TKPOA Aquatic Invasive Species Program

2019 End of Season Report

Prepared for

Tahoe Keys Property Owners Association

South Lake Tahoe, California

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TAHOE KEYS INTEGRATED MANAGEMENT PLAN

2019

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1.0 INTRODUCTION

The Tahoe Keys have 172 acres of waterways with 1,529 homes and townhouses along with commercial businesses. The waterways include the Lake Tallac Lagoon (a storm water collection basin for South Lake Tahoe), the West Lagoon, and the East Lagoon. Both the West and East lagoons have direct connections to Lake Tahoe via the West and East channels.

The Keys Lagoons have an overabundance of aquatic plants, also known as aquatic macrophytes. Aquatic macrophytes became a problem in the 1980's when invasive weeds were first introduced to the lagoons. There are now 3 macrophyte species causing problems for boaters of the keys. These species are Eurasian watermilfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*), and the native coontail (*Ceratophyllum demursum*). The species thrive during the summer when growing conditions are ideal. Every winter aquatic macrophytes die off and deposit a layer of detritus that decomposers break down into nutrients that fuel plant growth the following year. This excessive plant growth is a major cause for poor water quality in the Tahoe Keys lagoons. The TKPOA has been attempting to find a solution to this problem for decades.

Lahontan Regional Water Quality Control Board (LRWQCB) issued the TKPOA a Waste Discharge Requirements (WDRs) permit: Executive Order No. R6T-2014-0059. This specifies that the TKPOA must improve the control of aquatic invasive plants in the Tahoe Keys lagoons. The WDRs also state that the TKPOA must develop an Integrated Management Plan (IMP) for aquatic macrophytes and a Nonpoint Source Plan (NPS Plan) to improve water quality (Lahontan 2014). The TKPOA voluntarily added Baseline Water Quality Program in 2016. The goal of the Baseline Water Quality Program is to establish an inventory for several water quality and sediment parameters. The baseline data will be used in future years to detect changes in water quality resulting from aquatic plant control methods implemented under the IMP and to monitor surface water input for the NPS Plan.

Property in and around the Tahoe Keys lagoons is controlled by multiple landowners including individual property owners, Tahoe Keys Property Owners Association, Tahoe Keys Beach and Harbor Association, Tahoe Keys Marina along with other commercial and governmental ownership. The TKPOA maintains the waterways for boating and other recreation. However, the ownership situation makes managing the waterways difficult as owners are not required to adapt to the TKPOA best management practices for the Integrated Management Plan (IMP).

The Water Quality (WQ) Department has been consulting with local agencies, universities and scientists to better understand the problem and develop effective solutions. Proposed solutions are presented to the TKPOA Water Quality Board to determine if a project is feasible and how it could be best implemented. The WQ Department has already implemented several projects to help mitigate the aquatic vegetation nuisance in the Tahoe Keys. The WQ Department aims to develop a lasting solution that will reduce biomass of aquatic vegetation in all 172 acres of the Tahoe Keys Lagoons. The ideal solution would improve the water clarity, reduce the spread of Aquatic Invasive Species (AIS) and protect famed clarity of Lake Tahoe

2.0 2019 AIS PROGRAM

The WDRs issued to the TKPOA state five objectives that the IMP was to accomplish; therefore, the first Goal of the IMP is to fulfill the objectives named in the WDRs. These objectives are:

- Eliminate the spread of aquatic invasive species from the Tahoe Keys to greater Lake Tahoe.
- Enhance the overall water quality of the Tahoe Keys lagoons and Keys Marina thereby improving Lake Tahoe water quality and associated clarity.
- Reduce habitat for non-native fish and enhance habitat for native fish in the Tahoe Keys lagoons and Keys Marina.
- Restore and maintain established beneficial recreational uses, including water contact safety in the Keys lagoons and commercial uses in the Keys Marina Implement a combination of cost-effective control measures that are feasible for long-term management of aquatic invasive plants
- Implement a combination of cost-effective control measures that are feasible for long-term management of aquatic invasive plants.

The TKPOA AIS Programs aim to effectively implement solutions to fulfill these objectives. During the 2019 season the WQ Department's AIS staff conducted the projects outlined in this report to meet the WDR's set by LRWQCB.

Since 2016, the AIS staff have been implementing projects that attempt to control the aquatic vegetation of the Tahoe Keys. 2019 projects include; the Boat Backup Station, seabin and bubble curtain project and the Laminar Flow Aeration Project along with water quality sampling at 36 sites throughout the Keys Lagoons and Lake Tallac.

Week	Water Quality 16 Sites (YSI Readings)	Water Quality Lake Tallac 14 Sites (YSI Readings)	Water Quality LFA Sites (YSI Readings)	LFA Sites Sample Testing (Lab Sample Tests)	LFA Cyanobacteria Sample	Point Cyanobacteria Sample	Logger Data (Temperature, Dissolved Oxygen)	Macrophyte Survey	Hydroacoustic Scan: East and West Marinas, Lake Tallac and Lake Tahoe	Hydroacoustic Scan: LFA Sites	Hydroacoustic Scan: UV Light Sites	Bottom Barrier Inspections	Groundwater Sampling	Backup Station Monitoring	Boat Count
4/15 - 4/19			x	x	x	x				x					
4/22 - 4/26			x												
4/29 - 5/3															
5/6 - 5/10			x							x					
5/13 - 5/17									x			x			
5/20 - 5/24	x	x	x												
5/27 - 5/31		x							x			x			
6/3 - 6/7	x	x	x	x	x	x				x					
6/10 - 6/14							x		x		x	x			
6/17 - 6/21									x			x		x	
6/24 - 6/28			x	x	x	x			x	x	x	x		x	
7/1 - 7/5	x	x	x	x	x					x				x	
7/8 - 7/12								x	x			x		x	
7/15 - 7/19	x	x	x	x	x		x			x	x			x	
7/22 - 7/26									x		x	x		x	x
7/29 - 8/2	x	x	x	x	x					x				x	
8/5 - 8/9									x		x	x		x	
8/12 - 8/16	x		x	x	x					x			x	x	
8/19 - 8/23		x							x		x	x	x	x	
8/26 - 8/30	x	x	x	x	x	x				x			x	x	
9/2 - 9/6									x		x	x		x	
9/9 - 9/13	x	x	x	x	x	x				x				x	
9/16 - 9/20									x		x	x		x	
9/23 - 9/27	x	x	x	x	x					x	x			x	
9/30 - 10/4									x		x	x		x	
10/7 - 10/11	x	x	x	x	x					x				x	
10/14 - 10/18									x		x	x		x	

Figure 1: 2019 AIS projects

3.0 2019 WATER QUALITY DATA COLLECTION

AIS staff continued collecting water quality data for the IMP and required permits during the 2019 season. The sampling programs are conducted to ensure that the TKPOA is meeting requirements set by the LRWQCB WDRs and meeting the Water Quality Objectives (WQO) stated in the WDRs. Samples and data were also collected for the State Water Board funded Laminar Flow Aeration (LFA) project and one stormwater sampling event.

3.1 Water Quality Sampling

3.1.1 Summary

The Water Quality Sampling Program was conducted for the 2019 season. In 2016, the program sampled water quality and sediment parameters from 13 sites. During the 2019 season, AIS staff collected water quality chemistry data from 30 locations in the East and West lagoons along with Lake Tallac. Changes made to the Baseline WQ Report during the 2018 season were: sites were added and data was collected at 5 different depths in the water column to better characterize water in the lagoons. These changes were carried out in the 2019 season as well.

Figure 2: 2019 Water Quality Sampling Map

Figure 2 displays the locations of the 30 sites where water quality measurements were taken during 2019. Lake Tallac sites 5 and 7 are the same location as Water Quality sites 5 and 7.

3.1.2 2019 Sampling Overview

In 2019, the AIS staff sampled the sites shown in figure 2 every other week. 10 water quality parameters were measured during 26 sampling events at 30 sites over the course of the aquatic plant growing season from early May to mid-October (Table 1). Due to budget constraints the TKPOA did not sample for nutrient contents at the water quality sites but did at the Laminar Flow Aeration Sites which will be discussed in Section 3.2.

Parameter	Method of Measurement	Description
Depth	YSI ProDSS or Water Sounder	Depth in meters of water at each site. Used to determine the 5 sampling points in the water column.
Temperature	YSI ProDSS and YSI 1020	Measure of acidity or alkalinity of water, with pH 7 being neutral. Surface, mid-point, and bottom were collected during the season to monitor effects of plant biomass on overall pH.
Specific Conductance	YSI ProDSS	Measure in micro Siemens per centimeter (µS/cm) of dissolved ionic particles in the water. Acts as a good indicator of Total Dissolved Solids.
Dissolved Oxygen	YSI ProDSS and YSI 1020	Amount (in parts per million) of oxygen present in water. An important parameter in water quality assessment due to its influence on aquatic organisms. Concentrations of DO that are either too high or too low can be harmful to aquatic life and can affect water quality (Fondriest Environmental Inc. 2016).
pH	YSI ProDSS	Measure of acidity or alkalinity of water, with pH 7 being neutral. Surface, mid-point, and bottom were collected during the season to monitor effects of plant biomass on overall pH.
Phytocyanin (PC)	YSI ProDSS	A measure of Phytocyanin in the water column. Phytocyanin is a blue-copper containing pigment found in harmful algae.
Chlorophyll (CHL)	YSI ProDSS	Chlorophyll content in the water column.
Ammonium	YSI ProDSS	Measure of Ammonium in the water column. Ammonium is a key nutrient for plant growth.
Oxidation Reduction Potential	YSI ProDSS and YSI 1020	Oxidation Reduction Potential (ORP) recorded in millivolts. This is a key component in water quality to determine the health of an ecosystem.
Turbidity (FNU)	YSI ProDSS	Measurement of water clarity using Formazin Nephelometric Units

Table 1: List of Monitored Parameters

3.1.3 Methods and Materials

a. Equipment

The following list includes the equipment that was utilized for each sampling.

- YSIProDSS
- YSI Calibration Log
- Pen/ Pencil/ Sharpie
- Site Map (Figure 2)
- Calibration Solutions
- Water Quality Data Sheet
- Water Level Sounder (Weighted rope with half meter increments to measure depth)
- 250 milliliter (mL) bottle
- Cooler
- Ice packs

Figure 3: YSI ProDSS

b. Calibration

Calibration was conducted prior to each sampling event. Calibrations were done using the calibration solutions for ammonium (1 mg/L, 100 mg/L), pH (4, 7, and 10), turbidity (0 FNU, 12.4 FNU), Oxidation Reduction Potential (Zobelle Solution, mV), PC (RFU), Chlorophyll (RFU), DO (ppm), and conductivity (1000 mS/cm). The calibration data was logged and kept on file for that sampling event. Appendix A contains the calibration record.

c. Methods

On the day of collection, once all equipment was loaded onto the boat the AIS staff filled out the Data Sheet, indicating the date, sampling type, wind speed and direction and air temperature.

Data was collected at each site using the YSI ProDSS and a YSI Pro 1020. Depth of each site was determined using measured markings on the YSI ProDSS cable. The cable has measured marks every 0.5 meters so depth was only accurate to the nearest half meter. The depth was used to determine the sampling depth for the 5 different points in the water column. These points included bottom (B), quadrant 1 (1), middle (M), quadrant 3 (3), and surface (S).

Once depth was determined the instruments were raised 6 inches off the bottom and left to run for roughly a minute, to ensure the reading had stabilised. The temperature, DO, turbidity, electrical conductivity, pH, oxidation reduction potential (ORP), ammonium, were then recorded

onto the data sheet along with the site number and time. These measurements were repeated at each quadrant. Additional data for turbidity and conductivity was collected at the mid point. Data from the data sheet was entered into the database workbook and the original hardcopy was scanned to be saved as an electronic copy.

Cyanobacteria samples were collected from water quality sampling sites 4 different times throughout the 2019 season. The rest of the cyanobacteria sampling occurred during the LFA sampling regime. For cyanobacteria sampling the 250 mL bottles were filled between 1-11.8 inches. This ensures that the sample is not contaminated by anything that may have been in the bottle. The sample was then obtained and deposited in the cooler and stored on ice. The cooler was then shipped to Bend Genetics where samples were analysed for cyanobacteria. Proper Chain of Custody (COC) forms were filled out to ensure proper handling of samples.

3.1.4 Results

Six sites were chosen to display WQ data from 2019. These sites were picked because they represent typical conditions found in the Tahoe Keys Lagoons. WQ 11 is in Lake Tahoe and represents near shore conditions of Lake Tahoe. WQ 15 is an open water lagoon that experiences mixing with other areas, this section can represent typical chemistry of most open water areas inside the West lagoon. WQ 16 is in a dead end lagoon with historical high water temperatures and low circulation. WQ 8 is another dead end area on the opposite end of the West lagoon from WQ 16, these two sites represent typical conditions found in dead end areas. WQ 3 is located in the East Lagoon and is expected to represent conditions in the Keys Lagoons. Finally, WQ 5 is in Lake Tallac and is expected to represent conditions found throughout the main body of Lake Tallac. These sites can give us an idea on the general state of the water quality in the Keys to ensure that the TKPOA is on its way to meet the WQ Objectives stated by the LRWQCB's WDR. Box-and-Whisker Plots are used to show results from collected data. Figure 4 represents the upper quartile, median, and lower quartile for the dataset. Extending arms from the box represent the maximum and minimum dataset values while dots outside the arms are outliers.

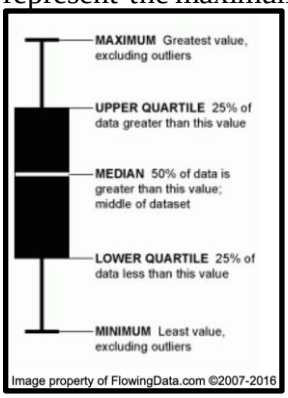

Figure 4: Box and whisker plot description

a. <u>Dissolved Oxygen</u>

The dissolved oxygen content varied by what depth and where the measurement was taken. The bottom often had low dissolved oxygen while the mid point and surface had higher content. Figure 5 displays dissolved oxygen content from 6 of the water quality sampling sites. At WQ 11 the average D.O. Level was 9.51 mg/L, the lowest level was at the bottom which was 6.31 mg/L and the highest is 11.75 mg/L. At WQ 15 the average D.O. for WQ 15 was 10.5 mg/L while the

minimum D.O. was found at the bottom and was 0.05 and the highest was in the middle and was 11.95 mg/L. The results from WQ 8 and 16 are relatively similar because they represent similar conditions, the lowest D.O. was 0.09 mg/L, the average was 8.05 mg/L and the highest was WQ 8 at 13.0 mg/L. WQ 5 in Lake Tallac had the lowest average D.O. levels the lowest recorded level was 0.11 mg/L while the average was 6.49 mg/L and the maximum was 13.15 mg/L.

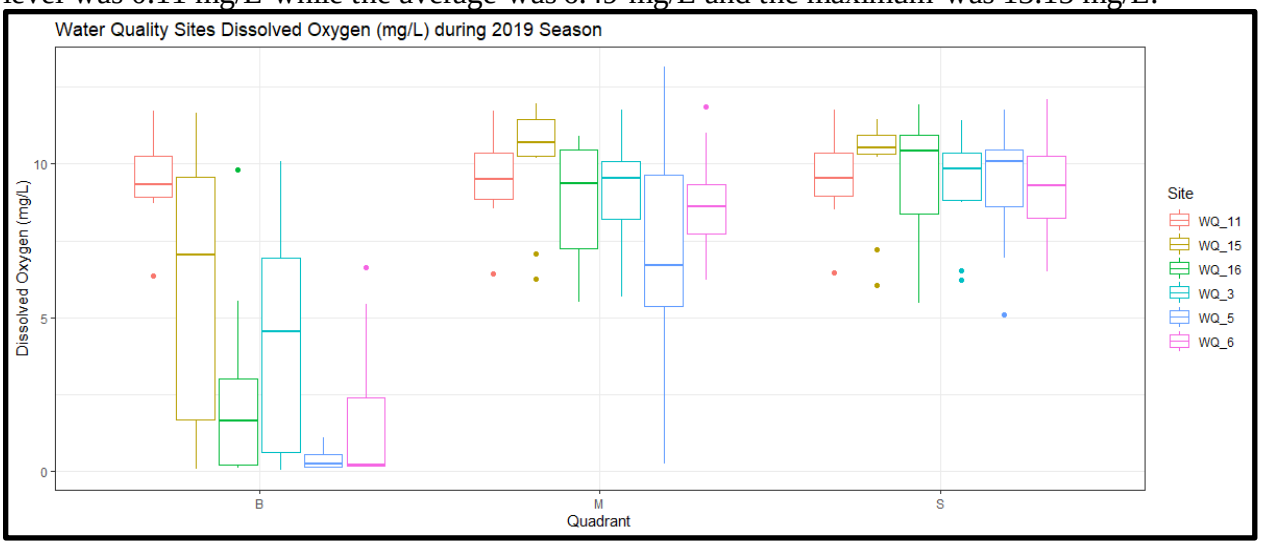

Figure 5: Dissolved oxygen for Water Quality Sites

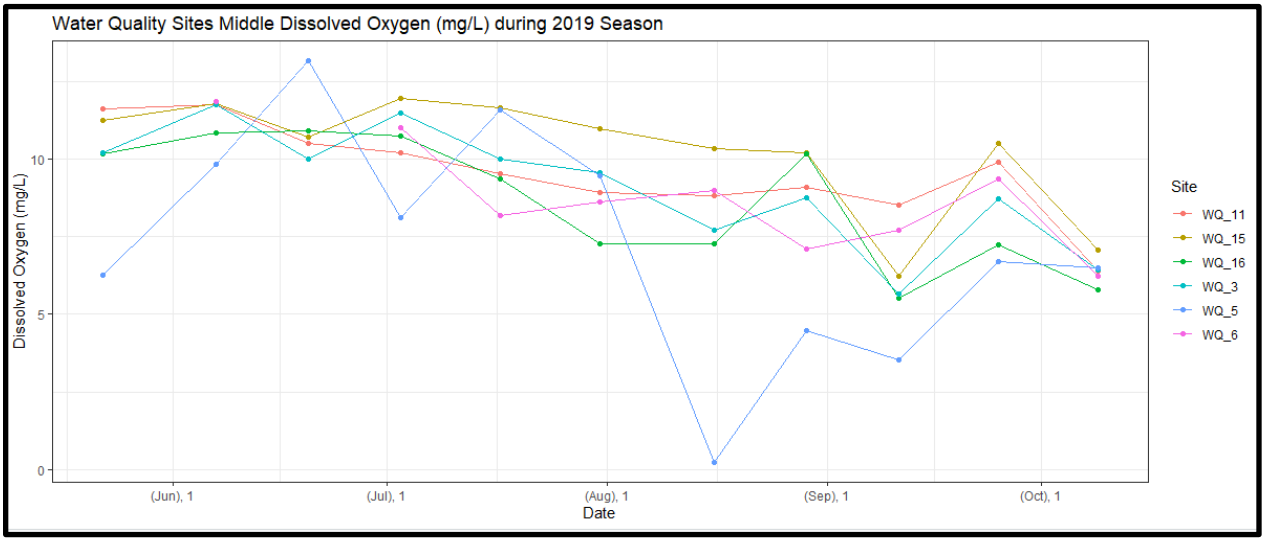

Figure 6: Mid point dissolved oxygen levels May-October

b. <u>Temperature</u>

Figure 8 shows that temperature is dependent on the time of year. Warmest temperatures were observed mid July through early September. Lowest temperatures were observed at the bottom of the water column while highest were at the surface.

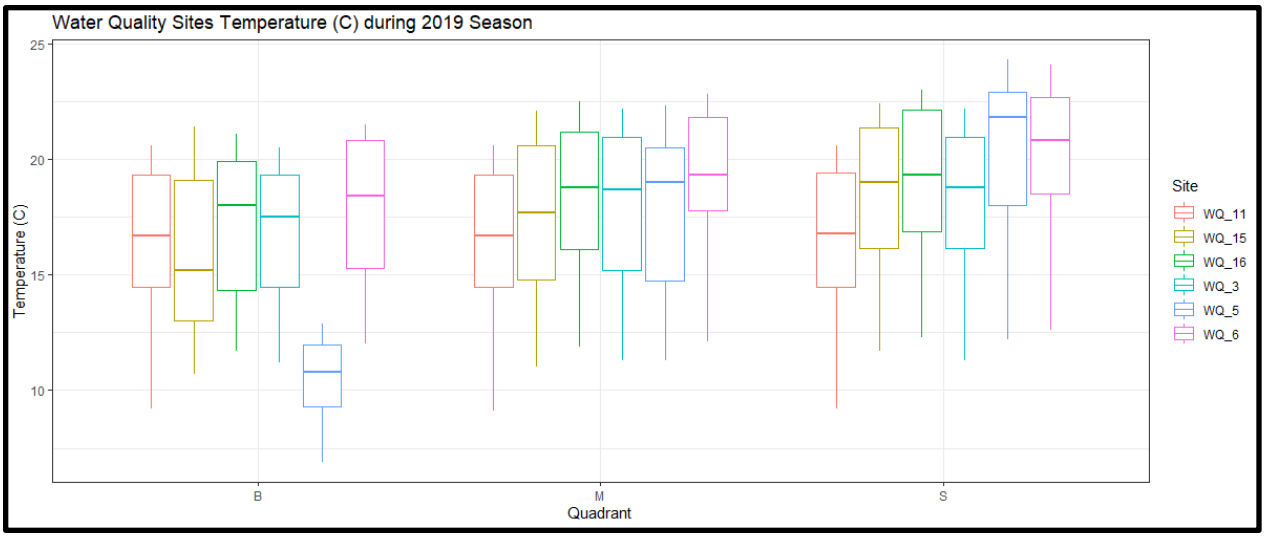

Figure 7: Bottom, middle and surface temperature for water quality sites.

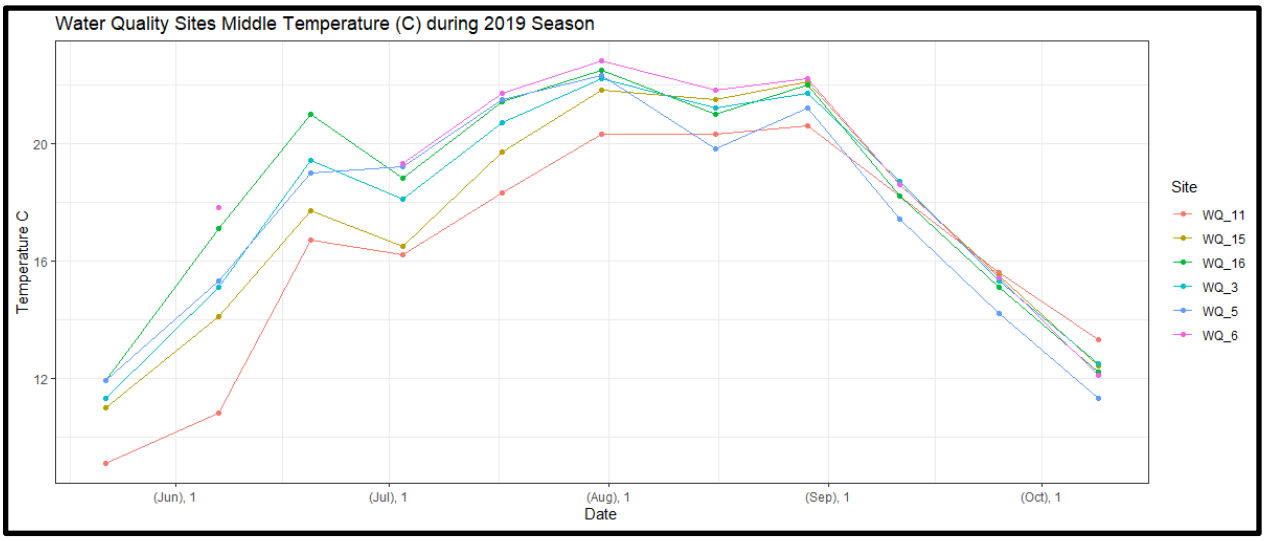

Figure 8: Middle Temperature Plot for water quality sites.

c. <u>pH</u>

The pH levels in the lagoons become highest mid June and stay high until the beginning of September. This increase is due to photosynthesis of the plants causing the water to become more basic. pH levels are lower at the bottom of the water column compared to the surface but are on average higher in the middle due to photosynthesis of the plants. Figure 10 shows WQ 11 having lower pH than other sites throughout the season. Table 1 contains averaged data from WQ 8, 15 and 16 to gain an average pH for the Tahoe Keys lagoons.

For the middle quadrant WQ 11 had an average pH of 8.01, a minimum of 7.49 and maximum of 8.18. WQ 15 had an average of 8.73, a minimum of 7.65 and a maximum of 9.64. WQ 16 had an average of 8.37 a minimum of 7.41 and a maximum of 9.38. WQ 3 had an average of 8.46 a maximum of 9.44 and minimum of 7.41. WQ 5 had an average of 7.34 a minimum of 6.57 and a maximum of 9.05. WQ 8 had an average of 8.96, minimum of 7.72 and maximum of 9.270. The average for site 8, 15 and 16 is 8.68. However, this data is only from mid May through mid October. The year round averages are lower because this data was taken during the growing season when pH is higher.

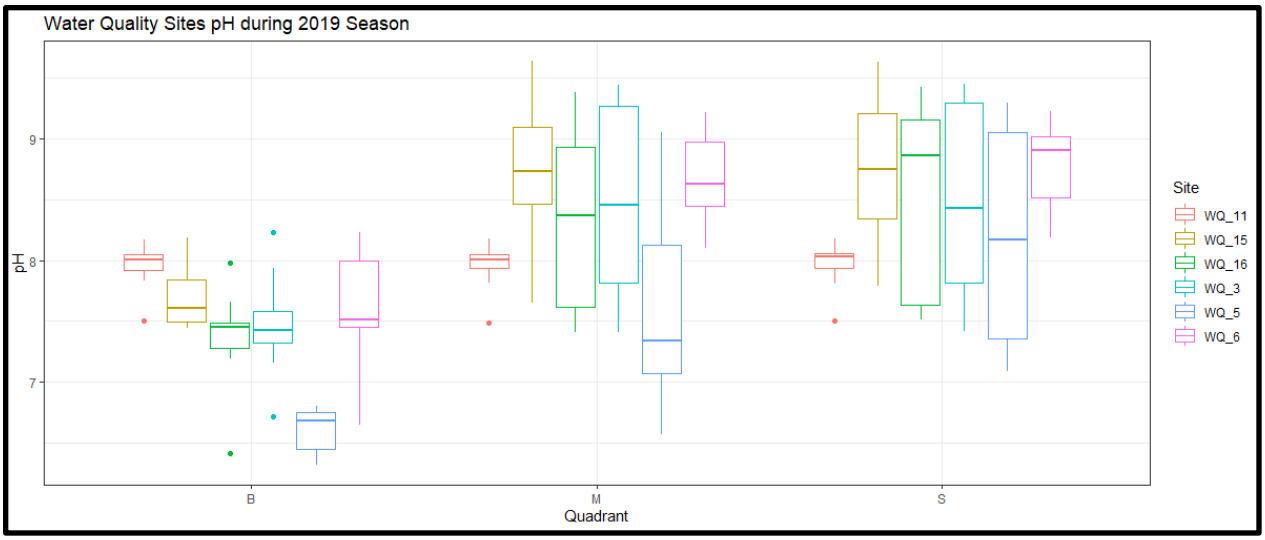

Figure 9: Bottom, middle and surface pH

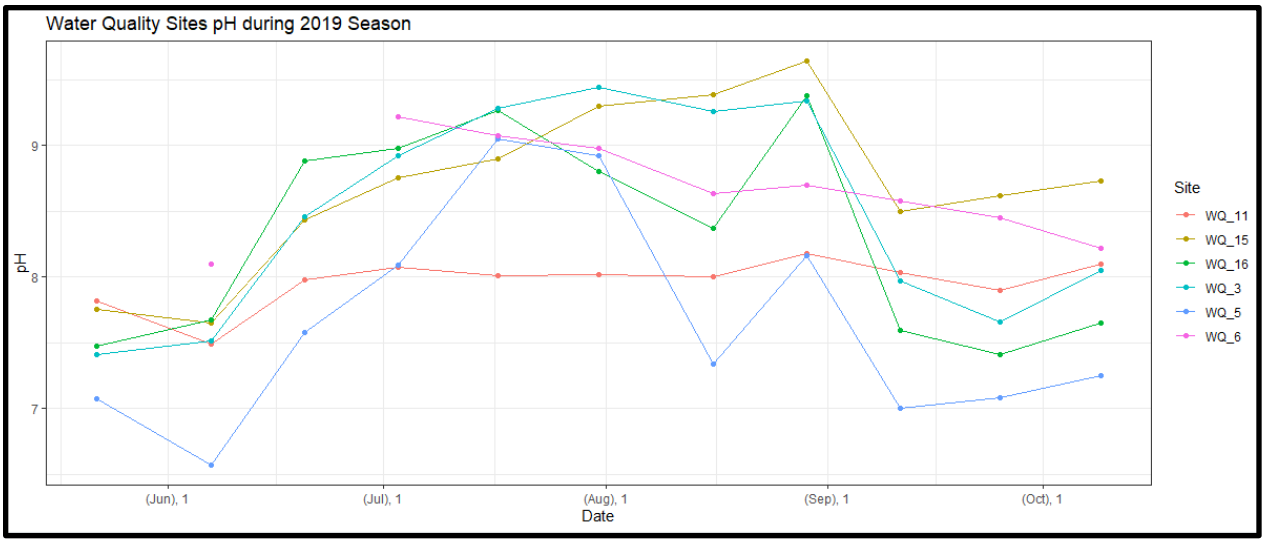

Figure 10: Middle pH Plot

d. <u>Oxidation Reduction Potential</u>

The Oxidation Reduction Potential (ORP) can be a good indicator of a water body's overall condition. The TKPOA monitored ORP to better understand what is occuring in the Lagoons.

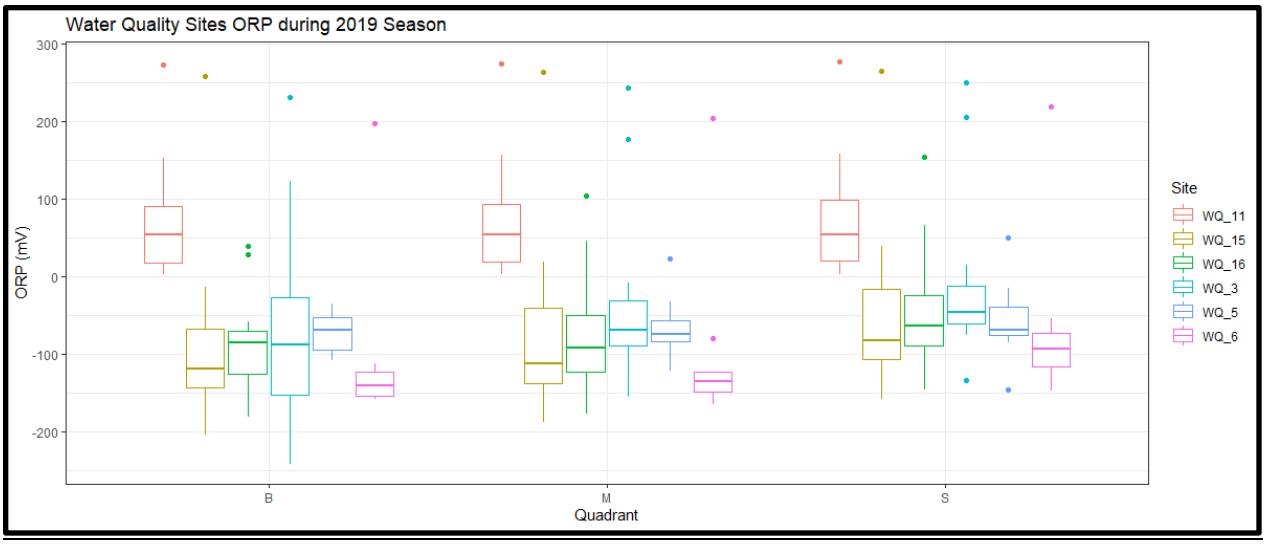

Figure 11: Oxidation Reduction Potential for water quality sites

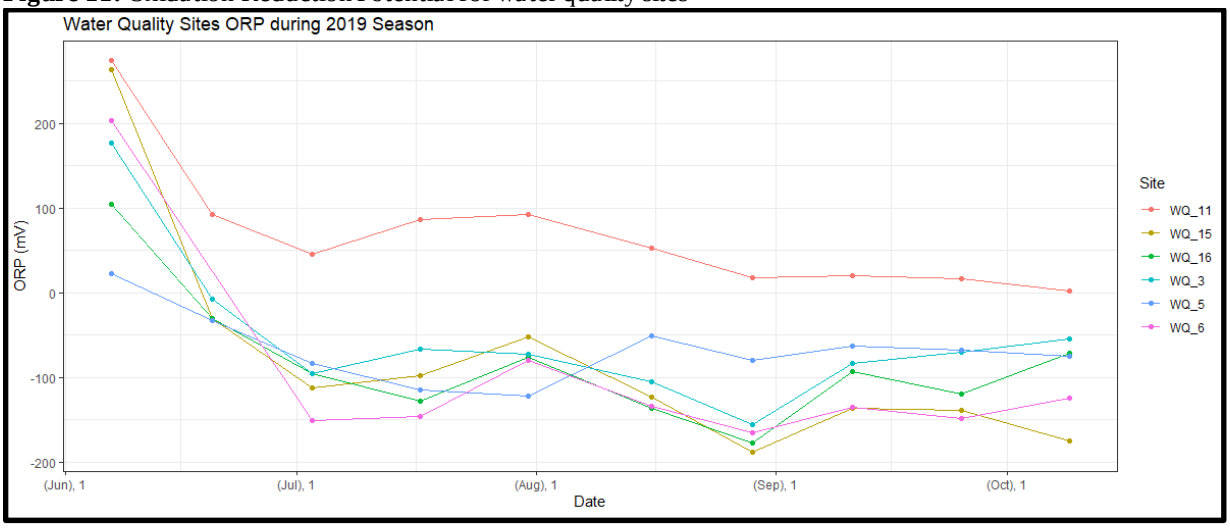

Figure 12: Middle ORP Plot for water quality sites

e. Turbidity

Figures 13 and 14 show turbidity results from WQ sampling. It can be observed that the first sampling had negative readings, this was due to a calibration error, these results can be considered invalid. Turbidity appeared to be highest in September when the cyanobacteria bloom was occuring. Turbidity readings were recorded in the middle of the water column.

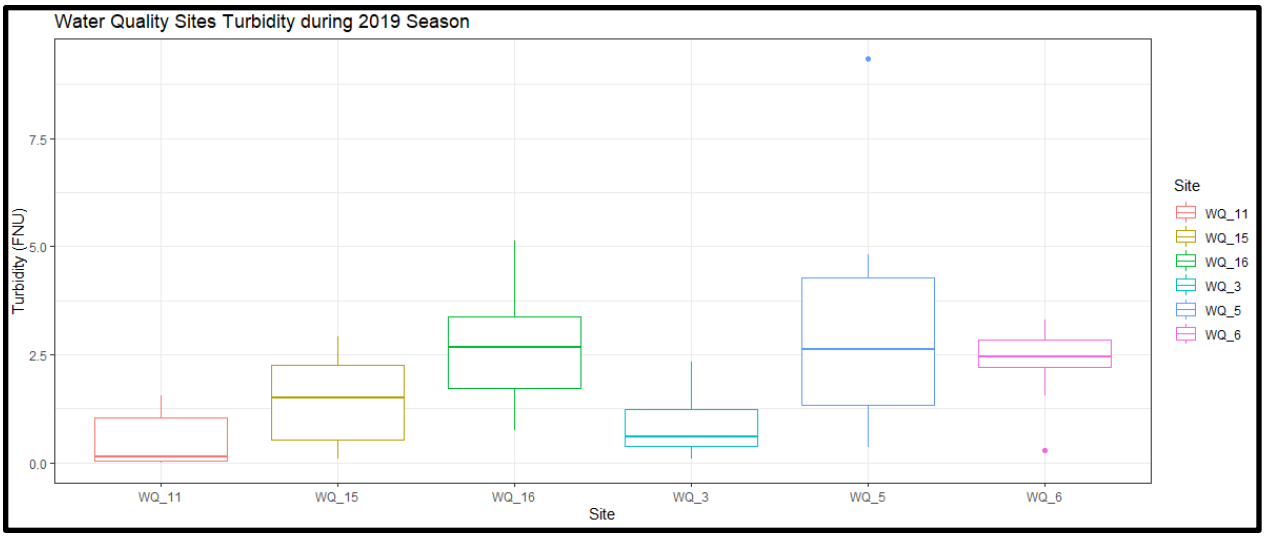

Figure 13: Turbidity range for WQ sites

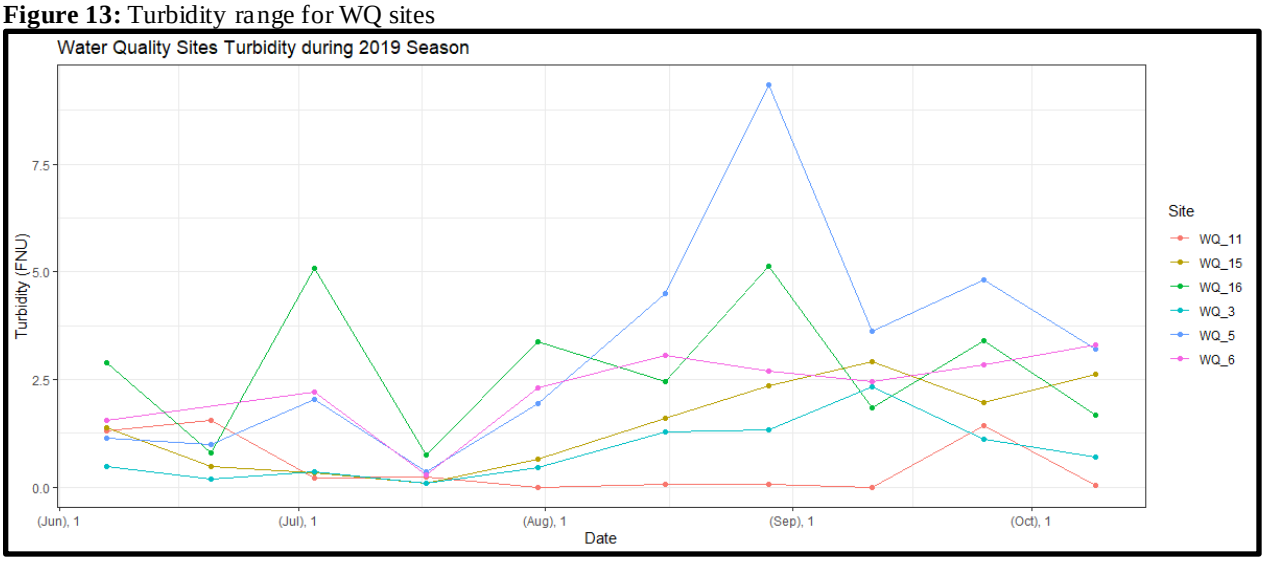

Figure 14: Turbidity for WQ sites

f. <u>Conductivity</u>

The conductivity of the lagoons is a good indicator of the overall health of the water column. Figures 15 and 16 show the conductivity measurements taken during the 2019 season. It can be observed that WQ 5, located in Lake Tallac has much higher conductivity than the rest of the sites.

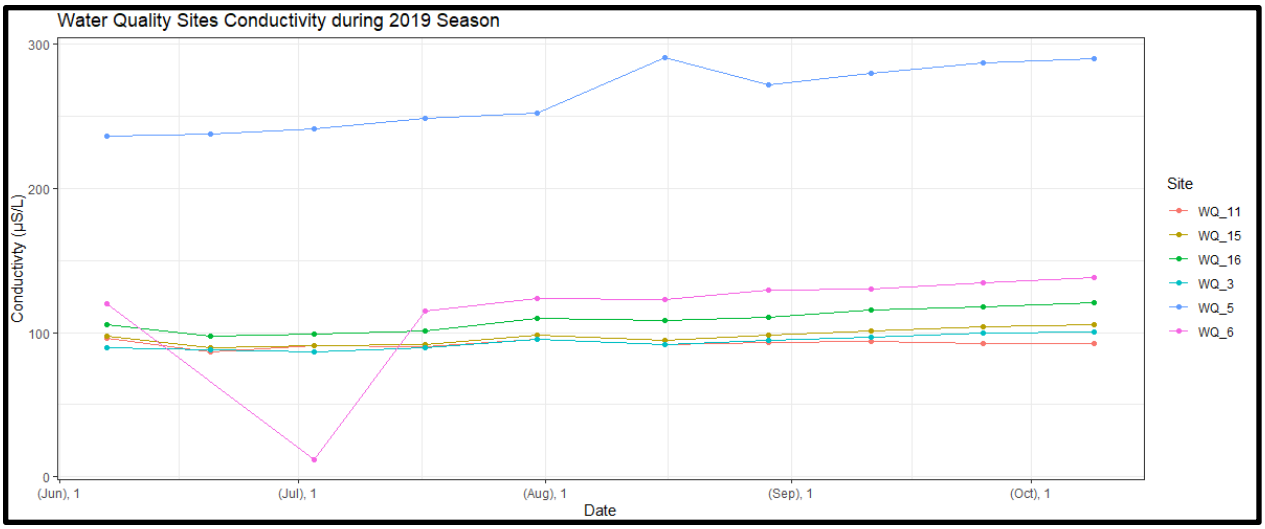

Figure 15: Conductivity for WQ sites May-October

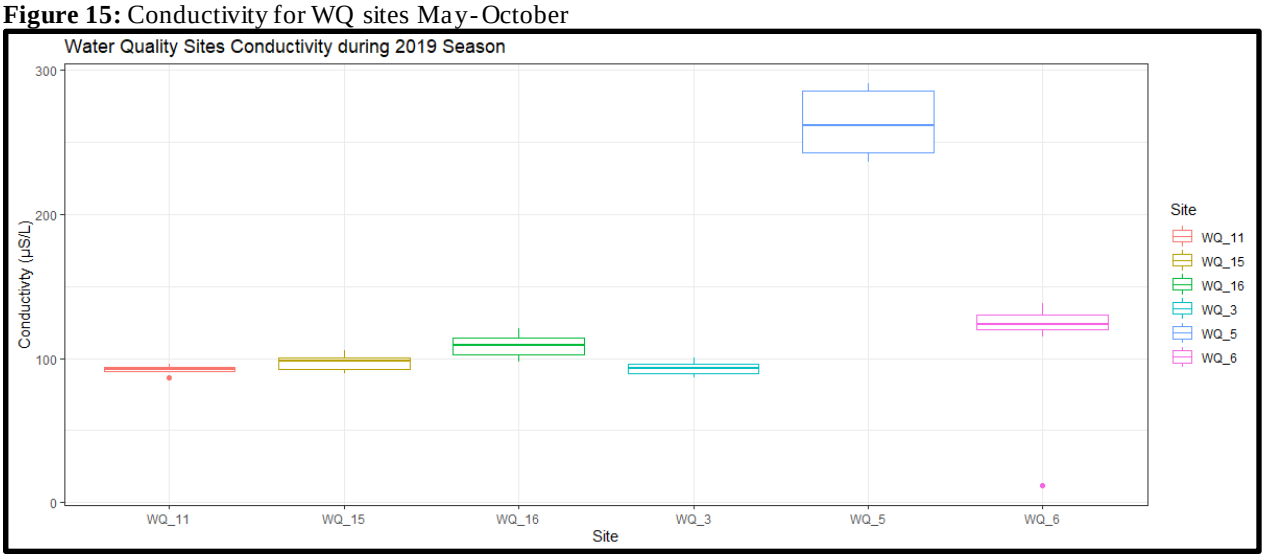

Figure 16: Conductivity Range for WQ sites

3.1.5 Discussion

The WDR permit issued by LRWQCB states "Tahoe Keys Lagoons are physically connected to Lake Tahoe and have no site-specific water quality objectives (WQOs) of their own, so Lake Tahoe WQOs apply." This means that even though the environment of the Tahoe Keys Lagoons is drastically different from Lake Tahoe Proper they still need to meet the same objectives. As displayed in the figures above the chemistry inside the lagoons is much different than in Lake Tahoe proper.

The Tahoe Keys was constructed with a water circulation system to keep water in the lagoons as clean as possible. This system used coagulation to reduce Total Dissolved Solids (TDS) and decrease turbidity helping keep the lagoons relatively clear. The Tahoe Keys is investigating if reactivativation of the circulation system is feasible. If this system were to be reactivated the TKPOA has the ability to monitor changes in water quality that may be caused by the reactivation.

Year	Total Nitrogen (TN), mg/L	Total Phosphorus	Total Dissolved Solids (TDS)	pH	Turbidity (NTU)

		(TP), mg/L	(mg/L)		
2007	0.28	0.030	74	9.16	0.75
2008	0.15	0.033	84	7.67	1.46
2009	0.33	0.043	87	9.15	7.97
2010	0.20	0.019	101	8.87	1.20
2011	0.18	0.023	71	8.31	1.72
2012	4.57	0.019	No data	8.88	No data
2013	0.24	0.026	81	7.97	1.88
2016	0.397	0.025	25.8	9.12	1.56
2017	0.647	0.033	31.39	7.84	2.27
WQO	**0.15**	**0.008**	**60**	**7.0-8.4**	**3.00**

Table 2: Water Quality Objectives and past years results (TKPOA 2016)

3.1.6 2020 Recommendations

In order to better monitor WDR and WQO compliance it is recommended that the TKPOA WQ Department monitor for Total Nitrogen and Total Phosphorus for at least one site in the East lagoon, West lagoon and Lake Tallac.

During the 2019 season cyanobacteria sampling was conducted based on observations of cyanobacteria blooms. For the 2020 season, it is recommended that cyanobacteria monitoring be conducted at specific sites once a month for more consistent data. This will help track where, when and under what conditions cyanobacteria blooms occur. Since the Tahoe Keys Lagoons are a phosphorus limited environment it is also recommended that phosphorus data is collected at these cyanobacteria sites to determine if the blooms are caused by increased phosphorus levels.

3.2 Laminar Flow Aeration Project

In an attempt to improve water quality of the Tahoe Keys lagoons as a part of the WDR requirements issued by LRWQCB the TKPOA AIS staff implemented a Laminar Flow Aeration (LFA) project in a section of the lagoons. This project will possibly help improve water quality of the lagoons in order to meet WQO stated in the LRWQCB's WDRs.

LFA is a technology used for improving water quality in water bodies where there is low dissolved oxygen and buildup of fine organic sediment. The LFA has been successfully used in wastewater treatment plants to reduce organic material. It is hypothesized that increased dissolved oxygen (D.O.) in the sediment layer creates a reaction that turns ammonia into nitrite. Researchers believe that this process is partially responsible for the reduction of organic matter seen in other LFA studies. The increase in D.O. and disruption of the organic matter by LFA aid in hydrolysis of carbohydrates and lipids, and protolyzation of proteins to amino acids, which

can lead to nitrification and denitrification. This technology has the potential to reduce the aquatic macrophyte problem in the Tahoe Keys Lagoons.

LFA technology uses microporous ceramic disks that are placed throughout the area to be aerated. These disks are connected by self-sinking hoses connected to an air compressor. Air is pumped through the system creating a dual density fluid that rises and creates circulation. This both oxygenates the water through the introduction of air and circulates oxygen from the surface to the bottom of the water column, where dissolved oxygen is typically the lowest.

Refer to Appendix B for the 2019 Laminar Flow Aeration End of Season Report

Figure 17: LFA project area view from Venice drive bridge looking North

3.3 First Flush Sampling

To evaluate the water quality of the runoff from TKPOA-owned facilities and the quality of the runoff entering the Tahoe Keys lagoons from City of South Lake Tahoe (CLST) owned storm drains and upgradient properties for which CSLT is responsible for stormwater runoff, the TKPOA conducted water sampling and laboratory analysis at selected locations within the Tahoe Keys in November 2019. The sampling was designed to occur after the first significant storm event of the season that was anticipated to produce runoff from both TKPOA-owned facilities and upgradient areas within the CSLT. This "first flush" runoff sampling was performed to identify the pollutants and nutrients that accumulate over the dry season and then are washed into the Tahoe Keys lagoons once the wet season begins. The "first flush" runoff is not intended to be representative of the average stormwater quality over the season, but may represent reasonable maximum anticipated nutrient levels.

Water samples were collected from surface water drainages, within storm drain inlets, or from the outlet of storm drains where accessible and above the lake level. Figure 1 shows the eleven sampling locations. SW 1 is in the surface drainage at the south end of the Lake Tallac canal, just north of Tahoe Valley Elementary School. SW 2 is a storm drain outlet that enters the west part of Lake Tallac and drains areas along 15th Street south of the Tahoe Keys. SW 3 and 4 drain relatively small areas within the western part of the West Lagoon area of the Tahoe Keys. SW 5

drains an area along Venice Drive just west of Christy Drive. SW 6 is a TKPOA-CSLT shared stormwater drain system that collects stormwater from TKPOA-owned common areas and townhomes along Ala Wai Boulevard. SW 5 and 6 are located in or receive drainage from potentially sensitive drainage areas that are identified in the January 2018 NPS Plan. SW 7 receives the runoff from single family residences and the TKPOA common areas, including the Pavilion, between Ala Wai Boulevard and Capri Drive. SW 8 receives runoff from single family residences, several townhomes, the TKPOA common area, and the Tahoe Keys Village commercial area along Lake Tahoe Boulevard and Danube Drive. SW 9 primarily drains runoff from outside of the Tahoe Keys along Tahoe Keys Boulevard. SW 10 and 11 are surface runoff drainages from South Lake Tahoe. These 2 locations drain from the intersection of Highway 89 and Highway 50 and nearby South Lake Tahoe neighborhoods. Other than the surface runoff at SW 1 and the shared drain system at SW 6, other locations are all CSLT-only stormwater drains.

Refer to Appendix C for the 2019 First Flush Report

Figure 18: 2019 First Flush Site Map

Figure 19: 2018 Map and Storm Drains by SEA

4.0 AQUATIC VEGETATION CONTROL PROJECTS

The homeowners in the Tahoe Keys have been dealing with noxious, invasive aquatic vegitation since the 1970s. In years past the TKPOA has utilized mechanical harvesters to clear aquatic vegetation from waterways . With the AIS program, the TKPOA WQ Department aims to help homeowners get rid of the aquatic vegetation through integrated strategies. The department has programs that help prevent aquatic vegetation growth and mitigate the spread of fragments to Lake Tahoe. The effectiveness of each treatment is monitored throughout its deployment and analysed to determine how the treatment can be improved.

4.1 Mechanical Harvesting

During 2019, the TKPOA conducted mechanical harvesting in the Tahoe Keys Lagoons. These harvesters have been utilized since the 1970s to control aquatic vegetation. Historically, the aquatic harvesters and skimmer boat crews were the primary means for the TKPOA to control the aquatic vegetation. Recently, harvesting has continued to be the primary means accompanied with other methods to meet the requirements of the WDR issued by the LRWQCB in 2014.

The TKPOA Board of Directors approved the Water Quality Committee recommendation to a one year pilot project that altered the standard harvesting schedule set by the 2016 TKPOA BOD Scope and Direction on Harvesting Operations. In previous years, harvesting operations began in June and ended at the completion of the boating season which was in early October. The 2019 Pilot Project, harvesting operations began in June but at a limited level, then went full operational after the July 4th holiday and ended in November. Due to the fewer harvesters, the main objective during the boating season was to keep the navigation lanes clear and if time permitted focus on docks and shorelines. Starting in October, the objective shifted from the navigation lanes to focus on homeowners docks and shorelines (if the harvester could fit into the area). The reason for this was to harvest around the plants growing cycle and try to reduce the amount of plant biomass that would turn into nutrient loaded organic material in the sediment. The schedule change resulted in substantially greater late-season weed harvest, as shown in Figure 20. The later harvest is intended to minimize nutrient levels in the water due to weed decay over the winter.

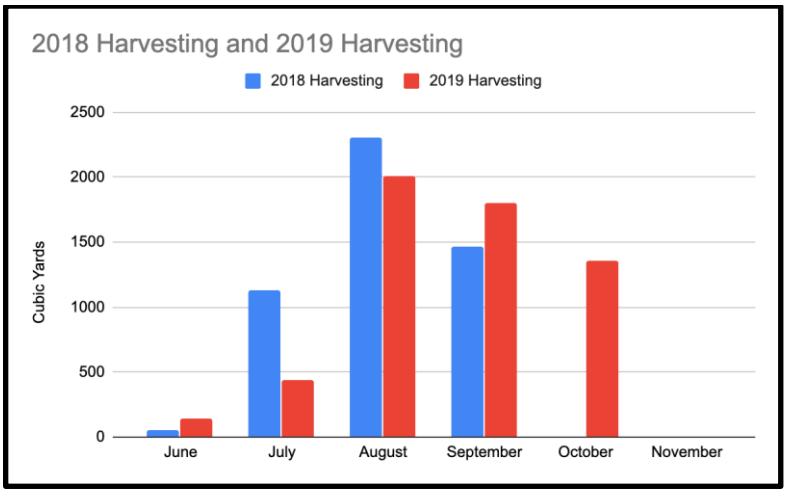

Figure 20: 2018 and 2019 harvesting totals throughout the season

During the 2019 harvesting season, the Water Quality Department removed 6,274 cubic yards of plants and plant fragments from the water. This was broken down into 5,747 cubic yards that were removed by the harvesters and 526 cubic yards that were removed by the skimmer boats. The table below is the 2019 End of Season Harvesting and Fragment Control (Table 3.)(Refer to Appendix D for the 2019 End of Season Harvesting Report)

	Jun-19			Jul-19				Aug-19				
	Jun 10-16	Jun 17-23	Jun 24-Jun 30	July 1-7	Jul 8-14	Jul 15-21	Jul 22-28	Jul 29-Aug 4	Aug 5-11	Aug 12-18	Aug 19-25	Aug 26-Sep 1
Hours Worked on Water (Harvesters and boats combined)	143	243	168	148	220	336	243	276	226	286	292	265
Days Worked (same as above combined)	5	7	7	6	7	7	7	7	7	7	7	6
Maintenance Hours	0	0	0	0	0	19	19	22	10	17	10	15
Harvester weed removal (Cubic yards)	46	20	74	26	59	133	225	241	453	310	471	531
Boat weed removal (Cubic yards)	4	11	1	3	7	21	15	20	23	37	43	38
Total Weed Removal (Cubic Yards)	50	32	75	29	66	154	240	261	476	347	513	569

	Sep-19				Oct-19					Nov-19		Season
	Sep 2-8	Sep 9-15	Sep 16-22	Sep 23-29	Sep 30-Oct 6	Oct 7-13	Oct 14-20	Oct 21-27	Oct 28-Nov 3	Nov 4-10	Nov 11-17	
Hours Worked on Water (Harvesters and boats combined)	221	224	202	201	180	173	140	149	116	68	76	4,598
Days Worked (same as above combined)	6	7	7	7	7	5	5	5	5	5	5	164
Maintenance Hours	10	16	8	9	7	5	5	8	3	2	2	167
Harvester weed removal (Cubic yards)	677	724	190	214	710	315	117	150	63	0	0	5,747
Boat weed removal (Cubic yards)	37	35	34	26	29	31	20	27	32	15	19	526
Total Weed Removal (Cubic Yards)	714	758	224	239	739	346	136	177	95	15	19	6,274

Table 3: Volume of Weeds Removed in 2019 (cubic yards).

Variable	2018	2019	Percent Change
Harvesters	4,964 Ft^3 Collected	5,547 Ft^3 Collected	+13.62
Boat Crews	792 Ft^3 Collected	526 Ft^3 Collected	-33.58
Overall	5,756 Ft^3 Collected	6,274 Ft^3 Collected	+8.25
Number of Harvesters	5	5	3

Table 4: Biovolume collected

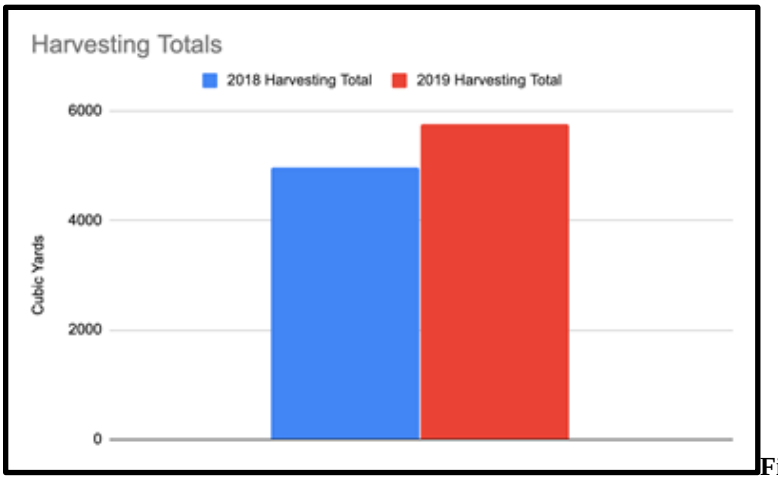

Figure 21: 2018 and 2019 Season Totals

4.2 Boat Backup Station, Bubble Curtain and Seabins

Aquatic macrophyte fragments have been dispersing from the Tahoe Keys into Lake Tahoe since the infestation began. Currently, weeds thrive in the stagnant lagoons with warm temperatures and poor water clarity. The invasive weeds struggle to survive in the Lake Tahoe proper due to increased clarity and lower temperatures. However, in recent years Tahoe's average temperature has increased, and is predicted to continue moving towards warmer temperatures (Coats, R., et al., 2006). Warmer habitat could lead to a more hospitable environment for invasive plant species in the near future. This prompted the TKPOA to develop a system that would prevent a majority of fragments from dispersing into the lake.

The TKPOA implemented the Boat Backup Station in 2016 and has continued to improve on the design. The system now utilizes the combined strategies of the boat backup station, bubble curtain, bottom barriers and seabins. The boat backup station notifies boaters to back up, ensuring that weeds caught on their props and rudders are dislodged before they enter the lake. The bubble curtain creates a barrier at the west lagoon that prevents the dislodged fragments from dispersing into the lake. The seabins placed on the sides of the channel collect fragments that are funneled towards them due to the v-shape of the bubble curtain (Figure 22). The backup station is also cleaned up by a skimmer crew every weekday around 8:30 and 3:30 in the summer. This crew collects fragments, empties the sea bins and records the volume and species of the weeds that were collected. This gives the TKPOA a quantifiable number for the volume of weeds that the system prevented from entering the lake. These combined methods help reduce the amount of weeds that enter Lake Tahoe.

Several improvements were implemented in the 2019 season based on 2018 observations. In 2018 the bubble curtain airline encountered buildup of vegetation around the air line reducing the flow of bubbles. To fix this, in 2019 the bubble curtain was underlined with bottom barriers to reduce buildup of vegetation. This solution proved moderately effective, some vegetation built up around the line due to sediment settling on the barriers.

Refer to Appendix E for the boat backup station, bubble curtain and seabin report

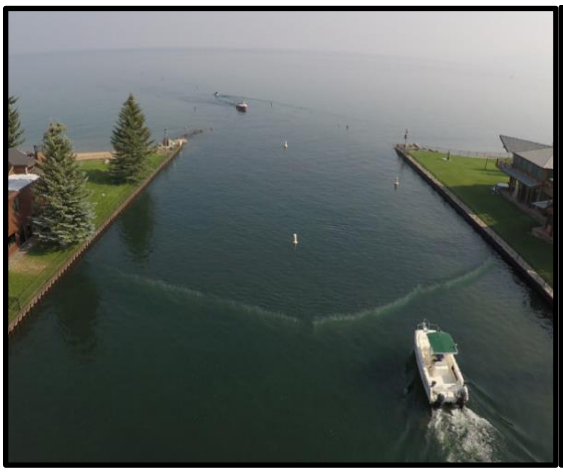

Figure 22: Bubble Curtain

Figure 23: Underwater Bubble Curtain

Figure 24: Seabin and bubblecurtain with accumulation of weeds

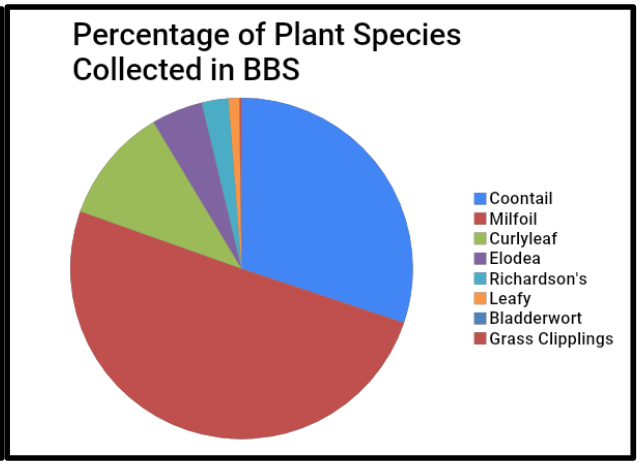

Figure 25: Percentage of Plants collected from boat backup station monitoring.

Date	Time	Boats observed	Boats that backed up on their own	Boats that were instructed on the Boat Backup Station	Boats that failed to yield for instruction or compliance
6/21/2019	1400-1530	27	18	9	0
6/28/2019	1345-1530	6	3	2	1
7/11/2019	1415-1530	15	11	3	1
7/12/2019	1415-1530	14	13	0	1
7/18/2019	1400-1500	15	11	3	1
7/19/2019	1230-1500	59	45	7	7
8/9/2019	1300-1515	56	45	10	1
8/23/2019	1400-1500	19	12	5	2
8/30/2019	1300-1515	26	22	2	2
9/6/2019	1400-1600	13	6	6	1
9/13/2019	1430-1530	12	8	3	1
9/20/2019	1315-1530	26	21	3	2
9/27/2019	1330-1515	6	4	2	0
		294	219	55	20
Percents			74.49%	18.71%	6.80%
Percent Totals			93.20%		6.80%

Table 5: 2019 Boat Backup Station Monitoring Results

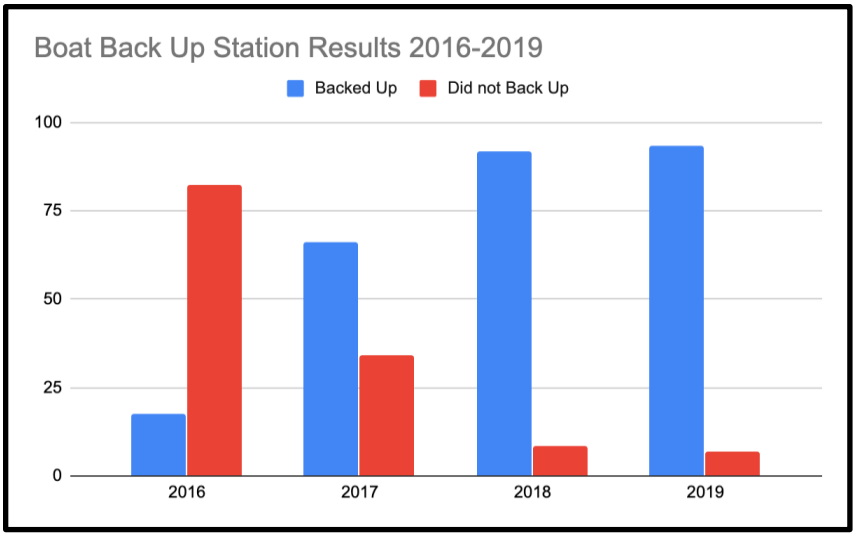

Figure 26: 2016-2019 Boat Backup Monitoring Results

4.2.1 Sea Bin Recommendations

At the beginning of the 2019 season, the AIS staff planned to install two Sea Bins in the West channel. One Sea Bin was installed in the West channel at the beginning of the 2019 season. It was not possible to install the second seabin due to the lack of a stable mounting point. However, electric outlets for the second Sea Bin were installed. The AIS staff plans to install two sea bins at the beginning of the 2020 season. These Sea Bins will be mounted on two pilons placed on each side of the channel.

The Sea Bin that was in place during the 2019 season was effective at collecting weeds; it did have a few problems. Boat wakes and waves from the lake often knocked the collection net out of the bin. It is recommended that for the 2020 season that the WQ Department implement a way to shield the Sea Bin from waves and boat wakes. Another improvement that would benefit the collection team would be to implement an easier way to empty the sea bin basket or designing a new basket. The bin also had problems with water levels dropping, preventing it from working properly. It is recommended that the Sea Bins are placed on a floating platform with a wave attenuator facing towards the lake. This solution should help alleviate some of the problems that occurred during the 2019 season.

4.2.2 Bubble Curtain Recommendations

The bubble curtain performed adequately throughout the 2019 season. This is due to the compressors being replaced at the beginning of the season with new compressors. However, the new units are beginning to deteriorate. The units were recalled due to abnormal wear during extended use. It is recommended for the 2020 season that the WQ department purchase a compressor that has more output and is rated for continuous use.

4.3 Bottom Barriers

Bottom barriers are a proven way to eliminate aquatic vegetation growth. In 2010, a partnership of agencies implemented bottom barriers in Emerald Bay. This project used around 5 acres of

bottom barriers coupled with diver assisted hand pulling. When the barriers were removed there was only sand beneath them.

Due to the success at Emerald Bay the TKPOA WQ Department decided to experiment with bottom barriers in the Keys Lagoons. In 2017, the department experimented with a large scale bottom barrier at the end of one of the lagoons. The large scale bottom barrier proved to be effective at eliminating weed growth while they were in place (TKPOA 2017). However, large scale bottom barriers are not feasible for the entirety of the Keys Lagoons due to cost.

It can be seen in figure 27 that the weeds have around 100% return rate once the barriers are removed. Figure 27 shows that the return was also seen 2 years after removal. Due to these downsides the department decided to not implement a large scale bottom barrier test in 2019. Instead the WQ Department continued to use a more small scale program to help homeowners deal with aquatic vegetation along their docks and shoreline.

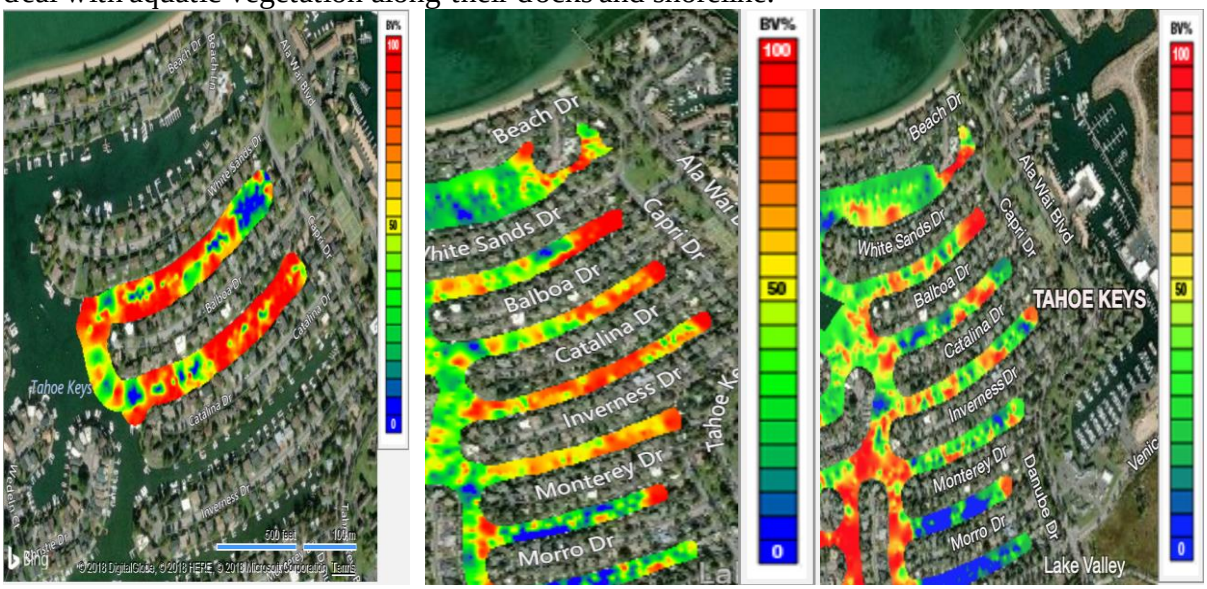

Figure 27: Skipper Cove Large Scale Bottom Barrier Project. Left Hydro-Acoustic Scan was taken October 12, 2017, the middle is from September 20, 2018 and the right was taken September 16, 2019.

Similar to years past, in 2019 Tahoe Keys homeowners were able to obtain bottom barriers by putting down a $50 deposit. The homeowners then needed to install the bottom barriers around their own docks; most homeowners used local dive companies for installation . This prevented weeds from growing up beneath their boats where they would become tangled in their boat propeller. At the end of the season the bottom barriers need to be removed and returned to the WQ Department. The homeowners are required to write an end of season report to get their deposit back. These reports help the WQ Department determine how effective the bottom barriers are in certain regions. The homeowners that borrow the TKPOA bottom barriers often report that the barriers were successful and helped keep their dock area clear of weeds. However, homeowners also reported that a large amount of weeds grew around their barriers.

Refer to Appendix F for the 2019 Bottom Barrier End of Season Report.

4.4 Lake Tallac Yellow Pond Lily Removal

The canal in Lake Tallac is home to many invasive and native species. One of particular concern is the Yellow Pond Lily. This plant has a deep root system and is capable of growing even when cut because the entire root system needs to be taken out. This Pond Lily is taking over its current habitat and has the potential of spreading into the canals/lagoons and possibly out into the lake. This has made controlling this species a top priority for the WQ Department.

The AIS Program has been attempting to secure funding to remove the Yellow Pond Lily from Lake Tallac's Canal since 2016. In 2019, the WQ Manager, along with homeowners assistance, presented to the City of South Lake Tahoe City (CSLT) Council the ongoing and future problems that the Yellow Pond Lily presents to the area along the CSLT stormwater system. This presentation was successful and one-third of the funding was secured for this project that is projected to take place in Spring 2020.

5.0 AQUATIC VEGETATION MONITORING PROJECTS

Certain aquatic vegetation can negatively impact water quality more than others. Also more dense vegetation can hinder boaters. In an effort to determine where water quality might be worse in the lagoons the TKPOA monitors vegetation types and density. These programs help track the year to year changes in vegetation along with density in certain areas. The AIS program plans to implement more programs in coming years.

5.1 Annual Macrophyte Survey

The Annual Macrophyte Survey was conducted once during the 2019 season. The survey sampled 588 points throughout the Tahoe Keys Lagoons and Lake Tallac. At each point a sample is taken by raking the bottom with a sampling rake (Figure 28). The sample is then analysed and the percentage of each species is estimated. The percentage and species is recorded on a data sheet, input to GIS software and checked against archived data to determine what plants are growing where. These results were published and are incorporated into the 2019 Macrophyte Report created by Sierra Ecosystem Associates.

Figure 28: Sampling thatch rake used for macrophyte survey

5.2 Hydroacoustic Scans

Throughout the 2019 season the AIS staff mapped plant density in the Tahoe Keys Lagoons. This was done using an HDS 7 Lowrance system with a HDI 83/200 Transducer mounted on the AIS boat and Biobase software that determines plant density based on the structure scan produced by the Lowrance system. The AIS Staff added a scanner to the TKPOA Architecture Control Committee (ACC) boat later in 2019 as well. The hydroacoustic scans map where plant density is greatest and if needed the WQ Department Manager can direct harvesters to the high density areas to clear up the areas.

Figure 29: LowRance for Hydroacoustic Scans Survey

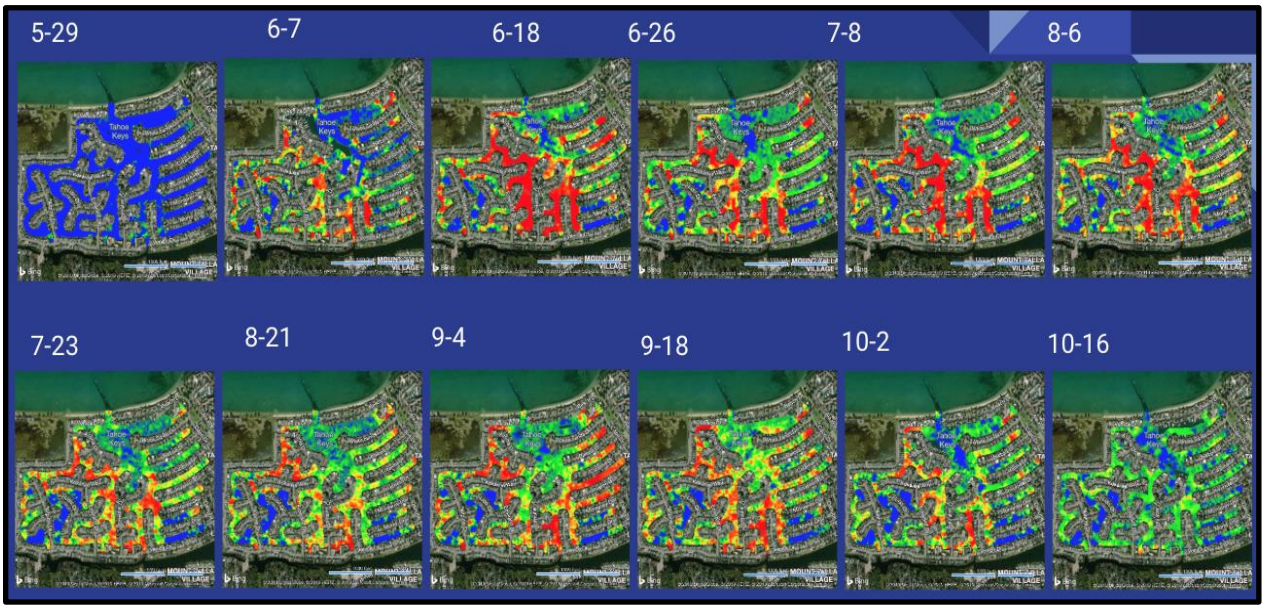

Figure 30: 2019 Hydroacoustic Scan Compilation

5.3 Ultraviolet Light Treatment

Incentive Resources Incorporated (IRI) has been testing UV Light treatment to reduce aquatic vegetation biomass at different sites throughout Lake Tahoe. Recent successes at Lakeside Marina suggest that UV light treatment might be viable in the Tahoe Keys. In late 2019, the company began running tests in a small section of the Keys Lagoons. The test site was utilized due to the warm turbid waters with excessive plant growth. The area also has vertical walls and uneven rocky edges along with an uneven bottom with many natural and man-made obstacles. IRI will be conducting a larger scale UV Light Project inside the TKPOA waterway during the 2020 season.

6.0 OTHER AIS PROJECTS

6.1 Radar Systems

Large boat wakes can increase shoreline erosion, deteriorate bulkheads and cause damage to boats and docks. The TKPOA WQ Department has been encouraging people to slow down while traveling in the lagoons to reduce their wake but staff and security can not always be there to monitor the speed of boats. The WQ Department had purchased two radar systems at the beginning of the 2018 season. One to display boaters speeds as they approach the West Channel along with one for the East Channel. These systems were to inform boaters of their speed so they would slow before entering the channel.

The radar system in the West Channel has been functioning properly for the entire 2019 season. The TKPOA would like to use the West Channel system to monitor boat traffic coming into the Keys. This would help track the amount of boats in The Keys over time. The system for the East Channel was removed shortly after installation due to complaints from homeowners. The WQ Department then decided that this system could be mounted on a mobile platform to display the speeds of boaters as they pass by it in the lagoons. The Department consulted with a local dock company to construct such a platform. This system was installed midway through the 2019 season, at a key intersection where it would be visible to the most boaters in the Tahoe Keys.

Figure 31: Mobile Radar System in West Lagoon

6.2 TKPOA Boat Count

Due to the commonness of rental properties in the Tahoe Keys and resulting flux of boat numbers it is important to track the amount of boats that are inside the West Lagoon. In 2019, the WQ Department and security split into 7 groups for 8 sections of the lagoon. The number of

boats in each section was recorded. This gave the TKPOA a total number of boats in the West Lagoon, not including kayaks, pedal boats or other non motorized vessels.

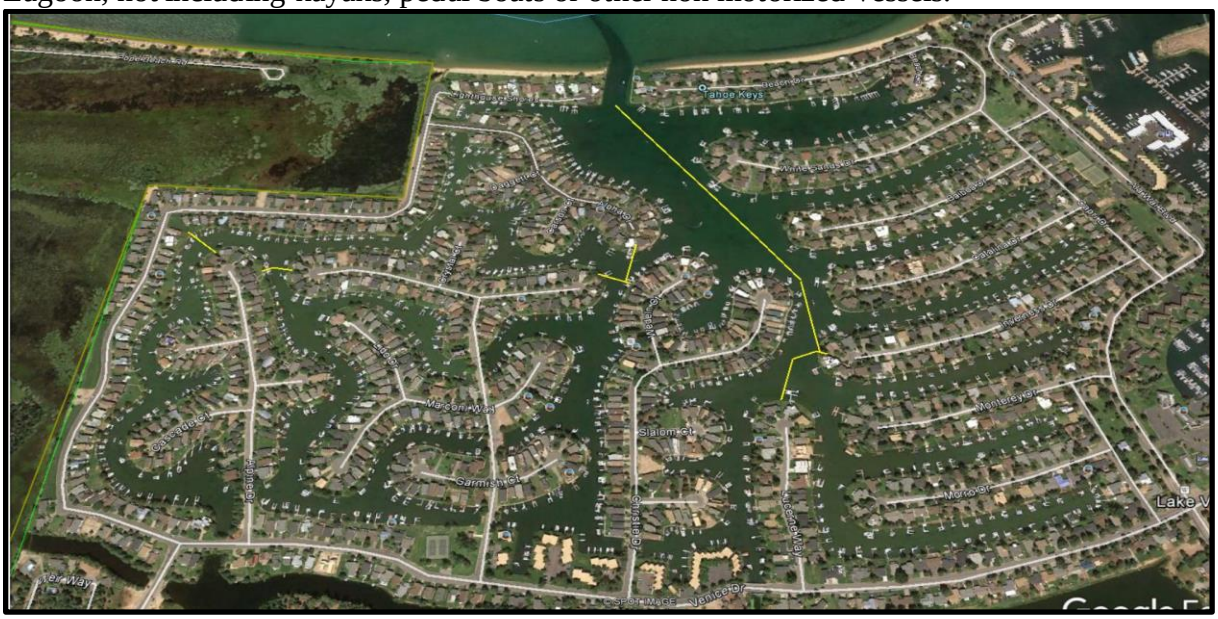

Figure 32: Map of 2018 Boat Count Sections.

6.3 Google Maps and GIS Database

The AIS program staff has been using Google Earth for its internal mapping needs. Google Earth is a good tool to show locations of sites but it is not very good for data analysis. Due to this, the TKPOA WQ Department purchased GIS software late in the 2019 season. The AIS staff has been working to import maps into the new database which will be operational in the 2020 season.

6.4 Water Quality Administrative Record

The WQ Department Staff compiled all of the documented correspondences that took place between the TKPOA and outside organizations in regards to the AIS Program. These correspondences were cataloged by month and year in both paper and electronic copies. This has allowed the TKPOA Board of Directors and the Water Quality Committee to have documented records of the Association's AIS Program efforts.

6.5 Nutrient Input Control

The Tahoe Keys Lagoons are a phosphorus limited environment. This means that growth of aquatic vegetation is mostly controlled by the amount of phosphorus released into the lagoons. In 2016, TKPOA BOD banned phosphorus fertilizers in an attempt to control the growth of aquatic vegetation. The results of the 2018 and 2019 first flush sampling indicate that this ban was effective in reducing the amount of phosphorus in runoff that enters the Tahoe Keys West Lagoon.

6.6 Cigarette Butt Collector and Monitoring

Cigarette butts contain carcinogenic chemicals that can be harmful to the environment if not disposed of properly. To help with proper disposal the League to Save Lake Tahoe (LTSLT) has a program where they supply cigarette butt canisters to companies around the basin. In late 2019

the TKPOA volunteered to participate in the program. The LTSLT provided a cigarette butt collector to place on the TKPOA public beach. This canister will help monitor how many cigarette butts are disposed of at this location. AIS staff has procured 4 more canisters to be installed throughout the Keys.

7.0 PUBLIC OUTREACH

7.1 Lunch and Learn

Prior to the kickoff of the boating season, the TKPOA WQ Manager hosts a presentation to the community which is called Lunch and Learn. This is designed to educate the property managers, landscape companies, hot tub companies, and nursery employees on the TKPOA AIS management plan, TKPOA landscaping policy and procedures, and TKPOA rules and regulations.

7.2 TKPOA Hosted League to Save Lake Tahoe Eyes on the Lake Training Events

TKPOA hosted six sessions of the League to Save Lake Tahoe's Eyes on the Lake training program. This is a volunteer citizen science program to prevent the spread of aquatic invasive species in Lake Tahoe. The TKPOA WQ Staff also participated in training prior to the harvesting season.

7.3 Board of Directors and Cove Advisors Meetings

The TKPOA WQ Department Manager attends all of the BOD and Cove Advisor meetings during the operational Season. This is to inform members of the Harvesting Operations, AIS Program project updates and ongoing efforts to control the AIS Problem.

7.4 Best Management Practices (BMP)

In an undeveloped environment, runoff from precipitation is absorbed into the ground and filtered through soil, wetlands, and root systems. As urbanization of the Lake Tahoe Basin increases, wetlands, wet meadows and riparian habitat are removed or threatened. Compromising these habitats removes the basin's natural water treatment and filtration system. As impervious surfaces (such as pavement) increase, filtration is further distrubed. Disrupted filtration contributes to an input of nutrients and sediment into the lake, decreasing its renowned clarity.

The biggest cause for concern regarding the Lake's clarity decline is presence of nitrogen, phosphorus, and fine sediment. The best way we can decrease input of these factors into the Lake is to implement Best Management Practices (BMP) on all properties. BMP implementation is particularly important in the Keys because of the close proximity to Lake Tahoe. In 2018, only 340 out of the 1,151 parcels in the keys had BMP certifications. Of the certified parcels, only 191 had full certifications and 149 had Source Control Certifications. In the near future, we aim to make BMP information more readily available and for every home in the Keys to be BMP certified.

8.0 2020 PROJECTS

8.1 Ultrasonic Algae Treatment

Since 2017 the Tahoe Keys Lagoons have had an influx of blooms of harmful algae. These algae blooms have been getting worse every year and the cause is not yet known. It is recommended in the 2020 season that the TKPOA purchase an ultrasonic unit that reduces harmful algae but is harmless to native fish and other wildlife.

8.2 Biowaste to Bioasset

The WQ Department harvests thousands of pounds of aquatic vegetation every year. Currently, this vegetation has been trucked away at an immense cost to the homeowners. The department has been attempting to find a use for these weeds. It was suggested that these weeds be turned into pellets to be used in wood fireplaces. (See Appendix G)

8.3 Floating Wetlands

Floating wetlands have been a proven way to effectively and economically remove nutrients from the water. Lake Tallac has an abundance of nutrients in the water column which fuel excessive aquatic vegetation growth, mainly coontail, every season. These nutrients could be removed from the water column by implementing floating wetlands. Proper implementation of floating wetlands could lead to a reduction of total biomass in Lake Tallac. If this implementation is successful floating wetlands could be implemented in the Tahoe Keys lagoons to reduce aquatic vegetation growth for homeowners.

8.4 Sediment Level Monitoring

As mentioned earlier in the report, the organic layer of muck at the bottom of the Keys Lagoons that fuels annual aquatic vegetation growth. Along with earlier studies in the early 2000s, in 2016 and 2017 sediment samples were taken at a few of the water quality sampling sites. These samples helped gauge the nutrient levels and composition of the sediment to determine how to best approach getting rid of it. For the 2020 season, the TKPOA AIS program will conduct sediment sampling for the LFA sites and other areas in the Tahoe Keys lagoons.

8.5 Mobile Education Center

Education and outreach important factors in controlling the AIS of Lake Tahoe. The more people know about the problem and how they contribute to it, the easier it is to implement solutions that people will follow. The AIS staff would like to increase their education outreach program. As a part of this enhanced outreach, the WQ manager is seeking approval to purchase a mobile education center to be placed in Tahoe Keys common areas. This platform would include aquatic plant samples from the Keys waterways, a screen displaying educational material pertaining to many aspects of AIS projects. This platform would inform homeowners of AIS problems and hopefully encourage them to comply with current and future AIS projects.

8.6 East Channel Bubble Curtain

The bubble curtain across the TKPOA West Channel has proven to be effective at preventing fragments of aquatic vegetation from entering Lake Tahoe. In 2020, AIS staff plan to install a TRPA funded bubble curtain across the East Channel. The AIS staff plan to monitor the project the same way the West Channel Backup Station and Bubble Curtain was monitored in 2019.

9.0 COLLABORATIONS

9.1 League to Save Lake Tahoe

Over the summer, TKPOA continued its partnership with the LTSLT. Similar to last summer, six Eyes on the Lake Trainings were held at the pavilion. A strong effort was made to encourage Tahoe Keys homeowners to attend the training. Flyers were posted in the pavilion, notices were placed in the Keys Breeze, and e-blasts were sent out to the homeowners a week before each training. This was done to inform homeowners about the aquatic weeds and the problems they pose to the entire lake.

In addition to hosting the Eyes on the Lake Trainings, the LTSLT staff was also taken on the WQ Department's Boston Whaler to observe the extent of the weed problem in the Tahoe Keys, collect samples of plants for training activities and to create pressings. The League to save lake tahoe has given us a whole bunch of money for our projects.

9.2 Local College

Lake Tahoe Community College which is located in South Lake Tahoe and Sierra Nevada College which is located in Incline Village both use the TKPOA Waterways for classroom and lab instruction. The classes that are taught are Environmental Science, Biology, Ecology, Aquatic Ecology, and Hydrology. The WQ Staff provides ongoing AIS Programs brief for each of the classes to inform the students of the ongoing efforts by the TKPOA Homeowners.

10.0 ABBREVIATIONS AND ACRONYMS

AIS	Aquatic Invasive Species
BMI	Benthic Macroinvertebrates
GIS	Geographic Information System
GPS	Global Positioning System
IMP	Integrated Management Plan
IWMP	Integrated Weed Management Plan
LFA	Laminar Flow Aeration
LRWQCB	Lahontan Regional Water Quality Control Board
LTSLT	League to Save Lake Tahoe
SEA	Sierra Ecosystem Associates
TKPOA	Tahoe Keys Property Owners Association
TRPA	Tahoe Regional Planning Agency
WDRs	Waste Discharge Requirements
WQO	Water Quality Objective
WET Lab	Western Environmental Testing Laboratory

11.0 LIST OF PREPARERS

Name	Education	Role
Gregory J Hoover TKPOA	B.S. Biology and Environmental Sciences A.A Natural Science A.A. Environmental Technology and Sustainability: Biological Resources	Principle in Charge Contributing Author Data Analysis
Michael Bangs TKPOA	B.S. Environmental Sciences with Applied Geology Emphasis	Primary Author Data Collection Data Analysis
Vesper Rodriquez TKPOA	A.A. Visual & Performing Arts: Digital Music Technology A.A. Environmental Technology and Sustainability: Physical Resources - In Progress	Contributing Author Data Collection
Katherine Walton TKPOA	B.S. Human Nutrition, Foods and Exercise with Minor in Psychology	Contributing Author Data Collection
Haley Lazar	B.S. Environmental Science-	Contributing Author

TKPOA	Ecology A.A. Natural Science	
Dona Olsen TKPOA	A.A. Environmental Technology and Sustainability: Physical Resources and Biology	Data Collection
Stephanie Ferjo TKPOA	B.S. Environmental Science w/ Concentration in Natural Resource Management	Data Collection

12.0 REFERENCES

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8.) TKPOA 2016e. 2016 Macrophyte Survey Report for the Tahoe Keys Lagoons. Prepared for the Tahoe Keys Property Owners Association. Prepared by Sierra Ecosystem Associates.

13.0 APPENDICES

Appendix A

2019 TKPOA Calibration Log

Appendix B

2019 TKPOA Laminar Flow Aeration EOS Report

Appendix C

2019 First Flush Sampling Report

Appendix D

2019 TKPOA Harvesting EOS Report

Appendix E

2019 TKPOA Boat Backup Station EOS Report

Appendix F

2019 TKPOA Bottom Barrier EOS Report

Appendix G

Biowaste to Bioasset