APPENDIX J

Water Resources Supporting Documentation

- Table J-1 Wells Data Base
- Table J-2 Water Chemistry Data
- Hydrographs
- DWR Drillers Logs of Wells
- Water/Waste Water Report
- Numerical Groundwater Model
- Table J-1 Results of Numerical Groundwater Modeling Storage Coefficient of 0.20
- Table J-2 Results of Numerical Groundwater Modeling Storage Coefficient of 0.05
- Figures
- USGS Superposition Model
- Groundwater Model Data Files (CD-ROM)

Table J-1 Wells Data Base

TABLE J-1
WELLS DATABASE
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
02S/17E-30E01S	--	--	850	624	uncased	Jan-33	325	525				
02S/17E-30E01S	--	--							1/30/1933	7		
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Dec-54	150	931				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jun-55	154.94	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Sep-55	155.2	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Dec-55	155.6	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Feb-56	155.2	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Feb-56	155.1	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Feb-56	155	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-56	155	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		May-56	154.88	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jul-56	155.3	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Aug-56	155.3	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Sep-56	155.7	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		May-57	155.21	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		May-57	155.65	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jun-57	155.48	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Aug-57	155.49	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Sep-57	155.37	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-57	155	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-58	155.1	926				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		May-58	155.4	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Sep-58	155.6	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jan-59	155.7	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-59	155.6	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jun-59	155.8	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Sep-59	155.71	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Dec-59	155.74	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-60	155.6	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jun-60	155.9	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-60	155.93	925				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jan-61	156.14	924				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-61	156.81	924				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-61	157.49	923				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-61	157.77	923				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-62	158.79	922				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-63	159.28	921				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-63	159.34	921				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-64	159.49	921				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-64	159.53	921				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-65	159.81	921				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-65	160.21	920				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-66	161.95	919				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-66	162.94	918				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-67	163.38	917				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-67	163.78	917				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-69	165.06	916				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		May-70	164.86	916				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-70	166.17	914				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-71	166.54	914				

TABLE J-1
WELLS DATABASE
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jan-72	165.04	916				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jun-72	166.67	914				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-73	166.31	914				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Sep-73	167.72	913				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Feb-74	167.72	913				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-74	167.48	913				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Apr-75	167.88	913				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-75	168	913				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Mar-76	168.25	912				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Nov-76	168.91	912				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Apr-77	169	912				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-77	169.43	911				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		May-78	169.08	912				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-78	169.75	911				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Apr-79	168.65	912				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-79	170.49	910				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Apr-80	170.55	910				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-80	170.2	910				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Apr-81	170.03	911				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Oct-81	171.49	909				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Apr-82	170.89	910				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jan-83	169.73	911				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Aug-84	167.24	913				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Feb-85	166.44	914				
03S/15E-04J01S	33.93667885	-115.4099836	1,081	575		Jun-85	166.27	914				
03S/18E-03Q01S	--	--	1,675	17		Jun-61	13	1662				
03S/18E-11A01S	--	--	1,580	40		Jun-61	37	1543				
04S/15E-13C01S	--	--	683	452	220-248, 317-328	Feb-61	188	495	Feb-32	450		
04S/16E-19M01S	--	--	610	585		Oct-61	127	483				
04S/16E-19N01S	--	--	600	151		Apr-61	112	488				
04S/16E-21N01S	--	--	565	39		Apr-61	--	--				
04S/16E-29R01S	--	--	545	110		Jun-61	80	465				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Apr-61	79.95	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Sep-61	80	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Oct-61	79.93	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Nov-61	79.92	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Dec-61	79.94	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Jan-62	79.92	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Feb-62	79.94	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Mar-62	79.93	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Apr-62	79.86	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		May-62	79.93	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Jun-62	79.97	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Nov-62	79.96	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Mar-63	79.96	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Oct-63	80	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Mar-64	80.04	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Mar-65	80.11	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Nov-65	80.27	460				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Oct-66	79.1	461				

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PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Mar-67	78.93	461				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		Oct-67	78.76	461				
04S/16E-29R01S	33.7902952	-115.3202862	540	110		May-70	78.25	462				
04S/16E-30D01S	--	--	603	610		Oct-61	114	489	Oct-60	5075	110	
04S/16E-30D01S	33.8008503	-115.3347034	603	610		May-61	113.91	489	Oct-60	5075	110	
04S/16E-30D01S	33.8008503	-115.3347034	603	610		Jun-61	114.3	489				
04S/16E-30D01S	33.8008503	-115.3347034	603	610		May-70	118.53	484				
04S/16E-31D01S	--	--	595	600	135-597	Jun-61	95	500	Jun-61	2328	44	
04S/16E-31R01S	--	--	555	36		Apr-61	--	--				
04S/16E-32D01S	--	--	555	610	265-555	Jun-61	79	476				
04S/16E-32D01S	--	--							Oct-61	2750	80	
04S/16E-32E01S	--	--	555	77	63-95, 245-252	Apr-61	--	--				
04S/16E-32M01S	--	--	555	555		Jun-61	74	481				
04S/16E-32M01S	--	--							Jun-61	2000		
04S/16E-32M01S	33.7797398	-115.333592	548	555		Apr-61	71.41	477	Jun-61	2000		
04S/16E-32M01S	33.7797398	-115.333592	548	555		Apr-61	71.61	476				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Jun-61	71.43	477				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Jun-61	73.46	475				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Feb-62	69.32	479				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Mar-62	70.29	478				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Apr-62	72.45	476				
04S/16E-32M01S	33.7797398	-115.333592	548	555		May-62	73.82	474				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Aug-62	79.95	468				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Sep-62	79.57	468				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Nov-62	77.17	471				
04S/16E-32M01S	33.7797398	-115.333592	548	555		May-70	77.25	471				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Apr-79	66.95	481				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Jul-80	72.87	475				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Jan-81	74.16	474				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Oct-81	86.9	461				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Apr-82	82.01	466				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Jan-83	90.29	458				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Jul-84	121.88	426				
04S/16E-32M01S	33.7797398	-115.333592	548	555		Feb-85	120.8	427				
04S/16E-35Z01S	--	--	470	--		Jan-17	13	457				
04S/17E-06C01S	--	--	500	501		Oct-61	22	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jan-32	22.5	478	Apr-61	106		
04S/17E-06C01S	33.85918308	-115.2394237	500			May-52	21	479				
04S/17E-06C01S	33.85918308	-115.2394237	500			Sep-54	21.2	479				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-56	21.4	479				
04S/17E-06C01S	33.85918308	-115.2394237	500			May-57	21.6	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Sep-59	21.9	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Apr-61	21.82	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Nov-61	22.4	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jan-62	22.2	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-62	22.14	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Nov-62	22.41	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-63	22.22	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-63	22.31	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-64	22.41	478				

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FOR CHUCKWALLA GROUNDWATER BASIN
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WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
04S/17E-06C01S	33.85918308	-115.2394237	500			Nov-64	22.4	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-65	22.51	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Nov-65	22.3	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-66	22.5	478				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-66	22.74	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-67	22.55	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-67	22.95	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Apr-68	22.8	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Nov-68	22.71	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Apr-69	25.02	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-69	24.72	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Apr-70	23.15	477				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-70	23.55	476				
04S/17E-06C01S	33.85918308	-115.2394237	500			Mar-71	23.57	476				
04S/17E-06C01S	33.85918308	-115.2394237	500			Apr-79	23.88	476.12				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jul-80	24.4	476				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jan-81	24.52	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Oct-81	25.23	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Apr-82	26.69	473				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jan-83	25.01	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jul-84	25.31	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Feb-85	25.42	475				
04S/17E-06C01S	33.85918308	-115.2394237	500			Jun-85	25.65	474				
05S/14E-24R01S	--	--	1,072	733		Jan-33	570	502				
05S/14E-35L01S	--	--	1,270	600	349-784	Sep-61	570	700				
05S/14E-35L01S	--	--	1,270	641		Sep-61	571	699				
05S/14E-35L01S	--	--	1,190	877	526-746	Sep-61	485	705				
05S/14E-35L01S	--	--	1,369	501	400-501	Nov-80	Dry	--				
05S/14E-35L01S	--	--	1,342	805	599-799	Nov-80	635	708				
05S/14E-35L01S	--	--							Nov-61	2		
05S/14E-35L02S	--	--							Nov-61	6		
05S/15E-01E01S	--	--	645	755	215-788	Oct-61	146	499				
05S/15E-01L01S	--	--	640	790		Oct-61	139	501				
05S/15E-01L01S	--	--							Mar-61	1674	42	
05S/15E-01L01S	--	--							Mar-60	3150		
05S/15E-02E01S	--	--							Nov-60	3300	56	
05S/15E-12N01S	--	--	688	746	--	May-61	173	515				
05S/15E-12N01S	33.7440238	-115.3781377	671	746		Apr-61	173	498	May-61	1900		
05S/15E-12N01S	33.7440238	-115.3781377	671	746		Jun-67	172	499				
05S/15E-12N01S	33.7440238	-115.3781377	671	746		May-70	172	499				
05S/15E-12N01S	33.7440238	-115.3781377	671	746		Mar-92	190	481				
05S/15E-12N01S	33.7440238	-115.3781377	671	746		Mar-00	183	488				
05S/15E-13B01S	--	--	650	788	--	Sep-61	160	490				
05S/15E-14E01S	--	--	750	799	--	Nov-61	245	505				
05S/15E-14J01S	--	--	710	63	--	--	--	--				
05S/15E-15E01S	--	--	805	808	--	Nov-61	313	492				
05S/15E-23N01S	--	--	880	409	--	Mar-61	367	513				
05S/15E-27B01S	--	--	900	644	553-625	Oct-61	395	505				
05S/15E-27B01S	33.71390794	-115.4038719	900	644		May-58	395	505				
05S/15E-27B01S	33.71390794	-115.4038719	900	644		Mar-61	395	505				

TABLE J-1
WELLS DATABASE
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
05S/15E-27B01S	33.71390794	-115.4038719	900	644		Jun-61	395	505				
05S/15E-27B02S	--	--	900	--	224-705	--	--	--				
05S/15E-27H01S	--	--	904	598	--	Mar-61	429	475				
05S/15E-29F01S	--	--	1,046	680	--	Sep-61	366	680				
05S/15E-2E01S	--	--	700	728	--	Oct-61	210	490				
05S/16E-05B01S	--	--	560	114	--	Jul-61	71	489				
05S/16E-05B02S	--	--	548	715	--	Oct-61	69	479				
05S/16E-05E01S	--	--	570	124	--	--	--	--				
05S/16E-05F01S	33.7679373	-115.3378755	544			Oct-00	79	464				
05S/16E-05F02S	33.76787344	-115.3380088	545	250		Jun-99	81	464				
05S/16E-05F02S	33.76787344	-115.3380088	545	250		Oct-00	80	465				
05S/16E-05F02S	33.76787344	-115.3380088	545	250		Oct-00	80	465				
05S/16E-05M01S	33.765729	-115.3441312	557			Oct-00	90	467				
05S/16E-06N01S	--	--	604	723	228-331, 334-722	Jun-61	126	478				
05S/16E-07M01S	--	--	614	648		Jun-61	61	553				
05S/16E-07M01S	--	--	611	789	280-789	Jul-61	126	485				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Apr-61	121	483	Feb-59	1324	94	
05S/16E-07M01S	33.749171	-115.3573315	604	648		Apr-61	126	478	Feb-58	3634	110	
05S/16E-07M01S	33.749171	-115.3573315	604	648		Jun-61	125	479	Jun-61	1118	124	
05S/16E-07M01S	33.749171	-115.3573315	604	648		Jun-61	127	477	Apr-59	707		
05S/16E-07M01S	33.749171	-115.3573315	604	648		Jun-61	127	477	Apr-61	1115		
05S/16E-07M01S	33.749171	-115.3573315	604	648		Jun-61	126	478				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Jun-61	128	476				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Jun-61	129	475				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Aug-61	127	477				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Oct-61	124	480				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Oct-61	124	480				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Oct-61	125	479				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Oct-61	125	479				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Nov-61	127	477				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Nov-62	140	464				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Apr-70	128	476				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Oct-91	194	409				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Feb-92	189	415				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Mar-92	190	414				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Sep-92	188	415				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Apr-93	183	421				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Sep-93	182	421				
05S/16E-07M01S	33.749171	-115.3573315	604	648		Apr-94	179	425				
05S/16E-07P01S	--	--	608	347	248-296, 299-347	Apr-61	121	487				
05S/16E-07P01S	33.74557395	-115.3533147	598	347		Sep-52	108	490				
05S/16E-07P01S	33.74557395	-115.3533147	598	347		Jun-90	213	385				
05S/16E-07P01S	33.74557395	-115.3533147	598	347		Oct-90	208	390				
05S/16E-07P01S	33.74557395	-115.3533147	598	347		Mar-91	199	399				
05S/16E-07P01S	33.74557395	-115.3533147	598	347		Feb-92	188	410				
05S/16E-07P02S	33.7453656	-115.3535703	598	767		Oct-00	137	462				
05S/16E-08F01S	--	--	560	206	103-168, 172-188	Sep-61	83	477				
05S/16E-08K01S	--	--	555	212	124-162, 178-180	Jun-61	83	472				
05S/16E-09E01S	--	--	545	--		Jun-61	--	--				
05S/16E-10Z01S	--	--	--	76		Jun-61	74	--				

TABLE J-1
WELLS DATABASE
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
05S/16E-18M01S	--	--	646	790		Apr-61	161	485				
05S/16E-18Q01S	--	--	660	37		Jun-61	--	--				
05S/16E-22N01S	--	--	653	516		Dec-61	188	465				
05S/16E-25F01S	--	--	598	680		May-61	135	463				
05S/16E-36M01S	--	--	730	357	261-357	Sep-61	274	456				
05S/17E-17F01S	33.70807585	-115.2488671	574	698		Apr-61	108	466				
05S/17E-17F01S	33.70807585	-115.2488671	574	698		May-70	111	463				
05S/17E-17F01S	33.70807585	-115.2488671	574	698		Mar-92	113	461				
05S/17E-19Q01S	--	--	535	760	314-758	Apr-61	76	459				
05S/17E-19Q01S	33.71446456	-115.2472004	538	760		Apr-61	76	462				
05S/17E-19Q01S	33.71446456	-115.2472004	538	760		Apr-61	76	462				
05S/17E-19Q01S	33.71446456	-115.2472004	538	760		May-70	75	463				
05S/17E-19Q01S	33.71446456	-115.2472004	538	760		Feb-92	82	456				
05S/17E-20F01S	--	--	465	10								
05S/17E-21Z01S	--	--				Jan-17	98					
05S/17E-29E01S	--	--	533	983		Apr-61	84	449				
05S/17E-29H01S	--	--	495	1,025	uncased	Aug-61						
05S/17E-30F01S	--	--	570	720	120-288, 314-698	Apr-61	108	462				
05S/17E-30G01S	33.7079481	-115.2388196	543			Mar-00	116	428				
05S/17E-30P01S	--	--	620	147		Jun-61						
05S/17E-30P01S	33.70057607	-115.2494227	607	152		May-57	150	457				
05S/17E-33N01S	--	--	597	758	266-758	Apr-61	173	424				
05S/17E-33N01S	33.6861321	-115.2210885	592	758		Apr-61	173	419				
05S/17E-33N01S	33.6861321	-115.2210885	592	758		Apr-61	173	419				
05S/17E-33N01S	33.6861321	-115.2210885	592	758		Oct-61	173	419				
05S/17E-33N01S	33.6861321	-115.2210885	592	758		Apr-70	175	417				
06S/15E-24E01S	33.63391075	-115.3774823	1,995	22		Aug-61	17	1978				
06S/15E-24E02S	33.63529958	-115.3794268	2,000	22		Aug-61	19	1981				
06S/15E-24E03S	33.63279968	-115.3758156	1,995	14		May-52	10	1985				
06S/15E-30Q01S	33.61613324	-115.4580404	2,200	15		Aug-61	12	2188				
06S/17E-03M01S	--	--	565	818		Apr-61	190	375				
06S/17E-03M01S	33.67641019	-115.2035878	566	818		Apr-61	190	376				
06S/17E-03M01S	33.67641019	-115.2035878	566	818		Apr-61	190	376				
06S/19E-28R01S	33.6130791	-114.9955244	354			Sep-90	81	273				
06S/19E-28R01S	33.6130791	-114.9955244	354			Sep-90	82	272				
06S/19E-28R01S	33.6130791	-114.9955244	354			Feb-92	81	273				
06S/19E-32K01S	33.60406264	-115.0196002	390			Feb-92	104	286				
06S/19E-32K01S	33.60406264	-115.0196002	390			Mar-00	97	293				
06S/19E-32K02S	33.6041904	-115.0196919	390			Feb-92	110	280				
06S/20E-33C01S	33.61002386	-114.9013548	392			Sep-90	134	258				
06S/20E-33C01S	33.61002386	-114.9013548	392			Feb-92	135	257				
06S/20E-33L01S	33.60465735	-114.9017964	388	800		Feb-02	125	262				
07S/18E-14F01S	33.56214983	-115.073652	563	1,000		Dec-82	300	263				
07S/18E-14F01S	33.56214983	-115.073652	563	1,000		Feb-92	270	292				
07S/18E-14F01S	33.56214983	-115.073652	563	1,000		Mar-00	270	293				
07S/18E-14H01S	33.56226096	-115.0650739	546	985		Jan-83	270	276				
07S/18E-14H01S	33.56226096	-115.0650739	546	985		Feb-92	258	288				
07S/18E-14H01S	33.56226096	-115.0650739	546	985		Mar-00	257	289				
07S/19E-04R01S	33.5849549	-114.9955658	424			Sep-90	144	280				
07S/19E-04R01S	33.5849549	-114.9955658	424			Mar-00	144	279				

TABLE J-1
WELLS DATABASE
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
07S/20E-04R01S	33.5839135	-114.8910764	418			Jun-61	152	266				
07S/20E-04R01S	33.5839135	-114.8910764	418			Oct-61	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Nov-61	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Jan-62	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Mar-62	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Apr-62	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			May-62	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Oct-62	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Mar-63	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Oct-63	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Mar-64	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Nov-64	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Mar-65	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Nov-65	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Mar-66	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Oct-66	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Mar-67	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Oct-67	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Oct-69	151	267				
07S/20E-04R01S	33.5839135	-114.8910764	418			Apr-70	151	267				
07S/20E-16M01S	33.5591308	-114.9053349	456	1,200		Jun-05	202	254				
07S/20E-16M01S	33.5591308	-114.9053349	456	1,200		Sep-90	206	250				
07S/20E-16M01S	33.5591308	-114.9053349	456	1,200		Feb-92	207	249				
07S/20E-16M01S	33.5591308	-114.9053349	456	1,200		Feb-92	206	250				
07S/20E-17C01S	33.56891386	-114.9166326	433			Feb-92	174	259				
07S/20E-17G01S	33.5644973	-114.9155269	444	1,200		Dec-87	203	241				
07S/20E-17G01S	33.5644973	-114.9155269	444	1,200		Sep-90	189	254				
07S/20E-17G01S	33.5644973	-114.9155269	444	1,200		Feb-92	186	257				
07S/20E-17G01S	33.5644973	-114.9155269	444	1,200		Feb-92	188	256				
07S/20E-17G01S	33.5644973	-114.9155269	444	1,200		Mar-00	199	244				
07S/20E-17K01S	33.55918915	-114.9121462	457	1,200		Dec-87	205	252				
07S/20E-17K01S	33.55918915	-114.9121462	457	1,200		Feb-92	201	256				
07S/20E-17K01S	33.55918915	-114.9121462	457	1,200		Feb-92	199	257				
07S/20E-17K01S	33.55918915	-114.9121462	457	1,200		Feb-92	200	257				
07S/20E-17L01S	33.55882247	-114.9202159	458	1,200		Oct-92	213	245				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Apr-61	168	275				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Apr-70	172	271				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Jul-79	173	269				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Jul-80	169	274				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Jan-81	169	274				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Sep-81	169	274				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Mar-82	170	273				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Jan-83	171	272				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Jul-84	171	272				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Feb-85	171	272				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Jun-85	173	270				
07S/20E-18H01S	33.5625251	-114.926355	443	1,139		Feb-92	183	259				
07S/20E-18K01S	33.5600363	-114.9319802	449	1,200		Oct-92	193	256				
07S/20E-18R01S	33.5573475	-114.9270467	454	1,160		Oct-92	202	252				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-82	248	258				

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FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	COMMENTS
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Feb-92	232	273				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-00	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Oct-00	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jan-01	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Feb-01	234	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-01	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-01	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jul-01	235	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Nov-01	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Nov-01	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-02	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-02	235	271				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Oct-02	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Oct-02	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jun-03	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jun-03	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Nov-03	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Nov-03	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-04	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-04	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Aug-04	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Dec-04	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-05	235	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Aug-05	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Aug-05	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Feb-06	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Feb-06	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		May-06	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		May-06	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Aug-06	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Aug-06	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Dec-06	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Dec-06	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Feb-07	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Feb-07	236	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		May-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		May-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Sep-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Sep-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Sep-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Dec-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Dec-07	237	269				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Mar-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jun-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jun-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Sep-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Sep-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Sep-08	236	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jan-09	235	270				

TABLE J-1
WELLS DATABASE
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA
PROJECT BEACON

WELL DATA[1]			WELL COMPLETION DATA			GROUNDWATER LEVELS			WELL PERFORMANCE DATA[2]			COMMENTS
STATE WELL NUMBER	LATITUDE	LONGITUDE	Ground Surface Elevation	Total Depth	Perforation Interval(s)	Depth to Groundwater		Groundwater Elevation	Pumping Test Date	Pumping Rate	Specific Capacity	
	NAD 83	NAD 83	feet-msl	feet-bgs		Date	feet-bgs	feet-msl	Mo/Yr	gpm	gpm/ft	
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Jan-09	235	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-09	235	270				
07S/20E-28C01S	33.53725089	-114.8991372	506	830		Apr-09	235	270				
07S/20E-28C02S	33.5372481	-114.8989955	505	1,100		Nov-89	234	271				

NOTES

1 Data as provided in the USGS National Water Information System Database - http//:nwis/waterdata.usgs.gov/ and the Department of Water Resources Database - http://wdl.water.ca.gov/gw/

2 Data obtained by historical documents

DEFINITIONS

NAD-83	North American Datum 1983
feet-msl	feet above mean sea level
feet-bgs	feet below ground surface
Mo	month
gpm	gallons per minute
gpm/ft	gallons per minute per foot of drawdown
--	data not provided or available in USGS or DWR database.

Table J-2 Water Chemistry Data

TABLE J-2
WATER CHEMISTRY DATA
FOR CHUCKWALLA GROUNDWATER BASIN
SOLAR MILLENIUM, LLC
PALEN SOLAR POWER PROJECT
RIVERSIDE COUNTY, CALIFORNIA

WELL DATA[1]									WATER CHEMISTRY																							
STATE WELL NUMBER (DWR)	STATE WELL NUMBER (USGS)	LATITUDE	LONGITUDE	Well Owner	Published Use	Year	Status (op)	Lithologic Log (YES)	Sample Date	EC	Temperature	pH	Total Dissolved Solids (TDS)	Silica	Calcium	Magnesium	Sodium	Potassium	Alkalinity		Sulfate	Chloride	Fluoride	Nitrate and Nitrite (as N)	Nitrate (NO_3)	Arsenic	Boron	Iron	Manganese	Hardness ($CaCO_3$)	COMMENTS
		NAD 83	NAD 83						Mo/Yr	(micro-mohs at 25 C)	Degrees Centigrade	pH units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Bicarbonate mg/L	Carbonate mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	
03S/18E-11A01		--	--	--	--	--	--	--	Sep-61	22,000	--	7.2	**12300**	--	585	208	6720	86	1480	0	1110	**2780**	2.9	--	**25**	--	20	--	--	2300	2, L1
03S/18E-11A01S	003S018E11A001S	--	--	--	--	--	--	--	1965	--	--	--	**12,300**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
03S/18E-3Q01		--	--	--	--	--	--	--	May-52	1,230	--	8.1	**713**	--	51	8	216	--	342	--	66	202	--	--	1.8	--	0.3	--	--	160	2, L1
04S/16E-29R01		33.7902952	-115.3202862	--	--	--	--	--	May-61	1,230	--	8.3	**730**	--	--	1	274	4.3	290	18	165	110	**4.4**	--	5.6	--	1.2	--	--	3	2, L2
04S/16E-30D01		33.8008503	-115.3347034	--	--	--	--	--	Mar-61	925	--	8	**584**	--	17	1	179	2.7	82	0	219	90	3.6	--	9.3	--	0.6	--	--	--	2, L2
04S/16E-31D01		--	--	--	--	--	--	--	Oct-61	1,060	--	8	**626**	--	16	0	201	2.7	134	0	212	96	**9.5**	--	5.6	--	0.6	--	--	40	2, L2
04S/16E-32D01		--	--	--	--	--	--	--	Jun-61	925	--	7.1	**925**	--	14	0	176	2	63	0	171	113	**7.9**	--	1.2	--	0.4	--	--	35	2, L2
04S/17E-6C01		33.85918308	-115.2394237	--	--	--	--	--	Sep-61	6,900	--	7.4	**4,160**	--	393	14	1130	18	49	0	**442**	**2100**	2.9	--	9.3	--	1.8	--	--	1040	2, L1
05S/14E-24R01		--	--	--	--	--	--	--	Jan-33	--	--	--	**987**	--	--	--	--	--	--	--	--	**398**	--	--		--	--	--	--	82.5	2, L2
05S/15E-12N01		33.7440238	-115.3781377	--	--	--	--	--	May-61	720	--	7.9	424	--	14	0	129	2.7	88	0	115	74	**8.7**	--	8.7	--	0.3	--	--	35	2, L2
05S/15E-13B01		--	--	--	--	--	--	--	May-61	1,560	--	7.8	**865**	--	49	5	251	5.5	67	0	128	**351**	**6.8**	--	6.8	--	0.6	--	--	143	2, L2
05S/15E-1L01		--	--	--	--	--	--	--	Mar-60	660	--	**8.7**	445	--	72	10	130	1.6	59	7	112	69	**12**	--	1.9	--	0.5	--	--	221	2, L2
05S/15E-27H01		--	--	--	--	--	--	--	May-60	2,960	--	--	**2,072**	--	7.3	--	--	--	76	0	--	**782**	4	--	--	--	--	--	--	455	2, L2
05S/15E-29F01		--	--	--	--	--	--	--	Nov-61	--	--	--	274	--	8	12	2	2.3	204	0	9	14	3.9	--	25	--	0.3	--	--	40	2, L2
05S/15E-29F01S	005S015E29F001S	--	--	--	--	--	--	--	1979	--	--	--	274	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
05S/16E-10Z01		--	--	--	--	--	--	--	Dec-17	--	--	--	**3,460**	--	399	7.3	699	0	1950	129	**286**	8.8	--	--	--	--	--	0.4	--	1020	2, L2
05S/16E-18M01		--	--	--	--	--	--	--	Jul-61	748	--	**8.6**	**459**	--	5	0	158	0.8	67	12	122	85	**8.8**	--	9.9	--	0.4	--	--	13	2, L2
05S/16E-22N01		--	--	--	--	--	--	--	Dec-61	2,410	--	8	**1,310**	--	72	0	409	4.7	21	0	144	**645**	3.1	--	5.6	--	0.9	--	--	178	2, L2
05S/16E-25F01		--	--	--	--	--	--	--	May-58	1,170	--	8	**648**	--	40	--	200	--	92	0	120	238	--	--	3.7		0.9	--	--	--	2, L1
05S/16E-32M01		--	--	--	--	--	--	--	Nov-61	88	--	8.2	**532**	--	12	0	16	16	43	0	162	124	**7.4**	--	3.7	--	0.7	--	--	30	2, L2
05S/16E-36M01		--	--	--	--	--	--	--	Nov-59	808	--	8.3	**524**	--	20	2	159	4.3	116	6	113	131	**5.2**	--	6.2		0.7	--	--	60	2, L1
05S/16E-5B01		--	--	--	--	--	--	--	May-61	865	--	7.9	**516**	--	16	0	161	3.1	107	0	147	94	**7**	--	**12**	--	0.2	--	--	40	2, L2
05S/16E-5B02		--	--	--	--	--	--	--	May-61	687	--	7.5	400	--	9	0	129	1.6	79	0	108	74	**8.7**	--	10	--	0.4	--	--	23	2, L2
05S/16E-6N01		--	--	--	--	--	--	--	Sep-61	704	--	--	390	--	8.4	0.5	134	0	110	73	82	8.1	**10**	--	10	--	0.5	--	--	23	2, L2
05S/16E-7M01		33.749171	-115.3573315	--	--	--	--	--	Aug-61	717	--	8.2	418	--	12	0	134	2.3	79	0	105	82	**6.8**	--	**14**	--	0.3	--	--	30	2, L2
05S/16E-7M02		--	--	--	--	--	--	--	Jul-61	717	--	8.7	416	--	6	0	143	1.6	55	12	106	89	**6.9**	--	1.9	--	0.3	--	--	15	2, L2
05S/16E-7P01		--	--	--	--	--	--	--	May-59	700	--	7.6	420	--	8	0.6	141	2.6	88	0	105	78	**7.8**	--	**12**	--	0.3	--	--	23	2, L2
05S/16E-8F01		--	--	--	--	--	--	--	May-57	806	--	8	481	--	8	2	156	2.1	109	0	140	82	**8**	--	3	--	0.6	--	--	--	2, L2
05S/17E-20F01		--	--	--	--	--	--	--	Oct-58	1,320	--	7.4	**803**	--	50	6	225	0.7	104	0	241	203	1.8	--	2.1	--	0.1	--	--	150	2, L1
05S/17E-30F01		--	--	--	--	--	--	--	Jan-60	--	--	8.1	**695**	--	30	--	240	--	90	0	155	225	--	--	--	--	0.6	--	--	75	2, L1
05S/17E-30P01		--	--	--	--	--	--	--	May-57	1,160	--	8	**783**	--	12	2	240	75	420	0	89	150	0.3	--	2	--	0.4	--	--	38	2, L1
06S/17E-3M01		--	--	--	--	--	--	--	Jan-59	--	--	7.4	--	--	26	--	--	--	79	--	--	131	--	--	--	--	2.5	--	--	--	2, L1
06S/19E-33A01S	006S019E33A001S	--	--	--	--	--	--	--	1959	--	--	--	**2,150**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
06S/20E-33C01S	006S020E33C001S	33.61002387	-114.89968800	--	--	--	--	--	Apr-79	--	--	--	**2,330**	38	67	0.6	800	16	--	--	**450**	**950**	**6.3**	--	--	--	--	--	--	170	1
Federal Drinking Water Standards4										--	--	6.5 - 8.5[S]	500[S]	--	--	--	--	--	--	--	250[S]	250[S]	4[P]	1[P]	10[P]	10[P]	--	300[S]	50[S]	--	
California Drinking Water Standards[4,9]										--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	45[P]	50[P]	--	--	--	--	

NOTES

--	Data not provided/No published drinking water standard
1	Data as provided in the USGS National Water Information System Database - http//:nwis/waterdata.usgs.gov/ and the Department of Water Resources Database - http://wdl.water.ca.gov/gw/
2	Data provided by DWR Bulletin 91-7 (May 1963)
3	Data provided by DWR Bulletin 19-24 (August 1979)
4	Drinking Water Standards from "Drinking Water Standards and Health Advisories Table", USEPA, June 2007
5	California Drinking Water Standards use the Federal Standards unless otherwise noted.
P	Primary Drinking Water Standard Maximum Contaminant Level (MCL)
S	Secondary Drining Water Standard for Odor, Taste, Appearance
8.7	Bolded values exceed either primary or secondary drinking water standards.

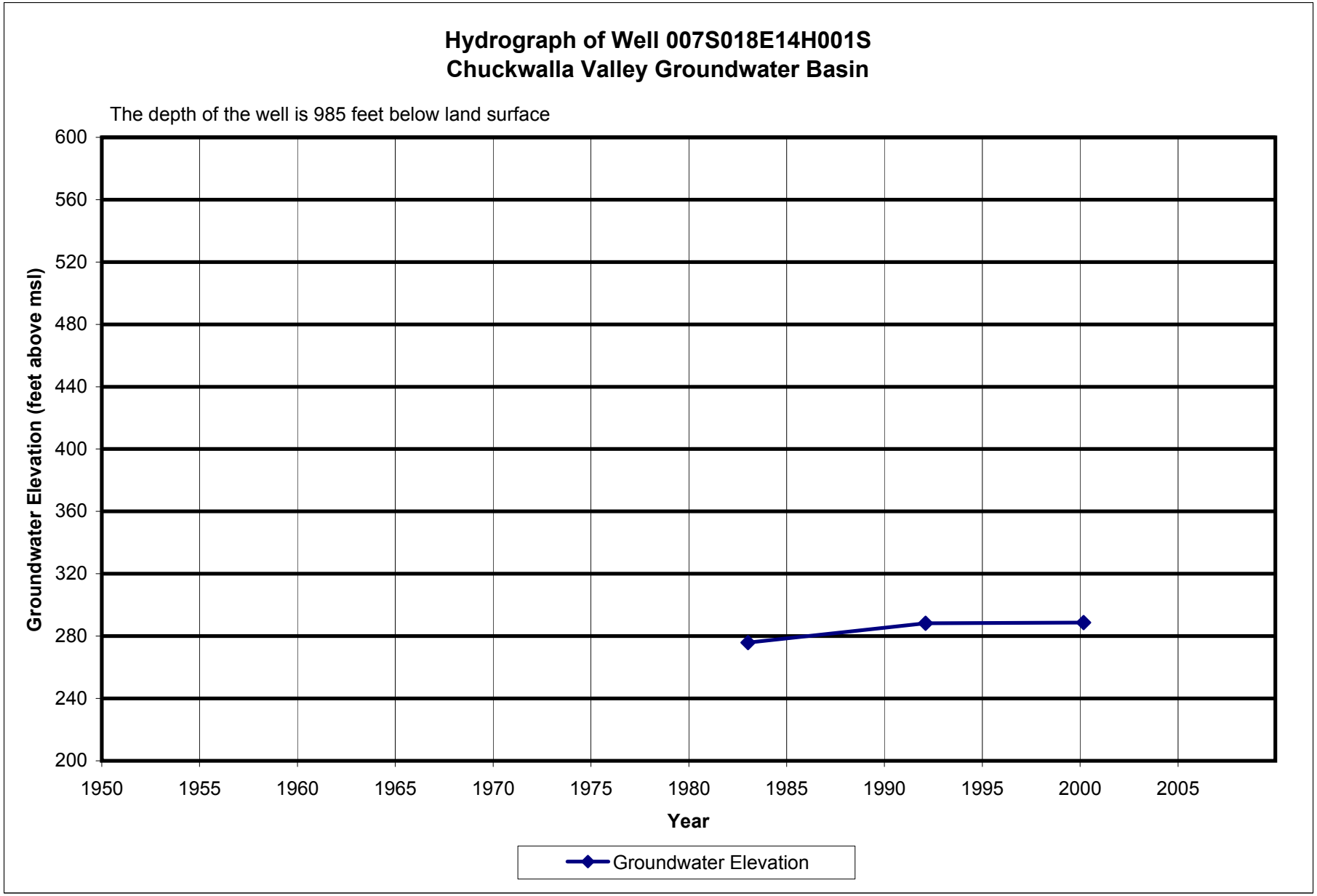
DEFINITIONS

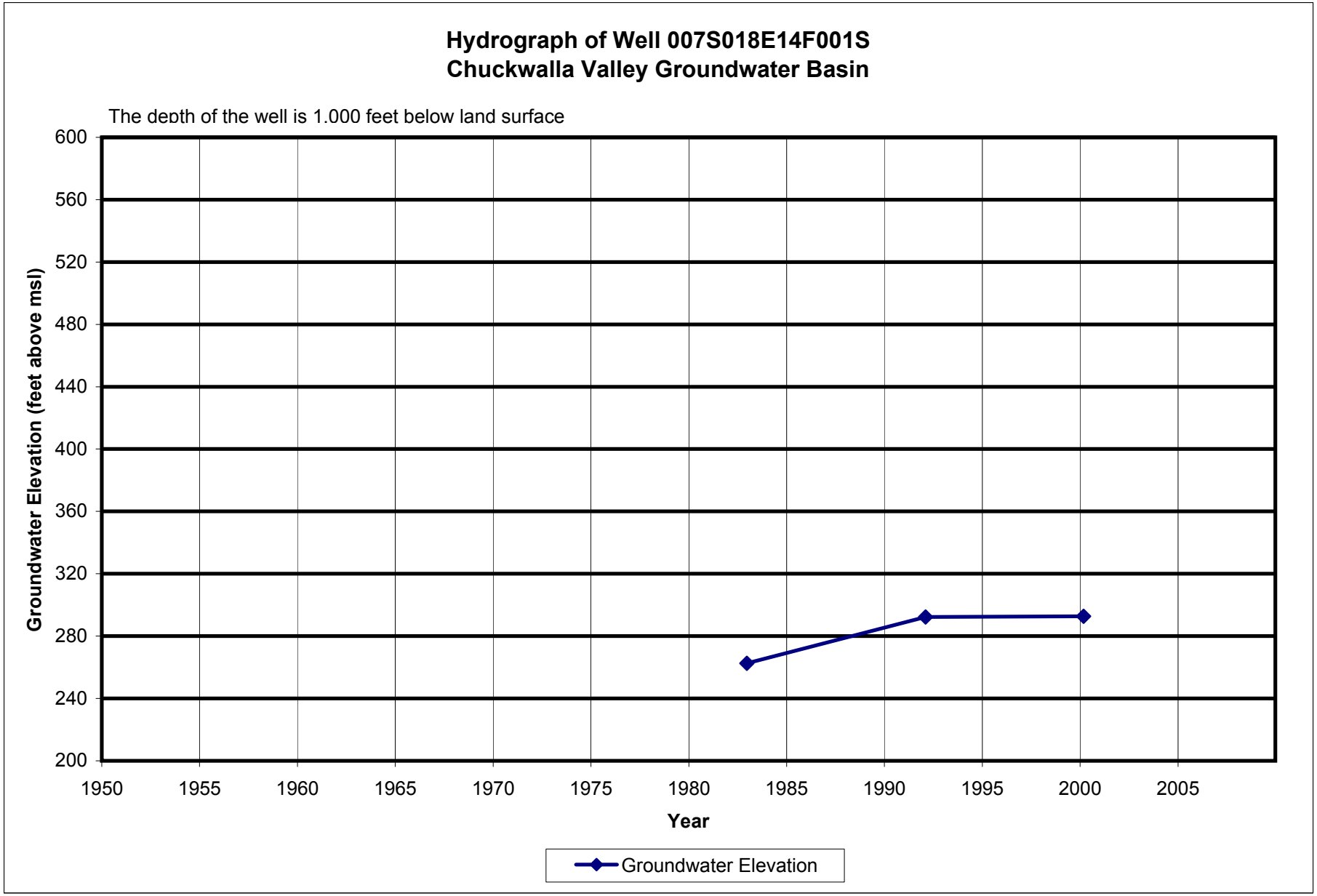
NAD-83	North American Datum 1983
mg/L	Miligram per Liter
ug/L	Microgram per Liter

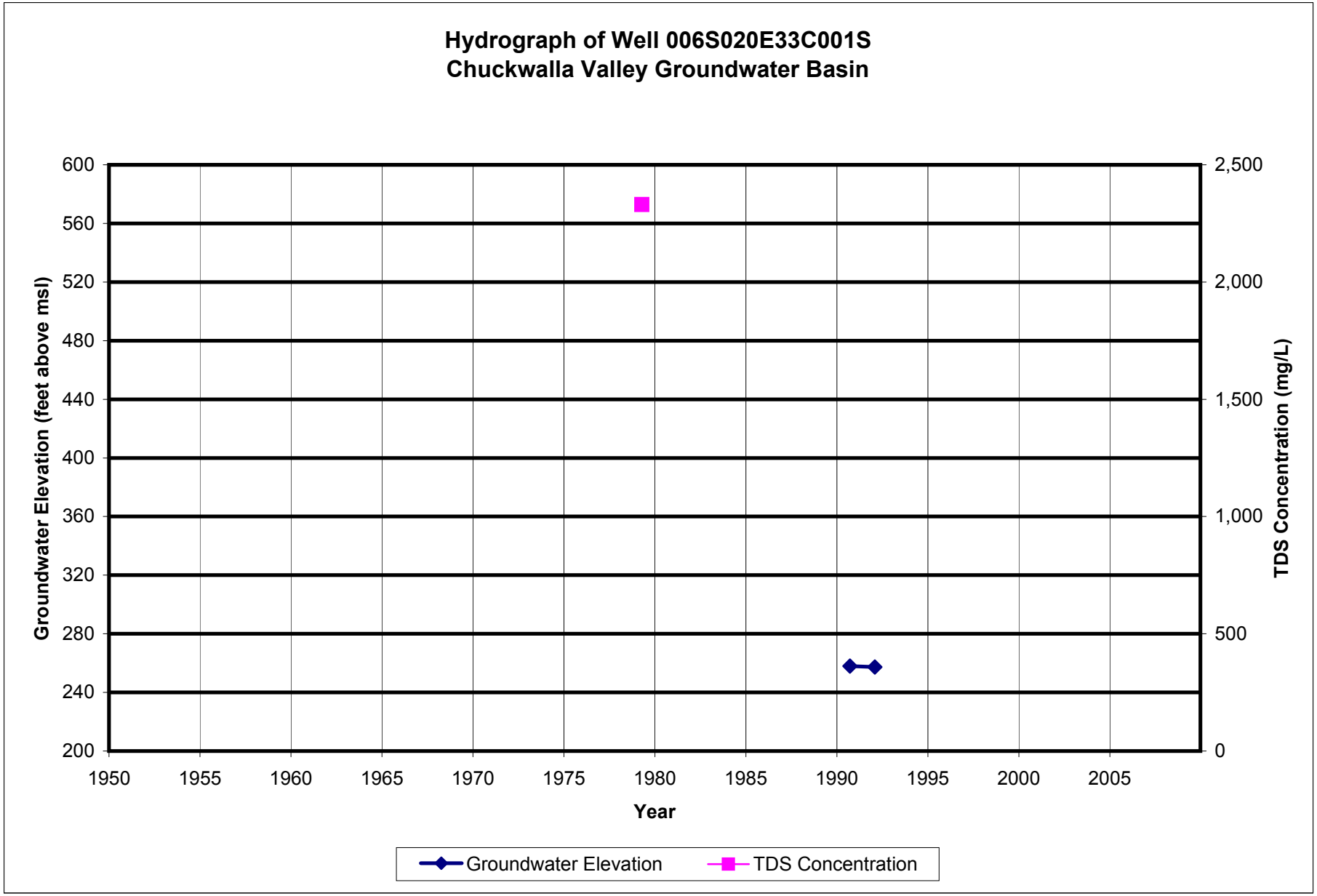
LOCATIONS

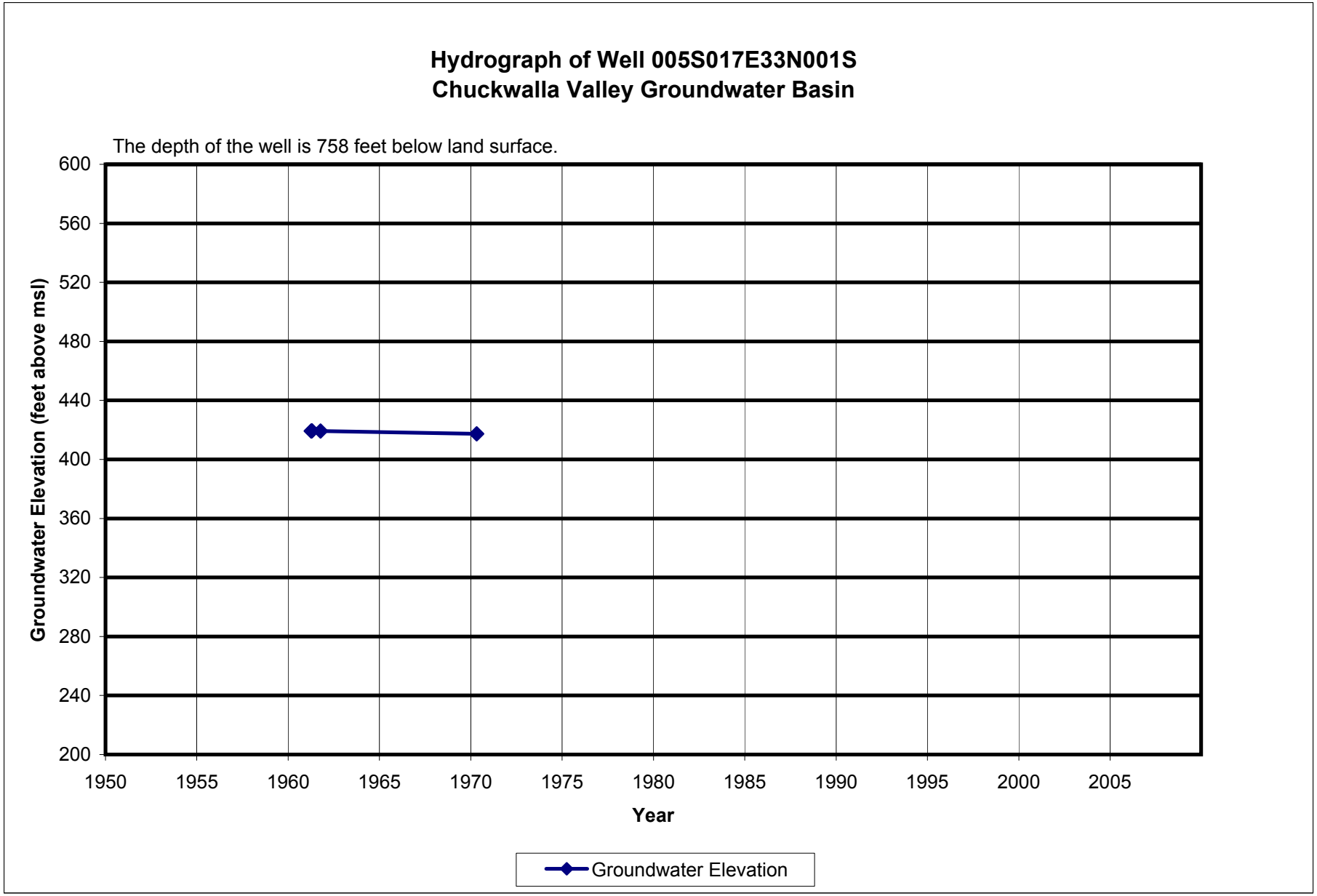
L1	Palen Valley
L2	Upper Chuckwallah Valley

Hydrographs


Hydrograph of Well 007S018E14H001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 985 feet below land surface
Groundwater Elevation (feet above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

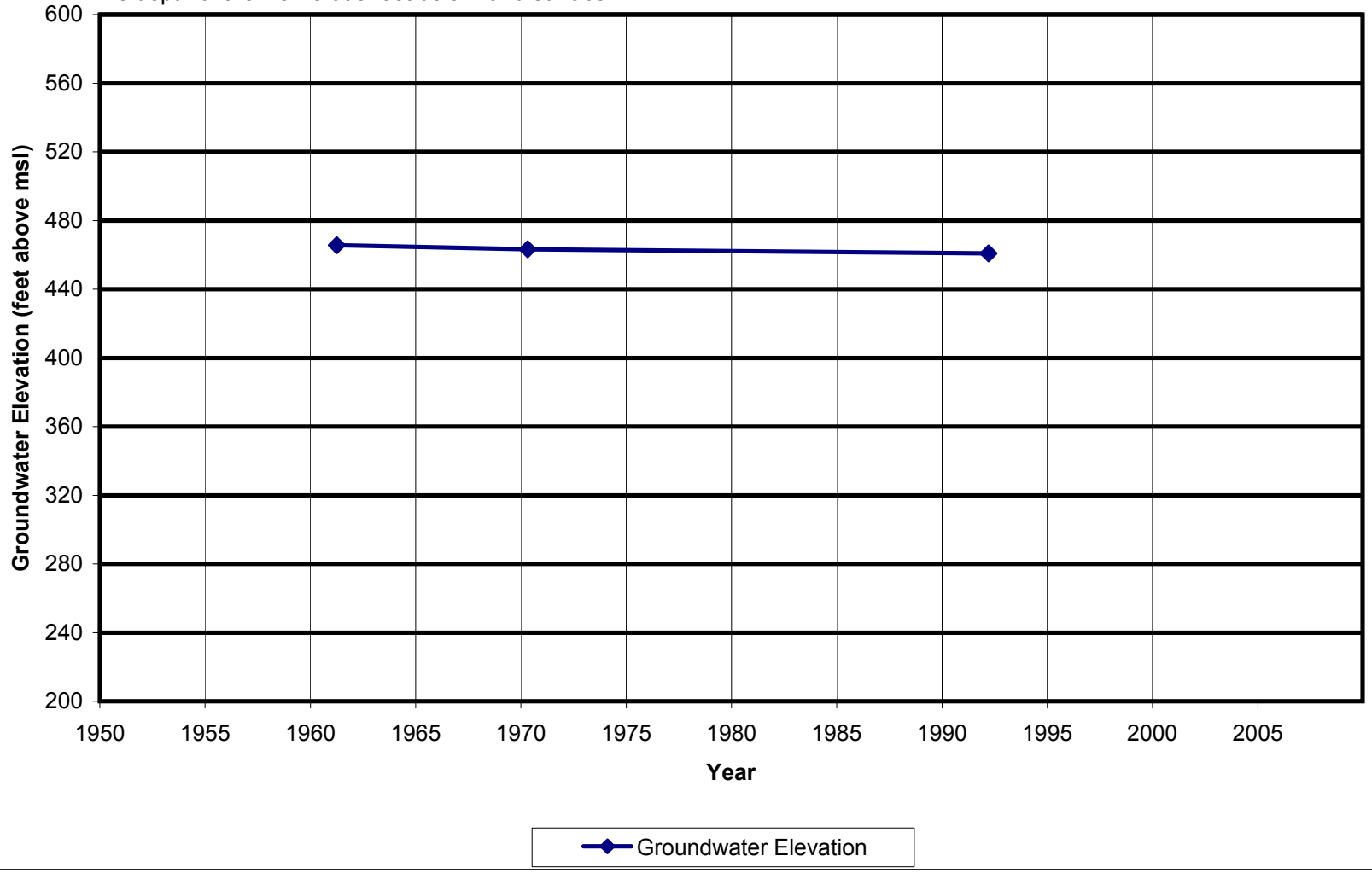

Hydrograph of Well 007S018E14F001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 1.000 feet below land surface
Groundwater Elevation (feet above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

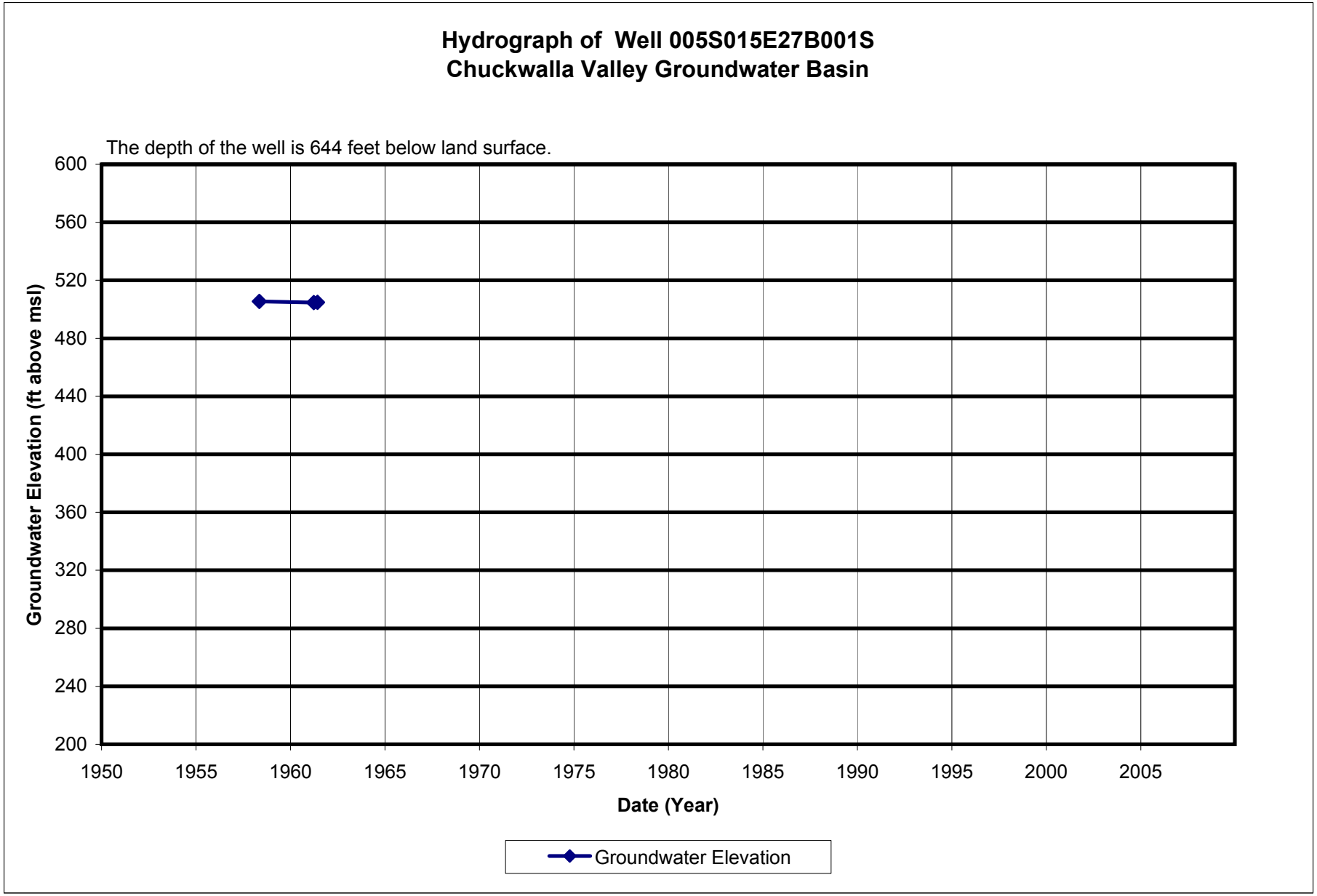

Hydrograph of Well 006S020E33C001S
Chuckwalla Valley Groundwater Basin
Groundwater Elevation (feet above msl)
600
560
520
480
440
400
360
320
280
240
200
TDS Concentration (mg/L)
2,500
2,000
1,500
1,000
500
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation
TDS Concentration

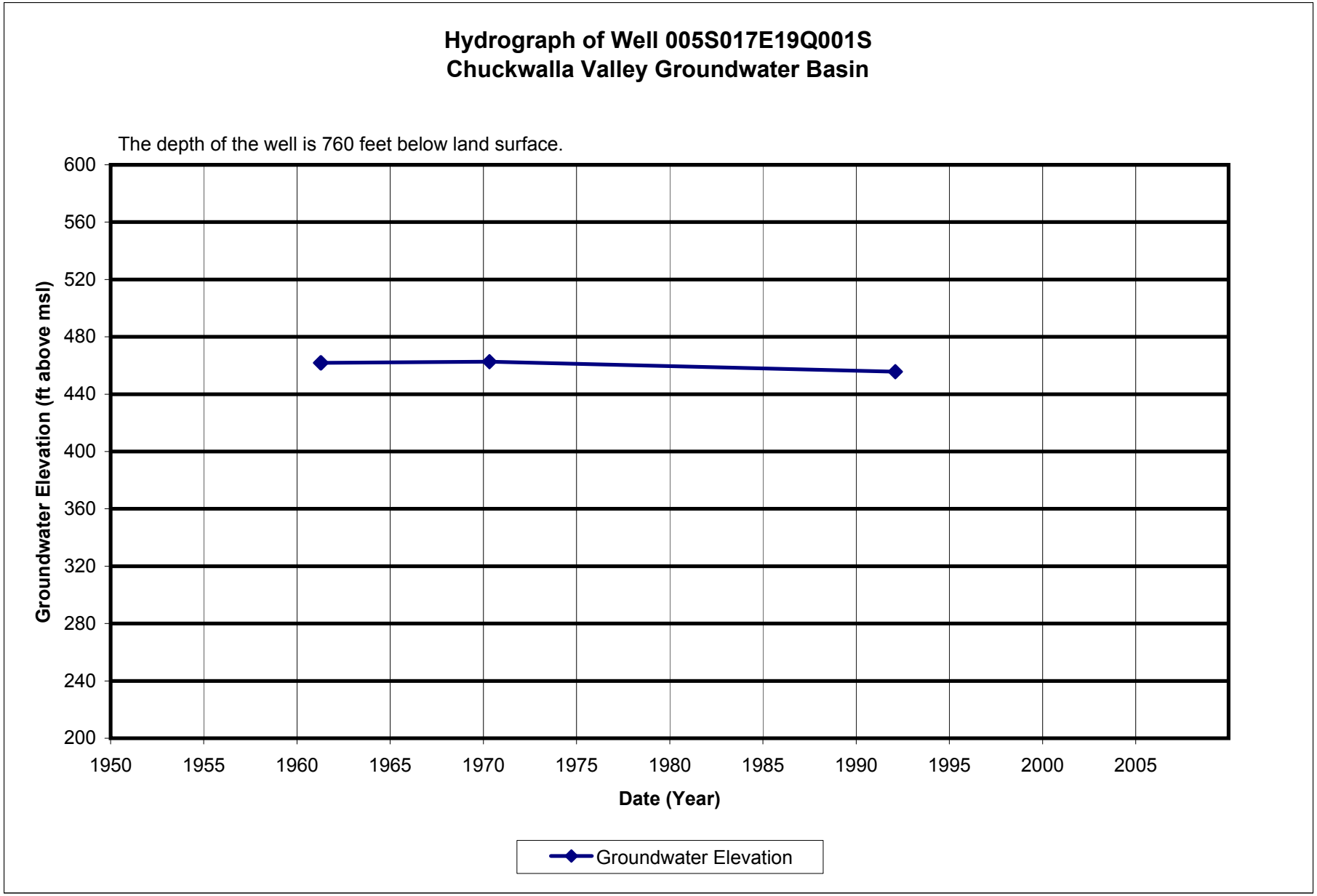

Hydrograph of Well 005S017E33N001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 758 feet below land surface.
Groundwater Elevation (feet above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

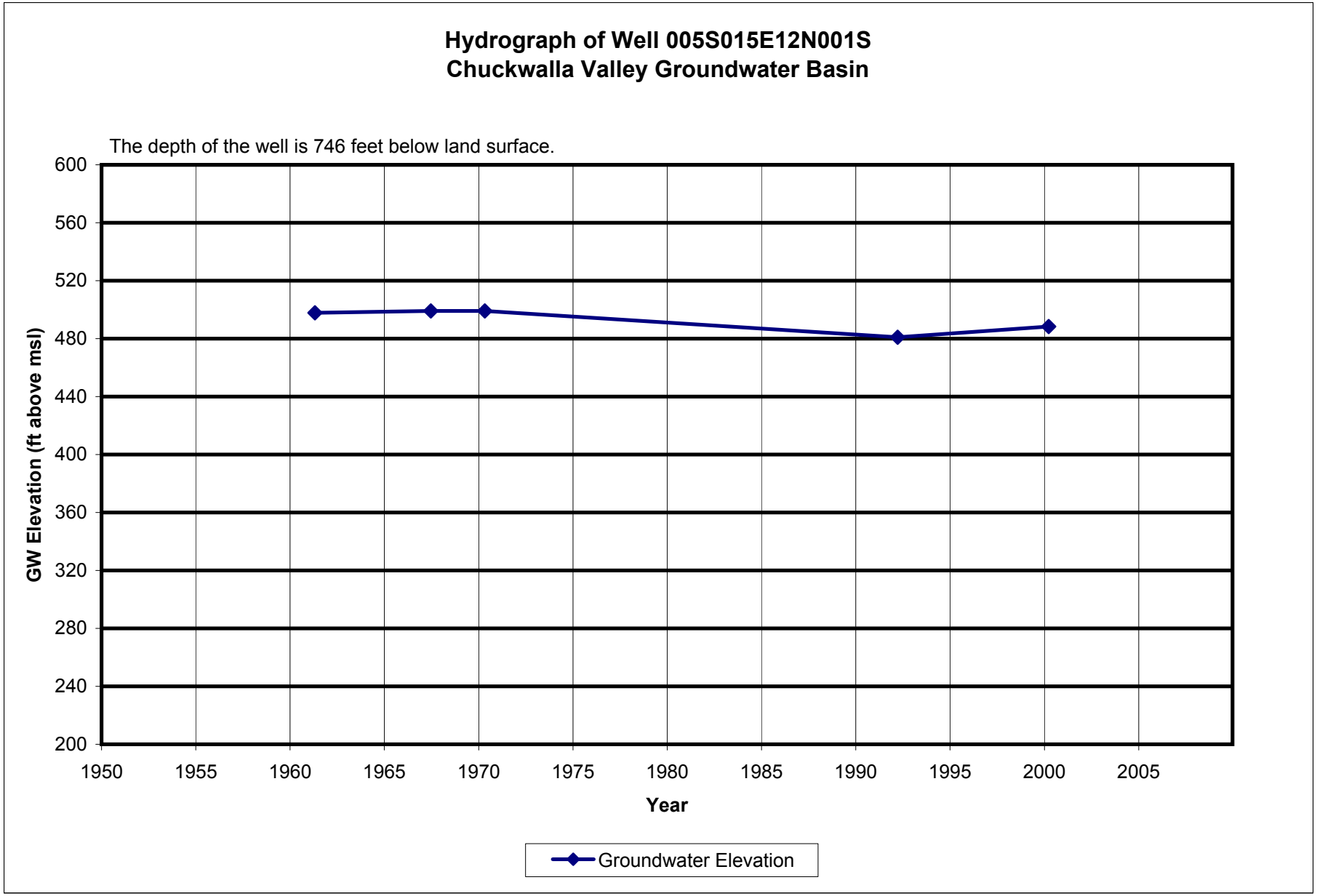
Hydrograph of Well 005S017E17F001S
Chuckwalla Valley Groundwater Basin

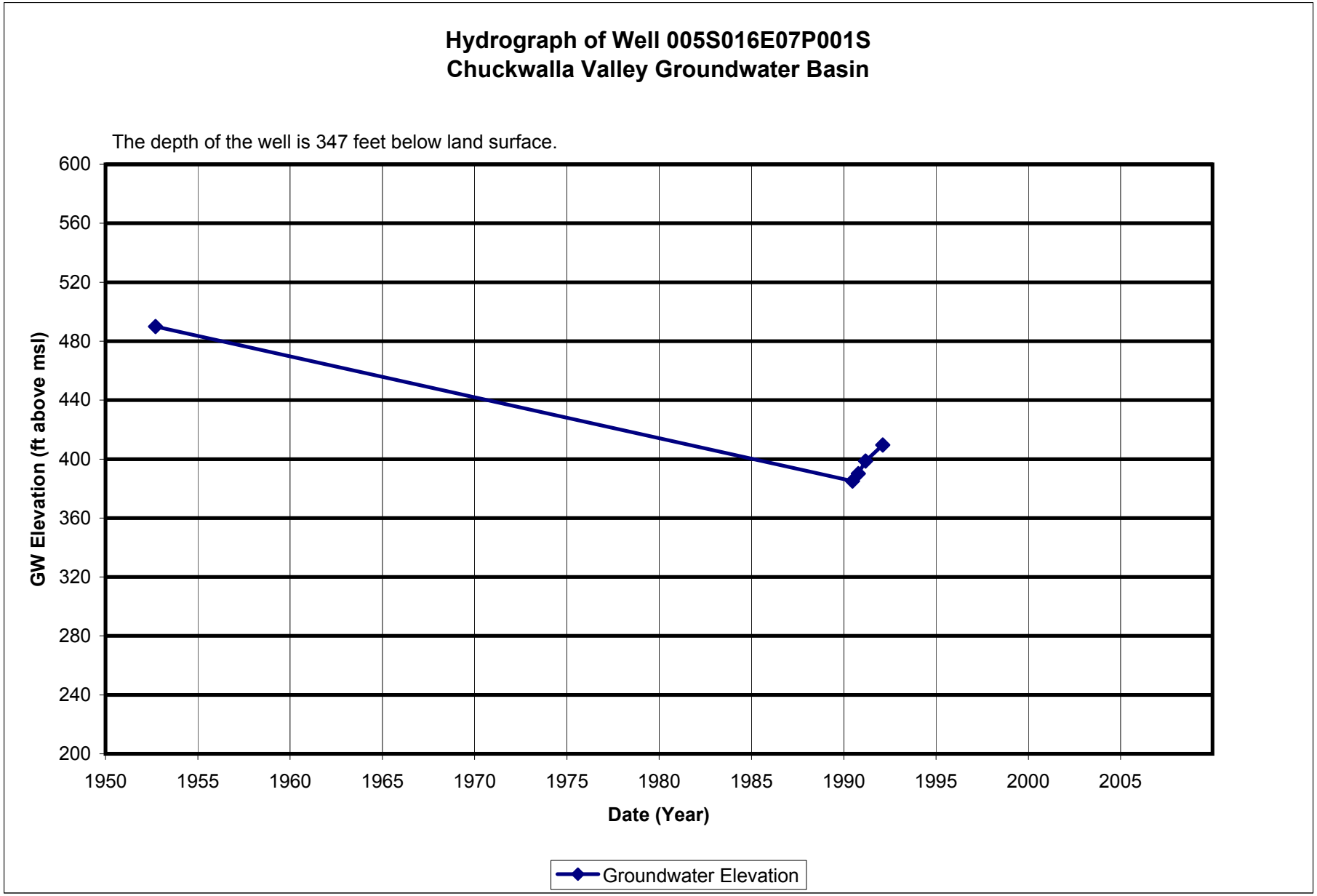
The depth of the well is 698 feet below land surface.

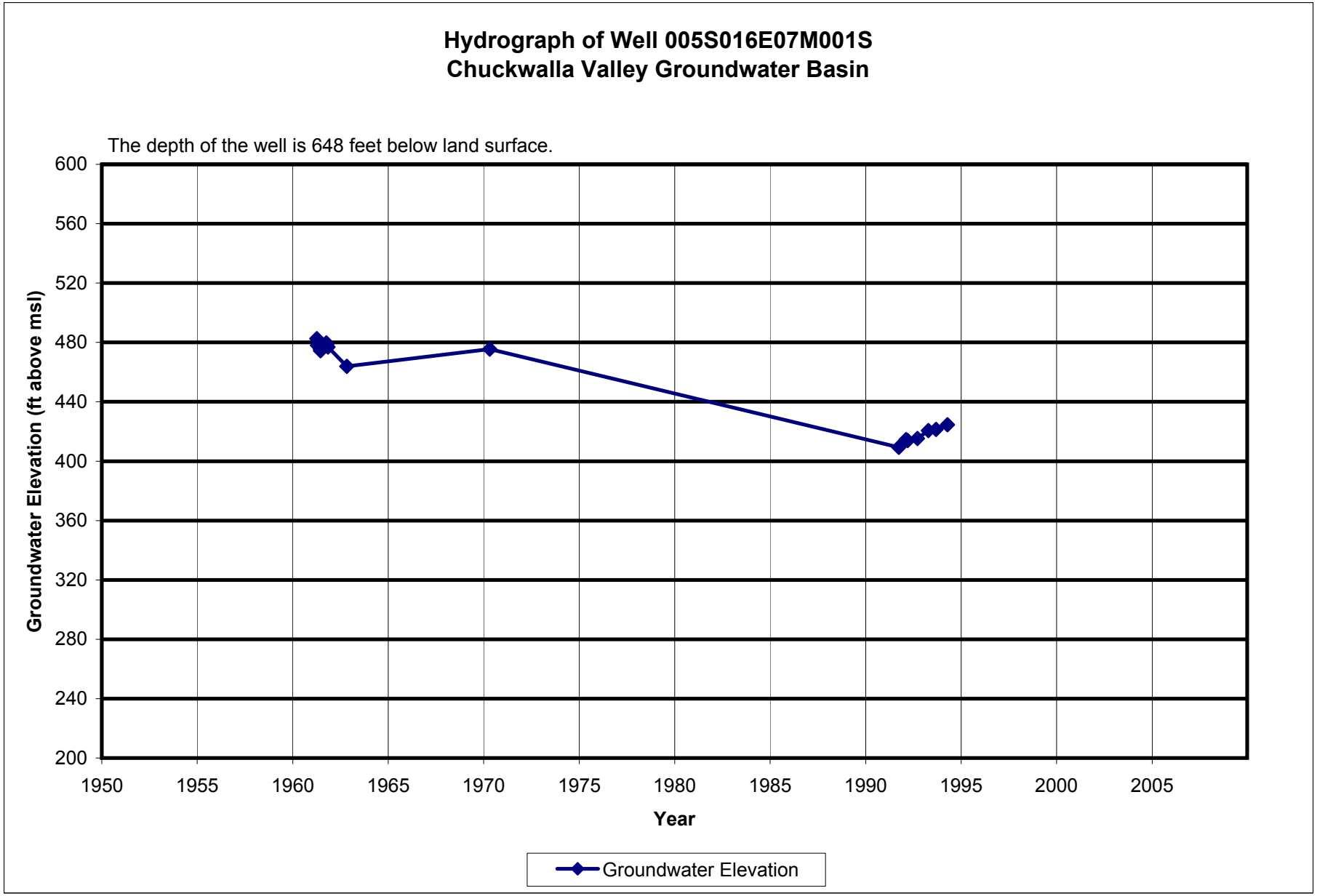


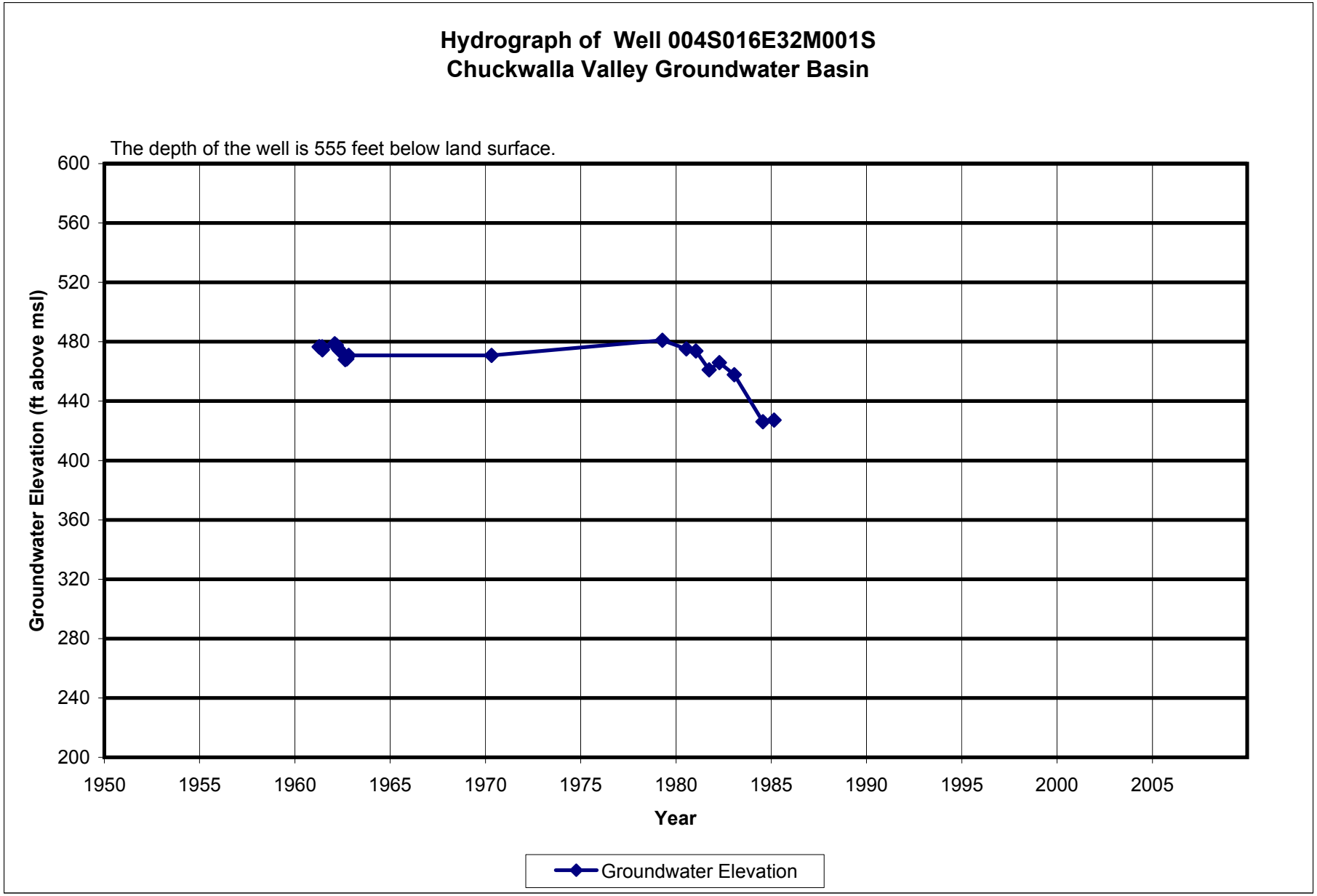

Hydrograph of Well 005S015E27B001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 644 feet below land surface.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Date (Year)
Groundwater Elevation


Hydrograph of Well 005S017E19Q001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 760 feet below land surface.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Date (Year)
Groundwater Elevation


Hydrograph of Well 005S015E12N001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 746 feet below land surface.
GW Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

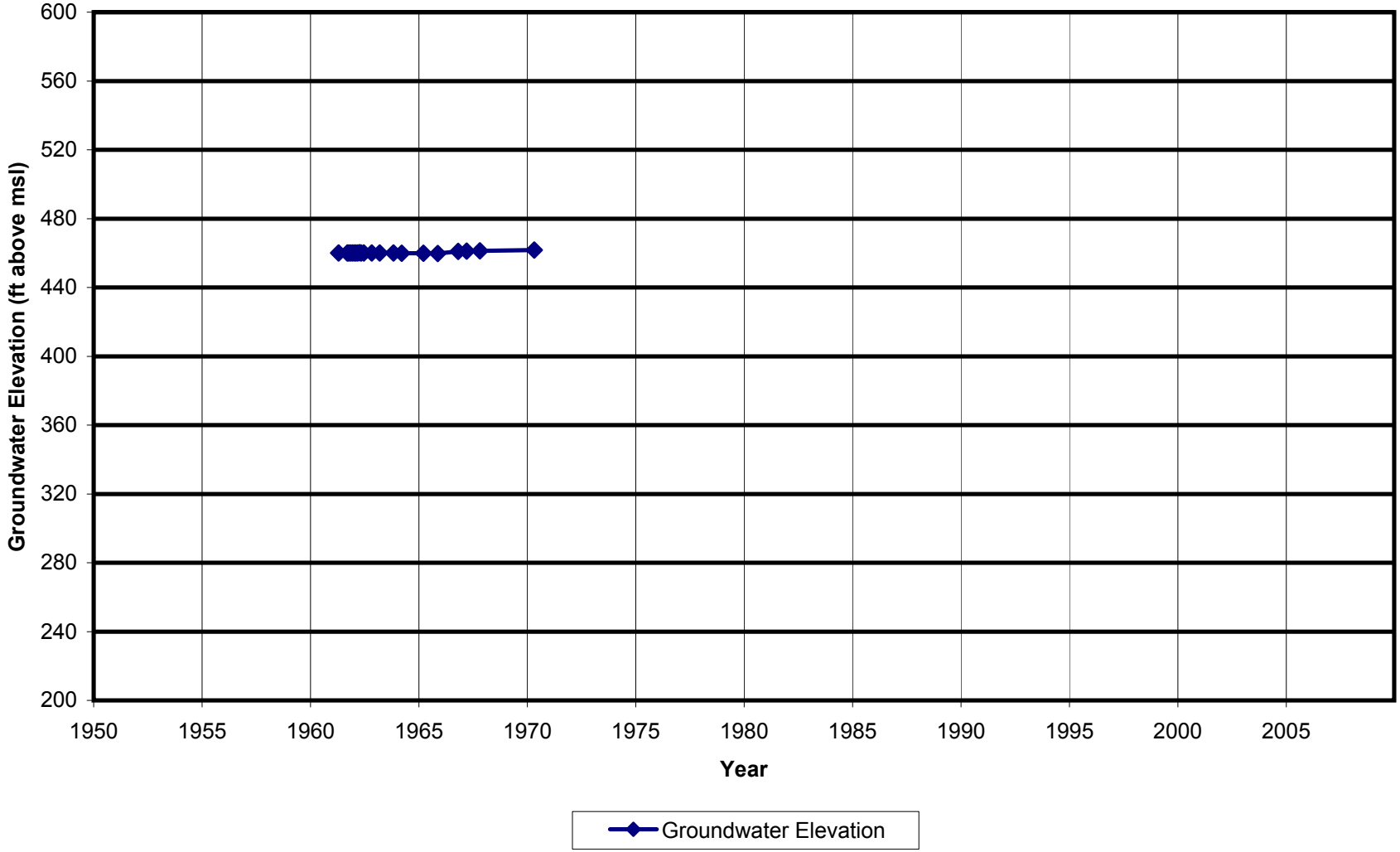

Hydrograph of Well 005S016E07P001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 347 feet below land surface.
GW Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Date (Year)
Groundwater Elevation

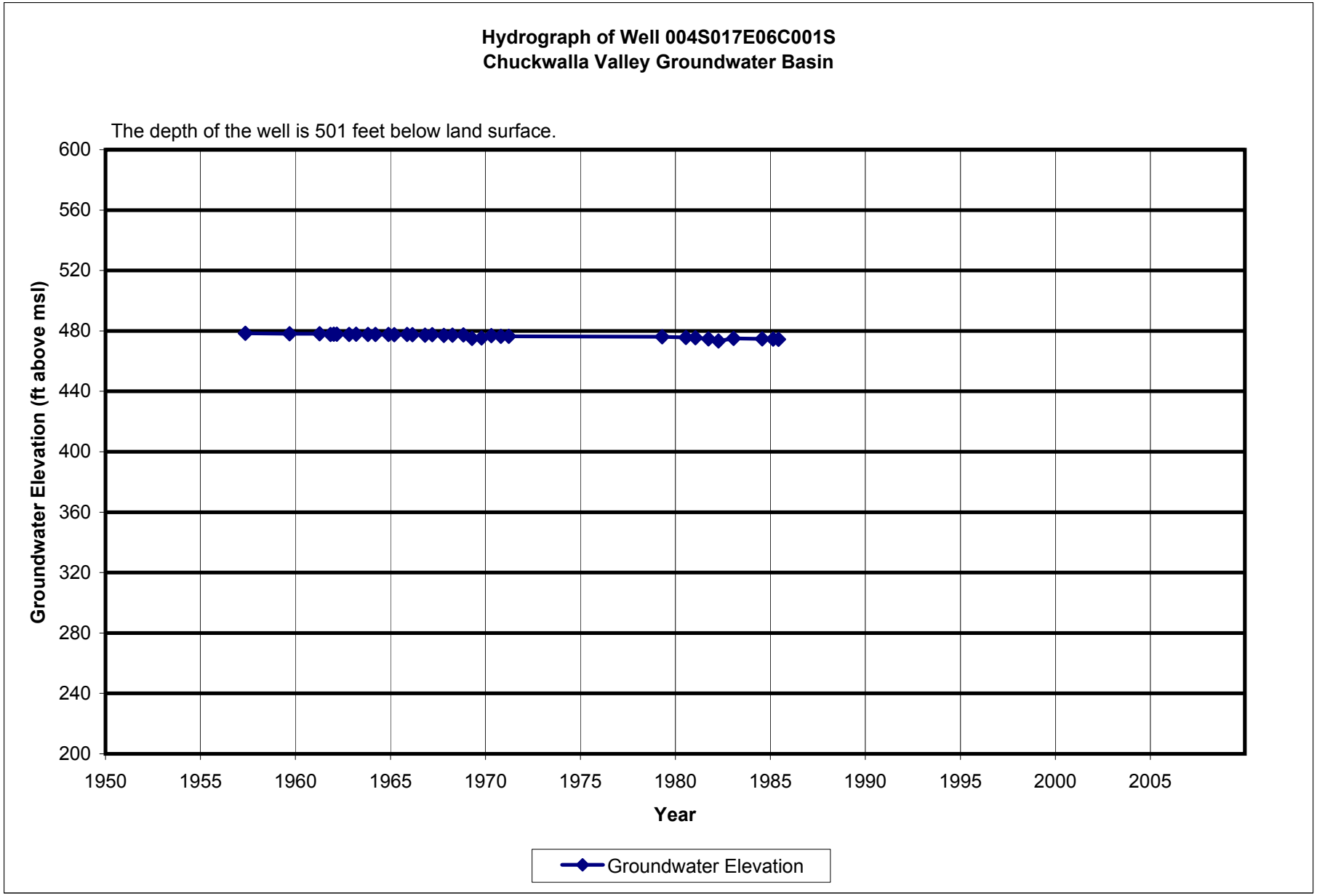

Hydrograph of Well 005S016E07M001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 648 feet below land surface.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

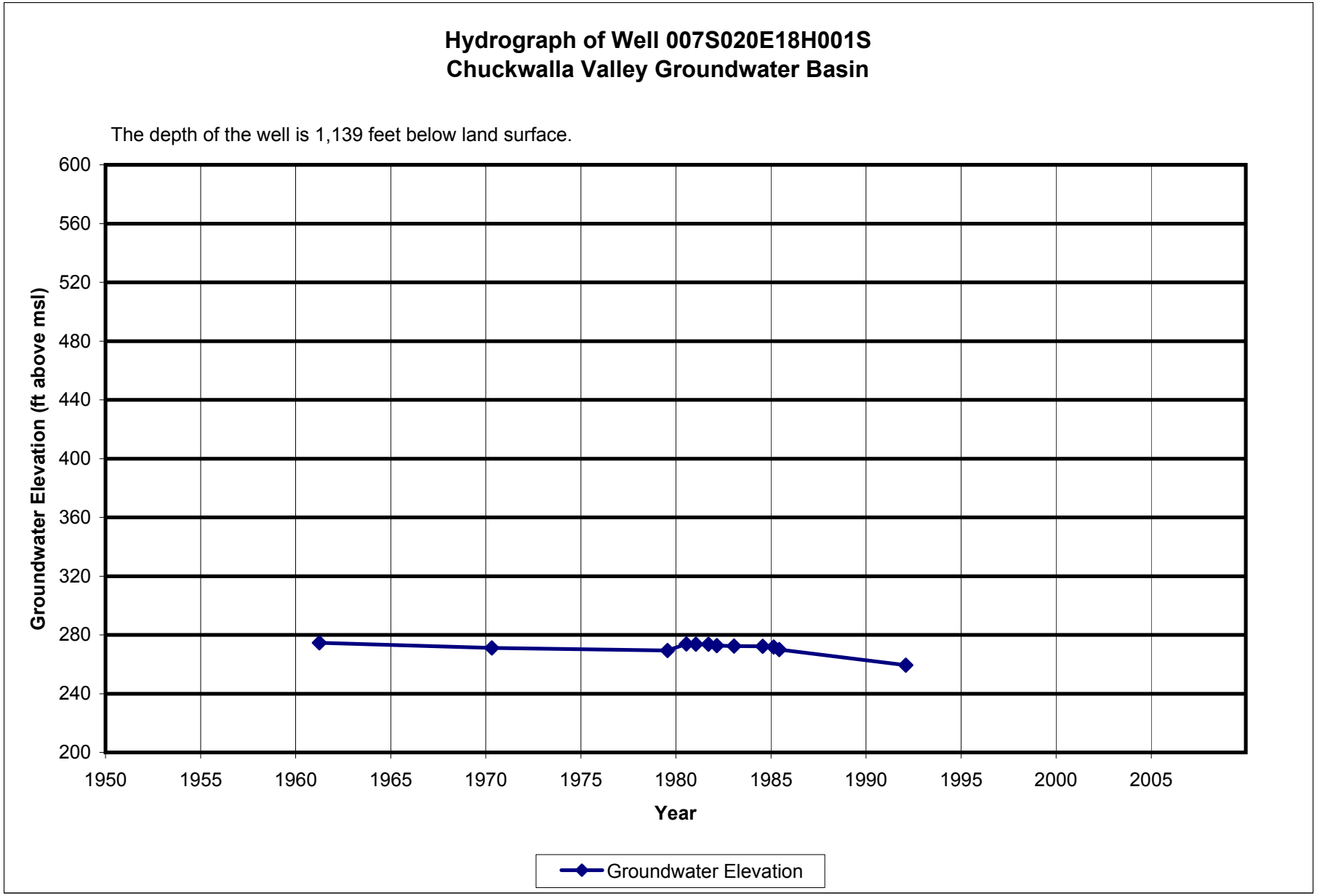

Hydrograph of Well 004S016E32M001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 555 feet below land surface.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

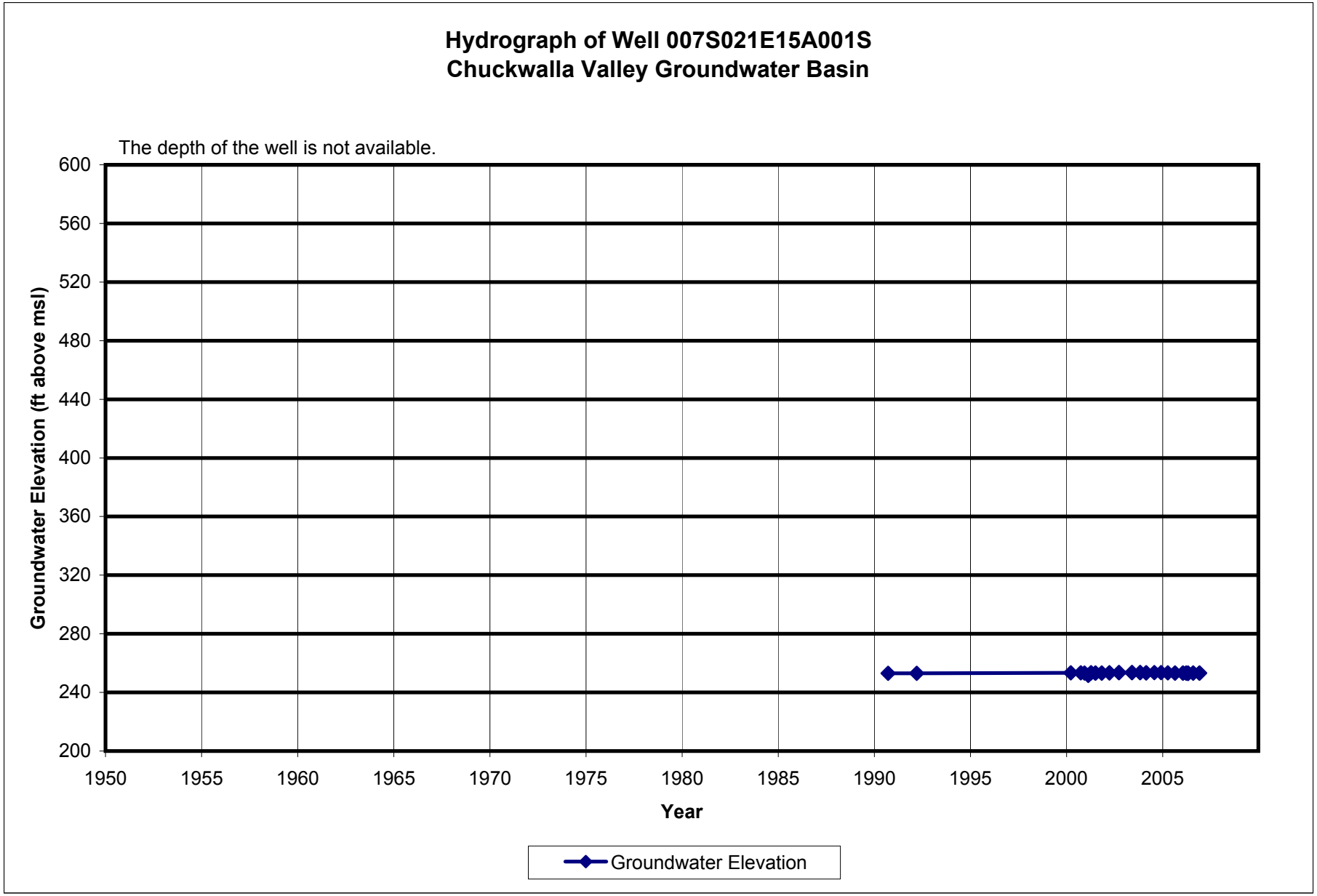
Hydrograph of Well 004S016E29R001S
Chuckwalla Valley Groundwater Basin

The depth of the well is 109.7 feet below land surface.




Hydrograph of Well 004S017E06C001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 501 feet below land surface.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation


Hydrograph of Well 007S020E18H001S
Chuckwalla Valley Groundwater Basin
The depth of the well is 1,139 feet below land surface.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation


Hydrograph of Well 007S021E15A001S
Chuckwalla Valley Groundwater Basin
The depth of the well is not available.
Groundwater Elevation (ft above msl)
600
560
520
480
440
400
360
320
280
240
200
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Groundwater Elevation

DWR Drillers Logs of Wells

Table 3.--Drillers' logs of wells

4/15-13C1. The Metropolitan Water District of Southern California. Altitude about 683 ft. Drilled by Metropolitan Water District in 1932. 16-inch casing, perforated 220-248 and 317-328 ft. Yield 450 gpm.

Sand and rock -------	6	6	Sand and gravel ------	39	254
Sand, cemented ------	23	29	Sand, "heaving" ------	58	312
Clay and gravel -----	15	44	Sand and gravel ------	12	324
Gravel ----------	5	49	Sand, "heaving" ------	16	340
Sand, cemented ------	137	186	Sand and clay --------	91	431
Sand, fine ----------	29	215	Clay, red ----------	21	452

4/16-31D1. John Penfield. Altitude about 595 ft. Drilled in 1961. 15-inch casing. Yield 2,328 gpm with 52 ft drawdown.

No record ----------	300	300
Sand, fine to very coarse, quartz predominating, subrounded, dark fragments (volcanics?) increasing with depth, occasionally interbedded with silt ----------	20	320
Sand, fine to coarse, interbedded with light-tan silt --------	20	340
Sand and gravel, coarse to fine ----------	20	360
Sand, fine to very coarse, interbedded with silt, increasing with depth ----------	60	420
Sand and gravel, very coarse to fine, quartz predominating, interbedded with light-gray-tan silt ----------	100	520
Sand, fine to coarse ----------	20	540
Silt and clay, interbedded with medium to coarse sand --------	20	560
Sand, very coarse, interbedded with silt ----------	20	580
Sand, fine to medium ----------	20	600

4/16-32D1. Walter Palladine. Altitude about 555 ft. Drilled by James E. Wright, Jr., in 1953. 14-inch casing, perforated 137-597 ft. Yield 2,750 gpm with 34 ft drawdown. Well drilled to 733 ft, backfilled and cased to 610 ft.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface material ----	5	5	Clay, brown, fine sand layers ------	129	373
Sand and gravel; layers	45	50	Gravel, coarse, and boulders ---------	222	595
Sand, coarse, gravel	5	55	Gravel, coarse -----	80	675
Boulders, small -----	10	65	Bedrock ----------	58	733
Sand, coarse; gravel; layers ----------	64	129			
Clay ----------	115	244			

4/16-32M1. Walter Palladine. Altitude about 555 ft. Drilled by Vanderpool Drilling Co. in 1958. 14-inch casing to 255 ft, 12-inch casing 255 to 555 ft, perforated 265-555 ft. Yield 2,000 gpm.

Sand, fine ----------	40	40	Sand, coarse, with clay ----------	180	350
Sand ----------	40	80	Sand, extra coarse	118	468
Sand, coarse --------	30	110	Gravel, small, in clay ----------	87	555
Clay, sandy ---------	60	170			

4/17-6C1. Harold Stark. Altitude about 500 ft. Drilled by the Metropolitan Water District of Southern California in 1932. 16-inch casing, perforated 63-95 and 245-252 ft. Bailer-tested 106 gpm with no drawdown.

Clay and gravel -----	17	17	Gravel ----------	9	88
Clay, yellow, hard --	14	31	Clay and gravel ----	19	107
Clay and gravel -----	5	36	Clay, brown, hard, sticky ----------	138	245
Clay, brown,hard ----	11	47	Clay and gravel ----	7	252
Clay and gravel -----	15	62	Clay, brown, hard, sticky ----------	249	501
Clay ----------	1	63			
Gravel ----------	13	76			
Clay and gravel -----	3	79			

5/14-24R1. The Metropolitan Water District of Southern California. Altitude about 1,072 ft. Drilled by Metropolitan Water District in 1933. 62-inch uncased hole.

	Thickness (feet)	Depth (feet)
Sand; gravel and boulders	344	344
Boulders	46	390
Sand; gravel and boulders	159	549
Boulders or "ledge"	3	552
Sand; gravel; boulders	16	568
Boulders, cemented	27	595
Sand, hard; gravel	13	608
Sand; gravel; small boulders	27	635
Gravel, water-bearing	15	650
Gravel, cemented; boulders	7	657
Sand, brown; gravel	3	660
Sand; gravel and boulders	8	668
Sand, cemented; gravel	6	674
Gravel and boulders	3	677
Gravel, cemented; boulders	52.9	729.9
Boulders	2.9	732.8

5/15-1L1. Franna Farms. Altitude about 640 ft. Drilled by F. R. Squire in 1960. 16-inch casing, perforated 348.75-784.05 ft. Yield 3,150 gpm with 74 ft drawdown after 30 hours.

Topsoil; clay and silt	20	20
Gravel, small; hard sand	49	69
Sand, hard; rock	46	115
Clay and sand, "broken"	44	159
Sand, very fine; gravel, small; clay, "broken"	181	340
Sand, coarse; gravel, small to medium; clay, "broken"	340	680
Sand, coarse; gravel, small to medium	104	784
Clay	5.9	789.9

5/15-12N1. Frank Kanne. Altitude about 688 ft. Drilled in 1961. 16-inch casing, perforated 526-746 ft. Yield 1,900 gpm.

No record	150	150
Sand, fine to coarse, quartz and feldspar predominating	25	175
Sand, medium, angular	25	200
Sand, fine to very coarse, subrounded, quartz and feldspar predominating, few dark fragments; small amount of silt	100	300
Sand, fine to very coarse; clay	25	325
Gravel, fine; sand, medium to coarse, some very dark fragments; clay	75	400
Clay, light-gray, interbedded with fine to medium sand	25	425

5/15-12N1.--Continued.

	Thickness (feet)	Depth (feet)
Gravel, medium to coarse, subrounded, dark fragments increasing; interbedded occasionally with clay	25	450
Sand, very coarse, and medium gravel, interbedded with clay	50	500
Sand, very fine to coarse, quartz predominating, some dark fragments (volcanics?)	75	575
Sand, very fine, ran, interbedded with clay	25	600
Sand, fine to coarse, quartz predominating	45	645
Sand, fine to coarse, interbedded with gray clay	45	690
Clay, occasionally interbedded with medium to coarse sand	15	705
Sand, fine to medium, occasional fragments 1/8- to 1/4-inch diameter	25	730
Clay, light-gray	16	746

5/15-13B1. Franna Farms. Altitude about 650 ft. Drilled by F. R. Squire in 1959. 16-inch casing to 350 ft, 12-inch casing to 788 ft, perforated 215-788 ft. Yield approximately 3,200 gpm with 190 ft of drawdown after 10 hours of pumping.

Sand, fine; small gravel	120	120
Sand, fine; clay; broken formation with both	180	300
Sand, fine; small gravel; clay	50	350
Sand, coarse; gravel; clay; broken formation	438	788

5/15-27B1. California Division of Highways. Altitude about 900 ft. Drilled by Henderson and sons in 1954. 10-inch casing to 637 ft, perforated 553-625 ft.

Gravel; sand, silty	389	389
Gravel; sand, silty, with some broken rock	3	392
Loam, sandy; some pea gravel	17	409
Loam, black, sandy; small amount stagnant water	20	429
Loam; sand, coarse, angular; small amount water	124	553
Sand, coarse, silty, with some gravel up to 3/4 inch, increasing amount of water	14	567
Loam, sandy; sufficient water for drilling	10	577
Sand, coarse, silty; gravel up to 3/4 inch; alternate layers 6 to 8 ft	48	625
Sand, coarse, conglomeratic, "tight," with silty clay matrix	19	644

5/16-5B2. R. E. Anderson. Altitude about 548 ft. Drilled by owner in 1960. 14-inch casing to 305 ft, 12-inch casing 305 to 705 ft, perforated 224-705 ft. Yield 3,926 gpm with 48.5 ft drawdown.

	Thickness (feet)	Depth (feet)
Surface soil; sand; gravel	110	110
Clay, sandy; streaks of sand and cobbles	110	220
Clay, brown	45	265
Sand, coarse; gravel	45	310
Clay, brown	30	340
Clay, sandy	20	360
Sand, coarse	75	435
Gravel	35	470
Sand, coarse; gravel; streaks of cobblestone	245	715

5/16-6N1. A. E. Peterson. Altitude about 604 ft. Drilled by Armstrong and Fowler in 1960. 16-inch casing to 334 ft, 12-3/4 inch casing 334 to 722 ft, perforated 228-331 and 334-722 ft. Casing hung 1 ft off bottom. Yield 3,850 gpm with 54 ft drawdown.

Surface sand, clay and cobbles	120	120
Sand, fine, with streaks of clay	90	210
Sand, medium to coarse, with thin streaks of light-brown clay	150	360
Sand, fine; silt	50	410
Sand, medium to coarse, with streaks of clay	130	540
Sand, coarse, with streaks of conglomerate	183	723

5/16-7M2. H. C. Brown. Altitude about 611 ft. Drilled by owner in 1959. 14-inch casing to 300 ft, 12-inch casing 300 to 789 ft, perforated 280-789 ft. Yield 3,082 gpm with 83.1 ft drawdown.

Surface sand, clay streaks and gravel	90	90
Sand, buff to light-brown, fine to medium, quartzitic	115	205
Clay with streaks of fine to medium sand	75	280
Clay, buff to tan, with silty streaks	40	320
Sand, light-brown, medium to coarse, quartzitic, subangular, with streaks of clay at base	85	405
Clay, light-brown, with streaks of silt and fine sand	70	475
Sand, buff to tan, medium to coarse, with hard places in streaks, some basalt fragments noted	90	565
Sand, buff, coarse, with streaks of silty clay	105	670
Sand, light-tan to brown, cobbles in streaks, coarse, quartzitic, basalt and greenstone fragments noted, very high porosity and permeabilities	119	789

5/16-7P1. Southern Counties Gas Co. Altitude about 608 ft. Drilled by James E. Wright, Jr., in 1952. 10-inch casing to 296 ft, 8-inch 296 to 347 ft, perforated 248-296 and 299-347 ft.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface soil --------	5	5	Rock, large ---------	5	302
Sand and gravel, cemented ----------	155	160	Rock and gravel with clay streaks -------	15	317
Clay ----------	100	260	Rock; gravel --------	30	347
Gravel and clay in layers ----------	11	271			
Rock; gravel --------	26	297			

5/16-8F1. Desert Center Airport. Altitude about 560 ft. Drilled by Roscoe Moss Co. in 1942. 14-inch casing to 206 ft, perforated 103-168 and 172-188 ft. Yield 125 gpm with 62 ft drawdown.

Sand, coarse --------	82	82	Clay; gravel to 1 inch	12	168
Clay, sandy ---------	21	103	Sand, packed; clay ---	8	176
Sand; gravel to 1 inch	15	118	Sand, coarse ---------	12	188
Clay, sandy ----------	38	156	Clay, sandy ----------	18	206

5/16-8K1. Desert Center Airport. Altitude about 555 ft. Drilled by Roscoe Moss Co. in 1942. 14-inch casing to 212 ft, perforated 103-124, 162-178, and 180-198 ft. Yield 180 gpm with 20 ft drawdown.

Sand, coarse --------	84	84	Sand; clay ----------	16	176
Clay ----------	19	103	Clay, sandy ----------	4	180
Sand; gravel to $1\frac{1}{2}$ inches ----------	21	124	Sand; gravel to $1\frac{1}{2}$ inches ----------	14	194
Clay, sandy ---------	36	160	Clay, with soft streaks	18	212

5/16-36M1. Charles Carr. Altitude about 730 ft. Drilled by James E. Wright, Jr., in 1955. 6-inch casing to 357 ft, perforated 261-357 ft.

Rock and sand -------	34	34	"Granite rock" -------	6	[illegible]
Pea gravel ----------	3	37	Clay; sand; rock -----	23	[illegible]
Sand, tight; rock ---	4	41	Gravel, hard packed --	6	[illegible]
Sand, loose ---------	11	52	Sand, coarse; gravel	11	[illegible]
Gravel, light; rock	5	57	Gravel, coarse -------	11	[illegible]
Sand, medium; gravel	18	75	Clay; sand ----------	8	[illegible]
Clay ----------	98	173	Clay, hard ----------	6	[illegible]
Rock; gravel --------	24	197	Sand; gravel ---------	9	[illegible]
Sand and rock; clay	37	234	Sand, tight ----------	12	[illegible]
Clay ----------	17	251	Clay ----------	14	[illegible]

5/17-19Q1. H. G. Tacke. Altitude about 535 ft. Drilled by Coachella Valley Pump and Supply, Inc., in 1958. 14-inch casing to 302 ft, 12-inch casing 302 to 758 ft, perforated 314-758 ft. Yield 1,600 gpm.

	Thickness (feet)	Depth (feet)
Surface sand and gravel	123	123
Clay and gravel, mixed	46	169
Sand; gravel	9	178
Clay; gravel	94	272
Sand, fine	4	276
Clay	52	328
Gravel	8	336
Clay	4	340
Sand; gravel with light clay streaks	223	563
Clay; gravel streaks	127	690
Clay, with fine sand	50	740
Clay	20	760

5/17-29E1. Edna A. Tacke. Altitude about 533 ft. Drilled by Coachella Valley Pump and Supply, Inc., in 1958. 14-inch casing to 307 ft, 12-inch casing 307 to 981 ft, perforated 103-295 and 321-981 ft. Yield 1,250 gpm.

	Thickness (feet)	Depth (feet)
Surface sand and gravel	95	95
Clay	43	138
Sand and gravel	19	157
Clay	13	170
Sand and gravel	11	181
Clay	33	214
Sand and gravel, with clay	16	230
Clay	11	241
Sand and gravel	9	250
Clay and shale, with sandy streaks	41	291
Shale	119	410
Clay, with sandstone caps	50	460
Sand; gravel; shale in streaks	211	671
Shale; sand; gravel	89	760
Shale with light streaks; sand	77	837
Sand, fine; shale	34	871
Shale, with streaks of fine sand and gravel	59	930
Sand, fine; gravel	8	938
Shale	12	950
Sand, fine; gravel	13	963
Sand; gravel; shale	20	983

5/17-33N1. Lloyd Loveland. Altitude about 597 ft. Drilled by Coachella Valley Pump and Supply, Inc., in 1958. 14-inch casing to 254 ft, 12-inch casing 254 to 758 ft, perforated 266-758 ft.

Surface sand -------	102	102	Clay streaks; sand --	340	558
Clay; sand; gravel	18	120	Sand streaks; "sand-stone cappings"-----	202	758
Clay ----------	88	208			
Sand; gravel -------	8	216			

6/12-10K1. Altitude about 1,747 ft. Drilled by Lyon Brothers Well Contractors in 1932. 12-inch casing. Well dry.

Sand, gray, packed	158	158	"Decomposed granite"	10	[illegible]
Sand, cemented; clay	82	240	Clay, brown, hard ---	20	[illegible]
"Decomposed granite"	80	320	"Decomposed granite"	90	[illegible]
Clay, yellow --------	10	330			

6/17-3M1. C. W. Budd. Altitude about 565 ft. Drilled by J. B. Baker in 1958. 12-inch casing, perforated 165-680 ft.

	Thickness (feet)	Depth (feet)
Alluvial fill	48	48
Clay, sandy; gravel	9.5	57.5
Clay, brown	18.5	76
Shale, tan	49	125
Shale, blue-gray	11	136
Clay, brown (water at 165 ft)	32	168
Clay, tan, sandy	7	175
Clay, tan	23	198
"Hard sandstone ledge"	6	204
Clay, sandy	26	230
Clay, brown	31	261
Shale, hard	14	275
Clay, tan; "hard ledges"	123	398
Clay, tan, sandy	21	419
Sandstone, hard	31	450
Sandstone, young	5	455
Sand, gray, loose	14	469
Clay, gray; sandy streaks	62	531
Clay, sticky	23	554
Shale, brown, hard	144	698
"Chenle" shale	33	731
Shale, brown	78	809
Clay, sticky	9	818

6/19-33A1. Hopkins Well. Altitude about 358 ft. Drilled in 1911. 8-inch casing, perforated 1,175-1,200 ft. Log from U.S. Geological Survey Water-Supply Paper 497, p. 242.

Soil, probably fine sand and silt	60	60
Clay	40	100
Alternate sand and clay	500	600
Sand, sandrock, and gravel	300	900
Not given; presumably sand and gravel	275	1,175
Water-bearing gravel; good water	25	1,200
Bedrock, probably schist or granite		

7/20-18H1. Vada McBride. Altitude about 445 ft. Drilled by Moffitt and Wells in 1959. 14-inch casing to 343 ft, 12-inch casing 343 to 1,083 ft, perforated 853-1,083 ft. Yield 1,000 gpm with 90 ft drawdown.

	Thickness (feet)	Depth (feet)
Sand, coarse; gravel	54	54
Clay	29	83
Sand, fine; clay	12	95
Sand and gravel	6	101
Clay	6	107
Sand, fine, with clay streaks	7	114
Sand and gravel, with clay streaks	6	120
Sand, fine, with clay streaks	40	160
Clay, with fine sand streaks	27	187
Sand, fine	8	195
Clay, sticky	40	235
Rocks	1	236
Clay	23	259
Sand, fine, cemented	5	264
Sand, fine to medium	31	295
Clay	10	305
Sand, fine to coarse	4	309
Sand, fine, cemented	7	316
[Material], fine to coarse, mixed with clay streaks	36	352
Sand, gray, streaks	11	363
Sand, fine, tight	11	374
Clay, brown	26	400
Sand, fine	10	410
Clay; shale	15	425
Sand, fine, free	3	428
Sandstone, tight	2	430
Clay, brown, with sand streaks	6	436
Clay, brown	5	441
Sand, fine, with gravel	9	450
Clay	2	452
Pebbles, fine to medium	16	468
Sand, fine to medium, free	4	472
Clay	9	481
Sand and clay, tight	4	485
Sand, fine; gravel, with clay streaks	6	491
Sand, fine, with clay streaks	10	501
Sand, fine, with gravel and clay streaks	9	510
Gravel, fine to medium	20	530
Clay, streaks	5	535
Gravel, fine to medium, with clay streaks	23	558
Clay, brown	2	560
Sandstone	3	563
Clay, brown	12	575
Sand; clay	8	583
Sand, fine to medium; clay	27	610
Sand; clay	2	612
[Material], fine to coarse	35	647

7/20-18H1.--Continued.

	Thickness (feet)	Depth (feet)
Gravel, fine to medium	10	657
Sand, fine, with clay streaks	22	679
Sand, fine; gravel with clay	21	700
Clay	4	704
Sand, fine; gravel with clay streaks	17	721
Sand, fine, cemented, with clay streaks	23	744
Sand, fine; gravel	10	754
Rocks, rough, hard	3	757
Sand, fine, with clay streaks	6	763
Rock, rough	1	764
Shale, white and brown; clay	9	773
Sand, fine to coarse	21	794
Clay; fine sand	9	803
Clay, blue	2	805
Shale, hard	1	806
[Material], fine to coarse	6	812
Sand, fine; clay	20	832
Sand, fine to medium, tight	10	842
Sandstone, gray, fine; shale	7	849
Clay; shale	11	860
Clay, blue	3	863
Sandstone	1	864
Sand, fine; gravel with clay streaks	10	874
Sand, fine	11	885
[Material], fine to coarse, with clay streaks	9	894
Shale; gravel; lime	9	903
Sand, fine; gravel with sandstone streaks	24	927
Sandstone, hard, free	3	930
Sand, fine; gravel	23	953
Sand, fine; coarse gravel; sandstone in streaks	22	975
Sand, fine; coarse gravel	14	989
Sand, rough, mixed with gravel	8	997
[Material], fine to medium; coarse gravel	23	1,020
Sand, fine; gravel	10	1,030
Sand, fine, with clay streaks	33	1,063
Gravel with clay streaks	38	1,101
Sand, fine to coarse	18	1,119
Sand, tight, cemented	2	1,121
[Material], fine to coarse	6	1,127
Clay	2	1,129
Sand, fine to coarse, free	8	1,137
Sand, cemented	2	1,139

Water/Waste Water Report

AECOM

SOLAR MILLENNIUM
PALEN SOLAR POWER PROJECT

Water / Wastewater Report

May 2009

AECOM Water

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SOLAR MILLENNIUM
PALEN SOLAR POWER PROJECT

Water / Wastewater Report

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DRAFT

Solar Millennium
Palen Solar Power Project
Water / Wastewater Report

Section 1 Water 1

1.1 Introduction 1

1.2 Water Requirements 1

1.3 Water Quality Requirements 3

1.4 Water Source 3

1.5 Water Treatment 5

1.6 Conceptual Facilities Sizing 5

1.7 Treatment Criteria 6

1.8 Fire Flow Requirements 6

1.9 Storage 7

1.10 Construction Water 7

Section 2 Wastewater 7

2.1 Introduction 7

2.2 Wastewater Sources and Quantities 7

2.3 Wastewater Treatment 8

2.4 Construction Waste Water 8

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Section 1 Water

1.1 Introduction

The Palen Solar Power Project (PSPP) Plan of Development has been prepared to support applications for design and development of two 242 MW commercial solar parabolic trough power generating stations. This Report presents water demands for the power plants and describes sources, uses, and treatment requirements for that water. In order to obtain economies of scale, it is assumed that a single water plant will supply water to both generating stations.

1.2 Water Requirements

The Palen Solar Power Project requires water for a number of consumptive uses:

- Domestic potable uses include drinking water, showering, toilets, hand washing, etc.
- Power cycle makeup water to supply the steam driving the steam turbine generators (This water is recycled and does not constitute consumptive use).
- Mirror wash water to maintain solar collector efficiency
- Ancillary equipment heat rejection, for cooling generators, pumps, and other equipment.
- Dust suppression
- Construction water, which will be required only during the construction period.

Note that water will not be used for condensing steam in the power generation cycle. This will be a “dry” plant, using air-cooled condensers rather than water cooled condensers.

Table 1 presents anticipated water requirements associated with various uses for each month of the year. **Table 1** shows both the total water use and the consumptive use (power cycle makeup water is non-consumptive because it is recycled).

Power Cycle Makeup Water and Ancillary Heat Rejection were determined based upon anticipated power production rates for each month as provided by the Solar Millennium’s power cycle engineers.

Mirror Wash Water use was estimated based upon experience at other locations with similar climatic conditions.

Domestic Potable Use was estimated based upon the number of employees and number of hours expected to be worked during the year. An average consumption of 37 gallons per person per day was assumed for each employee.

Dust suppression is required to maintain power production. It is proposed that unpaved roadways will be wetted on a regular basis for dust control. In order conserve water supplies, concentrate from the water treatment process will be used for this purpose.

It can be seen from **Table 1** that of the 99 million gallon (MG) of water needed annually (74 MG consumptive use) the maximum monthly demand is anticipated to be about 12 MG (8.7 MG consumptive use) of water. Minimum monthly demand is anticipated to be about 2.6 MG (2.0 MG consumptive use).

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Table 1
Anticipated Monthly Water Use
Palen Solar Power Project

Month	Power Cycle Makeup Water[1] (gallons)	Mirror Wash Water (gallons)	Domestic Potable Water (gallons)	Dust Suppression Water (gallons)	Ancillary Equip. Heat Rejection (gallons)	Total	Consumptive Use
January	575,000	1,060,000	166,000	210,000	609,000	2,621,000	2,046,000
February	1,396,000	2,120,000	166,000	450,000	1,479,000	5,611,000	4,215,000
March	2,296,000	2,120,000	166,000	610,000	2,433,000	7,625,000	5,329,000
April	2,585,000	4,241,000	166,000	846,000	2,739,000	10,576,000	7,991,000
May	3,128,000	4,241,000	166,000	944,000	3,314,000	11,793,000	8,665,000
June	**3,163,000**	**4,241,000**	**166,000**	**950,000**	**3,352,000**	**11,872,000**	**8,709,000**
July	2,780,000	4,241,000	166,000	882,000	2,945,000	11,013,000	8,233,000
August	2,778,000	4,241,000	166,000	882,000	2,943,000	11,009,000	8,231,000
September	2,222,000	4,241,000	166,000	782,000	2,354,000	9,764,000	7,542,000
October	1,971,000	2,120,000	166,000	552,000	2,088,000	6,898,000	4,927,000
November	1,293,000	2,120,000	166,000	430,000	1,370,000	5,380,000	4,087,000
December	920,000	2,120,000	166,000	364,000	975,000	4,545,000	3,625,000
TOTAL	**25,107,000**	**37,106,000**	**1,992,000**	**7,902,000**	**26,601,000**	**98,707,000**	**73,600,000**
AVERAGE	**69,000**	**102,000**	**5,000**	**22,000**	**73,000**	**270,000**	**202,000**
MAX DAILY	**105,000**	**141,000**	**6,000**	**32,000**	**112,000**	**396,000**	**290,000**

[1.] Power cycle makeup is recycled and not included in the consumptive use total.

1.3 Water Quality Requirements

The PSPP will be classified by the California Department of Public Health (CDPH) as a “non-community, non-transient” water system. Under this classification, the potable water system must meet the requirements of the Federal Safe Drinking Water Act and State Title 22 for potable water for mineral and microbial water quality.

Power cycle makeup water must meet and exceed the requirements for boiler feed water for boilers operating at up to 100 bar (1500 psi) pressure. **Table 2** presents quality requirements for boiler feed water. Achieving water of the quality required for power cycle makeup will entail use of desalination (reverse osmosis [RO] or electrodialysis reversal [EDR]) followed by ion exchange (IX) demineralization.

In order to minimize scaling on the mirrors, mirror wash water must have low dissolved solids. However, demineralized water as needed for power cycle makeup will not be required. Therefore, water from the primary desalination process (RO or EDR) will be used for this purpose.

While ancillary equipment heat rejection water quality does not need to be as good as power cycle makeup water, it will benefit from low dissolved solids and especially from the low scaling tendency of desalinated water.

There is no specific quality requirement for dust suppression water. It is presently anticipated that concentrate from the desalinating processes (RO or EDR) will be used for dust suppression. This water is expected to have total dissolved solids (TDS) of less than 13,000 mg/L. If necessary, water for dust suppression may be augmented by water from the well developed to provide construction water.

1.4 Water Source

The preferred water source for the PSPP will be groundwater supplied by new wells located within the solar site boundary. It is assumed that two wells will be required for redundancy.

Water quality from local irrigation wells is not available. However, water quality information for wells serving the Chuckawalla and Ironwood State Prisons, located about 15 miles southeast of the PSPP site, show total dissolved solids (TDS) of 700 to 2000 mg/L, with the majority of samples below 1500 mg/L. These wells exhibit high fluoride concentrations of about 6 to 10 mg/L, which exceed the California Maximum Contaminant Level of about 1 mg/L. No information is available on arsenic concentrations.

Based upon the information from the prison wells and the fact that the local well water is used for irrigation, it is assumed that the water TDS is no more than 1500 mg/L.

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Table 2
Boiler Water Quality Requirements

		Working Pressure (Bar)						
		0 - 15	15 - 25	25 - 35	35 - 45	40 - 60	60 - 75	75 - 100
Boiler water								
M **alkalinity**	French degrees	100	80	60	40	15	10	5
P alkalinity		0.07 M	0.07 M	0.07 M	0.07 M	> 0.5 M	> 0.5 M	> 0.5 M
SiO2	mg/l	200	150	90	40	15	10	5
TDS		4000	3000	2000	1500	500	300	100
Phosphates		30 to 100	31 to 100	20 to 80	21 to 80	10 to 60	10 to 40	5 to 20
pH		10.5 to 12				10 to 11		
Make up water		Softened or softened and carbonate free				Demineralized		

References
'*Water treatment handbook*' Vol. 1-2, Degremont, 1991
'*Industrial water conditioning*', BeltsDearborn, 1991
UUUUhttp://www.thermidaire.on.ca/boiler-feed.html

1.5 Water Treatment

As noted above, water used for power cycle makeup, mirror washing, and ancillary equipment heat rejection will require treatment for reduction of dissolved solids. This type of treatment process is known as desalination, and can be accomplished by either thermal processes (evaporation/condensation) or membrane processes such as reverse osmosis (RO) or electrodialysis reversal (EDR). Considering the relatively good quality of the source water, it is unlikely that thermal processes would be cost effective. Accordingly, only membrane processes are considered here. The proposed treatment process for the various water uses is presented schematically in **Figure 1**. Since RO and EDR produce similar product water quality and waste streams, further discussion will reference only RO for simplicity. Selection of the process to be used at PSPP will be made during the final design process.

Membrane desalination processes split the feed stream into two streams: 1) a product water stream (permeate) with reduced salinity and 2) a concentrate stream containing the majority of the salts that were in the feed stream. Desalination processes are usually designed to operate with the highest safe recovery (recovery is the fraction of feedwater recovered as permeate) in order to minimize water loss, since the concentrate would normally be considered a waste stream. In this case, it appears that the highest safe recovery is 92%.

RO treatment can be expected to provide product water with TDS of 20 mg/L or less and silica concentration of 3 mg/L or less, which substantially exceeds the requirements for “Boiler Water” given in **Table 2**. However, in order to provide the demineralized water quality needed for power cycle makeup it will be necessary to provide ion exchange demineralization as a final treatment step after RO. Ion exchange demineralization can be done using either permanently installed equipment or portable demineralizers. Permanently installed equipment requires regeneration onsite, which requires storage and disposal of significant quantities of sulfuric acid and sodium hydroxide (caustic). Alternatively, portable demineralizers are taken offsite for regeneration at the supplier’s warehouse, so no onsite storage of chemicals is required. Offsite regeneration is recommended for the PSPP. This will eliminate the need to store regeneration chemicals on site and minimize on site production of hazardous wastes. These demineralizers will be provided as forklift-moveable fiberglass “bottles” that will be traded out when exhausted and returned to the supplier for regeneration. Demineralization systems will be installed at each power block to minimize piping and provide the best water quality.

It is anticipated that all of the power cycle makeup water will be recycled and reused as feed to the RO system. This will reduce the salinity of the RO feed and improve the RO recovery. Because of the very low TDS of the makeup to the ancillary equipment heat rejection cooling tower, it is expected that blowdown will not be required. Rather, drift (windblown mist) will provide the necessary salt removal. If blowdown is required, it will be recycled to the RO system.

It may be more advantageous to recycle the power cycle makeup water to the IX demineralizer rather than to the RO. This modification will be evaluated during final design.

Water from the new wells may require treatment to meet the requirements of the CDPH for domestic potable water supplies. Based on the assumed water quality, it is estimated that both TDS and fluoride concentrations must be reduced, which indicates the need for a desalination process. Following desalination the water will require addition of chlorine to prevent growth of pathogenic organisms. Use of a solid calcium hypochlorite system is recommended. Since the source water is groundwater there is no need to meet the requirements of the Surface Water Treatment Rule (and its amendments).

1.6 Conceptual Facilities Sizing

Figure 2 presents a conceptual layout of the water plant. From **Table 1** it can be seen that the maximum anticipated monthly water demand is slightly less than 12 million gallons, which is equivalent to about 400,000 gallons per day. Sufficient storage will be provided to allow hourly and daily peak demands to be taken from storage, so that maximum water treatment capacity will be 400,000 gallons per day. However, considering that

the PSPP will only be producing power during daylight hours, it is recommended that the water treatment facilities be capable of providing the total 400,000 gallons in 12 hours of operation. This will allow the treatment process to be operated using self-generated power, which is expected to be substantially less expensive than power taken from the grid.

In order to provide redundancy it is recommended that the treatment process be provided using two identical trains, each capable of providing 400,000 gallons over 24 hours of operation. By operating both trains during normal operation, the maximum daily demand can be provided in 12 hours as discussed in the previous paragraph. In the event that one train is not available, the other train can be operated for the full 24 hours of a day to meet the plant demand.

1.7 Treatment Criteria

Table 4 summarizes the types of treatment (i.e., RO and IX) required for each of the various water demands at the PSPP during the maximum demand month (June). The quantity of water to be treated on a daily basis has been included so that tentative sizing of each treatment process can be identified.

Table 4
Treatment Capacities

Use	Domestic	Power Cycle Makeup	Mirror Washing	Anc. Equipment Heat Reject.	Dust Control
RO	X	X	X	X	X[1]
IX		X			
Daily Capacity, gallons	6,000	105,000	141,000	112,000	32,000

Total RO permeate capacity will be the sum of the Domestic, Power Cycle Makeup, Mirror Washing, and Ancillary Equipment Heat Rejection capacities, or 364,000 gallons per day (253 gallons per minute). Total IX demineralizer capacity will be 105,000 gallons per day (73 gallons per minute). Therefore, at each of the two demineralizer facilities (one at each power block – see **Figure 1**) the capacity will be approximately 52,500 gallons per day (37 gallons per minute).

1.8 Fire Flow Requirements

The location of the PSPP is such that it will fall under the jurisdiction of the Riverside County Fire Department, specifically the Indio Office. Based on the requirements of Riverside County, the piping system supplying the fire hydrants must be sized to convey a potential fireflow of 5,000 gallons per minute (gpm) with an actual fireflow of 2,500 gpm being available from any two adjacent hydrants for two hours[2]. Fire pumps as well as twelve inch minimum piping will be needed to convey the required flows. Maximum hydrant spacing will be 330 feet throughout the Power Block area. Minimum fire water storage volume per power block will be 300,000 gallons.

[1] Dust control will use the concentrate from the RO process.
[2] Fireflow requirements per Ordinance No. 787.1 of the County of Riverside.

1.9 Storage

Storage tanks will be provided at each power block for treated water and fire flow requirements. RO concentrate storage will be provided at only one power block.

Treated water storage at each power block will consist of a 1.0 million gallon (MG) tank (or alternatively two 500,000 gallon tanks). These tanks will meet the requirements of the CDPH for potable water storage (e.g., NSF 61 approved lining, screened vents, etc.). Each tank will provide water for domestic use, power cycle makeup, mirror wash, ancillary equipment heat rejection, and fire water. Excluding the fire water volume, each tank will provide about three days' storage for these uses.

Concentrate from the reverse osmosis process will be stored in a concentrate storage tank until used for dust control. This tank is recommended to be a 250,000 gallon tank, providing about one weeks' storage volume.

1.10 Construction Water

Construction water requirements for the site will consist of providing water for all construction related activities. These activities include:

- dust control for areas experiencing construction work as well as mobilization and demobilization,
- dust control for roadways,
- water for grading activities associated with both cut and fill work,
- water for soil compaction in the utility and infrastructure trenches,
- water for soil compaction of the site grading activities,
- water for stockpile sites,
- water for the various building pads, and
- water for concrete uses on site.

The predominate use of water during construction will be for grading activities which will have a steady rate of work each month. The grading schedule for the site has been spread to cover the total construction period and therefore there should be no definable peak but rather a steady state condition of water use. The average water use for this site is estimated to be about 390,000 gallons per working day. Total construction water use for the duration of the project is estimated to be about 295,000,000 gallons. Construction water is expected to be provided by an onsite well that will be drilled for that purpose. Potable water during construction will be brought onsite in trucks and held in day tanks.

Section 2 Wastewater

2.1 Introduction

The Palen Solar Power Project (PSPP) Plan of Development has been prepared to support applications for design and development of two 242 MW commercial solar parabolic trough power generating stations. This report presents anticipated wastewater sources and amounts and proposed methods of wastewater disposal.

2.2 Wastewater Sources and Quantities

The Palen Solar Power Project will produce one primary wastewater stream and one temporary stream:

- Sanitary wastewater produced from administrative centers and operator stations.
- Construction related waste.

Note that the power generation cycle will not produce cooling tower blowdown. This will be a “dry” plant, using air-cooled condensers rather than water cooled condensers.

Sanitary wastewater production will not exceed domestic water use. As described in the Water Report, maximum domestic water use will be less than 166,000 gallons per month (approximately 5,500 gallons per day). It is anticipated that the wastewater would be consistent with domestic sanitary wastewater and would have Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) in the range of 150 to 250 mg/L.

The construction phase will produce an additional temporary wastewater stream due to onsite employees.

2.3 Wastewater Treatment

Sanitary wastes will be collected for treatment in septic tanks and disposed via leach fields located at the power block as well as at the admin area and warehouse area. If separate control rooms with restrooms are located at the remote power blocks, smaller septic systems will be provided to receive sanitary wastes at those locations. Based on the current estimate of 5,500 gallons of sanitary wastewater production per day a total leach field area of approximately 11,000 square feet will be required spread out at multiple locations. It is also recommended that an additional 11,000 square feet of land be kept undeveloped for purposes of constructing replacement leach fields should that be necessary.

2.4 Construction Waste Water

Sanitary wastes produced during construction will be held in chemical toilets and transported offsite for disposal by a commercial chemical toilet service.

Any other wastewater produced during construction will be collected by the contractor in Baker tanks and transported offsite for disposal in a DPH approved manner.

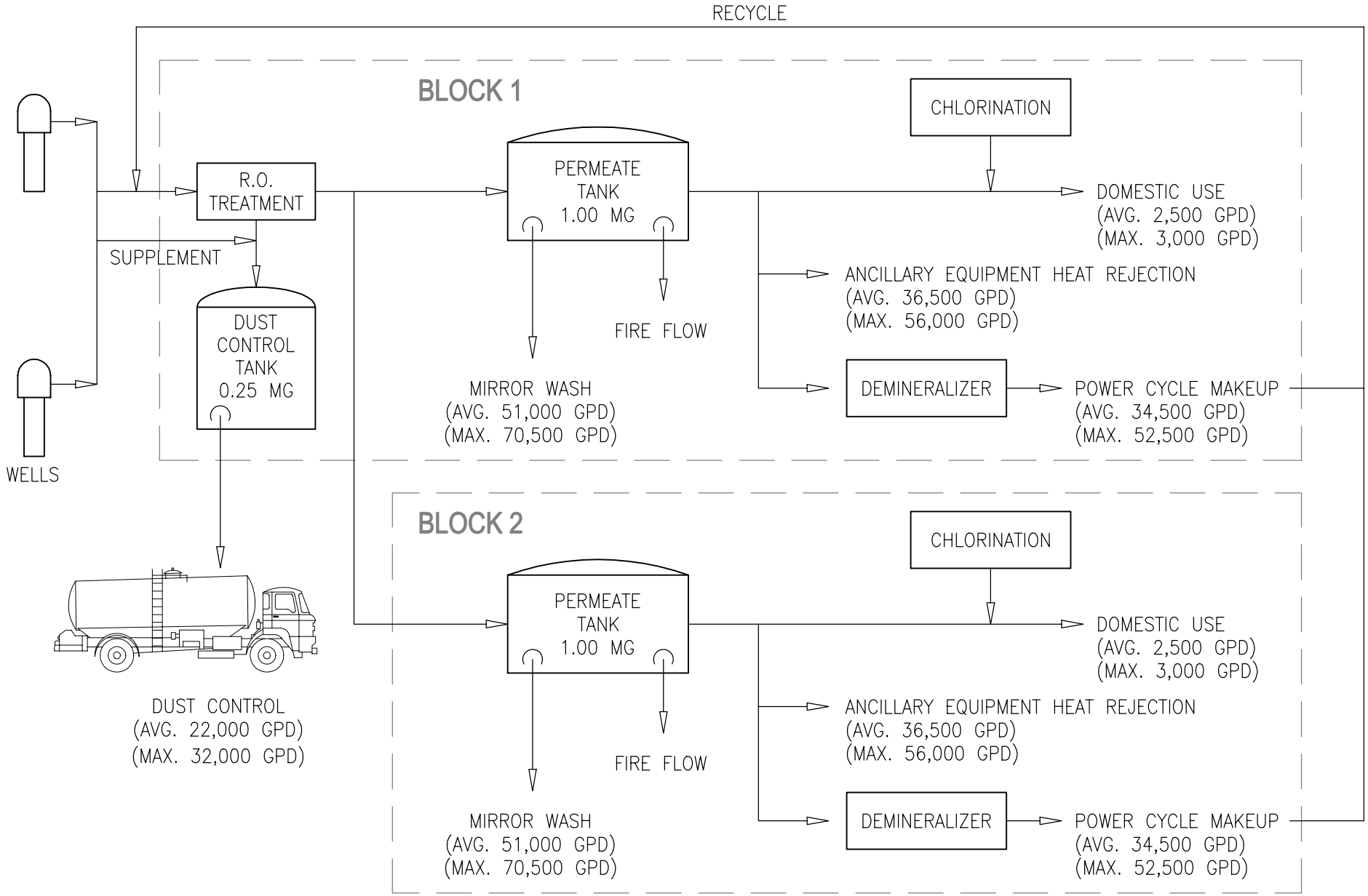

FIGURE 1
PALEN SOLAR POWER PROJECT
WATER SYSTEM SCHEMATIC

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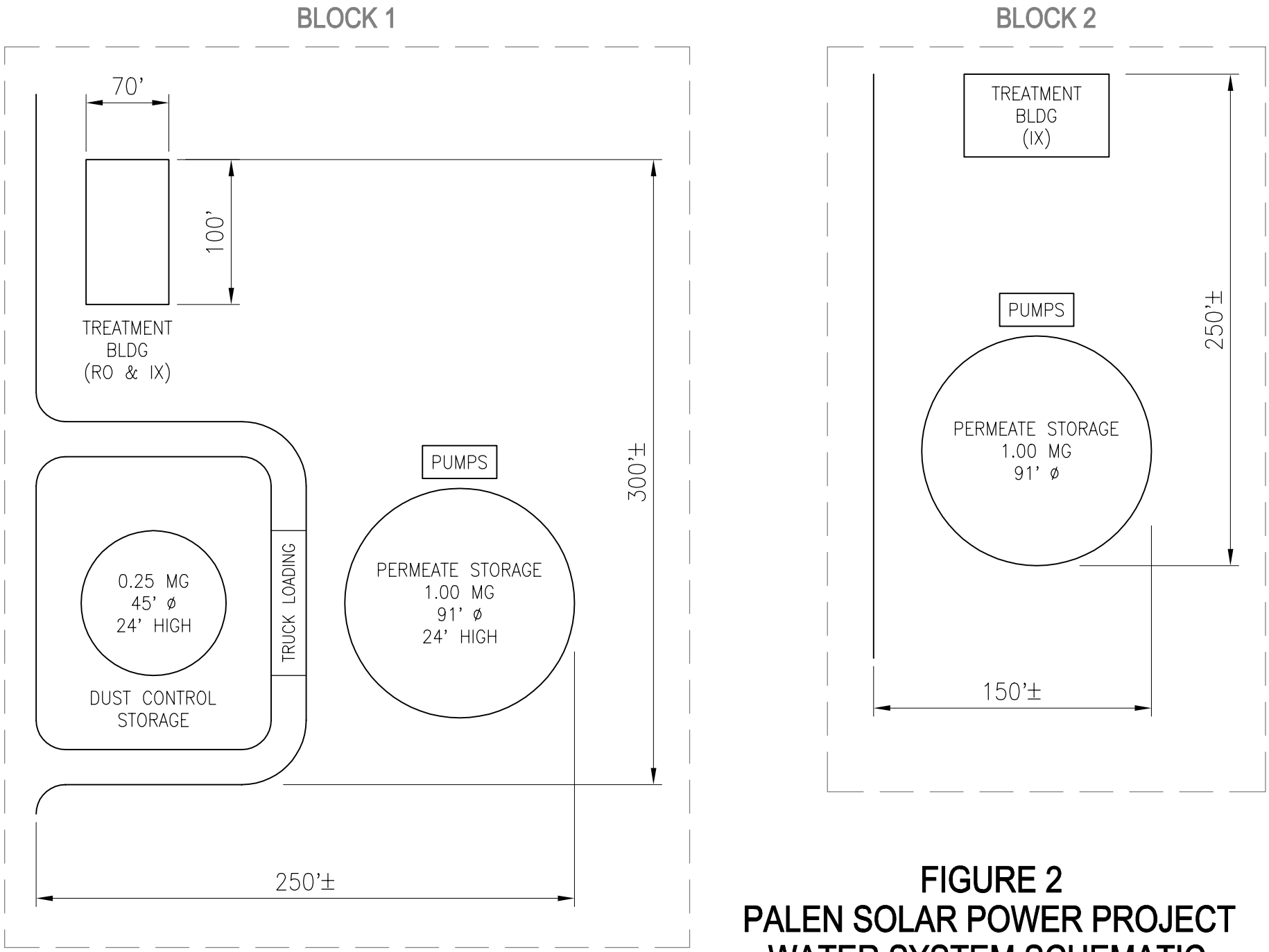

FIGURE 2
PALEN SOLAR POWER PROJECT
WATER SYSTEM SCHEMATIC

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Numerical Groundwater Model

APPENDIX J

NUMERICAL GROUNDWATER MODEL
EVALUTION OF PROPOSED PROJECT PUMPING
DURING CONSTRUCTION AND OPERATION
PALEN SOLAR POWER PROJECT
CHUCKWALLA VALLEY, RIVERSIDE COUNTY

INTRODUCTION

A regional model developed by the USGS incorporation with the USBR for evaluation of the potential for depletion of the Colorado River from pumping in sub-adjacent groundwater basins was selected for the Project (Leake and others 2008). The regional model is a two-dimensional superposition model developed using MODFLOW code (MacDonald and Harbaugh 2000) for the Parker-Palo Verde-Cibola area, which includes the Chuckwalla Valley Groundwater Basin and the Project site. The model is a simple two-dimensional model, employing a simple vertical geometry and a large grid spacing to evaluate the impacts from groundwater pumping on recharge to the Colorado River. Major features of the model include:

- Two dimensional and uniform 0.25 mile grid spacing
- Two statistically derived low and average transmissivity values (6,300 feet squared per day [(ft^2/d)] and 26,000 ft^2/d) for a conservative and an average values
- A constant storage coefficient or specific yield (0.2)
- A uniform saturated thickness of the aquifer (500 feet)

An existing numerical groundwater model developed by the USGS was selected to evaluate the impacts from proposed Project pumping because:

- The model included the PSPP site and was of sufficient detail and complexity to adequately evaluate impacts from the modest pumping proposed for the Project.
- It had undergone review by the USGS and USBR. As such, the model had undergone significant peer review prior to being published.

The Project is a dry-cooled facility that will use about 300 acre-feet per year (afy) of groundwater from two onsite wells for all operational activities, including mirror washing (the largest use, accounting for more than one-third of the total). The peak water usage during the summer months is about 396,000 gallons per day (gpd) or about 275 gallons per minute (gpm) under an assumption of continuous pumping. The average water use of the 30-year life of the Project is about 200 gpm. Winter usage will be less owing to the lower ambient temperature, and lesser requirements for process water and water for dust suppression. During construction, the Project will use an average of approximately 480 afy over a 39-month period or an average of about 600 gpm.

The model was used as a preliminary tool to simulate cone of depression, and how the project pumping might impact adjacent water supply wells.

MODEL SETUP and INPUT PARAMETERS

The superposition model by Leake, et al (2008) adopts a uniform grid spacing of 0.25 miles or 1,320 feet. To better resolve the rapid change in drawdown near the pumping well, the model grid spacing was refined as follows (Figure J-1):

- 30 feet from the pumping well for the first 300 feet
- 100 feet further out from the well for one mile or 5,280 feet
- The grid spacing gradually increases from 100 feet to 1,320 feet for the remainder of the model domain

Following licensing of the project, construction activities are expected to take place over a period of approximately 39 months. It is anticipated that water use during this period will be from onsite groundwater supplied from well 5/17-33N01 or additional wells as needed to provide an adequate water supply for construction and domestic purposes. Following construction, well 5/17-33N01 and a backup supply well will be used to provide the operation water supply for the Project. The pumping rate is assumed to be 125,134 cubic-feet per day (cfd) (650 gpm) during 3.25 years (39 months) of construction period and 38,500 cfd (200 gpm) during 30 years operational period.

The model was used to evaluate Project impacts from proposed pumping for construction and operational water supply over a range of Transmissivity and storage coefficients as follows:

Transmissivity of

- 6,300 ft2/d
- 26,000 ft2/d
- 93,600 ft2/d

Storage Coefficients of

- 0.05
- 0.20

The predicitive results showing the drawdown at the pumping well and the distance to a drawdown of 5 feet and 1 foot are provided on Tables J-1 and J-2.

MODEL RESULTS

The drawdown contours showing the cone of depression for the range of transmissivity and storage coefficients are shown on Figures J-2 through J-7. As can be seen from Table J-1 and J-2, the maximum drawdown occurs at the end of construction period. As would be expected, the drawdown at the well and the radius of influence increase with lower transmissivity and decrease with higher transmissivity.

The maximum drawdown and radius of influence at well 5S/17E-33N01 during the operational period at a pumping rate of 200 gpm is about 10 and 800 feet, respectively. The maximum drawdown and radius of influence at well 5S/17E-33N01 during the construction period at a pumping rate of 650 gpm is about 25 and 3,800 feet, respectively.

The maximum drawdown is much smaller than the assumed model layer thickness, 500 feet. The modeling result of maximum drawdown is consistent with general understanding that superpostion model can be applied if the basin-wide drawdown of the unconfined aquifer is 10 percent or less of saturated thickness (Reilly at al., 1987). The model results show that no well within a one-mile radius of the project site will be impacted by a drawdown of 5 feet or more.

Model Limitation

The modeling results presented in this report are based on a simplified groundwater model with homogeneous transmissivity and specific yield, which are derived from previous USGS superposition model efforts. Therefore the presented modeling result is considered preliminary. The actual cone of depression will vary subject to site specific aquifer properties, the heterogeneity of the aquifer and other model constraints at the site.

At the time of this writing, a plan for site specific aquifer testing is underway. After the testing is conducted, the site specific aquifer data, in combination with previously basin-wide hydrogeologic data will be evaluated. The model may be refined considering heterogeneity of the aquifer properties if warranted and the model results will be better representation of impact from groundwater pumping.

The electronic model files used in the simulations are attached. Additionally, the original USGS model report from Leake and others, 2008 is attached for reference.

Table J-1 Results of Numerical Groundwater Modeling Storage Coefficient of 0.20

TABLE J-1
RESULTS OF NUMERICAL GROUNDWATER MODELING
PROPOSED CONSTRUCTION AND OPERATIONAL WATER USE
STORAGE COEFFICIENT OF 0.20
PALEN SOLAR POWER PROJECT
CHUCKWALLA VALLEY, RIVERSIDE COUNTY, CALIFORNIA

MODEL SCENARIO[1]	Pumping Rate Construction/Operation (gpm)	Period Construction/Operation (years)	Storage Coefficient	Transmissivity	Maximum Depression in the Pumping Well	Distance to a Drawdown of 5 Feet[2]	Distance to a Drawdown of 1 foot[2]
			--	(ft2/day)	(ft)		
Construction							
Average Transmissivity	650	3.25	0.2	26,200	6.14	15	5,220
Low Transmissivity	650	3.25	0.2	6,300	23.20	1,640	8,160
Maximum Transmissivity	650	3.25	0.2	93,600	1.90	--	390
Operation							
Average Transmissivity	200	30	0.2	26,200	2.35	--	1,617
Low Transmissivity	200	30	0.2	6,300	8.57	240	13,430
Maximum Transmissivity	200	30	0.2	93,600	0.78	--	--

Notes

1 Model results shown on Figure J-2 through J-4 of this technical memorandum.
2 Distance measured from the pumping well to the referenced contour.

Table J-2 Results of Numerical Groundwater Modeling Storage Coefficient of 0.05

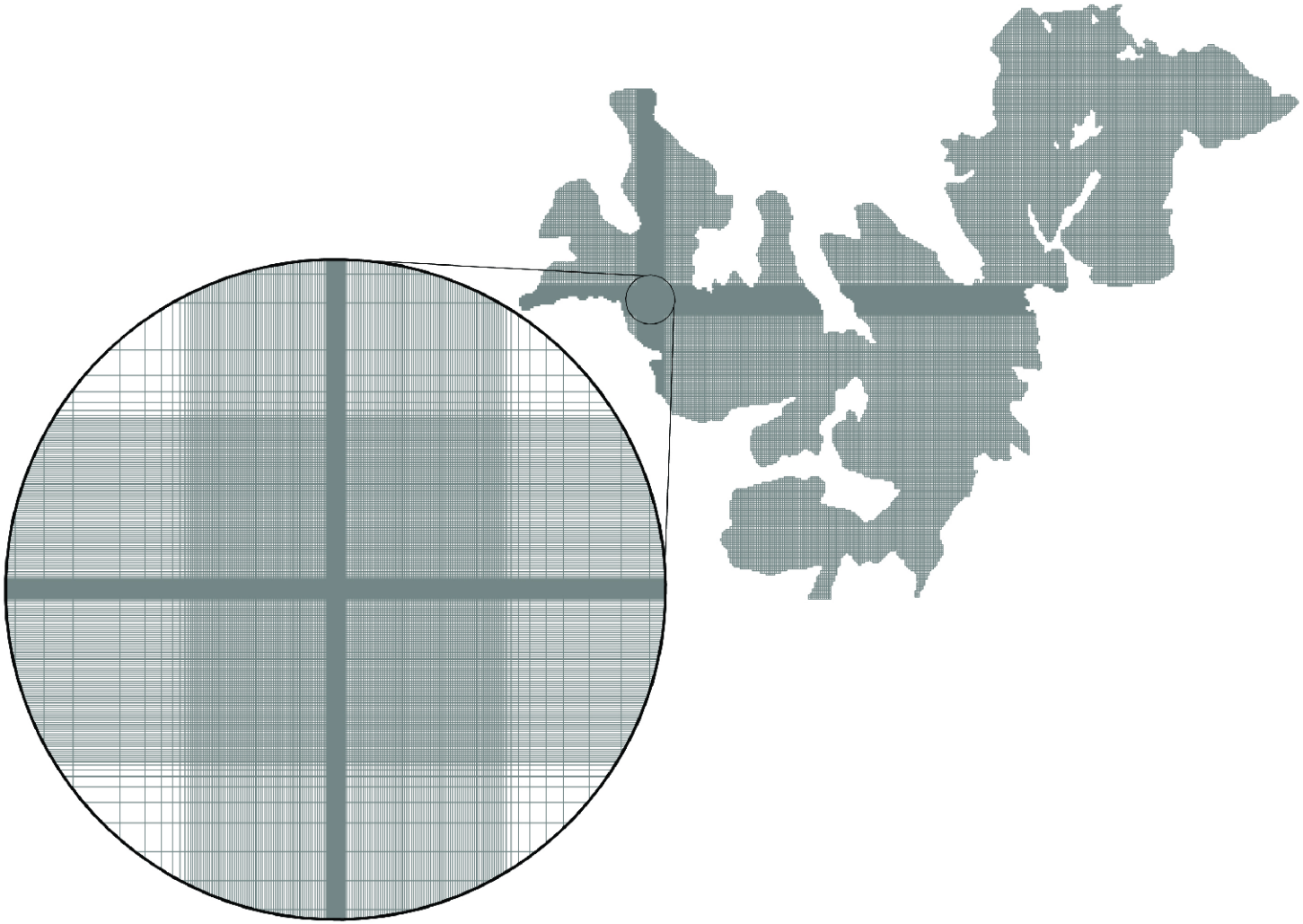
TABLE J-2
RESULTS OF NUMERICAL GROUNDWATER MODEL
CONSTURCTION AND OPRATIONAL WATER USE
STORAGE COEFFICIENT - 0.05
PALEN SOLAR POWER PROJECT
CHUCKWALLA VALLEY, RIVERSIDE COUNTY, CALIFORNIA

MODEL SCENARIO[1]	Pumping Rate Construction/Operation (gpm)	Period Construction/Operation (years)	Storage Coefficient	Transmissivity	Maximum Depression in the Pumping Well	Distance to a Drawdown of 5 Feet[2]	Distance to a Drawdown of 1 foot[2]
			--	(ft2/day)	(ft)		
Construction							
Average Transmissivity	650	3.25	0.05	26,200	6.85	75	11,940
Low Transmissivity	650	3.25	0.05	6,300	25.47	3,780	16,340
Maximum Transmissivity	650	3.25	0.05	93,600	2.16	--	1,380
Operation							
Average Transmissivity	200	30	0.05	26,200	2.84	--	12,710
Low Transmissivity	200	30	0.05	6,300	9.74	730	35,350
Maximum Transmissivity	200	30	0.05	93,600	1.14	--	45

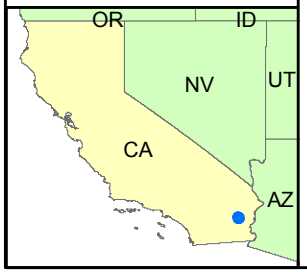
Notes

1 Model results shown on Figure J-5 through J-7 of this technical memorandum.
2 Distance measured from the pumping well to the referenced contour.

Figures



Project Location



Palen Solar Power Project

Figure J1
Groundwater Superposition Model

Solar Millennium

AECOM

Project: 12944-002
Date: August 2009

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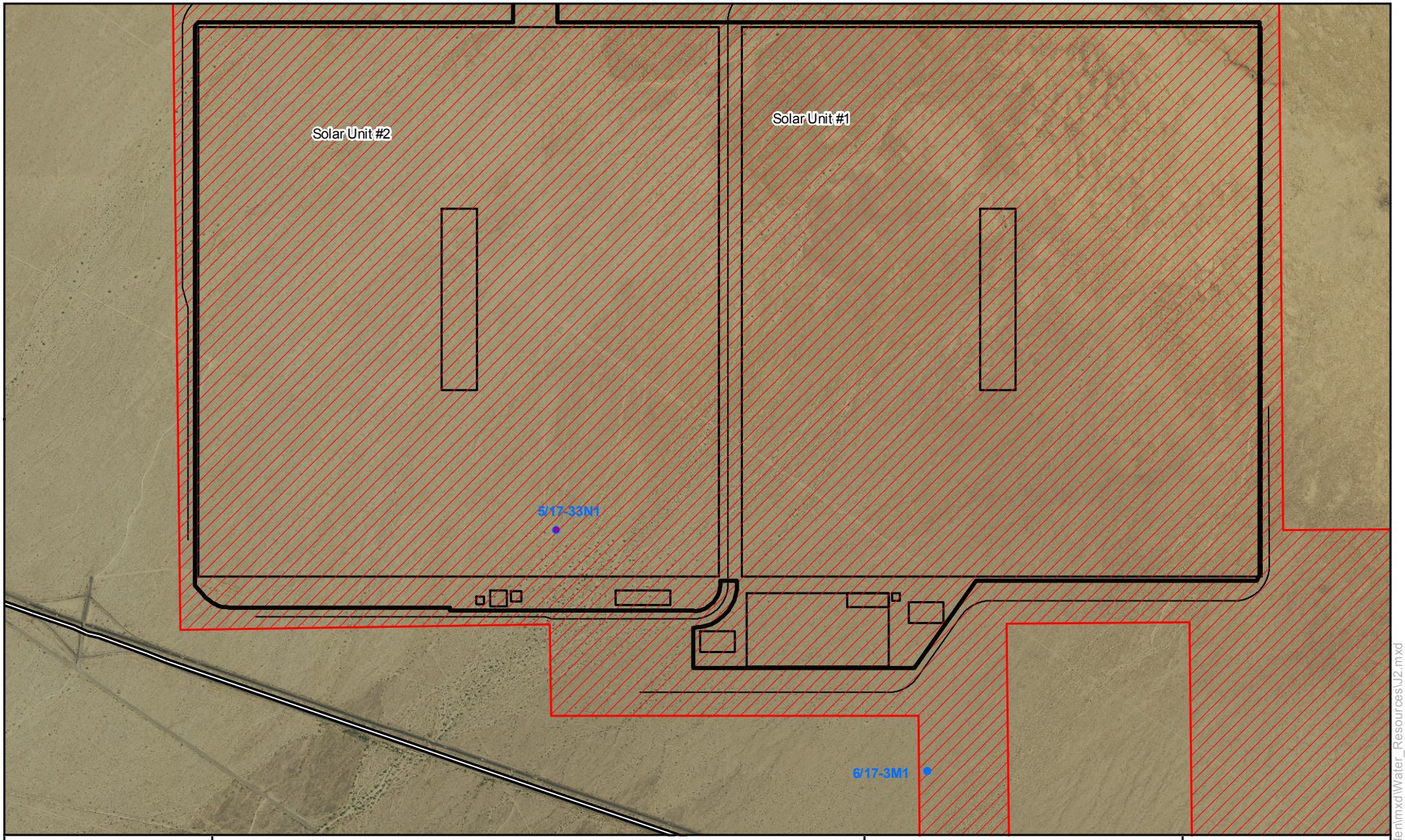

Map Location

Legend

- Project Right-of-Way
- Facility Footprint
- 1 Mile Radius of Right-of-Way
- Location of Groundwater Well Location based on Latitude and Longitude in USGS Database
- Approximate Location of Groundwater Well Location based on the State Well Number (No other coordinates available)
- Drawdown at 5 Feet Assuming T-26,200ft^2/d S-0.2; Q-650gpm

Data Sources:
Air Photo, California Spatial Information Library, NAIP, 2005 Riverside County

0 2,000 4,000 Feet

Palen Solar Power Project

Figure J2
Predicted Drawdown During Construction Period (Average Transmissivity)

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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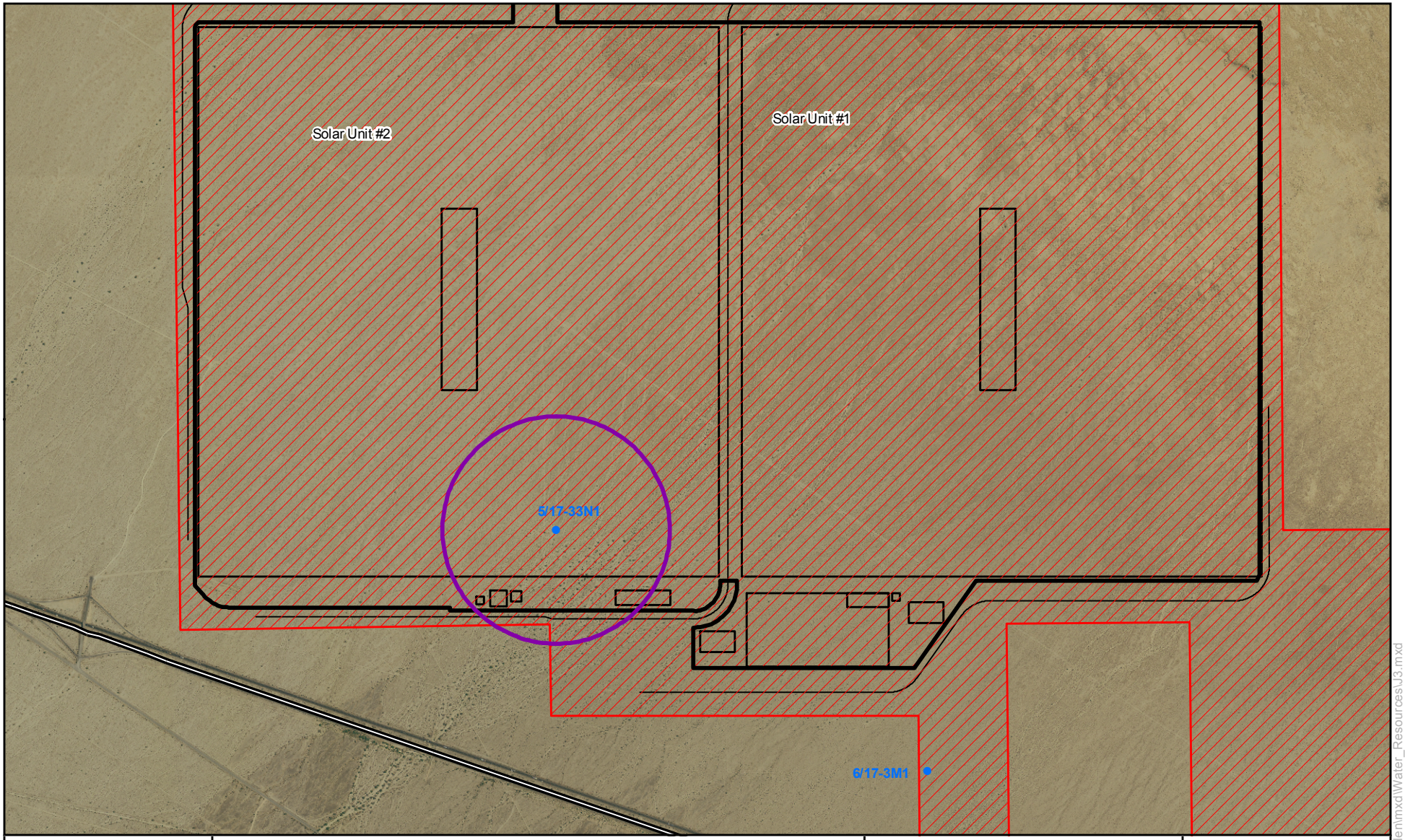

Map Location

Legend

- Project Right-of-Way
- Facility Footprint
- 1 Mile Radius of Right-of-Way
- Location of Groundwater Well Location based on Latitude and Longitude in USGS Database
- Approximate Location of Groundwater Well Location based on the State Well Number (No other coordinates available)
- Drawdown at 5 Feet Assuming T-6,300ft^2/d S-0.2; Q-650gpm

Data Sources:
Air Photo, California Spatial Information Library, NAIP, 2005 Riverside County

0 2,000 4,000 Feet

Palen Solar Power Project

Figure J3
Predicted Drawdown During Construction Period (Low Transmissivity)

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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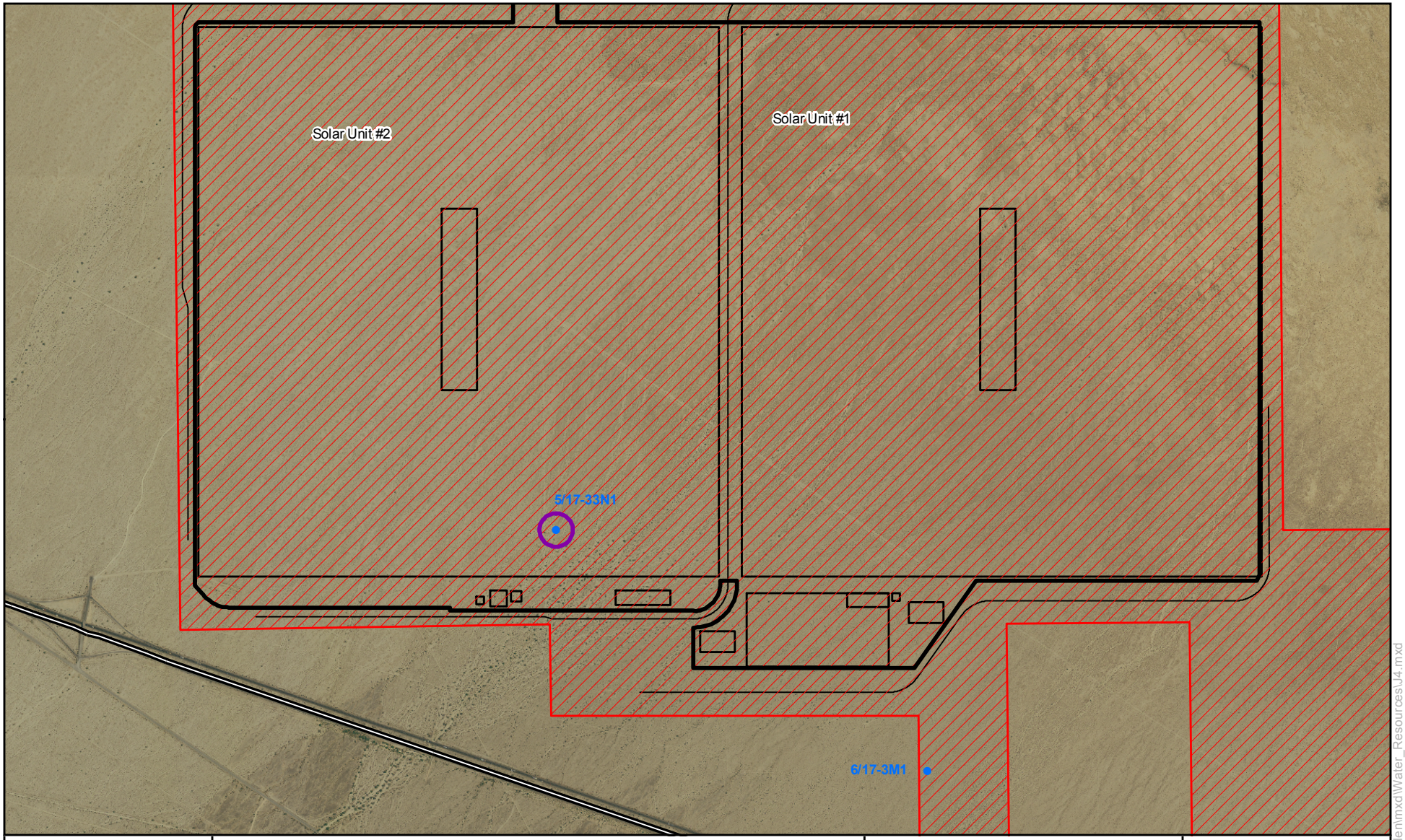

Map Location

Legend

- Project Right-of-Way
- Facility Footprint
- 1 Mile Radius of Right-of-Way
- Location of Groundwater Well Location based on Latitude and Longitude in USGS Database
- Approximate Location of Groundwater Well Location based on the State Well Number (No other coordinates available)
- Drawdown at 5 Feet Assuming T-6,300ft^2/d S-0.2; Q-200gpm

Data Sources:
Air Photo, California Spatial Information Library, NAIP, 2005 Riverside County

0 2,000 4,000 Feet

Palen Solar Power Project

Figure J4
Predicted Drawdown During Operation Period (Low Transmissivity)

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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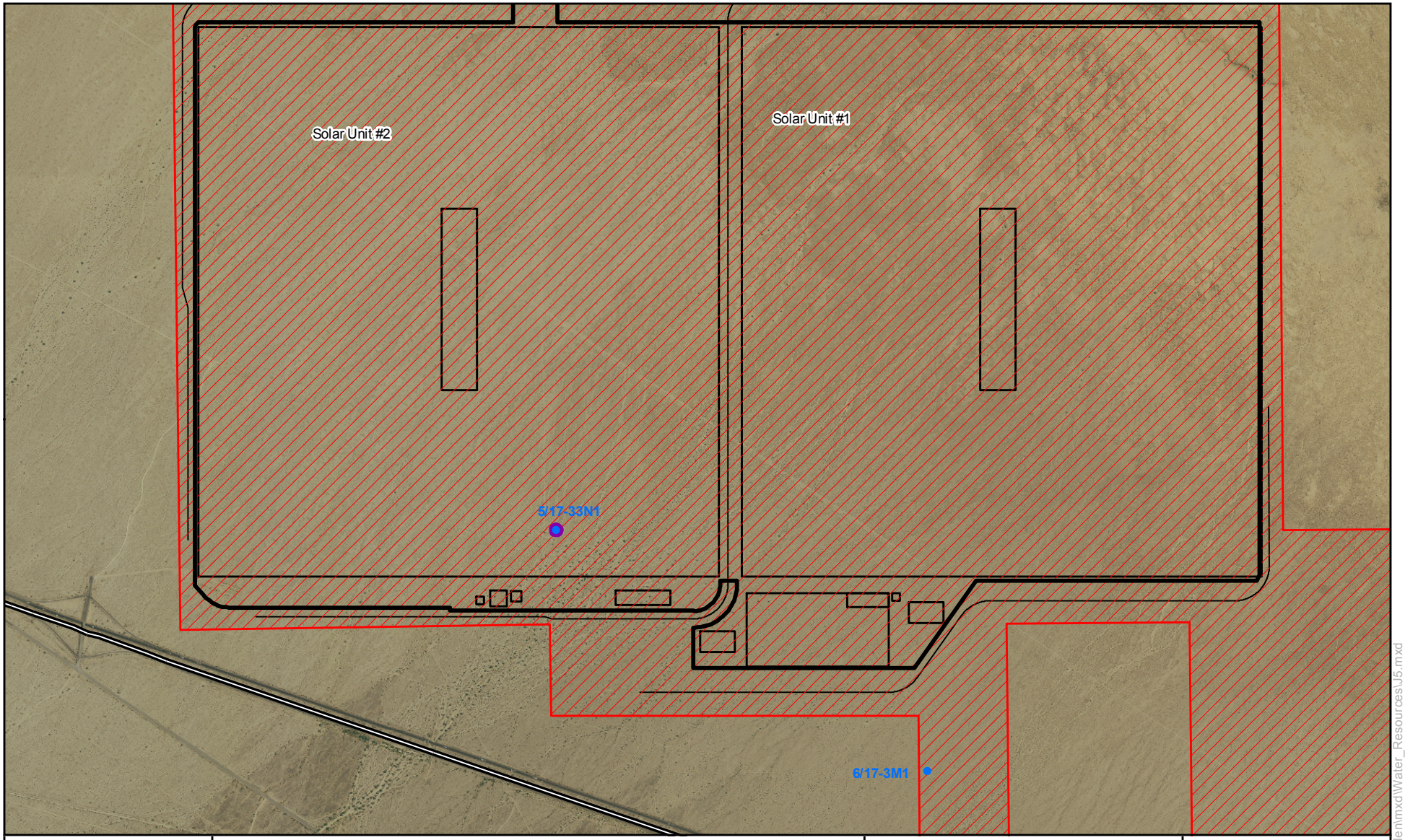

Map Location

Legend

- Project Right-of-Way
- Facility Footprint
- 1 Mile Radius of Right-of-Way
- Location of Groundwater Well Location based on Latitude and Longitude in USGS Database
- Approximate Location of Groundwater Well Location based on the State Well Number (No other coordinates available)
- Drawdown at 5 Feet Assuming T-26,200ft^2/d S-0.05; Q-650gpm

Data Sources:
Air Photo, California Spatial Information Library, NAIP, 2005 Riverside County

0 2,000 4,000 Feet

Palen Solar Power Project

Figure J5
Predicted Drawdown During Construction Period (Average Transmissivity)

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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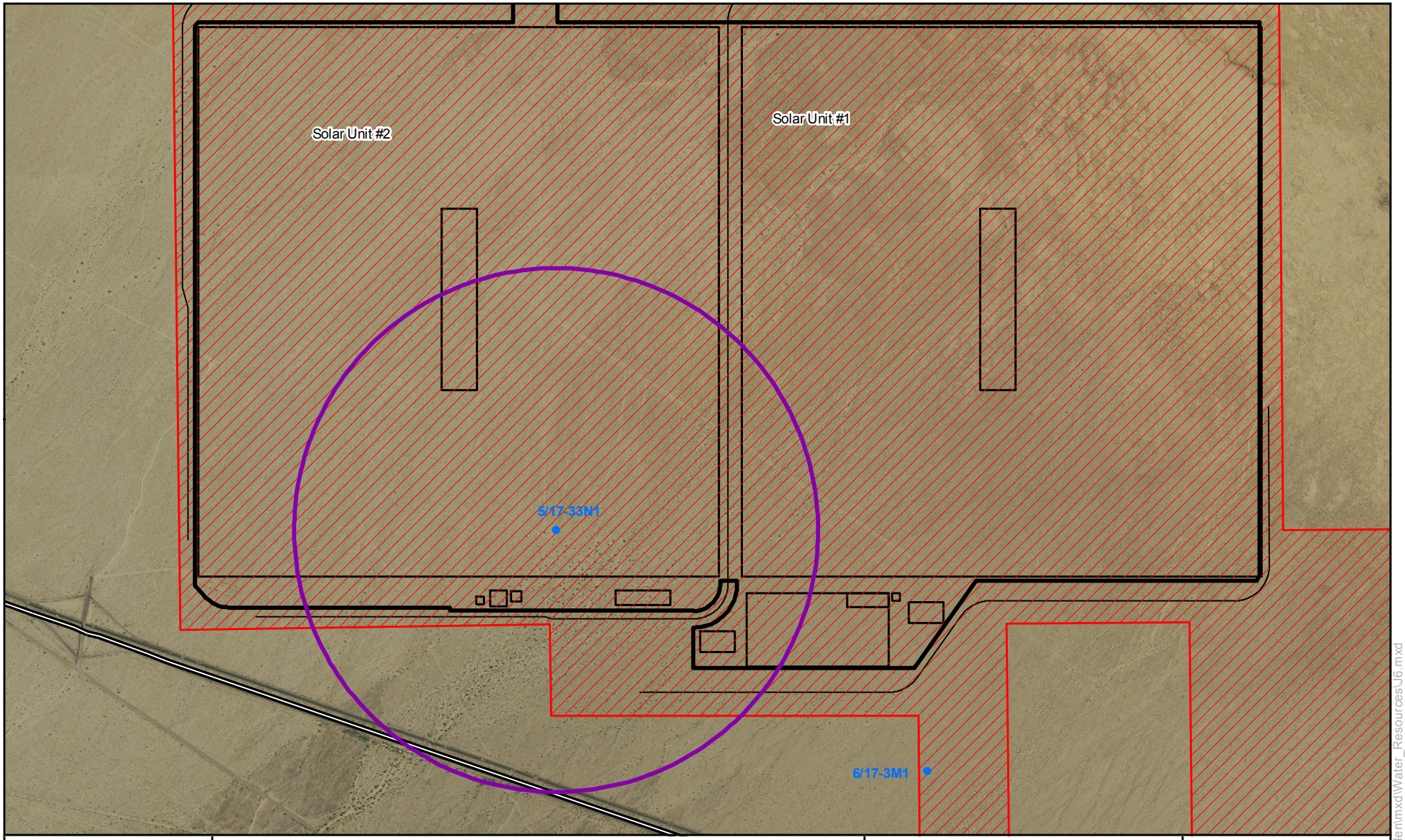

Map Location

Legend

- Project Right-of-Way
- Facility Footprint
- 1 Mile Radius of Right-of-Way
- Location of Groundwater Well Location based on Latitude and Longitude in USGS Database
- Approximate Location of Groundwater Well Location based on the State Well Number (No other coordinates available)
- Drawdown at 5 Feet Assuming T-6,300ft^2/d S-0.05; Q-650gpm

Data Sources:
Air Photo, California Spatial Information Library, NAIP, 2005 Riverside County

0 2,000 4,000 Feet

Palen Solar Power Project

Figure J6
Predicted Drawdown During Construction Period (Low Transmissivity)

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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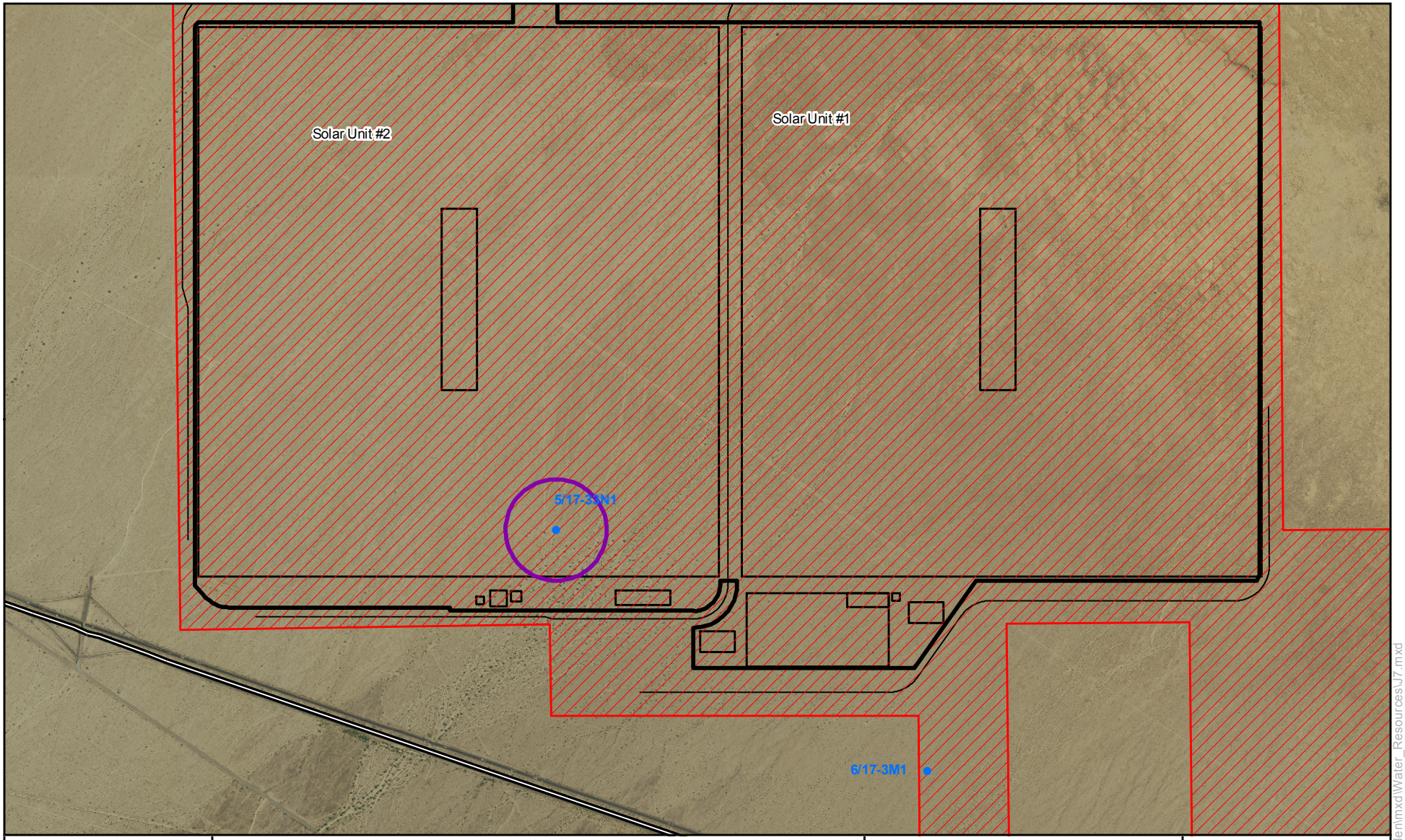

Map Location

Legend

- Project Right-of-Way
- Facility Footprint
- 1 Mile Radius of Right-of-Way
- Location of Groundwater Well Location based on Latitude and Longitude in USGS Database
- Approximate Location of Groundwater Well Location based on the State Well Number (No other coordinates available)
- Drawdown at 5 Feet Assuming T-6,300ft^2/d S-0.05; Q-200gpm

Data Sources:
Air Photo, California Spatial Information Library, NAIP, 2005 Riverside County

0 2,000 4,000 Feet

Palen Solar Power Project

Figure J7
Predicted Drawdown During Operation Period (Low Transmissivity)

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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USGS Superposition Model

Use of Superposition Models to Simulate Possible Depletion of Colorado River Water by Ground-Water Withdrawal

Scientific Investigations Report 2008–5189

U.S. Department of the Interior
U.S. Geological Survey

Use of Superposition Models to Simulate Possible Depletion of Colorado River Water by Ground-Water Withdrawal

By Stanley A. Leake, William Greer, Dennis Watt, and Paul Weghorst

Prepared in cooperation with Bureau of Reclamation

Scientific Investigations Report 2008–5189

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

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FRONT COVER—The Lower Colorado River and adjacent farmland. Photograph from the Bureau of Reclamation.

Contents

Abstract 1
Background 1
Acknowledgments 1
Approach 2
Areas Simulated 4
Aquifer Properties 4
Transmissivity 4
Storage Coefficient 5
Characteristics of Models 7
Procedure for Computing and Displaying Areal Representation of Depletion 12
Results 12
Detrital-Virgin Area 12
Lake Mohave Area 13
Mohave Valley Area 13
Parker-Palo Verde-Cibola Area 13
Laguna Dam Area 13
Yuma Area 13
Summary and Conclusions 13
References Cited 25

Figures

1. Study area along the lower Colorado River 2
2. Sources of water to a well through time in a river-aquifer system, expressed as a fraction of the pumping rate 3
3. Cumulative distribution functions for best-fit log-normal distributions of transmissivity along the Lower Colorado River 8
4. Model grid and features of the Lake Mohave ground-water superposition model 9
5. Vertical section along row 40 of the Lake Mohave ground-water superposition model 10
6. Results from sensitivity tests of the riverbed conductance parameter in the Lake Mohave ground-water superposition model for two withdrawal locations 10
7. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 980 feet squared per day 14
8. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day 15
9. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day 16
10. Percent depletion in 100 years by pumping wells within the Lake Mohave model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 and 26,200 feet squared per day 17
11. Percent depletion in 100 years by pumping wells within the Mohave Valley model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 and 26,200 feet squared per day 18
12. Percent depletion in 100 years by pumping wells within the Parker-Palo Verde-Cibola model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day. 19

13. Percent depletion in 100 years by pumping wells within the Parker-Palo Verde-Cibola model area of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day 20
14. Percent depletion in 100 years by pumping wells within the Yuma and Laguna model areas of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day 21
15. Percent depletion in 100 years by pumping wells within the Yuma and Laguna model areas of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day 22
16. Percent depletion in 100 years by pumping wells within the Yuma model area of the Colorado River aquifer assuming a transmissivity rate of 15,500 feet squared per day 23
17. Percent depletion in 100 years by pumping wells within the Yuma model area of the Colorado River aquifer assuming a transmissivity rate of 45,900 feet squared per day 24

Tables

1. Transmissivity values above Laguna Dam used for statistical analysis 5
2. Transmissivity values below Laguna Dam used for statistical analysis 6
3. Characteristics of superposition models constructed for parts of the flood plain and river aquifer adjacent to the lower Colorado River 11

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Leakance	
foot per day per foot [(ft/d)/ft]	1	meter per day per meter

Vertical coordinate information is referenced to the National Vertical Geodetic Datum of 1929 (NGVD 29).
Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).
Elevation, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Use of Superposition Models to Simulate Possible Depletion of Colorado River Water by Ground-Water Withdrawal

By Stanley A. Leake, William Greer[1], Dennis Watt[2], and Paul Weghorst[3]

Abstract

According to the "Law of the River," wells that draw water from the Colorado River by underground pumping need an entitlement for the diversion of water from the Colorado River. Consumptive use can occur through direct diversions of surface water, as well as through withdrawal of water from the river by underground pumping. To develop methods for evaluating the need for entitlements for Colorado River water, an assessment of possible depletion of water in the Colorado River by pumping wells is needed. Possible methods include simple analytical models and complex numerical ground-water flow models. For this study, an intermediate approach was taken that uses numerical superposition models with complex horizontal geometry, simple vertical geometry, and constant aquifer properties. The six areas modeled include larger extents of the previously defined river aquifer from the Lake Mead area to the Yuma area. For the modeled areas, a low estimate of transmissivity and an average estimate of transmissivity were derived from statistical analyses of transmissivity data. Aquifer storage coefficient, or specific yield, was selected on the basis of results of a previous study in the Yuma area. The USGS program MODFLOW-2000 (Harbaugh and others, 2000) was used with uniform 0.25-mile grid spacing along rows and columns. Calculations of depletion of river water by wells were made for a time of 100 years since the onset of pumping. A computer program was set up to run the models repeatedly, each time with a well in a different location. Maps were constructed for at least two transmissivity values for each of the modeled areas. The modeling results, based on the selected transmissivities, indicate that low values of depletion in 100 years occur mainly in parts of side valleys that are more than a few tens of miles from the Colorado River.

Background

The Consolidated Decree of the United States Supreme Court in Arizona v. California, 547 U.S.150 (2006) recognizes that consumptive use of water from the Colorado River can occur by underground pumping. According to the "Law of the River," users within the lower Colorado River Basin States can divert tributary inflow before it reaches the Colorado River. Once the water reaches the Colorado River, however, entitlements are required for diversions. For wells pumping in the aquifer connected to the river, determination of a tributary source of ground water pumped can be difficult. Wilson and Owen-Joyce (1994), and Owen-Joyce and others (2000) presented the "Accounting-Surface Method." The accounting surface is defined by ground-water levels that would occur if the Colorado River were the only source and sink for water in the connected aquifer. The theory is that static (non-pumping) ground-water levels in the aquifer that are higher than the accounting surface indicate the presence of tributary water. The accounting-surface method could be used by managers to determine the need for entitlements for river water for wells pumping in the river aquifer. Wiele and others (2008) presented an updated accounting surface based on conditions in 2007–2008.

Wilson and Owen-Joyce (1994) and Owen-Joyce and others (2000) defined the "river aquifer" as the saturated ground-water system adjacent to the Colorado River, including the flood plain sediments, older alluvial sediments, and sediments in connected adjacent valleys (fig. 1). The accounting surface was defined over the area of the river aquifer beyond the Colorado River flood plain.

The accounting surface includes some parts of the river aquifer that are many tens of miles from the Colorado River. The States along the lower Colorado River have expressed interest in Federal water managers considering the timing over which wells at great distance would deplete water in the Colorado River. To further understand the temporal effects of pumping wells on the Colorado River, Reclamation subsequently set up the Non-Contract Use Modeling technical team to explore methods of assessing the timing over which wells would deplete water in the Colorado River. Team members include staff of the Bureau of Reclamation (Reclamation) and the U.S. Geological Survey (USGS). This report describes the method developed by the technical team and results for larger portions of the river aquifer along the lower Colorado River.

Acknowledgments

Ruth Thayer of Reclamation in Boulder City, Nevada, provided leadership and direction for the Non-Contract Use

[1]Bureau of Reclamation, Yuma, Arizona
[2]Bureau of Reclamation, Boulder City, Nevada
[3]Formerly of Bureau of Reclamation, Denver, Colorado

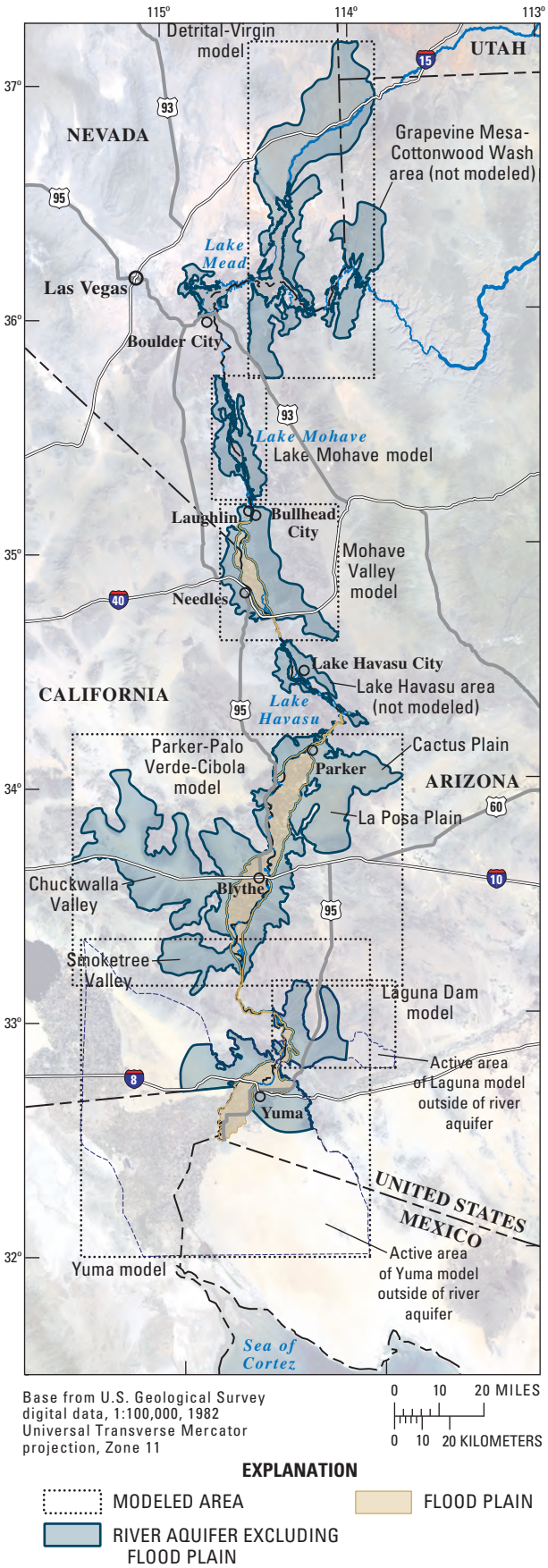


Figure 1. Study area along the lower Colorado River.

Modeling technical team. Jeff Addiego, formerly of Reclamation in Boulder City, Nevada, helped with aspects relating to the water-accounting procedures. Carroll Brown, of the Reclamation in Yuma, Arizona, contributed advice on aspects of geology. Sandra Owen-Joyce, of the USGS in Tucson, Arizona, helped with previous work on the accounting-surface method, including the river aquifer. Steve Belew, Reclamation in Boulder City, and Jim Monical, USGS in Tucson, helped with spatial data sets needed to construct models and mapping of model results.

Approach

C.V. Theis (1940) provided the first comprehensive description of the sources of water to pumped wells. He indicated that pumped water initially comes from storage in the aquifer. With time, however, cones of depression can spread to areas of ground-water recharge and discharge, resulting in additional sources of increased inflow to the aquifer and decreased outflow from the aquifer. Along the Colorado River, the interest is in depletion of surface-water resources from ground-water pumping. The depletion can result from decreased flow from the aquifer to the river, increased flow from the river to the aquifer, or a combination of these two conditions.

An example of the progression of depletion over time for a point in a hypothetical aquifer is shown in figure 2. At time zero, when pumping starts, the source of all of the water pumped by the well is from ground-water storage. With time, however, this source decreases and the complementary source, depletion of surface water, increases. At the end of 50 years in this example, only 5 percent (a fraction of 0.05) of the pumping rate is from ground-water storage, and 95 percent is from depletion of surface water. If the well pumping was continued indefinitely, a new steady-state condition would be reached in which all of the well pumping rate would be depletion of surface water, assuming that water available in surface-water bodies is sufficient to supply the total rate of well pumping.

The time over which depletion of river water by underground pumping occurs is dependent on the river and aquifer geometry, location of the pumping, and the aquifer hydraulic diffusivity, T/S, where T is transmissivity and S is storage coefficient. It is important to note that depletion of surface water by pumping ground water is independent of the rates and directions of ground-water flow. For example, depletion can occur from decreased flow from the aquifer to the river and increased flow from the river to the aquifer. For both of these cases, the amount of water in the river is reduced and the total depletion of the flow in the river is the sum of the two quantities. If the flow system changed by means such as changing recharge amounts or locations and (or) changing river stages, the total depletion by a well would be the same as depletion by a well at the same location in the unchanged system as long as the changes to the system did not affect the aquifer diffusivity and the location of the surface-water features.

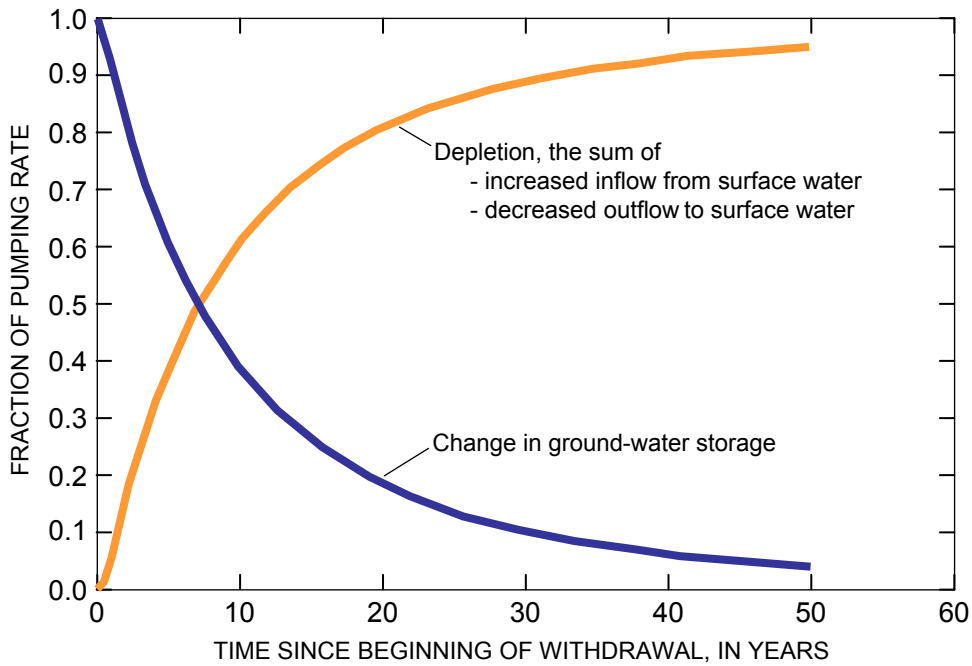


Figure 2. Sources of water to a well through time in a river-aquifer system, expressed as a fraction of the pumping rate.

If the interest is in total depletion, mathematical solution can be done using the principle of superposition in an analytical or numerical method that solves for changes in a system that is initially static. In a solution using the superposition approach, total depletion from a surface-water boundary from ground-water pumping is directly computed, and individual components of decreased flow from the aquifer to the river and increased flow from the river to the aquifer cannot be computed. The simplest approach to calculating depletion from ground-water pumping is the analytical solution by Glover and Balmer (1954). This approach assumes the river is a line source—straight and infinitely long, and fully penetrates the thickness of the aquifer, which extends an infinite distance away from the river. Using the theory of image wells, depletion in a bounded aquifer can be computed by the analytical solution, with a lateral no-flow boundary that is parallel to the river. Aquifer properties are assumed to be homogeneous. Because of the complex geometry of the Colorado River and the river aquifer (fig. 1), the analytical solution by Glover and Balmer (1954) is difficult to apply, especially in and around side valleys that are a part of the river aquifer.

A more common approach to calculating depletion is to use calibrated numerical ground-water flow models. Such models approximate the vertical and horizontal geometry of the aquifer, as well as flow patterns within the aquifer. The approach generally includes first running the model without a pumping well of interest and saving model-computed rates of ground-water flow to and from the river. The next step involves running the model again, this time with the pumping center added, again saving model-computed rates of ground-water flow to and from the river. For the two model runs, depletion is calculated as the sum of the decrease in ground-water flow to the river and increase in ground-water flow from the river.

Calibrated ground-water flow models do not exist for most parts of the lower Colorado River aquifer, and construction of such models was beyond the scope of this study. For this study, an approach was taken that is intermediate to the approaches using analytical solutions and calibrated numerical models. The intermediate approach uses numerical models that incorporate the complex horizontal geometry of the aquifer and river, but incorporate the simplifying principle of superposition, and the simple vertical geometry and homogeneity assumptions that are part of the analytical-solution approach.

Numerical superposition models for evaluating possible depletion of water in the Colorado River by ground-water pumping in the connected river aquifer were constructed for select areas along the lower Colorado River from Lake Mead to the Yuma area. The areas modeled include the river aquifer as defined by Wilson and Owen-Joyce (1994) and Owen-Joyce and others (2000). In a few of the modeled areas, the model boundaries extend beyond the defined river aquifer boundary where the defined boundary does not represent a physical no-flow boundary. Some general aspects of the modeling strategy are as follows:

1. Depletion is calculated using numerical superposition or change models. In plan view the aquifers are complexly shaped, based on the outline of the mapped river aquifer, with any mapped no-flow areas removed from the active model domain. In cross-sectional view the aquifers are simple two-dimensional horizontal slabs.

2. Models are constructed for the largest of the river-aquifer areas from Lake Mead to the Yuma area along the lower Colorado River. Smaller areas of the river aquifer are not modeled where experience with larger models indicates that computed depletion of surface water after 100 years of withdrawal for narrow sections is relatively high.
3. The models do not represent spatial variations of aquifer hydraulic properties. The models use a constant storage coefficient (specific yield), and two or more statistically derived transmissivity values. The transmissivity values are selected to simulate aquifer hydraulic diffusivity that represents (a) a conservative (or low) value that would underestimate depletion, and (b) an average value.
4. The only surface-water boundaries included in the models are the Colorado River, reservoirs along the river, and wetlands connected to the river.
5. Depletion is mapped for 100 years of withdrawal for the area of the river aquifer outside of the flood plain. The period of 100 years is commonly used as a timeframe in water management rules, such as Assured Water Supply criteria of the State of Arizona (http://www.azwater.gov/dwr/WaterManagement/Content/OAAWS/default.asp, accessed October 10, 2008).

Further details on implementation of the method are given in the following sections.

Areas Simulated

Models were constructed for six areas of the river aquifer. Starting with the most upstream reach, models included (1) Detrital-Virgin, (2) Lake Mohave, (3) Mohave Valley, (4) Parker-Palo Verde-Cibola, (5) Laguna Dam, and (6) Yuma area (fig. 1). The two largest river-aquifer areas not modeled are the Grapevine Mesa-Cottonwood Wash area and the Lake Havasu Area.

Aquifer Properties

Aquifer hydraulic diffusivity is the aquifer property that controls the rate that the depletion curve (fig. 2) progresses from zero at the start of pumping, towards 1.0 as pumping time continues. Diffusivity is T/S, where T is transmissivity and S is the storage coefficient. A lower transmissivity will result in slower propagation of drawdown and slower progression of depletion from zero to 1.0 through pumping time and a higher transmissivity will result in faster propagation of drawdown and progression of depletion through time. Conversely, a lower storage coefficient will result in faster progression of depletion and a higher storage coefficient will result in slower progression of depletion. The distribution of diffusivity, or the distributions of both transmissivity and storage coefficient over the entire river aquifer is not known, so the approach taken here calculates depletion using (a) a uniform low (or conservative from the standpoint of effects of a pumping well on the river) estimate of diffusivity and (b) a uniform average estimate of diffusivity. For this study, low and average diffusivities were computed using an estimate of the average storage coefficient and estimates of the low and average transmissivity. Methods and rationales for selecting these values are given in the following two sections.

Transmissivity

Although detailed distributions of transmissivities for the river aquifer are not known, many estimates of transmissivity for sediments in the river aquifer were published by Metzger and Loeltz (1973, table 2), Metzger and others, (1973, table 5), and Olmstead and others, (1973, table 7). The best of these estimates were used to develop log-normal distributions of transmissivity for several subreaches of the river aquifer. From those log-normal distributions, low and average transmissivity values were selected.

The best values of transmissivity were selected from Metzger and Loeltz (1973, table 2), Metzger and others, (1973, table 5), and Olmstead and others, (1973, table 7) using the following two criteria:

1. Only transmissivity values from tests in the younger and older alluvium of the lower Colorado River are used.
2. Test results are listed in the source reports as being fair, good, or excellent, in terms of conformance to theoretical values and reliability of the estimate.

Published values were available for Mohave Valley, Parker-Palo Verde-Cibola, and Yuma areas. The first two of these areas are above Laguna Dam, and the Yuma area is below Laguna Dam. Published values of transmissivity that meet the criteria are generally higher in the Yuma area than in the areas above Laguna Dam. For this reason, separate log-normal distributions of transmissivity were developed for reaches above and below Laguna Dam. Transmissivity values used are given in tables 1 and 2. In some cases, the source documents listed multiple estimates for an individual well. Where these estimates met the criteria for inclusion in the analysis, multiple values for the same well were included.

The statistical analyses used 25 estimates of transmissivity upstream of Laguna Dam (table 1) and 58 estimates downstream of Laguna Dam (table 2). Best-fit log-normal distributions to these data are shown in figures 3*A* and 3*B*. The low estimate of transmissivity was selected as the value for which probability is 0.05 (5 percent) that transmissivity is less than or equal to the value. The average estimate of transmissivity was selected as the value for which probability is 0.5 (50 percent) that transmissivity is less than or equal to the value. The low and average estimates of transmissivity for areas upstream of Laguna Dam are 6,300 ft^2/day (47,000 gal/day/ft), and 26,200 ft^2/day (196,000 gal/day/ft), respectively (fig. 3*A*). The low and average estimates of transmissivity for

Table 1. Transmissivity values above Laguna Dam used for statistical analysis.
[Type of test: D, drawdown; R, recovery; S, specific capacity; numbers in square brackets are range interval tested, in depth below land surface, in feet]

Well Name	Other Identifier	Transmissivity, in gallons per day per foot	Transmissivity, in feet squared per day	Method of analysis
Mohave Valley (Metzger and Loeltz, 1973, table 2)				
(B-18-22)15aab	D. Hulet	240,000	32,100	R
(B-18-22)27bbc	G. McKellip	600,000	80,200	D
(B-18-22)27bbc	G. McKellip	900,000	120,300	R
(B-18-22)27bbc	G. McKellip	240,000	32,100	S
9N/23E-29F1	City of Needles	600,000	80,200	R
9N/23E-29F1	City of Needles	300,000	40,100	S
9N/23E-32K1	City of Needles	450,000	60,200	R
9N/23E-32K1	City of Needles	70,000	9,400	S
11N/21E-36G2	Soto Brothers	94,000	12,600	R
11N/21E-36G2	Soto Brothers	75,000	10,000	S
11N/21E-36Q1	W. Riddle	160,000	21,400	D
11N/21E-36Q1	W. Riddle	170,000	22,700	R
11N/21E-36Q1	W. Riddle	140,000	18,700	S
Parker Valley (Metzger and others, 1973, table 5)				
(B-7-21)14dcd	USBIA No.8	460,000	61,500	R
(B-9-20)11dbc	USBIA No.2	400,000	53,500	R
(B-9-19)5ddd	USGS LCRP-15	300,000	40,100	R [175-199]
(B-7-21)14acd	USBIA No.7	75,000	10,000	R
(B-7-21)23acd	USBIA No.9	120,000	16,000	D,R
(B-7-21)23dcd	USBIA No.10	40,000	5,300	D,R
Palo Verde Valley (Metzger and others, 1973, table 5)				
5S/22E-28C2	U.S. Citrus Corp	64,000	8,600	R
6S/22E-11H1	H. M. Neighbor	700,000	93,600	R
6S/22E-15Q1	E. Weeks	290,000	38,800	R
6S/22E-35R2	Southern Counties Gas Co	150,000	20,100	R
8S/21E-13A1	USGS LCRP-16	63,000	8,400	D
8S/21E-13A1	USGS LCRP-16	170,000	22,700	R

areas downstream of Laguna Dam are 15,500 ft^2/day (116,000 gal/day/ft) and 45,900 ft^2/day (343,000 gal/day/ft), respectively (fig. 3*B*).

Storage coefficient

In aquifers such as the river aquifer along the lower Colorado River, the storage coefficient accounts for processes including (a) draining and filling of pore spaces at the water table, (b) contraction and expansion of the aquifer skeleton, and (c) decompression and compression of water in the pore spaces. The property that accounts for the first of these processes is designated as the aquifer specific yield. The property that accounts for the remaining two of these processes is the elastic aquifer storage coefficient. In the river aquifer along the lower Colorado River, the specific yield accounts for the dominant mechanism of storage change. Specific yield in the river aquifer is several orders of magnitude larger than the elastic storage coefficient, and therefore is used to define low and average diffusivity. The best estimate of specific yield in the area is from Loeltz and Leake (1983). They published estimates of specific yield from neutron-probe studies along both sides of the Colorado River at 18 cross sections, spaced at approximate 1-mile intervals. The average specific-yield value from these studies was about 0.2, and this value is used in this study of depletion along the lower Colorado River.

Table 2. Transmissivity values below Laguna Dam used for statistical analysis; all transmissivity values are from Olmstead and others (1973, table 7).

[Type of test: D, drawdown; R, recovery; LA, leaky artesian analysis with observation wells; numbers in square brackets are interval tested, in depth below land surface, in feet]

Well Name	Other Identifier	Transmissivity, in gallons per day per foot	Transmissivity, in feet squared per day	Type of test
16S/22E-29Gca2	USGS LCRP-26	570,000	76,200	R
16S/23E-8Ecc	USBR CH5	340,000	45,500	D
16S/23E-8Ecc	USBR CH5	750,000	100,300	R
16S/23E-22Fdc	H. Mitchell	440,000	58,800	R
16S/23E-9Naa	M. E. Spencer	300,000	40,100	R
16S/23E-8Ecc	USGS LCRP-23	240,000	32,100	R
16S/23E-10Rcc	Dover and Webb	420,000	56,100	R
(C-7-22)14bcd	USGS LCRP-14	110,000	14,700	R
(C-8-21)19dad	F. J. Hartman	230,000	30,700	R
(C-8-21)30cdc	F. J. Hartman	1,800,000	240,600	R
(C-8-22)13bdd2	S. Sturges	65,000	8,700	R
(C-8-22)18cbd	Powers	610,000	81,600	R
(C-8-22)18ddd	Powers	800,000	107,000	R
(C-8-22)19ccc	USBR CH702	68,000	9,100	R
(C-8-22)21ddd	B. Church	390,000	52,100	R
(C-8-22)22caa	B. Church	430,000	57,500	R
(C-8-22)22cda1	B. Church	320,000	42,800	R
(C-8-22)22cda2	B. Church	380,000	50,800	R
(C-8-22)25bad	F. J. Hartman	400,000	53,500	R
(C-8-22)26adb	S & W	290,000	38,800	R
(C-8-22)28aaa	B. Church	350,000	46,800	R
(C-8-22)30cab	C. Lord	380,000	50,800	R
(C-8-22)30ddd	C. Lord	360,000	48,100	R
(C-8-22)34aaa	W. R. Whitman	960,000	128,300	R
(C-9-23)20cdd	YCWUA 5	250,000	33,400	D
(C-9-23)29adb	Yuma Mesa Fruit Growers	600,000	80,200	D
(C-9-23)30cba2	YCWUA 6	200,000	26,700	D
(C-9-24)13cdd	USBR CH3	300,000	40,100	D
(C-9-24)13cdd	USBR CH3	300,000	40,100	R
(C-9-24)36aaa	McDaniel & Sons, Inc.	160,000	21,400	R
(C-10-23)12aba1	J. F. Nutt	210,000	28,100	D
(C-10-23)12aba1	J. F. Nutt	260,000	34,800	R
(C-10-23)12bda	J. F. Nutt	500,000	66,800	R
(C-10-23)15aab	J. F. Nutt	270,000	36,100	R
(C-10-23)31bbb1	USGS LCRP-1	280,000	37,400	LA
(C-10-24)12bcc2	YCWUA 8	260,000	34,800	R
(C-10-24)13bbd1	YCWUA 9	540,000	72,200	R
(C-10-25)1bba	P. R. Sibley	443,000	59,200	R
(C-10-24)2cda	F. Jeffries	460,000	61,500	R
(C-10-24)35cab	J. F. Barkley	600,000	80,200	R
(C-11-23)34bbc	USGS LCRP-30	1,300,000	173,800	R
(C-11-24)2abd	J. F. Nutt	1,100,000	147,100	D and R
(C-11-24)23bcb	USGS LCRP 10	740,000	98,900	R
(C-11-25)3dac	E. Hughes	730,000	97,600	R
(C-9-23)17abc1	YCWUA 3	230,000	30,700	D
(C-8-22)34add	USBR CH750	150,000	20,100	R

Table 2. Transmissivity values below Laguna Dam used for statistical analysis; all transmissivity values are from Olmstead and others (1973, table 7)—Continued.

[Type of test: D, drawdown; R, recovery; LA, leaky artesian analysis with observation wells; numbers in square brackets are interval tested, in depth below land surface, in feet]

Well Name	Other Identifier	Transmissivity, in gallons per day per foot	Transmissivity, in feet squared per day	Type of test
(C-8-22)35caa1	USBR CH704	340,000	45,500	R [435-570]
(C-8-22)35caa1	USBR CH704	1,100,000	147,100	R [99-170]
(C-8-22)35caa2	USBR CH751	190,000	25,400	R
(C-8-22)35cca	Az. Western College	230,000	30,700	R
(C-8-22)35cad	USBR CH752	200,000	26,700	R
(C-8-23)25acb	Gunther and Shirley	260,000	34,800	R
(C-8-23)25dab	Gunther and Shirley	300,000	40,100	R
(C-8-23)26bac	G. Ogram	180,000	24,100	R
(C-8-23)27ada	USBR CH701	330,000	44,100	D
(C-8-23)27ada	USBR CH701	230,000	30,700	R
(C-8-23)27ddd1	Carter	120,000	16,000	R
(C-8-24)22ccd	McLaren Produce Co.	300,000	40,100	D

Characteristics of Models

All models were constructed and implemented in the same way, with the major differences being the geometry of the domain and surface-water features simulated and the transmissivity values tested. Simulations were carried out with the USGS model program MODFLOW-2000 (Harbaugh and others, 2000). Common characteristics of the models are as follows:

1. Each model domain represents a major contiguous area of saturated alluvium and adjacent saturated older alluvium along the lower Colorado River. The lateral boundaries of the active model domain were determined by the outermost position of (a) the "river aquifer" as mapped by Wilson and Owen-Joyce (1994) or (b) the Colorado River alluvium upstream and downstream boundaries of each model where no adjacent river aquifer was mapped. The areas modeled are shown in figure 1. Coordinates for perimeters of the active model domains were prepared in the coordinate system defined by Universal Transverse Mercator Zone 11, 1927 North American Datum. In some areas, the model perimeters were smoothed to remove unnecessary details in the river aquifer boundaries.

2. Units of length in the models are feet. As discussed in following sections, however, some computations used coordinates in meters to construct model data sets. Units of time in the models are days.

Model grids were oriented with rows in an east-west direction and columns in a north-south direction. The origin of each model is the northwest corner of the domain, so that model rows increment in a southerly direction and model columns increment in an easterly direction (fig. 4). The lateral grid spacing was 0.25 mile (402.3 m) along rows and columns.

The number of rows in each model, N_{row}, was computed as

$$N_{row} = INT\left[\frac{(Y_{\max} - Y_{\min})}{\Delta} + 0.49999\right],$$

where

INT is a function that converts a real number to an integer by truncating digits to the right of the decimal place,

$Y_{\max}$ is the maximum of all UTM easting coordinates (in meters) along the model perimeter,

$Y_{\min}$ is the minimum of all UTM easting coordinates (in meters) along the model perimeter, and

Δ is the grid spacing (402.3 m).

Similarly, the number of columns in each model, N_{col}, was computed as

$$N_{col} = INT\left[\frac{(X_{\max} - X_{\min})}{\Delta} + 0.49999\right],$$

where

$X_{\max}$ is the maximum of all UTM northing coordinates (in meters) along the model perimeter,

$X_{\min}$ is the minimum of all UTM northing coordinates (in meters) along the model perimeter.

The active part of the model grid was determined in a two-step process using the model perimeter polygon and polygons denoting areas of no flow within the model perimeter (fig. 4). Areas of no flow can occur where low permeability rocks are surrounded by the river aquifer. For the first step,

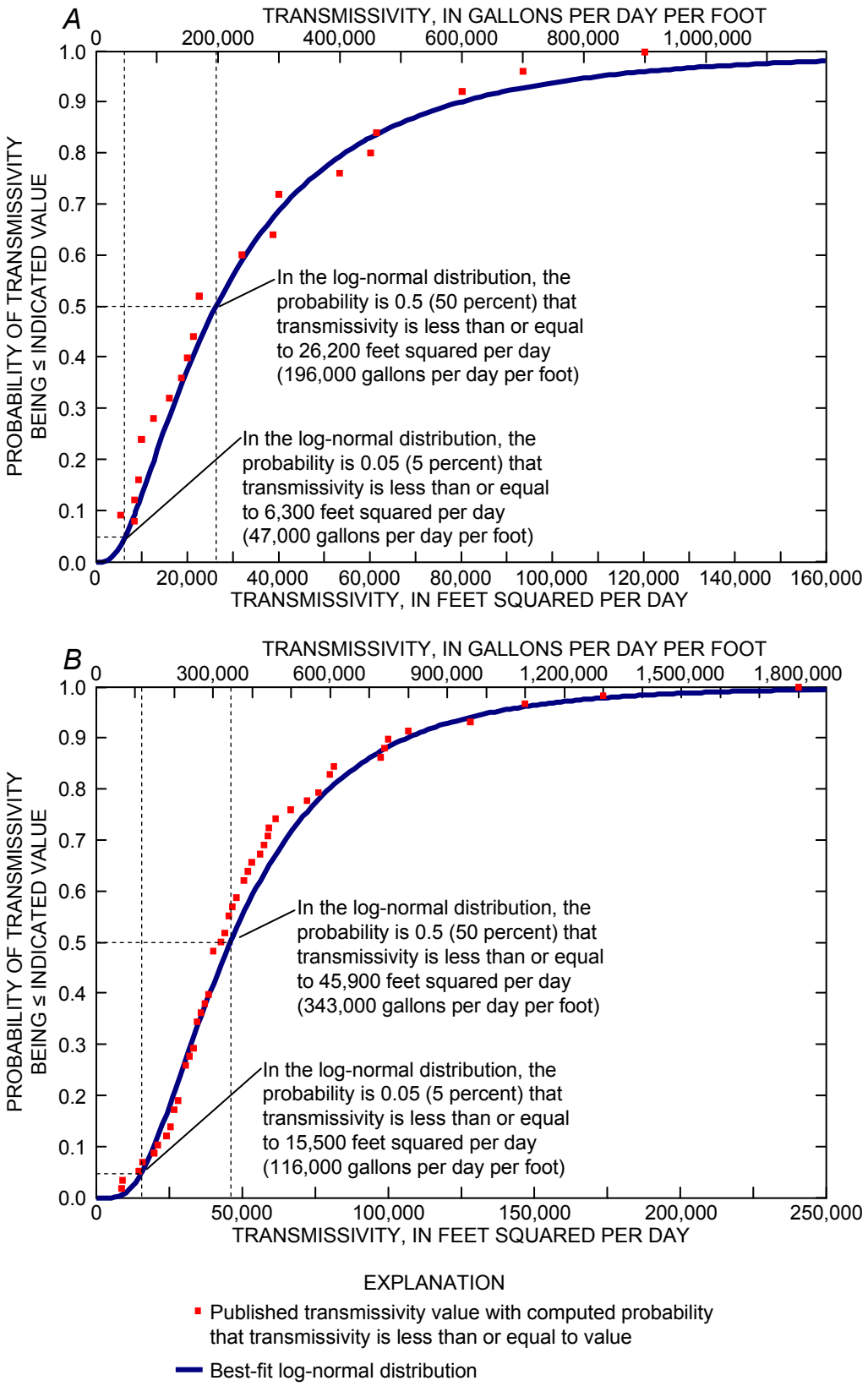


Figure 3. Cumulative distribution functions for best-fit log-normal distributions of transmissivity along the Lower Colorado River. *A*, Distribution function for data north of the Yuma area. *B*, Distribution function for data in the Yuma area.

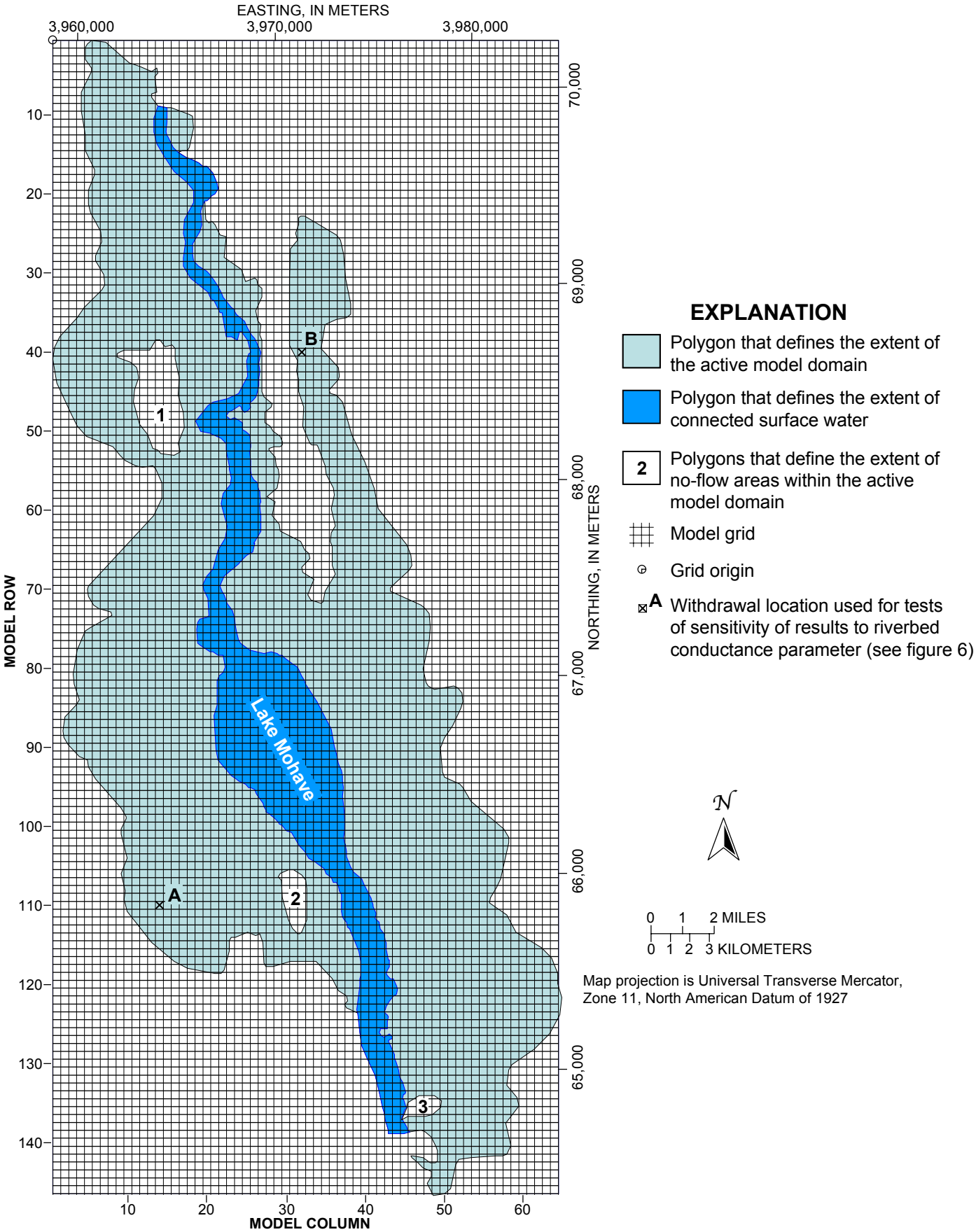


Figure 4. Model grid and features of the Lake Mohave ground-water superposition model.

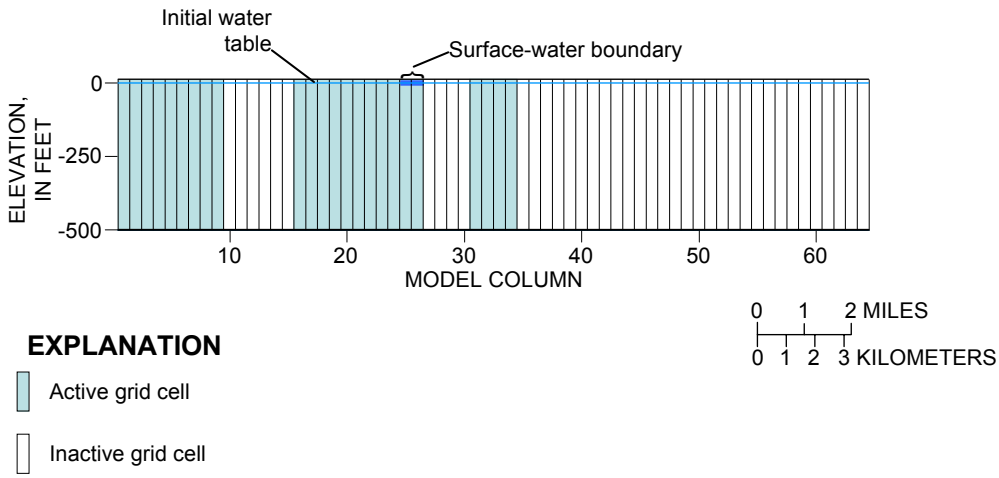


Figure 5. Vertical section along row 40 of the Lake Mohave ground-water superposition model.

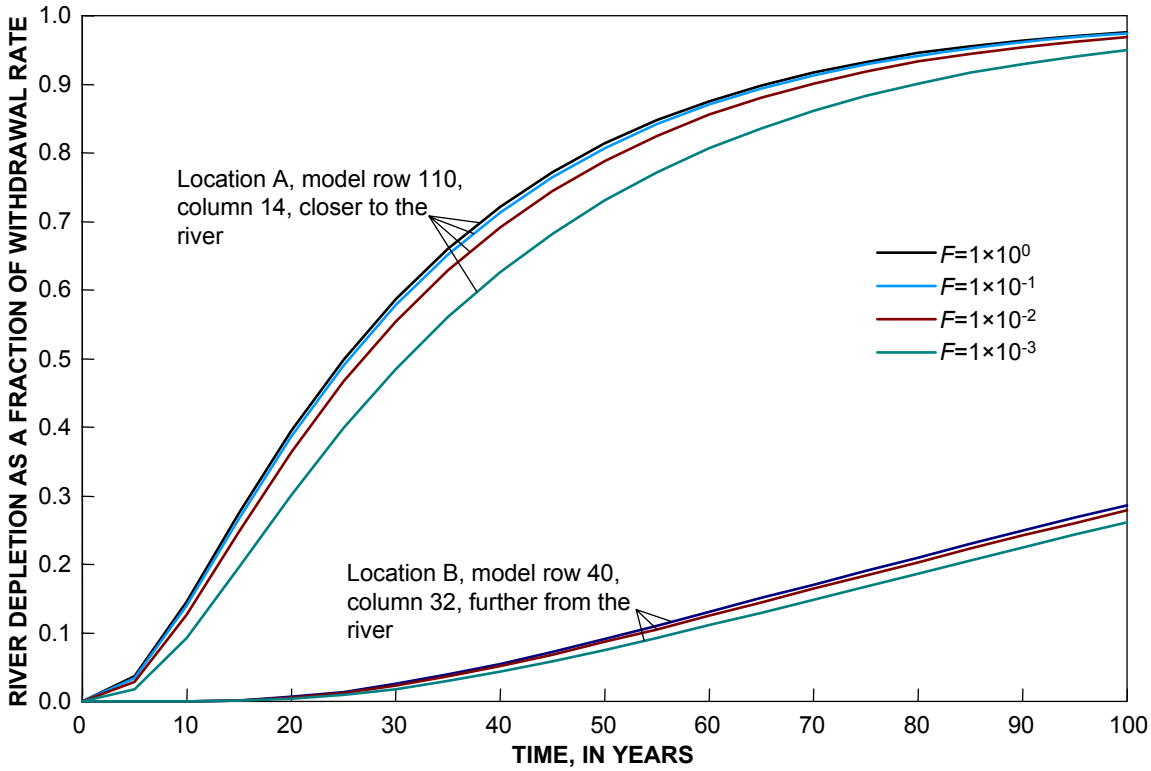


Figure 6. Results from sensitivity tests of the riverbed conductance parameter in the Lake Mohave ground-water superposition model for two withdrawal locations (see fig. 4). Multiple depletion curves were generated by multiplying all conductance values by the parameter *F*.

Table 3. Characteristics of superposition models constructed for parts of the flood plain and river aquifer adjacent to the lower Colorado River.
[Transmissivity values run: Yes, depletion analysis was completed for value; No, depletion analysis was not completed for value.]

Model name	UTM Easting of west edge of grid, meters[1]	UTM Northing of north edge of grid, meters[1]	Number of model rows	Number of model columns	Number of active model cells	Transmissivity values run, feet squared per day (gallons per day per foot)				
						980 (7,300)	6,300 (47,000)	15,500 (116,000)	26,200 (196,000)	45,900 (343,000)
Detrital-Virgin	719593.75	4116963.00	396	148	21,025	Yes	Yes	No	Yes	No
Lake Mohave	702348.12	3958695.50	146	64	4,103	No	Yes	No	Yes	No
Mohave Valley	706260.69	3897829.00	160	139	8,976	No	Yes	No	Yes	No
Parker-Palo Verde-Cibola	636450.00	3789000.00	296	388	40,292	No	Yes	No	Yes	No
Laguna Dam	730897.38	3672455.25	103	145	6,302	No	Yes	No	Yes	No
Yuma	640414.62	3691950.25	374	340	59,645[2]	No	Yes	Yes	Yes	Yes

[1]Coordinates are UTM Zone 11, North American Datum of 1927.

[2]For the model in the Yuma area, depletion was not calculated for active model cells in Mexico and areas in USA west of the area of the accounting surface published by Owen-Joyce and others (2000). A total of 16,147 simulations were made for each of four transmissivity values.

all cells that were more than 50 percent within the model perimeter were denoted as active, and all cells that were 50 percent or less within the model perimeter were denoted as inactive. Second, all cells that were more than 50 percent within any area of no flow were denoted as inactive.

3. Each model consists of one layer of cells with a bottom elevation of –500 ft and an initial head elevation of 0 ft for each active cell (fig. 5). This results in a uniform starting saturated thickness of 500 ft. The top elevation of the model was set at a uniform elevation of 10 ft.

4. Connected surface-water features were simulated using the River Package of MODFLOW-2000. For all models, river stages were set to an elevation of zero, thereby allowing computation of change in flow to or from surface-water features that result from change in head in connected cells. In the River Package, the degree of connection between the surface water and a connected cell is controlled by the riverbed conductance term, C_{riv}, which is defined as

$$C_{riv} = K_{rb} A / b_{rb},$$

where

K_{rb} is the vertical hydraulic conductivity of the riverbed,

A is the area of the river in the cell, and

b_{rb} is the thickness of the riverbed.

Large riverbed conductance values were specified so that simulated surface-water features are hydraulically well connected to underlying model cells. This approach approximates a specified-head boundary at the location of surface-water feature. For the Parker-Palo Verde-Cibola model the River Package data set was constructed using the program RIVGRID (Leake and Claar, 1999), using an approximate river centerline, an assumed river width of 100 ft, an assumed K_{rb} of 50 ft/day, and an assumed b_{rb} of 5 ft. The area, A, used to compute the riverbed conductance, C_{riv} is computed by program RIVGRID as the product of the length of the river traversed in a cell by the centerline and the assumed river width. The average value of C_{riv} for the Parker-Palo Verde-Cibola model was 2.3×10^5 ft^2/day. For all other models A was computed as the area of intersection of a polygon representing the Colorado River and (or) reservoirs (fig. 4) and the model cell. The quantity was set at 0.929 day^{-1}, therefore the maximum conductance (for the case of a cell entirely within the river/reservoir polygon) is about 1.62×10^6 ft^2/day. The average riverbed conductance for the Mohave Valley model is 7.3×10^5 ft^2/day. For the Lake Mohave model (fig. 4) the average riverbed conductance was 1.3×10^6 ft^2/day reflecting a wider surface-water body than is present in the Mohave Valley model.

The sensitivity of model results to the value of riverbed conductance was tested using the Lake Mohave model. Depletion curves were computed by the model for withdrawal at two locations. For the first point, labeled “A” on figure 4, depletion can occur when effects of withdrawal propagate about 4.5 miles northeastward to the edge of Lake Mohave. For the second point, labeled “B” on figure 4, depletion can occur when effects of withdrawal propagate about 14 miles along a side valley and then southwestward to the edge of Lake Mohave. Because of the shorter distance to surface water, depletion occurs more rapidly from withdrawals at point A than at point B. For each location, depletion curves were computed using a multiplication factor, F, of 1×10^{-1}, 1×10^{-2}, and 1×10^{-3}, for all riverbed conductance values (fig. 6). Curves shown for $F=1\times10^0$ use the original riverbed conductance values. As can be seen on figure 6, differences in depletion calculated with the original riverbed conductance values and with values that are three orders of magnitude lower are relatively minor, with

the greatest differences occurring at location A. This observation along with the fact that thick, low-permeability riverbed sediments are not known to occur along the lower Colorado River leads to the conclusion that the strategy of using relatively high riverbed conductance values is reasonable.

A summary of characteristics of the six superposition models is given in table 3. The Laguna and Yuma models included parts of the model domain that extend beyond the mapped area of the river aquifer (fig. 1). The Laguna model was extended to the east because of uncertainty in where the river aquifer ends. An extension of the model domain such as this tends to slow down the progression of simulated depletion through time in comparison to that simulated in a model that includes a no-flow boundary. The Yuma model was extended southward and westward into the delta region of the Colorado River to reflect the continuous nature of the ground-water flow system thought to exist there.

Estimates of depletion in all models were made using the low and average transmissivity values from data upstream of Laguna Dam, 6,300 ft^2/day (47,000 gal/day/ft) and 26,200 ft^2/day (196,000 gal/day/ft), respectively. In addition, for the Yuma area, estimates of transmissivity were made using low and average transmissivity values derived from data downstream from Laguna Dam. Finally, for the Detrital-Virgin model, depletion also was calculated using a lower estimate of transmissivity, 980 ft^2/day (7,300 gal/day/ft). This was done because there were no published estimates of transmissivity in this area in the sources of data used in the statistical analyses. Transmissivity from one location in the Virgin Valley was inferred to be about 980 ft^2/day (7,300 gal/day/ft) from hydraulic conductivity and thickness estimates in a report by Las Vegas Water District (1992).

Procedure for Computing and Displaying Areal Representation of Depletion

A computer program was written to run each superposition model repeatedly to calculate depletion at 100 years for every active model grid cell. The program required that most MODFLOW data sets for the model be constructed prior to running the program. Steps taken by the program to calculate depletion for each active cell in the model grid are as follows:

1. Calculate the northing and easting of the cell center in Universal Transverse Mercator Zone 11 coordinates.
2. Construct a MODFLOW-2000 Well Package data set for a single well at the row and column location of the cell using the flow rate of -1.431×10^5 ft^3/day (a withdrawal of 1,200 acre-ft/year). The final results are independent of this rate because the system responds linearly to withdrawal (Leake and Reeves, 2008). The superposition model only considers the effects of the well being added, not effects of other wells that may exist in the real system.
3. Run the model.
4. Open the listing file from the model run and read the induced flow from the river in the volumetric mass balance for a simulation time of 100 years.
5. Divide the induced flow rate by the withdrawal rate to get the fraction of withdrawal rate that is accounted for as depletion at 100 years.
6. Save information including row and column location, northing and easting, and depletion fraction at 100 years.

When these steps are completed for each active cell in the model grid, the program is terminated. The northing and easting coordinates and depletion values then can be mapped using a geographic information system or other contouring program. The grid spacing of 0.25 mile results in a dense network of points for mapping over the area of the river aquifer.

Note that the method as implemented requires one simulation (model run) for each cell in the model grid for each transmissivity value used. For example, the Parker-Palo Verde model has 40,292 active model cells, requiring a total of 80,584 simulations for two uniform values of transmissivity. For the Yuma model, the active area is much larger than the area over which Owen-Joyce and others (2000) mapped the accounting surface. The mapped depletion, however, was restricted to a subarea of the model domain, requiring a total of 64,588 simulations for four uniform transmissivity values.

Results

Distributions of simulated depletion in the six model areas are shown on maps in figures 7–17. The maps show the simulated depletion at 100 years for one pumping well, as a function of the position of that well. Values shown are depletion as a percentage of the well pumping rate, expressed as colored areas in ten intervals ranging from 0–10 to 90–100. Supplemental contours showing 1 percent and 5 percent depletion are shown where values in this range were computed. Depletion percentages are not shown for areas within the flood plain of the Colorado River or areas underlying surface water. In the following discussions of results for the six areas modeled, particular focus is on any areas where depletion is 5 percent or less in 100 years.

Detrital-Virgin Area

This area includes Detrital Valley south of Lake Mead and the much larger Virgin Valley north of Lake Mead. With the lowest transmissivity value tested, 980 ft^2/day (7,300 gal/d/ft), the 5 percent depletion contour is within 5–10 miles of Lake Mead (fig. 7). Results for the two higher transmissivity values shown in figures 8 and 9, increased depletion can be seen by the increasing distance of the 5 percent contour from Lake Mead. For the highest value tested, 26,200 ft^2/day (196,000 gal/d/ft), depletion is greater than 5 percent in all of Detrital Valley and in all but the uppermost part of Virgin Valley.

Lake Mohave Area

This area was the smallest among the six areas modeled. For the two transmissivity values tested, 6,300 and 26,200 ft^2/day (47,000 and 196,000 gal/d/ft), no areas of depletion less than 10 percent were simulated (fig. 10). The lowest values of depletion are in a narrow north-south trending side valley on the east side of the river.

Mohave Valley Area

In this area, depletion simulated using the higher transmissivity value tested, 26,200 ft^2/day (196,000 gal/d/ft), is higher than 50 percent over the entire model domain (fig. 11). Using the lower value tested, 6,300 ft^2/day (47,000 gal/d/ft), a small area of depletion less than 5 percent was simulated in a side valley in the southeast part of the model domain.

Parker-Palo Verde-Cibola Area

This area is the largest river-aquifer area modeled and is the most complex in terms of horizontal geometry. Side valleys in the river aquifer include Chuckwalla and Smoketree Valleys in the west-central and southwest part of the area, and Cactus and La Posa Plains in the northeast part of the area. Using the lower transmissivity value tested, 6,300 ft^2/day (47,000 gal/d/ft), 5 and 1 percent simulated depletion contours can be seen in each of these side valleys (fig. 12). With the higher transmissivity value tested, 26,200 ft^2/day (196,000 gal/d/ft), only Chuckwalla Valley has simulated depletion values less than 10 percent (fig. 13).

Laguna Dam Area

This area includes the part of the river aquifer that is immediately above Laguna Dam. Much of this part of the river aquifer is east of the river. Using the lower transmissivity value tested, 6,300 ft^2/day (47,000 gal/d/ft), 5 and 1 percent simulated depletion contours can be seen around Castle Dome Plain (fig. 14). With the higher transmissivity value tested, 26,200 ft^2/day (196,000 gal/d/ft), simulated depletion is greater than 10 percent for the entire area (fig. 15).

Yuma Area

For the Yuma area, depletion was simulated for the area of the accounting surface mapped by Owen-Joyce and others (2000). For the two transmissivity values used in models upstream from Laguna Dam, 6,300 and 26,200 ft^2/day (47,000 and 196,000 gal/d/ft), areas of depletion of 5 percent or less were simulated with the lower of these values (fig. 14), but no areas of depletion of 10 percent or less were simulated with the higher value (fig. 15). Depletion also was simulated using two additional transmissivity values, 15,500 and 45,900 ft^2/day (116,000 and 343,000 gal/d/ft). For the lower transmissivity, a small area of depletion less than 10 percent was simulated on the west side of the mapped area in southeastern Imperial Valley (fig. 16). For the higher transmissivity, simulated depletion is greater than 20 percent throughout the model domain (fig. 17).

Summary and Conclusions

The Accounting-Surface Method was developed (Wilson and Owen-Joyce, 1994; Owen-Joyce and others, 2000; Wiele and others, 2008) to provide water managers with a possible tool help evaluate the need for entitlements by wells pumping in the river aquifer. To further understand temporal effects of pumping wells on the Colorado River, Reclamation set up a technical team to assess timing over which wells at great distance would deplete water in the Colorado River. Possible methods for calculating depletion of surface water from ground-water pumping range from simple analytical solutions to complex numerical ground-water flow models. For this study, an intermediate approach was taken, using numerical superposition models with complex horizontal geometry and simple vertical geometry. Six areas of the river aquifer along the lower Colorado River were modeled. Published transmissivity values were analyzed to determine low and average transmissivity values. A value of 0.2 was used for the aquifer specific yield (or storage coefficient) in all models. All model grids consisted of one layer of cells, with model rows and columns oriented in east-west and north-south directions, respectively.

Distribution of depletion was simulated using MODFLOW-2000. One simulation was done for each active cell in the model grid for each transmissivity value tested. Maps were prepared to show the simulated depletion at 100 years for one pumping well, as a function of the position of that well.

Areas in which simulated depletion at 100 years was less than or equal to 5 percent generally occurred only in side valleys with the lower or more conservative transmissivity values tested. For the smaller areas modeled, and for the river aquifer within the river valley adjacent to the flood plain in all models, simulated depletion at 100 years was generally in the range of 10–100 percent of the pumping rate.

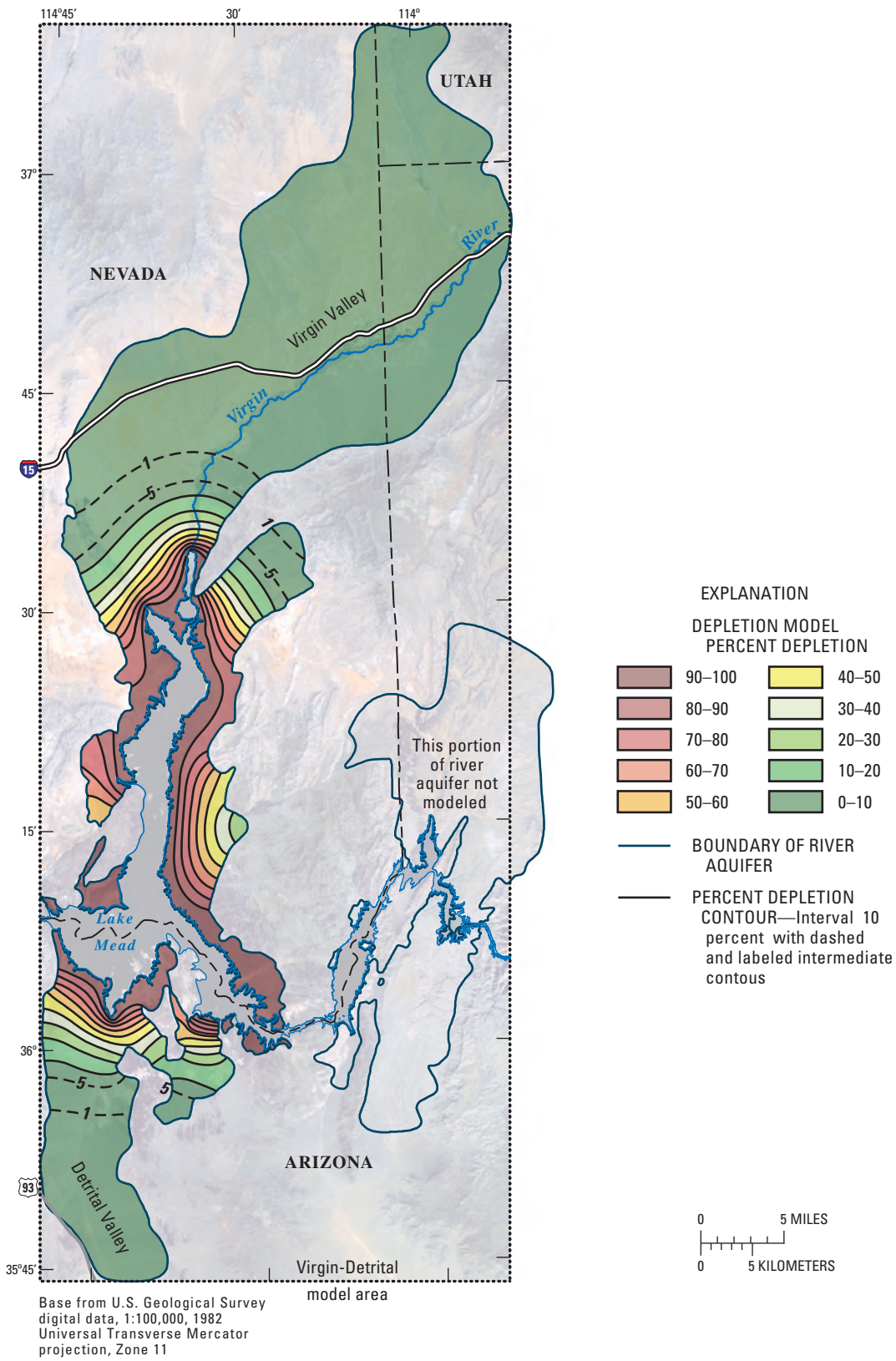


Figure 7. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 980 feet squared per day (7,300 gallons per day per foot).

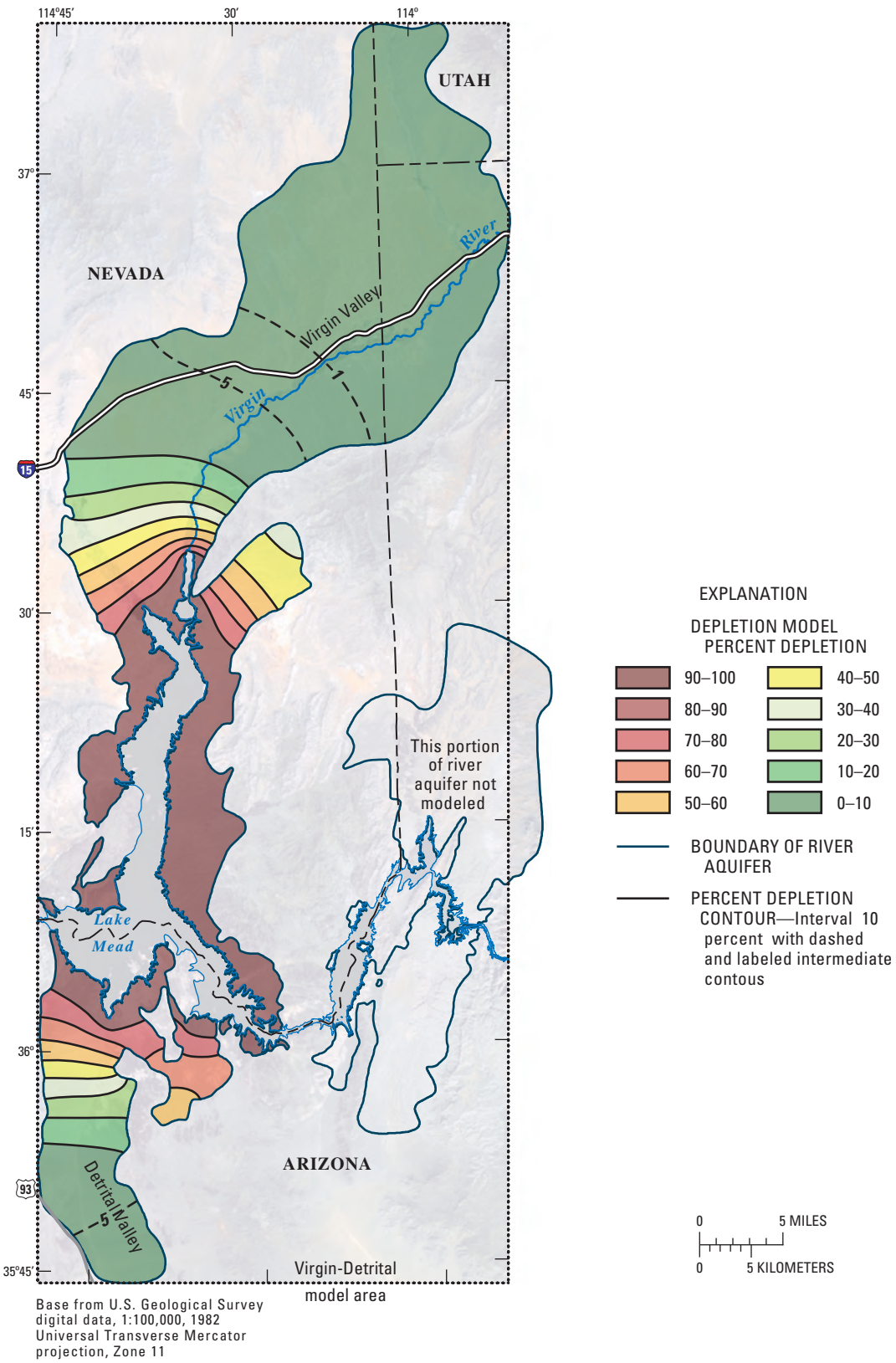


Figure 8. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day (47,000 gallons per day per foot).

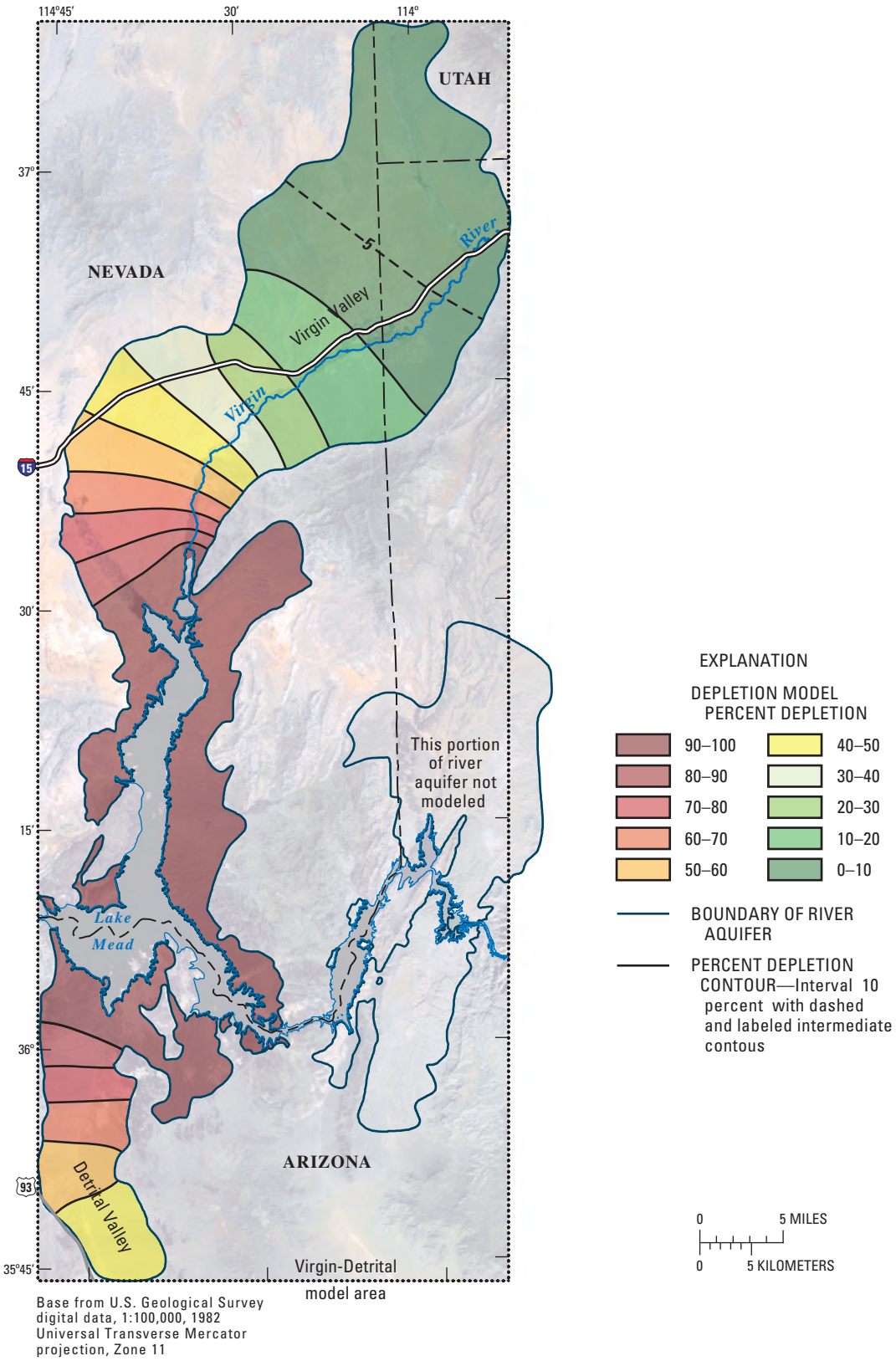


Figure 9. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day (196,000 gallons per day per foot).

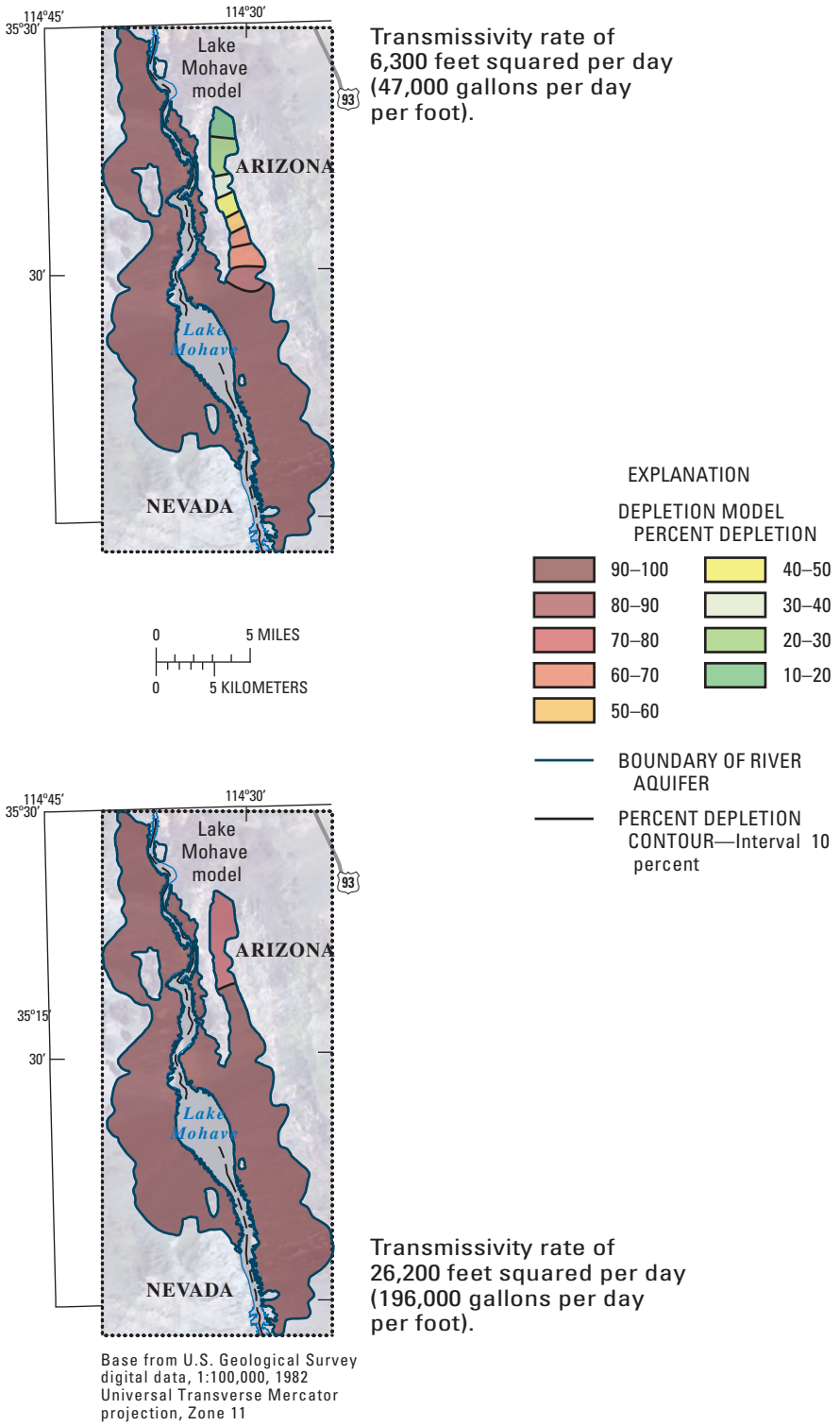


Figure 10. Percent depletion in 100 years by pumping wells within the Lake Mohave model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 and 26,200 feet squared per day (47,000 and 196,000 gallons per day per foot).

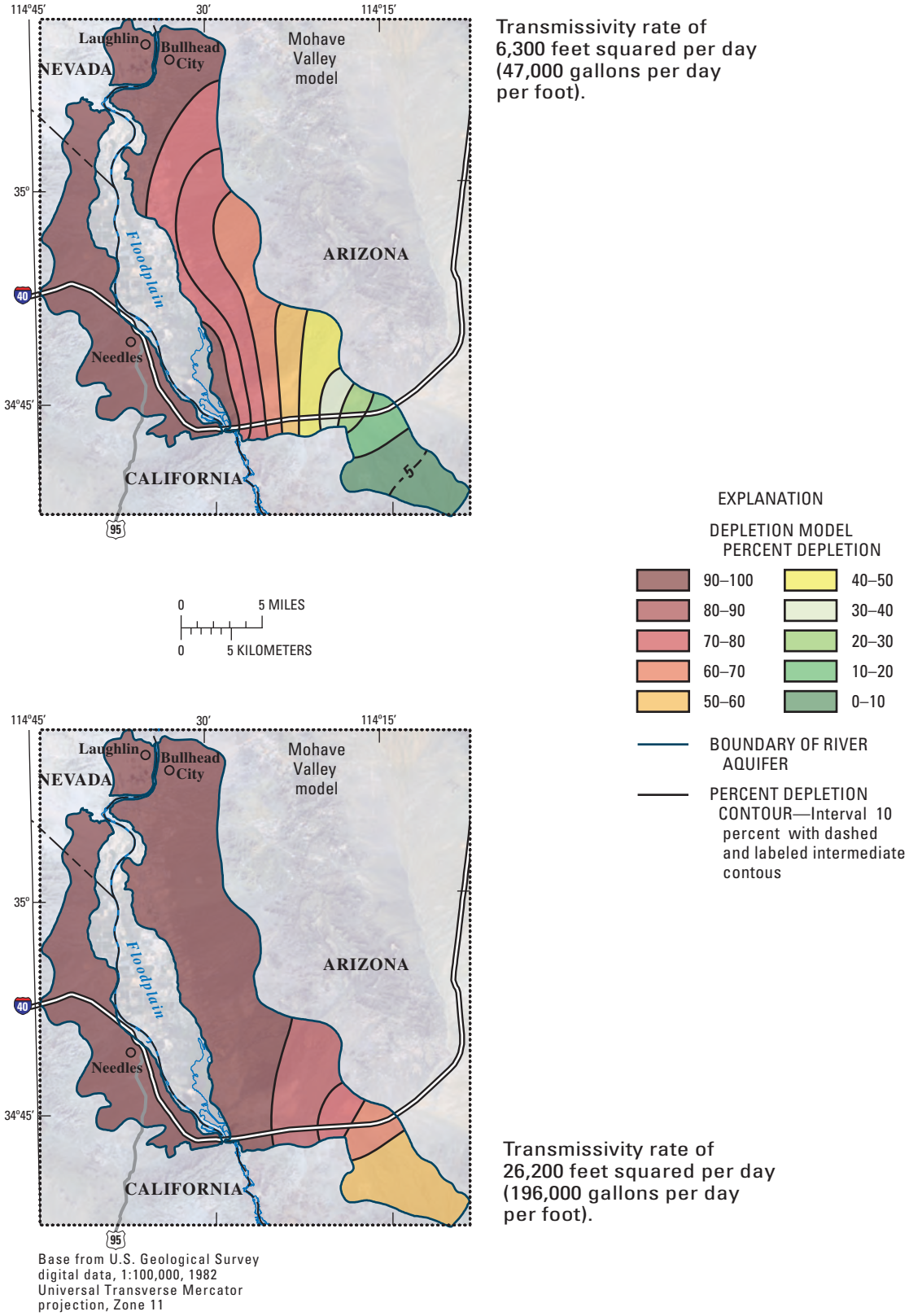
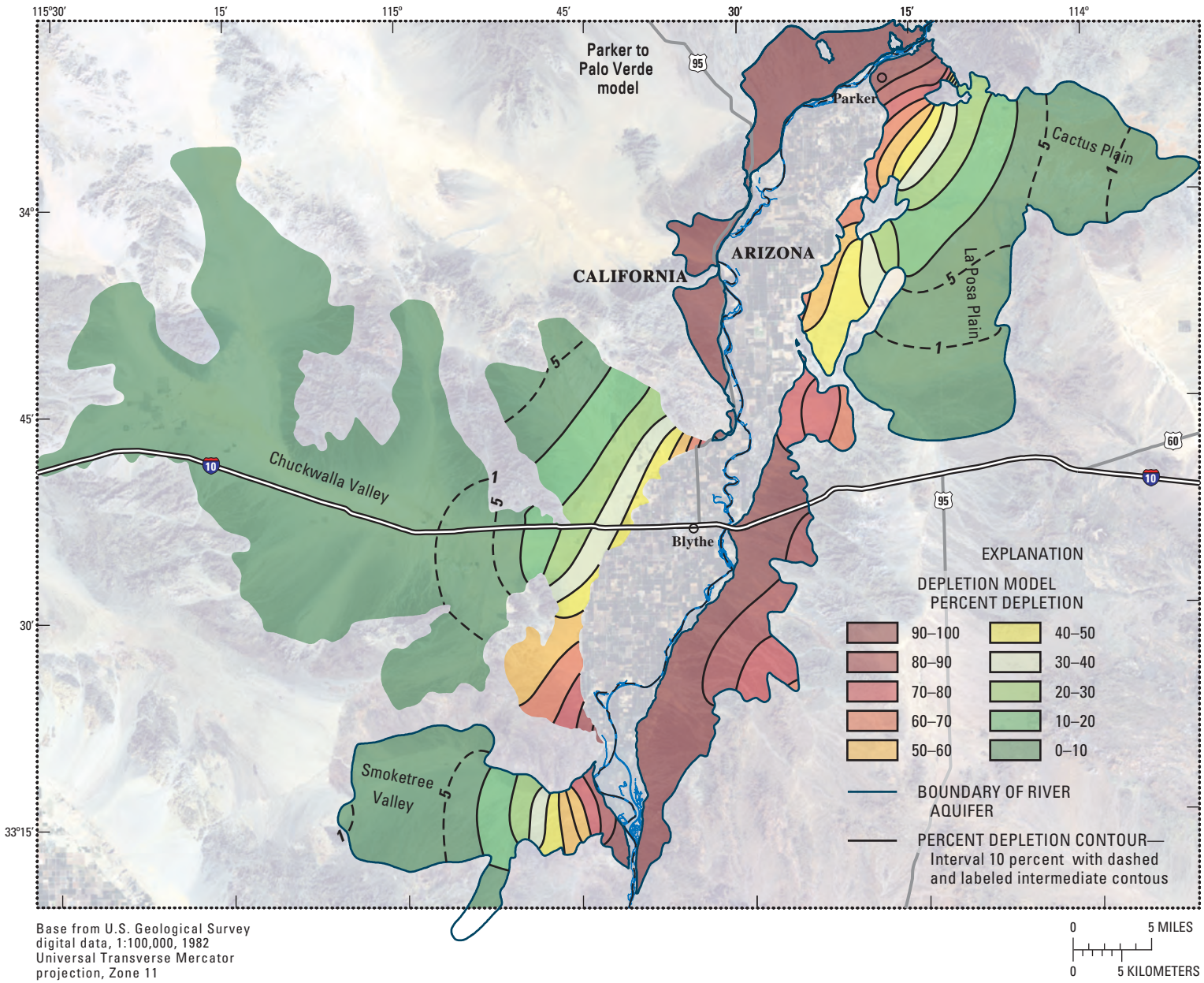
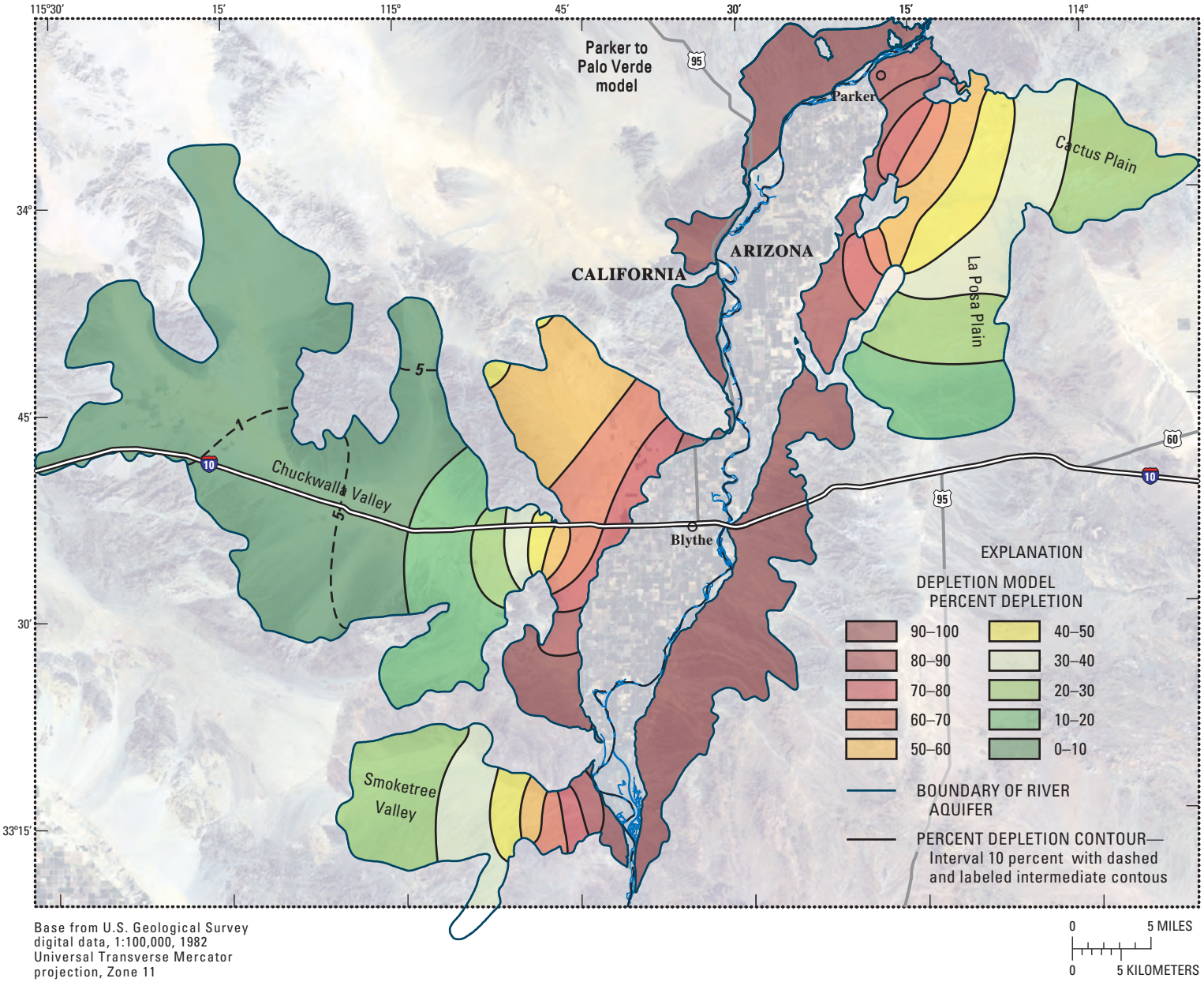


Figure 11. Percent depletion in 100 years by pumping wells within the Mohave Valley model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 and 26,200 feet squared per day (47,000 and 196,000 gallons per day per foot).



Base from U.S. Geological Survey digital data, 1:100,000, 1982
Universal Transverse Mercator projection, Zone 11

Figure 12. Percent depletion in 100 years by pumping wells within the Parker-Palo Verde-Cibola model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day (47,000 gallons per day per foot).



Base from U.S. Geological Survey digital data, 1:100,000, 1982
Universal Transverse Mercator projection, Zone 11

Figure 13. Percent depletion in 100 years by pumping wells within the Parker-Palo Verde-Cibola model area of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day (196,000 gallons per day per foot).

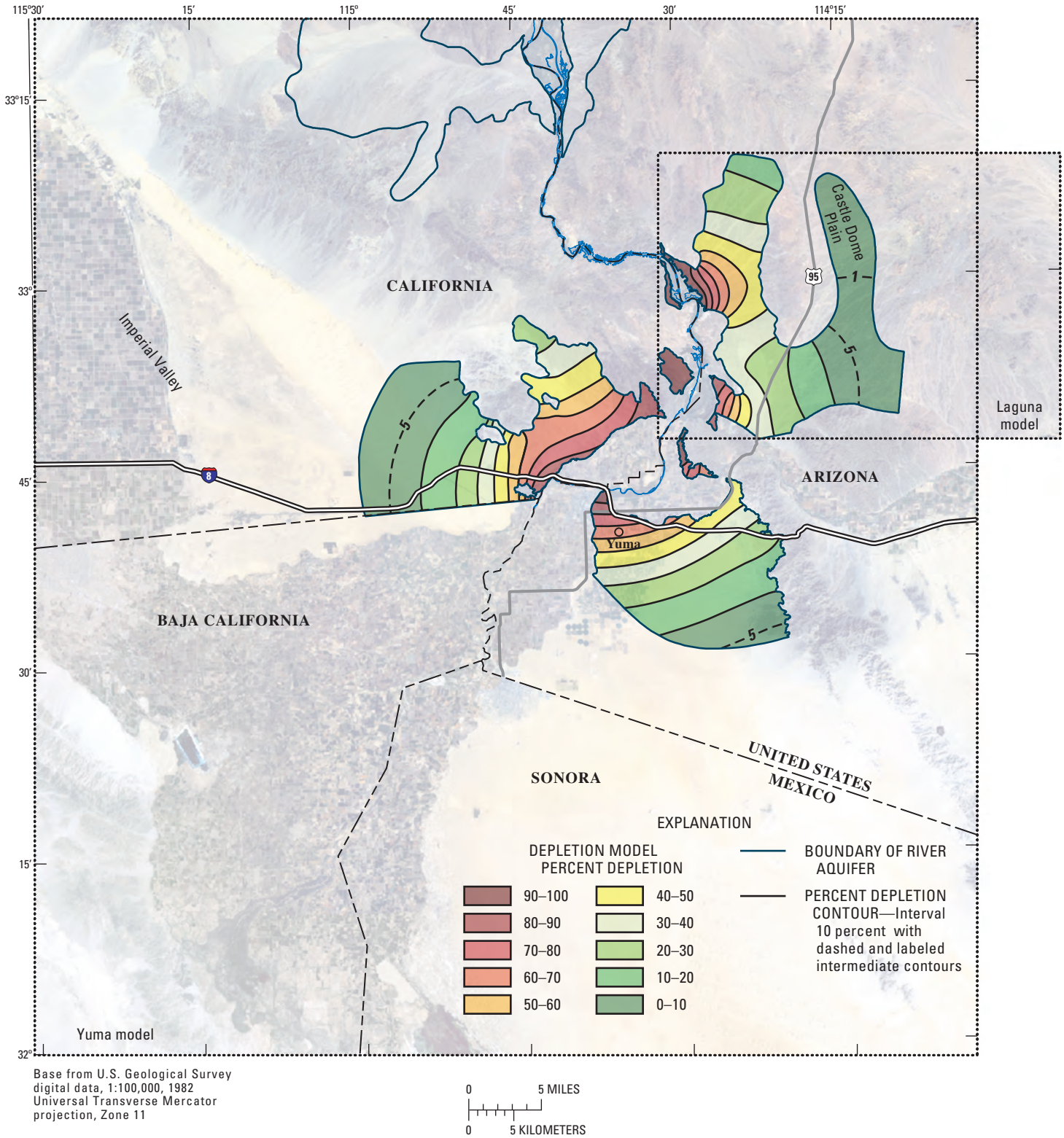
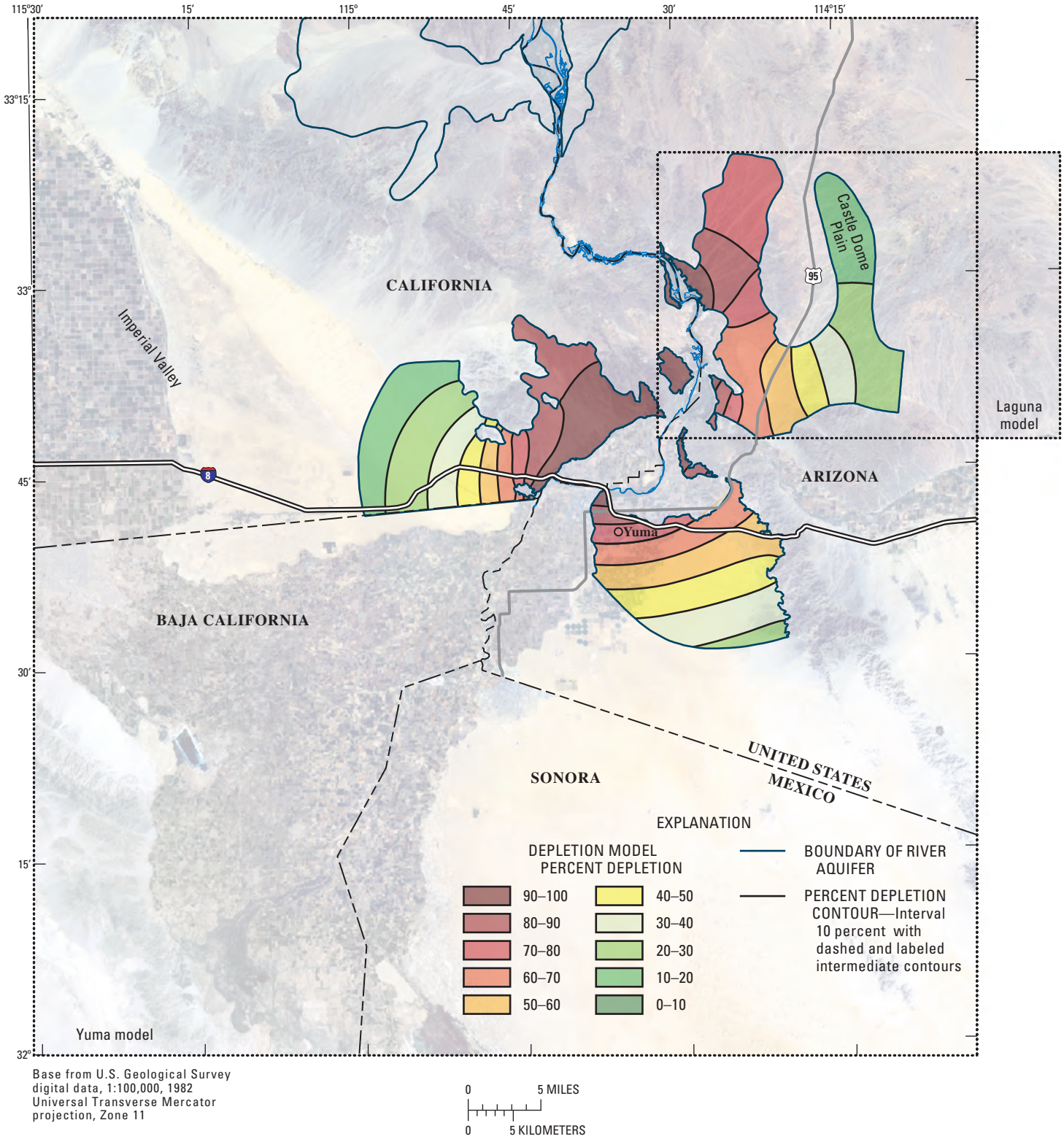


Figure 14. Percent depletion in 100 years by pumping wells within the Yuma and Laguna model areas of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day (47,000 gallons per day per foot).



Base from U.S. Geological Survey digital data, 1:100,000, 1982
Universal Transverse Mercator projection, Zone 11

Figure 15. Percent depletion in 100 years by pumping wells within the Yuma and Laguna model areas of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day (196,000 gallons per day per foot).

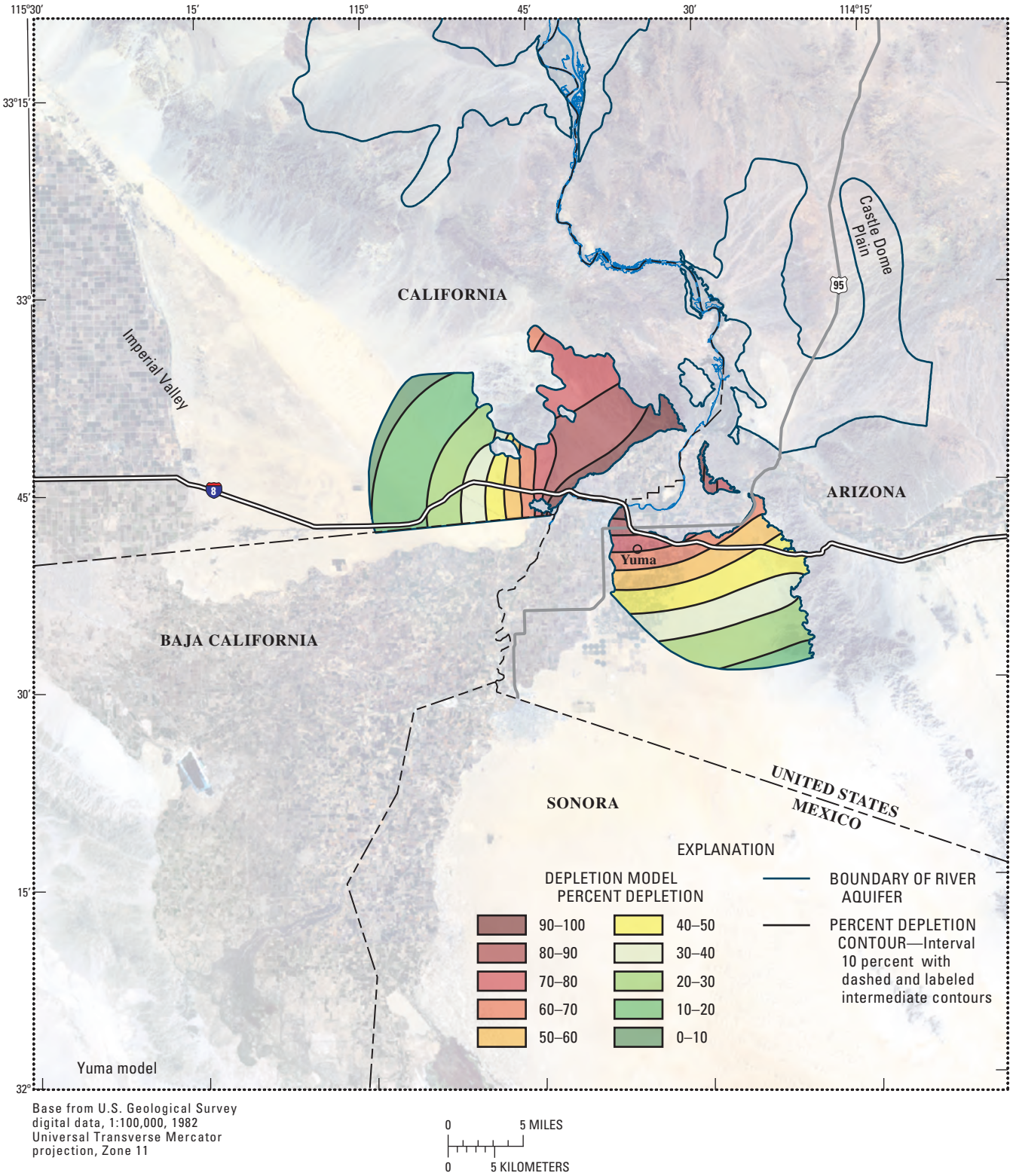


Figure 16. Percent depletion in 100 years by pumping wells within the Yuma model area of the Colorado River aquifer assuming a transmissivity rate of 15,500 feet squared per day (116,000 gallons per day per foot).

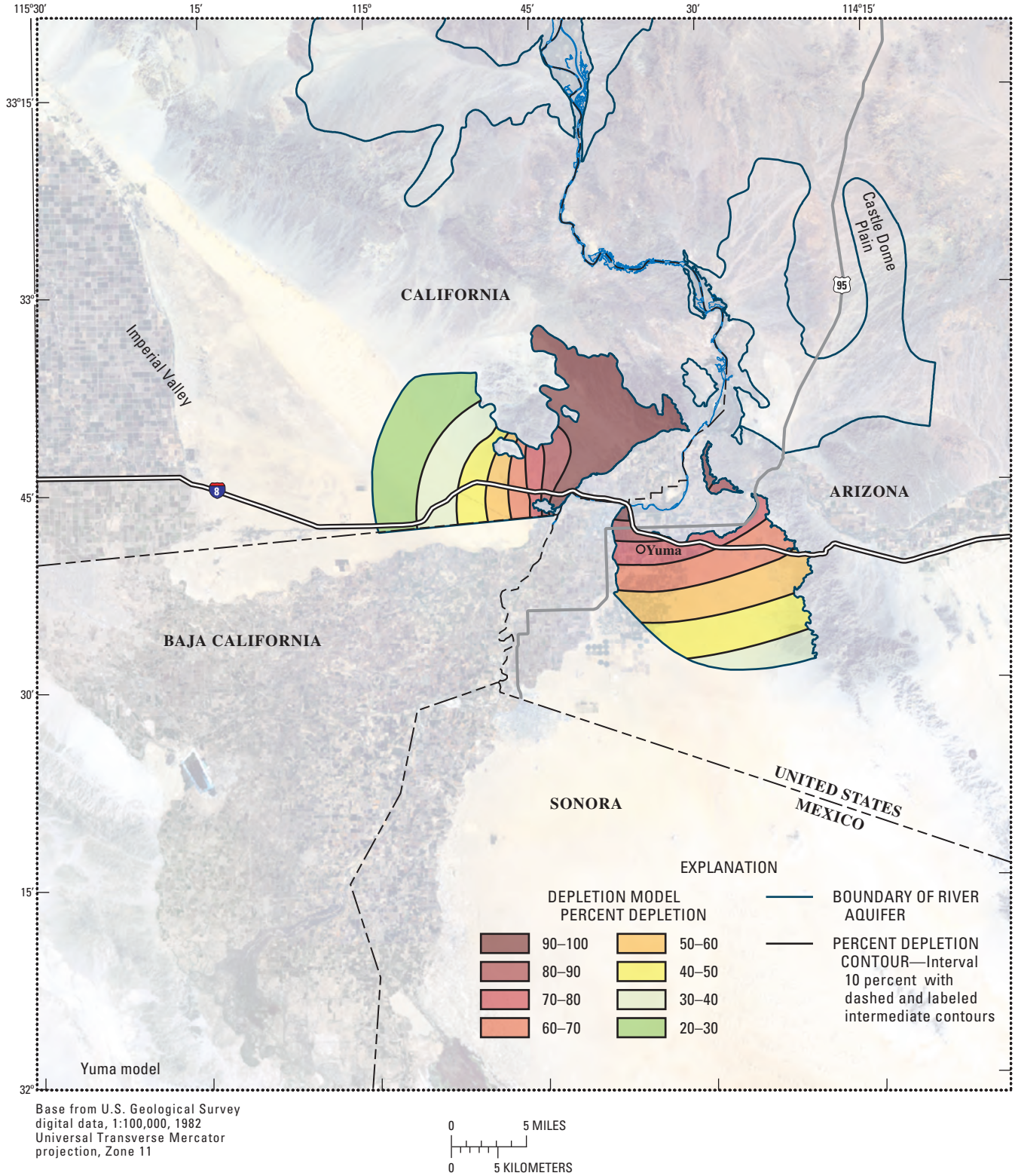


Figure 17. Percent depletion in 100 years by pumping wells within the Yuma model area of the Colorado River aquifer assuming a transmissivity rate of 45,900 feet squared per day (343,000 gallons per day per foot).

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