Lake Management Plan for Herons Landing

Sanibel Florida

Prepared by SCCF Marine Lab in Cooperation with

Herons Landing HOA and The City of Sanibel

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Introduction

In March 2017, a group of concerned residents of the Herons Landing development met with City of Sanibel Natural Resources Department and Sanibel Captiva Conservation Foundation (SCCF) Marine Lab to discuss the perceived poor water quality within the lake (Herons Landing western lake) located north of Osprey Court. In that meeting, the residents expressed their concerns regarding a strong hydrogen sulfide odor emanating from the lake, dark coloration of the water and a lack of aquatic life in the lake.

As part of a baseline study of 72 lakes on Sanibel in 2016 (Sanibel Community Lakes Baseline Water Quality Report), the Herons Landing western lake was ranked poorest in water quality of all lakes surveyed on the island. Its proximity to the former Sanibel Bayous Wastewater Treatment Plant percolation ponds was hypothesized as a reason for high nutrient and chlorophyll *a* concentrations found in that study. The Bayous Developments relied upon this wastewater treatment plant until 2007 when all homes in the area were connected to the City's centralized sewer system. In March 2008, The City of Sanibel purchased the former wastewater treatment plant percolation pond site and developed plans to properly close the ponds. Following Florida DEP guidelines, the percolation ponds were pumped, filled with sand, inspected and closed in 2009. In 2015, as part of a reclamation effort, the city dug two smaller ponds on the former perc pond site and planted aquatic and terrestrial vegetation to aide in removing any nutrients still present.

After considering the concerns of lakefront property owners, the City of Sanibel agreed to further investigate the water quality issues in the lake. A small study was undertaken by SCCF Marine Lab at the City's request which included further sampling of the lake itself and installation and sampling of groundwater monitoring wells on the former percolation pond site (now owned by the City and William Broder). The study also included boring into the former percolation pond substrate to analyze the substrate and surrounding groundwater for metals most commonly associated with domestic wastewater. Results of that study were published in a report by the SCCF Marine Lab and distributed to the stakeholders and the City (Appendix 2). That study found the lake to be hypereutrophic (excessively-productive) with high levels of Chlorophyll *a* fueled by extremely high levels of phosphorus (P) and nitrogen (N) in the water column. The dominant planktonic organism in the water column was sulfur-reducing bacteria and the lake itself was hypoxic (very low oxygen conditions). These conditions explain the strong sulfur odors and lack of aquatic life in the lake. The concentration of phosphorus was near the highest value of any ambient surface water samples taken by the SCCF Marine Laboratory on Sanibel. Stormwater runoff from the low density residential land use around the lake did not lend itself to producing such poor water quality, suggesting influence from another source such as groundwater nutrient inputs from the percolation pond site. . However, certain practices (e.g. fertilization, removal of shoreline vegetation) of the residential community can be a contributing factor to the poor health of the waterbody and can exacerbate the existing issues.

In 2017, Florida Gulf Coast University's (FGCU) Southwest Florida Aquatic Ecological Group performed a health assessment of the lake's function (study data available in Appendix 2). Similar to SCCF findings, the investigation performed by FGCU confirmed the presence of a hypoxic environment, poor water clarity likely due to the persistence of sulfur-reducing bacteria in the water column, and exceptionally high concentrations of nitrogen and phosphorus that drive the TSI to a state of hypereutrophy. Additionally, FGCU also performed sediment coring to characterize the conditions in the lake bed sediments. Three cores were taken along a transect and although the muck (flocculated material and organic sediment) thickness was not large in size, the nutrient content was very high, especially phosphorus. Furthermore, the approximately half of each core was comprised of flocculated material which is an unconsolidated material that can easily be re-suspended into the water column. This is important to note because if the flocculent material is stirred back into the water column it increases the amount of nutrients available to algae for growth.

Hydrogen Sulfide is easily detected in the air at concentrations as low as 0.5 ppb. This concentration would generally equate to a Hydrogen Sulfide concentration near 0.5 mg/l in the water. Sulfides that exceed 1 mg/l in the water will generate the very noticeable and objectionable rotten egg odor (McVay 2009). Due to the strong rotten egg odor often found at the western lake at Herons Landing, it likely has sulfide concentrations above 1 mg/l.

Monitoring wells installed at the former percolation pond site showed groundwater from that site flows into the Herons Landing western lake. Sampling by SCCF found the concentration of phosphorus and nitrogen in the groundwater was greater than the concentration found in the lake. This evidence suggests that groundwater flows from the former percolation pond site and is a source of nutrient input to the study lake. Using level loggers installed in the monitoring wells, estimates of groundwater flow volumes to the lake from the former wastewater pond site were made during a 2 week period in the 2017 dry season. During that period, the nitrogen and phosphorus load to the lake from the wastewater site was 2.1 kg/day N and 0.5 kg/day P. If this data is extrapolated, 748 kg N and 143 kg P would be expected to flow in to the Herons Landing lake annually. Stormwater runoff estimates were also made to compare loads from stormwater sources to the lake to the groundwater loads. Using Sanibel-specific nutrient concentrations and runoff coefficients, annual stormwater loading of N and P is 30.3 and 4.6 kg/yr. Stormwater inputs from the lake's watershed were less than 5% of the estimated groundwater inputs. This finding suggests that BMPs targeting only stormwater runoff will have little effect on the lake's water quality. Groundwater sources must also be addressed in the lake management plan.

The high nitrogen and phosphorus concentration in the groundwater are likely the persistence of legacy nutrients (i.e. nutrients that have been accumulating in the soils/sediments) from the former wastewater treatment plant. Treated domestic wastewater once stored in the percolation ponds was likely high in sulfur compounds (a characteristic of domestic waste) and the groundwater from that site can contribute additional sulfate to the lake. The sulfate binds with lake sediments releasing phosphorus which is normally held by the sediments. The phosphorus released from the sediments contributes to potential algae blooms.

Over the last decades many community lakes have become eutrophic due to nutrient loading from wastewater, fertilizers, and other residential practices. The relationship between sulfide production and phosphorus release in eutrophic lake sediments is critical due to the significance of phosphorus in limiting primary production (algae growth, etc.) (Wetzel, 1983; Murray, 1995; NuÈrnberg, 1996; Kleeberg, 1997). The formation and precipitation of insoluble iron sulphide compounds leads to reduced binding of phosphate to iron oxides (NuÈrnberg, 1996; Kleeberg, 1997) and results in a release of phosphate from the sediments which may increase eutrophication of lakes (Ohle, 1953; Caraco, Cole & 1Likens, 1993; Smolders & Roelofs, 1993; Sùndergaard, Windolf & Jeppesen, 1996). In other words, high sulfate concentrations and lack of oxygen in the groundwater or near the lake sediment-water interface will prevent phosphorus from binding with iron in the sediments. This makes the phosphorus available for consumption leading to greater primary production (algae blooms).

In addition, an accumulation of dissolved sulphides may inhibit recolonization by benthic fauna (organisms that live in the lake sediment) as a result of toxicity. Similarly, the concentration of dissolved sulphide may control recolonization by rooted macrophytes (plants) in the littoral zone (Lamers, Tomassen & Roelofs, 1998). These considerations will be important in the lake restoration efforts.

Currently the lake experiences few if any cyanobacteria (blue-green algae) blooms because they are often limited by a lack of iron in the water column; iron is an element that is necessary for the growth and proliferation of cyanobacteria. In an aquatic environment with little to no oxygen, a process (referred to as reduction) occurs that transforms the compound sulphate into the compound iron sulphide making iron unavailable to cyanobacteria. In fresh waters the potential for sulphate reduction rate is limited but in ocean waters it can be much higher (Boudreau & Westrich, 1984). Therefore, sulphate reduction rates (and associated problems such as odor and higher phosphorus) will be greater in the Herons Landing lake due to the occasional inflow of estuarine waters from Clam Bayou. The lake will have higher soluble P concentrations originating from the sediments due to its higher salinity and sulphate reducing environment. These conditions promote the binding of iron to sulphide which would normally bind the soluble phosphorus (Caraco, Cole & Likens, 1990; Blomqvist, Gunnars & Elmgren, 2004). As stated above, low oxygen or reducing environments will cause iron to preferentially bind to sulphide rather than phosphorus. This increases the concentration of phosphorus in the water column which can provide the fuel necessary to stimulate an algae bloom.

Low levels of oxygen at the sediment interface must be must be addressed to prevent binding of iron to sulphide and the release of phosphorus. In addition, a reduction in the amount of sulfur coming in to the lake (from groundwater) would be beneficial to improving lake water quality.

The western lake at Herons Landing is eutrophic with mean nitrogen, phosphorus and chlorophyll *a* concentrations exceed state water quality criteria. The trophic state index is above

100, well over an acceptable value of 60. Even during sun-lit daylight hours, the lake remains anoxic (devoid of oxygen). Normally, photosynthetic organisms (e.g. plants, algae) produce oxygen in the water column, but the lack of aquatic plants and the dominance of sulfur-reducing bacteria limit oxygen production in the lake. Sampling on November 20, 2017 revealed a large abundance of euglenoids (microorganisms) and sulfate reducing bacteria (which produce a strong sulfur odor).

The current poor water quality can effect property values and reduce enjoyment of the lake. The homeowners association will benefit from a management plan with specific objectives designed to achieve the goal of reduced odors and improved water quality.

Lake Ownership and Watershed Characteristics

According to the Lee County Property Appraiser's website, each individual Herons Landing Homeowner with waterfront on the lake owns a section of the lake approximately parallel to their property's side boundary lines and reaching entirely to the shoreline on the other side of the lake (Figure 1). In other words, each homeowner on the lake owns a piece of the western lake and together the Herons Landing property owners own the entire lake. The properties adjacent to the lake and to the north are owned by the City of Sanibel and by William Broder the original developer of Herons Landing (Figure 1). These two parcels comprise the former percolation pond site. The parcel boundaries north of the lake extend only to the lake's shoreline.

A GIS analysis revealed 9 homes currently exist within the western lake's 573,000 square foot (13.2 acre) watershed with an estimated total impermeable surface area of 20% (Table 1). The existing homes are zoned within the City of Sanibel's mid-island ridge and altered land ecozones. The property located north of the lake is classified primarily as altered land. These classifications permit a developed homesite to contain a maximum of 30 to 35% impermeable surface (depending on mid-ridge or altered land zone). All sites met the requirements, although two were at maximum allowable impermeable surface.

Most homesites had a vegetative buffer adjacent the lake as encouraged by The City of Sanibel, with a notable exception at 5406 Osprey which has sod mowed to the water's edge (Appendix 1). The backyard of 5418 Osprey Ct. has mulch to a rip-rapped water's edge with no vegetative buffer. With the lake's watershed boundaries are the properties north of the lake owned by the City of Sanibel and National Development Corporation as well as those homes north of Osprey Court (Figure 2).

Table 1. GIS analysis results for the watershed of the Herons Landing western lake.

Address	Area (Sq. Ft.)						Percent Total Land Area					
	Total Land Area	Drive And Walkways	.% Shell or Paver	House	Sod or Mulch	Canopy or Veg	Drive And Walkways	House	Total Impermeable	Sod or Mulch	Canopy or Veg	Total Permeable
5398 Osprey Ct.	29,976	0	0	0	0	29,976	0	0	0	0	100	100
5402 Osprey Ct.	18,743	2,481	80	5,562	824	9,877	3	30	32	4	53	68
5406 Osprey Ct.	20,312	3,726	80	3,790	3,146	9,651	4	19	22	15	48	78
5410 Osprey Ct.	20,770	2,458	80	4,383	1,317	12,612	2	21	23	6	61	77
5414 Osprey Ct.	15,309	1,812	80	4,271	1,087	8,139	2	28	30	7	53	70
5418 Osprey Ct.	14,249	1,155	0	4,118	1,969	7,006	8	29	37	14	49	63
5422 Osprey Ct.	20,325	1,397	0	3,919	3,336	11,672	7	19	26	16	57	74
5426 Osprey Ct.	16,970	2,295	80	3,447	3,002	8,226	3	20	23	18	48	77
5430 Osprey Ct.	16,743	960	80	3,230	0	12,552	1	19	20	0	75	80
Sanibel Parcel	128,065	0	0	0	0	128,065	0	0	0	0	100	100
Broeder 1	80,663	0	0	0	62,550	18,113	0	0	0	78	22	100
Broeder 2	61,995	0	0	0	16,822	45,173	0	0	0	27	73	100
Parcel Total	444,120	16,284		32,720	94,053	301,062	4	7	11	21	68	89
Lakes,Roads,ROR	129,575	64,575		0	65,000	0	50	0	50	50	0	50
Total Watershed	573,695	80,860		32,720	159,053	301,062	14	6	20	28	52	80

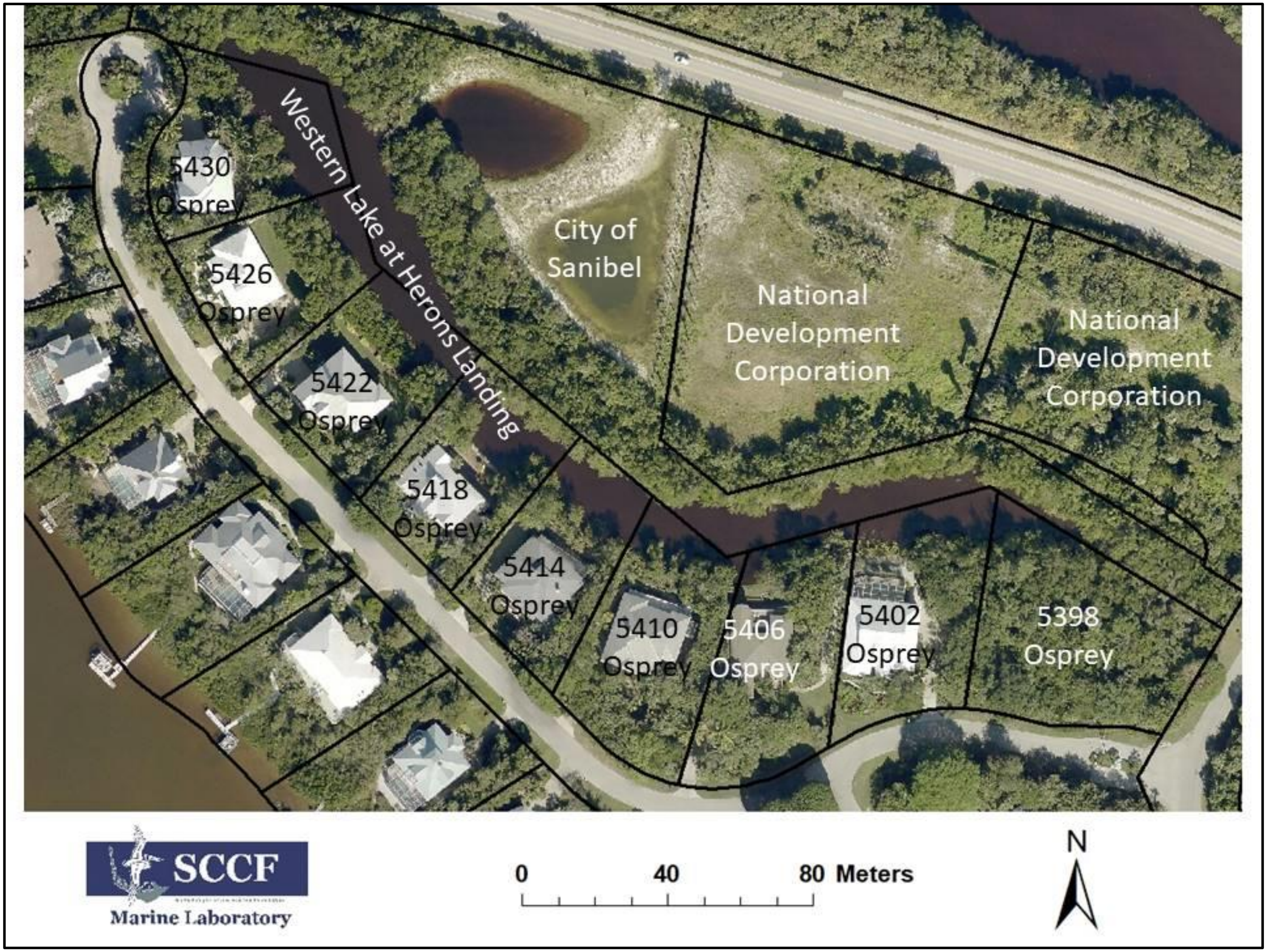


Figure 1. The western lake at Herons Landing showing property boundaries, the City of Sanibel's nutrient removal ponds north of the lake and addresses.

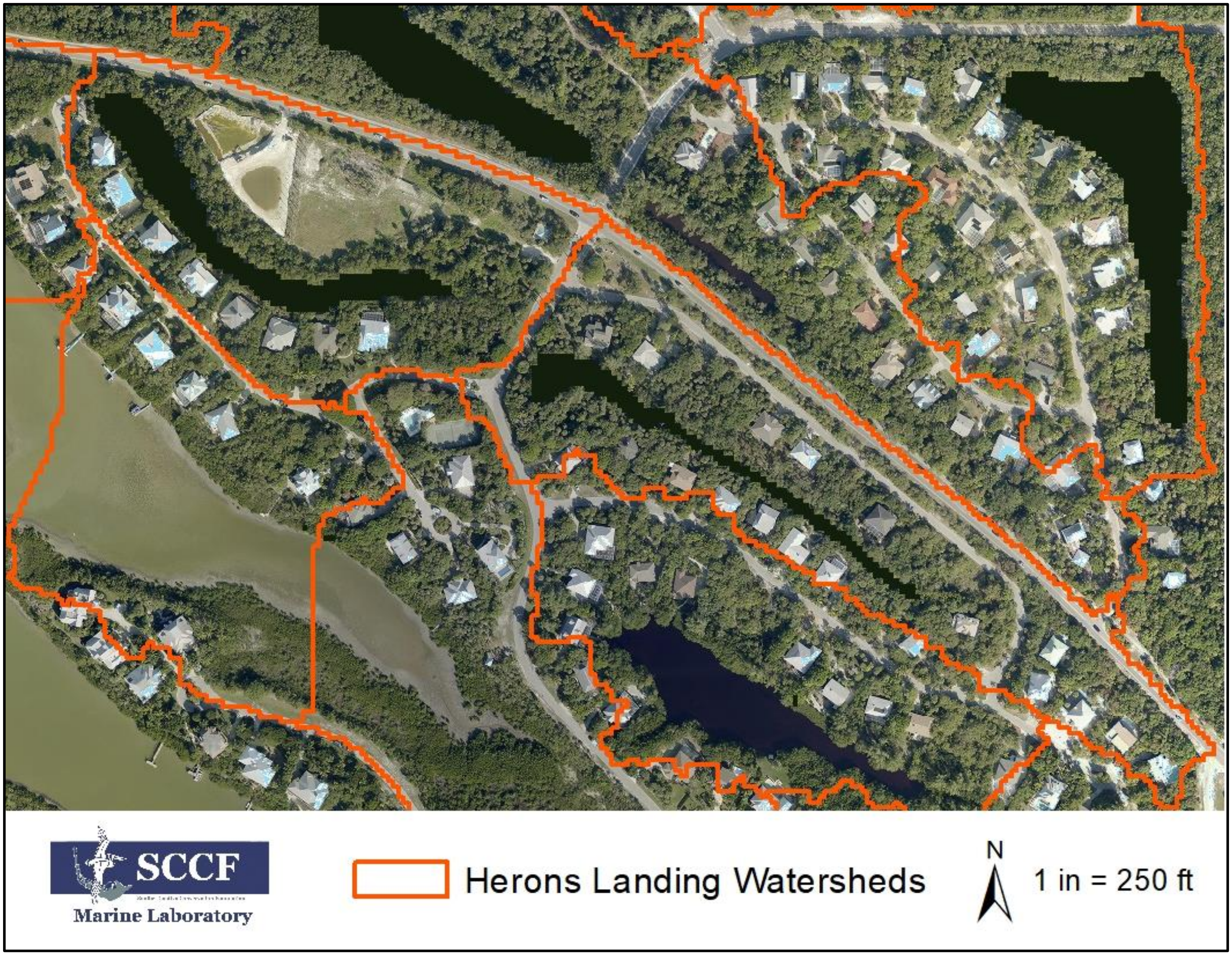


Figure 2. The Herons Landing area watersheds delineated in ArcGis10® using Lee County Lidar elevation data. The drainage basins for this can periodically connect through overflow structures, or during large rain events, or high tides.

Lake Working Group Organization

The stakeholding homeowners will organize a working group that will respond to needs and develop a vision for what the lake will be. The vision developed will include goals for lake use, wildlife, plants, water quality, water clarity, color, odor and more. The Herons Landing lake recovery effort will take constant input and effort with no end date. It can take many years to achieve water quality improvements and restore natural functions in impaired waterbodies. The lake east of the project lake is periodically connected to this lake and has similar water quality characteristics. The property owners around that lake may be a logical group to invite into the lake management group and expand the focus of the effort to those two lakes and possible the entire community. Both adults and children are encouraged to attend meetings and have inputs. Many times the younger age group knows the lake better than the adults from their exploration. Children will also be able to track the changes in water quality through time, hopefully seeing the positive results of a community lake management plan. Group members will want to decide how financial needs of lake restoration may be met – through dues, fees, etc.

Lake Working Group Goals & Vision for the Future

The Herons Landing western lake is an artificial waterbody created when fill material was removed from the site to elevate the adjacent building sites. The waterbody now acts a stormwater runoff basin for the development. Depending on tide and lake surface elevation the lake is periodically connected to Clam Bayou (estuary) to the northwest and to an excavated lake to the southeast (via a water control structure). The original intended uses of the Herons Landing Lake were not recreation or an aesthetically-pleasing wildlife habitat. However, the stakeholders hope that the lake can become a positive feature in their neighborhood, producing a pleasing backdrop for their homes and providing diverse wildlife habitat with emergent and submerged native vegetation along the littoral zone. The restoration efforts should provide conditions which support a healthy ecological community consisting of phytoplankton, zooplankton, invertebrates and fish.

The overarching goal of the lake management plan is to improve water quality so that the current strong hydrogen sulfide odor is reduced to an unnoticeable level (less than 3-5 ppm per OSHA), dissolved oxygen is increased to relieve anoxia (> 2 mg/l) and a diverse, natural community of flora (plants) and fauna (animals) develops in the lake. Significant reduction in the abundance of sulfur-reducing bacteria in the water column will be required to achieve the improved odor objectives, and a significant reduction in overall chlorophyll *a* (phytoplankton) by decreasing high nutrient concentrations through the implementation of best management practices (BMPs) will be included as an objective. Along with reduced chlorophyll *a*, a reduction in turbidity associated with chlorophyll should be measurable (improved water clarity). It is understood that the brown, turbid appearance of the lake is partly natural and partly due to a high concentration of microbes. With improved management of pollutant inputs and in-lake restoration activities, obtaining a less turbid appearance should be possible.

This lake management plan will be **adaptive** in nature and will be updated periodically by the lake working group based upon findings of new research and monitoring. **The lake working group will be responsible for the future improvement of their lake (meeting the objectives and goals of this plan)**.

Specific Objectives to Help Achieve the Lake Management Plan Goal

As stated in the previous section, the overarching goal of the lake management plan is to improve water quality so that the current strong hydrogen sulfide odor is reduced to an unnoticeable level (less than 3-5 ppm per OSHA), dissolved oxygen is increased to relieve anoxia (> 2 mg/l) and a diverse, natural community of flora and fauna develops in the lake. To achieve this goal, the homeowners association, the City of Sanibel and the SCCF Marine Laboratory have identified the following objectives which, once achieved should produce progress in realizing the goal of lake rehabilitation:

1. Develop monitoring plan for water, groundwater, air
2. Determine sulphate levels in water column, groundwater, and water-sediment interface
3. Determine pre-mitigation H_2S levels in air over lake
4. Reduce nutrient and sulfur loading rates from percolation ponds
5. Eliminate or drastically decrease abundance of sulfate-reducing bacteria in lake system
6. Increase oxygen concentration in water column
7. Increase oxygen concentration at sediment surface
8. Establish aquatic vegetation and healthy littoral zone
9. Reduce possible sulfur inputs via groundwater from former percolation pond site
10. Significantly reduce nitrogen and phosphorus concentrations in water column
    a. Reduce inputs from groundwater
    b. Reduce inputs from sediments – oxygenate
    c. Reduce inputs from stormwater runoff
11. Significantly reduce chlorophyll *a* concentrations
12. Increase abundance and diversity of beneficial zooplankton and phytoplankton
13. Provide habitat for native fish
14. Improve sediment sulfur content (reduce) and iron (increase) concentrations.
15. Reduce lake salinity to reduce sulphate reduction rate, iron sulphide and internal P loading

Each of these objectives will require activities and action plans to make them possible, but there are existing technologies and methods for addressing each objective.

Potential Best Management Practices

To achieve the objectives listed in the previous section, specific best management practices (BMPs) will be required. In this section we describe some potential BMPs and the positive impact they would have on lake water quality. There are a wide variety of BMPs available and their cost/unit P or N removed can vary greatly. Different BMPs will address different objectives identified in this study required to meet the goal of better water and air quality. Some potential BMPs are presented in table form (Table 1) with the water quality objective addressed identified and a rough estimated cost given if available.

Reduction of nutrient and sulfur loads from groundwater inputs would be a complex undertaking. By decreasing the concentration of N, P and sulfur in the groundwater or by decreasing the flowrate of groundwater to the Herons Landing western lake, nutrient loads are reduced. With no additional groundwater intervention, groundwater laden with legacy nutrients and sulfur will continue to flow in to the western lake until legacy concentrations subside on the former wastewater pond site. By implementing BMPs in the western lake the odor and low oxygen levels can be controlled but the lake will remain hypereutrophic for an indefinite period. In that state the lake will likely support fish and plants but will constantly have algae blooms, low water clarity, and possible fish kills. However, it may be able to sustain life and the odor problem will be reduced.

One possible groundwater mitigation strategy would be to increase the evaporative capacity of ponds on the former wastewater pond site. With greater evaporation from those ponds, additional groundwater flow will be intercepted by these ponds, reducing groundwater flow to the Herons Landing western lake. By digging the treatment ponds deeper and adding surface area (and additional ponds), flow gradients will be directed towards the ponds. Vegetation and floating islands in the ponds can then be used to decrease nutrient concentrations. Going forward, the lake management team will need to investigate other possibilities for groundwater mitigation.

One of the main objectives of BMPs will be to create an aquatic environment debilitating to sulphate reducing bacteria, thereby reducing hydrogen sulphide odors. Increasing the oxygen content within the water column and at the water/sediment surface, reducing sulfur inputs from groundwater and extermination of existing bacteria within the waterbody are actions which can work together to achieve this goal. An aeration or water circulation system will be essential to fight anoxic conditions currently prevalent in the waterbody. A well-oxygenated water column will reduce the production of hydrogen sulfide gas and allow phosphorus to bind to iron which then settles into the sediments making the phosphorus unavailable for algal consumption. There are a wide variety of available systems which can provide aeration and circulation. Whole lake mixing will provide re-oxygenated water to the lower (hypolimnion) and upper (epilimnion) portions of the lake and is the appropriate choice for circumstances encountered here. Circulation of the water will help control cyanobacteria blooms which may become more likely due to aeration of the sediments (iron is released). A number of system configurations are available including pump/venturi and air-lift circulation. A system which pumps bottom water through a venturi and homogeneously discharges throughout the lake system may be a good choice as it moves larger volumes of water and provides better aeration.

Studies have shown that hydrogen peroxide treatment of the lake can reduce or eliminate sulphate reducing bacteria in the water column. A number of lake management companies offer this service. It is important that hydrogen peroxide is added at sufficient amounts to adequately kill existing bacteria populations. This (one time) service should be performed just **after** installation and startup of an aeration/circulation system. The objective is to kill off the sulphate bacteria and then reduce their chance of re-establishing by providing an aerated water column with the circulation system.

Another potential BMP is addition of ferrous sulfate for H_2S control. The PRI-SC® process is a patented technology that combines the use of iron salts (either FeCl2, FeCl3 or FeSO4) and hydrogen peroxide or other oxidant in a unique fashion, whereby an iron salt is added as the primary sulfide control agent in the upper reaches of the lake system (or groundwater discharge system), and hydrogen peroxide is added at specific points downstream to "regenerate" the spent iron (FeS). The regeneration step effectively oxidizes the sulfide to elemental sulfur and in the process "frees up" the iron for subsequent sulfide and phosphorus control further downstream. In the case of the Herons Landing lake, ferrous sulfate would be added to the lake to bind up the hydrogen sulphide and after effective odor control, hydrogen peroxide would be added to regenerate the spent iron sulphide (to further control odors) and mineralize the sulfur.

Media-filled phosphorus filters are under investigation as potential BMPs in many locations. One possible filter would consist of iron slag media placed in a simple flow-through tank which pumps from the lake and discharges back into the lake. The iron slag will bind dissolved P and reduce the P concentrations to low levels. The slag would periodically be removed or regenerated. This system could be used in series with a pumped venturi circulation system with the same pumps used to supply the treatment filter.

The best cost/benefit ratios for reducing N and P in a stormwater pond are usually found in vegetative plantings such as increasing buffer zones, adding tree canopy to the landscape, and adding littoral plantings. However, the situation at the Herons Landing western lake is unusual with large nutrient inputs from groundwater flow originating from the former wastewater perc ponds and lake-wide anoxic conditions. Before vegetation can be successfully planted within the lake, the low oxygen levels must be addressed.

Many of the most effective BMPs aid in the improvement of water quality with little to no cost and only require behavioral changes of the communities that live adjacent to waterbodies. These BMPs include:

1. Adhere to the Fertilizer Ordinance – Sanibel has a strict fertilizer ordinance that prohibits the application of fertilizer within 25 feet of any waterbody or stormwater conveyance system. This prevents the likelihood of granular fertilizer being washed into waterbodies in stormwater or irrigation runoff.
2. Florida-Friendly Plants – Homeowners should choose plants that are low maintenance, disease resistant, and/or Florida-friendly. Native plants are highly recommended because they are adapted to Sanibel's environment and require little to no maintenance (i.e. fertilizer and irrigation).
3. Proper Irrigation – Excess water from irrigation running off into the waterbodies may contain nutrients or materials that could cause water to appear murky. To prevent runoff, application rates should not exceed the soil's ability to absorb and retain water or exceed available moisture storage in the root zone. Knowledge of your plants is imperative. Plants require more water during seed, flower, and fruit production, but require less water when dormant. During colder months or those with shorter day periods most plants are not actively growing, therefore irrigation, if any, should be reduced. Additionally, homeowners, especially those that irrigate with re-use water, should ensure that their sprinklers are not spraying directly into the water.
4. Pet Waste Disposal – Decaying pet waste that enters a waterbody will release nutrients that promote symptoms of eutrophication such as algae blooms. The decaying pet waste, which is being metabolized by bacteria, will consume and reduce the amount oxygen in the water column.
5. Runoff Control – Controlling nutrients at the source is often the most inexpensive method for protecting water quality. Homeowners can implement features that have the ability to deflect or slow roof and pavement runoff. Downspouts should be positioned in such a way as to aim roof runoff at a porous surface (e.g. low lying shell, gravel pit, or vegetative buffer). Roof runoff can also be collected in a rain garden or a rain barrel.
6. Eliminate or Minimize Turf Grass - Property owners should consider replacing turf grass with native groundcovers. Planted and mulched areas require significantly less water than turf grass. Native groundcovers require less fertilizer, and can be easily fertilized with natural materials like compost. If homeowners do choose to install turf grass, understanding the type of turf grass on your property can greatly reduce impacts to water quality. When selecting turf grass, homeowners should take into account such things as salt, drought, and shade tolerance of each species. Choosing an unsuitable species of turf grass for the property can result in the need for excess fertilizer and irrigation to revive ill-adapted species.
7. Proper Mowing Techniques – Mowing turf grass at the correct height increases turf density and root health while also increasing weed suppression. When grass is mulched, rather than collected in a bag, the clippings contain nutrients that act as fertilizer. Grass that is mowed too short will result in a reduction of root depth

making it harder for the turf to access water in the soil. Moreover, short turf blades and roots have less carbohydrate storage, which makes it harder to recover from environmental stresses to the lawn. Mowing high results in deeper roots, which encourages the development of drought tolerant turf thus reducing irrigation needs. Contrary to popular belief, watering turf infrequently can be beneficial to a lawn. This practice will also train turf roots to grow deeper, and allow the lawn to better withstand drought. Always make sure the mower blade is sharp because turf cut with a dull blade will require more irrigation to recover. Mowing height for shaded turf should raised by 30% since it has less access to light. Therefore the turf needs more surface area to perform photosynthesis or else it will start to thin.

These low cost BMPs should always be incorporated into any management plan and implemented wherever possible. Other potential BMPs which may address the conditions found in Herons Landing western lake are listed in the following table but represent only a subset of possibilities. Others may be found to be more cost effective at addressing the objectives of this plan. This plan is meant to be adaptive and incorporate new ideas based upon new research and information. The plan will be constantly improving and updated.

Table 2. Potential BMPs to achieve objectives of the Herons Landing Lake Management Plan.

BMP ID	Description	Objectives Addressed	Cost $	P Remval	N Remval	Sulfur Remval
Bubble aeration	**Bubble type**	**Increase O2**	**$12,000 -30,000**	**yes**		**yes**
Water circulation	**Pump or air compressor**	**Circulate water to increase O2**	**$10,000 – 45,000**	**yes**		**yes**
Lake H2O2 treatment	**Hydrogen Peroxide Treatment of Lake (ex: Green Clean)**	**Kill sulphate reducing bacteria-add O2**	**$5,000**			**yes**
Media packed filter for P	**Use steel slag, Bold & Gold for P removal**	**Reduces P concentrations**	**?**	**yes**		
Iron salt treatment	**Add iron salt to lake to remove H2S**	**Remove H2S and P**	**?**	**yes**		**yes**
Alum treatment	**Add alum to lake**	**Binds with P**	**?**	**P**	**possible**	**no**
Irrigation with lake water	**Use lake water for lawn irrigation**	**Oxygenates lake, reduces N and P**	**?**	**yes**	**yes**	**yes**
Phoslock, Struvite, or lime addition	**Add these to lake – P binding**	**P reduction**	**$-$$$**	**yes**	**no**	**?**
Vegetative buffers	**Some lawns can increase buffer quality**	**Stormwater runoff quantity and quality**	**$387 /acre**	**Yes – 5%**	**Yes - 4%**	**no**
Expand treatment ponds	**Increase depth/area of vegetated ponds Bayous WWTP site**	**Remove N and P, decrease nutrient load to west lake**		**yes**	**yes**	**yes**
Floating island	**Vegetated islands west lake**	**Increases lake N and P removal**	**$8 -120 /sq.ft.**	**yes**	**yes**	**no**
Floating island	**Vegetated islands bayous ponds**	**Increases N and P removal**	**$8 -120 /sq.ft.**	**yes**	**yes**	**no**
H2O2 treatment of groundwater	**Inject H2O2 in to groundwater**	**Convert H2S to elemental S**	**?**	**possible**	**no**	**yes**
Groundwater treatment - filters	**Pump GW through media filters**	**Remove H2S and P**	**?**	**yes**	**possible**	**yes**
Littoral shelf	**Plant aquatic vegetation**	**Remove N and P**	**$1/sq.ft.**	**yes – 8%**	**yes – 5%**	**no**
Mechanical algae removal	**Use manual techniques to remove any blooms**	**Remove N and P**	**?**	**yes**	**yes**	**no**
Lake dredging	**Removal of sediment from lake**	**Remove N and P**	**$$$**	**yes**	**yes**	**yes**
Reduce lake salinity	**Increase elevation of lake inflow channel**	**Prevent H2S and P release from sediments**	**$**	**?**	**yes**	**yes**

Performance Measures for Evaluating Best Management Practices

Activities intended to help achieve the goal of reduced odor and improved water quality must be evaluated based upon their ability to demonstrate improvement at an acceptable cost (cost/benefit). Performance measures must be used to determine if actions taken produce measurable progress toward goals and objectives.

Based upon the goals and objectives of the plan, performance measures which can be used to monitor change include:

- **H_2S in lake water** – Hach kit - $50.00. USEPA recommends a surface water concentration less than 0.002 mg/L. **Monthly or quarterly (3 sample locations)**. Downward trend in lake water H_2S is an objective.
- **H_2S odor** (air) – as measured by H2S monitor ($150.00) – **monthly measurement (3 sample locations)**. Objective is downward trend.
- **Oxygen** concentration in lake water column. Using calibrated sonde. Possibly **continuous deployment or monthly 24 hour deployment**. Objective is increasing trend. Monitor for 1st year ($1,500).
- **Bi-annual** lake water column **nutrient** (N and P) monitoring (**1-3 samples**). Objective is downward trend ($2,200/yr.).
- **Bi-annual** groundwater **nutrient** (N and P) and flow monitoring (**2-4 samples**). Objective is downward trend ($2,800/yr.).
- **Sulfate reducing bacteria concentration (quarterly - 3 sample locations)** (H2S bacteria test kit ($150) – "Bart" from Hach, Aquagenix CBT kits or microscope). Objective is decreasing trend.
- **Chlorophyll *a*** ($1,740/yr. nutrient monitoring) concentration in water column. **Quarterly (3 sample locations).** Objective is downward trend.
- **Sediment redox state (bi-annual, 3 sample locations ($400/yr.**). Increasing redox value over time at surface of sediment.
- **Sediment sulphate** concentration (**bi-annual – 3 locations**).
- **Sediment iron** concentration – The Fe:P ratio should exceed 10 if it is to regulate phosphorus release and should exceed 15 to prevent phosphorus release from oxidized sediments (**bi annual – 3 locations** $1,200/yr.)(Sondergaard et al. 2003).
- **Sediment depth** and % organics of sediment cores (**bi-annual, 3 locations,** $1200/yr.).
- **Discharges** to and from lake (annual flow through overflow channels/structures).
- **Plankton abundance and species richness (quarterly,** $1200/yr.**).** An increasing trend in abundance and richness will be objective.

These performance measures can be analyzed using repeated measures statistical evaluation in addition to trend analyses. **Typically, trend analyses will require several years of data before significant trends may be detected.** Repeated measure analyses require significant monitoring of the performance measure before an action is implemented and then similar monitoring effort after the action is implemented.

Water Quality Monitoring

Regular water testing will provide the management group the ability to analyze water quality trends. It is normal for water quality to change from season to season because of factors such as precipitation, water depth, temperature, etc. A record of monthly water quality measurements will help identify seasonal and long term changes in the lake and will help track progress toward objectives. Test kits can be purchased online that test the pH, dissolved oxygen, turbidity, iron, hydrogen sulphide, nitrogen and phosphorus such as those from LaMotte or Hach.

Fish & Wildlife

Urban lakes provide much-needed habitat for Florida's wildlife. After water quality improves, stocking the Herons Landing lake with native fish will be an important consideration. Most waterbodies on Sanibel are now dominated by non-native cichlid fish. These fish can out-compete native fish and cause water quality deterioration due to their feeding strategies. It is better to establish a strong population of native bass and sunfish before cichlids find their way in to the lake. Large bass and sunfish are capable of eating small cichlids which will inevitably find their way into the lake.

With the development of proper habitat, the lake watershed can also be managed for other desirable wildlife such as wading birds. Visit the Florida Fish and Wildlife Conservation Commission website for more information.

Drainage Structures – Flow Measurement

To better evaluate the factors affecting water quality, estimates of any surface water discharges into or from the lake should be made so that salinity changes, dilution effects, etc. can be considered in controlling nutrients. The Herons Landing western lake has two known discharge points. One is a control structure at the southeast end of the lake which separates this lake from an adjoining lake to the east in Herons Landing. The other discharge location is a heavily vegetated channel at the northwest end of the can connect the lake to Clam Bayou at extremely high tides or lake levels. The Lake Working Group will need to coordinate with The City on how to best monitor discharges at these two locations. This section of the management plan will be updated once a plan is agreed upon.

Inflow of estuarine water to the lake can detrimentally affect water quality by producing conditions that promote the release of phosphorus and hydrogen sulphide from the sediment into the water column. Adjacent hydraulic connections can also allow the discharge of very poor quality water to other waterbodies, spreading the problems of the western lake. Flow measurement is important to the overall management of this lake.

Lake Working Group Meetings and Work Days

Regular meetings of the Working Group will facilitate progress towards improving the lake's water quality. When activities are decided upon, actual hands-on working days may also be required. These meetings and work days should be discussed and a schedule derived as work progresses. It has taken years for this lake to degrade to its current state; it will also take years to recover. In the meantime, plan some workdays and have some fun! For an example Adopt-A-Pond Workday Report (download at the AAP website).

Date: ________________ Workday Report Pond Group #:_________ Pond Name/Location: ____ Purpose and Summary: ____

____

_____ ____

APPENDIX 1

Photos of land use adjacent to the western lake of Herons Landing.

Figure 2. Backyard of 5390 Osprey Court on 11-20-2017. Undeveloped parcel.

Figure 3. Backyard of 5402 Osprey Court on 11-20-2017.

Figure 4. Backyard of 5406 Osprey Court on 11-20-2017.

Figure 5. Backyard of 5410 Osprey Court on 11-20-2017.

Figure 6. Backyard of 5414 Osprey Court on 11-20-2017.

Figure 7. Backyard of 5418 Osprey Court on 11-20-2017.

Figure 8. Backyard of 5422 Osprey Court on 11-22-2017.

Figure 9. Backyard of 5426 Osprey Court on 11-20-2017.

Figure 10. Backyard of 5430 Osprey Court on 11-20-2017.

APPENDIX 2

Herons Landing Community Lake Eutrophication Evaluation

Summary of Findings

Herons Landing Community Lake Eutrophication Evaluation

Summary of Findings

SCCF Marine Laboratory for the City of Sanibel

July 3, 2017

Mark Thompson

SCCF

Sanibel-Captiva Conservation Foundation

Stormwater Pond Eutrophication Study

The results summarized here represent findings from a short term (current conditions) evaluation of eutrophication indicators for a lake in Herons Landing, Sanibel located just north of Osprey Court, Bayous Development, Sanibel Florida (Figure 1). The study was requested and funded by the City of Sanibel Natural Resources Department in response to citizen concerns about the condition of their stormwater pond and reviewing results from the Sanibel Community Lakes Baseline Water Quality Study. Located adjacent and just north of the pond is the site of a former package wastewater treatment plant (WWTP) and percolation ("perc") ponds originally installed by developers of the Heron's Landing Subdivision, but since decommissioned by the City of Sanibel. The perc ponds were filled in 2009 and closed per Florida DEP standards. The property is now divided into two parcels. The City owns the western-most parcel and has dug two ponds which have been planted with native vegetation in an effort to remove nutrients through vegetation Best Management Practices (BMPs). The eastern parcel is owned by National Development LLC of Miami and is currently zoned as "utilities" according to the Lee County Tax Appraiser's Office (http://www.leepa.org/Display/DisplayParcel.aspx?folioid=10005748 accessed May 8, 2017).

The SCCF Marine Laboratory developed a sampling protocol which included discrete surface water sampling at three sites on April 13, 2017, groundwater sampling and flow monitoring at the former wastewater perc ponds, and three composite soil samples taken April 20th 2017 (Figure 1). Surface water samples were analyzed in the field for dissolved oxygen, pH, temperature, CDOM, turbidity and salinity. These samples were also evaluated by a NELAC certified laboratory for nitrogen (N) and phosphorus (P) constituents and for chlorophyll *a*.

Four temporary groundwater monitoring wells were installed April 13, 2017 at the former perc pond site. The monitoring design allows for flow estimates between two wells – one upstream and one downstream. One well set was installed to estimate groundwater flow from the eastern parcel of the former perc ponds and one set estimated groundwater flow from the western parcel (Figure 1). Due to land surface elevations, and the proximity of the stormwater pond, groundwater flow was hypothesized to be primarily toward the stormwater pond from the former perc pond area. Continuously recording level loggers were installed in each well and groundwater flow was estimated from the difference in head between wells along with soil properties and distance between wells. Groundwater samples were taken by using a Masterflex pump to flush wells and pump samples up to containers. Samples were collected on April 20th, one week after initial well installation. Groundwater samples were analyzed for the same constituents as the surface water samples.

To estimate the capacity of soil on the perc pond site to hold phosphorus, a soil phosphorus storage capacity (SPSC) test was performed on samples collected April 20th. Three composite soil samples were collected from the former perc pond site. One composite sample was collected from 10 random subsamples within the eastern parcel. Sample 2 was collected by taking 10 random subsamples from the western parcel (City-owned) within the footprint of the vegetated ponds constructed by the City. The ponds were nearly dry during the sampling period, allowing us to sample what is periodically inundated by water. A third sample consisted of 10 random subsamples taken from the upland area in between the ponds of sample 2. The sampling locations were established from a GIS generated map with random points generated within a boundary for each area sampled for soil characteristics. Samples were shipped to University of Florida Soils Testing Laboratory in Gainesville, to be extracted using the Mehlich 3 procedure and analyzed for phosphorus, iron and aluminum, which are needed for SPSC evaluation. The evaluation will determine the capacity of the soils to hold (or release) phosphorus during rainfall events).

Analyses results are included in Table 1. Surface water samples were very consistent between the three stations sampled. All results exceeded state water quality standards for phosphorus and nitrogen. Phosphorus levels were 2 orders of magnitude greater than state criteria while nitrogen levels were about 7 times greater than criteria. Phosphorus values in the stormwater lake were similar to groundwater levels from the perc pond site. Nitrogen levels were greater in the groundwater than in the stormwater pond.

Chlorophyll *a* levels in the stormwater lake were very high exceeding 300 ug/l for all 3 samples. The trophic state index (TSI) is a measure of overall waterbody eutrophication. It is an index which combines the indicators of eutrophication together (nitrogen, phosphorus and chlorophyll *a*) in a single score, which can be compared to other lakes and evaluation criteria. A lake with a TSI value over 60 is considered to be of poor water quality. **The TSI score for the Herons Landing lake was 118**, making this waterbody **the most eutrophic waterbody** (by score) so far evaluated on Sanibel. This is consistent with a previous evaluation of the lake located just downstream of the subject lake, which ranked as the poorest water quality of lakes surveyed to that time on Sanibel (Thompson and Milbrandt 2016).

Groundwater concentrations of phosphorus recorded during this evaluation exceeded all groundwater sample concentrations taken from monitoring wells at 50 sites on Sanibel during a study in 2015-2016 (Thompson and Milbrandt 2016). Nitrogen concentrations were as high as the greatest values found during that study (which occurred at Golf Course sites).

Groundwater flow rates were evaluated from April 20th through May 5th, 2017 during an extended dry period but which also included three significant rain events (Figures 2 and 3). The 14 day flow evaluation period is insufficient to get a true annual estimate of groundwater flow; however the estimates are valid for this period of time. Well water levels and estimated flowrates are shown in figures 2 and 3, along with the response of water level to rain events. Data indicated that groundwater flowed from the perc pond sites towards the stormwater lake during this period, as predicted. Soil characteristics were similar at both monitoring well measurement sites (Well 1-2, Well 3-4). Groundwater flow estimates are shown in Table 2.

Groundwater flow towards Herons Landing stormwater pond was greater from the eastern portion of the perc pond area than the western portion where the City has constructed vegetated wildlife ponds. We speculate that evapotranspiration from the ponds on this portion of the surveyed area decrease groundwater flowrate towards the Herons Landing waterbody. Localized groundwater flow gradients towards connected lakes are a widely published and observed phenomenon. Groundwater in the eastern portion of the studied area is responding to a larger elevation gradient towards flowing towards the Herons Landing lake without as much diversion toward other sinks such as the lakes found on the western portion.

Estimates of groundwater nutrient loads transported from the perc pond site to the Herons Landing waterbody are shown in Table 2. Though estimating loads from only two weeks' worth of flow data is not recommended, an estimate was made for the dry season. By extrapolating values obtained during the study period estimates show **groundwater phosphorus and nitrogen loads into the studied lake are extremely great.** The loading rates are driven by the extremely high nutrient concentrations in the groundwater coupled with hydraulically conductive soil. During the wet season, the flow gradient may vary greatly from the results of our two week study due to changing groundwater elevations relative to pond elevations and evapotranspiration rates. Estimates of wet season flows and loads were not made for this study.

Based on dry season sampling, nutrient loading rates from the eastern portion of the former perc pond were much greater (88 % of N load and 75% of P load) than the western (Table 2). This is driven primarily by the greater flow rates from that area as explained above.

Soil analyses showed all three sets of samples were similar and contained low levels of aluminum and iron which bind phosphorus, yet had a high pH which can help soil bind phosphorus (Table 3). The phosphorus saturation ratio (PSR) values of all three samples (Table 3) were greater than the threshold capacity of the soil to hold phosphorus. The ability of soil to hold phosphorus (soil phosphorus storage capacity - SPSC) is estimated from PSR. SPSC values are shown in Table 3. Positive SPSC values indicate the soil has the capacity to absorb that amount of P. Negative values indicate the soil will release P whenever there is water saturating the soil. The SPSC values for the three samples taken were negative, suggesting soils on the former perc pond site will release P to the groundwater during a rain event. Sandy soils typically have lower P holding capacity but are not usually saturated with P.

Groundwater concentrations of nutrients on the former perc pond site were the highest measured at any sampled location on Sanibel. Soil on the site is saturated with phosphorus and does not have the capacity to hold any additional P, but instead leaches P whenever the soils are saturated with rain or water table inundation. The Herons Landing stormwater pond just south of the study site has the highest concentrations of nutrients found in any waterbody on or adjacent Sanibel. The waterbody is anaerobic, producing hydrogen sulfide gases. Ammonia concentrations in the waterbody are high enough to be toxic to most fish. Chlorophyll *a* values above 300 ug/l suggest the water column is filled with phytoplankton – probably with few grazers due to the lake's poor water quality. Aquatic plant life may be absent due to anaerobic conditions.

Sampling suggests the main source of nutrients in the subject stormwater pond is groundwater from the former perc pond site. Groundwater flowrates and concentrations are relatively high, producing at a minimum, large seasonal nutrient loads. The groundwater flow from the western portion of the perc site owned by the City of Sanibel is significantly less than the western portion of the site. This may be due to the installation of vegetated ponds on that portion of the site which produce additional evapotranspiration and "pull" groundwater toward them, diverting flow that would otherwise enter the Herons Landing stormwater pond. Addition of vegetated ponds on the eastern portion of the site may help divert loads from the impacted stormwater pond, and periodic harvesting of plant material will help remove nutrient loads.

The magnitude of nutrient loading from the perc pond site suggest legacy nutrients from the former percolation ponds are having major effects on nearby waterbodies through groundwater connections. The soil currently covering the former perc ponds are primarily sands with low organic content which has little capacity to hold phosphorus and is saturated to the point that it releases P whenever inundated with groundwater or stormwater percolation.

The estimated surface area of the former perc pond is 61,200 square feet (1.4 acres). With an estimated maximum depth of 10 feet, the volume of waste held was 612,000 cubic feet (4.6 million gallons). Typical WWTPs do a poor job removing nitrogen and phosphorus. Effluent from the City of Sanibel Donax wastewater treatment plant contains phosphorus concentrations of around 1-3 mg/l and nitrogen of 3-5 mg/l. The groundwater concentrations found on the perc pond site are higher than these values, but the former Bayous WWTP was probably not as efficient as the Donax plant. Typical WWTPs produce effluent with nitrogen values around 15 mg//l and phosphorus 3 mg/l. If typical wastewater effluent values are used as an estimate for nutrients in wastewater from the former Bayous plant, we can estimate the mass of N and P contained within the former perc ponds to be about 265 kg N and 55 kg P. These values may be used as targets for the amount of N and P which need to be removed from the perc pond site through BMPs.

Residents living on the study lake have complained of intense odors of hydrogen sulfide. A grab sample in early April revealed the lake had a bloom of some type of sulfur-producing bacteria (Rick Bartleson personal communication). The salinity of the pond is about half the strength of seawater, which along with low oxygen levels is optimal for many sulfur producing bacteria.

Based on the existing conditions of the Herons Landing pond studied, including very low dissolved oxygen, high chlorophyll *a*, hydrogen sulfide off-gassing, absence of fish, and high ammonia concentrations the following best management practices would be recommended:

1. Aeration – to resolve the low dissolved oxygen problem, convert ammonium into safer nitrogen forms that are less toxic to fish and other aquatic life, allows plants, fish and zooplankton to survive, increases the rate of organic decomposition rate and decreases sulfur odors.
2. Littoral zone aquatic vegetation planting – plants use nutrients and remove them from the water column. If harvested, nutrients will be removed from system.
3. Floating treatment wetlands – floating mats with vegetation which removes nutrients from water column, and promote denitrification (removal of N from system).
4. Fish and zooplankton stocking after establishment of aeration.
5. Possible introduction of native mussels to filter chlorophyll *a* from water column.
6. Adherence to the fertilizer ordinance's 25ft no-fertilizer buffer zone near waterbodies.
7. Lake-friendly landscaping – choose native plants that are low maintenance and require little to no additional fertilizer.
8. Dredging of organic sediments from the bottom of the stormwater lake. This would be a more costly and last resort alternative. Removal of nutrient enriched sediment from the bottom would reduce internal loading of nutrients within the system.

Additional potentially useful BMPs will become apparent once aeration has been implemented and aquatic vegetation can be established.

Testing for Metals at Former Wastewater Percolation Pond Site.

To address concerns expressed by Herons Landing residents, soil and groundwater at the former perc pond site adjacent to the Herons Landing stormwater pond was tested for 5 metals (lead-Pb, copper-Cu, cadmium-Cd, mercury-Hg and arsenic-As) potentially present in domestic wastewater.

Samples were collected using a hand auger to bore through the sediment beneath the western pond now in place at the former perc-pond site. On the May 25th, 2017 sampling date, the pond was dry, providing access for hand auger operation. A composite soil sample was obtained from a layer of high organic content material encountered at an elevation of- 0.53 meters below mean sea level (MSL) (approximately 4 feet below the sediment surface). This layer was sampled as it would represent the bottom (sediment layer) of the percolation pond previously existing at the site. In addition, a well casing was installed in the augered hole by pounding a 3 inch PVC pipe to an elevation of -3.35 meters below MSL (approximately 13.5 feet below the existing sediment surface). A groundwater sample was collected from the well using a Masterflex tubing pump from an elevation of about -3 meters. Before sampling, the well was pumped for 1 hour at a rate of 150 ml/minute (9 liters purged). Samples were put on ice and delivered to Benchmark Laboratories for metals analyses per EPA methods.

Results show metals levels in the sediment sample were well below probable effects level concentrations (Table 4) as defined by Macdonald (1998). Sediment sample results were also below mean background soil concentrations for arsenic and mercury, while above background concentrations for lead, cadmium and copper. Since this site was a former wastewater perc pond site, metals levels would be expected to be above natural background levels. Lead was highest relative to mean probable effect level at 1/5th the effect level.

Results of groundwater analyses show cadmium, lead and arsenic below class 3 marine surface water criteria, while only cadmium exceeded the drinking water standard (Table 4).

Figure 1. Location of Herons Landing stormwater pond, Former WWTP perc ponds, sampling sites, and wells.

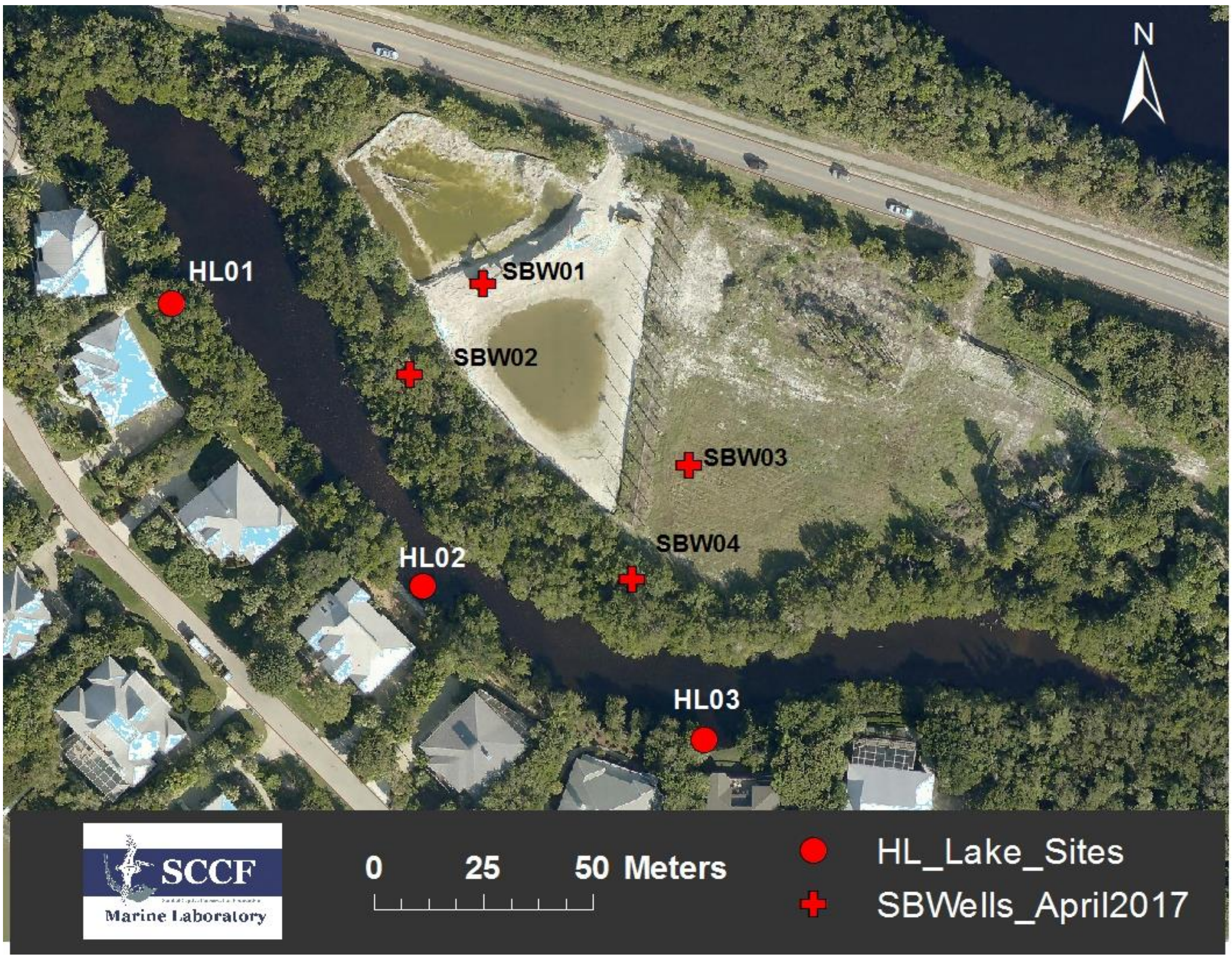
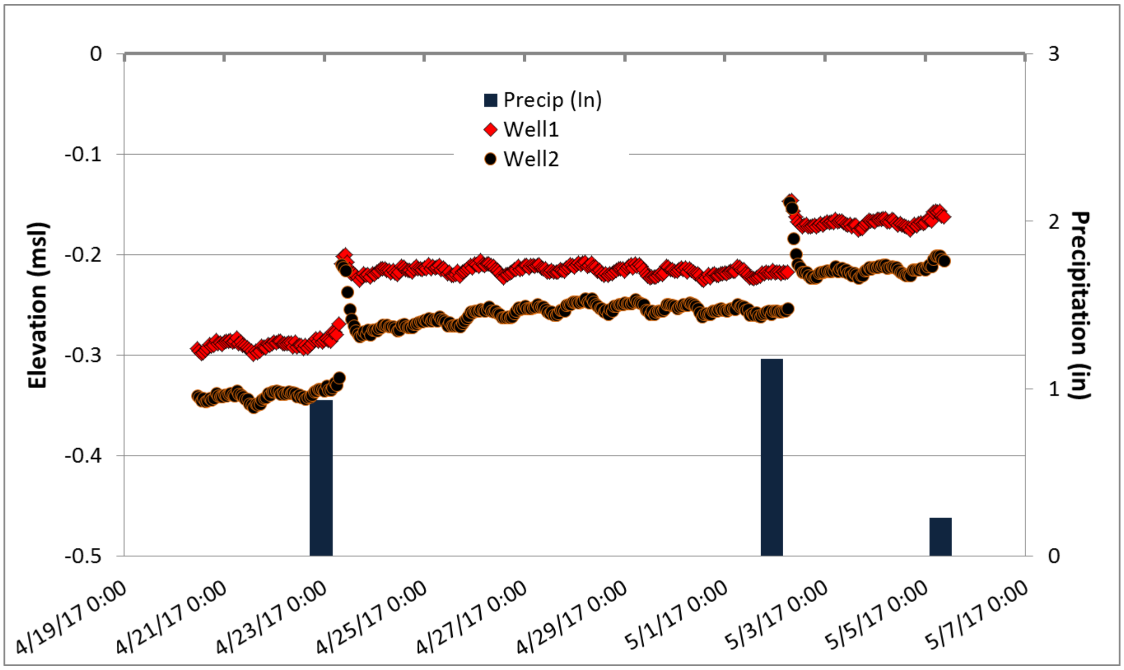


Figure 2. Groundwater level and estimated flow at the western well sites evaluated in this study. Graphs show well water level and flow in response to rain events which occurred during the period.



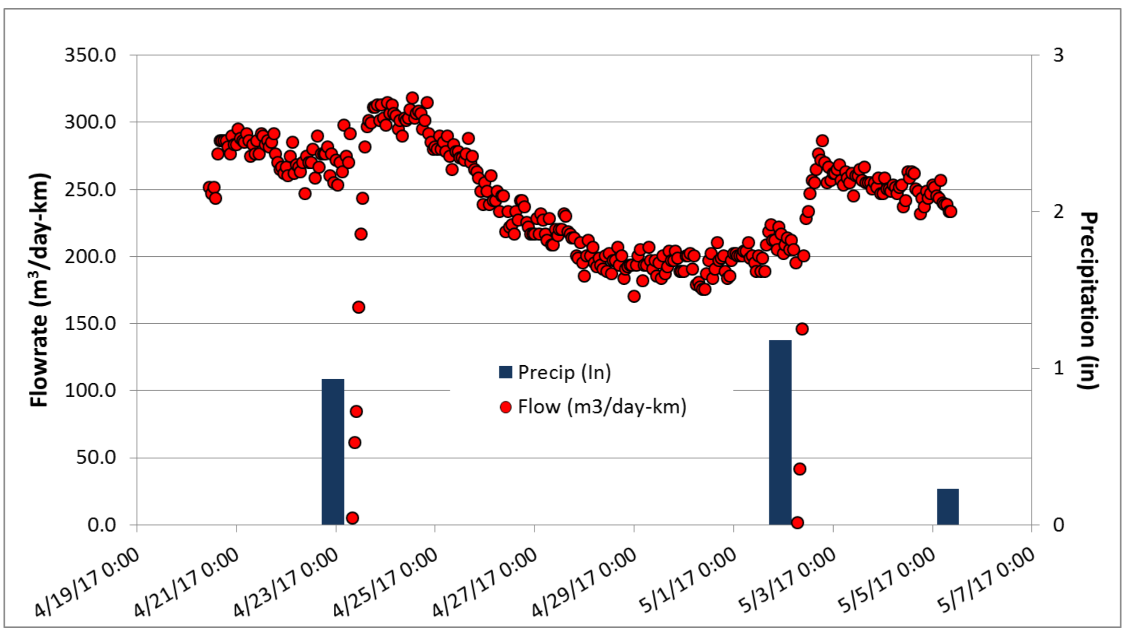
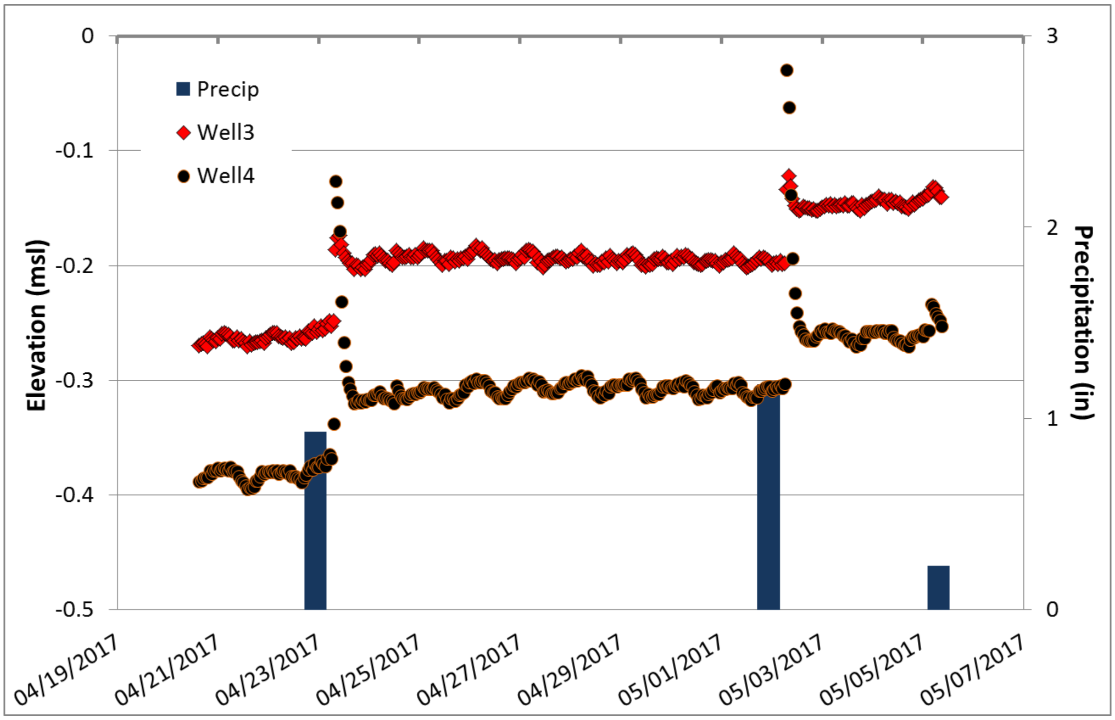


Figure 3. Groundwater level and estimated flow at the eastern well sites evaluated in this study. Graphs show well water level and flow in response to rain events which occurred during the period.



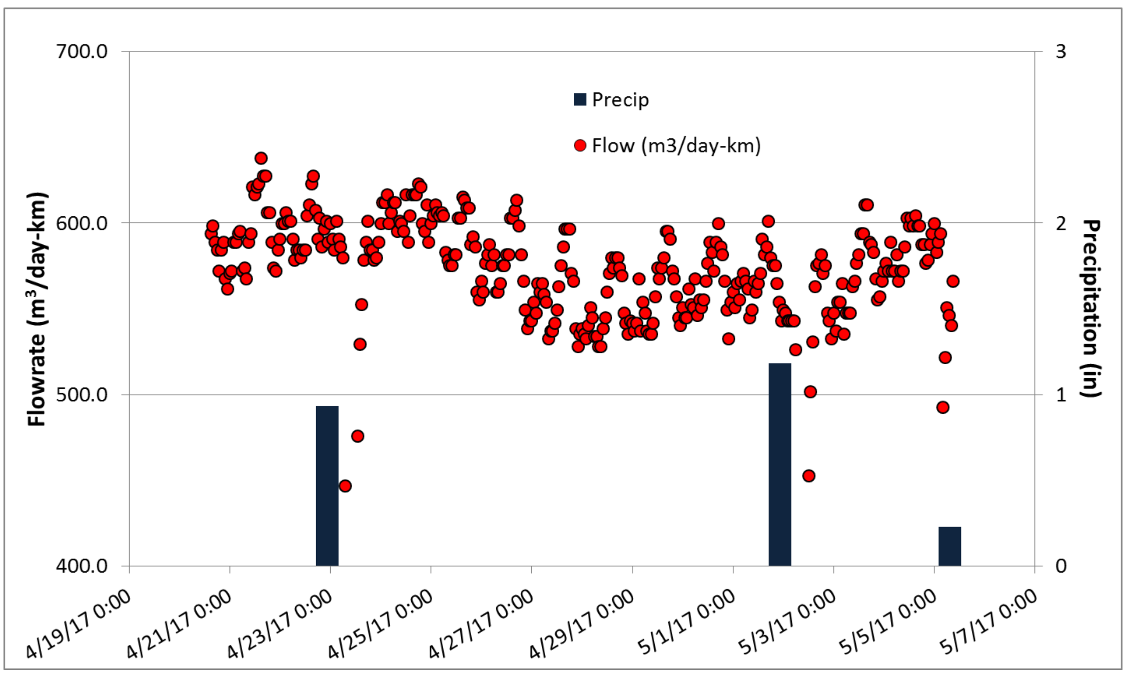


Figure 4. Imagery from 2005 showing the former percolation ponds and the adjacent Herons Landing stormwater pond. Perc pond surface area was approximately 61,200 square feet.

Table 1. Water quality results for surface water samples and groundwater samples collected during this evaluation. Bold values indicate a result is greater than Florida state water quality

Station Identification	**HL01**	**HL02**	**HL03**	**State Criteria**	**SBW01**	**SBW02**	**SBW04**
Sample Type	Lake	Lake	Lake	Lake	Groundwater	Groundwater	Groundwater
Total Phosphorus (mg/l)	**4.37**	**4.43**	**4.64**	**0.05**	2.96	4.88	4.74
Total Nitrogen (mg/l)	**8.78**	**8.14**	**8.06**	**1.27**	49.36	9.56	22.741
Inorganic Phosphorus (mg/l)	3.5	4.01	3.74	0.04 - 90th%	2.5	4.56	4.07
Inorganic Nitrogen (mg/l)	3.467	3.401	3.249	0.139 - 90th%	20.66	1.121	5.081
Ammonia (mg/l)	**3.46**	**3.39**	**3.24**	**0.2**	20.6	1.11	5.04
Chlorophyll a (ug/l)	**332**	**361**	**346**	**20**	-	-	-
Salinity (PSU)	18.1	18.1	18.1	**-**	8.9	12.4	9
Dissolved Oxygen %	**4**	**7**	**13**	**38**	0	0	0
pH	8	7.9	8	**-**	7	7.1	7.2
Temperature C	22.64	22.7	22.6	**-**	26.1	24.4	23.7
Turbidity NTU	73	103.1	107		7.5	11	9.4
CDOM QSE	321	319	321	**-**	-	-	-

criteria.

Table 2. Results of estimated groundwater flow and nutrient loads from the two sets of wells installed for this study. Estimates were interpolated from two weeks' worth of data for the dry season (October-May) only.

Location	Flowrate (m3/day)	TN Loading (kg/day)	IN Loading (kg/day)	TP Loading (kg/day)	OP Loading (kg/day)	.% TN Load	.% TP Load
Eastern Parcel	79.4	1.81	0.40	0.38	0.32	0.88	0.75
Western Parcel (City of Sanibel)	25.5	0.24	0.03	0.12	0.12	0.12	0.25
Total Daily	104.9	2.05	0.43	0.50	0.44	1	1
Dry Season Estimate	**20,770**	**406**	**86**	**99**	**87**		

Table 3. Results of soil phosphorus index testing at former percolation pond site. Negative soil phosphorus storage capacity values indicate soils release P when inundated rain or groundwater.

Location	Phosphorus (mg/kg)	Iron (mg/kg)	Aluminum (mg/kg)	pH	Magnesium (mg/kg)	Calcium (mg/kg)	Phosphorus Saturation Ratio	SPSC (mg/kg)	Does Soil Hold or Release P?
Eastern Parcel	6.0	25.0	0.0	8.1	68.0	302.0	0.45	-6.30	release
Western Parcel Pond Sediments	9.0	7.5	0.0	8.0	90.0	324.0	2.03	-34.70	release
Western Parcel Upland Soils	7.0	9.5	0.0	8.8	52.0	337.0	1.33	-8.4	release

Table 4. Results from sampling groundwater and sediment for metals at former Bayous wastewater treatment plant percolation ponds.

	Sediment Sample Concentration (Mg/Kg)	Sediment Probable Effects Level Concentration (Mg/KG)	Southern Florida Soil Background Concentration (Mg/Kg)	Groundwater Sample Conc. (ug/l)	Drinking Water Standard (ug/l)	Class III Marine Waters (ug/l)
Lead (Pb)	15.3	60	1.95	1.94	15	8.5
Copper (Cu)	3.22	75	1.4	NT	1.3	3.7
Arsenic (As)	0.192	16	0.48	1.59	10	50
Cadmium (Cd)	0.38	2.5	0.04	7.3	5	8.8
Mercury (Hg)	0.031	0.5	0.162	NT	2	0.025

APPENDIX 2

Excerpts from:
Limnological health assessment of Seven Sanibel Island ponds

A study by the Southwest Florida Aquatic Ecology Group
FGCU
Serge Thomas Ph.D.
November 2017

Herons Land West Lake Findings

v. Heron landing pond

When visited, Heron Landing pond surface water was -0.17m NAVD'88. The volume of the pond was then 8,595m³ for a planar surface area of 4,774m² and a mean depth of 1.9m.

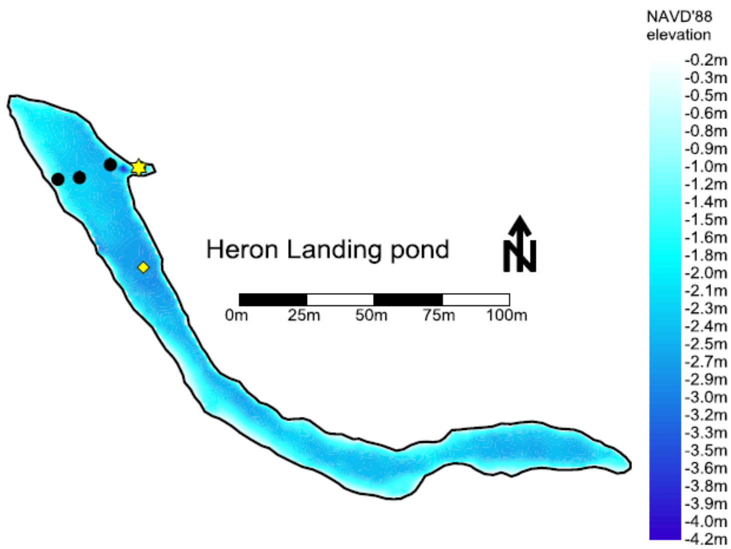


Figure 12. Bathymetry of Heron Landing pond

The average bottom hardness of Heron Landing pond was 0.44 as calculated with surfer and its bottom was harder than its shelf. SAV cover was found intermittently on the shelf but not in the deepest portions of the pond.

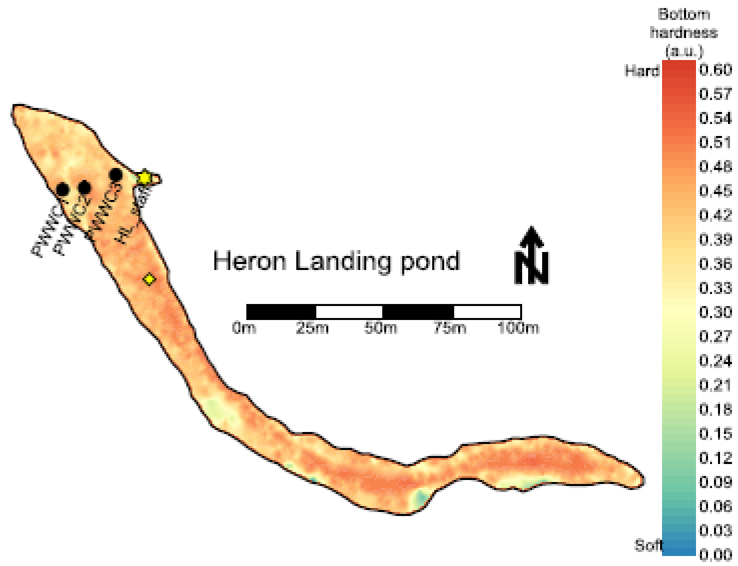


Figure 13. Bottom hardness of Heron Landing pond

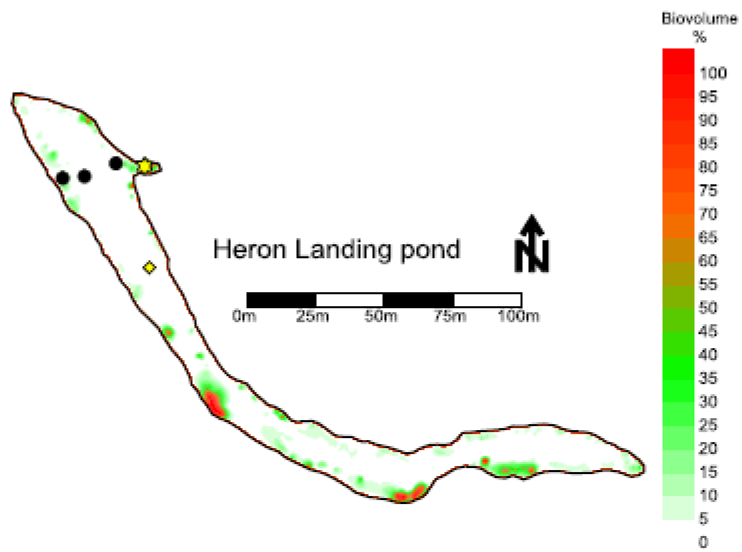


Figure 14. SAV cover in Heron Landing pond

	Elevation	Volume	Planar area	Mean depth	bottom hardness	SAV
Ponds	NAVD'88 (m)	m^3	m^2	m	a.u.	%
Beach Villa	0.247	414	522	0.8	~0.3	spotty on shelf, sparse in deep portion
Bike Path Trail	-0.5	27,055	15,007	1.8	0.39	spotty to sparse on shelf
Chateau sur Mer	-0.27	9,791	8,219	1.2	0.37	spotty on shelf, sparse in deep portion
Golf Course	0.247	12,679	8,218	1.6	0.47	fair cover on shelf
Heron Landing	-0.17	8595	4,774	1.9	0.44	spotty to sparse on shelf
Sanctuary	0.17	9,007	4,540	2.1	0.42	fair cover on shelf
The Dunes	0.103	207,700	81,404	2.6	0.41	very sparse on shelf and deeper portion

Table 1. Summary of mapping characteristics

v. Heron landing pond

The water column is being destratified in Heron Landing pond since the temperature curve represents mixing occurring between the epi and hypolimnion. DO are alarming low and typical of anoxia. pH is typical of brackish and saline water which agrees with the specific conductance. Specific conductance is also lower on the surface than in deeper water and shows a weak halo/pycnocline which is being destroyed. ORP is very negative showing a very reducing environment in par with the anoxia observed. Water clarity is very poor as PAR profiles prove very challenging as light would attenuate too quickly. Particulates other than phytoplankton and likely heterotrophic bacteria and other particulates attenuate light in the water column.

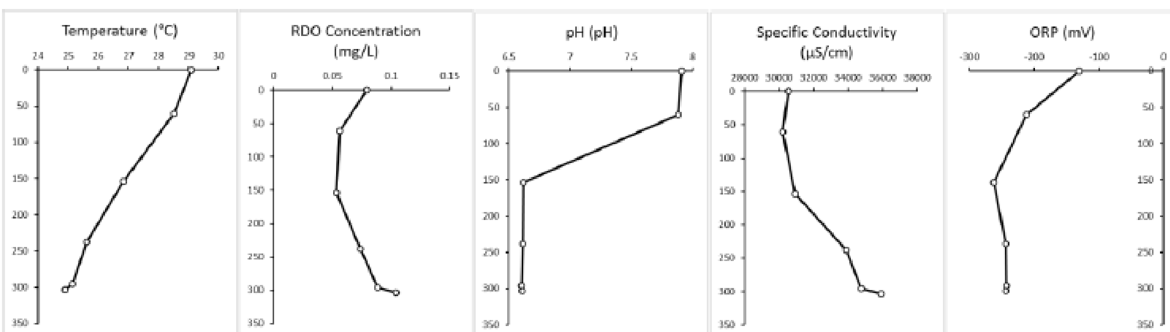


Figure 23. From left to right, water column profiles of temperature, DO, pH, specific conductance and ORP in Heron Landing pond

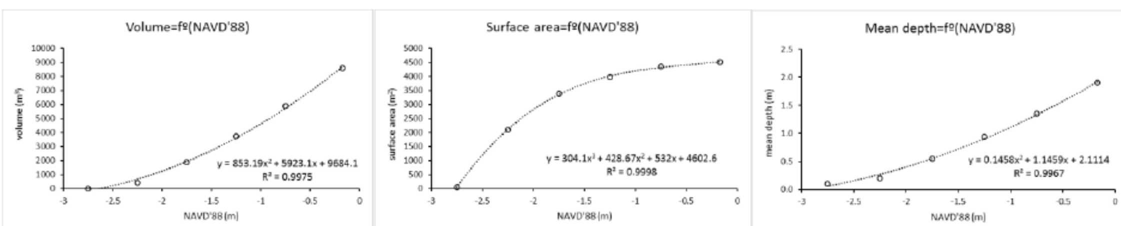
	Total alkalinity	Chl*a*	NOx	NH4	TN	SRP	TP	TN/TP	Limitation	TSI(SD)	TSI(Chl*a*)	TSI(TP)	TSI(TN)	TSI(Combo)
Ponds	mg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	no units	P, N, both	a.u.	a.u.	a.u.	a.u.	a.u.
Beach Villa	129.5	6.0	0.024	0.033	0.799	0.016	0.027	29.6	both	54.3	42.7	43.3	54.8	48.7
Bike Path Trail	194.0	36.9	0.040	0.061	2.571	0.071	0.021	125.4	P	84.0	68.8	38.2	79.9	63.6
Chateau sur Mer	297.0	22.3	0.039	0.041	1.576	0.037	0.078	20.3	both	68.6	61.5	62.9	69.4	65.4
Golf Course	192.0	31.6	0.016	0.062	2.423	0.048	0.117	20.7	both	64.2	66.5	70.6	78.6	68.4
Heron Landing	507.0	63.2	0.079	0.533	3.030	4.120	3.821	0.8	N	91.5	76.5	135.4	83.4	84.0
Sanctuary	269.0	49.6	0.025	0.049	1.965	0.284	0.650	3.0	N	54.3	73.0	102.5	74.1	63.6
The Dunes	258.0	66.1	0.020	1.578	4.162	0.132	0.171	24.3	both	84.6	77.2	77.6	90.3	81.9

Table 3. Summary table of the water chemistry and overall water quality assessment via the TSI.

v. Heron landing pond

Heron Landing has high total alkalinity showing an eventual good connection between the pond water and the surrounding lime rich environment. Such alkalinity could limit algal and SAV growth as carbonates dominate. Cyanobacteria however can thrive in such environments and it seems to be the case as chl *a* concentration is quite high but not enough to compensate the high biological oxygen demand of the water and likely of the sediment. Nitrogen, but especially, phosphorus (*a fortiori* as labile phosphorus) levels are especially high in this pond and drive the TSI to hypereutrophy+. The pond is limited in nitrogen which can select nitrogen fixing cyanobacteria but with such high levels of nutrients, it is doubtful that any limitation exists. Ammonia levels are high linked especially to the reducing properties of the water (i.e. low ORP).

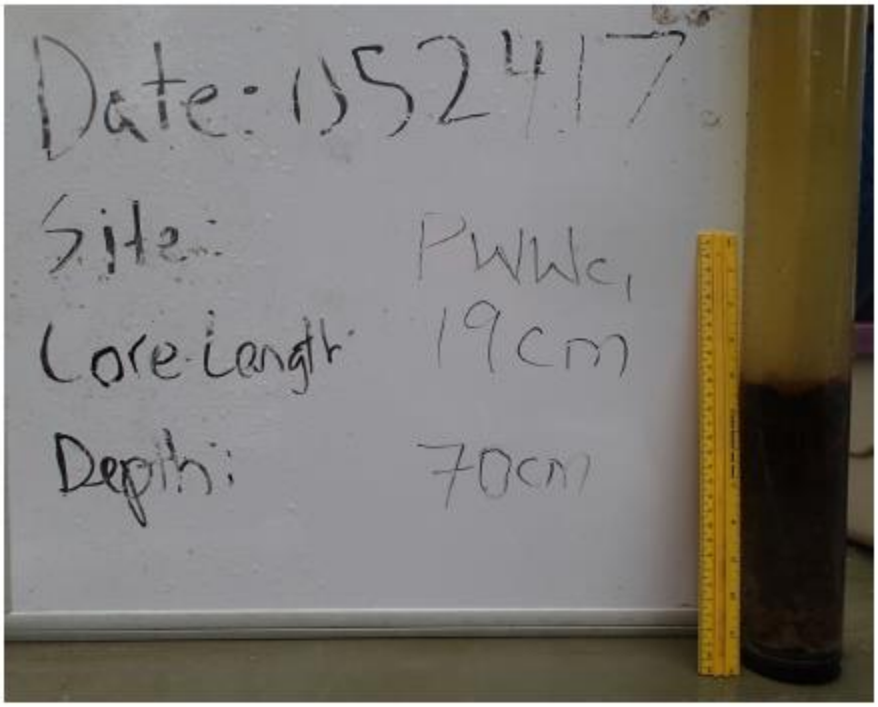
5. Heron Landing pond (3/22/17)



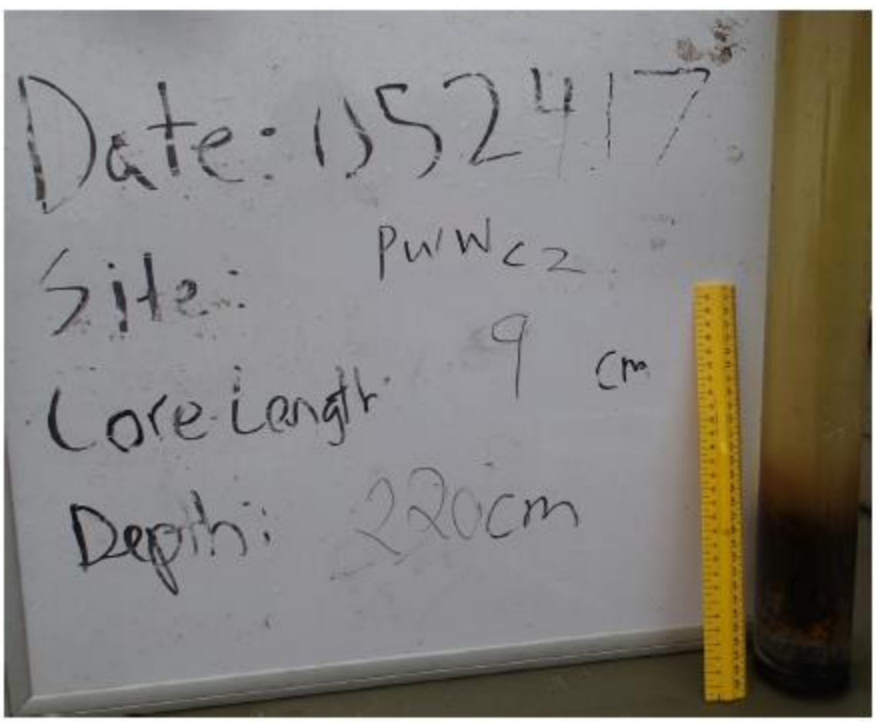
Appendix1_ 5. Morphometric relations for Heron Landing pond

Water level: -0.166m, top of post 0.234m

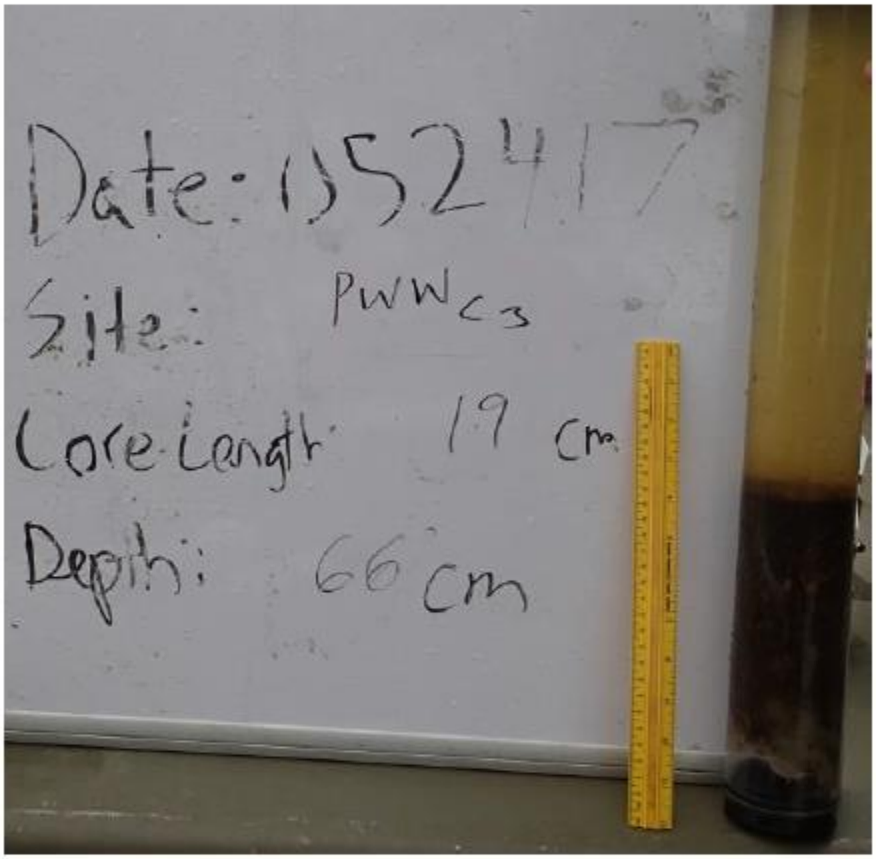
5. Heron Landing pond (3/22/17)



Appendix2_ 17. Core 1, Heron Landing Pond



Appendix2_ 18. Core 2, Heron Landing Pond



Appendix2_ 19. Core 3, Heron Landing Pond