The Ecology of Lake Abert: Analysis of Further Development

A Special Report

by

George P. Keister, Jr.
Oregon Department of Fish and Wildlife
April, 1992

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ABSTRACT

Lake Abert is a unique body of water in Oregon as well as the United States. It can be many times more saline than the ocean and its hydrology is near the same as before modern agriculture began in the area. The lake provides an important stop-over location for migrating shorebirds, waterfowl, and other waterbirds. The annual use was estimated at 1,664,000 use-days for shorebirds and 760,000 use-days for waterfowl during 1991. The lake serves as nesting habitat for approximately 100 pairs of the state threatened snowy plover (*Charadrius alexandrinus nivosus*). As many as 345 snowy plovers, up to 40% of Oregon's interior population, have been counted there in June. The bird life of Lake Abert depends on the highly productive aquatic life which includes the alkali fly (*Ephydra hians*), brine shrimp (*Artemia salina*), and several species of algae. Based on literature review, the optimum salinity for aquatic life at Lake Abert is probably in the range of 30 - 80 g/l (total dissolved solids) which corresponds to a current lake level of ranging from ~4,258 to 4,252 ft. The critical salinity range begins at about 100 - 130 g/l (<4,250 ft). The salinity of the lake changes with lake level and time. The salt load is lost when the lake dries but much of it is regained as the lake again fills and continues to increase due to diffusion of solutes from below the bottom of the lake. A model of the water balance of the lake was created and used to determine the impact of present or future development projects that divert water from the lake. This analysis indicates that a present diversion of more than 4,400 ac-ft/year will produce significant, adverse impacts to the Lake Abert ecosystem. Impacts of the proposed River's End Project were analyzed and several operational alternatives are presented that would provide enough water for the reestablishment of part of the historic Chewaucan Marsh and water for irrigation during some years without significant impacts. Recommendations are included.

INTRODUCTION

Lake Abert is located about 25 miles north of Lakeview and 18 miles east of Paisley, Oregon. At high water levels, it covers about 60 square miles and is as much as 16 feet deep. Its salinity ranges from .8 to 4 times that of the ocean, making it the most saline body of water in Oregon and one of the most in the United States. It is an important stop-over location for numerous species of shorebirds and other waterbirds during spring and fall migration. It provides nesting habitat for several species including the western snowy plover, which is listed as state threatened and federally as category 2. It is also a location used by ducks, primarily the northern shoveler (*Anas clypeata*), during fall.

Lake Abert was much larger in Pleistocene times (last 2.5 million years) when, as Lake Chewaucan, its level was 280 feet above the present lake bed (Phillips and Van Denburgh 1971). However, water levels dropped as the climate became drier. The maximum level during the last 100 years was about 4,262 feet above sea level during the summer of 1984.

The major sources of water inflow to the lake are the Chewaucan River and direct rainfall, although there is a small amount of inflow from springs around the lake. Before 1915, the Chewaucan drainage flowed from the western mountains into the Chewaucan Marsh and then into Lake Abert. However, the marsh was drained between 1884 and 1915 (Phillips and Van Denburgh 1971, P. B13). The land was converted to agricultural use and some of the waters of the Chewaucan were then used to irrigate the land. By 1965 the water lost from Lake Abert due to irrigation was about equal to that lost to evaporation from Chewaucan Marsh prior to development (Phillips and Van Denburgh 1971, p. B13). Since 1963, only 8.43 cubic feet per second (cfs) of new water rights have been issued for the Chewaucan River out of a total appropriation of 565 cfs which represents only a 1.5% increase (this does not include the River's End Project). Therefore, the hydrology of Lake Abert is probably still very near the same as before modern agriculture began.

In addition to irrigation, another potential impact on the lake ecosystem is a commercial shrimp operation which began at the lake in 1981, and has since increased its catch from 3,935 pounds in that year to 39,300 pounds in 1990.

The goals of this report are to review what is known of the ecology of Lake Abert and evaluate the effects of future development around the lake, particularly those projects that deprive water from the lake. The specific objectives are as follows:

1. Review the biological interactions at Lake Abert.
2. Describe the geochemical relationships of Lake Abert.
3. Develop a model of the hydrology of Lake Abert.
4. Use the model to assess the impact of future developments which deprive water from Lake Abert and provide a method for reevaluation as conditions change.
5. Evaluate the effects of the River's End Project and provide recommendations that safeguard the Lake Abert ecosystem.

ACKNOWLEDGMENTS

This effort would not have been possible without the previous work at Abert Lake by K. Phillips and A. Van Denburgh, K. Boula, D. Herbst, F. Conte, and M. Stern. Constructive criticism of this manuscript was provided by K. Boula, D. Herbst, F. Conte, M. Stern, J. Jehl, A. Van Denburgh, D. Carlson, G. Robart, M. Potter, R. Bartels, L. Conn, M. St. Louis, and C. Foster.

BIOLOGY

Bird Life

The saline waters and extensive mud flats of Lake Abert provide important habitat for migrating shorebirds during spring and fall. Total numbers of shorebirds counted during the fall of 1991 was about 23,000 (Table 1). Phalaropes, both Wilson's (*Phalaropus tricolor*) and northern (*Phalaropus lobatus*), American avocets (*Recurvirostra americana*), and western (*Calidris mauri*) and least(*Calidris minutilla*) sandpipers, normally make up the bulk of those counted (See App. 1 for complete count). Phalarope numbers during fall of most years have been documented in the 4,000 to 18,000 range; however, as many as 70,000 were counted in 1982 (Table 1, Jehl, pers. comm.).

Single counts do not reflect turnover nor the total use of the area because different species peak at different times. However, during 1991, multiple counts were done between mid July and late September (Morawski and Stern, 1991) and total fall use of Lake Abert by shore birds was estimated by calculating the area under the use vs. time curve (Fig. 1). This analysis yields an estimate of about 1,300,000 use-days for shorebirds from July through September, 1991. This estimate of use, however, is probably conservative for some years when higher numbers of some species are present, such as in 1982 (Table 1).

Table 1. Waterbird count summary at Abert Lake, Oregon, 1982 - 1991.

Year	1991[a] Fall	1991[a] Spring	1990[a] Fall	1990[a] Spring	1989[e] July	1988[e] July	1987[b] Fall	1986[b] Fall	1985[c] Fall	1984[c] Fall	1983[d] Fall	1982[d] Fall
Species												
Gulls	2,630	30	456	143								
Avocets	6,217	1,367	1,056	919							5,000	5,000
Phalaropes	8,508	36	30,800[e]	2	9,841	8,000	6,135	17,689	4,500	6,395	13,000	65,000[e]
Peeps*	5,420	4,595	6,455									
B.N. Stilts	55	8										
Other Shorebirds	210	435	199	74			1,977	6,603			10,000	3,000
Total	23,040	6,471	38,966	1,138	9,841	8,000	8,112	24,292	4,500	6,395	28,000	73,000
Waterbirds	1,884	538	43									
Ducks	7,500							14,000[e]			7,000	7,000

* Least and western sandpipers

a Counts done cooperatively by Oregon Dep. Fish & Wildl. (ODFW)/US Fish and Wildl. Ser./Bureau of Land Manage.

b Counts done by ODFW

c Jehl (1988)

d Boula and Jarvis (1984)

e Jehl (pers. comm.); phalaropes were Wilson's

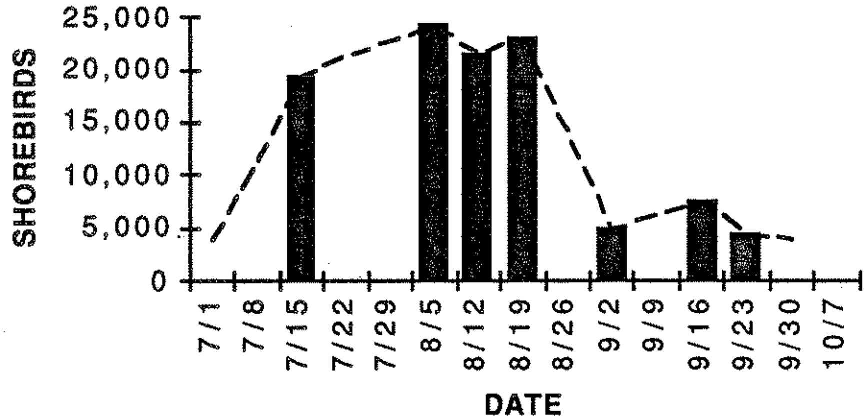

Fig. 1. Total number of shorebirds at Abert Lake, Oregon, 1991 (Data from Morawski and Stern, 1991).

Spring use by shorebirds has been documented at a lower level (Table 1). However, spring counts were conducted in late May and might have missed the peak of the migration. If the ratio of total number of use-days during fall to that during spring equals the ratio of peak counts during the same period, the total estimated use during the spring is (6,471/23,040) x 1,300,000 = 364,000 use-days. And the total year-long use by migrating shore birds is estimated at 364,000 + 1,300,000 = 1,664,000 use-days.

In addition to migrating shore birds, Lake Abert provides nesting habitat for about 1,000 breeding pairs of American avocets and 100 pairs of western snowy plovers (Kristensen et al. 1991). Lake Abert is one of the most important areas for nesting and staging snowy plovers in Oregon, with counts in June varying from 345 to 170 since 1980 (Fig. 2). Snowy plovers counted at Lake Abert represent 33 to 40% of the total number counted each year in the interior of Oregon.

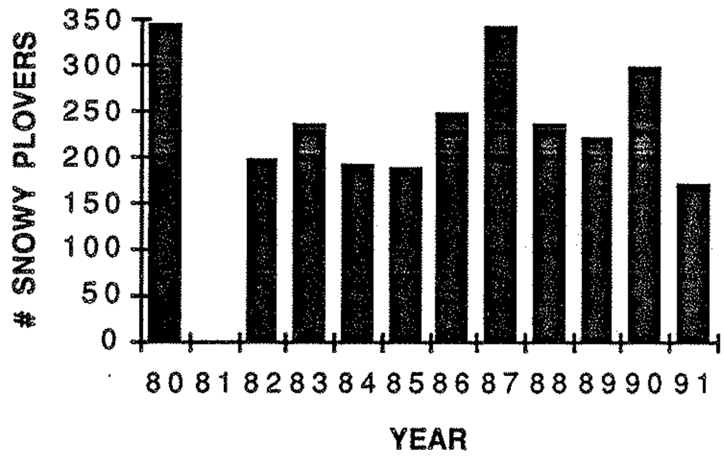

Fig. 2. Snowy plovers counted at Lake Abert, Oregon in June, 1980 - 1991. Data for 1980 from Herman et al. (1988), after 1980 from ODFW counts.

In addition to shorebirds, as many as 1,884 waterbirds have been counted (Table 1), the most common of which include gulls (*Larus spp.*) and eared grebes (*Podiceps nigricollis*) (see App. 1 for complete count). Other species counted include as many as 500 Canada geese (*Branta canadensis*) and 21,000 ducks (unpublished data, ODFW 1991). The primary duck species observed at Lake Abert is the northern shoveler. Other ducks using the lake, usually at lower numbers, include: ruddy ducks (*Oxyura jamaicensis*), mallards (*Anas platyrhynchos*), green-winged teal (*Anas crecca*), gadwall (*Anas strepera*), American wigeon (*Anas americana*), redhead (*Aytha americana*), lesser scaup (*Anthya affinis*) and hooded merganser (*Lophodytes cucullatus*) (unpublished data, ODFW; Kristensen et al. 1991). Based on numbers of ducks counted at different periods during the fall and winter of 1990 and 1991 (~7,000 - late Sept., ~21,000 - late Oct., ~4,000 - Dec., ~400 - Jan.; unpublished data, ODFW) about 760,000 use-days are estimated.

Lake Abert serves the important function of allowing migrating birds to increase their condition before continuing their long distance migrations (Jehl 1988, p. 52-53). This is especially important for the small shorebirds whose long-distance migration may range from the Arctic to South America. Boula and Jarvis (1984) found that the fall diet of most migrating birds at Lake Abert was dominated by the alkali fly. Brine shrimp occurred frequently only in the diets of northern shovelers and eared grebes (*Podiceps nigricollis*).

Most shorebirds use the shallow lake margins or mud flats, particularly at the north end of the lake. However, some species, such as phalaropes, grebes, gulls, and waterfowl use the deeper water.

In 1989, American avocets nested on the open playa near the lake edge or springs and in saltgrass/Nevada bulrush flats near freshwater ponds and seeps (Kristensen et al. 1991). Snowy plovers nested on the playa and in adjacent saltgrass flats (Stern et al. 1990). Both species feed in shallow water, primarily at the northern and northwestern shores of the lake.

Lake fluctuations probably do not adversely affect shorebird populations except at extreme highs and lows. At extremely high levels, snowy plover nesting habitat can be lost. This was seen at Harney Lake after 1980 when numbers dropped from 436 counted that year to 0 during the early 1980s when the lake flooded. By 1986, 27 were counted and the count has increased, as lake levels receded, to 79 in 1991 . However, at Abert Lake, with very high water levels between 1983 (4,258.8 feet) to 1986 (4,261.74 feet), the lowest count experienced was 193 in 1984. Evidently, even these levels were not high enough to flood out all of the nesting habitat. However, if levels reached the 4,265.7 foot level, which has been attained in the past (Phillips and Van Denburgh 1971), significant amounts of snowy plover nesting habitat may be lost. As lake levels decrease, more and more habitat becomes available for shorebirds due to greater edge area and more mud flats becoming available. However, lower lake levels may increase the distance between snowy plover nesting areas and feeding areas at the lake edge. There may be some impact on snowy plover broods moving from nesting to feeding areas during periods of low lake levels. Only at extremely low water levels would the prey base be limiting to birds due to excessive salinity.

Aquatic Life

The highly productive aquatic life provides the food resource utilized by birds at Lake Abert. The two primary food sources for birds are the alkali fly and brine shrimp. These species feed primarily on benthic algae (Conte and Conte 1988, Herbst and Bradley 1989).

The alkali fly is the most important food species for birds at the lake and it is normally the most common macroinvertabrate in Abert Lake (Herbst 1988). It feeds on benthic algae and detritus (Herbst 1990). Females deposit eggs on hard substrate such as rocks and mats of algae. In addition, larvae and pupae depend on attachment to hard substrate, such as rocks, for survival in their wave-washed shallow habitat (Herbst 1990). At Lake Abert rocky habitat occurs primarily on the eastern shore.

Comparison of brine shrimp, alkali flies, or other aquatic life between two different saline lakes must be made with care due to differences in water chemistry and species adaptations. However, Mono Lake in California has similar water chemistry to Lake Abert and species are similar. Therefore, work done at both locations are useful, I believe, in determining approximate salinity limits.

The salinity range of the alkali fly appears to be as high as 200 g/l of total dissolved solids (TDS) at Mono Lake, but larval survival is substantially reduced above 150 g/l (Herbst et al. 1988). Studies conducted by Herbst (1988) at both Mono Lake and Abert Lake indicated that the optimum levels of salinity for alkali fly production occurs between 30 and 80 g/l. Below 30 g/l there was a marked increase in number and abundance of other macro invertebrates which may have limited the alkali fly due to predation and competition. Above 80 g/l physiological stress began to limit alkali fly numbers. Patten et al. (1987) believes that alkali fly populations at Mono Lake would be greatly reduced above 130 g/l.

Therefore as lake levels are reduced at Lake Abert, alkali flies may suffer reductions both due to high salinity and the lack of hard substrate as the waters pull away from the eastern shore.

Brine shrimp have been studied at a number of locations; however, while similar, they may be different species. Much work has been done at Mono Lake on *Artemia monica* and some work has been done on *Artemia salina* at Lake Abert. Early work by Croghan (1958a, 1958b) indicates that adult brine shrimp can survive from 10 to 600% concentration of sea water (~3 g/l - 200 g/l). However, work by Dana and Lenz (1986) indicated that 133 g/l is probably the limit for survival of the species at Mono Lake and that optimum productivity probably occurred below 76 g/l. Patten et al. (1987) stated that brine shrimp were expected to decrease in abundance at Mono Lake at salinitys above 120 g/l and the decrease would be severe at above150 g/l.

Conte and Conte (1988) studied brine shrimp populations at Lake Abert in 1980 through 1982 when salinity ranged from 40 g/l to 80 g/l. They estimated a biomass of 6.6 million kg (14.5 million lb) and a commercial harvest of 0.05% of the shrimp biomass. The estimated use of shrimp by birds was 0.01% of the biomass. Since that time shrimp harvest has increased to 39,300 lb in 1990, and shrimp production has probably declined as the salinity has risen to approximately 115 g/l in October of 1991. Because the decline in shrimp biomass at current lake levels is not known, the present proportion of the biomass taken through commercial shrimp harvest and by birds cannot be determined.

Since benthic algae are the primary food source for brine shrimp and alkali flies, it is important to determine the range of salinitys that affect them. Herbst and Bradley (1989) studied benthic algaes in Mono and Abert Lakes. There were three major species of algae in Lake Abert: the diatom *Nitzschia frutulum*, the filamentous blue-green algae *Oscillatoria spp.*, and the filamentous green algae *Ctenocladus circinnatus*. The filamentous green and blue-green algaes were dominant at lower salinitys and diatoms were more common above 100 g/l. While algae was present at 150-200 g/l, data showed that the optimum tolerance range for algal productivity was 50-150 g/l at Mono Lake and 25-100 g/l at Lake Abert. Patten et al. (1987) believed that at Mono Lake productivity is likely to decrease more rapidly above 150 g/l.

While the review of the literature does not provide an exact salinity level that is absolutely critical for the species present, the following conclusions can be made:

1. The optimum salinity range for the current aquatic life in Lake Abert is probably from 30-80 g/l (corresponds to current lake levels of ~ 4,258 - 4,252 ft).
2. The critical salinity range (salinity at which productivity of the aquatic system is severely reduced) probably begins above 100-130 g/l (below a current water level of about 4,250 ft).

GEOCHEMISTRY

To understand the dynamics of the biological situation at Abert Lake, it is necessary to understand the changing chemistry of the lake with lake level and time.

The solute load of Lake Abert is made up primarily (96%) of sodium, carbonate, bicarbonate, and chloride. Potassium and sulfate make up another 3% (Van Denburgh 1975). The relative proportion of the constituents has not shown an appreciable change through time (Van Denburgh 1975).

The salinity of the lake varies with lake level (Fig. 3). The lake level in October 1991 was 4,250 feet above sea level and the salinity was about 115 g/l (or 115,000 ppm) of total dissolved solids (Herbst, pers. comm.), which puts the current salinity of the lake in the critical biological range.

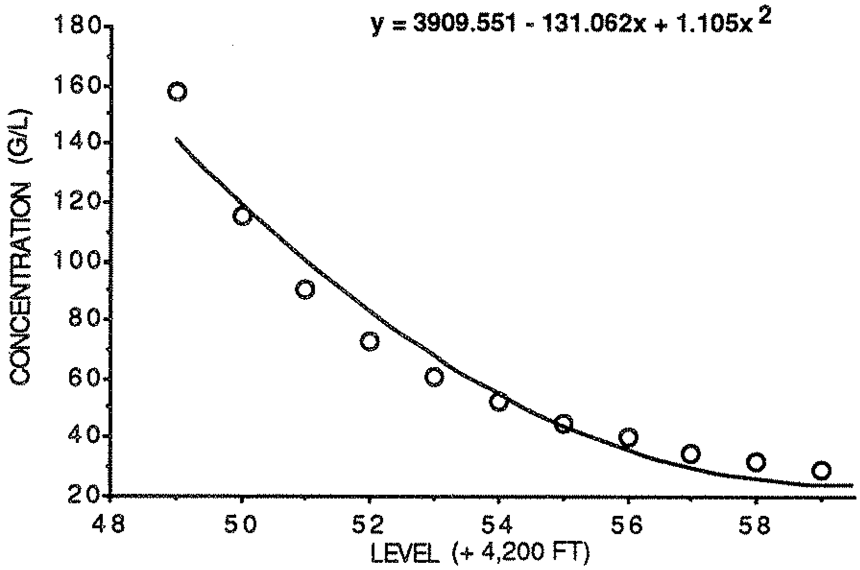

Fig. 3. Salinity of Lake Abert, Oregon vs. lake level, 1991. Data points are calculated from 1991 data (Table 2) and the curve is the regression line that fits the points.

While the present relationship between salinity and lake level is shown in Fig. 3, the solute load changes with time. When closed-basin, saline lakes dry up, they lose salt load due to precipitation of salts and removal of precipitate by wind (Van Denburgh 1975, p. C22). The last time this happened at Abert Lake was in 1937. However, much of the solute tonnage is regained during return to high levels and the salt load was up to 8 million tons by 1939 (Van Denburgh 1975, p. C23). The salt load in Lake Abert has continued to increase since 1937 and the current salt load is about 17.2 million tons, although the rate of increase has declined (Fig. 4). The source of the increasing salt load appears to be the upward diffusion of solutes from interstitial brines below the bottom of Lake Abert. The increase in solute load in the lake as a result of inflow from the Chewaucan River is negligible (Van Denburgh 1975).

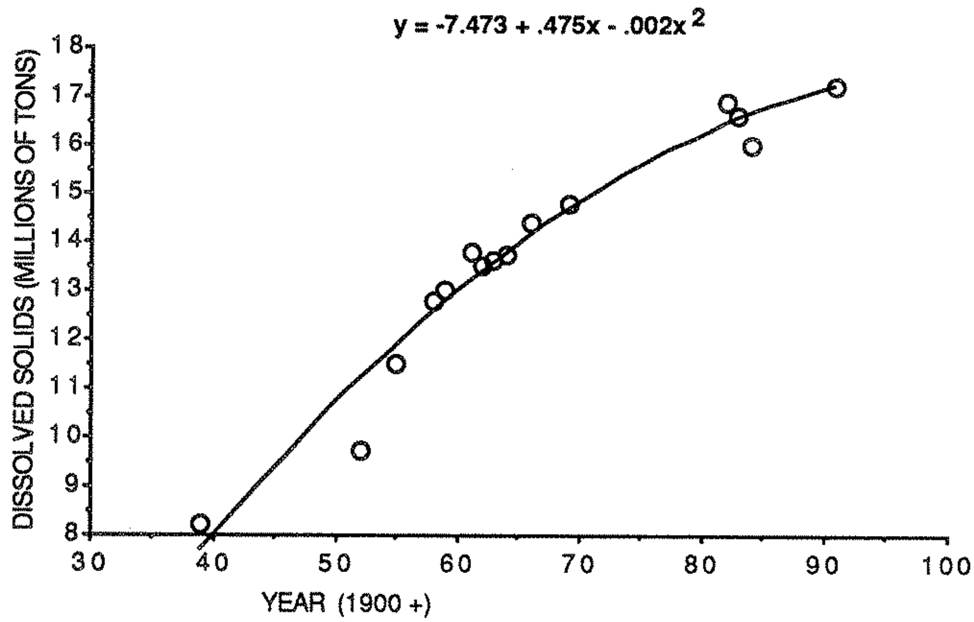

Fig. 4. Salt load vs. time at Lake Abert, Oregon. Data is from Van Denburgh (1975) for 1939 - 1969, Van Denburgh (pers. comm.) for 1982, Herbst (1988) for 1983, 1984, and Herbst (pers. comm.) for 1991.

This increasing salt load has the biological effect of increasing the lake level necessary to achieve both critical and optimum salinity conditions (Table 2). For example in 1938, when the salt load was about 8 million tons, a level of 4,248 feet was necessary to achieve 110 g/l (critical) and 74 g/l (optimum) was reached at 4,249 feet. By 1959, about 13 million tons of salt was dissolved in the lake and the critical level was 4,249 feet (120 g/l) and optimum was between 4,251 feet (68 g/l) and 4,256 feet (30 g/l). In 1991, with 17.2 million tons of salt, the critical level is below about 4,250 feet (115 g/l) and optimum is between about 4,252 feet (73 g/l) and 4,258 feet (32g/l).

Table 2. Relationships with lake level at Abert Lake, Oregon.

LEVEL (Ft above sea level)	AREA (acres)	AREA (sq. mi.)	VOLUME (ac-ft)	EVAPORATION (1000 ac-ft)	CONCENTRATION (g/l)							
Salt Load (millions of Tons)					21	20	19	18	17.2	15	13	8
4244		0.0	0									
4245	8000	12.5	4	26	>200	>200	>200	>200	>200	>200	>200	>200
4246	12400	19.4	15	40	>200	>200	>200	>200	>200	>200	>200	>200
4247	19100	29.8	31	62	>200	>200	>200	>200	>200	>200	>200	188
4248	24800	38.8	54	80	>200	>200	>200	>200	>200	>200	179	110
4249	28100	43.9	80	90	193	184	175	166	158	138	120	74
4250	30500	47.7	110	98	141	134	127	121	115	100	87	54
4251	32400	50.6	141	104	110	105	99	94	90	78	68	42
4252	33900	53.0	174	109	89	85	80	76	73	64	55	34
4253	35300	55.2	209	114	74	71	67	63	61	53	46	28
4254	36300	56.7	245	117	63	60	57	54	52	45	39	24
4255	37300	58.3	282	120	55	52	50	47	45	39	34	21
4256	38200	59.7	320	123	48	46	44	41	40	35	30	18
4257	39000	60.9	358	126	43	41	39	37	35	31	27	16
4258	39700	62.0	397	128	39	37	35	33	32	28	24	15
4259	40300	63.0	437	130	35	34	32	30	29	25	22	13
4260	40800	63.8	478	131	32	31	29	28	27	23	20	12
4261	41300	64.5	516	133	30	29	27	26	25	21	19	11
4262	41600	65.0	560	134	28	26	25	24	23	20	17	11

The only thing that can break the cycle of increasing salt load is the almost complete drying of the lake and removal of salt precipitates by the action of the wind (Van Denburgh 1975). While biological problems become precipitous for both aquatic and bird life at low levels as the lake is drying, the lake can quickly return to a productive state as it refills due to a much reduced salt load. The periodic drying of the lake serves to maintain long-term productivity of the lake and at lower lake levels due to the resulting lower salt load.

HYDROLOGY AND MODELING

Phillips and Van Denburgh (1971) described the hydrology of Lake Abert from 1916 through 1963. A model was developed based on data from 1951-62, when yearly lake level data were available, and used to determine the water balance of the lake for the entire 1916-1963 period. Van Denburgh (1975) updated this model for the 1916-1965 period, and had very similar results.

I used the same procedure to determine the annual inflow to Lake Abert from 1951 to 1990. A water balance (Water in = Water out) was used to calculate inflow each water year (October-September) as the change in the volume of the lake, plus the water evaporated, minus the volume of precipitation on the lake (see App. B for lake levels recorded since 1951 at Lake Abert, relationships necessary to calculate volume and surface areas as a function of lake level, and inflow calculations). Besides having more years with which to calculate inflows, another difference between my calculations and previous efforts was my use of rainfall records at Paisley instead of Valley Falls. This was necessary because the gauging station at Valley Falls was moved in 1965 to a location 3 miles south, resulting in a significantly higher average rainfall. Rainfall at Paisley was slightly lower than at Valley Falls before 1965 ($\bar{x}$ (1926-1964)) = 9.75 in., 12.33 in.; at Paisley and Valley Falls, respectively), and I believe may better reflect what was experienced at Lake Abert. Phillips and Van Denburgh (1971, p. B12) agreed that precipitation at Valley Falls may have been a little higher than at Lake Abert.

The calculated inflows to Lake Abert were found to be significantly correlated to annual precipitation ($p < 0.001$, $r = 0.691$) and flows measured at Paisley ($p < 0.001$, $r = 0.913$) (Fig. 5). Because calculated inflows had a higher correlation with flows at Paisley than with rainfall, that relationship was used to construct the model for the period of 1926 through 1990. The equation derived was very similar to those developed by Phillips and Van Denburgh (1971) and Van Denburgh (1975):

$I = 1.183P - 53{,}593$ (This study)
$I = 1.25P - 68{,}750$ (Phillips and Van Denburgh 1971)
$I = 1.187P - 44{,}000$ (Van Denburgh, personal comm.)
Where, I = Inflow in ac-ft,
P = Flow at Paisley in ac-ft.

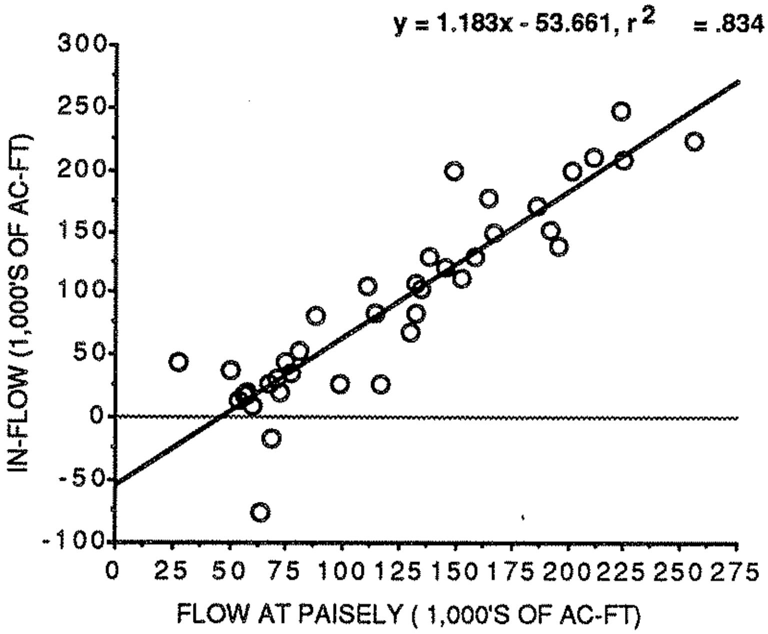

Fig. 5. In-flow to Lake Abert, Oregon vs. flow rates at Paisley, 1951 - 1990.

The slopes of the three regression lines are very similar. However, the intercepts are slightly different, possibly due to the fact that I was able to analyze 40 years of data versus only 12 and 13 years for the past two studies. As did Van Denburgh (1975, p. C7), I assumed that the flow was never less than 2,500 ac-ft due to ground-water flows.

The model was tested for accuracy by comparing lake levels predicted by the model to known lake levels (Fig. 6). The lake was thought to be dry in 1926, 1930, 1931, 1933, 1934, and 1937 (Phillips and Van Denburgh 1971, p. 89). This model was begun in 1926 and the level was assumed to be dry. Thereafter, the model showed the lake to be dry in 1931, 1933, and 1934, but not for 1930 and 1937. For the 39 years between 1951 and 1990, the average difference between measured and calculated lake levels was 0.12 feet. The maximum differences were 2.41 feet in 1961 and 2.80 feet in 1977, but these measurements were actually made during August and June of those years, respectively, while calculations were made on an October to September basis.

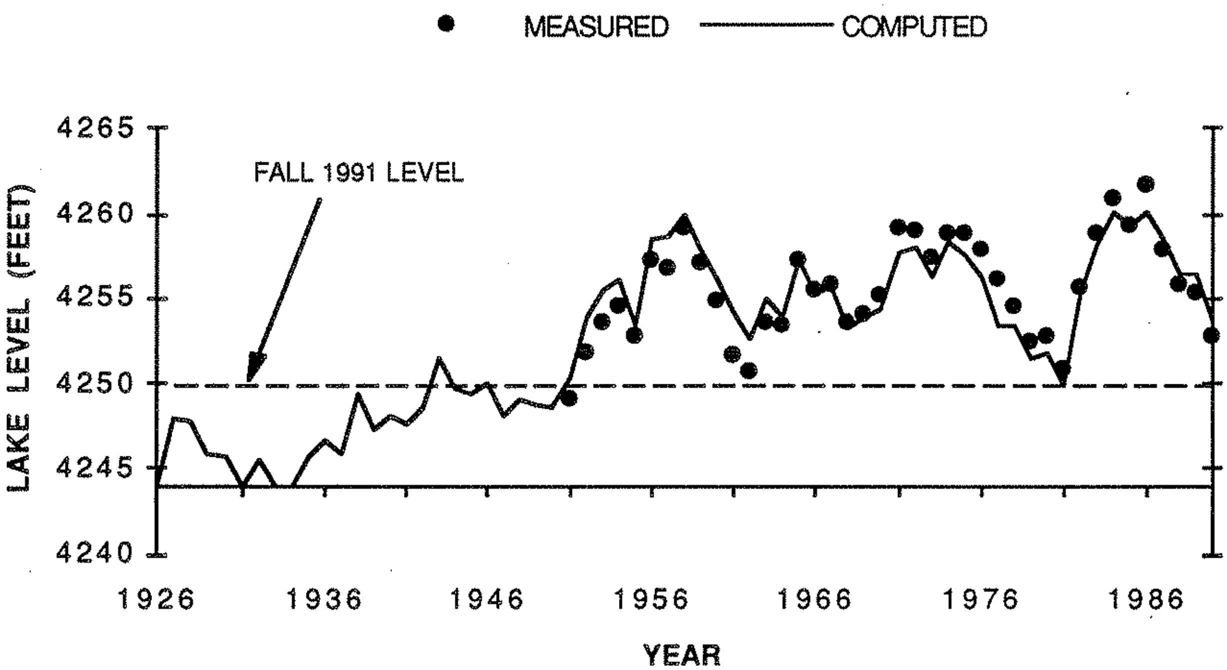

Fig. 6. Comparison of lake levels computed by the model and measured levels at Lake Abert, Oregon.

For the 1926-1990 period, the average precipitation at Paisley was 10.19 in. (Table 3). Average flow at Paisley was 107,376 ac-ft. The model indicates an average inflow to Lake Abert of 74,654 ac-ft (70% of the flow at Paisley). Average lake level was 4,252.46 feet, which corresponds to a volume of approximately 198,000 ac-ft and surface area of 54 square miles.

The current level of 4,250 feet is considered to be very low and is, relative to the 1951-1990 period. However, this level would be considered high for the 1920-1950 period (Fig. 6, Phillips and Van Denburgh 1971). For the last 64 years the lake has tended to fill in spurts, such as during the years 1951-54 (Fig. 6) when over 117,000 ac-ft flowed into the lake each year for 4 years (Table 3). Or in 1982-84 when 213,055 ac-ft flowed into Lake Abert in 1982, followed by two more years of over 166,000 ac-ft. In contrast, there have been several other periods when flows have been extremely low for several consecutive years, such as 1944-1950.

Table 3. Model of the water balance of Abert Lake, Oregon, 1926 - 1990.

EVAPORATION=		3.22 FT				EVAPORATION	
		FLOW AT				MINUS	NET
	PRECIP.	PAISELY	IN-FLOW	LAKE	VOLUME	PRECIPITATION	LOSS
YEAR	(IN)	(AC-FT)	(AC-FT)	LEVEL	(AC-FT)	(FT)	(AC-FT)
1926	4.03	32,450	2,500	4244.0	0	2.88	0
1927	12.43	126,400	95,938	4248.0	68,491	2.18	27,447
1928	7.86	94,520	58,224	4247.7	61,719	2.57	64,997
1929	5.25	44,240	2,500	4245.9	15,098	2.78	49,121
1930	9.46	58,230	15,293	4245.7	11,085	2.43	19,306
1931	4.41	24,700	2,500	4244.0	0	2.85	21,255
1932	8.01	74,210	34,198	4245.6	7,204	2.55	26,993
1933	6.26	55,100	11,591	4244.0	0	2.70	27,865
1934	8.29	40,170	2,500	4244.0	0	2.53	16,428
1935	7.24	76,230	36,587	4245.8	12,540	2.62	24,047
1936	9.13	97,340	61,560	4246.7	34,312	2.46	39,789
1937	7.67	62,810	20,711	4245.9	14,414	2.58	40,609
1938	10.56	161,200	137,107	4249.3	105,042	2.34	46,479
1939	5.83	54,850	11,295	4247.3	49,922	2.73	66,415
1940	12.54	101,800	66,837	4248.1	72,855	2.18	43,904
1941	11.03	71,700	31,228	4247.6	59,264	2.30	44,819
1942	9.57	110,800	77,484	4248.5	82,415	2.42	54,332
1943	11.33	170,900	148,582	4251.4	165,059	2.28	65,938
1944	11.26	61,720	19,422	4249.7	114,746	2.28	69,736
1945	7.73	96,500	60,567	4249.4	105,613	2.58	69,699
1946	9.80	114,200	81,506	4250.0	122,238	2.40	64,881
1947	8.16	57,360	14,264	4248.2	73,544	2.54	62,959
1948	13.86	102,900	68,138	4249.0	95,454	2.07	46,228
1949	10.04	88,660	51,292	4248.7	88,855	2.38	57,891
1950	5.88	98,510	62,945	4248.5	82,761	2.73	69,038
1951	8.53	144,800	117,706	4250.3	132,632	2.51	67,834
1952	13.77	196,400	178,748	4253.9	242,190	2.07	69,191
1953	13.01	157,900	133,203	4255.4	292,628	2.14	82,764
1954	10.82	145,400	118,415	4256.1	317,898	2.32	93,146
1955	7.54	51,100	6,859	4253.4	224,482	2.59	100,295
1956	19.48	255,900	249,137	4258.4	411,312	1.60	62,287
1957	12.49	130,300	100,552	4258.7	422,363	2.18	89,501
1958	15.04	164,500	141,011	4260.0	482,768	1.97	80,606
1959	6.82	58,040	15,069	4257.9	388,993	2.65	108,844
1960	7.47	72,150	31,761	4256.0	315,197	2.60	105,557
1961	9.61	67,650	26,437	4254.1	248,170	2.42	93,464
1962	9.84	74,740	34,825	4252.5	197,193	2.40	85,802
1963	18.34	167,000	143,968	4255.0	279,896	1.69	61,265
1964	9.71	87,960	50,464	4253.8	237,739	2.41	92,620
1965	16.47	210,500	195,429	4257.2	359,857	1.85	73,311
1966	8.51	70,920	30,306	4255.3	288,669	2.51	101,493
1967	11.22	131,800	102,327	4255.6	300,030	2.29	90,966
1968	8.20	56,940	13,767	4253.2	217,524	2.54	96,274
1969	10.95	134,600	105,639	4253.8	238,734	2.31	84,428
1970	9.63	137,500	109,070	4254.4	256,931	2.42	90,873
1971	11.76	223,100	210,335	4257.6	378,163	2.24	89,103
1972	5.64	151,700	125,868	4258.0	390,881	2.75	113,150
1973	7.46	76,880	37,356	4256.2	322,544	2.60	105,694
1974	11.91	191,900	173,425	4258.3	405,411	2.23	90,558
1975	7.89	110,100	76,656	4257.6	376,579	2.56	105,488
1976	10.89	79,980	41,024	4256.3	323,666	2.31	93,938
1977	6.72	28,420	2,500	4253.3	223,662	2.66	102,504
1978	11.63	116,000	83,635	4253.4	225,866	2.25	81,432
1979	7.69	66,860	25,503	4251.4	163,502	2.58	87,867
1980	12.75	113,900	81,151	4251.8	175,162	2.16	69,491
1981	10.43	58,360	15,447	4249.9	120,397	2.35	70,211
1982	22.79	225,400	213,055	4255.3	289,495	1.32	43,958
1983	16.86	201,600	184,900	4258.2	402,115	1.82	72,281
1984	15.19	186,100	186,564	4260.1	488,738	1.95	79,941
1985	10.10	97,730	62,022	4259.4	453,779	2.38	96,981
1986	12.48	148,500	122,083	4260.0	486,750	2.18	89,111
1987	10.55	63,890	21,989	4258.5	412,717	2.34	96,022
1988	10.08	59,940	17,316	4256.5	332,753	2.38	97,280
1989	8.00	131,600	102,090	4256.5	331,241	2.55	103,602
1990	6.47	53,850	10,112	4253.8	236,942	2.68	104,411
MEAN	10.19	107,376	74,654	4252.5			

Note: For modeling purposes numbers are used for calculation at the accuracy shown, however inflow, volume, and net loss are accurate to approximately 100 ac-ft.

IMPACTS OF FURTHER DEVELOPMENT

Currently, commercial activities associated with Lake Abert include water withdrawal from the Chewaucan River for irrigation of pasture land and a commercial shrimp fishery on the lake. Further development could take many forms. At least two major impacts of further development should be considered in regard to the health of the Lake Abert ecosystem: harassment to wildlife and water withdrawal. Harassment to wildlife may be a very important consideration for those developments proposed near or on the lake. This is not only important for migrant bird species, but especially for nesting species such as the snowy plover. Harassment has shown to be quite detrimental to coastal populations of snowy plovers which have been in severe decline.

Withdrawal of too much water could cause significantly lower lake levels and more dry years than normally would be experienced. This may result in higher average salinity levels, more frequent disruption to aquatic life, and even failure of the ecosystem. However, withdrawals at high lake levels may have the beneficial effect of reducing the frequency of extreme high levels. This would serve to maintain the lake in the optimum salinity range more often and reduce the gain in salt tonnage caused when high waters redissolve salts precipitated on the higher beaches.

The model developed herein is useful in determining the effects of any project that would withdraw water from the system. The amount of water to be withdrawn can be entered into the model from 1926 through 1991 and the resulting lake levels compared to those levels without the project. The following comparisons will be made to evaluate the significance of the effects:

1. The maximum level for the 64-year period.
2. The number of dry or nearly dry (<4,000 ac-ft) years.
3. The number of years, lake levels are below the critical level (4,250 ft, 115 g/l TDS).
4. The number of years, lake levels are within the optimum range (4,252 ft, 73 g/l - 4,258 ft, 32 g/l).

The Oregon Department of Fish and Wildlife desires no new projects that cause an increase in the number of dry years or a significant increase in the number of years the lake is below critical levels or out of the optimum salinity range. Therefore, significance is defined by any increase in the number of dry or nearly dry years or by an increase of 5% in the number of years that were below critical levels or out of the optimum range. For example, during the 64-year period between 1926 and 1990, there were 25 years below the critical level of 4,250 feet and 27 years within the optimum range of 4,252 to 4,258 feet. If a certain water withdrawal rate would have caused the number of years that lake levels were below the critical level to increase by two, the change in that criteria would be said to be significant because it is more than 0.05 x 25 = 1.25 years.

When different withdrawal rates were analyzed in this manner, it was found that an annual withdrawal of at least 4,700 ac-ft was necessary to produce a significant increase in the number of years the lake would have been below critical (from 25 years without the withdrawal to 27 years with it). There would also have been one more dry or nearly dry year (1932) and the maximum lake level would have been reduced from 4,260.08 feet to 4,259.21 feet. The number of years within the optimum range (4,252 - 4,258 ft) would have been the same (27 years). It would be possible to withdraw 4,400 ac-ft without having an effect on the number of dry years but would have an insignificant (as defined) increase of 1 in the number of years below the critical level (4,250 feet). There would be an increase of 2 in the number of years within the optimum range.

A withdrawal of 2,900 ac-ft would not affect the number of dry years or years below the critical level. At that withdrawal rate there would be an increase of 4 in the number of years within the optimum range.

As described previously, the salt load of Lake Abert will increase through time unless the lake becomes dry. Therefore, it may be necessary to periodically reevaluate the effects of any particular withdrawal rate as the salt load increases or is lost. To do that, critical and optimum lake levels must be determined by sampling Lake Abert water and determining dissolved solids concentration. The following description of sampling method by A. S. Van Denburgh (pers. comm.) should be followed:

> The sample should be obtained at least a foot offshore, from water at least half a foot deep, at the official lake-level gage located midway along the east shore. Concurrently, a lake-level measurement should be made. To help ensure a homogenous lake-water body, these activities should take place in about September, when inflow to the lake is minimal. The lake must be calm or almost calm at the time of measurement (with only a gentle breeze, at the most: early morning generally is the calmest). If the lake and immediately adjacent areas are likely to have received more than light precipitation recently, the sampling and lake-level measurement should be deferred until at

least 2 weeks after the storm, to allow rehomogenization of the lake-water body.

Total dissolved solids (TDS) should be determined by a lab using precise drying and weighing procedures or by accurate specific gravity determination and calculation of TDS from a relationship between TDS and specific gravity of Abert Lake water (Herbst 1988, p 152). Table 2 can be used to determine salt load and critical and optimum lake levels. The effects of any withdrawal rate can then be evaluated using the model and criteria described above.

River's End Ranch Project

The River's End Ranch is located along the Chewaucan River about a quarter of a mile from the mouth at Lake Abert. The proposed project would increase the height of the dam across the river from 4,277 to 4,280 feet elevation. This would result in the potential of having a 650-acre, freshwater marsh which would directly benefit waterfowl and water birds (including white-faced ibis (*Plegadis chihi*), herons, and egrets). A net increase in wetland, marsh habitat in southeastern Oregon would be realized if the freshwater marsh could be created without a significant, negative impact to the Lake Abert ecosystem. Indirect benefits of the marsh might be realized by a nearby nesting pair of bald eagles (*Haliaeetus leucocephalus*), wintering bald eagles, and peregrine falcons (*Falco pereginus*). Bald eagles are classified federally as threatened in Oregon and peregrines are endangered. There is currently a peregrine reintroduction program in the Warner Basin to the east of Lake Abert and at Summer Lake to the west, which has resulted in increased numbers of peregrine sightings in the area. Abert rim offers good nesting habitat. With the rich food source that would be provided by the marsh during the peregrine nesting season, nesting by peregrines on Abert rim would be encouraged.

In addition to the marsh, a recently approved water right would permit pumping water from the pool behind the dam for irrigation. To evaluate the effects on Lake Abert from this project, it is necessary to define the new water to be used on an annual basis.

The new water used is the new appropriation for irrigation plus the evaporation on the 650 acre marsh minus the old water right for irrigation and evaporation on the 360 acre pond (created by the existing 4,277 ft elevation dam). According to the Oregon Water Resources Department, the old water right, which has existed since 1927, is for 527.12 ac-ft/yr.

The new right for irrigation is 3,875.6 ac-ft/yr. The evaporative water loss from the 650-ac freshwater marsh, if kept full all the time, would be 2,184 ac-ft/yr (using 3.36 ft/yr loss for freshwater; Phillips and Van Denburgh 1971, p. B15). The present evaporative water loss from the 360-acre pool is estimated to be 625 ac-ft, assuming a current operation that has a full pool, April throuth June; a half full pool, July and August; and an empty pool, September through March (evaporation rates were determined from Phillips and Van Denburgh 1971 and Van Denburgh 1975 [App. F.]). Therefore, the maximum <u>new</u> water to be used by this project would be 3,875.6 + 2,184 - 527.12 - 625 ~ 4,908 ac-ft/yr.

The effects of the full project (Fig. 7) are relatively slight but visible and significant, based on criteria defined above. The calculated, average flow rate into Lake Abert, 1926-1990, would have been reduced from about 74,654 to 70,132 ac-ft (6.1% reduction). The model-generated, maximum level would have been reduced from 4,260.08 to 4,259.17 feet. There would have been no more dry years but one more near dry year. The number of additional years with levels below the critical level of 4,250 feet would have been two. The number of years with levels less than the lower, optimum limit (4,252 ft, 73 g/l) would have increased from 29 to 34. This would have been offset by an increase of 5 years that were above the upper optimum limit (4,258, 32 g/l) that would have been within that limit due to the project, for a net effect of no change in years with lake levels at optimum (27 years in both cases). Therefore, out of the 4 criteria that were analyzed, 2 had a significant increase, the number of dry years and the number of years below critical.

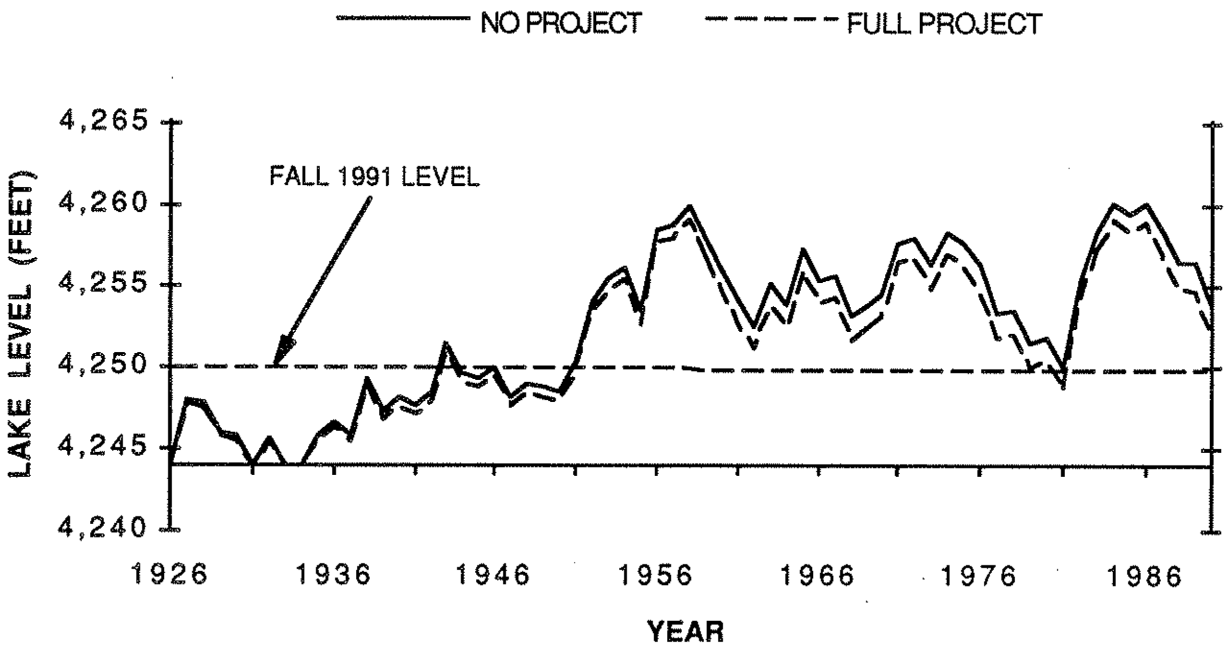

Fig. 7. Comparison of no project to the full River's End Project at Lake Abert, Oregon.

Several other operational alternatives which provide for less than the full project were evaluated and results are summarized in Table 4. One alternative (Table 4, option 8) provides for only the creation of the 650-acre marsh. If the marsh were drawn down each June to 360 acres (dam level of 4,277 ft) and refilled during the winter, the total evaporative loss would be about 1,626 ac-ft (using monthly evaporation rates given by Phillips and Van Denburgh 1971 and Van Denburgh 1975 [App. F.]). This represents a new water use of 1,626 - 527 - 625 ~ 474 ac-ft/year. The average flow rate into the lake would be reduced by 0.6%. The maximum lake level would be reduced to 4,259.98 ft. There would be no more dry years, no more years below the critical level, and the same number of years within the optimum range (4,252 - 4,258 ft). A July draw-down date (option 7) may be more beneficial to waterbirds because of nesting and brood rearing considerations, but would use more new water (632 ac-ft/year). Results would be almost identical. The average flow rate would be reduced by 0.8% with a maximum lake level of 4,259.95 ft. There would be no more dry years, years below the critical level, or out of the optimum range. Therefore the impact to Lake Abert of both options that only provide for creation of the 650-acre marsh would be negligible.

The full project but with a June draw-down (option 5), would result in a new water use of 3,875.6 + 1,626 - 527.12 - 625 ~ 4,350 ac-ft/yr. No significant impact would result; however, there would be 1 more year below the critical level. There would be 2 more years within the optimum range. The full project with a July draw-down (option 3) would result in a new withdrawal of ~ 4,508 ac-ft/yr, 1 more nearly dry year, 1 more year below critical, and 1 more year within the optimum range (Table 4.). The yearly withdrawal rate would have to be as low as 2,900 ac-ft (option 6) before no more years below critical would be seen. This alternative would provide the benefit of 2 more years within the optimum range.

Table 4. Summary of effects of different withdrawal rates under current (1991) conditions (17.2 million tons of salt) on Lake Abert, Oregon, 1926 - 1990.

		Criteria				
Water Withdrawal & Operational Options	Average Withdrawal (ac-ft/% Decrease in Flow)	Maximum Level (ft)	#Dry Years*	#Years Below Critical (4,250 ft.)	#Years Within Optimum (4,252 - 4,258 ft)	# Years of Maximum Irrigation
No new projects	0 / 0	4,260.1	4	25	27	0
Continuous Withdrawal						
1. 10,000 ac-ft	10,000/12.1	4,258.4	8 **	29 **	25 **	64
2. 4,908 ac-ft (Full River's End Project)	4,908/6.1	4,259.2	5 **	27 **	27	64
3. 4,508 ac-ft (Full irrigation with marsh draw-down during July)	4,508/5.6	4,259.2	5 **	26	28	64
4. 4,400 ac-ft	4,400/5.4	4,259.3	4	26	29	0
5. 4,350 ac-ft (Full irrigation with marsh draw-down during June)	4,350/5.4	4,259.3	4	26	29	64
6. 2,900 ac-ft	2,900/3.6	4,259.5	4	25	29	0
7. Marsh only (July draw-down)	632/0.8	4,260.0	4	25	27	0
8 Marsh only (June draw-down)	474/0.6	4,260.0	4	25	27	0

* Less than 4,000 ac-ft

** Significant, adverse impact

While the full project with a June draw-down (option 5) could now be accommodated without a significant adverse impact and 2,900 ac-ft/yr of new water could be used without any noticeable affect, I wondered what affect these operations would have in the future if the lake continued to gain salt at the rate described by Fig. 4. It can be seen that

20 million tons or salt are needed to change the critical level from 4,250 to 4,251 feet and the optimum range from 4,252 - 4,258 to 4,252 - 4,260 feet (Table 2). Using the equation shown in Fig. 4., 20 million tons of salt would be reached in the year 2014. No withdrawal under the conditions of 20 million tons of dissolved salt would result in 26 years below critical and 34 years within optimum (Table 5). All the irrigation alternatives thus far discussed would cause significant adverse impacts. The withdrawal rate would have to be lowered to 1,100 ac-ft/yr before no change could be detected. This alternative (Table 5, option 6) would result in an increase of 2 years within the optimum range. However, a higher water use could be allowed during those years when lake levels are above critical (4,251 ft) without producing a significant, adverse impact. If enough new water (632 ac-ft) was withdrawn to maintain the 650 acre marsh each year with a July draw-down, and 2,900 ac-ft/yr was allowed when the lake level was 4,251 feet or above (Table 5, option 9), there would be no significant impacts. However, there would be 1 more year below critical which would be somewhat offset by 1 more year within the optimum range (Table 6). Under this alternative, the marsh would be maintained each year and when lake levels are above 4,251 feet, 2,900 - 632 = 2,268 ac-ft/yr of new water would be available for irrigation.

Table 5. Summary of effects of different withdrawal rates under future (~2014) conditions (20 million tons of salt) on Lake Abert, Oregon, 1926 - 1990.

		Criteria				
Water Withdrawal & Operational Options	Average Withdrawal (ac-ft/% Decrease in Flow)	Maximum Level (ft)	#Dry Years*	#Years Below Critical (4,251 ft.)	#Years Within Optimum (4,252 - 4,260 ft)	# Years of Maximum Irrigation
No new projects	0/0	4,260.1	4	26	34	0
Continuous Withdrawal						
1. 4,908 ac-ft	4,908/6.1	4,259.2	5**	29**	31**	64
(Full River's End Project)						
2. 4,508 ac-ft	4,508/5.6	4,259.2	5**	29**	32**	64
(Full irrigation with marsh draw-down during July)						
3. 4,400 ac-ft	4,400/5.4	4,259.3	4	28**	33	0
4. 4,350 ac-ft	4,350/5.4	4,259.3	4	28**	33	64
(Full irrigation with marsh draw-down during June)						
5. 2,900 ac-ft	2,900/3.6	4,259.5	4	28**	35	0
6. 1,100 ac-ft	1,100/1.4	4,259.9	4	26	36	0
7. Marsh only (July draw-down)	632/0.8	4,260.0	4	26	36	0
8 Marsh only (June draw-down)	474/0.6	4,260.0	4	26	36	0
Withdrawal Rate Dictated by Lake Level						
July draw-down of the marsh and:						
9. 4,251 Cutoff	1,958/2.5	4,259.6	4	27	35	0
(with 632 ac-ft minimum & 2,900 ac-ft maximum)						
	10					
10. 4,251 Cutoff	1,033/1.3	4,259.8	4	26	36	0
(with 632 ac-ft minimum & 1,300 ac-ft maximum)						

* Less than 4,000 ac-ft

** Significant, adverse impact

Table 6. Water balance at Abert Lake, Oregon with a new withdrawal of 632 ac-ft when below a lake level of 4,251 ft in elevation and 2,900 ac-ft when above.

EVAPORATION=		3.22 FT					EVAPORATION			
YEAR	PRECIP. (IN)	FLOW AT PAISELY (AC-FT)	LOSS (AC-FT)	IN-FLOW (AC-FT)	LAKE LEVEL	VOLUME (AC-FT)	MINUS PRECIPITATION (FT)	INFLOW LEVEL	LAKE AREA (AC)	NET LOSS (AC-FT)
1926	4.03	32,450	632	2,500	4,244.00	0	2.88		0	0
1927	12.43	126,400	632	95,306	4,247.96	67,946	2.18	48.98	25,054	27,361
1928	7.86	94,520	632	57,592	4,247.69	60,816	2.57	49.09	25,412	64,722
1929	5.25	44,240	632	2,500	4,245.87	14,553	2.78	45.22	9,637	48,762
1930	9.46	58,230	632	14,661	4,245.69	10,268	2.43	44.47	5,946	18,947
1931	4.41	24,700	632	2,500	4,244.00	0	2.85	45.02	8,693	20,879
1932	8.01	74,210	632	33,566	4,245.55	6,749	2.55	45.79	12,319	26,816
1933	6.26	55,100	632	10,959	4,244.00	0	2.70	44.90	8,104	27,553
1934	8.29	40,170	632	2,500	4,244.00	0	2.53	44.23	4,771	16,280
1935	7.24	76,230	632	35,955	4,245.76	11,934	2.62	46.07	13,590	24,022
1936	9.13	97,340	632	60,926	4,246.62	33,414	2.46	47.23	18,493	39,449
1937	7.67	62,810	632	20,079	4,245.82	13,411	2.58	45.85	12,569	40,083
1938	10.56	161,200	632	136,475	4,249.30	103,812	2.34	49.51	26,810	46,073
1939	5.83	54,850	632	10,663	4,247.21	48,521	2.73	47.98	21,434	65,954
1940	12.54	101,800	632	66,205	4,248.09	71,317	2.18	47.22	18,482	43,409
1941	11.03	71,700	632	30,596	4,247.57	57,666	2.30	47.60	19,980	44,247
1942	9.57	110,800	632	76,852	4,248.44	80,748	2.42	48.80	24,412	53,770
1943	11.33	170,900	2,900	145,682	4,251.31	161,100	2.28	51.70	32,999	65,330
1944	11.26	61,720	632	18,790	4,249.56	111,032	2.28	49.68	27,358	68,858
1945	7.73	96,500	632	59,935	4,249.24	102,382	2.58	49.23	25,894	68,584
1946	9.80	114,200	632	80,874	4,249.85	119,250	2.40	49.69	27,371	64,007
1947	8.16	57,360	632	13,632	4,248.07	70,813	2.54	47.99	21,502	62,069
1948	13.86	102,900	632	67,506	4,248.89	92,846	2.07	48.27	22,540	45,474
1949	10.04	88,660	632	50,660	4,248.65	86,384	2.38	49.08	25,394	57,121
1950	5.88	98,510	632	62,313	4,248.43	80,482	2.73	48.85	24,580	68,215
1951	8.53	144,800	632	117,074	4,250.25	130,368	2.51	50.21	28,974	67,188
1952	13.77	196,400	2,900	175,848	4,253.78	237,485	2.07	53.82	37,353	68,731
1953	13.01	157,900	2,900	130,303	4,255.19	285,477	2.14	55.58	39,724	82,311
1954	10.82	145,400	2,900	115,515	4,255.83	308,313	2.32	56.12	40,229	92,679
1955	7.54	51,100	2,900	3,959	4,253.02	213,123	2.59	53.22	36,284	99,149
1956	19.48	255,900	2,900	246,237	4,258.12	397,718	1.60	57.20	40,930	61,642
1957	12.49	130,300	2,900	97,652	4,258.31	405,919	2.18	58.94	41,167	89,451
1958	15.04	164,500	2,900	138,111	4,259.57	463,182	1.97	59.39	41,051	80,847
1959	6.82	58,040	2,900	12,169	4,257.36	366,326	2.65	58.04	41,180	109,025
1960	7.47	72,150	2,900	28,861	4,255.34	290,633	2.60	55.21	39,323	104,554
1961	9.61	67,650	2,900	23,537	4,253.34	223,457	2.42	52.91	35,672	90,713
1962	9.84	74,740	2,900	31,925	4,251.74	173,776	2.40	51.43	32,333	81,605
1963	18.34	167,000	2,900	141,068	4,254.34	256,158	1.69	53.65	37,051	58,687
1964	9.71	87,960	2,900	47,564	4,253.04	213,674	2.41	54.01	37,651	90,048
1965	16.47	210,500	2,900	192,529	4,256.53	334,314	1.85	56.05	40,171	71,888
1966	8.51	70,920	2,900	27,406	4,254.51	261,771	2.51	55.32	39,443	99,949
1967	11.22	131,800	2,900	99,427	4,254.81	272,278	2.29	54.49	38,386	88,920
1968	8.20	56,940	2,900	10,867	4,252.29	190,526	2.54-	52.41	34,638	92,619
1969	10.95	134,600	2,900	102,739	4,253.01	212,824	2.31	52.62	35,083	80,441
1970	9.63	137,500	2,900	106,170	4,253.59	231,466	2.42	53.81	37,329	87,527
1971	11.76	223,100	2,900	207,435	4,256.98	351,375	2.24	56.98	40,820	87,526
1972	5.64	151,700	2,900	122,968	4,257.24	361,639	2.75	57.86	41,147	112,704
1973	7.46	76,880	2,900	34,456	4,255.37	291,672	2.60	55.14	39,230	104,423
1974	11.91	191,900	2,900	170,525	4,257.52	372,950	2.23	57.14	40,901	89,246
1975	7.89	110,100	2,900	73,756	4,256.73	341,901	2.56	57.13	40,898	104,805
1976	10.89	79,980	2,900	38,124	4,255.26	287,713	2.31	54.90	38,939	92,311
1977	6.72	28,420	2,900	2,500	4,252.34	192,013	2.66	52.53	34,895	98,200
1978	11.63	116,000	2,900	80,735	4,252.48	196,167	2.25	51.76	33,152	76,582
1979	7.69	66,860	632	24,871	4,250.55	138,959	2.58	50.74	30,495	82,079
1980	12.75	113,900	2,900	78,251	4,251.02	152,412	2.16	50.42	29,572	64,798
1981	10.43	58,360	632	14,815	4,249.23	101,985	2.35	49.24	25,933	65,242
1982	22.79	225,400	2,900	210,155	4,254.75	270,089	1.32	54.06	37,741	42,052
1983	16.86	201,600	2,900	182,000	4,257.70	380,441	1.82	58.40	41,210	71,648
1984	15.19	186,100	2,900	163,664	4,259.58	463,876	1.95	59.76	40,901	80,229
1985	10.10	97,730	2,900	59,122	4,258.75	425,455	2.38	59.14	41,125	97,543
1986	12.48	148,500	2,900	119,183	4,259.40	455,013	2.18	59.23	41,100	89,626
1987	10.55	63,890	2,900	19,089	4,257.84	377,853	2.34	57.80	41,134	96,249
1988	10.08	59,940	2,900	14,416	4,255.50	296,154	2.38	55.49	39,634	96,115
1989	8.00	131,600	2,900	99,190	4,255.44	294,024	2.55	55.58	39,729	101,320
1990	6.47	53,850	2,900	7,212	4,252.63	201,024	2.88	52.60	35,033	100,212
MEAN	10.19	107,376	1,958	72,779	4,252.03					

Note: For modeling purposes numbers are used for calculation to the accuracy shown, however inflow, volume, and net loss are accurate to approximately 100 ac-ft.

CONCLUSIONS

Lake Abert provides significant and unique habitat for several bird species, including an estimated 1,664,000 annual use-days for shorebirds, and is one of the most important nesting, brood rearing, and staging areas for the state threatened snowy plover. The bird life at the lake depends on a healthy aquatic life, particularly alkali flies, brine shrimp, and algae, which in turn depends primarily on lake waters which are below the critical salinity range that begins at about 100 - 130 g/l. The lake level measured during fall 1991 was 4,250 feet in elevation, which corresponds to a salinity of 115 g/l. Levels below 4,250 feet will produce even higher salinitys. However if the lake dries, a loss of some of the 17.2 million tons of salt will result, producing an optimum salinity range at lower lake levels as the lake later refills.

The analysis performed herein indicates that a diversion rate of up to 4,400 ac-ft of new water could be withdrawn without significant, adverse effects on the Lake Abert ecosystem at the current salt load of 17.2 million tons. A future salt load of 20 million tons would be achieved by the year 2014 if the salt load continues to increase as projected and the lake does not go dry. Under the projected conditions, enough water could be withdrawn to reestablish part of the historic Chewaucan Marsh and provide some new water for irrigation without adverse impacts on the Lake Abert ecosystem (Table 5). For the River's End Project, the alternative (Table 5, option 9) that would allow for the most irrigation without causing significant, adverse impacts to Lake Abert is 2,900 ac-ft/yr of new water when the lake level is above 4,251 feet and 632 ac-ft/yr (enough for the marsh with at July draw-down) when below.

RECOMMENDATIONS

The following recommendations are made based on the previous discussion and analysis.

1. Studies of aquatic life should be made at high salinity levels to compliment those made in the early 1980s at low to medium salinity levels.
2. No projects should be approved that would cause unacceptable levels of harassment to wildlife or increase water appropriations so that significant, adverse effects are created at Lake Abert. New appropriations should be analyzed as an addition to those resulting from the Rivers End Project.
3. For the River's End project, an agreement should be signed between the Landowner, Oregon Department of Fish and Wildlife, and the U.S. Fish and Wildlife Service that stipulates the following:
    a. An in-line totalizing flow meter shall be installed by the landowner on the irrigation pump for the project. It shall be in proper calibration and yearly flows shall be reported to the Water Resources Department.
    b. The 650-acre marsh shall be drawn down to 360 acres between July 1 and September 1.
    c. Irrigation water (no more than 2,268 ac-ft/yr) can only be pumped from the created pool on those years that lake levels are greater than 4,251 feet as measured by the Water Resource Department watermaster. On years when levels are below 4,251 feet, only 632 ac-ft per year can be used to maintain the marsh.
    d. Failure to comply with 3. d above will be grounds to cancel the water right.
    e. The operation of this project will be reevaluated if the lake goes dry, or every 5 years, and may be amended as necessary to protect the integrity of the Lake Abert ecosystem.
4. Because the salt load in the lake changes with time, samples of the lake should be taken during September at the lake level gauge and the lake level recorded every 2 years. Samples should be analyzed for the determination of Total Dissolved Solids.

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APPENDICES

Appendix A. Southeastern Oregon shorebird census, fall 1991.

SPECIES	SUMMER LAKE	MALHEUR REFUGE	ABERT LAKE	WARNER BASIN	TOTAL
Black-bellied Plover	4	1			5
Snowy Plover	8	14	99		121
Semi-palmated Plover		2	6		8
Killdeer	4	936	59	27	1,026
Black-necked Stilt	213	1,338	55	6	1,612
American Avocet	14,830	2,482	6,217	20	23,549
Greater Yellowlegs	20	52	2		74
Lesser Yellowlegs	13	134	6	1	154
Yellowlegs ssp.	36		3		39
Solitary Sandpiper		4			4
Willet	5	5	4	3	17
Spotted Sandpiper	9	153	18	1	181
Long-billed Curlew		46			46
Marbled Godwit	3	6			9
Ruddy Turnstone	1		4		5
Sanderling					0
Western Sandpiper	40	3,624	3,748	1	7,413
Least Sandpiper		86	224	15	325
Least/Western Sandpiper	4,029	5,224	1,448		10,701
(Ratio)	30%	4%	10%		
Baird's Sandpiper	3	95	2		100
Pectoral Sandpiper	7	1	1		9
Stilt Sandpiper					0
Dunlin	25	3			28
Dowitcher	1,464	2,362	6		3,832
Common Snipe					0
Wilson's Phalarope	348	271	1,343		1,962
Red-necked Phalarope	20	823	4,615		5,458
Phalarope spp.			2,550	6	2,556
Total	21,082	17,662	20,410	80	59,234
Great Blue Heron	19	245	1		265
Great Egret	76	92		6	174
Snowy Egret	2	38			40
Cattle Egret				2	2
Black- crowned Night Heron	4	44			48
White Pelican	69	4,856		22	4,947
Franklin's Gull		55			55
Ring-billed Gull	1,079	425	2,370	130	4,004
California Gull	58	29	260	1	348
Bonaparte's Gull.		14			14
Herring Gull					0
Gull spp.	606	44			650
Western Grebe		2			2
Pied-billed Grebe					0
Eared Grebe			1,850		1,850
Caspian Tern	2	180			182
Forester's Tern		297			297
Black Tern		3			3
Double-crested Cormorant	42		1		43
Sandhill Crane	10			17	27
White-faced Ibis	197	15	32	2	246
American Bittern	1				1
Total	2,165	6,339	4,514	180	13,198

Appendix B. In-flow calculation for Lake Abert, Oregon.

EVAPORATION= 3.22 FT

YEAR	PRECIP. (IN)*	LAKE LEVEL**	LAKE VOLUME (AC-FT)	EVAPORATION MINUS PRECIPITATION (FT)***	LAKE AREA (AC)	NET LOSS (AC-FT)****	IN-FLOW (AC-FT)
1951	8.53	4,249.10	92,438	2.51	25,449		
1952	13.77	4,251.86	170,778	2.07	33,381	60,962	139302
1953	13.01	4,253.53	224,497	2.14	36,847	74,998	128717
1954	10.82	4,254.48	257,181	2.32	38,370	87,189	119873
1955	7.54	4,252.78	199,782	2.59	35,415	95,613	38214
1956	19.48	4,257.28	362,481	1.60	40,964	60,976	223674
1957	12.49	4,256.78	342,695	2.18	40,708	88,988	69202
1958	15.04	4,259.13	439,400	1.97	41,126	80,470	177175
1959	6.82	4,257.00	351,348	2.65	40,832	108,662	20610
1960	7.47	4,254.80	268,537	2.60	38,809	103,433	20623
1961	9.61	4,251.69	165,576	2.42	32,972	86,826	-16136
1962	9.84	4,250.60	133,400	2.40	30,101	75,687	43511
1963	18.34	4,253.58	226,178	1.69	36,935	56,701	149480
1964	9.71	4,253.36	218,810	2.41	36,540	88,569	81201
1965	16.47	4,257.18	358,489	1.85	40,920	71,554	211233
1966	8.51	4,255.38	289,567	2.51	39,512	100,975	32053
1967	11.22	4,255.83	306,279	2.29	39,973	90,812	107524
1968	8.20	4,253.58	226,178	2.54	36,935	97,546	17446
1969	10.95	4,254.06	242,541	2.31	37,737	86,153	102515
1970	9.63	4,255.10	279,343	2.42	39,188	92,982	129785
1971	11.76	4,259.08	437,244	2.24	41,138	89,965	247866
1972	5.64	4,259.05	435,953	2.75	41,145	113,139	111847
1973	7.46	4,257.33	364,483	2.60	40,984	106,699	35229
1974	11.91	4,258.78	424,399	2.23	41,190	91,522	151439
1975	7.89	4,258.78	424,399	2.56	41,190	105,550	105550
1976	10.89	4,257.78	382,693	2.31	41,129	95,182	53476
1977	6.72	4,256.15	318,373	2.66	40,257	108,244	43924
1978	11.63	4,254.46	256,477	2.25	38,341	88,456	26559
1979	7.69	4,252.43	188,577	2.58	34,677	94,163	26264
1980	12.75	4,252.70	197,202	2.16	35,250	75,434	84060
1981	10.43	4,250.78	138,573	2.35	30,604	77,407	18778
1982	22.79	4,255.68	300,670	1.32	39,828	46,515	208611
1983	16.86	4,258.82	426,103	1.82	41,185	73,519	198953
1984	15.19	4,260.85	516,158	1.95	40,170	79,491	169546
1985	10.10	4,259.30	446,762	2.38	41,079	96,619	27222
1986	12.48	4,261.74	557,860	2.18	39,256	87,565	198664
1987	10.55	4,257.90	387,608	2.34	41,156	94,115	-76137
1988	10.08	4,255.70	301,415	2.38	39,848	96,394	10201
1989	8.00	4,255.24	284,438	2.55	39,353	101,113	84136
1990	6.47	4,252.71	197,524	2.68	35,271	100,028	13114

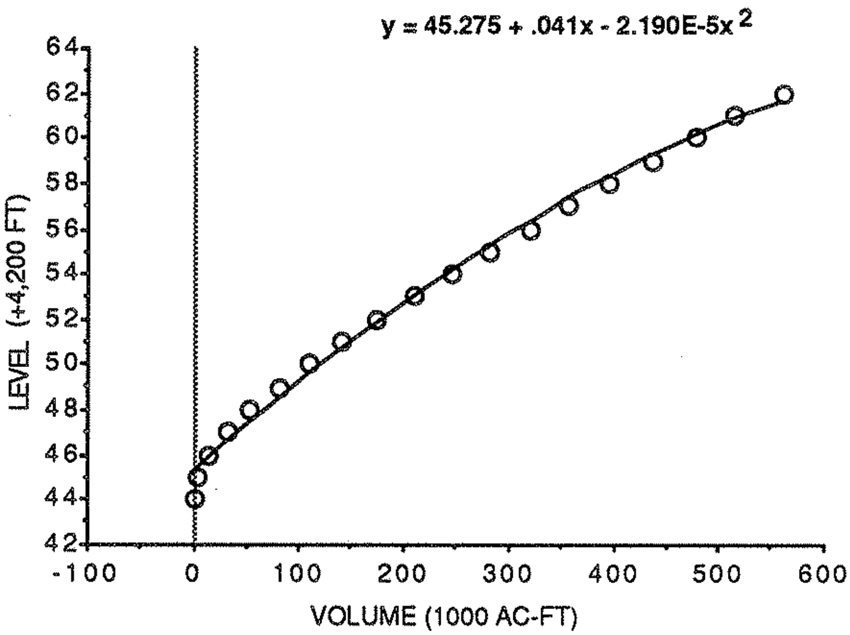
* Precipitation is from Paisely (G. Taylor, State Climitalogist, Dep. Atmos. Sci., Or. St. Univ., Corvallis)

** Lake levels were those taken as close as possible to October each year and were measured by the Lakeview. watermaster.

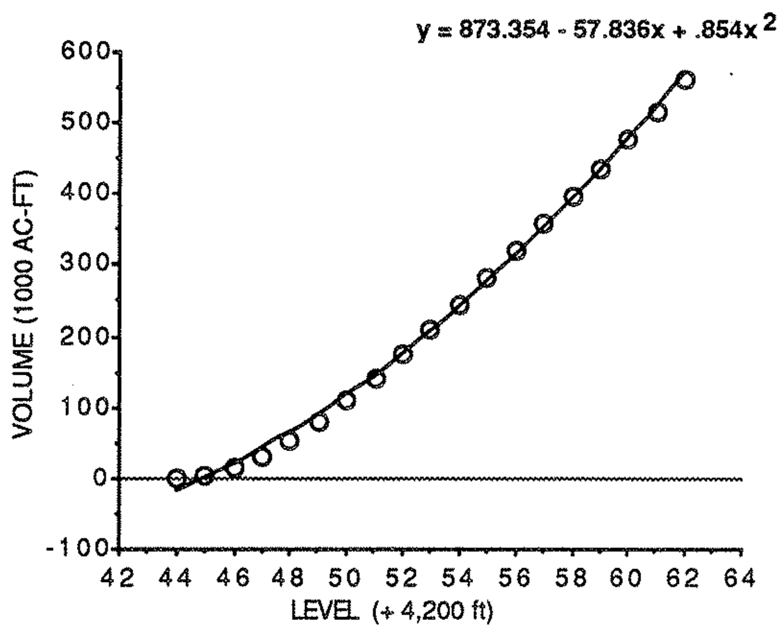
*** Evaporation is given by Phillips and Van Denburgh (1971, p B12)

**** Net loss is the difference between evaporation and precipitation times the average lake area.

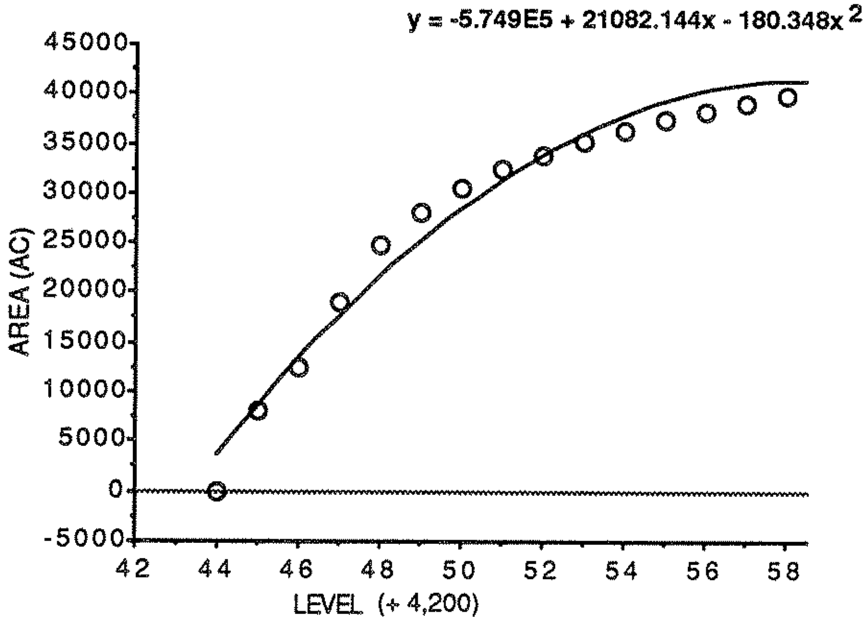
Note: Lake volume, net loss, and in-flow are accurate to approximately 100 ac-ft and area to 100 ac.



Appendix C. Level vs. volume for Lake Abert, Oregon.



Appendix D. Volume vs. level for Lake Abert, Oregon.



Appendix E. Surface area vs. level at Lake Abert, Oregon.

Appendix F. Monthly evaporation rates for freshwater at Abert Lake as determined from Phillips and Van Denburgh (1971) and Van Denburgh (1975).

MONTH	EVAPORATION (IN.)
JANUARY	0.71
FEBRUARY	1.27
MARCH	2.20
APRIL	3.48
MAY	4.47
JUNE	5.68
JULY	7.24
AUGUST	6.39
SEPTEMBER	4.26
OCTOBER	2.49
NOVEMBER	1.35
DECEMBER	0.78
TOTAL	40.32