APPENDIX F

REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER

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APPENDIX F-1
REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER BELOW THE LOWER NARROWS TO EVALUATE LOSING STREAM LENGTH VERSUS FLOW RATE

Tables

Figures

APPENDIX F-2
REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER ABOVE THE LOWER NARROWS TO EVALUATE GAINING STREAM LENGTH VERSUS FLOW RATE

Tables

Figures

APPENDIX F-1

REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER

BELOW THE LOWER NARROWS TO EVALUATE

LOSING STREAM LENGTH VERSUS FLOW RATE

REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER BELOW THE LOWER NARROWS TO EVALUATE LOSING STREAM LENGTH VERSUS FLOW RATE

The Mojave River is largely an intermittent stream, but flows perennially in the southern Transition Zone (TZ) where it enters the TZ at the bedrock gap of the Lower Narrows. Upon entering the TZ, the Mojave River channel winds northward past the communities of Oro Grande, La Delta, Bryman, and Helendale, then exits the TZ across the Helendale fault. The path of the Mojave River through the TZ past these locations is shown on Figure F-1. The Mojave River below the Lower Narrows is a losing stream, in which base flows typically infiltrates into the dry river channel shortly after entering, and rarely reach the Helendale fault except during large storm flows. In 1981, a significant addition to Mojave River flow in the TZ began as the Victor Valley Wastewater Reclamation Authority (VVWRA) treatment plant began discharging treated wastewater across the river from Oro Grande.

This evaluation was conducted to identify potential relationships within the TZ between the length of losing stream and flow rates measured at the Lower Narrows. Flow lengths and discharge rates from the VVWRA treatment plant are also compared. With all other factors being equal, flow lengths should be directly proportional to flow rates. Variations from the proportional relationship can be explained by local variations in channel infiltration rates. For example, with a locally decreased infiltration rate, a uniform increase in flow rate should produce a comparably greater flow length. The relationship can also be influenced by factors that increase or decrease the surface flow velocity, such as channel width, depth, and vegetation density.

Infiltration rates can also be controlled by variations in the permeability of subsurface deposits. Low permeability clay deposits at about 75 to 100 feet beneath the river surface are suspected of supporting groundwater in shallower sand and gravel deposits and keeping groundwater in reach of riparian vegetation root zones. Without these clay lenses, groundwater in the shallow sediments would tend to migrate downward during pumping of nearby deeper wells. These lower permeability deposits are also thought to influence infiltration rates and the travel length per unit flow rate in the Mojave River channel.

Collection of Flow Length and Flow Rate Data

To conduct the evaluation, historical annual aerial photographs taken along the Mojave River were reviewed to estimate the distance reached by surface flows passing the Lower Narrows and by discharges from the VVWRA treatment plant. The photographs reviewed were made available by Mojave Water Agency and are listed in Table F-1. For flows measured at the Lower Narrows and discharges from the VVWRA treatment plant, flow lengths were measured from the Lower Narrows along the Mojave River channel. Flow lengths were measured to the nearest 100 feet. The channel lengths are measured along the path of the Mojave River as shown on the USGS topographic map[1] reproduced in part on Figure F-1. The locations where surface flows become absent in the channel are shown on Figure F-1. The evaluation assumes measured flow rates have reached equilibrium with measured flow lengths.

Historical flow rates were obtained from stream gage data recorded at the Lower Narrows gage operated by USGS[2]. Average daily flow rates in cubic feet per second (cfs) were compiled for the day of the photograph date and for the seven days prior to the photograph date. These flow rate data are listed in Table F-2 for each photograph date. Table F-2 notes if significantly larger than average flows were measured in the 30 days prior to the photograph date. VVWRA discharges to the Mojave River began in 1981. For the 1985 to current water year, VVWRA treatment plant discharge rates are daily averages in cfs as reduced from annual totals[3] in acre-feet per water year. Pre 1985 Water Year VVWRA discharges were obtained through verbal communication with the Mojave River Watermaster.

In Table F-2, flow lengths from VVWRA are identified separately from flow lengths past the Lower Narrows. In these instances, a length of dry channel was observed between flow past the Lower Narrow and the VVWRA discharge point. The VVWRA treatment

[1] U.S. Geological Survey, 1982, Topographic Map Of Victorville California, 1:100 000-Scale Metric.

[2] U.S. Geological Survey Steam Gage Data for Station Number 10261500

[3] Mojave Water Agency Watermaster, 2001, Watermaster Seventh Annual Report, Water Year 1999-00.

plant flows lengths were also measured from the Lower Narrows although they originate from the treatment plant located approximately 23,000 feet from the Lower Narrows.

Flow rates are graphed versus flow lengths on Figure F-2. Only the flows rates measured on the day of the aerial photograph are graphed, as the daily flow averaged over seven days were nearly identical and do not add significantly to the evaluation. Different shape symbols are used for VVWRA discharges and flow past the Lower Narrows. Different shading is used for flows past the Lower Narrows that are either pre VVWRA discharge operations (pre 1981) or post VVWRA discharge operations (post 1981). None of the aerial photographs reviewed had combined flows from the Lower Narrows and VVWRA discharges, except in instances were storm flows exited the TZ and were not shown on Figure F-1 or graphed on Figure F-2. The general trends of the graphed data are shown as dashed lines on Figure F-2. The locations of communities and geographic reference points are shown along the top of Figure F-2.

Relationships of Flow Rate and Flow Length

Comparison of stream flow lengths and flow rate shows that Mojave River surface water follows approximately four linear relationships through then TZ. These relationships are listed in the below chart and summarized in the following paragraph.

Mojave River within the Transition Zone - Interpreted Relationships of Flow Length to Flow Rate

	Mojave River Length, L (feet)		Flow Rate, Q (cfs)		Slope (dQ/dL)	1/Slope (dL/dQ)
Location	Begin	End	Entering	Exiting	(cfs/1,000 feet)	(feet/cfs)
Lower Narrows	0	8,000	0.0	13.0	1.6	600
Oro Grande to La Delta	8,000	33,000	13.0	21.0	0.3	3,100
La Delta to Bryman	33,000	42,000	21.0	30.0	1.0	1,000
Bryman to Helendale	42,000	62,000	30.0	32.0	0.1	10,000

Mojave River surface water travels the shortest length per unit flow rate (600 feet/cfs) in the first 8,000 feet past the Lower Narrows. At 1.6 cfs/1,000 feet, this is the most rapid infiltration rate observed along the river length in the TZ. As is shown on Figure F-2, two possible lines fit the data directly downstream of the Lower Narrows. The lower-slope line does not appear to continue with the remaining flow data and may represent anomalous conditions, perhaps due to temporary narrow channelized river flows. With a similar infiltration rate, flow contained in a narrow channel would tend to travel farther than a similar flow rate in a wider channel. A greater infiltration volume would occur in the wider channel due to the grater surface area.

Between Oro Grande, the VVWRA plant, and La Delta, Mojave River surface flow travels approximately five times farther per unit flow rate (3,100 feet/cfs) than it does just past the Lower Narrows. This indicates a lower infiltration rate (0.3 cfs/1,000 feet) along this river length than the previous upstream length. Based on these flow relationships, approximately 18 cfs of flow at the Lower Narrows is needed for flow to reach the VVWRA treatment plant. All observed aerial photographs show VVWRA discharges passing La Delta. Between La Delta and Bryman, VVWRA discharges begin to disappear in the subsurface. VVWRA discharges graphed on Figure F-2 plot below the Lower Narrows data. If the 18 cfs required for Lower Narrows flow to reach the VVWRA plant were added to the VVWRA discharges, the VVWRA data would plot directly on the Lower Narrows data.

Between La Delta and Bryman, both VVWRA discharge data and pre 1981 Lower Narrows data show Mojave River surface flows travel a shorter distance per unit flow rate (1,000 feet/cfs) along this river length than the immediate upstream length. This indicates an increased infiltration rate (1.0 cfs/1,000 feet) along this river length than the previous upstream length.

Between Bryman and about 10,000 feet south of Helendale, Mojave River surface flow travels the farthest per unit flow rate (10,000 feet/cfs) than it does in the upstream river lengths below the Lower Narrows. This indicates the lowest infiltration rate (0.1 cfs/1,000 feet) along this river length compared with the three other upstream lengths.

Sufficient data are not available to adequately evaluate the ratio of flow length to flow rate for the Mojave River for between Helendale and the Helendale fault. Only two flow data points occur along this river length. These two data points plot at lower flow rates than data from the up steam length and may be anomalous. Although they plot lower on the graph, a line fit between these two data points is nearly the same slope as the line for the data between Bryman and Helendale, suggesting no change in the relationship of flow length and flow rate along this river length.

Infiltration Rate Variation, Shallow Clay Lenses, and Dense Riparian Vegetation

Variation in observed river channel infiltration rates coincides with the occurrence of shallow clay lenses and areas of dense riparian vegetation. The occurrence and variations of these three factors are shown on Figure F-3 as varying width parallel bars oriented in a north-south direction. Projection of the bar ends and changes in width eastward to the river mark the limit of the occurrence or variation. For the infiltration rate bars, the wider bars corresponding to infiltration rates (greater than 1 cfs per 1,000 feet of river channel, while the narrower bars correspond to rates less than 1 cfs per 1,000 feet of river channel. Areas of dense riparian vegetation are shown on Figure F-3 based on their relative coverage of the channel[4]. Wider bars are shown were dense riparian vegetation covers 71 to 100 percent of the channel bottom and thinner bars are shown where they cover 41 to 70 percent of the channel bottom. The lack of a bar for dense riparian vegetation indicates the channel width is less than 41 percent or riparian vegetation is not considered dense. The occurrence of the shallow clay lenses are derived from Cross Section A-A' in the Mojave River Transition Zone Recharge Project Phase I Report. Wider bars are show on Figure F-3 for thicker more continuous clay lenses at a depth of approximately 75 to 100 feet.

Just up stream from the Lower Narrows, infiltration rates are highest at approximately 1.6 cfs per 1,000 feet of river channel. This high rate occurs where there is no occurrence of significant shallow clay lenses. This area is the Forebay of the Floodplain aquifer in the TZ, where groundwater recharge can flow into both the deep and shallow zones of the aquifer. Immediately down stream of the Forebay near Oro Grande, shallow clay lenses begin and correspond with a lower infiltration rate and dense riparian vegetation. Above these clay lenses is the shallow zone of the Floodplain aquifer. About a half mile from the VVWRA treatment plant, the clay lenses thicken and correspond with increase riparian vegetation density. This condition continues northward past the VVWRA treatment plant. Near La Delta, infiltration rates increase and correspond with less dense riparian vegetation and decreased thickness and decreased continuity of shallow clay lenses. Near Bryman, infiltration rates again decrease and correspond with an increase in dense riparian vegetation and resumed clay lens continuity. A few miles north of Bryman, thick continuous clay lenses do not occur in the Floodplain aquifer, and no distinction is made between deep and shallow zones. Flow data north of Bryman near Helendale are rare and thus estimated infiltration rates up to the Helendale fault are less certain. Available data show no significant change in infiltration rate between Bryman and the Helendale fault despite the lack of the clay lenses and lack of areas of dense riparian vegetation in the Helendale area.

[4] U.S. Geological Survey, 1996, Riparian Vegetation And Its Water Use During 1995 Along The Mojave River, Water Resources Investigations Report 96-4241.

Summary

Review of the historical aerial photographs indicates base flow follows several linear mathematical relationship in the losing stream portion of Mojave River down stream of the Upper Narrows. Surface flows in the Mojave River channel travel shorter distances per unit flow rate between the Lower Narrows and Oro Grande and between La Delta and Bryman. With all other factors being equal, this indicates more infiltration along these lengths of the Mojave River. Between Oro Grande and La Delta and between Bryman and Helendale, surface flows in the Mojave River channel travel longer distances per unit flow rate. With all other factors being equal, this indicates less infiltration along these lengths of the Mojave River.

Higher infiltration rates in the southern TZ correspond with an area of the Floodplain aquifer lacking significant clay lenses. This area between the Lower Narrows and Oro Grande is referred to as the Forebay. Lower infiltration rates between Oro Grande and Bryman correspond with subsurface clay lenses that divide the Floodplain aquifer into shallow and deep zones. The occurrence of these clay lenses also corresponds with areas of dense riparian vegetation. An increase in infiltration rate near Bryman corresponds with a break in the continuity of the clay lenses, which in turn corresponds with a smaller area of dense riparian vegetation.

The variation in infiltration rate and the occurrence of subsurface clay lenses should be utilized to support future recharge goals. Recharge to transport water downstream or to supply riparian vegetation should be conducted in areas of lower infiltration and greater thickness and continuous clay lenses. Recharge to replenish pumping in the deeper zone of the Floodplain aquifer or Regional aquifer should be conducted in areas of higher infiltration rate with less continuous clays, such as in the Forebay or near La Delta.

TABLE F-1

AERIAL PHOTOGRAPHS REVIEWED

Aerial Photograph							
MONTH	**YEAR**	**Photo Date**	**Photo Type**	**Photograph Series**	**Photograph Number**	**Photo Interpreted By**	**Comments**
Aug	1969	08/22/69	Black & White	None Provided	2653-3 to 2653-6	Phil Richards, URS Corporation	Good Photo depicting end of surface flow. VVWRA plant not constructed at this date.
Jun	1971	06/15/71	Black & White	None Provided	2920-3 to 2920-6	Phil Richards, URS Corporation	Good Photo depicting end of surface flow within main channel. VVWRA plant not constructed at this date.
Jun	1972	06/29/72	Black & White	0-31; 052; 051; 050	3 to 6	Phil Richards, URS Corporation	Poor photo, shaded channel assumed to represent surface water. VVWRA plant not constructed at this date.
Jun	1972		Black & White			Phil Richards, URS Corporation	These 1972 photographs were not provided for review. A separate 1972 photograph series was reviewed.
Jul	1973	07/19/73	Black & White	None Provided	3358-3 to 3358-6	Phil Richards, URS Corporation	A small area between 16,000 and 18,000 feet distance was observed with shading that may indicate saturated soils in main channel. Also, between 24,000 to 30,0000 feet, the vegetated area on the west side of the channel may be saturated based on photo shading. VVWRA plant not constructed at this date.
Jul	1973		Black & White			Phil Richards, URS Corporation	These photographs were not provided for review and likely do not cover the inhabited Transition Zone area along the Mojave River based on the description of the photographed area.
Jul	1977	07/14/77	Black & White	None Provided	2920-3 to 2920-6	Phil Richards, URS Corporation	None
Aug	1978	08/22/78	Black & White	UAgII 3052 153.19	3-4 to 3-13; 4-1 to 4-11; 5-5	Phil Richards, URS Corporation	Poorer quality photo with whites bleached out. VVWRA plant is under construction.
Sept	1981	09/27/81	Black & White	None Provided	2185-1 photos 3-6	Phil Richards, URS Corporation	North of Route 66, sun reflecting off very narrow channel, then channel is lost in vegetation.
Aug	1982		Black & White			Phil Richards, URS Corporation	Photograph series is a combination of 1981 and 1982 photos, site covered by 1981 photos and not 1982 photos
Oct	1983	10/20/83	Black & White	UAGI 6069 152.00	3-6 to 3-8; 4-1 to 4-8	Phil Richards, URS Corporation	B&W photos are much more subjective; nevertheless this photograph clearly depicts the end of surface flow
Jan	1984	01/29/84	Black & White	None Provided	13-10 to 13-11; 12-1 to 12-2; 10-2; 9-4; 8-3;	Phil Richards, URS Corporation	Again, channel narrows and braids in vegetated area near treatment plant. Flow extends well beyond the northern limits of the Transition Zone.
May & Jun	1985	05/20/85	Color Infrared	UAgII 3090 153.23	13-10 to 13-11; 12-2; 11-2; 10-2; 9-4	Phil Richards, URS Corporation	Not as large a flow as in other photographs. Photographs are not as clearly depicting surface flow as others.
May & Jun	1985	05/21/85	Black & White	UAgII 3090 153.23	13-11; 2-2; 11-2;10-2; 9-4&5;	Phil Richards, URS Corporation	Poor quality photo, flow appears in channels to 62,200 feet then reappears in what looks to be an engineered channel road crossing
Aug & Sept	1987	08/10/87	Color Infrared	MWA	13-10; 11-2;	Phil Richards, URS Corporation	Only indicated photos where flow stops; however, all photos were reviewed.
Aug & Sept	1987	08/10/87	Black & White	MWA	11-2; 9-5; 12-2 to 12-3; 13-10	Phil Richards, URS Corporation	Same distances as color
Jun & Jul	1989	06/27/89	Color Infrared	WILD 15 / 4 UAG Nr 13040 152.67	13-11 (7464); 12-2 to 12-3;	Phil Richards, URS Corporation	Very narrow channel. Photographs do not extend north of Oro Grande.
Jun & Jul	1989	07/25/89	Color Infrared	WILD 15 / 4 UAG Nr 13040 152.67	13-10 (9568);	Phil Richards, URS Corporation	Very narrow channel. Flow exists and extends beyond 33,000 feet, the limit of the photograph. Photographs do not extend to Bryman
Jun & Jul	1989	07/25/89	Black & White	WILD 15 / 4 UAG Nr 13040 152.67	11-2, 10-2, & 9-5	Phil Richards, URS Corporation	Many photographs with different dates. Fair to Poor quality. 7/25/89 used from Lower Narrows flow and 7/15//89 used for VVWRA plant flow.
Jun & Jul	1989	07/15/89	Black & White	WILD 15 / 4 UAG Nr 13040 152.67	9-4 & 9-5	Phil Richards, URS Corporation	Many photographs with different dates. Fair to Poor quality. 7/25/89 used from Lower Narrows flow and 7/15//89 used for VVWRA plant flow.
Jun & Jul	1989	07/15/89	Color Infrared	WILD 15 / 4 UAG Nr 13040 152.67	9-4 to 9-5; 10-1 to 10-2; 11-1 to 11-2	Phil Richards, URS Corporation	Northern part of site, north of treatment plant in view. Lower Narrows not covered by photographs
Jun & Jul	1991	06/21/91	Color Infrared	WILD 15/4 UAG Nr. 13040 152.67	4685-4685; 4693; 4659; 4654; 4710 (11-2)	Phil Richards, URS Corporation	Good photos, flow is clearly visible
Apr	1992	04/03/92	Color Infrared	Mojave River	17 to 24	Phil Richards, URS Corporation	Clearly large surface flow in this photo. Channel becomes braided and very spread out between 20,000 to 30,000 feet near treatment plant where the vegetation is dense. Flow in channel gets very wide in main channel at 43,000 feet. Flow extends well beyond the Transition Zone.

TABLE F-1

AERIAL PHOTOGRAPHS REVIEWED

Aerial Photograph							
MONTH	**YEAR**	**Photo Date**	**Photo Type**	**Photograph Series**	**Photograph Number**	**Photo Interpreted By**	**Comments**
Jun & Jul	1993	09/23/93	Color Infrared	MWA; Wild 15/4 UAG Nr.13013 153.64	11-6; 10-3; 9-3; 8A-10 to 8A-11	Phil Richards, URS Corporation	Good photos, flow is clearly visible
Jun & Jul	1993	09/16/93	Color Infrared	MWA; Wild 15/4 UAG Nr.13013 153.64	12-13;	Phil Richards, URS Corporation	Not reviewed because better photographs were available for the same month (see 9/23/93).
Jul	1995	07/06/95	Color Infrared	MWA 95-947 WILD 15 / 4 UAG Nr.13013 153.64	12-14 (2011); 9-2 (2047)	Phil Richards, URS Corporation	Good photos, flow is clearly visible; only noted photos where the flow stops; however, all photos were reviewed
Jul & Sept	1996	07/08/96	Color Infrared	WILD 15 / 4 UAGA-F Nr 13157 153.08	12-12&13; 11-5&6;10-6; 9-2;	Phil Richards, URS Corporation	Fair photo, flow is very channelized
Jun	1997	07/01/97	Color Infrared	MWA 97-0768 WILD 15 / 4 UAG Nr.13013 153.64	12-13&14; 11-6; 10-6;	Phil Richards, URS Corporation	6/28/97 depicts the central and northern portion, 7/1/97 photographs used for the Lower Narrows and 6/28/97 photographs used for VVWRA
Jun	1997	06/28/97	Color Infrared	MWA 97-0768 WILD 15 / 4 UAG Nr.13013 153.64	12-13&14; 11-6; 10-6;	Phil Richards, URS Corporation	6/28/97 depicts the central and northern portion, 7/1/97 photographs used for the Lower Narrows and 6/28/97 photographs used for VVWRA
Jun	1998	06/27/98	Color Infrared	WILD 15/4 UAGA-F Nr.13157 153.08	12-13; 11-6; 10-6; 9-2 & 9-1	Phil Richards, URS Corporation	None
Jun	1999	06/16/99	Color Infrared	WILD 15/ 4 UAGA-F Nr 13157 153.08	12-13; 11-6; 9-2; 8A-5	Phil Richards, URS Corporation	Used 6/16/99 for Lower Narrows and 6/17/99 for VVWRA plant
Jun	1999	06/17/99	Color Infrared	WILD 15/ 4 UAGA-F Nr 13157 153.08	12-13; 11-6; 9-2; 8A-5	Phil Richards, URS Corporation	Used 6/16/99 for Lower Narrows and 6/17/99 for VVWRA plant
Jun	2000	06/19/00	Color Infrared	WILD 15 / 4 UAGA-F Nr 13157 153.08	12-3; 11-6; 10-6; 9-2; 8A-5	Phil Richards, URS Corporation	very good photo, flow is extremely channelized in narrow channels
Jun	2001	06/05/01	Color Infrared	WILD 15 / 4 UAGA-F Nr 13157 153.08	12-13 & 14; 11-6; 10-6; 9-2; 8A-5	Phil Richards, URS Corporation	very good photo, flow is extremely channelized in narrow channels
Jun & Jul	2002	07/19/02	Color Infrared	WILD 15 / 4 UAG-S No 13367 153.19	12-13&14; 11-6; 10-6; 9-2; 8A-5	Phil Richards, URS Corporation	very good photo, flow is extremely channelized in narrow channels

TABLE F-2

FLOW RATES AND FLOW LENGHTS

		Flow Rates Lower Narrows				VVWRA Treatment Plant Discharge			Flow Length Past Lower Narrows (feet)		
Photo Date	**Photo Type**	**Same Day Average Flow Rate (cfs)**	**7 Day Previous Average Flow Rate (cfs)**	**30 Day Previous Average Flow Rate (cfs)**	**Significantly Different Flow in past 30 Days**	**VVWRA Discharge AF/WY**	**VVWRA Avg. Flow 1 day (cfs)**	**Same day Total MR LN and VVWRA**	**From Flow Past Lower Narrows Gage, Alone**	**From Flow From VVWRA, Alone**	**From Flow Past The Lower Narrows And from VVWRA, Combined**
08/22/69	Black & White	29.0	29.0	30.4	No	0	0.0	29.0	41,200		
06/15/71	Black & White	32.0	28.6	22.4	6/10/71, 38 cfs	0	0.0	32.0	57,500		
06/29/72	Black & White	15.0	15.0	14.5	6/7/72, 23 cfs	0	0.0	15.0	20,000		
07/19/73	Black & White	9.0	9.0	11.8	No	0	0.0		5,400		
07/14/77	Black & White	21.0	23.5	23.6	No	0	0.0	21.0	33,000		
08/22/78	Black & White	15.0	15.1	15.9	No	0	0.0		14,000		
09/27/81	Black & White	18.0	17.3	17.1	No	266	0.4		8,000		
10/20/83	Black & White	31.0	33.6	31.2	10/1/83, 53 cfs	3,543	4.9	35.9	59,500		
01/29/84	Black & White	49.0	49.9	48.7	Large Discharges 31-34 days prior. 90-737 cfs	3,543	4.9	53.9	> 92,000		
05/20/85	Color Infrared	23.0	21.9	24.0	No	3,915	5.4	28.4	87,000		
05/21/85	Black & White	23.0	22.0	24.0	No	3,915	5.4	28.4	62,200		
08/10/87	Color Infrared	7.6	8.3	9.1	No	4,601	6.4		4,000	36,800	
08/10/87	Black & White	7.6	8.3	9.1	No	4,601	6.4		4,000	36,800	
06/27/89	Color Infrared	4.3	4.7	6.2	No	6,330	8.7		3,200		
07/15/89	Black & White	3.0	3.1	4.1	No	6,330	8.7			39,000	
07/15/89	Color Infrared	3.0	3.1	4.1	No	6,330	8.7			39,800	
07/25/89	Color Infrared	3.0	3.0	3.4	No	6,330	8.7		2,500		
07/25/89	Black & White	3.0	3.0	3.4	No	6,330	8.7		2,200		
06/21/91	Color Infrared	8.5	8.6	11.1	No	7,387	10.2		6,100	46,000	
04/03/92	Color Infrared	174.0	352.3	182.3	13 days prior, Q > 100 cfs with peak at 657 cfs	7,331	10.1	184.1			> 92,000
09/16/93	Color Infrared	3.7	3.5	5.0	No	7,753	10.7				

TABLE F-2

FLOW RATES AND FLOW LENGHTS

		Flow Rates Lower Narrows				VVWRA Treatment Plant Discharge			Flow Length Past Lower Narrows (feet)		
Photo Date	Photo Type	Same Day Average Flow Rate (cfs)	7 Day Previous Average Flow Rate (cfs)	30 Day Previous Average Flow Rate (cfs)	Significantly Different Flow in past 30 Days	VVWRA Discharge AF/WY	VVWRA Avg. Flow 1 day (cfs)	Same day Total MR LN and VVWRA	From Flow Past Lower Narrows Gage, Alone	From Flow From VVWRA, Alone	From Flow Past The Lower Narrows And from VVWRA, Combined
09/23/93	Color Infrared	3.7	6.0	4.6	No	7,331	10.1		17,000	57,500	
07/06/95	Color Infrared	6.8	7.1	8.5	No	7,949	11.0		4,000	51,000	
07/08/96	Color Infrared	2.2	2.7	3.8	No	8,475	11.7		2,200	43,700	
06/28/97	Color Infrared	2.4	2.7	3.9	No	8,705	12.0			45,650	
07/01/97	Color Infrared	2.3	2.5	3.6	No	8,705	12.0		2,200		
06/27/98	Color Infrared	2.5	2.8	4.0	No	9,353	12.9		14,300	60,400	
06/16/99	Color Infrared	6.9	8.3	10.0	No	8,744	12.1		4,900		
06/17/99	Color Infrared	6.2	8.1	9.8	No	8,744	12.1			48,800	
06/19/00	Color Infrared	2.1	2.6	3.9	No	9,006	12.4		5,300	49,000	
06/05/01	Color Infrared	2.0	2.6	3.5	No	9,286	12.8		6,200	51,700	
07/19/02	Color Infrared	Data Not Yet Posted by USGS							5,900	45,650	

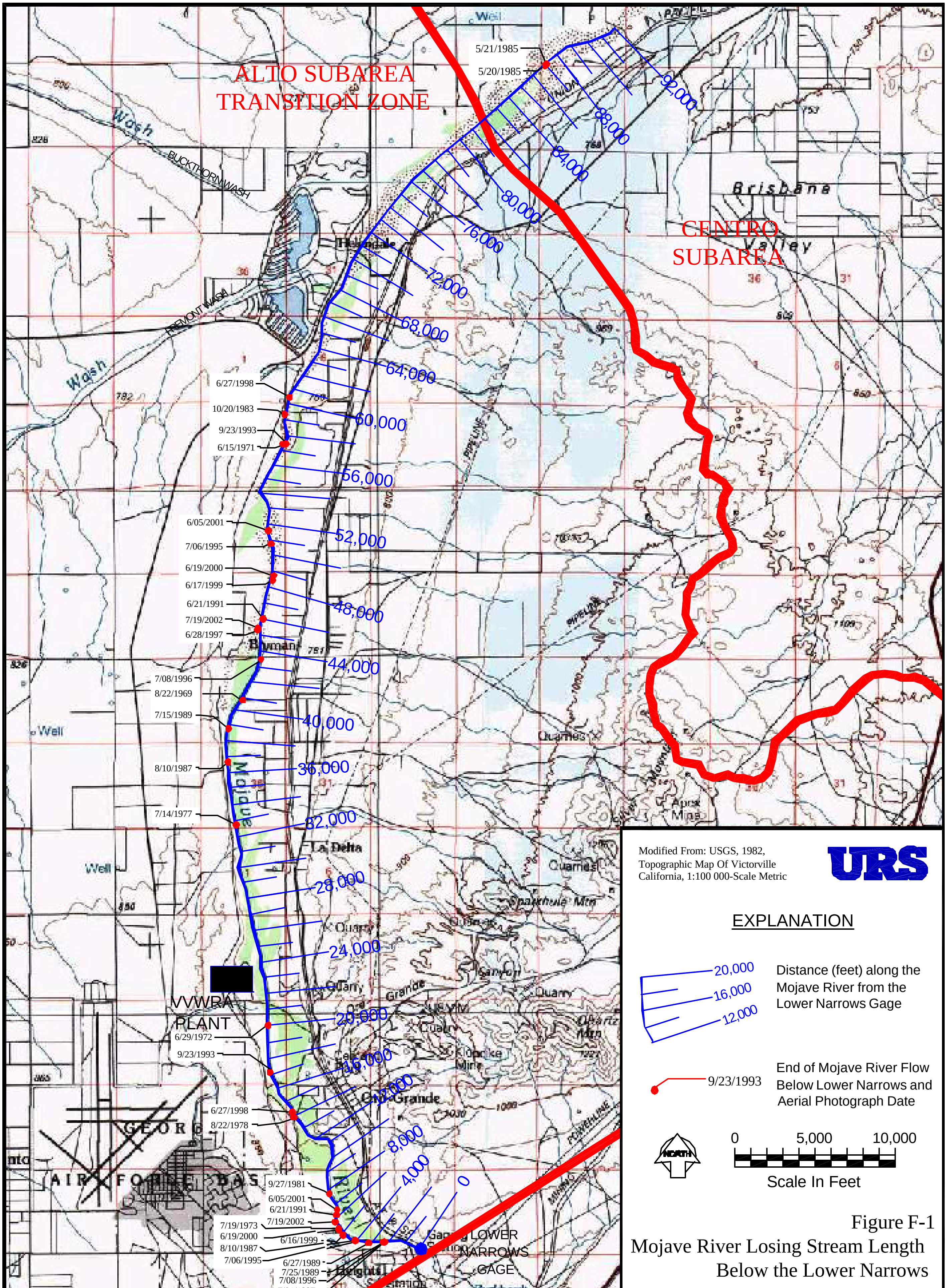

Figure F-1
Mojave River Losing Stream Length
Below the Lower Narrows

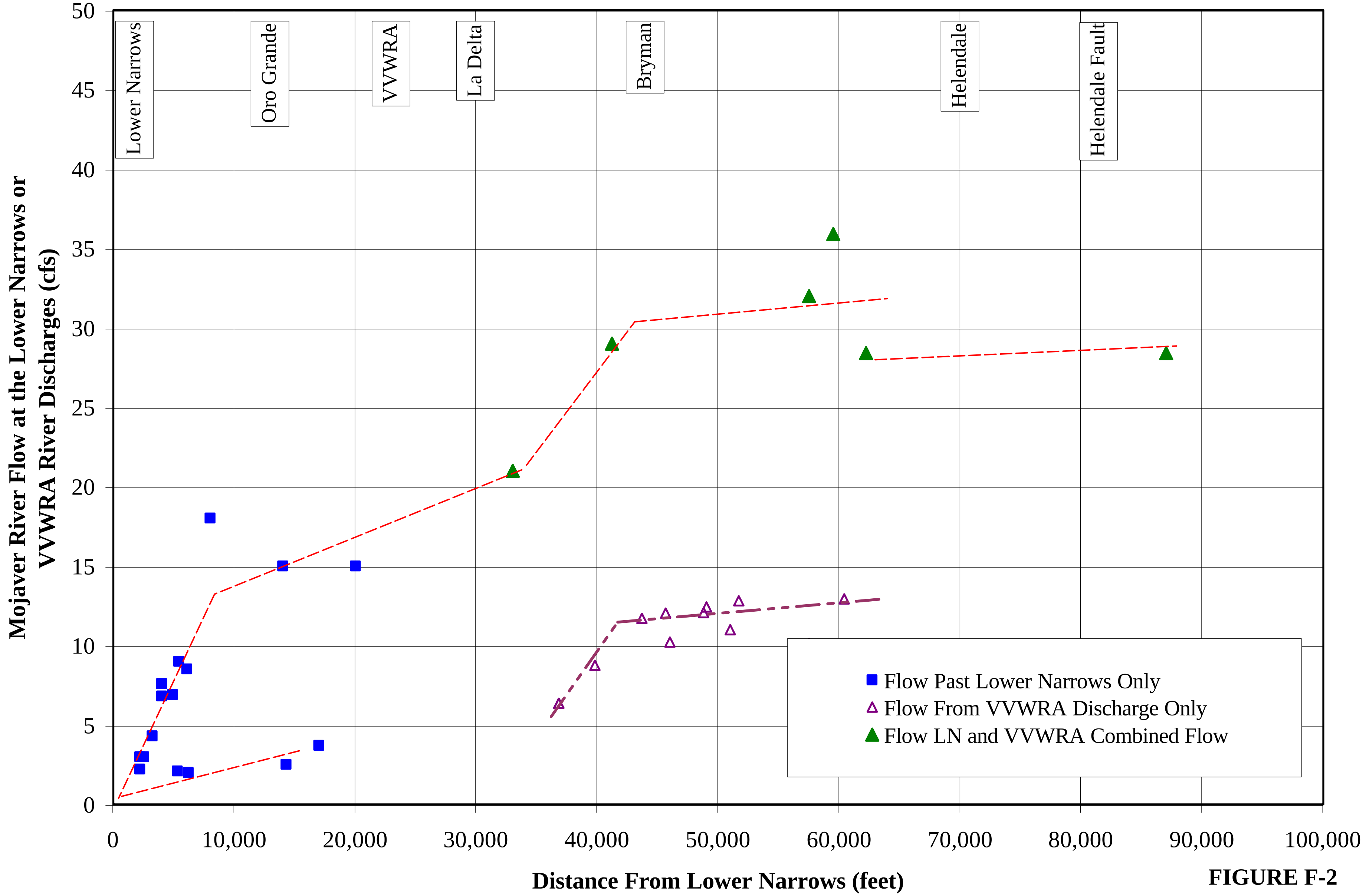

FIGURE F-2
FLOW LENGTH VS FLOW RATE
WITHIN THE TRANSITION ZONE

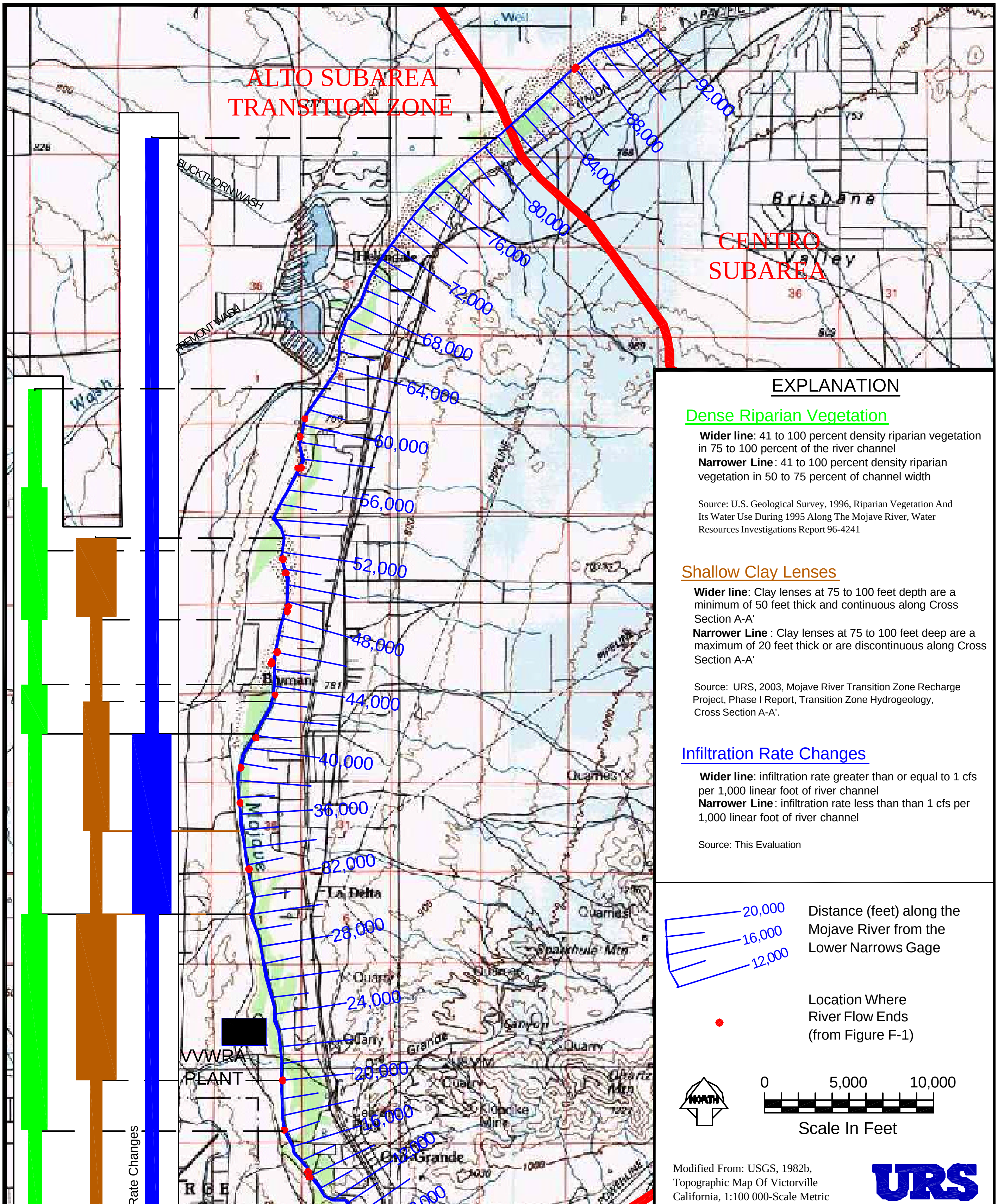

Figure F-3
Occurrence of Infiltration Rate Variations, Shallow Clay Lenses, and Dense Riparian Vegetation Along the Mojave River

APPENDIX F-2

REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER ABOVE THE LOWER NARROWS TO EVALUATE GAINING STREAM LENGTH VERSUS FLOW RATE

APPENDIX F-2
REVIEW OF AERIAL PHOTOGRAPHS OF THE MOJAVE RIVER ABOVE THE LOWER NARROWS TO EVALUATE GAINING STREAM LENGTH VERSUS FLOW RATE

The Mojave River is largely an intermittent stream, but flows perennially in the upper Alto Subarea between the Upper and Lower Narrows and upstream of the Upper Narrows where groundwater rises to form surface water. Aerial photographs of the Mojave River and flow data from Lower Narrows stream gage were reviewed to evaluate if a relationship exists between gaged flow and the length of gaining stream above the Lower Narrows. A relationship between base flow rate and length of gaining stream could be used as a water management tool to evaluate Alto Subarea overdraft recovery and to predict annual base flow.

Mojave River base flow upstream of the Lower and Upper Narrows originates largely as rising groundwater from the upper Alto Subarea. The Mojave River gains water as the northerly flowing groundwater in the upper Alto Subarea rises as the groundwater basin shallows near the Upper Narrows. Base flow can vary based on local water level elevations and direct discharges to the river. Figure F-4 is a map of the Mojave River in the upper Alto Subarea between the Lower Narrows and Bear Valley Road. Points shown on Figure F-4 are the locations where river flows were observed to begin directly up stream of the Lower Narrows. The river centerline is also show on Figure F-4 with distance labels in feet along the river centerline from the Lower Narrows. The Lower Narrows is used as the origin as it is the point where flows are measured.

Further to the south, flow in the Mojave River can originates from storm runoff on the north-facing slopes of the San Bernardino Mountains. Near the base of the mountains south of Hesperia, the river flows are impounded at Silverwood Lake. Approximately 6 miles downstream of Silverwood Lake, the Mojave River passes through the unregulated Mojave River flood control dam and normally dry reservoir. From the Mojave Dam, the river channel leaves the mountains turning northward across broad alluvial deposits west of Hesperia and on towards Victorville. South of Victorville, two fish hatcheries have historically discharged water to the Mojave River. Fish hatchery discharges were observable on several aerial photographs, but infiltrated prior to reaching flows originating from rising groundwater directly upstream of the Upper Narrows.

River flows attributed to rising groundwater were generally observed between Bear Valley Road and the Mojave Narrows Regional Park.

Collection of Flow Length and Flow Rate Data

To conduct the evaluation, historical annual aerial photographs were reviewed to estimate the lengths were surface flows occurred along the Mojave River between the Mojave River Dam and the Lower Narrows. The photographs reviewed were made available by Mojave Water Agency and are listed in Table F-3. For each year, several flow areas were observed in the river typically originated from either the Mojave River Dam, from near the fish hatcheries, or from directly up stream of the Upper Narrows. The lengths of all observed flows were measured to the nearest 100 feet using the scale shown on Figure F-3 along the Mojave River channel. Although only the flows immediately up stream of the Upper Narrows are evaluated, all observed flows are listed in Table F-4. The locations were measured along the centerline of the Mojave River as shown on the USGS topographic map[1] reproduced in part on Figure F-4. Only the locations where surface flows appear directly up stream of the Upper Narrows are shown as points on Figure F-4. The evaluation assumes measured flow rates have reached equilibrium with measured flow lengths.

Historical flow rates were obtained from stream gage data recorded at the Lower Narrows gage operated by USGS[2]. Average daily flow rates in cubic feet per second (cfs) were compiled for the date of the photograph and for the seven days prior to the photograph date. The flow rate data are listed in Table F-4 for each photograph. Table F-4 also notes if flows differing from that on the photograph date by as much as 50 percent in the 30 days prior to the photograph date. For comparison, Table F-4 also contains the annual base flow determined by the Mojave River Watermaster for the water year encompassing the date of each photograph. Base flow for each water year is reduced to a 365-day average flow in cfs.

Flow rates are graphed versus flow lengths on Figure F-5. Only the flows rates measured on the day of the aerial photograph are graphed, as the daily flow averaged over the previous seven days were nearly identical and do not add significantly to the evaluation.

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[1] U.S. Geological Survey, 1982, Topographic Map Of Victorville California, 1:100 000-Scale Metric.

[2] U.S. Geological Survey Steam Gage Data for Station Number 10261500

Only the 1992 photograph showed continuous storm flow from the Mojave River dam to the Lower Narrows and is not represented on Figure F-5. When flow from a fish hatchery was observed on a photograph, a length of dry channel was always observed between it and flow directly up stream of the Upper Narrows. The locations of streets and geographic reference points are shown along the top of Figure F-4.

Relationships of Flow Rate and Flow Length

Comparison of stream flow rates and flow lengths shows that Mojave River flows originating directly up stream of the Upper Narrows surface water follow a mathematical relationship. The best-fit relationship, shown as a dashed line on Figure F-4, is a curved line matching the equation:

A) Flow (cfs-day) = Distance (feet)$^{6.748}$ x 1.547×10^{-30}

The equation has a statistical fit of R-squared = 0.80. R-squares is a statistical indicator which compares the accuracy of the model wherein a perfect fit would result in an R squared of 1, a very good fit near 1, and a very poor fit near 0.

For water management, this equation can be used to predict base flow from an observed point were river flow begins. Conversely, the equation can be used with a desired base flow to estimate the location of where groundwater should rise to obtain the desired base flow. The inverse of equation A can be used to predict distance with a given flow value. The inverse of equation A is:

B) Distance(feet) = Flow (cfs-day)$^{0.1482}$ x 26,150

Predicted base flows and distances to flow origin are contained in Table F-5 for both equation A and equation B. It should be noted that the annual (365-day average) base flow corresponding to the water year in which each photograph was taken is generally greater than base flow measured on the day the photograph was taken. This is likely because most of the photographs were taken during summer months when base flows are expected to be near the lowest values of the year. This should have no impact on the mathematical relationship, as base flows are dependant predominately on water levels, which are in turn dependant largely on seasonal groundwater pumping.

Summary

Review of the historical aerial photographs indicates base flow follows a curved mathematical relationship in the gaining stream portion of Mojave River up stream of the Upper Narrows. The relationship can be used as a groundwater management tool to monitor recovery of over draft in the upper Alto subarea. The relationship can be used to gage over draft recovery by noting where surface water flows originates directly up stream of the Upper Narrows compared to the location required to match a desired base flow goal.

In an example of how the relationship can be used, the Judgment After Trial[3] established an initial subsurface flow obligation of 2,000 acre-feet per year (AFY), and a base flow obligation of 21,000 AFY from the Alto Subarea to the Centro Subarea. From table F-5, a base flow of 21,000 AFY corresponds with an average daily base flow of 29 cfs and a length of gaining stream (or point of flow origin) starting at approximately 43,100 feet up stream of the Lower Narrows. In another example, with a hypothetical discharge of 9,500 AFY from VVWRA in the Transition Zone counted towards the Alto Subarea obligation, a base flow of 11,500 AFY (21,000 AFY minus 9,500 AFY) corresponds in Table F-5 with a an average base flow of 15.6 cfs and a point of flow origin at approximately 39,400 feet up stream of the Lower Narrows.

Review of the historical aerial photographs indicated fish hatchery discharges near Bear Valley Road infiltrate prior to reaching flows originating from rising groundwater directly upstream of the Upper Narrows. This indicates that during summer months, fish hatchery discharge rates do not have a contemporary or equivalent impact on base flow measurements.

[3] Riverside County Superior Court, 1996, Judgment After Trial, Mojave Basin Area Adjudication, City of Barstow et al. V. City of Adelanto et al. Riverside Superior Court Case no. 208568.

TABLE F-3

AERIAL PHOTOGRAPHS REVIEWED
MOJAVE RIVER ABOVE THE LOWER NARROWS

MONTH	YEAR	Photo Date	Photo Type	Photograph Series	Photograph Numbers	Photo Interpreted By	Flow Length Above Lower Narrows (feet)	Comments (All photographs were reviewed starting with the year 2002 and then back to 1969. Comment terminology is also developed in that order.)
Aug	1969	08/22/69	Black & White	2653	9 (Dam to Hesperia golf course); 10-11 (Hesperia Golf to Spring Valley Lake area [not developed in this photo); 11-12 (Spring Valley Lake are to Upper Narrows); 3&11 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 88,000 (blue and gray); 42,300 to 0 (blue and gray)	See 1981-82 comments.
Jun	1971	06/15/71	Black & White	2920	9 (Dam to Hesperia golf course); 10-11 (Hesperia Golf to Spring Valley Lake); 11-12 (Spring Valley Lake to Upper Narrows); 3&11 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 72,900 (blue); 47,500 to 36,000 (blue [narrow channel flow with flow clearly coming from six adjacent ponds]); 34,000 to 0 (blue-gray)	Flow likely is continuous from 47,500 to 0, but I could not see channel well from photo quality. The entire length of flow is a very narrow flow.
Jun	1972	06/29/72	Black & White	None Provided	9 (Dam to Hesperia golf course); 10-11 (Hesperia Golf to Spring Valley Lake); 11-12 (Spring Valley Lake to Upper Narrows); 3&11 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 89,000 (blue); 36,000 to 0 (blue and gray)	See 1981-82 comments.
Jul	1973	07/19/73	Black & White	3358	9 (Dam to Hesperia golf course); 10 (Hesperia Golf to Spring Valley Lake); 11-12(Spring Valley Lake to Upper Narrows); 3 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 89,000 (blue); 36,000 to 0 (blue and gray)	See 1981-82 comments.
Jul	1977	07/14/77	Black & White	2920	9 (Dam to Hesperia golf course); 10 (Hesperia Golf to just south of Spring Valley Lake); 11-12(Spring Valley Lake to Upper Narrows); 3&12 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 89,000 (blue); 89,000 to 72,500 (gray); 42,000 to 0 (starting from left side of bank with runofff flow into wash)	See 1981-82 comments.
Aug	1978	08/22/78	Color Infrared	UAgII 3052 153.19	1-11,2-1 to 2-6, (Dam to Hesperia golf course); 2-6 to 2-13 (Hesperia Golf to Spring Valley Lake); 3-1 to 3-9 (Spring Valley Lake to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 86,000(blue); 86,000 to 83,000(gray);47,000 to 45,100 Blue runoff from pond; 42,000 to 0; starting from left side of bank with runofff flow into wash. Looks like its coming from a treatment plant.	See comment for 2002. Great quality photo. By far the best photos of the wash. The stretch from 42,000 to Lower Narrows is consistently braided in all photos. The blue often blurs into gray with tiny veins of blue within gray. Photos often show reflection of sun off surface water for positive identification.
Aug	1981 & 1982 various	1/26/82(9, 10, 11); 9/27/81(3)	Black & White	2185-1	9 (Dam to Hesperia Lake); 10 (Hesperia golf course to Trout Farm south of Bear Valley Road); 11(Trout Farm to Upper Narrows); 3 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 85,000 (blue); 34,000 to 0 (blue and gray)	Black and White Photo so "blue" means what I think is surface water. Quality of photo is not as good as others, but I can clearly see "gray" areas and "Blue" lines, but in some areas of "blue" are braided with "gray".
Oct	1983	10/20/83	Black & White	UAGI 6069 152.00	Not applicable	Phil Richards, URS Corporation	Not applicable	Not provided, therefore not reviewed.
Jan	1984	01/29/84	Black & White	None Provided	Not applicable	Phil Richards, URS Corporation	Not applicable	Not provided, therefore not reviewed.
May & Jun	1985	5/19/85(18);5/20/85(17,16,15,14,	Color Infrared	UAgII 3090 153.23	18-3 (Dam); 17-3 (Hesperia Lake); 16-10 (Hesperia golf course to Trout Farm south of Bear Valley Road); 15-10 (Trout Farm to Spring Valley Lake); 14-11 (Spring Valley Lake to Upper Narrows); 13-10 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 82,000 (blue); 37,000 to 0 (blue)	See comment of 2002. Great quality photo. Some exposure bleaching out of photo 13-10 so can't see "blue" through entire length. "Blue" is visible from the point of bleaching near the cement factory north of I-15 so I think flow is continuous.
May & Jun	1985	05/21/85	Black & White	UAgII 3090 153.23	Not applicable	Phil Richards, URS Corporation	Not applicable	Not provided, therefore not reviewed

TABLE F-3

AERIAL PHOTOGRAPHS REVIEWED
MOJAVE RIVER ABOVE THE LOWER NARROWS

MONTH	YEAR	Photo Date	Photo Type	Photograph Series	Photograph Numbers	Photo Interpreted By	Flow Length Above Lower Narrows (feet)	Comments (All photographs were reviewed starting with the year 2002 and then back to 1969. Comment terminology is also developed in that order.)
June & Aug	1987& 1988	6/29/88(18-17); 8/10/87(15,14,13)	Color Infrared	MWA	18-3 (Dam); 17-2&3 (Hesperia Lake); 16-9&10 (Hesperia golf course to Trout Farm south of Bear Valley Road); 15-10 (Trout Farm to Spring Valley Lake); 14-11(Spring Valley Lake to Upper Narrows - Photo 14-10 missing); 13-10 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 92,200 (Welsh Road) (blue); 92,200 to 69,000 (narrow to meandering gray -See 2002 comment about gray): 36,000 to 0 (blue)	See comment for year 2002. Great quality photo.
May	1989	05/25/89	Color Infrared	BLM	Not applicable	Phil Richards, URS Corporation	Not applicable	No coverage in river area
Jun & Jul	1989	6/27/89; 7/25/89; 6/7/89	Black & White	WILD 15 / 4 UAG Nr 13040 152.67	Not applicable	Phil Richards, URS Corporation	Not applicable	Not great quality so did not spend time reviewing these photos. Instead please see 1989 color for description of wash that year.
June	1989	6/7/89(18-16); 6/27/89(15-14); 7/25/89(13)	Color Infrared	WILD 15 / 4 UAG Nr 13040 152.67	18-3 (Dam); 17-2&3 (Hesperia Lake); 16-9&10 (Hesperia golf course to Trout Farm south of Bear Valley Road); 15-10 (Trout Farm to Spring Valley Lake); 14-10 (Spring Valley Lake to Upper Narrows); 13-10 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 92,000 (Welsh Road) (blue); 34,000 to 0 (blue)	See comment of 2002. Great quality photo. Water observed at 34,000 gets very narrow in places. The flow appears continuous, but may be intermittent between the Upper and Lower Narrows in 7/25/89 photo.
June	1991	6/20/91(18-14); 6/21/91(13)	Color Infrared	WILD 15/4 UAG Nr. 13040 152.67	18-3 (Dam); 17-2&3 (Hesperia Lake); 16-9&10 (Hesperia golf course to Trout Farm south of Bear Valley Road); 15-10 (Trout Farm to Spring Valley Lake); 14-10 (Spring Valley Lake to Upper Narrows); 13-10 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 78,200 (blue); 52,000 to 41,000 (very narrow blue from ponds); 26,100 to 0 (blue to narrow and braided blue)	See comment of 2002. Great quality photo. Jess Ranch Golf Club was not built. That site is an agricultural area. A series of increasingly narrow (north to south) ponds are located on east bank of wash (53,000 to 57,000), then at 52,000 "blue" flow coming off ponds.
Apr	1992	04/03/92	Color Infrared	Mojave River	6 (Dam); 7(Hesperia Lake); 10 (Hesperia to Jess Ranch Golf courses); 13 (Jess Ranch golf to Spring Valley Lake); 15-16 (Spring Valley Lake to Upper Narrows);16-17 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 0 (water)	See comment of 2002. Great quality photo. Photos clearly depict major flow along entire river from the Mojave Dam to the Lower Narrows. For all comments "blue" and "water" are used interchangeably. Jess Ranch Golf Course is under construction.
June	1993	6/28/93(17); 616/93(15,16, 13,12); 6/23/93(14);	Color Infrared	MWA; Wild 15/4 UAG Nr.13013 153.64	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 14-12 (Jess Ranch golf to Spring Valley Lake); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 68,100 (blue); small short flow from right bank 49,000 to 48,500 and 47,000 to 45,100 (blue); flow starting from left bank at 42,000 to 0 (blue)	See comment of 2002. Great quality photo.
Jul	1995	7/12/95(17-16); 7/6/95(15-12)	Color Infrared	MWA 95-947 WILD 15 / 4 UAG Nr.13013 153.64	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 14-12 (Jess Ranch golf to Spring Valley Lake); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 82,000 (blue); 69,200 to 68,000 (blue); 38,800 to 14,200 (intermittent blue); 12,200 to 0 (blue)	See comment of 2002. Great quality photo. Flow at 68,000 is clearly coming from the right bank, then dies out around Rock Springs Road. The flow at 38,800 to 14,200 is intermittent. It should be commented that the water in the wash for every year is always wider and more apparent at 27,000.
July	1996	7/8/96(17-12)	Color Infrared	WILD 15 / 4 UAGA-F Nr 13157 153.08	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 14-12 (Jess Ranch golf to Spring Valley Lake); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to about Welsh Road (92,200) (blue); 30,000 to 14,200 (blue); 11,000 to 0(blue)	See comment of 2002. Great quality photo.
July	1997	7/2/97(17-14); 7/1/97(	Color Infrared	MWA 97-0768 WILD 15 / 4 UAG Nr.13013 153.64	17-19 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 14-12 (Jess Ranch golf to Spring Valley Lake); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	30,000 to 0 (water)	See comment of 2002. Great quality photo. Between 21,000 and 25,000 and again between 12,000 and 15,000 the observable blue (water) becomes very narrow, but still visible. During review of the 1997 photos, I noticed a photo number 14-12 for the first time. I did not document a 14 photo series for 1998 to 2002. Because these have already been refiled, I could not check if the 14 series occurs for those years.
Jun	1998	6/26/98(17); 6/29/98(16); 6/27/98(15-12)	Color Infrared	WILD 15/4 UAGA-F Nr.13157 153.08	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 71,000 with 6/29/98 photo (water) or Dam to 69,100 with 6/27/98 photo; 39,000 to 41,600 gray; 37,700 to 0 (water)	See comment of 2002. Great quality photo.

TABLE F-3

AERIAL PHOTOGRAPHS REVIEWED
MOJAVE RIVER ABOVE THE LOWER NARROWS

MONTH	YEAR	Photo Date	Photo Type	Photograph Series	Photograph Numbers	Photo Interpreted By	Flow Length Above Lower Narrows (feet)	Comments (All photographs were reviewed starting with the year 2002 and then back to 1969. Comment terminology is also developed in that order.)
Jun	1999	6/22/99(17); 6/19/99(16);6/16/99(15-12)	Color Infrared	WILD 15/ 4 UAGA-F Nr 13157 153.08	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 90,200 (Havenhurst Road) (water); Havenhurst Road to 85,500 (gray); 30,000 to 0 (water)	See comment of 2002. Great quality photo.
Jun	2000	6/28/00(17-14); 6/19/00(13-12)	Color Infrared	WILD 15 / 4 UAGA-F Nr 13157 153.08	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 90,200 (just above Havenhurst Road) (water); 30,000 to 0 (water)	See comment of 2002. Great quality photo. No gray discussed because wash, including channel area, appeared very dry and lacked the characteristics depicted in the years 2002 and 2001.
Jun	2001	6/6/01(17-13); 6/5/01(12)	Color Infrared	WILD 15 / 4 UAGA-F Nr 13157 153.08	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam to 90,200 (Havenhurst Road) (water); Havenhurst Road to 37,000 (gray - see comments); 30,000 to 15,700 (blue); 11,000 to 0 (water)	See comment of 2002. Great quality photo. As with 2002, gray braided area in they wash meets Rock Springs Road where the wash has an earthen channel. The "gray" seen up stream becomes less distinct in the channel, but is still present (intermittent?). I will indicate when this channel is "all gray", "not gray", or "intermittent gray". In this photo, the channel starts off before Rock Springs Road (68,000) as very gray then fades slightly, and then more gray before Lemon Street (57,000). The gray color then fades again, narrows, and becomes intermittent from south of Bear Valley Road to Spring Valley Lake (49,000 to 37,000).
Jun & Jul	2002	8/2/02(17,16); 7/30/02(15-13); 7/19/02(12)	Color Infrared	WILD 15 / 4 UAG-S No 13367 153.19	17-18 (Dam); 16-18 (Hesperia Lake); 15-12 (Hesperia to Jess Ranch Golf courses); 13-12&13 (Spring Valley Lake to Upper Narrows); 12-13 (I-15 to Lower Narrows)	Phil Richards, URS Corporation	Mojave River Dam (95,600) to 79,500 (gray), 77,200 to 67,000 (gray); 58,500 to 37,000 (gray); 30,000 to 15,700 water (certain blue seen only 24,000 to 15,700, above that was shadows); 11,000 to 0 (blue)	To start the review, I looked at the river stretch from the Mojave River Dam to Lower Narrows for years 1993 (an El Nino year), 1999, 2000, 2001, and 2002. The trend I can see is that there are two types of evidences of surface flow. 1) dark blue (on the infra red photos) indicating surface flow and 2) dark gray areas in the wash indicating recent flow, wet soil, and/or very shallow flow. Dark blue areas are very obvious and less subjective, but gray areas are somewhat more subjective. The gray areas vary from year to year and may represent recent surface flow. The gray areas are also somewhat intermittent. Some infra red photos are too dark so that dark areas or shadows can be mistaken for water. I will therefore indicate which photos are of a good enough quality to indicate surface conditions. For this year, photo 13-12 is too dark.

TABLE F-4

FLOW RATES AND FLOW LENGTHS
MOJAVE RIVER ABOVE THE LOWER NARROWS

			Short Term Flow Rates Lower Narrows				Flow Rates for The Water Year						
Photo Date	Photo Year	Photo Type	Same Day Average Flow Rate (cfs)	7 Day Previous Average Flow Rate (cfs)	30 Day Previous Average Flow Rate (cfs)	First Flow Differing by 50% in past 30 Days	Water Year (ending)	Base Flow (AFY)	Base Flow 365-day average (cfs-day)	Storm Flow (AFY)	Flow Length Below Mojave Dam (feet)	Flow From Fish Hatcheries (feet)	Flow Length Above Lower Narrows (feet)
08/22/69	1969	Black & White	29.0	29.0	30.4	None	1969	23,745	33	267,385	7,600	None	42,300
06/15/71	1971	Black & White	32.0	28.6	22.4	None	1971	20,437	28	0	22,700	11,500	34,000
06/29/72	1972	Black & White	15.0	15.0	14.5	23 cfs on 6/7/72	1972	15,943	22	6,861	6,600	None	36,000
07/19/73	1973	Black & White	9.0	9.0	11.8	None	1973	18,095	25	16,619	6,600	None	36,000
07/14/77	1977	Black & White	21.0	23.5	23.6	None	1977	27,546	38	664	6,600	None	42,000
08/22/78	1978	Color Infrared	16.0	15.4	15.9	None	1978	21,509	30	187,615	9,600	1,900	42,000
01/26/82	1981 & 1982 various	Black & White	56.0	37.9	40.2	Low of 32 cfs 1/3/82	1982	20,421	28	14,929	10,600	None	34,000
	1983	Black & White											
	1984	Black & White											
05/20/85	1985	Color Infrared	23.0	21.9	24.0	None	1985	20,161	28	895	13,600	None	37,000
	1985	Black & White											
08/10/87	1987& 1988	Color Infrared	7.6	8.3	9.1	None	1987	14,191	20	277	3,400	None	36,000
	1989	Color Infrared											
	1989	Black & White											
06/27/89	1989	Color Infrared	4.3	4.6	6.1	6.6 cfs of 6/8/89	1989	11,487	16	0	3,400	None	34,000
06/20/91	1991	Color Infrared	8.5	8.7	10.0	12.0 cfs on 6/2/91	1991	9,023	12	1,937	17,400	11,000	26,100
04/03/92	1992	Color Infrared	174.0	352.3	182.3	691 cfs on 3/26/92	1992	8,635	12	15,925	95,600	Continuous	95,600
06/28/93	1993	Color Infrared	34.0	43.4	39.0	53 cfs on 6/24/93	1993	9,707	13	275,693	27,500	3,900	42,000
07/06/95	1995	Color Infrared	6.8	7.1	8.5	11 cfs on 6/6/1995	1995	7,472	10	105,807	13,600	24,600	38,800
07/08/96	1996	Color Infrared	2.2	2.7	3.8	3.5 cfs of 6/28/97	1996	6,552	9	4,630	3,400	15,800	30,000
07/01/97	1997	Color Infrared	2.3	2.5	3.6	3.5 cfs on 6/18/97	1997	6,619	9	1,592	None	None	30,000
06/29/98	1998	Color Infrared	13.0	13.9	25.0	21 cfs on 6/9/98	1998	10,162	14	73,355	24,600	None	37,700
06/16/99	1999	Color Infrared	6.9	8.3	10.0	12 cfs on 6/5/99	1999	8,970	12	328	5,400	None	30,000
06/19/00	2000	Color Infrared	2.1	2.6	3.9	3.3 cfs on 6/12/00	2000	6,322	9	668	5,400	None	30,000
06/05/01	2001	Color Infrared	2.0	2.6	3.5	3.0 cfs on 5/23/01	2001	5,345	7	273	5,400	14,300	30,000
07/30/02	2002	Color Infrared	1.5	1.1	1.1	None	2002	4,515	6	274	16,100	14,300	30,000

TABLE F-5
RELATIONSHIP BETWEEN
FLOW LENGTH OF RISING WATER ABOVE THE LOWER NARROWS
AND FLOW RATE AT THE LOWER NARROWS

Base Flow			**First Point of Rising Water** (1)
cfs-day	AF/day	AFY	Distance Above Lower Narrows (feet)
1.4	3	1,000	27,433
2.1	4	1,500	29,132
2.8	5	2,000	30,401
3.5	7	2,500	31,423
4.1	8	3,000	32,284
4.8	10	3,500	33,030
5.5	11	4,000	33,690
6.2	12	4,500	34,283
6.9	14	5,000	34,823
7.6	15	5,500	35,318
8.3	16	6,000	35,777
9.0	18	6,500	36,203
9.7	19	7,000	36,603
10.4	21	7,500	36,979
11.1	22	8,000	37,335
11.7	23	8,500	37,672
12.4	25	9,000	37,992
13.1	26	9,500	38,298
13.8	27	10,000	38,590
14.5	29	10,500	38,870
15.2	30	11,000	39,139
15.9	32	11,500	39,398
16.6	33	12,000	39,647
17.3	34	12,500	39,888
18.0	36	13,000	40,120
18.7	37	13,500	40,345
19.3	38	14,000	40,563
20.0	40	14,500	40,775
20.7	41	15,000	40,980
21.4	42	15,500	41,180
22.1	44	16,000	41,374
22.8	45	16,500	41,563
23.5	47	17,000	41,747
24.2	48	17,500	41,927
24.9	49	18,000	42,103
25.6	51	18,500	42,274
26.3	52	19,000	42,441
26.9	53	19,500	42,605
27.6	55	20,000	42,765
28.3	56	20,500	42,922
29.0	58	21,000	43,075
29.7	59	21,500	43,226
30.4	60	22,000	43,373
31.1	62	22,500	43,518
31.8	63	23,000	43,660
32.5	64	23,500	43,799
33.2	66	24,000	43,936
A) Distance(feet) = Flow (cfs-day)$^{0.1482}$ x 26,150 R-squared = 0.80			

First Point of Rising Water (1)	**Base Flow** (2)		
Distance Above Lower Narrows (feet)	cfs-day	AF/day	AFY
25,000	0.7	1.46	533
25,400	0.8	1.62	593
25,800	0.9	1.80	659
26,200	1.0	2.00	731
26,600	1.1	2.22	809
27,000	1.2	2.45	895
27,400	1.4	2.71	989
27,800	1.5	2.99	1,090
28,200	1.7	3.29	1,201
28,600	1.8	3.62	1,320
29,000	2.0	3.97	1,450
29,400	2.2	4.36	1,590
29,800	2.4	4.77	1,742
30,200	2.6	5.22	1,906
30,600	2.9	5.71	2,083
31,000	3.1	6.23	2,274
31,400	3.4	6.79	2,480
31,800	3.7	7.40	2,701
32,200	4.1	8.05	2,938
32,600	4.4	8.75	3,194
33,000	4.8	9.50	3,468
33,400	5.2	10.31	3,761
33,800	5.6	11.17	4,076
34,200	6.1	12.09	4,413
34,600	6.6	13.08	4,773
35,000	7.1	14.13	5,158
35,400	7.7	15.26	5,569
35,800	8.3	16.46	6,008
36,200	8.9	17.74	6,475
36,600	9.6	19.11	6,974
37,000	10.4	20.56	7,505
37,400	11.1	22.11	8,069
37,800	12.0	23.75	8,670
38,200	12.9	25.50	9,308
38,600	13.8	27.36	9,986
39,000	14.8	29.33	10,706
39,400	15.8	31.42	11,469
39,800	17.0	33.64	12,278
40,200	18.1	35.99	13,135
40,600	19.4	38.47	14,042
41,000	20.7	41.10	15,003
41,400	22.1	43.89	16,019
41,800	23.6	46.83	17,092
42,200	25.2	49.94	18,227
42,600	26.8	53.22	19,425
43,000	28.6	56.68	20,690
43,400	30.4	60.34	22,024
B) Flow (cfs-day) = [Distance (feet)$^{6.748}$ x 1.547x10^{-30} R-squared = 0.80			

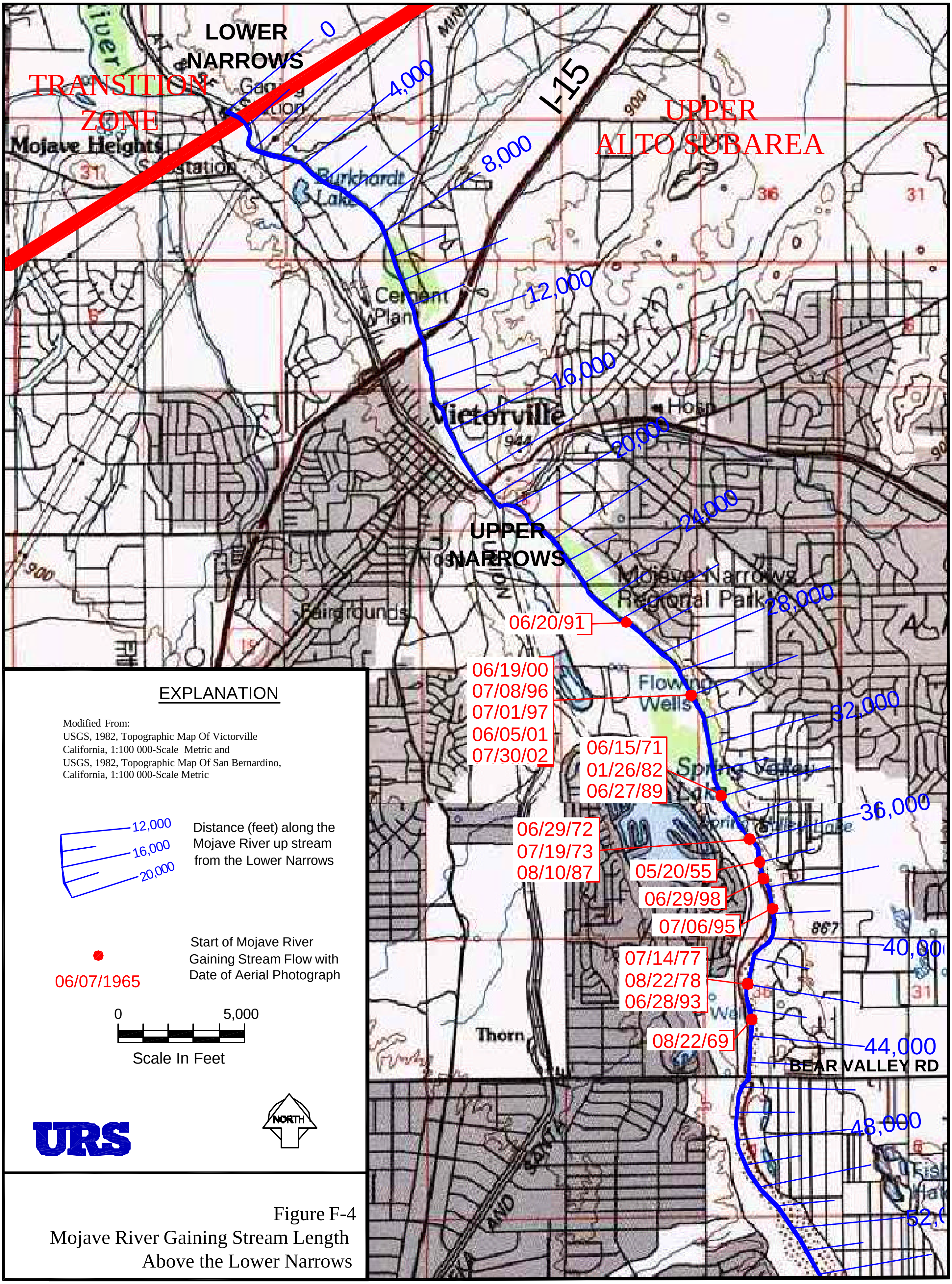
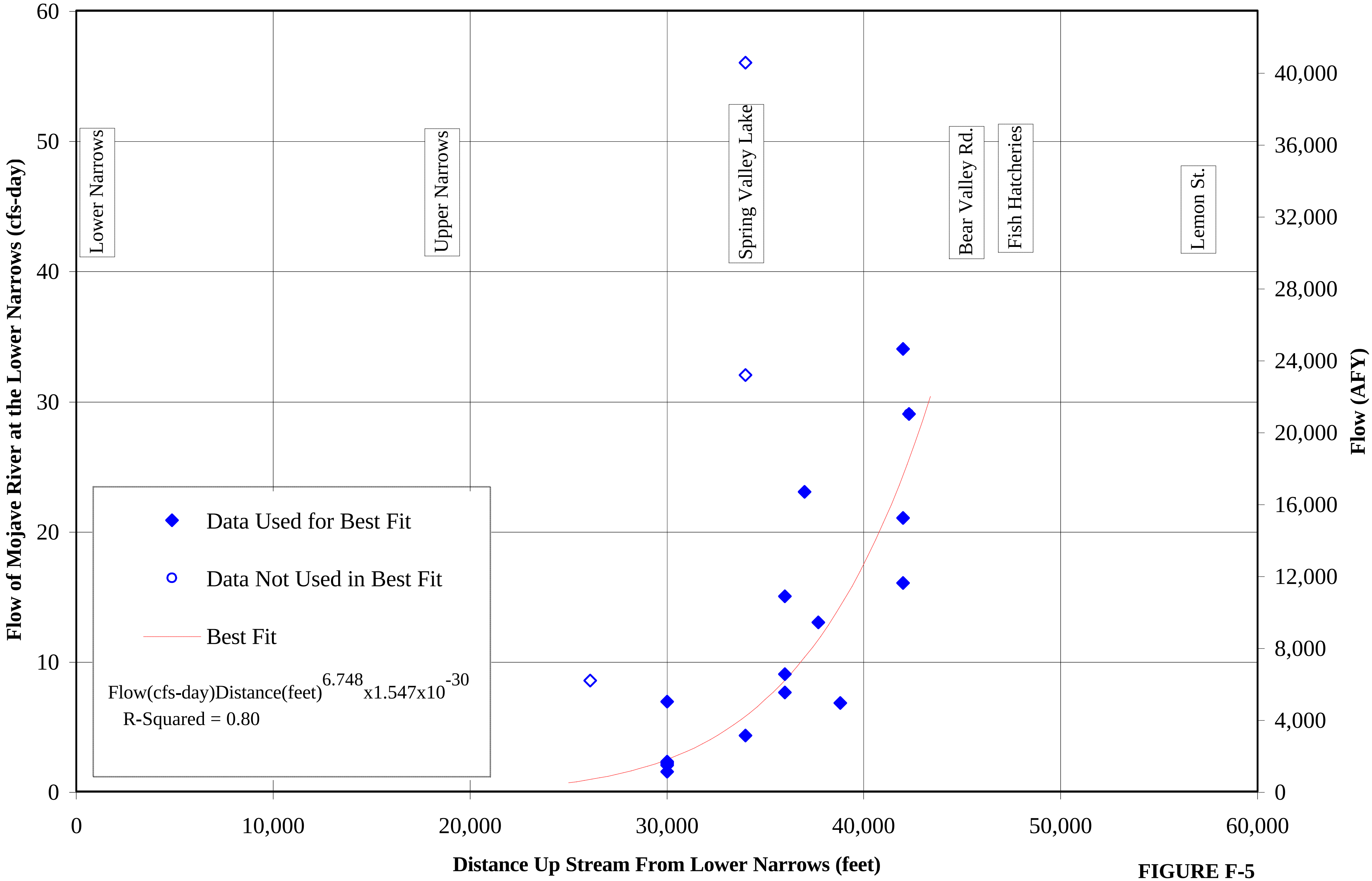


Figure F-4
Mojave River Gaining Stream Length
Above the Lower Narrows



URS

FIGURE F-5
MOJAVE RIVER FLOW
ABOVE THE LOWER NARROWS

APPENDIX G

SUMMARY OF THE GEOLOGIC EVOLUTION

OF THE MOJAVE DESERT

APPENDIX G

SUMMARY OF THE GEOLOGIC EVOLUTION

OF THE MOJAVE DESERT

This summary of the Mojave Desert geologic origin is a synopsis distilled from several chapters of *The Cordilleran Orogen: Conterminous U.S.* (Burchfiel, et al., 1992), which represents a vast collection of research synthesized into a geologic history of the western margin of the North American continent.

PRECAMBRIAN

During the Precambrian Era, the Mojave area was submerged off the continental margin and was receiving miogeoclinal deposition of sand and silt from the north. Where remaining, these now metamorphosed deposits of quartzite and siltstone can be found in the western and northeastern Mojave Desert.

PALEOZOIC

During the early Paleozoic Era, deposition in the Mojave area continued as basinal sediments shed from the continent at a transition between deep water and the shallower edge of the continental shelf. Lower Paleozoic flysch, conglomerate, quartzite, siltite, and argillite rocks can be found in the central Mojave Desert along with dolostone and subordinate limestone. Juxtaposition of the deeper and shallower water deposits is interpreted by some to be the result of the Antler orogeny. During the Antler orogeny, an island arc collided with the northeast-trending continental margin thrusting deep-ocean siliceous strata eastward over co-eval shallow water rocks of the continental shelf along the Roberts Mountain thrust. Basinal sediments originating from the colliding island arc occurred off the continental margin. Rocks similar to the Roberts Mountain allochthon of Nevada can be found in the El Paso Mountains in the northern Mojave Desert.

During the later Paleozoic, marine deposition continued. Pennsylvanian-age shallow-water continental platform sediments consisting predominately of carbonates can be found in outcrop along the southwest Mojave Desert margin. Permian-age left-lateral faulting along the continental margin created local extensional forces and small pull-apart basins, which filled with thick turbidite deposits. These deposits now occur as metasedimentary rocks in the western Mojave Desert. Near the close of the Permian, the onset of a major island arc collision within the continental margin (the Somona Orogeny) renewed thrust faulting and produced greenschist metamorphism of sediments now found in the central Mojave Desert. In the region now exposed in the southwest Mojave Desert and in the San Bernardino Mountains, Mississippian and older sediments were intruded and uplifted, resulting in broad erosion to the east from a western highland

MESOZOIC

During the Mesozoic Era, older rocks in the Mojave area were disrupted and impacted by several orogenic and intrusive events. During the Triassic, the Somona orogeny continued producing sparse but widespread intrusion of granitic plutons throughout the Mojave area. Intrusions imparted high-temperature, low-pressure metamorphism of the country rock. The western Sonoma highland persisted during the Triassic shedding sandstone and conglomerate to the east. During the Jurassic Period, regional northwest-trending left-lateral offset of lower Paleozoic structures and crystalline terranes occurred in the Mojave along the theorized Mojave-Sonora megashear. Renewed subduction along the margin in the late Jurassic and Cretaceous brought about the Nevadan Orogeny and produced widely distributed granitic plutons in the Mojave. These plutons intruded Precambrian crystalline basement and Paleozoic sedimentary cover. For much of the Mesozoic, plutonism and coeval metamorphism weakened the crust resulting in ductile deformation at scattered locations. During the late Cretaceous and early Eocene, the Mojave area experienced widespread tectonism, magmatism, and local sedimentation. In the eastern Mojave area, rapid uplift produced a highland and was followed by Tertiary deposition of continental sediments on rocks once deep within the crust.

CENOZOIC

During the Cenozoic, decreased subduction activity was followed by extension, normal faulting, and volcanism then late Cenozoic right-lateral faulting, extension, and broad sedimentary basin formation. During the Paleocene and Eocene, plutonism, metamorphism, and ductile thrusting continued. During the Oligocene, the Pacific Plate collided at an angle with the North American continent resulting in the right-lateral San Andreas transform fault at the point of impact. During the Oligocene and Miocene, extension and volcanism along high-angle normal faulting was prevalent in the central and eastern Mojave. Extension resulted in the development of ranges separated by broad sediment-filled basins, including the Barstow-Bristol trough. Tertiary-age alluvial and fluvial sediments are up to several thousand-feet thick in areas throughout the Mojave lying locally between normally faulted mountain ranges. These alluvial sediments include the Crowder Sandstone and Punchbowl Sandstone exposed in Cajon Pass. During the middle Miocene, sediment starved closed basins developed saline water, resulting in economic evaporite deposits, notably the Kramer borate deposits in the central Mojave. By the late Miocene, sparsely distributed basalt flows occurred over an eroded land surface, most notably the Cima, Pisgah, and Amboy volcanics in the central Mojave.

The late Cenozoic saw the development of sub-parallel northwest-trending right-lateral strike-slip faults stepping northeastward from the San Andreas fault. Individual displacement on these faults is small. Of those northwest-trending faults, the Helendale, Lenwood, Camp Rock, and Calico faults are the most extensive in the middle Mojave. The Helendale and several smaller named and inferred faults transect the TZ and are described under local geology. As the San Andreas system developed along the southern Mojave, the left-lateral Garlock transform fault became active along the northern Mojave resulting in the formation of marginal sag ponds and pull-apart basins. The Garlock fault separates the Mojave from an area of larger extension to the north. Along the southern

Mojave border, uplift of the San Bernardino and San Gabriel Mountains along the San Andreas and other fault began during the Pliocene and continues to present day. These ranges composed predominately Cretaceous and older crystalline rocks are the source of alluvial sediments now shed to the north into the Mojave Desert. Material shed from the San Gabriel Mountains formed the Victorville Alluvial Fan that grew to an extent of nearly 20 miles before the fan was cut off from its sediment source by movement along San Andreas fault. These northwardly deposited sediments overlie southerly deposited sediments originating from an ancestral river that flowed south from highlands north of the present day Barstow.

APPENDIX H

ESTIMATES OF SUBSURFACE FLOW

INTO AND OUT OF THE TRANSITION ZONE

APPENDIX H

ESTIMATES OF SUBSURFACE FLOW

INTO AND OUT OF THE TRANSITION ZONE

This Appendix presents a summary of estimated subsurface groundwater flow into and out of the Transition Zone (TZ). Subsurface flow into the TZ has been estimated by Albert A. Webb and Associates (Webb, 2000), URS under the current study, and has been simulated by groundwater flow modeling (USGS (2001a). Subsurface flow out of the TZ across the Helendale fault into the Centro Subarea has been estimated by DWR (1967), URS under the current study, and has been simulated by the by the groundwater model presented in USGS (2001a). Subsurface flow calculations performed by Webb (2000), DWR (1967), Mendez (USGS, 2001a) and URS are based on Darcy's Law. Darcy's Law states that flow (Q) is equal to the product of hydraulic conductivity (K), groundwater gradient (I), and area (A). Because transmissivity (T) is the product of hydraulic conductivity (K) and saturated thickness (b), and because area (A) is the product of saturated thickness (b) and aquifer width (w), Darcy's original equation of $Q = KIA$ can be rewritten as $Q = TwI$. Both Webb (2000) and URS used this form of Darcy's equation to estimate subsurface flow into and out of the TZ.

Webb (2000) estimated 4,590 AFY of subsurface underflow into the TZ from the upper Alto Subarea. Webb (2000) estimated this value based on published transmissivity values (USGS, 1971) and groundwater gradients between wells and widths corresponding to segments of the boundary between the TZ and the upper Alto Subarea. USGS (2001a) derived a maximum value of 3,501 AFY of subsurface flow across the same boundary by using a MODFLOW model of the Mojave River Basin. USGS (2001a) used published transmissivity values (USGS, 1971) updated with recent aquifer tests and other information. Transmissivity values published by USGS (1971) were used in the calculations made by Webb (2000), USGS (2001a), and URS under the current study. Although the published (USGS, 1971) transmissivity contours do not cover the entire study area, they do offer adequate coverage of the southern and northern TZ boundaries and represent the best transmissivity data available on a basin-wide scale.

WEBB CALCULATIONS

Although Webb (2000) did not publish fully documented inflow calculations, the Webb calculations are reproducible based on the published description of the method used. Webb (2000) divided the southern boundary of the TZ into three segments (aquifer widths) measuring 4.0, 5.25, and 3.0 miles in length from east to west, respectively. Transmissivity values used by Webb (2000), as published by USGS (1971), ranged from 10,000 and 25,000 gallons per day per foot (gpd/ft). The gradients used by Webb (2000) for these calculations were not published but are here estimated from 1998 water level data. Table H-1 shows the inflow values of Webb (2000) as reproduced during the current study.

USGS SIMULATION

USGS (2001a) modeled subsurface flow into the TZ using a 2-layer, three-dimensional flow model that utilized transmissivity values and boundaries first modeled using an electric analog model (USGS, 1971). Although USGS (2001a) published the transmissivity values used in their model, reproduction of their flow estimates was not easily duplicated by this study using Darcy's equation. The manual calculation utilized published USGS (2000) water level data and the aquifer widths used by Webb (2000). The Webb (2000) aquifer widths were used for easy comparison. Table H-2 shows the attempted duplication of the USGS inflow calculation. The inflow value of 2,040 AFY shown in Table H-2 was obtained by Darcy's equation, using the transmissivity values published in USGS (2001a). The inflow value estimated with these calculations is lower than the 3,501 AFY value simulated in the model.

URS CALCULATION

The hydrologic boundaries of the southern TZ do not coincide with administrative boundaries. Buried faults, inferred from gravity data and groundwater elevation data, control the flow of groundwater into the southern TZ from the upper Alto Subarea. For the current study, URS calculated flow across the Shadow Mountains fault and Adelanto fault into the southern TZ. These calculations were performed using 1998 groundwater gradients (Figure 6 of this report) and transmissivity value distribution as published in USGS (1971). Table H-3 shows these inflow calculations as 4,891 AFY.

INFLOW SUMMARY

The values for subsurface flow from the upper Alto Subarea to the TZ as estimated by Webb (2000), USGS (2001a) and URS are 4,590 AFY, 3,501 AFY and 4,891 AFY, respectively. Each of these inflow values was estimated using the transmissivity data published in USGS (1971). These calculations are sensitive to minor changes in transmissivity and gradient. These parameters are sensitive enough that the three inflow values for the southern TZ are essentially equivalent given the existing parameter variability. Each value produced by each of the researchers is estimated and does not represent an absolute value for inflow into the TZ from the upper Alto Subarea. As knowledge of the basin increases and more data becomes available, these numbers may change. However, they do represent best estimates based on existing data.

SUBSURFACE FLOW OUT OF THE TZ

USGS (2001a) calculated a subsurface flow volume of approximately 1,566 AFY across the Helendale fault from the northern TZ to the Centro Subarea. USGS (2001a) also refers to a personal communication from a Gregory Mendez who estimated that subsurface outflow across the Helendale fault might be as high as 5,000 to 6,000 AFY. The DWR (1967) estimated subsurface flow across the Helendale fault to be approximately 2,000 AFY based on Darcy's Law. It is unknown what transmissivity or groundwater gradient data was used by for the DWR calculation. The Judgment uses the value estimated by DWR (1967). No other known estimates or calculations of subsurface flow across the Helendale fault have been published.

USGS (2001a) modeled subsurface flow out of the TZ using the Mojave River Basin model cited previously. The model was based on transmissivity values and boundaries first modeled using an electric analog model (USGS, 1971). Although USGS (2001a) published the range of transmissivity values used in their model, their flow values were not duplicated using Darcy's equation. The value estimated using Darcy's equation was significantly lower than that simulated by the model.

Under the current study, URS estimated subsurface outflow using transmissivity values published by USGS (1971), 1998 groundwater elevations (gradients), and aquifer widths along the Helendale fault. Table H-4 shows the URS outflow calculations.

The subsurface outflow value from the TZ to the Centro Subarea estimated by Gregory Mendez (USGS, 2001a) ranges from 5,000 to 6,000 AFY. The model presented in USGS (2001a) simulated subsurface flow across the Helendale fault at 1,566 AFY. URS estimates, under the current study, approximately 4,579 AFY subsurface flow across the Helendale fault. The 1,566 AFY outflow value reported by USGS (2001a) appears to be low in relation to values estimated by others.

Each of these values was estimated using published transmissivity data (USGS, 1971). Although the method used by Mendez (USGS, 2001a) to estimate 5,000 to 6,000 AFY flow value is not documented, it is assumed that a Darcian type calculation was used. The estimates performed by Mendez, USGS (2001a), and URS are sensitive to minor changes in transmissivity. These calculations are sensitive enough that the values for subsurface flow out of the TZ as estimated by Mendez and URS are essentially equivalent given the existing parameter variability. The values produced by these researchers are estimates and do not represent absolute values for flow Centro Subarea form the TZ. As knowledge of the basin increases and more data becomes available, these numbers may change. However, they do represent best estimates based on existing data.

Table H-1. Approximation of Webb (2000) Calculations of Subsurface Flow Into the Transition Zone

						I	w	T=Kb	Q	
Segment of Southern Transition Zone Administrative Boundary	Up Gradient Groundwater Elevation (ft)	Down Gradient Groundwater Elevation (ft)	Difference in Groundwater Elevation Between Wells (ft)	Distance Between Wells (ft)	Gradient (ft/ft)	Average Gradient (ft/ft)	Distance along southern TZ boundary (ft)	Transmissivity (ft^2/day)	Flow (ft^3/d)	Total Flow Per Segment (AFY)
Lower Narrows to Highway 395	2762	2587	175	21648	0.00808	0.00693	21120	1875	274535	2,300
	2670	2612	58	10032	0.00578					
West of Highway 395	2910	2762	148	36960	0.00400	0.00400	27720	1720	190920	1,600
West End of Southern Boundary	2925	2802	123	33792	0.00364	0.00364	15840	1430	82448	691
Total Subsurface Flow (AFY)										**4,591**

Table H-2. Estimate of Subsurface Flow Into the Southern Transition Zone using USGS (2001) Transmissivity Values

						I	w	T=Kb	Q	
Segment of Southern Transition Zone Administrative Boundary	Up Gradient Groundwater Elevation (ft)	Down Gradient Groundwater Elevation (ft)	Difference in Groundwater Elevation Between Wells (ft)	Distance Between Wells (ft)	Gradient (ft/ft)	Average Gradient (ft/ft)	Distance along southern TZ boundary (ft)	Transmissivity (ft^2/day)	Flow (ft^3/d)	Total Flow Per Segment (AFY)
Lower Narrows to Highway 395	2762	2587	175	21648	0.00808	0.00693	21120	1375	201325	1,687
	2670	2612	58	10032	0.00578					
West of Highway 395	2910	2762	148	36960	0.00400	0.00400	27720	250	27750	233
West End of Southern Boundary	2925	2802	123	33792	0.00364	0.00364	15840	250	14414	121
Total Subsurface Flow (AFY)										**2,040**

Table H-3. Subsurface Flow Across Adelanto and Shadow Mountain Faults in the Southern Transition Zone Estimated by URS.

1 Mile Fault Segments Numbered From West to East	Up Gradient Groundwater Elevation (ft)	Down Gradient Groundwater Elevation (ft)	Difference in Groundwater Elevation Between Points (ft)	Distance Between Points (ft)	I	w	T=Kb	Q		
					Gradient (ft/ft)	Distance along southern TZ boundary (ft)	Transmissivity (ft^2/day)	Flow (ft^3/d)	Flow (AF/day)	Flow (AFY)
1	2850	2695	155	15840	0.00979	5280	1336	69027	1.58	578
2	2856	2725	131	15840	0.00827	5280	1336	58339	1.34	489
3	2867	2775	92	15840	0.00581	5280	668	20485	0.47	172
4	2883	2785	98	15840	0.00619	5280	668	21821	0.50	183
5	2883	2770	113	15840	0.00713	5280	668	25161	0.58	211
6	2880	2750	130	15840	0.00821	5280	668	28947	0.66	243
7	2882	2750	132	15840	0.00833	5280	668	29392	0.67	246
8	2880	2750	130	15840	0.00821	5280	668	28947	0.66	243
9	2875	2750	125	15840	0.00789	5280	668	27833	0.64	233
10	2783	2725	58	15840	0.00366	5280	668	12915	0.30	108
11	2766	2710	56	15840	0.00354	5280	668	12469	0.29	104
12	2750	2700	50	15840	0.00316	5280	668	11133	0.26	93
13	2743	2700	43	15840	0.00271	5280	1336	19149	0.44	160
14	2739	2700	39	15840	0.00246	5280	1875	24375	0.56	204
15	2736	2620	116	15840	0.00732	5280	5010	193720	4.45	1623
Total Subsurface Flow (AFY)										**4,891**

Table H-4. Subsurface Flow Across Helendale Fault into the Centro Subarea as Estimated by URS.

					I	w	T=Kb	Q		
1 Mile Fault Segments Numbered From East to West	Up Gradient Groundwater Elevation (ft)	Down Gradient Groundwater Elevation (ft)	Difference in Groundwater Elevation Between Points	Distance Between Points (ft)	Gradient (ft/ft)	Distance along southern TZ boundary (ft)	Transmissivity (ft^2/day)	Flow (ft^3/d)	Flow (AF/day)	Flow (AFY)
Floodplain Aquifer 1	2400	2381	19	5280	0.00360	5280	13360	253840	5.83	2,127
Floodplain Aquifer 2	2392	2381	11	5280	0.00208	5280	13360	146960	3.37	1,231
Regional Aquifer 1	2392	2381	11	5280	0.00208	5280	5010	55110	1.27	462
Regional Aquifer 2	2390	2381	9	5280	0.00170	5280	3340	30060	0.69	252
Regional Aquifer 3	2388	2381	7	5280	0.00133	5280	3340	23380	0.54	196
Regional Aquifer 4	2388	2381	7	5280	0.00133	5280	2338	16366	0.38	137
Regional Aquifer 5	2388	2381	7	5280	0.00133	5280	1336	9352	0.21	78
Regional Aquifer 6	2388	2382	6	5280	0.00114	5280	1336	8016	0.18	67
Regional Aquifer 7	2390	2385	5	5280	0.00095	5280	668	3340	0.08	28
Total Subsurface Flow in the Floodplain Aquifer (AFY)										**3,358**
Total Subsurface Flow in the Regional Aquifer (AFY)										**1,220**
Total Subsurface Flow Across the Helendale Fault (AFY)										**4,579**