

SURVEY REPORT

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Surveys were completed by the National Park Service (NPS) from April 23, 2007 to April 26, 2007 along Rincon Creek in Saguaro National Park (SAGU). The objectives of the surveys were 1) to get measuring point (MP) elevations for the seven RC-Wells (RC-1 through RC-7); 2) to relate Rincon Creek staff gage elevations at Pool A and Pool C to RC-Well MP elevations; and 3) to obtain spatial (latitude/longitude) and elevation (NAVD 88)¹ data for Pool A and C and the RC-Wells (**Figure 1**).

Two types of surveys were completed. First, auto-level surveys (discussed in *Section 1* below) were completed which: 1) established MP elevations for each RC-Well, 2) linked elevations between RC-Well Transect #1 (RC-1, RC-2, and RC-3) and Pool A; and 3) linked elevations between RC-Well Transect #2 (RC-4, RC-5, RC-6, and the Lunt Well) and Pool C. Second, a global positioning system (GPS) survey (discussed in *Section 2* below) was conducted which provided spatial and NAVD 88 elevation data for Pool A, Pool C, RC-Well Transects #1 and #2, and RC-7. Additional GPS data were collected along the study reach and can be found in *Section 4* of the Survey folder.

Water year folders containing water level data for Pool A (Station #320745110365701), Pool C, and the RC-Wells² refer to this Survey Report for elevation data. The elevations reported in this document replace previous RC-Well elevations surveyed by Hawkeye Land Surveying, Co. and hand measured by Haley and Aldrich, Inc. (*Section 4* of the Survey folder).

1. Auto Level Surveys

Auto level surveys were conducted with an SDL 30 Sokkia (SN# 7155) on April 23rd, 25th, and 26th, 2007. A peg test was performed on April 23, 2007, prior to the first survey, the resultant collimation error (0.000128 feet) was within manufacturer's specifications and USGS guidelines for level surveys. *Section 3* of the Survey Folder contains all field forms for the peg test and auto level surveys. Auto level survey elevations were measured to 0.001 foot and are reported to 0.01 foot using standard rounding.

¹ The North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum established for vertical control surveying in the United States of America based upon the General Adjustment of the North American Datum of 1988.

² RC-1 Station #320745110370101; RC-2 Station #320743110370001; RC-3 Station #320741110370001. Pool C and RC-4 through RC-7 are not continuous gaging stations and do not have station numbers.



Project Location Map: April 2007 Survey

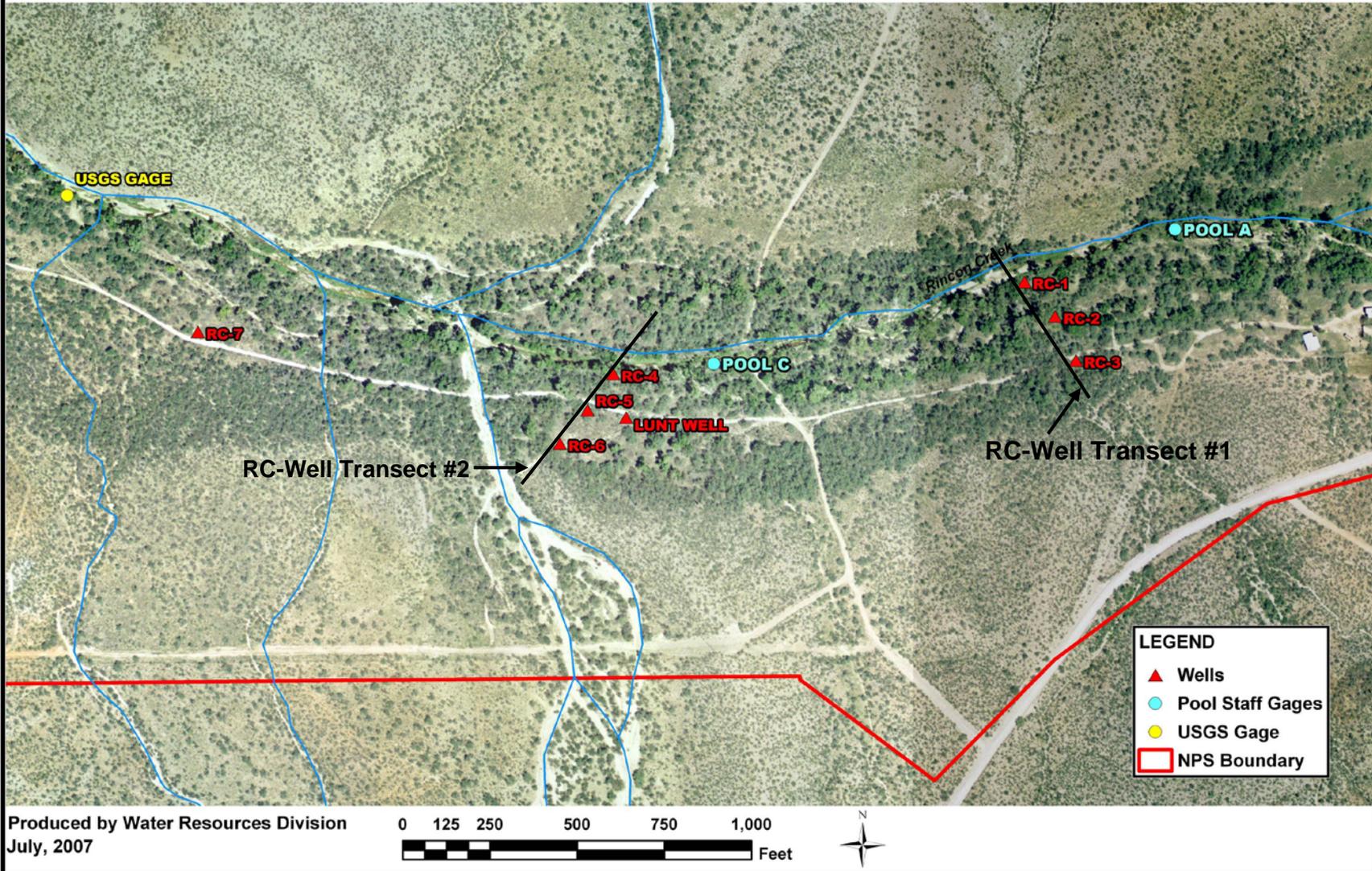


Figure 1: Survey Location Map

A. RC-Wells:

On April 23, 2007 three surveys were performed to obtain relative elevations for each RC-Well for the top of steel casing³(TOC/Steel), the measuring point on the top of the PVC casing (TOC/MP), and the benchmark (BM). The first survey included RC-Well Transect #1, the second survey included RC-Well Transect #2, and the third survey was of RC-7. A relative base elevation of 10.000 feet was input for each survey and closure errors ranged from 0.000 to -0.001 feet. See **Figure 2** for a photo and sketch of these survey points and **Table 1** for the surveyed elevations.

Table 1

Site: SAGU - Rincon Creek RC-Wells					
Date: 4/23/2007					
Closure Error: 0.000 to -0.001					
RC-Wells Transect #1: RC-1, RC-2, and RC-3		RC-Wells Transect #2: RC-4, RC-5, RC-6, and Lunt Well		RC-7	
Survey Location	Relative Elevation (in feet)	Survey Location	Relative Elevation (in feet)	Survey Location	Relative Elevation (in feet)
RC-1 BM	7.48	RC-4 BM	7.23	RC-7 BM	10.00
RC-1 TOC / MP	9.88	RC-4 TOC / MP	9.80	RC-7 TOC / MP	12.48
RC-1 TOC / Steel	10.74	RC-4 TOC / Steel	9.99	RC-7 TOC / Steel	12.71
RC-2 BM	10.00	RC-5 BM	10.00		
RC-2 TOC / MP	11.87	RC-5 TOC / MP	11.83		
RC-2 TOC / Steel	12.42	RC-5 TOC / Steel	12.23		
RC-3 BM	14.22	RC-6 BM	10.56		
RC-3 TOC / MP	16.09	RC-6 TOC / MP	13.18		
RC-3 TOC / Steel	16.32	RC-6 TOC / Steel	13.44		
		Lunt Well MP	11.98		
10.000 - entered as relative base elevation for each survey					

B. Pool A and RC-Well Transect #1:

On April 25, 2007 an auto level survey was performed to link Pool A gage datum⁴ to RC-Well Transect #1 elevations. Reference marks (RM-1, RM-2, and RM-3) and staff gages (OVS-1 and OVS-2)⁵ at Pool A were surveyed first and then the Pool A base⁶ (the ground rod) was used as a turning point to a setup approximately 200 feet downstream to survey RC-1. All three survey points on RC-1 were surveyed, closure errors ranged between 0.000 and -0.001 feet (see **Table 2** for surveyed elevations).

³ The top of steel casing was surveyed because it was the only point surveyed during the Hawkeye survey of the RC-Wells. It is not considered an accurate survey point due to the large and uneven surface area of the top of steel casing. It is unknown what exact point on the top of steel was surveyed by Hawkeye. The center point was surveyed during the April, 2007 surveys.

⁴ Gage datum is the elevation relative to 0.000 on the staff gage, in which all water levels are based. See Pool A and Pool C Water Year folders for additional survey information.

⁵ Survey points on the OVS's (outer vertical staff gages) at Pool A and Pool C are from the top of the staff plate or bolts installed on the staff plate for elevation control.

⁶ The base is the reference mark on which all reference mark elevations are based (it is considered the most stable).

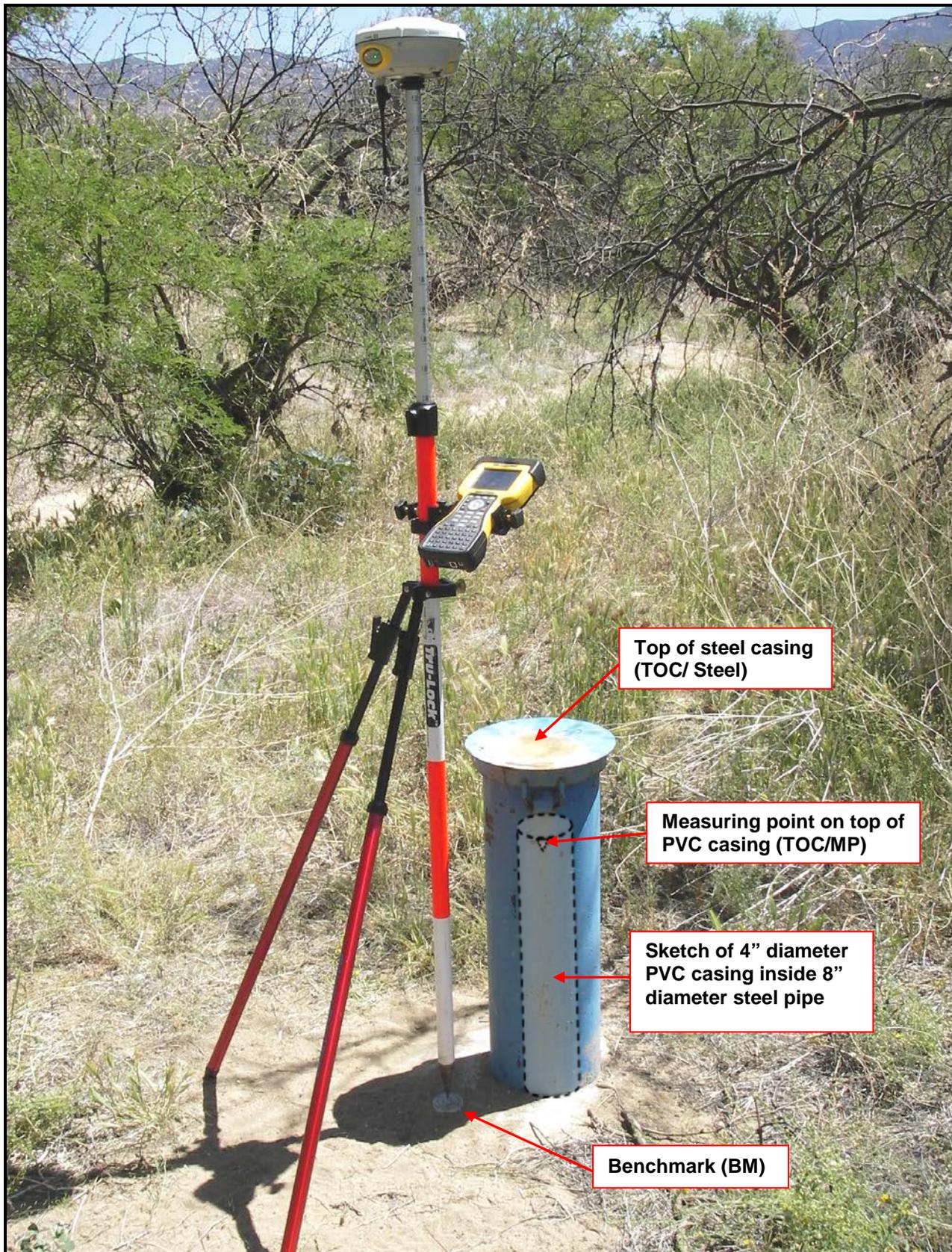


Figure 2: Survey setup and sketch of RC-5 (Tim Smith, April 26, 2007).

Table 2

Site:	SAGU - Rincon Creek Pool A and RC-1
Date:	4/25/2007
Closure Error:	0.000 to -0.001 feet
Survey Location	Pool A Gage Datum Elevation (in feet)
Pool A: Ground Rod	9.33
Pool A: RM-1	6.61
Pool A: RM-2	4.96
Pool A: RM-3	5.62
Pool A: OVS-1	3.09
Pool A: OVS-2	5.50
RC-1 BM	3.75
RC-1 TOC/MP	6.15
RC-1 TOC / Steel	7.01
9.33 = entered as base elevation relative to gage datum (from annual surveys at Pool A; see Pool A WY folders for annual survey data)	

Since RC-1 was surveyed relative to Pool A gage datum, elevations for RC-2, and RC-3 from **Table 1** could be calculated to Pool A gage datum as well. A correction of -3.73 feet (calculated in **Table 3**) was applied to RC-2 and RC-3 elevations based on the differences between the RC-1 relative surveyed elevations (**Table 1**) and the Pool A gage datum surveyed elevations (**Table 2**). Calculated elevations for RC-2 and RC-3 based on Pool A gage datum are shown in **Table 4**.

Table 3

	Pool A gage datum elevation from Table 2		Relative elevation from Table 1		Difference between Pool A gage datum elevation (Table 2) and relative elevation (Table 1)
RC-1 BM	3.75	-	7.48	=	-3.73
RC-1 TOC/MP	6.15	-	9.88	=	-3.73
RC-1 TOC / Steel	7.01	-	10.74	=	-3.73
average correction				=	-3.73

Table 4

Location	Calculated RC-Well elevations based on Pool A Gage Datum (using elevations from Table 1 and the correction calculated in Table 3)
RC-2 BM	6.27
RC-2 TOC / MP	8.14
RC-2 TOC / Steel	8.69
RC-3 BM	10.49
RC-3 TOC / MP	12.36
RC-3 TOC / Steel	12.59

C. Pool C and RC-Well Transect #2:

On April 26, 2007 a survey was performed to link Pool C gage datum to RC-Well Transect #2 elevations. Reference marks (RM-1, RM-2, RM-3, and RM-4) and staff gages (OVS-1 and OVS-2) at Pool C were surveyed first and then Pool C RM-4 was used as a turning point to setup downstream to survey RC-4. All three survey points on RC-4 were surveyed, closure errors ranged between 0.000 and -0.001 feet (see **Table 5** for surveyed elevations).

Table 5

Site:	SAGU - Rincon Creek Pool C, RC-4, RC-5, RC-6, and Lunt Well
Date:	4/26/2007
Closure Error:	0.000 to -0.001 feet
Survey Location	Gage Datum Elevations (in feet)
Pool C: RM-1	13.05
Pool C: RM-2	9.89
Pool C: RM-3	5.53
Pool C: RM-4	4.09
Pool C: OVS-1 (top of metal)	3.34
Pool C: OVS-2 (bolt) ¹	4.12
RC-4 BM	4.80
RC-4 TOC/MP	7.37
RC-4 TOC / Steel	7.55
13.050 = entered as base elevation relative to gage datum (from annual surveys at Pool C; see Pool C WY folders for annual survey data)	

Since RC-4 was surveyed relative to Pool C gage datum, elevations for RC-5, RC-6, and the Lunt Well from **Table 1** could be calculated to Pool C gage datum as well. A correction of -2.43 feet (calculated in **Table 6**) was applied to RC-5, RC-6, and the Lunt Well elevations based on the differences between RC-4 relative surveyed elevations (**Table 1**) and Pool C gage datum surveyed elevations (**Table 5**). Calculated elevations for RC-4, RC-5, and the Lunt Well based on Pool C gage datum are shown in **Table 7**.

Table 6

	Pool C gage datum elevation from Table 5		Relative elevation from Table 1		Difference between Pool C gage datum elevation (Table 5) and relative elevation (Table 1)
RC-4 BM	4.80	-	7.23	=	-2.43
RC-4 TOC/MP	7.37	-	9.80	=	-2.43
RC-4 TOC / Steel	7.55	-	9.99	=	-2.44
average correction				=	-2.43

Table 7

Location	Calculated Well elevations based on Pool C Gage Datum (using elevations from Table 1 and the correction calculated in Table 6)
RC-5 BM	7.57
RC-5 TOC / MP	9.40
RC-5 TOC / Steel	9.80
RC-6 BM	8.13
RC-6 TOC / MP	10.75
RC-6 TOC / Steel	11.01
Lunt Well MP	9.55

2. GPS Survey:

Elevation and spatial data was collected from a survey conducted by Tim Smith (NPS GPS Program Coordinator) on April 24th – 26th, 2007. A Trimble® R8 GNSS System rented from Vectors, Inc. Denver, CO was used to perform the survey. All points were established with carrier-phase GPS to an accuracy of better than 2 centimeters (cm) or 0.07 feet horizontal and 3 cm (or 0.1 foot)⁷ vertical. NGS OPUS program was used to provide control for the survey. Conventional dual-frequency GPS RTK and Static survey techniques were used. NAD83 (CORS96), UTM, zone 12 was used for horizontal coordinates and NAVD 88, Geoid03 were used for the vertical coordinates. See the *List of Abbreviations* and *List of Definitions / Explanation of Terms* in *Section 1* of the Survey Folder for more information on the GPS terminology used.

Static surveys were conducted on the RC-3 BM, RC-6 BM, and RC-7 BM. See **Table 9** for NAVD 88 elevations and spatial information (and *Section 2* of the Survey Folder). All NAVD 88 elevations were measured to 0.001 meters and are reported to 0.01 foot⁸. Northing and Easting were measured to 0.001 meter and are reported to 0.01 foot. Latitude and Longitude were measured to the 0.00001 meter and are reported to the 0.01 foot. Standard rounding and the U.S. Survey foot conversion of 1 meter to 39.37/12 foot was used.

Table 9

Survey Point	Northing	Easting	Elevation (feet)	Latitude	Longitude
RC-3 BM	3554722.52	536156.35	3166.00	32d07'41.92N	110d37'00.04W
RC-6 BM	3554649.61	535705.31	3153.75	32d07'39.61N	110d37'17.27W
RC-7 BM	3554747.85	535389.26	3144.93	32d07'42.83N	110d37'29.32W

Since the NAVD 88 elevation of the RC-3 BM was surveyed to be 3,166.00 feet (**Table 9**), NAVD 88 elevations of the remainder of Transect #1 and Pool A could be calculated from the Pool A gage datum elevations in **Tables 2** and **4**. Calculated NAVD 88 elevations are shown in **Table 10**. Elevation of gage datum (0.00 feet on the staff plate at Pool A) was calculated to be 3,155.51 feet.⁹

⁷ 3 cm = 0.098425 feet

⁸ NAVD 88 elevations are reported to the 0.01 foot because the survey accuracy is “better than 0.1 feet”.

⁹ By subtracting the Pool A gage datum elevations in Table 10 from the corresponding NAVD 88 elevations you get a Pool A gage datum (0.00 feet) elevation of 3,155.51 feet.

Table 10

Survey Location	Pool A Gage Datum Elevation (in feet) from Tables 2 and 4	Calculated Elevations (NAVD 88 in feet) (based on RC-3 BM elevation from Table 9)
Pool A: Ground Rod	9.33	3164.84
Pool A: RM-1	6.61	3162.12
Pool A: RM-2	4.96	3160.47
Pool A: RM-3	5.62	3161.13
Pool A: OVS-1	3.09	3158.60
Pool A: OVS-2	5.50	3161.01
RC-1 BM	3.75	3159.26
RC-1 TOC/MP	6.15	3161.66
RC-1 TOC / Steel	7.01	3162.52
RC-2 BM	6.27	3161.78
RC-2 TOC / MP	8.14	3163.65
RC-2 TOC / Steel	8.69	3164.20
RC-3 BM	10.49	3166.00
RC-3 TOC / MP	12.36	3167.87
RC-3 TOC / Steel	12.59	3168.10
9.331 = entered as base elevation relative to gage datum (from annual surveys at Pool A; see Pool A WY folders for annual survey data)		
3166.00 = entered as GPS surveyed elevation (from Table 9)		

Since the NAVD 88 elevation of the RC-6 BM was surveyed to be 3,153.75 feet (**Table 9**), NAVD 88 elevations of the remainder of Transect #2 and Pool C could be calculated from the Pool C Gage Datum elevations from **Tables 5** and **7**. Calculated NAVD 88 elevations are shown in **Table 11**. Elevation of gage datum (0.00 feet on the staff plate at Pool C) was calculated to be 3,145.62 feet.¹⁰

Table 11

Survey Location	Pool C Gage Datum Elevation (in feet) from Tables 5 and 7	Calculated Elevations (NAVD 88 in feet) (based on RC-6 BM elevation from Table 9)
Pool C: RM-1	13.05	3158.67
Pool C: RM-2	9.89	3155.51
Pool C: RM-3	5.53	3151.15
Pool C: RM-4	4.09	3149.71
Pool C: OVS-1 (top of metal)	3.34	3148.96
Pool C: OVS-2 (bolt)	4.12	3149.74
RC-4 BM	4.80	3150.42
RC-4 TOC/MP	7.37	3152.99
RC-4 TOC / Steel	7.55	3153.17
RC-5 BM	7.57	3153.19
RC-5 TOC / MP	9.40	3155.02
RC-5 TOC / Steel	9.80	3155.42
RC-6 BM	8.13	3153.75
RC-6 TOC / MP	10.75	3156.37
RC-6 TOC / Steel	11.01	3156.63
Lunt Well MP	9.55	3155.17
13.050 = entered as base elevation relative to gage datum (from annual surveys at Pool C; see Pool C WY folders for annual survey data)		
3153.75 = entered as GPS surveyed elevation (from Table 9)		

¹⁰ By subtracting the Pool C gage datum elevations in Table 11 from the corresponding NAVD 88 elevations you get a Pool C gage datum (0.00 feet) elevation of 3,145.62 feet.

Finally, since the NAVD 88 elevation of the RC-7 BM was surveyed to be 3,144.93 feet (**Table 9**), NAVD 88 elevations of the remaining two survey points on RC-7 could be calculated from **Table 1**. Calculated NAVD 88 elevations are shown in **Table 12**.

Table 12

Survey Location	Relative Elevation (in feet) from Table 1	Calculated Elevations (NAVD 88 in feet) (based on RC-7 BM elevation from Table 9)
RC-7 BM	10.00	3144.93
RC-7 TOC / MP	12.48	3147.41
RC-7 TOC / Steel	12.71	3147.64
3144.93 = entered as GPS surveyed elevation (from Table 9)		

3. Summary:

Final NAVD 88 elevations are listed in Tables 10, 11, and 12 for survey points at Pool A, Pool C, and the RC-Wells. All NAVD 88 elevations are accurate to better than 0.1 feet¹¹ (GPS elevation accuracy); however, relative elevations within Table 10 (RC-Well Transect #1 and Pool A) are within 0.01 feet (auto-level elevation accuracy). The same goes for elevations within Table 11 and within Table 12. This enables well levels and surface water levels to be compared to each other with greater precision since all water level records are worked up to 0.01 feet. When comparing elevations between Pool A and C, or RC-Well Transects #1 and #2, or RC-7, the accuracy is within 0.1 feet (GPS elevation accuracy) since an auto-level survey was not performed to link these transects together.

¹¹ Reported to 0.01 feet