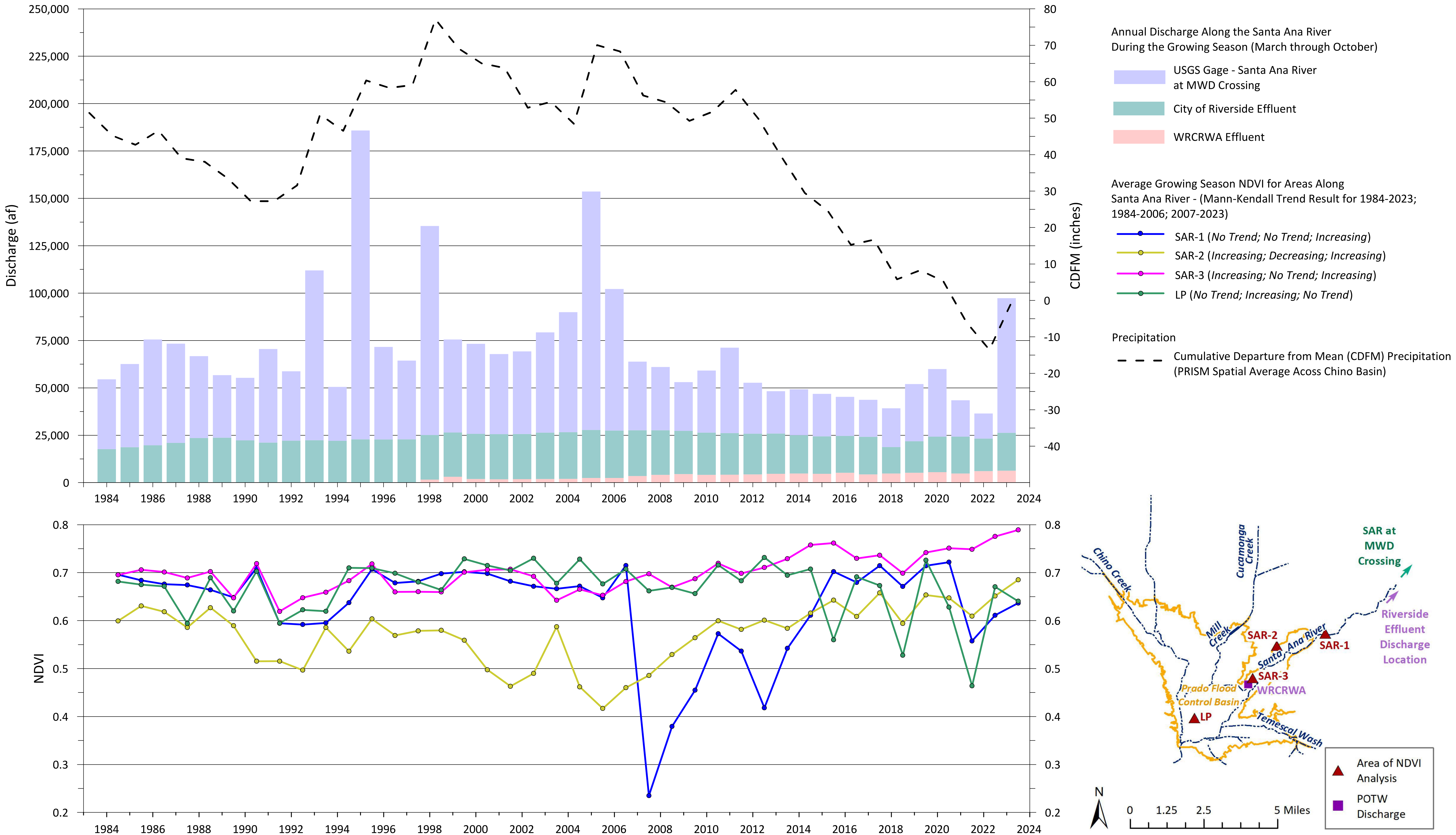
Surface-Water Discharge versus NDVI
Mill Creek Area for 1984-2023

Figure 3-19b



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Surface-Water Discharge versus NDVI
Santa Ana River and LP Area for 1984-2023

Figure 3-19c

3.6 Other Factors and Their Relationships to Riparian Habitat

Other factors that can affect the extent and quality of riparian habitat in the Prado Basin analyzed in this Annual Report include wildfire, Arundo management, pests, and development/construction. These factors are unrelated to Peace II Agreement implementation.

This section characterizes what is known about these factors and compares them to trends in the extent and quality of the riparian habitat to determine their impacts, as characterized by the NDVI.

3.6.1 Wildfire

Available wildfire perimeter data from the FRAP database[22] were compiled within the Prado Basin extent for the period of 1950-2022.[23] The FRAP database shows that wildfires occurred in the Prado Basin in 1985, 1989, 2007, 2015, 2018, and 2020. Figure 3-20a shows the spatial extent of these wildfires, mapped over the 2023 air photo. The most recent wildfire was along the southern portion of the Prado Basin in December 2020. In the 2023 air photo much of this area has dark green vegetation indicative of regrowth in those areas. Some of the areas within the western portion of the 2020 wildfire boundary and in the 2018 wildfire area along the Chino Creek have some less vegetated (green) areas.

Figure 3-20b shows the spatial extent of the most recent wildfires in 2015, 2018, and 2020, overlying a side-by-side of the change map of NDVI from 2022 to 2023 and the 2023 air photo for the lower portions of Chino Creek, Mill Creek, SAR and lower Prado Basin area. The locations of the wildfires in 2015 and 2020 align with several of the notable areas of NDVI increase shown on the NDVI change map, and areas of green vegetated land cover in the air photo in lower Prado Basin. The NDVI increases could be due in part to post-fire vegetation re-growth coupled with a wet year and increase in the green perennial plants. The change map of NDVI also shows large patches of NDVI decreases within the boundary of the 2018 wildfire along the southern Chino Creek, and the southern portion of the 2020 wildfire, and air photo shows brown land cover in these same areas; however, these changes are likely not caused from these historic fires since there has been observed vegetation regrowth since these fires as documented in previous Annual Reports (WEI, 2020; West Yost, 2022).

Figures 3-21a through 3-21c are time-series charts that explore the relationship between other factors that can impact riparian vegetation and NDVI for three reaches in the Prado Basin: Chino Creek, Mill Creek, and the SAR. The figures show the Average Growing-Season NDVI for 14 defined areas of riparian habitat discussed in Section 3.1 and shown in Figures 3-6, 3-7a, 3-7b, and 3-8a through 3-8n. Wildfire occurrences, annotated by year, are shown on the charts if their extent intersects with the extent of the defined area of NDVI analysis. Previous Annual Reports have described that the NDVI time series for the entire riparian vegetation extent (Figure 3-5) and other impacted defined areas indicated NDVI declines after the 2015, 2018, and 2020 fires, followed by increases in some of these areas as the vegetation starts to regrow (WEI, 2019; 2020; West Yost, 2021; 2022).

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[22] Link (Website for California Department of Forestry and Fire Protection's Fire and Resource Assessment Program).

[23] Data is updated in late April for the previous year; 2023 data were not available for this annual report.

3.6.2 Arundo Removal

The OCWD and SAWA[24] are the main entities that implement habitat restoration programs, including the removal and management of Arundo in the SAR watershed for the promotion of native habitat for endangered or threatened species. The OCWD and SAWA sometimes work collaboratively with each other on these programs and with other stakeholders in the watershed, such as the Santa Ana Watershed Project Authority (SAWPA), the USFWS, California Department of Fish and Wildlife (CDFW), ACOE, Santa Ana Water Board, Counties of Riverside and San Bernardino, and several cities. There are many ongoing programs throughout the Prado Basin for the management and maintenance of riparian habitat that include the management of Arundo. SAWA publishes an annual report on the status of all habitat restoration projects they are involved with in the watershed (SAWA, 2020). Figure 3-22a shows the locations of known areas where habitat restoration activities have occurred recently in the Prado Basin, including the management and removal of Arundo. The current known habitat restoration activities include 400 acres in the regrowth area of the 2015 wildfire, where the OCWD has been controlling the regrowth of Arundo, and the removal and management of Arundo at various location along the SAR led by SAWA between 2019 and 2023. The area outlined in green is a 287-acre area where the ACOE removes and manages Arundo growth. These areas and activities are not inclusive of all activities currently occurring in the Prado Basin, but are the known locations identified for the PBHSP where there are current Arundo removal and management activities and notable impacts to vegetation in the PBHSP.

In 2022 and 2023 the ACOE removed Arundo on 26.5 acres of a 287-acre habitat mitigation site on their property identified by ACOE as Riparian Parcel 2, which is shown in Figure 3-22a (Siddiqui, N., email communication, 2023). From January through May 2023, SAWA continued with on-going maintenance in areas where Arundo had previously been removed but did not remove Arundo in any new areas. In May, the grant funding that supported the Arundo removal efforts expired and no Arundo removal or maintenance was performed for the remainder of the year. Overall, from 2019 to 2023, SAWA helped remove and manage Arundo on 2,066 square meters along the SAR. Figure 3-22b shows the spatial extent of the Arundo removal and management areas from 2019 to 2023, overlying a side-by-side of the change map of NDVI from 2022 to 2023, and the 2023 air photo for the lower portions of Chino Creek, Mill Creek, SAR and lower Prado Basin. The location of these Arundo removal and management areas align predominantly with areas of notable NDVI increases as shown on the NDVI change map and areas of green land cover in the 2023 air photo. Areas of Arundo removal and continued management where NDVI has increased suggest regrowth by native vegetation in those areas coupled with an above average wet year.

3.6.3 Polyphagous Shot Hole Borer

PSHB, from the group known as ambrosia beetles, is a relatively new pest in Southern California. PSHB burrows into trees and introduces fungi that assists in establishing colonies. Infection caused by the fungi can cause a dark stain surrounding the entry holes, discolored bark, leaf discoloration and wilting, and die off of entire branches or trees.

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[24] SAWA is a non-profit agency with a five-member board, consisting of one member from the OCWD and the remaining from four resource conservation districts (RCDs) in the watershed, including the Riverside-Corona RCD, Temecula-Elsinore-Anza RCD, San Jacinto RCD, and Inland Empire RCD.

In spring 2016, OCWD biologists observed die off of riparian trees in patches throughout the Prado Basin, especially arroyo and black willows, and confirmed that the cause was from PSHB (ACOE and OCWD, 2017; OCWD 2020). Although PSHB arrived prior to 2016, this was the first notable die off in the Prado Basin. Since 2016, OCWD biologists have noted that the presence of PSHB began widespread throughout the Prado Basin and reduced tree canopy cover, but tree mortality remained confined to small local patches (Zembal, R., personal communication, 2018). OCWD biologists observed that the affected trees that had not died were showing signs of severe infestation, exhibiting branch failure, significant staining, and crown sprouting after the upper branches had died back. (ACOE and OCWD, 2017). In infected trees, crown sprouting allows some of the trees to persist, but the PSHB have been observed to attack the recently emerged limbs once they grow to two to three inches in diameter, causing the sprouting to be temporary. The die back and crown sprouting has resulted in a reduction of canopy in many areas (OCWD, 2020). Canopy loss in heavily infested areas may allow faster-growing invasive non-native species to colonize and out-compete native trees and shrubs in the understory (OCWD, 2020).

In 2016 and 2017, OCWD biologists in the Prado Basin worked with the University of California, Riverside, the USFWS, and SAWA to actively monitor the occurrence and impact of PSHB within Prado Basin riparian habitat. These agencies conducted studies on how to potentially protect certain areas of the Prado Basin from PSHB using attractants and deterrents; however, there were too many trees to effectively protect the entire forest (Zembal, R., personal communication, 2018). Traps were placed throughout the lower portion of Prado Basin and along the SAR by the OCWD and SAWA. The total number of PSHB beetles trapped at each location between August 2016 and April 2017 ranged from seven to 2,092.

Figure 3-22a shows the locations where the presence of PSHB has been documented within the Prado Basin from 2016 to 2022 by: PSHB traps deployed by the OCWD and SAWA between August 2016 and April 2017; and the USBR vegetation surveys performed in 2016, 2019, and 2022.

Table 3-3 summarizes the presence of the PSHB during the 2016, 2019, and 2022 USBR vegetation surveys at all the sites surveyed. During the 2016 USBR vegetation surveys, the presence of the PSHB was identified at 30 of the 37 survey sites. At these sites, all the trees identified with the presence of PSHB were noted as “stressed,” except one which was noted as “dead.” The 2016 USBR surveys were the first site-specific surveys that documented the presence and abundance of PSHB for the PBHSP. During the 2019 USBR vegetation surveys, the presence of the PSHB was identified at only seven of the 30 sites that were originally identified with PSHB presence in 2016 and were only at sites along Chino and Mill Creeks. The reduced presence of the PSHB from 2016 to 2019 correlated to less stressed trees at each of the survey sites; however, the PSHB had an adverse impact from 2016 to 2019, as evidenced by the increased percentage of dead trees and some reductions in percent canopy cover at the survey sites (see Table 3-3).

During the 2022 USBR vegetation surveys, the presence of the PSHB was identified 11 of the 30 sites that were identified with PSHB presence in 2016 and/or 2019. The presence of the PSHB does not correlate to a trend in the increase of stressed or dead tress at the affected sites from 2019 to 2022.

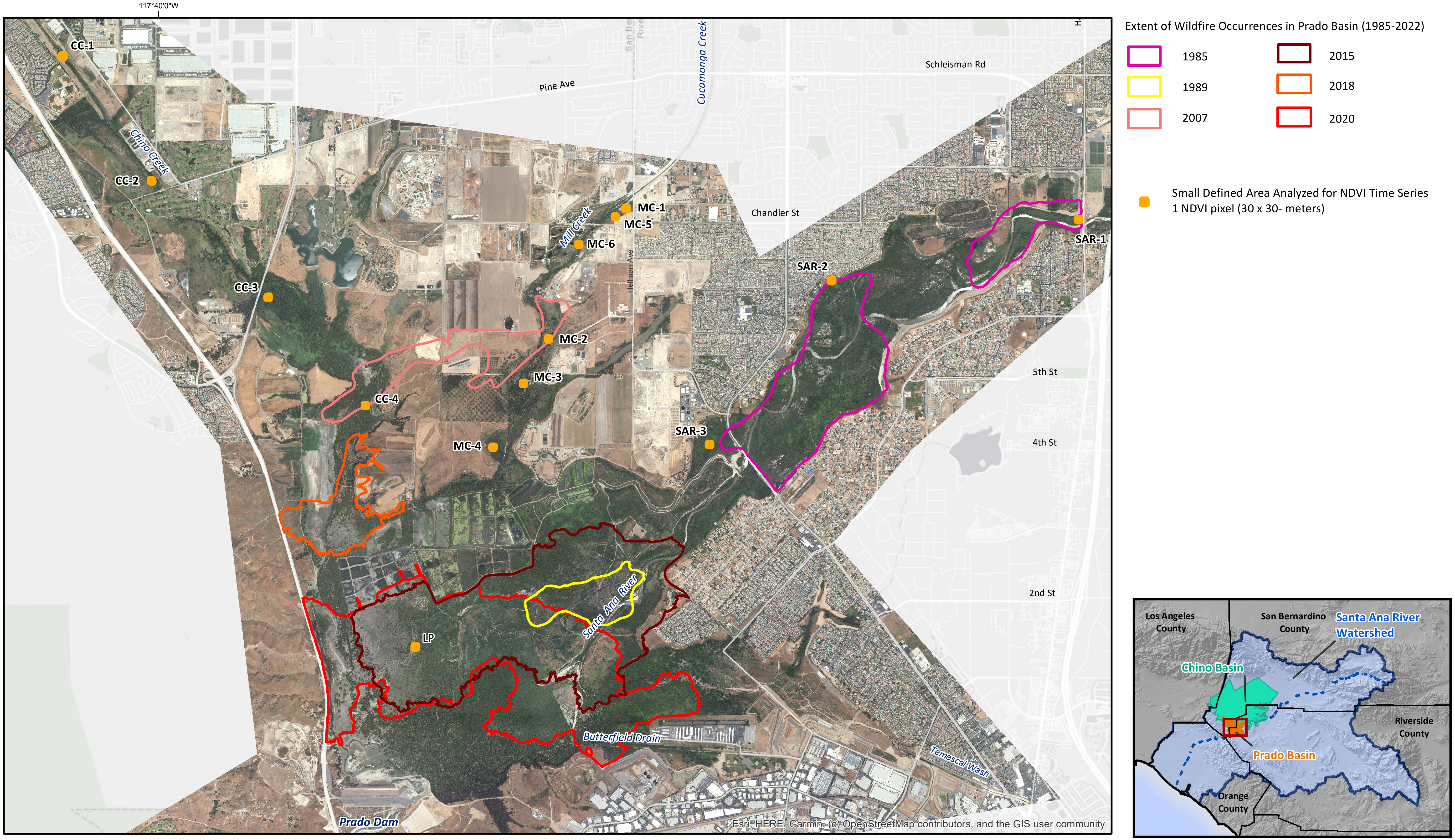
Figures 3-21a through 3-21c are time-series charts that explore the relationship between PSHB occurrence and NDVI for three reaches in Prado Basin: Chino Creek, Mill Creek, and the SAR. These figures show the Average Growing-Season NDVI for the defined areas of riparian habitat discussed in Section 3.1 and shown in Figures 3-6, 3-7a, 3-7 b, and 3-8a through 3-8n. For each defined area, the percentage of infected trees within each survey site that is within the area are plotted on the charts. At all the sites within the small areas where the PSHB was first noted in 2016, the percentage of trees impacted decreased or stayed the same from 2016 to 2019 (many to zero percent). With few exceptions, at most of the sites within the small areas the percentage of trees impacted remained stable or decreased from 2019 to 2022 (many to zero percent). These exceptions are site X7 at CC-3 along Chino Creek where the percentage increased from 0 to 33 and site X10 at MC-1 along Mill Creek where the percentage increased from 0 to 18; however, the NDVI at both areas is showing an increasing trend from 2019 to 2022, indicating that the presence of the PSHB in 2022 is likely not causing a notable negative impact in these areas.

3.6.4 Miscellaneous Factors

There are a few areas in the NDVI change map from 2022 to 2023 in Figure 3-3 of notable NDVI decreases in large patches in the main Prado Basin and in lower Chino Creek, that are not within areas where there are significant groundwater level declines and are not correlated to other factors described in this Annual Report that are demonstrated to have an impact to the riparian vegetation. These areas include: 1) the area behind Prado Dam, 2) the lower portion of Chino Creek, and 3) a 41.8-acre area in lower Prado Basin near the SAR. Comparison of the 2022 and 2023 air photos for these areas shows that there are changes to the land that are the cause of the notable NDVI decreases. Figure 3-23 shows the boundary of these three areas superimposed on the NDVI change map for 2022 to 2023, and the 2022 and 2023 air photos. Figure 3-23 also shows: (i) the location of the Prado Dam conservation pool area between the 470 and 498 ft-amsl elevation contours (blue dashed line) and between the 498 and 505 ft-amsl elevation contours (magenta dashed line); and (ii) time-series chart of the daily elevation of the conservation pool from 1984 through September 2023. The following describes the observations for each of these areas of notable NDVI decrease:

- **Behind Prado Dam**. Comparison of the air photos show that from 2022 to 2023 there is less bright green land cover of perennial grasses and shrubs, replaced by bare, gray land. This area behind Prado Dam is seasonally inundated when the surface water conservation pool is held behind the dam. Because of the above average wet year, the conservation pool was behind Prado Dam from November 7, 2022 to June 20, 2023 and August 17, 2023 to September 9, 2023, which is a longer period than most previous years, hence there was little to no growth of the perennial grasses and shrubs in this area.
- **Lower portion of Chino Creek**. Comparison of the air photos from 2022 to 2023 show that there is less bright green land cover of perennial grasses and shrubs, replaced by bare, gray/brown land. This area of Chino Creek is part of the Prado Dam conversation pool area between the 470 ft-amsl to 498 ft-amsl elevation when the surface water is held behind the dam. Because of the above average wet year, the conservation pool elevation was 498 ft-amsl or higher from January 5 until May 23, 2023, which is a longer period than previous years, hence there was little to no growth of the perennial grasses and shrubs in this area.
- **41.8-acre area in lower Prado Basin near the SAR**. Comparison of the air photos show that between 2022 and 2023 the vegetated area goes from bright green to a well-defined cleared area and brown surface. The appearance of this change seems to be from an intentional land clearing. This area falls outside OCWD's and SAWA's Arundo management areas (McMichael, D., email communication, 2024). This land is owned by ACOE and falls within one of their habitat mitigation sites where they removed 26.5 acres of Arundo in 2022 and 2023 (Siddiqui, N., email communication, 2024). In 2022 and 2023 the ACOE

removed Arundo on 26.5 acres of a 287-acre habitat mitigation site on their property identified by ACOE as Riparian Parcel 2, which is included in Figure 3-22a (Siddiqui, N., email communication, 2023). The area is also adjacent to OCWD property where OCWD has been implementing a Sediment Management Demonstration Project to dredge and dispose of up to 120,000 cubic yards of sediment from the Prado Basin. In addition to this area, the ACOE granted temporary easement to allow OCWD to construct an access road and implement storage and handling of sediment on ACOE property within the 41.8 acre area where surface changes have been observed (ACOE and OCWD, 2017). The specific reason/s for the observed decrease in NDVI is not confirmed, and more research is required to determine the exact causes if deemed necessary. However, these decreases are not due to decreasing groundwater levels from Peace II implementation. Figure 3-11 indicates that there has been between one and three feet of change between 2016 to 2023 in this area, which is in the very southern portion of Prado Basin outside of the influence of Peace II activities.



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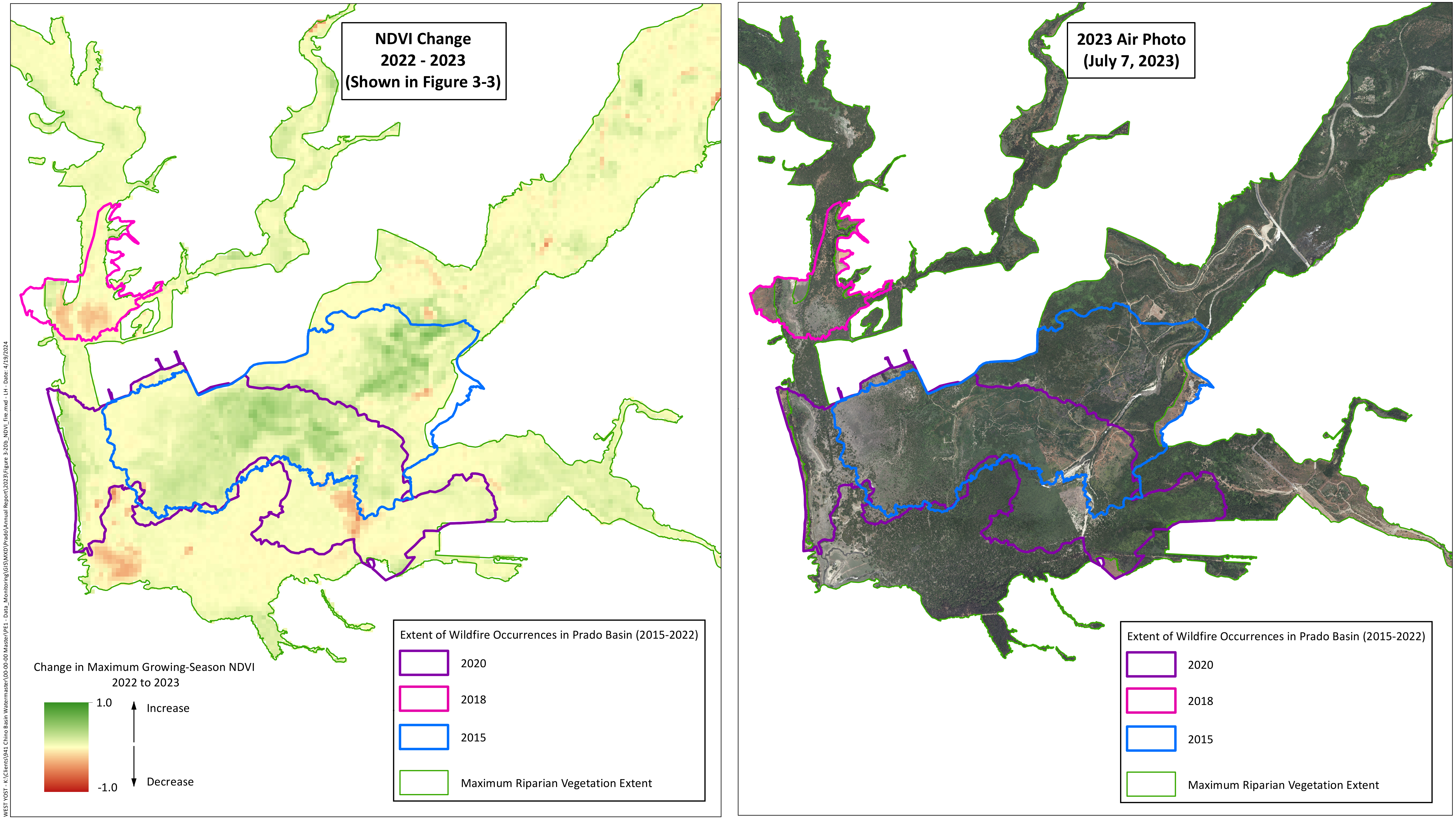
Location Map of Other Factors That Can Affect Riparian Habitat
Wildfire

Figure 3-20a



WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GIS\MXD\Prado\Annual Report\2023\Figure 3-20b_NDVI_Fire.mxd - LH - Date: 4/19/2024

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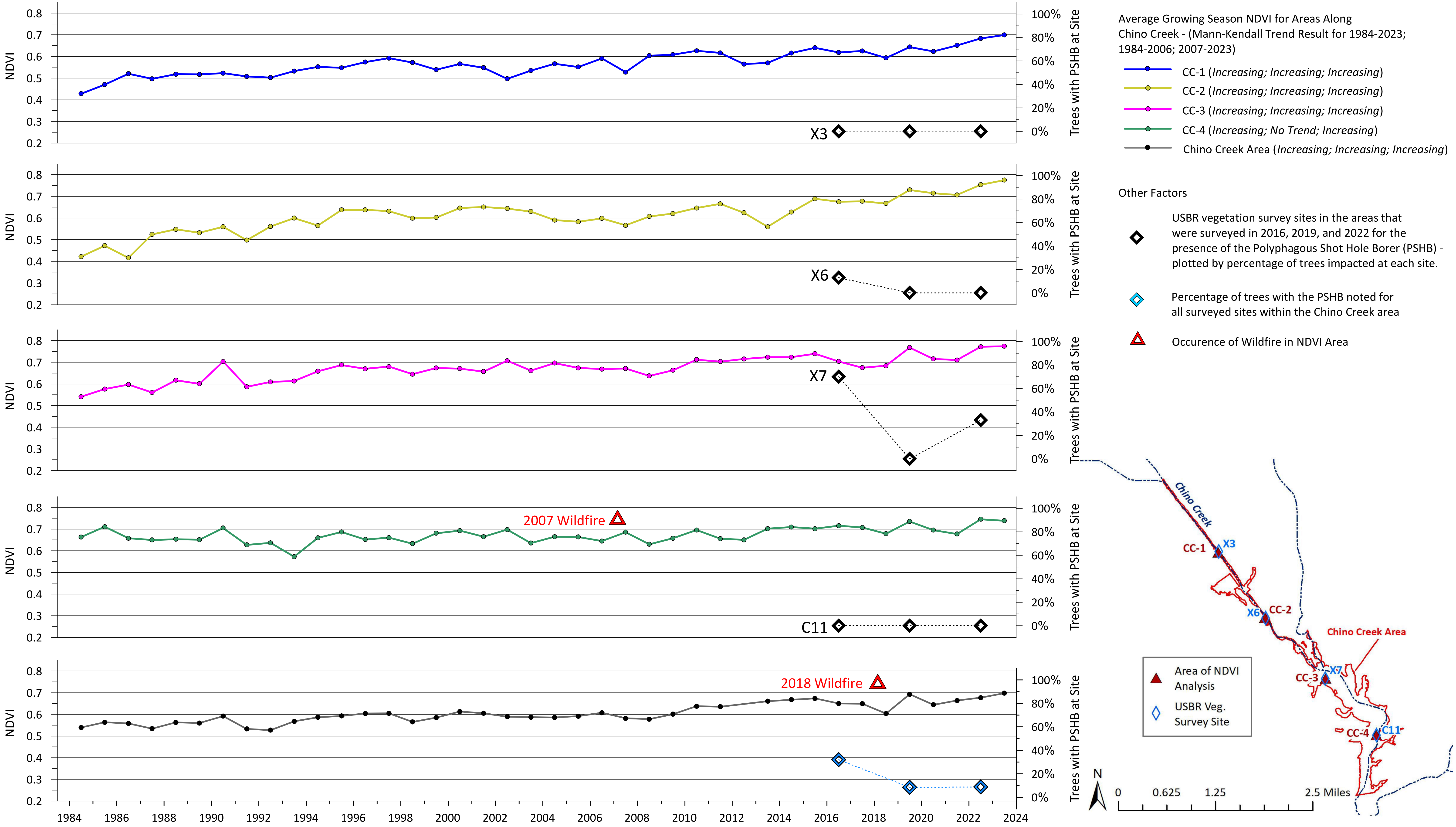
Spatial NDVI Change 2022-2023 and 2023 Air Photo with Prado Basin Wildfires in 2015, 2018, and 2020

Figure 3-20b



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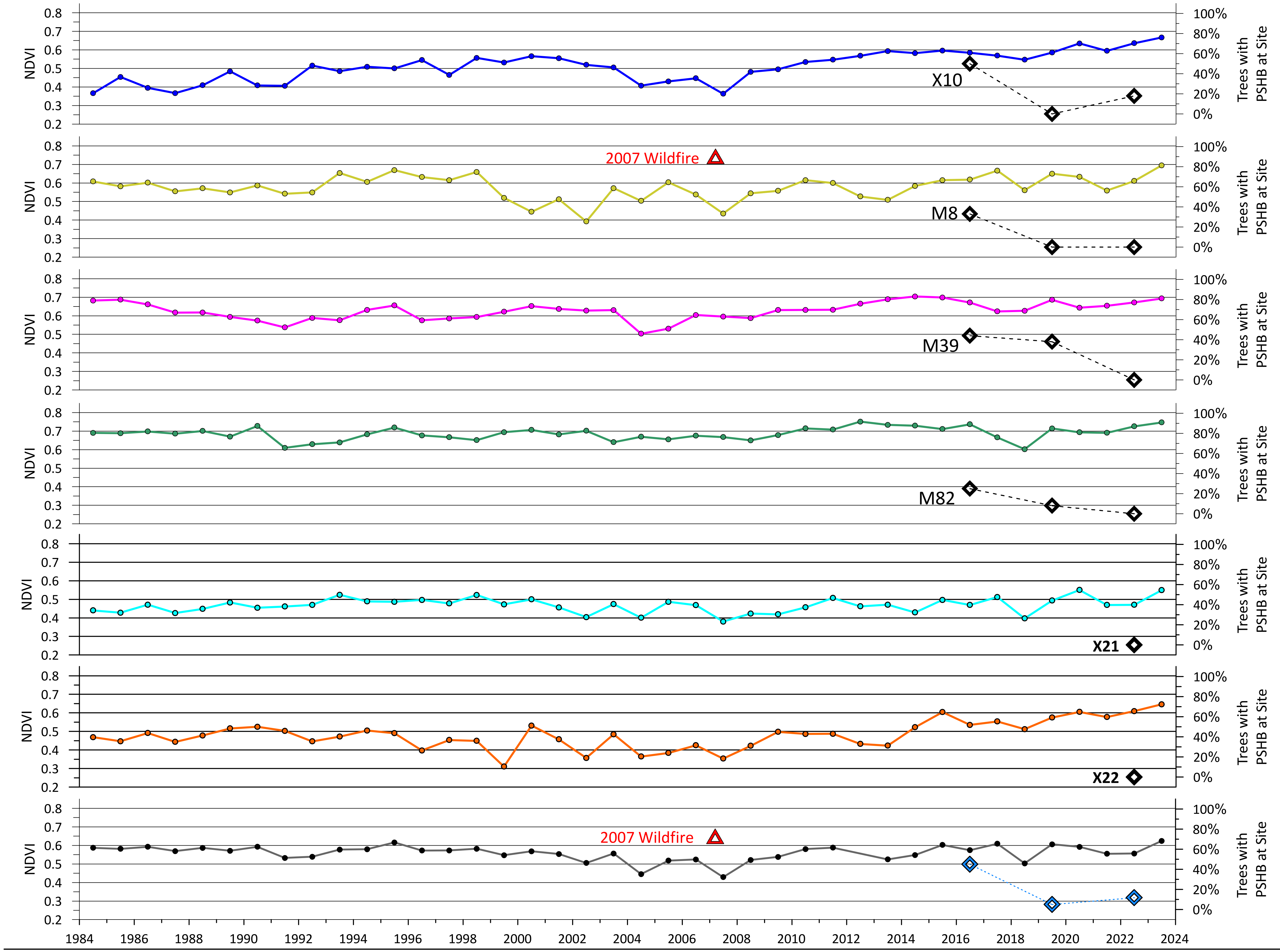
Other Factors that Affect Riparian Habitat verus NDVI

Chino Creek Area for 1984-2023

Figure 3-21a



Average Growing Season NDVI for Areas Along Mill Creek - (Mann-Kendall Trend Result for 1984-2023; 1984-2006; 2007-2023)

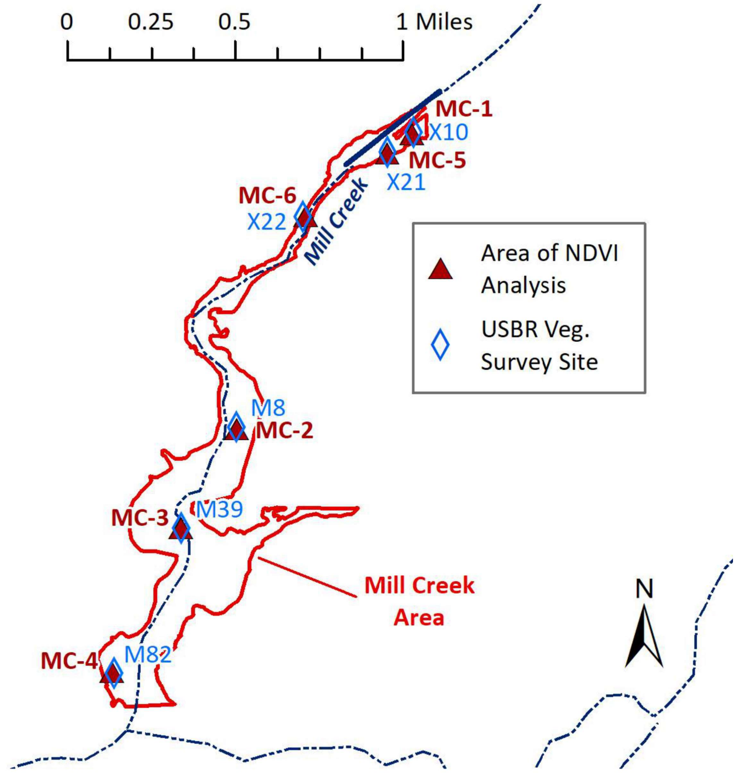
- MC-1 (*Increasing; Increasing; Increasing*)
- MC-2 (*No Trend; No Trend; Increasing*)
- MC-3 (*Increasing; No Trend; Increasing*)
- MC-4 (*No Trend; No Trend; No Trend*)
- MC-5 (*No Trend; No Trend; Increasing*)
- MC-6 (*Increasing; No Trend; Increasing*)
- Mill Creek Area (*No Trend; Decreasing; Increasing*)

Other Factors

◇ USBR vegetation survey sites in the areas that were surveyed in 2016, 2019, and 2022 for the presence of the Polyphagous Shot Hole Borer (PSHB) - plotted by percentage of trees impacted at each site.

◇ Percentage of trees with the PSHB noted for all surveyed sites within the Mill Creek area

△ Occurence of Wildfire in NDVI Area



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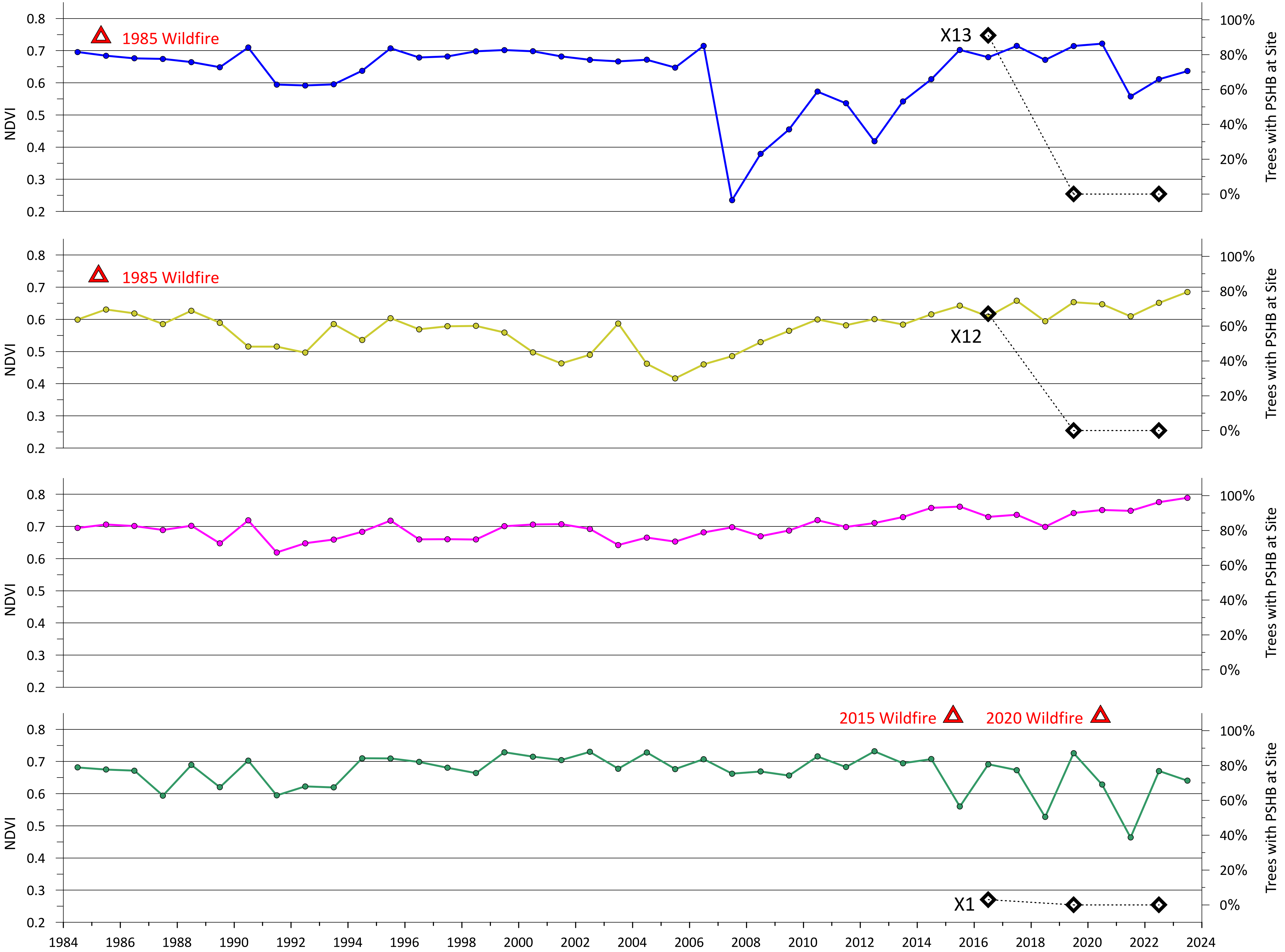
Other Factors that Affect Riparian Habitat verus NDVI
Mill Creek Area for 1984-2023

Figure 3-21b



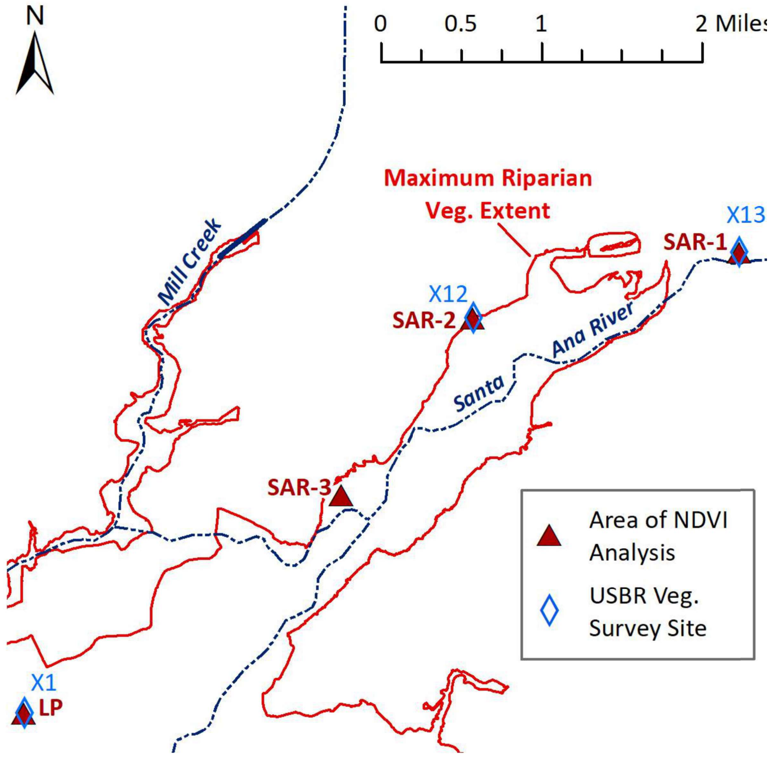
Average Growing Season NDVI for Areas Along Santa Ana River - (Mann-Kendall Trend Result for 1984-2023; 1984-2006; 2007-2023)

- SAR-1 (*No Trend; No Trend; Increasing*)
- SAR-2 (*Increasing; Decreasing; Increasing*)
- SAR-3 (*Increasing; No Trend; Increasing*)
- Lower Prado (*No Trend; Increasing; No Trend*)

Other Factors

◇ USBR vegetation survey sites in the areas that were surveyed in 2016, 2019, and 2022 for the presence of the Polyphagous Shot Hole Borer (PSHB) - plotted by percentage of trees impacted at each site.

△ Occurence of Wildfire in NDVI Area



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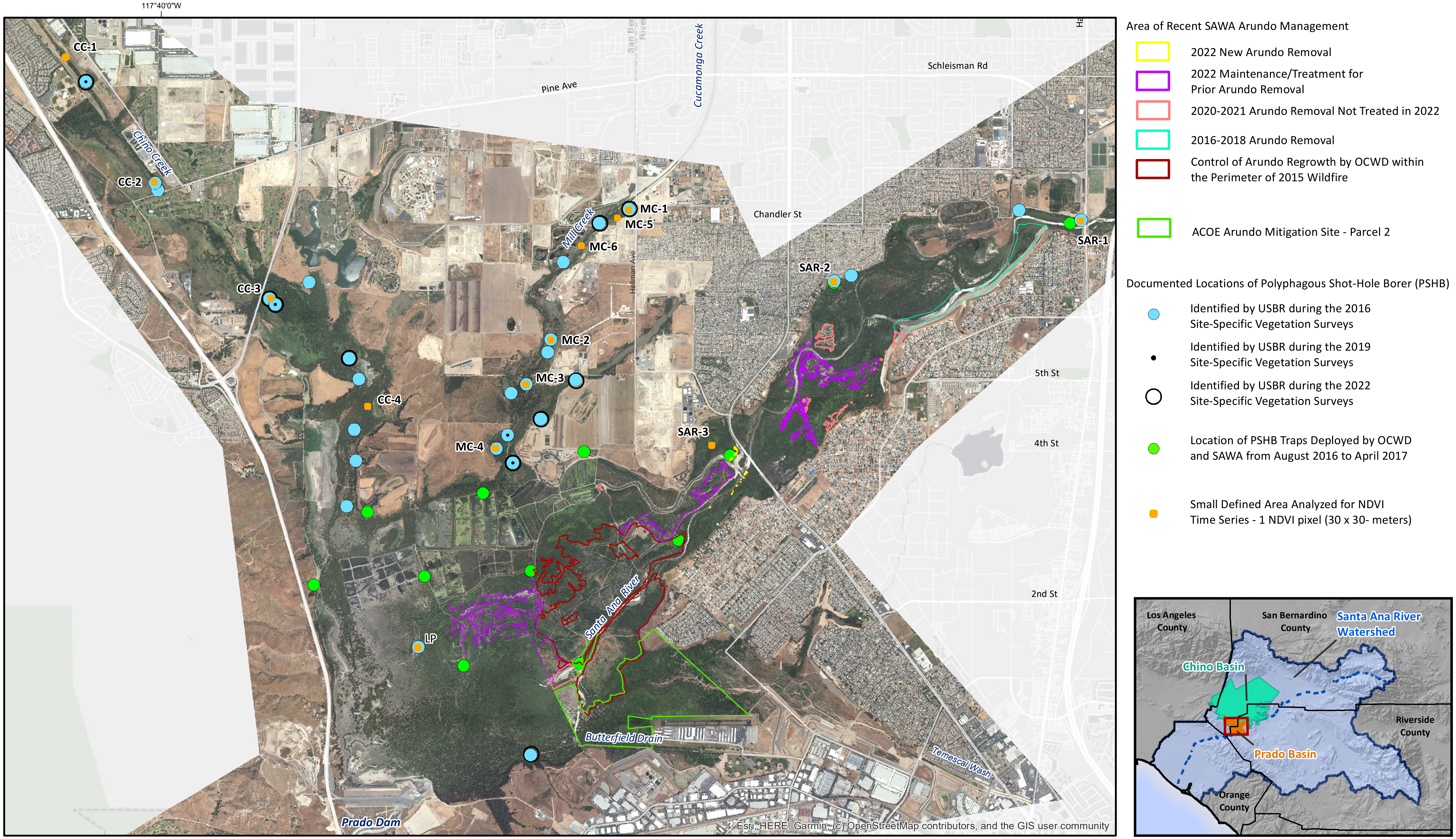
Other Factors that Affect Riparian Habitat verus NDVI
Santa Ana River and Lower Prado Area for 1984-2023

Figure 3-21c



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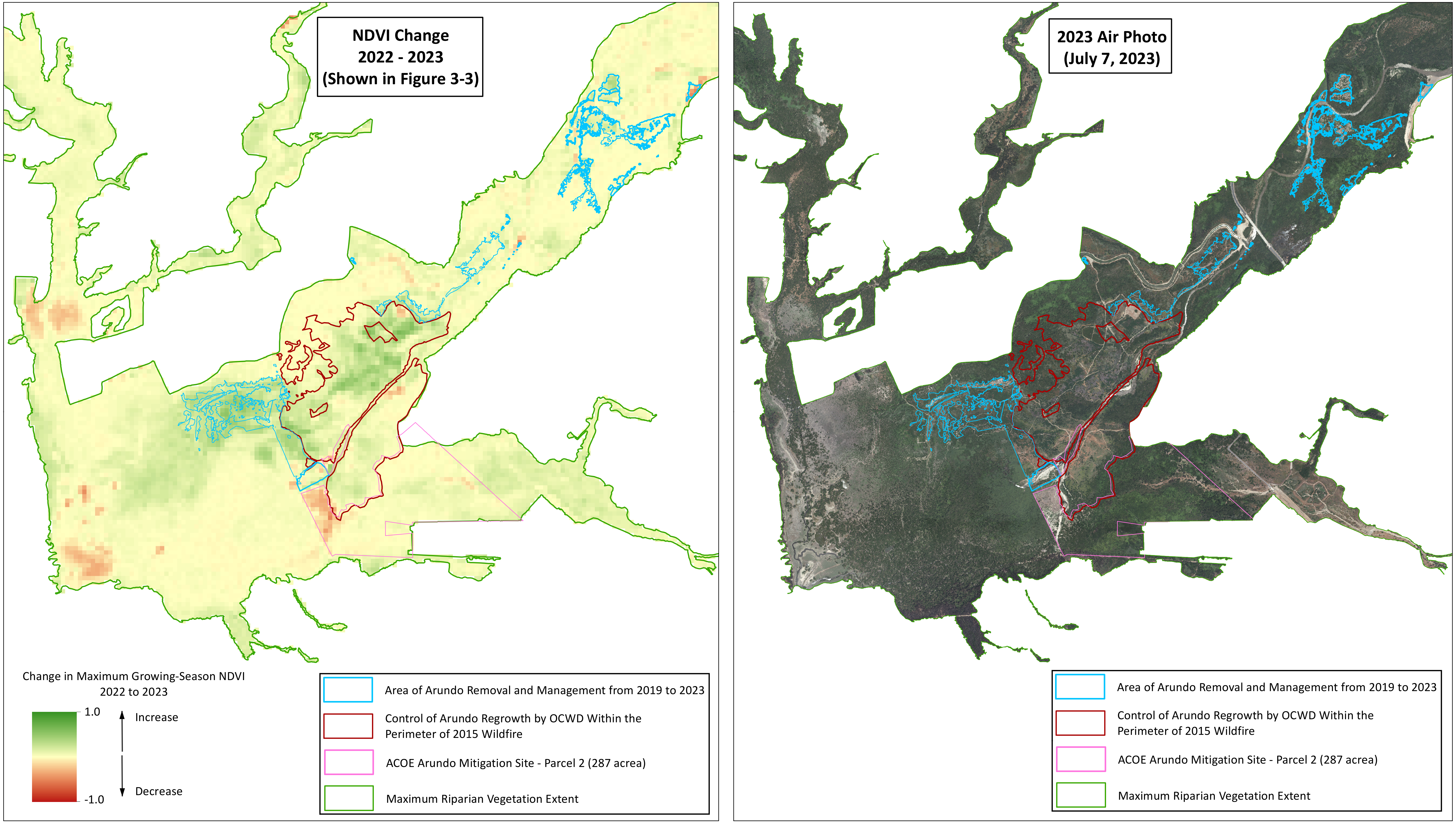
Location Map of Other Factors That Can Affect Riparian Habitat
Arundo and PSHB

Figure 3-22a



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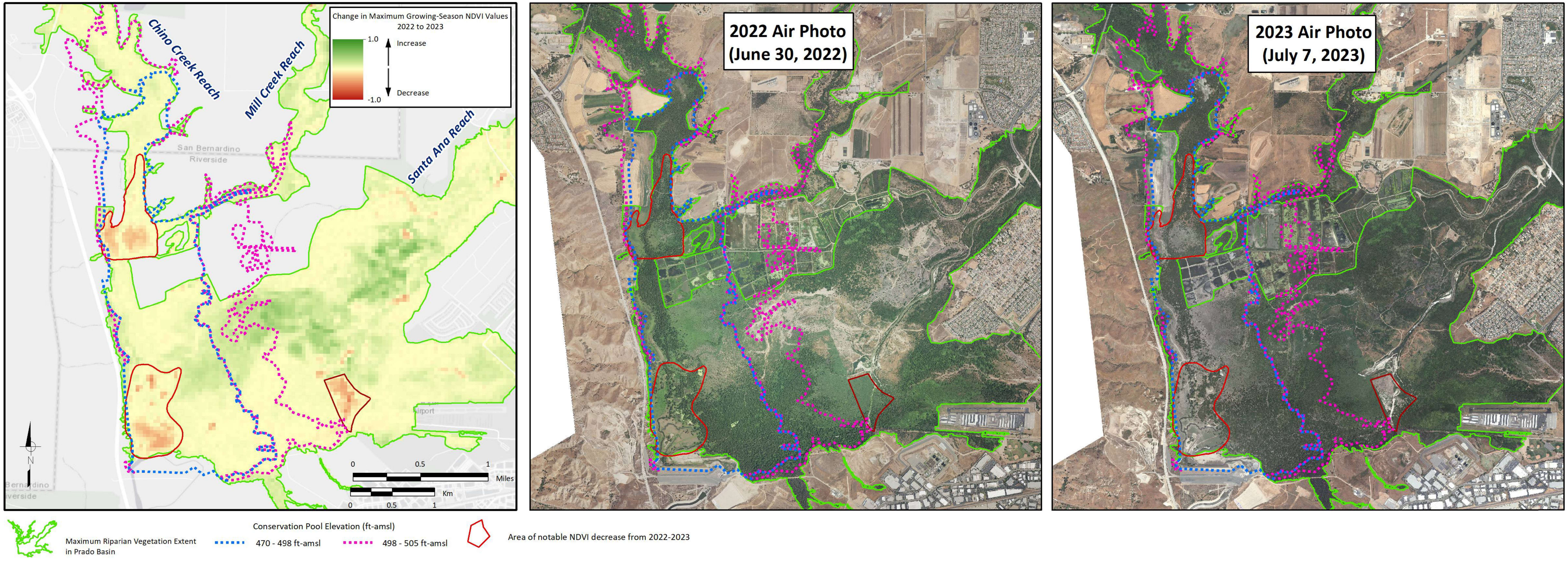
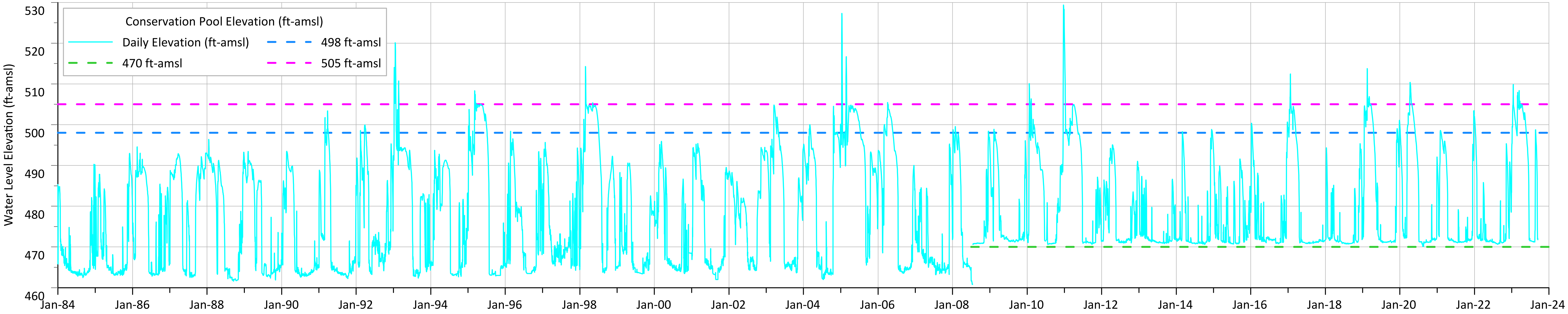
Spatial NDVI Change 2022-2023 and 2023 Air Photo with Prado Basin Arundo Removal and Management from 2019-2023

Figure 3-22b





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WEST YOST - K:\Clients\941 Chino Basin Watermaster\00-00-00 Master\PE1 - Data_Monitoring\GRAPHER\GRF\Prado\AnnualR\Figure X_Prado Dam Elevation.gpj - lhedley - 4/23/2024

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Prado Dam Elevations and NDVI Change

Figure 3-23

3.7 Analysis of Prospective Loss of Riparian Habitat

The meaning of "prospective loss" of riparian habitat in this context is the "future potential loss" of riparian habitat. Watermaster's most recent (2020) predictive modeling results[25] were used to identify areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement by projecting future groundwater-level conditions in the Prado Basin area through 2030. To perform this evaluation, the predictive model results were mapped and charted to identify areas, if any, where groundwater levels are projected to decline to depths that may adversely impact the riparian habitat in the Prado Basin.

Figure 3-24 is a map that shows the 2020 model-predicted change in groundwater levels in the Prado Basin area over the period of 2018-2030 from the planning scenario used to recalculate the Safe Yield of the Chino Basin in 2020 using Watermaster's updated groundwater-flow model (WEI, 2020). The map shows that groundwater levels are predicted to remain steady across most of the Prado Basin area through 2030. The stability in groundwater levels is explained in part by projected declines in groundwater production from private wells in the area, the IEUA's delivery of treated recycled water to this area for direct uses (such as outdoor irrigation), and the fact that most of the Chino Basin Desalter production will occur to the north and northeast. Figure 3-24 shows that the most likely area where groundwater levels are projected to decline by 2030 is the northern portions of Mill Creek and the SAR.

Figure 3-25 is a time-series chart of the 2020 model-predicted groundwater levels at the PBHSP monitoring wells for the period of 2018 to 2030. These wells are strategically located adjacent to the riparian habitat south of the Chino Desalter well field to understand the potential impacts of Peace II implementation on groundwater levels and the riparian habitat. The chart shows:

- Groundwater levels are projected to fluctuate seasonally at all PBHSP monitoring wells by about one to two feet.
- Groundwater-level trends are projected to remain stable at most of the PBHSP monitoring wells through the duration of the Peace II Agreement (through 2030).
- At two of the PBHSP monitoring wells, groundwater levels are projected to experience declines of about one to three feet from 2018 to 2030, which may represent a threat for prospective loss of riparian habitat:
    - **PB-2 above the northern reach of Mill Creek.** The 2020 model predicts a decline in groundwater levels at PB-2 of about three feet from 2018 to 2030. Figure 3-11 shows that groundwater levels declined at PB-2 by about five feet from 2018 to 2023, which is greater than the decline predicted by the model through 2030. And groundwater levels have declined by about four feet through 2023 in the riparian vegetation extent along Mill Creek just to the south. Figure 3-12 shows the current (Fall 2023) depth-to-groundwater where the riparian vegetation is growing along the northernmost reaches of Mill Creek ranges from about 10-15 ft-bgs. Hence, if the groundwater levels continue to decline along Mill Creek, then it could result in adverse impacts to the riparian habitat in this area.

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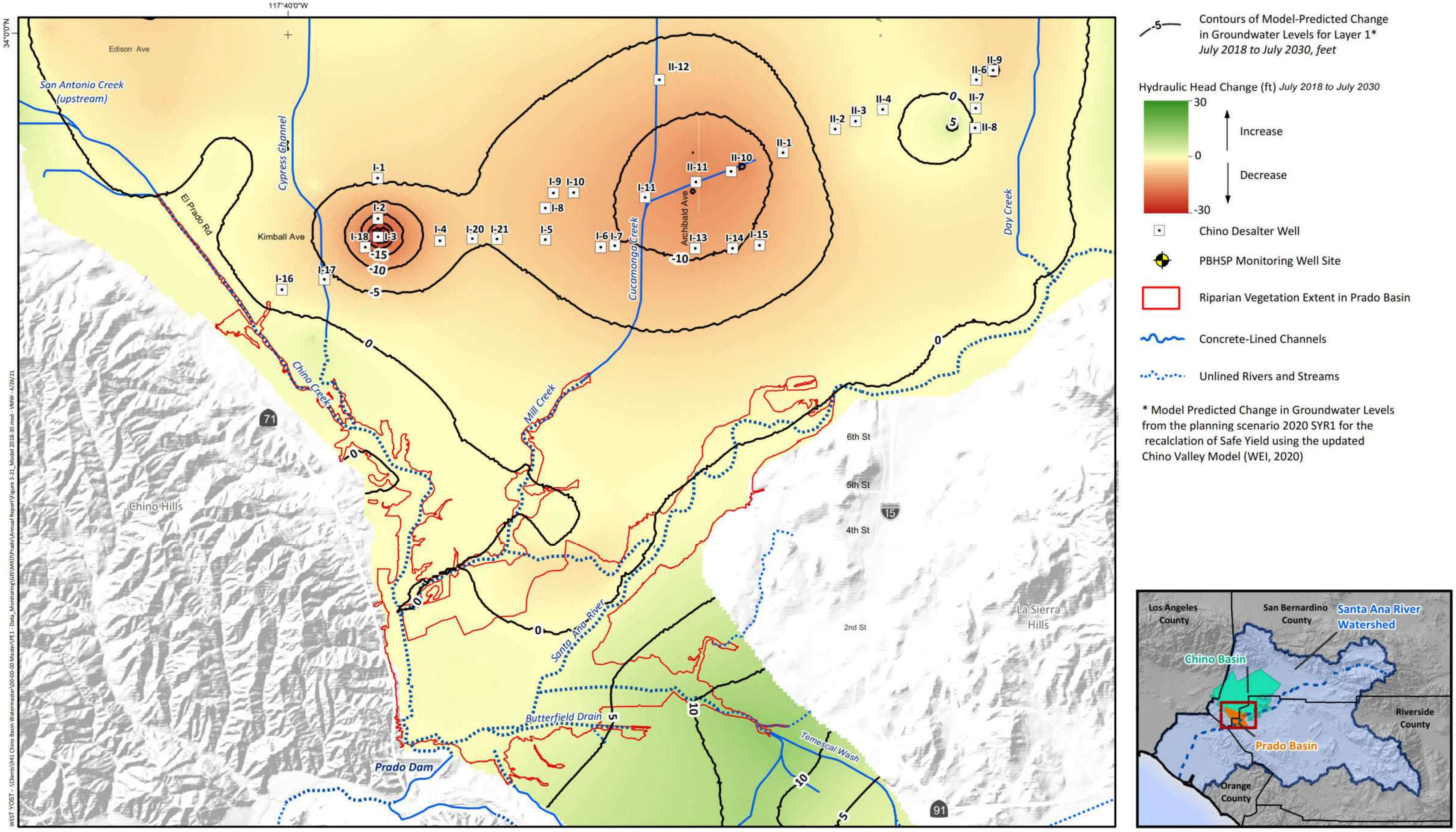
[25] The predicted groundwater level changes through 2030 were made with the 2020 Chino Valley Model (CVM) for Scenario 2020 SYR1 for Layer 1 of the aquifer. The results of this model scenario were used to recalculate the 2020 Safe Yield of the Chino Basin (WEI, 2020). Scenario SYR1 is based on the water demands and water supply plans provided by the Watermaster parties, Chino Basin parties' planning assumptions on pumping groundwater and conducting recharge operations, planning hydrology that incorporates climate change impacts on precipitation and ET0, and assumptions regarding cultural conditions and future replenishment.

- **PB-3 along the northern portion of the SAR.** The 2020 model predicts a decline in groundwater levels at PB-3 of about one foot from 2018 to 2030. Figure 3-13c shows that groundwater levels declined at PB-3 by about 1.5 feet, from 2018 to 2023, which is greater than the decline predicted by the model through 2030. Figure 3-12 shows the current (Fall 2023) depth-to-groundwater where the riparian vegetation is growing along the northernmost reaches of the SAR ranges from 4-8 ft-bgs. If groundwater levels continue to decline at similar or higher rate through 2030, then it could result in a depth to groundwater greater than 15 ft-bgs and adverse impacts to the riparian habitat in this area. However, the groundwater-level declines in this northern reach of the SAR near PB-3 are not a concern for the riparian vegetation at this time because the depth to groundwater in this area is shallow (4 to 8 ft-bgs) and is supported by SAR recharge.



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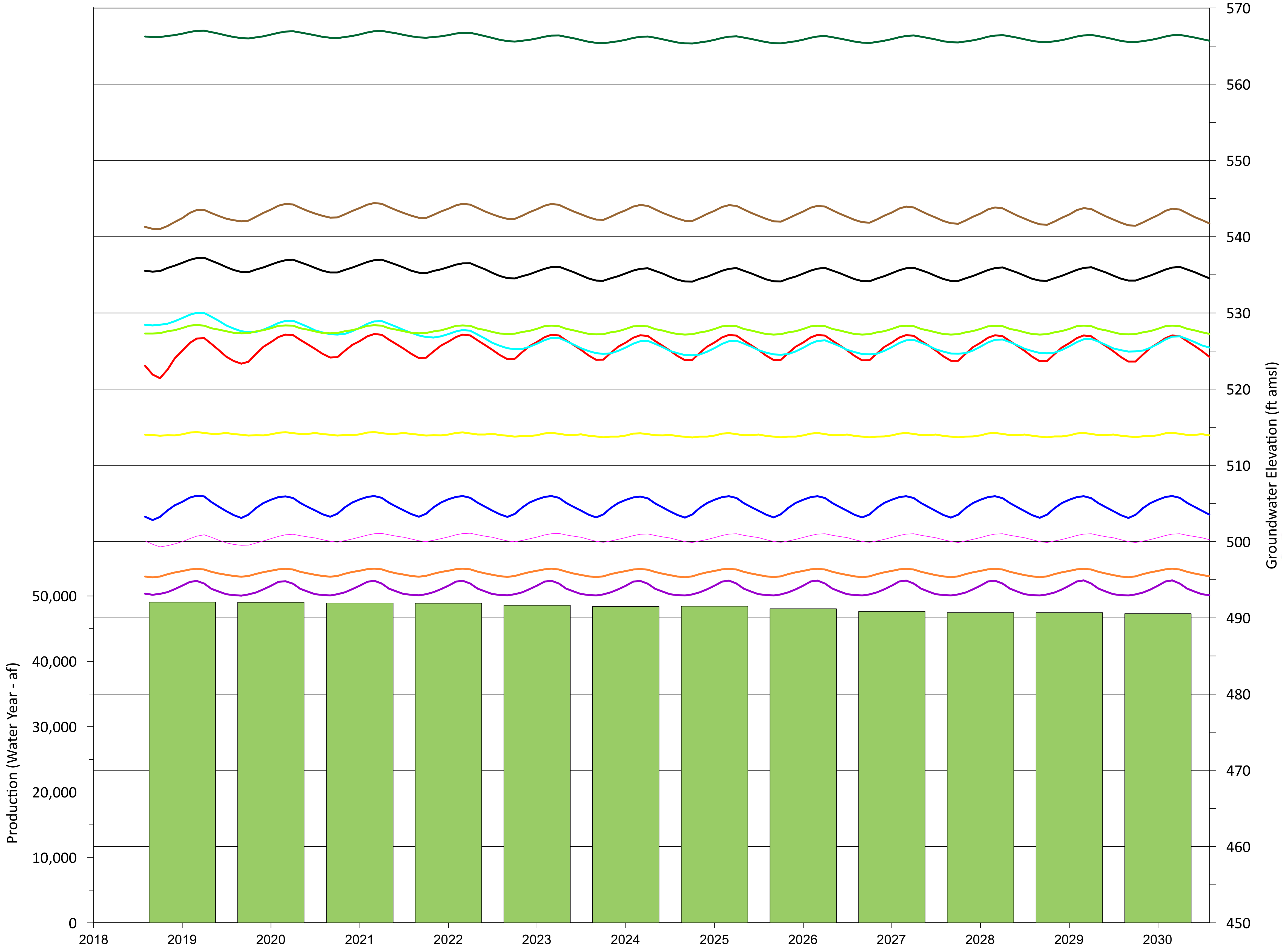
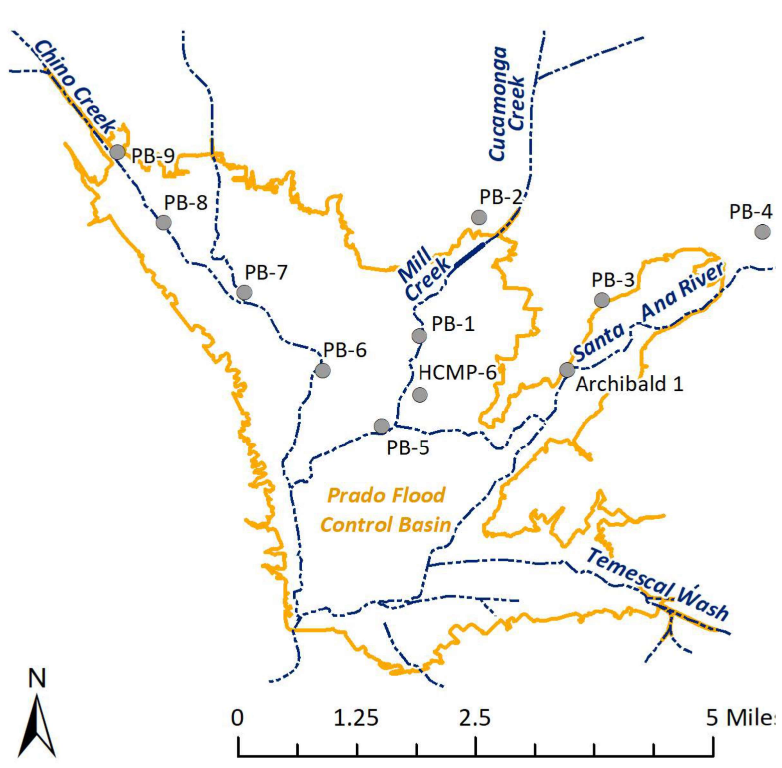
Predicted Change in Groundwater Level
2018 to 2030 - Scenario 2020 SYR1

Figure 3-24



*Model Simulated Groundwater Elevations and Pumping from the planning scenario 2020 SYR1 for the 2020 recalculation of Safe Yield using the updated Chino Basin groundwater-flow model (WEI, 2020)

Well Locations



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Predicted Change in Groundwater Levels
2018 to 2030 - Scenario 2020 SYR1

Figure 3-25

4.0 CONCLUSIONS AND RECOMMENDATIONS

The monitoring and mitigation requirements in the Peace II SEIR call for annual reporting for the PBHSP. Annual reports include recommendations for ongoing monitoring and any adaptive management actions required to mitigate any measured loss or prospective loss of riparian habitat that may be attributable to the Peace II Agreement.

The following describes the main conclusions of this annual report and provides recommendations for future monitoring, reporting, and mitigation, if any.

4.1 Main Conclusions and Recommendations

4.1.1 Conclusions

The main conclusions of the PBHSC Annual Report for WY 2023 are:

- Based on the analysis of NDVI time series, NDVI spatial change maps, and air photos, the quality (greenness) of the riparian habitat vegetation increased across most of the Prado Basin from 2022 to 2023. All of the observed increases were relatively minor and within the range of one-year changes observed historically. Some of these increases were greater than the average one-year change in NDVI observed over the historical period. These increases occurred during a time of above-average precipitation, slightly cooler temperatures, and historically high stream discharge conditions in WY 2023. There were three notable areas of decreases in greenness observed from the spatial analysis of NDVI and air photos: (i) two of the areas appear to be related to the above-average precipitation and the resulting large, persistent conservation pool held behind Prado Dam; and (ii) the other area was caused by an undetermined land use change, but could be related to Arundo removal by the ACOE or activity related to OCWD's Sediment Management Demonstration Project. None of these decreases in greenness were related to declining groundwater levels and there is no degradation trend in the riparian habitat that is contemporaneous with declining groundwater levels during Peace II Agreement.
- Over this past year from 2022 to 2023, groundwater levels at the PBHSP monitoring wells along Chino Creek, Mill Creek and the SAR in the Prado Basin increased at most of the wells, likely as a result of the increased precipitation and stream discharge.
- Since groundwater-level measurements commenced at the PBHSP monitoring wells in 2015, there have been some increasing and decreasing trends in groundwater levels observed along the reaches of Chino Creek, Mill Creek, and SAR. From September 2016 to September 2023, groundwater levels throughout most of riparian vegetation extent have changed less than +/-5 feet, but there are some notable areas of change:
  - In the northern portion of Mill Creek just south of the PB-2 monitoring well, groundwater levels declined by about eight feet from 2016 to 2022. These declines in groundwater levels were likely due to increased pumping at the Chino Desalter wells to the north. During 2023, groundwater levels increased about four feet. There has been no observed decline in the greenness of the riparian vegetation in this area.
  - In the northern reach of Chino Creek, groundwater levels increased by about ten feet from 2016 to 2023. These increases in groundwater levels were likely due to decreased pumping in the area.

- The depth to groundwater in the northernmost reach of Mill Creek where the groundwater levels have declined the most (near PB-2) is estimated at 10-15 ft-bgs in WY 2023. Additional declines in groundwater levels in this area could result in adverse impacts to the riparian habitat.
- The groundwater-level declines in the northern reach of the SAR (near PB-3) are not a concern for the riparian vegetation because the depth to groundwater in this area is shallow (4 to 8 ft-bgs) and is supported by SAR recharge.

4.1.2 Recommendations

Based on the conclusions above, the PBHSP monitoring and reporting should continue to monitor the extent and quality of the riparian habitat and the factors that can influence it as it has been conducted through WY 2023. As described in the conclusions above, there continues to be notable declines in groundwater levels near the riparian habitat along the northern portion of Mill Creek, however groundwater levels increased over this last year and the threat to riparian vegetation health has decreased, but it remains important to monitor. The additional monitoring set up in WY 2022 in the northernmost reach of Mill Creek should continue and remains important to monitoring any potential impact to the extent and quality of the riparian habitat that could be caused by the lowering of groundwater levels in this area.

The high-frequency monitoring of groundwater elevation, temperature, and EC for each pair of PBHSP monitoring wells and nearby surface water field measurements that was initiated in 2023, should continue in order to better characterize groundwater/surface water interactions and therefore its importance to the long-term sustainability of the riparian habitat.

4.2 Recommended Mitigation Measures and/or Adjustments to the AMP

This annual report documented no trend in the degradation of the extent or quality of riparian habitat along Chino Creek, Mill Creek, or the SAR that is contemporaneous with decreasing groundwater levels during the implementation of the Peace II Agreement. As such, no mitigation measures are proposed at this time.

No adjustments to the AMP are recommended at this time.

4.3 Recommended PBHSP for Fiscal Year 2024/25

Based on preliminary analysis of the PBHSP data for WY 2023, a draft *Technical Memorandum Recommended Scope and Budget of the Prado Basin Habitat Sustainability for FY 2024/25* was submitted to the PBSHC on March 7, 2024. On March 21, 2024, Watermaster's Engineer presented the recommended scope and budget for FY 2024/25 to the PBHSC for consideration. There were no changes recommended by the PBHSC on the proposed FY 2024/25 scope of work, and a final scope of work and budget was submitted to the PBHSC and will go through the Watermaster and the IEUA FY 2024/25 budgeting process in May and June of 2024. The scope of work for the PBHSP for FY 2024/25 is shown in Table 4-1 as a line-item cost estimate.

The following describes the scope of work by major task for the PBHSP for FY 2024/25:

Task 1. Groundwater Monitoring Program

The monitoring of groundwater levels in the Prado Basin is a key component of the PBHSP because declining groundwater levels could be a factor related to Peace II implementation that adversely impacts riparian vegetation. Sixteen monitoring wells were installed specifically for the PBHSP in 2015. These wells, plus monitoring wells HCMP-5/1 and RP2-MW3, are monitored for groundwater levels. The 18 monitoring wells are equipped with integrated pressure-transducers/data-loggers (hereafter referred to as transducers) that measure and record water-level measurements and temperature readings every 15 minutes. This task includes quarterly field visits to all 18 PBHSP monitoring wells to download the data from the transducers, and the processing, checking, and uploading of the water level, temperature, and EC data to the PBHSP database. The scope of this task is slightly larger than the previous fiscal year as it includes processing, checking, and uploading of EC data collected by the transducers installed at 10 of the 18 wells, in addition to the water level and temperature data. The inclusion of the high-frequency temperature and EC data is a recommendation resulting from the evaluation of and replacing the pilot monitoring program as discussed in Task 2 below.

Task 2. Surface-Water Monitoring Program

Surface-water data from the Santa Ana River and the tributaries that cross Prado Basin are used to evaluate groundwater/surface-water interactions and their importance to the impact on groundwater levels and riparian habitat, and to characterize the influence of surface-water discharge on the riparian habitat.

From FY 2018/19 to FY 2022/23, a pilot monitoring program was conducted to determine if the high-frequency data enhances and better reveals the interpretation of groundwater/surface-water interactions previously studied for the PBHSP. The pilot monitoring program included the installation of transducers that record EC, temperature, and water levels at 15-minute intervals at two locations in Chino Creek and the same high-frequency monitoring at four nearby monitoring wells (PB-7 and PB-8 clusters). Additionally, during the first two years of the pilot monitoring program, surface water and groundwater-quality samples were collected to support the high-frequency data. During the pilot monitoring program, there were monitoring challenges with the surface water monitoring component; periodically, the transducers within the creek were lost during large storm events, and the transducers consistently experienced the accumulation of mud, which compromised the accuracy of the data.

Key conclusions from the analysis of the pilot monitoring program data in the Annual Report for 2022 were that the pilot program could be discontinued and, in its place: use the high-frequency monitoring of EC, temperature, and water level for each pair of PBHSP monitoring wells (Task 1), most of which was already being collected, and collect quarterly field measurements for EC and temperature of the surface water flowing in the streams adjacent to the monitoring wells (Task 2.1). Not all of the transducers in the wells measure EC data in addition to the temperature and water level, and the plan is to replace them at the end of their useful lives with transducers that also collect EC measurements. During this last fiscal year, some transducers were replaced and currently there are 10 wells that measure EC in addition to the temperature and water level. As described above, Task 1 includes the processing, checking, and upload to the database of the high-frequency temperature, EC, and water level data collected at all the PBHSP monitoring wells.

Task 2.1 is to collect field measurements of temperature and EC at four surface water sites in Chino and Mill Creeks near the PB-1, PB-2, PB-7, and PB-8 wells and to process and upload the data to the database. The addition of the manual surface water measurements is new for this fiscal year to implement the recommendations to the monitoring program in the Annual Report for 2022 in place of the pilot monitoring program. The effort to collect, process, and upload the manual measurements is minimal since it can be done during the quarterly field visits to the monitoring wells to download the transducer data.

Task 2.2 includes the annual collection of the surface water data from four publicly-available data sets which include: the United States Geological Survey (USGS) daily discharge measurements at six sites along the Santa Ana River and its tributaries; daily discharge and water-quality data from Publicly-Owned Treatment Works (POTWs) that are tributary to Prado Basin; US Army Corps of Engineers (ACOE) daily measurements of reservoir elevation and releases from the reservoir at Prado Dam; and Watermaster's quarterly surface-water-quality monitoring at two sites along the Santa Ana River. The USGS, POTW, and ACOE data for water year 2024 will be collected, processed, checked, and uploaded to the PBHSP database. This sub task does not include the processing, checking, and uploading of the Watermaster-collected quarterly water quality data on the Santa Ana River data, which is performed under a Watermaster task for the Maximum Benefit Monitoring Program. The scope of this sub task is consistent with the work performed for the previous fiscal year.

Task 3. Climate Monitoring Program

Climatic data are evaluated in the vicinity of the Prado Basin to characterize trends, and to determine if these trends contribute to impacts on the riparian habitat. The climate monitoring program utilizes two types of publicly available, spatially-gridded datasets. Task 3 includes the annual collection of the spatially-gridded datasets for water year 2024 (October 2023 – September 2024), and the checking and uploading of the data to the PBHSP database. The scope of this task is consistent with the work performed for the previous fiscal year.

Task 4. Riparian Habitat Monitoring Program

Monitoring the extent and quality of the riparian habitat in the Prado Basin is a fundamental component of the PBHSP to characterize how the riparian habitat changes over time. To characterize the impacts of Peace II implementation on the riparian habitat (if any) it is necessary to understand the long-term historical trends of its extent and quality and the factors that have affected it. The current riparian habitat monitoring program consists of both regional and site-specific components. The proposed riparian habitat monitoring program for FY 2024/25 is described in the subsections below.

Regional Monitoring:

The regional monitoring of riparian habitat is performed via two independent methods that complement each other: mapping and analysis of the riparian habitat using (i) air photos and (ii) the normalized distribution vegetation index (NDVI) derived from the Landsat remote-sensing program. Tasks 5.1, 5.2, and 5.3 are for the collection and compilation of the regional monitoring data, including:

- Perform a custom flight (via outside professional services) to acquire a high-resolution air photo (three-inch pixel) of the Prado Basin during summer 2024. The cost for the air photo is shared with OCWD.
- Catalog and review in ArcGIS the extent of the riparian vegetation in the 2024 high-resolution air photo in of the Prado Basin.
- Collect, review, and upload the Landsat NDVI data for water year 2024.

Site-Specific Monitoring:

The site-specific monitoring of the riparian habitat consists of periodic field surveys of the riparian vegetation at selected locations. These surveys provide an independent measurement of vegetation quality that can be used to “ground truth” the regional monitoring of the riparian habitat, as well as the occurrence of the Polyphagous Shot-Hole Borer, a pest that increases tree mortality. The United States Bureau of Reclamation (USBR) along with the OCWD[26] has conducted field surveys once every three years at approximately 36 sites. The most recent triennial field survey was conducted in the summer of 2022, and it included two new sites along the northern portion of Mill Creek to increase monitoring at this location where there is potential for impacts to the riparian habitat from the observed decline in groundwater levels. The next field survey is scheduled for the summer of 2025. There is no scope or budget proposed for site-specific monitoring for FY 2024/25.

Task 5. Prepare Annual Report of the PBHSC

This task involves the analysis of all data sets collected by the PBHSP through water year 2024, including the data collected in Tasks 1 through 4 and for other as-needed factors that can impact the riparian habitat. The results and interpretations generated from the data analysis will be documented in the *Annual Report for Prado Basin Habitat Sustainability Committee for Water Year 2024*. This task includes the effort to prepare an administrative draft report for Watermaster and IEUA staff review, a draft report for the review by the PBHSC, and a final report including comments and responses. A PBHSC meeting will be conducted in May 2025 to review the draft report and facilitate comments on the report. The scope of this task is consistent with the work performed for the previous fiscal year.

Task 6. Project Management and Administration

This task includes the effort to prepare the PBHSP scope, schedule, and budget for the subsequent fiscal year. A draft *Technical Memorandum Recommended Scope and Budget of the Prado Basin Habitat Sustainability Program for FY 2025/26* will be submitted to the PBHSC in February/March 2025. A PBHSC meeting will be conducted in March 2025 to review the draft recommended scope and budget and facilitate comments. Also included in this task is project administration, including management of staffing and monthly financial reporting. The scope of this task is consistent with the work performed for the previous fiscal year.

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[26] OCWD staff provides assistance to the USBR in the field as in-kind services.

Table 4-1. Work Breakdown Structure and Cost Estimate
Prado Basin Habitat Sustainability Program - Fiscal Year 2024/25

				Labor Total		Other Costs, dollars					Totals, dollars			
	Task Description	Notes	No. of sites	Person Days	Total, dollars	Travel	Equipment Rental	Outside Pro	Total	Notes	Recommended Budget 2024/25	Budget Prior FY 2023/24	IEUA Share 2024/25	CBWM Share 2024/25
Task 1. Groundwater Monitoring Program				**20.8**	**31,214**				**950**		**32,164**	**28,514**	-	**32,164**
1.1	Download Transducer Data from PBHSP Wells (Quarterly)		18	11.0	15,809	750	200		950		16,759	14,818		
1.2	Process, Check and Upload Water Level, Temperature, and EC Transducer Data from PBHSP Wells (Quarterly)		18	9.8	15,405				0		15,405	13,696		
Task 2. Surface Water Monitoring Program				**2**	**7,844**				**200**		**8,044**	**7,045**	-	**8,044**
2.1	Collect , Process, and Upload Field Measurements of Temperature and EC at Four Surface Water Sites (Quarterly)		4	3.0	4,676		200		200		4,876	4,107		
2.2	Collect, Check, and Upload Surface Water Discharge and Quality Data from POTWs, USGS; and Dam Level Data from the ACOE (Annual)			2.0	3,168				0		3,168	2,938		
Task 3. Climate Monitoring Program				**1.3**	**2,596**				**250**		**2,846**	**2,606**	**1,423**	**1,423**
3.1	Collect, Check, and Upload Climatic Data (Annual)			1.3	2,596			250	250		2,846	2,606		
Task 4. Riparian Habitat Monitoring Program				**13.0**	**27,648**				**13,000**		**40,648**	**39,408**	**20,324**	**20,324**
4.1	Perform a Custom Flight to Acquire a High-Resolution 2024 Air Photo of the Prado Basin			1.3	3,060			13,000	13,000	(a)	16,060	15,776		
4.2	Catalog, and Review the Extent of the Riparian Vegetation in the 2024 Air Photo of the Prado Basin			2.5	5,432				0		5,432	5,912		
4.3	Collect, Check, and Upload 2024 Landsat NDVI Data to the PBHSP Database			9.3	19,156				0		19,156	17,720		
Task 5. Prepare Annual Report of the PBHSC				**50.3**	**93,954**				**100**		**94,054**	**87,814**	**47,027**	**47,027**
5.1	Analyze Data and Prepare Admin Draft Report for CBWM/IEUA			37.8	68,762				0		68,762	64,182		
5.2	Incorporate CBWM/IEUA Comments and Prepare Draft Report: Submit Draft Report to PBHSC			4.8	8,720				0		8,720	7,808		
5.3	Meet with PBHSC to Review Draft Report			4.8	10,380	100			100		10,480	9,292		
5.4	Incorporate PBHSC Comments and Finalize Report			3.0	6,092				0		6,092	6,532		
Task 6. Project Management and Administration				**9.8**	**21,962**				**100**		**22,062**	**21,414**	**11,031**	**11,031**
6.1	Prepare Scope and Budget for FY 2025/26			3.5	7,502				0		7,502	7,506		
6.2	Meet with PBHSC to Review Scope and Budget for FY 2025/26			3.3	7,212	100			100		7,312	7,332		
6.3	Project Administration and Financial Reporting			3.0	7,248				0		7,248	6,576		
	Totals			**97**	**$ 185,218**	**$ 950**	**$ 400**	**$ 13,250**	**$ 14,600**		**$ 199,818**	**$ 186,801**	**$ 79,805**	**$ 120,013**

(a) This is half of the cost for the outside professional. OCWD will pay the other half.

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Appendix A

NDVI

A.1 BACKGROUND

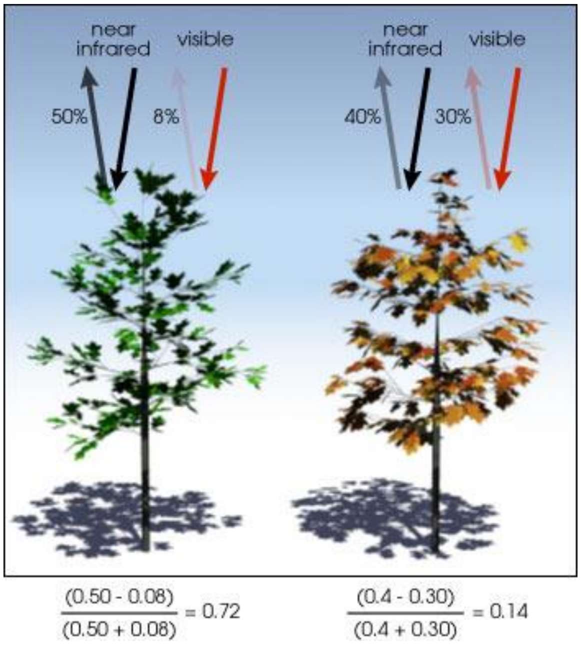
Multi-spectral remote-sensing measurements of the Earth's surface from satellites are a verifiable means of deriving complete spatial coverage of environmental information. Remote-sensing measurements have been collected in a consistent manner over time. They are updated regularly and can be analyzed retrospectively, which has made these measurements useful in various types of ecological and environmental monitoring, including vegetation monitoring (USDA, 1996; Schidt and Karnieli, 2000; Campbell, 2007; Lillesand et al., 2008; Xie et al., 2008; Jones and Vaughnan, 2010).

Remote sensing-based methods of vegetation monitoring commonly use vegetation indices that can be calculated from the wavelengths of light absorbed and reflected by vegetation (Jensen, 2007). NDVI is a widely used numerical indicator of vegetation extent and quality that is calculated from remote-sensing measurements (Ke et al., 2015; Xue,J and Su, B., 2017). Moreover, NDVI is an index of greenness correlated with photosynthesis and can be used to assess temporal and spatial changes in the distribution, productivity, and dynamics of vegetation (Pettorelli, 2013). NDVI is calculated from visible and near-infrared radiation reflected by vegetation using the following formula:

$$NDVI = \frac{(NIR - VIS)}{NIR + VIS}$$

Where: **NIR** = the spectral reflectance of near infrared radiation
VIS = the spectral reflectance of visible (red) radiation

During photosynthesis, healthy vegetation absorbs incoming visible light and reflects a large portion of near-infrared radiation. Unhealthy or dormant vegetation absorbs less visible light and reflects less near--infrared radiation. The figure[1] illustrates NDVI:



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[1] Nasa.gov

Near-infrared radiation and visible light spectral reflectance are both expressed as ratios of the reflected radiation over the incoming radiation (values between 0 and 1); therefore, NDVI estimates range between -1.0 and 1.0. Negative NDVI estimates correspond to standing water, and low positive values (0 to 0.1) correspond to non-vegetated areas, such as barren rock and sand, snow, and water. NDVI estimates ranging from 0.1 to 1.0 correspond to vegetated areas, with very low-end estimates indicating sparse, unhealthy, or dormant vegetation, and increasing estimates towards 0.9 indicating higher amounts of dense, healthy green vegetation.

Advantages and Limitations.

NDVI was chosen as a method for characterizing and monitoring the riparian habitat for the PBHSP for the following reasons:

- Peace II activities could cause regional changes in groundwater levels, which potentially could result in regional impacts to the riparian habitat that is dependent on shallow groundwater. The regional scale of NDVI makes it an appropriate “first indicator” of regional changes in the extent and quality of riparian vegetation. And, it has been widely used in the past to support similar environmental monitoring and management programs (Peters et al., 2002; Pinzon et al., 2004; Wang et al., 2004; Weiss et al., 2004; Intera, 2014; Verbesselt et al, 2010; Gandhi et al., 2015).
- There is a long time-series of historical NDVI (early 1980s to present) that spatially covers the entire Prado Basin. These datasets can be used to characterize the history of the spatial extent and quality of the riparian vegetation prior to and after the implementation of Peace II activities (2007).
- In the future, it is likely that multi-spectral remote sensing will continue to collect the commonly measured spectral bands that are used to calculate NDVI (red and near-infrared) and that these data will be available for use as part of the PBHSP at a low cost.

Like most monitoring tools, NDVI has its limitations, which can reduce its reliability and usefulness. Important examples include:

- Cloud cover, water vapor, and atmospheric contaminants can lead to false decreases in NDVI estimates compared to clear days (Tanre et al., 1992; Achard and Estreguil, 1995; Chen et al., 2004; Hird and McDermid, 2009).
- Satellite degradation, sensor errors, and data transmission errors can lead to false increases in NDVI estimates (James and Kalluri, 1994).
- Changes in soil moisture can lead to changes in NDVI estimates that are not necessarily related to changes in vegetation (Pettorelli, 2013).
- NDVI is a composite view of plant species diversity, form, structure, density, and vigor. As such, changes in NDVI may be caused by various changes in riparian habitat (Markon et al., 1995; Markon and Peterson, 2002). In other words, NDVI does not provide a complete picture of how and why vegetative changes are occurring; it simply indicates a change in vegetation.
- In densely vegetated areas, NDVI estimates have been shown to plateau during the growing season, indicating that NDVI can underestimate the green biomass in densely vegetated areas (Tucker et al., 1986).

These limitations demand that NDVI data be screened and filtered to identify or remove errors and noise. To reduce or eliminate noise, processing algorithms can be applied to "smooth" the time-series data and reveal patterns of change over time. For example, a smoothing technique applied in this report was the averaging of all NDVI from the growing season months. The average values are then plotted on time-series charts to display long-term trends in growing season vegetation quality.

The limitations also demand that NDVI not be interpreted in isolation. Interpretations of NDVI (vegetative changes) should be (i) verified with other georeferenced datasets, such as air photos and field vegetation surveys, and (ii) explained by comparison to datasets of causal factors of vegetative changes, such as water availability.

A.2 LANDSAT PROGRAM AND NDVI

The USGS and the National Aeronautics and Space Administration (NASA) jointly manage the Landsat Program[2], a series of Earth-observing satellite missions that began in 1972 with sensors that observe the Earth's surface and transmit information to ground stations that receive and process multi-spectral, remote-sensing data. Landsat satellites use technology that collects scenes of remote sensing measurements at the same time and location on the Earth's surface at a temporal frequency of about every two weeks. Landsat remote sensing measurements (Landsat imagery) is acquired in scenes that are approximately 106 by 115 miles. Landsat imagery is the only data source with more than thirty-years of continuous records of global land surface conditions at a spatial resolution of tens of meters (Tuck et al., 2004). Landsat imagery is among the most widely used satellite imagery in ecology and conservation studies (Pettorelli, 2013), and the data have been available for no cost since about 2010.

The United States Geological Survey (USGS), in compliance with the Global Climate Observing System[3], produces spectral indices products from Landsat imagery to support land surface change studies, which includes NDVI from 1982 to present (USGS, 2016). The USGS uses remote sensing imagery from the Landsat satellites—*Landsat 4, Landsat 5, Landsat 7, Landsat 8, and Landsat 9* (*Landsat 4, 5, 7, 8, and 9*)—to generate NDVI estimates of the Earth's surface at a 30 x 30-meter pixel resolution. To apply the necessary atmospheric corrections and generate a surface reflectance product, the USGS uses a specialized software called Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) to post-process the Landsat imagery (USGS 2015; 2017a). This surface reflectance product is then used to determine NDVI, among the other spectral indices. The spectral indices products are available for the USGS Landsat Collection 2 Level-2.[4]

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[2] Nasa.gov

[3] Global Climate Observing System Link

[4] Prior to 2022, this program utilized NDVI from the USGS Landsat Collection 1 Level-1, but that collection has been discontinued by the USGS. In 2022, NDVI from the entire period of record from 1984 to 2022 was obtained and uploaded to the project database to have a consistent record of NDVI from the same collection so that there are no changes in the NDVI analyzed in time series that were attributable to the difference in the spectral indices products from different Landsat Collections over time .

A.3 Collection, Review, and Analysis of NDVI for the PBHSP

Collection

NDVI from the Landsat imagery for the period 1982 to 2023 were collected from the USGS, using the Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface[5] (USGS 2017b). The interface requires a bulk request in the form of a text file list of specific Landsat scenes using the Landsat scene identifier ID.[6] To obtain complete spatial coverage of the Prado Basin area, NDVI was requested for all Landsat scenes for Path 040, Rows 036 and 037.[7] Table 1 below summarizes the Landsat satellites and periods for which NDVI was obtained to produce a near-continuous NDVI record.

Table 1. Landsat Satellites

Satellite	Instrument	Launched	Ended	Period of NDVI Data Obtained from USGS
Landsat 4	Thematic Mapper	July 16, 1982	December 14, 1993	1982 - 1983
Landsat 5	Thematic Mapper	March 1, 1984	June 5, 2013	1984 - 2011
Landsat 7	Enhanced Thematic Mapper	April 15, 1999	Still active	1999 - 2016
Landsat 8	Operational Land Imager	February 11, 2013	Still active	2013 - 2023
Landsat 9	Operational Land Imager 2 and Thermal Infrared Sensor 2	September 27, 2021	Still active	2021-2023

NDVI from scenes produced from the *Landsat 4, 5, 7, 8, and 9* satellites were obtained from the USGS for the period 1982 through 2023. The source and frequency of availability of NDVI from the USGS varies over the period of record:

- From 1982 to 1989, NDVI is from Landsat 4 and 5 and is patchy, ranging from a frequency of eight days to one year.
- From 1990 to 1999, NDVI is from Landsat 5 at a frequency of about 16 days.
- From 1999 to 2011, NDVI is from Landsat 5 and 7 at a frequency of seven to eight days.
- In 2012, NDVI is from Landsat 7 at a frequency of 14 to 16 days.

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[5] USGS Link

[6] Landsat imagery is captured in scenes that are about 106 by 114 miles. Each Landsat scene has a unique scene ID based on the specific Landsat satellite, Landsat path number, Landsat row number, and date the image was collected.

[7] The Prado Basin is in an area of the Landsat path 040 that straddles Rows 036 and 037. Landsat scenes from Path 040 Row 036 and Path 040 Row 037 overlap each other throughout most of the Prado Basin region, but both are required to obtain complete spatial coverage of the Prado Basin.

- From 2013 to 2023, NDVI is from Landsat 7 and 8 at a frequency of seven to eight days.
- Since November 2021, NDVI is from Landsat 7, 8, and 9 at a frequency of one to eight days.

NDVI were cataloged, processed, and uploaded into HydroDaVE^{SM}, a database management software that manages gridded datasets and features tools for viewing and extracting data.[8] There is some overlap of NVDI data in areas where there is NVDI from Landsat scenes from Rows 036 and 037. HydroDaVE has the ability to compute a stacked average for Landsat scenes from Rows 036 and 037 for each NDVI pixel they overlay[9] when viewing and extracting NDVI data.

Review

Spatial NDVI were reviewed for disturbances that can be caused by cloud cover, unfavorable atmospheric conditions, or satellite equipment malfunction. In HydroDaVE^{SM}, maps were prepared of spatial NDVI for the entire Prado Basin region for each date. The maps were reviewed and documented to identify specific dates for exclusion due to cloud cover or other disturbances. Erroneous NDVI estimates were discernable because NDVI patterns of permanent landscape features were distorted and/or NDVI estimates were clearly not consistent with estimates typically observed for a particular area both seasonally and over time. On average, about 31 percent of the NDVI were identified as erroneous and excluded from the analysis. Most of which were rejected because of cloud coverage, which was further verified by referencing and viewing the specific Landsat scene on the USGS *EarthExplorer* website.[10]

After excluding erroneous NDVI estimates, there was one date for 1982, and there were no dates for 1983; as such, the time-series data discussed throughout Section 3 of the report include NDVI estimates for 1984 to 2023.

NDVI estimates derived from *Landsat 7* satellite imagery since mid-2003 have to be further reviewed date-by-date for the occurrence of spatial data gaps, resulting from the failure of the Scan Line Corrector (SLC) on the *Landsat 7* satellite, which accounts for the satellite's forward motion. SLC failure results in data gaps along scan line paths of variable widths and occurrences. An estimated 22 percent of any given *Landsat 7* scene is lost because of SLC failure; however, the imagery acquired between these gaps is valid and useable for analysis.[11] All NDVI estimates derived from *Landsat 7* satellite imagery since 2003 were evaluated spatially date-by-date to determine if the valid portion of the data covers the defined areas of interest used for the temporal analysis of NDVI in the time series discussed in Section 3 of this report. Date-by-date analysis is necessary because the spatial position and size of the data gaps from the *Landsat 7* satellite vary for each date. Generally, areas of interest for NDVI analysis that are larger than about 400 square meters cannot use any NDVI determined from *Landsat 7* satellite imagery because it would include data gaps within the area; while areas of interest less than 400 square meters can use NDVI determined from the *Landsat 7* satellite imagery if the data gap area is not within the area of interest. During 2012, the *Landsat 7* satellite was the only Landsat satellite collecting data. Therefore, there are no data for the

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[8] Hydrodave Link

[9] Not all dates will have Landsat scenes for both Rows 036 and 037 if cloud cover was greater than 20 percent in one of them; Landsat scenes with a percent cloud cover greater than 20 percent were not obtained from the USGS for this study.

[10] Earthexplorer Link

[11] Landsat Link

areas of interest larger than 400 square meters during 2012. After the launch of the *Landsat 9* satellite in 2022, there were several dates without spatial data gaps from the *Landsat 7* satellite.

Analyses of Time-series Data

HydroDaVE^{SM} contains features to calculate and extract a spatial average NDVI for a designated area and time period. The NDVI spatial average for each available date is plotted in time-series charts to analyze seasonal and temporal changes for a defined area. Time-series charts of NDVI for various areas in the Prado Basin are first introduced in Section 3.1 of this report.

When viewing time-series charts of NDVI for the period of record, it should be noted that a methodological factor that can affect observed NDVI trends is the difference between the technology of the *Landsat 4, 5, and 7* satellites, and the *Landsat 8 and 9* satellites. The *Landsat 4, 5, and 7* satellites use thematic mapper technology to scan the land surface, whereas *Landsat 8* and *Landsat 9* use operational land imager sensors. It has been well documented that the NDVI estimates obtained from the operational land imager sensors used on the *Landsat 8 and 9* satellites generate slightly higher index values for vegetated land cover (Xu and Guo 2014; She et al., 2015). In order to analyze the time-series of NDVI derived across all Landsat satellites for the period of record, a bias-correction factor of -0.05, derived from literature review (Li et al., 2014; Flood, 2014: and Ke et al., 2015), was used to transform all Landsat 8 and 9 NDVI estimates such that all historical NDVI estimates could be analyzed collectively (Roy et al., 2016). The *Landsat 9* satellite was launched into orbit in 2022, and since then, NDVI has been available from *Landsat 7, 8, and 9* satellites. During 2023, data was collected from both the *Landsat 8 and 9* satellites on some of the same dates. On these dates, only NDVI from the *Landsat 9* satellite was used.

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Appendix B

Mann-Kendall Analysis of NDVI

B.1 Introduction

The Mann-Kendall statistical trend test (Mann-Kendall test) was performed on the average growing-season NDVI metrics (NDVI) for the period of 1984 to 2023 for all 18 areas where NDVI are analyzed for the *Annual Report of the Prado Basin Habitat Sustainability Committee Water Year 2023*. The Mann-Kendall test was utilized to evaluate whether the average growing-season NDVI increased, decreased, or remained stable over time.

B.2 Methods

The Mann-Kendall test is a non-parametric statistical trend test. It is analogous to parametric trend testing such as regression (linear regression) except the data do not need to have a particular probability distribution (normal) and be accurately described by a particular measure of centrally tendency (mean, standard deviation, etc.) (Helsel and Hirsch, 2002).

To perform the test, the NDVI values are ordered chronologically and the signs (+/–) are recorded for all of the possible differences between a given NDVI value and every NDVI value that preceded it in the time series. The Mann-Kendall test statistic **S** is defined as the number of positive differences (+) minus the number of negative differences (–). From **S** and the number of NDVI values, **n**, the **τ** coefficient (analogous to the **r** correlation coefficient in linear associations) is then calculated. The **τ** coefficient represents the strength of the monotonic relationship between time and NVDI values with a possible range of -1 to 1. A perfect positive trend would yield a **τ** coefficient equal to 1, and a perfect negative trend would yield a **τ** coefficient equal to -1.

The Mann-Kendall test utilizes the null hypothesis that there is no trend. If the **S** test statistic and **τ** coefficient are significantly different than zero, the null hypothesis is rejected, and a trend exists. The level of statistical significance is expressed as a p-value between 0 and 1. The smaller the p-value the stronger the evidence that the null hypothesis should be rejected. In this study, a p-value of less than or equal to 0.05 was used to determine if a trend existed. In summary, the three possible outcomes of the test are

- Increasing trend (p-value ≤ 0.05, $\tau > 0$)
- No trend (p-value > 0.05)
- Decreasing trend (p-value ≤ 0.05, $\tau < 0$)

B.4 Data Analysis and Results

The Mann-Kendall **S** test statistic, **τ** coefficient and p-value were computed for average-growing season NDVI from 1984 to 2023 for the 18 areas in Prado Basin, using the python package *pyMann-Kendall* (Hussain, 2019). Table B-1 through B-3 lists the results of the Mann-Kendall test for the three time periods of interest: 1984 through 2023 (entire period of record); 1984 through 2006 (period prior to the Peace II Agreement); and 2007 through 2023 (period after the Peace II Agreement implementation).

Table B-1. 1984 to 2023

Area	n (number of NDVI values)	S Test Statistic	τ coefficient	p-value	Trend
Riparion Vegetation Extent	39	93	0.13	2.66E-01	No Trend
Chino Creek Area	39	487	0.66	4.13E-09	Increasing
Mill Creek Area	39	-47	-0.06	5.78E-01	No Trend
Upper Mill Creek Area	39	289	0.39	4.94E-04	Increasing
CC-1	40	556	0.71	1.00E-10	Increasing
CC-2	40	514	0.66	2.27E-09	Increasing
CC-3	40	508	0.65	3.48E-09	Increasing
CC-4	40	272	0.35	1.59E-03	Increasing
MC-1	40	470	0.60	4.65E-08	Increasing
MC-2	40	78	0.10	3.70E-01	No Trend
MC-3	40	228	0.29	8.17E-03	Increasing
MC-4	40	158	0.20	6.74E-02	No Trend
MC-5	40	100	0.13	2.49E-01	No Trend
MC-6	40	228	0.29	8.17E-03	Increasing
SAR-1	40	-70	-0.09	4.21E-01	No Trend
SAR-2	40	176	0.23	4.15E-02	Increasing
SAR-3	40	358	0.46	3.19E-05	Increasing
LP	40	-20	-0.03	8.25E-01	No Trend

Table B-2. 1984 to 2006

Area	n (number of NDVI values)	S Test Statistic	τ coefficient	p-value	Trend
Riparion Vegetation Extent	23	45	0.18	2.45E-01	No Trend
Chino Creek Area	23	123	0.49	1.27E-03	Increasing
Mill Creek Area	23	-119	-0.47	1.83E-03	Decreasing
Upper Mill Creek Area	23	-29	-0.11	4.60E-01	No Trend
CC-1	23	129	0.51	7.23E-04	Increasing
CC-2	23	141	0.56	2.18E-04	Increasing
CC-3	23	135	0.53	4.02E-04	Increasing
CC-4	23	5	0.02	9.16E-01	No Trend
MC-1	23	89	0.35	2.01E-02	Increasing
MC-2	23	-55	-0.22	1.54E-01	No Trend
MC-3	23	-51	-0.20	1.87E-01	No Trend
MC-4	23	-35	-0.14	3.69E-01	No Trend
MC-5	23	41	0.16	2.91E-01	No Trend
MC-6	23	-65	-0.26	9.10E-02	No Trend
SAR-1	23	11	0.04	7.92E-01	No Trend
SAR-2	23	-139	-0.55	2.68E-04	Decreasing
SAR-3	23	-25	-0.10	5.26E-01	No Trend
LP	23	85	0.34	2.65E-02	Increasing

Table B-3. 2007 to 2023

Area	n (number of NDVI values)	S Test Statistic	τ coefficient	p-value	Trend
Riparion Vegetation Extent	16	22	0.18	3.44E-01	No Trend
Chino Creek Area	16	68	0.57	2.56E-03	Increasing
Mill Creek Area	16	50	0.42	2.74E-02	Increasing
Upper Mill Creek Area	16	86	0.72	1.30E-04	Increasing
CC-1	17	82	0.60	8.48E-04	Increasing
CC-2	17	100	0.74	4.54E-05	Increasing
CC-3	17	68	0.50	5.78E-03	Increasing
CC-4	17	60	0.44	1.51E-02	Increasing
MC-1	17	100	0.74	4.54E-05	Increasing
MC-2	17	62	0.46	1.20E-02	Increasing
MC-3	17	52	0.38	3.57E-02	Increasing
MC-4	17	22	0.16	3.87E-01	No Trend
MC-5	17	62	0.46	1.20E-02	Increasing
MC-6	17	100	0.74	4.54E-05	Increasing
SAR-1	17	76	0.56	2.01E-03	Increasing
SAR-2	17	94	0.69	1.28E-04	Increasing
SAR-3	17	92	0.68	1.78E-04	Increasing
LP	17	-28	-0.21	2.66E-01	No Trend

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Appendix C

Draft 2022 Prado Basin Vegetation Survey Report

MARCH 3, 1849

United States Department of the Interior

BUREAU OF RECLAMATION
P.O. Box 25007
Denver, CO 80225-0007

IN REPLY REFER TO:
86-68560
1.3.11

VIA ELECTRONIC MAIL ONLY

Memorandum

To: Leslie Cleveland, Water Resources Manager
Southern California Area Office (SCAO-7200)

From: Aaron Murphy, Ecologist
Hydraulic Investigations and Laboratory Services (86-68560)

Subject: Prado Basin Vegetation Survey

Please find attached the final report for the Prado Basin Vegetation Survey (EcoLab-LCP23-2023-03). This memorandum documents the vegetation surveys and data analysis conducted in the Prado Basin, CA in October 2022. These surveys were done to support the Inland Empire Utilities Agency (IEUA) and Chino Basin Watermaster at the request of the Southern California Area Office (SCAO). Any questions about the surveys or memorandum should be addressed to Aaron Murphy at 303-445-2157 (amurphy@usbr.gov) or Scott O'Meara at 303-445-2216 (someara@usbr.gov).

Attachment

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Prado Basin Vegetation Survey – October 2022

Riverside and San Bernardino Counties, California
Chino Basin Watermaster and Inland Empire Utilities Agency
Prado Basin Habitat Sustainability Program

U.S. Department of the Interior 7 June 2023

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Prado Basin Vegetation Survey – October 2022

Riverside and San Bernardino Counties, California
Chino Basin Watermaster and Inland Empire Utilities Agency
Prado Basin Habitat Sustainability Program

Technical Service Center
Hydraulic Investigations and Laboratory Services
Ecological Research Laboratory

EcoLab-LCP23-2023-03

Aaron Murphy, Ecologist
Scott O’Meara, Botanist

Cover Photo: Misty morning at the Orange County Water District office. (Reclamation/Aaron Murphy)

Contents

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Introduction

The United States Bureau of Reclamation (Reclamation) has been monitoring riparian vegetation within the Prado Flood Control Basin (Prado Basin) since 2003 to support the Inland Empire Utilities Agency (IEUA) and Chino Basin Watermaster (Watermaster). This report details vegetation monitoring surveys conducted in October 2022 by Reclamations' Technical Service Center. Similar vegetation monitoring surveys were conducted by Reclamation in 2007, 2013, 2016, and 2019.

The IEUA, Watermaster, and the Orange County Water District (OCWD) are concerned about the quality of water flowing into the Santa Ana River. In the southern Chino Basin, as agricultural/dairy land uses are converted to urban, there is more water recycled and reused, both of which result in less groundwater pumping and the potential for poor quality groundwater to become rising groundwater to the Santa Ana River. Groundwater pumping by a regional municipal well field across the southern Chino Basin was proposed in the Watermaster's Optimum Basin Management Program to control groundwater levels in southern Chino Basin, including the Prado Basin, and to limit rising groundwater and its water-quality impacts to the Santa Ana River and downstream beneficial users.

In the Prado Basin, riparian habitat could be impacted by decreasing groundwater levels caused by the groundwater pumping plan. Riparian habitats are an ecologically important part of the landscape. They contain higher levels of species richness than other habitats and are essential to promoting regional biodiversity. Conservation of the riparian habitat of the Prado Basin is important to IEUA, Watermaster, OCWD, Reclamation, and other entities involved in water and habitat conservation.

Riparian habitat along Mill and Chino Creeks, and in the Prado Basin, is dominated by native plants, including: Goodding's willow (*Salix gooddingii*), red willow (*Salix laevigata*), arroyo willow (*Salix lasiolepis*), sandbar willow (*Salix hindsiana*), Fremont cottonwood (*Populus fremontii*), and black cottonwood (*Populus trichocarpa*). Riparian species are generally phreatophytic, meaning they must maintain root contact with water. A decrease in groundwater elevation could negatively affect recruitment, density, and vigor of existing trees.

The riparian area in the Prado Basin is also breeding habitat for two endangered songbirds, Least Bell's Vireo (*Vireo bellii pusillus*) and Southwestern Willow Flycatcher (*Empidonax trailii extimus*), as well as for the Yellow-billed Cuckoo (*Coccyzus americanus*), a threatened species. An active and successful management program has made this area vital to the recovery of the Least Bell's Vireo.

Study Area

There are approximately 6,000 acres of riparian vegetation in the Prado Basin (Figure 1). This constitutes the largest riparian area of willow woodlands in Southern California, and it is home to rare, threatened, and endangered species. One endangered songbird, the Least Bell's Vireo (Vireo bellii pusillus) builds nests within dense riparian shrubs. This species is a California state and federally listed endangered species, and the Prado Basin is designated as critical habitat. In addition to ecological concerns, the Prado Basin is important for flood control, water storage, and water quality improvement.

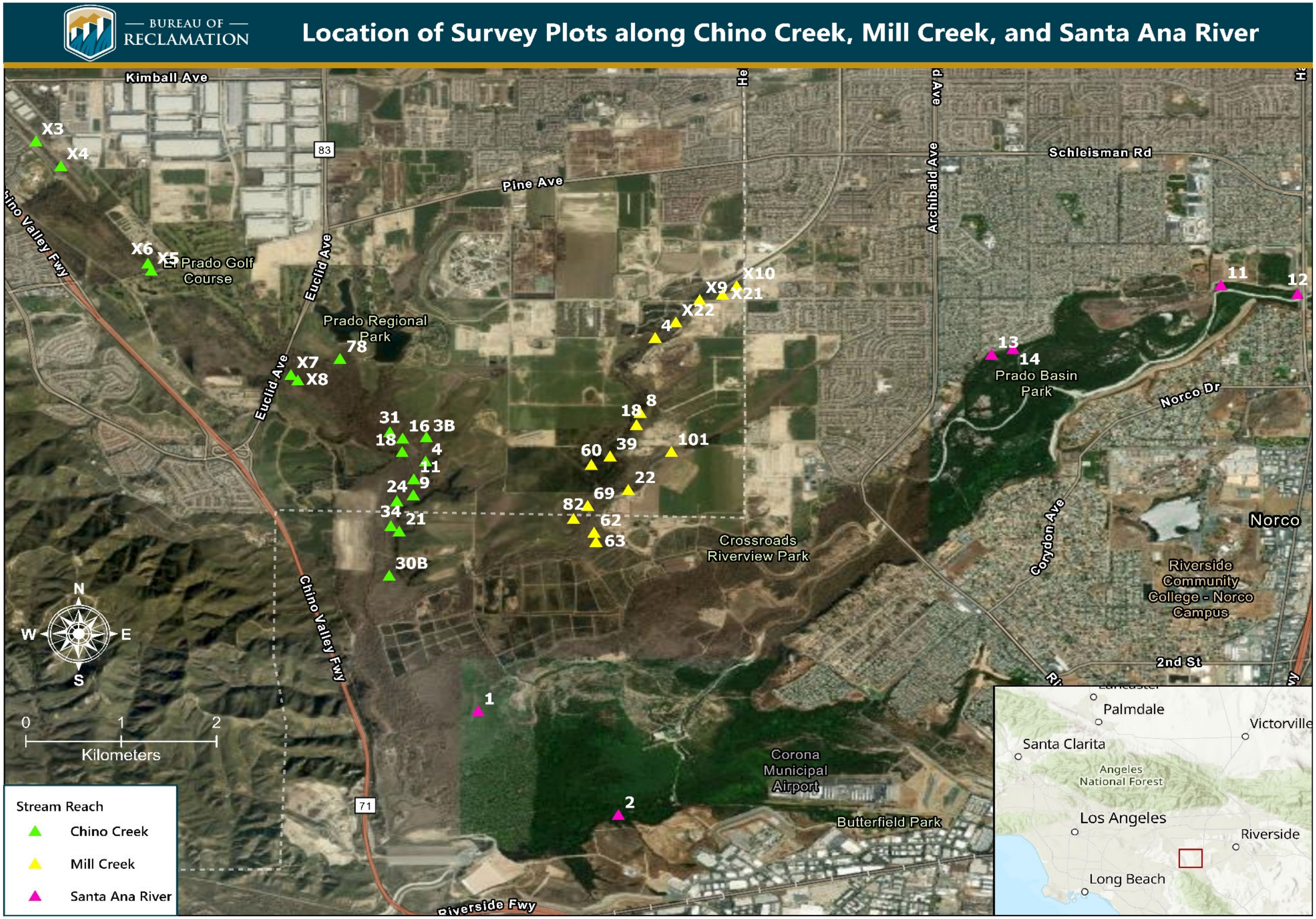


Figure 1. Map of Prado Basin study area with locations of 2022 survey plots.

Methods

The field sampling protocol developed in 2003 has been modified over time to achieve overall study goals with the available resources.

Monitoring History Performed by Reclamation in Prado Basin for IEUA/Watermaster

- *June 2003* - Mill Creek was chosen as the study area and Chino Creek was chosen as the control area for vegetation monitoring based on analysis of a depth-to-water hydraulic model by Wildermuth Environmental Inc. (WEI).
- *November 2003* - Aerial photographs were taken of the entire Prado Basin, including the riparian areas along Mill Creek, Chino Creek, the Santa Ana River, and Temescal Creek.
    - Aerial photographs were used to delineate riparian areas into cover types. Wetland and deep-water habitats were mapped and classified according to the United State Fish and Wildlife Service (USFWS) wetland hierarchical classification system (Cowardin et al, 1979).
- *March 2004* - Pilot data were collected at Mill Creek (18 plots) and Chino Creek (15 plots) to determine necessary sample size and sampling methodology.
- *October 2007* - Permanent plots were established at locations near the 2004 pilot locations and marked with t-posts. A sampling methodology was established; vegetation data were collected and trees were tagged.
- *October 2013* – The monitoring protocol was adjusted. Herbaceous vegetation was excluded as it was deemed less relatable to groundwater and too labor intensive to monitor. Variable radius plots were established at each monitoring site and vegetation data were collected.
- *October 2016* - Additional permanent plots were established at 14 locations adjacent to shallow monitoring wells along Mill Creek, Chino Creek, and the Santa Ana River. Data were collected at 37 permanent plots (23 survey previously and 14 new) using the 2013 monitoring protocol.
- *September 2019* – The 37 permanent plots surveyed in 2016 were surveyed using the 2013/2016 protocol. No new plots were established, but additional trees were tagged and recorded (Figure 1).
- *October 2022* – The 37 permanent plots surveyed in 2019 were surveyed along with two additional plots established along Mill Creek bringing the total number of plots to 39 (Figure 1). The monitoring protocol was modified to eliminate the collection of tree diameter at breast height, tree height, and lowest leaf height since these variables were not used in the assessment of riparian health.

Initial Monitoring (2003 & 2007)

The original monitoring plan used a fixed area sampling method to measure species composition, density, and basal area. Nested variable quadrats based on vegetation layer were used at each sampling point. Live and dead trees, saplings, shrubs, and seedlings were counted by species within their respective quadrat sizes.

For overstory species, diameter at breast height (DBH), height, and/or stem diameter 30 cm above the ground for shrubs, were measured. Canopy cover was estimated using four spherical densiometer measurements per plot, 5 meters from the plot center in each of the four cardinal directions. Photo points were also taken from the center of the quadrat in each of the four cardinal directions. In 2007, plots were permanently marked with t-posts and trees were tagged in order to conduct identical measurements over time.

Modified Monitoring (2013, 2016, & 2019)

From 2013 to 2019 monitoring was conducted at the locations established in 2007. An additional 14 plots were established in 2016: 6 on Chino Creek (18 total plots), 2 on Mill Creek (13 total plots), and 6 on the Santa Ana River (6 total plots). This brought the basin study total to 37 monitoring plots across three stream reaches.

Shrubs and saplings (DBH <8 cm) were the only component of the understory monitored. Herbaceous vegetation was excluded after 2007 as it was deemed less relatable to groundwater and is more labor intensive to monitor. Within the plots, the DBH was measured for each sapling, or Diameter at Root Collar (DRC) for shrubs. Shrub stems branching below 10 cm counted as individual stems, and downed trees were not counted. Species, height, and distance/azimuth from the center point were also recorded for each plant.

Trees with DBH >8 cm were monitored within variable radius plots: 5 or 10 meters to contain approximately 10 trees. Each tree within the plot was identified to species and was visually assessed for the presence of shot-hole borer (*Euwallacea* sp.) and for health condition (Live/Dead/Stressed). Tree measurements included DBH, total height and low-crown height (Crown Ratio), and percent canopy cover. Canopy cover was estimated using four spherical densiometer measurements per plot, 5 meters from the plot center in each of the four cardinal directions.

For each variable (DBH, height, percent canopy cover, basal area, stem density, and crown ratio), the average value was derived for each plot surveyed during each survey year. The percentage of Live/Dead/Stressed trees was calculated. Species composition was evaluated at the site level. The presence of shot-hole borer was also evaluated.

Current Monitoring (2022)

Monitoring was conducted at the 37 locations established between 2007 - 2016. Two additional plots were established along the northern part of Mill Creek (Figure 1).

Understory Sampling

Shrubs and saplings (trees with DBH <8 cm) are the only component of the understory monitored. Herbaceous vegetation was excluded after 2007 as it was deemed less relatable to groundwater and is more labor intensive to monitor. Saplings and shrubs were assessed for health condition (Live/Dead/Stressed) and identified to species level. Shrubs often have multiple stems that branch below 10 cm above the ground and the number of stems was counted. Downed trees were not counted.

Overstory Sampling

Trees with DBH >8 cm are monitored within variable radius plots. Plots were designed to have radii of 5 or 10 meters and to contain approximately 10 trees. The radius of the plot is held constant across sampling years regardless of changes to tree count. Each tree within the plot was identified to species and was visually assessed for the presence of shot-hole borer (*Euwallacea* sp.). Adult beetles burrow exit holes through the bark and the damage takes on a "shotgun blast" appearance.

Each tree was assessed for health condition (Live/Dead/Stressed). The Stressed condition was applied to trees that had dead sections or other visible damage, but that were clearly still alive. Canopy cover was recorded using four spherical densiometer measurements per plot, approximately 1 meter from the plot center in each of the four cardinal directions.

Plot Photos

Photographs were taken in each of the cardinal directions from the center of the plot. Photos are not included in this report due to file size, but will be provided to West Yost on behalf of Watermaster/IEUA.

Data Analysis

For each plot the percentage of Live/Dead/Stressed trees was calculated, along with the percent infested by shot-hole borer. The average percent canopy cover and number of trees per hectare was also calculated for each plot. Species composition was evaluated at the stream reach level.

Results

This section presents results from surveys conducted in 2022 along the three stream reaches, Chino Creek, Mill Creek, and Santa Ana River. A summary of measured and calculated variables for each plot can be found in Attachment 1.

Canopy Cover

Mean canopy cover exceeded 70% at all 3 steam reaches in 2022 (Table 1). Mean canopy cover along Chino Creek (81.5%) was higher than along Mill Creek (76.2%) and the Santa Ana River (72.7%). All measurements of mean canopy cover per plot can be found in Attachment 1.

Table 1. Mean (standard error), maximum, and minimum canopy cover found at the plot level within each stream reach, Prado Basin 2022.

	Chino Creek	Mill Creek	Santa Ana River
Mean Cover	81.5% (6.6)	76.2% (7.9)	72.7% (13.4)
Maximum Cover	100%	100%	98.7%
Minimum Cover	4.2%	0.0%	19.3%

Shrubs

Mule fat (*Baccharis salicifolia*), Mexican elderberry (*Sambucus mexicana*), and tree tobacco (*Nicotiana glauca*) shrubs were found in four plots along Mill Creek (Table 2). No shrubs were observed within the surveyed plots along Chino Creek or Santa Ana River.

Table 2. Summary of shrub coverage at Mill Creek survey plots, Prado Basin 2022.

Mill Creek Plot	Species	Total Stems
8	*Sambucus mexicana*	10
X9	*Baccharis salicifolia*	13
X22	*Baccharis salicifolia*	8
X22	*Nicotiana glauca*	3
62	*Baccharis salicifolia*	7

Saplings

Saplings (DBH < 8cm) were found along Chino Creek (80 total saplings observed), Mill Creek (23), and the Santa Ana River (8) in 2022. In addition to common riparian species such as Goodding's and arroyo willow, sapling species included: boxelder (*Acer negundo*), velvet ash (*Fraxinus velutina*), sycamore (*Platanus* sp.), eucalyptus (*Eucalyptus* sp.), and tree-of-heaven (*Ailanthus altissima*).

Eucalyptus are non-native trees that can form monotypic groves and outcompete native species. Five eucalyptus saplings were found in Plot 18 along Chino Creek in 2019 and all were still living in 2022. There are currently no tagged eucalyptus trees within Plot 18.

Tree-of-heaven is a clonal invasive species that forms dense thickets and is designated a moderate threat by the California Invasive Plant Council (CAL-IPC). One tree-of-heaven sapling was observed in Plot 10 along Mill Creek. There are no tagged tree-of-heaven trees in Plot 10. However, additional tree-of-heaven saplings were observed outside the plot radius.

The highest densities of saplings were found along Chino Creek (Table 3). In Plot 21, all tagged trees were burned during the Euclid Fire (June 2018) and Gooding's willow saplings have re- sprouted near dead remnants. In Plot 1 (Santa Ana River), a fire burned all tagged trees in 2021 and several Gooding's willow saplings have emerged in the plot.

Overstory Trees

Goodding's willow was the most abundant overstory species found in all stream reaches (Table 4). Other species observed included velvet ash, Fremont cottonwood, arroyo and red willow, boxelder, sycamore, tree-of-heaven, and eucalyptus.

Table 3. Mean (standard error) values for density (saplings/ha) of live saplings. Percentages of Live(L)/Dead (D)/Stressed (S) saplings and species at each stream reach, Prado Basin 2022.

Metrics	Chino Creek	Mill Creek	Santa Ana River
Density (saplings/ha)	259.9 (65.2)	72.2 (30.2)	42.4 (26.8)
Sapling Health			
Live	60.0%	65.2%	66.7%
Dead	21.3%	17.4%	0.0%
Stressed	18.8%	17.4%	33.3%
Species Composition			
Goodding's willow	68.8%	87.0%	100.0%
Arroyo willow	10.0%	-	-
Boxelder	11.3%	-	-
Eucalyptus	6.3%	-	-
Velvet ash	3.8%	4.3%	-
Sycamore	-	4.3%	-
Tree-of-heaven	-	4.3%	-

Table 4. Percentages of Live/Dead/Stressed overstory trees and species composition found at each stream reach, Prado Basin 2022.

Tree Health	Chino Creek	Mill Creek	Santa Ana River
Live	58.3%	47.7%	46.0%
Dead	16.6%	18.9%	26.5%
Stressed	25.1%	33.3%	27.4%
Species Composition			
Goodding's willow	76.8%	95.5%	74.3%
Velvet ash	9.5%	1.8%	-
Arroyo willow	5.2%	-	13.3%
Boxelder	4.7%	-	-
Eucalyptus	2.4%	-	4.4%
Red willow	1.4%	-	-
Sycamore	-	0.9%	-
Tree-of-heaven	-	0.9%	-
Fremont cottonwood	-	0.9%	8.0%

The proportion of live, dead, and stressed trees on each plot was highly variable throughout the Prado Basin in 2022. At the stream reach level, Chino Creek had the highest percentage of live trees and lowest percentage of dead trees (Figure 2). More than 25% of trees at all locations were classified as stressed. The highest percentage of dead trees (26.5%) was found in the Santa Ana River area. The plots in the Santa Ana stream reach have been impacted by fire (Plot 1) and extensive grape vine infestations (Plot 2 and Plot 13) since the 2019 surveys.

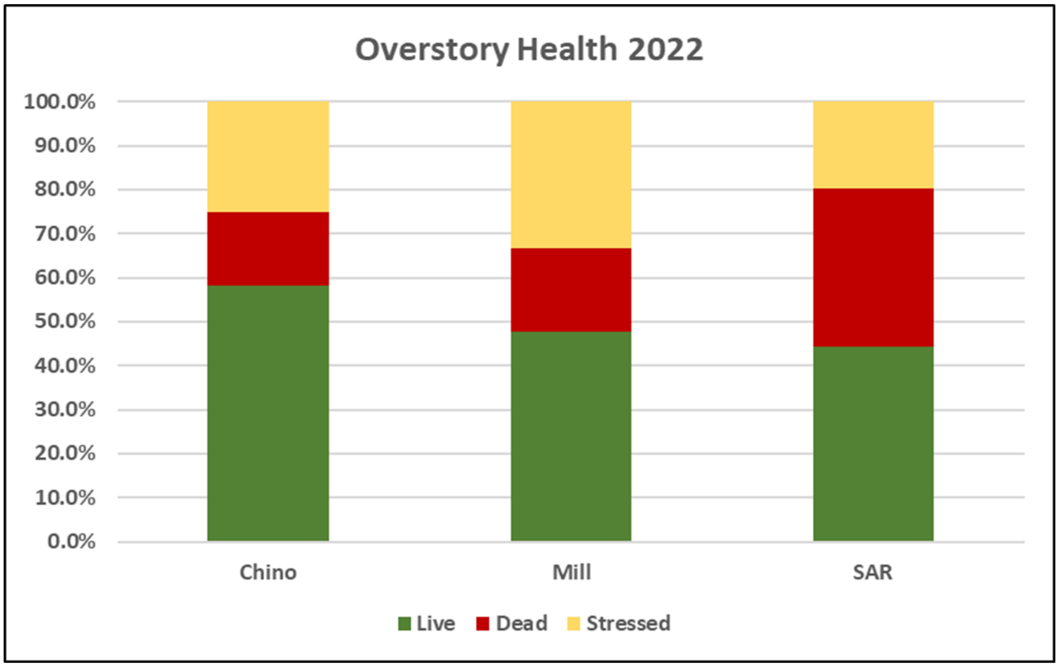


Figure 2. Percentages of Live, Dead, and Stressed trees at each site, Prado Basin 2022.

The health of live and stressed trees was assessed to compare changes from 2016 to 2019 with changes from 2019 to 2022 (Figure 3). Live trees changed at the same percentage in both time periods. Among stressed trees, 49% changed from stressed to live between 2019 and 2022. This was higher than the 29% change from 2016 to 2019.

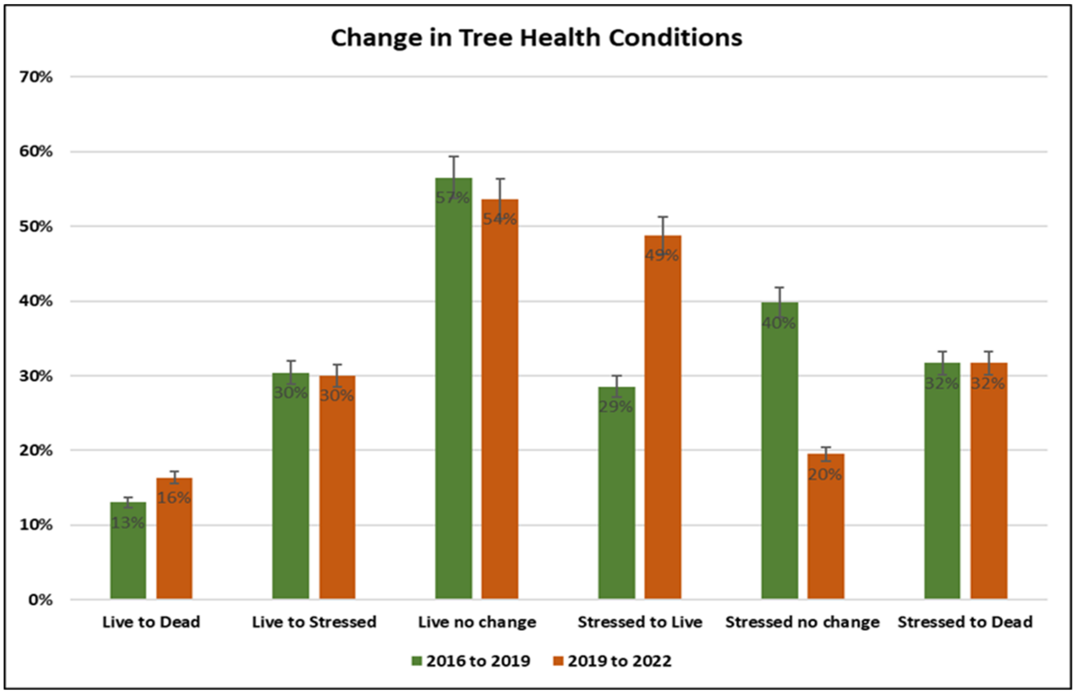


Figure 3. Changes in health conditions for live and stressed trees between 2016 and 2022. Shown with standard error bars.

Shot-Hole Borer

The shot-hole borer is a burrowing beetle found on a wide range of host plants, that spreads fungal pathogens within the vascular system. The beetles are known to prefer healthy trees and were first documented in the vegetation surveys in 2016.

The presence of shot-hole borer was noted in plots along all stream reaches (Table 5). Shot-hole borer was documented as present if there was obvious damage to the tree. Evidence of shot-hole borer damage was found on live (3), stressed (15), and dead (1) trees and in Gooding's willow, velvet ash, arroyo willow, and boxelder. No saplings were found with shot-hole borer damage.

Table 5. Percentage of trees with shot-hole borer observations at each stream reach in Prado Basin.

Shot-hole Borer	Chino Creek	Mill Creek	Santa Ana River
2016	28.1%	56.5%	44.2%
2019	2.5%	9.2%	0.0%
2022	3.3%	9.0%	1.8%

Temporal Comparison

Changes in overstory health between 2019 and 2022 were evaluated for all stream reaches. At Chino Creek and Mill Creek the percentage of live, unstressed trees increased by 12-13%, while the percentage along the Santa Ana River decreased by 9% (Figure 4). The percentage of dead trees in the Santa Ana River reach increased by 20%. Much of the increase in dead trees in the Santa Ana

River plots could be explained by the impacts of a fire at Plot 1 and grapevine competition in Plots 2 and 13. Extensive grapevine was observed wrapped around trees in Plots 2 and 13 during the 2022 surveys. Grapevine can damage trees by breaking off tree tops or limbs and by reducing the sunlight that reaches leaves.

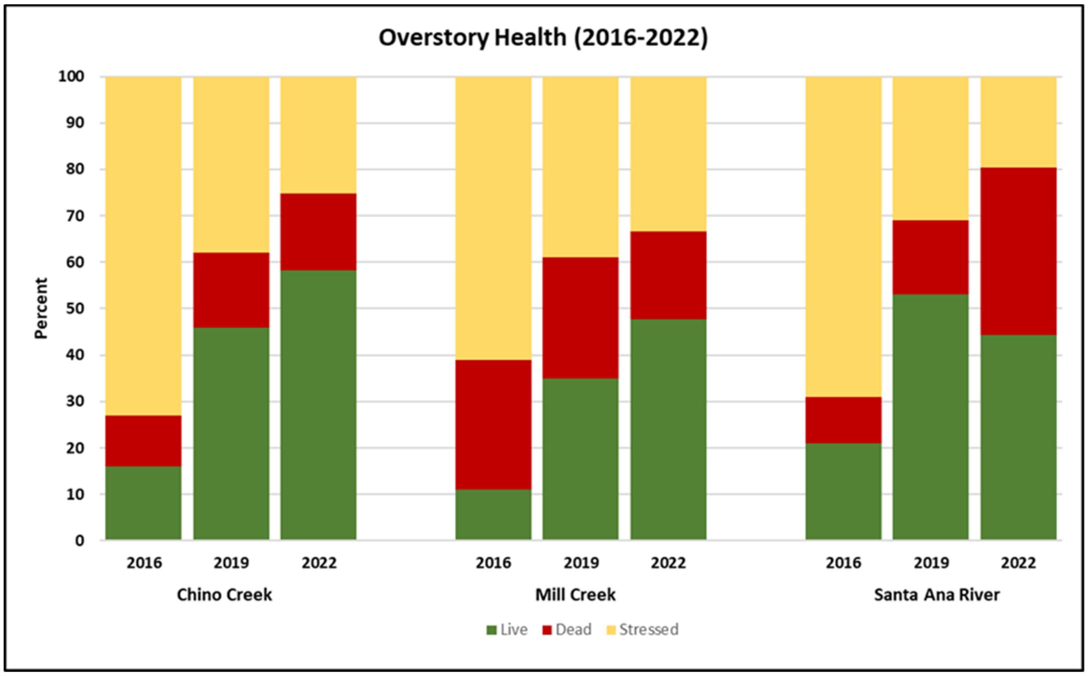


Figure 4. Overstory health from 2016 to 2022 along Chino Creek, Mill Creek, and the Santa Ana River.

Canopy cover is an estimate of how much of the ground is covered by overstory vegetation. Differences in cover between sampling years are to be expected due to natural variation and climatic changes. Fire, flood, or extreme weather events can also impact the canopy cover particularly at the plot level. There have been no meaningful changes to mean canopy cover along Chino Creek or Mill Creek since 2013 (Figure 5). Mean canopy cover in the Santa Ana River plots decreased by 20% from 2019 to 2022, primarily because of losses at Plot 1 (fire) and Plot 13 (grapevine competition).

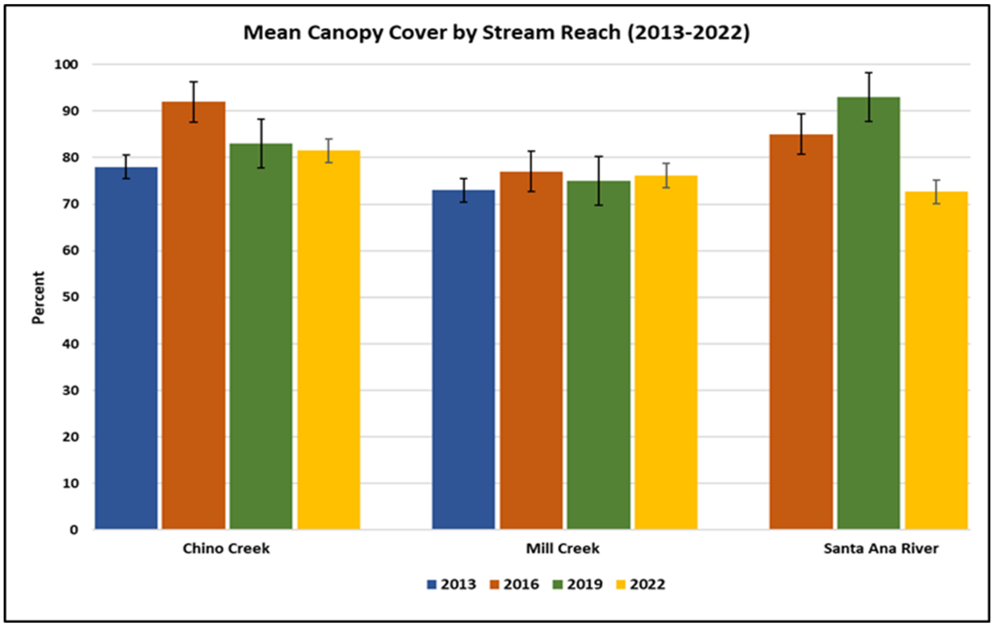


Figure 5. Mean canopy cover and standard error bars from 2013 to 2022 along Chino Creek, Mill Creek, and the Santa Ana River.

Changes to sapling recruitment were also evaluated. From 2019 to 2022 changes to sapling density along all three stream reaches were minimal (Figure 6).

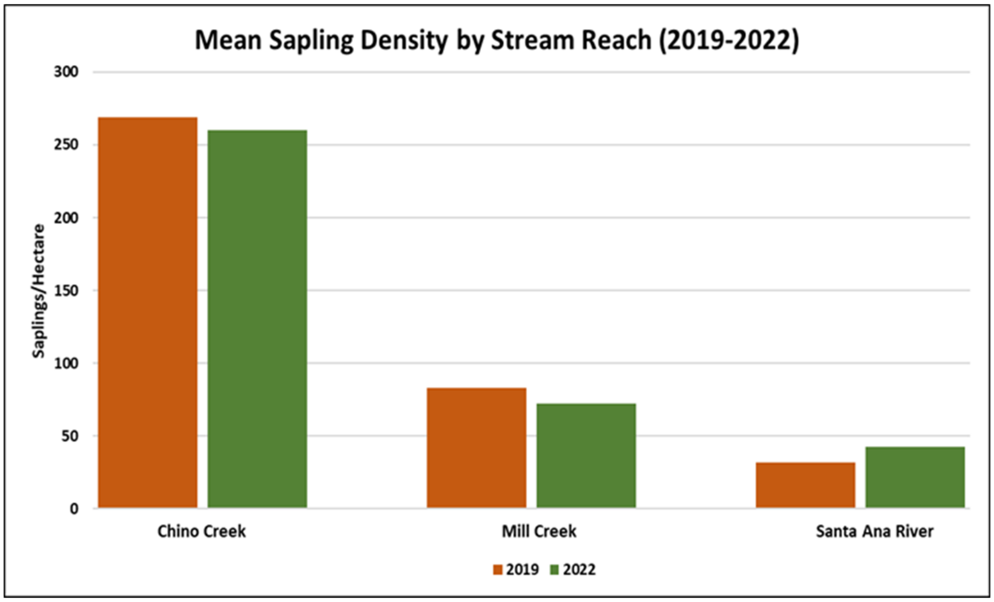


Figure 6. Mean sapling density from 2019 to 2022 along Chino Creek, Mill Creek, and the Santa Ana River.

Discussion

The riparian zone in the Prado Basin is highly variable and dynamic. Vegetation along all three stream reaches is affected by flood, wind, and fire events, as well as variations in precipitation and growing seasons. The presence of the invasive polyphagous shot-hole borer may further confuse potential stream reach effects. Trees in all reaches have fallen and re-sprouted, often with multiple stems, further confounding the analysis. Due to these variables, as well as the modifications to the monitoring protocol over time, it is difficult to derive long-term trends or conclusions.

Remotely sensed imagery allows for a more complete interpretation of riparian health. The monitoring conducted during this study was limited to 39 small plots spread throughout a 4,300-acre riparian zone. NDVI for the entire Prado Basin can provide a more complete overview of changes and identify potential trouble spots. The most effective use of the field monitoring data in Prado Basin may be to validate the remote sensing data, which is better suited for a full-scale analysis of the Prado Basin at a more frequent time interval.

The observed canopy cover can be compared to NDVI data for each plot to provide a measure of ground truthing. Canopy cover across all stream reaches was compared for 2013 to 2022 (Figure 5). The mean canopy cover percentage for Chino Creek and Mill Creek plots has remained relatively consistent. Canopy cover in the Santa Ana River plots was reduced by 20% in 2022, primarily due to losses from a fire in Plot 1 and grapevine competition in Plots 2 and 13.

Based on the field surveys, overstory health improved along Chino Creek and Mill Creek from 2019 to 2022 but slightly declined along the Santa Ana River (Figure 4). The percentage of dead trees along the Santa Ana River increased in 2022, due to a fire in Plot 1 and grapevine competition in Plots 2 and 13. The increase in live, unstressed trees along Chino and Mill Creeks was somewhat surprising given the drought conditions of the last several years. Changes to sapling recruitment could also indicate potential problems with the riparian habitat. However, there was no change in sapling density along any stream reach from 2019 to 2022 (Figure 6).

A simple analysis was conducted to compare how live and stressed trees changed between 2016 to 2019 and from 2019 to 2022 (Figure 3). Live trees changed to stressed or dead at approximately the same percentage during both time periods. The same percentage of stressed trees changed to dead during both time periods, but the percentage of stressed trees that changed to live was greater from 2019 to 2022. The percentage of trees infested with shot-hole borer along each stream reach remained consistent from 2019 to 2022 (Table 5).

Environmental monitoring programs should be regularly reevaluated to ensure the best available tools are being used. Remotely sensed NDVI data may provide a more complete picture of the health of the riparian vegetation than ground-based surveys and was used by Watermaster and IEUA for the Prado Basin Habitat Suitability Program to monitor during the 2019 surveys. Uncrewed aerial systems (UAS) can carry a variety of sensors and could provide data on canopy cover, canopy height, and other overstory parameters (Cromwell et al 2021, Jin et al 2020, Miraki & Sohrabi 2022,). The complex habitat and extensive tree cover in the Prado Basin would likely limit the ability of UAS to exactly duplicate the current ground truthing, but could cover a much larger area in a shorter amount of time. Assessing the canopy cover over permanent sites from above, instead of below, should be possible using UAS and simple RGB sensors. Either satellite or UAS remote sensing would provide data over a much larger area than targeted, ground based surveys.

Acknowledgements

We would like to thank the staff of the OCWD for their help in conducting the Prado Basin vegetation monitoring. Their expertise and assistance were essential to completing the survey.

References

Cromwell, C., Giampaolo, J., Hupy, J., Miller, Z., & Chandrasekaran, A. (2021). A systematic review of best practices for UAS data collection in forestry-related applications. *Forests*, 12(7):957. https://doi.org/10.3390/f12070957

Jin C, Oh C-y, Shin S, Wilfred Njungwi N, Choi C. (2020). A comparative study to evaluate accuracy on canopy height and density using UAV, ALS, and fieldwork. *Forests*. 2020; 11(2):241. https://doi.org/10.3390/f11020241

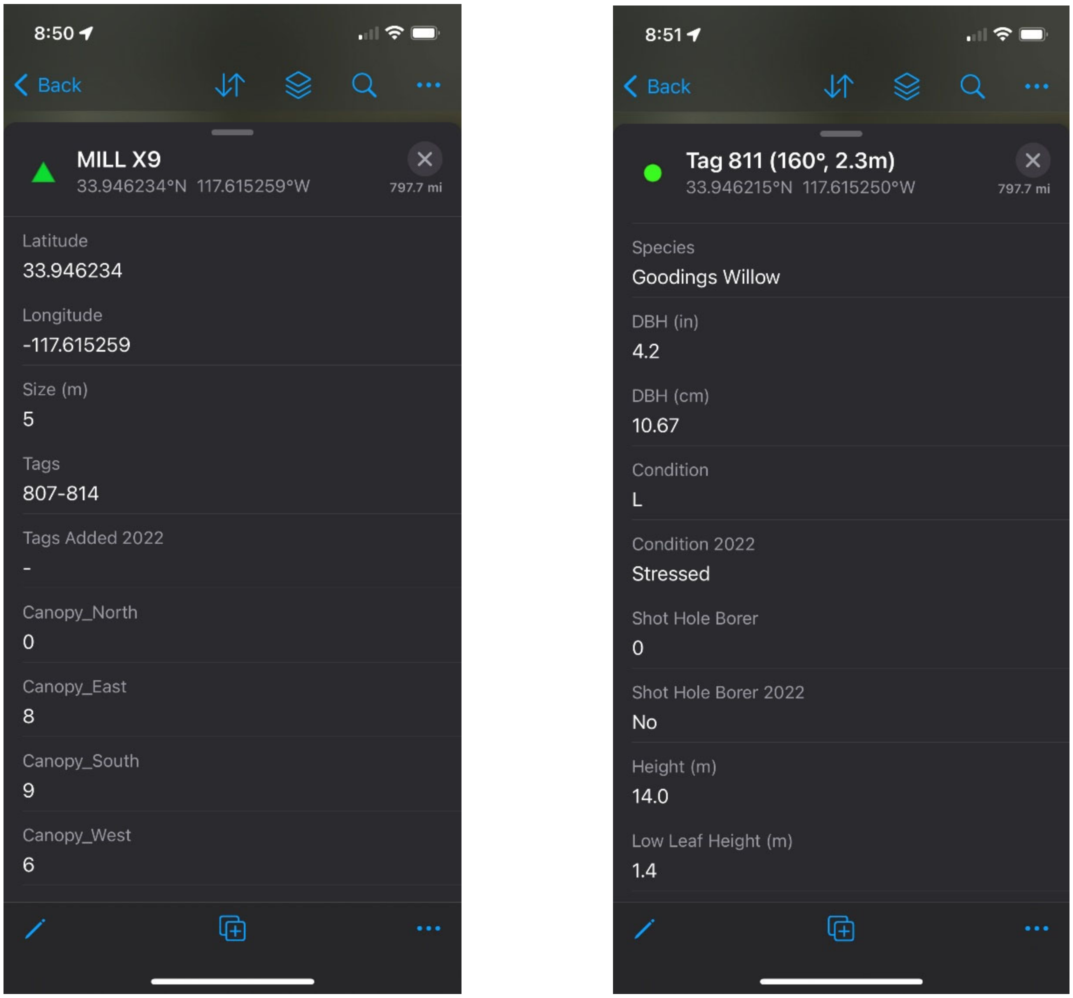
Miraki, M. & Sohrabi, H. (2022). Using canopy height model derived from UAV imagery as an auxiliary for spectral data to estimate the canopy cover of mixed broadleaf forests. *Environmental Monitoring and Assessment*, 194(45). https://doi.org/10.1007/s10661-021-09695-7

Attachment 1. Plot Summary Data

SITE	PLOT	COVER (%)	LIVE (%)	STRESSED (%)	DEAD (%)	SHB PRESENT	SHB (%)	TREES PER HECTARE
CHINO	4	86	63	5	32	NO	0	637
CHINO	9	99	50	33	17	NO	0	764
CHINO	11	94	73	9	18	NO	0	382
CHINO	16	27	50	29	21	NO	0	573
CHINO	18	81	100	0	0	NO	0	1401
CHINO	21	4	75	0	25	NO	0	1019
CHINO	24	99	64	27	9	NO	0	891
CHINO	31	98	68	16	16	YES	11	700
CHINO	34	91	0	100	0	NO	0	764
CHINO	78	95	33	42	25	NO	0	541
CHINO	30B	98	50	25	25	NO	0	1273
CHINO	3B	100	43	43	14	NO	0	1273
CHINO	X3	69	100	0	0	NO	0	891
CHINO	X4	45	40	60	0	YES	40	1019
CHINO	X5	96	78	22	0	NO	0	1401
CHINO	X6	100	50	29	21	NO	0	2292
CHINO	X7	84	33	67	0	YES	33	318
CHINO	X8	100	39	33	28	YES	6	3056
MILL	4	0	0	50	50	YES	50	95
MILL	8	64	0	100	0	NO	0	509
MILL	X9	94	50	50	0	YES	8	2292
MILL	X10	88	73	18	9	YES	18	1655
MILL	18	98	40	30	30	YES	10	414
MILL	22	94	0	67	33	YES	50	1273
MILL	39	91	33	33	33	NO	0	255
MILL	60	45	11	67	22	NO	0	477
MILL	62	79	40	20	40	YES	20	764
MILL	63	100	0	0	100	NO	0	159
MILL	69	70	83	17	0	NO	0	223
MILL	82	97	55	27	18	NO	0	446
MILL	101	94	57	30	13	YES	4	955
MILL	X21	91	80	20	0	NO	0	191
MILL	X22	38	78	22	0	NO	0	350
SAR	1	19	44	0	56	NO	0	286
SAR	2	79	33	61	6	YES	11	923
SAR	11	95	67	17	17	NO	0	891
SAR	12	99	53	0	47	NO	0	1910
SAR	13	46	20	0	80	NO	0	637
SAR	14	97	50	0	50	NO	0	1019

Attachment 2. 2022 Data Collection

In 2022, paper data sheets were replaced with forms created in ESRI's ArcGIS FieldMaps application. This reduced the amount of paper used and allowed the data collected to be uploaded to ArcGIS Online almost instantly. This method worked as expected and no issues were encountered.



MILL X9
33.946234°N 117.615259°W

Latitude
33.946234

Longitude
-117.615259

Size (m)
5

Tags
807-814

Tags Added 2022
-

Canopy_North
0

Canopy_East
8

Canopy_South
9

Canopy_West
6

Tag 811 (160°, 2.3m)
33.946215°N 117.615250°W

Species
Goodings Willow

DBH (in)
4.2

DBH (cm)
10.67

Condition
L

Condition 2022
Stressed

Shot Hole Borer
0

Shot Hole Borer 2022
No

Height (m)
14.0

Low Leaf Height (m)
1.4

Figure 1. Images of the field collection app in FieldMaps. The screenshot on the left is the form used to collect canopy cover at each plot center and save photographs. The screenshot on the right is the form used to collect individual tree data.

Appendix D

Response to Draft Annual Report of the PBHSP for WY 2023

U.S. FISH AND WILDLIFE SERVICE (REBECCA CHRISTENSEN)

Hello,

Thank you for the opportunity to comment on the Draft Annual Report of the Prado Basin Habitat Sustainability Program, Water Year 2023. Our comments are as follows:

Comment 1 – Section 1.3 - The Peace II Agreement and its Subsequent EIR

"Watermaster performed modeling studies to predict the extent and magnitude of the drawdown associated with the implementation of the Peace II Agreement, using the planned capacity of 7,700 afy of the CCWF (WEI, 2007)."

During the meeting on May 8th, it was noted that this model is updated every few years with newer data. We recommend including a description of these model updates, and that they will be discussed later in the report, as this section reads as if the model is the original from 2007.

Response:

Section 1 of the report describes the background and objectives of the Prado Basin Habitat Sustainability Program (PBHSP). This sentence in Section 1.3 refers to the 2007 modeling results performed for the Peace II Agreement Subsequent Environmental Impact Report (SEIR). These 2007 modeling results showed that there was the potential for groundwater levels to decrease near the habitat in the Prado Basin, which led to the inclusion of the PBHSP as mitigation measure in the SEIR (4.4-3). The purpose of the mitigation measure was to develop and implement an adaptive management program to monitor the extent and quality of the Prado Basin riparian habitat that could be potentially impacted by the predicted decreases in groundwater levels. Section 2 of the report describes the monitoring program and how Watermaster's updated groundwater-flow model is used as a predictive tool to project future groundwater levels to identify areas of prospective loss of riparian habitat that may be attributable to the Peace II Agreement. Section 3.7 of the report describes the results of the most recent predictive Chino Basin groundwater modeling performed in 2020 and the interpretations of these results.

Updates were made to the third and fourth paragraphs of Section 1.3 (including a new footnote 3) to better clarify that the modeling work performed in 2007 was for the Peace II SEIR and that the implications of this modeling work are what led to the development of the PBHSP. Additionally, these updates explain that the updated model and planning data are used as part of the PBHSP.

Comment 2 – Section 1.3 - The Peace II Agreement and its Subsequent EIR

"The drawdown throughout most of the Prado Basin was predicted to be less than five feet by 2030."

While this may be true for most of the basin, the southern portion near Temescal Wash shows -10 to -15 ft in an area that is occupied by LBV and Flycatcher. Consider overlaying the map of LBV/flycatcher habitat with these model results and discuss if monitoring in the southern portion of the basin is occurring.

If the lowering in the southern portion of the basin is not a result of the implementation of the Peace II agreement, we recommend noting this and describing why it changed and is included.

Response:

The Temescal Wash area is outside of the Chino Basin hydrologic boundary and is not an area that is influenced by pumping at the Chino Desalter well field. Therefore, any changes in groundwater levels in this area are not from changes in groundwater levels due to pumping at the Chino Desalter well field and implementation of the Peace II Agreement. Updates were made to the last sentence of the third paragraph in Section 1.3 (including a new footnote 4) to specify that the 2007-predicted drawdown of 0 to 5 feet occurs near the riparian habitat areas along the northern portion of Prado Basin near the northern reaches of Chino Creek, Mill Creek, and the SAR, and that the Temescal Wash area is not in the area of influence from the implementation of the Peace II Agreement.

Comment 3 – Figure 2-1

This figure and any other pertinent figures showing monitoring wells, should include the OCWD wells within Prado Basin.

Response:

The primary purpose of Figure 2-1 is to show all the sites where vegetation monitoring occurs in the Prado Basin, not groundwater monitoring. The locations of USBR vegetation survey sites shown in the figure were established specifically for the PBHSP and have been refined as needed for this adaptive monitoring program. For example, in 2016, USBR vegetation survey sites were added near each PBHSP monitoring well cluster, which is why the location of the PBHSP wells are shown in this figure.

The OCWD monitoring wells are shown in subsequent figures that describe the regional groundwater monitoring and analysis; including: (i) Figure 2-2 showing all the wells where groundwater data was collected in 2023; and (ii) Figures 10a and 10b showing wells with groundwater elevation data and groundwater elevation contours for 2016 and 2023.

Comment 4 -Section 2.1.1.1 – Multi-Spectral Remote Sensing Data

"The Normalized Difference Vegetation Index (NDVI), derived from remote sensing measurements by Landsat Program satellites, is used to assess the extent and quality of the riparian vegetation in the Prado Basin over a long-term historical period."

Does this process account for quality only in vibrancy of green or are there ways it accounts for quality specific to the listed species of interest?

Response:

NDVI accounts for the vibrancy of green and is not species-specific for vegetation. The remainder of the first paragraph of Section 2.1.1.1 was slightly revised to further explain how NDVI is not species specific, and how data can be compared to site-specific data in the field, and the purpose of using NDVI for regional analysis both spatially and temporally: *"Although NDVI does not provide species-specific vegetation information, the regional scale of NDVI makes it an appropriate 'first indicator' of regional changes in the extent and quality of riparian vegetation. Additionally, there is NDVI data for the entire extent of the Prado Basin dating from the early 1980s to present, which allow us to characterize the history of the spatial extent and quality of the riparian vegetation prior to and after the implementation of Peace II activities (2007). A limitation of NDVI data is that it is a composite view of plant species diversity, form, structure, density, and vigor. As such, changes in NDVI may be caused by various changes in riparian* *habitat (Markon et al., 1995; Markon and Peterson, 2002). In other words, NDVI does not provide a complete picture of how and why vegetative changes are occurring; it simply indicates a change in vegetation. These changes can then be compared to changes seen in air photos and data gathered from the USBR vegetation surveys, which provide more information about canopy cover, tree health, and the presence of beetles in specific areas."*

Note that Appendix A of the report provides more background information on NDVI, further explains why NDVI was chosen as an analytical tool for the PBHSP and discusses additional advantages and limitations of NDVI.

Comment 5 - Section 2.3 – Prospective Loss of Riparian Habitat

"For this Annual Report, Watermaster's most recent groundwater model projections were used to characterize future groundwater-level conditions in the PBHSP study area. This model projection was the simulation of planning scenario "2020 SYR1" for the 2020 recalculation of Safe Yield using the updated Chino Basin groundwater-flow model (WEI, 2020)"

Consider including a map of these updated results similar to the 2005 results showed in Figure 1-3.

Response: Section 2 of the report is a description of the monitoring, data collection, and methods for the PBHSP and how modeling work is utilized. Section 3.7 of the report describes the results of the most recent Chino Basin groundwater model (in 2020), which was used to predict changes to groundwater levels from 2018-2030 and includes a figure of the results (Figure 3-24).

Comment 6 – Section 3.0 – Results and Interpretations [General]

(General) There is no discussion of the groundwater data collected by Orange County Water District (OCWD) and potential ties to riparian habitat as there is for the Mill Creek wells (for example). OCWD's Prado Basin Water Conservation and Habitat Assessment 2022-2023 states "Monthly monitoring from 2016-2023 revealed that groundwater levels have steadily dropped at most well sites except those located deeper in the forest where groundwater is replenished by the inundation pool. The northernmost wells have experienced the most dramatic groundwater decline as shown in the hydrographs for PD9, 10, 11, and PD12 groundwater depths to slow and stabilize, but the level has not returned to historic levels." The referenced hydrographs then show the groundwater elevation has dropped by approximately 2-4 feet. There does not appear to be vegetation monitoring stations near these wells, so we don't have data as to whether there is accompanying riparian vegetation decline.

Response:

As described in Section 2.2.1.2 of the report, Watermaster/IEUA use groundwater level data from all wells in the study area (not just the PBHSP monitoring wells) to characterize how groundwater levels have changed over time in the Prado Basin Groundwater Monitoring Program (GMP) study area. OCWD wells PD 9, 10, and 12 (not PD 11) are part of the designated monitoring network used to prepare annual groundwater elevation contours for the fall, and the resulting net change in groundwater levels since 2016. Figure 3-10a shows the groundwater elevation contours for fall 2016 and includes the OCWD wells labeled by the groundwater level data used to prepare the 2016 contours. In the draft report, Figure 3-10b showed the groundwater elevation contours for fall 2023 and did not include the OCWD wells because the data was not available. Watermaster collects the water level data from OCWD on a routine basis for these OCWD wells, however the available data frequency has been a challenge; the data is not consistently collected every month, and the OCWD was not able to collect measurements at these wells because of flooding, resulting in no measurements for August- December 2023. OCWD also indicated that they did not know when they could measure these wells again. Hence these OCWD wells were not initially used to prepare the fall 2023 groundwater elevation contours or the subsequent analysis of the net change in water levels since 2016 in Figure 3-11.

As you have indicated, the hydrographs for OCWD wells PD 9, 10, and 12 do show groundwater elevation has dropped by approximately 2-4 feet since 2016, even though they have been relatively steady over the past few years. In the draft report, the map of net change in water levels from 2016-2023 in Figure 3-11 does not show a decline in this area. To address that the fall 2023 groundwater elevation contours were redone using estimated levels at OCWD wells PD 9, 10, and 12, and then the subsequent analysis of the net change in water levels since 2016 in Figure 3-11 was updated to reflect the new groundwater elevation estimates. The results in Figure 3-11 now show that there is a 2-4 ft decrease in this area along, and north of, the Santa Ana River. Watermaster will work with OCWD to ensure that these wells can continue to be monitored, so that estimated values will not have to be used in the future.

Figure 3-12 of the depth to groundwater in the Prado Basin in 2023 was also revised based on the newly revised groundwater elevation contour for 2023. The depth to groundwater estimated for this area is between 6 to 10 ft-bgs. Note that this range is an estimate that relies on a digital elevation model (DEM) of ground surface elevation to subtract the groundwater elevation from to estimate depth to groundwater; however, these values are close to the actual measured depth to groundwater at these wells in 2023 (7 to 9 f-bgs). Therefore, impacts to the riparian vegetation is not a concern at this time because the depth to groundwater is not greater than 15 ft-bgs. If groundwater levels continue to decline and result in a depth to groundwater greater than 15 ft-bgs, there could be adverse impacts to the riparian habitat in this area. This is a similar analysis from what is described in Section 3.7 for the northern Santa Ana River near well PB-3.

Furthermore, in Figure 3-3 the regional change in the NDVI analyzed year-to-year has not indicated a notable decline in NDVI in this area. If groundwater levels continue to decline in this area and/or NDVI starts to notably decrease, some more focused monitoring of the habitat can be done, similar to what was done in 2022 for the northern portion of Mill Creek just south of PB-2.

Comment 7 – Section 3.1.2 – Quality of the Riparian Habitat

"…NDVI is an indicator of the photosynthetic activity of vegetation and therefore can be used to interpret the health or 'quality' of the riparian vegetation."

We recommend further describing how NDVI captures vegetation quality and how this may or may not capture the habitat quality required for the listed species.

Response:

See response to Comment 4. There is text in the first paragraph of Section 2.1.1.1 that further explains how NDVI is used to assess vegetation quality.

Comment 8 – Figures 3-8l and 3-8n (SAR-2 and LP)

These figures show the USBR surveys decreasing by nearly 60% over years when NDVI increased. Please discuss these discrepancies.

Response:

The USBR prepared a final report of the findings and results from the 2022 vegetation surveys, which is Appendix C to this Annual Report. The USBR report describes that the reduced canopy cover at the X13 plot in the SAR-2 area is due to an increase in dead trees due to grapevine competition, and the reduce canopy cover at the X1 plot in the LP area is due to a fire in 2020.

The following text was added to the end of Section 3.1.2.4.1 of the report to explain the discrepancy in the canopy cover measurements and average NDVI:

"The trend in the Average Growing-Season NDVI compared to the trend in the percent canopy cover measurements from the USBR surveys in 2022 do not align for two areas along the SAR (SAR-2 and LP):

- *At the X13 plot within SAR-2, the USBR noted multiple dead trees in 2022 due to grapevine competition (reduced canopy cover to 46%). The NDVI did not show a related decrease, likely due to the greenness of the grapevines.*
- *At the X1 plot within LP, the USBR noted an increase in dead trees in 2022 due to a fire in December 2020 (reduced canopy cover to 19%). The NDVI decreased in 2021 as a result of the fire and began to rebound in 2022. The NDVI increase in 2022 is likely from the rebound in the green perennial ground cover and not from the regrowth of trees."*

Comment 9 – Section 3.1.3 – Analysis of Vegetation Surveys

"The measurements of percent canopy cover from the USBR vegetation surveys are the most appropriate measured data for ground-truthing the NDVI."

We request further discussion of this ground truthing and how the USBR measurements are or are not consistent with NDVI.

Response:

The remainder of the second paragraph of Section 3.1.3 goes on the further explain how percent canopy cover and NDVI relate. Additional text was added to (i) describe how the USBR support the use of the observed canopy cover for ground truthing and (ii) describe the discrepancy in the canopy cover measurements and average NDVI that was added to the report per the response to Comment 8. The remainder of second paragraph of Section 3.1.3 reads:

"The USBR indicates that 'the observed canopy cover can be compared to NDVI data for each plot to provide a measure of ground truthing' (USBR, 2023). Percent canopy cover is a measurement of the percentage of the ground surface area that is directly covered by the vertical projections of tree crowns (USDA, 1999). Although there is no direct quantitative relationship between percent canopy cover and NDVI, percent canopy cover is a metric of the areal density of the vegetation that is reflecting visible and near-infrared light and therefore can be used for comparison with the NDVI analysis. The percent canopy cover at the survey location (10-meter radius plot) within the small areas of NDVI analysis (30x30-meter pixel) in Figures 3-8a through 3-8n are charted with the NDVI time-series data. For the areas on Figures 3-8a through 3-8n, the percent canopy cover measurements show variability over the years and no clear increasing or decreasing trends. For most of the areas the trends in the NDVI time-series data align with

the percent canopy cover measurements. There are a few notable exceptions for the areas along the SAR which are described in Section 3.1.2.1.4."

Comment 10 – Figure 3-11

a) Why is the maximum extent of vegetation used in this figure instead of the Prado Basin outline, as is shown in the model results and other plots? Please add the Prado Basin outline to this figure for easier comparison to the model results and existing conditions.

b) The model estimated the changes in groundwater from 2005 to 2030 and this record starts in 2016. Could comparisons be made from the 2005 condition the model used?

c) This figure appears to show a slight increase in groundwater elevation at the OCWD wells that they have reported a decrease at, however, the scale is too large to show much change either way.

Response:

a) The extent of the riparian vegetation in the Prado Basin is used on all of the figures that present vegetation health, including maps that show NDVI data and air photos, as well as the current figures that present estimated groundwater level conditions and changes. The extent of the riparian vegetation in the Prado Basin is shown in these maps to assess the relationship between the health of the riparian vegetation and groundwater level changes. The maps with the maximum riparian vegetation extent that show groundwater level conditions include: (i.) Figure 3-11 on the change in groundwater levels from 2016-2023; (ii.) Figure 3-12 on the depth to groundwater; and (iii.) Figure 3-24 on the 2020 predictive modeling results of groundwater levels. The Prado Basin boundary will not be added to these maps for these reasons.

b) The period of analysis for this report begins in 2016 because that is when the PBHSP monitoring began and data collection started. The historical model estimates, which were originally used for evaluating the potential impacts of implementing the Peace II Agreement, start in 2005 because that was when the 2007 model projection estimates began.

c) See response to Comment 6. This figure was updated to use estimated data from the OCWD wells.

Comment 11 – Figure 3-12

a.) Could a difference plot similar to Figure 3-11 be done for changes in depth to groundwater over time?

b.) This figure does not reflect what OCWD reports, it has the decreasing groundwater elevation wells in the > 0 to ≤ 5 range, while they are now between > 5 and ≤ 10. This type of discrepancy, and the lack of showing the wells, and the lack of further discussion, is what led us to believe that OCWD's data is not being considered (per our comment during the May 8th meeting).

Response:

a.) Figure 3-12 shows the current depth to groundwater based on the current (2023) groundwater elevation and a DEM of ground surface elevation. The difference in depth to groundwater from

2016 to 2023 would be the same difference in the change in groundwater elevations from 2016 to 2023 shown in Figure 3-11, and therefore would not provide any additional information.

b.) See response to Comment 6. This figure was updated to use estimated data from the OCWD wells. Figure 3-12 now estimates the depth to groundwater near these OCWD wells as being between about 6 to 10 ft-bgs. Note that this range is an estimate that relies on a DEM of ground surface elevation to subtract the 2023 groundwater elevation from; however, these values are close to the actual depth to groundwater measurements at these wells in 2023 (7 to 9 ft-bgs).

Comment 12 – Section 3.2.3 – Groundwater Levels Compared to NDVI

"Where the measured and model-estimated groundwater elevations overlap in time, the model-estimated elevations mimic the seasonal fluctuations and longer-term trends of the measured elevations and are typically no more than 10 feet different."

Ten feet is a significant amount of difference as ground water that is 10 ft lower than expected could easily result in the decline of vegetation (i.e., both willow species and mulefat). Please include additional details as to why this difference is acceptable.

Response: This difference of up to 10 feet is acceptable because the model-estimated groundwater elevations are estimates from the model grid cell in that location. These model-estimated groundwater elevations were made prior to the construction of the PBHSP monitoring wells and, therefore, were not able to be calibrated with actual measurements at the wells. The historical model-estimated groundwater elevations are not used to assess specific groundwater elevation conditions historically, but to evaluate the general long-term and seasonal trends in these areas prior to the collection of actual data at the well locations. The last sentence in the first paragraph in Section 3.2.3 was modified slightly to read: "*This supports the use of these model-estimated groundwater elevations in this analysis to evaluate general historic trends prior to when there were actual water level measurements."*

Comment 13 – Section 3.5.2 – Stream Discharge Compared to NDVI

"…the main observations and conclusions for the 2023 period are that there were above average discharge conditions in Mill Creek and the riparian vegetation did not change significantly, and NDVI increases all along Mill Creek reach."

This statement seems to highlight the disconnect between riparian vegetation and what NDVI is measuring. Does this sentence mean that the increase in NDVI just demonstrates an increase in the vegetation greenness?

Response:

This sentence means that even though NDVI increased throughout the Mill Creek area, the increase in NDVI is within the historical range of year-to-year changes in NDVI and, therefore, is not considered a significant change in the greenness of the vegetation, or the health of the vegetation as a whole.

This sentence (last sentence in last paragraph under Section 3.5.2 Mill Creek) has been updated in the report to be more clear:

"Hence, the main observations and conclusions for the 2023 period are that there were above average discharge conditions in Mill Creek and although NDVI increased all along Mill Creek reach, the increase was not significant in comparison to other year-to-year changes in NDVI."

Comment 14 – Figure 3-24

This figure doesn't tell us much about the Prado Basin. We request a second figure be added that is zoomed closer into the Prado Basin with a smaller scale (maybe +/- 10).

Response:

Figure 3-24 shows the entire GMP Study Area, as shown in Figure 2-2 and other subsequent figures in the report on groundwater level and production trends and conditions. The GMP Study Area includes the entire Prado Basin and Chino Desalter well field to the north. The primary purpose of the predictive modeling analysis for the PBHSP (shown in Figure 3-24) is to predict potential future changes in groundwater levels in the Prado Basin riparian habitat area as a result of pumping at the Chino Desalter wells. Therefore, the GMP Study Area should be used for this figure.

The figure shows the relative magnitude of change in groundwater levels for the entire GMP using a color symbology and contour lines with an interval of five feet. This is the same scale that was used in the 2007 modeling work for the Peace II Agreement SEIR to predict the potential impact to groundwater levels from the Peace II Agreement implementation. The color symbology shows the magnitude and rate of change between the contours. We are unable to change the contour interval in Figure 3-24 for this report but can consider using a different contour interval when reporting results from future model updates.