APPENDIX
10.5 Low Flow Study

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Low Flow Study of the Santa Ana River

Between the

Rialto Drain and the MWD Crossing

Submitted to:

John A. Claus

Director of Water Reclamation

Submitted by:

Thomas J. McGill, Ph.D

Vice President, Natural Resources

Michael Baker INTERNATIONAL

JN 131284

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INTRODUCTION

With the extended drought in California, limitations on State Water Project (SWP) supplies, the current overdraft of the Bunker Hill Basin, and compliance with SBX-7 (which requires urban water retailers to reduce per capita water demands by 20% by 2020), the City of San Bernardino Municipal Water Department (SBMWD) faces the challenge of satisfying its anticipated water demands through innovative solutions, independent of traditional imported water supplies. To meet this challenge, SBMWD commissioned a Recycled Water Planning Investigation Report to assess the feasibility of using recycled water to augment its water supply.

SBMWD owns and operates the San Bernardino Water Reclamation Plant (SBWRP). The SBMWD and the City of Colton are members of a Joint Powers Agency that owns and operates the Rapid Infiltration and Extraction (RIX) Facility. Currently, the SBWRP treats approximately 22 million gallons per day (mgd) of raw wastewater from the City of San Bernardino, the City of Loma Linda, and the East Valley Water District to secondary standards. The SBWRP conveys this secondary-treated effluent to the RIX facility for tertiary treatment and then discharges it to the Santa Ana River (SAR). The City of Colton conveys an additional 5.3 mgd of secondary-treated effluent to the RIX facility for tertiary treatment and discharge to the river. RIX currently discharges approximately 31.3 mgd to the Santa Ana River. Exhibit 1, *Regional Location*, shows the location of the various wastewater discharge facility within the general area of the project site.

SBMWD filed a Petition for Change with the State Water Resources Control Board (SWRCB) on April 22, 2010 (Petition revised June 7, 2010), pursuant to Water Code Section 1211 (and in accordance with Water Code Sections 461, 13500 e*t seq*. and 13575 *et seq*.,) to decrease current recycled water discharge from the RIX facility to the Santa Ana River from approximately 35.7 mgd (55.2 cfs) to approximately 11.9 mgd (18.4 cfs). This would initially provide approximately 23.8 mgd (44.2 cfs) of recycled water for reuse.

This petition was protested by several parties, including the U.S. Fish and Wildlife Service (USFWS) in a July 29, 2010 letter. The letter stated that the Santa Ana sucker (SASU) is dependent on the discharges from the RIX facility to help maintain suitable habitat for spawning and foraging and that the proposed decrease in outflow would reduce the available habitat for SASU in the SAR. In response to the concerns raised by USFWS, SBMWD prepared several technical studies to assess the potential project impacts to SASU habitat from reductions in discharges from the RIX facility. This reports presents the results from each of these studies, provides an analysis of potential impacts to SASU habitat and provides recommendations for a phased approach for reducing discharges that will avoid and minimize impacts to SASU habitat.

PROJECT DESCRIPTION

The Clean Water Factory (CWF) project will treat effluent from the San Bernardino Water Reclamation Plant to a quality approved for recharge as set by the California Division of Drinking Water (DDW) and the Santa Ana Regional Water Quality Control Board (Regional Board). The treated effluent will be conveyed

to the Waterman Basin and the East Twin Creek Spreading Grounds. Recycled water spread at these facilities will artificially recharge the Bunker Hill Groundwater Basin and, more specifically, the Bunker Hill A Management Zone, as described in the Water Quality Control Plan for the SAR Watershed. The project also may divert this water west of the RIX Facility to the Chino Basin and/or east of the SBWRP to the Redlands Basins. The project will also treat a side stream of SBWRP effluent to a quality approved for direct irrigation use and convey the tertiary treated recycled water to customers that can benefit from a non-potable water supply.

There are two primary components of the project for its implementation. The first aspect is the reduction in the amount of water that would be discharged from the RIX facility to the SAR, in million gallons per day (mgd) by phase, through the year 2035, as shown in Table 1 below. The phased reduction is conceptual, and may be modified through the Environmental Impact Report process and through consultation with regulatory agencies and other stakeholders. The reduction in discharge is anticipated to occur over five phases, based on the expected need for this water to be recharged over time. The reduction in discharge also has implications for the potential impacts to the federally-threatened SASU, due to changes in the depth and habitat characteristics of the SAR resulting from reduced discharge, which may affect the suitability of the SASU habitat and is addressed by this report.

Table 1: Proposed RIX Discharge Phased Reduction Scenarios[1]

	Baseline[2]	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Zero[3]
RIX	53.0	44.9	38.4	32.2	26.3	20.8	0
Rialto Drain	9.5						
Model SAR Input	62.5	54.4	47.9	41.7	35.8	30.3	9.5

cfs = cubic feet per second, SAR=Santa Ana River

Notes:

1. The Project assumes phased discharge reduction approach, with additional reductions in discharge occurring every five years.
2. For the model, baseline discharge was based on average RIX discharge measured on October 18-19, 2012. Average discharge was approximately 53 cfs. Annual RIX discharge has varied from 55.7 cfs in 2010 to 48.4 cfs in 2013.
3. The Zero scenario assumes a RIX shutdown, for instance for maintenance, in which case all discharge would come from the Rialto Drain, and a total flow volume of 9.5 cfs is used as a model assumption.

The second component of the project is the actual facilities improvements that would be necessary to accommodate the diversion of wastewater discharge from the RIX facility into the Bunker Hill Basin (via the SBWRP). These improvements would include the following: increased water treatment capabilities; pipes, pumps, and reservoirs needed for the conveyance system that would transport water from the SBWRP or RIX Facility to the Waterman Basin and the East Twin Creek Spreading Grounds, the Chino Basin, and/or Redlands Basins; pipelines and associated improvements needed to distribute recycled water to direct use customers; and improvements at the Waterman Basin and East Twin Creek Spreading Grounds,

and/or the Chino Basin or Redlands Recharge Basins (see Exhibit 1). Improvements to increase water treatment capabilities would generally occur within the boundaries of the existing SBWRP or RIX Facility plant site and are addressed through separate biological studies and are included in the CEQA documentation for the Clean Water Factory project.

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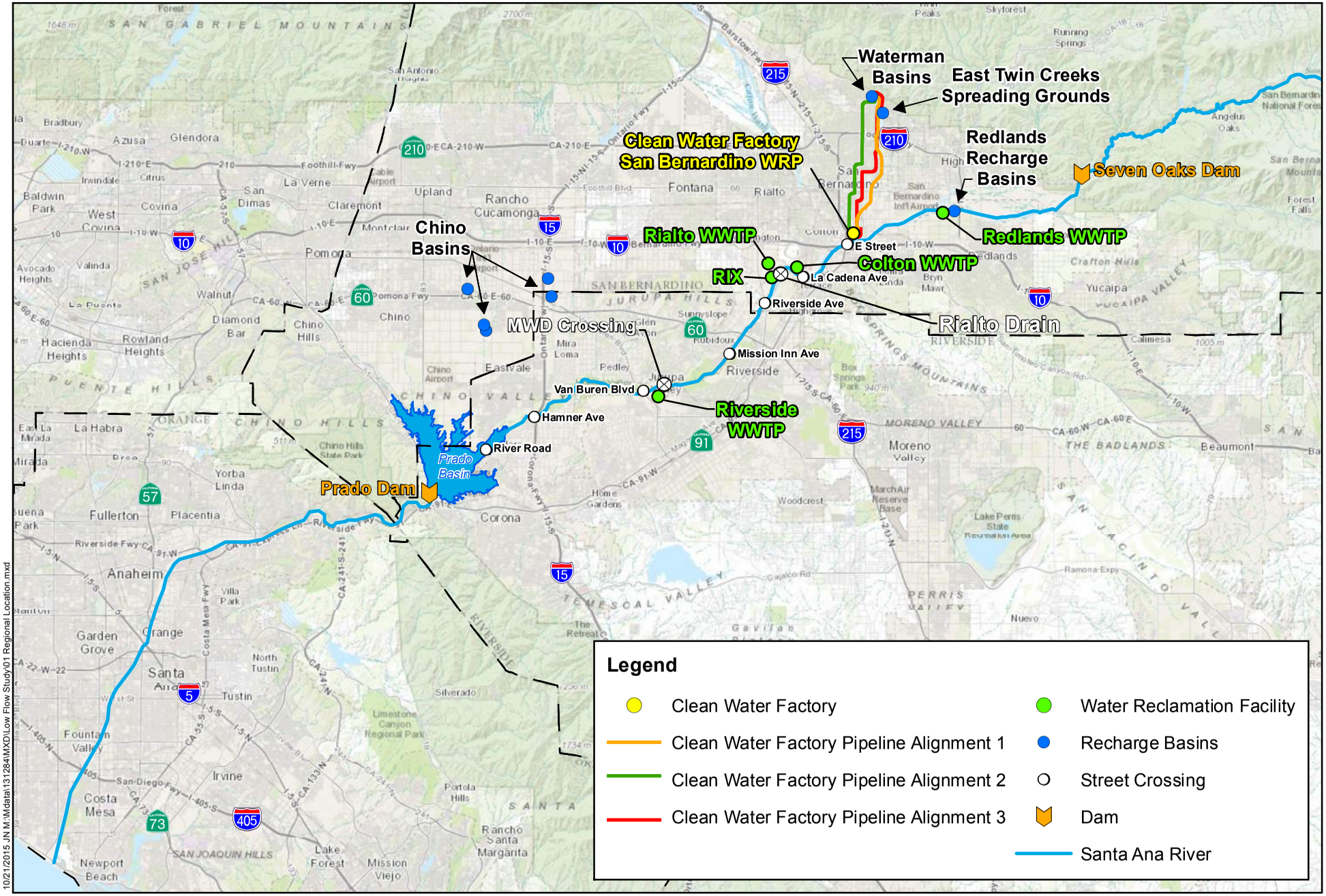

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LOW FLOW STUDY

Regional Location

Exhibit 1

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BACKGROUND

Reclaimed water from the RIX facility and treated wastewater discharged by the City of Rialto into the Rialto Drain are the primary sources of water in the middle reach of the SAR during dry-weather conditions. The RIX facility began discharging into the SAR in 1996, just downstream of the Rialto Drain. Since that time, flows in the river have been continuous from the Rialto Drain downstream to Prado Dam. The City of San Bernardino is currently evaluating the potential reuse of a portion of the water discharged from the RIX facility to the SAR. Implementation of the proposed project, the Clean Water Factory Project, would result in the phased reductions in discharges to the SAR from the RIX facility over time through the course of five phases.

Four technical studies were prepared to address the issue of reduced discharges to the SAR from the RIX facility and to determine if impacts could potentially occur to SASU habitat. Wildermuth Environmental, Inc. (WEI) analyzed historic (WEI 2013) and current (WEI 2014a) dry-weather discharges and depth relationship in the SAR from the Rialto Drain, just upstream of the RIX facility, down to the MWD Crossing, approximately 6 miles downstream of RIX. GEI Consultants (GEI) focused on this same stretch of the SAR and evaluated the potential impacts to SASU from the phased reduction in RIX flow, based on modeled changes in physical habitat in the Santa Ana River (GEI 2014). Michael Baker International (Michael Baker) then conducted a sediment transport modeling study of this stretch of the river to evaluate whether reduced flows from RIX would continue to be sufficient to remove sand deposited during high-deposition flood events, maintaining the suitability of SASU habitat within this area of the SAR (Michael Baker 2015). Using the combined results from these four studies, Michael Baker prepared an adaptive management approach that assessed the identified impacts, determined the significance of identified impacts and recommended biological monitoring measures and an adaptive management approach for protecting the SASU and its habitat in the SAR through recommended programs for low flow management, habitat management, and sediment management.

The present report provides a summary of each of the five technical studies: 1) *Historical Hydrologic Analysis of Dry-Weather Discharge Conditions in the Santa Ana River* (WEI 2013); 2) *Dry-Weather Discharge and Depth Analysis of the Santa Ana River from RIX to MWD Crossing* (WEI 2014a); 3) *In-Depth Analysis of the Santa Ana River HEC-RAS Hydraulic Modeling Result for the River Reach Between RIX and the MWD Crossing* (WEI 2014b); 4) *Evaluation of the Phased RIX Flow Reduction Plan on Santa Ana Suckers, Based on Predicted Changes in Physical Habitat in the Santa Ana River from the Rialto Drain to the MWD Crossing* (GEI 2014); and 5) *Clean Water Factory Rapid Infiltration/Extraction (RIX) Low-Flow Sediment Scour and Transport Modeling in the Santa Ana River*. The report also provides an analysis of the potential impacts as well as recommendations for avoiding and minimizing the identified impacts.

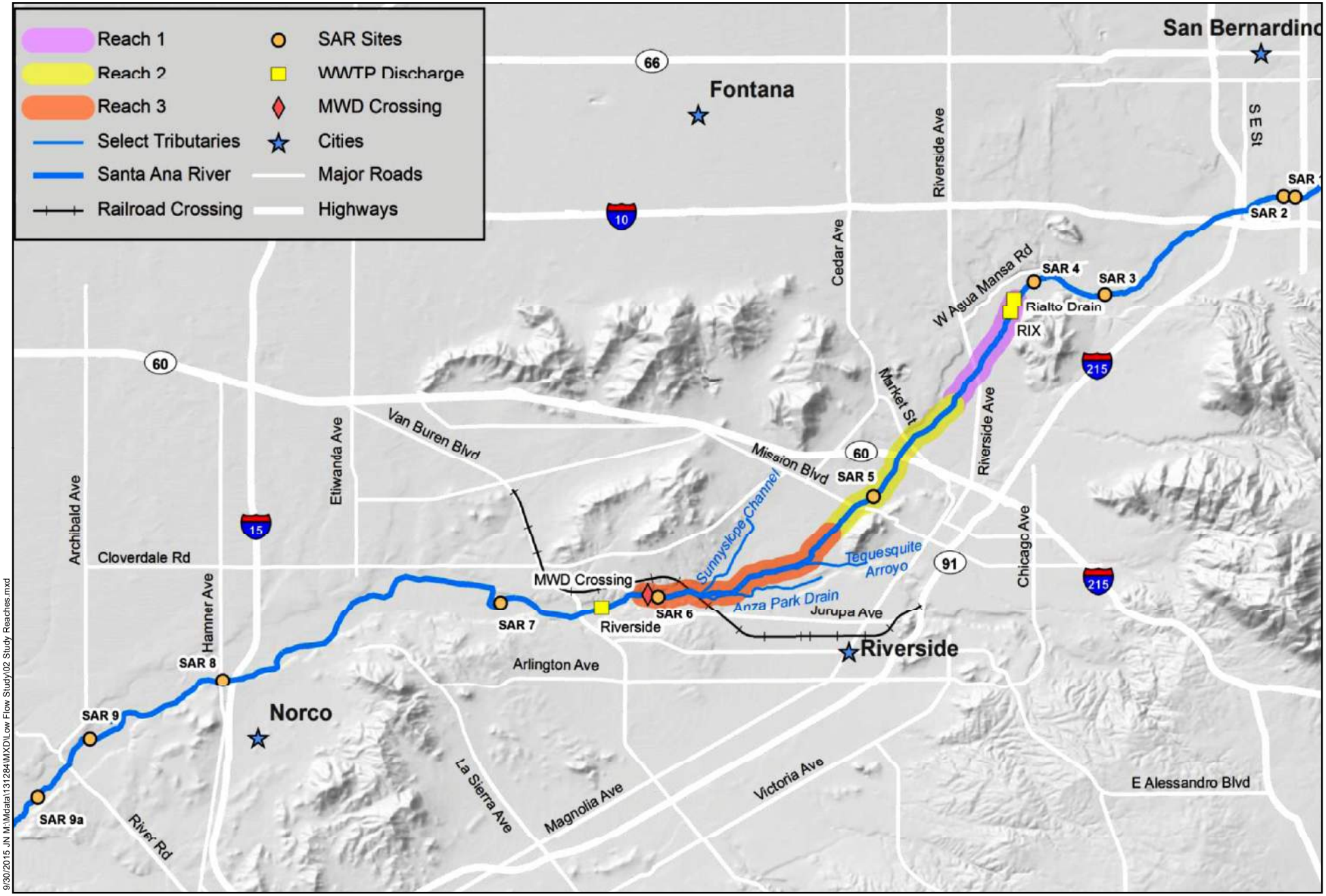
Hydrologic Analyses of the Santa Ana River

WEI prepared a historic hydrologic analysis of dry-weather discharge conditions in the Santa Ana River (WEI 2013), as well as a dry-weather discharge and depth analysis of the Santa Ana River from RIX to the MWD Crossing (WEI 2014a). The results for these two studies were developed to characterize the potential impacts of reducing flows from RIX on the SAR environment and hydrology. These data were also used to determine the availability of SASU habitat in the River and to assess potential impacts to SASU habitat from reduced discharges from RIX (GEI 2014). The following is a brief summary of each of WEI's studies. Appendices A and B provide a full text of each of the full studies.

Historical Hydrologic Analysis of Dry-Weather Discharge Conditions in the Santa Ana River (WEI 2013)

WEI conducted an historic hydrologic analysis of dry-weather conditions in the SAR from E Street in San Bernardino, CA to River Road in the City of Chino (WEI 2013). The study characterized the historic hydrology in terms or wet and dry reaches, dry-weather discharge variability, discharge top width and flow depth variability, and surface and groundwater interaction. Flow rates, river width and depth were estimated for 11 years between 1938 and 1977 (1938, '48, '52, '53, '54, '59, '62, '66, '67, '74, '77). The study identified six segments in the River between E Street and River Road (Segment 1 – E Street to RIX, Segment 2 – RIX to Riverside Avenue, Segment 3 – Riverside Avenue to Mission Boulevard, Segment 4 – Mission Boulevard to Van Buren Boulevard, Segment 5 – Van Buren Boulevard to Hamner Avenue, and Segment 6 – Hamner Avenue to River Road. Segments 2 through 4 correspond to the current study area (see Exhibit 2, *Study Reaches*). Table 2 provides the results for WEI's historic analysis and shows the average flow, average width, and average maximum depth for each segment. The analysis also identified several differences in hydrological characteristics between segments upstream and downstream of Mission Boulevard. Above Mission Boulevard, there were dry river segments in 7 of the 11 years analyzed. Below Mission Boulevard, river flows were continuous in all years and the river was typically much wider and consisted of a single channel. Above Mission Boulevard, the river is narrower, shifting, and often braided. River top width ranged between 0 and 180 feet upstream of Mission Boulevard while the river top width was between 0 to 240 feet downstream of Mission Boulevard. Depth also differed, ranging from 0 to 2 feet with most depths less than 0.5 foot upstream of Mission Boulevard while the river depth ranged from 0 to 3 feet with most depths less than 1 foot downstream of Mission Boulevard.

Historically (based on data from 1938 through 1977), the SAR was characterized in the study as dry more often, narrower, and shallower upstream of Mission Boulevard than downstream of Mission Boulevard. This historic analysis also suggests that Reach 3, encompassing the Riverside Narrows and portions downstream, has consistently provided enough water to support fish populations.



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Source: GEI Consultants

LOW FLOW STUDY

Study Reaches

Exhibit 2

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Table 1: Minimum, maximum, and average flow, width, and maximum depth for six stream segments of the Santa River for 11 years from 1938 to 1977. (Data from WEI 2013, Table from GEI 2014)

Segment	Average Flow (cfs)				Average Width (ft)				Maximum Depth (ft)			
	Min	Max	Ave	N	Min	Max	Ave	N	Min	Max	Ave	N
Above Riverside Narrows												
E St to RIX	1	42	19	11	0	90	46	6	0	0	0	2
RIX to Riverside (Reach 1)					0	66	25	9	0	1.6	0.7	9
Riverside to Mission (Reach 2)					0	28	10	9	0	1.8	0.6	8
Mission to Van Buren (Reach 3)					17	50	37	8	0.94	2.9	1.9	8
Below Riverside Narrows[1]												
Van Buren to Hamner	33	126	60	11	19	100	60	10	0.33	2.6	1.2	10
Hamner to River Rd					52	121	79	9	0.37	0.8	0.5	9

1 Riverside Narrows was defined as at MWD Crossing, which is located within Reach 3.

***Dry-Weather Discharge and Depth Analysis of the Santa Ana River from RIX to MWD Crossing* (WEI 2014a);** and ***In-depth Analysis of the Santa Ana River HEC-RAS Hydraulic Modeling Results for the River Reach between RIX and the MWD Crossing.* (WEI 2014b).**

WEI prepared a hydrologic analysis of the Santa Ana River from RIX to the MWD Crossing (WEI 2014a and 2014b). To estimate changes in depth and width of the river during various phases of reduction of discharges from RIX during dry-weather conditions, WEI developed a gradually-varied, steady-flow, Hydrologic Engineering Centers River Analysis System (HEC-RAS) hydraulic model. Details of the modeling are available in Appendix B.

Data used to develop the model included:

- River channel geometry data using Light Detection and Ranging (LiDAR) remote sensing flown on October 12, 2012;

- Discharge data collected at three sites in the study area at intervals prior to, during and after RIX shutdown to calibrate the model. Cross-sectional data was gathered at each of the three data collection points;
- An additional 24 cross-sections surveyed by WEI to better characterize the stream channel in Study Reach 1 (Rialto Drain to 0.6 mile below Riverside Avenue), an area of interest due to the greater number of SASU in this reach than farther downstream; and
- Discharge data for the SAR, for RIX, and for the City of Rialto's wastewater treatment plant.

Simulations from the resulting hydraulic model provided estimates of depth, wetted width, and average water column velocity at each of the transect locations between the Rialto Drain and the MWD Crossing. The SAR was characterized as a losing stream from the Rialto Drain downstream to Mission Boulevard, a gaining stream from Mission Boulevard downstream to the Railroad Crossing, and a losing stream from the Railroad Crossing downstream to the MWD Crossing (WEI 2014a).

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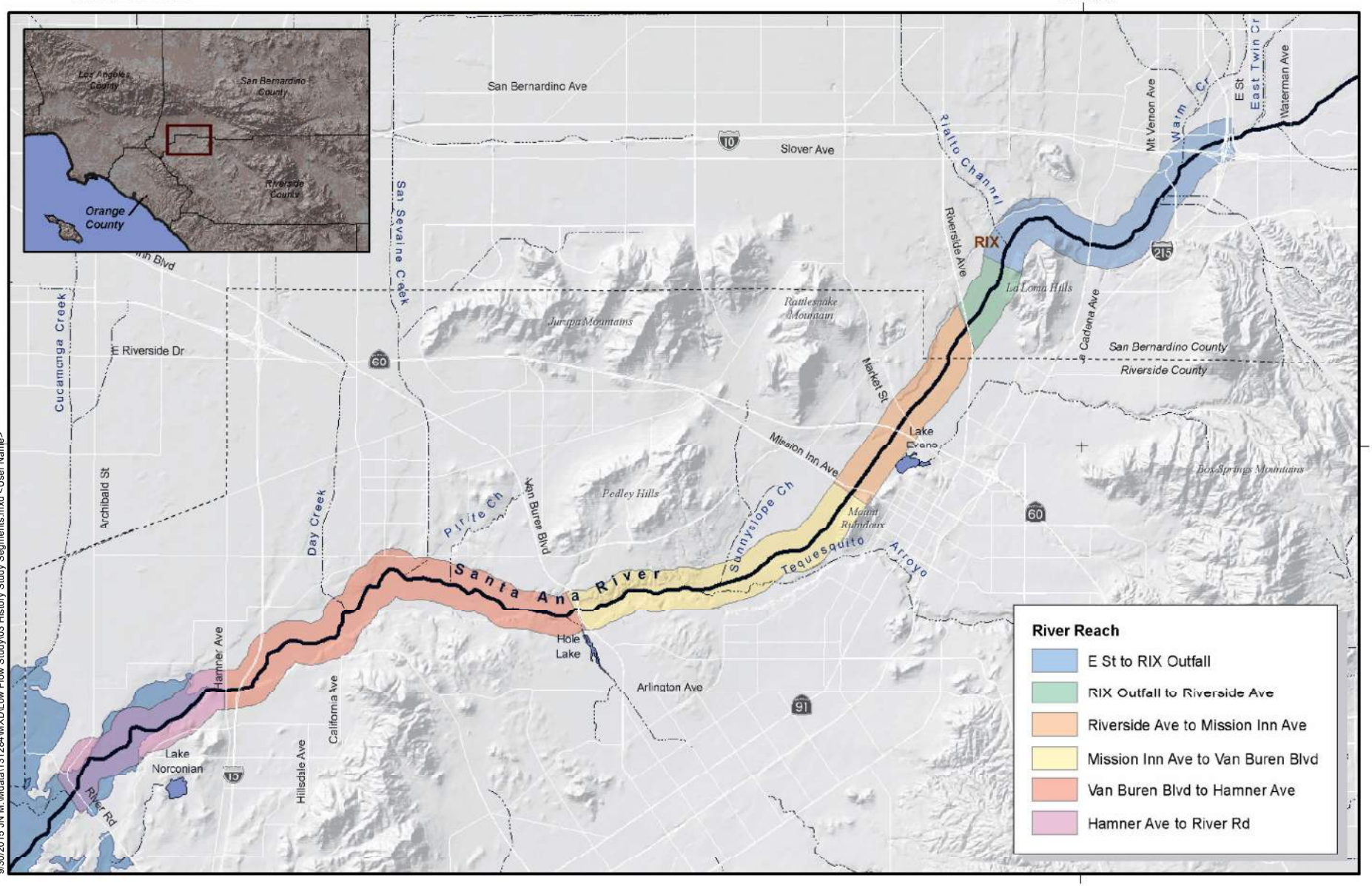

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WILDERMUTH ENVIRONMENTAL INC.
23692 Birtcher Drive
Lake Forest, CA 92630
949.420.3030
www.wildermuthenvironmental.com

Author: MAP
Date: 5/17/2013
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0 1 2 3 Miles
0 2 4 Kilometers

LOW FLOW STUDY

Historic River Study Segments

Exhibit 3

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WEI then used the original hydraulic model (WEI 2014a) to develop a supplemental model that produced more detailed depth and velocity data in the context of the Clean Water Factory project's phased RIX reduction plan (WEI 2014b). The same transects and basic calibration data (e.g., flow measurements before and during RIX shutdown) were used, except instead of producing one maximum velocity and average water column velocity per transect, a series of depths and velocities across each transect were produced. This allowed integration of SASU habitat utilization data on depth and velocity to be compared more directly to instream hydrology (current and projected), as detailed below. Modeling was conducted for flows corresponding to the baseline flow and the five phases of the proposed RIX reduction (Table 3).

Table 3: RIX, Rialto, and Santa Ana River flow at the upstream end of the study area (Model SAR Input) for baseline flow and the five phases of RIX reduction.

RIX Scenario	Baseline	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
RIX (cfs)	53.0	44.9	38.4	32.2	26.3	20.8
Rialto (cfs)	9.5	9.5	9.5	9.5	9.5	9.5
Model SAR Input (cfs)	62.5	54.4	47.9	41.7	35.8	30.3

The modeling results from WEI two studies (WEI 2014a and 2014b) determined that at a 52% reduction in RIX discharge from the baseline level of 63 cubic feet per second (cfs) to the Phase 5 flows of 30 cfs would result in a 13% reduction in the maximum depth in Reach 1 (from 2.08 to 1.82 ft) and in Study Reach 3 (from 1.56 to 1.35 ft)(see Table 4). In Study Reach 2, a 15% decrease in maximum depth occurs at Phase 3, a reduction in discharge to 42 cfs, and at Phase 5 the reduction in maximum depth is 25%. In general, the overall depth showed minor decreases as a result of the first three phases in Study Reaches 1 and 3, with somewhat greater changes in Study Reach 2. The maximum depth remained consistently greater in Study Reach 1 than in Study Reaches 2 and 3 during all phases of reduction.

Table 4: Minimum, maximum, and average of maximum transect depths (ft) for each reach for baseline flow and the five phases of RIX reduction. Data from WEI (2014b), Table from GEI (2014). Values in parentheses indicate total Santa Ana River flow at the upstream end of the study reach, values in brackets indicate percent change in Santa Ana River flow, and n values represent the number of transects evaluated per reach.

Phase (SAR cfs)	Reach 1 (n = 22)			Reach 2 (n = 33)			Reach 3 (n = 36)		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Baseline (63)	0.82	2.08	1.26	0.48	1.68	0.99	0.33	1.56	0.61
Phase 1 (54)	0.80	2.06	1.24	0.45	1.58	0.94	0.31	1.52	0.58
Phase 2 (48)	0.79	2.02	1.21	0.42	1.50	0.89	0.30	1.49	0.56
Phase 3 (42)	0.76	1.97	1.18	0.39	1.42	0.84	0.28	1.45	0.54
Phase 4 (36)	0.74	1.90	1.13	0.37	1.34	0.79	0.26	1.41	0.52
Phase 5 (30)	0.70	1.82	1.08	0.33	1.26	0.73	0.23	1.35	0.49
Percent Change from Baseline									
Phase 1 [-14]	-2	-1	-2	-6	-6	-5	-6	-3	-5
Phase 2 [-24]	-4	-3	-4	-13	-11	-10	-9	-4	-8
Phase 3 [-33]	-7	-5	-6	-19	-15	-15	-15	-7	-11
Phase 4 [-43]	-10	-9	-10	-23	-20	-20	-21	-10	-15
Phase 5 [-52]	-15	-13	-14	-31	-25	-26	-30	-13	-20

Decreases in the average wetted width with the 52% reduction in RIX discharge at Phase 5, from 63 cfs to 30 cfs, was only 5%, from 33.5 to 31.8 ft in Study Reach 1 (see Table 5). Although the average wetted width in Study Reach 2 at Phase 5 was similar to Study Reach 1 at 31.2 ft, this represents a 13% decrease from baseline. Average wetted widths in Study Reach 3 were greater at 73.6 ft at baseline, with a 7% reduction to 68.3 ft at Phase 5. Overall, the average stream width exhibited little change through all five phases of the project in Study Reaches 1 and 3 and through the first four phases in Study Reach 2.

Table 5: Minimum, maximum, and average transect wetted widths (ft) for each reach for baseline flow and the five phases of RIX reduction. Data from WEI (2014b), Table from GEI (2014). Values in parentheses indicate total Santa Ana River flow at the upstream end of the study reach, values in brackets indicate percent change in Santa Ana River flow, and n values represent the number of transects evaluated per reach.

Phase (SAR cfs)	Reach 1 (n = 22)			Reach 2 (n = 33)			Reach 3 (n = 36)		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Baseline (63)	18.8	55.1	33.5	20.67	69.5	35.9	37.7	157.4	73.6
Phase 1 (54)	18.8	52.7	33.2	20.67	64.4	35.2	35.8	157.4	73.1
Phase 2 (48)	18.8	52.7	33.0	18.87	63.2	33.5	33.9	157.4	72.1
Phase 3 (42)	18.8	52.7	32.6	16.21	63.2	33.0	33.9	157.4	70.8
Phase 4 (36)	17.9	52.7	32.1	16.21	63.2	32.3	32.0	157.4	69.6
Phase 5 (30)	17.9	52.7	31.8	15.06	53.1	31.2	28.2	157.4	68.3
Percent Change from Baseline									
Phase 1 [-14]	0	-4	-1	0	-7	-2	-5	0	-1
Phase 2 [-24]	0	-4	-1	-9	-9	-7	-10	0	-2
Phase 3 [-33]	0	-4	-3	-22	-9	-8	-10	0	-4
Phase 4 [-43]	-5	-4	-4	-22	-9	-10	-15	0	-5
Phase 5 [-52]	-5	-4	-5	-27	-24	-13	-25	0	-7

The greatest reduction in average stream velocity from baseline with the 52% in flow reduction in RIX discharge from baseline level of 63 cfs to 30 cfs at Phase 5 was 41% in Study Reach 1, 22% in Study Reach 2 and 10% in Study Reach 3 (see Table 6). In all instances the average stream velocity remained above 1.0 cfs and is considered suitable for SASU. Utilization studies by SMEA in 2003 and 2004 found that SASU prefer deeper and slower velocity habitat (SMEA 2003 & 2004).

Table 6: Minimum, maximum, and average of average transect velocities (ft/s) for each reach for baseline flow and the five phases of RIX reduction. Data from WEI (2014b), Table from GEI (2014). Values in parentheses indicate total Santa Ana River flow at the upstream end of the study reach, values in brackets indicate percent change in Santa Ana River flow, and n values represent the number of transects evaluated per reach.

Phase (SAR cfs)	Reach 1 (n = 22)			Reach 2 (n = 33)			Reach 3 (n = 36)		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Baseline (63)	1.36	2.26	1.77	0.96	2.22	1.62	0.95	2.01	1.51
Phase 1 (54)	1.20	1.99	1.57	0.87	2.00	1.53	0.94	1.96	1.46
Phase 2 (48)	1.13	1.79	1.42	1.04	1.92	1.48	0.93	1.91	1.43
Phase 3 (42)	1.01	1.61	1.28	0.95	1.80	1.41	0.96	1.90	1.40
Phase 4 (36)	0.90	1.44	1.16	0.90	1.70	1.33	1.00	1.87	1.37
Phase 5 (30)	0.79	1.37	1.04	0.79	1.67	1.27	0.98	1.80	1.36
Percent Change from Baseline									
Phase 1 [-14]	-12	-12	-11	-9	-10	-6	-1	-2	-3
Phase 2 [-24]	-17	-21	-20	8	-14	-9	-2	-5	-5
Phase 3 [-33]	-26	-29	-28	-1	-19	-13	1	-5	-7
Phase 4 [-43]	-34	-36	-34	-6	-23	-18	5	-7	-9
Phase 5 [-52]	-42	-39	-41	-18	-25	-22	3	-10	-10

An Evaluation of Changes in the Physical Habitats in the Santa Ana River and Impacts on the Santa Ana Sucker

Fisheries biologists with GEI Consultants have been studying the SASU and its habitats within the Santa Ana River since the early 1990s (Chadwick and Associates 1992). GEI was hired by San Bernardino Municipal Water Department to evaluate the potential impacts to SASU habitat from the phased reduction in RIX discharges into the river.

Evaluation of the Phased RIX Flow Reduction Plan on Santa Ana Suckers, Based on Predicted Changes in Physical Habitat in the Santa Ana River from the Rialto Drain to the MWD Crossing (GEI 2014)

Using the hydraulic data generated by WEI in their modeling of hydrologic conditions in the Santa Ana River between the Rialto Drain and MWD Crossing (WEI 2014a and 2014b), presented above, as well as habitat studies of SASU by SMEA (2003 & 2004), GEI Consultants (GEI) quantified the potential impacts to SASU habitat from the phased reductions in flows from RIX (GEI 2014). SMEA sampled five sites from Riverside Avenue to Mission Boulevard and calculated the percentage of juvenile and adults within defined depth, bottom velocity and substrate categories. Data from all five sites were averaged together by GEI to determine average depth, bottom velocity and substrate utilization for juveniles and adults. To ensure that the average depth, velocity and substrate utilization data used to model habitat were appropriate, the relationships were compared to published curves for other sucker species, in particular the mountain sucker (Rempel et al. 2012) and white sucker (Twomey et al. 1984). Habitat utilization curves based on depth and substrate were then developed by GEI for use in the Physical Habitat Simulation System (PHABSIM) modeling for juvenile and adult SASU. PHABSIM is a component of the Instream Flow Methodology (IFIM)(Bovee 1982) and is used for evaluating the effects of changes in flow on fish habitat availability in streams. The final step in the modeling process was to combine the SASU utilization curves with the modeled hydraulic data to produce the quantity of useable habitat (or weighted usable area (WUA)) for juveniles and adult SASU for the baseline flow and the five phases of RIX reduction.

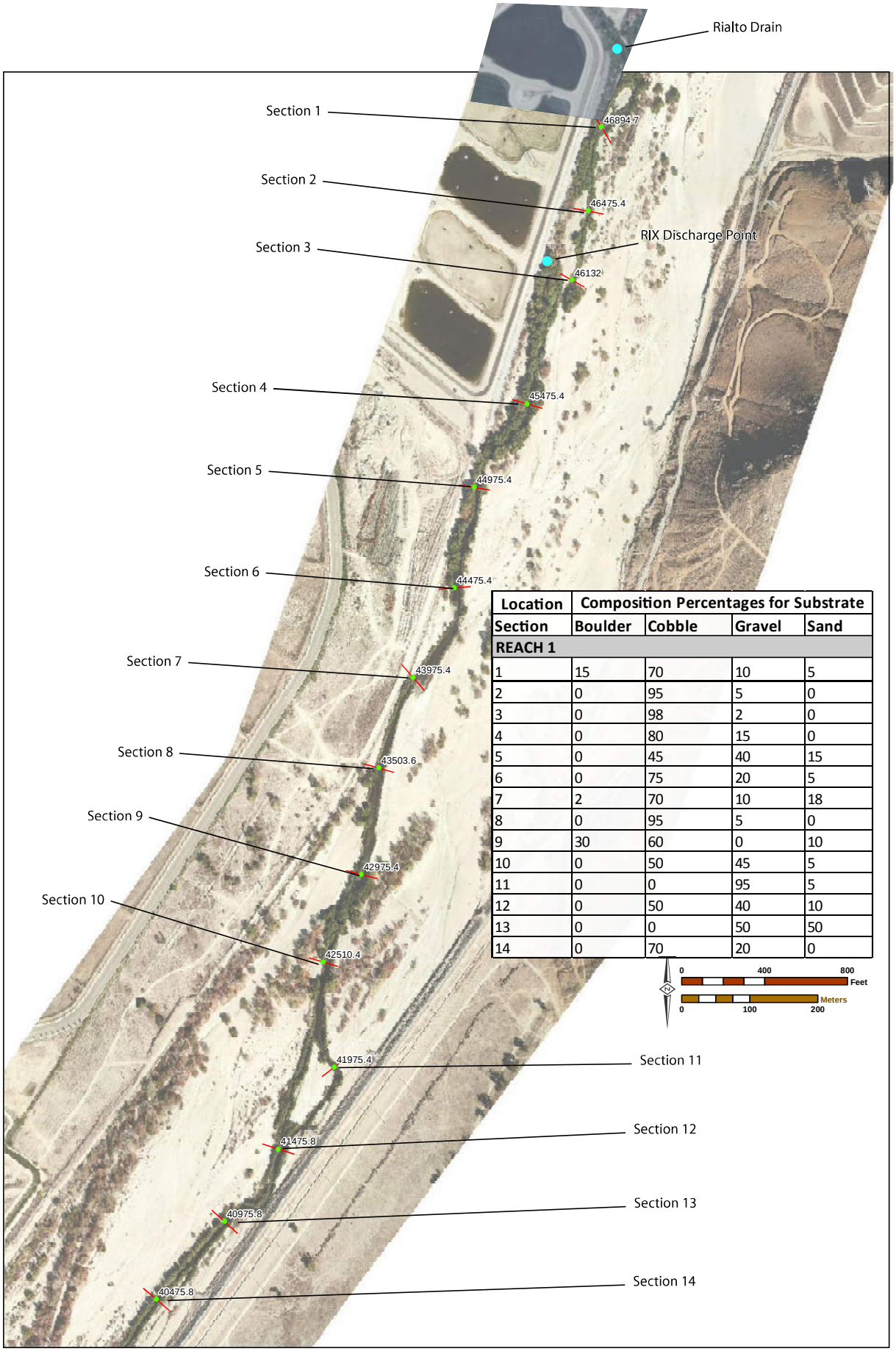
A step-wise approach was used to evaluate the relative influence of the depth, velocity, and substrate variables on the useable habitat. Four models were evaluated: 1) depth only, 2) depth and substrate, 3) depth and velocity, and 4) depth, velocity and substrate. The model that incorporated depth and substrate was chosen as the most appropriate model for assessing potential impacts to SASU. Substrate data was a constant for each reach: Study Reach 1 was predominantly gravel and cobble; Study Reach 2 was a mixture of gravel and sand substrate; and Study Reach 3 was predominantly sand substrate. Exhibit 4a and 4b, Substrate Data, shows the distribution of coarse substrate within Study Reach 1 down to 0.75 below Riverside Avenue in Study Reach 2.

Table 7 provides a summary of the modeled WUA for each phase within each reach. Adult SASU habitat was greatest in Reach 3 for baseline flows and for each of the five phases of RIX reduction. Based on the generated utilization curves for depth, the amount of available SASU habitat in Study Reach 3 is four times the amount modeled as available SASU habitat in Reach 1 and two times the amount of available SASU habitat in Study Reach 2. For all three reaches, adult WUA decreased with decreasing flow, due to associated decrease in depth. A review of the data show that for Study Reach 1 there is relatively small reductions in available adult SASU habitat for Phases 1 (2.7%) and 2 (6.8%). Subsequent phases each resulted in an additional 6 to 8% reduction in available adult SASU habitat per phase. In Study Reaches 2 and 3, available adult SASU habitat was reduced by approximately 10% for each phase of reduction from baseline flows.

Table 7: Depth and Substrate Model Results - Adult Santa Ana sucker weighted usable area (WUA) (sq ft), percent change in WUA from baseline, and WUA as a percent of total area at baseline flow for each reach for baseline and the five phases of RIX reduction. Values in parentheses indicate total Santa Ana River flow at the upstream end of the study reach, and n values represent the number of transects evaluated per reach. (Table from WEI 2014b).

Phase (SAR cfs)	Reach 1 (n = 22)			Reach 2 (n = 33)			Reach 3 (n = 36)		
	WUA (sq ft)	% change from baseline	WUA as % of total area at baseline	WUA (sq ft)	% change from baseline	WUA as % of total area at baseline	WUA (sq ft)	% change from baseline	WUA as % of total area at baseline
Baseline (63)	118,449	--	32.2	102,445	--	13.6	71,931	--	4.5
Phase 1 (54)	115,195	-2.7	31.3	90,927	-11.2	12.1	64,307	-10.6	4.0
Phase 2 (48)	110,369	-6.8	30.0	81,400	-20.5	10.8	58,634	-18.5	3.6
Phase 3 (42)	103,682	-12.5	28.2	72,192	-29.5	9.6	52,951	-26.4	3.3
Phase 4 (36)	95,163	-19.7	25.9	62,352	-39.1	8.3	46,685	-35.1	2.9
Phase 5 (30)	85,714	-27.6	23.3	52,687	-48.6	7.0	41,697	-42.0	2.6

Table 8 below provides a summary of the modeled WUA for each phase within each reach for juvenile SASU. A review of the data show that for Study Reach 1 there is relatively small reductions in available juvenile SASU habitat for Phases 1 (1.9%) and 2 (4.6%). Subsequent phases each resulted in an additional 4 to 6% per phase. In Study Reaches 2 and 3, available juvenile SASU habitat was reduced by approximately 7% for each phase of reduction from baseline flows. The amount of juvenile WUA as a function of total area was high for all flows and reaches compared to adult WUA. Changes among phases of flow from baseline flow for juvenile SASU were smaller compared to adult WUA.



Location	Composition Percentages for Substrate			
Section	Boulder	Cobble	Gravel	Sand
REACH 1				
1	15	70	10	5
2	0	95	5	0
3	0	98	2	0
4	0	80	15	0
5	0	45	40	15
6	0	75	20	5
7	2	70	10	18
8	0	95	5	0
9	30	60	0	10
10	0	50	45	5
11	0	0	95	5
12	0	50	40	10
13	0	0	50	50
14	0	70	20	0

Prepared by:
WILDERMUTH ENVIRONMENTAL INC.
23692 Birtcher Drive
Lake Forest, CA 92630
949.420.3030
www.wildermuthenvironmental.com

Substrate Data

LOW FLOW STUDY

From Rialto Drain to 0.75 Miles Below Riverside Ave

Exhibit 4a

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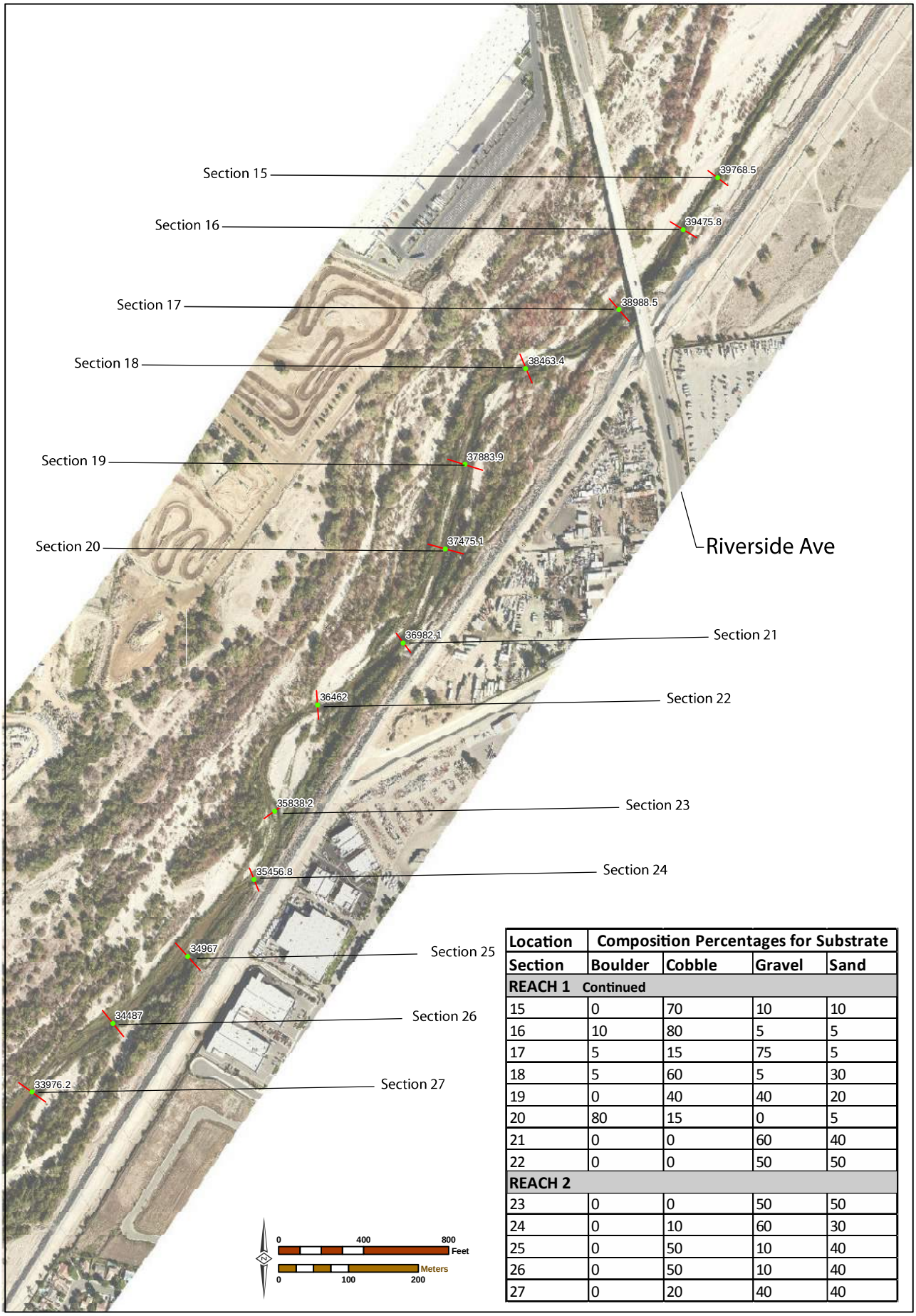

Location	Composition Percentages for Substrate			
Section	Boulder	Cobble	Gravel	Sand
REACH 1 Continued				
15	0	70	10	10
16	10	80	5	5
17	5	15	75	5
18	5	60	5	30
19	0	40	40	20
20	80	15	0	5
21	0	0	60	40
22	0	0	50	50
REACH 2				
23	0	0	50	50
24	0	10	60	30
25	0	50	10	40
26	0	50	10	40
27	0	20	40	40

Prepared by:
WILDERMUTH ENVIRONMENTAL INC.
23692 Birtcher Drive
Lake Forest, CA 92630
949.420.3030
www.wildermuthenvironmental.com

Substrate Data

LOW FLOW STUDY
From Rialto Drain to 0.75 Miles Below Riverside Ave

Exhibit 4b

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Table 8: Depth and Substrate Model Results - Juvenile Santa Ana sucker weighted usable area (WUA) (sq ft), percent change in WUA from baseline, and WUA as a percent of total area at baseline flow for each reach for baseline and the five phases of RIX reduction. Values in parentheses indicate total Santa Ana River flow at the upstream end of the study reach, and n values represent the number of transects evaluated per reach. (Table from WEI 2014b)

	Reach 1 (n = 22)			Reach 2 (n = 33)			Reach 3 (n = 36)		
Phase (SAR cfs)	WUA (sq ft)	% change from baseline	WUA as % of total area at baseline	WUA (sq ft)	% change from baseline	WUA as % of total area at baseline	WUA (sq ft)	% change from baseline	WUA as % of total area at baseline
Baseline (63)	125,816	--	34.2	116,448	--	15.5	100,420	--	6.2
Phase 1 (54)	123,447	-1.9	33.6	108,175	-7.1	14.4	90,916	-9.5	5.6
Phase 2 (48)	120,030	-4.6	32.7	100,444	-13.7	13.4	83,059	-17.3	5.2
Phase 3 (42)	115,037	-8.6	31.3	91,366	-21.5	12.2	74,818	-25.5	4.6
Phase 4 (36)	108,462	-13.8	29.5	82,576	-29.1	11.0	66,750	-33.5	4.1
Phase 5 (30)	101,165	-19.6	27.5	73,079	-37.2	9.7	59,223	-41.0	3.7

Impact Analysis

The potential for impacts to SASU were based on the modeled changes in hydrologic conditions and as a result of changes in the amount of useable habitat (WEI 2014b). Changes in amount of useable habitat based on percent change from baseline was used as the evaluating tool. Changes less than 10% were recognized as unlikely to result in any effects to SASU habitat and that the change would not be measurable or of perceptible consequence and within the range of natural variability. Changes less than 10 percent were described as having "no impact." Changes from 10 to 25% were characterized as potentially measureable, but not substantial, likely not outside the range of natural variability, and described as having "less than significant impact." Changes greater than 25% were considered to be measurable, substantial or potentially substantial, outside the range of natural variability, and were described as having "potentially significant impact."

The reduction in adult WUA from baseline for Study Reach 1 was 2.7%, 6.8%, 12.5%, 19.7% and 27.6% for Phases 1 through 5, respectively (Table 7). Juvenile WUA did not exceed a 10% reduction from baseline until Phase 4 (Table 8). Impacts to Study Reach 1 adult SASU, thus, were characterized as "No Impact" for the first two phases, "Less than Significant" for Phases 3 and 4, and "Potentially Significant Impact" for Phase 5 (Table 8). For juvenile SASU, impacts were characterized as "No Impact" from baseline flows through Phase 3 and Less than Significant for Phases 4 and 5 (Table 8). The greater negative impact designations in the later phases are largely associated with reduction in depth which would indicate that depth is an important habitat variability in influencing SASU abundance. SMEA (2010) did a principal component analysis of habitat characteristics and SASU abundance and suggests that substrate is also an important variable in explaining variation in SASU abundance. The coarse substrate that provides a forage base and substrate for spawning in Study Reach 1 should help the Santa Ana population persist in this reach.

Table 9: Impact designations based on changes in habitat for Santa Ana suckers in the Santa Ana River. All "Less than Significant" and "Potentially Significant" impacts are considered negative. (Table from GEI 2014)

Phase (SAR cfs)	Reach 1	Reach 2	Reach 3
Phase 1 (54)	No Impact	Less than Significant	Less than Significant
Phase 2 (48)	No Impact	Less than Significant	Less than Significant
Phase 3 (42)	Less than Significant	Potentially Significant	Potentially Significant
Phase 4 (36)	Less than Significant	Potentially Significant	Potentially Significant
Phase 5 (30)	Potentially Significant	Potentially Significant	Potentially Significant

For Study Reaches 2 and 3, the reduction in adult WUA from baseline exceed 10% during Phase 1 but did not exceed 25% until Phase 3. Based on the sensitivity analysis presented in Table 8, impacts to adult SASU were characterized as "Less than Significant Impact" for Phases 1 and 2 and "Potentially Significant Impact" for Phases 3 through 5. For juvenile SASU, impacts were characterized as "No Impact" from baseline for Phase 1, "Less than Significant Impact" for Phases 2 and 3, and "Potentially Significant Impact" for Phases 4 and 5. It should be noted that the modeled reductions for Study Reaches 2 and 3 are likely less than predicted since these two reaches are modeled based on stream depths that represent more of an average value based on the trapezoidal stream geometry used in the model, as opposed to Study Reach 1 that used actual cross sectional data for the stream bottom channel shape from field measurements. The boundary for coarse substrate in Study Reach 2 has been measured to extend from the upper 25% of the reach to 100% of the reach. Study Reach 3 has relatively poor substrate conditions, primarily sand,

with coarser substrate confined to discrete areas of scour located along stream banks and islands that provide additional depth and coarse substrate that is not accounted for in the model.

In their study, GEI noted that impact designations are based on modeling a static channel, where changes in hydraulic characteristics and habitat availability are based only on reduction in flows from RIX. In reality, the SAR is a very dynamic river with winter floods capable of scouring away riparian vegetation and islands, relocating the active channel and redistributing substrate. Thus, it is likely that the channel should adapt to reduction in flows from RIX and will be periodically reset from flooding events.

Based on their analysis, GEI concluded that the significance determinations for SASU shown in Table 9 are conservative (GEI 2014). Given the general tolerance and resiliency of SASU, as well as the predicted changes in habitat from reduced RIX flow in context of changes to the channel that occur during storm events, project operations are likely to result in lower level of impacts that what was predicted by the model.

Sediment Scour and Transport Modeling

WEI conducted hydraulic modeling for the SAR between RIX and the MWD Crossing (WEI 2014a and 2014b) that characterized the relationship between the current dry-weather discharge from RIX and the effects of reducing the discharge on river depth. WEI's report provided some additional modeling, using the results from the HEC-RAS model (WEI 2014a and 2014b), to provide some predictability of changes in available physical habitat for the SASU within the river. However, bottom substrate or sediment is an integral component of suitable SASU habitat. In particular, concern was raised regarding the reduction in flows from RIX and whether the reduced flows would hinder the hydrologic processes of sediment transport and scour needed to maintain the coarser substrate found in SASU habitat. Michael Baker International (2015) developed a low-flow sediment scour and transport model to determine whether the phased reduction in flows from RIX would hinder the removal of episodic sandy deposition that occurs during storm events. Specifically, the model would determine if the reduced flows from RIX would still be able to scour the sandy patches off the cobble substrate and flush the scoured sands downstream following periodic storm events and the timeframes in which this would occur.

Clean Water Factory Rapid Infiltration/Extraction (RIX) Low-Flow Sediment Scour and Transport Modeling in the Santa Ana River (Michael Baker 2015)

Michael Baker used a Vortex Lattice Scour-Burial Model (Jenkins et al. 2007) to model the Santa Ana River bathymetry between RIX and the MWD Crossing based on the river channel cross section data provided by WEI (WEI 2014a and 2014b). Current forcing and water surface elevations were input to the Vortex Lattice Model at each of the cross sections previously identified by WEI (WEI 2014a). Michael Baker verified that the HEC-RAS modeled data accounted for percolation and groundwater upwelling along the length of the Santa Ana River between RIX and the MWD Crossing. As a result, the sediment scour and transport results from the Vortex Lattice Model does account for the variations in discharge along the river's length within the study area due to percolation and groundwater upwelling. The Vortex Lattice

Model was developed at the Scripps Institution of Oceanography and has been validated in field experiments in both river and coastal environments conducted by the Office of Naval Research's Mine Burial Program. These experiments involved the prediction of scour, burial and movement of mines disguised to resemble cobbles. Appendix D provides details on the vortex lattice technique and its application to the SAR between RIX and the MWD Crossing.

For the SAR, cobble was replicated from cobble size distribution measurements provided by USGS. The model was then initiated using SAR bathymetry, and river hydrology from WEI (2014b) for a range of RIX discharge rates from a Q=0 mgd to a discharge of Q=64 mgd. In addition, gravel and cobble size inputs to determine bed roughness were provided by USGS California Water Science Center in Sacramento, CA, using sediment (bedload) transport measurements gathered in Study Reach 1 on June 26, 2014 and January 14, 2015, which were then used to calibrate the model against measured bedload transport rates.

The baseline conditions of the model were created to reflect the type and amount of substrate recorded during a 2015 survey (Michael Baker 2015).

Reach 1: RIX to 0.6 miles downstream of Riverside Avenue

- *Station 46132 to 42975: 100% cobble/gravel exposure*
- *Station 42975 to 40475 95% cobble/gravel exposure with 5% sand*
- *Station 40475 to 36462 75% cobble/gravel exposure with 25% sand*
- *Station 36462 to 32586 50% cobble/gravel exposure with 50% sand*

Reach 2: 0.6 miles downstream of Riverside Avenue to 0.6 miles downstream of Mission Inn Avenue

- *Station 32586 to 18976 50% cobble/gravel exposure with 50% sand*

These 2015 conditions were used as the end states of two separate modeling simulations: 1) meeting the above mentioned modeling goals for Study Reach 1; and/or 2) meeting the above mentioned modeling goals for Study Reaches 1 and 2 combined, beginning with an initial condition of total sediment cover of the cobble bed in the inset channel of the SAR. The initial condition required a sand blanket of sufficient thickness to cover every riffle in Study Reaches 1 and 2. The sand blanket varied in thickness from 0 cm at the banks to between 22 cm and 55 cm in the center of the channel. The physical volume of the blanket was calculated at 122.6 cubic meters in Reach 1 and 79.7 cubic meters in Study Reach 2, where a cubic meter of medium to coarse sand weighs 1.6 metric tons.

The model was run for 10 different stream flow rates normalized to the Riverside Avenue Bridge site: Q=0 mgd, Q=4.8 mgd, Q= 6.1 mgd, Q=19.5 mgd, Q=23.6 mgd, Q=26.9 mgd, Q=29 mgd, Q=35.1 mgd, Q=40.4 mgd and Q=64 mgd. For each of these flow rates, the model was run until the modeling goals were achieved for cobble/gravel exposures in Study Reach 1 and Reach 2 as described above. A detailed analysis of the results from the modeling is presented in Appendix D, Figures 9-17. The modeling shows that scour and the resulting exposure of cobble/gravel substrate is not uniform following burial of a post-storm blanket. There are regions of scour hot spots where cobble and gravel will be exposed very rapidly, resulting in areas that will provide immediate available, post-storm suitable substrate for SASU. Generally, these scour hot spots are caused by six types of kinematic or dynamic conditions that are prevalent through these two reaches of the river: 1) contractions of the inset channel width; 2) turns or bends in the inset channel; 3) bifurcation of the inset channel; 4) increase in bed gradient of the inset channel; 5) increase in hydraulic gradient due to ground water upwelling; and 6) hydraulic jumps from super-critical flows velocities at higher RIX discharge rates. All of these kinematic conditions are prevalent throughout this stretch of the river, particularly in Study Reaches 1 and 2.

The presentation of final results focused on 3 of the 10 flow rates to bracket the expected variability in the inset channel; Q=23.6 mgd (the flow rate measure by USGS during field measurements); Q=29 mgd (operational mean discharge from RIX in 2014); and Q=64 mgd (maximum permitted discharge form RIX). Exhibit 5, *Simulated Scour History of Sand Blanket Over Gravel/Cobble Riffles*, shows the simulated scour history of the sand blanket over cobble/gravel riffles in the combined Study Reach 1 and Study Reach 2 sections of the SAR as a function of sustained discharge rates in the inset channel. Scour and transport does not occur uniformly over time. Rather, it begins at a slow rate but, as larger cobble is exposed, vortex shedding and scour is created in the wake of the exposed cobbles and scour and transport rates increase quickly. The process continues to accelerate over time until most of the cobble in the given area is exposed. A review of Table 10 below, *Summary of Result of Modified Scenarios*, shows that scour exposes cobble/gravel back to baseline levels throughout Study Reach 1 in a predicted 5.8 days when inset channel flow rates are equivalent to the 2014 RIX discharge average of Q=29 mgd. For Reaches 1 and 2 combined, the cobble/gravel becomes exposed back to baseline levels in 9.6 days. However, the scour and transportation rates are highly non-linear and can be increased dramatically to achieve scour goals in Study Reach 1 and 2 in less than a day at flow rates approaching the maximum permitted discharge rate of Q=64 mgd.

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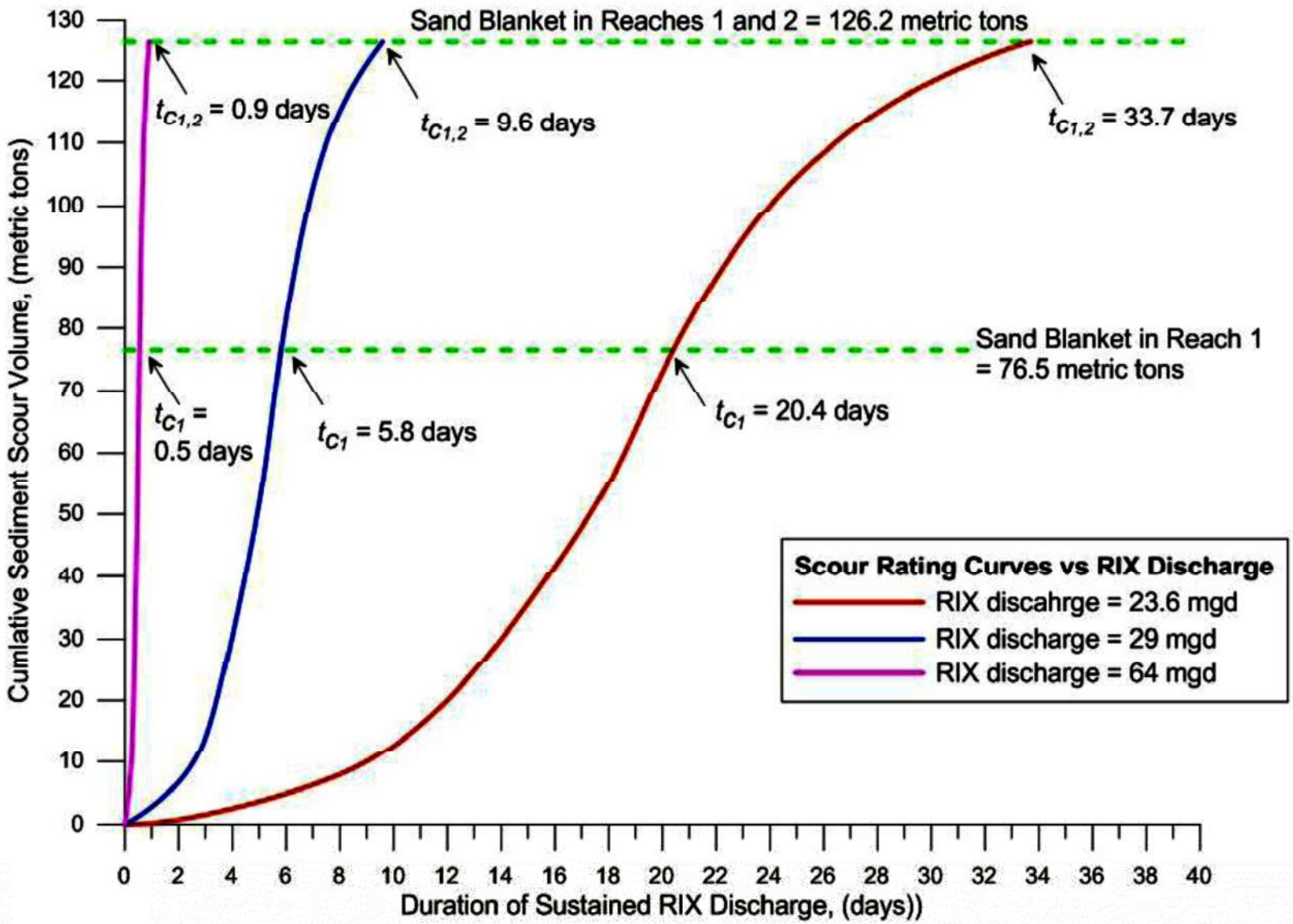

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Michael Baker INTERNATIONAL

LOW FLOW STUDY

Simulated Scour History of Sand Blanket Over Gravel/Cobble Riffles

Source: Michael Baker International

Exhibit 5

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Extrapolating the data for the three rates to all ten flow rates, a graphic was created, Exhibit 6, *RIX Discharge Duration Curves*, which shows continuous projections of discharge duration needed to clear post-flood sand coverage from the cobble/gravel bed. From these results, it was concluded that the minimum threshold for achieving sand scour in the inset channel occurs at a discharge rate of Q=4.8 mgd or 8.9 cfs. It was also determined that the restoration of the 2015 baseline conditions of the river following a rare, high-deposition flood event is within the operating capabilities of RIX. The expectation is further enhanced by the fact that coverage of the cobble bed by sand is a wet-weather occurrence, when percolation losses of stream flow are expected to be minimal along Study Reach 1.

Table 10: Summary of Results of Modified Scenarios

Inset Channel Stream Flow Rates at Riverside Ave Bridge	Initial Sediment Transport Rate	Average Sediment Transport Rate	Flow Duration to Achieve Scour Goals Reach- l (removal of 76.5 tons of sand)	Flow Duration to Achieve Scour Goals Reach- l & 2 (removal of 126.2 tons of sand)
23.6 mgd	0.46 metric tons/day	3.75 metric tons/day	20.4 days	33.7 days
29 mgd	4.96 metric tons/day	13.2 metric tons/day	5.8 days	9.6 days
64 mgd	86.5 metric tons/day	142 metric tons/day	0.5 days	0.9 days

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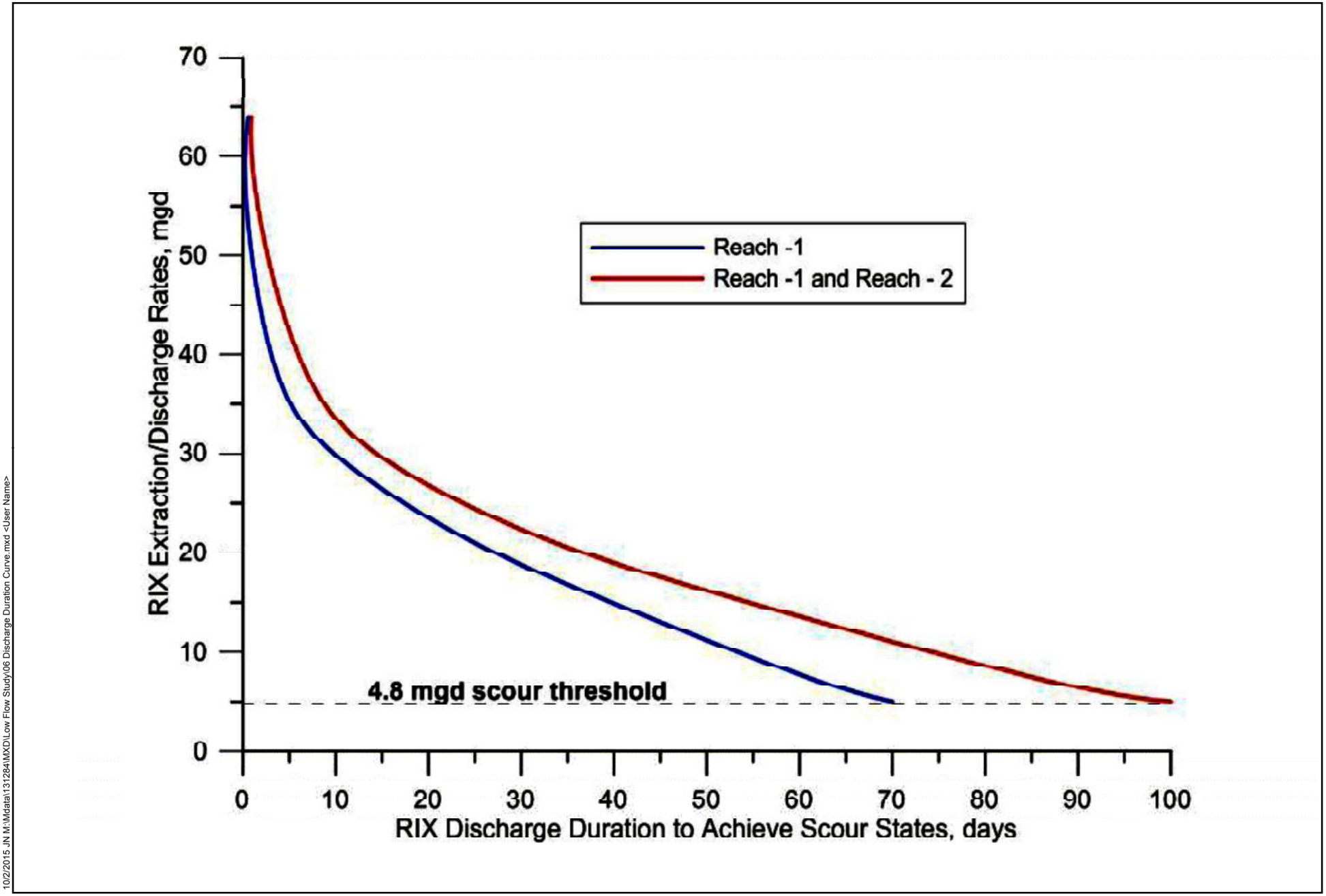

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Michael Baker INTERNATIONAL

Source: Michael Baker International

LOW FLOW STUDY

RIX Discharge Duration Curves

Exhibit 6

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DISCUSSION

As noted by Moyle and Yoshiyama (1992), SASU tolerates a wide range of stream conditions and can inhabit flowing streams with varying waters depths, velocities, and substrates. Studies by Chadwick and Associate in the early 1990s for SASU in the SAR found that SASU was absent in Study Reach 1, rare in Study Reach 2, but abundant at the MWD Crossing in Study Reach 3 where depths were relatively more shallow than currently observed in Study Reach 1 (Chadwick and Associates 1992). Shifting sand substrate was as prevalent then as it is today in Study Reach 3, indicating that the SASU is adaptable and able to populate reaches without greater depths and the desired substrate now present in Study Reach 1. Chadwick and Associates (1992) found that SASU were most abundant in Study Reach 3 in areas of scour associated with the stream banks and margins of vegetated islands. These habitat features are still present today in Study Reach 3. However, SASU shifted their population upstream to Study Reach 1 between 2004 and 2005 which now has deeper habitats and coarse substrates. Even with the reductions in average depth in Study Reach 3 that will occur with reducing discharges from RIX (WEI 2014a), the localized deeper areas of scour along stream banks and island edges should remain, as they do now and did before RIX discharge was added to the river.

The changes in habitat with reductions in RIX flow as modeled by GEI (GEI 2014) represent the predicted habitat characteristics resulting solely from the reduction in RIX flow. Potential long-term changes in stream morphology or substrate conditions that would be associated with changes in RIX flow would also affect useable habitat and should be monitored over time as part of an adaptive management program (presented below). For example, winter flow events are capable of relocating the active channel, and scouring away bank and island vegetation, effectively “resetting” the stream channel. Reestablishment of bank vegetation and islands can occur rather quickly as documented by GEI following a 2010 storm event (See Appendix C).

By implementing the RIX flow reductions as a phased plan, the river is likely to reestablish a new dynamic equilibrium state providing habitat similar to that currently observed. The phased approach would allow time for additional monitoring of SASU populations and collection of additional data on habitat utilization and channel hydraulics to allow more quantitative PHABSIM modeling to better predict changes for later phases.

From the above studies, Michael Baker was able to assess the impacts to the instream habitat, determine the potential significance of identified impacts and recommend biological monitoring measures and adaptive management measures for protecting the SASU and its habitat in the SAR. The resulting adaptive management plan includes monitoring programs for low flow management, habitat management, sediment transport, and the management of SASU populations.

Clean Water Factory Adaptive Management Plan

Although the above studies indicate that the potential changes to the hydrology of the Santa Ana River and availability of SASU habitat will be negligible during the first three phases of reduction, a 15-year period, the current drought conditions in the Inland Empire, combined with the dynamic nature of the SAR between Prado and Seven Oaks Dams, creates a potentially large level of uncertainty that must be built into a management program for habitat within and immediately adjacent to the SAR. Adaptive management is a recognized method for "learning by doing" when there is such uncertainty in the response of an ecosystem, here the in-stream and riparian habitats associated with the SAR, to a proposed action. The proposed action, a phased reduction in discharge of treated wastewater from the RIX facility, can and will be carefully monitored and managed to ensure that all potential responses are assessed, monitored and corrected, if needed, during each and every phase of the project. It is also important to note that the Clean Water Factory is the first in a series of water related projects that have the potential to affect instream and riparian habitats associated with the SAR. Having a robust and well-managed adaptive management program in place can be used to effectively create a regional solution for managing the SAR ecosystem and the numerous sensitive species it supports.

In designing a management plan and monitoring program for the CWF Project, it is recognized that the modeling results are likely conservative for expected changes in the habitat conditions and effects that could occur to SASU in the SAR—providing flexibility in the implementation of a monitoring and adaptive management program. Reductions in flow will be implemented using a five-phased approach with each phase approximately five years apart. For example, during Phase 1, discharge at the RIX Facility/Rialto Drain will be reduced from 62.5 cfs to 54.4 cfs over a five year period. Phase 2 will further reduce discharge into the Santa Ana River from 54.4 cfs to 47.9 cfs from years 6 through 10. This process of incrementally reducing discharge will continue through the five phases until year 25 when discharges will be reduced to a final discharge flow rate of 30.3 cfs. This represents a total reduction in discharge flow rates of 52% over existing baseline conditions.

Based on the model (WEI 2014b), it was determined that at Phase 5 in Study Reach 1 the maximum and average maximum depths for all transects would be 1.82 and 1.08 ft, respectively – both depths are greater than the average depth of 0.7 ft that supported SASU in Study Reach 3 in the Saiki et al. (2007) study. Furthermore, coarse substrates should remain in Study Reach 1 with reductions in RIX flow, given the availability and supply of coarse substrates within Study Reach 1 and the scour capability from RIX within this reach (Michael Baker 2015). Thus, conditions in Study Reach 1 with full reductions in RIX flow at year 25 should still provide sufficient habitat to support its current population of SASU.

Similarly, modeling found that the average maximum depth was 0.99 ft at baseline in Study Reach 2 and would remain above 0.7 ft depth through all reduction phases. In Study Reach 3, the average maximum depth at baseline was 0.61 ft, below that previously documented by Saiki et. al., and was reduced to 0.49 ft, a 20% reduction, at Phase 5. These reductions are expected to have negligible effects on SASU habitat through Phase 2, and likely, Phase 3, given that the model for these two reaches used a trapezoidal

channel that averaged depths and did not account for deeper pools in areas of scour that were included in the modeling for Study Reach 1.

This expected continued availability of SASU habitat through at least the first three phases of flow reduction provides an opportunity to develop and implement an adaptive management plan that will track the reductions in discharges from RIX and the resulting changes in depth, width, velocity, and available SASU habitat during the first fifteen years of expected negligible effects. Based on this conclusion, the following biological goals and objectives are proposed for defining management actions for managing the instream habitats and Santa Ana River SASU populations. The data gathered will allow a reliable and timely feedback on the monitored SAR in-stream and riparian habitats, as well as the SASU population:

- **Biological Goal 1**: Achieve Negligible Loss of Available Sucker Habitat
    - **Objective**: Track and respond to changes in Availability of Sucker Habitat
- **Biological Goal 2**: Achieve Negligible Loss of Riparian Habitats
    - **Objective**: Track and respond to changes in Riparian Habitats within each Reach
- **Biological Goal 3**: Protect Populations of Santa Ana Sucker in the Santa Ana River
    - **Objective**: Manage Population Level of Sucker for each Reach of the River

The following management actions will be implemented for Biological Goal 1 - Achieve Negligible Loss of Available Sucker Habitat:

Establish Baseline Conditions: The first step in setting up a framework for implementing an adaptive management plan is to document baseline conditions for in-stream habitats, type of substrate present, and adjacent riparian habitats within each reach. Pockets of deep pools should also be noted as well and measurements taken to determine depth. All information gathered in the field will be mapped using GPS in the field on an aerial photograph using an iPad. Representative photos of site conditions will be imbedded into KMZ files, keyed to the aerial photograph. The existing LiDAR maps flown by the City of San Bernardino will be used to define the existing conditions for the SAR. The river will be walked, as part of the above survey, to note any recent changes in river geometry from the LiDAR data. The presence or absence of deeper habitat along the stream banks and along the edges of islands within the river will be recorded on the aerial photograph and documented in GIS.

Refine Habitat Model. Additional cross sections should be established and stream conformation data gathered in Study Reaches 2 and 3, similar to the type of data gathered in Study Reach 1 to refine the habitat model. Data needed are depth, width and flow measures at set intervals along each cross section. This will allow for more accurate modeling of available SASU habitat. In addition, further investigation is needed to provide refinement to velocity data so that it can be incorporated into the habitat model. GEI (GEI 2014), in developing the habitat model, concluded that the current velocity data generated by the model did not reflect the fine-scale variability in flows that likely occur in the river and were not

incorporated into the analysis. This further discussion is needed to determine how to capture this information.

Track Changes in Depth, Width and Flow Rates. Once baseline conditions have been recorded, changes in these hydrologic conditions will be routinely tracked by periodic measurements at all cross sections. The frequency for gathering data will be established in coordination with the City of San Bernardino and will reflect seasonal changes in flow as well as programmed reductions in discharge from RIX.

Track Changes in Substrate Distribution and Habitat Conditions. The SAR is a dynamic ecosystem that is constantly changing. However, it will be necessary to track changes in substrate distribution and other habitat conditions, presence of deep pools, etc., and correlate those changes to the reductions in discharges from RIX. It will be important to distinguish between changes associated with ongoing river dynamics, e.g., storm events, and those attributable to reduction in discharges. Quarterly surveys, as well as surveys storm events of the river will be conducted to document the distribution of substrate and other habitat features such as deep pools, etc.

Re-run Habitat Model. As means of validating the data gathered to track changes in baseline conditions within the river, the habitat model will be re-run annually using the actual discharge rates from RIX for that year. The two sets of data, field measurements and predicted conditions using the model, will be compared to document the accuracy of the model and to refine the modeling, if needed.

The following management actions will be implemented for Biological Goal 2 - Achieve Negligible Loss of Available Riparian Habitat:

Monitor Areal Extent and Distribution of Riparian Habitat. Riparian habitats along the banks of the SAR provide shade and escape cover for SASU. Its presence throughout Study Reach 1 may represent one factor in the shift in abundance of SASU in this reach. Recording and tracking changes in the areal extent and distribution of riparian habitat along each reach of the river will be done using aerial photographs and will be ground-verified in the field. This will be important in determining a cause and effect relationship between natural changes in riparian habitat from changes in river geometry, e.g., changes resulting from a storm event, and those changes that can be attributed to decreased flows and changes in wetted width associated with reductions in discharges from RIX.

Conduct Vegetation Inventories Annually. Vegetation monitoring will also be used to quantify any changes in riparian habitat. Monitoring will be conducted at representative transect sites selected and established within each reach of the river. In addition, the use of the California Rapid Assessment Method (CRAM) will be explored as a means of assessing the health of the riparian habitats at a select number of vegetation transects. CRAM analyses assess four attributes of riverine systems: 1) buffer and landscape; 2) hydrology; 3) physical structure; and 4) biotic structure.

The following management action will be implemented for Biological Goal 3 - Protect Populations of Santa Ana Sucker Habitat in the Santa Ana River:

Conduct Annual Santa Ana Sucker Survey. The Santa Ana sucker Conservation Program has been conducting annual counts of the SASU population in the SAR since 2001. As part of the management plan, the continued availability of these data, as well as their direct applicability to the CWF adaptive management process will be evaluated. If these existing counts will not continue or are determined not to be directly applicable, an independent assessment program will need to be established.

Correlate Population Distribution with Hydrologic Features, Available Sucker Habitat and Riparian Habitat. Population data gathered during the annual SASU survey will be correlated with the annual assessment of hydrologic conditions in the SAR. The correlation will be used to determine habitat characteristic needed to support a healthy SASU population and provide insight into management options needed to maintain SASU habitat.

Evaluation of Results

Monitoring data will be compared against baseline conditions annually. The evaluation process will document any noted changes, explain why the change may have occurred and include recommendations for future action. Clearly distinguishing between changes associated with ongoing river dynamics, e.g., storm events, and those attributable to reduction in discharges will be important to implementing an effective management approach. The essence of an effective adaptive management program includes the ability to recognize the outcome, to correlate the outcome in a cause and effect relationship with physical and/or environmental changes in the riverine environment, and to adjust management action accordingly. The evaluation and suggested management changes will not be made in isolation but will be integrated with the overall management structure of the CWF project and coordinated with USFWS.

Adjustment/Revision of Hypotheses & Management

Information gained through the monitoring process will be used to verify or update the models. The data will also be used to adjust the original forecast on expected changes to river hydrology and modifications to SASU habitat, as well as to adjust management actions, as needed. Biological goals and objectives will be reviewed and adjusted to ensure that they remain consistent with the overall goal of protecting and maintaining the riverine environment for the SASU in the SAR.

In order to better facilitate necessary changes after project initiation, anticipated adjustments to management actions will be considered at the outset and will be developed jointly by SBMWD, Michael Baker, WEI and GEI. The monitoring and evaluation process is not intended to be a rigid process that could hinder adaptation. It is important that the uncertainties identified at project initiation are reduced over time. Or, if they remain unresolved, they continue to be identified for monitoring and evaluation. New uncertainties may also be identified through the evaluation process.

Documenting Management Actions and Communicating Results

Documenting management actions and communicating results are crucial elements of adaptive management. The San Bernardino Municipal Water Department and/or its consultants will provide technical oversight to ensure planning documents are available and that they are updated as needed. All survey and monitoring results will be memorialized in annual technical reports and made available in both hard copy, as well as electronic format. A separate GIS database will be developed and maintained by the City for recording survey and monitoring results, in addition to formal technical reports.

Conclusion

Given the model results and the interpretation of these results, Phases 1 and 2 will have a negligible effect on SASU habitat in all reaches (GEI 2014). Potential minor impacts are not expected to occur until Phase 3 and only in Study Reaches 2 and 3. Minor impacts which are predicted for Study Reaches 2 and 3 during Phase 3 will not occur for at least 10 years after project implementation. The phased approach provides the opportunity to design and implement a biological monitoring and adaptive management approach for effectively managing the stream environment through the various phases of flow reduction from the RIX facility. The expectation is that with the acquisition of additional data for Study Reaches 2 and 3 and refinement of the habitat model, the predicted impacts will be further reduced for each of the reaches. Continued monitoring and model refinement to better reflect actual site conditions will ensure that any trend in adverse conditions/impacts can be noted early and adaptive management measures will be developed and implemented early in response to the identified issue. As noted above, negligible effects are predicted for at least the first 10 years. Trends that will need to be monitored include: the actual reduction in average depths; the continued availability of deeper pools within each reach; the continued availability of coarse substrate throughout Study Reach 1 and along areas of scour in Study Reaches 2 and 3; loss of wetted width greater than 10% for anyone reach; loss and/or other changes in riparian habitat; and changes in SASU population distribution.

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Appendix A:

Historic Hydrologic Analysis of Dry-Weather Discharge Conditions in the Santa Ana River

(WEI, May 2013)

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May 20, 2013

Somach Simmons and Dunn Attorneys at Law
Andrew M. Hitchings, Attorney
500 Capitol Mall, Suite 1000
Sacramento, CA 95814

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Subject: ***Historic Hydrologic Analysis of Dry-Weather Discharge Conditions in the Santa Ana River from E St to River Rd***

Dear Mr. Hitchings:

The City of San Bernardino Municipal Water Department (SBMWD) is conducting assessments to address the potential impacts of the proposed Clean Water Factory[1] project on the Santa Ana River's environment and hydrology and Santa Ana Sucker habitat. To help meet these assessments, Wildermuth Environmental, Inc. (WEI) completed a historical hydrologic analysis of dry-weather discharge conditions in the Santa Ana River from E St (City of San Bernardino) to River Rd (City of Chino) for the 1938 to 1977 period.

The objective of this investigation was to characterize the Santa Ana River's historical hydrology in terms of: wet and dry reaches, dry-weather discharge variability, discharge top width and flow depth variability, and surface water and groundwater interaction. All available historical aerial photos, topographic maps, surface water discharge data, wastewater treatment plant and imported water discharge data, and groundwater level data were compiled, reviewed, and summarized. The results of this investigation provide a historical record of Santa Ana River dry-weather discharge between 1938 and 1977 for subsequent use by other scientists to characterize Santa Ana Sucker habitat over the 1938 to 1977 period.

Background: Santa Ana River Historical Hydrology

This investigation focused on the segment of the Santa Ana River shown in Figure 1 over the 1938 to 1977 period. Between 1938 and 1977, the Santa Ana River Watershed climate

[1] The proposed Clean Water Factory will treat effluent from the San Bernardino Water Reclamation Plant to a quality approved for recharge—as set by the California Department of Public Health and the Santa Ana Regional Water Quality Control Board—and convey the recycled water to the Waterman Basins, the East Twin Creek Spreading Grounds, and the Devil Canyon and Sweetwater Basins for surface spreading.

was predominantly dry, punctuated with a few wet years. Figure 2 illustrates precipitation variability in the Santa Ana River Watershed between 1900 and 2012. Moreover, Figure 2 shows precipitation totals by water year (October 1 to September 30) for the San Bernardino County Hospital recording station plotted with a cumulative departure from mean precipitation (CDFM) curve. A CDFM precipitation curve is a measure of the consecutive and cumulative relationship of each year's precipitation to the long-term mean. When the CDFM curve line is descending (left to right), the period has less precipitation than average, while an ascending line denotes a period with greater than average precipitation. Over the entire precipitation record, the Santa Ana River Watershed experienced multiple wet and dry periods. For the investigation period (1938-1977), there was a wet period from 1934 to 1944, followed by a prolonged dry period from 1945 to 1976 (32 years) that was punctuated by short-lived (1-2 years) wet periods. From 1977 to 2010, the CDFM precipitation curve for the Santa Ana River watershed shows two wet-dry cycles.

During the 1945 to 1976 dry period, Santa Ana River dry-weather discharge between E St and Mission Inn Ave Bridge typically percolated to the underlying groundwater, leaving most of this reach dry (SBVMWD & WMWD, 2004).[2] Downstream of Mission Inn Ave Bridge, river discharge was usually continuous due to City of Riverside wastewater treatment plant discharge and rising groundwater. The USGS gage at the MWD Crossing (see Figure 4) marks the "Riverside Narrows."[3]

Sometime between 1978 and 1983, Santa Ana River discharge became continuous from E St to Prado Dam. Continuous discharge in the river can be attributed to: prolonged high groundwater levels in the San Bernardino Basin Area upstream of the San Jacinto fault and subsequent groundwater discharge to the river upstream of the fault; a steady increase in wastewater discharge to the river by the Cities of Colton, Rialto, and San Bernardino; and a very wet period from 1978 through 1983. In 1996, the Cities of Colton and San Bernardino comingled their discharge for treatment at the Rapid Infiltration and Extraction facility (RIX). The RIX discharge point to the Santa Ana River is located just downstream of the Rialto Channel discharge point. Since 1996, the Santa Ana River reach between E St and the Rialto Channel has been dry except during storm events. Figure 3 shows a time-history of the wastewater treatment plants' discharge as well as non-tributary discharge to the river from 1935 to 2000. Specifically, Figure 3 shows that during the investigation period, wastewater discharge to the river was about 5,000 acre-ft/yr in 1938 and gradually increased to about 42,000 acre-ft/yr by 1977—an increase of about 37,000 acre-ft.

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[2] San Bernardino Valley Municipal Water District and Western Municipal Water District. (2004). *Santa Ana River Water Right Applications for Supplemental Water Supply Draft Environmental Impact Report, Appendix A: Surface Water Hydrology*. San Bernardino: Authors.

[3] CA Department of Water Resources. (1971). *Meeting Water Demands in the Chino-Riverside Area Bulletin No. 104-3*. Sacramento: Authors.

Methods: Data Collection and Analysis

Aerial Photographs

Historical Santa Ana River aerial photography was collected from national, state, county, university, and private data sources for the 1938 to 1977 period. The investigation area included the river reach from E St to just downstream of River Rd. Table 1 shows the season and year, river reach coverage, and aerial photo source. For most years, photo coverage was complete between Riverside Ave and River Rd. The aerial photos were acquired as digital scans and black and white vertical photos with scales ranging between 1:20,000 and 1:36,000. All photos were georeferenced in ArcGIS using identifiable control points or objects (i.e. road intersections) from historic USGS topographic 7.5-minute quadrangle base maps.

The historical aerial photos were used to identify river wet and dry reaches, measure discharge top width, document discharges to the river and diversions from the river, and assist in identifying reaches of potential groundwater and surface water interaction. Aerial photo analysis consisted of georeferencing each photo, identifying and digitizing the river thalweg (centerline), and creating river stations every 1,000 feet (ft) from 1,000 ft downstream of River Rd to E St. At each river station, the left and right banks were marked and digitized, and the discharge top width was measured using GIS tools. Each river bank location was reviewed by multiple WEI scientists and engineers to best establish the locations of the river banks. Note that there were limitations to using aerial photography in identifying river banks and measuring discharge top width. These limitations include poor photo resolution, lack of contrasting photo color and tone, small photo distortions due photo acquisition, and inherent georeferencing errors. The discharge top width results presented in this report are best estimates given the quality of each photo. Historical aerial photos were also reviewed to identify any discharge and diversion points as well as surface water and groundwater interaction along the river.

Historic Topographic Maps

Santa Ana River historical topographic maps were collected from the Riverside Flood Control and Water Conservation District (RCFCWCD) and the San Bernardino County Flood Control District (SBCFCD) for the river reach between E St and River Rd. Table 2 shows the river reach, corresponding topographic map year, and source. The majority of the topographic maps were created in the late 1950s and 1960s. The only exception was the river reach between the RIX Facility (future location) and Riverside Ave, which was created in 1996. Additionally, there were almost no topographic maps that corresponded to any of the historic aerial photo dates collected. The only exception was 1959 for the river reach between Mission Inn Ave and Van Buren Blvd. All topographic maps were acquired as

digital scans and had a contour interval of 4 ft. All topographic maps were georeferenced using each map's geographic coordinate system and coordinate values.

The topographic maps were used to generate channel cross-sections and estimate river flow depth. Each of the scanned topographic maps' contour lines and spot elevations were digitized within a 1,000-foot buffer surrounding the Santa Ana River and merged, and a ground surface raster was created using the Spatial Analyst Extension in ArcGIS. Channel cross-sections were developed from the surface raster. Santa Ana River historic flow depths were estimated using the channel cross-sections and discharge top width. The discharge top width was fitted to a channel cross-section by trial and error, and flow depth was calculated from the difference between the estimated water surface and channel bottom elevation. Flow depth measurements using historic topographic map cross-sections were only measured at major road crossings for the river reach between River Rd and the Metropolitan Water District of Southern California Upper Feeder (MWD Crossing). This was done for two reasons: 1) the river's alignment was typically consistent at major road crossings, and 2) topographic maps at major crossings mapped a well-defined channel.

Between MWD Crossing and the RIX outfall, the river channel alignment is not well defined in historic topographic maps. In lieu of topographic maps, LiDAR and channel survey data acquired in October 2012 and February 2013, respectively, were used to generate cross-sections and estimate flow depths from MWD Crossing to the RIX outfall. Due to historic channel alignment variability, flow depth measurements were estimated where the 2012/2013 river alignment was in close proximity to historic river alignment. The same approach of fitting the measured discharge top width in the channel cross-sections was employed to calculate flow depth from MWD Crossing to the RIX outfall.

From the RIX outfall to E St, no depth measurements were estimated. This was due to a poorly defined main channel in the historic topographic maps as well as a lack of any river thalweg elevation or channel survey data available upstream of the Rialto Channel.

Surface Water Discharge Data

A number of USGS gages were used in the Santa Ana River between E St and River Rd from 1938 to 1977. Figure 4 shows the station locations, the six river reaches analyzed, and points of historical discharge. All available discharge data were obtained from the USGS National Water Information System. Daily discharge data were reviewed and plotted in conjunction with the aerial photo dates to assist in interpreting and identifying river discharge patterns, floods or other large discharge events, and dry reaches. In this investigation, the river segments from E St to MWD Crossing are defined as above the Riverside Narrows and from MWD Crossing to River Rd as below the Riverside Narrows.

Wastewater, Imported Water, and Groundwater Discharge Data

Wastewater discharges to the Santa Ana River for the investigation period include those from the Cities of San Bernardino, Rialto, Colton, and Riverside (Figure 4). Available discharge records begin in 1934 for the Cities of San Bernardino and Riverside, 1937 for the City of Rialto, and 1939 for the City of Colton. All wastewater treatment plant data were tabulated from the *Orange County Water District vs. City of Chino, et al., Litigation Engineering Appendix*[4] and the Santa Ana River Watermaster's annual reports.

Records show two imported water discharge points along the Santa Ana Valley Pipeline in the vicinity of Colton and at the Santa Ana River, as shown in Figure 4. Imported water discharge data indicate that discharge to the Santa Ana River only occurred in water year 1972-73.[5]

No groundwater was pumped from the artesian zone of the San Bernardino Basin Area to the Santa Ana River during the investigation period. In water year 1984-85,[6] groundwater was pumped from the San Bernardino Basin Area in an effort to lower groundwater levels in the area underlying the City of San Bernardino. As Figure 3 shows, about 6,245 acre-ft of groundwater was pumped from the San Bernardino Basin Area and discharged to the river in water year 1984-85.

Groundwater Data

WEI collects and maintains groundwater well and level data that can be accessed through a relational database management system called HyDroDaVE^{sm}. For this investigation, groundwater data were available beginning in the late 1930s for a two mile (mi) buffer along the Santa Ana River from the Prado Flood Control Basin to upstream of E St. All groundwater data reviewed for each aerial photo year were checked for quality and analyzed to establish groundwater level trends and conditions. Groundwater well locations were checked against well completion reports (when available).

Groundwater level data were used to generate groundwater elevation rasters to assist in analyzing potential locations of surface water and groundwater interaction: after review of the groundwater level data, groundwater elevation data were plotted in ArcGIS and hand-contoured, and the groundwater elevation contours were converted to rasters using the

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[4] Joint Engineering Committee. (1968). *Orange County vs. City of Chino, et al., Case No. 117628, Appendix "A" Basic Data*.

[5] Santa Ana River Watermaster. (1974). *Third Annual Report of the Santa Ana River Watermaster 1972-73*. Riverside: Authors.

[6] Santa Ana River Watermaster. (1986). *Third Annual Report of the Santa Ana River Watermaster 1984-85*. Riverside: Authors.

Spatial Analyst Extension in ArcGIS. For each aerial photo year, the groundwater elevation was extracted along the river's thalweg.

Results: Historic Aerial Photograph Analysis

Summer 1938

Aerial photograph coverage for 1938 was available from Riverside Ave to approximately 0.6 mi upstream of River Rd. Aerial photos were taken on June 3, 1938 from Riverside Ave to Market St; on July 5, 1938 for a 1.2 mi segment downstream of Market St; and on May 30, 1938 from Market St to below River Rd.

Figure 5 shows Santa Ana River discharge from March to July 1938. The very large 1938 Santa Ana River flood occurred in March. Peak discharge recorded at Warm Creek near Colton (USGS gage 11065800, located near the confluence of Warm Creek and the Santa Ana River) was 10,200 cubic feet per second (cfs) on March 2nd. Peak discharge recorded at the Riverside Narrows (USGS gage 11066500) was 3,200 cfs on March 1st with a sustained discharge of about 2,400 after March 1st. After the month March, discharge in the Santa Ana River subsided to about 48 cfs at Warm Creek near Colton, 66 cfs at the Riverside Narrows, and 45 cfs at Hamner Ave (USGS gage 1167500). River discharge continued to subside through July with 30 cfs of discharge recorded at Warm Creek near Colton and 28 cfs of discharge at both the Riverside Narrows and Hamner Ave. Table 3 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at Warm Creek near Colton[7] and wastewater discharges by the Cities of Rialto and Colton. The actual discharge was probably greater as the discharge from the Santa Ana River upstream of its confluence with Warm Creek was not included. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 47 cfs between May 30th and June 3rd and at least 30 cfs on July 5th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows plus wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 74 cfs on May 30th.

Figure 6 shows groundwater elevations for summer 1938 conditions between E St and River Rd. From E St to about river station (RS) 84000, groundwater levels range from the surface to about 20 feet-below ground surface (ft-bgs). Downstream of RS 84000, groundwater elevations indicate gaining conditions.

[7] This station includes the wastewater discharge from the City of San Bernardino in 1938.

Review of the summer 1938 aerial photos shows that the Santa Ana River was still inundated with the March flood waters. For the majority of the river between Riverside Ave and River Rd, water was visible from bank to bank. And, bank to bank width measurements varied from about 220 to 800 ft. There were segments of the river where a main channel was more pronounced (based on the gray-scale color contrast), but the adjacent channel areas showed evidence of river flows and/or wet ground. Width measurements for the more pronounced main channels varied from about 65 to 345 ft. No depth measurements were made due to channel erosion, which likely resulted from flood waters. Appendix A contains the 1938 aerial photos zoomed in at scale of 1:300 and annotated with the river stations.

Summer 1948

Aerial photo coverage for 1948 was available between E St and River Rd. All aerial photos were taken on July 10, 1948.

Figure 7 shows Santa Ana River discharge for July 1948. River discharge at E St was very low and varied from 0 to 1 cfs. River discharge varied from 22 to 42 cfs at the Riverside Narrows and from 21 to 36 cfs at Hamner Ave. Table 4 summarizes recorded discharge plus wastewater treatment plant discharge data. River discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at E St and the wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 1 cfs on July 10th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows plus the wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 27cfs and 43 cfs on July 10th and July 20th, respectively.

Figure 8 shows groundwater elevations for summer 1948 conditions between E St and River Rd. From E St to about RS 102000, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 25 ft-bgs. From RS 102000 to River Rd, groundwater elevations indicate potential gaining conditions.

Figure 9 shows the discharge top width measured from aerial photos, the flow depth estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. The discharge top width varied from about 0 to 241 ft with flow depth varying from about 0 to 2.6 ft. The river was dry from E St to about RS 85000. Table 5 summarizes the measured discharge top width and estimated flow depth for each of the six river reaches shown in Figure 4.

The following text summarizes the discharge top width measurements, estimated flow depths, and any undocumented discharges to or diversions from the river. Appendix B contains the 1948 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

RS 129000 to 106500 [E St to RIX Outfall (future location)]**:** This reach was observed as dry. Some discharge to the river was identified at its confluence with Warm Creek. This discharge from Warm Creek completely percolated into the channel bottom before reaching RS 124000. Another discharge point was identified upstream of RS 120000: a Riverside Canal discharge point that diverted water from Warm Creek. Any discharge to the river from the Riverside Canal completely percolated into the channel bottom before reaching RS 120000.

RS 106500 to 101165 [RIX Outfall (future location) to Riverside Ave]**:** This entire reach was observed as dry.

RS 101165 to 83850 (Riverside Ave to Mission Inn Ave Bridge)**:** This reach was observed as dry except where discharge to the river was observed at RS 84000 (Lake Evans outfall). The discharge top width at RS 84000 was approximately 24 ft wide.

RS 83850 to 56750 (Mission Inn Ave Bridge to Van Buren Blvd)**:** The discharge top width varied from approximately 0 to 139 ft with flow depth varying between approximately 0 and 2.6 ft. River braiding was observed between RS 80000 and 72000. The upstream limit of groundwater contribution to surface water was identified at about RS 80500. This was based on increased vegetation and potentially wet ground observed in aerial photos.

RS 56750 to 18900 (Van Buren Blvd to Hamner Ave)**:** The discharge top width varied from approximately 38 to 241 ft with flow depth varying between approximately 1.2 and 1.9 ft. A diversion point from the river was identified downstream of RS 39000 (irrigation canal).

RS 18900 to 0 (Hamner Ave to River Rd)**:** The discharge top width varied from approximately 15 to 211 ft with flow depth varying between approximately 0.5 and 0.6 ft.

Summer 1952

Aerial photo coverage for 1952 was only available between La Cadena Ave and 1 mi downstream of Market St and from downstream of Van Buren Blvd to below River Rd. Aerial photos were taken on July 11, 1952 and July 31, 1952 for upstream and downstream of Van Buren Blvd, respectively.

Figure 10 shows Santa Ana River discharge from June 30 to July 31, 1952. River discharge at E St was 0 cfs for the month of July. Between June 30th and July 9th, discharge at the

Riverside Narrows averaged approximately 123 cfs and approximately 116 cfs at Hamner Ave. River discharge dropped to approximately 91 cfs at the Riverside Narrows and 88 cfs at Hamner Ave on July 12th. From July 12th to July 31st, discharge varied between 81 and 96 cfs at both the Riverside Narrows and Hamner Ave. Table 6 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated as the sum of the discharge at the Santa Ana River at E St and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 1 cfs on July 11th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows plus wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 128 cfs and 89 cfs on June 30th and July 31st, respectively.

Figure 11 shows groundwater elevations for summer 1952 conditions between E St and River Rd. From E St to about RS 88500, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 60 ft-bgs. From RS 88500 to River Rd, groundwater elevations indicate gaining conditions.

Figure 12 shows the discharge top width measured from aerial photos and the flow depth estimated from historic topographic and river channel LiDAR/survey data. For the available aerial photo coverage, the discharge top width varied from about 0 to 170 ft with the flow depth varying from about 0 to 0.7 ft. Dry reaches were identified between RS 118000 and 89000. Table 7 summarizes the measured discharge top width and the estimated flow depth for each of the six river reaches. The following text summarizes discharge top width measurements, estimated flow depths, and any undocumented discharges to or diversions from the river. Appendix C contains the 1952 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

RS 132200 to 108460 [E St to RIX Outfall (future location)]**:** Aerial photo coverage was partial for this reach. Where aerial photo coverage was available, the river was observed as dry.

RS 108460 to 101800 [RIX Outfall (future location) to Riverside Ave]**:** This entire reach was observed as dry.

RS 101800 to 85750 (Riverside Ave to Mission Inn Ave Bridge)**:** Aerial photo coverage was only available between RS 101000 and 89000. This segment of the river was observed as dry. A discharge point to the river was identified at RS 99000 (storm channel).

***RS 85750to 58480 (Mission Inn Ave Bridge to Van Buren Blvd)*:** No aerial photo coverage.

***RS 58480 to 19550 (Van Buren Blvd to Hamner Ave)*:** The discharge top width varied from approximately 47 to 144 ft with flow depth varying between approximately 0.5 and 0.7 ft. A diversion from the river was identified just downstream of RS 40000 (irrigation canal).

***RS 19550 to 0 (Hamner Ave to River Rd)*:** The discharge top width varied from approximately 26 to 170 ft with flow depth varying between approximately 0.3 and 0.5 ft.

Fall 1953

Aerial photo coverage for 1953 was only available from 1 mi upstream of La Cadena Ave to 0.3 mi downstream of Riverside Ave, from Mission Inn Ave to 0.7 mi downstream of Van Buren Blvd, and from Bain St to below River Rd. Aerial photos were taken on September 22, 1953 and September 23, 1952 for upstream and downstream of Van Buren Blvd, respectively.

Figure 13 shows Santa Ana River discharge for September 1953. Zero discharge was recorded at E St in September. At both the Riverside Narrows and Hamner Ave, discharge was fairly constant at approximately 111 cfs. Table 8 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at E St and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 1 cfs on September 22nd. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows plus wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 126 cfs on September 23rd.

Figure 14 shows groundwater elevations for fall 1953 conditions between E St and River Rd. From E St to about RS 86000, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 80 ft-bgs. From RS 86000 to River Rd, groundwater elevations indicate gaining conditions.

Figure 15 shows the discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. The discharge top width varied from about 0 to 132 ft, and flow depth varied from about 0 to 2.9 ft. Dry reaches were identified between RS 123000 and 114000, RS 104000 and 101000, and RS

86000 and 80000. Table 9 summarizes the measured discharge top width and estimated flow depths for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depths, and any undocumented discharges to or diversions from the river. Appendix D contains the 1953 aerial photos zoomed in at scale of 1:300 and annotated with river stations, left and right banks, and discharges and diversions.

***RS 132100 to 109000 [E St to RIX Outfall (future location)]*:** Aerial photo coverage was partial for this reach. A dry segment of the river was identified between RS 123000 and 114000. Where there was aerial photo coverage, the discharge top width varied from approximately 0 to 54 ft. Flow depth was not measured for this reach. A discharge point to the river was identified at RS 113000 (canal).

***RS 109000 to 102540 [RIX Outfall (future location) to Riverside Ave]*:** The river was observed as dry between RS 104000 and 103000. The discharge top width varied from approximately 0 to 20 ft and flow depth varied between approximately 0 and 0.6 ft.

***RS 102540 to 86360 (Riverside Ave to Mission Inn Ave Bridge)*:** Aerial photo coverage was only available between RS 102000 and 101000. Where aerial photo coverage was available, the river was observed as dry.

***RS 86360 to 58855 (Mission Inn Ave Bridge to Van Buren Blvd)*:** The river was observed as dry between RS 86000 and 80000. The discharge top width varied from approximately 0 to 118 ft with flow depth varying between 0 and 2.9 ft. RS 84000 was identified as the approximate upstream limit of rising groundwater. Discharge points to the river were identified at RS 79000 (storm channel located along the future site of the Tequesquite Landfill), downstream of RS 74000 (Sunnyslope Channel), and at the MWD Crossing (RS 65175)—a large blowout from the Upper Feeder pipe was captured in the photo.

***RS 58855 to 19525 (Van Buren Blvd to Hamner Ave)*:** There was no aerial photo coverage between RS 54000 and 47000. For the remaining river, the discharge top width varied from approximately 22 to 131 ft with flow depth varying between approximately 0.6 and 0.7 ft. A diversion from the river was identified just downstream of RS 40000 (irrigation canal) and upstream of RS 7000. A discharge point to the river was identified upstream of RS 35000 (City of Riverside WWTP).

***RS 19525 to 0 (Hamner Ave to River Rd)*:** The discharge top width varied from approximately 28 to 132 ft with flow depth varying between approximately 0.2 and 0.5 ft. A discharge point to the river was identified just upstream of RS 4000.

Winter 1954

Aerial photo coverage for 1954 was only available from 1.1 mi upstream of Riverside Ave to 1 mi downstream of Mission Inn Ave and from Van Buren Blvd to Etiwanda Ave. Aerial photos were taken on February 16, 1954 and February 7, 1954 upstream and downstream of Van Buren Blvd, respectively.

Figure 16 shows Santa Ana River discharge for February 1954. Up to February 7th, discharge was constant at about 2 cfs at E St and 39 cfs at the Riverside Narrows. River discharge surged to 145 cfs at E St and 356 cfs at the Riverside Narrows on February 14th. Between February 14th and 16th, discharge averaged about 6 cfs at E St and about 46 cfs at the Riverside Narrows. Table 10 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at E St and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 5 cfs on February 16th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of USGS gage discharge at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 51 cfs on February 7th.

Figure 17 shows groundwater elevations for winter 1954 conditions between E St and River Rd. From E St to about RS 94000, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 60 ft-bgs. From RS 94000 to River Rd, groundwater elevations indicate gaining conditions.

Figure 18 shows the discharge top width measured from aerial photos and the flow depth estimated from historic topographic data. Table 11 summarizes measured discharge top width and estimated flow depth (where data is available) for each of the six river reaches. Appendix E contains all of the 1954 aerial photos zoomed in at scale of 1:300 and annotated with river stations, left and right banks, and discharges and diversions.

The discharge top width and estimated flow depth were only determined for a segment of the river from Van Buren Blvd to Hamner Ave. The discharge top width varied from about 36 to 88 ft with a single depth measurement of 2.6 ft estimated at Van Buren Blvd. Between the future RIX outfall discharge point and the Mission Inn Ave Bridge, the aerial photos show evidence of the river being inundated with flood waters. The river in this reach was heavily braided with segments reaching approximately 400 ft wide. A diversion from the river was identified just downstream of RS 40000 (irrigation canal). Discharge points to the river were identified at RS 100000 (storm channel located along the future site of the Tequesquite Landfill) and just downstream of RS 36000 (City of Riverside WWTP).

Fall 1959

Aerial photo coverage for 1959 was complete from 0.8 mi upstream of Riverside Ave to River Rd. Aerial photos were taken on October 15, 1959 and November 6, 1959 upstream

of Van Buren Blvd and between October 15-16, 1959 and on November 6, 1959 downstream of Van Buren Blvd.

Figure 19 shows Santa Ana River discharge from October to November. Between October 1st and 16th, discharge averaged about 2 cfs at Waterman Ave (USGS gage 11056200) and was fairly constant at about 19 cfs at the Riverside Narrows. At Hamner Ave, discharge was variable between 17 and 21 cfs prior to October 16th. On November 3rd, discharge surged to 22 cfs at Waterman Ave, 45 cfs at the Riverside Narrows, and 32 cfs at Hamner Ave. Table 12 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at Waterman Ave and wastewater discharges by the Cities of San Bernardino, Rialto, and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 22 cfs on October 15th and 16th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS discharge estimate at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 31 and 36 cfs on October 16th and November 6th, respectively.

Figure 20 shows groundwater elevations for fall 1959 conditions between E St and River Rd. From E St to about Mission Inn Ave Bridge, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 150 ft-bgs. Downstream of RS 83000 to River Rd, groundwater elevations indicate gaining conditions. A small reach of the river between RS 66000 and 38000 exhibits minor losing conditions with groundwater levels up to 10 ft-bgs.

Figure 21 shows the discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. The discharge top width varied from about 0 to 117 ft, and flow depth varied from about 0 to 1.9 ft. Dry reaches were identified between RS 101000 and 77000 and at RS 34000. Table 13 summarizes the measured discharge top width and estimated flow depth for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depths, and any undocumented discharges to or diversions from the river. Appendix F contains the 1959 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

RS 128330 to 105820 [E St to RIX Outfall (future location)]**:** No aerial photo coverage.

RS 105820 to 99000 [RIX Outfall (future location) to Riverside Ave]**:** This river reach had partial aerial photo coverage. Discharge was only observed between RS 103000 and

102000 with an average discharge top width of approximately 11 ft and flow depth of approximately 1.0 ft. From RS 101000 to 99000, the river was observed as dry.

***RS 99000 to 83000 (Riverside Ave to Mission Inn Ave Blvd)*:** This entire reach was observed as dry.

***RS 83000 to 55465 (Mission Inn Ave Bridge to Van Buren Blvd)*:** The river was observed as dry between RS 83000 and 77000. The discharge top width varied from approximately 0 to 56 ft with flow depth varying between approximately 0 and 1.9 ft. The discharge top width was difficult to distinguish due to poor resolution aerial photographs, dense vegetation, and channel braiding. We identified the upstream start of dense vegetation at RS 78000 to be the approximate upstream limit of groundwater and surface water interaction. A discharge point was identified just downstream of RS 76000 (storm channel located along the future site of the Tequesquite Landfill).

***RS 55465 to 19915 (Van Buren Blvd to Hamner Ave)*:** The discharge top width varied from approximately 0 to 55 ft with flow depth varying between approximately 0 and 0.6 ft. The discharge top width was not measured for several river stations due to the lack of a clearly defined channel in the aerial photos. A dry reach was identified between RS 35000 and 34000. River diversions were identified downstream of RS 47000 (canal) and at RS 39000 (irrigation canal). A discharge point to the river was identified at RS 44000 and from an earthen embankment located just east of RS 34000.

***RS 19915 to 0 (Hamner Ave to River Rd)*:** The discharge top width varied from approximately 37 to 117 ft with flow depth varying between approximately 0.1 and 0.5 ft.

Winter 1962

Aerial photo coverage for 1962 was complete from 0.5 mi upstream of Riverside Ave to River Rd. Aerial photos were taken on January 30, 1962 between River Rd and the 60 freeway and on January 28, 1962 from 0.5 mi upstream of Riverside Ave to the 60 freeway.

Figure 22 shows Santa Ana River discharge for the month of January. Between January 1st and 19th, discharge averaged about 23 cfs at Colton Ave (USGS gage 11066050) and about 25 cfs at the Riverside Narrows. River discharge surged to about 244 cfs at Colton Ave and to about 296 cfs at the Riverside Narrows between January 20th and 21st. From January 23rd to the end of the month, discharge averaged about 20 cfs at Colton Ave and about 34 cfs at the Riverside Narrows. Table 14 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at Colton Ave and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 22 cfs on

January 30th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 42 cfs on January 30th.

Figure 23 shows groundwater elevations for winter 1962 conditions between E St and River Rd. From E St to about Mission Inn Ave Bridge, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 100 ft-bgs. Downstream of RS 83000 to River Rd, groundwater elevations indicate predominantly gaining conditions. A small reach of the river between RS 66000 and 42000 exhibits losing conditions with groundwater levels up to about 15 ft-bgs.

Figure 24 shows the discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. For the river reach between Riverside Ave and River Rd, discharge top width varied from about 0 to 130 ft. River flow depth varied from about 0 to 1.5 ft. Dry reaches were identified between RS 101000 and 90000, at RS 86000, and between RS 80000 and 77000. Table 15 summarizes measured discharge top width and estimated flow depth for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depth, and any undocumented discharges to or diversions from the river. Appendix G contains the 1962 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

***RS 129325 to 105800 [E St to RIX Outfall (future location)]*:** No aerial photo coverage.

***RS 105800 to 99000 [RIX Outfall (future location) to Riverside Ave]*:** This reach had partial aerial photo coverage between RS 101000 and 99000. Where aerial photo coverage was available, the river was observed as dry.

***RS 99000 to 83000 (Riverside Ave to Mission Inn Ave Bridge)*:** The river was observed as dry between RS 98000 and 90000 and at RS 86000. Where river discharge was observed in this reach, the discharge top width varied from approximately 0 to 36 ft with flow depths varying between approximately 0 and 0.8 ft. River banks were difficult to identify in this reach due to discontinuous river flow patterns.

RS 83000 to 55500 *(Mission Inn Ave Bridge to Van Buren Blvd)*: The river was observed as dry between RS 80000 and 77000. The discharge top width varied from approximately 0 to 75 ft with flow depths varying between approximately 0 and 1.5 ft. River banks were difficult to distinguish in this reach due to poor resolution aerial photographs and channel braiding. We identified the upstream start of dense vegetation at RS 80000 to be the approximate upstream limit of groundwater and surface water interaction. A discharge

point to the river was identified just downstream of RS 76000 (storm channel located along the future site of the Tequesquite Landfill).

***RS 55500 to 19735 (Van Buren Blvd to Hamner Ave)*:** The discharge top width varied from approximately 8 to 75 ft with flow depth varying between approximately 0.3 and 1.5 ft. River banks were difficult to distinguish in some segments of this reach due to poor aerial photo resolution, heavy vegetation, and/or channel braiding. Diversions from the river were identified just downstream of RS 39000 (irrigation canal) and 19000 (canal). Discharge points to river were identified at RS 44000 and 33000.

***RS 19735 to 0 (Hamner Ave to River Rd)*:** River banks were difficult to distinguish in this reach due to poor resolution aerial photographs. Where identified, discharge top width varied from approximately 39 to 130 ft with a flow depth approximately 0.4 ft. A diversion was identified just downstream of RS 19000. Discharge points to the river were identified at RS 1000 and upstream of RS 0.

Spring 1966

Aerial photo coverage for 1966 was complete between E St and River Rd. All aerial photos were taken on April 16, 1966.

Figure 25 shows Santa Ana River discharge for the month of April. From April 1st to the 16th, discharge averaged about 31 cfs at Colton Ave and about 24 cfs at the Riverside Narrows. Table 16 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at Colton Ave and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 40 cfs on April 16th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 42 cfs on April 16th.

Figure 26 shows groundwater elevations for spring 1966 conditions between E St and River Rd. From E St to just downstream of Mission Inn Ave Bridge, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 90 ft-bgs. Downstream of RS 76000, groundwater elevations indicate predominantly gaining conditions. A small reach of the river between RS 10000 and 22000 exhibits losing conditions with groundwater levels up to about 20 ft-bgs.

Figure 27 shows the discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the

approximate upstream limit of surface water and groundwater interaction. For the river reach between E St and River Rd, the discharge top width varied from about 7 to 197 ft. River flow depth varied from about 0.1 to 1.9 ft. Table 17 summarizes measured discharge top width and estimated flow depth for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depths, and any undocumented discharges to or diversions from the river. Appendix H contains the 1966 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

RS 127735 to 103600 [E St to RIX Outfall (future location)]**:** The discharge top width varied from approximately 24 to 197 ft. Flow depth was not measured for this reach. River flow patterns varied from a single river channel to a braided river. Discharge points to the river were identified at RS 129000 (East Twin Creek – City of San Bernardino WWTP), RS 123000 (Warm Creek discharge), and RS 110000 (City of Colton WWTP).

RS 103600 to 96870 [RIX Outfall (future location) to Riverside Ave]**:** The discharge top width varied from approximately 15 to 184 ft and flow depth was approximately 0.8 ft. River flow was predominantly in braided channels.

RS 96870 to 79590 (Riverside Ave to Mission Inn Ave Bridge)**:** The discharge top width varied from approximately 12 to 54 ft with flow depths varying between approximately 0.3 and 0.9 ft. River flow patterns varied from a single river channel to a braided river. Some discharge to the river was identified upstream of RS 93000 (storm channel).

RS 79590 to 52680 (Mission Inn Ave Bridge to Van Buren Blvd)**:** The discharge top width varied from approximately 7 to 112 ft with flow depth varying between approximately 0.1 and 1.9 ft. River flow patterns varied from a single river channel to a braided channel with discontinuous flow observed between RS 72000 and 68000. Between RS 73000 and 69000, the channel showed evidence of wet ground. The upstream start of the observed wet ground also potentially marked the upstream limit of groundwater contribution to the river. The wet ground and narrow channel may be the result of discharge upstream of RS 71000 (storm channel located along the future site of the Tequesquite Landfill).

RS 52680 to 16580 (Van Buren Blvd to Hamner Ave)**:** The discharge top width varied from approximately 16 to 131 ft with flow depth varying between approximately 0.5 to 1.3 ft. Diversions from the river were identified just upstream of RS 52000 and 36000 (irrigation canal). Discharge points to the river were identified upstream of RS 49000 (City of Riverside WWTP) and downstream of RS 44000, RS 37000 (irrigation canal), RS 33000 (irrigation canal), and RS 31000 (discharge from Hole Lake through a canal).

RS 16580 to 0 (Hamner Ave to River Rd)**:** The discharge top width varied from approximately 43 to 146 ft with flow depth varying between approximately 0.2 and 0.5 ft. A

diversion was identified downstream of RS 16000. Discharge points to the river were identified upstream of RS 14000, 7000, and 1000. A levee dividing the river was observed in the aerial photos between RS 14000 and 11000.

Spring 1967

Aerial photo coverage for 1967 was complete from 1.3 miles downstream of E St to River Rd. Most of the aerial photos were taken on May 15, 1967; the section of river between La Cadena Ave and Riverside Ave was photographed on July 15, 1967.

Figure 28 shows Santa Ana River discharge from May to July. For the early part of May, discharge was constant at about 9 cfs at E St and about 22 cfs at the Riverside Narrows. For the week prior to July 15th, discharge varied between 6 and 10 cfs at E St and between 40 and 44 cfs at the Riverside Narrows. Table 18 summarizes recorded discharge plus wastewater treatment plant discharge data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at E St and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 15 cfs on May 15th and July 15th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 45 cfs on May 15th.

Figure 29 shows groundwater elevations for spring 1967 conditions between E St and River Rd. From E St to just downstream of Mission Inn Ave Bridge, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 70 ft-bgs. Downstream of RS 76000, groundwater elevations indicate gaining conditions.

Figure 30 shows ths discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. The discharge top width varied from about 0 to 161 ft. Flow depth varied from about 0 to 2 ft. A dry reach was identified between RS 76000 and 75000. Table 19 summarizes measured discharge top width and estimated flow depths for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depth, and any undocumented discharges to or diversions from the river. Appendix I contains the 1967 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

***RS 129000 to 105000 [E St to RIX Outfall (future location)]*:** The discharge top width varied from approximately 23 to 144 ft. River flow depth was not measured for this reach.

River flow patterns varied from a single river channel to a braided river. Discharge points to the river were identified at RS 109000 (canal) and west of RS 108000.

***RS 104000 to 98212 [RIX Outfall (future location) to Riverside Ave]*:** The discharge top width varied from approximately 35 to 94 ft with flow depth varying between approximately 1.1 and 1.6 ft.

***RS 98212 to 81730 (Riverside Ave to Mission Inn Ave Blvd)*:** The discharge top width varied from approximately 6 to 18 ft with river flow depth varying between 0.2 and 0.9 ft. River flow patterns varied from a single river channel to a braided river.

***RS 81730 to 54500 (Mission Inn Ave Blvd to Van Buren Blvd)*:** The discharge top width varied from approximately 0 to 161 ft with flow depth varying between approximately 0 and 2 ft. A dry reach was identified between RS 76000 and 74000. River flow patterns varied from a single river channel to a braided river. Between RS 74000 and 67000, the channel showed evidence of wet ground. The upstream start of this observed wet ground may potentially mark the upstream limit of groundwater contribution to the river. The wet ground and narrow channel may also be the result of discharge at RS 74000 (storm channel located along the future site of the Tequesquite Landfill). Another discharge point was identified upstream of RS 72000.

***RS 54500 to 17921 (Van Buren Blvd to Hamner Ave)*:** The discharge top width varied from approximately 20 to 102 ft with flow depth varying between approximately 0.1 and 0.3 ft. River diversions were identified just upstream of RS 54000 and 37000 (irrigation canal). Discharge points to the river were identified at RS 51000 (City of Riverside WWTP) and downstream of RS 35000 (canal).

***RS 17921 to 0 (Hamner Ave to River Rd)*:** The discharge top width varied from approximately 18 to 158 ft with flow depth varying between approximately 0.3 and 0.8 ft. A diversion was identified downstream of RS 17000. Discharge points to the river were identified downstream of RS 15000 and 4000.

Summer 1974

Aerial photo coverage for 1974 was complete from Riverside Ave to River Rd. All aerial photos were taken on May 24, 1974.

Figure 31 shows Santa Ana River discharge for May 1974. From May 1st to the 24th, river discharge at E St varied between 18 and 26 cfs. River discharge was fairly constant at MWD Crossing (USGS gage 11066460), varying between 25 and 29 cfs. At Mission Inn Ave Bridge (USGS gage 11066440), zero discharge was recorded for the entire month of May. Table 20 summarizes recorded discharge plus wastewater treatment plant data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana

River at E St and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 33 cfs on May 24th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 52 cfs on May 24th.

Figure 32 shows groundwater elevations for summer 1974 conditions between E St and River Rd. From E St to about RS 84000, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 55 ft-bgs. From RS 84000 to River Rd, groundwater elevations indicate gaining conditions.

Figure 33 shows the discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. The discharge top width varied from about 0 to 170 ft with estimated flow depth varying from about 0 to 1.8 ft. Dry reaches were observed between RS 82000 and 80000 and between RS 76000 and 73000. Table 21 summarizes the measured discharge top width and estimated flow depths for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depths, and any undocumented discharges to or diversions from the river. Appendix J contains the 1974 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

***RS 127325 to 103270 (E St to RIX Outfall [future location])*:** No aerial photo coverage.

***RS 103270 to 96360 (RIX Outfall [future location] to Riverside Ave)*:** The discharge top width varied from approximately 30 to 92 ft with river flow depth varying between approximately 0.4 and 1.3 ft.

***RS 96360 to 79620 (Riverside Ave to Mission Inn Ave Bridge)*:** Between RS 96000 and 83000, the discharge top width varied from approximately 0 to 78 ft with river flow depth varying between approximately 0 and 1.8 ft. Between RS 82000 and 80000, the river was observed as dry. A discharge point to the river was identified just upstream of RS 93000 (storm channel).

***RS 79620 to 53000 (Mission Inn Ave Blvd to Van Buren Blvd)*:** The river was observed as dry at RS 79000 and from RS 76000 to 73000. From RS 78000 to 77000, the discharge top width varied between approximately 8 and 25 ft. River discharge observed between RS 78000 and 77000 was the result of discharge from the Lake Evans outfall (RS 79000) and possibly rising groundwater. The upstream limit of groundwater contribution to the river

was identified at about RS 80500. This was based on increased vegetation and potentially wet ground observed in the aerial photos. From RS 72000 to 53000, the discharge top width varied from approximately 12 to 170 ft with flow depth varying between 0.1 and 1.5 ft. Some river braiding was noted between RS 67000 and 64000. A discharge point to the river was identified just upstream of RS 73000 (storm channel located along the future site of the Tequesquite Landfill).

***RS 53000 to 17085 (Van Buren Blvd to Hamner Ave)*:** The discharge top width varied from approximately 20 to 109 ft with flow depth varying between 0.5 and 1.5 ft. River braiding was noted between RS 23000 and 19000. A discharge point to the river was identified at RS 37000 (City of Riverside WWTP). An embankment located in the channel, about 225 ft wide, was identified at approximately RS 50500.

***RS 17085 to 0 (Hamner Ave to River Rd)*:** The discharge top width varied from approximately 22 to 116 ft with flow depth varying between approximately 0.3 and 0.5 ft.

Summer 1977

Aerial photo coverage for 1977 was complete from 0.6 mi downstream of E St to River Rd. All aerial photos were taken on May 20, 1977.

Figure 34 shows Santa Ana River discharge for the month of May. A large discharge event was recorded on May 9th: river discharge was 90 cfs at E St, 1,640 cfs at Mission Inn Ave Bridge, and 504 cfs at MWD Crossing. After May 11th, discharge averaged about 24 cfs at E St, 0 cfs at Mission Inn Ave Bridge, and 29 cfs at MWD Crossing. Table 22 summarizes recorded discharge plus wastewater treatment plant data. Discharge above the Riverside Narrows was approximated by the sum of the discharge at the Santa Ana River at E St and wastewater discharges by the Cities of Rialto and Colton. Using this approach, discharge to the Santa Ana River upstream from the Riverside Narrows was estimated to be at least 30 cfs on May 20th. Santa Ana River discharge below the Riverside Narrows was estimated as the sum of the USGS gage discharge at the Riverside Narrows and wastewater discharge from the City of Riverside. Using this approach, discharge to the Santa Ana River just downstream of the Riverside Narrows was estimated to be at least 55 cfs on May 20th.

Figure 35 shows groundwater elevations for summer 1977 conditions between E St and River Rd. From E St to about RS 80000, the Santa Ana River was a losing stream with groundwater levels ranging from near ground surface to approximately 72 ft-bgs. From RS 80000 to River Rd, groundwater elevations indicate gaining conditions.

Figure 36 shows the discharge top width measured from aerial photos, flow depths estimated from historic topographic and river channel LiDAR/survey data, as well as the approximate upstream limit of surface water and groundwater interaction. The discharge

top width varied from about 0 to 158 ft with estimated flow depth varying from about 0 to 0.9 ft. Dry reaches were observed between RS 90000 and 83000 as well as between RS 80000 and 77000. Table 23 summarizes the measured discharge top width and estimated flow depths for each of the six river reaches. The following text summarizes the discharge top width measurements, estimated flow depth, and any undocumented discharges to or diversions from the river. Appendix K contains the 1977 aerial photos zoomed in at scale of 1:300 and annotated with the river stations, left and right banks, and discharges and diversions.

RS 129000 to 104720 (E St to RIX Outfall [future location])**:** The discharge top width varied from approximately 10 to 158 ft. River flow depth was not estimated for this reach. Between RS 126000 and 123000, no single channel was identified, but the observed wetted top width reached about 430 ft. River flow patterns observed in this reach varied from a single channel to a braided river. Discharge points to the river were identified just upstream of RS 111000 (City of Colton WWTP) and just downstream of RS 106000 (City of Rialto WWTP).

RS 104720 to 98110 (RIX Outfall [future location] to Riverside Ave)**:** The discharge top width varied from approximately 7 to 17 ft with flow depth varying between approximately 0.3 and 0.6 ft.

RS 98110 to 82000 (Riverside Ave to Mission Inn Ave Bridge)**:** Between RS 98000 and 91000, river flow patterns were observed to be braided and discontinuous. Where flow was observed, top width varied from approximately 0 to 18 ft with river flow depth varying between approximately 0 and 0.3 ft. From RS 90000 to 83000, the river was observed to be dry. At RS 82000, flow was observed in the channel, but the source of discharge was identified to be from the Lake Evans outfall, which is just upstream of RS 82000. Another discharge point was identified upstream of RS 94000 (storm channel).

RS 82000 to 54430 (Mission Inn Ave Bridge to Van Buren Blvd)**:** River discharge was observed at RS 82000 (Lake Evans outfall), but the river was dry from RS 80000 to 77000. The upstream limit of groundwater contribution to the river was identified at approximately RS 77000, based on wet ground and heavy vegetation observed in aerial photos. From RS 76000, the discharge top width varied from approximately 0 to 91 ft with river flow depth varying between approximately 0 and 0.9 ft. Discharge points to the river were observed at RS 75000 (storm channel located along the future site of the Tequesquite Landfill) and downstream from RS 61000 (runoff from the river's side slopes).

RS 54430 to 17225 (Van Buren Blvd to Hamner Ave)**:** The discharge top width varied from approximately 25 to 87 ft with river flow depth varying between approximately 0.5 and 0.9 ft. A discharge point to the river was observed just upstream of RS 53000 (discharge from Hole Lake).

RS 17225 to 0 (Hamner Ave to River Rd): The discharge top width varied from approximately 25 to 102 ft with depth varying between approximately 0.4 and 0.5 ft. A diversion was observed just downstream of RS 16000.

Conclusions

This investigation analyzed the historical dry-weather hydrology of the Santa Ana River for the time period between 1938 and 1977. Aerial photos, topographic maps, surface water discharge, groundwater levels, and wastewater treatment plant discharge data were used to analyze and document changes in historic Santa Ana River dry-weather hydrology. The following summarizes the analyses and observations made in this investigation:

1. Aerial photo analysis was an adequate tool for identifying river flow patterns, wet and dry reaches, river discharge top width, discharges to the river, and diversions from the river. The limitations in using historic aerial photos to identify channel banks are a lack of photo coverage, photo scale, poor resolution, and/or gray-scale contrast.

2. There was a limitation in using historic topographic maps (with a contour interval of 4 ft) to estimate flow depths: river flow depths that measured less than 0.5 ft were considered to be below the resolution of the topographic maps.

3. The period from 1945 to 1976 was a prolonged dry period in the Santa Ana River region and therefore represents a critical habitat period for aquatic creatures dependent on the Santa Ana River.

4. The Santa Ana River, between E St and Mission Inn Ave Bridge was typically a narrow, shifting, and braided channel with discontinuous discharge, and dry segments.

5. Dry and/or discontinuous river segments (where photo coverage was available) upstream of Mission Inn Ave Bridge were identified in the 1948, 1952, 1953, 1959, 1962, 1974, and 1977 aerial photographs.

6. The Santa Ana River downstream of Mission Inn Ave Bridge was typically a wider single channel that shifted but had continuous discharge due to rising groundwater and wastewater discharges.

7. Upstream of Mission Inn Ave Bridge, the Santa Ana River discharge top width ranged between 0 and 180 ft. River flow depth ranged between 0 and 2 ft and was mostly below 0.5 ft when discharge was observed in the photos.

8. Downstream of Mission Inn Ave Bridge, the Santa Ana River discharge top width ranged between 0 and 240 ft. River flow depth ranged between 0 and 3 ft and was mostly below 1 ft.

9. The river channel alignment from E St to River Rd was variable between 1938 and 1977.

10. The tail-end of flooding events in the Santa Ana River was visible in the 1938 and 1954 aerial photos.

11. The upstream limit of groundwater contribution to the river was about 0.75 mi upstream of Mission Inn Ave, and based on groundwater elevation data, rising groundwater was identified through to River Rd.

12. Various unknown or undocumented discharges to and diversions from the river were identified in most reaches for every photo year analyzed.

We appreciate the opportunity to assist in this hydrologic analysis of the Santa Ana River. Please contact me or Mark Wildermuth if you have any questions, comments, or concerns.

Wildermuth Environmental, Inc.

Mike Blazevic, PG
Senior Scientist I

Mark J. Wildermuth, PE
President and Principal Engineer

Enclosures:

Tables 1 through 23

Figures 1 through 36

Appendix A – 1938 aerial photos (Disk)

Appendix B – 1948 aerial photos (Disk)

Appendix C – 1952 aerial photos (Disk)

Appendix D – 1953 aerial photos (Disk)

Appendix E – 1954 aerial photos (Disk)

Appendix F – 1959 aerial photos (Disk)

Appendix G – 1962 aerial photos (Disk)

Appendix H – 1966 aerial photos (Disk)

Appendix I – 1967 aerial photos (Disk)

Appendix J – 1974 aerial photos (Disk)

Appendix K – 1977 aerial photos (Disk)

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Tables

Tables 1 through 23

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Table 1
Historical Aerial Photo Availability for the Santa Ana River Between E St and River Rd

Aerial Photo Date	Aerial Photo Coverage for the River Reaches						Photo Source
	E St to RIX Outfall	RIX Outfall to Riverside Ave	Riverside Ave to Mission Inn Ave	Mission Inn Ave to Van Buren Blvd	Van Buren Blvd to Hamner Ave	Hamner Ave to River Rd	
Summer 1938	×	×	×	✓	✓	×	UCSB
Summer 1948	✓	✓	✓	✓	✓	✓	USGS
Summer 1952	×	✓	×	×	✓	✓	USGS
Fall 1953	×	✓	×	✓	×	✓	UCSB
Winter 1954	×	✓	✓	×	×	×	UCSB
Fall 1959	×	×	✓	✓	✓	✓	UCSB
Winter 1962	×	×	✓	✓	✓	✓	RCFCWCD
Spring 1966	✓	✓	✓	✓	✓	✓	USGS
Spring 1967	×	✓	✓	✓	✓	✓	UCSB
Summer 1974	×	✓	✓	✓	✓	✓	RCFCWCD
Summer 1977	×	✓	✓	✓	✓	✓	UCSB

✓ Complete photo coverage

× Incomplete photo coverage

Table 2
Historical Topographic Map Availability for the Santa Ana River Between E St and River Rd

River Reach	Topographic Map Year	Source
E St to RIX Outfall	1962, 1964	SBCFCD
RIX Outfall to Riverside Ave	1964, 1996	RCFCWCD
Riverside Ave to Mission Inn Ave	1965, 1968	RCFCWCD
Mission Inn Ave to Van Buren Blvd	1959, 1963, 1965, 1968	RCFCWCD
Van Buren Blvd to Hamner Ave	1958, 1963, 1968	RCFCWCD
Hamner Ave to River Rd	1961, 1968	RCFCWCD

Table 3
Santa Ana River Discharge Summer 1938

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	6/3/1938	99000 to 88000	47 cfs[a]	0.1 cfs[b]	47 cfs
SAR Discharge Above Riverside Narrows	7/5/1938	88000 to 84000	30 cfs[a]	0.1 cfs[b]	30 cfs
SAR Discharge Above Riverside Narrows	5/30/1938	84000 to 54000	48 cfs[a]	0.1 cfs[b]	48 cfs
SAR Discharge Below Riverside Narrows	5/30/1938	54000 to 4000	70 cfs[c]	4 cfs[d]	74 cfs

[a]SAR discharge at USGS gage 11065800 (Warm Crk near Colton)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 4
Santa Ana River Discharge Summer 1948

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	7/10/1948	129000 to 56750	0 cfs[a]	1 cfs[b]	1 cfs
SAR Discharge Below Riverside Narrows	7/10/1948	56750 to 5000	22 cfs[c]	5 cfs[d]	27 cfs
SAR Discharge Below Riverside Narrows	7/20/1948	5000 to 0	38 cfs[c]	5 cfs[d]	43 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 5
Santa Ana River Top Width and Estimated Flow Depth in Summer 1948

Reach No.	Santa Ana River Reach Name	River Station		July-48					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrow									
1	E St to RIX Outfall	129000	106500	0	0	0	0.00	0.00	0.00
2	RIX Outfall to Riverside Ave	106500	101165	0	0	0	0.00	0.00	0.00
3	Riverside Ave to Mission Inn Ave Bridge	101165	83850	0	24	12	No Depth Measurement		
4	Mission Inn Ave Bridge to Van Buren Blvd	83850	56750	0	139	40	0.00	2.56	1.17
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	56750	18900	38	241	100	1.16	1.90	1.53
6	Hamner Ave to River Rd	18900	0	15	211	121	0.52	0.59	0.56

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

Table 6
Santa Ana River Discharge Summer 1952

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	7/11/1952	118000 to 59000	0 cfs[a]	1 cfs[b]	1 cfs
SAR Discharge Below Riverside Narrows	6/30/1952	59000 to 43000 23000 to 0	123 cfs[c]	5 cfs[d]	128 cfs
SAR Discharge Below Riverside Narrows	7/31/1952	43000 to 23000	84 cfs[c]	5 cfs[d]	89 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 7
Santa Ana River Top Width and Estimated Flow Depth in Summer 1952

Reach No.	Santa Ana River Reach Name	River Station		June-52 and July-52					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrow									
1	E St to RIX Outfall[2]	131200	108460	0	0	0	0.00	0.00	0.00
2	RIX Outfall to Riverside Ave	108460	101800	0	0	0	0.00	0.00	0.00
3	Riverside Ave to Mission Inn Ave Bridge[3]	101800	85750	0	0	0	0.00	0.00	0.00
4	Mission Inn Ave Bridge to Van Buren Blvd	85750	58480	No Photo			No Photo		
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave[4]	58480	19550	47	144	84	0.50	0.65	0.57
6	Hamner Ave to River Rd	19550	0	26	170	97	0.28	0.45	0.36

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

[2]No aerial photos available upstream of RS 118000

[3]No aerial photos available between RS 101000 and 87000

[4]No aerial photos available between RS 87000 and 59000

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Table 8
Santa Ana River Discharge Fall 1953

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	9/22/1953	123000 to 59000	0 cfs[a]	1 cfs[b]	1 cfs
SAR Discharge Below Riverside Narrows	9/23/1953	59000 to 0	114 cfs[c]	12 cfs[d]	126 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 9
Santa Ana River Top Width and Estimated Flow Depth in Fall 1953

Reach No.	Santa Ana River Reach Name	River Station		September-53					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrow									
1	E St to RIX Outfall[2]	132100	109000	0	54	27	Depth Not Measured		
2	RIX Outfall to Riverside Ave	109000	102540	0	20	10	0.00	0.55	0.38
3	Riverside Ave to Mission Inn Ave Bridge[3]	102540	86360	0	0	0	0.00	0.00	0.00
4	Mission Inn Ave Bridge to Van Buren Blvd	86360	58855	0	118	44	0.00	2.86	1.33
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave[4]	58855	19525	22	131	77	0.56	0.65	0.60
6	Hamner Ave to River Rd	19525	0	28	132	87	0.22	0.45	0.34

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

[2]No aerial photos available upstream of RS 123000

[3]No aerial photos available between RS 101000 and 87000

[4]No aerial photos available between RS 55000 and 47000

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Table 10
Santa Ana River Discharge Winter 1954

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	2/16/1954	108000 to 58000	3.8 cfs[a]	1 cfs[b]	5 cfs
SAR Discharge Below Riverside Narrows	2/7/1954	58000 to 36000	39 cfs[c]	12 cfs[d]	51 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 11
Santa Ana River Top Width and Estimated Flow Depth in Winter 1954

Reach No.	Santa Ana River Reach Name	River Station		February-54					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrow									
1	E St to RIX Outfall	132100	109000	No Photo			No Photo		
2	RIX Outfall to Riverside Ave[2]	109000	102540	Not Determined			Not Determined		
3	Riverside Ave to Mission Inn Ave Bridge[2]	102540	86360	Not Determined			Not Determined		
4	Mission Inn Ave Bridge to Van Buren Blvd	86360	58855	No Photo			No Photo		
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave[3]	58855	19525	36	88	61	2.64	2.64	2.64
6	Hamner Ave to River Rd	19525	0	No Photo			No Photo		

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

[2]Aerial photos show evidence for flooding, and subsequesntly width and depth were not determined

[3]No aerial photos available between RS 35000 and 20000

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Table 12
Santa Ana River Discharge Fall 1959

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	10/15/1959	103000 to 84000	2.3 cfs[a]	20 cfs[b]	22 cfs
SAR Discharge Above Riverside Narrows	11/6/1959	84000 to 55000	1.9 cfs[a]	20 cfs[b]	22 cfs
SAR Discharge Below Riverside Narrows	10/15/1959	55000 to 24000	21 cfs[c]	11 cfs[d]	32 cfs
SAR Discharge Below Riverside Narrows	10/16/1959	24000 to 8000	20 cfs[c]	11 cfs[d]	31 cfs
SAR Discharge Below Riverside Narrows	11/6/1959	8000 to 0	25 cfs[c]	11 cfs[d]	36 cfs

[a]SAR discharge at USGS gage 11056200 (SAR at Waterman Ave)

[b]Discharge to SAR from Cities of San Bernardino, Colton, and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

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Table 13
Santa Ana River Top Width and Estimated Flow Depth in Fall 1959

Reach No.	Santa Ana River Reach Name	River Station		October-59					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrows									
1	E St to RIX Outfall	128330	105820	No Photo			No Photo		
2	RIX Outfall to Riverside Ave	105820	99000	0	22	11	0.77	1.13	0.95
3	Riverside Ave to Mission Inn Ave Bridge	99000	83000	0	0	0	0.00	0.00	0.00
4	Mission Inn Ave Bridge to Van Buren Blvd	83000	55465	0	56	17	0.00	1.90	1.04
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	55465	19915	0	55	19	0.00	0.56	0.42
6	Hamner Ave to River Rd	19915	0	37	117	69	0.10	0.46	0.28

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

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Table 14
Santa Ana River Discharge Winter 1962

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	1/28/1962	101000 to 86000	17 cfs[a]	4 cfs[b]	21 cfs
SAR Discharge Above Riverside Narrows	1/30/1962	86000 to 55500	18 cfs[a]	4 cfs[b]	22 cfs
SAR Discharge Below Riverside Narrows	1/30/1962	55400 to 0	28 cfs[c]	14 cfs[d]	42 cfs

[a]SAR discharge at USGS gage 11066050 (SAR at Colton Ave)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 15
Santa Ana River Top Width and Estimated Flow Depth in Winter 1962

Reach No.	Santa Ana River Reach Name	River Station		January-62					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrows									
1	E St to RIX Outfall	129325	105800	No Photo			No Photo		
2	RIX Outfall to Riverside Ave	105800	99000	0	0	0	0.00	0.00	0.00
3	Riverside Ave to Mission Inn Ave Bridge	99000	83000	0	36	8	0.00	0.80	0.40
4	Mission Inn Ave Bridge to Van Buren Blvd	83000	55500	0	75	29	0.00	1.46	0.73
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	55500	19735	8	75	38	0.27	1.46	0.73
6	Hamner Ave to River Rd	19735	0	39	130	74	0.36	0.37	0.37

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

Table 16
Santa Ana River Discharge Spring 1966

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	4/16/1966	129000 to 52700	34 cfs[a]	6 cfs[b]	40 cfs
SAR Discharge Below Riverside Narrows	4/16/1966	52600 to 0	21 cfs[c]	21 cfs[d]	42 cfs

[a]SAR discharge at USGS gage 11066050 (SAR at Colton Ave)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 17
Santa Ana River Top Width and Estimated Flow Depth in Spring 1966

Reach No.	Santa Ana River Reach Name	River Station		April-66					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrows									
1	E St to RIX Outfall	127735	103600	24	197	90	Depth Not Measured		
2	RIX Outfall to Riverside Ave	103600	96870	15	184	64	0.77	0.77	0.77
3	Riverside Ave to Mission Inn Ave Bridge	96870	79590	12	54	26	0.34	0.93	0.71
4	Mission Inn Ave Bridge to Van Buren Blvd	79590	52680	7	112	33	0.14	1.86	0.59
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	52680	16580	16	131	46	0.45	1.31	0.95
6	Hamner Ave to River Rd	16580	0	43	146	80	0.15	0.54	0.35

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

Table 18
Santa Ana River Discharge Spring 1967

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	5/15/1967	122000 to 118000	9 cfs[a]	6 cfs[b]	15 cfs
SAR Discharge Above Riverside Narrows	7/15/1967	118000 to 101000	9 cfs[a]	6 cfs[b]	15 cfs
SAR Discharge Above Riverside Narrows	5/15/1967	101000 to 55000	9 cfs[a]	6 cfs[b]	15 cfs
SAR Discharge Below Riverside Narrows	5/15/1967	55000 to 0	22 cfs[c]	23 cfs[d]	45 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066500 (SAR at Riverside Narrows)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 19
Santa Ana River Top Width and Estimated Flow Depth in Spring 1967

Reach No.	Santa Ana River Reach Name	River Station		May-67					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrows									
1	E St to RIX Outfall[2,3]	129000	105000	23	144	68	Depth Not Measured		
2	RIX Outfall to Riverside Ave[3]	105000	98212	35	94	66	1.05	1.60	1.33
3	Riverside Ave to Mission Inn Ave Bridge	98212	81730	6	18	8	0.15	0.92	0.34
4	Mission Inn Ave Bridge to Van Buren Blvd	81730	54500	0	161	45	0.00	1.99	1.03
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	54500	17921	20	102	54	0.11	0.33	0.22
6	Hamner Ave to River Rd	17921	0	18	158	66	0.26	0.75	0.51

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

[2]No aerial photos were available from RS 129000 to 121000

[3]Between RS 117000 and 101000 the aerial photos were taken on 7/15/1967

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Table 20
Santa Ana River Discharge Summer 1974

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	5/24/1974	103000 to 53000	26 cfs[a]	7 cfs[b]	33 cfs
SAR Discharge Below Riverside Narrows	5/24/1974	53000 to 0	25 cfs[c]	27 cfs[d]	52 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066460 (SAR at MWD Crossing)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 21
Santa Ana River Top Width and Estimated Flow Depth in Summer 1974

Reach No.	Santa Ana River Reach Name	River Station		May-74					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrow									
1	E St to RIX Outfall	127325	103270	No Photo			No Photo		
2	RIX Outfall to Riverside Ave	103270	96360	30	92	65	0.40	1.31	0.99
3	Riverside Ave to Mission Inn Ave Bridge	96360	79620	0	78	28	0.00	1.77	0.89
4	Mission Inn Ave Bridge to Van Buren Blvd	79620	53000	0	170	50	0.00	1.46	0.73
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	53000	17085	20	109	68	0.48	1.45	0.96
6	Hamner Ave to River Rd	17085	0	22	116	62	0.33	0.45	0.39

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

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Table 22
Santa Ana River Discharge Summer 1977

Reach	Date	River Station	USGS Gage	WWTP	Sum
SAR Discharge Above Riverside Narrows	5/20/1977	126000 to 55000	24 cfs[a]	8 cfs[b]	30 cfs
SAR Discharge Below Riverside Narrows	5/20/1977	55000 to 0	29 cfs[c]	26 cfs[d]	55 cfs

[a]SAR discharge at USGS gage 11059300 (SAR at E St)

[b]Discharge to SAR from Cities of Colton and Rialto WWTP

[c]SAR discharge at USGS gage 11066460 (SAR at MWD Crossing)

[d]Discharge to SAR from City of Riverside WWTP plus rising groundwater

Table 23
Santa Ana River Top Width and Estimated Flow Depth in Summer 1977

Reach No.	Santa Ana River Reach Name	River Station		May-77					
				Top Width (ft)			Depth (ft)[1]		
		From	To	Min	Max	Mean	Min	Max	Mean
Santa Ana River Reach Above Riverside Narrow									
1	E St to RIX Outfall[2]	129000	104720	10	158	89	Depth Not Measured		
2	RIX Outfall to Riverside Ave	104720	98110	7	17	12	0.30	0.64	0.46
3	Riverside Ave to Mission Inn Ave Bridge	98110	82000	0	18	7	0.00	0.27	0.13
4	Mission Inn Ave Bridge to Van Buren Blvd	82000	54430	0	91	39	0.00	0.94	0.47
Santa Ana River Reach Below Riverside Narrows									
5	Van Buren Blvd to Hamner Ave	54430	17225	25	87	49	0.48	0.85	0.66
6	Hamner Ave to River Rd	17225	0	25	102	52	0.36	0.50	0.43

[1]Flow depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

[2]No photo coverage from RS 129000 to 126000

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Figures

Figures 1 through 36

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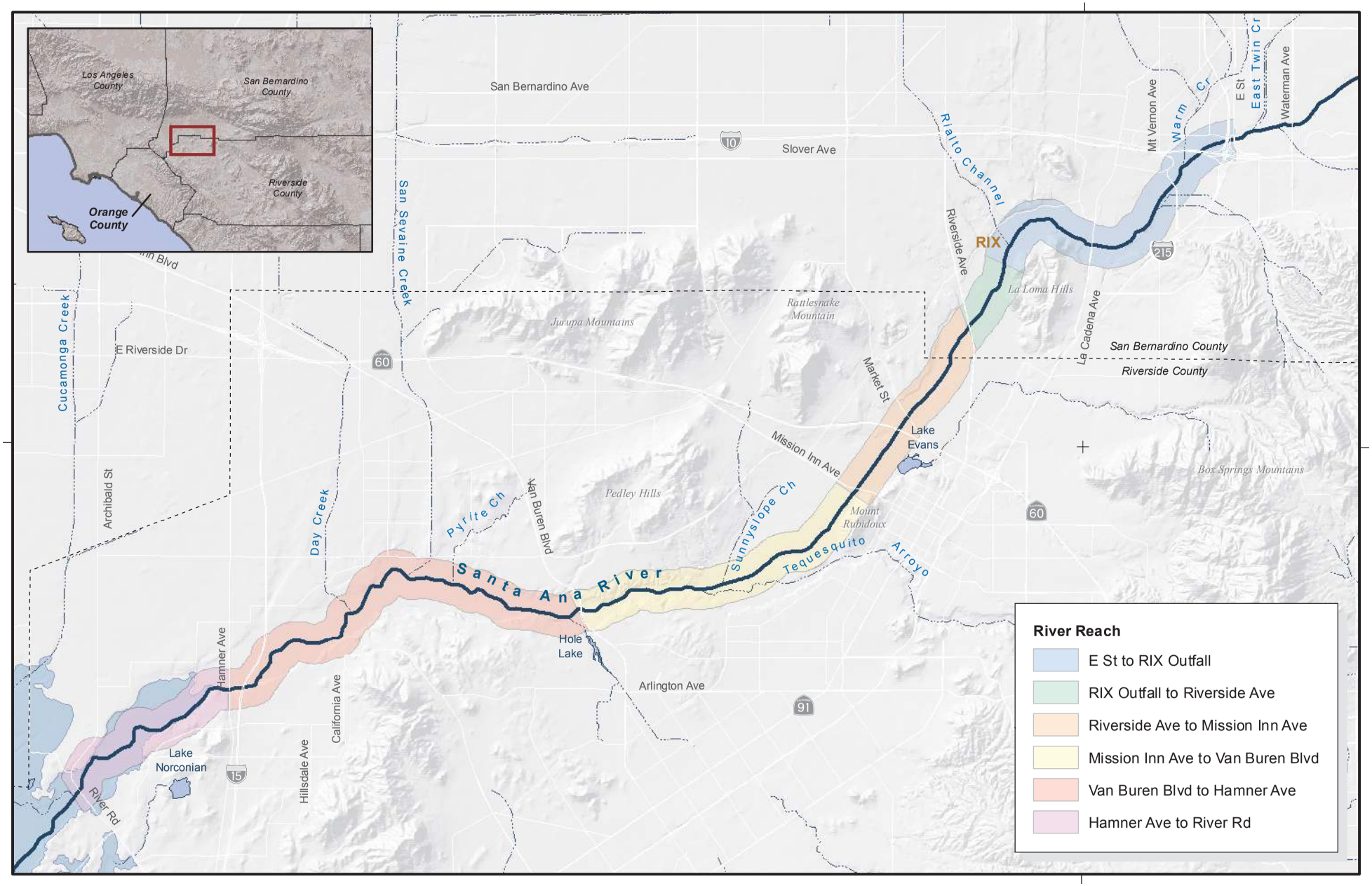

Produced by:

WILDERMUTH ENVIRONMENTAL INC.

23692 Birtcher Drive
Lake Forest, CA 92630
949.420.3030
www.wildermuthenvironmental.com

Author: MAB
Date: 5/17/2013
File: LocationMap.mxd

0 1 2 3 Miles
0 2 4 Kilometers

Location Map

Santa Ana River (E St to River Rd)

Figure 1

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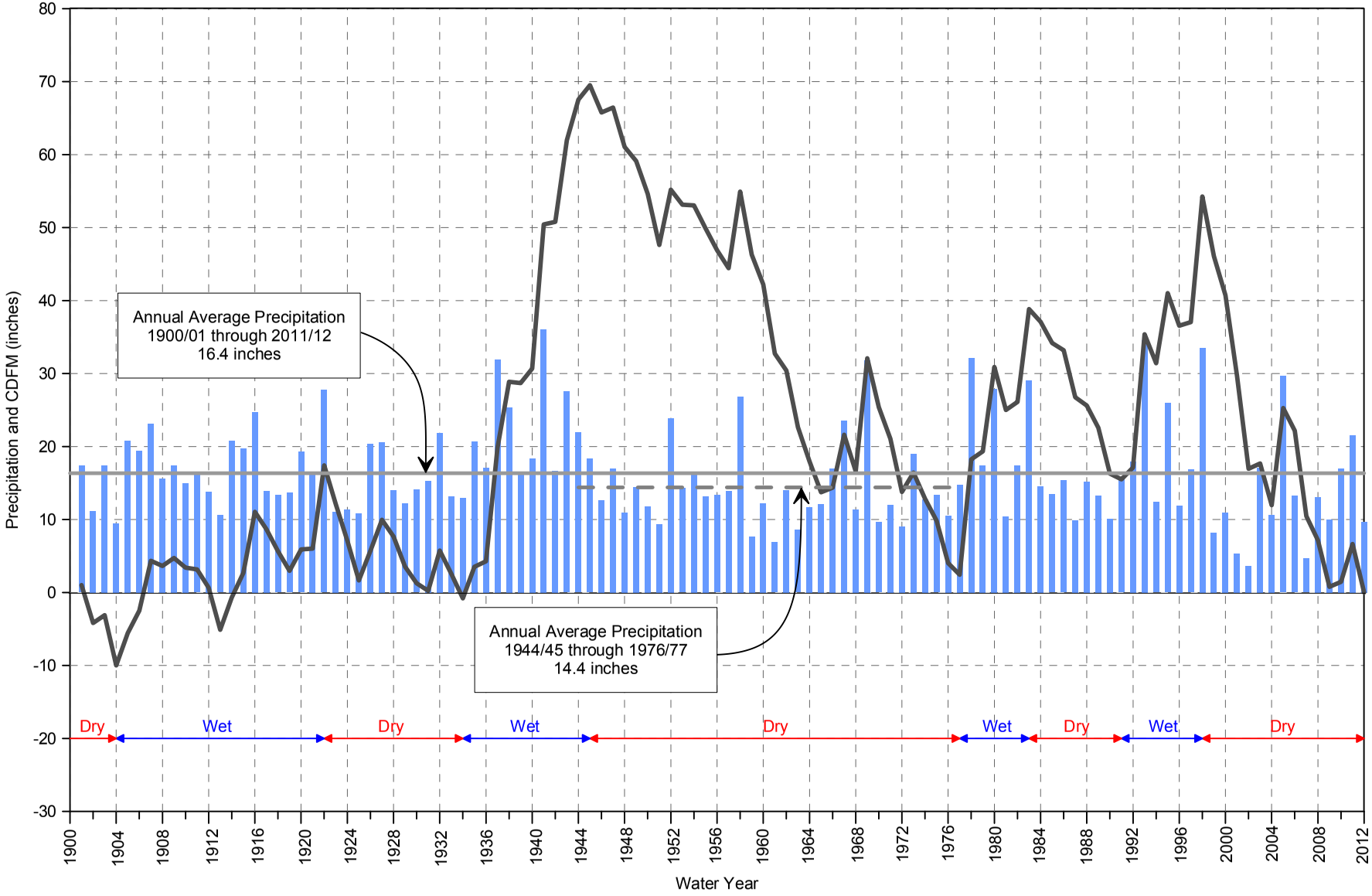
Figure 2
Annual Precipitation at the San Bernardino County Hospital



Date: 05/16/2013
File: SBC_Precip_CDFM.grf

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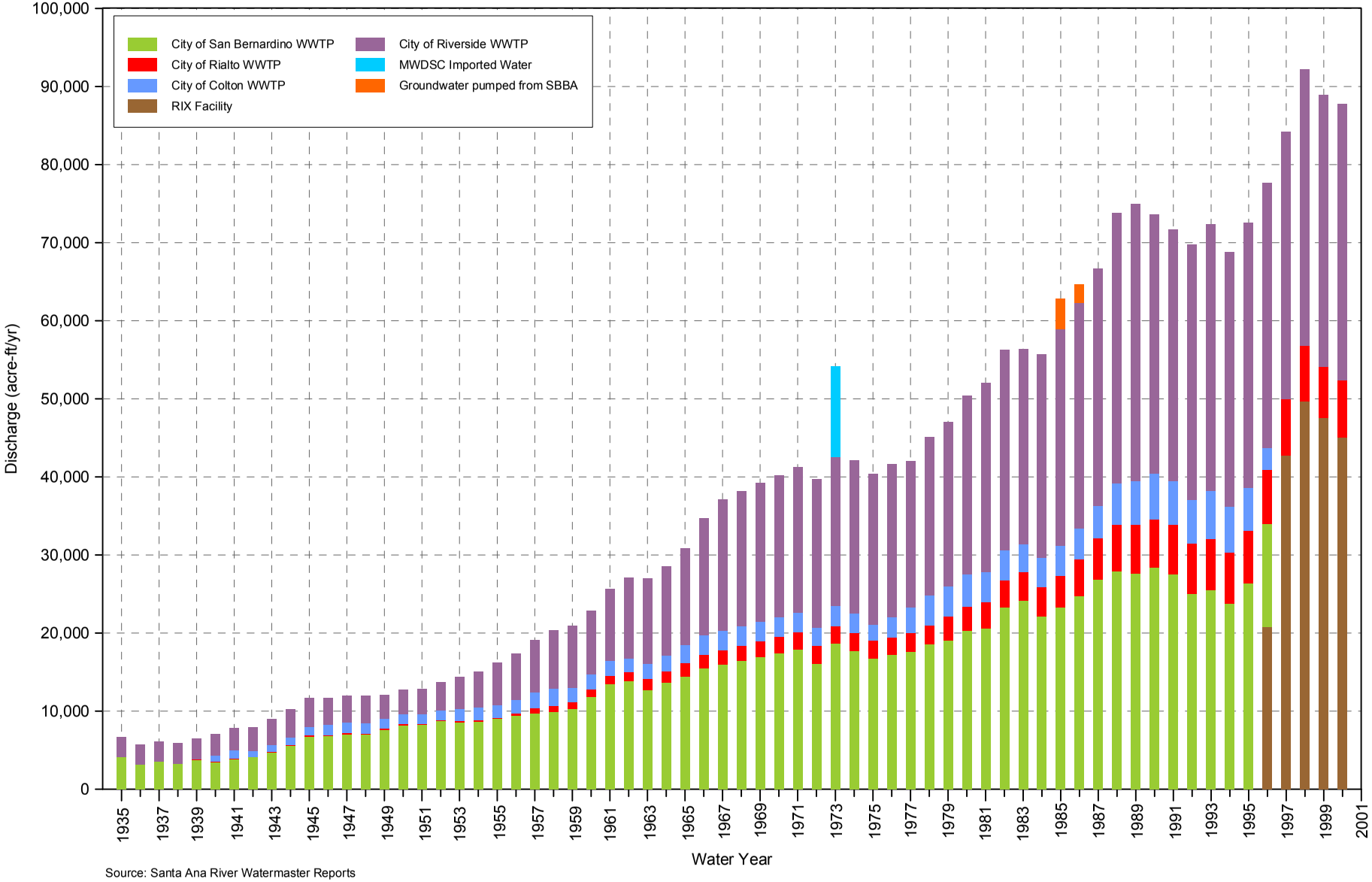
Figure 3
Recycled Water, Imported Water, and Groundwater Discharge to the Santa Ana River
Water Year 1934/35 to 1999/2000



Source: Santa Ana River Watermaster Reports

Date: 05/16/2013
File: WWTP_OtherQ.grf

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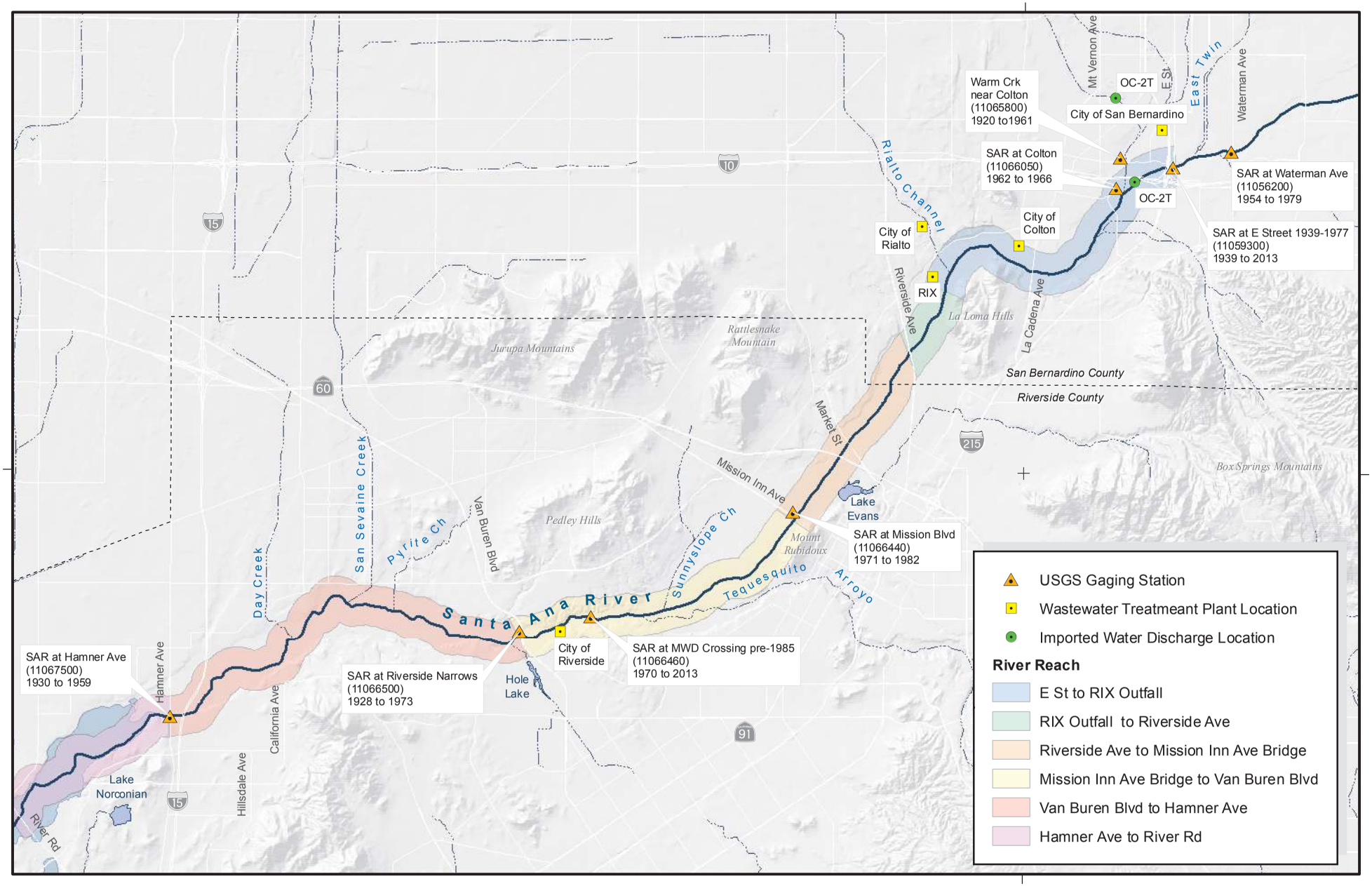

Produced by:

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Author: MAB

Date: 5/17/2013

File: StreamGage_WWTP_NonMap.mxd

0 1 2 3 Miles

0 2 4 Kilometers

USGS Stream Gage Data, Wastewater Treatment Plant, and Non-Tributary Water Discharge Locations

Santa Ana River (E St to River Rd) from years 1938 to 1977

Figure 4

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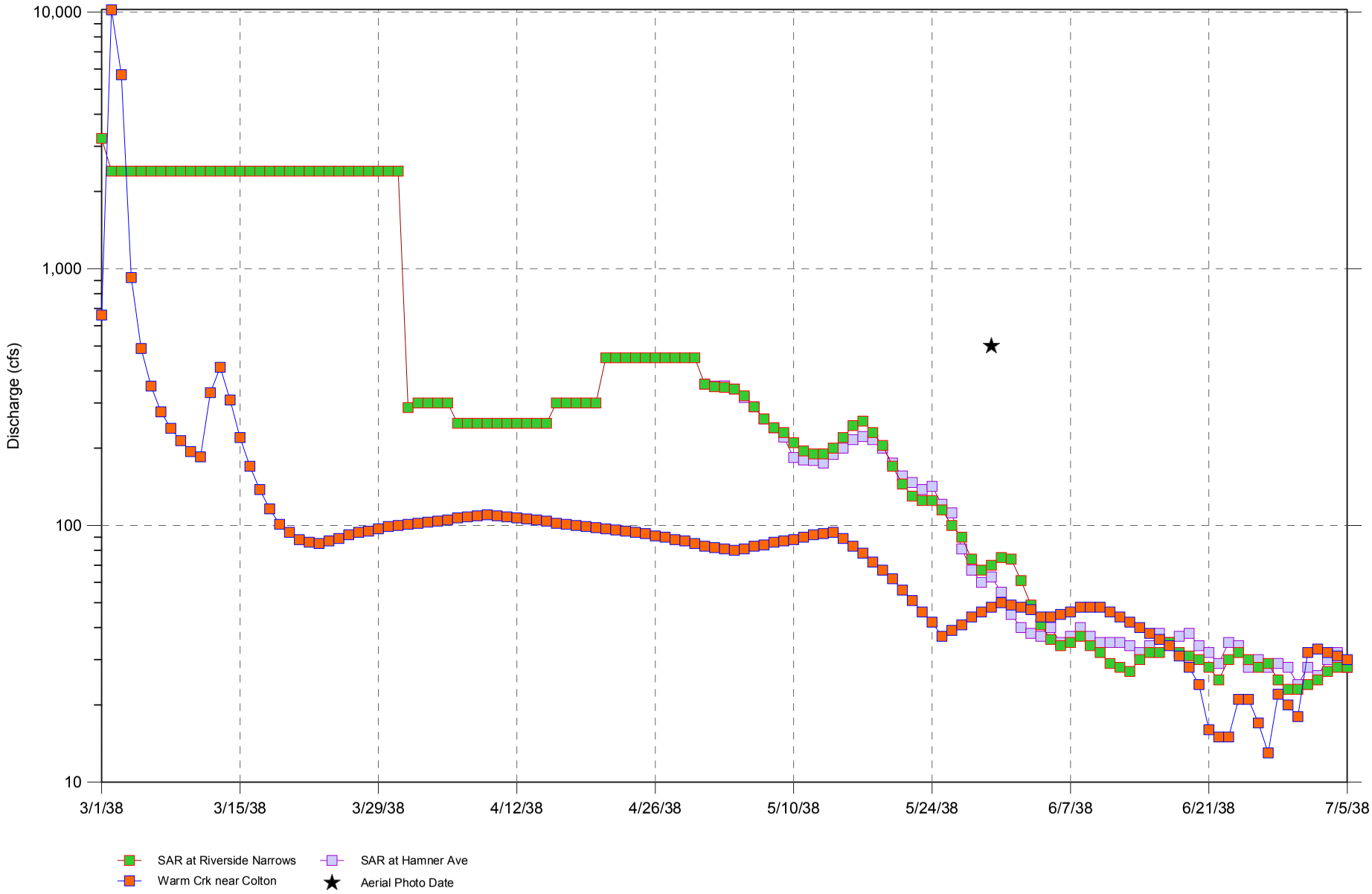
Figure 5
USGS Gaging Station Discharge Data: March to July 1938



Date: 05/16/2013
File: 1938_Q.grf

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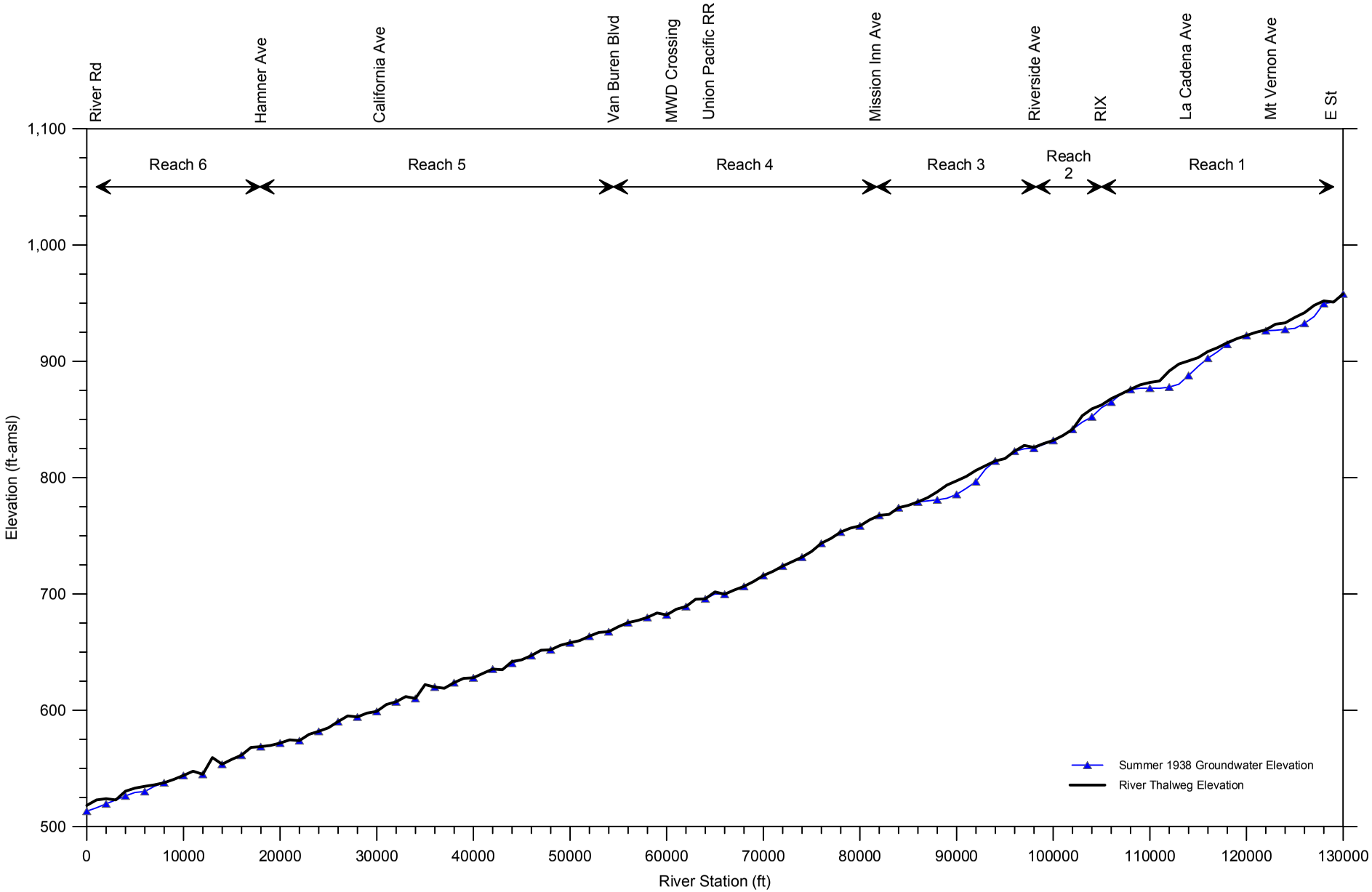
Figure 6
Santa Ana River Historic Groundwater Elevation Summer 1938



Date: 05/16/2013
File: SAR_1938HistoricGW.grf

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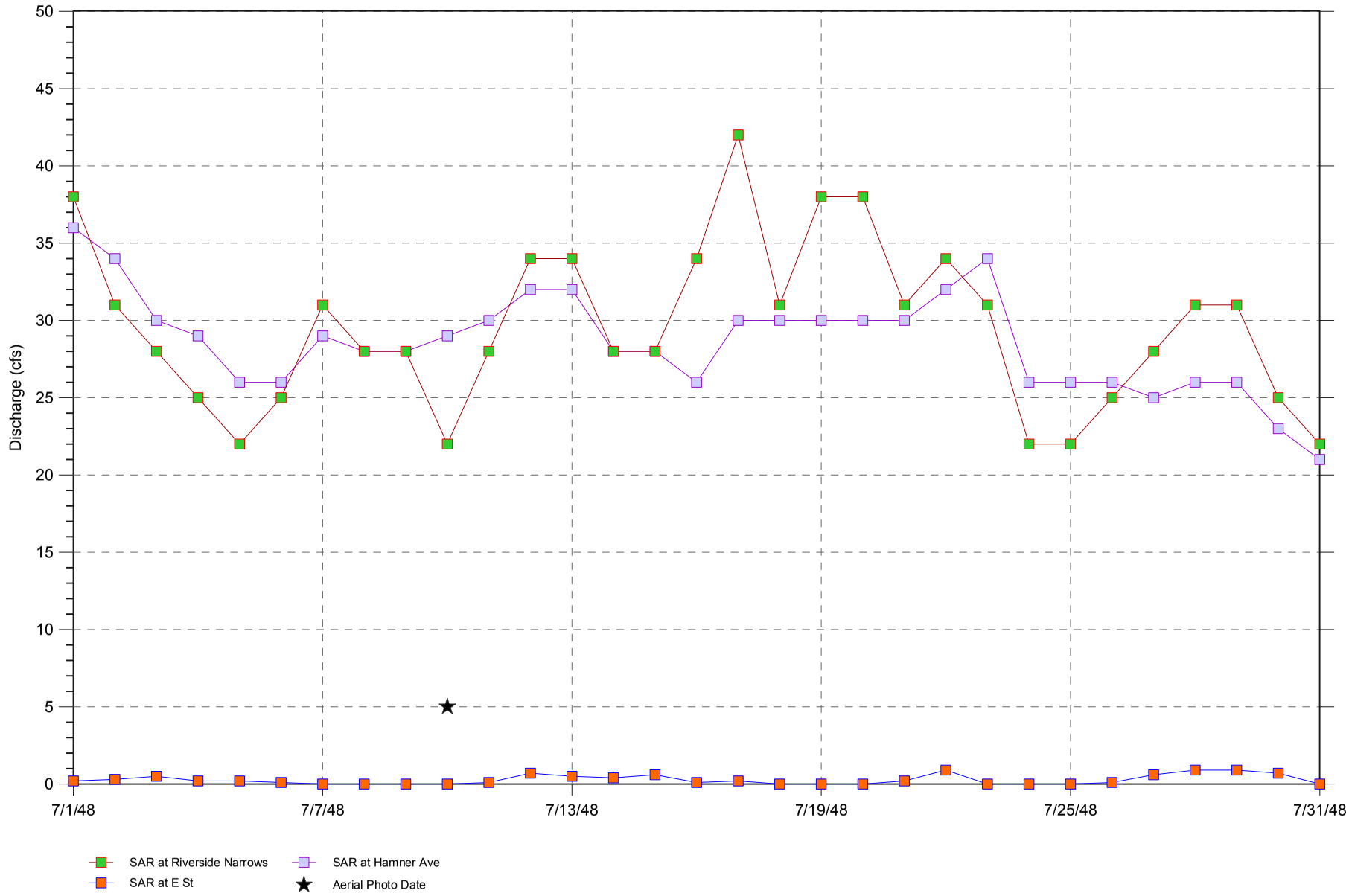
Figure 7
USGS Gaging Station Discharge Data: July 1948



Date: 05/16/2013
File: 1948_Q.grf

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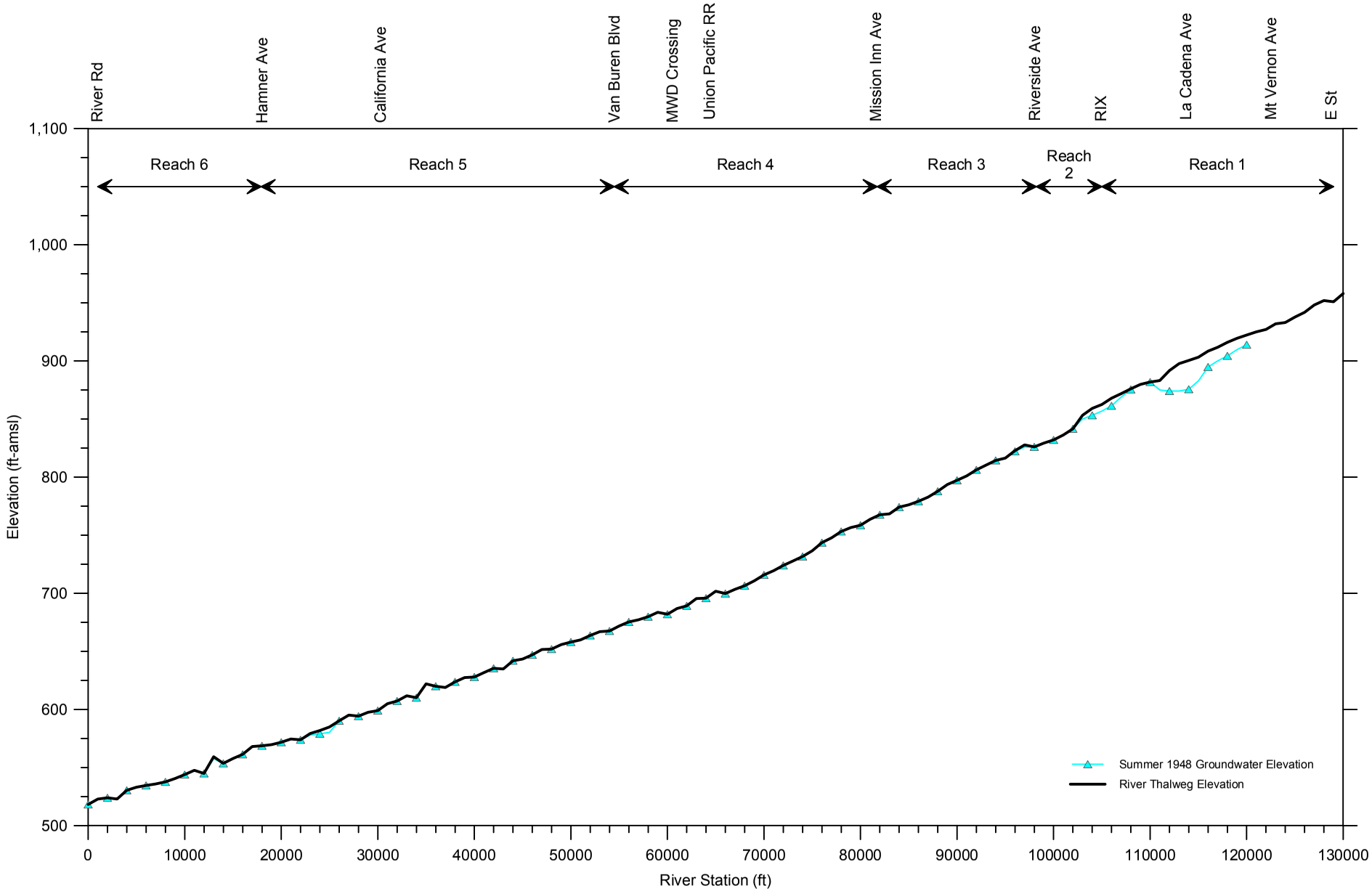
Figure 8
Santa Ana River Historic Groundwater Elevation Summer 1948



Date: 05/16/2013
File: SAR_1948HistoricGW.grf

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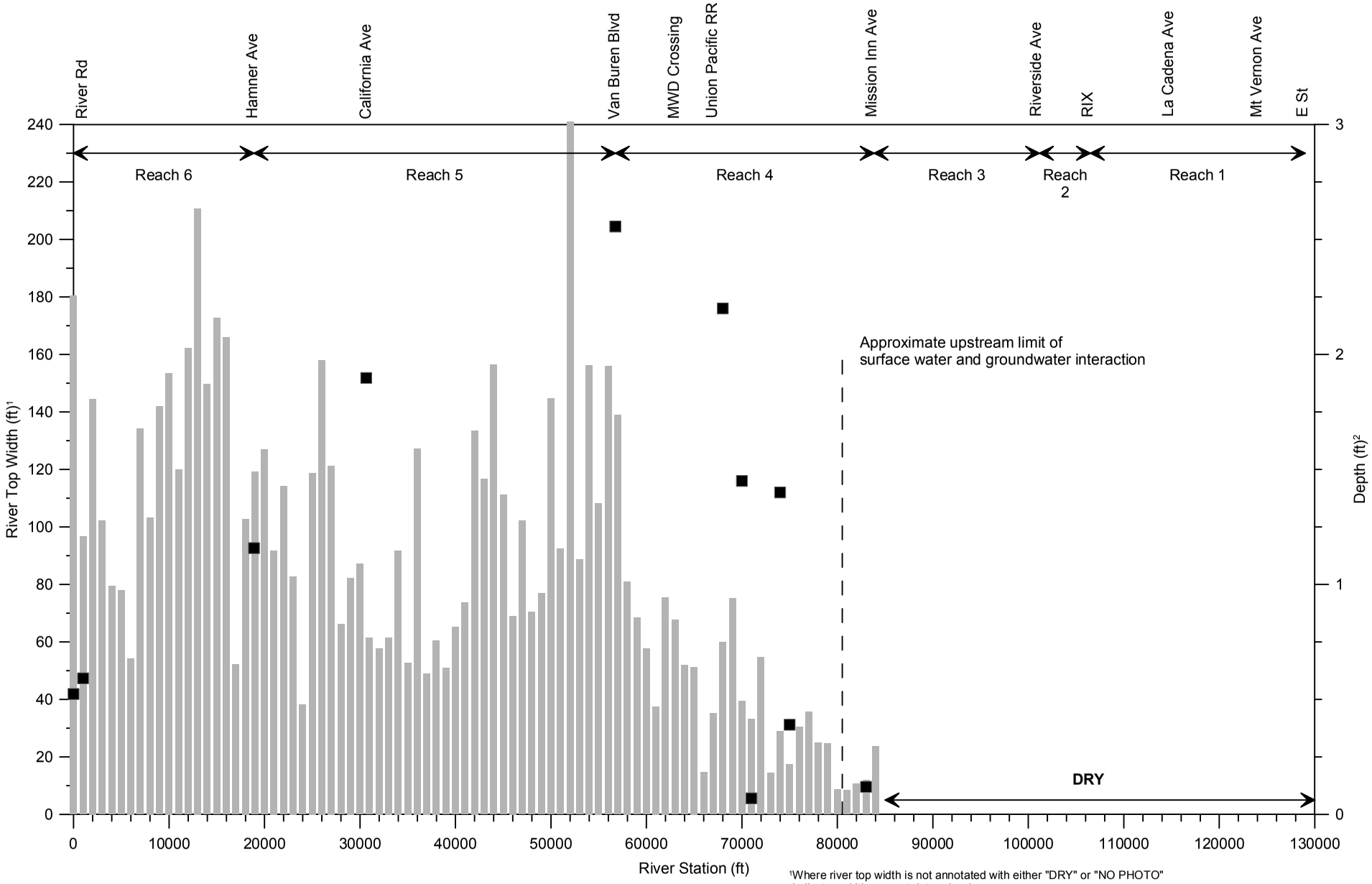
Figure 9
Santa Ana River Top Width and Estimated Flow Depth in Summer 1948



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1948SAR_WidthSummary.grf

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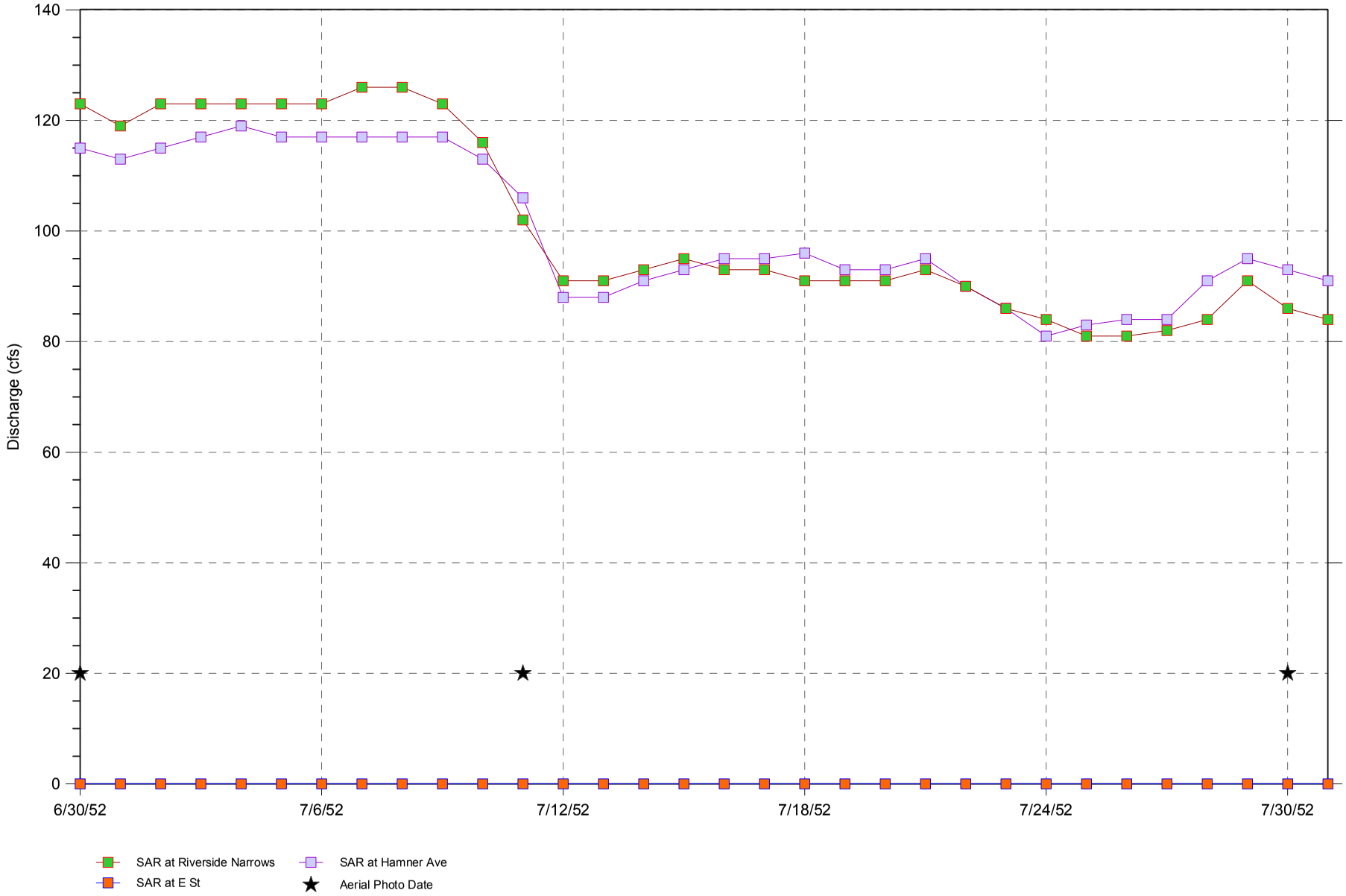
Figure 10
USGS Gaging Station Discharge Data: July 1952



Date: 05/16/2013
File: 1952_Q.grf

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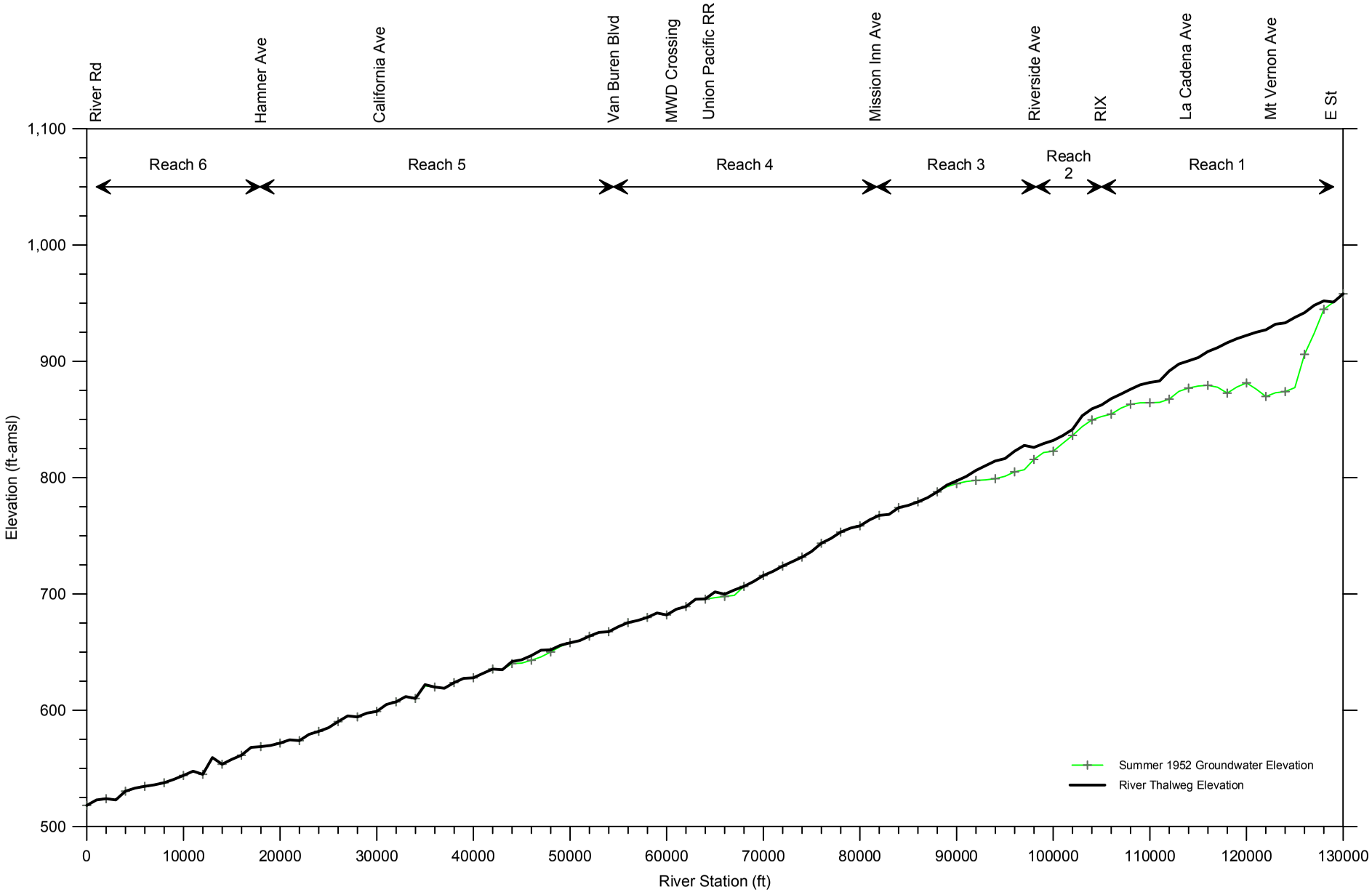
Figure 11
Santa Ana River Historic Groundwater Elevation Summer 1952



Date: 05/16/2013
File: SAR_1952HistoricGW.grf

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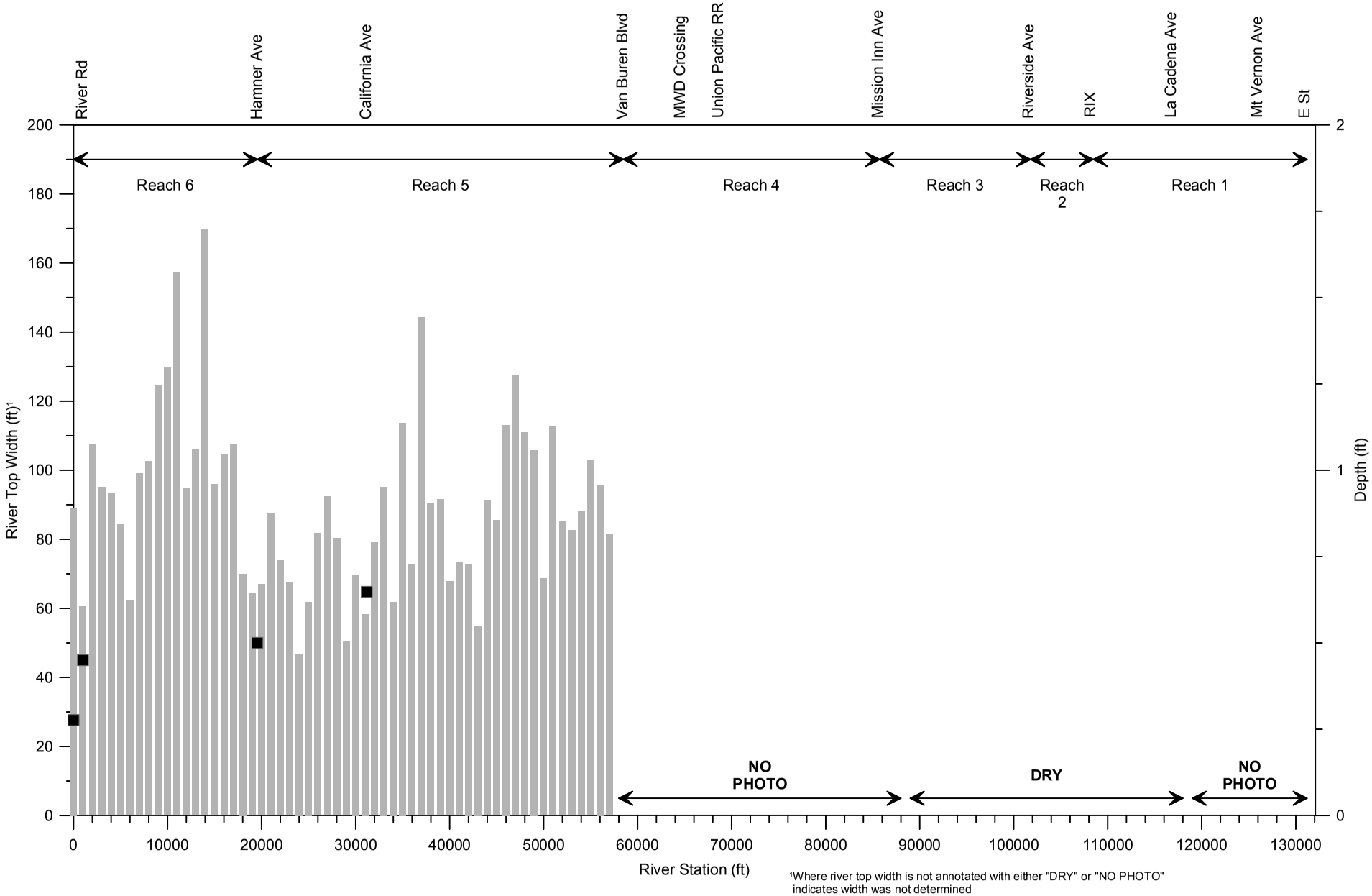
Figure 12
Santa Ana River Top Width and Estimated Flow Depth in Summer 1952



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

Date: 05/16/2013
File: 1952SAR_WidthSummary.grf

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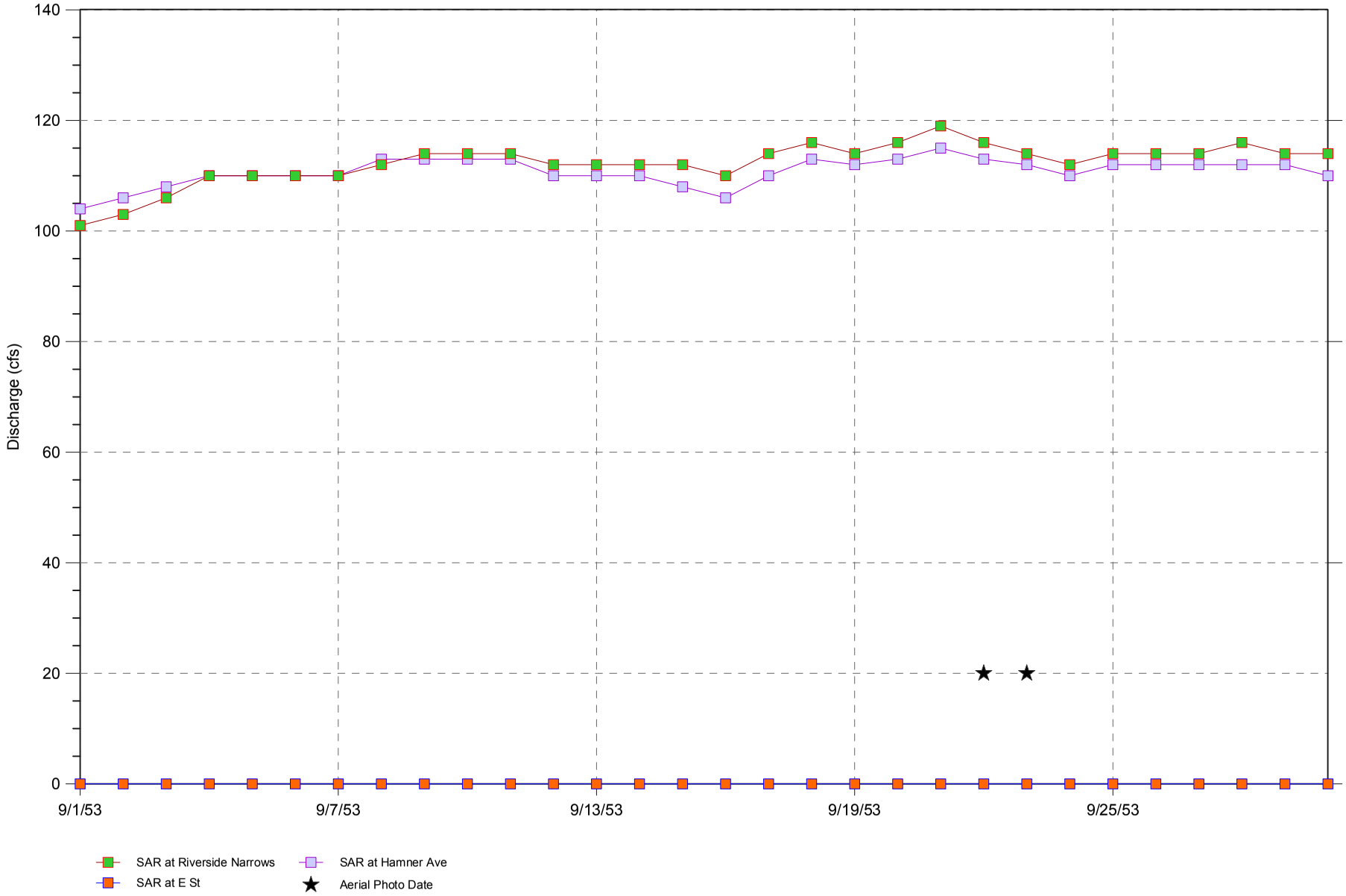
Figure 13
USGS Gaging Station Discharge Data: September 1953



Date: 05/16/2013
File: 1953_Q.grf

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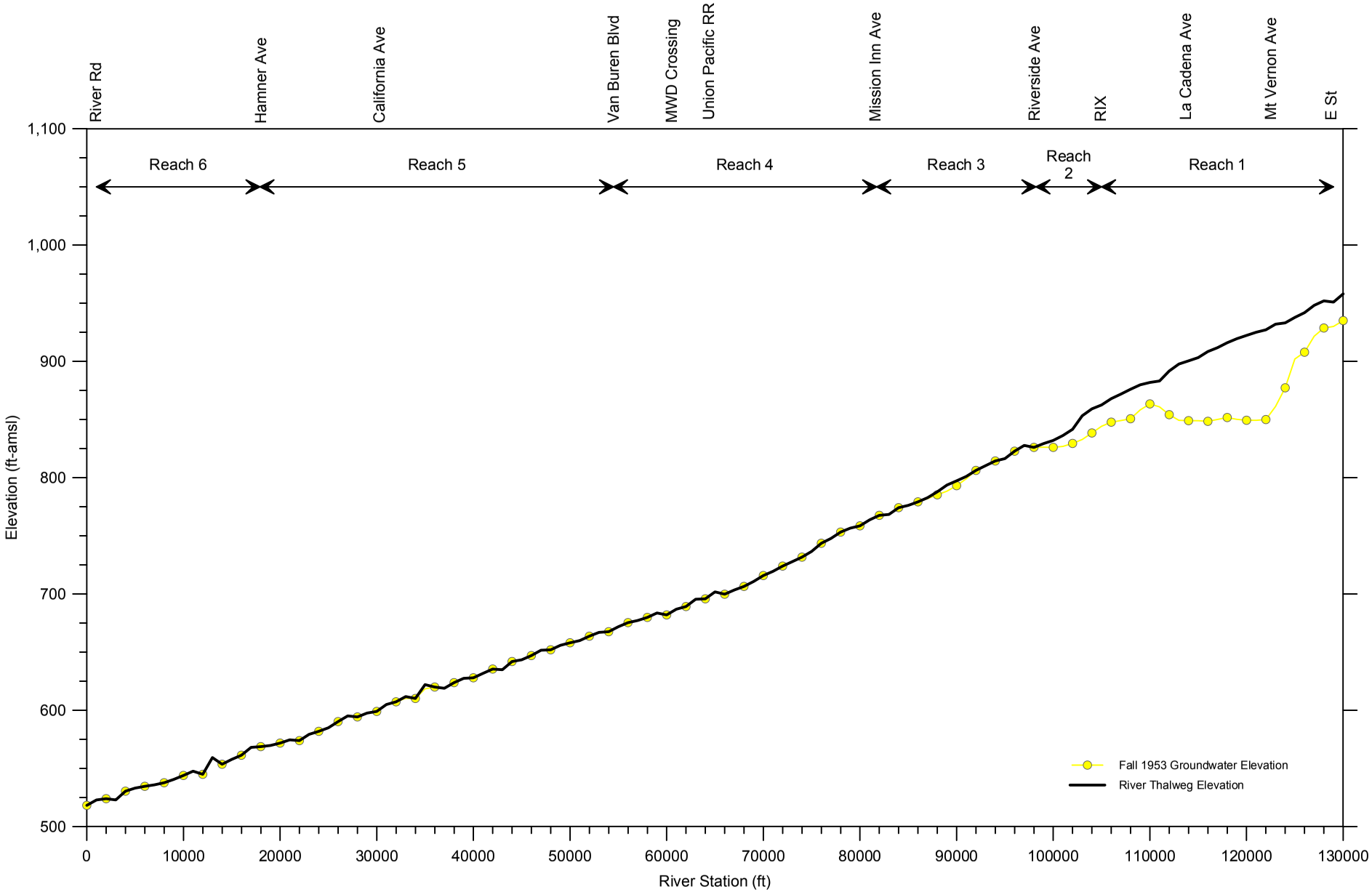
Figure 14
Santa Ana River Historic Groundwater Elevation Fall 1953



Date: 05/16/2013
File: SAR_1953HistoricGW.grf

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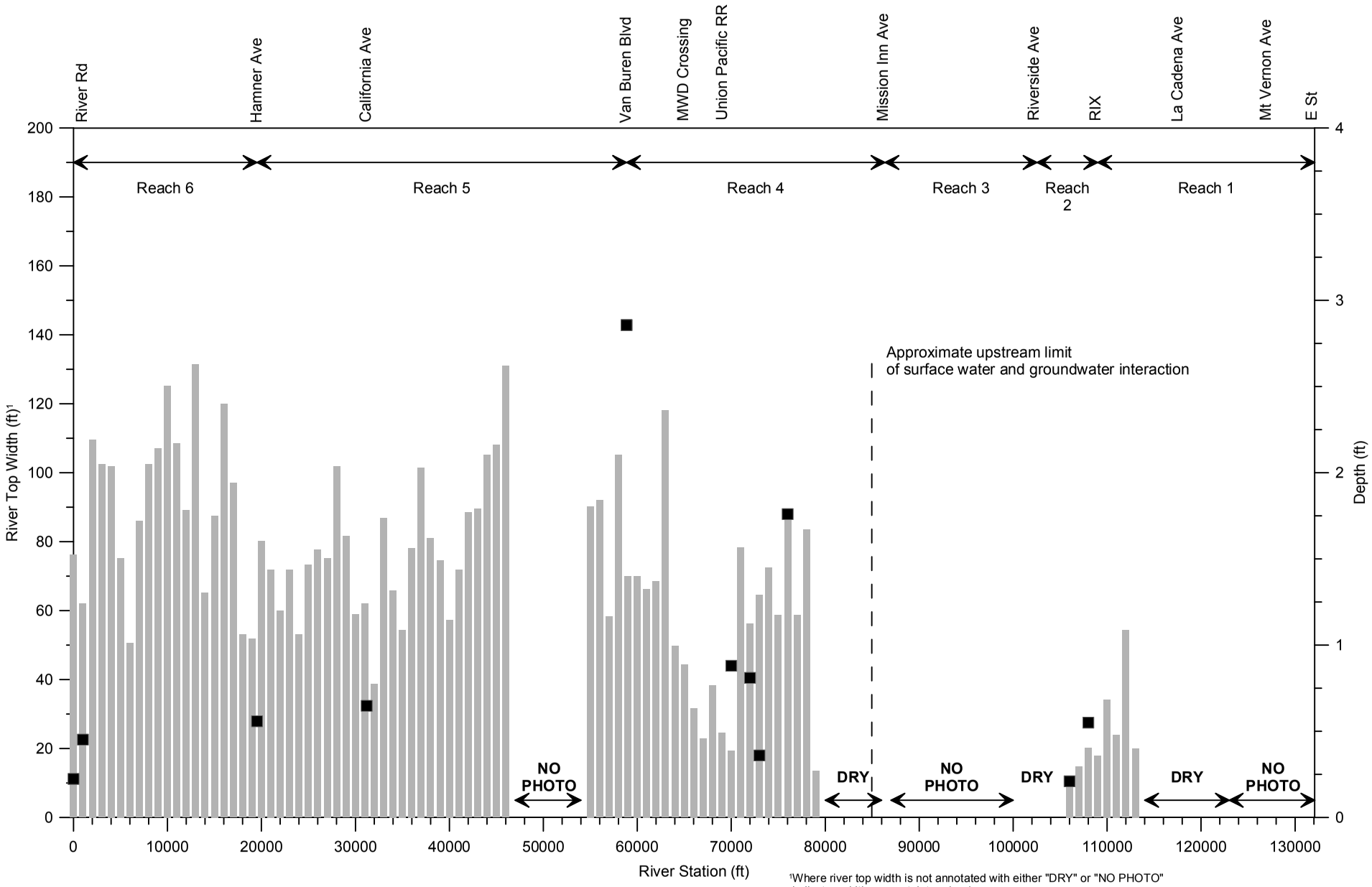
Figure 15
Santa Ana River Top Width and Estimated Flow Depth in Fall 1953



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1953SAR_WidthSummary.grf

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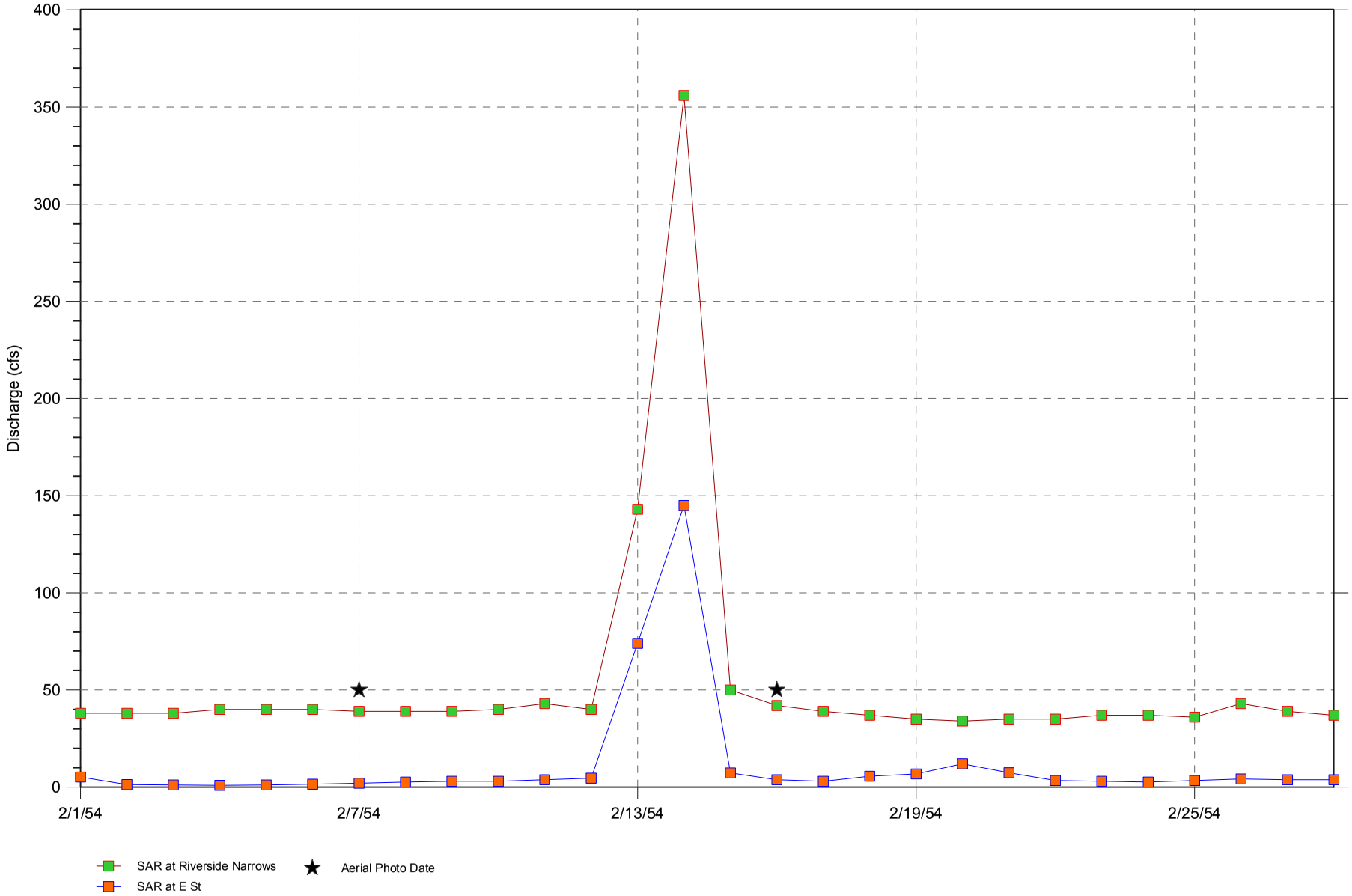
Figure 16
USGS Gaging Station Discharge Data: February 1954



Date: 05/16/2013
File: 1954_Q.grf

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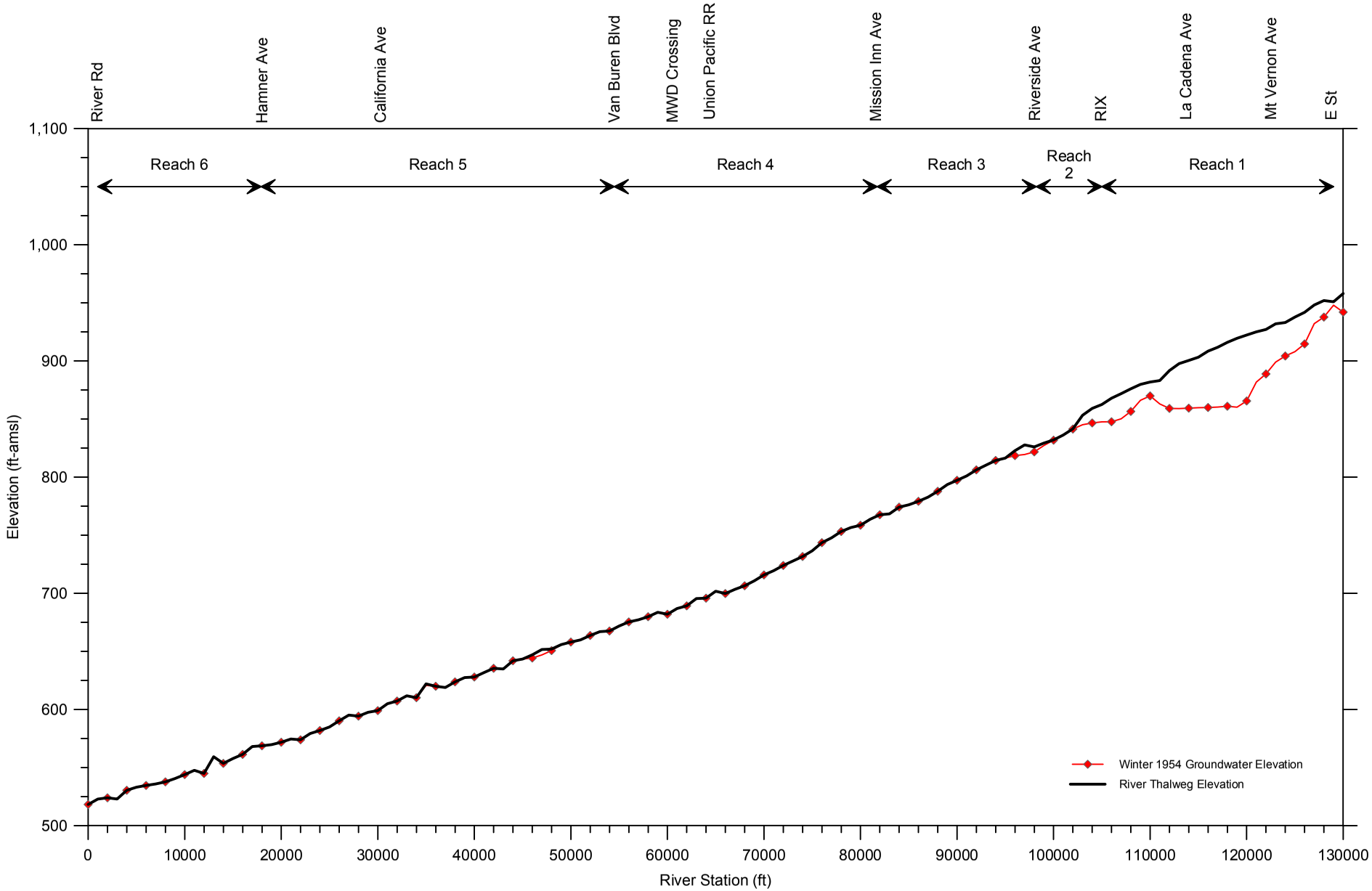
Figure 17
Santa Ana River Historic Groundwater Elevation Winter 1954



Date: 05/16/2013
File: SAR_1954HistoricGW.grf

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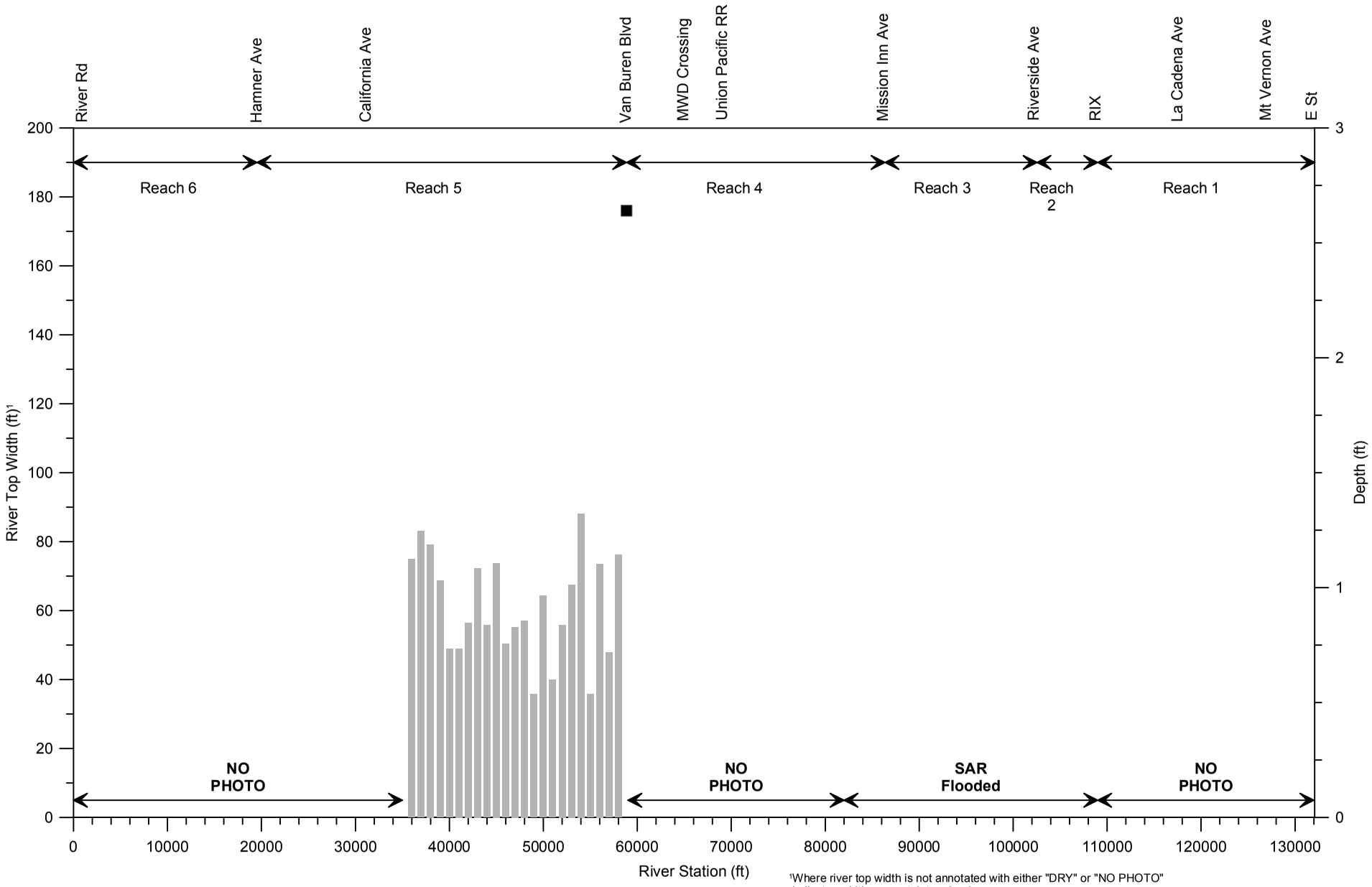
Figure 18
Santa Ana River Top Width and Estimated Flow Depth in Winter 1954



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1954SAR_WidthSummary.grf

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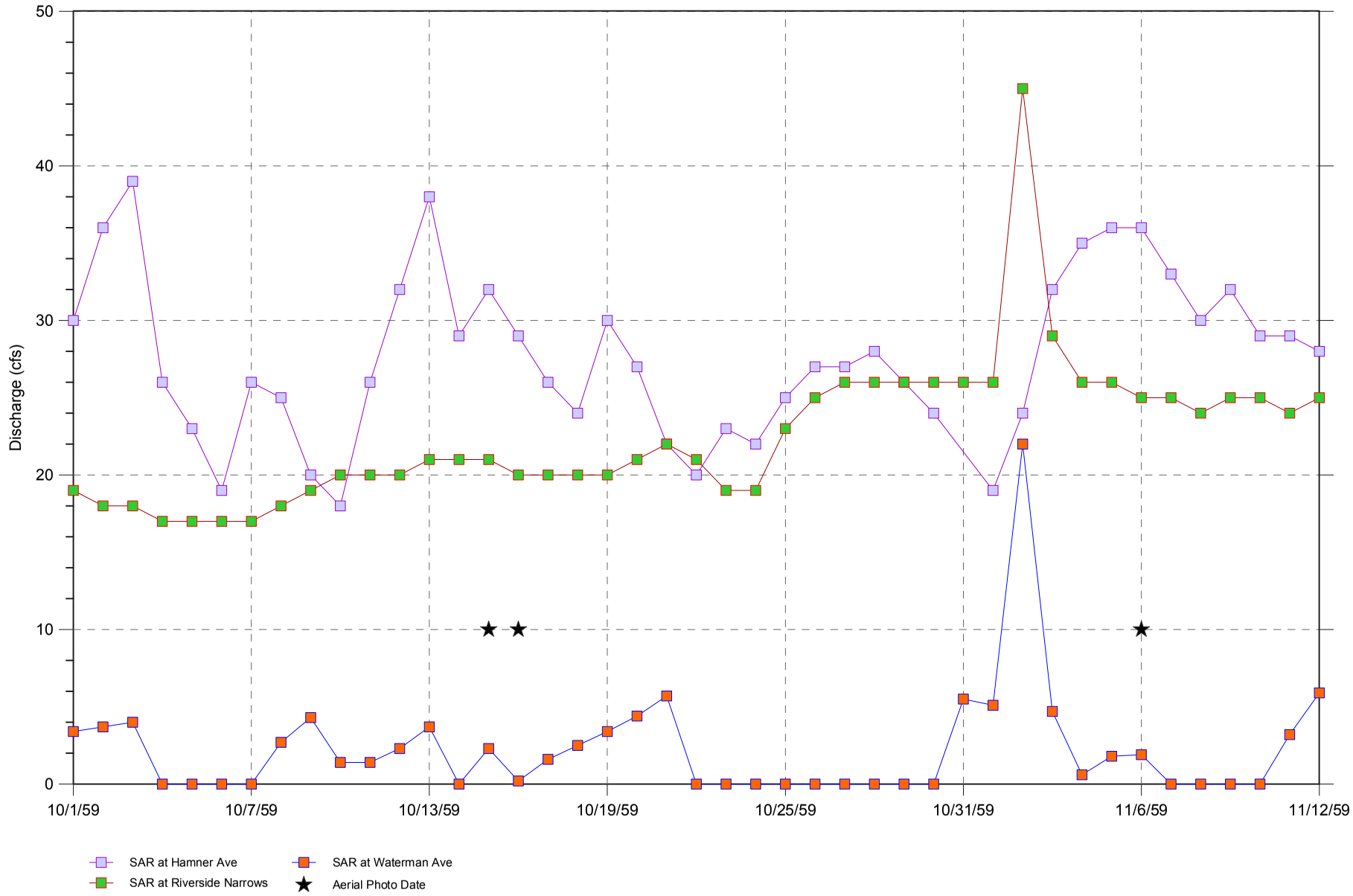
Figure 19
USGS Gaging Station Discharge Data: October to November 1959



Date: 05/16/2013
File: 1959_Q.grf

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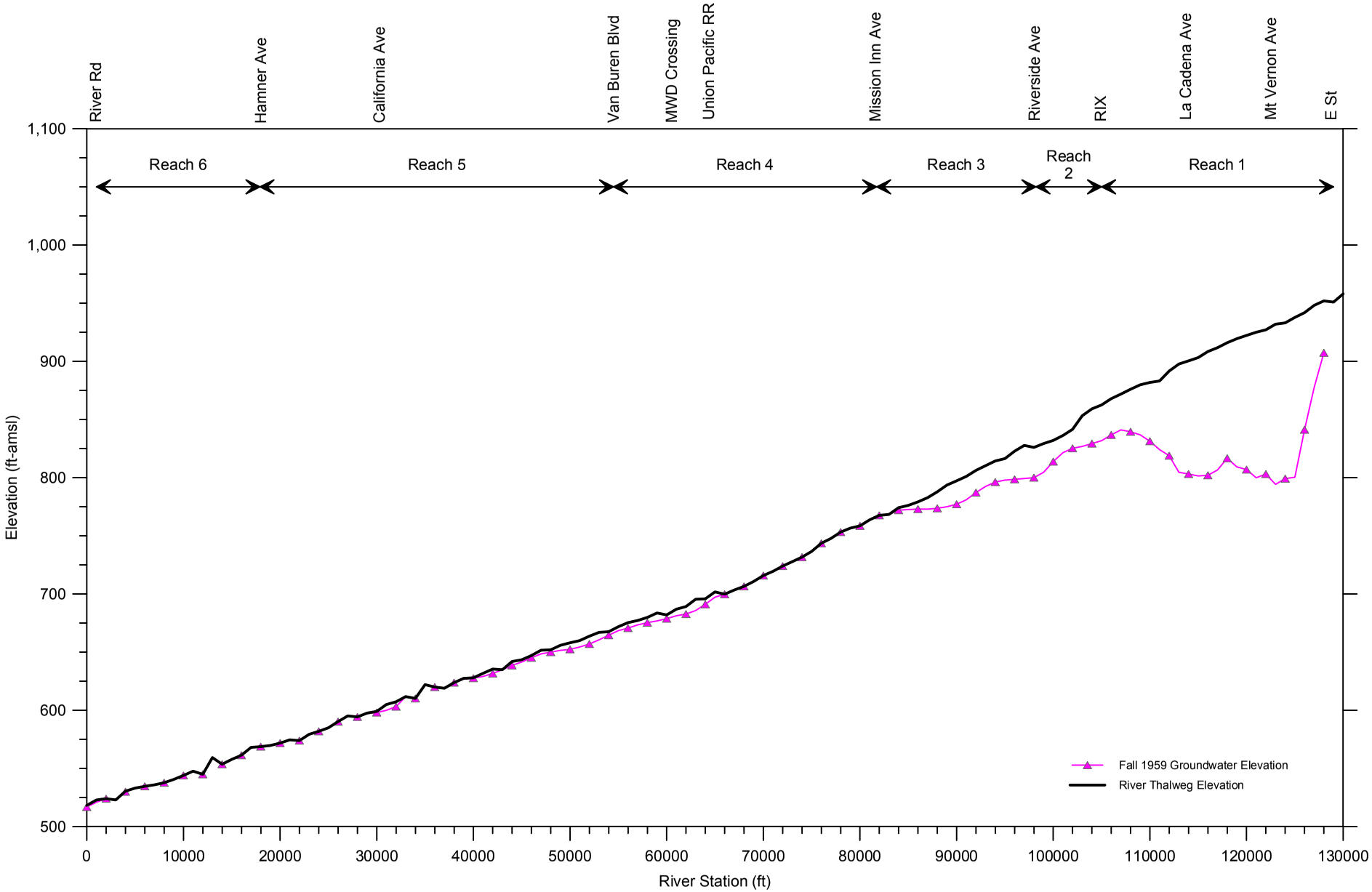
Figure 20
Santa Ana River Historic Groundwater Elevation Fall 1959



Date: 05/16/2013
File: SAR_1959HistoricGW.grf

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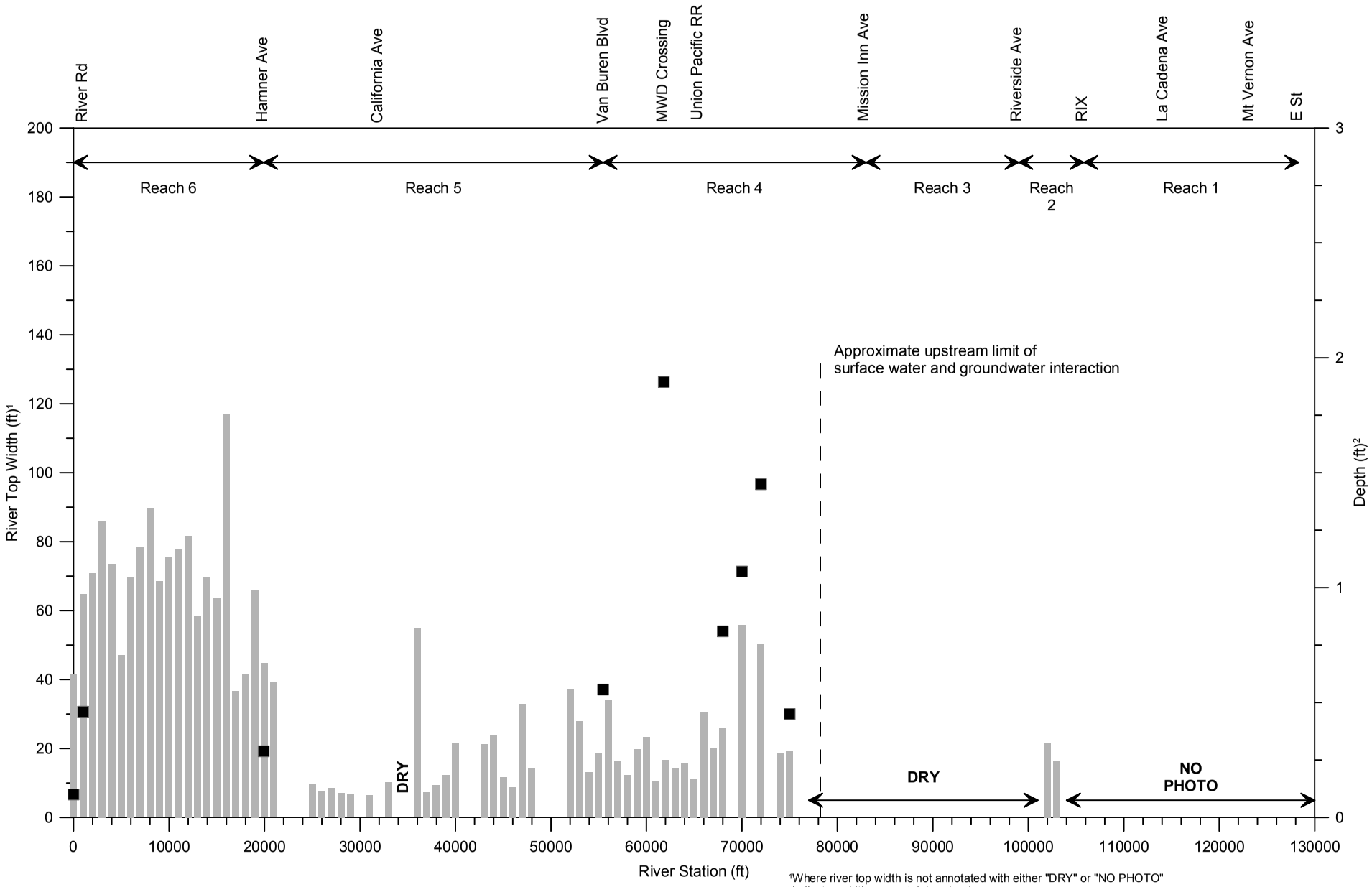
Figure 21
Santa Ana River Top Width and Estimated Flow Depth in Fall 1959



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1959SAR_WidthSummary.grf

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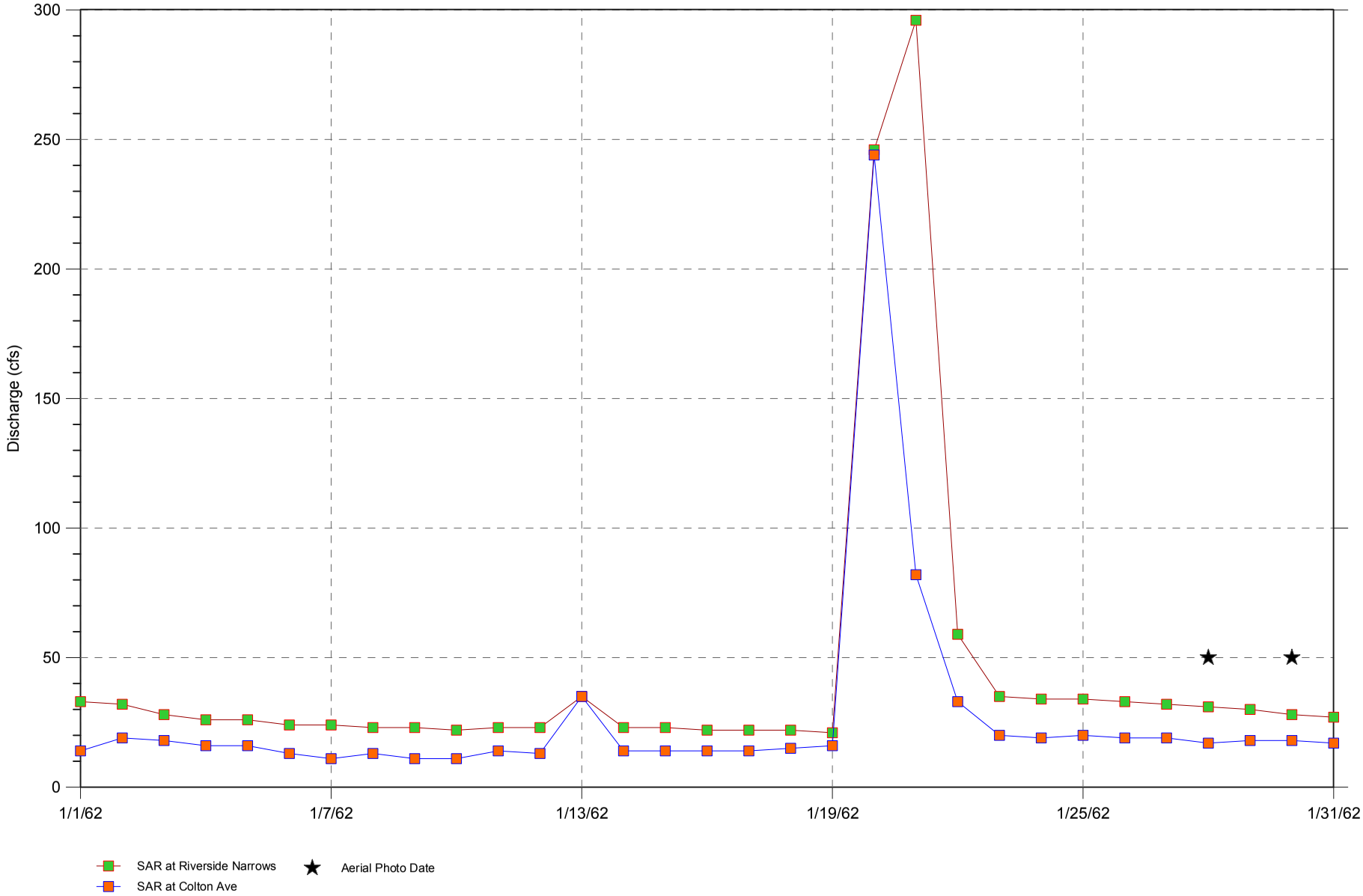
Figure 22
USGS Gaging Station Discharge Data: January 1962



Date: 05/16/2013
File: 1962_Q.grf

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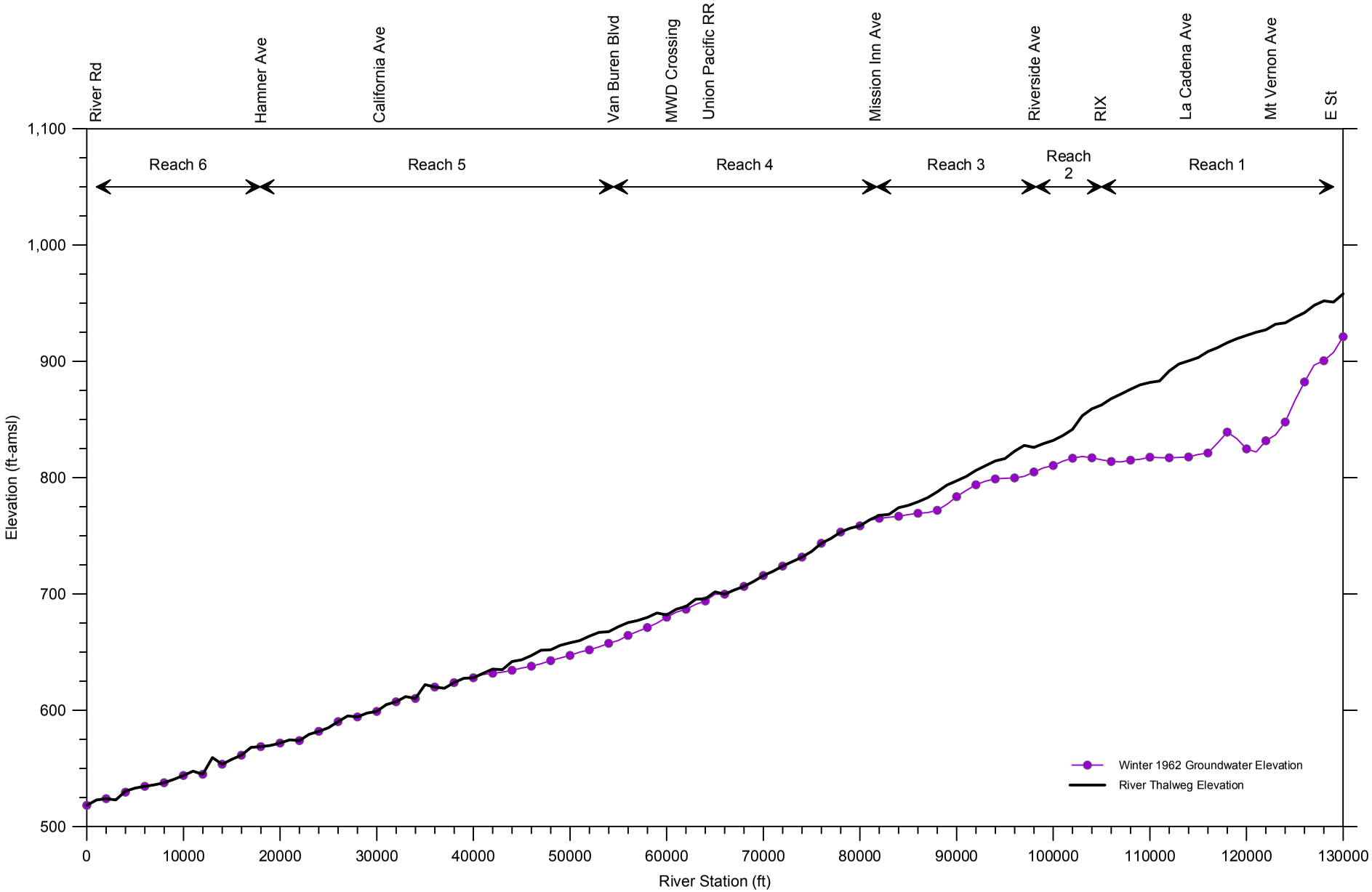
Figure 23
Santa Ana River Historic Groundwater Elevation Winter 1962



Date: 05/16/2013
File: SAR_1962HistoricGW.grf

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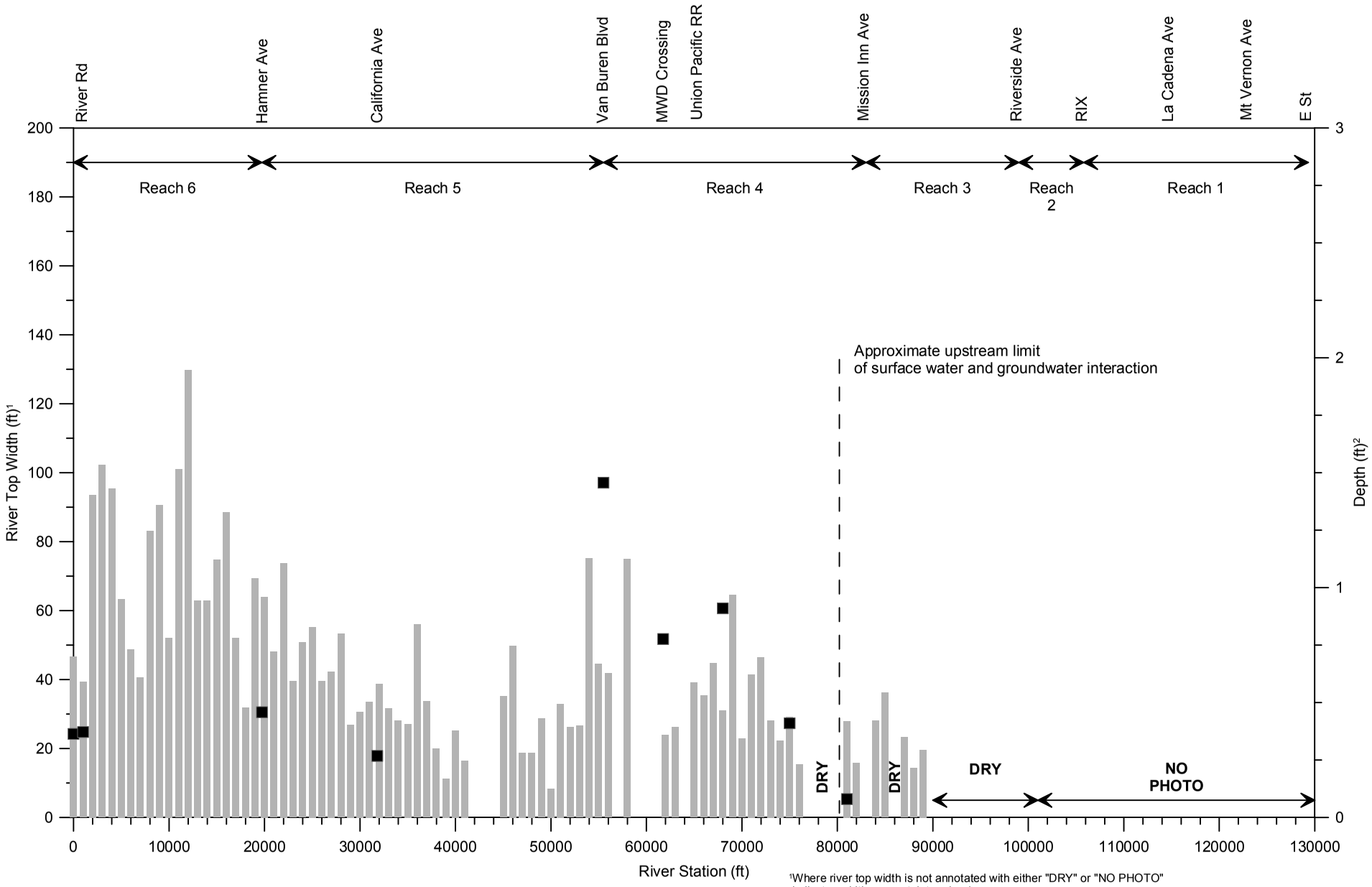
Figure 24
Santa Ana River Top Width and Estimated Flow Depth in Winter 1962



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1966SAR_WidthSummary.grf

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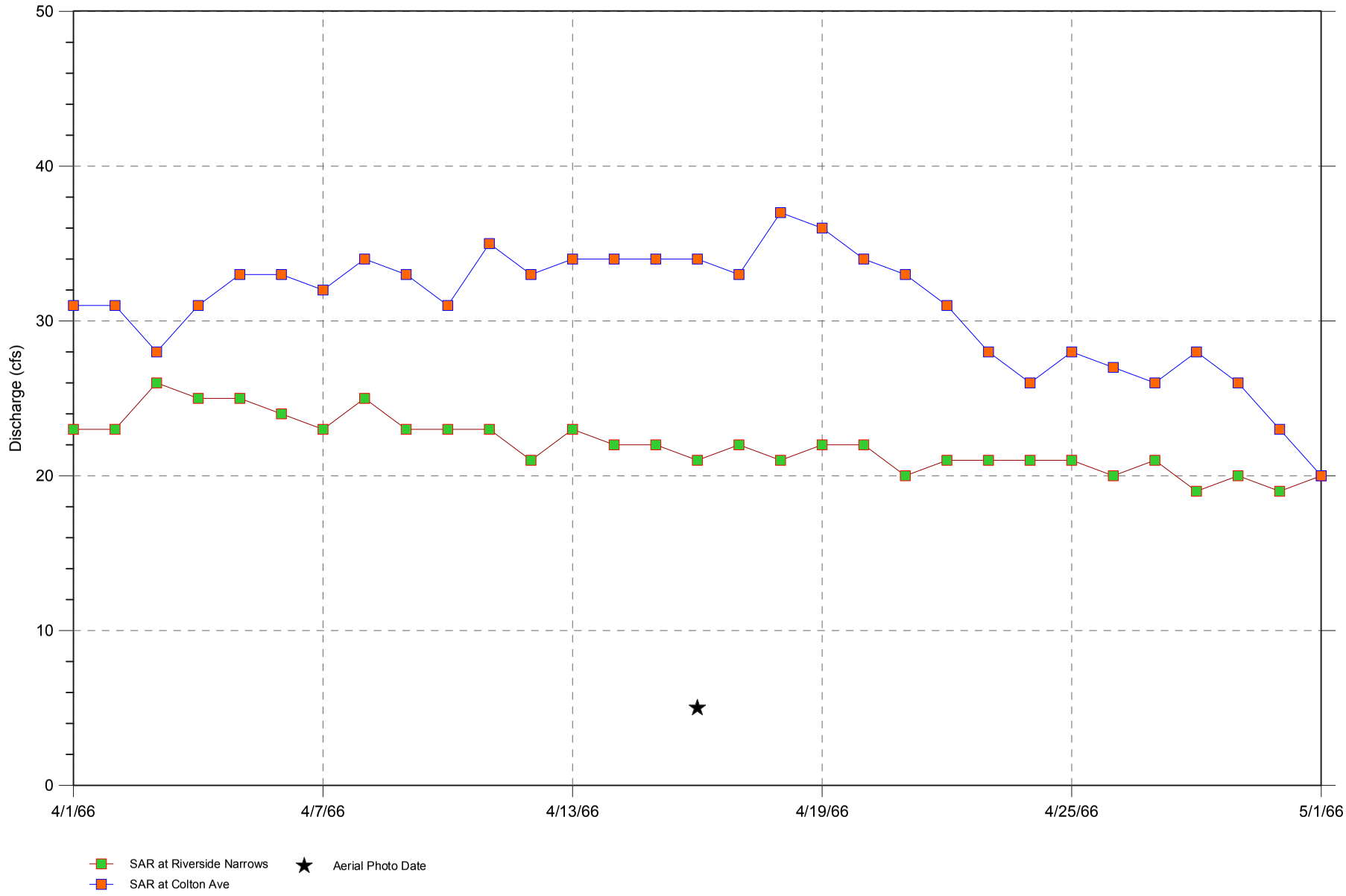
Figure 25
USGS Gaging Station Discharge Data: April 1966



Date: 05/16/2013
File: 1966_Q.grf

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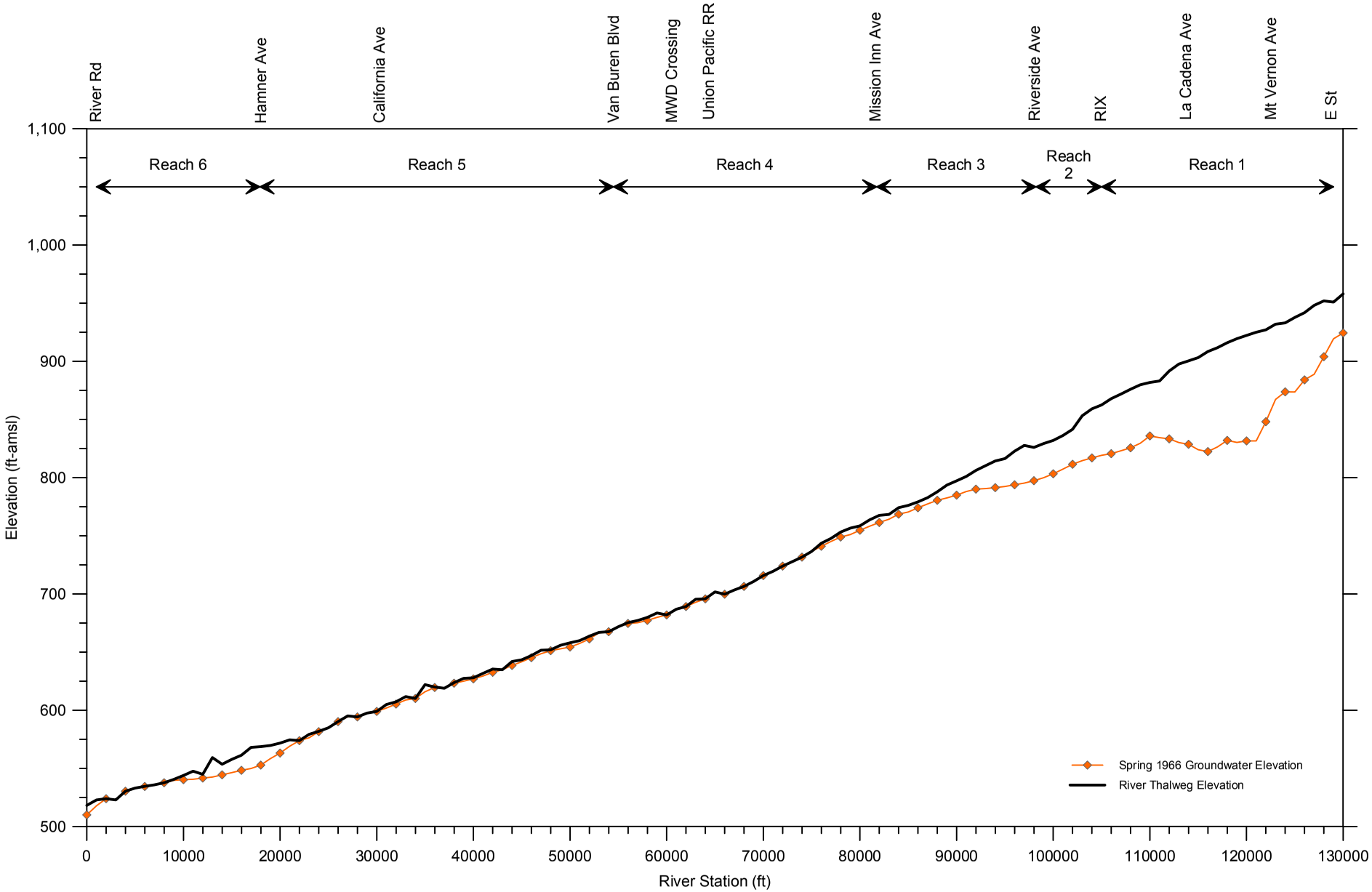
Figure 26
Santa Ana River Historic Groundwater Elevation Spring 1966



Date: 05/16/2013
File: SAR_1966HistoricGW.grf

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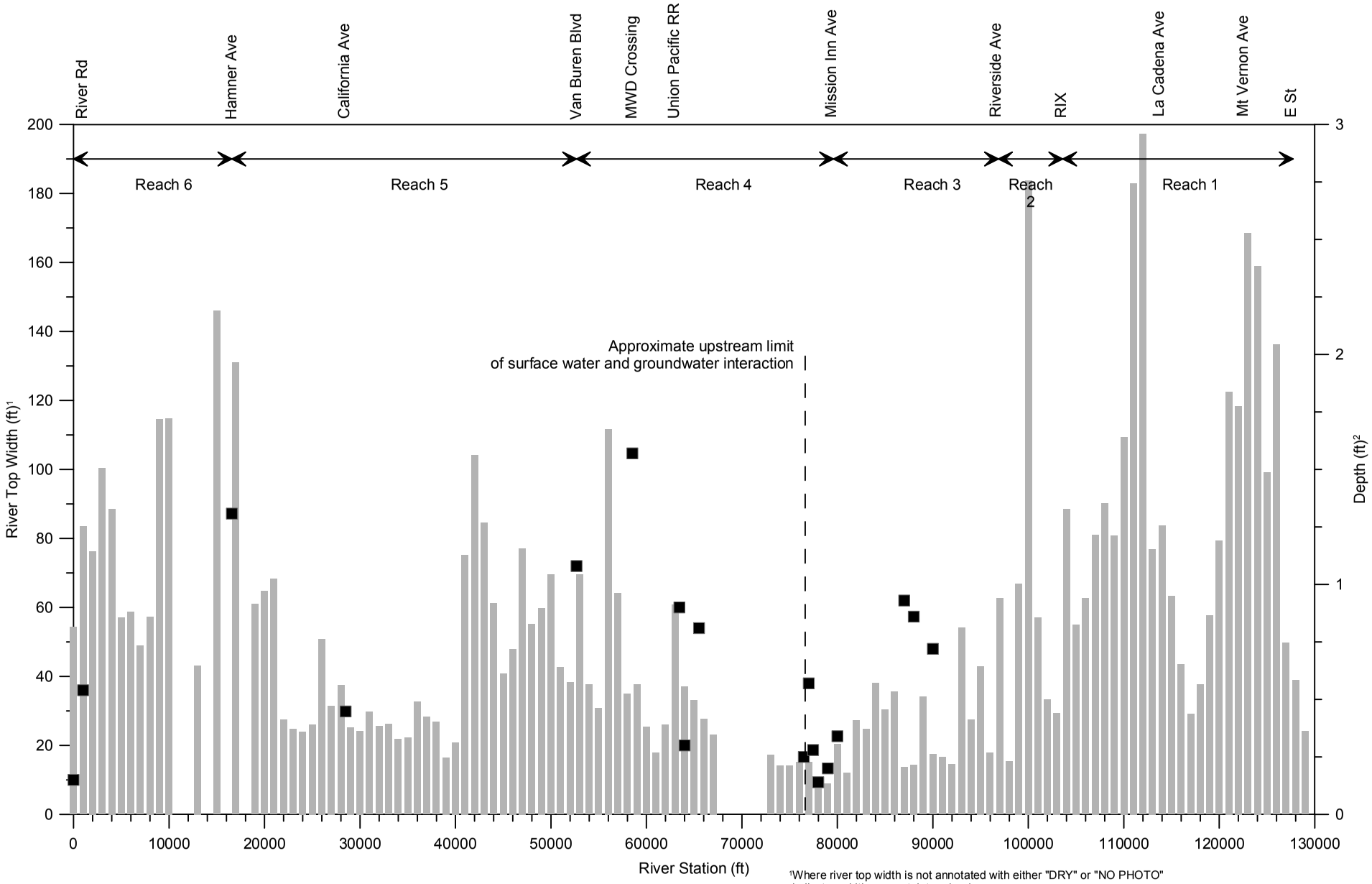
Figure 27
Santa Ana River Top Width and Estimated Flow Depth in Spring 1966



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1966SAR_WidthSummary.grf

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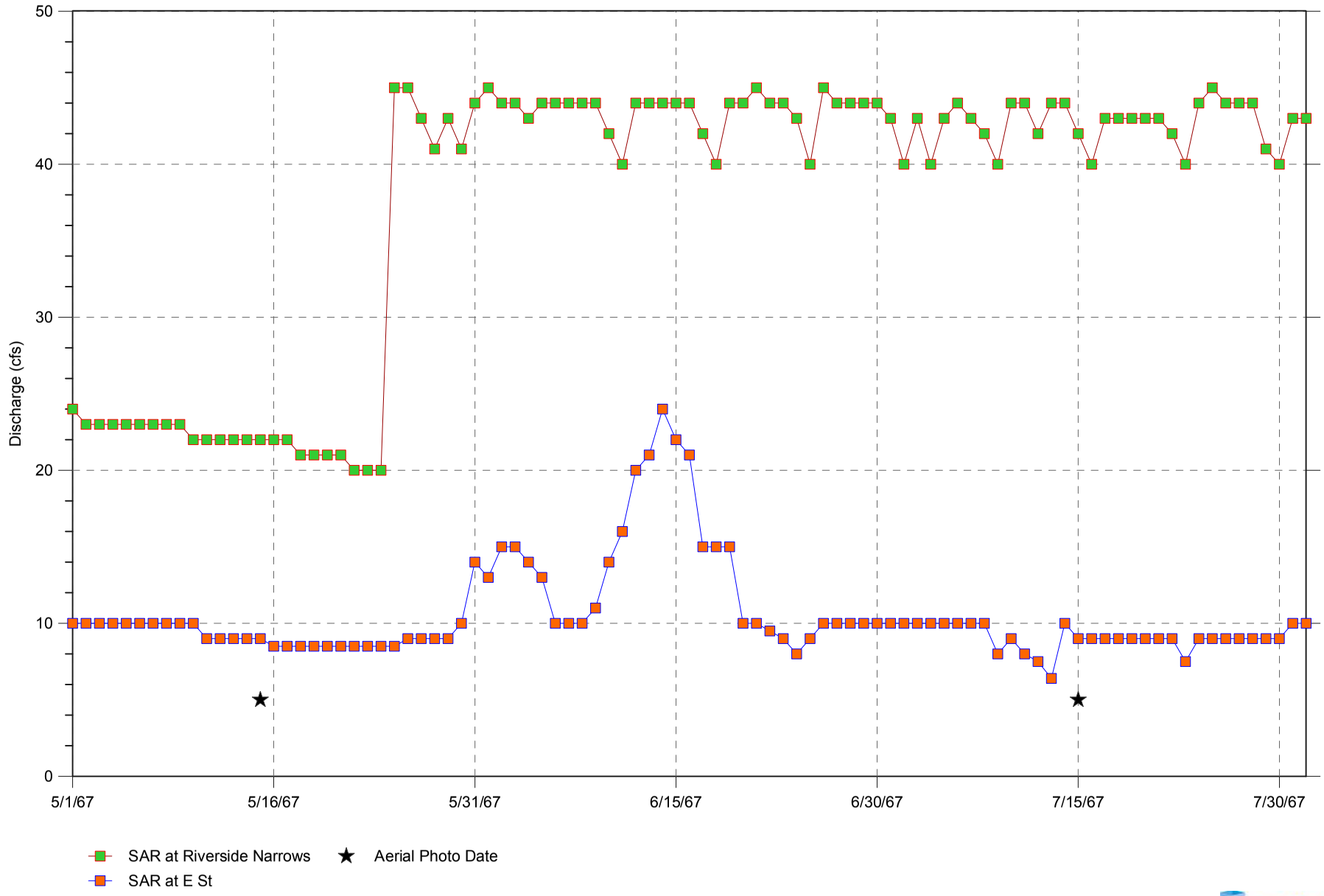
Figure 28
USGS Gaging Station Discharge Data: May to July 1967



Date: 05/16/2013
File: 1967_Q.grf

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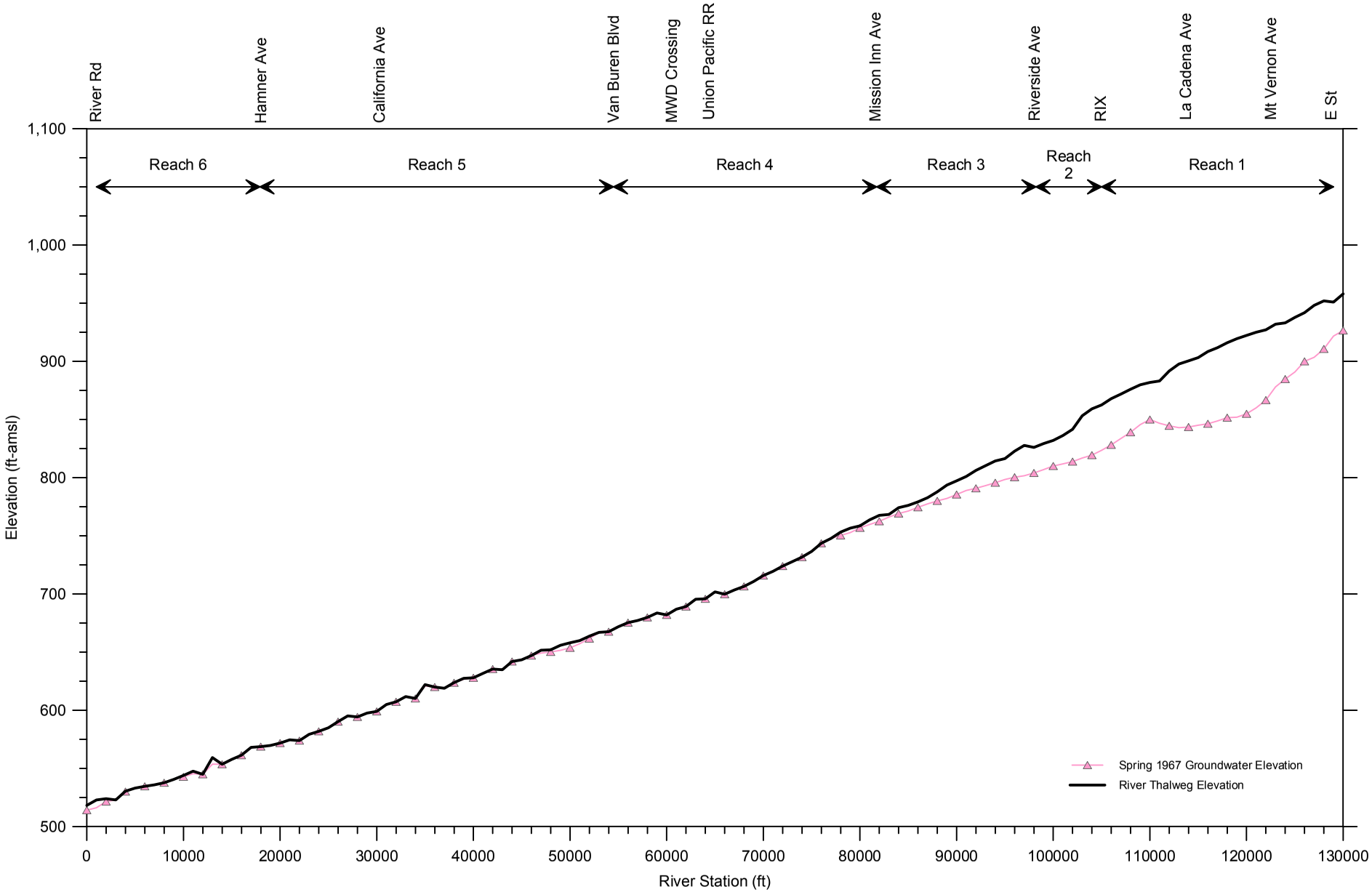
Figure 29
Santa Ana River Historic Groundwater Elevation Spring 1967



Date: 05/16/2013
File: SAR_1967HistoricGW.grf

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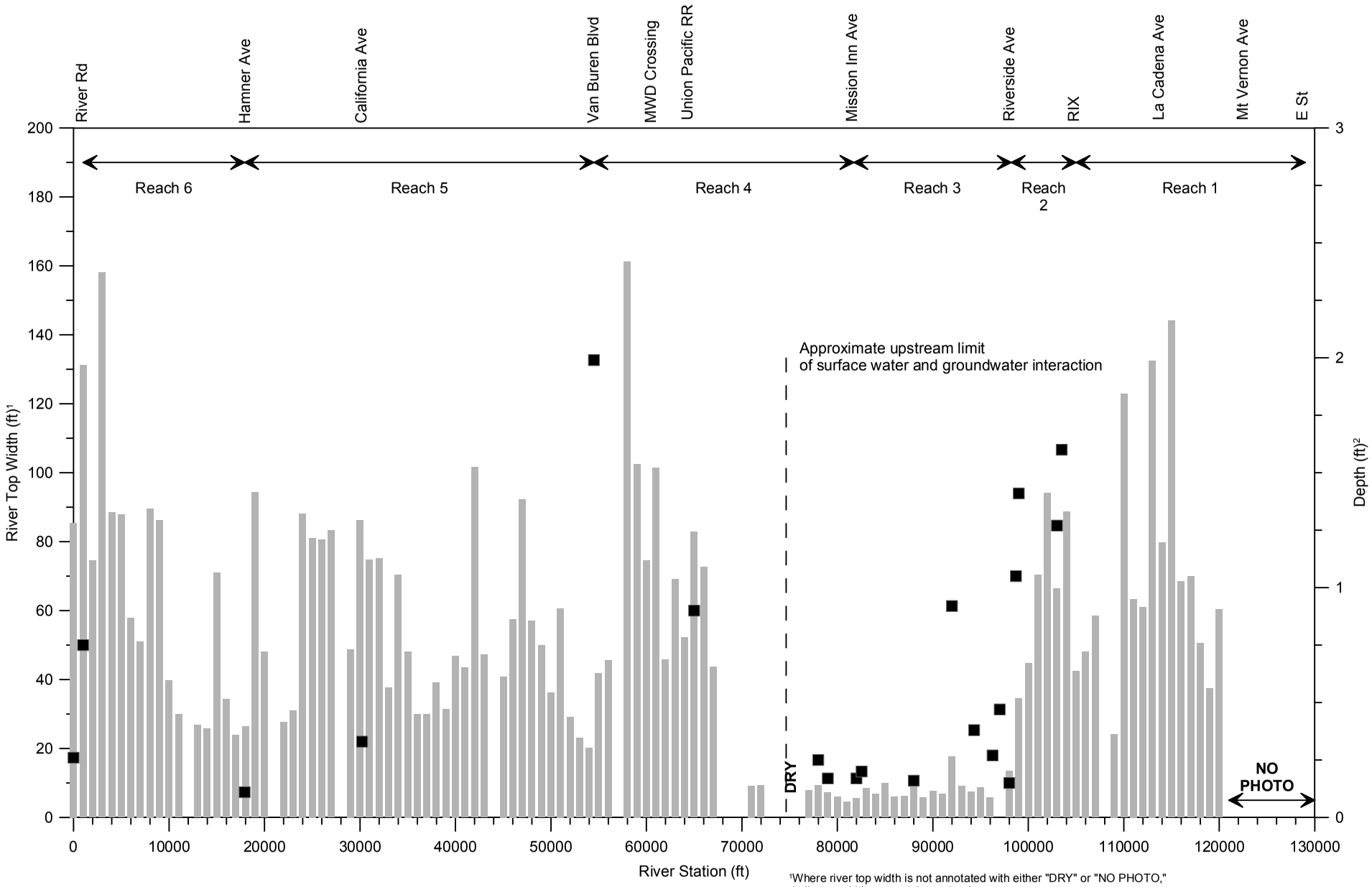
Figure 30
Santa Ana River Top Width and Estimated Flow Depth in Spring 1967



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO," indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1967SAR_WidthSummary.grf

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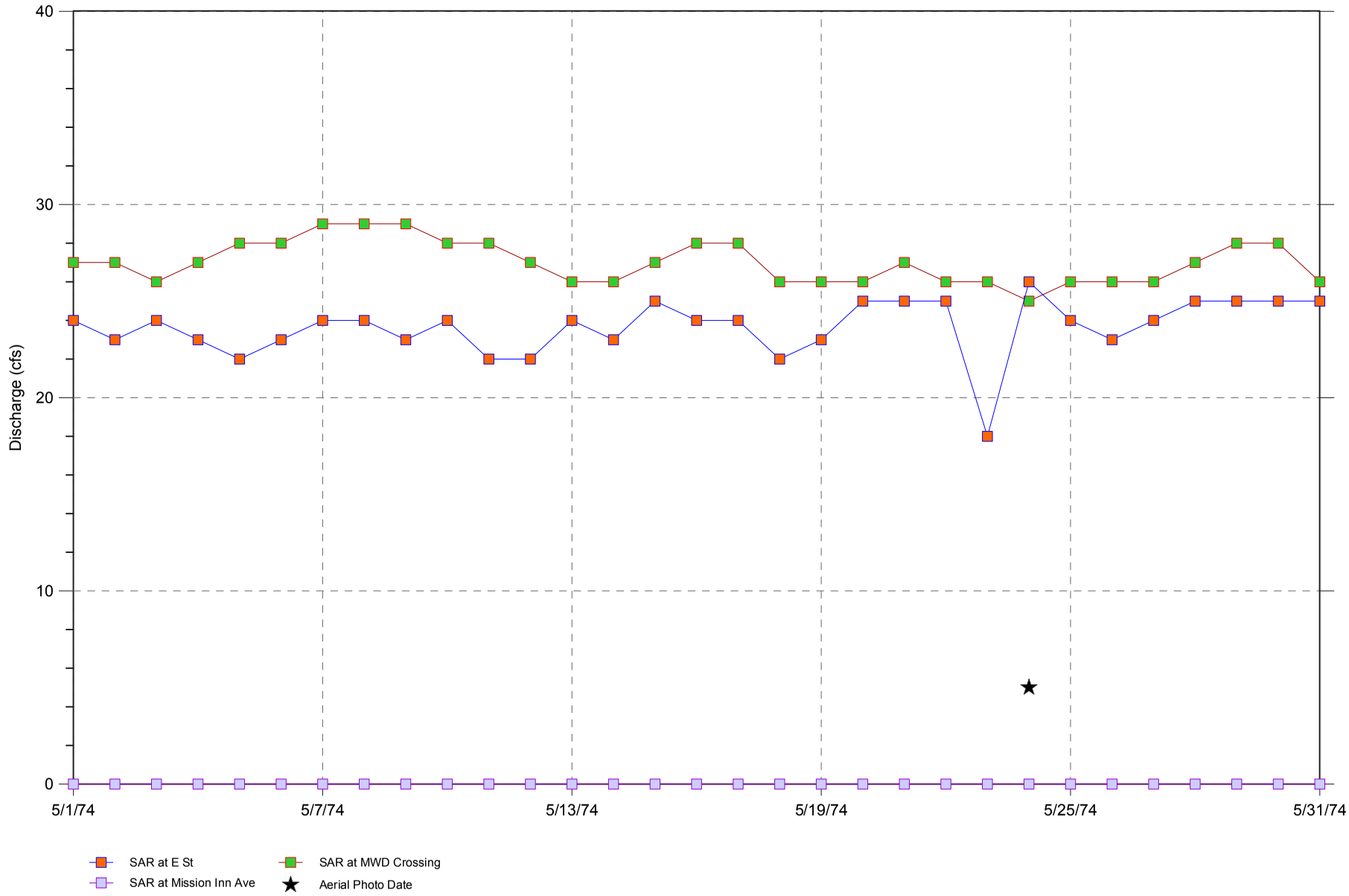
Figure 31
USGS Gaging Station Discharge Data: May 1974



Date: 05/16/2013
File: 1974_Q.grf

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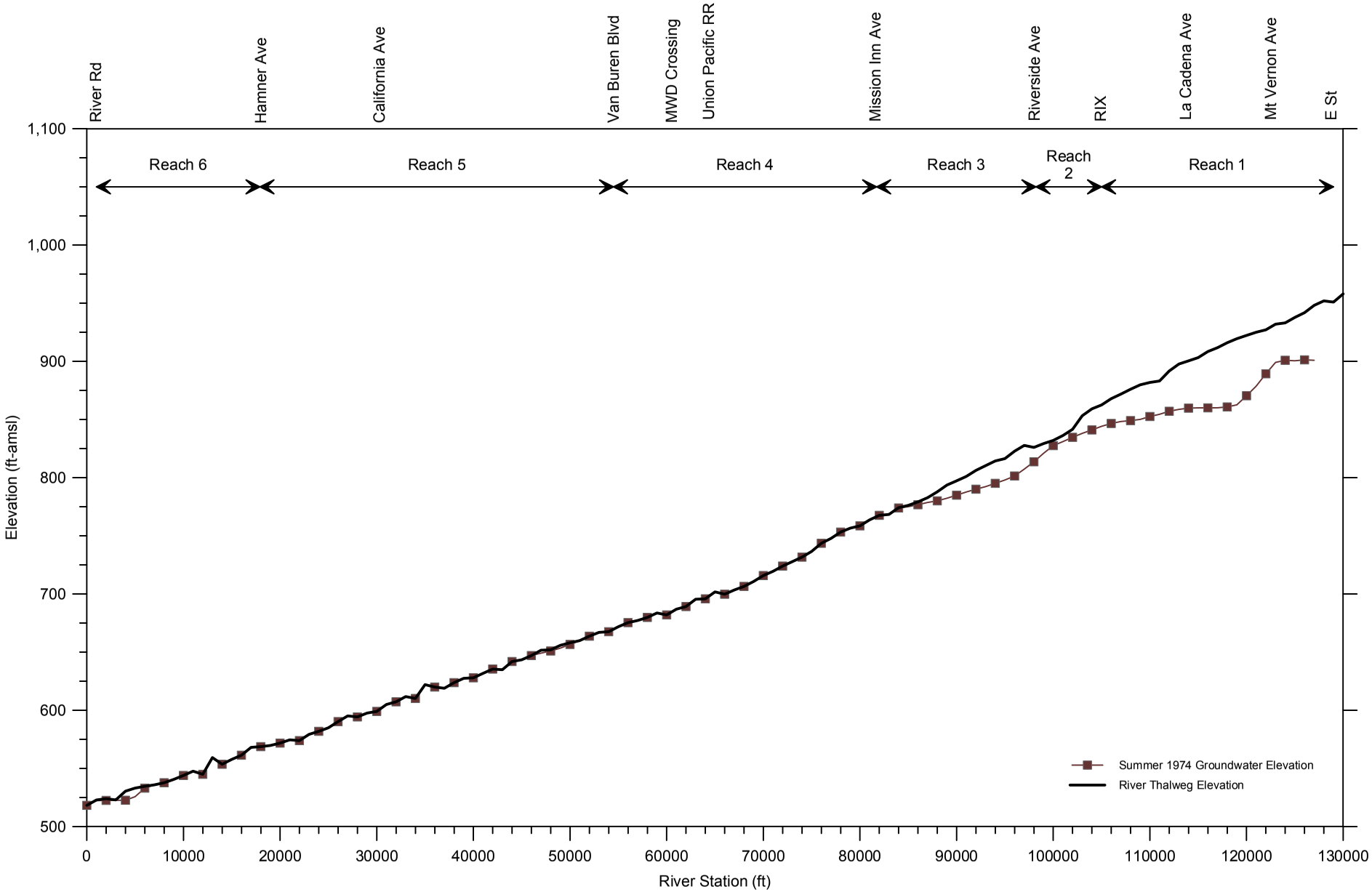
Figure 32
Santa Ana River Historic Groundwater Elevation Summer 1974



Date: 05/16/2013
File: SAR_1974HistoricGW.grf

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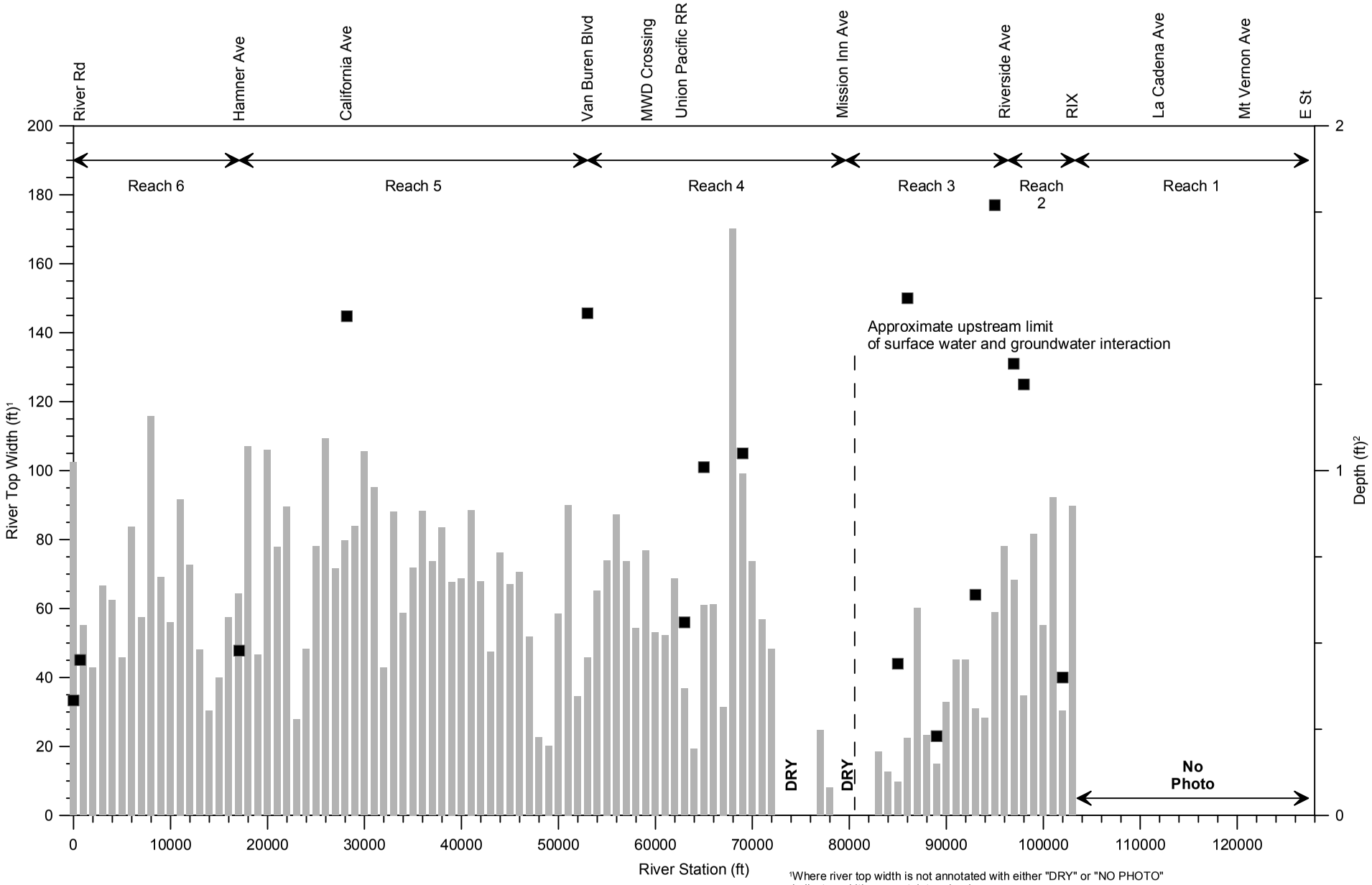
Figure 33
Santa Ana River Top Width and Estimated Flow Depth in Summer 1974



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1974SAR_WidthSummary.grf

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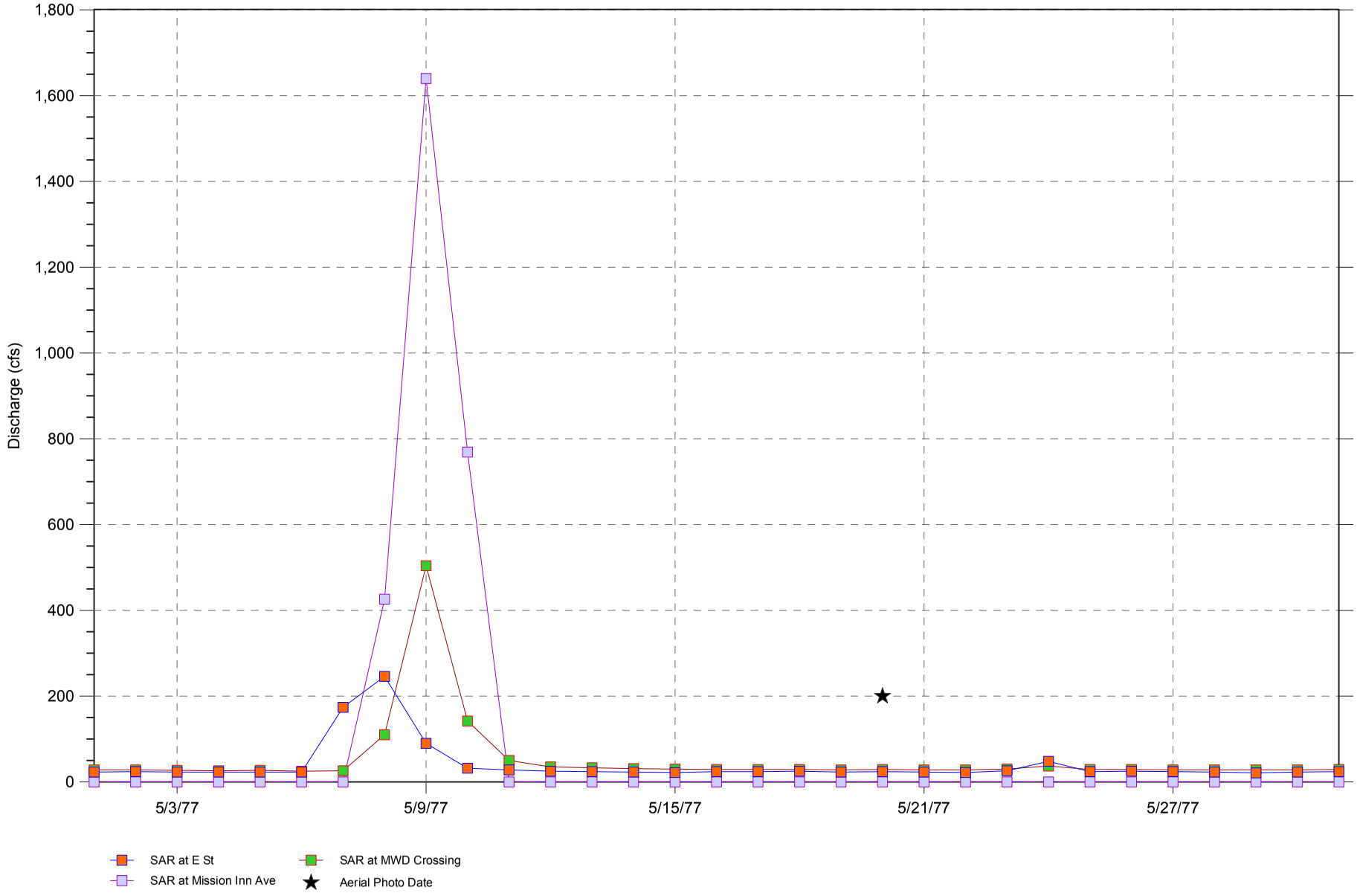
Figure 34
USGS Gaging Station Discharge Data: May 1977



Date: 05/16/2013
File: 1977_Q.grf

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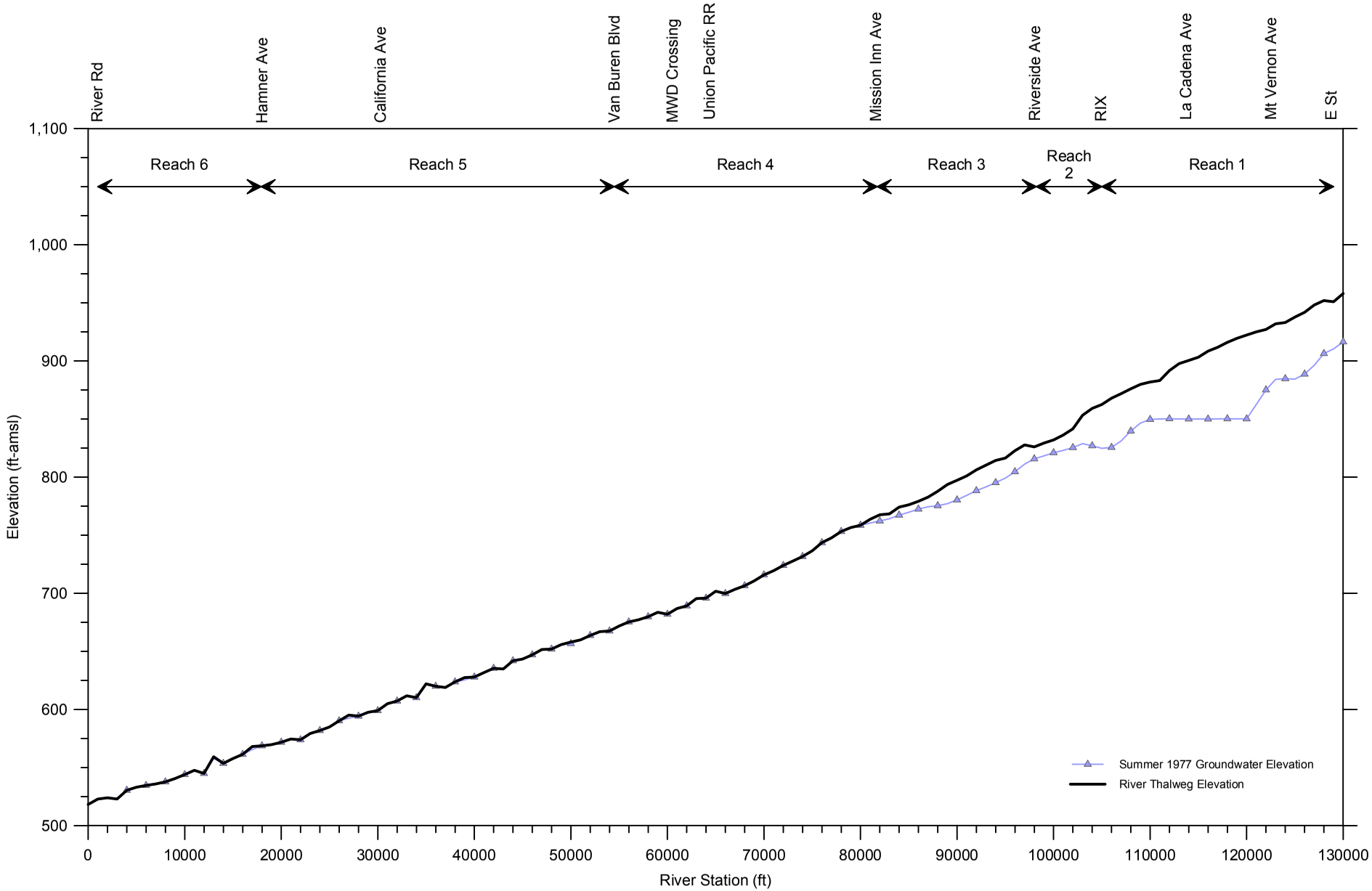
Figure 35
Santa Ana River Historic Groundwater Elevation Summer 1977

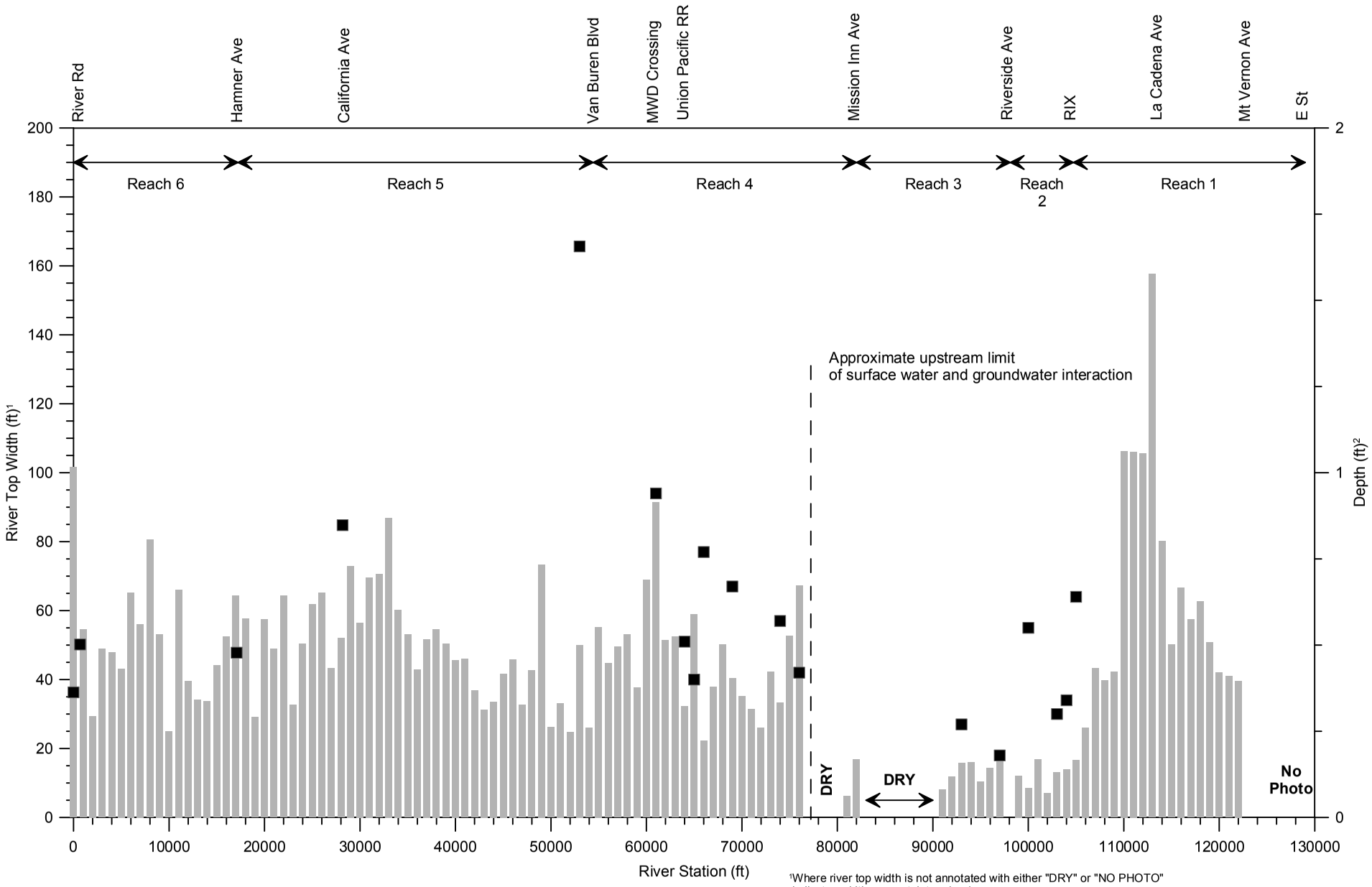


Date: 05/16/2013
File: SAR_1977HistoricGW.grf

WILDERMUTH ENVIRONMENTAL INC.

Priviledged and Confidential
Attorney-Client Privilege
Attorney Work-Product

Figure 36
Santa Ana River Top Width and Estimated Flow Depth in Summer 1977



[1]Where river top width is not annotated with either "DRY" or "NO PHOTO" indicates width was not determined

[2]River depth < 0.5 ft is considered to be below the resolution of the topographic data between River Rd and MWD Crossing

River Top Width ■ River Flow Depth

Date: 05/16/2013
File: 1977SAR_WidthSummary.grf

WILDERMUTH ENVIRONMENTAL INC.

Appendix A

1938 Aerial Photos

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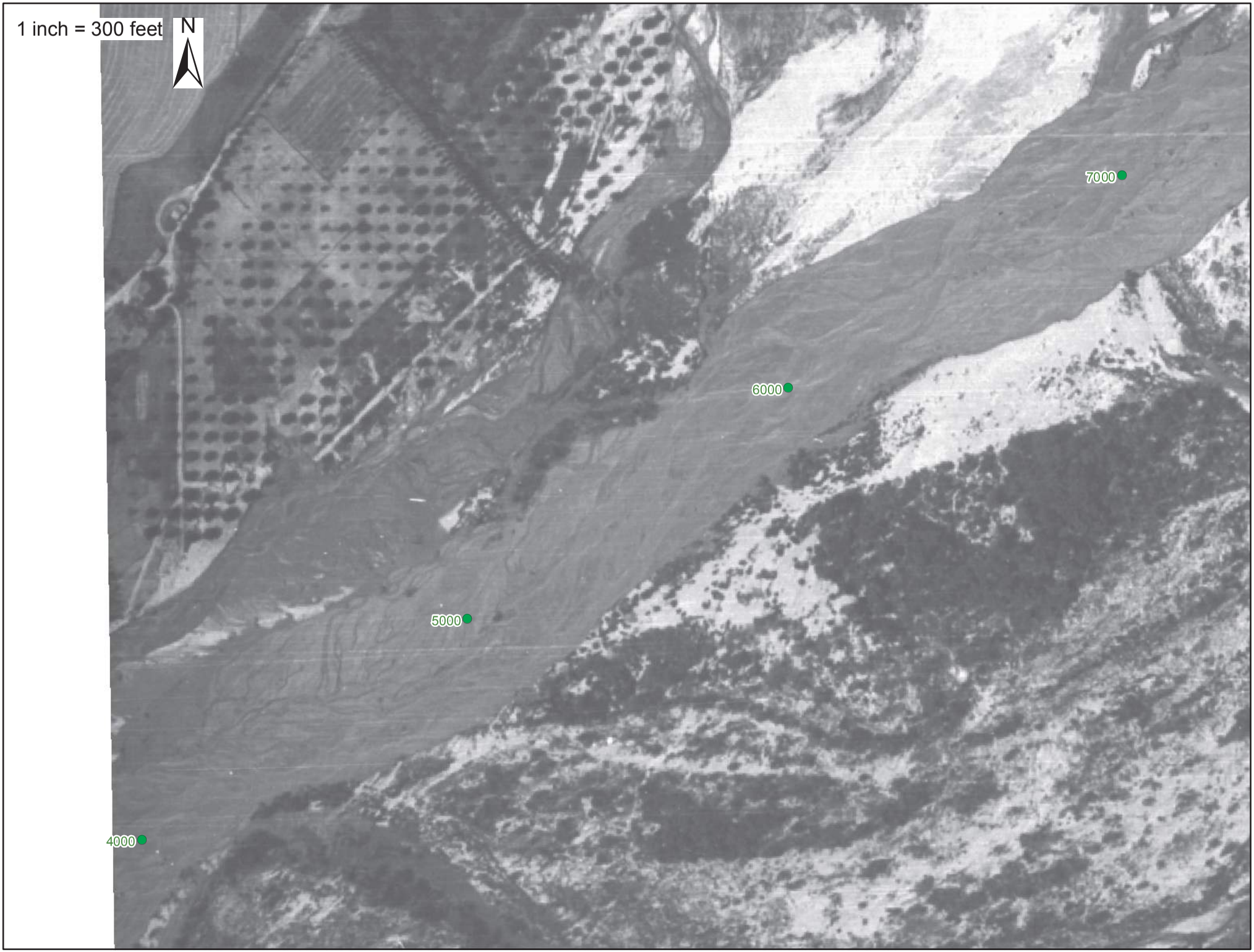
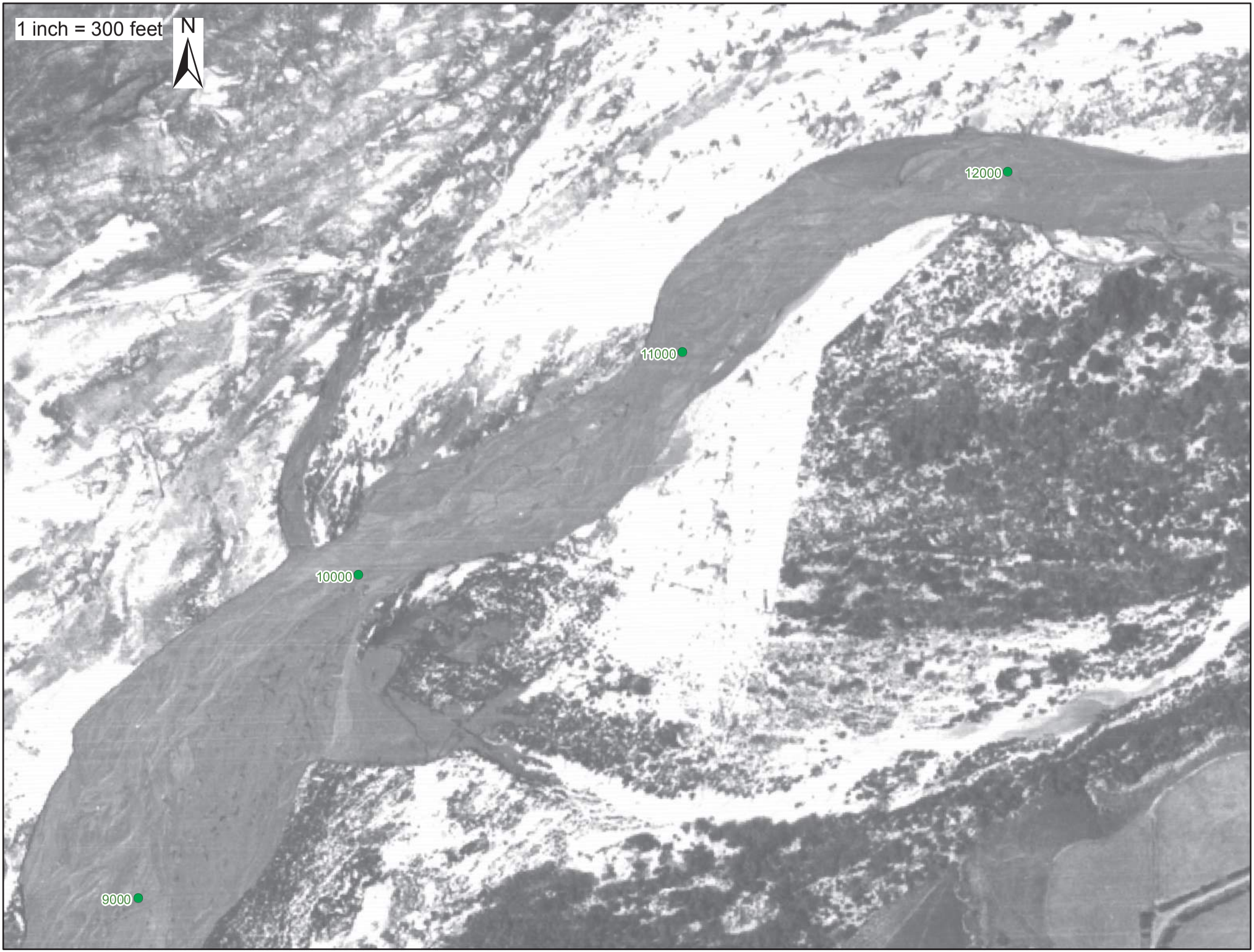
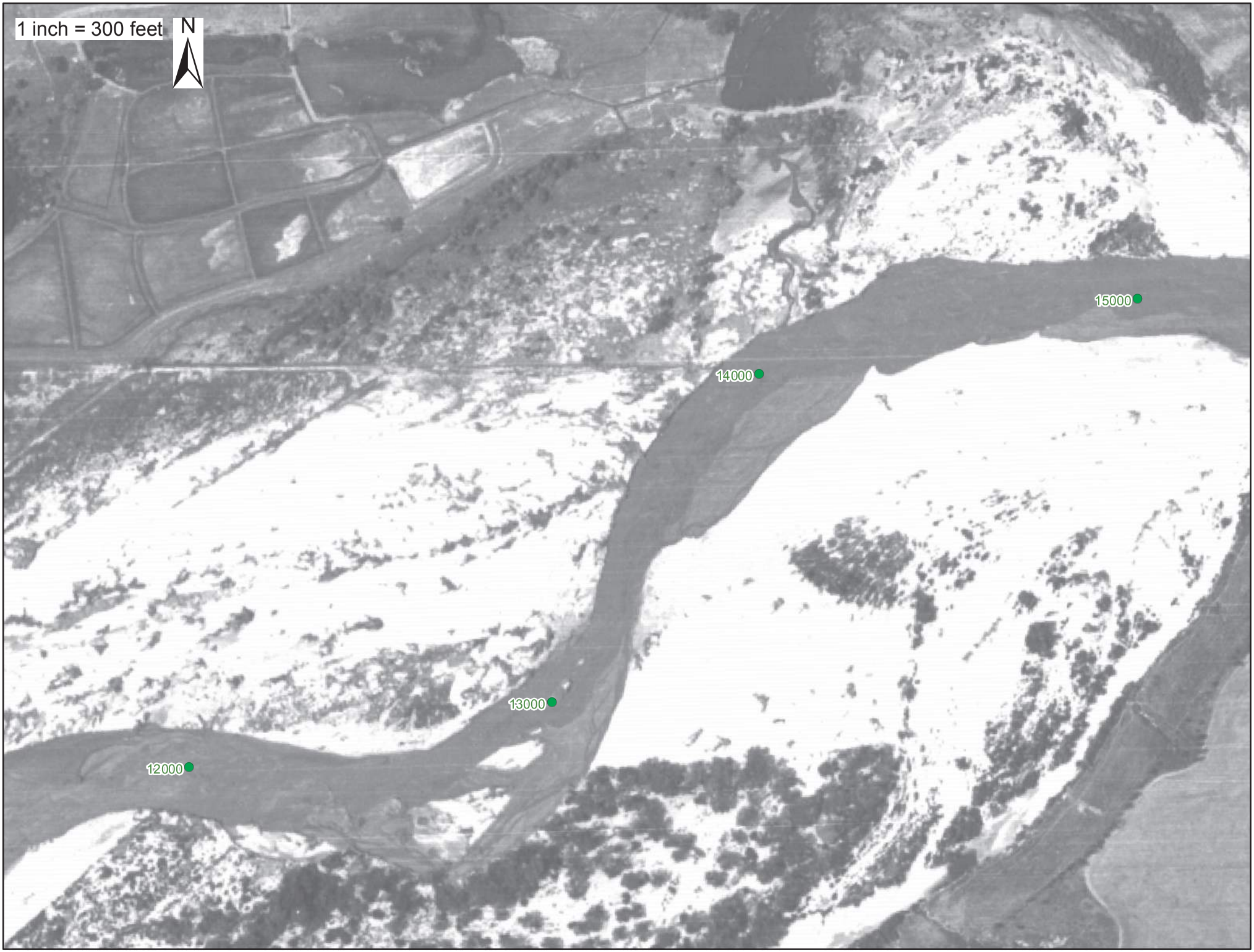
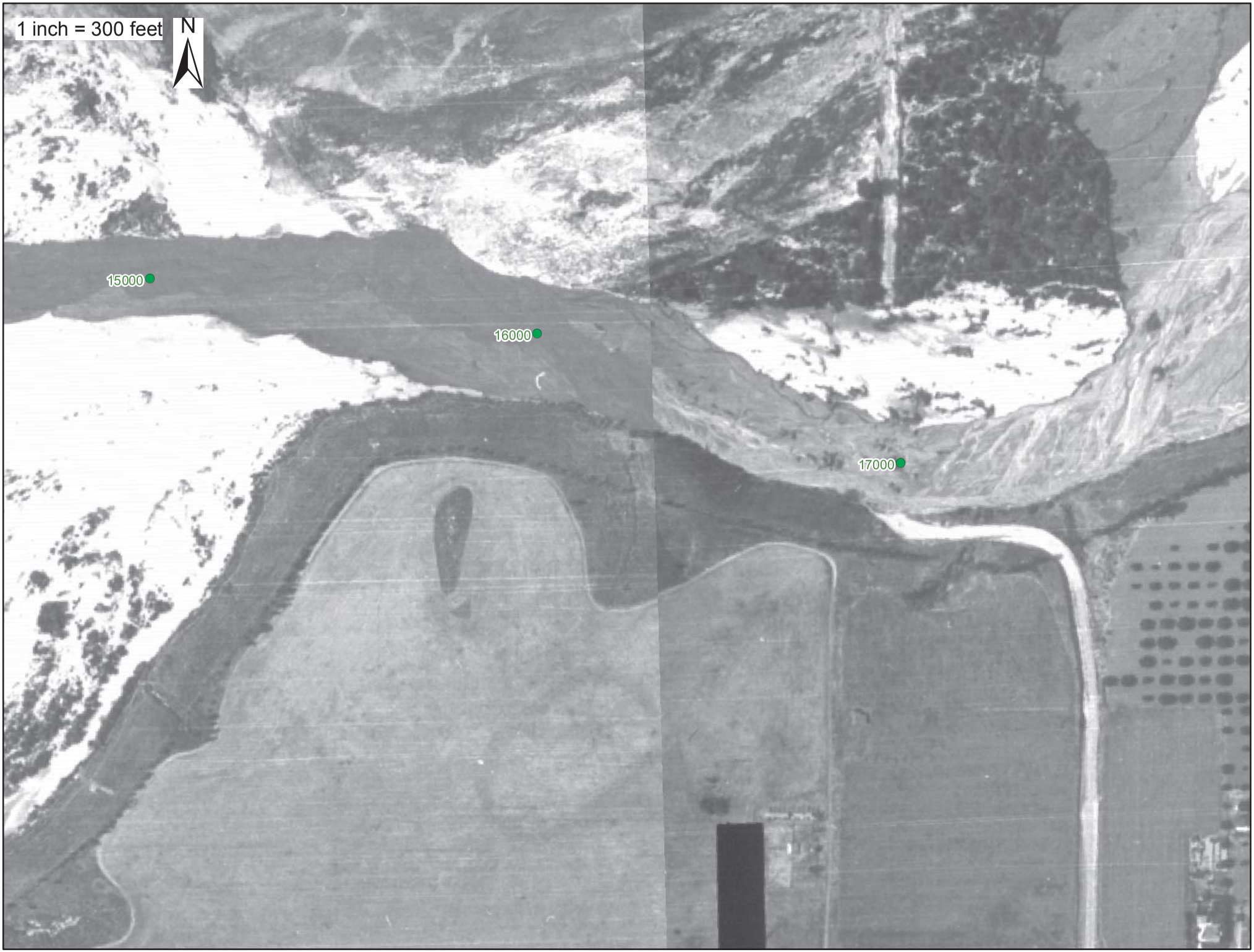
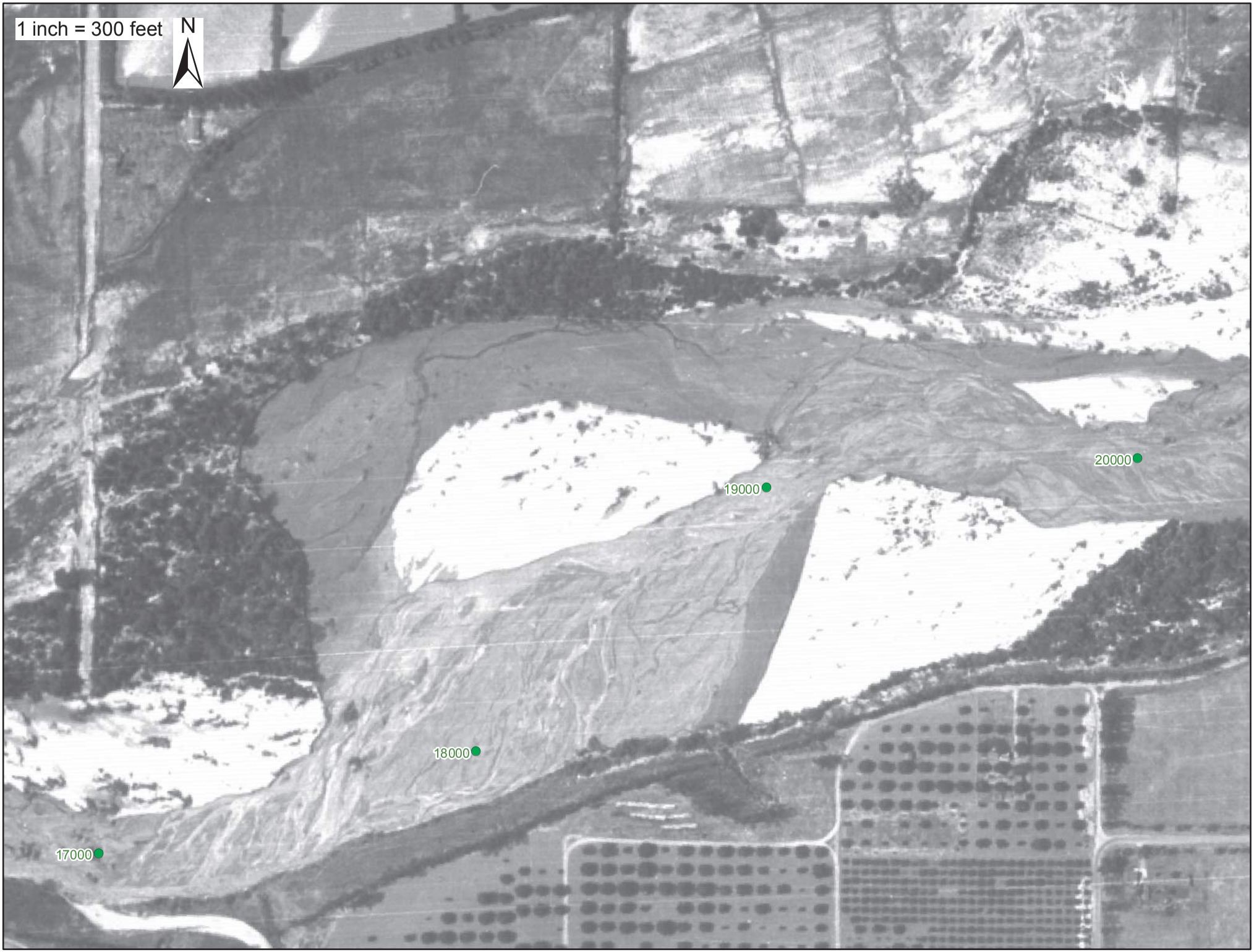

1 inch = 300 feet
N
7000
6000
5000
4000

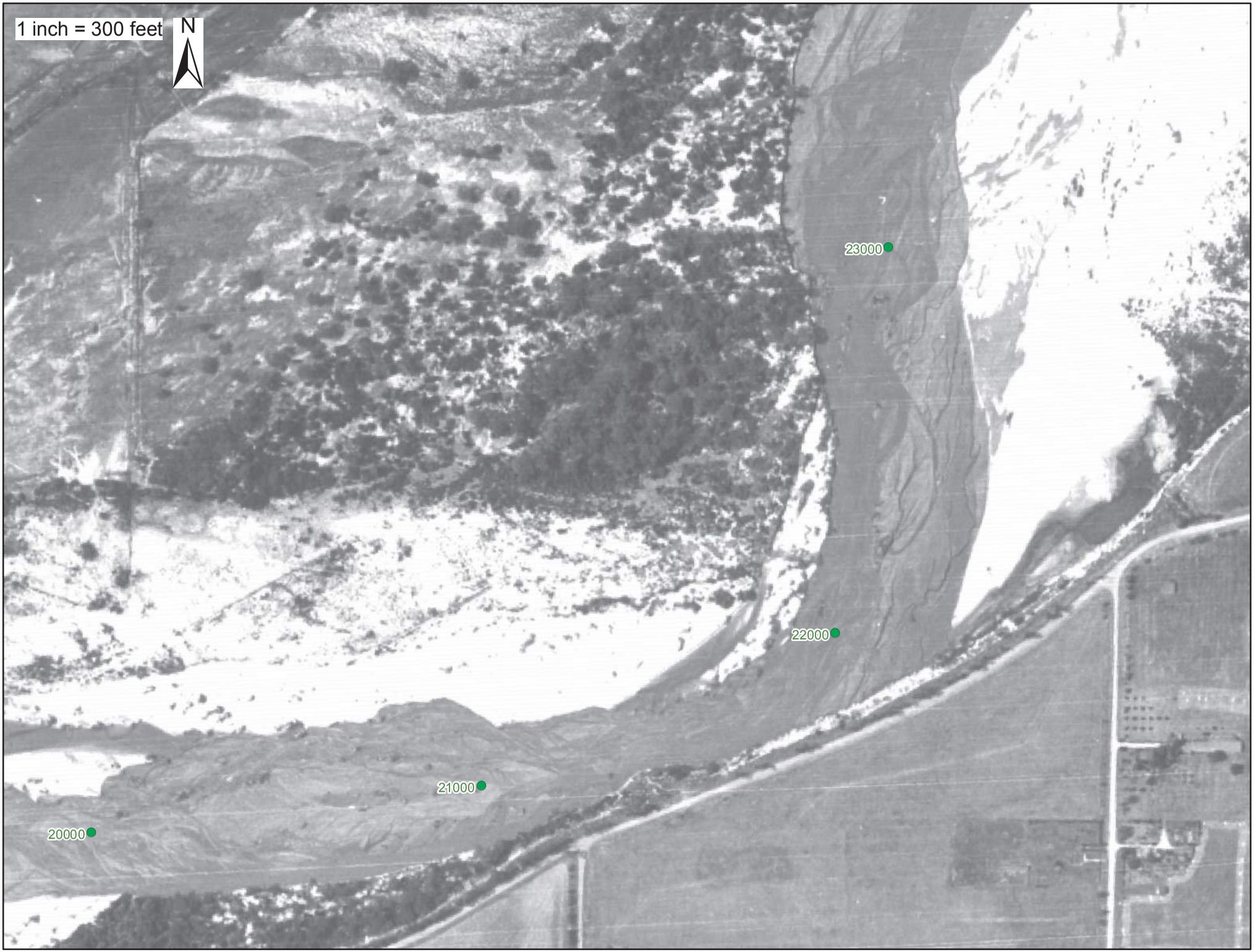
1 inch = 300 feet
N
9000
8000
7000

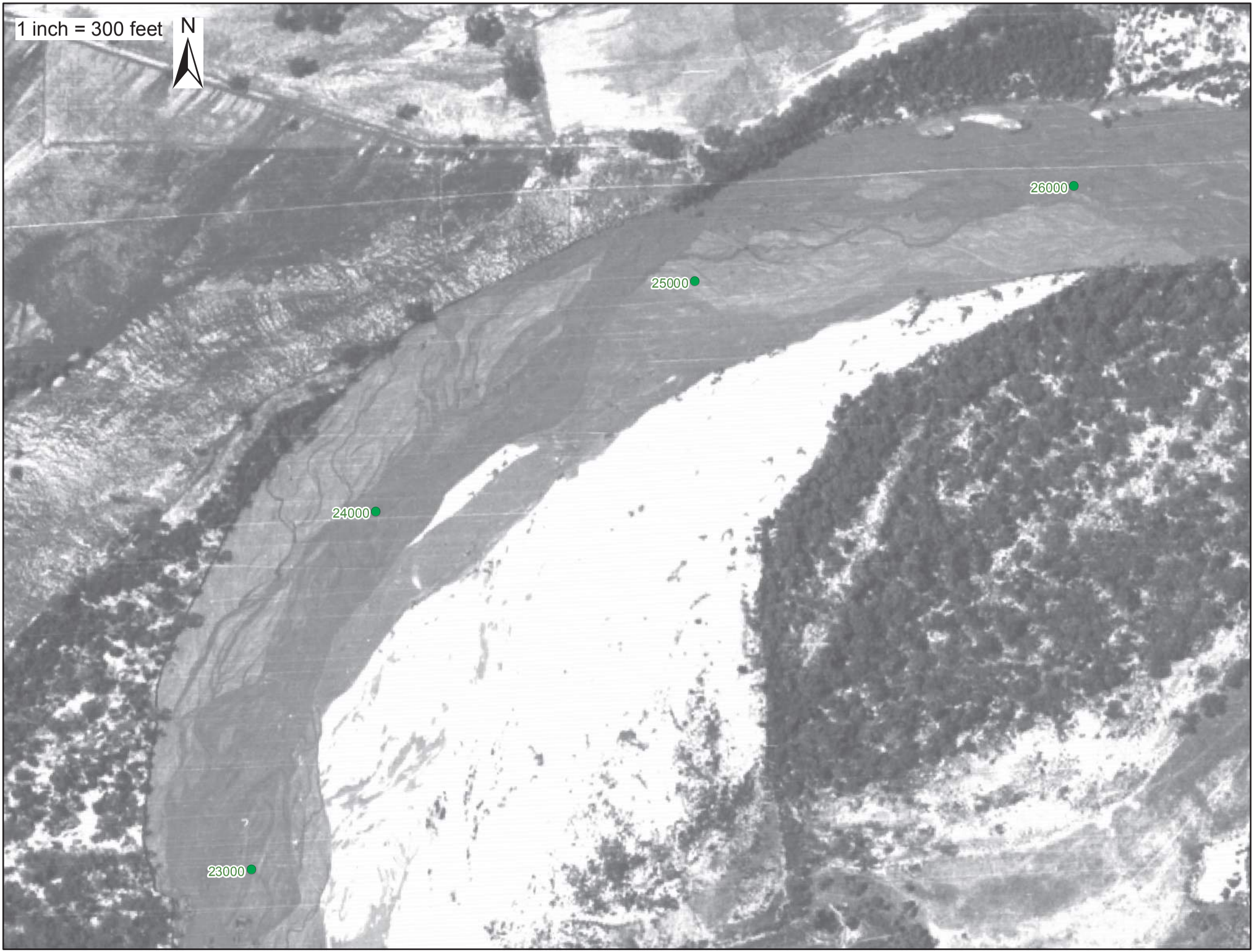

1 inch = 300 feet
N
12000
11000
10000
9000

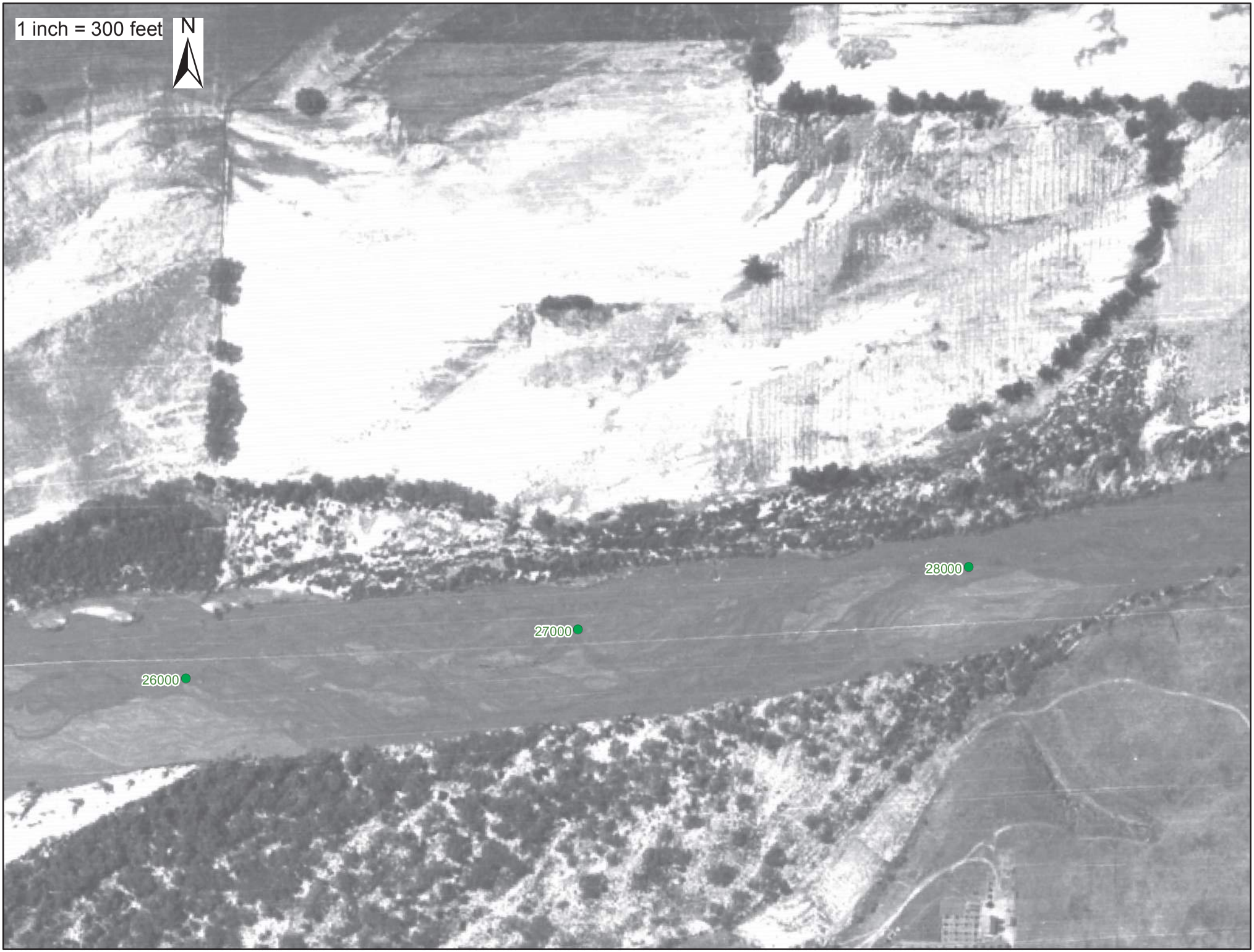

1 inch = 300 feet
N
15000
14000
13000
12000

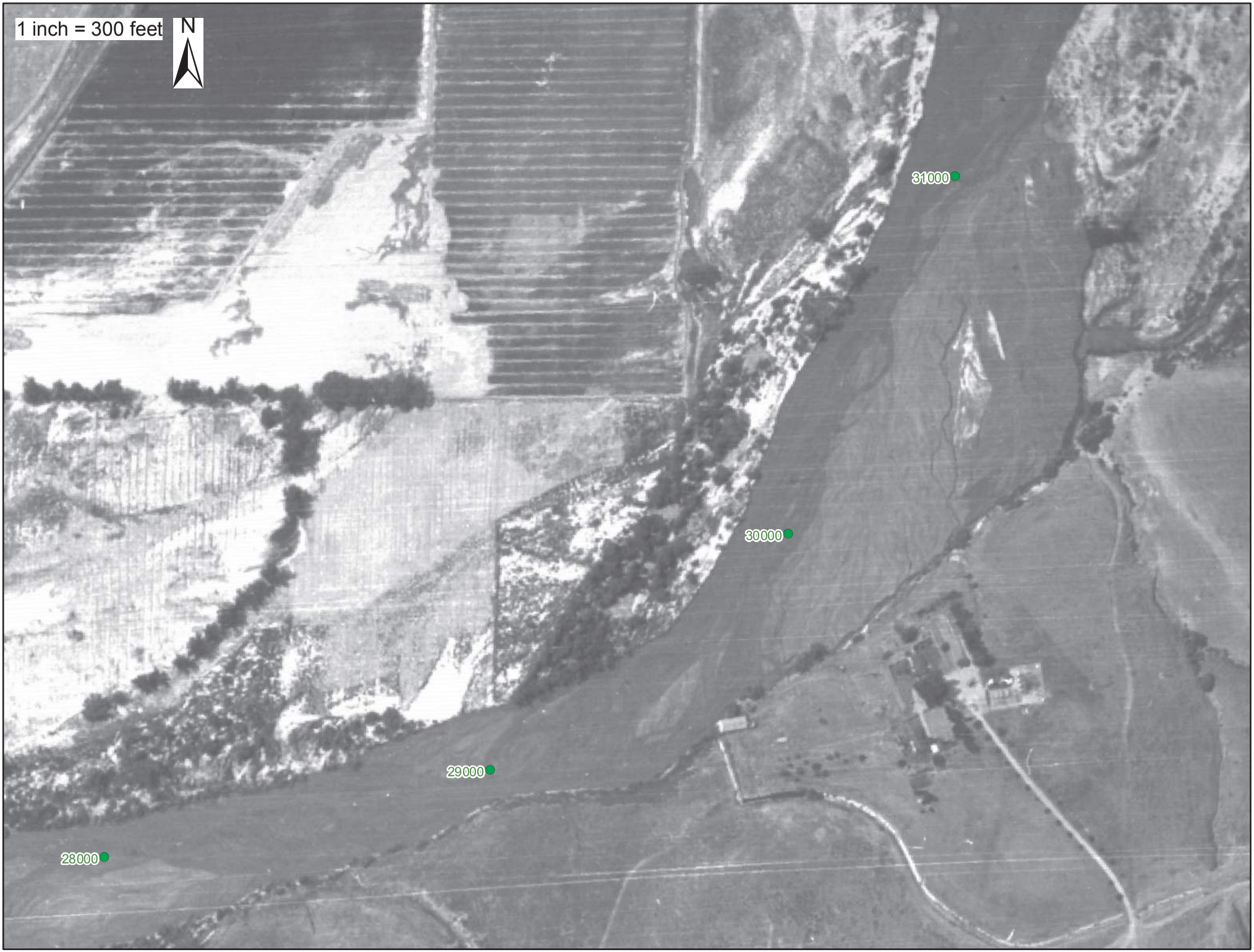

1 inch = 300 feet
N
15000
16000
17000


1 inch = 300 feet
N
20000
19000
18000
17000


1 inch = 300 feet
N
23000
22000
21000
20000


1 inch = 300 feet
N
26000
25000
24000
23000


1 inch = 300 feet
N
28000
27000
26000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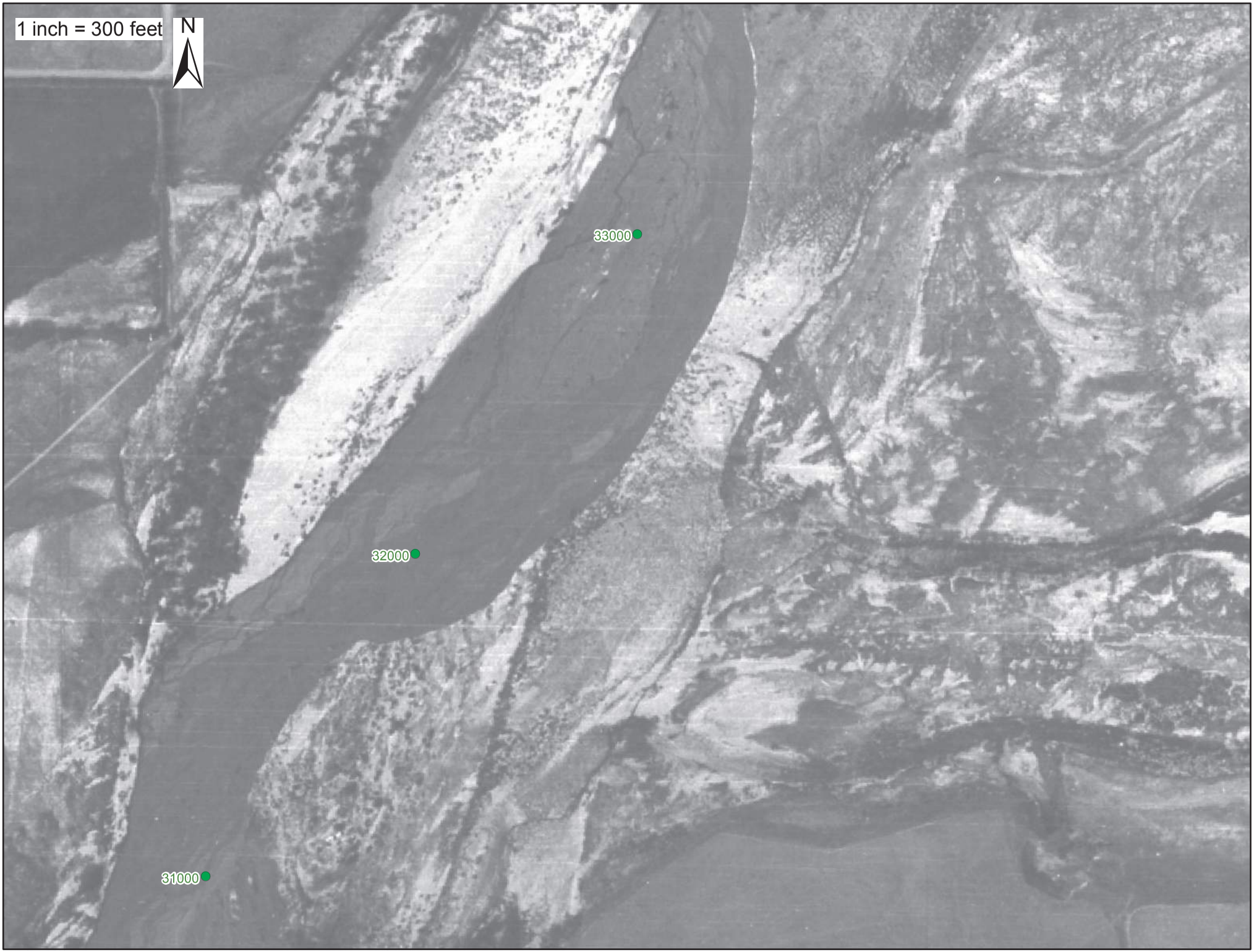
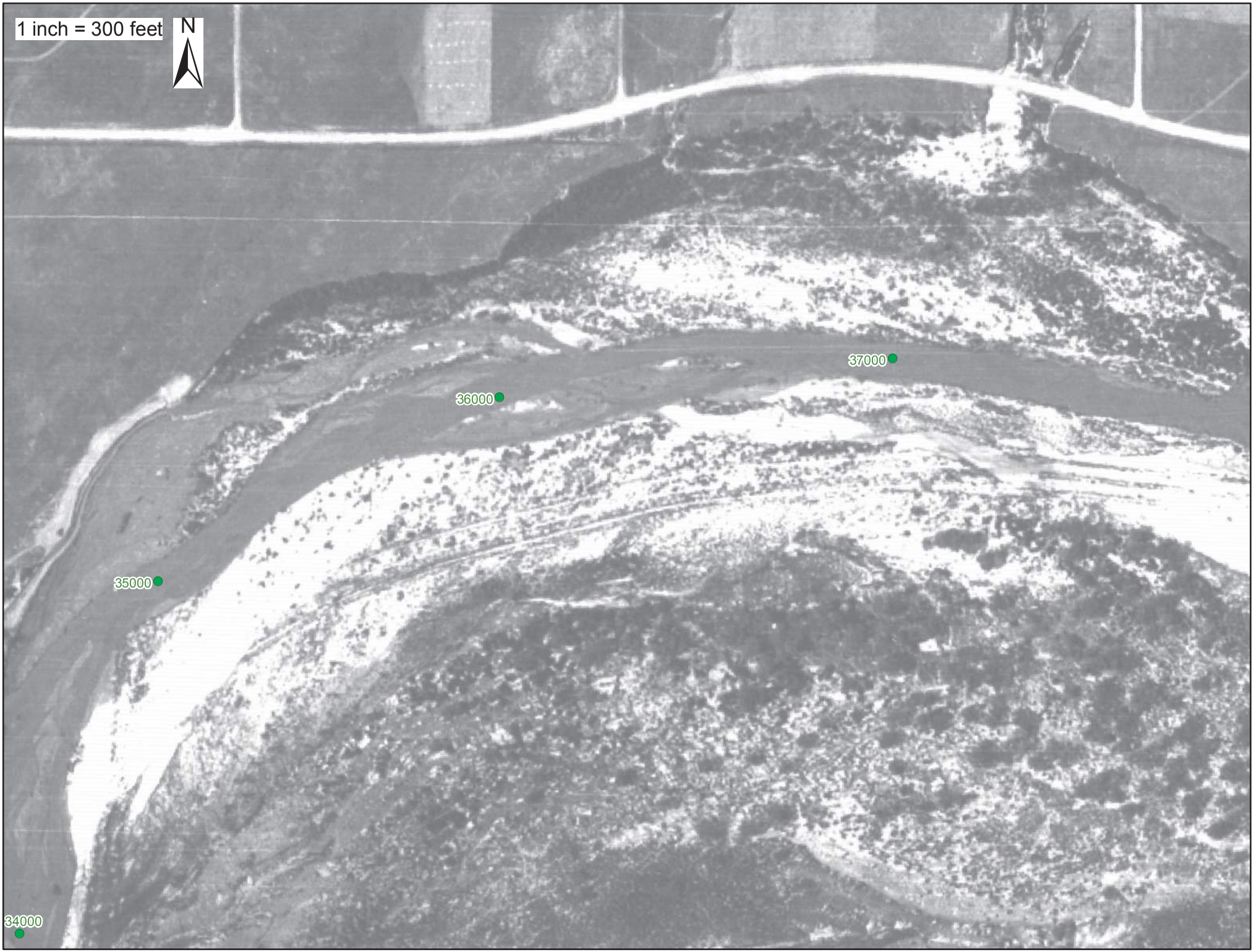
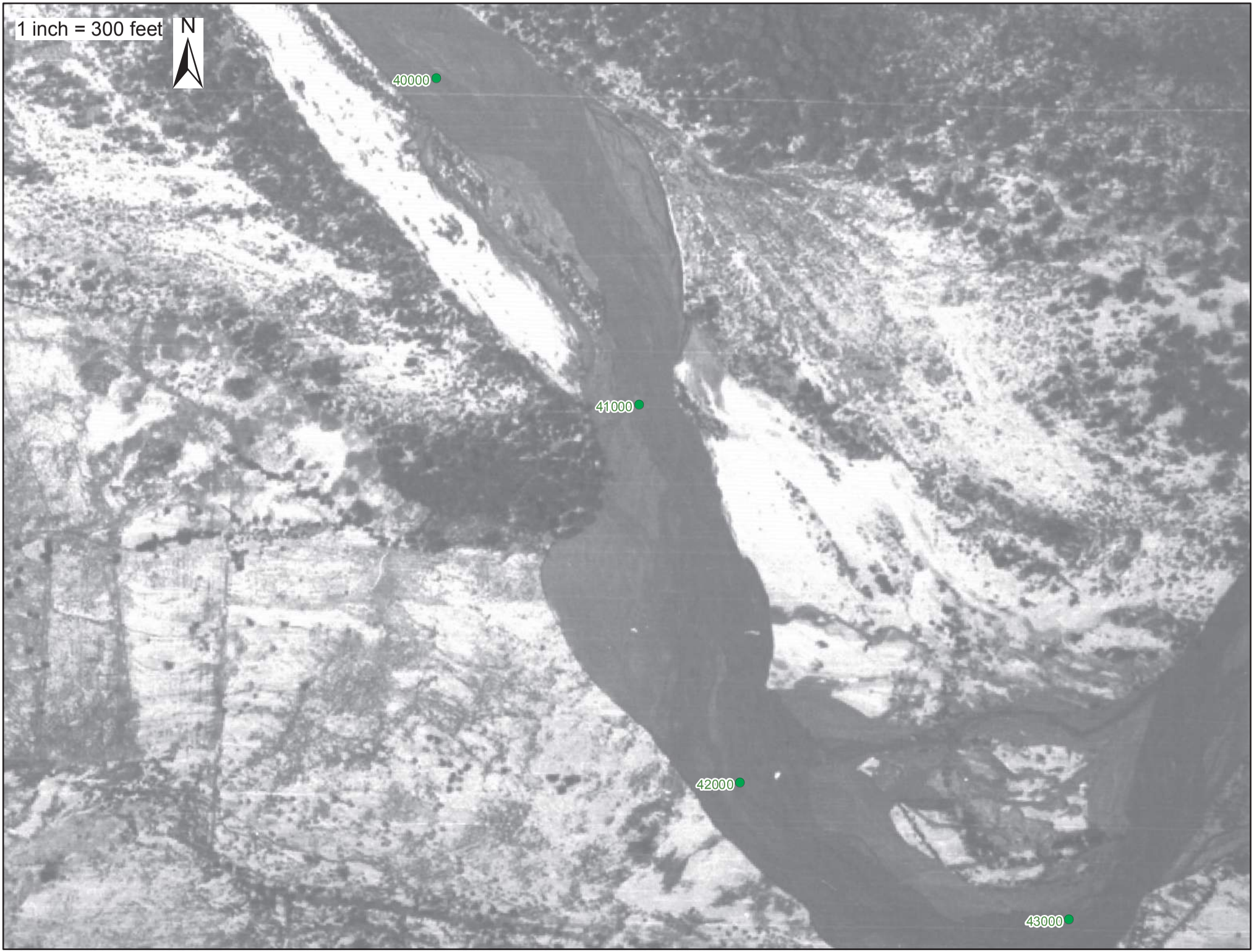
N
31000
30000
29000
28000

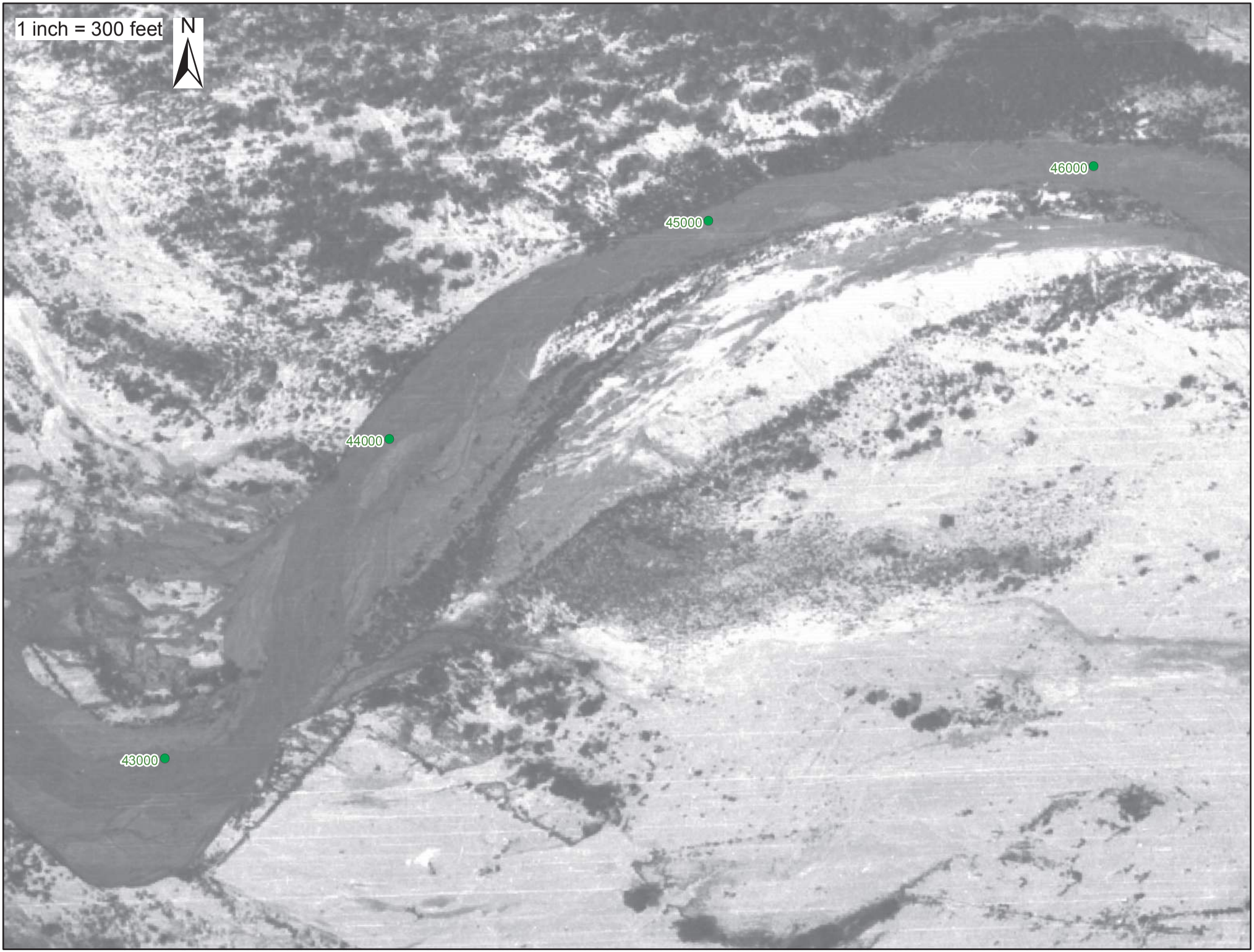

1 inch = 300 feet
N
33000
32000
31000

1 inch = 300 feet
N
35000
34000
33000

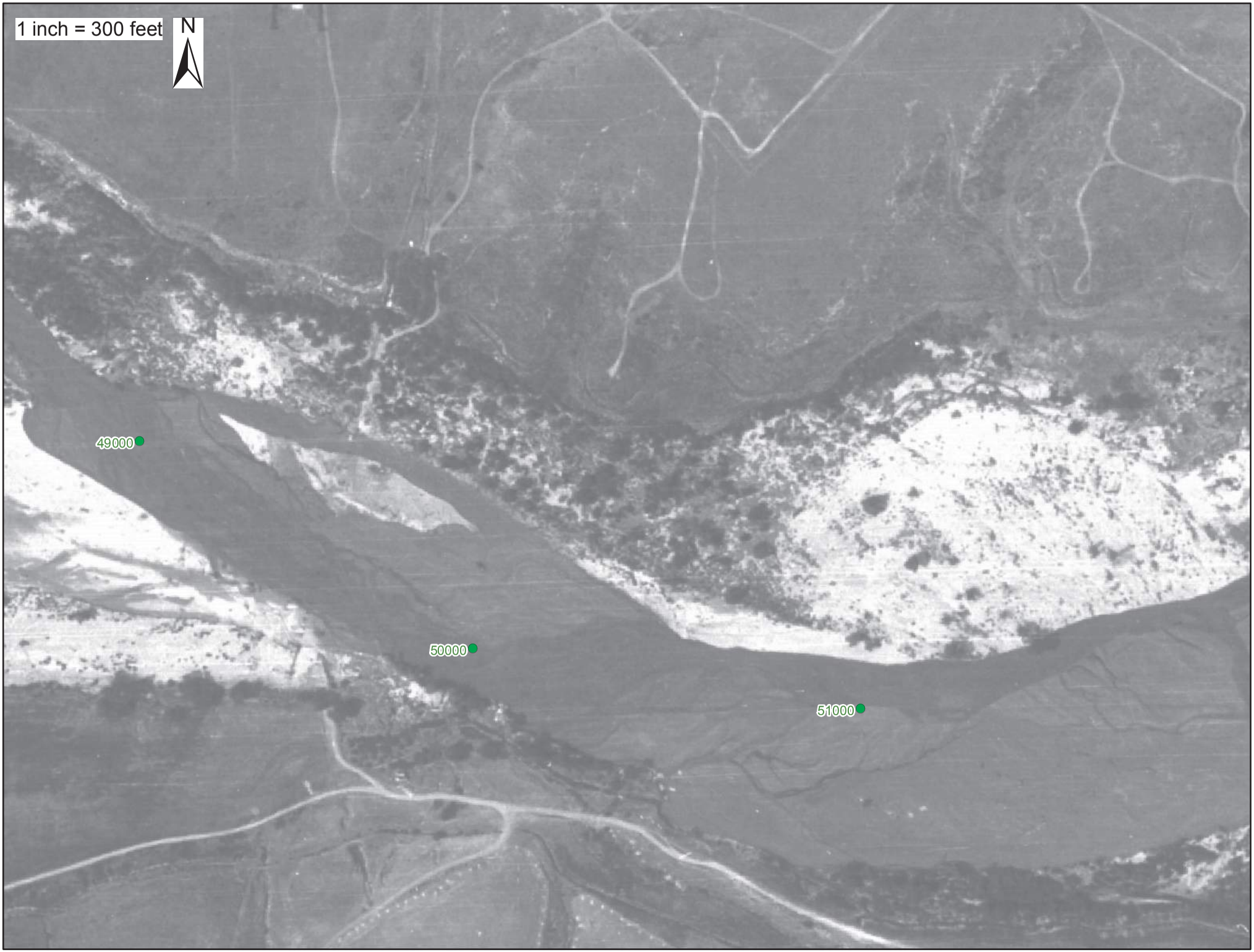

1 inch = 300 feet
N
37000
36000
35000
34000

1 inch = 300 feet
N
37000
38000
39000
40000

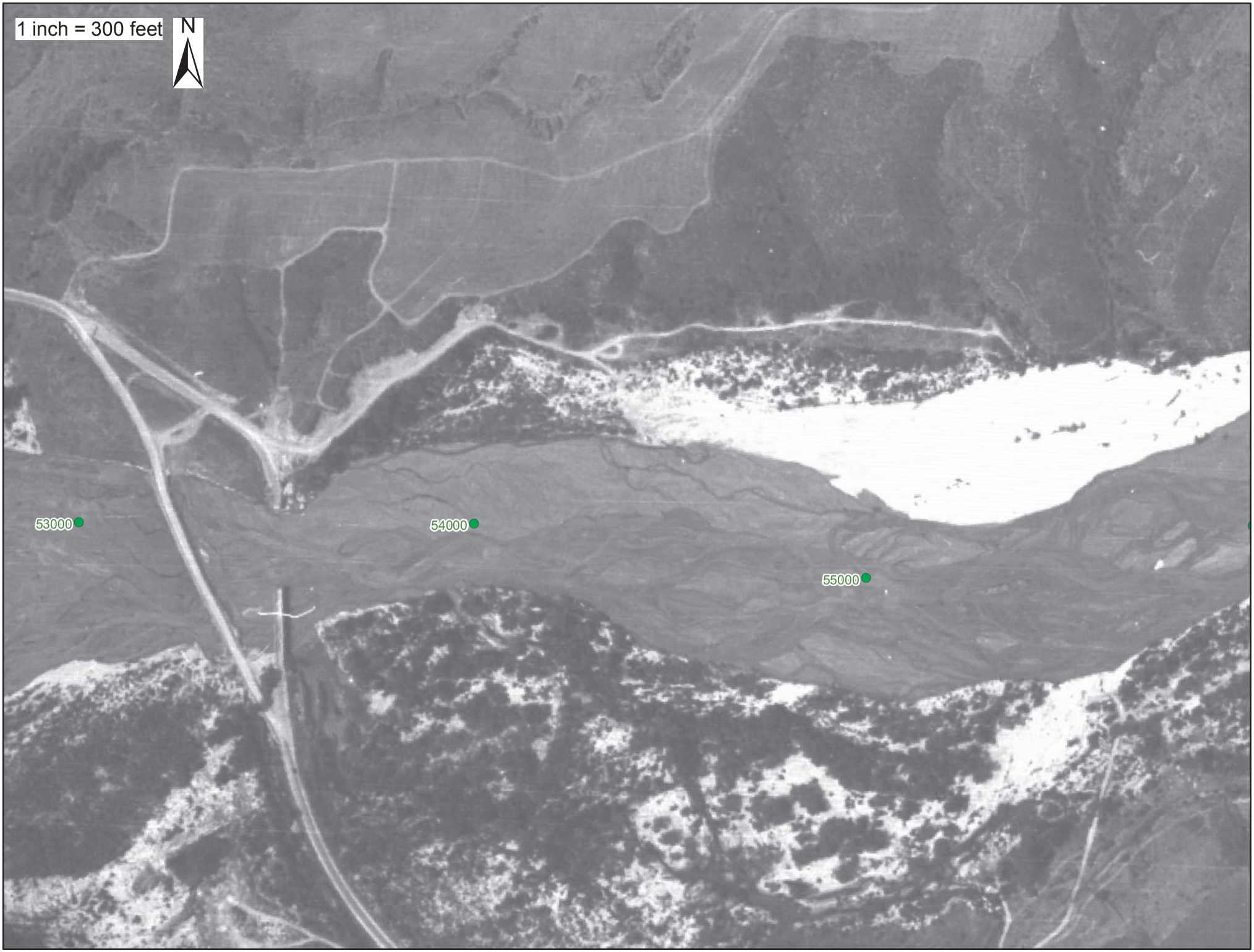

1 inch = 300 feet
N
40000
41000
42000
43000


1 inch = 300 feet
N
46000
45000
44000
43000

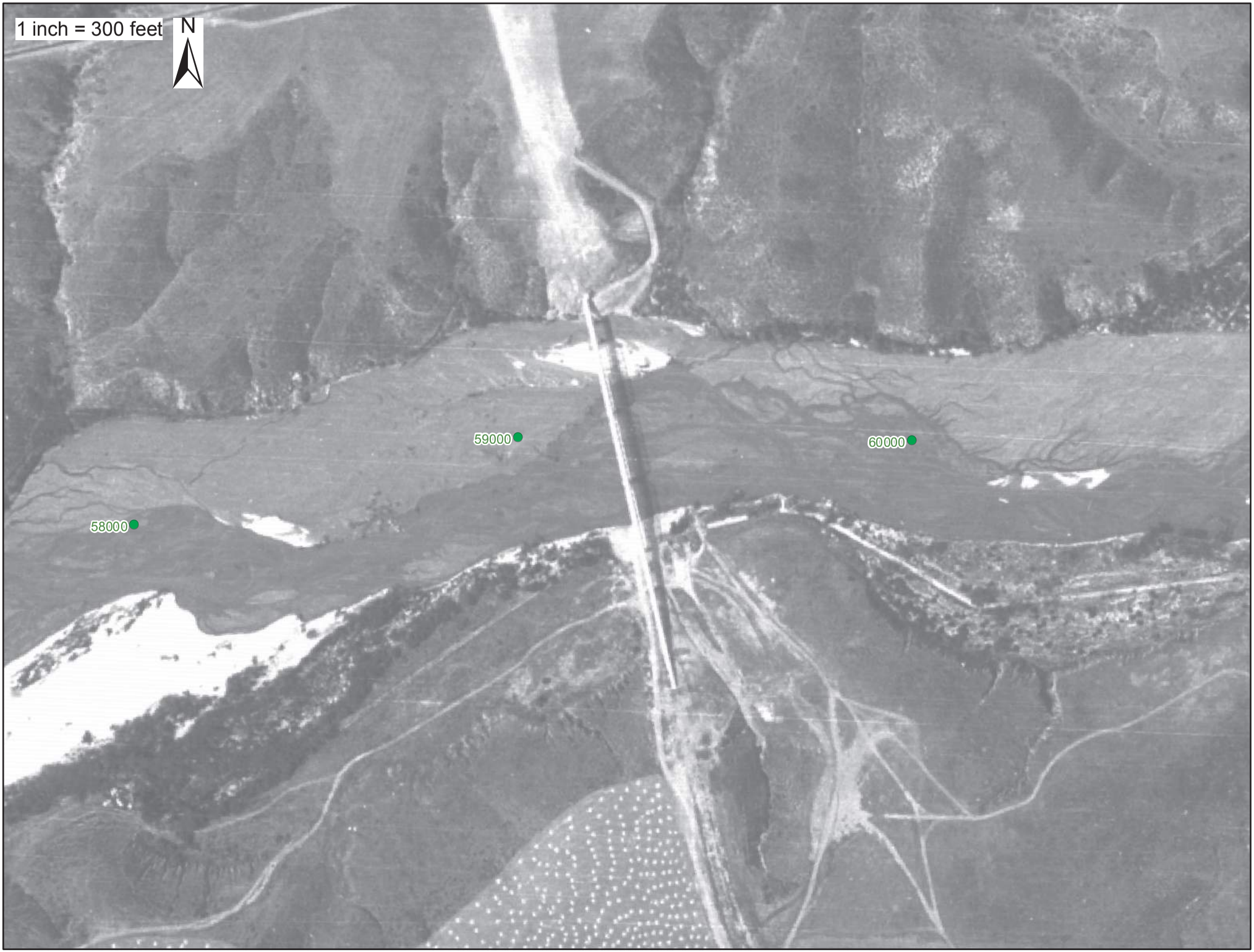
1 inch = 300 feet
N
46000
47000
48000
49000

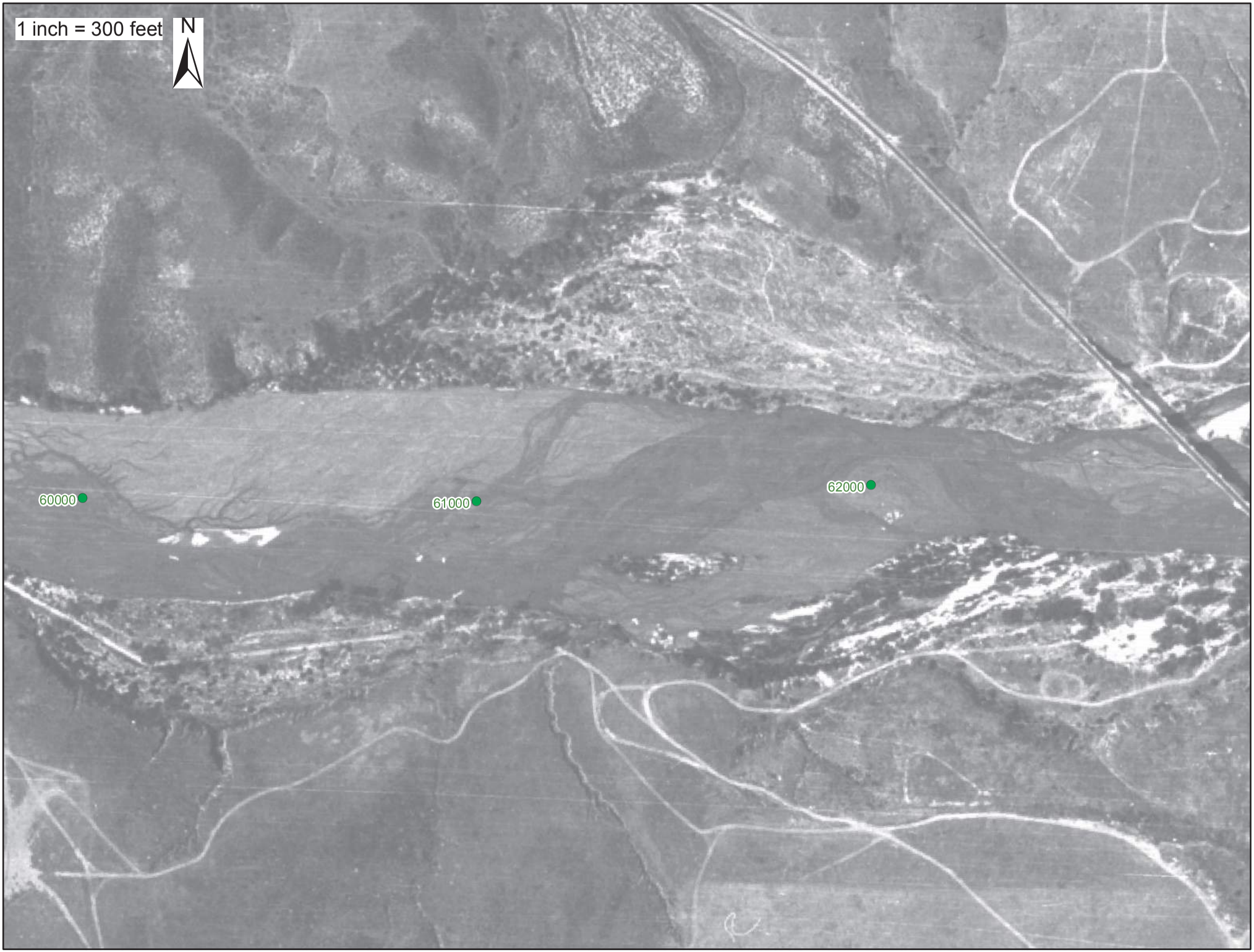

1 inch = 300 feet
N
49000
50000
51000

1 inch = 300 feet
N
53000
52000
51000

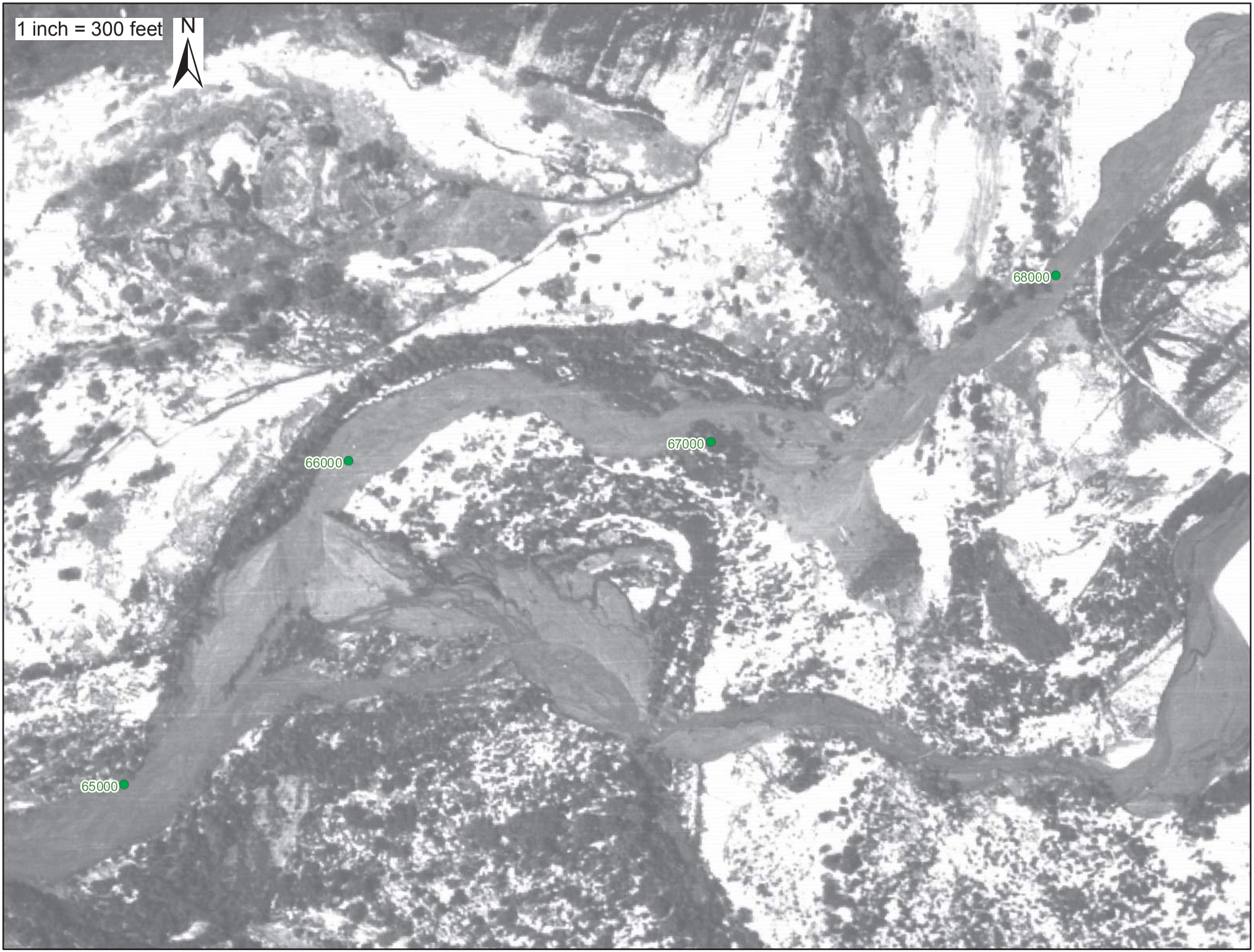

1 inch = 300 feet
N
53000
54000
55000

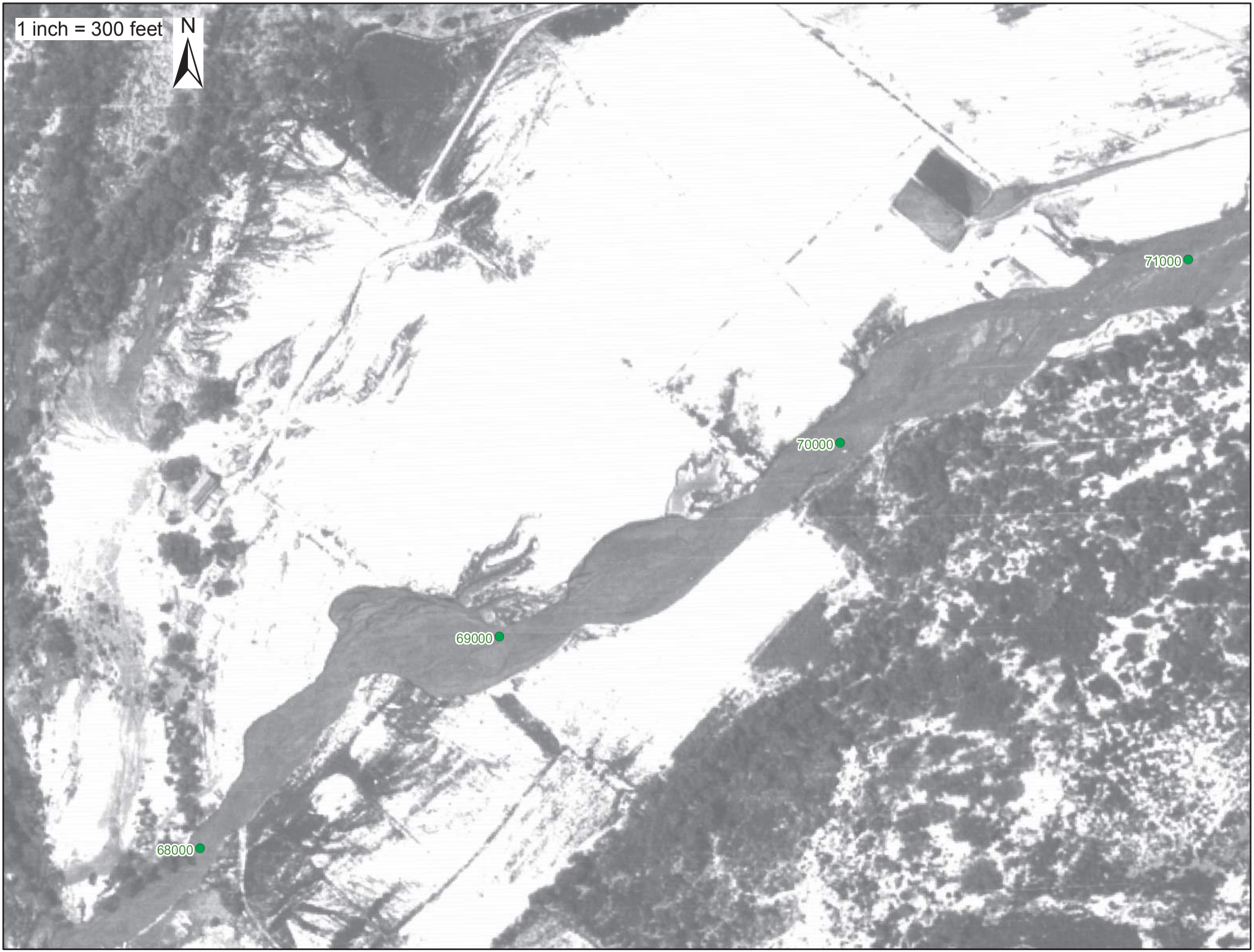
1 inch = 300 feet
N
58000
57000
56000
55000

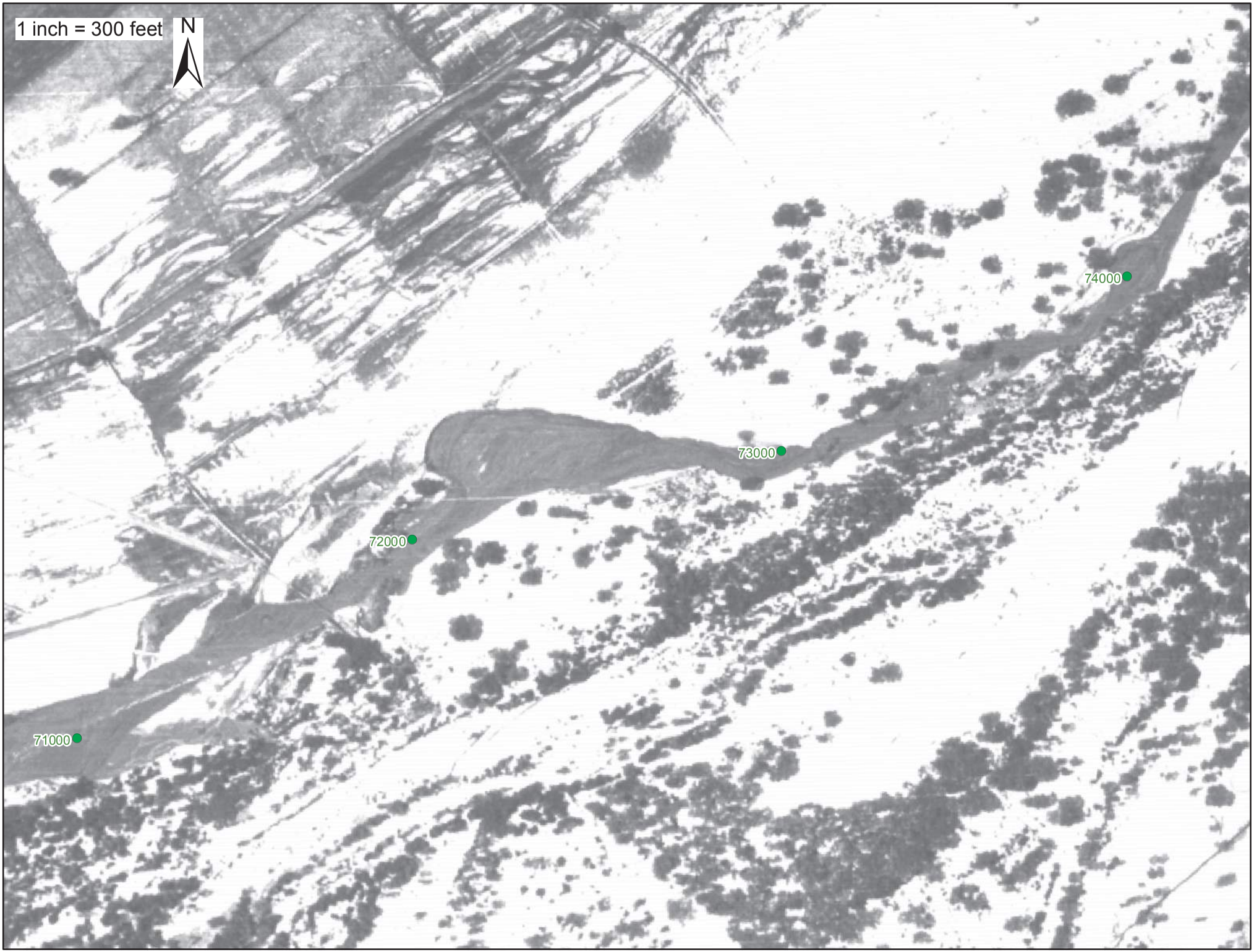

1 inch = 300 feet
N
59000
60000
58000

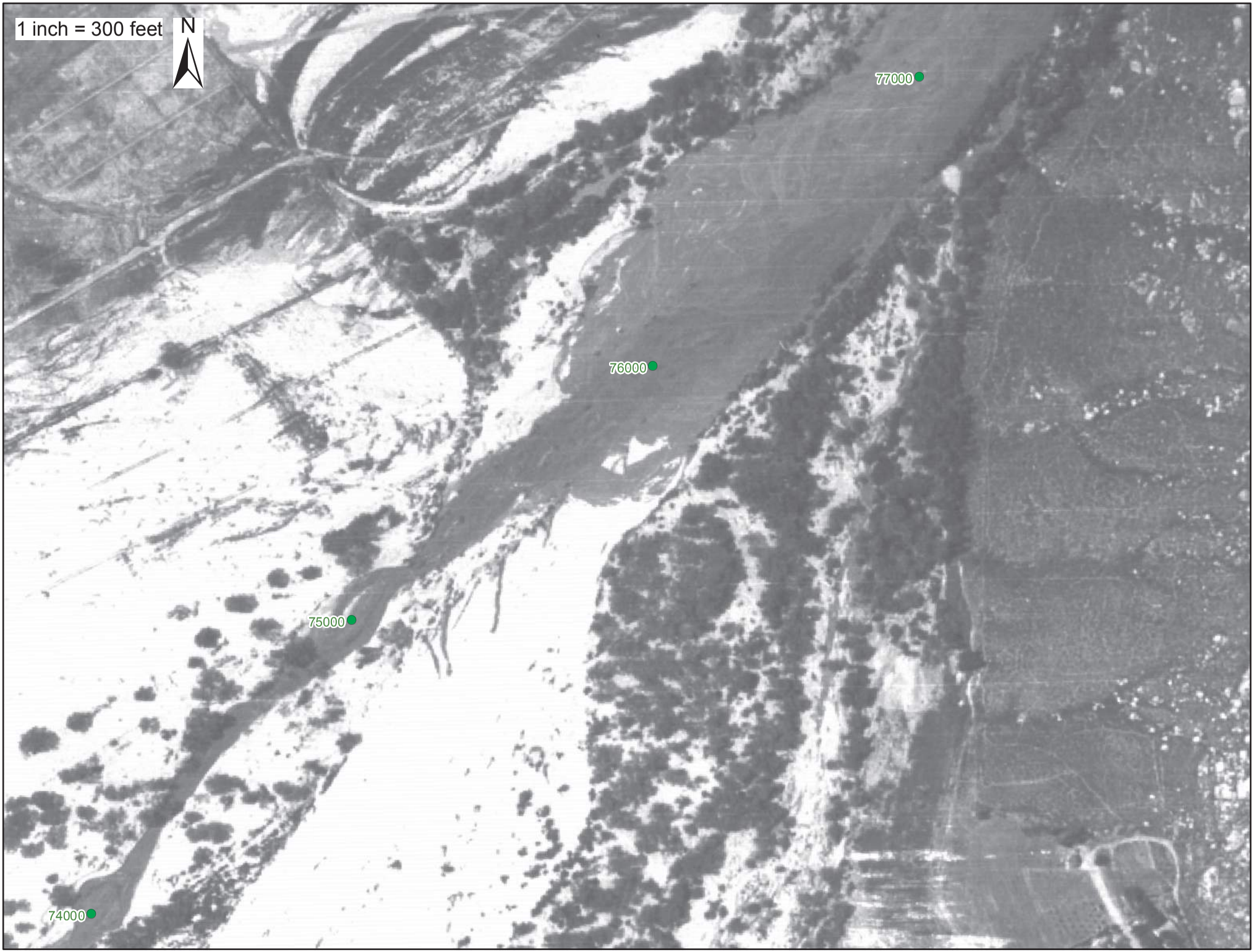

1 inch = 300 feet
N
60000
61000
62000

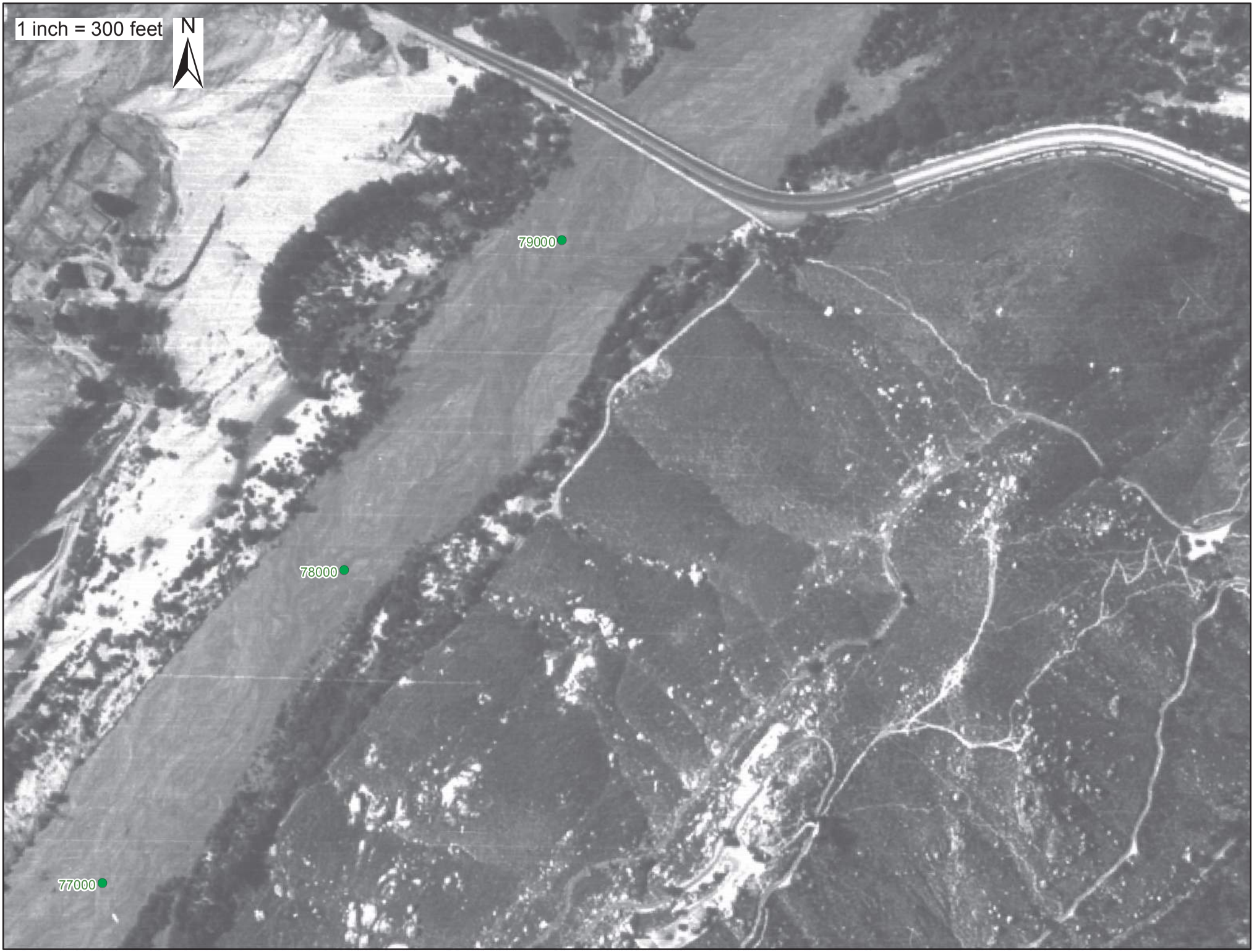
1 inch = 300 feet
N
62000
63000
64000
65000


1 inch = 300 feet
N
68000
67000
66000
65000

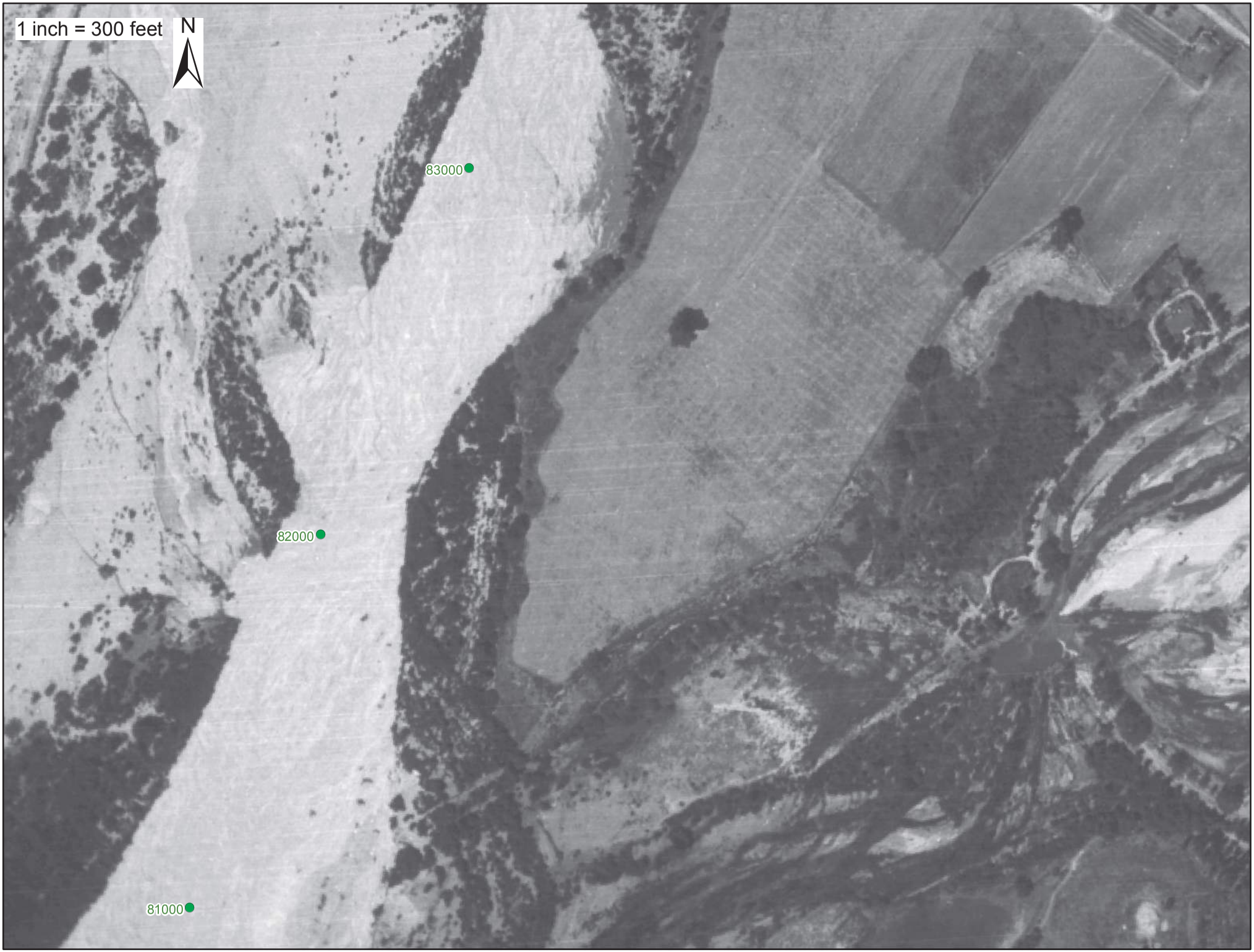

1 inch = 300 feet
N
71000
70000
69000
68000


1 inch = 300 feet
N
74000
73000
72000
71000

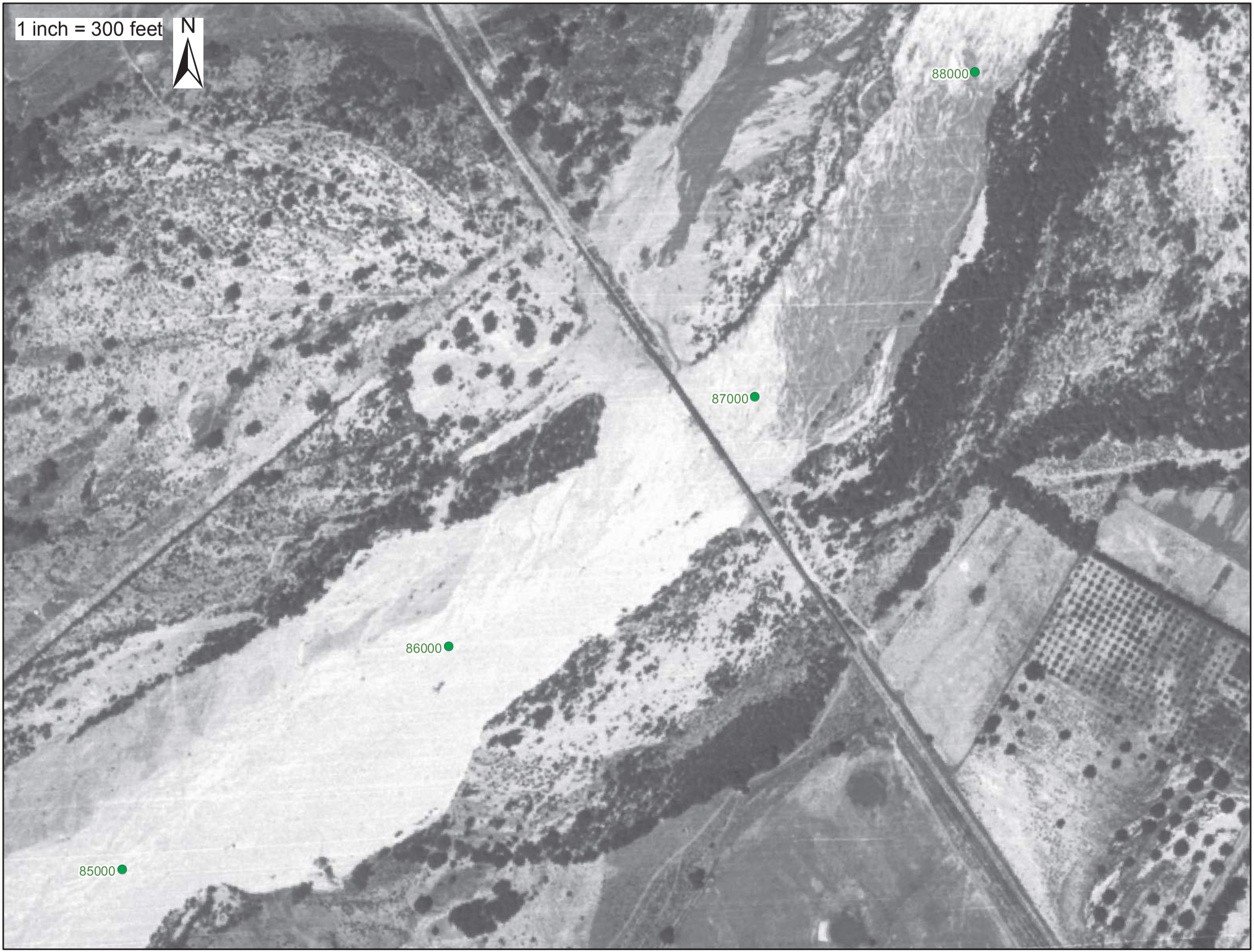

1 inch = 300 feet
N
77000
76000
75000
74000

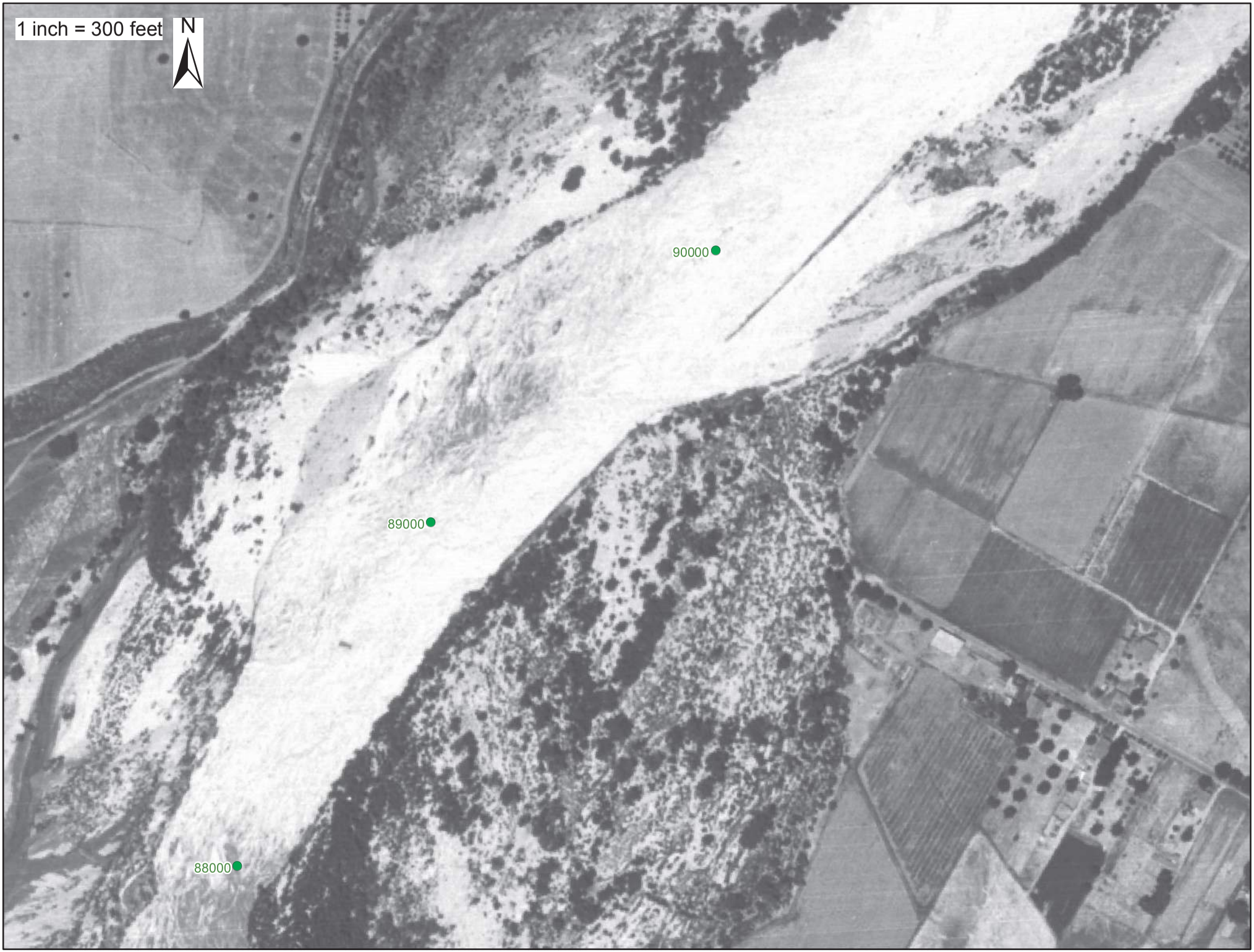

1 inch = 300 feet
N
79000
78000
77000

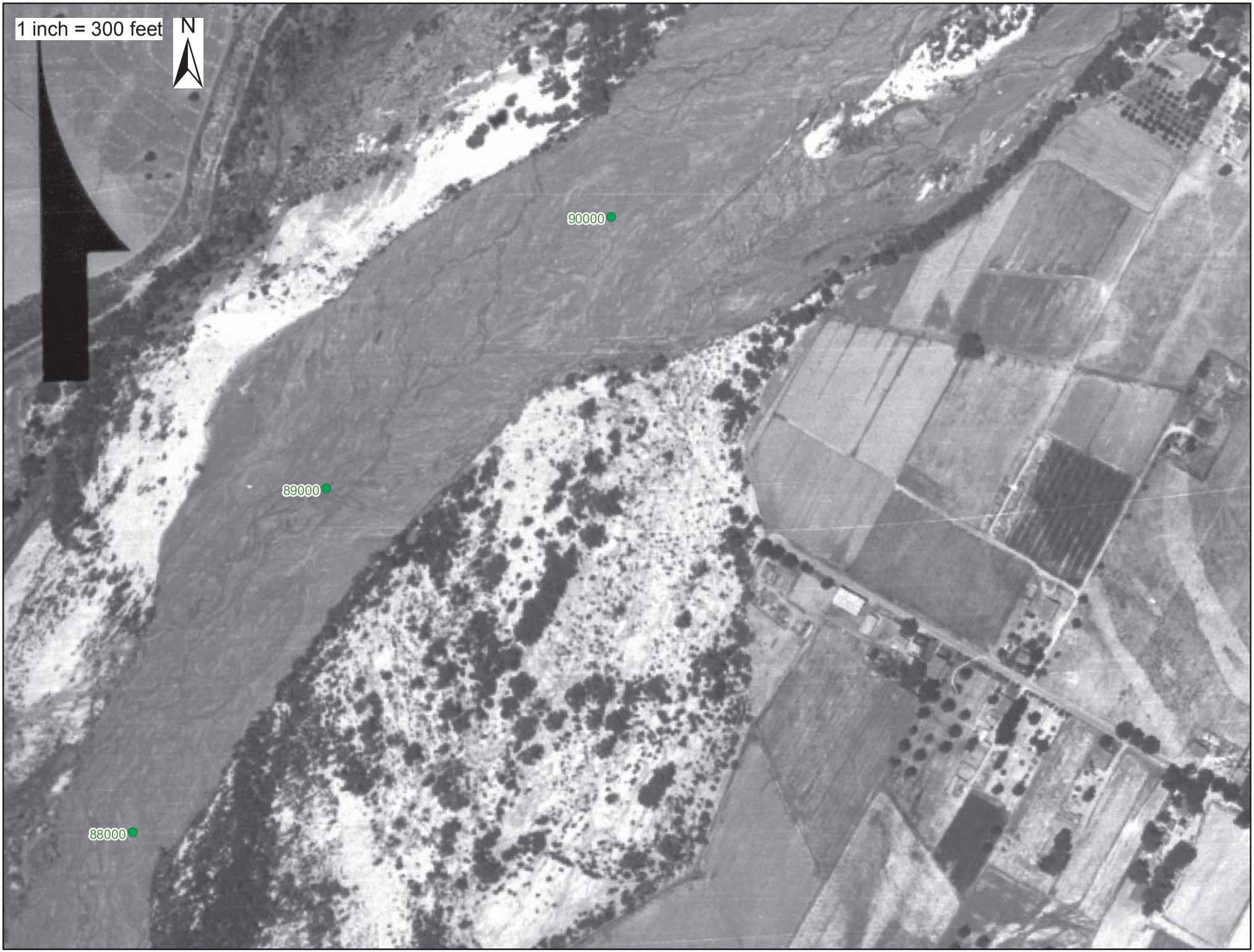
1 inch = 300 feet
N
81000
80000
79000


1 inch = 300 feet
N
83000
82000
81000

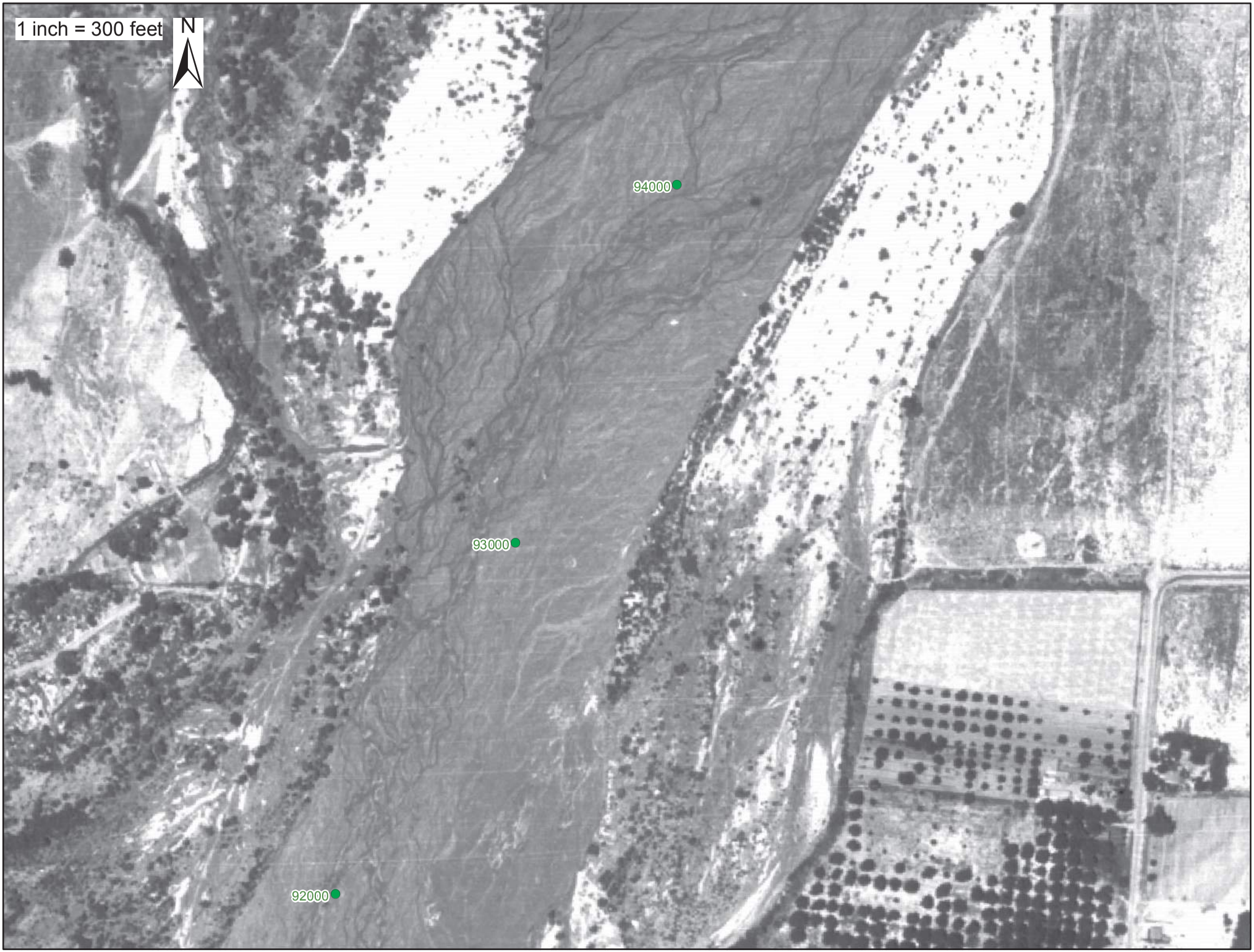
1 inch = 300 feet
N
85000
84000
83000

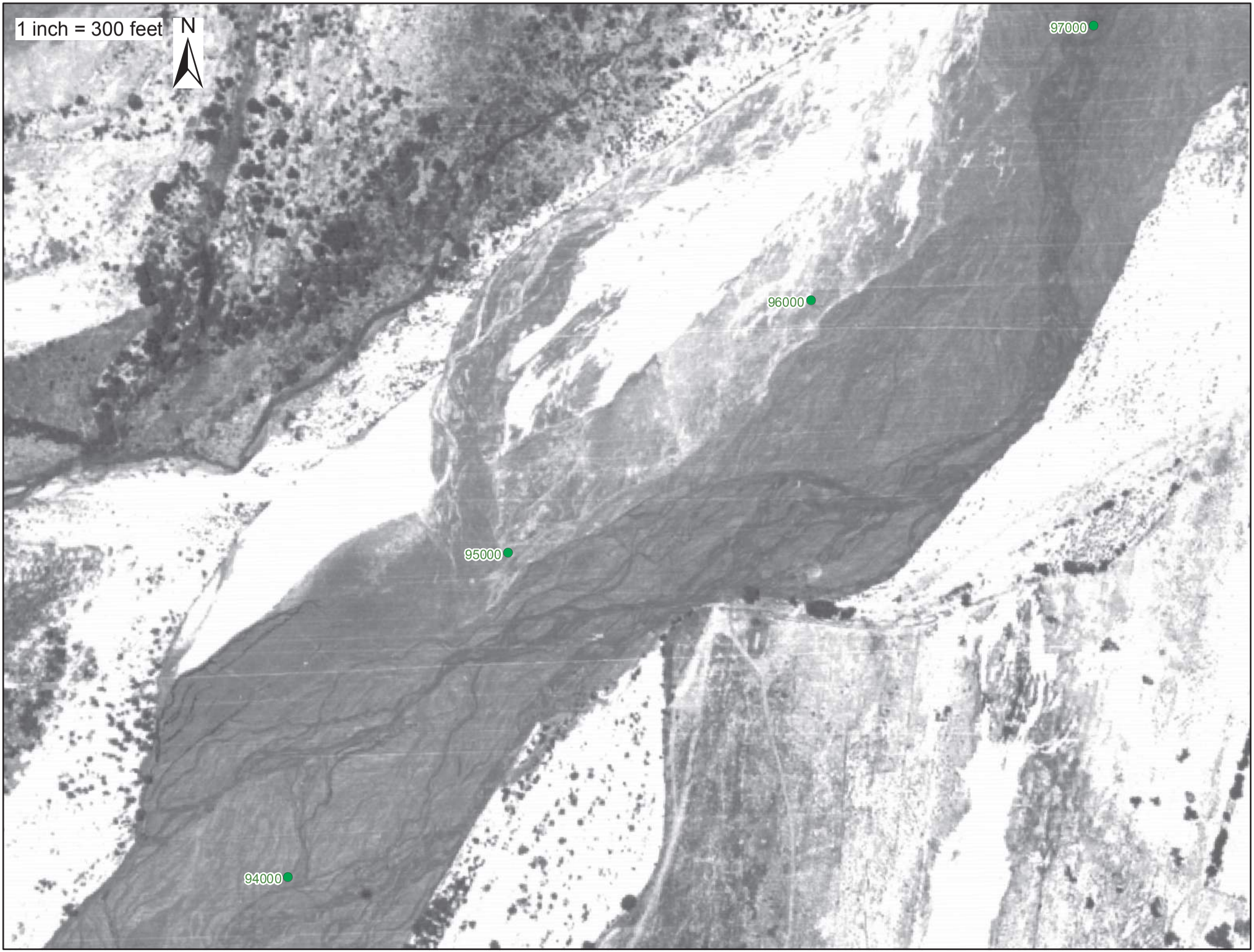

1 inch = 300 feet
N
88000
87000
86000
85000


1 inch = 300 feet
N
90000
89000
88000

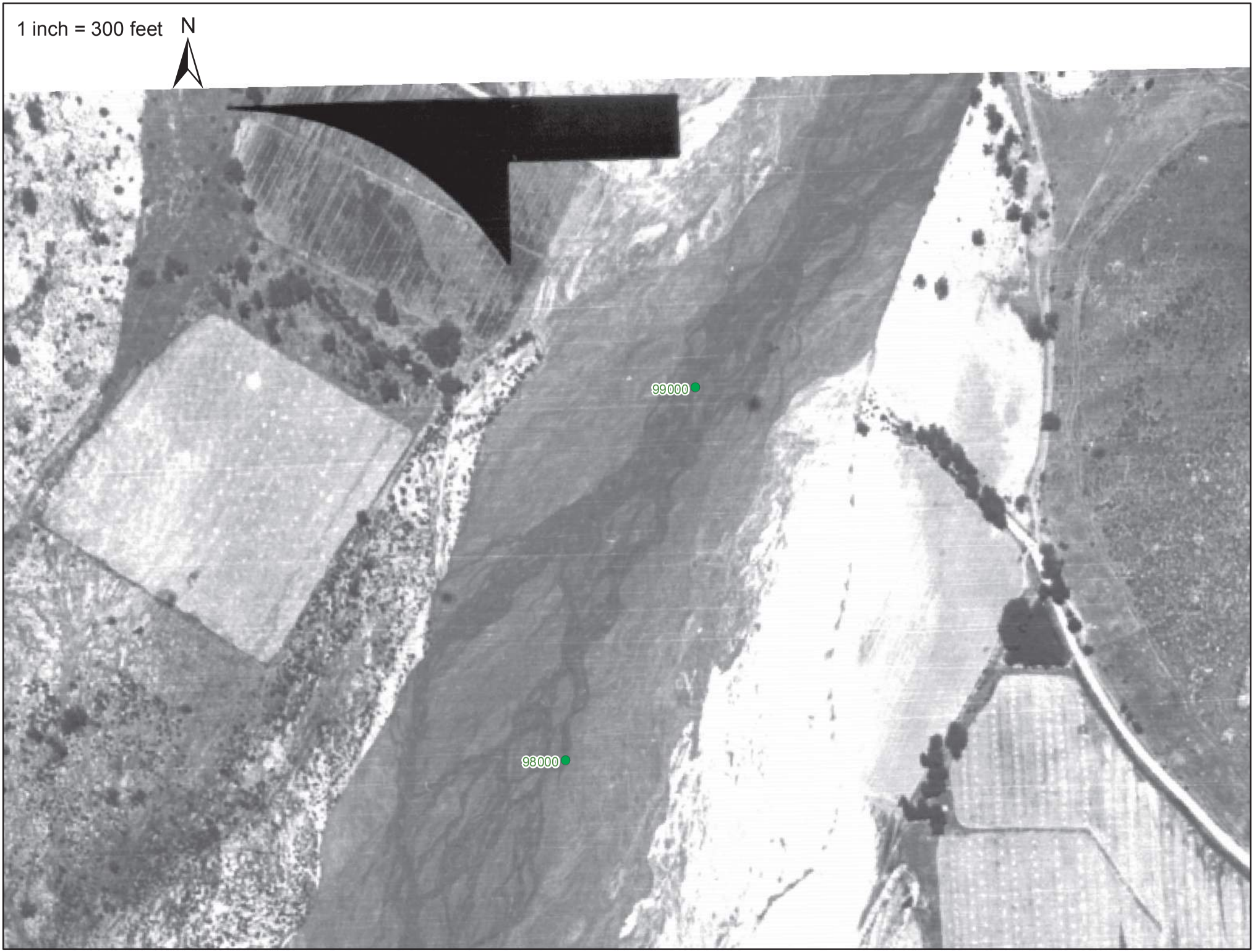

1 inch = 300 feet
N
90000
89000
88000

1 inch = 300 feet
N
92000
91000
90000


1 inch = 300 feet
N
94000
93000
92000


1 inch = 300 feet
N
97000
96000
95000
94000

1 inch = 300 feet
N
99000
98000
97000


1 inch = 300 feet
N
99000
98000

Appendix B

1948 Aerial Photos

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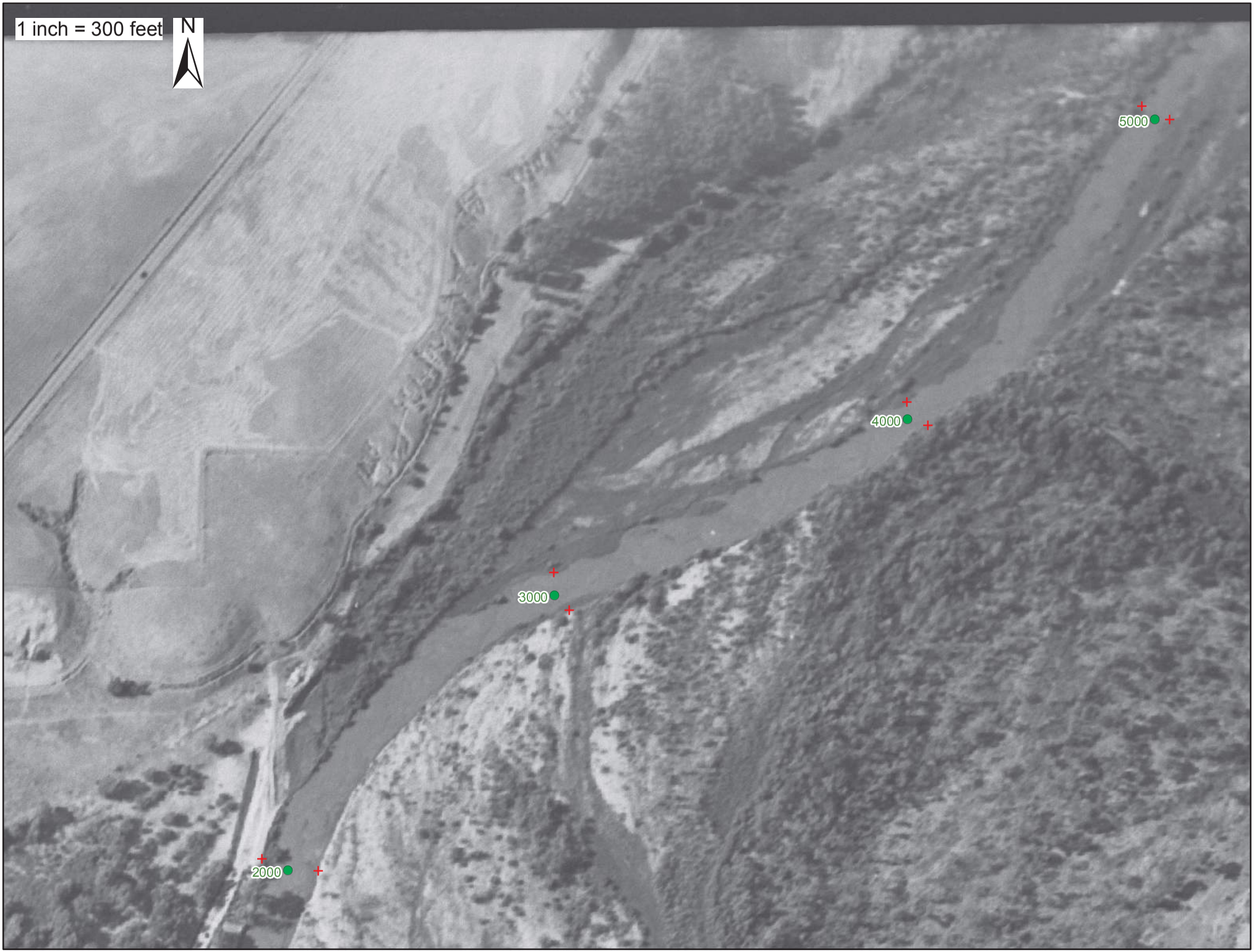
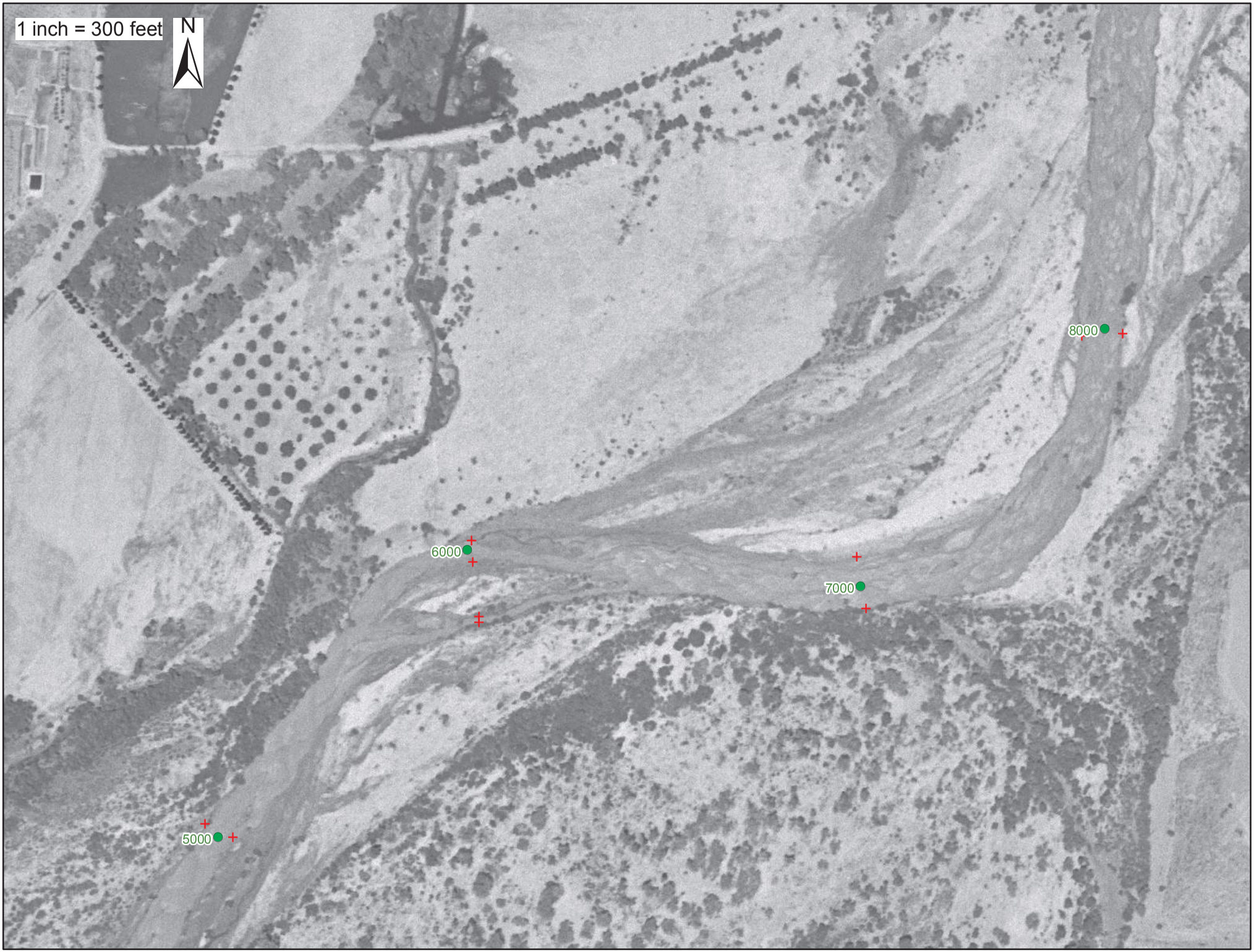
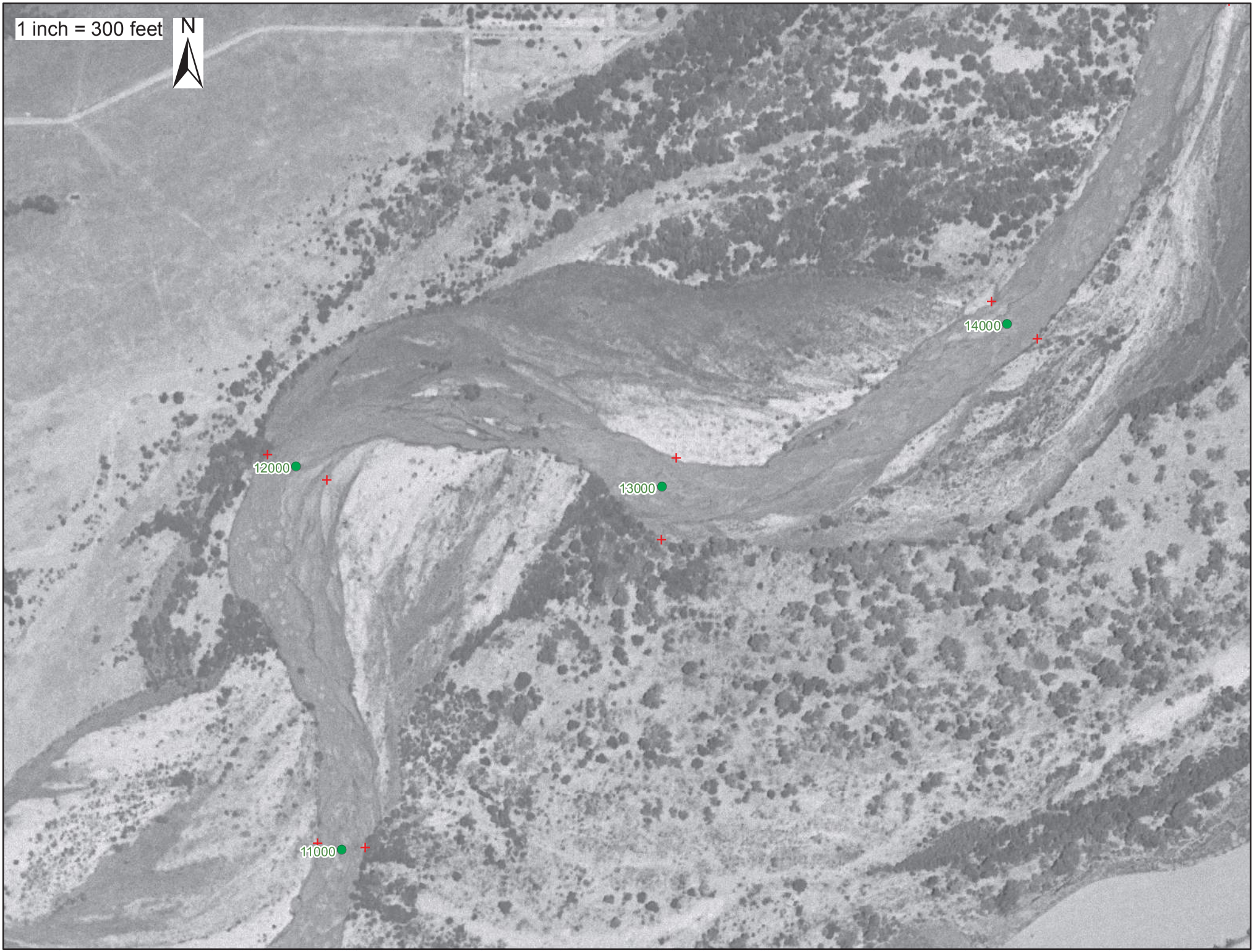
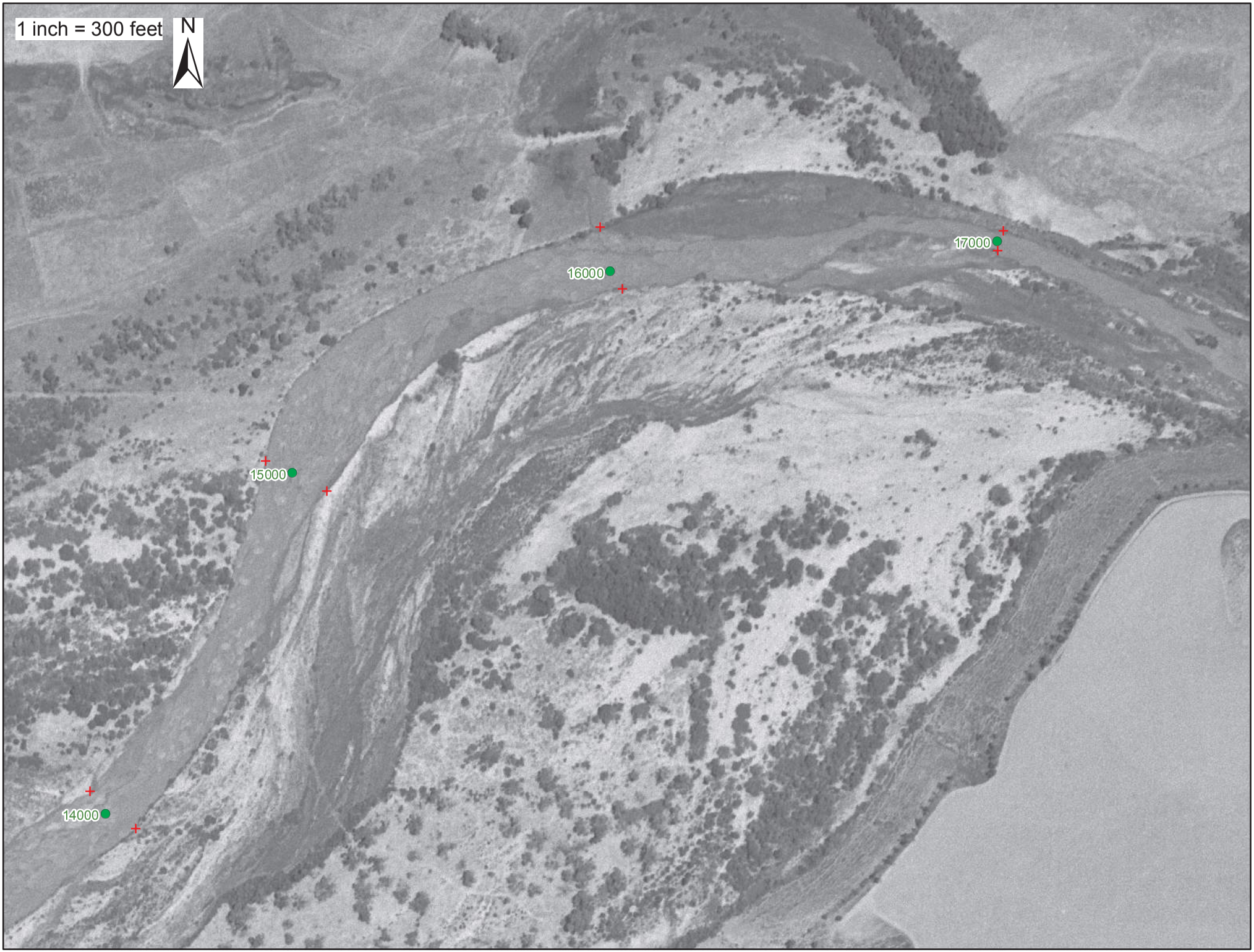
1 inch = 300 feet
N
2000
1000
0


1 inch = 300 feet
N
5000
4000
3000
2000


1 inch = 300 feet
N
8000
6000
7000
5000

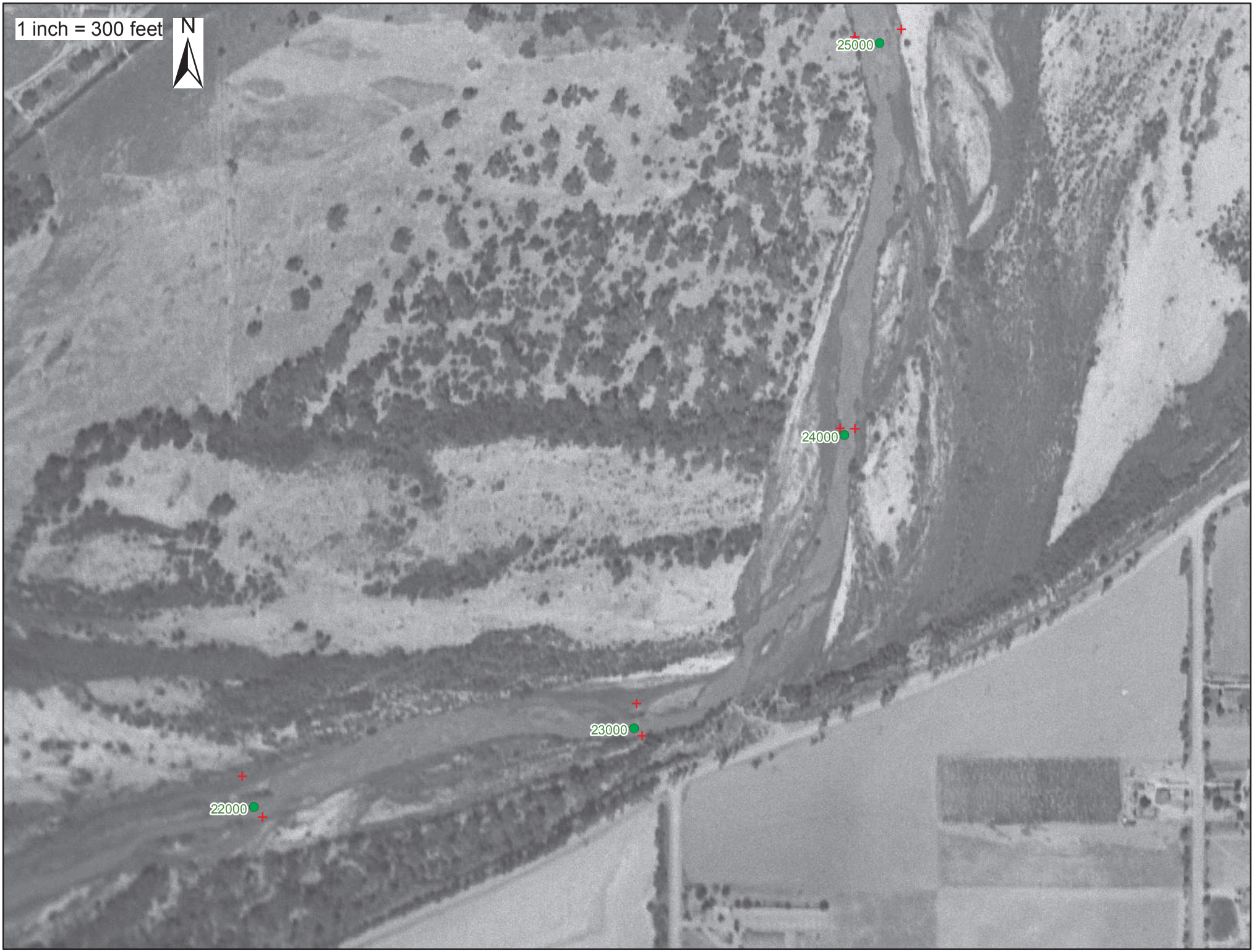
1 inch = 300 feet
N
11000
10000
9000
8000


1 inch = 300 feet
N
14000
12000
13000
11000


1 inch = 300 feet
N
17000
16000
15000
14000

1 inch = 300 feet
N
17000
18000
19000
20000

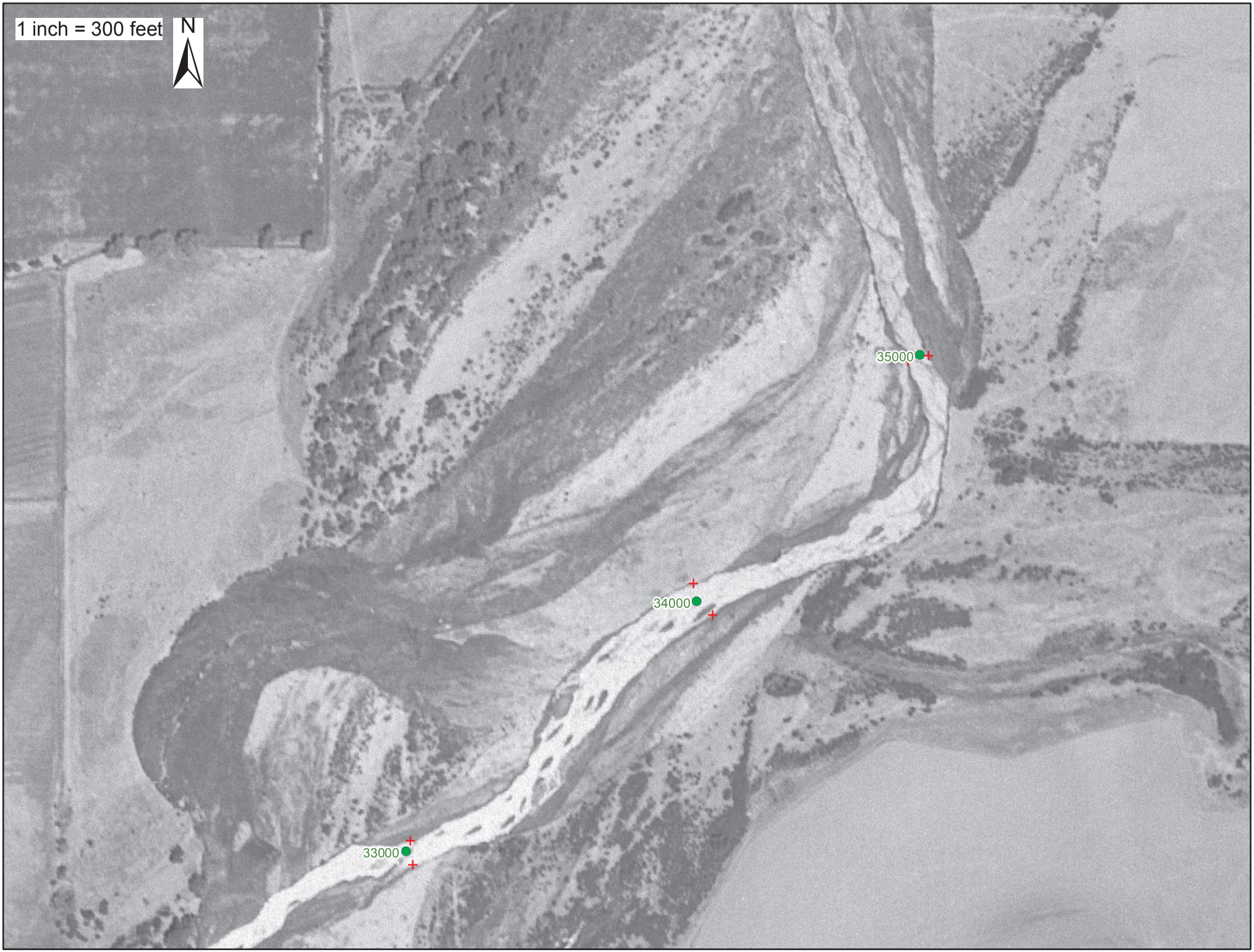
1 inch = 300 feet
N
19000
20000
21000

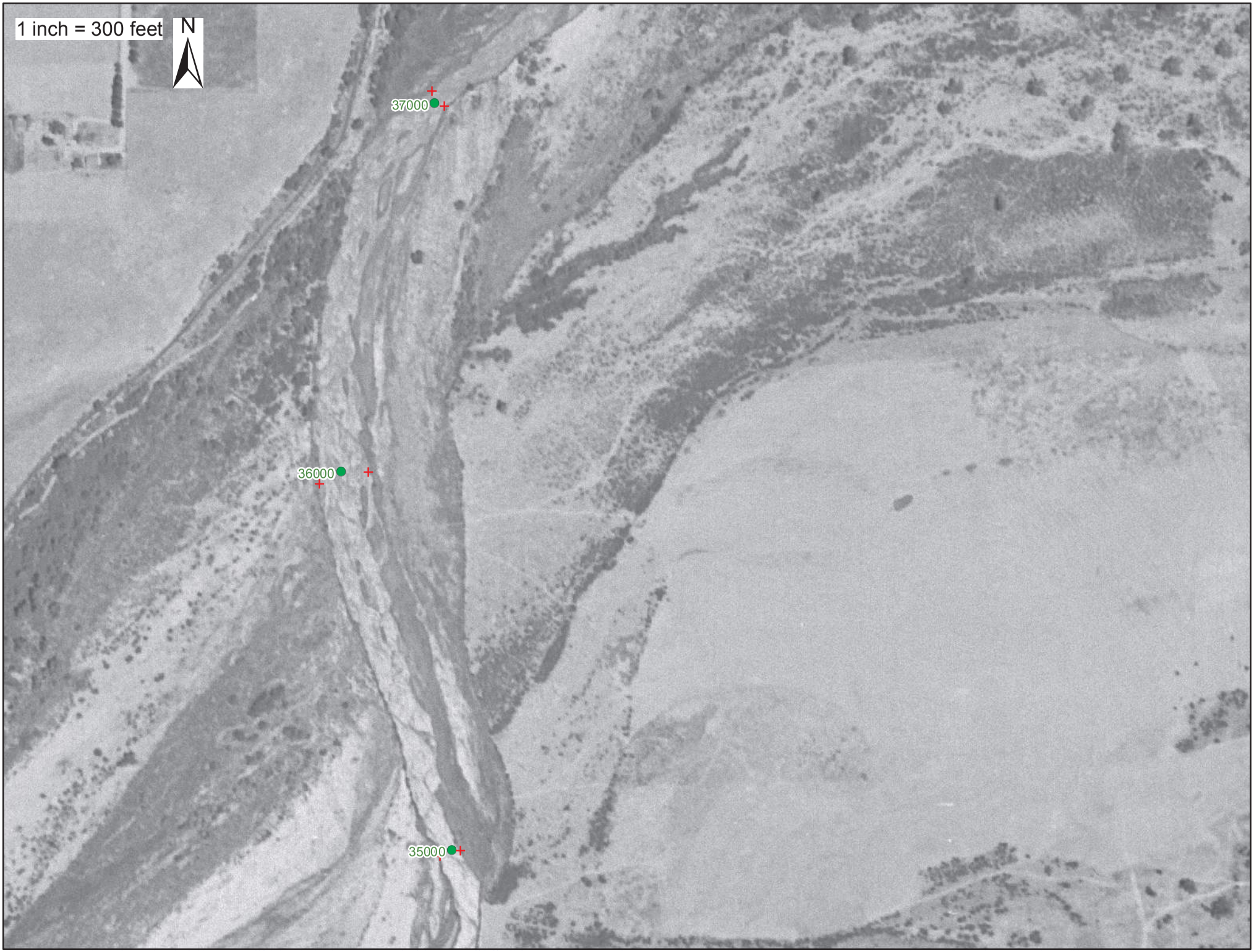

1 inch = 300 feet
N
25000
24000
23000
22000

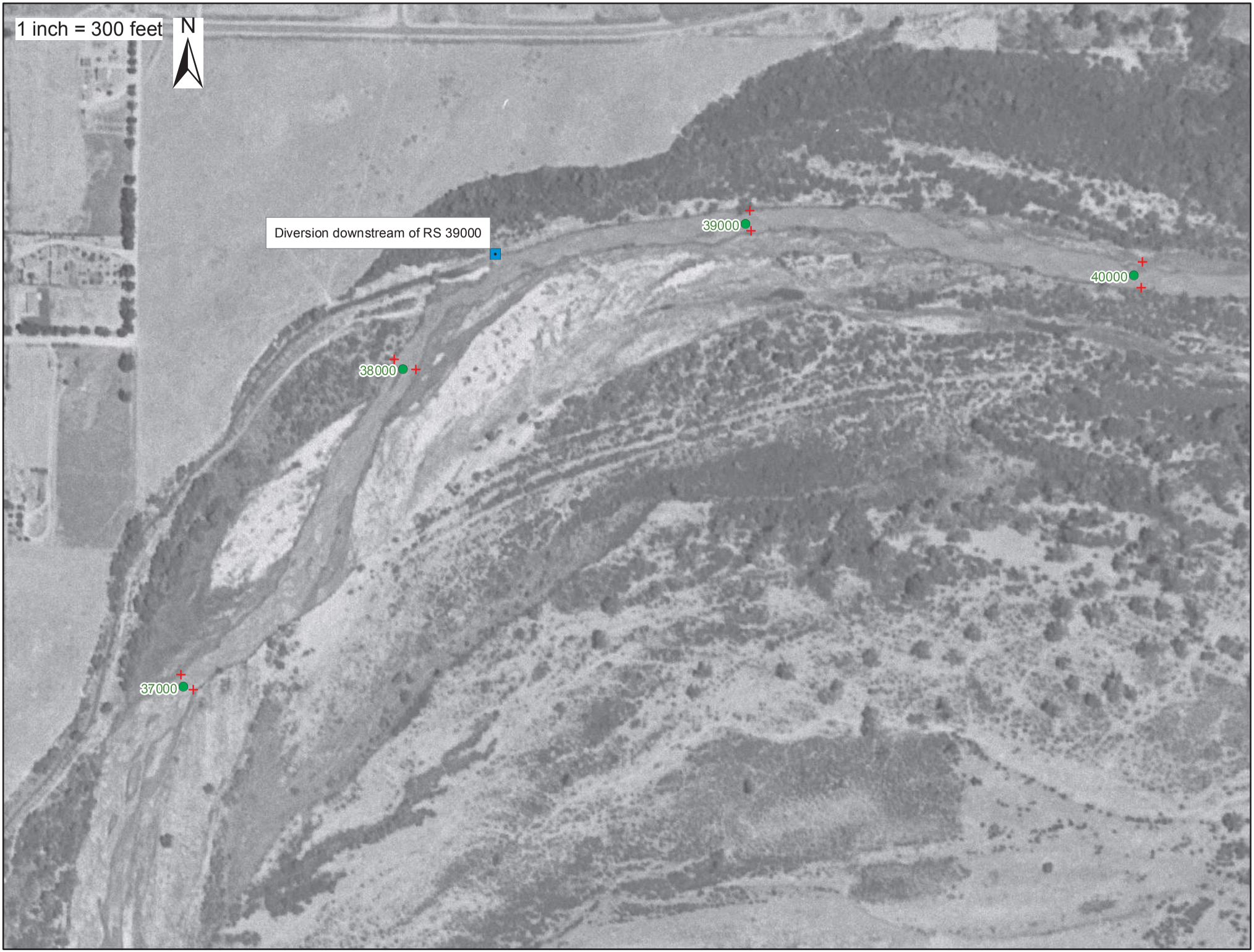
1 inch = 300 feet
N
28000
27000
26000
25000

1 inch = 300 feet
N
28000
29000
30000

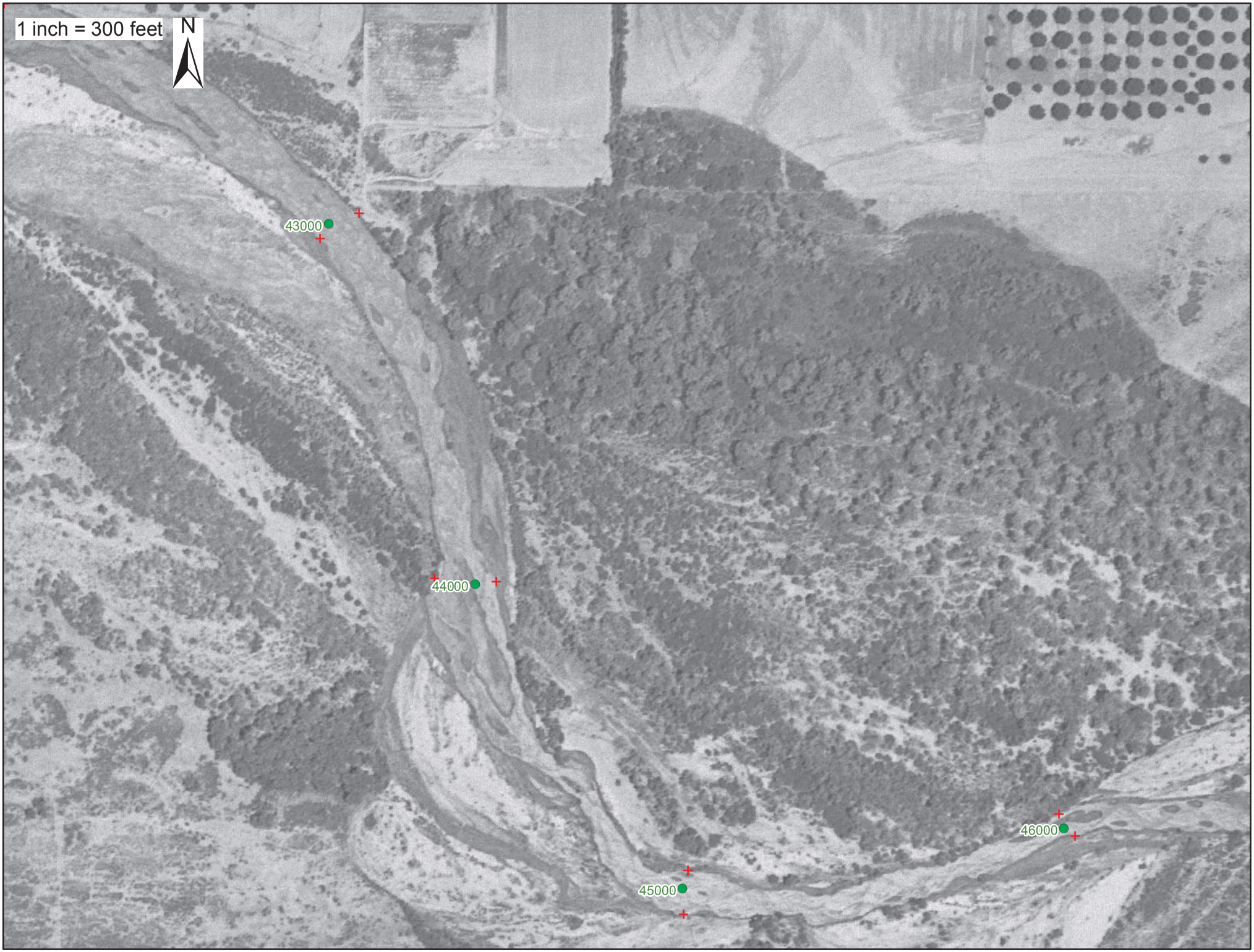
1 inch = 300 feet
N
33000
32000
31000
30000

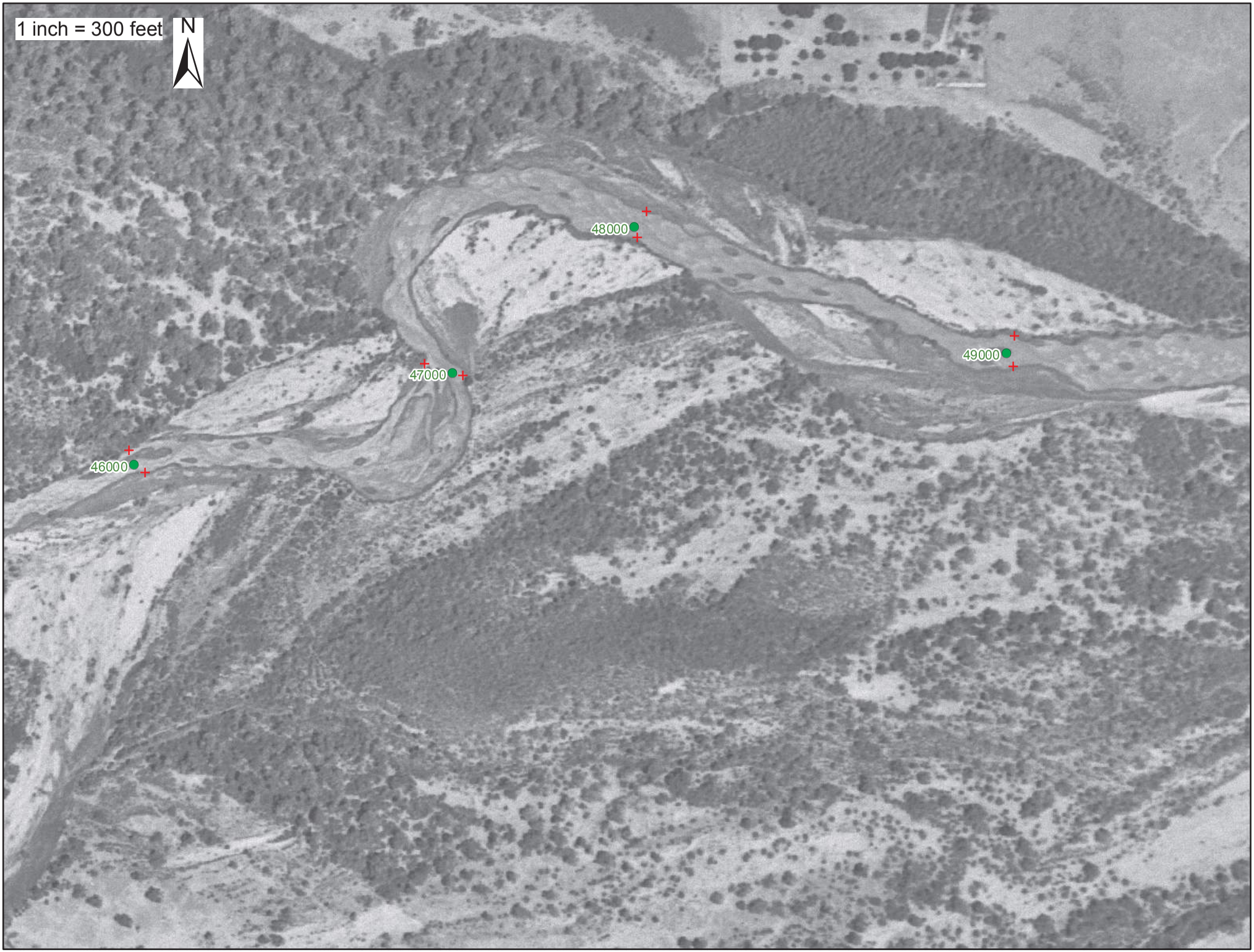

1 inch = 300 feet
N
35000
34000
33000

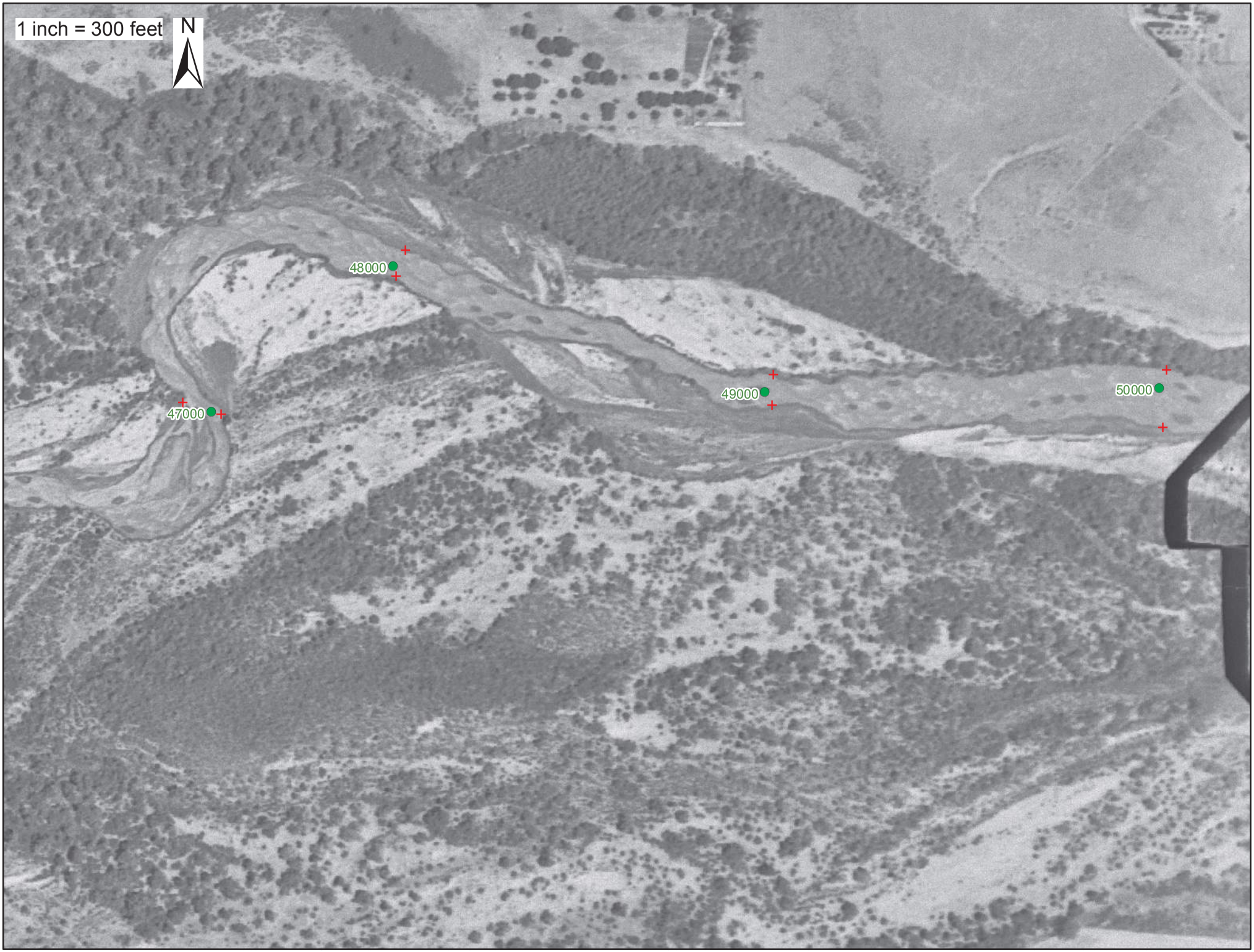

1 inch = 300 feet
N
37000
36000
35000

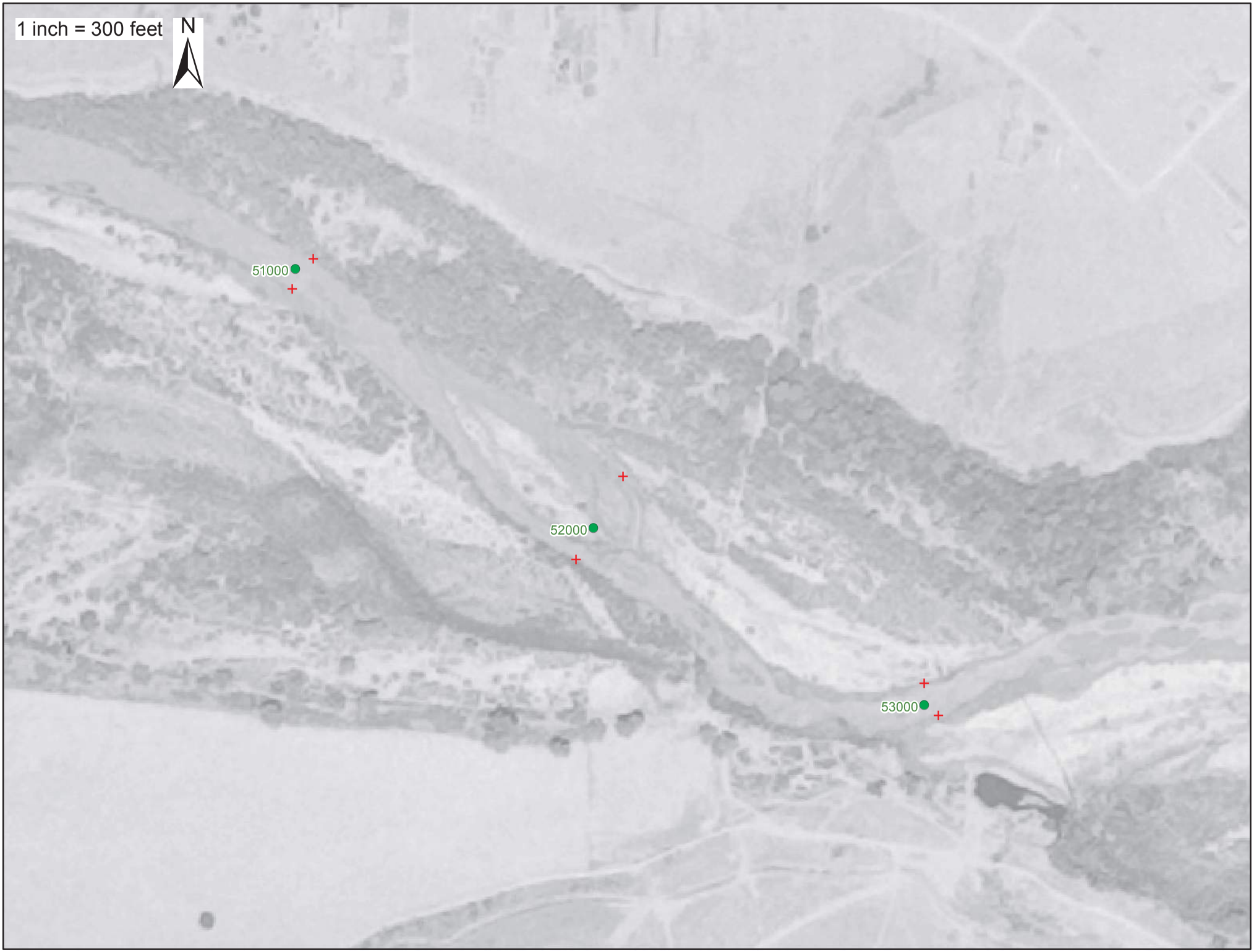

1 inch = 300 feet
N
Diversion downstream of RS 39000
39000
40000
38000
37000

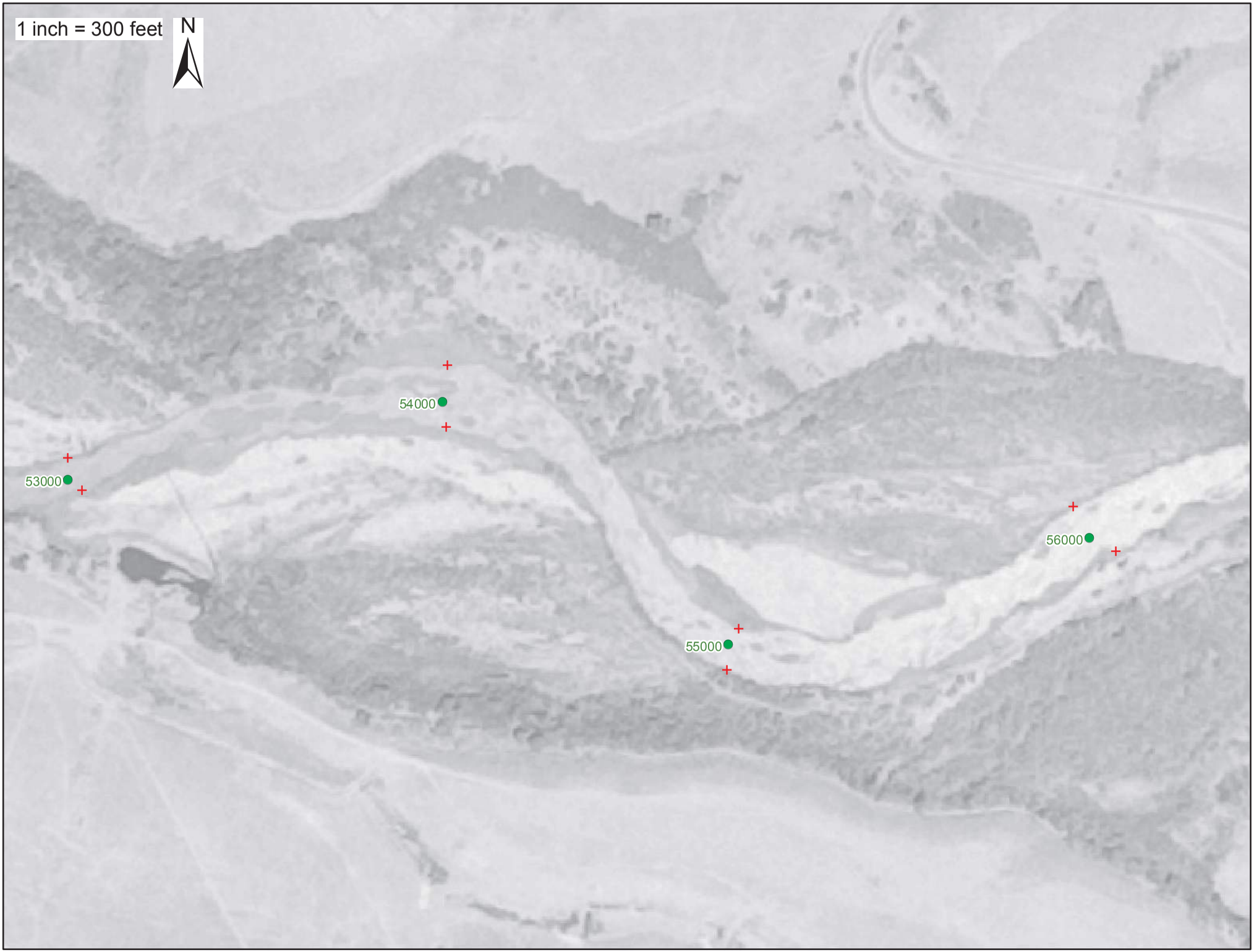
1 inch = 300 feet
N
40000
41000
42000

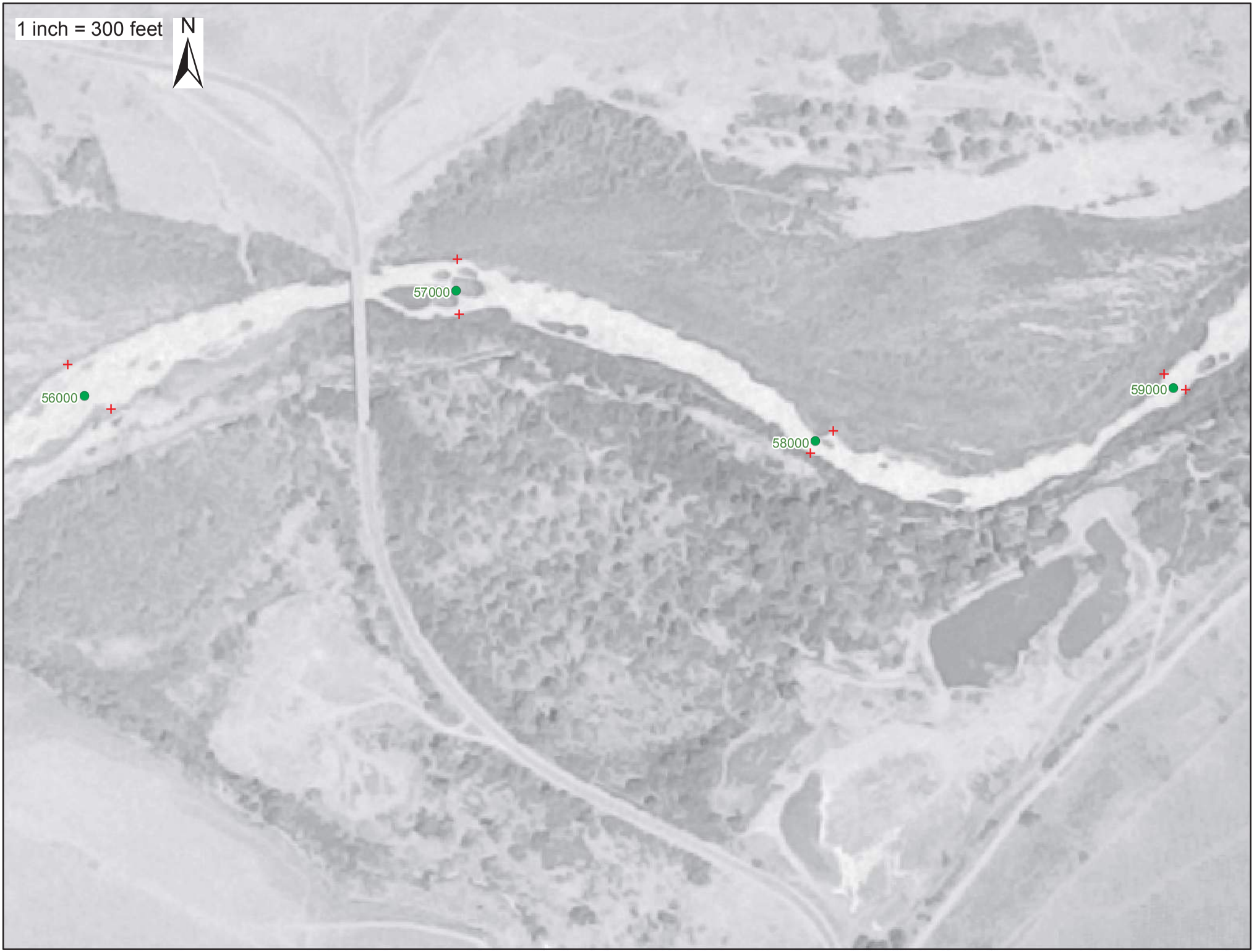

1 inch = 300 feet
N
43000
44000
45000
46000

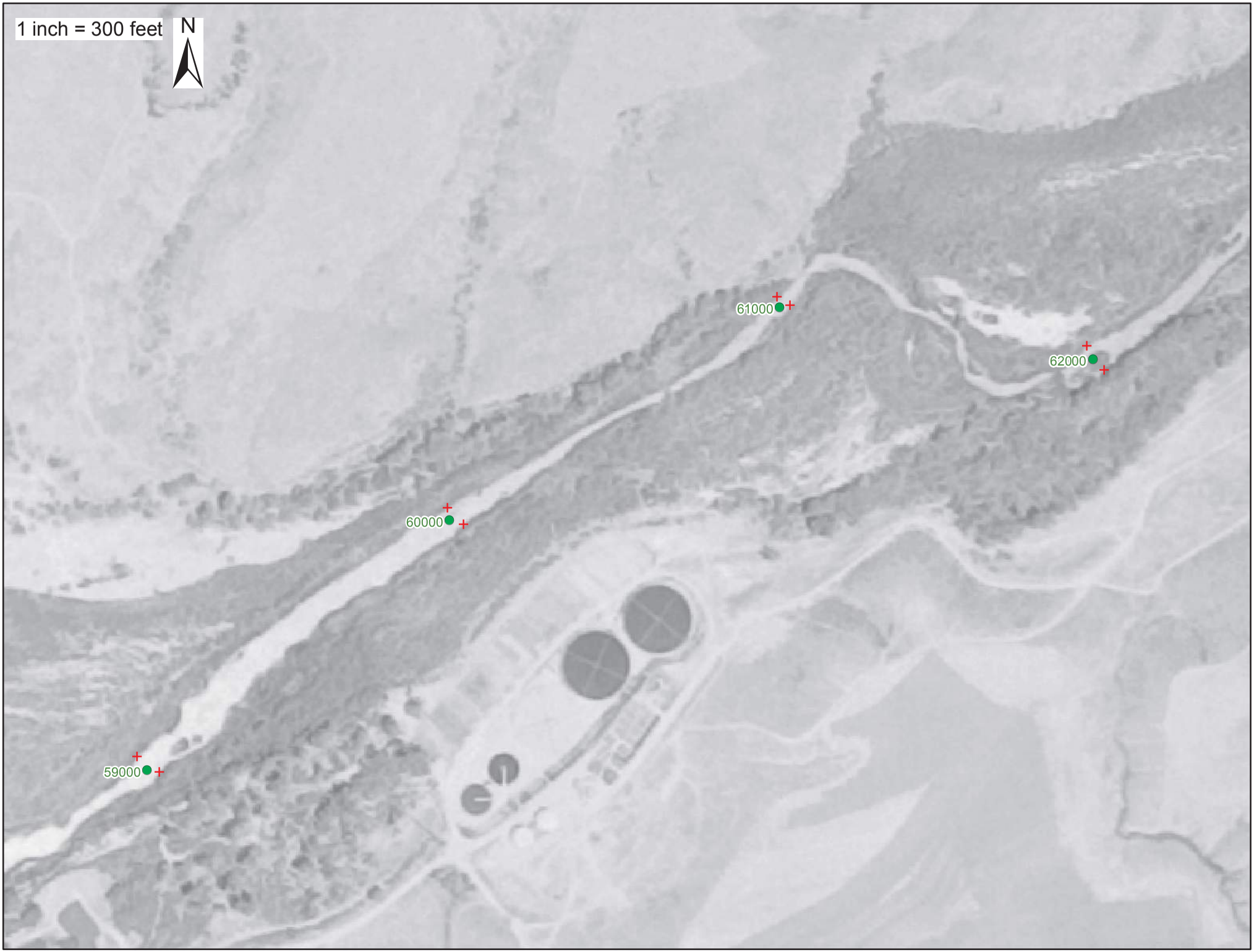

1 inch = 300 feet
N
48000
49000
47000
46000

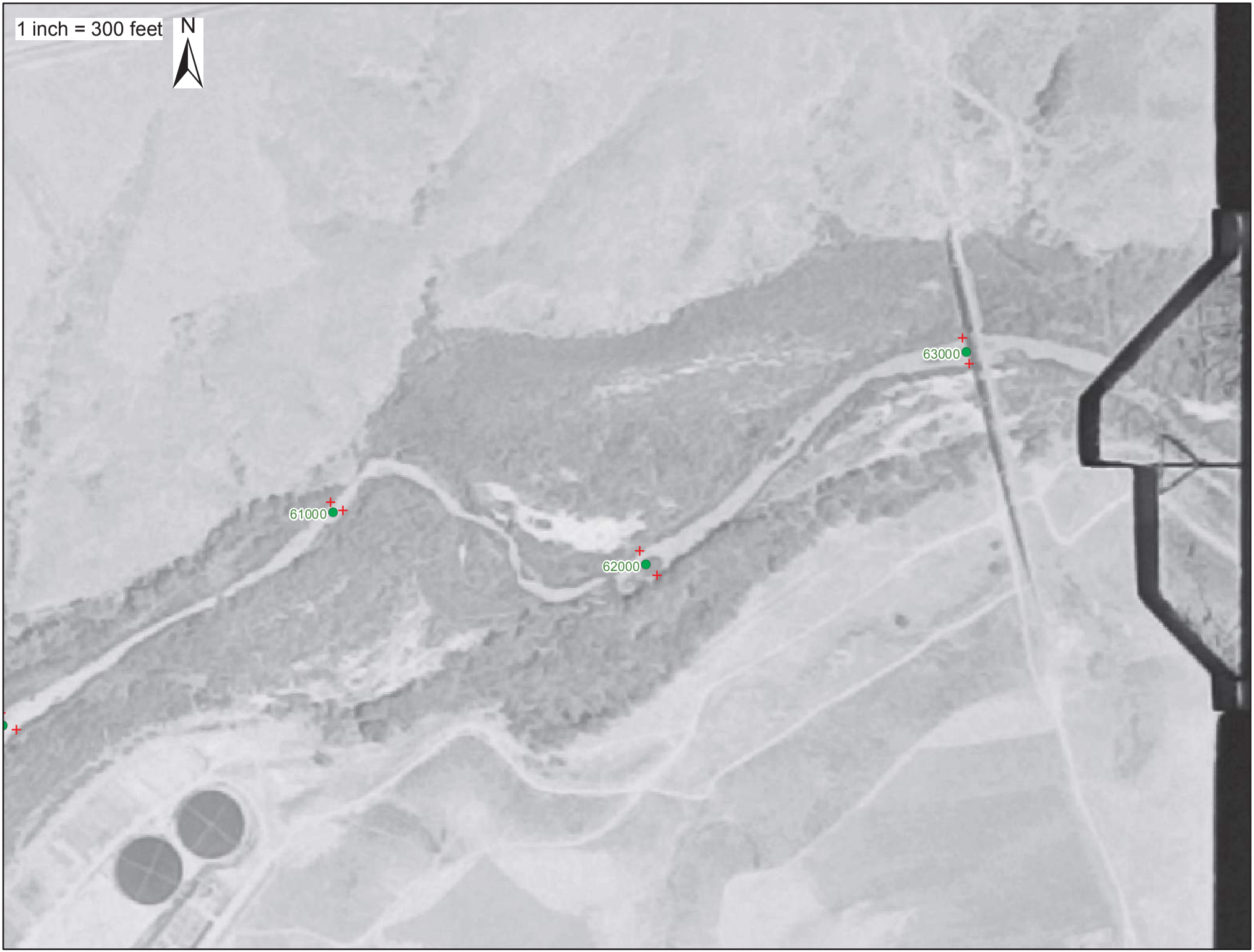

1 inch = 300 feet
N
48000
47000
49000
50000


1 inch = 300 feet
N
51000
52000
53000


1 inch = 300 feet
N
54000
53000
56000
55000


1 inch = 300 feet
N
57000
56000
58000
59000

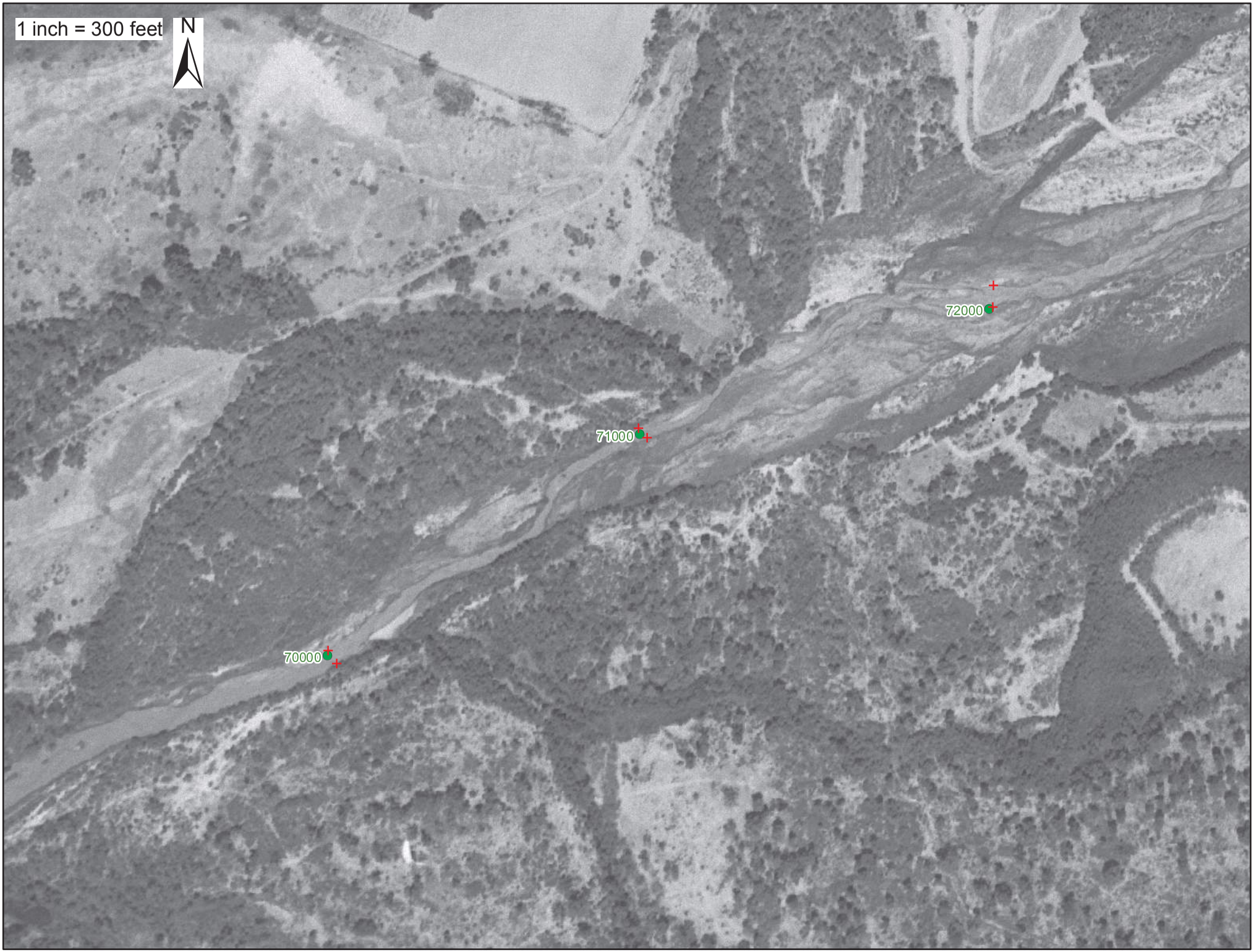

1 inch = 300 feet
N
61000
62000
60000
59000

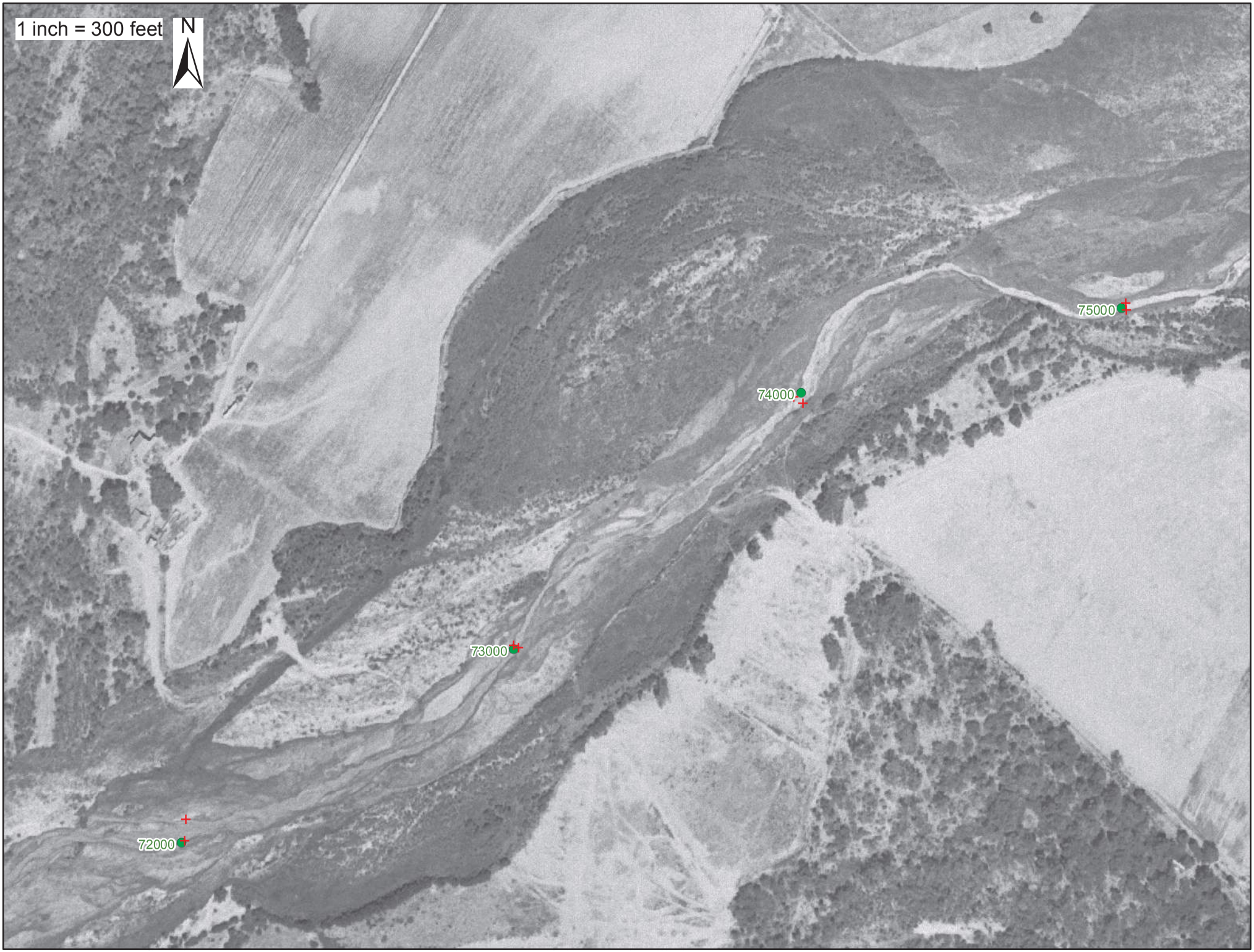

1 inch = 300 feet
N
61000
62000
63000

1 inch = 300 feet
N
64000
65000
66000

1 inch = 300 feet
N
66000
67000
68000
69000

1 inch = 300 feet
N
67000
68000
69000


1 inch = 300 feet
N
72000
71000
70000


1 inch = 300 feet
N
75000
74000
73000
72000

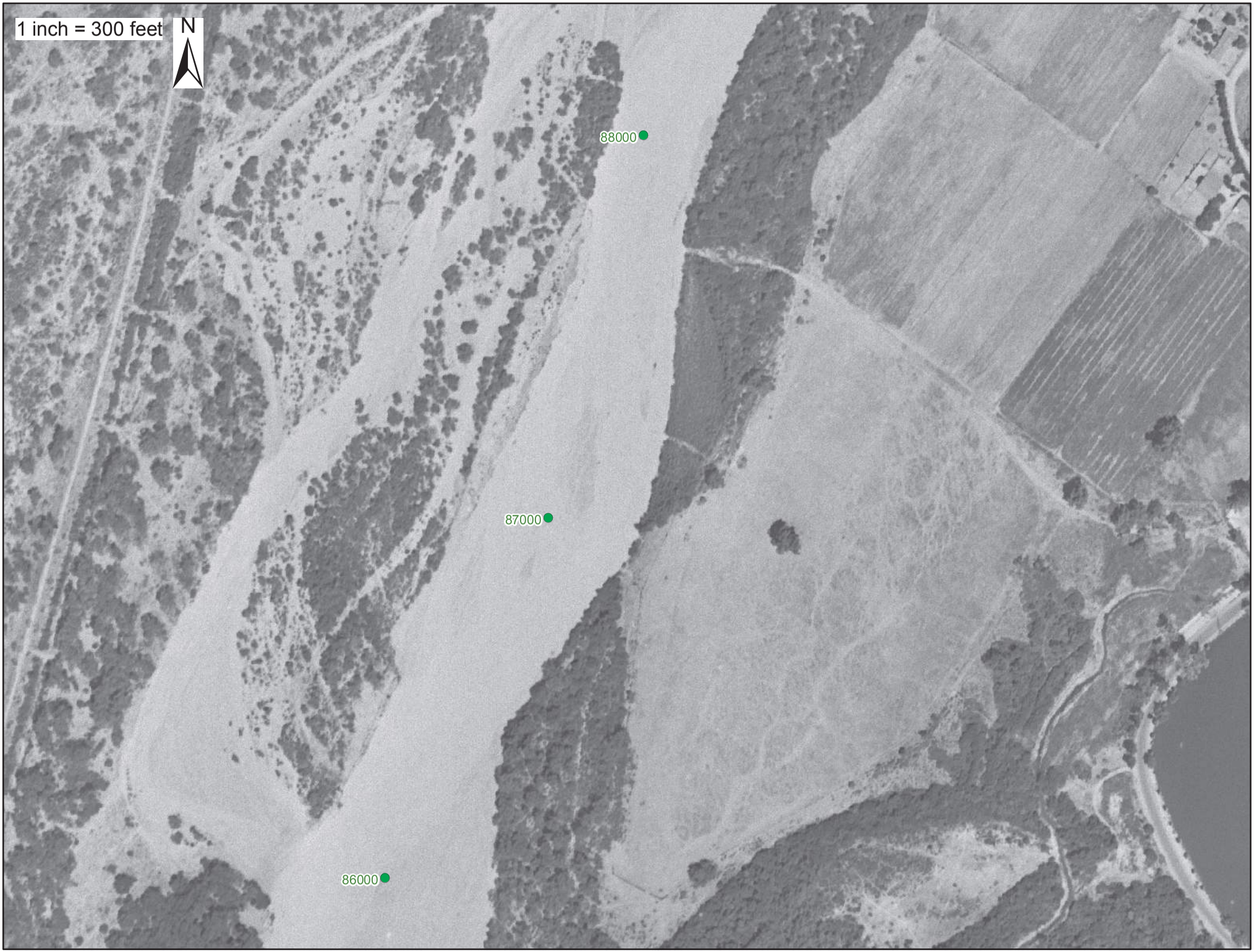
1 inch = 300 feet
N
78000
77000
76000
75000

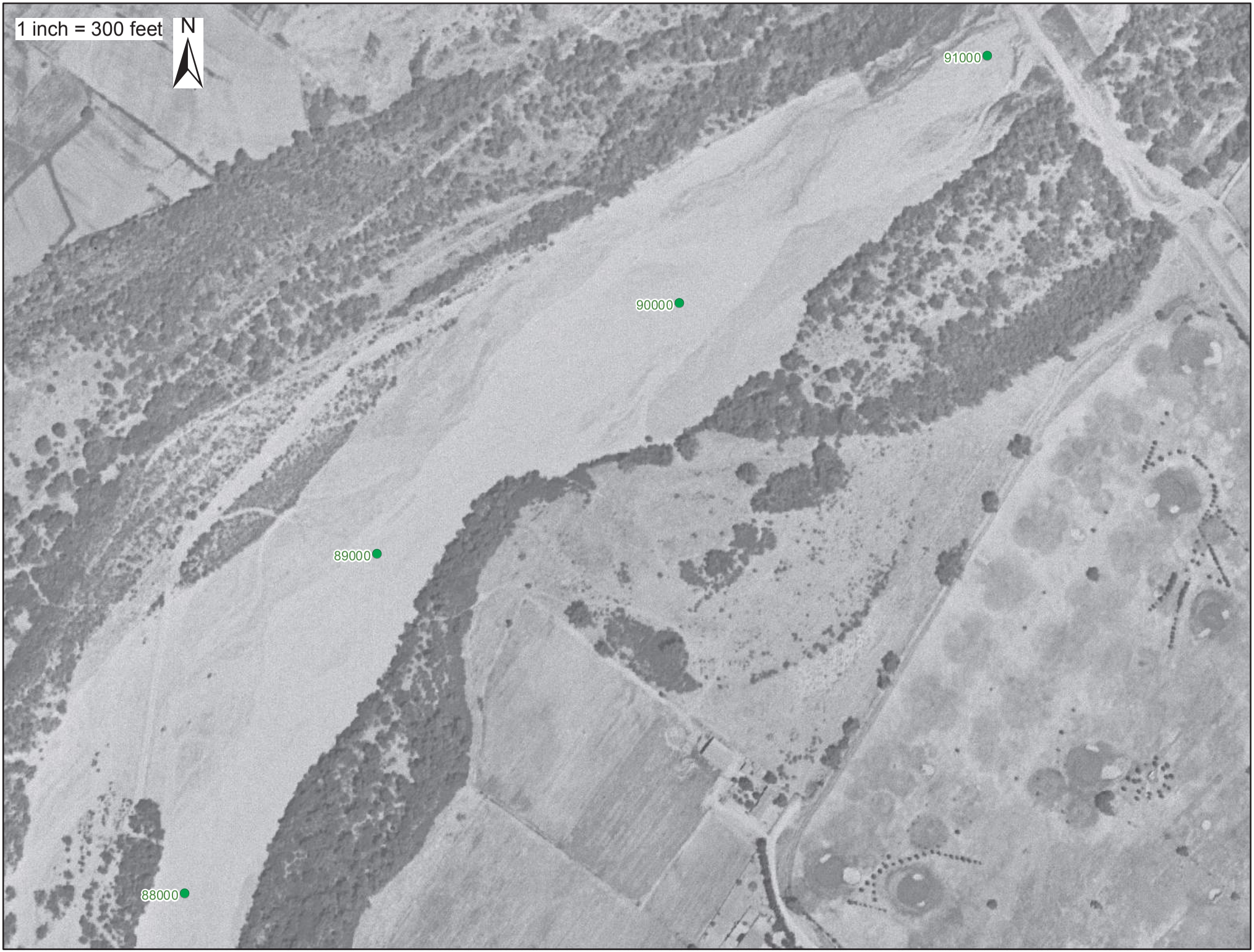
1 inch = 300 feet
N
80000
79000
78000

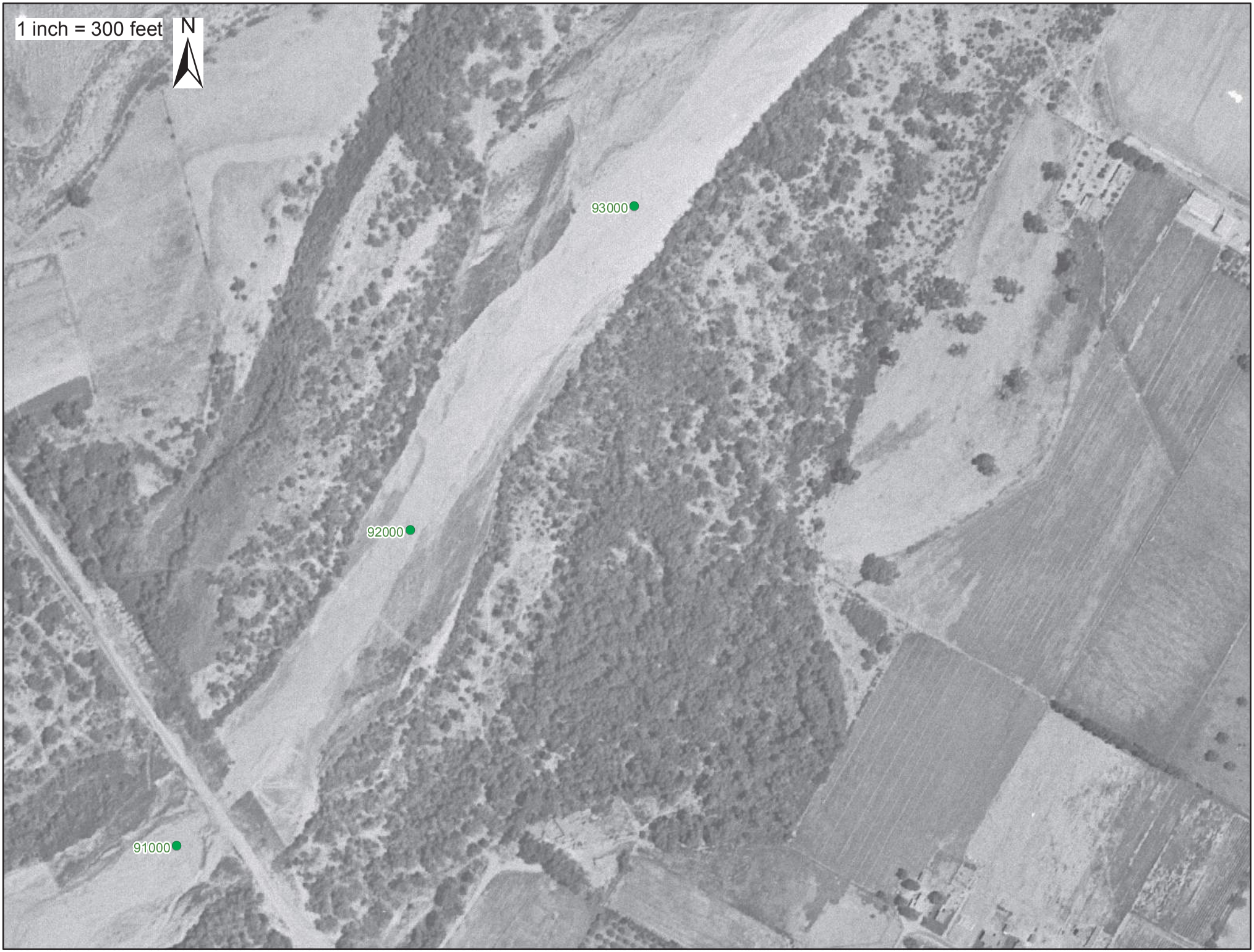
1 inch = 300 feet
N
82000
81000
80000

1 inch = 300 feet
N
Discharge at RS 84000
84000
83000
82000

1 inch = 300 feet
N
86000
85000
Discharge at RS 84000


1 inch = 300 feet
N
88000
87000
86000


1 inch = 300 feet
N
91000
90000
89000
88000

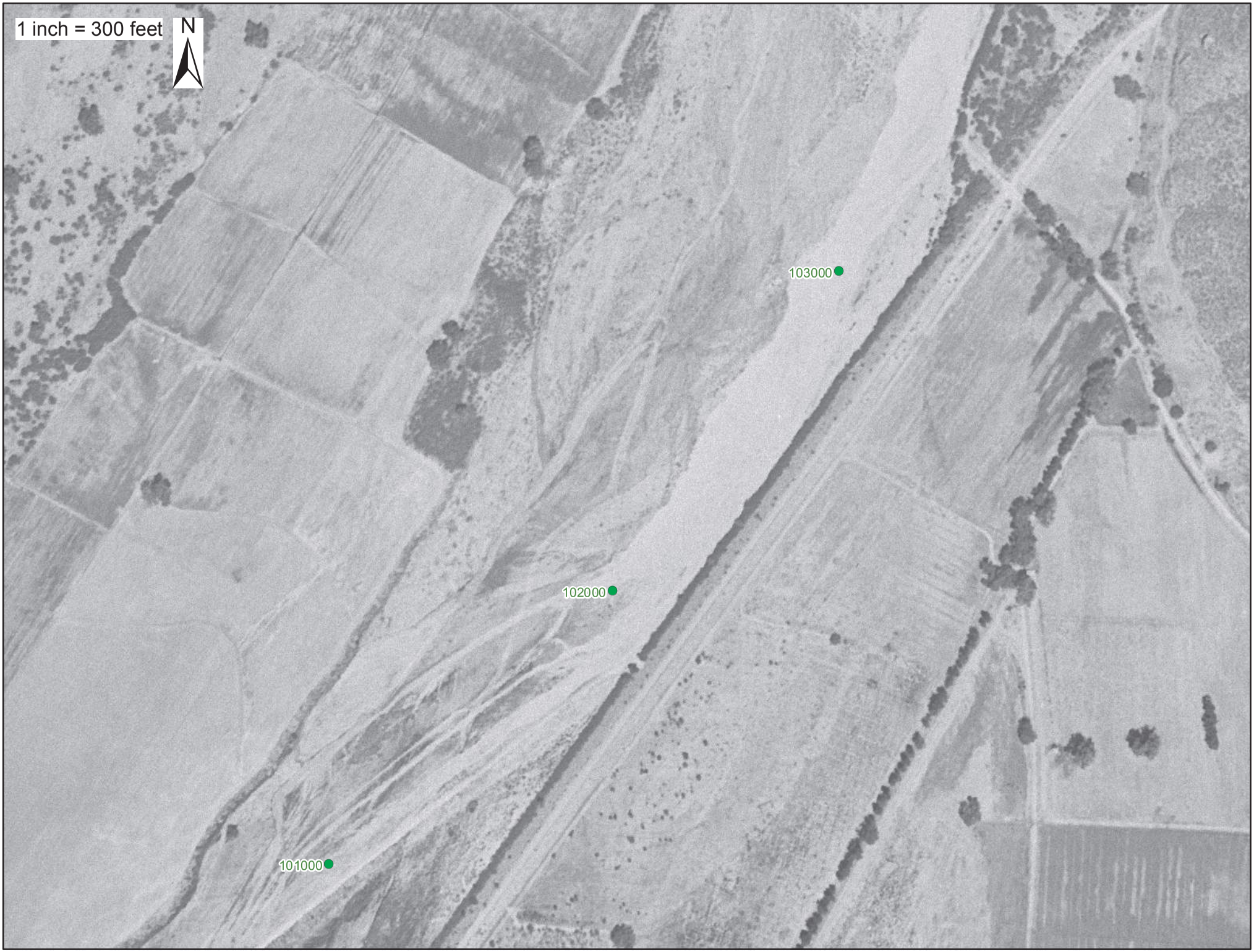

1 inch = 300 feet
N
93000
92000
91000

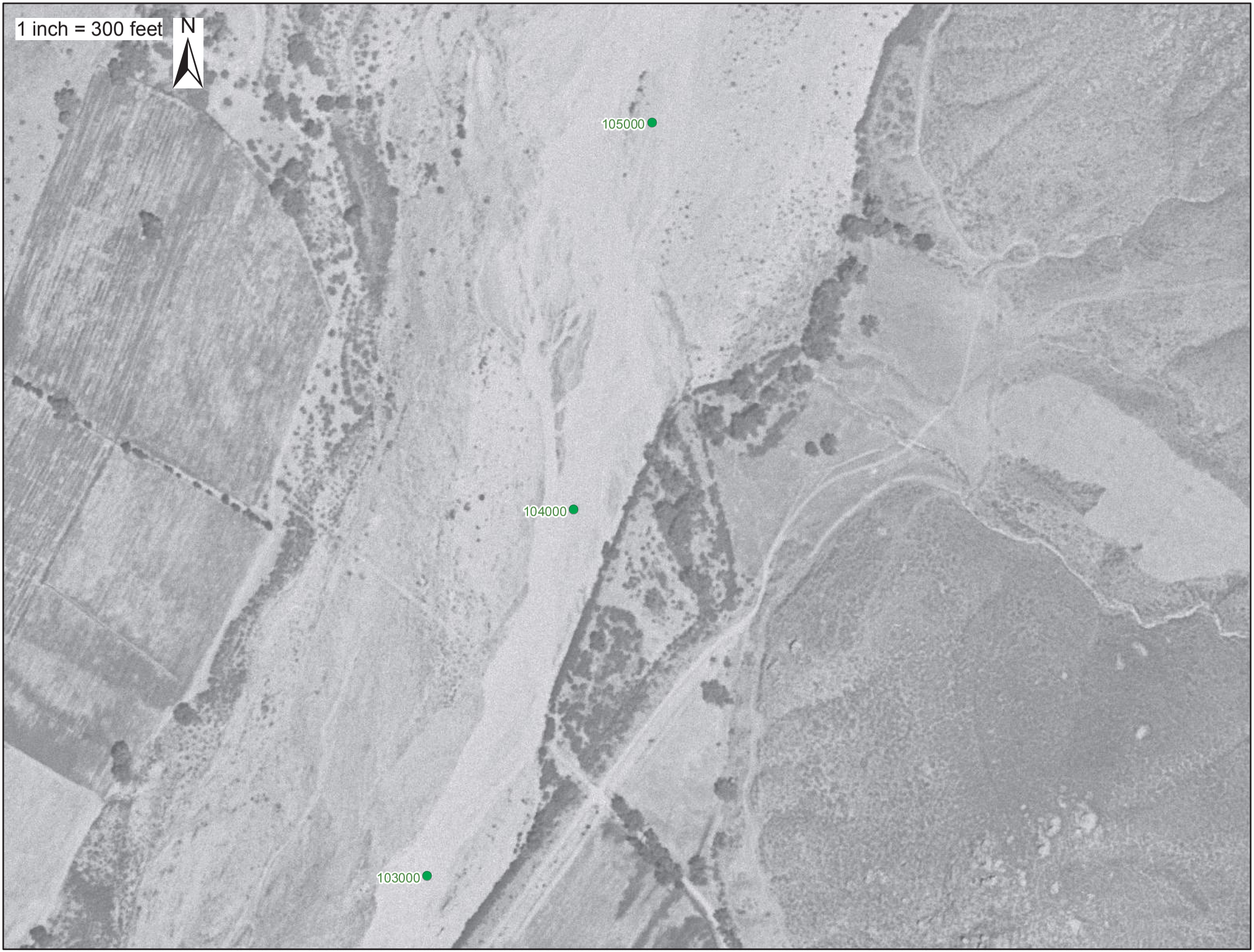
1 inch = 300 feet
N
95000
94000
93000

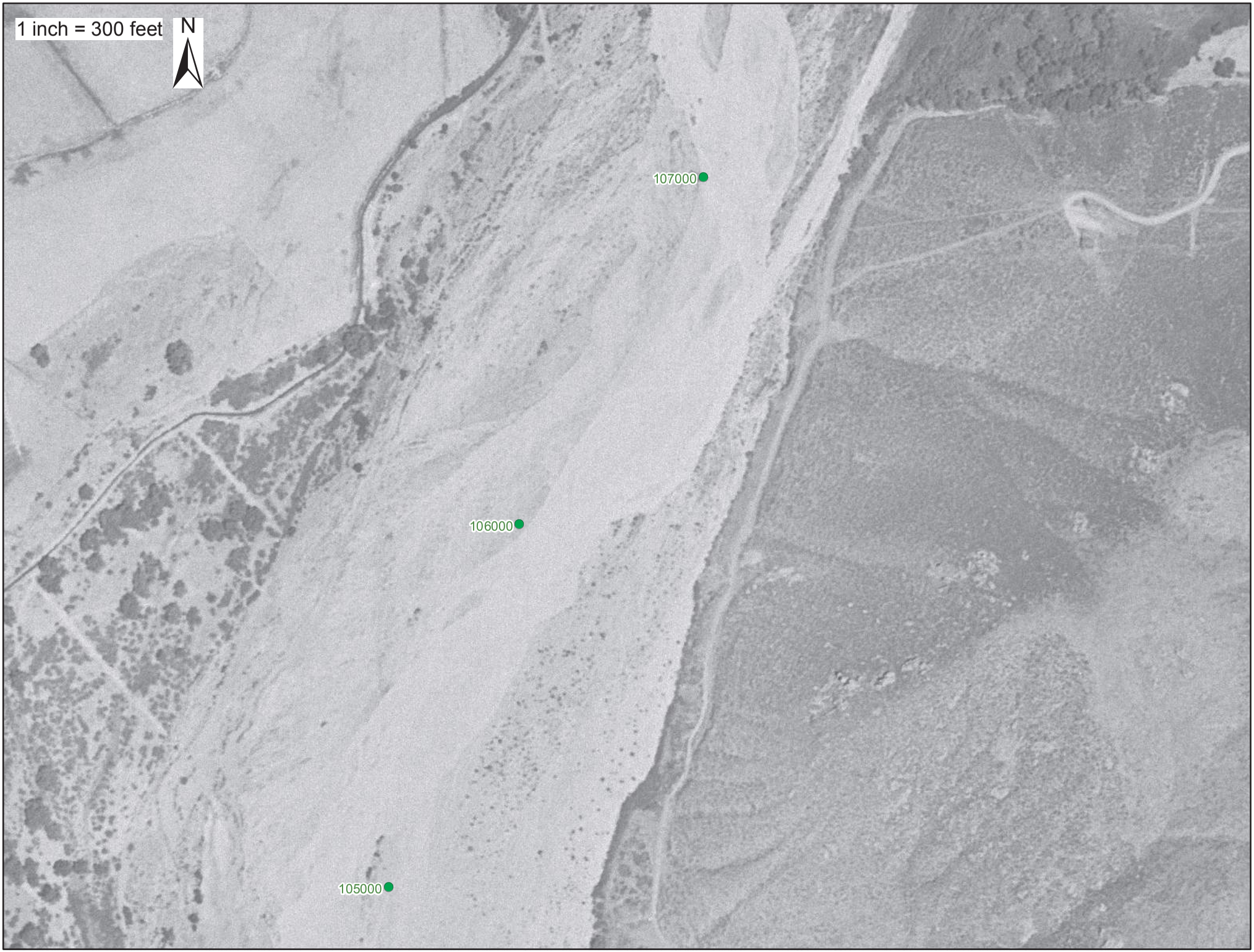
1 inch = 300 feet
N
97000
96000
95000

1 inch = 300 feet
N
99000
98000
97000

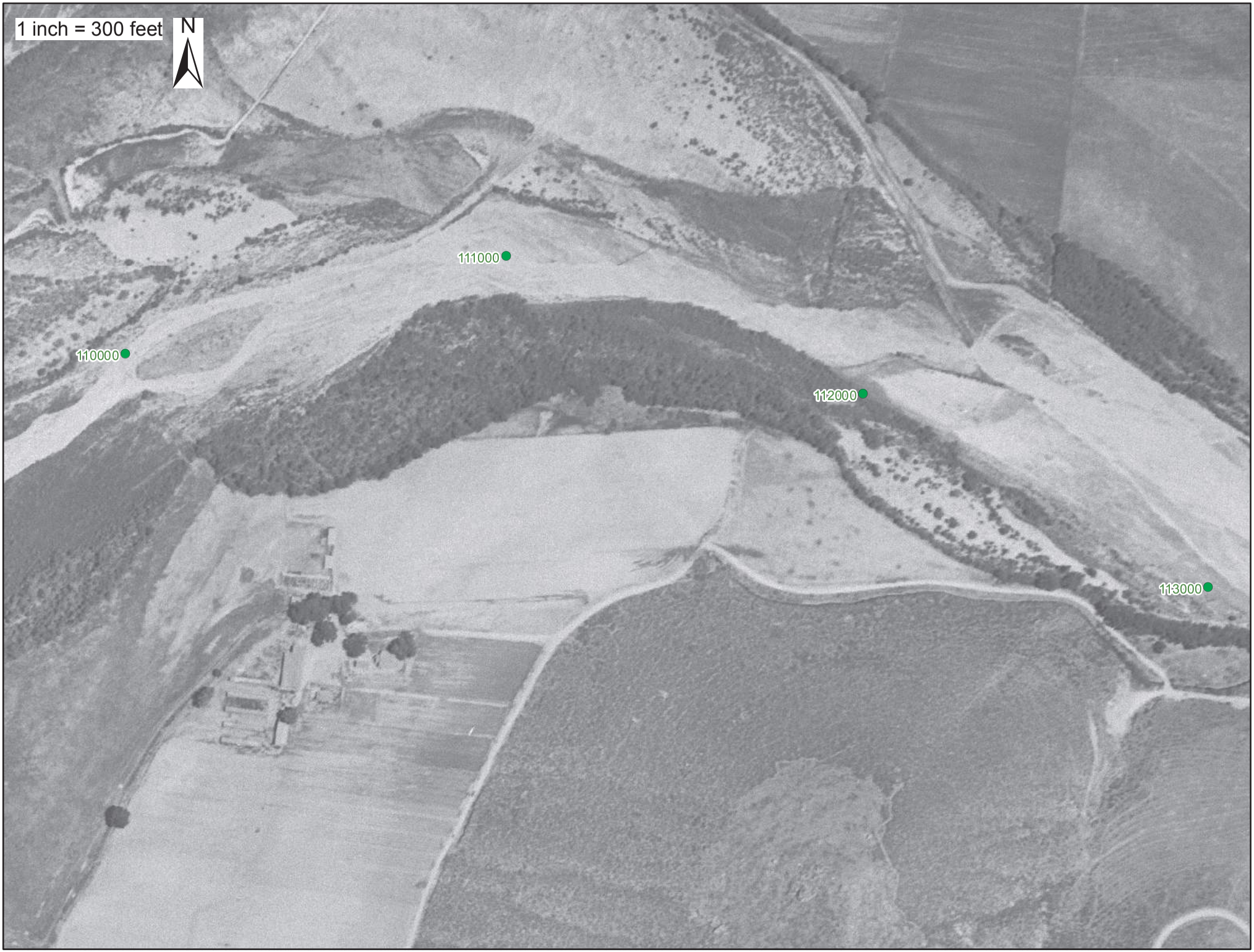
1 inch = 300 feet
N
101000
100000
99000


1 inch = 300 feet
N
103000
102000
101000

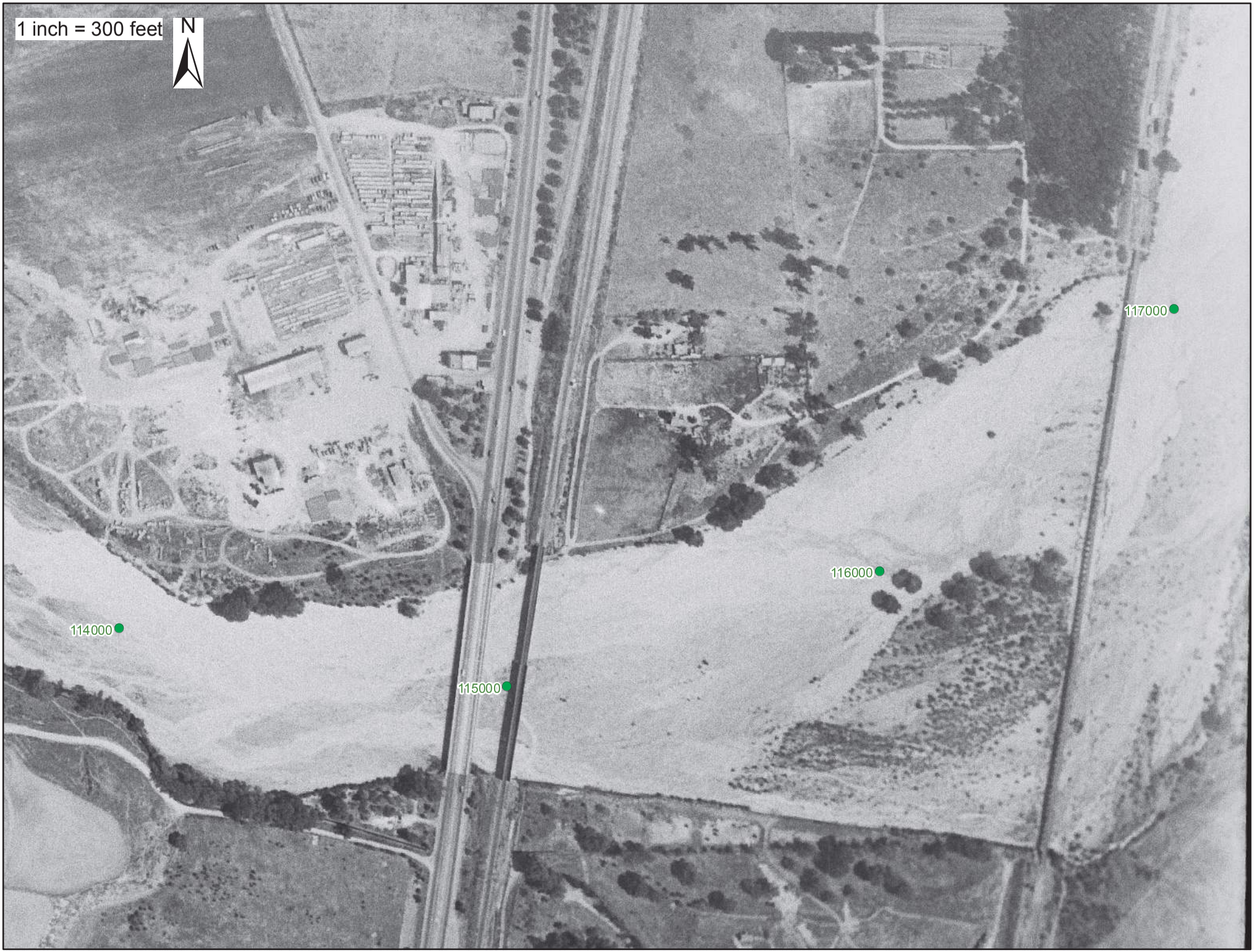

1 inch = 300 feet
N
105000
104000
103000

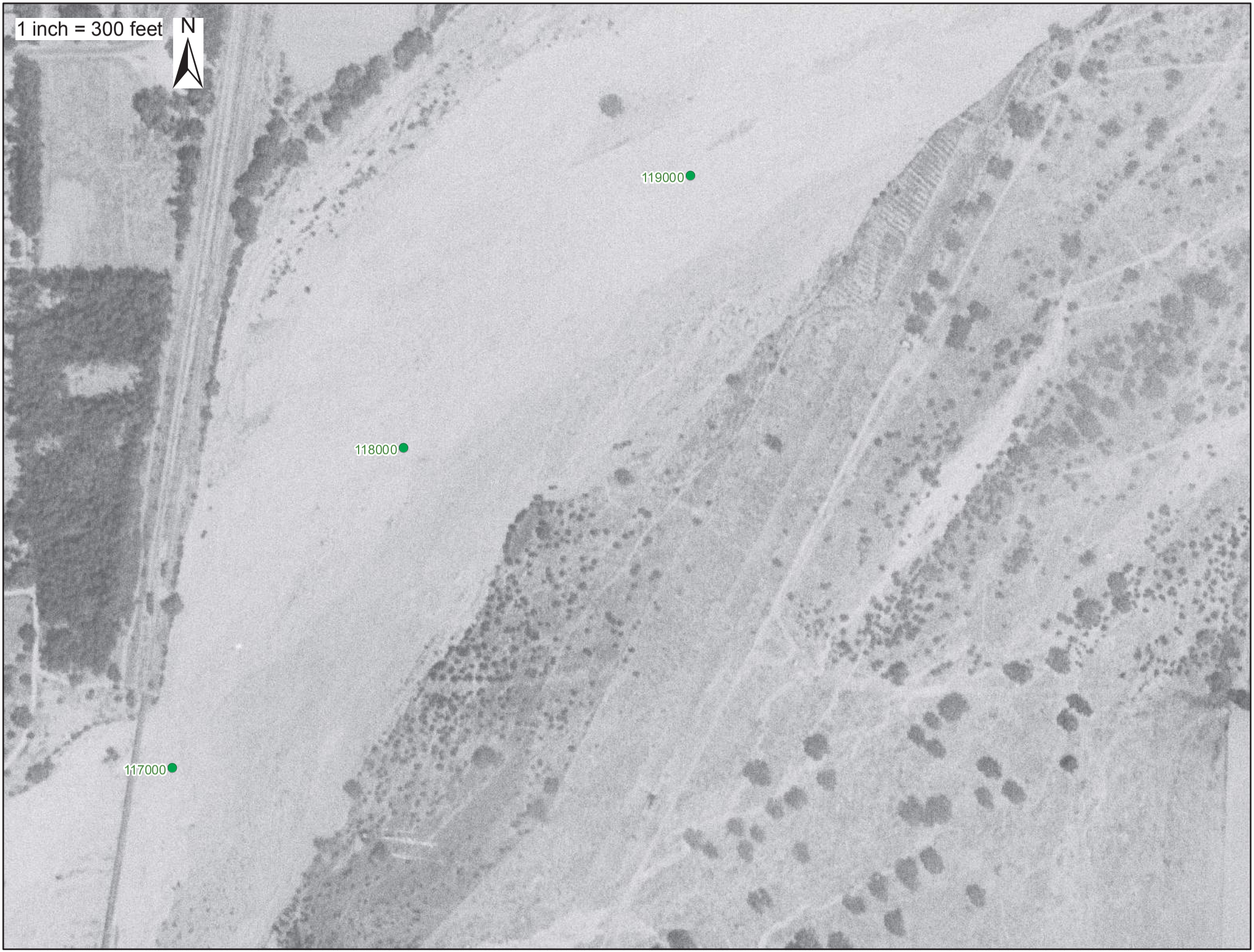

1 inch = 300 feet
N
107000
106000
105000

1 inch = 300 feet
N
110000
109000
108000
107000


1 inch = 300 feet
N
111000
110000
112000
113000

1 inch = 300 feet
N
112000
113000
114000
115000


1 inch = 300 feet
N
114000
115000
116000
117000


1 inch = 300 feet
N
119000
118000
117000

1 inch = 300 feet
N
122000
Discharge west of RS 121000
121000
120000
119000

1 inch = 300 feet
N
125000
Discharge upstream of RS 124000
124000
123000
122000

1 inch = 300 feet
N
127000
126000
125000
Discharge upstream of RS 124000

1 inch = 300 feet
N
129000
128000
127000

1 inch = 300 feet
N
131000
130000
129000
128000

Appendix C

1952 Aerial Photos

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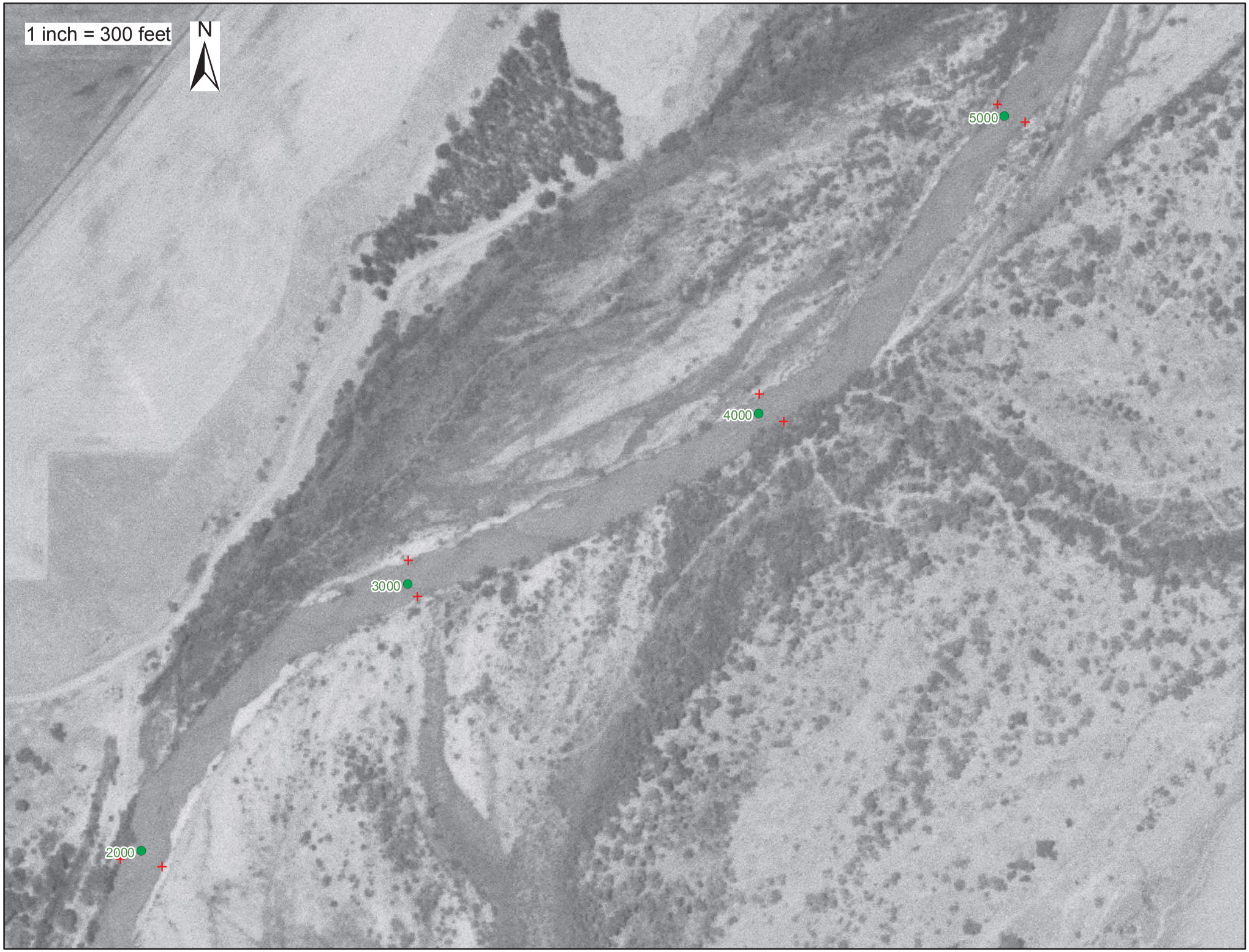
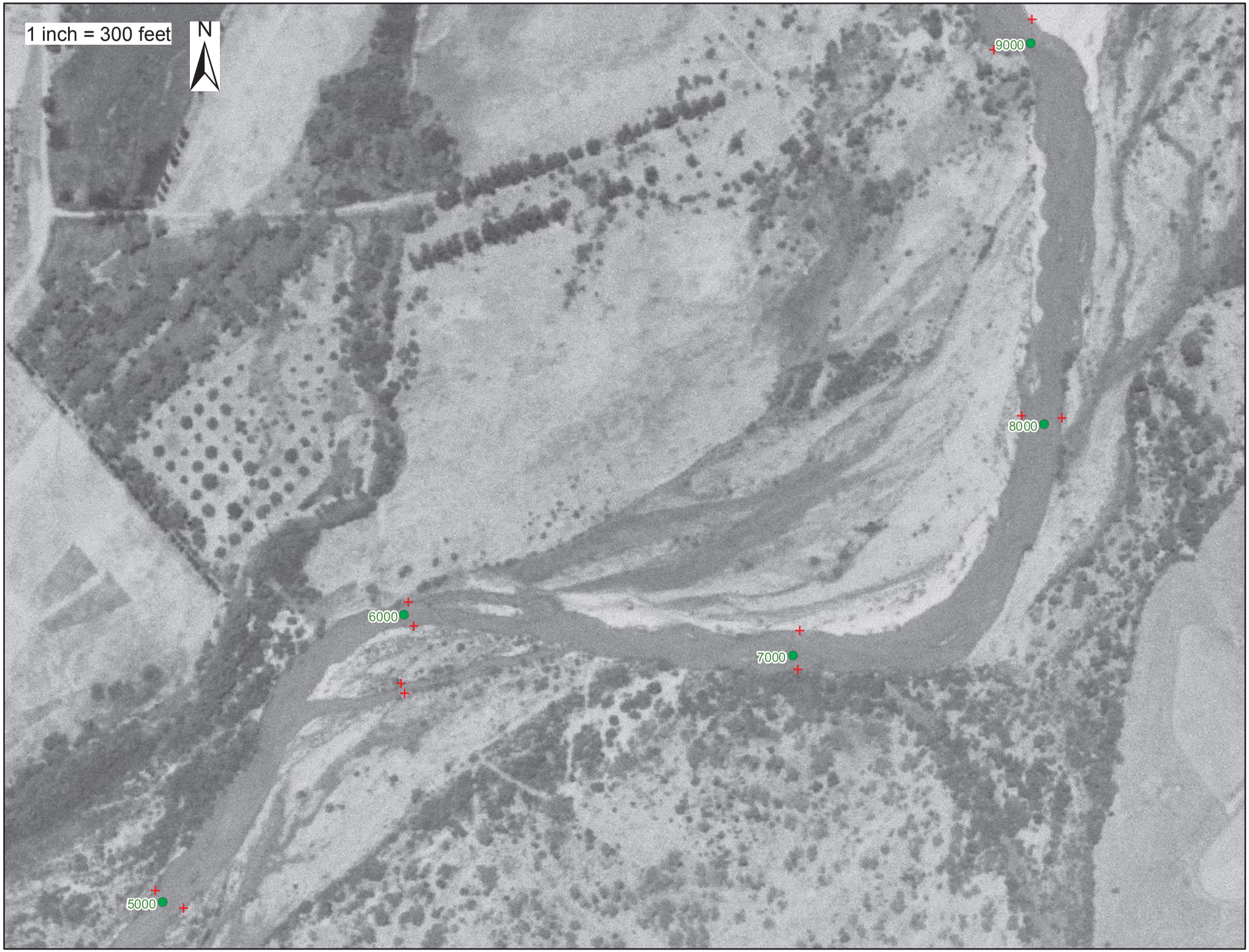
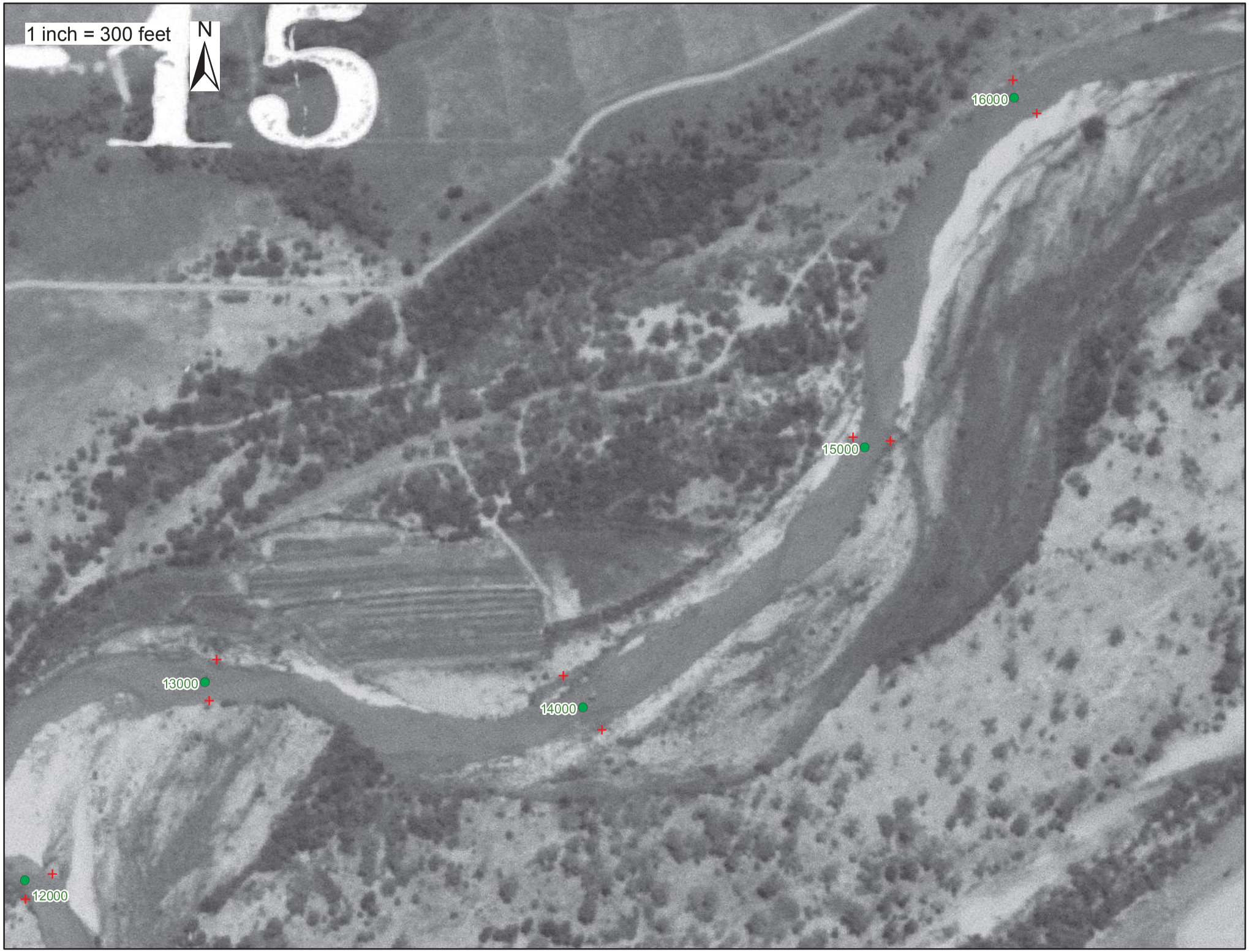
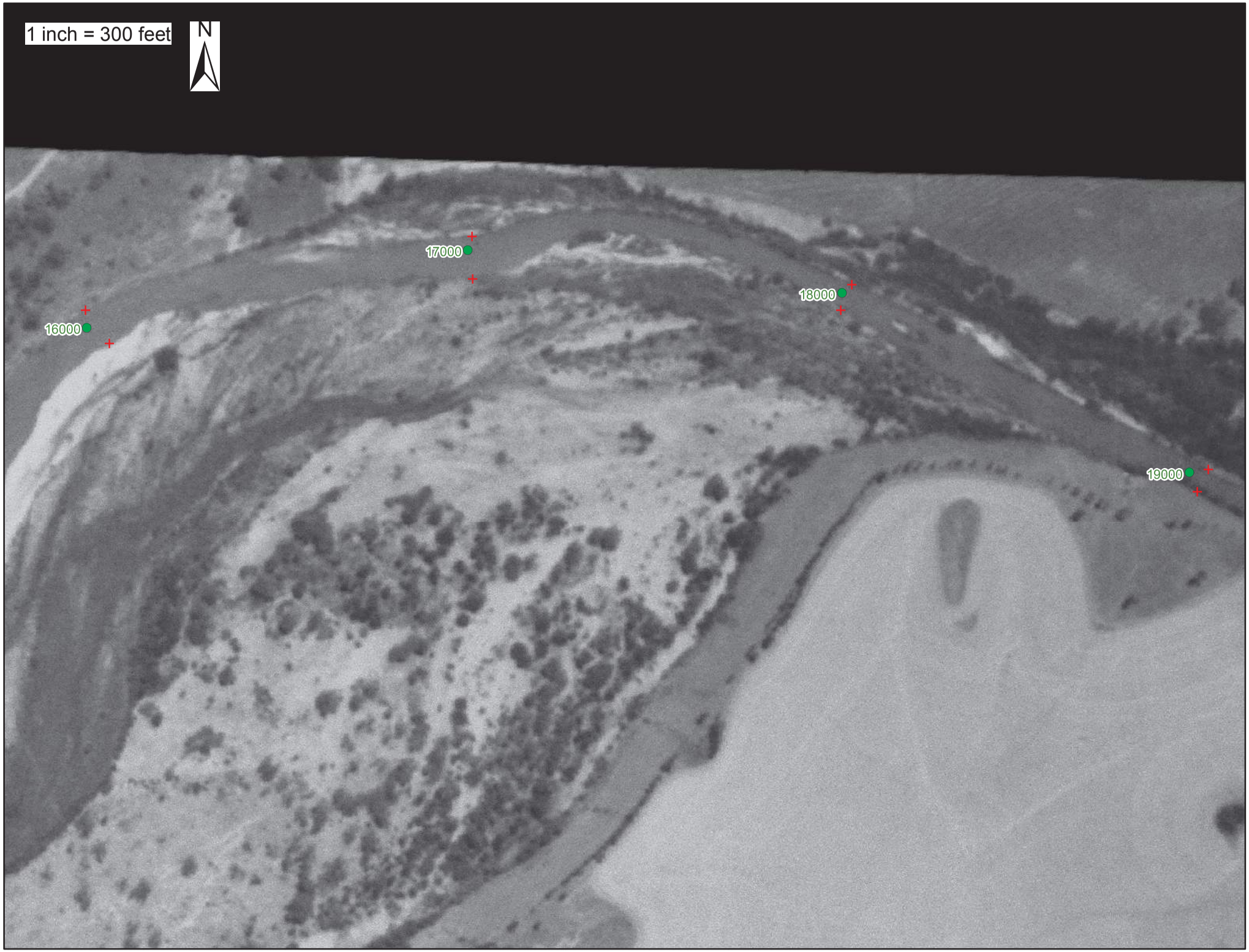
1 inch = 300 feet
N
2000
1000
0


1 inch = 300 feet
N
5000
4000
3000
2000


1 inch = 300 feet
N
9000
8000
6000
7000
5000

1 inch = 300 feet
N
13000
12000
10000
11000
9000


1 inch = 300 feet
N
16000
15000
13000
14000
12000


1 inch = 300 feet
N
16000
17000
18000
19000

1 inch = 300 feet

N

1 inch = 300 feet
N
25000
24000
23000

1 inch = 300 feet
N
29000
28000
27000
26000
25000

1 inch = 300 feet
N
29000
30000
31000
32000

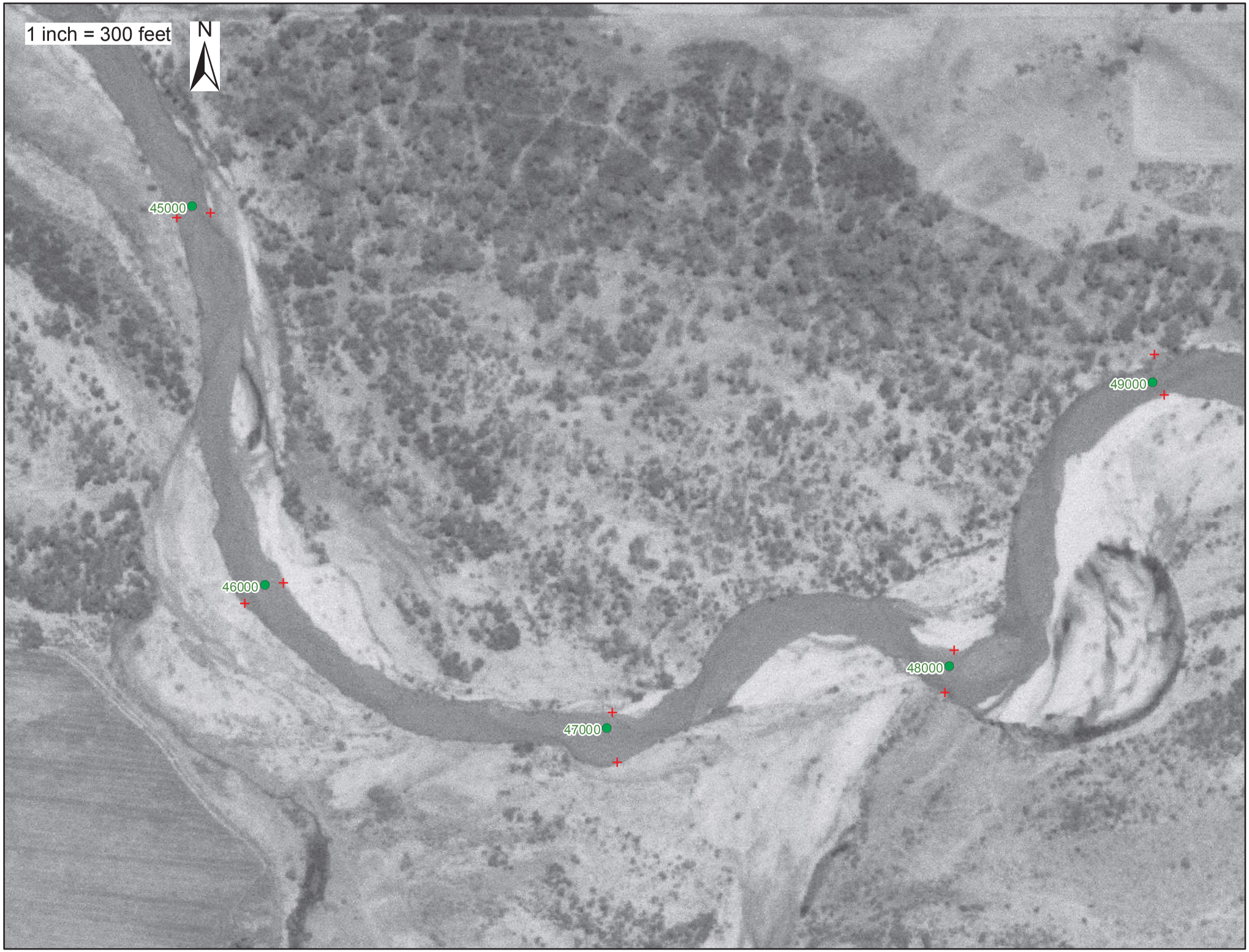
1 inch = 300 feet
N
35000
34000
33000
32000

1 inch = 300 feet
N
37000
36000
35000

1 inch = 300 feet
N
39000
38000
37000

1 inch = 300 feet
N
Diversion downstream of RS 40000
40000
41000
42000
39000

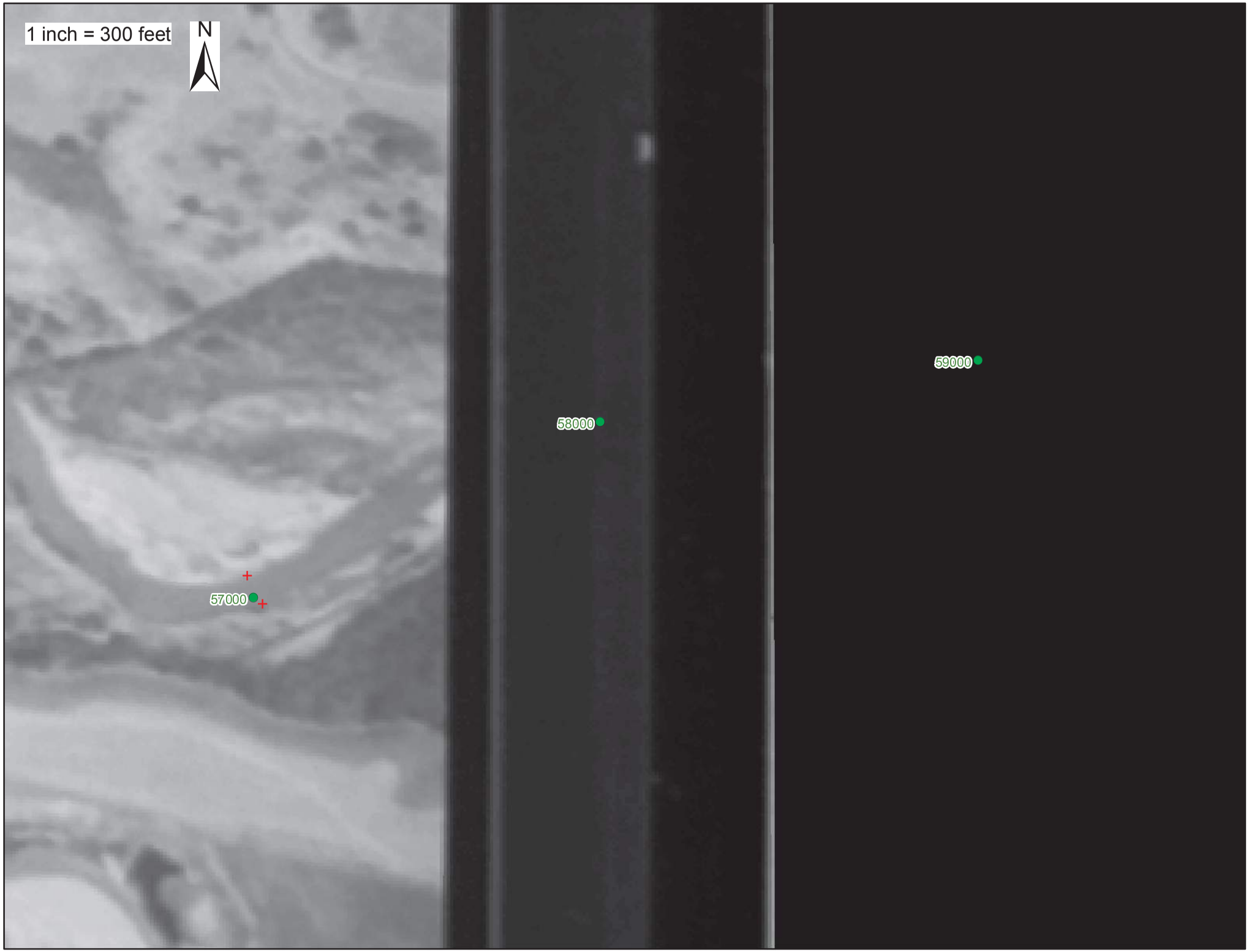
1 inch = 300 feet
N
43000
44000
45000


1 inch = 300 feet
N
45000
46000
47000
48000
49000

1 inch = 300 feet
N
49000
50000
51000

1 inch = 300 feet
N
51000
52000
53000
54000

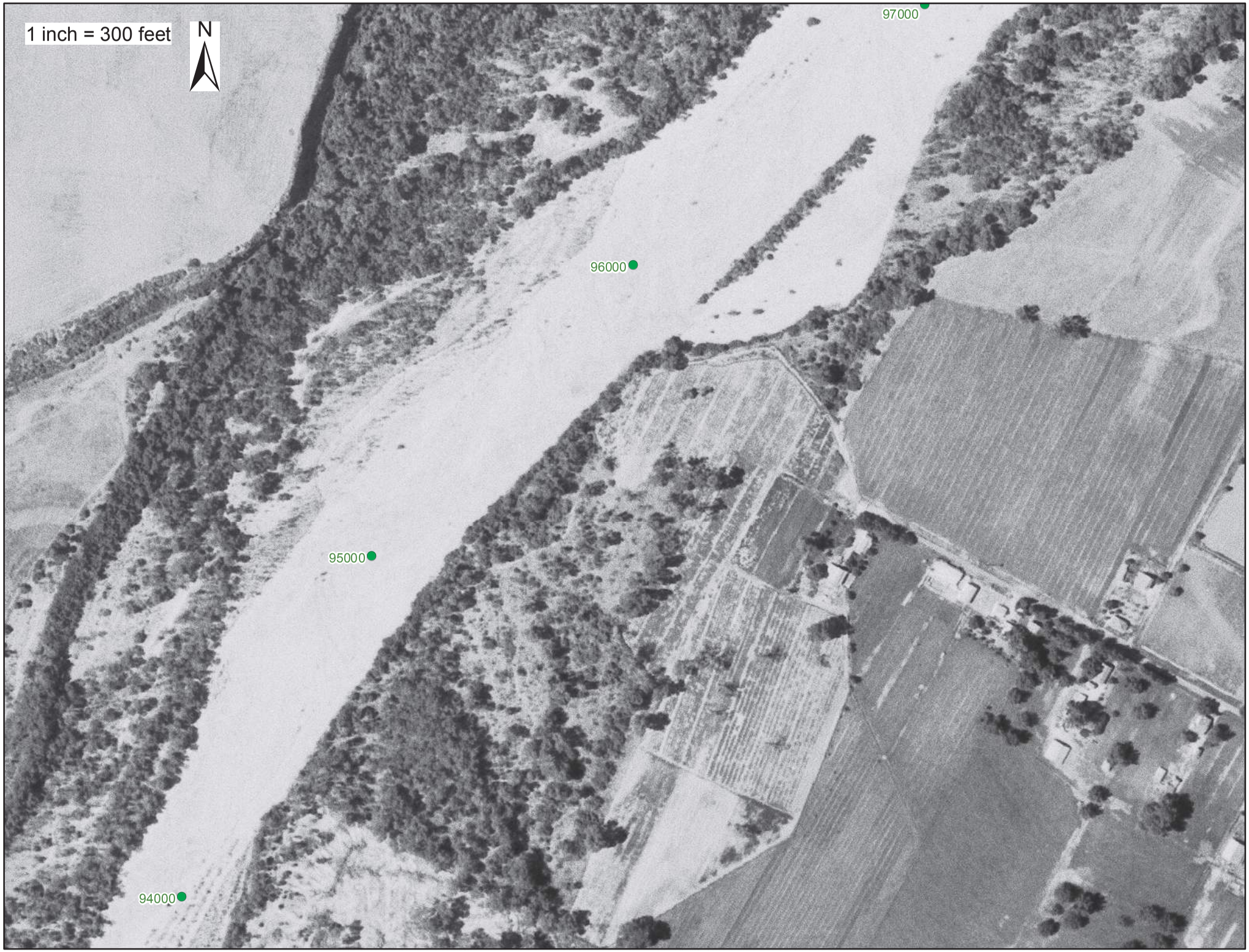
1 inch = 300 feet
N
53000
54000
55000
56000


1 inch = 300 feet
N
57000
58000
59000

1 inch = 300 feet
N
90000
89000
88000

1 inch = 300 feet
N
92000
91000
90000

1 inch = 300 feet
N
94000
93000
92000


1 inch = 300 feet
N
97000
96000
95000
94000

1 inch = 300 feet
N
Discharge upstream of RS 99000
99000
98000
97000

1 inch = 300 feet
N
101000
100000
Discharge upstream of RS 99000
99000

1 inch = 300 feet
N
103000
102000
101000

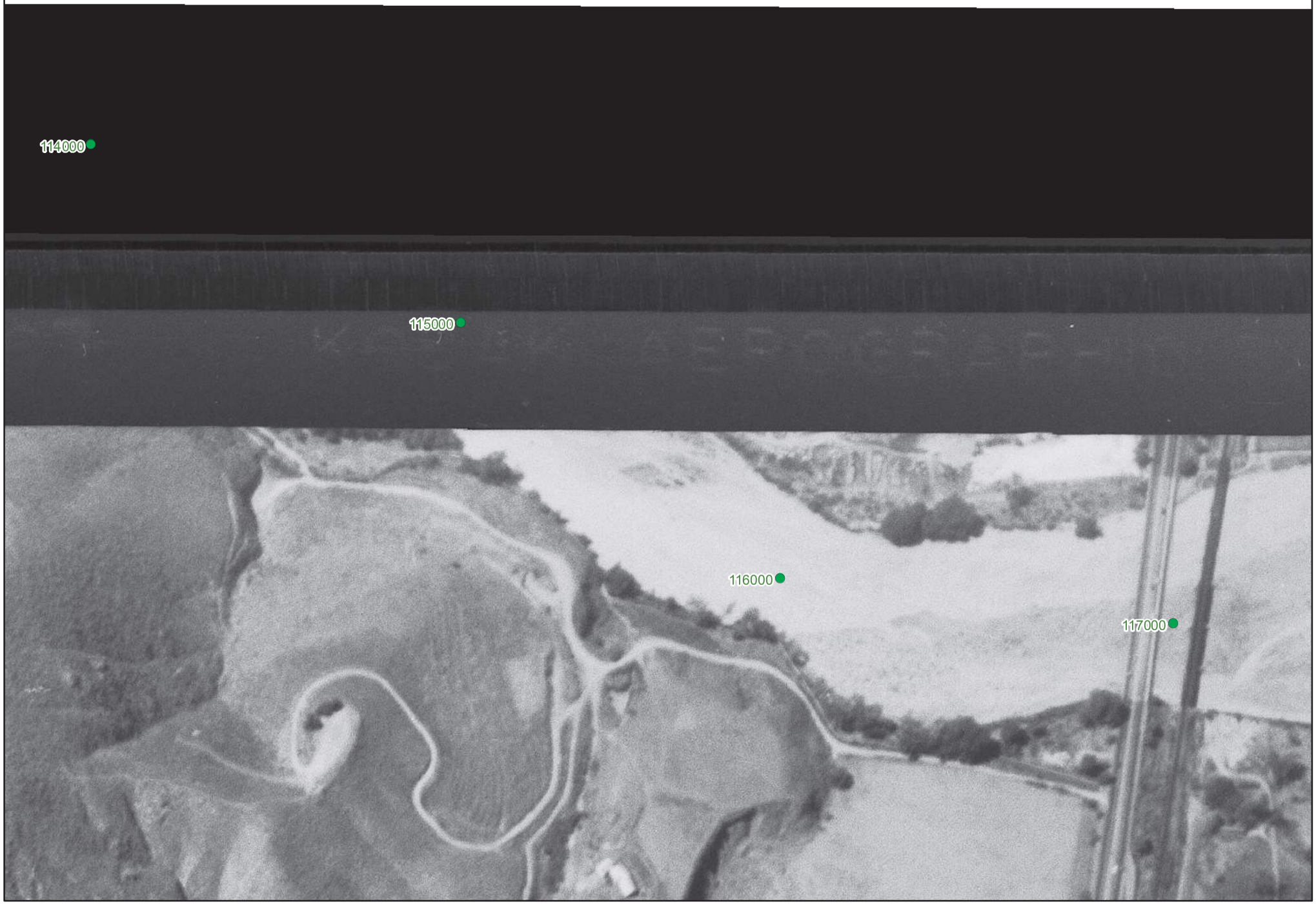
1 inch = 300 feet
N
105000
104000
103000

1 inch = 300 feet
N
107000
106000
105000

1 inch = 300 feet
N
109000
108000
107000

1 inch = 300 feet
N
111000
110000
109000

1 inch = 300 feet



1 inch = 300 feet

N

USGS
science for a changing world

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Appendix D

1953 Aerial Photos

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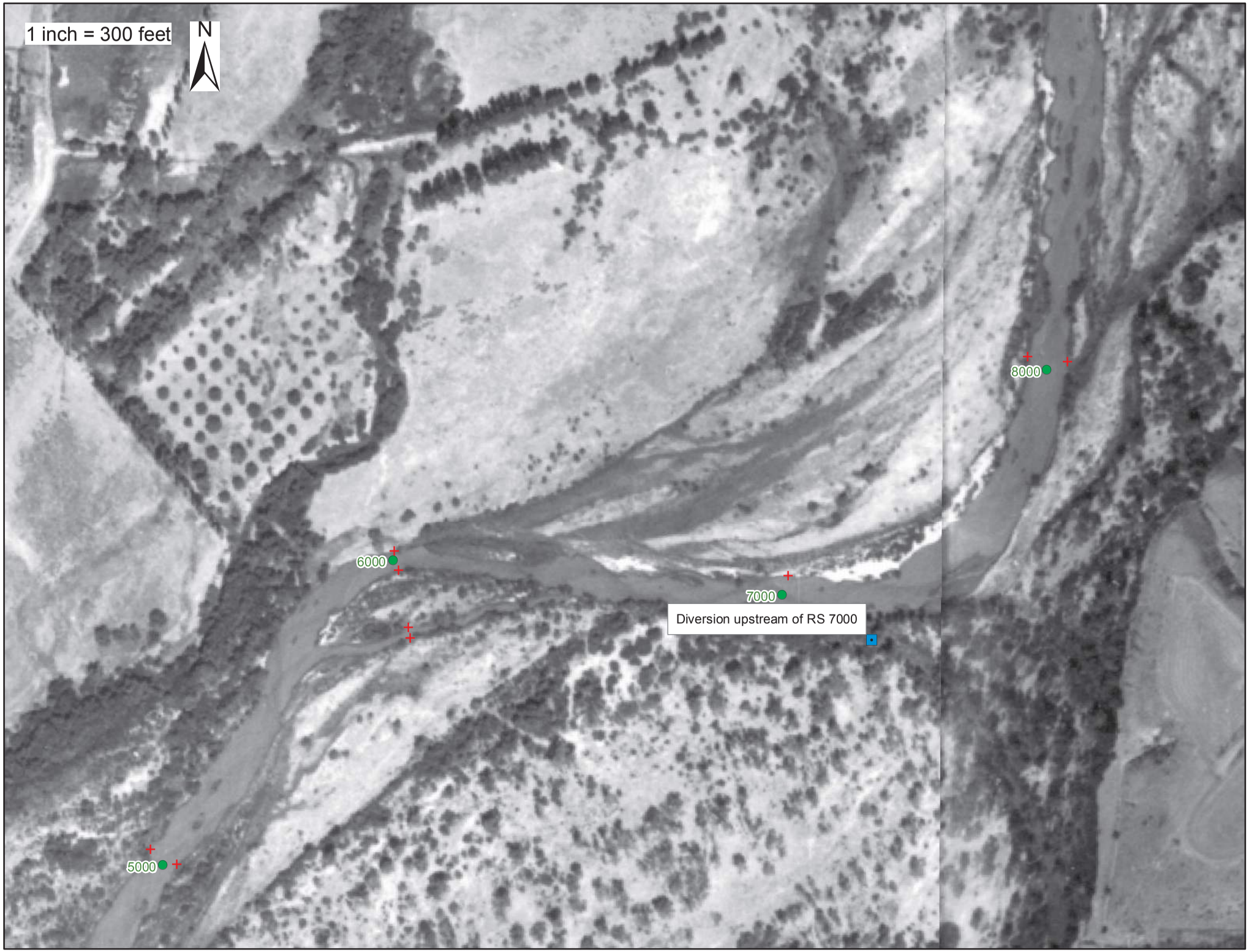
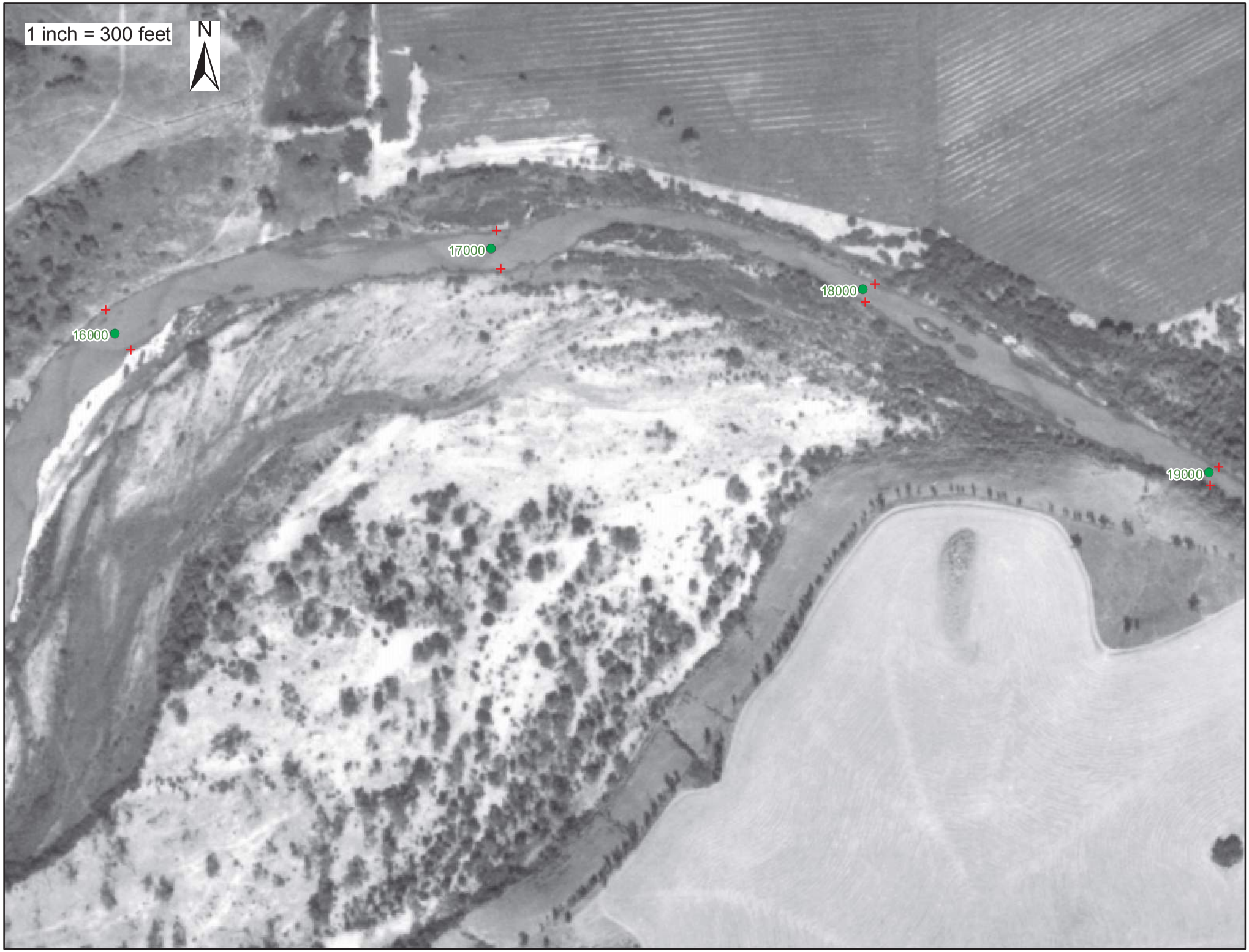
1 inch = 300 feet
N
2000
1000
0

1 inch = 300 feet
N
5000
Discharge upstream of RS 4000
4000
3000
2000


1 inch = 300 feet
N
8000
6000
7000
Diversion upstream of RS 7000
5000

1 inch = 300 feet
N
12000
10000
11000
9000
8000

1 inch = 300 feet
N
16000
15000
13000
14000
12000


1 inch = 300 feet
N
16000
17000
18000
19000

1 inch = 300 feet
N
18000
19000
20000
21000

1 inch = 300 feet
N
23000
22000
21000

1 inch = 300 feet
N
26000
25000
24000
23000

1 inch = 300 feet
N
29000
28000
27000
26000

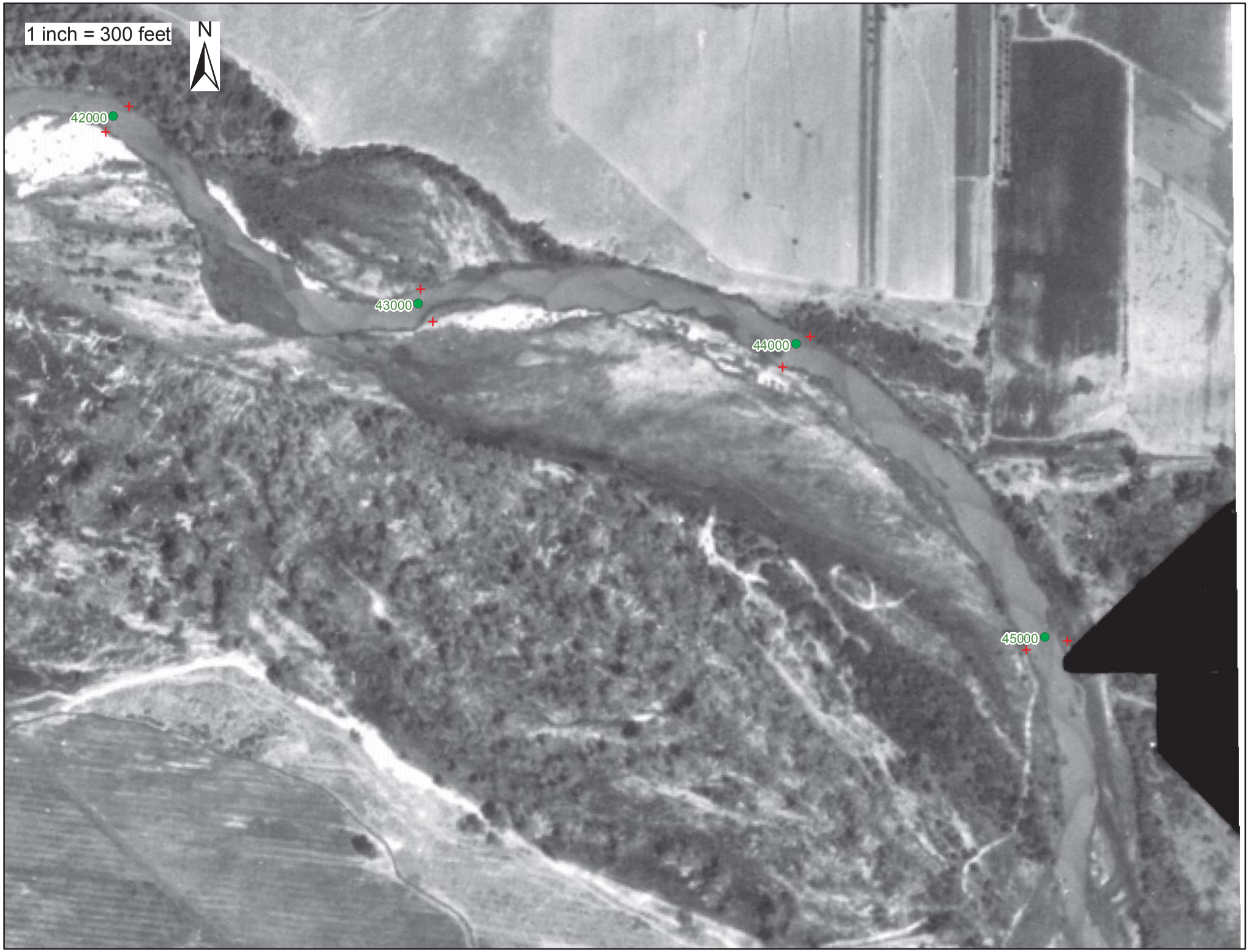
1 inch = 300 feet
N
28000
29000
30000

1 inch = 300 feet
N
34000
33000
32000
31000

1 inch = 300 feet
N
37000
36000
35000
Discharge upstream of RS 35000
34000

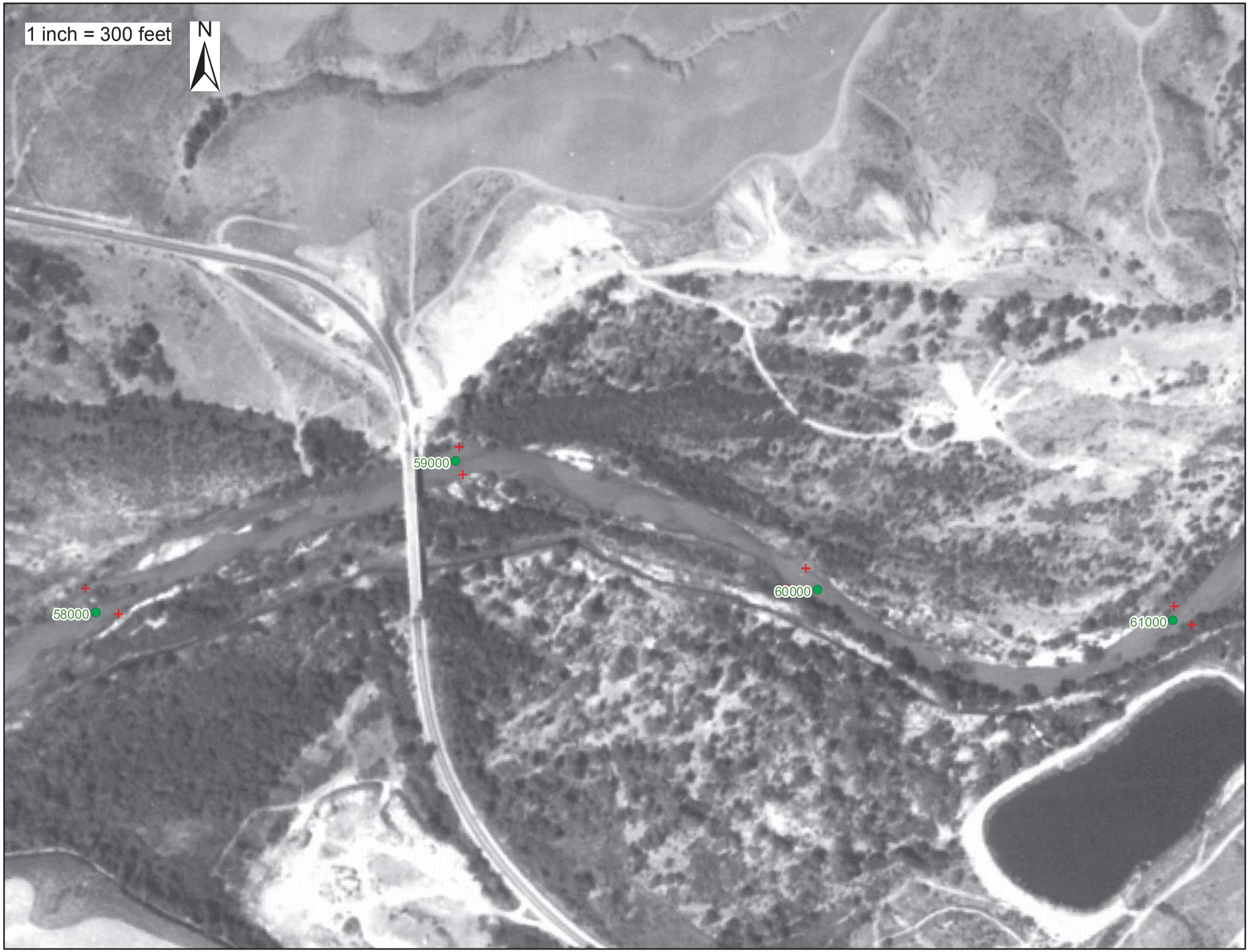
1 inch = 300 feet
N
39000
38000
37000

1 inch = 300 feet
N
Diversion downstream of RS 40000
40000
41000
42000
39000


1 inch = 300 feet
N
42000
43000
44000
45000

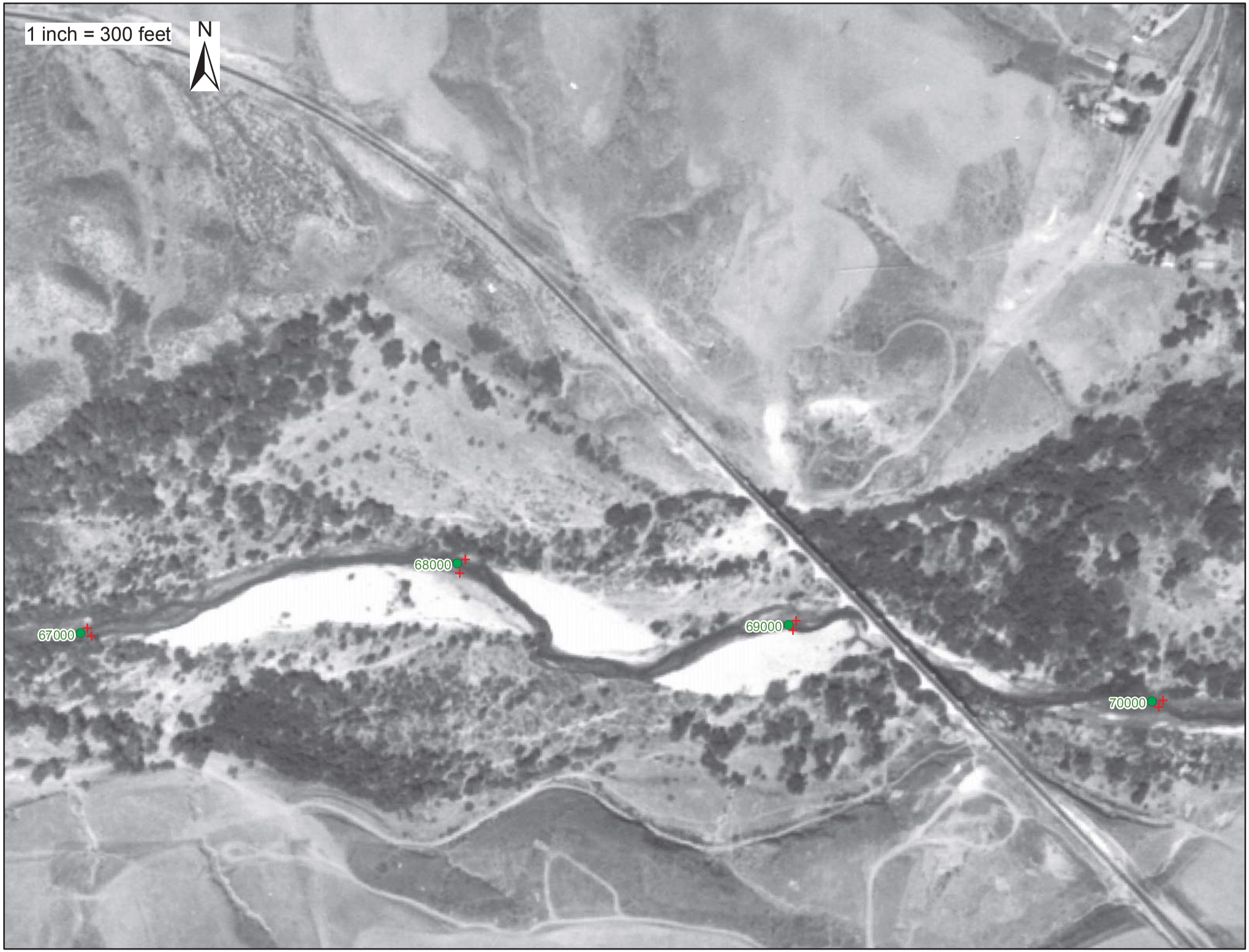
1 inch = 300 feet
N
43000
44000
45000
46000

1 inch = 300 feet
N
56000
55000
58000
57000


1 inch = 300 feet
N
59000
58000
60000
61000

1 inch = 300 feet
N
63000
64000
62000
61000

1 inch = 300 feet
N
Discharge at MWD Crossing
65000
67000
66000
64000

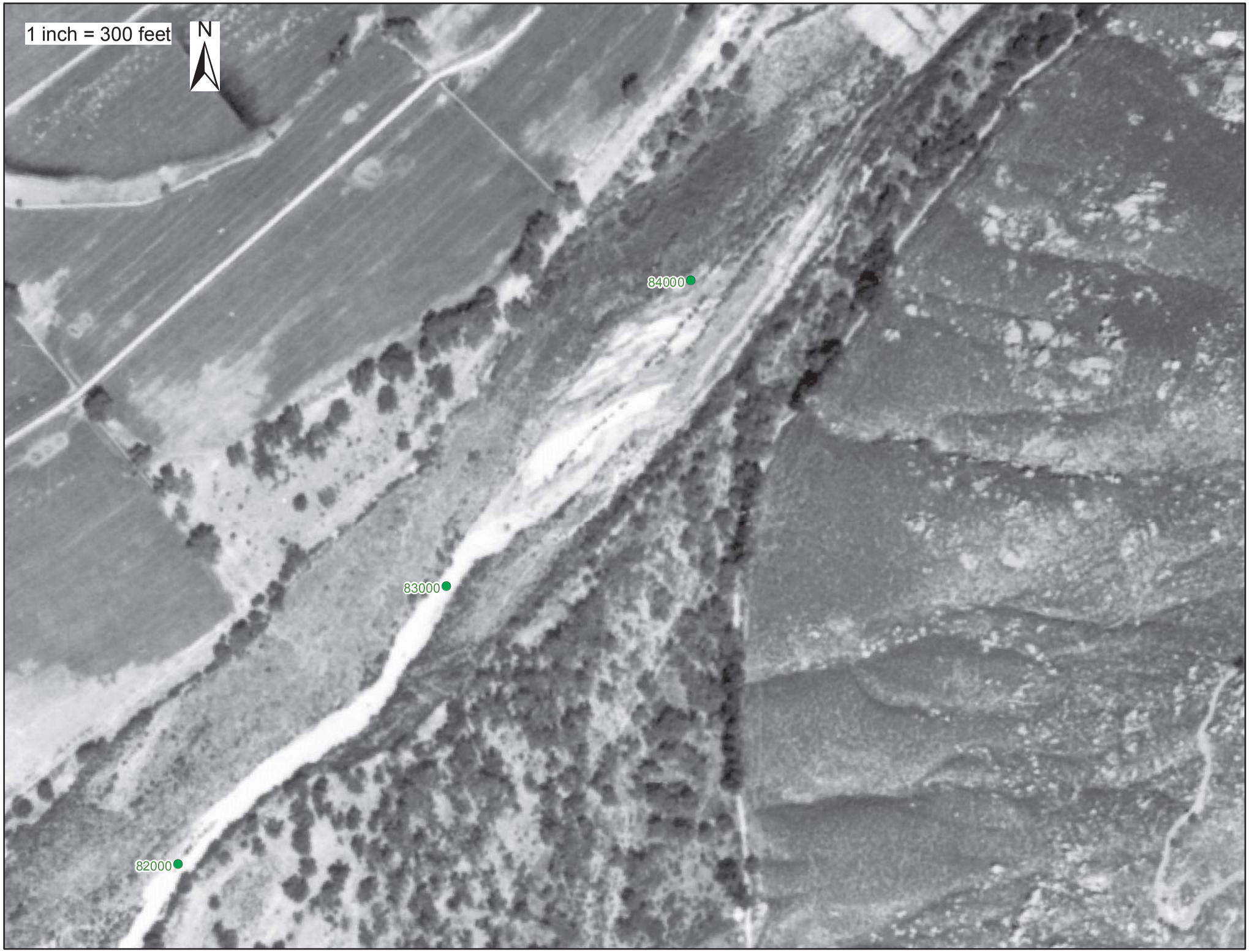

1 inch = 300 feet
N
68000
67000
69000
70000

1 inch = 300 feet
N
70000
71000
72000
73000

1 inch = 300 feet
N
76000
75000
74000
Discharge downstream of RS 74000
73000

1 inch = 300 feet
N
79000
78000
77000
76000

1 inch = 300 feet
N
82000
81000
80000
Discharge upstream of RS 79000
79000


1 inch = 300 feet
N
84000
83000
82000

1 inch = 300 feet
N
86000
85000
84000

Appendix E

1954 Aerial Photos

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