BUREAU OF RECLAMATION SEEPAGE INVESTIGATIONS ALONG THE SAN LUIS CANAL / CALIFORNIA AQUEDUCT NEAR EAGLE FIELD ROAD

SJRECWA – 1

REGIONAL GEOLOGY SECTION
SACRAMENTO, CALIFORNIA

June 28, 2002

MEMORANDUM TO THE TECHNICAL FILES

FROM: Robert L. Turner, Geologist

SUBJECT: Seepage Investigations Along the San Luis Canal/California Aqueduct at Mile 89.5 (approximate Station 1040+00) Near Eagle Field Road - Central Valley Project, California

Introduction

During the period June 3 through June 25, 2002, eight observation/sampling wells were installed by Reclamation's Drill Crew along two profiles perpendicular to the San Luis Canal/California Aqueduct at Miles 89.5 and 89.7. Figure 1 shows the general location of these sites and the layout of these wells. Five wells were installed along the north profile (Profile A) and three along the south profile (Profile B). An existing Department of Water Resources (DWR) Right of Way (ROW) well was incorporated into the southern profile as ROW-4B. Profile A was located to transect a known seepage area at Mile 89.5, while Profile B, located at Mile 89.7, was to serve as a test control area away from the seepage. A ninth well was proposed for the far east side of Profile B, but crops and irrigation prevented access. This well will be installed in October 2002.

The purpose of these wells is to determine if canal seepage in this area significantly contributes to the amount of drainage water leaving Grasslands Water District. Data obtained from the drilling and observation wells provided the following:

1. Subsurface geology.
2. Subsurface moisture content of soils above the water table.
3. Groundwater flow direction.
4. Groundwater gradient.
5. Is there a groundwater mound beneath the canal?
6. Are there water quality differences between the upslope and downslope groundwater caused by the inflow of canal water?

Background

Water districts downslope (east and northeast) of the San Luis Canal/California Aqueduct are concerned about leakage from the canal in the vicinity of Mile 89.5. Most important, they believe that seepage visible at the surface adjacent to the toe of the left embankment of the canal just north of Eagle Field Road is indicative of greater vertical leakage through the lining into the groundwater. Recent underwater inspection of this section of the canal showed broken and displaced lining. The groundwater gradient is generally to the east and northeast in this area and the concern is that the leakage from the canal is adding to the volume of subsurface drainage water in the Grasslands Drainage Area (GDA). The GDA is under severe limitation regarding the amount of subsurface drainage water that can be discharged from the area.

There are no irrigation or domestic wells in the west Eagle Field Road area. The canal at Mile 89.5 is in elevated cut/fill, with the right (west) side of the canal in cut and the left (east) side in fill. Invert is in original ground. Eleven Canal Right-Of-Way observation wells installed years ago by the Department of Water Resources (DWR) north of Mile 89.5 and adjacent to and at the base (original ground) of the canal were located in the field on September 27, 2001. Eight were dry at depths below ground level shallower than 38 feet, two wells were locked, and the remaining one had groundwater at 39 feet below ground. A DWR groundwater elevation map for spring 1999 does not show groundwater elevations for the study area but does show the 140-foot elevation contour about three miles to the northeast.

The seepage area of concern is just north of Eagle Field Road on the left (northeast toe) of the canal embankment (see Figure 1) in an area of some past land subsidence due to hydrocompaction. The seepage area encompasses an area on the left canal embankment of about 20 feet perpendicular to the canal and about 200 feet long. The slope is heavily vegetated due to the seepage. On June 3, 2002, a small seep of clear water flowing at about one gal/min is present about halfway up the slope. During the drilling of the new observation wells, it was discovered that the ponded seepage and the associated vegetation (at the toe of the embankment) lies above an old asphalt roadway. This asphalt surface prevents the local infiltration of seepage water. The water level in the ponded area fluctuated about three-inches daily (nearly drying the area in the late afternoon) in response to evaporation during the hot daytime hours.

DWR has installed numerous pressure grout wells on the inside left canal operating road in an attempt to stop the seepage but has been unsuccessful in these attempts. There are several other sections to the north that have also been grouted, and most of those attempts appear to have been successful.

DWR conducted a ponding test of Pool 14 from January 1 to February 18, 2002. Some of the data are summarized in Table 1 and the total daily gain/loss for the pool is shown graphically in Figure 2. Pool 14 is approximately 10 miles long. The canal gained a total of 3,900 acre-feet of water during that period of time. DWR believes that questionable instrument accuracy may have contributed to the results noted in the test.

Drilling Procedures and Well Data

The eight wells were drilled by Reclamation's Mobile B-90 drill rig using the hollow-stem flight-auger, dry coring system. The core samples from each well were geologically logged by an on-site geologist and samples were collected for lab analyses of soil properties, including moisture content. Wells were drilled about ten feet below the water table and completed with two-inch diameter PVC pipe with the bottom ten feet perforated with 0.020-inch factory slots. A sand pack was placed opposite the perforated interval and the upper portion of each well above the sand pack was sealed with bentonite pellets. Each well was pumped for development upon completion and the water was tested for electrical conductivity (EC), an indicator of total dissolved solids. All wells except ROW-4B pumped dry within two minutes and groundwater was a light brown color that did not clear up with successive pumping. ROW-4B was manually bailed because no pump was available to fit in the 1-1/2-inch diameter well. Table 2 shows the well completion information and groundwater sample electrical conductivity for each well. The geologic logs are not completed at the present time.

Results of Drilling Investigations

The results of the drilling investigations are discussed below:

1. **Subsurface geology** - Geologic logs for the eight new wells are attached to this memo. Cores recovered in this drilling program consisted of predominantly sandy, silty clay with occasional thin sand lenses overlying predominantly sands with occasional thin clay layers. The sands were generally encountered at about 10 feet above the water table. Well completion data for the DWR ROW well, ROW-4B, was not available. Canal as-built construction geology maps described the subsurface soils in the Mile 89.5 area to be silty clay to clayey sand.

2. **Subsurface saturation of soils above the water table** - Samples obtained during drilling at each well shows most soil above the water table was only slightly moist to moist. There were no saturated zones above the water table. The soils encountered in the well in the surface seepage area, OW-02-4A, showed that the subsurface was just slightly moist until 36 feet below ground.

3. **Groundwater flow direction** - Each well was surveyed for elevation and location by MP-222 using a local coordinate system. These values are shown in Table 2. Groundwater level measurements are also shown in Table 2. Elevations show groundwater flow direction to be to the east, generally coinciding with the ground slope direction.

4. **Groundwater gradient** - By using the groundwater elevations for OW-02-1A, -1B, and -5A, the groundwater gradient across the study area calculates to be about 35 feet per mile to the east. This assumes that the wells farthest west and east reflect true groundwater

elevations without the influence of the canal mound. The Department of Water Resources (DWR) groundwater map for spring 1999 does not show elevations for the study area. However, it does place the 140-foot elevation contour about three miles to the northeast, or an average groundwater gradient of about 50 feet per mile, assuming the same aquifer.

5. **Is there is a groundwater mound beneath the canal?** - Groundwater elevations show higher groundwater levels beneath the canal than east or west of the canal, indicating that a groundwater mound is present beneath the canal under both Profiles A and B (Figure 4). The mound is more pronounced beneath Profile B, where no visual seepage is indicated, than under Profile A, where there is a seepage area and water ponding east of the canal. This pronounced mound is most likely due to the low permeability soils at this location that retard horizontal and vertical migration of canal seepage water. The soils at Profile A have a higher permeability resulting in a less pronounced groundwater mound.

6. **Are there water quality differences between the upslope and downslope groundwater caused by the inflow of canal water?** - Each well except ROW-4B was pumped to obtain a groundwater sample. Each well pumped dry within about two minutes and could not sustain a flow of about two gal/min for more than a minute. A bailer was used to obtain a sample from ROW-4B due to the small diameter of the casing. Table 2 and Figure 4 show the results of the groundwater electrical conductivity (EC) measurements for all wells and the canal water. EC is an indicator of total dissolved solids. The EC of the canal water was 490 uS/cm.

The EC of the two up-gradient wells (OW-02-1A and -1B) was 1,320 and 2,650 uS/cm, respectively. It is assumed that the higher EC upslope is indicative of the local groundwater absent canal seepage. The upslope well OW-02-1A has an EC lower than the other upslope well OW-02-1B; this may be due to dilution of the groundwater by the deep percolation of applied canal water used to irrigate the land to the west of OW-02-1A. EC for wells on the canal's Right-of-Way roads ranged from 510 to 560 uS/cm (similar to the EC for canal water of 490 uS/cm), indicating that the canal water is leaking into the shallow groundwater aquifer and diluting the water.

The EC for ROW-4B (1,665 uS/cm) is anomalous compared to the other wells right next to and downslope of the canal. The well perforations are unknown for this well. Another well completed in a manner similar to the other OW wells is scheduled to be drilled at a later date.

Conclusions

Based upon the results stated above, we conclude that the canal is leaking in the areas both north and south of Eagle Field Road, and this seepage is contributing to the groundwater flow to the east. The ponded water in the seepage area appears to be the direct result of canal losses through a horizontal conduit above ground level. The ponding is enhanced by the presence of an old

asphalt surface adjacent to the canal beneath the catchment area that prevents infiltration. The seepage is not indicative of vertical leakage from the canal to the groundwater.

To estimate the volume of vertical seepage from the canal would require estimates for many unknowns. Among these would be the following:

1. The condition of the canal concrete lining - Past underwater inspection of the canal concrete lining shows it intact in some places and open in others, resulting in large differences in canal loss to the soil interface.

2. The transmissivity of the soils beneath and adjacent to the canal - Near-surface soils at Mile 89.5 and 87.5 contain a high percentage of fines, whereas, near-surface soils at Station 1033, located about 0.2 miles to the north, consist of a high percentage of sand and gravels deposited by Laguna Seca Creek.

3. The determination of groundwater levels under the canal at many locations - For example, seepage in the Mile 89.5 area is free-fall to the water table; this condition would maximize the vertical gradient for recharge. Canal water and groundwater are in continuity at Mile 87.5 along Profile B which would greatly minimize the gradient.

4. The length of the canal that is leaking.

We can use the following assumptions to approximate canal leakage in this area:

- Canal length of one mile.
- Transmissivity of from 10^2 to 10^3 ft^2/day (reasonable for the clayey soils).
- Groundwater gradient of about 35 ft/mile.
- All groundwater moving to the east is from canal leakage. This assumption ignores groundwater subinflow from the west, an unknown quantity, and the deep percolation of applied irrigation water.

Using the above assumptions, leakage would range from about 3,500 to 35,000 cubic feet per day (29 to 290 acre-feet per year) per mile length of canal.

Liz Partridge (TO-431) has researched the predicted losses for the canal and these are summarized below:

1. The Designer's Operating Criteria for the canal states that the seepage losses are estimated to be 100 cfs for the 102 miles of the canal. If we assume that the District is influence by

seepage from about 10 miles of canal, this is roughly equal to 7,100 acre-feet per year, or about 710 acre-feet per mile length of canal.

2. The Technical Report of Design and Construction for the San Luis Unit assumes that the seepage rate would be .07 cubic feet per foot of wetted surface per day. This is roughly equivalent to 5,730 acre-feet per year for the 10-mile stretch, or about 570 acre-feet per year.

Robert L. Turner, Geologist

Noted: _____ 9/17/02
Joel F. Sturm, Head, Geology Section Date

Noted: _____ 9-17-02
Charles L. Howard, Regional Geologist Date

Attachments

cc: TO-431 (Partridge), SCCAO-400 (Buelna), MP-400, Central Files
(w/att to each)

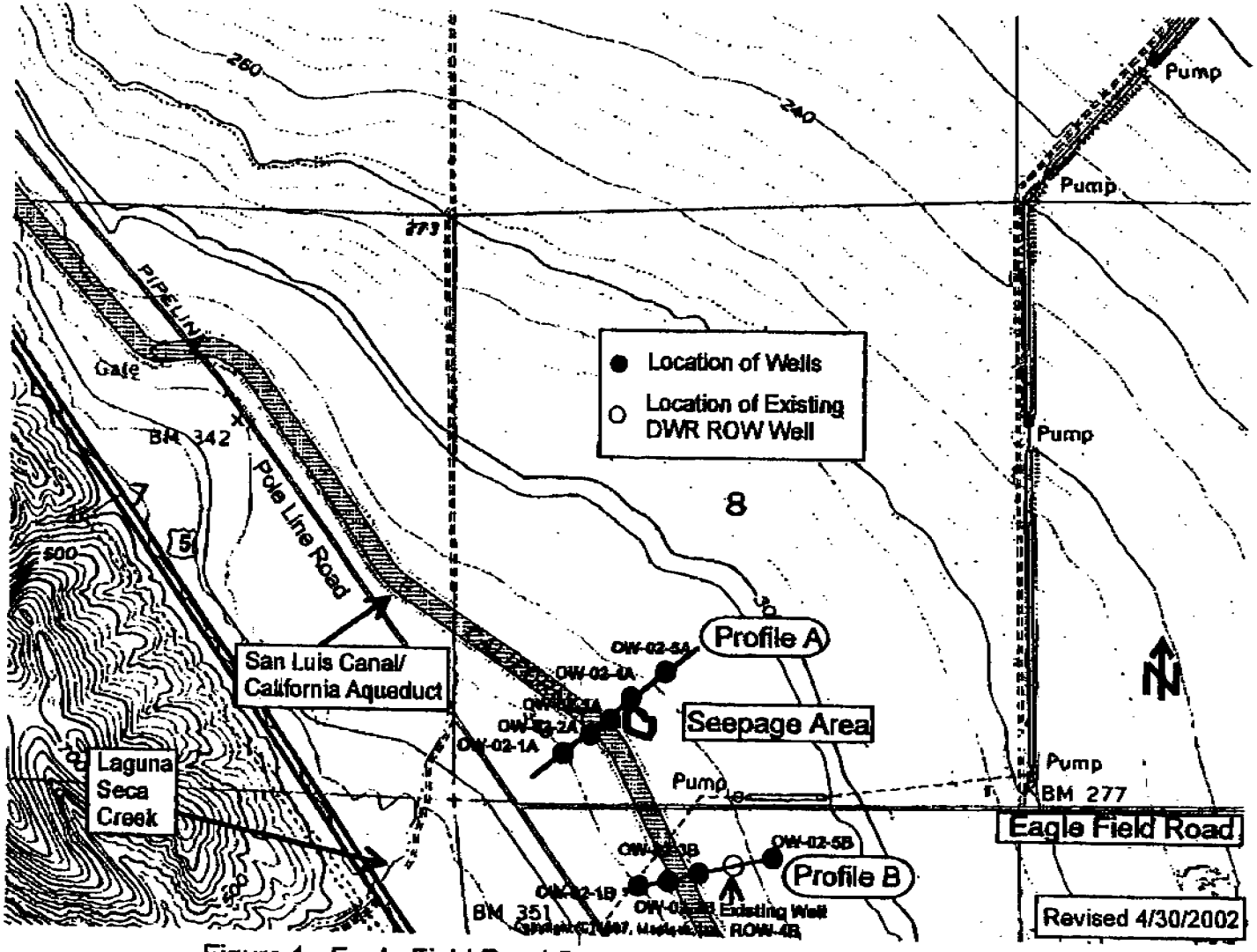

Figure 1: Eagle Field Road Seepage - General Location of Wells Along the San Luis Canal/California Aqueduct Near Mile 89.5

Table 1: Pool 14 Ponding Test by DWR - Jan. 1 thru Feb. 18, 2002 (Partial results)

DATE	Pool Elevation	Surface Area	Pool Storage	Storage Change	Pool Losses	Pool Losses	Accu.Losses
Jan. 1	329.70	7569900	2804	-53	+146	146	146
2	330.27	7667400	2902	98	+270	270	416
3	330.38	7686300	2921	19	+142	142	558
4	330.60	7723900	2959	38	+302	302	860
5	330.04	7628100	2862	-97	+117	117	977
6	329.56	7546000	2780	-82	+332	332	1309
7	330.05	7629800	2864	84	+382	382	1691
8	329.78	7583600	2817	-47	+115	115	1806
9	329.64	7559700	2793	-24	+183	183	1989
10	329.80	7587000	2821	28	-60	-60	1929
11	330.24	7662300	2897	76	+319	319	2248
12	329.86	7563100	2797	-100	+12	12	2260
13	329.98	7617800	2851	54	+249	249	2509
14	330.13	7643500	2878	27	+152	152	2661
15	330.29	7670900	2906	28	-35	-35	2626
16	330.49	7705100	2940	34	+157	157	2783
17	330.06	7631500	2866	-74	-14	-14	2769
18	329.92	7607600	2841	-25	+144	144	2913
19	329.70	7569900	2804	-37	+15	15	2928
20	330.01	7623000	2857	53	+159	159	3087
21	330.27	7667400	2902	45	+79	79	3166
22	329.86	7597300	2831	-71	-23	-23	3143
23	330.12	7641800	2876	45	+56	56	3199
24	329.65	7561400	2795	-81	-49	-49	3150
25	329.94	7611000	2845	50	+54	54	3204
26	330.14	7645200	2879	34	+187	187	3391
27	330.74	7747900	2984	105	+226	226	3617
28	330.52	7710200	2946	-38	+28	28	3645
29	330.34	7679400	2914	-32	+154	154	3799
30	330.47	7701700	2937	23	+127	127	3926
31	330.20	7655500	2890	-47	+44	44	3970
Feb. 1	330.61	7725600	2961	71	+267	267	4237
2	330.62	7727300	2963	2	+85	85	4322
3	330.54	7713600	2949	-14	+133	133	4455
4	329.74	7576800	2811	-138	-93	-93	4362
5	330.06	7631500	2866	55	+228	228	4590
6	330.16	7648600	2883	17	+159	159	4749
7	330.06	7631500	2866	-17	-2	-2	4747
8	330.56	7717100	2952	86	+218	218	4965
9	330.36	7682800	2918	-34	-324	-324	4641
10	330.26	7665700	2900	-18	-222	-222	4419
11	330.26	7665700	2900	0	-26	-26	4393
12	330.46	7700000	2935	35	-14	-14	4379
13	330.46	7700000	2935	0	+123	123	4502
14	330.66	7734200	2970	35	-6	-6	4496
15	331.16	7819700	3057	87	-30	-30	4466
16	331.16	7819700	3057	0	-98	-98	4368
17	330.96	7785500	3022	-35	-328	-328	4040
18	330.96	7785500	3022	0	-136	-136	3904

Pool Evaporation = Evaporation in LBDD weather station pan X pool surfTotal Gain = 3,970
Days with rain are not used for test, because inflow from drain inlets is not measured. Known data will be shown.
Daily pool losses are for the time ending at 2400 hours. Plus (+) is gain, and minus (-) is loss.

Pacheco W.D. meter 69.67L'B' not working 1/1 - 1/31/02. San Luis W.D. meter 92.73L'B' not working 1/1 - 2/18/02

*No data available.
**These days are based on hourly flow average.

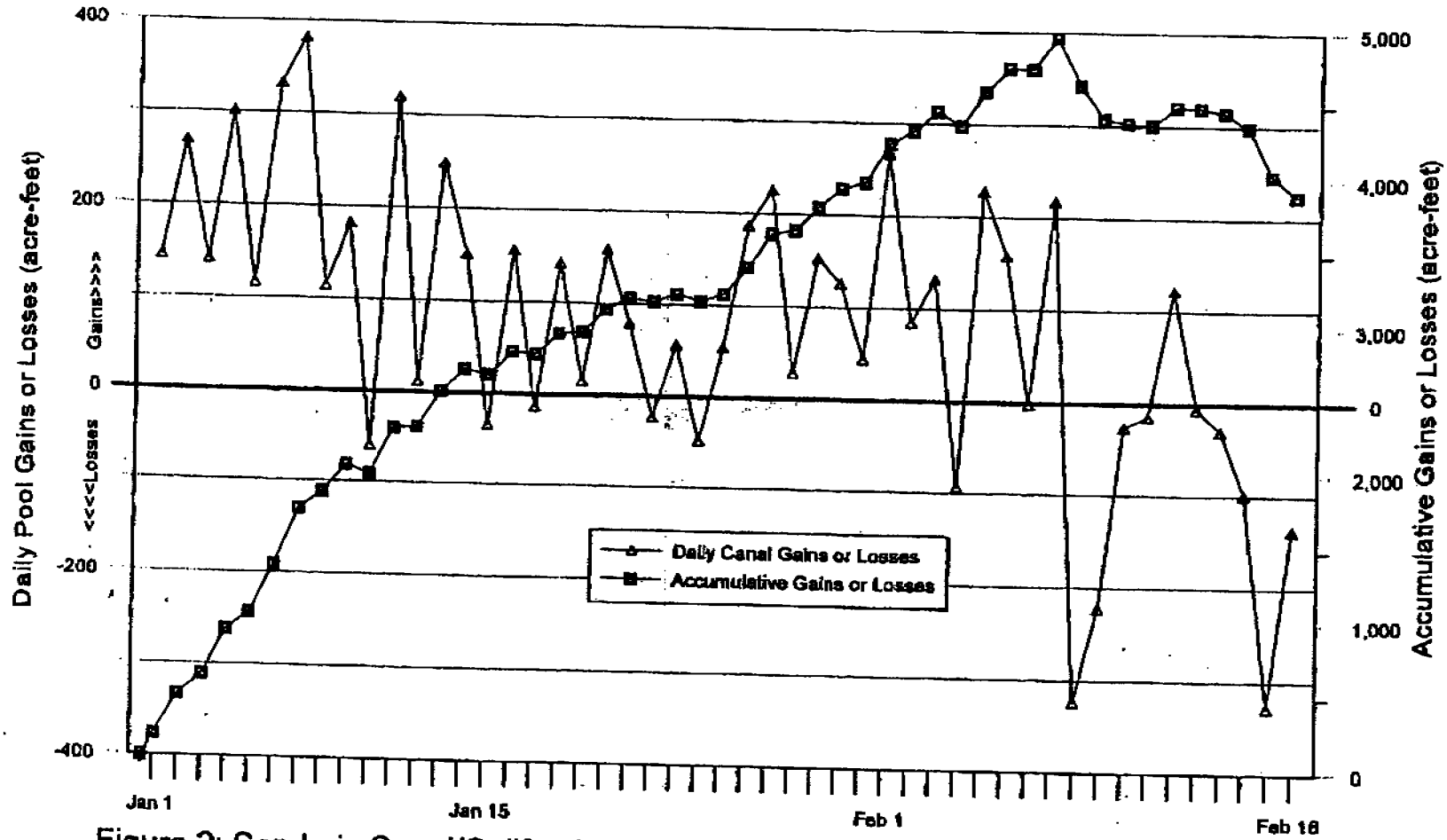

Figure 2: San Luis Canal/California Aqueduct - Pool 14 Test - January to February 2002

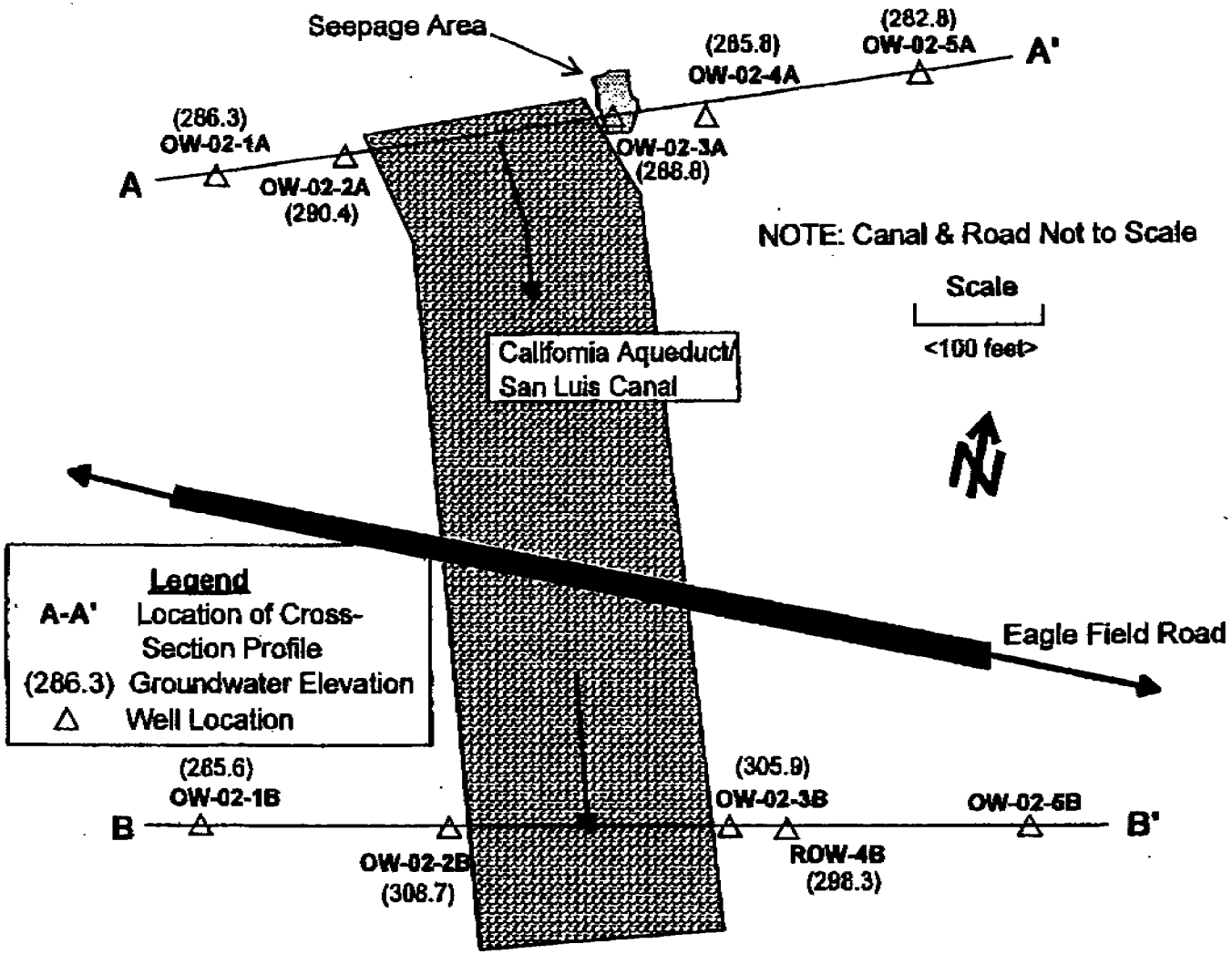

Figure 3: Eagle Field Road - Location of Wells and Groundwater Elevations

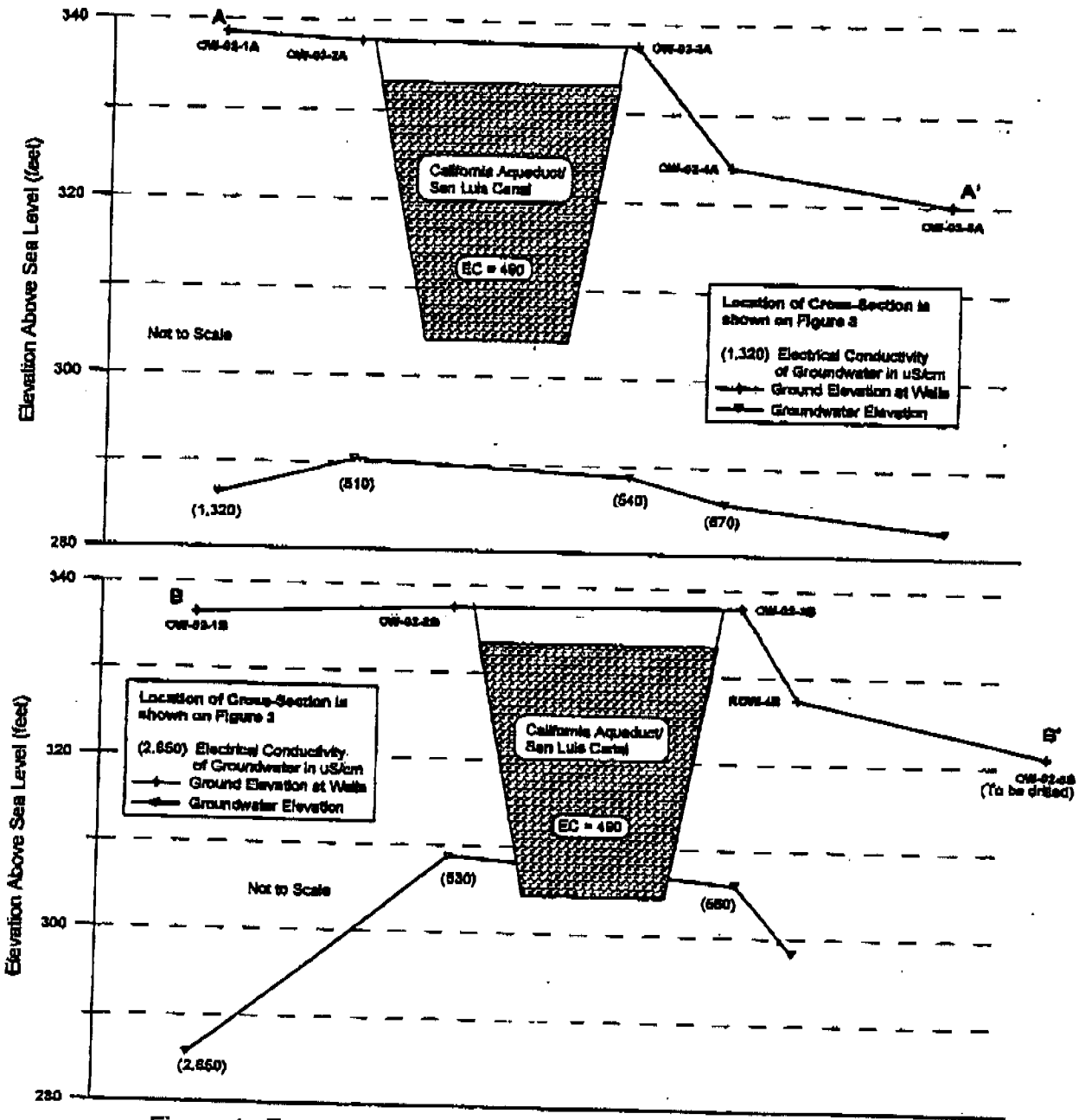

Figure 4: Eagle Field Road - Cross-Sections thru A-A' and B-B'

Table 2 - Eagle Field Road/Grasslands Seepage Well Data

Well I.D.	Northerly [a]	Easterly [a]	Total Depth	Perforations [b]	Ground Elevation [c]	Depth to Groundwater [d]	Groundwater Elevation	Electrical Conductivity [e]
	(feet)	(feet)	(feet)	(feet)	(feet)	(feet)	(feet)	(uS/cm)
<< Profile A >>								
OW-02-1A	9652.9	5114.4	65.0	53.8 - 63.8	338.6	52.1	286.5	1320
OW-02-2A	9617.9	5011.8	60.0	48.7 - 58.7	337.8	47.0	290.8	510
OW-02-3A	9547.4	4799.2	59.0	49.0 - 59.0	337.5	48.4	289.1	538
OW-02-4A	9548.1	4725.7	49.3	38.7 - 48.7	324.1	37.9	286.2	670
OW-02-5A	9470.9	4557.7	49.5	39.5 - 49.5	320.0	36.9	283.1	695
<< Profile B >>								
OW-02-1B	10874.8	5128.2	60.0	49.0 - 59.0	336.5	50.6	285.9	2650
OW-02-2B	10880.6	4930.9	40.0	29.3 - 39.3	337.5	28.6	308.9	530
OW-02-3B	10880.3	4709.5	40.0	29.3 - 39.3	337.9	31.4	306.5	560
ROW-4B [f]	10884.0	4664.8	45.3 [g]	[f]	327.5	28.1	299.4	1,665
OW-02-5B	10879.6	4475.9			321.2		Not Drilled	

[a] From a field survey by MP-222 using a local coordinate system.

[b] All wells (except previously existing ROW-4B) drilled to approximately 10 feet below water table and completed with 2-inch PVC pipe, with the lower 10 feet 0.020-inch factory-slotted PVC. Sand pack installed opposite perforated intervals and bentonite pellets installed above sand pack to surface.

[c] From ground surface. Wells OW-2A, -3A, -2B and 3B are on top of canal embankment adjacent to ROW Road.

[d] An indicator of total dissolved solids. Electrical conductivity of the canal water is 490 uS/cm.

[e] An existing California Department of Water Resources well with no available completion data.

[g] Measured in the field