5 Flow, Salt and Selenium Mass Balances in the San Luis Drain

October 1, 2001 – December 31, 2002

Michael C. S. Eacock[1]
Nigel W.T. Quinn[2]

Grassland Bypass Project

1 Natural Resource Specialist, US Bureau of Reclamation, South-Central California Area Office, 1243 N Street, Fresno, California 93721 (559) 487-5133 ceacock@mp.usbr.gov
2 Staff Geological Scientist/Water Resources Engineer, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Building 70A-3317H, Berkeley, California 94720 (510) 486-7056 nquinn@lbl.gov

Summary

Although lined with concrete along the 28 mile reach utilized by the Grassland Bypass Project (GBP), about 4,000 acre-feet of water entered the San Luis Drain (SLD) between Stations A and B during the fifteen month study period of October 2001 – December 2002. This was a fourteen percent increase in the SLD (Table 1a). The increases in flow occurred during October, November, and December 2001, and during August through December 2002. The reason for differences in flow may be due to water seeping into the SLD when adjacent wetlands are flooded.

There was a net increase in salt load of about 9,000 tons (seven percent) during the fifteen month study period (Table 2a).

There was a three percent increase of about 149 pounds of selenium between the monitoring sites during the fifteen month study period (Table 3a). The difference in selenium between the sites may be due to measurement error, microbial uptake, adsorption to sediments, volatilization, or seepage of seleniferous water into the drain between Stations A and B.

Tables 1b, 2b, and 3b summarize monthly flows, salt loads, and selenium loads that passed Stations A and B during the six water years of the Project. Tables 1c, 2c, and 3c summarize monthly flows, salt loads, and selenium loads that passed Stations A and B during the six calendar years of the Project. Table 4 summarizes the effects of rainfall and evapotranspiration on the volume of water in the SLD.

Note that the historical concentration and load values have been updated and differ from those in the 1999 Annual Report and errata sheets.

Background

Seepage into the SLD most likely occurs through cracks and one-way weep valves that equalize hydraulic pressure to prevent the concrete lining from buckling. Along the SLD, the water surface elevation of adjacent wetlands, when flooded in the fall and winter, is often higher than the elevation of water in the SLD.

Leakage from the SLD can occur where the concrete lining is fractured or between adjacent concrete panels. Other losses from the SLD include direct evaporation of water and evapotranspiration by algae and aquatic plants.

Flow Differences between Stations A and B

Tables 1a, 1b, and 1c summarize the amount of water that flowed past Stations A and B during the six years of the Project. Figure 1 compares the monthly flows of water that passed Stations A and B during the fifteen month reporting period.

About 4,000 acre-feet more water flowed past Station B than Station A during the fifteen month study period, representing a 14 percent increase in flow (Table 1a). There was increase flow during October 2001 through March 2002 and again during August 2002 through December 2002 while adjacent wetlands were flooded. The increase in flow during the 2002 Water Year was eleven percent, compared to increase of four to six percent in previous Water Years (Table 1b). The increase in flow during the 2002 Calendar Year was nine percent, compared to increase of four to seven percent in previous Calendar Years (Table 1c).

Table 4 calculates the net water gain or loss in acre-feet per month by taking into account precipitation and evaporation from the surface area of the Drain. Once precipitation and evaporation are accounted for, the difference in flow between Stations A and B ranges from zero percent to six percent for February through July 2002 (Column 17). These differences are within the margin of error for flow measurements specified in the Quality Assurance Project Plan (Reclamation, et. al. 2002). The remaining months (October 2001 – January 2002, August – September 2002) show large increases in flow (16 - 43 percent), most likely seepage into the drain from adjacent wetland ponds.

Salt Mass Balance between Stations A and B

Tables 2a, 2b, and 2c compare monthly and annual loads of salt in water that passed Stations A and B during the six years of the Project. There was a seven percent increase of about 9,000 tons of salt between Stations A and B during the fifteen month study period (Table 2a). There was a four percent increase of salts during the 2002 Water Year of about 4,400 tons (Table 2b).

Figure 2 shows the monthly loads of salt in water that passed Stations A and B during WY 2002.

Since salinity is a conservative chemical constituent, the monthly salt load measured at Station A should be identical to that at Station B. An increase in salt load must infer inflow of saline water into the SLD from adjacent wetlands if other factors such as precipitation and evaporation are taken into account. A decrease in salt load would infer the loss of saline water from the drain.

The WY 2002 monthly differences in salt loads, ± 15 percent, are probably the result of cumulative errors from different analytical methods and equipment. Flow at Station A is measured as flow over a sharp-crested weir with a precision of ± 5 percent. The USGS developed a stage-discharge rating curve for Station B; the accuracy of flow measurements with this method is between – 4 % and + 6 percent.
Drift in the EC sensor response can also affect the computation of salt load. However, EC is measured with identical sensors and methods at both sites. USGS staff consider the EC sensor at Station B to be accurate within three percent. In previous years, algae bio-fouling of the probe at Station B has caused errors of more than 30 percent during summer months, but diligent maintenance prevented this from occurring and kept the rate of error less than ten percent. The difference in flow-weighted average EC between the stations was about eight percent (4,492 vs. 4,116 μS/cm), as shown in Table 2a.

Selenium Mass Balance between Stations A and B

A simple mass balance of selenium was calculated to better understand the dynamics of selenium mass transport and mass transfer within the San Luis Drain. Selenium is a non-conservative chemical constituent. The data are presented in Tables 3a, 3b, and 3c. Despite the seepage inflow, there was a three percent difference in the loads of selenium that passed each station during the fifteen month study period (Table 3a). About 153 pounds of selenium entered the drain between Station A and Station B during the 2002 Water Year (Table 3b). More

selenium passed Station B than Station A during every month except January 2002, April 202, and December 2002.

The largest increases occurred during December 2001, May 2002, and August 2002 (Table 3a). The pattern of increases in selenium does not coincide with the increases in flows while adjacent wetlands are flooded.

The monthly differences in selenium loads are within the range of error caused by the different methods of measuring flow and collecting water samples at each station. Flow data, when combined with continuous and discrete selenium data, are used to compute this mass balance. As mentioned before, flow is measured differently at each site, and selenium sampling does not occur at the same frequency at both Stations A and B.

During WY 2002, selenium samples were collected by auto-samplers at both sites. At Station B, seven samples were collected each day; the composite of each day's samples were analyzed in the laboratory. At Station A, seven daily samples were mixed to produce a single weekly composite for analysis.

Figure 3 shows the monthly loads of selenium at both sites during the WY 2002.

Conclusions

In the six years of the GBP, there have been increases in the flow of water in the San Luis Drain during autumn, winter, and late summer months when adjacent wetlands are flooded. The eleven percent net increase in flow between Stations A and B was the highest during the Water Year 2002, compared to previous water years' increases of four to six percent (Table 1b).

The loads of salt have varied each water year from a net loss of six percent to a gain of four percent (Table 2b). These differences are within the realm of measurement error.

The water year loads of selenium have varied from a net loss of seven percent to a gain of six percent (Table 3b). These differences are within the realm of measurement and sampling error. The differences in selenium loads due to natural processes cannot be determined.

References

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Table 1a. Comparison of Flow Measurements (October 2001 - December 2002)

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A af/month	Station B af/month	Difference	Percent of Station B
Oct-2001	11	18	672	1,100	428	39%
Nov-2001	13	22	749	1,320	571	43%
Dec-2001	12	20	755	1,250	495	40%
Jan-2002	22	27	1,323	1,660	337	20%
Feb-2002	47	49	2,593	2,730	137	5%
Mar-2002	52	55	3,182	3,370	188	6%
Apr-2002	42	41	2,484	2,430	-54	-2%
May-2002	42	43	2,588	2,640	52	2%
Jun-2002	55	56	3,269	3,320	51	2%
Jul-2002	53	53	3,230	3,260	30	1%
Aug-2002	54	55	3,318	3,410	92	3%
Sep-2002	28	32	1,658	1,910	252	13%
Oct-2002	15	20	901	1,240	339	27%
Nov-2002	15	19	865	1,150	285	25%
Dec-2002	18	22	1,112	1,360	248	18%
Fifteen month average	32	35	1,913	2,143		
Fifteen month total			28,700	32,150	3,450	12%

Data sources: Station A - San Luis & Delta-Mendota Water Authority
Station B - US Geological Survey Site 11262895

Table 1b. Comparison of Flow Measurements, Water Years 1997 – 2002

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A af/month	Station B af/month	Difference	Percent of Station B
WY 1997	52	52	37,786	37,549	-237	-1%
WY 1998	61	64	43,550	45,940	2,390	5%
WY 1999	42	45	30,470	32,310	1,840	6%
WY 2000	40	43	29,350	31,260	1,910	6%
WY 2001	37	39	27,005	28,254	1,249	4%
WY 2002	36	39	25,822	28,400	2,578	9%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 1c. Comparison of Flow Measurements, Calendar Years 1997 - 2002

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A af/month	Station B af/month	Difference	Percent of Station B
CY 1997	51	52	36,580	37,478	898	2%
CY 1998	62	64	44,201	46,240	2,039	4%
CY 1999	41	45	29,869	32,250	2,381	7%
CY2000	40	42	28,939	30,210	1,271	4%
CY 2001	36	39	26,143	28,014	1,871	7%
CY 2002	37	39	26,524	28,480	1,956	7%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 2a. Comparison of Salinity and Salt Loads (October 2001 - December 2002)

	Flow-weighted Electrical Conductivity		Salt Loads			
	Station A µS/cm	Station B µS/cm	Station A tons/month	Station B tons/month	difference	Percent of Station B
Oct-2001	4,980	3,879	3,368	4,294	926	22%
Nov-2001	4,460	3,782	3,362	5,024	1,662	33%
Dec-2001	4,760	4,219	3,618	5,308	1,690	32%
Jan-2002	4,820	4,287	6,419	7,162	743	10%
Feb-2002	4,390	4,314	11,457	11,853	396	3%
Mar-2002	4,630	4,391	14,826	14,892	66	0%
Apr-2002	4,700	4,650	11,750	11,372	-379	-3%
May-2002	4,430	4,171	11,538	11,082	-456	-4%
Jun-2002	4,170	3,931	13,719	13,134	-585	-4%
Jul-2002	3,910	3,886	12,710	12,749	39	0%
Aug-2002	3,580	3,474	11,954	11,922	-32	0%
Sep-2002	4,350	3,843	7,258	7,387	129	2%
Oct-2002	5,040	4,177	4,570	5,213	643	12%
Nov-2002	4,870	4,182	4,240	4,840	601	12%
Dec-2002	4,900	4,556	5,484	6,236	752	12%
Fifteen month ave	4,533	4,116				
Fifteen month total			126,275	132,468	6,194	5%

Data sources: Station A - San Luis & Delta-Mendota Water Authority
Station B - US Geological Survey Site 11262895

Table 2b. Comparison of Salinity and Salt Loads, Water Years 1997 – 2002

	Flow-weighted Electrical		Salt Loads			
	Station A µS/cm	Station B µS/cm	Station A tons/month	Station B tons/month	difference	Percent of Station B
WY 1997	4,477	4,257	176,433	167,739	-8,694	-5%
WY 1998	4,625	4,439	195,263	205,104	9,841	5%
WY 1999	4,821	4,650	143,705	149,133	5,427	4%
WY 2000	4,478	4,301	129,368	134,994	5,626	4%
WY 2001	4,634	4,202	125,394	120,008	-5,386	-4%
WY 2002	4,432	4,069	111,981	116,180	4,198	4%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 2c. Comparison of Salinity and Salt Loads, Calendar Years 1997 – 2002

	Flow-weighted Electrical		Salt Loads			
	Station A µS/cm	Station B µS/cm	Station A tons/month	Station B tons/month	difference	Percent of Station B
CY 1997	4,627	4,354	173,154	169,236	-3,918	-2%
CY 1998	4,699	4,563	199,506	208,884	9,378	4%
CY 1999	4,767	4,532	139,922	146,530	6,607	5%
CY 2000	4,379	4,189	126,124	128,576	2,453	2%
CY 2001	4,668	4,200	121,678	119,266	-2,412	-2%
CY 2002	4,483	4,155	115,926	117,842	1,916	2%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 3a. Comparison of Selenium Measurements (October 2001 - December 2002)

	Flow-weighted Selenium Concentration		Total Selenium Loads			
	Station A µg/L	Station B µg/L	Station A lbs/month	Station B lbs/month	Difference	Percent of Station B
Oct-2001	61.8	39.9	113	118	7	6%
Nov-2001	71.5	42.1	146	148	6	4%
Dec-2001	57.4	49.3	118	170	50	30%
Jan-2002	73.6	54.6	265	246	(19)	-8%
Feb-2002	66.3	65.1	468	483	15	3%
Mar-2002	66.4	63.8	575	586	9	2%
Apr-2002	75.3	75.7	509	500	(9)	-2%
May-2002	46.2	50.6	325	363	38	11%
Jun-2002	43.9	44.0	390	397	7	2%
Jul-2002	39.1	41.1	343	365	21	6%
Aug-2002	34.2	34.7	308	322	64	20%
Sep-2002	50.4	46.4	227	241	14	6%
Oct-2002	89.7	63.9	220	216	(8)	-4%
Nov-2002	89.8	69.4	211	216	5	2%
Dec-2002	80.2	65.4	242	241	(1)	0%
Fifteen month ave	63.1	53.7				
Fifteen month totals			4,460	4,612	152	3%

Data Sources: Station A - Calculated from weekly composite samples collected by the Regional Board (Site MER562s)
Station B - Calculated from daily composite samples collected by the Regional Board (Site MER535s)

Table 3b. Comparison of Selenium Measurements, Water Years 1997 - 2002

	Average Flow-weighted		Total Selenium Loads			
	Station A µg/L	Station B µg/L	Station A pounds	Station B pounds	Difference	Percent of Station B
WY 1997	67.6	62.8	7,431	6,960	(471)	-7%
WY 1998	69.1	66.4	8,244	8,763	519	6%
WY 1999	66.5	58.9	5,257	5,124	(133)	-3%
WY 2000	65.7	54.0	4,669	4,603	(65)	-1%
WY 2001	62.6	56.0	4,493	4,377	(116)	-3%
WY 2002	57.2	50.6	3,737	3,940	203	5%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 3c. Comparison of Selenium Measurements Calendar Years 1997 - 2002

	Average Flow-weighted Concentration		Total Selenium Loads			
	Station A µg/L	Station B µg/L	Station A pounds	Station B pounds	Difference	Percent of Station B
CY 1997	67.1	60.8	7,170	6,854	(316)	-5%
CY 1998	70.5	67.8	8,415	8,872	457	5%
CY 1999	65.2	56.8	5,089	4,992	(97)	-2%
CY 2000	66.1	54.6	4,615	4,507	(108)	-2%
CY 2001	61.6	54.8	4,316	4,302	(14)	0%
CY 2002	62.9	56.2	4,033	4,170	137	3%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

4a. Grassland Bypass Project San Luis Drain Discharge Balance (October 2001 - December 2002)

	CIMIS Precipitation						CIMIS Evapotranspiration								
	Panoche inches (1)	Telles inches (2)	Los Banos inches (3)	Average inches (4)	Average feet (5)	Water Gain from Precip acre feet (6)	Panoche inches (7)	Telles inches (8)	Los Banos inches (9)	Average inches (10)	Average feet (11)	Water lost to Evap. acre feet (12)	Gain or Loss from Water Surface acre feet (13)	Station A acre feet	Station B acre feet
Oct-2001	0.37	-	0.51	0.29	0.02	2.5	4.28	4.16	3.94	4.13	0.34	(35.0)	(32.5)	672	1,100
Nov-2001	0.90	1.73	1.57	1.40	0.12	11.9	1.75	1.73	1.60	1.69	0.14	(14.4)	(2.5)	749	1,320
Dec-2001	1.49	1.32	2.05	1.62	0.14	13.7	0.98	0.83	0.82	0.88	0.07	(7.4)	6.3	755	1,250
Jan-2002	0.65	0.20	1.05	0.63	0.05	5.4	1.21	1.13	1.09	1.14	0.10	(9.7)	(4.3)	1,323	1,660
Feb-2002	0.13	0.16	0.34	0.21	0.02	1.8	2.36	2.37	2.07	2.27	0.19	(19.2)	(17.4)	2,593	2,730
Mar-2002	0.62	0.94	1.13	0.90	0.07	7.6	4.21	3.99	3.86	4.02	0.34	(34.1)	(26.5)	3,182	3,370
Apr-2002	0.24	0.39	0.19	0.27	0.02	2.3	5.83	5.50	5.12	5.48	0.46	(46.5)	(44.2)	2,484	2,430
May-2002	0.05	0.32	0.34	0.24	0.02	2.0	8.36	8.01	7.56	7.98	0.66	(67.7)	(65.7)	2,588	2,640
Jun-2002	-	0.64	-	0.21	0.02	1.8	9.32	8.97	8.62	8.97	0.75	(76.1)	(74.3)	3,269	3,320
Jul-2002	-	0.04	-	0.01	0.00	0.1	8.43	8.78	8.82	8.68	0.72	(73.6)	(73.5)	3,230	3,260
Aug-2002	-	-	-	-	-	-	7.11	7.46	7.46	7.34	0.61	(62.3)	(62.3)	3,318	3,410
Sep-2002	-	-	-	-	-	-	5.78	5.87	5.58	5.74	0.48	(48.7)	(48.7)	1,658	1,910
Oct-2002	-	-	-	-	-	-	4.13	4.10	3.83	4.02	0.34	(34.1)	(34.1)	901	1,240
Nov-2002	0.54	1.02	1.21	0.92	0.08	7.8	1.86	1.90	1.76	1.84	0.15	(15.6)	(7.8)	865	1,150
Dec-2002	2.07	2.46	3.27	2.60	0.22	22.1	1.08	1.08	1.05	1.07	0.09	(9.1)	13.0	1,112	1,360

Data sources: Precipitation and evapotranspiration: California Irrigation Management Information System
Station A flow: San Luis & Delta-Mendota Water Authority
Station B flow: US Geological Survey Site 11262895

Table 4b. Grassland Bypass Project San Luis Drain Discharge Balance, Water Years 2000 – 2002

	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water Gain from Precip acre feet	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water lost to Evap. acre feet	Gain or Loss from Water Surface acre feet	Site A acre feet	Site B acre feet
WY2000	4.38	4.65	7.84	5.62	0.47	47.7	58.04	58.87	56.44	57.78	4.82	(490)	(442)	29,350	31,260
WY2001	6.71	7.61	7.72	7.35	0.61	62.3	61.32	59.87	57.81	59.67	4.97	(506)	(444)	27,005	28,254
WY2002	4.45	5.74	7.18	5.79	0.48	49.1	59.62	58.80	56.54	58.32	4.86	(495)	(446)	25,822	28,400

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 4c. Grassland Bypass Project San Luis Drain Discharge Balance, Calendar Years 2000 – 2002

	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water Gain from Precip acre feet	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water lost to Evap. acre feet	Gain or Loss from Water Surface acre feet	Site A acre feet	Site B acre feet
CY2000	6.52	5.88	8.67	7.02	0.59	59.6	56.55	57.14	55.41	56.37	4.70	(478)	(419)	28,939	30,210
CY2001	2.76	3.05	4.13	3.31	0.28	28.1	7.01	6.72	6.36	6.70	0.56	(57)	(29)	26,143	28,021
CY2002	4.30	6.17	7.53	6.00	0.50	50.9	59.68	59.16	56.82	58.55	4.88	(497)	(446)	26,524	28,480

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Notes: Table prepared by Summers Engineering, updated by US Bureau of Reclamation

(1) - (3) Precipitation in inches for CIMIS Stations 007, 056, and 124.
(4) Average of (1) through (3)
(5) (4) / 12 conversion from inches to feet
(6) (5) x SLD surface area. SLD surface area = 28 mi x 30' top width = 101.8 ac
(7) - (9) Evapotranspiration in inches for CIMIS Stations 007, 056, and 124.
(10) Average of (7) through (9)
(11) (7) / 12 conversion from inches to feet
(12) (9) x SLD surface area. SLD surface area = 28 mi x 30' top width
(13) (6) + (12)
(14) From Table 1
(15) Net water volume gained from or lost to local high ground water =
(16) Average daily flow (cfs) of the Net Water Gain
(17) (15) / Station B flow (from Table 1) x 100%

Figure 1. Comparison of Flows in the San Luis Drain
October 2001 - December 2002

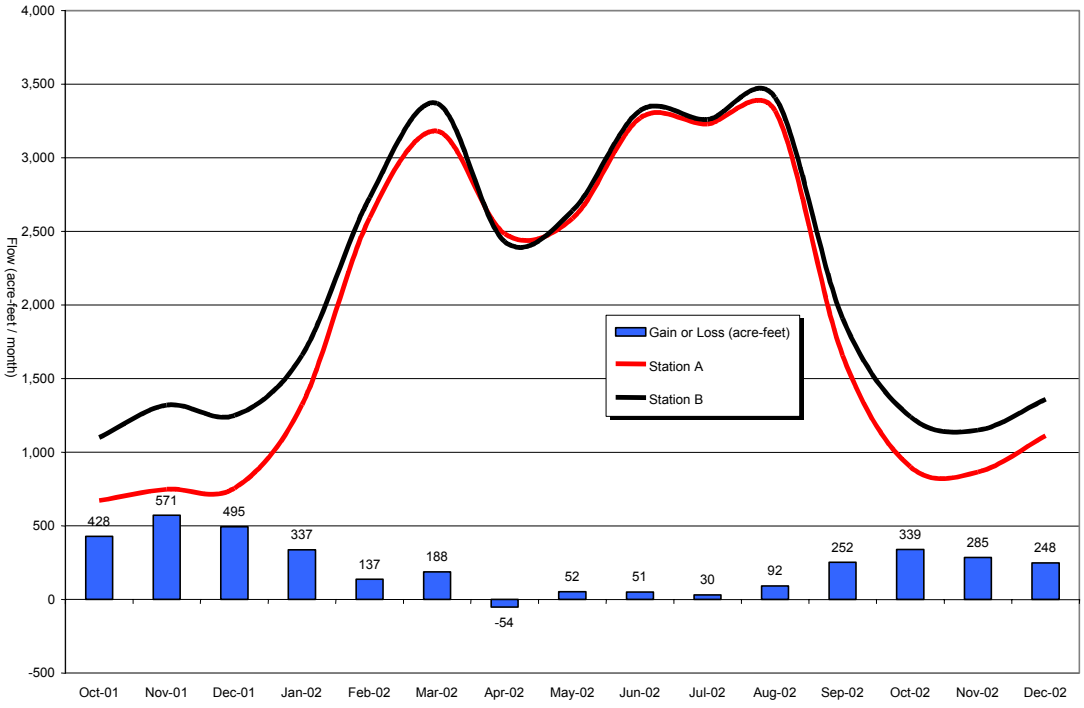

Figure 2. Comparison of Salt Loads in the San Luis Drain
October 2001 - December 2002

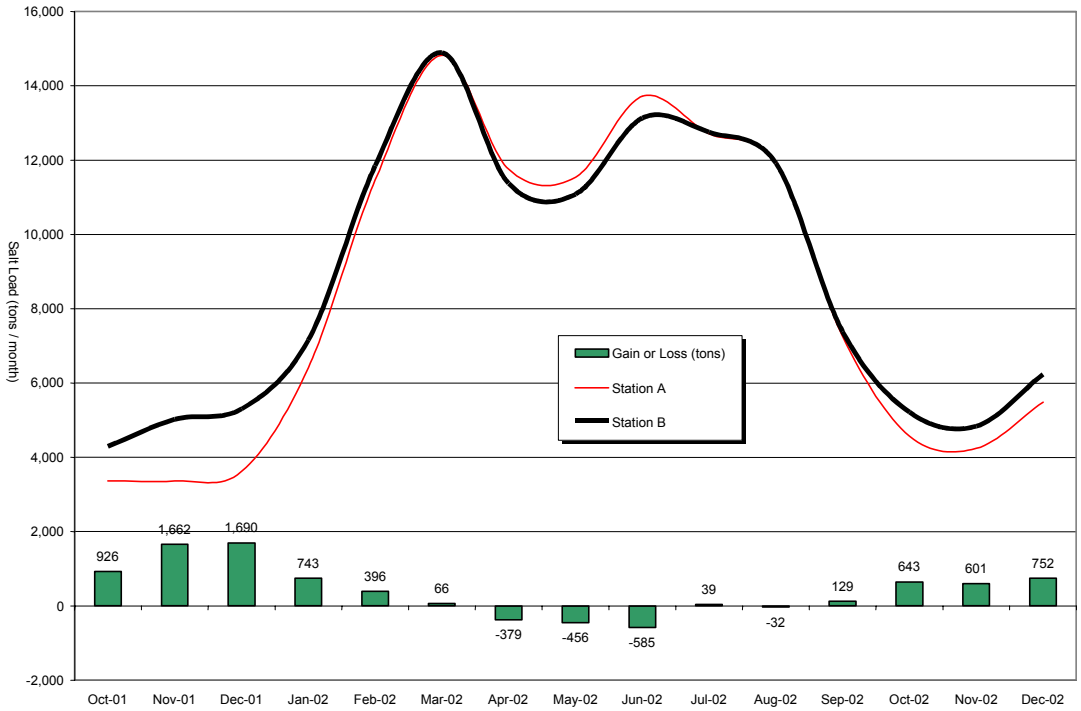

Figure 3. Comparison of Selenium Loads in the San Luis Drain
October 2001 - December 2002