FINAL

A Summary of Turbidity and Total Suspended Solids Investigations in the Bear Lake Marsh, 1997

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INTRODUCTION

Bear Lake, located on the border of Utah and Idaho (42° 00'N 111° 24'W) is a 171 km^2 oligotrophic body of water. The lake, which has a continuous lacustrian history of at least 28,000 years B.P. has developed a unique set of endemic fish species. In addition, the lake has maintained relatively pristine water quality.

In the early 1900s, the Bear River was diverted through the 45 km^2 marsh (located at the north end of the lake) and into Bear Lake. Water is now stored in the lake during spring runoff and removed during the mid to late summer for downstream irrigation. During both the fill and drain cycle there is some exchange of water between the internal canal system and the open waters (Mud Lake) of the marsh complex.

Prior to 1991, water entered Bear Lake through the Lifton Station site with overflow waters entering the lake through an emergency structure known as the causeway. The causeway was used only during high flow periods when the volume of water exceeded the capacity of the inflowing canals. Investigations during 1981-1983 by Ecosystems Research Institute (ERI 1983) indicated that when water was flowing through Lifton Station and the causeway simultaneously, water quality entering Bear Lake through the causeway was better (less total suspended solids and nutrients) when compared to Lifton Station. It was reasoned that the location of the causeway adjacent to Mud Lake compared to Lifton Station (adjacent to the canal system) was the mechanism leading to improved water quality.

In 1993, the failure of the causeway structure necessitated the rebuilding of this facility. The new structure, although built at the same location has automated gates and may have different hydrologic or geomorphic features when compared to the old structure. This issue has prompted the Idaho resource agencies to request an investigation as to the water quality impacts of the new structure on Bear River water entering Bear Lake. To that end, the following objectives were addressed during 1997.

1. Design and implement a monitoring program which will evaluate the location and design of the causeway structure relative to total suspended solids entering Bear Lake.
2. Evaluate the water quality impact of utilizing the water control structure (causeway) as the primary entrance point of Bear River water into Bear Lake.

METHODS

During 1997, four separate organizations collected water quality data within the Bear Lake marsh, causeway and/or Bear Lake. The U.S. Fish and Wildlife Service (USFWS) collected turbidity data throughout the marsh complex (18 open water stations) during six separate dates while PacifiCorp (PC) collected total suspended solids and turbidity data during eleven consecutive weeks at three open water stations.

The Bear Lake Regional Commission (BLRC), which maintains the monitoring program on

Bear Lake, added three additional stations to their annual program. These stations corresponded to the major inflows and outflows to the marsh. In addition to the above three programs, ERI established instantaneous turbidity monitors at the causeway, Stewart Dam and the outlet, which corresponded to PacifiCorp and BLRC sites (Figure 1). ERI also established sites immediately upstream and downstream of the causeway structure where grab samples were collected on a periodic basis. The complete data sets for all grab samples are provided in Appendix I.

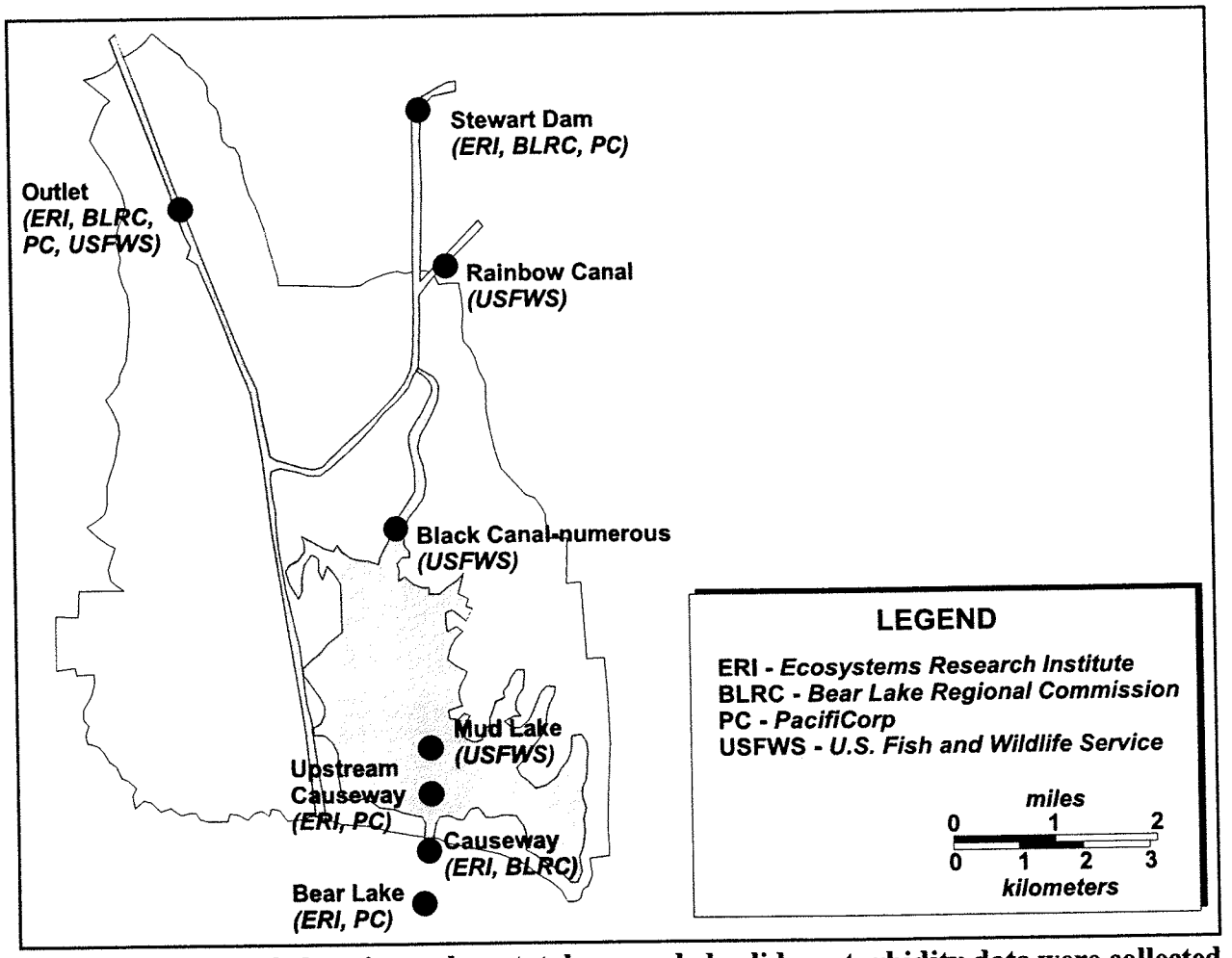

Figure 1. The sample locations where total suspended solids or turbidity data were collected during 1997.

RESULTS

The hydrology of the Bear Lake marsh complex is maintained by PacifiCorp under an agreement and in consultations with the USFWS Bear Lake Bird Refuge. The elevations of Mud Lake and the flows at the causeway and outlet can be seen in Figure 2 for the Bear Lake fill cycle in 1997. Prior to the fill cycle, Mud Lake elevations were raised above 5923 feet and were maintained at that elevation until the end of June (Figure 2). At that time elevations were dropped gradually 1.2 feet to 5921.8 feet. Elevations were further dropped in July in anticipation of draining Bear Lake water.

At the start of the investigation, flows entering Bear Lake through the causeway were approximately 400 cfs with 500 cfs being diverted through the outlet structure downriver. As flows increased at Stewart Dam due to spring runoff, flows through the causeway concurrently increased (with outlet flows remaining constant). As flows peaked (at approximately 3,000 cfs) the outlet was shut off and all flows passed through the marsh and entered Bear Lake through the causeway structure. Because of the volume of Bear River water and the rapid rise in Bear Lake water elevations, the outlet was opened at the end of the first week in June and remained open for the rest of the study period. Near the end of June, more Bear River water was flowing through the outlet canal than through the causeway into the Bear Lake (Figure 2). Causeway inflows to Bear Lake were stopped on July 7, 1997.

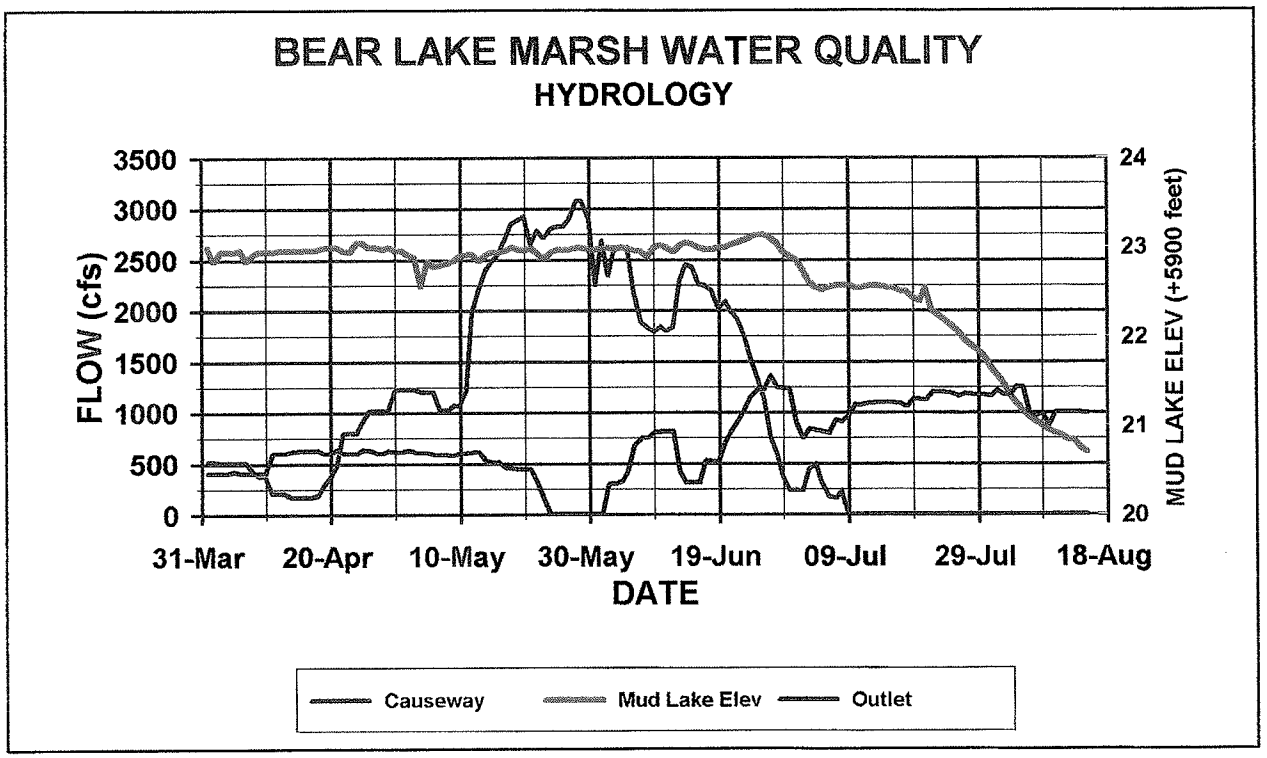

Figure 2. The elevations of Mud Lake and flows at the causeway and outlet structures during the lake fill cycle in 1997 (PacifiCorp Hydrology Section 1997).

The turbidity data (expressed as NTUs) for the study period where sample sites and sample dates were comparable can be seen in Table 1. It should be noted that not all sample sites collected in 1997 could be used in this analysis. For example, the USFWS collected data at 18 open water stations throughout the marsh. These sites did not correspond to the same locations as noted in Table 1 for PacifiCorp, ERI or BLRC sites. Although not used in the analysis, the open water data from USFWS can be seein in Appendix I of this report. The data in Table 1 demonstrates good agreement between all parties collecting grab sample data on the marsh, at approximately the same sites.

A more specific example of the comparison between grab samples collected at Stewart Dam, Mud Lake/Causeway and Bear Lake stations (downstream of the causeway) can be seen in Figure 3. These data represent the most systematic data sets collected with the grab sample protocol. As can be seen from this figure, there is good agreement between the two independent monitoring programs for all three sample stations. Because of this good agreement, the two data sets were combined for statistical analysis. These combined data are plotted in Figure 4.

During the lake fill cycle in 1997, ERI maintained three continuous turbidity monitors at Stewart Dam, causeway and outlet stations. Data were recorded and electronically stored every 30 minutes. These data can be seen in Figure 5. The comparison of the grab samples with the continuous data (Table 1) demonstrates the good agreement of all data sets. In addition, because of the high temporal resolution (every 30 minutes) the continuous data shows the dynamic nature of the river inflow and resultant outlet and causeway turbidity values.

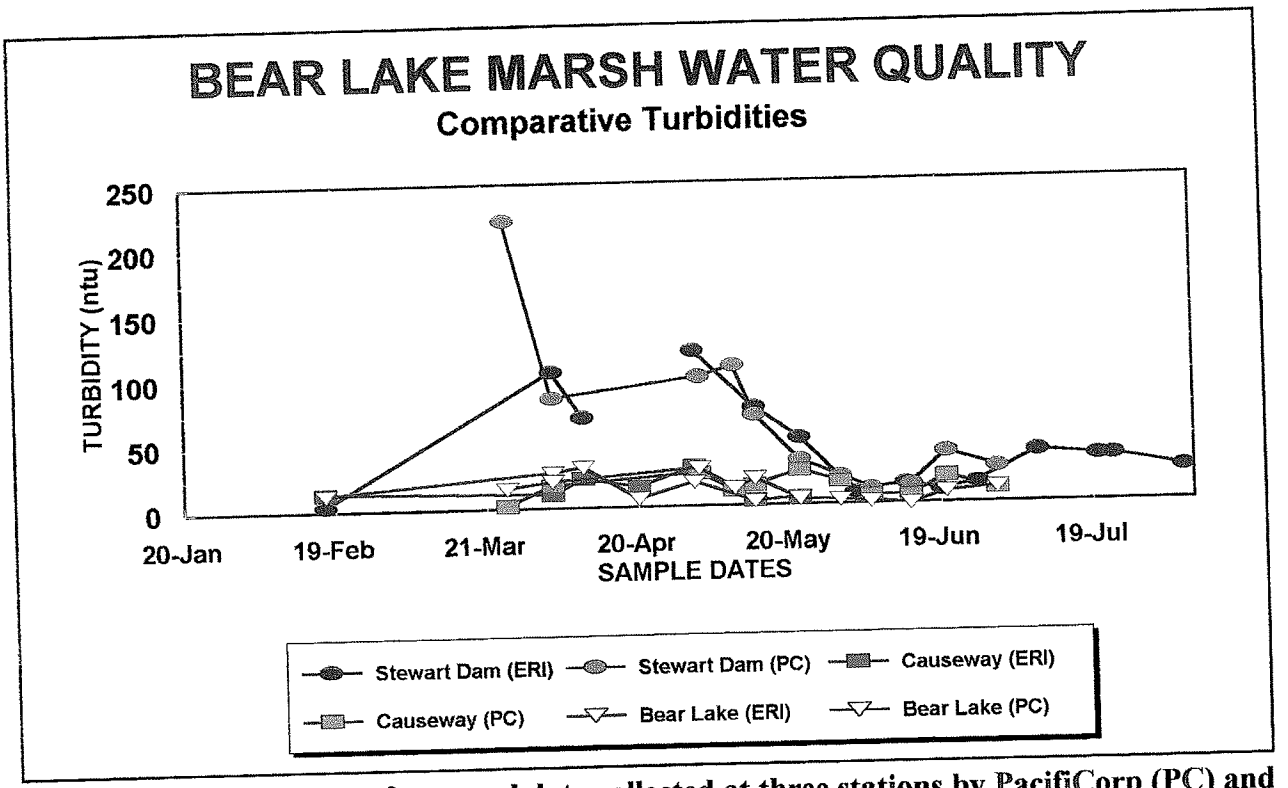

Figure 3. The comparison of temporal data collected at three stations by PacifiCorp (PC) and Ecosystems Research Institute (ERI) during 1997.

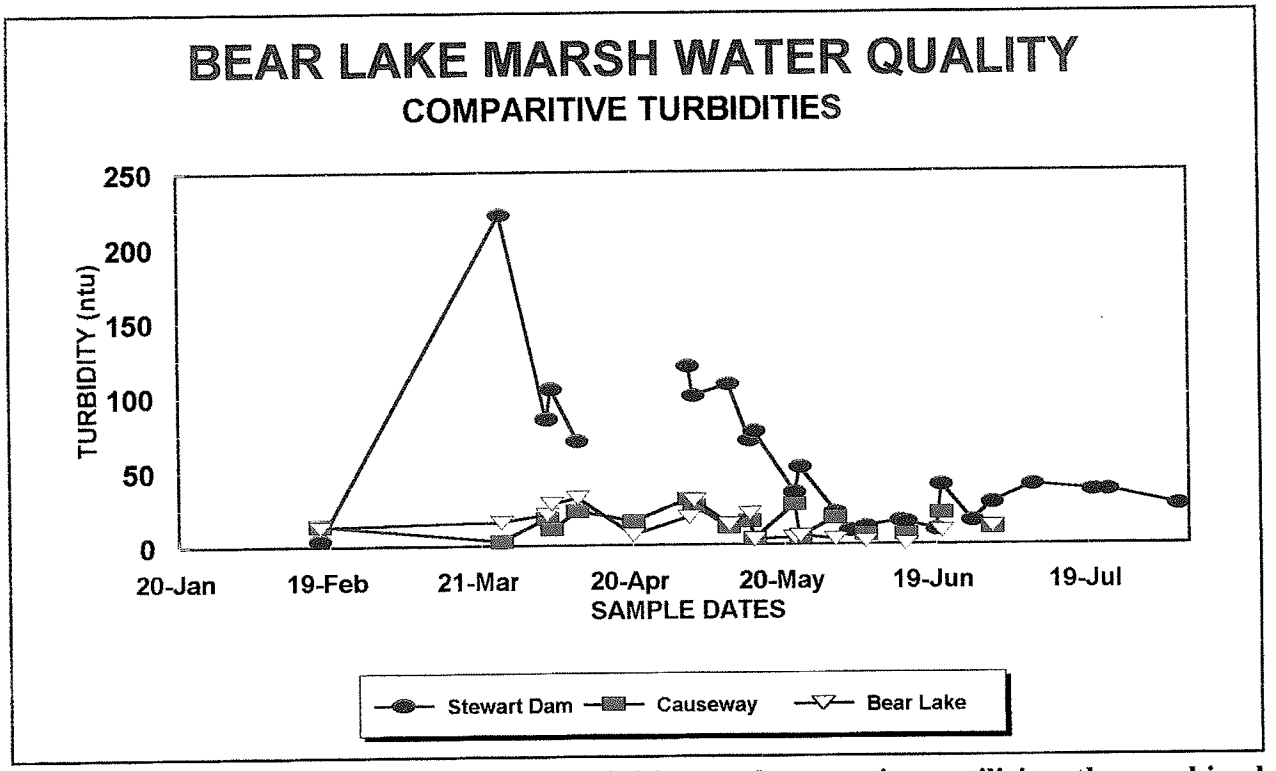

Figure 4. The temporal variation in turbidities at three stations utilizing the combined PacifiCorp and ERI data sets collected during the Bear Lake fill cycle in 1997.

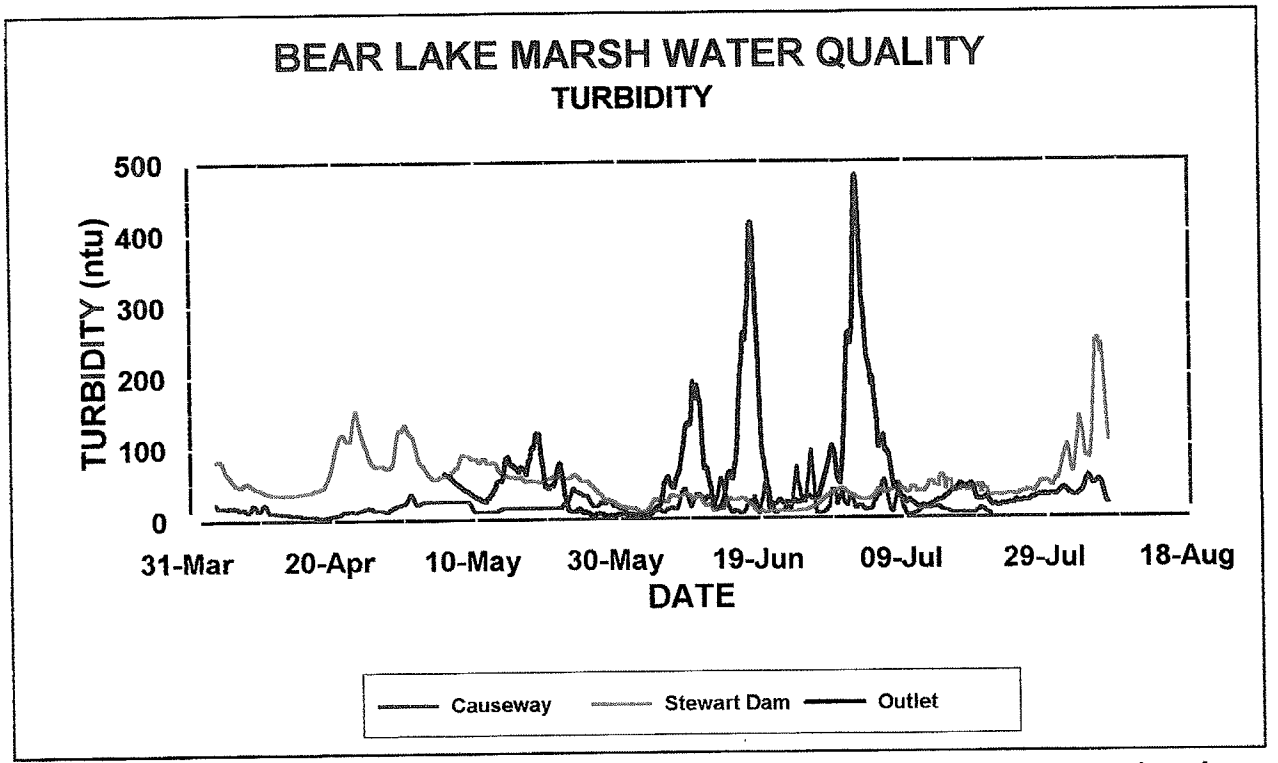

Figure 5. The instantaneous turbidity data collected every 30 minutes at three stations in the Bear Lake marsh, 1997.

Table 1. The comparison of the turbidiy (NTU) data sets collected at Stewart Dam, outlet and the causeway during 1997.

	Stewart Dam				Upstream of Causeway/Mud Lake				Bear Lake	
DATE	ERI (c)	BLRC (g)	PC (g)	USFWS (g)	ERI (c)	BLRC (g)	PC (g)	USFWS (g)	BLRC (g)	PC (g)
02/17/97	--	4	--	--	--	--	--	--	--	--
03/25/97	--	--	222	--	--	--	3	--	--	16
04/03/97	84	105	85	--	21.1	--	18	--	--	21
04/09/97	44	70	--	--	14.1	18	--	--	13	--
04/20/97	108	--	--	--	8.4	11	--	--	28	--
05/01/97	90	120	--	--	22	22	--	--	32	--
05/02/97	73	--	100	--	26	--	26	--	--	30
05/06/97	72	--	--	145	26	--	--	23.3	--	--
05/08/97	94	--	--	160	26	--	--	29	--	--
05/09/97	89	--	108	--	14	--	12	--	--	14
05/13/97	65	76	70	--	16	10	16	--	7	21
05/19/97	56	--	--	84	16	--	--	13	--	--
05/22/97	58	52	35	--	20	8.2	27	--	19	4.9
05/30/97	17	--	22	--	17.2	--	18	--	--	3.5
06/02/97	11	9.3	--	--	6.6	4	--	--	3.6	--
06/04/97	28	--	--	40	16.2	--	--	15	--	--
06/05/97	20	--	12	--	19.1	--	6.9	--	--	2
06/12/97	16	16	--	--	13	8.2	--	--	6.1	--
06/13/97	14	--	15	--	14	--	6.8	--	--	0.2
06/19/97	10	10	--	--	9.8	6	--	--	--	--
06/20/97	10	--	40	--	7.6	--	21	--	--	9
06/26/97	20	16	--	--	5.7	4.3	--	--	--	--
06/30/97	41	--	28	--	10.8	--	11	--	--	12

(c) = continuous sample; (g) = grab sample

DISCUSSION

The Bear River entering the Bear Lake marsh at Stewart Dam is considered impaired relative to its potential beneficial uses. High total suspended solids and excessive nutrients such as nitrogen and phosphorus are indications of this impairment. Historical investigations have indicated that the Bear Lake marsh, located at the north end of Bear Lake, improves the water quality of the Bear River prior to its entrance into Bear Lake. One objective the investigations conducted during 1997 was to evaluate the performance of the new causeway structure relative to this beneficial activity. The experimental design of the monitoring program was intended to determine if the causeway design contributed to the sediment load into Bear Lake. The results of this analysis can be seen in Figure 6. The statistical analysis indicates that the above (Mud Lake) and below (Bear Lake) causeway stations had mean values of 15.01 ± 1.91 and 13.46 ± 2.29 NTUs respectively, while the Stewart Dam station had an average of 57.87 ± 10.39 NTUs for the 1997 Bear Lake fill cycle. The two causeway stations were not significantly different from each other though both were significantly lower than the Stewart Dam site. The data indicates that on average, 75 percent of the sediment was removed by the Bear Lake marsh prior to its entrance into Bear Lake at the causeway.

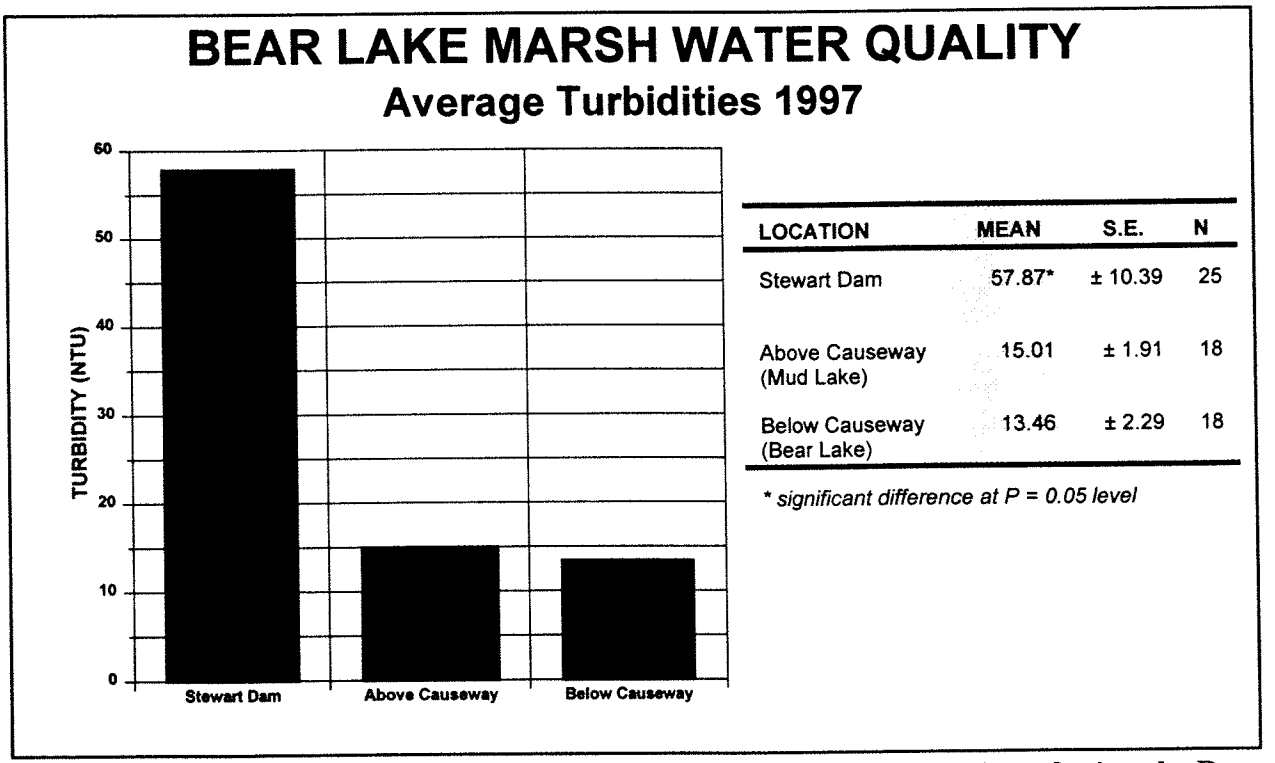

Figure 6. The comparisons of average turbidity at three monitoring stations during the Bear Lake fill cycle in 1997. The inset table lists the actual mean values, standard error and number of samples used in the analysis.

The second objective of the 1997 monitoring program was to determine the effectiveness of utilizing the causeway as a primary inflow location to maximize the improvement in water quality. Using the relationship between turbidity (NTU) and total suspended solids (TSS is a concentration of sediment as mg/liter) on paired samples, a regression relationship (Figure 7) was developed. This relationship with an r^2 of 0.91 was applied to the instantaneous turbidity data shown in Figure 5. Applying this concentration of sediment in the water and the associated flows at each station, the mass of sediment was calculated over the entire sampling period. The results of this analysis can be seen in Figure 8. By far, the greatest amount of mass entering the system occurred between the first of April and the end of May. During this period of time, over 40,000 kilograms of TSS per hour was removed from the Bear River prior to its entrance into Bear Lake (Figure 9). From the first of June through the seventh of July, the marsh was found to export sediment. During this period of time, water was being reduced through the causeway and routed down the Bear River (Figure 2). Internal channel hydrology between the Stewart Dam site and the outlet, combined with three summer storm events were believed to be the cause of this export of sediment (Figure 10).

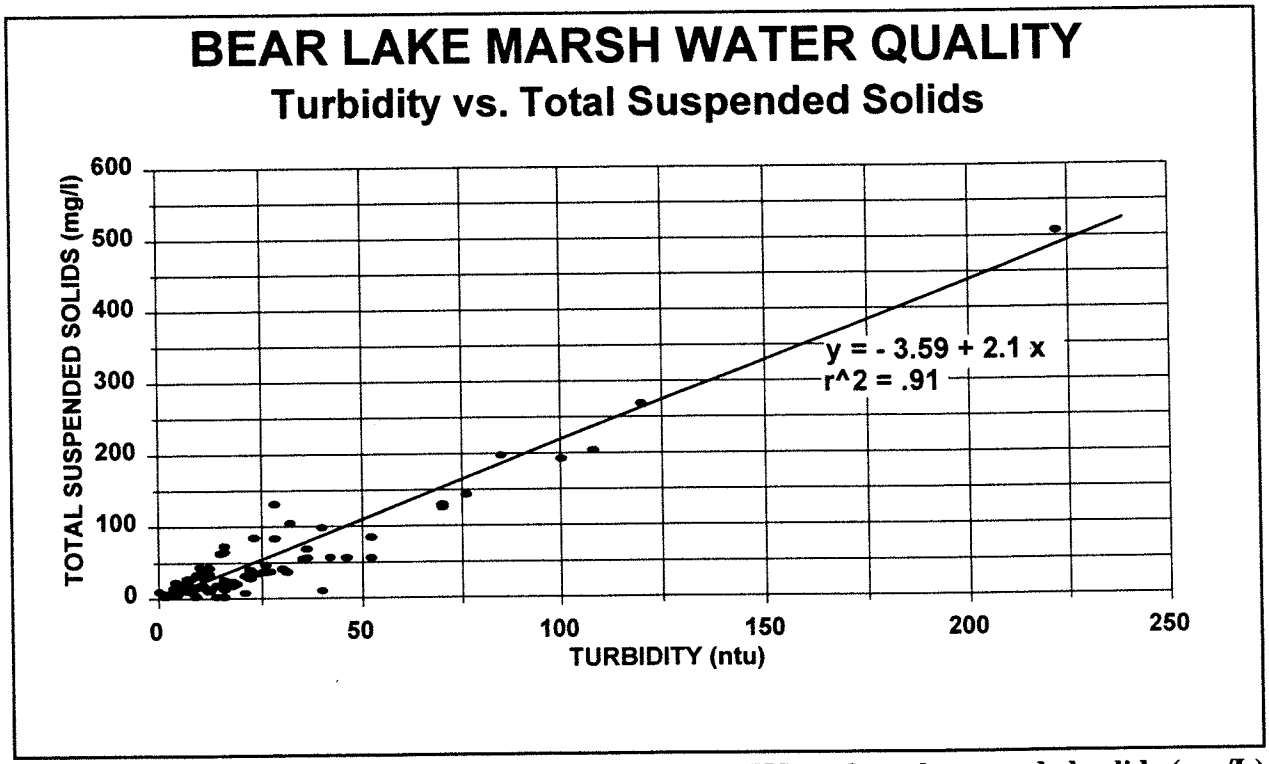

Figure 7. The linear relationship between turbidity (NTU) and total suspended solids (mg/L) for the same water samples collected at three stations in the Bear Lake marsh, 1997.

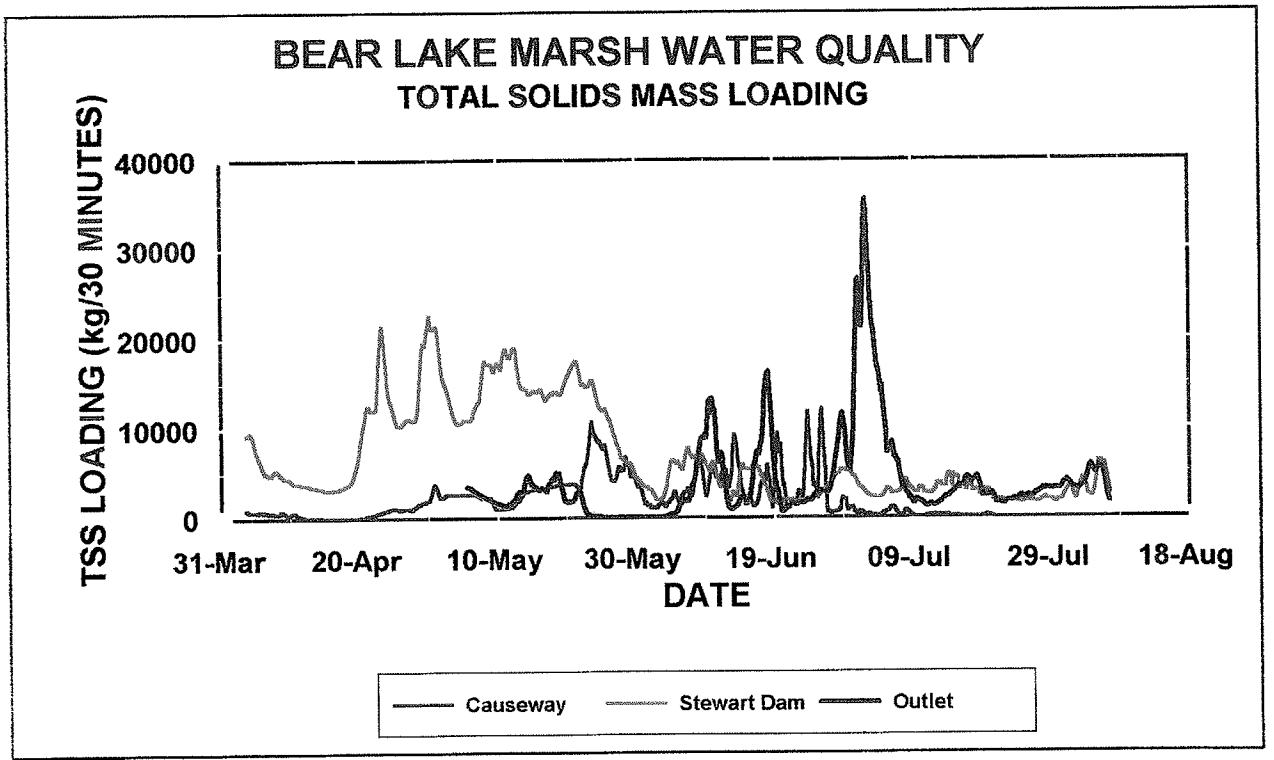

Figure 8. The mass (kg/30 minutes) movement of suspended solids at each sample location in the Bear Lake marsh during the lake fill cycle, 1997.

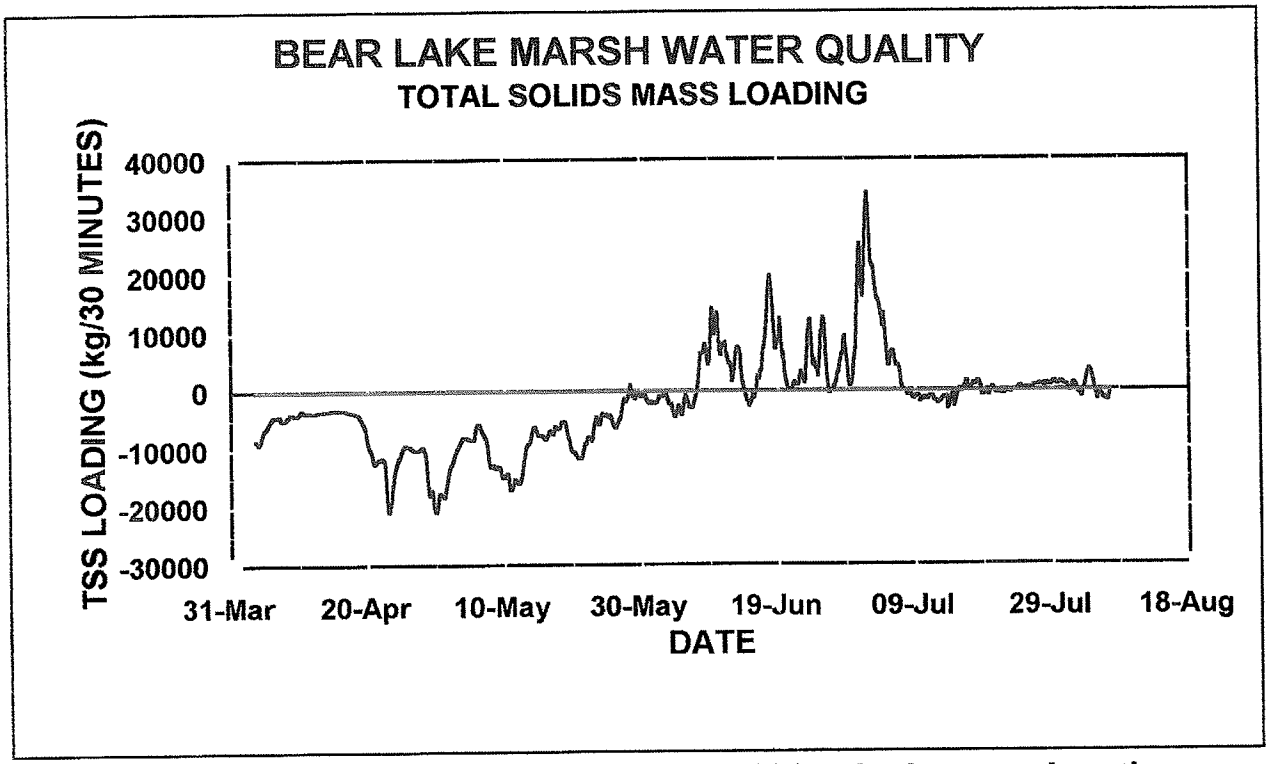

Figure 9. The mass balance of the Bear Lake marsh utilizing the three sample stations monitored during the Bear Lake fill cycle, 1997.

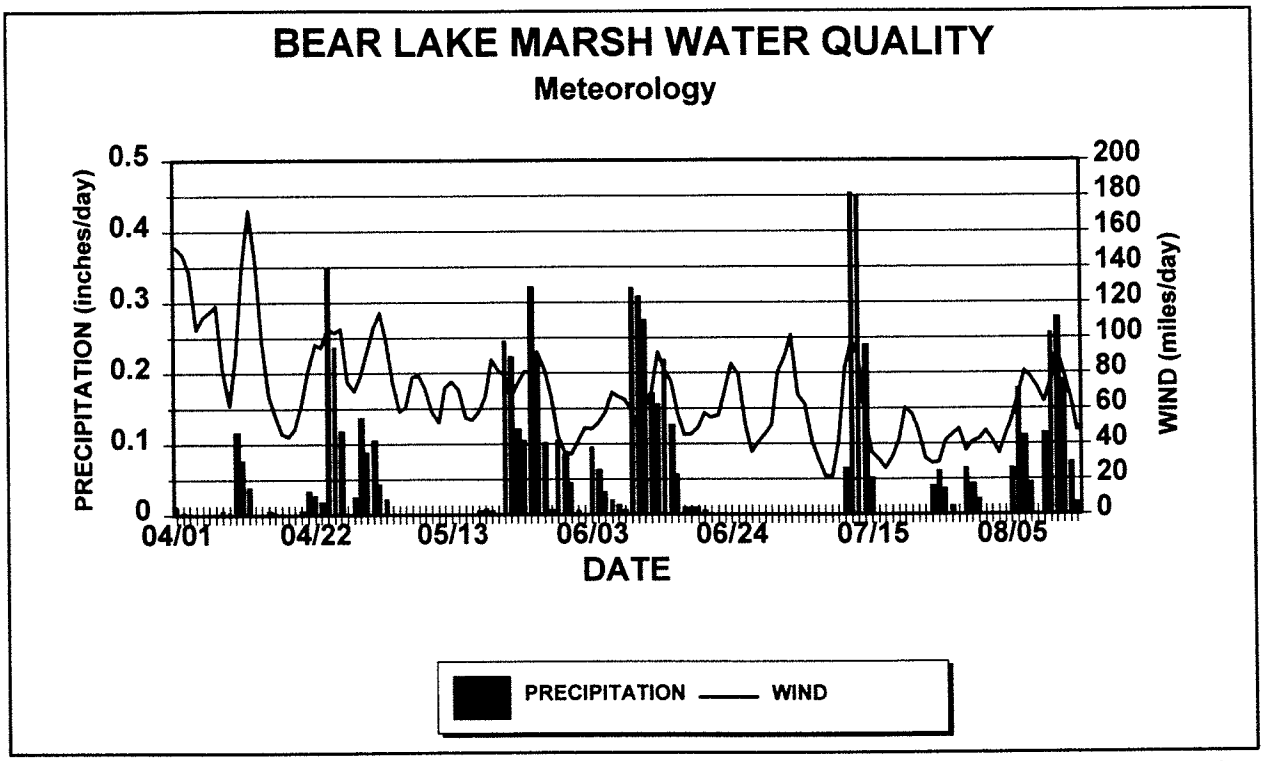

Figure 10. The wind speed and daily precipitation at Lifton Station for the study period during 1997.

CONCLUSIONS

1. During the study period, water flows were initially high through the causeway structure (May to June), but declined at the causeway and increased at the outlet site from mid-June through July.

2. The Bear River at Stewart Dam had impaired water quality during 1997, specifically high levels of total suspended solids, nitrogen and phosphorus.

3. Utilizing the grab samples, 75 percent of the turbidity and TSS was removed by the marsh as water flowed from Stewart Dam into Bear Lake at the causeway during the fill cycle in 1997.

4. There were no significant differences in turbidities or suspended solids immediately above and below the new causeway structure.

5. Utilizing the instantaneous data, there was a temporal change in the overall marsh efficiency in removing sediment ranging from a maximum removal of 40,000 kg/hr in April and May to a source of 40,000 kg/hour in June and July. Much of this sediment source was exported down the Bear River through the outlet structure as flows changed from entering Bear Lake at the causeway to the marsh outlet downstream into the Bear River.

APPENDIX I

Water Quality Data

ECOSYSTEMS RESEARCH INSTITUTE

	OUTLET		STEWART DAM		CAUSEWAY		CWY-UPSTREAM		CWY-DOWNSTREAM	
	TURB	TSS	TURB	TSS	TURB	TSS	TURB	TSS	TURB	TSS
02/17/97			4	5						
04/03/97			105							
04/09/97			70	130	18	24	14	19	13	14
04/20/97					11	18	11	17	28	84
05/01/97	52	85	120	269	22	28	23	85	32	105
05/13/97	42	57	76	143	10	16	16	13	7	28
05/22/97	18	18	52	56	8.2	9	31	37	19	21
06/02/97	1.5	4	9.3	34	4	23	4.1	16	3.6	15
06/12/97	14	3	16	3	8.2	28	5.4	18	6.1	19
06/19/97	11	33	10	44	6	17				
06/26/97	11	35	16	65	4.3	9				
07/08/97	16	26	40	99	6.7	11				
07/20/97	24	35	36	69						
07/23/97	25	37	36	57	8.3	11				
08/06/97	46	57	26	47						

U.S. FISH & WILDLIFE SERVICE: Bear Lake National Wildlife Refuge

DATE	Sample No.	Unit	Turbidity (NTU)		Remarks
05/06/97	1	RB (Rainbow) Unit	1.55	1.72	N. Rainbow
05/06/97	2	RB Unit	6.5	6.95	Subimpound Dike Pipe - wave action
05/06/97	3	RB Unit	2.65	2.75	Godwall Rd. N. End borrow ditch
05/06/97	4	RB Unit	9.43	10.28	Str. #4 borrow-wave action, also str. bleed thru.
05/06/97	5	Outlet Canal	39.1	40.2	N. end outlet canal
05/06/97	6	Outlet Canal	54	54.3	Above RB canal, near str #1 location
05/06/97	7	Outlet Canal	79.8	80.3	Below (s) of confluence with Rainbow canal
05/06/97	8	Outlet Canal	9.71	10.01	S. portion below entrance to Mud Lake
05/06/97	9	Rainbow Canal	143.8	145.7	Inlet canal near Str. #4 location
05/06/97	10	Black Channel-Mud L.	62.5	63.6	Southern portion Black channel
05/06/97	11	N.E. Mud Lake	13.79	14.35	NE Mud Lake area
05/06/97	12	N.W. Mud Lake	33.7	34.8	SW Mud Lake area
05/06/97	13	S.W. Mud Lake	23.1	25.4	SW Mud Lake area
05/06/97	14	S.E. Mud Lake	20.2	21.1	SE Mud Lake area
05/06/97	15	Mud Lake-Sulfur Bay	2.15	2.36	ML-Sulfur Bay area
05/06/97	16	N. West Canal	3.42	3.83	In large channel n. end W.C.- BL Imp.
05/06/97	17	N. West Canal	4.59	5.02	Large pond along channel WC-BL Imp.
05/06/97	18	N. West Canal	11.21	11.68	Up large channel before it enter out canal across str#1
05/06/97	19	W. Canal-Bl. Creek Channel	7.84	8.26	Channel upstream from split
05/06/97	20	W. Canal-Bunn L.	3.62	3.94	Middle Bunn Lake
05/06/97	21	S Bunn L. WC	1.95	2.11	S. End Bunn Lake
05/08/97	1	Rainbow Canal	158.2	160.7	200 m upstream Str.#4 area
05/08/97	2	Rainbow Canal	156.8	158.9	Mouth Black Channel
05/08/97	3	Mud L-Black Channel	175	176.9	Narrow north end BC
05/08/97	4	Mud L-Black Channel	102.1	105.1	Black Channel (see map)
05/08/97	5	Mud L-Black Channel	72.1	75	Black Channel (see map)
05/08/97	6	Mud L-Black Channel	62.3	63.1	Black Channel (see map)
05/08/97	7	Mud L-Black Channel	69.2	70.9	Black Channel (see map)
05/08/97	8	Mud L-Black Channel	53.1	53.9	Near where BC enters Mud L.
05/08/97	9	Mud L-Black Channel	23.9	24.2	0.30 mile S. of BC entrance toward causeway-ML
05/08/97	10	Mud L-Black Channel	27.8	29	0.60 mile in Mud L. toward causeway

DATE	Sample No.	Unit	Turbidity (NTU)		Remarks
05/19/97	1	Rb canal	82.5	83.5	
05/19/97	2	Rb canal	80.1	84.4	
05/19/97	3	Bl ch. ent	71.9	73.2	
05/19/97	4	Black Channel	63.6	65	
05/19/97	5	Black Channel	61.5	62.7	
05/19/97	6	Black Channel	61.6	62.4	
05/19/97	7	Black Channel	58.5	60.2	
05/19/97	8	Black Channel	53.9	57	
05/19/97	9	Mud Lake	22.4	24.4	
05/19/97	10	Mud Lake	12.4	13	
06/04/97	1	Rainbow	1.76	1.96	
06/04/97	2	Rainbow	3.86	4.92	
06/04/97	3	Rainbow	1.42	1.7	
06/04/97	4	Not taken			T swan nesting
06/04/97	5	Outlet Can.	14.8	15.5	
06/04/97	6	Outlet Can.	28.8	30	
06/04/97	7	Outlet Can.	36.6	38.4	
06/04/97	8	Outlet Can.	6.85	7.65	
06/04/97	9	Rainbow Canal	39.7	40.4	
06/04/97	10	Black Channel	20.6	21.7	
06/04/97	11	Mud Lake	14.69	15.14	
06/04/97	12	Mud Lake	13.76	15.56	
06/04/97	13	Mud Lake	11.8	12.5	
06/04/97	14	Mud Lake	8.38	9.76	
06/04/97	15	M.L.-s.e. Bay	2.68	3.02	
06/04/97	16	W.C.- n. end	1.28	1.6	
06/04/97	17	W.C.	0.98	1.07	
06/04/97	18	W.C.	2.17	2.62	
06/04/97	19	Bloom chan-WC	4.63	5.01	
06/04/97	20	Bunn L.-WC	0.98	1.11	
06/04/97	21	Bunn L.-WC	1.36	1.82	

DATE	Sample No.	Unit	Turbidity (NTU)		Remarks
07/15/97	1	Rainbow Unit	1.82	2.13	
07/15/97	2	Rainbow Unit	1.62	1.75	
07/15/97	3	Rainbow Unit	0.95	1.11	
07/15/97	4	No Sample			Swan nesting
07/15/97	5	Outlet Canal	37.4	43.2	
07/15/97	6	Outlet Canal	59.2	61.7	
07/15/97	7	Outlet Canal	9.45	10.23	
07/15/97	8	Outlet Canal	2.85	3.23	
07/15/97	9	Rainbow Canal	62.9	63.4	above Black channel ent.
07/15/97	10	Balck Channel	51.7	52.4	
07/15/97	11	Mouth BC in Mud Lake	20.1	22.3	
07/15/97	12	NW Mud Lake	20.8	21.7	
07/15/97	13	SW Mud Lake	6.68	7.12	
07/15/97	14	Just above causeway-ML	10.4	10.8	
07/15/97	15	SE Bay-ML	2.38	2.43	
07/15/97	16	WC N.End	0.53	0.56	
07/15/97	17	WC N.End	0.46	0.53	
07/15/97	18	WC-mid channel	14.4	15.2	
07/15/97	19	WC-Bloom Creek	3.68	4	
07/15/97	20	Bunn L. center	0.93	0.99	
07/15/97	21	s. end Bunn Lake	1.04	1.31	
07/15/97	30	Outlet Canal	39	41	S. of #5 mile or so
07/15/97	24	WC N. End	0.59	0.71	due w. of #30 in small pond
07/15/97	29	Out canal	29.7	32.4	
07/15/97	22	W.S. inter ponds	0.39	0.48	
07/15/97	25	Out Canal	49.4	54.3	below #6
08/07/97	1	Rainbow Unit	2.38	2.61	
08/07/97	2	Rainbow Unit	2.35	2.64	
08/07/97	3	Rainbow Unit	5.24	5.47	
08/07/97	4	Rainbow Unit	1.77	1.86	
08/07/97	5	Outlet Canal	33.9	34.3	
08/07/97	6	Outlet Canal	64.8	66.1	

DATE	Sample No.	Unit	Turbidity (NTU)		Remarks
08/07/97	7	Outlet Canal	64.3	65.1	
08/07/97	8	Outlet Canal	16.98	17.06	
08/07/97	9	Rainbow Inlet Canal	49.1	50.5	
08/07/97	10	Black channel midway S.	51.9	53	
08/07/97	11	Mud Lake near mouth Black	38.8	40	near mouth Black channel
08/07/97	12	NW Mud Lake	51.6	52.4	
08/07/97	13	SW Mud Lake	69.8	70.1	
08/07/97	14	Mud L.	57.8	58.2	in front of causeway
08/07/97	15	Mud Lake SE Bay	1.16	1.21	
08/07/97	16	W Canal N. end	0.63	0.78	n.end Bloom unit project
08/07/97	17	West canal	1.58	1.76	n.e. portion Bloom unit project
08/07/97	18	West canal	8.88	9.12	midway s along e. side channel
08/07/97	19	Bloom creek channel	12.3	13.7	
08/07/97	20	N. central Bunn Lake	2.52	2.65	
08/07/97	21	S. end Bunn Lake	1.18	1.29	

PACIFICORP

	BEAR LAKE		STEWART DAM		MUD LAKE	
	TURB	TSS	TURB	TSS	TURB	TSS
03/25/97	16	73	222	508	3	5
04/03/97	21	32	85	198	18	24
05/02/97	30	42	100	193	26	37
05/09/97	14	19	108	204	12	11
05/13/97	21	32	70	126	16	24
05/22/97	4.9	7	35	55	27	38
05/30/97	3.5	5	22	40	18	22
06/05/97	2	7	12	43	6.9	22
06/13/97	0.24	10	15	63	6.8	23
06/20/97	9	3.4	40	11	21	8
06/30/97	12	34	28	132	11	28