Upper Santa Ana River Integrated Model Summary Report

Part 2 of 5: Figures (Part 1)

DRAFT

Prepared For: San Bernardino Valley Municipal Water District

April 29, 2020

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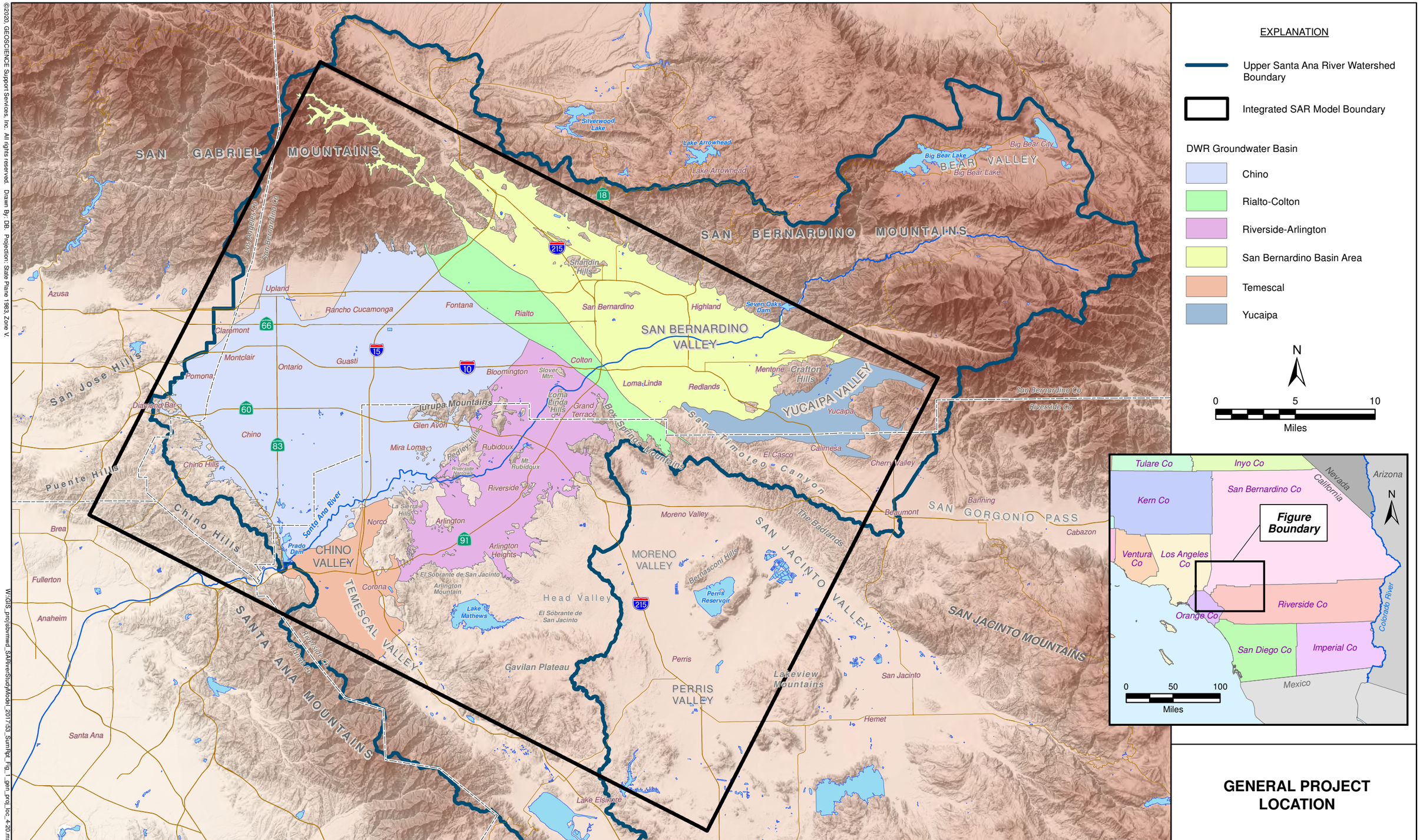

GENERAL PROJECT LOCATION

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 1

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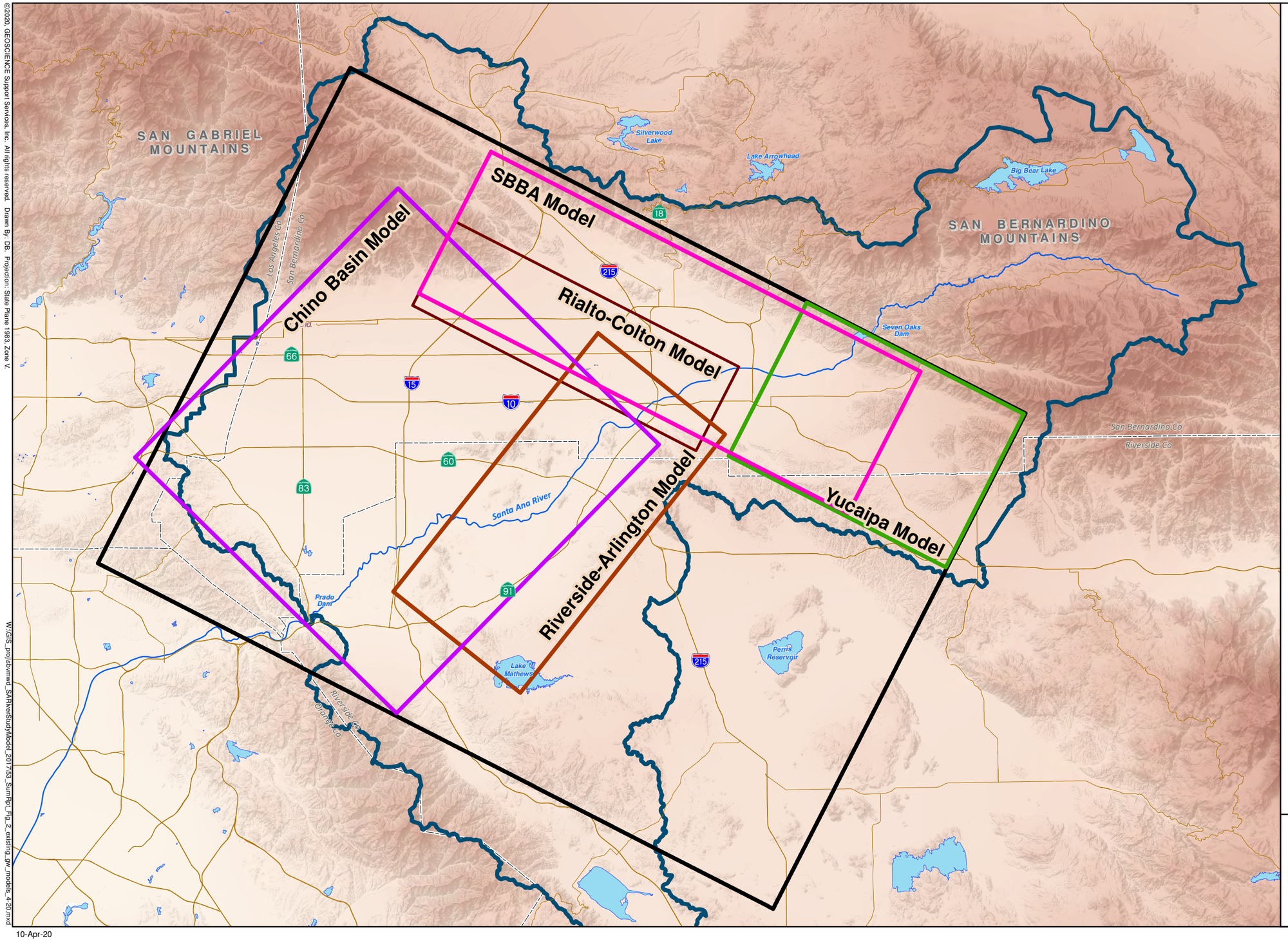

EXPLANATION

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Chino Basin Model Boundary (WEI, 2015)
- Rialto-Colton Model Boundary (GEOSCIENCE, 2015)
- Riverside-Arlington Model Boundary (WRIME, 2010)
- SBBA Model Boundary (Stantec and GEOSCIENCE, in progress)
- Yucaipa Basin Model Boundary (GEOSCIENCE, 2017)

N

0 5 10
Miles

PREVIOUS GROUNDWATER MODELS IN THE UPPER SANTA ANA RIVER GROUNDWATER BASIN

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 2

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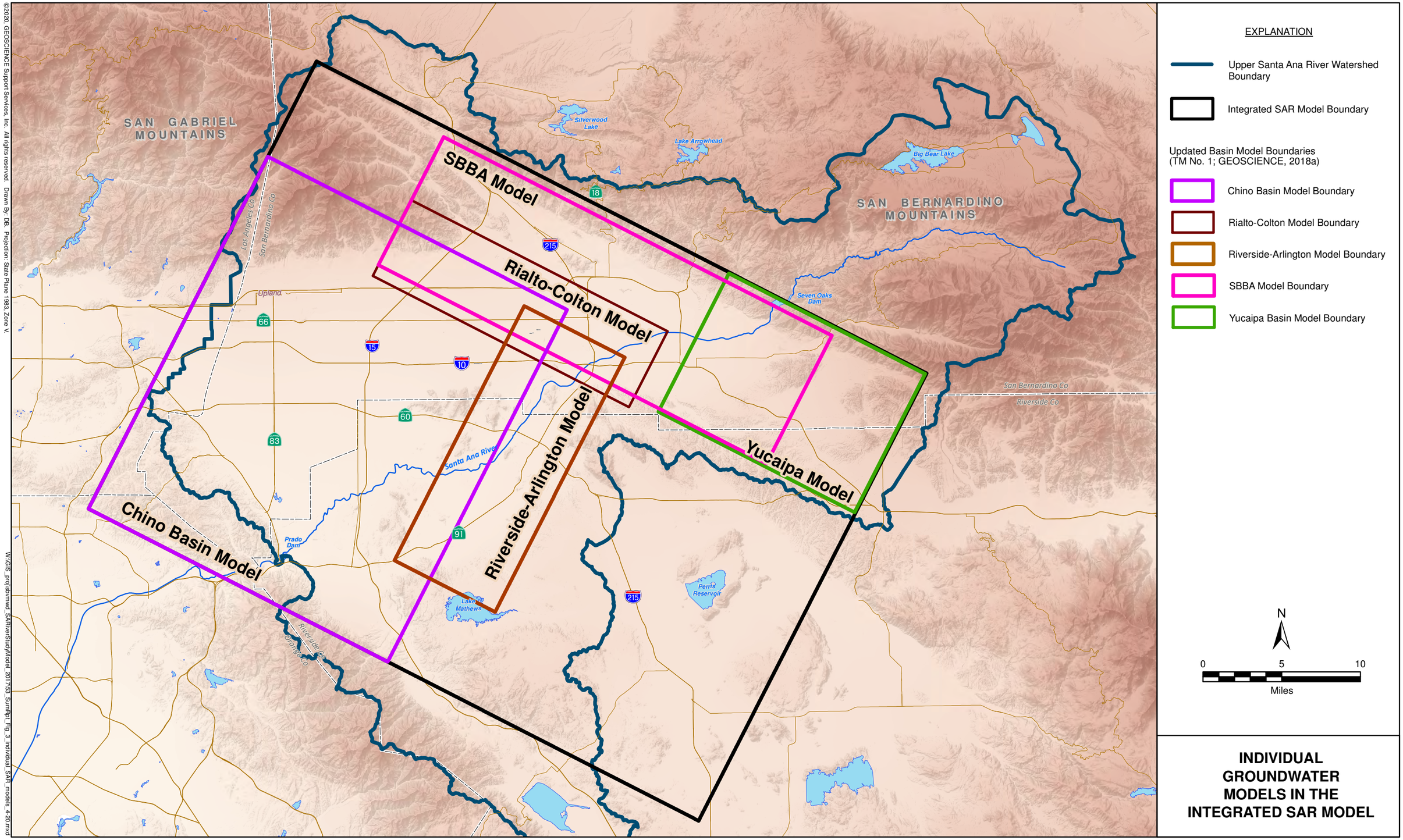

INDIVIDUAL GROUNDWATER MODELS IN THE INTEGRATED SAR MODEL

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FIGURE 3

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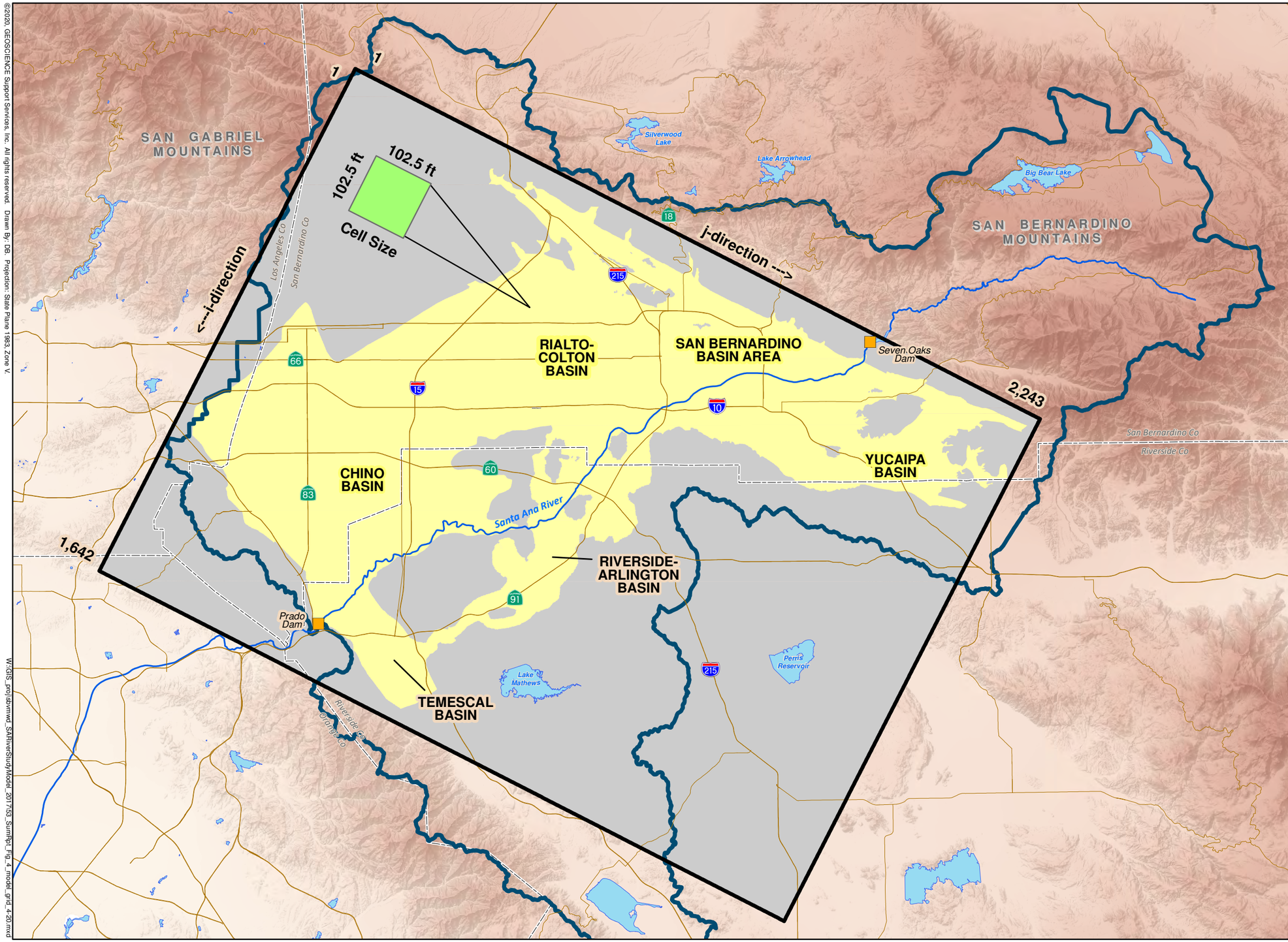

EXPLANATION

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Dam Location Used in Upper Santa Ana River Watershed Model

N

0 5 10
Miles

MODEL GRID OF THE INTEGRATED SAR MODEL

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FIGURE 4

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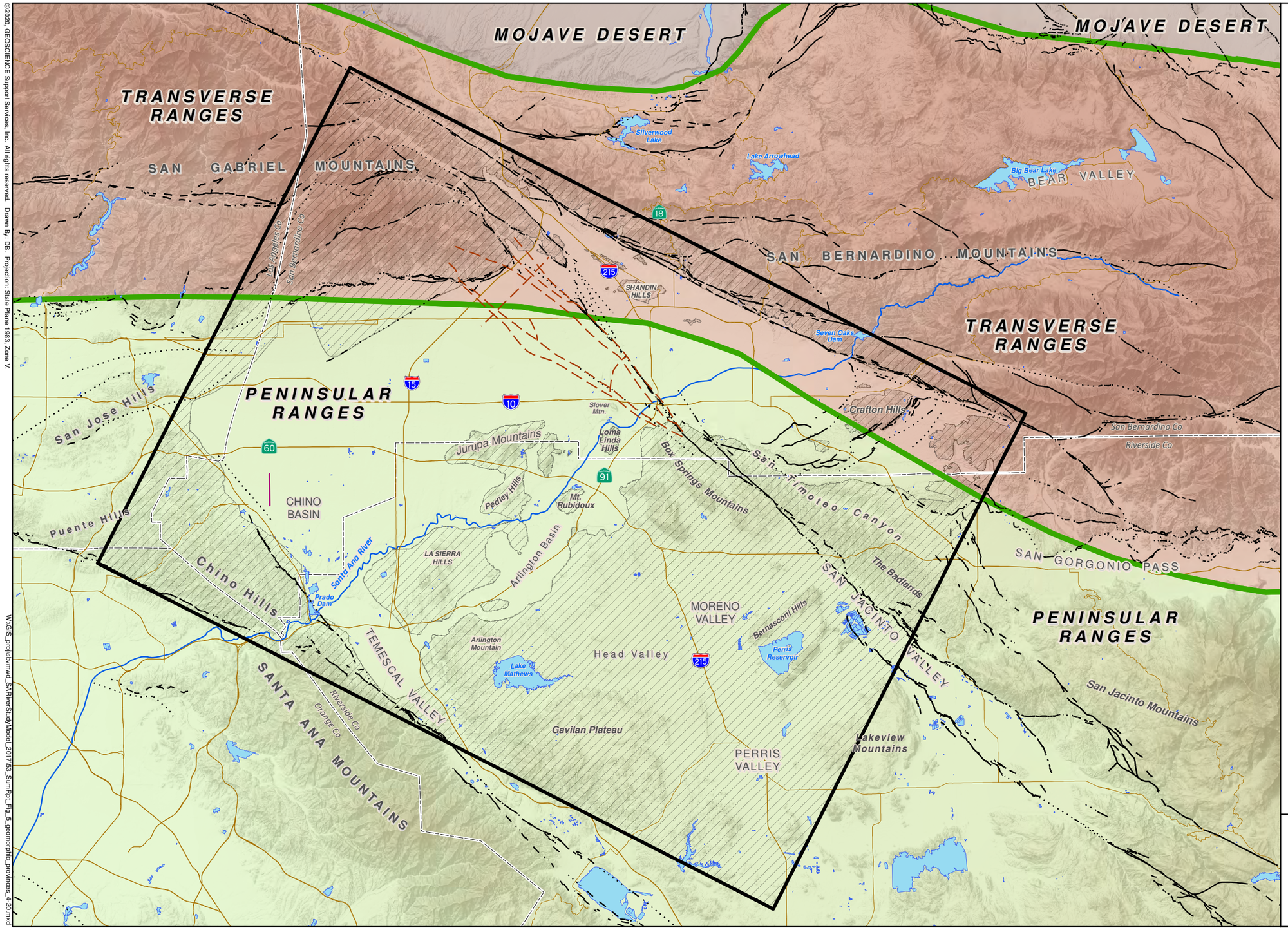

GEOMORPHIC PROVINCES OF THE INTEGRATED SAR MODEL AREA

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FIGURE 5

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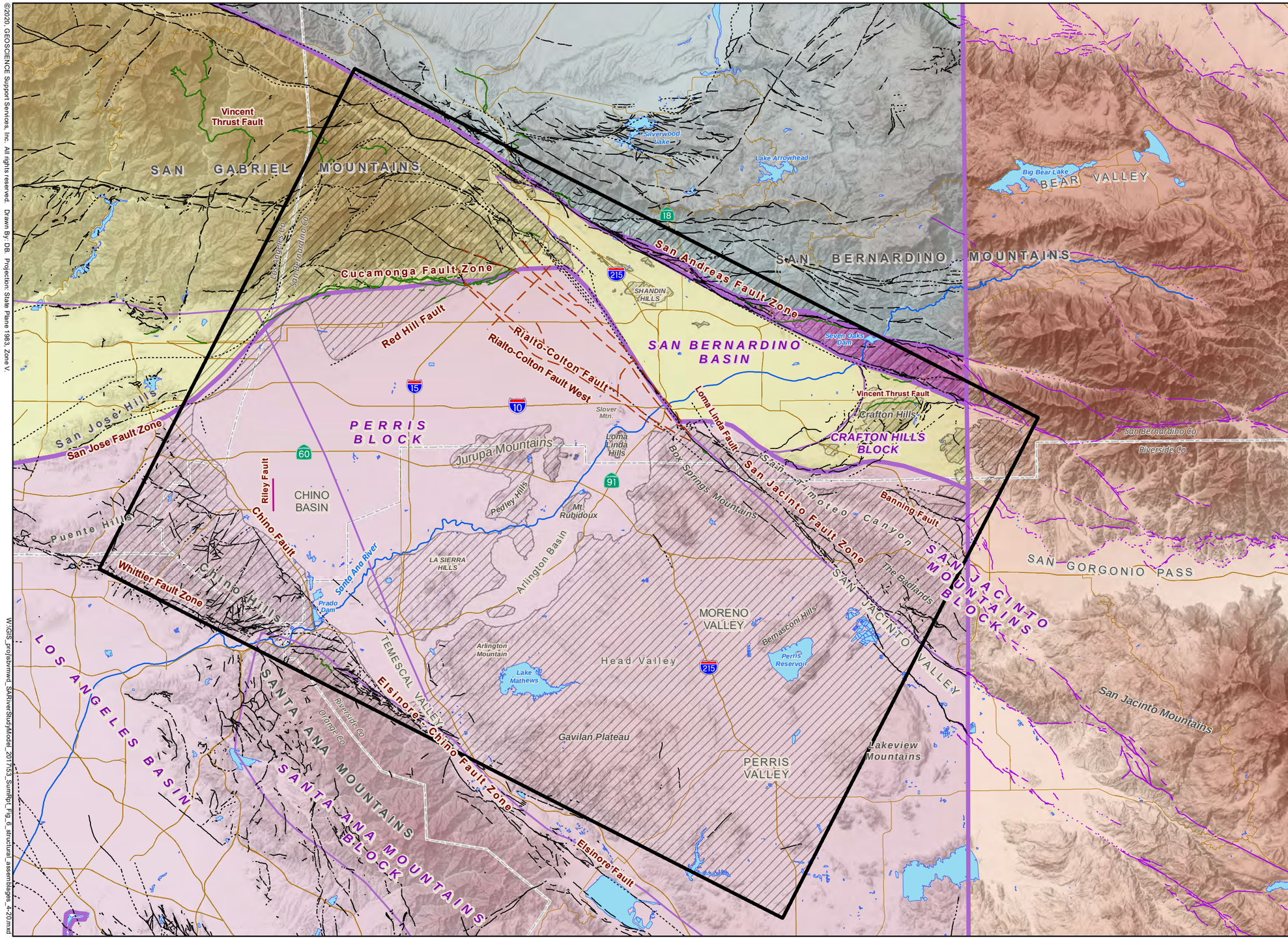

EXPLANATION

Integrated SAR Model Boundary

Integrated SAR Model Inactive Model Area

Structural Assemblage (Morton and Miller, 2006)

- Peninsular Ranges Assemblage
- San Bernardino Mountains Assemblage
- San Gabriel Mountains Assemblage
- Rocks Bounded by Mission Creek Segment of San of the Andreas Fault Zone, and the Mill Creek Fault
- Structural Block Boundary
- Riley Barrier (WEI, 2007)

Fault Classification (Morton and Miller, 2006)

- Well Constrained
- Moderately Constrained
- Inferred
- Thrust Fault
- Local Fault (Paulinski, 2012)

Fault Classification (USGS, 2017)

- Well Constrained
- Moderately Constrained
- Inferred

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Miles

STRUCTURAL ASSEMBLAGES OF THE INTEGRATED SAR MODEL AREA

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 6

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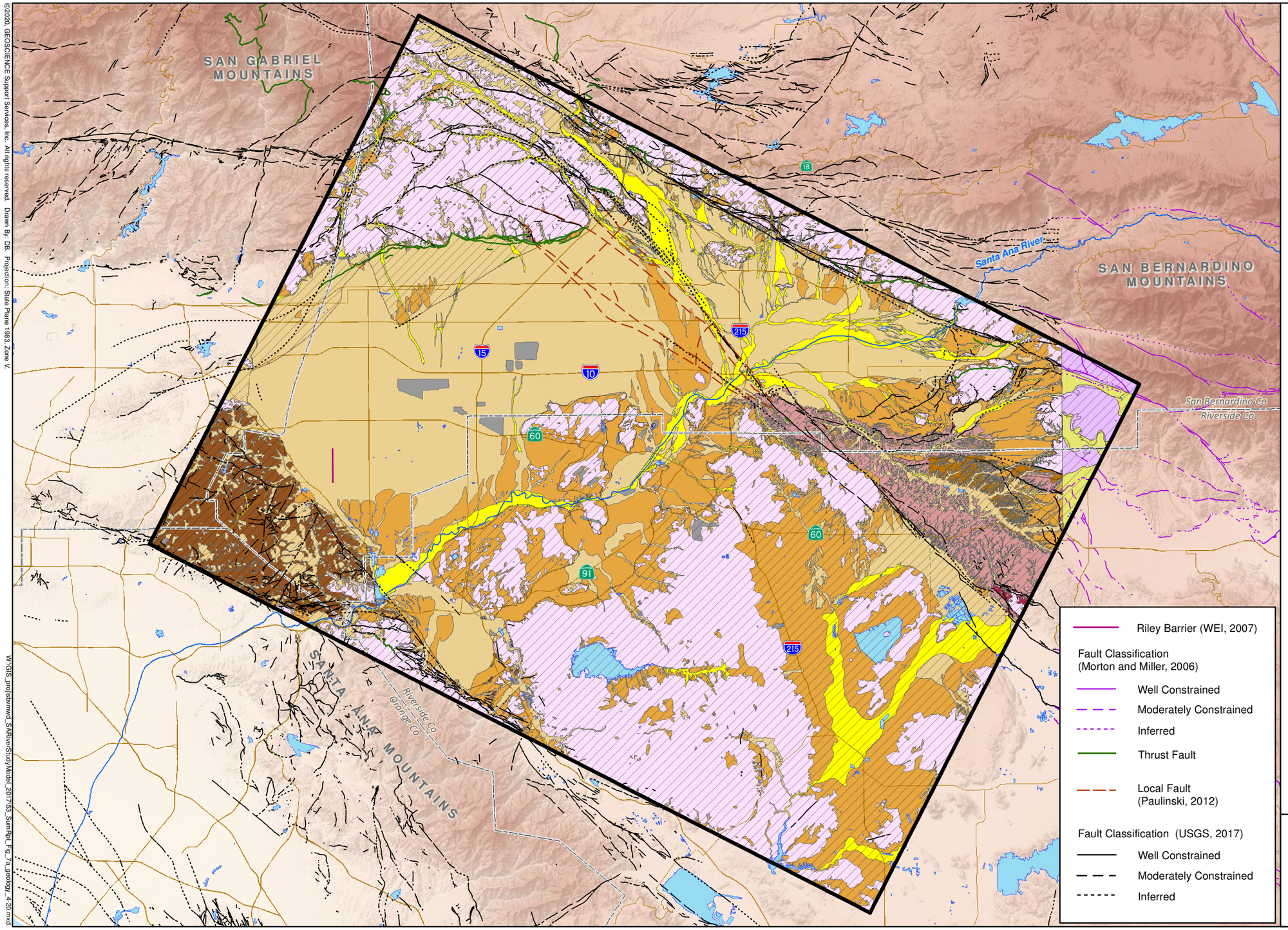

Integrated SAR Model Boundary

Integrated SAR Model No-Flow Cells

Geologic Units Generalized from
1) USGS OFR 2006-1217 (Morton and Miller, 2006)
2) USGS OFR 2010-1274 (Matti, et al., 2015)

- Artificial Fill
- Very Young and Young Axial-Channel and Wash Deposits (Holocene)
- Very Young and Young Alluvial Deposits (Pleistocene)
- Old and Very Old Alluvial Deposits (Pleistocene)
- Fernando Group (Plio-Pleistocene)
- LIve Oak Canyon Deposits (Pleistocene)
- San Timoteo Formation (Plio-Pleistocene)
- Mt. Eden (Miocene Sedimentary)
- Puente Formation (Miocene Sedimentary)
- Bedrock (Miocene and Older, Undifferentiated)

CDMG Geologic Map of CA
(Jennings, Strand, and Rogers, 1977)

- Alluvium (Pliocene to Holocene, Undifferentiated)
- Bedrock (Miocene and Older, Undifferentiated)

See Figure 7b for Detailed Geologic Legend

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Miles

GEOLOGIC MAP OF THE INTEGRATED SAR MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 7a

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Symbol	Name	Age	Geologic Unit
Qdg	Disturbed ground	Holocene	Artificial Fill
Qaf	Artificial fill	Holocene	Artificial Fill
Qw	Very young wash deposits	Holocene	Very Young and Young Axial-Channel and Wash Deposits
Qa	Very young axial-channel deposits	Holocene	Very Young and Young Axial-Channel and Wash Deposits
Qv	Very young alluvial-valley deposits	Holocene	Very Young and Young Axial-Channel and Wash Deposits
Qyw	Young wash deposits	Holocene	Very Young and Young Axial-Channel and Wash Deposits
Qyv	Young alluvial-valley deposits	Holocene	Very Young and Young Axial-Channel and Wash Deposits
Qf	Very young alluvial-fan deposits	Holocene	Very Young and Young Alluvial Deposits
Qc	Very young colluvial deposits	Holocene	Very Young and Young Alluvial Deposits
Qt	Very young talus deposits	Holocene	Very Young and Young Alluvial Deposits
Qsw	Very young slope-wash deposits	Holocene	Very Young and Young Alluvial Deposits
Qls	Very young landslide deposits	Holocene	Very Young and Young Alluvial Deposits
Qlv	Very young lacustrine and fluvial deposits	Holocene	Very Young and Young Alluvial Deposits
Qe	Very young eolian deposits	Holocene	Very Young and Young Alluvial Deposits
Qs	Very young surficial deposits	Holocene	Very Young and Young Alluvial Deposits
Qyf	Young alluvial-fan deposits	Holocene	Very Young and Young Alluvial Deposits
Qyc	Young colluvial deposits	Holocene	Very Young and Young Alluvial Deposits
Qyt	Young talus deposits	Holocene	Very Young and Young Alluvial Deposits
Qyls	Young landslide deposits	Holocene	Very Young and Young Alluvial Deposits
Qye	Young eolian deposits	Holocene	Very Young and Young Alluvial Deposits
Qys	Young surficial deposits	Holocene	Very Young and Young Alluvial Deposits
Qow	Old wash deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qof	Old alluvial-fan deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qoa	Old axial-channel deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qov	Old alluvial-valley deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qols	Old landslide deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qoe	Old eolian deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qos	Old surficial deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qvof	Very old alluvial-fan deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qvoa	Very old axial-channel deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qvols	Very old landslide deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qvos	Very old surficial deposits	Pleistocene	Old and Very Old Alluvial Deposits
Qvor	Very old regolith	Pleistocene	Old and Very Old Alluvial Deposits
Tf	Fernando Formation	Pleistocene	Fernando Group
Tfl	Fernando Formation - Lower Member	Pleistocene	Fernando Group
Qlo	Sedimentary Deposits of Live Oak Canyon	Plio-Pleistocene	Live Oak Canyon Deposits
Qstu	San Timoteo Beds - Upper Member	Plio-Pleistocene	San Timoteo Formation
Qsts	San Timoteo Beds - Upper Member, conglomeratic sandstone beds	Plio-Pleistocene	San Timoteo Formation
Qstr	San Timoteo Beds - Reche Canyon Member	Plio-Pleistocene	San Timoteo Formation
Qstcq	San Timoteo Beds - Upper Member, quartzite-bearing conglomerate beds	Plio-Pleistocene	San Timoteo Formation
Tstm	San Timoteo Beds - Middle Member	Plio-Pleistocene	San Timoteo Formation
Tstd	San Timoteo Beds - Middle Member, highly deformed sandstone and conglomerate	Plio-Pleistocene	San Timoteo Formation
Tstl	San Timoteo Beds - Lower Sandstone Member	Plio-Pleistocene	San Timoteo Formation
Tstf	San Timoteo Beds - Fine-Grained Member	Plio-Pleistocene	San Timoteo Formation
Tmeh	Mount Eden Formation of Fraser (1931) - Heterogeneous Member	Miocene	Mt. Eden
Tmea	Mount Eden Formation of Fraser (1931) - Arkosic and Lithis Sandstone Member	Miocene	Mt. Eden
Tp	Puente Formation - Undifferentiated	Miocene	Puente Formation
Tpscc	Puente Formation - Sycamore Canyon Member, conglomerate	Miocene	Puente Formation
Tpsc	Puente Formation - Sycamore Canyon Member	Miocene	Puente Formation
Tpy	Puente Formation - Yorba Member	Miocene	Puente Formation
Tpsqc	Puente Formation - Soquel Member, conglomerate	Miocene	Puente Formation
Tpsq	Puente Formation - Soquel Member	Miocene	Puente Formation
Tplv	Puente Formation - La Vida Member	Miocene	Puente Formation
	Undifferentiated consolidated sedimentary, metamorphic, and granitic rocks	Miocene and Older	Bedrock

Source: USGS OFR 2006-1217 (Morton and Miller, 2006) and USGS OFR 2010-1274 (Matti et al., 2015)

Q	Alluvium	Pliocene to Holocene	Alluvium
	Undifferentiated consolidated sedimentary, metamorphic, and granitic rocks	Miocene and Older	Bedrock

Source: CDMG Geologic Map of CA (Jennings, Strand, and Rogers, 1977)

GEOLOGIC LEGEND

See Figure 7a for Geologic Map

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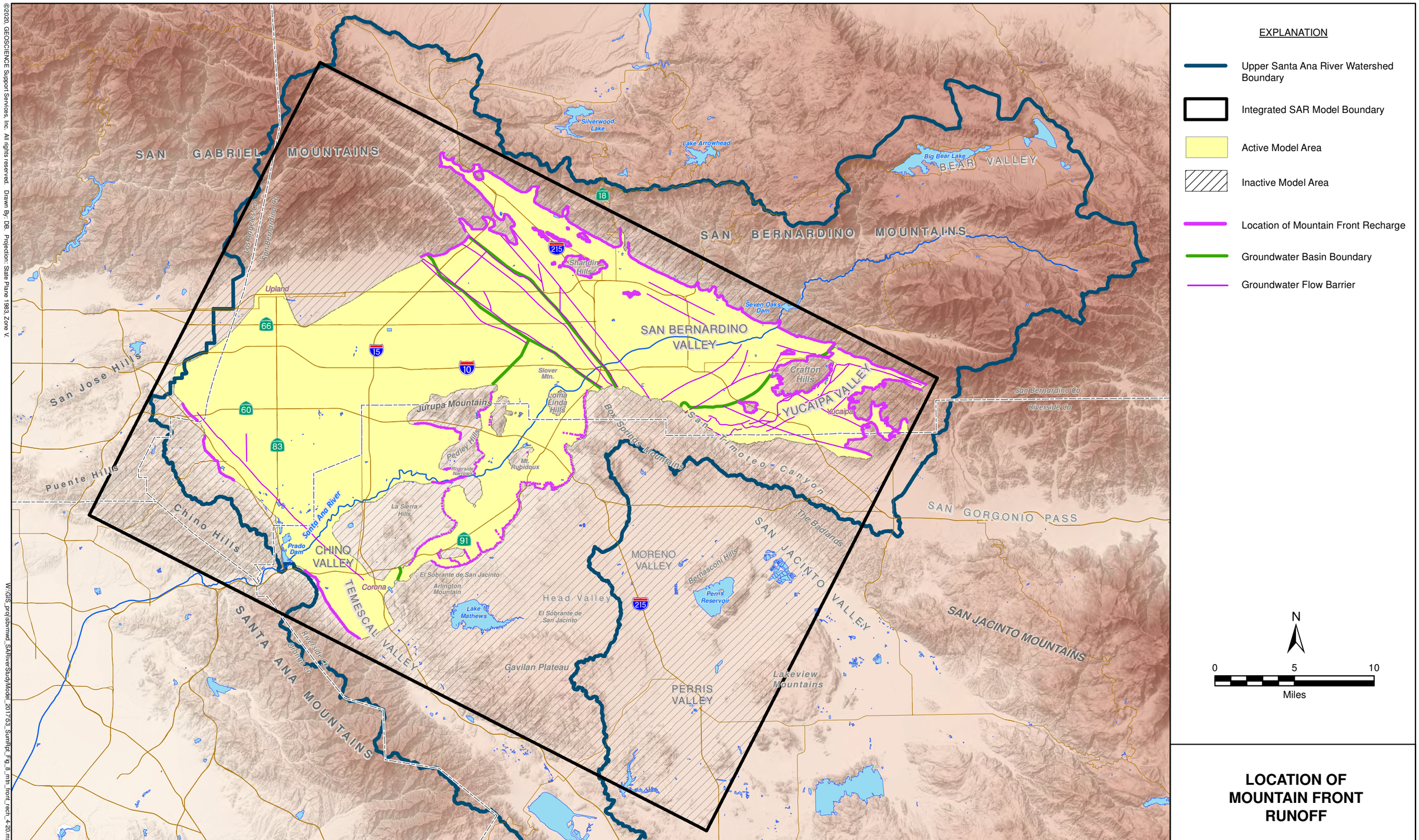

LOCATION OF MOUNTAIN FRONT RUNOFF

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 8

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Annual Recharge from Mountain Front Runoff

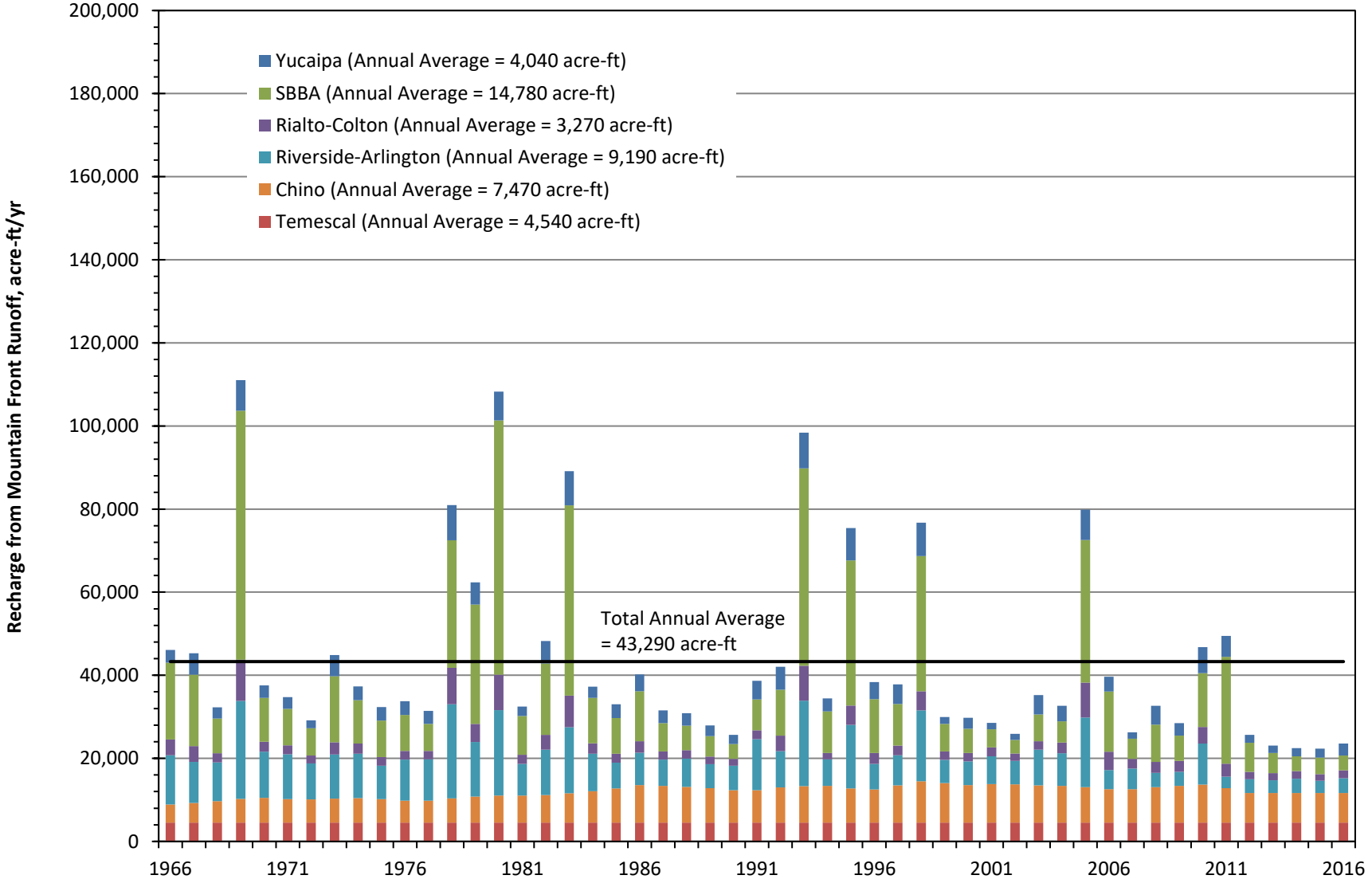
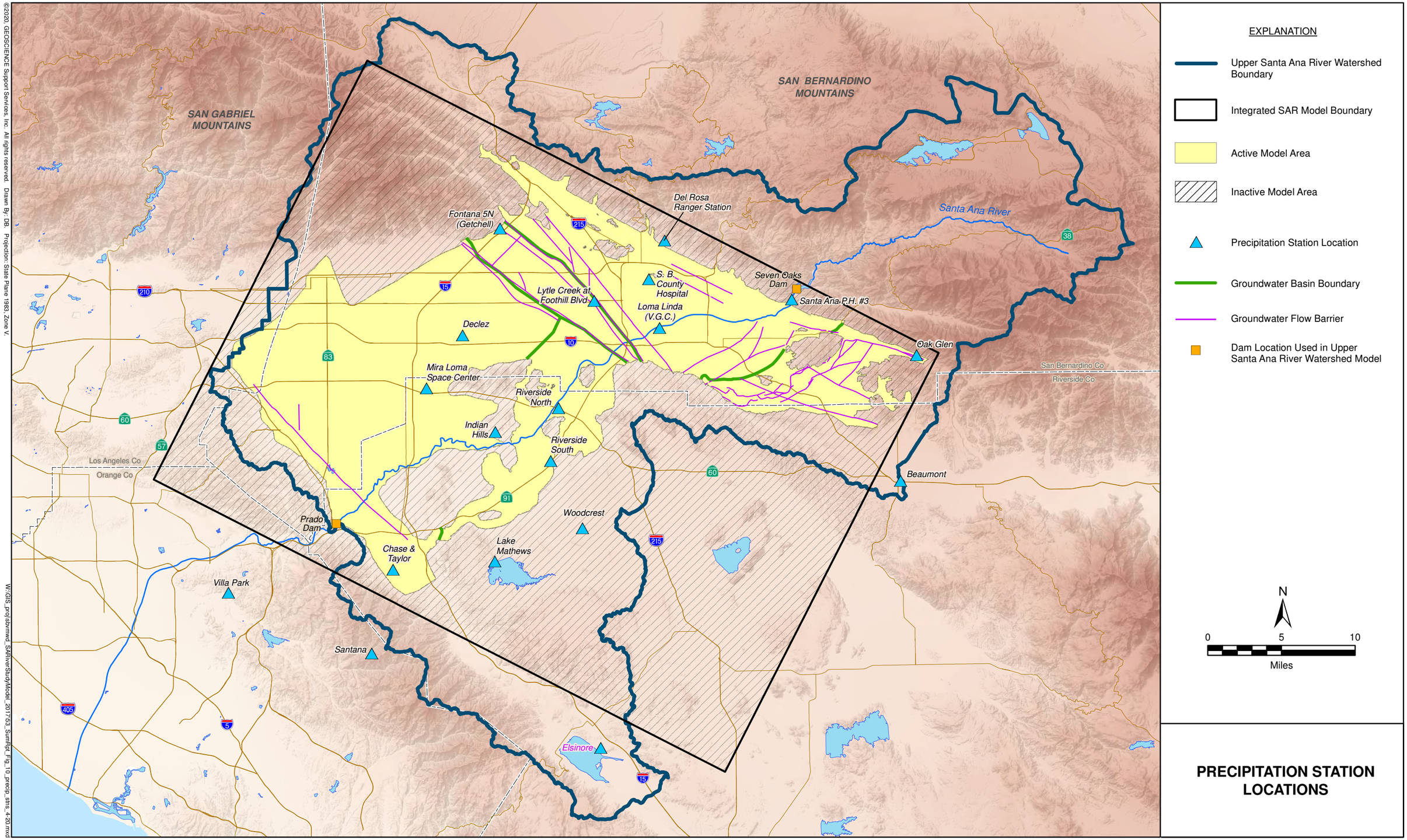


Figure 9



PRECIPITATION STATION LOCATIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 10

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Cumulative Departure from Mean Annual Precipitation
San Bernardino County Hospital Station (1883-2016)

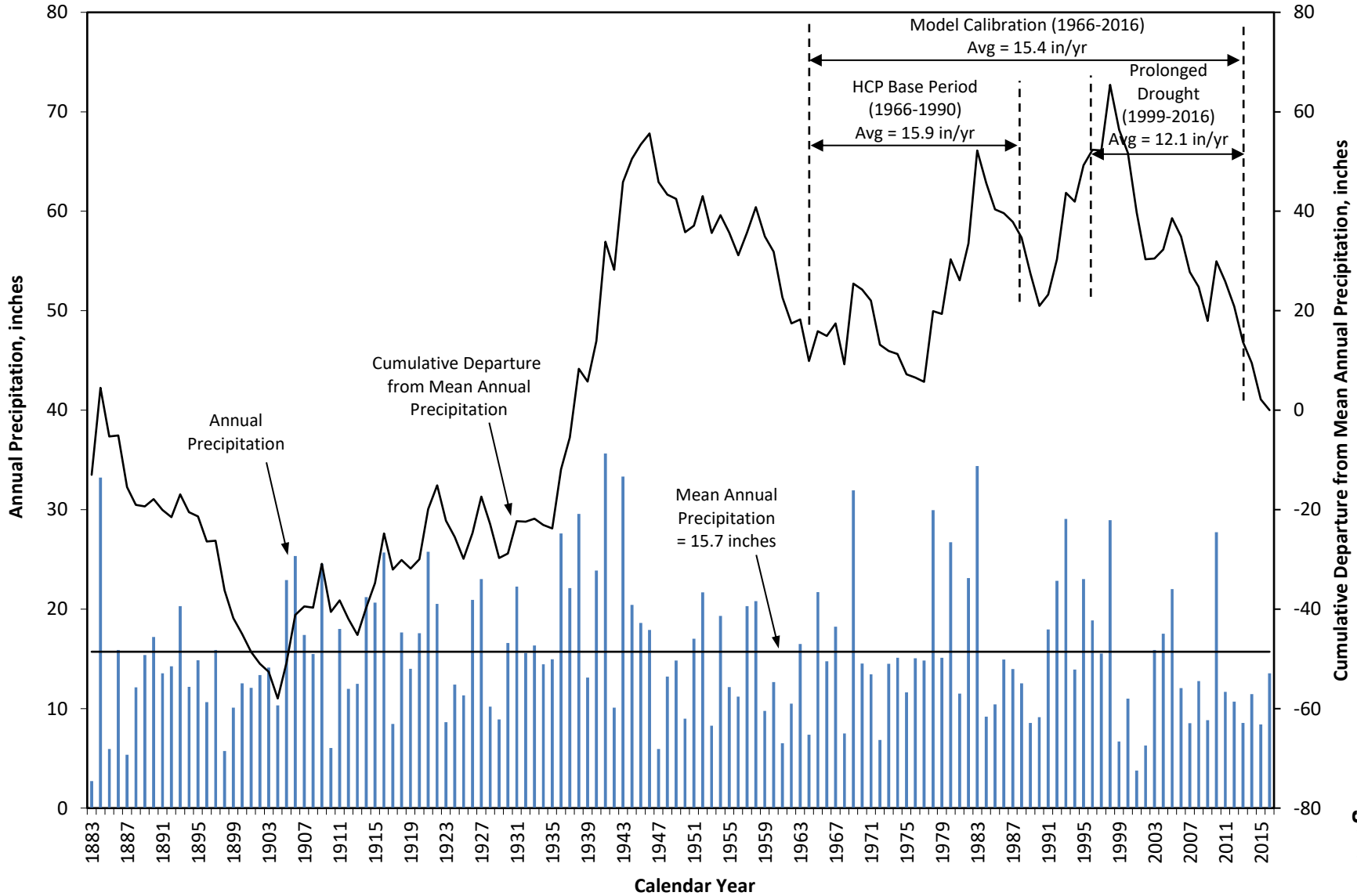


Figure 11

Annual Areal Recharge from Precipitation

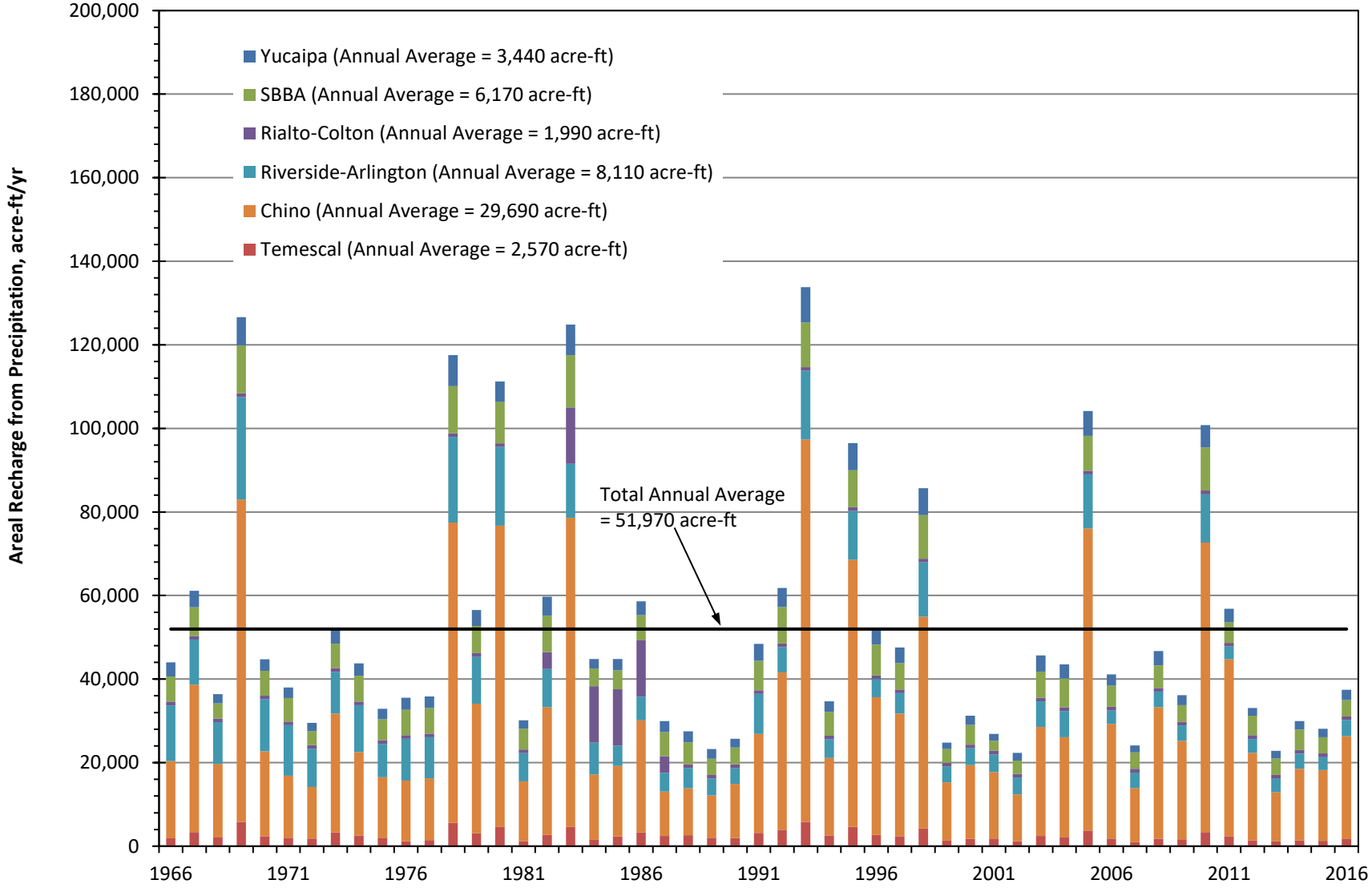
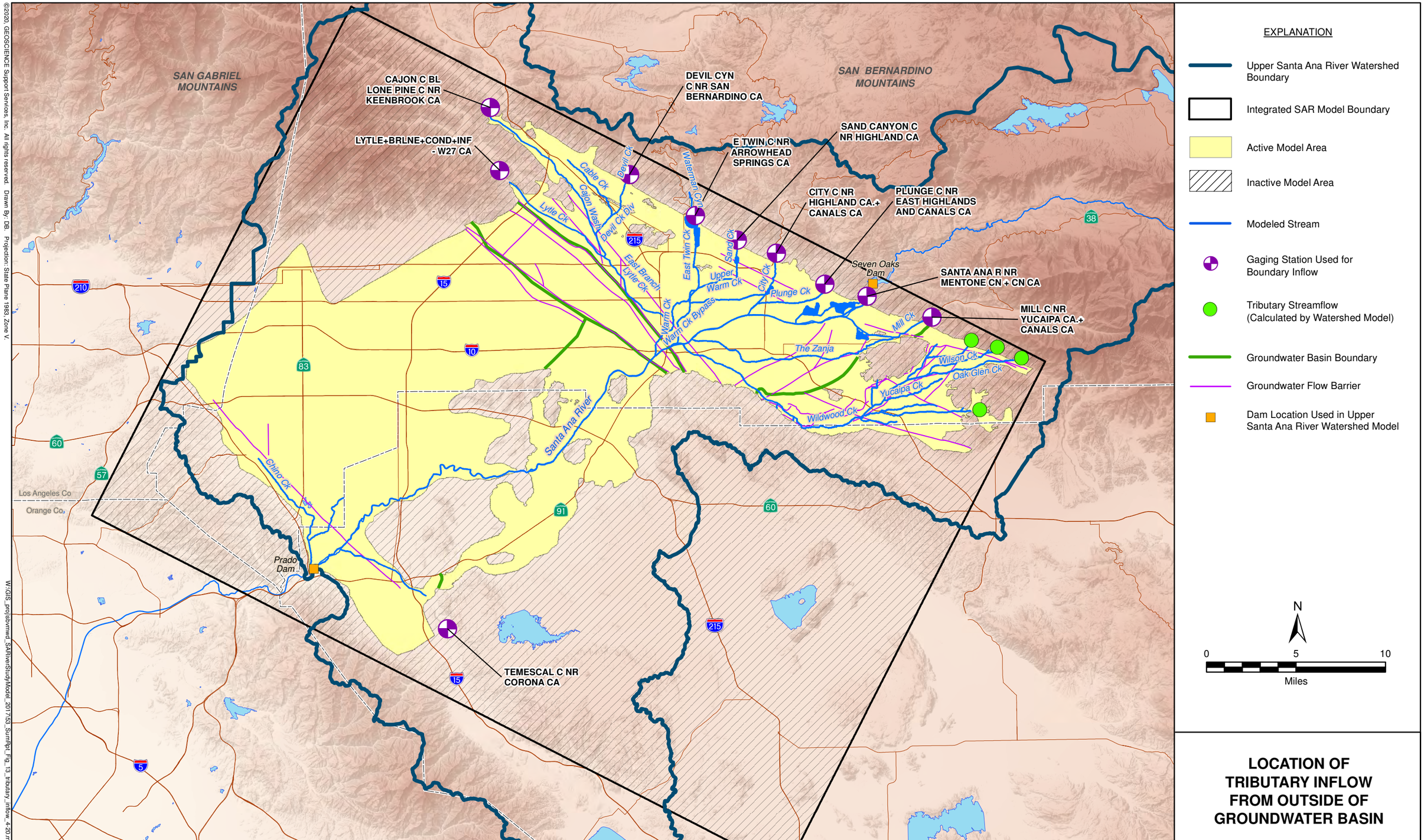


Figure 12



LOCATION OF TRIBUTARY INFLOW FROM OUTSIDE OF GROUNDWATER BASIN

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FIGURE 13

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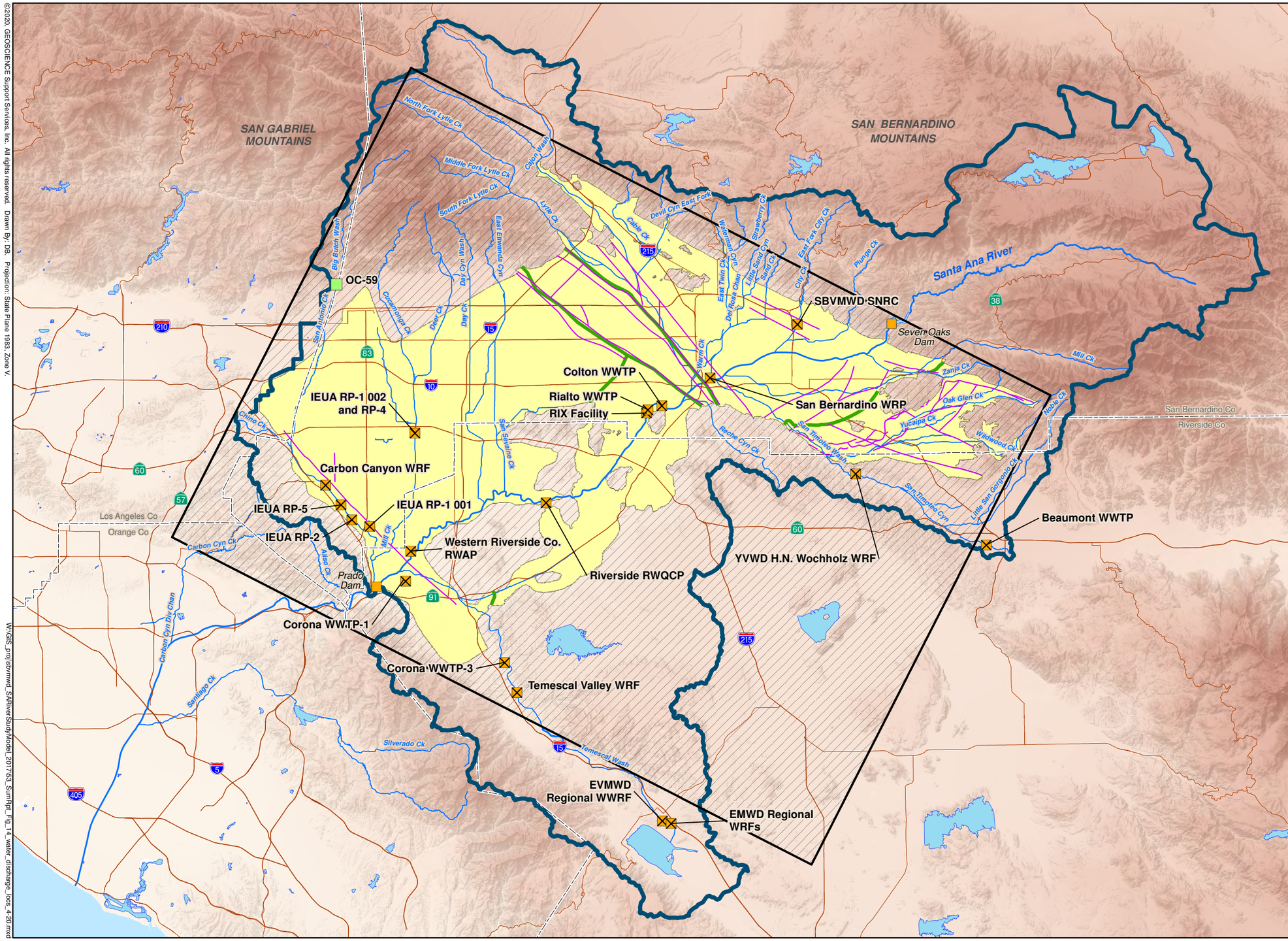

EXPLANATION

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model
- Recycled Water Discharge Point (https://www.waterboards.ca.gov)
- OCWD State Water Project Turnout Point (Orange County Water District)

N

0 5 10

Miles

RECYCLED WATER DISCHARGE POINT LOCATIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 14

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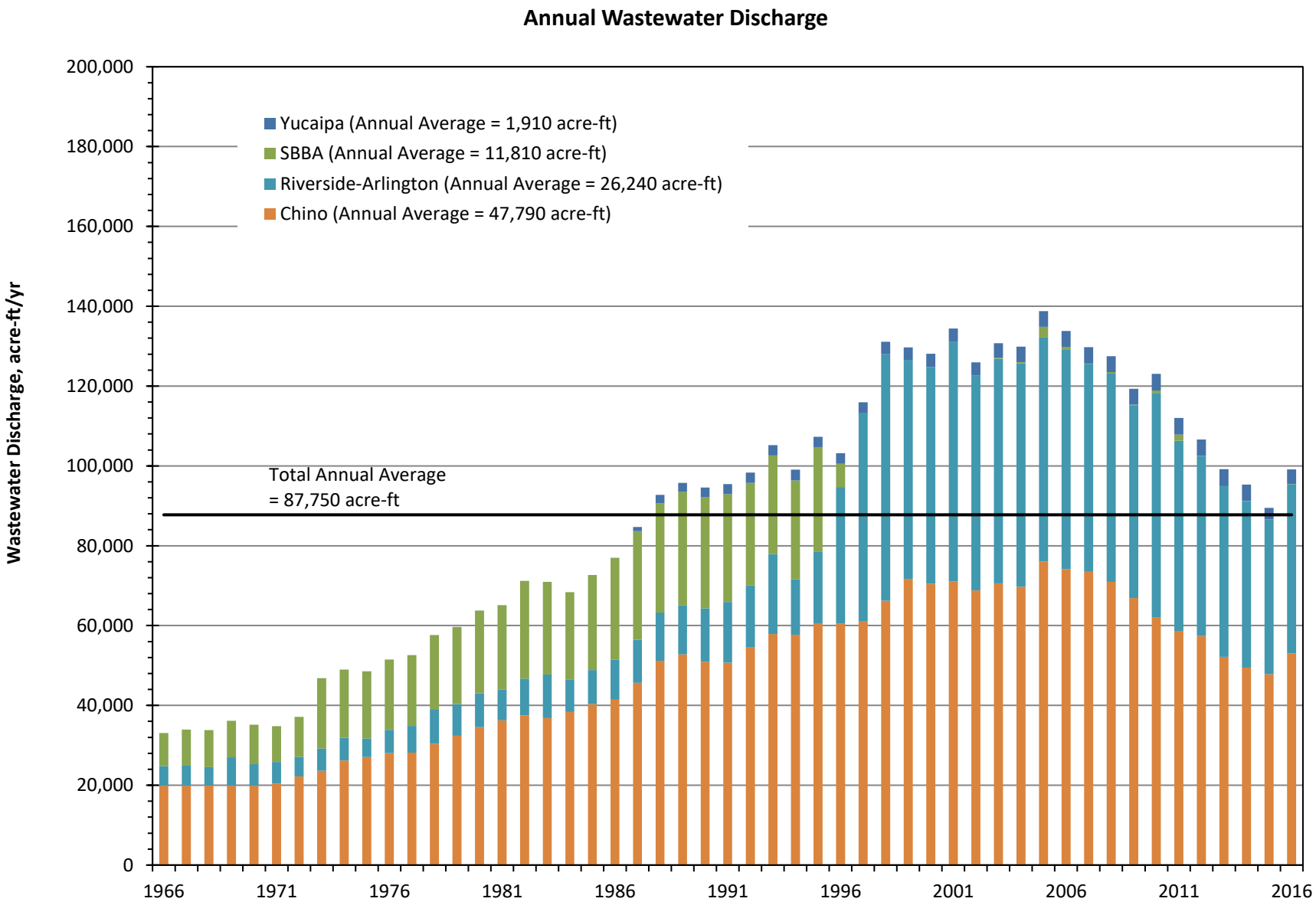
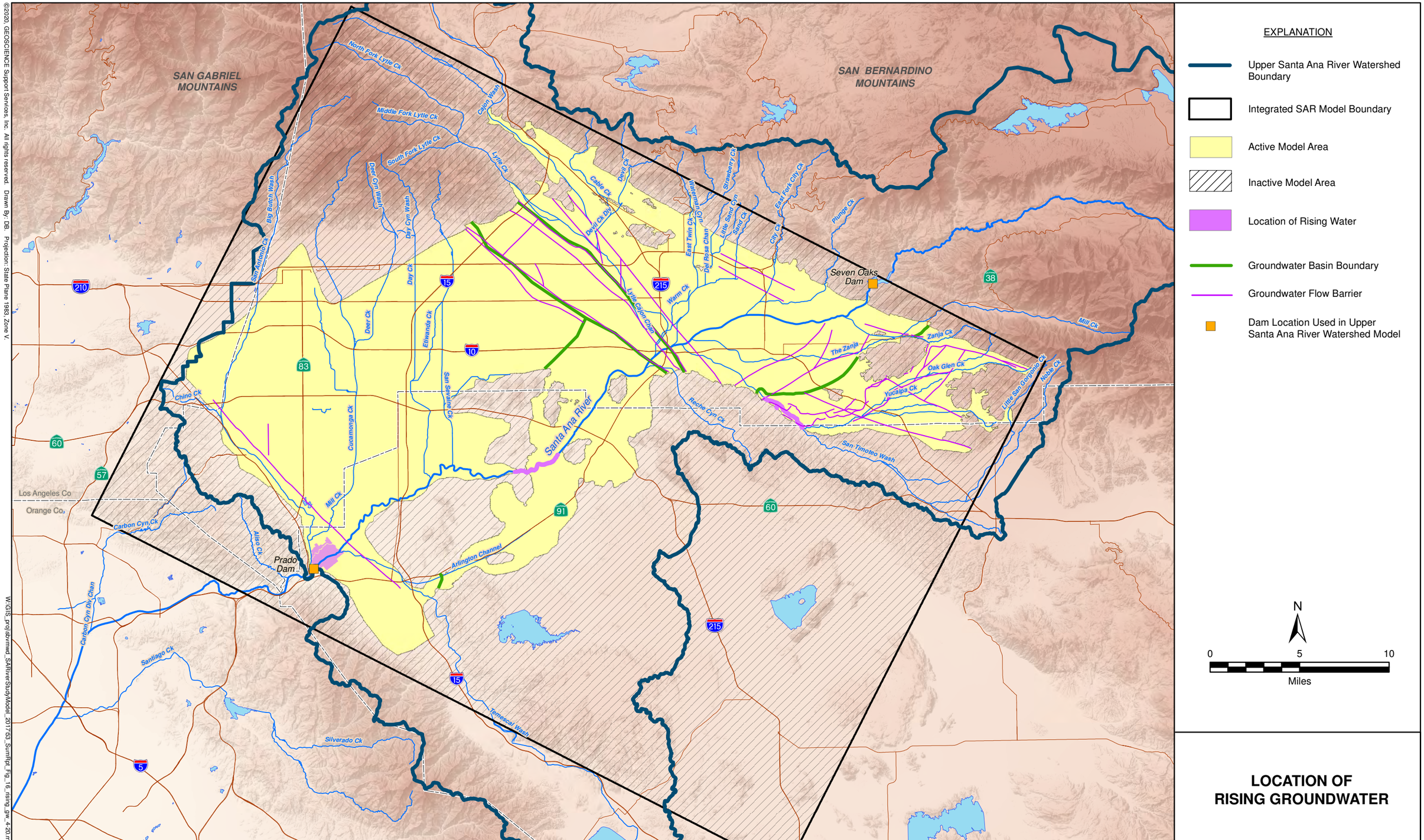

Annual Wastewater Discharge
Wastewater Discharge, acre-ft/yr
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
Yucaipa (Annual Average = 1,910 acre-ft)
SBBA (Annual Average = 11,810 acre-ft)
Riverside-Arlington (Annual Average = 26,240 acre-ft)
Chino (Annual Average = 47,790 acre-ft)
Total Annual Average
= 87,750 acre-ft

Figure 15



LOCATION OF RISING GROUNDWATER

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FIGURE 16

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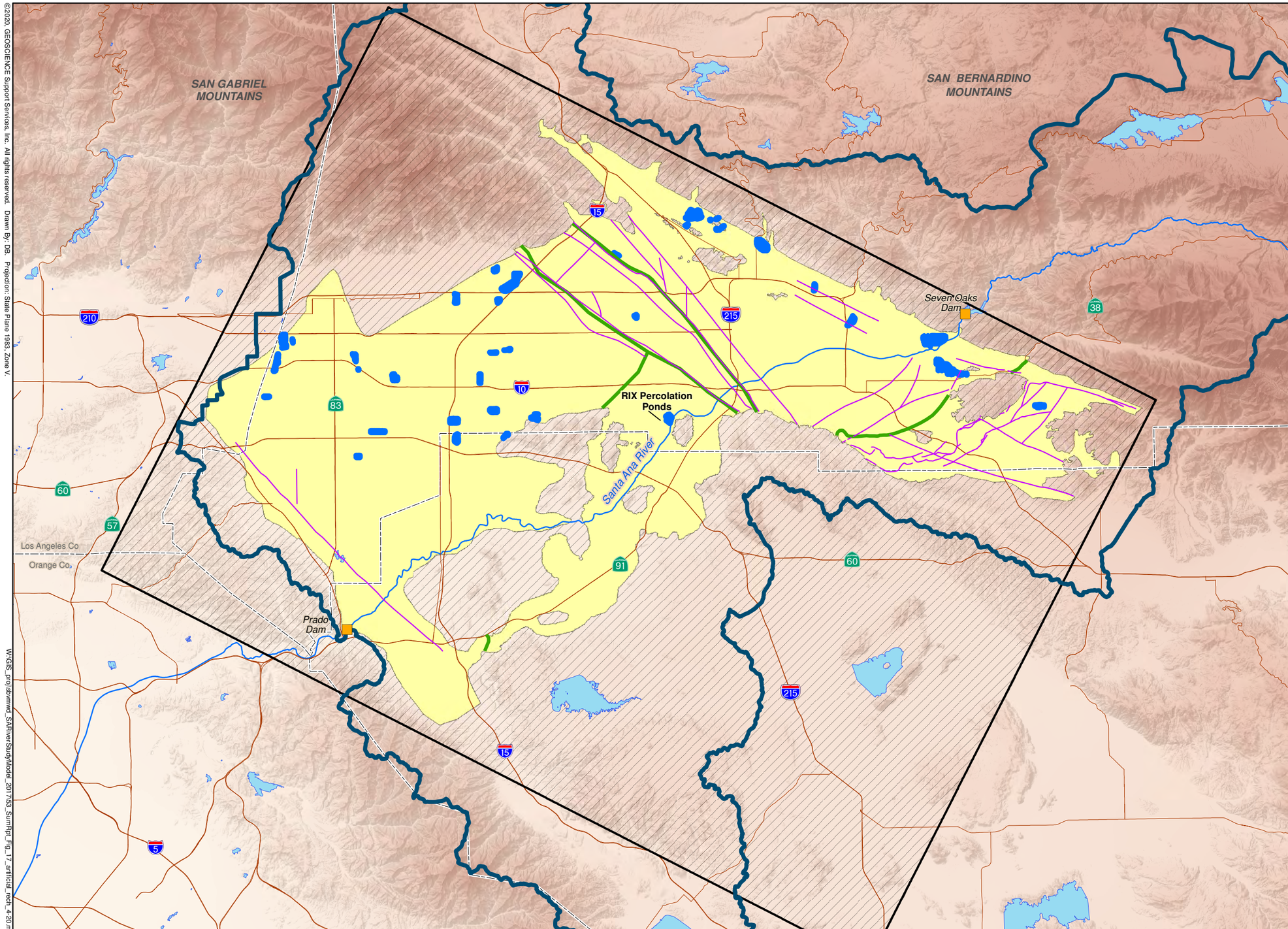

EXPLANATION

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Location of Artificial Recharge
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

N

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Miles

LOCATION OF ARTIFICIAL RECHARGE

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 17

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Annual Artificial Recharge

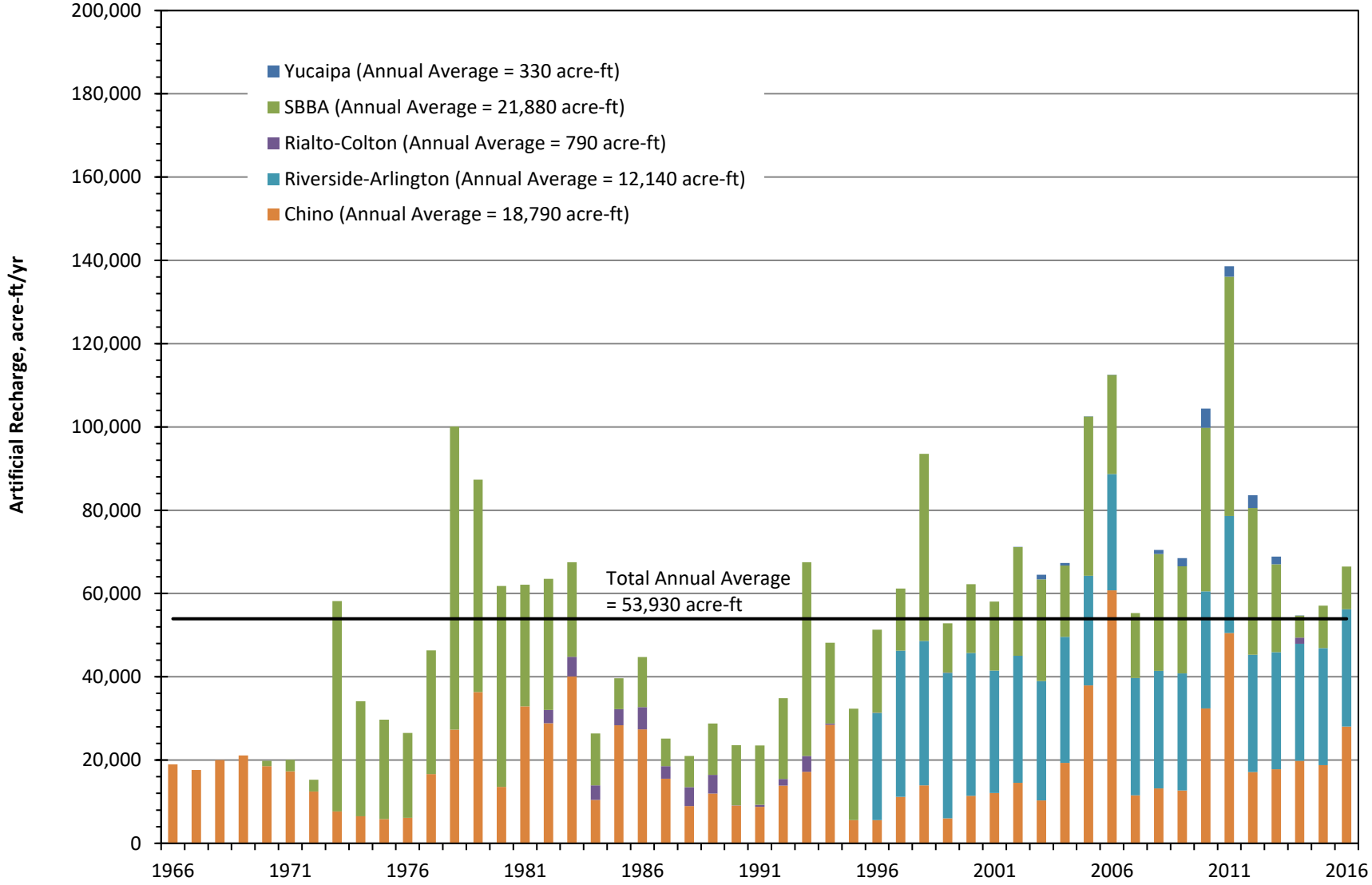

Figure 18

Annual Anthropogenic Return Flow

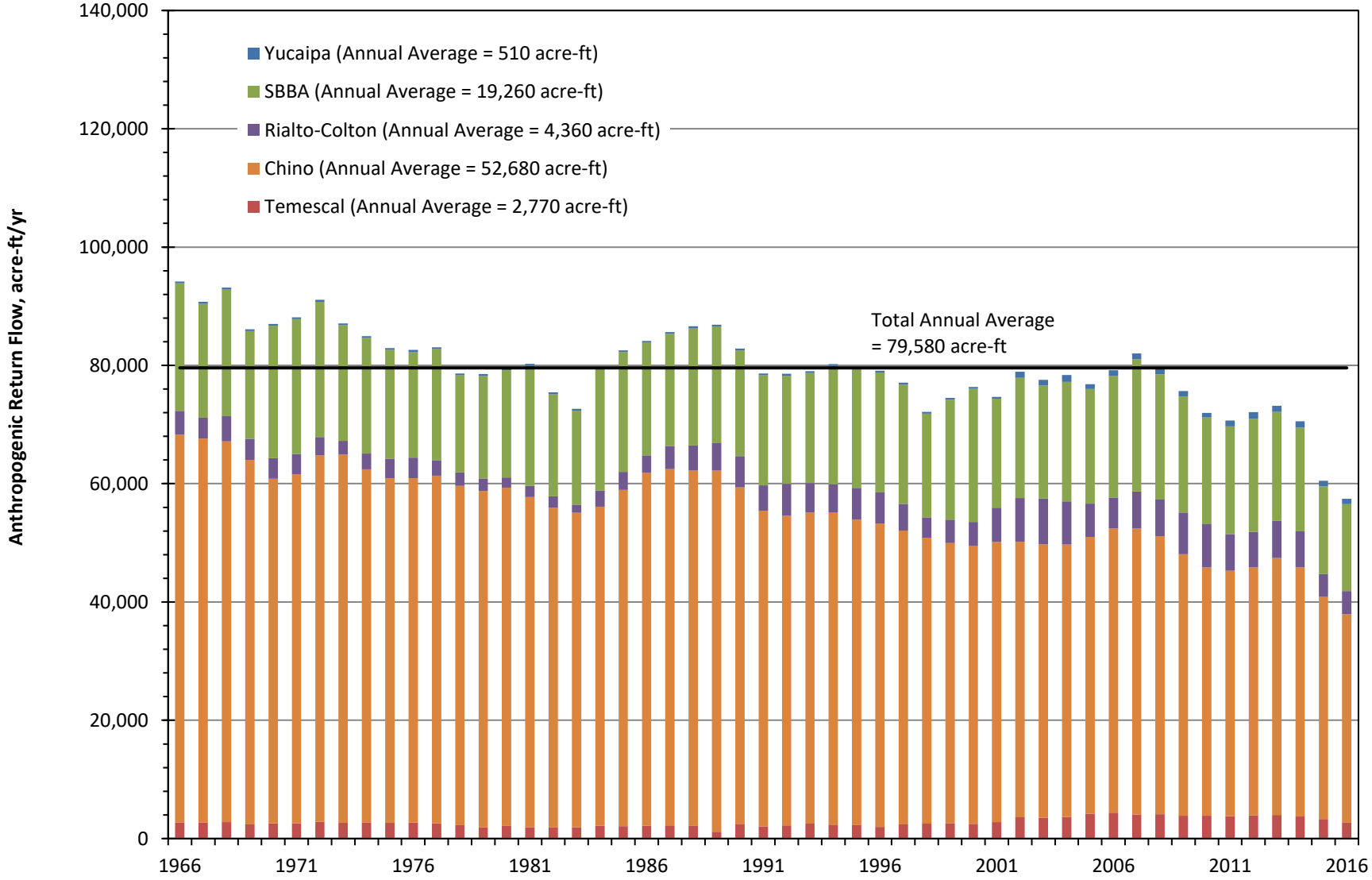

Figure 19

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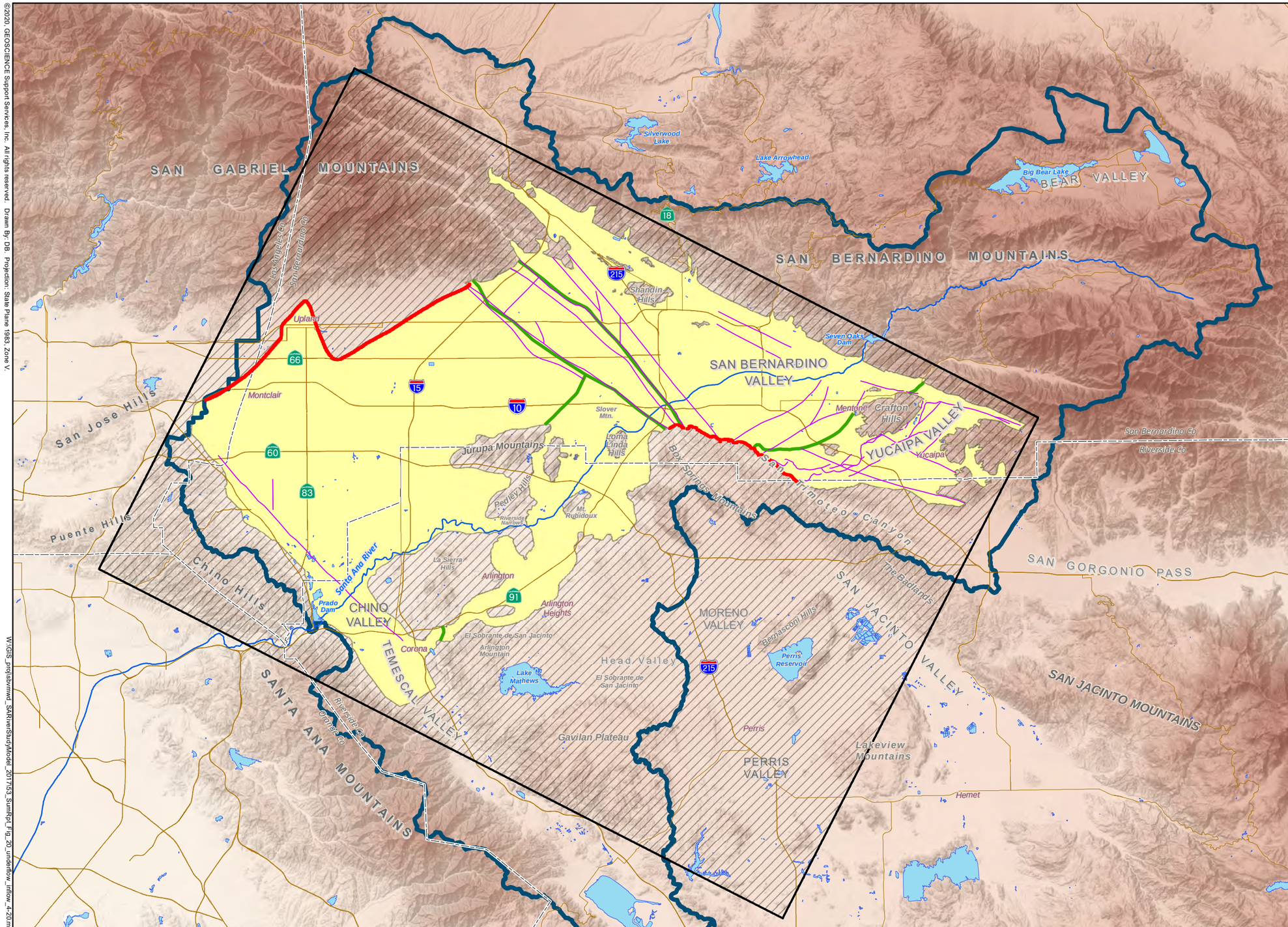

EXPLANATION

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Location of Underflow Inflow From Outside of the Groundwater Basin
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

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Miles

LOCATION OF UNDERFLOW INFLOW

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UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 20

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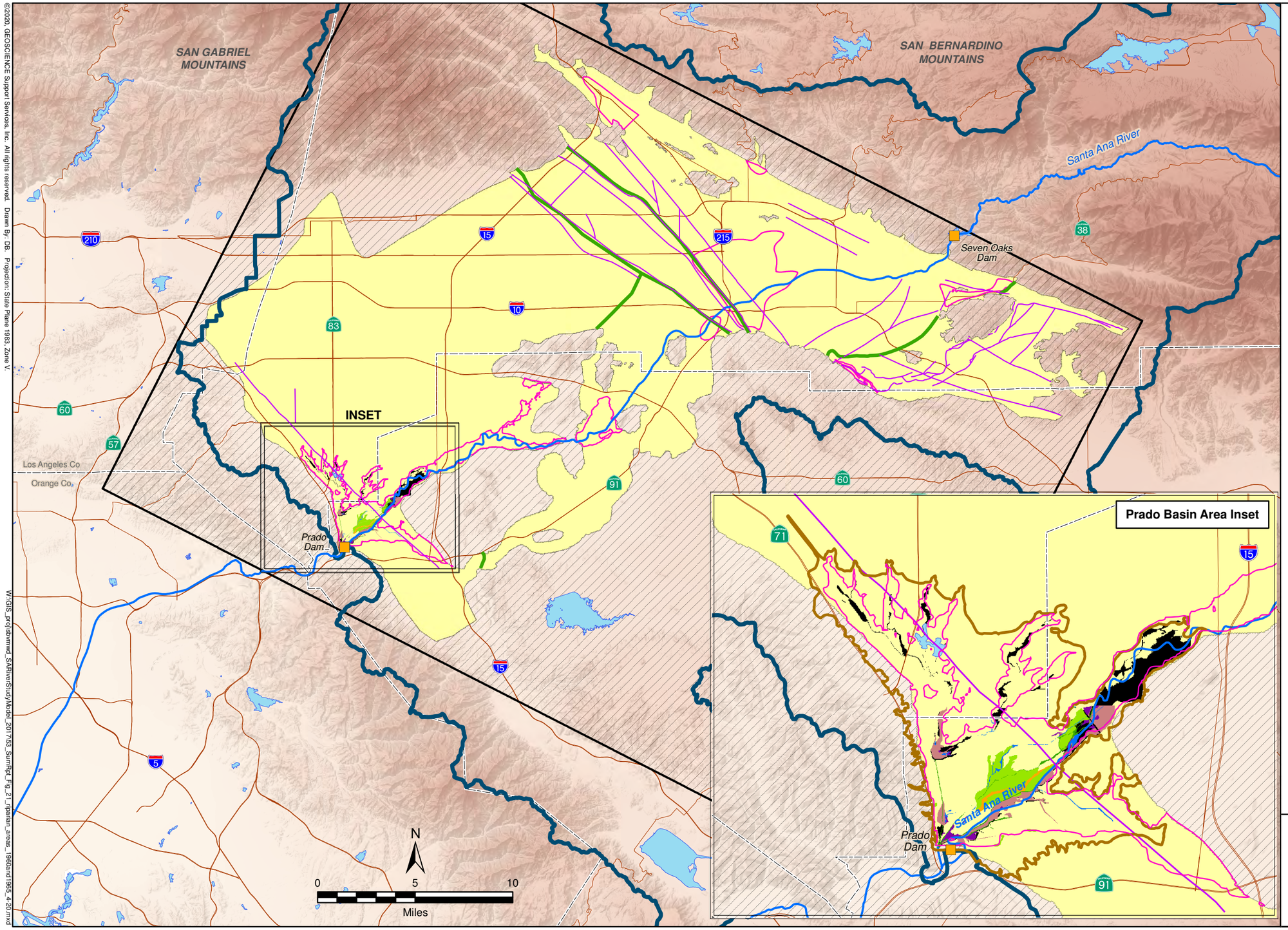

EXPLANATION

1965 Riparian Vegetation (Aspen)

- Deep-Rooted Riparian
- Giant Reed
- Obligate Wetland
- Open Water
- Shallow-Rooted Riparian
- Transitional Riparian
- Unvegetated Sandy Wash

- 1960 Total Riparian Extent (WEI,2017)

- Area of Shallow Groundwater (<20 ft) (Sources:
  1. Chino Basin and Riverside-Arlington Area BGW, 2018 - Based on post-1999 water level data from NWIS, CA DWR, and perennial streams from the NHD.
  2. SBBA Area - Matti and Carson, 1991 - Based on highest water level from 1973-1983.
  3. Yucaipa Model Area - GEOSCIENCE, 2017 - Based on high water levels and extent of riparian vegetation)
- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Prado Basin Area (WEI, 2004)
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

RIPARIAN AREA IN 1960 AND 1965 FOR THE INTEGRATED SAR MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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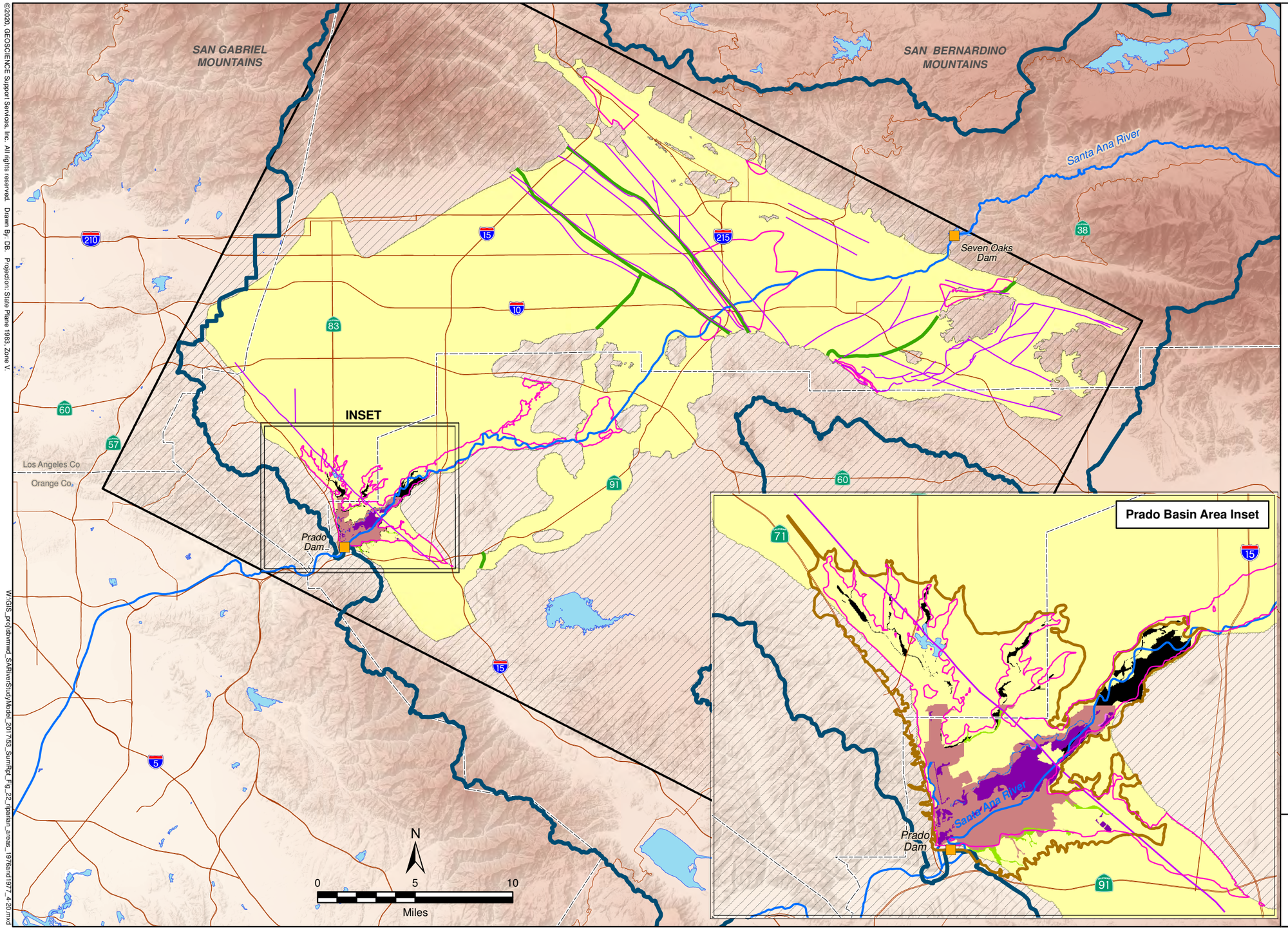
FIGURE 21

GEOSCIENCE



EXPLANATION

1976 Riparian Vegetation (Aspen)

- Deep-Rooted Riparian
- Giant Reed
- Obligate Wetland
- Open Water
- Shallow-Rooted Riparian
- Transitional Riparian
- Unvegetated Sandy Wash

1977 Total Riparian Extent (WEI,2017)

Area of Shallow Groundwater (<20 ft) (Sources:
1. Chino Basin and Riverside-Arlington Area BGW, 2018 - Based on post-1999 water level data from NWIS, CA DWR, and perennial streams from the NHD.
2. SBBA Area - Matti and Carson, 1991 - Based on highest water level from 1973-1983.
3. Yucaipa Model Area - GEOSCIENCE, 2017 - Based on high water levels and extent of riparian vegetation)

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Prado Basin Area (WEI, 2004)
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

RIPARIAN AREA IN 1976 AND 1977 FOR THE INTEGRATED SAR MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 22

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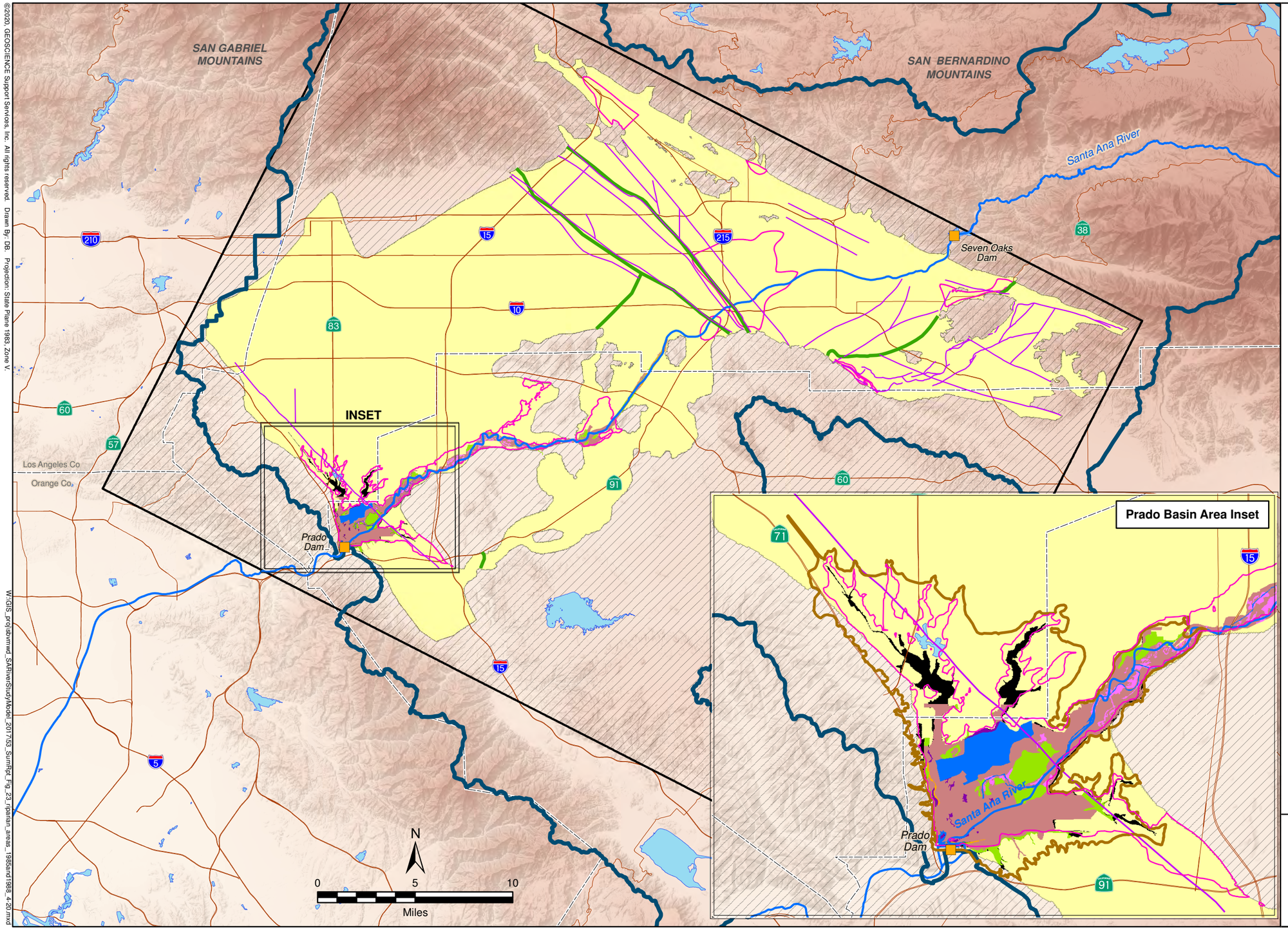

EXPLANATION

1988 Riparian Vegetation (Aspen)

- Deep-Rooted Riparian
- Giant Reed
- Obligate Wetland
- Open Water
- Shallow-Rooted Riparian
- Transitional Riparian
- Unvegetated Sandy Wash

1985 Total Riparian Extent (WEI,2017)

Area of Shallow Groundwater (<20 ft) (Sources:
1. Chino Basin and Riverside-Arlington Area BGW, 2018 - Based on post-1999 water level data from NWIS, CA DWR, and perennial streams from the NHD.
2. SBBA Area - Matti and Carson, 1991 - Based on highest water level from 1973-1983.
3. Yucaipa Model Area - GEOSCIENCE, 2017 - Based on high water levels and extent of riparian vegetation)

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Prado Basin Area (WEI, 2004)
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

RIPARIAN AREA IN 1985 AND 1988 FOR THE INTEGRATED SAR MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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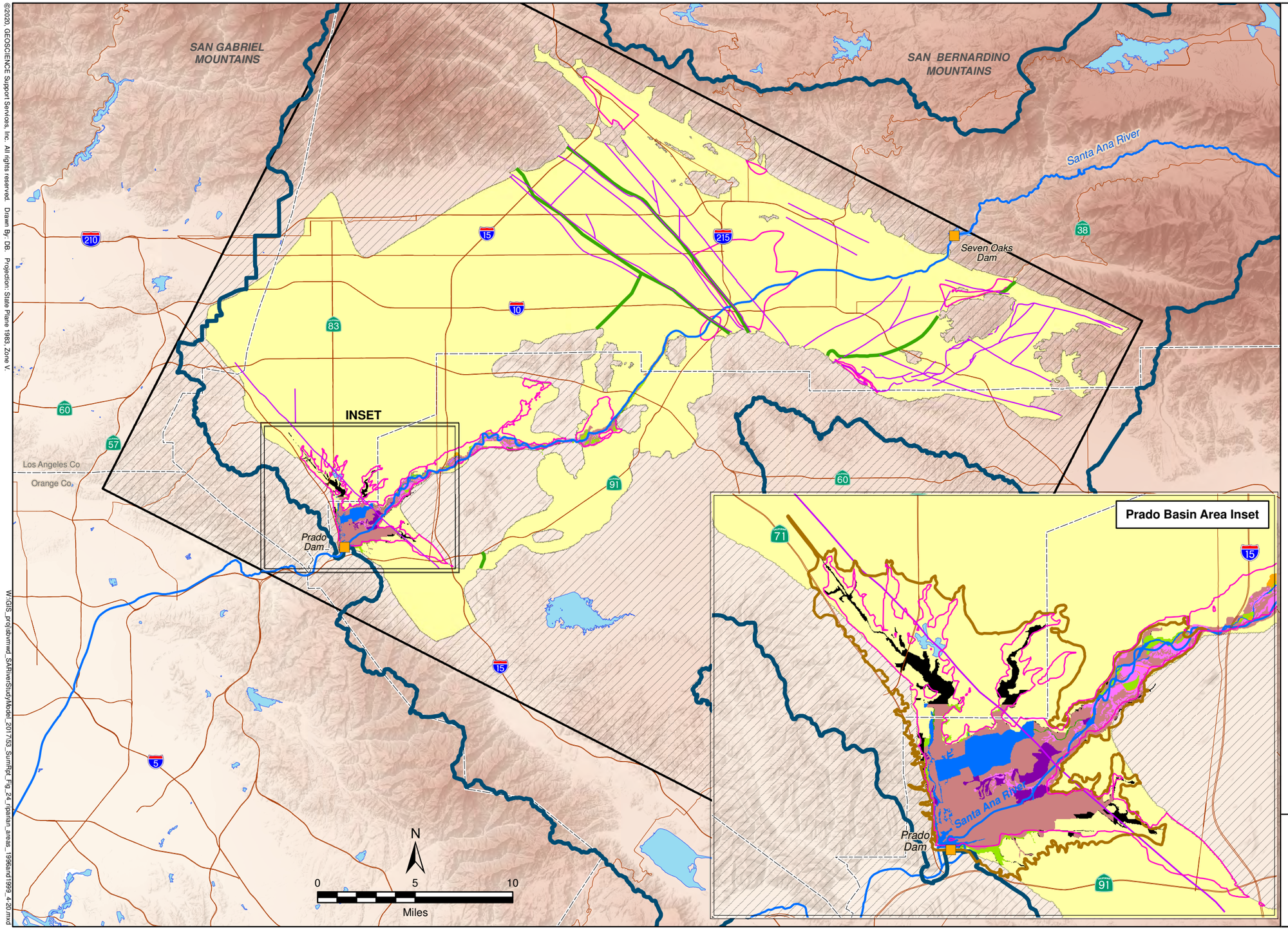
FIGURE 23

GEOSCIENCE



EXPLANATION

1996 Riparian Vegetation (Aspen)

- Deep-Rooted Riparian
- Giant Reed
- Obligate Wetland
- Open Water
- Shallow-Rooted Riparian
- Transitional Riparian
- Unvegetated Sandy Wash

1999 Total Riparian Extent (WEI,2017)

Area of Shallow Groundwater (<20 ft) (Sources:
1. Chino Basin and Riverside-Arlington Area BGW, 2018 - Based on post-1999 water level data from NWIS, CA DWR, and perennial streams from the NHD.
2. SBBA Area - Matti and Carson, 1991 - Based on highest water level from 1973-1983.
3. Yucaipa Model Area - GEOSCIENCE, 2017 - Based on high water levels and extent of riparian vegetation)

- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Prado Basin Area (WEI, 2004)
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

RIPARIAN AREA IN 1996 AND 1999 FOR THE INTEGRATED SAR MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 24

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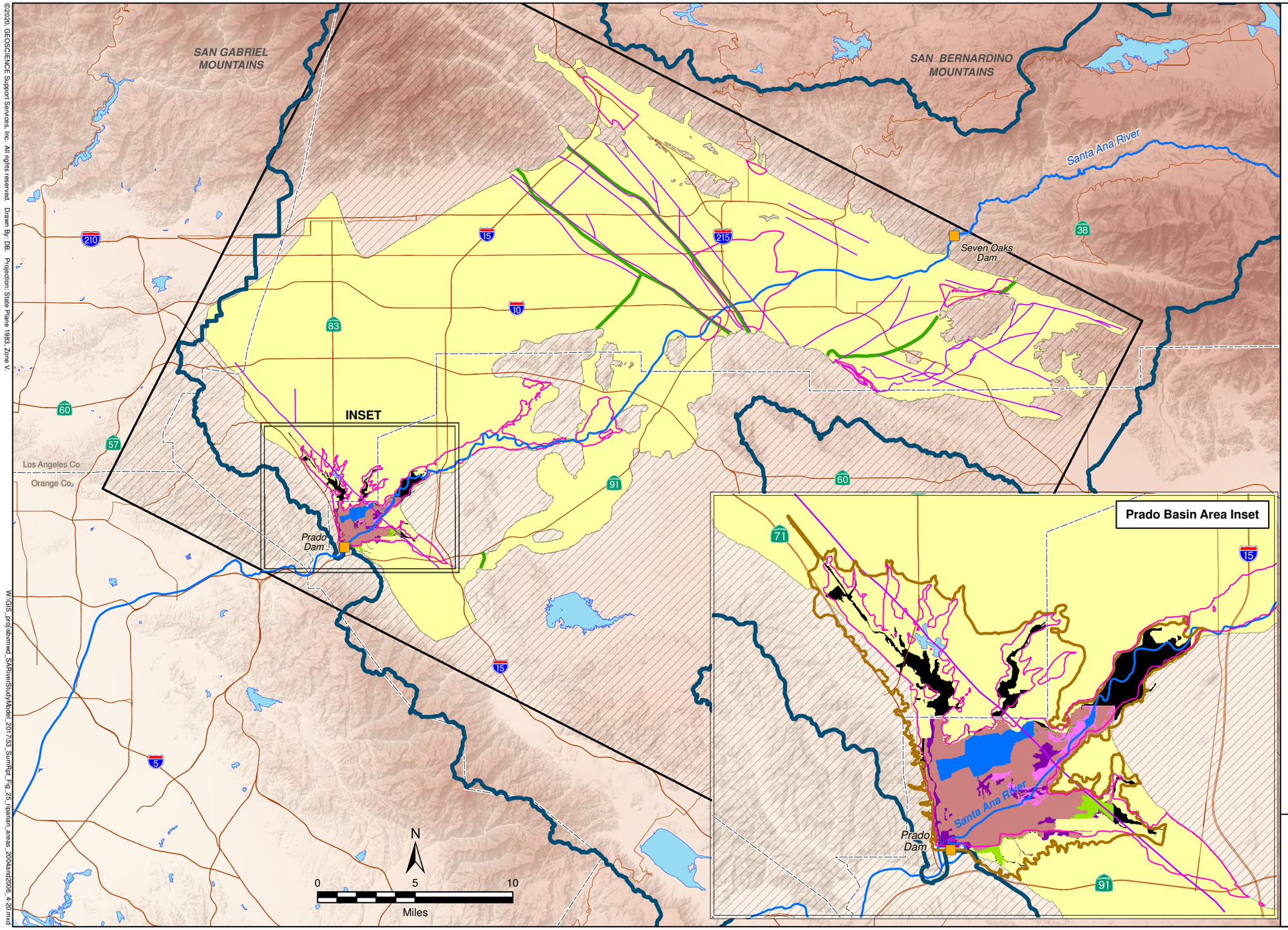

EXPLANATION

2004 Riparian Vegetation (Aspen)

- Deep-Rooted Riparian
- Giant Reed
- Obligate Wetland
- Open Water
- Shallow-Rooted Riparian
- Transitional Riparian
- Unvegetated Sandy Wash

- 2006 Total Riparian Extent (WEI,2017)

- Area of Shallow Groundwater (<20 ft) (Sources:
  1. Chino Basin and Riverside-Arlington Area BGW, 2018 - Based on post-1999 water level data from NWIS, CA DWR, and perennial streams from the NHD.
  2. SBBA Area - Matti and Carson, 1991 - Based on highest water level from 1973-1983.
  3. Yucaipa Model Area - GEOSCIENCE, 2017 - Based on high water levels and extent of riparian vegetation)
- Upper Santa Ana River Watershed Boundary
- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Prado Basin Area (WEI, 2004)
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

RIPARIAN AREA IN 2004 AND 2006 FOR THE INTEGRATED SAR MODEL

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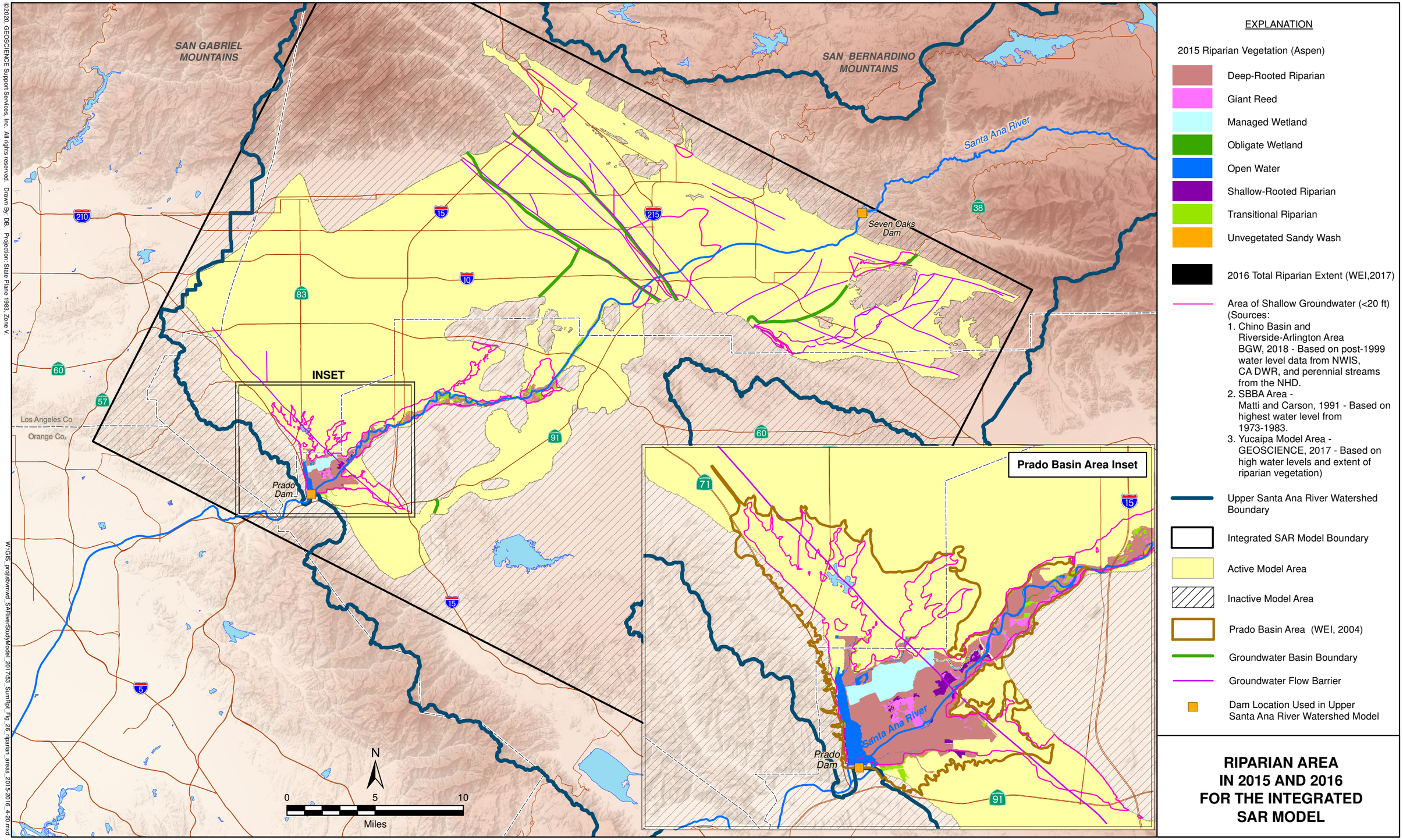

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 26

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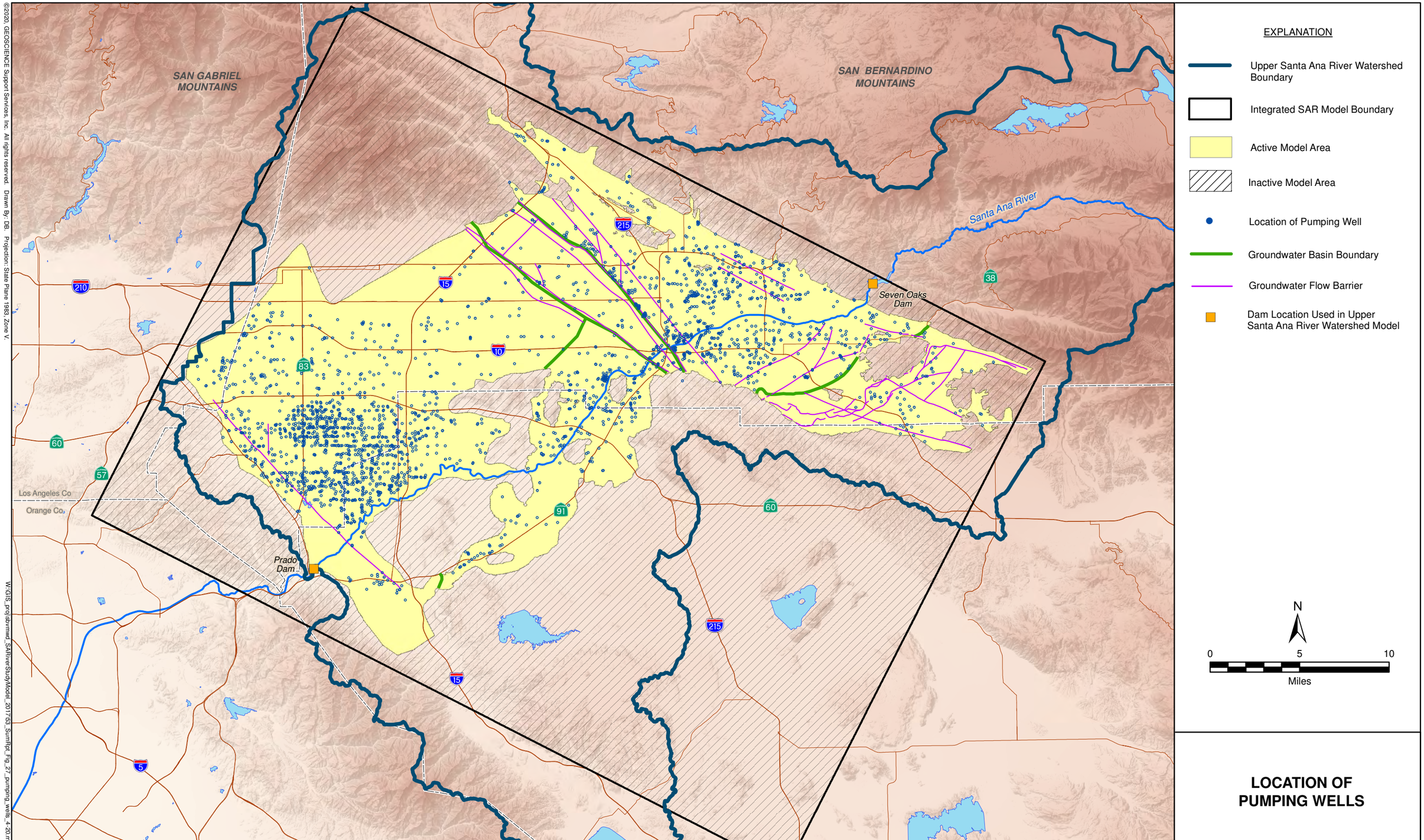

LOCATION OF PUMPING WELLS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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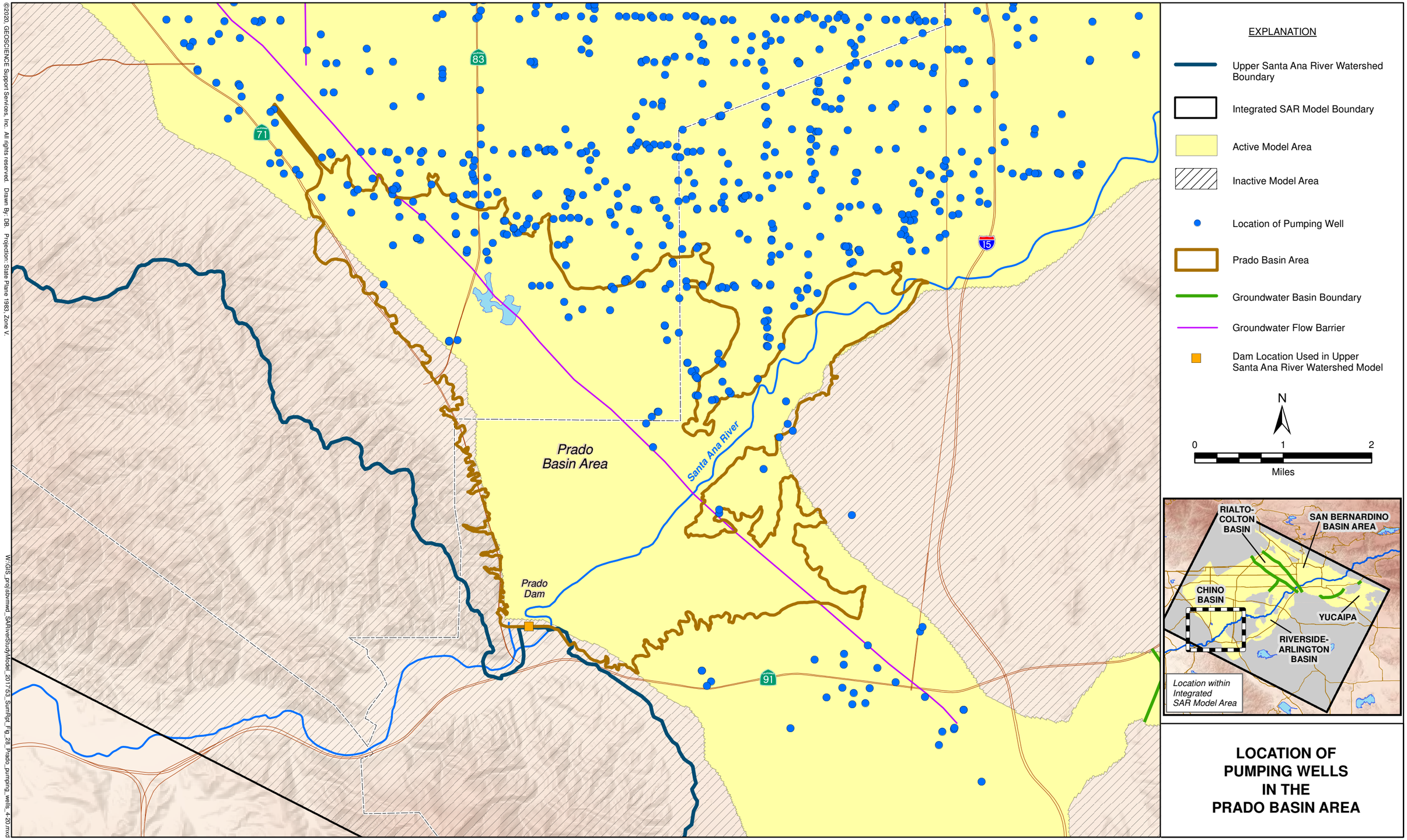
FIGURE 27

GEOSCIENCE



LOCATION OF PUMPING WELLS IN THE PRADO BASIN AREA

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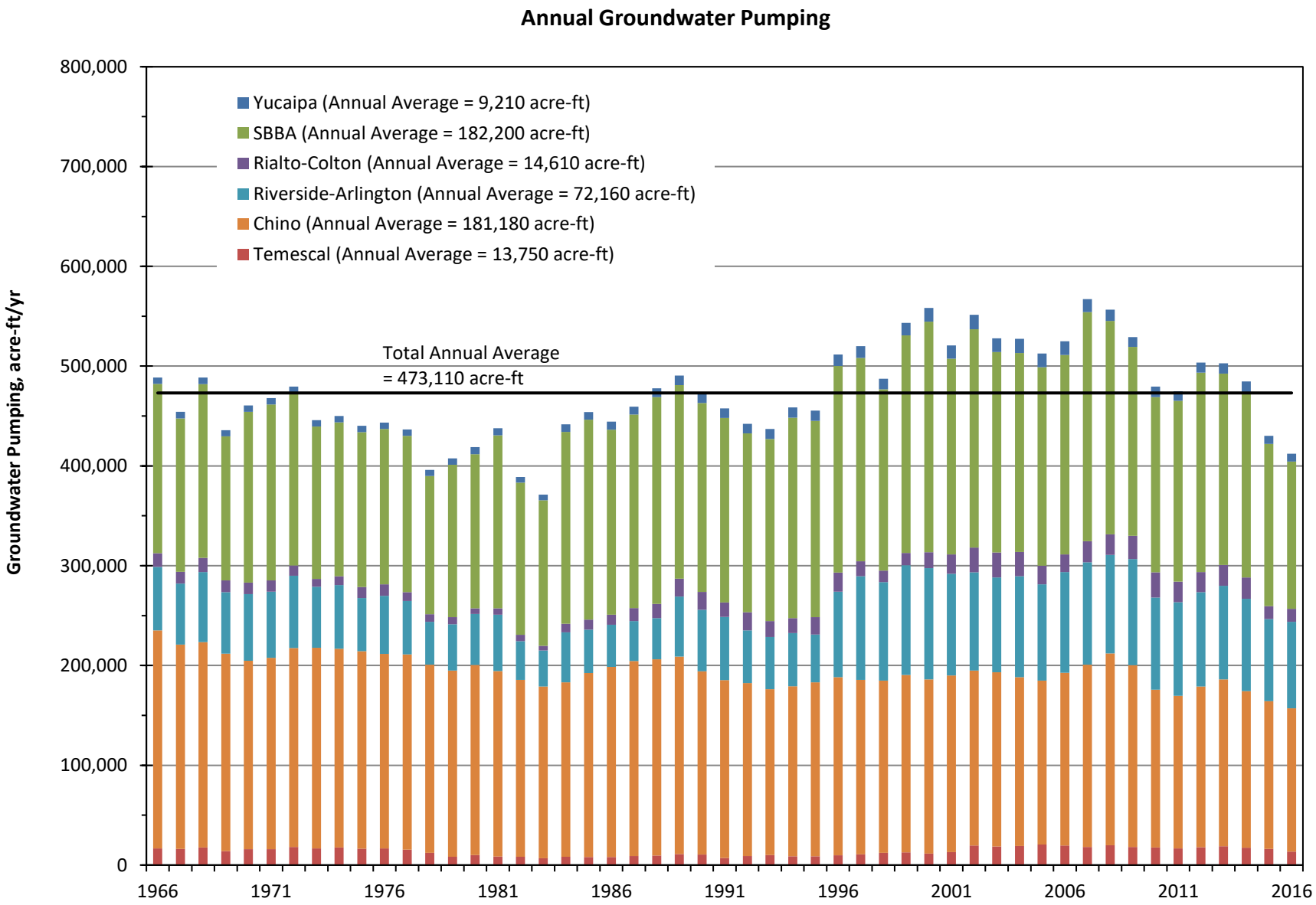
Annual Groundwater Pumping
Yucaipa (Annual Average = 9,210 acre-ft)
SBBA (Annual Average = 182,200 acre-ft)
Rialto-Colton (Annual Average = 14,610 acre-ft)
Riverside-Arlington (Annual Average = 72,160 acre-ft)
Chino (Annual Average = 181,180 acre-ft)
Temescal (Annual Average = 13,750 acre-ft)
Total Annual Average
= 473,110 acre-ft
Groundwater Pumping, acre-ft/yr
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 29

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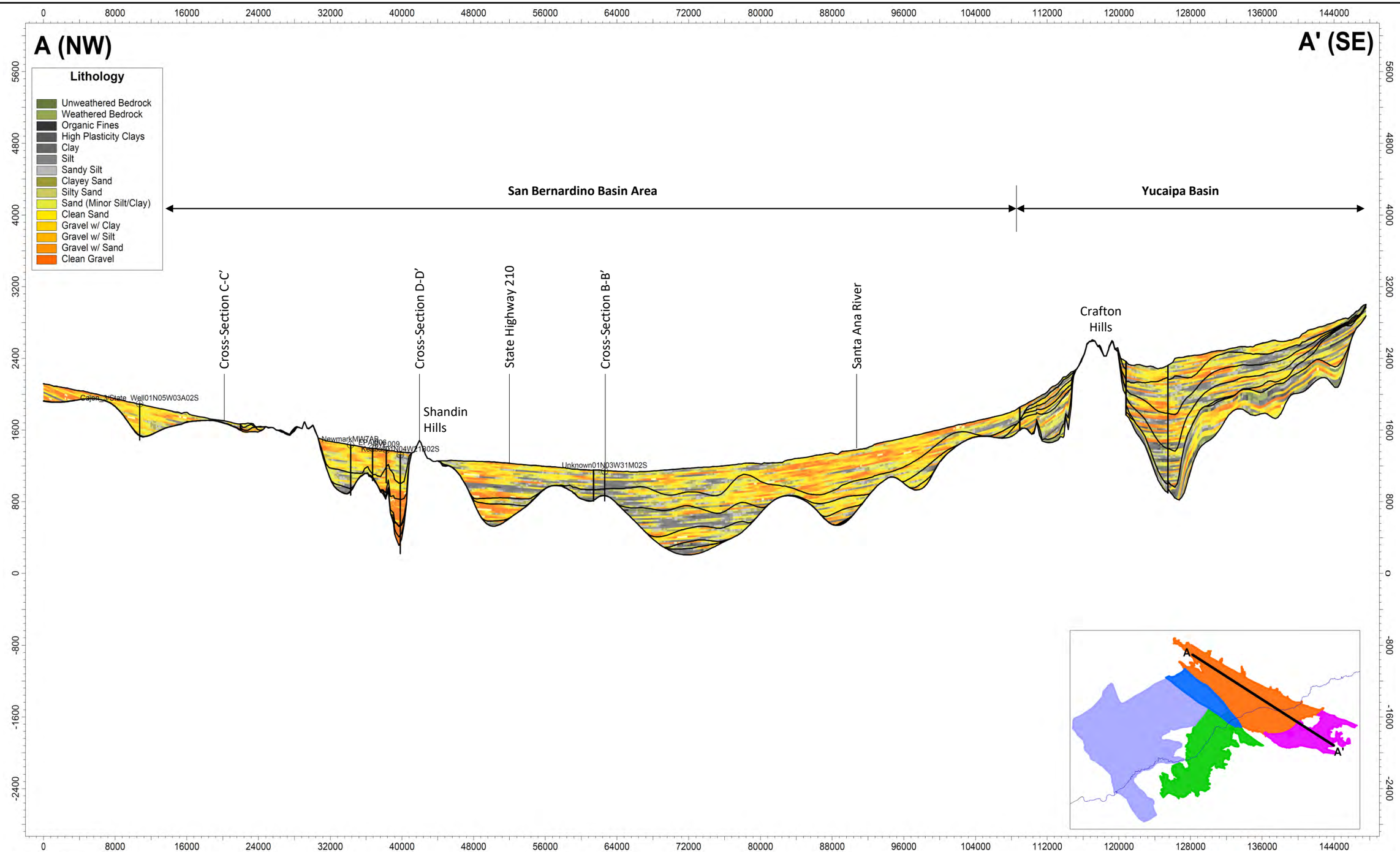

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

LITHOLOGIC CROSS-SECTION A-A'

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

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FIGURE 30

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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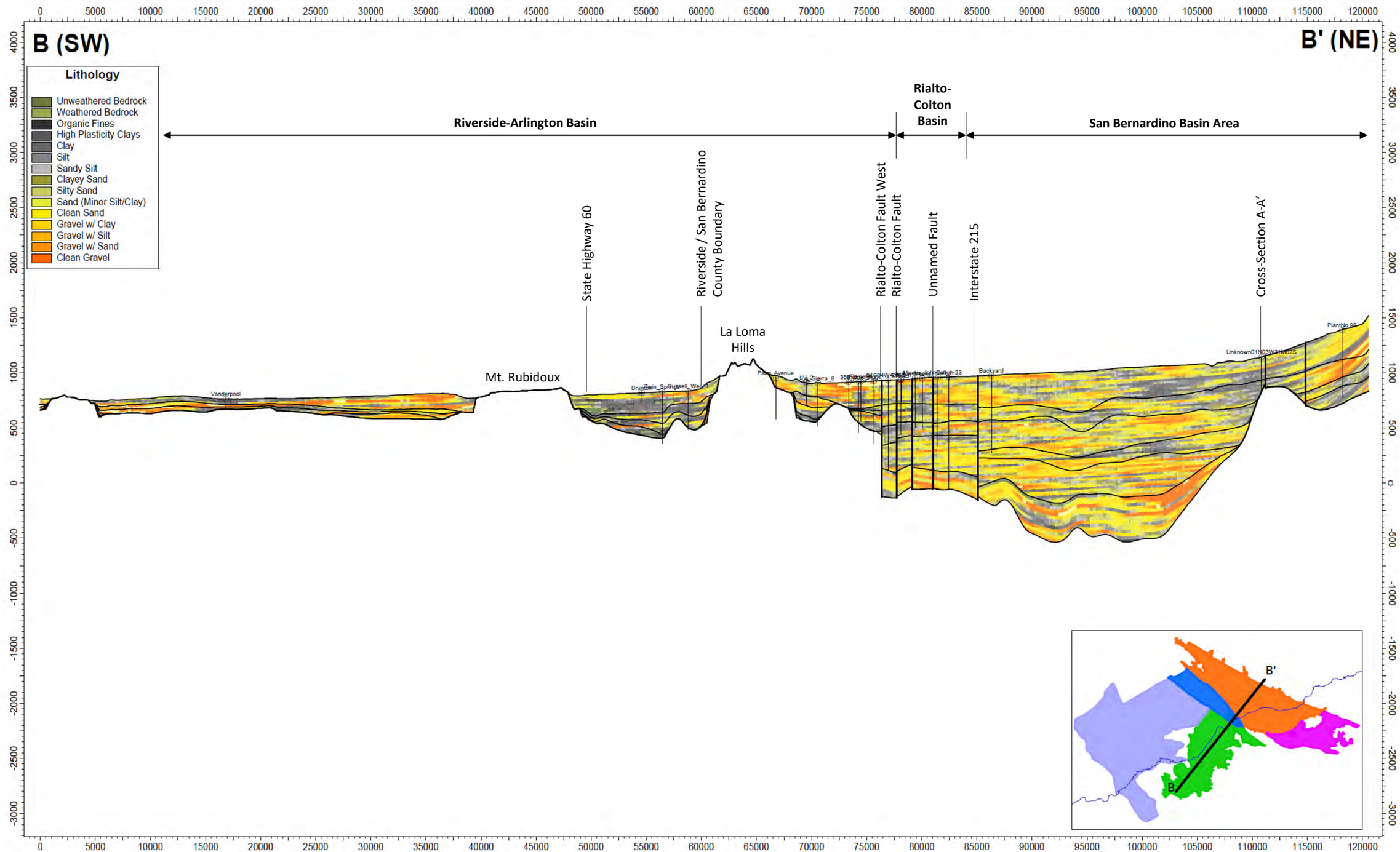

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

LITHOLOGIC CROSS-SECTION B-B'

10-Apr-20

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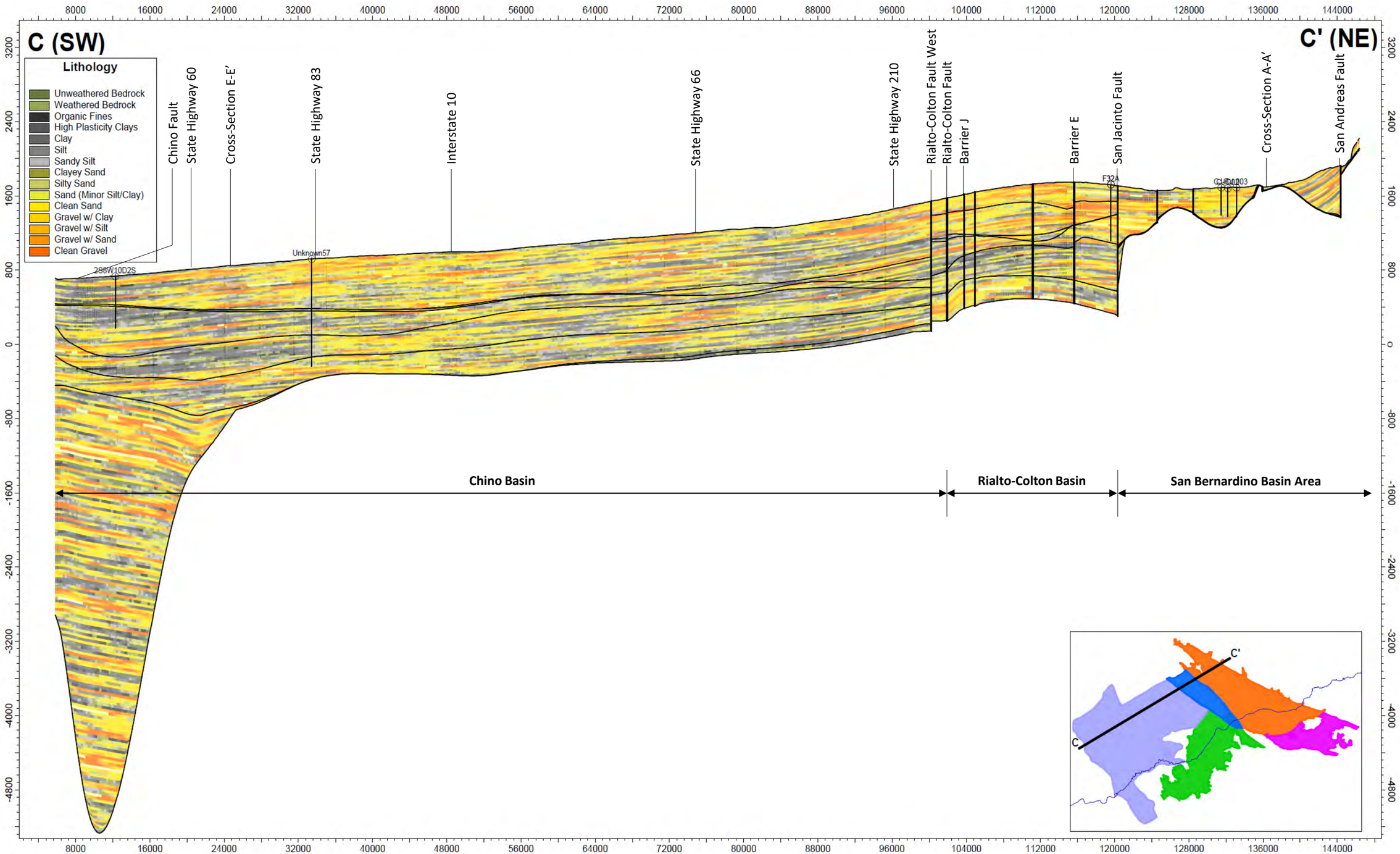

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

LITHOLOGIC CROSS-SECTION C-C'

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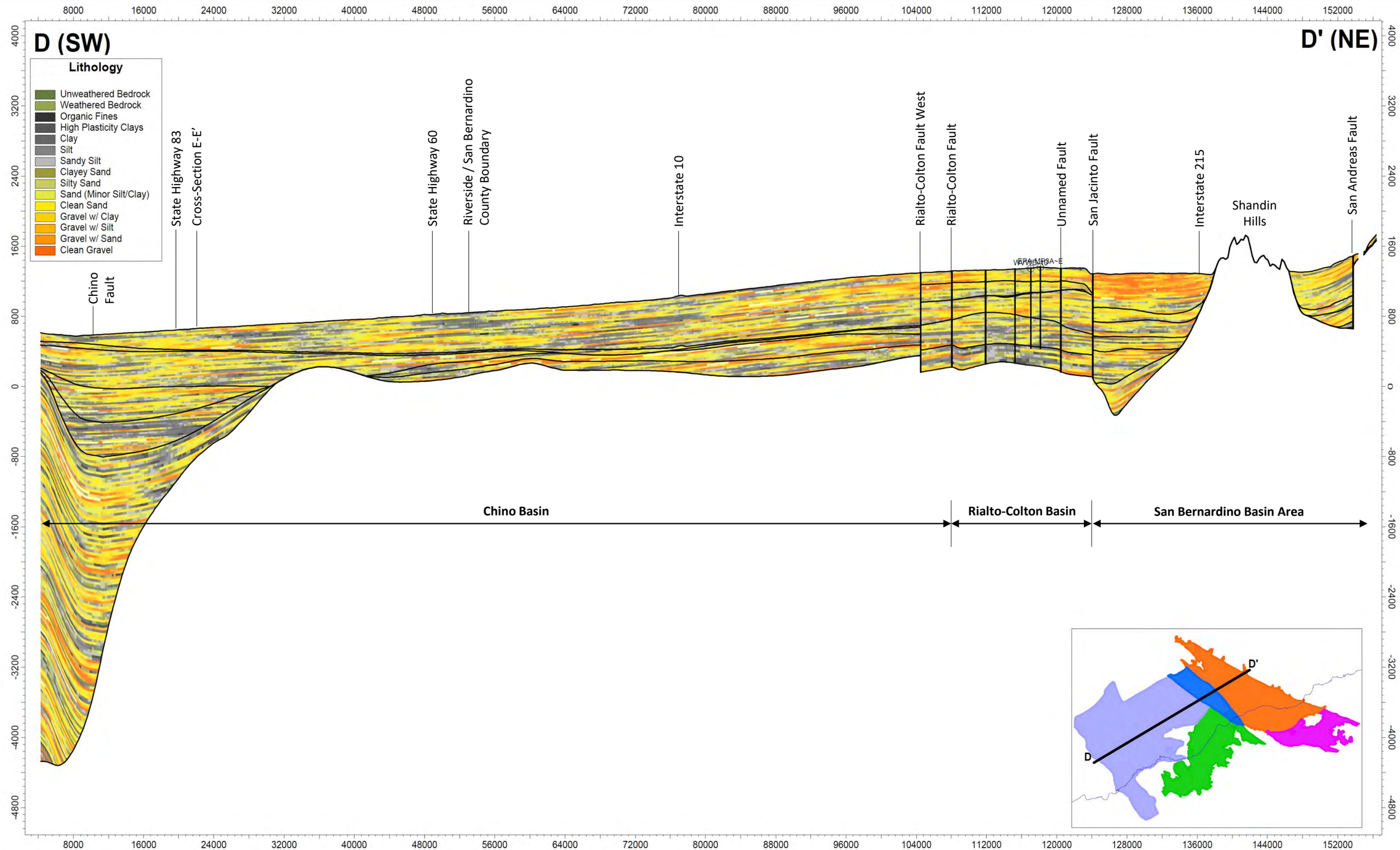

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

LITHOLOGIC CROSS-SECTION D-D'

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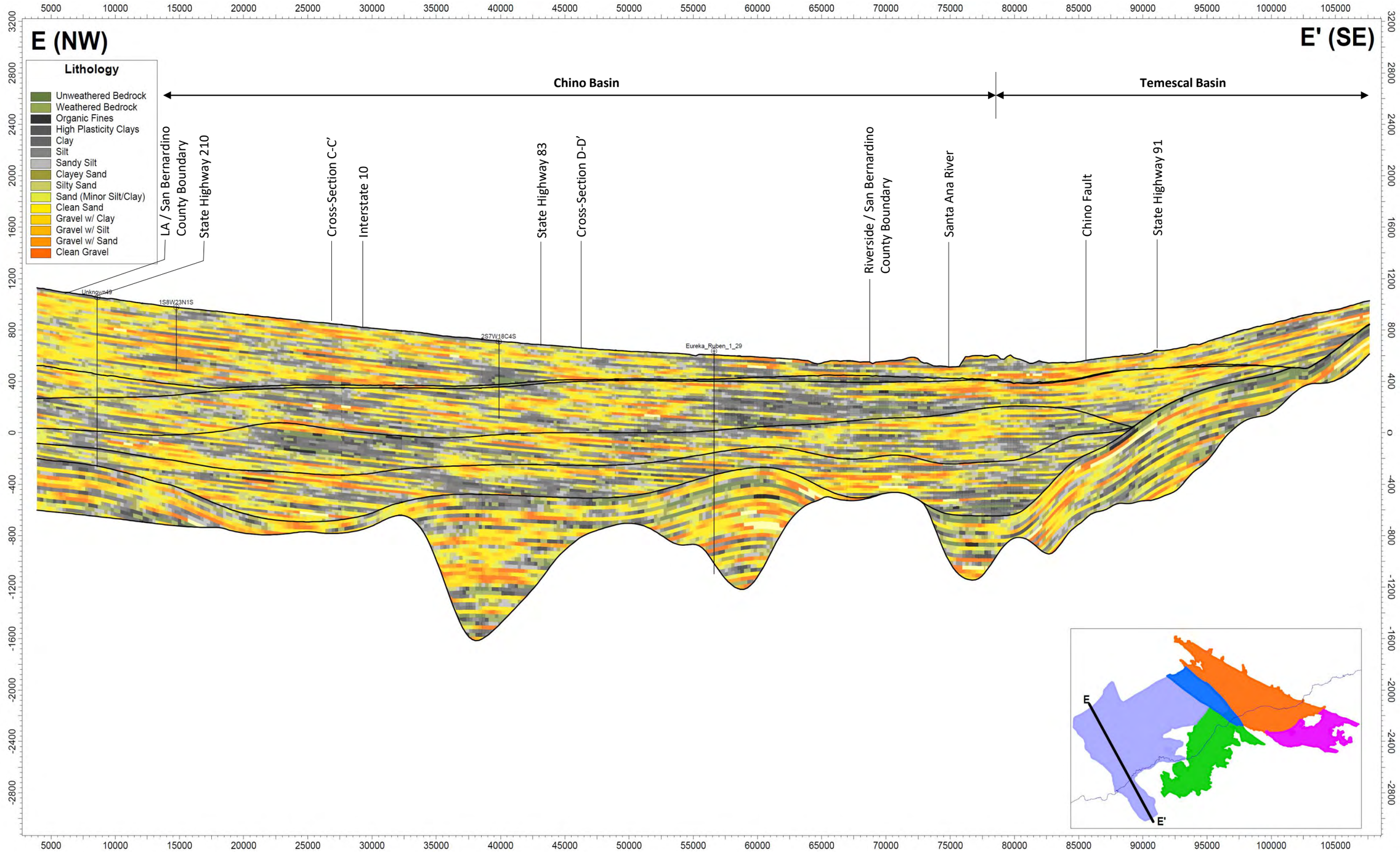

Z-Scale: 1:10
Well projection limit: 500'

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Geoinformation Management

LITHOLOGIC CROSS-SECTION E-E'

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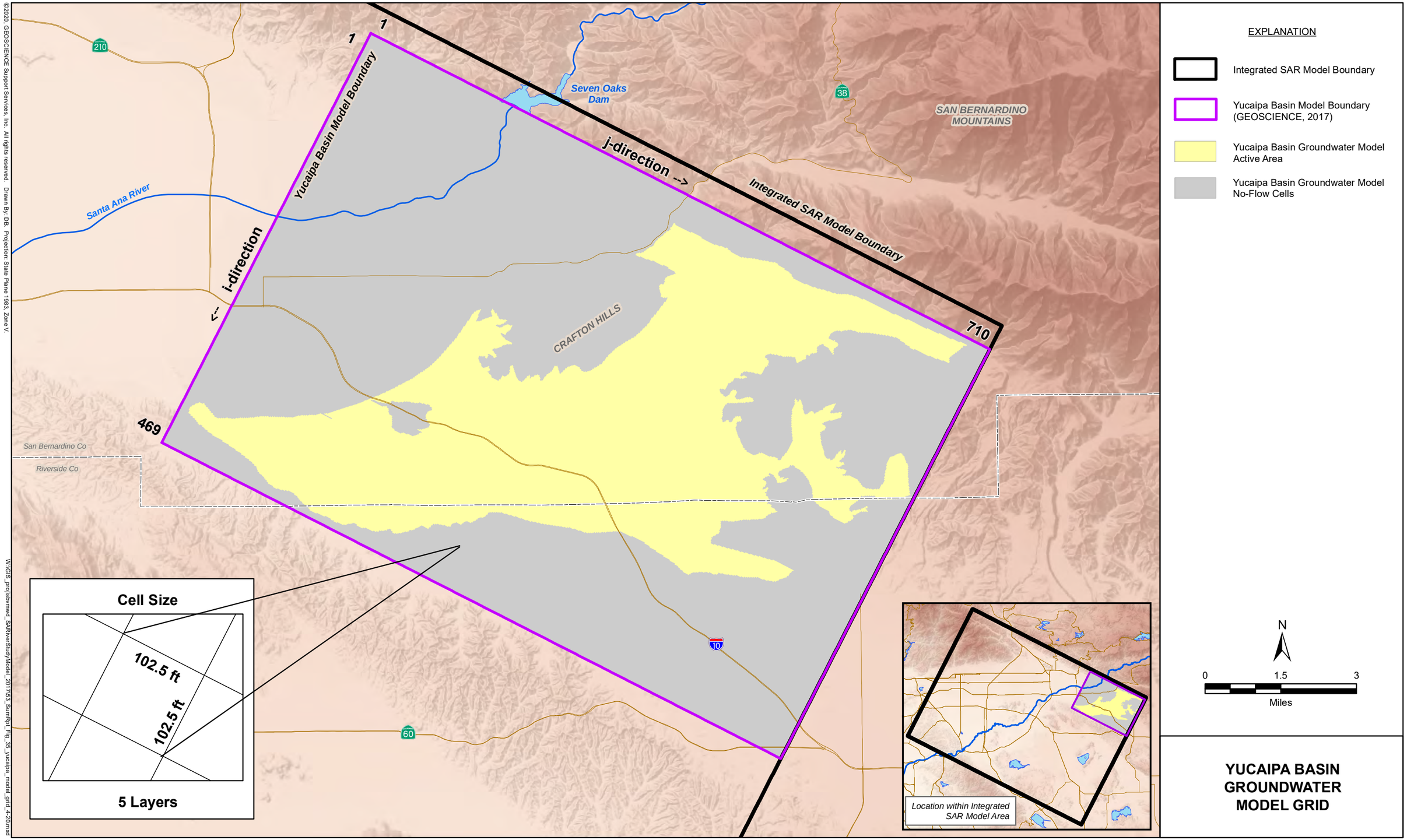

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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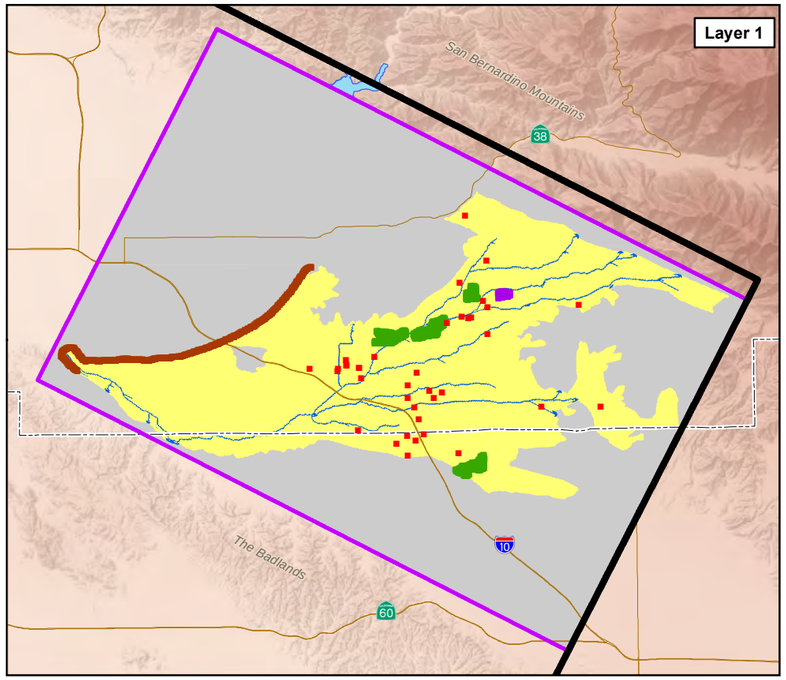
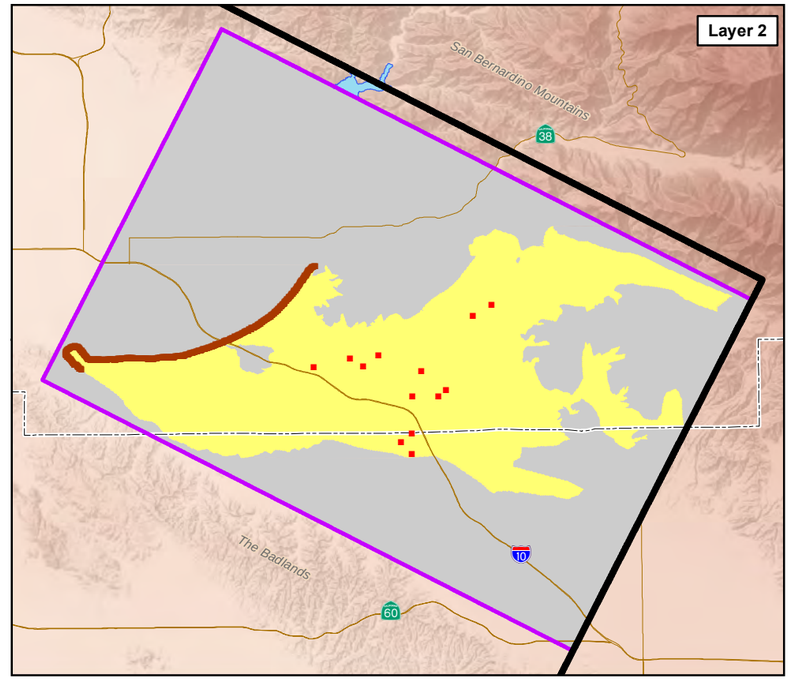
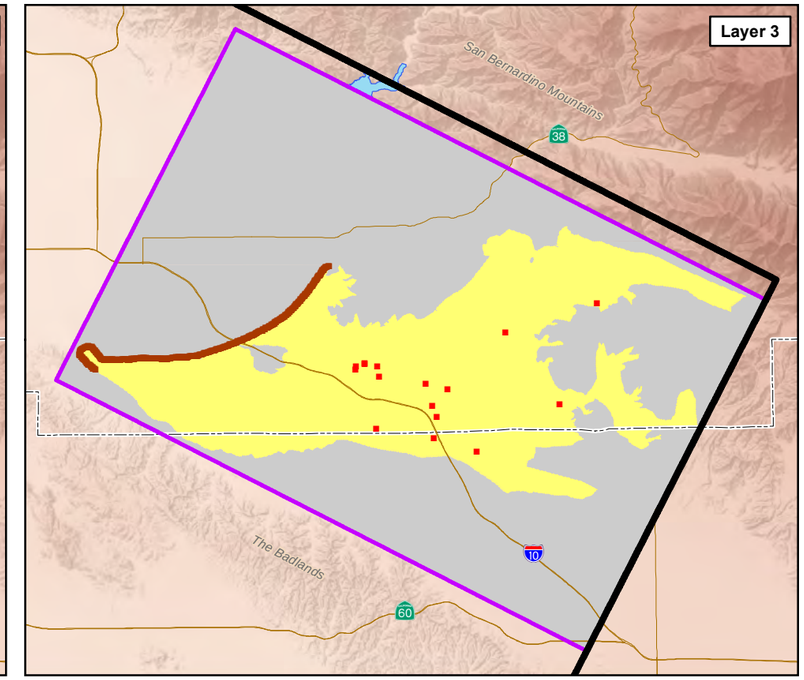
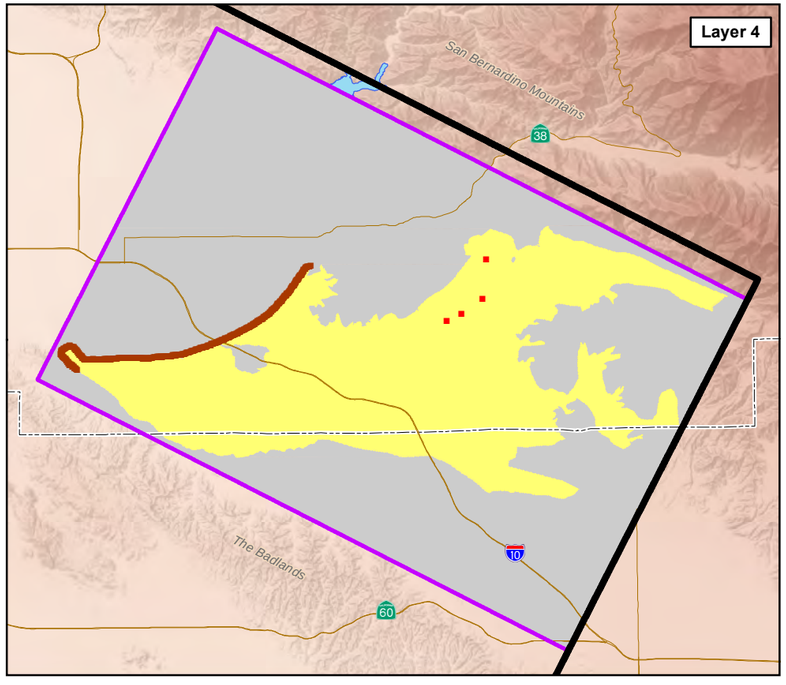
FIGURE 35

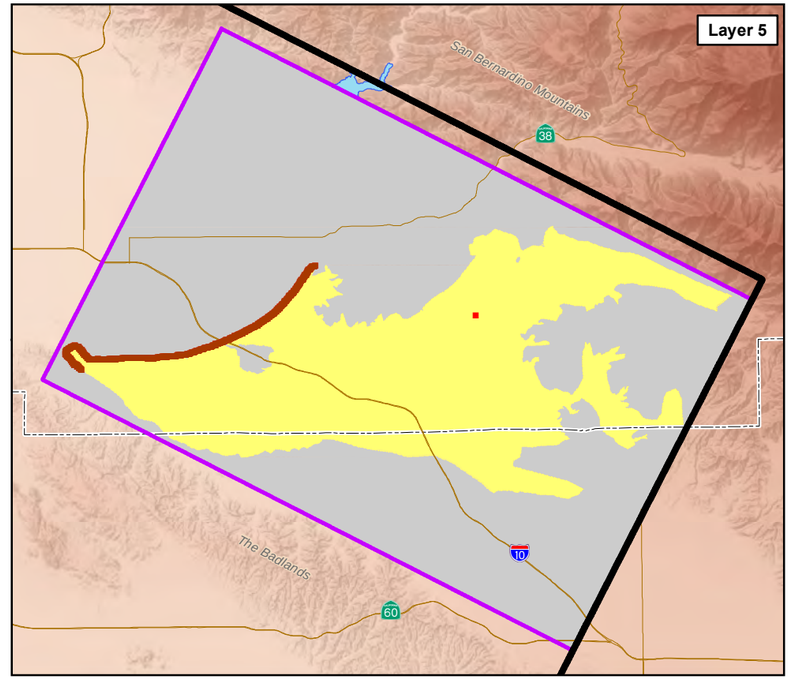
GEOSCIENCE









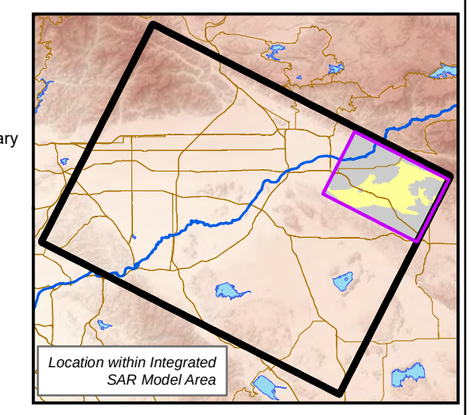


EXPLANATION

- Integrated SAR Model Boundary
- Yucaipa Basin Model Boundary (GEOSCIENCE, 2017)
- Active Model Cell
- No-Flow Cell
- Stream

Well (Specified Flux)

- Well Simulating Artificial Recharge
- Well Simulating Pumping
- Well Simulating Return Flow at Parks and Golf Courses
- Well Simulating Underflow Outflow



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0 3 6

Miles

BOUNDARY CONDITIONS OF THE YUCAIPA GROUNDWATER MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 36

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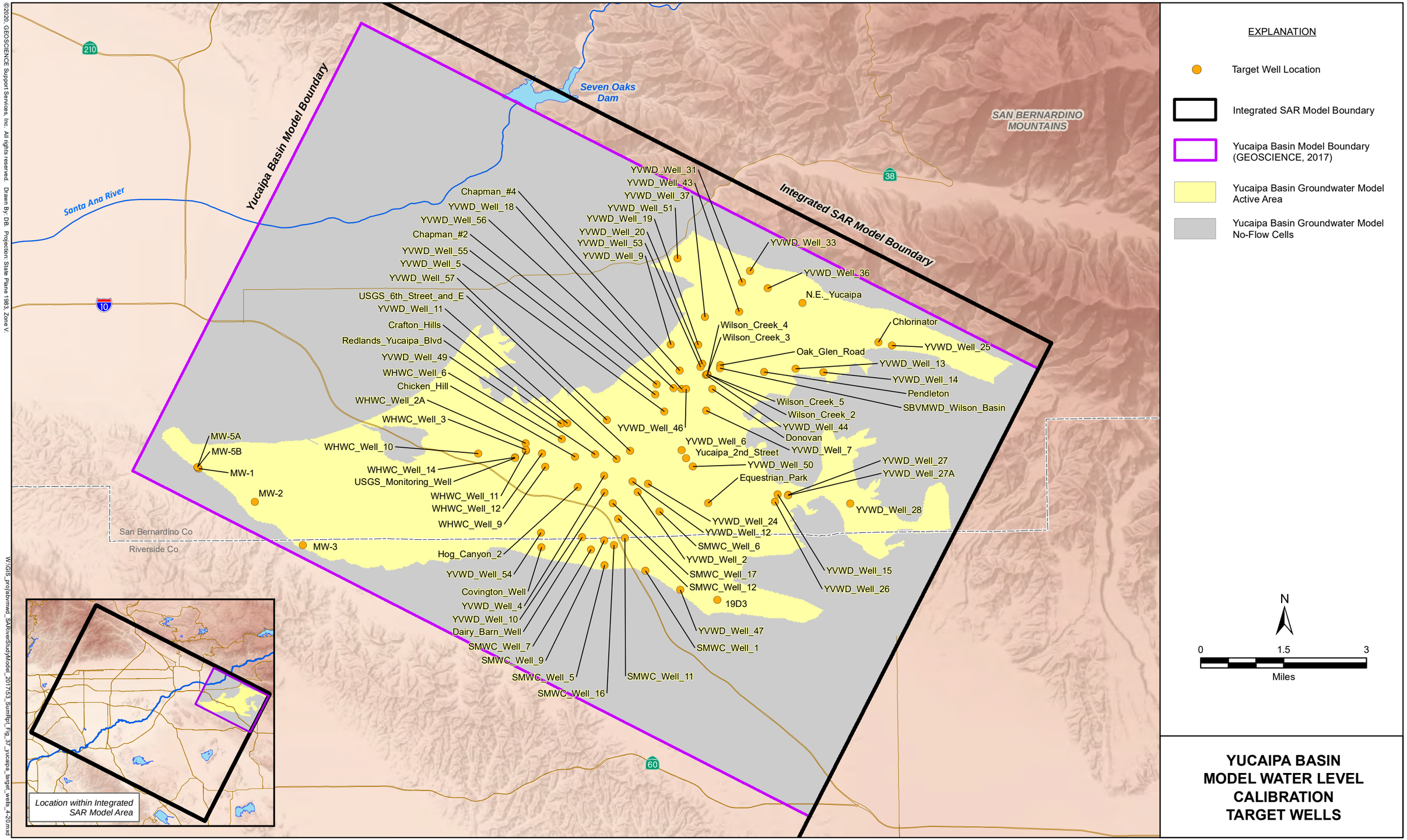

YUCAIPA BASIN MODEL WATER LEVEL CALIBRATION TARGET WELLS

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Scatterplot of Measured and Model-Simulated Water Level for the Yucaipa Basin Model 1966 to 2016

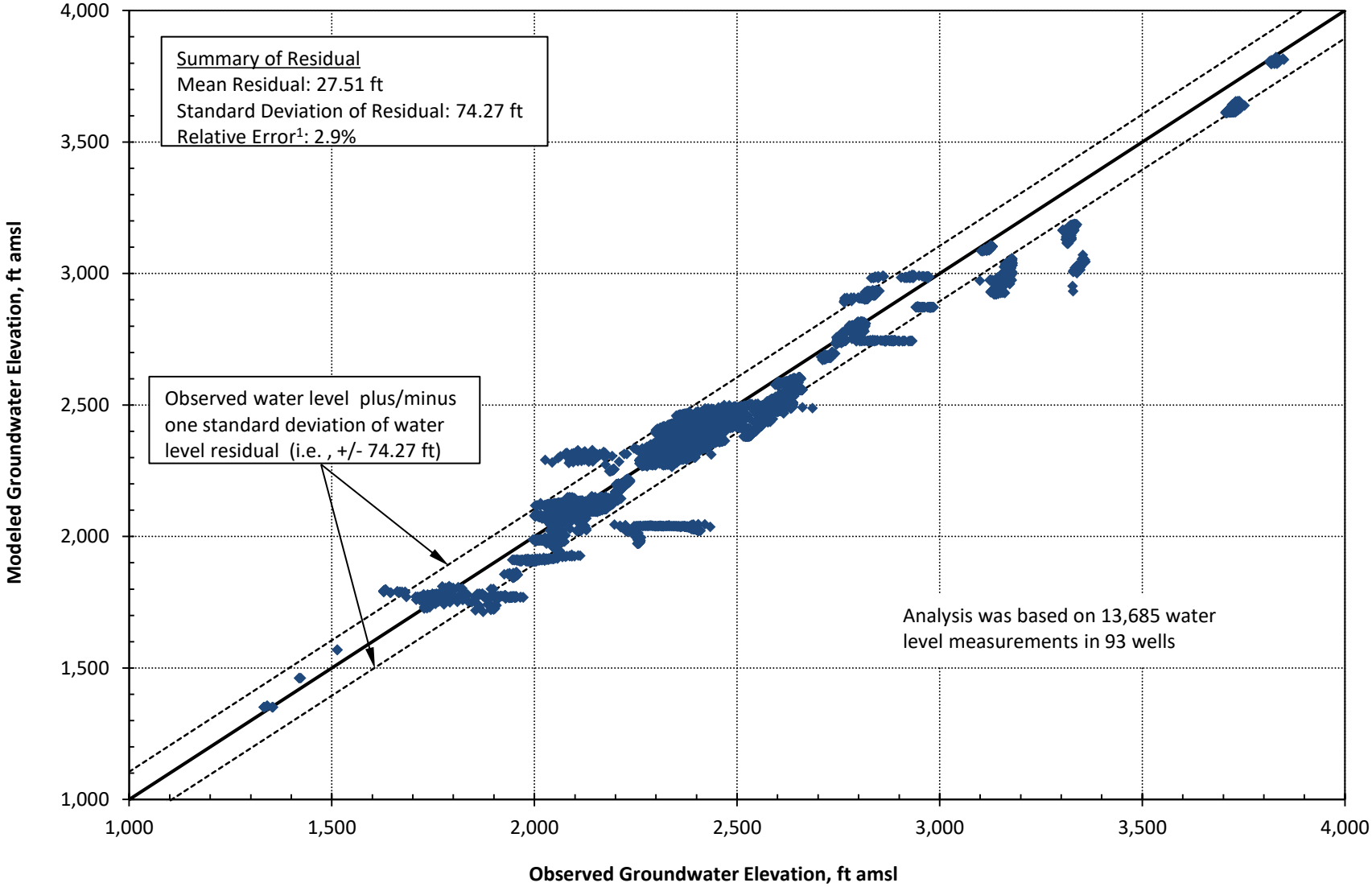

Figure 38

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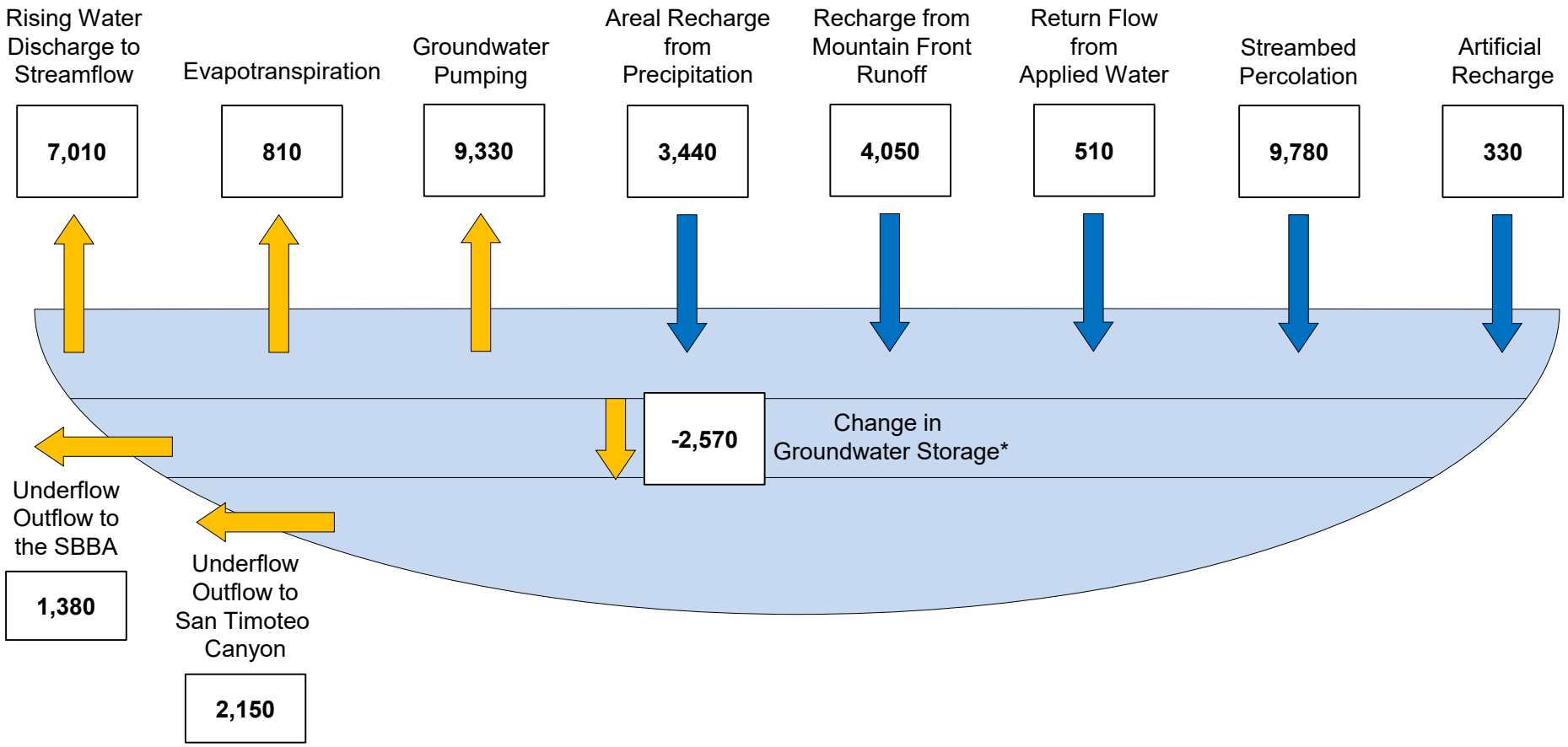

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR THE YUCAIPA BASIN MODEL 1966 to 2016

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Cumulative Annual Change in Groundwater Storage for the Yucaipa Basin Model
1966 - 2016

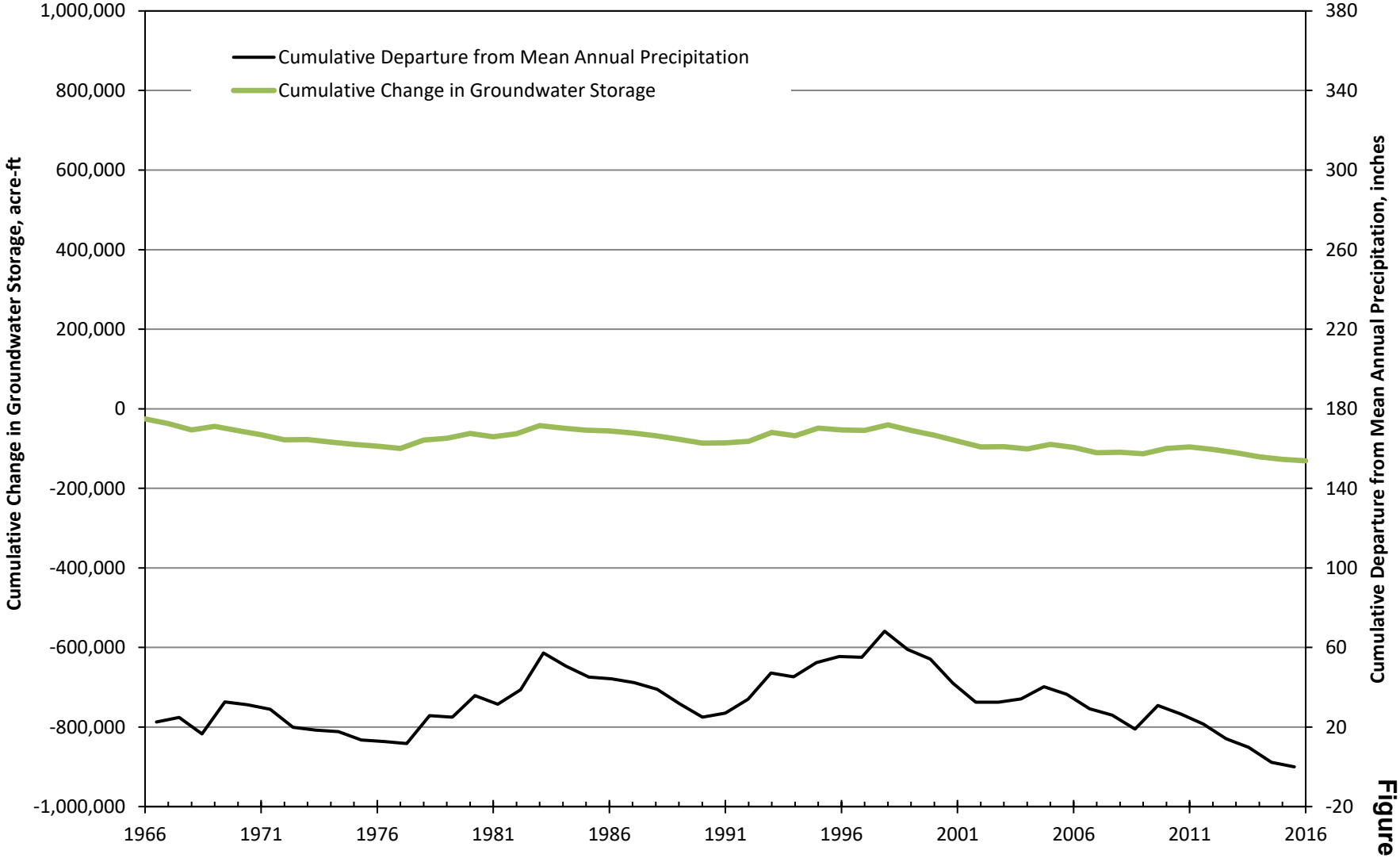
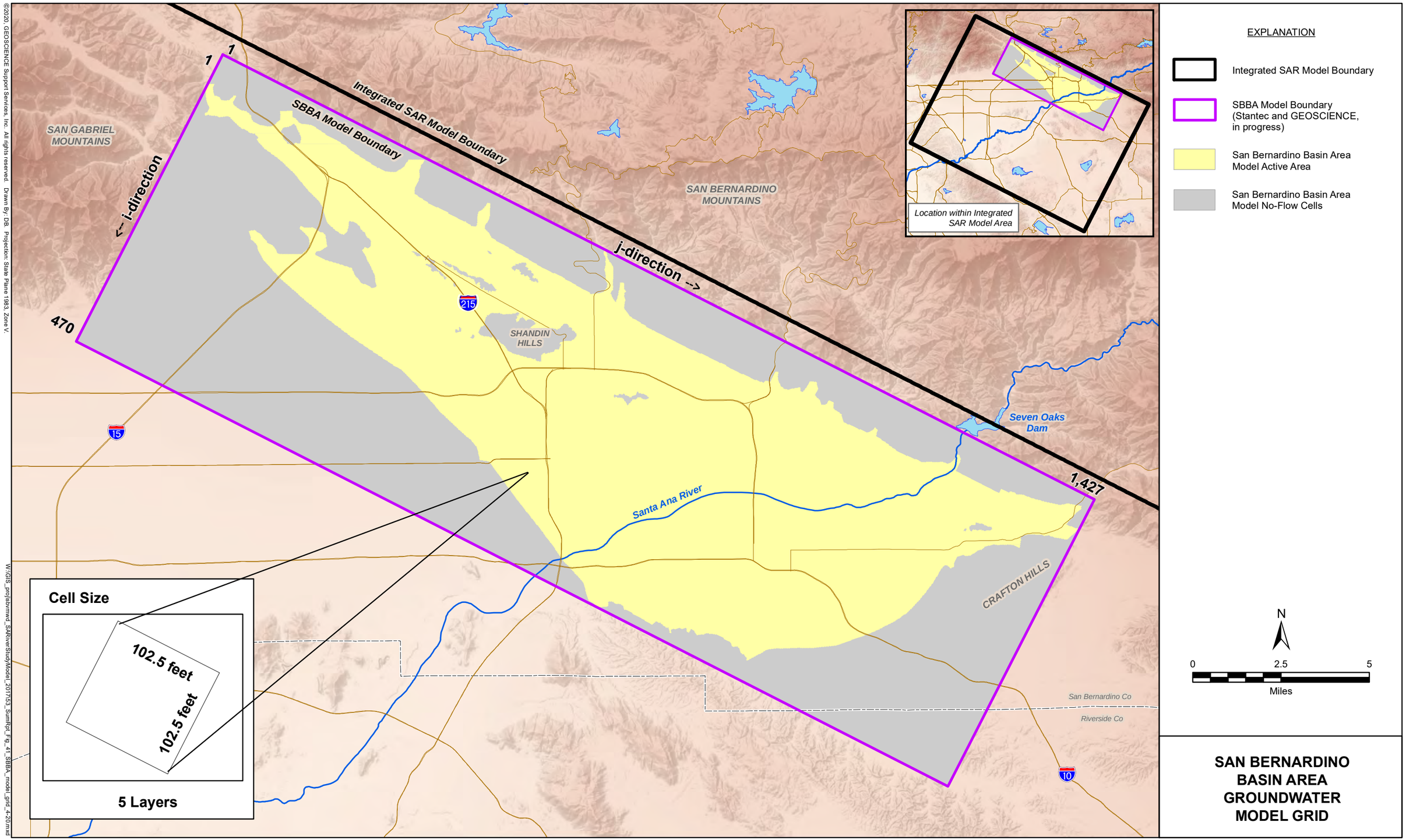


Figure 40



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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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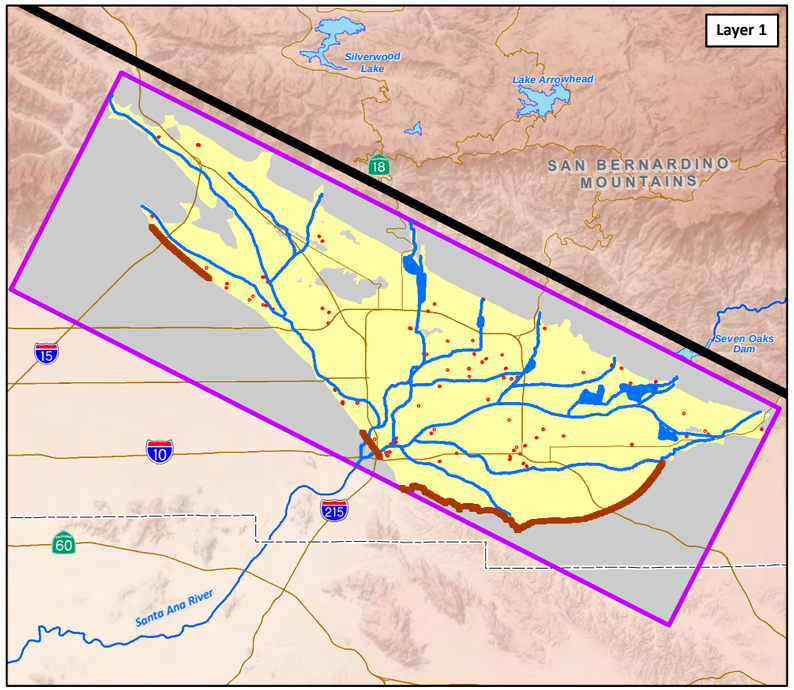
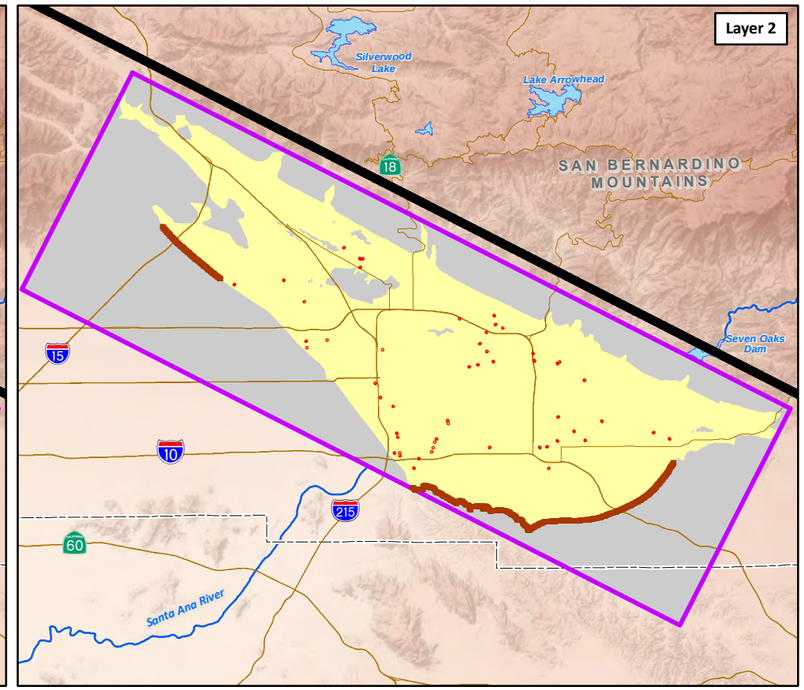
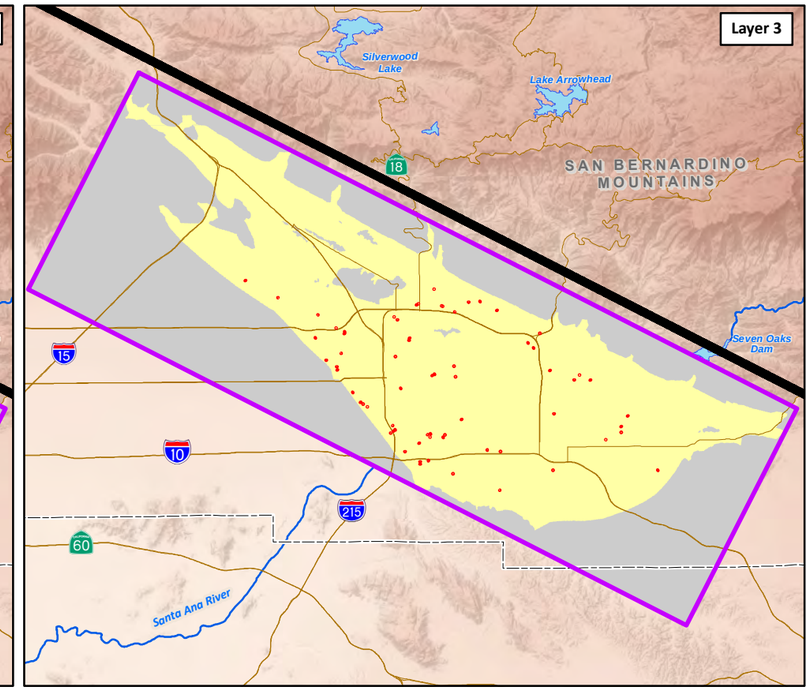
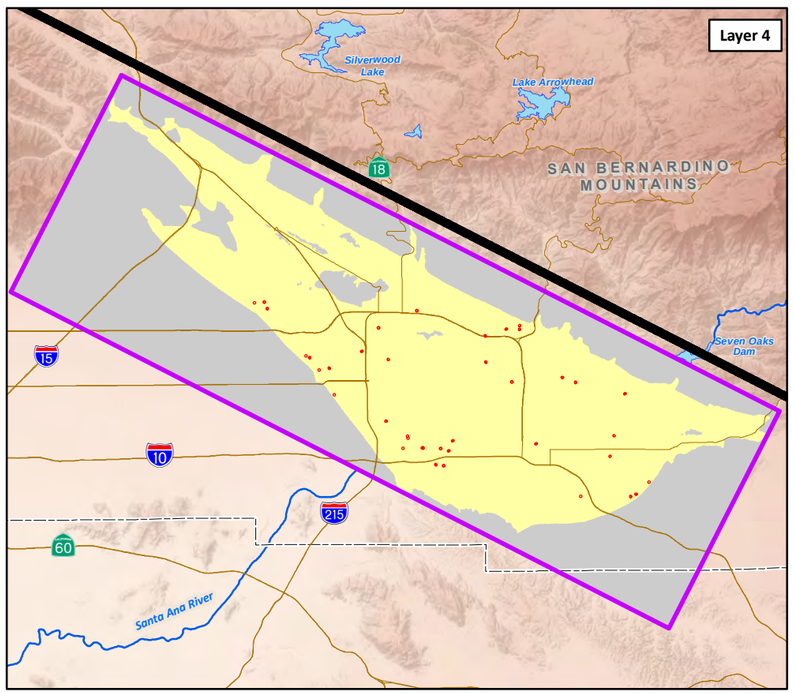
FIGURE 41

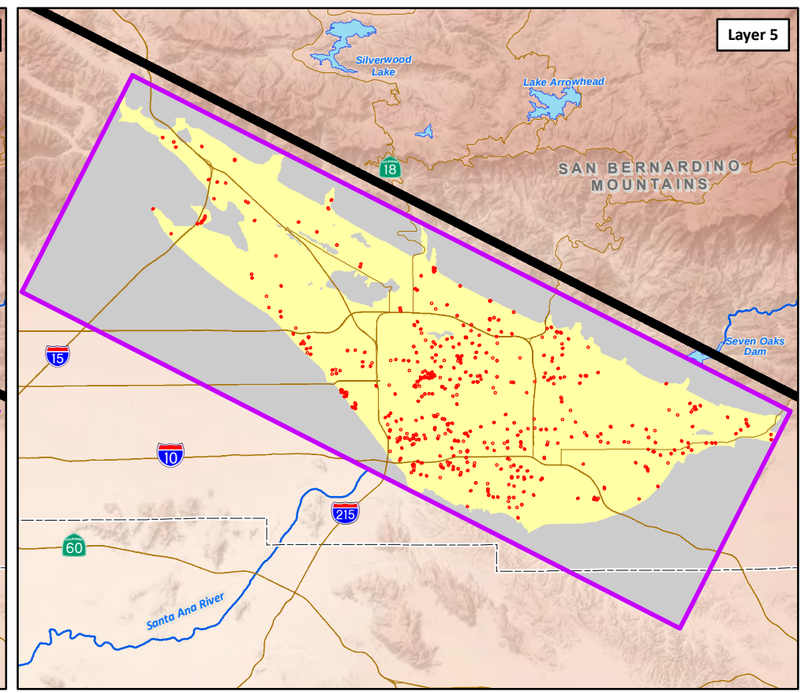
GEOSCIENCE





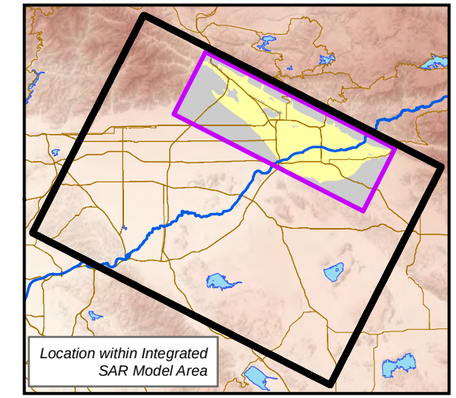






EXPLANATION

- Integrated SAR Model Boundary
- SBBA Model Boundary (Stantec and GEOSCIENCE, in progress)
- Active Model Cell
- No-Flow Cell
- Stream
- Well (Specified Flux)
- Well Simulating Underflow Outflow



N

0 5 10
Miles

BOUNDARY CONDITIONS OF THE SAN BERNARDINO BASIN AREA GROUNDWATER MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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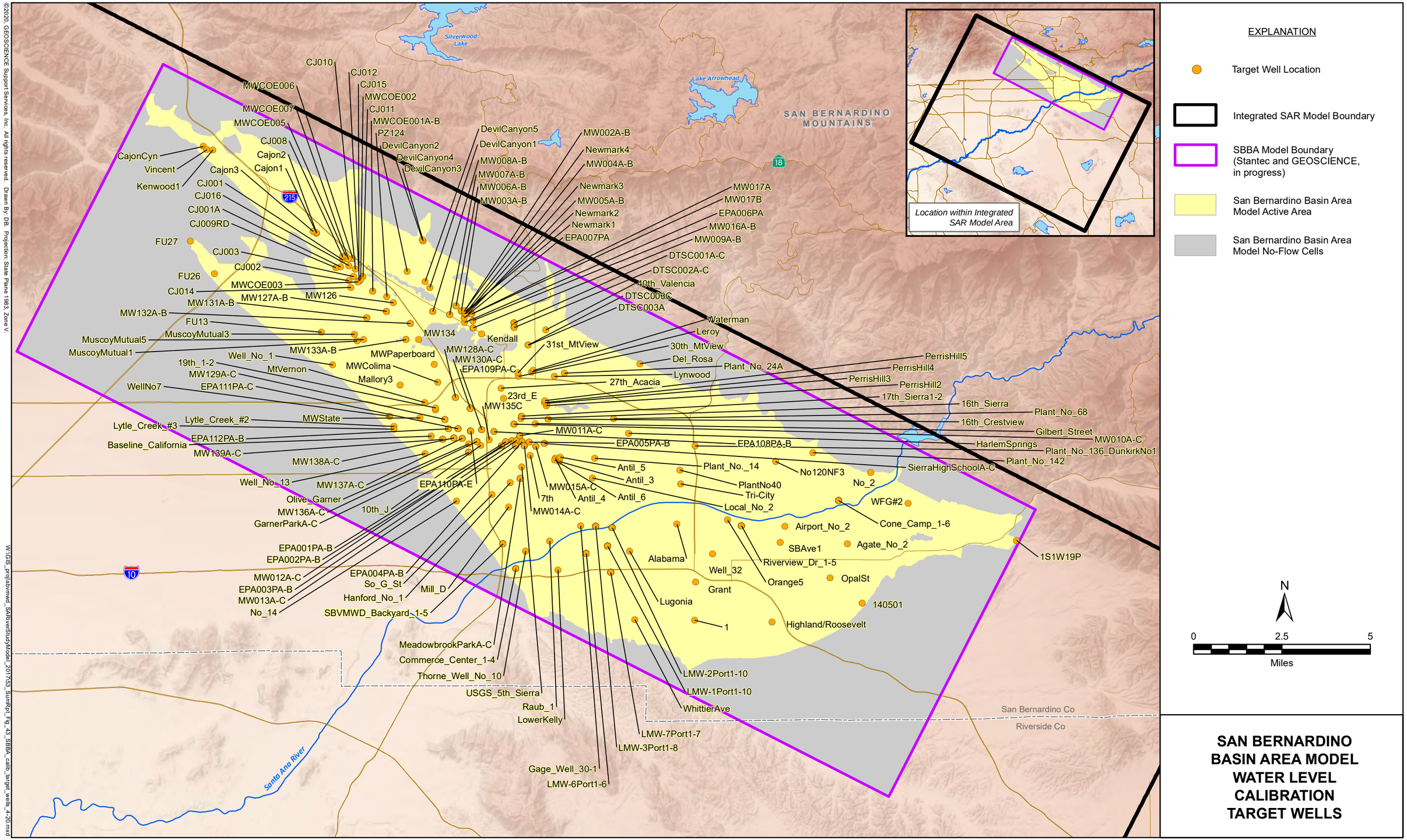
FIGURE 42

GEOSCIENCE



SAN BERNARDINO BASIN AREA MODEL WATER LEVEL CALIBRATION TARGET WELLS

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Scatterplot of Measured and Model-Simulated Water Level for the San Bernardino Basin Area Model 1966 to 2016

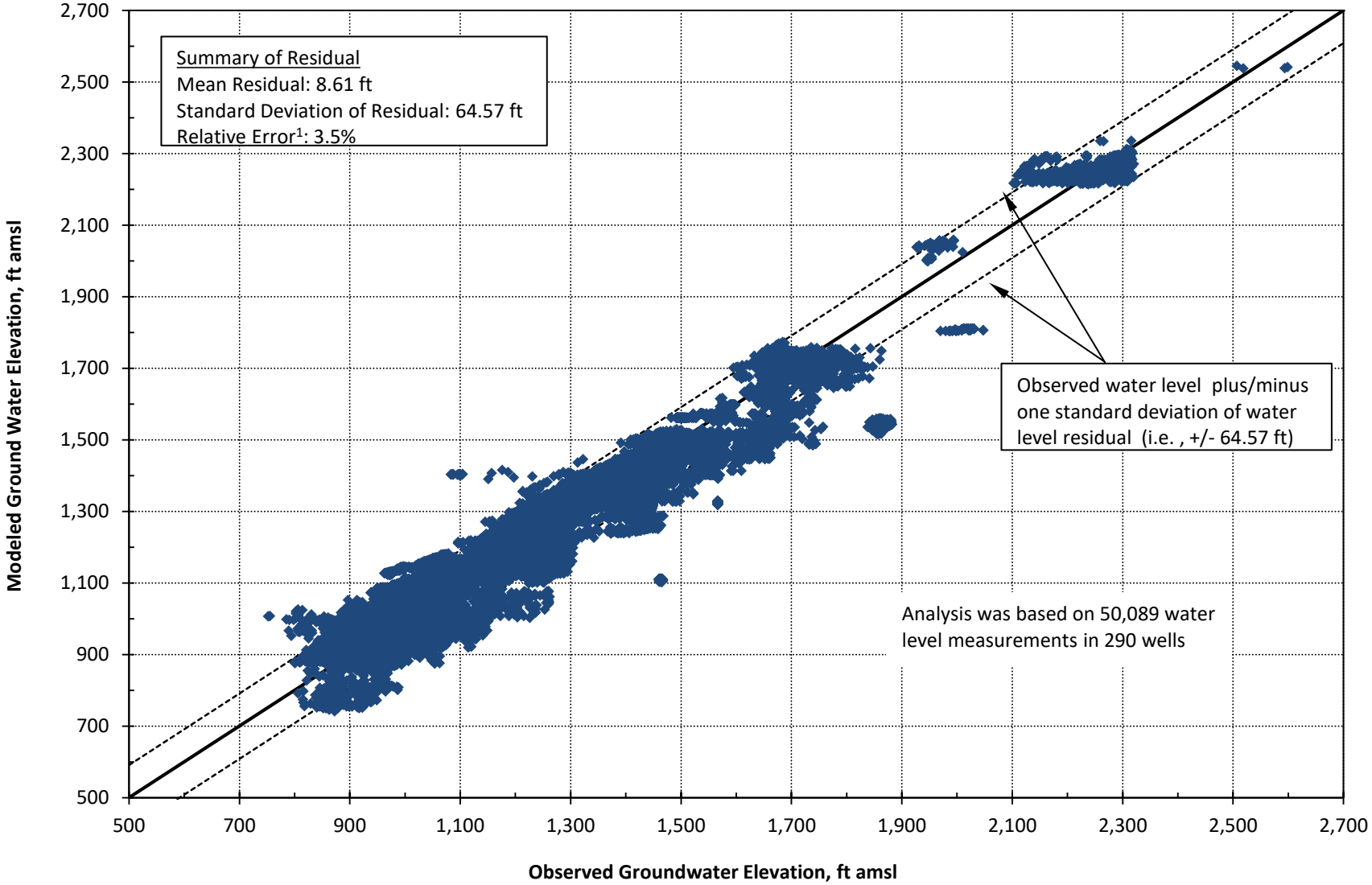

Figure 44

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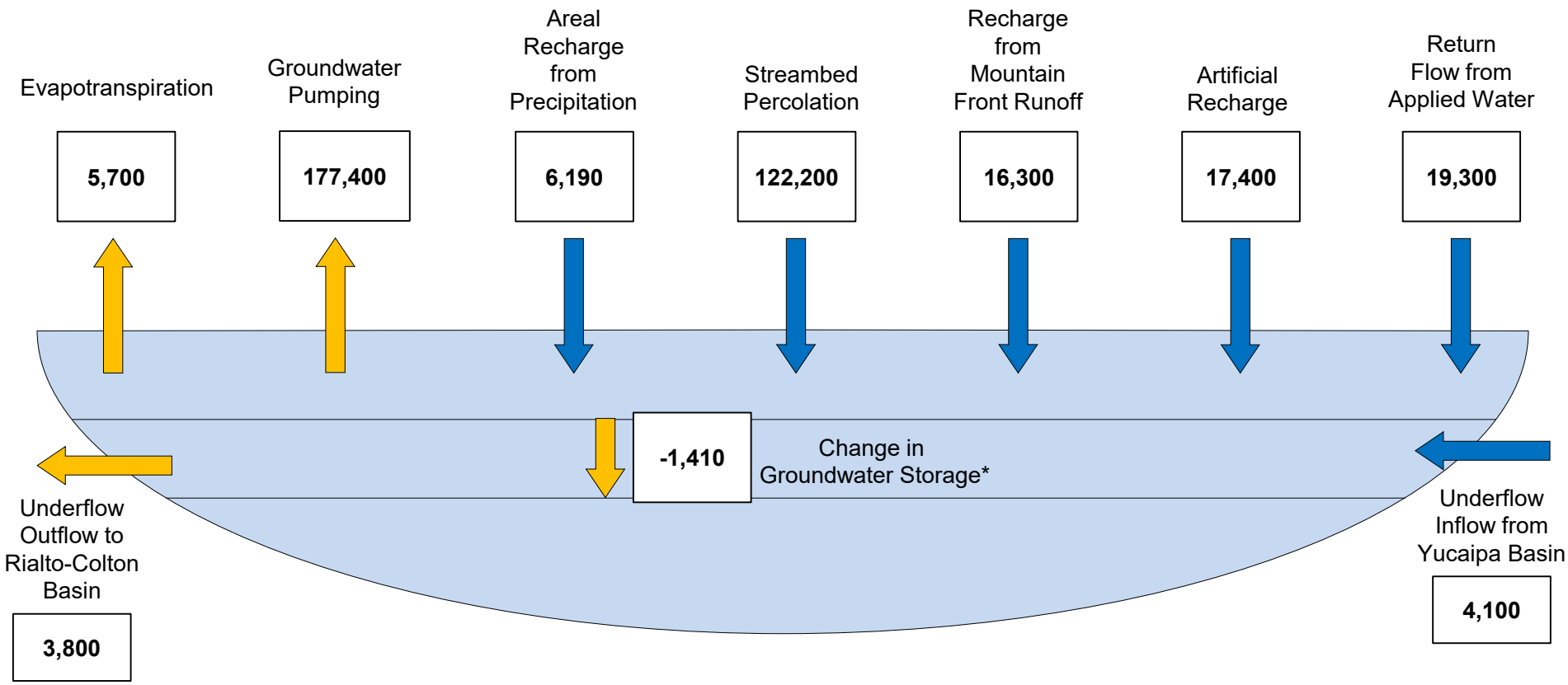

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR THE SAN BERNARDINO BASIN AREA MODEL 1966 to 2016

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Cumulative Annual Change in Groundwater Storage for the San Bernardino Basin Area Model
1966 - 2016

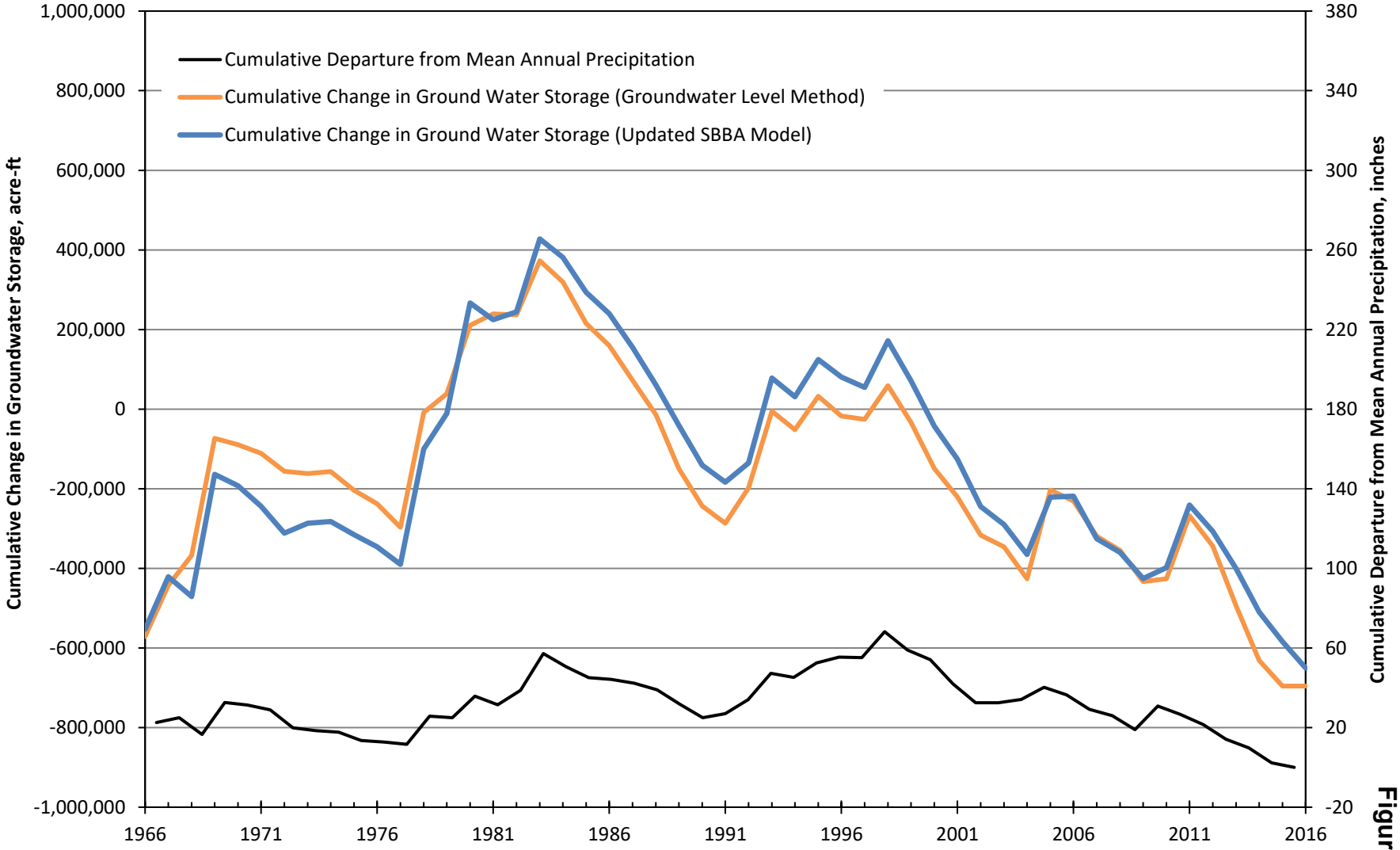
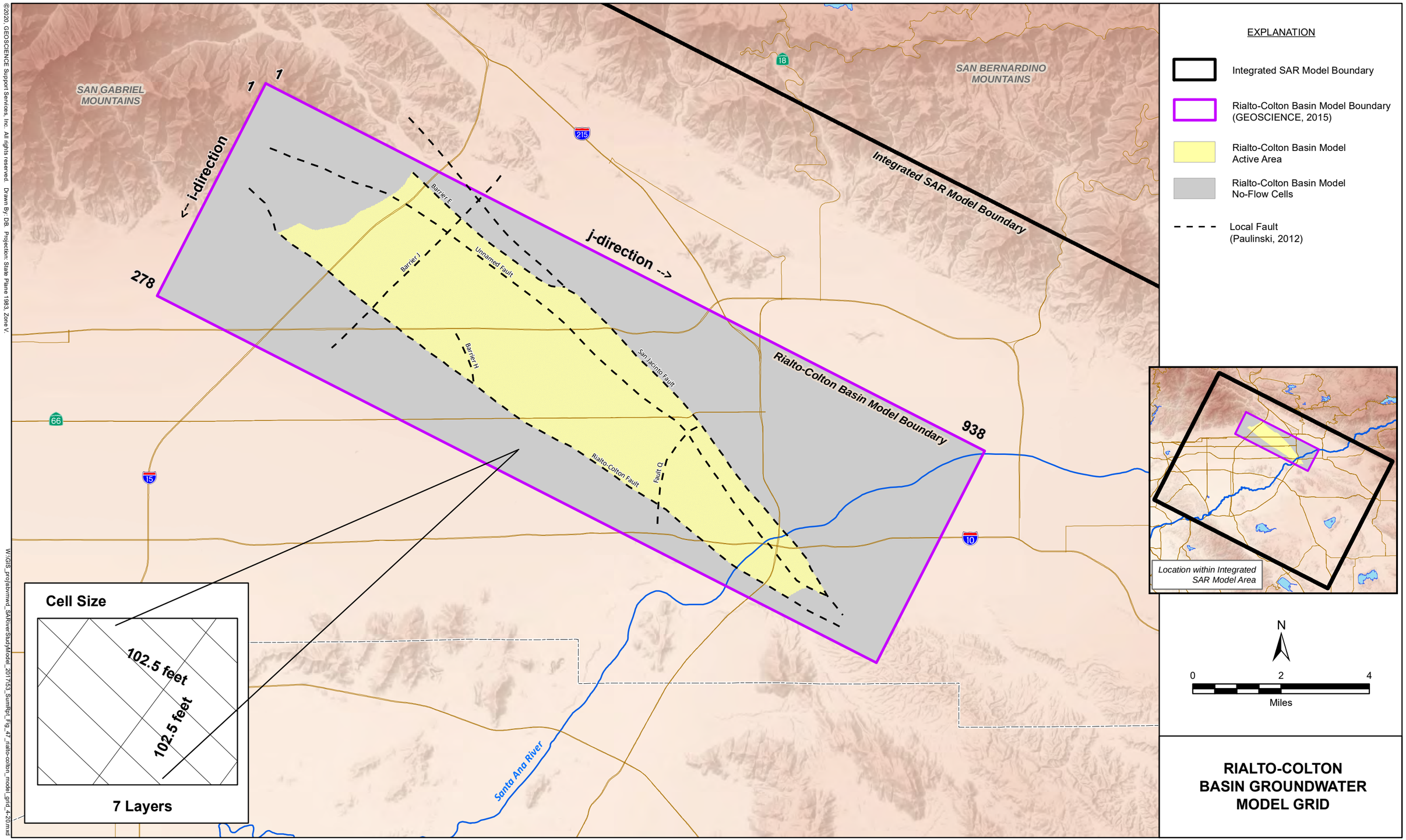


Figure 46



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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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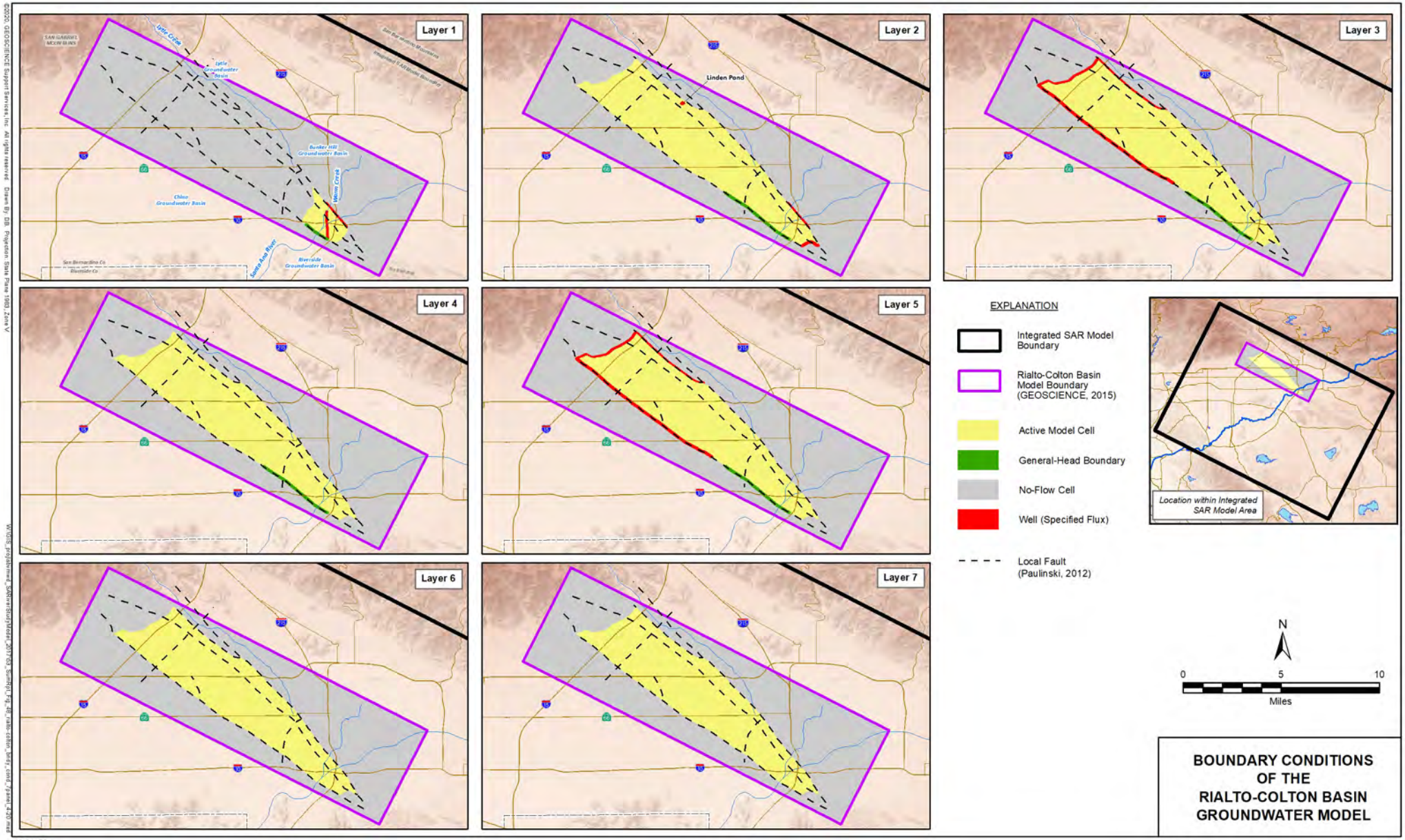
FIGURE 47

GEOSCIENCE



BOUNDARY CONDITIONS OF THE RIALTO-COLTON BASIN GROUNDWATER MODEL

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 48

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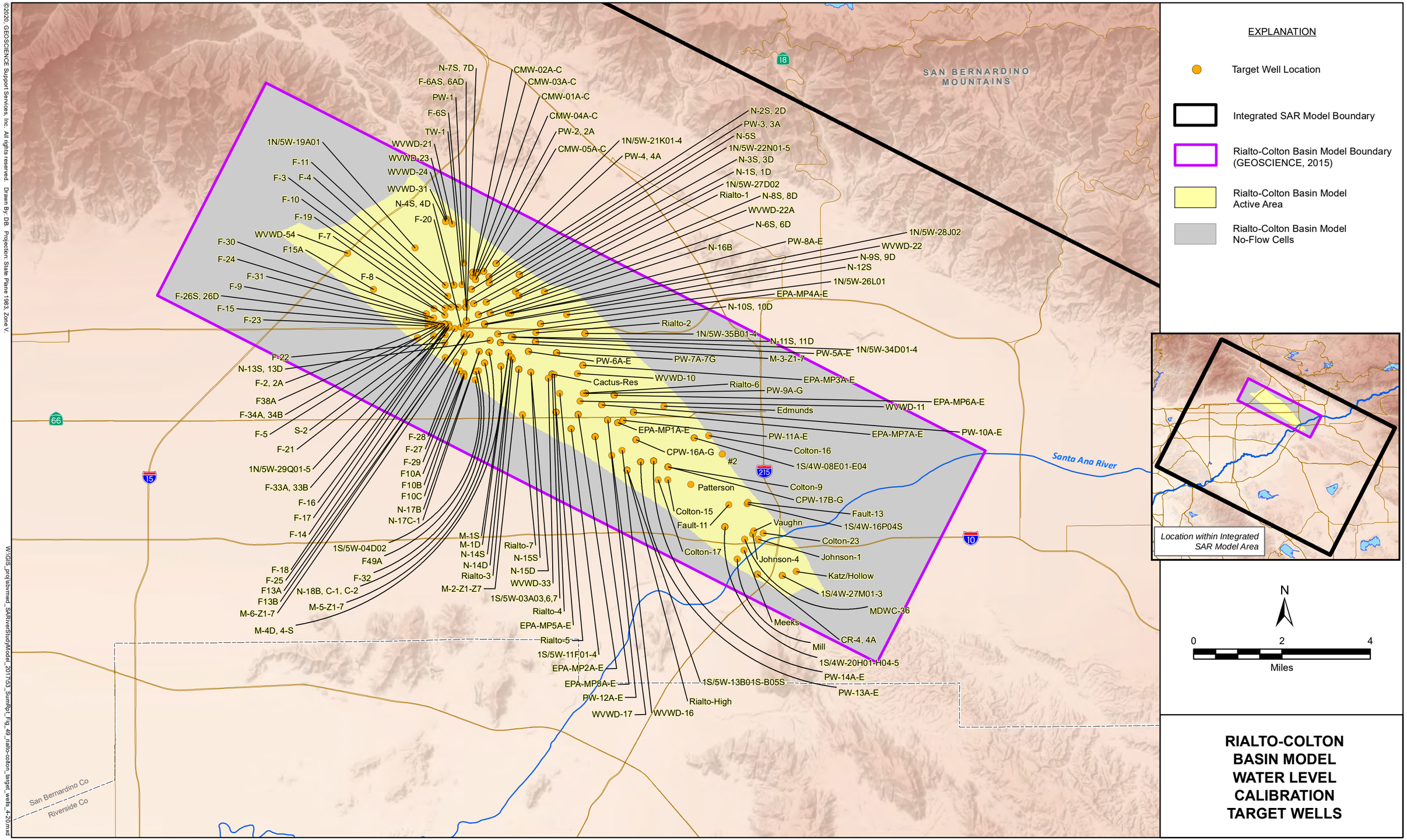

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RIALTO-COLTON BASIN MODEL WATER LEVEL CALIBRATION TARGET WELLS

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 49

GEOSCIENCE

DRAFT

Scatterplot of Measured and Model-Simulated Water Level for the Rialto-Colton Basin 1966 to 2016

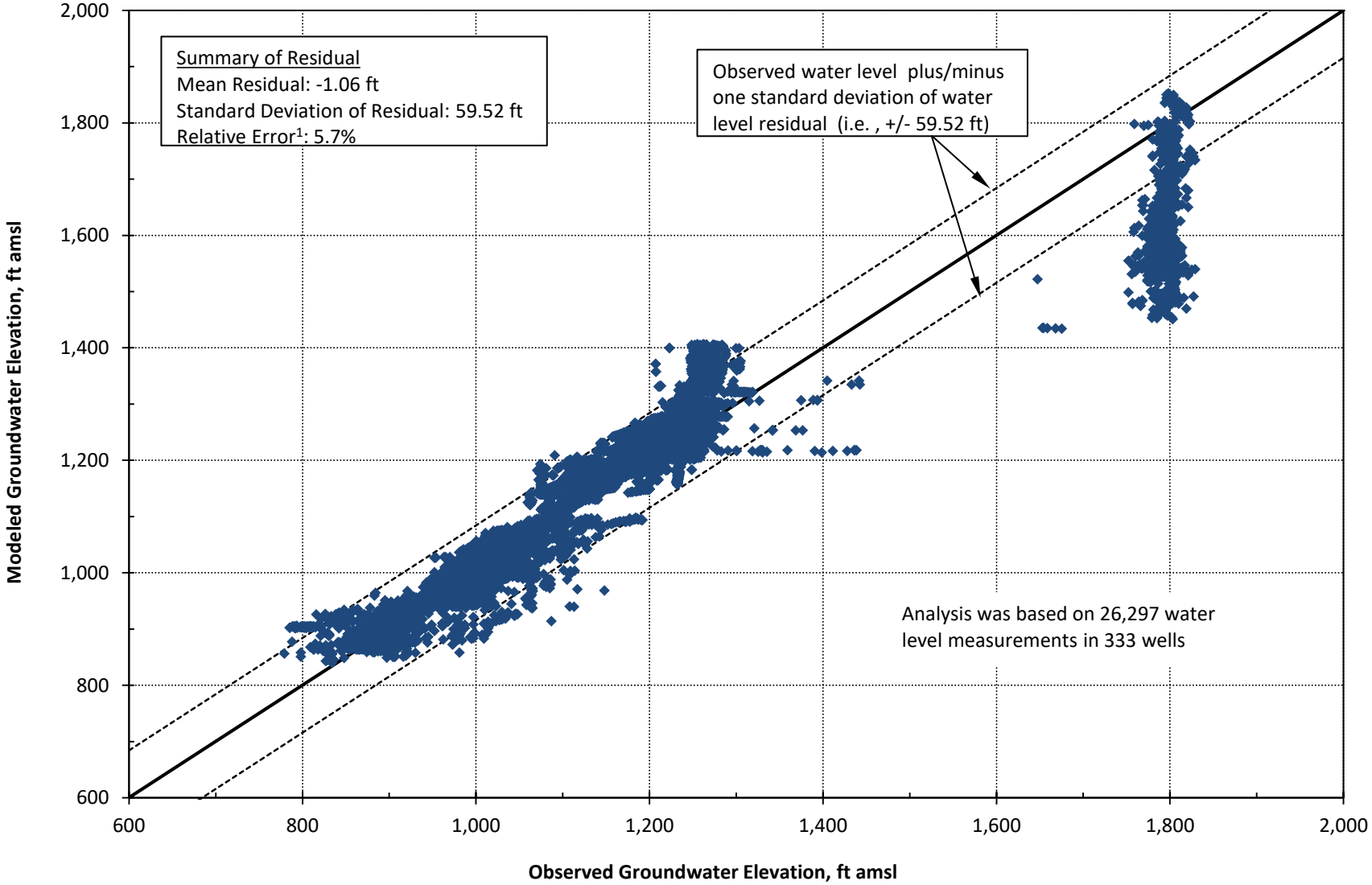

Figure 50

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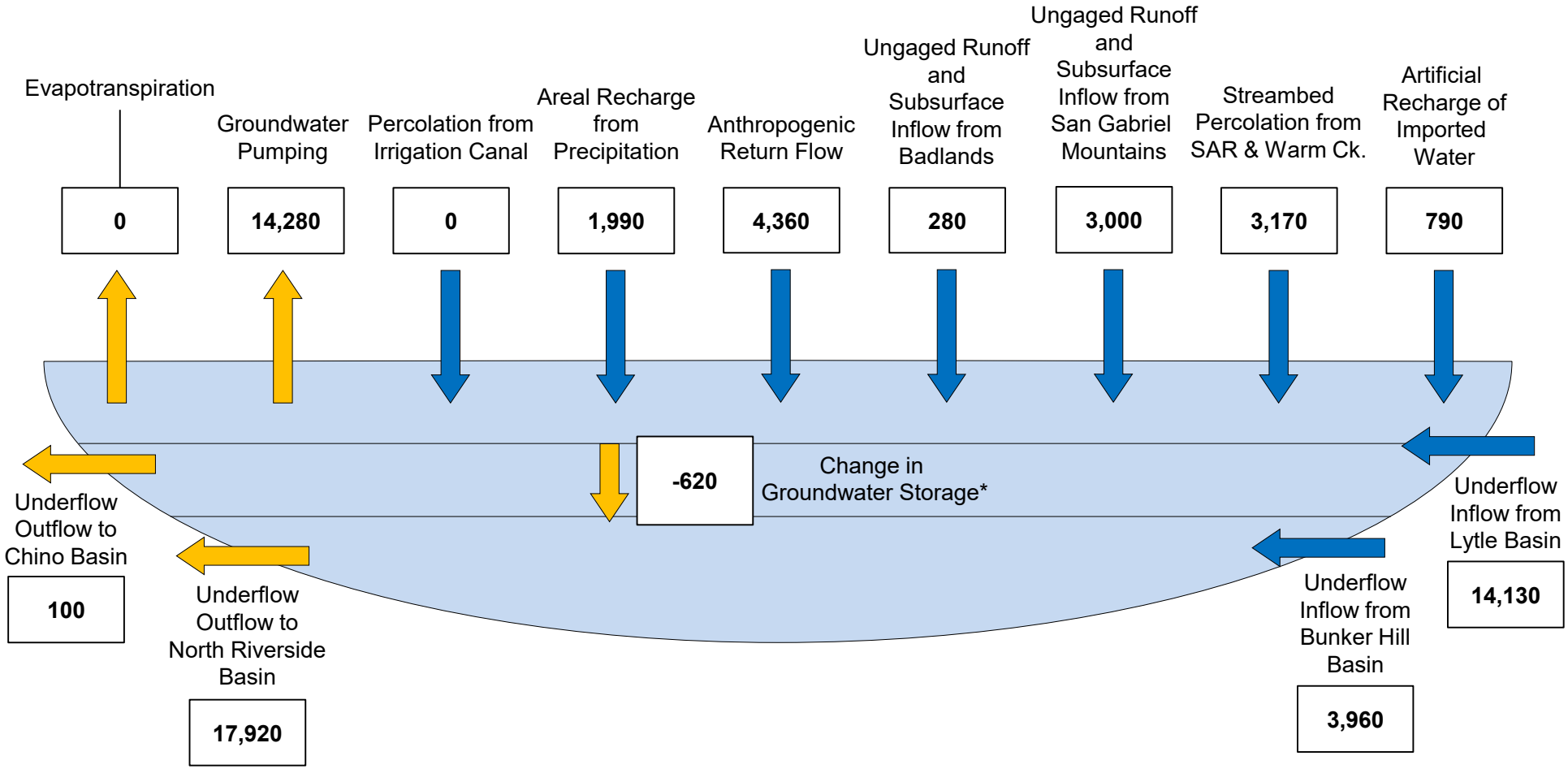

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR THE RIALTO-COLTON BASIN MODEL 1966 to 2016

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Cumulative Annual Change in Groundwater Storage for the Rialto-Colton Basin Model
1966 - 2016

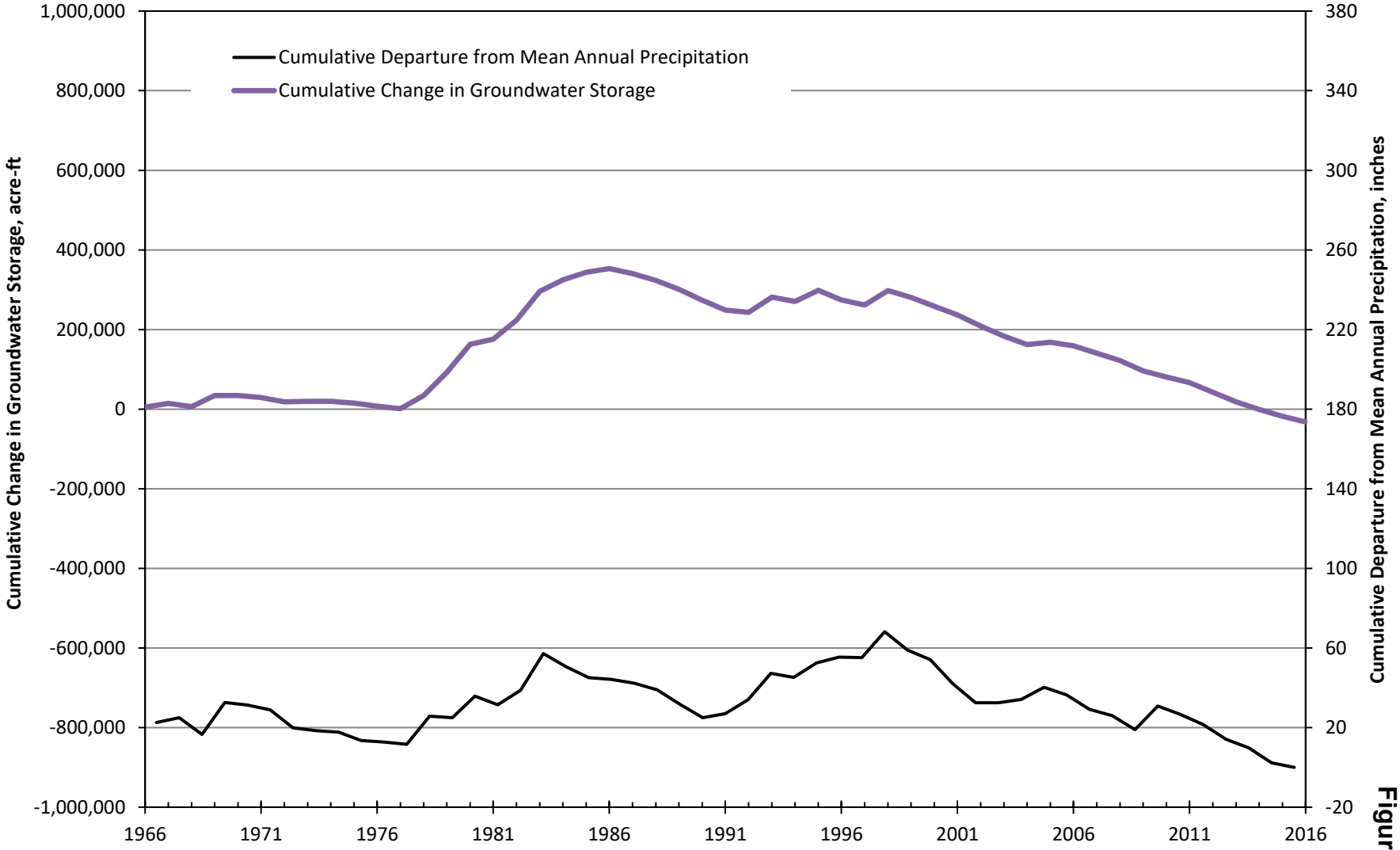
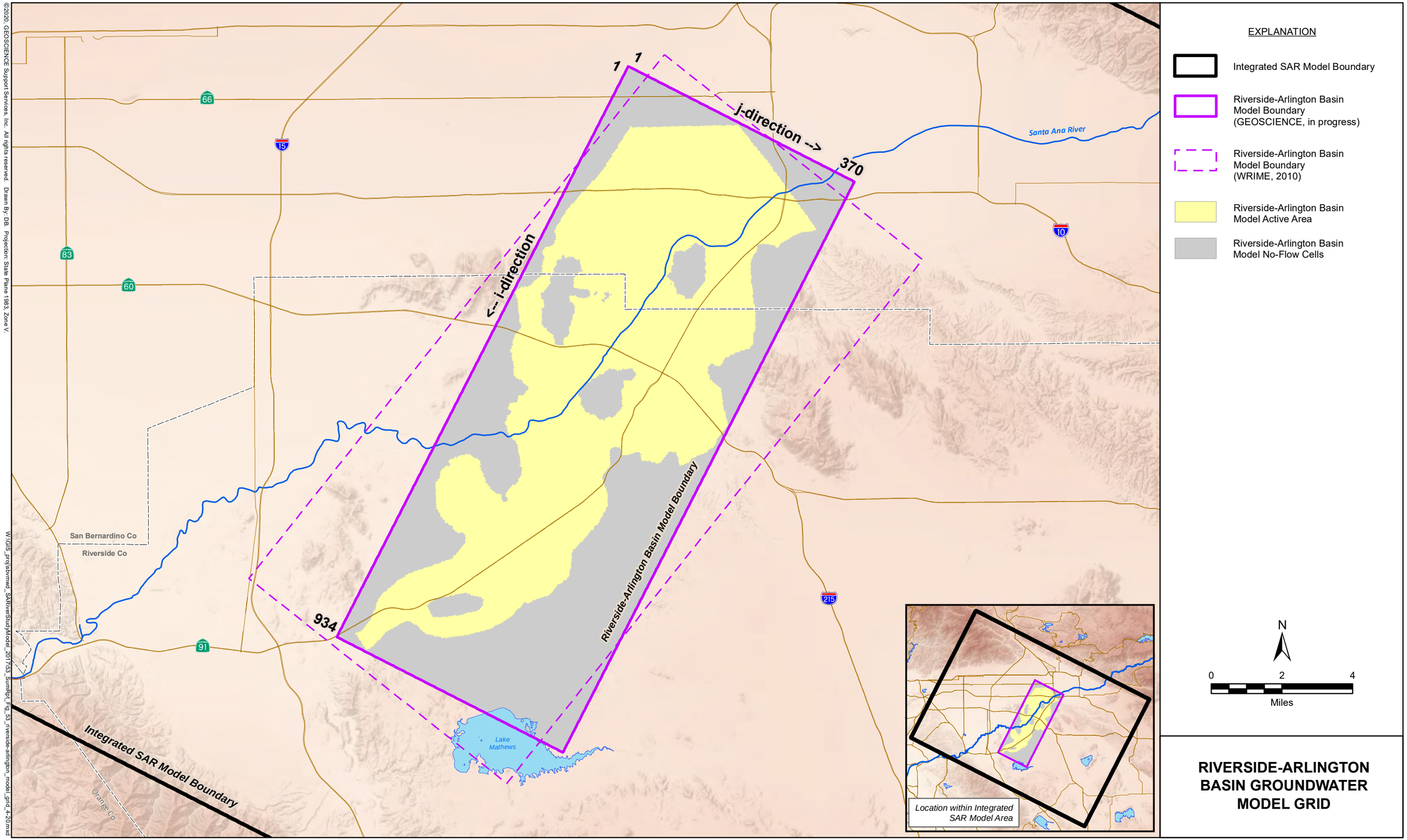


Figure 52



RIVERSIDE-ARLINGTON BASIN GROUNDWATER MODEL GRID

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 53

GEOSCIENCE

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EXPLANATION

- Integrated SAR Model Boundary
- Riverside-Arlington Basin Model Boundary (GEOSCIENCE, in progress)
- Riverside-Arlington Basin Model Boundary (WRIME, 2010)
- Active Model Cell
- General-Head Boundary
- No-Flow Cell
- Stream
- Well (Specified Flux)

N

0 4 8
Miles

BOUNDARY CONDITIONS OF THE RIVERSIDE-ARLINGTON BASIN GROUNDWATER MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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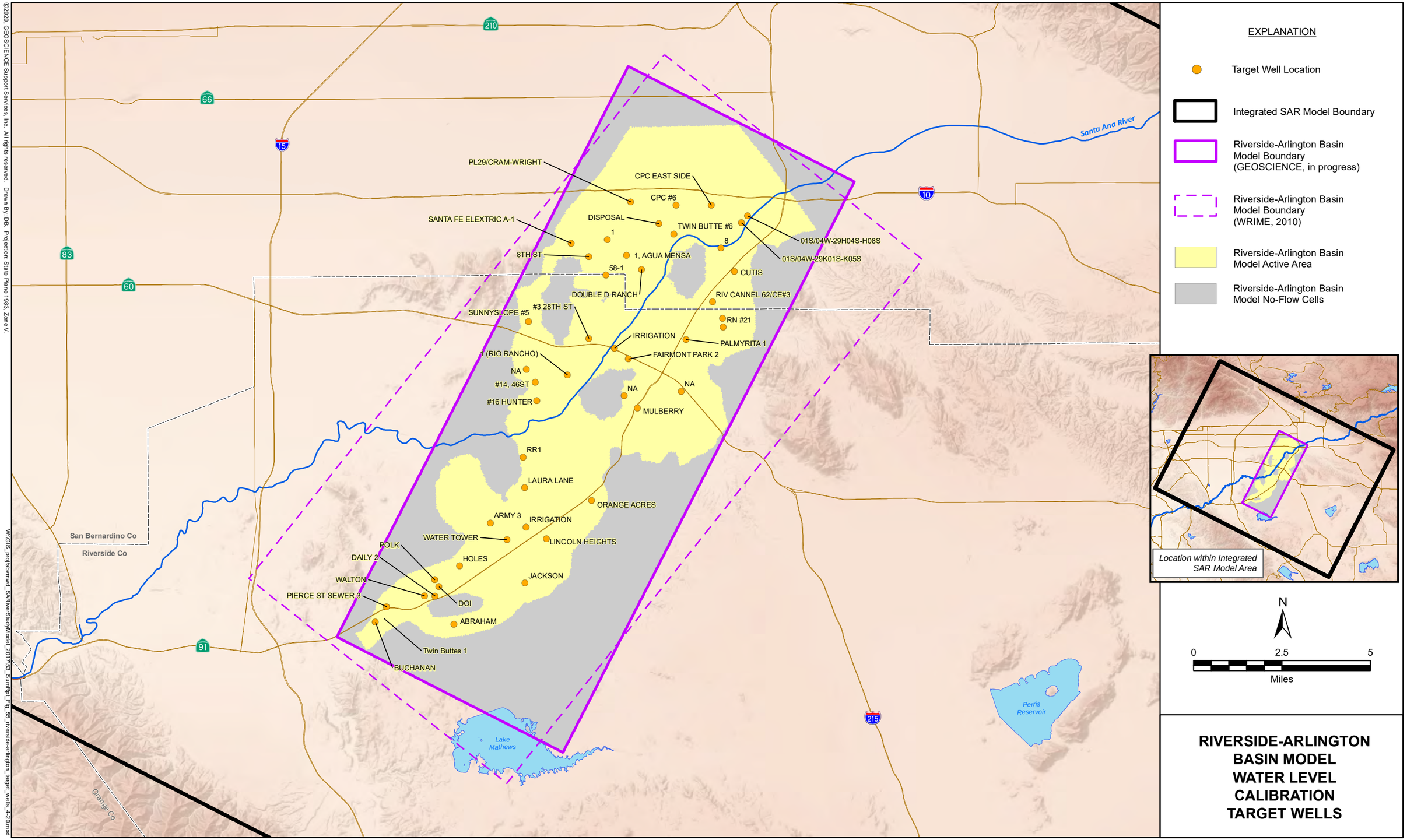
FIGURE 54

GEOSCIENCE



RIVERSIDE-ARLINGTON BASIN MODEL WATER LEVEL CALIBRATION TARGET WELLS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 55

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DRAFT

Scatterplot of Measured and Model-Simulated Water Level for the Riverside-Arlington Basin Model 1966 to 2016

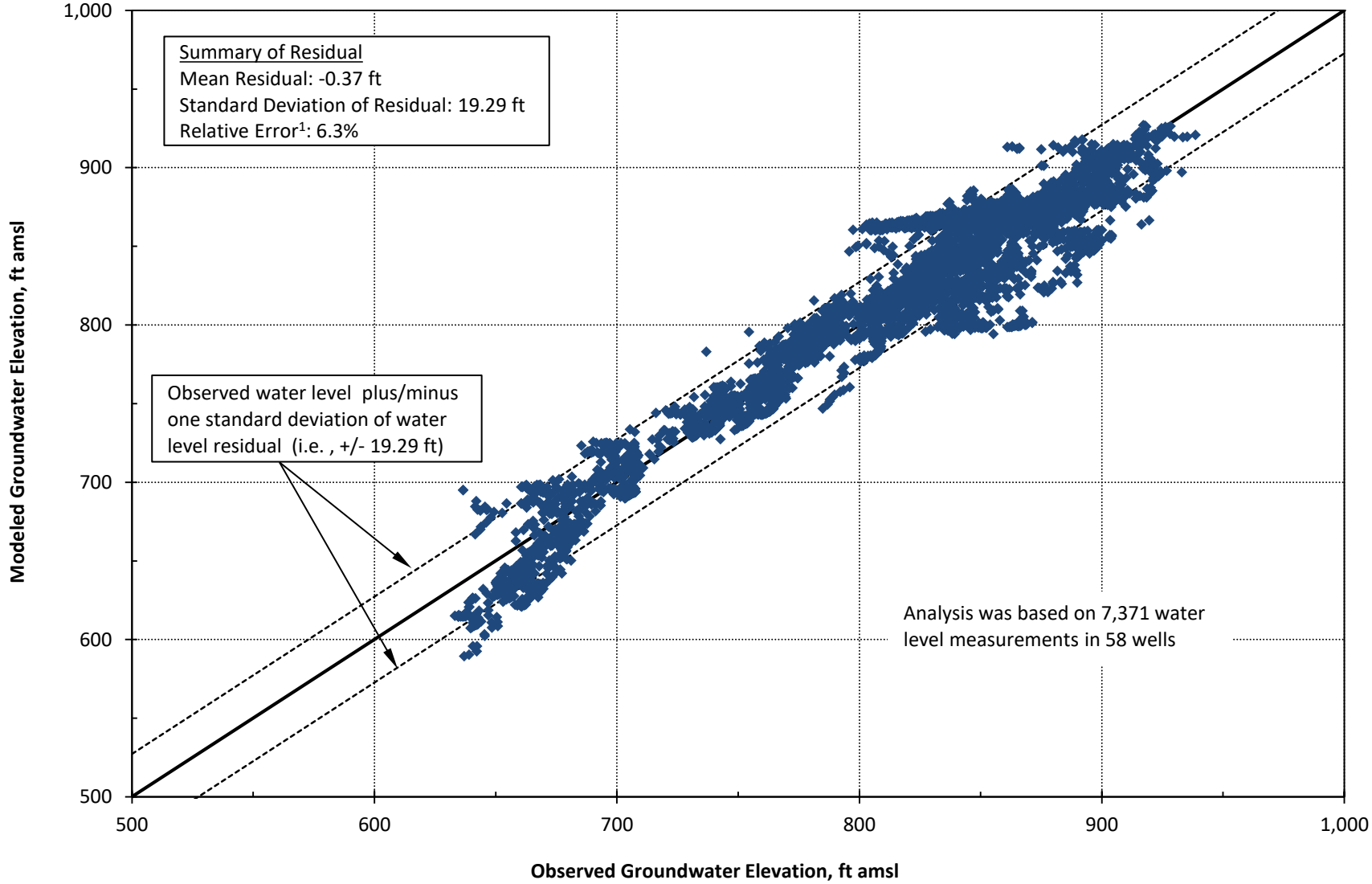

Figure 56

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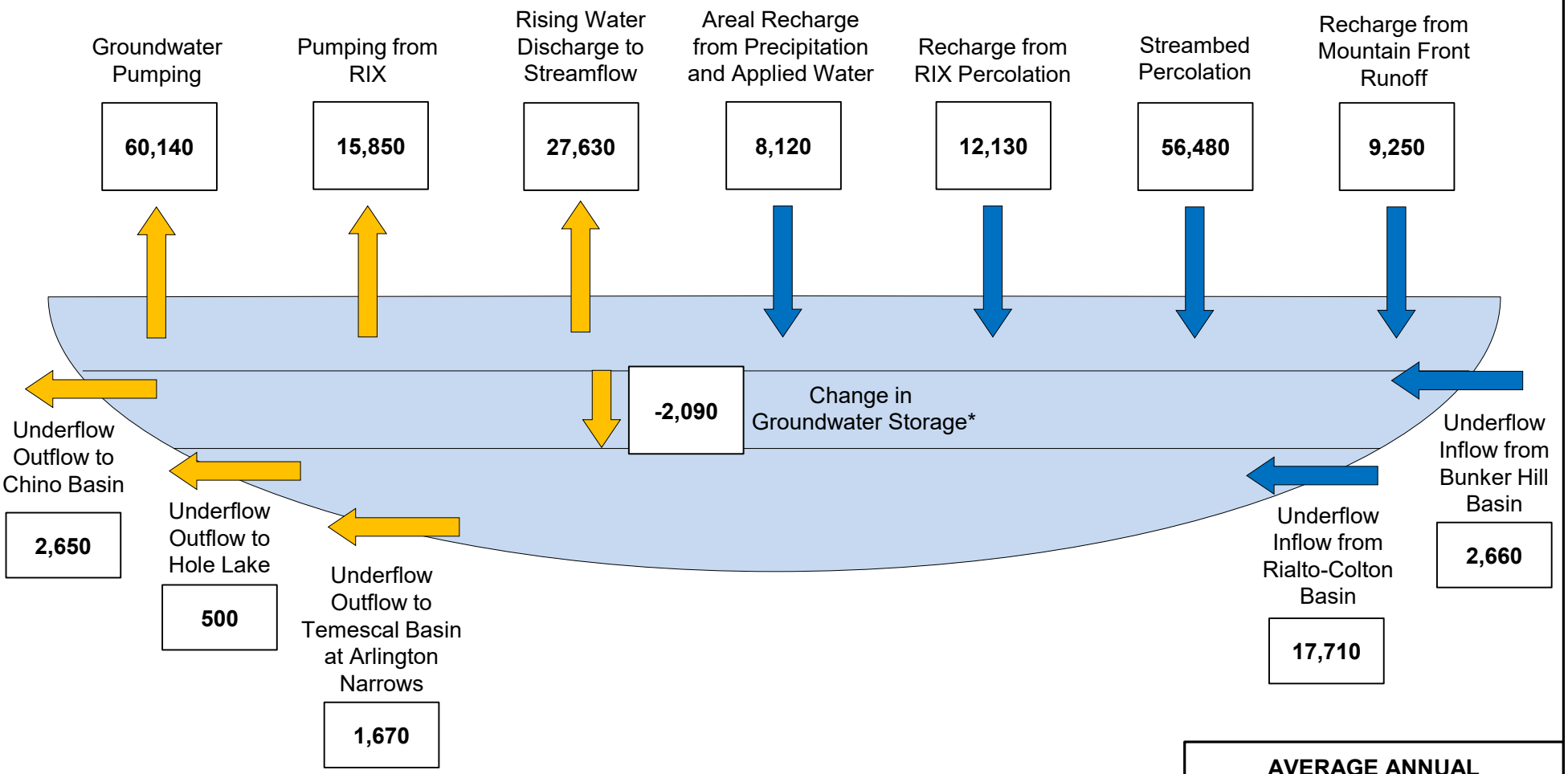

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR THE RIVERSIDE-ARLINGTON BASIN MODEL 1966 to 2016

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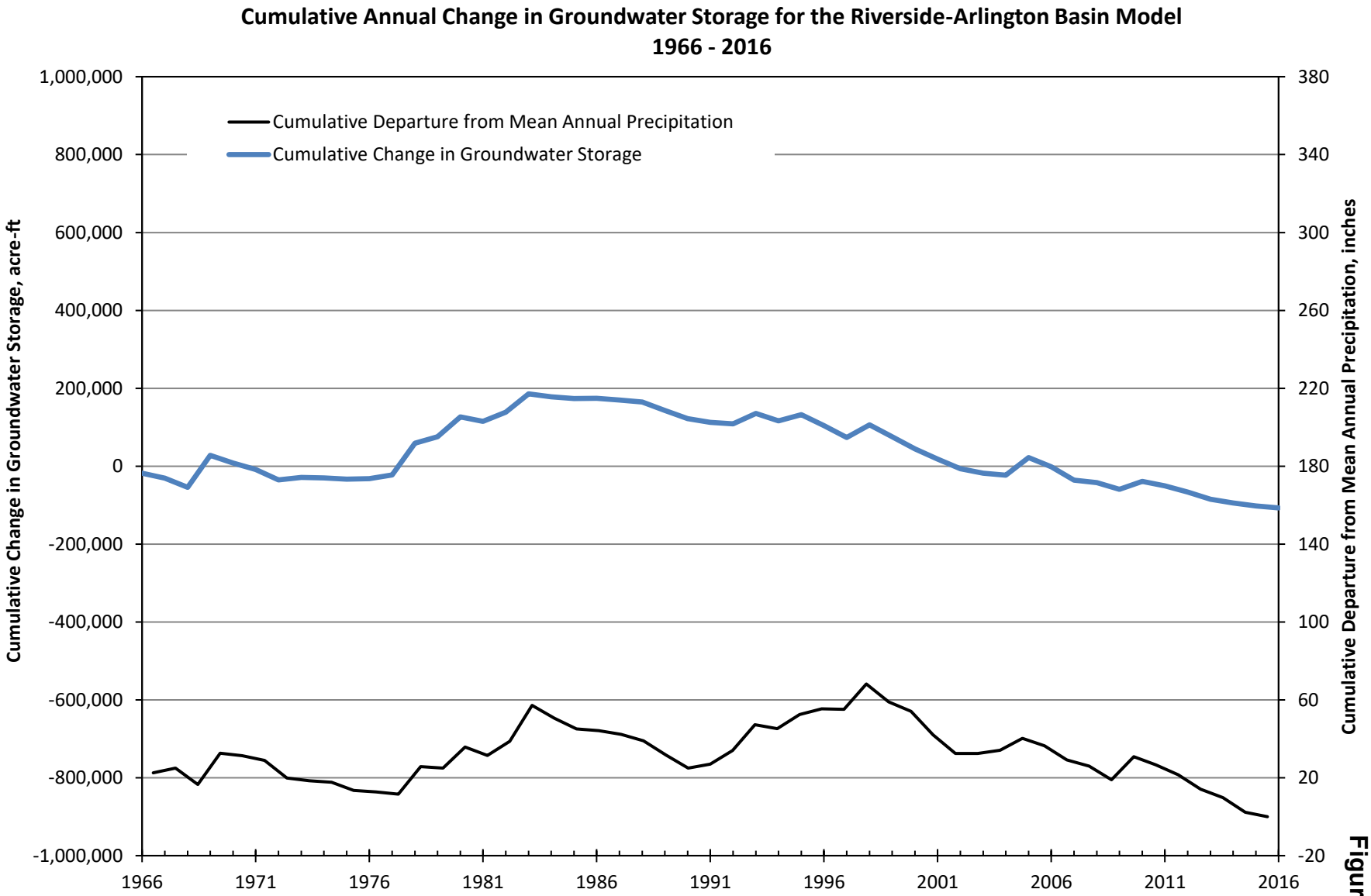
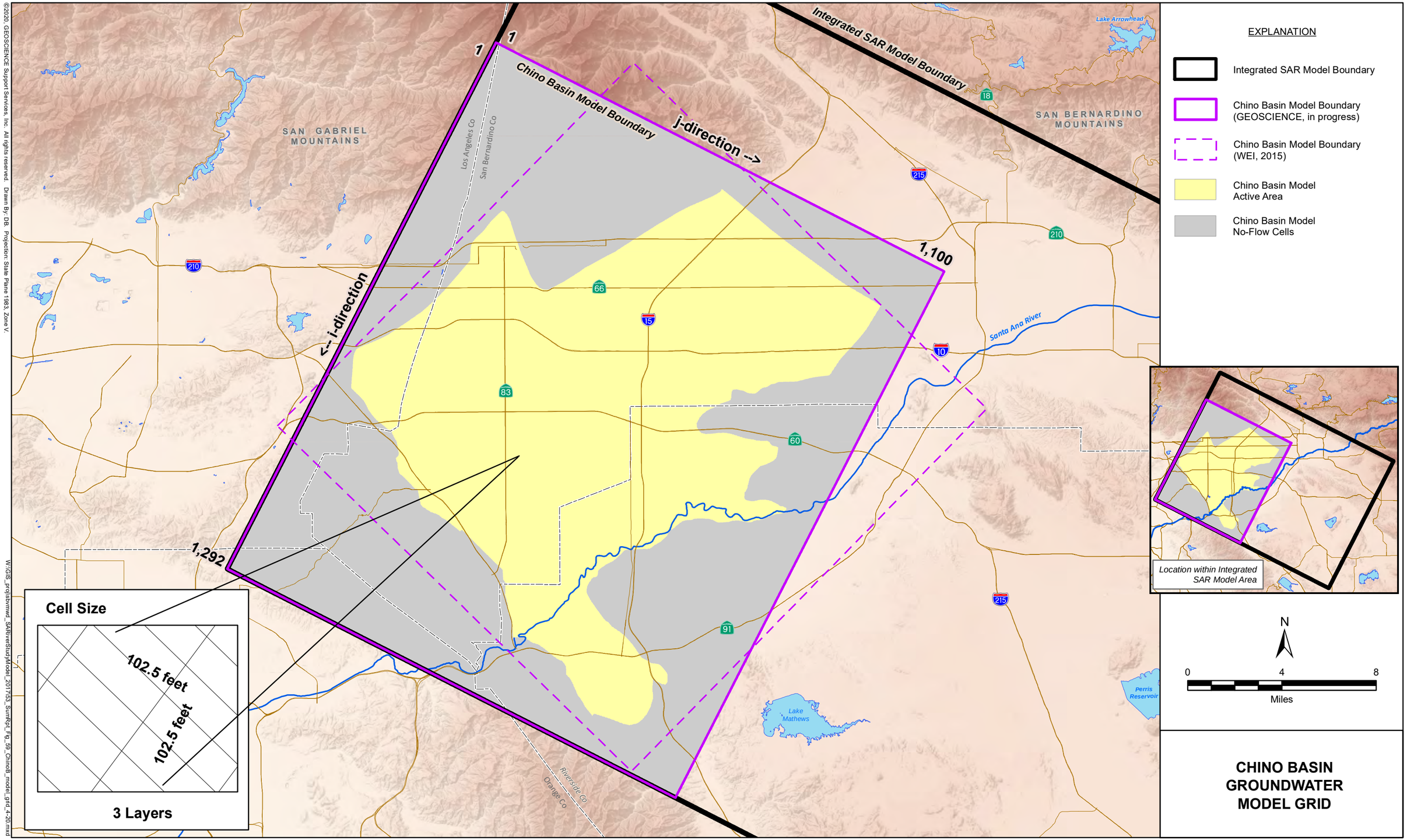


Figure 58



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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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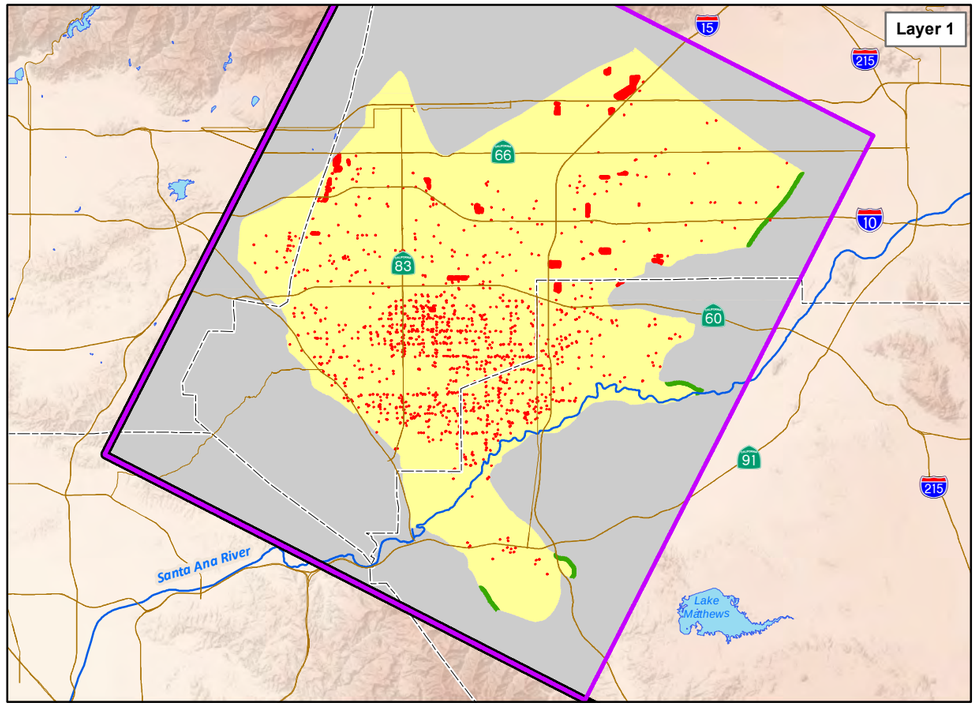
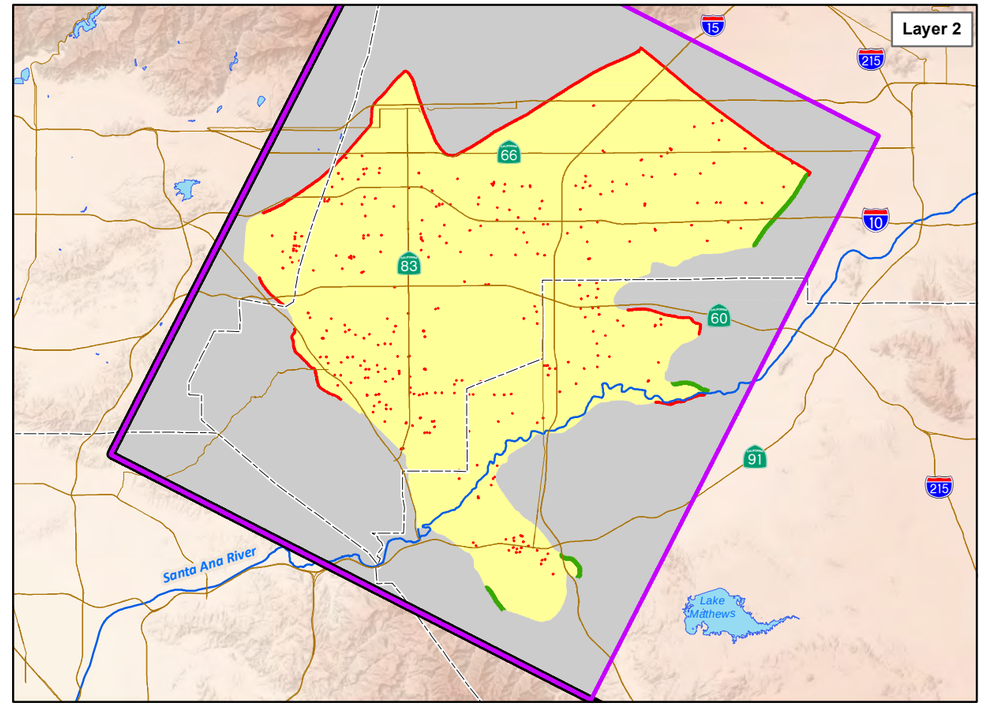
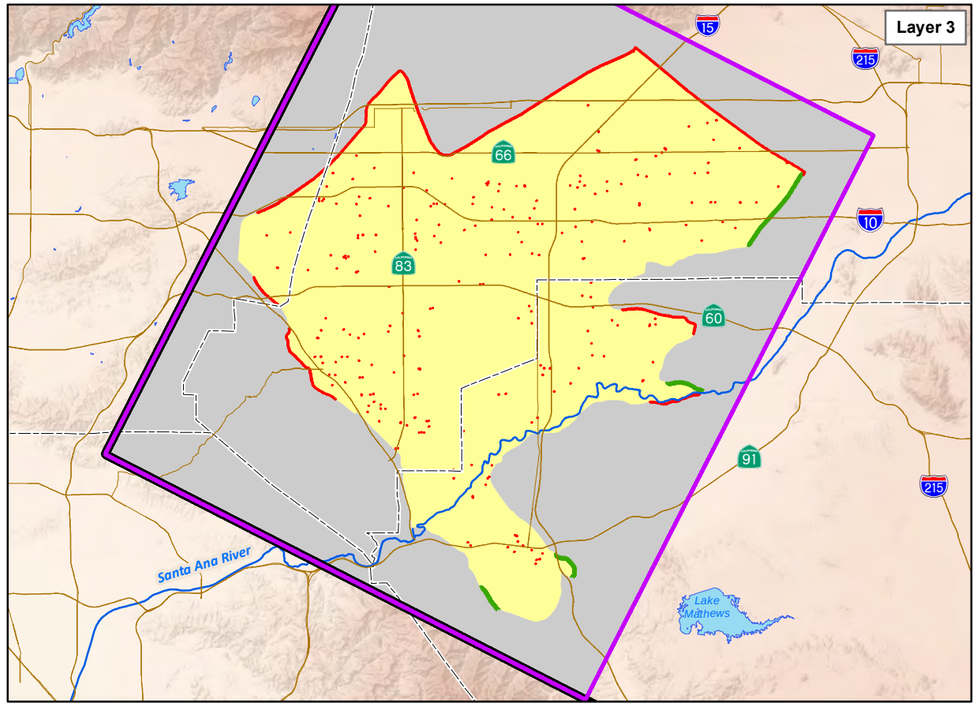
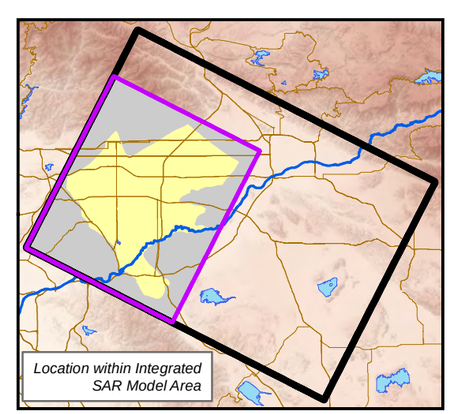
FIGURE 59

GEOSCIENCE









EXPLANATION

- Integrated SAR Model Boundary
- Chino Basin Model Boundary (GEOSCIENCE, in progress)
- Active Model Cell
- General-Head Boundary
- No-Flow Cell
- Well (Specified Flux)

N

0 5 10
Miles

BOUNDARY CONDITIONS OF THE CHINO BASIN GROUNDWATER MODEL

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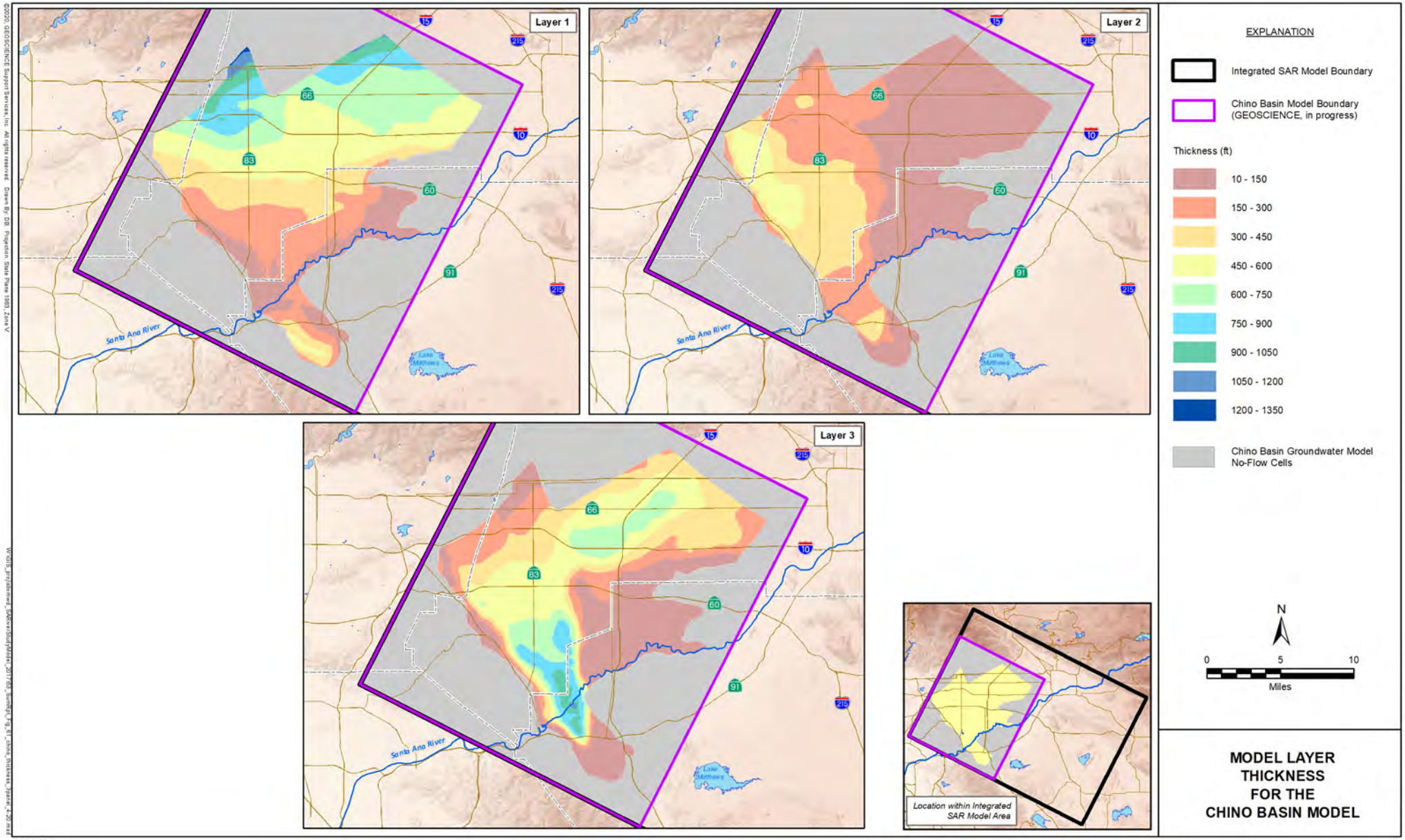

MODEL LAYER THICKNESS FOR THE CHINO BASIN MODEL

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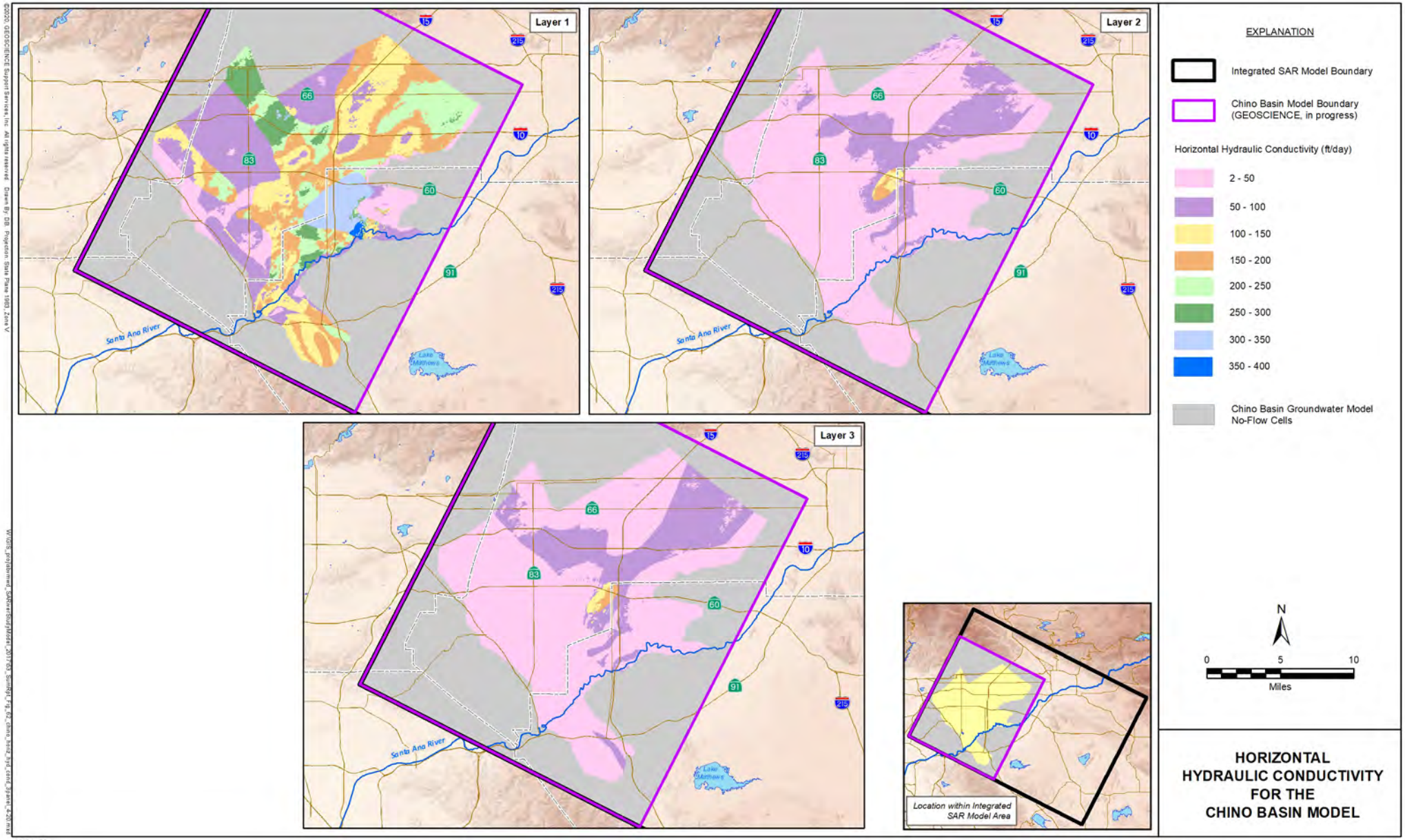

HORIZONTAL HYDRAULIC CONDUCTIVITY FOR THE CHINO BASIN MODEL

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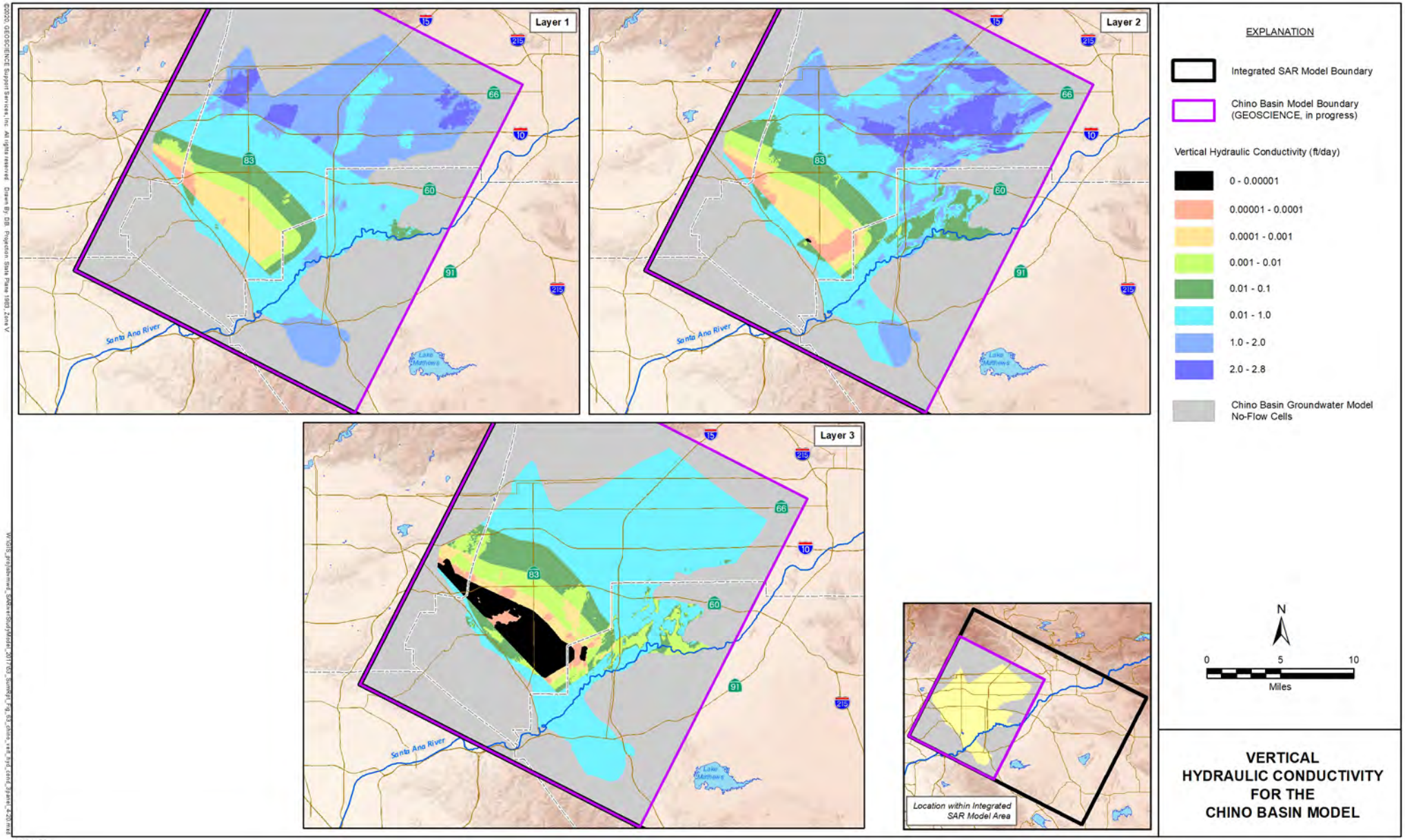

VERTICAL HYDRAULIC CONDUCTIVITY FOR THE CHINO BASIN MODEL

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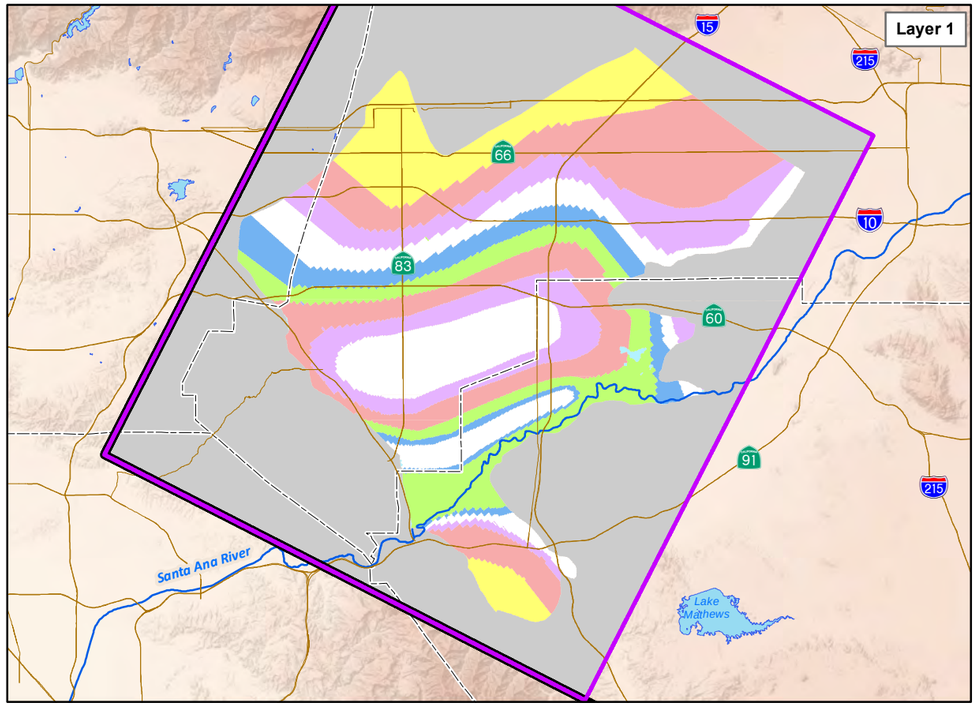

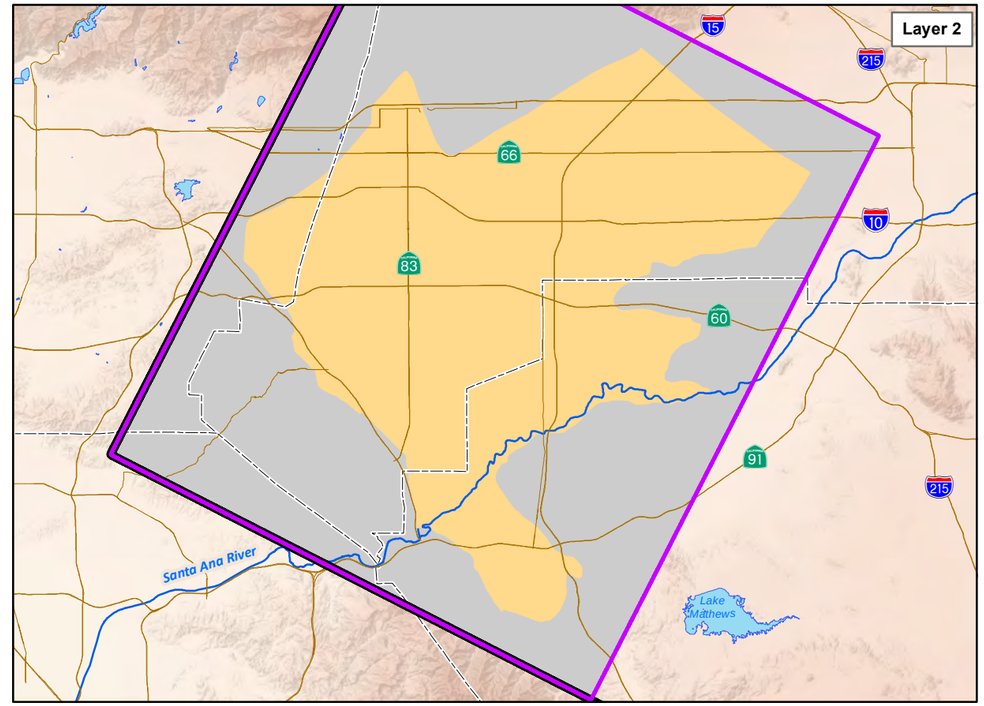

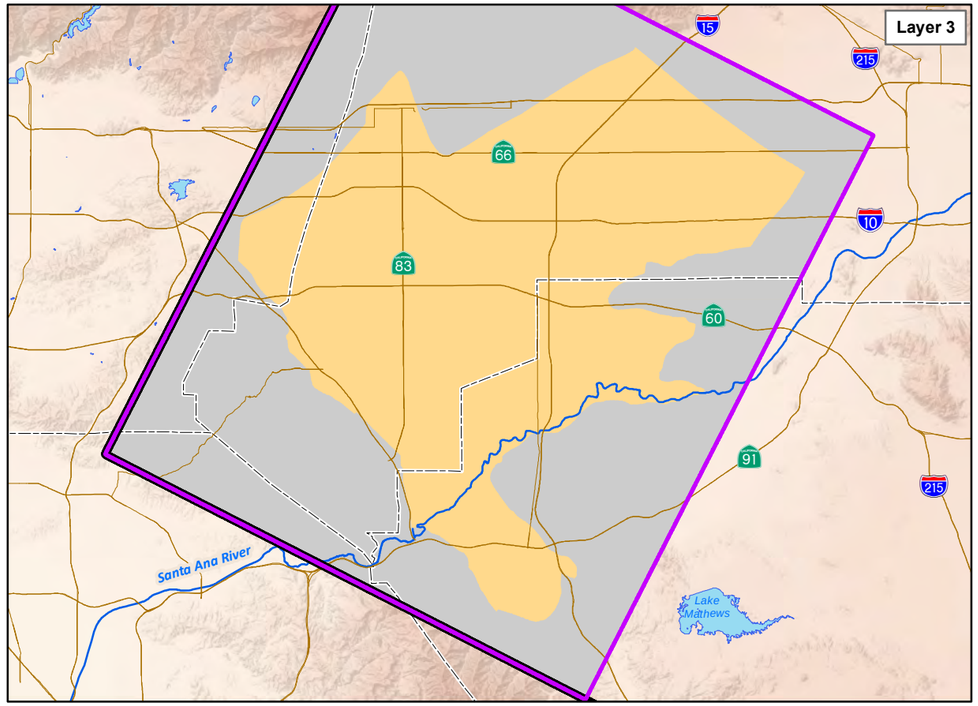

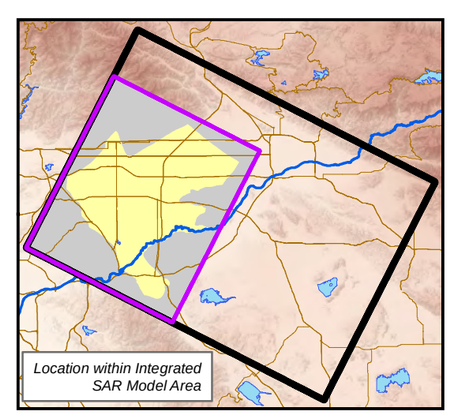

EXPLANATION

Integrated SAR Model Boundary

Chino Basin Model Boundary (GEOSCIENCE, in progress)

Secondary Storage Coefficient (Specific Yield, unitless)

- 0.060
- 0.062
- 0.083
- 0.093
- 0.100
- 0.104
- 0.114
- 0.124
- 0.155

Chino Basin Groundwater Model No-Flow Cells

N

0 5 10
Miles

SPECIFIC YIELD FOR THE CHINO BASIN MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 64

GEOSCIENCE

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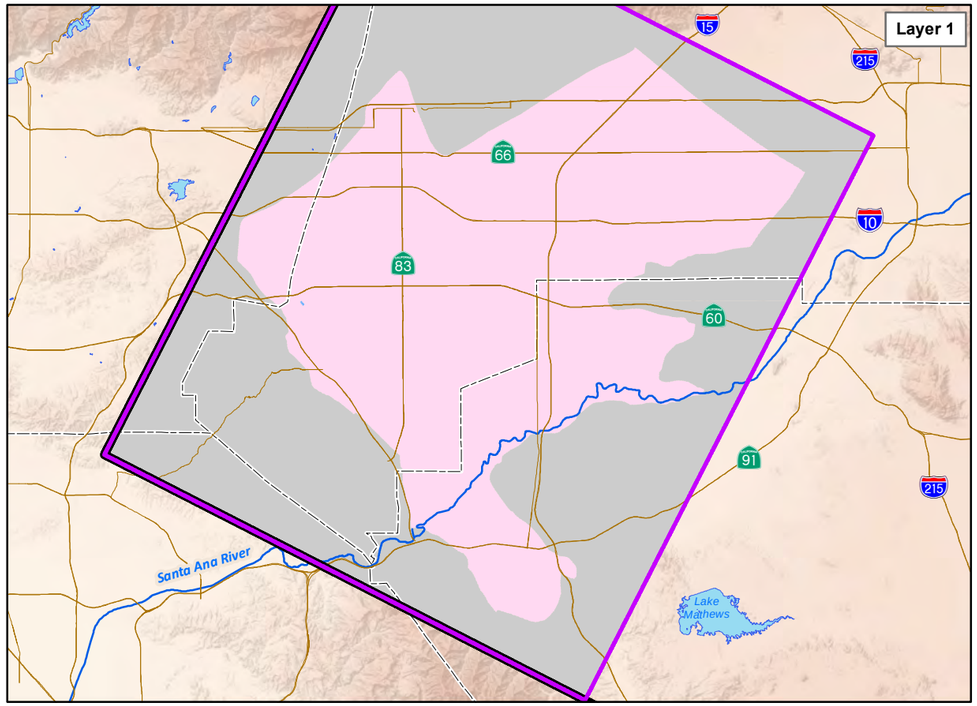

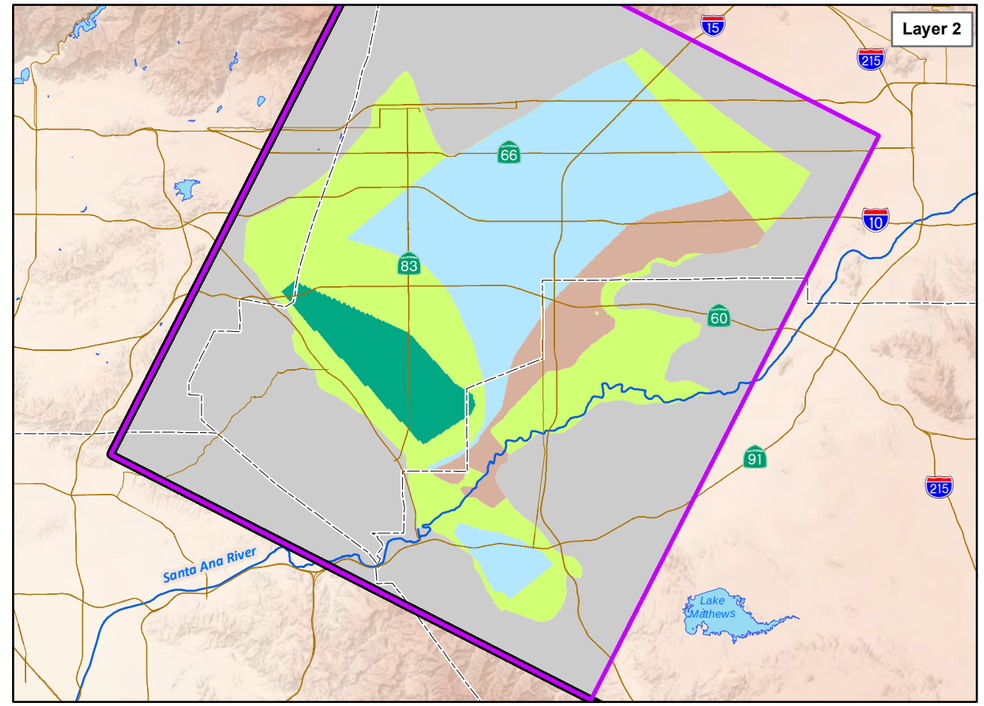

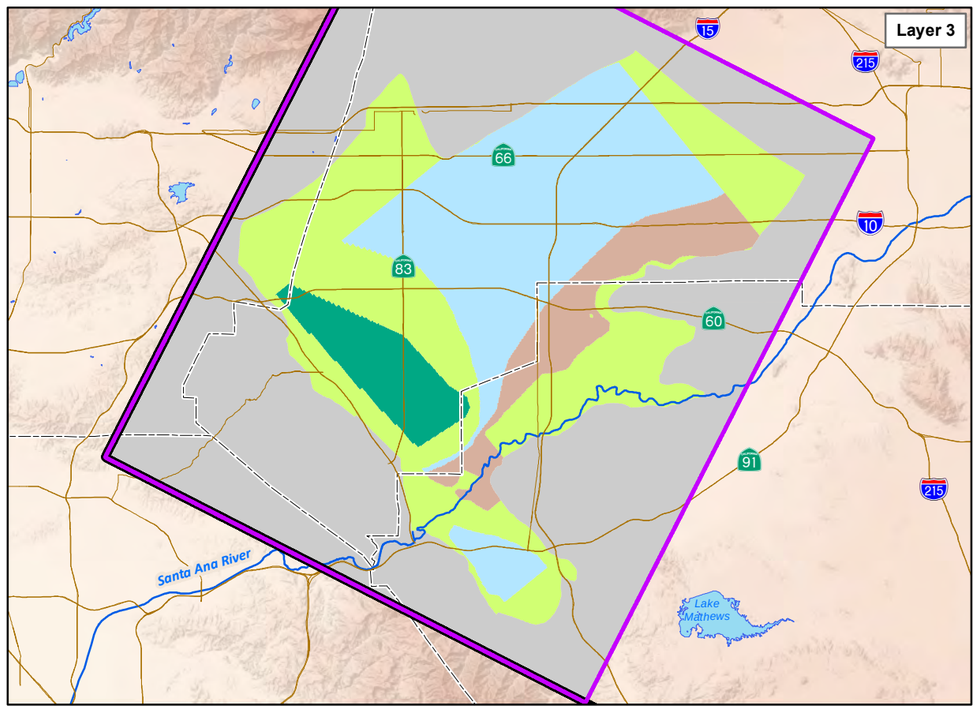

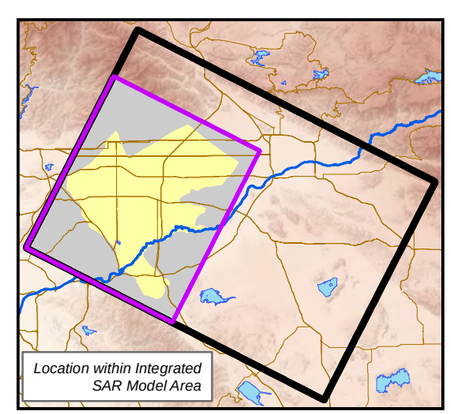

EXPLANATION

Integrated SAR Model Boundary

Chino Basin Model Boundary (GEOSCIENCE, in progress)

Primary Storage Coefficient (Storativity, unitless)

- 0.001
- 0.00001
- 0.000001
- 0.000066
- 0.000122
- 0.000549

Chino Basin Groundwater Model Active Area

Chino Basin Groundwater Model No-Flow Cells

N

0 5 10
Miles

STORATIVITY FOR THE CHINO BASIN MODEL

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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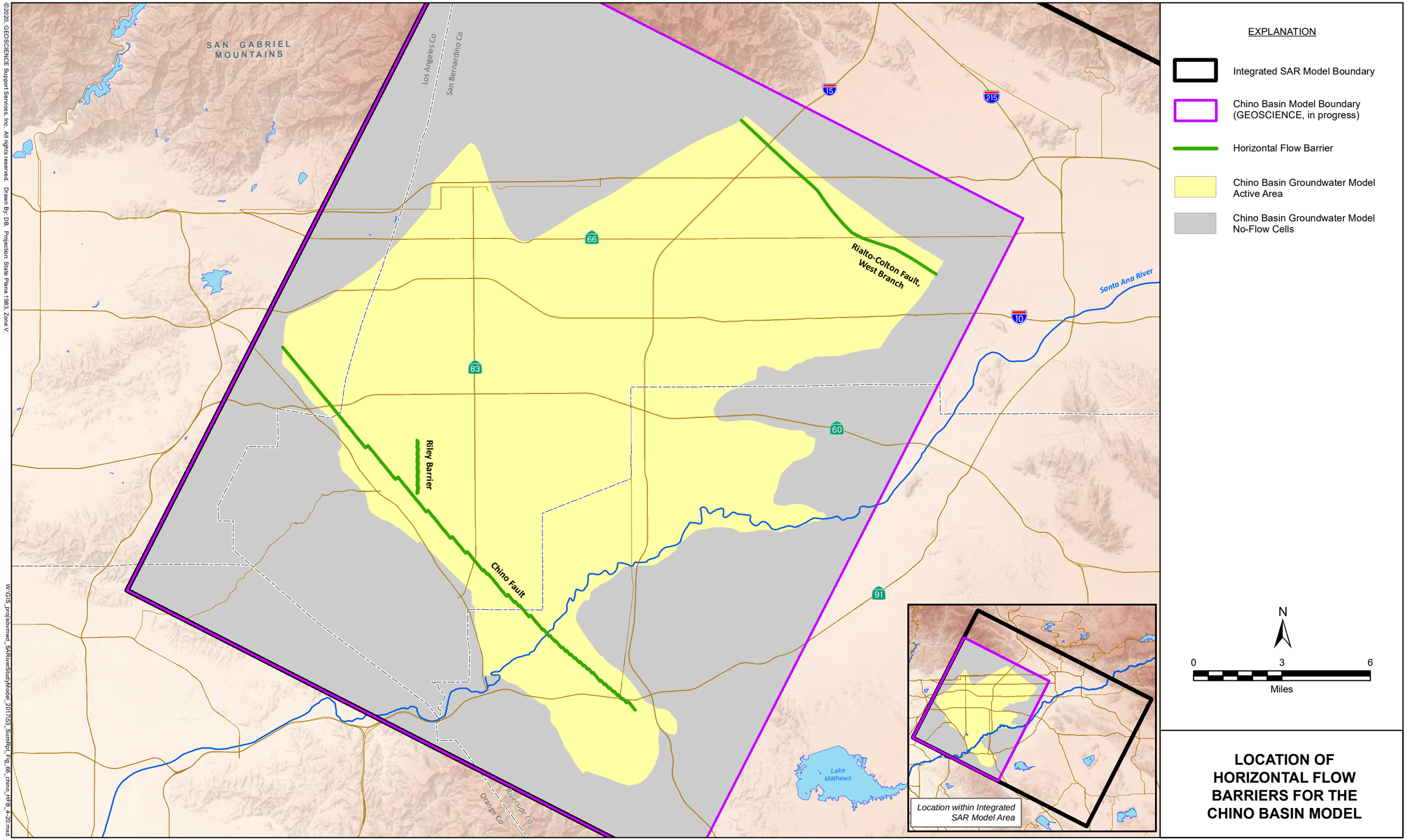
FIGURE 65

GEOSCIENCE



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LOCATION OF HORIZONTAL FLOW BARRIERS FOR THE CHINO BASIN MODEL

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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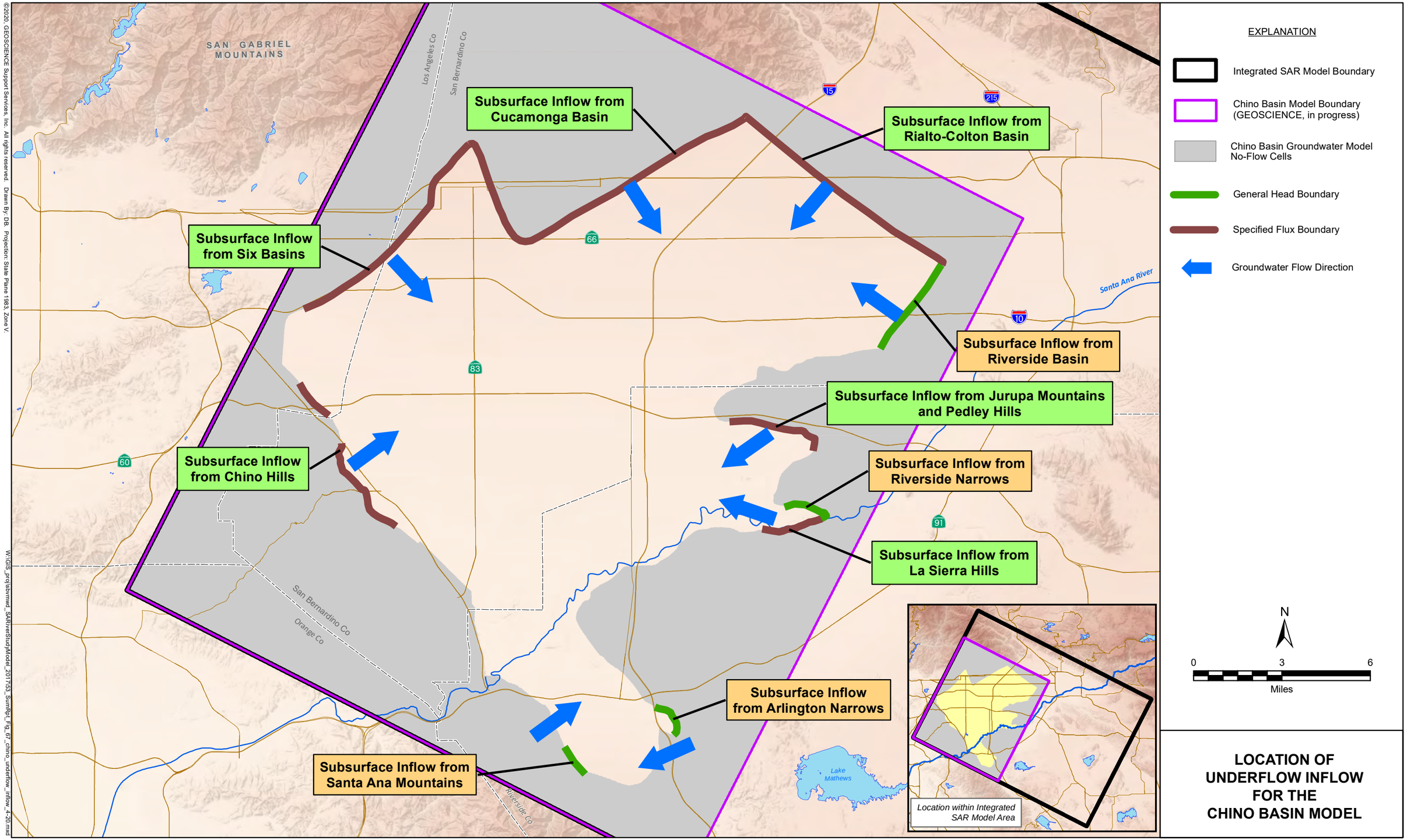
FIGURE 66

GEOSCIENCE



LOCATION OF UNDERFLOW INFLOW FOR THE CHINO BASIN MODEL

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_67_chino_underflow_inflow_4-20.mxd

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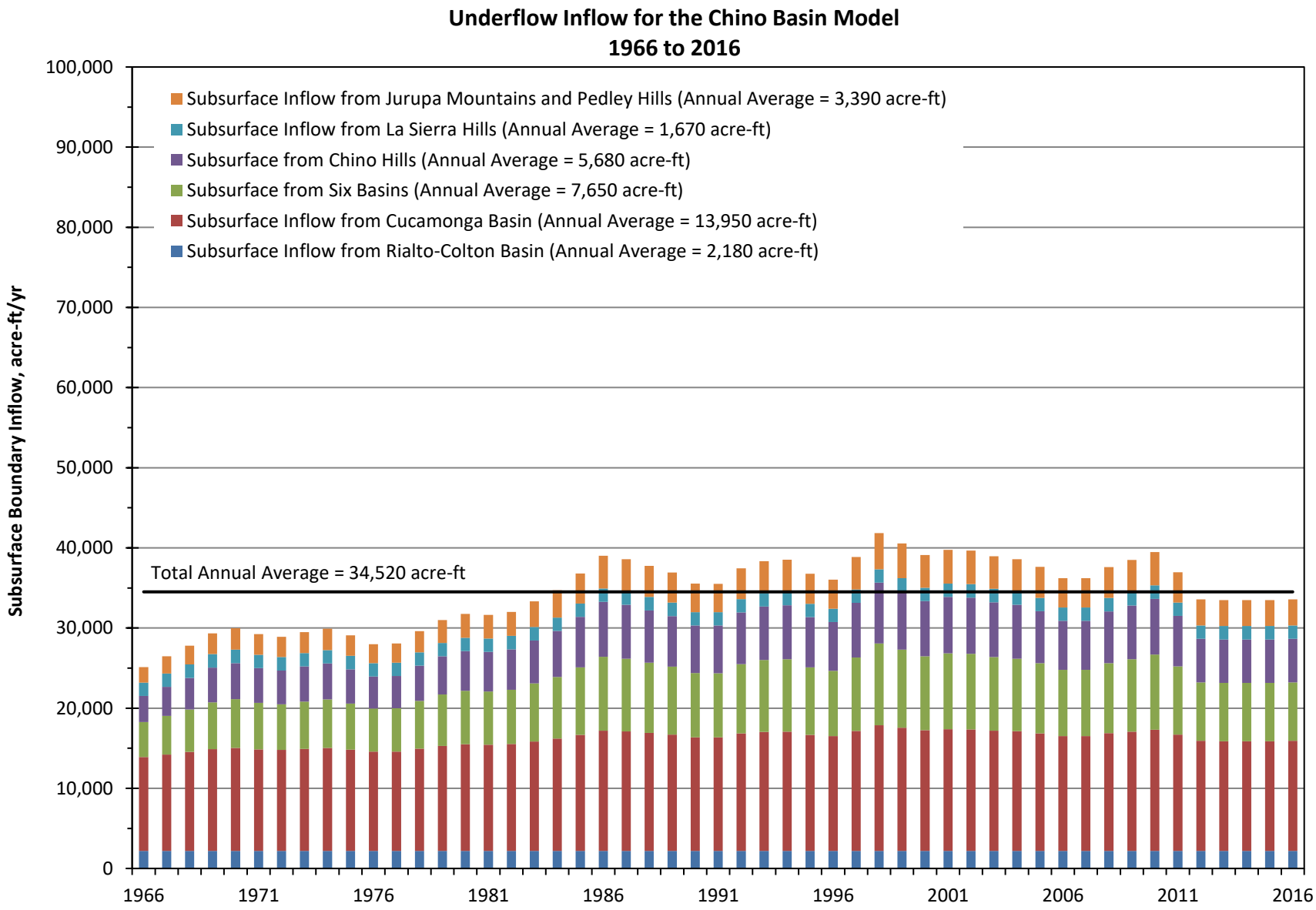
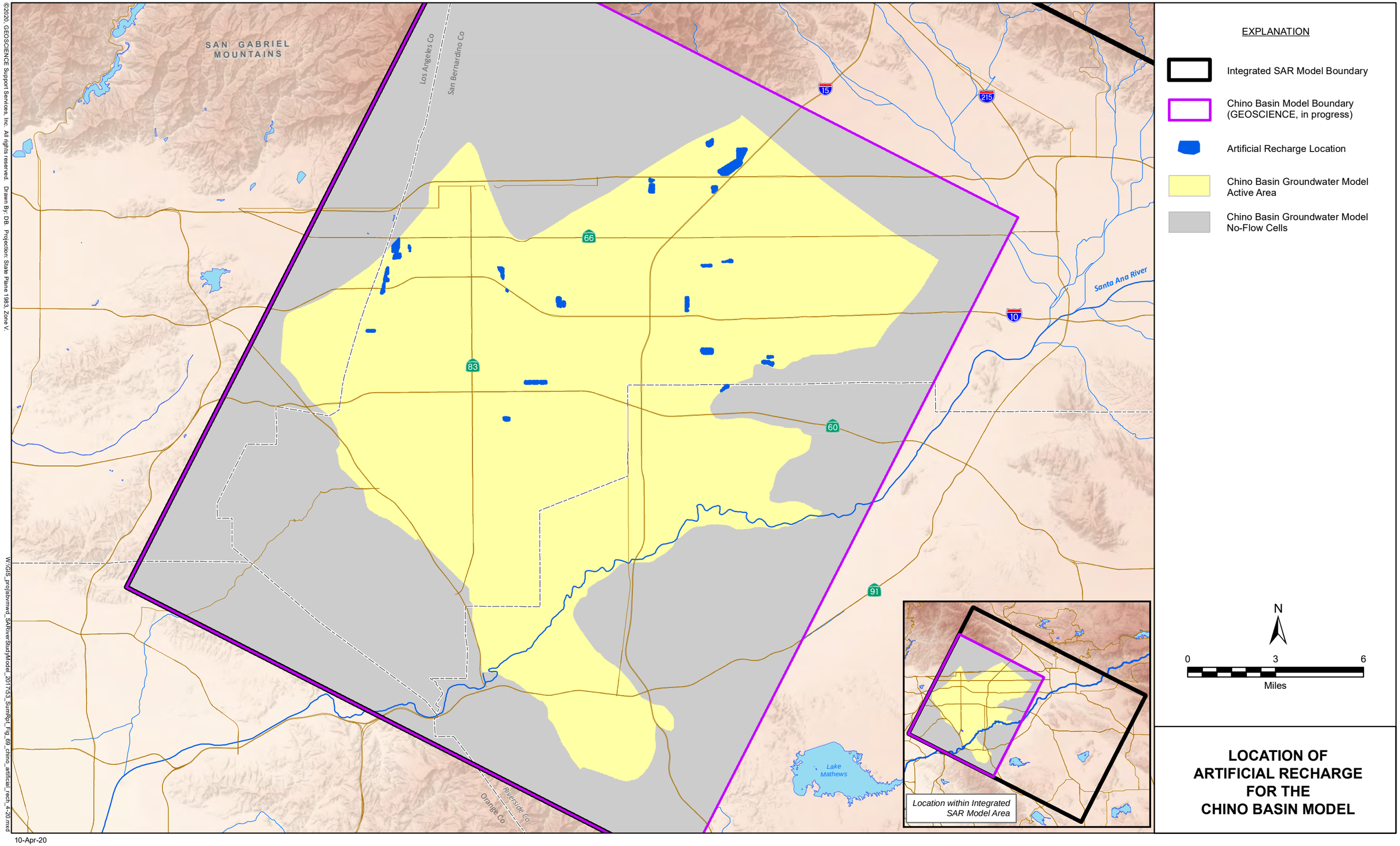

Underflow Inflow for the Chino Basin Model
1966 to 2016
Subsurface Inflow from Jurupa Mountains and Pedley Hills (Annual Average = 3,390 acre-ft)
Subsurface Inflow from La Sierra Hills (Annual Average = 1,670 acre-ft)
Subsurface from Chino Hills (Annual Average = 5,680 acre-ft)
Subsurface from Six Basins (Annual Average = 7,650 acre-ft)
Subsurface Inflow from Cucamonga Basin (Annual Average = 13,950 acre-ft)
Subsurface Inflow from Rialto-Colton Basin (Annual Average = 2,180 acre-ft)
Total Annual Average = 34,520 acre-ft
Subsurface Boundary Inflow, acre-ft/yr
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 68



LOCATION OF ARTIFICIAL RECHARGE FOR THE CHINO BASIN MODEL

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W:\GIS_proj\sbvmwd_SARiverStudyModel_201753_SumRpt_Fig_69_chino_artificial_rech_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 69

GEOSCIENCE

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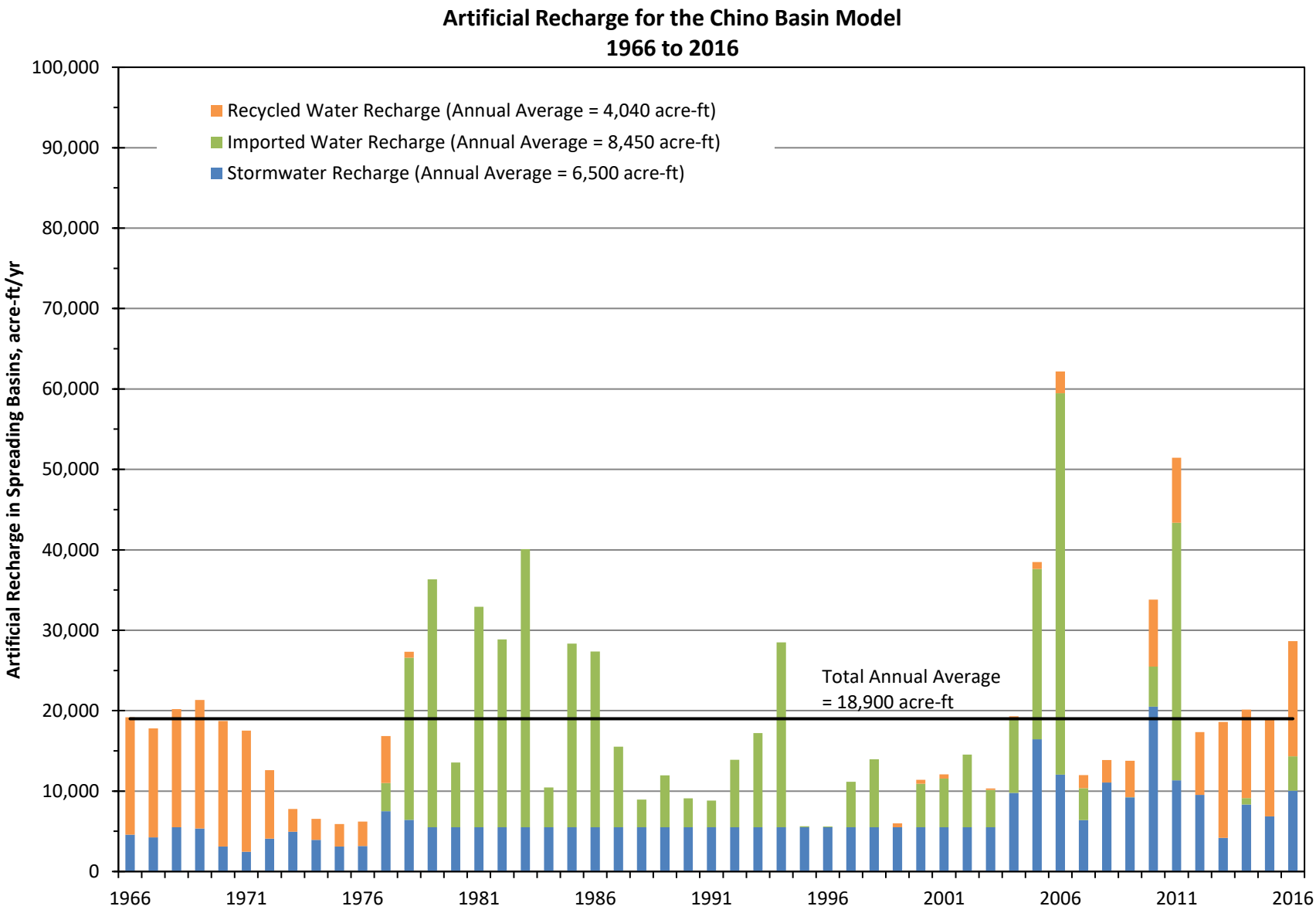
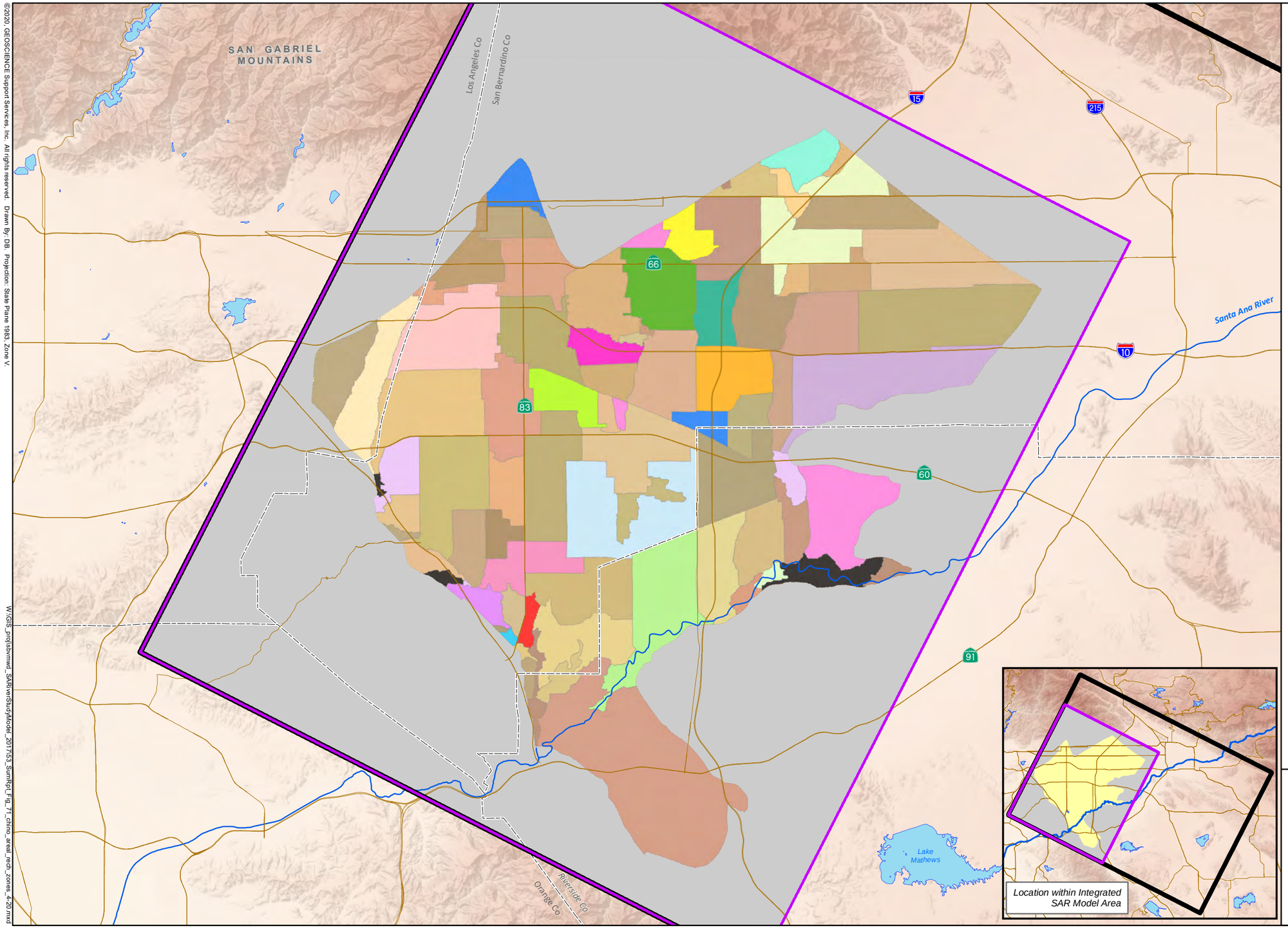


Figure 70



EXPLANATION

Integrated SAR Model Boundary

Chino Basin Model Boundary (GEOSCIENCE, in progress)

Areal Recharge Zones from Precipitation and Return Flow from Applied Water

Chino Basin Groundwater Model No-Flow Cells

N

0 3 6

Miles

LOCATION OF AREAL RECHARGE ZONES FROM PRECIPITATION AND ANTHROPOGENIC RETURN FLOW FOR THE CHINO BASIN MODEL

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W:\GIS_proj\sbvmwd_SARiverStudy\Model_2017\53_SumRpt_Fig_71_chino_areal_rech_zones_4-20.mxd

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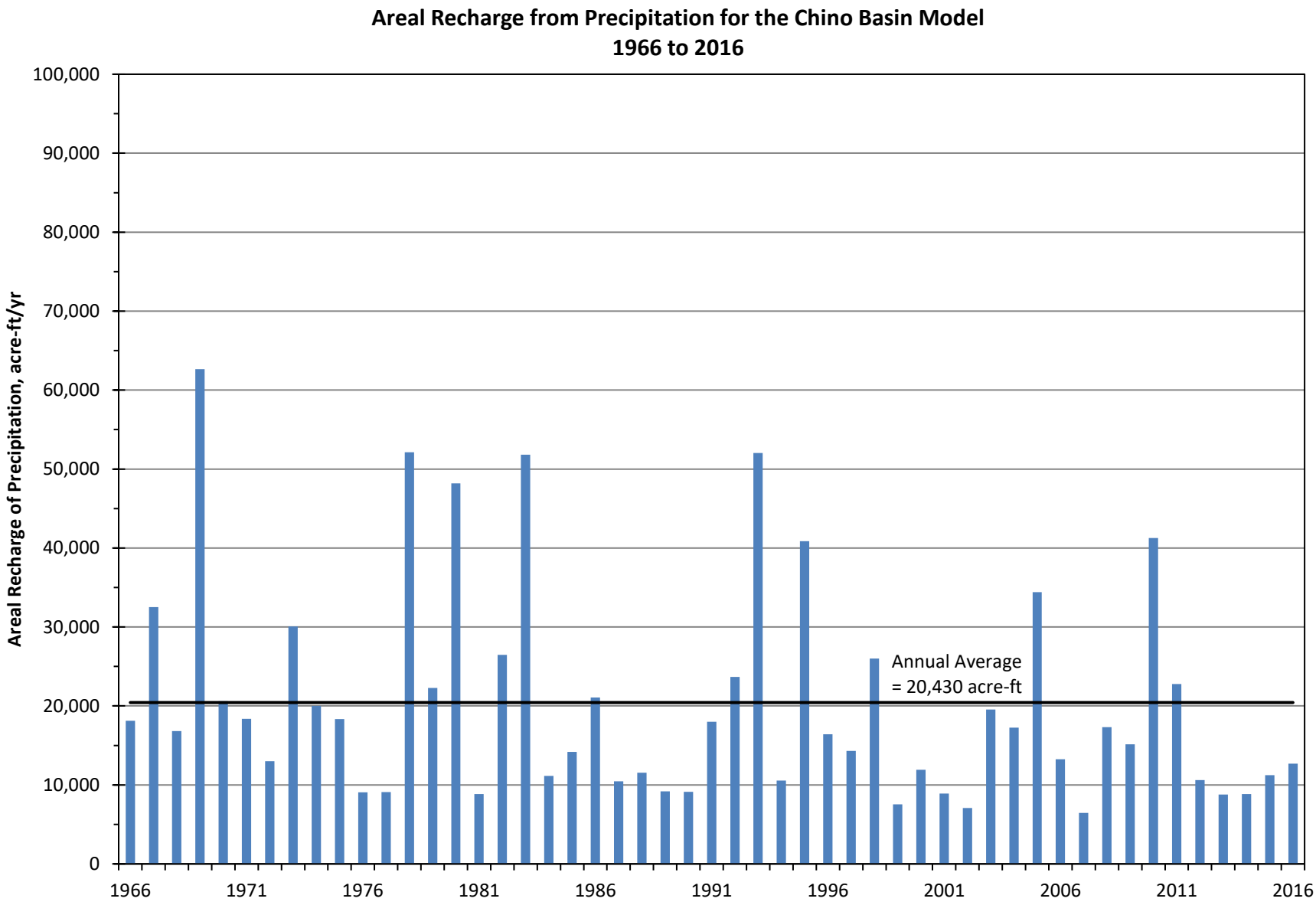

Areal Recharge from Precipitation for the Chino Basin Model
1966 to 2016
Areal Recharge of Precipitation, acre-ft/yr
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
Annual Average
= 20,430 acre-ft

Figure 72

DRAFT

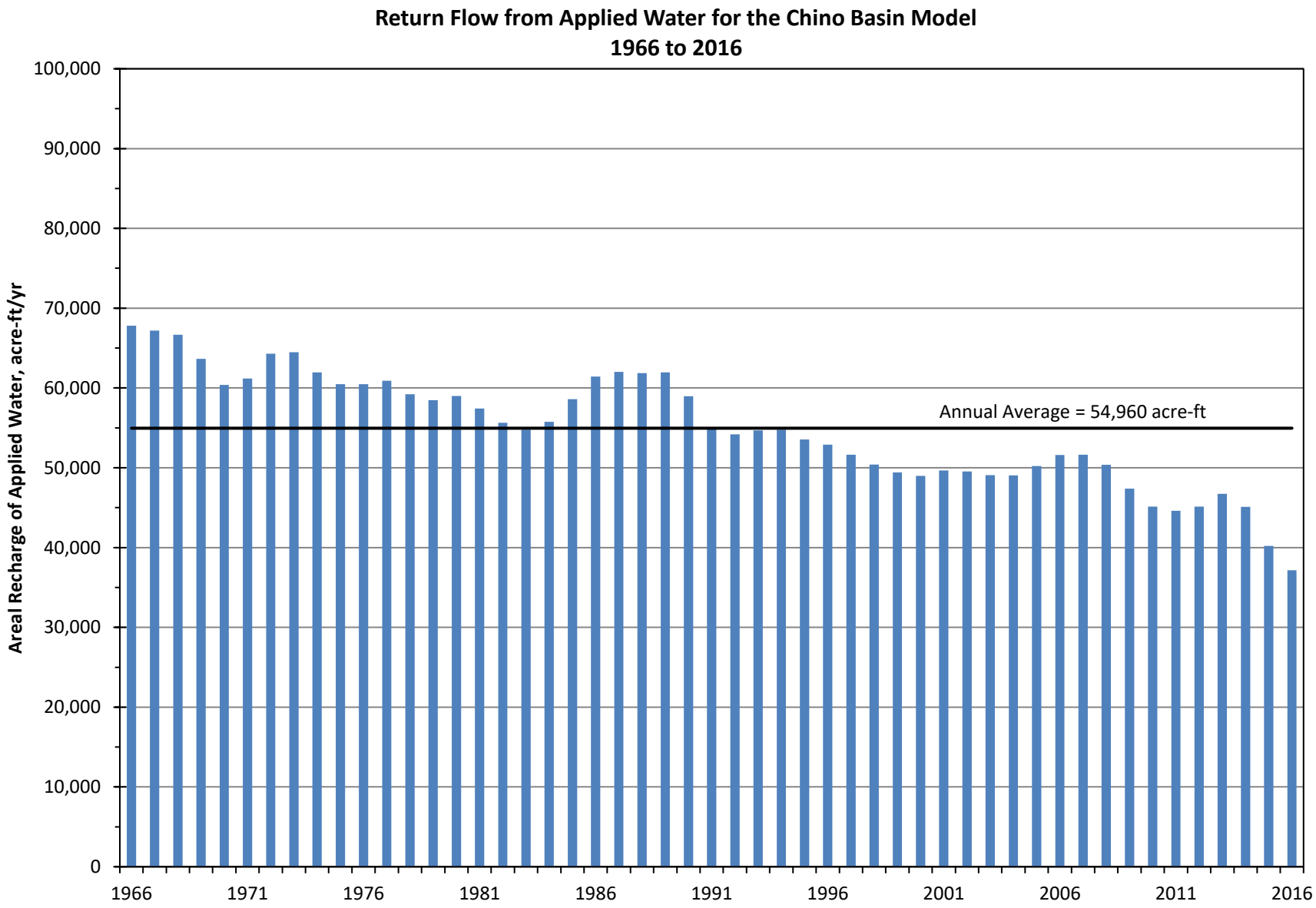
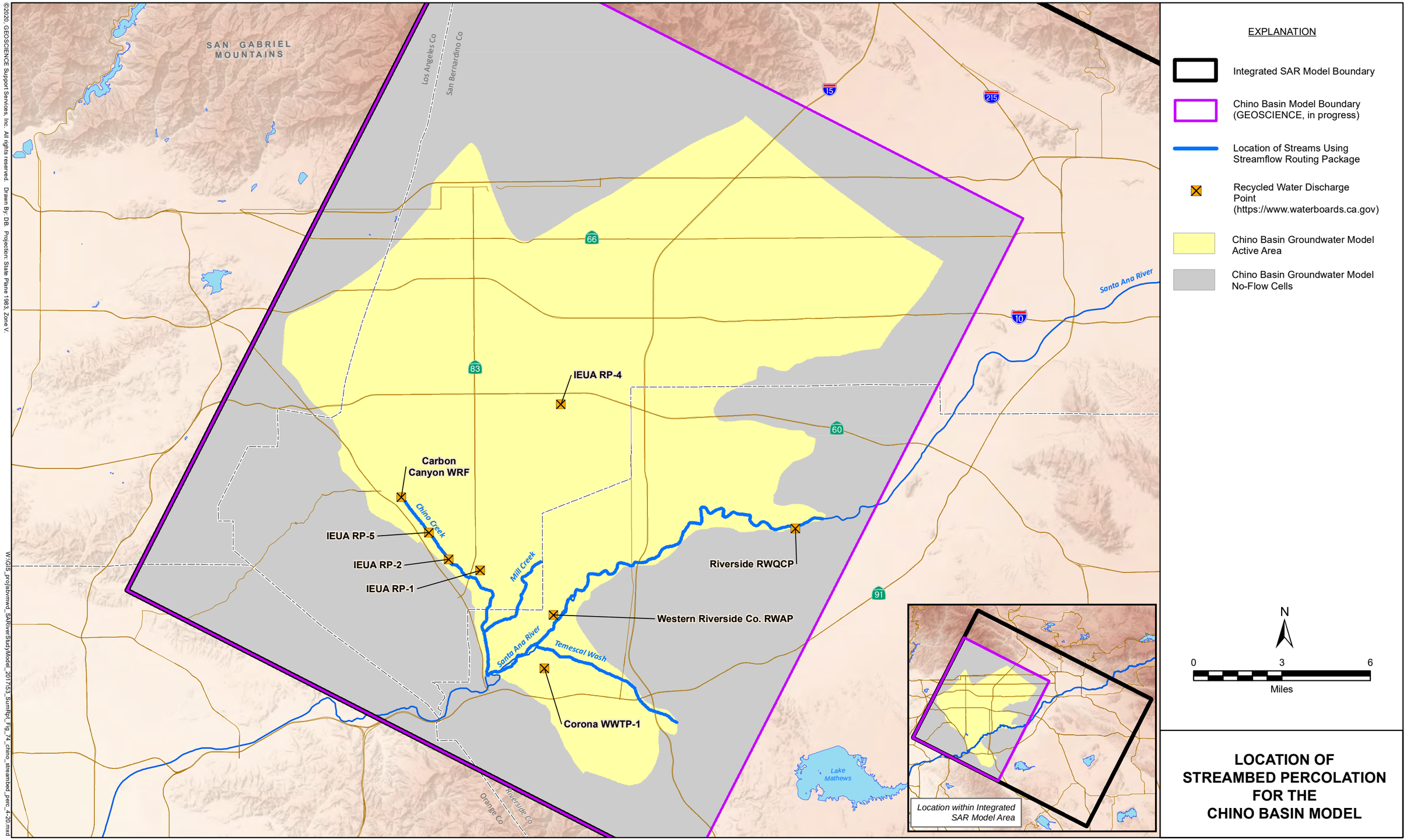


Figure 73



LOCATION OF STREAMBED PERCOLATION FOR THE CHINO BASIN MODEL

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W:\GIS_proj\sbvmwd_SARiverStudy\Model_2017\53_SumRpt_Fig_74_chino_streambed_perc_4-20.mxd

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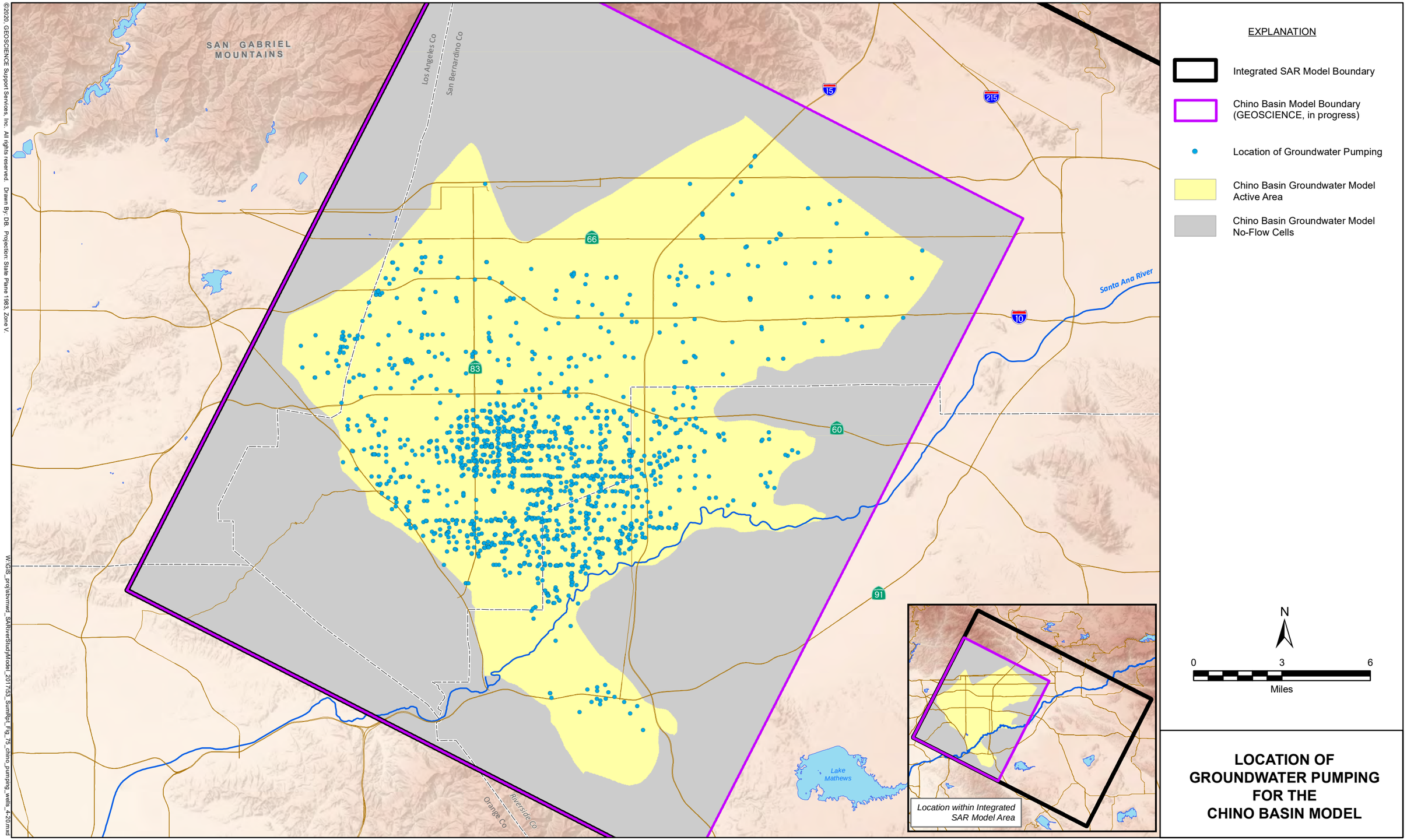

LOCATION OF GROUNDWATER PUMPING FOR THE CHINO BASIN MODEL

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W:\GIS_proj\sbvmwd_SARiverStudy\Model_2017\53_SumRpt_Fig_75_chino_pumping_wells_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 75

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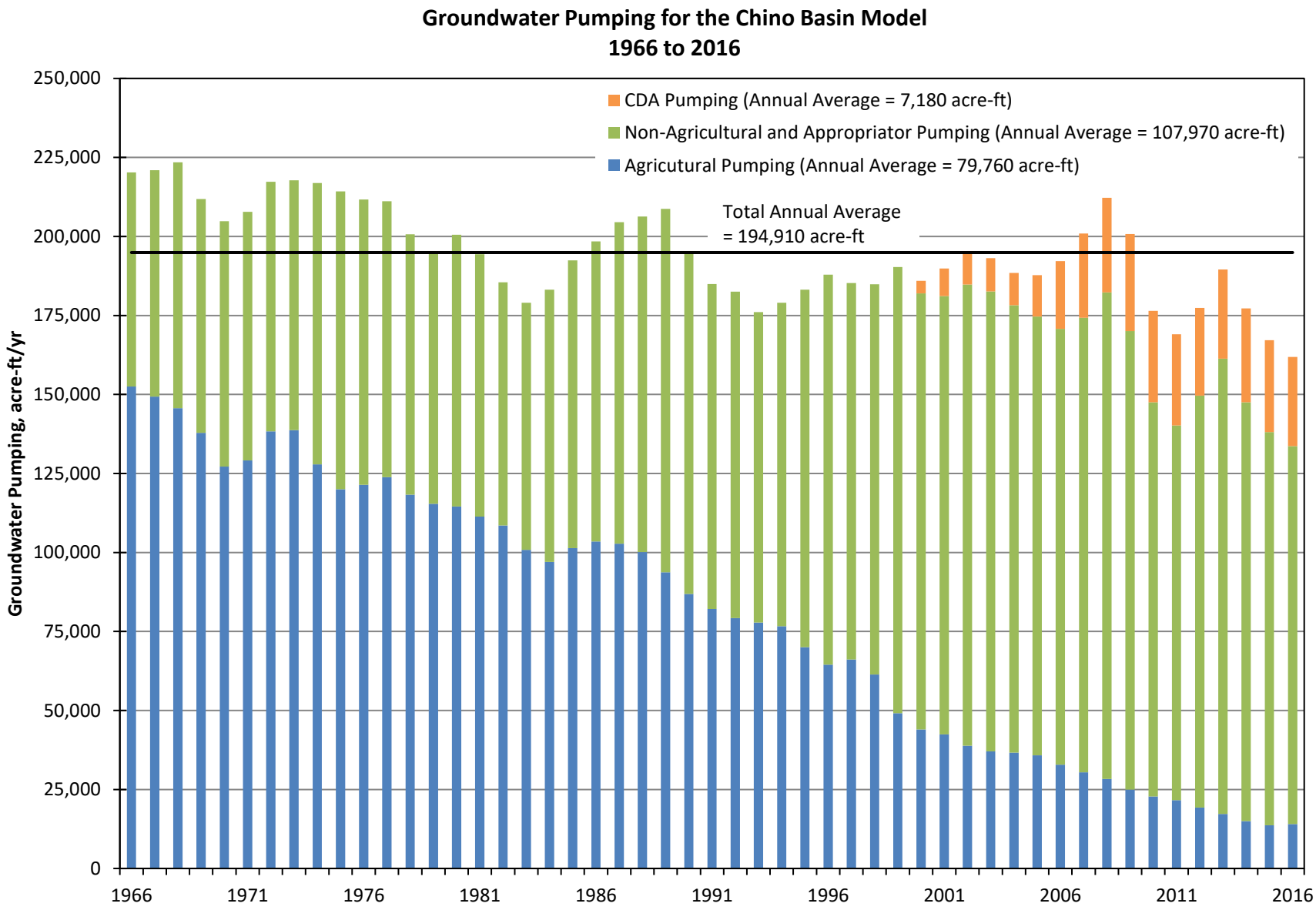
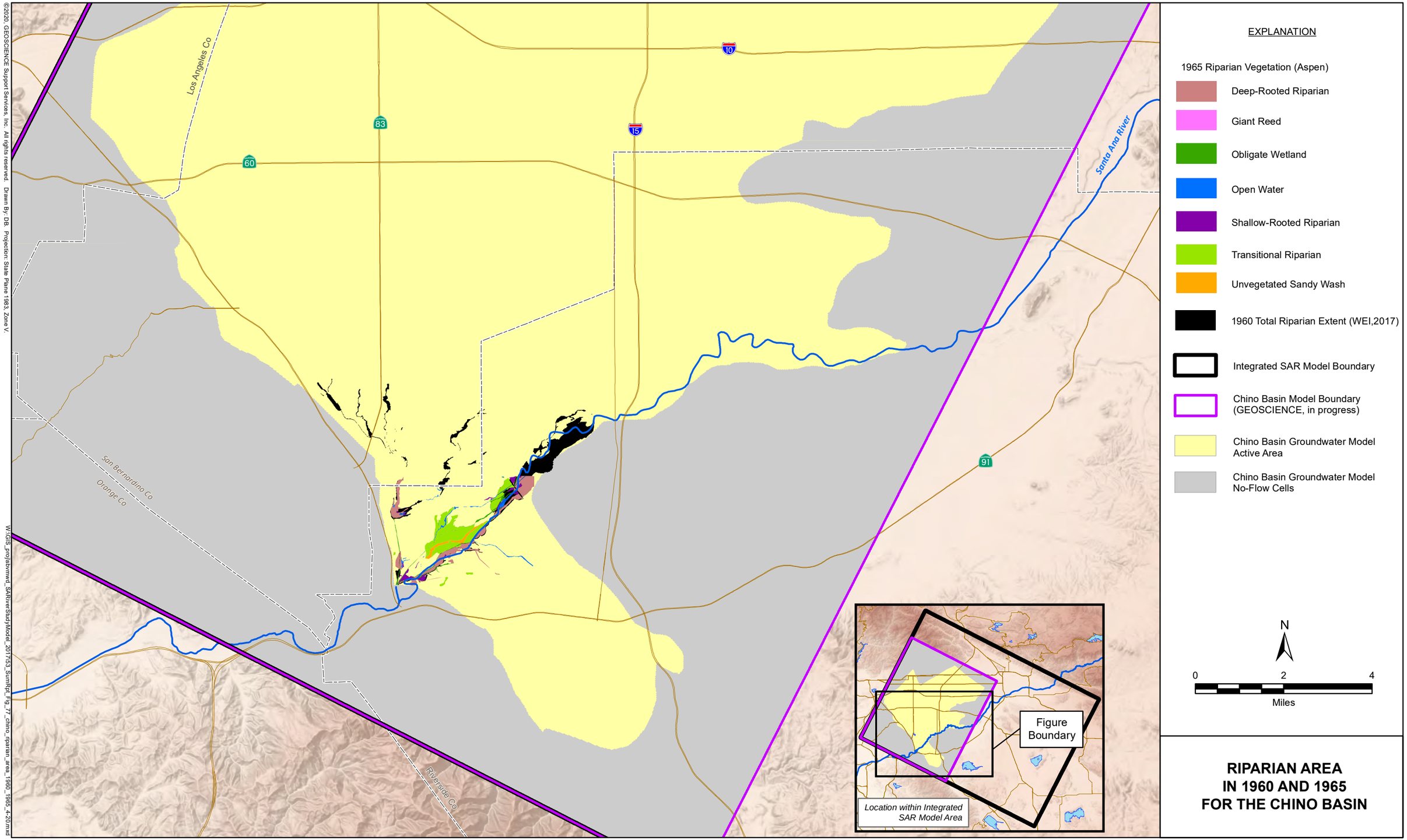

Groundwater Pumping for the Chino Basin Model
1966 to 2016
CDA Pumping (Annual Average = 7,180 acre-ft)
Non-Agricultural and Appropriator Pumping (Annual Average = 107,970 acre-ft)
Agricutural Pumping (Annual Average = 79,760 acre-ft)
Total Annual Average
= 194,910 acre-ft
Groundwater Pumping, acre-ft/yr
250,000
225,000
200,000
175,000
150,000
125,000
100,000
75,000
50,000
25,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 76



RIPARIAN AREA IN 1960 AND 1965 FOR THE CHINO BASIN

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_77_chino_riparian_area_1960_1965_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 77

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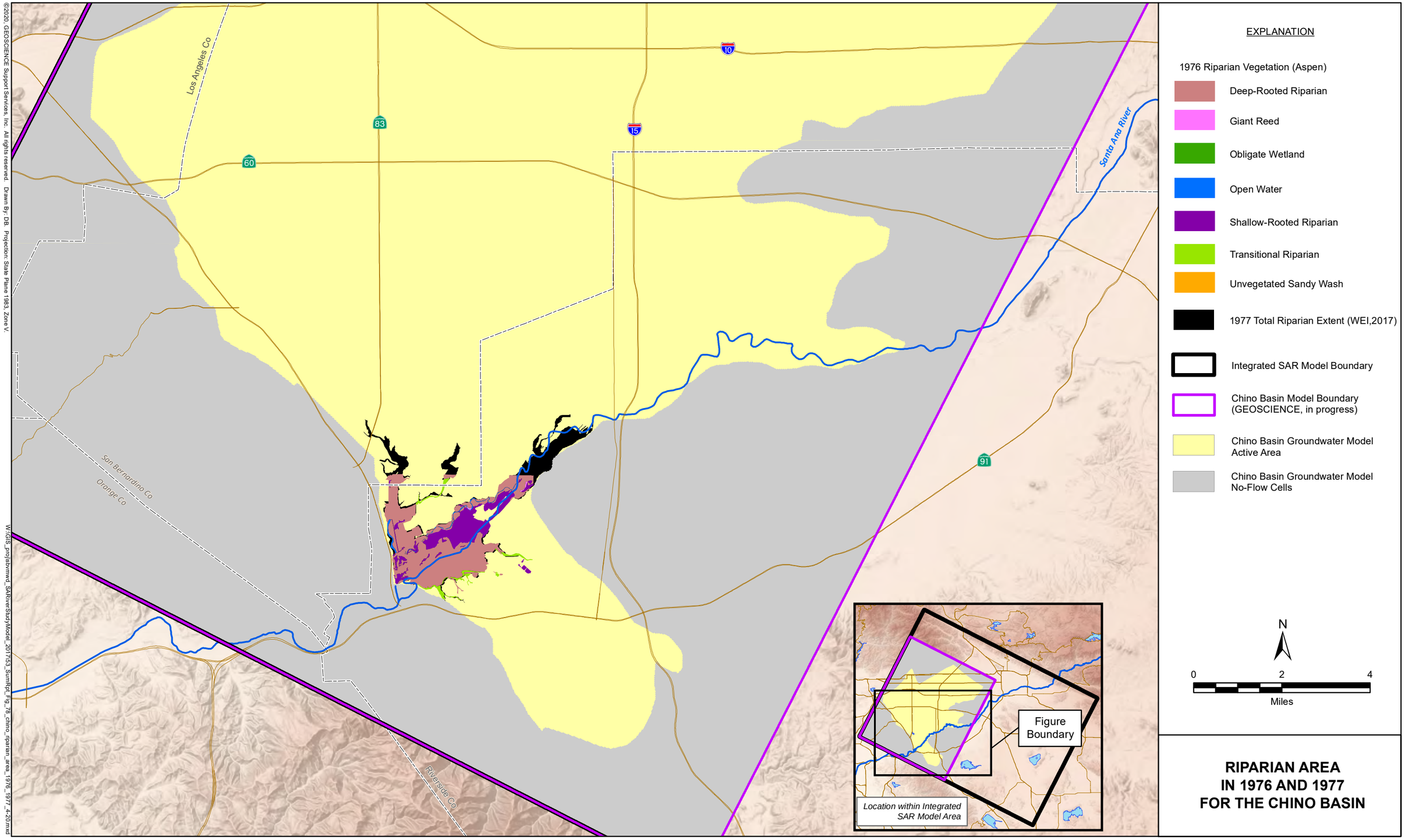

RIPARIAN AREA IN 1976 AND 1977 FOR THE CHINO BASIN

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_78_chino_riparian_area_1976_1977_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 78

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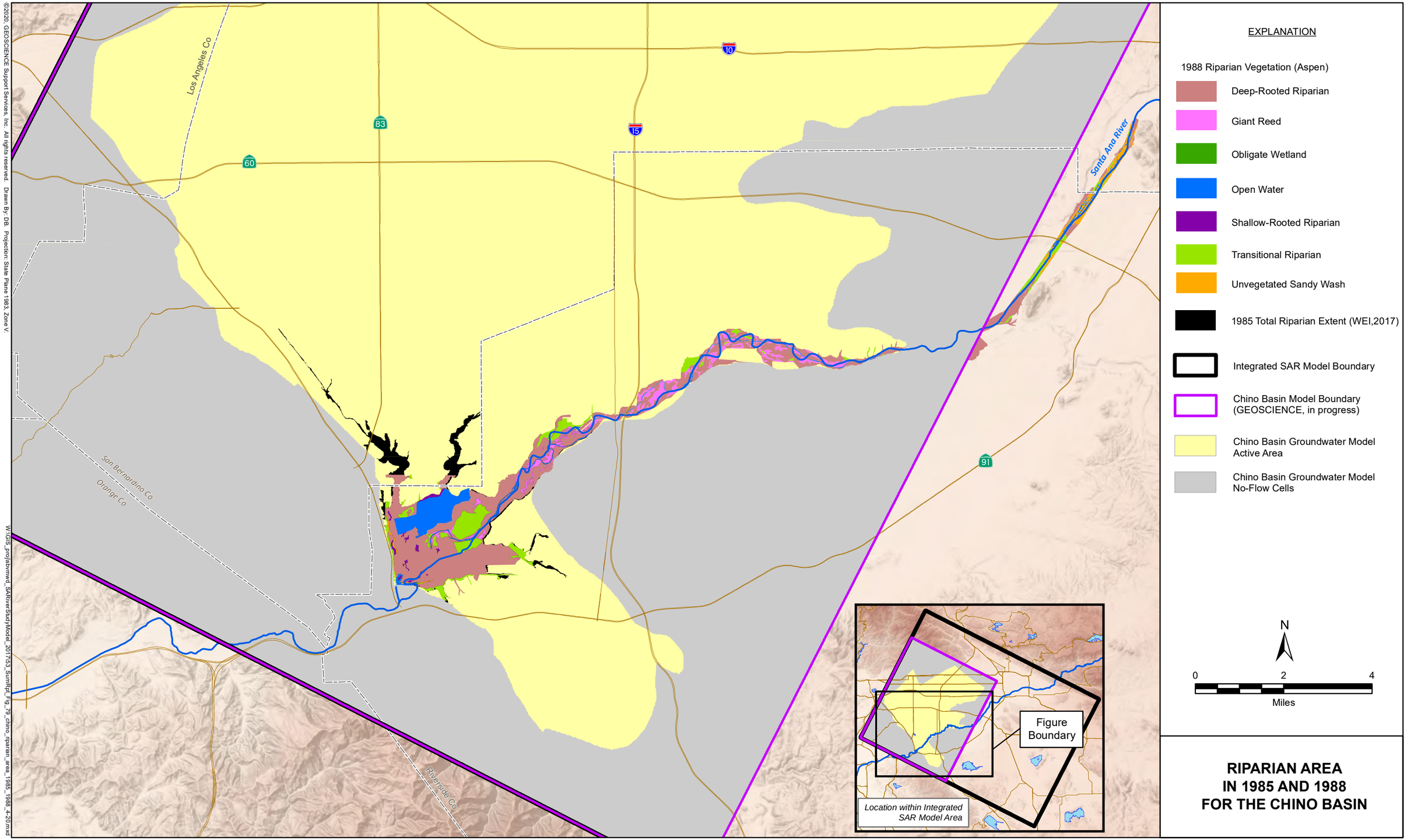

RIPARIAN AREA IN 1985 AND 1988 FOR THE CHINO BASIN

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W:\GIS_projs\bwmwd_SARiverStudyModel_2017\53_SumRpt_Fig_79_chino_riparian_area_1985_1988_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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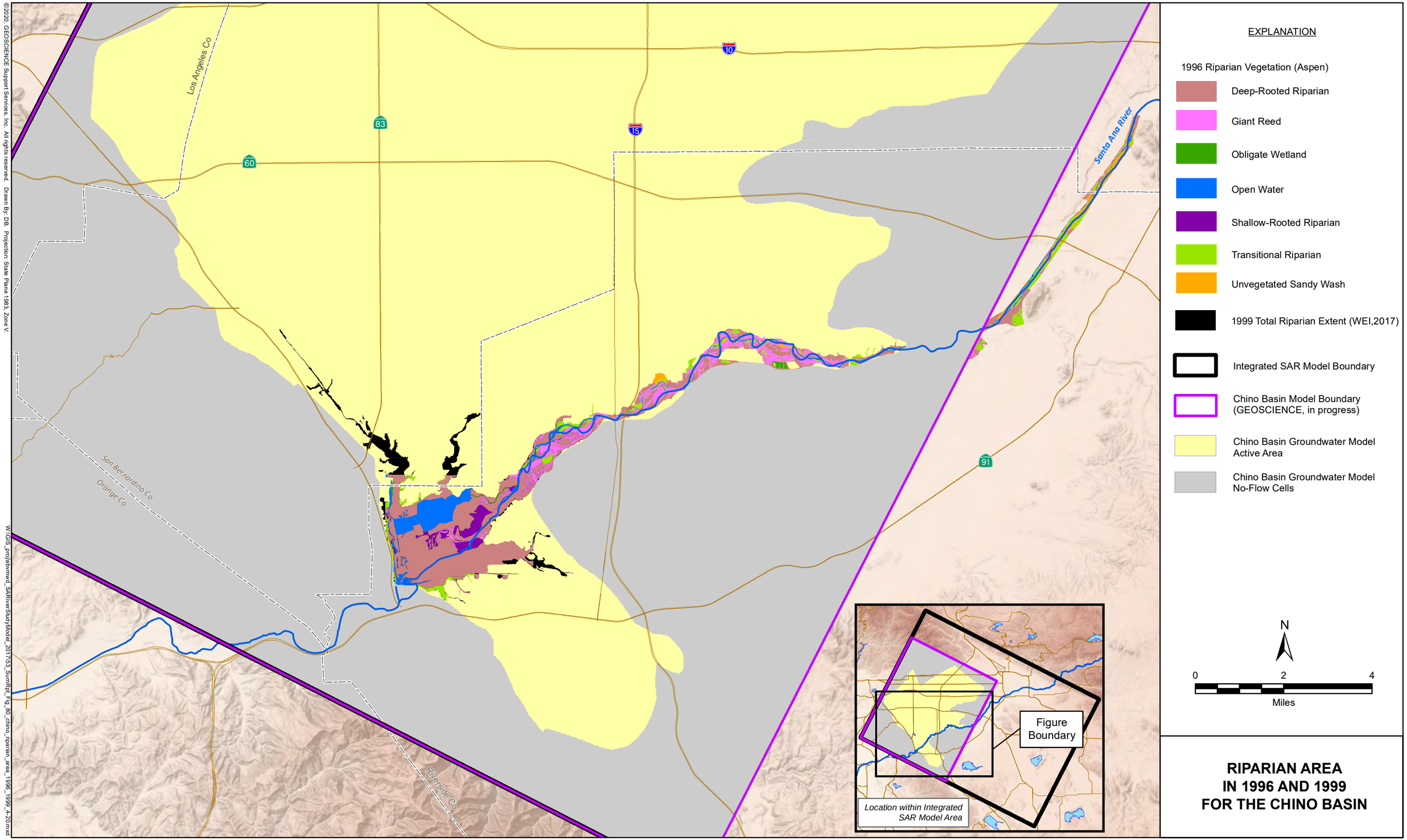
FIGURE 79

GEOSCIENCE



RIPARIAN AREA IN 1996 AND 1999 FOR THE CHINO BASIN

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W:\GIS_projs\bvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_80_chino_riparian_area_1996_1999_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 80

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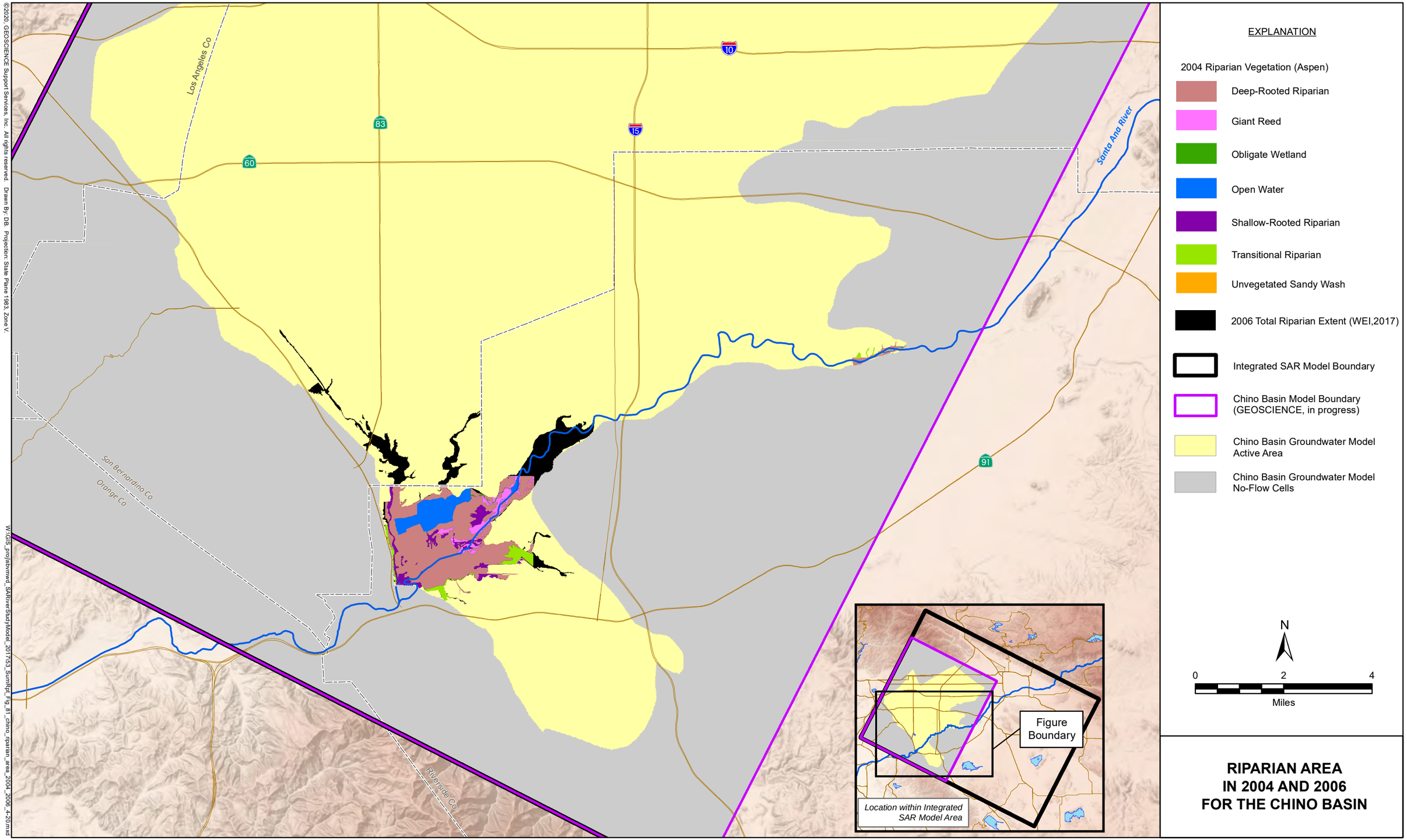

RIPARIAN AREA IN 2004 AND 2006 FOR THE CHINO BASIN

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_81_chino_riparian_area_2004_2006_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 81

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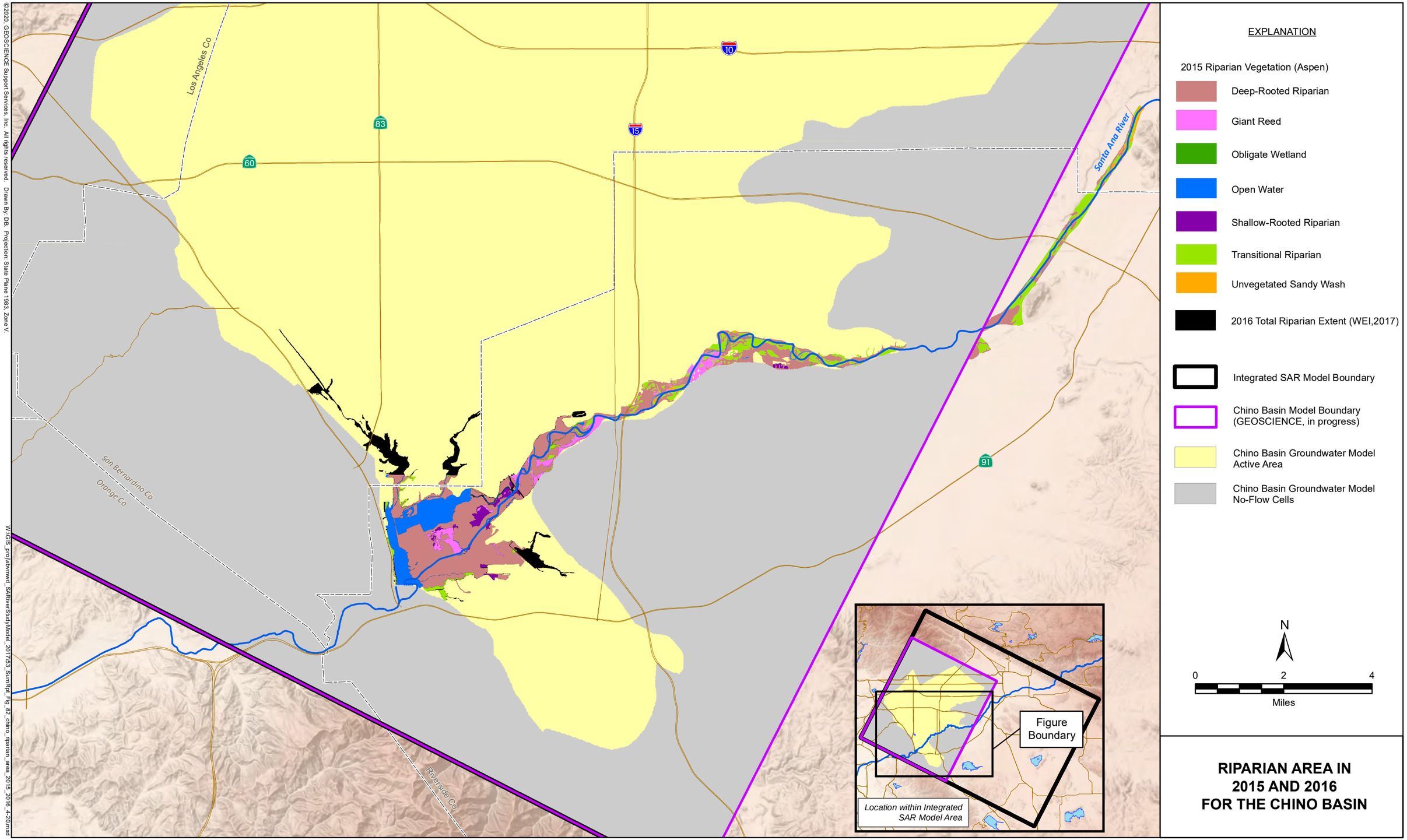

RIPARIAN AREA IN 2015 AND 2016 FOR THE CHINO BASIN

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_82_chino_riparian_area_2015_2016_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 82

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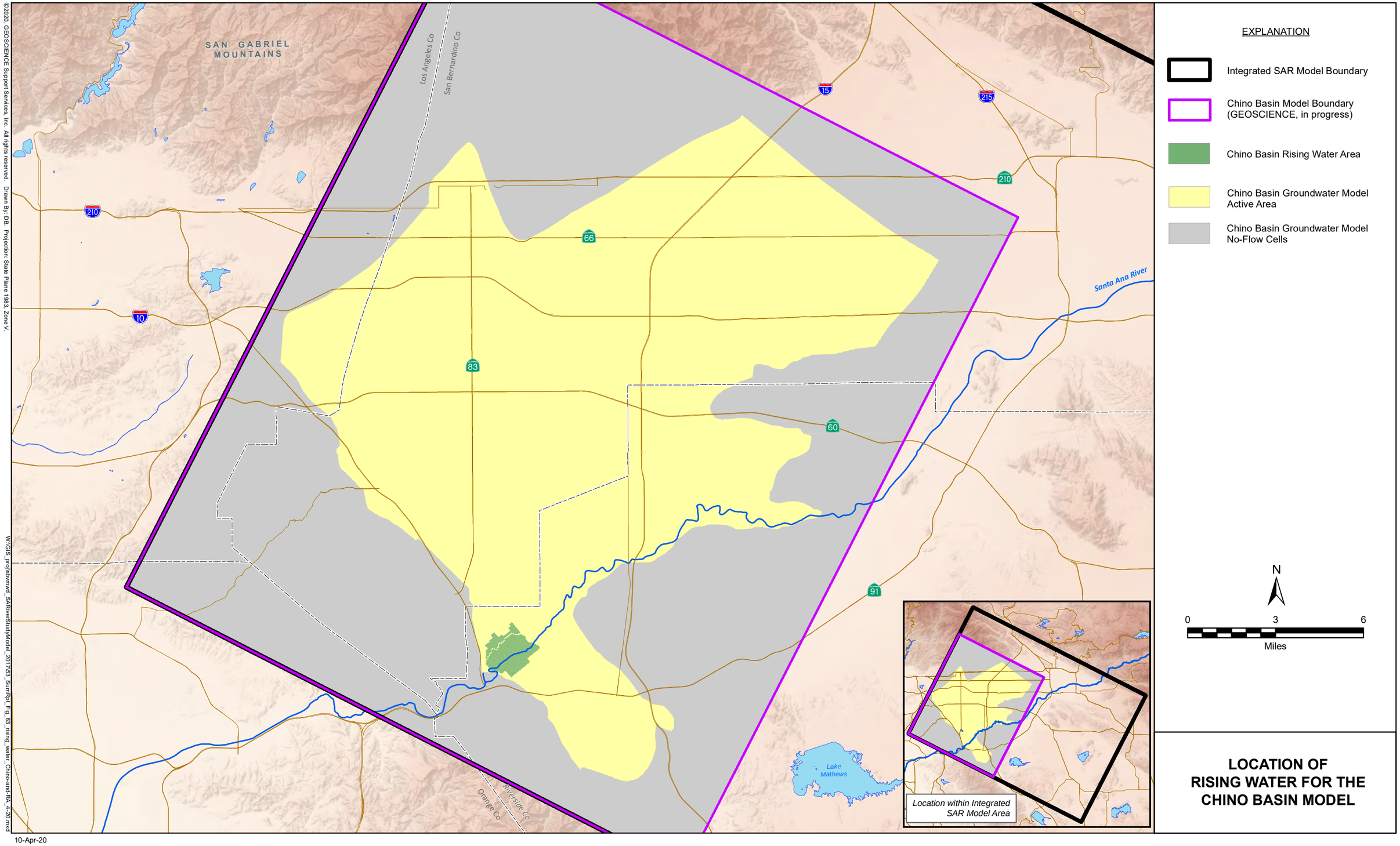

LOCATION OF RISING WATER FOR THE CHINO BASIN MODEL

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W:\GIS_proj\sbvmwd_SARiverStudy\Model_2017\53_SumRpt_Fig_83_rising_water_Chino-and-RA_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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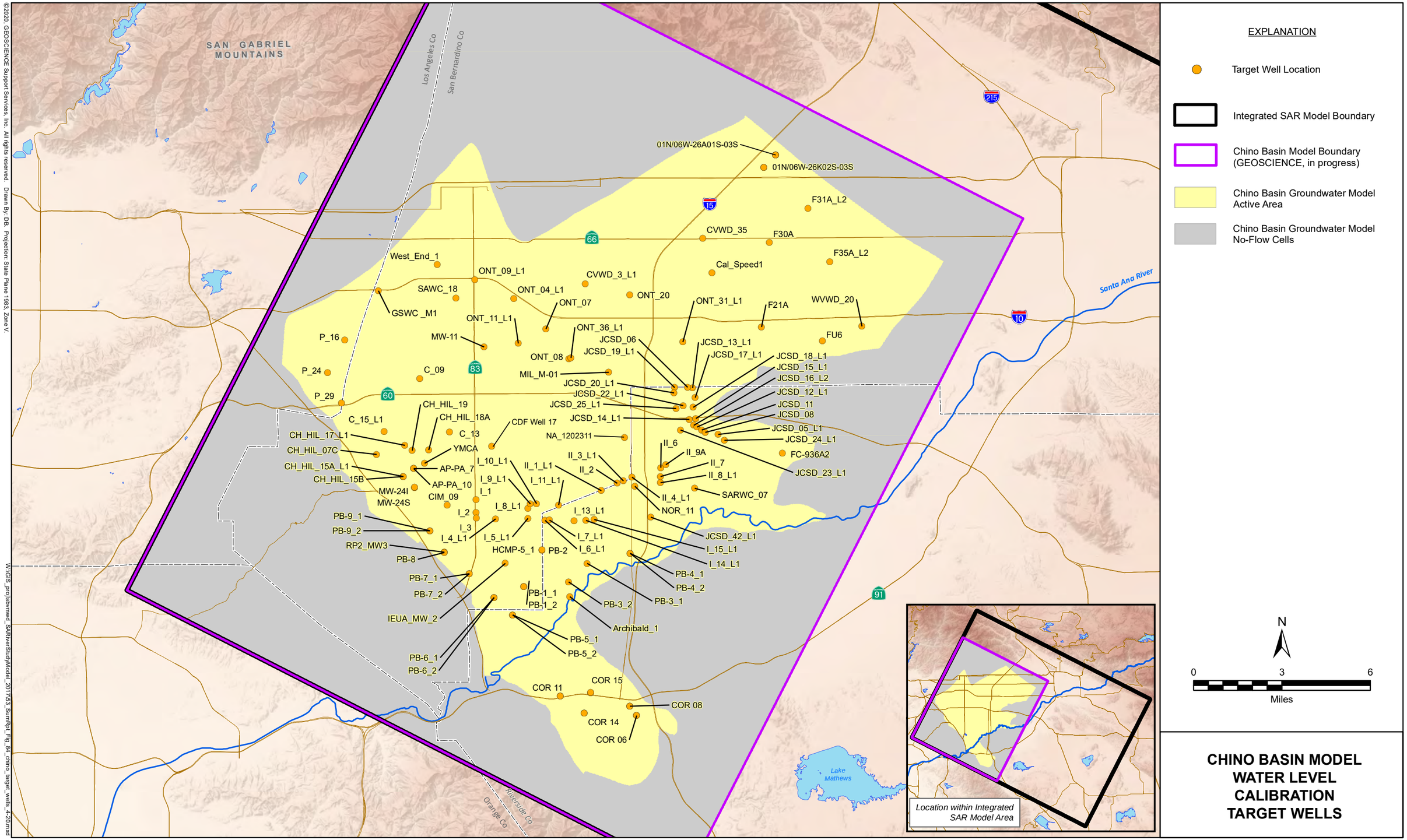
FIGURE 83

GEOSCIENCE



CHINO BASIN MODEL WATER LEVEL CALIBRATION TARGET WELLS

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Scatterplot of Measured and Model-Simulated Water Level for the Chino Basin Model 1966 to 2016

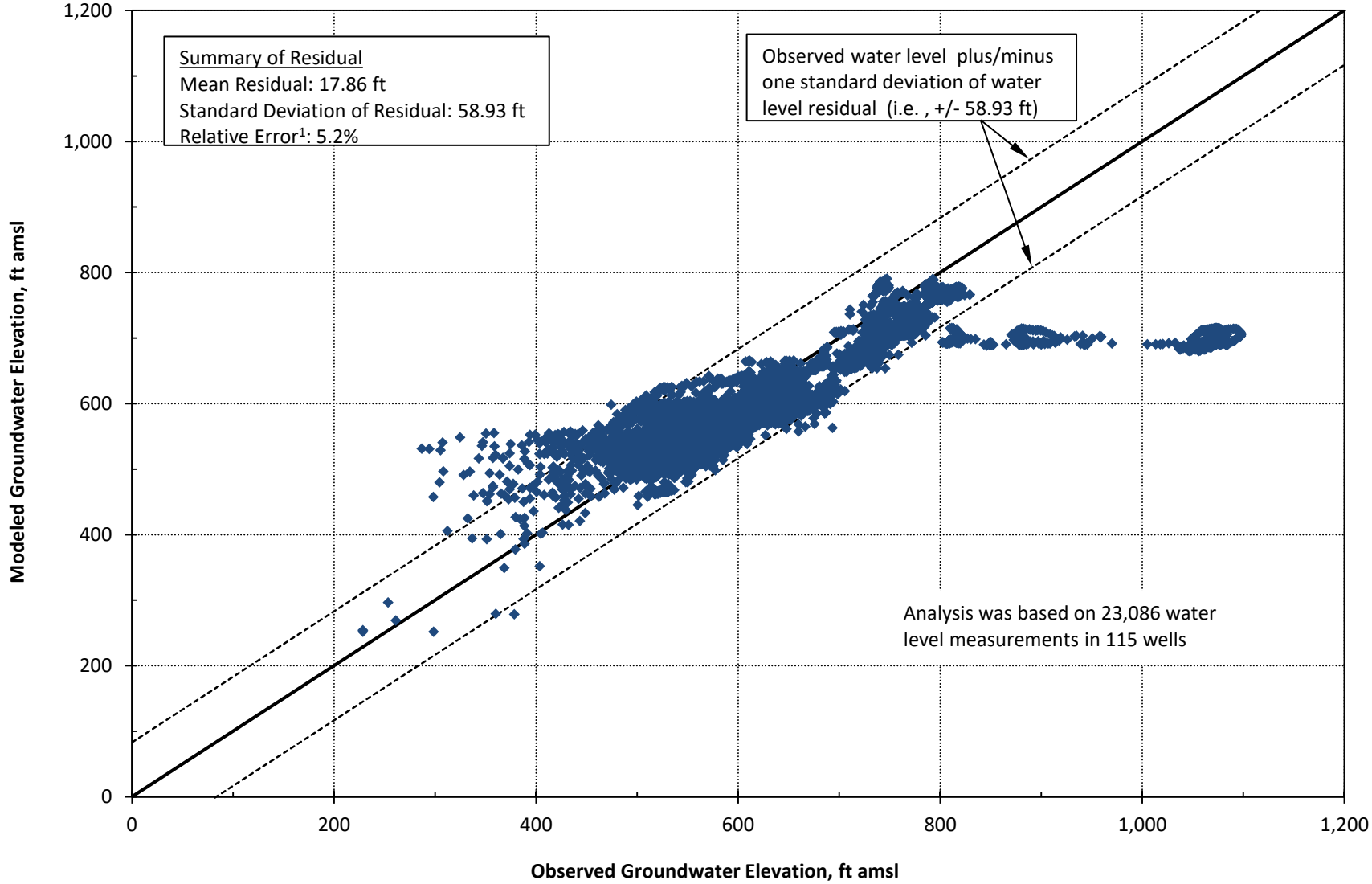

Figure 85

Scatterplot of Measured versus Model-Simulated Monthly Streamflow at the Santa Ana River below Prado Dam Gaging Station – January 1966 to December 2016

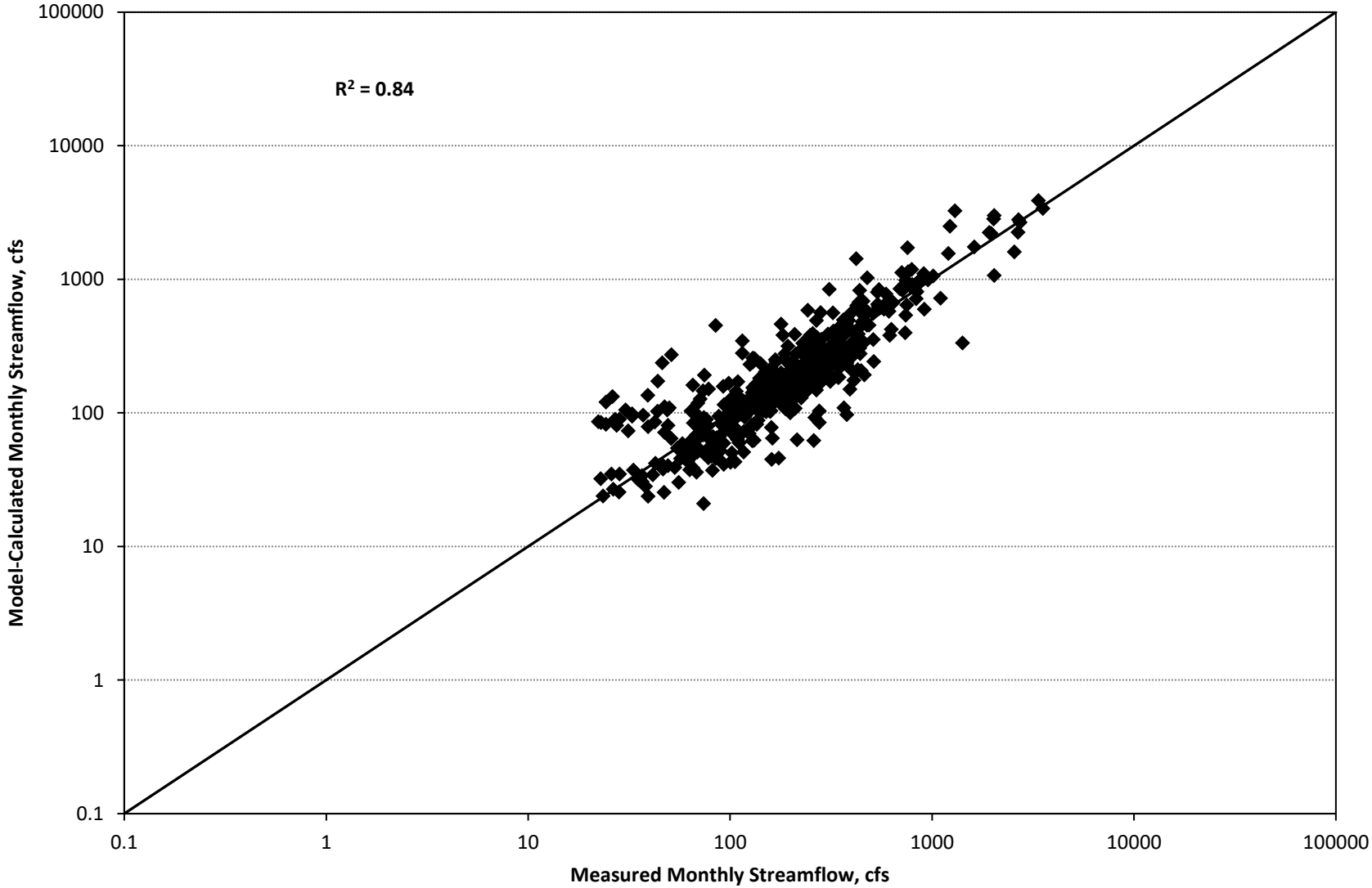

Figure 86

Measured versus Model-Simulated Monthly Streamflow at the Santa Ana River below Prado Dam Gaging Station– January 1966 to December 2016

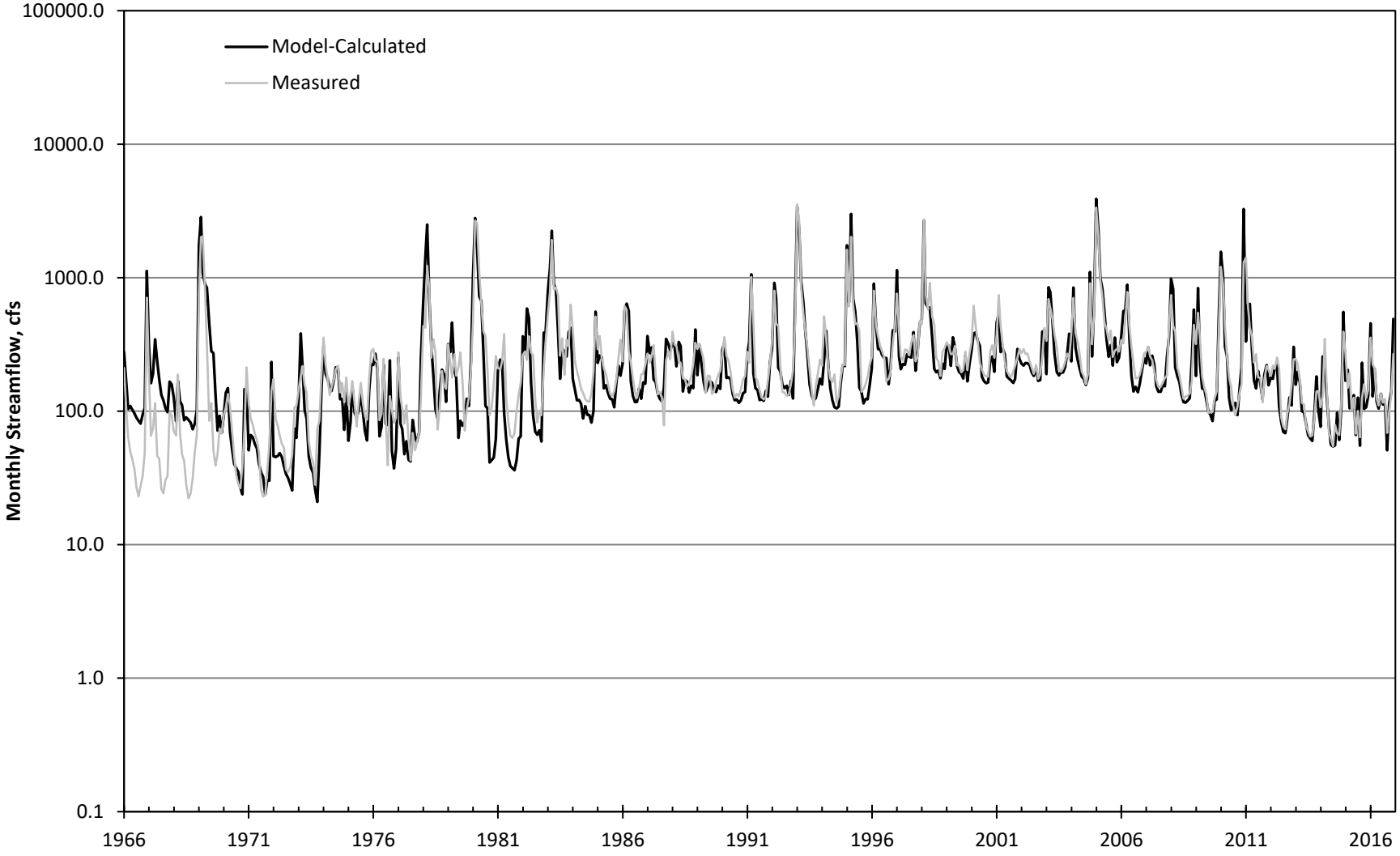

Figure 87

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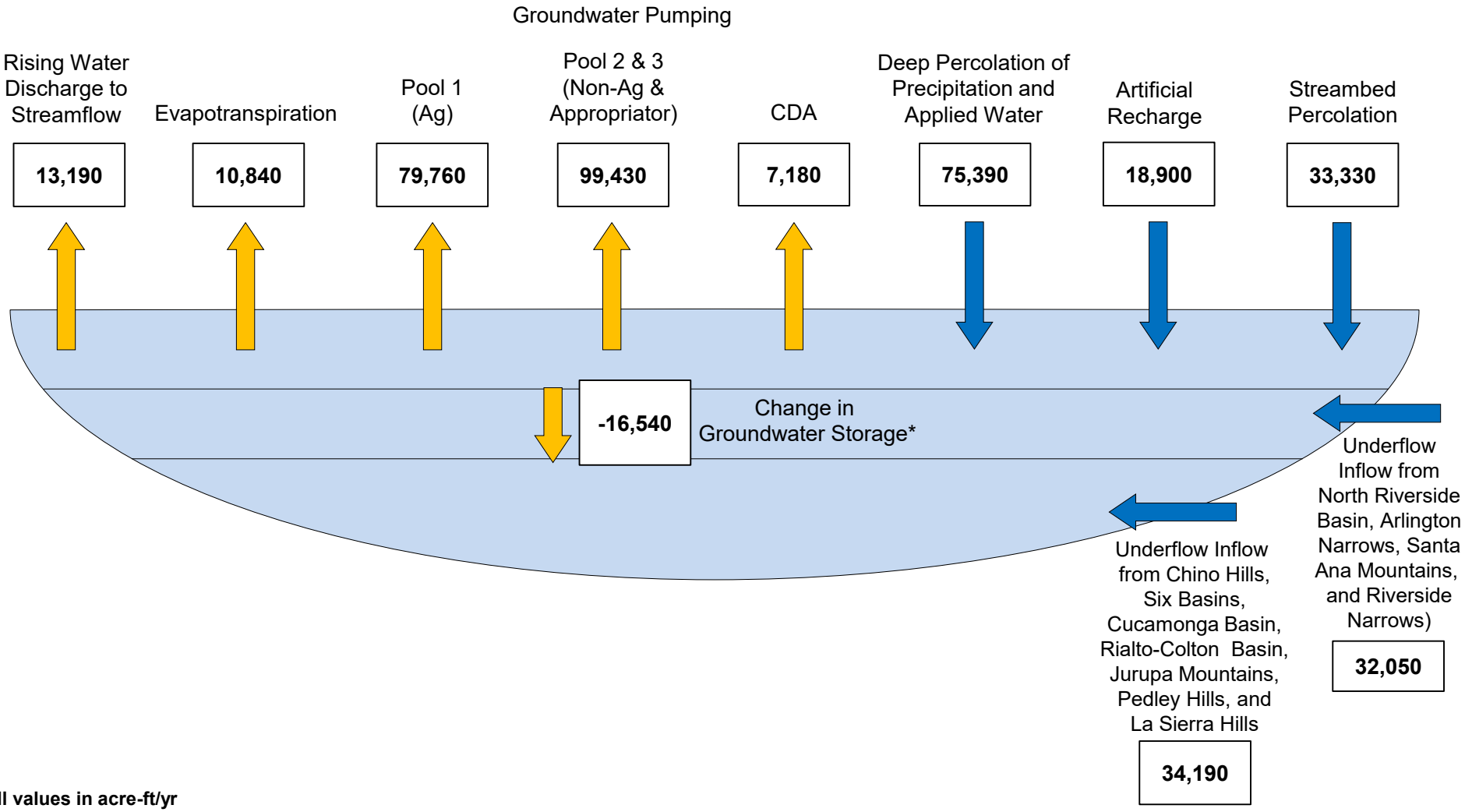

All values in acre-ft/yr

Note: Groundwater Pumping for Pool 2 & 3 (Non-Ag and Appropriator) is lower than model input by approximately 8,540 acre-ft/yr because of dry model cells. This will be resolved through further model calibration.

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR THE CHINO BASIN MODEL 1966 to 2016

X:\Projects\San_Bernardino_MUNI\31\Integrated_SAR_Model\(4)Technical_Memos\(8)Summary Report\Draft\Figures

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Cumulative Annual Change in Groundwater Storage for the Chino Basin Model
1966 - 2016

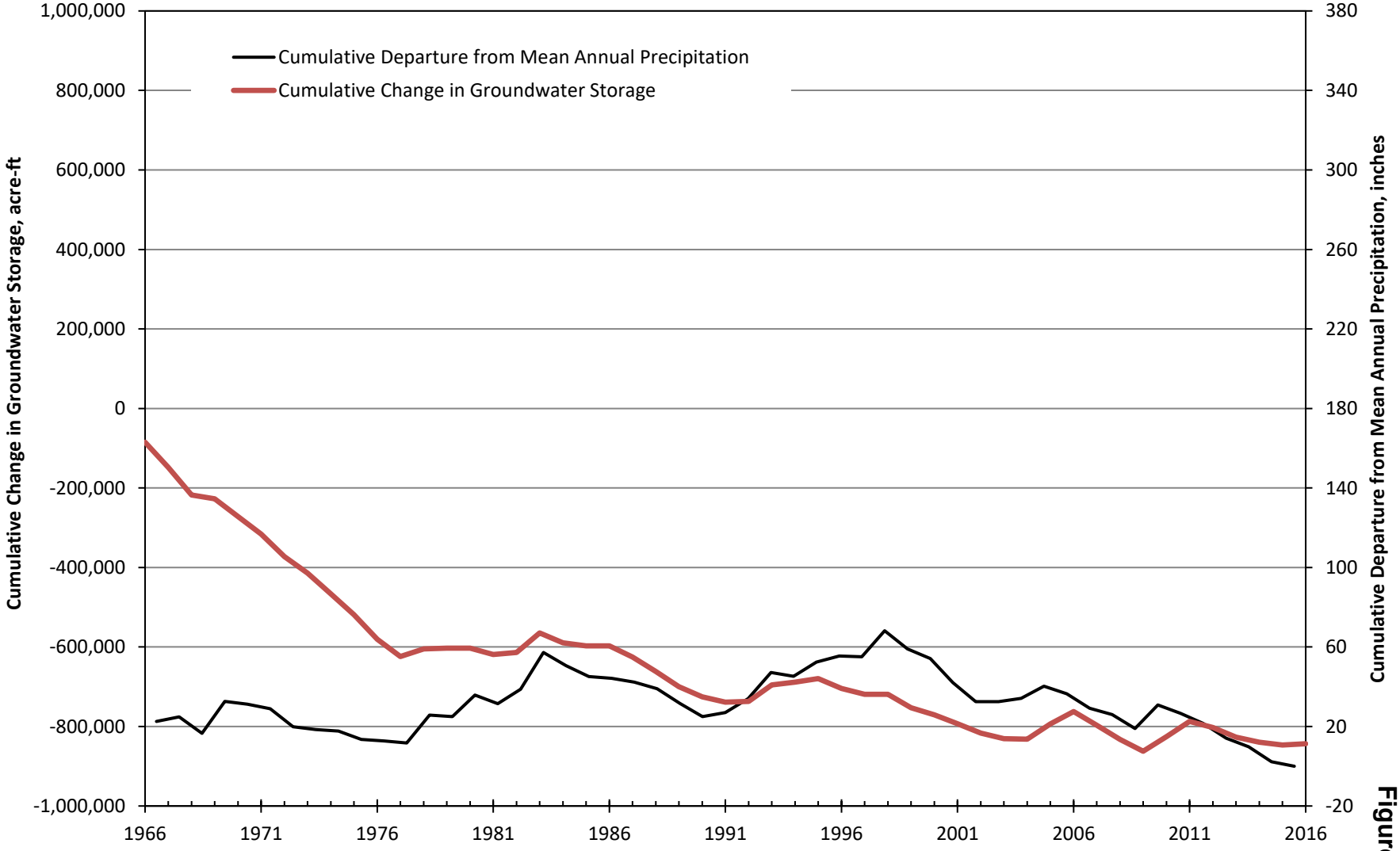
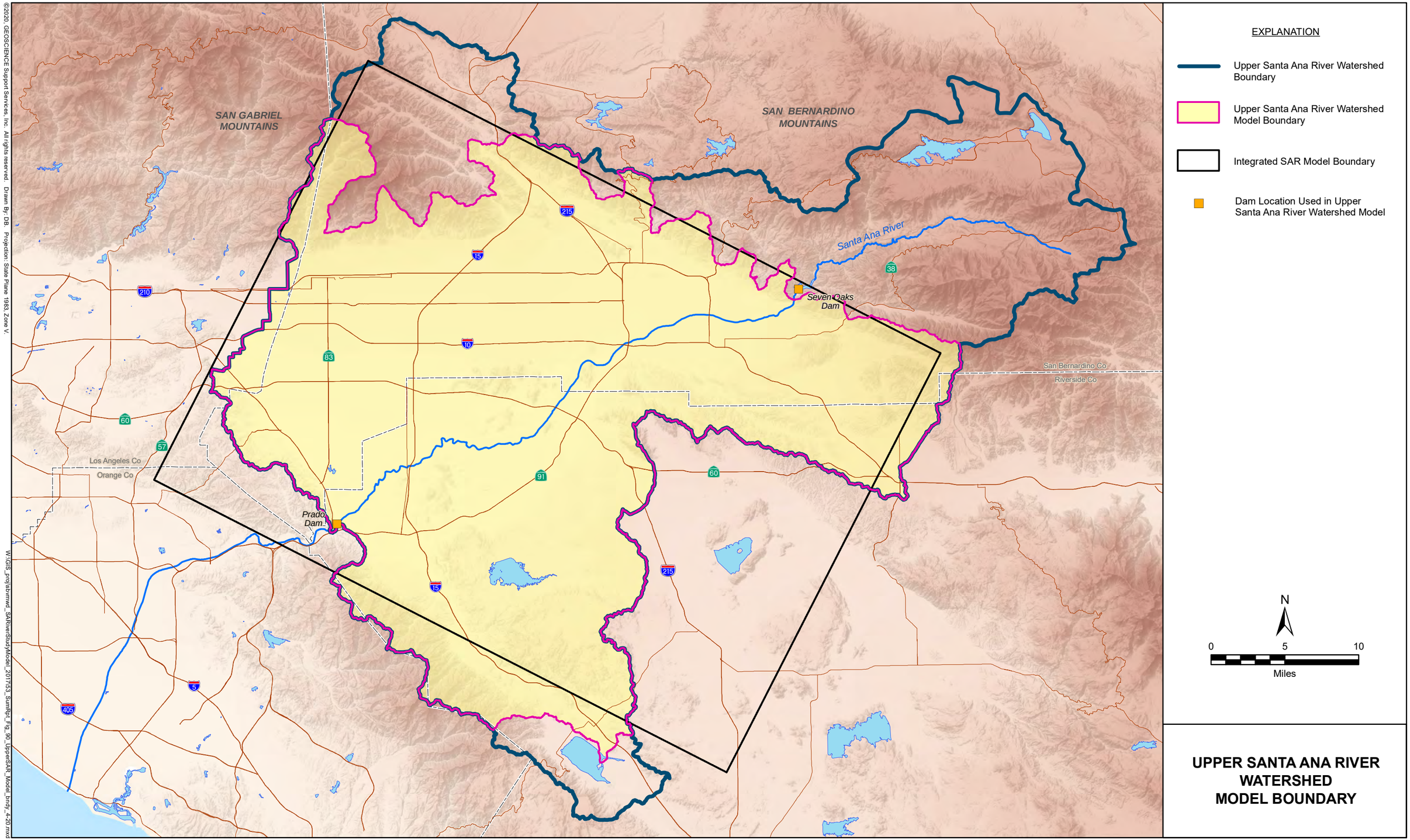


Figure 89



UPPER SANTA ANA RIVER WATERSHED MODEL BOUNDARY

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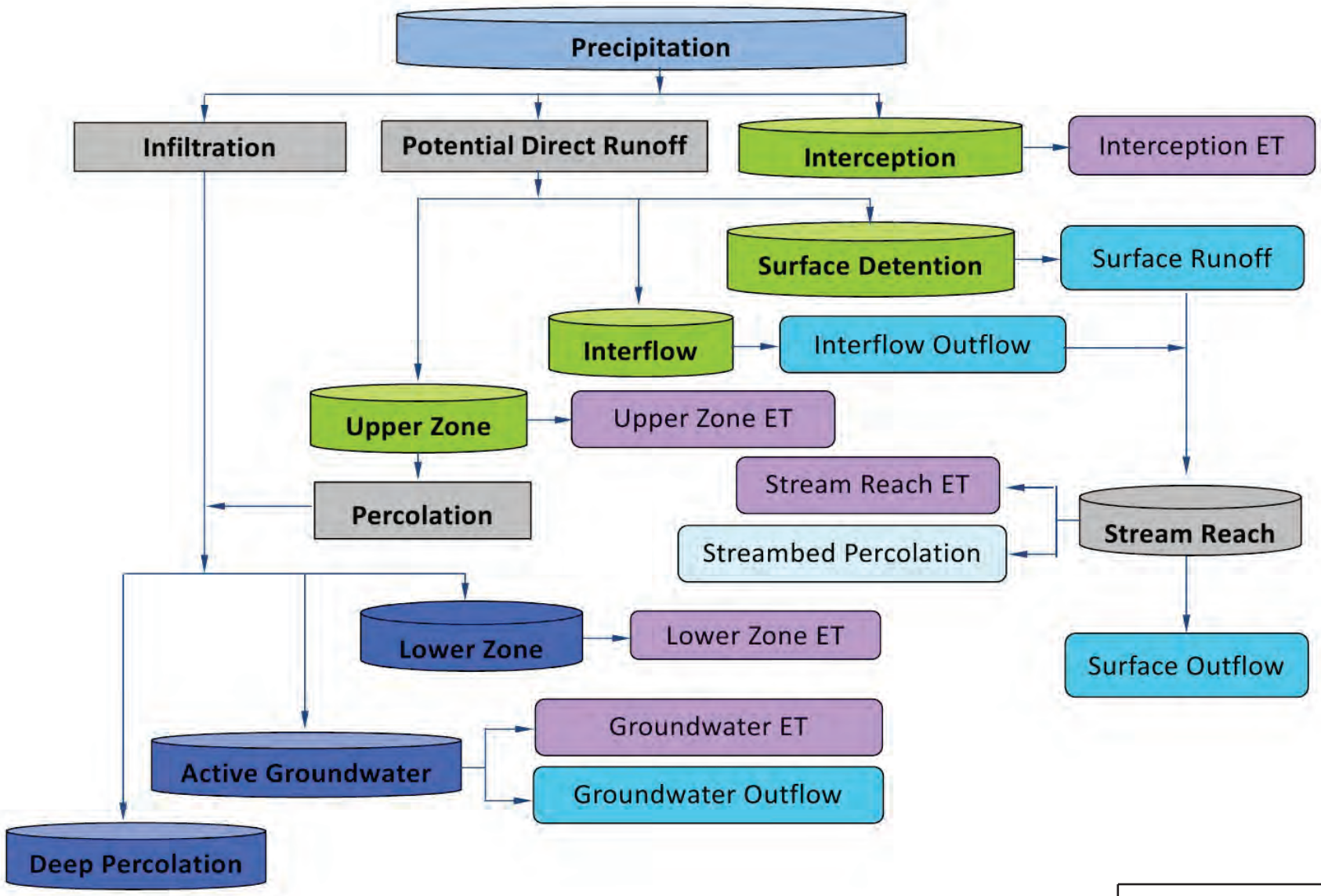

HSPF SCHEMATIC DIAGRAM

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FIGURE 91

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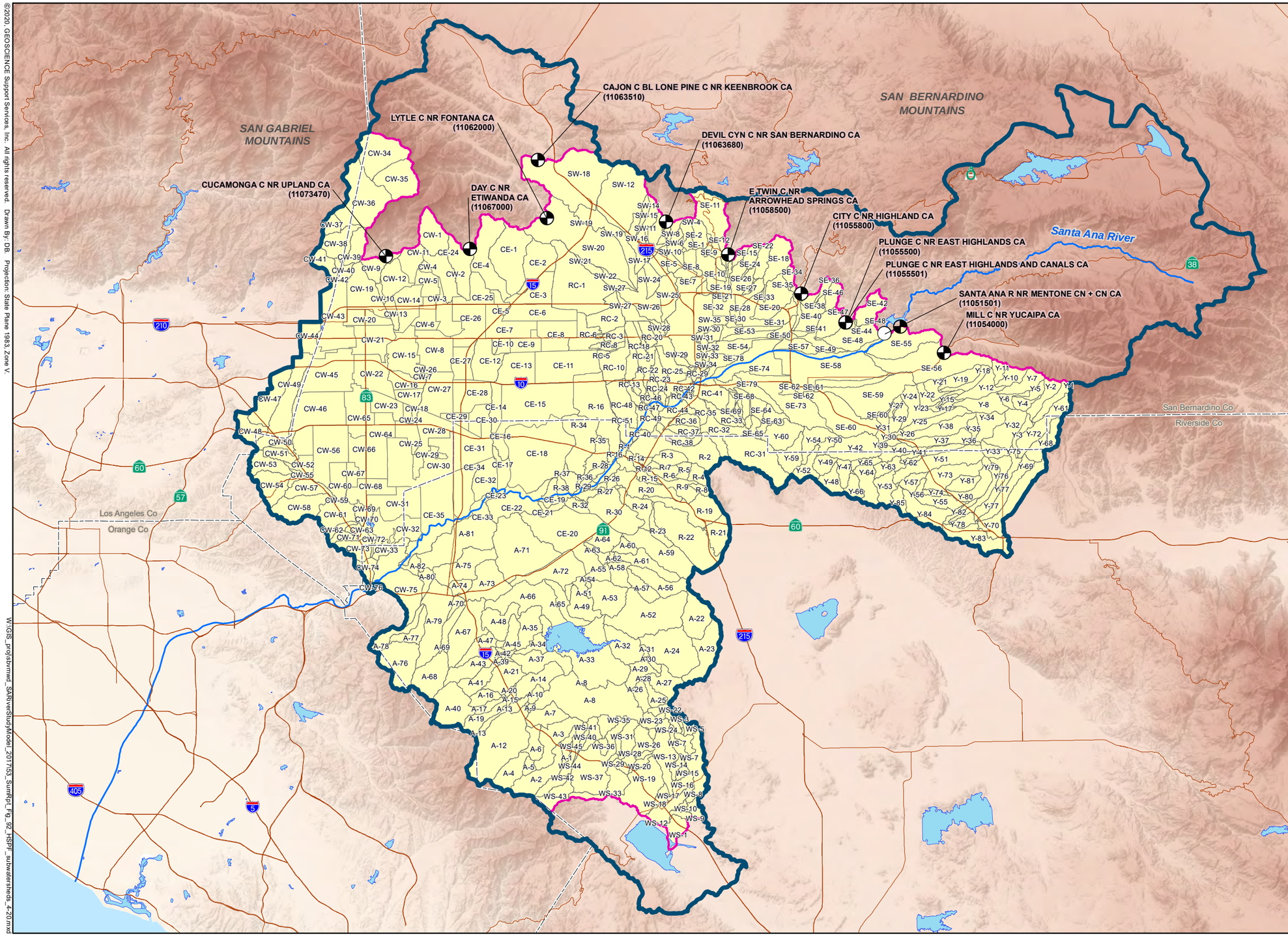

EXPLANATION

Y-27 Sub-Watershed Boundary and Designation

A = Arlington
CE = Chino East
CW = Chino West
O = Orange County
R = Riverside
RC = Rialto-Colton
SE = SBBA East
SW = SBBA West
WS = Warm Springs
Y = Yucaipa

Upper Santa Ana River Watershed Boundary

Upper Santa Ana River Watershed Model Boundary

Gaging Station Name and Number for Boundary Inflow

N

0 5 10
Miles

HSPF WATERSHED MODEL SUB-WATERSHEDS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 92

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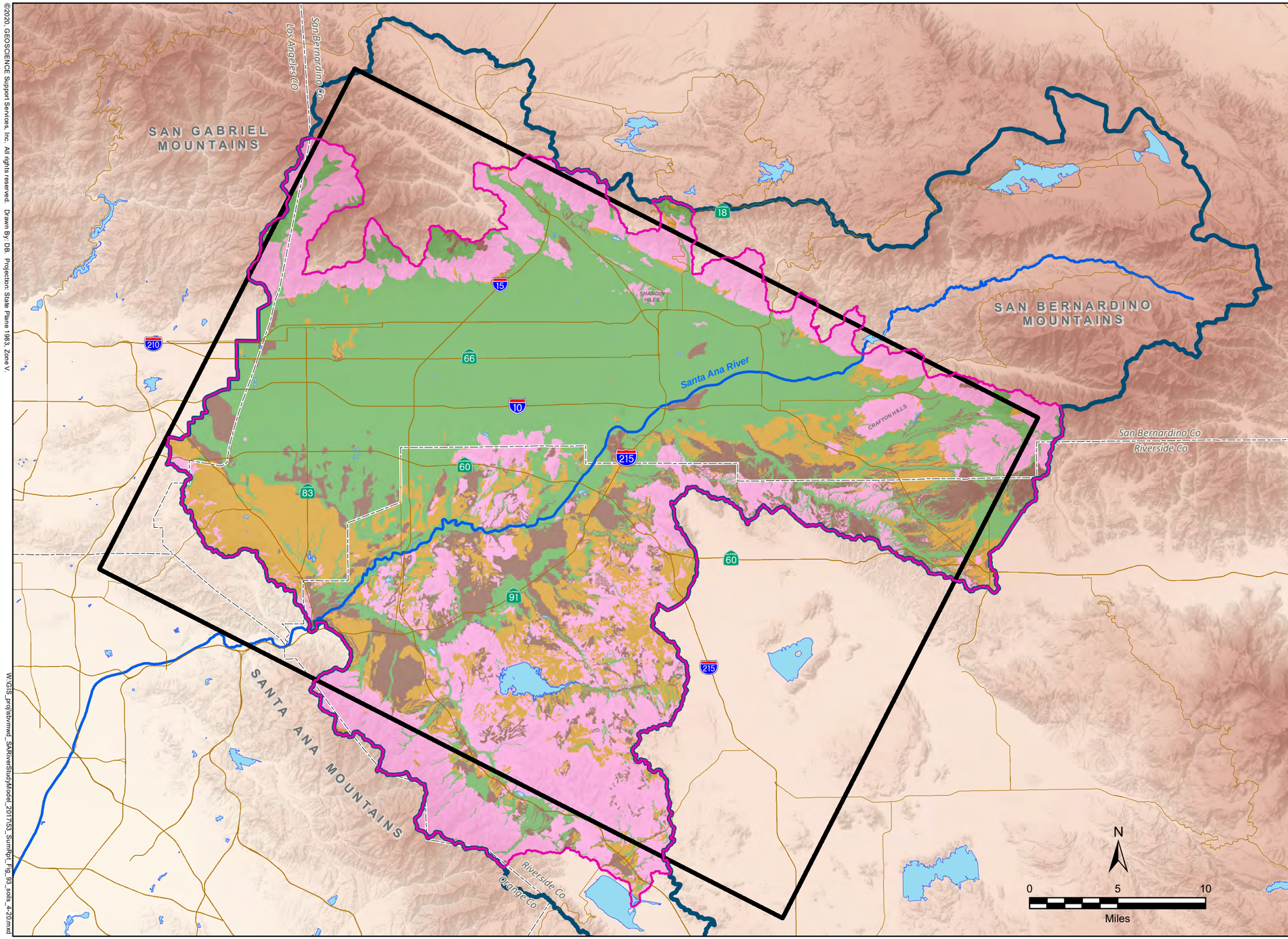

EXPLANATION

Upper Santa Ana River Watershed Boundary

Upper Santa Ana River Watershed Model Boundary

Integrated SAR Model Boundary

Soil Survey Geographic (SSURGO) Soil Type (Soil Survey Staff et al. 2011)

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

HYDROLOGIC SOIL TYPES IN THE WATERSHED MODEL AREA

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 93

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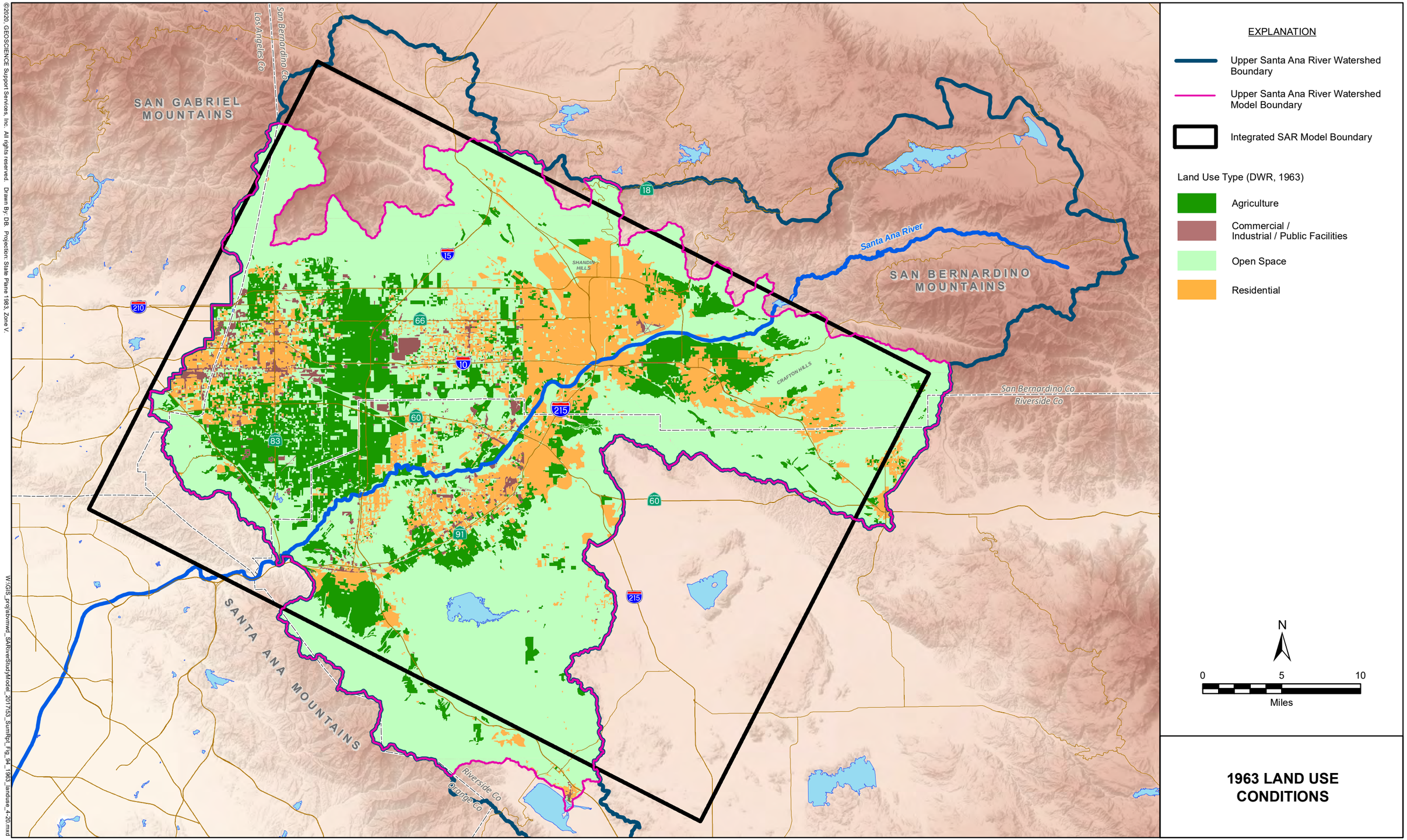

1963 LAND USE CONDITIONS

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W:\GIS_projs\bvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_94_1963_landuse_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 94

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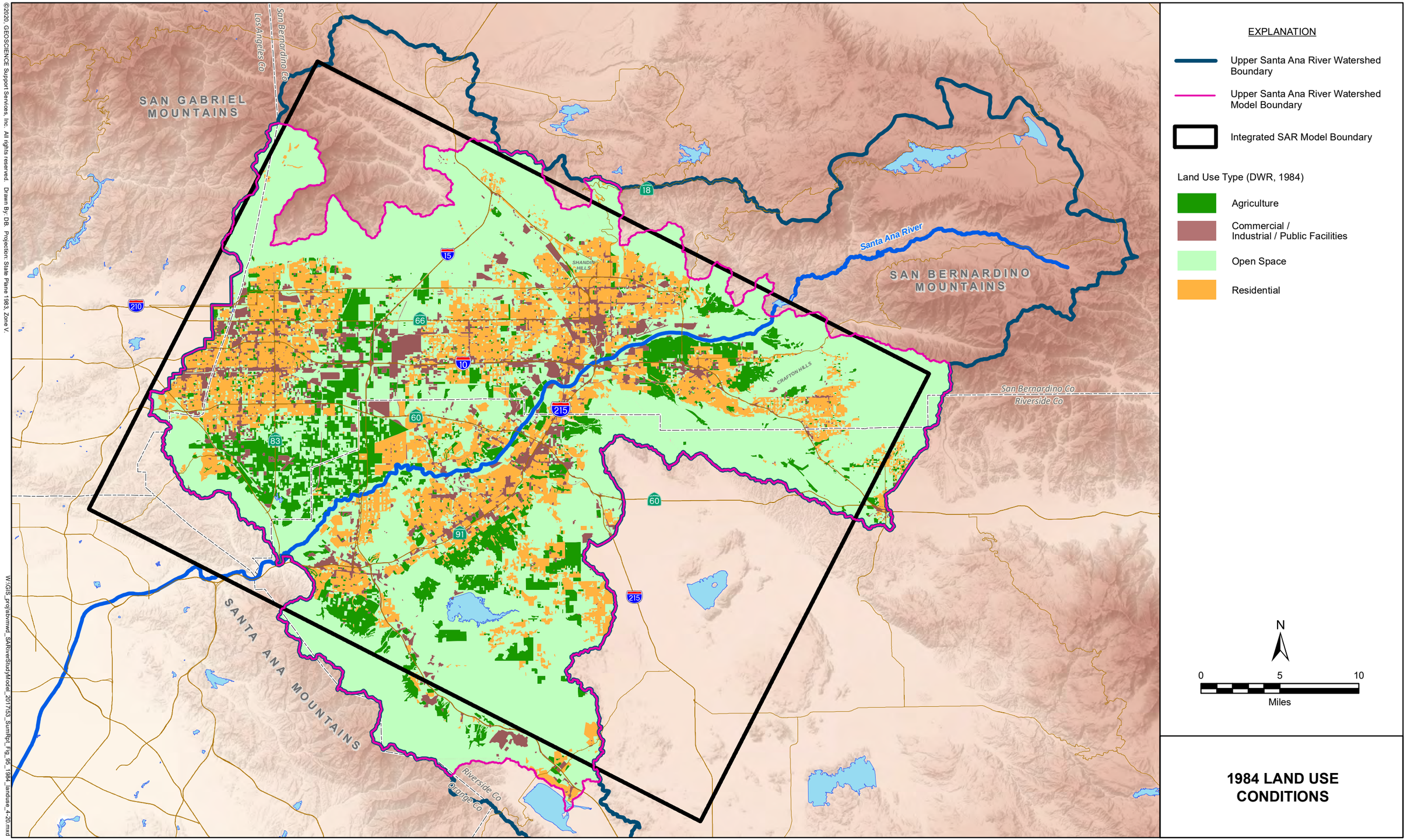

1984 LAND USE CONDITIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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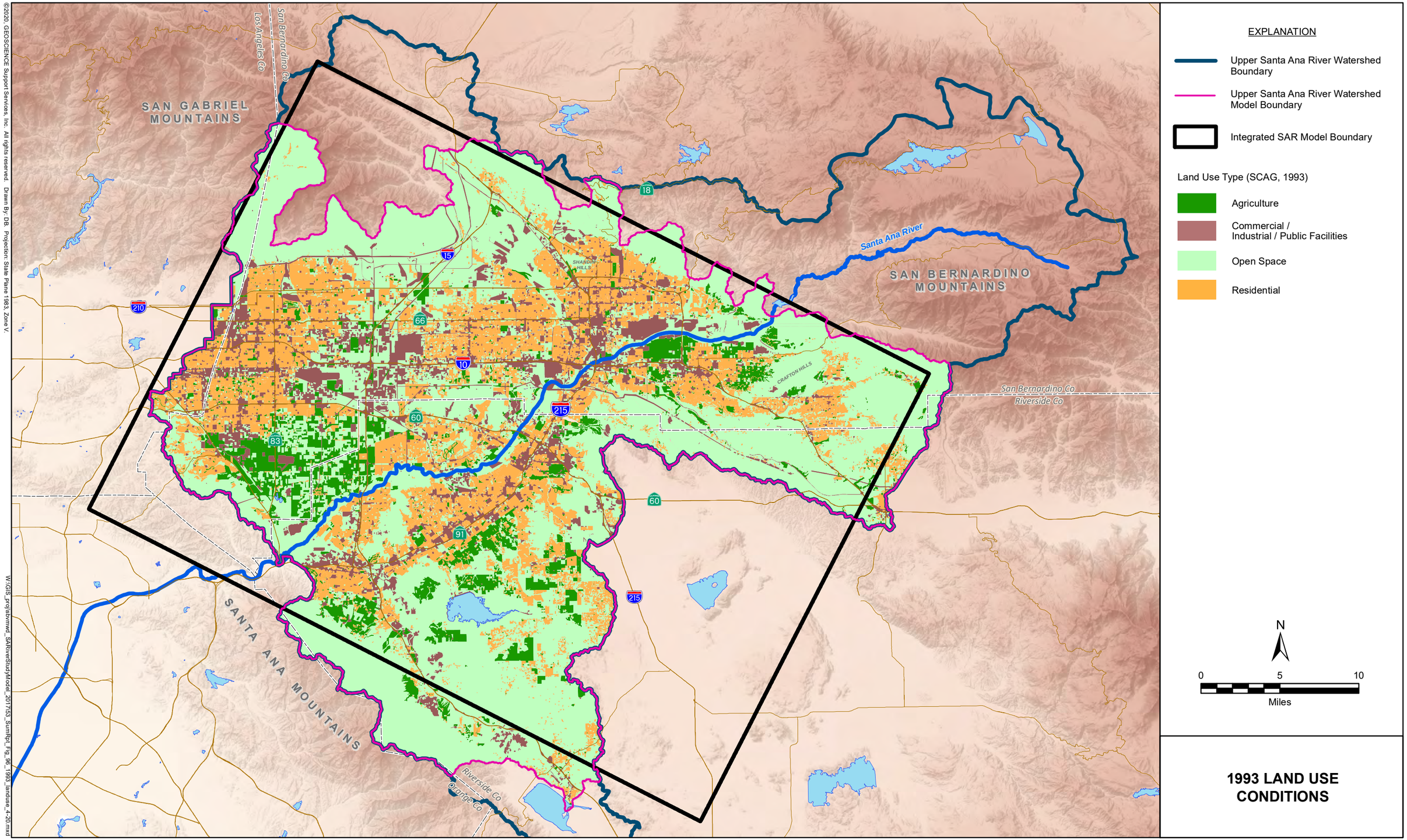
FIGURE 95

GEOSCIENCE



1993 LAND USE CONDITIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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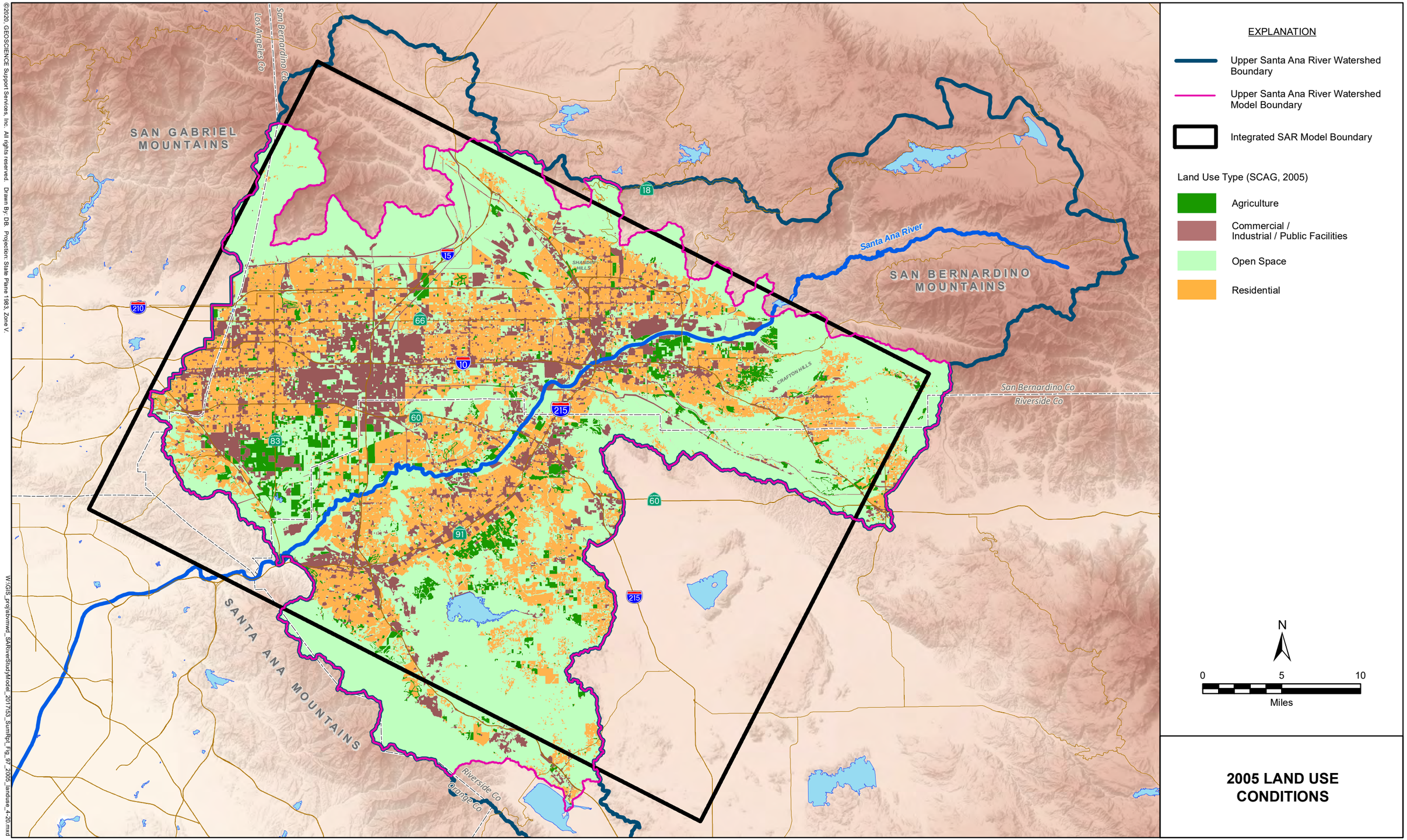
FIGURE 96

GEOSCIENCE



2005 LAND USE CONDITIONS

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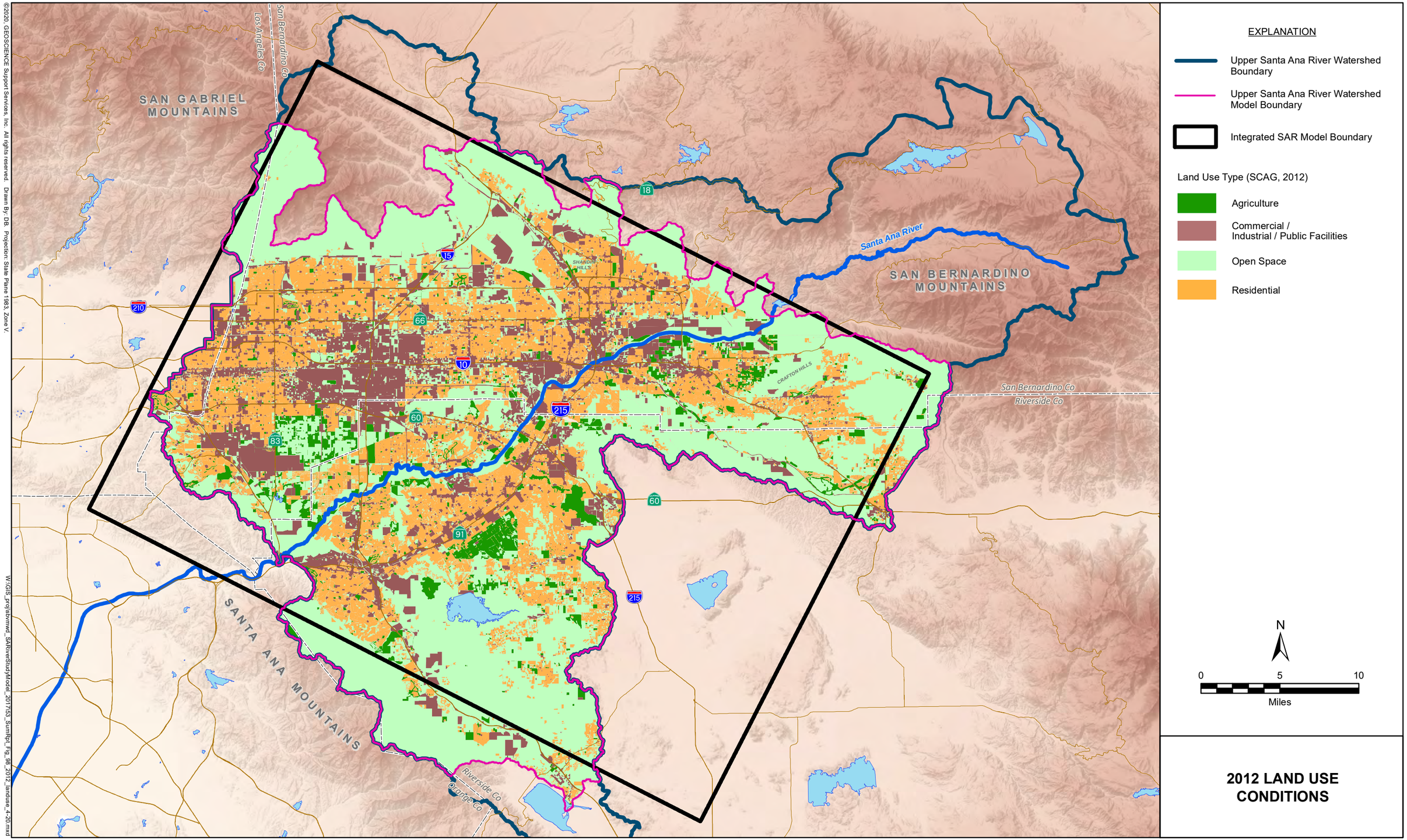

2012 LAND USE CONDITIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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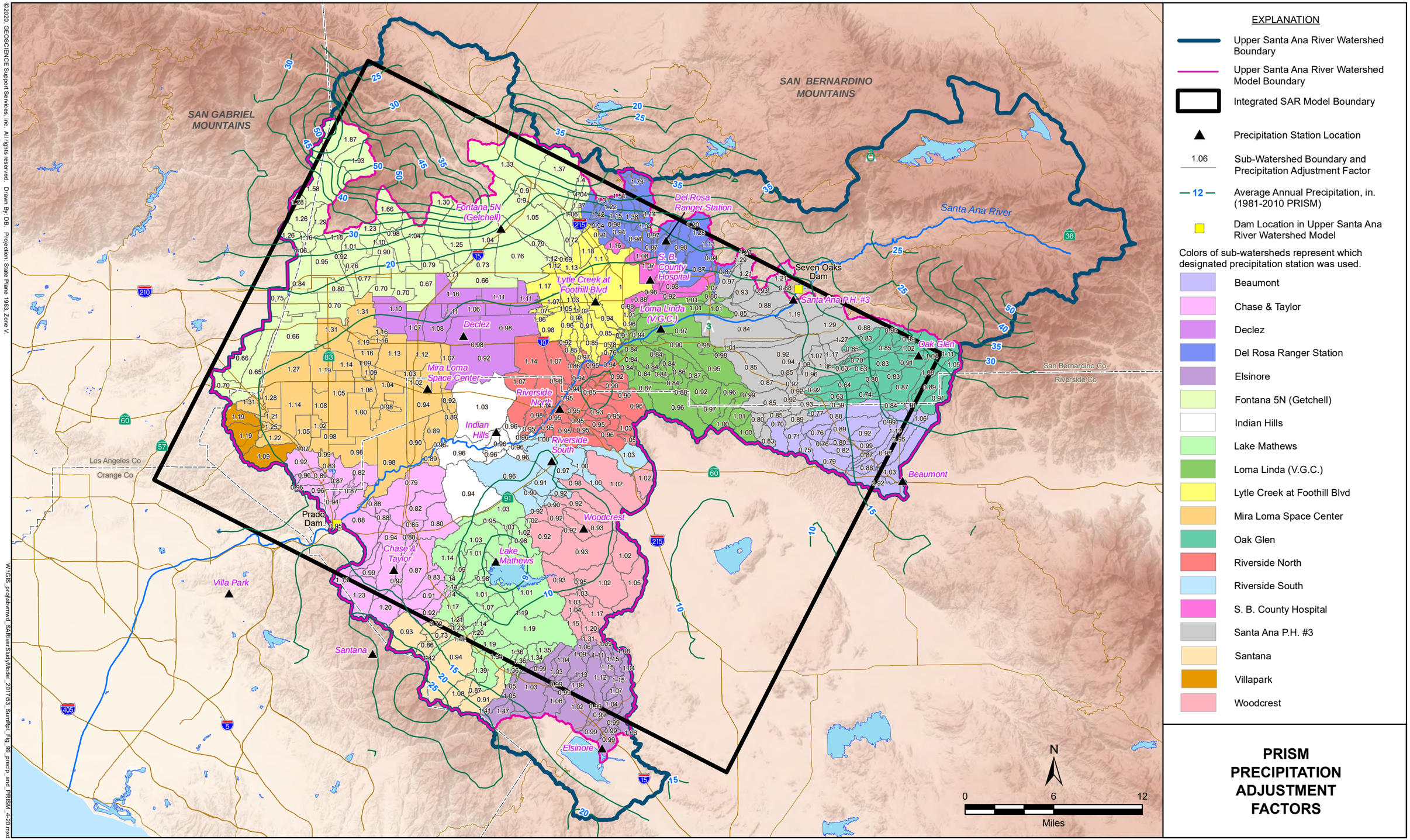
FIGURE 98

GEOSCIENCE



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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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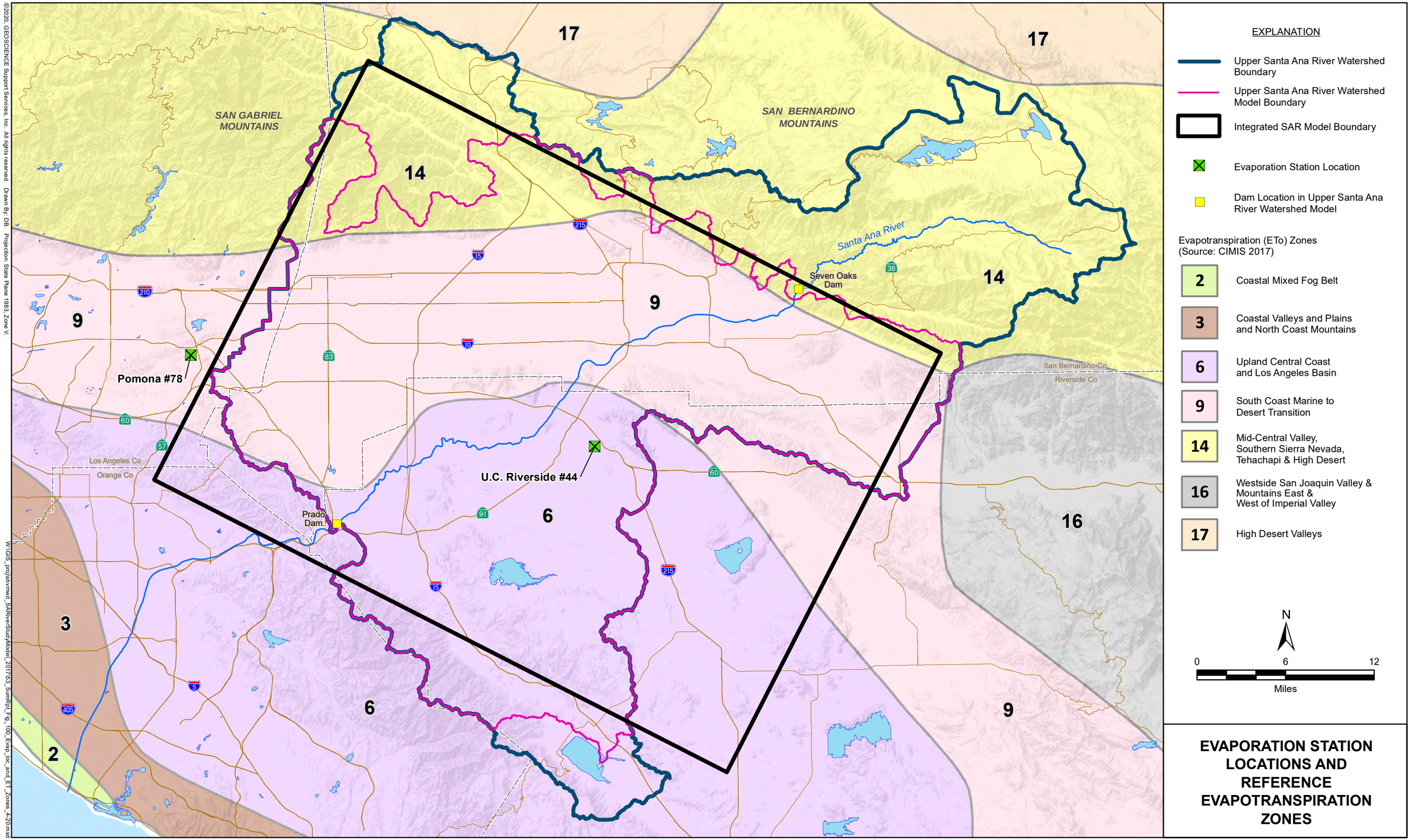
FIGURE 99

GEOSCIENCE



EVAPORATION STATION LOCATIONS AND REFERENCE EVAPOTRANSPIRATION ZONES

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W:\GIS_projsbvmwd_SARiverStudyModel_201753_SumRpt_Fig_100_Evap_loc_and_ET_Zones_4-20.mxd

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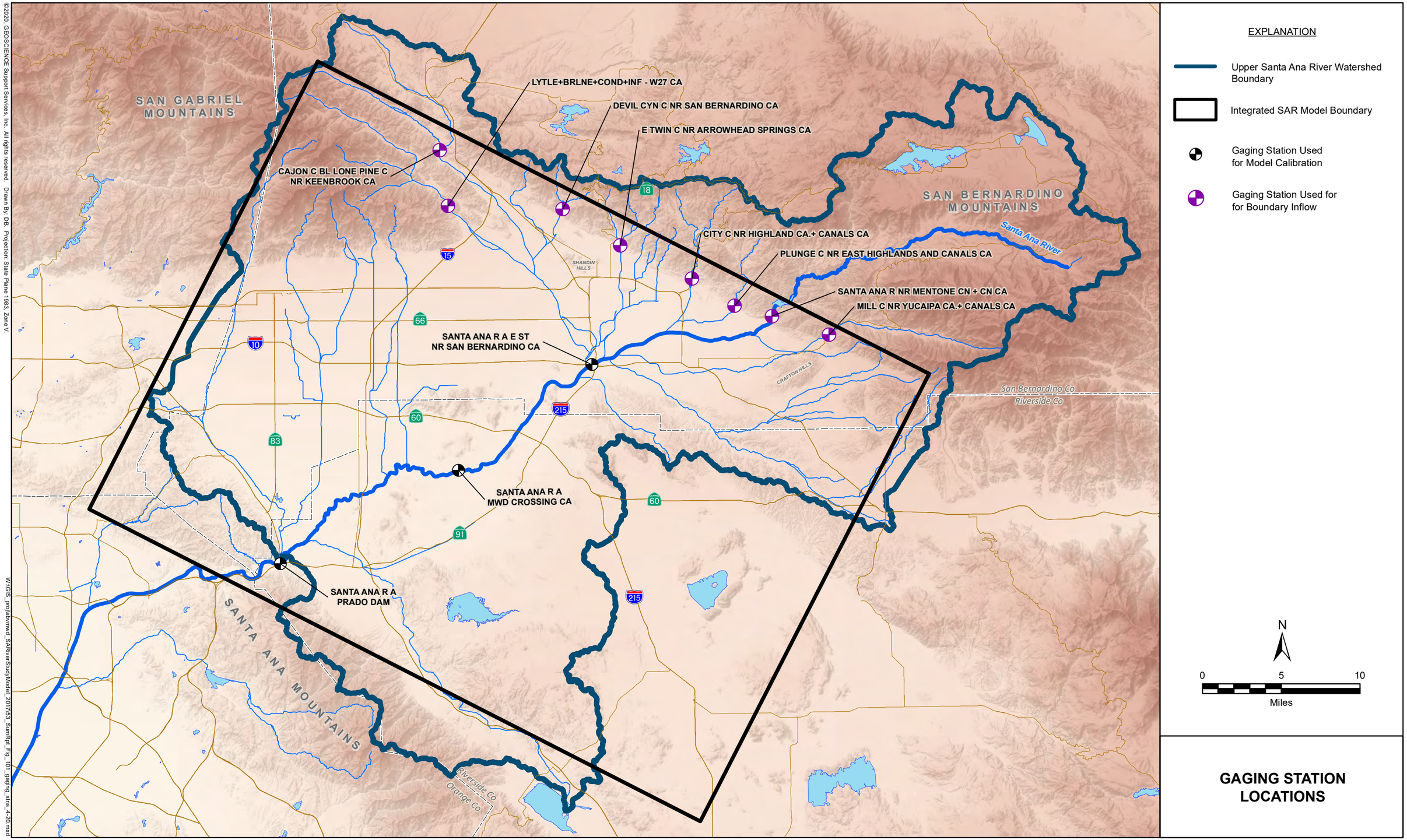

GAGING STATION LOCATIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 101

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Scatterplot of Measured and Model-Simulated Daily Streamflow at the Santa Ana River at E Street Gaging Station – January 1, 1966 to December 31, 2016 (Upper SAR Watershed Model)

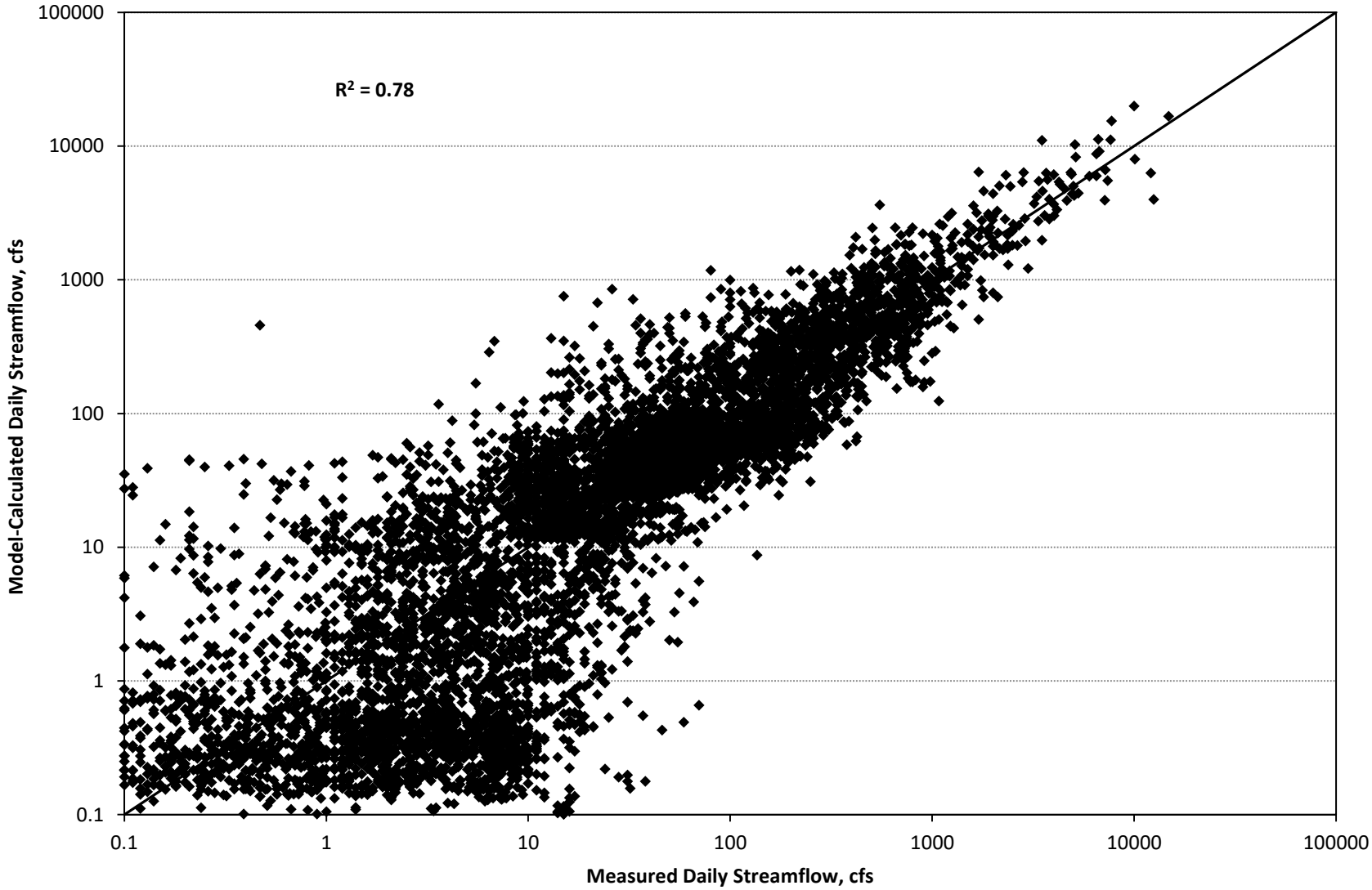

Figure 102

Scatterplot of Measured and Model-Simulated Daily Streamflow at the Santa Ana River at MWD Crossing Gaging Station – January 1, 1966 to December 31, 2016 (Upper SAR Watershed Model)

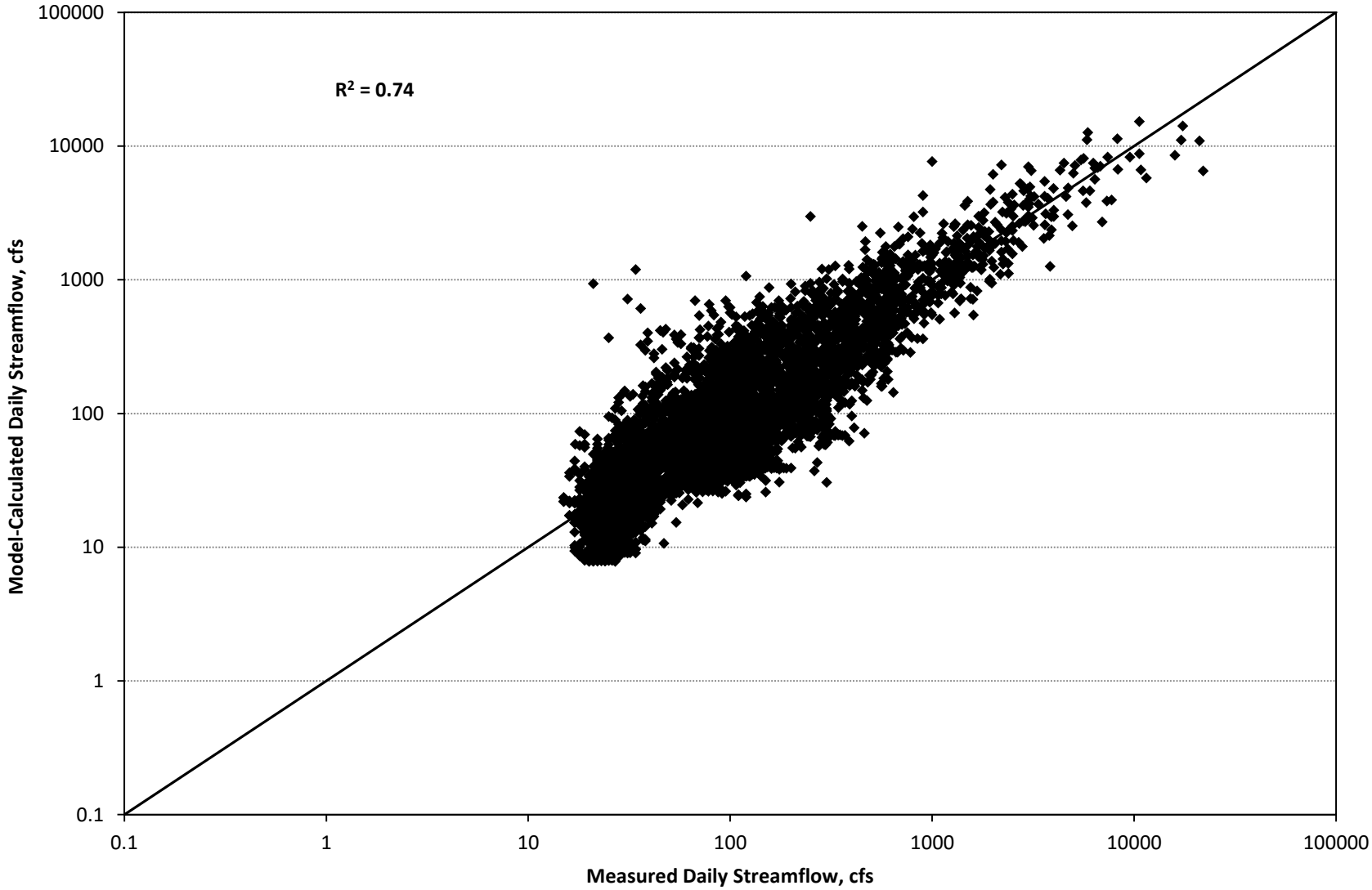

Figure 103

Scatterplot of Measured and Model-Simulated Daily Streamflow at the Santa Ana River Prado Dam Inflow – January 1, 1966 to December 31, 2016 (Upper SAR Watershed Model)

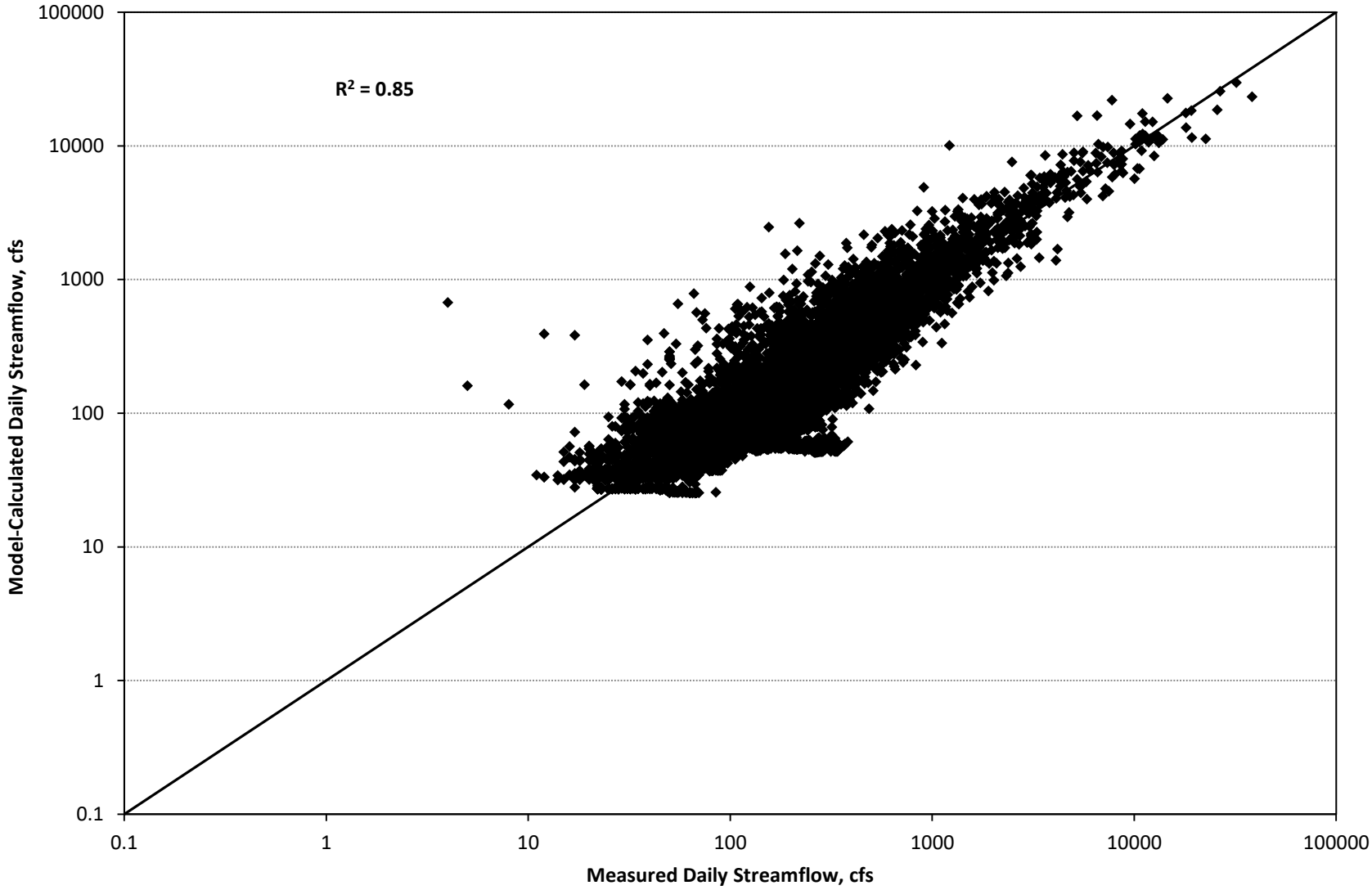

Figure 104

DRAFT

Scatterplot of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at E Street Gaging Station – January 1966 to December 2016 (Upper SAR Watershed Model)

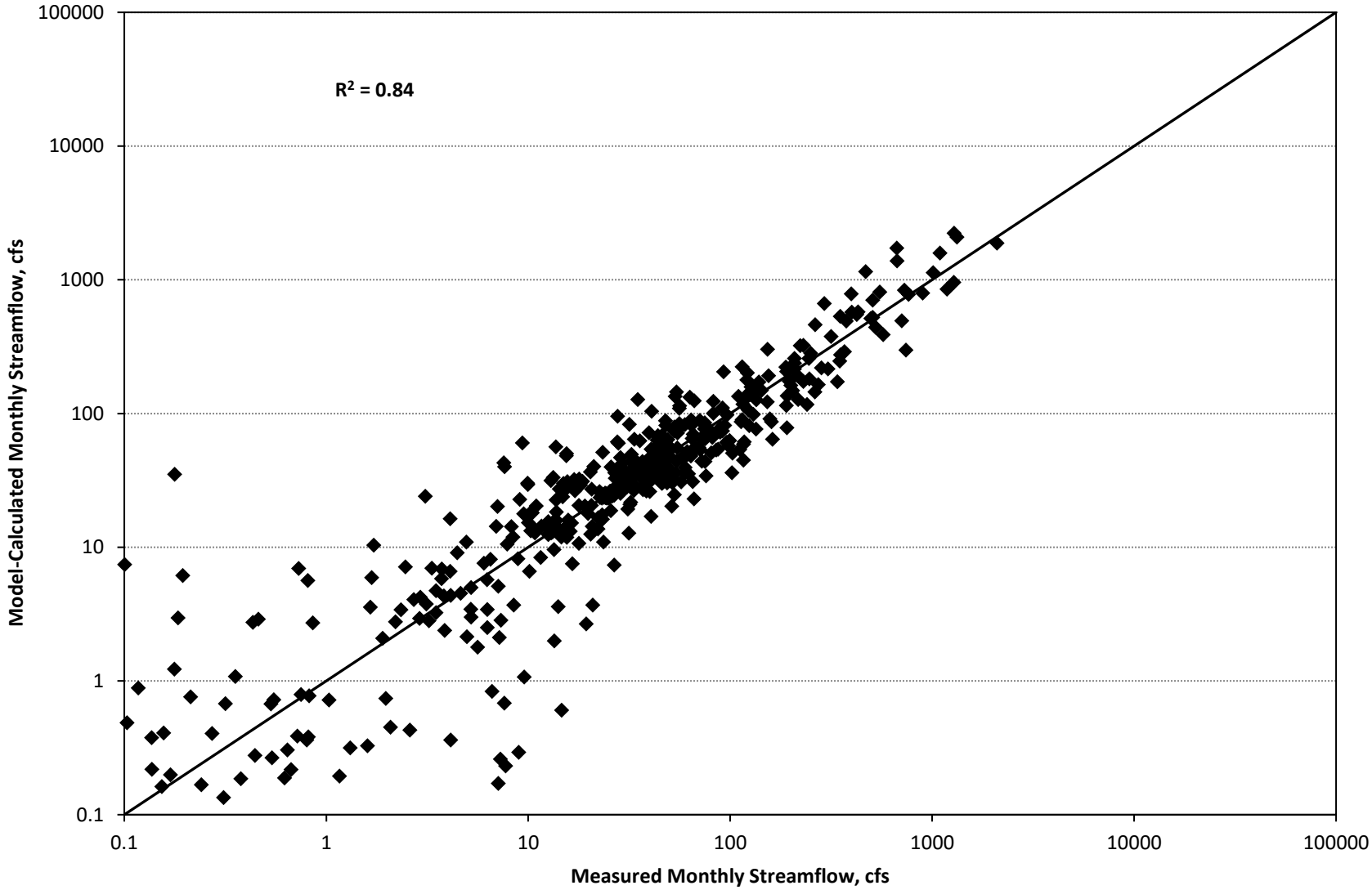

Figure 105

DRAFT

Scatterplot of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at MWD Crossing Gaging Station – January 1966 to December 2016 (Upper SAR Watershed Model)

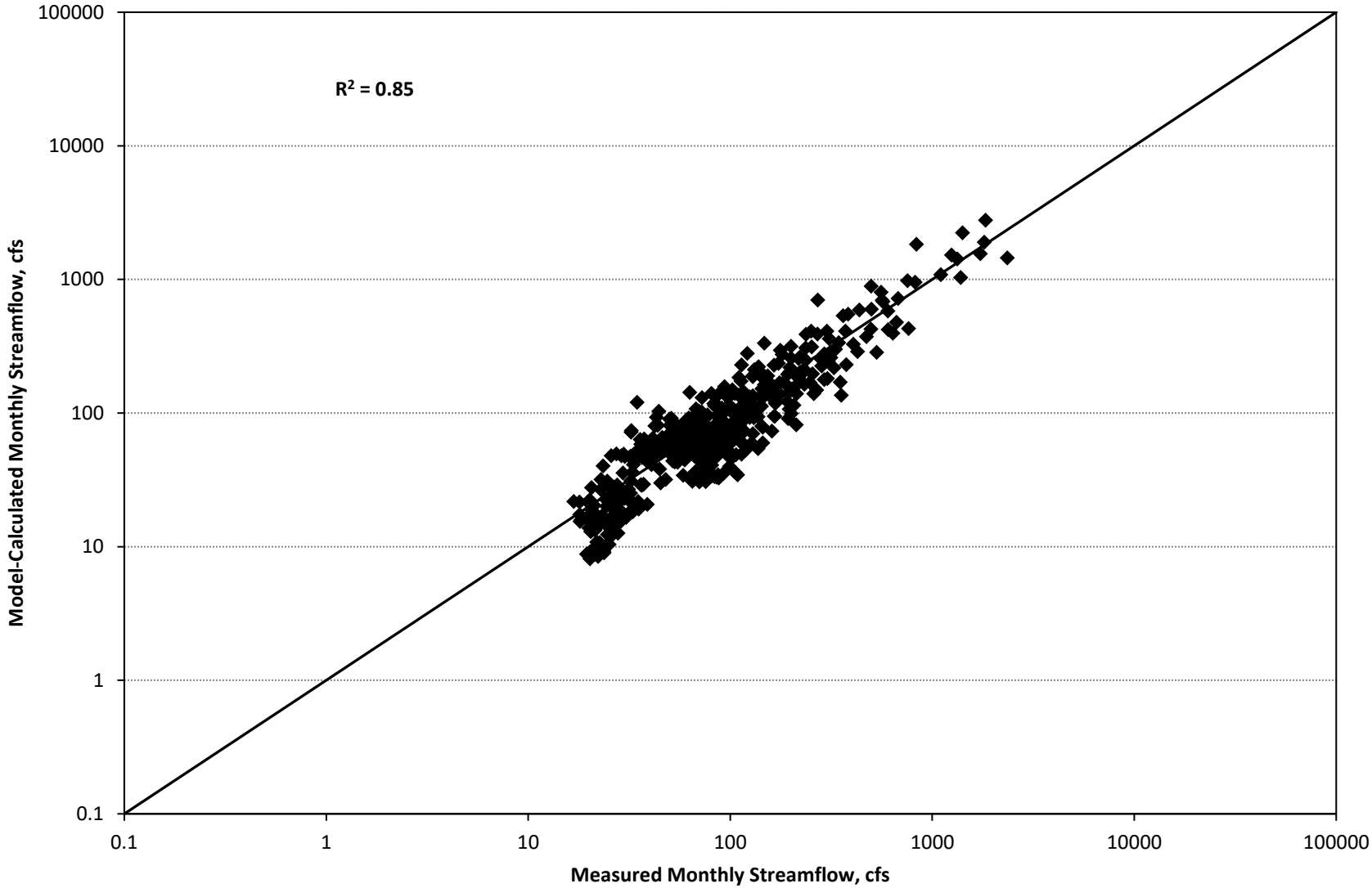

Figure 106

DRAFT

Scatterplot of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River Prado Dam Inflow – January 1966 to December 2016 (Upper SAR Watershed Model)

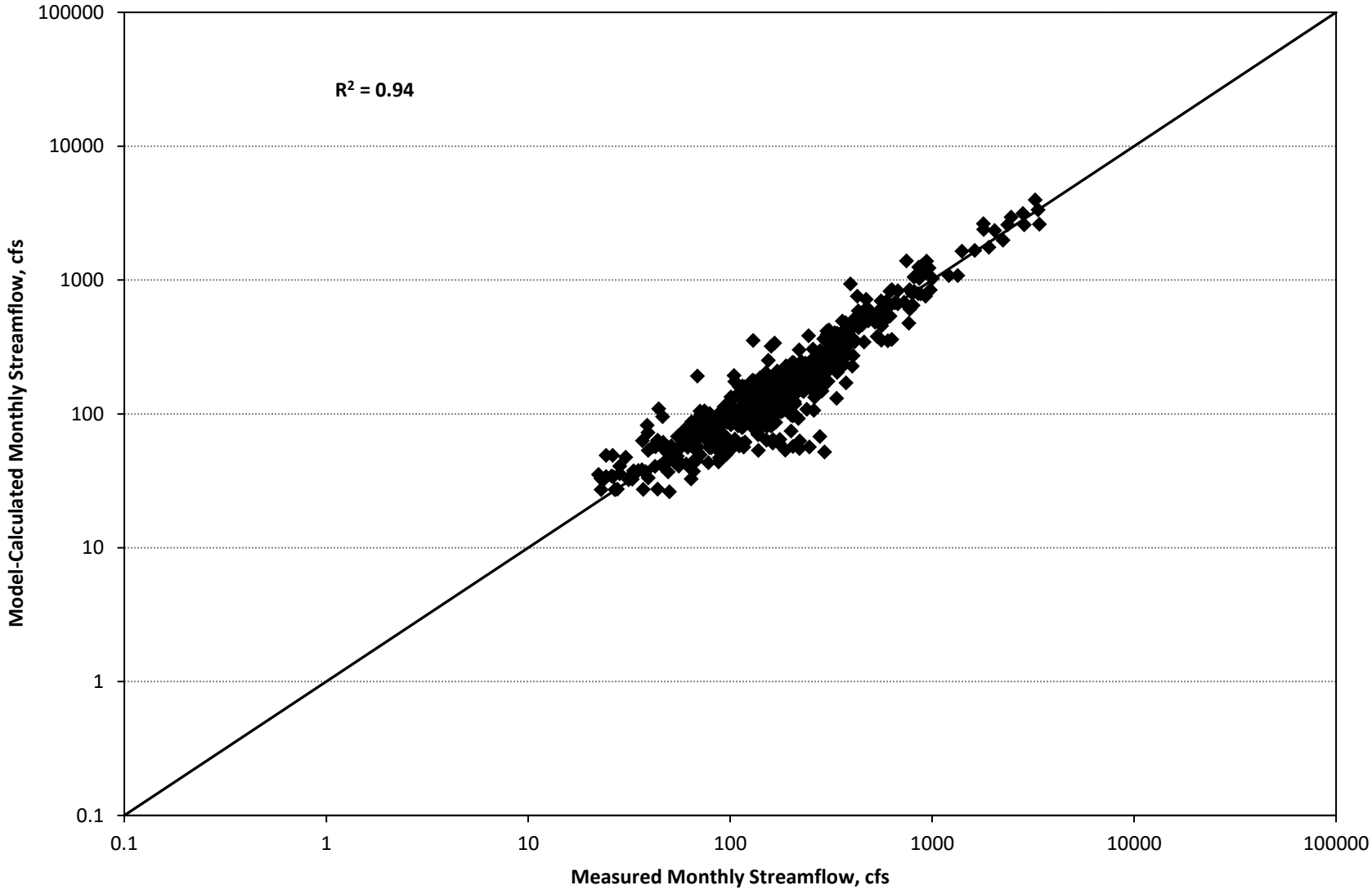

Figure 107

Hygrograph of Measured and Model-Simulated Daily Streamflow at the Santa Ana River at E Street Gaging Station – January 1, 1966 to December 31, 2016 (Upper SAR Watershed Model)

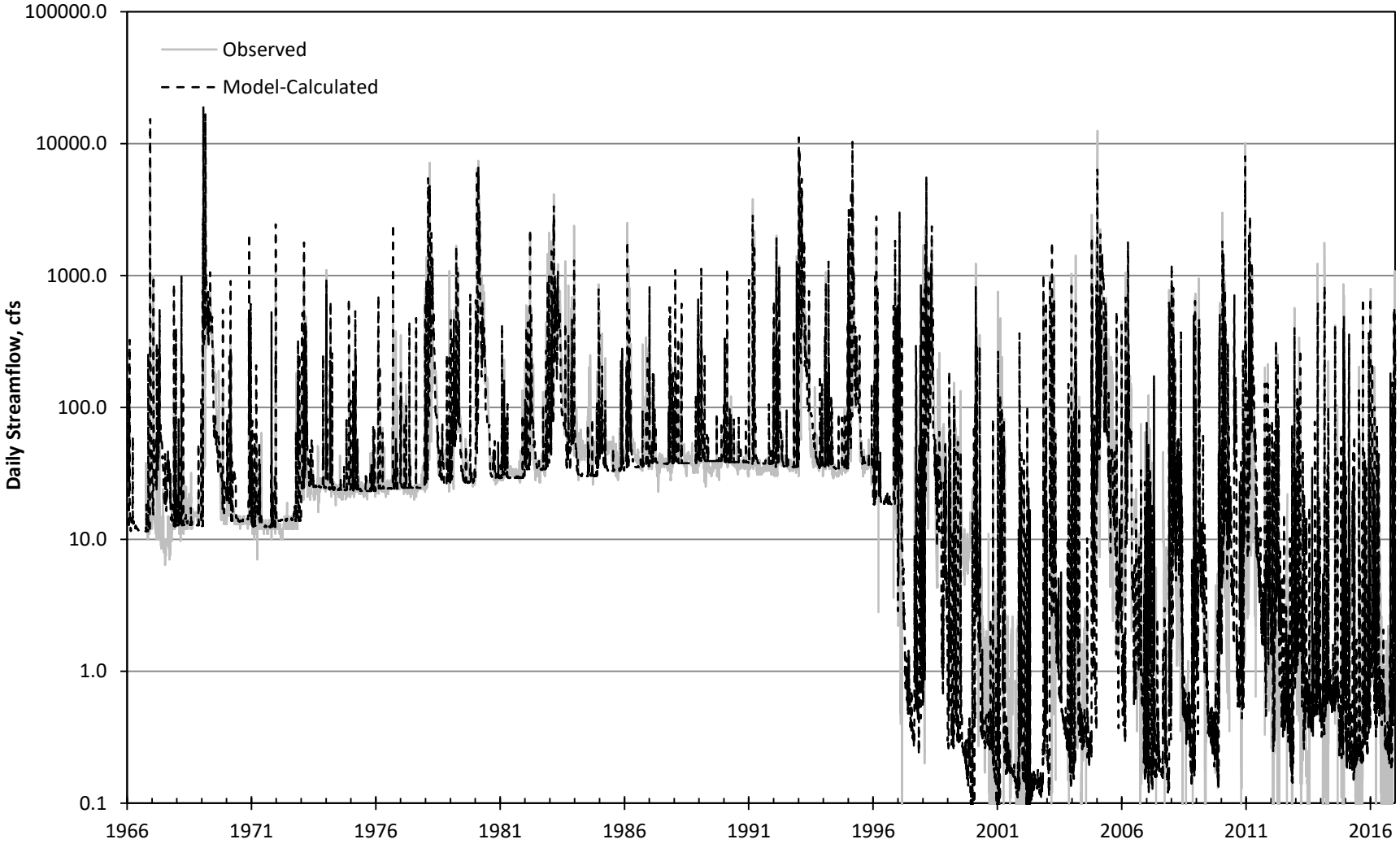

Figure 108

Hydrograph of Measured and Model-Simulated Daily Streamflow at the Santa Ana River at MWD Crossing Gaging Station – January 1, 1966 to December 31, 2016 (Upper SAR Watershed Model)

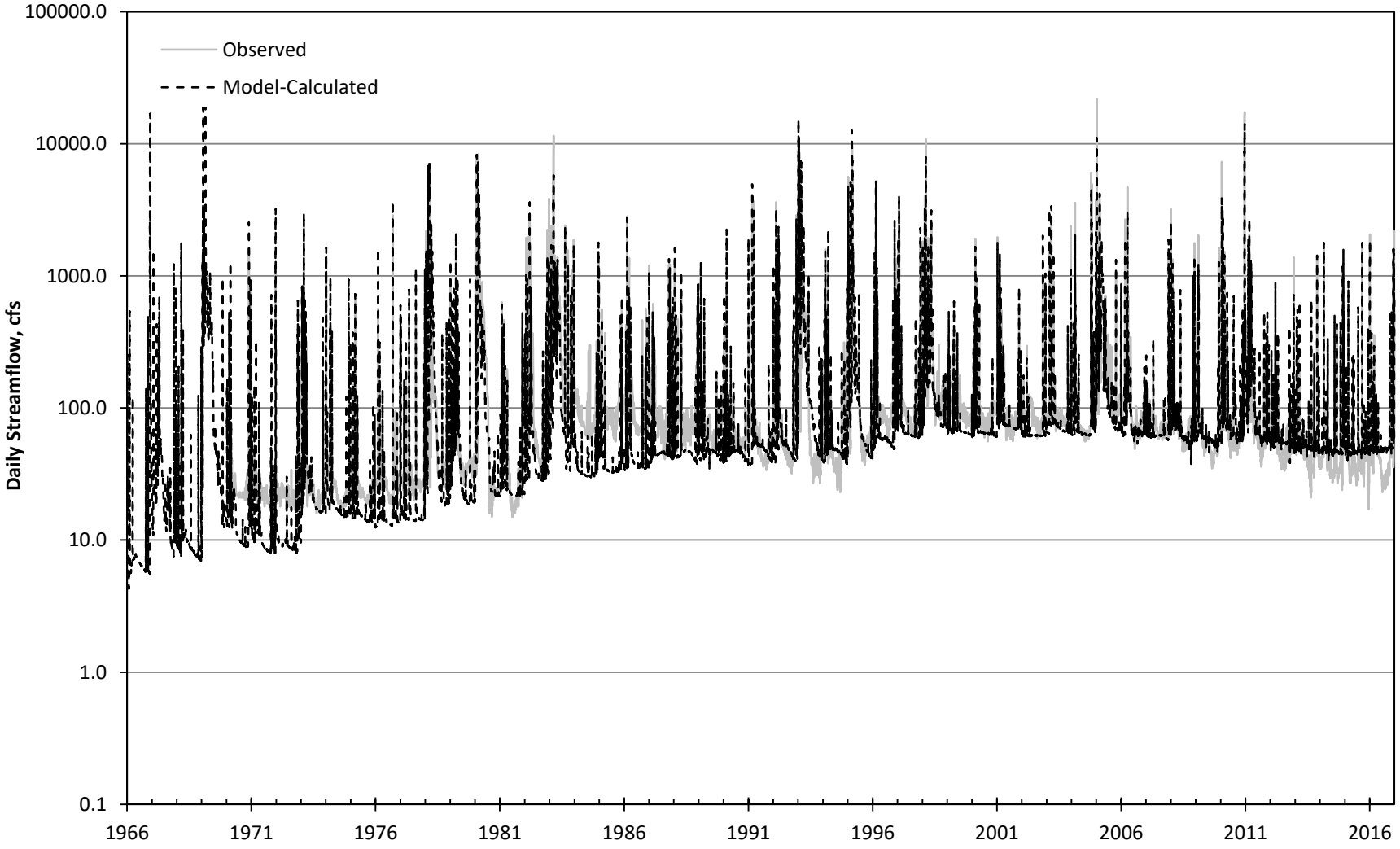

Figure 109

Hydrograph of Measured and Model-Simulated Daily Streamflow at the Santa Ana River Prado Dam Inflow – January 1, 1966 to December 31, 2016 (Upper SAR Watershed Model)

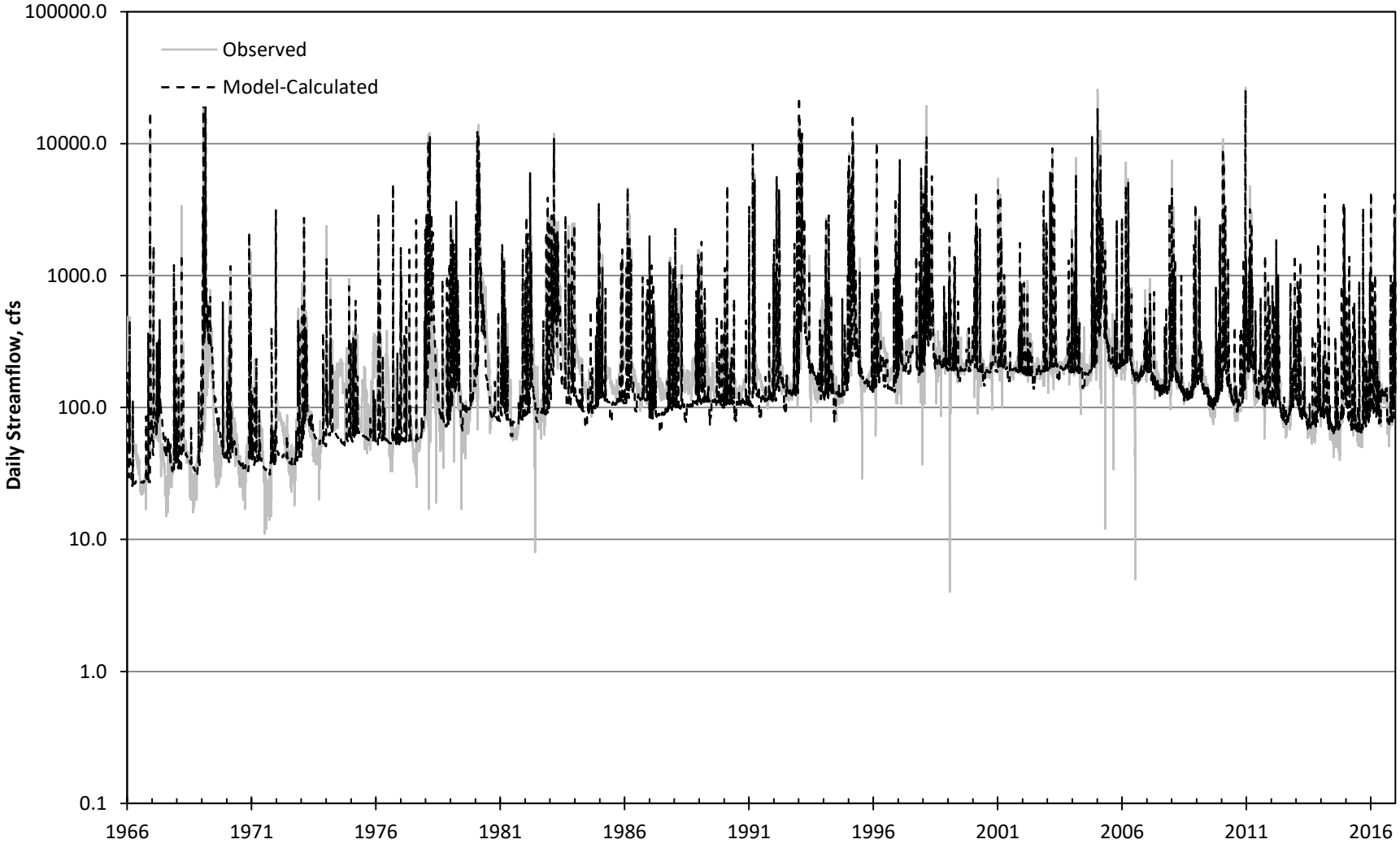

Figure 110

Hydrograph of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at E Street Gaging Station – January 1966 to December 2016 (Upper SAR Watershed Model)

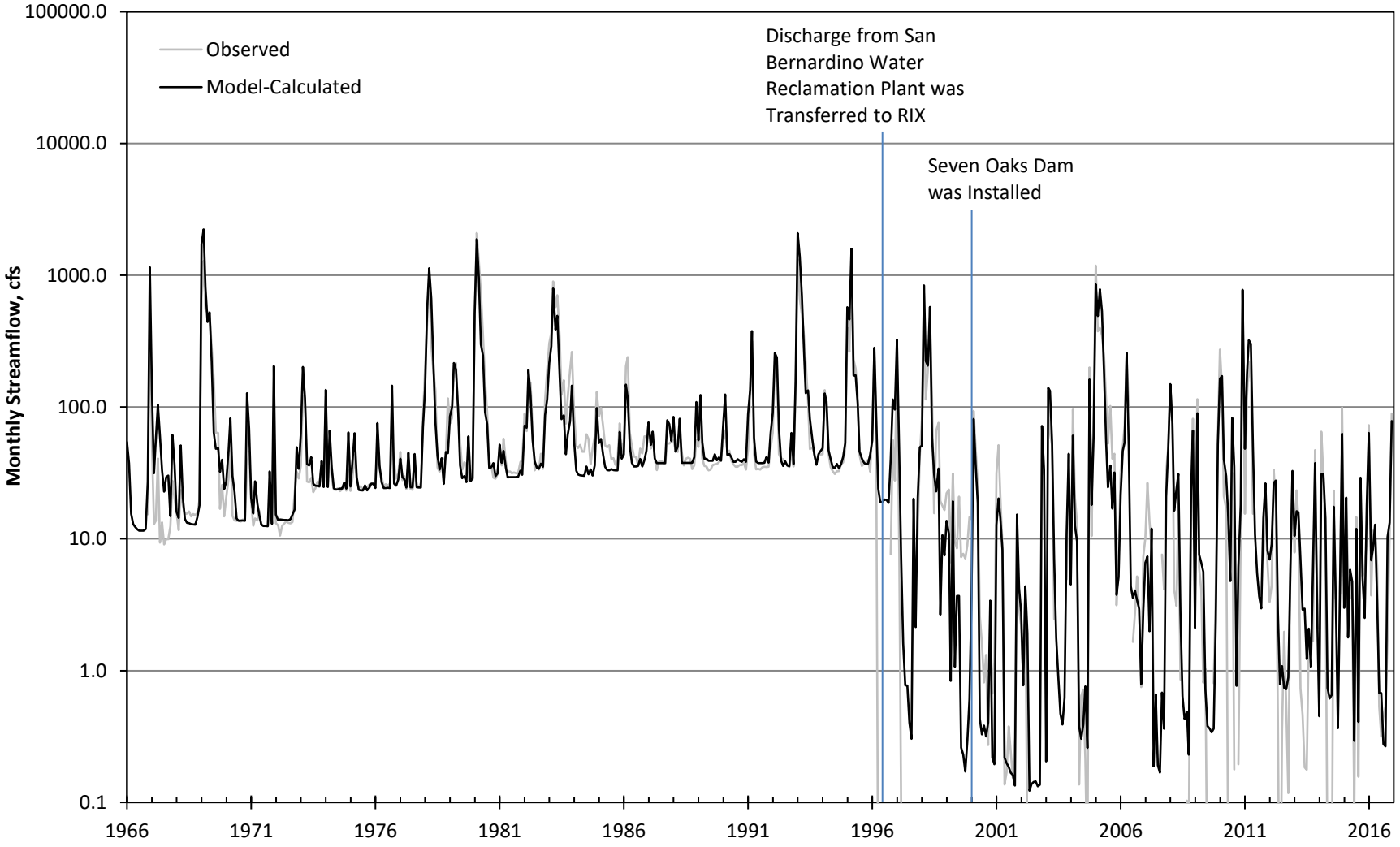

Figure 111

Hydrograph of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at MWD Crossing Gaging Station – January 1966 to December 2016 (Upper SAR Watershed Model)

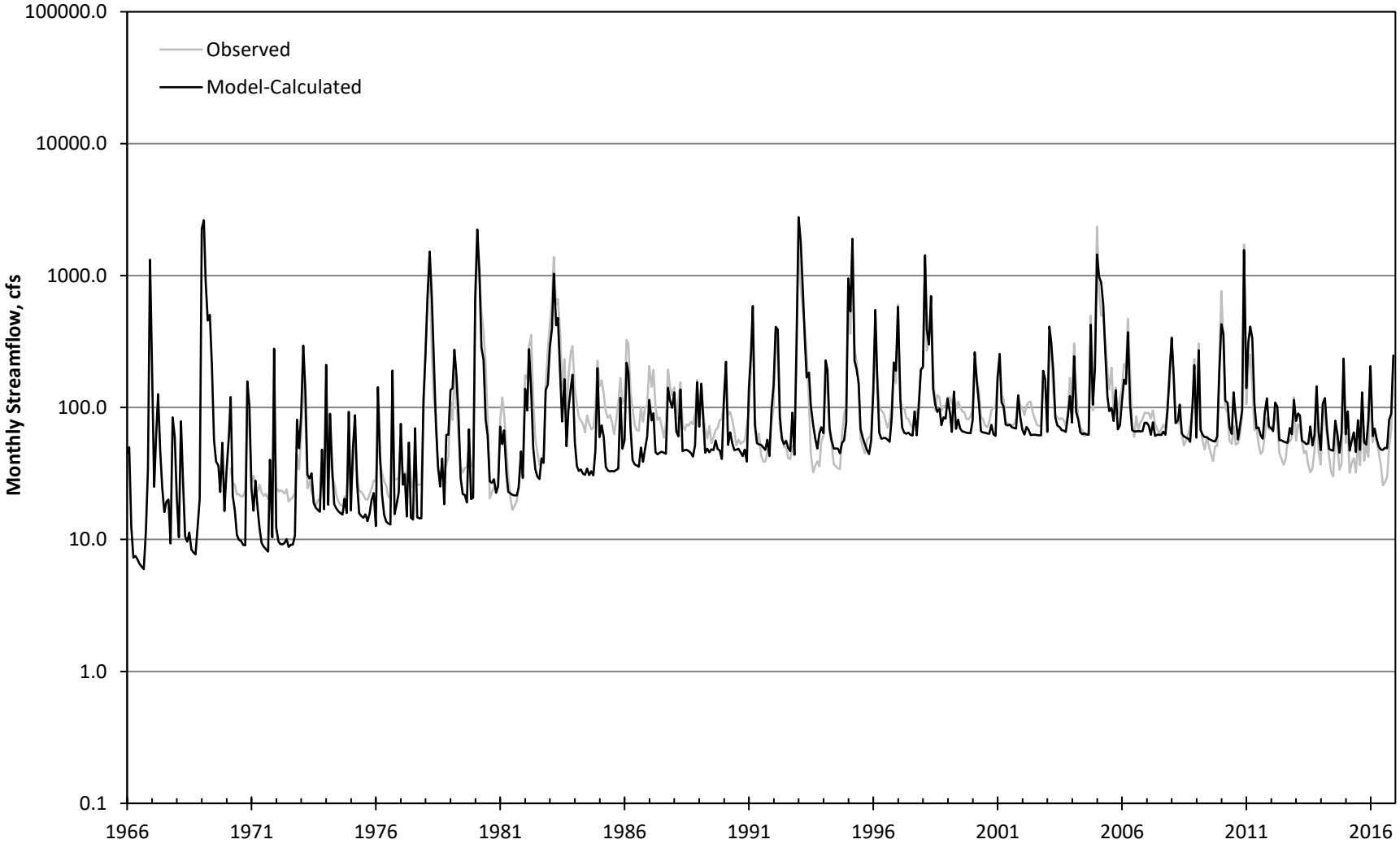

Figure 112

Hydrograph of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River Prado Dam Inflow – January 1966 to December 2016 (Upper SAR Watershed Model)

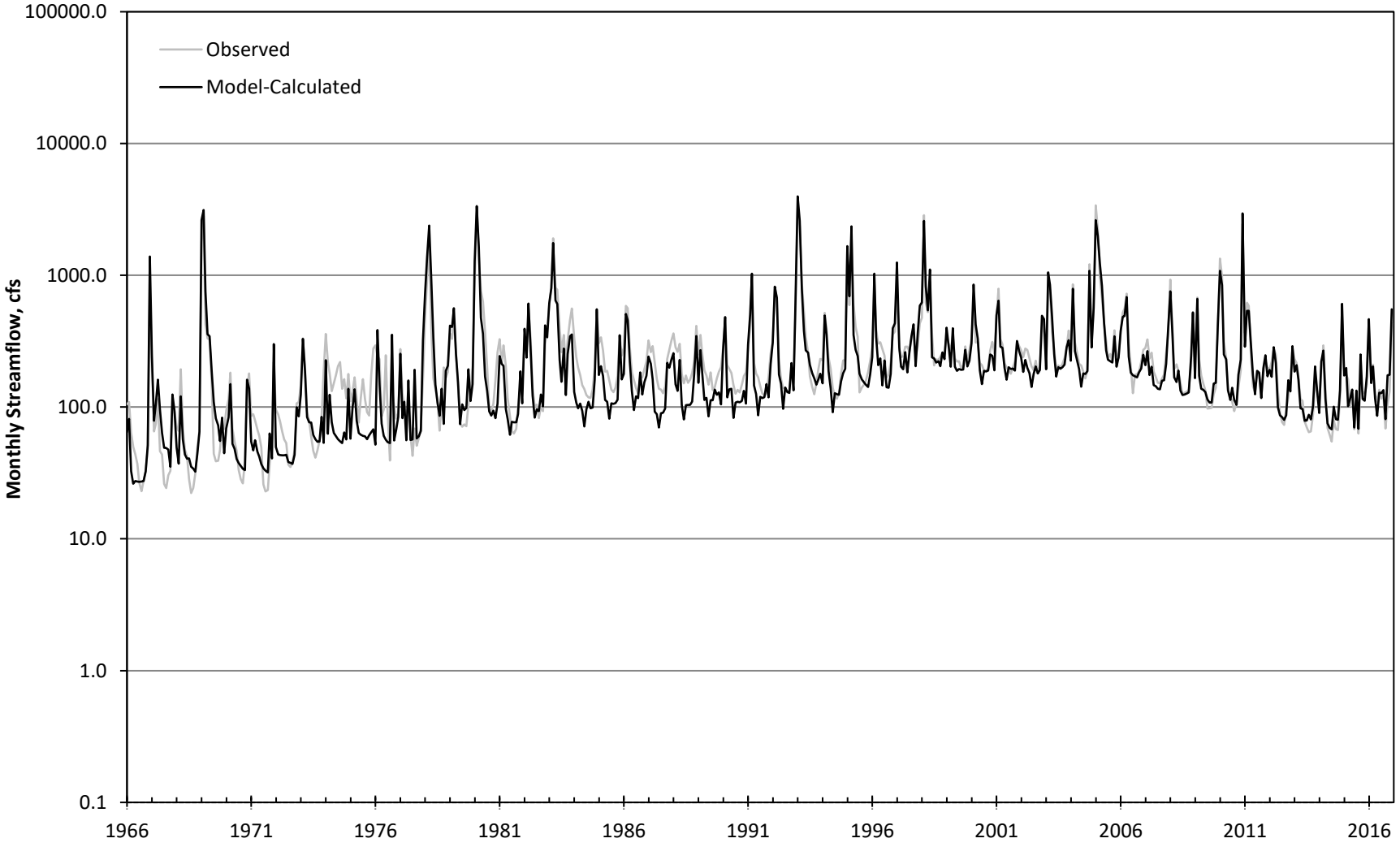

Figure 113

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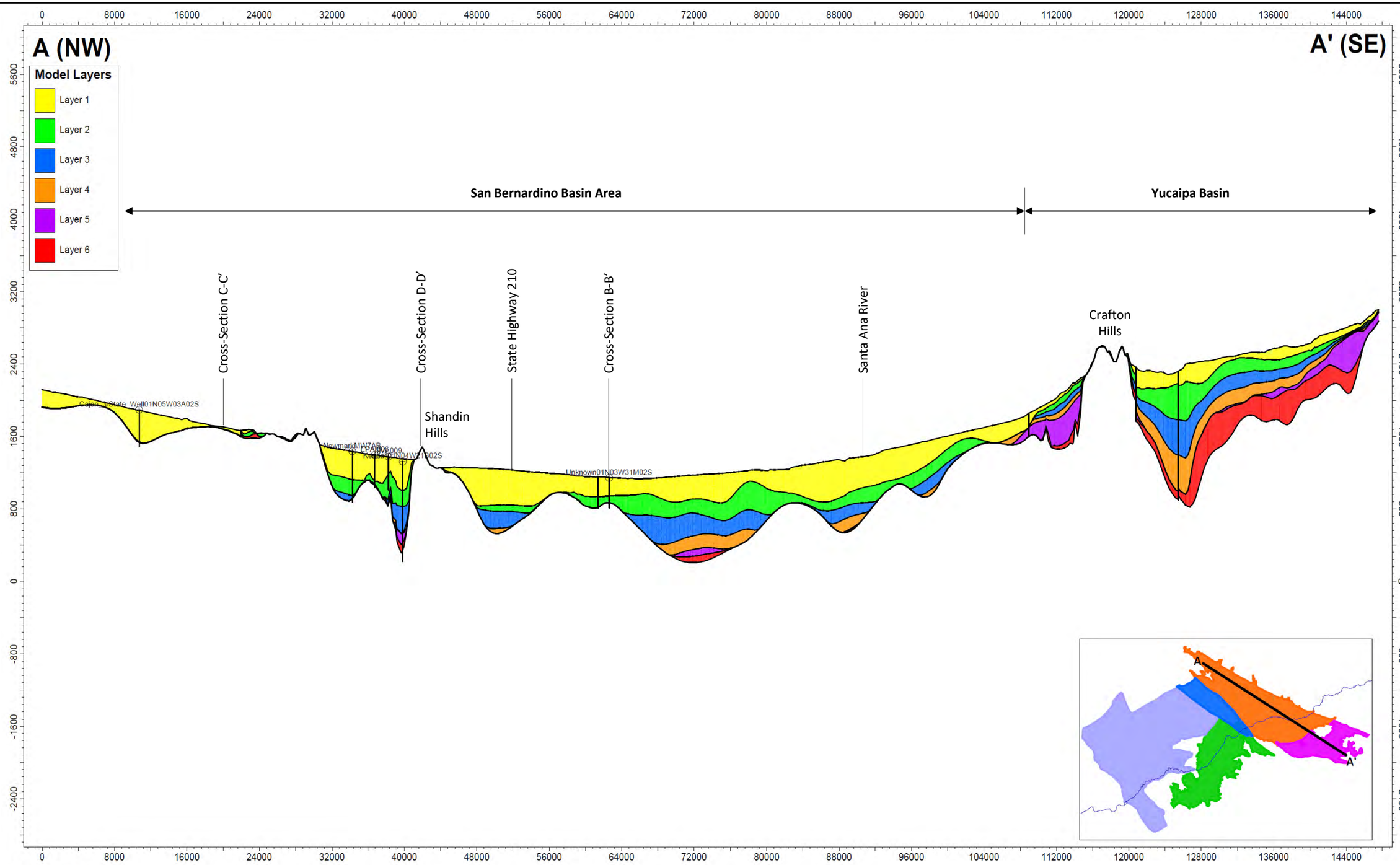

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

INTEGRATED SAR MODEL LAYERS - CROSS-SECTION A-A'

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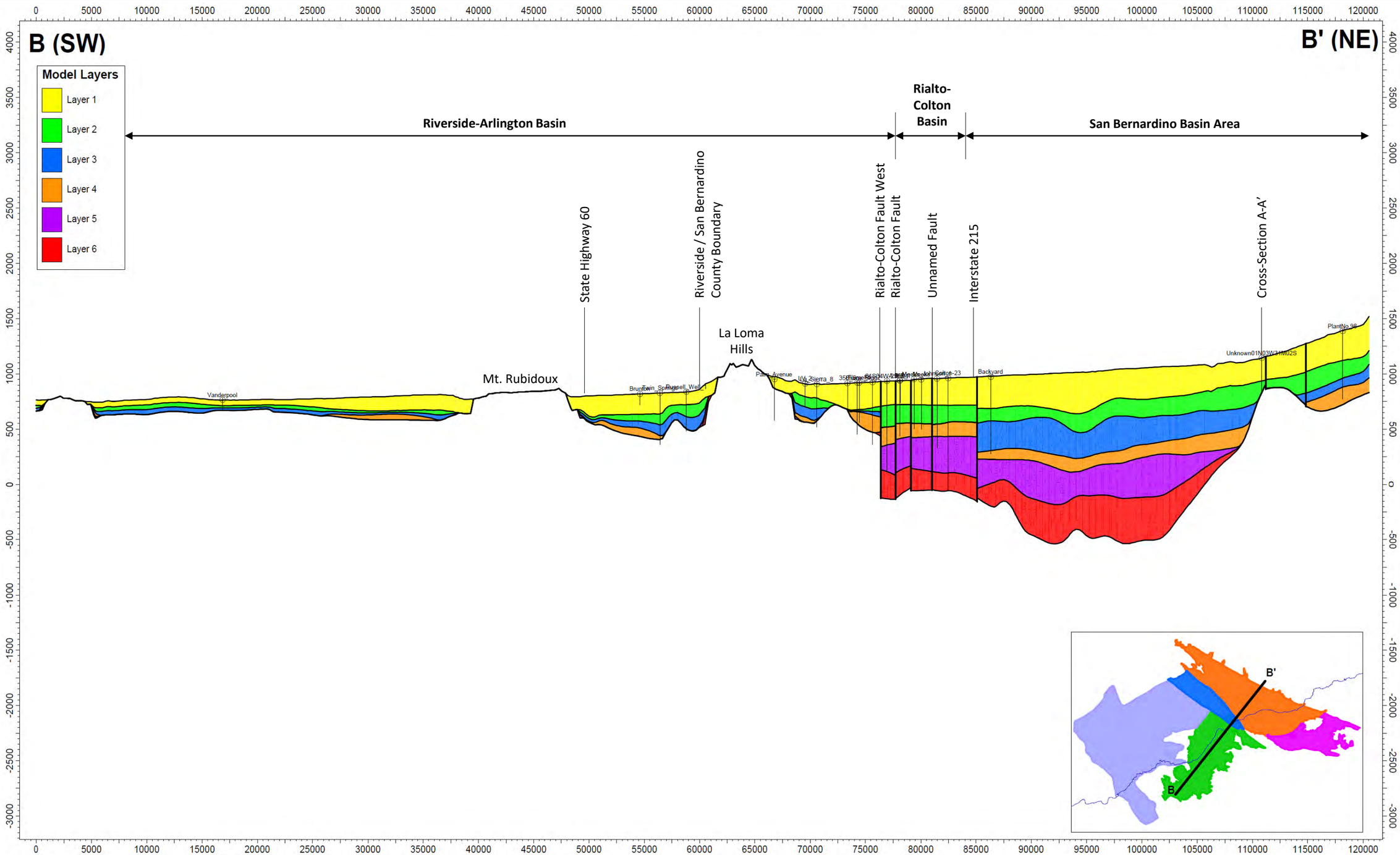

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

INTEGRATED SAR MODEL LAYERS - CROSS-SECTION B-B'

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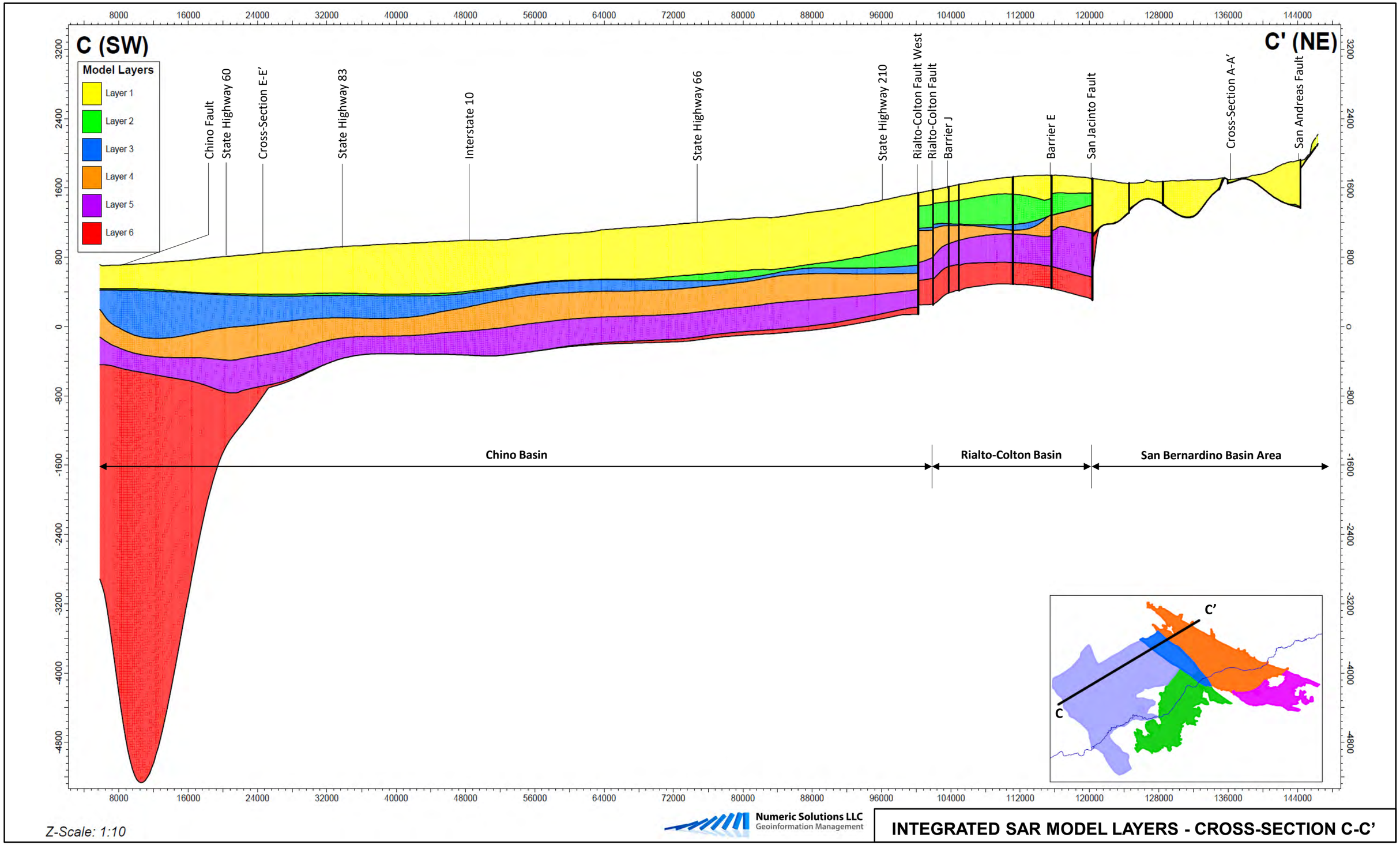

INTEGRATED SAR MODEL LAYERS - CROSS-SECTION C-C'

10-Apr-20

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

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FIGURE 116

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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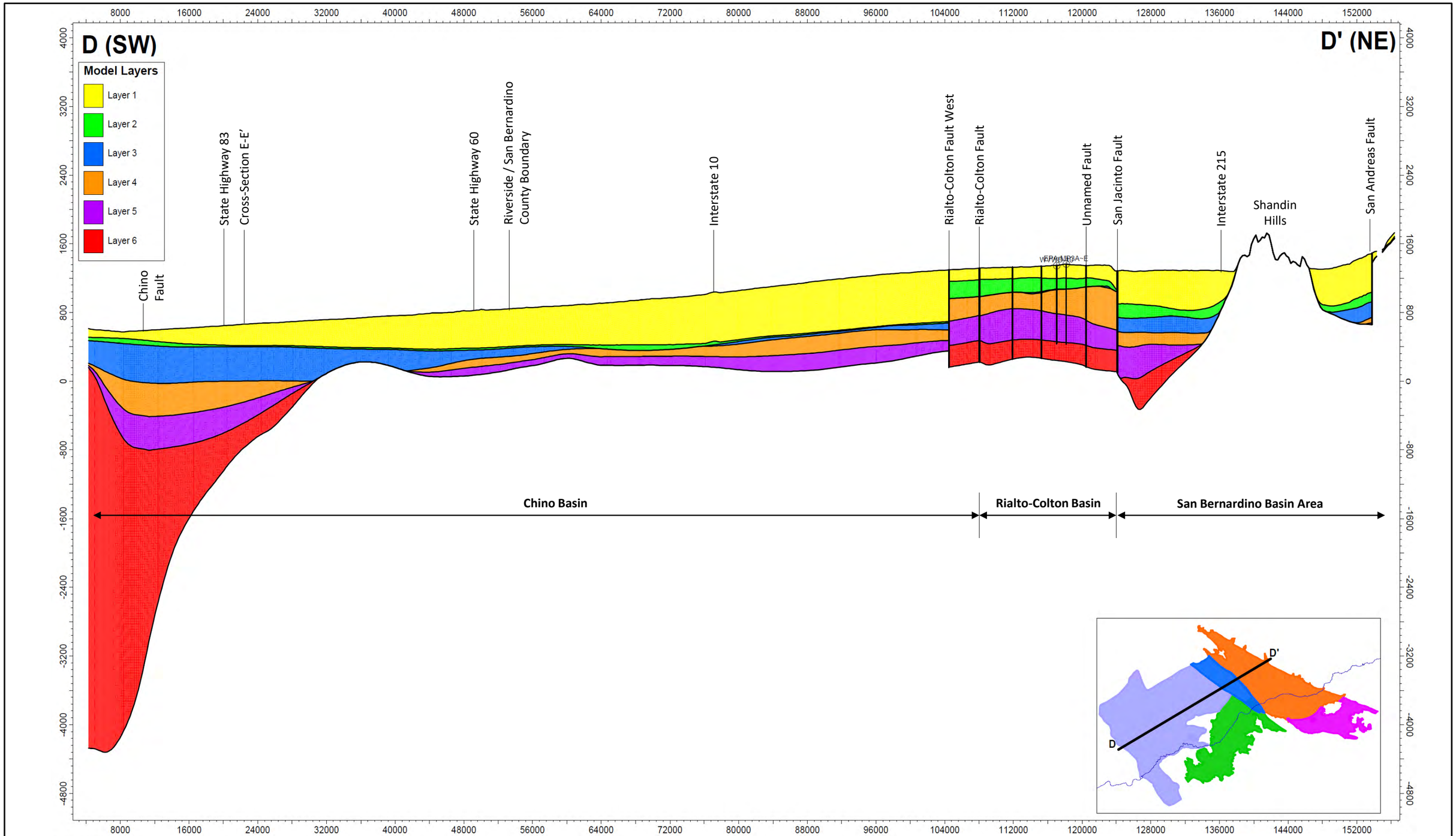

INTEGRATED SAR MODEL LAYERS - CROSS-SECTION D-D'

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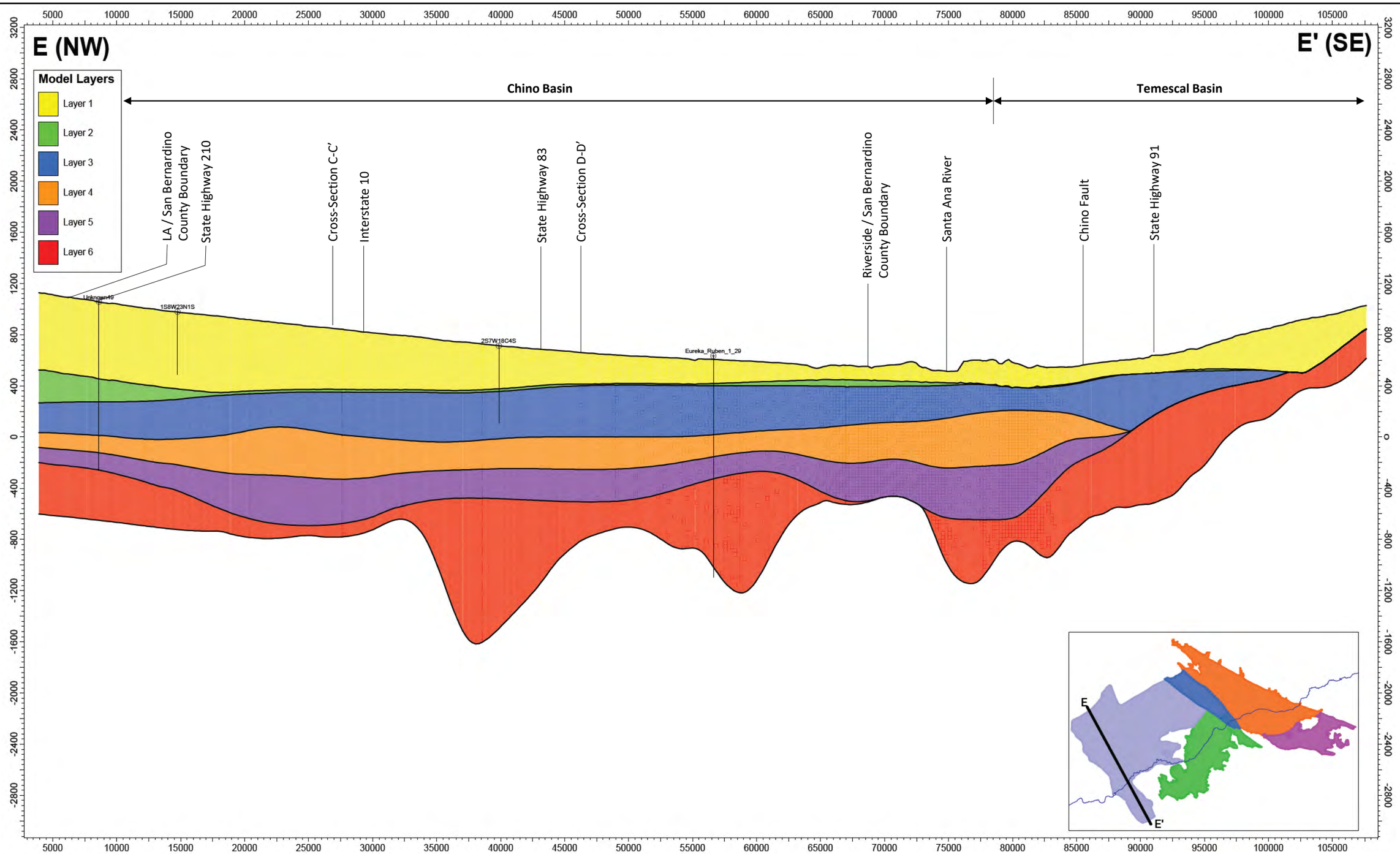

Z-Scale: 1:10
Well projection limit: 500'

Numeric Solutions LLC
Geoinformation Management

INTEGRATED SAR MODEL LAYERS - CROSS-SECTION E-E'

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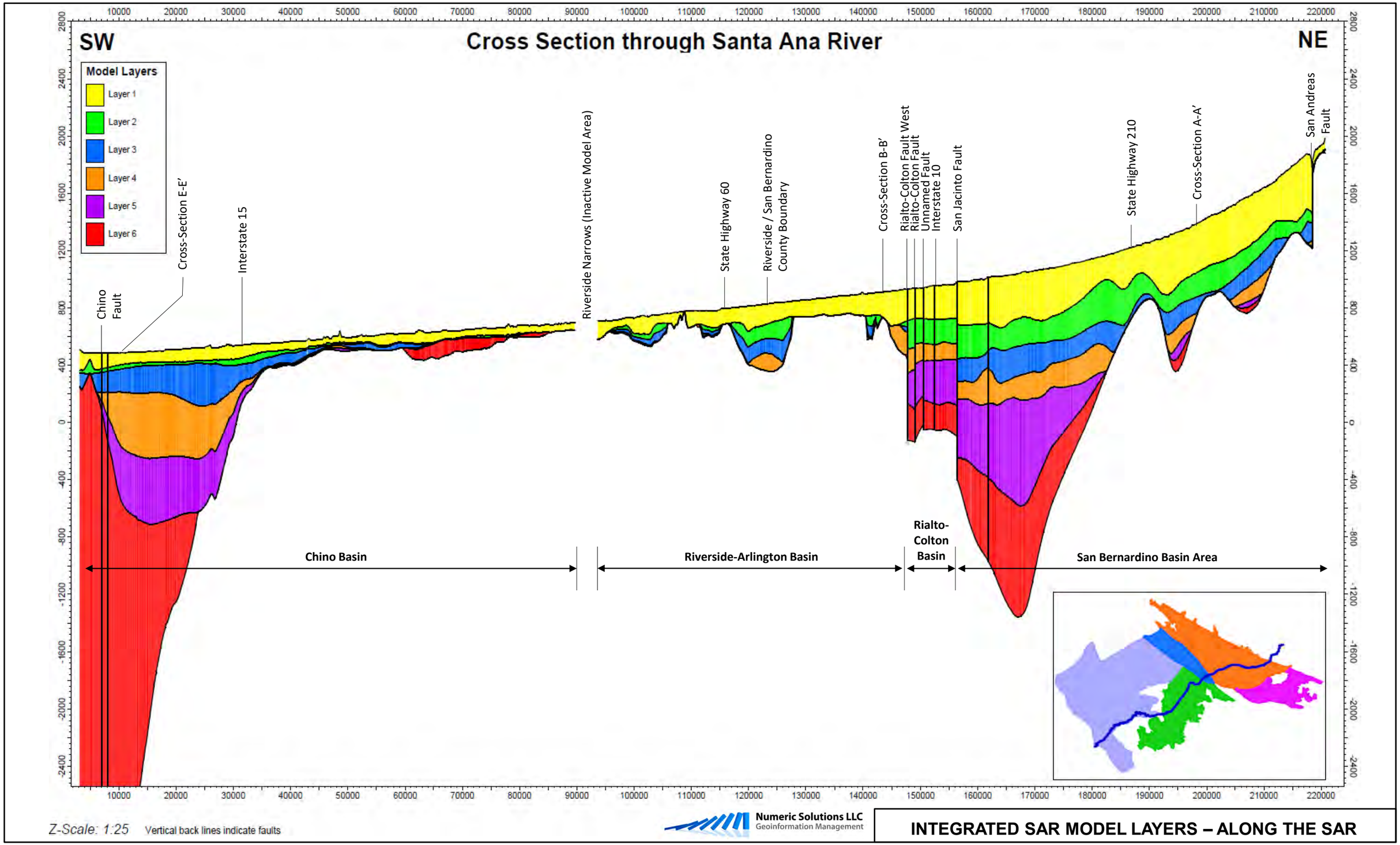

INTEGRATED SAR MODEL LAYERS – ALONG THE SAR

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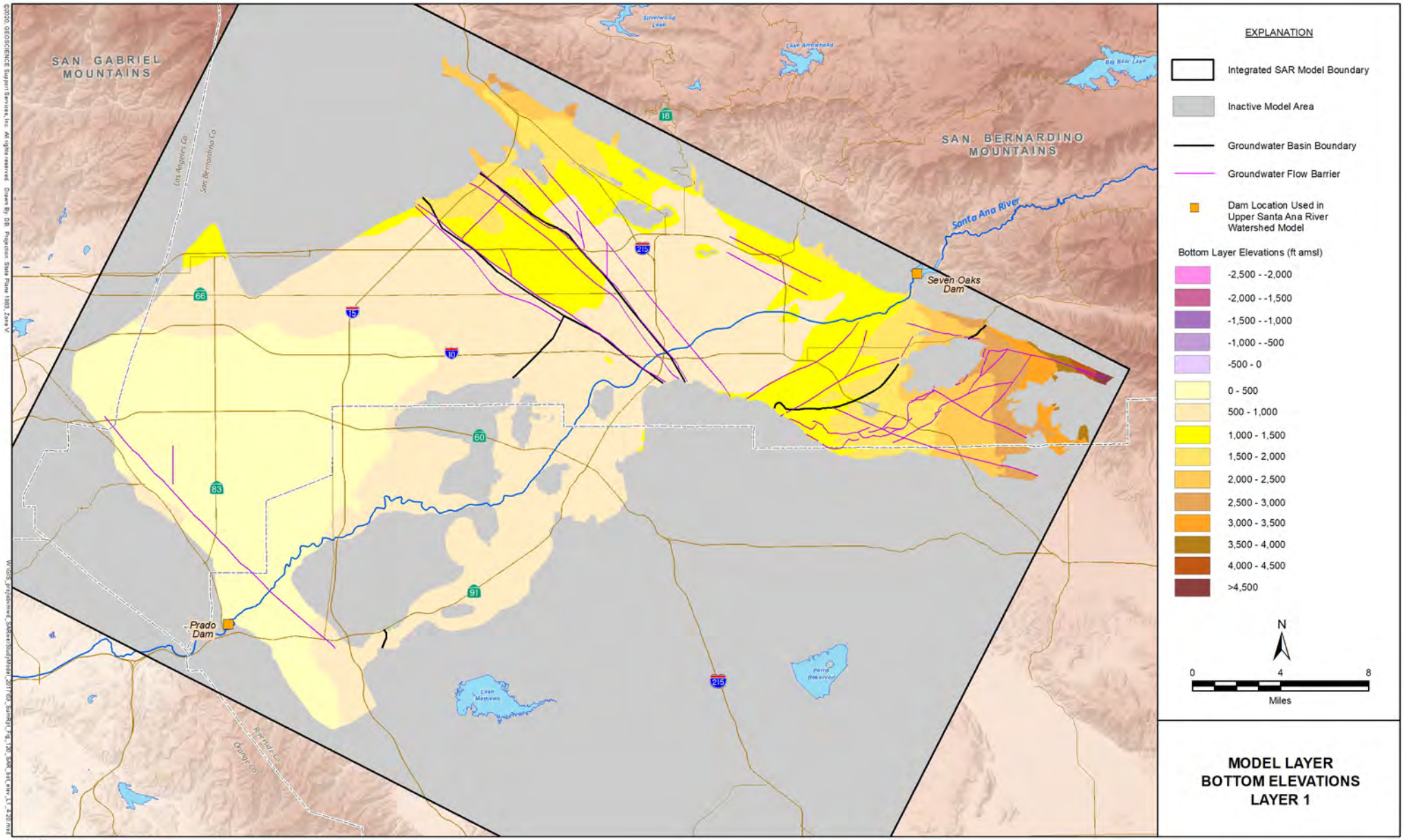

MODEL LAYER BOTTOM ELEVATIONS LAYER 1

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 120

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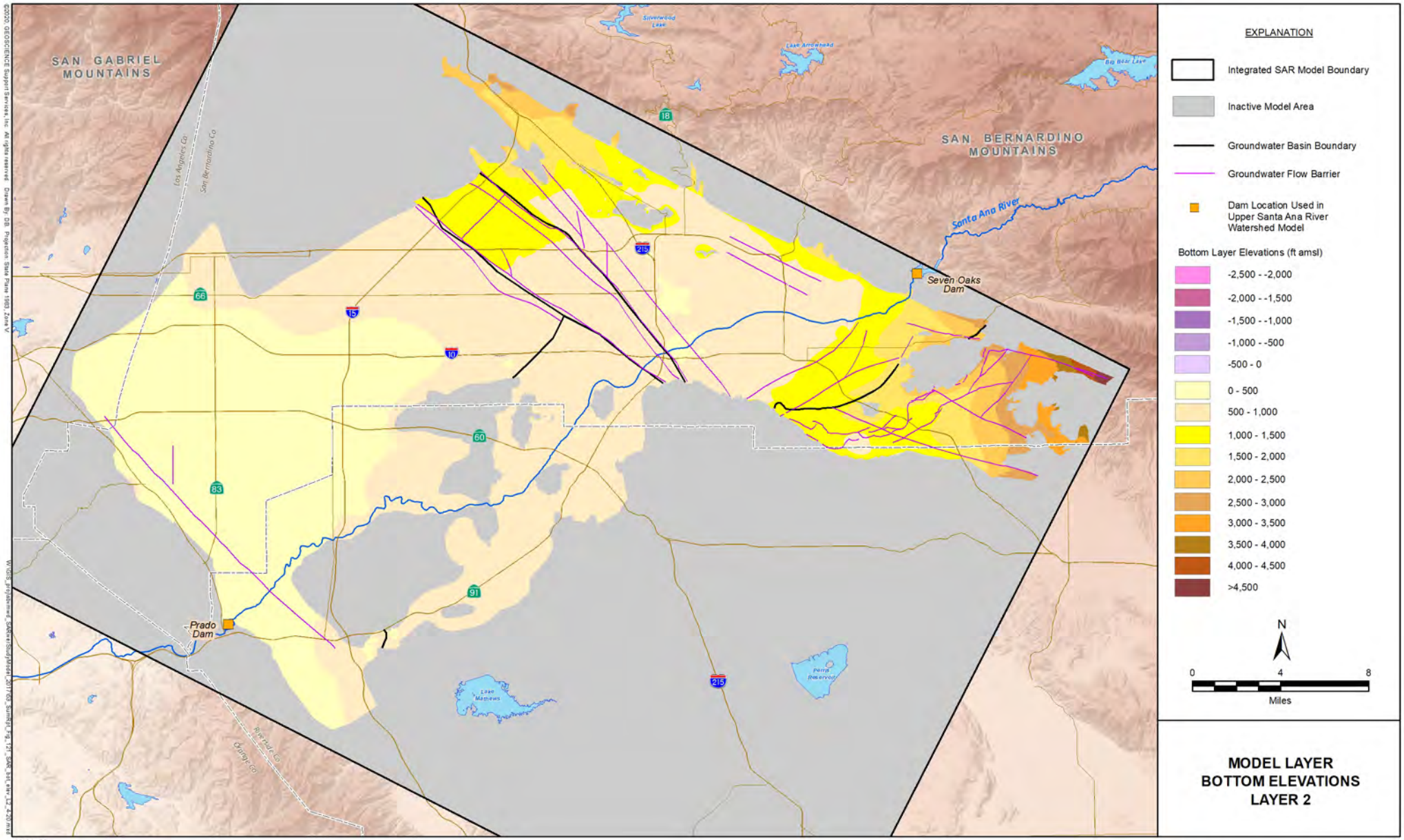

MODEL LAYER BOTTOM ELEVATIONS LAYER 2

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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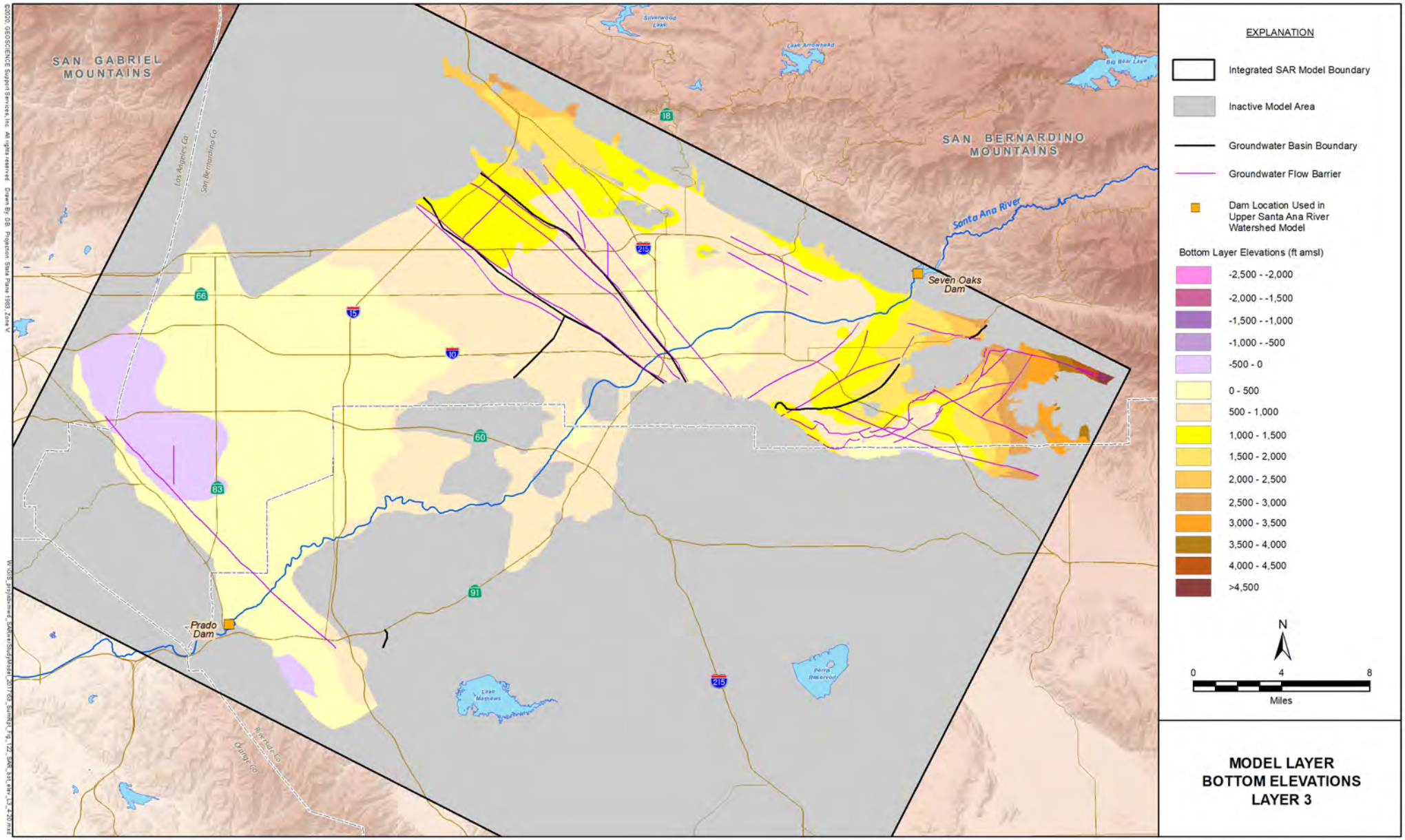
FIGURE 121

GEOSCIENCE



MODEL LAYER BOTTOM ELEVATIONS LAYER 3

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UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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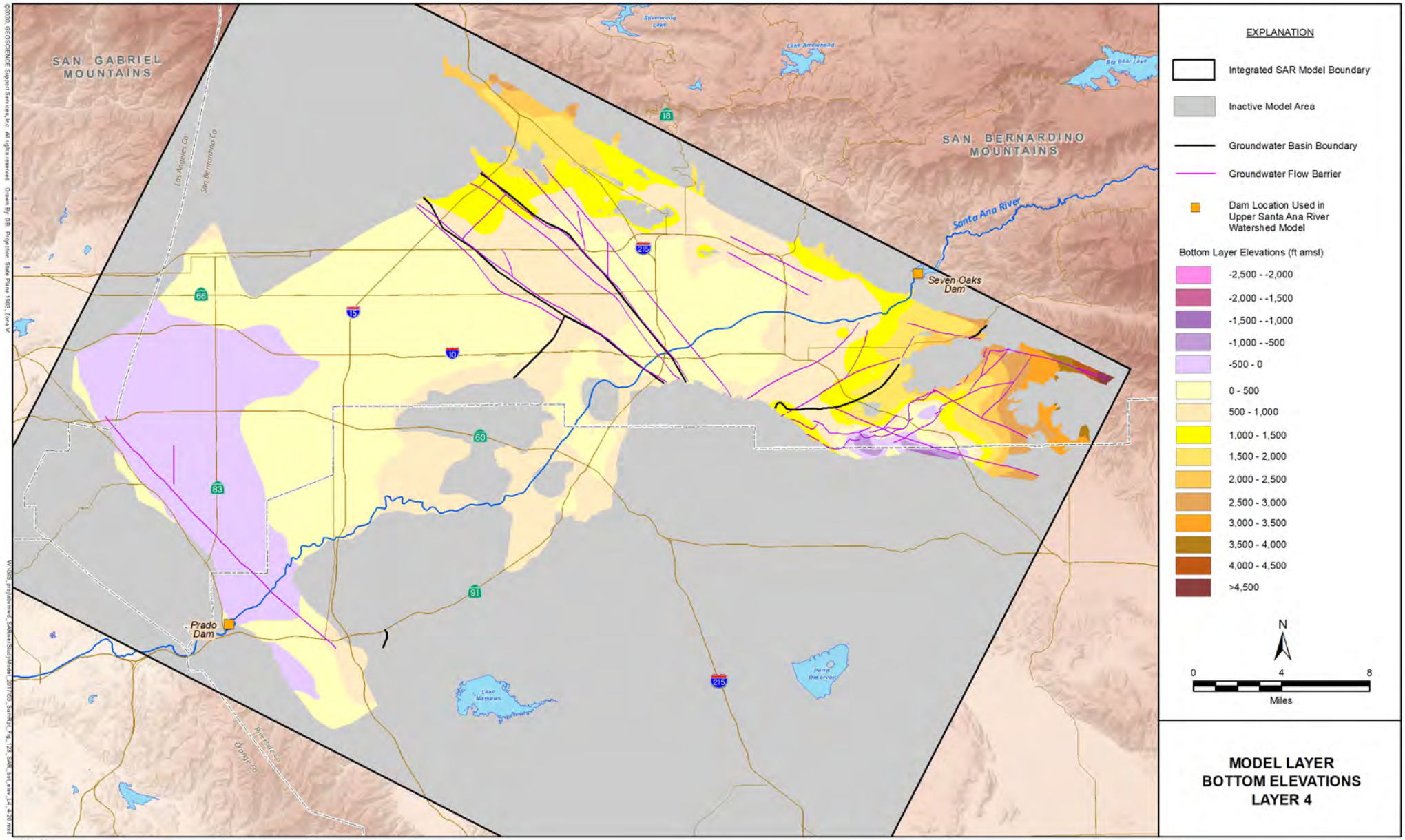
FIGURE 122

GEOSCIENCE



MODEL LAYER BOTTOM ELEVATIONS LAYER 4

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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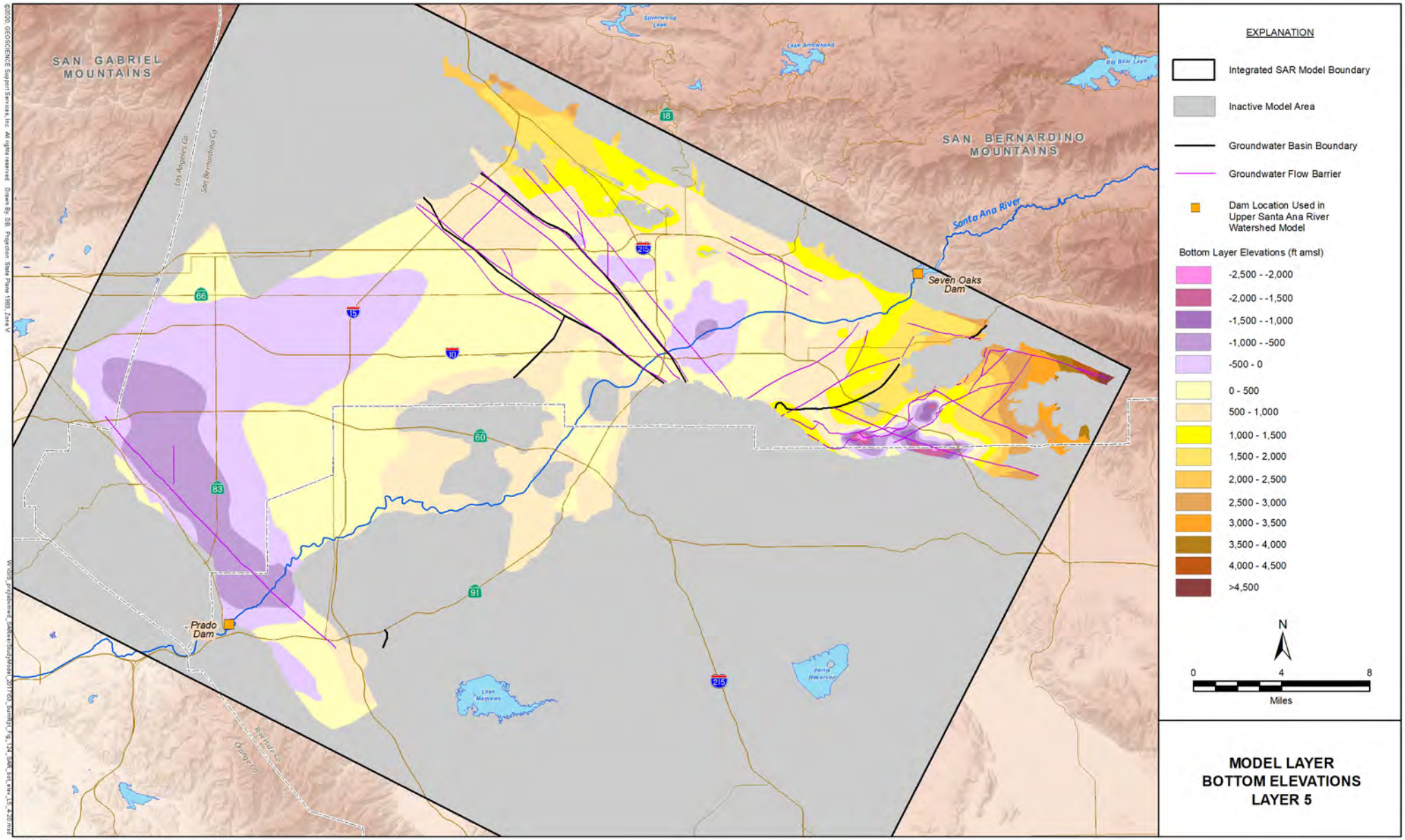
FIGURE 123

GEOSCIENCE



MODEL LAYER BOTTOM ELEVATIONS LAYER 5

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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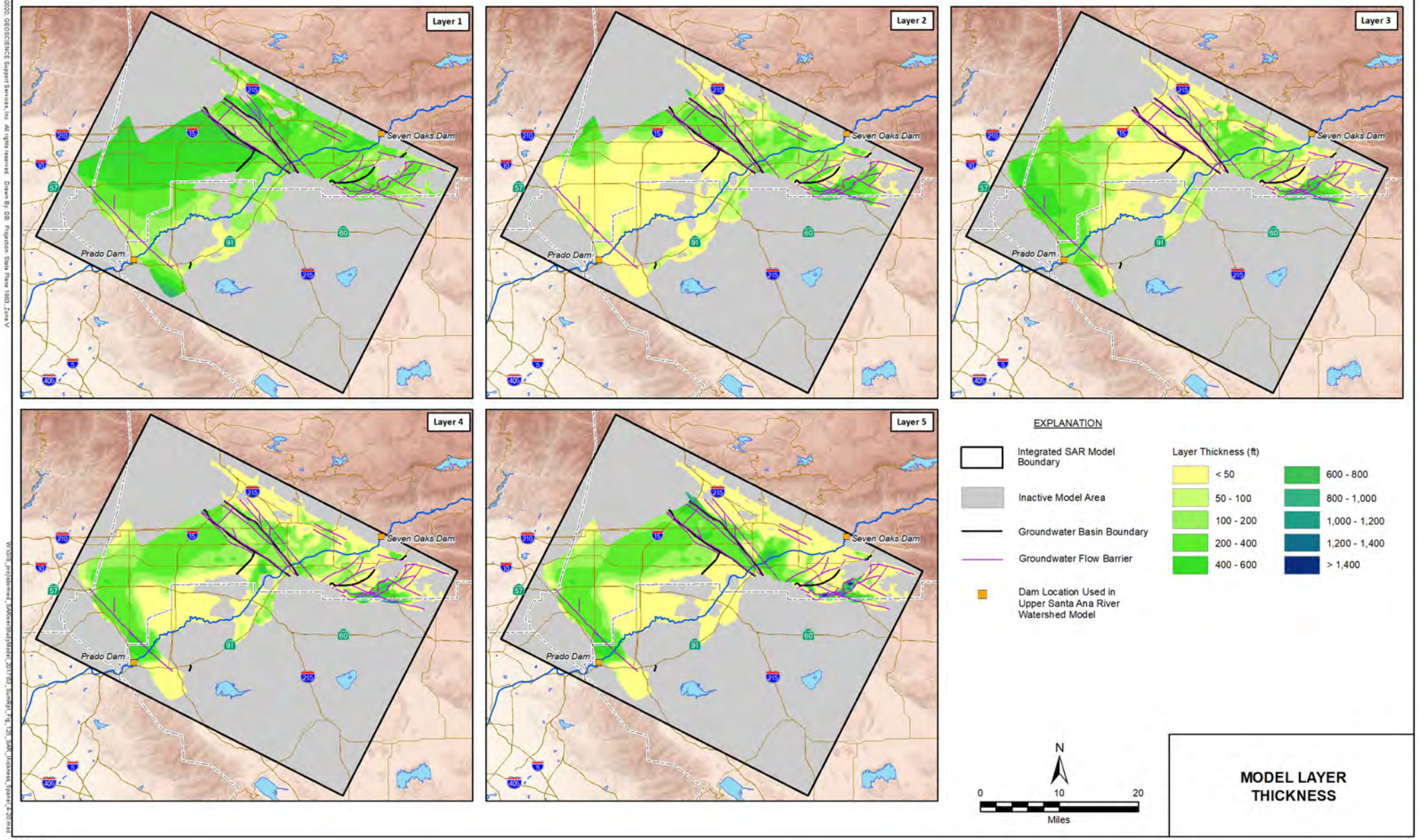
FIGURE 124

GEOSCIENCE



MODEL LAYER THICKNESS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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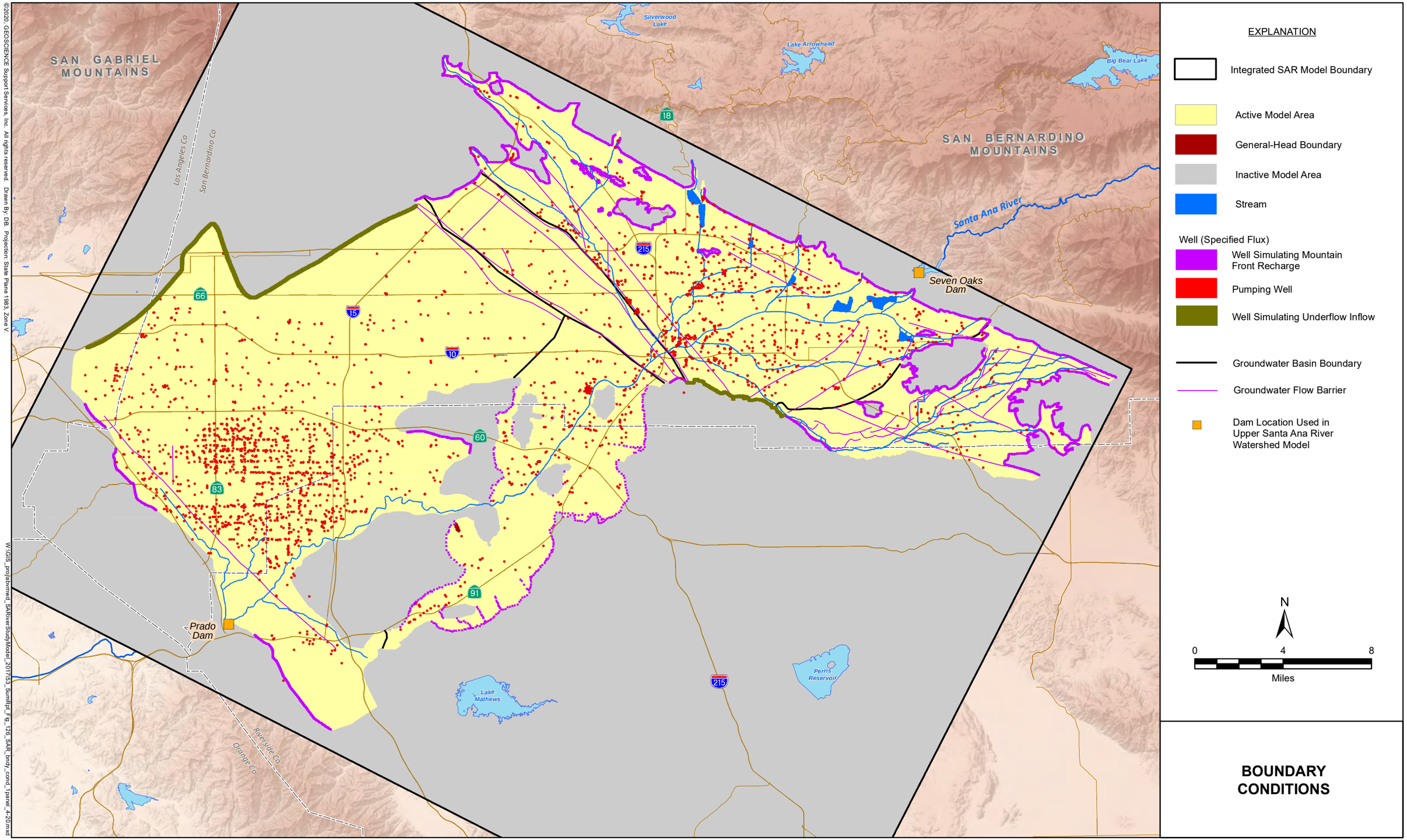
FIGURE 125

GEOSCIENCE



BOUNDARY CONDITIONS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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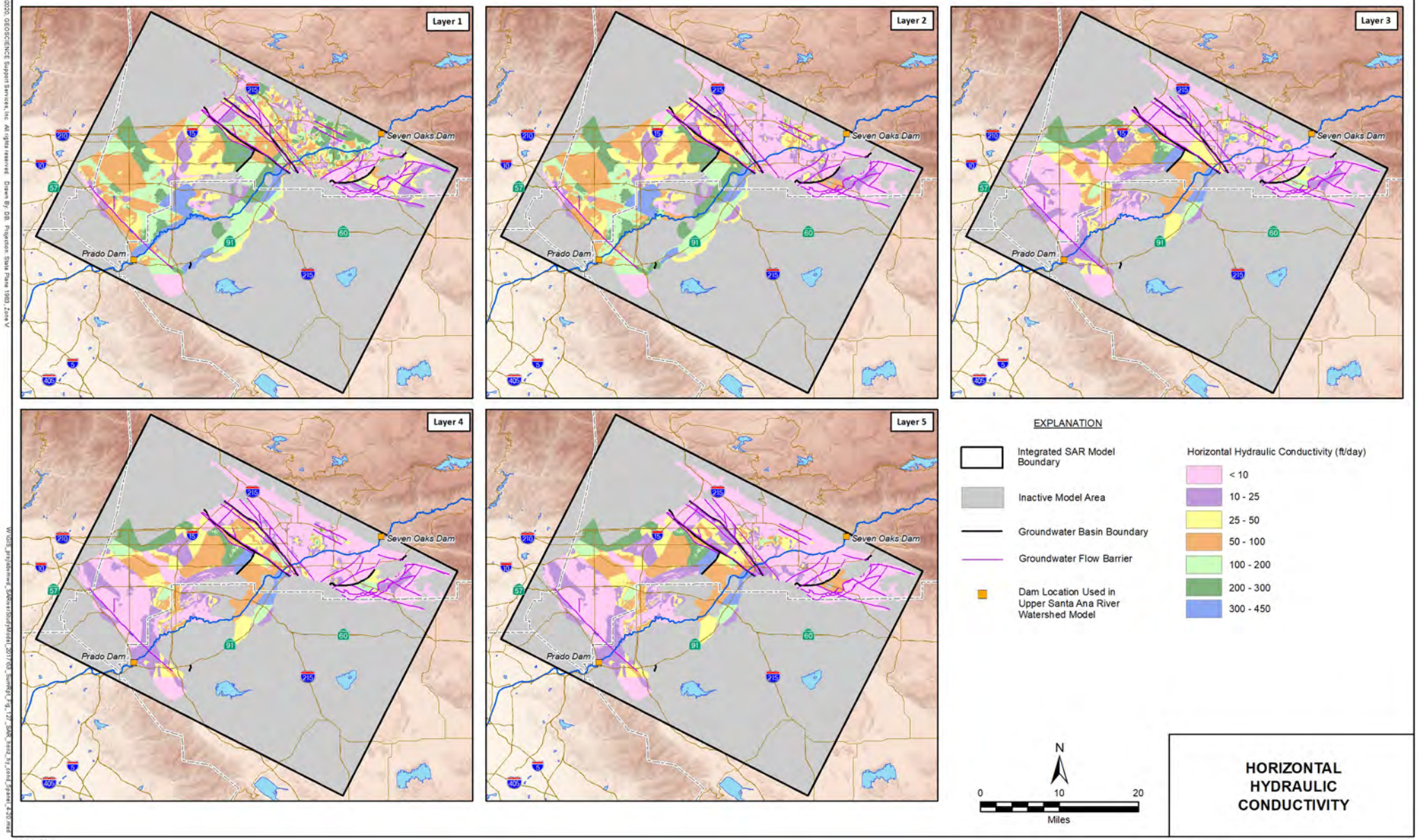
FIGURE 126

GEOSCIENCE



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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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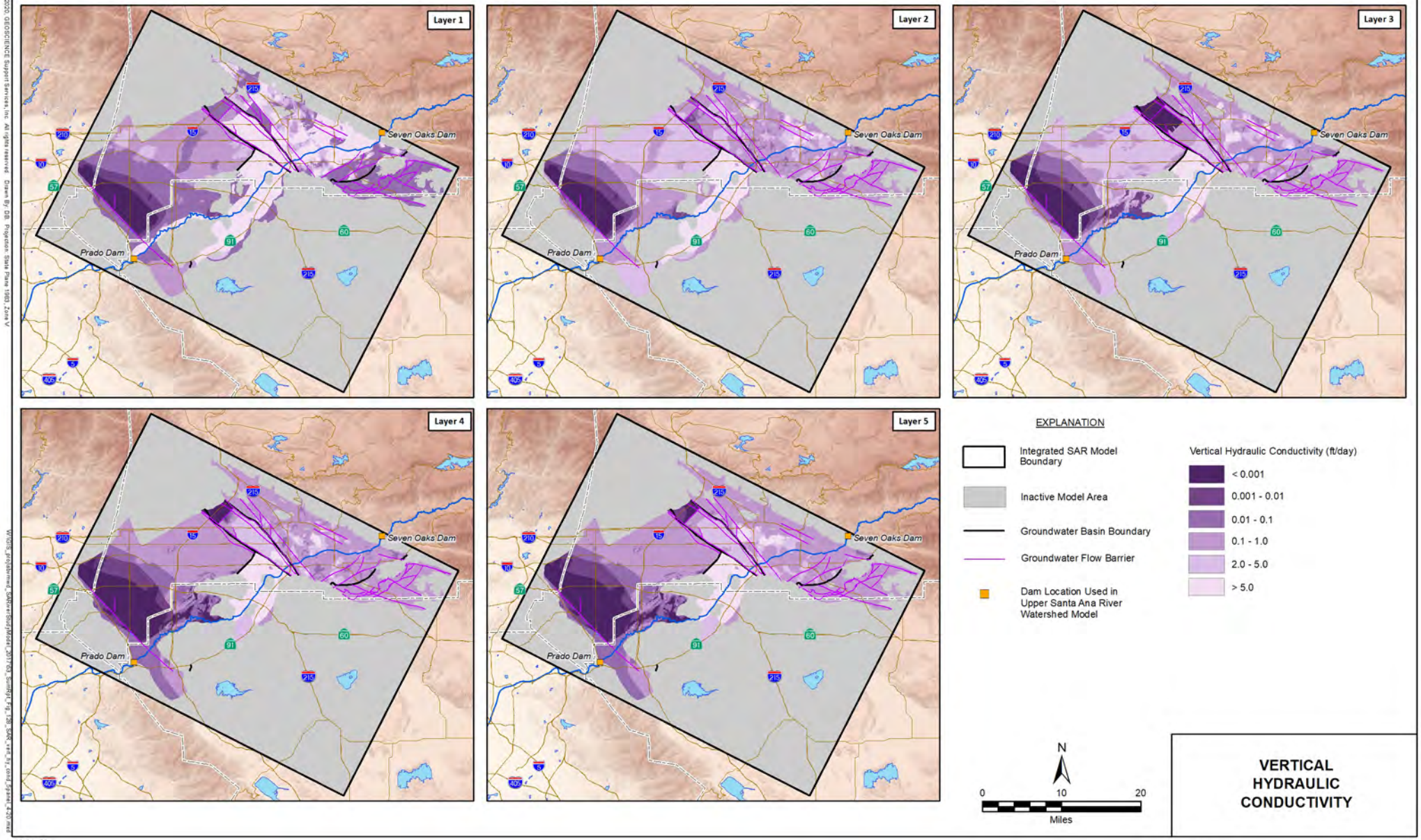
FIGURE 127

GEOSCIENCE



VERTICAL HYDRAULIC CONDUCTIVITY

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 128

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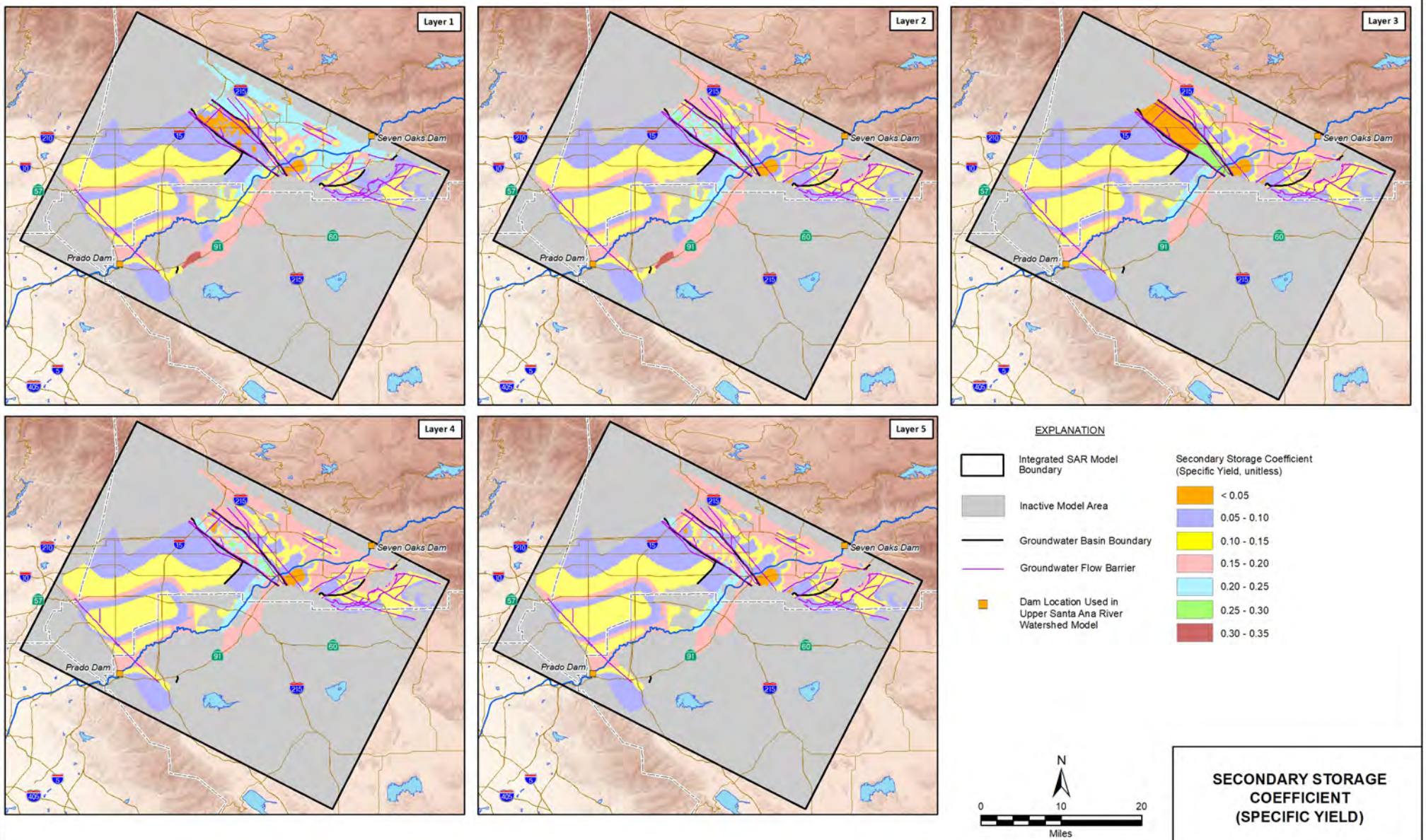

SECONDARY STORAGE COEFFICIENT (SPECIFIC YIELD)

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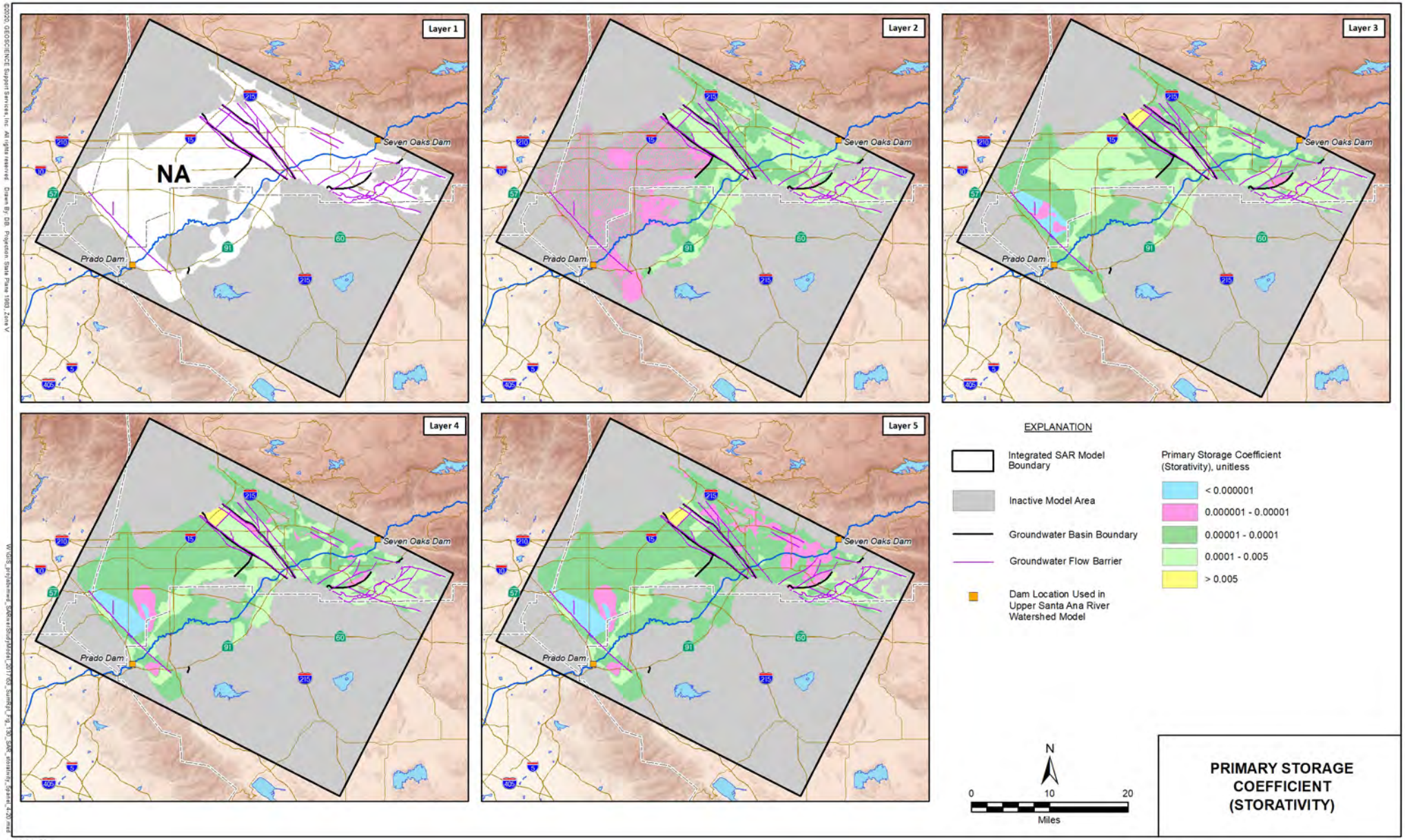

PRIMARY STORAGE COEFFICIENT (STORATIVITY)

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 130

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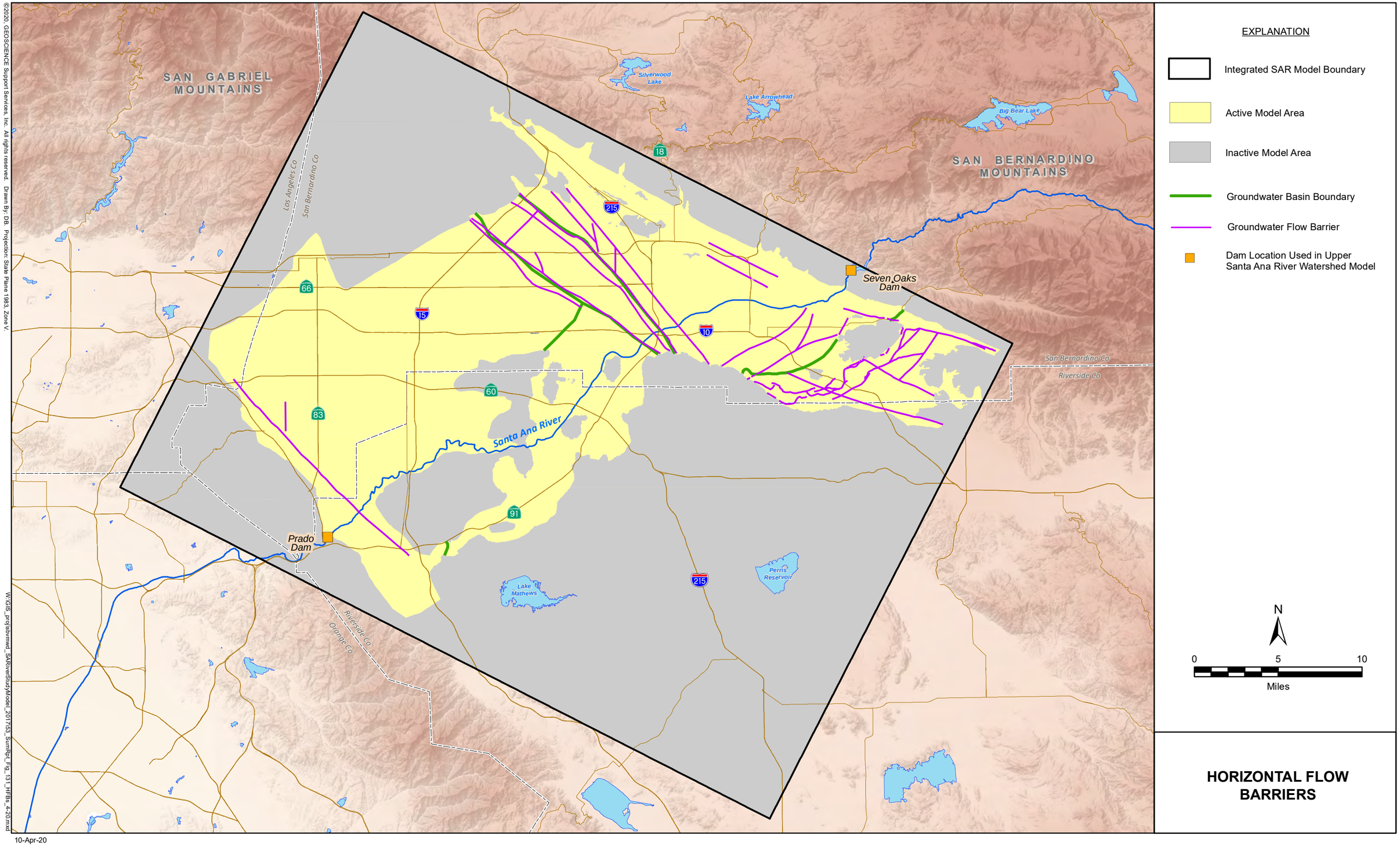

HORIZONTAL FLOW BARRIERS

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_131_HFBs_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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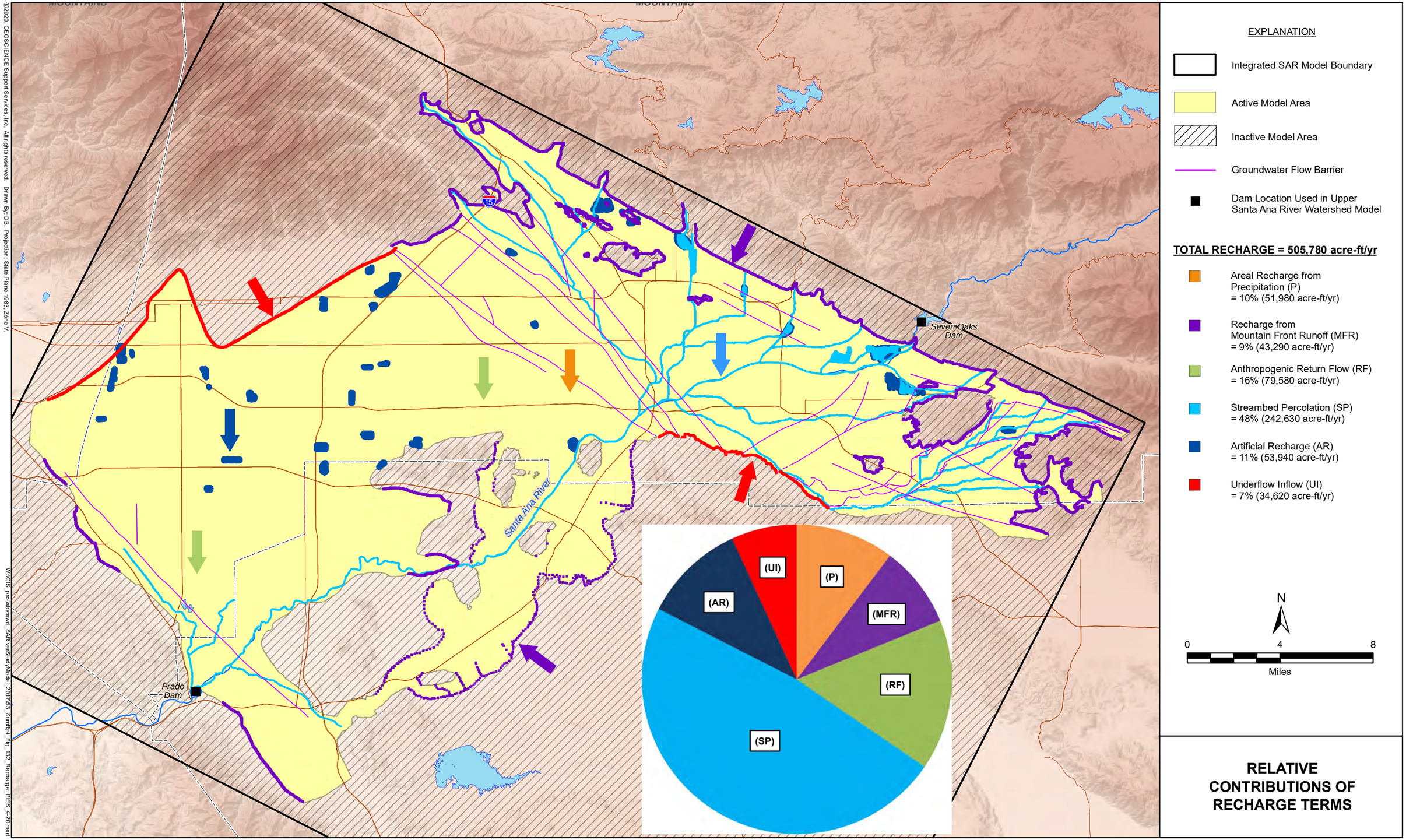
FIGURE 131

GEOSCIENCE



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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_132_Recharge_PIES_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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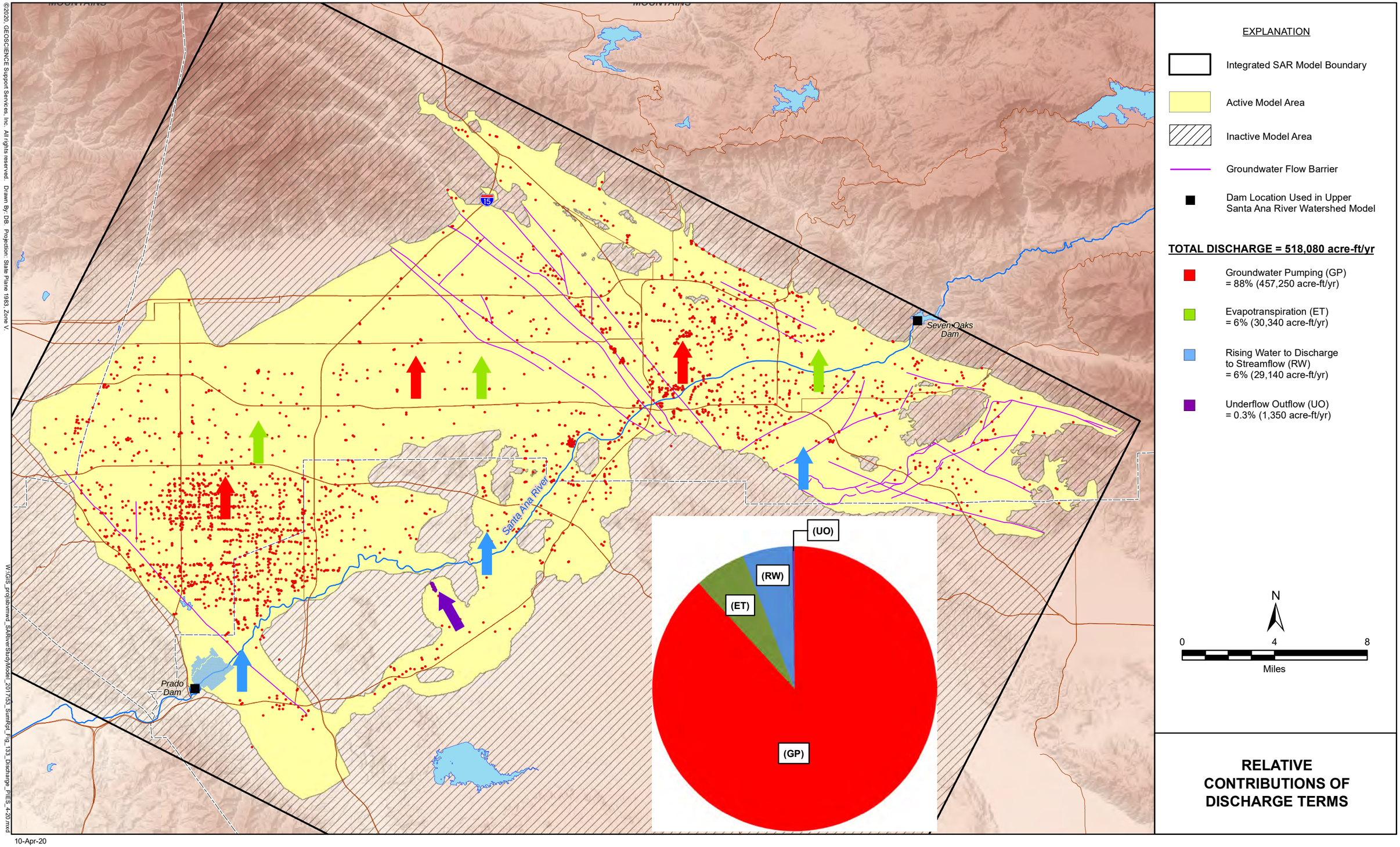
FIGURE 132

GEOSCIENCE



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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 133

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Annual Tributary Inflow from Outside of the Groundwater Basin

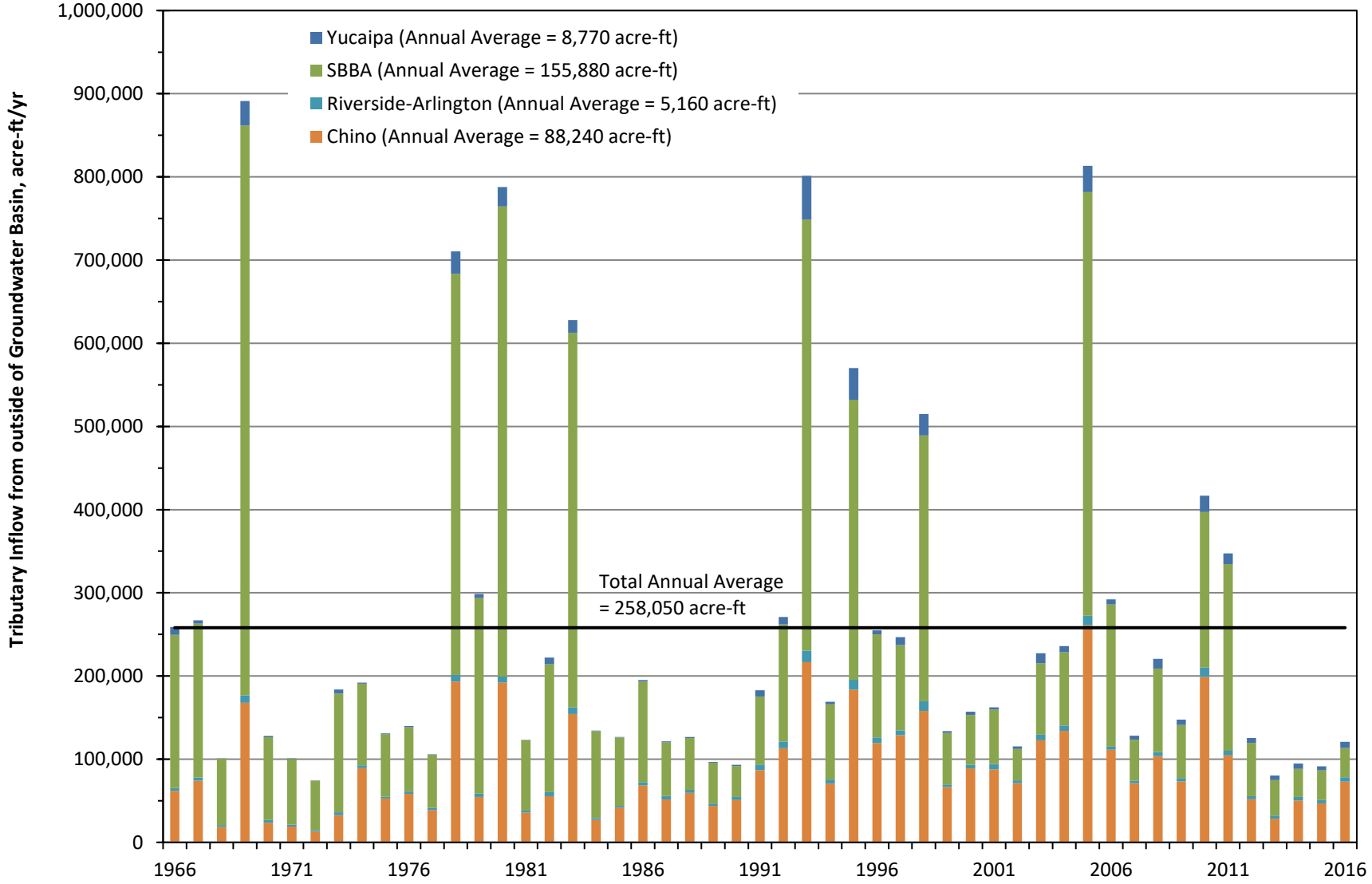

Figure 134

Annual Runoff Generated within the Groundwater Basin

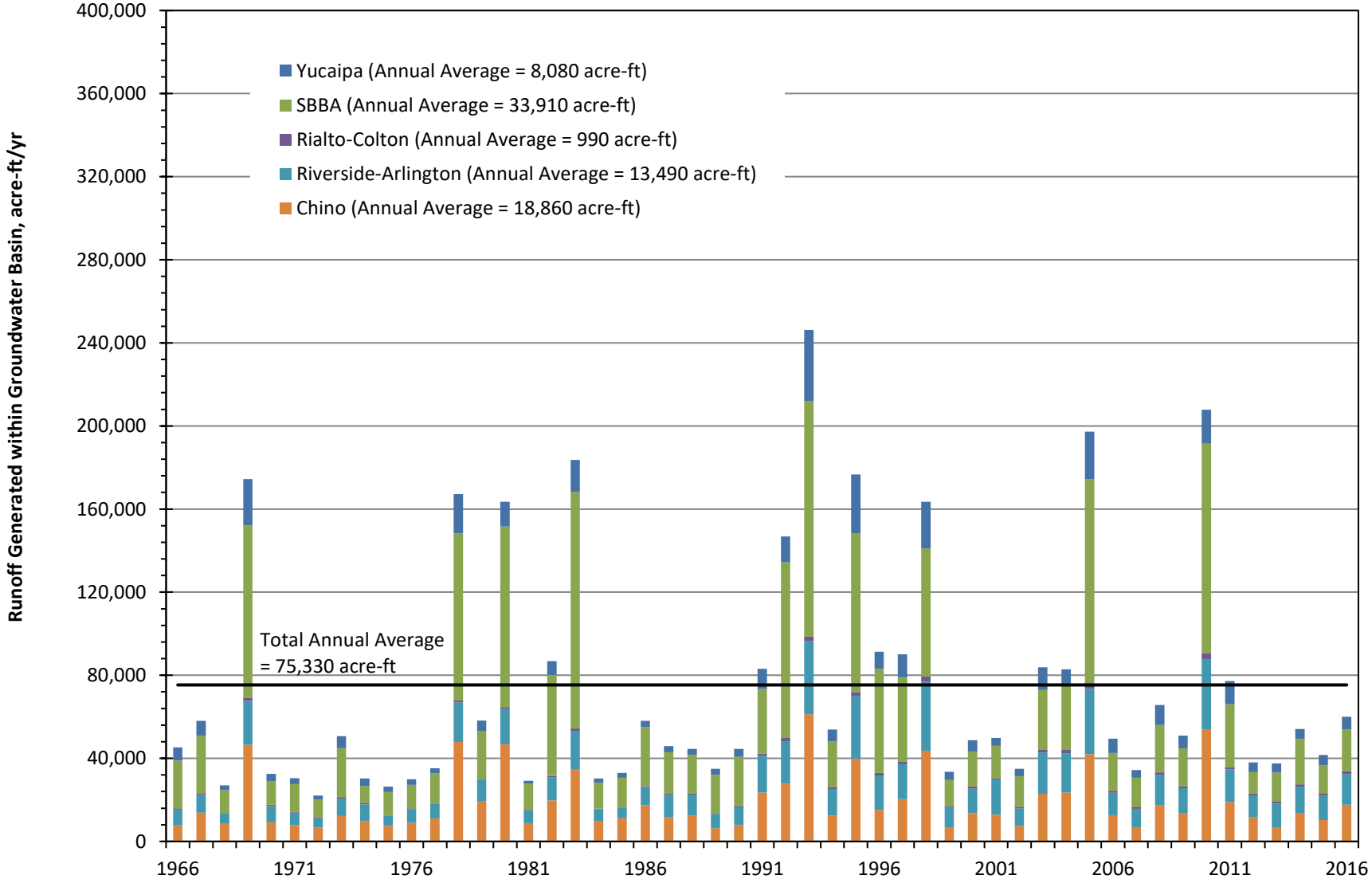

Figure 135

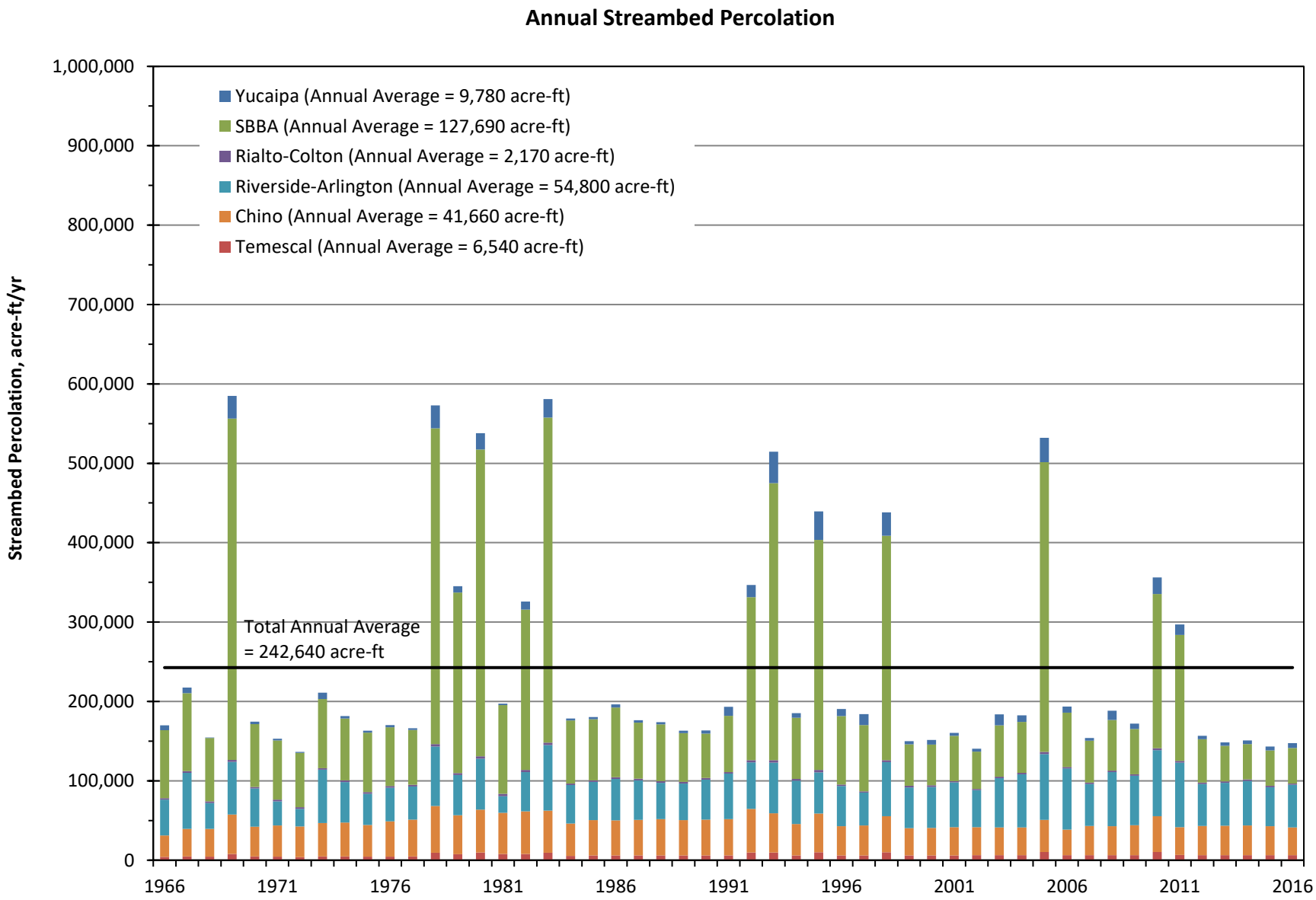
Annual Streambed Percolation
Yucaipa (Annual Average = 9,780 acre-ft)
SBBA (Annual Average = 127,690 acre-ft)
Rialto-Colton (Annual Average = 2,170 acre-ft)
Riverside-Arlington (Annual Average = 54,800 acre-ft)
Chino (Annual Average = 41,660 acre-ft)
Temescal (Annual Average = 6,540 acre-ft)
Total Annual Average
= 242,640 acre-ft
Streambed Percolation, acre-ft/yr
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 136

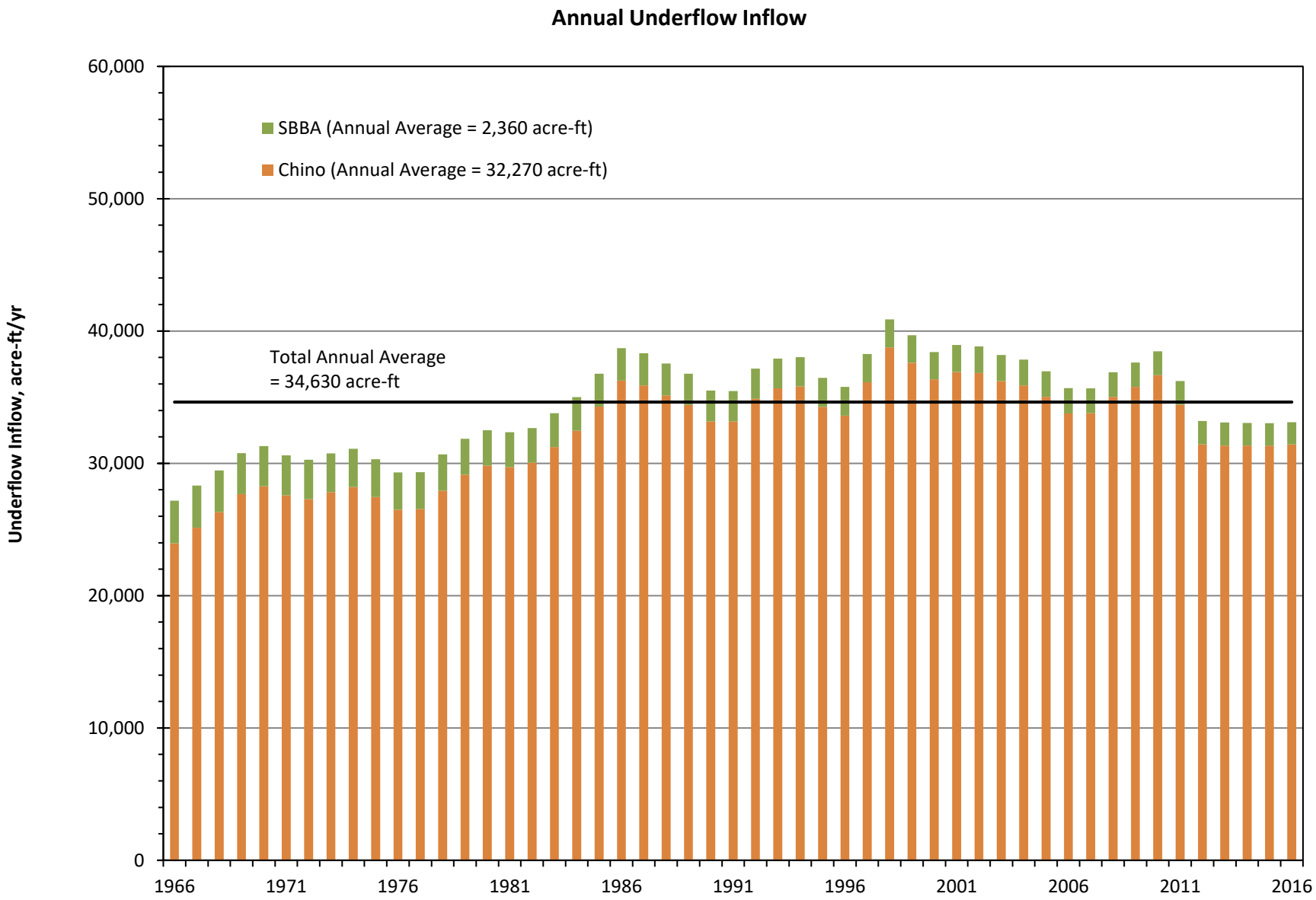
Annual Underflow Inflow
SBBA (Annual Average = 2,360 acre-ft)
Chino (Annual Average = 32,270 acre-ft)
Total Annual Average
= 34,630 acre-ft
Underflow Inflow, acre-ft/yr
60,000
50,000
40,000
30,000
20,000
10,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 137

Annual Evapotranspiration – Integrated SAR Model Area

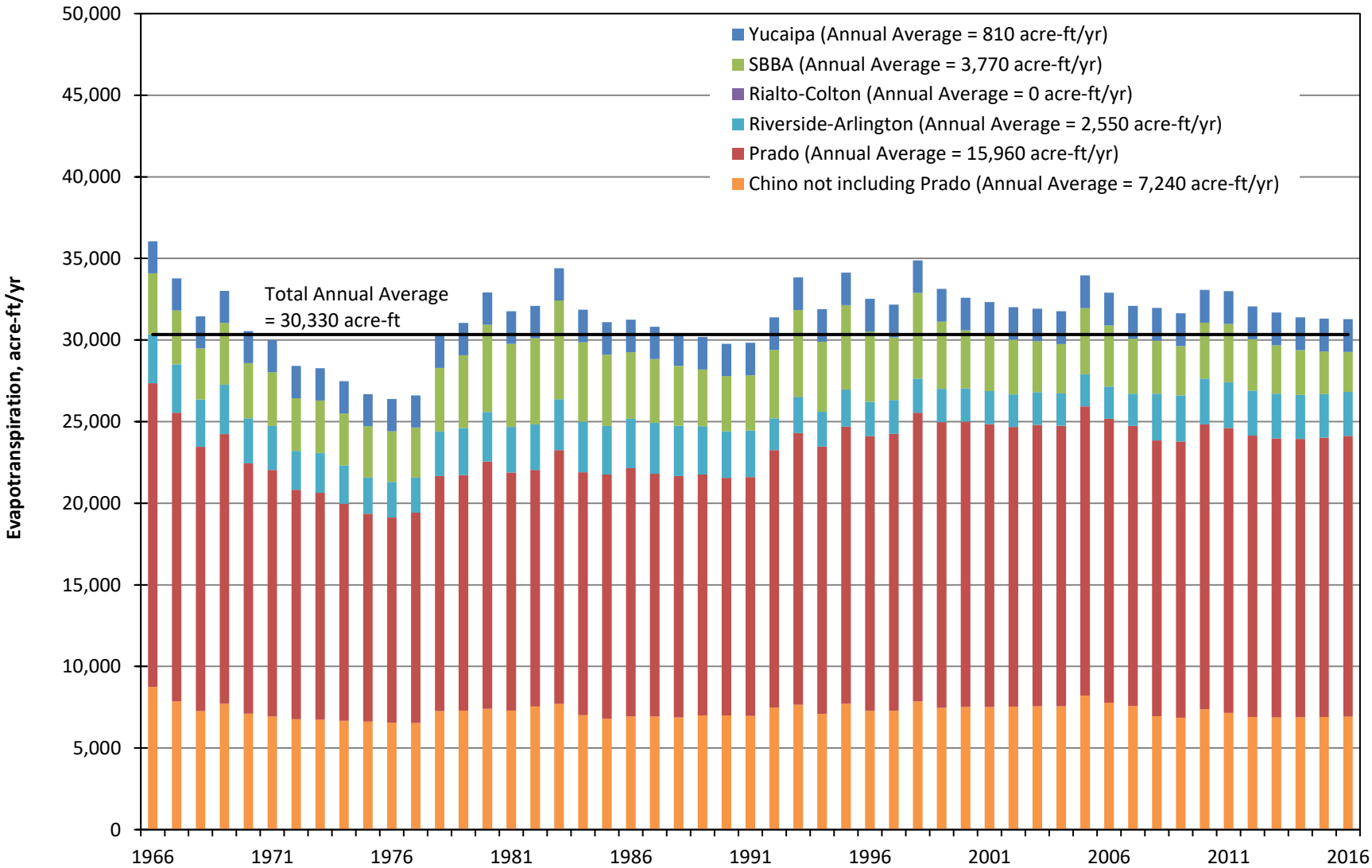

Figure 138

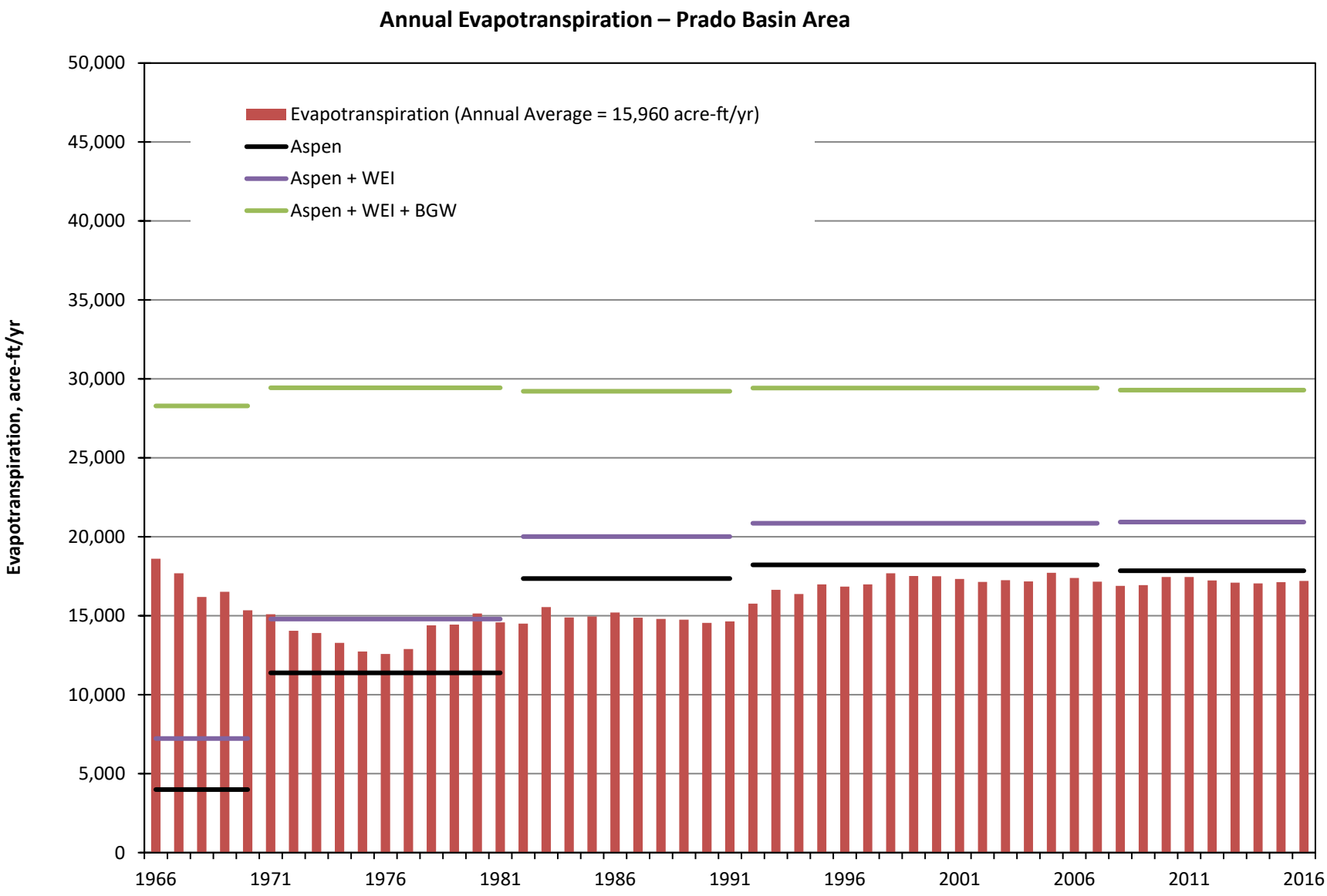
Annual Evapotranspiration – Prado Basin Area
Evapotranspiration (Annual Average = 15,960 acre-ft/yr)
Aspen
Aspen + WEI
Aspen + WEI + BGW
Evapotranspiration, acre-ft/yr
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 139

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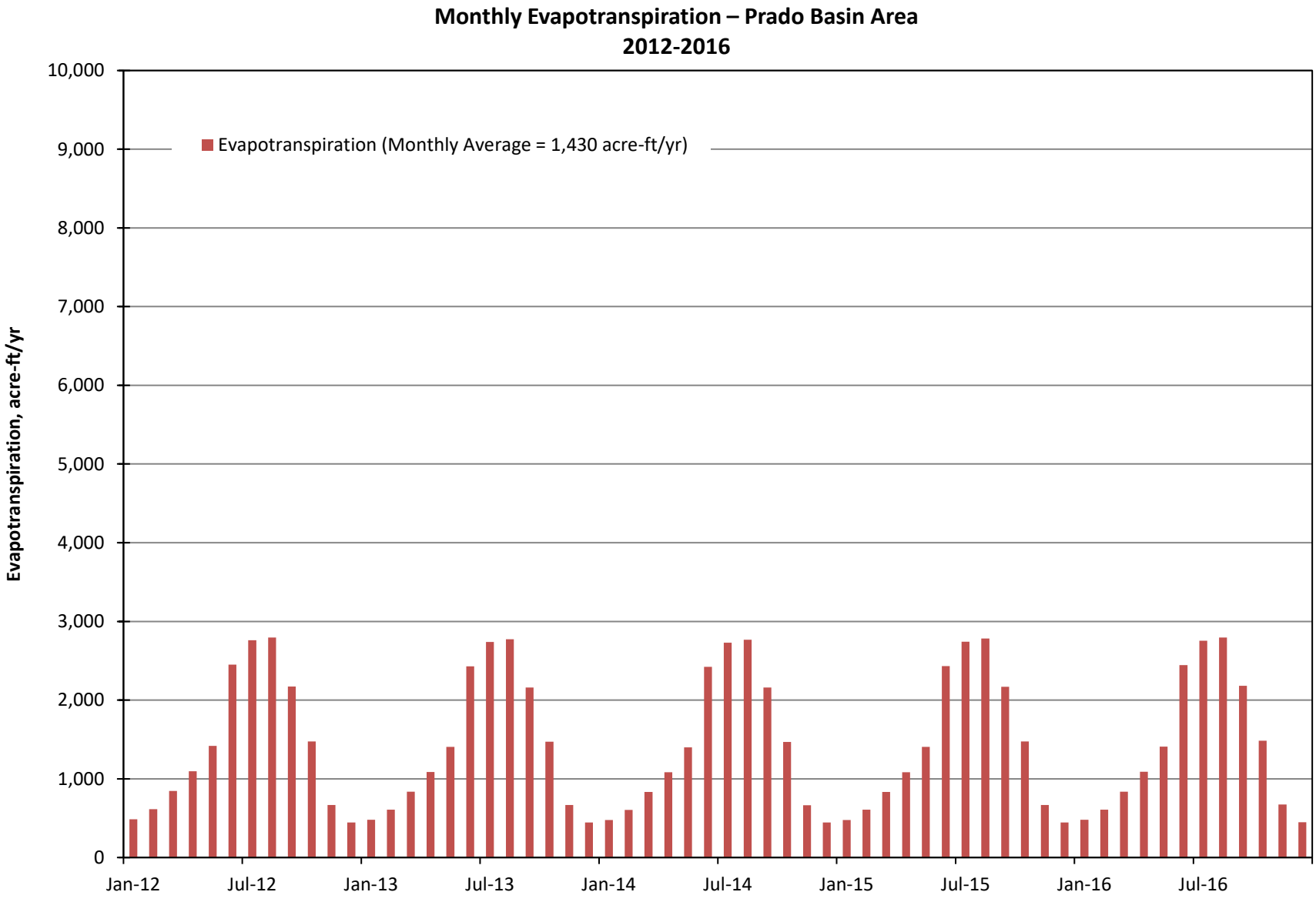

Figure 140

DRAFT

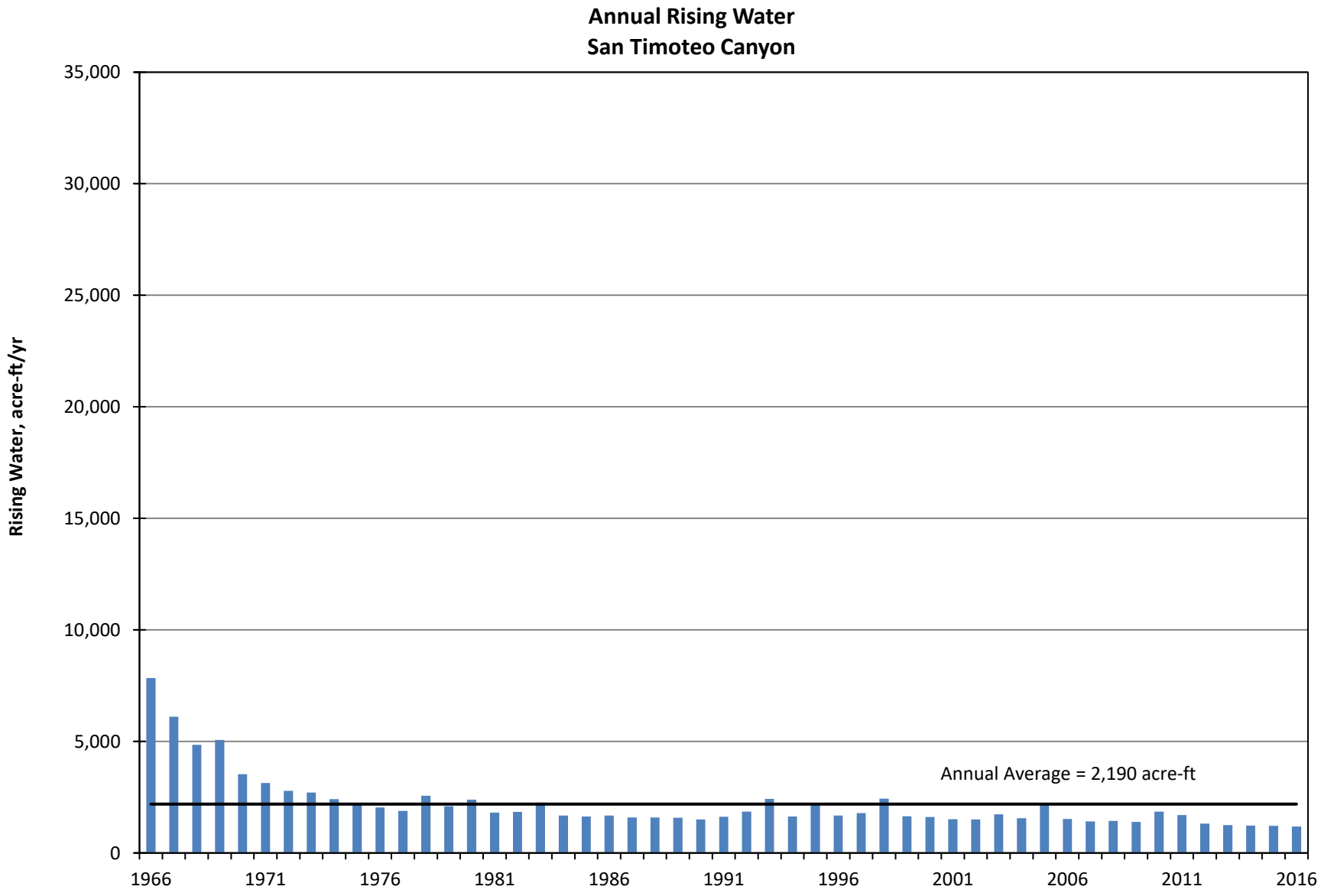

Figure 141

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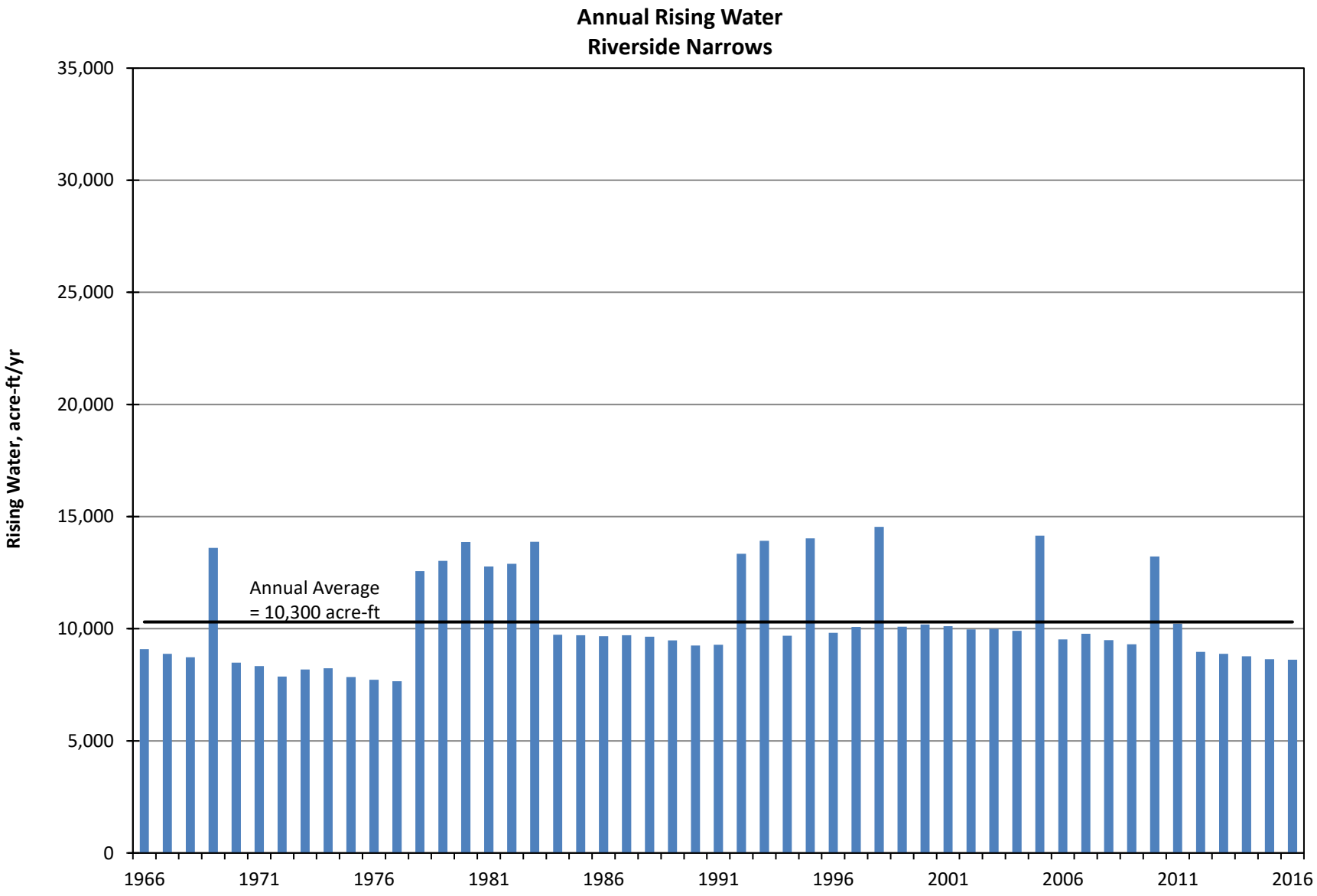

Figure 142

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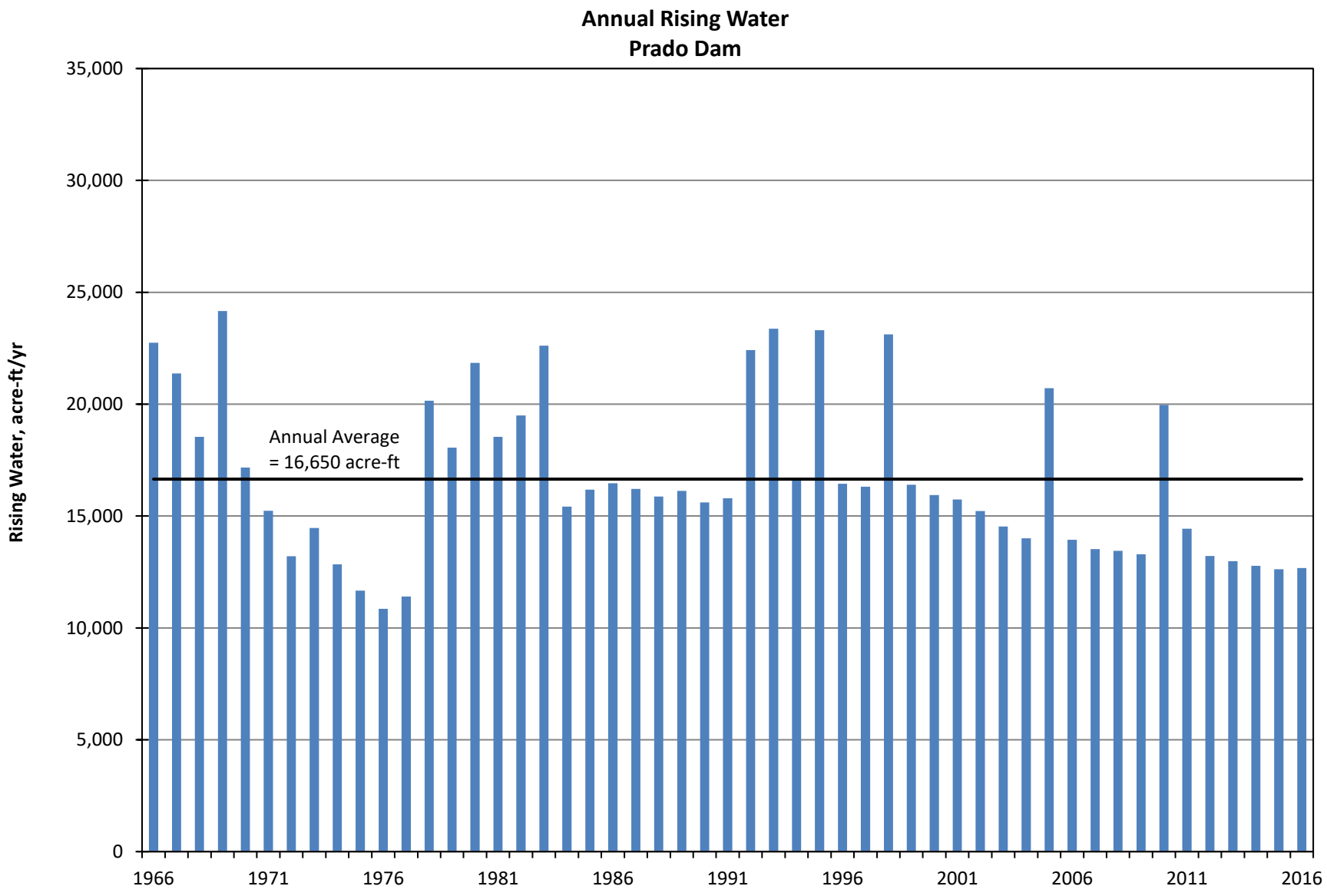

Figure 143

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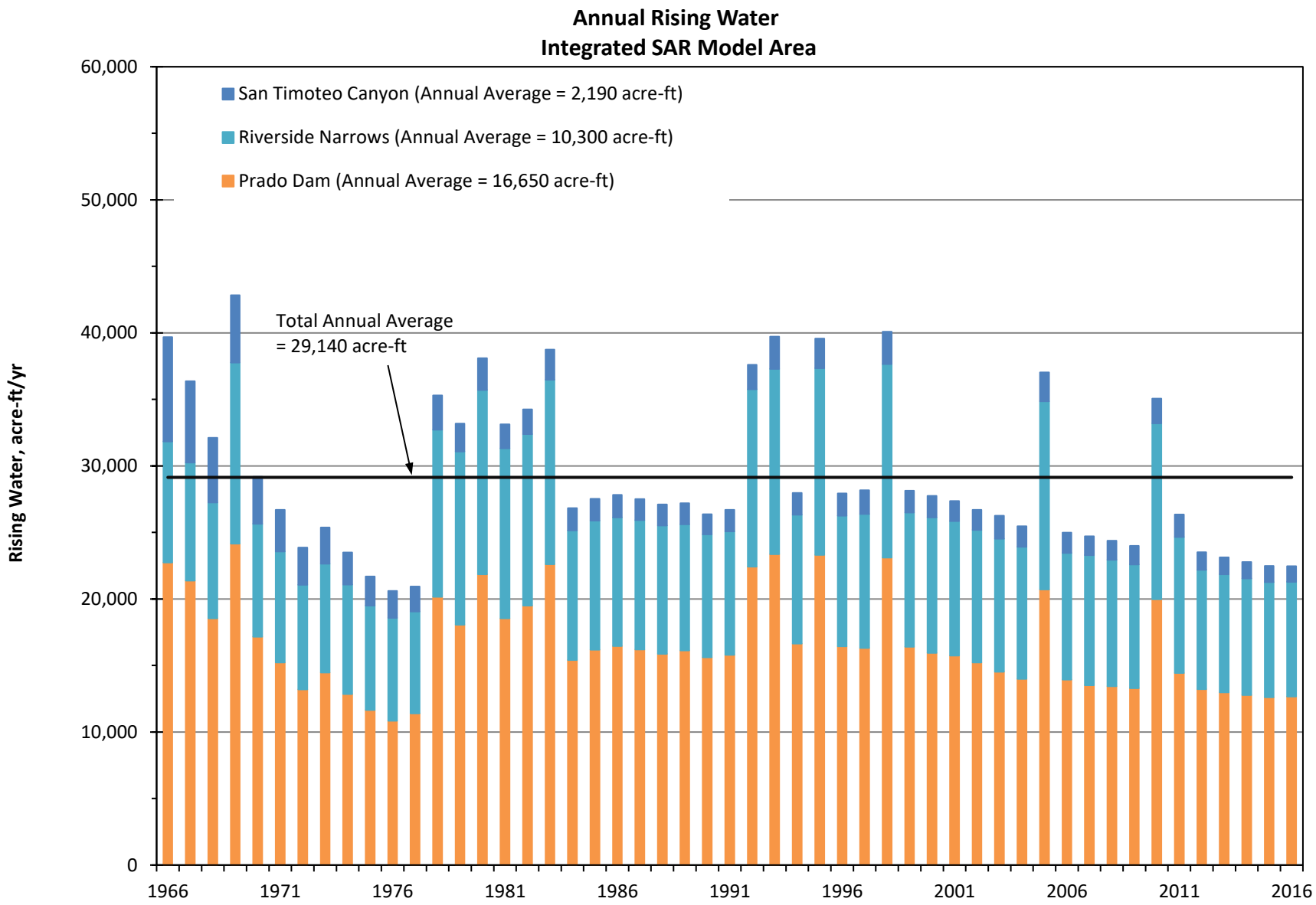
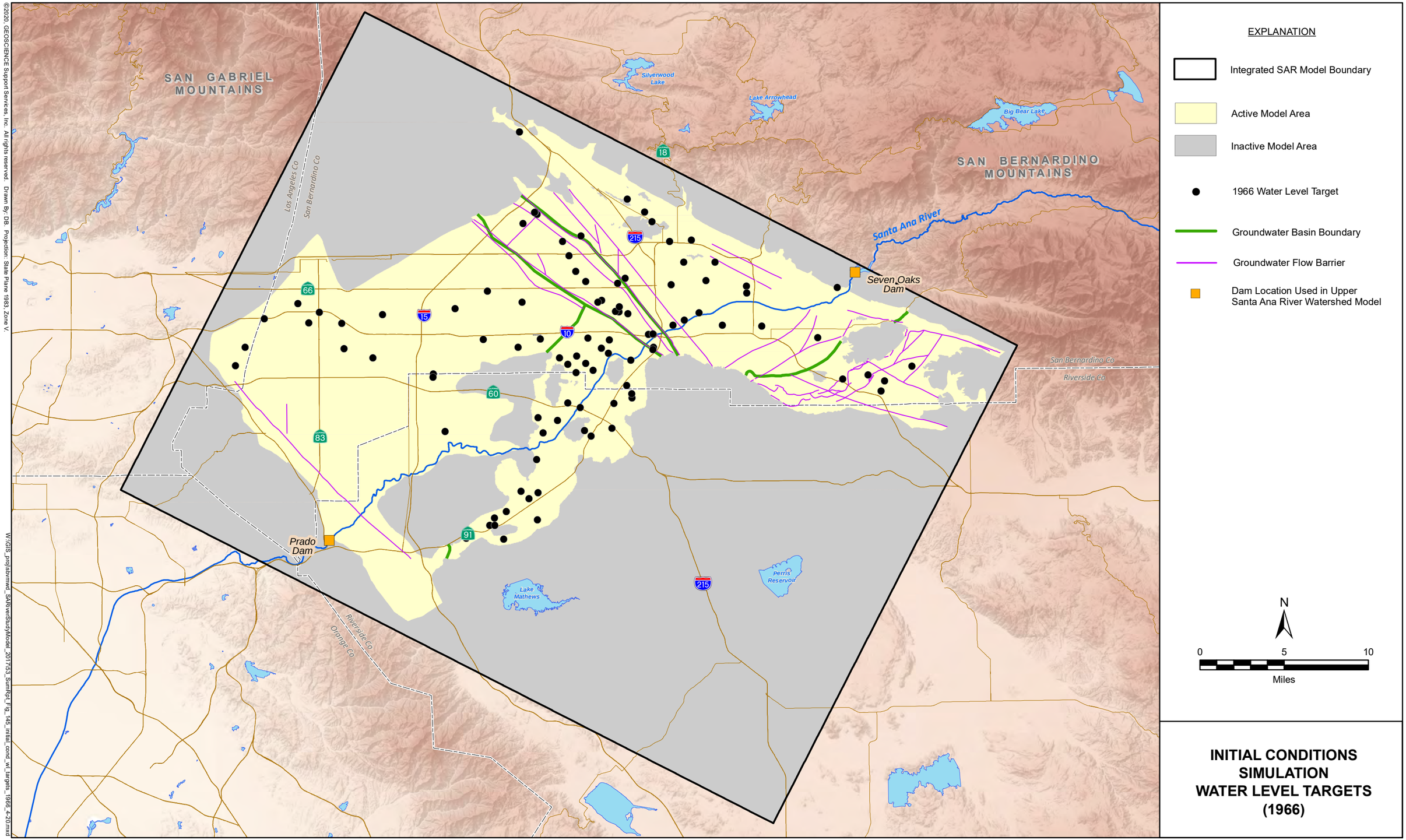


Figure 144



INITIAL CONDITIONS SIMULATION WATER LEVEL TARGETS (1966)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_145_initial_cond_w_targets_1966_4-20.mxd

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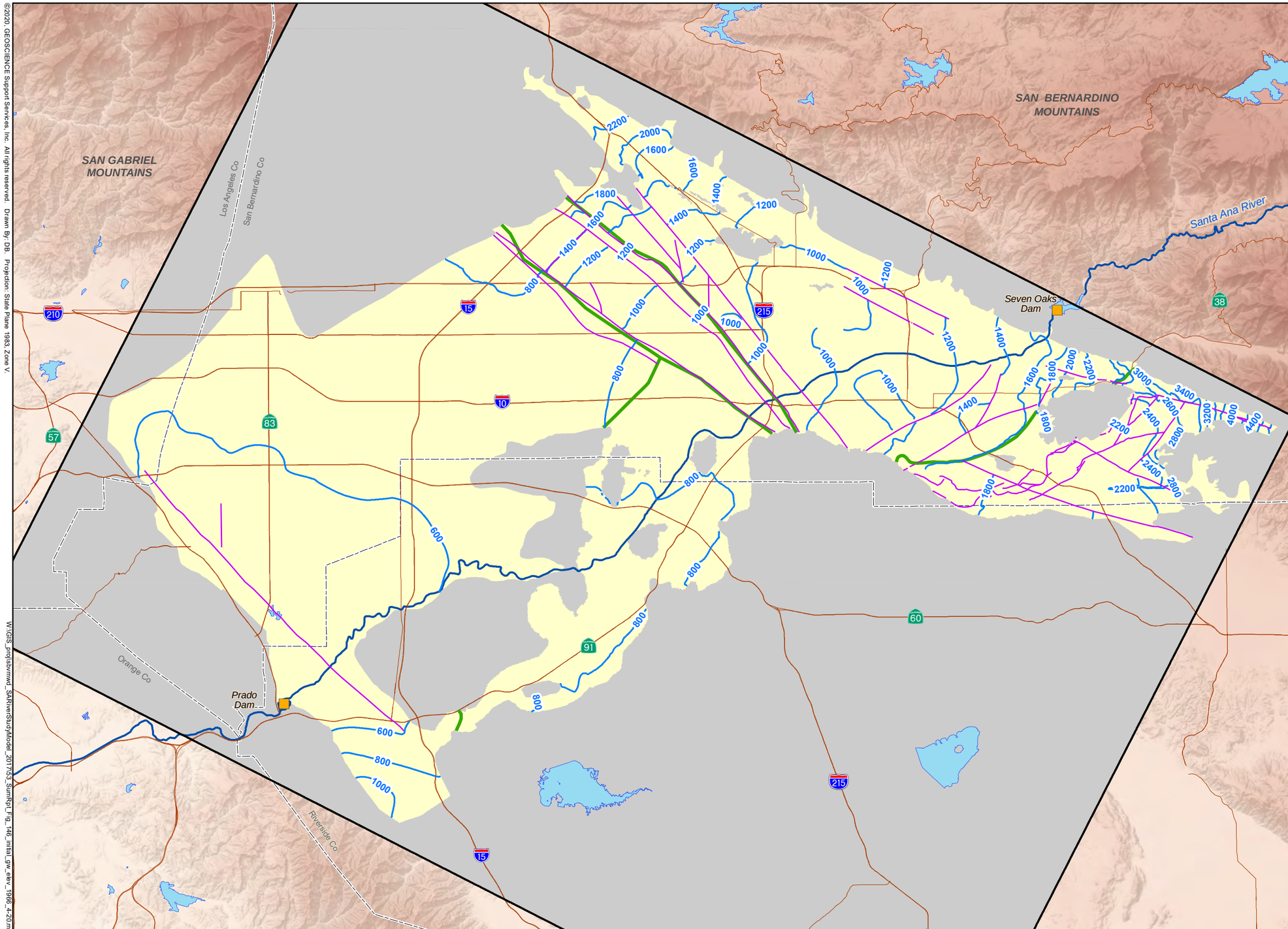

EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- 860 — Groundwater Elevations, ft amsl
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

N

0 4 8
Miles

INITIAL CONDITION MODELED GROUNDWATER ELEVATIONS (1966)

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_146_initial_gw_elev_1966_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 146

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Initial Condition Measured vs. Model-Calculated Water Levels (1966)

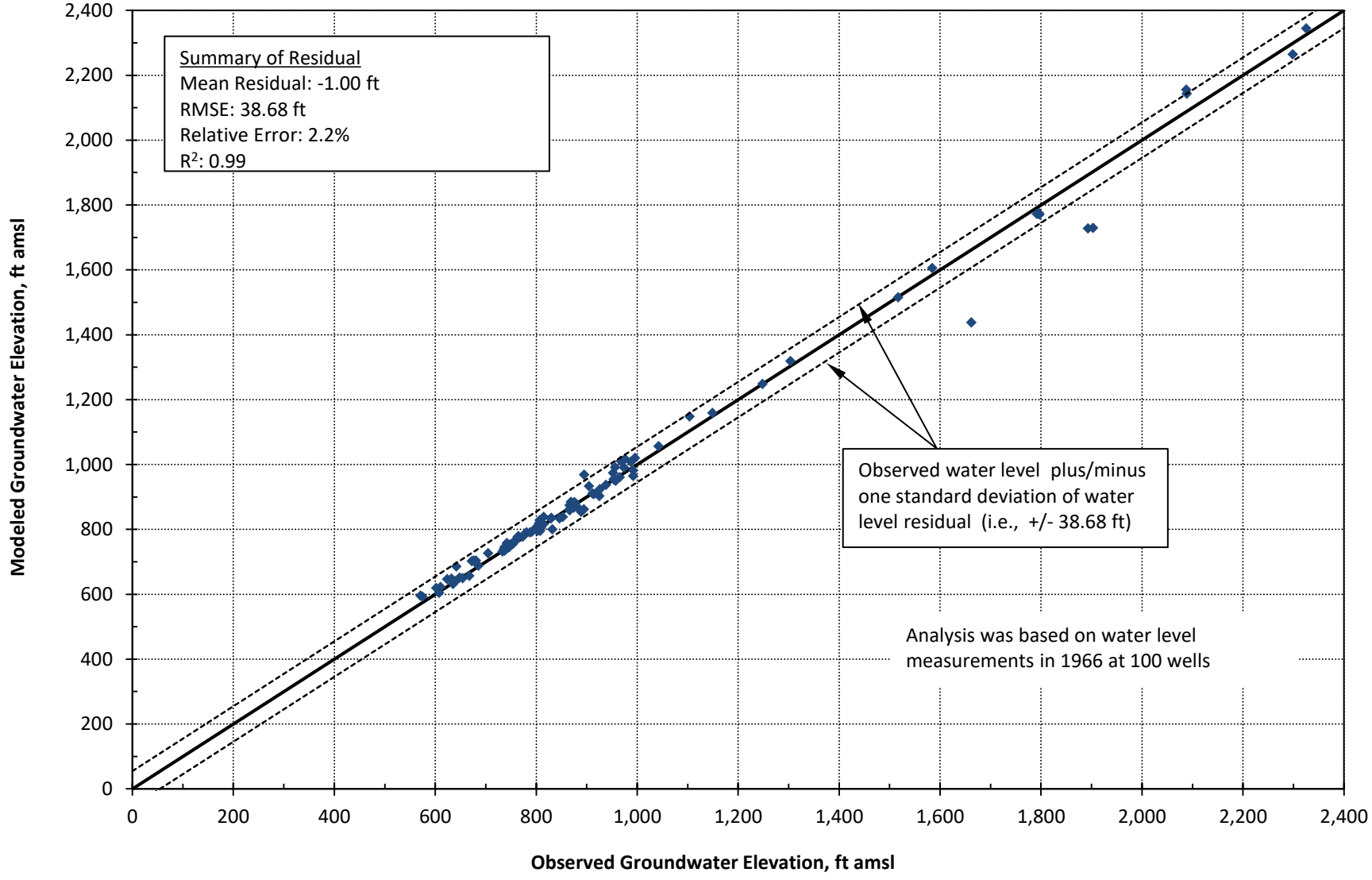
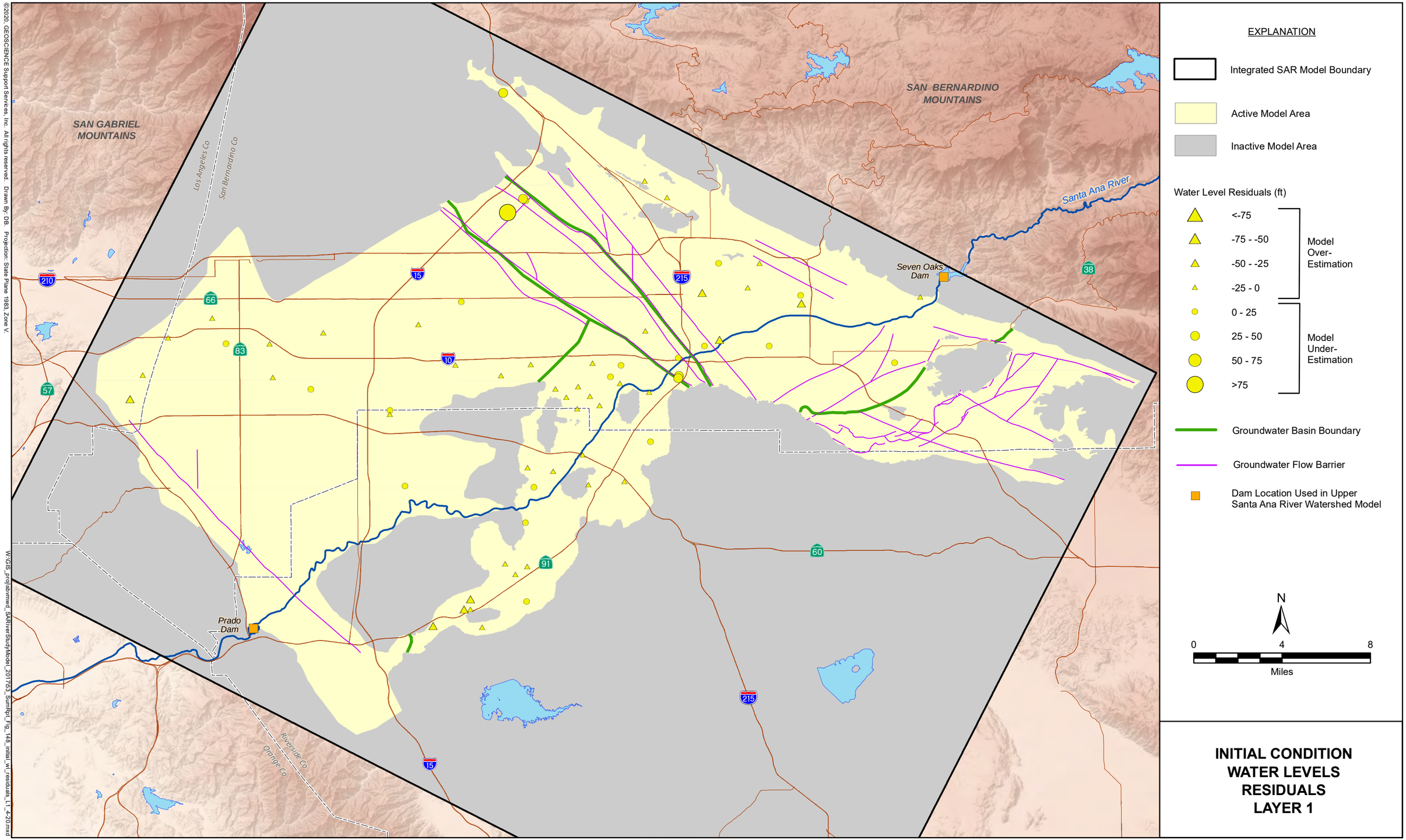


Figure 147



INITIAL CONDITION WATER LEVELS RESIDUALS LAYER 1

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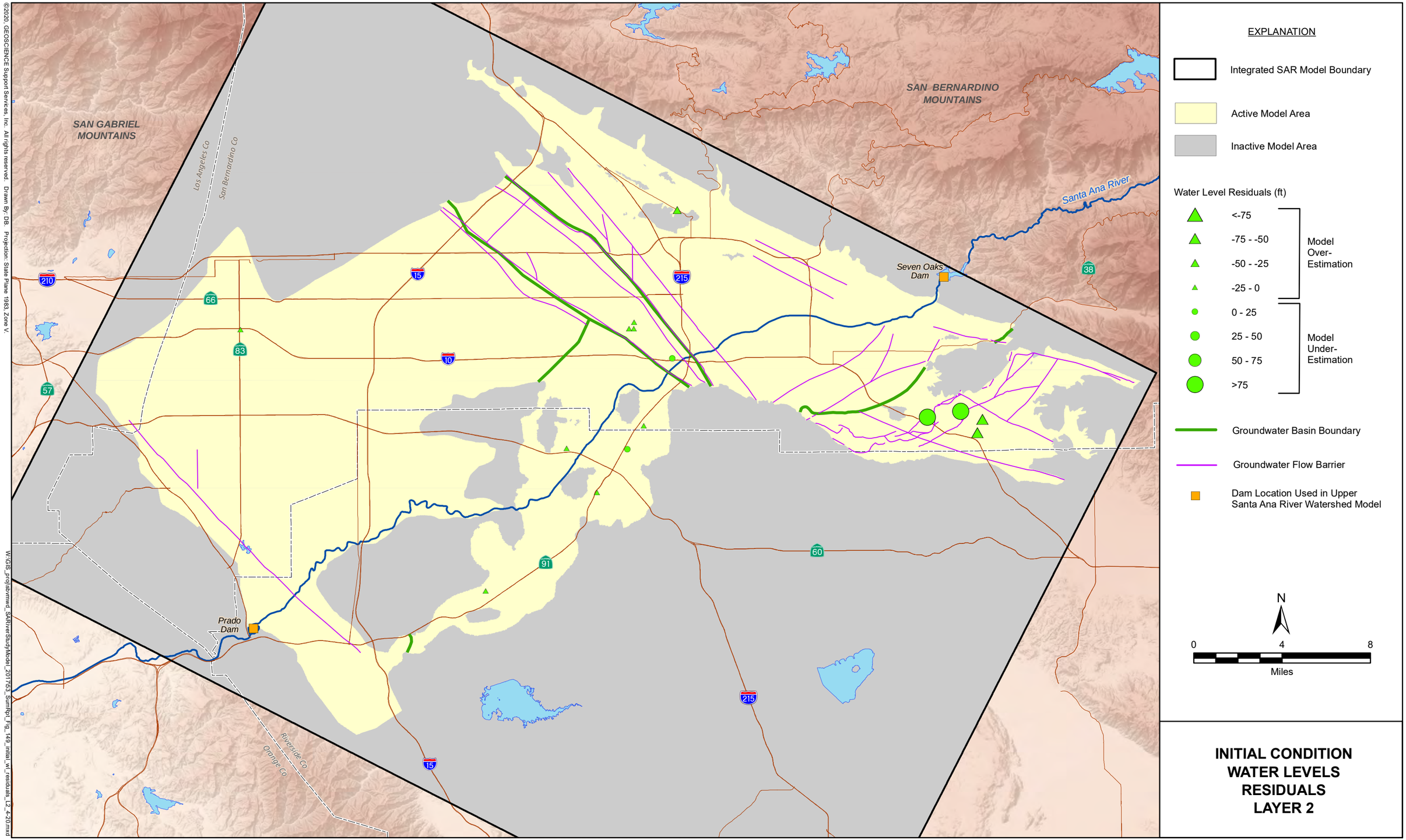

INITIAL CONDITION WATER LEVELS RESIDUALS LAYER 2

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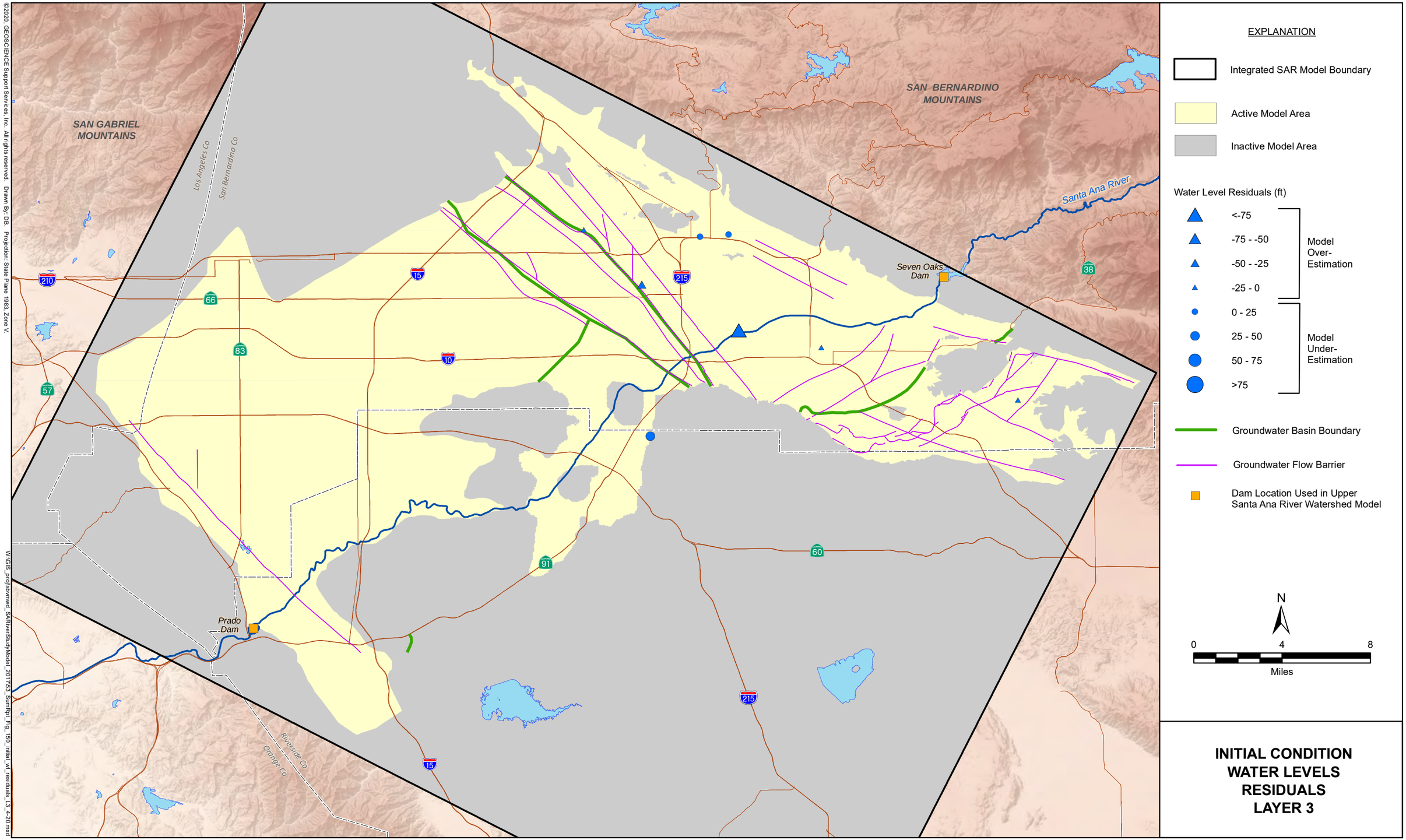

INITIAL CONDITION WATER LEVELS RESIDUALS LAYER 3

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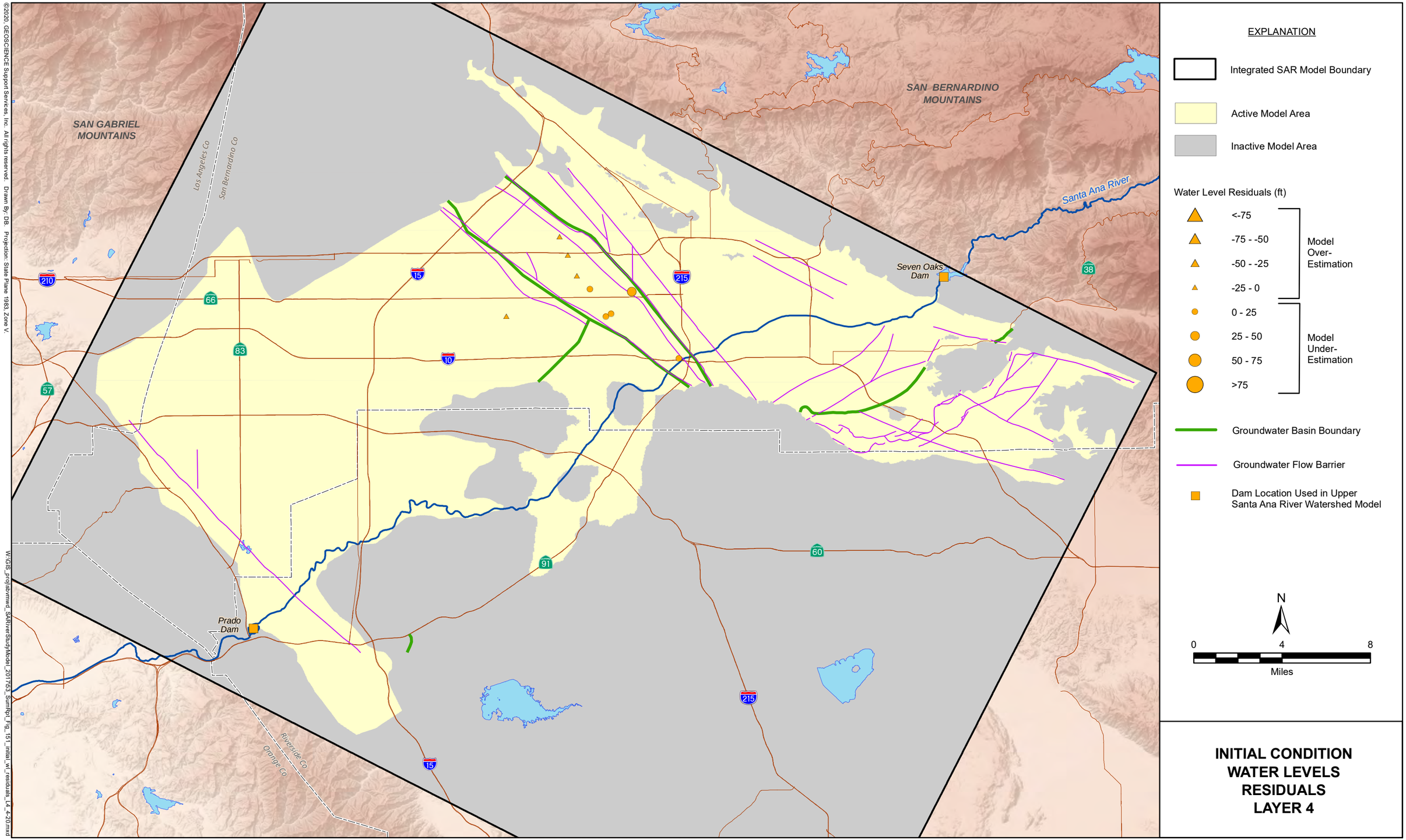
10-Apr-20



INITIAL CONDITION WATER LEVELS RESIDUALS LAYER 4

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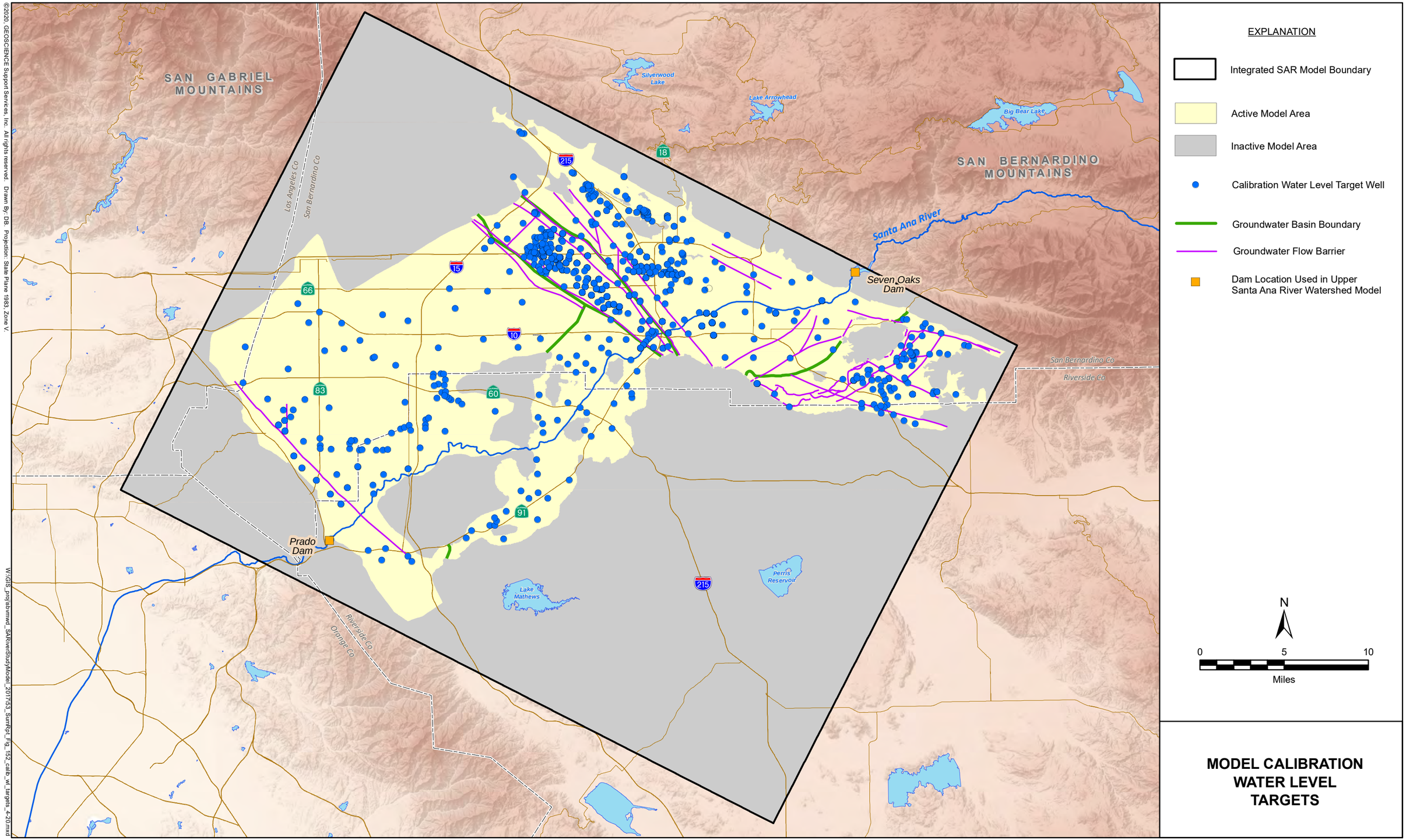

MODEL CALIBRATION WATER LEVEL TARGETS

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 152

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Measured vs. Model-Calculated Water Levels – All Layers (1966 to 2016)

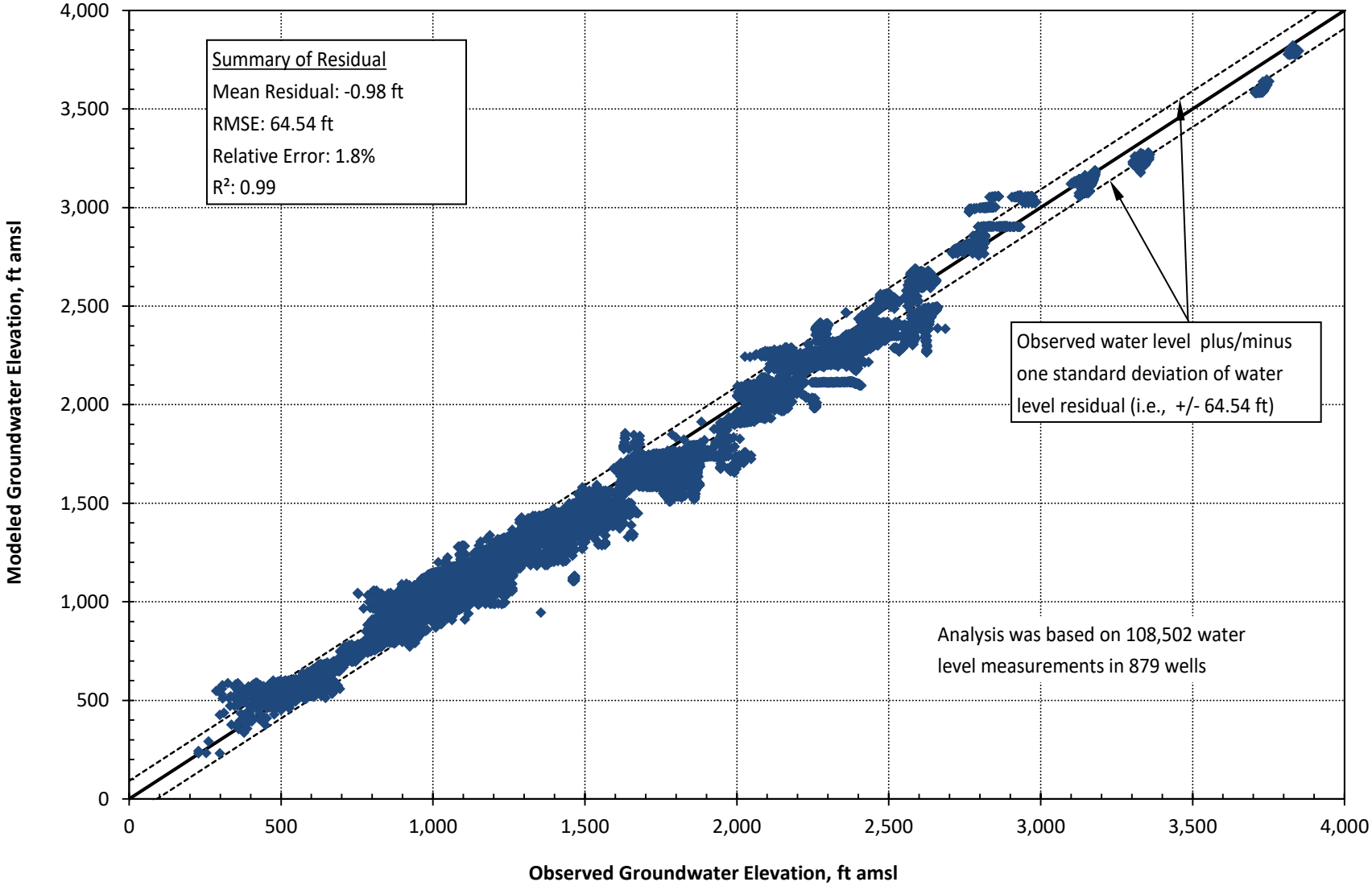

Figure 153

Measured vs. Model-Calculated Water Levels – All Layers (1966 to 1975)

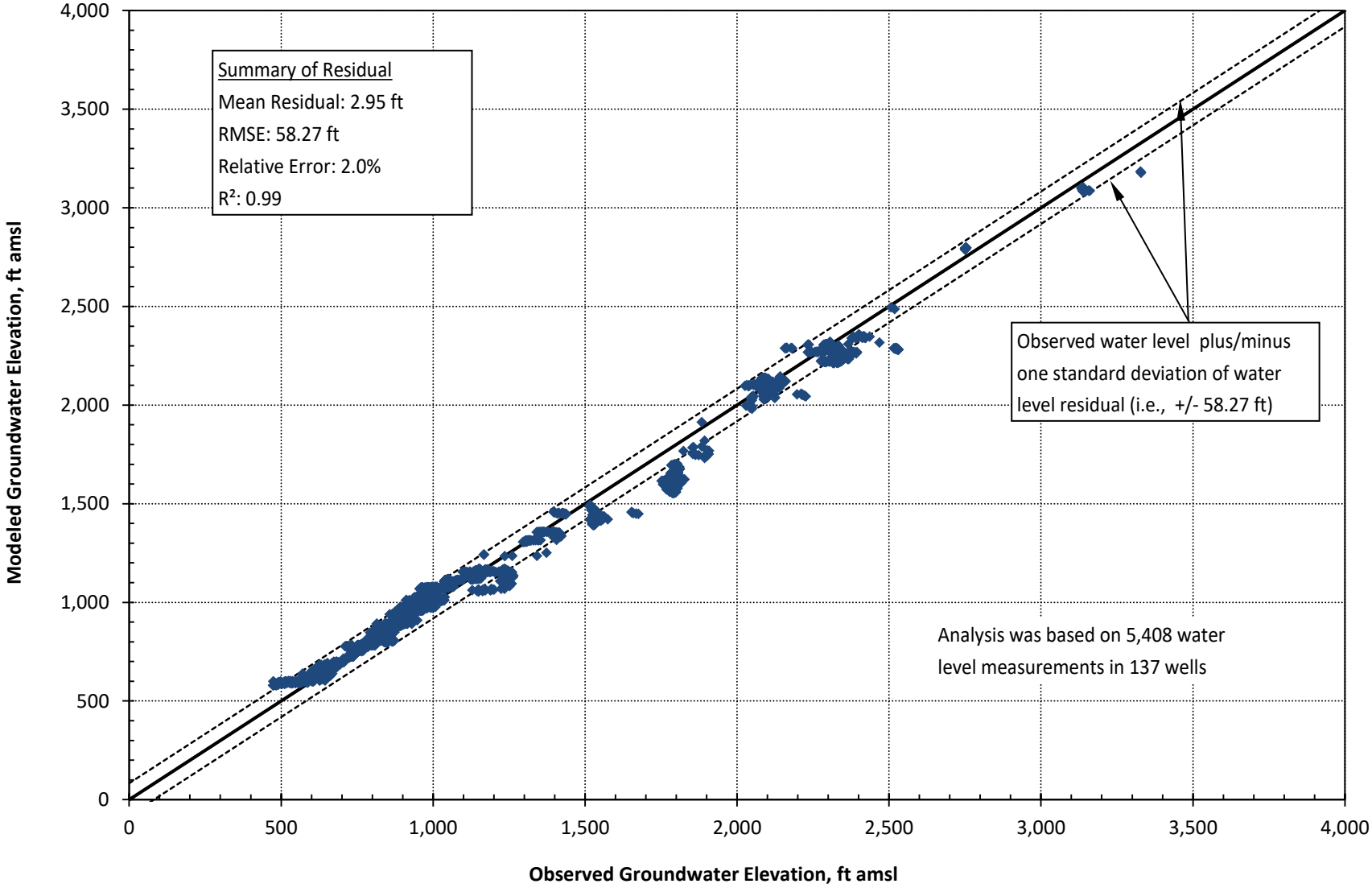

Figure 154

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Measured vs. Model-Calculated Water Levels – All Layers (1987 to 1996)

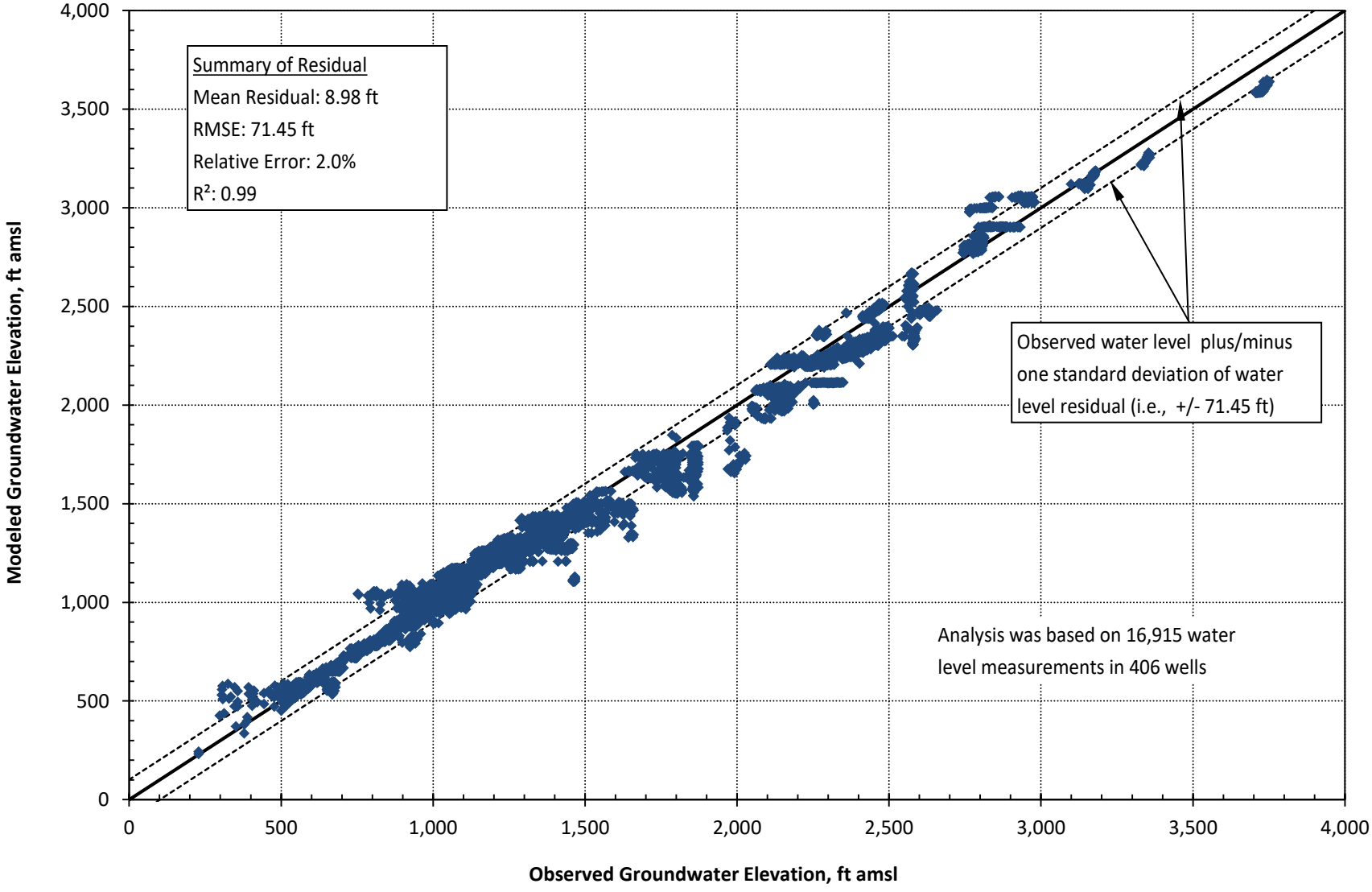


Figure 155

DRAFT

Measured vs. Model-Calculated Water Levels – All Layers (2007 to 2016)

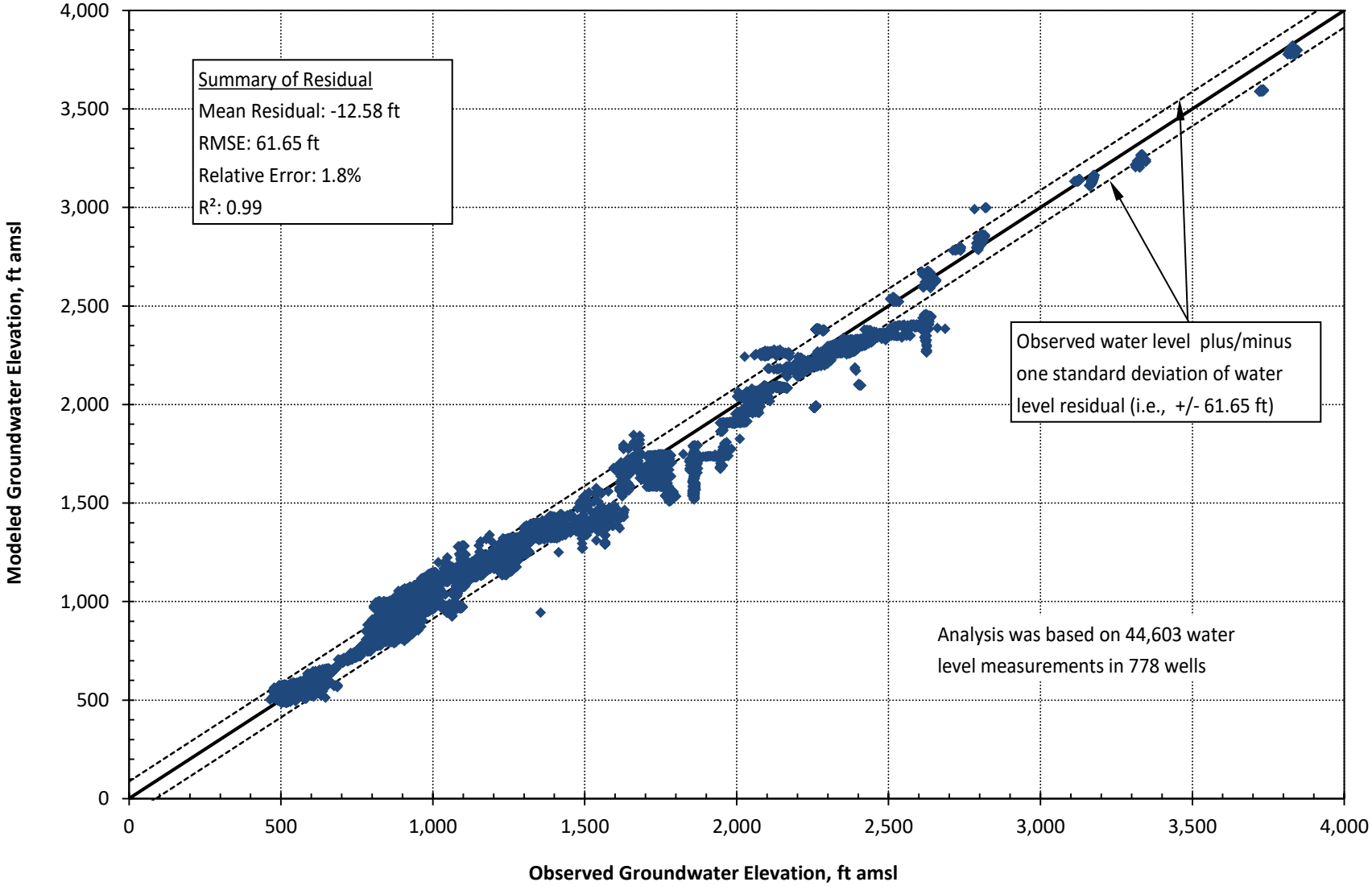
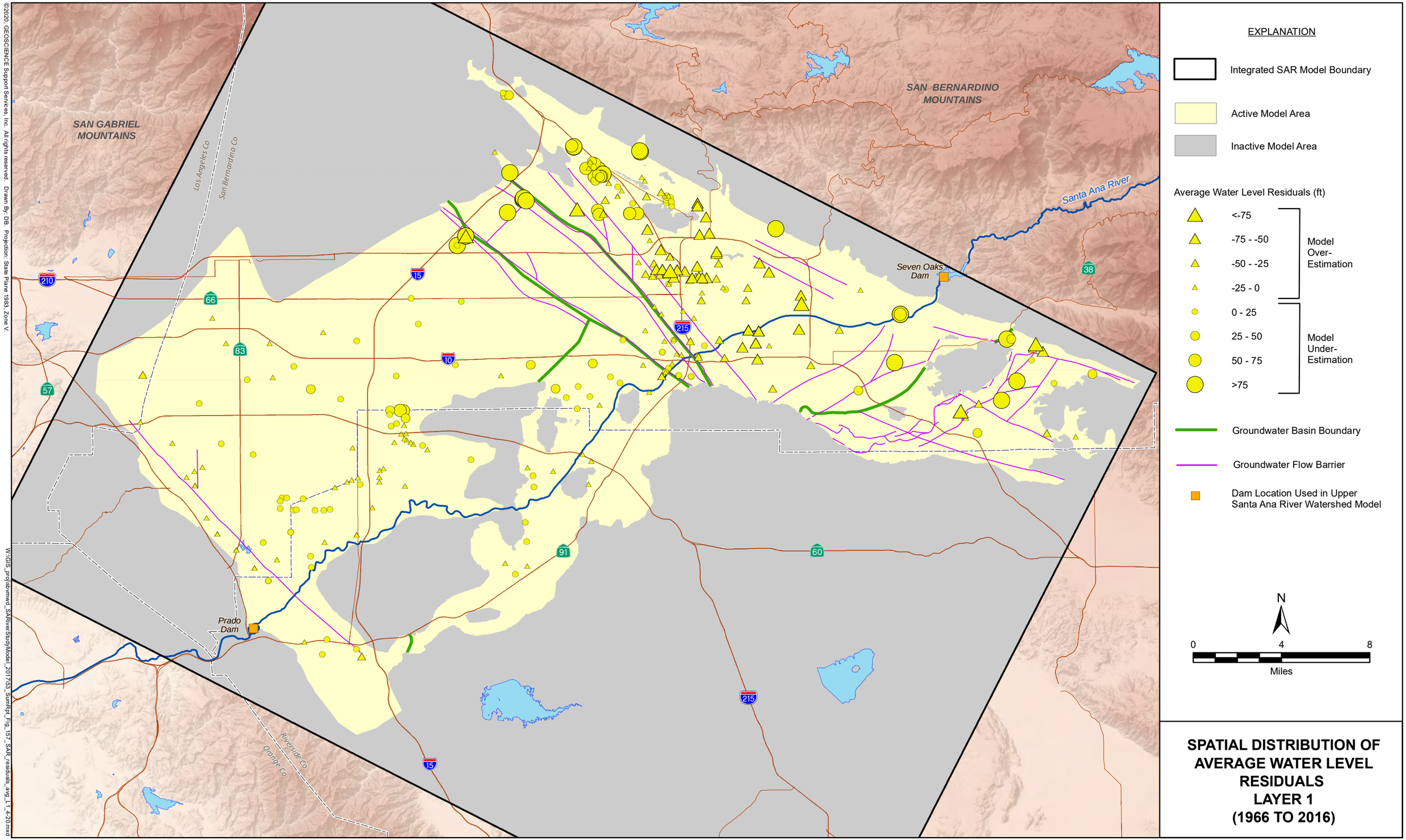


Figure 156



SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS LAYER 1 (1966 TO 2016)

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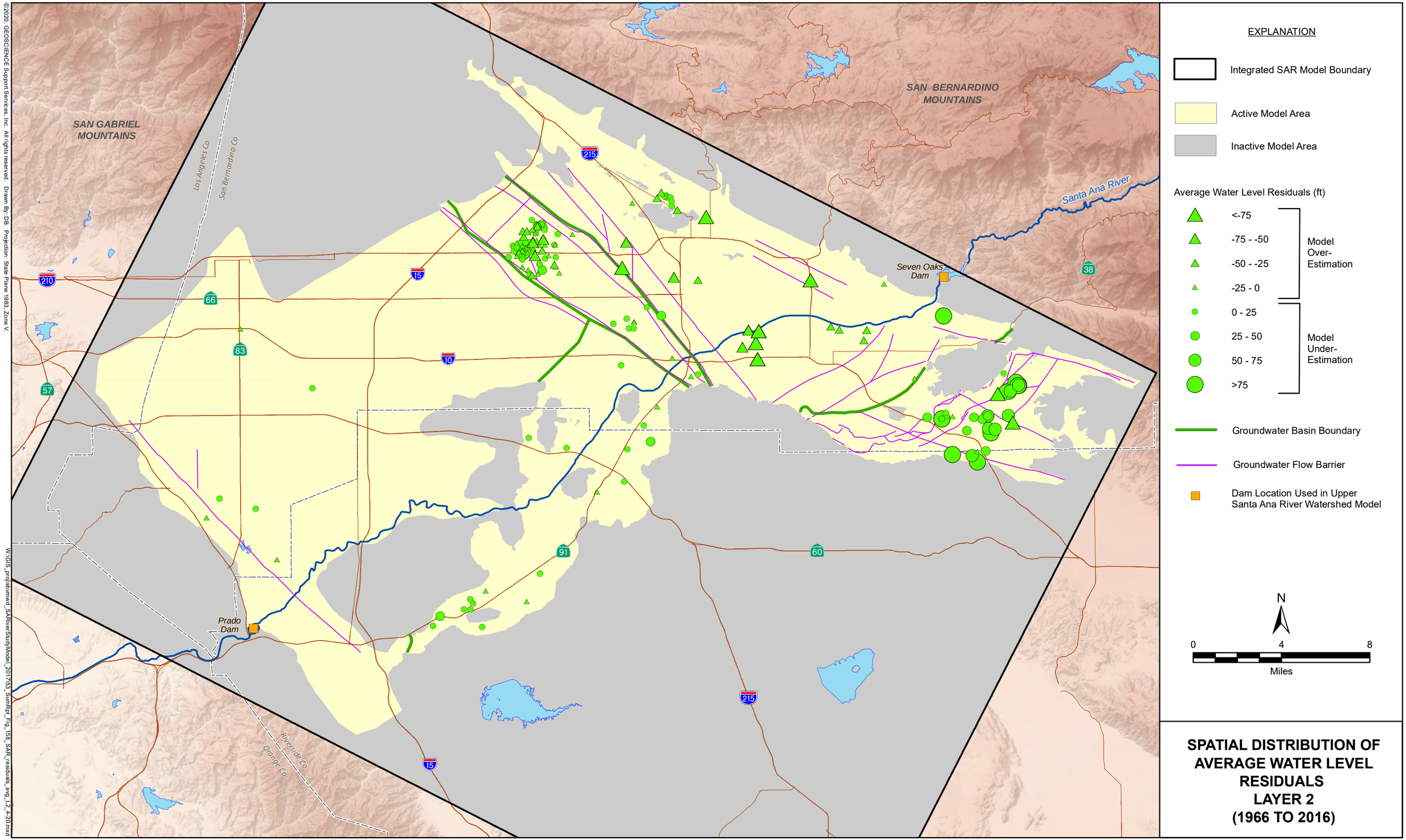

SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS LAYER 2 (1966 TO 2016)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_158_SAR_residuals_avg_L2_4-20.mxd

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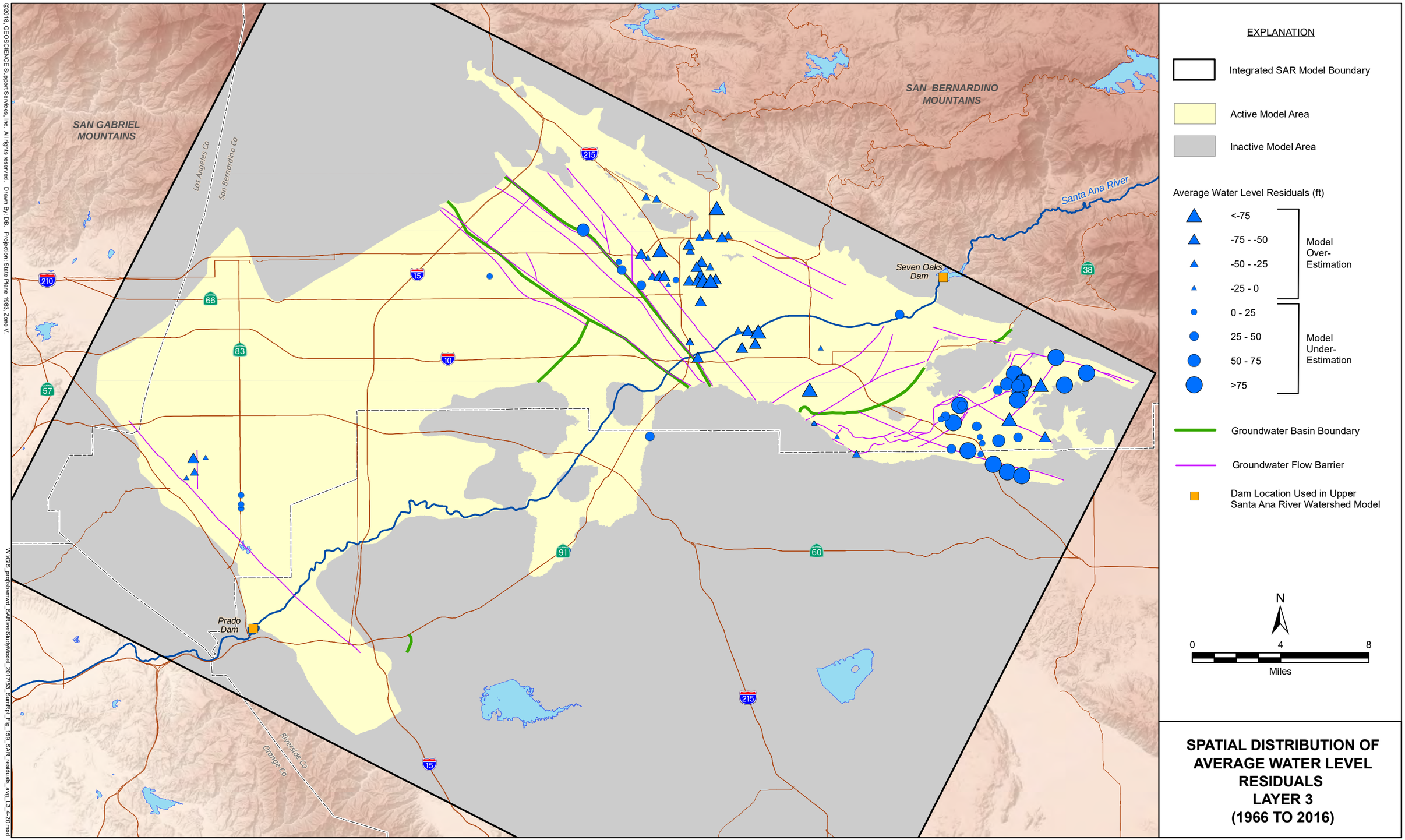

SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS LAYER 3 (1966 TO 2016)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_159_SAR_residuals_avg_L3_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 159

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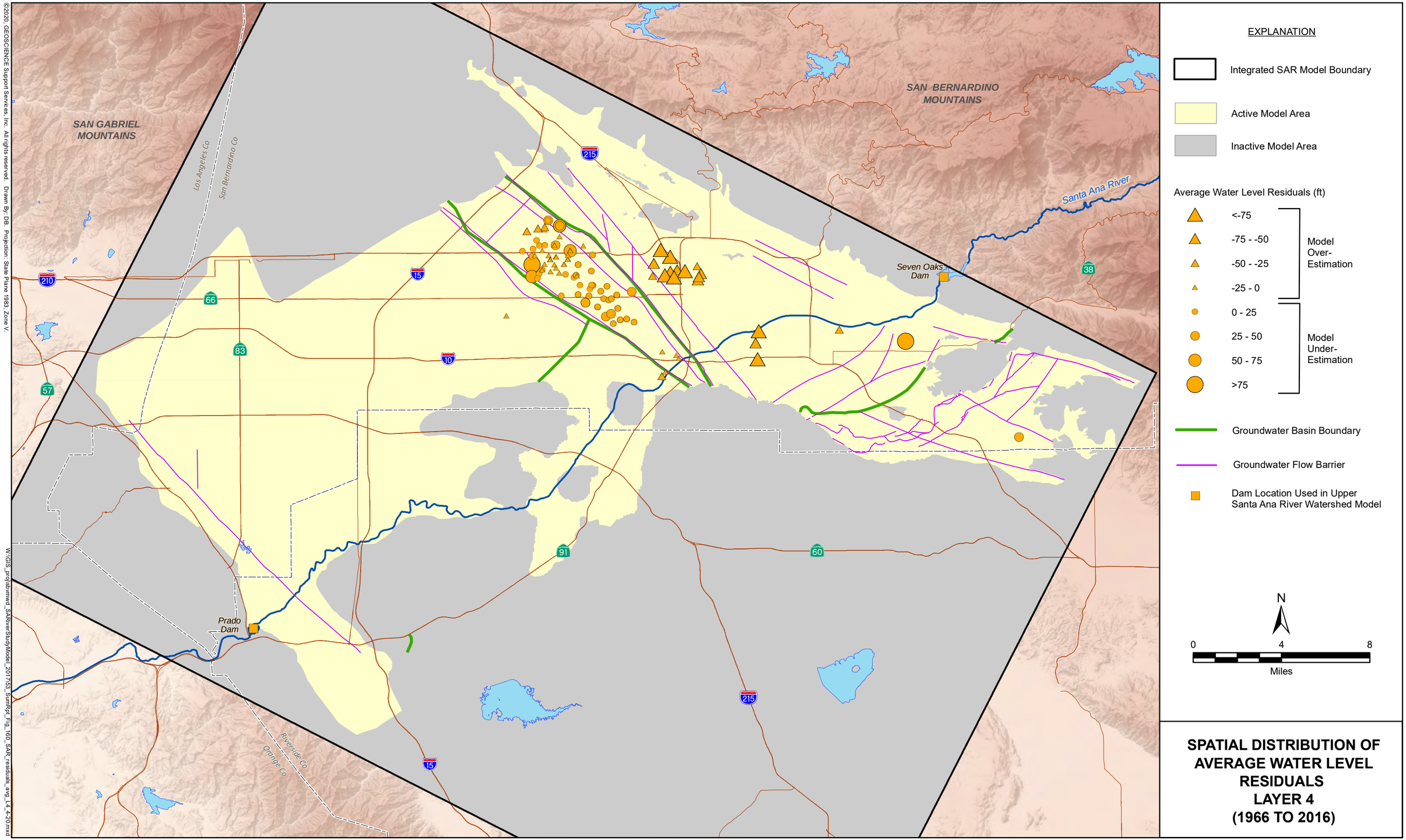

SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS LAYER 4 (1966 TO 2016)

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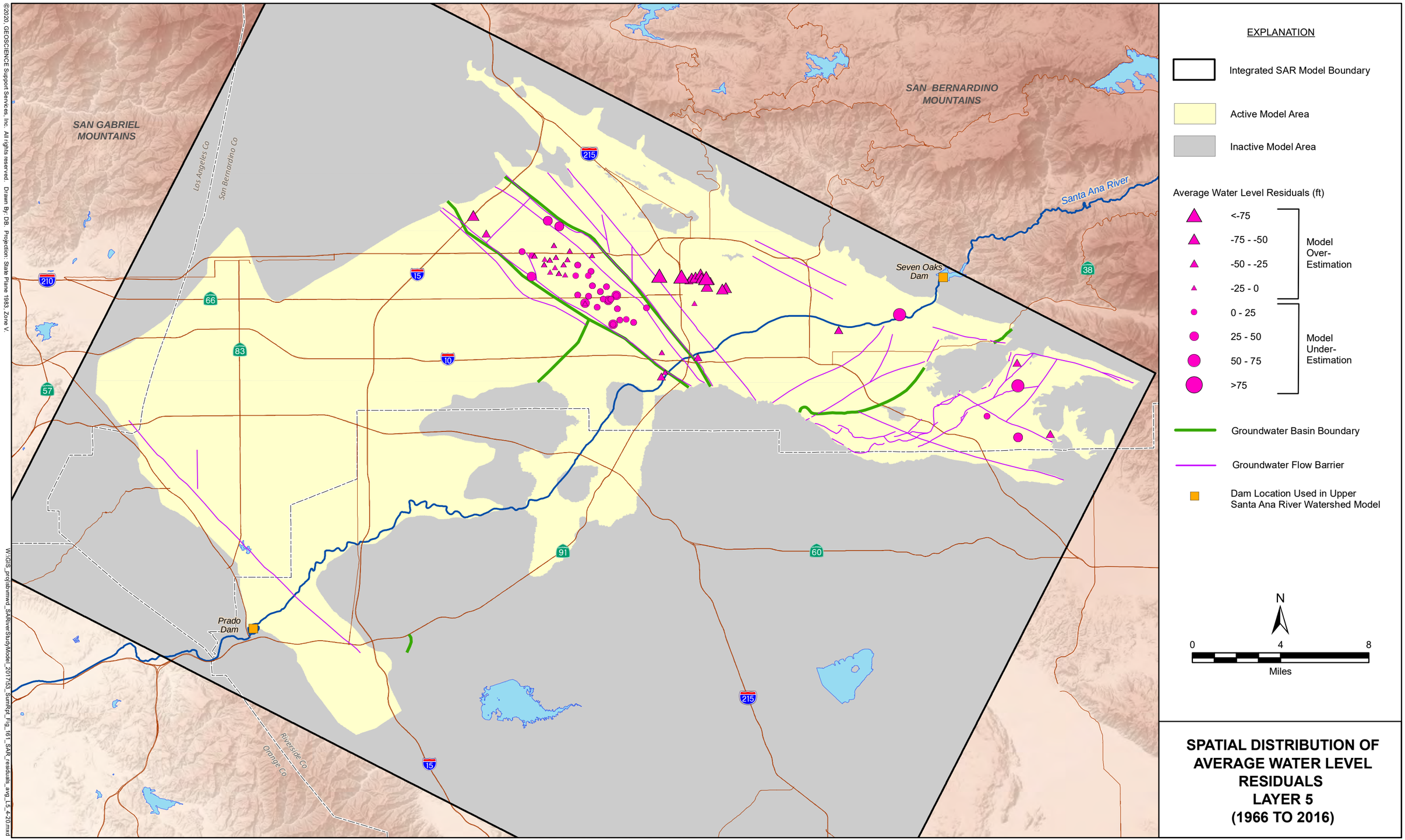
10-Apr-20



SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS LAYER 5 (1966 TO 2016)

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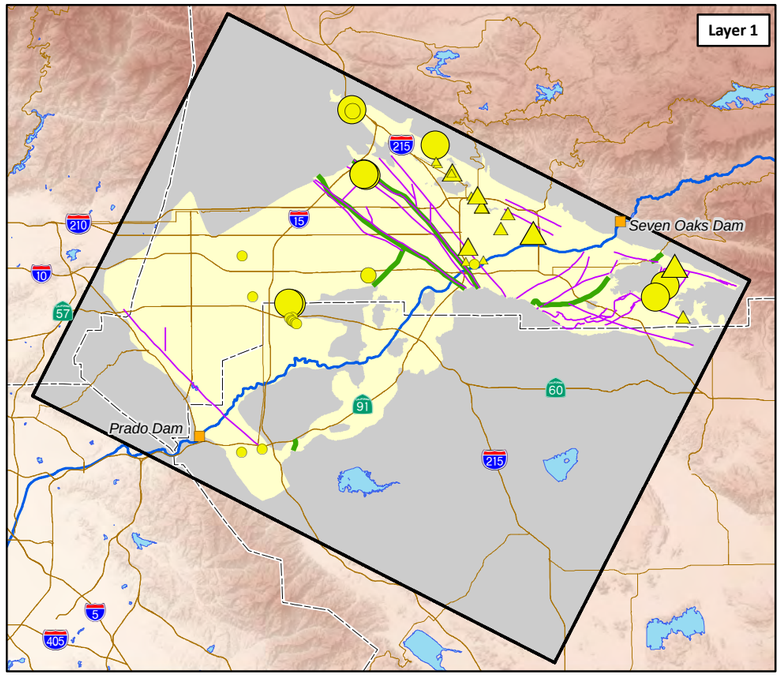

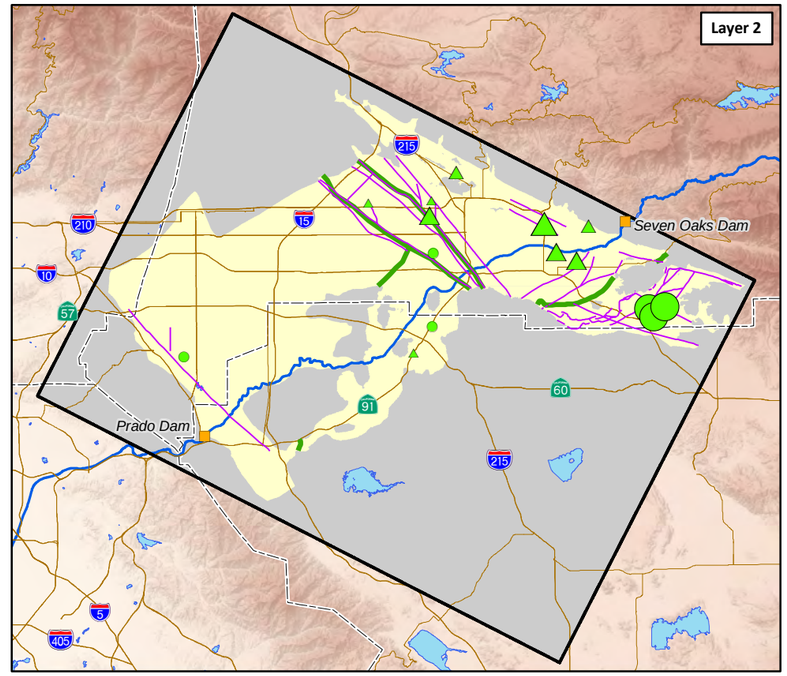

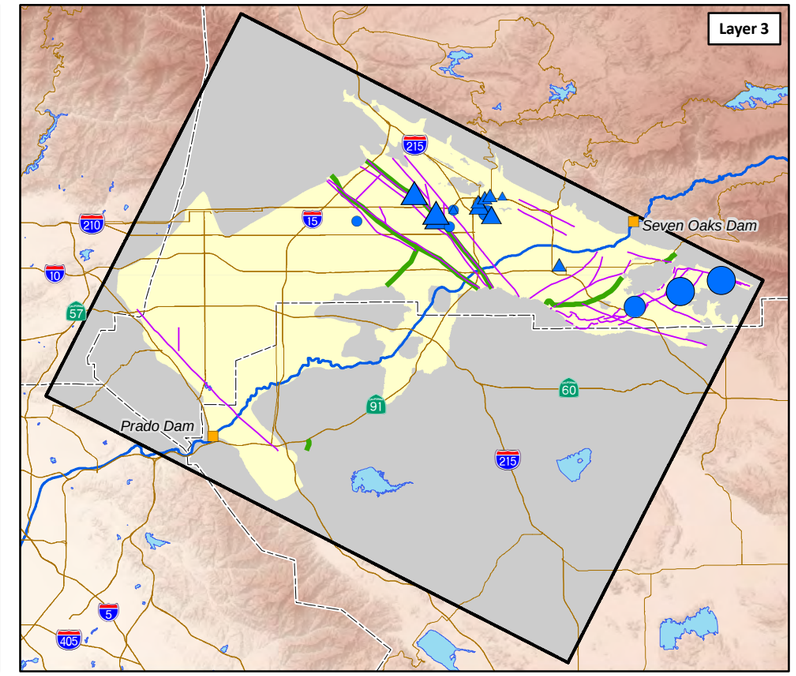

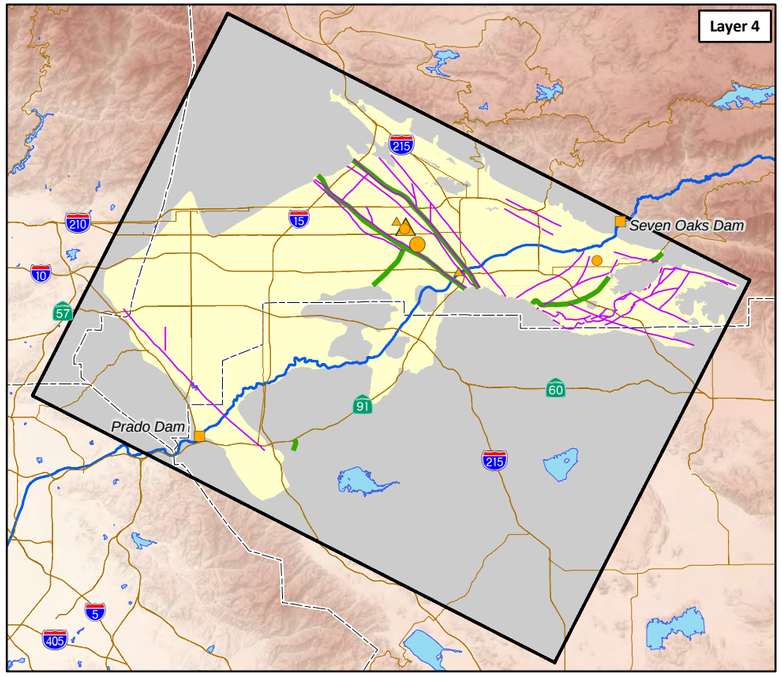

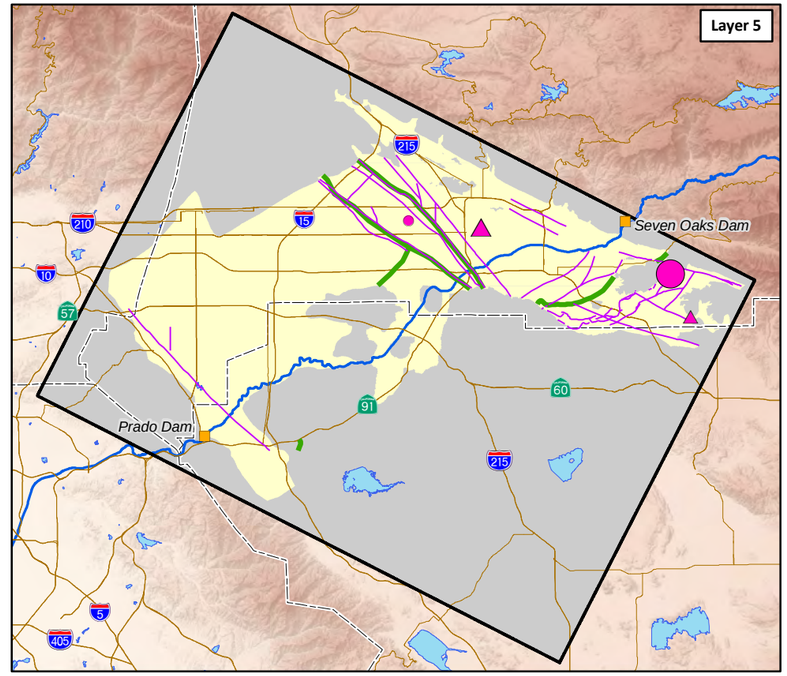

EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

Dry Hydrology Water Level Residuals, September 1990 (ft)

- Model Over-Estimation: <-75; -75 - -50; -50 - -25; -25 - 0
- Model Under-Estimation: 0 - 25; 25 - 50; 50 - 75; >75

Layer: 1, 2, 3, 4, 5

N

0 10 20
Miles

SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS DRY HYDROLOGY (SEPTEMBER 1990)

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_162_SAR_residuals_DRY_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 162

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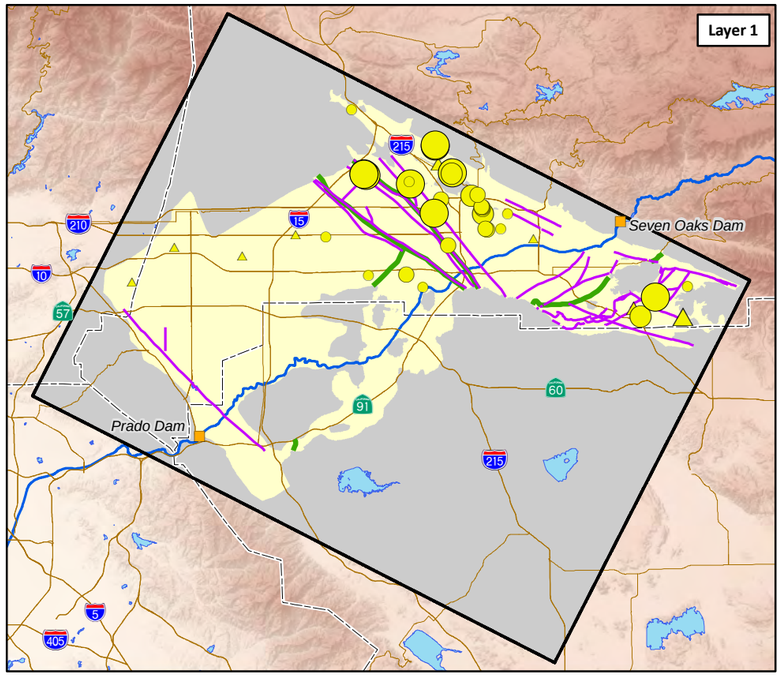

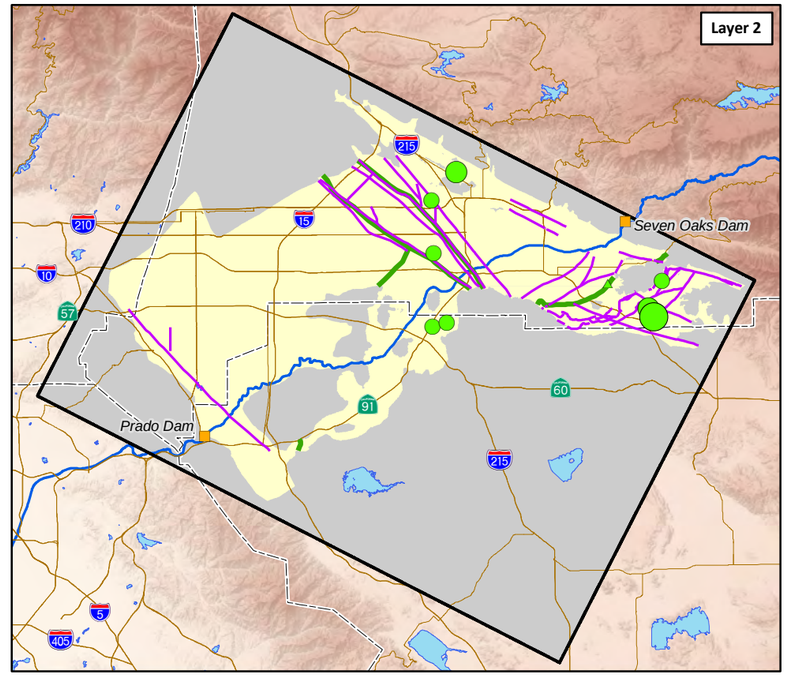

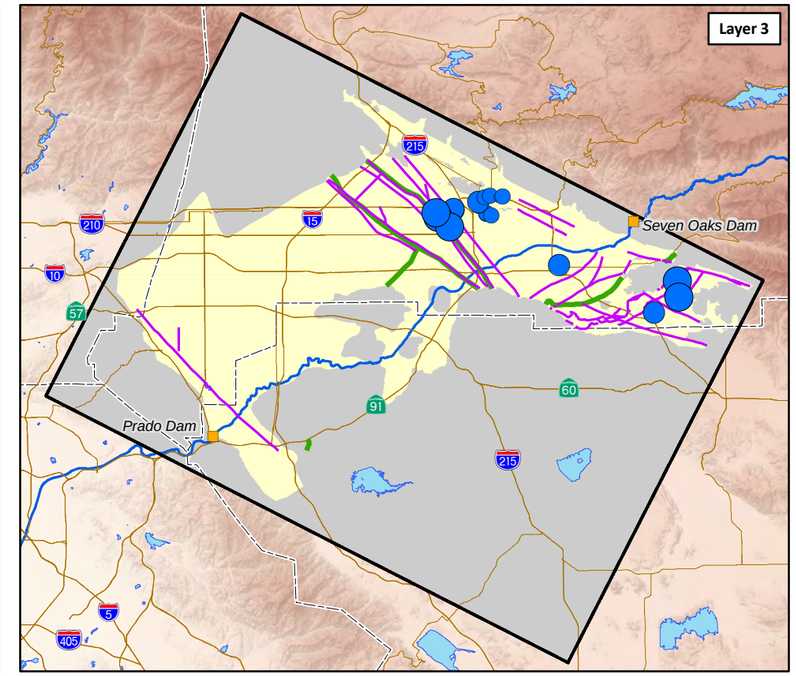

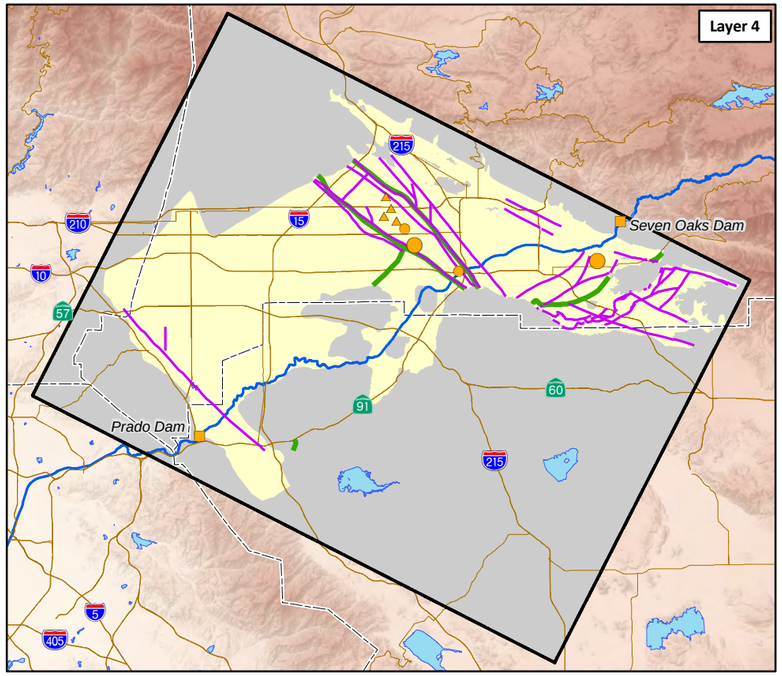

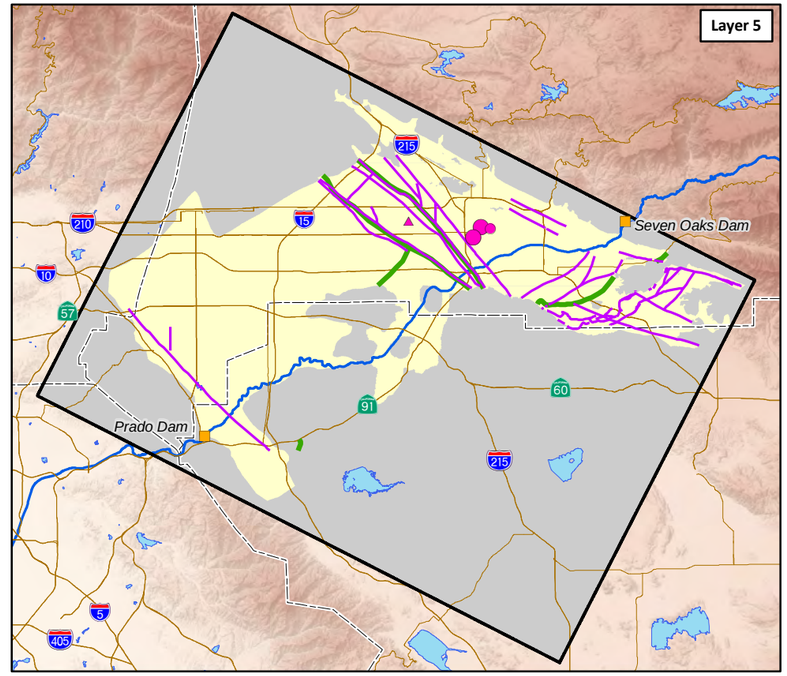

EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

Wet Hydrology Water Level Residuals, March 1983 (ft)

- Model Over-Estimation: <-75; -75 - -50; -50 - -25; -25 - 0
- Model Under-Estimation: 0 - 25; 25 - 50; 50 - 75; >75

Layer: 1, 2, 3, 4, 5

N

0 10 20
Miles

SPATIAL DISTRIBUTION OF AVERAGE WATER LEVEL RESIDUALS WET HYDROLOGY (MARCH 1983)

W:\GIS_proj\sbvmwd_SARiverStudyModel_201753_SumRpt_Fig_163_SAR_residuals_WET_4-20.mxd

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Temporal Distribution of Water Level Residuals in the Integrated SAR Model - All Layers (1966 to 2016)

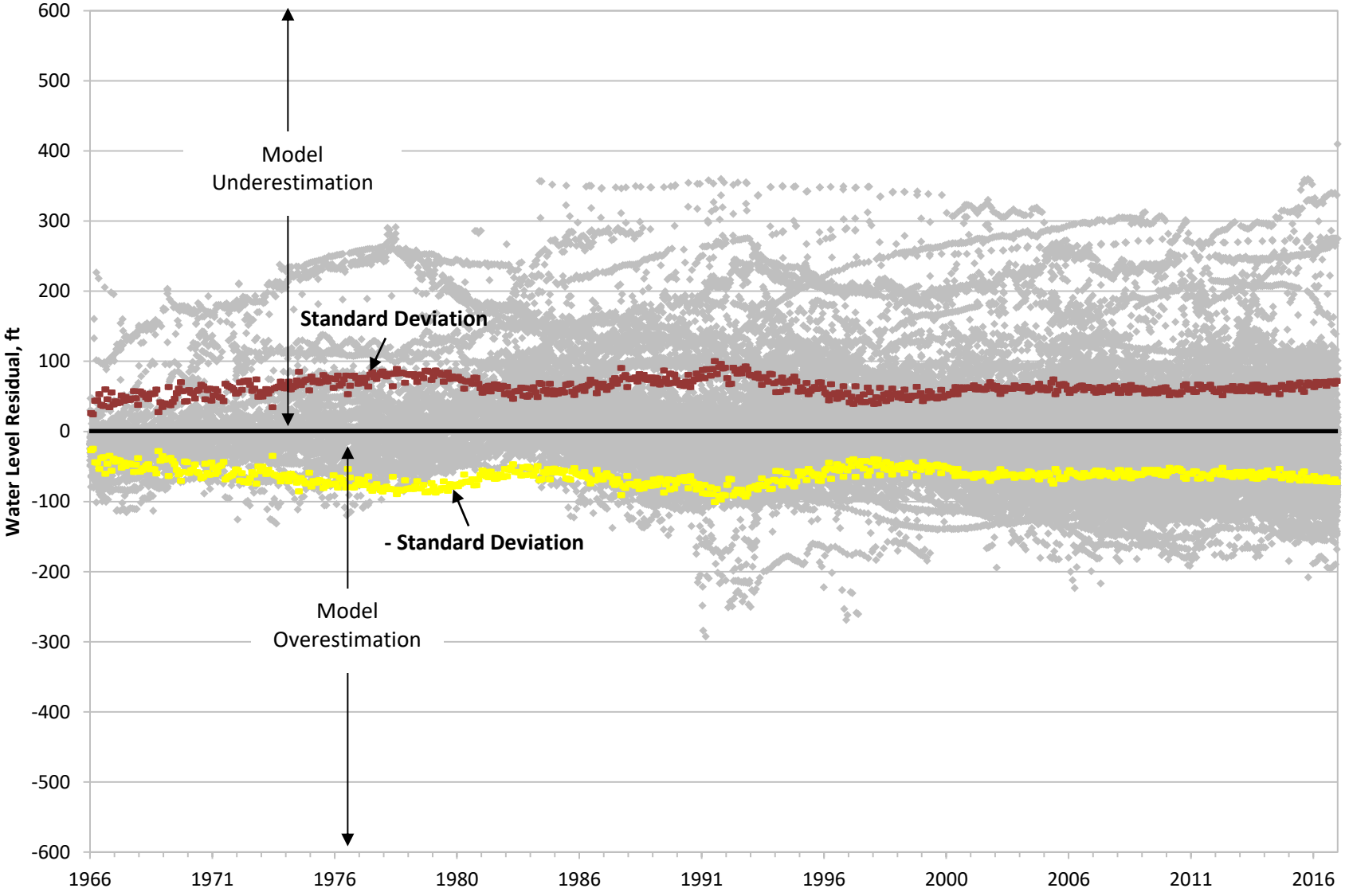


Figure 164

DRAFT

Histogram of Water Level Residuals in the Integrated SAR Model – All Layers (1966 to 2016)

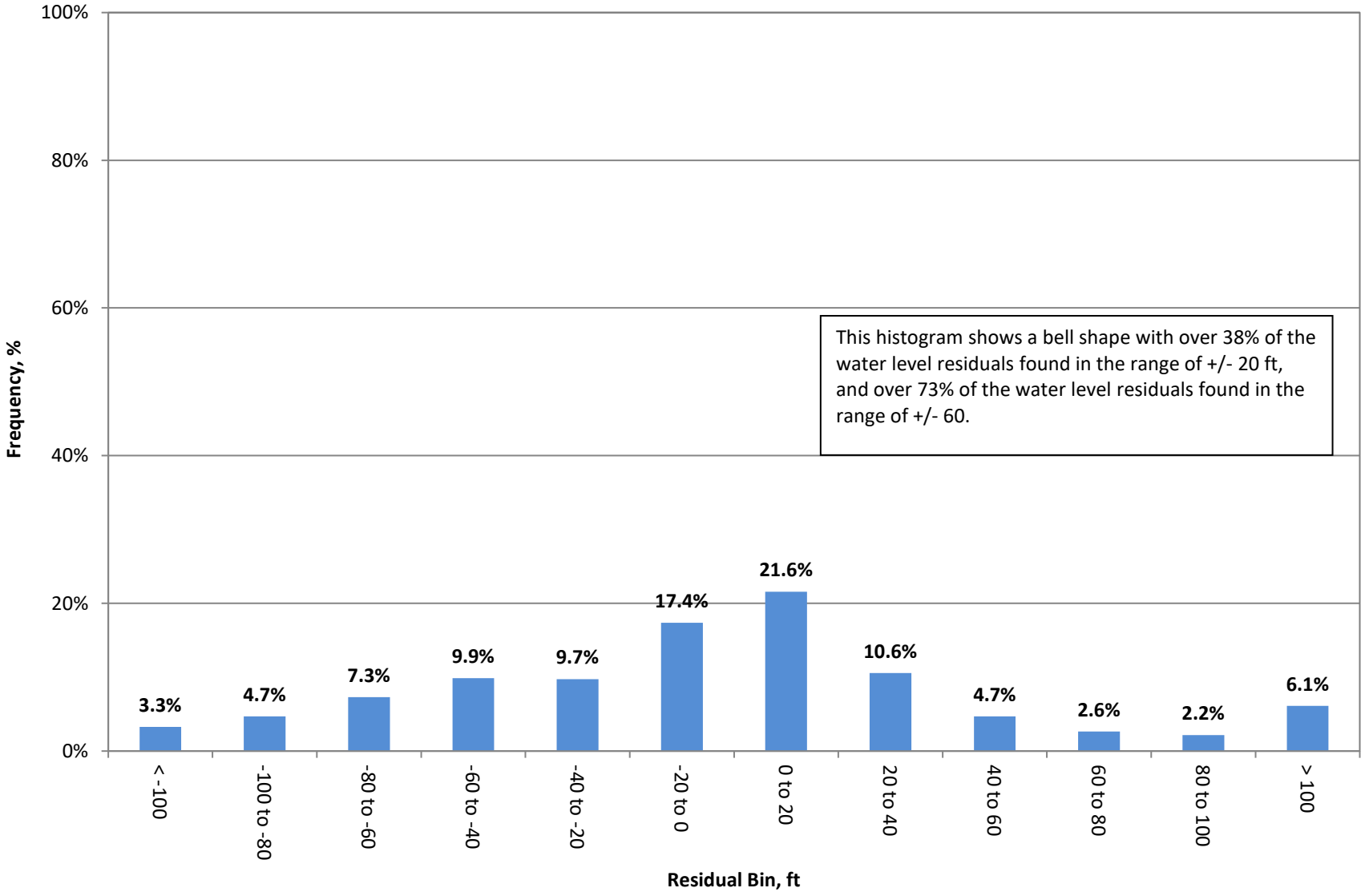
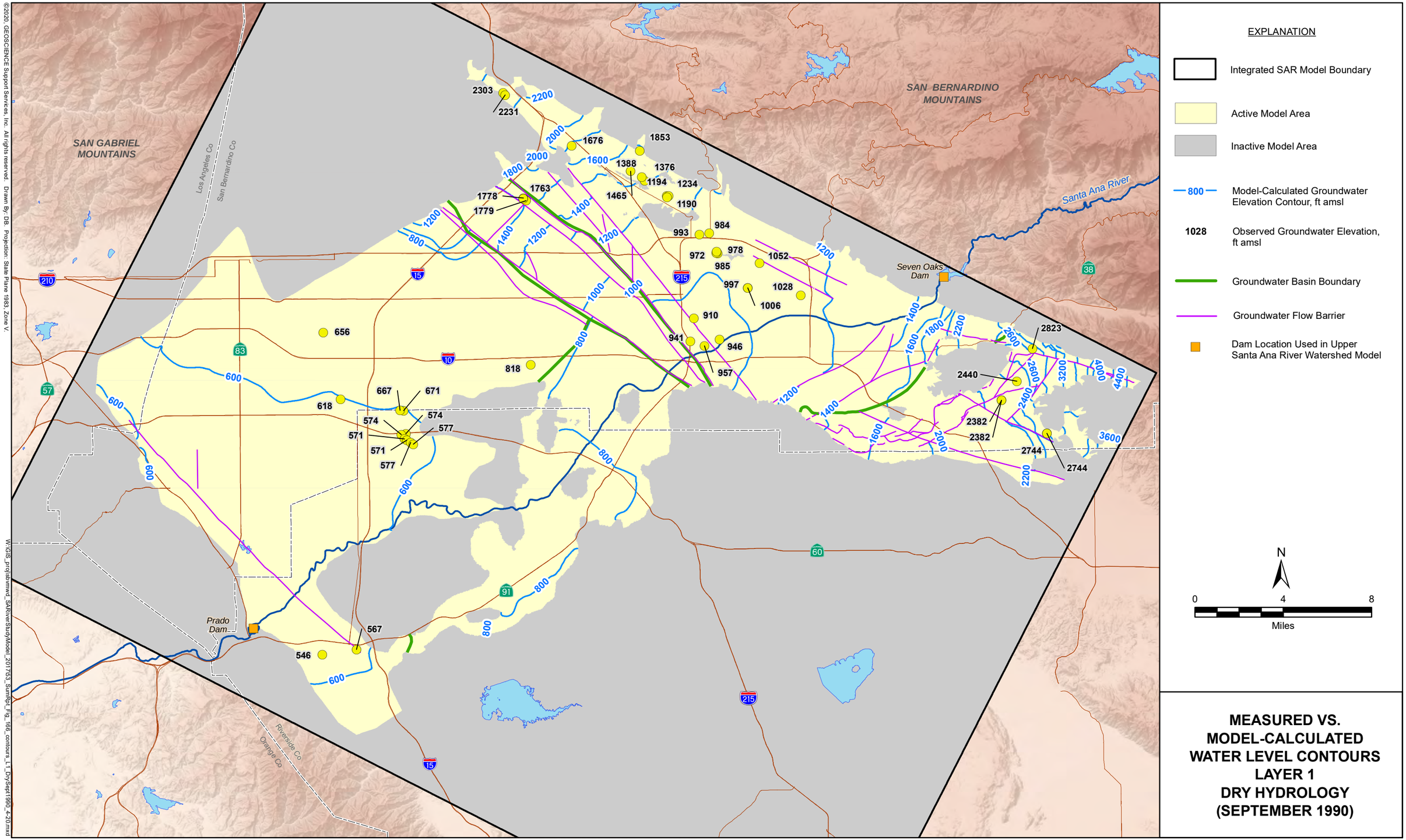


Figure 165



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 1 DRY HYDROLOGY (SEPTEMBER 1990)

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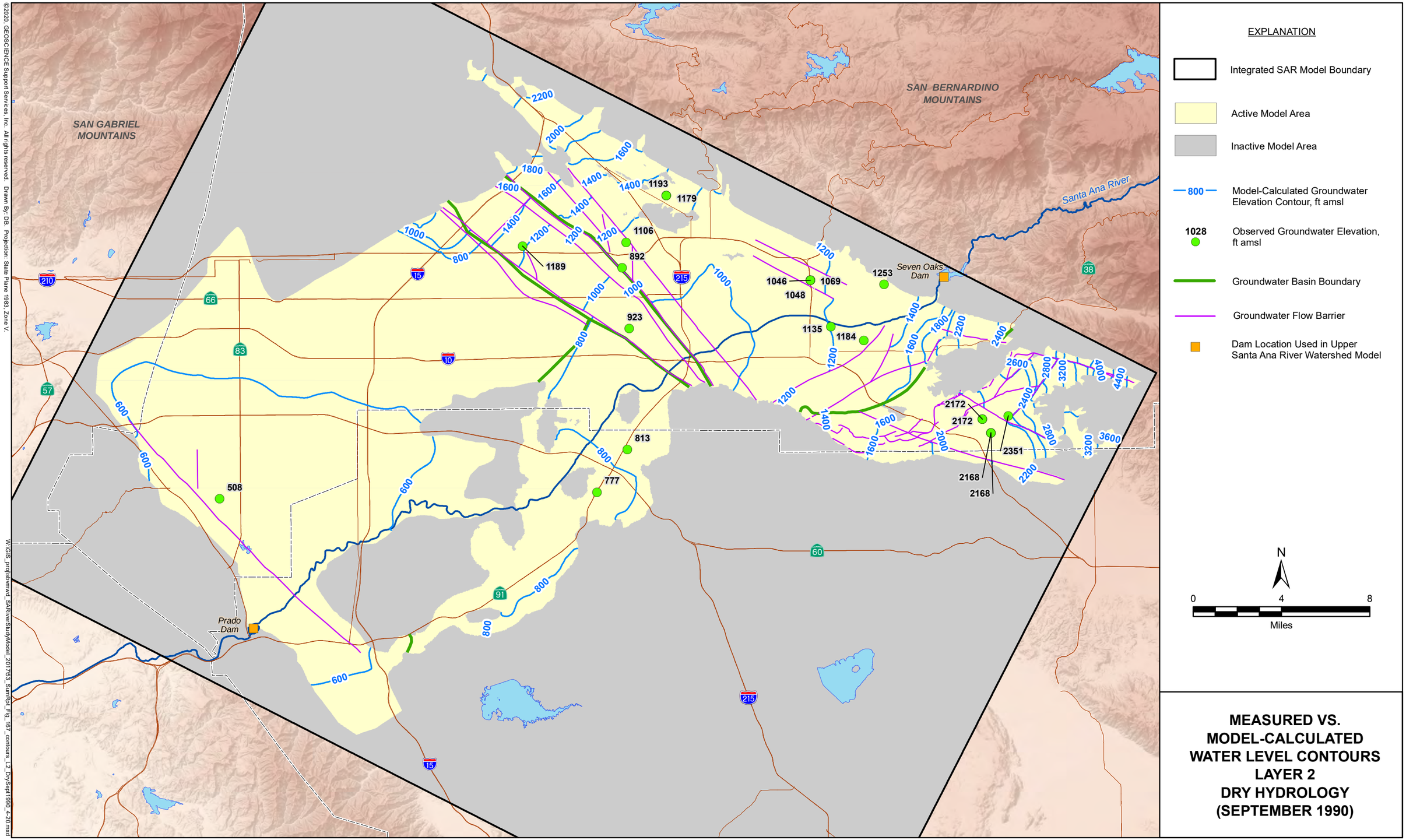
W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_166_contours_L1_Dry\Sept1990_4-20.mxd

10-Apr-20



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 2 DRY HYDROLOGY (SEPTEMBER 1990)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_201753_SumRpt_Fig_167_contours_L2_DrySept1990_4-20.mxd

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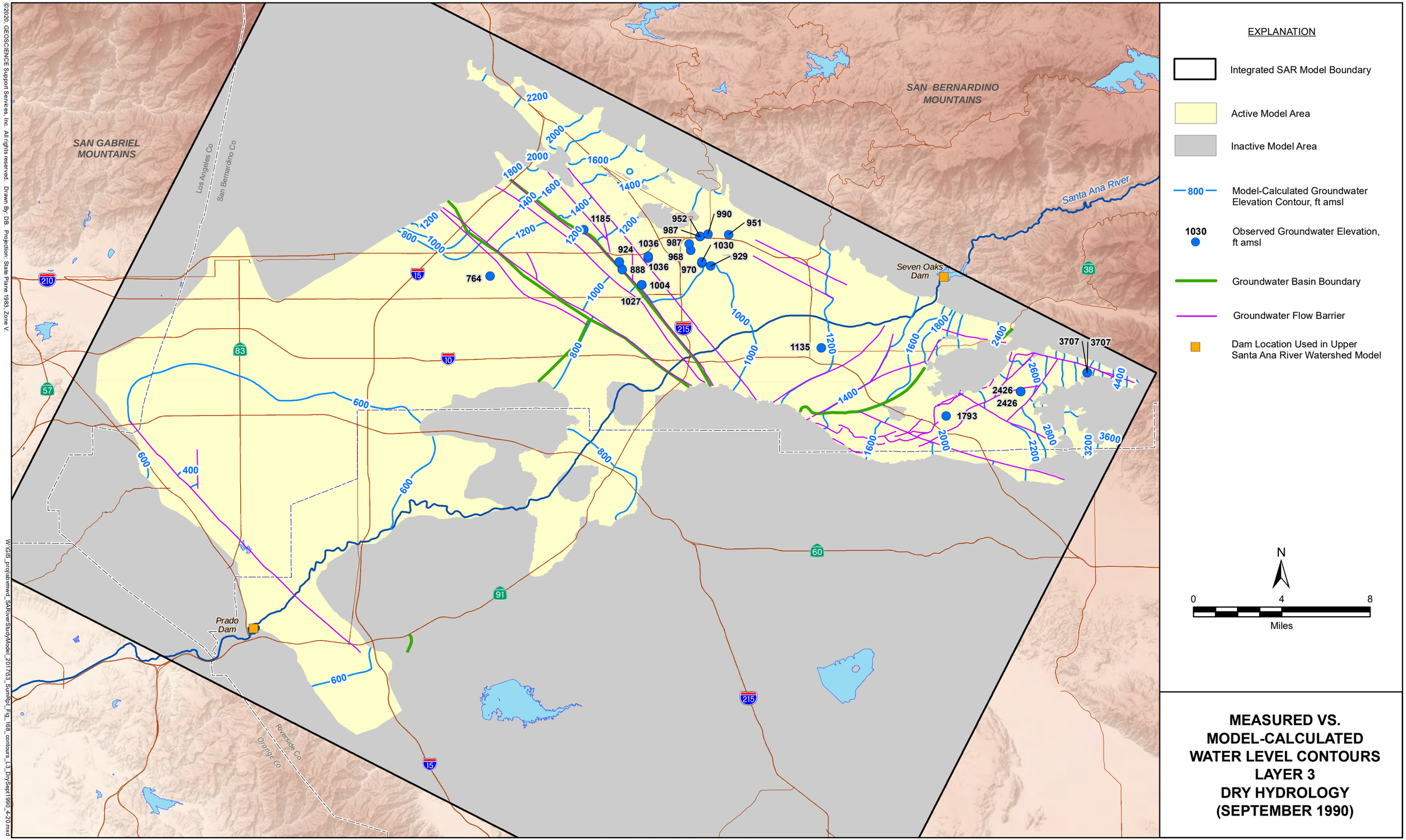

MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 3 DRY HYDROLOGY (SEPTEMBER 1990)

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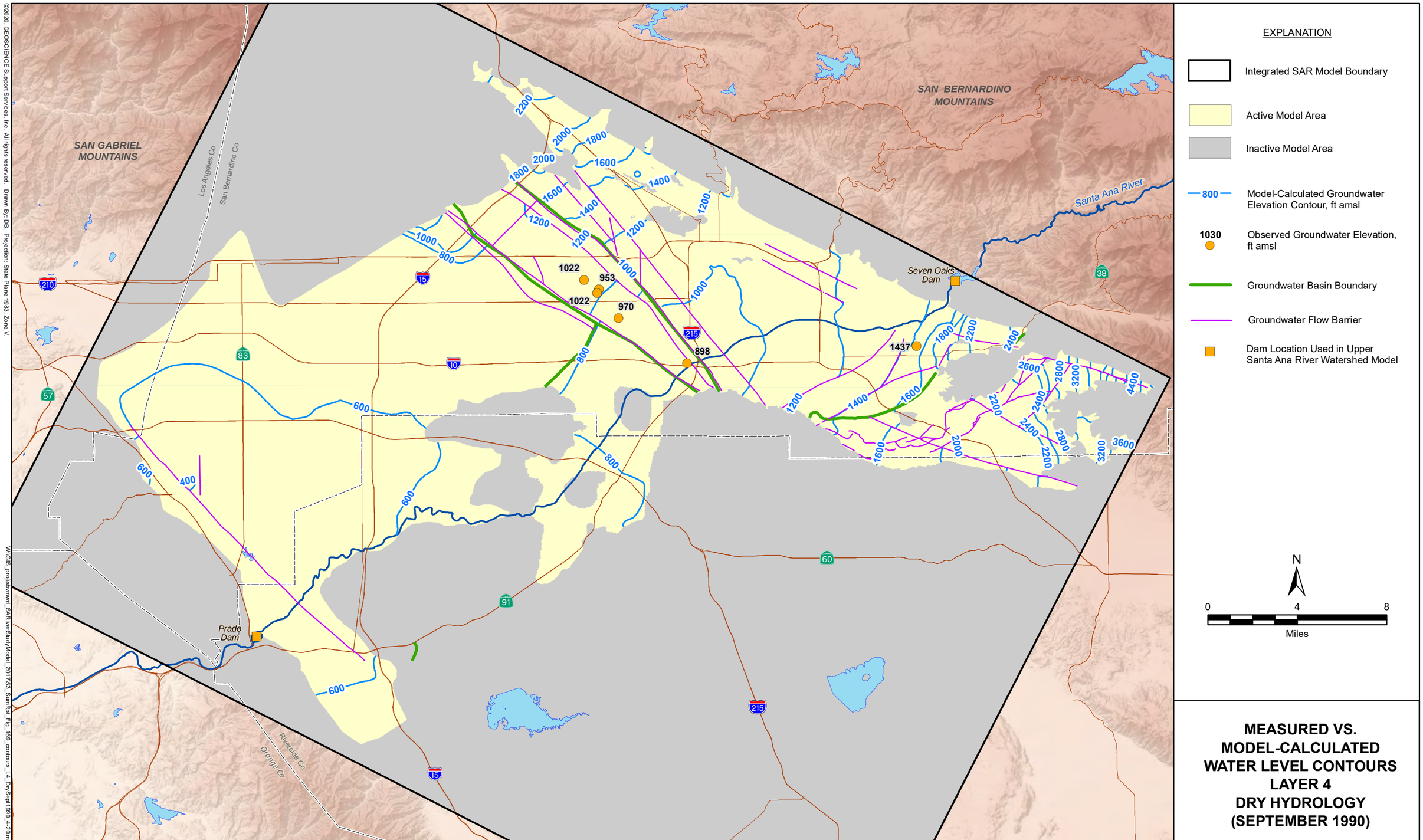
W:\GIS_proj\sbvmwd_SARiverStudyModel_201793_SumRpt_Fig_168_contours_L3_DrySept1990_4-20.mxd

10-Apr-20



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 4 DRY HYDROLOGY (SEPTEMBER 1990)

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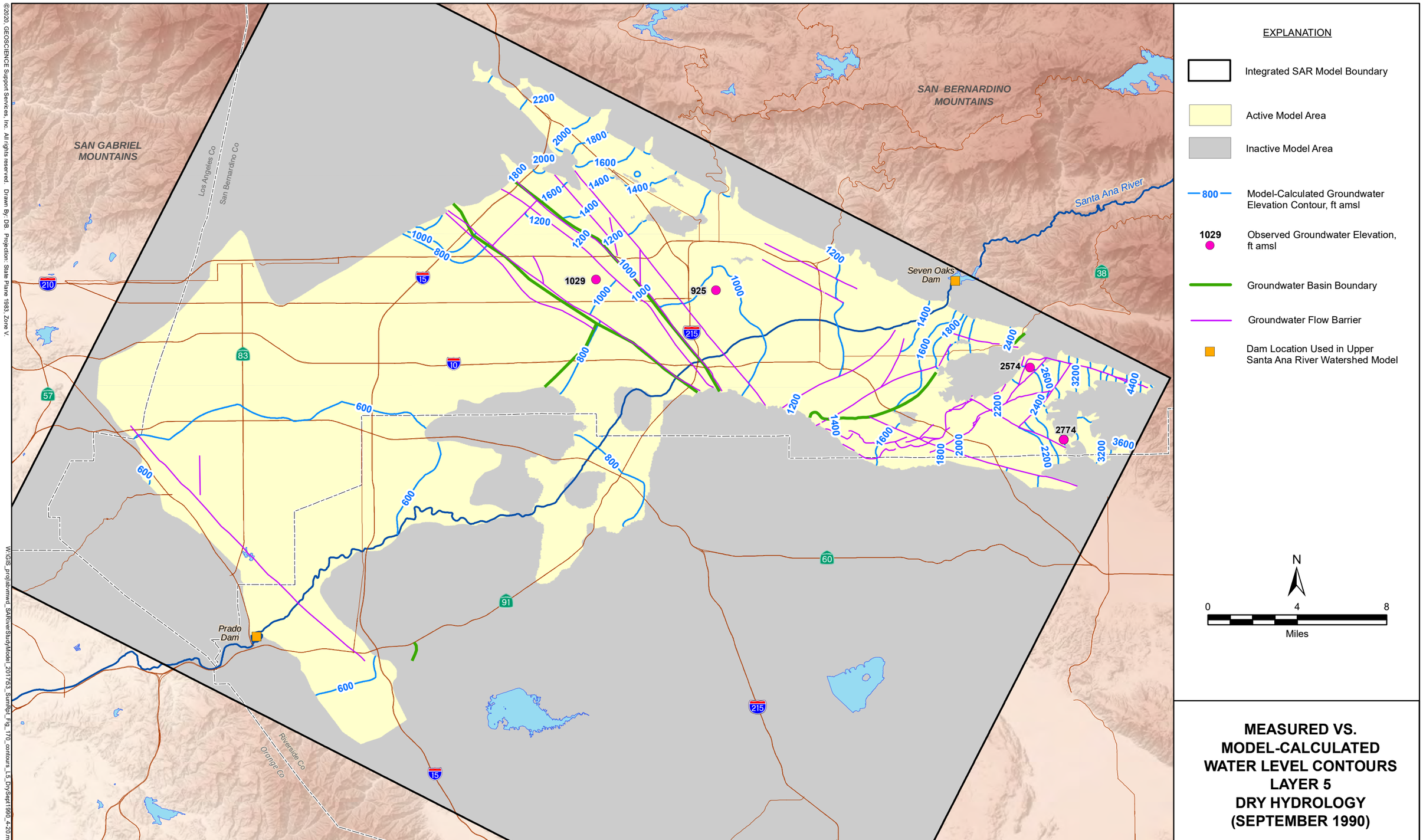
W:\GIS_proj\sbvmwd_SARiverStudyModel_201753_SumRpt_Fig_169_contours_L4_DrySept1990_4-20.mxd

10-Apr-20



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 5 DRY HYDROLOGY (SEPTEMBER 1990)

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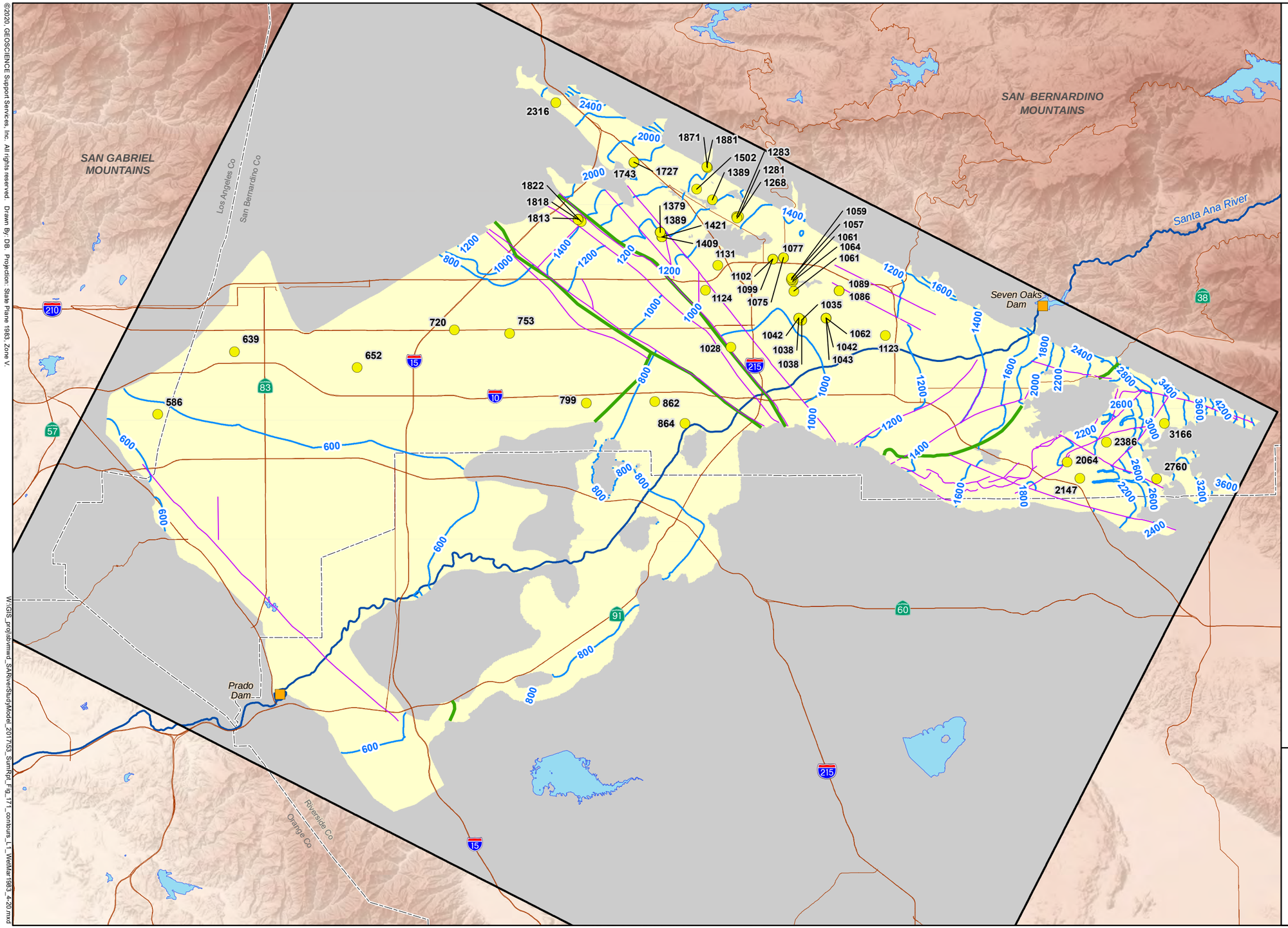
10-Apr-20



EXPLANATION

Integrated SAR Model Boundary

Active Model Area

Inactive Model Area

800 — Model-Calculated Groundwater Elevation Contour, ft amsl

1028 Observed Groundwater Elevation, ft amsl

Groundwater Basin Boundary

Groundwater Flow Barrier

Dam Location Used in Upper Santa Ana River Watershed Model

N

0 4 8

Miles

OBSERVED WATER LEVELS VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 1 WET HYDROLOGY (MARCH 1983)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_171_contours_L1_WetMar1983_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 171

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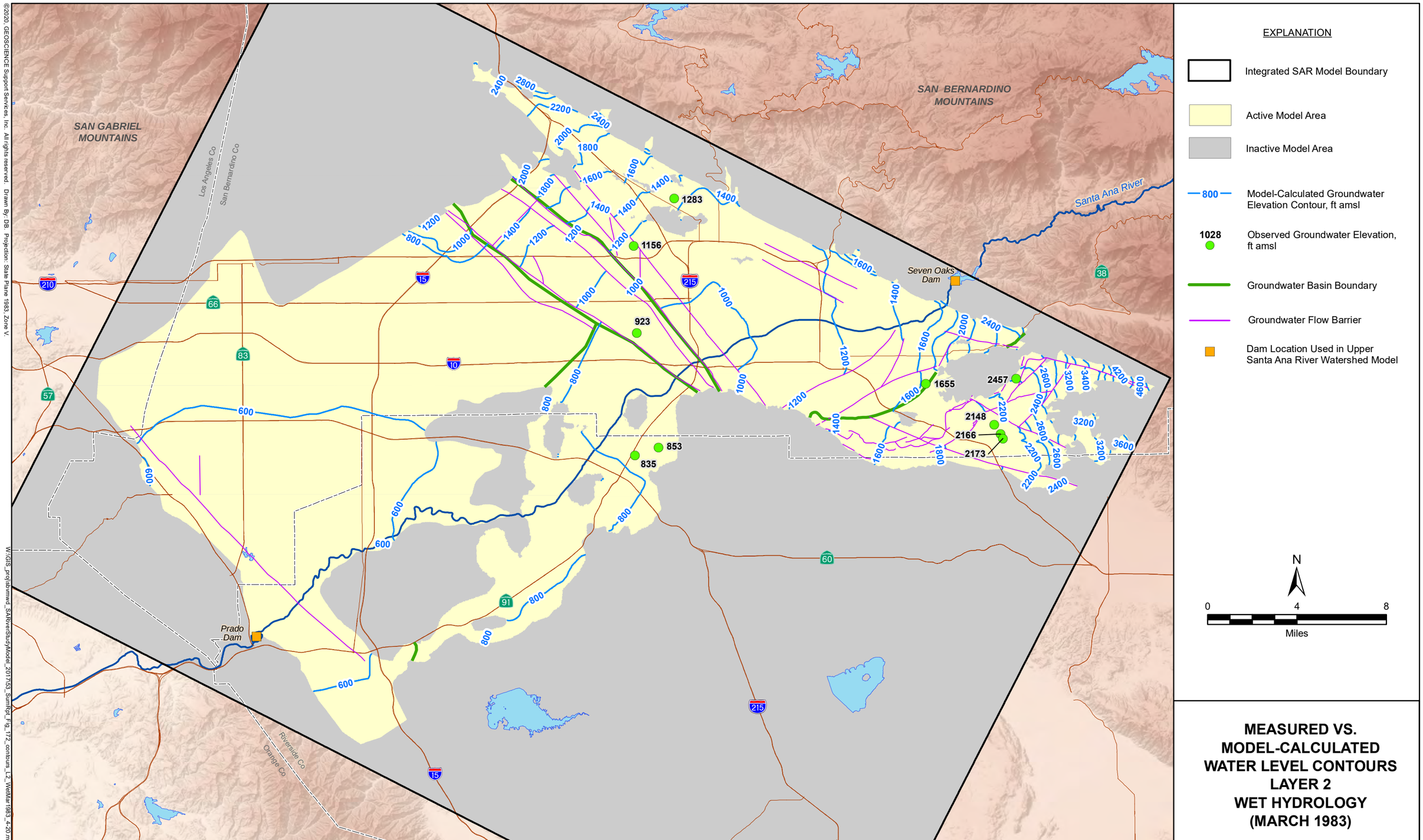

MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 2 WET HYDROLOGY (MARCH 1983)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_172_contours_L2_WetMar1983_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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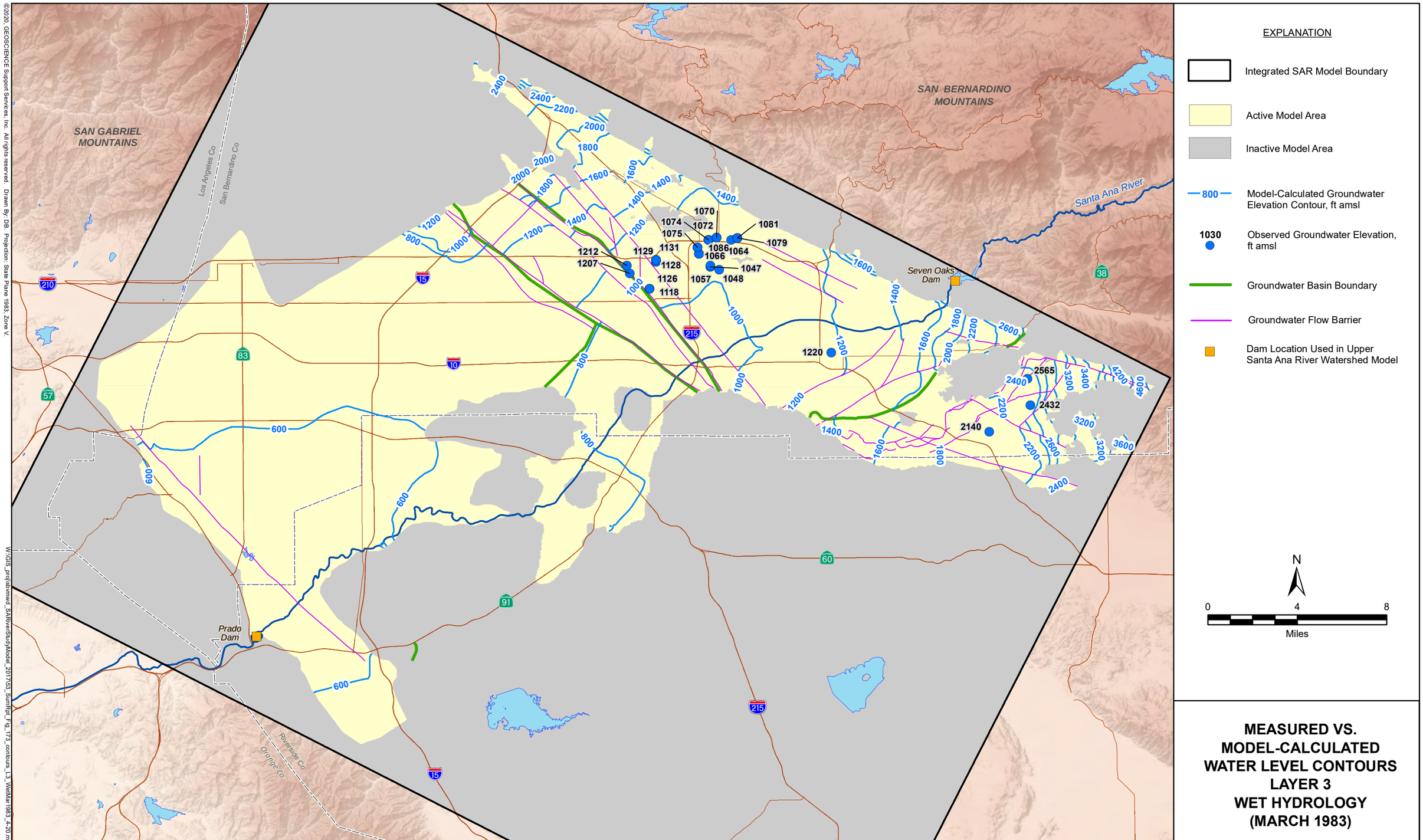
FIGURE 172

GEOSCIENCE



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 3 WET HYDROLOGY (MARCH 1983)

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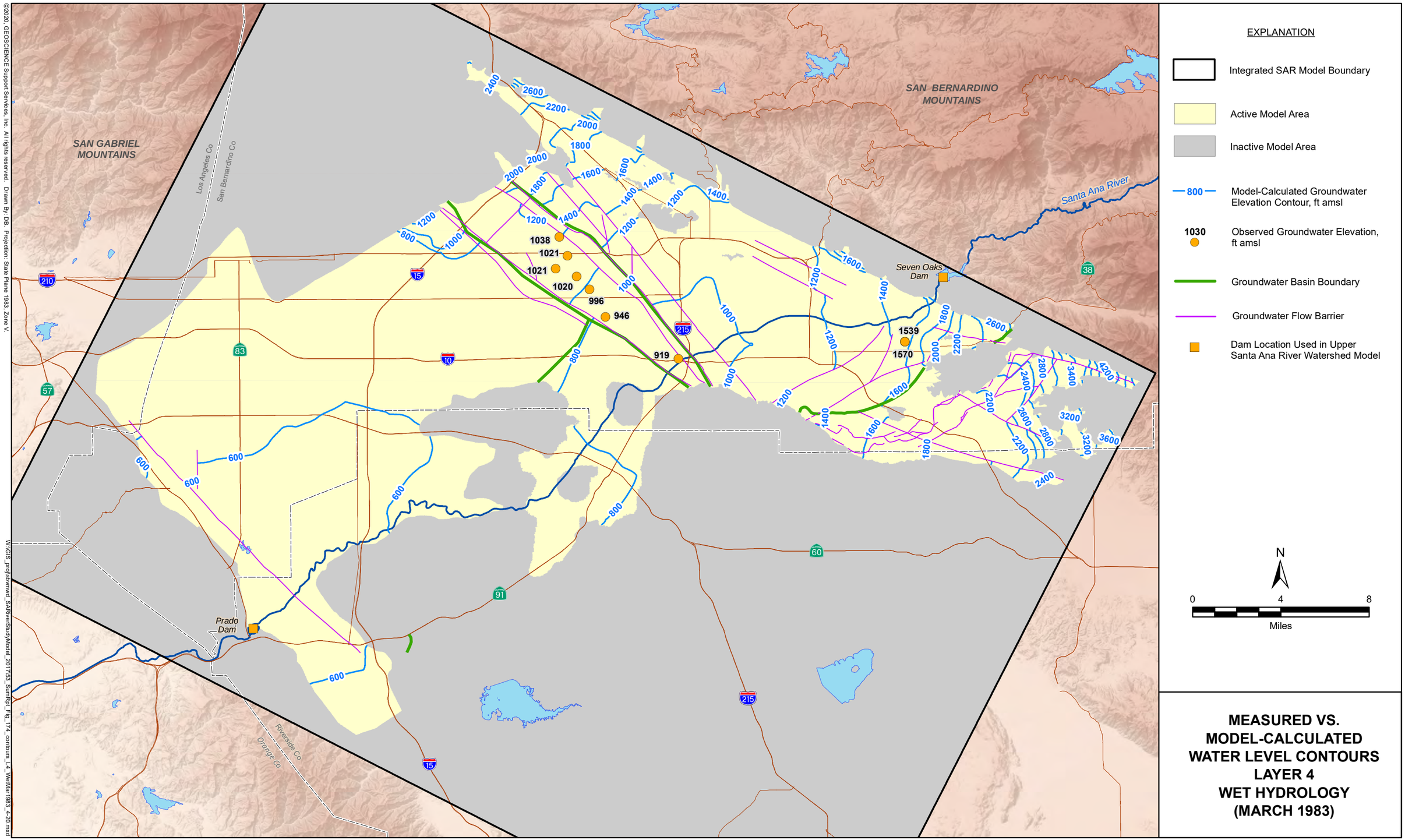
W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_173_contours_L3_WetMar1983_4-20.mxd

10-Apr-20



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 4 WET HYDROLOGY (MARCH 1983)

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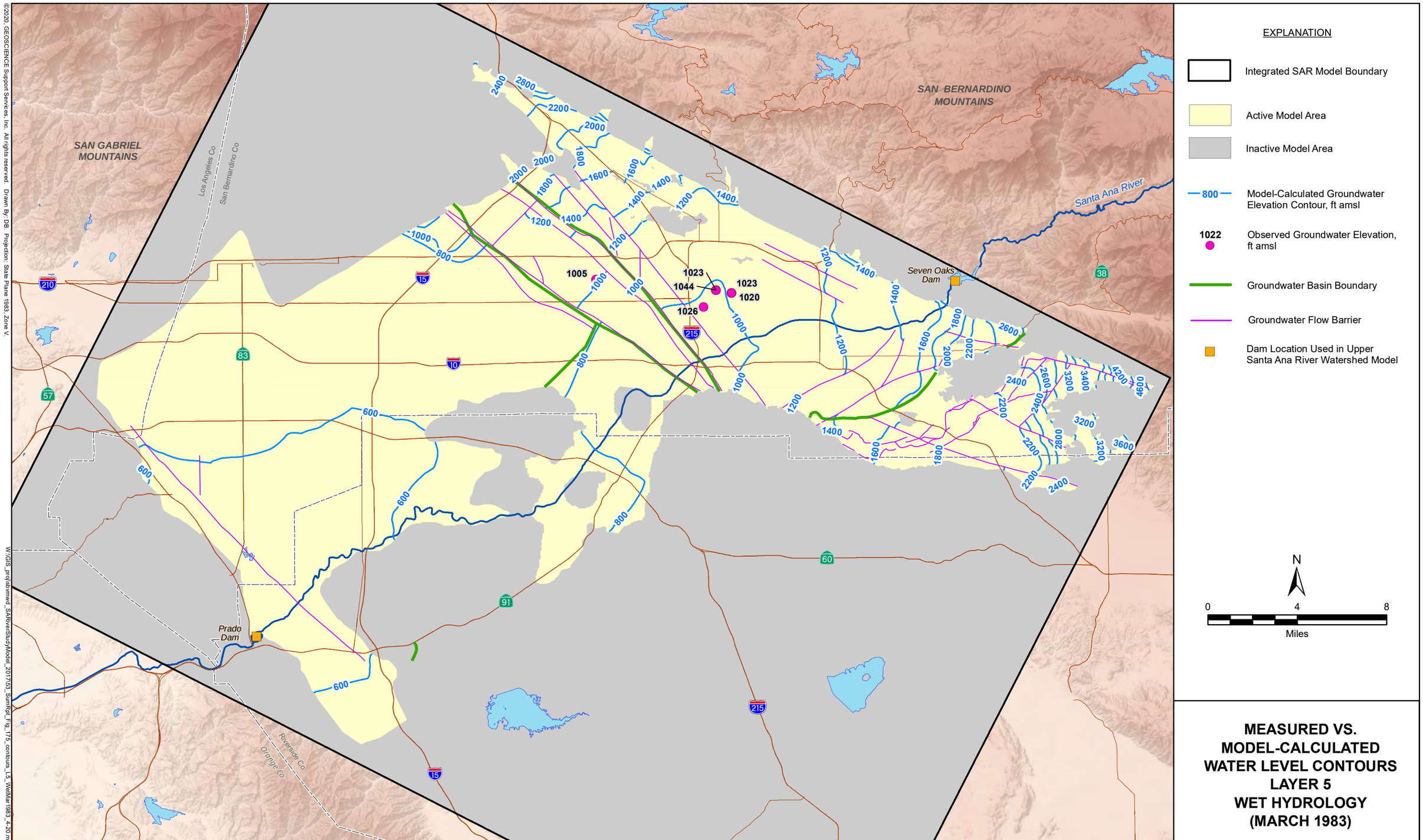
10-Apr-20



MEASURED VS. MODEL-CALCULATED WATER LEVEL CONTOURS LAYER 5 WET HYDROLOGY (MARCH 1983)

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_175_contours_L5_WetMar1983_4-20.mxd

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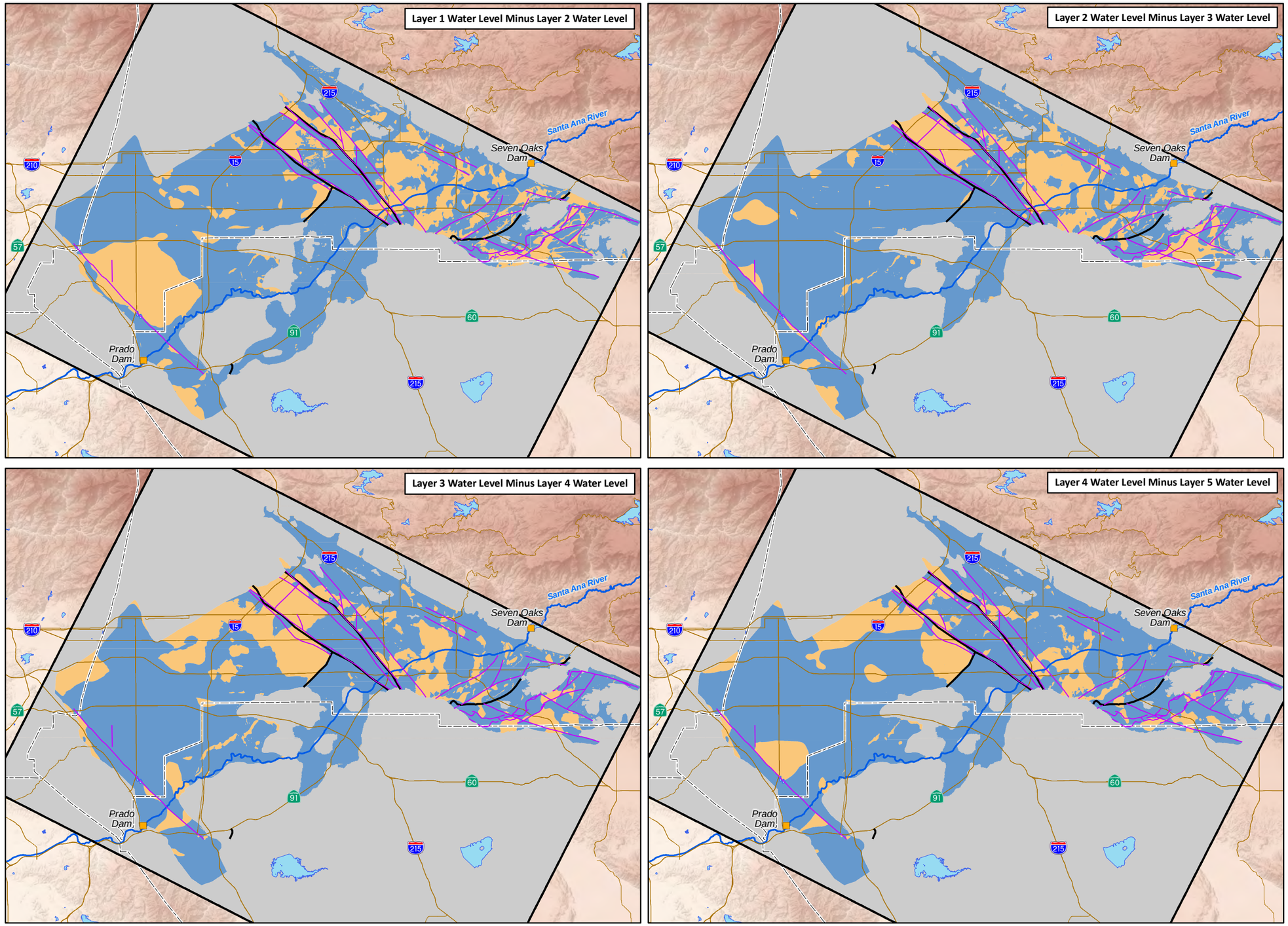

EXPLANATION

- Integrated SAR Model Boundary
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier
- Dam Location Used in Upper Santa Ana River Watershed Model

Vertical Movement of Water From One Layer to Another

- Downward Movement
- Upward Movement

N

0 8 16
Miles

AVERAGE MODEL-CALCULATED VERTICAL MOVEMENT OF WATER (1966 TO 2016)

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_176_vertical_movement_of_water_4panel_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 176

GEOSCIENCE

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Measured vs. Model-Calculated Water Levels in the Yucaipa Basin Model Area - All Layers (1966 to 2016)

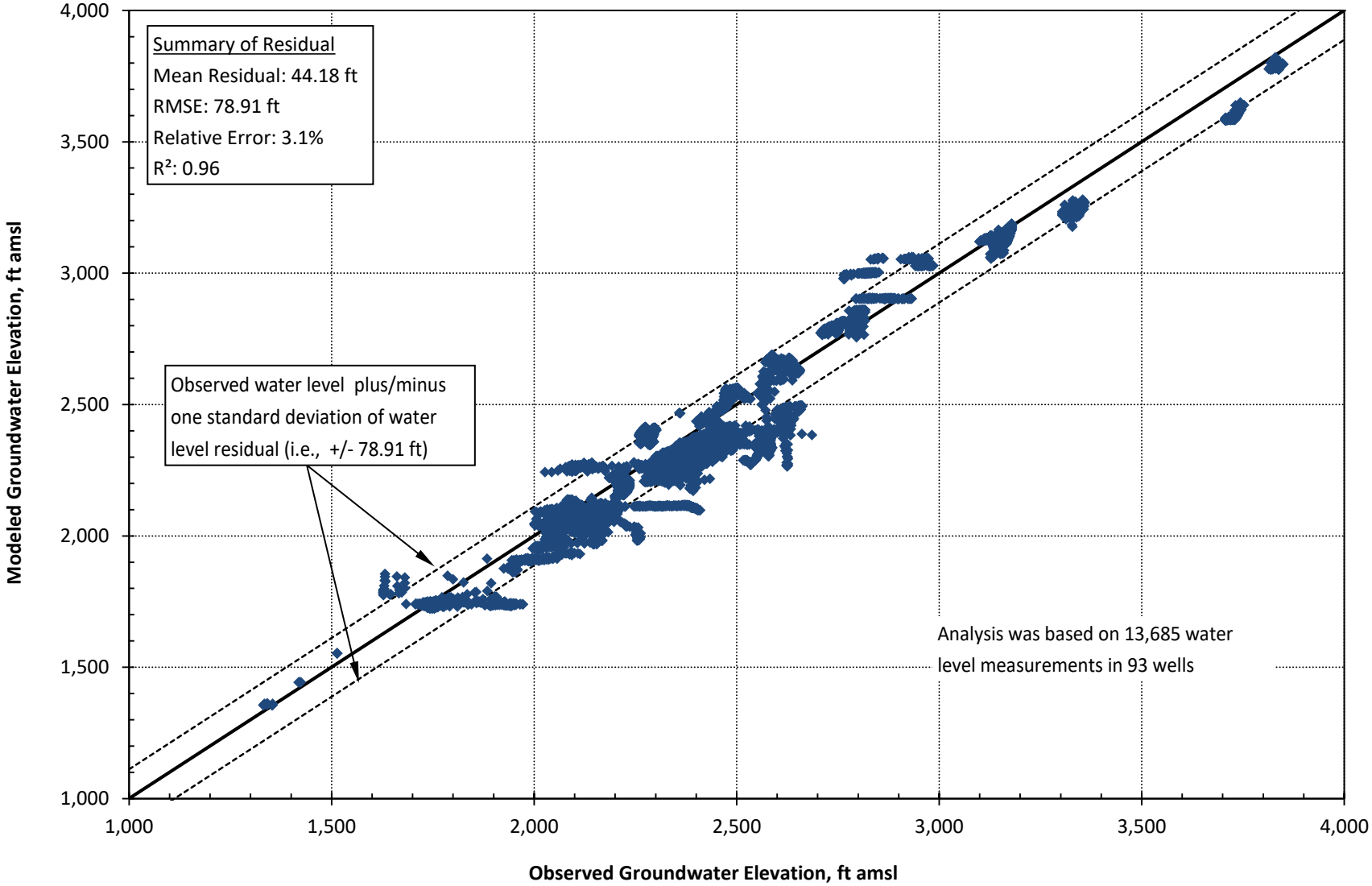


Figure 177

Measured vs. Model-Calculated Water Levels in Yucaipa Basin – Layer 1 (1966 to 2016)

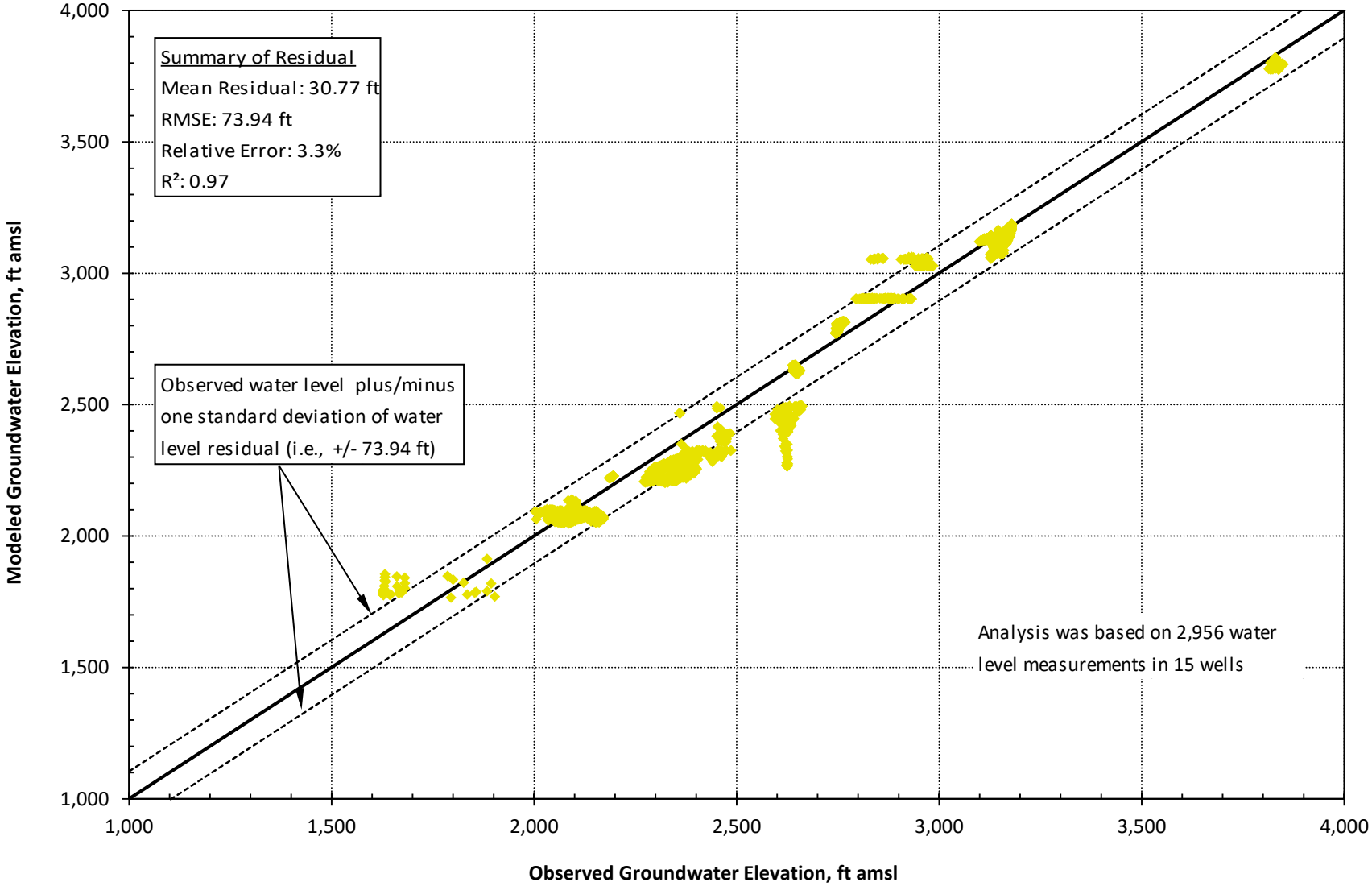


Figure 178

Measured vs. Model-Calculated Water Levels in Yucaipa Basin – Layer 2 (1966 to 2016)

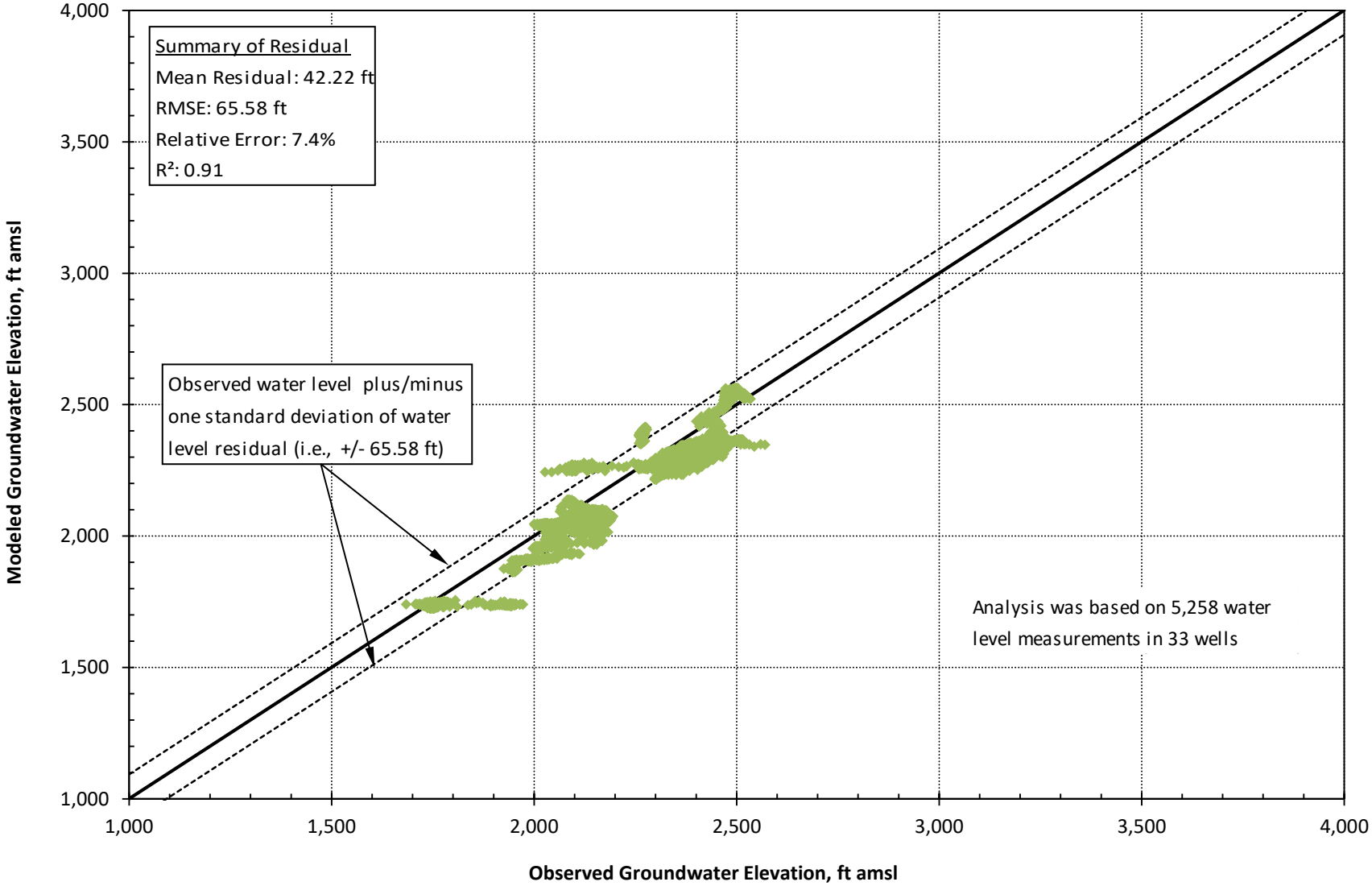


Figure 179

Measured vs. Model-Calculated Water Levels in Yucaipa Basin – Layer 3 (1966 to 2016)

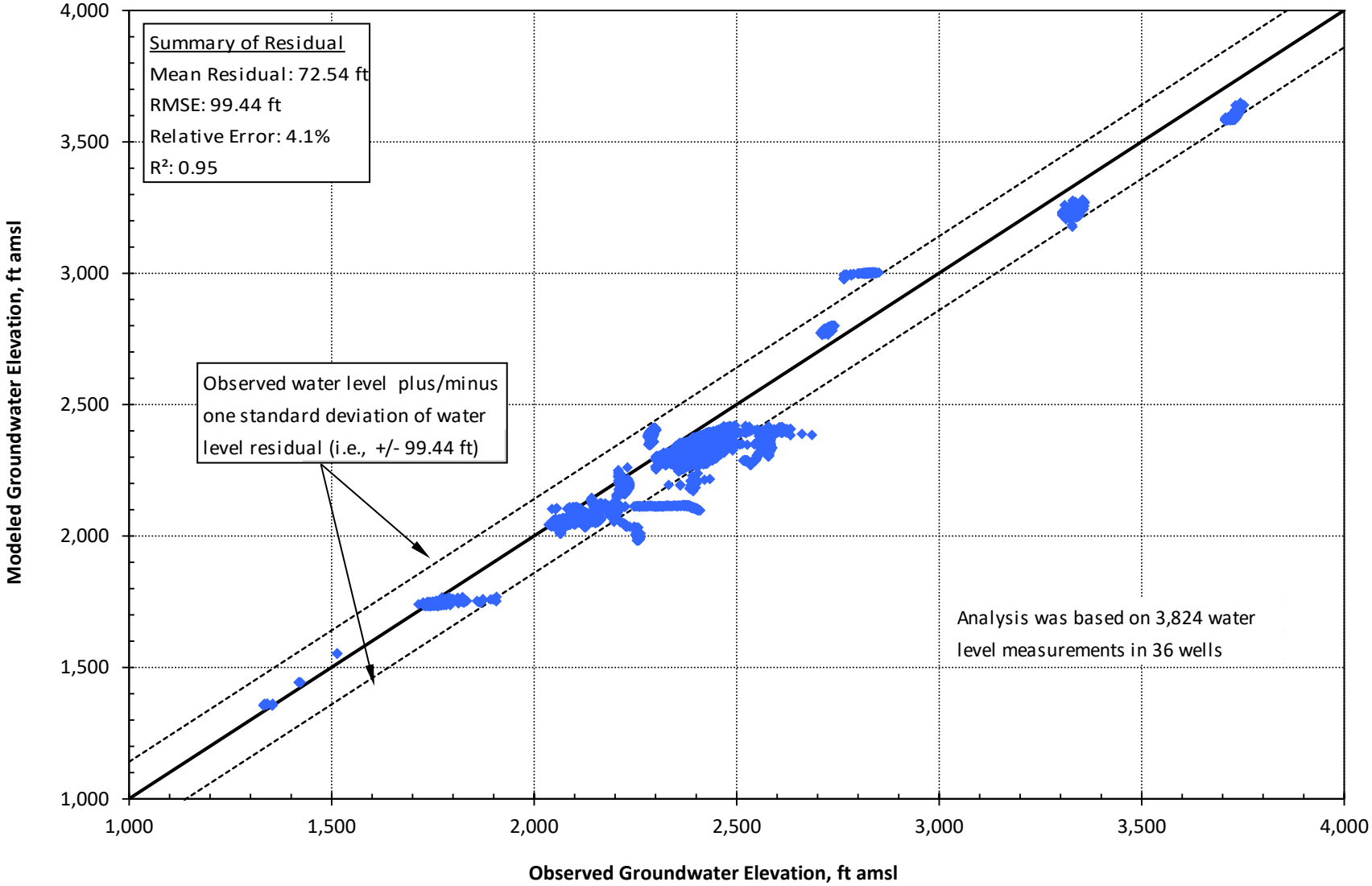


Figure 180

Measured vs. Model-Calculated Water Levels in Yucaipa Basin – Layer 4 (1966 to 2016)

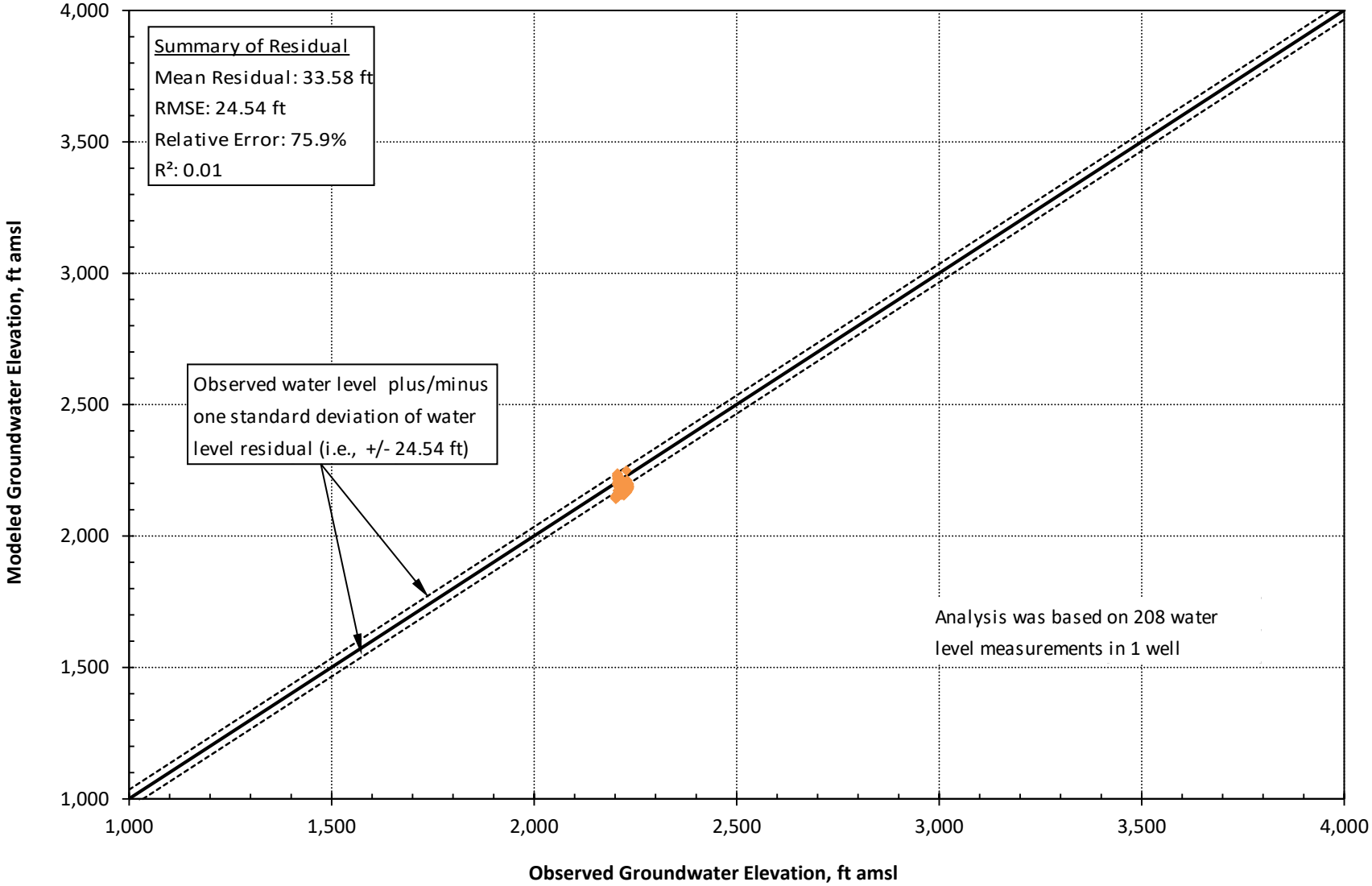


Figure 181

Measured vs. Model-Calculated Water Levels in Yucaipa Basin – Layer 5 (1966 to 2016)

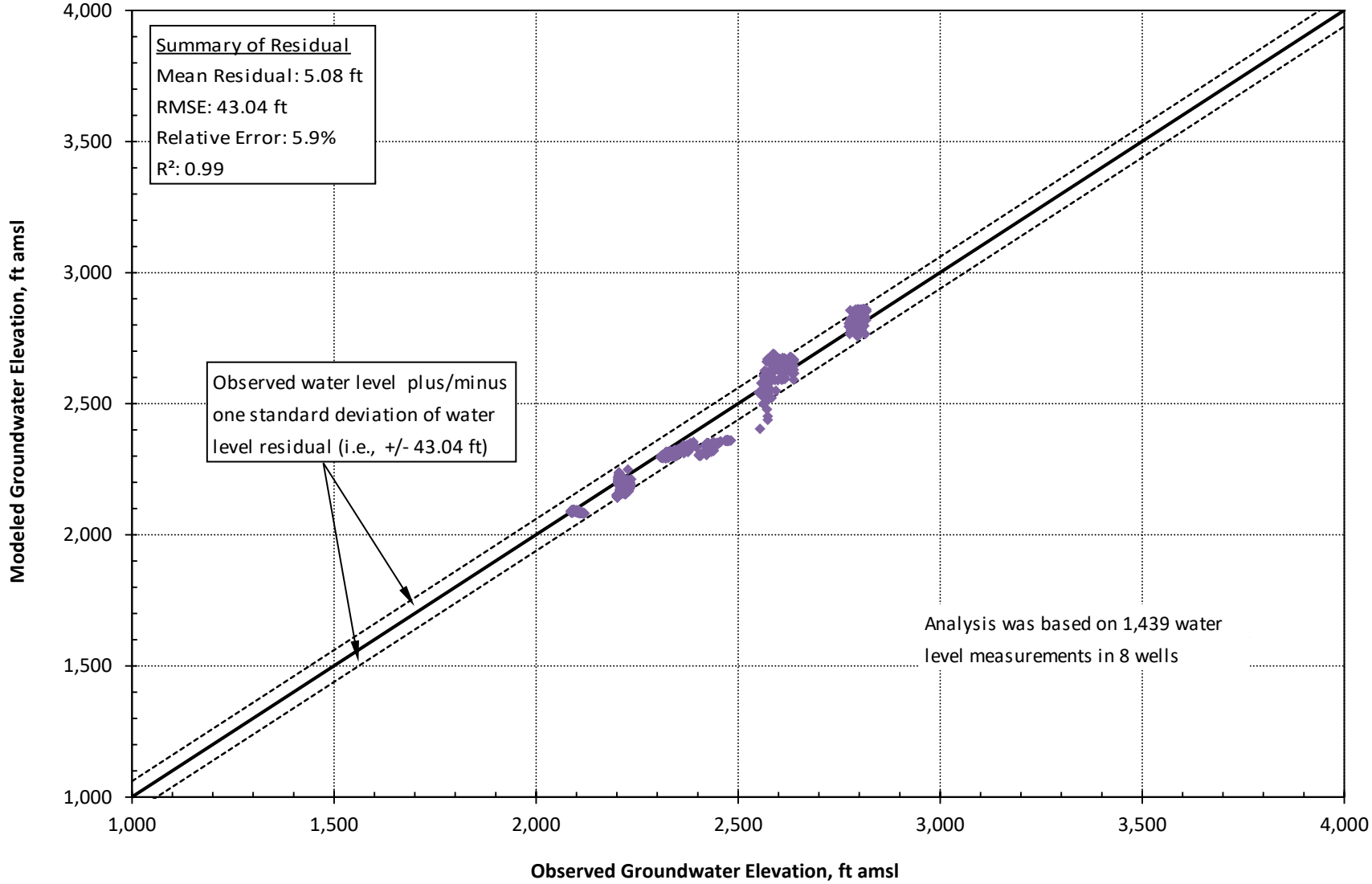


Figure 182

DRAFT

Temporal Distribution of Water Level Residuals in Yucaipa Basin - All Layers (1966 to 2016)

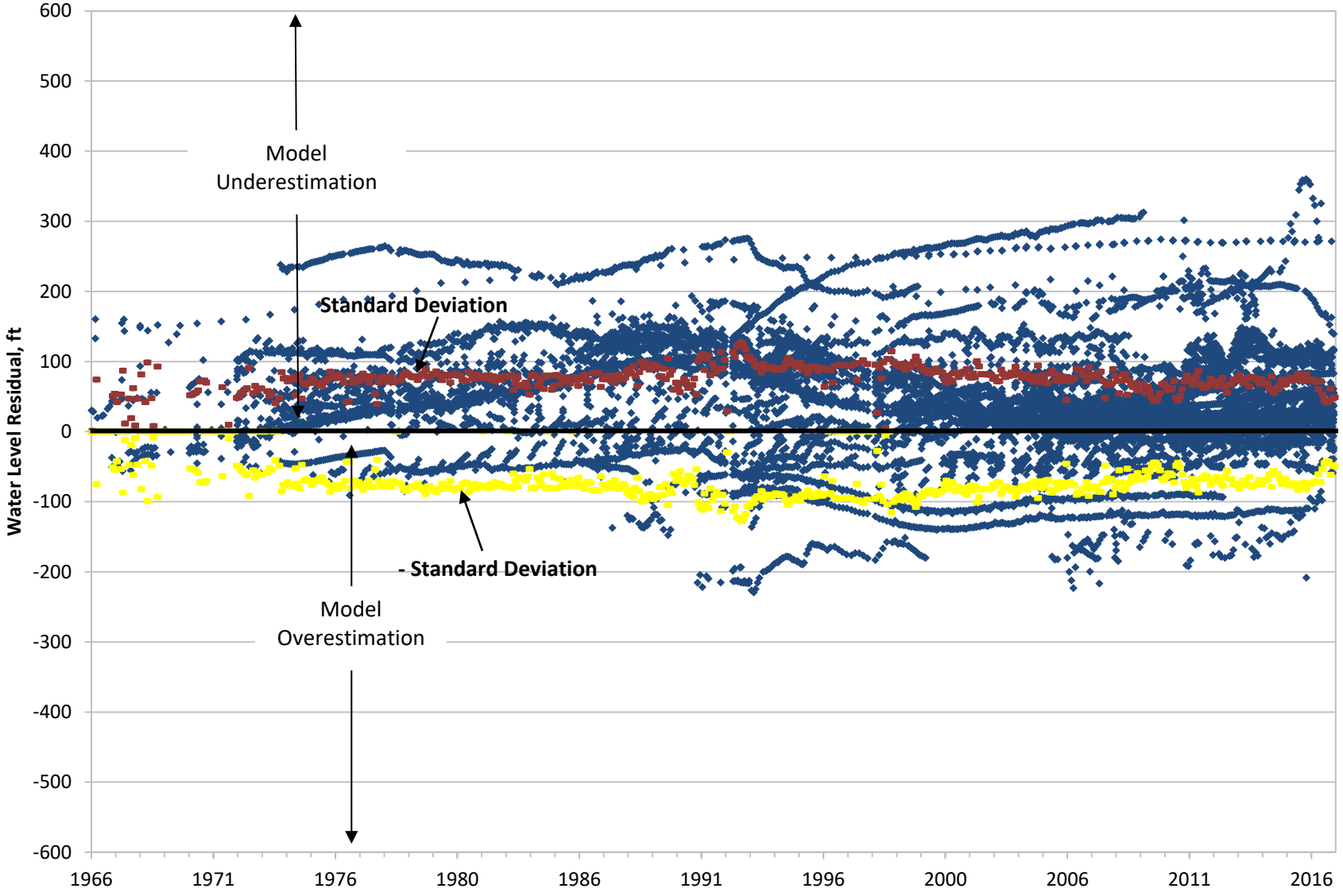


Figure 183

DRAFT

Histogram of Water Level Residuals in Yucaipa Basin – All Layers (1966 to 2016)

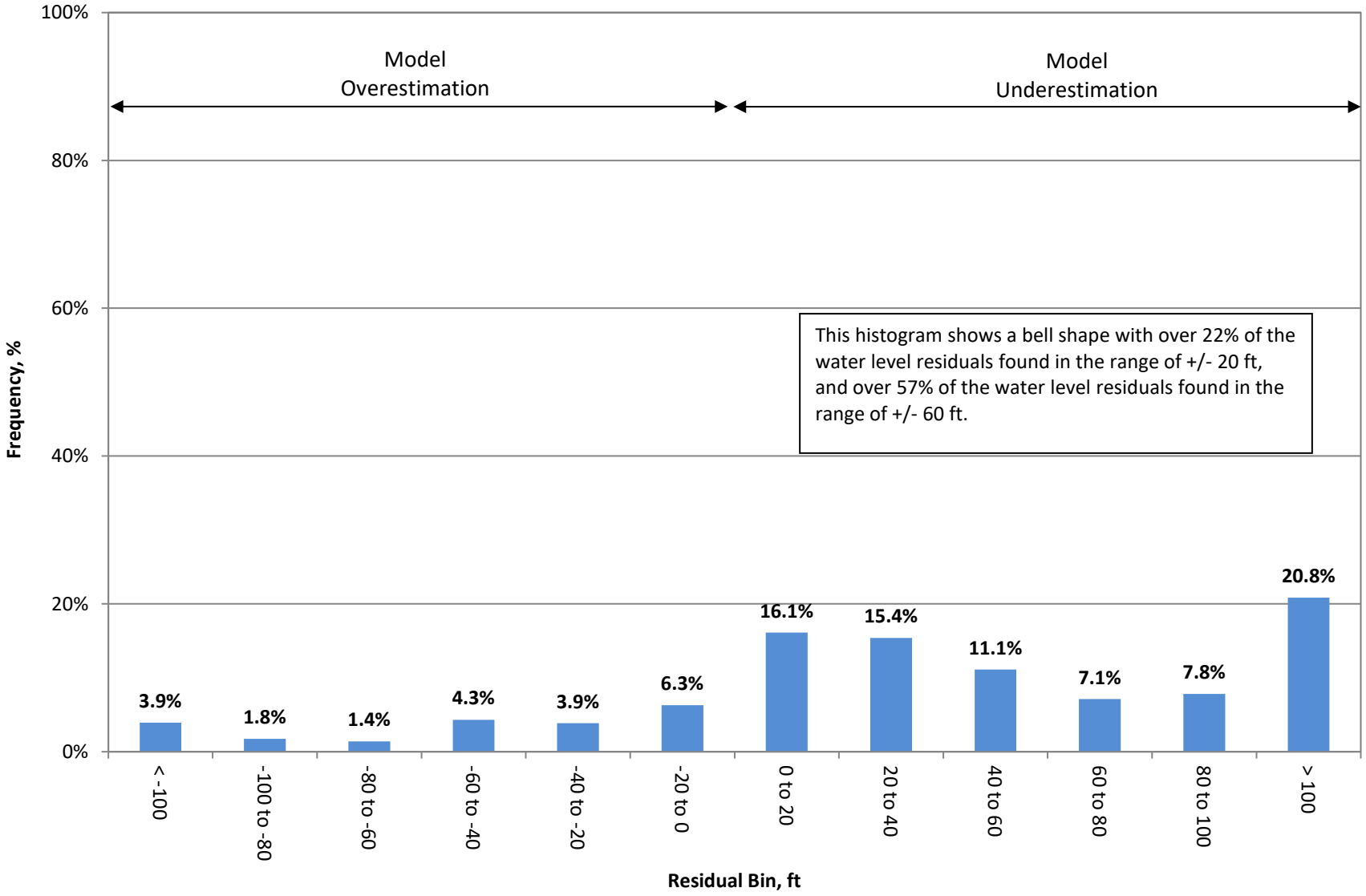
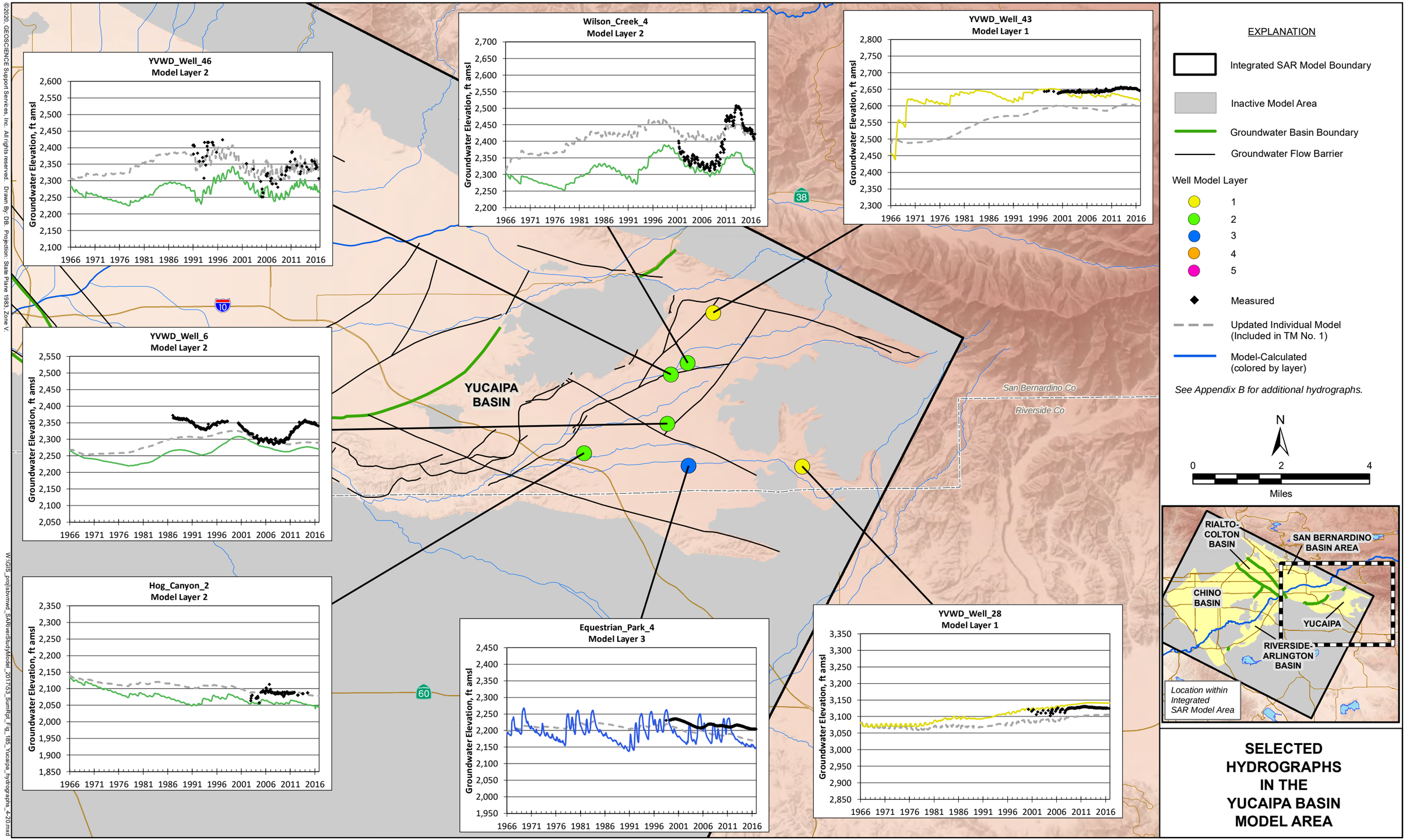


Figure 184



SELECTED HYDROGRAPHS IN THE YUCAIPA BASIN MODEL AREA

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W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_185_Yucaipa_hydrographs_4-20.mxd

10-Apr-20

DRAFT

Measured vs. Model-Calculated Water Levels in the SBBA Model Area - All Layers (1966 to 2016)

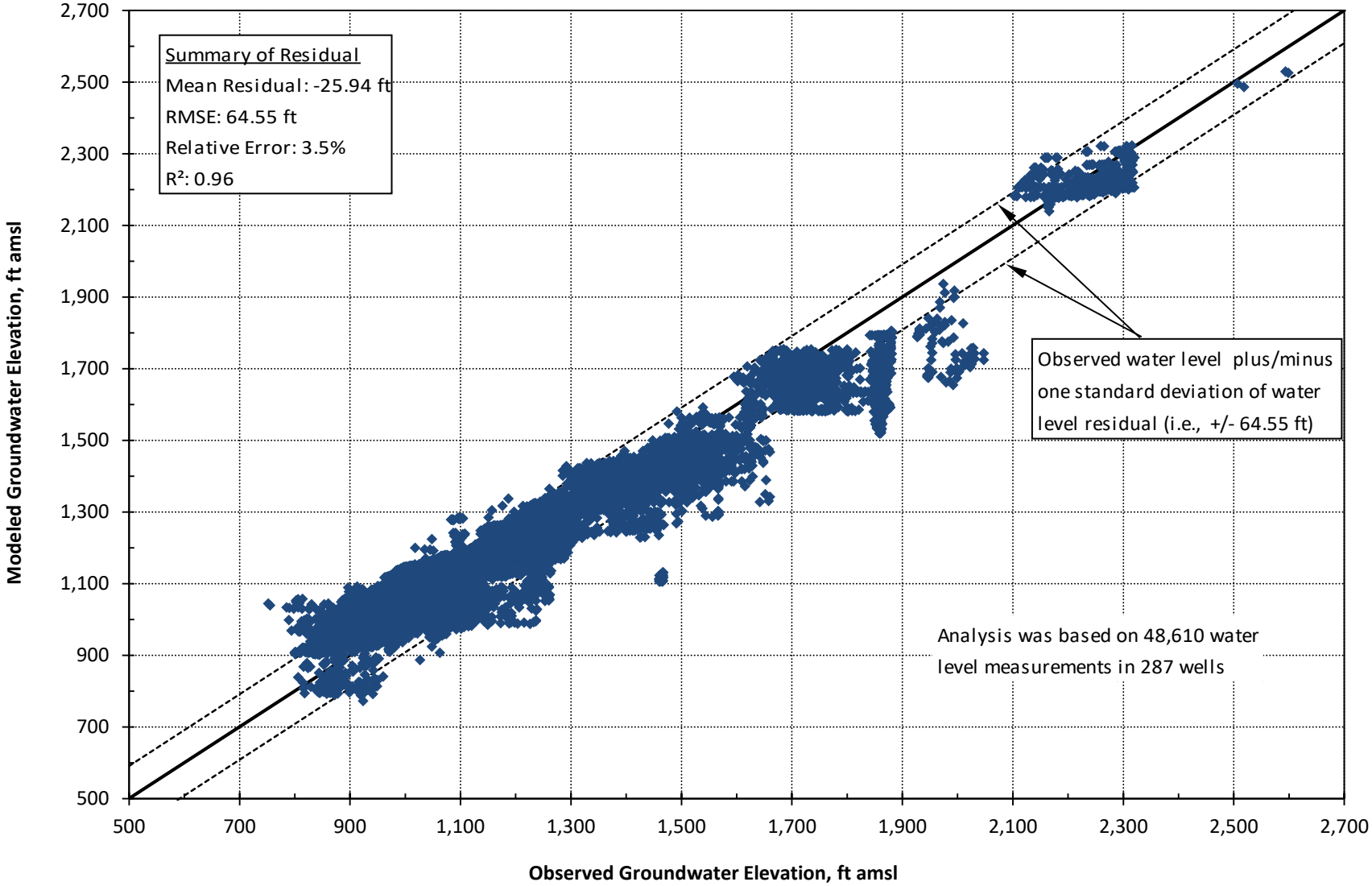

Figure 186

DRAFT

Measured vs. Model-Calculated Water Levels in the SBBA – Layer 1 (1966 to 2016)

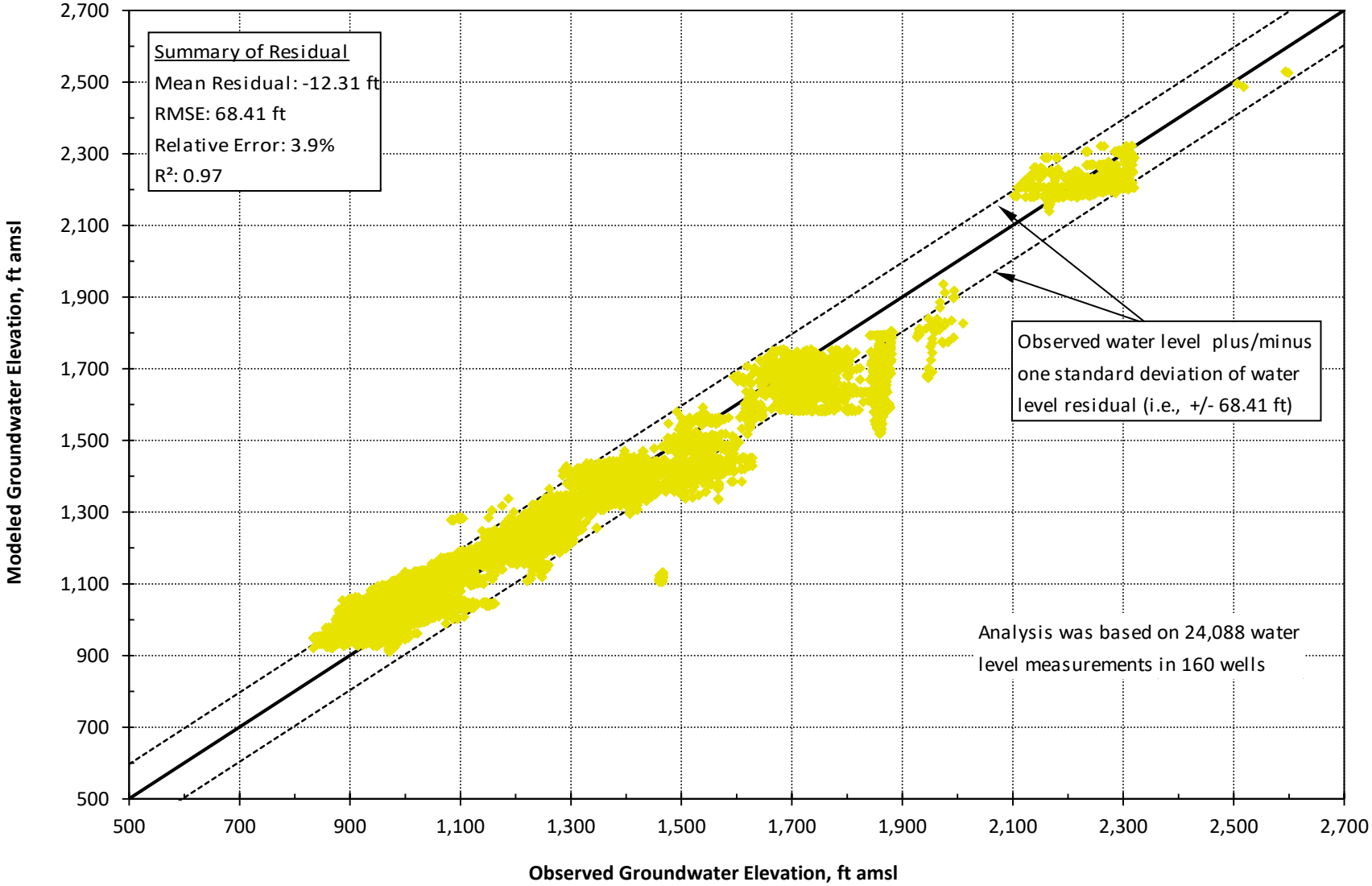

Figure 187

Measured vs. Model-Calculated Water Levels in the SBBA – Layer 2 (1966 to 2016)

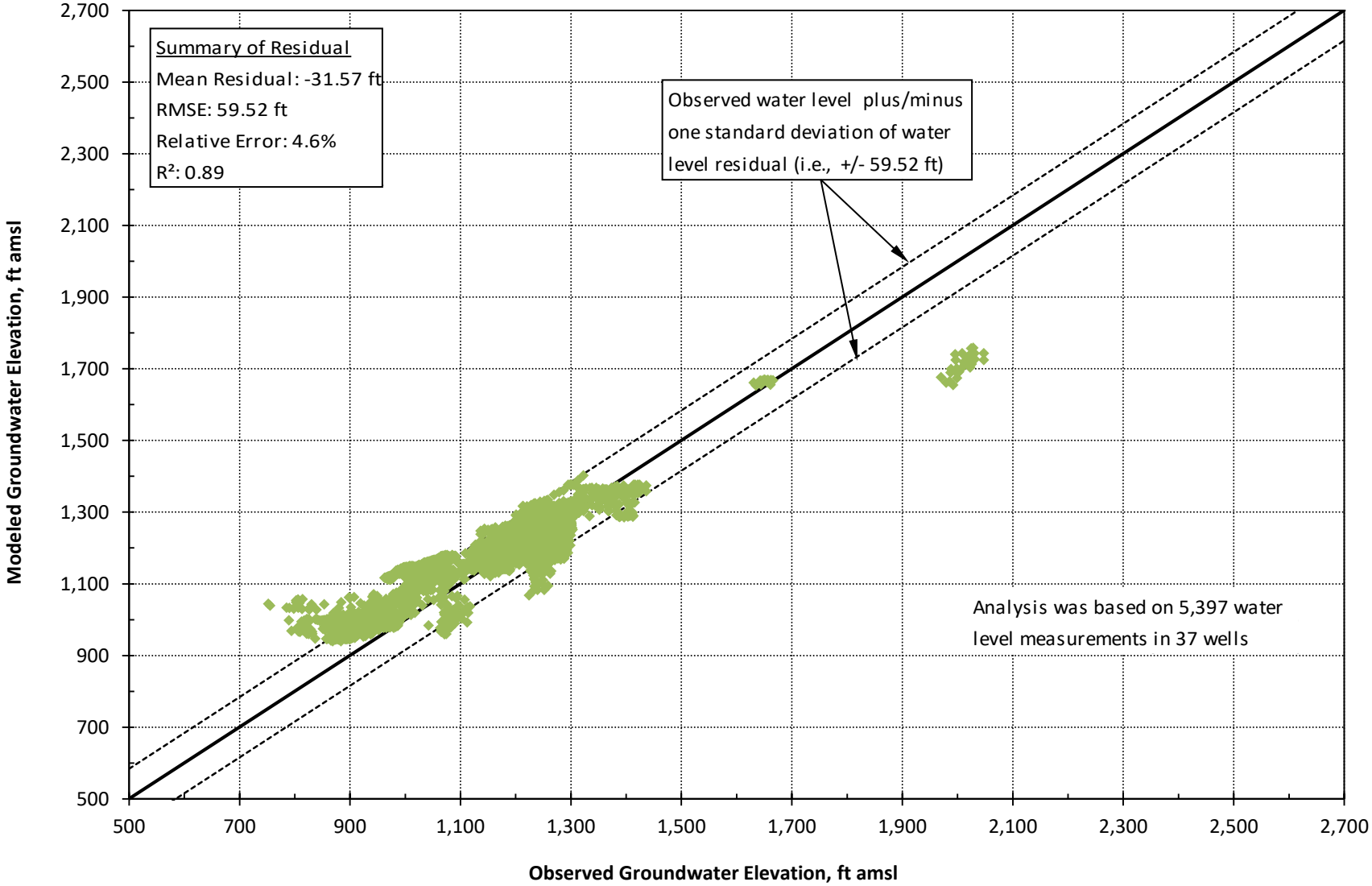

Figure 188

Measured vs. Model-Calculated Water Levels in the SBBA – Layer 3 (1966 to 2016)

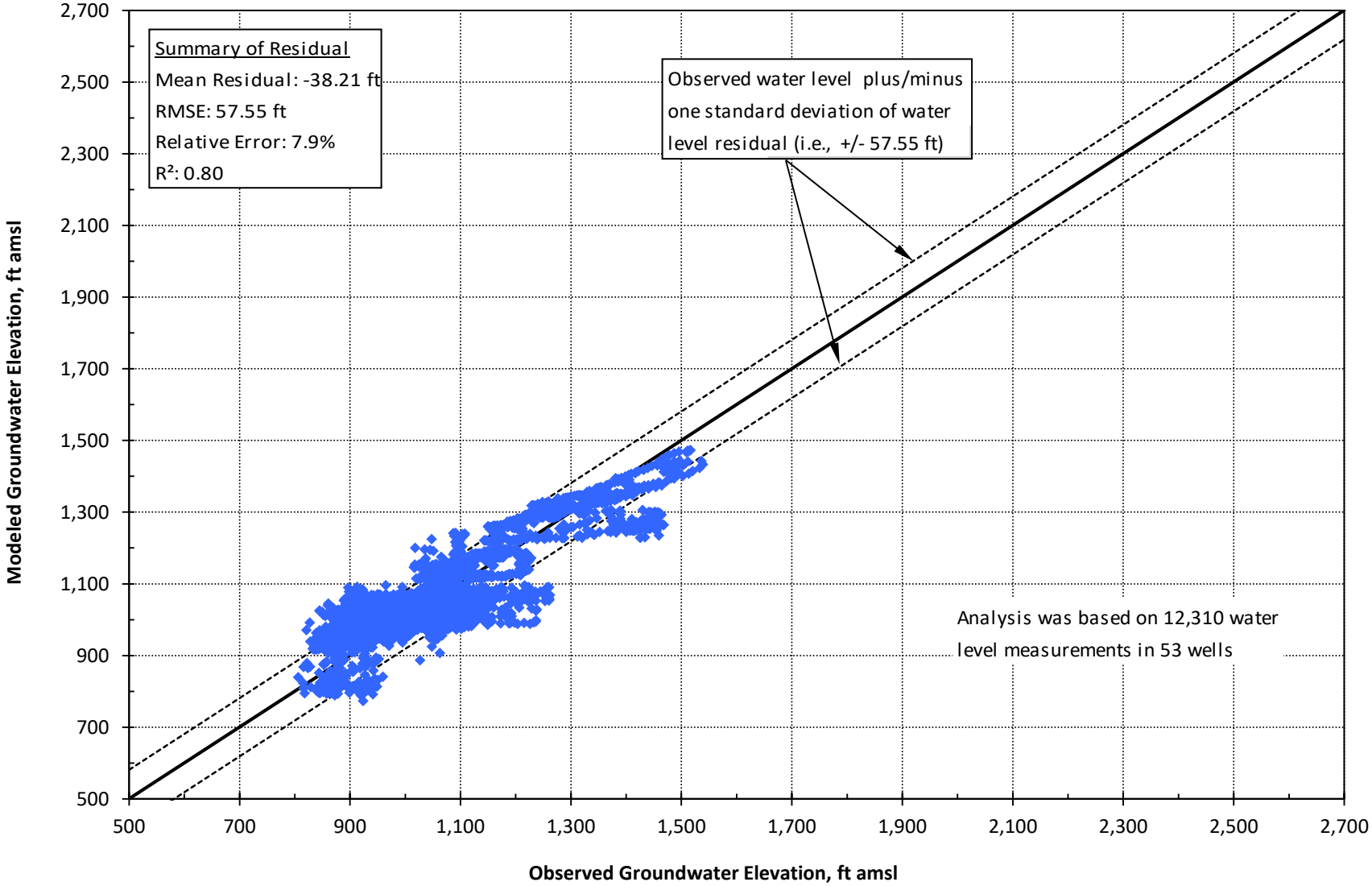

Figure 189

Measured vs. Model-Calculated Water Levels in the SBBA – Layer 4 (1966 to 2016)

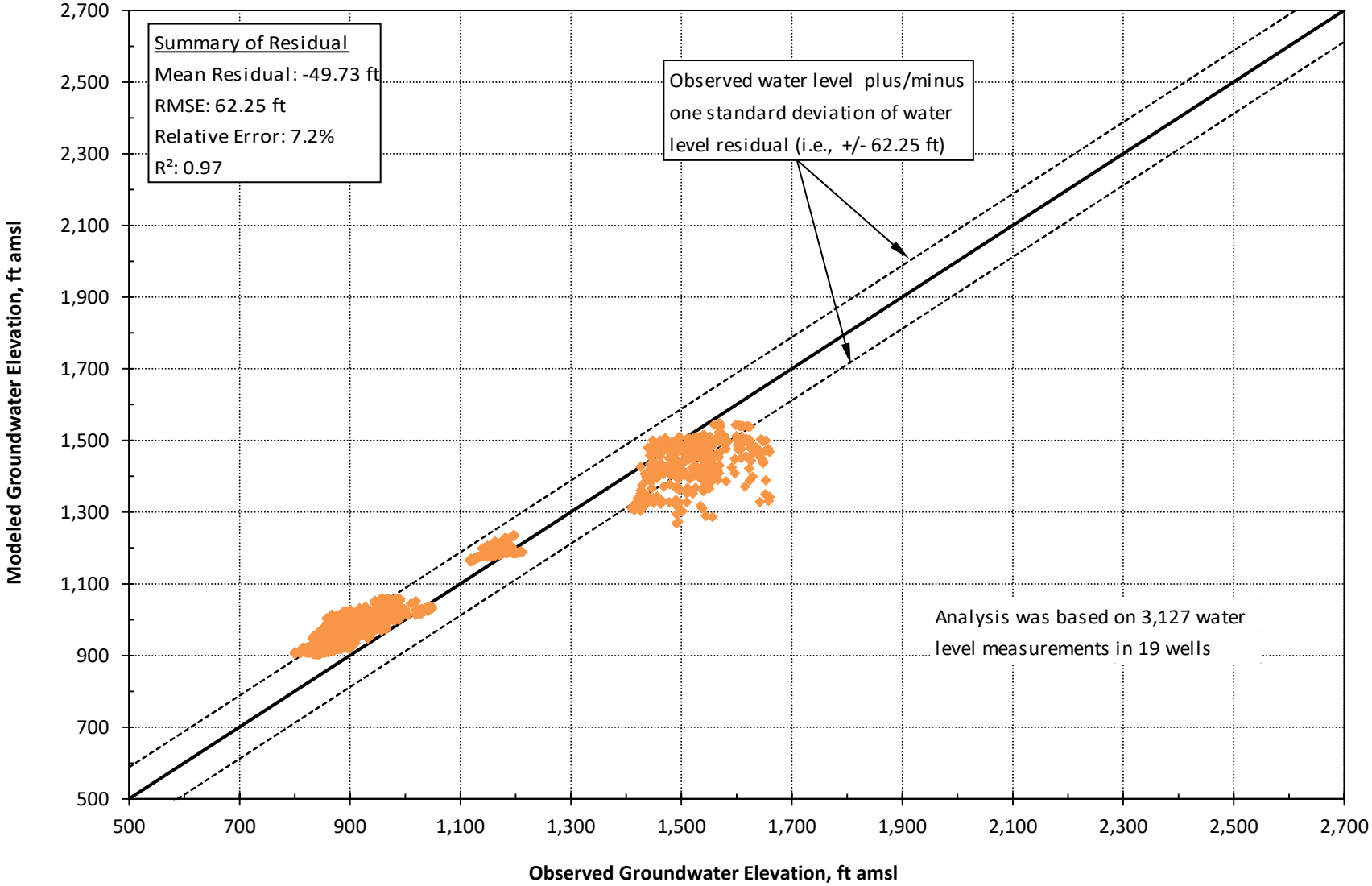

Figure 190

Measured vs. Model-Calculated Water Levels in the SBBA – Layer 5 (1966 to 2016)

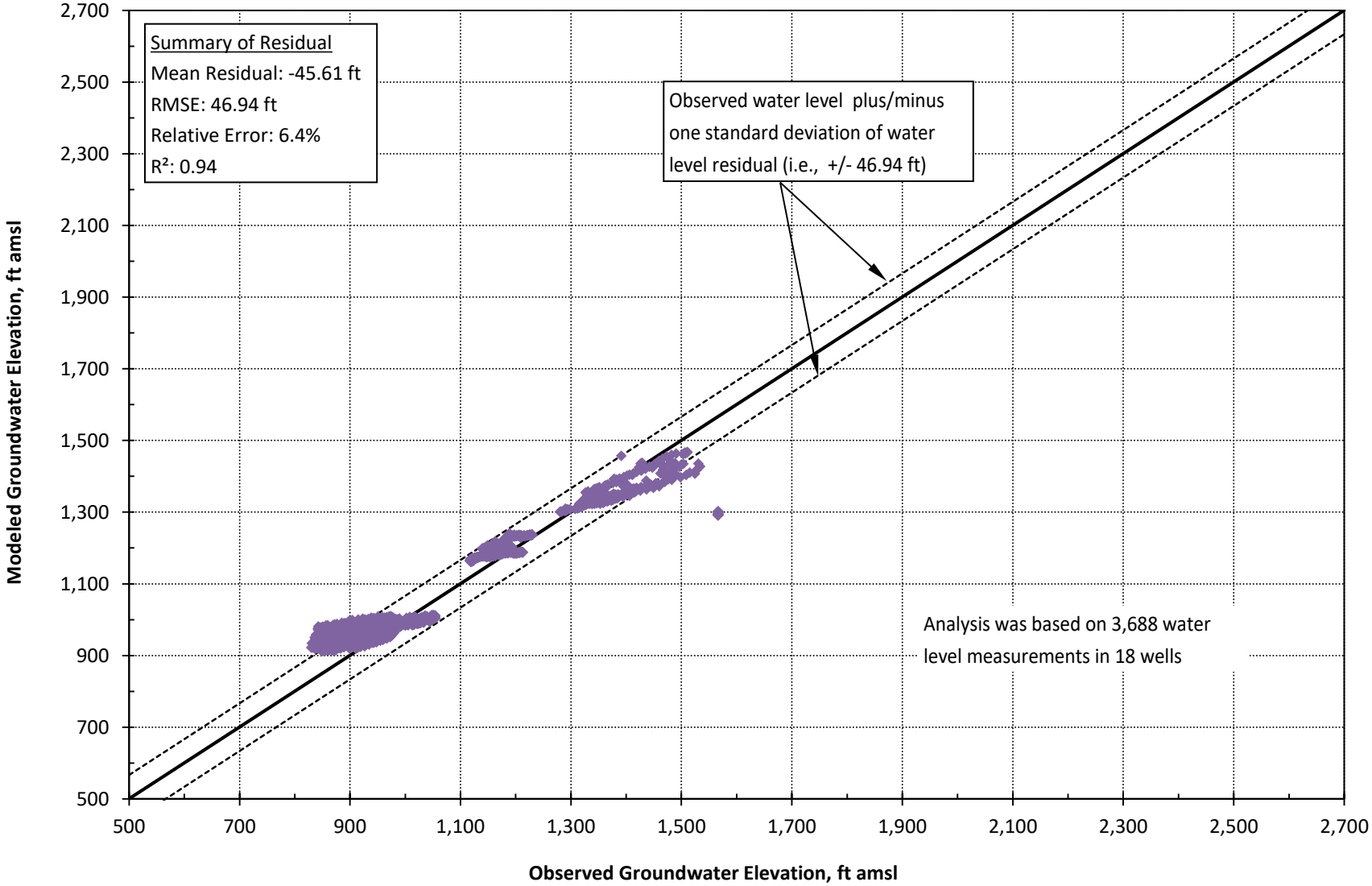

Figure 191

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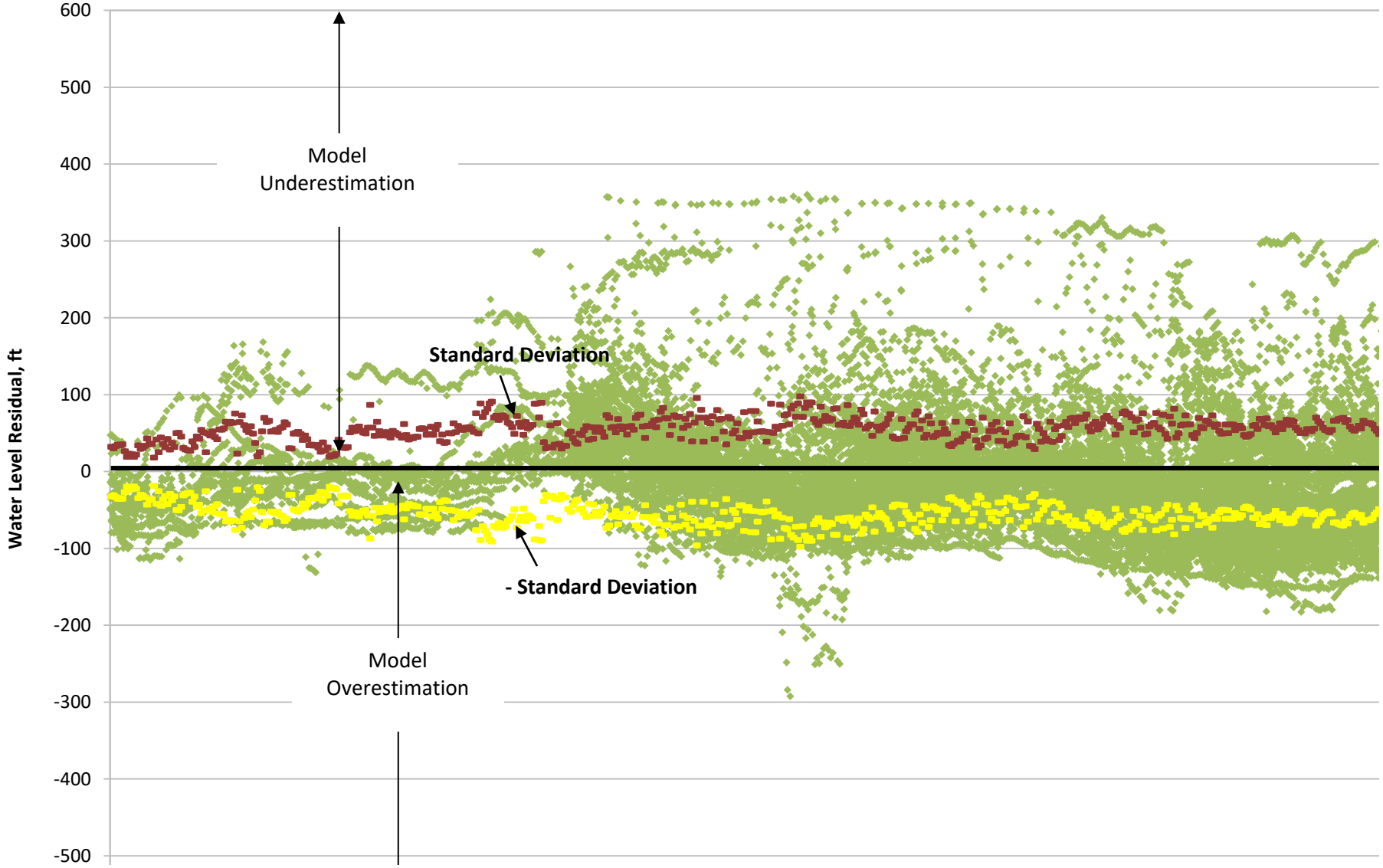
Temporal Distribution of Water Level Residuals in the SBBA - All Layers (1966 to 2016)



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Histogram of Water Level Residuals in the SBBA Basin – All Layers (1966 to 2016)

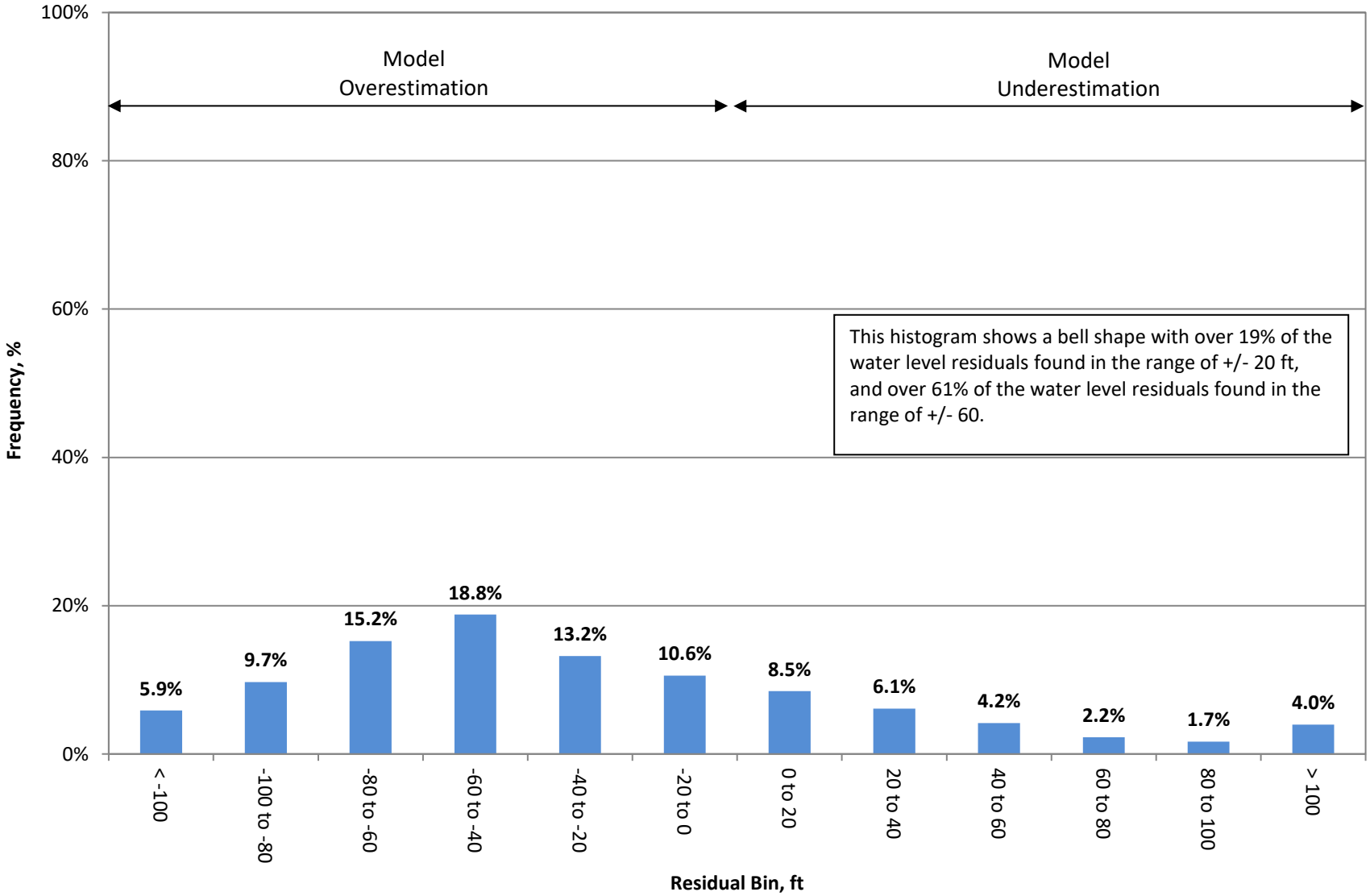
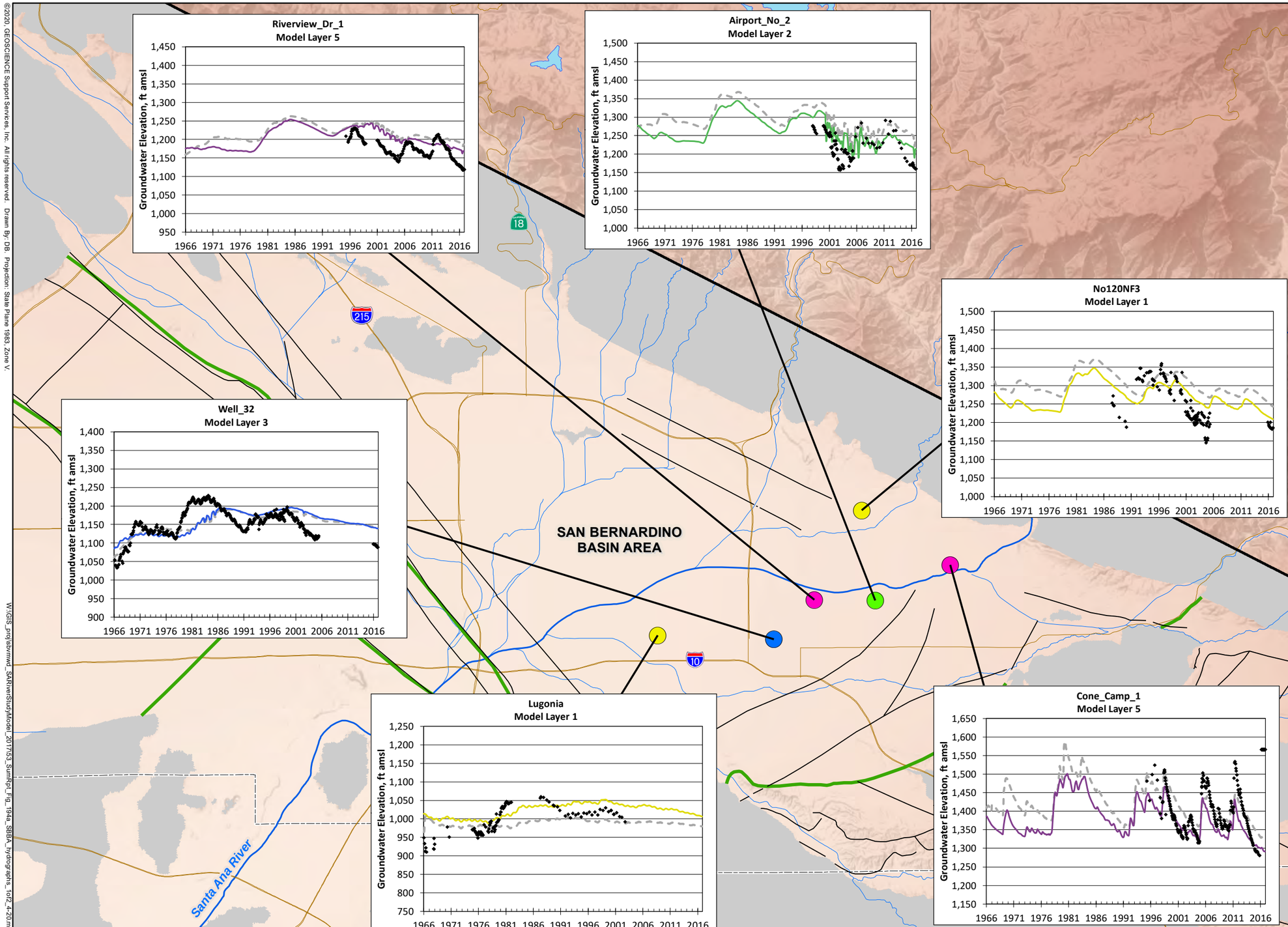


Figure 193



EXPLANATION

- Integrated SAR Model Boundary
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier

Well Model Layer

- 1
- 2
- 3
- 4
- 5

- Measured
- Updated Individual Model (Included in TM No. 1)
- Model-Calculated (colored by layer)

See Appendix C for additional hydrographs.

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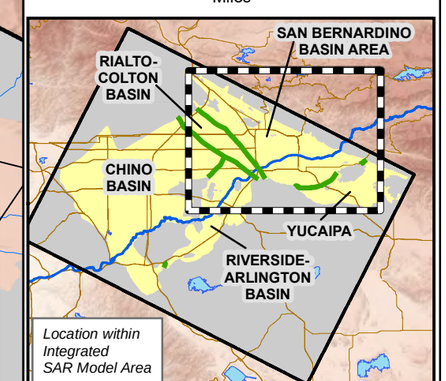

SELECTED HYDROGRAPHS IN THE SBBA MODEL AREA (1 OF 2)

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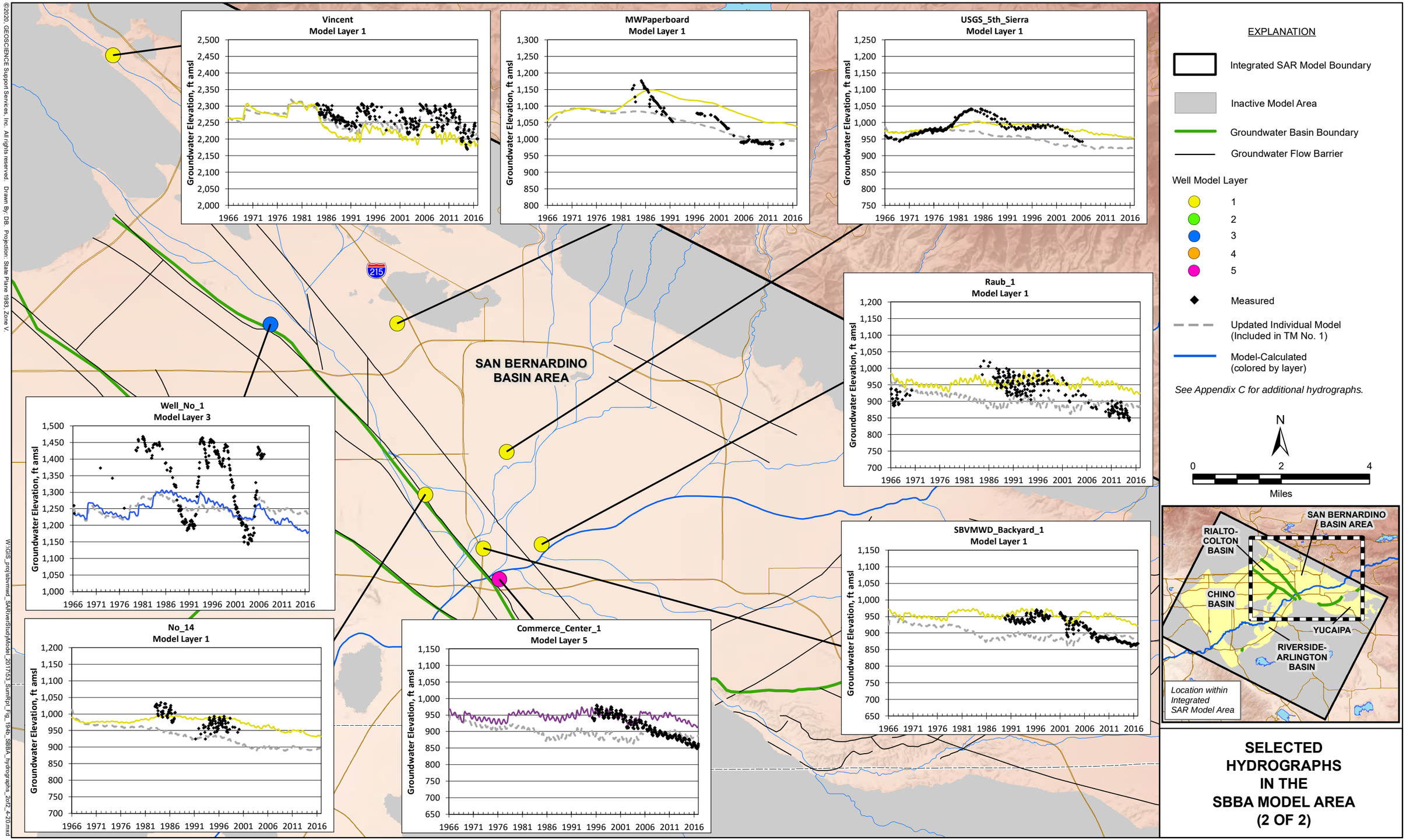

SELECTED HYDROGRAPHS IN THE SBBA MODEL AREA (2 OF 2)

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Measured vs. Model-Calculated Water Levels in Rialto-Colton Basin Model Area – All Layers (1966 to 2016)

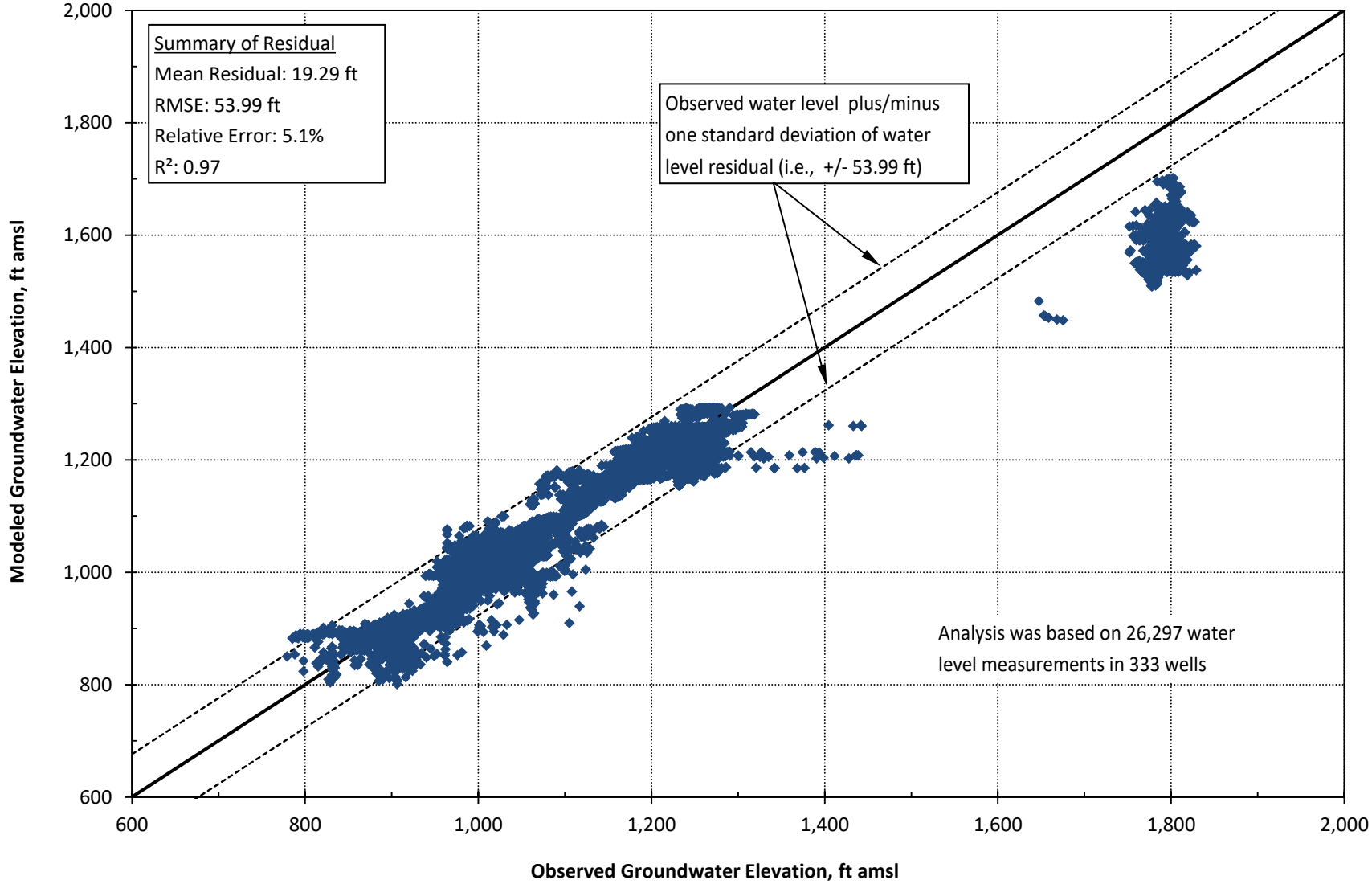

Figure 195

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Measured vs. Model-Calculated Water Levels in Rialto-Colton Basin – Layer 1 (1966 to 2016)

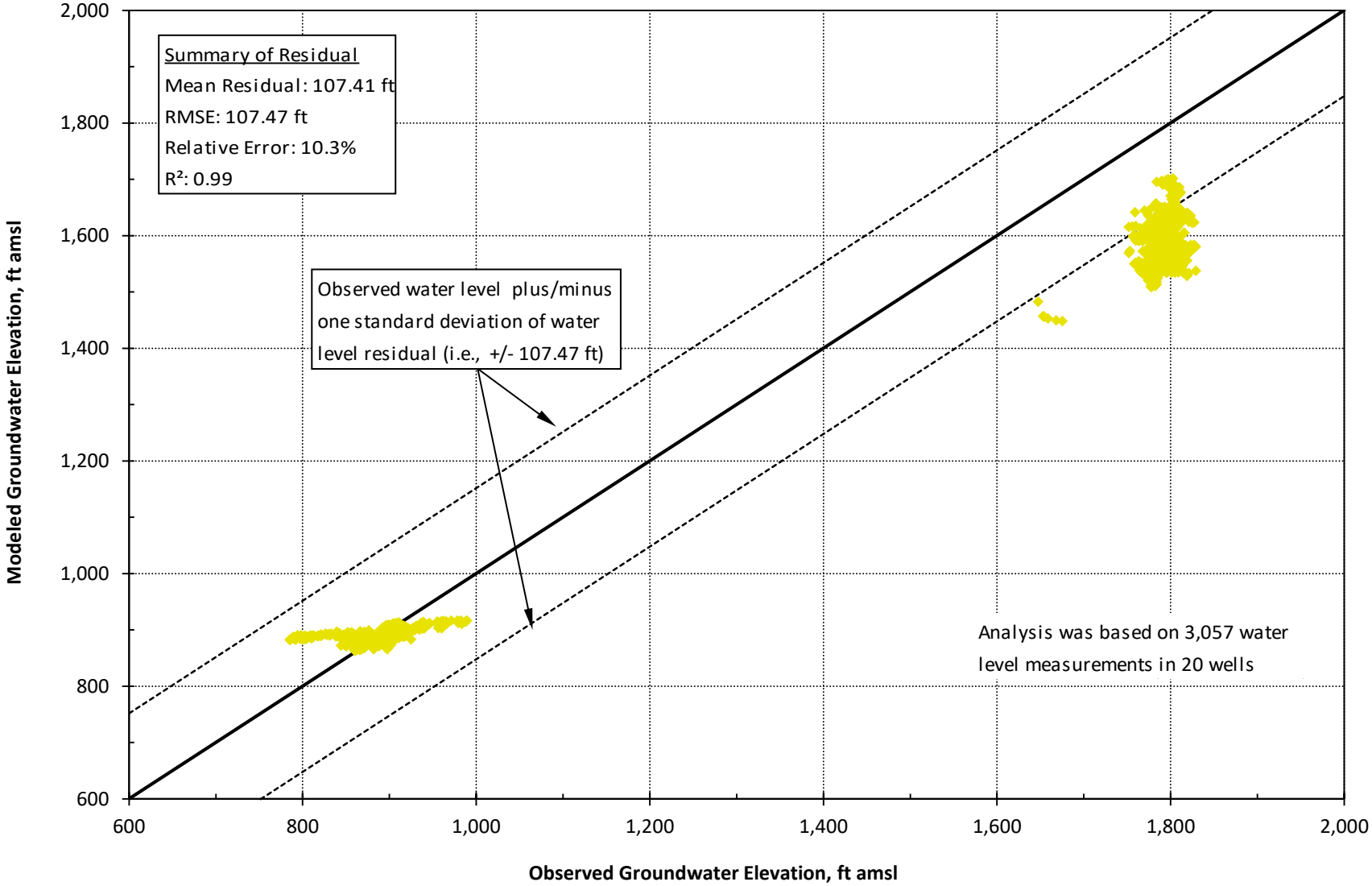

Figure 196

Measured vs. Model-Calculated Water Levels in Rialto-Colton Basin – Layer 2 (1966 to 2016)

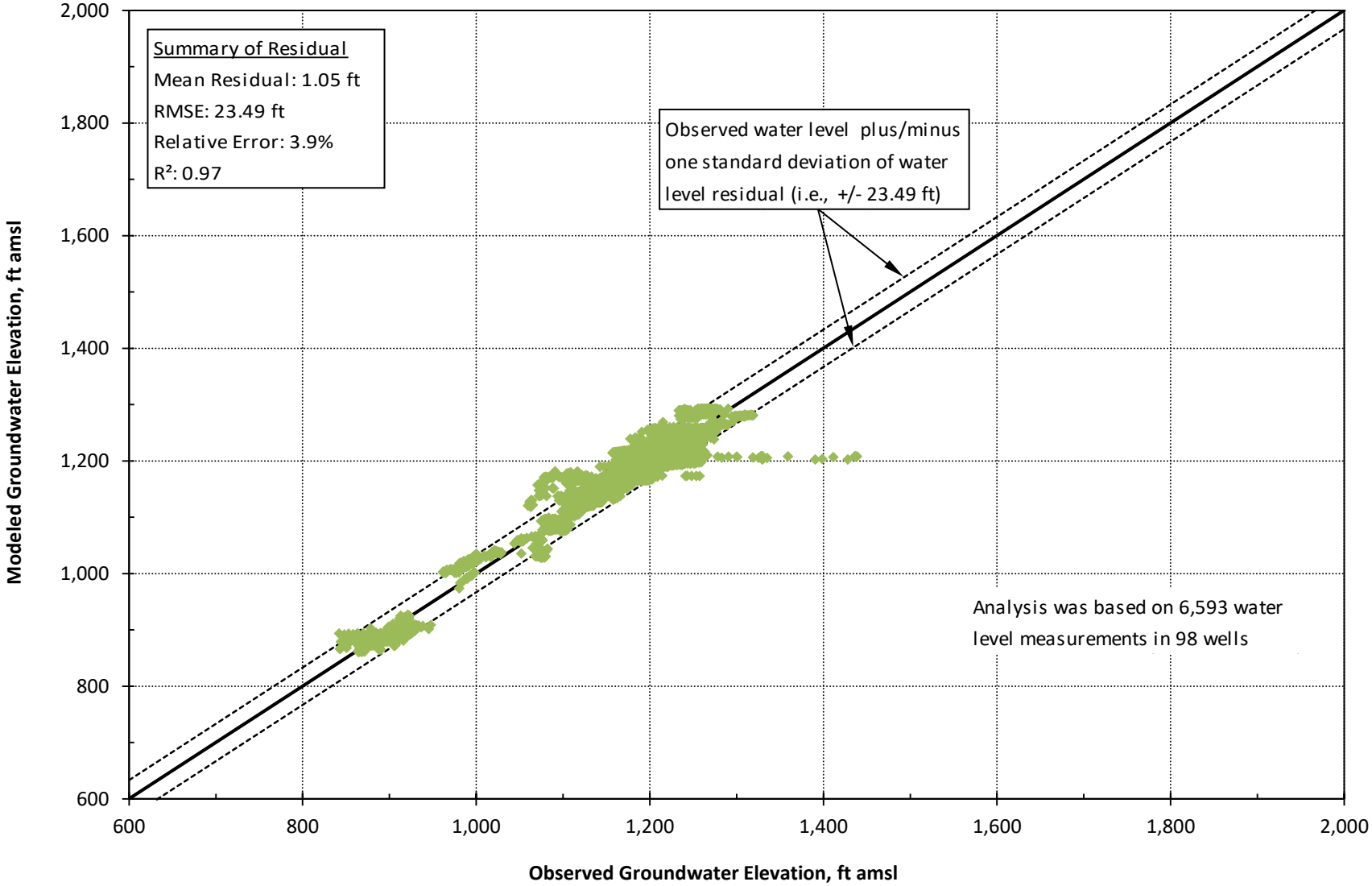

Figure 197

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Measured vs. Model-Calculated Water Levels in Rialto-Colton Basin – Layer 3 (1966 to 2016)

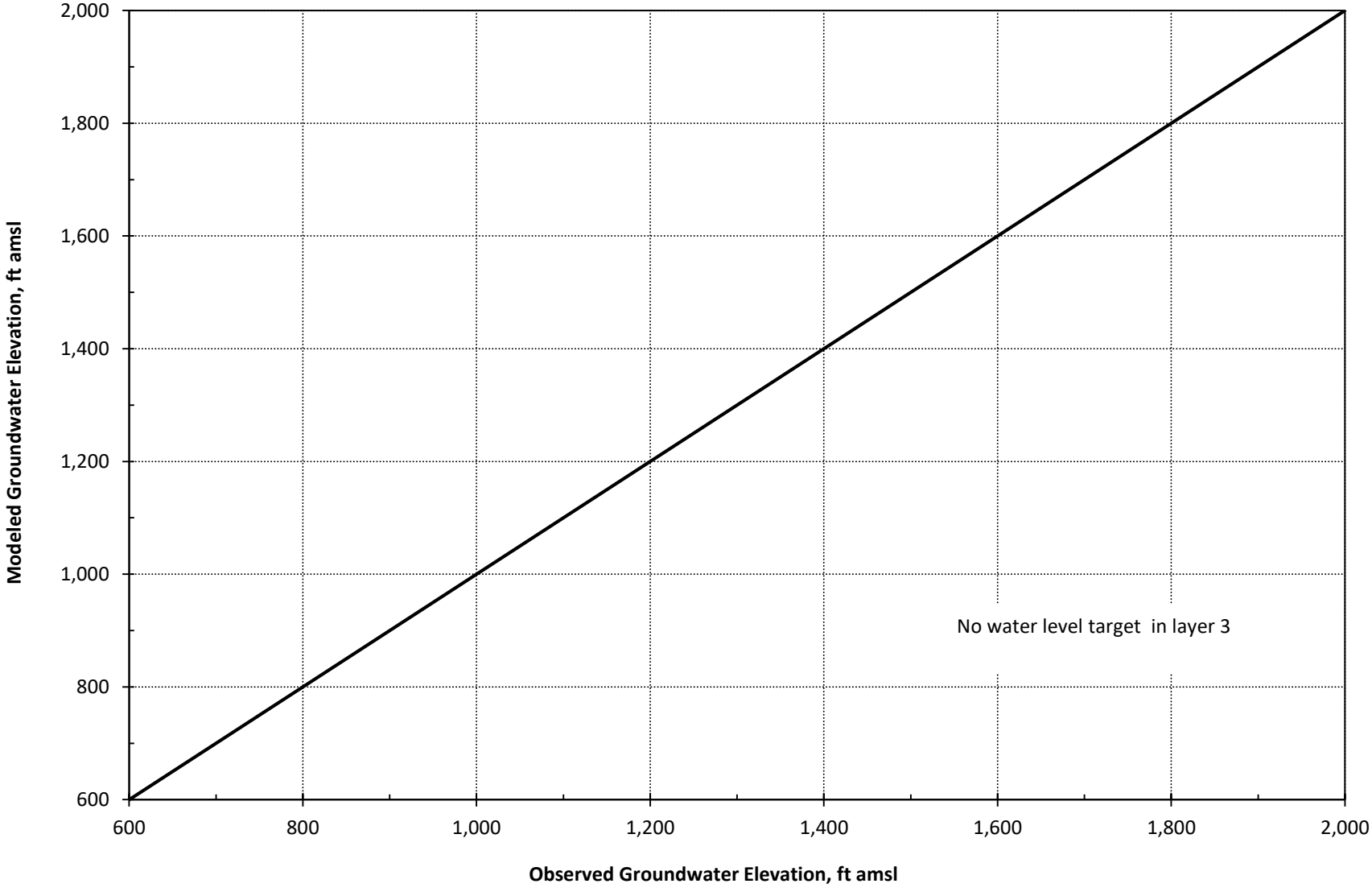

Figure 198

Measured vs. Model-Calculated Water Levels in Rialto-Colton Basin – Layer 4 (1966 to 2016)

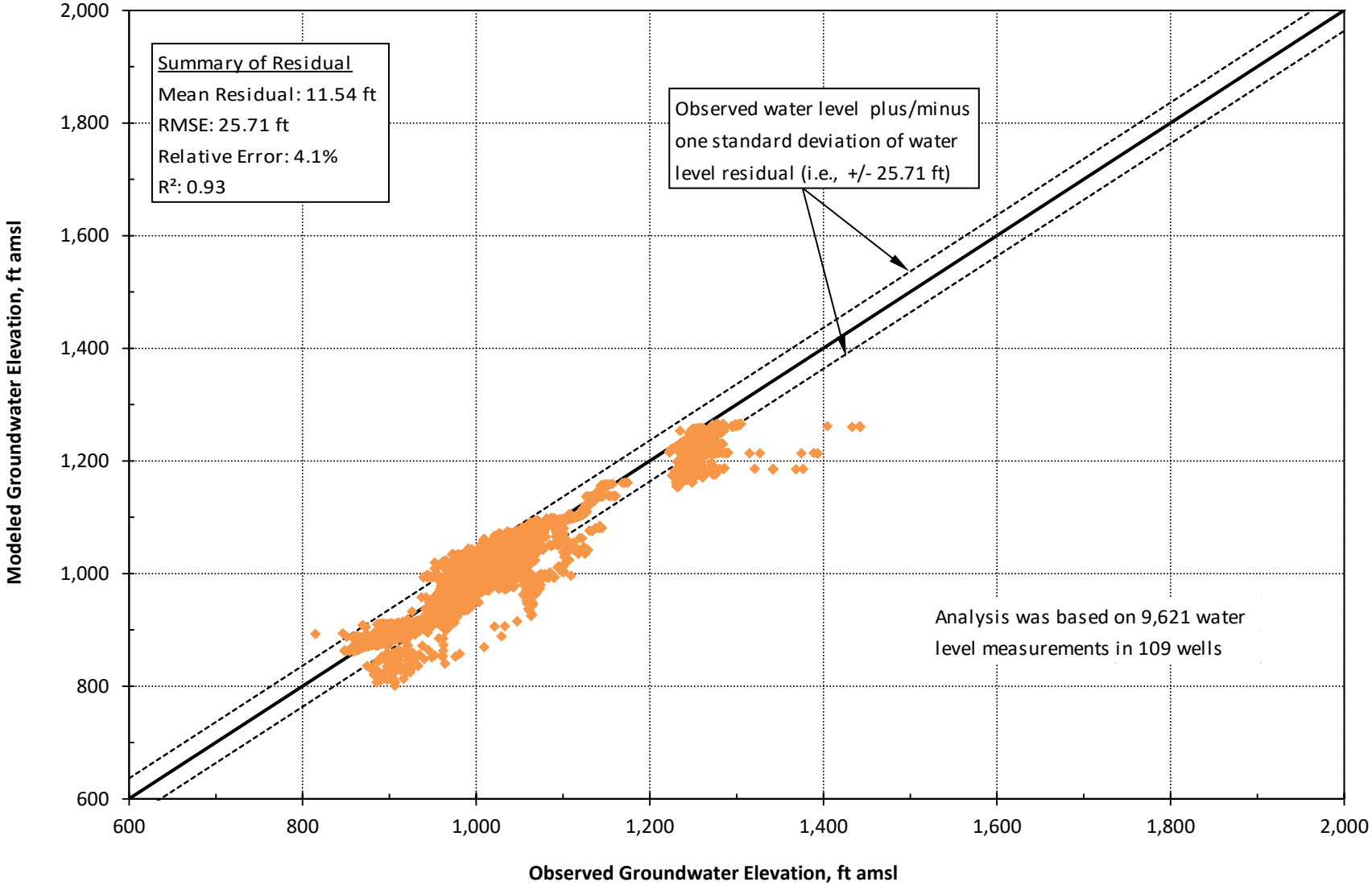

Figure 199

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Measured vs. Model-Calculated Water Levels in Rialto-Colton Basin – Layer 5 (1966 to 2016)

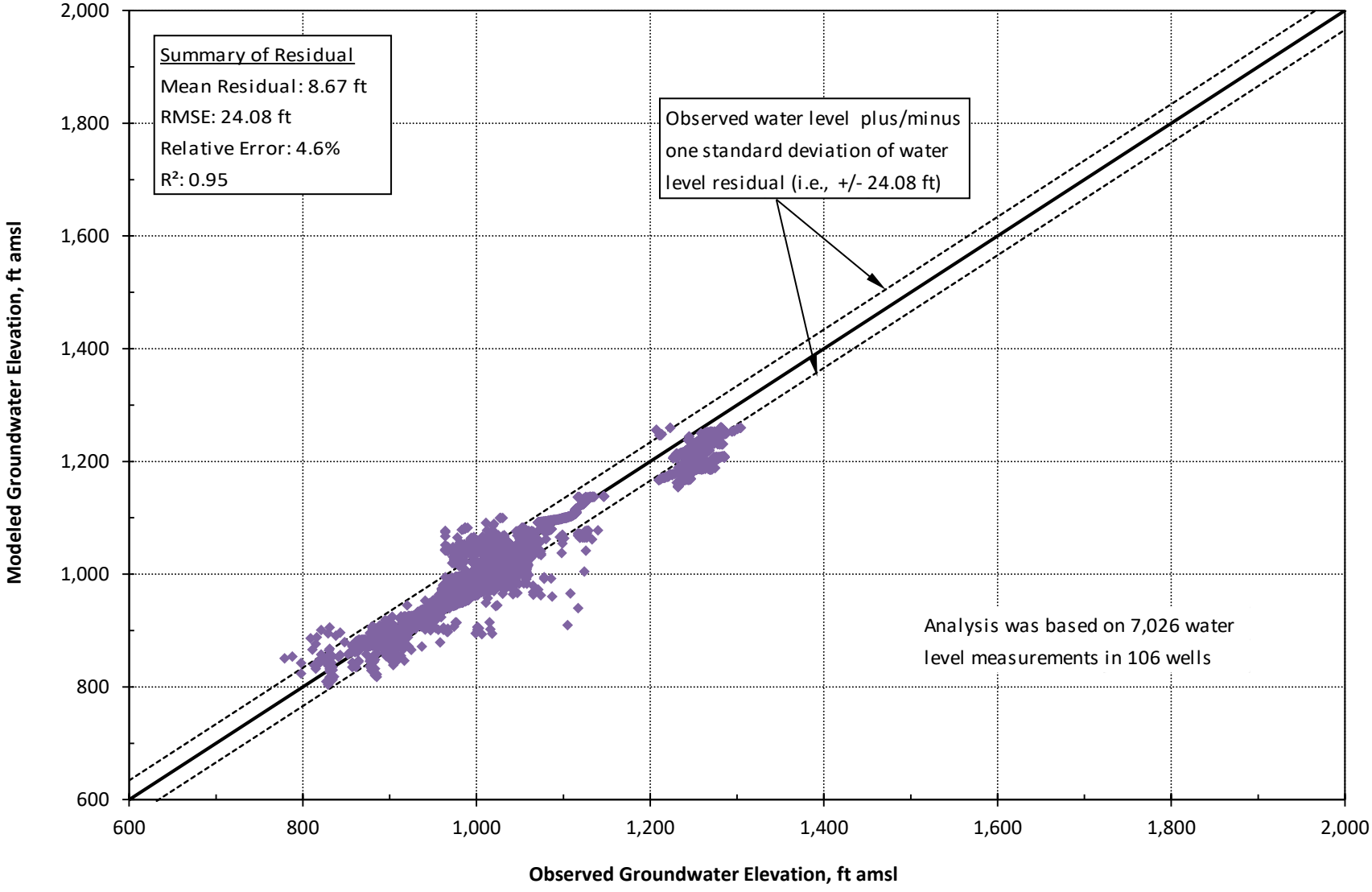

Figure 200

Temporal Distribution of Water Level Residuals in Rialto-Colton Basin – All Layers (1966 to 2016)

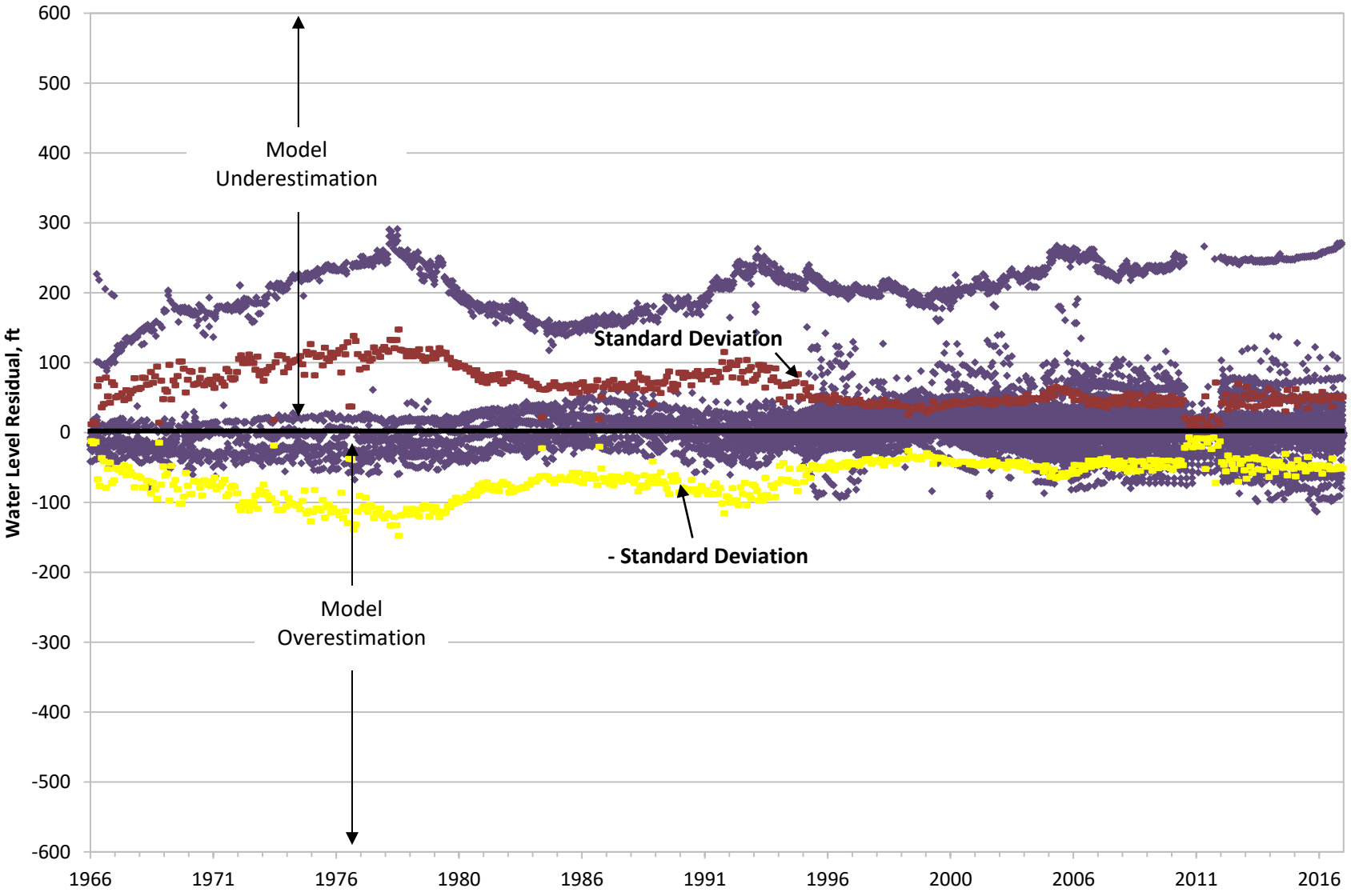

Figure 201

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Histogram of Water Level Residuals in Rialto-Colton Basin – All Layers (1966 to 2016)

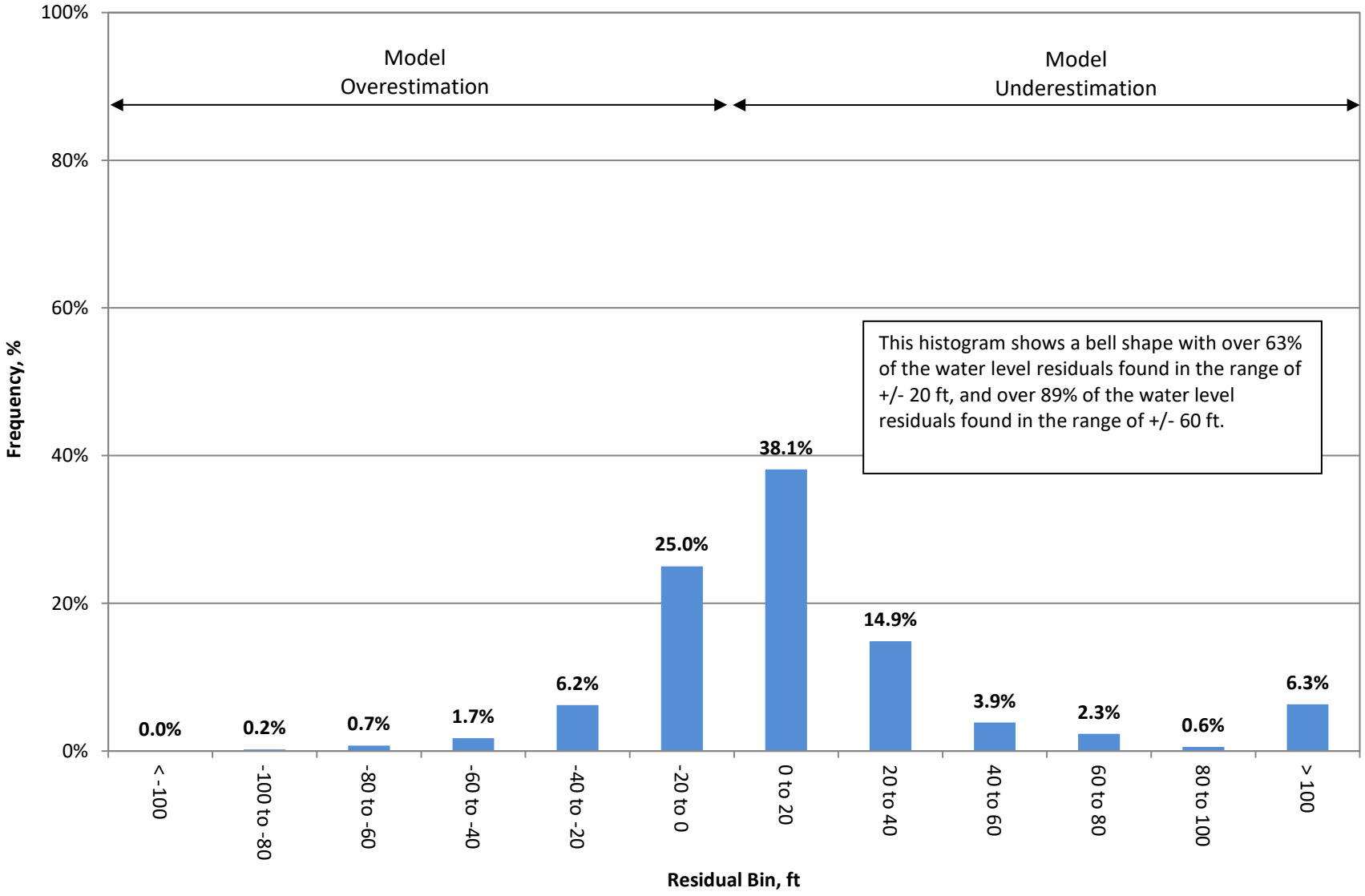

Figure 202

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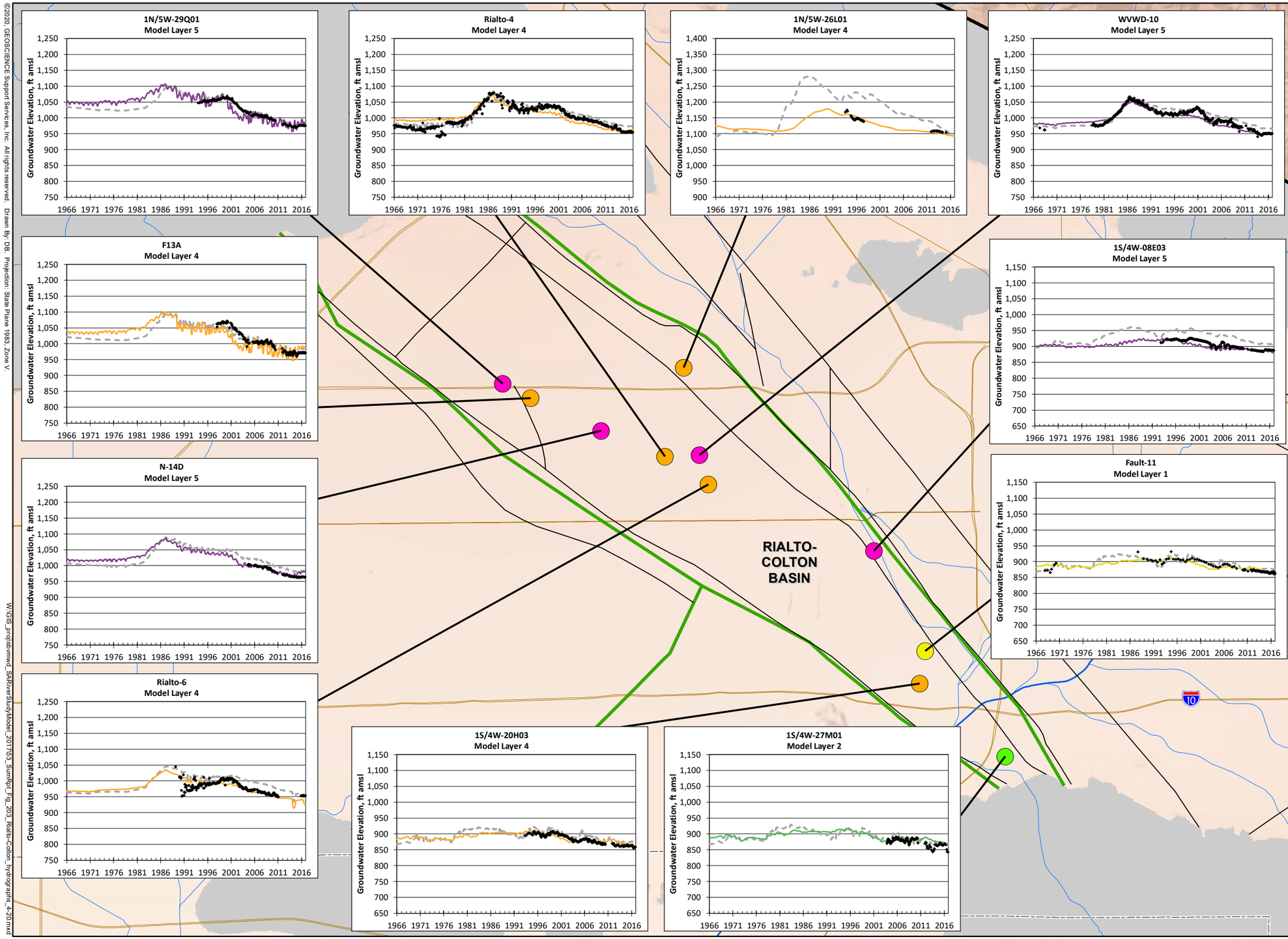

EXPLANATION

- Integrated SAR Model Boundary
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier

Well Model Layer

- 1
- 2
- 3
- 4
- 5

- Measured
- Updated Individual Model (Included in TM No. 1)
- Model-Calculated (colored by layer)

See Appendix D for additional hydrographs.

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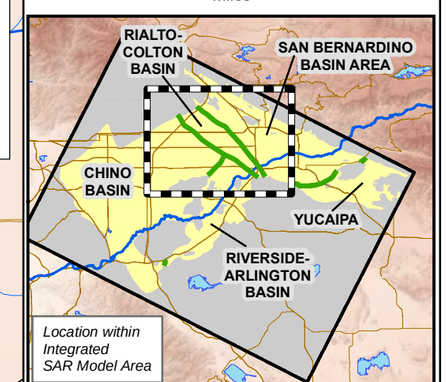

SELECTED HYDROGRAPHS IN THE RIALTO-COLTON MODEL AREA

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 203

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Measured vs. Model-Calculated Water Levels in Riverside-Arlington Basin Model Area – All Layers (1966 to 2016)

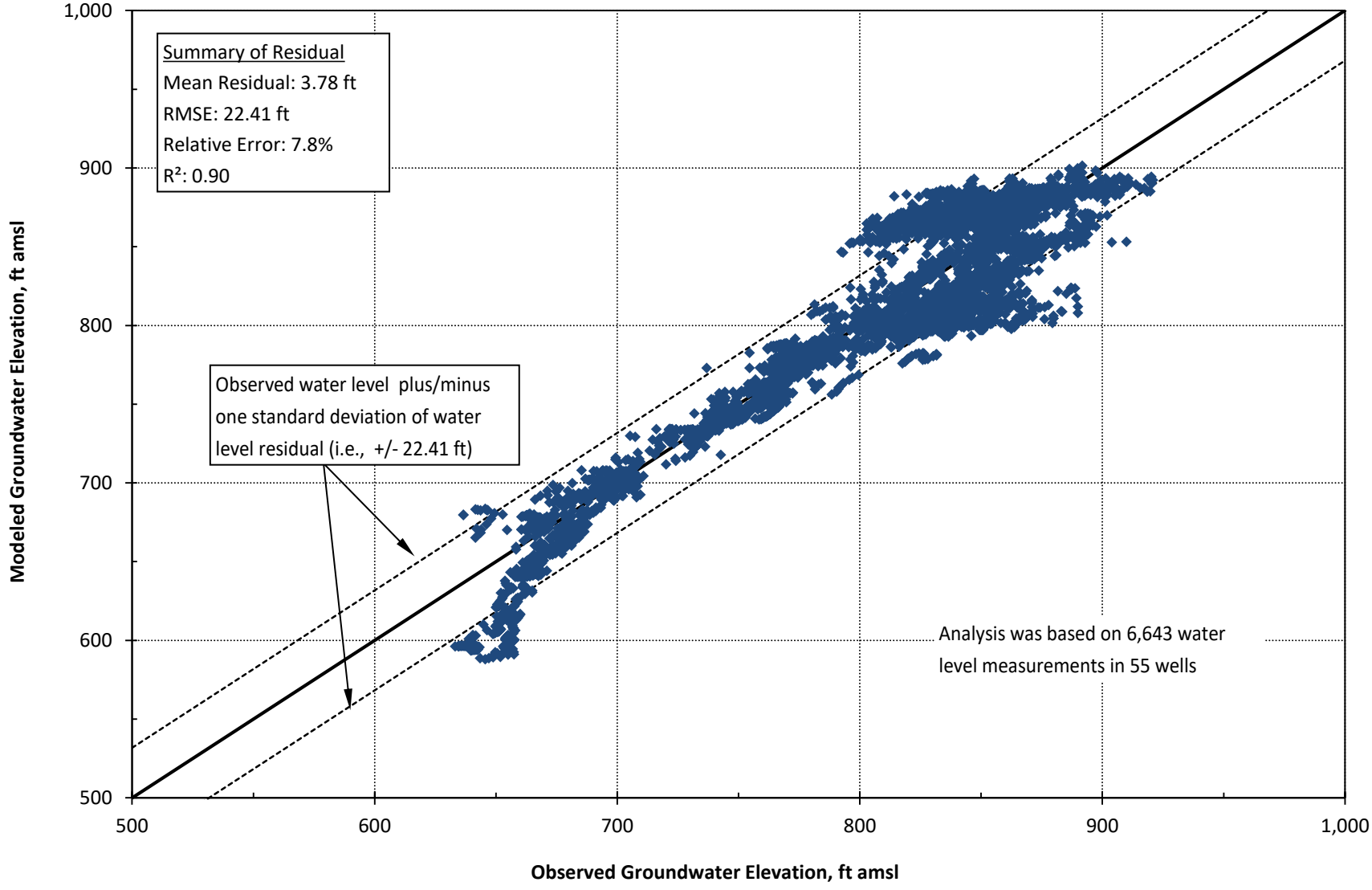

Figure 204

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Measured vs. Model-Calculated Water Levels in Riverside-Arlington Basin – Layer 1 (1966 to 2016)

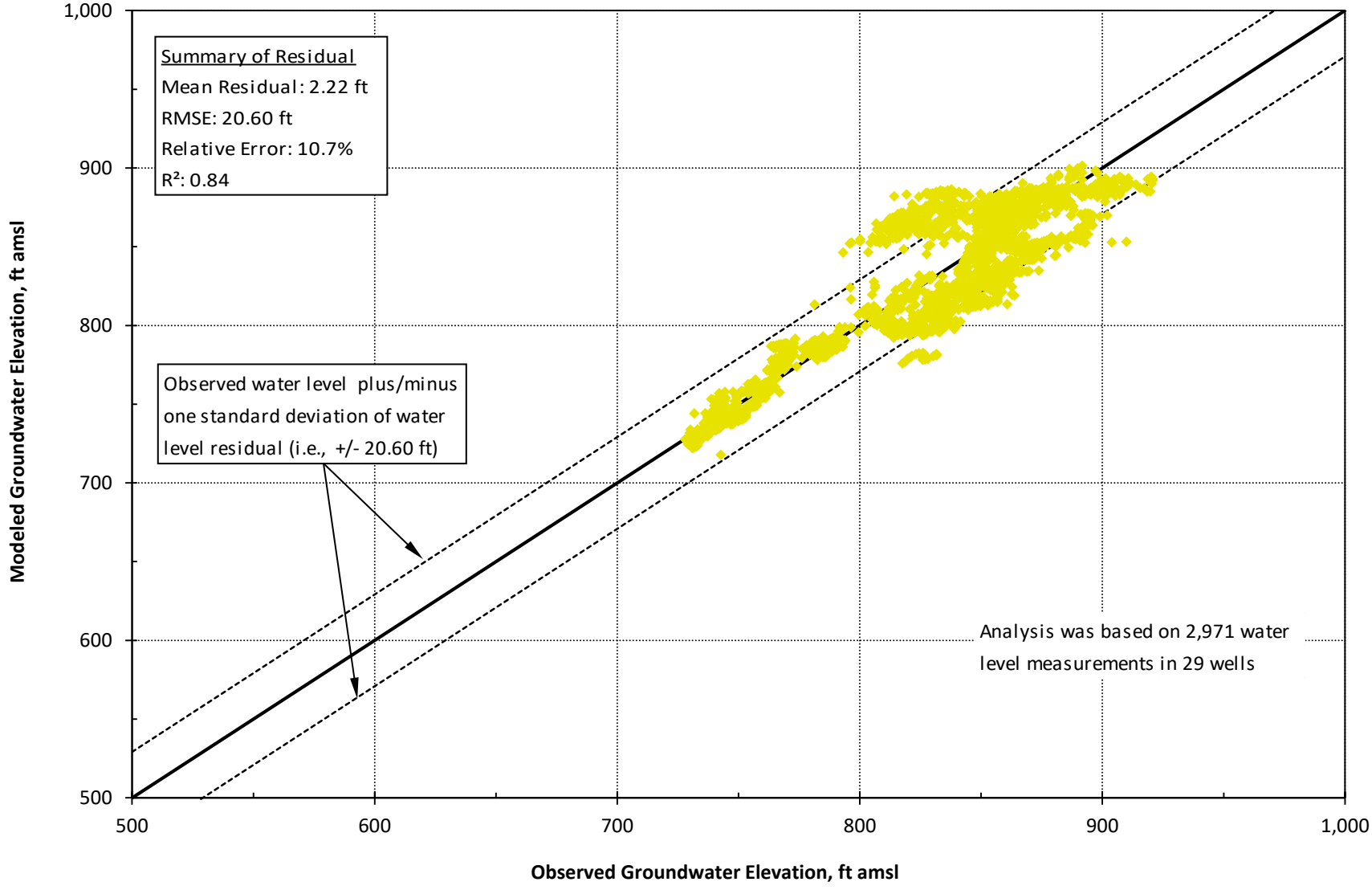

Figure 205

Measured vs. Model-Calculated Water Levels in Riverside-Arlington Basin – Layer 2 (1966 to 2016)

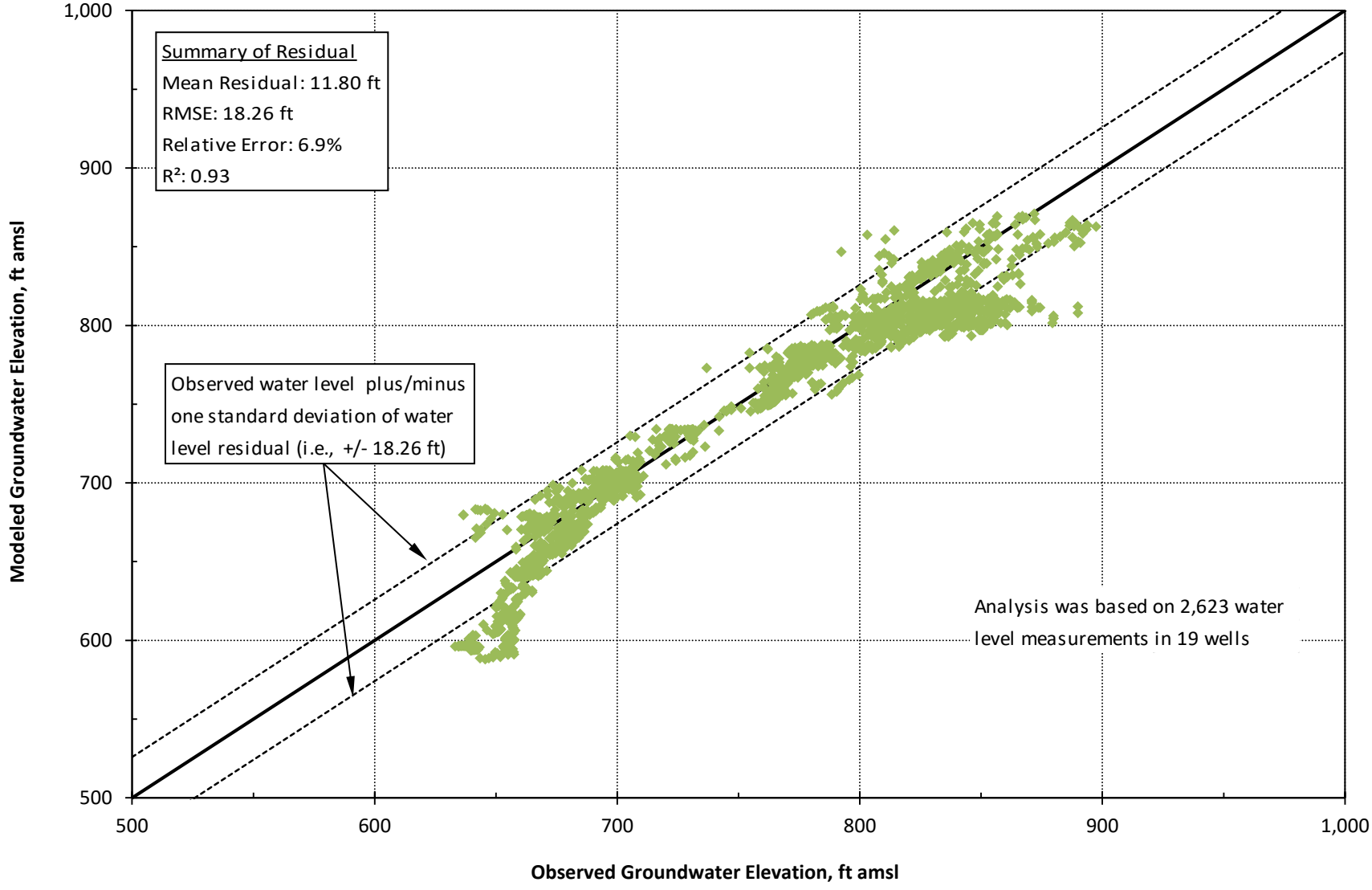

Figure 206

Measured vs. Model-Calculated Water Levels in Riverside-Arlington Basin – Layer 3 (1966 to 2016)

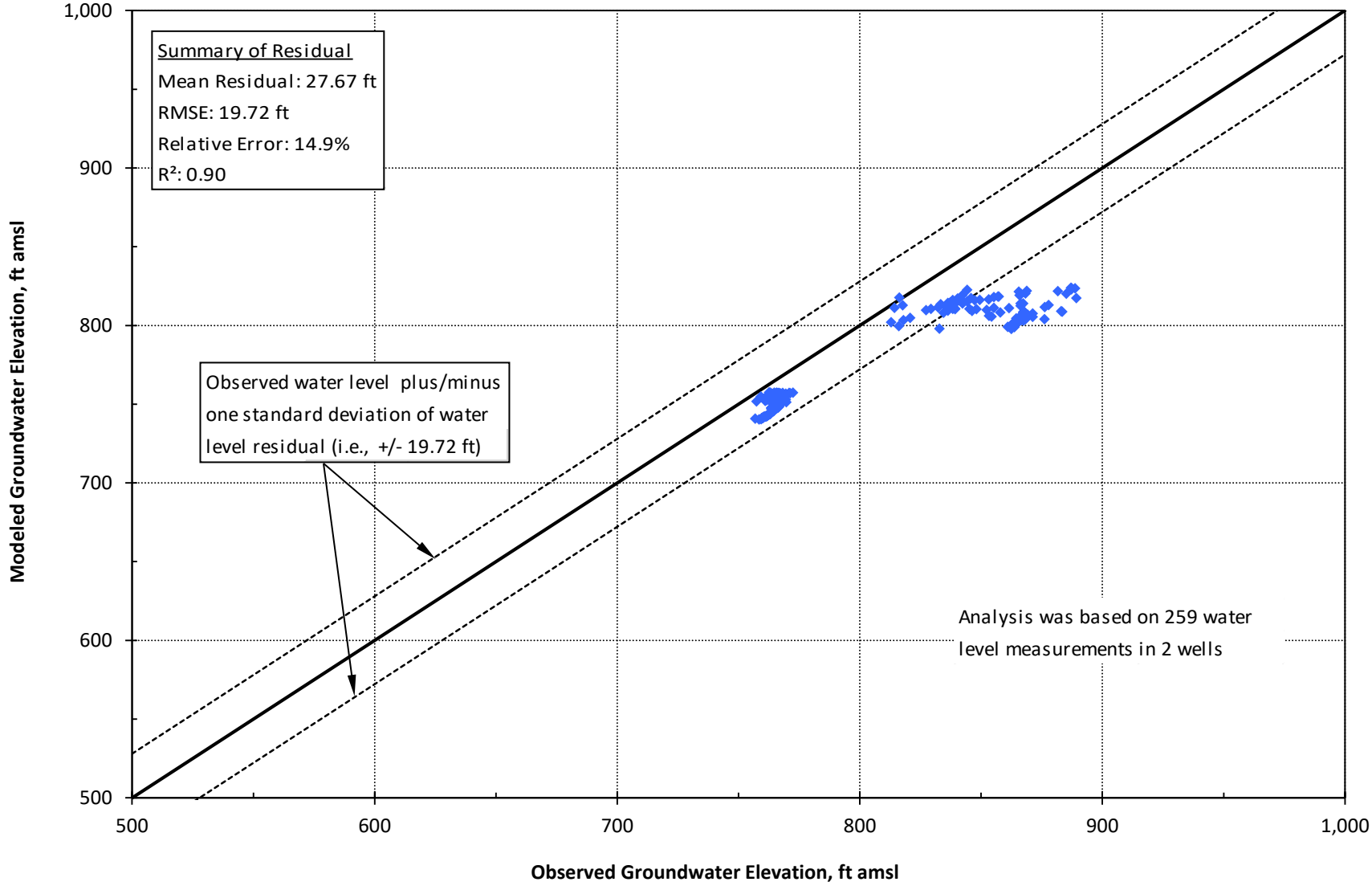

Figure 207

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Measured vs. Model-Calculated Water Levels in Riverside-Arlington Basin – Layer 4 (1966 to 2016)

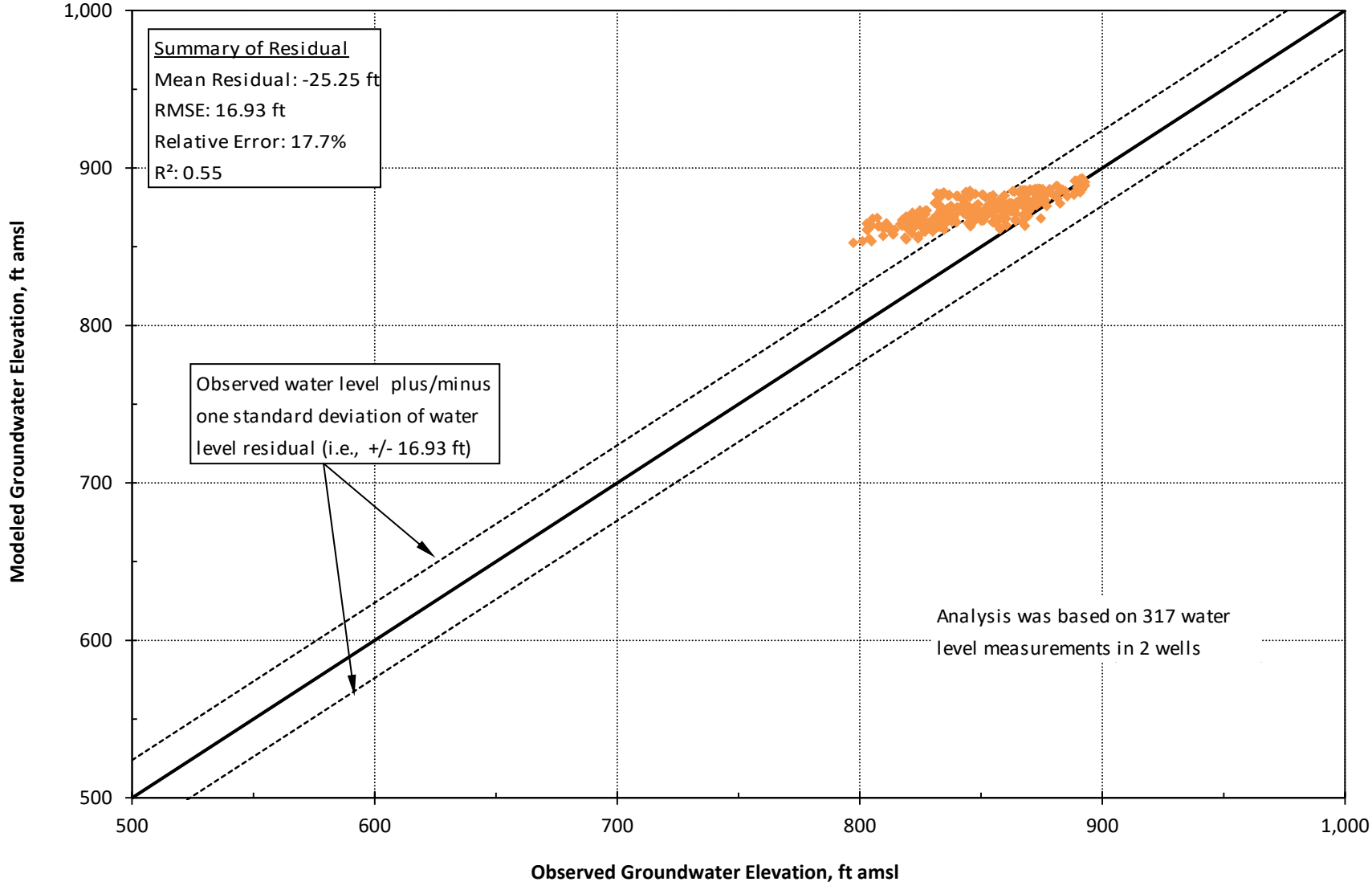

Figure 208

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Measured vs. Model-Calculated Water Levels in Riverside-Arlington Basin – Layer 5 (1966 to 2016)

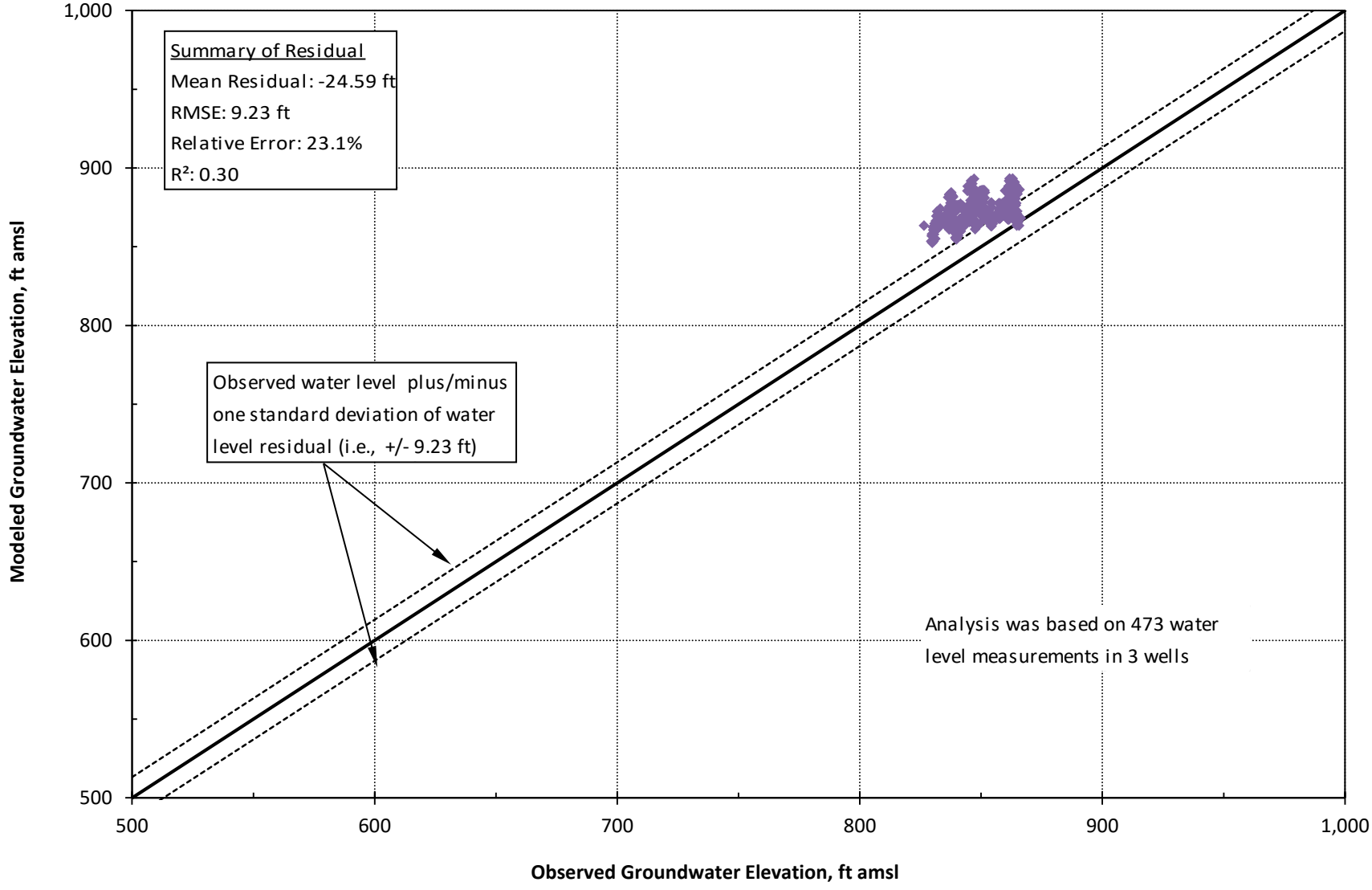

Figure 209

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Temporal Distribution of Water Level Residuals in Riverside-Arlington Basin – All Layers (1966 to 2016)

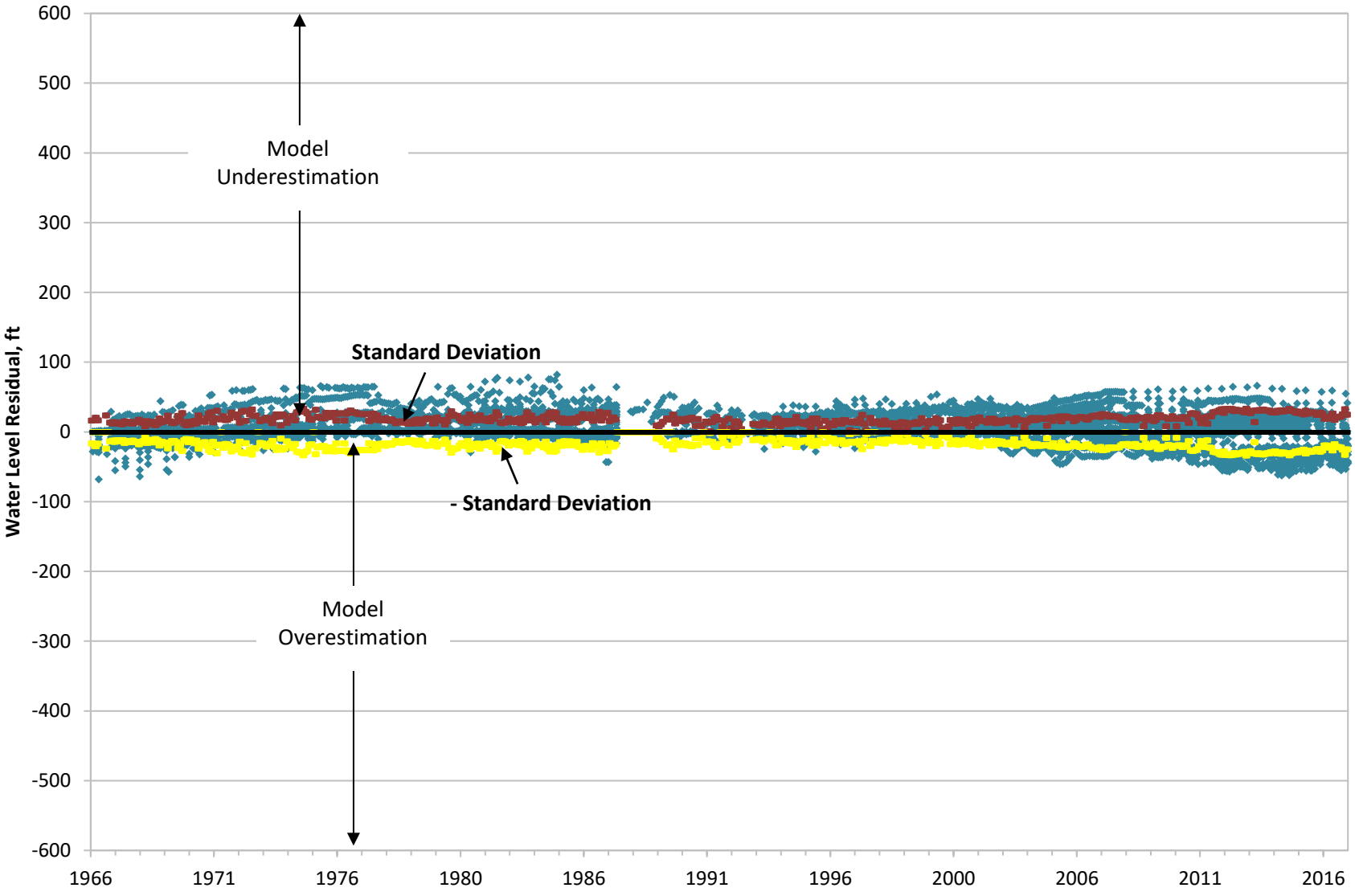

Figure 210

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Histogram of Water Level Residuals in Riverside-Arlington Basin – All Layers (1966 to 2016)

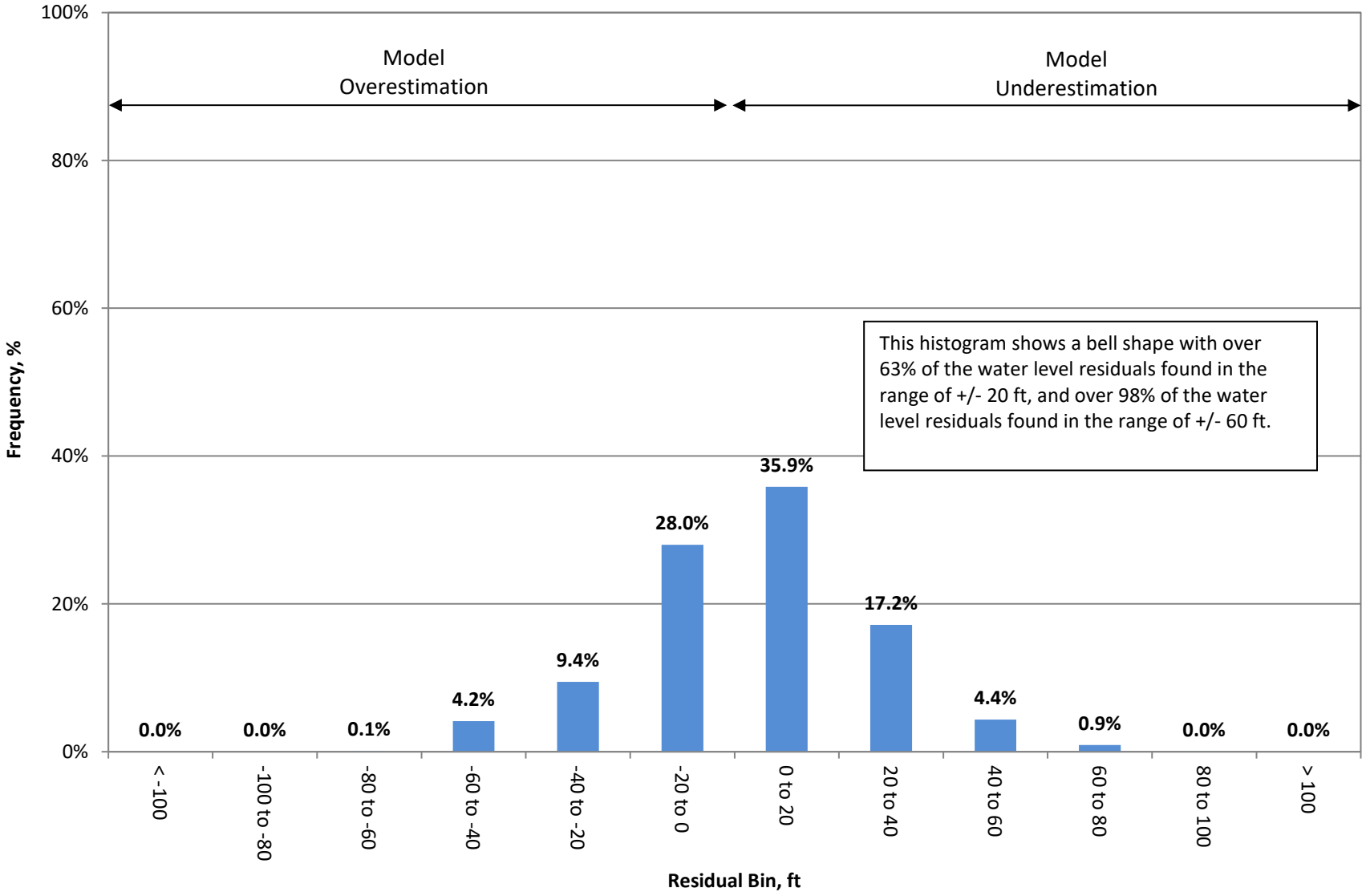
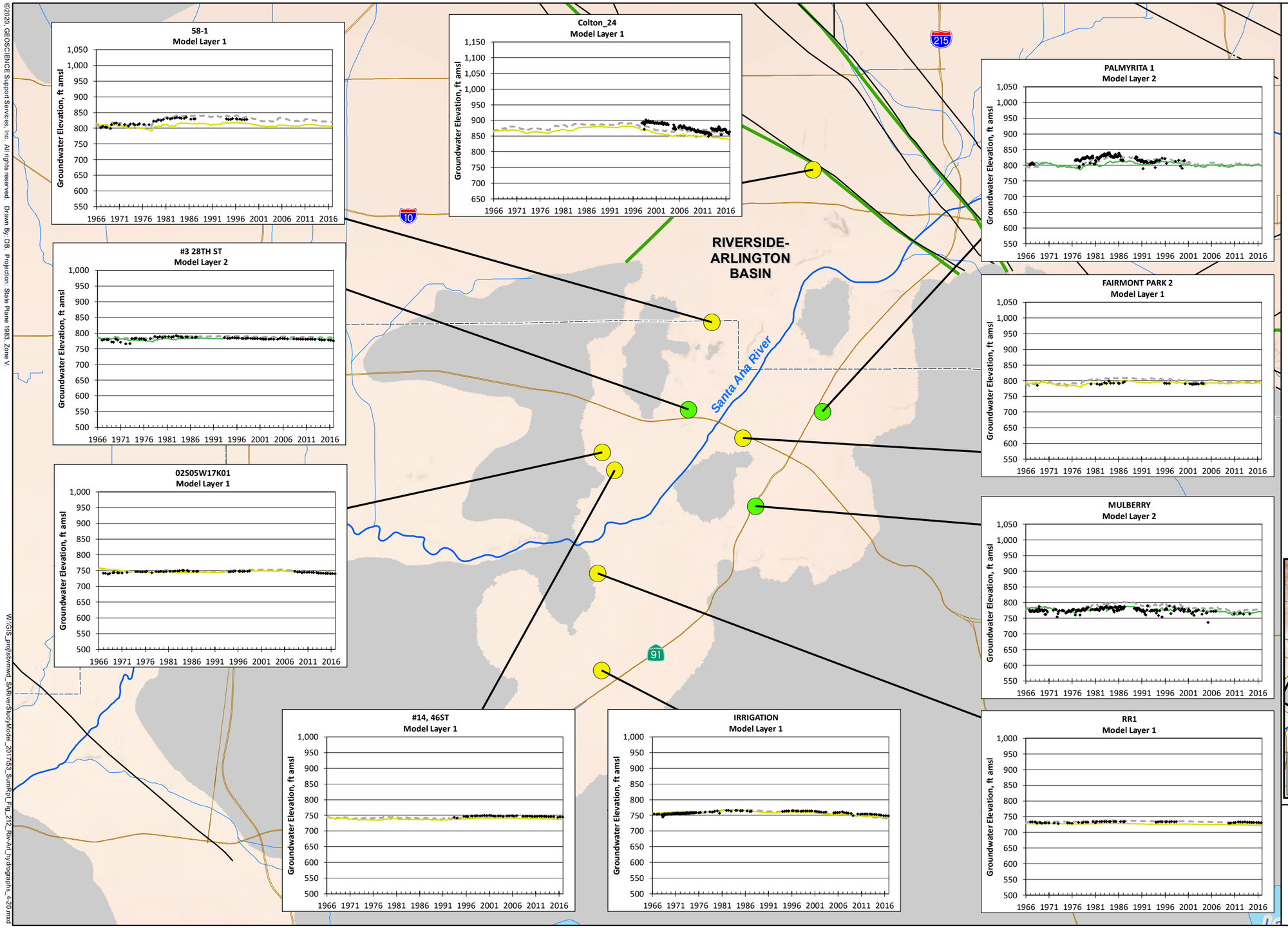


Figure 211



EXPLANATION

- Integrated SAR Model Boundary
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier

Well Model Layer

- 1
- 2
- 3
- 4
- 5

- Measured
- Updated Individual Model (Included in TM No. 1)
- Model-Calculated (colored by layer)

See Appendix E for additional hydrographs.

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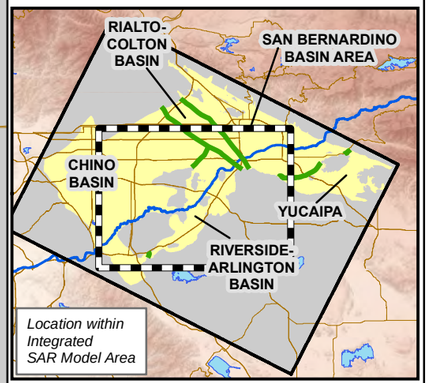

SELECTED HYDROGRAPHS IN THE RIVERSIDE-ARLINGTON BASIN MODEL AREA

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Measured vs. Model-Calculated Water Levels in the Chino Basin Model Area – All Layers (1966 to 2016)

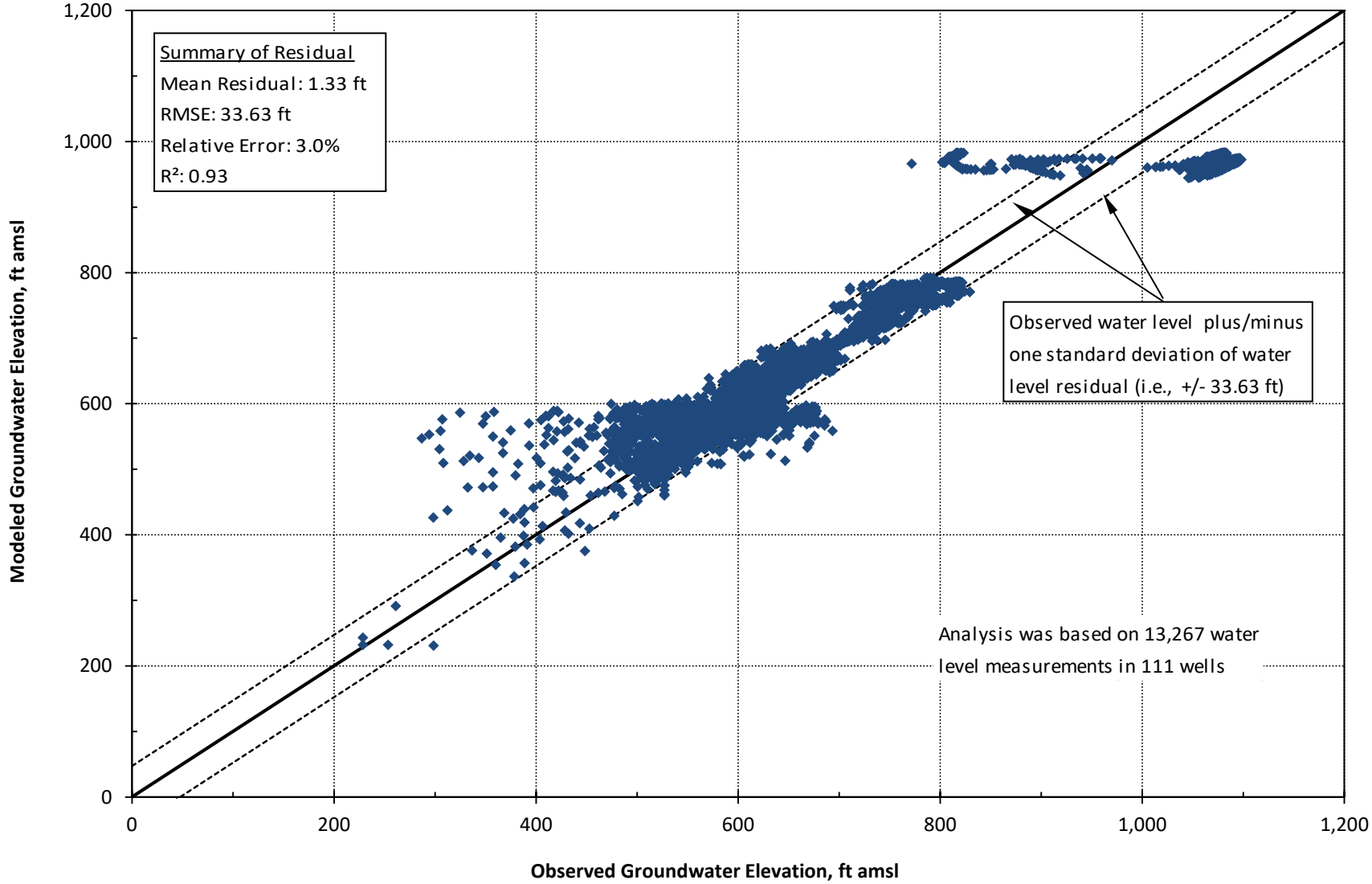

Figure 213

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Measured vs. Model-Calculated Water Levels in Chino Basin – Layer 1 (1966 to 2016)

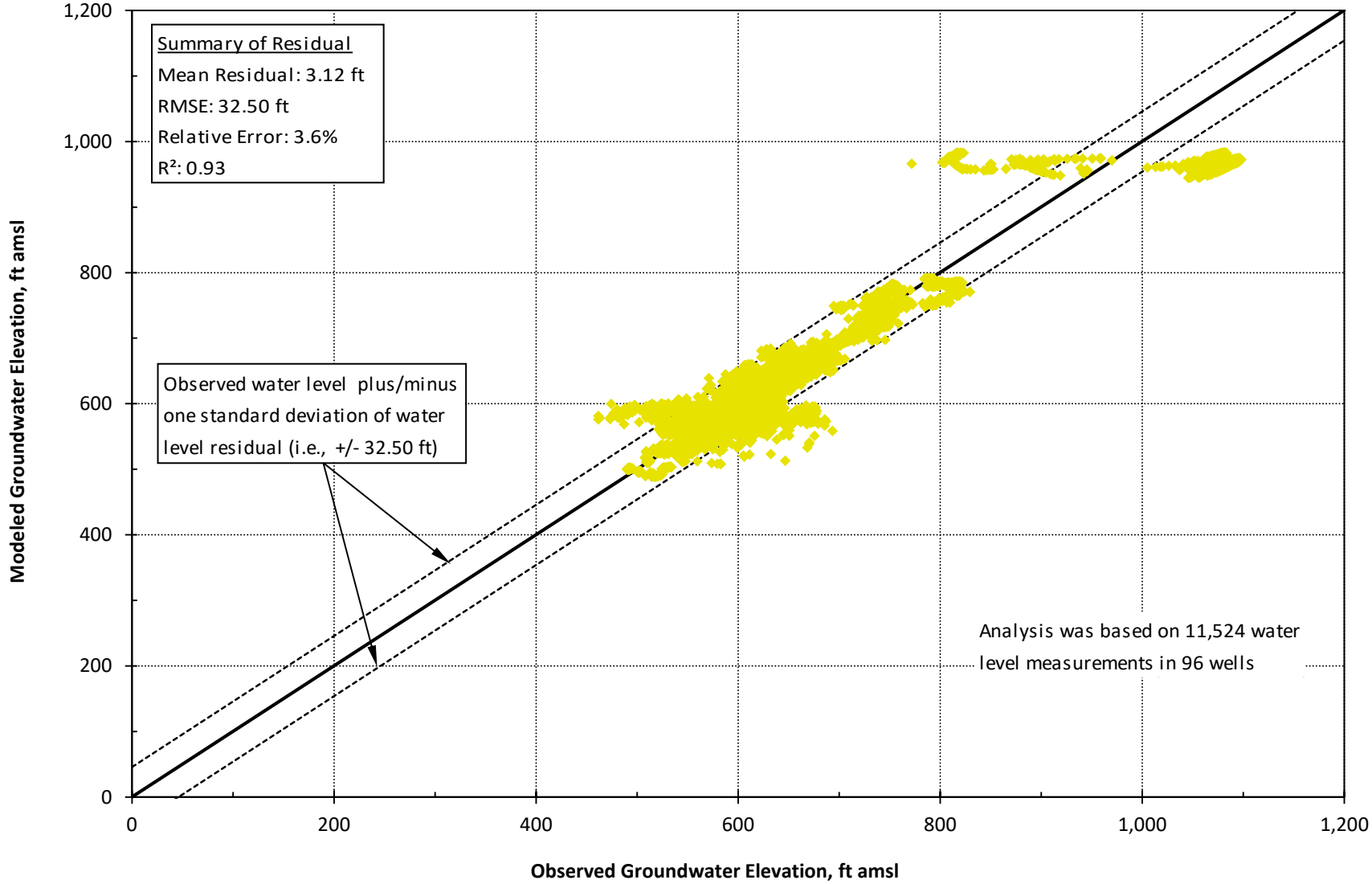

Figure 214

Measured vs. Model-Calculated Water Levels in Chino Basin – Layer 2 (1966 to 2016)

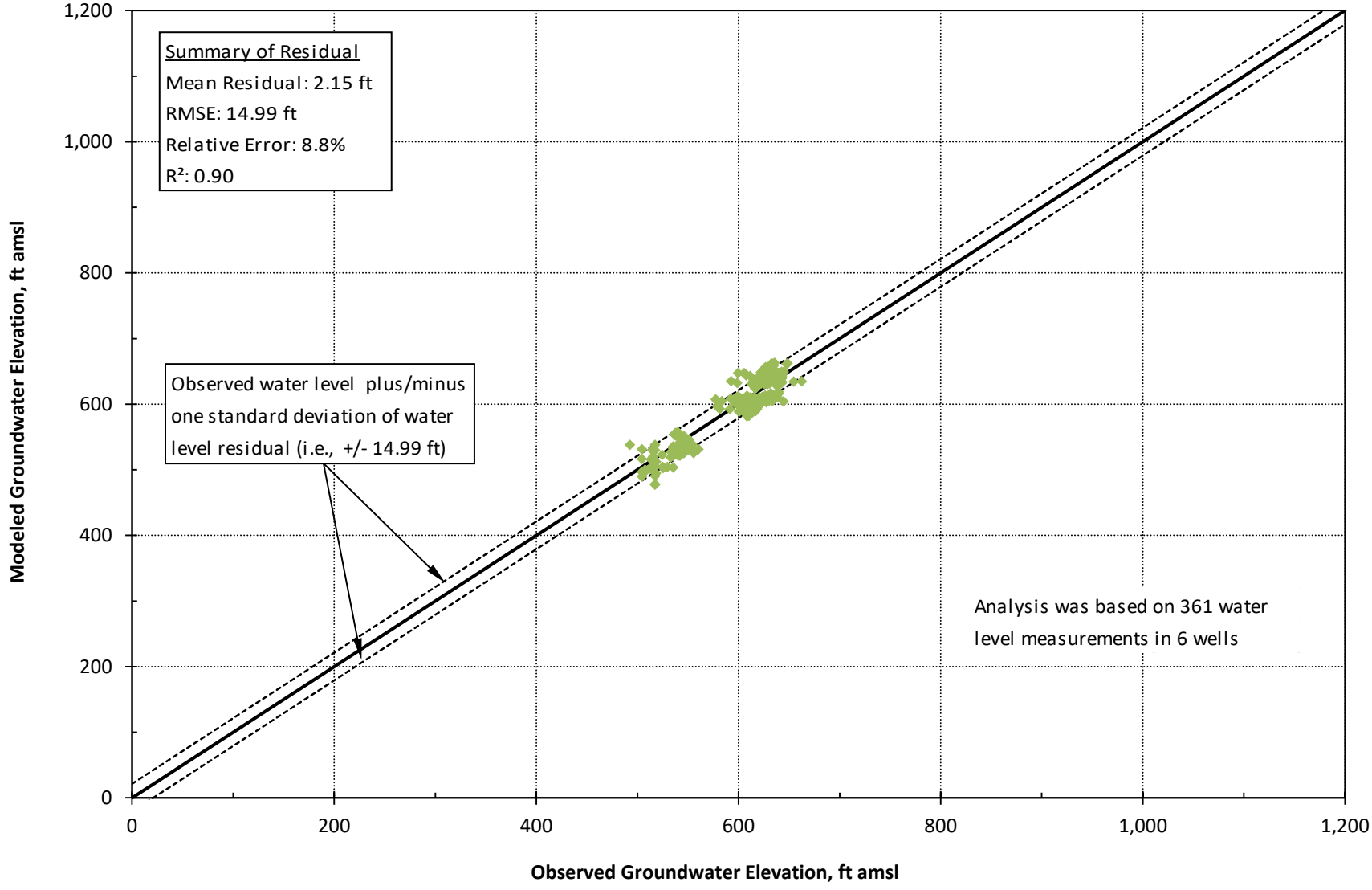

Figure 215

Measured vs. Model-Calculated Water Levels in Chino Basin – Layer 3 (1966 to 2016)

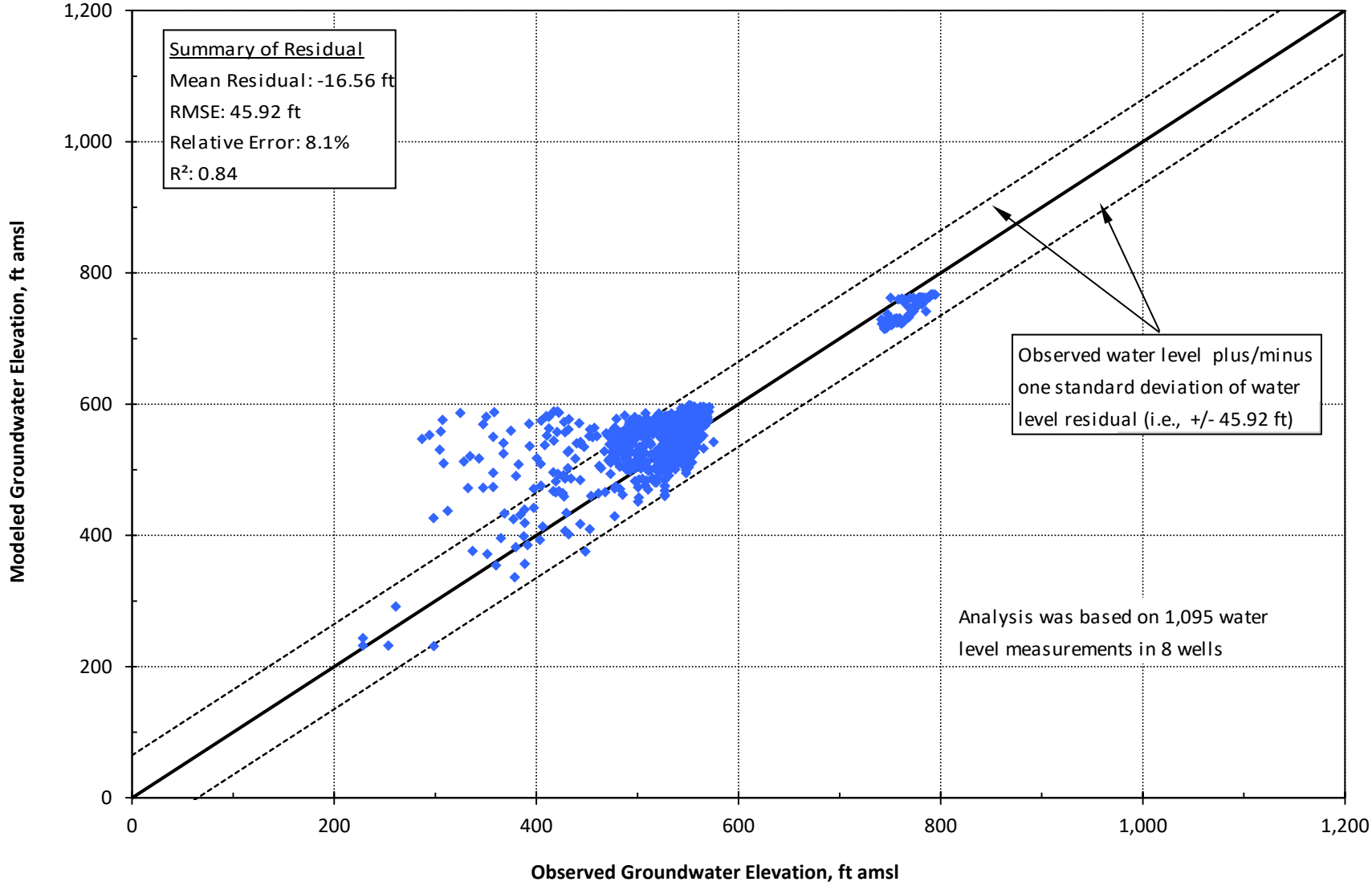

Figure 216

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Measured vs. Model-Calculated Water Levels in Chino Basin – Layer 4 (1966 to 2016)

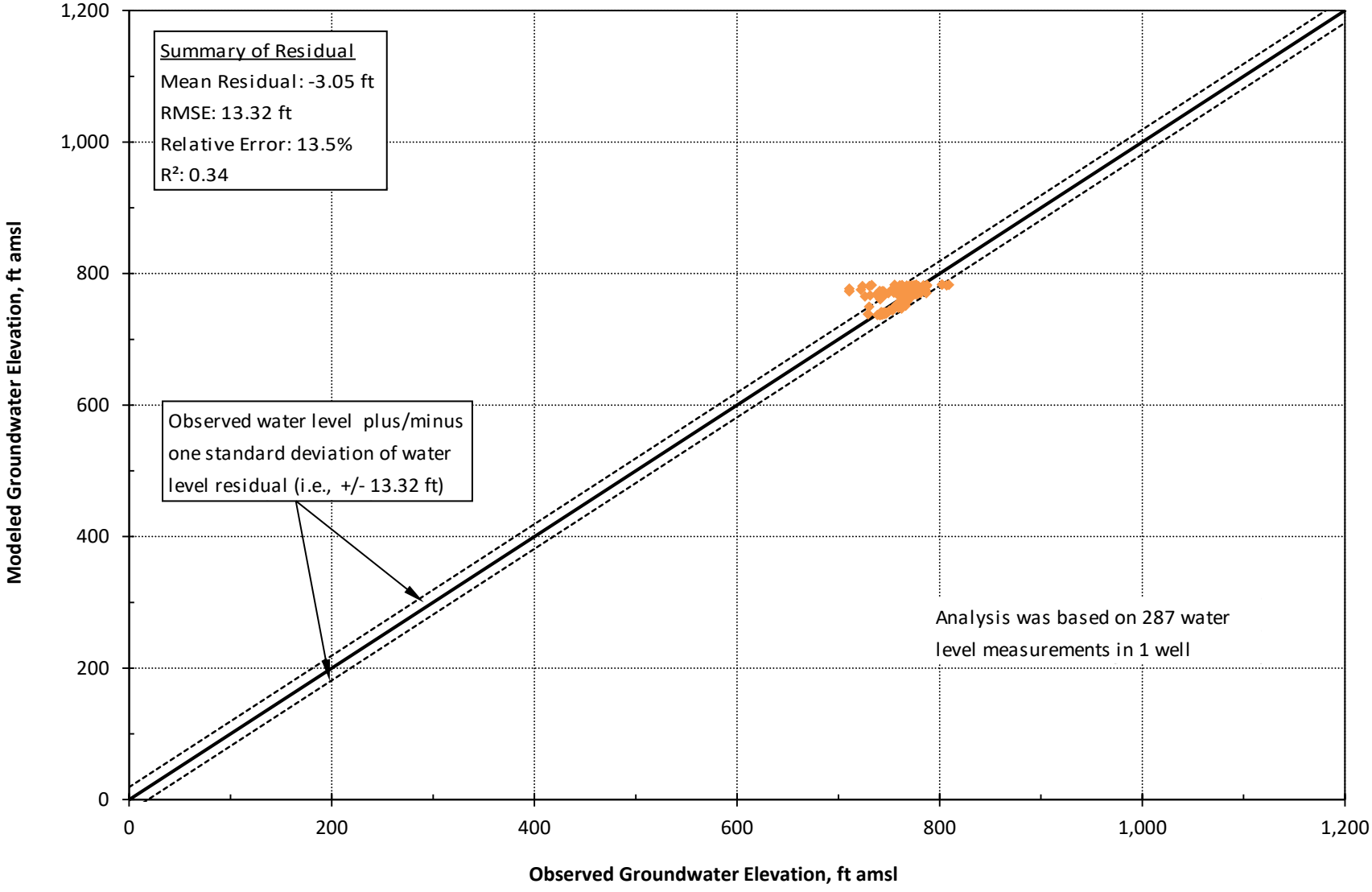

Figure 217

Measured vs. Model-Calculated Water Levels in Chino Basin – Layer 5 (1966 to 2016)

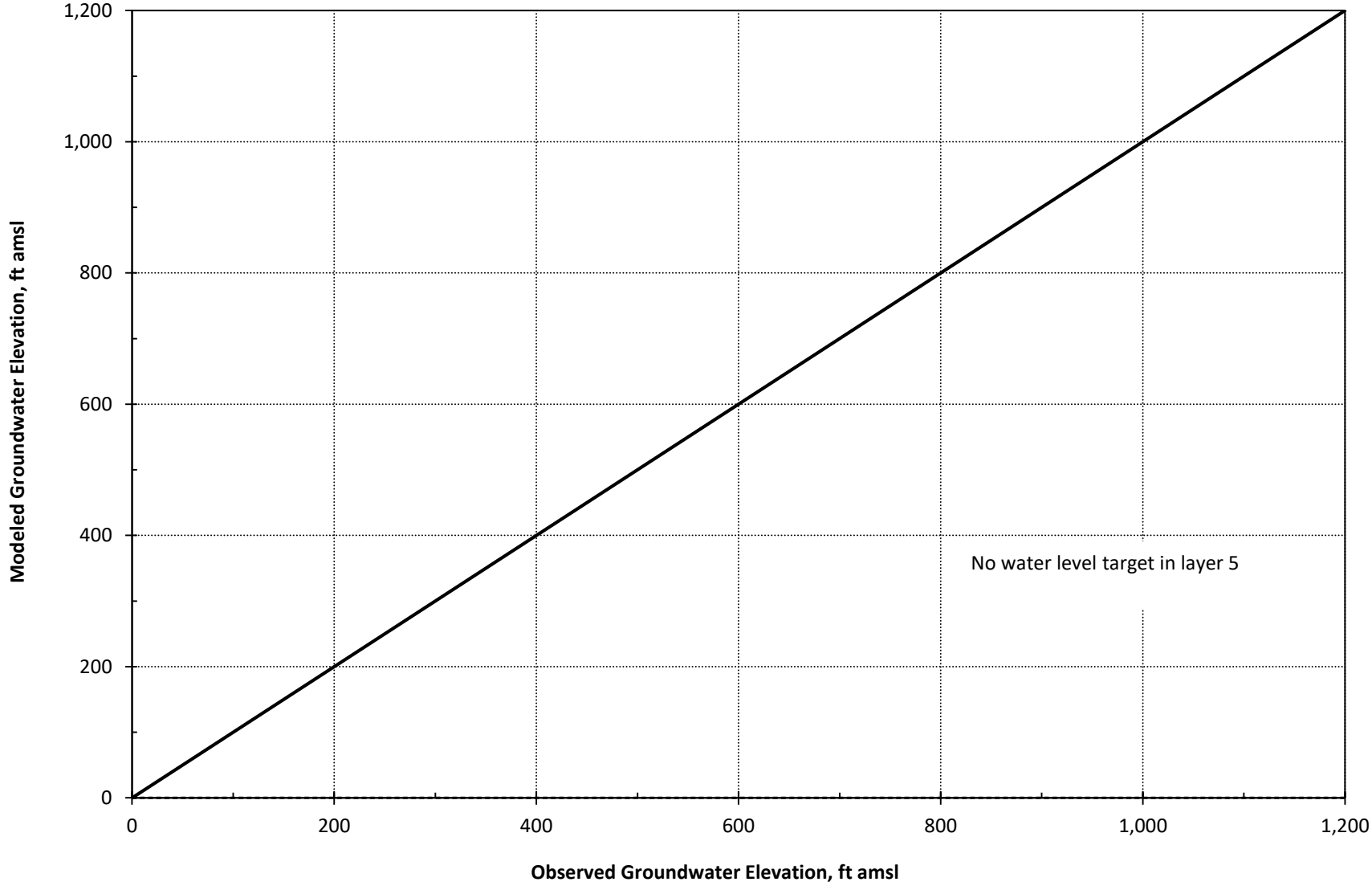

Figure 218

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Temporal Distribution of Water Level Residuals in Chino Basin - All Layers (1966 to 2016)

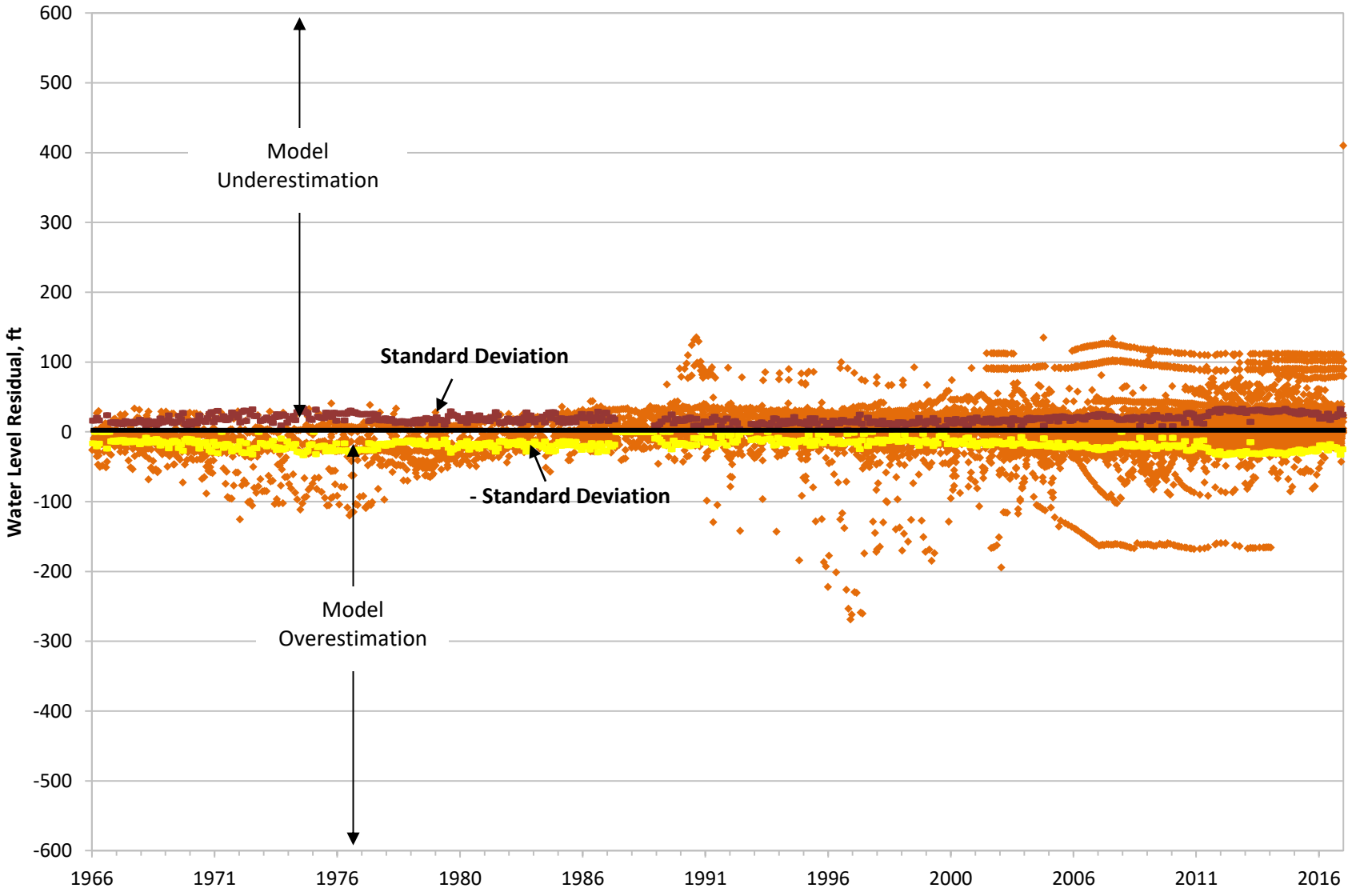

Figure 219

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Histogram of Water Level Residuals in Chino Basin – All Layers (1966 to 2016)

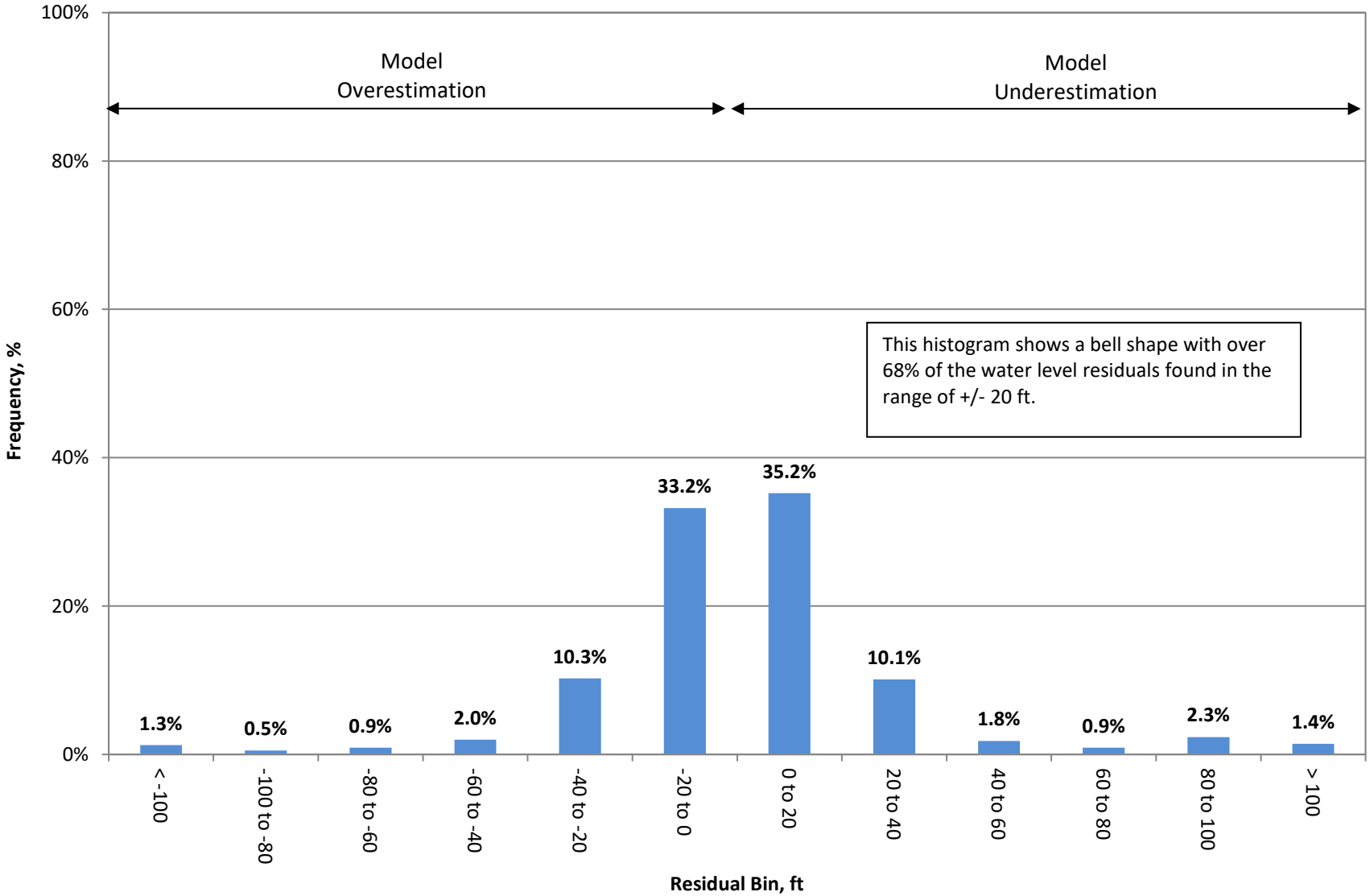
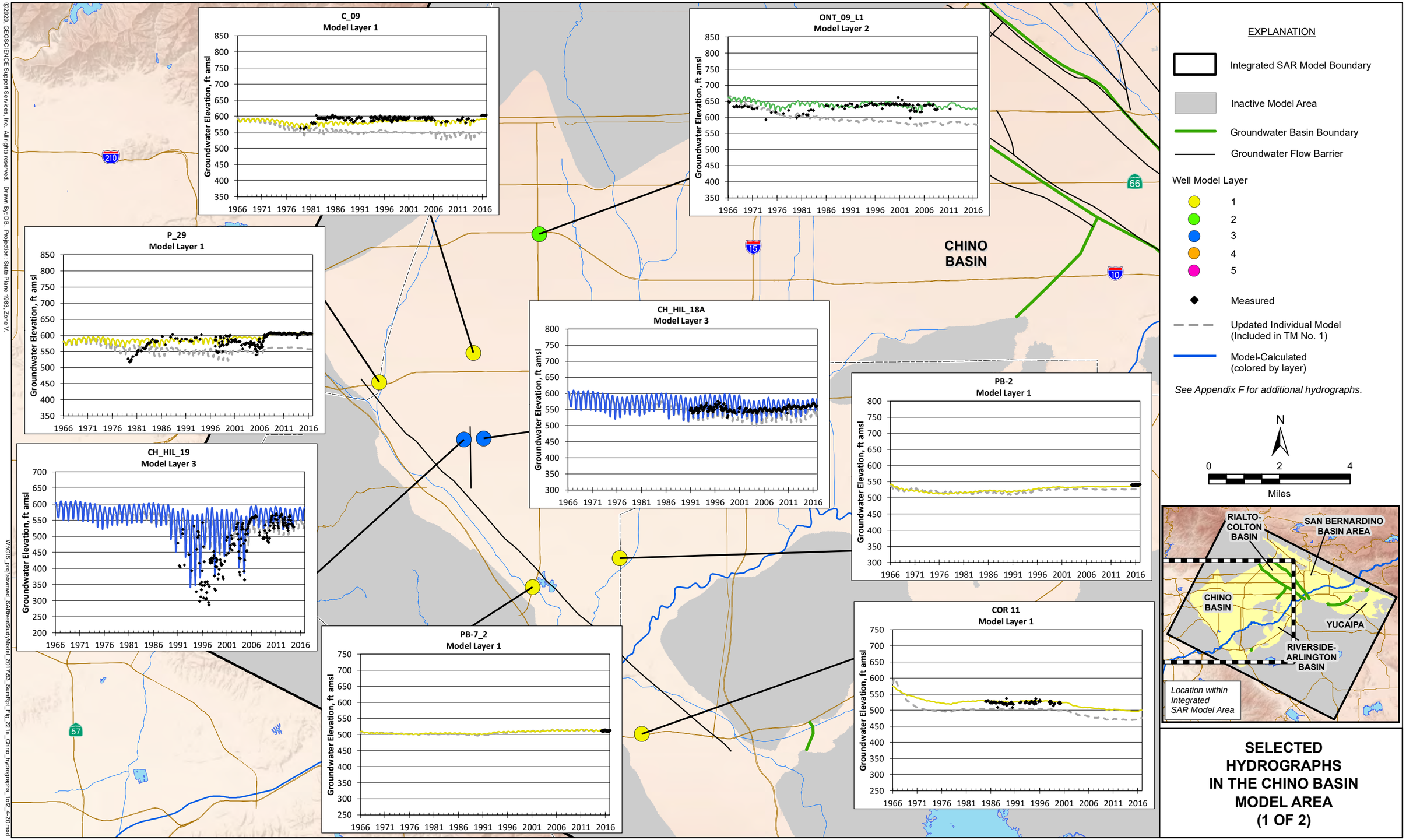


Figure 220



SELECTED HYDROGRAPHS IN THE CHINO BASIN MODEL AREA (1 OF 2)

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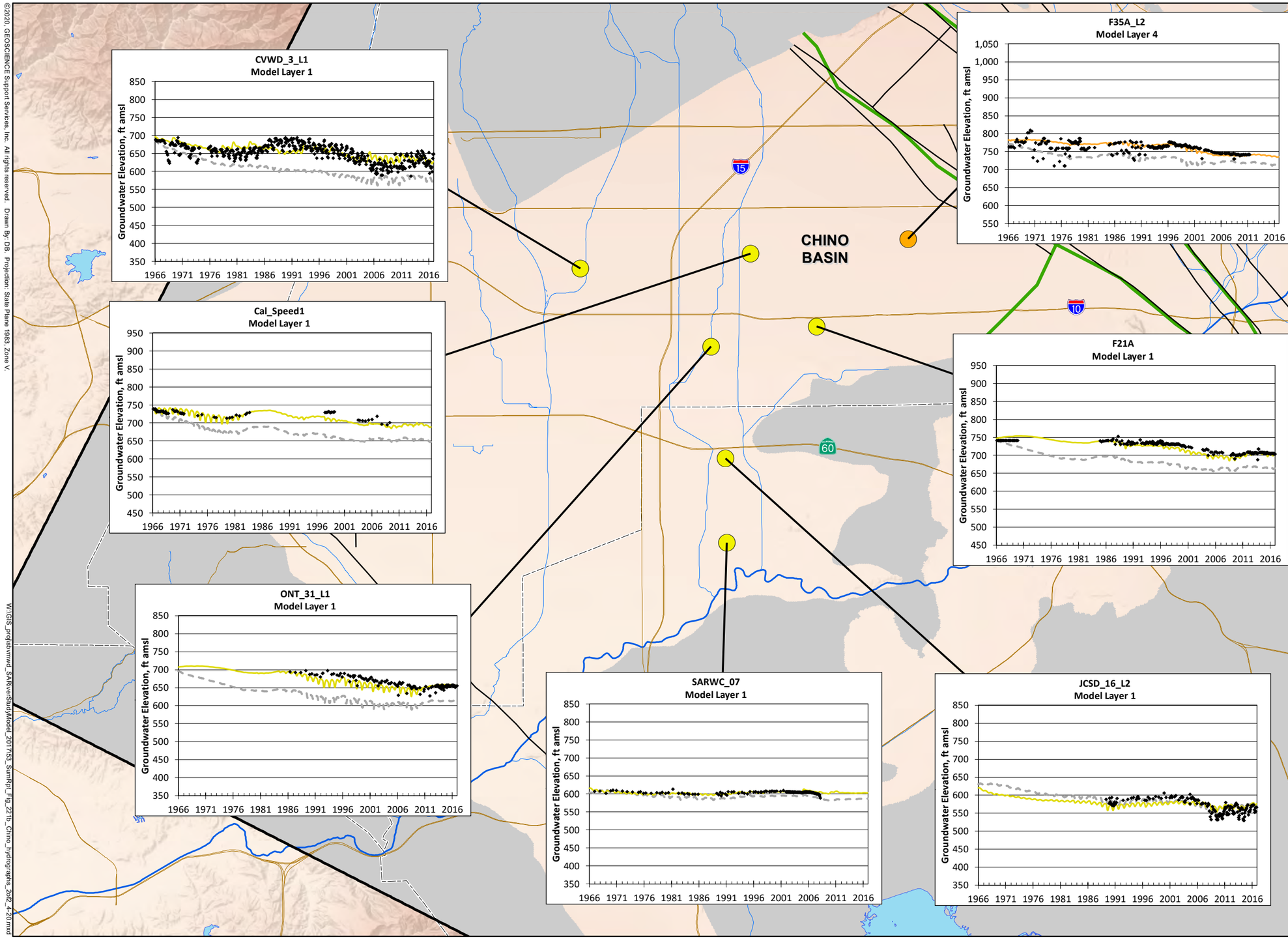

EXPLANATION

- Integrated SAR Model Boundary
- Inactive Model Area
- Groundwater Basin Boundary
- Groundwater Flow Barrier

Well Model Layer

- 1
- 2
- 3
- 4
- 5

- Measured
- Updated Individual Model (Included in TM No. 1)
- Model-Calculated (colored by layer)

See Appendix F for additional hydrographs.

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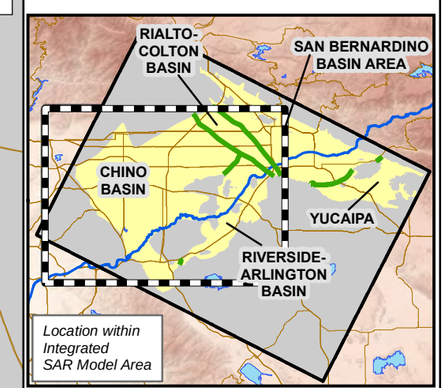

SELECTED HYDROGRAPHS IN THE CHINO BASIN MODEL AREA (2 OF 2)

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Measured vs. Model-Calculated Water Levels in the Prado Basin Area – All Layers (1966 to 2016)

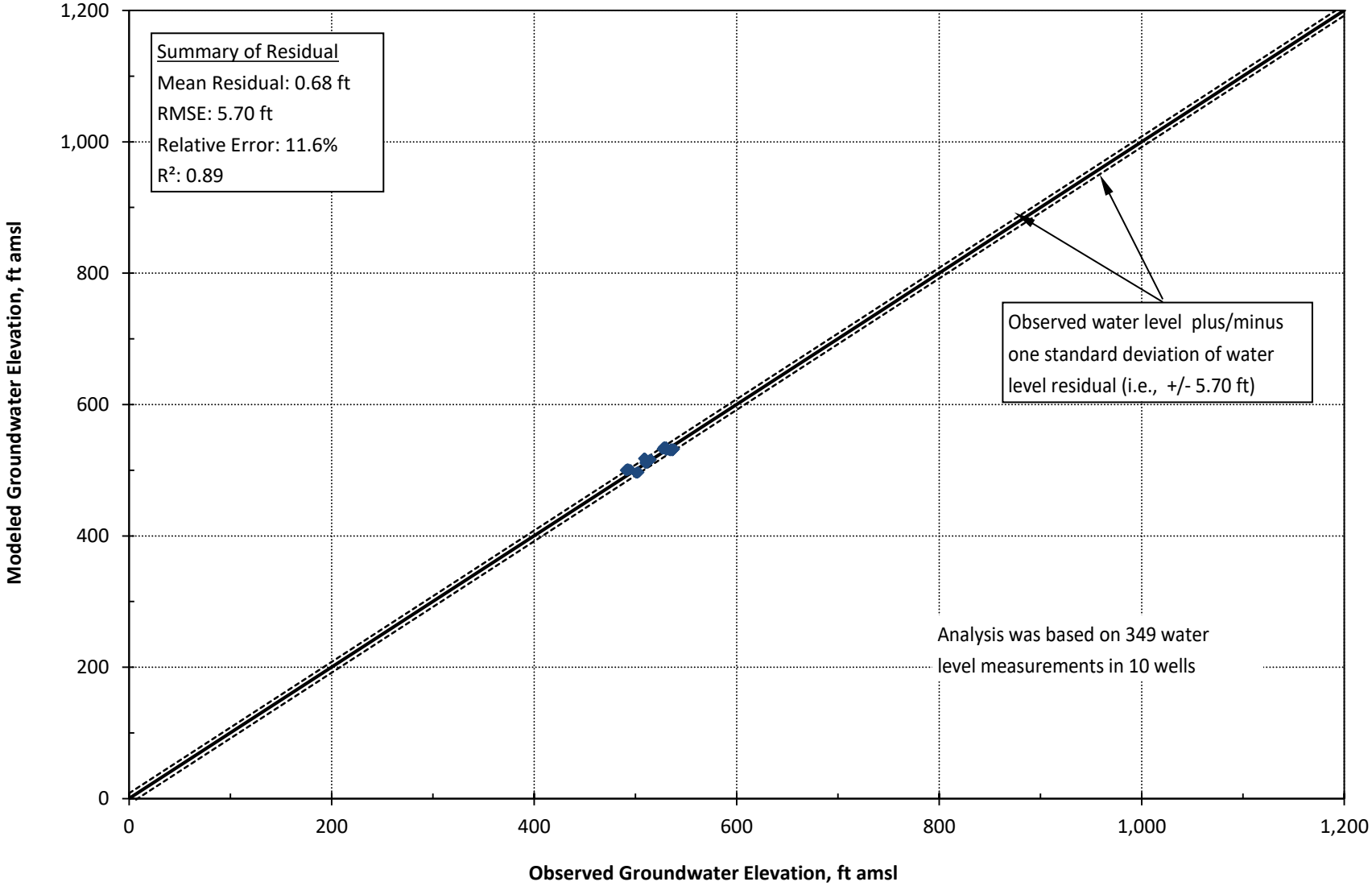

Figure 222

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Temporal Distribution of Water Level Residuals in Prado Basin Area – All Layers (1966 to 2016)

Figure 223

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Histogram of Water Level Residuals in Prado Basin Area – All Layers (1966 to 2016)

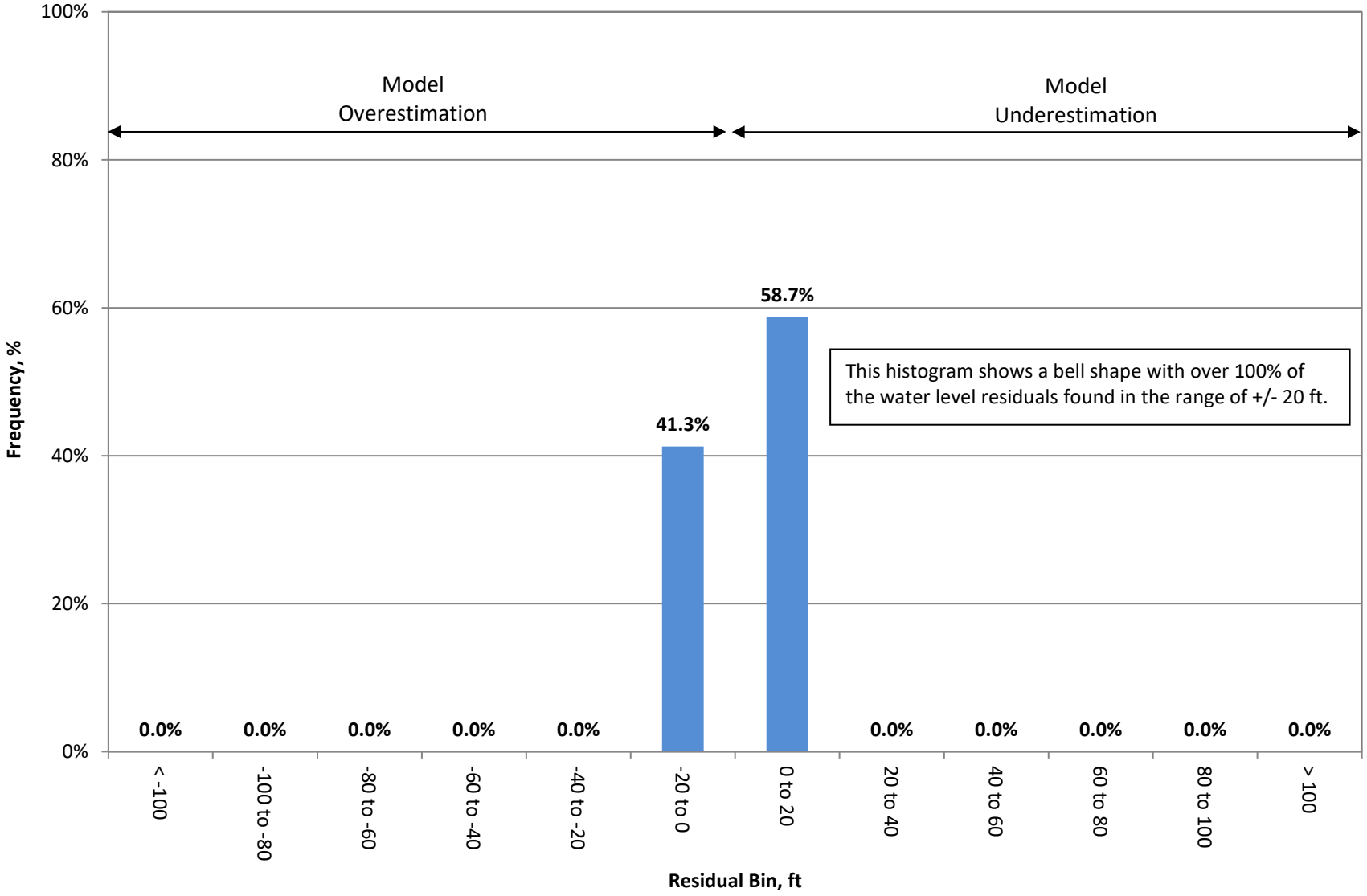

Figure 224

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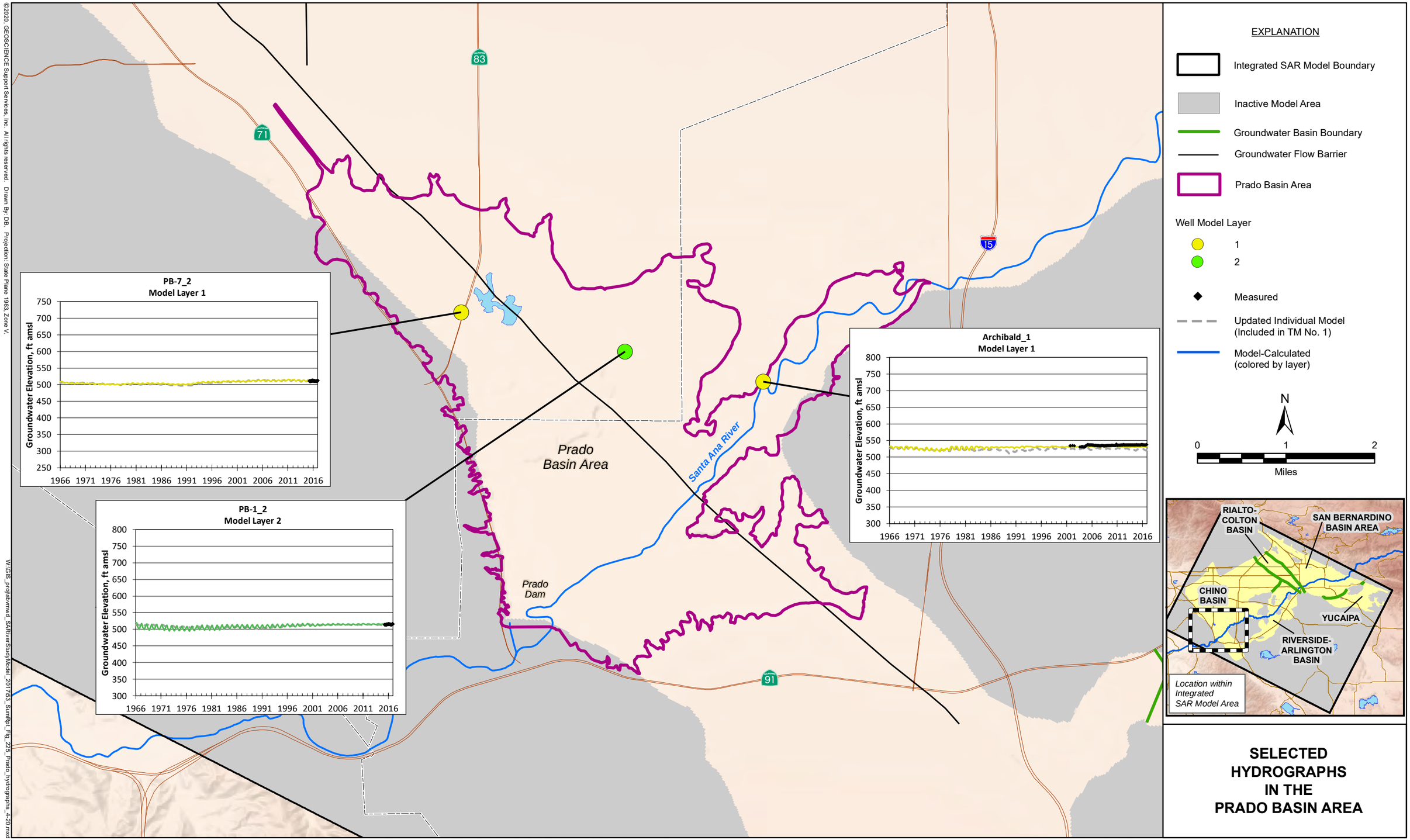

SELECTED HYDROGRAPHS IN THE PRADO BASIN AREA

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10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 225

GEOSCIENCE

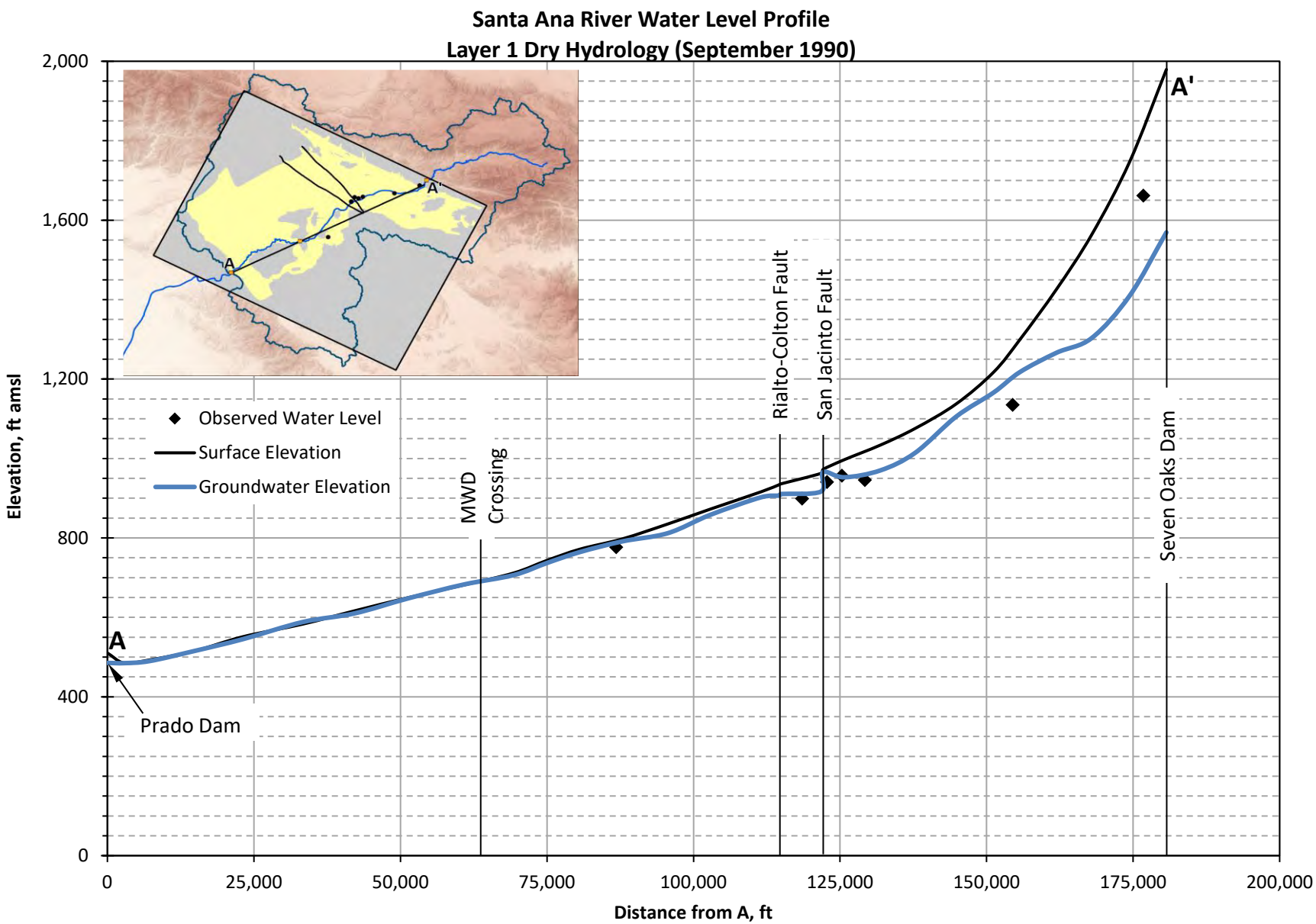
Santa Ana River Water Level Profile
Layer 1 Dry Hydrology (September 1990)
Elevation, ft amsl
2,000
1,600
1,200
800
400
0
Distance from A, ft
0
25,000
50,000
75,000
100,000
125,000
150,000
175,000
200,000
Observed Water Level
Surface Elevation
Groundwater Elevation
A
A'
Prado Dam
MWD Crossing
Rialto-Colton Fault
San Jacinto Fault
Seven Oaks Dam

Figure 226

DRAFT

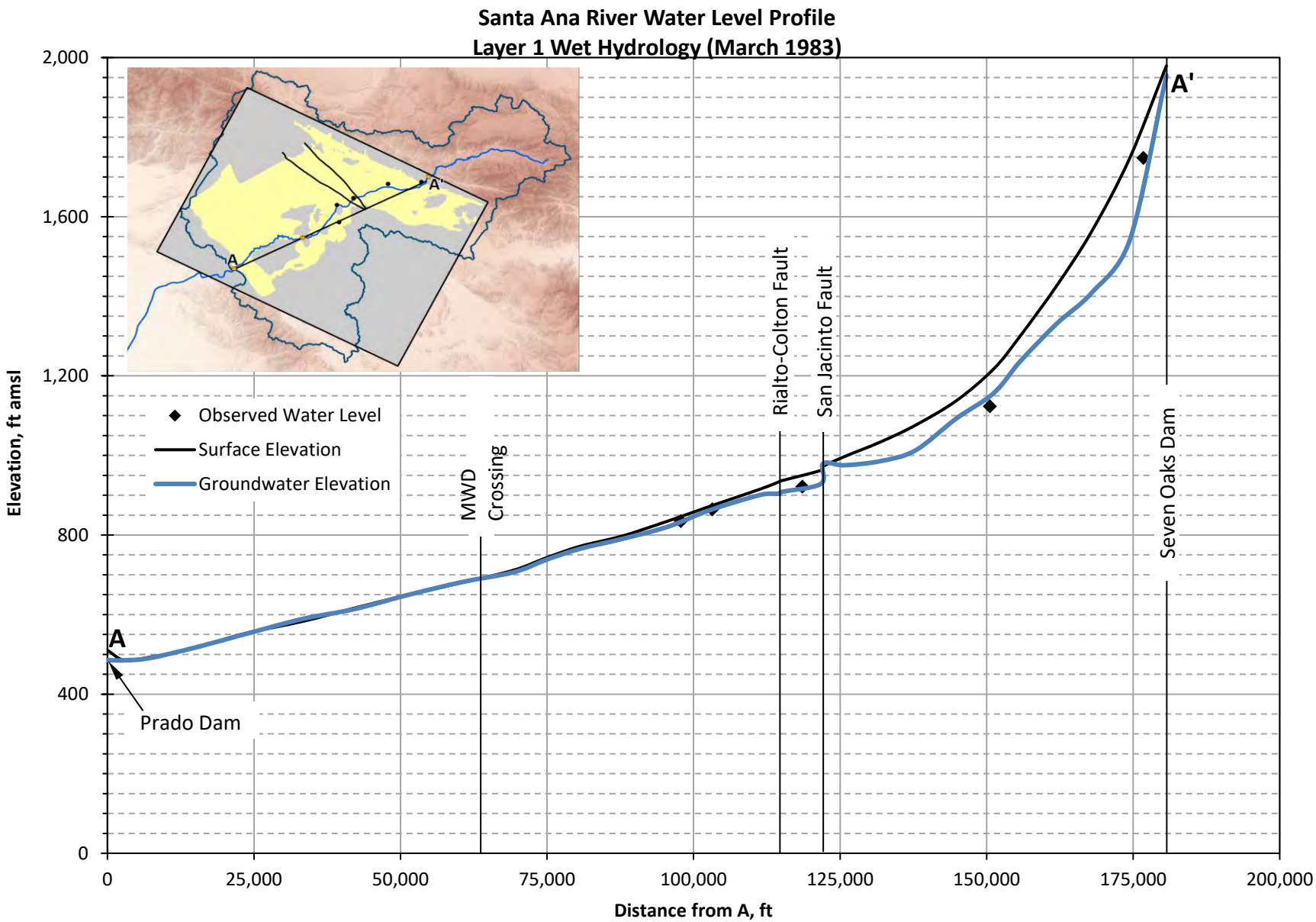

Figure 227

DRAFT

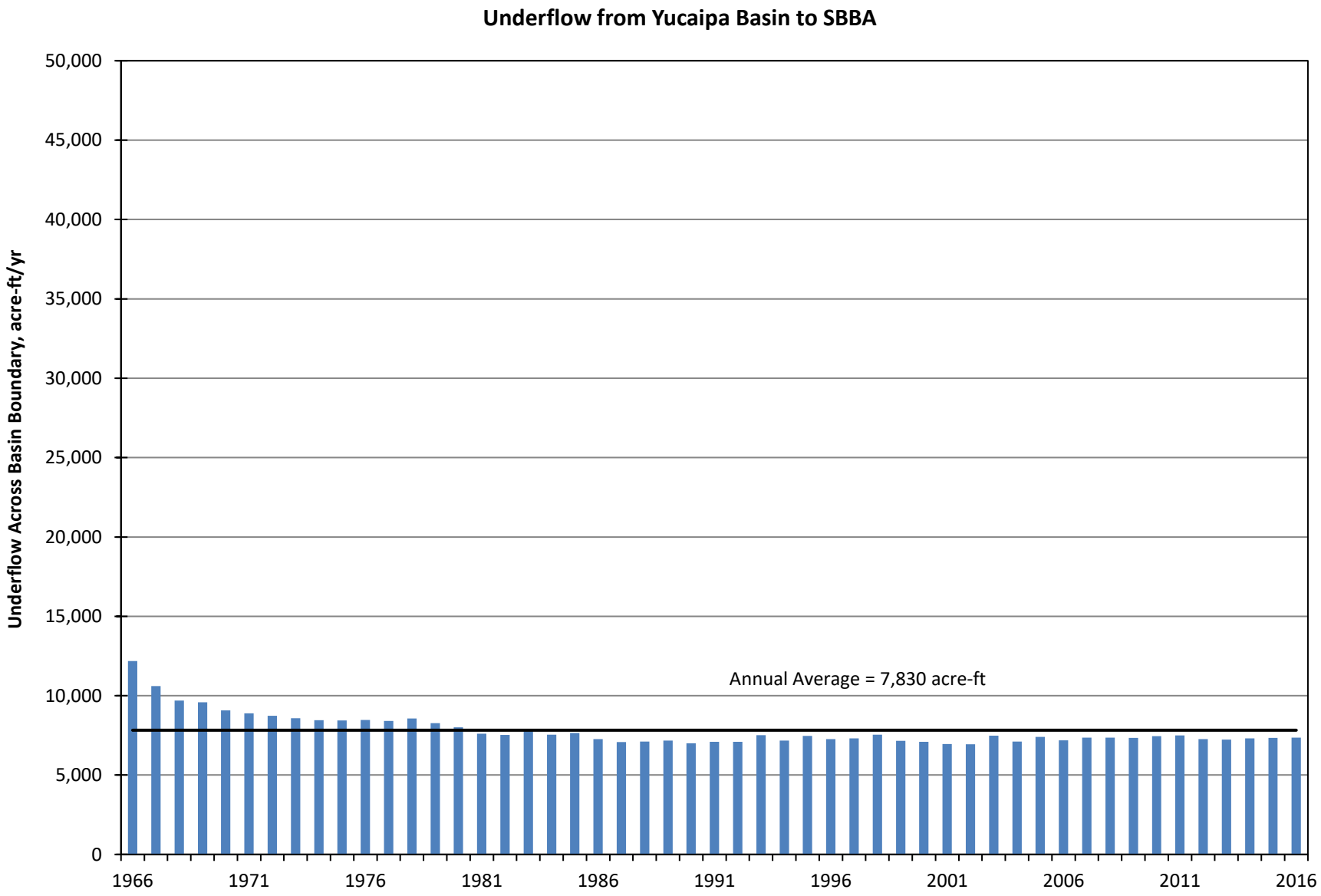

Figure 228

DRAFT

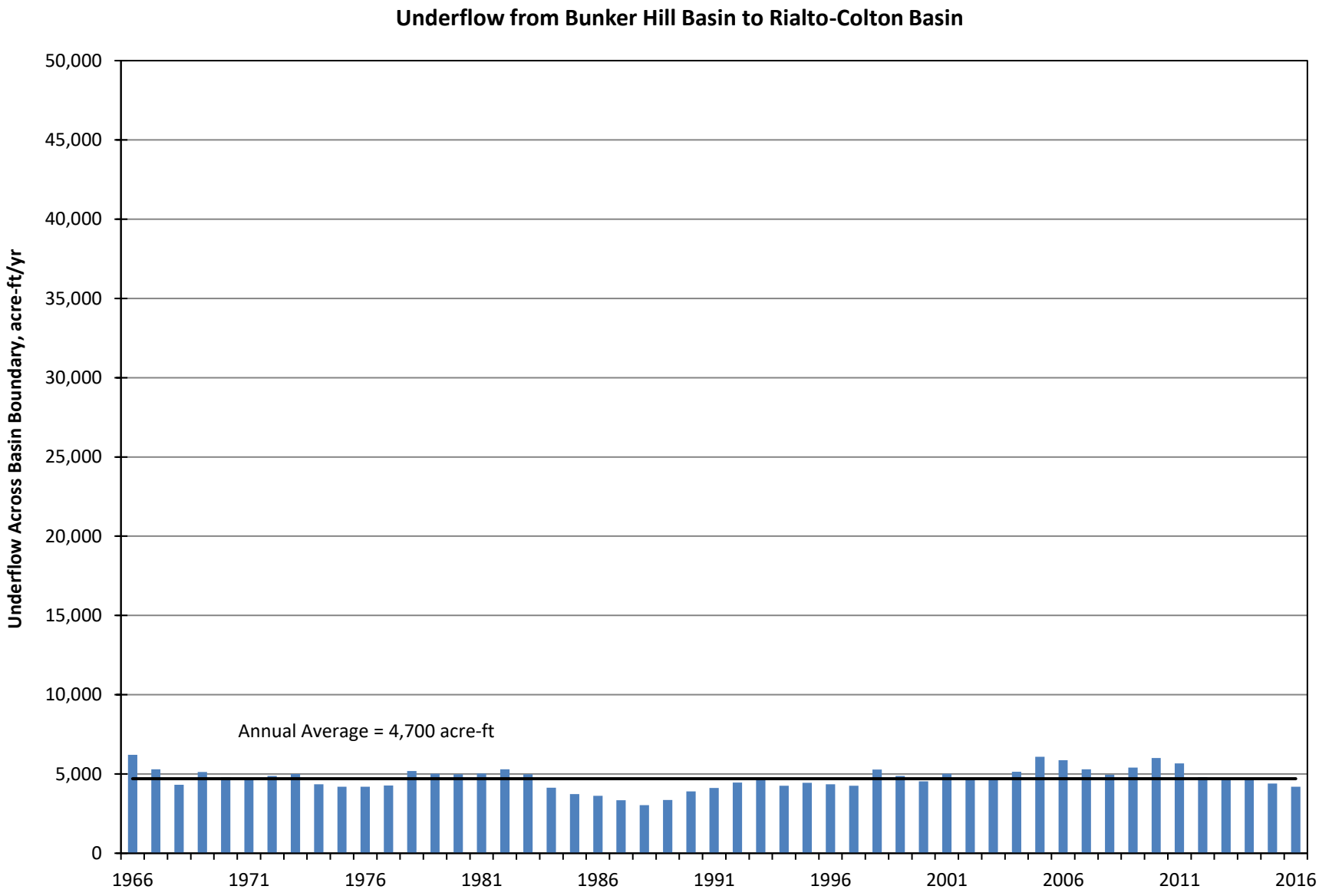

Figure 229

DRAFT

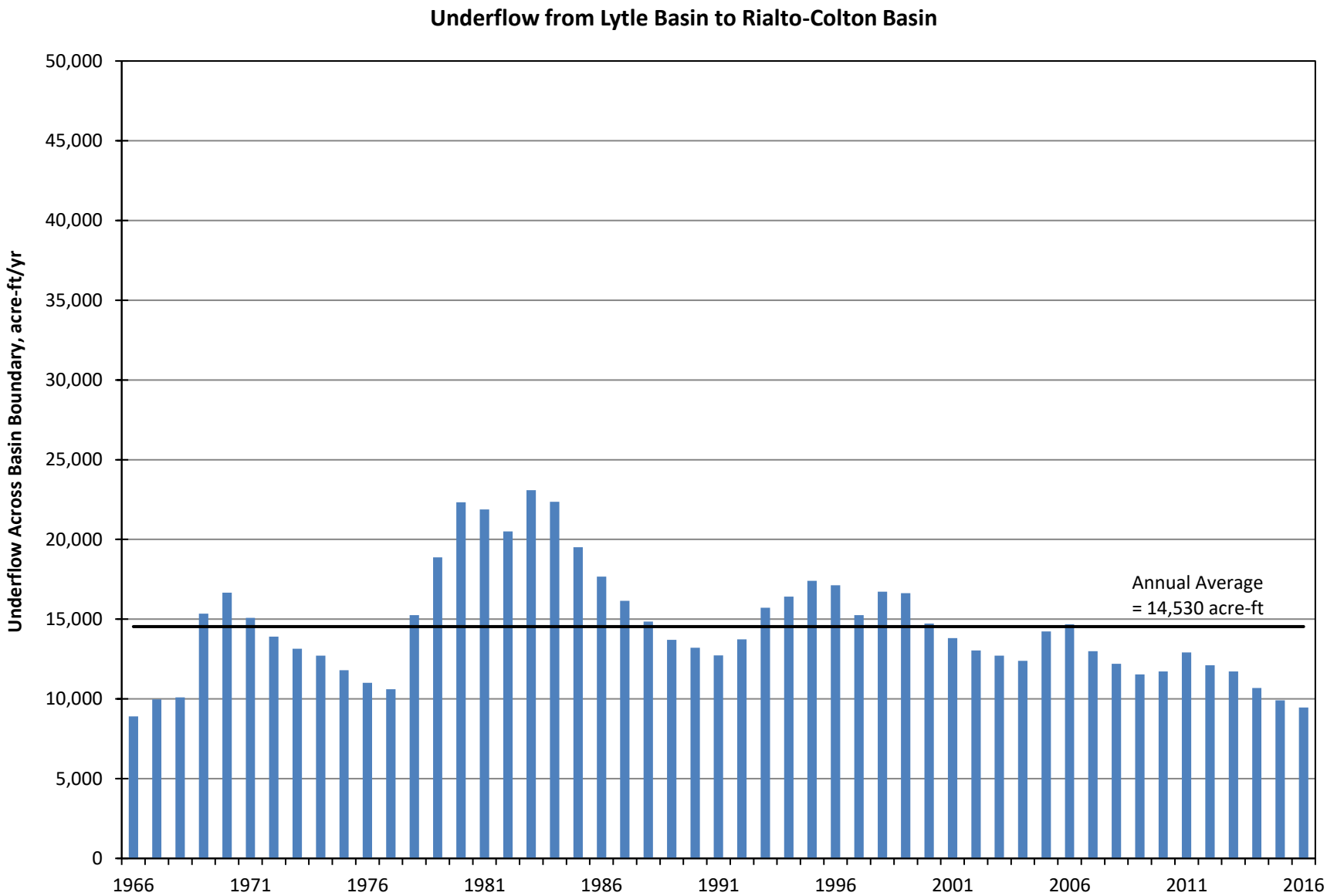

Figure 230

DRAFT

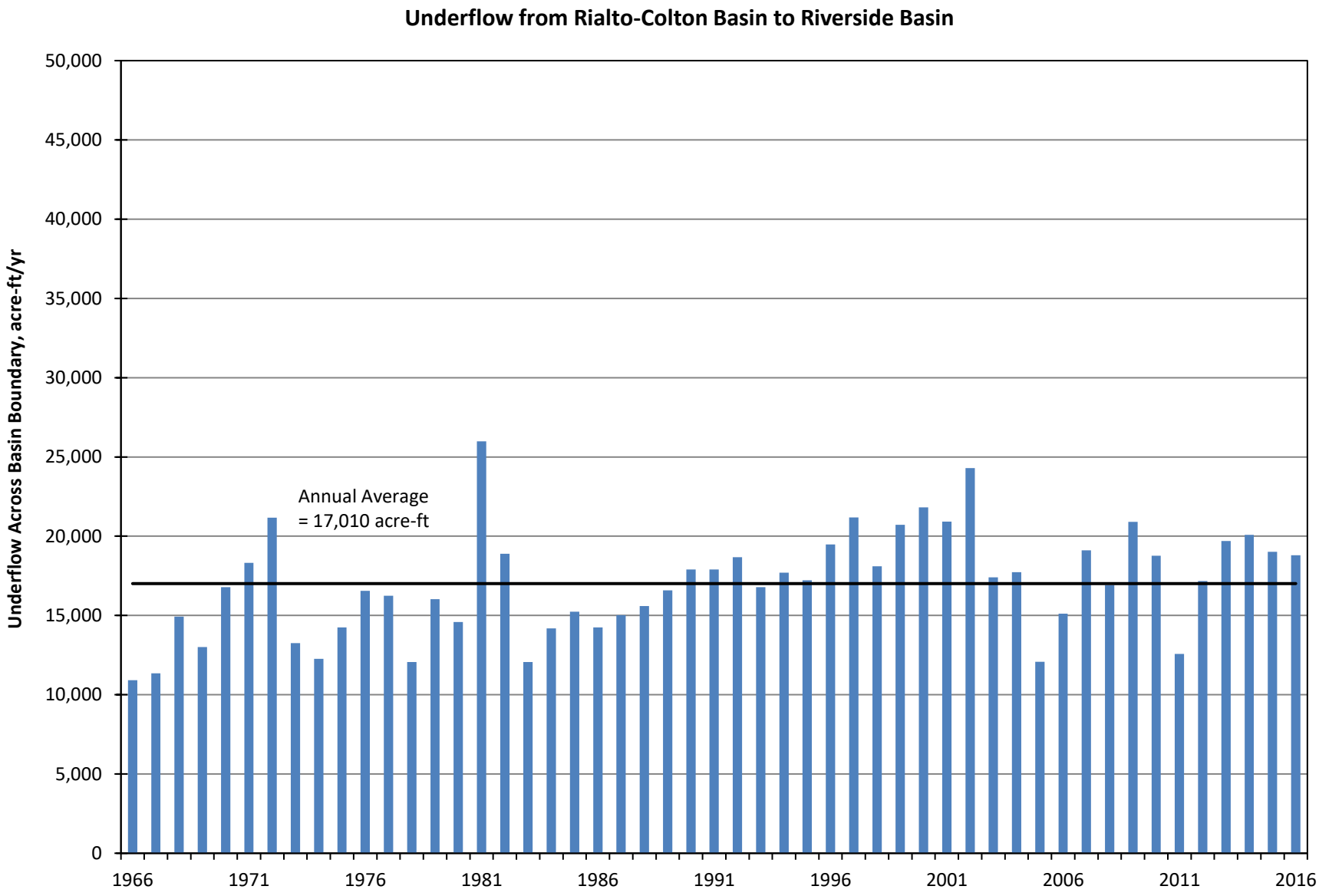

Figure 231

DRAFT

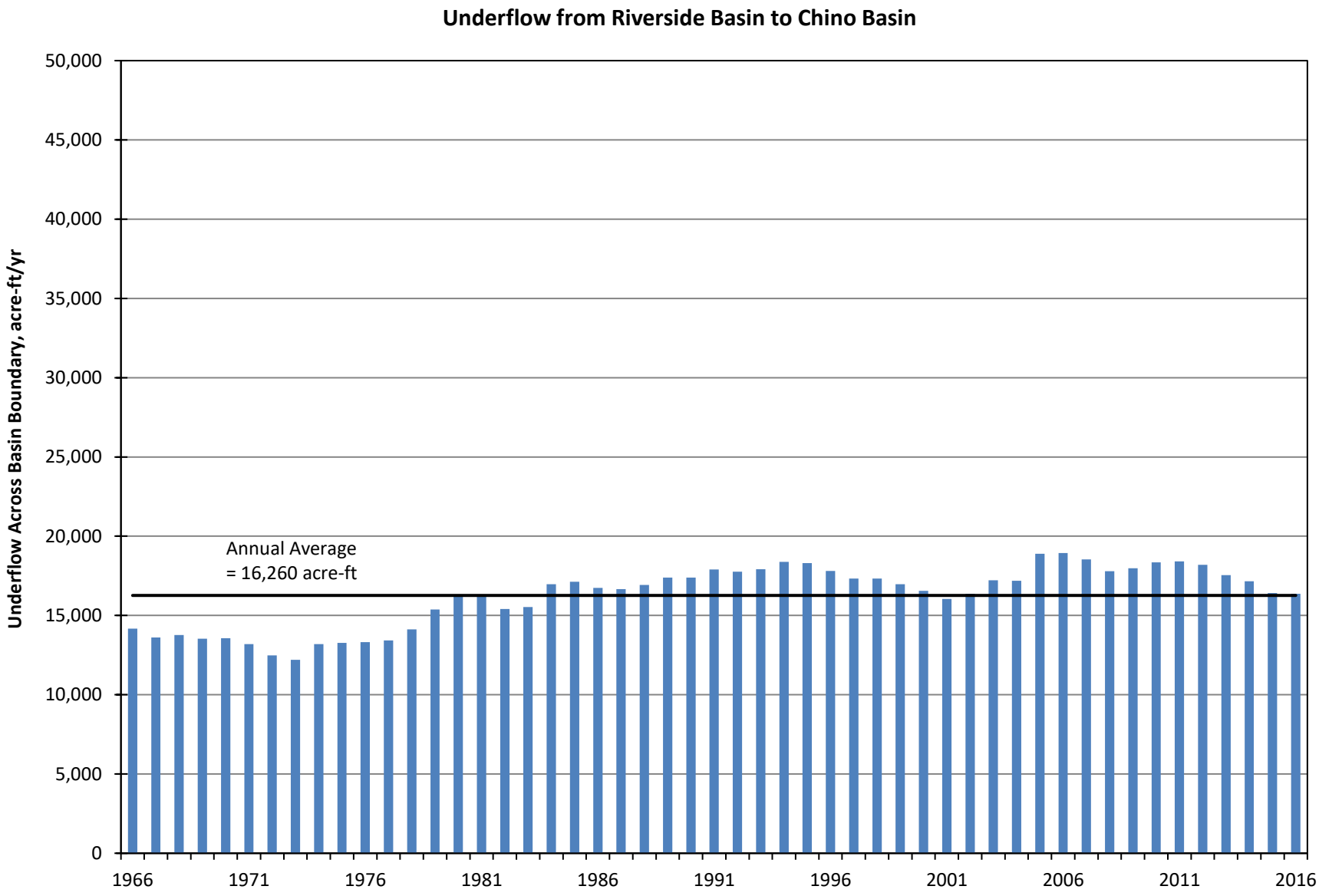

Figure 232

Scatterplot of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at E Street Gaging Station – January 1966 to December 2016 (Integrated SAR Model)

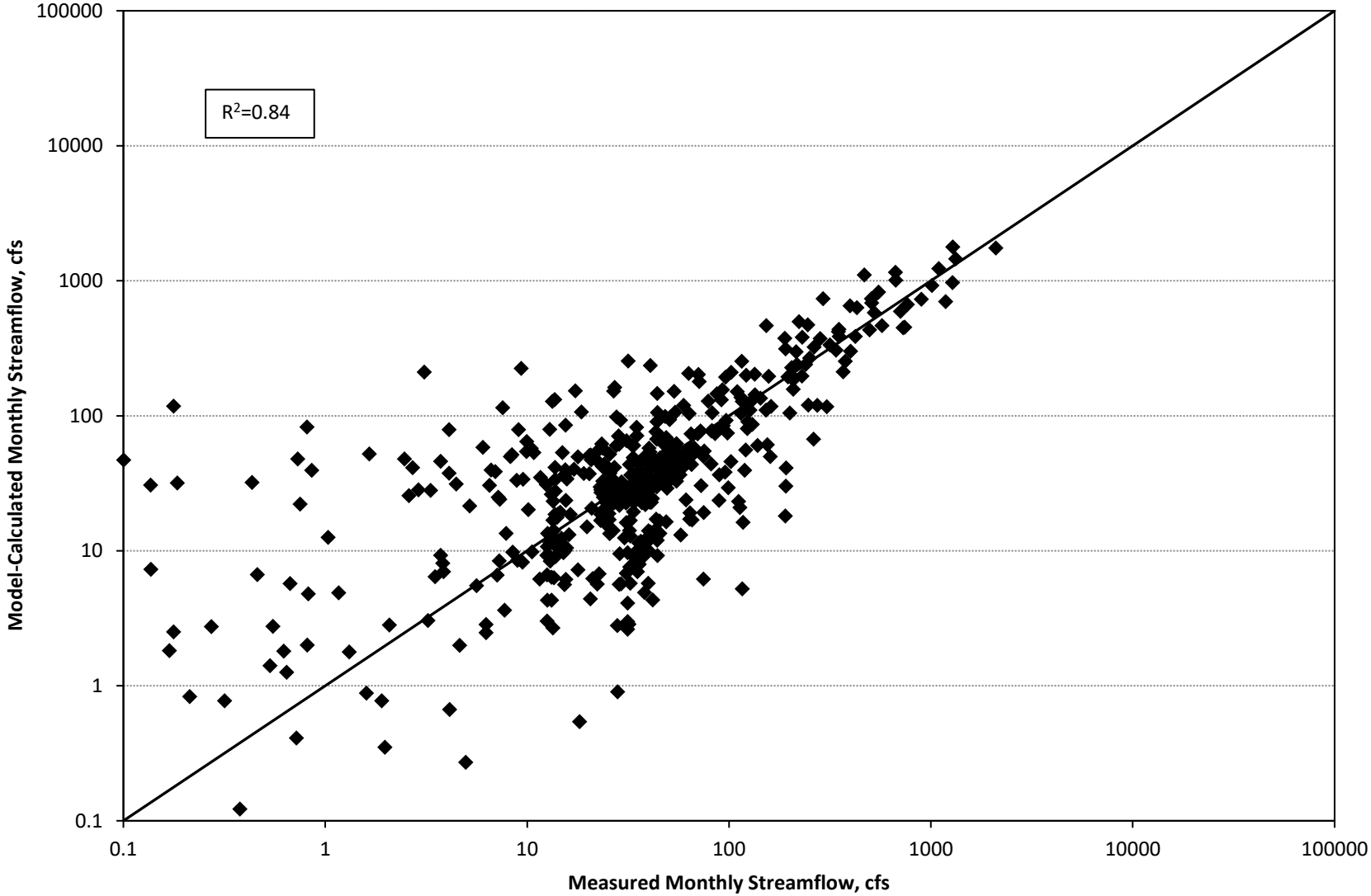

Figure 233

Scatterplot of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at MWD Crossing Gaging Station – January 1966 to December 2016 (Integrated SAR Model)

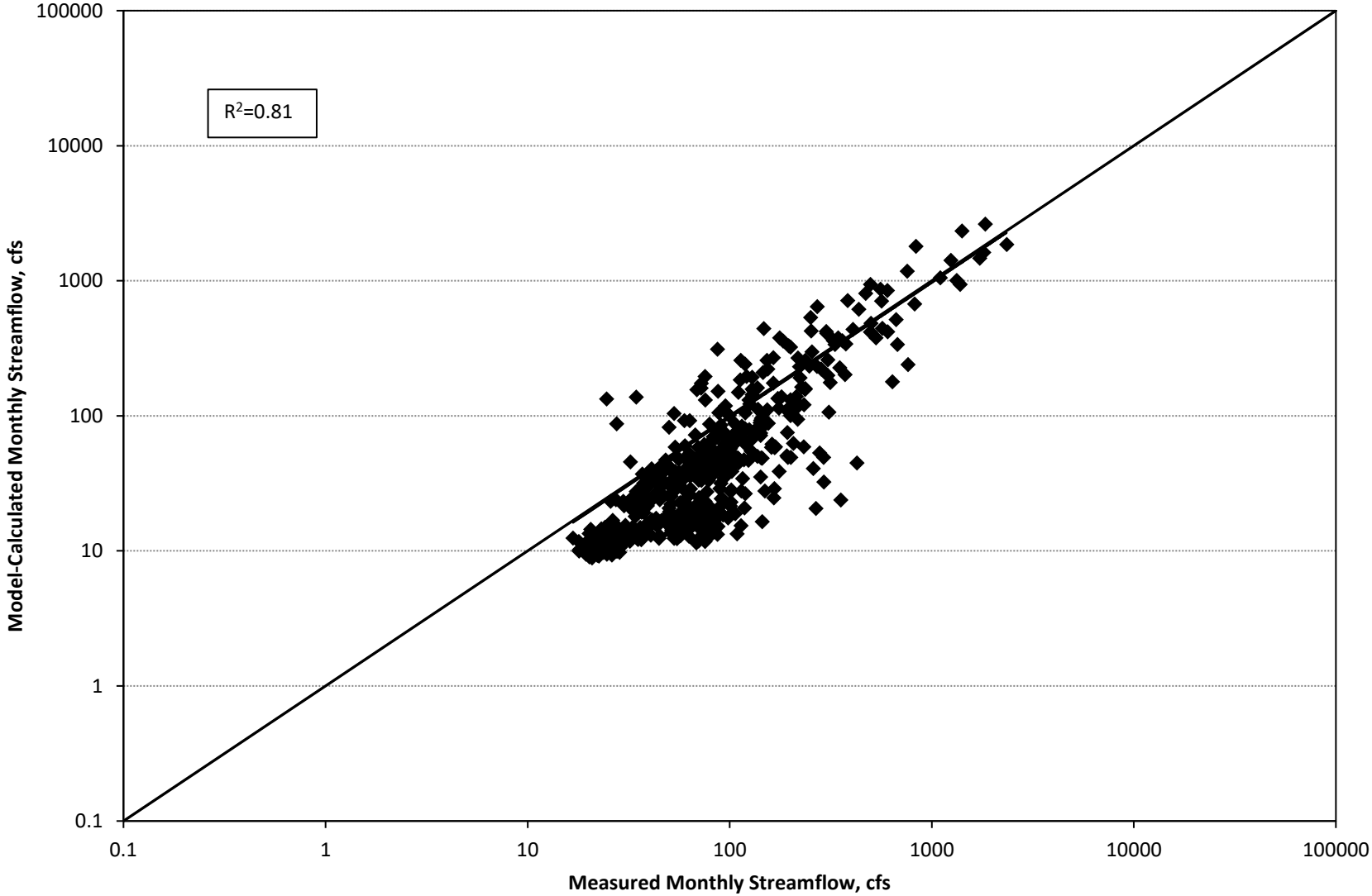

Figure 234

Scatterplot of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River Prado Dam Inflow – January 1966 to December 2016 (Integrated SAR Model)

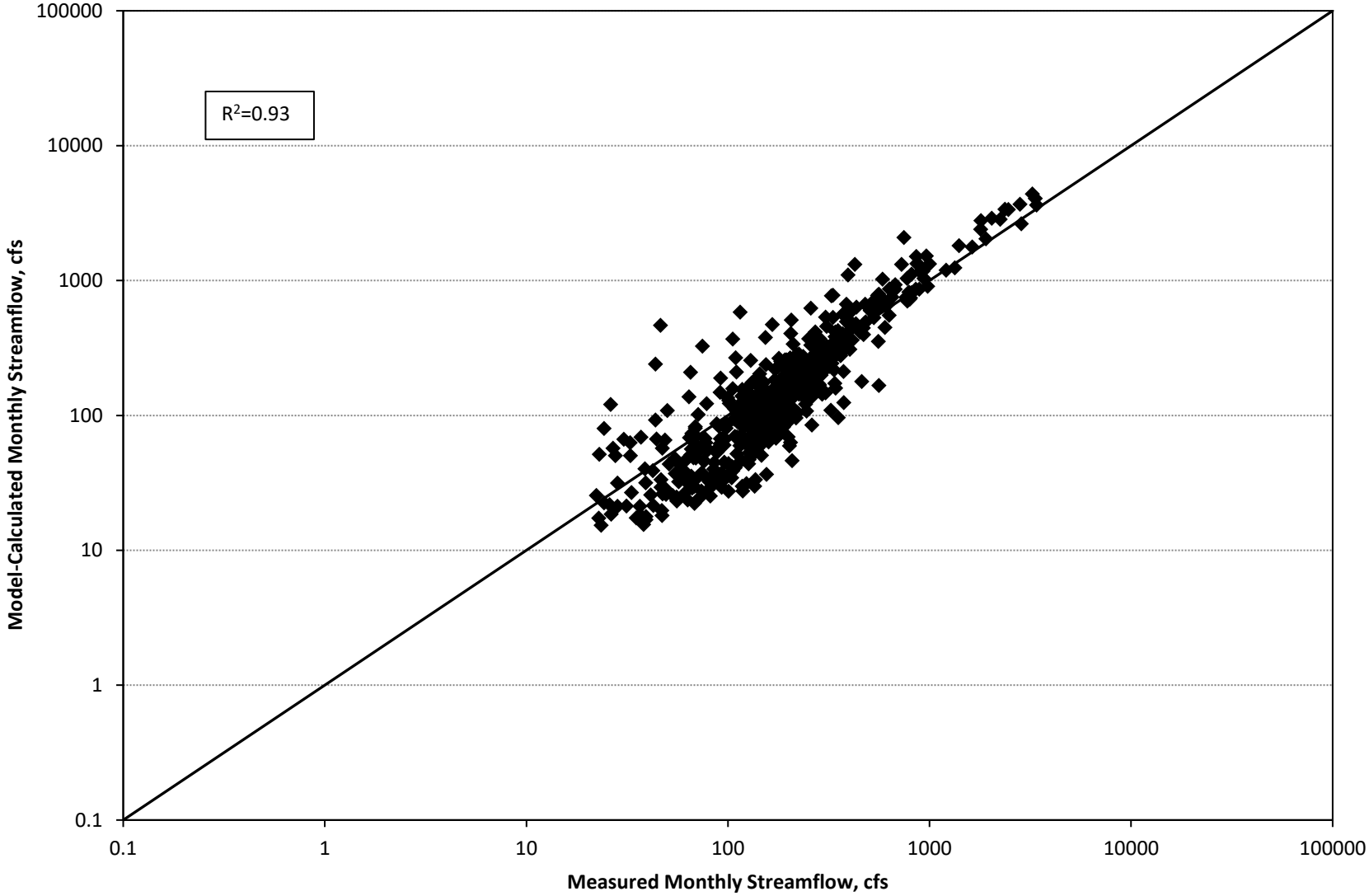

Figure 235

Hydrograph of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at E Street Gaging Station – January 1966 to December 2016 (Integrated SAR Model)

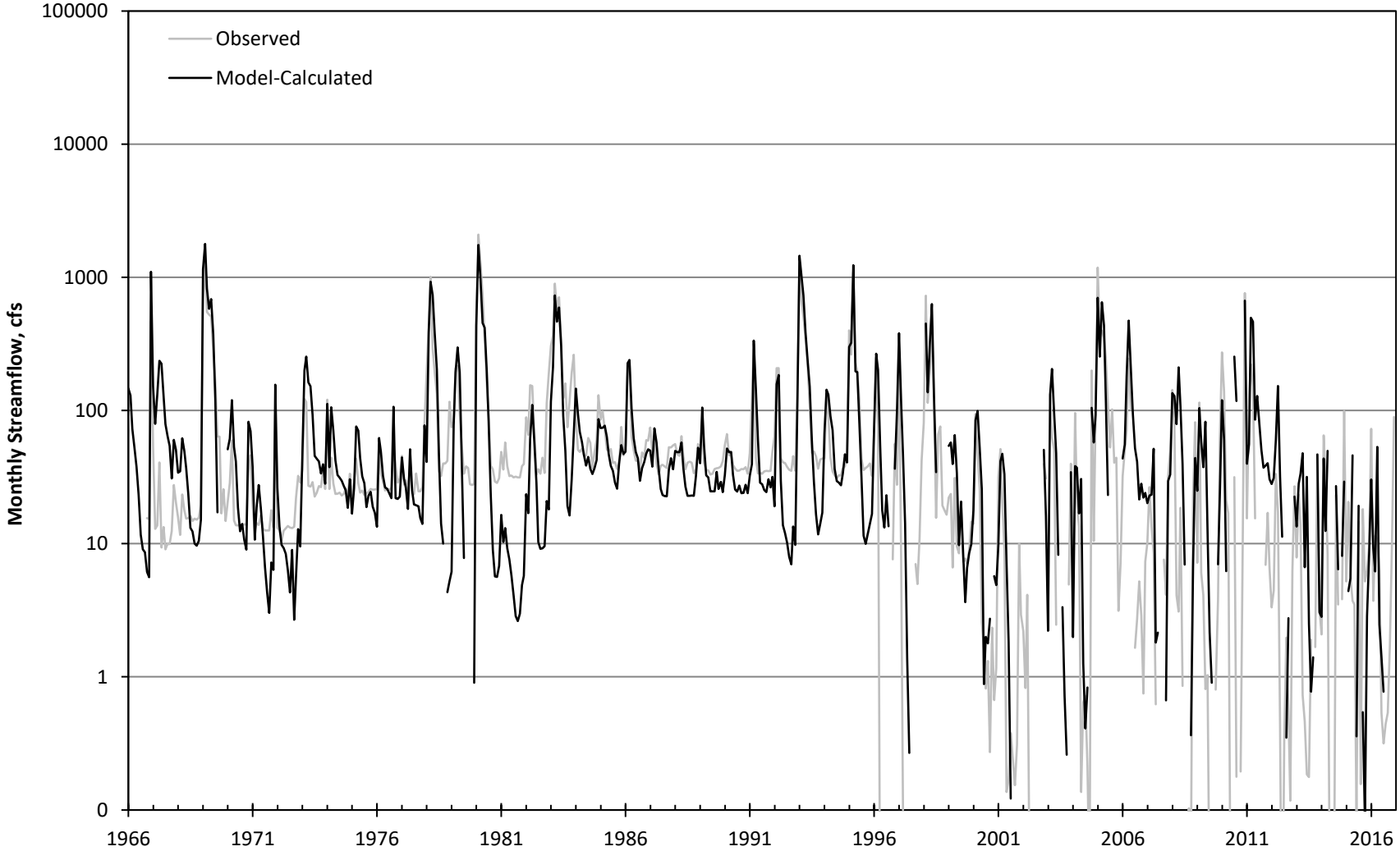

Figure 236

Hydrograph of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River at MWD Crossing Gaging Station – January 1966 to December 2016 (Integrated SAR Model)

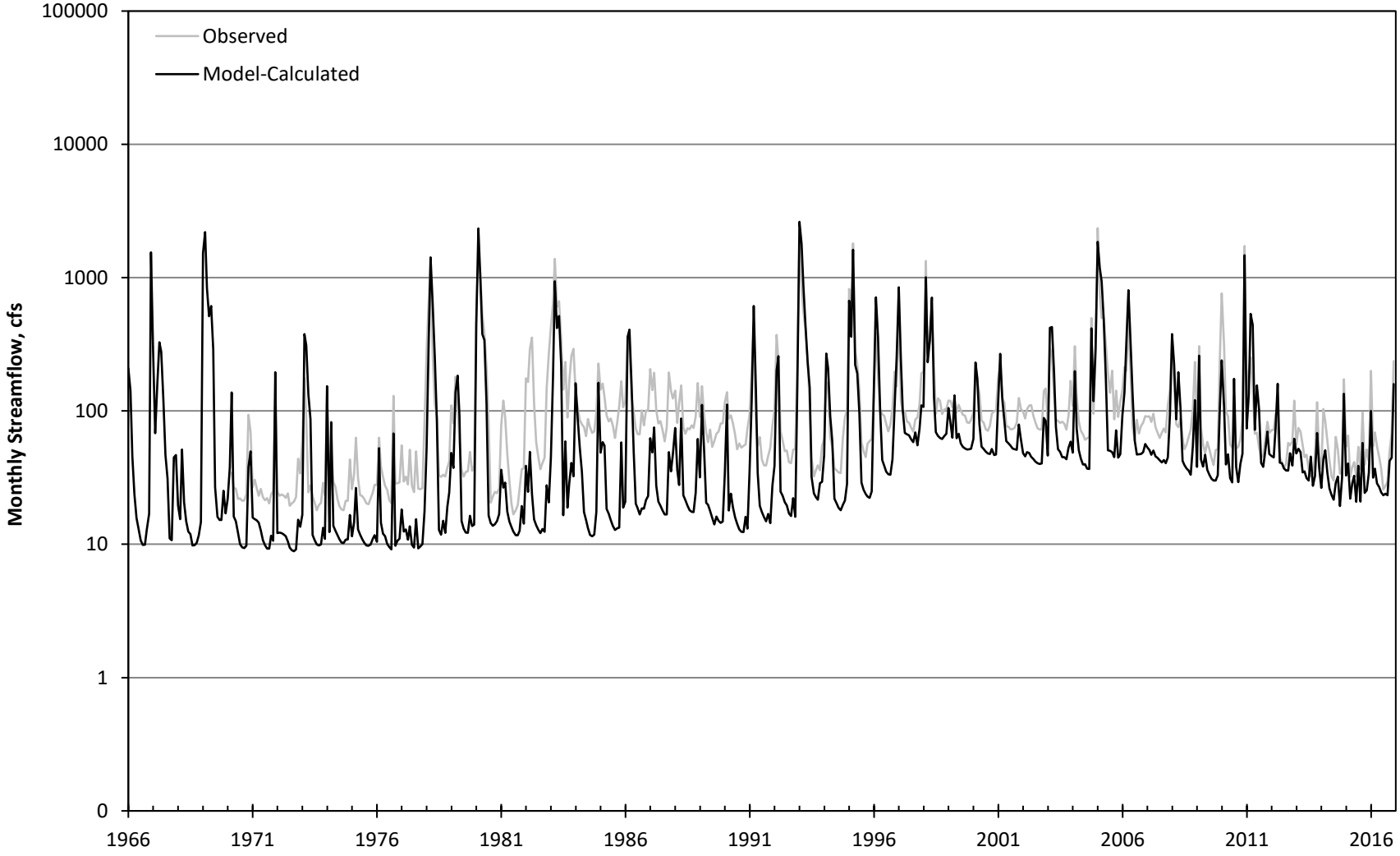

Figure 237

Hydrograph of Measured and Model-Simulated Monthly Streamflow at the Santa Ana River Prado Dam Inflow – January 1966 to December 2016 (Integrated SAR Model)

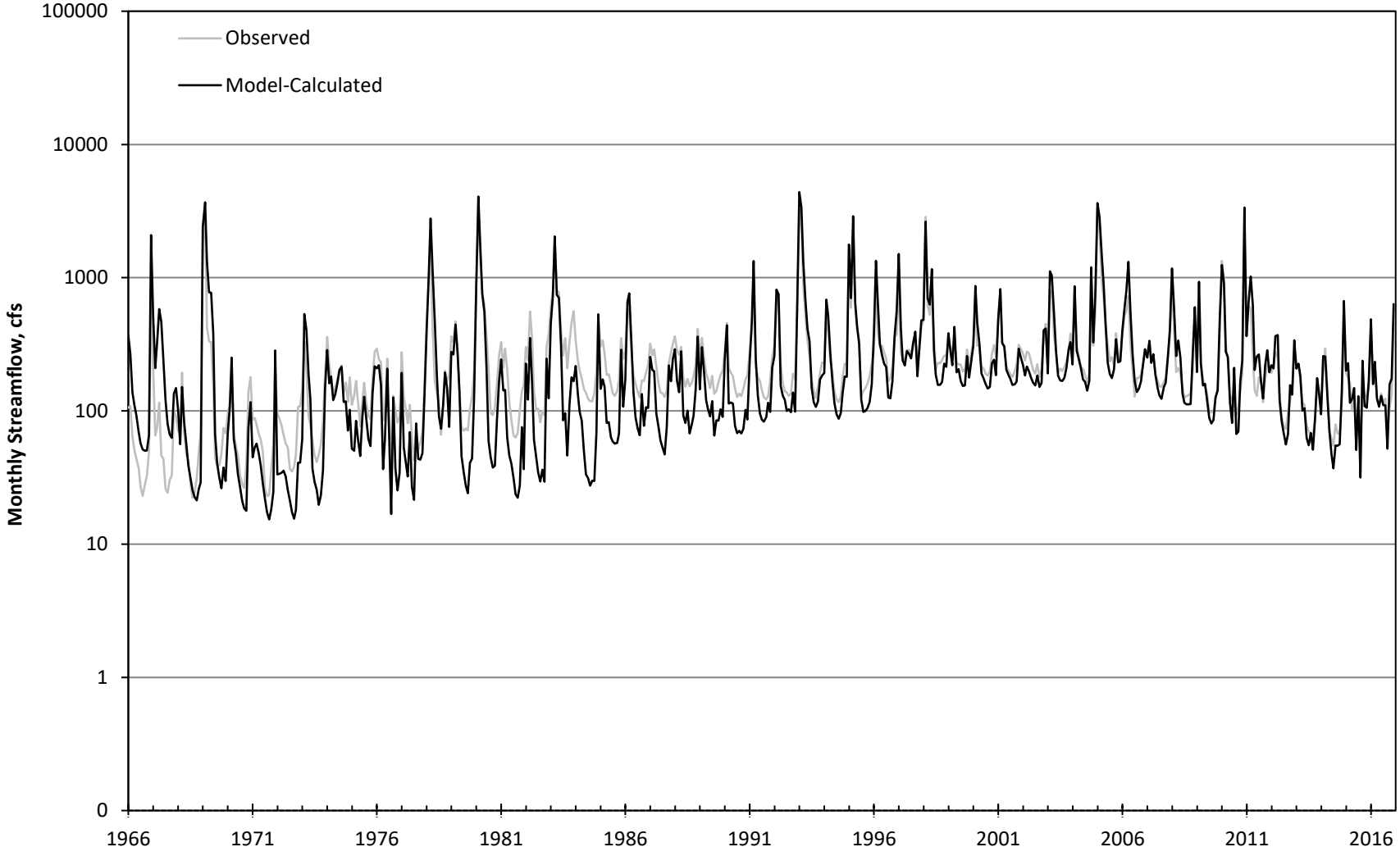

Figure 238

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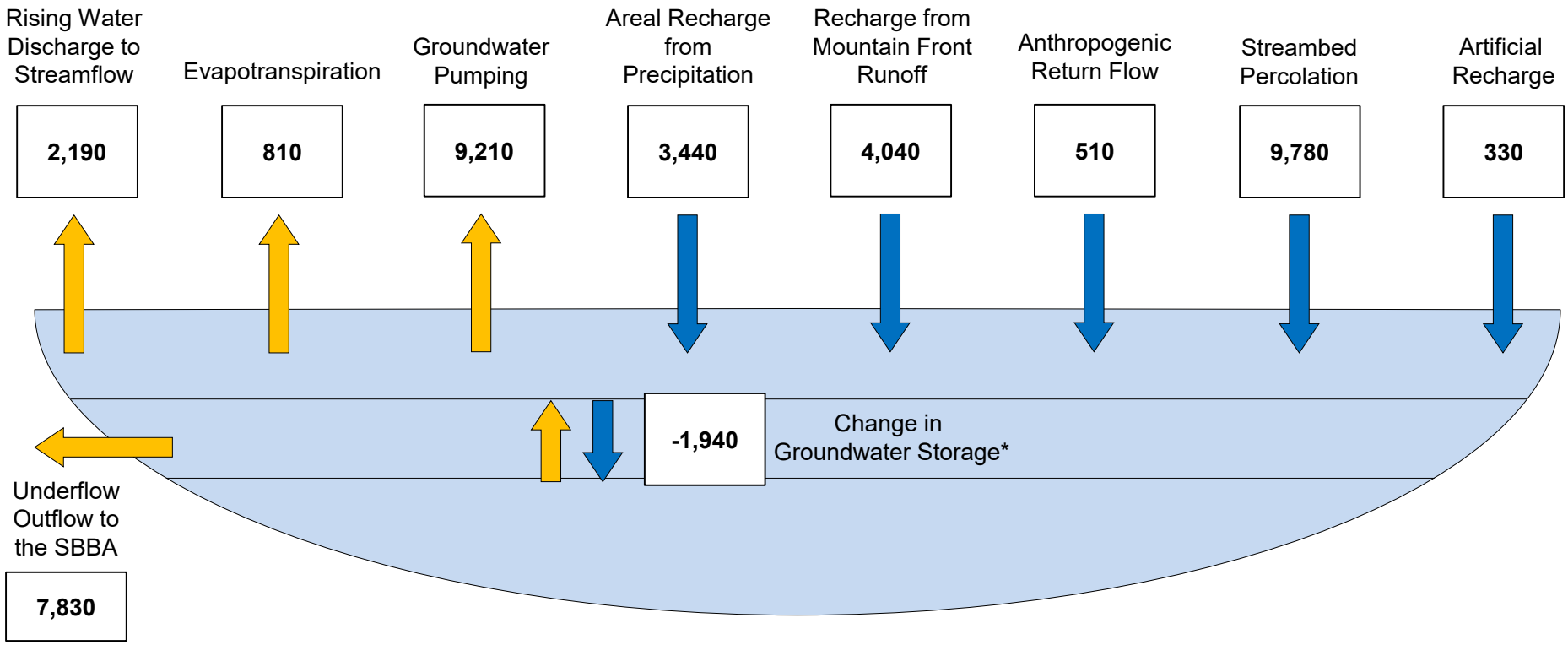
X:\Projects\San_Bernardino_MUNI\31\Integrated_SAR_Model\(4)Technical_Memos\(8) Summary Report\Draft\Figures



All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR YUCAIPA BASIN 1966 to 2016

10-Apr-20

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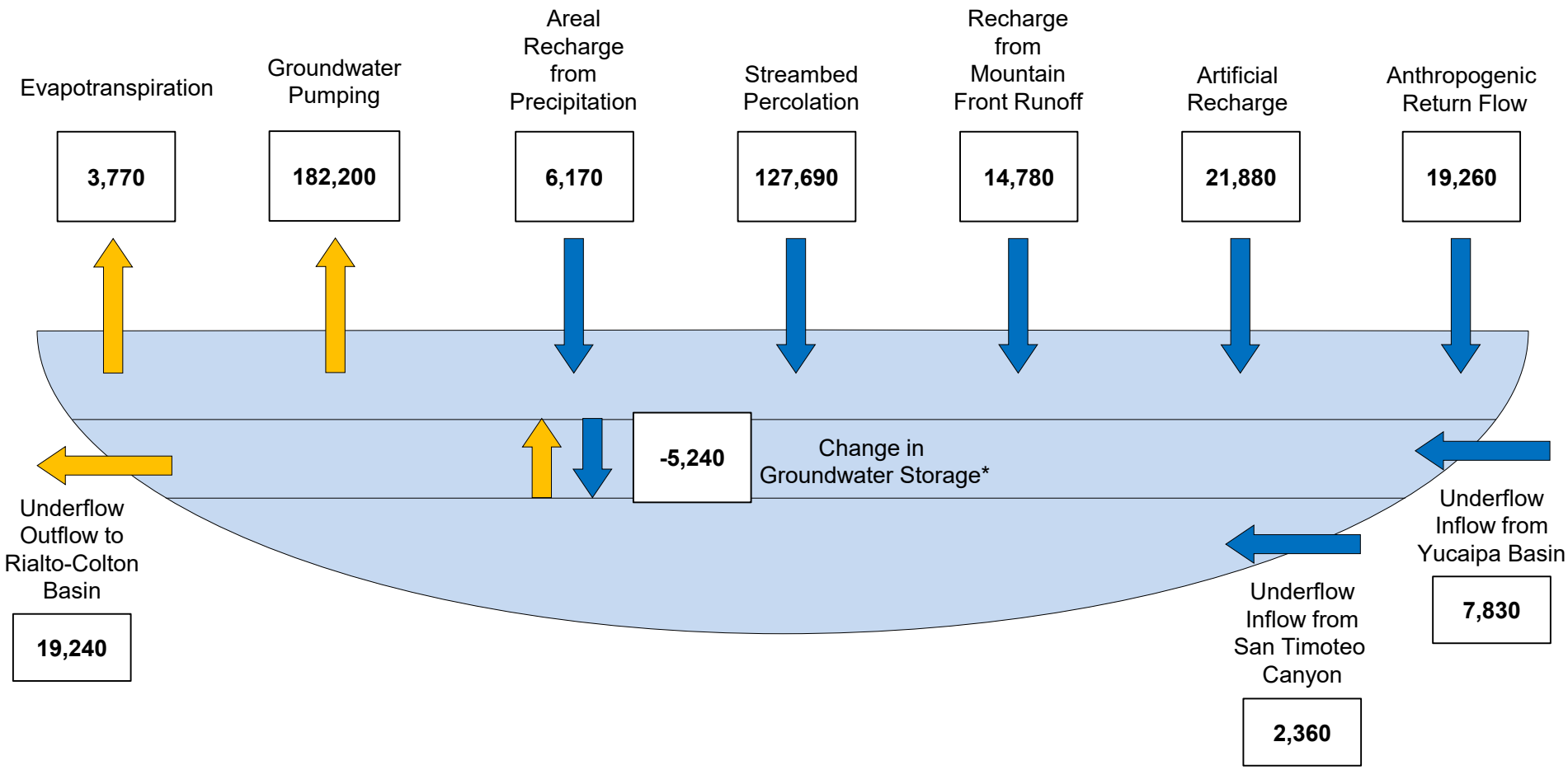

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR THE SBBA 1966 to 2016

10-Apr-20

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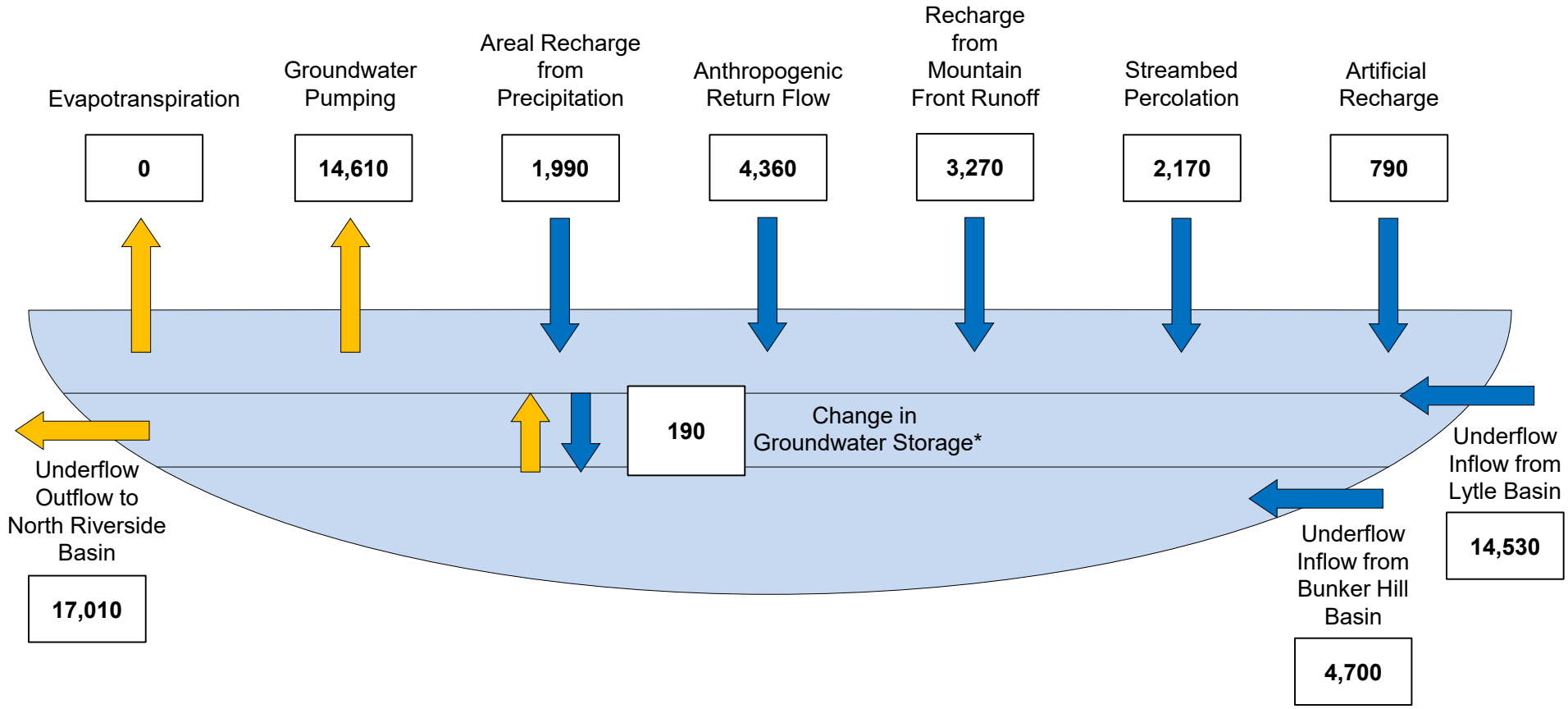
X:\Projects\San_Bernardino_MUNI\31) Integrated_SAR_Model\4)Technical_Memos\(8) Summary Report\Draft\Figures



All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR RIALTO-COLTON BASIN 1966 to 2016

10-Apr-20

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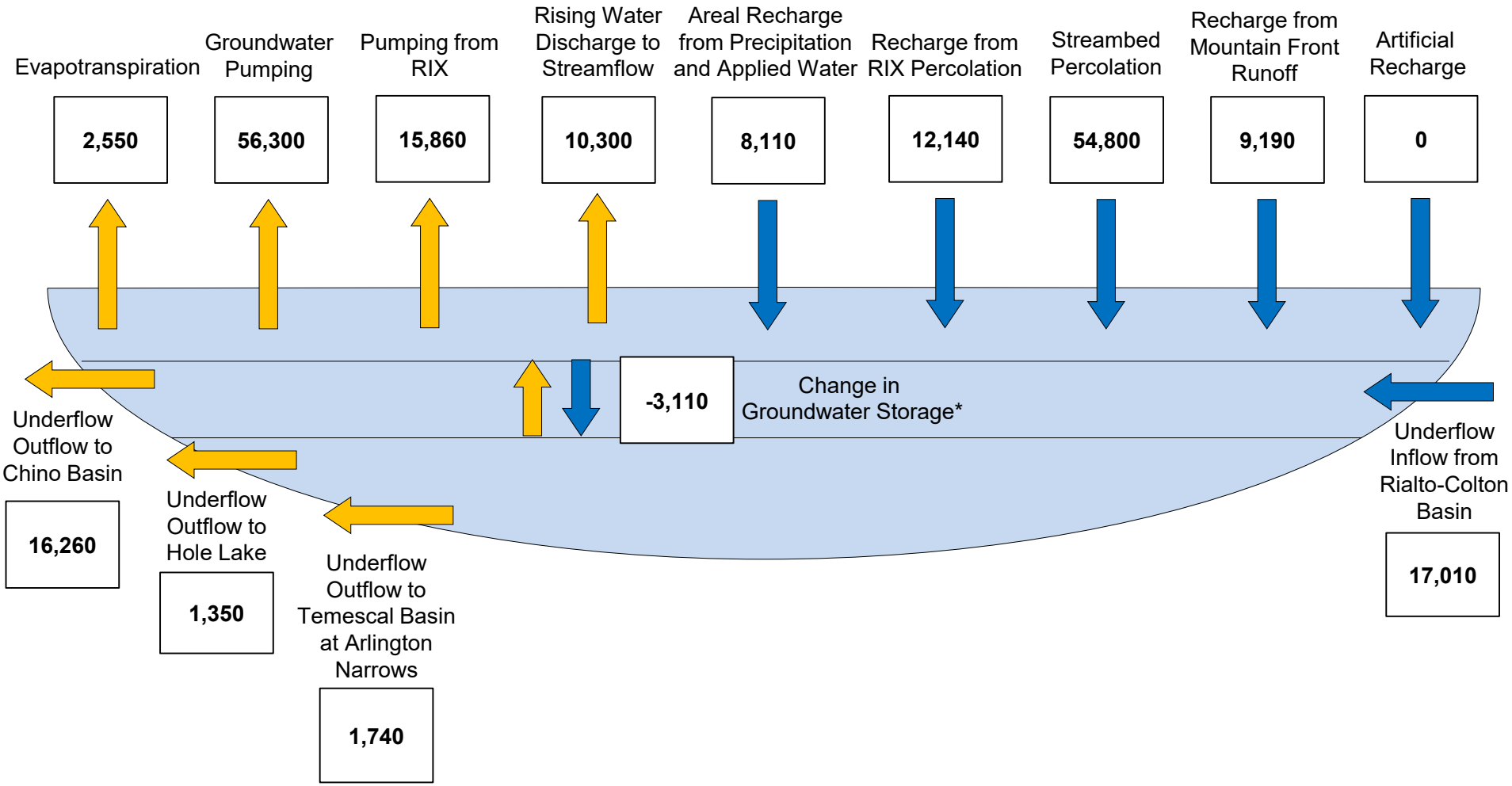

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR RIVERSIDE-ARLINGTON BASIN 1966 to 2016

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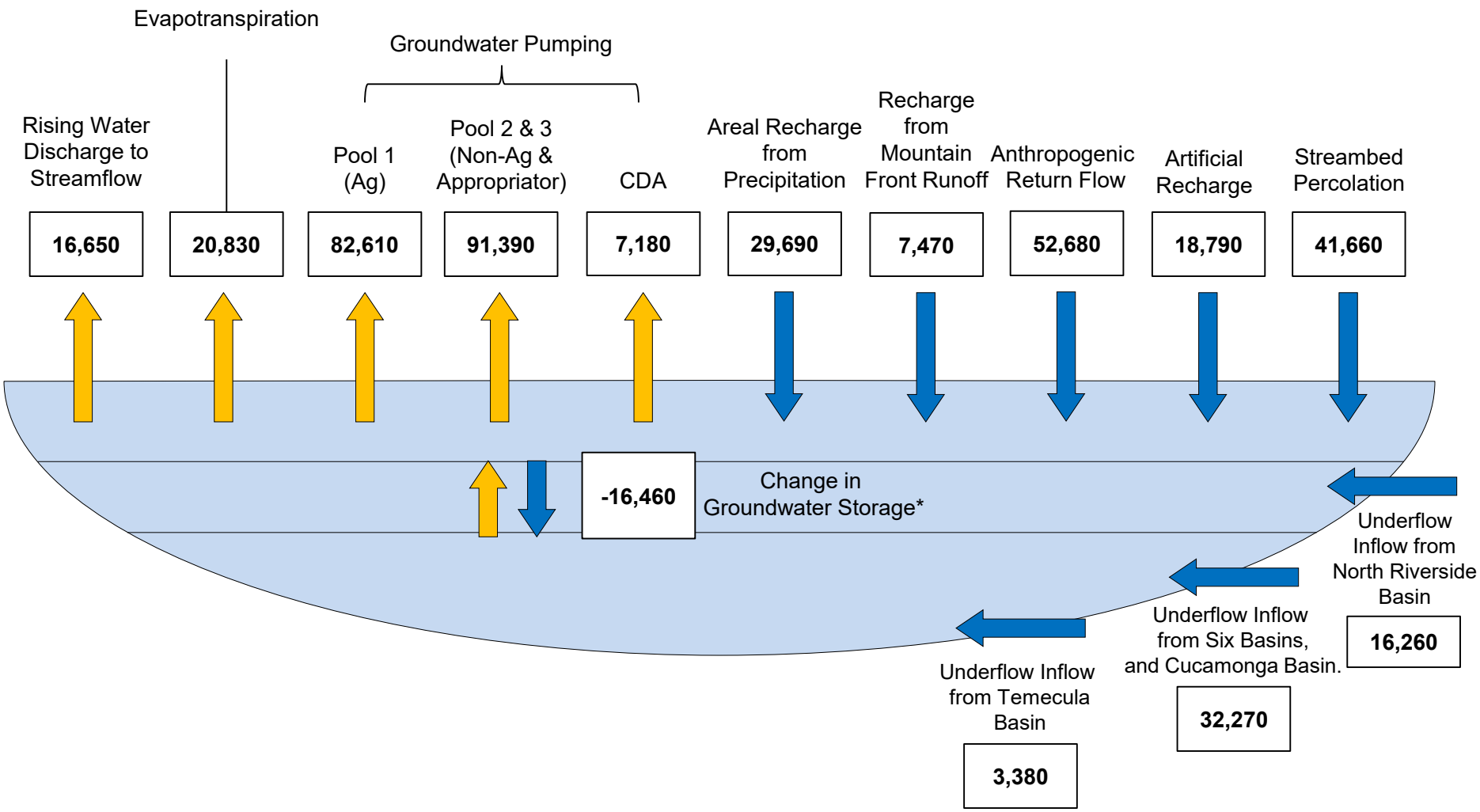

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR CHINO BASIN 1966 to 2016

10-Apr-20

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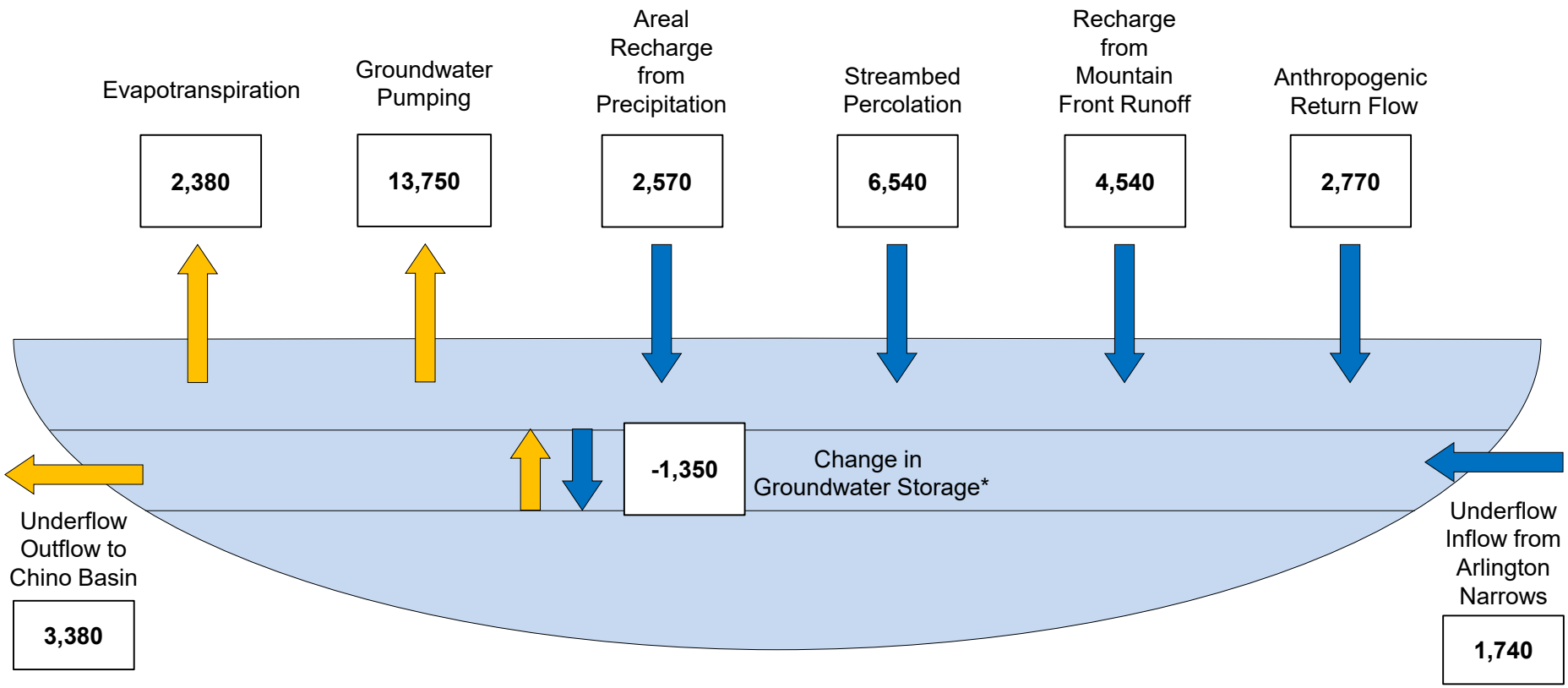

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR TEMESCAL BASIN 1966 to 2016

10-Apr-20

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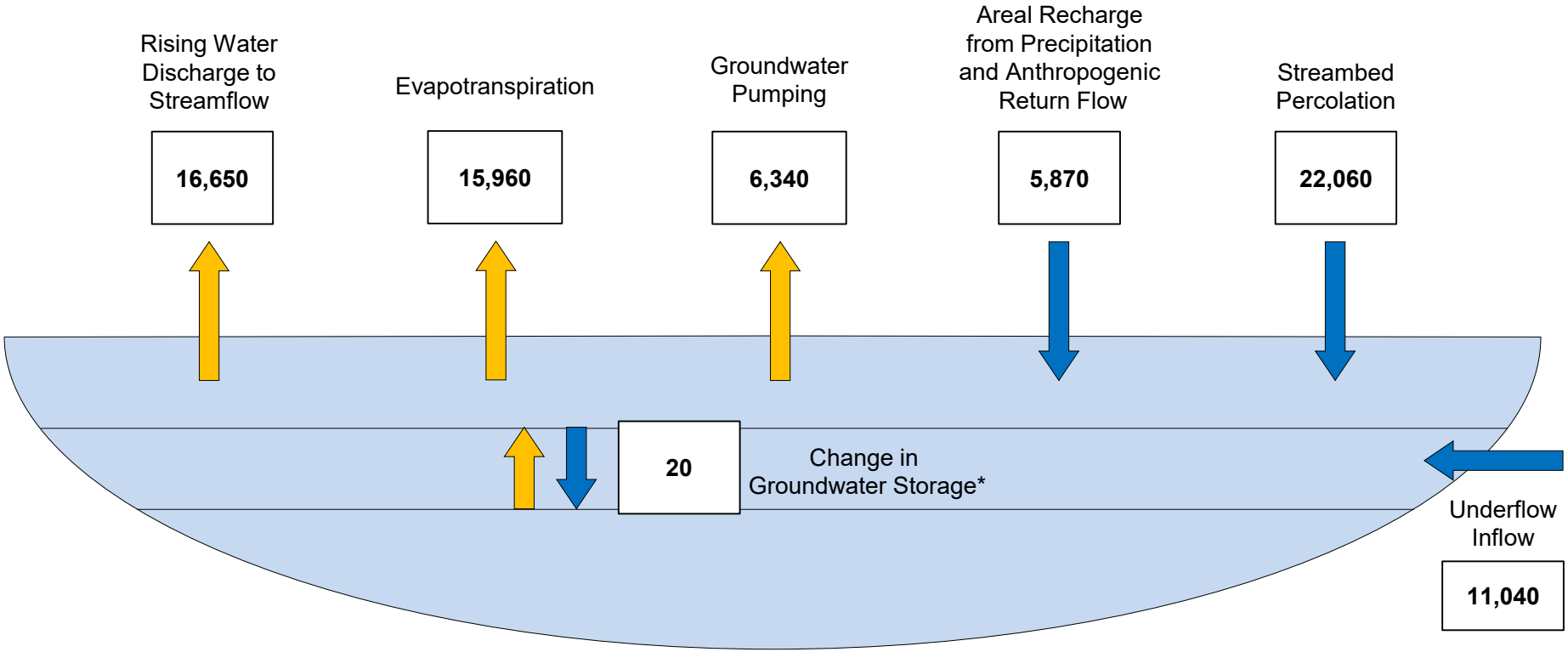

All values in acre-ft/yr

*A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage.

AVERAGE ANNUAL WATER BUDGETS FOR PRADO BASIN 1966 to 2016

10-Apr-20

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Cumulative Annual Change in Groundwater Storage for Yucaipa Basin
1966 - 2016

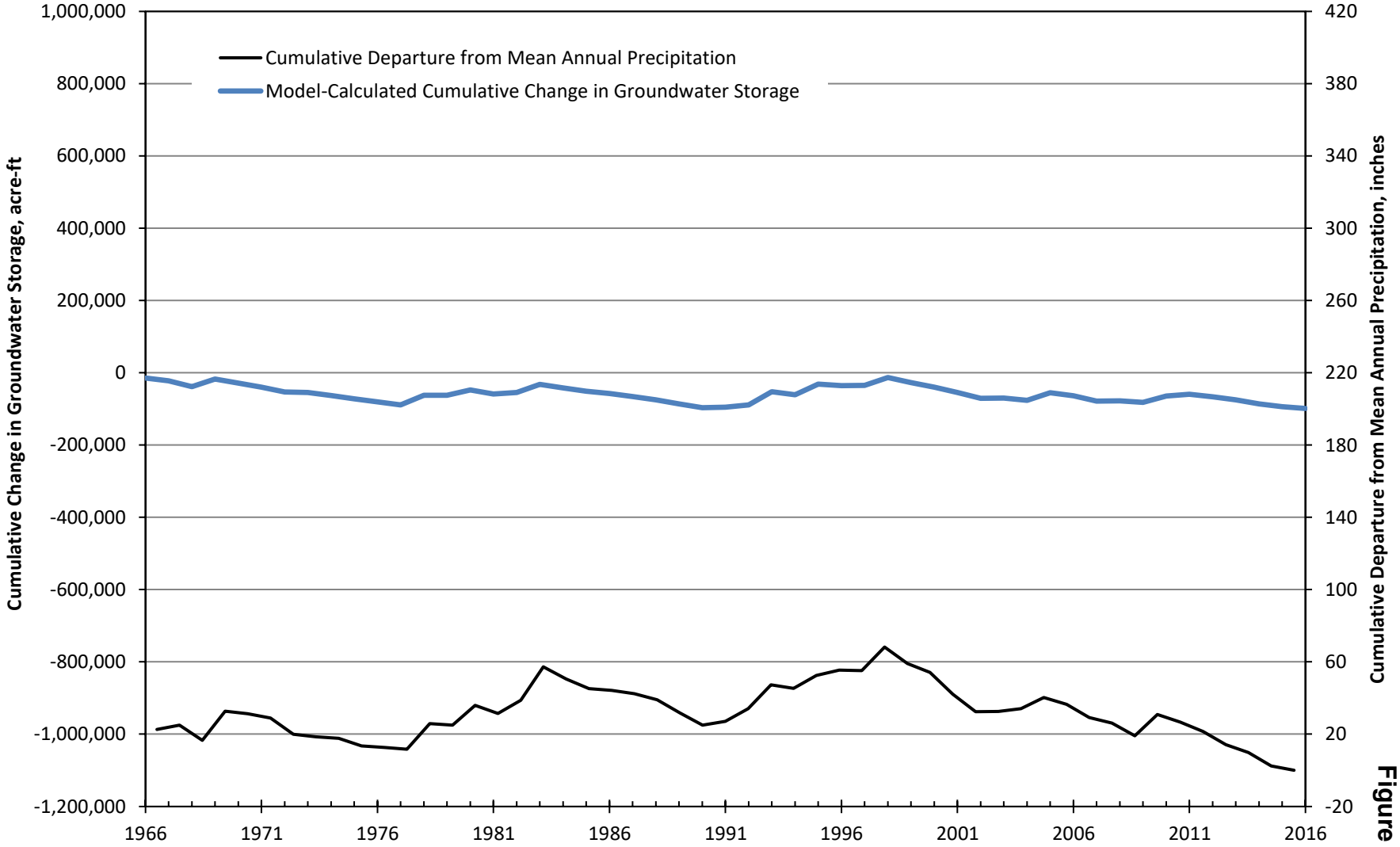


Figure 246

DRAFT

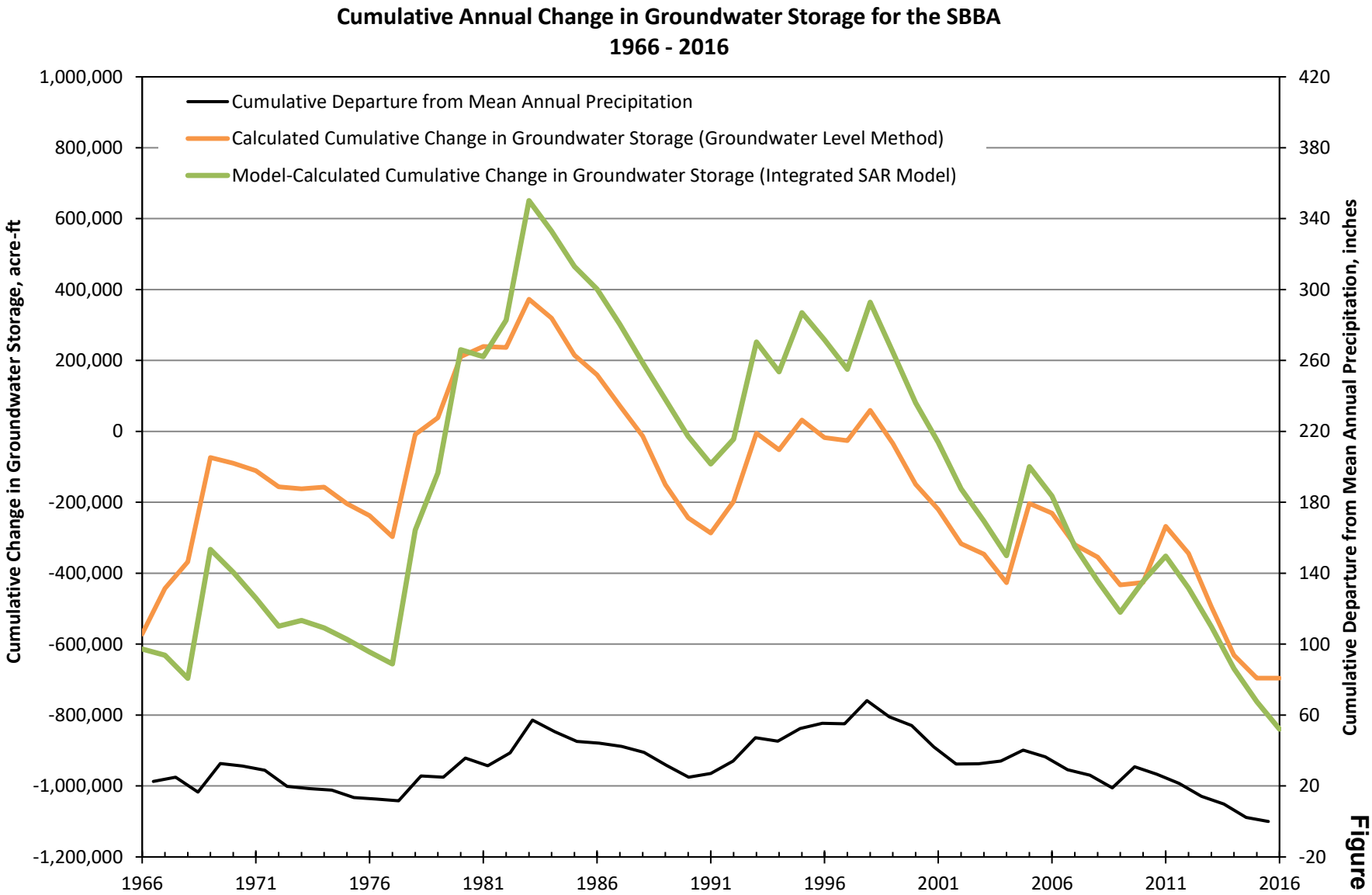


Figure 247

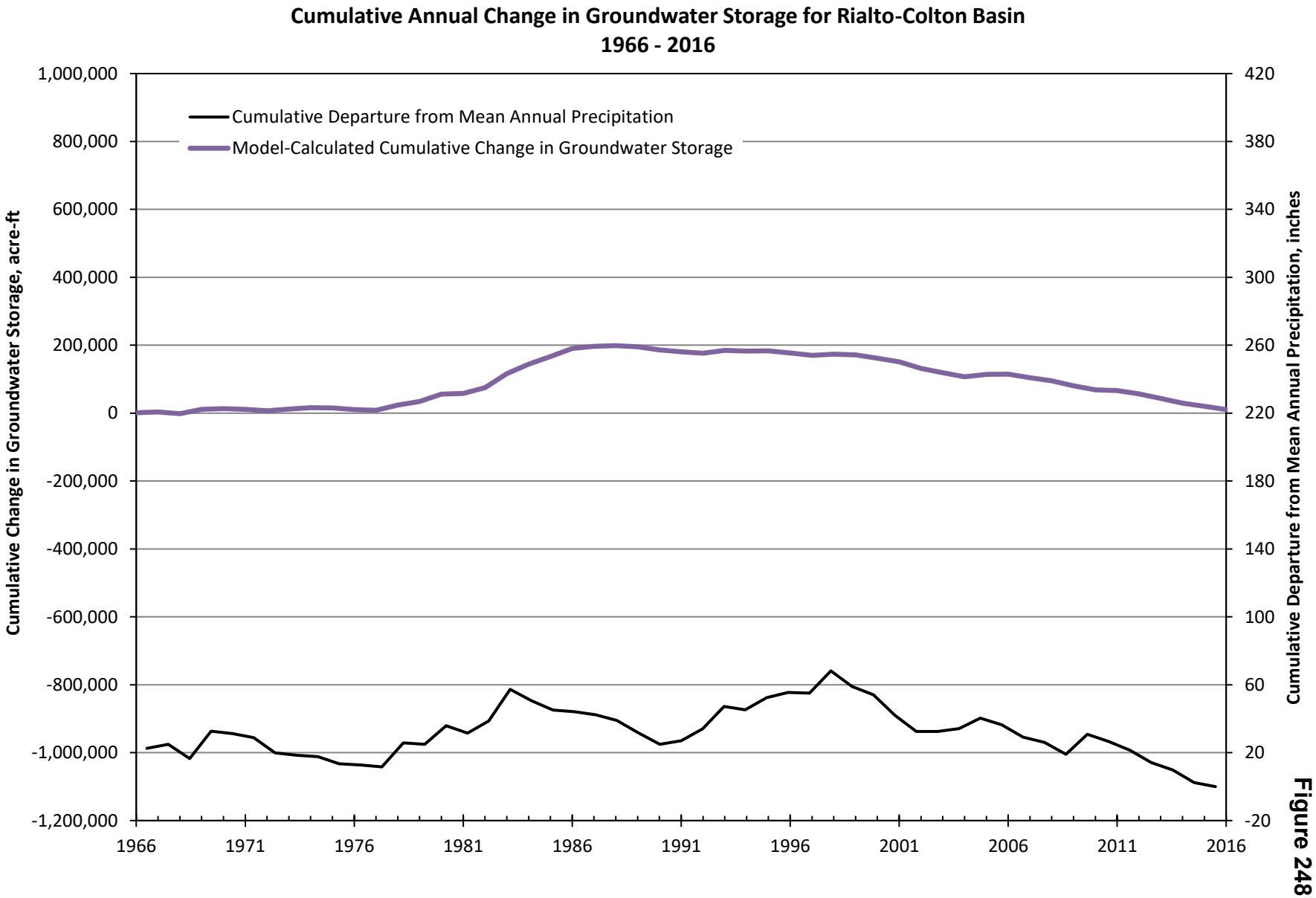

Cumulative Annual Change in Groundwater Storage for Rialto-Colton Basin
1966 - 2016
Cumulative Departure from Mean Annual Precipitation
Model-Calculated Cumulative Change in Groundwater Storage
Cumulative Change in Groundwater Storage, acre-ft
Cumulative Departure from Mean Annual Precipitation, inches
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
-400,000
-600,000
-800,000
-1,000,000
-1,200,000
420
380
340
300
260
220
180
140
100
60
20
-20
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 248

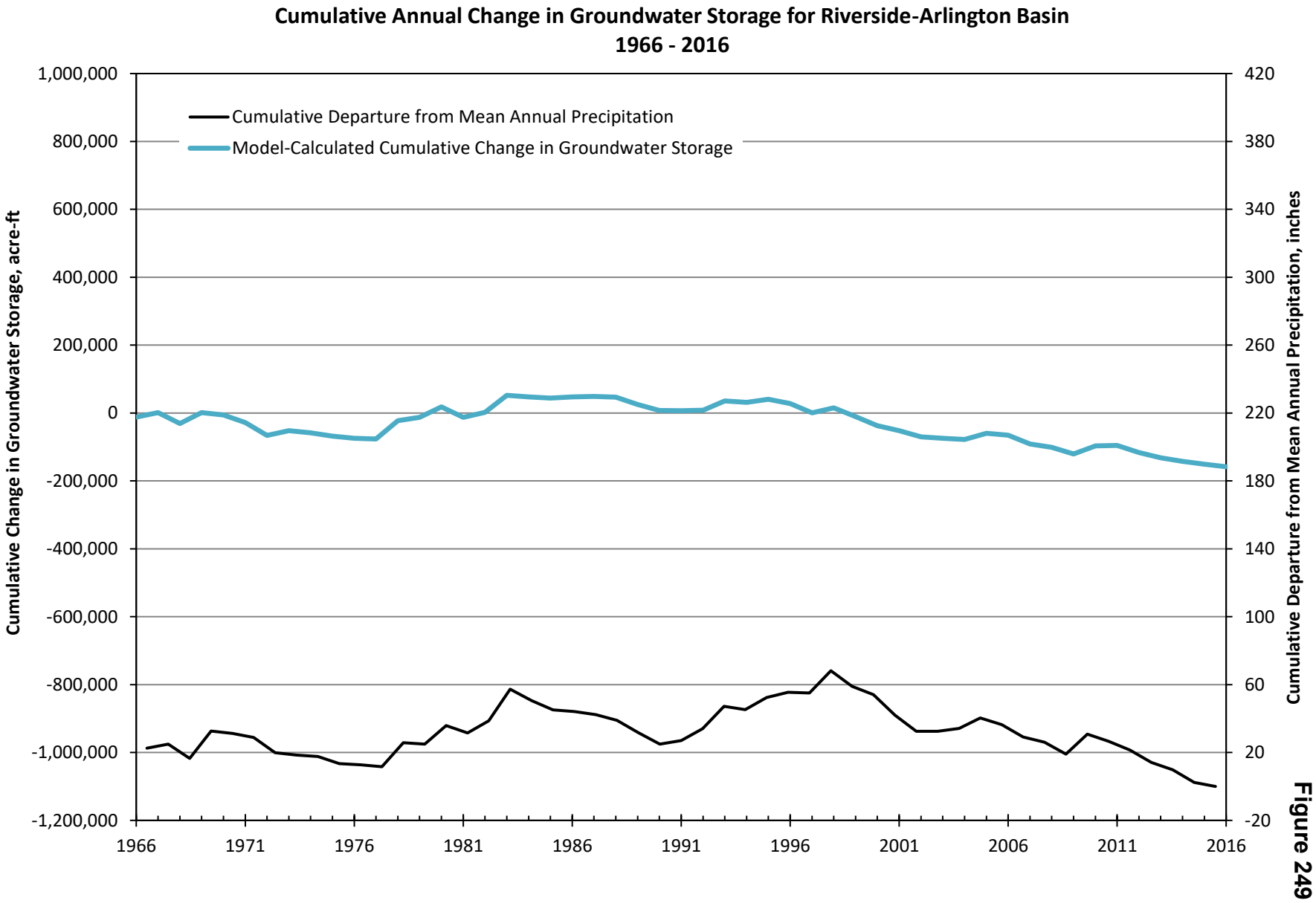

Cumulative Annual Change in Groundwater Storage for Riverside-Arlington Basin
1966 - 2016
Cumulative Departure from Mean Annual Precipitation
Model-Calculated Cumulative Change in Groundwater Storage
Cumulative Change in Groundwater Storage, acre-ft
Cumulative Departure from Mean Annual Precipitation, inches
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
-400,000
-600,000
-800,000
-1,000,000
-1,200,000
420
380
340
300
260
220
180
140
100
60
20
-20
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016

Figure 249

DRAFT

Cumulative Annual Change in Groundwater Storage for Chino Basin
1966 - 2016

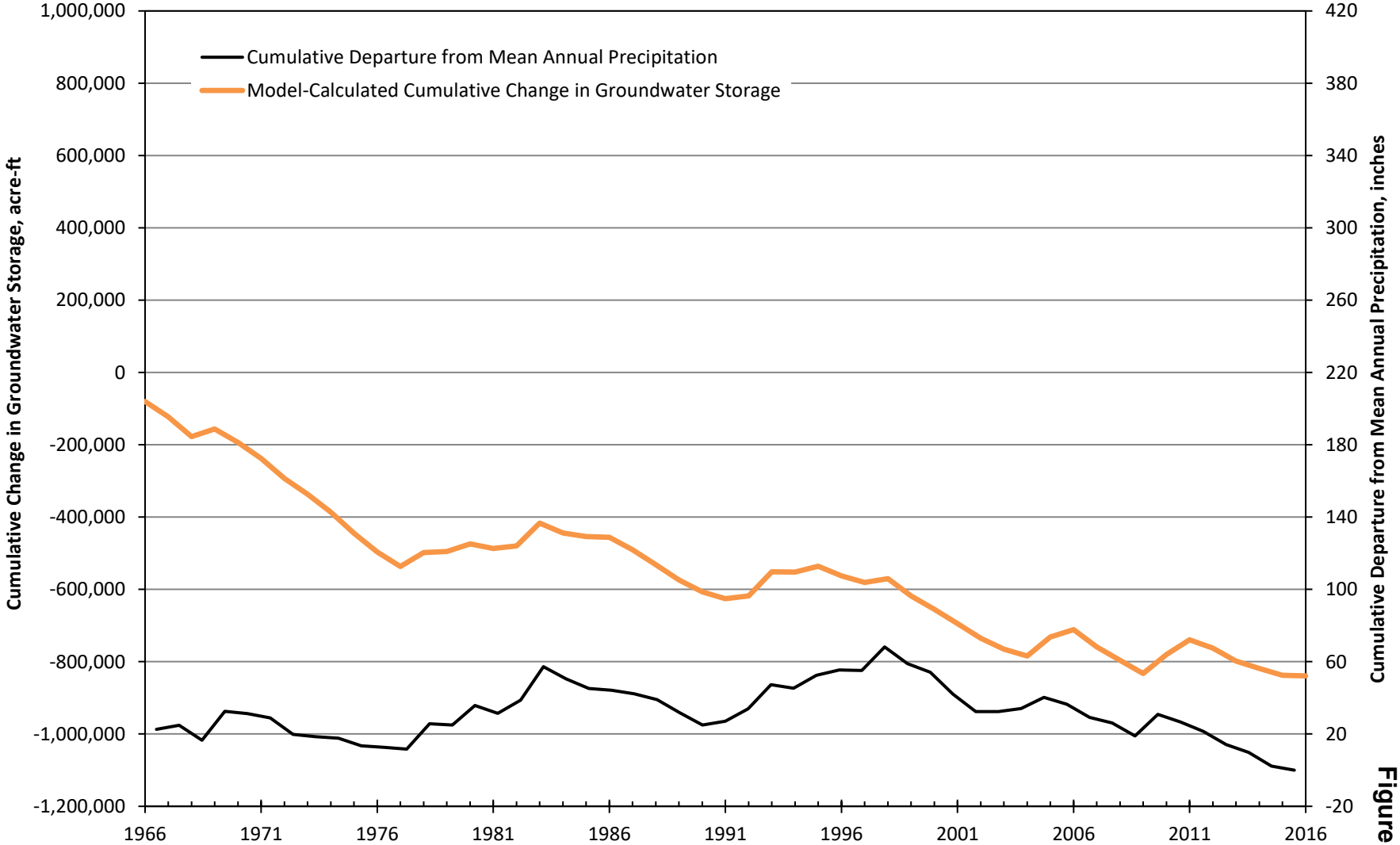


Figure 250

Cumulative Annual Change in Groundwater Storage for Temescal Basin
1966 - 2016

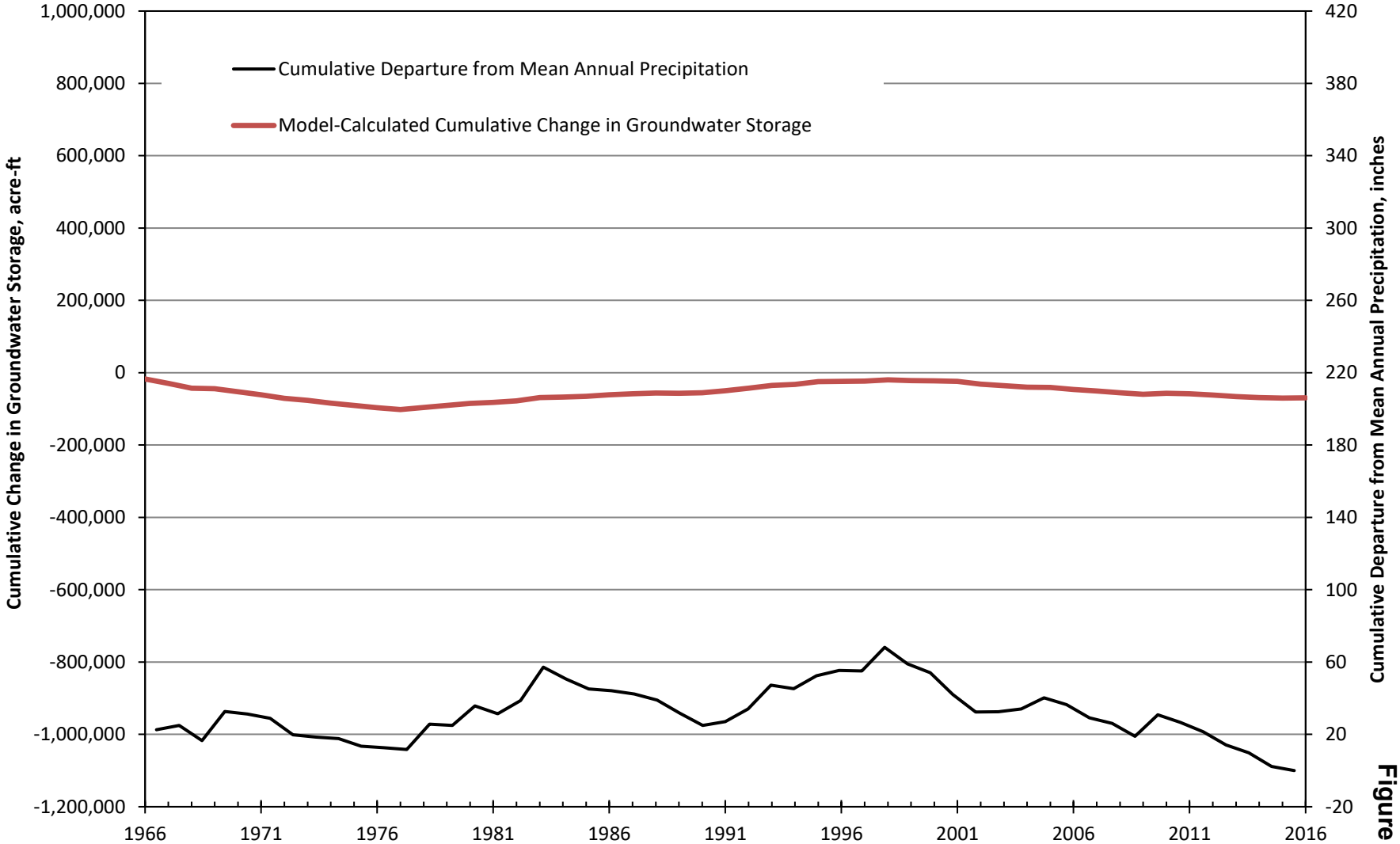
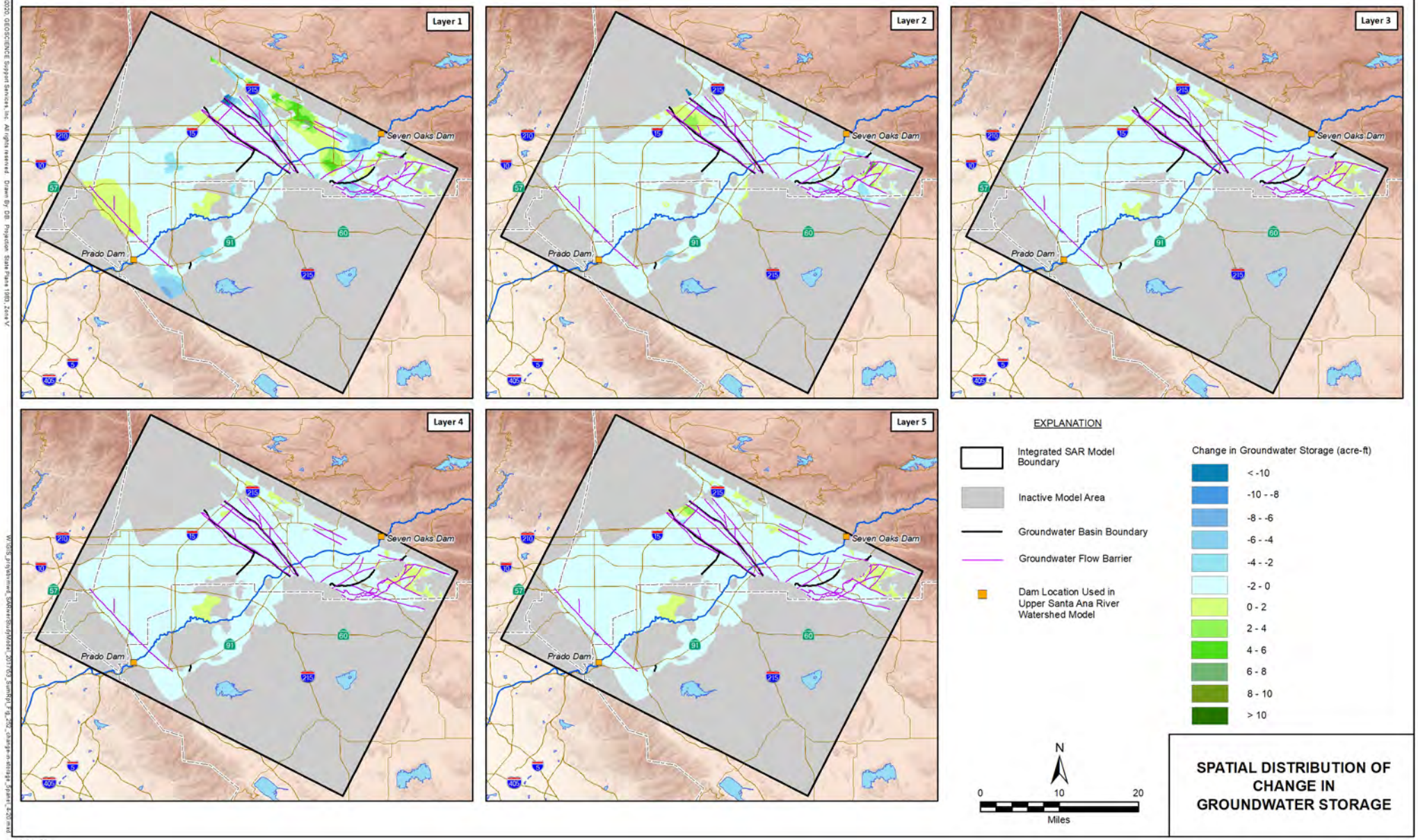


Figure 251



SPATIAL DISTRIBUTION OF CHANGE IN GROUNDWATER STORAGE

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 252

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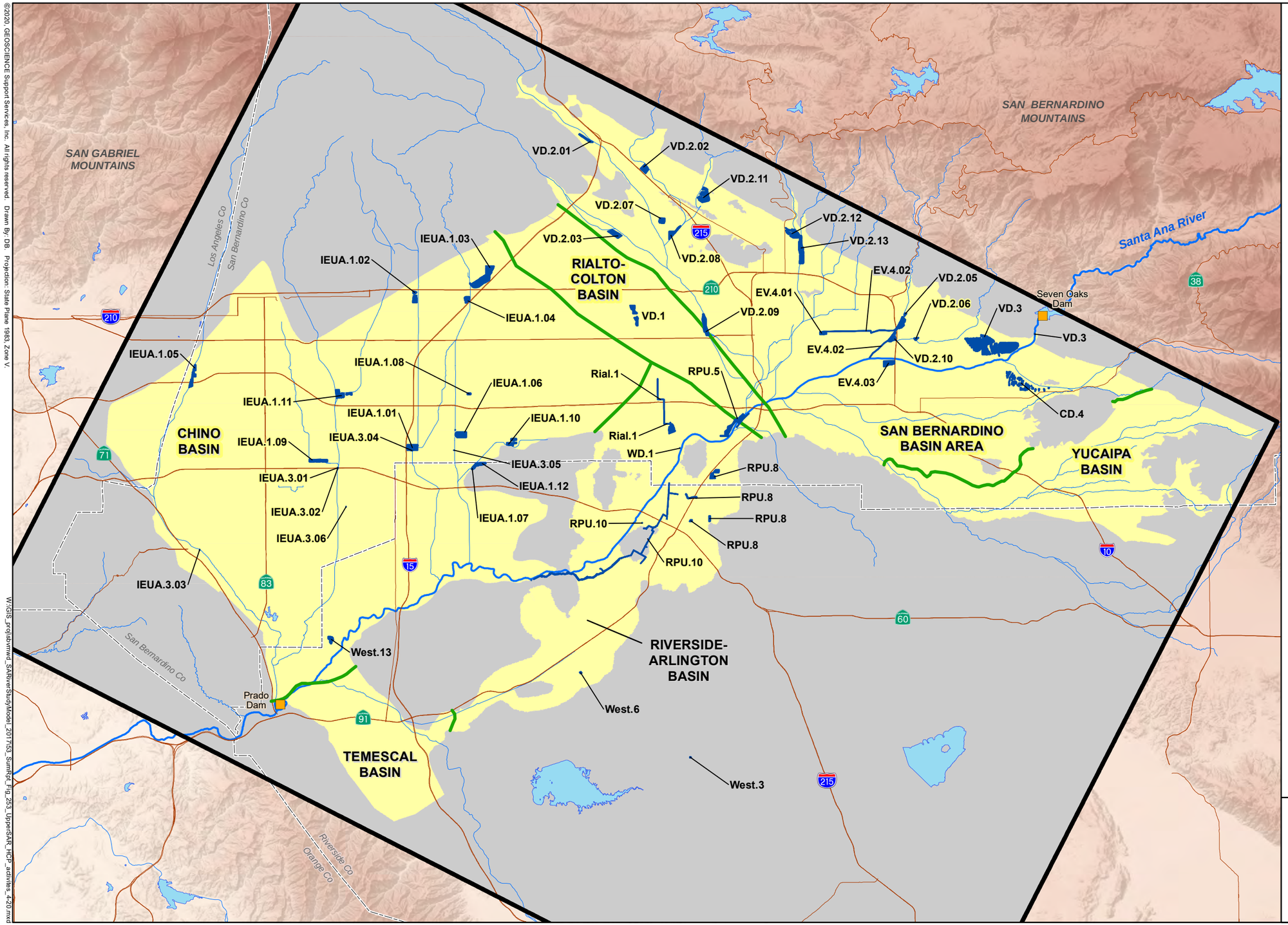

EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - VD.2.05 - Project ID
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description

N

0 4 8
Miles

LOCATION OF HCP COVERED ACTIVITIES (OVERVIEW)

W:\GIS_proj\sbvmwd_SARiverStudyModel_201753_SumRpt_Fig_253_UpperSAR_HCP_activities_4-20.mxd

10-Apr-20

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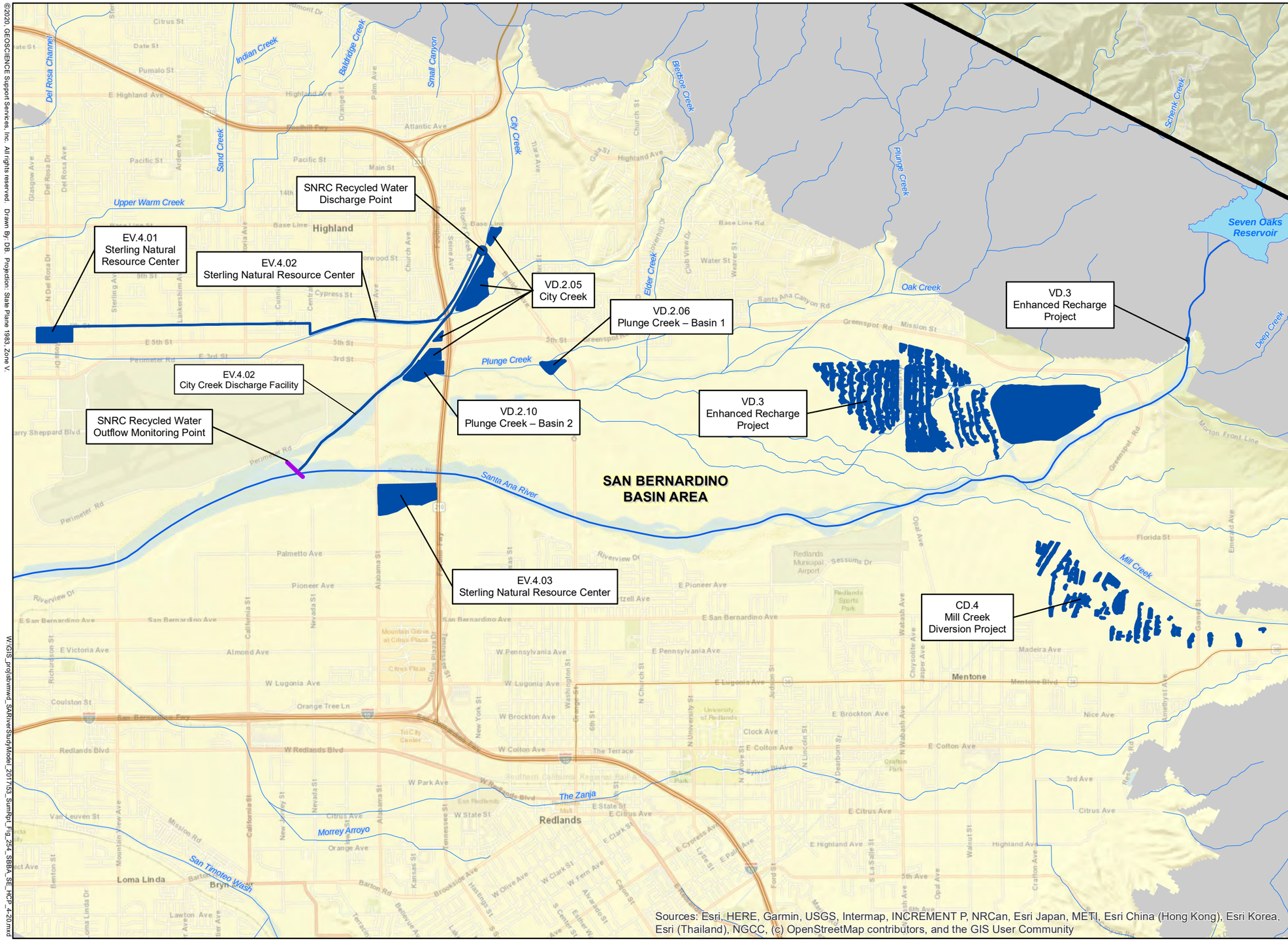
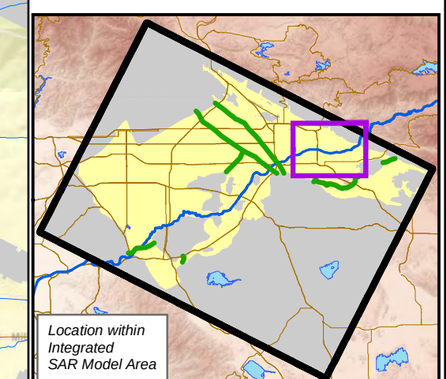


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - VD.2.05 City Creek — Project ID / Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 4,000 8,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - SBBA SOUTHEAST

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_254_SBBA_SE_HCP_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 254

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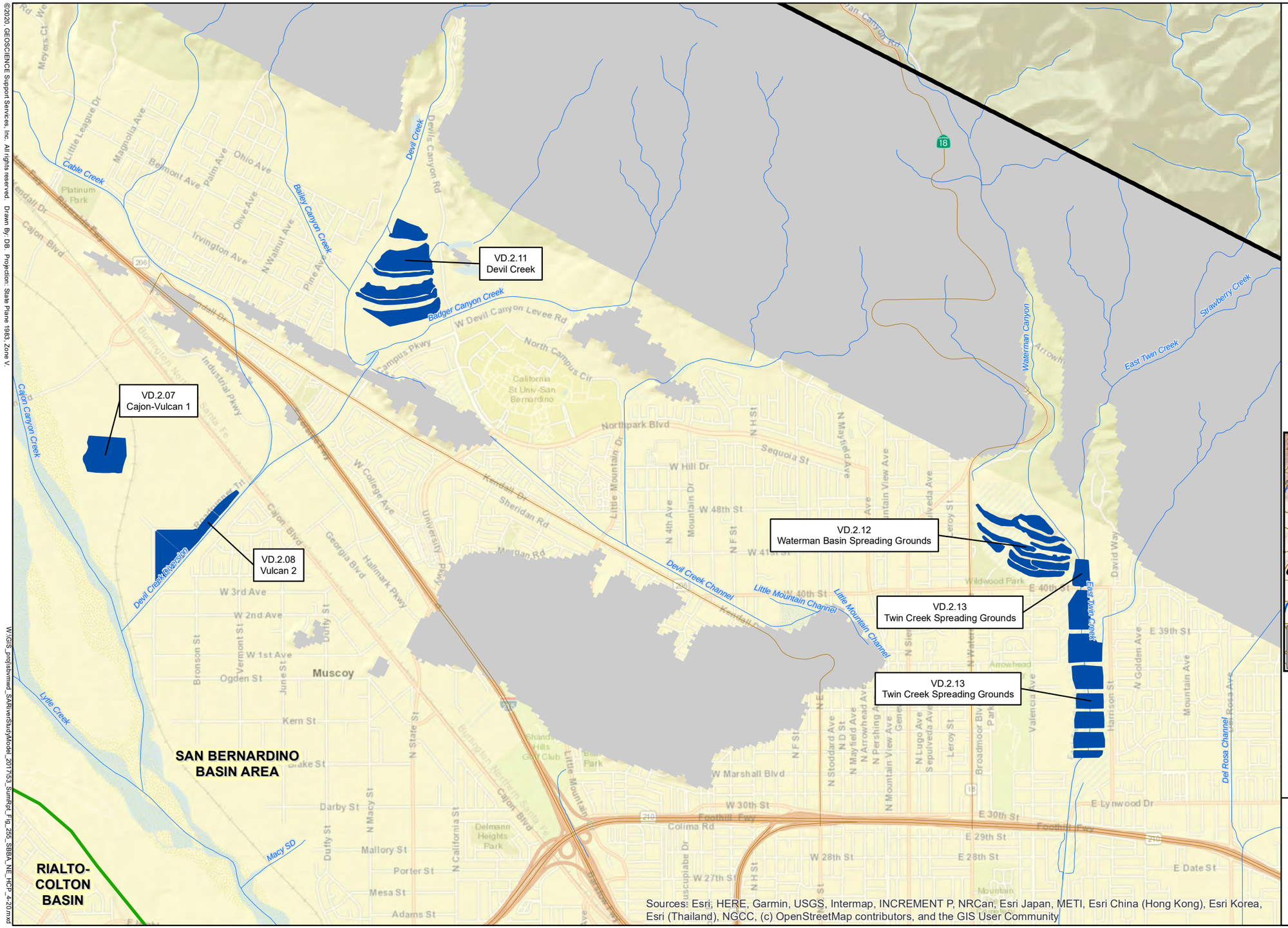


EXPLANATION

Integrated SAR Model Boundary

Active Model Area

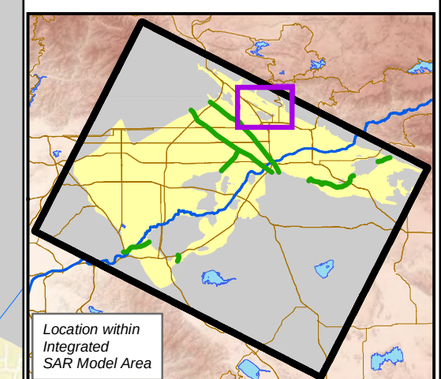
Inactive Model Area

Habitat Conservation Plan (HCP) Covered Activity

VD.2.11 - Project ID
Devil Creek - Name of HCP Project

Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - SBBA NORTHEAST

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_255_SBBA_NE_HCP_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 255

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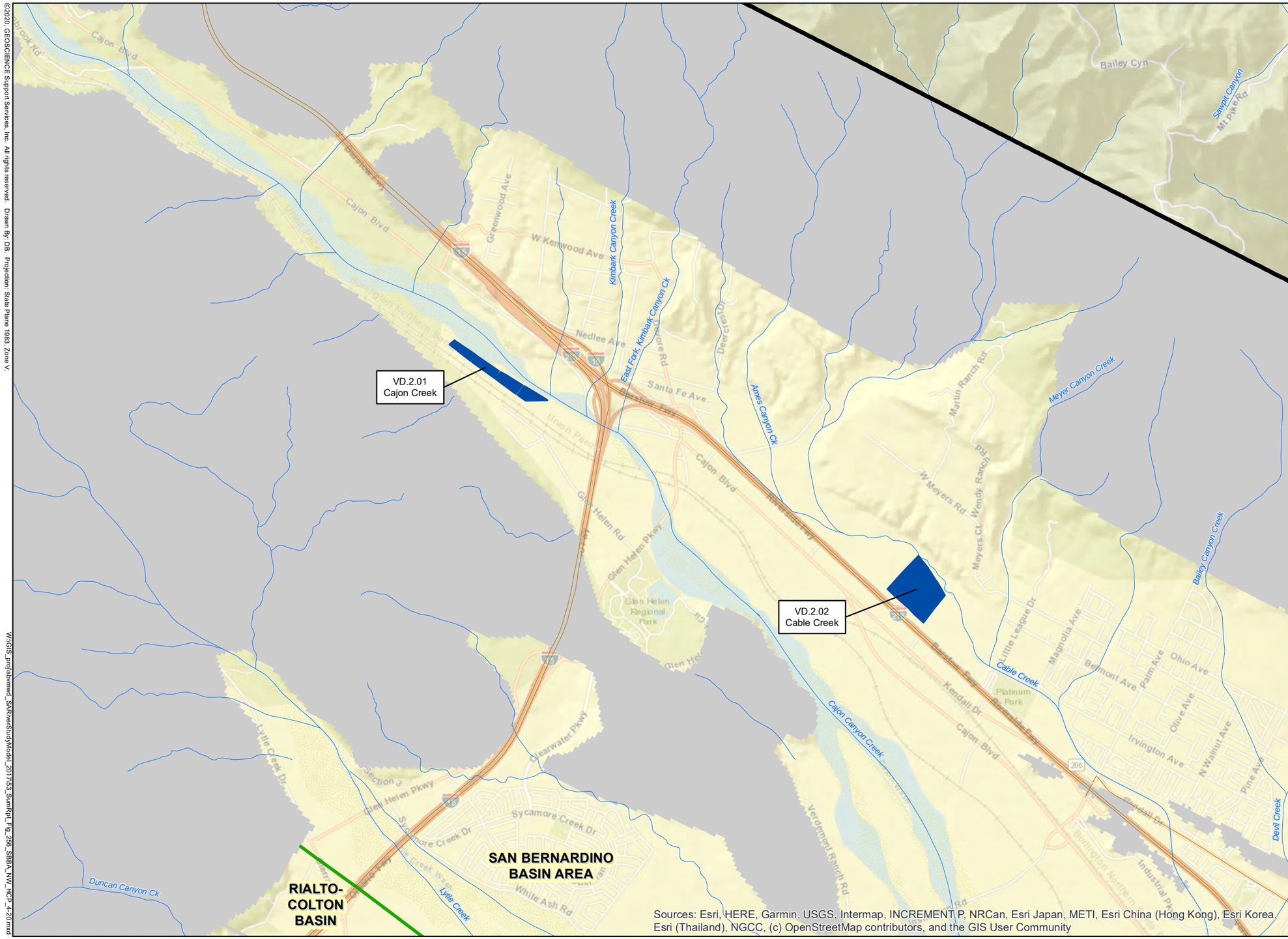
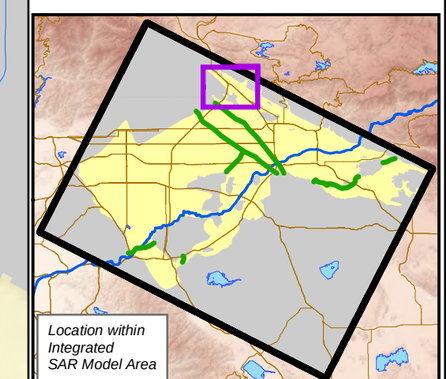


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - VD.2.02 - Project ID
  - Cable Creek - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - SBBA NORTHWEST

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_256_SBBA_NW_HCP_4-20.mxd

10-Apr-20

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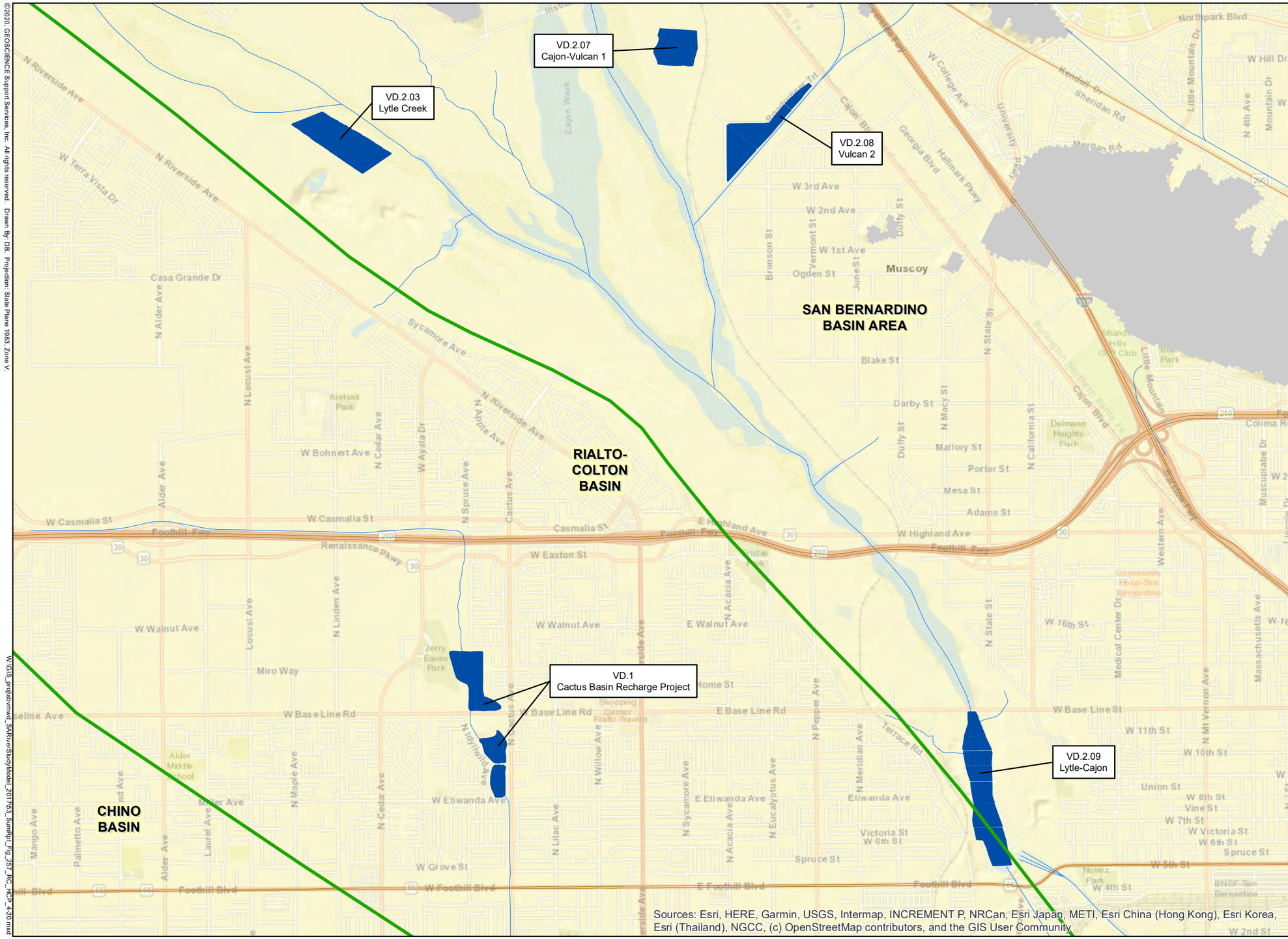
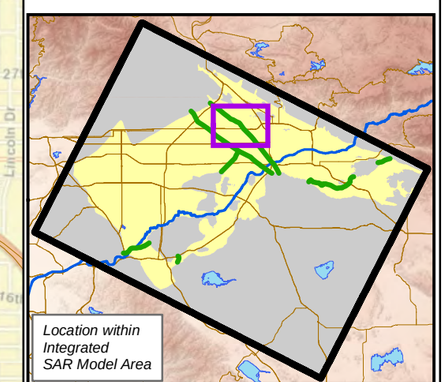


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity — VD.2.03 Lytle Creek
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - RIALTO-COLTON BASIN

W:\GIS_projsbvmwd_SARiverStudyModel_201753_SumRpt_Fig_257_RC_HCP_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 257

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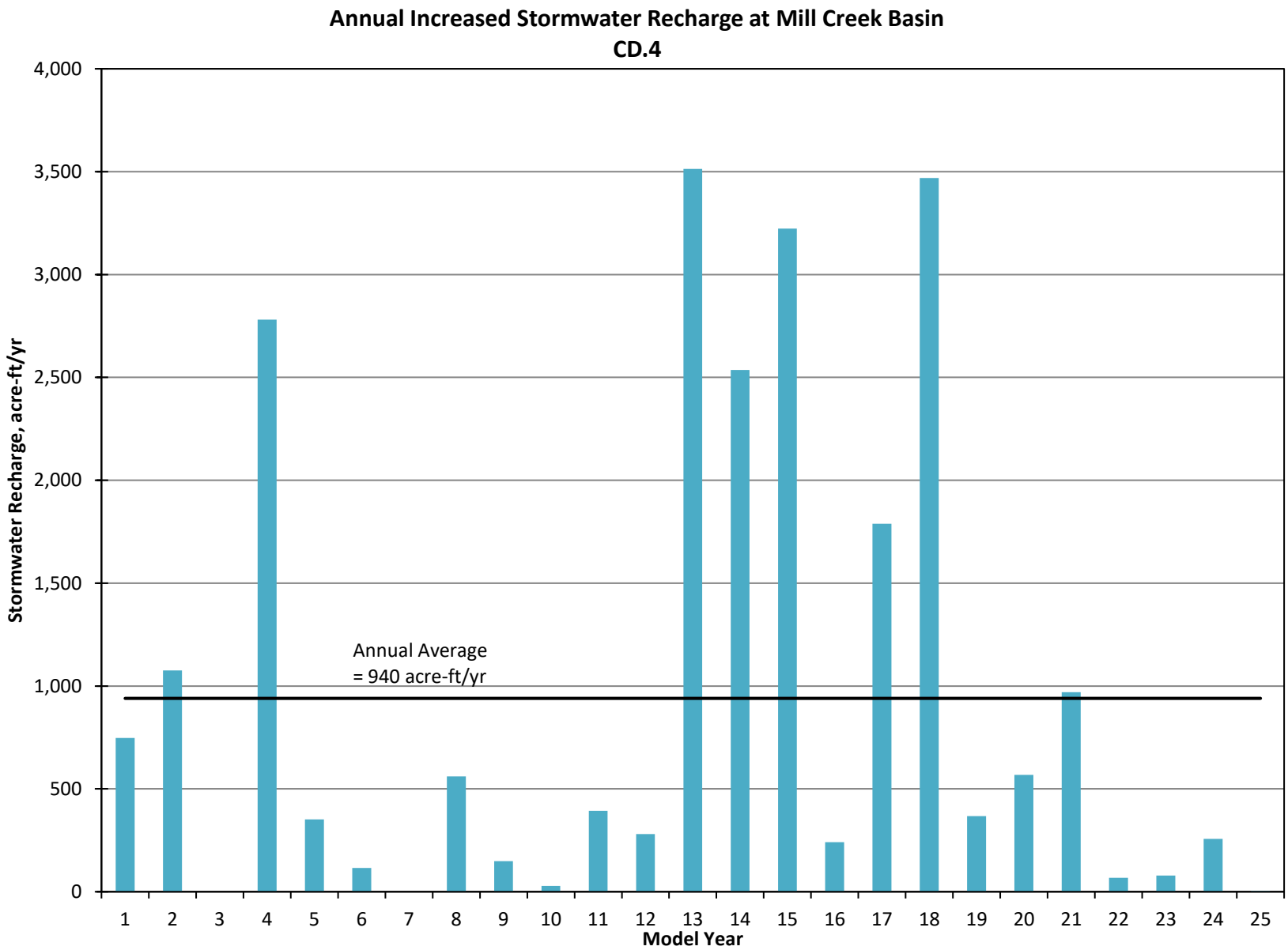

Figure 258

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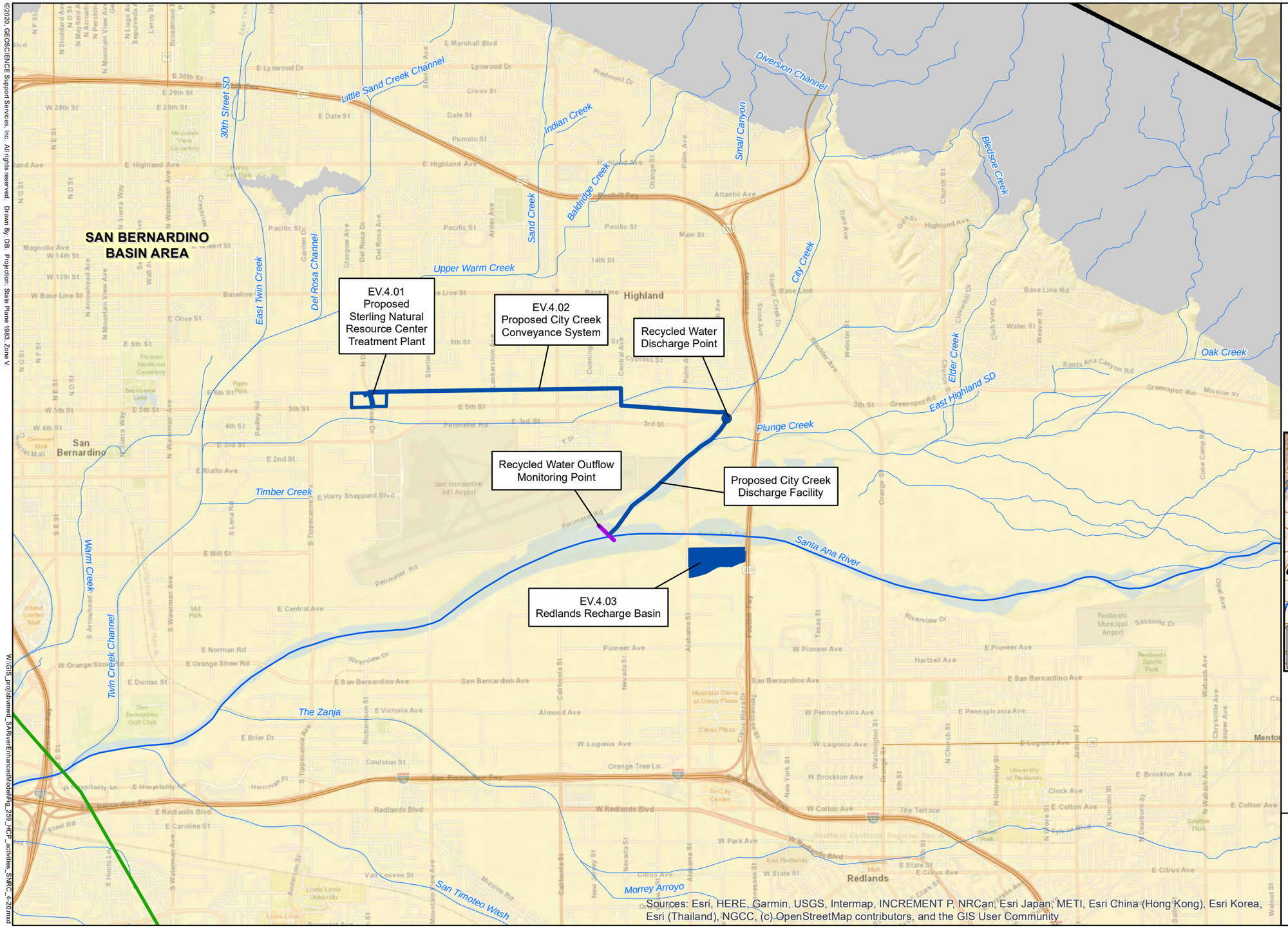
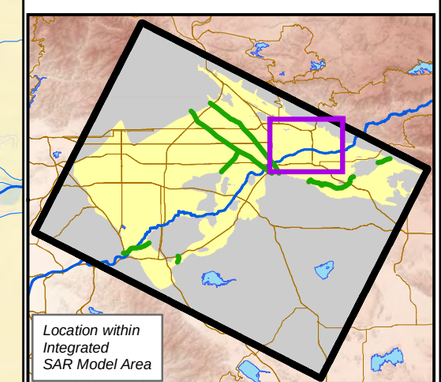


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - Project ID
  - Name of HCP Project
- EV.4.03 Redlands Recharge Basin
- Groundwater Basin Boundary

Refer to Table 2 for HCP Covered Activity Description



N

0 4,000 8,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - SNRC

W:\GIS_proj\sbvmwd_SARiverEnhancedModel\Fig_259_HCP_activities_SNRC_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 259

GEOSCIENCE

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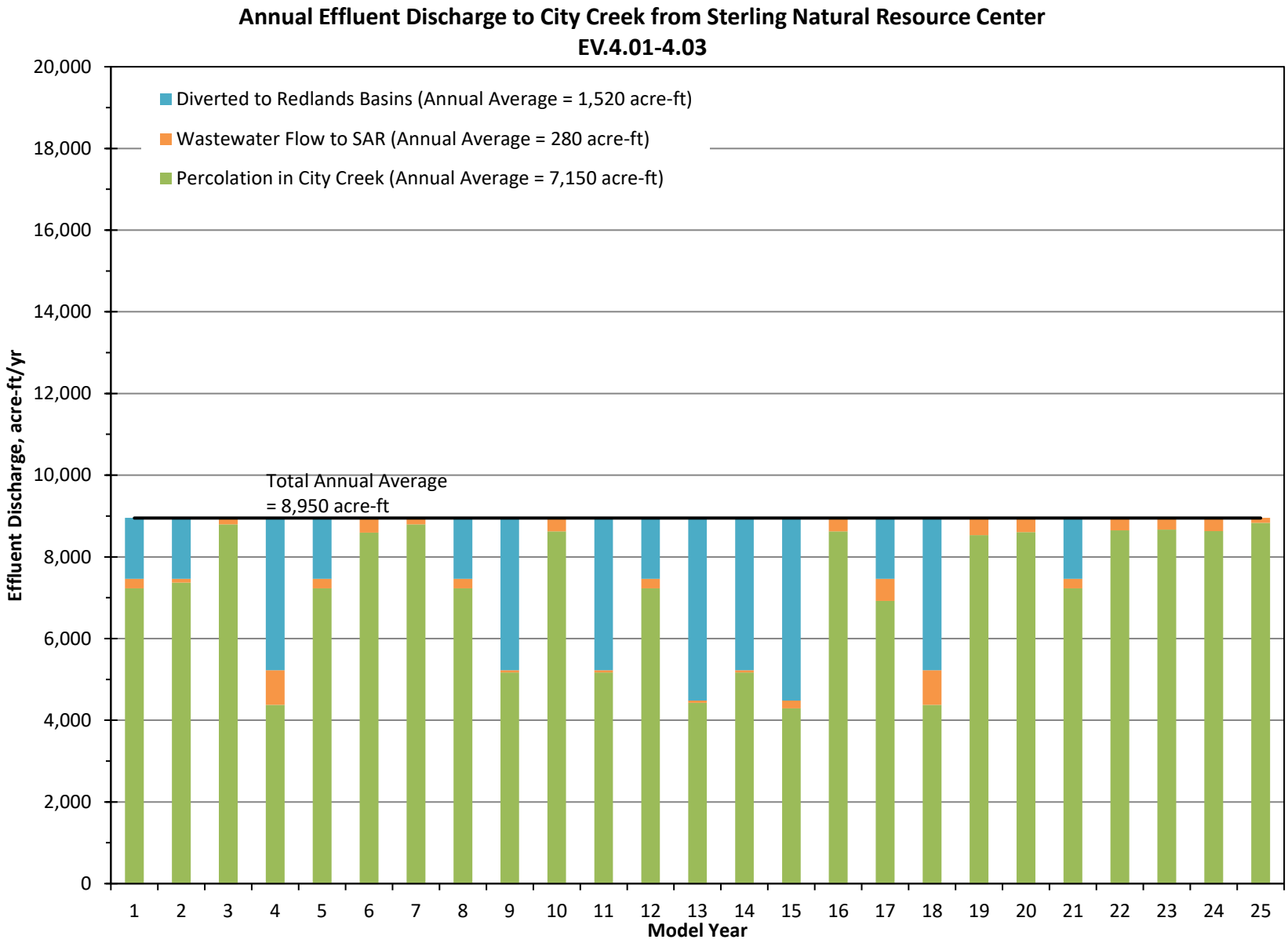

Figure 260

DRAFT

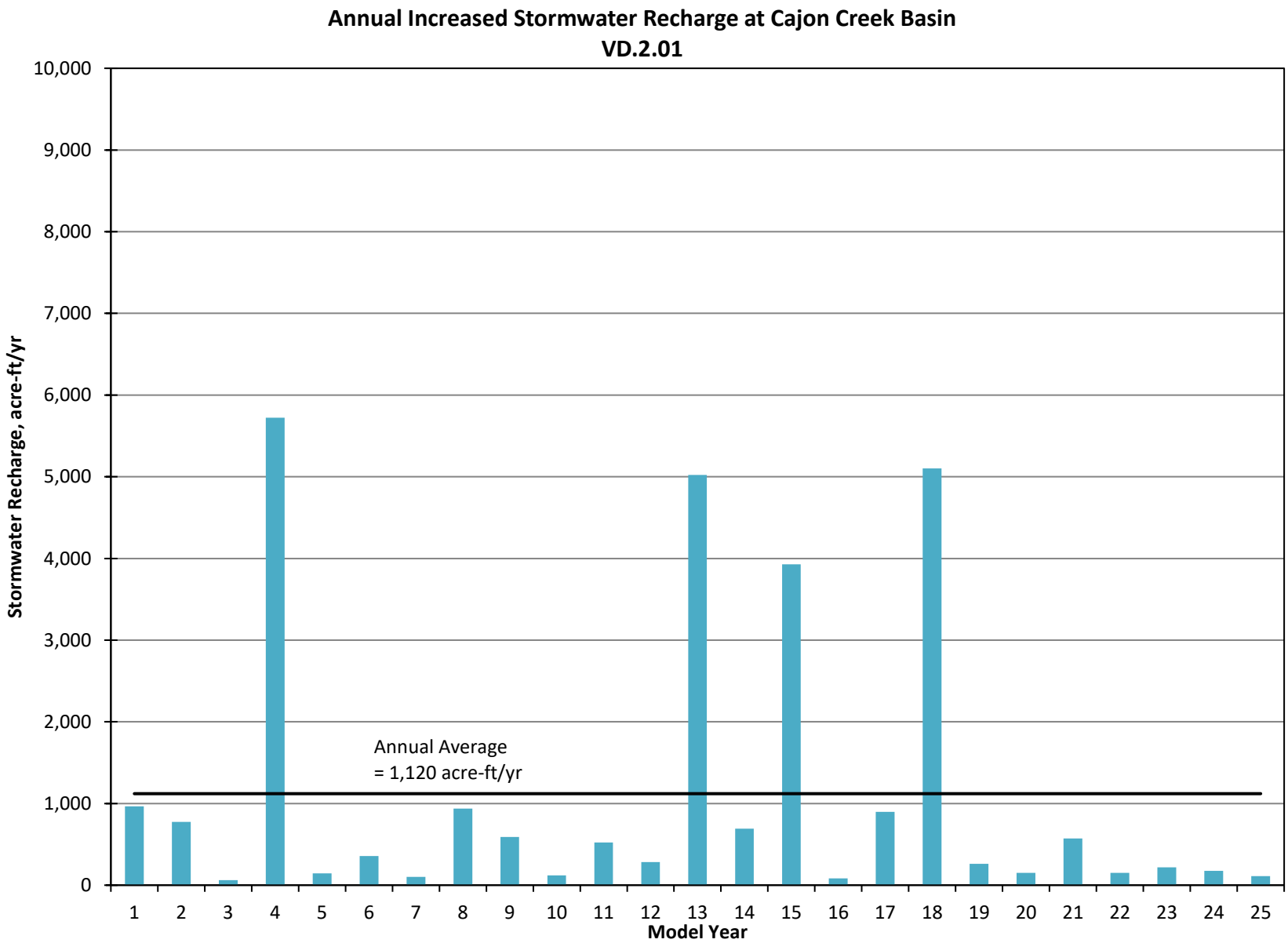

Figure 261

DRAFT

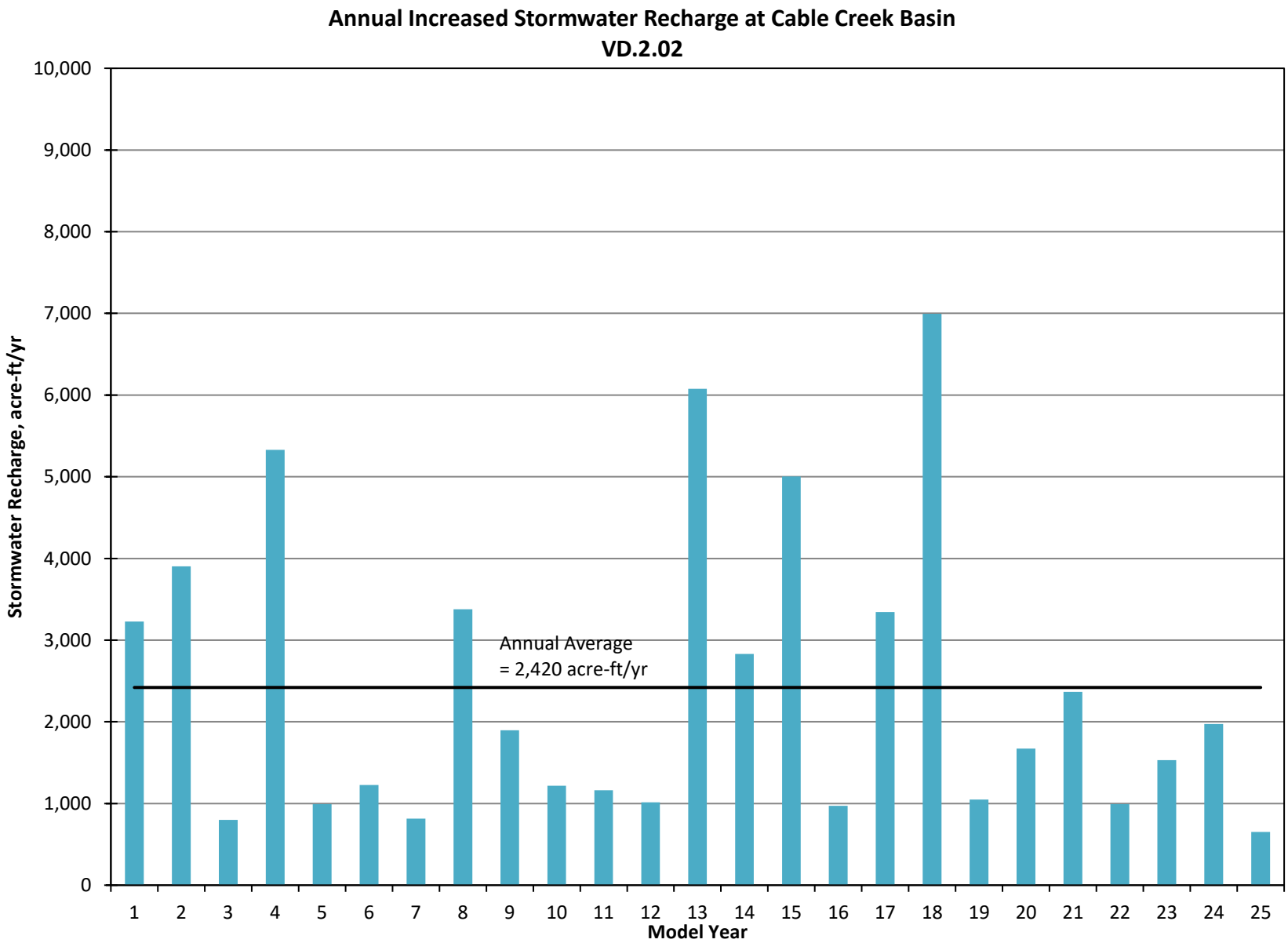

Figure 262

DRAFT

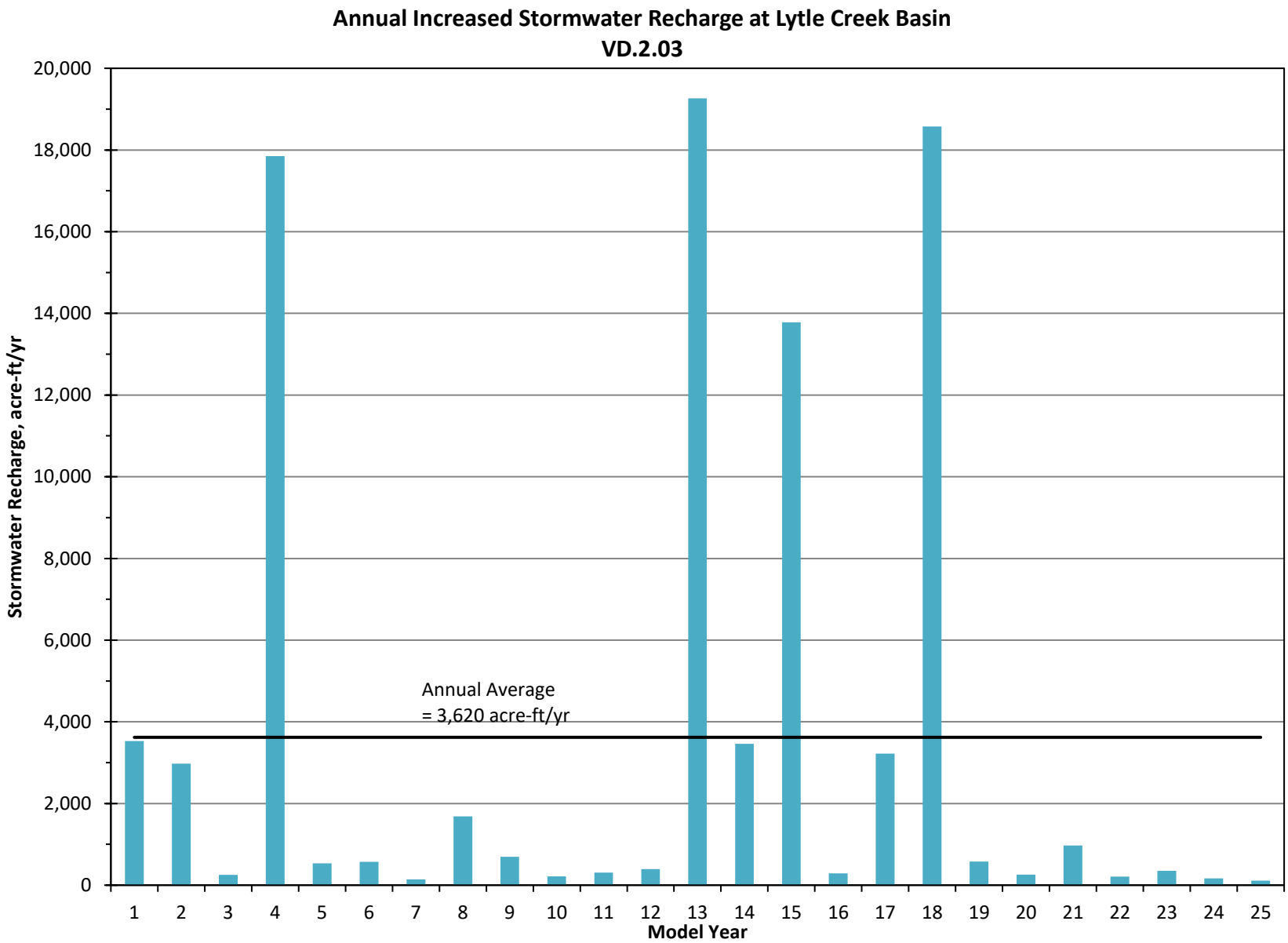

Figure 263

DRAFT

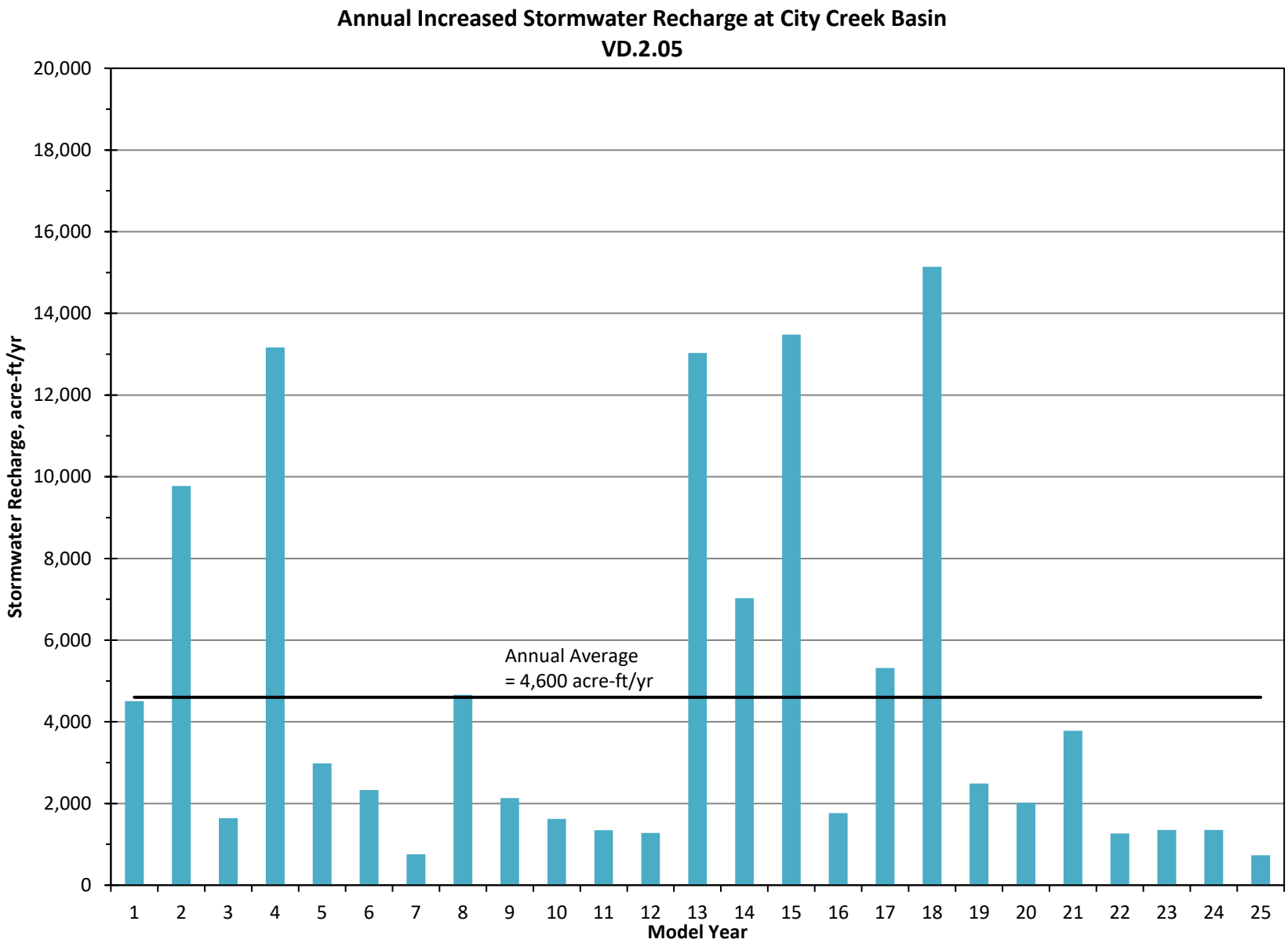

Figure 264

DRAFT

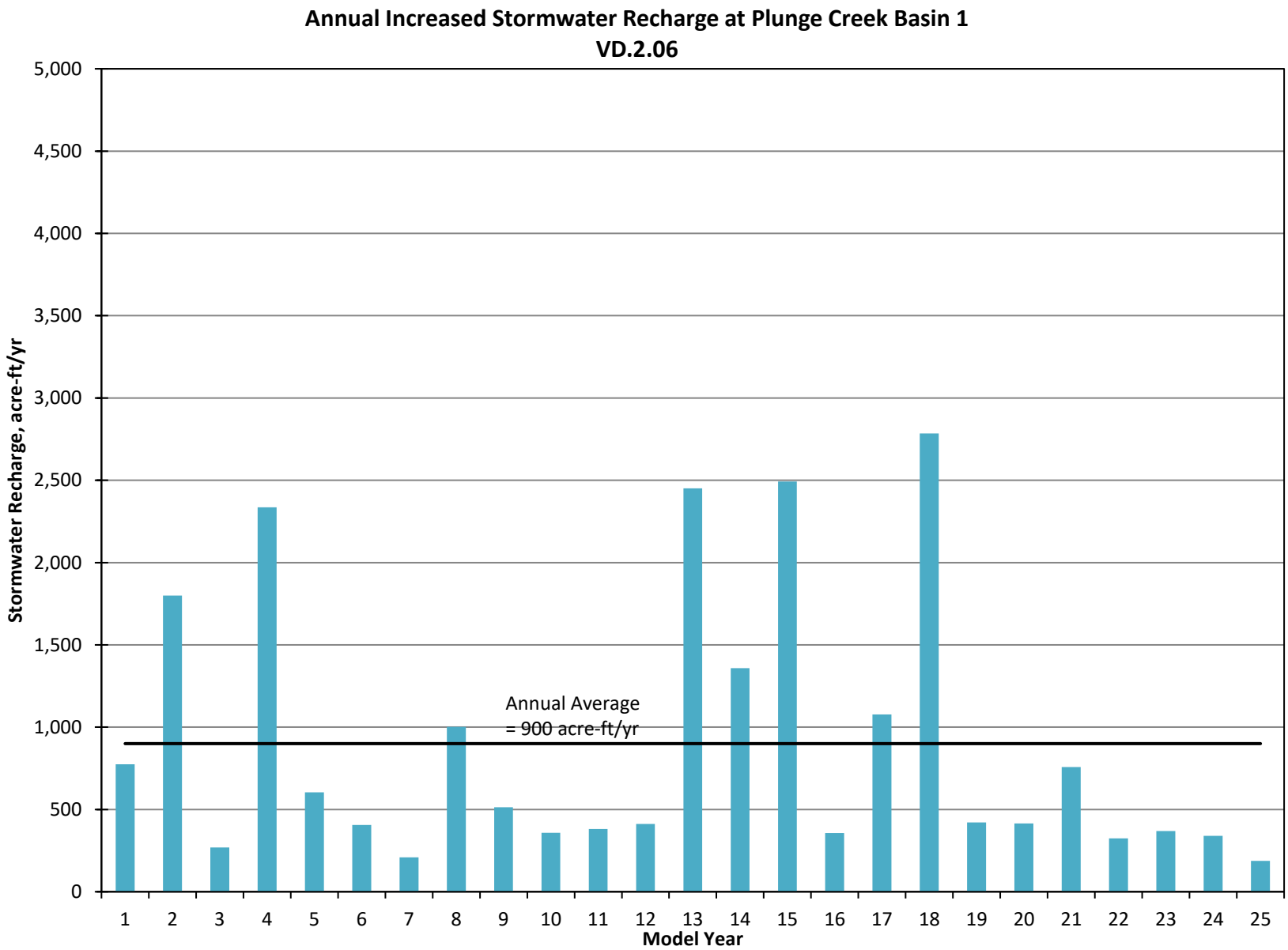

Figure 265

DRAFT

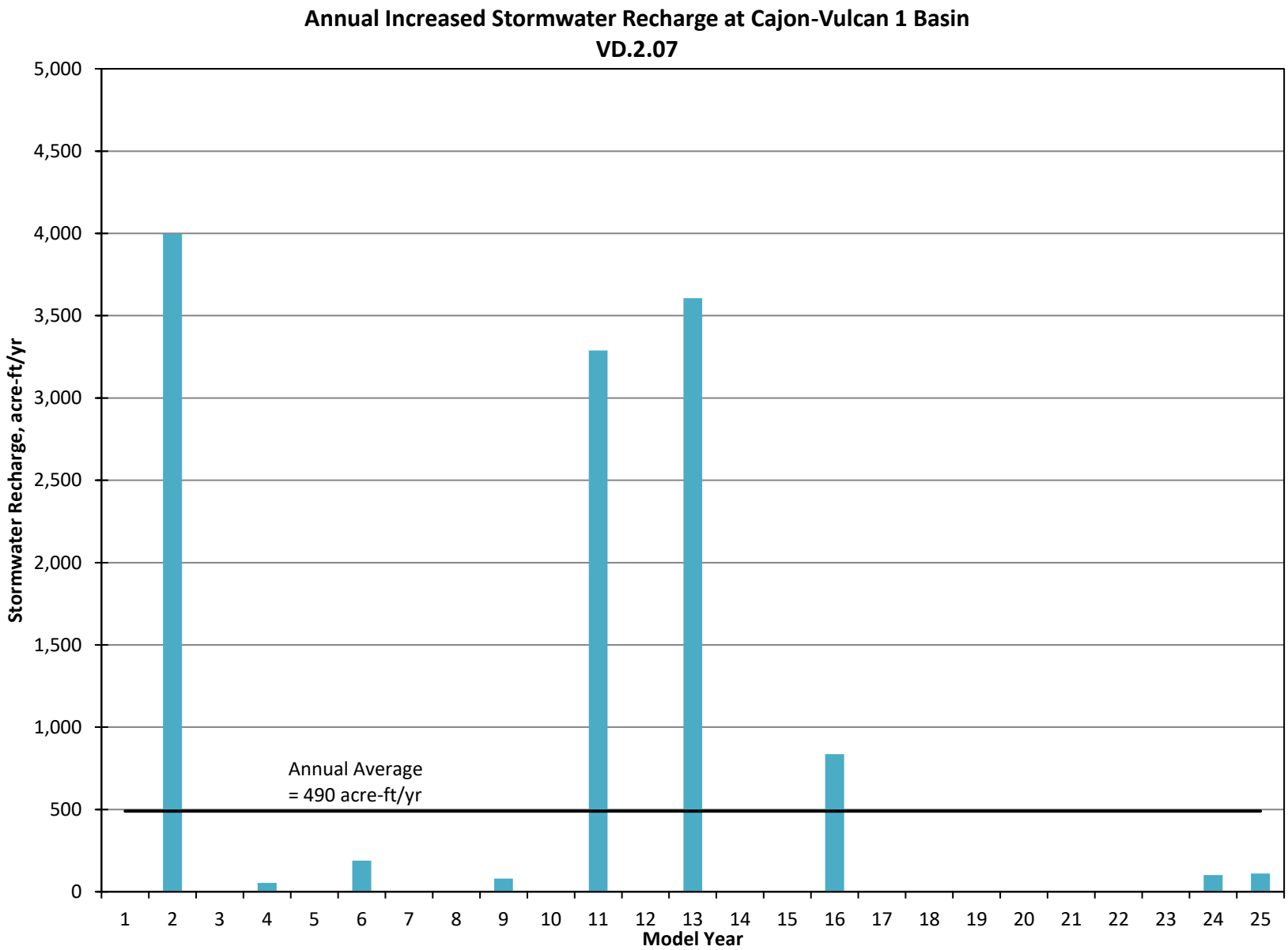

Figure 266

DRAFT

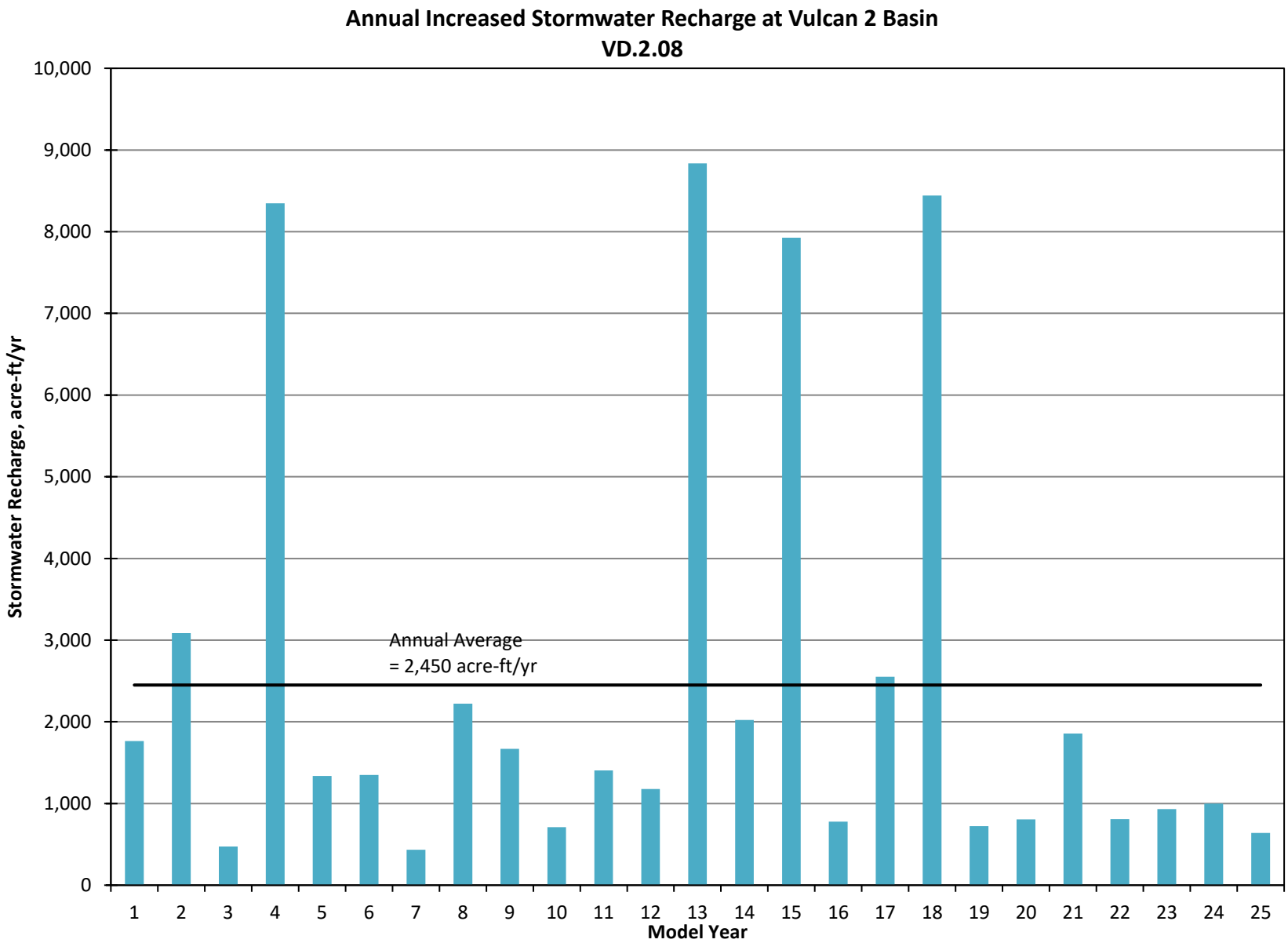

Figure 267

DRAFT

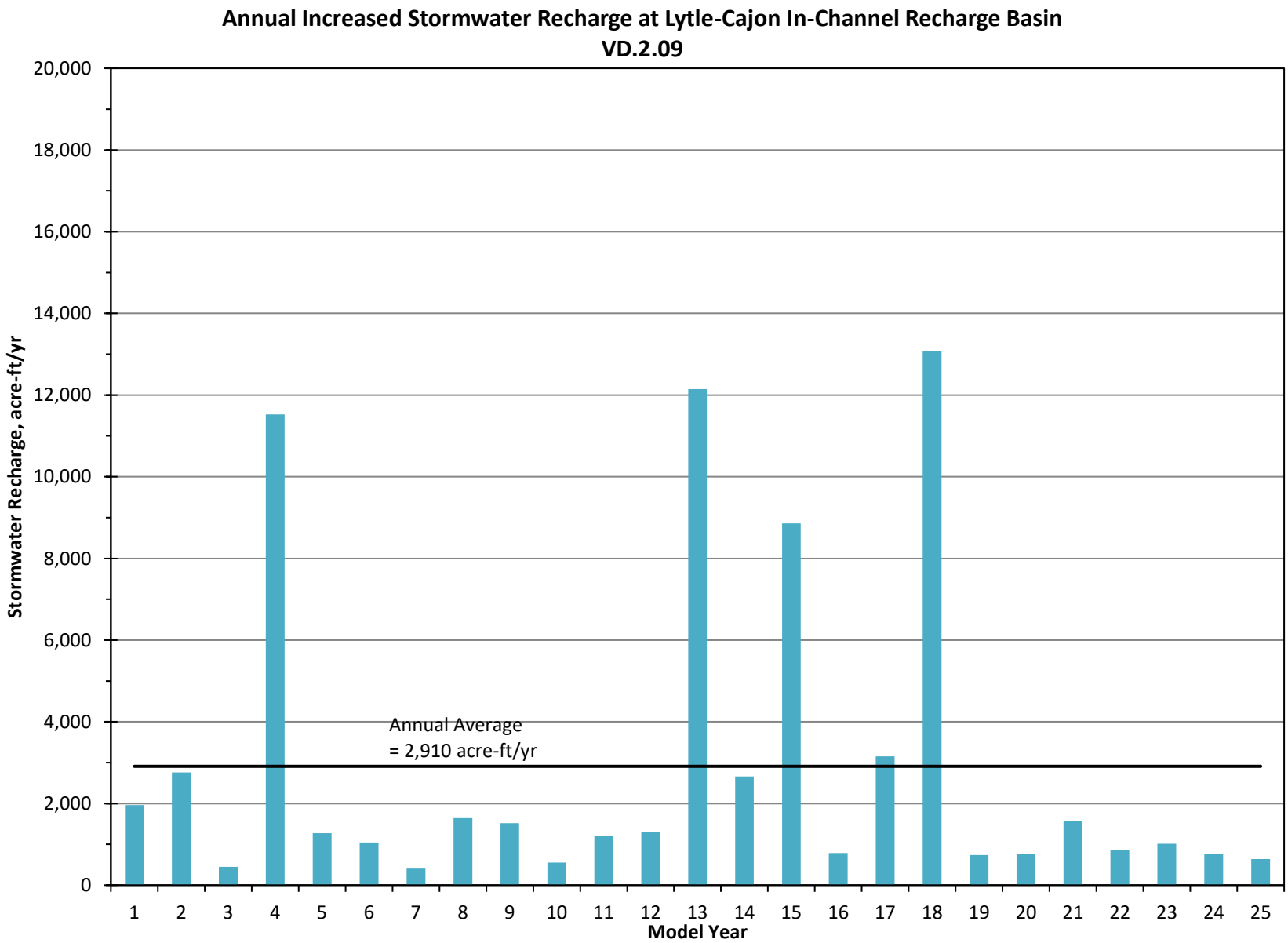

Figure 268

DRAFT

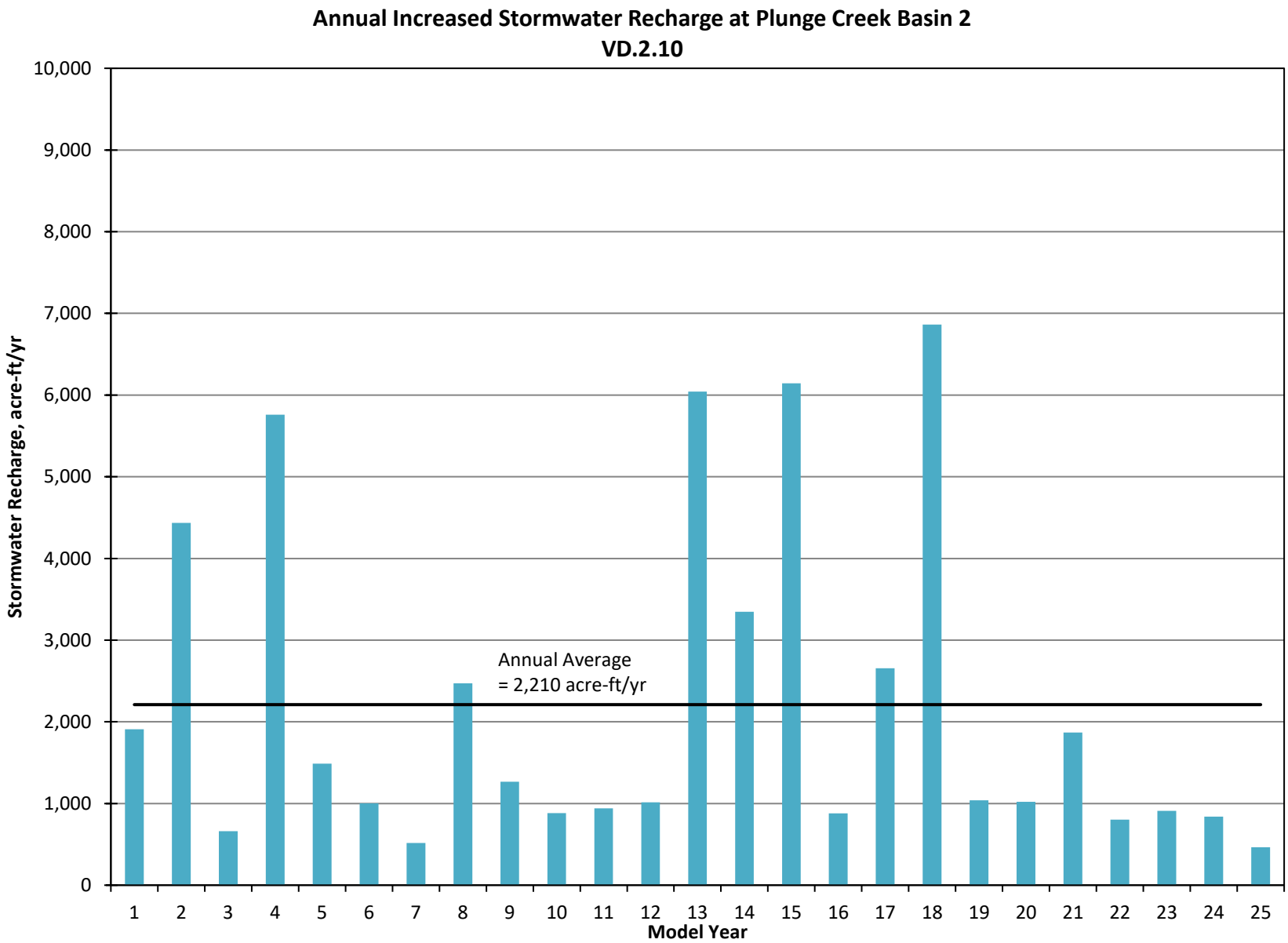

Figure 269

DRAFT

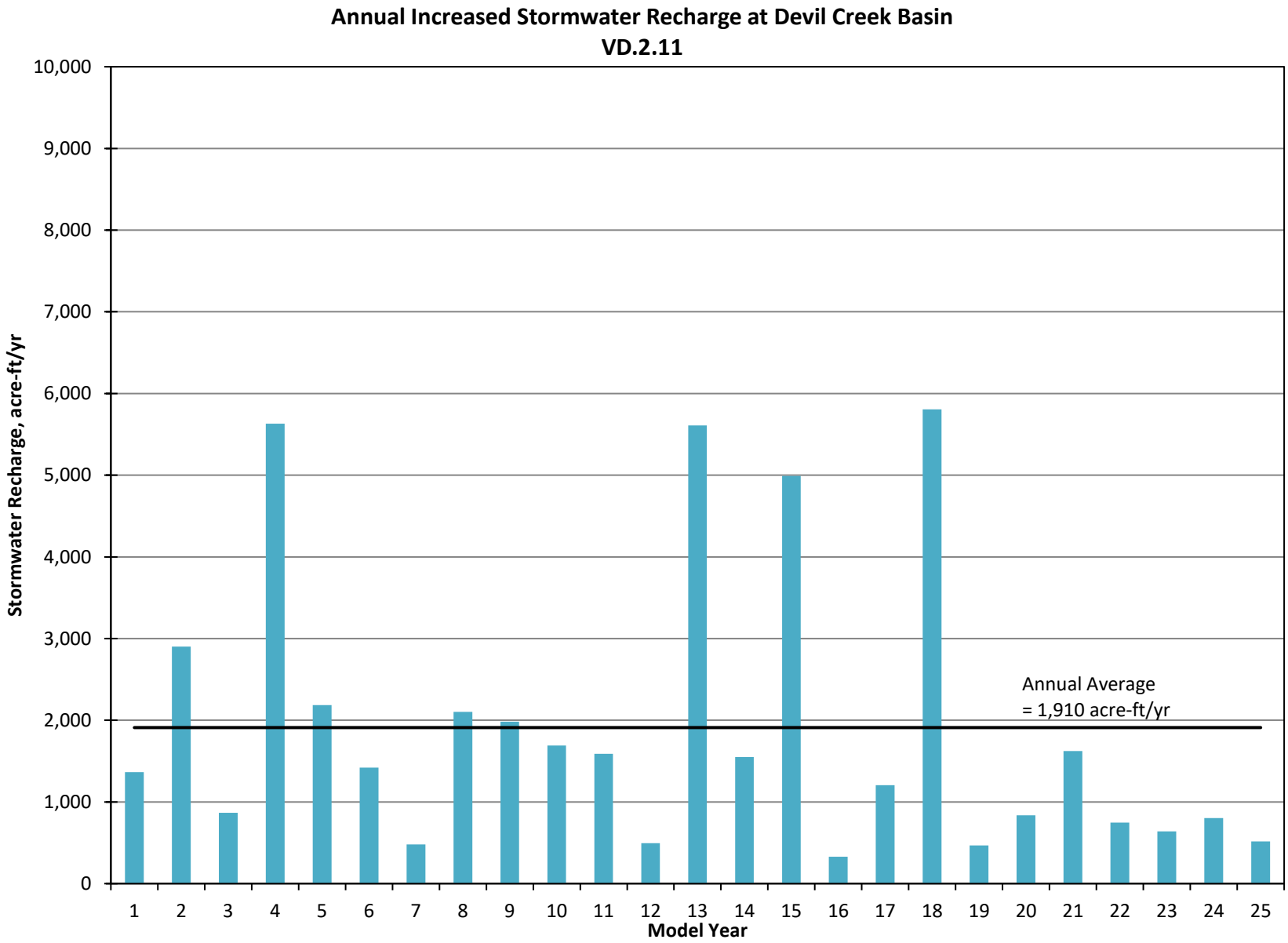

Figure 270

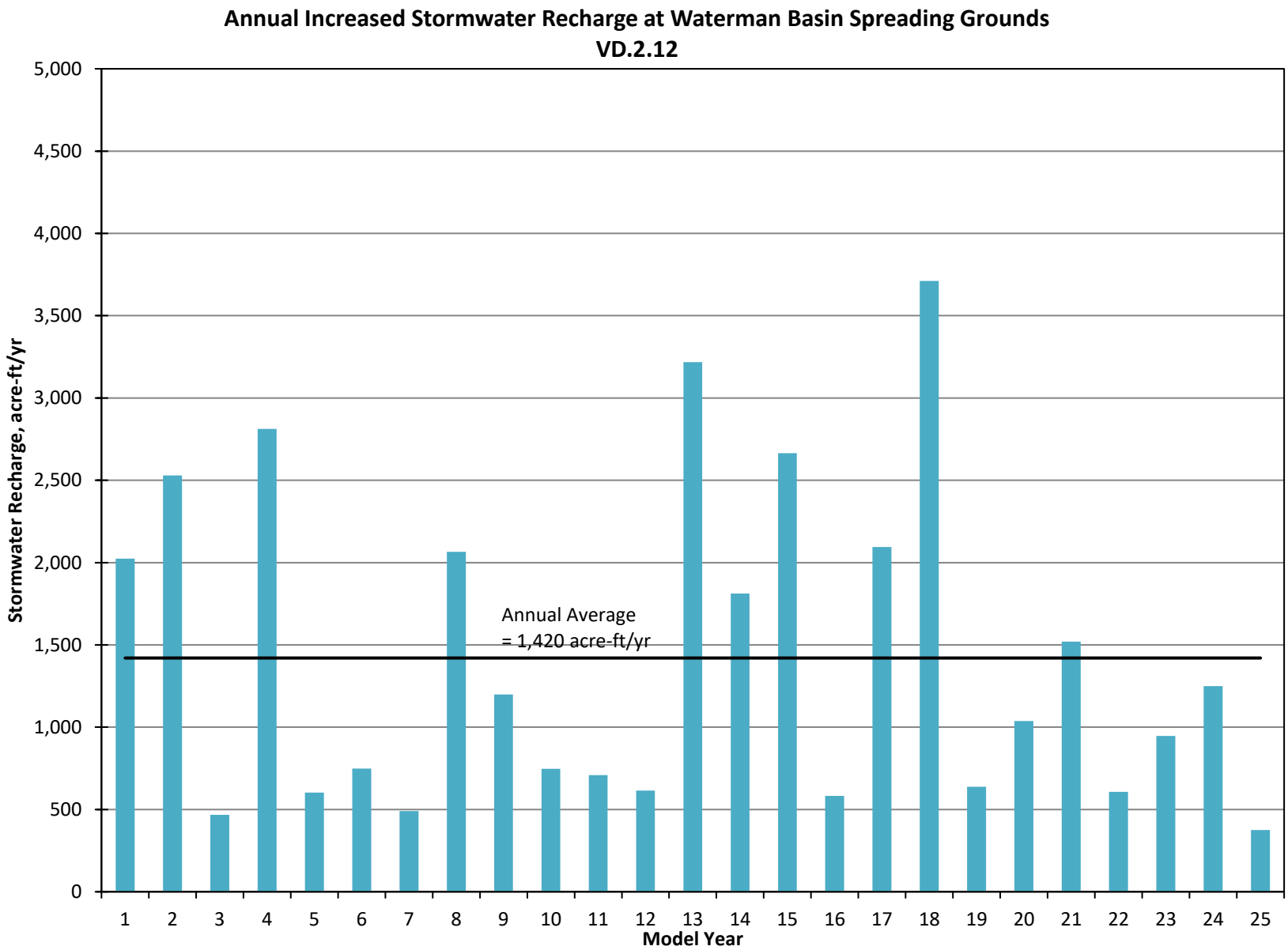
Annual Increased Stormwater Recharge at Waterman Basin Spreading Grounds
VD.2.12
Stormwater Recharge, acre-ft/yr
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Annual Average
= 1,420 acre-ft/yr
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Model Year

Figure 271

DRAFT

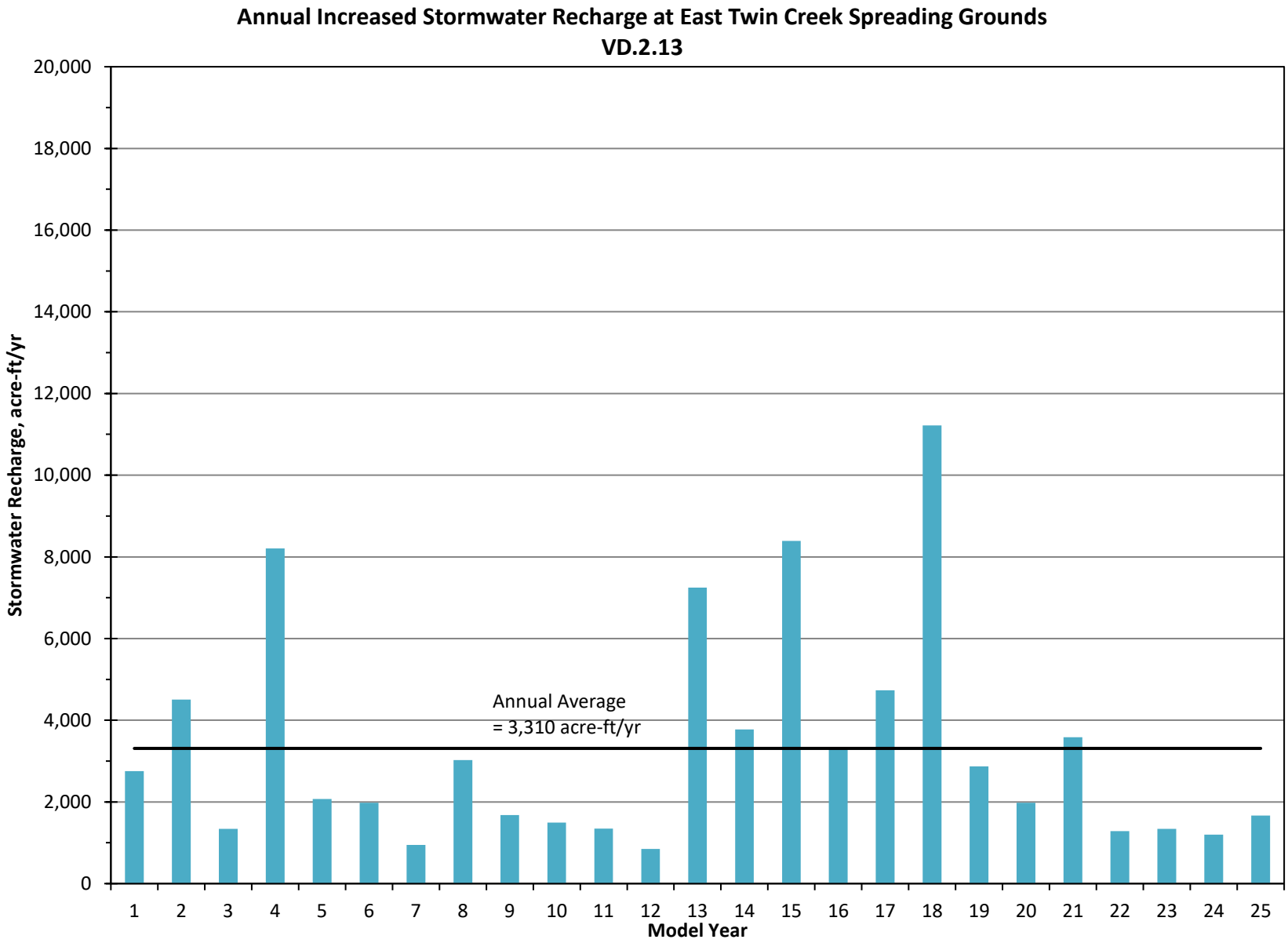

Figure 272

DRAFT

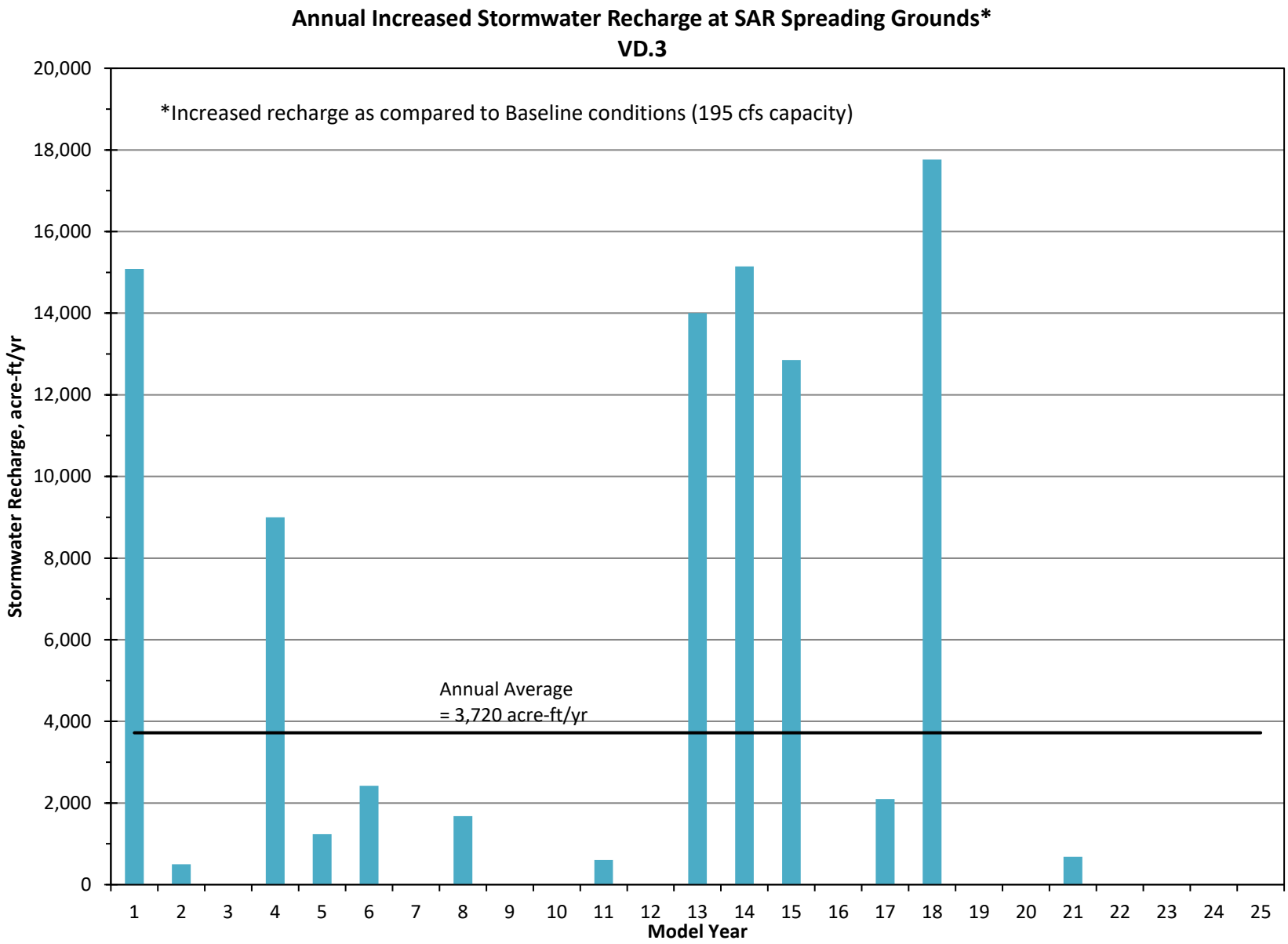

Figure 273

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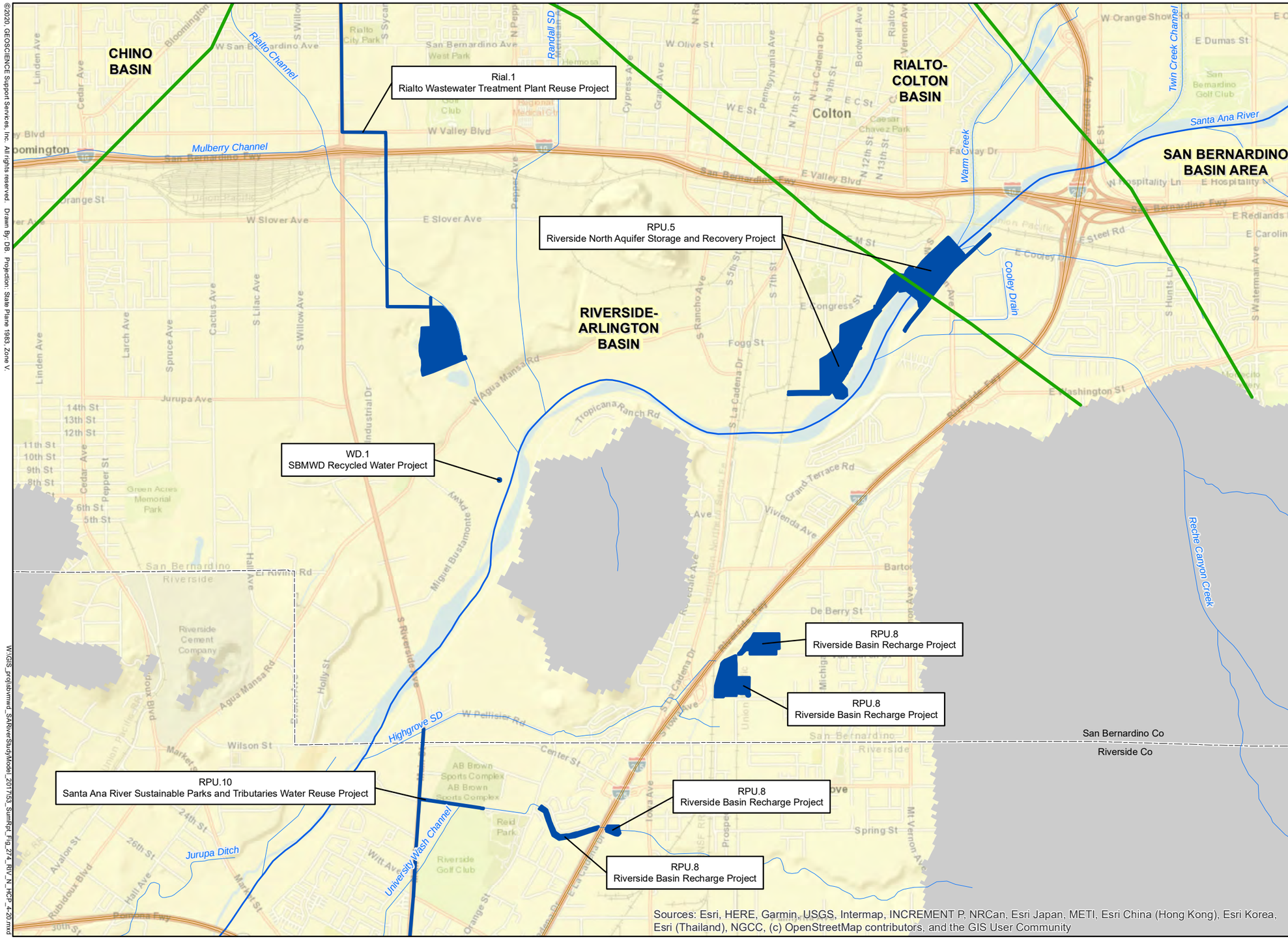
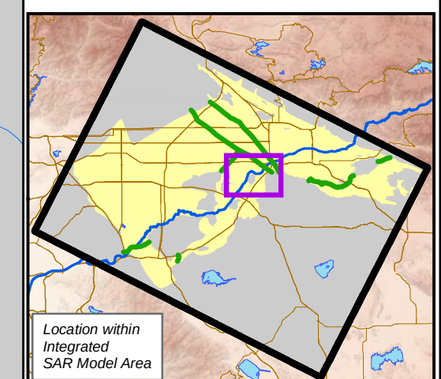


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - Project ID
  - Name of HCP Project
- RPU.8 Riverside Basin Recharge Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - RIVERSIDE NORTH

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_274_RIV_N_HCP_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 274

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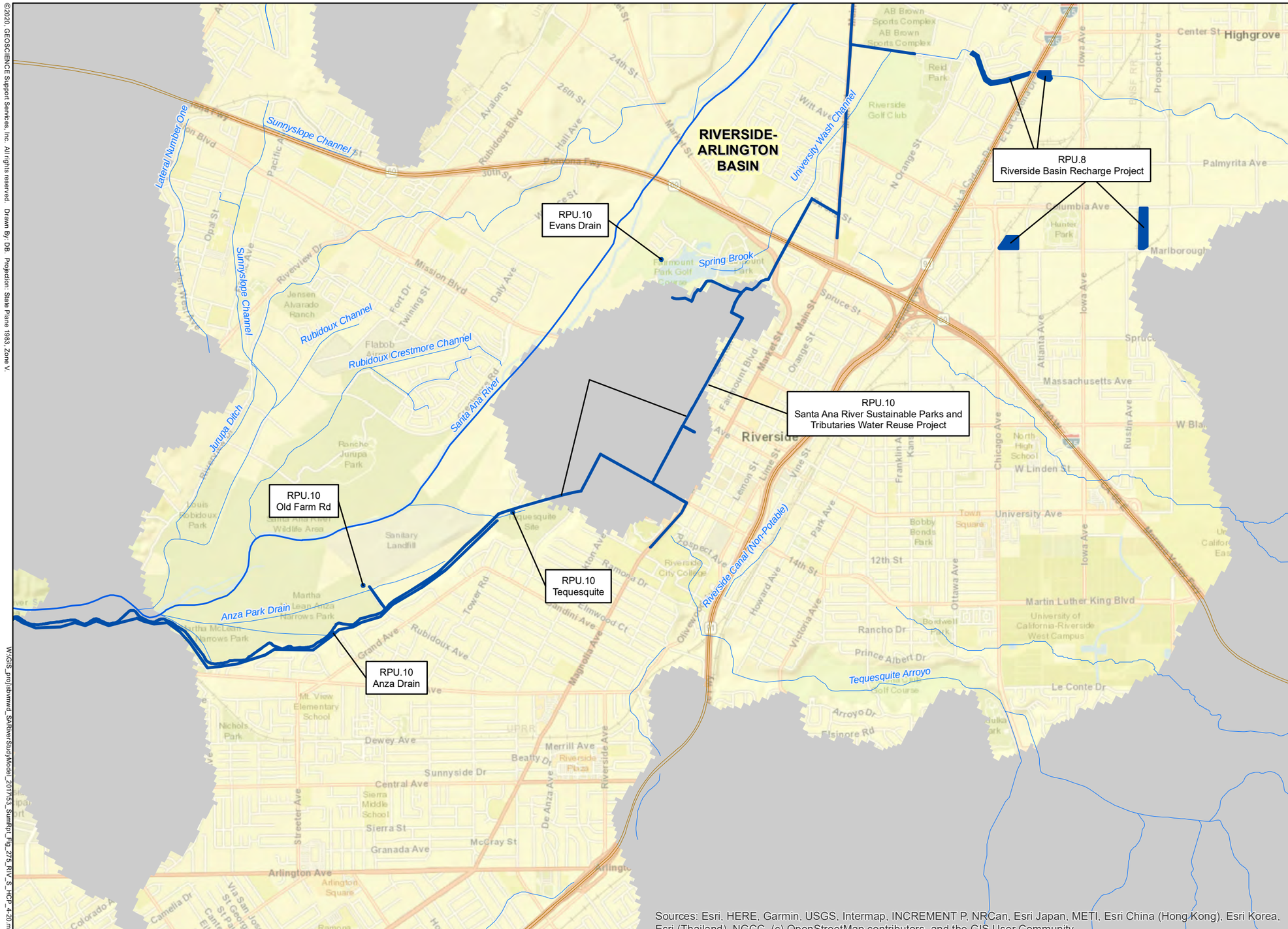
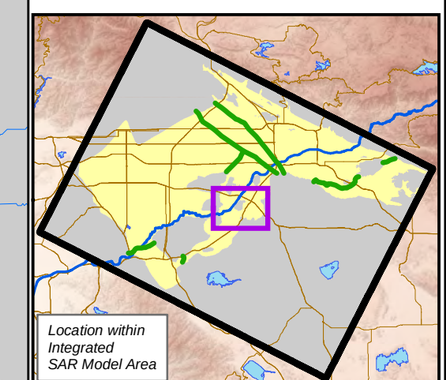


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- RPU.8 Riverside Basin Recharge Project — Habitat Conservation Plan (HCP) Covered Activity
  - Project ID
  - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - RIVERSIDE SOUTH

W:\GIS_Projects\bmwd_SARiverStudyModel_2017\53_SumRpt_Fig_275_RIV_S_HCP_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 275

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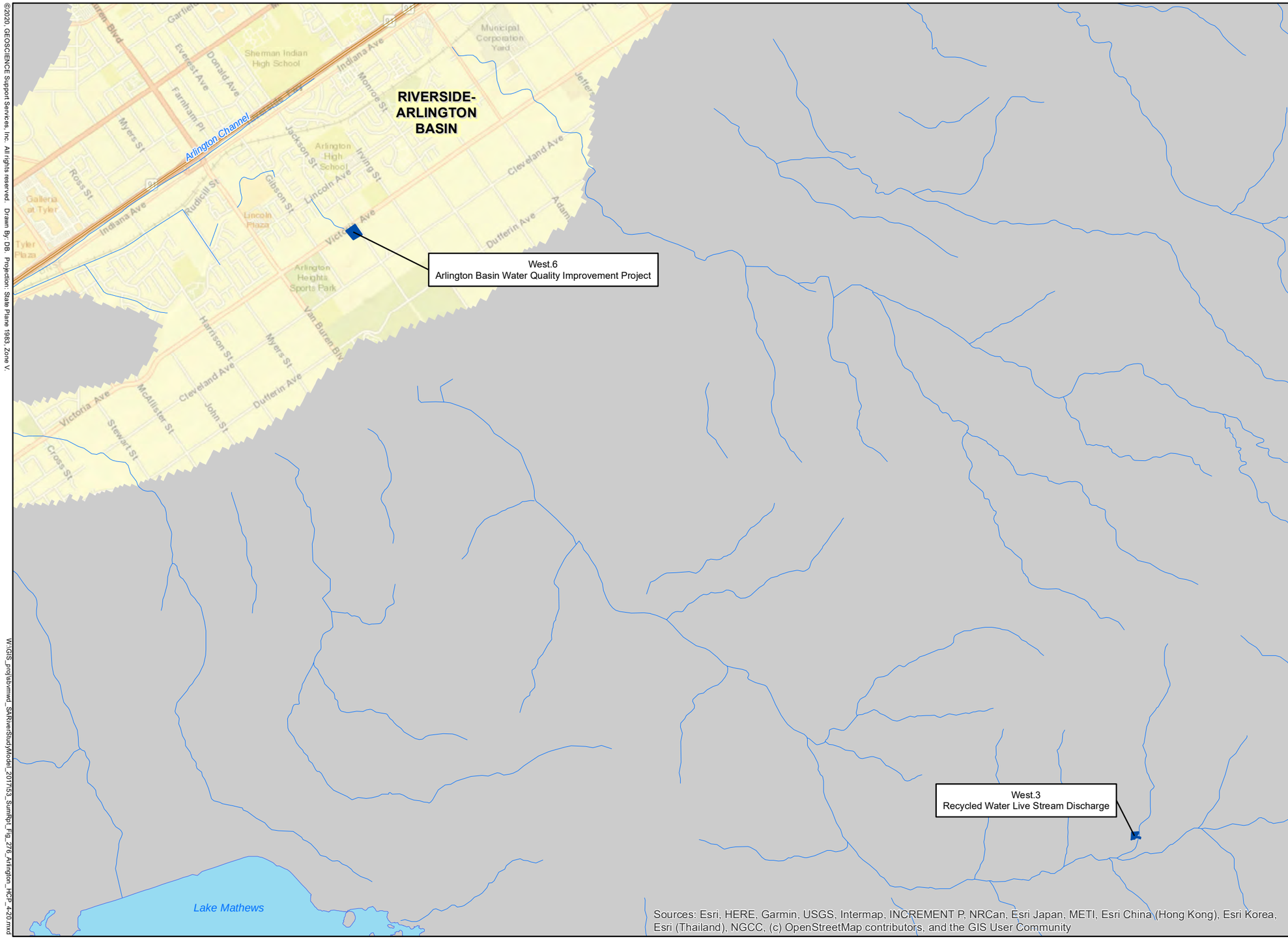
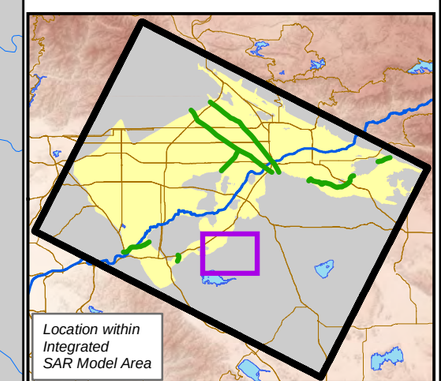


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - West.6 Arlington Basin Water Quality Improvement Project
  - Project ID
  - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - ARLINGTON

W:\GIS_proj\sbvmwd_SARtwrStudyModel_2017\53_SumRpt_Fig_276_Arlington_HCP_4-20.mxd

10-Apr-20

DRAFT

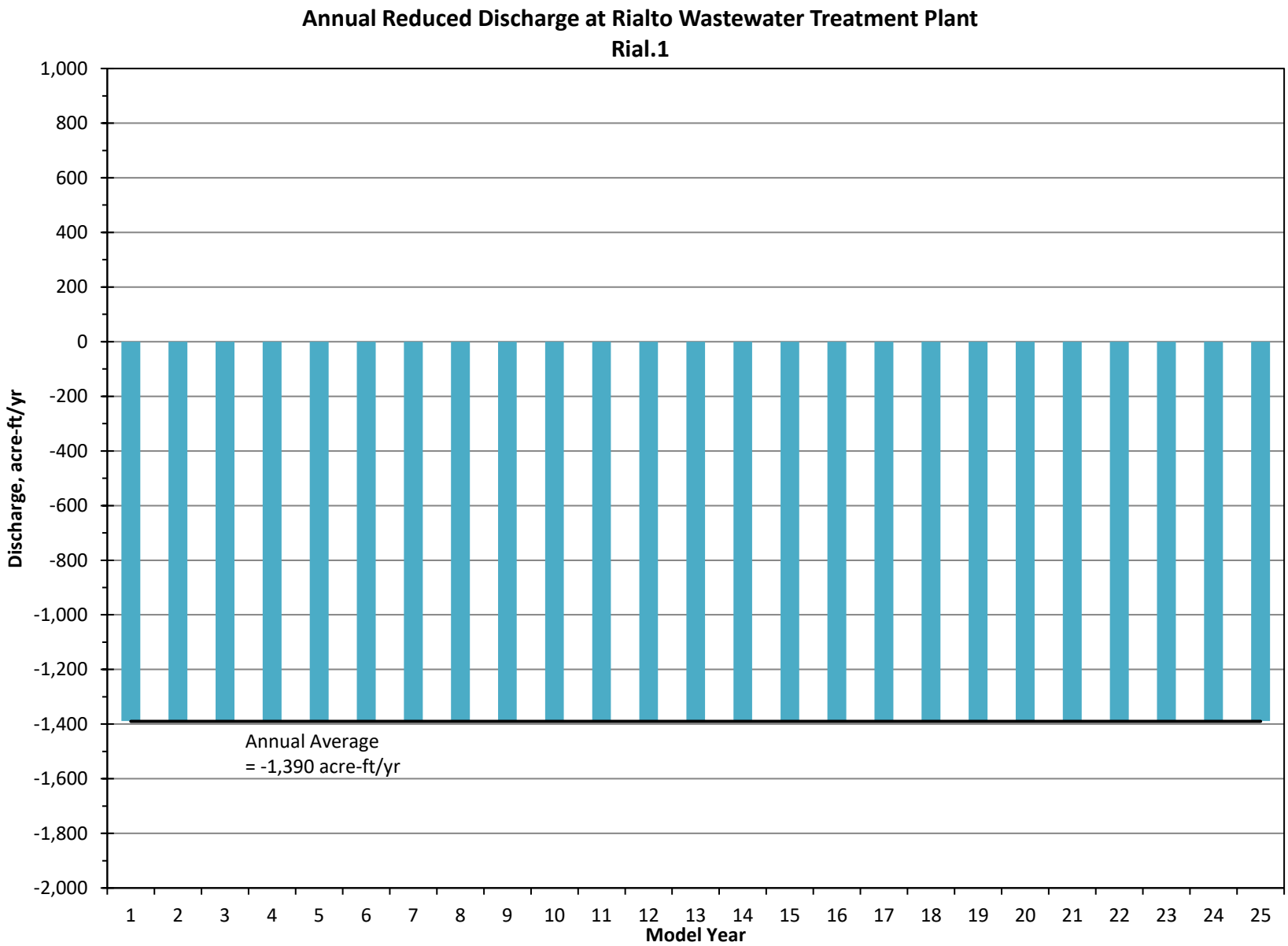


Figure 277

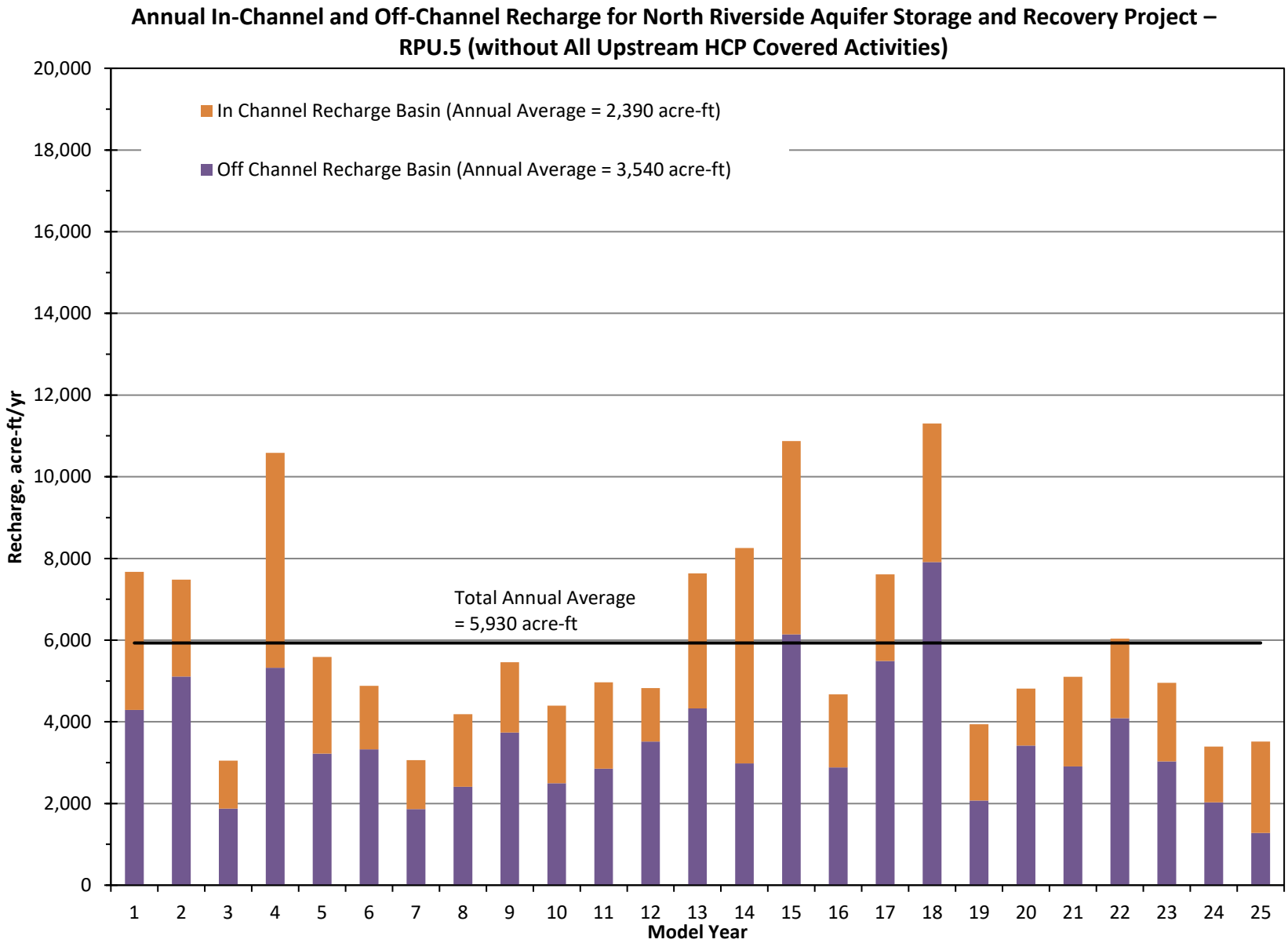

Annual In-Channel and Off-Channel Recharge for North Riverside Aquifer Storage and Recovery Project – RPU.5 (without All Upstream HCP Covered Activities)
In Channel Recharge Basin (Annual Average = 2,390 acre-ft)
Off Channel Recharge Basin (Annual Average = 3,540 acre-ft)
Total Annual Average
= 5,930 acre-ft
Recharge, acre-ft/yr
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Model Year

Figure 278a

Annual In-Channel and Off-Channel Recharge for North Riverside Aquifer Storage and Recovery Project – RPU.5 (with All Upstream HCP Covered Activities)

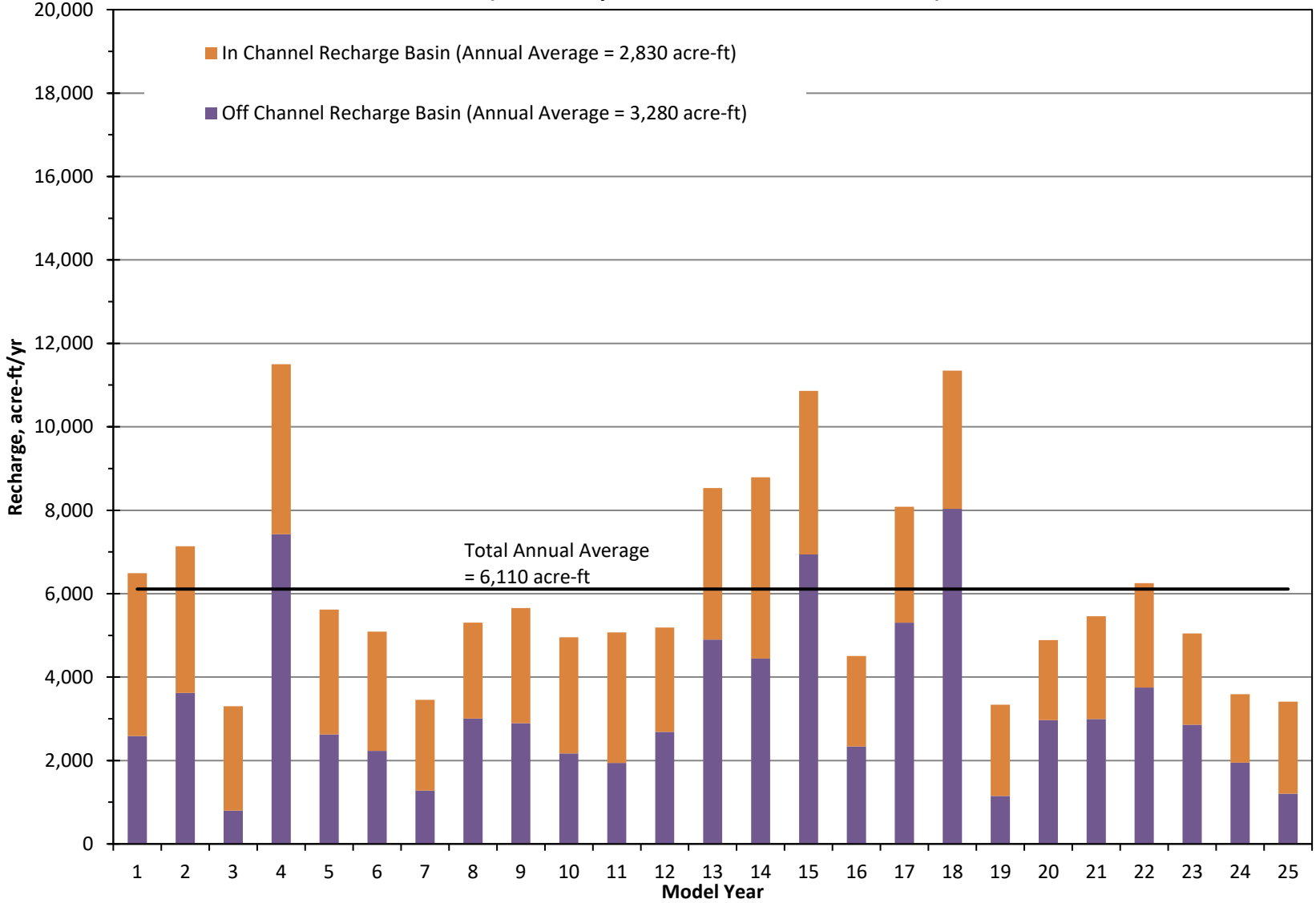


Figure 278b

DRAFT

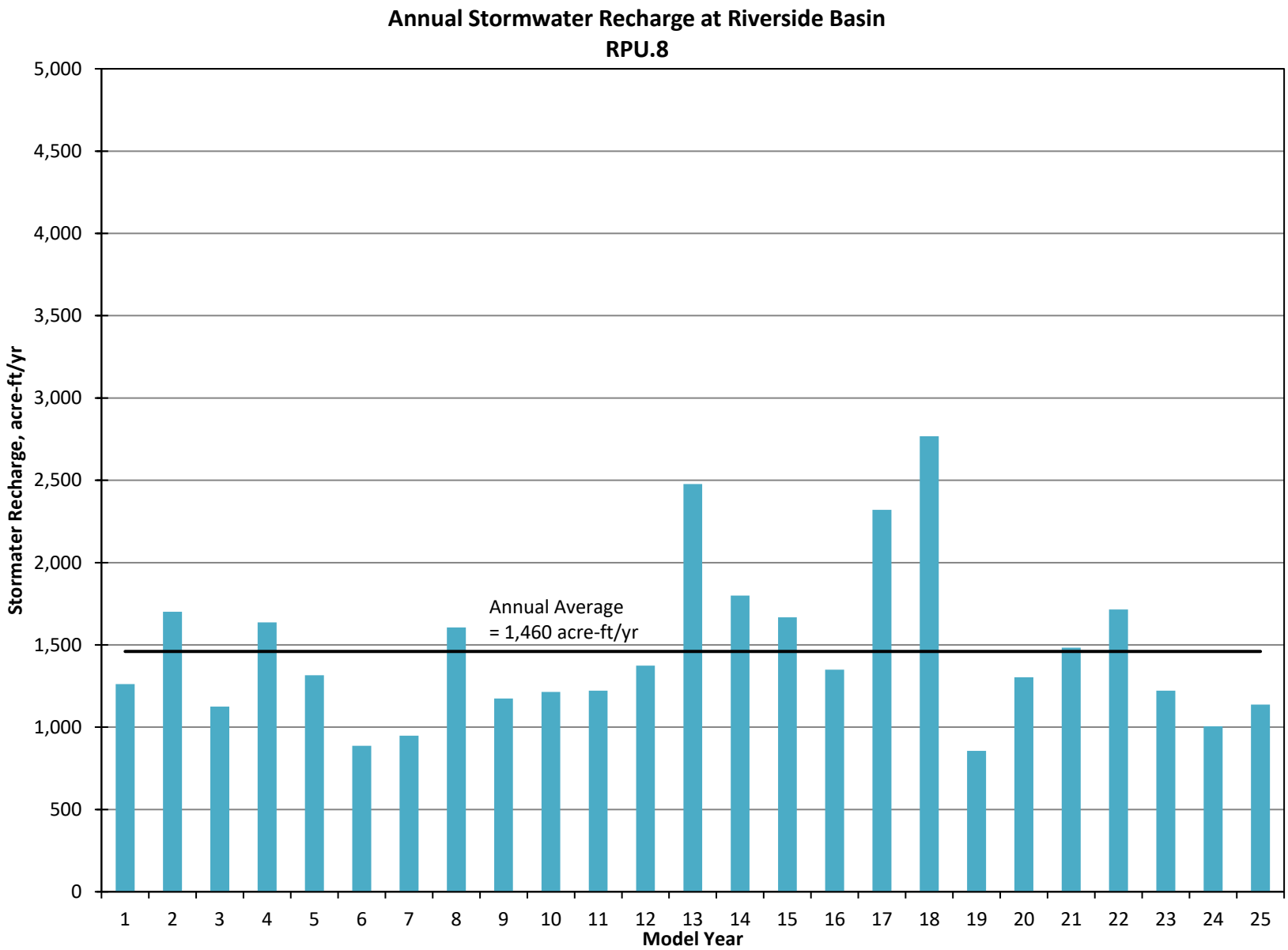


Figure 279

DRAFT

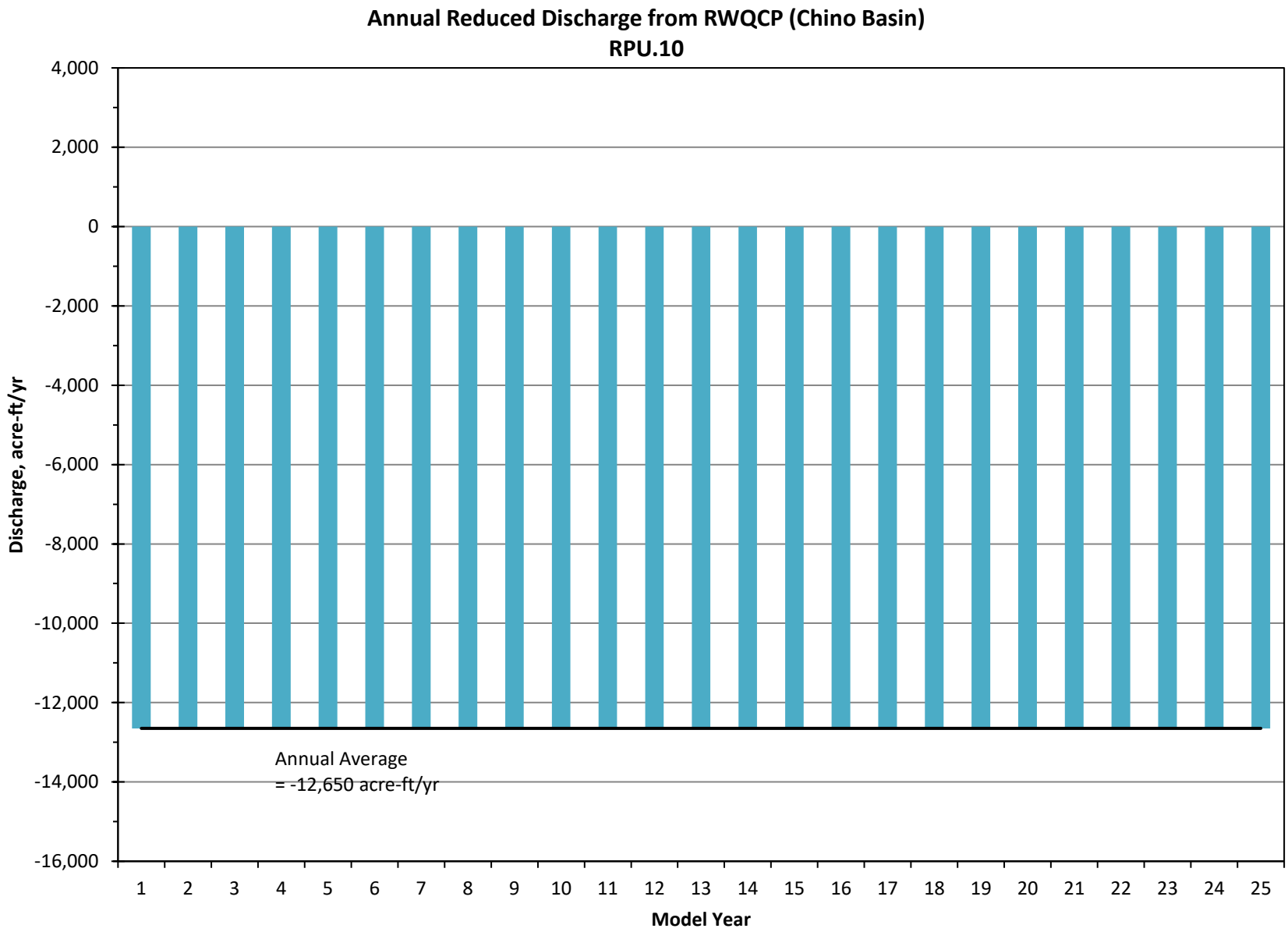


Figure 280

DRAFT

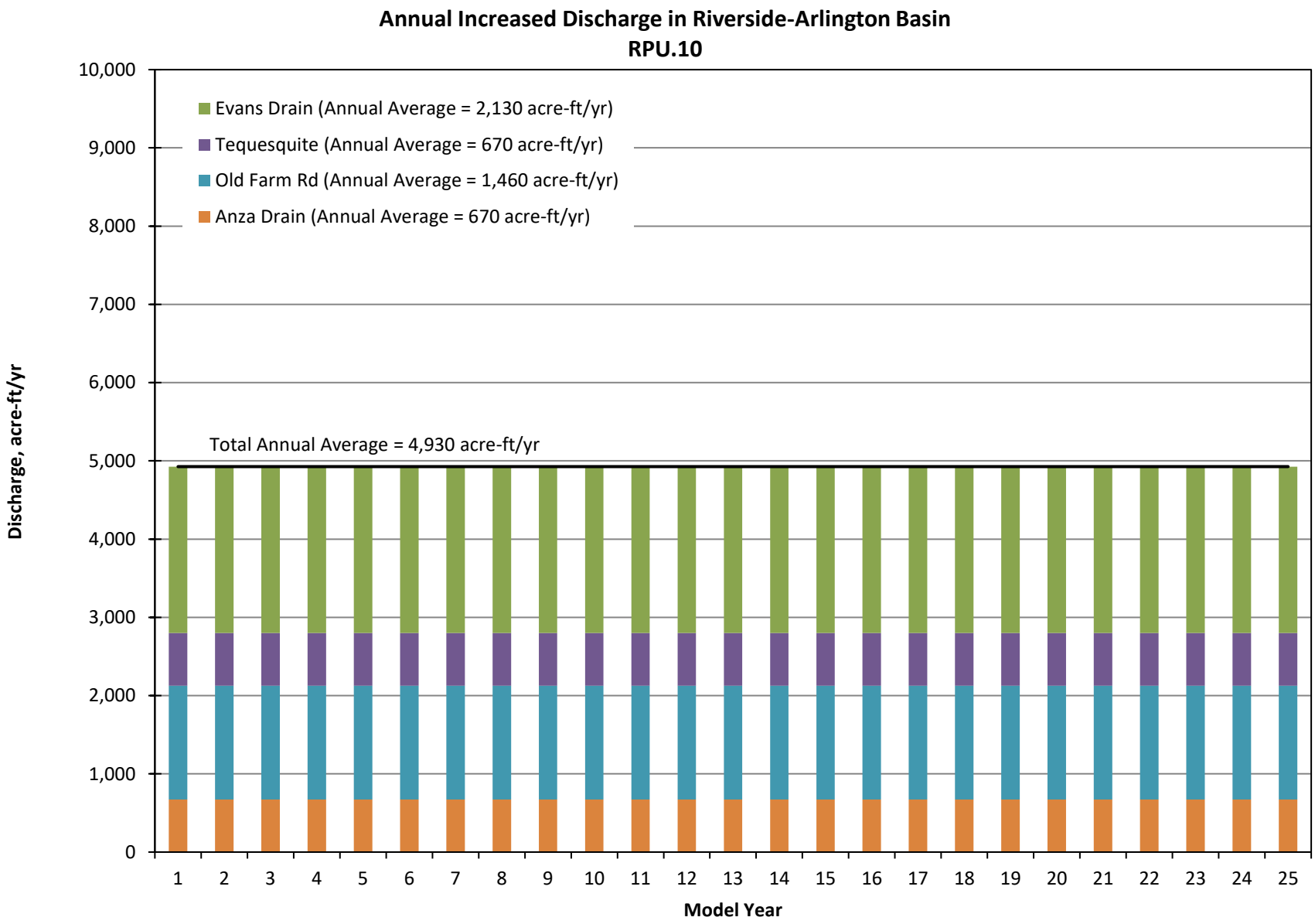


Figure 281

DRAFT

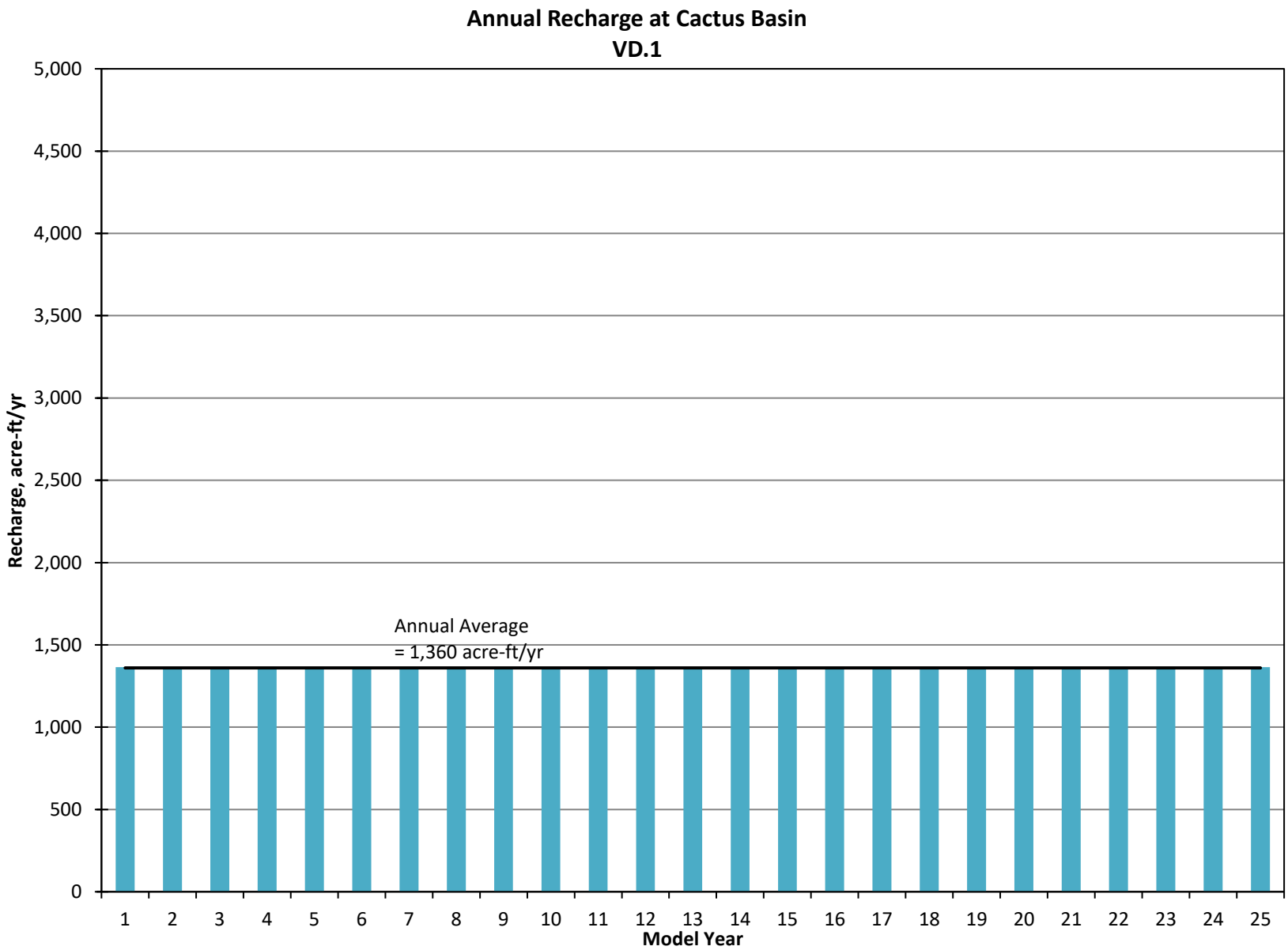


Figure 282

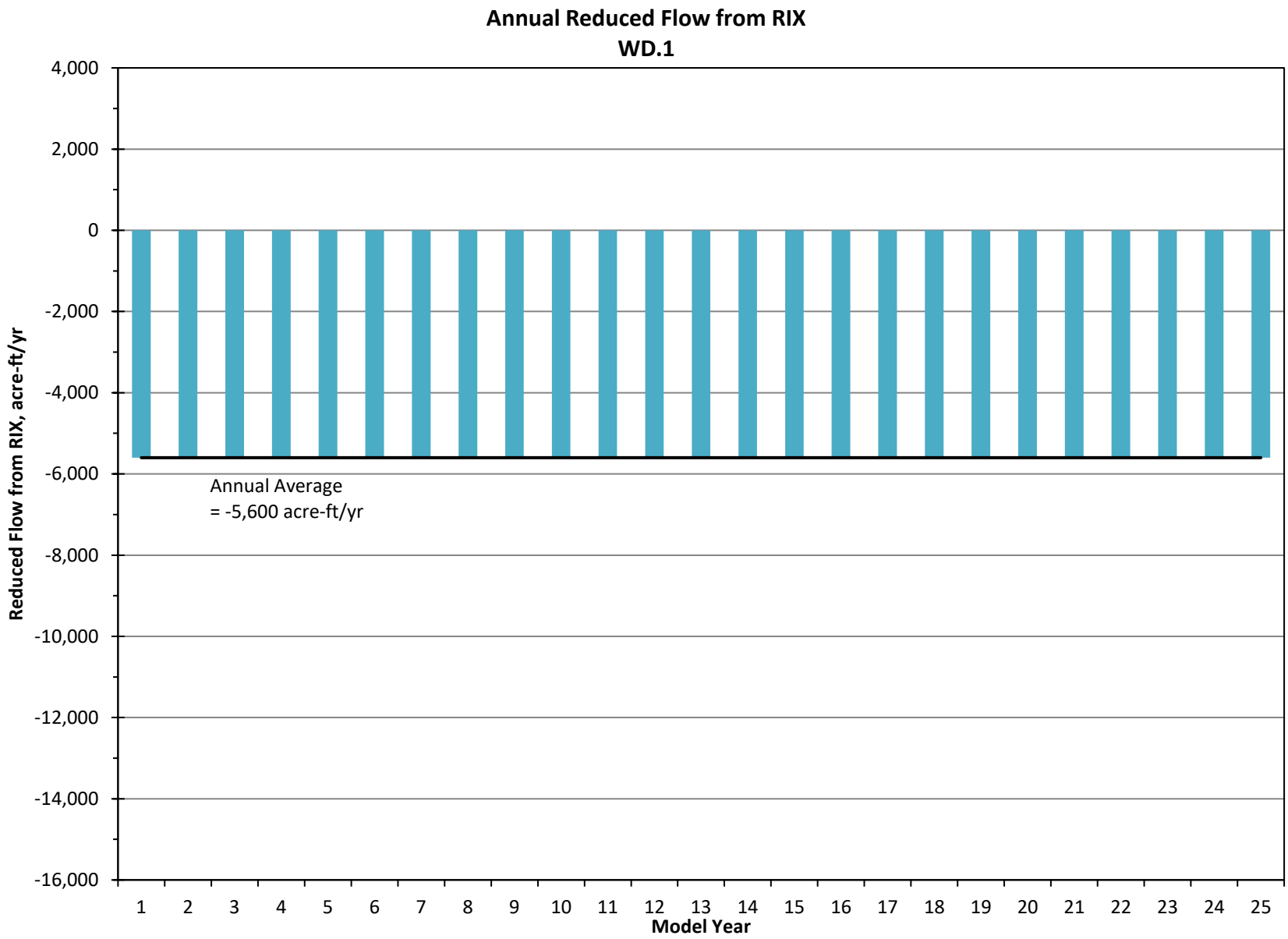

Annual Reduced Flow from RIX
WD.1
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
-12,000
-14,000
-16,000
Reduced Flow from RIX, acre-ft/yr
Annual Average
= -5,600 acre-ft/yr
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Model Year

Figure 283

DRAFT

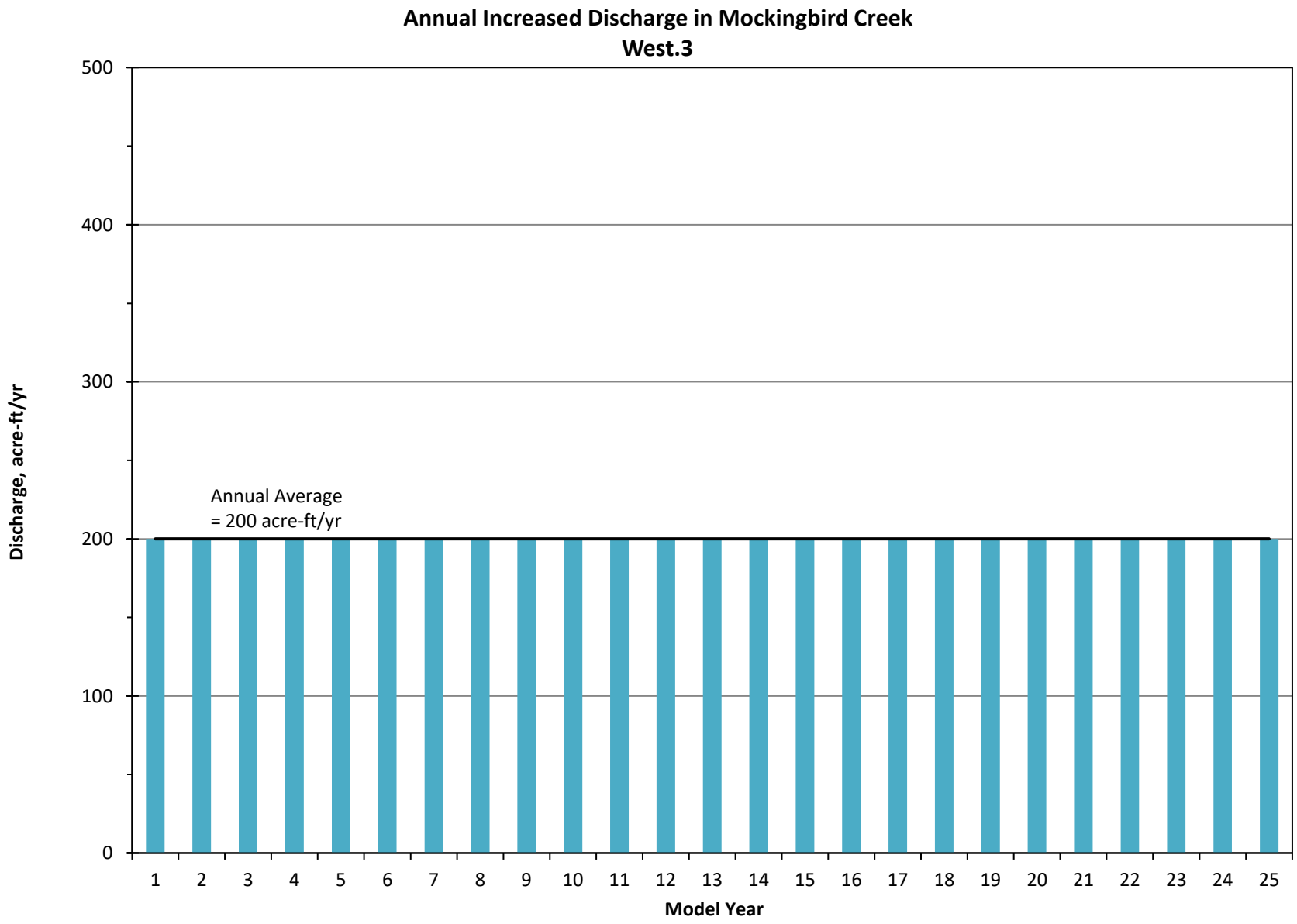


Figure 284

DRAFT

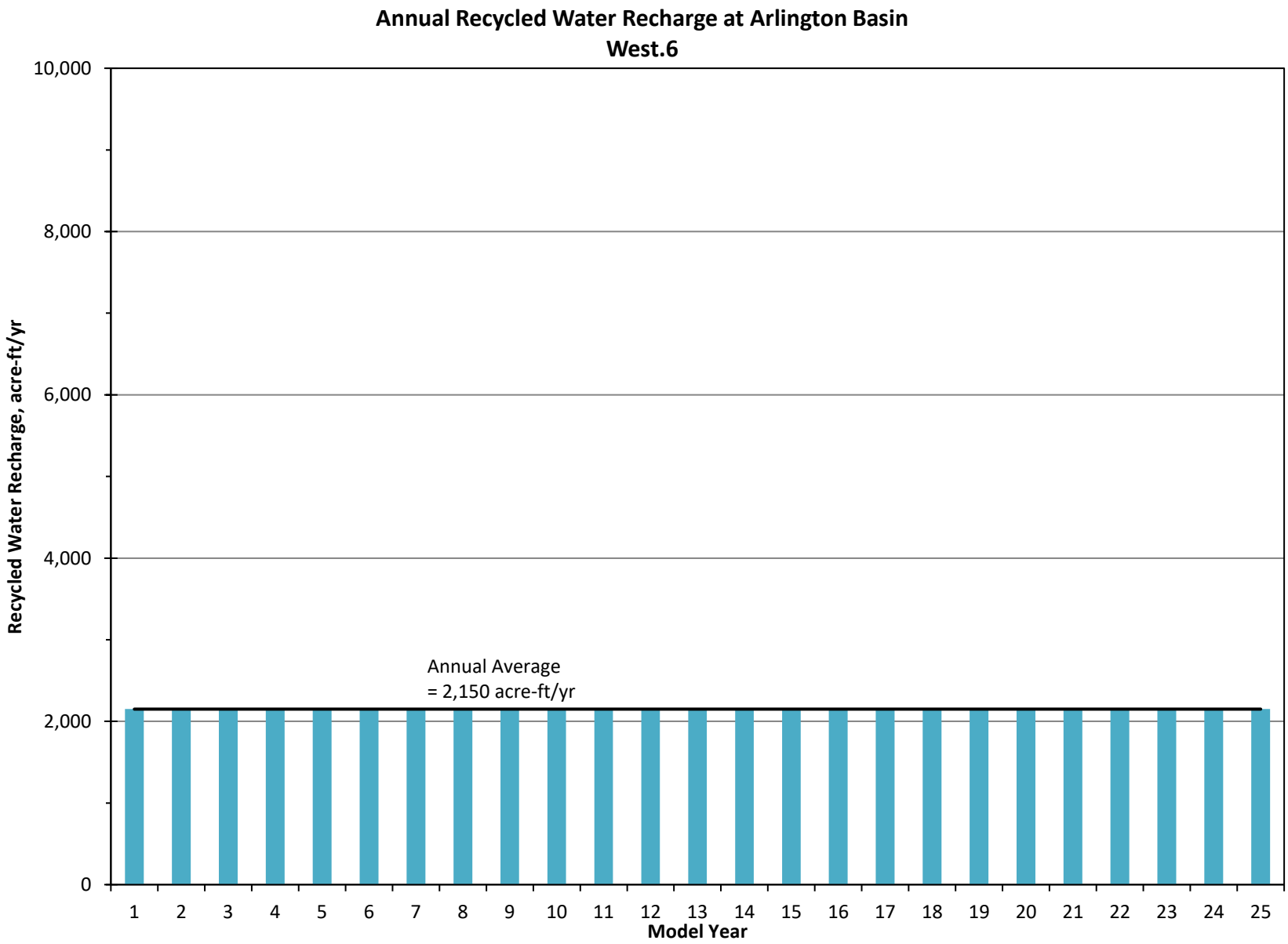


Figure 285

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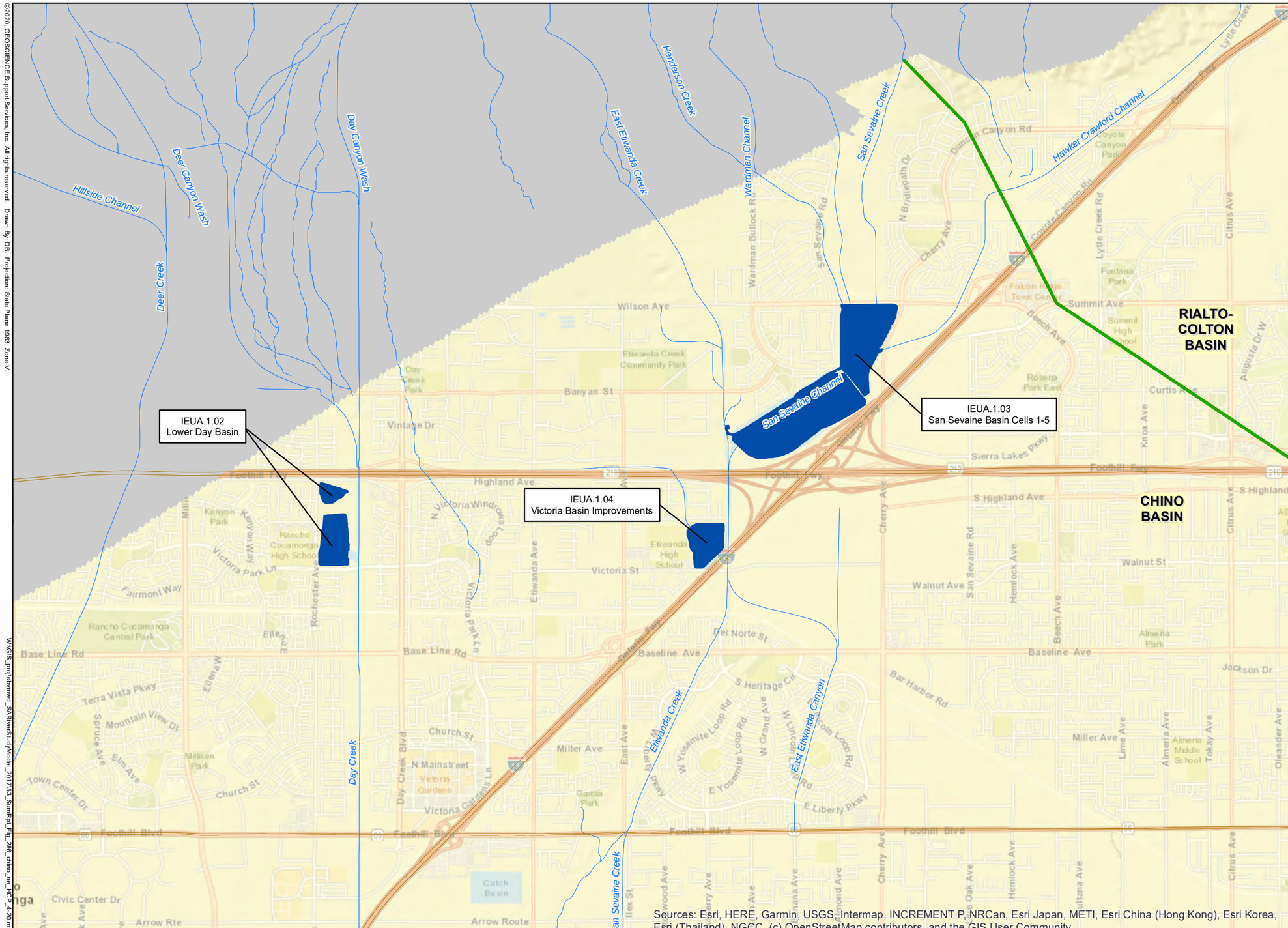
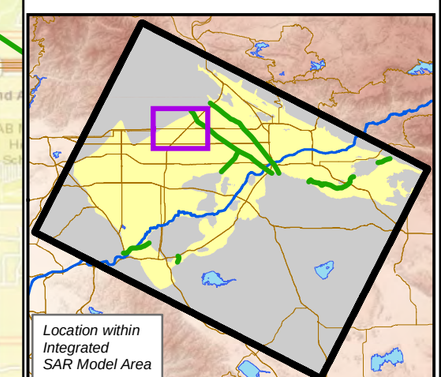


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - IEUA.1.02 Lower Day Basin — Project ID / Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - CHINO NORTHEAST

W:\GIS_proj\sbvmwd_SARiverStudy\Model_2017\53_SumRpt_Fig_286_chino_ne_HCP_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 286

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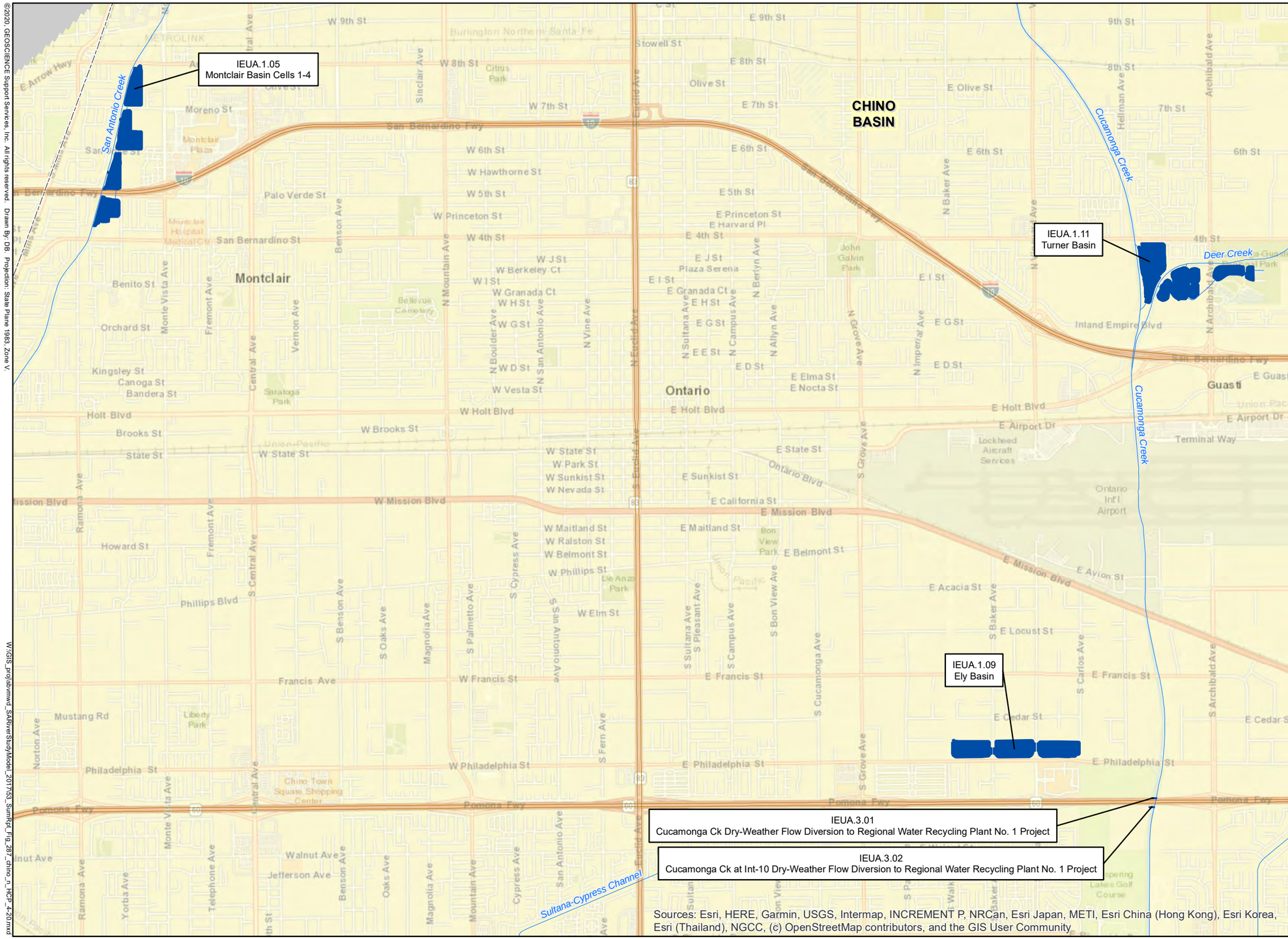
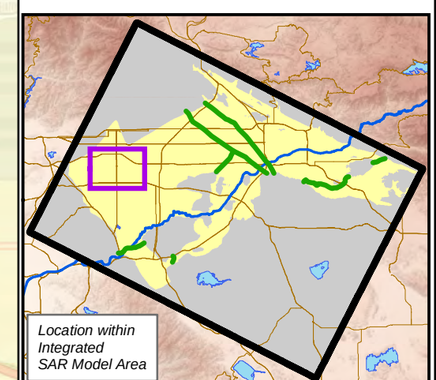


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - IEUA.1.11 Turner Basin
  - Project ID
  - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - CHINO NORTH

W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_287_chino_n_HCP_4-20.mxd

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SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 287

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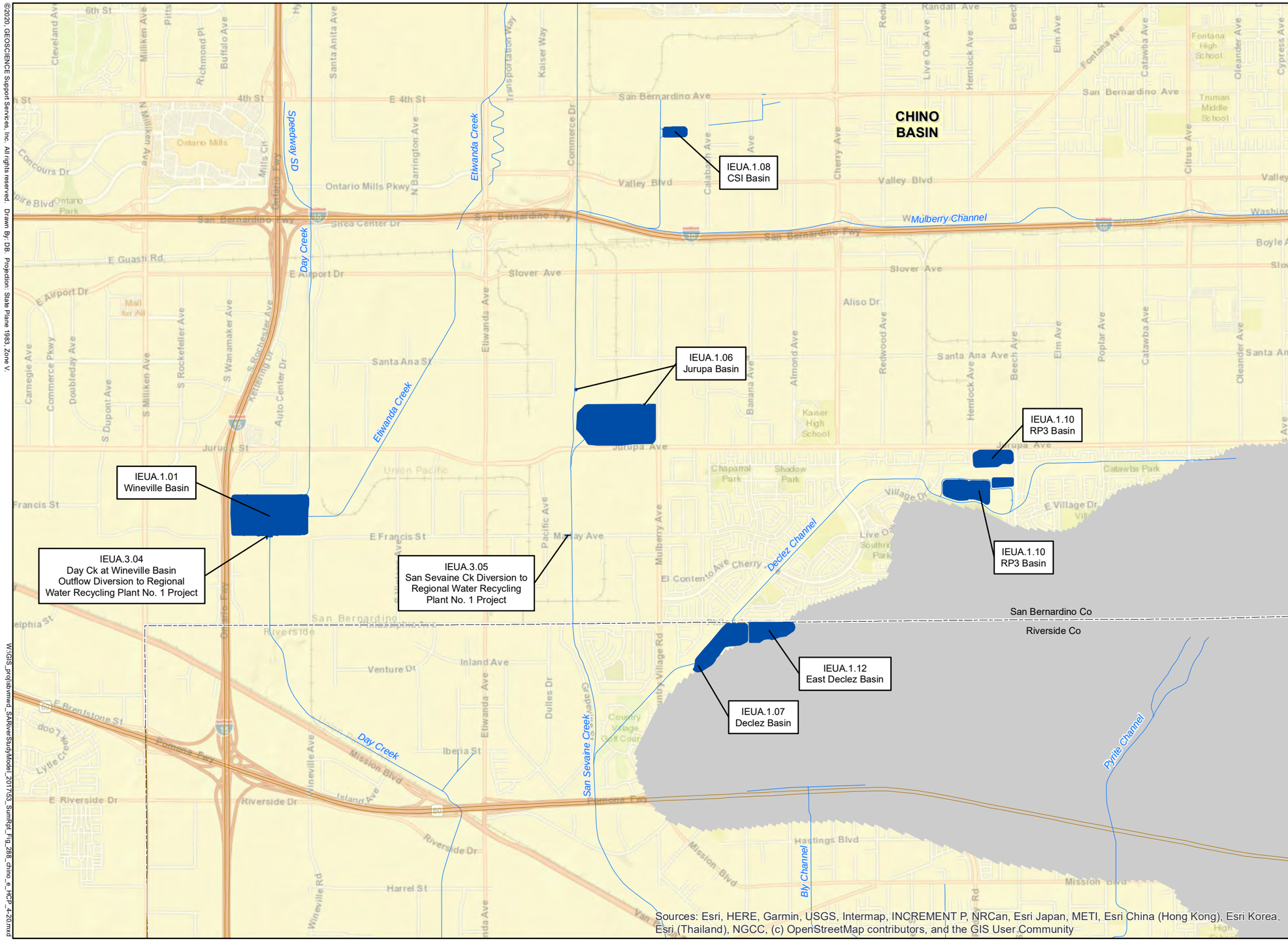
W:\GIS_proj\sbvmwd_SARiverStudyModel_2017\53_SumRpt_Fig_288_chino_e_HCP_4-20.mxd

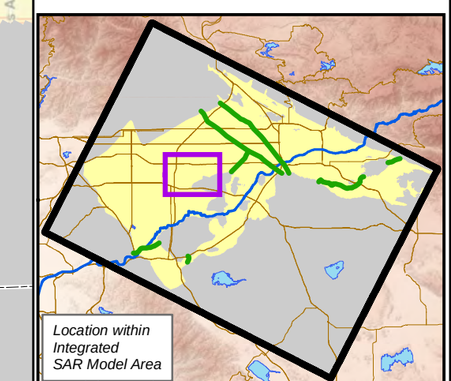


Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - IEUA.1.06 Jurupa Basin
  - Project ID
  - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - CHINO EAST

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 288

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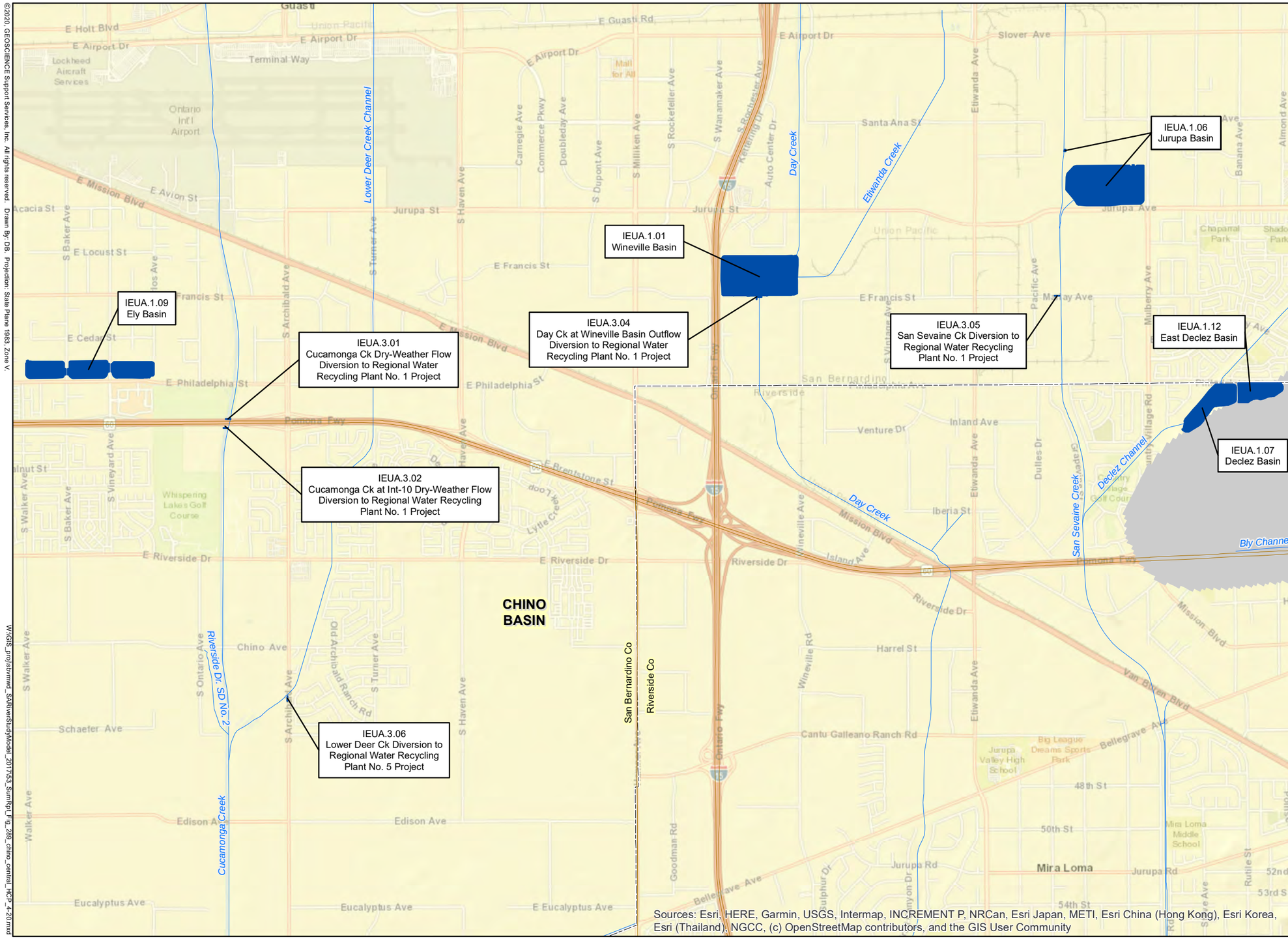
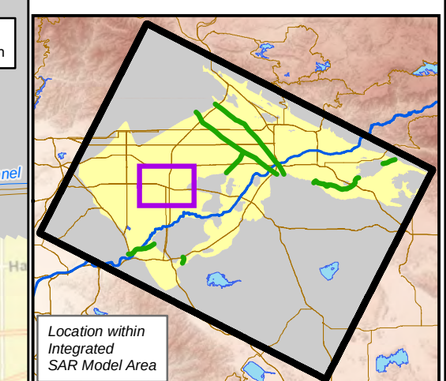


Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - IEUA.1.06 Jurupa Basin
  - Project ID
  - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000

Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - CHINO CENTRAL

W:\GIS_projs\bvmwd_SARivr\StudyModel_2017\53_SumRpt_Fig_289_chino_central_HCP_4-20.mxd

10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 289

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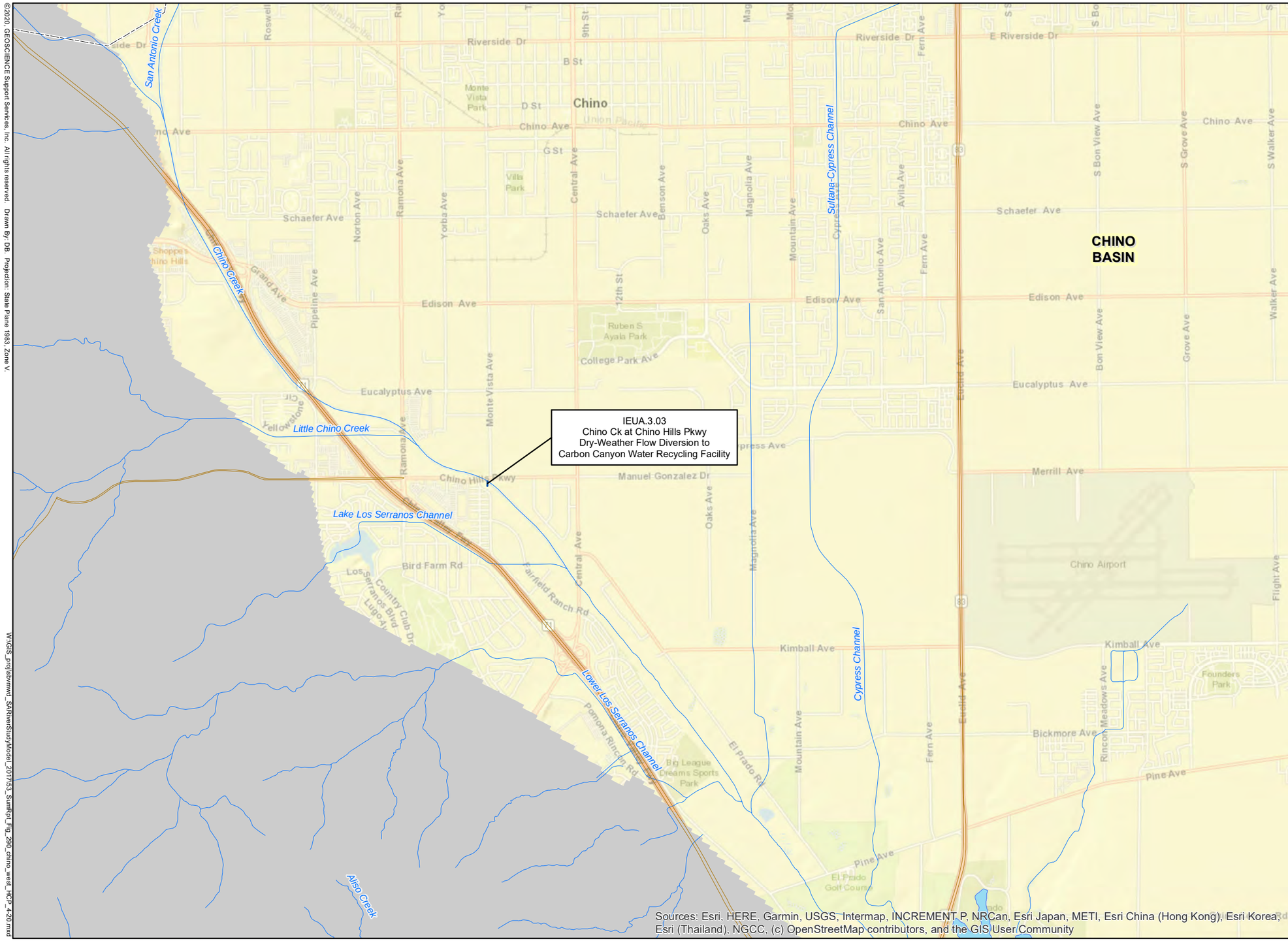
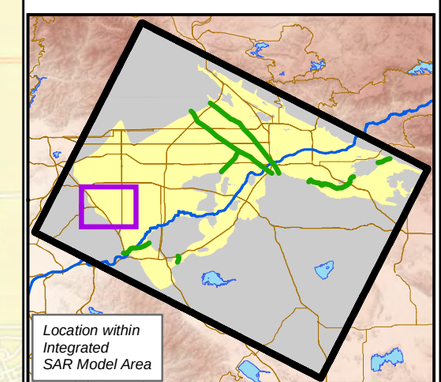


EXPLANATION

- Integrated SAR Model Boundary
- Active Model Area
- Inactive Model Area
- Habitat Conservation Plan (HCP) Covered Activity
  - IEUA.1.06 Jurupa Basin
  - Project ID
  - Name of HCP Project
- Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

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Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - CHINO WEST

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10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 290

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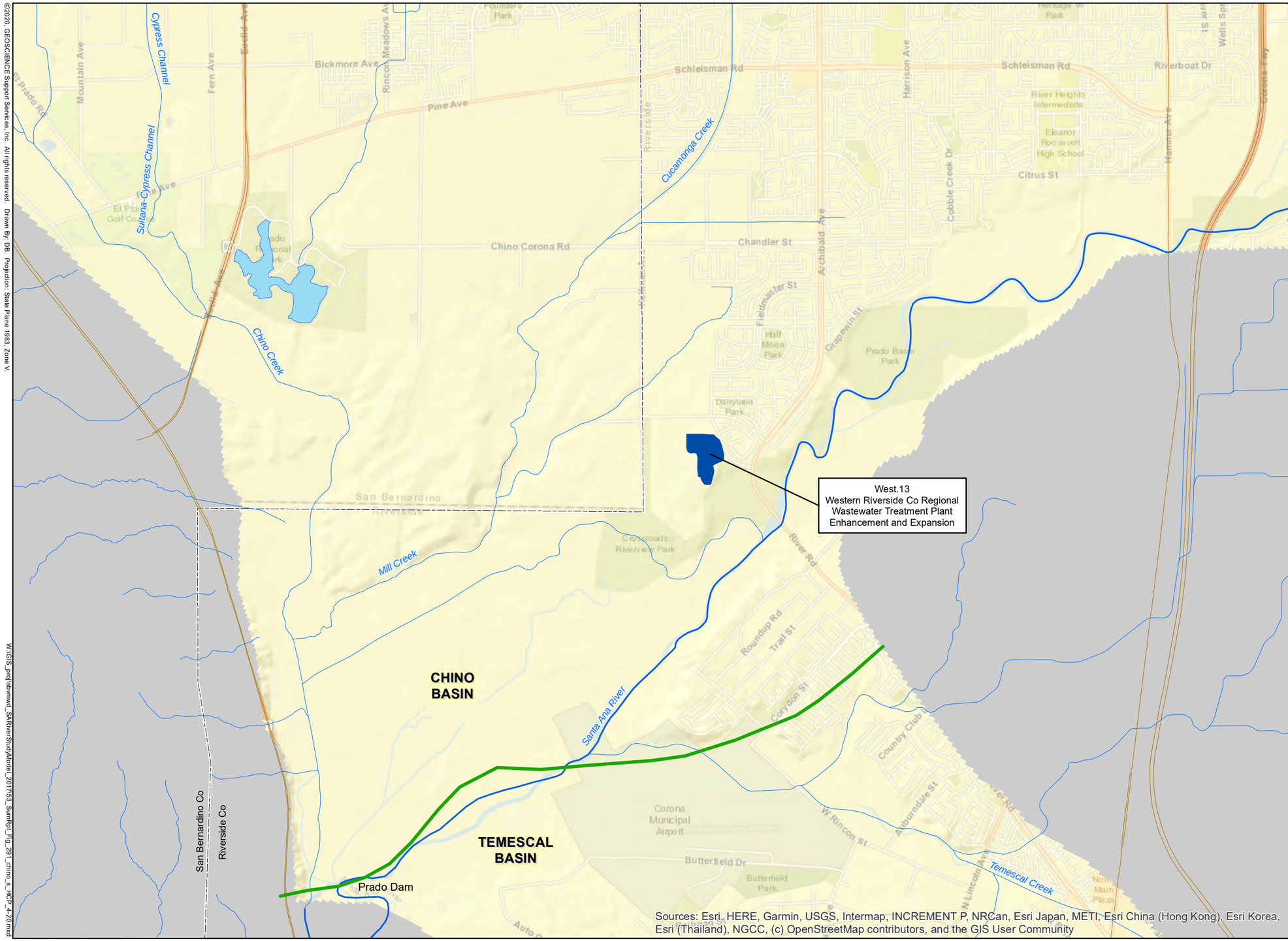


EXPLANATION

Integrated SAR Model Boundary

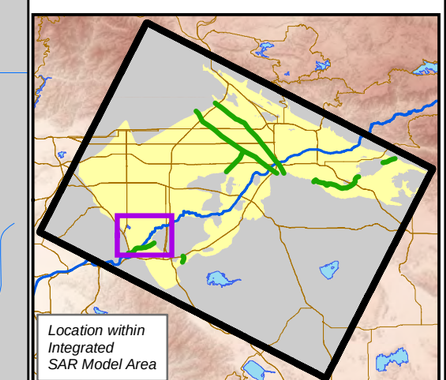
Active Model Area

Inactive Model Area

Habitat Conservation Plan (HCP) Covered Activity
IEUA.1.06 Jurupa Basin
- Project ID
- Name of HCP Project

Groundwater Basin Boundary

Refer to Table 17 for HCP Covered Activity Description



N

0 3,000 6,000
Feet

DETAILED LOCATION OF HCP COVERED ACTIVITIES - CHINO SOUTH

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10-Apr-20

SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

UPPER SANTA ANA RIVER INTEGRATED MODEL - SUMMARY REPORT

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FIGURE 291

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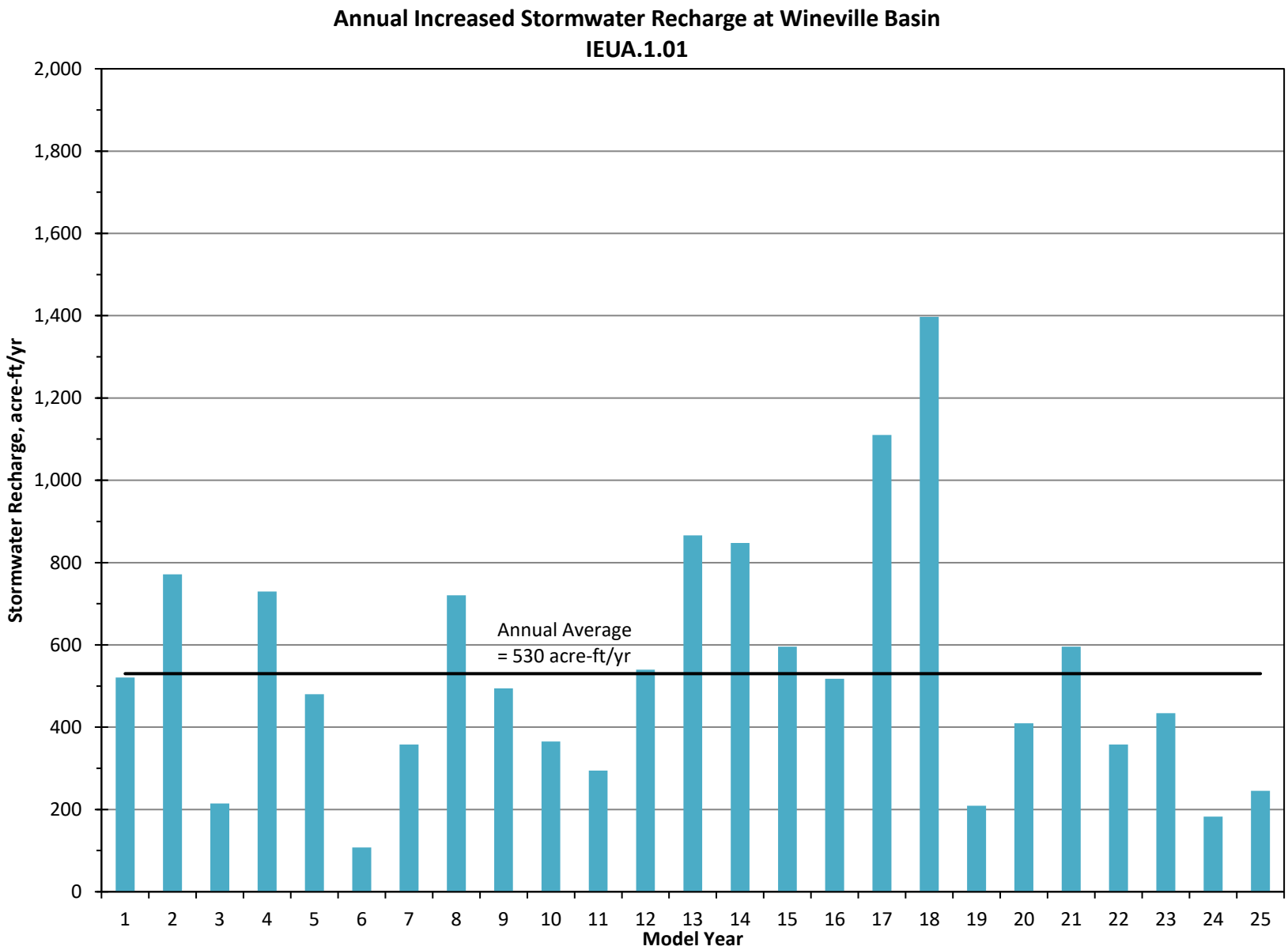

Figure 292

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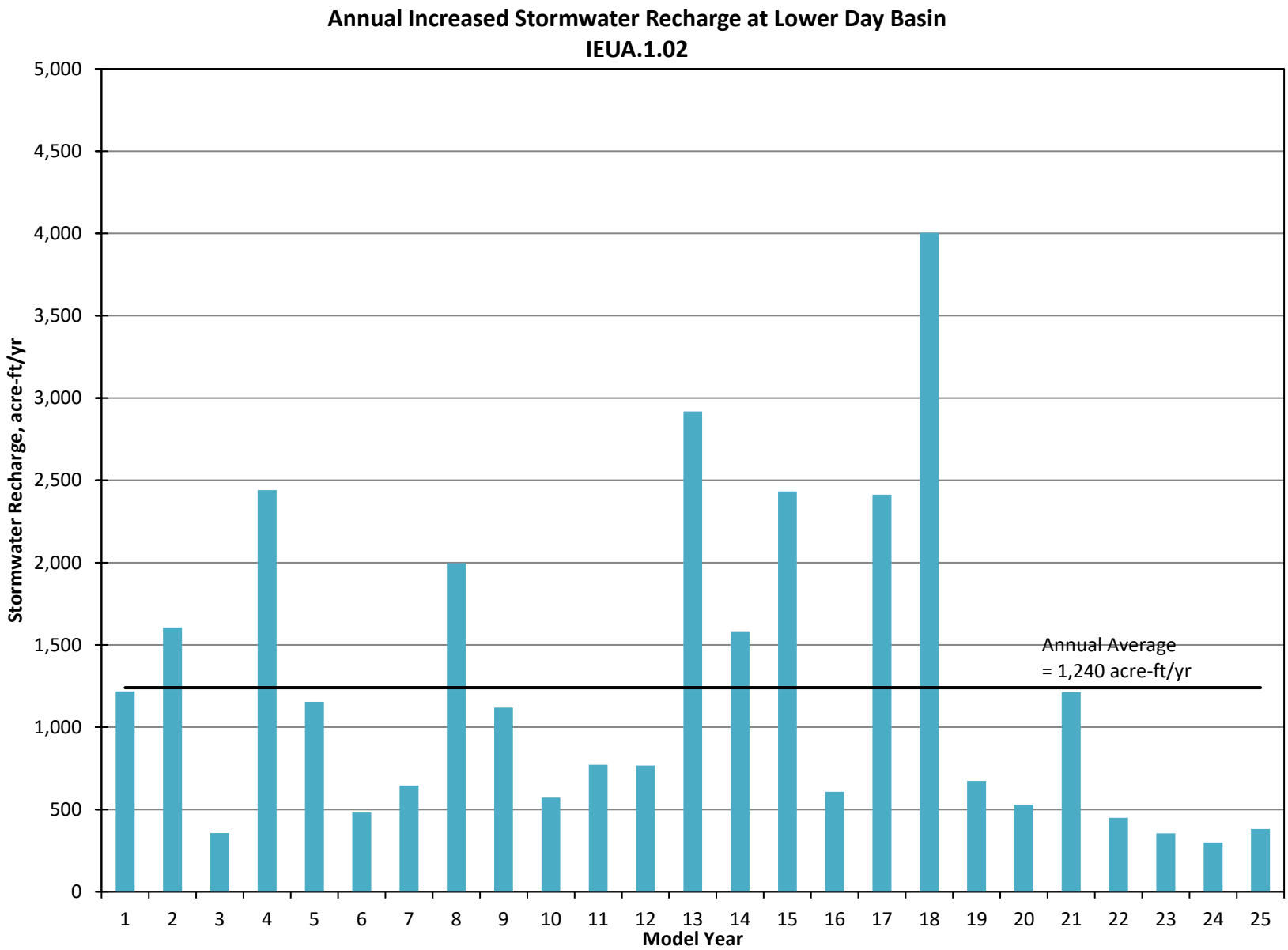

Figure 293

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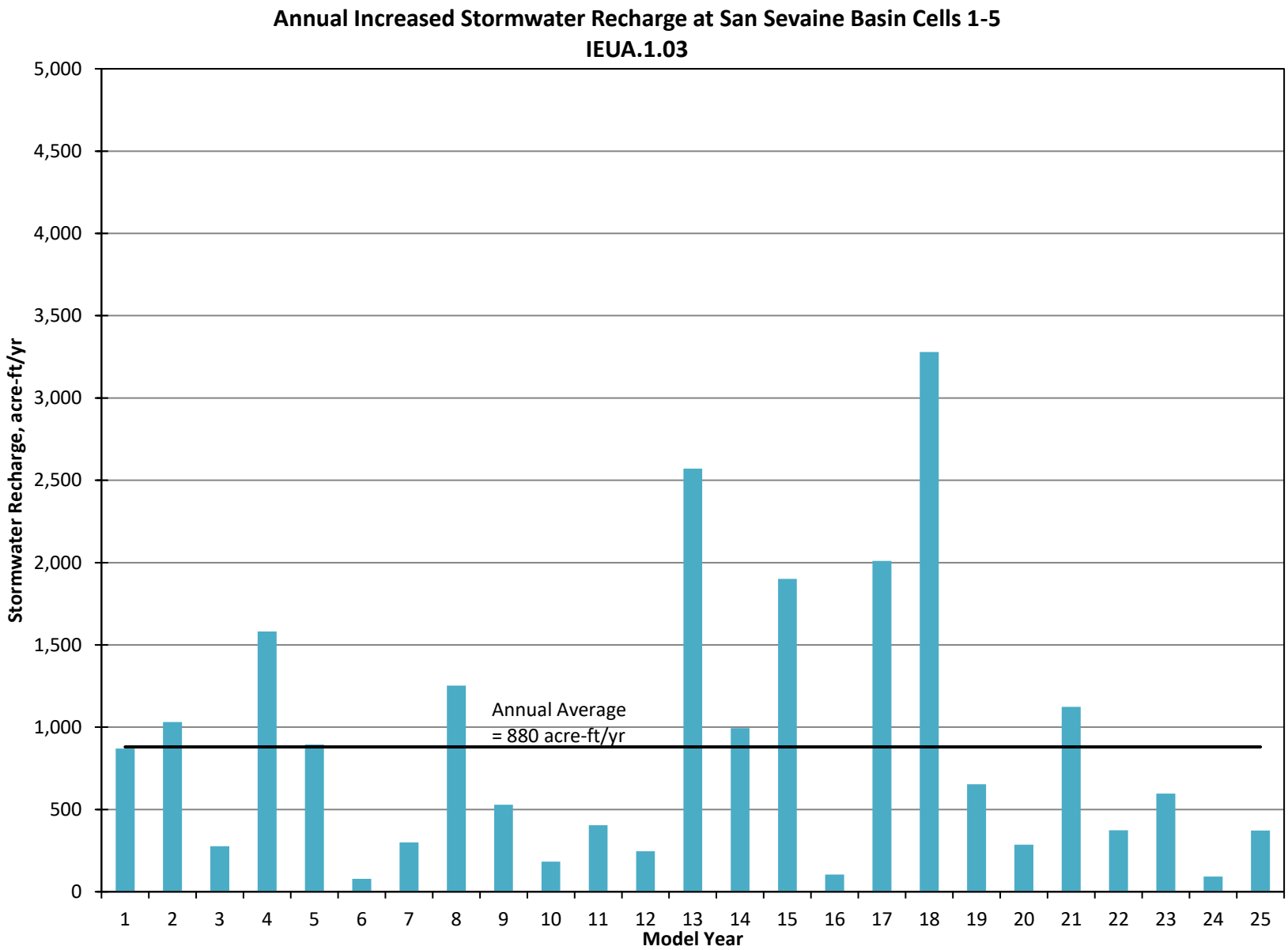

Figure 294

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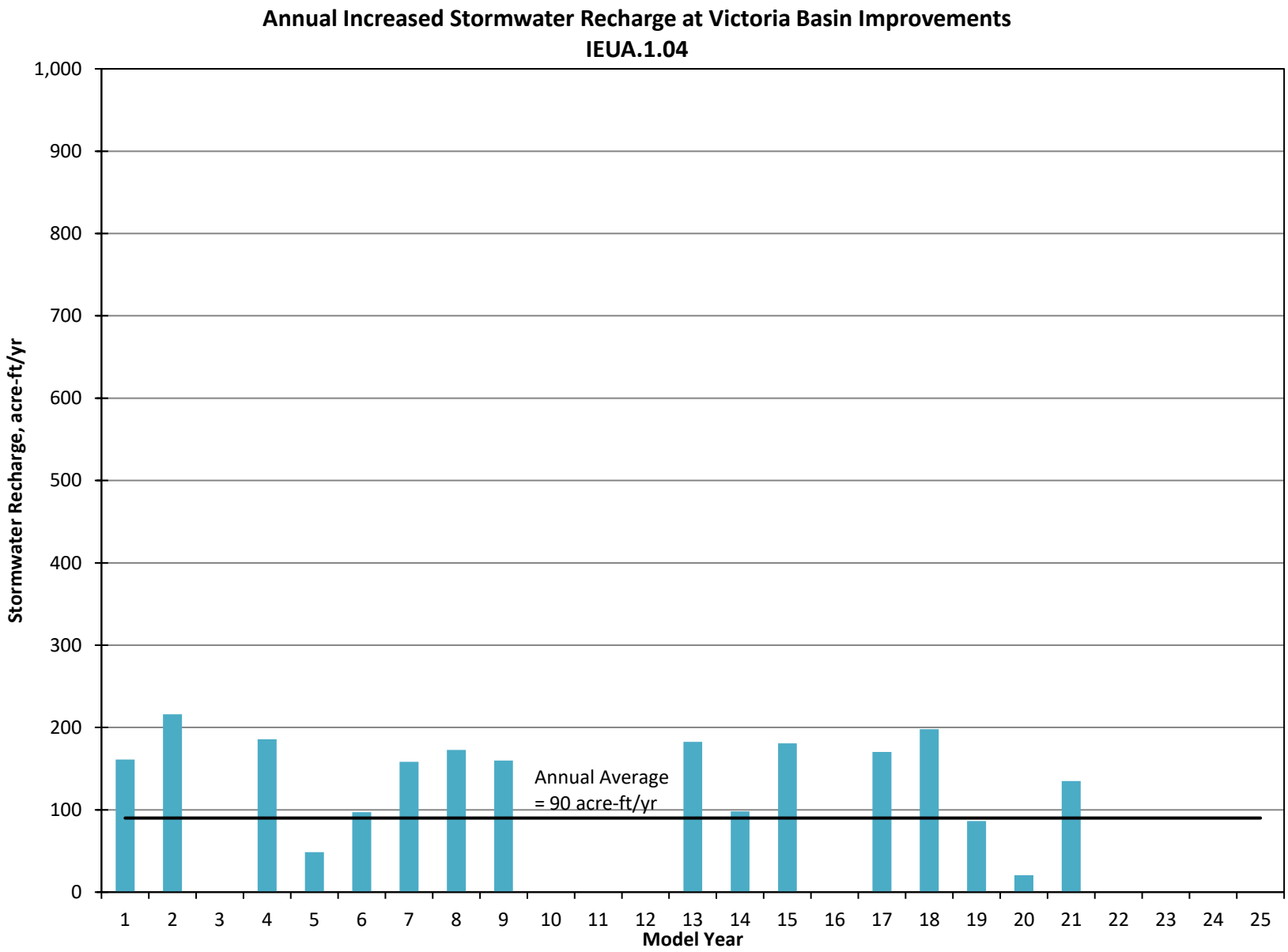

Figure 295

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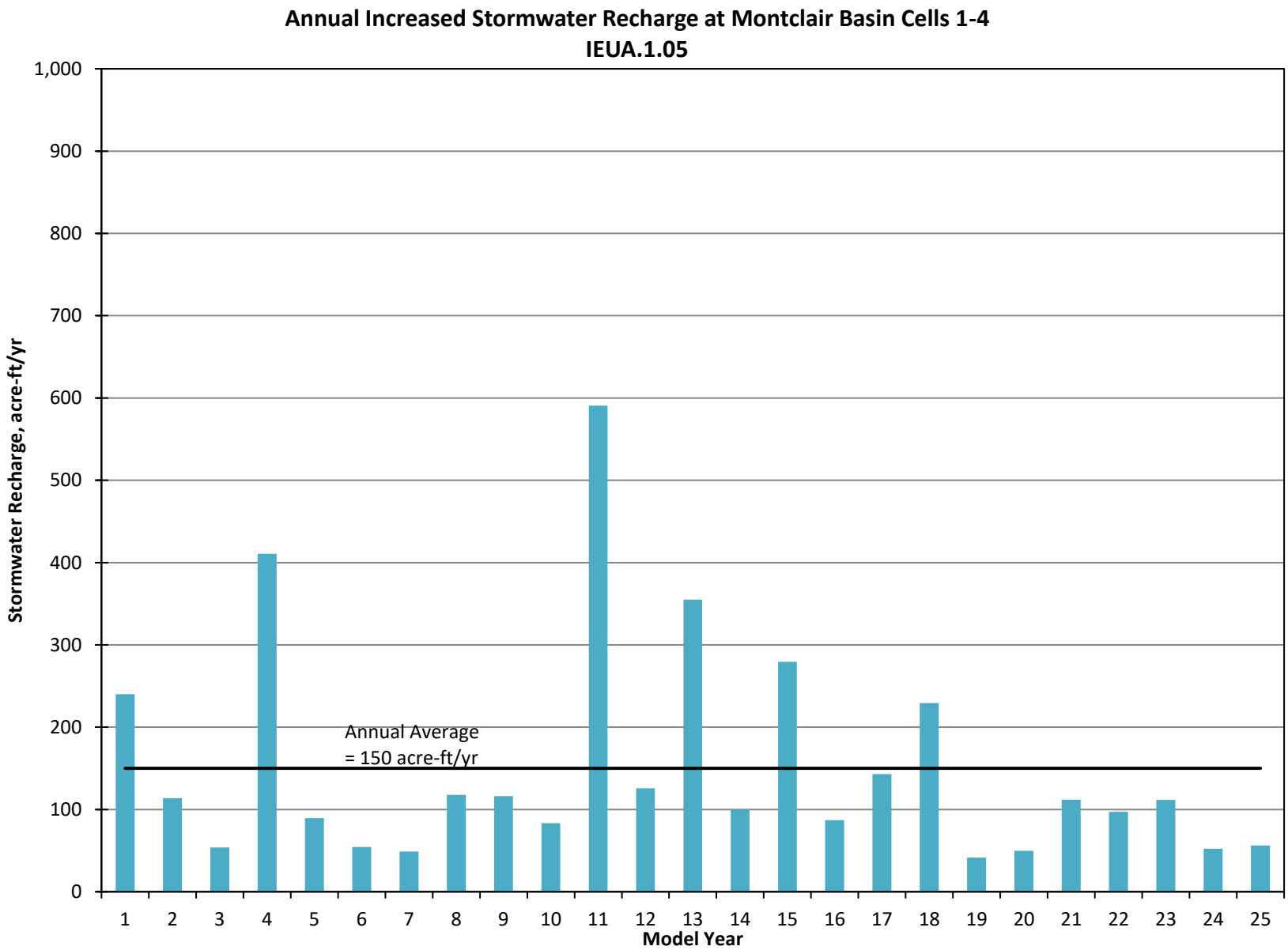

Figure 296

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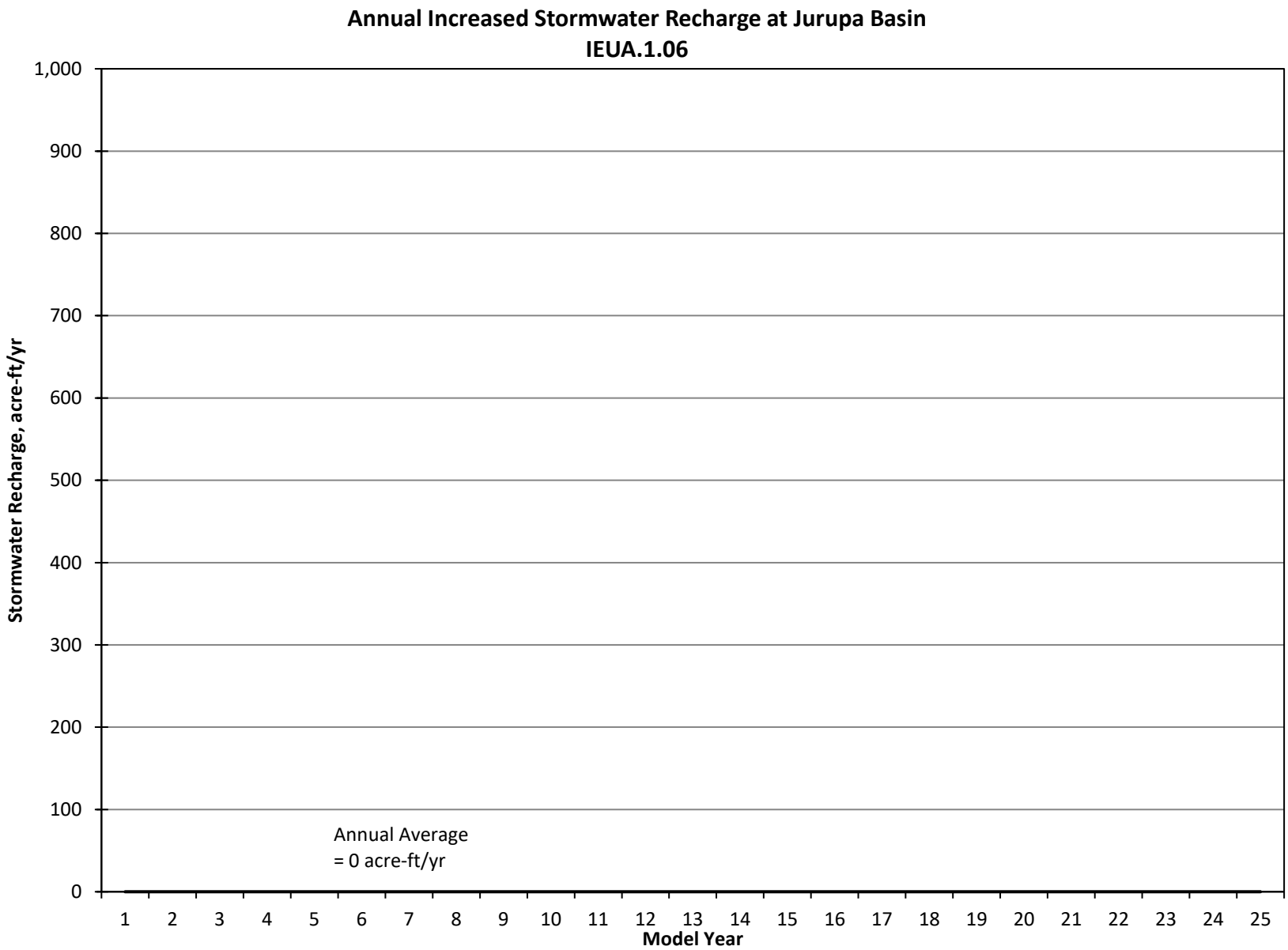

Figure 297

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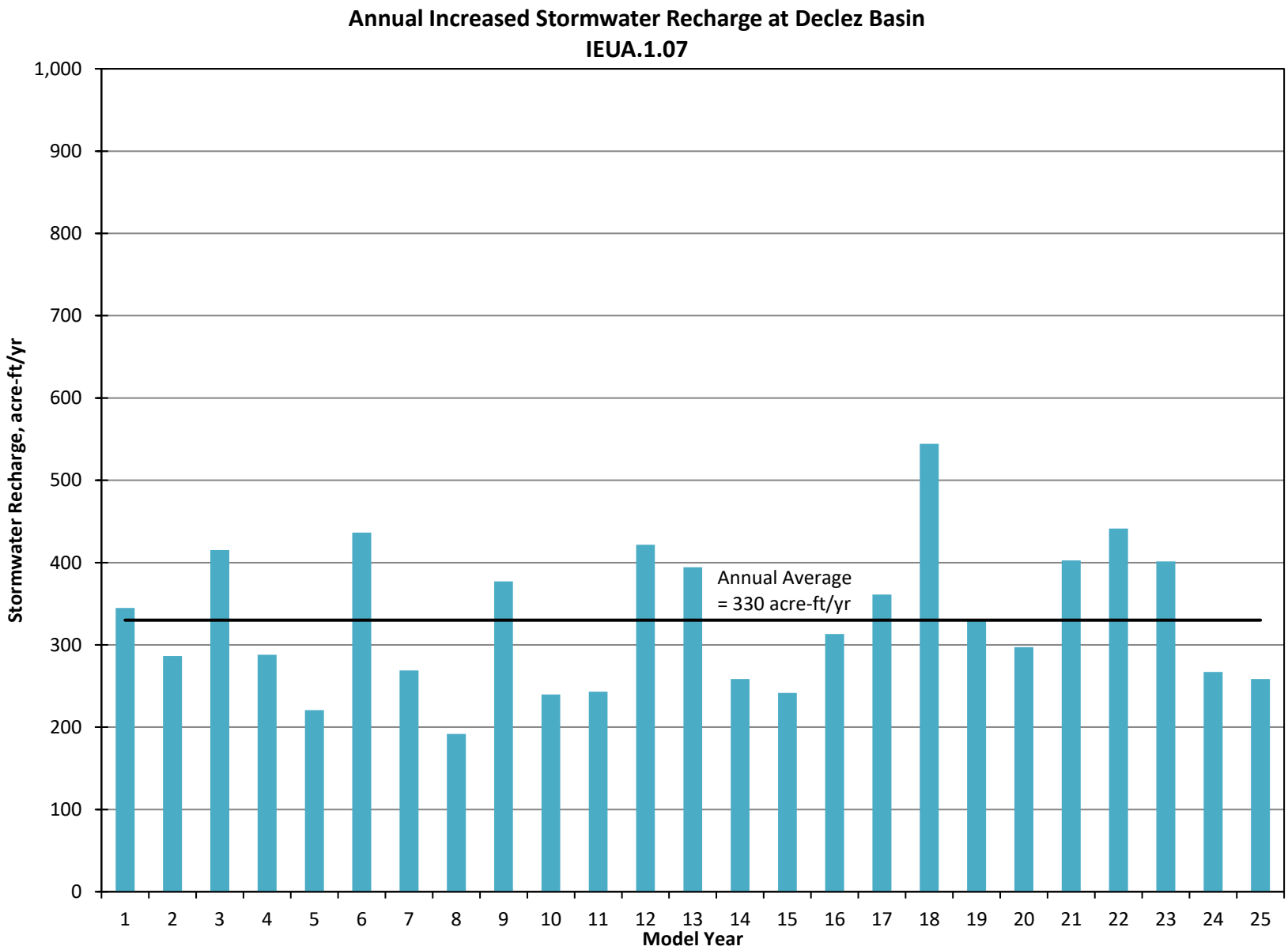

Figure 298

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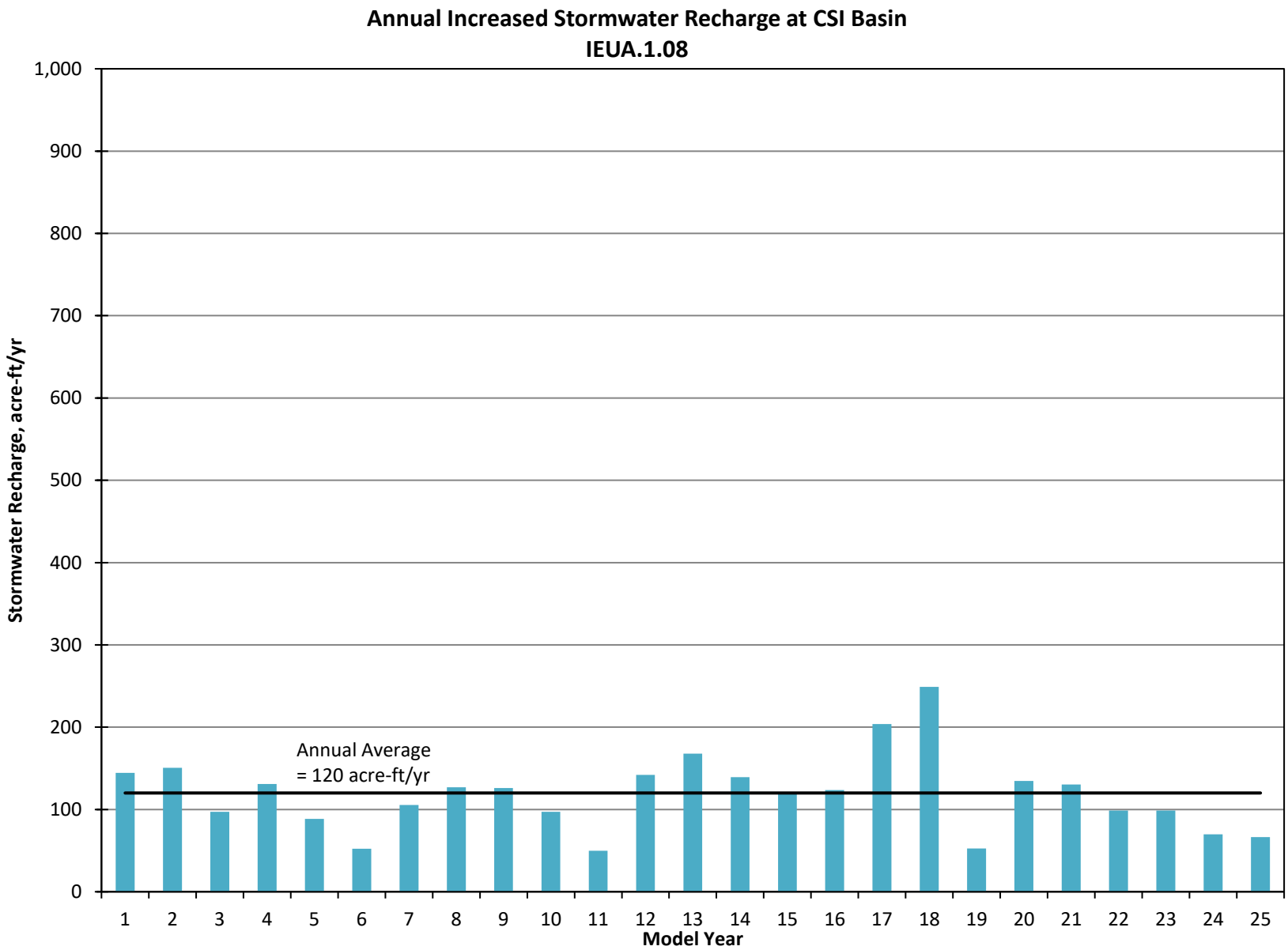

Figure 299

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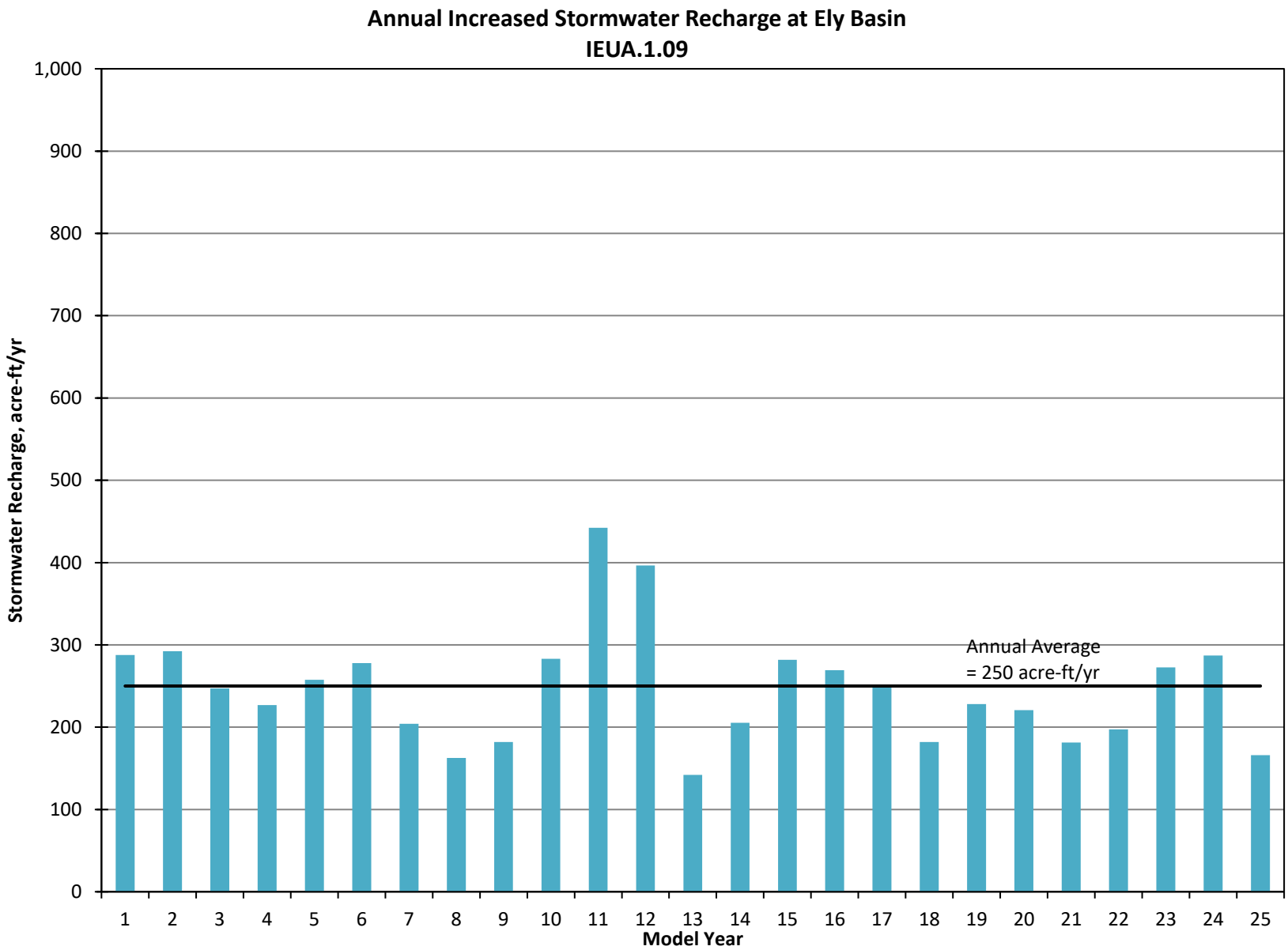

Figure 300

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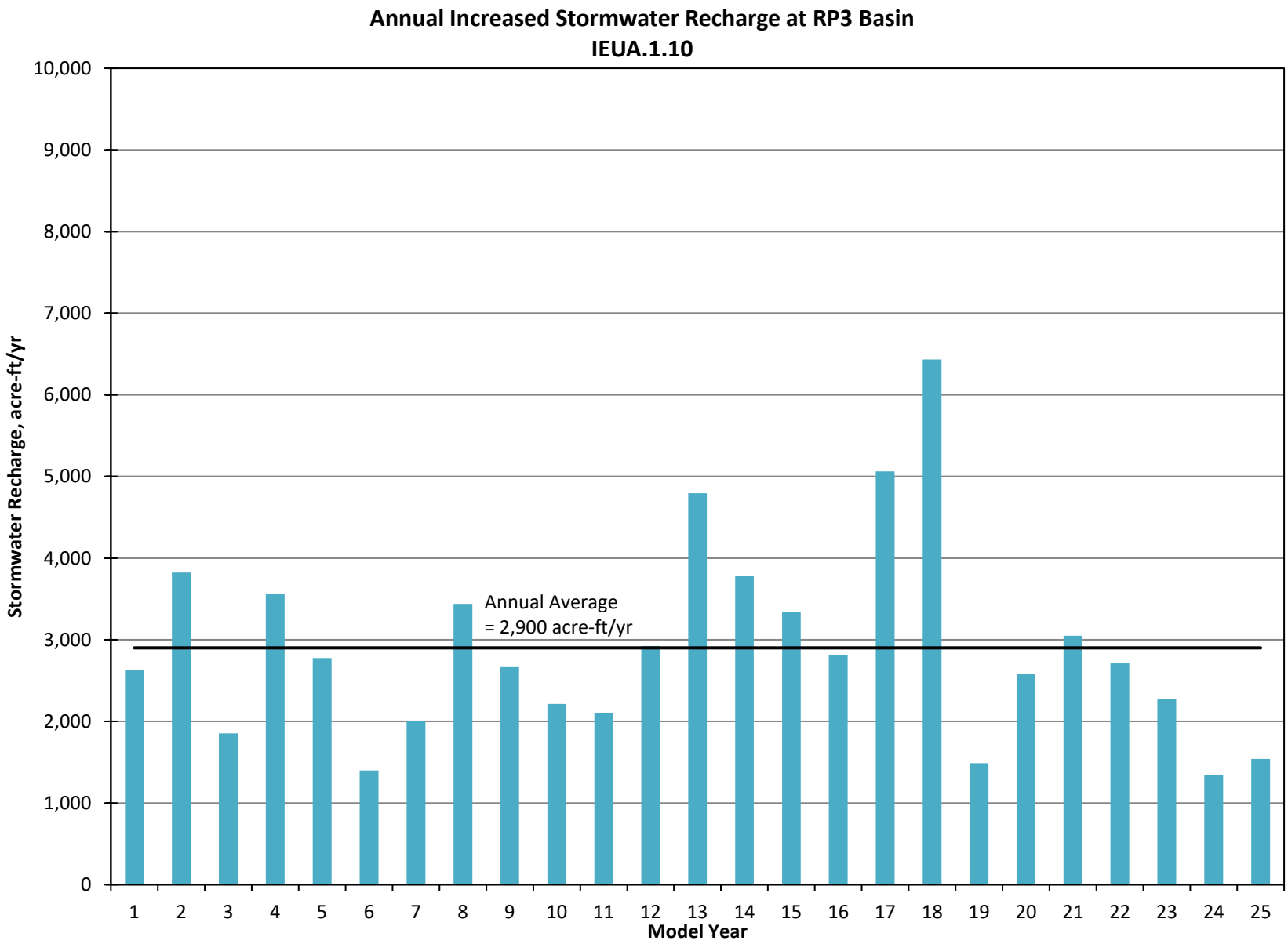

Figure 301

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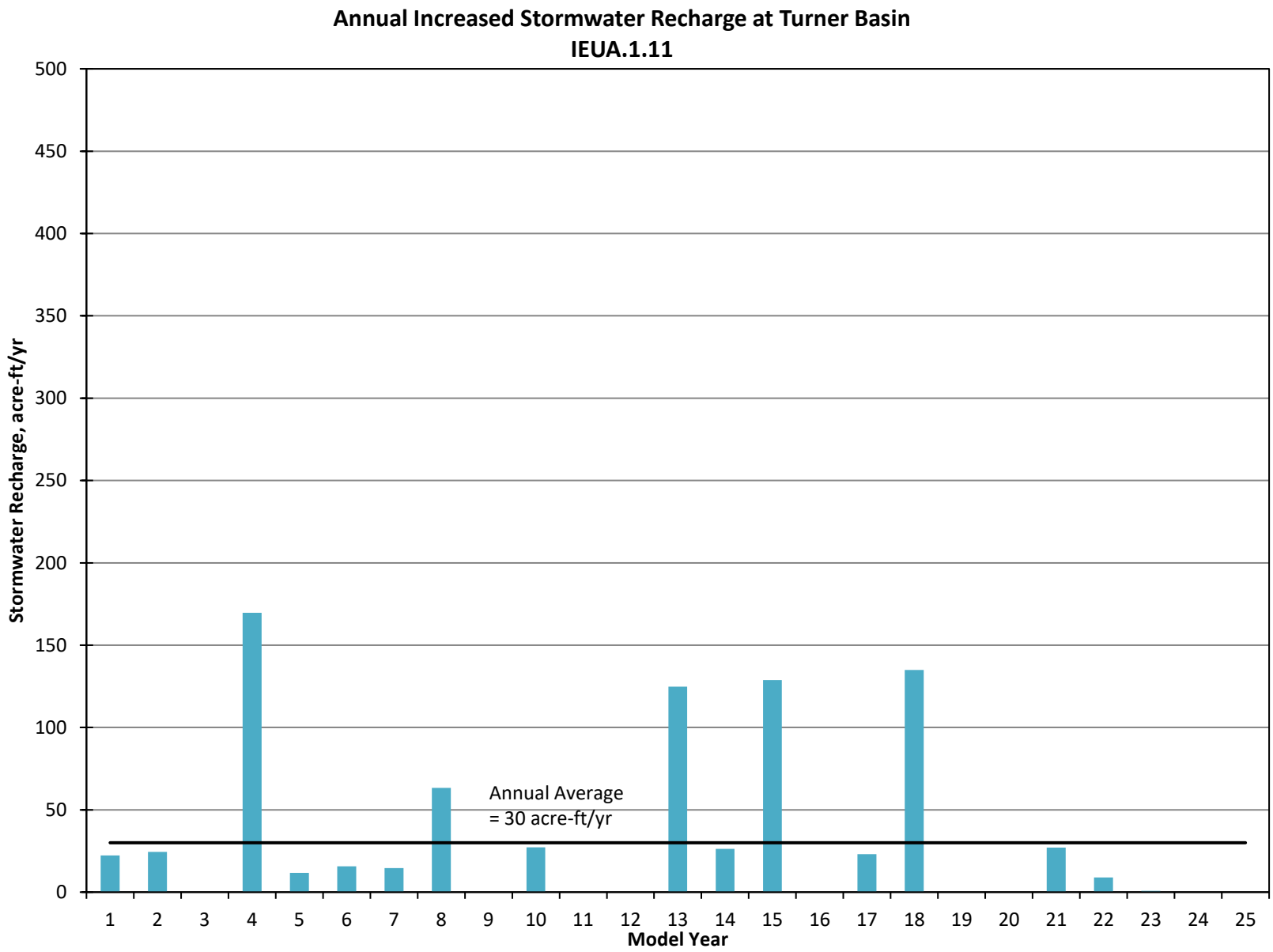

Figure 302

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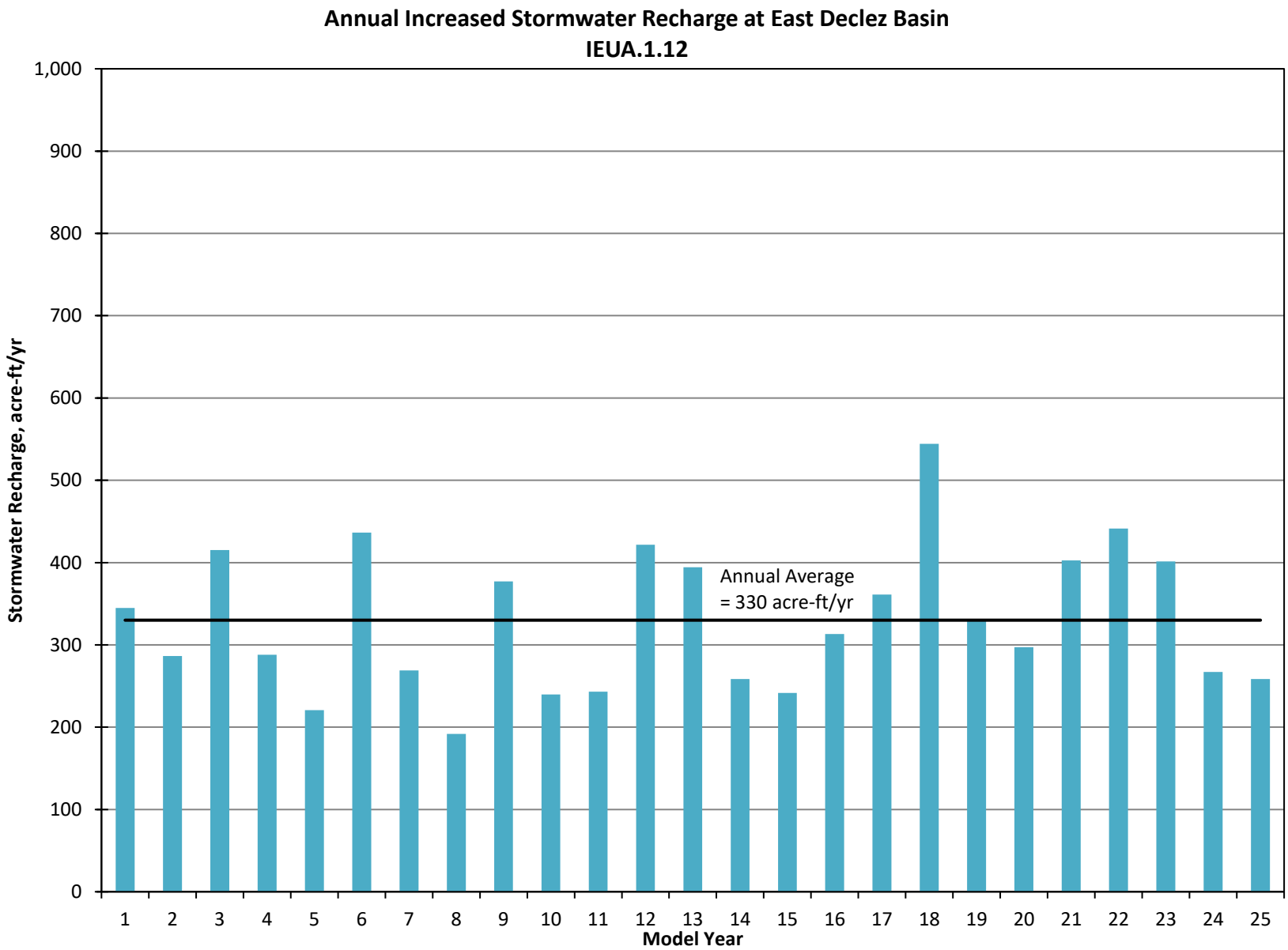

Figure 303

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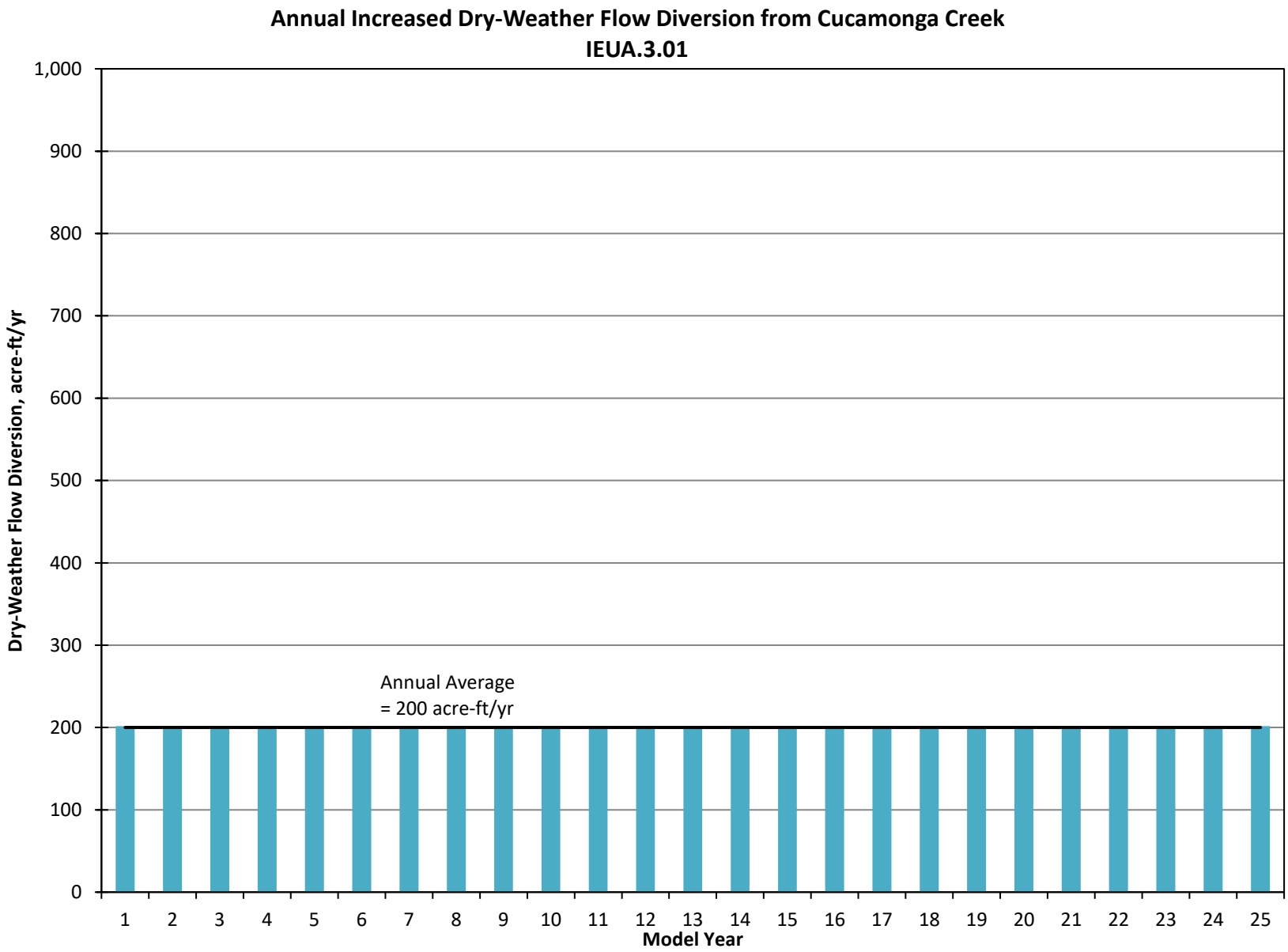

Figure 304

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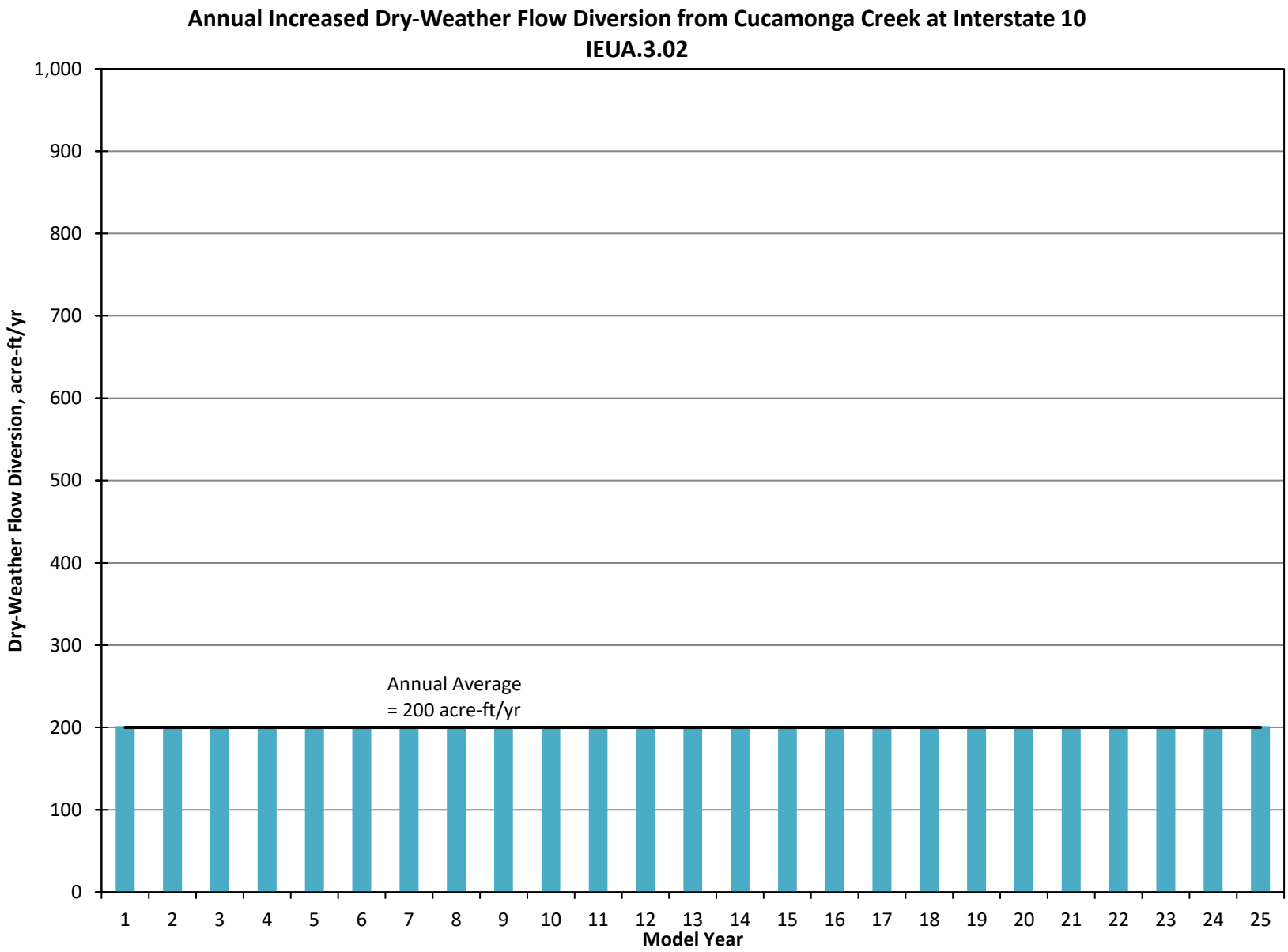

Figure 305

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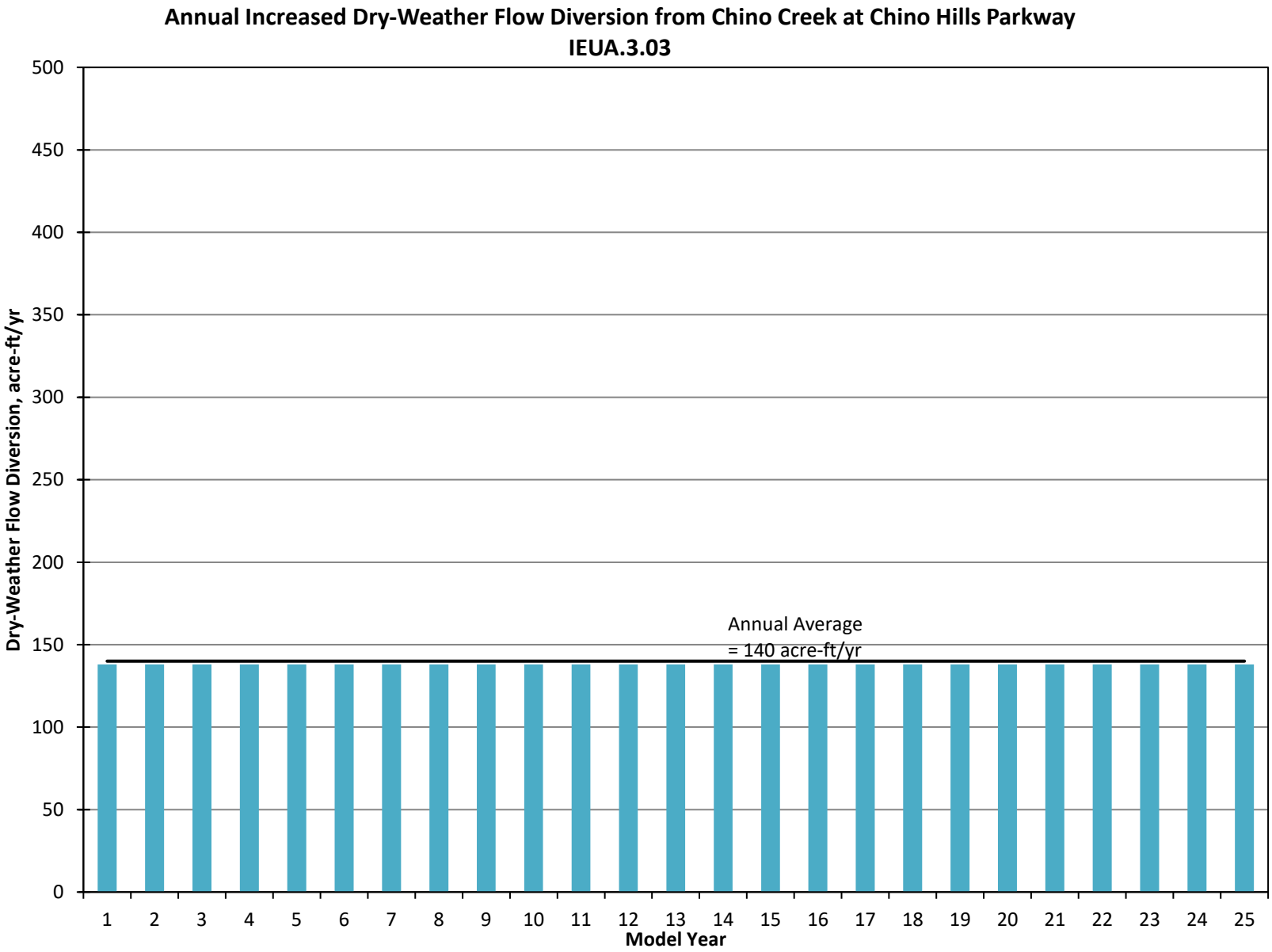

Figure 306

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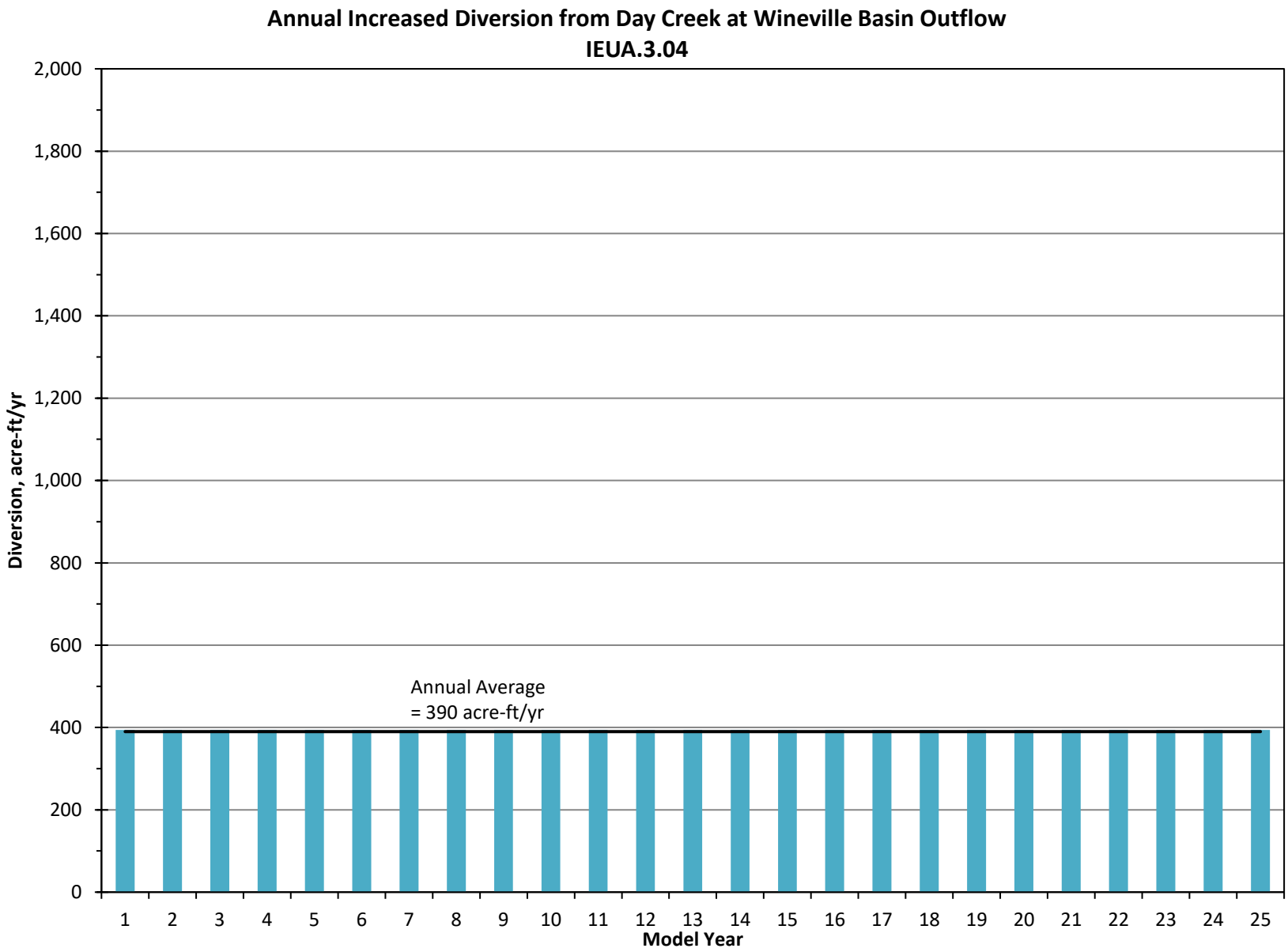

Figure 307

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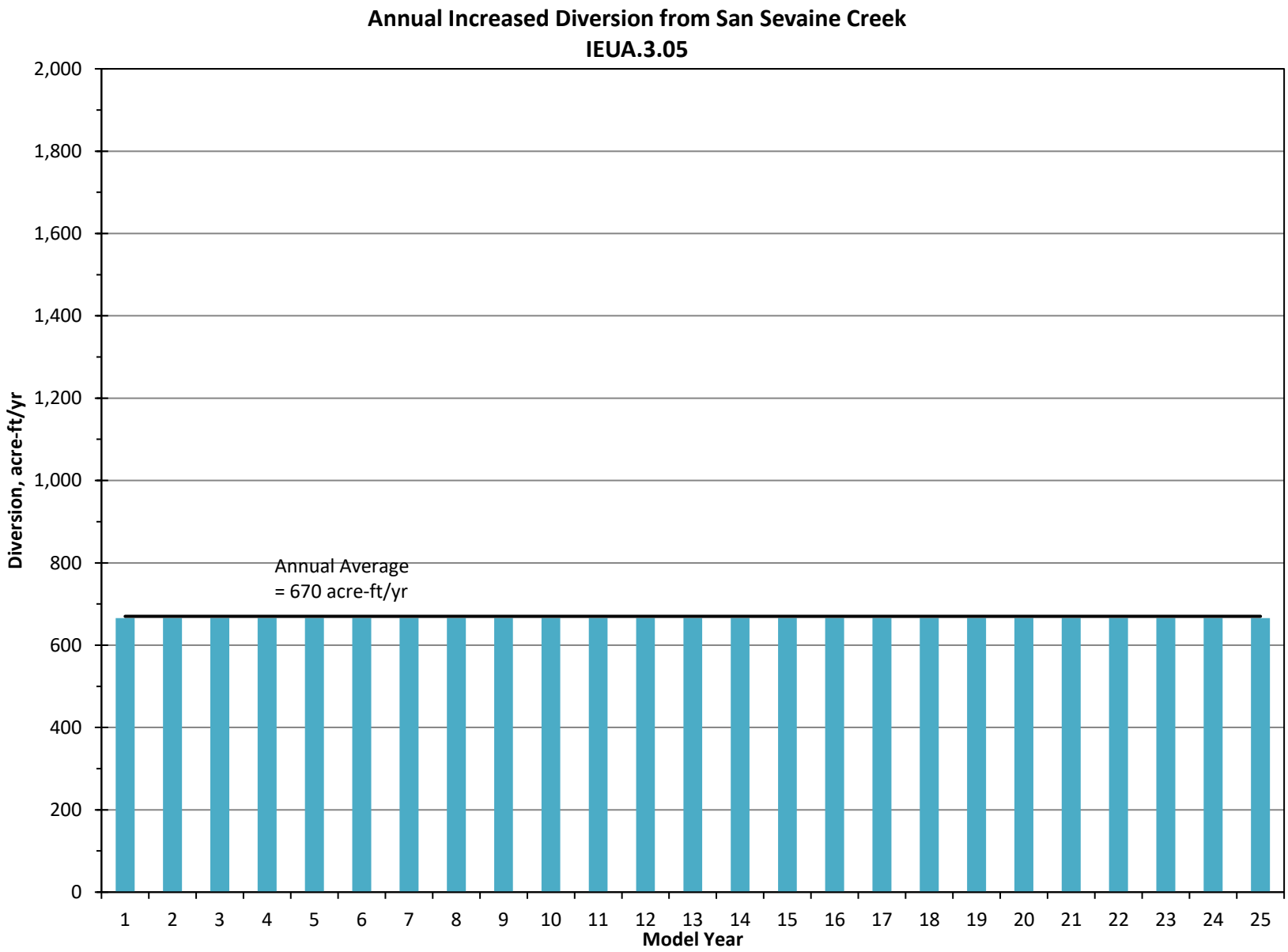

Figure 308

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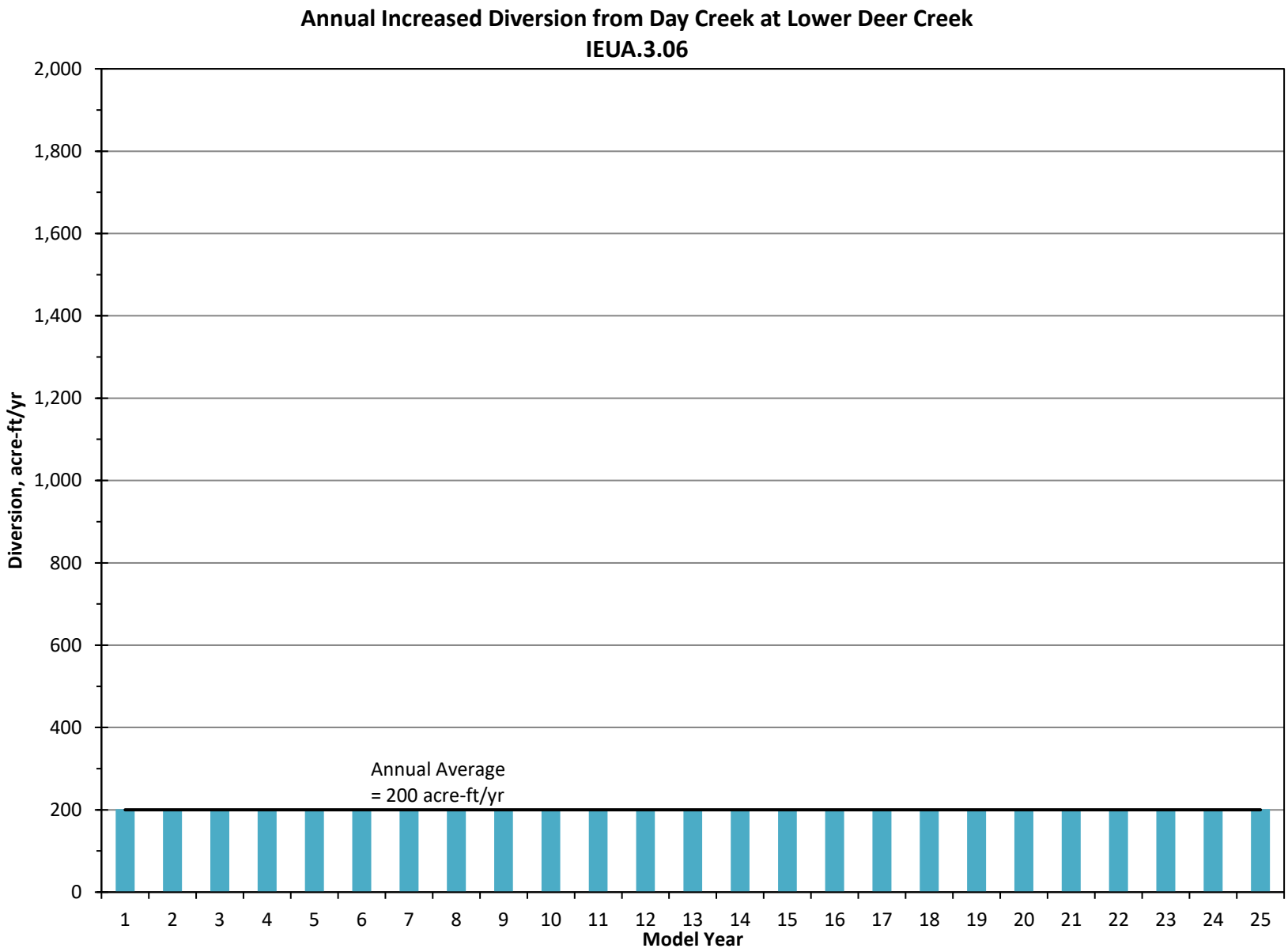

Figure 309

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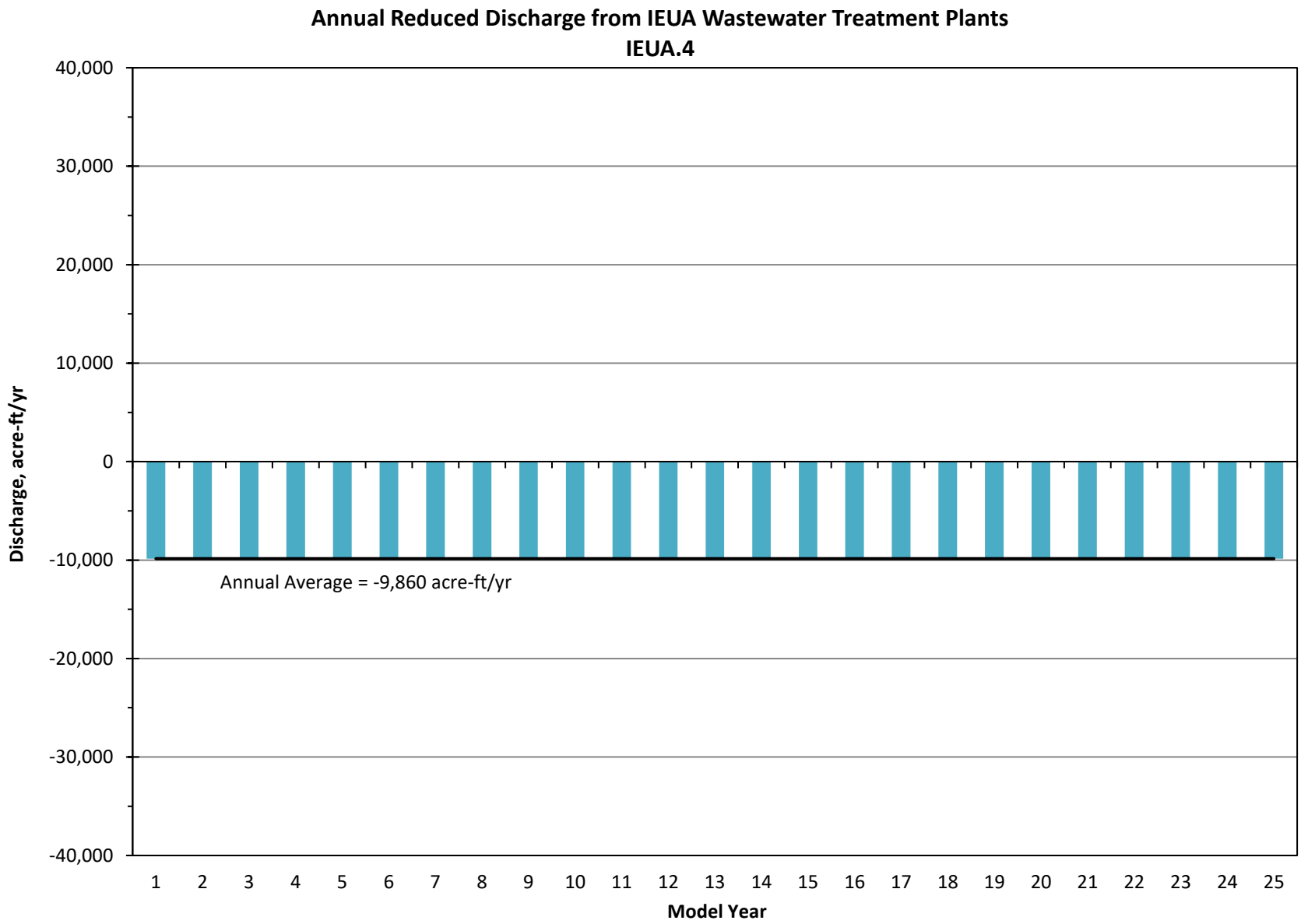

Figure 310

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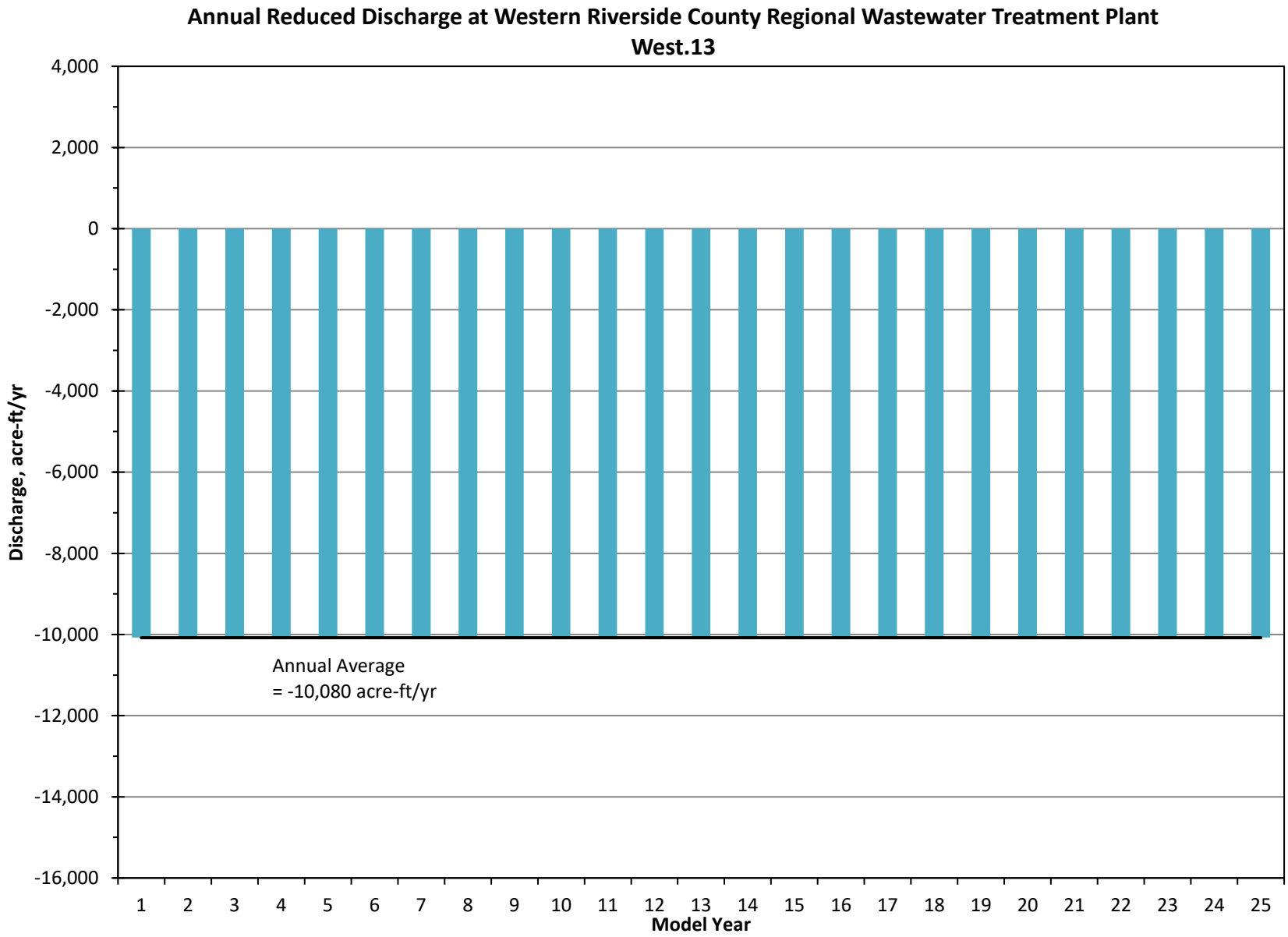

Figure 311

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