Annual Report of the

Prado Basin Habitat Sustainability Committee

Water Year 2015/2016

April 12, 2017

Committee DRAFT

Prepared for:

Inland Empire Utilities Agency
&
Chino Basin Watermaster

Prepared by:

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Acronyms, Abbreviations, and Initialisms

AF	acre-feet
AFY	acre-feet per year
AMP	Adaptive Management Plan
Basin Plan	Water Quality Control Plan for the Santa Ana River
BLM	Bureau of Land Management
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
CEQA	California Environmental Quality Act
Chino Basin	Chino Groundwater Basin
CIMIS	California Irrigation Management Information System
DBH	Diameter at Breast Height
FD	Fusarium Dieback
FRAP	Fire and Resource Assessment Program
GIS	Geographical Information System
GMP	Groundwater Monitoring Program
IEUA	Inland Empire Utilities Agency
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
NDVI	Normalized Difference Vegetation Index
NEXRAD	Next Generation Radar
NASA	National Aeronautics and Space Administration
NPS	National Park Service
OBMP	Optimum Basin Management Plan

Acronyms, Abbreviations, and Initialisms (cont'd)

OC-59	The OCWD's imported water turnout tributary to Prado Basin
OCWD	Orange County Water District
PBHSC	Prado Basin Habitat Sustainability Committee
PBHSP	Prado Basin Habitat Sustainability Program
POTWs	Publically Owned Treatment Works
Prado Basin	Prado Flood Control Basin
PSHB	Polyphagous Shot Hole Borer
QA/QC	Quality Assurance and Quality Control
Regional Board	California Regional Water Quality Control Board, Santa Ana Regional
RHMP	Riparian Habitat Monitoring Program
SEIR	Subsequent Environmental Impact Report
SWMP	Surface-Water Monitoring Program
TDS	Total Dissolved Solids
USBR	United States Bureau of Reclamation
UCSB	University of California Santa Barbara
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.

Section 1 – Introduction

This *2016 Annual Report of the Prado Basin Habitat Sustainability Committee* (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 Flood Control Basin (Prado Basin), the Chino Basin Optimum Basin Management Program (OBMP), the OBMP Implementation Plan and the Peace Agreement, the Peace II Agreement and the SEIR, the formation of the PBHSC, and the development of the adaptive management plan for the Prado Basin Habitat Sustainability Program (PBHSP).

1.1 Prado Flood Control Basin

Figure 1-1 shows the Prado Basin, located in the southern portion of the Chino groundwater basin (Chino 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 Watershed. The US Army Corps of Engineers, in coordination with the Orange County Water District (OCWD), regulates releases of water from Prado Dam for both purposes of flood control and groundwater recharge in downstream Orange County. Approximately 4,300 acres of riparian habitat has developed within the Prado Basin, creating the largest riparian habitat in Southern California.

The Santa Ana River flows through the Prado Basin from east to west. The tributaries of the Santa Ana River that flow into the Prado Basin include San Antonio/Chino Creek, Cucamonga/Mill Creek, and Temescal Creek. The major components of flow within the Santa Ana River and its tributaries are: runoff from precipitation, discharge of tertiary-treated effluent from wastewater treatment plants, rising groundwater, discharge of untreated imported water conveyed through Prado Basin for groundwater recharge in Orange County, and dry-weather runoff.

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

To the north of Prado Basin, the Chino Basin Desalter Authority (CDA) owns and operates a municipal well field. Figure 1-1 shows the location of the existing CDA wells. The well field pumps groundwater with high concentrations of total dissolved solids (TDS), nitrate, and volatile organic compounds (VOCs). 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. VOCs are currently treated through blending, and new treatment processes are being added to increase their removal. CDA operations are fundamental to achieving many of the management strategies outlined in the Chino Basin OBMP and Peace Agreements, which are discussed below.

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 *v.* City of Chino et al.) established pumping and storage rights in the Chino Basin. The Judgment established the 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 in the late 1990s (WEI, 1999). The OBMP maps a strategy to provide for enhanced yield of the Chino Basin and reliable high-quality water supplies for the development expected to occur. 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 Chino Basin Parties executed the Peace Agreement (CBWM, 2000), which codified their intent to implement the OBMP. The Peace Agreement included an OBMP Implementation Plan, which outlined the time frames 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, the support of regulatory efforts to improve water quality in the basin, storage management, and the implementation of management activities that will result in the reduced discharge of high-TDS/high-nitrate groundwater to the Santa Ana River, thus ensuring the protection of downstream beneficial uses in Orange County.

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 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, Watermaster executed the Peace II Agreement in 2007, which modified the OBMP Implementation Plan (CBWM, 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[1], by 400,000 acre-feet (AF) through 2030 (re-operation) and (ii) refining the planned expansion facilities of the Chino Basin Desalter program from about 30,000 to 40,000 acre-feet per year (AFY) of groundwater production. Re-operation is allocated specifically to offset production of 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 Santa Ana River. 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 (Basin Plan) (California Regional Water Quality Control Board, Santa Ana Regional [Regional Board], 2008). Hydraulic control ensures that the water management activities in the Chino Basin defined in the OBMP and Peace Agreement will not impair the beneficial uses designated for Santa Ana River water quality downstream of Prado Dam.

The expansion of the Chino Basin Desalters, described in Peace II Agreement, would be accomplished, in part, with the construction and operation of the Chino Creek Well Field (CCWF) in the southwest portion of Chino Basin (see Figure 1-2). 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; the actual capacity is 1,500 to 1,800 AFY.

In 2010, the IEUA certified the Peace II SEIR (Tom Dodson, 2010) to address the potential significant adverse environmental impacts that could result from implementing the Peace II Agreement. One of these potential impacts was the possible lowering of groundwater levels (drawdown) in the Prado Basin area, which could impact riparian vegetation that is dependent upon shallow groundwater. 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 (7,700 AFY) of the CCWF (WEI, 2007). Figure 1-2 (Figure 4.4-10 from the Peace II SEIR) shows the model-predicted drawdown in the Prado Basin area for the period of 2005 to 2030. In general, the drawdown in the Prado Basin area was predicted to be less than five feet by 2030.

Although the available modeling work indicated that implementing the Peace II Agreement would not cause significant adverse effects on the 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).

[1] 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 acre-ft through 2030.

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:

1. Watermaster, the IEUA, the OCWD, and other stakeholders that choose to participate to jointly fund the development of an adaptive management program to monitor Prado Basin riparian habitat.

2. Watermaster and the IEUA to convene the PBHSC, comprised of representatives from all interested parties to implement the adaptive management program.

3. 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 for any measured or prospective loss of riparian habitat resulting from Peace II activates.

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 is 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*. The annual reports are intended to document: the 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.

1.4 Annual Report Organization

This Annual Report for water year 2015/2016 is the first annual report prepared by Watermaster and the IEUA for the PBHSC. It documents the collection, analysis, and interpretations of the data and information generated by the PSHSP through September 30, 2016 and includes the following sections:

Section 1 – Introduction. This section describes the background of the PBHSP and the Annual Report.

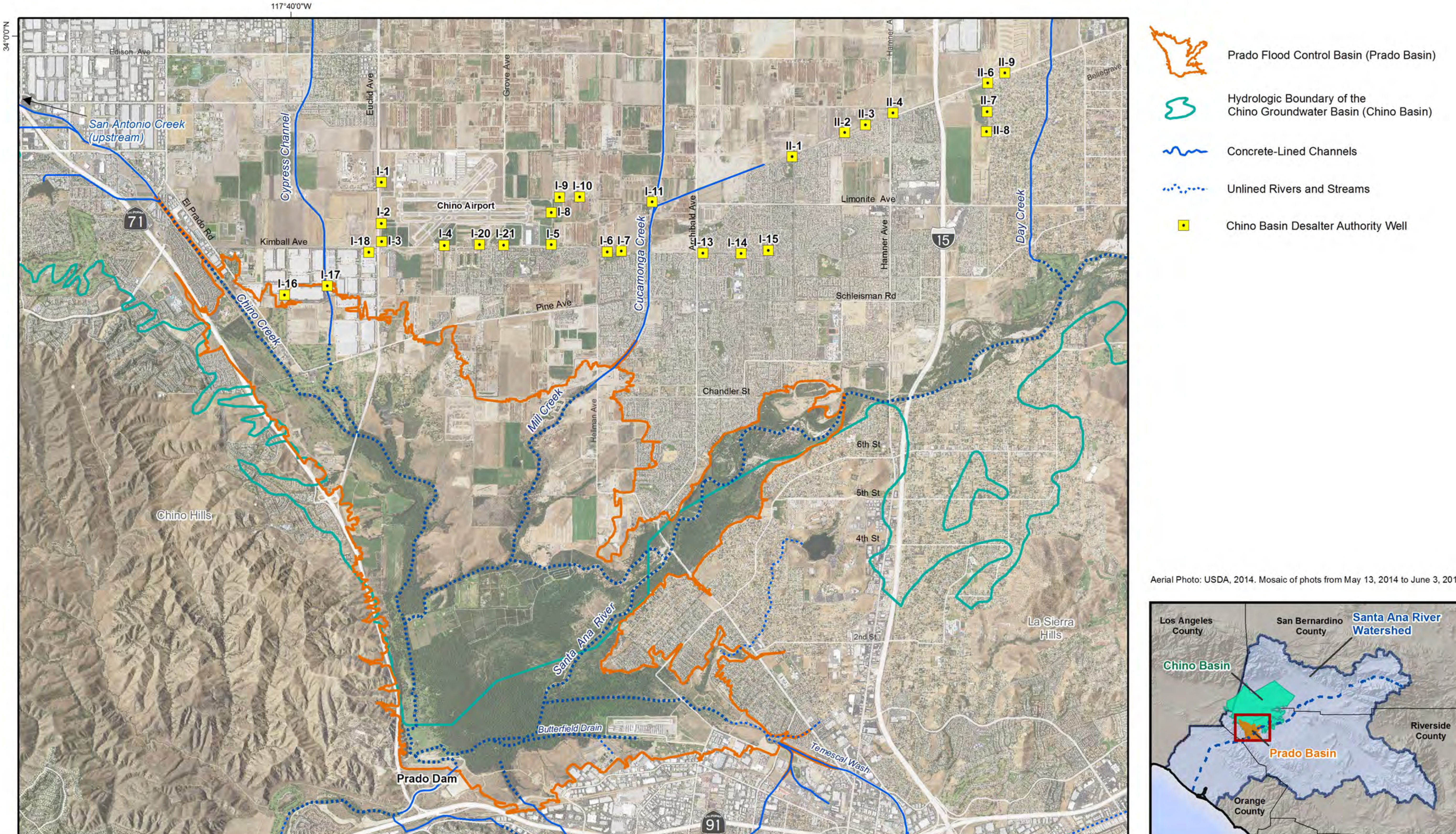
Section 2 – Monitoring, Data Collection, and Methods. This section describes the collection of historical information and the recent monitoring and groundwater-modeling activities performed during water year 2015/2016 for the PBHSP.

Section 3 – Results and Interpretations. This section describes the interpretations and results of the information, data, and groundwater-modeling results.

Section 4 – Conclusions and Recommendations. This section summarizes the main conclusions derived from the monitoring and modeling efforts through the prior water year and the recommended activities for the subsequent fiscal year, including a proposed scope-of-work, schedule, and budget.

Section 5 – References. This section lists the publications cited in the report.

Appendix A – 2017/18 Monitoring Program for the PBHSP. This appendix describes the PBHSP monitoring program for fiscal year 2017/2018, including recommended changes to the initial monitoring program described in Appendix A of the AMP (WEI, 2016).



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Author: VMW
Date: 4/12/2017
File: Figure 1-1

0 1 2 Miles
0 1 2 3 KM

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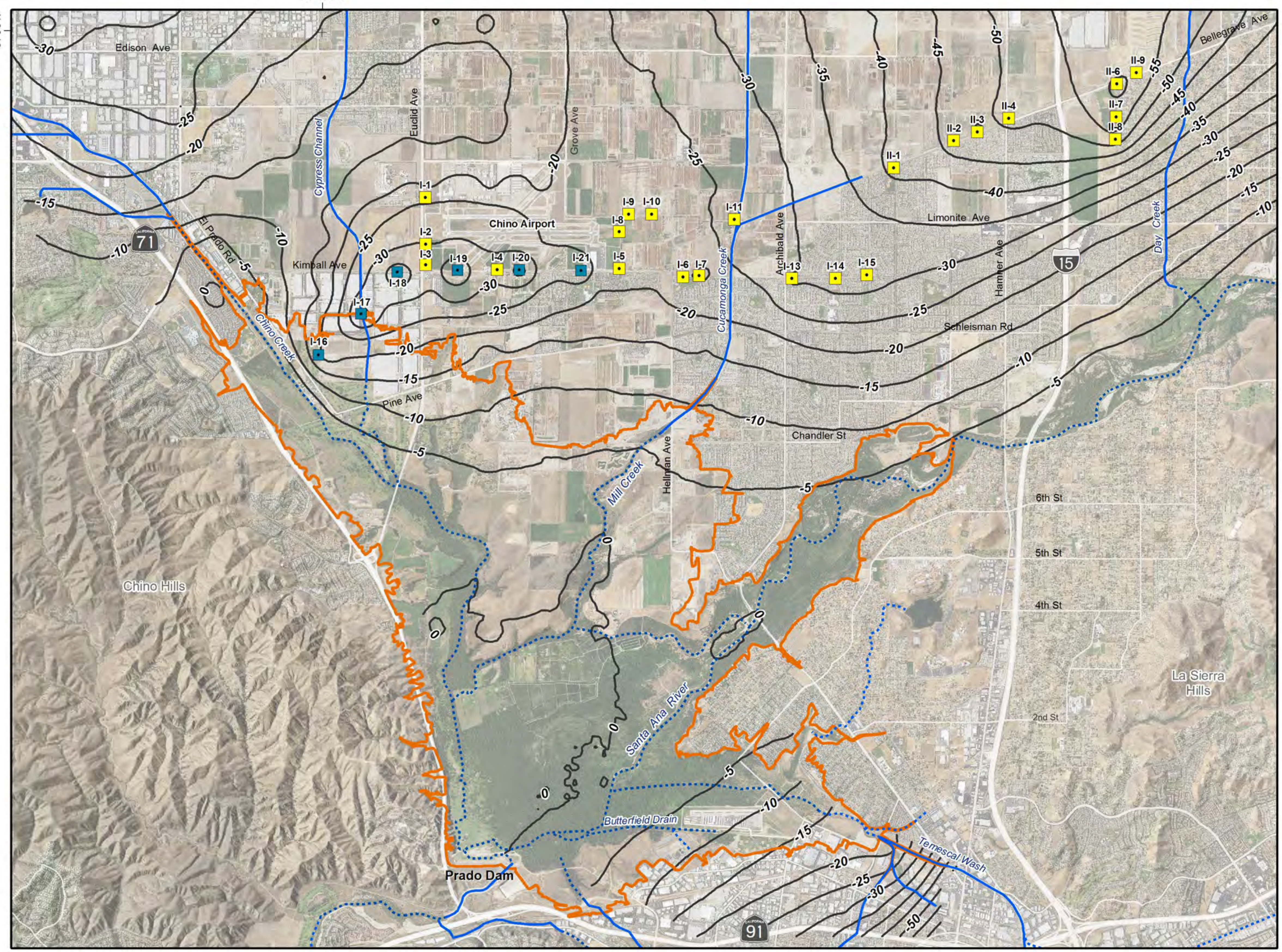
Prado Basin Area

Figure 1-1



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

Chino Basin Desalter Authority Well

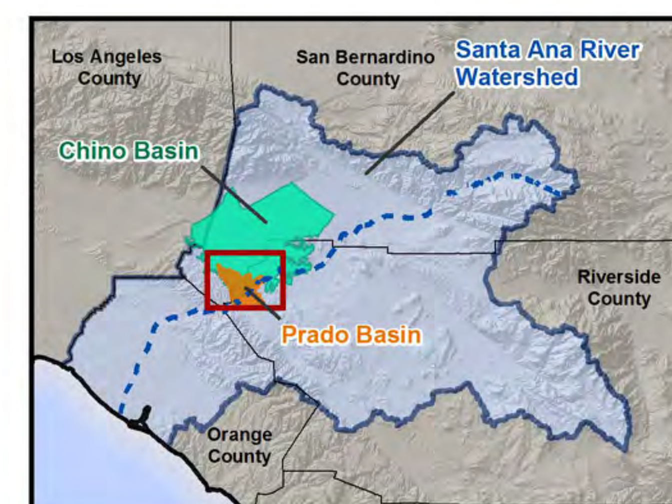
Chino Basin Desalter Authority Well – Planned Location of the Chino Creek Well Field (CCWF) in 2007 as modeled for the Peace II SEIR (Planned Capacity of 7,700 AFY) Actual Location of the CCWF Constructed in 2011-2012 Shown in Figure 1-1 (Actual Capacity 1,500 AFY)

Concrete-Lined Channels

Unlined Rivers and Streams

Prado Flood Control Basin (Prado Basin)

Aerial Photo: USDA, 2014. Mosaic of phots from May 13, 2014 to June 3, 2014



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File: Figure 1-2_PeaceII Model

0 1 2 Miles
0 1 2 3 KM

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Projected Change in Groundwater-Levels

FY 2005 to 2030 -- Peace II Alternative

Figure 1-2

Section 2 – Monitoring, Data Collection, and Methods

This section describes the collection of historical information and the recent monitoring and groundwater-modeling activities performed during water year 2015/2016 for the PBHSP.

The design of the PBHSP was based in part to answer to Question 1 from the AMP:

1. *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 Prado Basin include but are not limited to: groundwater levels, surface-water discharge, weather events, and long-term climate. Therefore, the PBHSP must include integrated monitoring and analysis programs for the riparian habitat, groundwater, surface water, weather, and climate.

Because this is the first year of the implementation of the AMP, the data collection efforts included the compilation of historical data to the present (water year 2015/2016). The period of data available for each data type varies, but all span time periods that include both pre- and post-Peace II implementation. Historical data that were collected and compiled for this effort were uploaded to Watermaster's centralized relational database, HydroDaVE^{SM}, and were used in the data analyses.

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:

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 the implementation of Peace II?*

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

Figure 2-1 displays the features of the RHMP. Two types of monitoring and assessment were performed in 2016: regional and site-specific. Regional monitoring and assessment is appropriate because the main potential stress associated with Peace II activities is the regional drawdown of groundwater levels. The intent of the site-specific monitoring and assessment is to verify and complement the results of the regional monitoring.

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: (i) multi-spectral remote-sensing data and (ii) air photos. The following subsections describe the data collected and how they are used to assess the riparian habitat in Prado Basin.

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.

This sub-section provides background information on the NDVI, explains why the NDVI was chosen as an analytical tool for the PBHSP and its advantages and limitations, and describes how NDVI estimates were compiled and used for this annual report.

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).

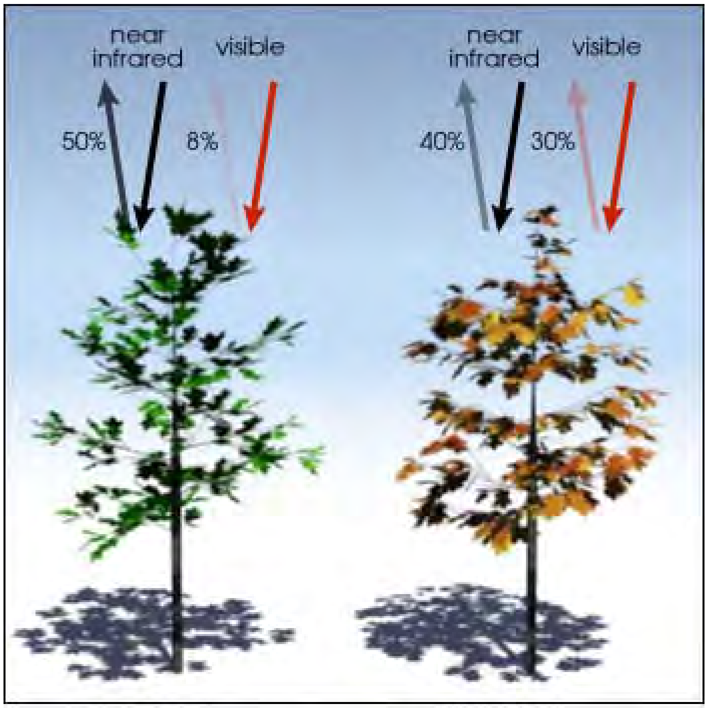
Remote sensing-based methods of vegetation monitoring commonly use vegetation indices that can be calculated from the wavelengths of light absorbed and reflected by vegetation (Jensen, 2007). The NDVI is a widely used numerical indicator of vegetation extent and quality that is calculated from remote-sensing measurements (Ke et al., 2015). Moreover, the 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). The NDVI is calculated from the visible and near-infrared radiation reflected by vegetation using the following formula:

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

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

Healthy vegetation during photosynthesis absorbs incoming visible light and reflects a large portion of the near-infrared radiation. Unhealthy or dormant vegetation absorbs less visible light and reflects less near-infrared radiation. The figure[2] below illustrates how the formula for NDVI works:

[2] http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

The 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 values range between -1.0 and 1.0. Negative NDVI values correspond to standing water, and very low positive values (<0.1) correspond to non-vegetated areas such as barren rock and sand, snow, and water. Values ranging from 0.1 to 0.9 correspond to vegetated areas, with very low-end values indicating sparse, unhealthy, or dormant vegetation, and increasing values towards 0.9 indicating higher amounts of dense, healthy green vegetation.

Advantages and Limitations. The 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, which is dependent on shallow groundwater. The regional scale of the 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 the 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 include the collection of the commonly measured spectral bands that are used to calculate the NDVI (red and near-infrared) and that these data will be available for use as part of the PBHSP at low cost.

Like most monitoring tools, the 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 values 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 values (James and Kalluri, 1994).

- Changes in soil moisture can lead to changes in NDVI values that are not necessarily related to changes in vegetation (Pettorelli, 2013).

- The NDVI is a composite view of plant species diversity, form, structure, density, and vigor. Therefore, changes in the NDVI may be caused by various changes in the riparian habitat (Markon et al., 1995; Markon and Peterson, 2002). In other words, the 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 values have been shown to plateau during the growing season, which indicates that NDVI can underestimate the green biomass in densely vegetated areas (Tucker et al., 1986).

These limitations demand that the NDVI be screened and filtered to identify or remove errors and noise in the data. To reduce or eliminate noise in the n NDVI, processing algorithms can be applied to "smooth" the time-series data and reveal patterns of change over time. An example of a smoothing technique applied in this report is the averaging of all of the 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 listed above also demand that the NDVI not be interpreted in isolation. Interpretations of the 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.

2.1.1.2 Landsat Program and NDVI

The USGS and the National Aeronautics and Space Administration (NASA) jointly manage the Landsat Program[3], a series of Earth-observing satellite missions that began in 1972 with

[3] https://landsat.gsfc.nasa.gov/about/

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 collect 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 imagery is acquired in scenes that are approximately 106 by 115 miles. Landsat satellite 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 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 USGS, in compliance with the Global Climate Observing System,[4] produces spectral indices products from Landsat imagery to support land surface change studies, which includes the NDVI from 1982 to present (USGS, 2016). The USGS uses remote sensing imagery from the Landsat satellites—*Landsat 4, Landsat 5, Landsat 7, and Landsat 8* (*Landsat 4, 5, 7, and 8*)—to generate the NDVI of the Earth's surface at a 30 x 30-meter pixel resolution. A specialized software called Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) is used by the USGS to post-process the Landsat imagery to apply the necessary atmospheric corrections to generate a surface reflectance product (USGS 2015; 2017a). This surface reflectance product is than used to determine the NDVI among the other spectral indices post-processed by the USGS.

2.1.1.3 NDVI Methods for the PBHSP

NDVI determined from Landsat remote sensing measurements for the period 1982 to 2016 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] The table below summarizes the Landsat satellites and the periods that the NDVI was obtained from them to produce a near-continuous NDVI record from 1982 through 2016.

Satallite	Instrument	Launched	Ended	Period of NDVI Data Obtained from USGS
Landsat 4	Thematic Mapper	July 16, 1982	December 14, 1993	1982 - 1983

[4] http://www.wmo.int/pages/prog/gcos/

[5] https://espa.cr.usgs.gov/login?next=https%3A%2F%2Fespa.cr.usgs.gov%2F

[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, the Landsat path number, the Landsat row number, and the date the Landsat image was collected.

[7] 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 Prado Basin.

Satallite	Instrument	Launched	Ended	Period of NDVI Data Obtained from USGS
Landsat 5	Thematic Mapper	March 1, 1984	June 5, 2013	1984 - 2011
Landsat 7	Enhanced Thematic Mapper	April 15, 1999	Still active	2012 - 2016
Landsat 8	Operational Land Imager	February 11, 2013	Still active	2013 - 2016

The NDVI from a total of about 1,000 scenes from the *Landsat 4*, *5, 7,* and *8* satellites were obtained from the USGS from 1982 through 2016. These Landsat scenes had a percent cloud cover of 20 percent or less. Landsat scenes with a percent cloud cover greater than 20 percent were not acquired.

The NDVI from all 1,000 Landsat scenes were cataloged, processed, and uploaded into HydroDaVE^SM^, a database management software that manages gridded-data sets.[8] HydroDaVE^SM^ contains a feature to compute a date-by-date stacked average for Landsat scenes from Path 040, Rows 036 and 037, where they overlap, for each NDVI pixel in a defined area.[9] The NDVI from the 1,000 Landsat scenes collected from the USGS for Path 040, Rows 036 and 037 were averaged date-by-date, resulting in about 550 individual dates with an NDVI between 1982 through 2016. There is only one date available for 1982, and no dates are available for 1983.

The spatial NDVI for the 550 dates between 1982 through 2016 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 the spatial NDVI for the entire Prado Basin region for all 550 dates. The maps were reviewed and documented to identify specific dates of NDVI that should not be used for analysis due to erroneous due cloud cover or other disturbances. Erroneous NDVI values were discernable because the NDVI patterns of permanent landscape features were distorted and/or NDVI values were clearly not consistent with the values typically observed for a particular area both seasonally and over time. About 80 dates with NDVI from the *Landsat 4, 5, 7, and 8* satellites (15 percent) were identified as erroneous and excluded from the analysis. Most of the dates were rejected because of cloud coverage in the Prado Basin region, which was further verified by referencing the specific Landsat scene on the USGS EarthExplorer website.[10]. After

[8] http://www.hydrodave.com/company/

[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] https://earthexplorer.usgs.gov/

reviewing for these disturbances, about 470 dates with NDVI from the *Landsat 4, 5, 7, and 8* satellites were determined available for analysis for the historical period.

Of the 470 dates with NDVI available for analysis, 92 of them were derived from *Landsat 7* satellite imagery from 2012 to 2016. The NDVI for these 92 dates had 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 that accounts for the forward motion of the satellite. The failure of the SLC 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 the failure of the SLC; however, the imagery acquired between these gaps is valid and useable for analysis.[11] All NDVI derived from *Landsat 7* satellite imagery from 2012 to 2016 for the 92 dates were evaluated spatially date-by-date to determine if the valid data covers the areas of interest used for the analysis of NDVI temporally 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 varies for each date. Generally, areas of interest for NDVI analysis that are larger than about 400 square meters could not use any NDVI determined from the *Landsat 7* satellite imagery because it would include a data gap area; while areas of interest less than 400 square meters could use about 70 percent of the NDVI from the *Landsat 7* satellite imagery.

In addition to determining a stacked average for each NDVI pixel for Landsat scenes that overlap, HydroDaVE^{SM} contains features to average and extract a date-by-date spatial average NDVI for a designated area and time period. The NDVI spatial average data can be plotted in time series charts to analyze seasonal and temporal changes for a defined area.

NDVI can also be extracted from HydroDaVE^{SM} and imported into other software tools for spatial and temporal analysis, including ESRI's ArcGIS for mapping and Golden Software's Grapher for time-series charting.

When viewing time series charts of NDVI for the period of record, it should be noted that the differences between the technology of the *Landsat 4, 5, 7, and 8* satellites could be a methodological factor that affects the observed NDVI trends. The *Landsat 4, 5, and 7* satellites use thematic mapper technology to scan the land surface, whereas *Landsat 8* uses operational land imager sensors. It has been documented that the NDVI obtained from the operational land imager sensors used on *Landsat 8* satellite could generate slightly higher index values for vegetated land cover (~0.4 to 1.0) and slightly lower index values for non-vegetated land cover (~0 to 0.3) compared to thematic mapper technology of the *Landsat 4, 5, and 7* satellites (Li et al., 2014), and the NDVI derived from *Landsat 8* (beginning in 2013) has an overall difference of ±0.05 compared to *Landsat 7* (Li et al., 2014; and Ke et al., 2015). In the time series charts presented in Section 3.1 of this report, the NDVI from 2013 to 2016 is from both *Landsat 7* and *8* satellites. Therefore, it is likely that an increase in NDVI post-2013 could be attributed in part (up to 0.05) to the difference in *Landsat 8* technology.

[11] https://landsat.usgs.gov/slc-products-background

2.1.1.4 Collection and Analysis of Air Photos

During water year 2015/2016, a reconnaissance effort was performed to compile, catalog, georeference, and analyze available historical air photos for the Prado Basin area. These air photos were collected from: United States Geological Survey (USGS) Earth Explorer; the United States Department of Agriculture (USDA) Aerial Photography Field Office; Eagle Aerial Solutions imagery; the University of California Santa Barbara (UCSB) Aerial Imagery Research Service; the United State Bureau of Reclamation (USBR); and air photos from the archives of the IEUA, the OCWD, Watermaster, and WEI.

Table 2-1 summarizes the air photos that were collected, compiled, and analyzed. About 55 air photos were collected for the period 1938-2016. For some years, there were more than one air photo. The air photos collected vary in scale, coverage, and quality. The air photo acquired for 2016 is a 60-centimeter resolution image of the entire Chino Basin obtained from the USDA Aerial Photography Field Office.

The georeferenced air photos were used to visually characterize the spatial extent of the riparian habitat in Prado Basin over a historical period from 1938-2016. The air photos can also be used to perform an independent check on the interpretations from the analysis of NDVI. This is accomplished by visually comparing the extent and density of the riparian habitat as shown in the air photos to the NDVI maps.

2.1.2 Site-Specific Monitoring of Riparian Habitat

The objective of the site-specific monitoring of riparian habitat is collect data that can be used to ground-truth the interpretations derived from the regional monitoring and assessment of the riparian habitat. The NDVI from remote sensing measurements should be integrated with georeferenced field observations for validation (Pettorelli et. al, 2013). Site-specific monitoring performed in the Prado Basin prior to the implementation of the AMP included vegetation surveys performed by the USBR in 2007 and 2013 (USBR, 2008b; 2015) and seasonal ground-based photo monitoring performed by the OCWD since 2010 (OCWD, 2015; Harvey, 2015). Figure 2-1 shows the locations of the USBR vegetation surveys and the OCWD photo-monitoring stations.

During water year 2015/2016, the RHMP included a site-specific monitoring effort to continue performing vegetation surveys at sites within the Prado Basin previously monitored by the USBR in 2007 and 2013 and also established and surveyed 14 additional sites that primarily located near the newly-constructed PBHSP monitoring wells (USBR, 2017). During October 2016, the USBR performed vegetation surveys at 38 sites: 24 sites were previously established sites by the USBR and 14 sites were new sites. The 2016 field survey methods were slightly modified by the USBR (as compared to past surveys) to more closely serve the objectives of the PBHSP. These modifications included: i) excluding analysis of the herbaceous vegetation cover (USBR, 2013; 2017) and ii) changing the surveyed sites from a fixed quadrant with nested plots for different vegetation types to a singular variable radius plot depending on vegetation density.

In 2016, the survey sites were designated and marked by a post in the center. The radius of the site varied from five to ten meters, depending on the vegetation density, targeting about ten trees per plot. The trees are marked by a permanent tag with a unique number, and the distance and azimuth from the center point were recorded for shrubs and saplings (tress with diameter < 8 centimeters). All marked trees were surveyed for health (live, dead, or stressed), species type, diameter at breast height (DBH), and height. Percent canopy cover was measured using a spherical densitometer from the center of the fixed plot to the edge in each of the four cardinal directions (north, south, east, and west). Shrubs and saplings were surveyed for species, height, and diameter (the diameter at root collar for shrubs and DBH for saplings). Photographs were taken at each site, including photos from the center in each of the four cardinal directions.

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, and climate. This section describes the methods employed to collect and analyze information on these factors to help answer the questions 5, 6, and 7 from the AMP:

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?*

2.2.1 Groundwater Monitoring Program

The Groundwater Monitoring Program (GMP) consists of three types of data: groundwater production, groundwater level, and groundwater quality. Watermaster is already implementing a robust groundwater monitoring program within the Chino Basin to support various basin management initiatives and activities, and all data within Watermaster's centralized relational database are available for the PBHSP.

Watermaster's groundwater monitoring network was expanded in 2015 specifically for the PBHSP by constructing 16 new piezometers at nine sites located along the fringes of the riparian habitat, 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 Prado Basin and upgradient areas to the north that encompass the CDA well field. Figure 2-2 also shows the wells in the study area where groundwater data was available in water year 2015/2016.

2.2.1.1 Groundwater Production

Groundwater production strongly 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 the extent and quality of riparian habitat. Groundwater production data along with groundwater level data is 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 quarterly groundwater production data from 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 water year 2015/2016, Watermaster collected groundwater production data at about 130 wells in the GMP study area.

2.2.1.2 Groundwater Level

The monitoring of groundwater levels in the Prado Basin is a key component of the PBHSP as the potential for declining water levels related to Peace II implementation could be a factor that adversely impacts riparian vegetation. 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 to any observed changes that have occurred in the extent and quality of the riparian habitat. Groundwater level data along with groundwater 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 a variety of groundwater management initiatives. The data are checked for QA/QC and uploaded to Watermaster's centralized relational database.

During water year 2015/2016, Watermaster collected groundwater-level data at 223 wells in the study area (see Figure 2-2). At 105 of these wells, water levels were measured by the well owners at varying frequencies and provided to Watermaster. The remaining 118 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. Groundwater-levels at the 18 PBHSP monitoring wells have been measured manually and with pressure transducers since May 2015.

2.2.1.3 Groundwater Quality

Water quality data can be used to understand the relative sources of groundwater in the Prado Basin. For the PBHSP, groundwater-quality data are compared to surface-water-quality data to characterize the interactions between groundwater and surface water 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 a variety of groundwater management initiatives. These data are checked for QA/QC and uploaded to Watermaster's centralized relational database.

During water year 2015/2016, groundwater-quality data were collected from 159 wells in the study area (see Figure 2-2). Of these wells, 96 were sampled by the well owners at varying frequencies. The remaining 84 wells are dedicated monitoring wells or private wells sampled by Watermaster either quarterly, annually, or triennially (every three years). The PBHSP monitoring wells were sampled quarterly during water year 2015/2016 for the parameters listed in Table 2-2. The water year 2015/2016 quarterly groundwater-quality sampling occurred during December 2015, March 2016, June 2016, and September 2016.

2.2.2 Surface-Water Monitoring Program

Surface-water discharge in the Prado Basin is another factor that can influence the extent and quality of riparian habitat as it has an influence on groundwater levels. Surface water discharge data are evaluated for the PBHSP to characterize historical and current trends in the discharge of the tributaries to the Santa Ana River in the Prado Basin and to assess if these trends correlate with changes in the extent and quality of 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). And, as noted in Section 2.2.1.3, surface-water quality is compared to groundwater-quality data to characterize the interaction between groundwater and surface 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 surface-water monitoring sites used for the PBHSP. The sites include Publicly-Owned Treatment Works (POTWs) discharge locations, USGS stream gaging stations, Watermaster and IEUA Maximum-Benefit Monitoring Program surface-water quality monitoring sites, and the OCWD's imported water turnout tributary to Prado Basin (OC-59).

During water year 2015/2016, historical and current surface water discharge and quality data for these sites were collected and compiled, checked for QA/QC, and uploaded to the Watermaster's relational database.

2.2.3 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 between trends in climatic data to trends in the extent and quality of the riparian habitat. Climatic data is 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 precipitation, temperature, evaporation, and potential evapotranspiration data in the vicinity of the Prado Basin. Figure 2-3 shows the location of stations where data are available and collected for the PBHSP. The sites include monitoring stations for the California Irrigation Management Information System (CIMIS) to collect potential evapotranspiration data, the Los Angeles County Department of Public Works pan evaporation station, and the spatially gridded climate datasets from Next-Generation Radar (NEXRAD) and the PRISM Climate Group for regional precipitation and temperature data. The Chino Basin boundary was used to extract the spatially gridded data for precipitation, and the Prado Basin boundary was used to extract the spatially gridded data for temperature. Climatic data are collected annually and uploaded to the Watermaster's relational database.

2.2.4 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 the riparian habitat in the Prado Basin. These factors include, but are not limited to: fire, disease, pests, and invasive species. To the extent necessary and possible, data and information on these factors are collected and analyzed to explore any relationships to changes in the extent and quality of the riparian habitat that have occurred over time.

During water year 2015/2016, two specific factors were identified as potential impacts to the Prado Basin riparian habitat: wildfires and an invasive pest known as the Polyphagous Shot-Hole Borer (PSHB). The following describes the information that was collected during water year 2015/2016 for these two factors and how they are used to explore relationships to changes that have occurred in the extent and quality of the riparian habitat.

2.2.4.1 Wildfires

Wildfires occur periodically in the Prado Basin and can reduce the extent and quality of the riparian habitat. For the PBHSP, the occurrence and location of wildfires are used to corroborate trends observed in riparian vegetation extent and health based on the analysis of NDVI time series.

To map wildfires, tire-perimeter data were collected from the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection (CAL FIRE) for 1950-2016. CAL FIRE, the USDA Forest Service Region 5 Remote Sensing Lab, Bureau of Land Management (BLM), and the Nation Parks Service (NPS), jointly developed a GIS layer database of the perimeters of fires for the State of California.[12] The methods to compile the data varied over time: data from 1950 to 2001 include CAL FIRE fires ≥300 acres and US Forest Service (USFS) fires ≥10 acres; and data from 2002 to 2016 include BLM and the NPS fires ≥10 acres, and CAL FIRE expanded criteria to include timber fires ≥10 acres, brush fires ≥50 acres, and wildland fires that destroyed three or more structures or caused $300,000 or more in damage.

[12] http://frap.fire.ca.gov/projects/fire_data/fire_perimeters_index

The FRAP database is the most complete digital record of fire perimeters in the State; however, it is still incomplete in many aspects: fires may be missing altogether because historical records were lost or damaged, fires were too small for the minimum cutoffs, documentation was inadequate, or fires have not yet been incorporated into the database. Currently, the wildfire data is uploaded to the database annually during the month of February.

2.2.4.2 Polyphagous Shot-Hole Borer (PSHB)

The PSHB (*Euwallacea fornicates)* is a pest that has been identified recently within the Prado Basin and has the potential to negatively impact the riparian habitat vegetation (USBR, 2016; Palenscar, K., verbal communication, 2016; McPherson, D., verbal communication, 2016). For the PBHSP, the occurrence of PSHB in the Prado Basin is used to corroborate trends observed in riparian vegetation extent and health based on the analysis of NDVI time series

The PSHB is a beetle that burrows into trees, introducing a fungus (*Fusarium euwallacea*) into the tree bark, which spreads a disease called Fusarium Dieback (FD).[13,14] 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). The OCWD biologists in the Prado Basin have been working with the University of California at Riverside, the United States Fish and Wildlife Service (USFWS), and the Santa Ana Watershed Association to actively monitor the occurrence and impact of PSHB within Prado Basin riparian habitat (Zembal, R., personal commination, 2017). To date, no reports have been prepared by these agencies that document PSHB impacts and occurrence in the Prado Basin.

Information on PSHB occurrence in the Prado Basin was obtained from the University of California, Department of Agriculture and Natural Resources online PBHB/FD Distribution Map[15] and from the USBR vegetation surveys of Prado Basin riparian habitat performed in 2016.

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 includes the following:

> *Annual reports will be prepared and 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).*

[13] http://ucanr.edu/sites/pshb/

[14] http://cisr.ucr.edu/polyphagous_shot_hole_borer.html

[15] http://ucanr.edu/sites/pshb/Map/

The meaning of "prospective loss" in this context is "future potential loss" of riparian habitat. Predictive modeling can be used to answer question 8 from the AMP:

8. *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 Prado Basin.

For this annual report, Watermaster's most recent groundwater model, the 2013 Chino Basin model (WEI, 2015), was used to characterize past and future conditions in the Chino Basin.

Table 2-1

Summary of Collected Historical Air Photos for the Prado Basin Region

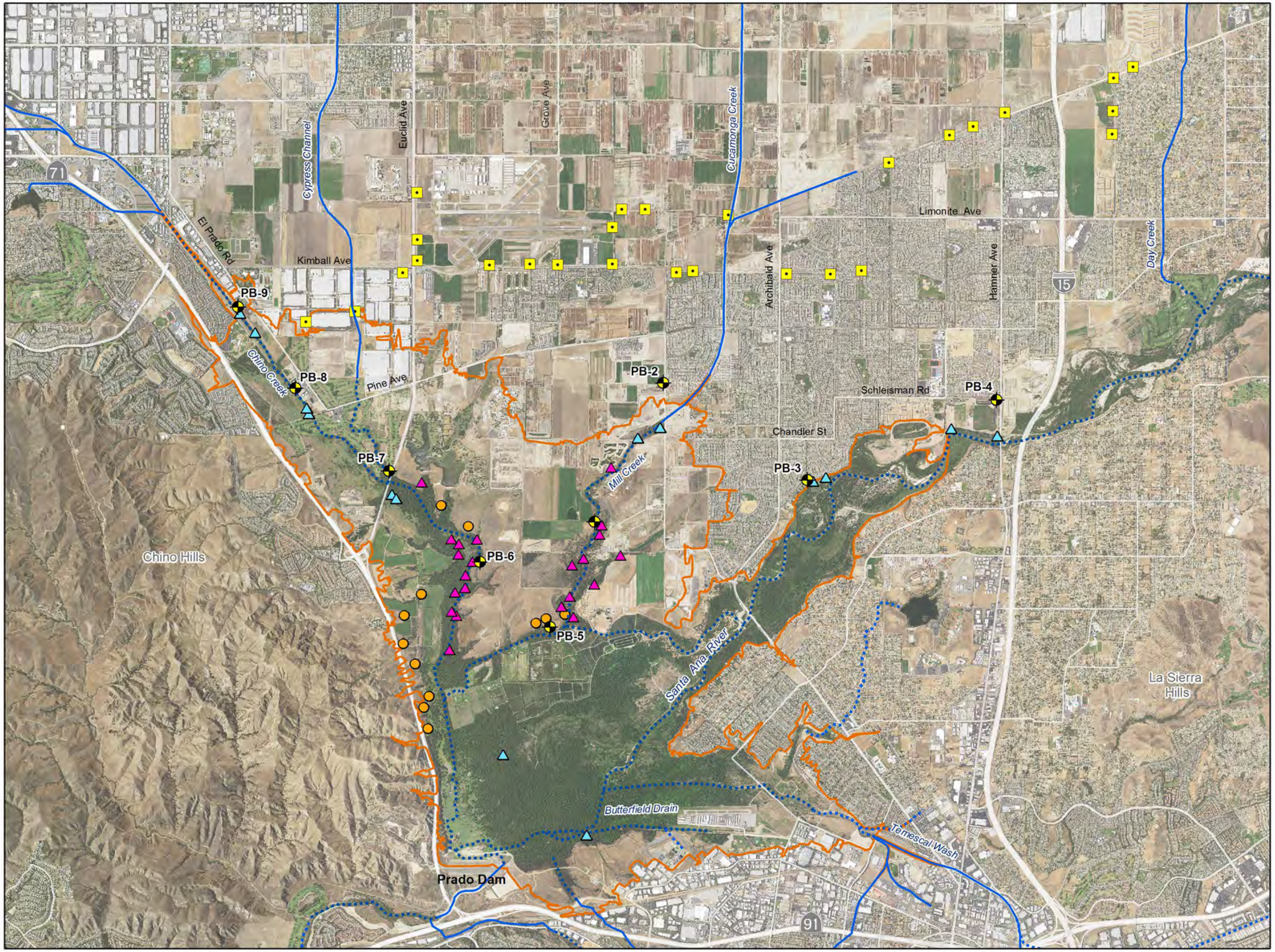
Year	Source	Date	Percent Coverage of the Prado Basin	Resolution (meters)	Quality	Georeferenced	Comments
1938	UCSB	5/27/1938 to 10/17/1938	100%	1.2	Good	no	Scanned black and white photo.
1946	USGS	12/29/1946	75%	0.7	Good	yes	Scanned black and white photo. The image borders need to be cropped.
1948	USGS	7/10/1948 to 7/20 1948	100%	0.5	Good	yes	Scanned black and white photo. Some image borders need to be cropped.
1952	USGS	6/30/1952	100%	0.8	Good	yes	Scanned black and white photo. The image borders need to be cropped.
1953	UCSB	9/22/1953 to 2/16/1954	100%	1	Very Good	no	Scanned black and white photo.
1959	UCSB	9/5/1959 to 11/6/1959	100%		Okay	no	Scanned black and white photo.
1959	USDA	10/15/1959 to 11/6/1959	100%	0.3	Very Good	no	Scanned black and white photo.
1960	UCSB	6/27/1960 to 7/13/1960	100%	0.6	Good	yes	Scanned black and white photo.
1960	Watermaster	2/9/1960	100%		Okay	yes	Scanned black and white photo.
1962	UCSB	1/30/1962	100%		Poor	no	Scanned black and white photo.
1965	UCSB	3/3/1965	100%		Good	yes	Scanned black and white photo.
1966	USGS	4/16/1966	100%	0.7	Okay	yes	Scanned black and white photo. Some image borders need to be cropped.
1967	UCSB	5/15/1967	100%		Good	no	Scanned black and white photo.
1968	UCSB	9/23/1968	100%		Good	no	Scanned black and white photo.
1973	UCSB	1/20/1973 to 1/23/1973	100%	1.1	Okay	yes	Scanned black and white photo.
1974	WEI	8/27/1974	100%	3.2	Good	yes	Scanned Colored photo.
1974	USGS	11/6/1974 to 9/18/1975	100%	7	Okay	yes	Scanned black and white photo.
1977	UCSB	2/1/1977	100%	1.1	Good	yes	Scanned black and white photo.
1977	WEI	11/2/1977	80%	3.1	Okay	yes	Scanned Colored photo.
1980	USGS	11/21/1980 to 12/24/1980	100%	2.1	Okay	yes	Scanned black and white photo.
1980	WEI	11/12/1980 to 12/24/1980	100%		Okay	no	Scanned black and white photo.
1980	UCSB		100%		Okay	no	Scanned black and white photo.
1984	WEI	2/12/1984	50%	1.2	Okay	no	Scanned Colored photo.
1985	USGS	9/13/1985	100%	5	Okay	yes	Scanned infared photo.
1985	USDA	7/28/1985	100%	0.7	Good	yes	Scanned infared photo.
1990	USGS		100%	3.5	Okay	yes	Scanned infared photo.
1990	UCSB	5/21/1990 to 5/22/1990	100%		Good	no	Scanned black and white photo.
1994	WEI	6/1/1994	100%	1	Okay	yes	Scanned black and white photo. A black line runs through the photo center.
1994	USGS	6/1/1994	100%	2.8	Okay	yes	Scanned black and white photo.
1994	USDA	6/1/1994	100%	0.5	Good	no	Scanned black and white photo. Some image borders need to be cropped.

Table 2-1
Summary of Collected Histrorical Air Photos for the Prado Basin Region

Year	Source	Date	Percent Coverage of the Prado Basin	Resolution (meters)	Quality	Georeferenced	Comments
1999	UCSB	1/14/1999	100%	1.8	Good	yes	Digital Colored photo.
2001	Eagle Aerial		100%	1	Good	yes	Digital Colored photo.
2002	Watermaster		100%	0.6	Very Good	yes	Digital Colored photo.
2003	Watermaster		100%	0.6	Very Good	yes	Digital Colored photo.
2003	USBR	12/2/2003	80%	0.2	Excellent	yes	Digital Colored photo.
2004	IEUA		100%	0.6	Very Good	yes	Digital Colored photo.
2005	Watermaster		100%	0.3	Very Good	yes	Digital Colored photo.
2005	IEUA		100%	0.3	Excellent	yes	Digital Colored photo.
2006	Watermaster		100%	0.3	Very Good	yes	Digital Colored photo.
2006	IEUA		100%	0.3	Excellent	yes	Digital Colored photo.
2007	Watermaster		100%	0.3	Very Good	yes	Digital Colored photo.
2007	IEUA		100%	0.3	Excellent	yes	Digital Colored photo.
2008	Watermaster		100%	0.3	Very Good	yes	Digital Colored photo.
2008	IEUA		100%	0.3	Good	yes	Digital Colored photo.
2009	Watermaster		100%	0.3	Very Good	yes	Digital Colored photo.
2009	OCWD	4/21/2009 to 5/8/2009	100%	0.1	Excellent	yes	Digital Colored photo.
2009	OCWD	1/26/2009 to 3/25/2009	100%	0.3	Excellent	yes	Digital Colored photo.
2010	Watermaster		100%	0.3	Very Good	yes	Digital Colored photo.
2010	IEUA		100%	0.3	Good	yes	Digital Colored photo.
2012	Watermaster		100%	1	Very Good	yes	Digital Colored photo.
2012	IEUA	1/28/2012 to 3/14/2012	100%		Very Good	no	Digital Colored photo.
2012	OCWD		100%	0.3	Very Good	yes	Digital Colored photo.
2012	OCWD		100%	0.1	Very Good	yes	Digital Colored photo.
2014	USDA	April and May 2014	100%	1	Good	yes	Digital Colored photo.
2014	OCWD	6/5/2014 to 6/6/2014	100%	0.1	Excellent	yes	Digital Colored photo.
2015	IEUA	5/11/2015	100%	0.1	Excellent	yes	Digital Colored photo.
2016	USDA	5/3/2016 to 6/14/2016	100%	0.6	Good	yes	Digital Colored photo.

Table 2-2
Parameter List for the Groundwater-Quality Monitoring Program

Analyte	Method
Major cations: Ca, Mg, K, Si, Na	EPA 200.7
Major anions: Cl, SO_4, NO_2, NO_3	EPA 300.0
Total Hardness	SM 2340B
Total Alkalinity (incl. Carbonate, Bicarbonate, Hydroxide)	SM 2320B
Ammonia Nitrogen	EPA 350.1
Arsenic	EPA 200.8
Boron	EPA 200.7
Chromium, Total	EPA 200.8
Hexavalent Chromium	EPA 218.6
Fluoride	SM 4500F-C
Perchlorate	EPA 314.0
pH	SM2330B/SM 4500-HB
Specific Conductance	SM 2510B
Total Dissolved Solids	EPA 160.1/SM 2540C
Total Kjeldahl Nitrogen (TKN)	EPA 351.2
Organic Nitrogen	EPA 351.2
Total Organic Carbon	SM5310C/E415.3
Turbidity	EPA 180.1
VOCs	EPA 524.2
1,2,3 -Trichloropropane (Low Detection)	CASRL 524M-TCP



Riparian Habitata Monitoring Program

Site-Specific Monitoring

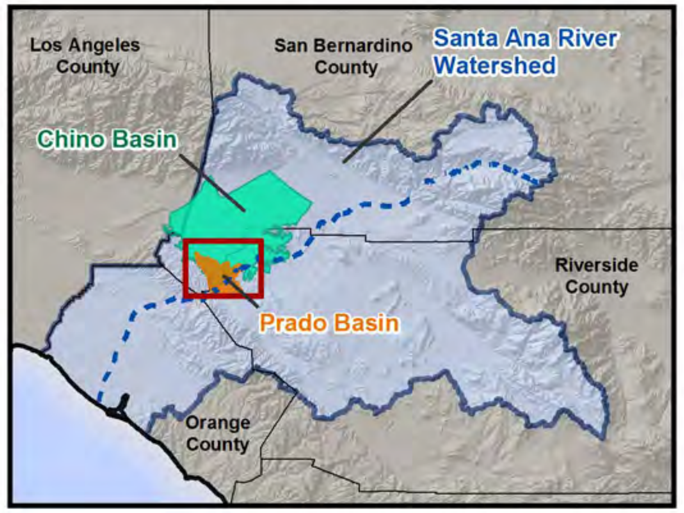
- USBR Vegetation Surveys 2007, 2013, and 2016
- USBR Vegetation Surveys 2016
- OCWD Photo Stations (2010 - 2016)

Regional Monitoring

- Prado Flood Control Basin (Prado Basin) - Area of Interest for Analysis of NDVI and Air Photos.

- Chino Basin Desalter Authority Well
- PBHSP Monitoring Well
- Concrete-Lined Channels
- Unlined Rivers and Streams

Aerial Photo: USDA, 2014. Mosaic of phots from May 13, 2014 to June 3, 2014



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

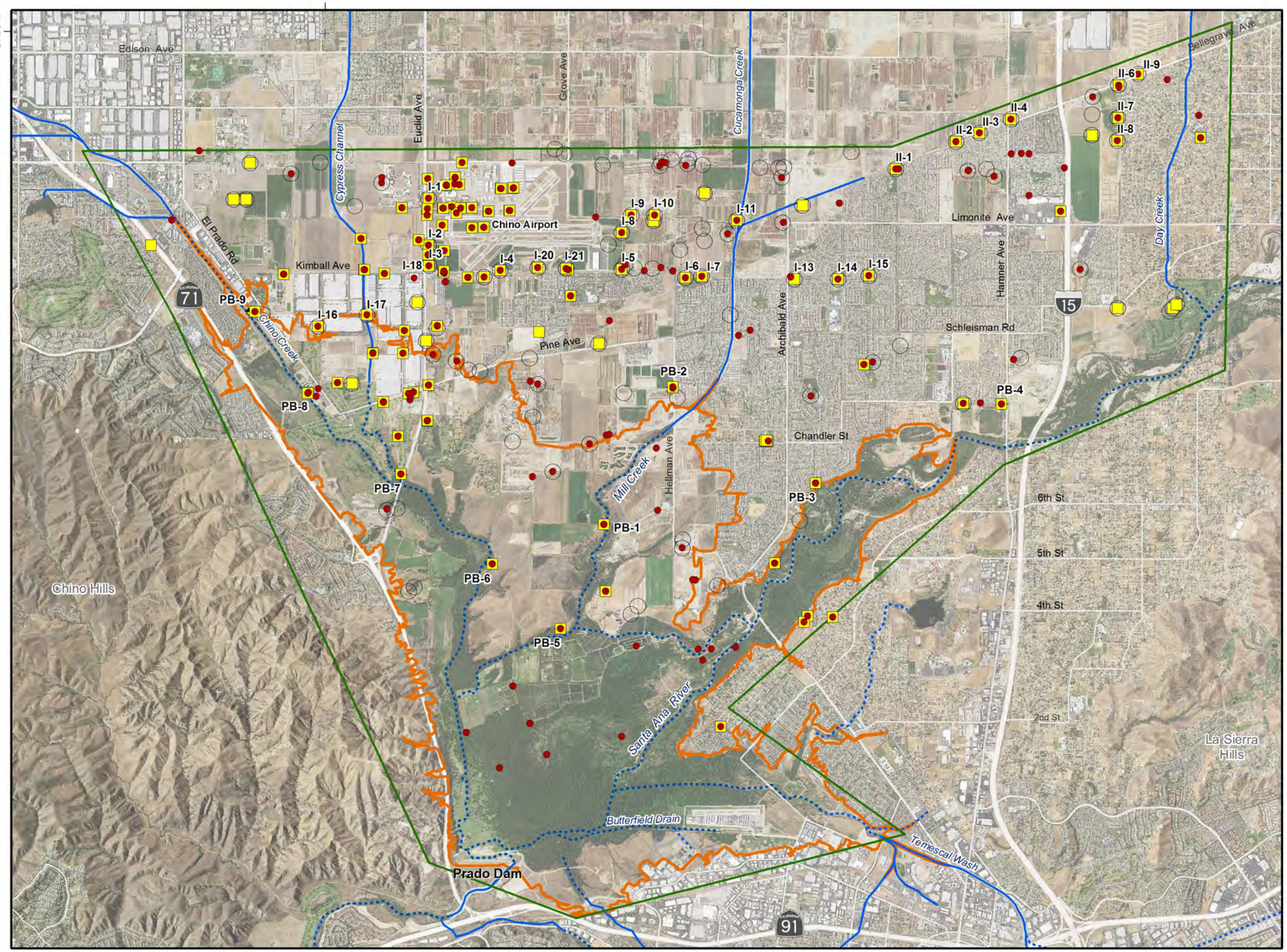
Author: VMW
Date: 4/12/2017
File: Figure 2-1 Veg Monitoring_NEW

0 1 2 Miles
0 1 2 3 KM

2016 Annual Report
Prado Basin Habitat Sustainability Committee

Riparian Habitat Monitoring Program

Figure 2-1



Wells with Groundwater Data - Water Year 2015/ 2016

- Wells with Production Data
- Wells with Water Level Data
- Wells with Water Quality Data

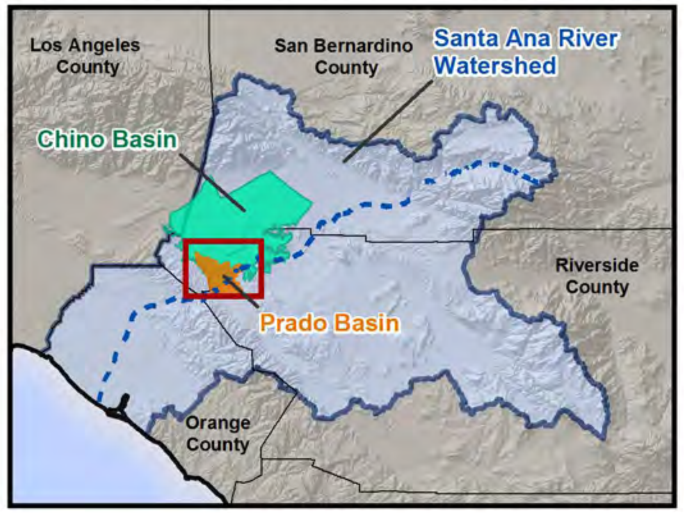
Wells Labeld on the Map:

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

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

- Groundwater Monitoring Program Study Area
- Concrete-Lined Channels
- Unlined Rivers and Streams
- Prado Flood Control Basin (Prado Basin)

Aerial Photo: USDA, 2014. Mosaic of phots from May 13, 2014 to June 3, 2014



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW
Date: 4/12/2017
File: Figure 2-2_Groundwater Monitoring Program

0 1 2 Miles
0 1 2 3 KM

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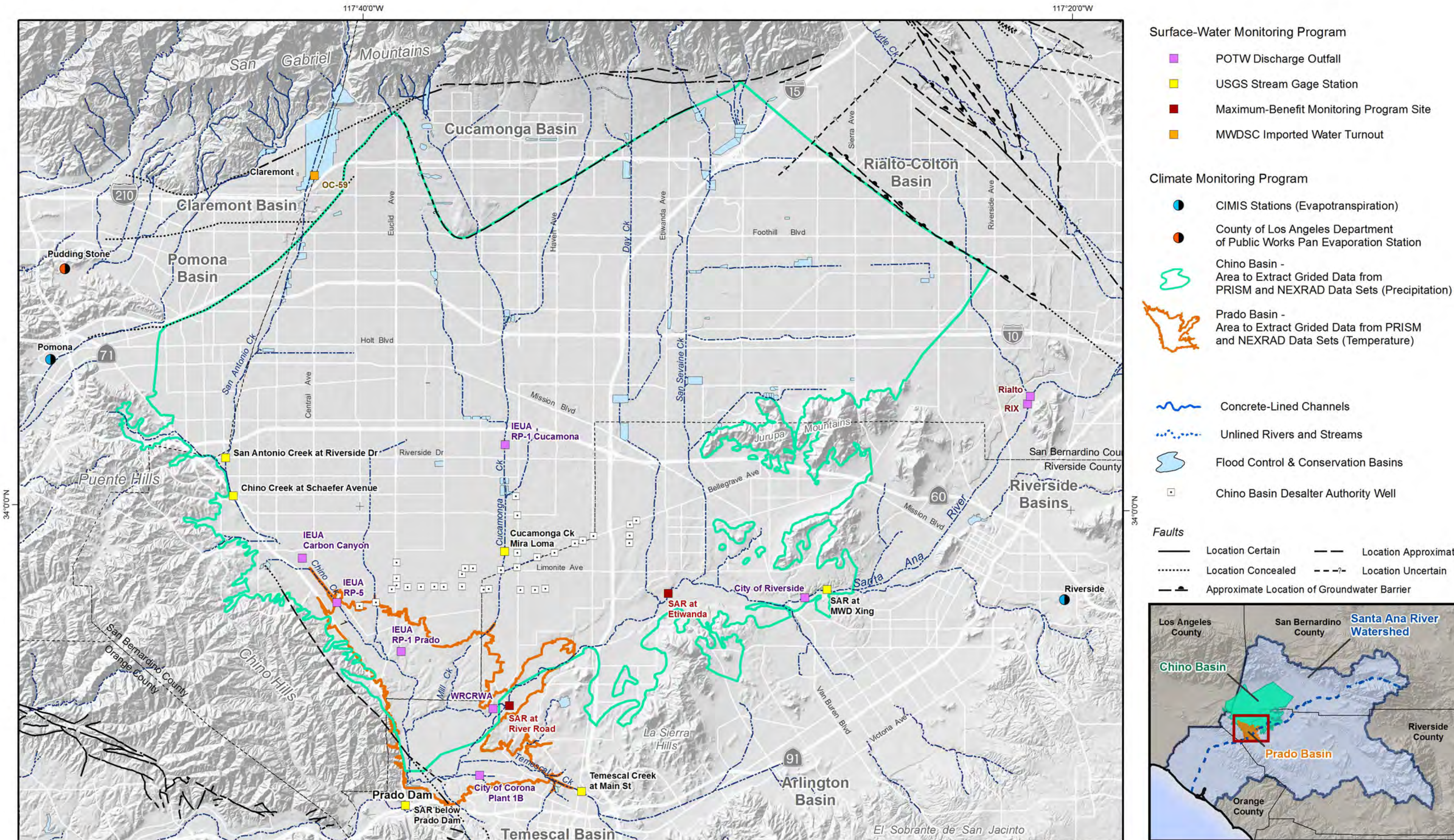
Groundwater Monitoring Program

Figure 2-2



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Date: 4/12/2017
File: Figure 2-3_Surface Water and Climate Monitoring

0 1 2 3 4 5 Miles
0 2 4 6 8 KM

2016 Annual Report
Prado Basin Habitat Sustainability Committee

Surface Water and Climate Monitoring Programs

Figure 2-3

This section describes the analysis and interpretation of the monitoring data and groundwater-modeling results for the PBHSP. The data collected spans various historical periods, based on data availability, and includes both pre- and post-Peace II implementation periods

The primary intent of this section is to identify trends in the riparian habitat and the factors that can impact the extent and quality of the riparian habitat and to understand cause-and-effect relationships, particularly cause-and-effect relationships that may be associated with Peace II implementation. The section begins with the analysis of trends in the extent and quality of the riparian habitat, and then describes factors that could have potentially impacted the extent and quality of the riparian habitat, including changes in groundwater levels, surface-water discharge, climate, and other factors, such as pests and wildfires. This section also includes a review of the most recent results of Watermaster's predictive groundwater-flow modeling of the Chino Basin to identify areas of prospective loss of riparian habitat.

3.1 Trends in Riparian Habitat Extent and Quality

The regional assessment of riparian habitat in the Prado Basin includes the analysis of air photos and NDVI to characterize trends in the extent and quality of the riparian habitat in Prado Basin over time. The regional assessment techniques are two independent methods that are analyzed comparatively to complement and corroborate each other. The site-specific monitoring of riparian habitat in the field is used to ground truth the regional monitoring and assessment.

3.1.1 Extent of the Riparian Habitat

The air photos collected and compiled for this annual report provide a long-term historical record of the extent and general visual characteristics of the riparian habitat in the Prado Basin. Air photo resolution and quality improved with time, which enhanced the ability to map and visually assess the riparian habitat.

Figure 3-1 is a time series of air photos from 1960, 1977, 1985, 1999, 2006, and 2016—one year from each decade, beginning in 1960. For each year, the extent of the riparian vegetation was digitized from the air photos, and the surface area was calculated. The table below summarizes the calculated surface area of the riparian vegetation extent based on the air photo analysis.

Year	Photo Date/s	Extent of Riparian Habitat in Prado Basin (square miles)
1960	6/27/1960 to 7/13/1960 [16]	1.85
1977	2/1/1977	4.35
1985	7/28/1985	6.16

[16] The air photo is a mosaic of images collected between June 27th and July 13th, 1960.

Year	Photo Date/s	Extent of Riparian Habitat in Prado Basin (square miles)
1999	1/14/1999	6.69
2006	Date Unknown	6.77
2016	5/3/2016 to 6/14/2016 [17]	6.79

The calculations show that the extent of the riparian vegetation increased from 1960 to 2016. From the 1930s to about 1960, large areas of the Prado Basin were managed to minimize the growth of riparian vegetation and its associated consumptive use of water in an effort to maximize flow in the Santa Ana River (Woodside, G., personal communication). Since the 1960s, the extent and density of the riparian habitat increased—the largest increases occurred between 1960 and 1977, a 235 percent increase. From 1977 to 1999, the extent of the riparian habitat increased by about 53 percent and has remained relatively constant through the present (2016).

Figures 3-2a through 3-2f are side-by-side maps of the air photos with the digitized extent of the riparian habitat compared to the NDVI of the Prado Basin for 1960, 1977, 1985, 1999, 2006, and 2016, respectively.[18] For each year, the date of the NDVI map corresponds to the peak NDVI value during the growing season for that particular year. The growing season for the Prado Basin riparian vegetation in is from March through October (Merkel, 2007; USBR, 2008). The dates of air photo acquisition are indicated on the air-photo map and may or may not correspond to a time during the growing season. Generally, NDVI estimates corresponds to the following land cover types during the growing season:

NDVI	Land Cover Indication During Growing Season
< 0	Water
0 - 0.3	Non-vegetated surfaces, such as urbanized land cover and barren land.
0.4 - 1.0	Vegetated land cover - increasing NDVI values indicate increasing photosynthetic activity of the vegetation

The Prado Basin riparian vegetation areas have NDVI values of about 0.6 to 0.8 during the growing season. Agricultural lands in the Prado Basin region can also have NDVI values > 0.6 during the growing season.

Two main conclusions drawn from the comparison maps in Figures 3-2a through 3-2f are:

1. They support the delineation of the extent of the riparian habitat as drawn from the air photos for 1985 through 2016. The dense riparian vegetation observed in the air

[17] The air photo is a mosaic of images collected between May 3rd and June 14th, 2016.

[18] NDVI data were not available for 1960 and 1977.

photos typically corresponds to NDVI values greater than about 0.6 on the NDVI maps.

2. The processing and georeferencing of NDVI estimates for this study were performed accurately.

3.1.2 Quality of the Riparian Habitat

As discussed and referenced in Section 2.1.1, the NDVI is a measure of the photosynthetic activity of vegetation and therefore can be used as an indicator of the health or "quality" of the riparian vegetation. In this section, the NDVI is analyzed spatially in maps and temporally in time-series charts for a series of defined areas throughout Prado Basin to characterize changes in the quality of riparian habitat from 1984 to the present. The defined areas where NDVI was analyzed temporally are shown on Figure 3-3. These areas include: the entire 2016 extent of the riparian habitat which is about 6.7 square miles (518,000 30 x 30-meter NDVI pixels); one large area in lower Prado Basin, which is about 20,300 square meters (677 30 x 30-meter NDVI pixels); and multiple smaller areas, primarily located along the northern reaches of the riparian habitat in Prado Basin near the new PBHSP monitoring wells—these smaller areas are 120-square-meters (four 30 x 30-meter NDVI pixels).

Figures 3-4, 3-5, and 3-6a through 3-6k are time-series charts of NDVI for each of the defined areas. There are three time-series curves of NDVI shown on each chart:

1. The spatial average of all NDVI pixels within the defined area of analysis. This curve characterizes the seasonal and long-term trends in NDVI for the area. These time series charts of NDVI clearly demonstrate that the riparian forest is deciduous, meaning that they shed their leaves and become dormant annually. The NDVI is higher in the growing season (March-October) and lower in the non-growing season (November-February).
2. The annual average of the spatial average of NDVI from (1) for the growing season only (March-October). This curve is a time-series smoothing technique that displays year-by-year changes and long-term trends in the average NDVI over the growing-season.
3. The maximum of the spatial average of NDVI from (1) for the growing season (March-October). This curve is a time-series smoothing technique that displays year-by-year changes and long-term trends in the maximum NDVI for the growing-season. Maximum NDVI typically occurs during the summer months.

NDVI maps and air photos are included on the time-series charts for spatial reference and as a visual check on interpretations derived from the time-series charts.

3.1.2.1 Analysis of the Prado Basin Riparian Habitat in Aggregate

Figure 3-4 is a time-series chart from 1984-2016 of the spatial average of all NDVI pixels that are within the entire 2016 extent of the riparian habitat in the Prado Basin. The 2016 riparian vegetation extent is about 6.7 square-miles, or 518,000 NDVI pixels.

The intent of the analysis of the riparian habitat in aggregate is to characterize the regional trends in NDVI for the Prado Basin as a whole. The trend is used as a basis of comparison to the trends in NDVI for each of the smaller defined areas.

Figure 3-4 shows that annual average and maximum NDVI for the growing season vary slightly from year-to-year, and the long-term NDVI trend based on the average has increased (0.58-0.65).[19] This long-term increasing trend in NDVI suggests that, as a whole, the riparian habitat in Prado Basin has not degraded and has become more robust since 1984.

3.1.2.2 Analysis of the Riparian Habitat in Lower Prado Basin

Figure 3-5 is a time-series chart from 1984-2016 of the spatial average of all NDVI pixels that are within the large defined area in the southern portion of Prado Basin (Lower Prado). The Lower Prado defined area is about 20,300 square meters, or 677 NDVI pixels.

The intent of this analysis is to characterize the trends in NDVI in an area of Prado Basin that is not expected to be impacted by Peace II implementation. The analysis is used as a basis of comparison to trends in NDVI for each of the smaller defined areas located further to the north along Chino Creek, Mill Creek, and the Santa Ana River.

Similar to the Prado Basin in aggregate, Figure 3-5 shows that annual average and maximum NDVI for the growing season vary slightly from year-to-year, and the long-term NDVI trend, based on the average, has increased (0.62-0.76). This long-term increasing trend in NDVI suggests that the riparian habitat in Lower Prado has not degraded and has become more robust since 1984.

3.1.2.3 Analysis of the Riparian Habitat along Chino Creek, Mill Creek, and the Santa Ana River

Figures 3-6a through 3-6k are time-series charts from 1984-2016 of the spatial average of four NDVI pixels (120 square meters) for defined areas located along Chino Creek, Mill Creek, and the Santa Ana River. The intent of this analysis to analyze smaller areas primarily located along the northern reaches of the riparian habitat in Prado Basin, which are most susceptible to impacts from the drawdown of groundwater levels associated with Peace II implementation. These sites are near the new PBHSP monitoring well sites to facilitate the comparison of riparian habitat quality to shallow groundwater levels. The analysis of NDVI time series for these smaller areas throughout the Prado Basin provides site-specific detail in NDVI trends that cannot be observed in the larger-scale analysis trends.

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[19] NDVI data derived from Landsat 8 (beginning in 2013) has an overall difference of ±0.05 compared to Landsat 4, 5, and 7 (Peng et al., 2013; and Ke et al., 2015). (See Section 2.1.1.3.) It is likely that increases in post-2012 NDVI time-series could be attributed in part to the inclusion of Landsat 8 imagery beginning in 2013, up to +0.05. The NDVI time series charts in Figures 3-4 and 3-5 do not include estimates from Landsat 7 (2012-2016) because it is unavailable for larger areas (See Section 2.1.1.3); therefore, this impact may be more notable. NDVI time-series charts in Figures 3-6a through 3-6k include NDVI estimates from both Landsat 7 and 8; therefore, this impact should be less of a factor for the average NDVI for the growing season because it is an average of both Landsat 7 and 8.

The table below summarizes the NDVI trends for the defined areas along Chino Creek, Mill Creek, and the Santa Ana River:

Figure	Location	Defined Area	Growing Season NDVI				
			1984 Max	2016 Max	1984 Avg.	2016 Avg.	Overall Trend[20]
3-6a	Chino Creek	CC-1	0.52	0.75	0.43	0.60	Increasing
3-6b	Chino Creek	CC-2	0.57	0.83	0.50	0.72	Increasing
3-6c	Chino Creek	CC-3	0.73	0.83	0.70	0.71	No Trend
3-6d	Chino Creek	CC-4	0.76	0.84	0.68	0.75	Increasing
3-6e	Mill Creek	MC-1	0.58	0.76	0.51	0.68	Increasing
3-6f	Mill Creek	MC-2	0.66	0.79	0.62	0.65	Increasing
3-6g	Mill Creek	MC-3	0.74	0.77	0.70	0.69	No Trend
3-6h	Mill Creek	MC-4	0.60	0.79	0.53	0.69	Increasing
3-6i	Santa Ana River	SAR-1	0.44	0.81	0.39	0.74	Increasing
3-6j	Santa Ana River	SAR-2	0.62	0.81	0.55	0.72	Increasing
3-6k	Santa Ana River	SAR-3	0.75	0.86	0.69	0.75	Increasing

Chino Creek (Figures 3-6a to 3-6d). Four defined areas were analyzed along Chino Creek: CC-1, CC-2, CC-3, and CC-4 (see locations on Figure 3-3). These sites were selected to characterize NDVI trends in areas of the Prado Basin that are located just southwest of the CDA well field.

These figures show that annual average and maximum NDVI for the growing season vary slightly from year-to-year and that the long-term NDVI trend, based on the average, has increased or remained the same at all four sites. These trends in NDVI suggest that the riparian vegetation along Chino Creek has become more robust since 1984.

***Mill Creek*. (Figures 3-6e to 3-6h).** Four defined areas were analyzed along Mill Creek: MC-1, MC-2, MC-3, and MC-4 (see locations on Figure 3-3). These sites were selected to characterize NDVI trends in areas of Prado Basin located just south of the CDA well field.

These figures show that annual average and maximum NDVI for the growing season vary slightly from year-to-year and that the long-term NDVI trend based on the average has increased or remained the same at all four sites. The MC-1 area on the northern region of Mill Creek and MC-4 along the southern region show the largest increasing trend in NDVI between the four sites. These trends in NDVI suggest that since 1984, riparian vegetation extent and quality along Mill Creek has stayed about the same along some portions and become more robust along others.

[20] The overall trend for each defined area is based on the comparison between the 1984 and 2016 average NDVI for the growing season.

Santa Ana River (Figures 3-6i to 3-6k). Three locations were analyzed along the floodplain of the Santa Ana River: SAR-1, SAR-2, and SAR-3 (see locations on Figure 3-3). These sites were selected to characterize NDVI trends in areas of Prado Basin located south of the CDA well field along the Santa Ana River.

These figures show that annual average and maximum NDVI for the growing season consist of both increasing and decreasing trends between 1984 to 2016, and the long-term NDVI trend, based on the average, has increased at all three sites. Inspection of the air photos in Figure 3-6i (for SAR-1) and Figure 3-6j (for SAR-2) suggests that variations in NDVI in the time-series charts are likely related to the meandering of the Santa Ana River channel and its associated erosion/deposition of sediments and re-establishment of vegetation on the sand bars. These trends in NDVI suggest that the riparian vegetation along the Santa Ana River has become more robust since 1984.

3.1.3 Analysis of Vegetation Surveys

The USBR performed vegetation surveys in 2016, which were a continuation and expansion of the surveys performed in 2007 and 2013. The 2016 survey included 14 new sites that were not previously surveyed. The variables measured or assessed during the vegetation surveys included tree condition (live, stressed, and dead), DBH, height, and percent canopy cover in the four-cardinal directions (north, south, east, and west) from the center of the plot. Additionally, the presence of the invasive PSHB was recorded. The measured parameters were used to calculate the following: average percent canopy cover; percentage of live, dead, and stressed trees; percentage of trees with the presence of the invasive PSHB; basal area; crown ratio; and plot density. Table 3-1 summarizes the calculated parameters for all sites surveyed in 2007, 2013, and 2016. Table 3-1 includes a description of each calculated parameter and the calculation method.

The percent canopy cover measurements from the USBR vegetation surveys are the most appropriate information for ground-truthing NDVI data. Where and when available, the average percent canopy cover for surveyed sites near the areas of NDVI analysis in Figures 3-6a through 3-6k are shown with the NDVI time-series data for comparison. 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, canopy cover is a metric of the areal density of the vegetation that is reflecting the visible light and near-infrared radiances and, therefore, should correlate with NDVI. Where percent canopy cover measurements are available for more than one year, they typically show stable or increasing trends, which corroborate the trends in the NDVI data. Table 3-1 shows that overall, the percent canopy cover for all surveyed sites each year has increased—the average percentages of canopy cover for all sites surveyed in 2007, 2013, and 2016 were 75%, 76%, and 86%, respectively.

3.1.4 Summary

This assessment of the riparian habitat in the Prado Basin, through the analysis of air photos, NDVI, and vegetation surveys, shows that the riparian habitat has increased in its extent and quality since the 1960s. There is no indication of a trend in degradation of the extent or quality of the riparian habitat along Chino Creek, Mill Creek, or the Santa Ana River that is contemporaneous with Peace II implementation.

Table 3-1
Summary of USBR Vegetation Surveys in 2007, 2013, and 2016 in Prado Basin

Site	Canopy Cover (%) [1]				Tree Condition (% surveyed per plot) [2]												Polyphagous Shot-Hole Borer [3]		Basal Area (m^2/ha) [4]			Density per plot (trees/ha) [5]			Crown Ratio [6]		
					Live				Stressed				Dead														
	2007	2013	2016	Change - 2007 to 2016	2007	2013	2016	Change - 2013 to 2016	2007	2013	2016	Change - 2013 to 2016	2007	2013	2016	Change - 2013 to 2016	Present in 2016	% of Trees	2007	2013	2016	2007	2013	2016	2007	2013	2016
Chino Creek Sites																											
Chino 3	59%	NM	NM	-	NM	NM	NM	-	NM		NM	-	NM		NM	-	NM	NM	36	NM	NM	127	NM	NM	NM	NM	NM
Chino 3B	NM	97%	96%	-	NM	100%	0%	-100%	NM	0%	100%	100%	NM	0%	0%	0%	no	0%	NM	6	30	NM	318	1019	NM	0.66	0.67
Chino 4	80%	94%	98%	18%	NM	100%	7%	-93%	NM	0%	80%	80%	NM	0%	13%	13%	no	0%	29	34	43	255	318	477	NM	0.71	0.84
Chino 9	92%	96%	95%	4%	NM	100%	0%	-100%	NM	0%	100%	100%	NM	0%	0%	0%	no	0%	32	39	33	382	318	318	NM	0.82	0.76
Chino 11	94%	96%	96%	2%	NM	100%	50%	-50%	NM	0%	42%	42%	NM	0%	8%	8%	no	0%	5	118	185	64	1146	1528	NM	0.75	0.75
Chino 16	46%	61%	81%	35%	NM	NM	27%	-	NM	NM	64%	-	NM	NM	9%	-	no	0%	23	34	28	127	318	350	NM	0.77	0.82
Chino 18	38%	87%	90%	52%	NM	100%	7%	-93%	NM	0%	67%	67%	NM	0%	27%	27%	yes	40%	26	21	94	127	605	1910	NM	0.86	0.68
Chino 21	98%	94%	88%	-10%	NM	100%	0%	-100%	NM	0%	100%	100%	NM	0%	0%	0%	yes	17%	73	103	83	414	1019	764	NM	0.72	0.63
Chino 24	93%	93%	98%	4%	NM	100%	6%	-94%	NM	0%	94%	94%	NM	0%	0%	0%	yes	6%	17	32	30	223	318	573	NM	0.72	0.75
Chino 30	79%	88%	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	60	8	NM	382	255	NM	NM	0.76	NM
Chino 30B	NM	NM	89%	-	NM		0%	0%	NM	NM	89%	-	NM	NM	11%	-	yes	100%	NM	NM	63	NM	NM	1146	NM	NM	0.74
Chino 31	82%	93%	97%	14%	NM	100%	7%	-93%	NM	0%	93%	93%	NM	0%	0%	0%	yes	7%	31	34	57	350	318	446	NM	0.78	0.82
Chino 34	96%	97%	89%	-7%	NM	100%	0%	-100%	NM	0%	67%	67%	NM	0%	33%	33%	no	0%	22	76	60	255	1019	764	NM	0.66	0.70
Chino 78	95%	98%	87%	-8%	NM	100%	0%	-100%	NM	0%	80%	80%	NM	0%	20%	20%	yes	80%	51	40	27	318	350	318	NM	0.74	0.87
Chino 81	92%	0%	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	6	NM	NM	72	NM	NM	NM	NM	NM
Chino 85	89%	0%	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	3	NM	NM	28	NM	NM	NM	NM	NM
Chino X3	NM	NM	93%	-	NM	NM	25%	-	NM	NM	75%	-	NM	NM	0%	-	no	0%	NM	NM	81	NM	NM	509	NM	NM	0.76
Chino X4	NM	NM	92%	-	NM	NM	0%	-	NM	NM	100%	-	NM	NM	0%	-	yes	100%	NM	NM	15	NM	NM	891	NM	NM	0.61
Chino X5	NM	NM	96%	-	NM	NM	75%	-	NM	NM	25%	-	NM	NM	0%	-	yes	25%	NM	NM	122	NM	NM	1019	NM	NM	0.82
Chino X6	NM	NM	98%	-	NM	NM	87%	-	NM	NM	13%	-	NM	NM	0%	-	yes	13%	NM	NM	69	NM	NM	1910	NM	NM	0.68
Chino X7	NM	NM	88%	-	NM	NM	0%	-	NM	NM	70%	-	NM	NM	30%	-	yes	70%	NM	NM	30	NM	NM	318	NM	NM	0.85
Chino X8	NM	NM	85%	-	NM	NM	0%	-	NM	NM	62%	-	NM	NM	38%	-	yes	46%	NM	NM	68	NM	NM	1655	NM	NM	0.82
Average	**81%**	**78%**	**92%**	**11%**	**-**	**100%**	**16%**	**-84%**	**-**	**0%**	**73%**	**73%**	**-**	**0%**	**11%**	**11%**	**yes**	**28%**	**30**	**45**	**62**	**223**	**525**	**884**	**-**	**0.75**	**0.75**
Mill Creek Sites																											
Mill 1	40%	0%	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	NM	-	NM	NM	4	NM	NM	80	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
Mill 4	38%	6%	0%	-38%	NM	0%	0%	0%	NM	63%	50%	-13%	NM	37%	50%	13%	yes	50%	6	NM	0	350	605	191	NM	0.63	0.73
Mill 8	66%	88%	82%	16%	NM	33%	33%	0%	NM	67%	0%	-67%	NM	0%	67%	67%	yes	33%	NM	3	4	NM	764	764	NM	0.00	0.91
Mill 11	75%	80%	NM	-	NM	90%	NM	-	NM	0%	NM	-	NM	10%	NM	-	NM	NM	10	24	NM	318	318	NM	NM	0.75	NM
Mill 18	62%	68%	78%	16%	NM	100%	38%	-63%	NM	0%	38%	38%	NM	0%	25%	25%	yes	38%	34	22	21	318	223	255	NM	0.92	0.91
Mill 22	89%	93%	96%	7%	NM	86%	0%	-86%	NM	0%	79%	79%	NM	14%	21%	7%	yes	64%	16	NM	80	382	1783	1910	NM	0.65	0.77
Mill 30	63%	63%	NM	-	NM		NM	-	NM		NM	-	NM		NM	-	NM	NM	12	35	NM	286	732	NM	NM	0.41	NM
Mill 35	81%	95%	NM	-	NM	100%	NM	-	NM	0%	NM	-	NM	0%	NM	-	NM	NM	4	40	NM	80	1401	NM	NM	0.78	NM
Mill 39	94%	87%	96%	2%	NM	92%	0%	-92%	NM	0%	67%	67%	NM	8%	33%	25%	yes	44%	18	23	21	350	382	286	NM	0.82	0.88
Mill 60	76%	90%	83%	6%	NM	86%	0%	-86%	NM	0%	93%	93%	NM	14%	7%	-7%	yes	29%	4	NM	22	103	1783	446	NM	0.72	0.85
Mill 62	66%	96%	96%	30%	NM	100%	0%	-100%	NM	0%	94%	94%	NM	0%	6%	6%	yes	94%	2	121	124	35	2165	2037	NM	0.76	0.72
Mill 63	70%	97%	78%	8%	NM	100%	0%	-100%	NM	0%	68%	68%	NM	0%	32%	32%	yes	41%	3	33	22	72	668	700	NM	0.70	0.82
Mill 67	75%	95%	NM	-	NM	100%	NM	-	NM	0%	NM	-	NM	0%	NM	-	NM	NM	6	105	NM	88	1655	NM	NM	0.77	NM
Mill 69	92%	84%	75%	-17%	NM	90%	0%	-90%	NM	0%	64%	64%	NM	10%	36%	26%	yes	64%	21	16	22	446	605	446	NM	0.87	0.92
Mill 82	92%	96%	56%	-36%	NM	100%	0%	-100%	NM	0%	75%	75%	NM	0%	25%	25%	yes	25%	6	30	29	95	382	382	NM	0.71	0.78
Mill 101	90%	94%	83%	-7%	NM	96%	0%	-96%	NM	0%	87%	87%	NM	4%	13%	9%	yes	83%	3	40	50	39	764	955	NM	0.72	0.79
Mill X9	NM	NM	94%	-	NM	NM	70%	-	NM	NM	30%	-	NM	NM	0%	-	yes	10%	NM	NM	47	NM	NM	1273	NM	NM	0.76
Mill X10	NM	NM	89%	-	NM	NM	0%	-	NM	NM	50%	-	NM	NM	50%	-	yes	50%	NM	NM	94	NM	NM	2037	NM	NM	0.82
Average	**69%**	**73%**	**77%**	**8%**	**-**	**84%**	**11%**	**-73%**	**-**	**9%**	**61%**	**52%**	**-**	**7%**	**28%**	**21%**	**yes**	**48%**	**10**	**41**	**41**	**203**	**949**	**899**	**-**	**0.68**	**0.82**
Santa Ana River Sites																											
SAR X1	NM	NM	58%	-	NM	NM	76%	-	NM	NM	5%	-	NM	NM	19%	-	yes	3%	NM	NM	28	NM	NM	1178	NM	NM	0.76
SAR X2	NM	NM	93%	-	NM	NM	11%	-	NM	NM	89%	-	NM	NM	0%	-	yes	17%	NM	NM	51	NM	NM	573	NM	NM	0.63
SAR X11	NM	NM	88%	-	NM	NM	27%	-	NM	NM	64%	-	NM	NM	9%	-	yes	82%	NM	NM	129	NM	NM	1401	NM	NM	0.91
SAR X12	NM	NM	96%	-	NM	NM	9%	-	NM	NM	91%	-	NM	NM	0%	-	yes	91%	NM	NM	45	NM	NM	2801	NM	NM	0.81
SAR X13	NM	NM	87%	-	NM	NM	0%	-	NM	NM	67%	-	NM	NM	33%	-	yes	67%	NM	NM	75	NM	NM	1146	NM	NM	0.69
SAR X14	NM	NM	88%	-	NM	NM	0%	-	NM	NM	100%	-	NM	NM	0%	-	yes	100%	NM	NM	63	NM	NM	1019	NM	NM	0.90
Average	**-**	**-**	**85%**	**-**	**-**	**-**	**21%**		**-**	**-**	**69%**		**-**	**-**	**10%**		**yes**	**60%**	**-**	**-**	**65**	**-**	**-**	**1353**	**-**	**-**	**0.78**
Average all Sites	**75%**	**76%**	**86%**	**11%**	**-**	**91%**	**15%**	**-76%**	**-**	**5%**	**68%**	**63%**	**-**	**4%**	**17%**	**13%**	**yes**	**40%**	**20**	**43**	**55**	**213**	**760**	**965**	**-**	**0.71**	**0.78**

Notes:

NM - Not Measured

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

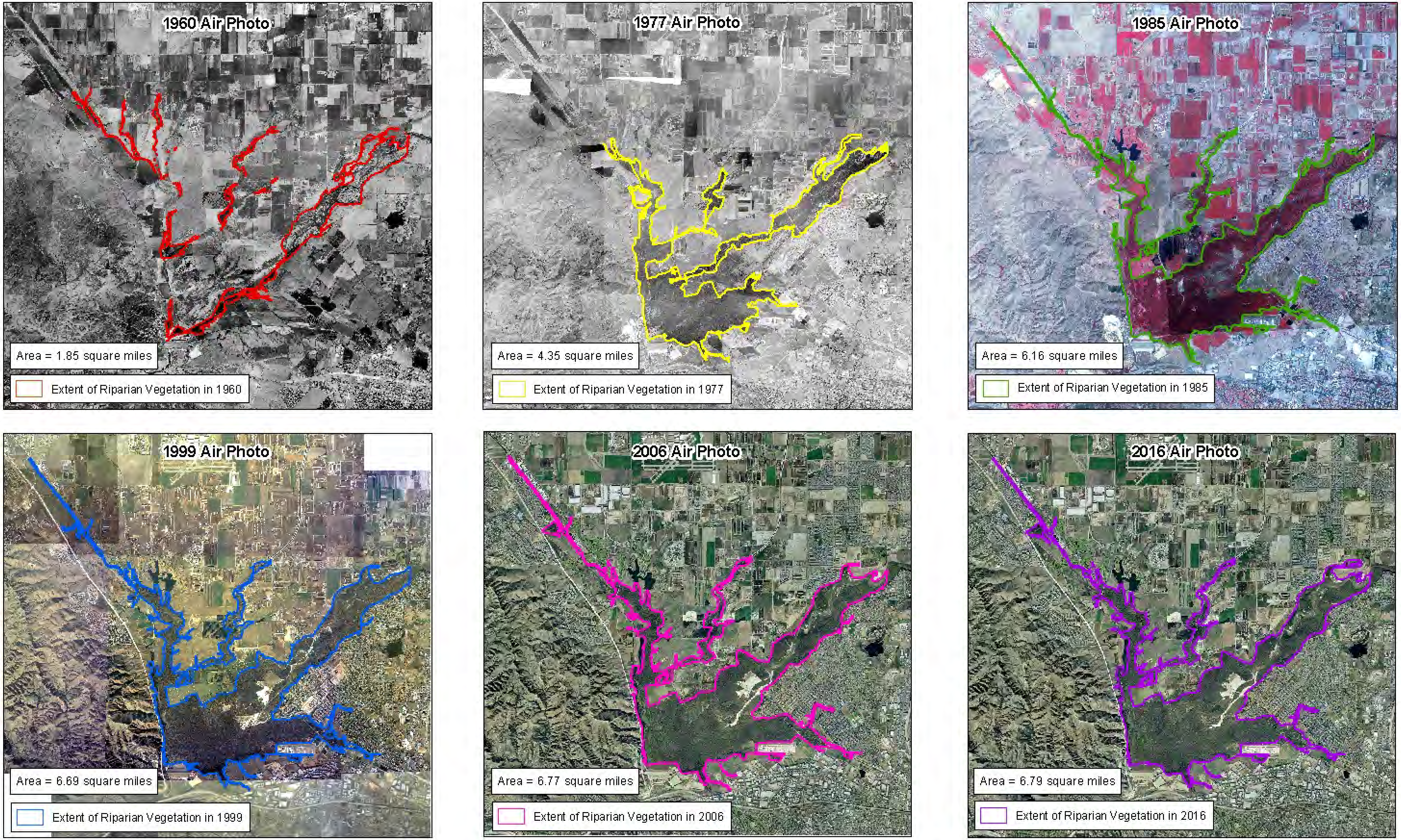
2- Tree condition is a qualitative measurement of the health of the tree. Trees were assessed and classified as "live", "stressed", or "dead". The percentage of each classification per plot is shown here.

3- In 2016 trees were assessed for the presence of polyphagous shot-hole borer. 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.

4- Basal area is a measurement of the amount of land occupied by the cross sectional area of tree stems. It is determined by measuring tree diameter at breast height (DBH). DBH is used to calculate the cross sectional areas of each tree stem in a plot, which are summed and divided by the total plot area.

5-Tree density is calculated by dividing the number of trees counted per plot by the plot area.

6-Crown ratio is the ratio of living crown height to total tree height. Living crown height was determined by subtracting the distance to the canopy bottom from the total height of the tree.



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW
Date: 4/8/2017
File: Figure 3-1_AirPhotos_VegExtent

0 1 2 Miles

0 1 2 3 KM

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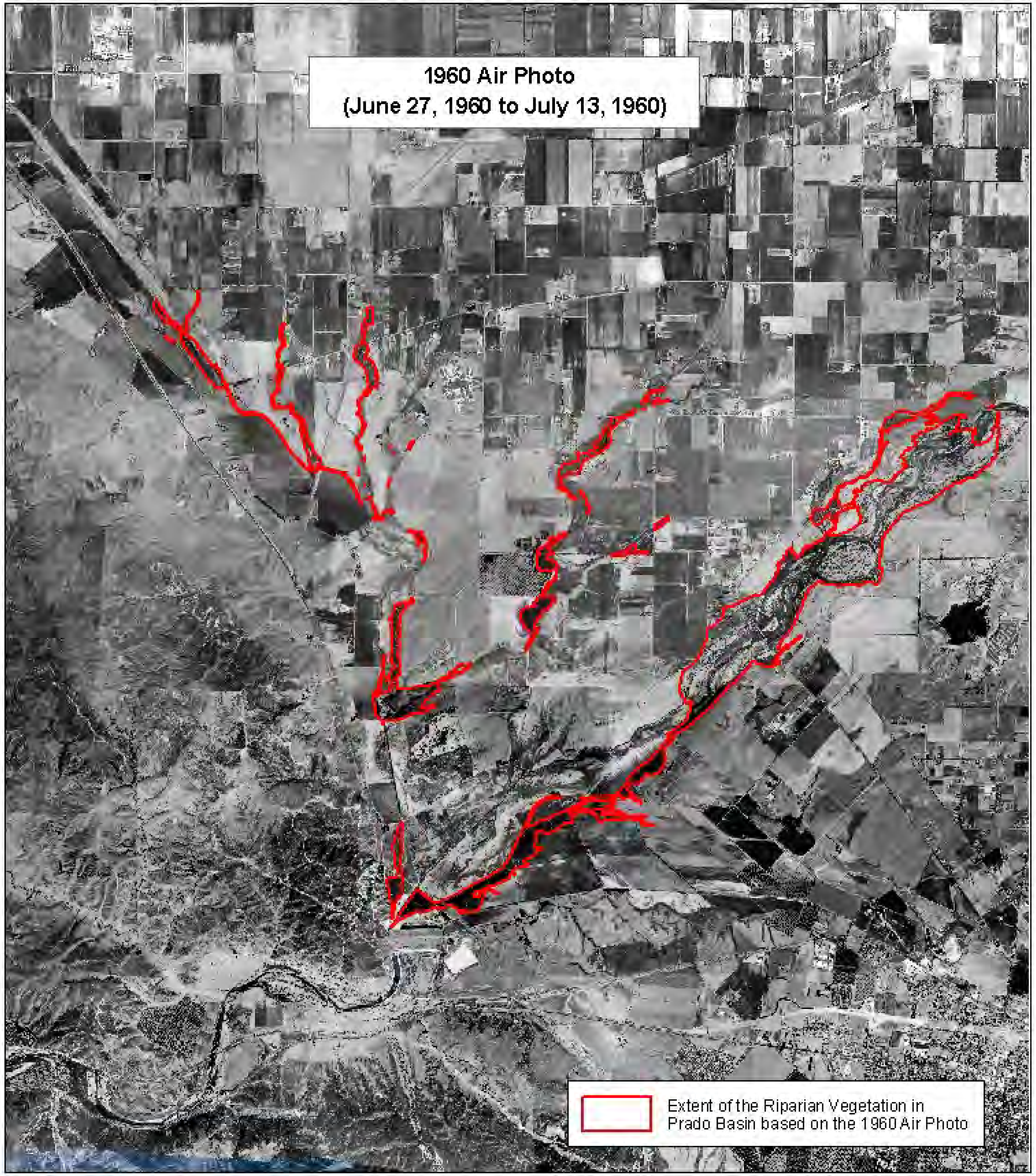
Prado Basin Habitat Sustainability Committee

Historical Air Photos and Extent of Riparian Vegetation

1960 to 2016

Figure 3-1



NDVI Not Available

Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: EM
Date: 4/9/2017
File: Figure 3-2a_1960_Prado_AirP_NDVI

0 1 2 Miles
0 1 2 3 KM

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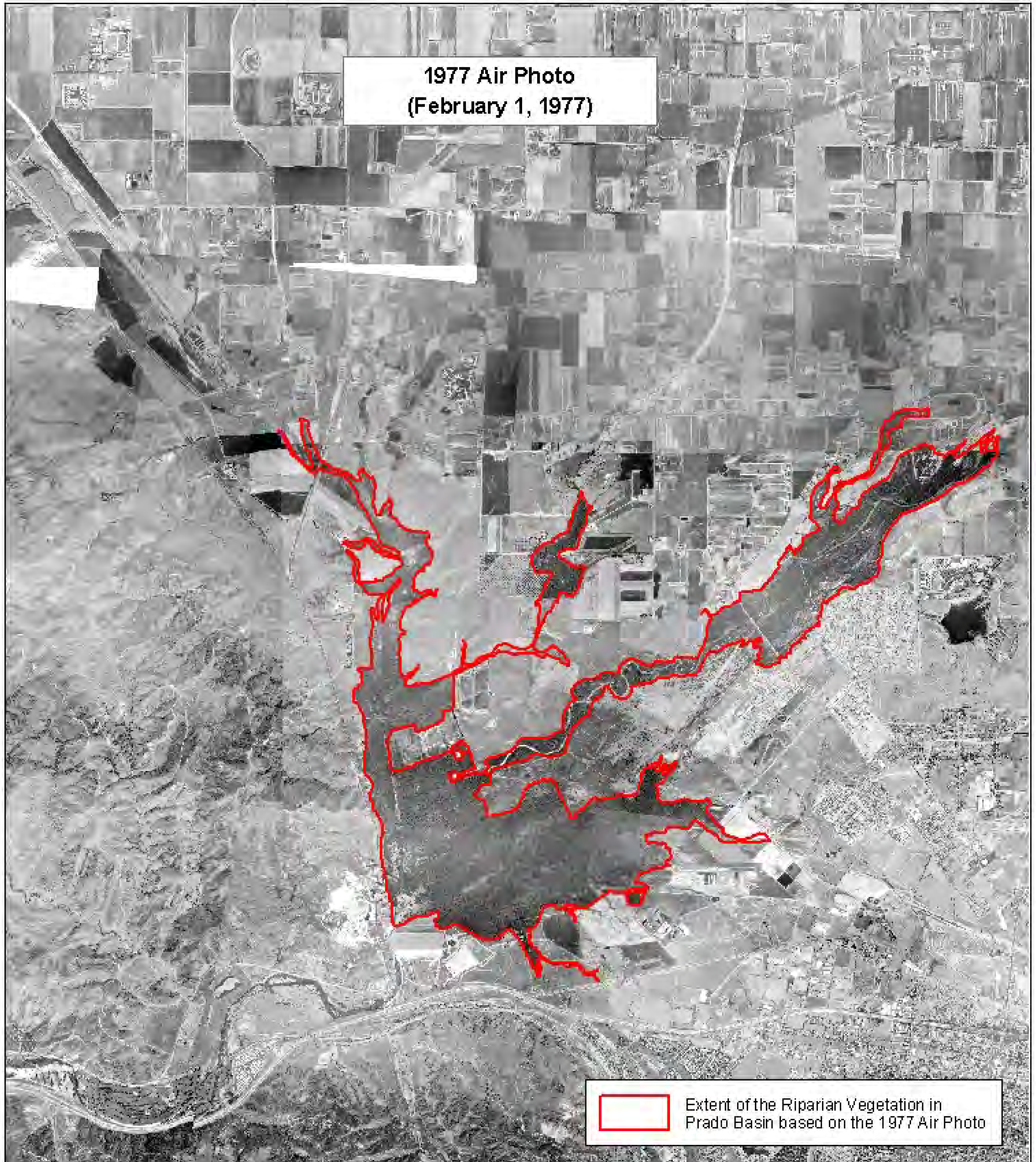
Prado Basin Habitat Sustainability Committee

1960 Air Photo and Spatial NDVI for the Prado Basin Area

Figure 3-2a



NDVI Not Available

Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: EH
Date: 4/8/2017
File: Figure 3-2b_1977_Prado_AirP_NDVI

0 1 2 Miles
0 1 2 3 KM

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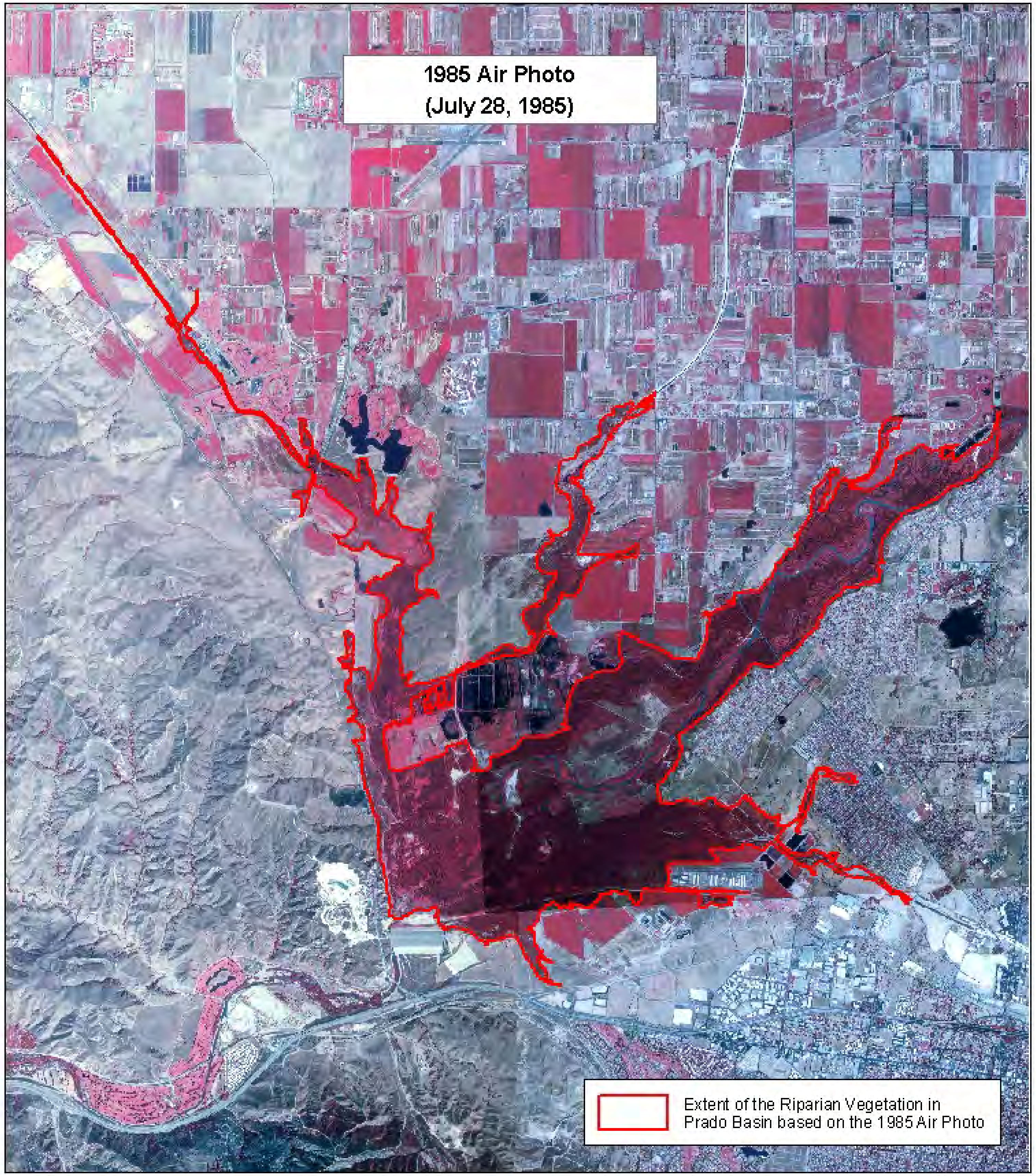
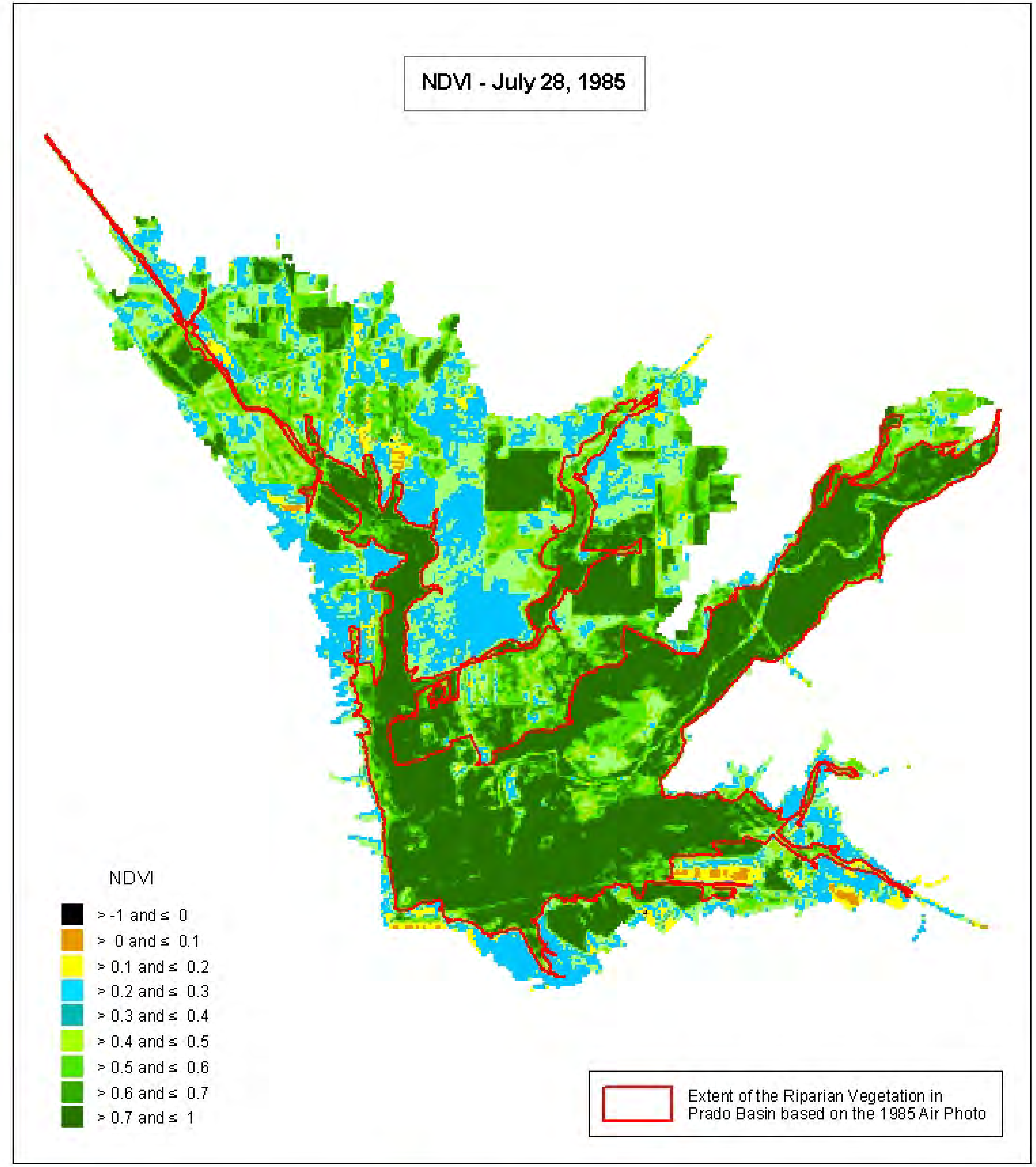
Prado Basin Habitat Sustainability Committee

1977 Air Photo and Spatial NDVI
for the Prado Basin Area

Figure 3-2b





Prepared by:
WEI
Wildermuth Environmental, Inc.

Author: EM
Date: 4/8/2017
File: Figure 3-2c_1985_Prado_AirP_NDVI

0 1 2 Miles
0 1 2 3 KM

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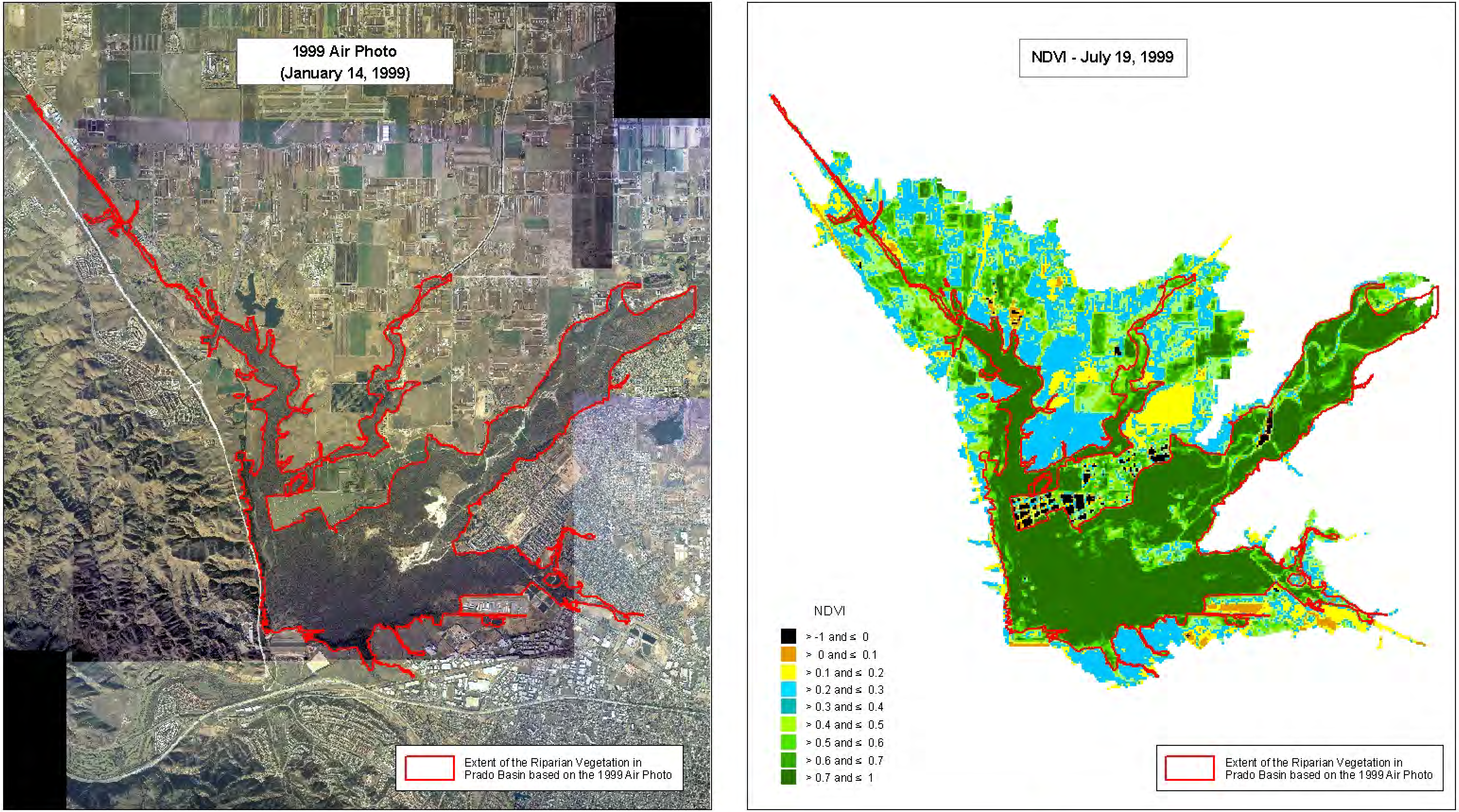
1985 Air Photo and Spatial NDVI for the Prado Basin Area

Figure 3-2c



Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: EM
Date: 4/8/2017
File: Figure 3-2d_1999_Prado_AirP_NDVI

0 1 2 Miles

0 1 2 3 KM

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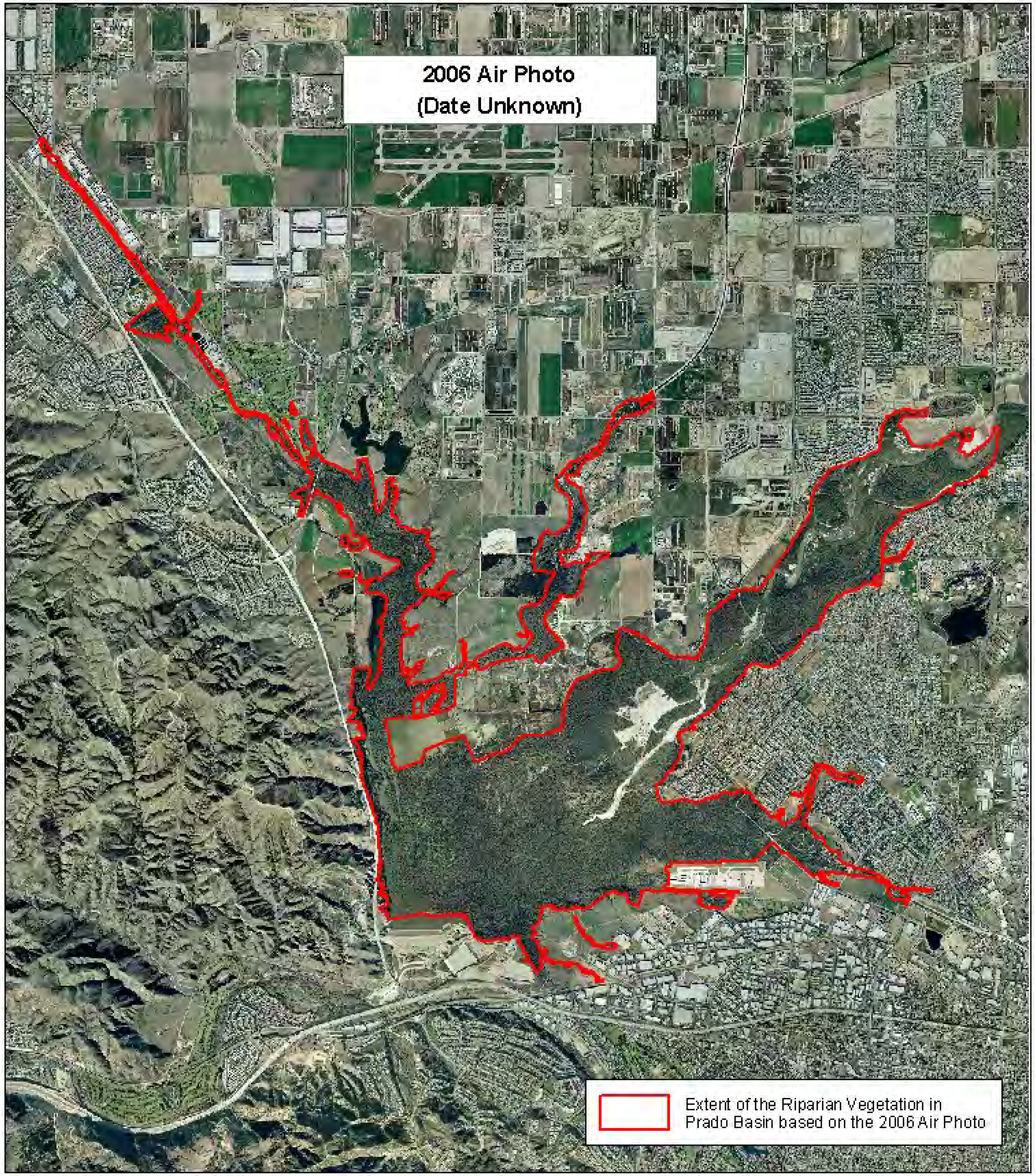
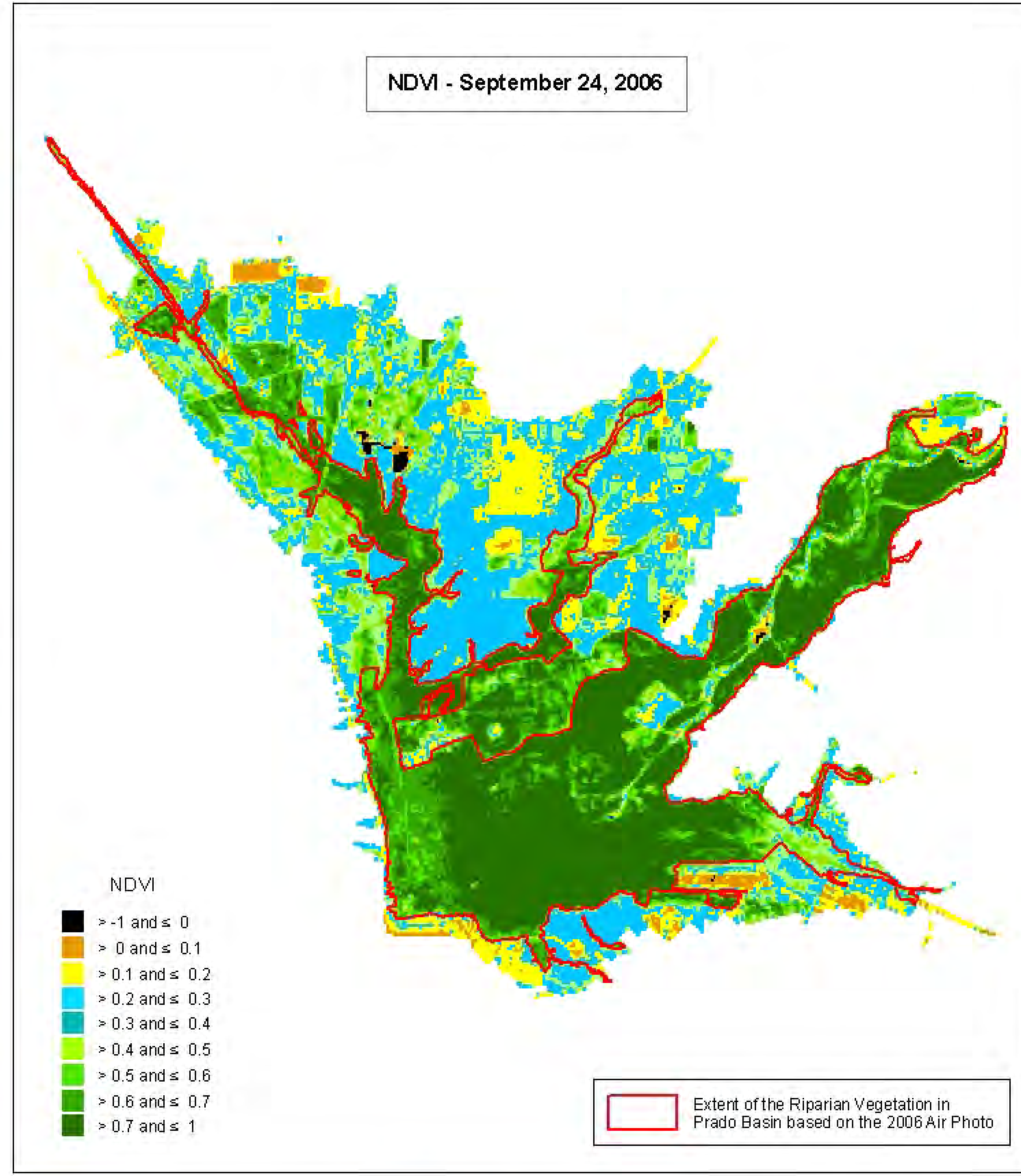
1999 Air Photo and Spatial NDVI for the Prado Basin Area

Figure 3-2d





Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: EM
Date: 4/8/2017
File: Figure 3-2e_2006_Prado_AirP_NDVI

0 1 2 Miles

0 1 2 3 KM

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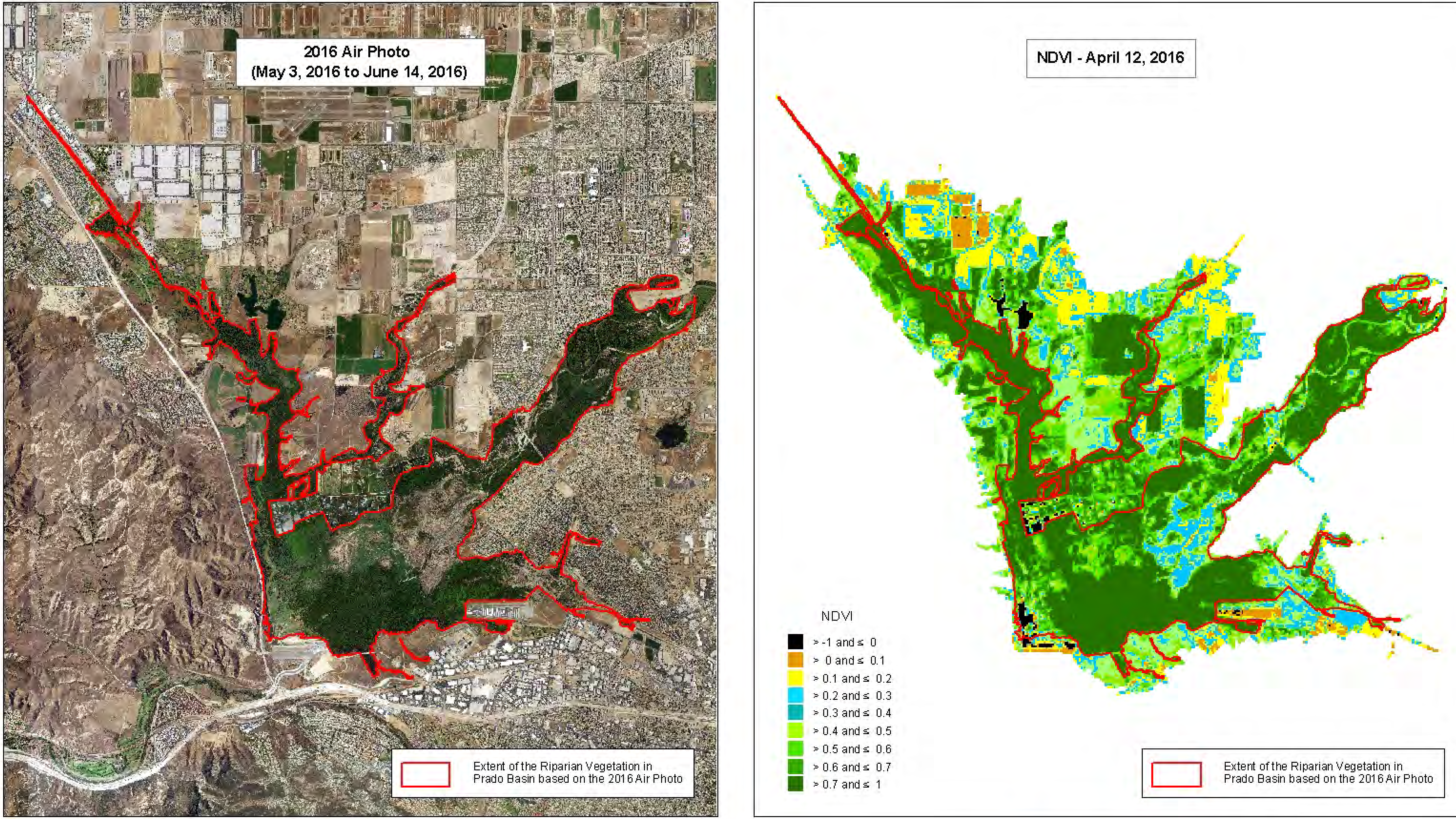
2006 Air Photo and Spatial NDVI for the Prado Basin Area

Figure 3-2e



Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: EM
Date: 4/8/2017
File: Figure 3-2f_2016_Prado_AirP_NDVI

0 1 2 Miles
0 1 2 3 KM

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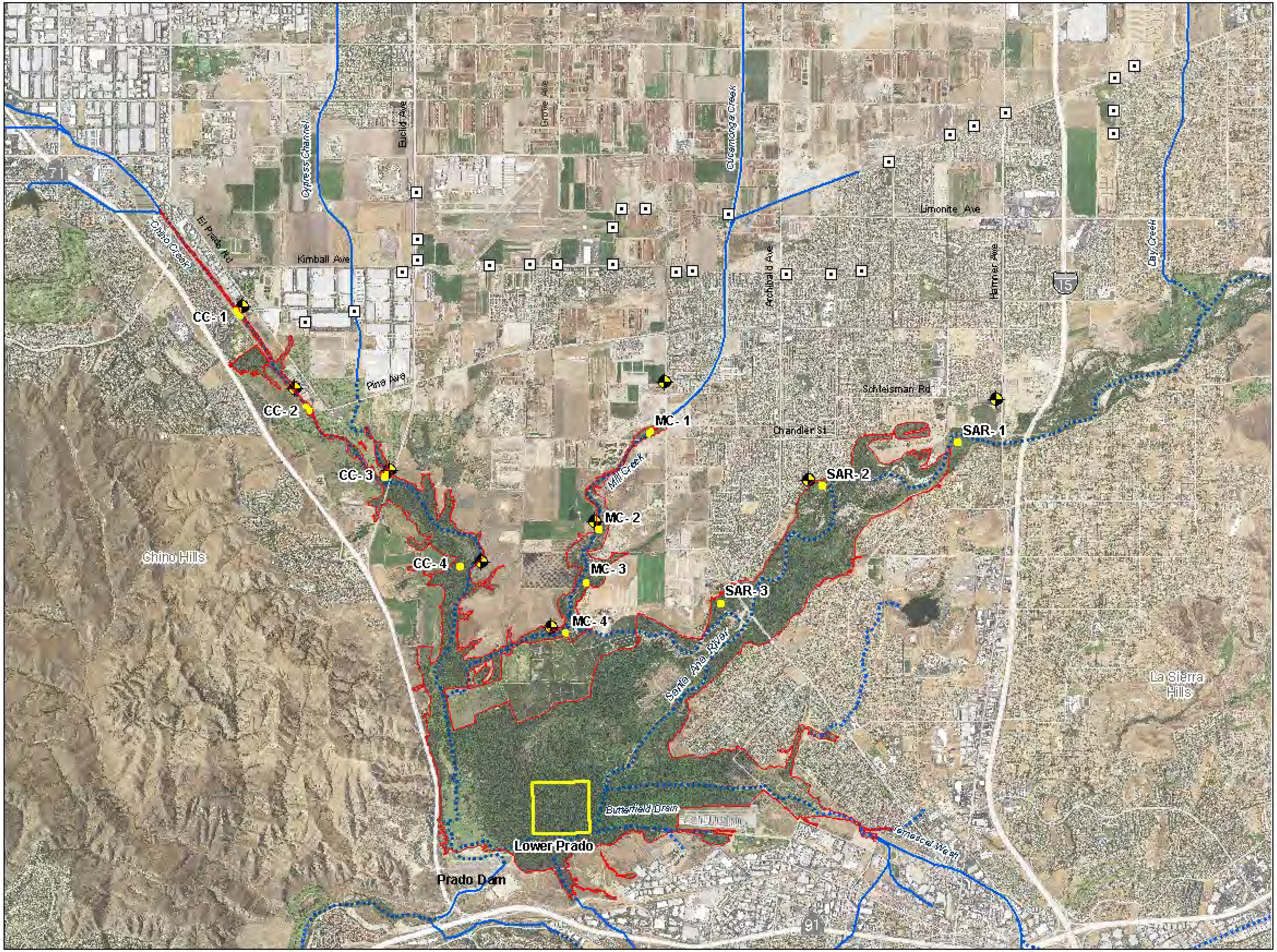
2016 Air Photo and Spatial NDVI for the Prado Basin Area

Figure 3-2f



Defined Areas Analyzed for NDVI Temporally in Time-Series Charts:

2016 Extent of Riparian Vegetation in Prado Basin (Figure 3-4)

20,300 square meters area (677 NDVI pixels) in Lower Prado (Figure 3-5)

120 square-meter area (four NDVI pixels) (Figures 3-6a through 3-6k)

PBHSP Monitoring Well Site

Chino Basin Desalter Well

Concrete-Lined Channels

Unlined Rivers and Streams

Aerial Photo: USDA, 2014. Mosaic of phots from May 13, 2014 to June 3, 2014

Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW
Date: 4/8/2017
File: Figure 3-3 Veg Monitoring_NDVI_Sites

0 1 2 Miles

0 1 2 3 KM

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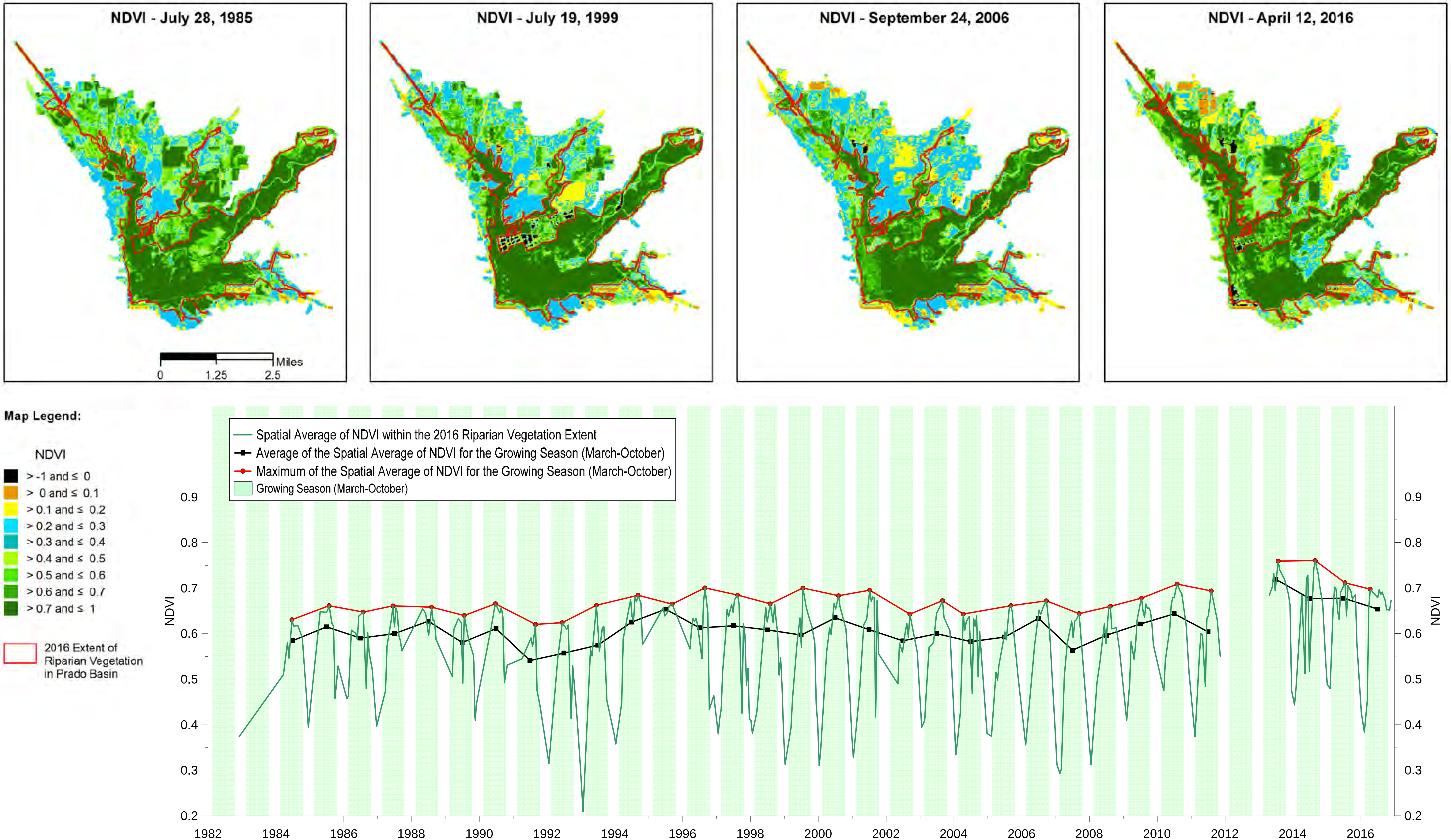
Prado Basin Habitat Sustainability Committee

Areas for Analysis of NDVI Time Series

Figure 3-3



Prepared by:

Author: EM
Date: 20170328
Filename: ndvi_time series_Prado_Spatial_NDVI.grf

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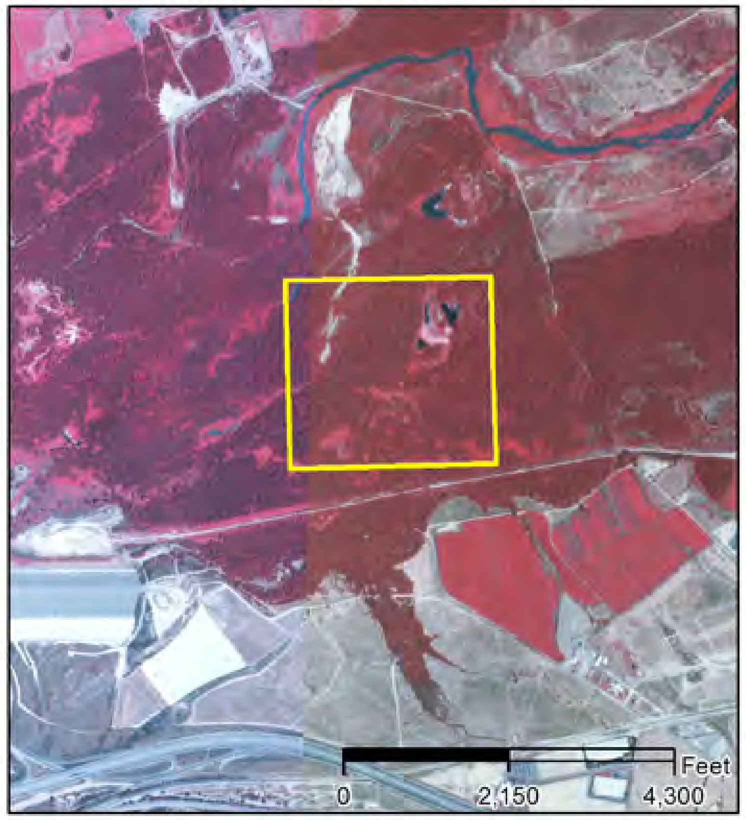
Time Series of NDVI for the 2016 Riparian Vegetaion Extent - ***1984 to 2016***

Figure 3-4

1985 Air Photo (July 28, 1985)



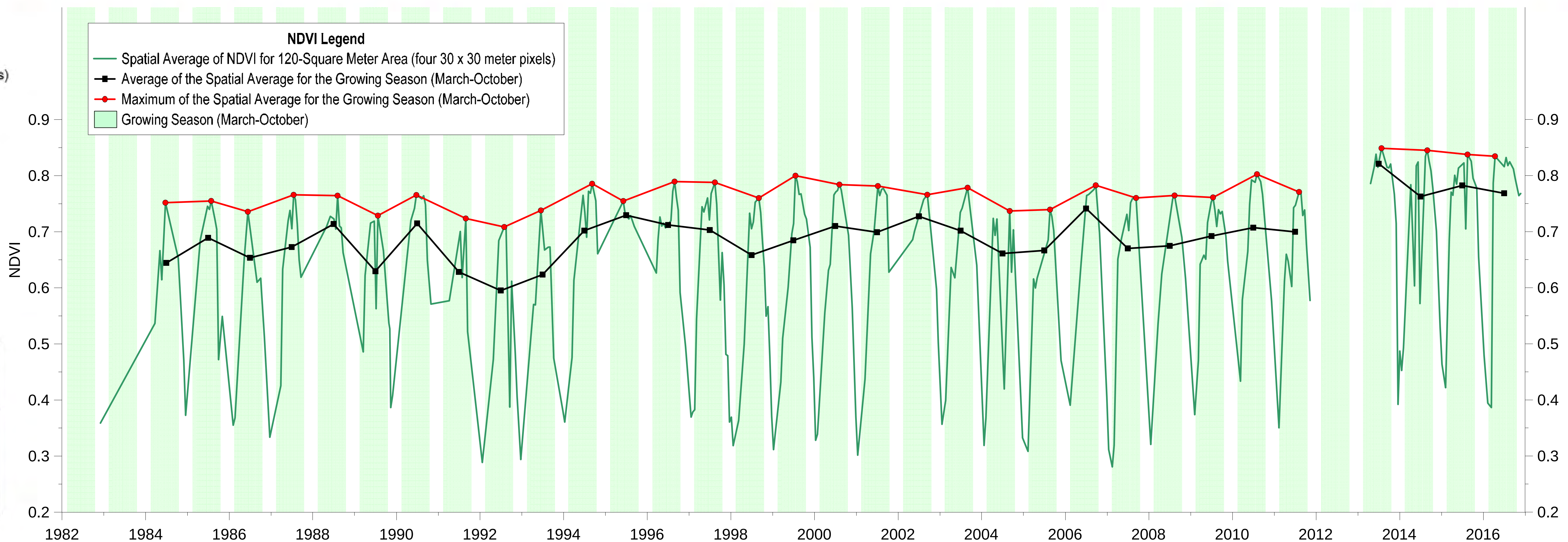
1999 Air Photo (January 14, 1999)

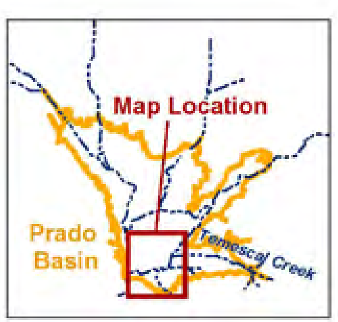
2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend

Location of Area Analyzed for NDVI (677 30 X 30 meter pixels)





Time Series of NDVI and Air Photos
Lower Prado Area for 1984 to 2016

Figure 3-5

1985 Air Photo (July 28, 1985)

1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend

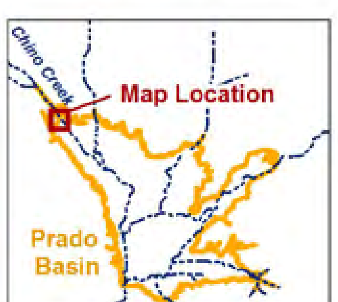
NDVI 30 x 30 Meter Pixel

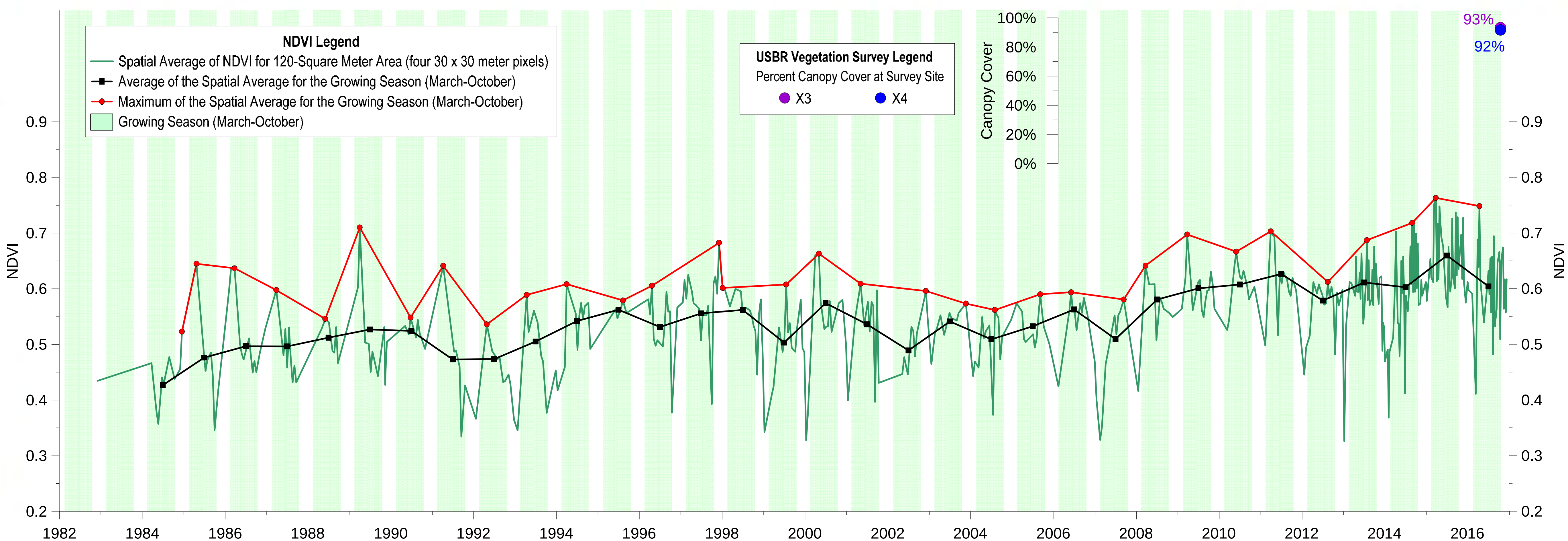
USBR Vegetation Survey Sites

X3

X4

PBHSP Monitoring Well Site





Prepared by:

WEI

WILDERMUTH ENVIRONMENTAL, INC.

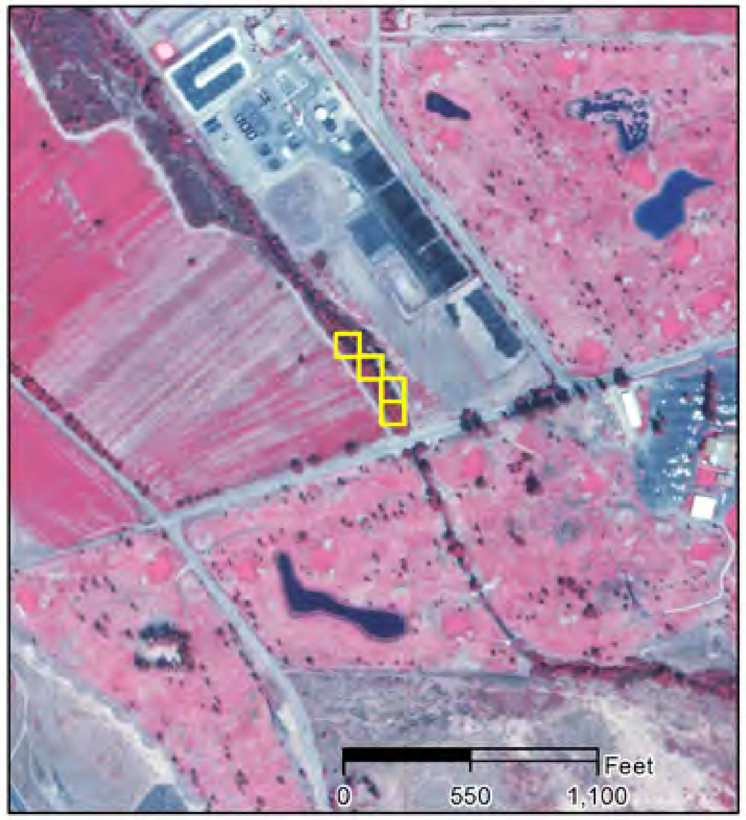
Author: VMW/RT
Date: 20170314
Filename: ndvi_time series_Chino Creek1.grf

2016 Annual Report
Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
CC-1 Area for 1984 to 2016

Figure 3-6a

1985 Air Photo (July 28, 1985)



1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend

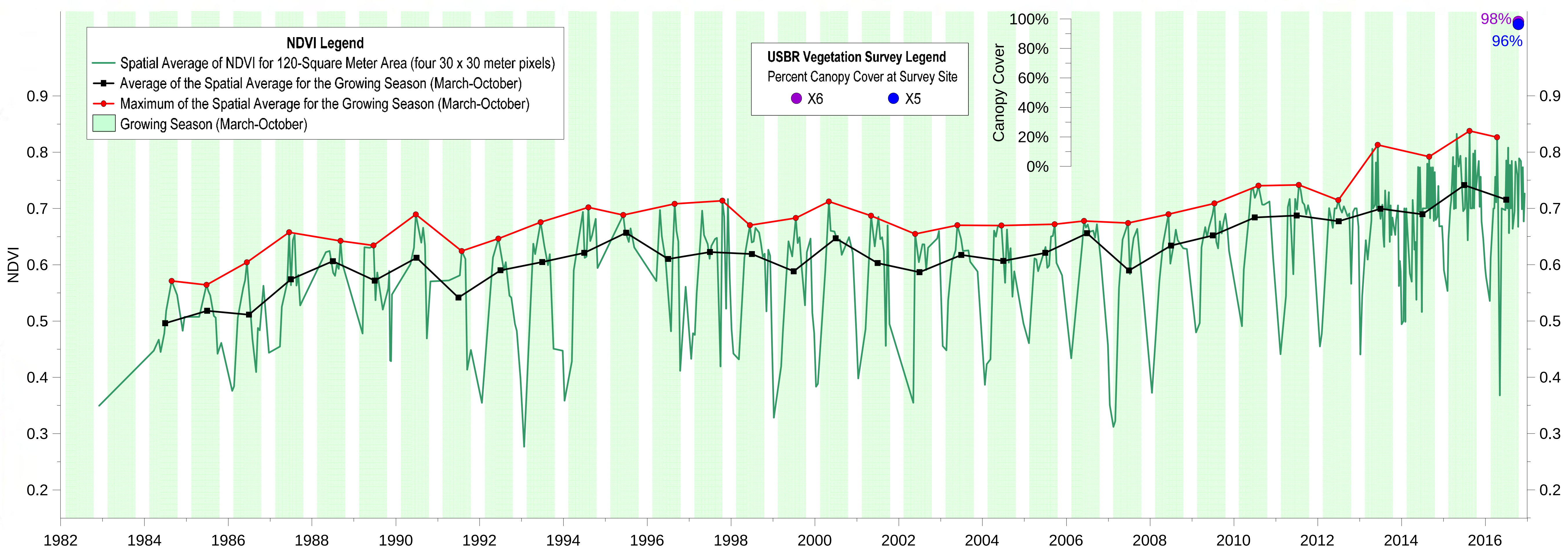
NDVI 30 x 30 Meter Pixel

USBR Vegetation Survey Sites

X6

X5

PBHSP Monitoring Well Site



Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: VMW/RT
Date: 20170314
Filename: ndvi_time series_Chino Creek 2.grf

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Time Series of NDVI and Air Photos
CC-2 Area for 1984 to 2016

Figure 3-6b

1985 Air Photo (July 28, 1985)

1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend:

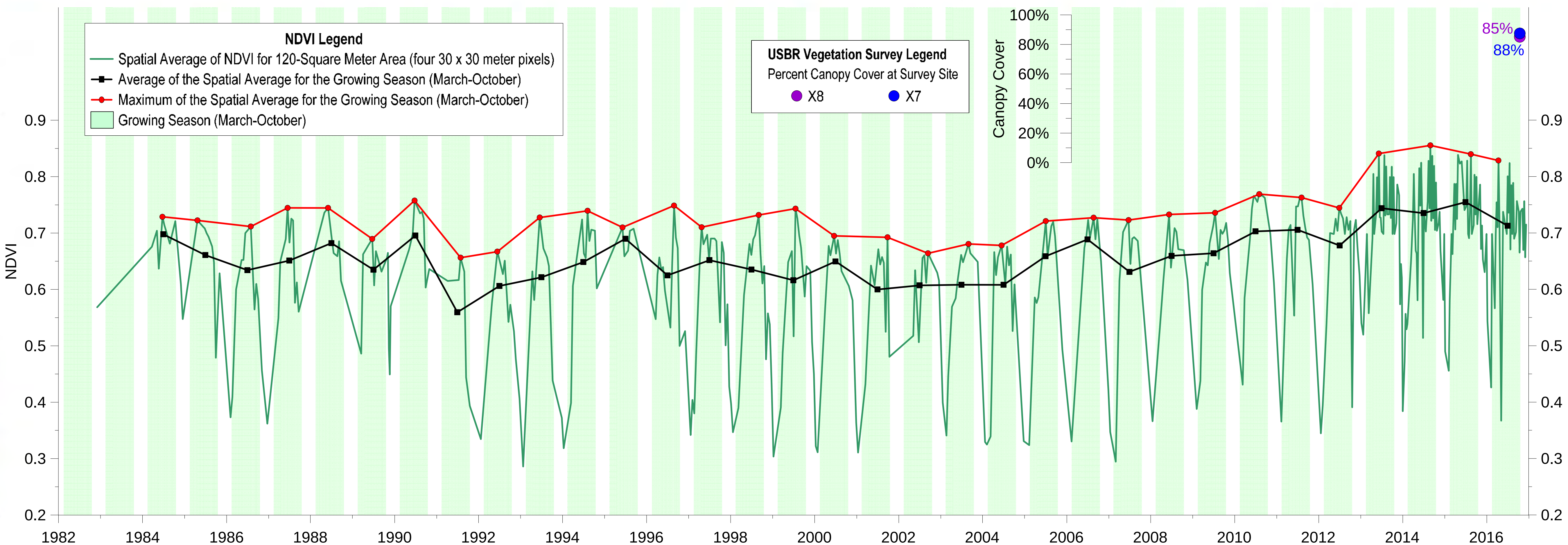
NDVI 30 x 30 Meter Pixel

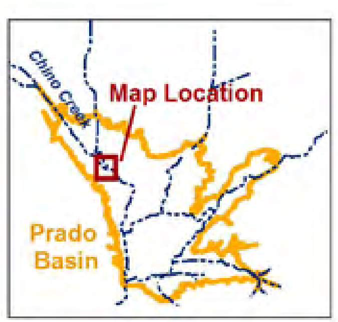
USBR Vegetation Survey Sites

X8

X7

PBHSP Monitoring Well Site





Prepared by:

WEI Wildermuth Environmental, Inc.

Author: VMW/RT
Date: 20170314
Filename: ndvi_time series_Chino Creek 3.grf

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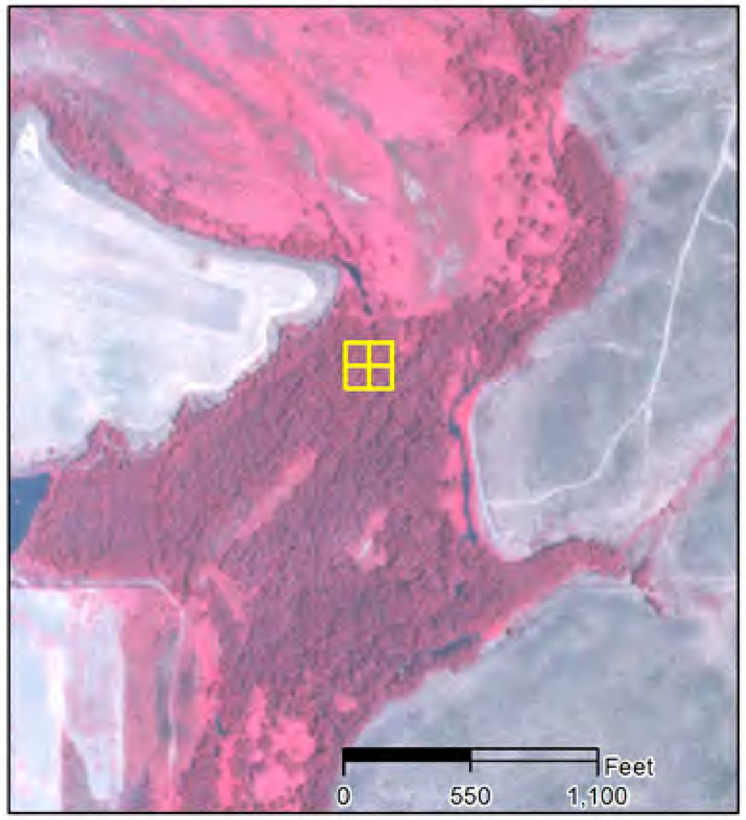
Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
CC-3 Area for 1984 to 2016

Figure 3-6c

1985 Air Photo (July 28, 1985)



1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

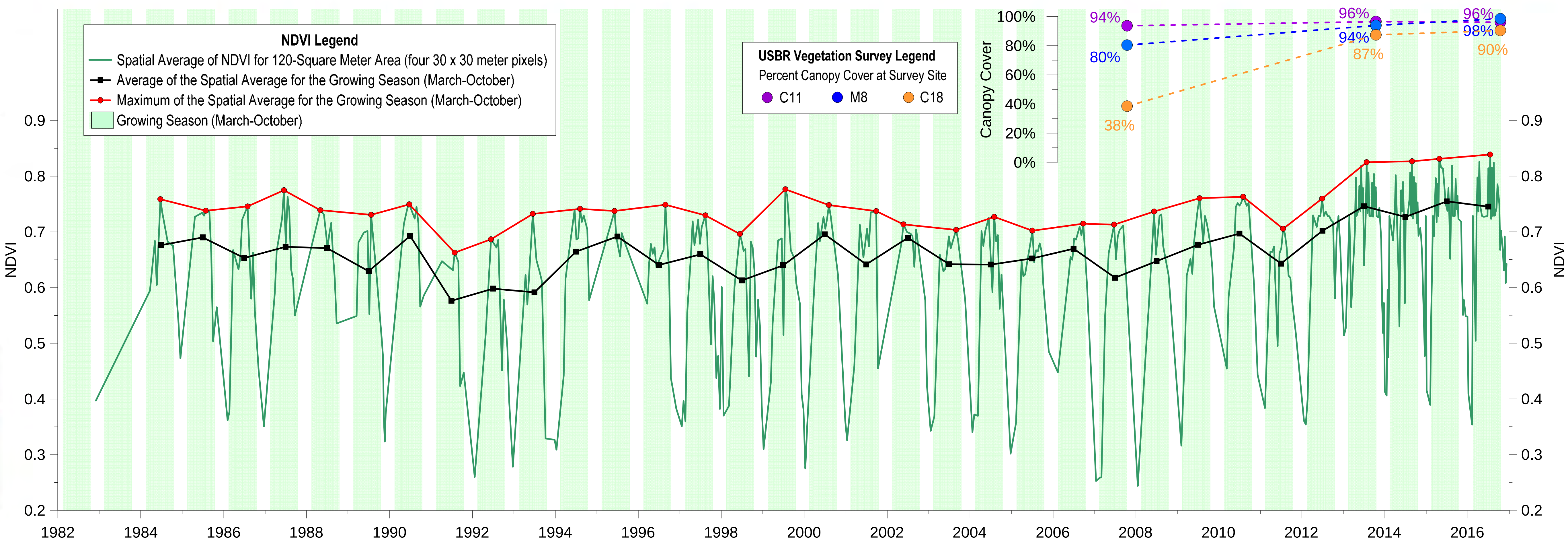
Map Legend

NDVI 30 x 30 Meter Pixel

USBR Vegetation Survey Sites

- C18
- C11
- C4

PBHSP Monitoring Well Site



Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: VMW/RT
Date: 20170314
Filename: ndvi_time series_Chino Creek 4.grf

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Time Series of NDVI and Air Photos
CC-4 Area for 1984 to 2016

Figure 3-6d

1985 Air Photo (July 28, 1985)

1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend:

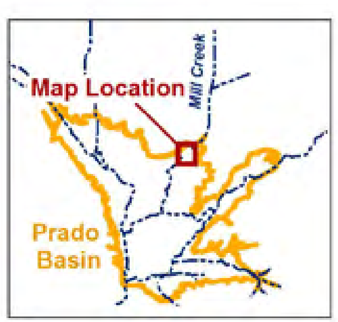
NDVI 30 x 30 Meter Pixel

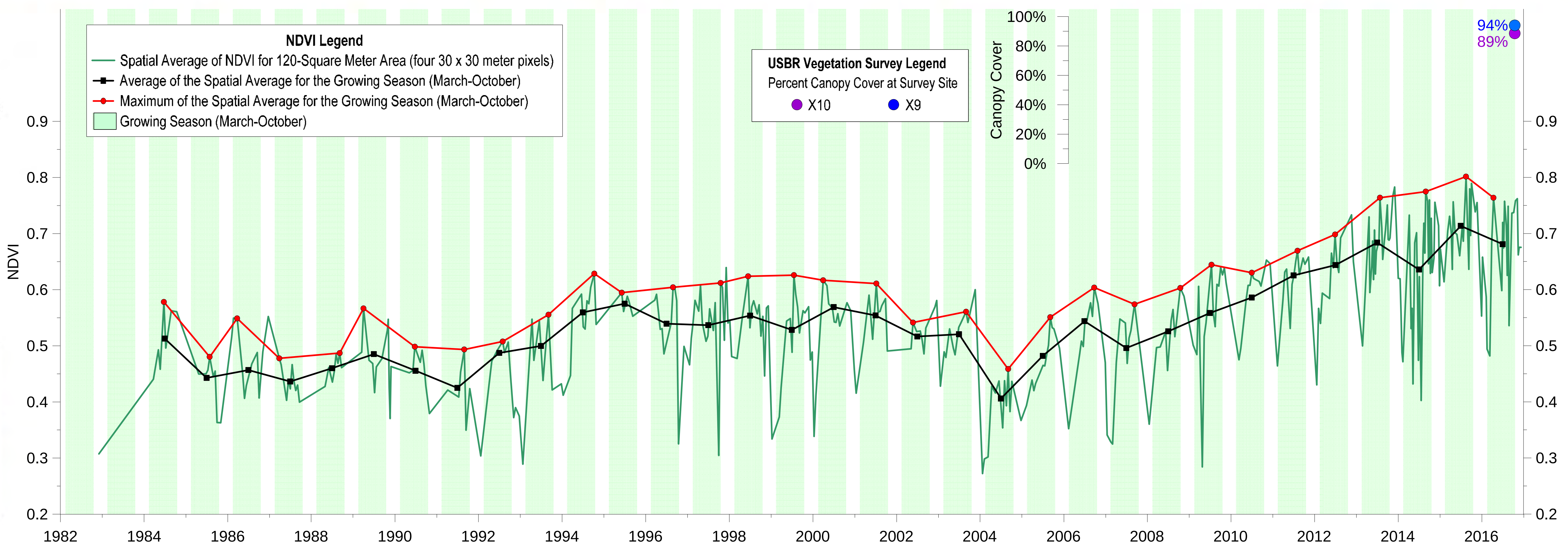
USBR Vegetation Survey Sites

X10

X9

PBHSP Monitoring Well Site





Prepared by:

WEI
Wildermuth Environmental, Inc.

Author: VMW/RT
Date: 20170414
Filename: ndvi_time series_Mill Creek 1.grf

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Time Series of NDVI and Air Photos
MC-1 Area for 1984-2016

Figure 3-6e

1985 Air Photo (July 28, 1985)

1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend:

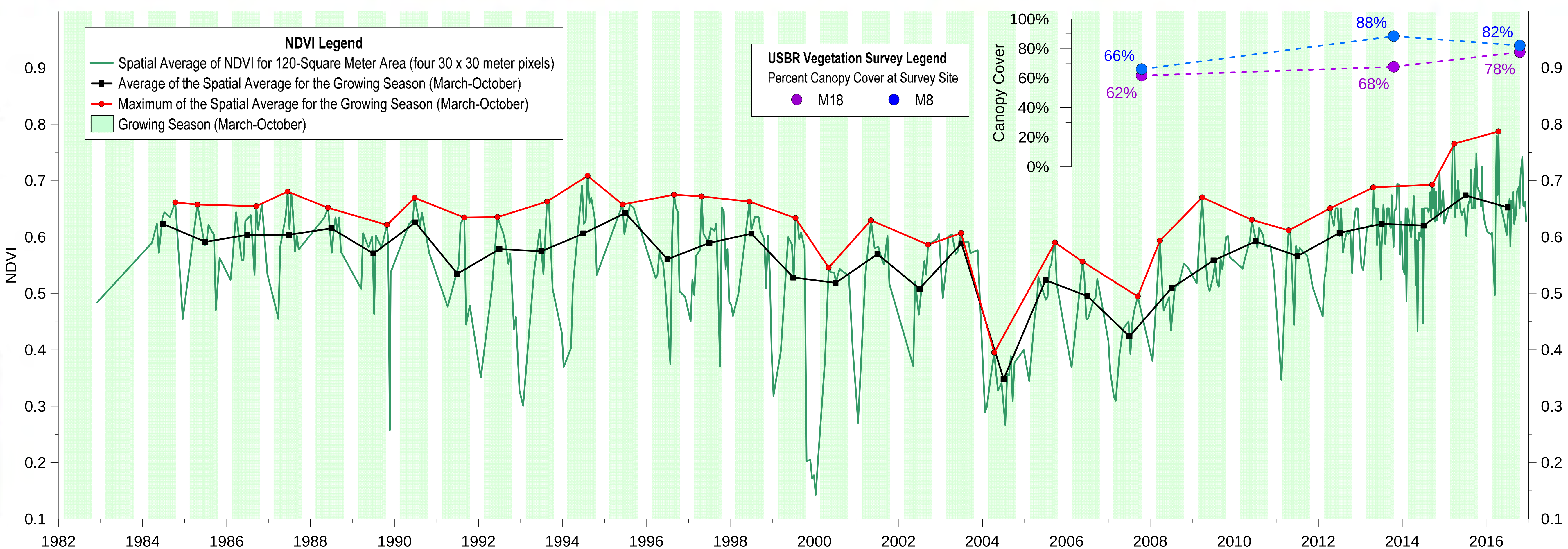
NDVI 30 x 30 Meter Pixel

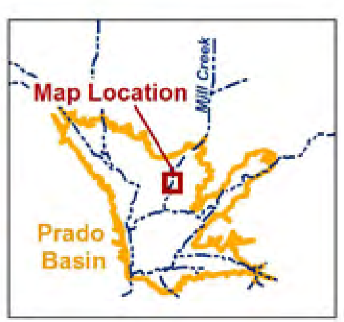
USBR Vegetation Survey Sites

M18

M8

PBHSP Monitoring Well Site





Prepared by:

Author: VMW/RT
Date: 20170314
Filename: ndvi_time series_Mill Creek 2.grf

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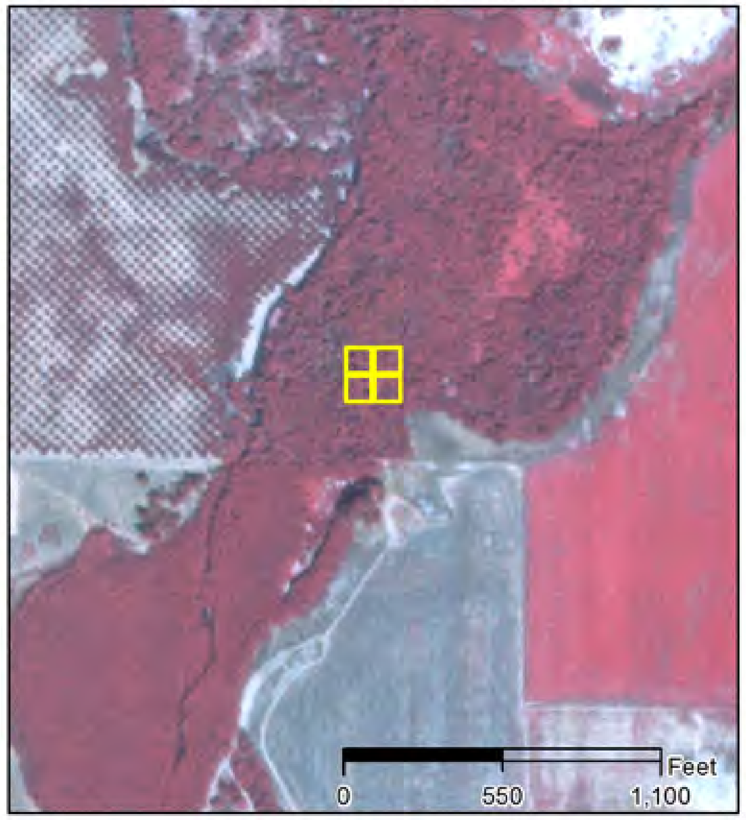
Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
MC-2 Area for 1984 to 2016

Figure 3-6f

1985 Air Photo (July 28, 1985)



1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend:

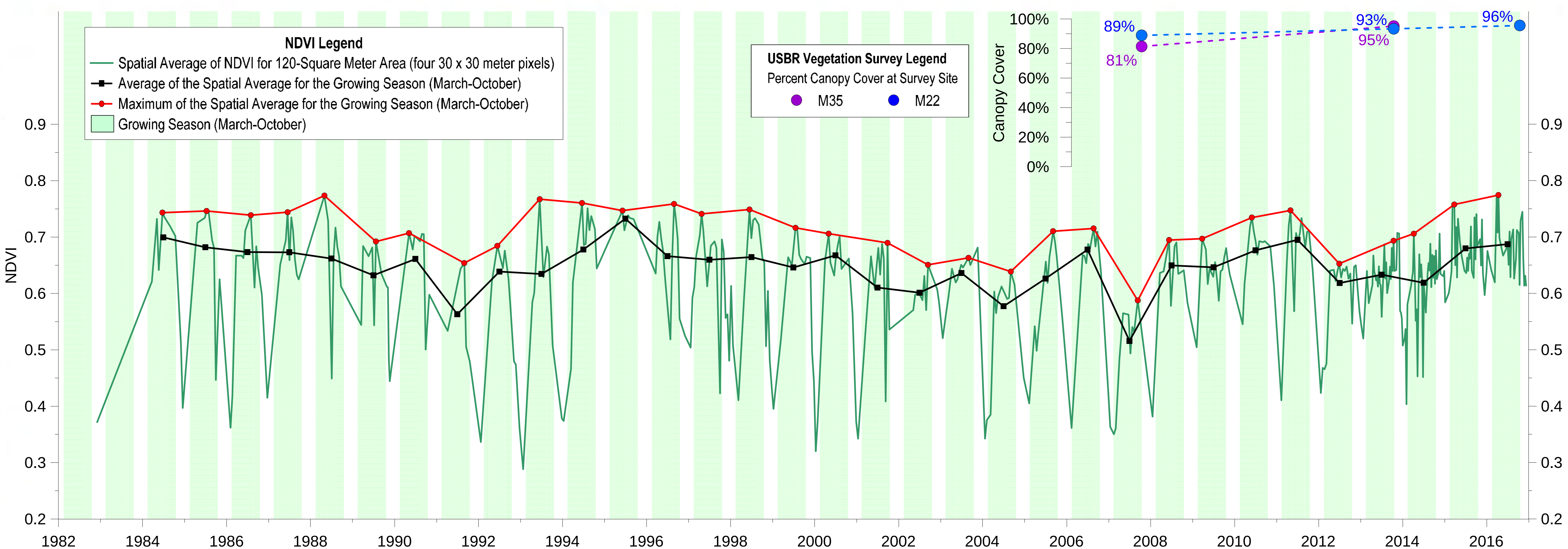
NDVI 30 x 30 Meter Pixel

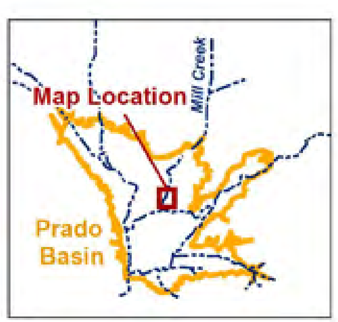
USBR Vegetation Survey Sites

M35

M22

PBHSP Monitoring Well Site





Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW/RT
Date: 20170314
Filename: ndvi_time series_Mill Creek 3.grf

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Time Series of NDVI and Air Photos
MC-3 Area for 1984 to 2016

Figure 3-6g

1985 Air Photo (July 28, 1985)

1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)

Map Legend:

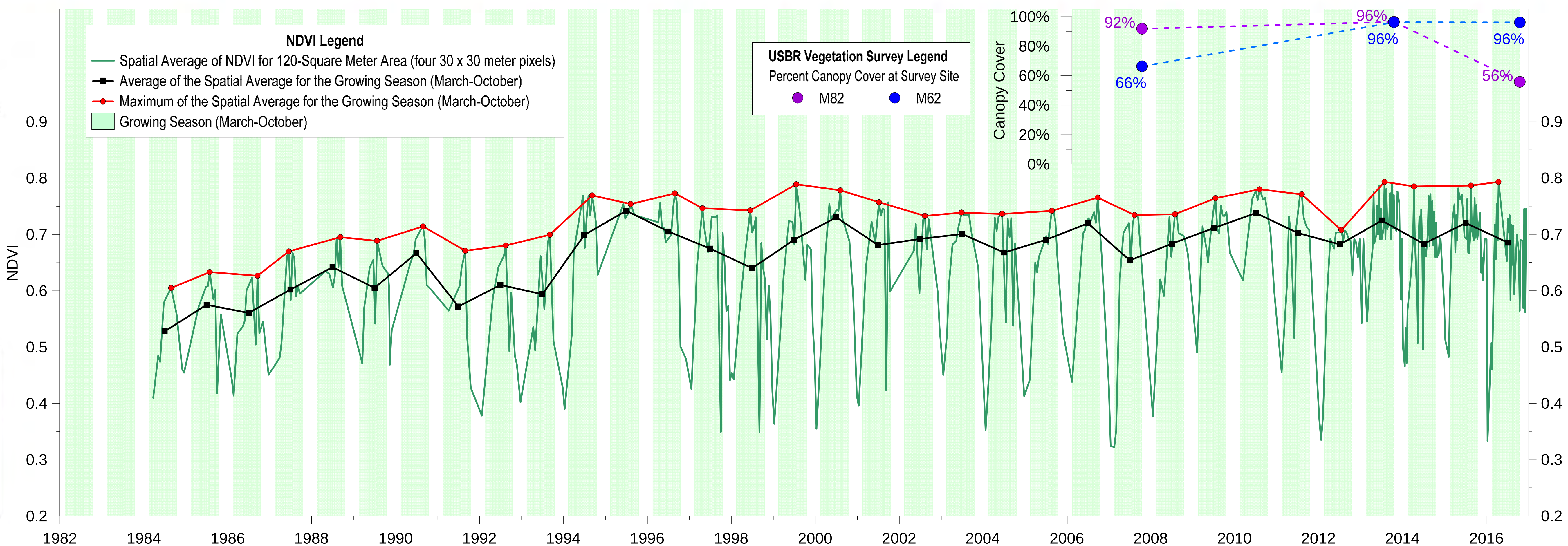
NDVI 30 x 30 Meter Pixel

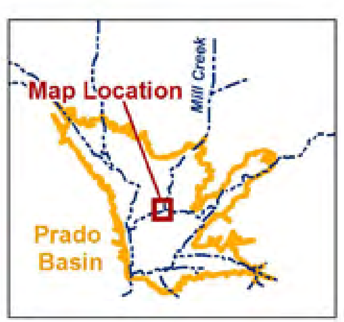
USBR Vegetation Survey Sites

M82

M62

PBHSP Monitoring Well Site





Prepared by:

Author: VMW/RT
Date: 20170414
Filename: ndvi_time series_Mill Creek 4.grf

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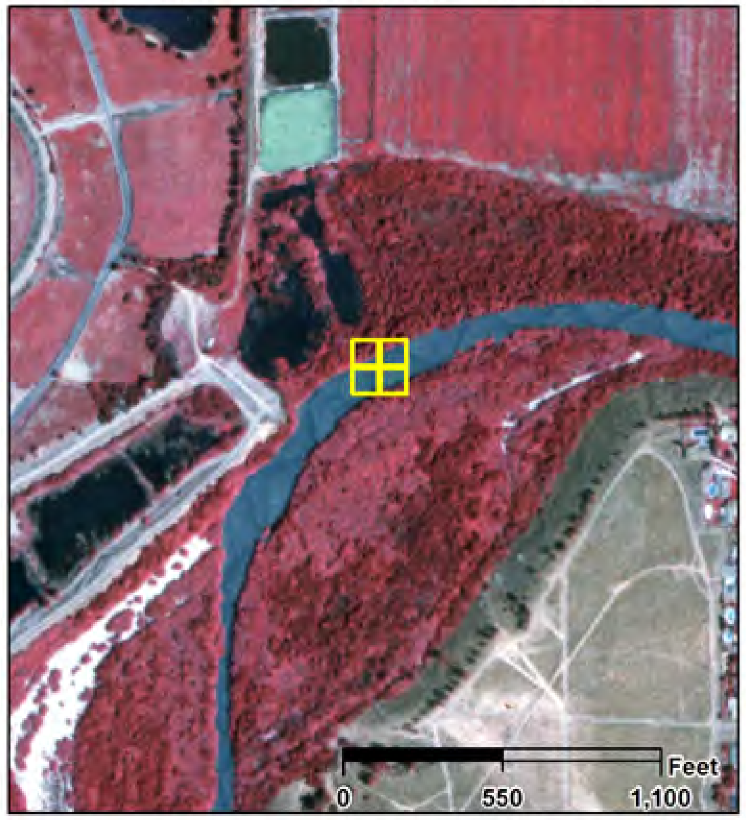
Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
MC-4 Area for 1984 to 2016

Figure 3-6h

1985 Air Photo (July 28, 1985)



1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

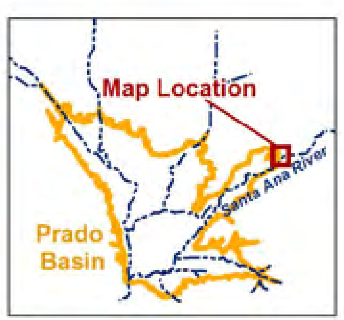
2016 Air Photo (May 3, 2016 to June 14, 2016)

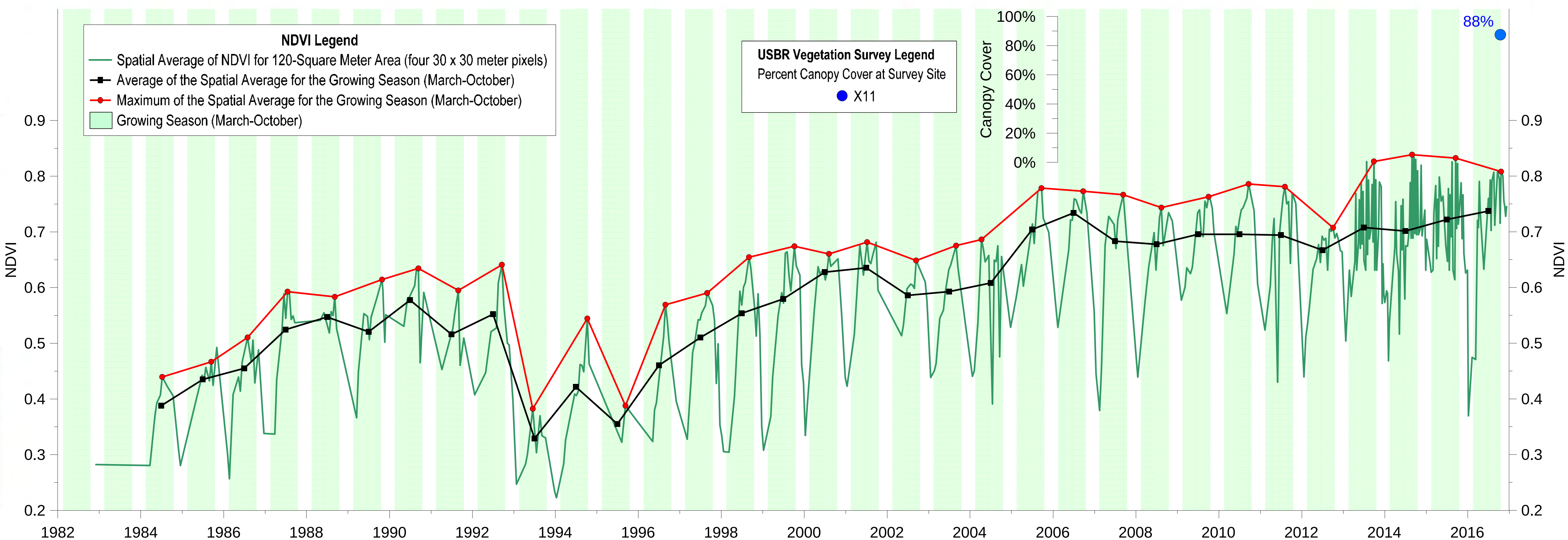
Map Legend

NDVI 30 x 30 Meter Pixel

USBR Vegetation Survey Sites

X11





Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW/RT
Date: 20170414
Filename: ndvi_time series_SAR 1.grf

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Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
SAR-1 Area for 1984 to 2016

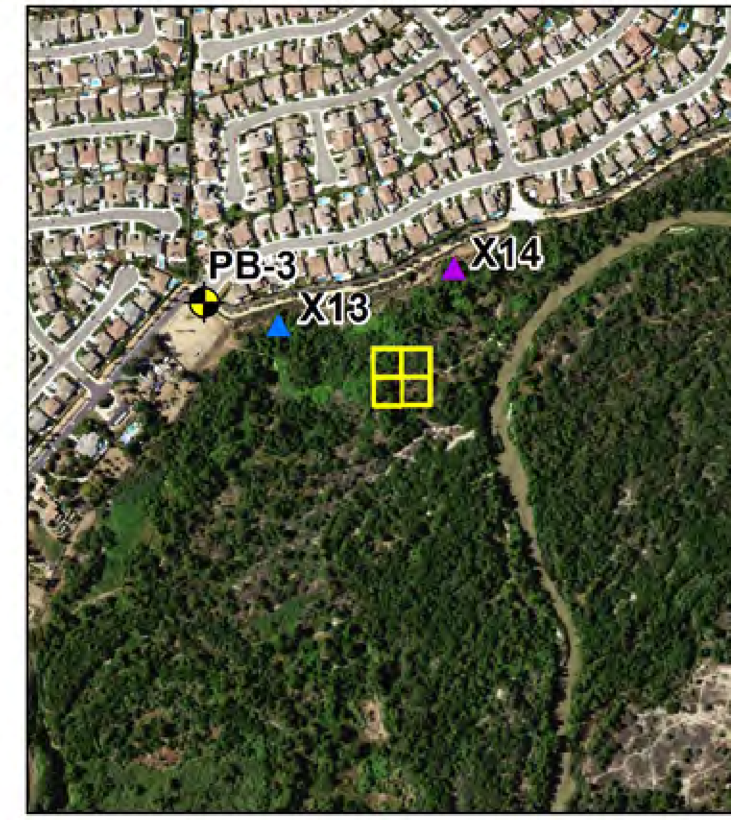
Figure 3-6i

1985 Air Photo (July 28, 1985)

1999 Air Photo (January 14, 1999)

2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)



Map Legend

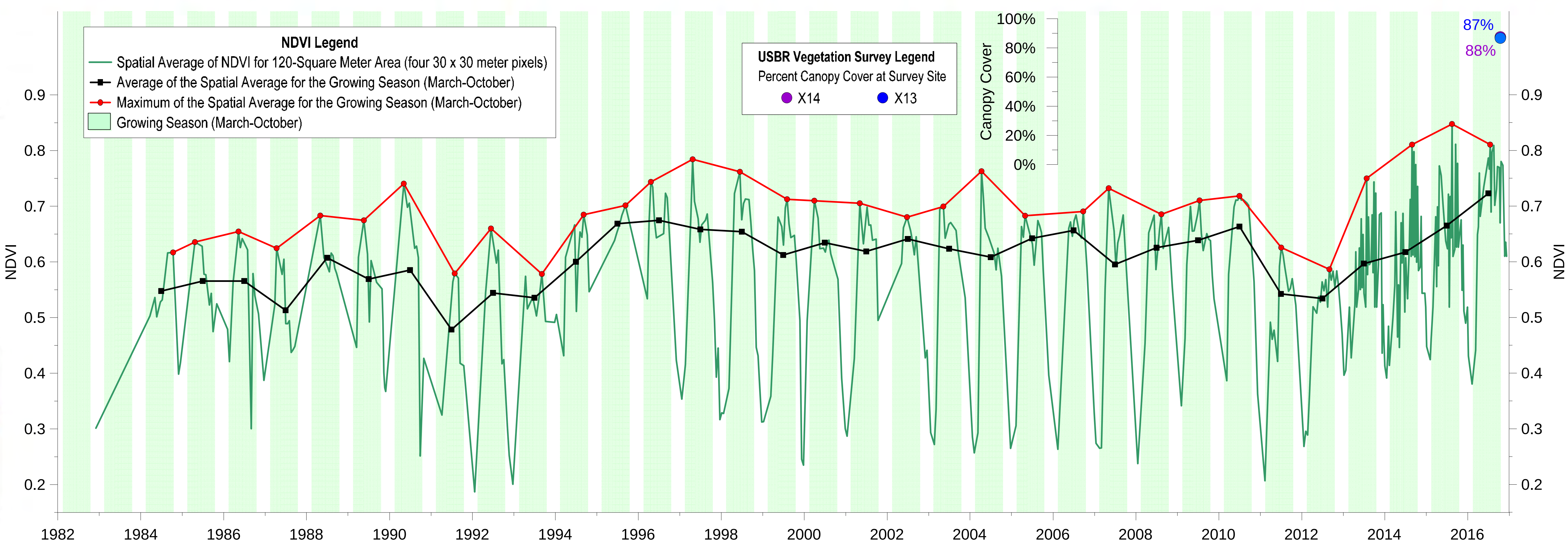
NDVI 30 x 30 Meter Pixel

USBR Vegetation Survey Sites

X14

X13

PBHSP Monitoring Well Site



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW/RT
Date: 20170414
Filename: ndvi_time series_SAR 2.grf

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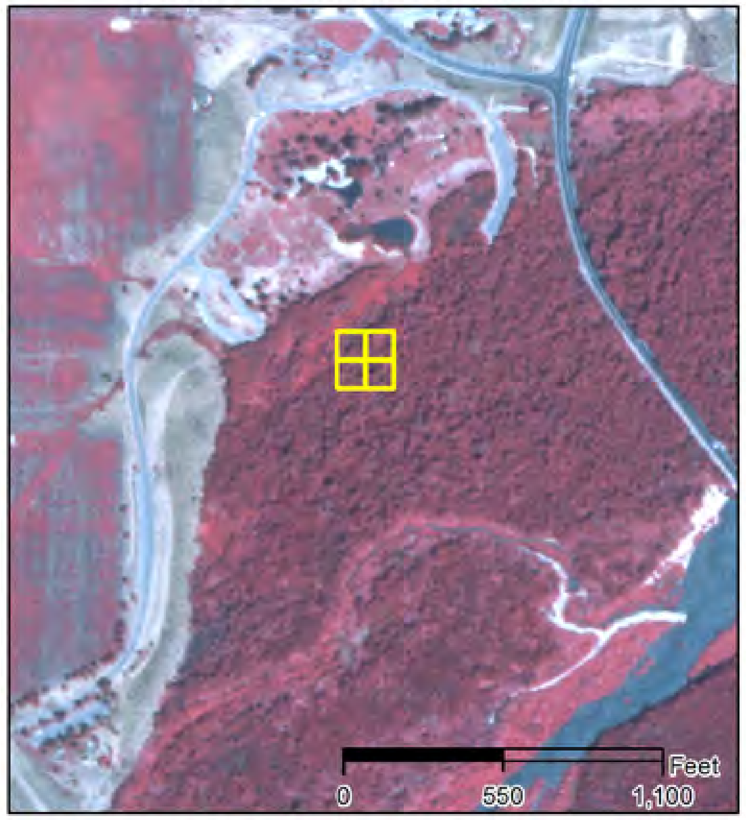
Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
SAR-2 Area for 1984-2016

Figure 3-6j

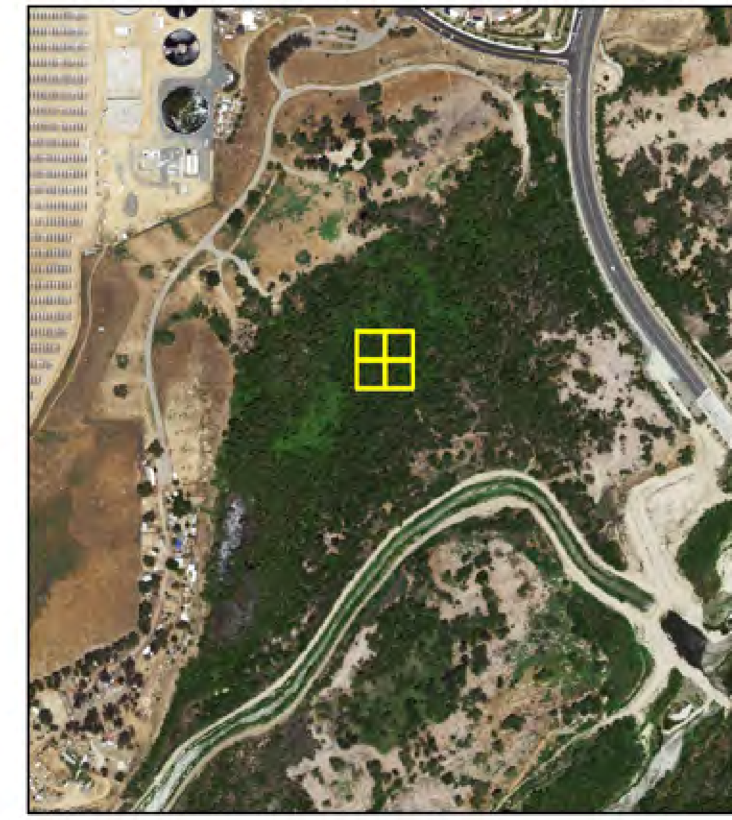
1985 Air Photo (July 28, 1985)



1999 Air Photo (January 14, 1999)

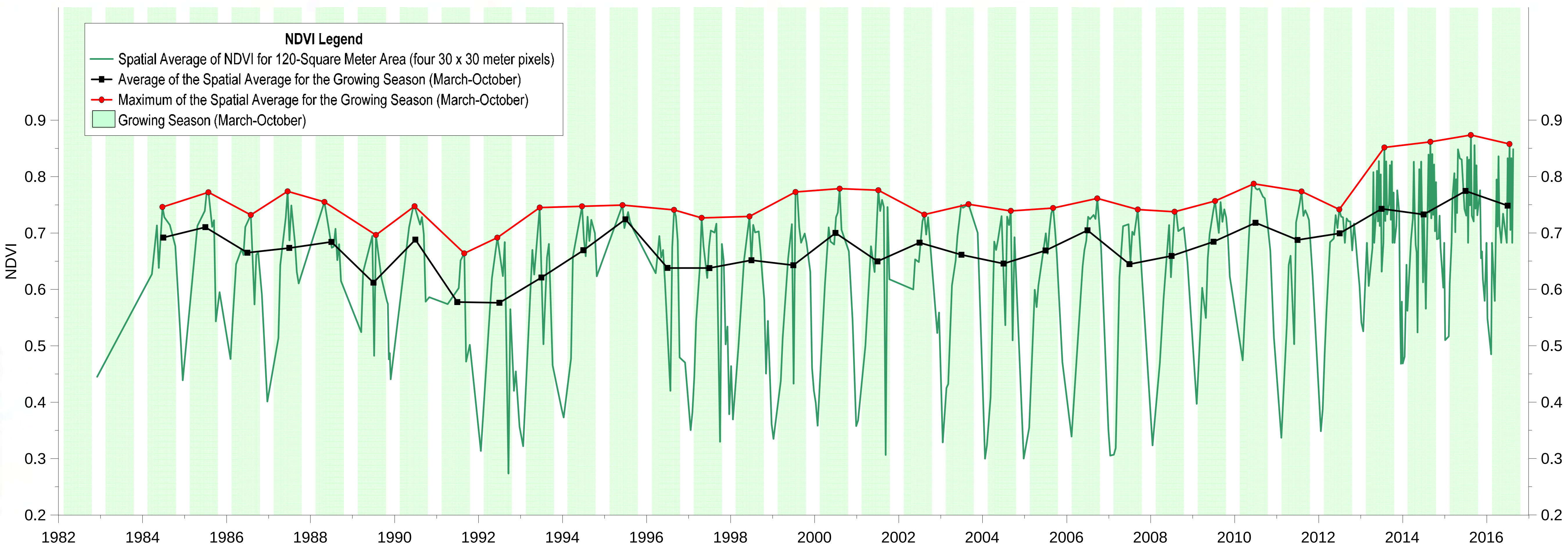
2006 Air Photo (Date Unknown)

2016 Air Photo (May 3, 2016 to June 14, 2016)



Map Legend

NDVI 30 x 30 Meter Pixel



Prepared by:

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: VMW/RT
Date: 20170414
Filename: ndvi_time series_SAR 3.grf

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Prado Basin Habitat Sustainability Committee

Time Series of NDVI and Air Photos
SAR-3 Area for 1984 to 2016

Figure 3-6k

Section 3.2 and subsequent sections are pending completion

Achard F., and Estreguil, C. 1995. *Forest classification of Southeast Asia using NOAA AVHRR data.* Remote Sensing of the Environment v. 56, pg. 198-208.

California Regional Water Quality Control Board, Santa Ana Region. (2008). Water Quality Control Plan Santa Ana River Basin (Region 8) 1995. Updated February 2008.

Campbell, 2007. *Introduction to remote sensing.* Fourth edition. Published 2007 Guilford Press.

Chino Basin Watermaster (CBWM). 2000. Peace Agreement, Chino Basin. SB 240104 v 1:08350.0001. 29 June 2000.

Chino Basin Watermaster (CBWM). 2007. *Peace II Agreement: Party Support for Watermaster's OBMP Implementation Plan, - Settlement and Release of Claims Regarding Future Desalters. SB 447966 v 1:008250.0001.* 25 October 2007.

Chino Basin Municipal Water District v. City of Chino et al., San Bernardino Superior Court, No. 164327. (1978).

Chen, J., Jonsson, P., Tamura, M, Gu, Z., Matsushita, B., and Eklundh, L. (2004) *A Simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky-Golay filter.* Remote Sensing of Environment v. 91, pg. 332-344.

Gandhi, M., Parthiban, S., Thummalu, N., and A., C. 2015. *Ndvi: Vegetation changes detection using remote sensing and gis – A case study of Vellore District.* Procedia Computer Science v. 57, pg. 1199-1210.

Hird, J., and McDermid, G. (2009). *Noise reduction of NDVI time series: An empirical comparison of selected techniques.* Remote Sensing of Environment v. 113, pg. 248-258.

H. T. Harvey & Associates (Harvey). 2015. *Prado Basin Preliminary Riparian Habitat Health and Vigor Assessment.* Memorandum to the Orange County Water District. October 26, 2015.

James, M., and Kalluri, S. 1994. The Pathfinder *AVHARR land data set; an improved coarse resolution data set for terrestrial monitoring.* International Journal of Remote Sensing v. 15, pg. 3347-3363.

Jenson, J. 2007. *Remote Sensing of the Environment: An Earth Resource Perspective*, second edition. Published 2007 by Prentice-Hall, Upper Sadle River, N.J.

Jones, H., and Vaughan, R. 2010. *Remote Sensing of Vegetation: Principles, Techniques and Applications.* Oxford University Press, Oxford.

Ke, Y., Im, J., Lee, J., Gong, H., and Ryu, Y. 2015. *Characteristics of Landsat 8 OLI-derived NDVI by comparison with multiple sensors and in-situ observations.* Remote Sensing of Environment v. 164, pg. 298-313.

Li, P., Jiang,L.,Feng,Z. 2014. *Cross Comparison of Vegetation Indices Derived from Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and Landsat-8 Operational Land Imager (OLI) Sensors.* Remote Sensing v. 6, pg. 310-329.

Lillesand,T., Kiefer, R, and Chipman, J. 2008. *Remote Sensing and Image Interpretation*, sixth edition. Published in 2008 by John Wiley & Sons, New York.

Markon, C., Fleming, M., and Binnian, E. 1995. *Characteristics of vegetation phenology over Alaskan landscape using AVHRR time-series data.* Polar Records v. 31, pg.179-190.

Markon, C., and Peterson, K. 2002. *The utility of estimating net primary productivity over Alaska using baseline AVHRR data.* International Journal of Remote Sensing, v.23, pg. 4571-4596.

McPherson, D., at United States Bureau of Reclamation. 2016. Verbal communication on November 2, 2016

Merkel & Associates, Inc. 2007. Evapotranspiration Analysis of the Prado Basin Santa Anan River, California. Prepared for Wildermuth Environemntal, Inc. November 2007.

Orange County Water District (OCWD). 2015. *Effects of Reduced Outflow from Prado Dam Water Conservation 2013/2014*. Prepared for the U.S. Fish & Wildlife Service. February 2015.

Palenscar, K., at United States Fish and Wildlife. 2016. Verbal communication on November 2, 2016

Peters, A., Walter-Shea, E., Ji, L, Vina, A., Hayes, M., and Svoboda, M.D. 2002. *Drought Monitoring with NDVI-Based Standardized Vegetation Index.* Photogrammetric Engineering & Remote Sensing v. 68, no. 1, pg. 71-75.

Pettorelli, Nathalie, 2013. *The Normalized Difference Vegetation Index.* First edition. Published 2013 by Oxford University Press.

Pinzon, J., Brown, M., and Tucker, C. 2004. Monitoring Seasonal and International Variations in Land-surface Vegetation from 1981-2003 Using GIMMS NDVI. https://landval.gsfc.nasa.gov/pdf/GIMMS_NDVI_8km_doc.pdf

Inland Empire Utilities Agency (IEUA) and Chino Basin Watermaster (CBWM). 2008. *Memorandum of Understanding, Cooperative Efforts for Monitoring Programs Between the Inland Empire Utilities Agency and the Chino Basin Watermaster, Bright Line Approach.* 17 December 2008.

Intera Inc. 2015. *Memorandum Remote-Sensing Based Evaluation of Temporal Changes in Riparian Vegetation Health Along Temescal Creek, Prado Reservoir, Corona, California.* Prepared for Orange County Water District. January 30, 2015.

Schimdt, H. and Karnieli, A. 2000. *Remote sensing of seasonal variability of vegetation in a semi-arid environment.* Journal of Arid Environments v.45, pg. 43-59.

Tanre, D., Holden, B., and Kaufman,Y. 1992. *Atmospheric correction algorithm for NOAA_AVHRR products; theory and application.* IEE Journal of Geosciences and Remote Sensing, v. 30, pg. 231-248.

Tom Dodson & Associates. 2000. *Program Environmental Impact Report for the Optimum Basin Management Program (SCH#2000041047).* Prepared for the Inland Empire Utilities Agency. July 2000.

Tom Dodson & Associates. 2010. *Final Subsequent Environmental Impact Report for the Inland Empire Utilities Agency Peace II Agreement Project.* Prepared for the Inland Empire Utilities Agency. 25 September 2010.

Tucker C., Justice, C., and Prince, S. 1986. *Monitoring the grasslands of Sahel 1984-1985. International Journal of Remote Sensing*, v. 71, pg. 1571-1581.

Tucker C., Grant, D., and Dykstra, J.D. 2004. *NASA's global orthorectified Landsat data set. Photogrammetric Engineering & Remote Sensing,* v. 70, pg. 313-322.

United States Bureau of Reclamation (USBR), Lower Colorado Regional Office. 2008. *Hydraulic Control Monitoring Plan, Task 5.2: Vegetation Survey at the Prado Reservoir, Report No 2 of 5*. Prepared for the Inland Empire Utilities Agency. March 2008.

United States Bureau of Reclamation (USBR), Lower Colorado Regional Office. 2015. Riverside and San Bernardino Counties, California Inland Empire Utility Agency *Hydraulic Control Monitoring Plan, Task 5.2: Report No 3 of 5*. Draft Report. April 2015.

United States Bureau of Reclamation (USBR). 2017. Southern California Area Office. *Prado Basin Vegetation Survey October 2016*. Draft Report. February 2017.

United States Department of Agriculture (USDA), 1996. *Using NDVI to Assess Departure From Average Greenness and its Relation to Fire Business.* Burgan, R.E., Hartford, R.A, and Eidenshink, J.C. General Technical Report INT-GTR-333. April 1996.

United States Department of Agriculture (USDA), 1999. *Percent Canopy Cover and Stand Structure Statistics from the Forest Vegetation Simulator*. April 1999.

United States Department of Agriculture (USDA), Forest Service Region Pacific Southwest Region – State and Private Forestry. 2013. *Pest Alert. New Pest Complex in California: The Polyphagous Shot Hole Borer, Euwallacea sp., and Fusarium Dieback, Fusarium euwallaceae*. R5-PR-032. November 4, 2013.

United State Geological Survey (USGS). 2013. Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) Algorithm Description. Open-File Report 2013-1057. 2013.

United State Geological Survey (USGS). 2016. Product Guide – Landsat Surface Reflectance-Derived Spectral Indices. Version 3.3. December 2016.

United State Geological Survey (USGS). 2017a. Product Guide – Landsat 4-7 Climate Data Record (CDR) Surface Reflectance. Version 7.2. January 2017.

United State Geological Survey (USGS). 2017b. User Guide – Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface. Version 3.7. January 2017.

Verbesselt, J., Hyndman, R., Newnham, G., and Culvenor, D. 2010. *Detecting trend and seasonal changes in satellite image time-series*. Remote Sensing of Environmental, v. 17, pg. 231-235.

Weiss, J., Gutzler, D., Allred Coonrod, J., and Dahm, C. 2004. *Long-term vegetation monitoring with NDVI in a diverse semi-arid setting central New Mexico, USA*. Journal of Arid Environments v. 58, pg. 249-272.

Wildermuth Environmental, Inc (WEI). 1999. *Optimum Basin Management Program. Phase I Report*. Prepared for the Chino Basin Watermaster. August 19, 1999.

Wildermuth Environmental, Inc (WEI). 2007. *2007 CBWM Groundwater Model Documentation and Evaluation of the Peace II Project Description. Final Report.* November 2007.

Wildermuth Environmental, Inc (WEI). 2015. *2013 Chino Basin Groundwater Model Update and Recalculation of Safe Yield Pursuant to the Peace Agreement (Final Report).* Prepared for the Chino Basin Watermaster. October 2015.

Wildermuth Environmental, Inc (WEI). 2016. *2016 Adaptive Management Plan for the Prado Basin Habitat Sustainability Program, Final.* Prepared for the Inland Empire Utilities Agency and Chino Basin Watermaster. August, 2016.

Wang, J., Rich, P., Price, K., and Kettle, W. 2004. *Relations between NDVI and tree productivity in the central Great Plains.* International Journal or Remote Sensing, v. 25, pg. 3127-3138.

Woodside, G., at Orange County Water District. 2017. Verbal communication on March 15, 2017.

Xie, Y., Sha, Z., and Yu, M. 2008. *Remote Sensing imagery in vegetation mapping: a review.* Journal of Plant Ecology. V. 1, no.1, pg 9-23.

Zembal, R., at Orange County Water District. 2017. Verbal communication on March 14, 2017.