Lakes and Reservoirs

Harney and Malheur Lakes are the defining terminus of the surface water flow in the Harney Basin. Other small impoundments and natural lakes are scattered across the basin, most only holding water temporarily. Malheur, Mud, and Harney Lakes (Figure 1) lay at the bottom of the ground surface of the basin. Water flows to Malheur Lake from the north via the Silvies River coming from the Blue Mountains, and from the south via the Donner und Blitzen River coming from the Steens Mountains. Harney Lake is the lowest portion of the basin and acts as a sump for the entire watershed. Harney Lake is considered a playa and receives water from Silver Creek and several springs via canals. Flows from these sources typically are lost through infiltration or evaporation (USFWS, 2013). Mud Lake lies between Malheur Lake and Harney Lake and when Malheur Lake overflows it first enters Mud Lake before entering Harney Lake during extreme high-water events.

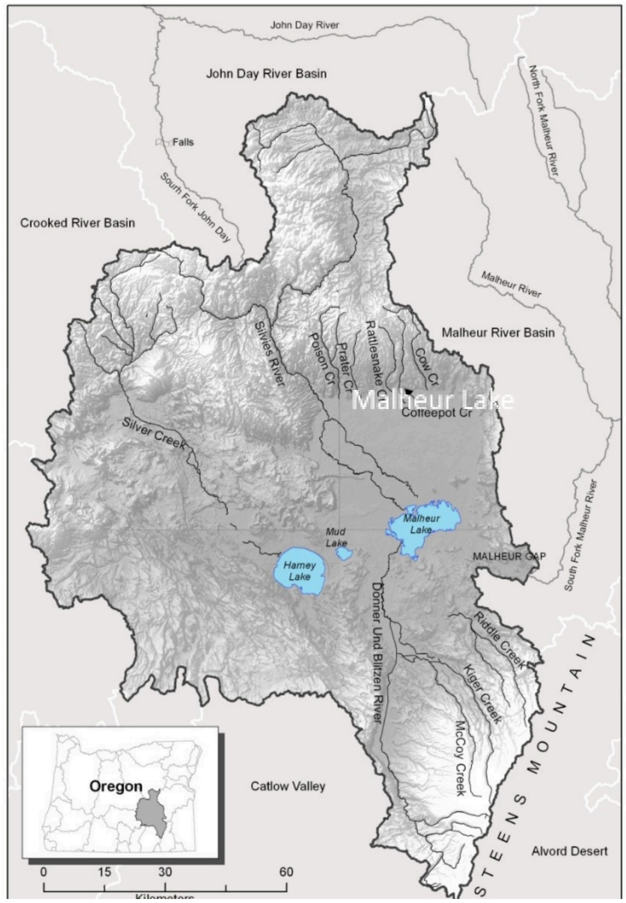

Figure: Harney, Mud and Malheur Lakes in the Harney Basin (from ODFW, 2018)

Historic Lake Conditions

The three basin lakes represent a remnant of a much larger waterbody that existed during the Pleistocene Epoch (Figure 2) when precipitation was greater and evaporation less. The Atlas of Oregon Lakes describes the Pleistocene Lake as: “At its highest level this "pluvial" lake is estimated to have been 900 square miles in surface area, with a maximum depth of 35 feet (Phillips and Van Denburgh 1971). It overflowed eastward into the Snake River via the Malheur River. Drainage was first through a channel near Princeton, and later through a gap at Crane when Pleistocene lavas blocked the former channel (Baldwin 1976). About 10,000 years ago warmer and drier conditions caused the pluvial lake to shrink, and the water no longer had an outlet to the sea. Much of this former lake bottom is now brush-covered desert and seasonally flooded grass-sedge meadowland, with Malheur and Harney Lakes existing as remnants of the former Pleistocene lake.”

The rise in lake levels would combine Malheur, Mud and Harney lakes into a deep lake at least four times over some 9,000 years. The USFWS describes the pluvial lake conditions as: “A lush, narrow band of wetland vegetation bordered the edges of this lake. As the water expanded southward into the Blitzen

Valley shallower areas developed into extensive cattail and tule marshes. Remnant shore lines of these pluvial lake occurrences are still evident along the south side of Harney and Mud lakes. Large gravel bars, formed under these large lakes, can be seen at various locations along the south side of the lakes and at the mouth of the Blitzen Valley.

Lake bed and lakeshore dune features have been studied by Dugas (1996) who explored the history and formation processes for these features."

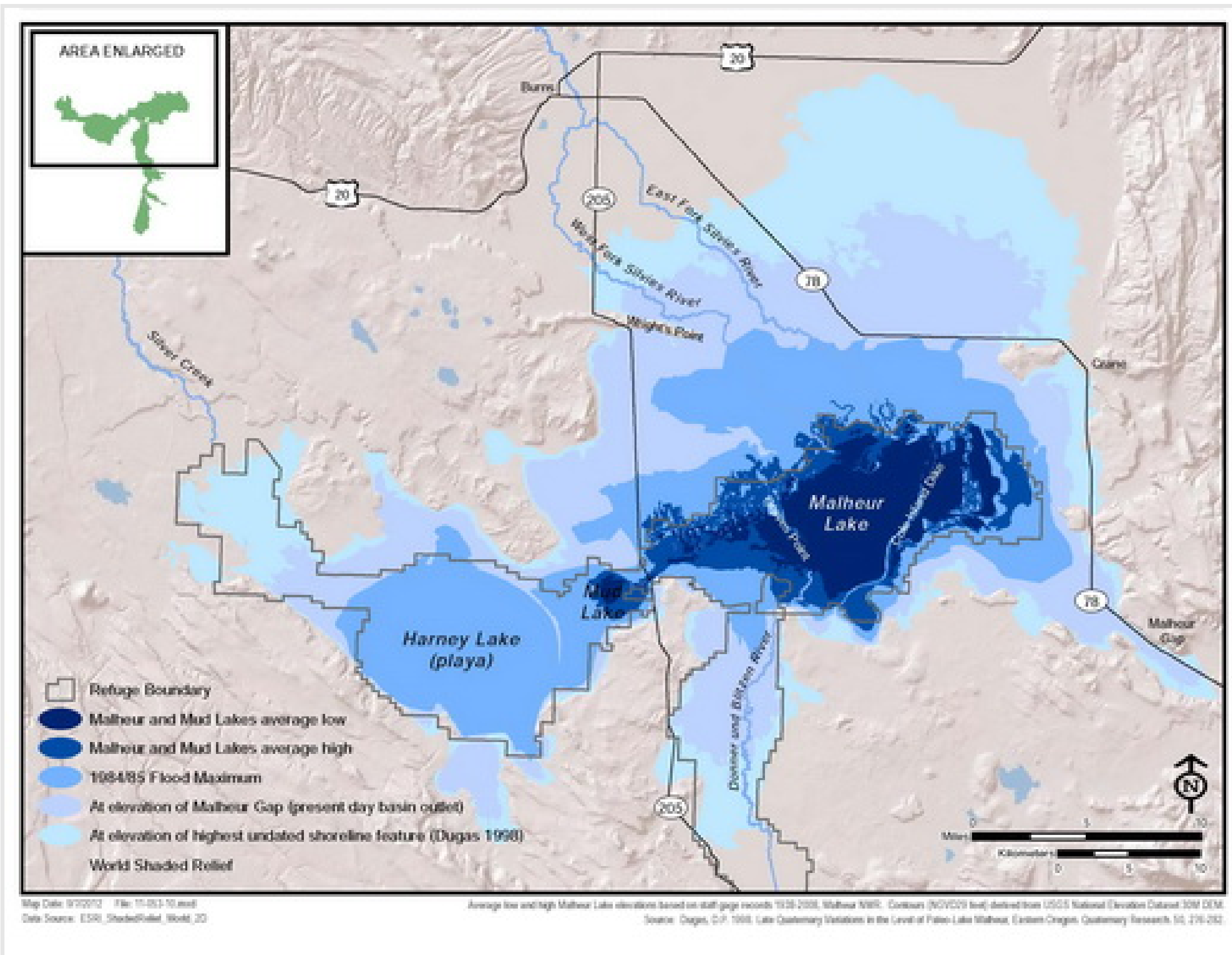

Figure 2: Pleistocene Lake levels in the Harney Basin (from Malheur National Wildlife Refuge web page, 2019)

Recent Lake Conditions

As the climate warmed and dried and evapotranspiration increased, the three lakes separated and have very different modern-day conditions. Harney Lake is a playa only retaining water during high precipitation events, Mud Lake is dependent on high stages of Malheur Lake, and Malheur Lake fluctuates widely both seasonally and yearly. The Lakes remain important waterbodies in an arid basin (Figure 3). Each lake is different and is affected by water resources in the basin in a different manner.

Figure 3: Malheur, Mud and Harney Lakes (Google Earth Image 2018)

Malheur Lake

The most prominent feature of the Harney basin is Malheur Lake, the shallow, fluctuating lake at the end of the perennial drainages in the basin. While affected by water resource development in the basin, it remains a focus of management for the Malheur National Wildlife Refuge. The resources of the lake basin and development of the basin as it affects Malheur Lake have been of interest for some time. Langston (2003) has written extensively about the development of the basin and the effects of water resource development on the lake system.

The Ecology of Malheur Lake

Malheur Lake is described in the Atlas of Oregon lakes (Johnson, 1985) as: "Malheur Lake is, in effect, a freshwater marsh, one of the largest in the country. It has long been one of the most productive waterfowl breeding areas in the United States, and is a vital migration habitat for birds on the Pacific Flyway. In 1908 President Theodore Roosevelt dedicated the area as a bird refuge, and the Malheur National Wildlife Refuge now comprises nearly 160,000 areas of open water, vast tule swamps, wild meadows, and wooded areas. It is a remarkable area, and well over 200 different species of birds have been found on and adjacent to the Malheur Refuge."

The variability of the lake has a significant influence on the ecology of Malheur Lake. The conditions of the lake were captured by Duebbert (1969) that reflect the conditions prior to that time. He (Duebbert, 1969) characterizes the Lake as:" Malheur Lake contains three distinct ecological units separated by two low north-south ridges, Graves Point and Cole Island." The western portion of the Lake is described as: "Emergent vegetation is mainly hardstem bulrush (*Scirpus acutus*), burreed (*Sparganium eurycarpum*), cattail (*Typha latifolia*), and Baltic rush (*Juncus balticus*). Pondweeds, mainly *Potamogeton pectinatus* and *P. pusillus*, are dominant submergent plants. Uplands are vegetated by saltgrass and greasewood.

This unit is flooded when the surface elevation of the lake reaches 4092.00 feet. It is one of the refuge's best waterfowl production areas."

The center portion of the lake is described as:" predominantly a hardstem bulrush marsh with interspersed open zones." The area is also described as:" water is deeper and more permanent than in the other units. Although bulrush dominates, shallower zones support good growths of burreed, cattail, Baltic rush, and sedges. Water milfoil (*Myriophyllum exalbescens*) is the most widespread and abundant submergent, although sago pondweed occurs abundantly in the northeast portion. Duck production on this unit is restricted mainly to its outer fringes. Herons, egrets, eared and western grebes, and black and Forster's terns are major nesting birds. Large numbers of pintails molt here (populations ranging from 20,000 to 25,000) along with fewer numbers of mallards, widgeons and other ducks."

The eastern portion of the Lake is described as:" the most alkaline portion of the lake and also has the most open water. When surface elevations reach 4091 feet, water flows eastward into this area through gaps in Cole Island ridge. This area contains the best stands of sago pondweed and traditionally has the greatest seed production. Low ridges are vegetated with nearly pure associations of Baltic rush and foxtail barley (*Hordeum jubatum*); higher areas are covered with saltgrass and greasewood."

The lake is described as having both significant stands of emergent vegetation (cattail, bulrush, sedges and rush) as well as "vast quantities of submerged plants-primarily sago pondweed that make Malheur Lake such good waterfowl habitat."

Malheur Lake historically provided rearing habitat for adfluvial redband trout but that use has been significantly diminished because access to the lake has been impaired or eliminated by dams and diversions on the tributary streams (Silvies River, Blitzen River, Silver Creek and others) and the lake was colonized by carp (*Cyprinus carpio*). An adfluvial fish is one that spawns in small headwater streams and migrates to a large productive lake to rear and mature. Currently, only redband trout in the Blitzen River have consistent access to Malheur Lake to rear. The Malheur National Wildlife Refuge has expended significant resources to provide access for redband trout to Malheur Lake by providing fish passage on the Blitzen River. Studies of migration and passage (Anderson, 2009) suggest: "the majority of Blitzen redband trout migrated upstream of Page Dam to spawn and that most trout spawned in the mainstem and not the tributaries." The Page Springs Gauging weir is a high priority fish passage barrier off refuge lands as identified by the ODFW Fish Passage Barrier Priority List (ODFW, 2019). The removal of this barrier is addressed in the Steens Mountain Cooperative Management and Protection Act of 2000 (PL 106-399). Section 302 § (4) states:" *(4) REMOVAL OF DAM—The Secretary shall remove the dam located below the mouth of Fish Creek and above Page Springs if removal of the dam is scientifically justified and funds are available for such purpose.*" To date the scientific justification to address the dam has not been developed. The conflict between stopping exotic fish (especially carp) from entering the upper watershed and the desire to allow redband trout to migrate downstream has not been fully resolved.

An additional eleven barriers have been identified in the Silvies River, Silver Creek, and Donner und Blitzen River tributaries and other tributaries (Table 1).

Table 1: Fish Passage Barriers in the Harney Basin (from ODFW, 2019)

Barrier Type	Barrier Name	Stream Name	Species Affected
dam	Page Springs Gauging Weir	Donner und Blitzen River	Redband Trout
dam	14 mi. upstream of 5 mile Dam	Silvies River	Redband Trout
dam	Yellowjacket Dam	Yellowjacket Creek (Silvies River tributary)	Redband Trout
dam	Old Mill Dam	Silvies River	Redband Trout (historical)
dam	Fivemile Dam	Silvies River	Redband Trout (historical)
dam	Chickahominy Reservoir	Chickahominy Creek (Silver Creek subbasin)	Redband Trout
dam	Kern Reservoir Dam	Dry Krumbo Creek (Donner und Blitzen tributary)	Redband Trout
Dam	Little Kiger Creek diversion	Little Kiger Creek (Donner und Blitzen tributary)	Redband Trout
dam	Alder Creek	Alder Creek (Silvies River tributary)	Redband Trout
dam	Kiger Creek Diversion	Kiger Creek (Donner und Blitzen tributary)	Redband Trout
dam	Cow Creek (lower)	Cow Creek Harney-Malheur Lakes subbasin)	Redband Trout
dam	Moon Reservoir	Silver Creek	Redband Trout (historical)

Anderson and others (2009) have described the history of blockage of passage as: "Extensive channelization of the river and construction of diversion ditches throughout the valley occurred principally between 1910 and 1915. Although some diversion dams were likely constructed during this early period, the current diversion structures were constructed in the 1930s by the Civilian Conservation Corps (Hosford and Pribyl 1983). These dams had fish passage provisions, but the efficiency of the passage structures was likely poor, based on historical reports of trout attempting passage stacking up below the dams (Hosford and Pribyl 1983). The introduction of carp (*Cyprinus carpio*) to Malheur Lake is thought to be an important factor in the decline of the large migratory redband trout and utilization of Malheur Lake (Bowers et al. 1999). The incredibly abundant carp populations may affect the trout population through food-chain interactions and by increasing turbidity in the lake, reducing the ability of the sight-foraging trout to find food (Bowers et al. 1999)."

Malheur Lake conditions have changed since the introduction of common carp. As described by Deubbert (1969) "After carp (*Cyprinus carpio*) were introduced into the Silvies River watershed in the early 1920's, these fish often became sufficiently numerous in the lake to be detrimental to submerged aquatic vegetation. By 1955 carp activity had created such turbidity that desirable submerged aquatics were nearly eliminated. In 1955 the carp population was controlled with rotenone, a fish toxicant. It was estimated that 1.5 million carp averaging 20 to 25 inches in length were killed. The beneficial effect was demonstrated the next year, when sago pondweed showed immediate response to improved growing conditions and covered 15,000 acres.

The MNWR Comprehensive Conservation Plan portrays the current conditions of Malheur Lake as: "The large invasive carp population in Malheur and Mud lakes and in the Blitzen and Silvies rivers has severely compromised submerged aquatic vegetation (e.g., sago pondweed); therefore, the lakes do not adequately support refuge purposes. Historically, Malheur Lake was a key staging area for canvasbacks and tundra swans in the Pacific Flyway. As a consequence of declining habitat quality, these and other waterfowl no longer stage in significant numbers on the lake except during years following major carp control efforts. Waterfowl production is less than 10 percent of its potential on the lake because of turbid water conditions related to carp and other factors. There were high numbers of canvasbacks using Malheur Lake during the falls of 1993 and 1994, after drought conditions and a carp control project in 1992. Duck production was estimated to be over 100,000 produced per year on Malheur Lake before the carp invasion (Cornely, 1982). During the 1980s, high water levels eliminated most emergent vegetation in Malheur Lake, causing a significant number of colonial birds to abandon nesting on Malheur Lake and shift to flooded private lands to the north. The large stands of hardstem bulrush that were present before the 1980s flood have not recovered. Historically, Mud Lake had an extensive bulrush community used by nesting canvasbacks; however, with low water levels there are minimal bulrush stands present on the lake."

The loss of emergent vegetation has reduced the value of Malheur Lake for resident waterfowl and colonial nesting waterbirds. Shorebirds use the periphery of the lake for foraging. Harney, Mud, and Malheur Lakes provide excellent feeding for shorebirds on receding mudflats and alkali playas. Tens of thousands of seasonal migrants are shorebirds. Twenty-seven shorebird species use the Refuge at various points throughout the year, including Western sandpipers, long-billed dowitchers, Wilson's phalaropes, Wilson's snipe and American avocets.

The Malheur Refuge is described by Audubon Society as an Important Bird Area having the following attributes: “Malheur is important to the watch-listed Western Snowy Plover, Long-billed Curlew, Franklin's Gull, Short-eared Owl, Greater Sage-Grouse, Bobolink, and Trumpeter Swan, all of which breed here. The Refuge has one of the highest Breeding Bird Survey counts for the watch-listed Brewer's Sparrow. The refuge's riparian habitat supports the highest known densities of Willow Flycatcher. Malheur Refuge supports up to 20% of the world's population of White-faced Ibis and significant breeding populations of American White Pelican, Cinnamon Teal, Redhead and Greater Sandhill Crane (the latter being 20% of Oregon's breeding population). Up to half of the entire population of Ross' Geese use the Refuge and surrounding private lands during migration. A significant proportion of the total populations of Green-winged Teal, American Wigeon, Northern Shoveler, Northern Pintail, Canvasback, and Ruddy Duck use the area as an important migratory stopover. During migration, this includes estimates of up to 100,000 Snow Geese, 15,000 Green-winged Teal, 15,000 Mallards, 250,000 Northern Pintail, 250,000 Northern Shovelers, 4,000 Canvasbacks, 2,000 Ring-necked Ducks, 5,000 Lesser Scaup, and 50,000 Ruddy Ducks. Breeding populations on the Refuge include up to 150 pairs of Green-winged Teal, 400 pairs of Northern Pintail, 200 pairs of Blue-winged Teal, 700 pairs of Northern Shoveler, 2,000 pairs of Gadwall, 400 pairs of American Wigeon, 800 pairs of Canvasback, 3,000 pairs of Redhead, 80 pairs of Lesser Scaup, and 2,500 pairs of Ruddy Ducks. Malheur Refuge supports an intermittent breeding population of California and Ring-billed Gulls, but the largest concentrations of these species don't occur until August. Up to 25,000 Ring-billed Gulls have been recorded on the Refuge during that time. Up to 1,300 pairs of Franklin's Gulls have nested at Malheur. Forster's Terns breed on the Refuge, and up to 350 pairs of Caspian Terns have nested in Malheur Lake when water levels are ideal. Up to 6,000 Black Terns regularly nest at Malheur Lake. Harney and Malheur Lakes support the majority of the shorebird population at the Refuge, especially during migration in spring and fall. In migration, concentrations have been recorded of up to 25,000 Western Sandpipers, 350 Pectoral Sandpipers, 35,000 Long-billed Dowitchers, 15,000 Wilson's Phalaropes, 15,000 American Avocets, and 200 Black-necked Stilts. The Western Snowy Plover is the most common breeding shorebird at Harney and Stinking Lakes, and up to 400 individuals have been seen there during the nesting season. From 100 to 600 pairs of Great Blue Herons nest on the Refuge every year in scattered colonies, though mostly around Malheur Lake. Similar numbers of Great Egrets breed on the Refuge. Over 200 pairs of Snowy Egrets have nested around Malheur Lake. The first Oregon breeding record of Cattle Egret also came from Malheur Lake in the mid-1980s, when 1-2 pairs nested for about 3 years. Numbers of Black-crowned Night-Herons vary widely year to year, but generally a few hundred pairs nest on the refuge. American White Pelicans are sporadic breeders depending on water levels in Malheur Lake, and up to 1,500 pairs have nested there. Malheur Refuge is a concentration point in winter for raptors of many species. Over 100 Rough-legged Hawks, 40 Red-tailed Hawks, 60 Northern Harriers, 10 American Kestrels, and 15 Bald Eagles have been recorded on Christmas Bird Counts.”

White pelicans are abundant at Malheur Refuge during spring, summer and fall. Malheur Lake historically supported large colonies of breeding white pelicans, but fluctuating hydrologic conditions determine whether pelicans use the lake as a breeding site. During high water years, breeding occurs on islands and other isolated areas in the lake. In low water years, most white pelicans do not breed at Malheur Lake but will often stay throughout the summer as non-breeders, sometimes in flocks numbering in the thousands. Abundant carp populations in Malheur Lake are particularly enticing to non-breeding pelicans in summer, and peak numbers are usually seen by mid-July and early August. By mid-fall, most of the pelicans at Malheur Refuge have departed south for the winter.

The Harney Basin Wetlands Initiative was formed to address water quality issues associated with carp in the Harney Basin and enhance/protect traditional flood irrigation practices benefitting migratory birds. The Initiative has used the expertise from Oregon State University and the U.S. Geological Survey to develop a model of the carp population and a physical model of the lake (Figure 4) model of the Lake. The physical model is being developed to evaluate alternative management approaches to reduce carp and enhance the likelihood of a change in state of the lake from a turbid system to a clear water system with abundant aquatic vegetation.

Current focus on the ecology of Malheur Lake is to better understand the dynamics between carp disturbance, wind and wave effects and turbidity dynamics that create conditions detrimental to nesting waterfowl and other waterbirds, prevent submerged aquatic vegetation and maintain a highly turbid lake condition.

The USGS is conducting studies of light transmission in Malheur Lake. Their description of the study context is:" The health of the aquatic ecosystem in Malheur Lake has been strongly compromised by a lack of light that supports development of vegetation in the lake. Such emergent and submerged plants

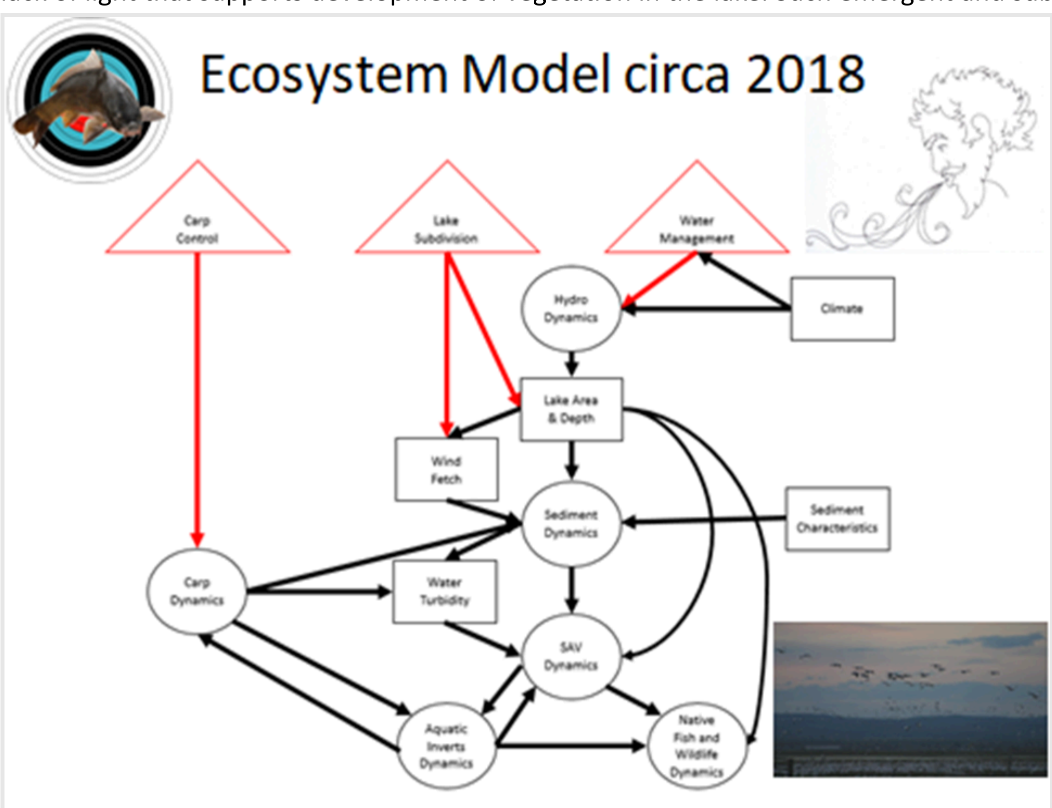

Figure 4: Conceptual Lake Ecosystem Model from Jason Dunham Presentation, 2018)

provide habitat for a variety of highly valued ecosystem services, including shorebirds, waterfowl, and a diversity of other wildlife species. The biggest limiting factor to the health of the lake is the common carp (*Cyprinus carpio*), a nonnative species with strong direct and indirect effects on water column turbidity. Indirect effects of carp include consumption and uprooting of aquatic vegetation, which leaves the bed sediment exposed and easily mobilized by winds. Direct effects include suspension of sediment by carp feeding activity.

The goal of this work is to create a quantitative empirical model that describes light in the water column as a function of location on the lake, depth (lake stage), incident solar radiation, wind speed and direction, and aquatic vegetation coverage. Successful calibration of the model with data collected at several locations will allow the results to be extrapolated to the entire lake in order to provide, for example, the area of the lake the meets a certain light threshold under given conditions, or the average light in the lake as a whole, or in a defined area of interest."

Population modeling has determined that eradication of carp from the lake will be extremely difficult. Therefore, it is important to understand what other pathways can be used for restoration in addition to carp management. An important pathway that requires more exploration is the influence of basic physical factors (e.g., lake bathymetry, sediment, wind, suspended material) on light availability in the water column. A more complete and quantitative understanding of these factors, when combined with other important biological processes, can provide clearer direction for managing the Refuge into the future.

Malheur Lake Hydrology

Malheur Lake occupies a shallow basin where relatively small amounts of water input can significantly affect the surface area of the lake. One of the largest inland marshes in the United States, Malheur Lake may vary dramatically in size (from 500 to 110,000 acres) but on average covers approximately 37,500 acres. The lake level changes through the seasons being highest in the early spring with snowmelt runoff primarily from the Blitzen River declining in relation to the evaporation rate of the summer. Malheur Lake generally fluctuates about 2 feet during the calendar year. In addition, the interannual variation in runoff also has a significant effect on lake levels and hydrology. Historically, the lake has dried during extreme droughts; for example, it was completely dry in 1934 and nearly dry in 1926, 1931-33, and 1961-62 (Phillips and Van Denburgh 1971).

At high-water levels the surface area can exceed 50,000 acres, with a maximum depth of about 6 feet. At a water surface elevation of 4091.5 feet (maximum depth = 2.5 feet), water flows through The Narrows, to Mud Lake. At higher water levels it breaches natural sand dunes and flows into Harney Lake which is the lowest point of the basin. There is no measured water budget for the lake prior to significant water resource development in the basin. Much of the basin lowlands were claimed under federal "Swampland Act" legislation (Pintarich, 1980) in the 1870's and 1880's which led to significant alteration of the stream systems for irrigation and drainage. The MNWR Comprehensive Conservation Plan (USFWS, 2013) explains: "Water was diverted into canals and ditches, flooding out sagebrush and inducing the growth of meadow grasses. This heavy irrigation had dramatic effect on basin landscapes, affecting not only uplands, but wetlands and the lakes. Giles French wrote of Peter French's irrigation projects: "His irrigation projects of themselves held water of Malheur Lake at a lower level, causing more dry land between the water and the meander line" (French 1964)."

In 1916 (Whistler and Lewis, 1916) contributions to Malheur Lake were characterized as: "Silver Creek is the main stream directly tributary to Harney Lake, and Silvies River is the main tributary from the north to Malheur Lake. In years of low run-off Blitzen River from south of Malheur Lake contributes the larger part of the inflow to the lake, but in years of high run-off the inflow from the north is greater than that from the south of the lake."

There has been significant alteration to the Lower Blitzen River, Silvies River, and Silver Creek. Between 1907 and 1913 several diversion dams were constructed for 17.5 miles along the Blitzen River with a multitude of ditches and dikes to manage water for agriculture purposes. Today, there are six active diversions on the Blitzen River (Table 2) that provide water for wildlife management on the Malheur Refuge (USFWS, 2013). The Refuge maintains a minimum flow of 25 cfs below the diversions for aquatic life. The mean annual discharge of the Blitzen River at the USGS gauge is estimated at 91,000 acre feet. The average flow reaching the lake from the Blitzen River is approximately 60,000 acre feet (USFWS, 2013). Similarly, while the Silvies River has a larger catchment there is significantly less inflow to the lake than would occur under natural conditions primarily due to upstream diversions and withdrawals, resulting in the Silvies River delivering water to the lake only two or three times in a decade (USFWS, 2013).

Table 2: Barrier Diversion Capacity for Structures providing water for the MNWR on the Blitzen River (USFWS, 2013)

Structures	Number of Diversion Canals	Cubic Feet per Second
Page Springs	2	200
Old Buckaroo	1	10
Grain Camp	2	303
Busse	2	166
Dunn	2	84
Sodhouse	1	37
Total	**10**	**800**

In 1932 Piper and Robinson (1932) indicated that the Silvies River had little surface connection to Malheur Lake. They characterized the influence as: "Only infrequently is the run-off so large that water flows entirely across the subarea into Malheur Slough and thence into Malheur Lake." The hydrology of Malheur Lake was studied for the 1972 and 1973 water years (Hubbard, 1975). Hubbard determined that the inflow of water to Malheur Lake is from four principal sources; surface runoff from the Silvies and Donner und Blitzen Rivers, Sodhouse Spring on the periphery of the lake, and direct precipitation on the lake surface. During spring flooding, water enters the lake through the East Fork and West Fork of the Silvies River channels and at many points between the two channels. Inflow from the Silvies amounted to 1% to 33% of the surface flow into Malheur Lake during these two water years. The Donner und Blitzen River contributed between 66% and 98% of the surface input to Malheur Lake in the same years. Hubbard (1975) states: "A comparison of flows monitored near the inflow points to the lake with records of flow for upstream gaging stations reflects the extensive diversions for irrigation in the Silvies River basin and for refuge management in the Donner und Blitzen River basin. Because of these diversions, a large quantity of the annual snowmelt runoff does not reach Malheur Lake."

Inflow from Sodhouse Spring was determined to be the only appreciable source of ground -water inflow to the lake, although some seepage from the shallow groundwater table may occur during periods of low lake level over a small area near the mouth of Donner und Blitzen River. Sodhouse Spring has been dry for the last several years (Chad Charges personal communication, 2019). The ongoing groundwater study has identified the water budget elements for Malheur and Harney Lakes (Figure 5). As the study is completed, measured or estimated inputs and outputs will be quantified.

Flows from the Blitzen River result primarily from snowmelt. With changing climate and a likely shift from snowmelt dominated to more rainfall dominated precipitation and runoff, the timing of flow contributions to Malheur Lake may be altered affecting the timing of shoreline changes.

The latest water budget estimate for Malheur Lake includes spring flow into the lake (USGS presentation 8/8/2019) is illustrated in Figure 6. The current estimate includes an estimate of some 10,000 acre feet/year from springs.

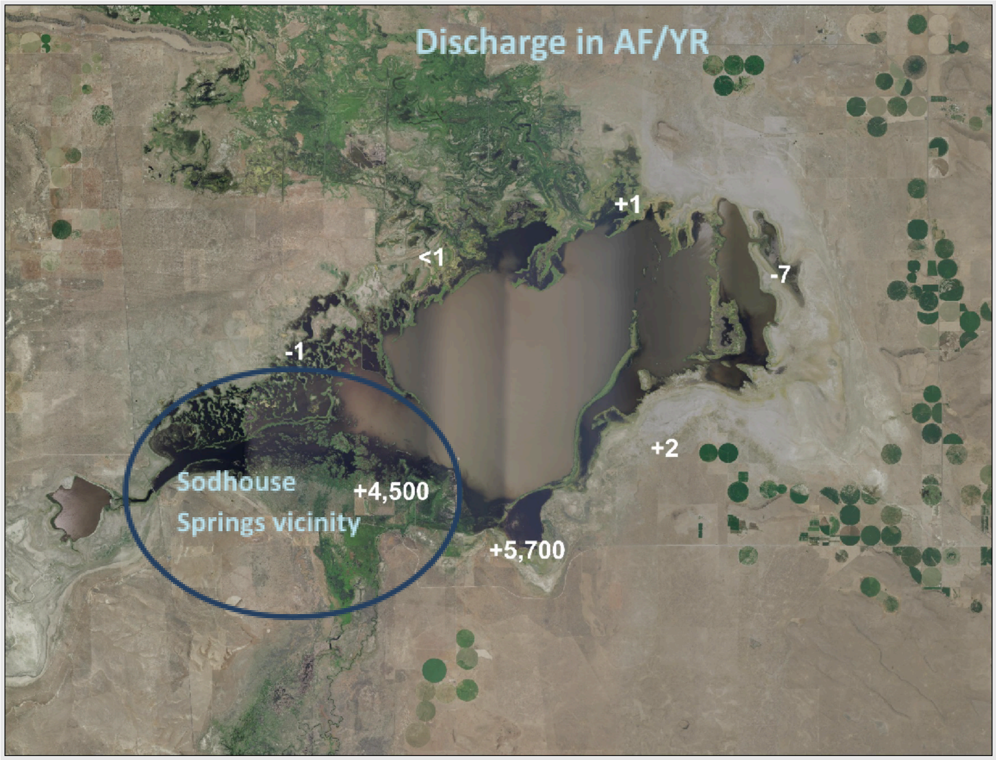

Figure 6: Spring discharge to Malheur Lake (from USGS 8/8/19)

Flow and Malheur Lake Levels

With the shallow basin, flow variation has a significant effect on lake levels. Figure 7 illustrates the significant variation in lake level for the last 75+ years. The elevation data is affected by the nature of the ponding and the location of measurement. There have not been consistent measurements over time but the general pattern of fluctuating surface water levels is a reasonable reflection of conditions on the ground. It appears that lake level variability has increased since the 1983-1984 high water years.

Recent modeling of the lake elevation of Malheur Lake by James Pearson (personal communication, 2019) has documented that the lake elevation is well modeled from flow in the Blitzen River and previous year lake level (Figure 8). Using data from 1982 to 2016 a model was developed to relate a number of variables to lake levels. The variables of Blitzen

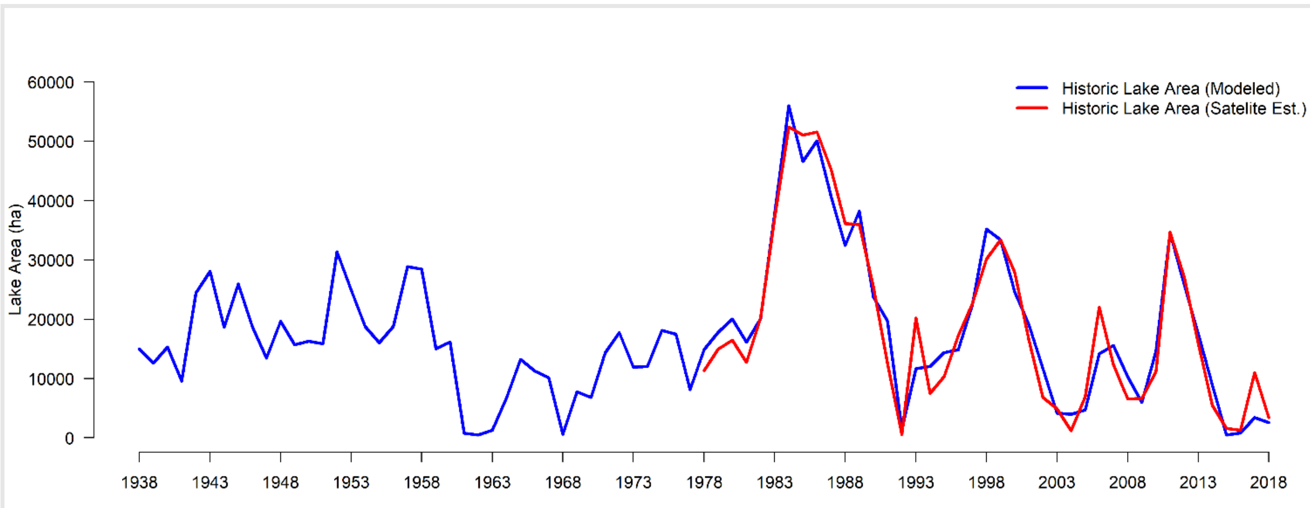

Figure 7: Peak yearly elevations of Malheur Lake from 1938-2018 (provided by James Pearson, 2018)

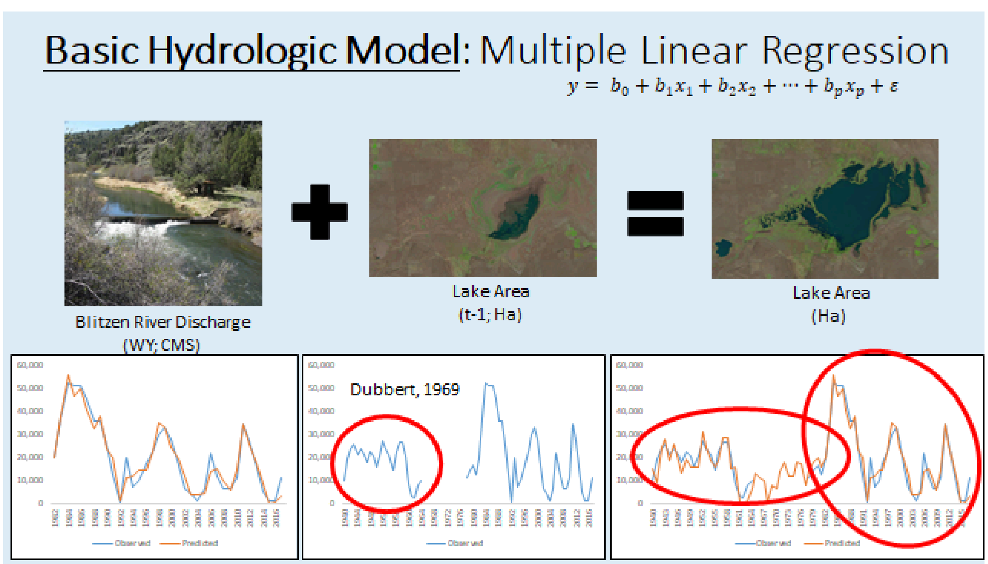

Figure 8: Hydrologic Model for Malheur Lake levels (Pearson, 2018)

River flow at the stream gauge and the previous year lake level were able to provide an accurate indication of the lake level. The model was used to check the period of record of lake levels from the 1940's to 1960, which showed a similarly accurate tracking of lake levels with Blitzen flow and previous year lake level.

While the recent correlation is expected since flows from the Silvies River only occasionally reach the Lake, the data from 1940-1960 is also well correlated (Figure 6). Both of these time periods occur well after the development of most surface water diversions in the basin. The model indicates that a significant majority of all water to Malheur Lake comes from the Blitzen valley through surface flow at this time.

Lake Level and Area Fluctuation

A significant feature of Malheur Lake is the annual and interannual fluctuation of the lake area. The fluctuation is a result of the relatively flat lake basin and high evaporative rate during the summer. Annual fluctuations provide different habitats for waterbirds with exposed shoreline a benefit for shorebirds and deeper water a benefit for dabbling, wading and diving birds. The annual fluctuation has a significant effect on the area of shoreline suitable for shorebirds (Figure 9).

The change in lake area habitats may have some effect on waterbird use. The monitored use of Malheur Lake is illustrated in Attachment A.

Shorebird Habitat of Malheur Lake

The Harney basin is recognized as meeting or exceeding the criteria as a Western Hemisphere Shorebird Reserve Network site (IWJV, 2013). Table 3 lists the shorebird species occurrences in the Great Basin Bird Conservation Area (adapted from IWJV, 2013).

Table 3: Great Basin Shorebird Seasonal Occurrence, Importance and Population Trend (from IWJV, 2013)

Great Basin Shorebirds			
Species	**Seasonal Occurrence[1]**	**Importance Score[2]**	**Population Trend[3]**
Black-bellied Plover	M	4	DEC
Snowy Plover	**B**,M	5	DEC
Semipalmated Plover	M	3	STA/U
Killdeer	M,B	4	STA/U
Black-necked Stilt	m,**B**	5	STA/U
American Avocet	M,**B**	5	STA/U
Greater Yellowlegs	M	3	STA/U
Lesser Yellowlegs	M	3	DEC
Solitary Sandpiper	M	3	DEC
Willet	M,**B**	5	STA/U
Spotted Sandpiper	M,B	4	STA
Upland Sandpiper	B	3	DEC
Whimbrel	M	3	STA
Long-billed Curlew	M,**B**	5	DEC
Marbled Godwit	M	4	DEC
Red Knot	M	3	DEC
Sanderling	M	3	DEC
Semipalmated Sandpiper	M	3	DEC
Western Sandpiper	M,**W**	5	DEC/U
Least Sandpiper	M	4	DEC
Baird's Sandpiper	M	4	STA/U
Pectoral Sandpiper	M	3	DEC
Dunlin	M	3	DEC
Long-billed Dowitcher	**M**	5	STA/U
Wilson's Snipe	m,W,B	4	DEC
Wilson's Phalarope	**M**,B	5	DEC
Red-necked Phalarope	**M**	5	DEC

[1]Seasonal occurrence of shorebird species adapted from Oring et al. (2000). Codes: M = Migrant, W = Wintering, B = Breeding. **B, M, W** = high concentrations, region extremely important to the species relative to the majority of other regions. B, M, W = common or locally abundant; region important to the species relative to other regions. b, m, w = uncommon to rare; region within species range but occurs in low abundance relative to other regions.

[2]5 = The area is critical for supporting hemispheric populations of the species; 4 = The area is important to supporting hemispheric or regional populations; 3 = The area is within the range of the species and the species occurs regularly within the region but in low abundance; 2 = The area is within the range, but in general, management is not warranted for this species

[3]DEC = decline, STA = stable, U = unknown

Different shorebirds utilize different depths of shallow water habitats. Using information on the birds of the Malheur National Wildlife Refuge (Littlefield, 1984), a list of typical species that use Malheur Lake as either migratory or resident habitat (Table 4).

Table 4: Malheur Lake Shorebird Guilds

Shorebird Guilds for Malheur Lake	
Water Depth	***Species Group*: Species**
< 15 cm	*Wading Birds: herons and egrets*, Malheur species: Greater sandhill crane, Great Blue heron, Common egret, white-faced ibis, sora, Virginia rail, American bittern
< 10 cm	*Shorebirds with long bills and legs*, Malheur species: Wilson's phalarope, American avocets, black-necked stilts, common snipe, long-billed dowitcher
< 5cm	*Shorebirds with short bills and legs*, Malheur species: snowy plover, western sandpiper

Using recently developed information, it is possible to model the area of different depths from detailed information on Malheur Lake bathymetry and water stage (Figure10). The relationship is modeled for average lake stage and average spring and fall lake stages.

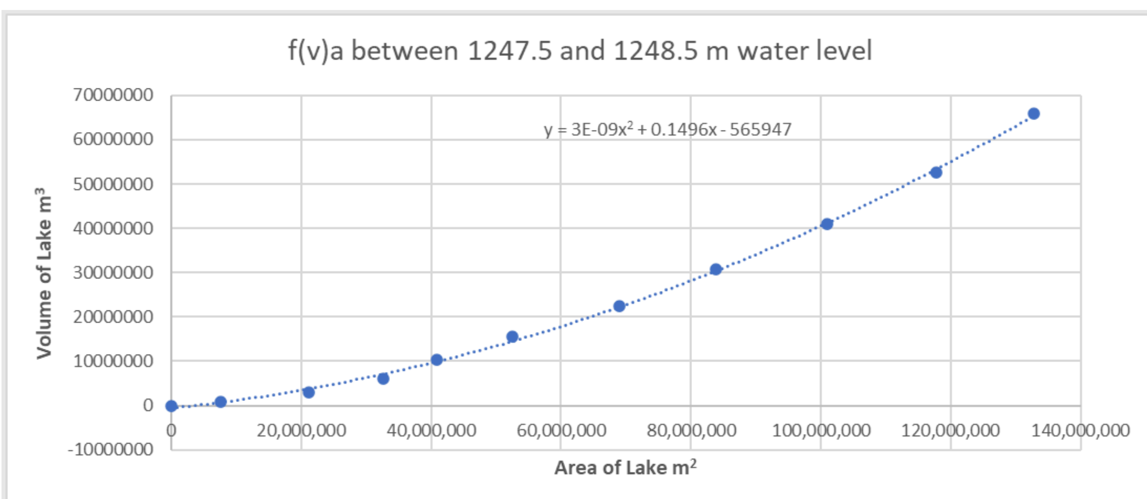

Figure 10: Malheur Lake Surface Area v. Lake Volume

This information can be used to evaluate the area of a given depth. Figure 11 illustrates the area of habitat available for shorebirds by lake stage for Malheur Lake. The Lake provides from over 750 hectares (1,850+ acres) to more than 3,000 hectares (7,400+ acres) of habitat on the periphery of the lake.

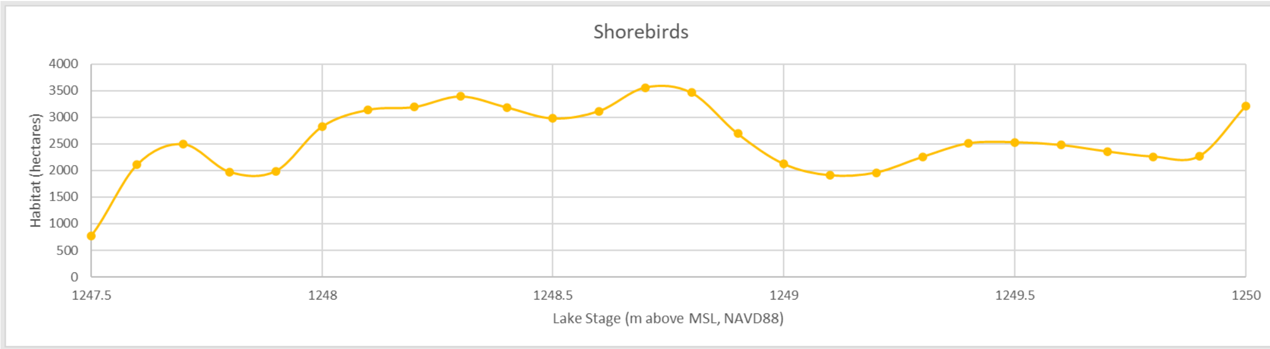

Figure 11: Shorebird Habitat by lake stage for Malheur Lake

The range of shallow water depths used by different shorebirds and waterbirds has been used to quantify shorebird habitat in other areas (Schaffer-Smith et al., 2018; Twedt, 2013; Isola et al., 2000; Colwell and Taft, 2000; Reiter et al., 2015). The depth increments and shorebird guilds using each depth increment is listed in Table 5.

From Schaffer-Smith et al., 2018. Quantifying shorebird habitat in managed wetlands by modeling shallow water depth dynamics. Ecol Appl. 28(6): 1534-1545. (and references therein)

Ecological Water Needs			*From* Schaffer-Smith et al., 2018. Quantifying shorebird habitat in managed wetlands by modeling shallow water depth dynamics. Ecol Appl. 28(6): 1534-1545. (and references therein)	-
Spp/Guild	**Depth min (m)**	**Depth max (m)**		
Diving Waterbirds	0.25	-		
Dabbling Ducks	0.05	0.25		
Wading Birds	0	0.15		
Shorebirds (long bill/legs)	0	0.1		
Shorebirds (short bill/legs)	0	0.05		

Using the same relationship between lake stage and lake surface area, areas of habitat for other waterbird guilds can be evaluated (Figure 12). These relationships show similar patterns among birds using shallow water (shorebirds, wading birds, and dabbling ducks) but an increasingly availability of habitat for diving ducks and other species that depend on deeper water.

Waterbird habitat varies along with seasonal and interannual variation in lake area. In average spring conditions when the lake is large (20,223 ha; Pearson, 2020) due to snowmelt runoff, diving waterbirds have > 16,000 ha of deep-water habitat while other waterbird guilds have < 6,000 ha of shallow wading or dabbling habitat (Fig. 12; Freed and others, in review). Due to the bathymetry of the lake, during wetter than average springs when the lake is larger than 21,000 ha, the amount of shallow wading, dabbling, and shorebird habitat actually decreases (Fig. 12; Freed and others, in review). In average fall conditions, the amount of wading and dabbling habitat remains roughly the same as spring conditions (about 5,000 ha) while shorebird habitat increases to roughly 3,000 ha and deeper habitat for diving waterbirds is only about 9,000 ha (Fig. 12; Freed and others, in review). The habitat for shallow waterbird guilds (dabbling ducks, wading birds, and shorebirds) is resilient to dry late-season conditions, but the amount of habitat available for diving waterbirds is highly sensitive to fluctuations in lake stage, area, and volume (Fig. 12; Freed et al., 2021). Under extremely dry conditions, such as the historic minimum lake area in 1992 of 80.9 ha (https://www.fws.gov/refuge/malheur/about/geology.html), habitat for all four waterbird guilds is negligible (although shorebirds are likely able to utilize the entirety of the lake area at that stage). These results suggest that changes in precipitation under projected future climate conditions and/or any changes in water management altering the amount of water that reaches Malheur Lake are likely to have a disproportionate impact on diving waterbirds. In severe cases of water shortage, all waterbird guilds are affected.

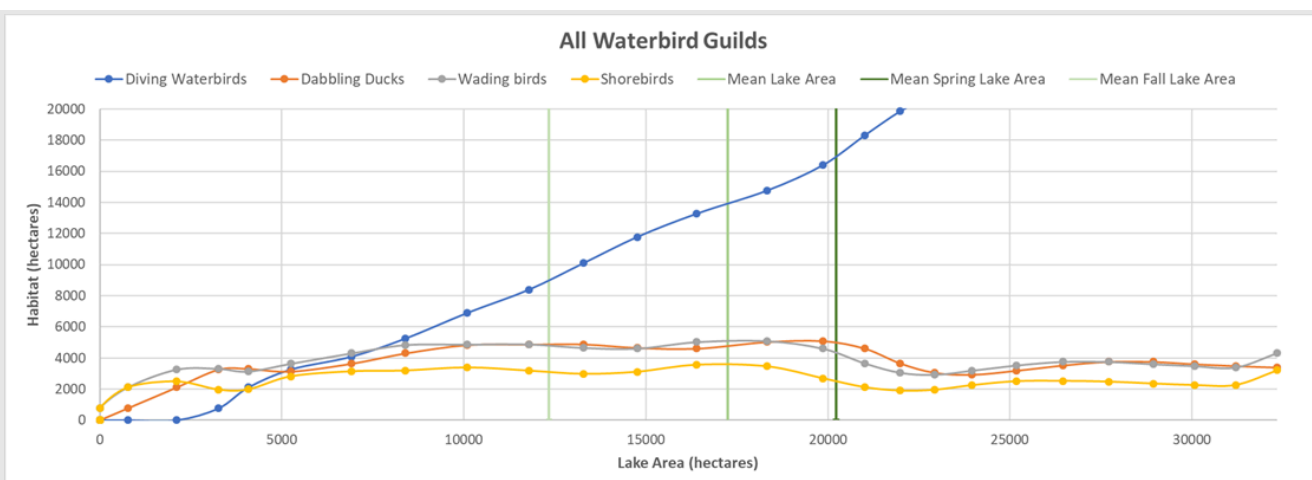

Figure 12: Waterbird habitat relationships to lake area for Malheur Lake

Mud Lake

The only surface outflow from Malheur Lake is at the outlet at The Narrows. When the surface of the lake exceeds (4,092 feet) water flows into Mud Lake and then, if not obstructed, into Harney Lake, the sump of the closed basin. Mud Lake is described in the MNWR Comprehensive Conservation Plan (USFWS, 2013) as **"**broad and shallow like Malheur Lake, and its surface area expands as water levels rise. Malheur Lake must reach a level of 4,093 feet msl before flows enter Mud Lake at the Narrows. Separated by a lunette dune, Harney and Mud lakes first begin to combine as water levels in Mud Lake rise and water begins to seep under the dune ridge between alternating silt and sand layers. A series of shallow ponds develop on Harney Lake parallel to the dune as water seeps under the dune ridge from Mud Lake. At elevations above 4,097.3 feet msl, the lunette dune separating Mud and Harney lakes may be breached at the Sand Gap, and the three lakes may become connected (Hamilton et al., 1986). This connection is subject to modification by natural and human processes, so the elevation at which water spills from Mud Lake into Harney Lake has varied. For example, in 1972-1973 the water level of Malheur Lake varied between 4,090.8 and 4,094.6 feet msl. During this time period the gap was dammed by private landowners to store water for irrigation before it flowed into Harney Lake and became salty (Hubbard, 1975)**."** The only source of water for Mud Lake is overflow from Malheur Lake. No streams feed the lake as it is a shallow remnant of the Pleistocene lake basin that included all three lakes.

Cultural Significance of Malheur Lake

Malheur Lake has been of significant to Great Basin Paiute people for millennia (Elston, et al., 2014). The Burns Paiute Tribe has identified culturally significant plants, animals, and other cultural materials in their Aboriginal Territorial Protection Policy adopted as Tribal Council Resolution No. 2006-12. Malheur Lake and its shoreline is identified as a Sacred Place and Traditional Cultural Properties of the Burns Paiute Tribe by Tribal Council Resolution No. 2016-01.

Malheur Lake is also of significance as one of the early National Wildlife Refuges, created by executive order of President Theodore Roosevelt in 1908, which at the time was a shallow marsh dominated by emergent beds of tule and bulrush.

Harney Lake

Harney Lake occupies the lowest portion of the basin. All surface drainage flows to the lake when flows are sufficient to overflow Malheur and Mud Lakes. Because it is the lowest portion of the basin and all water loss is through evaporation, Harney Lake is saline. The salts that accumulate have been a significant producer of brine shrimp in the past but the lake currently appears to be too salty for brine shrimp to survive.

Data from a 1931 study of precipitation and tree growth in the Harney Basin suggested that extreme fluctuations in water levels have been characteristic for at least the last two centuries (Piper et al., 1939). The fluctuating surface of the lake has not persisted long enough at any level to cut a prominent beach. The lake is presently a vast body of very shallow water in wet periods and a similarly vast alkali flat in dry periods. Silver Creek is described by Piper et al. (1939) as historically "discharged into Silver Lake, although in wet years a considerable fraction of the runoff passed onward to Harney Lake."

Harney Lake has no outlet. It receives water from the overflow of Malheur Lake, from Silver Creek, which drains southeastward from the southern Blue Mountains, and from a number of springs in and adjacent to the lake on the south and east sides. Via canals Double- O Spring provides 16 cfs to marshes and wet meadows both to the north and west of the Spring. Five other springs [Hughett (12.5 cfs), Barnyard (5.0 cfs), Basque (4.0 cfs), Johnson (2.0 cfs), and Cold springs (1.0 cfs)], all flow southeasterly before emptying into Harney Lake. Most of the springs are alkaline (Scharff and Davis 1962). Springs in and adjacent to the lake are small, but combine to a total 4.5 cfs, providing enough water to maintain small permanent wetlands. Temperatures of the springs vary from 21°C (70°F) to 42°C (108°F) (Piper et al. 1939). The hottest spring at Harney Lake, Harney Hot Spring, is on private land. Its temperature is 68°C (154°F). These springs appear to be affected by upgradient withdrawal of groundwater.

The MNWR Comprehensive Conservation Plan (USFWS, 2013) describes Harney Lake variability as: "Harney Lake is described as the most variable and unstable of the three lakes in the Harney Basin watershed and has varied during the historical period from completely dry to nearly 49,000 acres. Harney Lake itself is dry at about 4,079.7 feet msl, but after the dunes on the east side are breached, water quickly sheets over the surface area of the playa from 4,080 to 4,085 feet msl. The lake shoreline becomes relatively steep-sided from elevations of 4,085 to 4,100 feet msl, and under these conditions, the water overtops its defined margin and spreads over the lake plain on its western and northern sides (McDowell, 1992). Only during the flood of the mid-1980s did it reach this height. Harney Lake dries up completely during dry periods, with the lake becoming salty as water levels decline and salts accumulate on the playa. When wet, the lake is primarily open water with little aquatic vegetation."

Ecology of Harney Lake

The description of the Harney Lake Research Natural Area (Copeland, 1979) characterizes the Lake before the high water of the mid 1980's as: "The 11,300-ha lakebed is mainly devoid of vegetation. Bulrush communities (*Scirpus* spp.) surrounding small springs in the southern and eastern portions are the exceptions. In these areas, viscid bulrush is the dominant species in the deepest water: it supports emergent vegetation. It is replaced in successively shallower water by other bulrush species (*Scirpus olneyi*, *S. maritimus*, *S. neuadensis*). Associated species include alkali saltgrass and graceful arrow grass (*Triglochin concinnum* var. *debile*).

Birds are the best documented animals at Harney Lake. Observations in the Malheur area began in the 1870's, and annual censuses have been carried out by the Refuge since the 1940's. Although Harney Lake is limited in diversity of habitat and extent of wetland, many birds are permanent or transient residents, including some not commonly found in wetter parts of the Refuge. Harney Lake is an important nesting and resting area for migratory birds; nesting is almost exclusively limited to shorebirds. The vast expanse of open water protects a set of sand islands from coyotes and other predators, particularly in wet years. These protected nesting areas and an abundant invertebrate food supply are critical to the breeding success of Caspian terns (*Sterna caspia*), snowy plovers (*Charadrius alexandrinus*), and other species that favor more open nest sites. When water is present, Harney Lake continues to be an important resting area for thousands of ducks and geese during spring and fall migration. Since the mid-1960's, the lake has not filled as often. Factors involved include diversion of water, groundwater withdrawal, changes in the bottom topography of Malheur Lake, and drier weather patterns. Effects of the lower supply of water are not well understood but may include lowered nesting success of the above species and shifts of some migratory species, to other areas in the Pacific flyway."

Stinking Lake

Stinking Lake is a small, spring-fed alkaline lake. The lake is associated with a variety of salt desert plant communities composed of phreatophytes like black greasewood, shadscale, spiny hopsedge, alkali saltgrass and sea-blite. The lake is used by migratory shorebirds including American avocet, Wilson's phalarope, willet, and western sandpiper. The lake supports a speckled dace that appears to differ from other described dace and an isolated species of crayfish (*Pacifastus gambeli connectens)* (Copeland and Greene, , (Stinking Lake Research Natural Area, Supplement No. 12 (1982), available here (visited 11-11-2020) (http://www.fsl.orst.edu/rna/Documents/publications/stinking%20lake%20rna%20pub280.pdf). It is designated as a federal Research Natural Area:

"The Stinking Lake Research Natural Area (RNA) was established on March 4, 1975, to preserve an example of a small, spring-fed alkaline lake in southeast Oregon and the associated high desert vegetation and wildlife (fig. SL-1). Important natural features receiving protection include a variety of salt desert plant communities, a permanent cold spring and associated wetlands, and a large number of birds and small mammals. Of the numerous species of migratory and resident birds, 20 are listed as rare, threatened, or endangered. These include Swainson's hawks, golden eagles, prairie falcons, long-billed curlews and greater sandhill cranes." (*Id.*).

Fish Lake (text from Johnson et al., 1985)

Fish Lake is a small, remote alpine lake located high on the west slope of Steens Mountain in southeast Oregon. Steens Mountain was heavily glaciated during the Pleistocene Epoch and the landscape at higher elevations clearly shows the imprint of this activity. Several small lakes, of which Fish Lake is the largest, exist in depressions scoured out by the ice. The depressions are closed at their lower ends by glacial moraines, which impounded surface runoff to form the lakes. Fish Lake thus sits at the head of Fish Lake Valley, a classic U—shaped glacial trough. Its small drainage basin is relatively undisturbed and covered with alpine grasses and deciduous trees. Although it is only 16 acres in size, Fish Lake is nevertheless the largest mountain lake in the entire Malheur Lake Basin and for this reason attracts fishers and campers from a large area. The surrounding landscape is a semi-arid rangeland for the most part, although the valley floor south of the lake and most of the shoreline consists of marsh area.

The lake basin has a simple oval shape, and the greatest depth (30 feet) is located near the center. It is well sheltered from the wind and the water develops a pronounced thermal stratification. When visited in the summer of 1982, it was observed that the surface water was sufficiently transparent for light to penetrate below the thermocline, resulting in significant plant growth and a mild oxygen supersaturation in the hypolimnion. In other years, surface blooms of algae have reduced water transparency and there has been a corresponding oxygen deficit in the hypolimnion. This variation in the oxygen concentration in the hypolimnion is somewhat surprising for a lake located in an alpine setting. The concentrations of phosphorus and chlorophyll are also higher than would be expected.

Other Bodies of Water

Chickahominy Reservoir (text from Johnson et al., 1985)

Chickahominy Reservoir (also known as Clusters Lake) was created during 1951 and 1952 by the construction of a dam on Chickahominy Creek. It was built with private funds to provide storage of irrigation water for the Silver Creek Ranch. However, as of 1970 the reservoir had never filled to capacity and it proved to be inadequate for its intended purpose. It has since been obtained by the Oregon Department of Fish and Wildlife for sport fishing, and has developed into one of the best fisheries in southeastern Oregon.

the reservoir is shallow with a maximum depth at full pool of only 28 feet. Bottom material is composed primarily of silt, lava rock, and detritus from decaying vegetation. The concentrations of ions are above average for Oregon lakes, because of the arid climate of the area. During summer, surface water pH rises and sometimes exceeds 8.5. During mid to late summer surface water temperatures become quite warm. There is some growth of macrophytes in the shallow areas, and the reservoir contains some submerged and decaying sagebrush. Frequent blooms of planktonic algae occur during the summer, including species of blue-green algae, and there are reports of occasional winter fish kills owing to oxygen depletion after the die off of the planktonic algae and submerged macrophytes. The reservoir is in fact quite eutrophic, with high phosphorus concentration and limited water transparency.

Delintment Lake (text from Johnson et al., 1985)

Delintment Lake is a small artificial lake located on Delintment Creek, a tributary to Silver Creek in the northwest part of the Malheur Lake Drainage Basin. The site of the lake was originally beaver ponds surrounded by an open pine forest. It was improved by the Forest Service in 1940 to create a 35 acre lake, 12 feet deep, to be used for recreation. In 1953 it was further improved and enlarged to its present size by the cooperative effort of local interest groups. Surface runoff into the lake is intermittent, and from an area of about 1.2 square miles; on occasion water is diverted into the lake from a nearby stream.

Although it is shallow, Delintment Lake sometimes develops a thermal stratification. The concentration of ions is somewhat above average for the state as a whole, but typical of reservoirs east of the Cascades. However, the lake does have a history of water quality problems. The concentration of phosphorus is high and stimulates the growth of phytoplankton and macrophytes, which now cover most of the muddy bottom. Water transparency is average (8.9 feet; 2.7 m) and chlorophyl concentrations are moderately high. Based upon the concentration of phosphorus and the extensive growth of macrophytes, the lake is classified as eutrophic.

Water Storage Rights

There are water rights for a significant amount of water storage in the basin. The current estimate of total volume of water legally allowed to be stored annually within each sub-basin is nearly 41,350 acre feet (Table 6).

Table 6: Estimate of total volume of water legally allowed to be stored annually (OWRD, 2019)

Sub-basin (HUC-8)	Total Volume of Permitted Storage (ac-ft)
Silver	21,333

Harney-Malheur Lakes	9,904
Donner und Blitzen	9,241
Silvies	871
Total	**41,349**

Other Bodies of Water

Little is known or documented about other bodies of water in the basin. The following (Table 7) is an incomplete list of lakes and named impounded sites by Subbasin. The names come from the National Hydrographic database. The distinction between lakes, ponds and reservoirs may not be clear or distinct. These aquatic features are predominantly ephemeral holding water in the spring but drying during the summer.

Table 7: List of Lakes Reservoirs and Ponds from National Hydrographic Mapping

Subbasin	**Water Feature**		
	Lakes	Reservoirs	Ponds
Silvies River	Batts Camp, Lunch, Albert, Frank Schmidt, Twin, Buffalo, Yellowjacket (7)	Campbell, Halfway, Carter, Erenos, Umbrella Pine, Juniper Spring, Cherry Spring, Arntz, West Willow Creek, Shoeffer, Charley Creek, Green Flat, Clemens Spring, East Horton Basin, Panel Spring, Rocky Road, Juniper, Horse Spring, Dead End, West Bassout, Four Deer, Skull, Dry Gulch, Willow, Buck Spring, Emigrant, Dead Mule, Beaver Dam, Smith, Gunther, Divide, Larraneta, Upper West Fork, C7, Baker, Bull Run (36)	Hines Mill
Silver Creek	Delintment, Sheep, Hay, Blowhole, Yellowstone, China, Evening, Ryegrass, Boundary, Cream, Black, Rock, Dusenberry, Umbrite, Tyler, Cote, Hughet, Silver, Stinking, Derrick, Wolter, Upper Goose Egg, Lower Goose Egg, Old Jims, Little Ridge, Flynn, Flybee, Green,	Chickahominy, Camas, Mill, Sawmill Number One, Rough Creek, Dry Dam, Twin Springs, Roadside, Dry Mountain, Twin, Zoglmann, Box Spring, Bentonite, Powerline, Upper Rock Quarry Canyon, Sagehen Hill, Potato Hill, West Butte, Rock Bottom, Bunch Grass, Moon, Carvix, Antelope, Horseshoe, Palomino Rim, Snow Storm, Fry Canyon, Manoeuver	Windmill

	Deep, Meadow, Junction, Foster, Camel, Buckskin, Leary, Prentiss, Moon, Haines, Dry, Buzzard, Chicken Feed, Wash Pan, Deep Canyon (43)	Road, Wheatgrass, Rocky Draw, North Sheep Mountain, Lone Tree, Spring Canyon, Shroder, Little Juniper, Settlement, Goose Egg, Stormy, Sandy Bed, Three Forks, Prospectors, Stovepipe, Wildhorse Lake, North Wilson, Con, Pickett Spring, Alex Spring, Campbell, Stud Horse, Yellow Spot (51)	
Malheur –Harney	Bennett, Howell, Palomino, West Chain, East Chain, Chain, South Chain, Weaver, One O' Clock, Weed, Marter, Lone Treer, Antelope, Irish, Barton, White, Road (18)	Armstrong Canyon, Mortimer Canyon, Upper Jones Canyon, Cow Creek Road, Lower Jones Canyon, Corcoran, Steer Ridge, Angle, Big Spring, Crowcamp, Rock Hill, Rector, Crane Creek, Aspen, Oron Thompson, Lookout Butte, Cheatgrass, Teddy Springs, Basco Springs, Long Canyon, Two Forks , Rocky Hole, Horseshoe, Upper Butler, Second Lake, Lower Walker, Middle Butler, Dunn, Lower Butler, Little Antelope, Little Jack Creek, Jack Creek, Coyote, Lower Herlihy, New Hole, Twin Road, Upper Herlihy, Upper Hawkins, Bed Ground, Black Rim, Monument, Dry Lake, Smythe (43)	
Blitzen River	Buena Vista, Baca, Fish, Ham Brown, Corral, Lily, Fate, Frazier, Fivemile, Peanut, Honeymoon, Lost (12)	Krumbo, Kern, Bird Fence 1 & 2, Sagehen, Antelope, Gil Thompson, Thompson, Krumbo Mountain, Moon Hill, Whiskey Creek, Basin, Del Witzel, Lower Road, East Rim, End, Bridge Creek 1 & 2, Butte Creek, Frazier Field, Rock Creek, Tombstone, Fred Riddles, Horse Creek (24)	Knox, Unit Nine,

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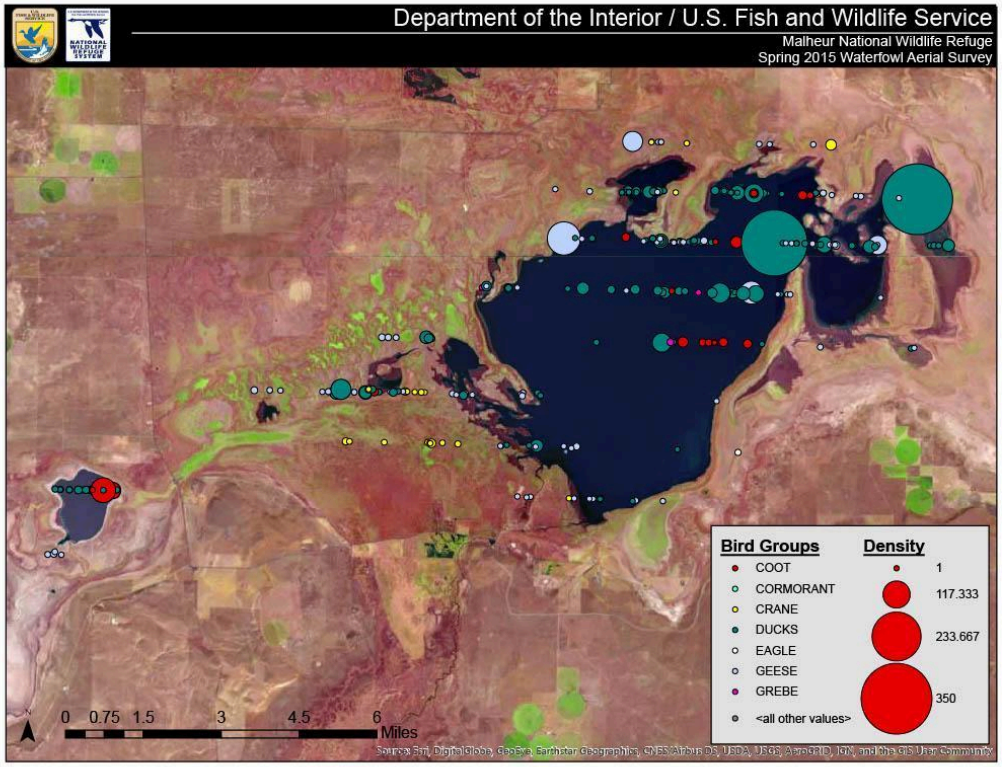
Attachment A

Waterbird Use of Malheur Refuge 2015



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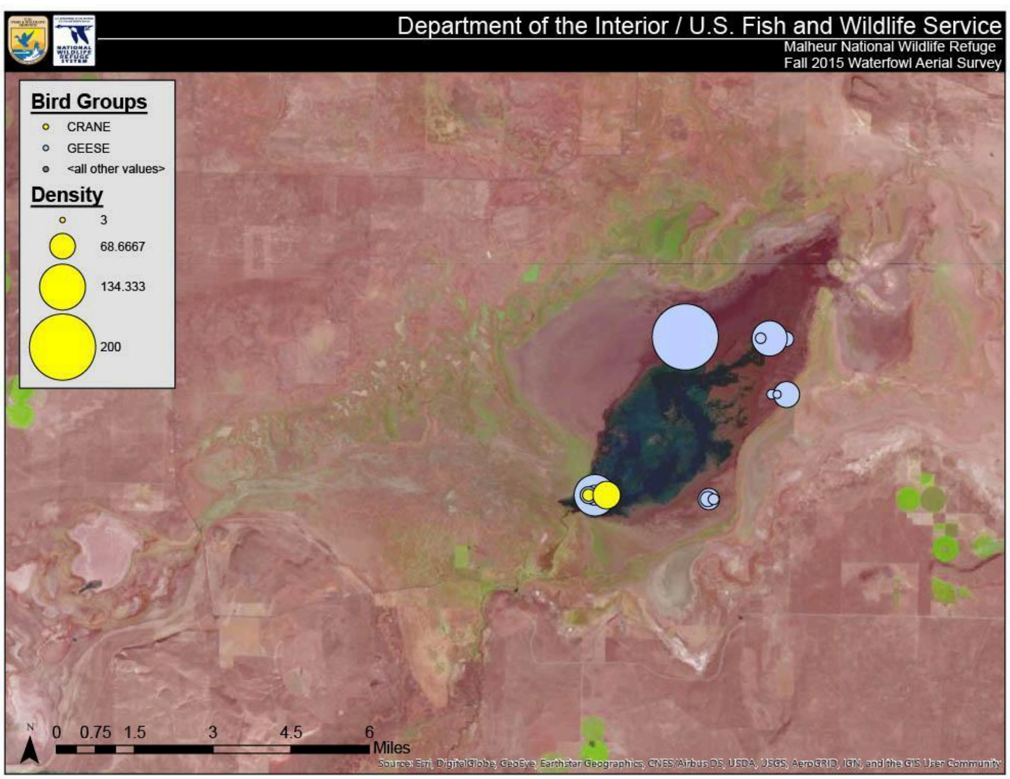
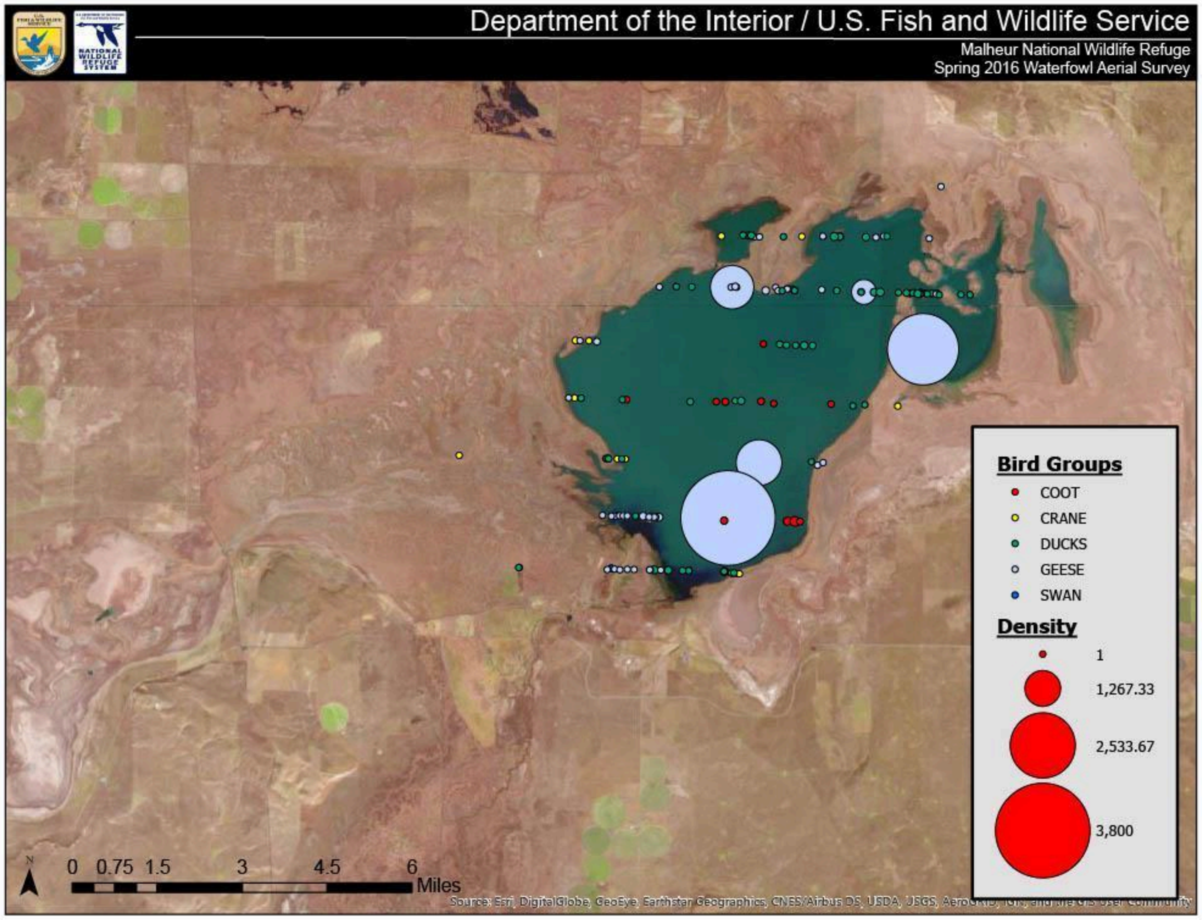


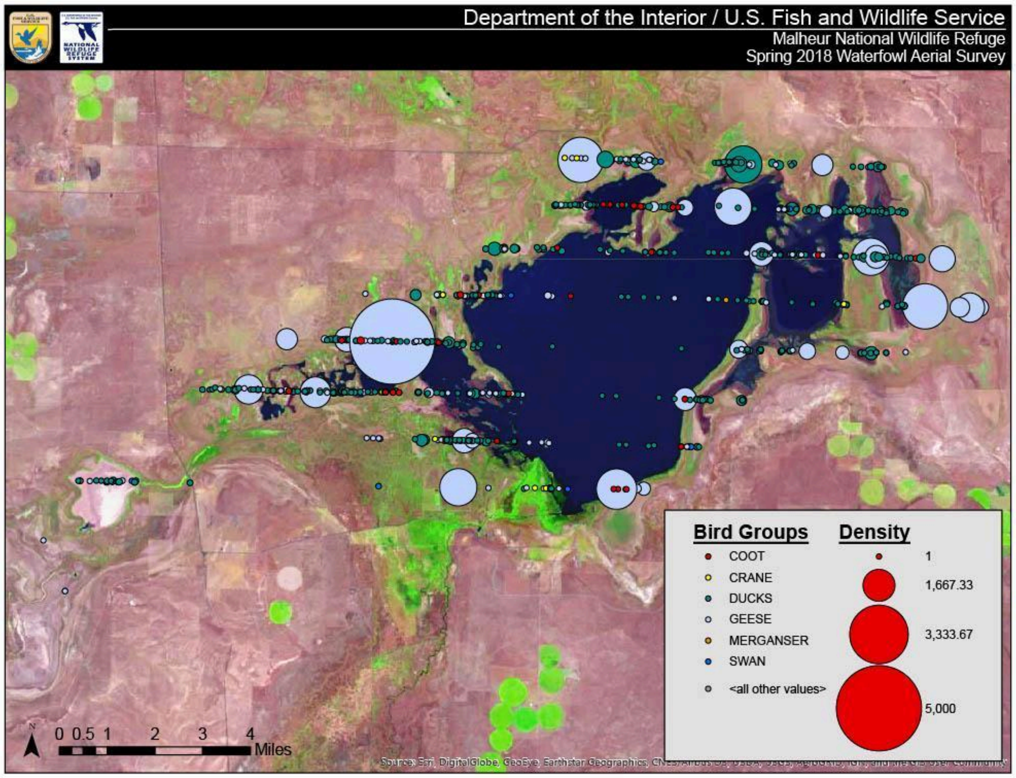
Attachment A

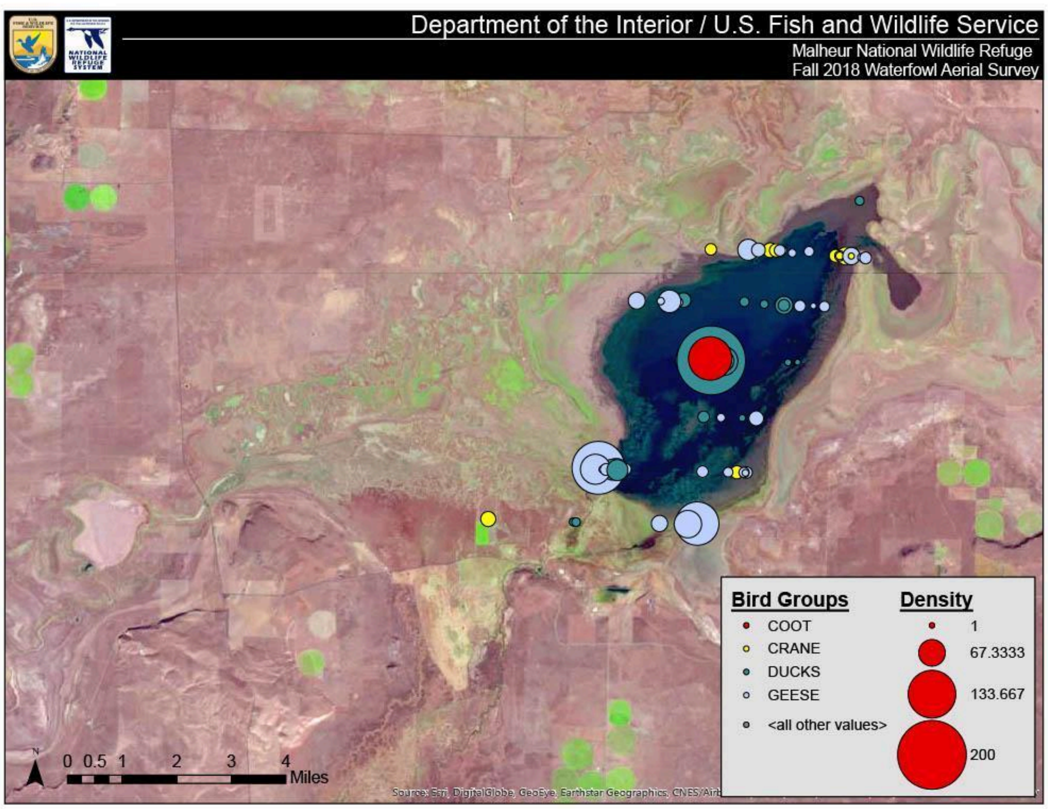
Waterbird Use of Malheur Refuge 2016 (Spring only)



Attachment A

Waterbird Use of Malheur Refuge 2018





Waterbird Use of Malheur Refuge 2019 (Spring)