V. Background

An ecosystem is comprised of life forms (plants, animals, bacteria, protozoans, and fungi), as well as the physical and chemical processes and characteristics of the environment. Ecology is the study of the interactions and interdependencies of all these components. Lakeside residents and the managers of these lakes require knowledge of the ecosystem and ecological processes occurring within the region for their management actions to be successful and not result in undesirable consequences.

Lakes are classified by how much eutrophication has occurred. Over time they will progress through the following stages or trophic states: oligotrophic, mesotrophic, eutrophic, and hypereutrophic. The term *trophic* comes from the Greek *trophe,* meaning "food or nourishment"; therefore the classes describe the amount of food (typically called productivity) in the lake. An oligotrophic (poorly-nourished) lake is characterized by low plant productivity and clear water with high visibility. Conversely, murky water, unpleasant odor, and an abundance of aquatic plants and algae are the indicators of a eutrophic or hypereutrophic lake. All lakes fall somewhere within this spectrum, and determining which trophic state a lake is experiencing is the first step in studying its ecosystem.

Lake Habitats and Food webs

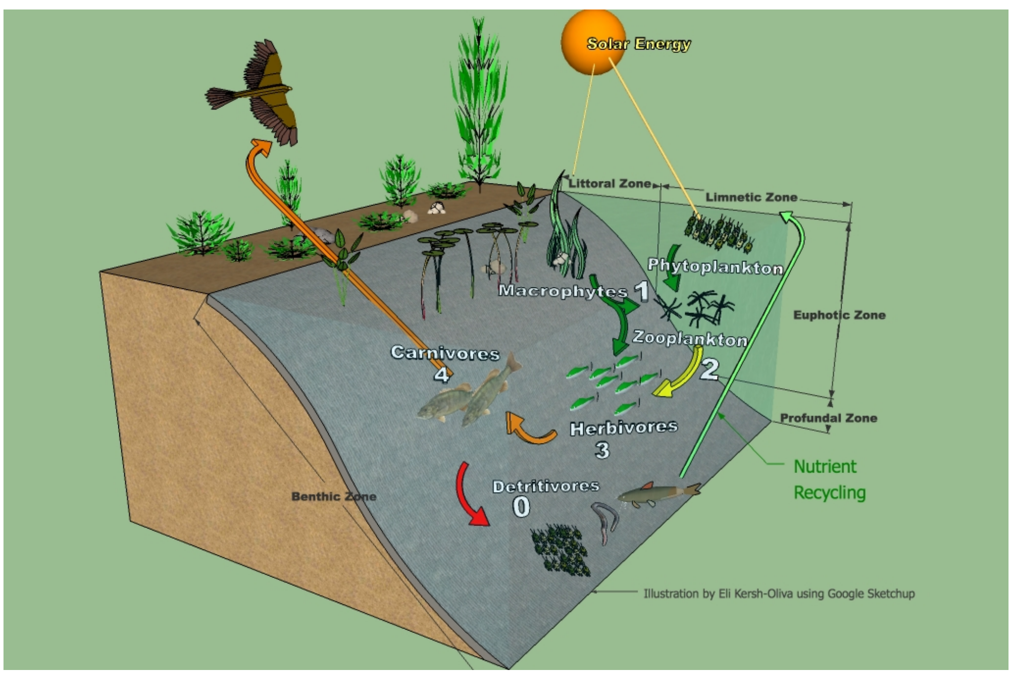


Figure 1: Food web and lake zone classifications.

The biological structure of a lake is directly tied to its physical characteristics. The type and abundance of plants and animals vary with respect to several features, including the shape and depth of a lake as well as its photic depth (the depth to which sunlight can penetrate).

The area along the shores of a lake where the photic depth reaches all the way to the bottom is called the littoral zone. The open water in the center of the lake, beyond the littoral zone is called the limnetic zone. This region is further divided into two portions; the upper portion where sunlight is present is the euphotic zone, and the lower portion is the profundal zone, extending to the bottom of the lake. The bottom is called the benthic zone; it extends several inches into the sediment (Figure 1).

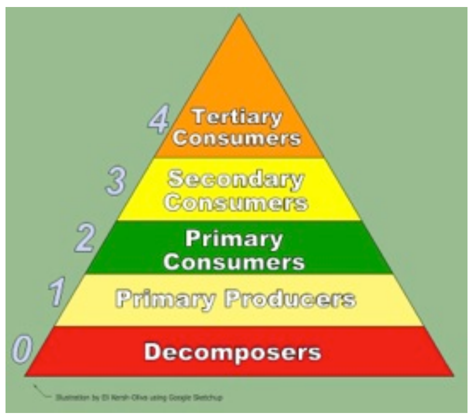


Figure 2: Trophic Pyramid

Each of these zones has very specific biota (life forms) that have evolved to survive in them, and all of these organisms have specific and important roles to play in the food pyramid that supports all the life in the lake (Figure 2). Phytoplankton, photosynthesizing microscopic organisms, float freely in the littoral and euphotic zones. They are autotrophs, which means they produce their own food. They create their energy via photosynthesis and constitute the base of the food pyramid (the first trophic level). They are called the primary producers; in aquatic environments the primary producers are algae, macrophytes (aquatic plants), and cyanobacteria (blue-green algae).

The primary producers are eaten by primary consumers - the second trophic level - these small herbivores include microscopic zooplankton, snails and some tiny fish. Secondary consumers - the third trophic level - are herbivores and planktivores such as aquatic insects, predatory zooplankton, and small fish. They in turn provide the food source for tertiary consumers such as piscivores (fish-eating fish) and fish-eating birds and other carnivores. The last members in the food chain are the decomposers and detritivores that reside in the profundal and benthic zones – they feed on all levels of the food chain. These are catfish, scavengers, fungi and bacteria. They play a vital role in breaking down the dead plant and animal material, recycling it to be reused by the primary producers. In a healthy ecosystem only a small amount of organic matter will actually accumulate as sediment on the bottom (Holdren et al., 2001).

Each time an organism is consumed, it transfers 10% to 20% of its energy up the chain, therefore a tertiary consumer such as a carnivorous fish depends on a large supply of smaller animals, which, in turn, depend upon an even larger supply of biological material for their food source (Holdren et al., 2001). This description of the food chain is a generalization of the diverse set of feeding interactions and the recycling of nutrients, referred to as the food web. Increases or decreases in the abundance of any organism in the web will reverberate throughout; leading to successive increases or decreases in available energy and nutrients.

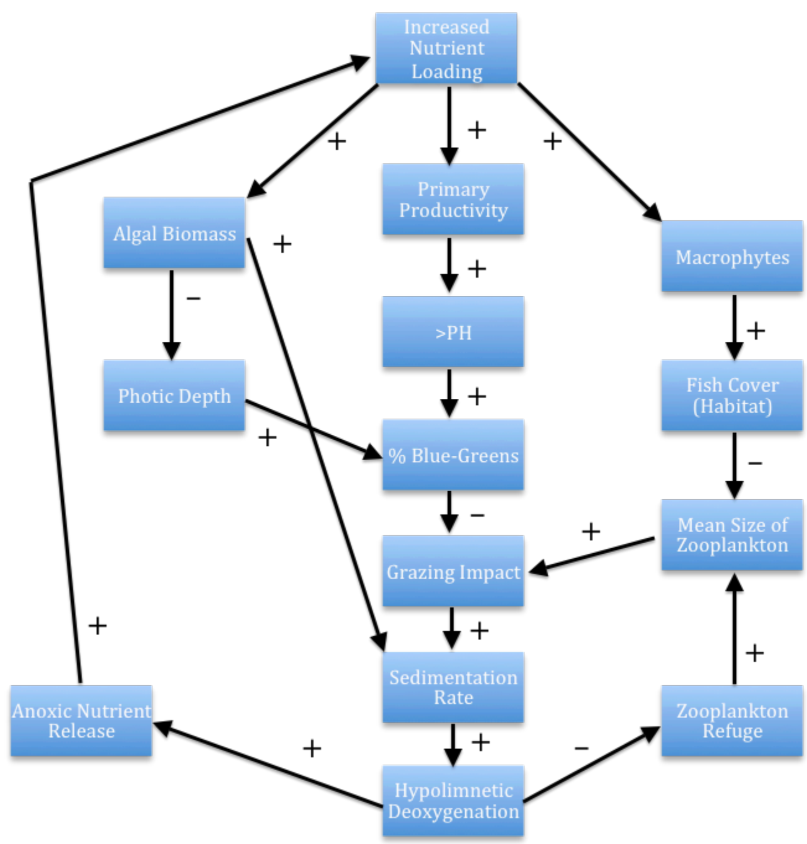
Chemical and Physical Interactions Within Lake Ecosystems

Figure 3 illustrates that predation is not the only phenomenon that impacts the food web. An increase in nutrient loading (i.e. forms of nitrogen and phosphorus) will boost primary productivity in the form of algal biomass and macrophytes. Their intensified growth will in turn directly impact the chemical and physical makeup of the ecosystem while increasing the food supply. Indirectly, these increases will affect the cycling of nutrients and ultimately influence eutrophication.

The chemical and physical properties of the water in a lake are also a result of the land from which they drain (the watershed). Watersheds extend to the highest points surrounding a waterbody; in the case of Emery Reservoir, these are the surrounding ridgelines indicated by the red dashed line on Map 3 – pg 24. As water flows over a watershed's surface as runoff or percolates through the soils, it interacts with all the components of the watershed. It weathers rocks, dissolving minerals and nutrients from them and the surrounding soils, ultimately transporting the material into the lake. One of the most important properties of water is that it is a solvent for a vast array of chemicals. About half of all natural elements dissolve in water, and almost all the nutrients required for living creatures are delivered to them dissolved in water (Holdren et al., 2001).

Although eutrophication is a natural process, human actions in the watershed often act as catalysts. Gardening fertilizers, manure, increasing erosion from development, and a plethora of other substances in the watershed will ultimately end up as runoff into the lake. Thus the constituents of the water in a lake are a direct result of the components that make up the watershed.

Lake managers trying to address aquatic plant growth must be aware of the interdependencies within and around the lake. Short-term or long-term management plans with a focus on recreational use of a lake still need to recognize the importance of supporting the existing aquatic species and wildlife in order to maintain a *healthy* and *clean* lake. Native aquatic plant communities are a necessary part of aquatic ecosystems; they provide food, shelter, and nesting sites, reduce erosion by stabilizing shorelines, and cycle nutrients in the ecosystem. Perhaps most importantly, aquatic plants are necessary to improve water clarity by competing with phytoplankton for nutrients (Gibbons et al., 1999).



A plus (+) indicates a positive influence.
A minus (-) indicates a negative influence.
Illustration adapted from Managing Lakes and Reservoirs, Holdren et al. 2001

Figure 3: Chemical and physical interactions within lakes.

Lake Turnover

Turnover occures when the warm water that floats above the thermocline begins to cool and sink to the bottom (Figure 4). Typically, this happens during the first cold spell in fall. As it sinks, it diminishes the thermocline and allows for the entire water column to circulate (turn over). Throughout the growing season, the decomposers use up much of the dissolved oxygen in the benthic and profundal zones, which can develop into anoxic conditions (low amounts of dissolved oxygen). The cooler, denser, oxygen-depleted water may also have high levels of nutrients, methane, and hydrogen sulfide produced by the decomposition of organic sediments. This bottom water can be lethal to fish and as the water turns over it may cause fish-kills as it rises back up through the water column (Phillips et al., 2000).

Figure 4: Lake turnover

The presence or lack of a thermocline in Emery Reservoir would indicate whether or not lake turnover would occure, or if dissolved oxygen and other constituents are distributed through the year possibly due to some other cause such as the continuous mixing of the water by the wind.

VI. Results

The geography, climate and land use patterns of a region play a large role in determining the characteristics of their water bodies. To gain an understanding of how the land has influenced the reservoir over the last 160 years, this section will review several aspects of the Emery Reservoir such as its land use history, the physical features of the reservoir and its watershed, and the prevailing climate and weather patterns of the immediate region.

History of Land Uses Surrounding Emery Reservoir

According the California Department of Water Resources, Division of Safety of Dams' website, Emery Dam was built in 1850. Over the last 164 years the owners' uses of the reservoir and surrounding property have changed several times. Only for the last fifty-five years has it been used for residential purposes. The Calaveras County Archives contain documents showing the property was originally referred to as Pillsbury's Reservoir, named for the first owner of record, Daniel Hackett Pillsbury. Pillsbury used the property for his dairy farm operation and purveyed surplus water to nearby communities.

Although the name Emery Reservoir was not attributed to the reservoir until the 1960s, it can be traced back to the Emery Gold & Water Company, which purchased the land in 1898. In 1901 the company improved the dam and built a pipeline in order to supply water for mining activity in the region (Alberts, 1967). During this time the surrounding properties were designated as quartz mine claims; several mineshafts still exist throughout the watershed.

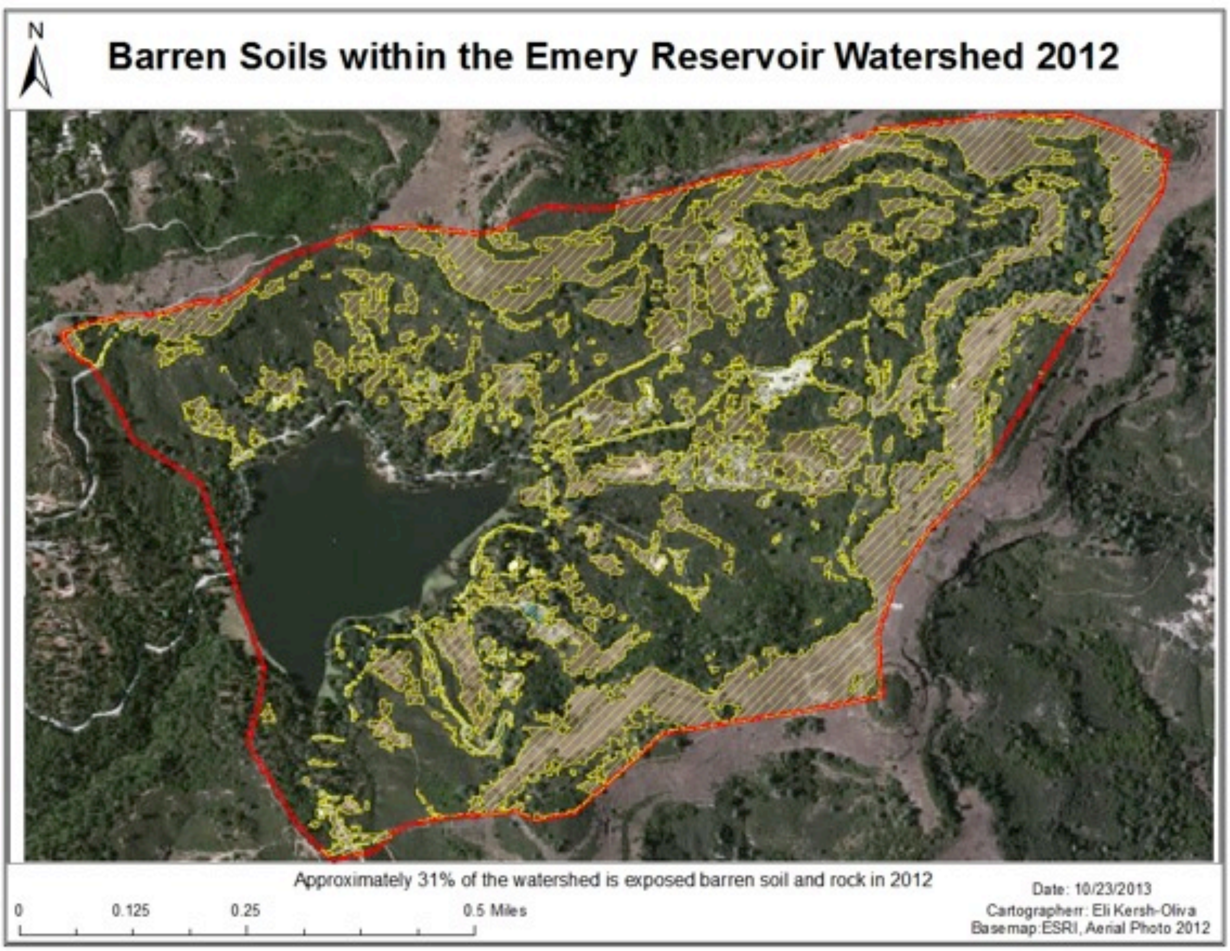
Dam constructed	1850
First recorded owner of property: Daniel Hacket Pilsbury	1861
Great flood, Pillsbury Dam Failure	1862
Emery Gold & Water Company builds pipeline	1898
Reported sightings of "lillypad like plants" by lake visitors	1940 - 1947
New owner closes the Reservoir to public and raises the dam	1948
Property Subdevided and incorporated as M-24 Ranch Asssociation	1965
Second Dam Failure	1966
Dam rebuiding begins	1968
Gulch Fire, suspected source of watershield	1993
Some Mechanical Harvesting and Herbicide Usage	1995-2001
Creation of Lake Action Committee. LAC requests for proposals and installs Solar Bee	2002-2004
Some Mechanical Harvesting & Hand Pulling	2004-2006
Clean bucket extraction of silt and plants	2007
Some Mechanical Harvesting and Herbicide Usage	2008-2010
Systematic Herbicide Application Program Implemented by Volunteer Residents	2012
Limited Regrowth Suggests Successful Supressesion of Watershield	2013

Table 1: Emery Reservoir timeline

USGS topo maps made during the 1940s attribute the name Brown's Lake to the reservoir, and local residents from nearby towns still know it by this name, although it is unclear from whom this name is derived. During this time the reservoir was open to the public as a popular picnic spot and swimming hole for nearby locals. The property was reportedly used as a cattle ranch, and the water from the reservoir was used for irrigation on adjacent properties. In 1948 a new owner purchased the property and reportedly raised the dam. Soon afterwards it was closed to the public, until 1965, when the property was subdivided and sold off. Table 1 highlights some of the major events in the history of Emery Reservoir.

Geography

The earthen dam that created Emery Reservoir lies at the mouth of a small box canyon and impounds the flow of McKinney's Creek, an ephemeral creek whose headwaters emerge from within the canyon. This canyon is a little over a mile long, three-quarters of a mile wide at its widest point, and it comprises the entire watershed that feeds Emery Reservoir.



Map 3: Barren Soil in Emery Reservoir's watershed, 2012

The canyon lies within an ecotone (*transitional zone*) between two terrestrial biomes; biome is a term for classifying ecosystems based on specific and similar animal and plant communities (Christopherson, 2012). Specifically, it is between the Mediterranean Shrub-land (MSh) - commonly referred to in California as Chaparral - and the Montane forest (Mf). The dominant vegetation in the watershed is *sclerophyllous* (meaning hard-leaves). It is comprised of manzanita, toyon, chamise and ceanothus, all of which are indicative of the Chaparral biome, however, the hillsides also contain the indicator tree species of a montane forest such as Ponderosa Pine, California Black Oak, and Sugar Pines (Olsen et al., 2001).

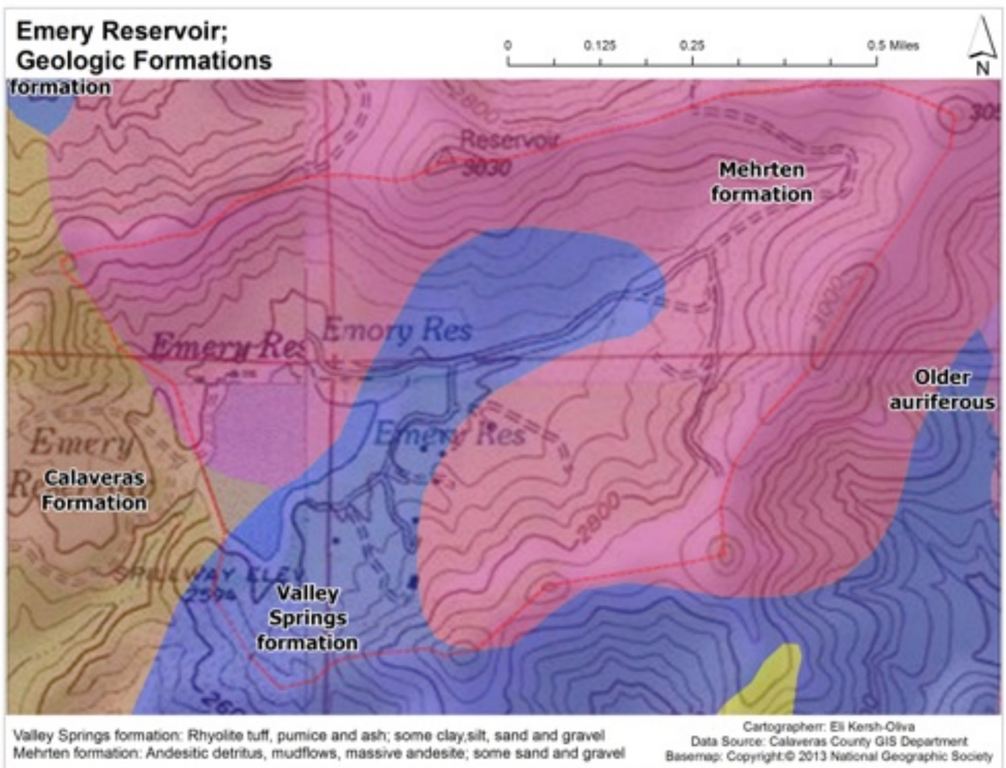
The watershed has significant amount of barren soil and exposed bedrock. Prior to 1965, there had been no permanent structures built within the watershed. As of 2012 there were 108 parcels that made up the M-24 Ranch Association, 38 of which were within the watershed of the reservoir and approximately 20 of those contained at least one permanent structure. Much of the exposed soil is surrounding the development of housing pads and roads within the watershed.

Geology

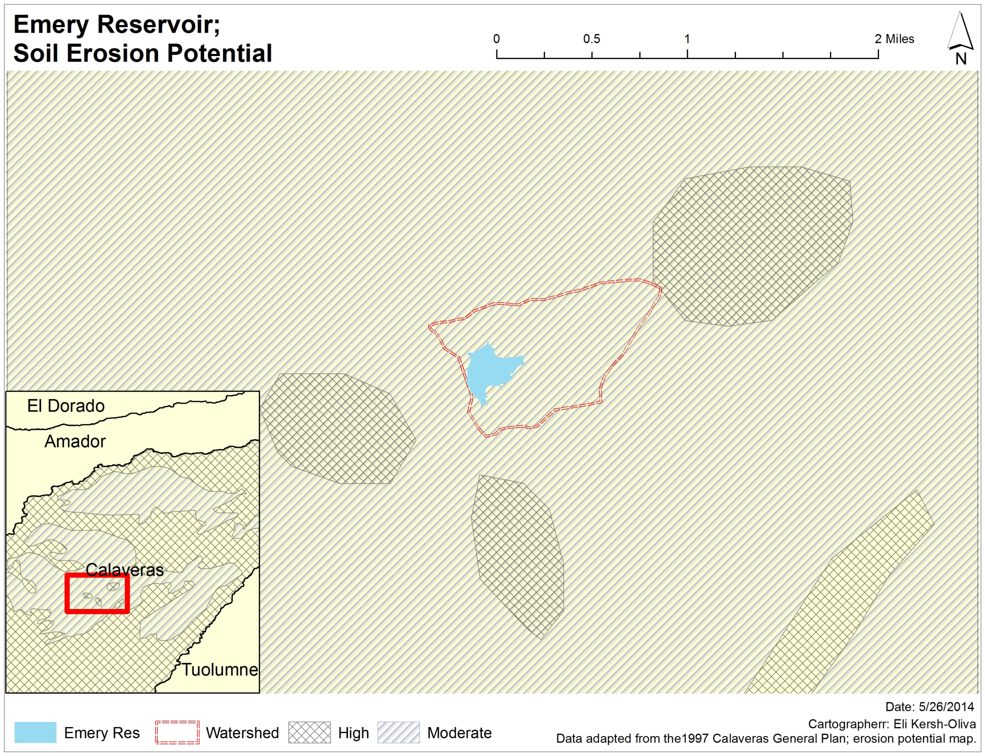
The geologic makeup of this region is divided into two major groups: the bedrock series – metamorphic rocks of the Paleozoic and Mesozoic age – with intrusive rocks of the Mesozoic age 66 to 250 mya (million years ago); and the superadjacent series (overlaying) of sedimentary and volcanic rocks of the Tertiary age between 2 and 65 mya (Clark and Lydon, 1962).

The watershed's topsoil consists of the latter series and is classified as the Mehrten and Valley Springs geologic formations, which formed during the early to mid-Pliocene and late Miocene Epochs (2 to 24 mya) (Map 4 – pg 26). The result is a landscape of vertical sandstone cliffs that surround the reservoir at the higher elevations (Picture 5), with shales, alluvial deposits and conglomerates forming the lower portion of the hillsides that extend down to the reservoir (Arkley, 2009). These deposits consist primarily of rock and soil whose parent material is volcanic in origin and high in mineral and nutrient content (Fisher et. al., 1997).

Picture 5: Sandstone cliffs surrounding Emery Reservoir



Map 4: Geologic Formations of Emery Reservoirs Watershed



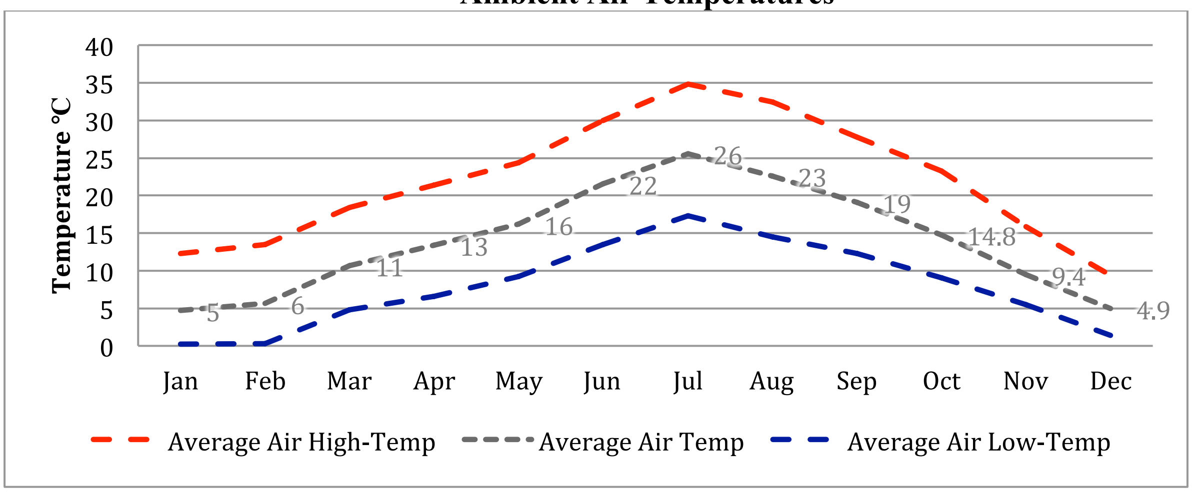
Map 5: Erosion Potential

Due to the brittle and dissolvable nature of these materials, unlike the underlying bedrock, these formations are classified as having a moderate to high erosion potential (Map 5 – pg 28).

Climate & Weather

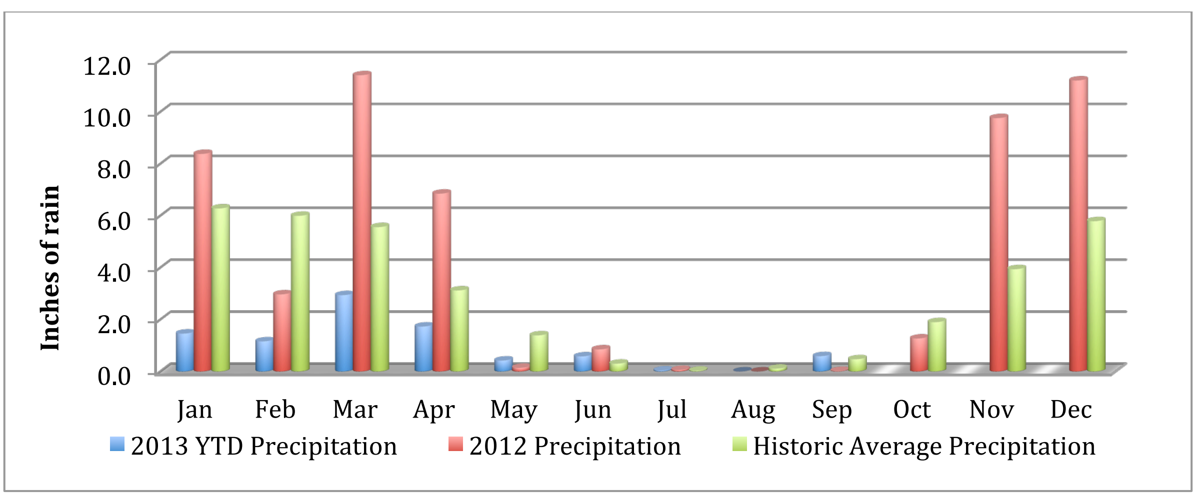
This region experiences a typical Mediterranean climate of hot, dry summers and cool, wet winters (Köppen climate classification, Csa). Typically, the warmest and driest month is July, the coolest month is December and the wettest month is January. The average annual precipitation is between 40 and 50 inches per year, approximately 50% of the rainfall occurs in winter, 30% in spring, 2% in summer and the remaining 18% in the fall.

Ambient Air Temperatures



Graph 1: Average annual temperature

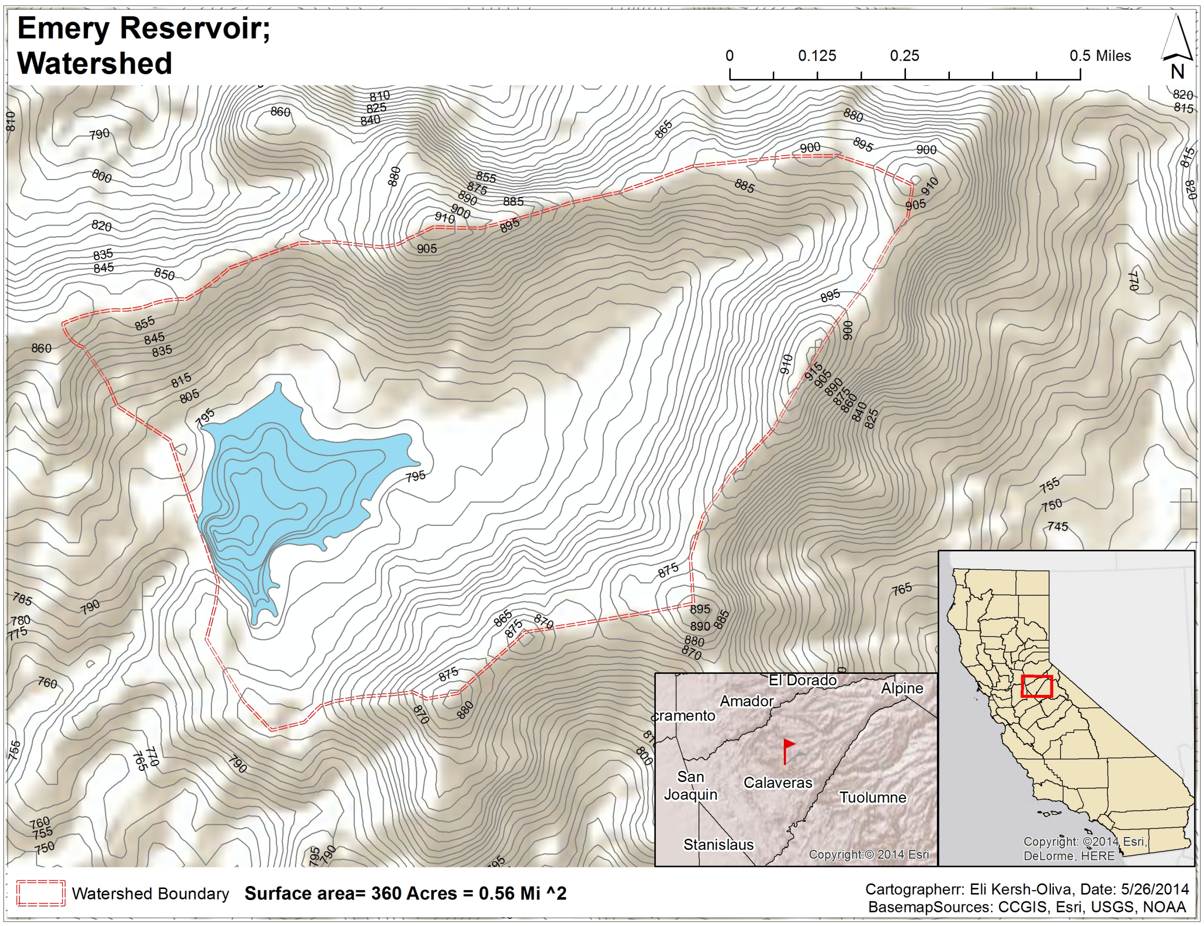
Precipitation: 2012, 2013 YTD, Average Annual



Graph 2: Average annual precipitation

Data obtained from Weather Station MESPC1, located within 1 mile of Emery

Residents assert there are underground springs that feed the lake, as suggested by their observations of localized variations in bottom water temperatures. However, it is not likely that springs flow year-round, rather only following periods of heavy rain. The level of the lake drops about 5 vertical feet over the course of the summer, lowering its volume by as much as 30%. This suggests that even if springs did flow year-round, their volume would be minimal, much less than water outputs due to evaporation and seepage. Water inputs into the lake are therefore likely primarily from surface runoff during the rainy season.



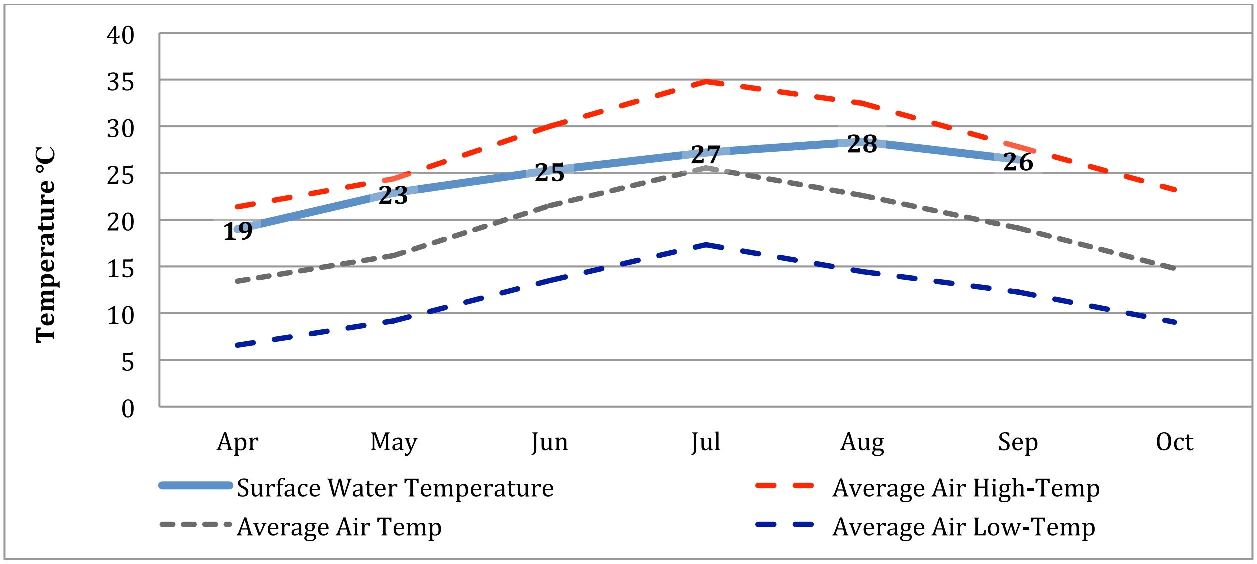
Map 6: Emery Reservoir Watershed

When at its typical spring-summer high level, the surface of Emery Reservoir is at an elevation of 2600 feet, with a surface area of 32-acres, a volume of 301 acre-feet, and an average depth of 8.7 feet (Appendix A). The drainage area of Emery Reservoir's watershed is approximately half of a square mile, which equates to ten times the surface area of the lake itself.

The ratio of drainage surface area to lake surface area between 7:1 and 10:1 is considered a large watershed (Holdren et al., 2001).

The reservoir's surface water temperature lags slightly behind that of the ambient air temperature but mimics the overall trend; the water's coolest recorded surface temperature was 18 °C (64°F) in March, and the highest was 28°C (83°F) in late August (Graph 3).

Ambient Air vs. Surface Water Temperature

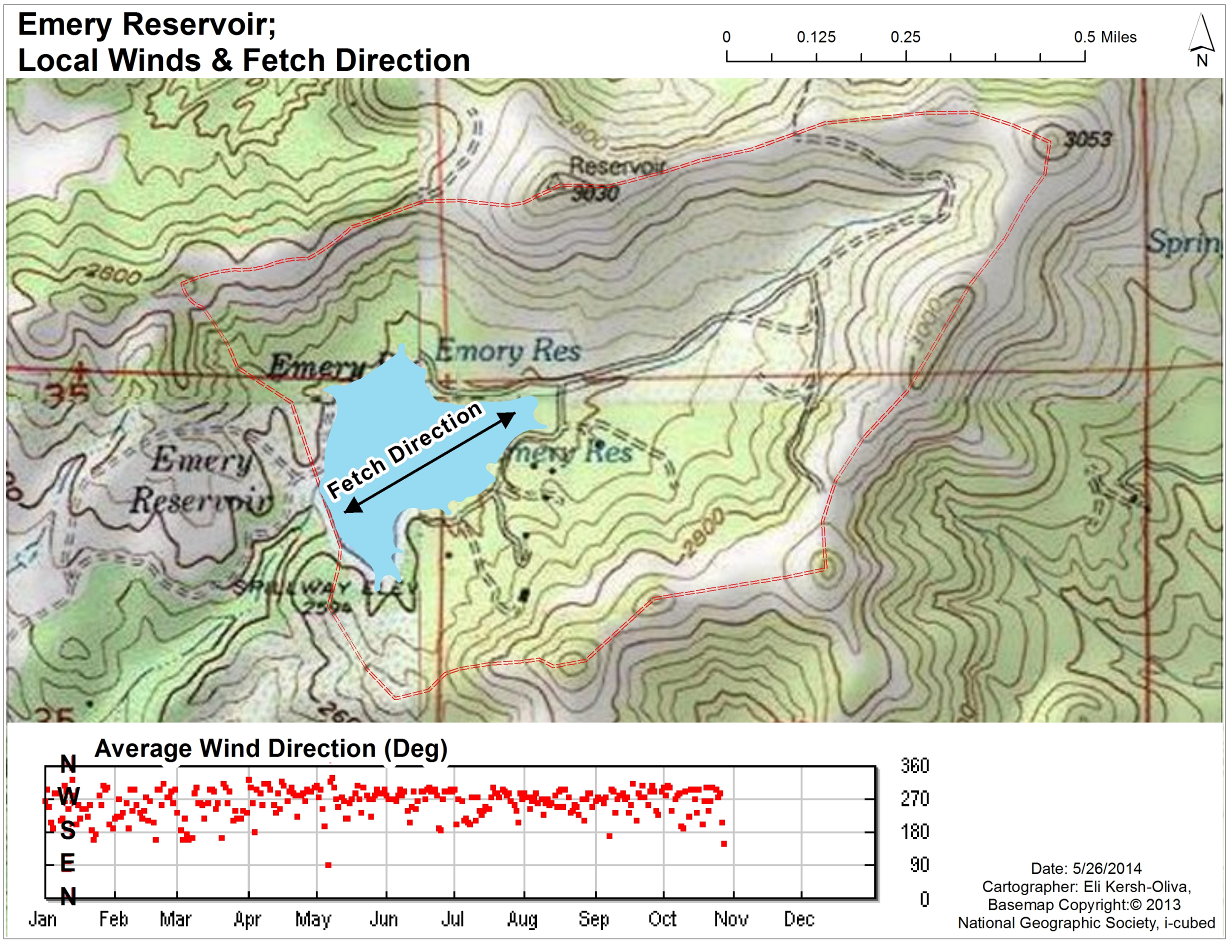


Graph 3: Ambient air and surface water temperatures

This relatively warm water in the summer months is in part due to the extensive shallow shoreline but is also influenced by the continual lateral and vertical circulation of the water column from the wind. Prevailing winds in this region blow from the west throughout most of the day, and shift to the south in the late afternoon (Map 7 – pg 31).

Within the watershed however, the wind behaves like mountain and valley breezes being channeled up the canyon to the northeast during the day as hot air rises, then reversing down the steep canyon in a southwesterly direction at night (Christopherson, 2012).

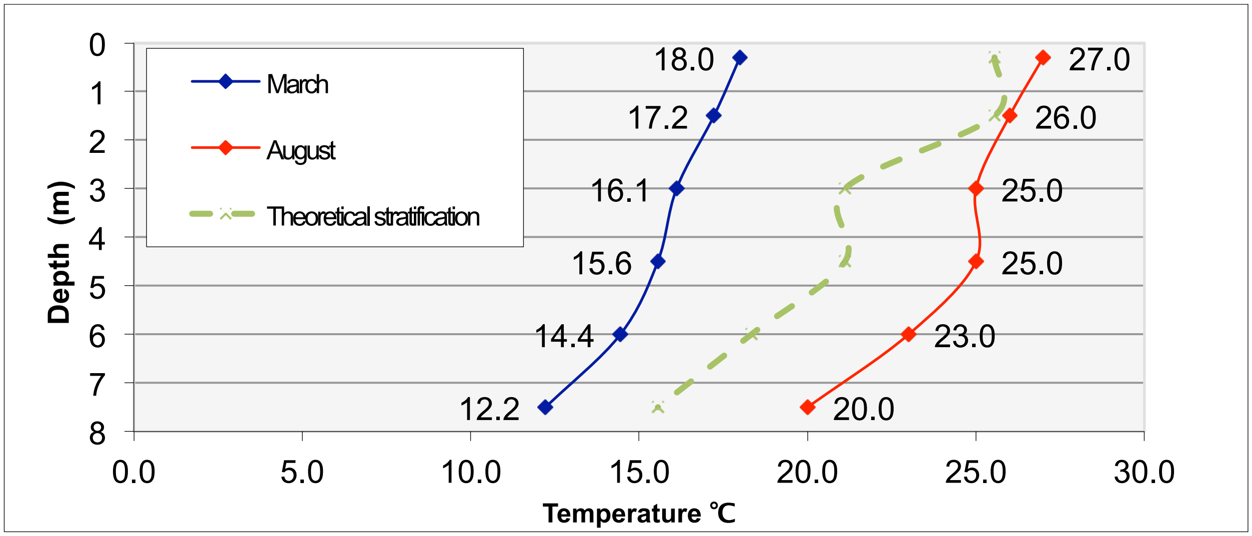
These winds blow across the longest axis of the lake thus creating a long fetch as illustrated by the black arrow in Map 7. The term fetch simply means the direction the wind pushes across the surface of a water body. As the wind disturbs the water's surface it acts to not only move the water laterally but to mix the water column vertically.



Map 7: Fetch Direction

The steady decline in the vertical temperature profile as seen in Graph 4 is likely a result of the combination of the shallowness of the lake and the long fetch. Vertical temperature profiles typically appear as a step-like line on a graph as it is depicted below by the green line. In a stratified lake the upper, warmer layer is separated from the cooler, lower layers by a thermocline. The thermocline is a layer of water that acts like a barrier, preventing the oxygen-rich surface water from mixing with the lower layer.

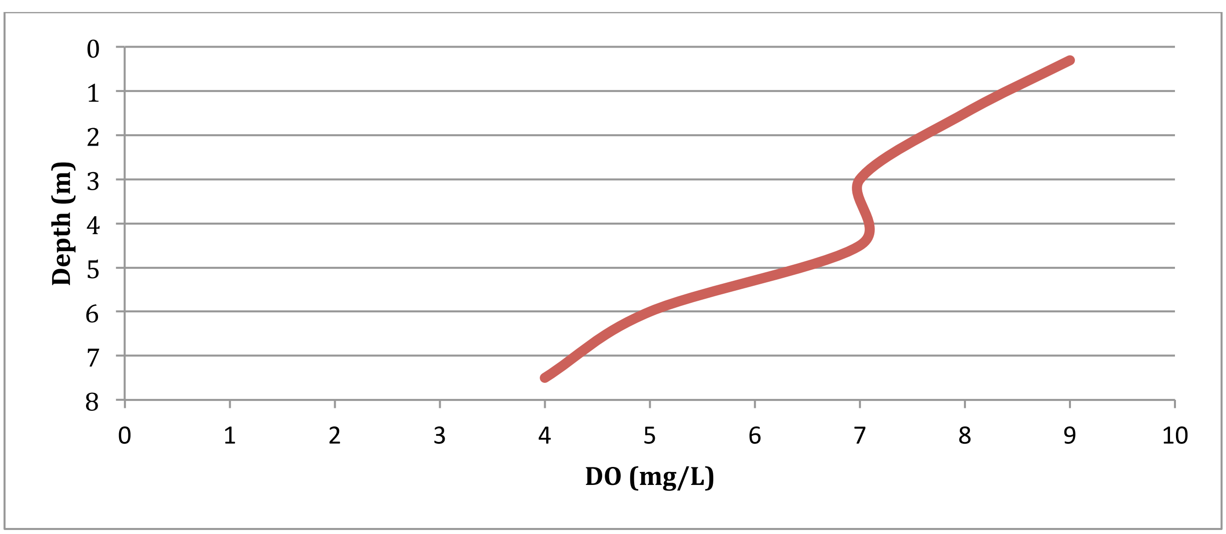
Vertical Temperature Profile



Graph 4: Vertical temperature profile

Graph 4 shows the gradual decline in temperature and a lack of thermal stratification in the waters of Emery Reservoir. This lack of a robust thermocline allows for the temperature to steadily decline, and allows for dissolved oxygen and nutrients to circulate through the lake. Measurements of dissolved oxygen (DO) in the reservoir show that there is a high level of DO at the bottom – enough to sustain most aquatic life (Graph 5). This high level of DO further indicates that there is significant vertical mixing within the reservoir.

Dissolved Oxygen at Depth



Graph 5: Dissolved oxygen depth profile

Determining Emery Reservoir's Trophic State

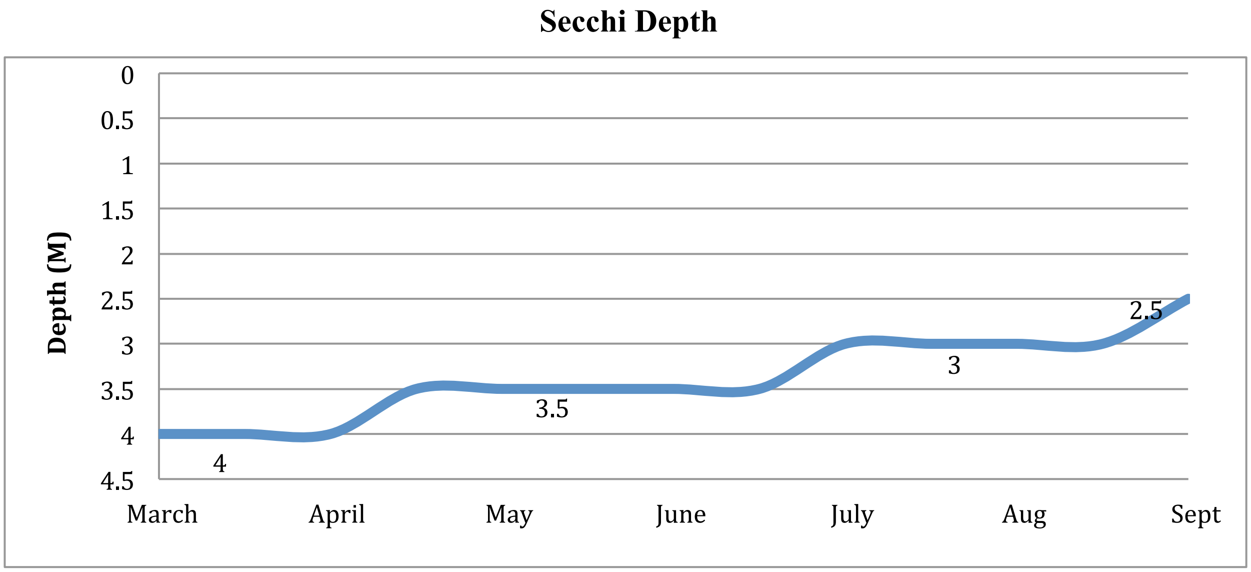
Quantitative data obtained from direct measurements of visibility and nutrient levels provided sufficient evidence to categorize Emery Reservoir as eutrophic. Technical analysis of erosion within the watershed suggests an increase in the rate of sedimentation over the last several decades. It is likely that these data are correlated, and that incremental increases in sedimentation year after year have been a significant source of eutrophication-causing nutrients.

The quantitative data for visibility and nutrient levels were assessed via Carlson's Trophic State Index (TSI). This index is a method for classifying lakes along the spectrum of eutrophication using a scale of 1 to 100. The index can be calculated using several water quality parameters; for this study, Secchi depth (SD) and total phosphorus (TP) measurements were used. There were no measurable levels of nitrogen in the water samples collected so it was not utilized in the calculation of the TSI number. These parameters are independent measures of eutrophication; they should not be averaged or combined in any way. Rather, they should be considered unique indicators to estimate eutrophication (Carlson, 1983).

The equations used in the creation of this index are widely used by limnologists throughout the United States. The coefficients used in the calculation of the index were constructed from data pertaining to the phosphorus-limited northern lakes of Minnesota, and therefore are not always an ideal fit for the nitrogen-limited lakes of the south, like Emery Reservoir (Holdren et al., 2001). Furthermore, the index does not account for the levels of phosphorous and nitrogen contained within the tissues of macrophytes in the lake. Therefore, the resulting numerical classification is open to some level of interpretation as it typically underestimates the trophic states of southern lakes (Gibbons et al, 2006). Despite the index's shortcomings, a better model has not yet been developed, and Carlson's index still provides valuable context for interpretation of the trophic state.

Quantitative Measurement of Visibility

The visibility of the water in Emery Reservoir decreased throughout the study period from approximately 4 meters (13 feet) to 2.5 meters (8 feet). This reduction in visibility is normal and is usually a result of the increase in algal biomass through the growing season. The assumption of the TSI is that the photic depth is a direct function of algal biomass, which in turn is a function of the level of available nutrients. Based on these assumptions, the resulting TSI value is a prediction of the lake's nutrient levels, and hence its trophic state.



Graph 6: Secchi depth

Carlson's TSI is calculated using the following formula for Secchi depth;

TSI = 60 – 14.41 (ln SD) *Where SD is measured in meters, and* ln *stands for natural log.*

Emery Reservoir's TSI (SD):

Maximum SD Measurement: **40.0** = 60 – 14.41 (ln 4.0m)

Minimum SD Measurement: **46.8** = 60 – 14.41 (ln 2.50m)

Average SD Measurement: **43.0** = 60 – 14.41 (ln 3.25 m)

Comparison of Trophic State Index to Water Quality Parameters			
Trophic State	**TSI**	**Secchi Disk (m)**	**Total Phosphorus (µg/L)**
Oligotrophic	0	64	0.75
	10	32	1.50
	20	16	3
	30	8	6
Mesotrophic	40	4	12
	50	2	24
Eutrophic	60	1	48
	70	0.500	96
	80	0.250	192
	90	0.120	338
	100	0.062	768

Table 2: Carlson's TSI

The original source of this table and the equations is Carlson, R.E. A Tropic State Index for Lakes. Limnology and Oceanography, 22, 1997:361-369.)

According to Carlson's TSI, any value between 40 and 59 is classified as mesotrophic (Table 2). Therefore, using this parameter, Emery Reservoir falls within this classification. As discussed, SD is a proxy measure for nutrient levels because these levels were also measured; they will yield a more accurate estimation from the TSI table.

Qualitative Assessment of Visibility

Qualitative assessment of the lake was via guidelines for empirical observations of eutrophication as outlined by Holdren's book Managing Lakes and Reservoirs. Qualitative observations of the abundance of macrophytes, algae, and cyanobacteria (blue-green algae) further supported the designation of the reservoir as eutrophic. The current abundance and distribution of plants are not at nuisance levels due to recent actions of spraying herbicides by the HOA during the 2012 and 2013 growing seasons. The good visibility in Emery Reservoir suggests a lower trophic state as was indicated by its score on Carlson's TSI for SD. Visibility in Emery Reservoir was fairly good and was primarily limited by a brownish coloration of the water during the first few months of the study. Brownish coloration is the result of decomposing organic matter in the lake such as leaves from surrounding trees and grass cuttings that leach tannins and lignins into the water.

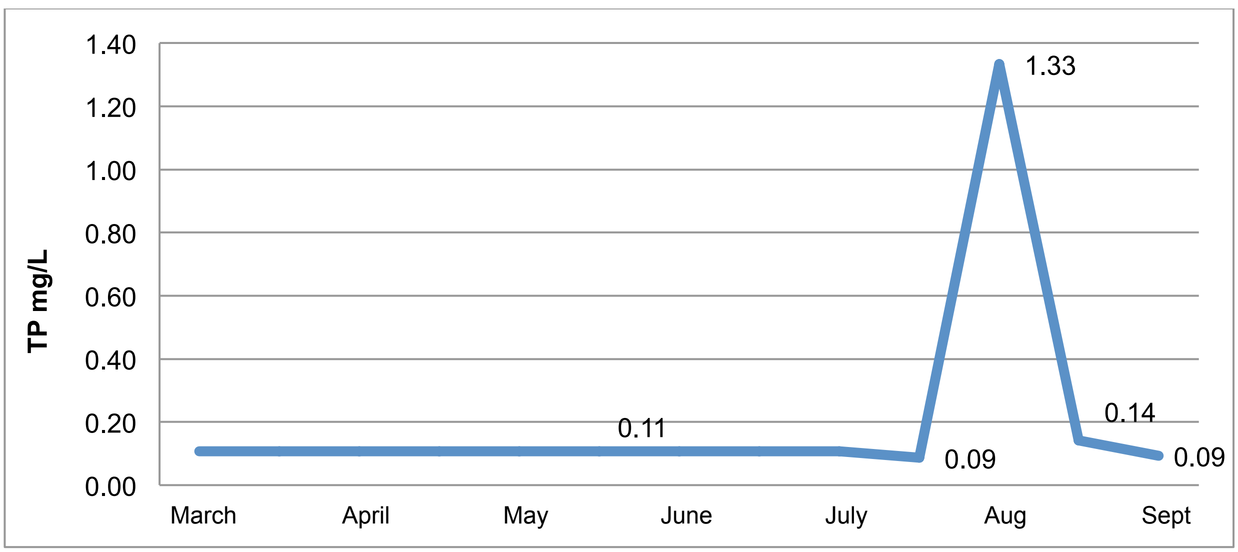
Around July, the water developed a more greenish coloration but still maintained relatively clear visibility. The greenish coloration of the water is the result of increasing levels of the chlorophyll a, the green pigment present in algae. The observation of the change in color suggests that there was a lower level of algal productivity in the lake in the spring, and that it reduced visibility as its mass increased throughout the summer (Holdren et al., 2001).

Quantitative Measurements of Nutrient Levels

Total phosphorus (TP) measurements were identical at each sample site in the lake and were consistent throughout most of the study period. In August, there was a large spike in the levels due to ash settling on the water from a very large nearby forest fire, the Rim Fire (Picture 6). For this reason, those measurements are considered outliers and have been omitted from the calculation of the TSI. Throughout the first five months of the study period, TP measurements were 0.11 mg/L; for the last two months TP was 0.09 mg/L. Carlson's TSI requires measurements of TP in µg/L. After converting mg/l to µg/L, the value of the maximum and minimum TP becomes approximately 110 µg/L and 90 µg/L, respectively.

Picture 6: Smoke and ash from the Rim Fire. September 10, 2013

Total Phosphorus



Graph 7: Total Phosphorous concentration

Carlson's TSI for TP is calculated using the following formula;

TSI = 14.42 (ln TP) + 4.15, *where TP is measured in* ***µg/L****, and* In *stands for the natural log.*

Emery Reservoir's TSI (TP):

Maximum TP Measurement: **71.9 =** 14.42 (ln 110) + 4.15

Minimum TP Measurement: **69.0 =** 14.42 (ln 90) + 4.15

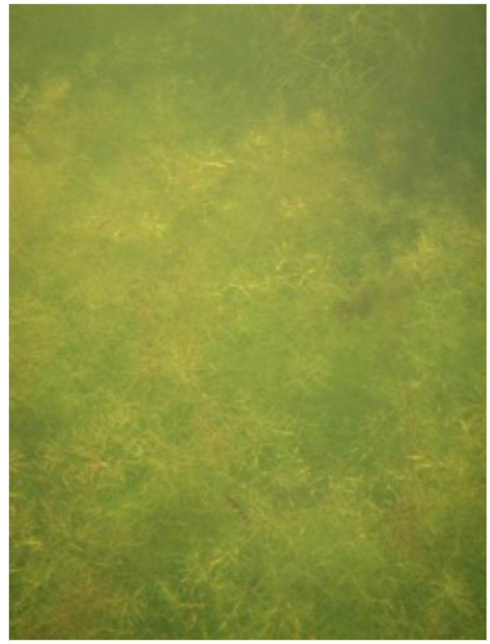
Average TP Measurement: **70.5 =** 14.42 (ln 100) + 4.15

According to Carlson's TSI, any value between 60 and 100 is classified as eutrophic. Therefore, using this parameter, Emery Reservoir falls within this classification (Table 2). The deviation between the TSI value using SD and TP may be a result of several factors. Some studies choose to average the values using the different parameters. The creator, Carlson, warns however, "There is no logic in combining a good predictor with two that are not." (Carlson, 1983). As phosphorous is a more direct measure of eutrophication, this value should be considered a better predictor of the trophic state.

Qualitative Assessment of Nutrient Levels

Observation of algae and macrophyte abundance was viewed as a proxy for nutrient levels. While there was only a small amount of suspended algae in the limnetic zone (the center of the lake), almost the entirety of the littoral zone (near shore) was covered in dense, mat-forming algae like Stonewort (Chara spp.) (Picture 7) and Brittlewort (Nitella spp.) (Picture 7. These algae are often mistaken for plants because of their leaf-like appearances. In these shallower areas along the shore, filamentous green algae was also abundant enough to be mat-forming in certain areas (Picture 9).

Picture 7: Stonewort Algae (Chara sp.)



Picture 8: Britlewort Algae (Nitella sp.)

Picture 9: Filamentous green algae (Cladophora)

In addition to the green algae, there were several locations within the lake that were supporting colonies of cyanobacteria (blue-green algae), a telltale sign of a eutrophic lake (Holdren et al., 2001). These bacteria colonized on the bottom sediments and appeared as green circular spots (Picture 10). As the colonies grew, they produced and trapped gases that eventually cause them to dislodge from the bottom and float to the surface (Picture 11). Some strands of cyanobacteria can become toxic to animals; there have been reports of livestock and pets being killed from ingesting them, and humans may develop rashes or skin irritation if they come into contact with them.

Picture 10: Cyanobacteria growing on sediment.

Picture 11: Colonies as seen from above the water's surface appear as green protruding bubbles.

Certain locations in the reservoir also exhibited dense growth of macrophytes. The bottom could not be seen or reached in some areas due to their abundance. Specifically, a plant called Coontail (Ceratophyllum demersum L.) grew throughout the reservoir in such dense stands that it was difficult to hoist a boat anchor out of the water without pulling up large and heavy quantities of the plant with it.

Picture 12: Curly Leaf Pondweed

Picture 13: Creeping Waterprimrose

Picture 14: Underwater photo of mixed plant species

The observation of the lake-wide presence and high density of macrophytes and algae suggests that they constitute a large proportion of the nutrient budget within the reservoir.

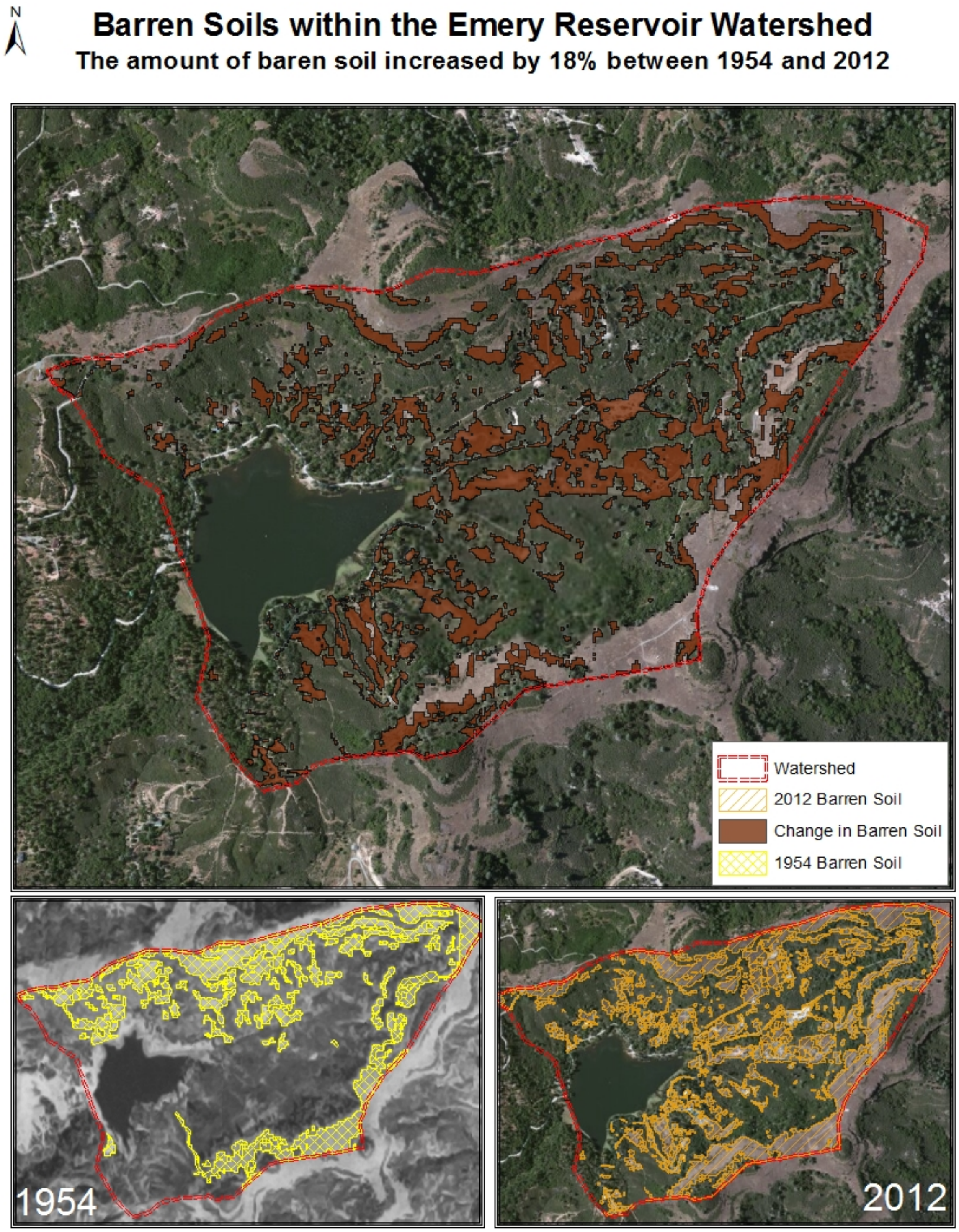
Although their biomass was not estimated, the relatively large quantity supports the assertion that the reservoir can be classified as eutrophic (Holdren et al., 2001).

Determining Contributing Factors of Eutrophication

As water flows across the watershed's surface as runoff (from either a rainstorm, as snowmelt, or other event), it transports varying levels of material with it. Because Emery Reservoir has a large ratio of watershed drainage area to water surface area as measured previously in Map 6 – pg 29, it has a greater potential to have a significant impact on the constituents within the reservoir's water. The combination of moderate to high erosion potential (Map 5 – pg 27) of the soils and the volcanic makeup of the geologic formations (Map 3 – pg 24) within the watershed is likely a major source contributing to the lake's eutrophication.

Quantitative Assessment of Groundcover Change in the Watershed

Remote sensing tools in ArcGIS reveal that currently, approximately 30% of the watershed is exposed soils. In 1954, prior to development within the watershed, that figure was only approximately 12%. This represents an increase in the percentage of barren ground by approximately 18% between the two time periods (Map 8 – pg 42).



Map 8: Change in Barren Soils

Using the remote sensing capabilities of ArcGIS, the unique spectral characteristics of features within the images were identified and classified. In layman's terms, a spectral signature is a specific color (pixel value) that can be used by a computer program to identify discrete features in an image; for example, soil has a unique numerical pixel value that can be used to distinguish it from water, vegetation or other features. The images were analyzed independently, because they were created using different instrumentation, and therefore, the pixel value of soil in one image is not the same as the values in the other (i.e. the 1954 image is black and white, the 2012 image is color).

Five classes were used to categorize features within each image: water, ground cover, trees, barren soil, and roads. The software then created a map of each image by assigning each pixel to one of the five classes, resulting in a mosaic of polygons that represent each class. The next step was to eliminate all the classes except barren soil and roads, producing a map that shows only the surface area within the watershed that is barren (lower inset maps from 1954 and 2012). The final step was to overlay the two images and subtract (erase) the earlier polygon areas from the latter. The result shows the change in that area over time, in this case, an increase in barren soil. This increase in barren land likely corresponds to an increase in erosion and increased sedimentation rates in the lake since 1954.

Qualitative Assessment of the Watershed

Empirical observation of the culverts and creeks that lead to the reservoir show signs of extensive erosion. Sediment accumulation in areas near Lakeside Drive – the road encircling the lake – had filled in or buried several culverts (Picture 15, left).

Picture 15: Sediment accumulation in Emery Reservoir's watershed, June 2013

Housing pads that had been built further away from the lake but that had no structures erected on them, appeared to have been graded several years prior to this study. There were no signs of erosion prevention measures in place around them and deep drainage patterns had been carved into the exposed soils leading towards the creeks and reservoir.

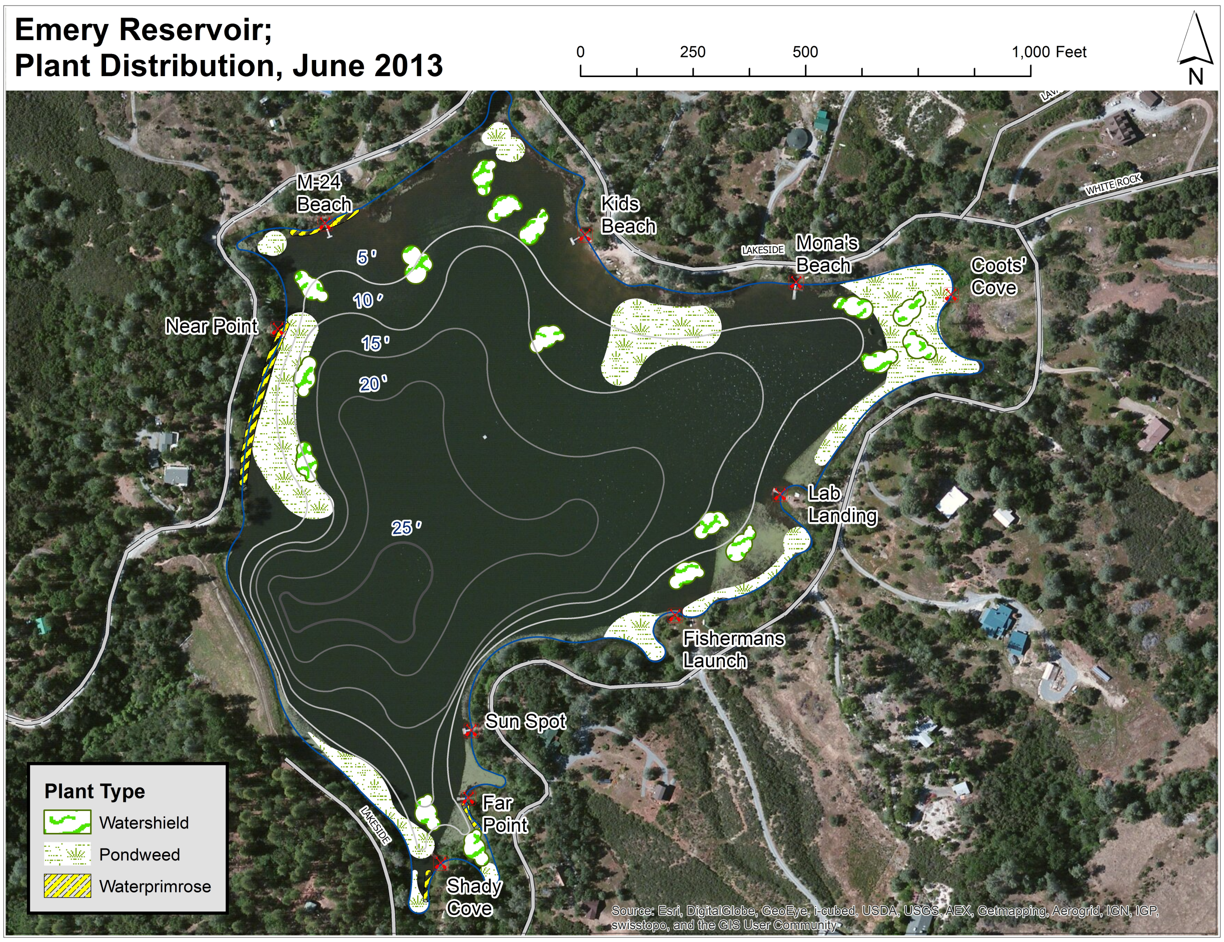
The members of the HOA had removed vegetation from within the creeks and drainage ditches surrounding the lake in order to increase the volume and velocity of the water running through them (Picture 15 right). This exacerbated the amount of erosion occurring within these areas due to the increased exposure of unprotected soils. Additionally, as the velocity of a flowing waterbody increases, so does its ability to carry suspended sediment, and therefore it is likely that this practice increased the amount of sediment entering the reservoir. In periods of heavy rain that were observed on March 31st and September 21st of 2013, brown plumes could be seen emanating from where the creeks and drainage ditches entered the reservoir.

Plant Distribution Mapping.

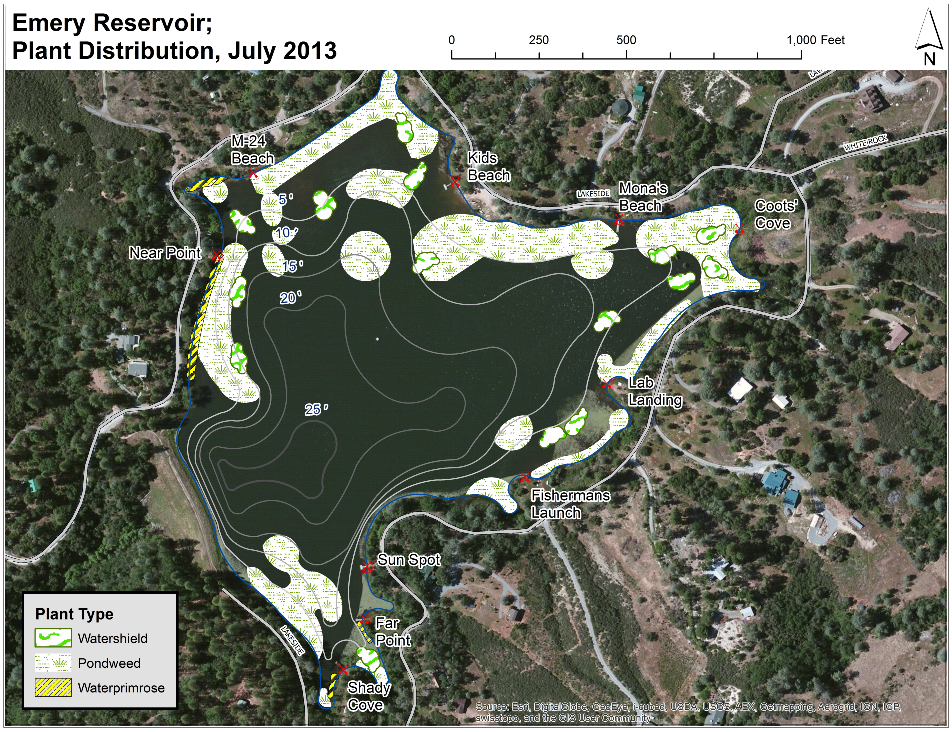
Of primary interest to the HOA were the types, abundance, and distribution of aquatic plants. Appendix B lists the sixteen plant species that were identified in the reservoir. Only two of these – Curly leaf Pondweed (Potamogeton crispis) and Creeping Waterprimrose (Ludwigia peploides) – are non-native and considered to be moderate and highly invasive, respectively, by the California Invasive Plant Council (CAL-IPC). Four of the sixteen plants are considered rare or threatened by the California Native Plant Society (CNPS): Leafy Pondweed (Potamogeton foliosus), Ribbonleaf pondweed (Potamogeton epihydrus), Water-Thread Pondweed (Potamogeton diversifolius), and Watershield. This designation means that the plants are not common in California but are common elsewhere in the country; therefore there are no restrictions regarding eradication or control efforts despite their designation. The remaining plants that were identified are all natives of California and are considered beneficial to the ecosystem.

Of all sixteen plants, M-24 members determined that 3 species were of special concern due to their abundance: Watershield, Ribbonleaf Pondweed, and Creeping Waterprimrose. The following series of maps catalogue the patterns of the growth of these species throughout the summer of 2013. It should be noted that several species of pondweed were present in the lake but for the purposes of the following maps, the “pondweed” classification refers primarily to Ribbonleaf.

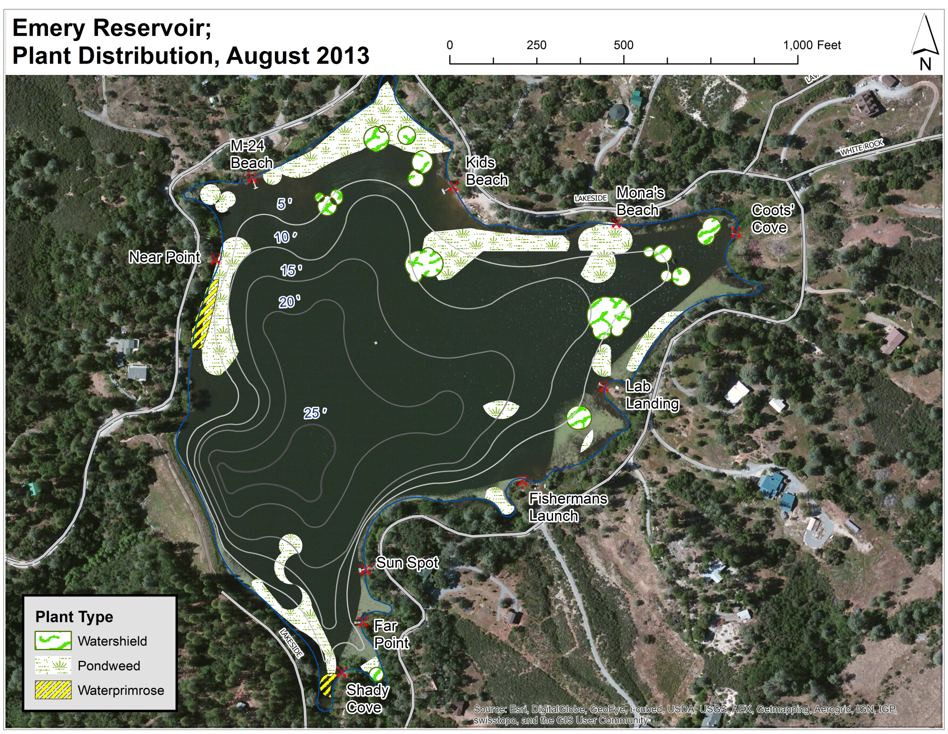
In June, dozens of patches of Watershield could be observed throughout the lake. Small patches of Ribbonleaf Pondweed were also starting to surface, which attracted the attention of members. Whether Ribbonleaf had been present in the reservoir prior to 2013 is unknown, but residents had not noticed its presence until the Watershield density had been reduced. Ribbonleaf pondweed rapidly increased between June and July (Map 9 – pg 45 and Map 10 – pg 47), however, it was observed in the latter half of the study period (Map 11 – pg 47 and Map 12 – pg 47) that the plant died off equally as quickly and was no longer visible in most of the reservoir by September.



Map 9: Plant distribution in June



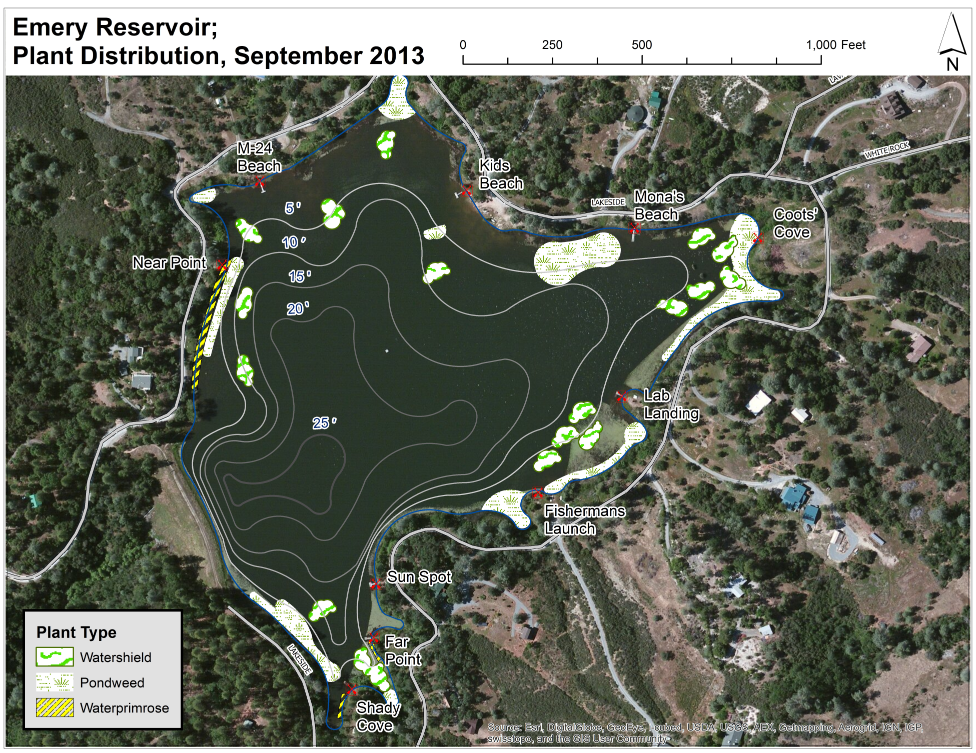
Map 10: Plant distribution in July



Map 11: Plant distribution in August

Both Creeping Waterprimrose and Watershield were sprayed with herbicides or removed by hand throughout the study period and the changes in their abundance and location depicted in all these maps was more a result of those actions than a result of their natural growth cycles. On the contrary, the persistence of Creeping Waterprimrose in a treated area demonstrates its designation as highly invasive by the CAL-IPC.

Watershield also persisted, though to a much lesser extent and its growth was limited to small patches. The use of systemic contact herbicides, applied by surface spraying, require direct contact with the plant tissue in order to be effective. Because Watershield can grow in deep water (up to 10'), new shoots still submerged at the time of treatment were unaffected and surfaced in previously treated areas.



Map 12: Plant distribution in September

The plant distribution mapping revealed the patterns and trends in the plants' lifecycles and, in the case of Watershield and Creeping Waterprimrose, their response to methods of control. Map 12 above shows one large area of pondweed in the northern part of the reservoir between Mona's Beach and Kids Beach that contained a dense growth of Curly Leaf Pondweed. This area should be monitored closely as this species has been known to spread rapidly and interfere with intended recreational uses.