Bingham Cienega Hydrology

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As part of the scope for the Bingham Cienega Management Plan, Pima County Staff has evaluated the hydrology and water resources of the Bingham Cienega Natural Preserve area and the A-7 Ranch area. This report summarizes much of the data compiled in annual Resource management reports by the Pima County Natural Resources Parks and Recreation (NRPR) to The Pima County Regional Flood Control District (RFCD). In addition, it summarizes information from the US Geological Survey (USGS), Arizona Department of Water Resources (ADWR) and the Nature Conservancy (TNC) due to their continual monitoring in this area of the Middle San Pedro River Basin.

Several trends have affected the portion of the San Pedro middle and lower Basin encompassed by the Pima County Bingham Cienega lands and A-7 holdings and other properties. That area is along the floodplain and pediments west of the Cochise-Pima County Line and south of the Pima-Pinal County line (Figure 1). First, the volume of ground water pumping had been reduced from 1990-2010, after several acquisitions and conservation easements by TNC and Pima County, and the trend has been downward since the 1970s. However, pumping has appeared to increase since 2010 because of drought and little restriction on the adjoining adjacent properties, and agreements for the A-7 Ranch properties. Second, the last 20 years of drought, especially the lack of winter rains, has resulted in large water level declines. The drought has affected the Bingham spring, which no longer flows as of 2008 (TNC, 2010). In 1968, the spring flowed as much as 494 gallons/minute (ADWR, 2009). However, in 1952-1953 and 1974-1978 spring flow was absent due to drought (Ronayne and Mattock III, 1996). Thus, it appears the spring and its flow is the most fragile component of the hydrologic system in the Preserve and local area.

In general, large areas of this portion of the San Pedro basin are characterized as having shallow depth to water along and near the San Pedro River and its tributaries. This is the result of consolidated sedimentary rocks and clay layers near tributary Edgar and Buehman Canyons and the extension of the Catalina Core complex bedrock at shallow elevations. However, deeper aquifer conditions prevail in the areas just south of Redfield Canyon and southeast of Buehman Canyon in the A-7 Ranch area. Mountain front recharge, underflow and streamflow seepage are the primary recharge inputs. Evapotranspiration, crop consumptive use with well pumping and underflow out are the primary sources of discharge of the system. Isotope results suggest San Pedro River recharge, underflow, and recharge from tributary canyons may be a critical component of recharge to the aquifer and the former flow at Bingham Spring (PAG, 2001). More recent tritium data suggest that recharge from tributary canyons are most responsible for the former flow at Bingham spring (Eastoe, 2017)

Water-Level Changes in Bingham Cienega and A-7 Area

Historic water levels from six well hydrographs show a significant declining trend since the late 1990s (Figure 2 and Table 1, Appendix A). Water level trends:

- Over the past 20 years, monitor wells on the Bingham Cienega Preserve have had average water level declines of about 1.3 feet per year (ft/yr). The well with the shallowest water levels, Kelly, has dropped from 5 feet below land surface (bls) in 1997 to 30 feet bls in 2017. However, those rates for Kelly well have changed over the past ten years to a decline of approximately 2.1 ft/yr since the drought has intensified and pumping in the area has increased.
- The A-7 area appears slightly more resilient, but water levels are deeper (close to 75-80 feet bls) and recoveries during wetter years show a larger recovery response. The declines in the last 20 years range from 0.6 to 0.9 ft/yr. with more fluctuation in decline and recovery. Water-level recovery in the last three years have been as much as 7-10 feet.

The Kelly Well is closest to the Bingham Spring, which has not flowed since spring of 2008. Based on reports from the TNC (2010, 2011), the spring and surface water has been periodic since 2002, and the last wetted period was between fall 2006 and spring 2008. During the last wetted period, the Kelly well went from a depth to water of 7.0 feet bls to 12.5 feet bls in June 2008. The Kelly well depth to water in 2016 was 30 feet bls, indicating the Cienega has transitioned to a mesic condition.

Figure 1. Middle San Pedro Study Area and Monitoring Wells

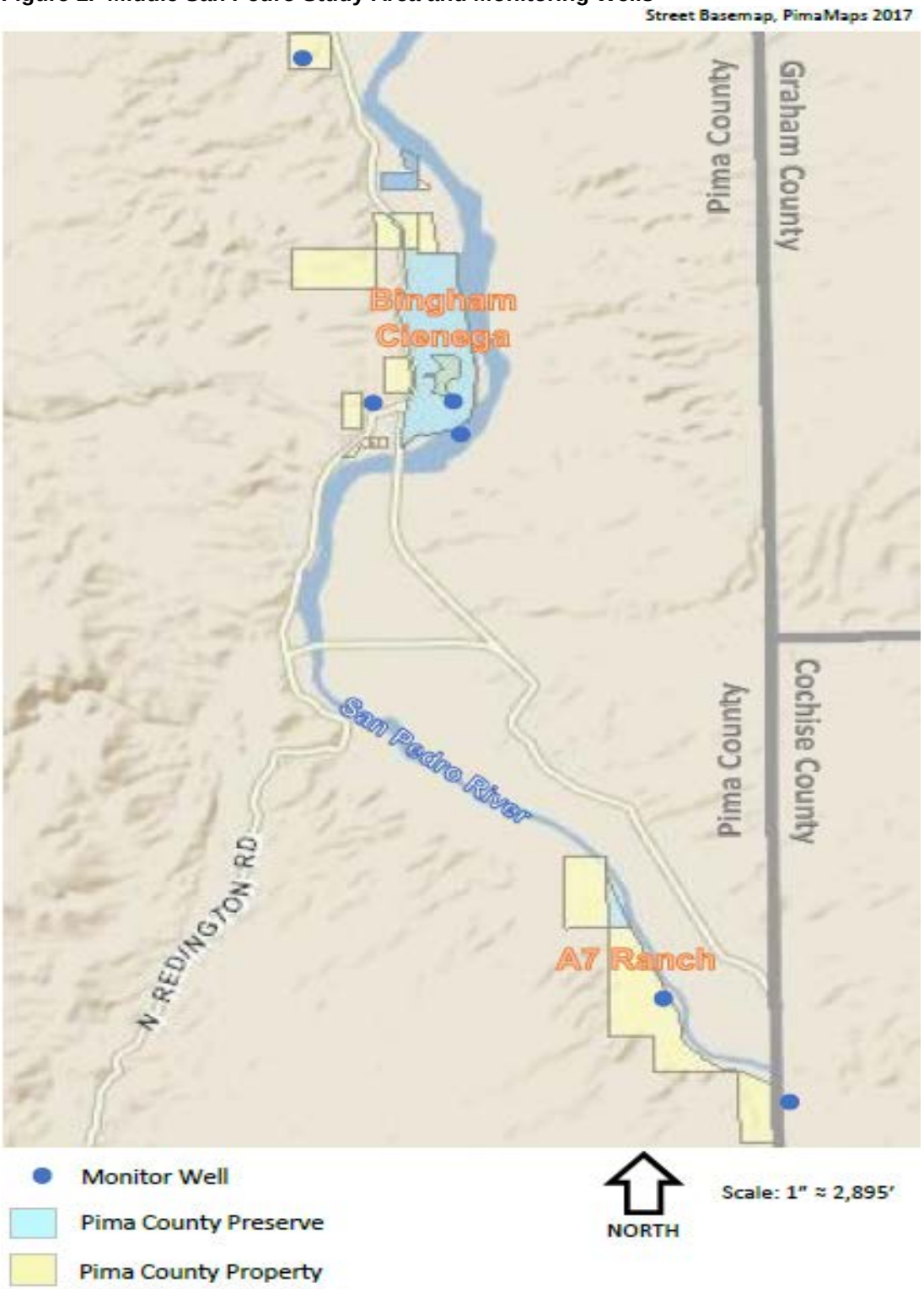


Figure 2. Bingham Cienega and A-7 San Pedro River Area Monitor Wells with Hydrographs

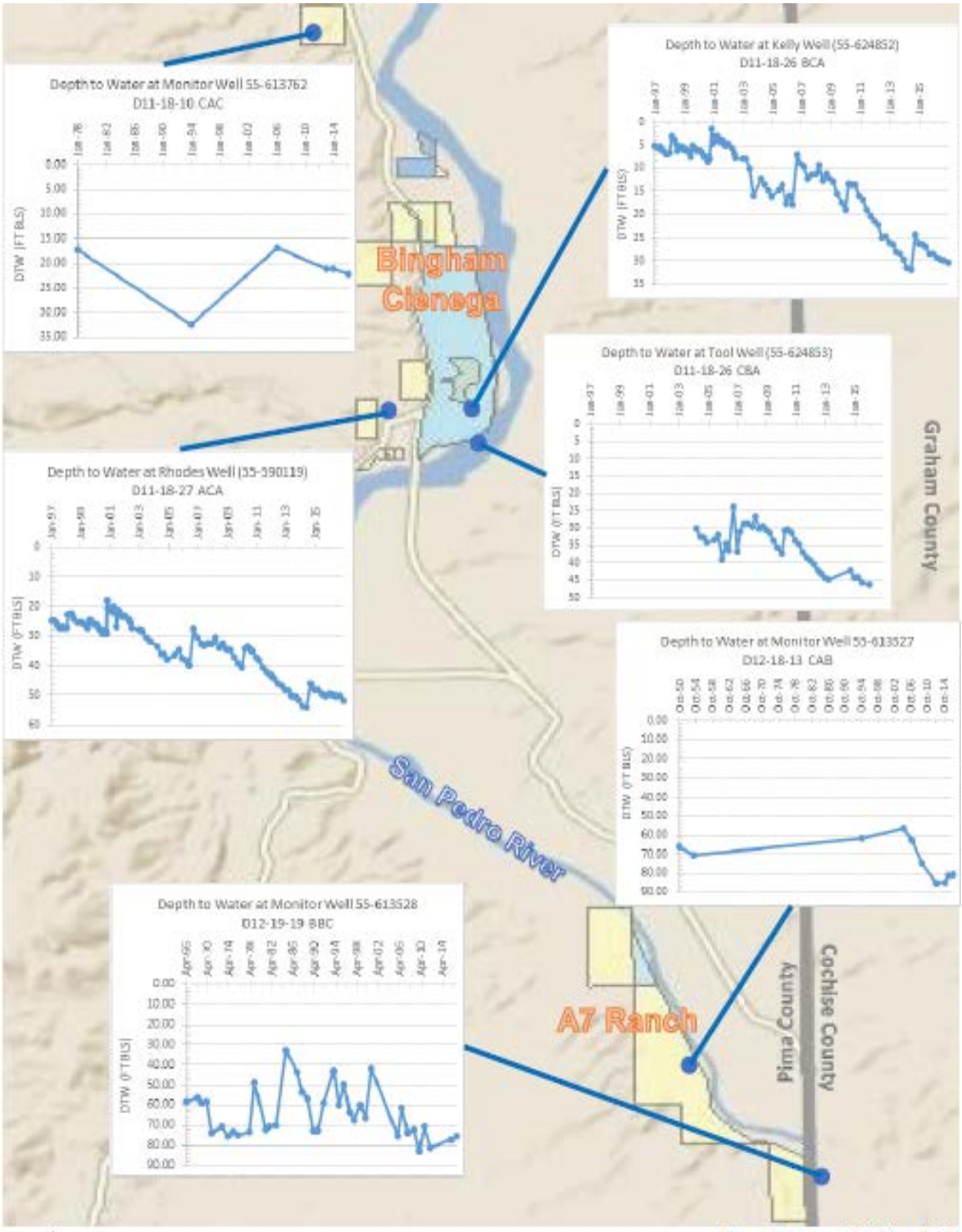


Table 1. 30-Year, 20-Year and 10-Year Water Level Changes along the San Pedro River from A7 Ranch to Bingham Cienega

Wells55- Registry	Well Location	30 Year Record Change	20 Year Record Change	10 Year Record Change
613762 (Diamond M)	D-11-18-10CAC		1994-2016 (22 yr.) +10.1 ft., +0.46 ft/yr	2006-2016 (10 yr.) -5.40 ft., -0.54 ft./yr.
624852 (Kelly)	D-11-18-26BCA		1997-2017 (20 yr.) -25.11 ft., -1.25 ft./yr.	2007-2017 (10 yr.) -21.05 ft., -2.10 ft./yr.
624853 (Tool)	D-11-18-26CBA			2007-2016 (9 yr.) -9.45 ft., -1.05 ft./yr.
627729 (Rhodes)	D-11-18-27ACA		1997-2017 (20 yr.) -26.91 ft., -1.34 ft./yr.	2007-2017 (10 yr.) -21.21 ft., -2.12 ft./yr.
615527 (A7 #1)	D-12-18-13CAB		1994-2016 (22 yr.) -18.9 ft., -0.86 ft./yr.	2006-2016 (10 yr.) -18.00 ft., -1.80 ft./yr.
613528 (A7 #2)	D-12-19-19BBC	1986-2016 (30 yr.) -31.9 ft., -1.06 ft./yr.	1996-2016 (20 yr.) -12.0 ft., -0.60 ft./yr.	2007-2016 (9 yr.) -1.70 ft., -0.19 ft./yr.
			Avg. # Yrs; Chg/yr 20.8yr.; -0.17 ft./yr.	**Avg. #Yrs; Chg/yr 9.7 yr.; -1.30 ft./yr.**
			w/o Diamond M Well Avg. # Yrs; Chg/yr 20.5 yr.; -1.01 ft./yr.	

Surface Water Flows and Relationship to Water Level Changes

Surface flow or lack thereof, on the San Pedro River significantly affects the recovery or decline of monitor well water levels on the Pima County Properties in the Redington area. Figure 3 shows the relationship between total annual flow in acre-feet (AF) at the Redington Bridge USGS gage and water levels in the six monitor wells in the vicinity. Notwithstanding, other inputs such as mountain front recharge and under flow are also probably increased when flood flows are high on the San Pedro River. However, stream flow is a good barometer, since it can be easily measured and correlated with riverbed recharge and subsequent water-level recoveries.

Three periods stand out related to water level recovery: 1999-2000; 2005-2006; and 2014. These periods show over 40,000 AF of annual flow. The following year or two water levels showed a good response and recovered to varying degrees. For the Kelly well in 2006, significant water level recovery was concomitant with Bingham Spring recovery (seeping) until March of 2008.

Periods of significant low annual river flow, below 10,000 AF, were 2001-2004; 2009, 2011-2013 and 2015-2016. The beginning of 2017 showed good winter flow, but as of this report, 2017 is not complete yet. Water level declines accompanied these periods, except for the A-7 wells in 2015-2016.

Figure 4 shows the combined flow data from two gages at Redington on the San Pedro River. This figure shows mean annual discharge at the gages from 1944-2016. In most cases, when the 5-year moving average fell below

40 cfs, the Bingham Spring dried up for a period, or these events preceded the Spring drying. The periods included 1952-1953, 1974-1977, 2002-2006, and 2018-2016.

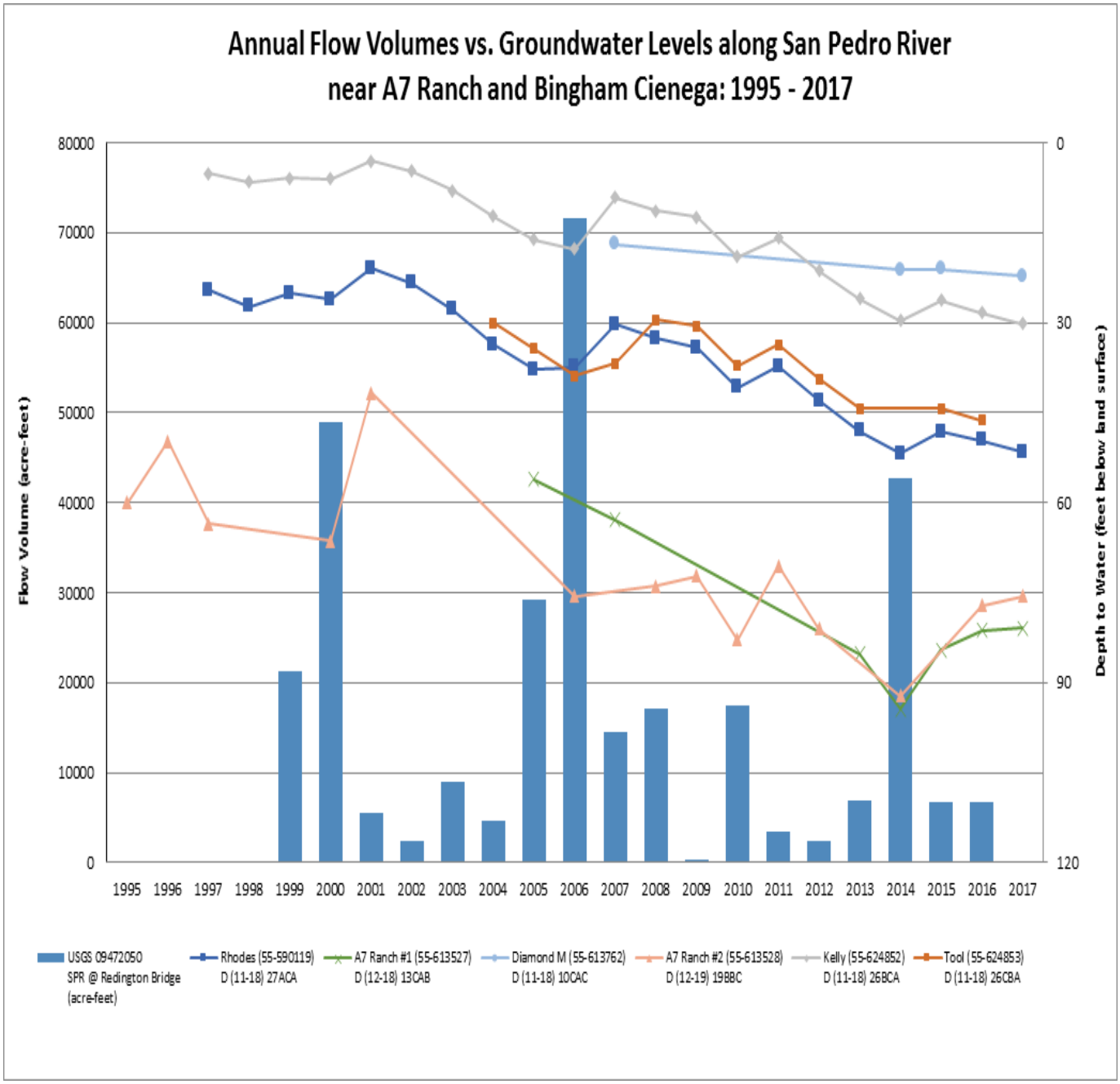


Figure 3. Total Annual Flow at the San Pedro Gage at the Redington Bridge south of Bingham Cienega

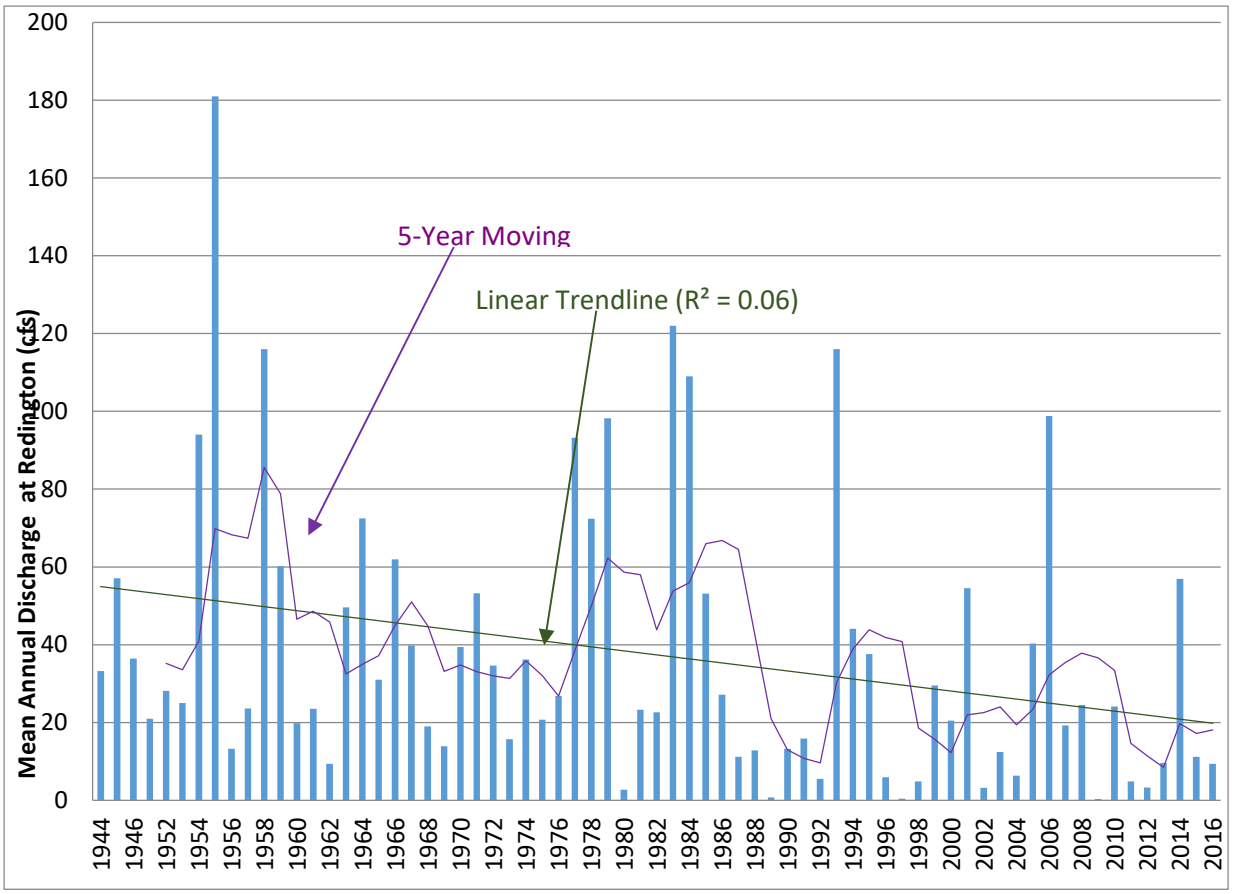


Figure 4. Mean Annual Discharge at the San Pedro Gage at the Redington south of Bingham Cienega

Rainfall

Pima County Natural Resources Parks and Recreation (NRP&R, 2017) annual report to PCRFCD on Bingham Cienega shows the annual rainfall from the residential inholding rain gage from July 1- June 30 of each fiscal year (i.e. 2016 is July 1, 2015-June 30, 2016) and annual calendar year rainfall. Table 1 is excerpted from the NRPR (2017) FY 2015-2016. Typically, about 45-50% of the rain falls during the monsoonal July-September quarter. About 40% of the rain falls October-March, during the winter and early spring. Elevated rainfall at the Preserve did not necessarily translate to high River flows. Average rainfall for the period July 1, 2002- June 30, 2016 was 12.92 inches/year. The rainfall inputs are important in contributing to the evapotranspiration (ET) requirements for the local riparian and mesic plants on the Preserve, especially since the connection between groundwater and the plants is lessening due to falling water levels. Rainfall is part of the input to the water balance.

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
12.81	14.81	16.42	8.05	12.62	16.74	16.18	13.08	8.11	10.62	8.89	13.99	13.93	14.64

Table 2. Annual Fiscal year (July 1-June 30) rainfall on the Bingham-Cienega Preserve.

Water Withdrawals

The following conclusions can be made regarding water withdrawals for the area:

- Of the over 70 wells in the area, most pumping volumes are from agricultural irrigation for use on the local ranches/farms.
- Pumping of wells appears focused in two main areas: The A-7 Ranch vicinity on Bayless and Berkalew Property and Pima County property; and the Area northeast of the Bingham Cienega Preserve on Bayless and Berkalew Property. The rest of the pumping is spread among private wells within the area.
- Pumping has been estimated based upon the amount of acreage cropped and on several assumptions and data gathered from reports and historical aerial photography. Google Maps and Pima County MapGuide have historical maps dating back to 1992 and include 1/1992; 10/1996, 4/2002, 9/2003, 6/2004, 4/2005. 8/2005, 6/2007, 6/2010, 9/2010, 6/2011, 3/2013, and 2/2016. Based on the photography and corroborated by other reports (Cordova and others, 2015), the estimated consumptive use was about 4.2 AF/acre.
- Since the 1990s about 170 acres northeast of the Preserve area has been primarily been cropped in alfalfa. Of that, about 50% had been cropped at any one time, leading to an estimate of about 270 AF/yr of irrigated land.
- Since the 1990s about 1,000 acres in the A-7 Ranch area has been primarily cropped in alfalfa. Of that amount, about 50% had been cropped at any one time, leading to an estimate of about 2,000 AF/yr of irrigated land.

Other withdrawals from the area include ET from phreatophytes and other native plants/trees along the San Pedro River and their use of rainfall for riparian and phreatophyte use. According to the recent USGS report on the Middle San Pedro Water Resources, ET accounts for 78% of water removal in the area from the 24 mile stretch from the Narrows, upstream of Cascabel to Redington (Cordova and others, 2015). As such, this output needs discussion in evaluating some of the reasons why the Bingham Cienega Preserve area has had a net water deficit in the last 10-20 years. Based on calculations extrapolated from estimates of ET on the San Pedro from the Narrows to Redington (Cordova and others, 2015), ET in the Bingham Cienega area to the Pinal County Line is about 412 AF/mile or about 1,936 AF/yr.

Water Balance

A preliminary water balance was prepared for the area from the Bingham Cienega preserve to Pinal County to estimate the inputs and outputs of the system. Table 3 summarizes the estimates.

Outflows	**AF/Yr**
Evapotranspiration: 412 AF/mi/yr over 4.7 miles	1,936
Irrigated Agriculture: 170 acres (50% irrigated) (4.2 AF/ac)	270
Local Wells and stock Ponds: 40 wells and 2 stock ponds	50
Underflow out (20 ft/mi)(1.2 mi) (20,000 gpd/ft)	540
Total Outflow	**2,796**
Inflows	
Mountain Front/Block Recharge 325 AF/mi over 4.7 miles	1,528
Average Streamflow recharge 60 AF/mi for 4.7 miles	282
Incidental Irrigation recharge	80
Underflow In	540
Total Inflow	**2,430**
Average deficit	**-366**

Table 3. Estimated water balance for the area from Bingham Cienega to the Pinal County Line

The most variable input in these estimates is streamflow recharge. Based on the Middle San Pedro study (Cordova and others, 2015) streamflow recharge varied from zero AF in 2009 to 150 AF/mile in 2001 and 140 AF/mile in 2006. The average from 2001-2009 was 60 AF/mi/yr. This input appears to control whether water levels will

recover or decline, and is dependent upon the climatic factors of generation of significant rainfall to generate surplus runoff events on the San Pedro River. Consistent runoff is needed to allow for water-level recovery.

As a check against the water balance deficit, we applied a documented water level decline of 1.2 ft/yr, a specific yield of 0.2 for a silty sand and an area of about 1,600 acres of aquifer from Bingham Cienega Preserve to the Pinal county line. The resulting derived deficit was 384 AF/yr, within 5% of the tabulated 366 AF/yr deficit.

A similar water balance can be generated for the A-7 area. This area is dominated by more pumping and less phreatophyte/native plant use. Water levels in this area have declined to the point that riparian vegetation cannot be sustained. A different estimate for ET is derived by estimating the total plant acreage for the area outside the cropped acreage and comparing it with other areas in the middle reach of the San Pedro watershed. Based on the information the ET is significantly less, about 36% of the other areas.

Outflows	**AF/Yr**
Evapotranspiration: 150 AF/mi over 4.6 miles	690
Irrigated Agriculture: (1,000 acres) (50% irrigated) (4.2 AF/ac)	2000
Local Wells and stock Ponds: 20 wells	20
Underflow out (20 ft/mi)(1.2 mi) (20,000gpd/ft)	540
Total Outflow	3,250
Inflows	
Mountain Front/Block Recharge (325 AF/mi/yr over 4.6 miles)	1,495
Average Streamflow recharge 60 AF/mi for 4.6 miles	276
Incidental Irrigation recharge	600
Underflow In	540
Total Inflow	**2,911**
Average deficit	**-339**

Table 4. Estimated water balance for the area from A-7 Ranch terminus to Redington

As a check against the water balance deficit, we applied a documented water level decline of about 0.8 ft/yr, a specific yield of 0.2 for a silty sand and an area of about 1,920 acres of aquifer from the terminus of the A-7 Ranch in Cochise County to the Redington (Redfield Canyon Road). The resulting derived deficit was 308 AF/yr, within 9% of the tabulated 339 AF/yr deficit.

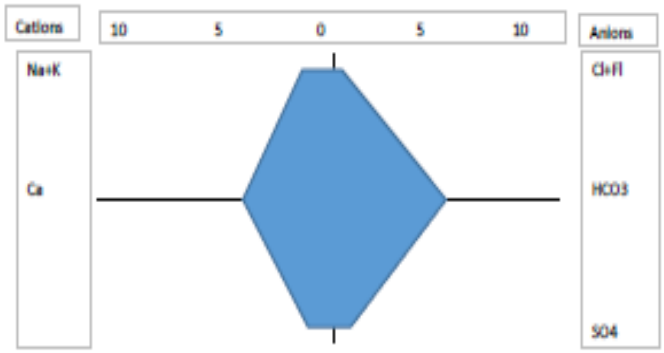
Groundwater Quality

The USGS report (Cordova and others, 2015) on the middle San Pedro watershed indicated that surface and alluvial groundwater in the Redington and Cascabel area of good quality, meeting primary drinking water standards and habitability of aquatic species. The water sampled in 2009 was a calcium bicarbonate type and was low in dissolved solids, below 500 mg/l. The tritium value of 3.3 TU (tritium units) indicates a mix of bomb and pre bomb water. The alluvial groundwater plotted closer to the summer precipitation water isotope $\delta^{18}O$ and δD, indicating that the water was recently lacking in winter precipitation recharge.

Other water samples for the area were found in Buehman Canyon Creek, sampled by the Arizona Department of Environmental Quality (ADEQ). Figure 5 shows Stiff diagrams of two samples taken in 2013. The sample is a calcium bicarbonate type, similar to samples taken by the USGS in 2009 along the San Pedro River.

BUEHMAN on 4/16/2013

Cations			Anions		
Ca (meq/l)	Mg (meq/l)	K+Na (meq/l)	Cl+Fl (meq/l)	HCO3 (meq/l)	SO4 (meq/l)
4.14	1.07	1.46	0.41	5.20	0.83



BUEHMAN on 2/14/2013

Cations			Anions		
Ca (meq/l)	Mg (meq/l)	K+Na (meq/l)	Cl+Fl (meq/l)	HCO3 (meq/l)	SO4 (meq/l)
4.24	1.07	1.74	0.61	5.00	1.23

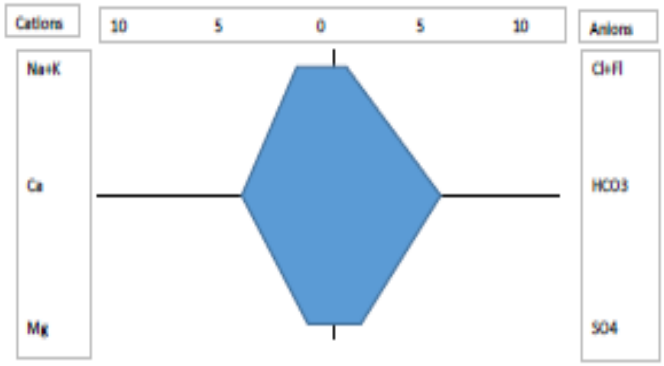


Figure 5.Stiff Diagrams of surface water samples from Buehman Canyon Creek in 2013.

The source of Bingham Cienega spring water was the subject of a past chemistry study culminating in a 2001 report (PAG, 2001). In October 2013, Chris Eastoe, University of Arizona Geology Department Isotope Laboratory Professor, discovered and ran the surface water sample taken from the Bingham Cienega spring in 2001 for tritium analysis. He informed Jennifer Becker, Pima County Regional Flood Control Principal Hydrologist, and others that the Spring sample bore the same tritium signature as current (1995-2001) rainwater at the time of collection, and could be an upper maximum of 50 years old (4.1 +/- 0.7 TU; 485 +/- 83 Bq/L). A mix of water sources is not ruled out, but the tritium results indicate that the spring water was dominated by relatively young water, post 1952 bomb water.

Summary of Findings

This report examines the Bingham Cienega and A-7 groundwater conditions in the Middle and beginning of the Lower San Pedro Basin. The basin is characterized, in general, by shallow depth to water along and near the San Pedro River. This condition is the result of shallow bedrock terminating on the west flanks of the basin near the River. Deeper aquifer conditions are found in the A-7 area. Additional key findings:

- The recent 20-year drought has caused significant declines in groundwater levels in the watershed.
- Stream flow at the Redington gage has fluctuated from a low of almost no flow in 2009 to over 70,000 AF in 2006. Water levels have recovered after flow years of over 40,000 AF in 2000, 2006 and 2014.
- The estimated water balance for the Bingham Cienega Preserve to the Pinal County Line indicates a net deficit of over 350 AF/yr. The most variable input is streamflow recharge and it has influenced the fluctuation in shallow alluvial water levels on and near the Preserve.

- The estimated water balance for the A-7 area indicates a net deficit of over 300 AF/yr. The most variable input is streamflow recharge and it has influenced the fluctuation in alluvial water levels on the near the Preserve. However, pumping in the area for irrigated agriculture has had an impact on declines.

- Water quality is good for most water indicators in the Basin, including low Total Dissolved Solids (TDS), and a dominant calcium bicarbonate water.

- Most Bingham Cienega basin alluvial wells and the former spring and surface water have oxygen and hydrogen isotopic results indicating summer dominant precipitation recharge from from San Pedro streamflow and contributing side canyons. Tritium sampling indicated the former Bingham Cienega Spring water was relatively young, within 50 years.

Recommendations

The following recommendations outline needed actions to understand and help recover the water resources in the area.

- Continue groundwater level, stream flow and precipitation monitoring at the Bingham Cienega Preserve and A-7 area. Evaluate areas where data is lacking and implement measures to begin collecting data in these areas as feasible. Actual well pumping data is needed, and efforts could be made to reach out to local Bayless and Berkalew Ranch representatives to obtain the data.

- Collaborate with the federal government and others to purchase land with water rights and consider establishment of conservation easements to minimize additional groundwater pumping in the Watershed.

- Collaborate with the local agricultural groups, landowners and others to reduce groundwater pumping in the Watershed by use of more drought tolerant grasses and crops, and any other reductions in irrigation demands.

- Support additional precipitation, stream, spring and groundwater sample analyses for stable and radiogenic isotopes. In addition, promote analysis of major ion chemistry. These tracers assist in evaluation of the hydrologic connection between upper elevation precipitation, groundwater and surface water flows. Such tracers can also more accurately assess groundwater ages, flow paths, and groundwater mixing. Sampling of the Kelly Well and an A-7 well is needed as data are several years old.

- Explore various opportunities to enhance groundwater recharge with natural channel design techniques. The use of design techniques such as berms, natural-material dams and manipulation of flows in tributary washes could retain surface flow, promote vegetative growth and improve recharge.

- Initiate a public awareness campaign to educate citizens of the important connection between water and riparian areas to promote more water conservation throughout the area. This campaign should target exempt well owners, especially those in sensitive shallow groundwater areas.

- Update all ranch plans and the Preserves Management Plan every five to ten years to address changing conditions.

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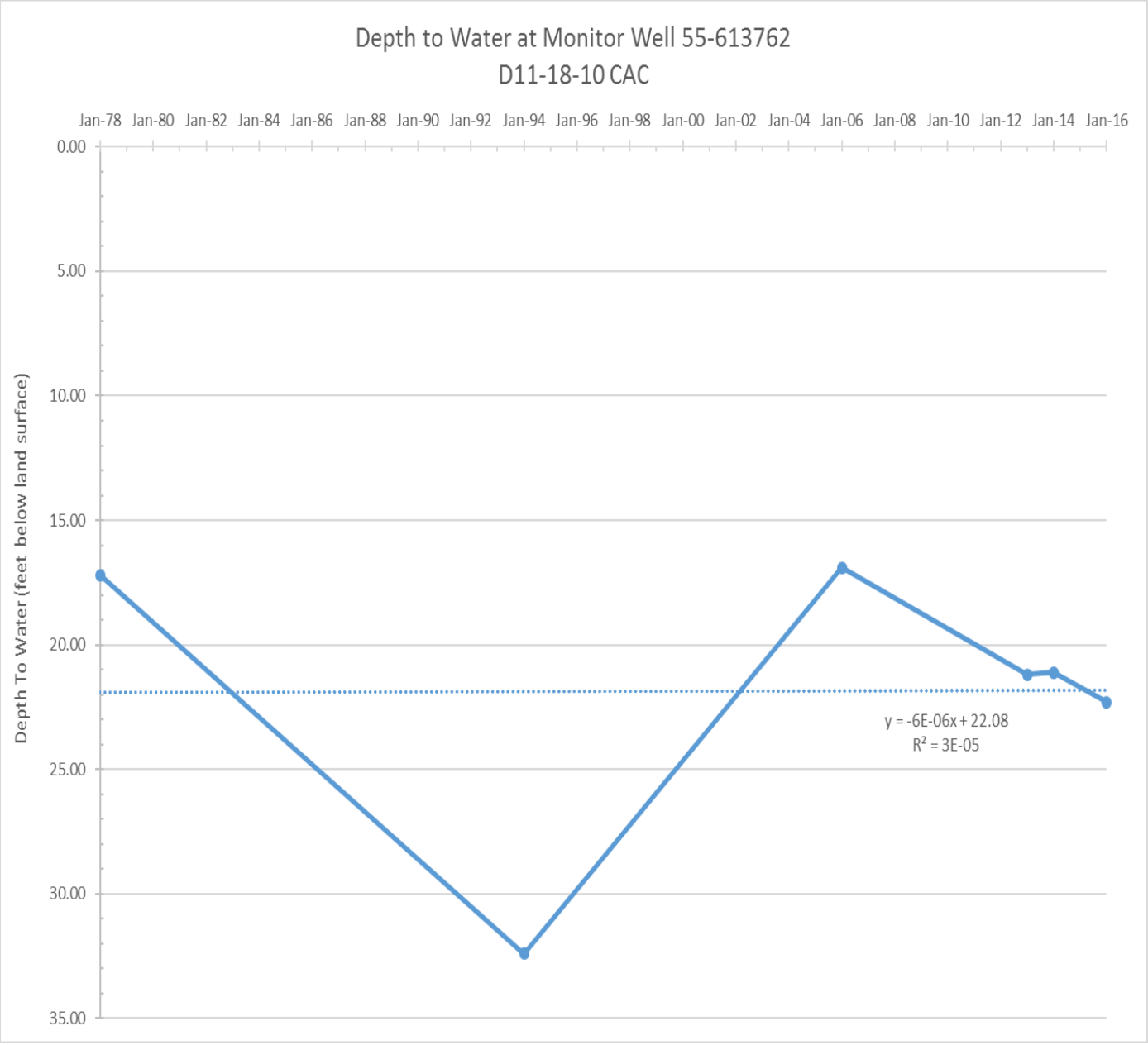
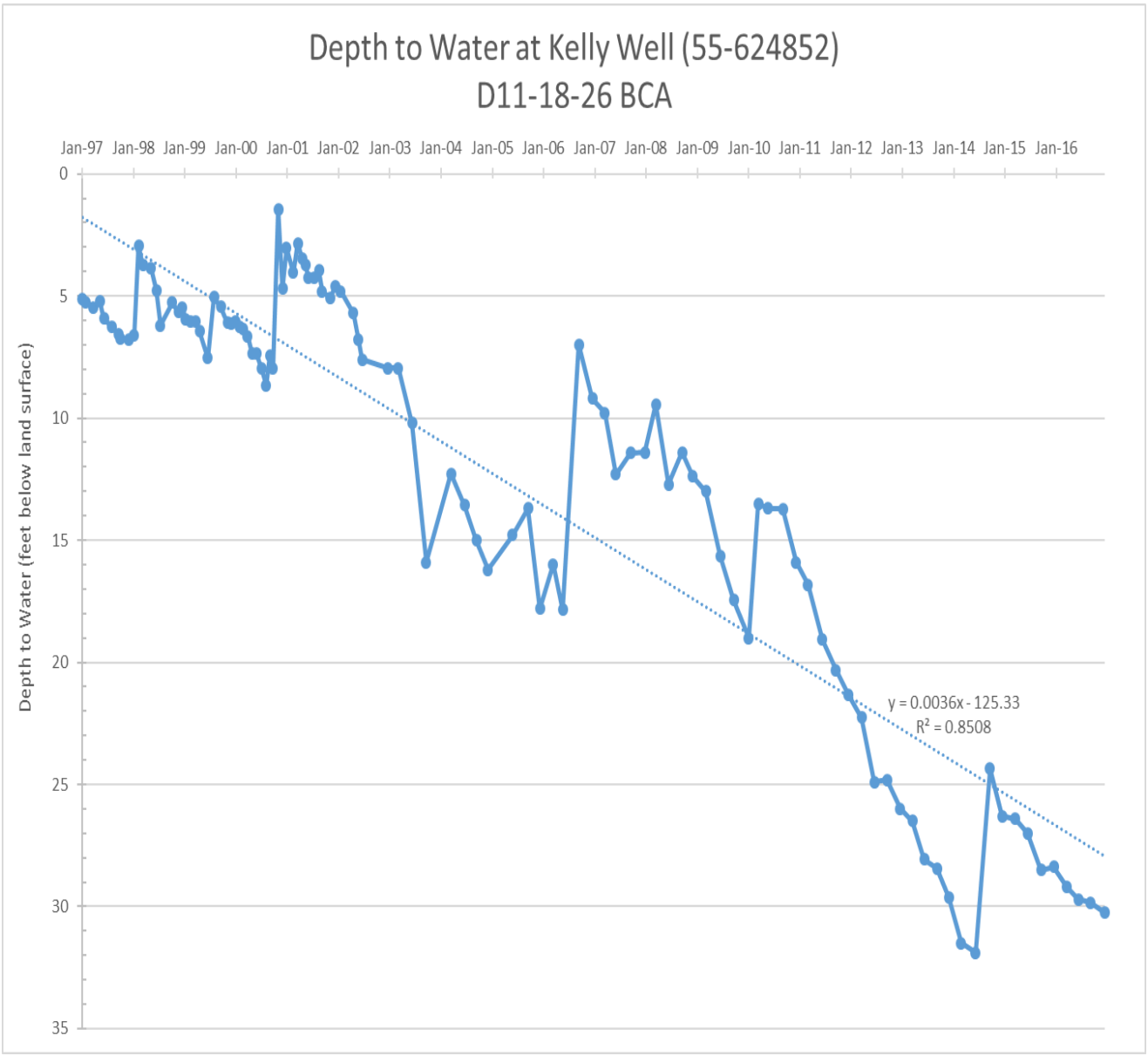
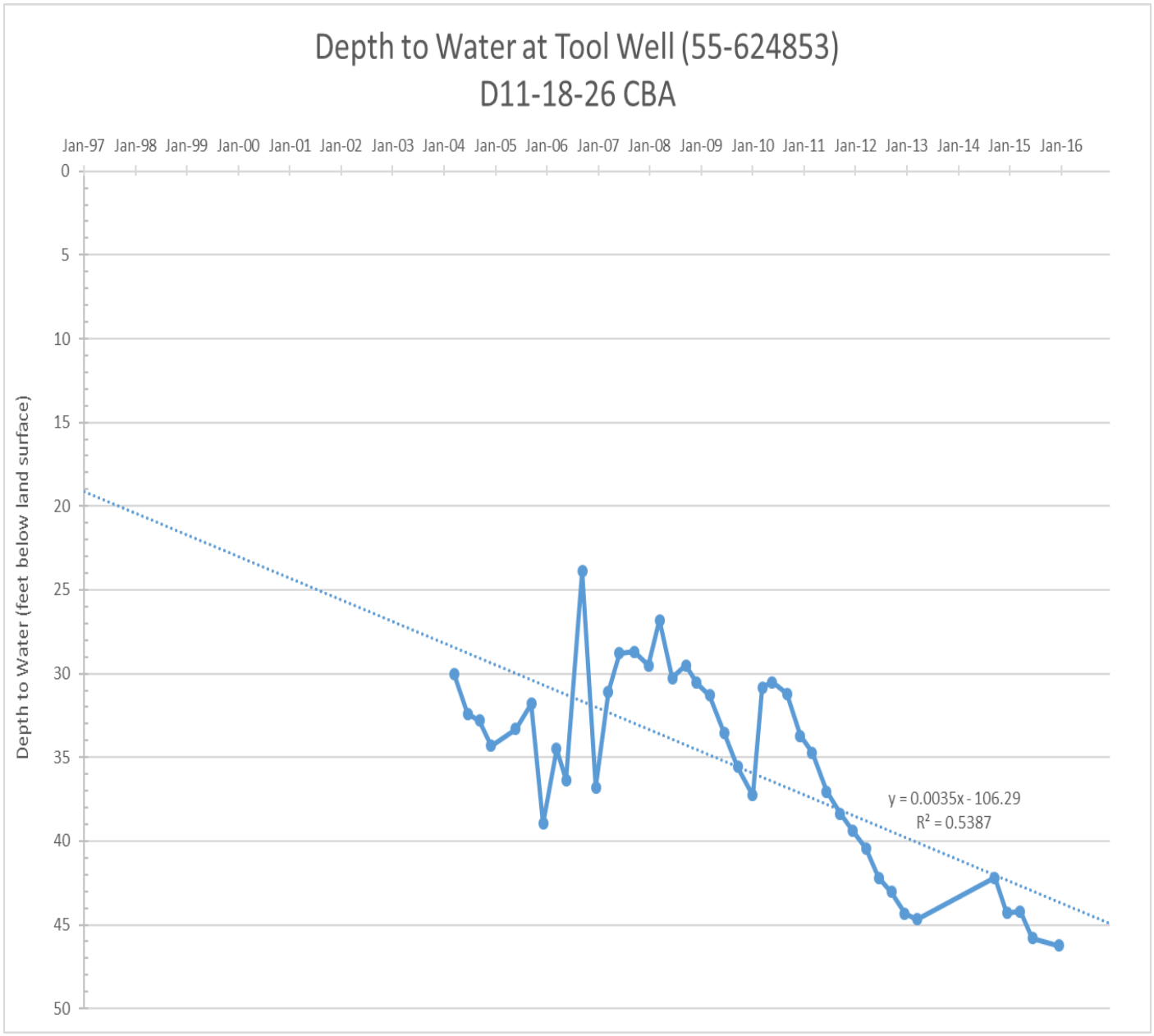
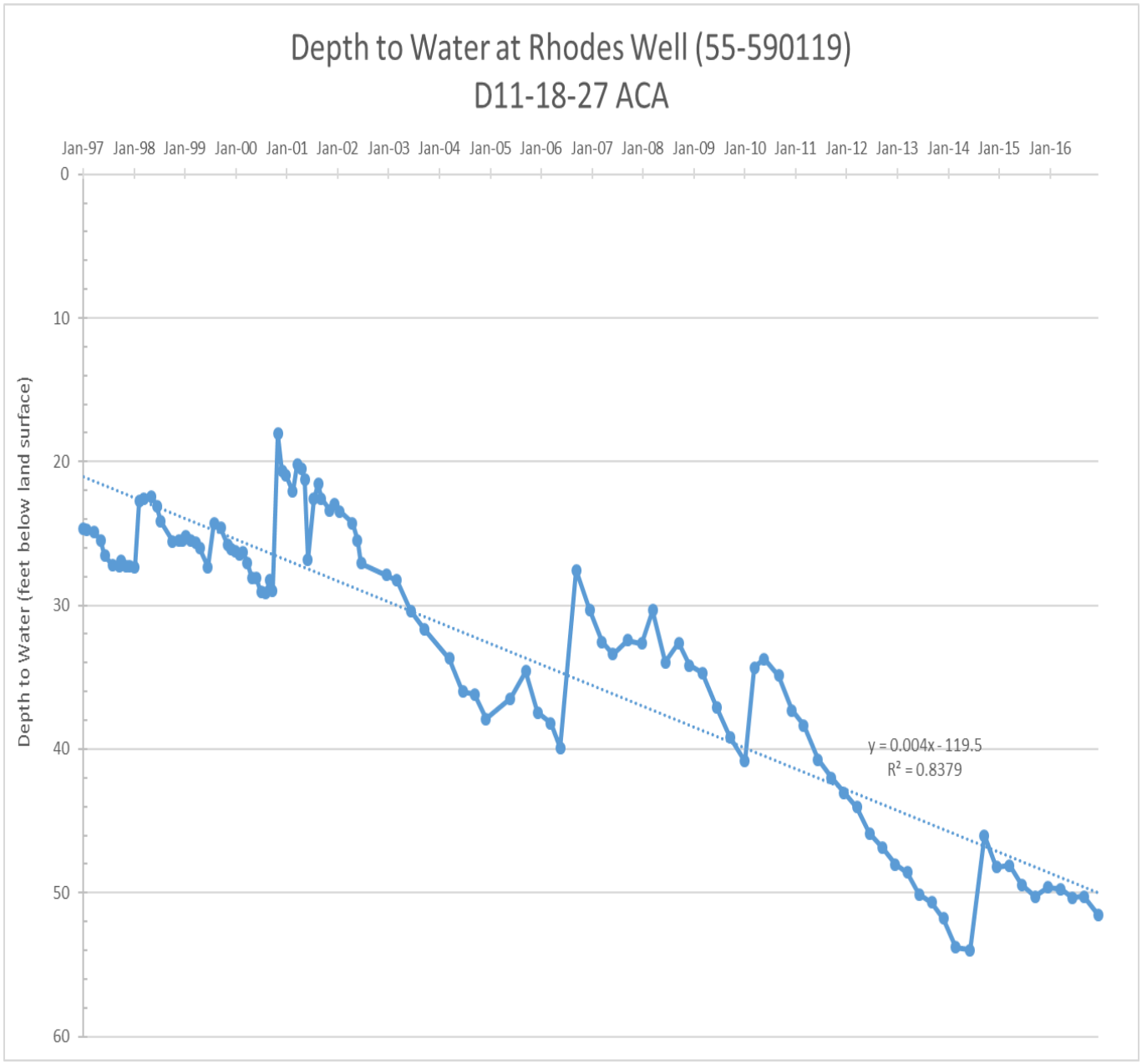
Appendix A: Detailed Hydrographs for Bingham Cienega/A7 Area

Diamond M Well

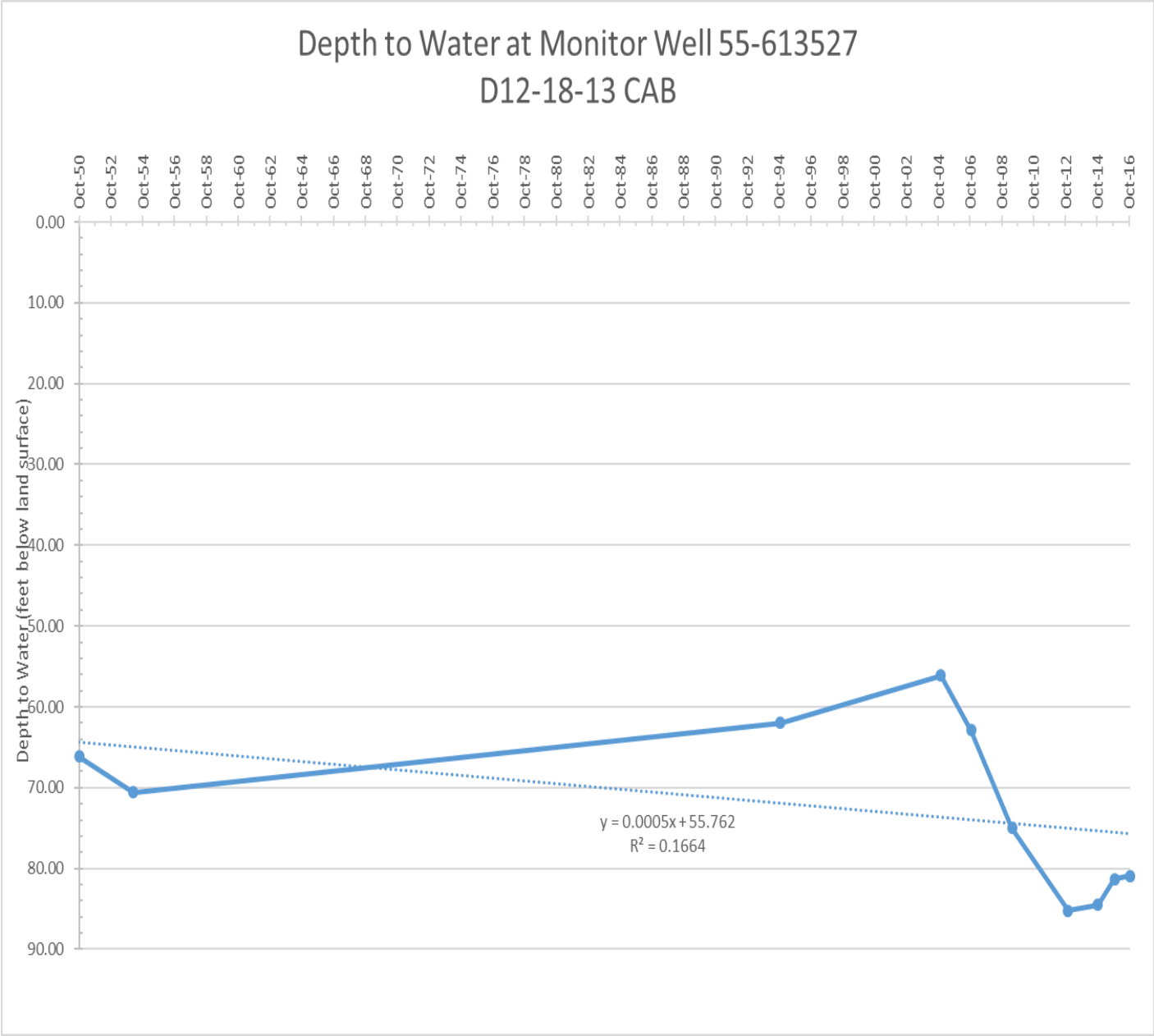



Depth to Water at Kelly Well (55-624852)
D11-18-26 BCA
Jan-97 Jan-98 Jan-99 Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05 Jan-06 Jan-07 Jan-08 Jan-09 Jan-10 Jan-11 Jan-12 Jan-13 Jan-14 Jan-15 Jan-16
0
5
10
15
20
25
30
35
Depth to Water (feet below land surface)
y = 0.0036x - 125.33
R² = 0.8508

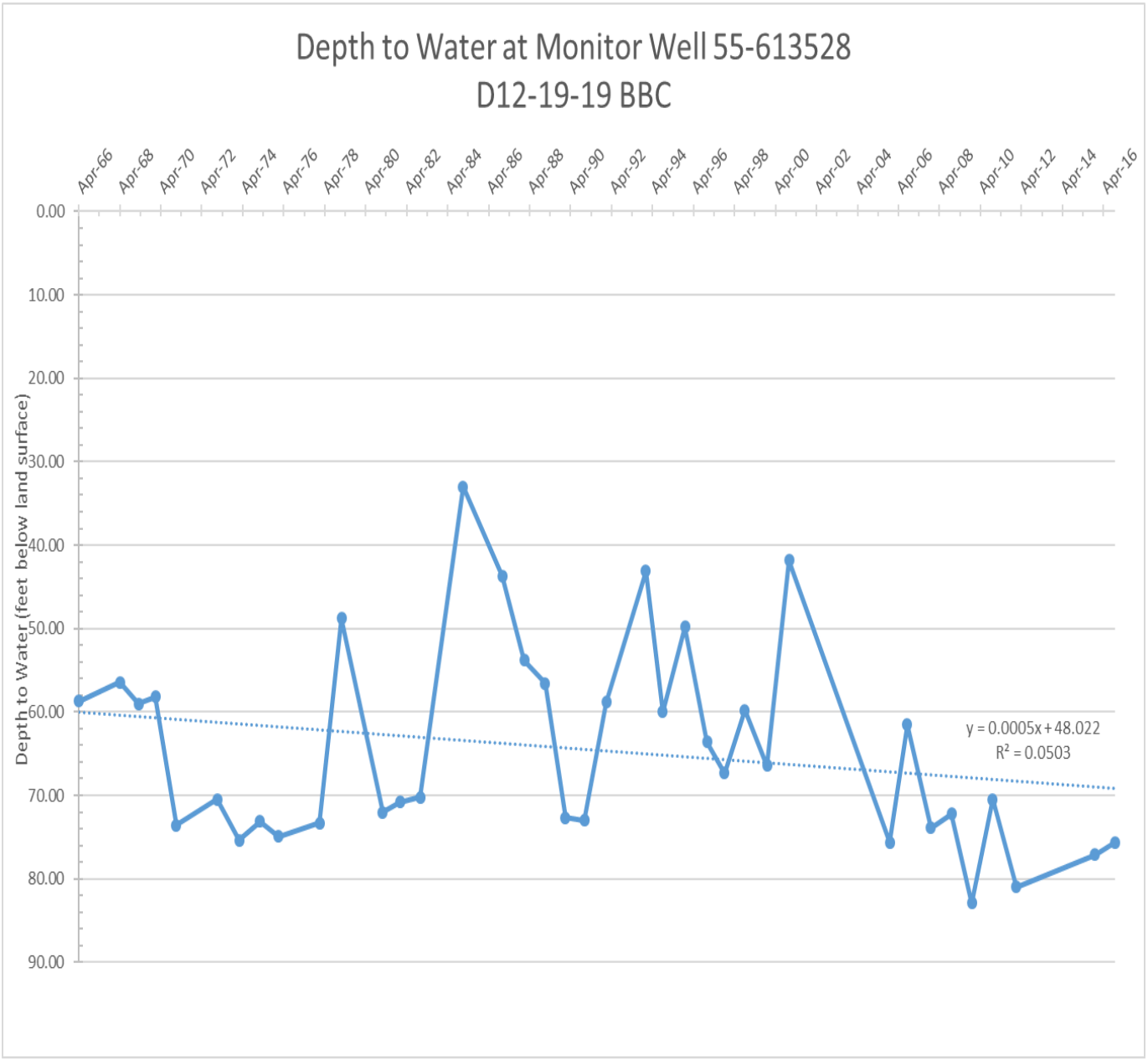

Depth to Water at Tool Well (55-624853)
D11-18-26 CBA
Jan-97 Jan-98 Jan-99 Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05 Jan-06 Jan-07 Jan-08 Jan-09 Jan-10 Jan-11 Jan-12 Jan-13 Jan-14 Jan-15 Jan-16
0
5
10
15
20
25
30
35
40
45
50
Depth to Water (feet below land surface)
y = 0.0035x - 106.29
R² = 0.5387


Depth to Water at Rhodes Well (55-590119)
D11-18-27 ACA
Jan-97 Jan-98 Jan-99 Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05 Jan-06 Jan-07 Jan-08 Jan-09 Jan-10 Jan-11 Jan-12 Jan-13 Jan-14 Jan-15 Jan-16
0
10
20
30
40
50
60
Depth to Water (feet below land surface)
y = 0.004x - 119.5
R² = 0.8379

A-7 # 1 Well


Depth to Water at Monitor Well 55-613527
D12-18-13 CAB
Depth to Water (feet below land surface)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Oct-50
Oct-52
Oct-54
Oct-56
Oct-58
Oct-60
Oct-62
Oct-64
Oct-66
Oct-68
Oct-70
Oct-72
Oct-74
Oct-76
Oct-78
Oct-80
Oct-82
Oct-84
Oct-86
Oct-88
Oct-90
Oct-92
Oct-94
Oct-96
Oct-98
Oct-00
Oct-02
Oct-04
Oct-06
Oct-08
Oct-10
Oct-12
Oct-14
Oct-16
y = 0.0005x + 55.762
R² = 0.1664

A-7 # 2 Well


Depth to Water at Monitor Well 55-613528
D12-19-19 BBC
Depth to Water (feet below land surface)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Apr-66
Apr-68
Apr-70
Apr-72
Apr-74
Apr-76
Apr-78
Apr-80
Apr-82
Apr-84
Apr-86
Apr-88
Apr-90
Apr-92
Apr-94
Apr-96
Apr-98
Apr-00
Apr-02
Apr-04
Apr-06
Apr-08
Apr-10
Apr-12
Apr-14
Apr-16
y = 0.0005x + 48.022
R² = 0.0503