CITY OF MIAMI BEACH SURFACE WATER QUALITY MONITORING PROGRAM REVIEW FEBRUARY, 2019

Contents

Surface Water Quality Monitoring

Program Review

City of Miami Beach

February, 2019

Executive Summary

This report describes a project that was launched by the City of Miami Beach (City) to develop a scientifically based evaluation of stormwater quality monitoring being conducted by the City at points of discharge (outfalls) and nearby waters. The evaluation was based on an examination of available monitoring data, a field observation of the present stormwater monitoring program, and information provided by City staff.

The existing monitoring program was found to be a useful screening level program, apparently adequate to provide a warning in the event that a substantial (e.g. long term and large) contamination event is experienced. The program is not conducted at a sufficient spatial density to immediately identify all instances of significant contamination, but with several dozen stations located about the City, including locations near stormwater outfalls and locations more removed from those outfalls, it is likely to provide a warning in the event that truly massive and persistent contamination is encountered. It is not reasonably possible to sample all locations at all times, so a perfect warning system is not a reasonable prospect, but the present program is a pragmatic and scientifically defendable approach that provides useful information in a balanced way given the present state of knowledge of the system. In short, the basic characteristics of the program are sound, results are useful, and it is recommended that it be continued and enhanced if a screening program is of continuing interest to the City.

Conduct of the field program was directly observed as a part of this assessment. The field crew that was observed was professional and effective in its actions, professional staff were clearly knowledgeable and intent on using the data to best effect, and the field sampling program over all was found to be well conceived and executed given its role as a screening or warning system.

However, there were some areas where practices could be improved, and a range of enhancements were identified for consideration. These include development of a comprehensive set of Standard Operating Procedures (SOPs) with associated Quality Control elements, encompassing among other things implementation of training standards for staff in the field, increased supervision, and improvements in some specific aspects of field technique.

In addition, recommendations are made for consideration in the event that there is interest in using the data for purposes beyond simple screening/warning functions. Tracking changes over time, for example, would likely best be served by extending and supplementing the current program. Recommendations are made as to refinements to the sampling program which will continue the existing useful monitoring results but better position it for uses beyond basic screening/warning functions.

After the SOPs noted above are developed and implemented, a moderate approach to enhancing the monitoring program is recommended, rather than any immediate dramatic changes. Moderation is suggested for two basic reasons. First, the sampling that has been done has not disclosed a major problem requiring dramatic action. Second, the existing data are not sufficient to confidently suggest what major changes to the program might be indicated. Therefore, a set of initial steps that will significantly improve data and results, while maintaining the essential vision of the present program, is recommended. In the future, if needed, more extensive revisions can be

made on a foundation of better information and more clearly demonstrated need. Of course, if the City develops a need for extended or different data in the short term, a more immediate update to the program may be warranted.

As well as recommendations regarding the conduct of field work, recommendations are made to explore the potential for improved laboratory outcomes; the conduct of the laboratory work carried out to date is not questioned as such, but there may be value in exploring the potential for alternative tests and improved resolution near detection limits.

Once the monitoring program was evaluated in the field, the available data arising from the program were assessed. Despite the limitations discovered during the field component of this assessment, and the screening level nature of the program, it was considered useful to explore the available data to determine if significant trends or other interpretations might emerge. Charts provided by the City of all parameters measured (appended to this report) were examined. The limited number of available observations made it difficult to demonstrate a cause and effect link between such factors as rainfall and stormwater quality, or to identify causes of observed bacterial concentrations. However, some basic information could be developed. For example, a review of the indicator bacteria data suggested the following:

- Statistically, there were few instances where there was reason to conclude that the stations nearest the outfalls differed from those further away. On the contrary, most of the data suggest that there is no statistical difference between these two cases from a cause and effect perspective.

- However, by aggregating data into larger sets, and by partitioning the data effectively, some added indications emerged. Generally, it was determined that in the aggregate, indicator bacteria at stations in close proximity to outfalls do not for the most part behave differently than those further away. There is an apparent increase in excursions from base conditions at locations closer to the outfalls compared to locations further away, but this increase is not universal. This preliminary finding requires further investigation.

- The system for the most part displays water quality characteristics consistent with typical stormwater discharges. Values measured in the field were largely unremarkable from this perspective.

With added data in the future, the present findings may change, and new findings may emerge.

In summary, for the present it seems reasonable to conclude that the available data, interpreted with an understanding of the field procedures employed to date, do not support a conclusion that there is a major difference in behavior during wet and dry periods. Further, the data do not support a conclusion that there is a continuing massive discharge of sanitary flows into this system.

Since the available data are not definitive, it would be appropriate to continue and potentially expand the present program if more concrete statistically defendable conclusions are desired. It is suggested that if monitoring does continue, analyses of the type contained herein should be extended and enhanced as data accumulates. In addition, supplementary monitoring might be indicated if and when the monitoring program begins to define patterns of behavior more certainly than is presently possible. For example, a strategy for targeted sampling at specific catchments might be considered if a particular outfall is found to discharge objectionable levels of contaminants of interest or if other indicators suggest a need for further investigation of water quality conditions and possible causal factors.

Introduction

This report describes a project that was launched by the City of Miami Beach (City) to develop a scientifically based evaluation of current monitoring practices associated with stormwater quality discharges from the City. Findings include an assessment of the adequacy of present monitoring practices, recommendations as to improvements to monitoring practices that might be considered, and an evaluation of the monitoring data gathered to date.

Approach

This project was carried out in a set of sub-tasks that included review of data provided by the City, site investigations, and analysis, as follows:

Review of Existing Analyses of Monitoring Data:

The City has been gathering water quality monitoring data at numerous stations near points of stormwater discharge, and as City staff have completed some analyses of the data. These analyses were provided by the City (see charts appended to this document), and reviewed as a part of the present evaluation. Initial impressions about the nature of the sampling program were developed based on this content, the conduct of the monitoring program to date was discussed with staff, and a site visit was planned accordingly.

Site Visit:

The site was visited at monitoring locations. With the aid of City staff, sampling locations were visited from the water by means of a boat and crew provided by the City. This was done at a time when sampling was being conducted. Factors relevant to potential sources of contamination were sought, and sampling technique was observed.

Analysis of Existing Data:

The City provided all available water quality data, as well as related meteorological data, obtained in the monitoring program noted above. Those data were examined, including all parameters but with an emphasis on indicator bacteria results, and statistical analyses were employed in an attempt to find meaningful correlations between locations and circumstances prevailing at each sample location. In addition, the data were scanned to determine if a meaningful assessment of positive or negative trends over time could be made.

Interviews:

Discussions were held with City staff to confirm information gained regarding conduct of the monitoring program, to better understand observations made in the field, and to verify related questions that arose as water quality data were examined.

Reporting:

This report was drafted, based on outcomes of the above steps.

The above series of steps were considered to constitute a useful basis for comment on the monitoring program and present monitoring results; however, wider resources were also available and considered.

Over all, it should be noted that the present work was necessarily limited to the interpretation of monitoring data from a program that is in its early stages, and that it cannot be considered to be the final determination of water quality behavior in this system; as time goes on, and added data are obtained, new insights may emerge. The project was not designed to extend or amend any monitoring or stormwater quality plans already in place, or to address questions of engineering design or interpretation. All content developed and communicated in this report is scientifically founded opinion based on information provided to the reviewer supplemented by activity viewed during field observations.

Field Observations

Monitoring Locations and General Observations

The monitoring sites were visited from the water, in a pattern that reflected practices during regular monitoring conducted by City staff with support from PACE. Locations monitored by the City are shown in Figure 1.

General Outfall Observations

All cases observed were on a calm and sunny day with no major rainfall or wind conditions. Although all locations were designated as either 'ambient' or 'outfall' by the City, it was evident that the nature of the outfalls themselves varied considerably from place to place. For reasons related to design, maintenance, and operations, the City outfalls display a range of configurations, and at the time of observation they were affected by a range of temporary operating conditions. Figures 2 through 7, provided by the City, provide a few representative examples of what was observed at the time of the visit. Some general observations are:

- In some cases, outfalls were fully submerged, while in others they were fully exposed. This will vary to some extent as affected by tide, but has the potential to impact monitoring results from location to location.
- In some cases, plastic barriers are in place, while in others they are not.
- Some outfalls are pumped, while some are gravity fed (pumping locations were not generally visible during the field visit, but were known to the City and identified as such).
- Active construction in the vicinity of some locations had left significant areas of bare earth and sediment in locations likely to enter the water at or near an outfall.
- Active construction in the vicinity of at least one location included a dewatering pump which discharged in the immediate vicinity of an outfall.
- Watercraft and moorings were adjacent to some outfalls, but were absent or less marked in others.
- Land uses near the points of outfall varied, including grassed areas, slip ways, urban construction, roadways, and so on.

In addition, it was noted that there were apparent outfall pipes (with active discharge observed) that were not among the City stormwater discharges of interest in this project but that nevertheless do, or could, contribute flows to the receiving water system. Over all, it was clear that there is a substantial possibility of variations in monitoring results as a function of the variations in conditions that prevail at each outfall location. The variability observed in outfall characteristics is a common fact of life in coastal environments, since needs and constraints vary from place to place and from time to time, so this observation should not be construed as a negative reflection on City practices. It is, however, a factor that complicates implementation of a comprehensive and consistent monitoring program.

Ambient	Outfall
22	21
24	23
26	25
28	27
30	29
32	31
34	33
36	35
38	37
40	39
63	62

Figure 1 City Monitoring Locations

Figure 2: Submerged outfall

Figure 3: Outfall below grassed right-of-way

Figure 4: Watercraft dockage near outfall

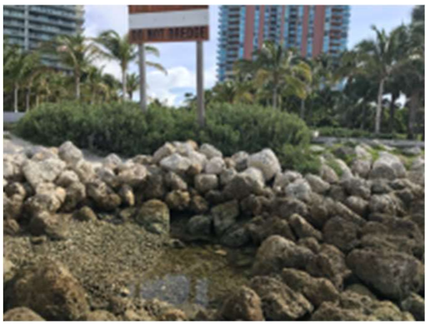


Figure 5: Rip-rap energy dissipation near outfall

Figure 6: Outfall below construction with open soil surface

Figure 7: Outfall with active dewatering under way during sampling

Monitoring Procedures

The monitoring crew which was present at the time of the field observations carried out in this review were visibly experienced in working together and were professional in their conduct. They worked smoothly and efficiently together, and there seemed to be no moments where activities were new, or unusual, or unpracticed. This comfort with established process is a desirable indicator for two major reasons. One is that it suggests that what was observed was indeed what is normally done; steps had been taken to minimize the likelihood that the crew would feel the added participants constituted a performance review, for exactly this reason. The other is that it suggests that the monitoring is carried out in a way that is consistent over time, which is fundamental to obtaining meaningful results in the long term.

It was also noted that there was no sense of a merely perfunctory attention to the monitoring process. Crew members were attentive, observant of each other's actions, and in vocal contact as they each played their part. Each person had a defined set of activities to fulfil, and they seemed to expect each other to follow a sequence of established patterns as samples were taken and results recorded. Field notes were legible and entered with evident care. It seemed apparent that the monitoring process had not degraded into a rote activity, which is a risk in prolonged programs of this type.

It was not visible that there was a crew chief, although each member carried out their functions in harmony and no intervention was required during the period where operations were observed. How decisions would be made in the event of an anomalous procedural outcome is therefore not known. In terms of boat discipline, however, the operator was clearly in charge and potentially might fill a leadership role in a broader context if needed.

Boat handling itself was masterful, with minimal wake, careful attention to rules of the waterway, and an efficient approach to and departure from each monitoring location. The boat was a highly effective and stable working platform, and clearly able to support operations in conditions much more adverse than were experienced during this field program. Although not within the scope of this investigation, it is noted that the boat was in good order, with safety devices apparently correct and in place, which speaks in part to the professional foundation of the field activity over all.

Sample labeling and sampling in the field appeared to be consistent with effective practices, with little likelihood of inadvertent mixups between samples or use of inappropriate sample containers. It must be recognized, however, that lab prep prior to field sampling, and transport and analysis after sampling, were not reviewed in the course of this project and cannot therefore be confirmed as either adequate or inadequate for purpose.

One facet of the team composition that was unexpected is that there seemed to be a gap in formal training. The individual doing the actual sampling was very consistent from instance to instance, and evidently intent on effective sampling in each case. However, when questioned, it was determined that the individual had had no formal training, but had been allocated to the crew at one point and had learned by observation bit by bit on the job. The individual in question was seen as a positive, professional, and effective crew member, but the apparent lack of formal training raises questions, not answerable at this time, about the efficacy of SOPs and QC measures guiding the monitoring program. Subsequent discussions with the City suggest that the person doing this aspect of the field work was not formally tasked with this function but was attempting to contribute to the program in an effective way; if so, and if this contribution is to be continued, a formal shift in training and preparation should be considered. If, however, this allocation of resources is not what was anticipated by the City, then it appears a major function is not being fulfilled by whoever was expected to undertake it. Resolution of this point is unclear at the time of writing.

Taken together, the review of field procedures suggests that the program is in most ways appropriate for a screening program which is in place to identify gross excursions of common water quality indicators.

The points of detail below outline factors that should be reviewed and perhaps adjusted, particularly if the monitoring data being gathered might be used at some point in the future for wider purposes than a general screening program.

Factor: Sample location consistency

Explanation

- In some cases, sampling was done immediately in front of an outfall, while in others it was offset by a few feet. Since the potential to sample directly from the outfall itself apparently exists, the reason for this variable designation of location is unknown.

Significance

- If the intent is that monitoring is only intended to provide a gross indicator of conditions in the general vicinity of an outfall, this is not necessarily a major problem. However, the shift in position relative to the outfall itself raises the possibility of sampling a mix of outfall flow and ambient flow, or missing an outfall plume altogether. This raises a question as to what exactly was being sampled in those stations identified as ‘outfall’. It is less of an issue in those stations identified as ‘ambient’.
- For someone attempting to analyze monitoring results, this undocumented variability in orientation relative to the outfall pipes constitutes an uncertainty in the meaning of a particular sample that could materially interfere with the ability to interpret monitoring data.

Factor: Sample recovery

Explanation

- In all cases, the sample recovery was taken by lowering a container into the water and allowing flow from the top inch or so of water to flow into the container.

Significance

- This factor means that surface skimming was generally what was being sampled. With a submerged outfall, particularly where temperature gradients might be significant, or where wind conditions might materially affect the top of the water column, this is a practice that could have the sample less reflective of what is coming out of the outfall, and more indicative of local conditions affected by wind and sunlight.

Factor: Sample cross-contamination

Explanation

- Between samples, the container was seldom rinsed in even a perfunctory way. It was generally emptied after sampling, and then dropped into the boat. It was then picked up and used for the next sample without substantial agitation or cleaning.

Significance

- When measuring such things as nutrients, this practice is probably of more theoretical interest than practical impact. However, when sampling bacteria, or (for example) perhaps when moving from a high turbidity location to a low turbidity location, it could have a consequence of 'blurring' results between one location and the next.

Factor: Sample equipment handling

Explanation

- It was observed that the sample container was at times picked up with the user putting fingers inside the vessel and a thumb outside.
- Particularly when sampling bacteria, and when not otherwise rinsing or cleaning the sampling apparatus between samples, this kind of handling of the container invites false positives arising from contamination not related to local waterway conditions.

Factor: Sediment resuspension

Explanation

- It was observed that in some locations, the propeller on the boat used was close enough to the bottom to mobilize significant visible quantities of sediment, despite care and attention by the operator to reduce or eliminate this effect.

Significance

- This resuspension, if sufficient to reach the surface (it was apparent but unproven that this was the case) could in effect have samples in such a case reflect whatever accumulated on the bottom, not what was discharged from the outfall.

Factor: Sample event selection

Explanation

- It was explained by the team that sampling excursions were planned for a particular sampling date in the future based on calendar availability. There has been no attempt to sample immediately after rainfall events.

Significance

- Lack of a conscious effort to sample during or immediately after rainfall events could be viewed as insignificant in the sense that it is a semi-random way to schedule a sampling event. However, it sharply reduces the opportunity to sample discharge conditions truly representative of a storm. In the very long term, it will probably be possible to estimate post event conditions that are randomly sampled according to the existing protocol, but it will make it a much less efficient process when it comes to determining what happens as a result of storm events.

Factor: Sample event exclusion

Explanation

- In cases where there is a significant rain/thunder/lightning condition, samples are not taken.

Significance

- This is a prudent safety factor. However, it further reduces the opportunity to gather data indicative of storm event conditions and therefore imposes a bias in the data. Auto-sampling, or a commitment to sampling immediately after the weather clears, would reduce this bias. It is not quantitatively known how often wet weather exclusion has been a factor in the past, but it should be avoided, if possible, in the future.

Factor: Sample sequence timing bias

Explanation

- During discussions with the crew, it was learned that sampling generally (but not perfectly) takes the same pattern each time the crew is deployed. There was a tendency to sample at one end of the system and efficiently work forward from there. The start and end times for each sampling episode were apparently reasonably consistent from instance to instance.

Significance

- Since this is a tidal system, and since sunlight intensity varies during the day, this raises the possibility of inserting a systematic bias into results because sampling at a given location will exhibit a correlation with tidal phase and time of day at different times of the cycle. Also, it suggests that a different crew with a different sampling sequence might inadvertently insert a counter-bias. Consideration should be given to evaluating sample patterns in ways that specifically address the potential of an internal bias based on timing.

Factor: Minimal record keeping during sampling

Explanation

- During sampling, a variety of conditions may be present which could affect results.
  - As shown in figure 7, there may be de-watering under way from activity in the catchment.
  - In some cases plastic silt barriers are in place, in some cases they are not, and in some cases they have failed.
  - There may be maintenance activity at the capture tanks above some of the outfalls.

None of these factors, or other observable factors that might affect water quality, are recorded by the sampling crew.

Significance

- The disturbances identified above, and others (observed waterfowl, marine activity, etc.) have the potential to affect water quality, some of them very significantly. It is a resonable prospect to train crews to identify and record such instances, and such information could be very helpful in interpreting anomalous monitoring results after the fact. A simple photograph of each site at the time of sampling could add to the ability to understand results. It might also make it easier to detect variations in sampling technique from person to person or from time to time during future reviews of the data and monitoring program.

Factor: Sample location resolution

Explanation

- Navigation to each sample point was essentially by visual position estimation. Known points on the shore or nearby were used to establish location along the shore, and visual estimates were used to establish position outward from the shore. Quantitative navigational aids were not observed in use for sample point station keeping, and questioning of the crew suggests that visual reference points are the basis for navigation.
- In some cases, the boat was noted to drift significantly while samples were being taken. In one case, a drift of about 40-50 feet was observed between the time a physical sample was taken, and the time an in-situ probe was read.

Significance

- From a larger perspective, approximating location as has been done might be adequate. As a gross indicator of major events, the lack of a tight definition of known sample location might be acceptable. However, if the data are eventually to be interpreted for modeling or cause/effect assessments, this 'fuzzy' approach to location could easily become problematic. The degree to which this matters is quite case specific. In one case, when the so-called ambient location was substantially off shore and in an open channel area, 50 feet or so might be insignificant. In another case, for example while sampling in a boat docking area where 50 feet was a substantial proportion of the distance to the outfall, or where other physical factors vary over short scales, it may not be. Either way, with location varying substantially during actual sampling, it can be interpreted that more than one point is actually being measured.
- If more than one person does the navigating, the question of interpretive consistency becomes material. It is likely that without quantitative direction, or a long and careful overlap so that a consensus on location is obtained, results developed by one person might reflect a consistently different set of locations from another.
- In any case, it is concluded that actual sample location varies from instance to instance, and that this variability needs to be acknowledged as a part of the monitoring data record keeping.

General Conclusions and Recommendations Regarding the Existing Field Monitoring Program

The overall conclusion gleaned from observation of the monitoring program techniques is that the results are able to deliver a screening level of understanding that there is or is not an episode of gross contamination at the times and places sampled. While the resolution is not fine enough to detect every possible instance of a high exceedance of desirable water quality parameter limits across the extent of the receiving water body, the sampling as it stands appeared to be a reasonable way to track conditions and detect major excursions. There is some likelihood of a false positive from time to time for bacteria, arising from the techniques employed, but there is only a limited chance of a false negative at the times and locations sampled. It is noted that the approach used might be considered to be inherently conservative method as a result.

Even if the present sampling program is to be supplemented by an expanded or more sophisticated approach, consideration should be given to maintaining it. It is sound in concept and has value in its own right.

Nevertheless, there are several things which should be considered from the perspective of preferred practice.

- If the present general approach to sampling is to be maintained, an alternative nomenclature to 'outfall' and 'ambient' should be considered to avoid confusion or inadvertent misrepresentation of results, and this nomenclature should be fully defined. For example, the stations presently termed 'outfall' might better be termed 'close proximity to outfall' and this new term might be defined as 'within a 15 foot (*estimated for purposes of this report*) radius of the outfall termination point'.
- A written SOP should be devised which formally specifies locations, techniques, QC requirements, and other details of sampling. This is a substantial task but is a necessary co-requisite to this kind of monitoring program. The SOP should include:
    - specific attention to recording observed factors or conditions that might affect water quality, such as the construction and dewatering examples that were observed in this case,
    - protocols for sample container refreshing between sample instances,
    - stated positioning requirements, including positive mechanisms to ensure different crews obtain similar results,
    - reconciliation of duplicate vs split sample techniques (uncertainty exists on the point in the present sampling), and
    - attention to standard QC elements characteristic of this kind of sampling program (there are established protocols for most of the elements of this program).
- Staff should be trained and confirmed fit for purpose before they are allocated to sampling. This training should include a thorough familiarity with the SOP.
- Periodic QC checks of sampling should be implemented, not because of doubts in the crew but because of the inherent need to verify technique in programs of this type. Annual refresher training should be considered.
- Consideration might be given to supplementing the outboard motor on the sampling craft with a trolling motor so that shallow locations can be approached with minimal chance of bottom sediment disturbance.
- If more than one crew is mobilized, periodic cross-appointments should be considered so as to surface possible differences in practice between crews.
- The striking professional motivation of the crew observed in this review should be respected and preserved with careful management, as it is largely attitude that translates an SOP into reality. The starting point in this case is strong, and a good place to build from.

Other aspects that should be considered, particularly if the results of the monitoring are to be used to track progressive changes over time, cause and effect, or other water quality behavior beyond a screening function, are:

- Consider a mechanism to directly sample from the outfall pipe itself. Even though exchange with the surrounding water will be a reality due to tidal swings, this will lead to a better understanding of true outfall contributions. For example, a tube driven by a peristaltic pump might be an effective option (provided suitable purging is implemented) and other techniques are available. It may be that sampling at the most immediate upstream junction is possible, and could be accomplished even in adverse weather conditions.
- Consider implementing a closer positioning protocol, so that a single and repeatable sample point is truly obtained.
- Consider definition of timing for successive sampling episode sequences (potentially a rotating sequence) to better account for periodic phenomena in the receiving system.

- As well as continuing to sample during dry weather, consider improvements leading to better capture of wet weather conditions. Internalizing field sampling by the City so that wet weather events can be reliability captured, or contracting with the current provider in a way that enables sampling immediately after (if not during) storm events, are two options that could lead to a better understanding of stormwater discharge contributions. This stronger discrimination of wet weather conditions could be done as a separate exercise from the screening program, and it could potentially be discontinued once a sufficient understanding of stormwater discharges is obtained.
- Consider adjusting sample points or sampling frequency according to potential contributing land uses and/or likely contaminant sources. There is significant variability in and around the extent of the City, and it is reasonable to consider this in refining sampling strategy.

It is noted that in this technical area, there are a vast number of field techniques that can add understanding to the complex set of factors that govern water quality in the receiving system. These include such things as dye studies, tracers, more complex parameter sets, and even quantitative modeling of transport and ecosystem response. These are not considered responsive to the immediate need as defined for the present assessment. Suggested improvements listed above are all intended to provide improvements in quality and dependability, leading to better and more useful results, without a massive upscale in level of effort.

A moderate approach is suggested for two reasons. First, the existing monitoring has not (as is discussed in the chapters below) disclosed that there is a massive problem to remedy. Second, the existing data do not provide enough information to confidently design a major monitoring program. Until one or both of these conditions is encountered, or until needs of the City change, it is suggested that a prudent and step by step approach is indicated. The set of suggested improvements outlined above constitute such an approach.

Examination of Existing Data

The available data were assessed in a two step evaluation process. First, time series plots and synoptic data for all parameters at all stations were examined in the form of results obtained by City staff. Second, a deeper examination of parameters of interest was conducted, considering all parameters but focused on indicator bacteria because of current questions as to potential sanitary discharges. It is noted that the data do not suggest that major sanitary discharges are a present issue, but that this second step was undertaken to determine to the extent possible what can be learned about indicator bacteria behavior in this system given the interest in this subject. Throughout this discussion, it should be noted that the screening level program which is in place, particularly given the early stage of data gathering, is not necessarily a preferred basis for interpretations beyond the immediate use as an indicator of emerging adverse conditions.

Review of Synoptic Data and Charts Made Available by the City

Parameters considered included:

- Fecal coliforms
- Enterococcus
- pH
- NH3
- Salinity
- Specific Conductance
- Dissolved Oxygen
- Total Kjeldahl Nitrogen

- Nitrate plus Nitrite
- Total Phosphorus
- Turbidity

Data and images made available by the City will not be appended to this report, but are available from City sources.

Over all, the available data demonstrate variability over the course of the year. There are instances where the data do suggest some variability in behavior between sites, but statistical tests show that for the most part, the available data are not numerous enough that, when partitioned, confident statements can be made as to the differences between locations or conditions. This limitation does not reflect an inadequacy in the monitoring program. It is a consequence of a short monitoring period, multiple cause and effect mechanisms, and limited sample density.

For example, an attempt to assess results in terms of precipitation, which is a major candidate cause of water quality impairment, was statistically undefendable because of the limited number of sample cases clearly associated with rainfall cases. There are few instances where the time lapse between a rainfall event is small enough that the sample can be considered reflective of rainfall conditions. Similar limitations exist with the other parameters. Temperature and salinity vary substantially due to the natural mixing processes in this type of water body, and the chosen sampling methods do not lend themselves to a useful cause and effect evaluation of presence or association with stormwater events. The Nitrogen and Phosphorus species do have short term implications (for example NH_3 as a directly toxic constituent) but express themselves in the long term as the nutrient cycle proceeds and a series of complex reactions with biological intermediaries take place. Dissolved oxygen may differ in stormwater and the receiving water, but the surface skimming approach to sampling which has been used makes it difficult or impossible to attribute what is measured to an outfall discharge or to simple reaeration near the surface. It is tempting to present the data none the less, but as the statistical underpinnings are limited, this is a potentially misleading course to take. The underlying causes for these results are discussed in the evaluation of the sampling program provided above. The sampling procedures, for reasons of design and safety, do not reliably occur during periods representative of stormwater discharges except incidentally, and the screening/warning nature of the sampling does not lend itself to cause and effect analysis. With the present sampling program, it will take time for the data base to accumulate substantial numbers of events associated with rainfall. Recommendations have been made to enhance the data base by adjusting the monitoring program if a quicker resolution of this issue is desired. With alternative sampling strategies and SOPs in place, it should be possible to relatively quickly identify stormwater discharges which contribute significant quantities of contaminants of interest.

In the mean time, the overall finding from the data that are available is still a useful one. There are indications of perturbations in the parameters measured from time to time, and some areas where there may be a difference between samples in the near vicinity of outfalls vs conditions further away; however, the clearest outcome is that there is no substantial support for a finding that there is a continuing instance of large discharges of raw sewage into the stormwater system. This result is consistent with the intent of the monitoring program, and inherently effective in that context.

Evaluation of Indicator Bacteria Records

The parameter of most interest in this instance is fecal coliforms (FC). The reality of indicator bacteria survival in the environment is a highly complex and evolving field and will not be explored further in this document, but for present purposes it is noted that FC are the first choice for exploration in this case in part due to the greater likelihood that FC in a sample gathered as a part of the present program reflects recent conditions more effectively. There are still many potential contributing sources of FC, and the elimination of FC due to natural processes (die-off) is still a complex result of many factors, so this remains a complex and difficult problem to assess. Nevertheless, some basic conclusions can be gleaned from the available data.

The first step in assessing the data was to explore the statistical behavior of the available records. Over all, there was little support for the hypothesis that there is a statistical difference between the stations in close proximity to outfalls and those further away. The figure below illustrates this outcome for a set of stations in the south-west quadrant of the system. It is noted that this set displayed the greatest potential differences between so-called 'outfall' and 'ambient' stations; extensive testing elsewhere tended to produce much worse results.

Outfall/Ambient	P-value
11/10	0.52
15/17	0.64
16/17	0.37
55/56	0.80
21/22	0.13
23/24	0.05
25/26	0.11
55/56	0.80

Outfall1/Outfall2	P-value
21/23	0.86
21/25	0.97
21/55	0.96
23/25	0.92
23/55	0.89
25/55	1.00

Ambient1/Ambient2	P-value
22/24	0.77
22/26	0.40
22/56	0.24
24/26	0.53
24/56	0.16
26/56	0.09

Figure 8: P-Values associated with various sample site pairs

As shown, in the first set of pairings, only one of the data sets showed a significant difference at a 5% level, which was marginal, namely stations 23 and 24. Examining the underlying data shows that this difference is statistically reasonable, as there is an apparent factor differentiating the two; the limited numbers of observations, and the significant variations in values, are the reason that the difference is found to be significant but statistically not as strong as it might be. None of the other stations, however, show such a difference. Station 25 and 26, for example, not only fail the statistical test, but an examination of the data shows that the difference which is present is largely due to a few outliers and that part of the data shows one station higher and part of the data shows the other station higher. So there is poor support when considering station pairs (nominally 'outfall' and 'ambient' pairs) to accept the conclusion that there is a difference between outfall stations and ambient stations.

This raised an option for consideration. Another way to view the data is that there are two sets, namely one representative of outfalls, and one representative of ambient conditions. It is physically reasonable to pursue this line of exploration. The second two tables in figure 8 provide added support. None of the permutations of the ambient and outfall stations considered were different enough to reject the notion that they were statistically unrelated; or in more conversational language, none of the pairs were proven to be different. Hence, there is conceptual as well as statistical support for aggregating outfall and ambient stations, and comparing the results.

It is acknowledged that there are a number of statistical questions raised by this approach, but as noted above it has the virtue that it enables comparison of the data in terms of two basic groups, which might be thought of as 'discharge dominated' and 'receiving system dominated'.

To evaluate this data set, two sets of stations were aggregated.

Ambient	Outfall
22	21
24	23
26	25
28	27
30	29
32	31
34	33
36	35
38	37
40	39
63	62

Figure 9: Groups aggregated as outfall or ambient representatives

These were stations in the general south-west of the area, and were considered to have enough physical similarity to support this aggregation. The result was two sets of 221 readings per group, considerably more significant than the 20 or so readings available in each individual station.

The test which was then performed showed that the groups could be taken as statistically different at a 5% level (P close to 0). A plot of the frequency of the two sets of data appears in figure 10 below.

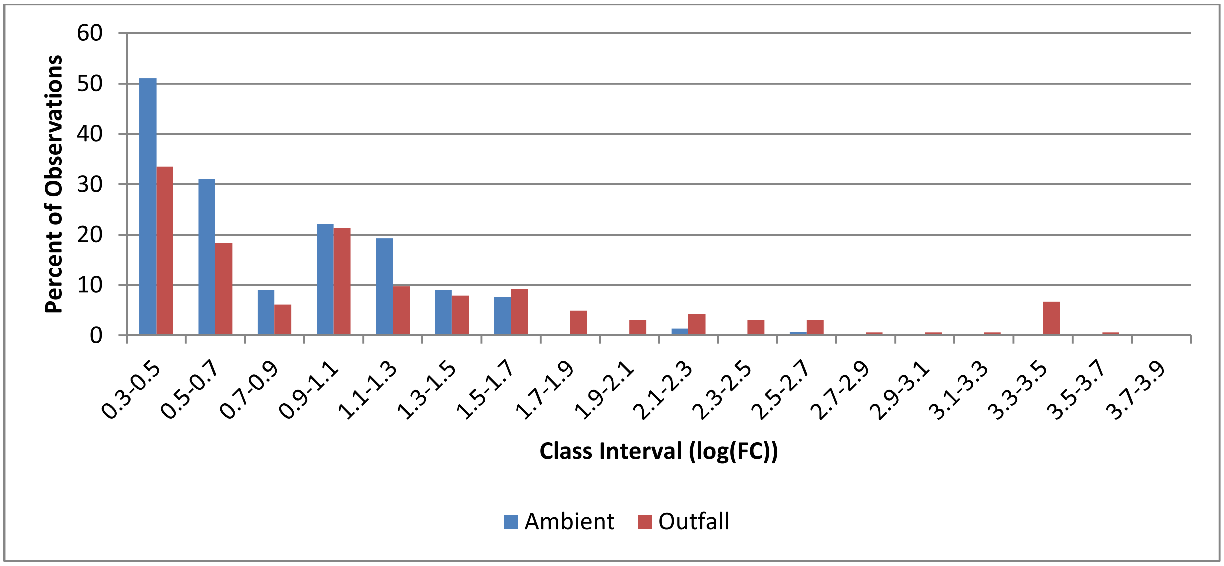


Figure 10: Frequency of FC Readings in Class Intervals

The results suggest that the records in close proximity to outfalls may tend to be higher, more often, than those somewhat removed from outfalls. Given the short duration of the sample set this is not an unequivocal result, but it is at least intuitively reasonable. It is notable that the highest values in this chart (equivalent to about 20,000 no/dL) are consistent with stormwater discharges and well below what might be expected from significant sanitary system discharges.

An interesting element of this graph is that it suggests that the reason for the difference between the two groups is mostly associated with higher values (50 no/dL, about 1.7 on the above graph). This suggestion led to a secondary analysis. The data were split into two groups, one at and below 50 no/dL, the other greater than 50 no/dL). The result is shown below. The data are not statistically distinguishable at a 5% level (P=.31).

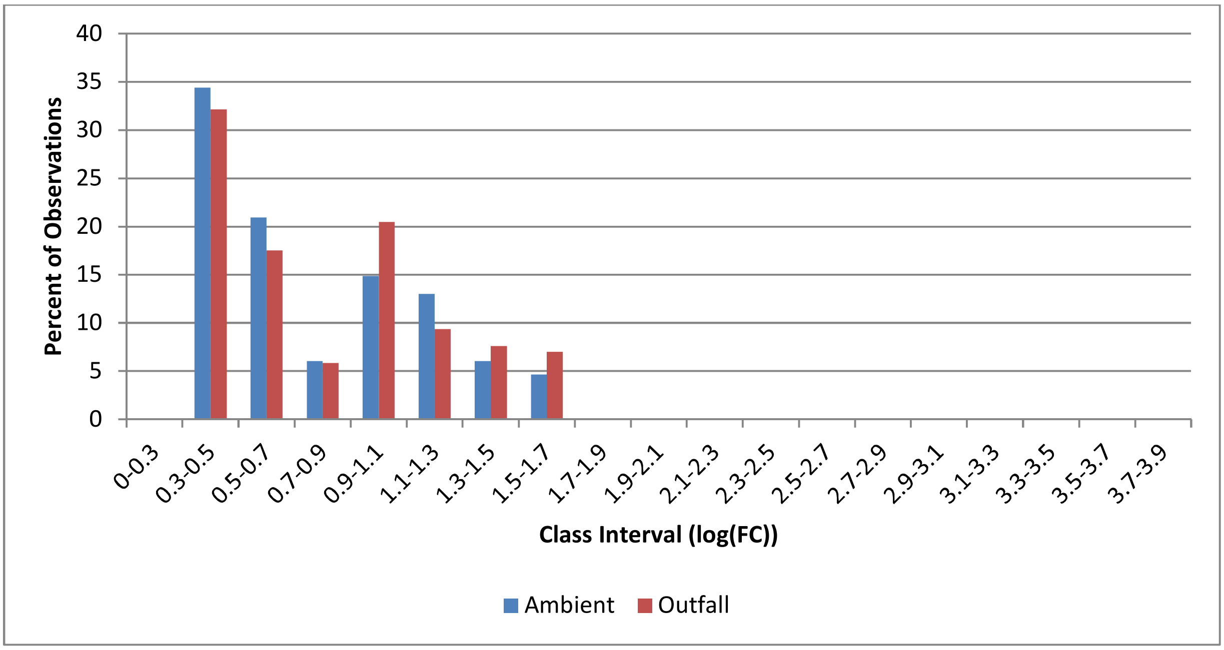


Figure 11: Frequency of FC Readings in Class Intervals,
Data Limited to instances <50 no/dL)

As shown, when the data are partitioned to reflect conditions below 50 no/dL, there is little difference between them. In three intervals, ambient is clearly higher, in three intervals outfall is clearly higher, and in one interval there is a marginal difference in favor of ambient being higher.

Enterococcus was not considered to be a preferred candidate for deeper analysis, it was considered reasonable to assess the data in a manner comparable to what was done with FC for the sake of completeness and comparison. In this case, a close examination of the underlying data showed that both the ambient and outfall stations displayed a large number of values which appeared to be compromised by lower detection limits. Consequently, the data were partitioned to eliminate these values. With that done, the results shown in Figure 12 emerged. In this case, the data nearer the outlet were found to be statistically indistinguishable from the data farther from the outlets. Figure 12 supports this interpretation, in that there appears to be an essentially random tendency for either case (ambient or outfall) to dominate any particular class interval.

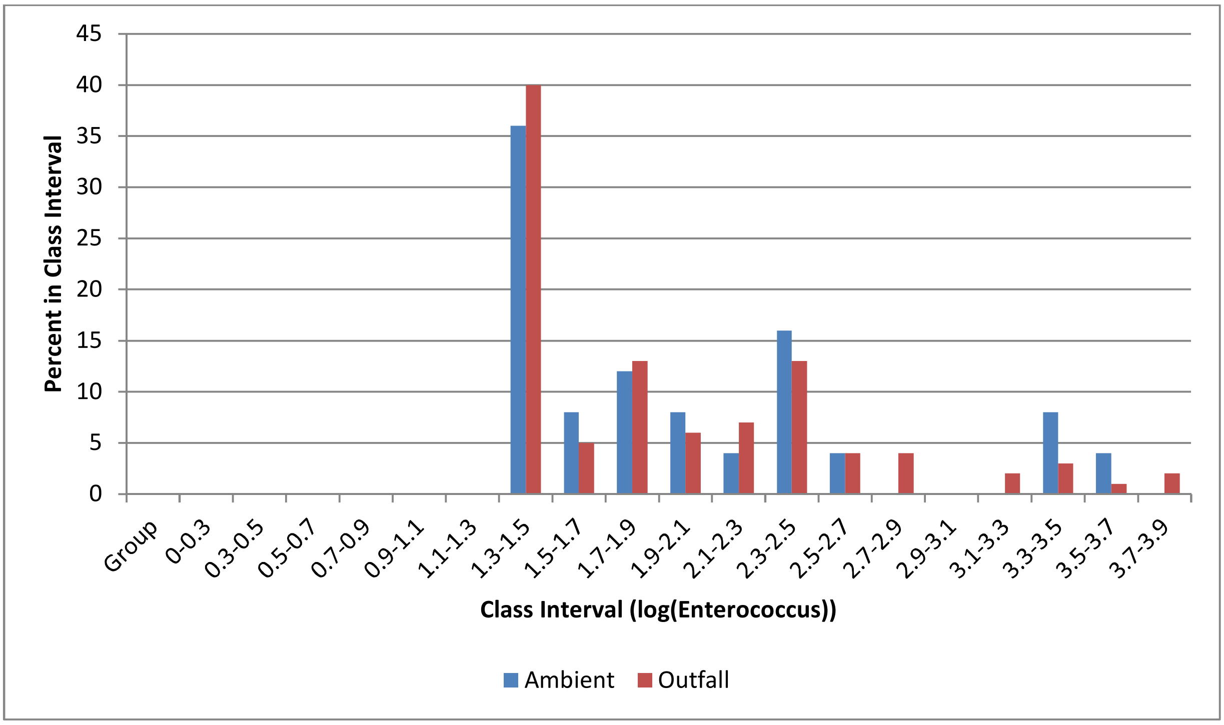


Figure 12: Frequency of Enterococcus Readings in Class Intervals

General Conclusions and Recommendations Regarding Available Data and Laboratory Results

A reasonable interpretation of these results is that the two populations (stations in close proximity to outfalls, and stations further away) behave in ways that are essentially the same, except for instances where the stations in close proximity to the outfalls may show somewhat lower excursions compared to those further away. As noted, these excursions do not tend to extend outside the bounds of what might be expected in stormwater, and tend to be well below levels indicative of substantial sanitary system contributions. Beyond that, however, the data are not adequate to support a meaningful cause/effect interpretation and are marginal in their ability to reflect system state.

Some improvements to the existing program can be considered:

- While the laboratory analyses carried out in support of the monitoring conducted in this assessment are assumed to be effective, it is suggested that there may be benefits to considering some adjustments to the program.
  - One is that there should be a discussion with the laboratory to evaluate the potential for improved results by specifying different analyses; this may resolve the apparent frequency of questionable results near the end of the analytical scales employed.
  - Another is that there is merit in considering, at least for some period of time, use of more advanced techniques to develop a refined data set better indicative of the likely sources and causes of contamination.
- It is clear that a wide range of statistics and other analytical tools could be further employed using these data. Among other things, the class intervals could be re-defined, partitioning could be re-visited, and alternative tests of significance employed. However, the limitations in data gathering noted above, and the

limitations in the ability to retain statistically significant sample sets with further partitioning of data, both indicate that the present analysis is a reasonable result for the present.

    - It is suggested that as further data accumulate, the present results can be reviewed, and further analyses attempted to add support or to refute the conclusions and interpretations herein.
    - In particular, an attempt may be made to explore excursions (high values) in association with stormwater events.
    - The ‘near miss’ nature of paired station comparisons in the south-west quadrant suggests that with more data, more convincing interpretations of similarities and differences may emerge. This could be considered in the future as well.

- It is likely that if the enhancements suggested in this assessment are implemented, particularly in terms of ways to better resolve actual outfall contributions, distinct differences in outfall discharges will emerge. These may be elusive to track. In such a situation, an enhanced testing element may prove to be useful (along with more specific laboratory analyses noted above). On a targeted basis, measurement of surface inflows to the conveyance system, together with selected measurements along the system, may make it possible to infer contaminant locations and types, and therefore zero in on specific contaminant sources. This kind of expansion should be considered if and when elevated contaminant concentrations are reliably encountered at specific discharge points.

For the present, it seems reasonable to conclude that the available data, interpreted in light of the field procedures employed, do not support the notion that there is a major difference in behavior during wet and dry periods, and do suggest that there is no support for the contention that a continuing massive discharge of sanitary flows is present in this system.

Throughout the foregoing discussion, it should be recognized that the monitoring program presently in place is a screening program, and that the use of the data for wider purposes brings with it a range of questions of intent and applicability.

Finally, it is noted that other monitoring activity undertaken by the City but not a part of the present work may lead to results that supplement or affect the conclusions and recommendations in this report. For example, it is understood that the City has elected to experiment with continuous monitoring of selected water quality parameters by means of recording probes placed at locations of interest in the waterways of interest. This kind of activity has the potential to improve the understanding of behavior governing water quality, and it is reasonable to recommend that results of this added monitoring be evaluated in concert with the other observations made by the City once it has been established that it has produced valid results.

Causes of Elevated Parameters in Stormwater Discharges

As noted throughout the foregoing text, present data do not support an analytical approach to evaluating contributing sources of contaminants. However, the problem at hand is by no means new or unique. It is clear, based on direct observations and on discussions with City staff, that a common range of potential contributors to undesirable discharges are present in this system. For indicator bacteria and many other sources these include:

- parks and greenways
- blueways (at road and bridge crossings)
- dog walkers (apparent commercial and private activity)
- residents (including homeless traffic, and potential illegal residential and/or industrial discharges)
- improper connections (cross connections)
- construction sites and/or unprotected soil surfaces
- waste pile storage and transfer points

- dog waste and trash receptacles in park areas
- formal and managed marine craft mooring areas
- ad hoc marine craft mooring zones
- beaches, dunes and associated vegetative cover areas
- other anthropogenic sources (grease traps, sanitary sewer overflows)

For other contaminants, and to some degree for nutrients and indicator bacteria, other land surfaces (roof tops, parking areas, roadways, urban surfaces etc.) all play their parts.

Some of these candidate sources raise the specter of direct human contamination, some are associated with wildlife (particularly avian, feline or canine sources), and some with other anthropogenic or other activities. The Stormwater Master Plan already in place addresses most of these, and the recent Stormwater Report Card provides a current update to practices followed by the City.

The City is clearly aware of these potential issues and working to eliminate problematic areas; this should be continued and encouraged. In addition, however, it is noted that the monitoring program has the potential to substantially improve the efficacy of measures targeting the above list. If receiving water consequences can be interpreted in terms of specific sources, it becomes reasonable to prioritize remediation efforts in favor of those sources. For this reason, the extensions and improvements in monitoring that are discussed in this report are recommended, not just as improvements in their own right, but as direct ways to more effectively eliminate problem areas within the control of the City.

Appendix A: Monitoring Data Made Available by the City of Miami Beach

MIAMIBEACH
City of Miami Beach, 1700 Convention Center Drive, Miami Beach, FL 33139, www.miamibeachfl.gov

TO: Dr. Charles Rowney

FROM: Elizabeth Wheaton, Environment and Sustainability Director

DATE: December 14, 2018

SUBJECT: **Water Quality Data Sampling Parameters and Scatter Graphs**

In late 2016, the city launched a voluntary water quality sampling program to build upon Miami-Dade County's existing ambient water quality sampling network. We modeled the design of our sampling program on the County's program design, including using the County's contract with PACE Analytical, to keep the program consistent with existing practices and allow the city's data to become a part of the regional monitoring network. This decision provides for a deeper understanding of conditions throughout the bay and allows an apples-to-apples comparison between sampling stations within the network.

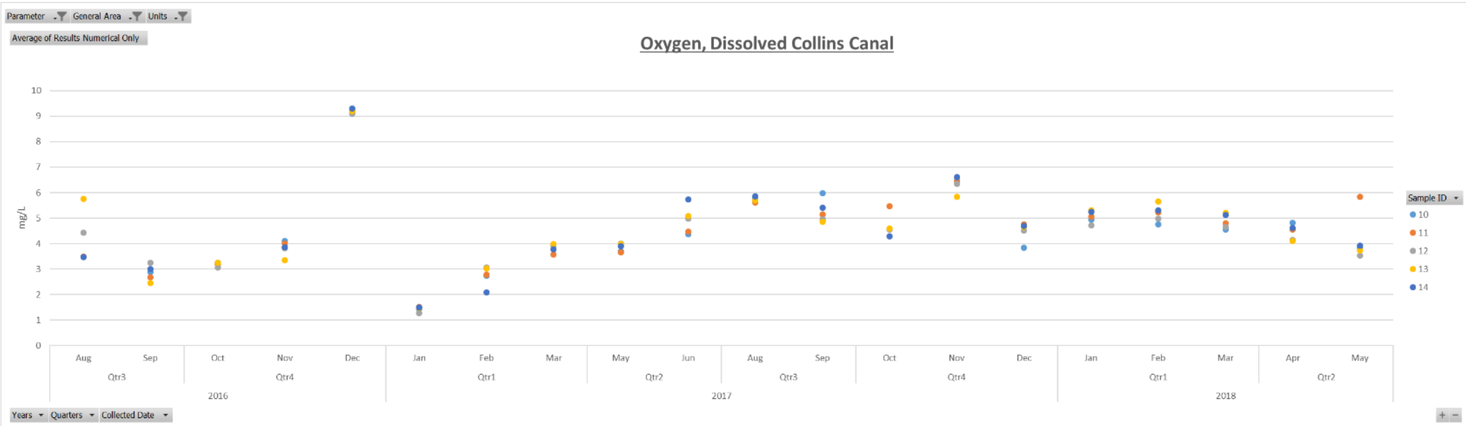
With these goals in mind, we established more than 60 water quality stations throughout the city's waterways, distributed along stormwater discharge points connected to different neighborhood types (commercial, single-family residential, multi-family residential), upstream land uses, and stormwater structure types in an effort to discern what differences, if any, exist among these. We tasked PACE Analytical with sampling monthly for the twelve parameters listed below. These parameters consist of biological, physical and chemical indicators of waterway health, are the most commonly sampled parameters by the industry, and mirror those sampled by the County.

Table 1 – List of Parameters Sampled in Miami Beach Water Quality Program	
Ammonia, Nitrogen	Total Kjeldahl Nitrogen
Nitrite and Nitrate	Total Phosphorus
Salinity	Specific Conductance
Ph	Dissolved Oxygen
Turbidity	Temperature
Enterococci	Fecal Coliforms

Attached to this memo are scatter graphs of the parameters for each sampling station to provide the public with a general understanding of the range in the sampling results. In the development of the graphs, the sampling stations were grouped into general areas, such as South Beach, Collins Canal, Venetian Islands, Indian Creek, Middle Beach and North Beach, that represent relatively similar upstream and in-water conditions in an attempt to provide a deeper understanding of the parameter ranges within each area and highlight the potential for variability between samples.

We opted for a visualization of the data using a scatter graph instead of a line graph due to the limited amount of data available after only one year of sampling and the variability between points for certain parameters. This approach provides a more scientifically-sound and accurate picture of how data at such a small sample size can be processed. Multiple years of data need to be collected to ensure that outliers do not skew the data set. These outliers can be influenced by variables such as field conditions and sampling methodologies. For example, Miami-Dade County reviews seven years-worth of data to produce their annual water quality sampling report. A logarithmic scale is provided on some of the parameters for a better visualization of the data by reducing the effect of outliers.

The city will continue to collect water quality samples on a monthly basis, using a refined methodology that takes into account the recommendations provided in your report and those received during the technical roundtable held on September 26, 2018. We are also leading discussions with other local municipalities and working with Miami-Dade County to expand upon and refine existing water quality monitoring efforts throughout the region. The data collected by these programs is critical in helping us making scientifically-based management decisions, focusing our stormwater management efforts where they are most needed, and in crafting a regional management framework to protect Biscayne Bay.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Average of Results Numerical Only
Oxygen, Dissolved Collins Canal
mg/L
Sample ID
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11
12
13
14
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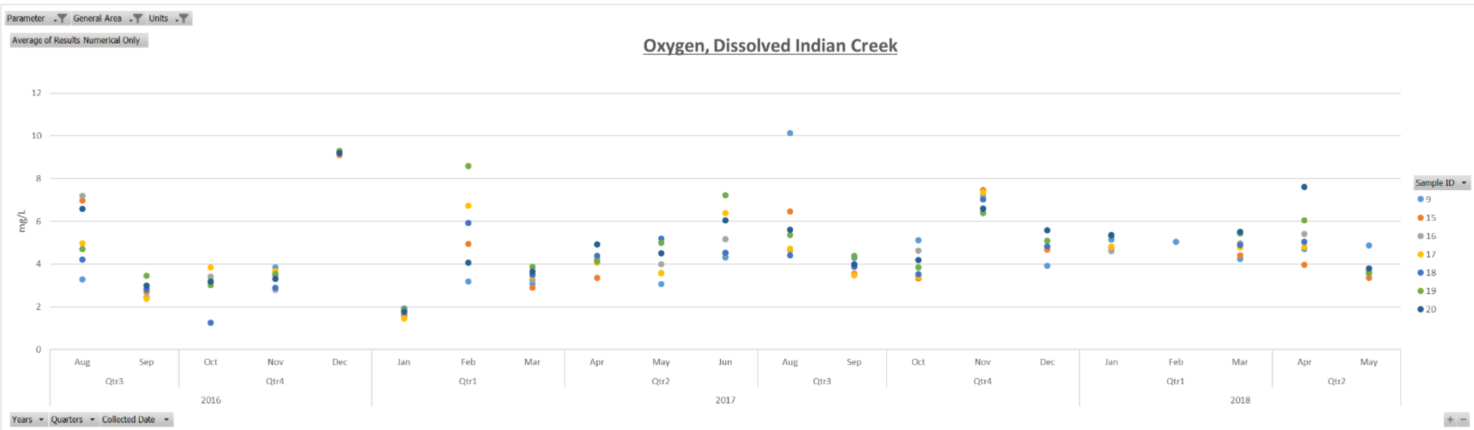
2016 2017 2018
Years Quarters Collected Date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Units
Average of Results Numerical Only
Oxygen, Dissolved Indian Creek
mg/L
Sample ID
9
15
16
17
18
19
20
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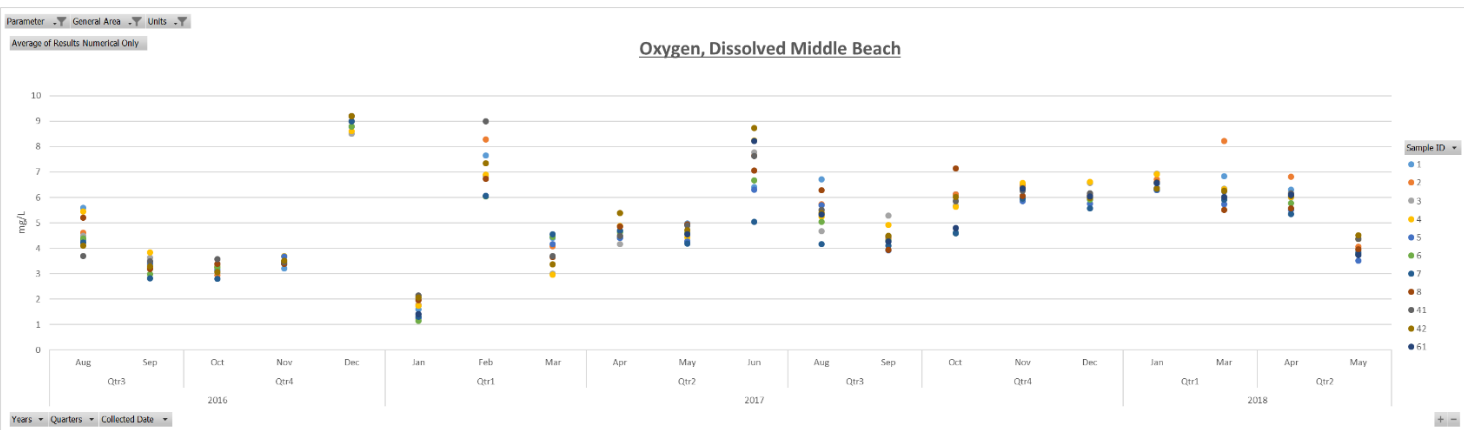
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years Quarters Collected Date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Units
Average of Results Numerical Only
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mg/L
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2
3
4
5
6
7
8
41
42
61
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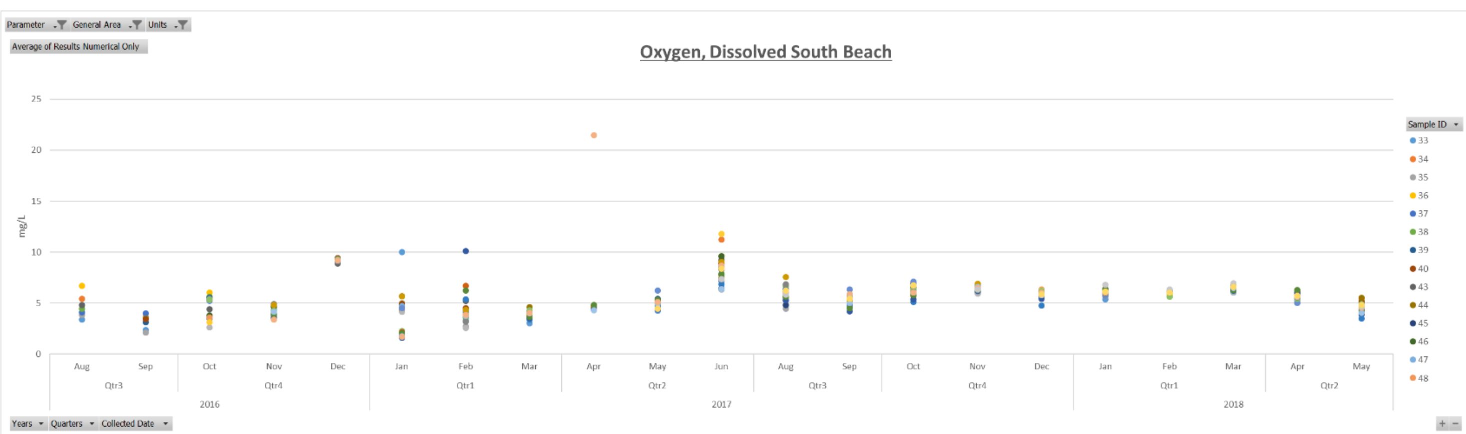
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46
47
48
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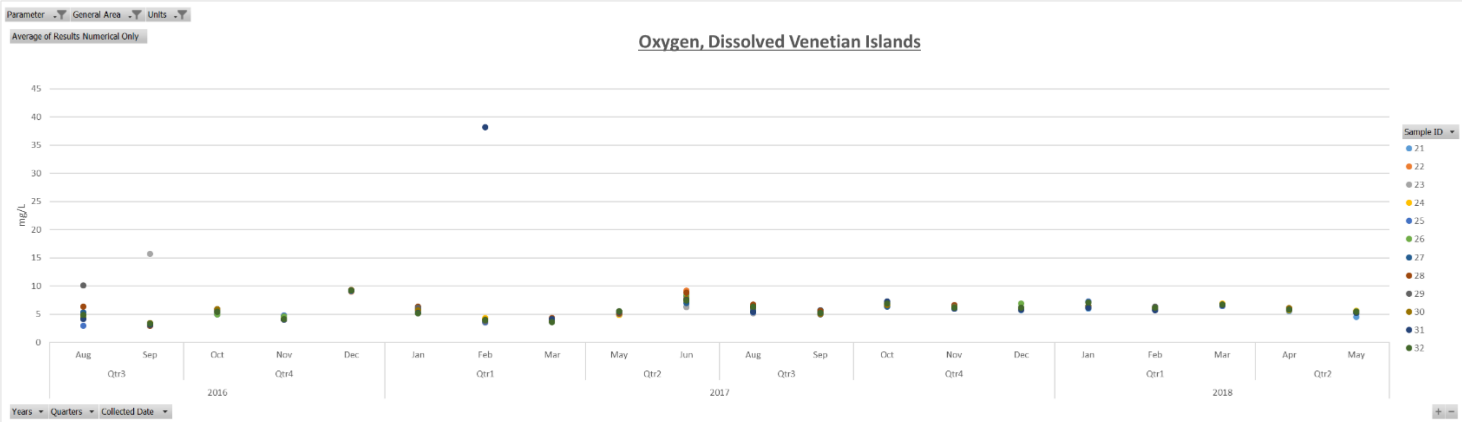
Years Quarters Collected Date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mg/L
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Mar
May
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Qtr4
Qtr1
Qtr2
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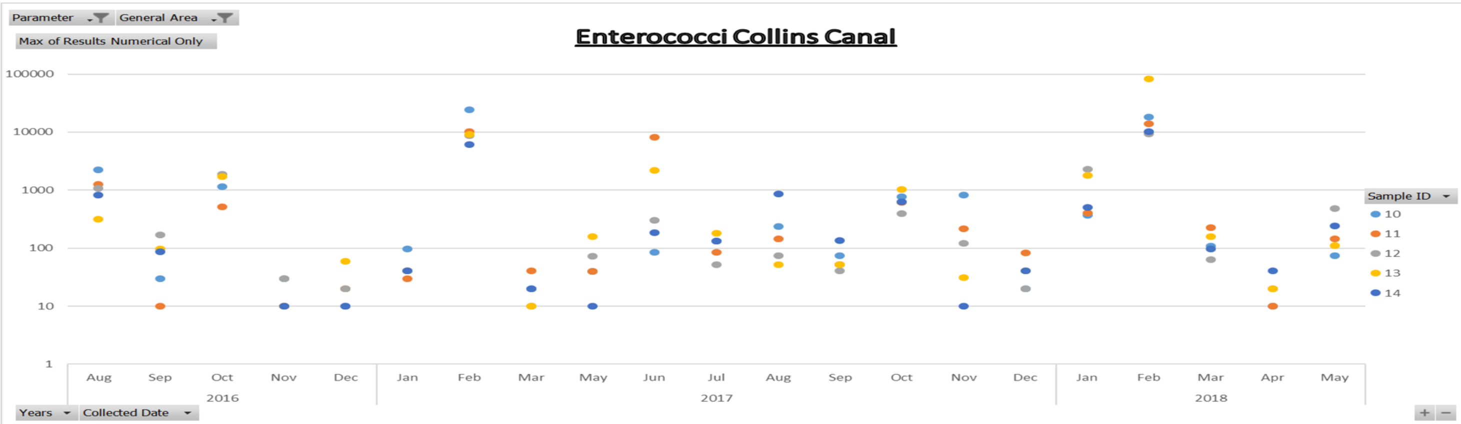
Quarters
Collected Date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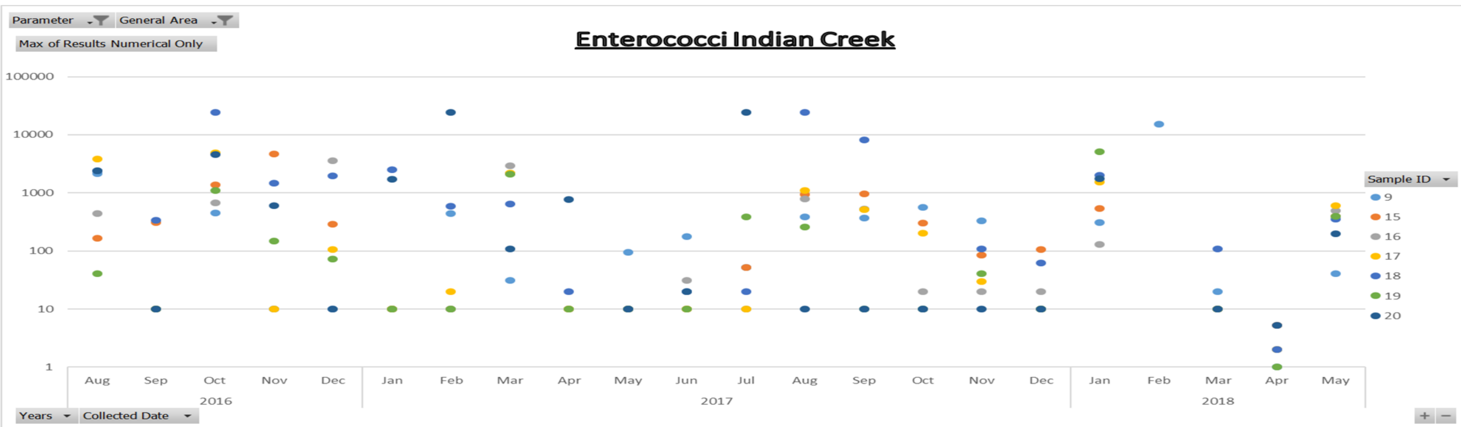
Years
Collected Date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Jan Feb Mar Apr May
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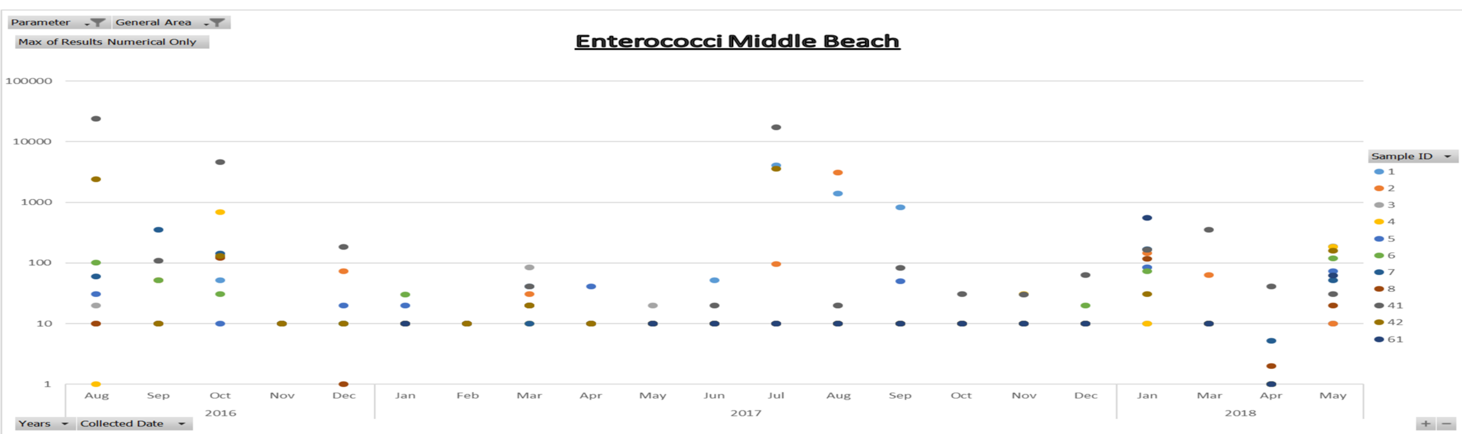
Collected Date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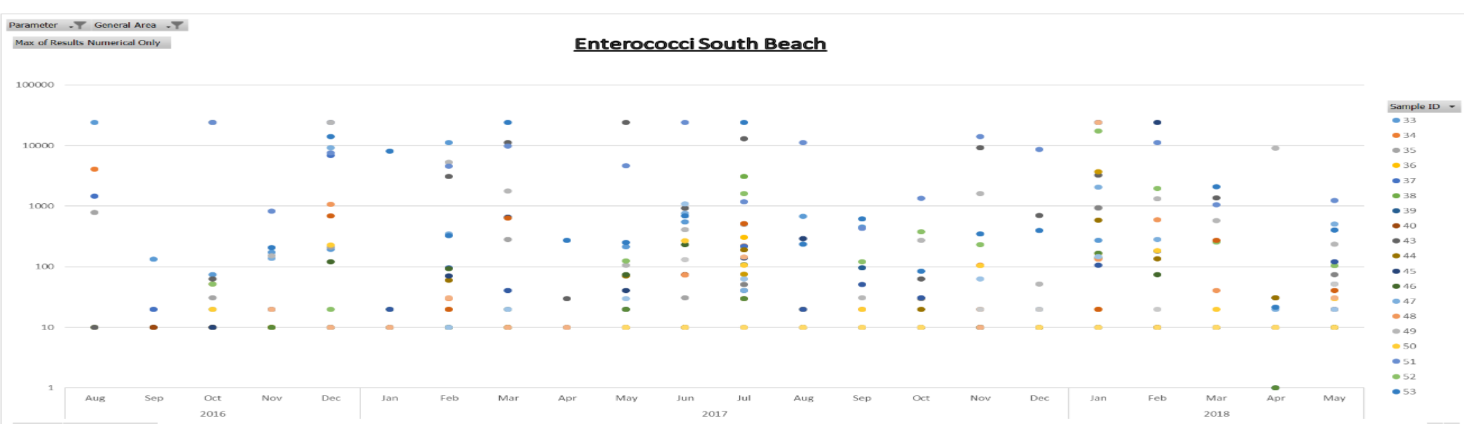
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2018
Sample ID
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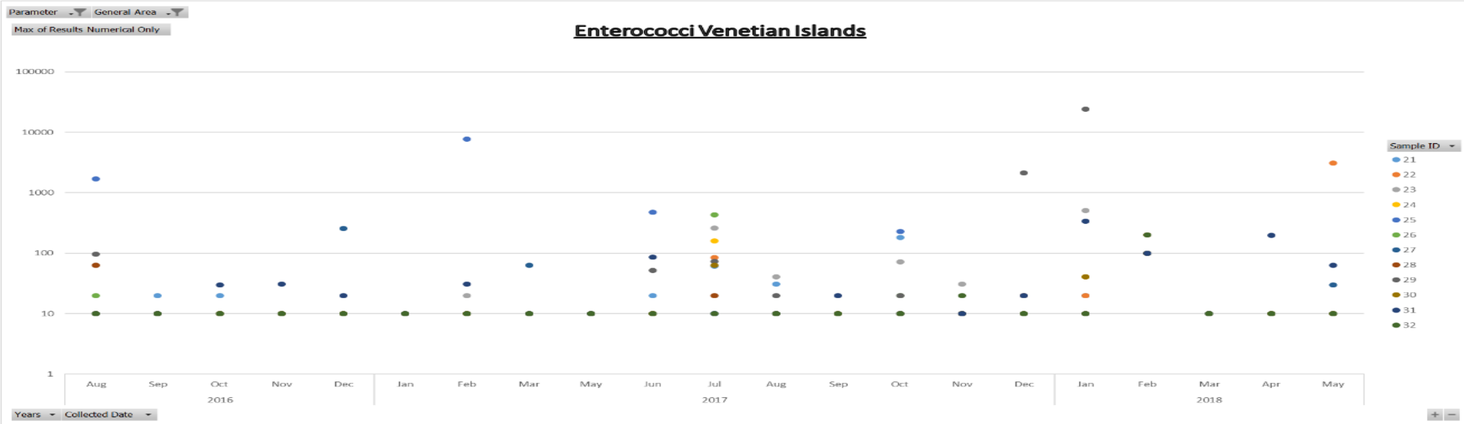
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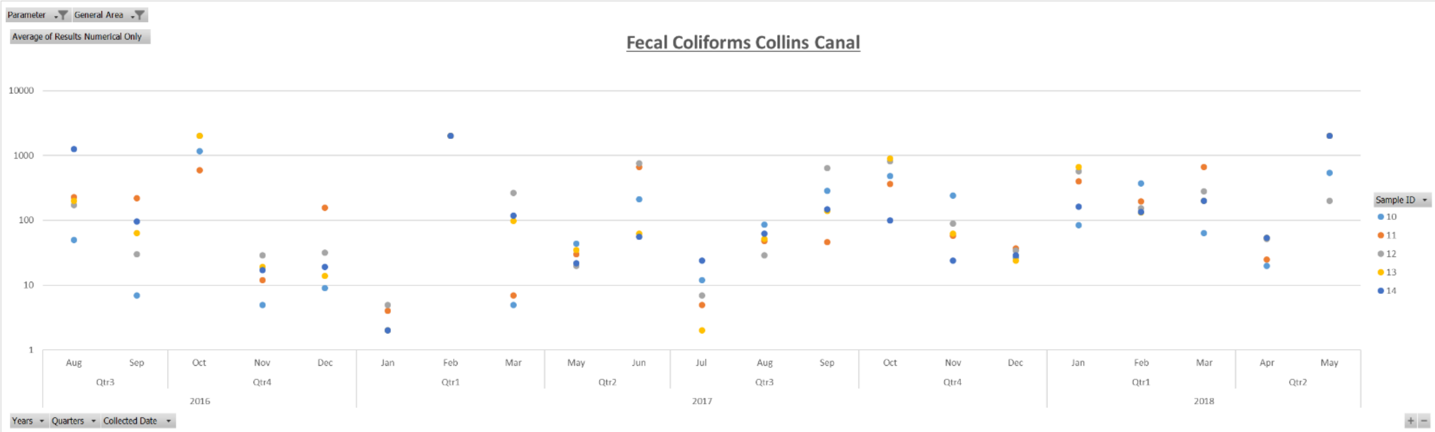
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Fecal Coliforms Collins Canal
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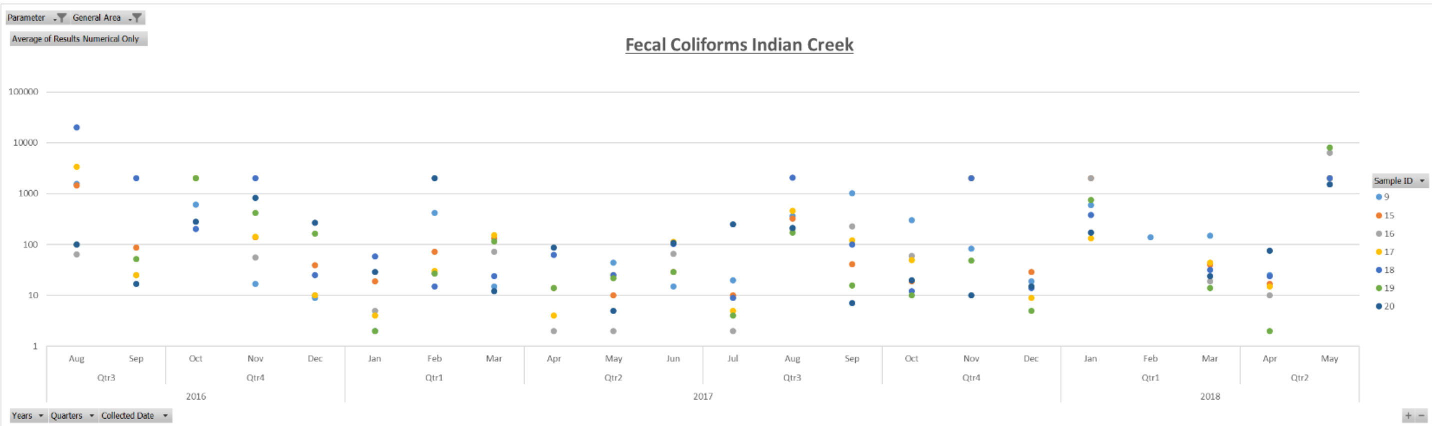
Years Quarters Collected Date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Average of Results Numerical Only
Fecal Coliforms Indian Creek
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Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
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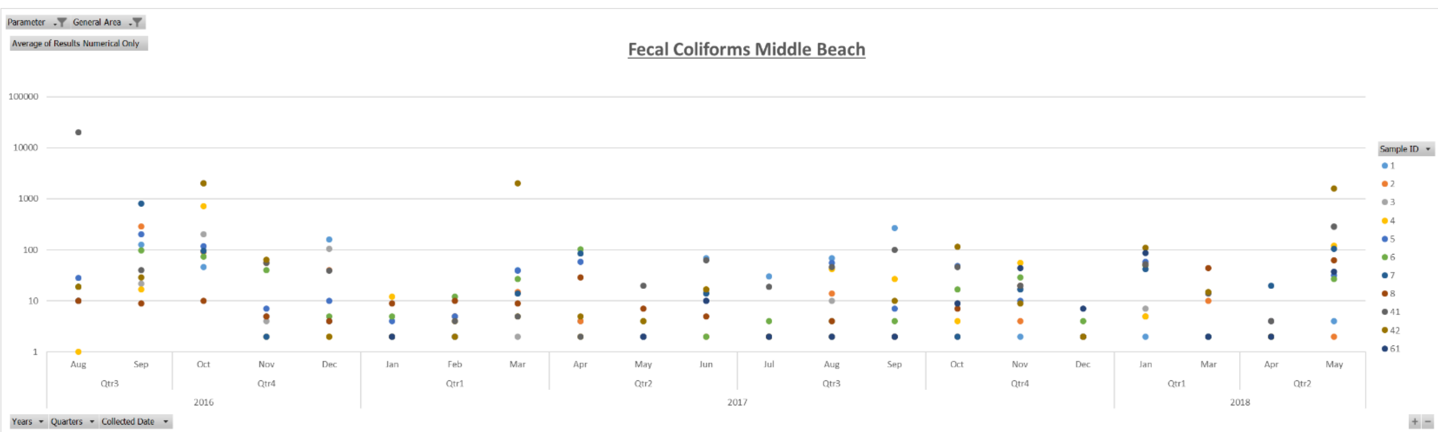
Years Quarters Collected Date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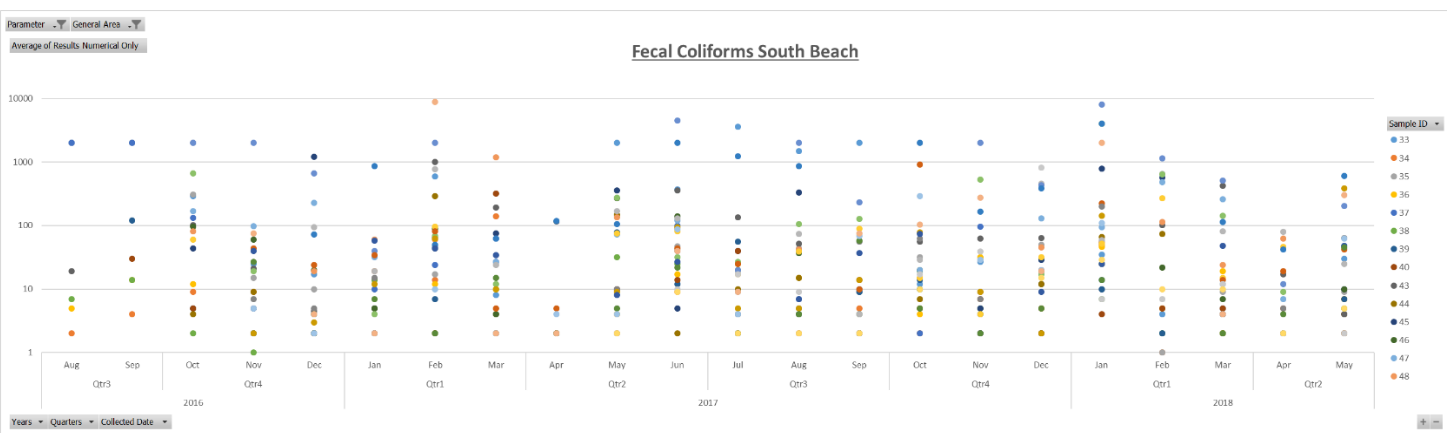
Years Quarters Collected Date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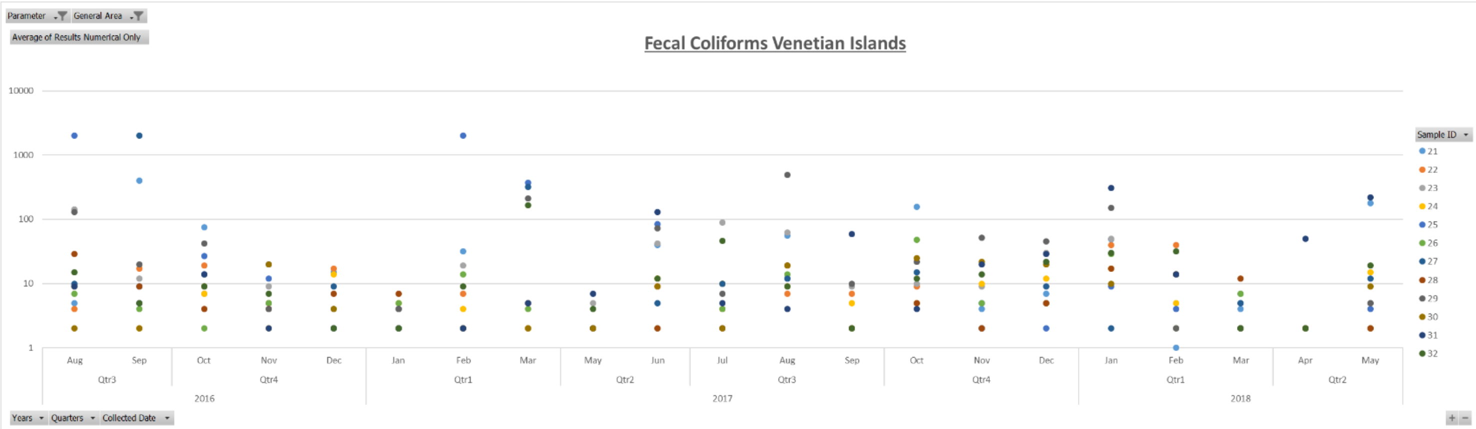
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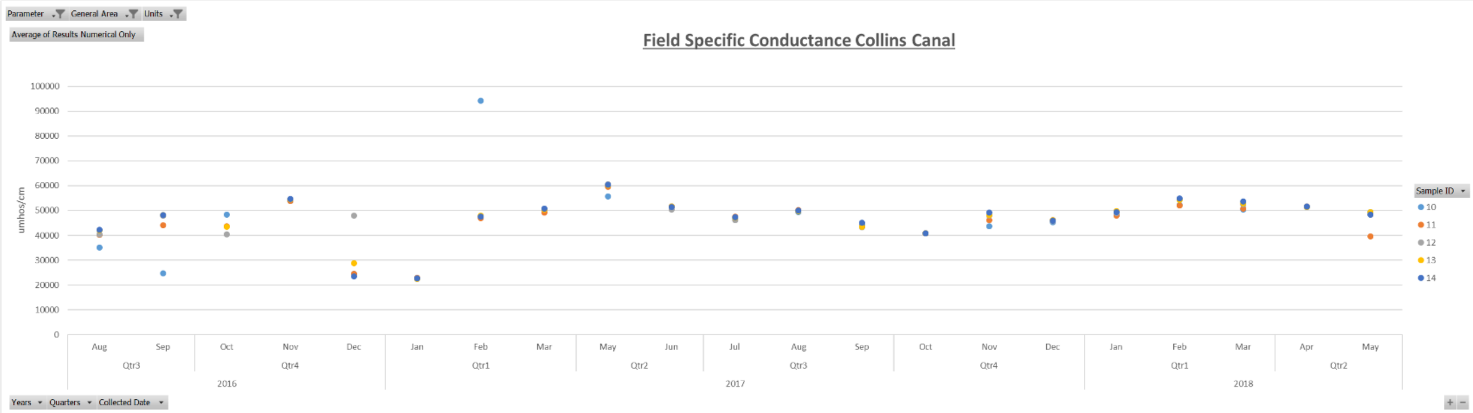
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Sample ID
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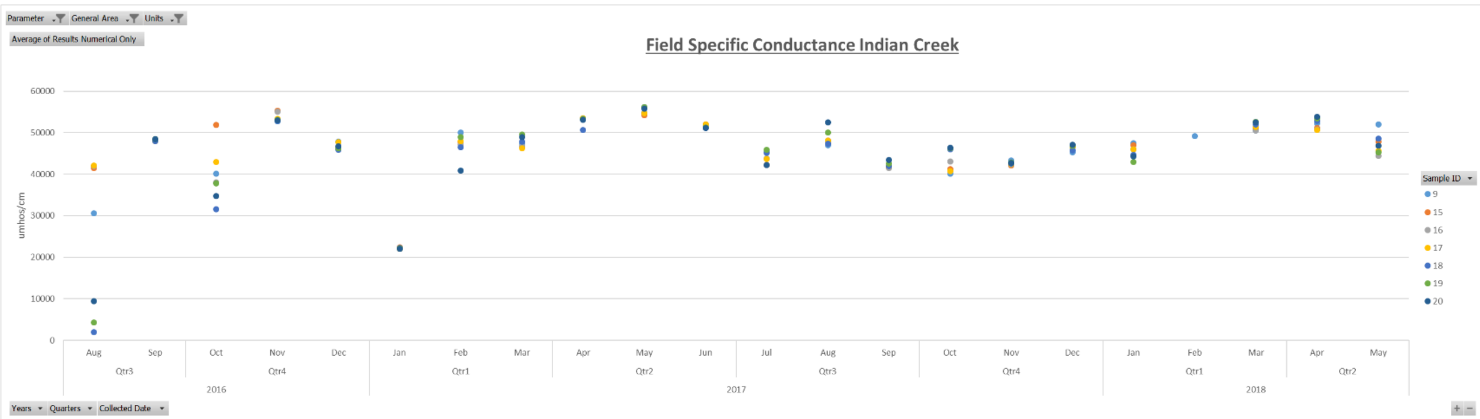
Years
Quarters
Collected Date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umhos/cm
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Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
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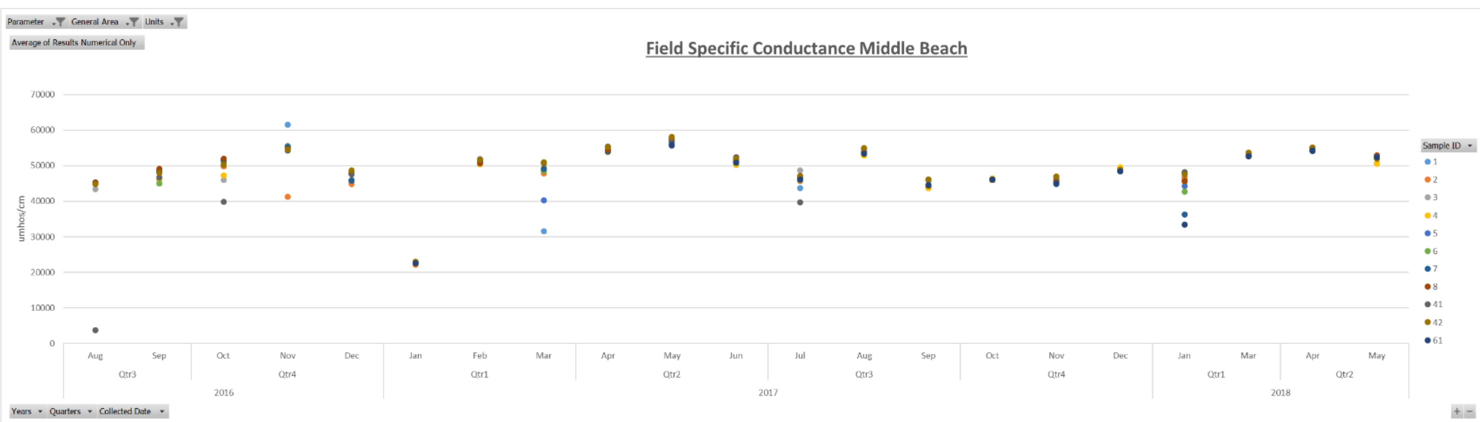
Years
Quarters
Collected Date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umhos/cm
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60000
50000
40000
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20000
10000
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Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
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41
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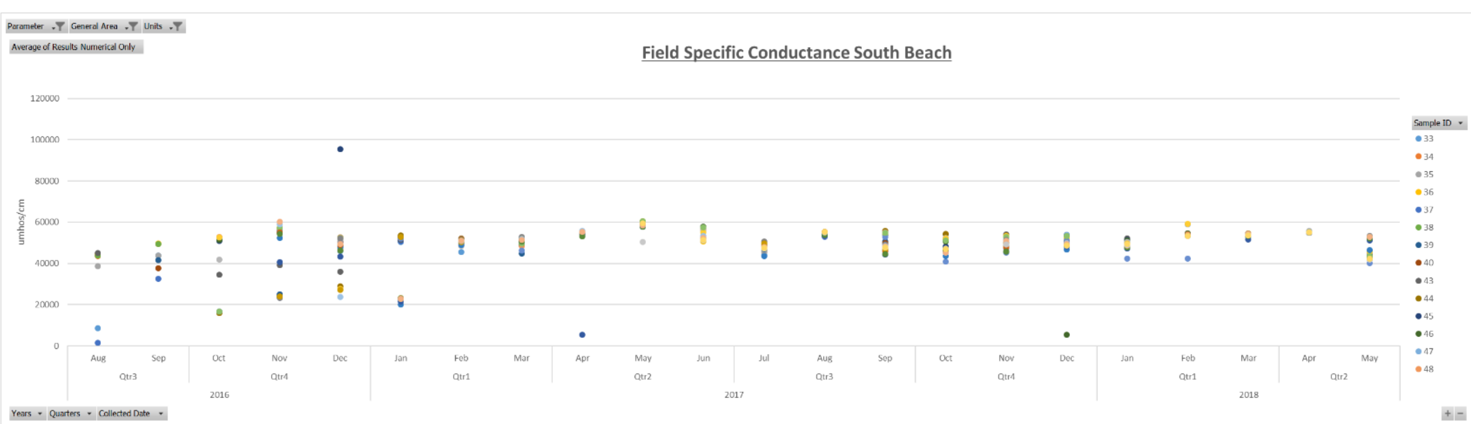
Years
Quarters
Collected Date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Average of Results Numerical Only
Field Specific Conductance South Beach
umhos/cm
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40000
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0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
33
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39
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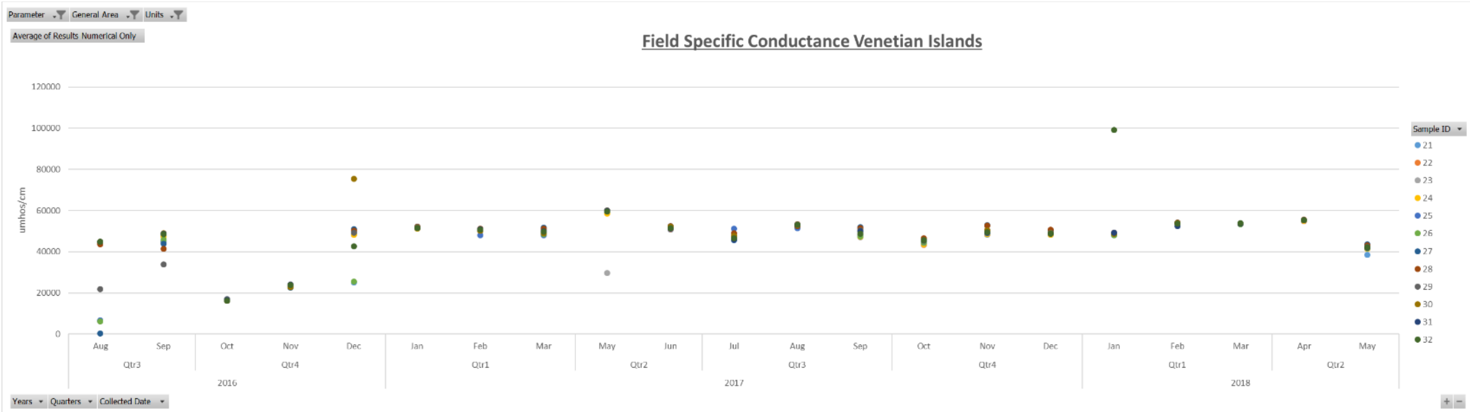
45
46
47
48
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field Specific Conductance Venetian Islands
umhos/cm
120000
100000
80000
60000
40000
20000
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2016
2017
2018
Sample ID
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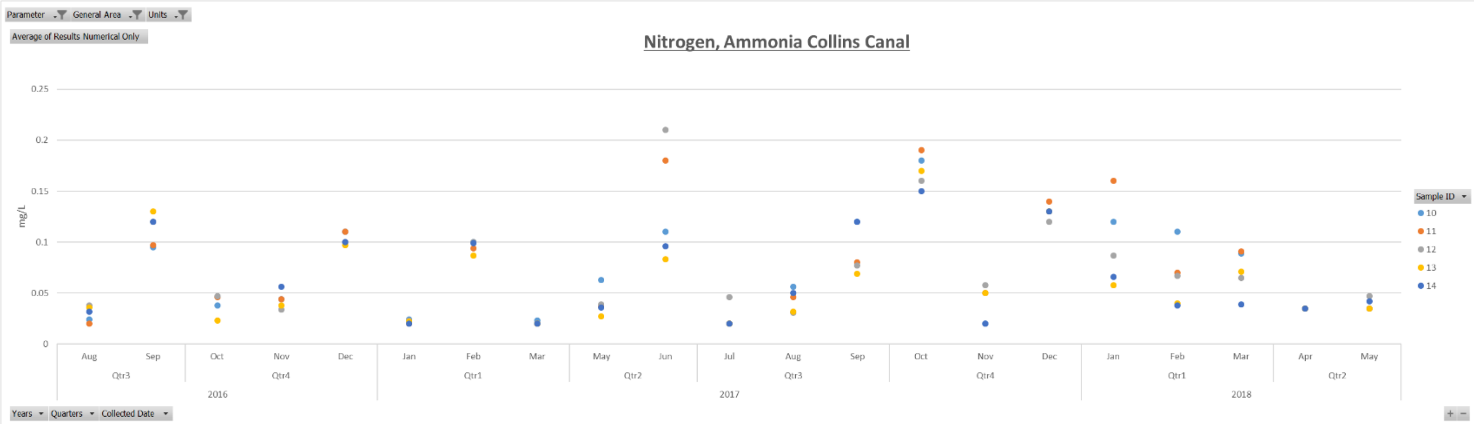
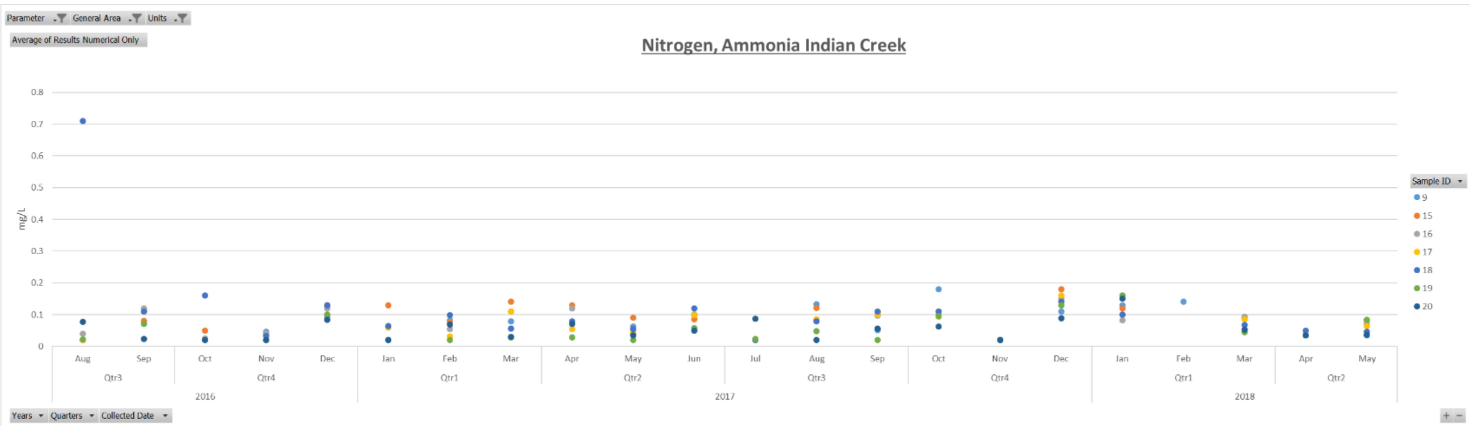
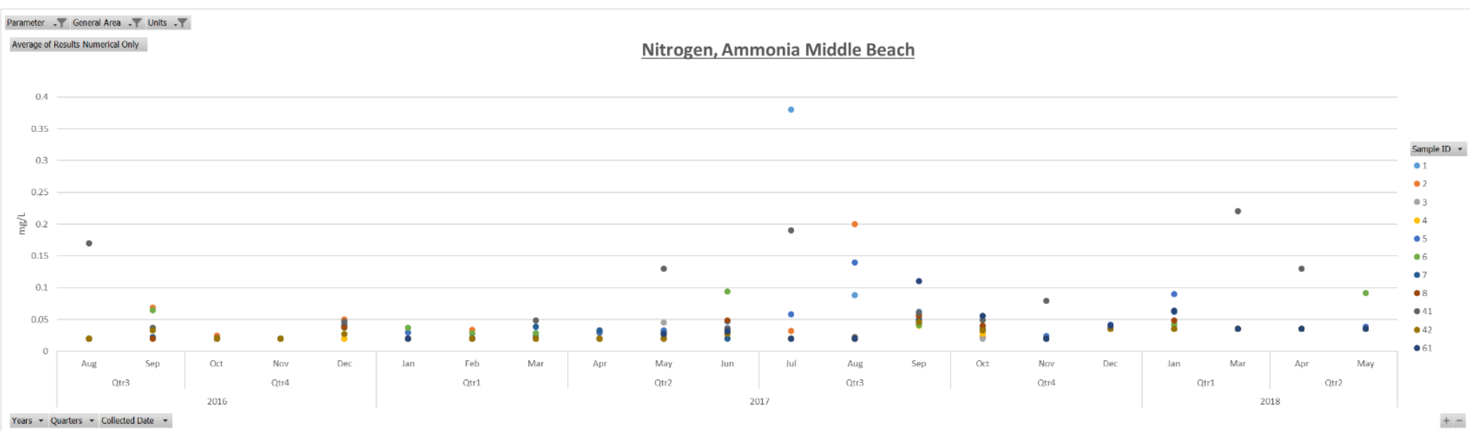
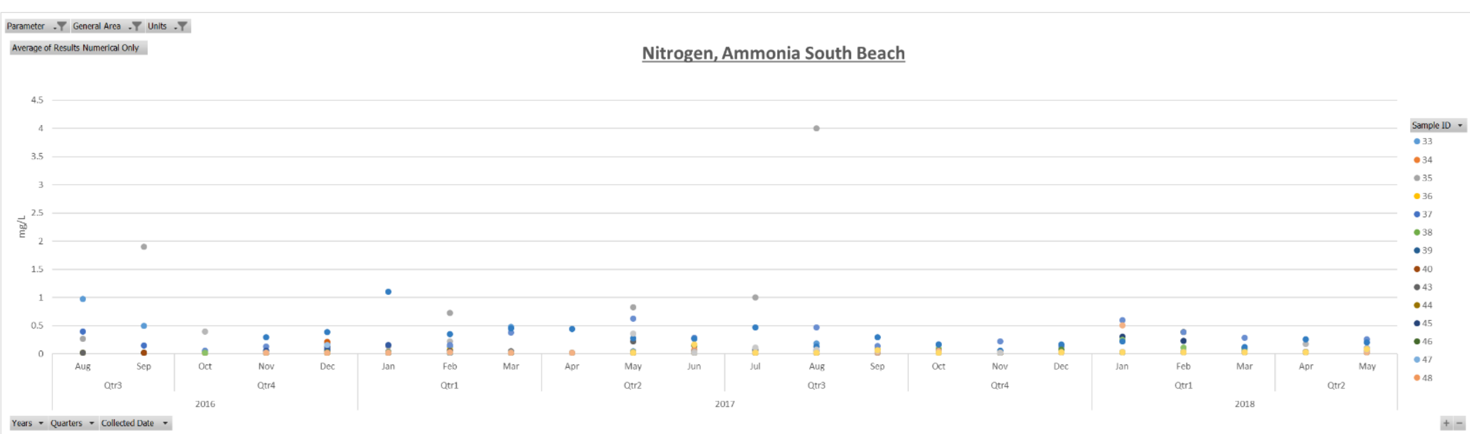
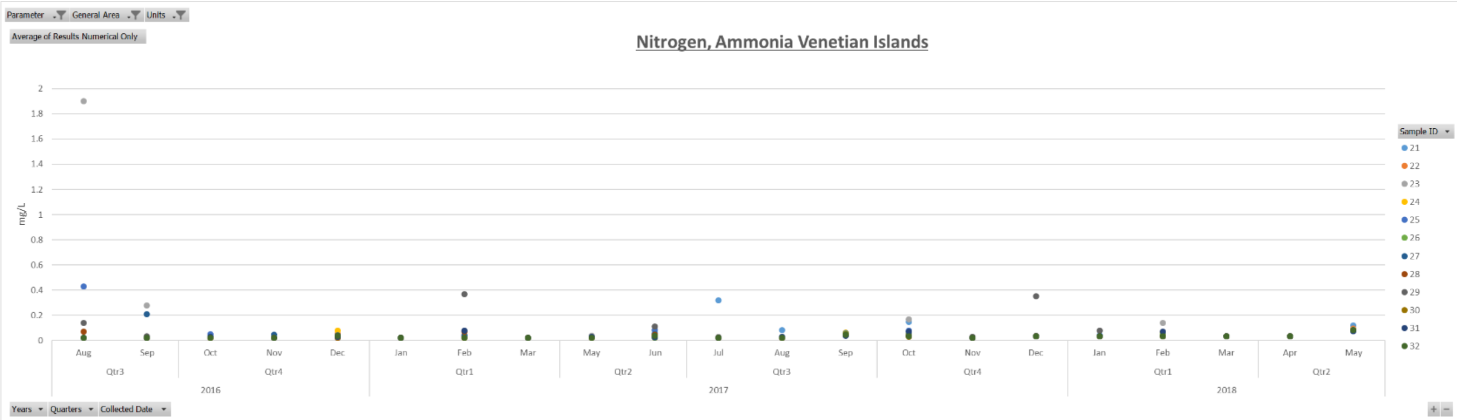
30
31
32
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Ammonia Collins Canal
mg/L
Sample ID
10
11
12
13
14
2016
2017
2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Ammonia Indian Creek
mg/L
Sample ID
9
15
16
17
18
19
20
2016
2017
2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Ammonia Middle Beach
mg/L
Sample ID
1
2
3
4
5
6
7
8
41
42
61
2016
2017
2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Ammonia South Beach
mg/L
Sample ID
33
34
35
36
37
38
39
40
43
44
45
46
47
48
2016
2017
2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Ammonia Venetian Islands
mg/L
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
21
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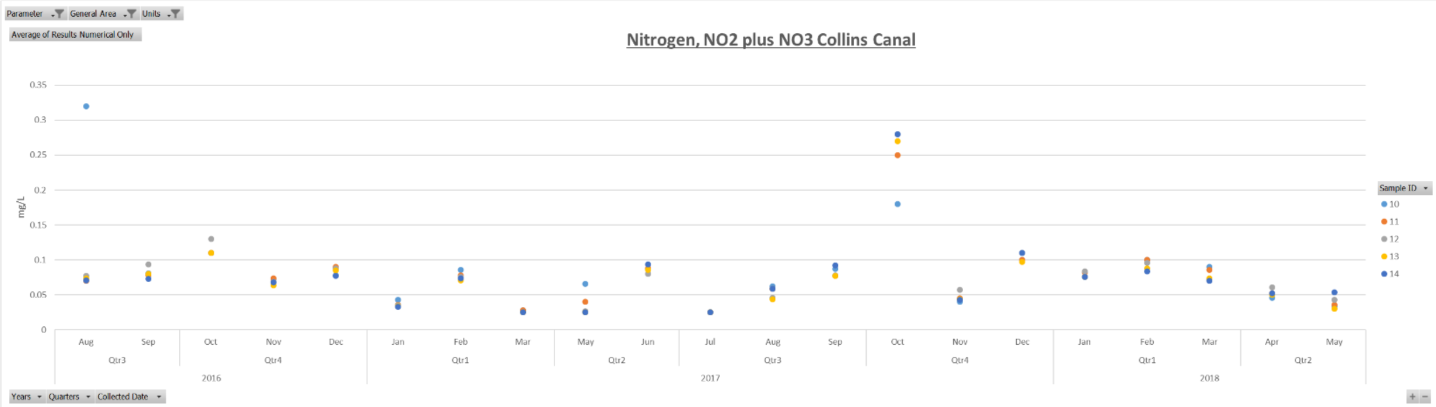
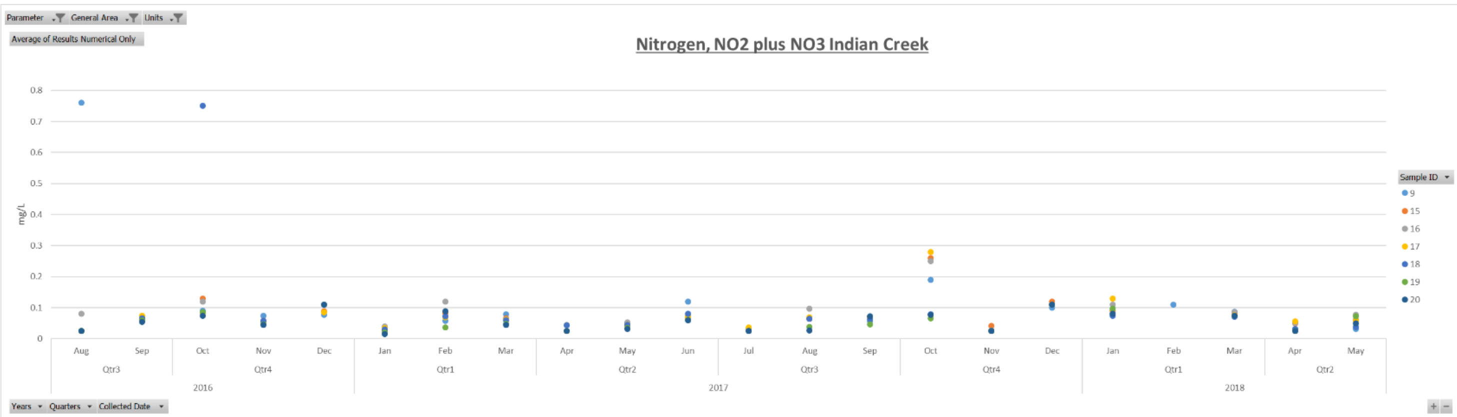
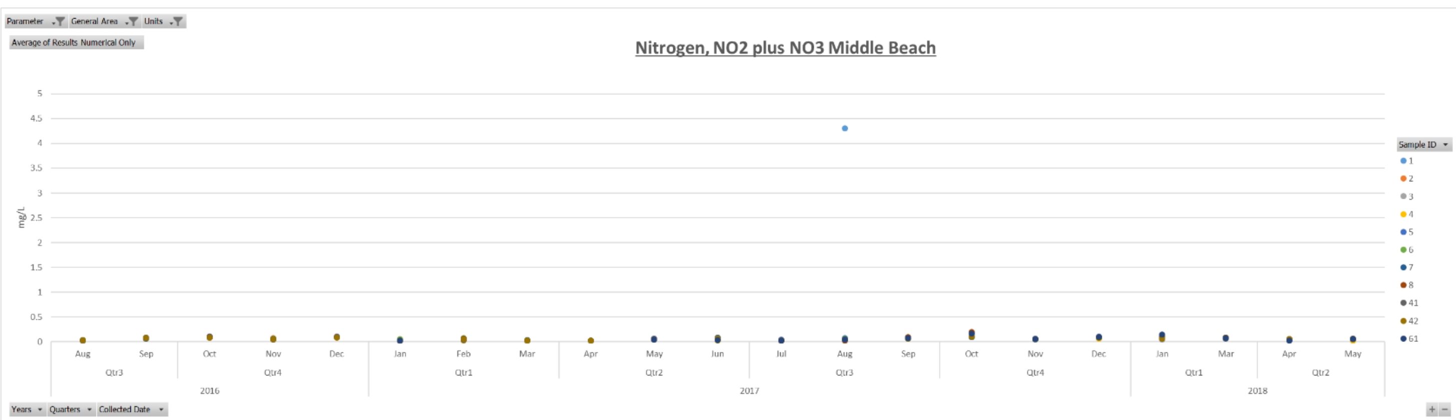
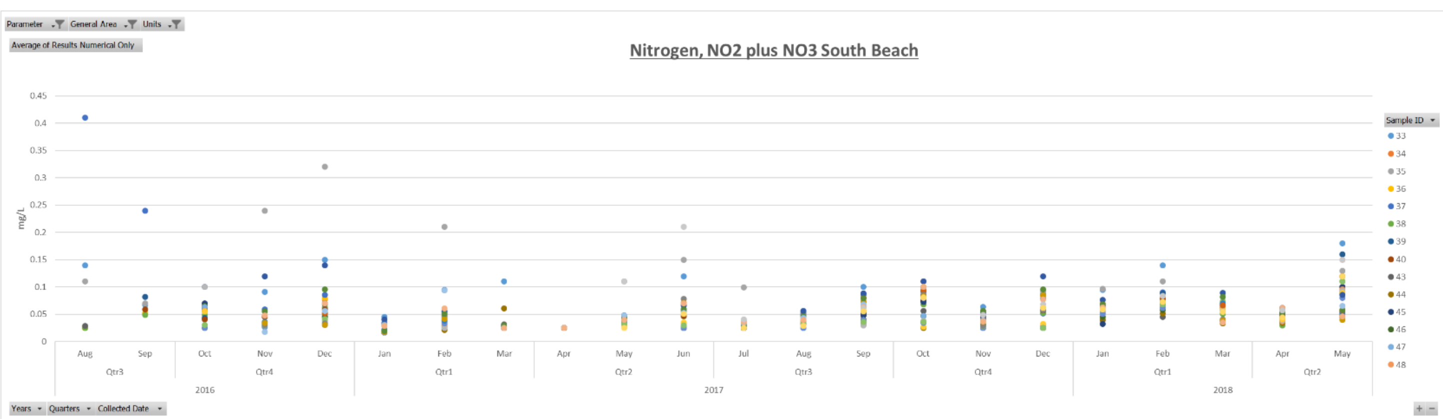
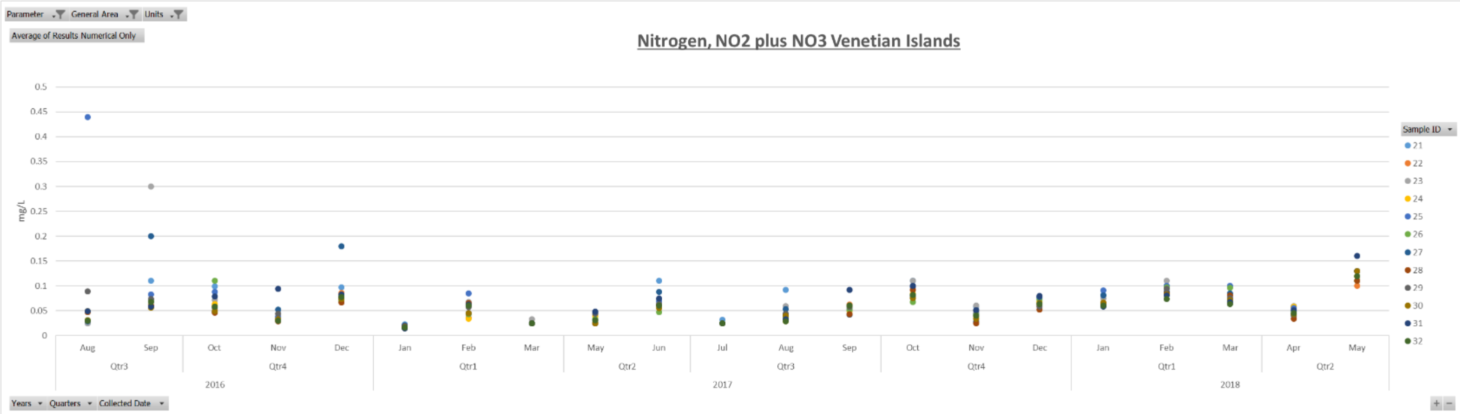
31
32
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, NO2 plus NO3 Collins Canal
mg/L
Sample ID
10
11
12
13
14
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, NO2 plus NO3 Indian Creek
mg/L
Sample ID
9
15
16
17
18
19
20
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, NO2 plus NO3 Middle Beach
mg/L
Sample ID
1
2
3
4
5
6
7
8
41
42
61
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, NO2 plus NO3 South Beach
mg/L
Sample ID
33
34
35
36
37
38
39
40
43
44
45
46
47
48
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years
Quarters
Collected Date



Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, NO2 plus NO3 Venetian Islands
mg/L
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Aug
Sep
Oct
Nov
Dec
Jan
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May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2016
2017
2018
Sample ID
21
22
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24
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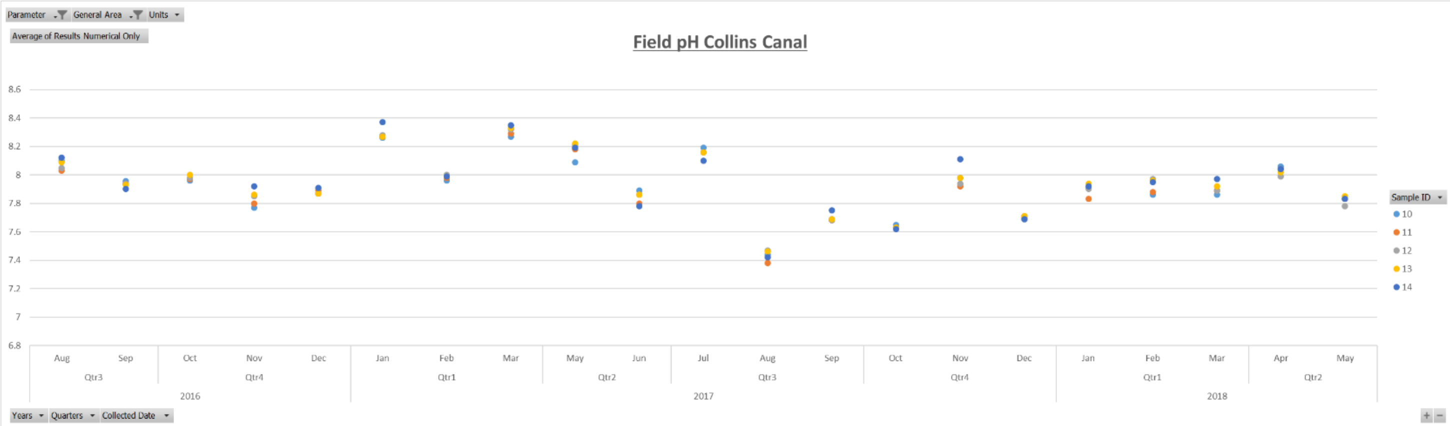
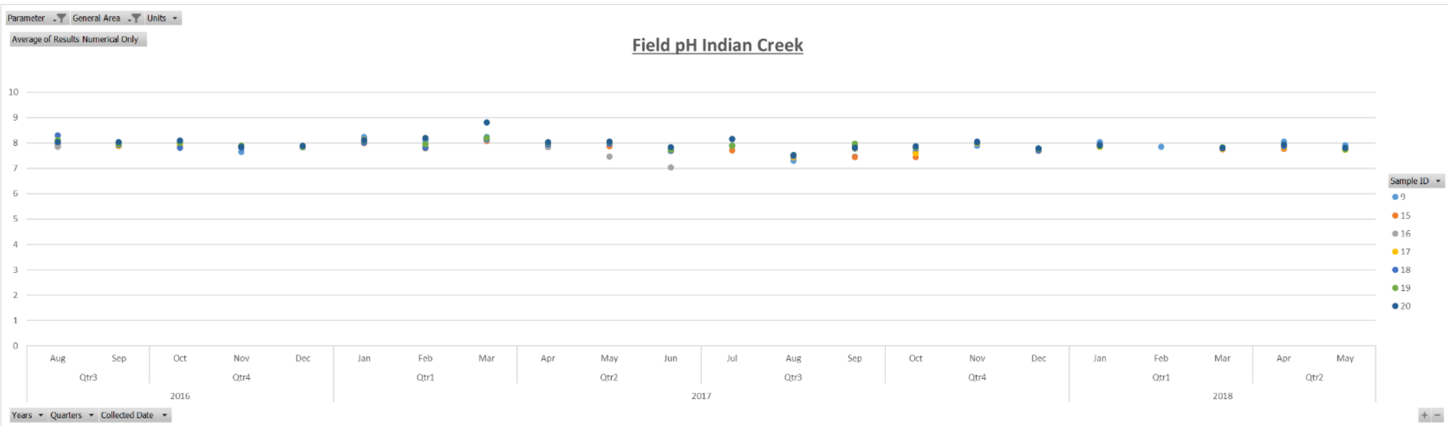
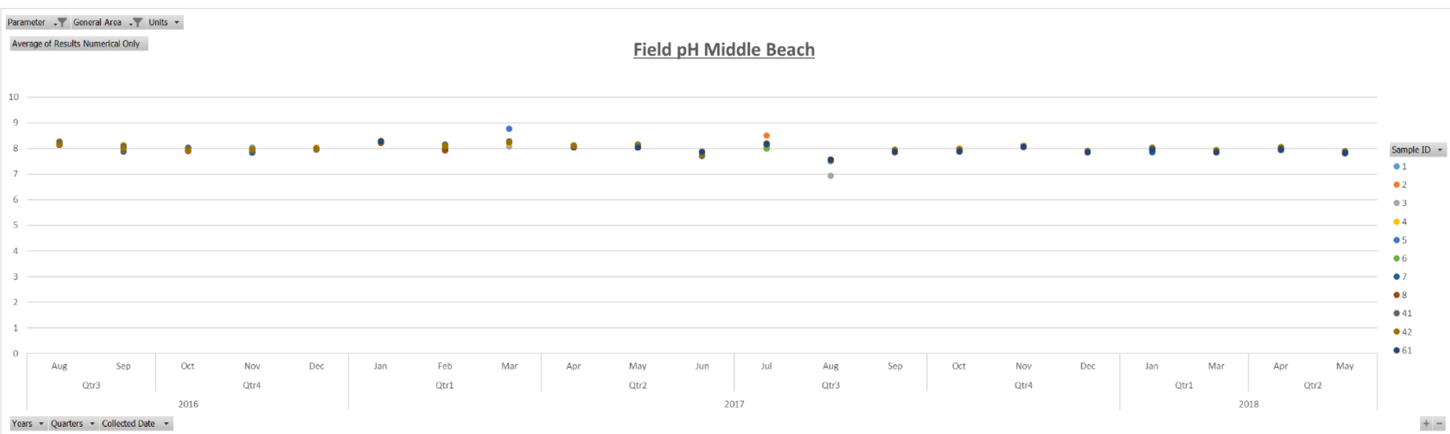
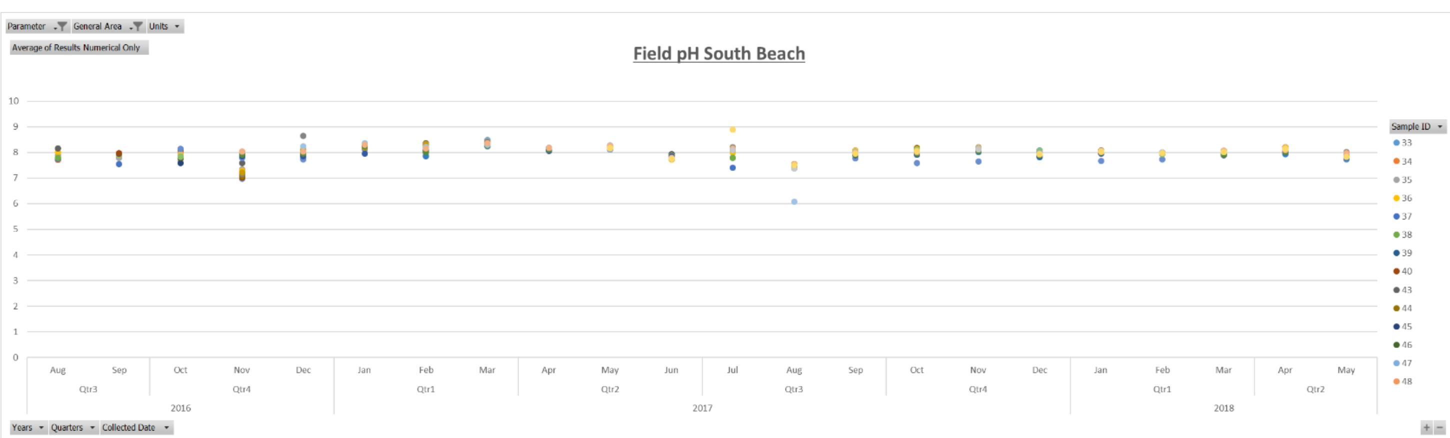
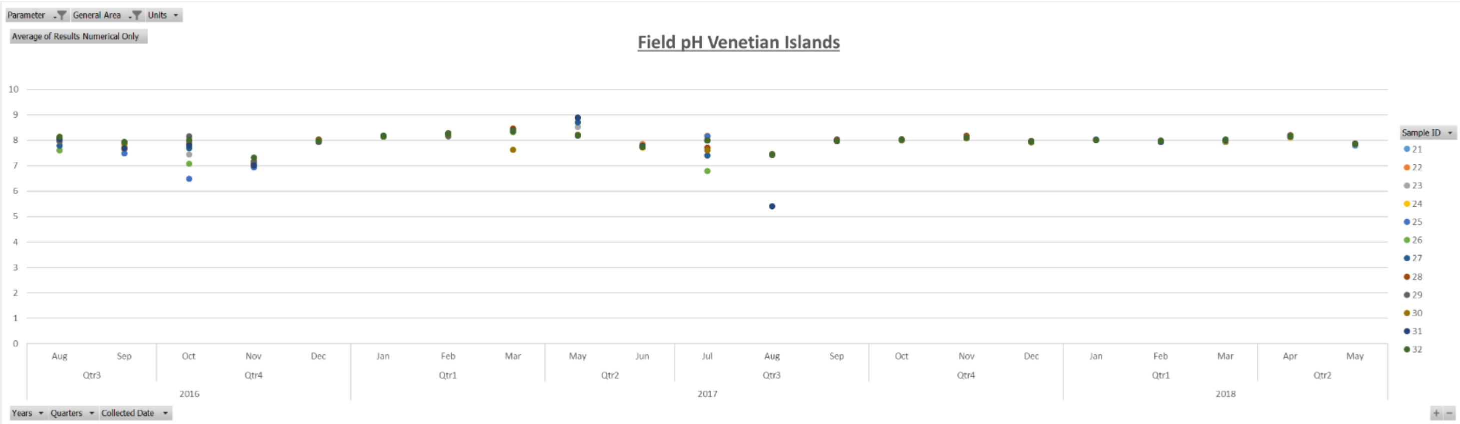
31
32
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field pH Collins Canal
Sample ID
10
11
12
13
14
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field pH Indian Creek
Sample ID
9
15
16
17
18
19
20
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field pH Middle Beach
Sample ID
1
2
3
4
5
6
7
8
41
42
61
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field pH South Beach
Sample ID
33
34
35
36
37
38
39
40
43
44
45
46
47
48
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field pH Venetian Islands
Sample ID
21
22
23
24
25
26
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28
29
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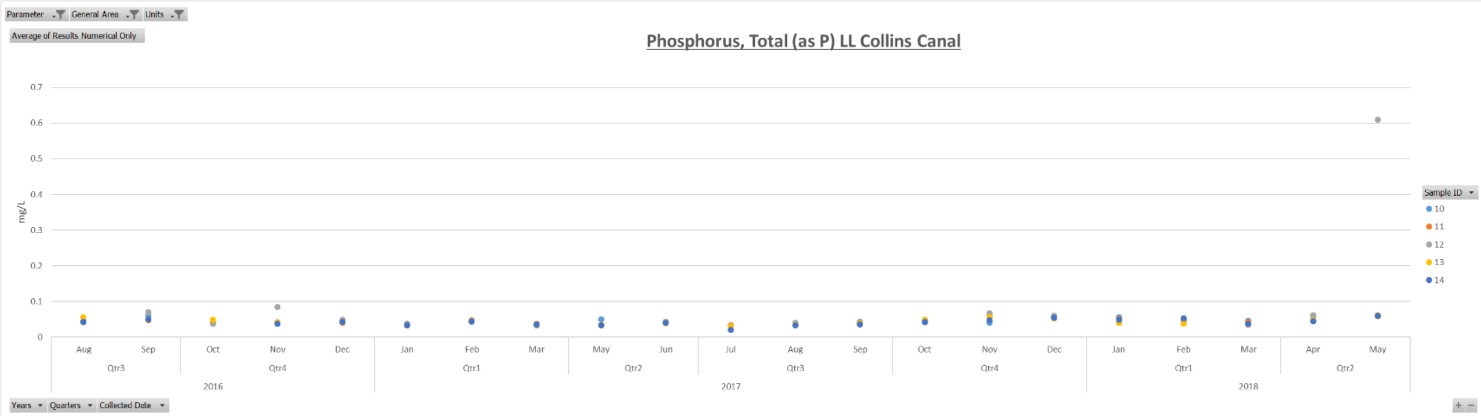
31
32
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
May
Jun
Jul
Apr
Qtr1
Qtr2
Qtr3
Qtr4
2016
2017
2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Phosphorus, Total (as P) LL Collins Canal
mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
10
11
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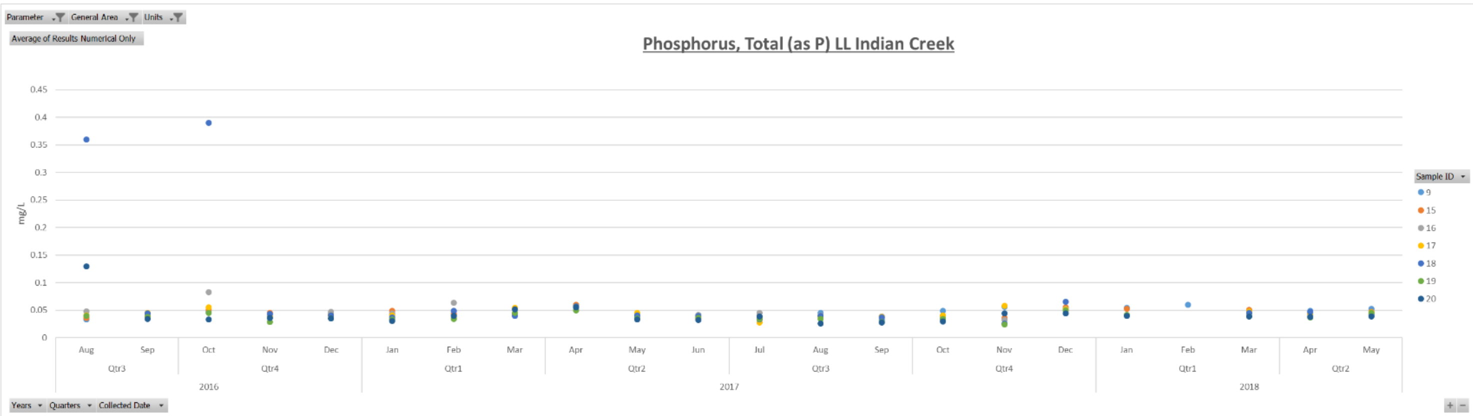
14
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Phosphorus, Total (as P) LL Indian Creek
mg/L
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
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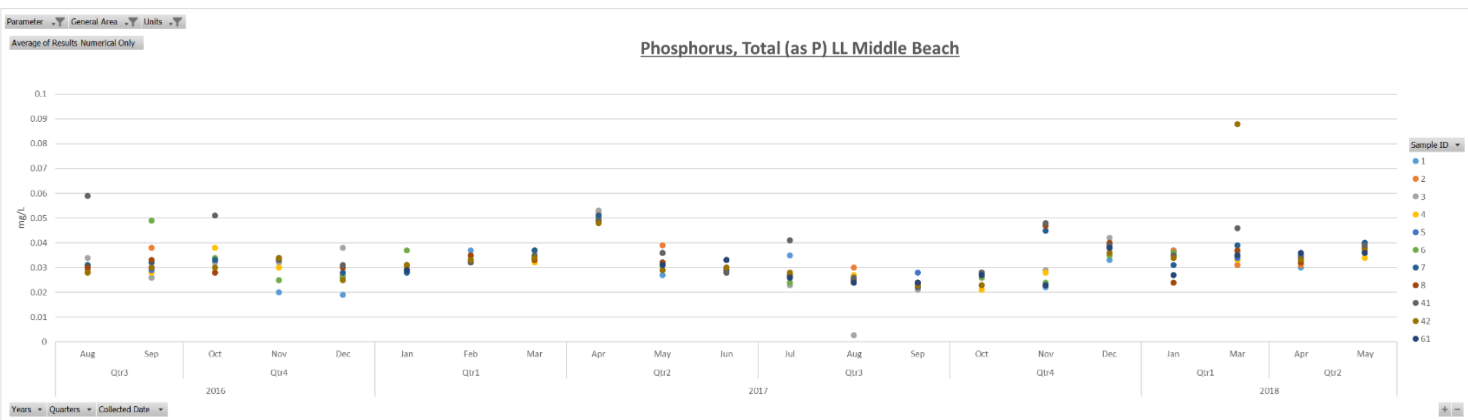
20
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Phosphorus, Total (as P) LL Middle Beach
mg/L
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
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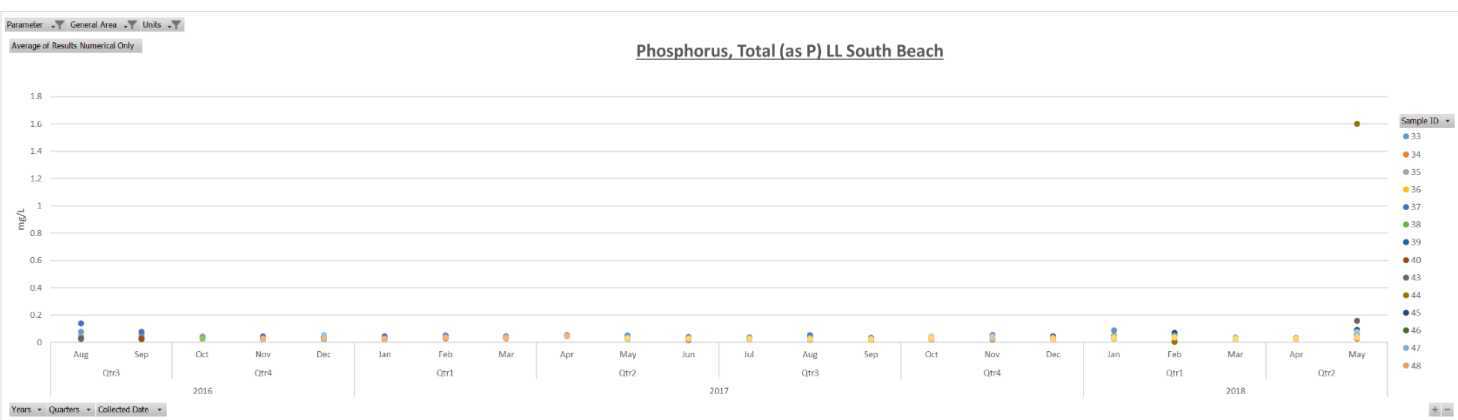
41
42
61
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Phosphorus, Total (as P) LL South Beach
mg/L
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
33
34
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37
38
39
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43
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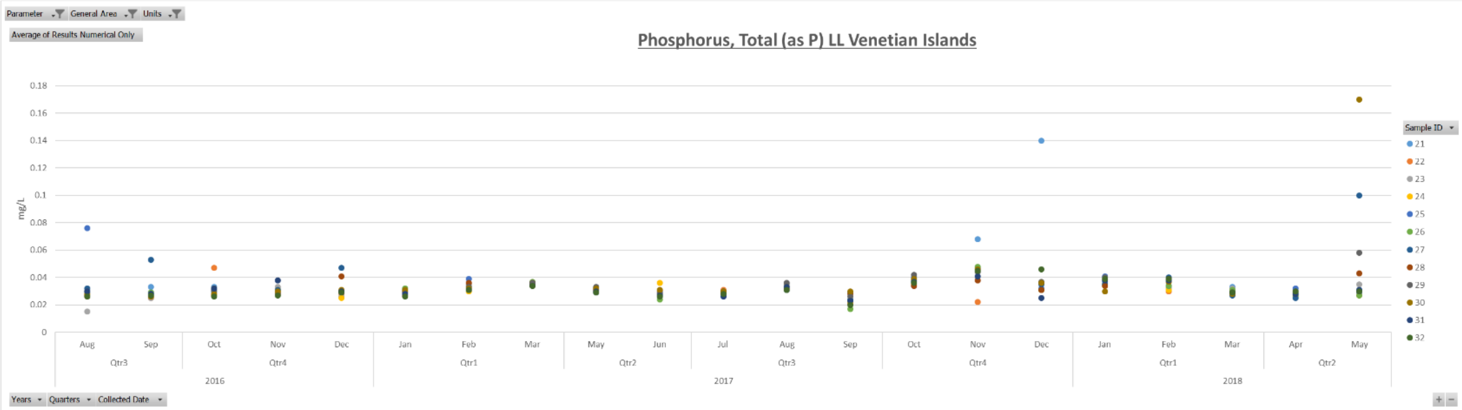
45
46
47
48
Years
Quarters
Collected Date



Parameter
General Area
Units
Average of Results Numerical Only
Phosphorus, Total (as P) LL Venetian Islands
mg/L
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2016
2017
2018
Sample ID
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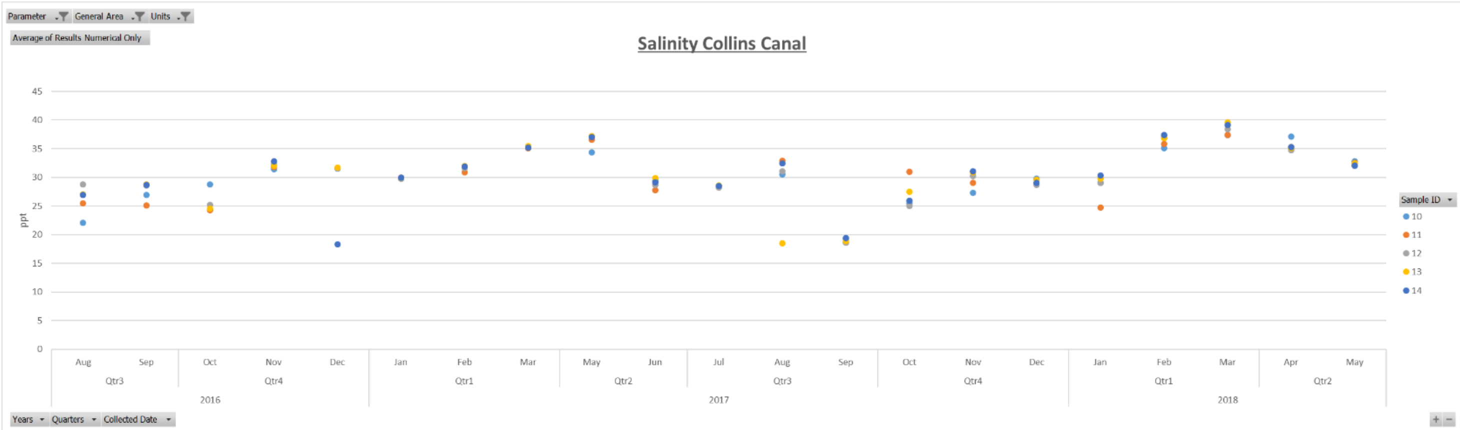
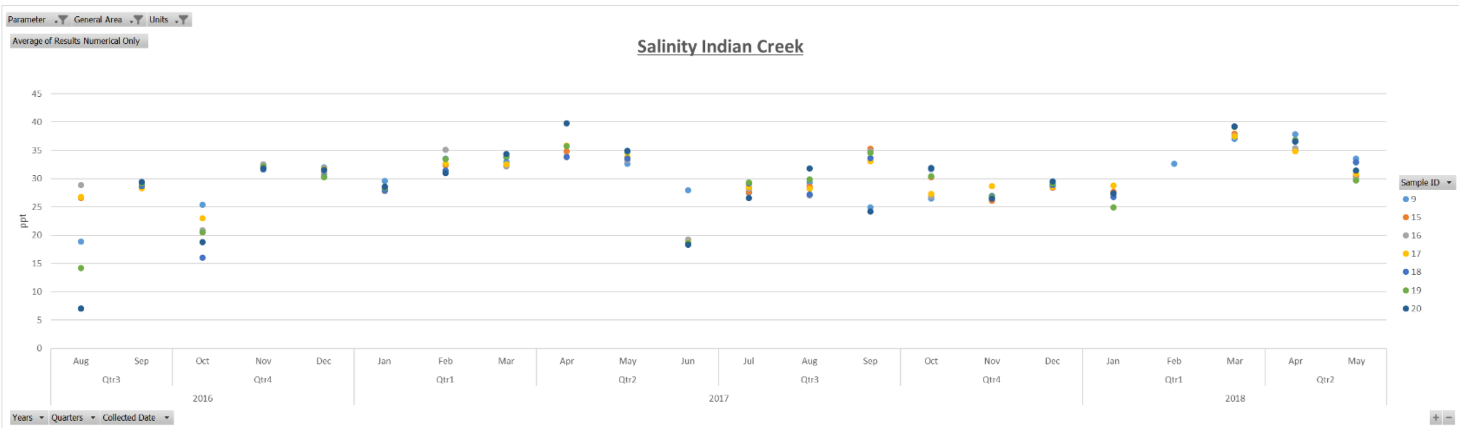
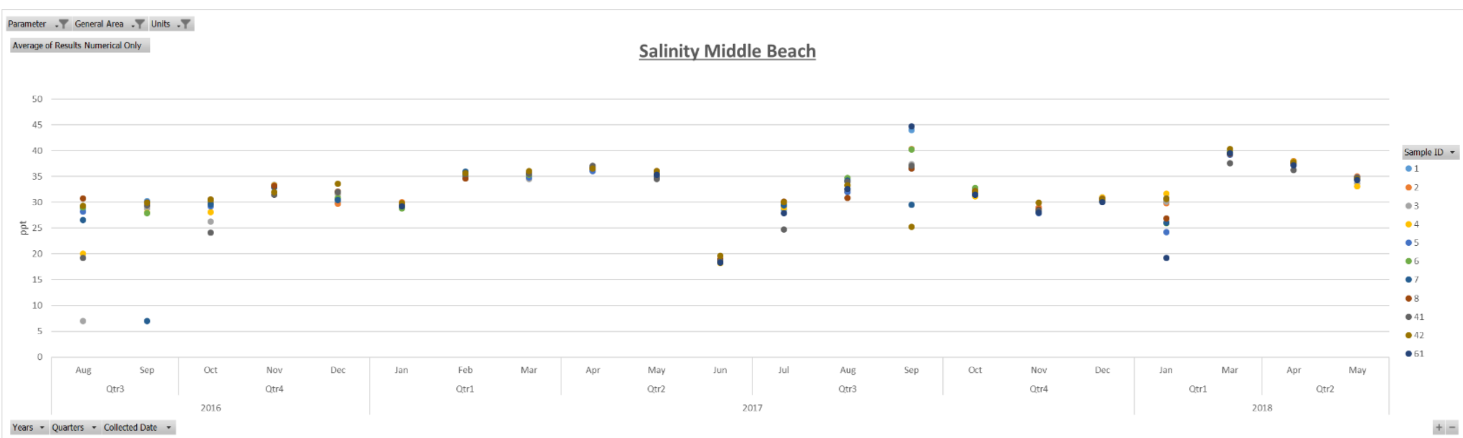
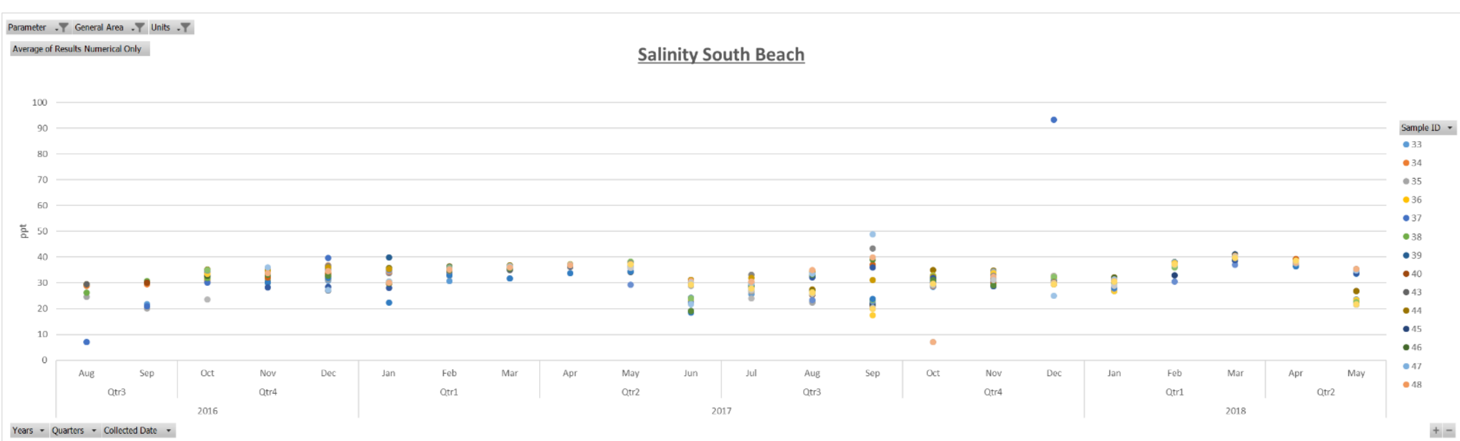
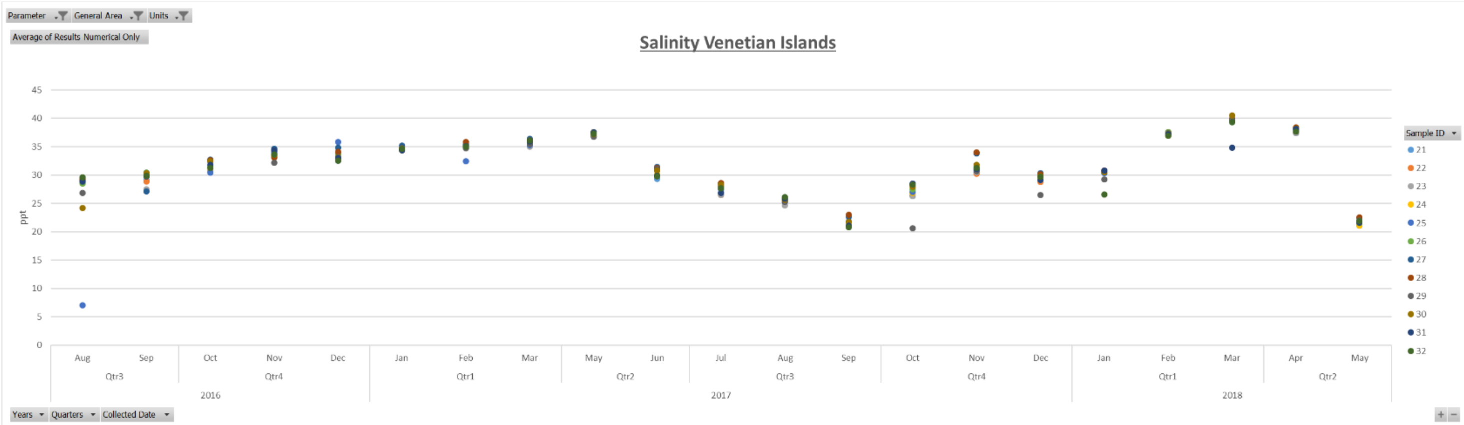
31
32
Years
Quarters
Collected Date

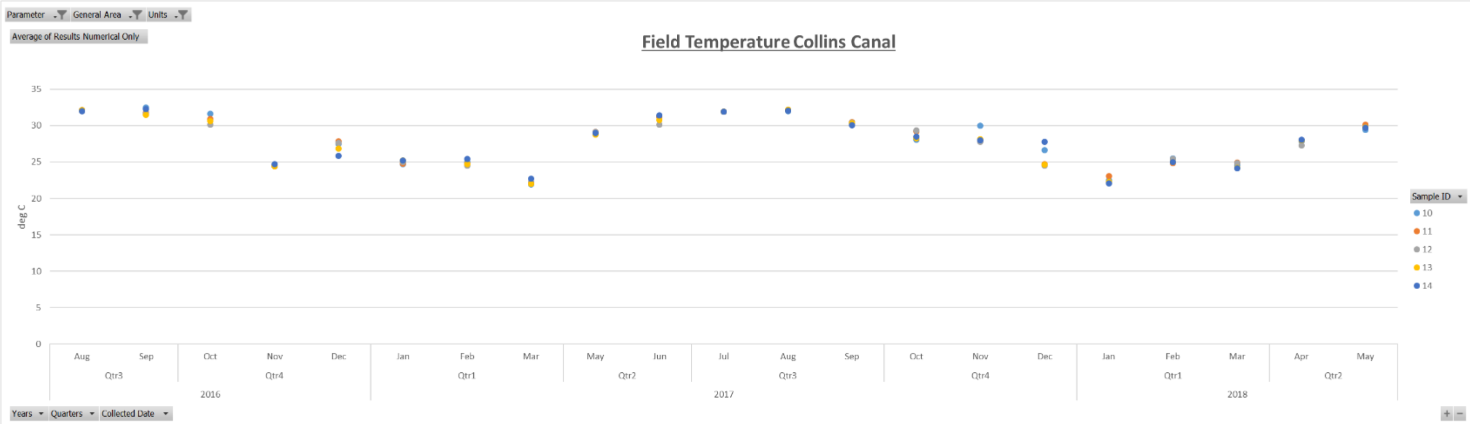

Parameter
General Area
Units
Average of Results Numerical Only
Salinity Collins Canal
ppt
Sample ID
10
11
12
13
14
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years Quarters Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Salinity Indian Creek
ppt
Sample ID
9
15
16
17
18
19
20
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years Quarters Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Salinity Middle Beach
ppt
Sample ID
1
2
3
4
5
6
7
8
41
42
61
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years Quarters Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Salinity South Beach
ppt
Sample ID
33
34
35
36
37
38
39
40
43
44
45
46
47
48
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years Quarters Collected Date


Salinity Venetian Islands
Parameter
General Area
Units
Average of Results Numerical Only
ppt
Sample ID
Years
Quarters
Collected Date
2016
2017
2018


Parameter
General Area
Units
Average of Results Numerical Only
Field Temperature Collins Canal
deg C
35
30
25
20
15
10
5
0
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
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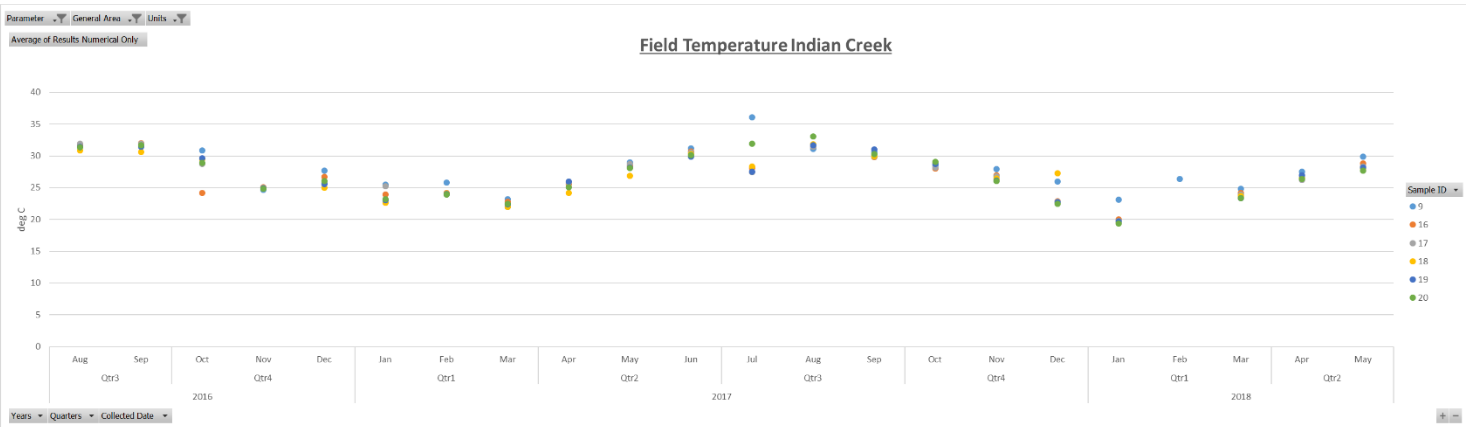
13
14
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field Temperature Indian Creek
deg C
40
35
30
25
20
15
10
5
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
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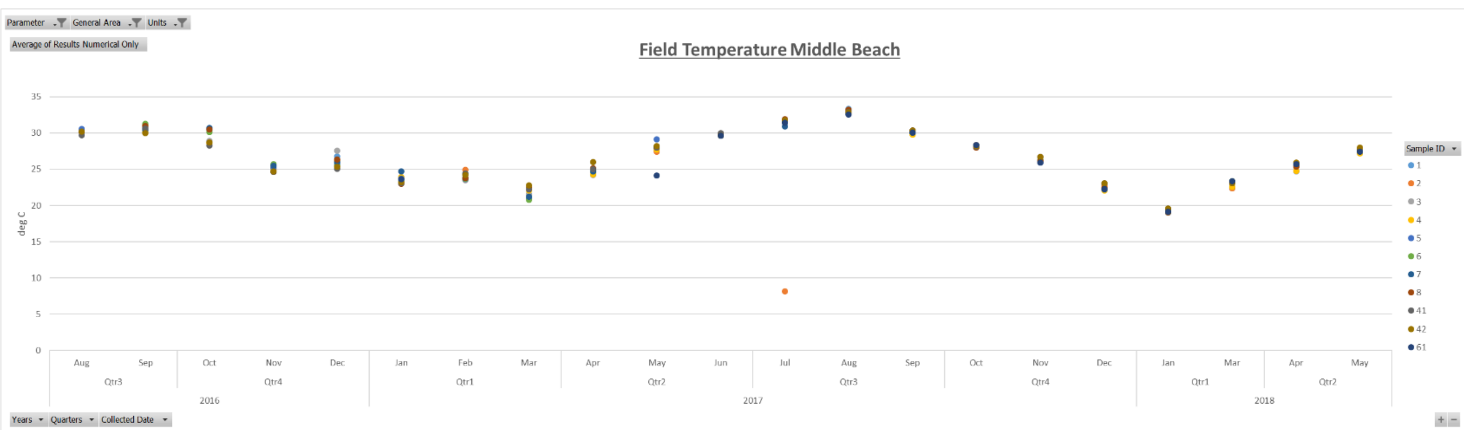
19
20
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field Temperature Middle Beach
deg C
35
30
25
20
15
10
5
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
1
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4
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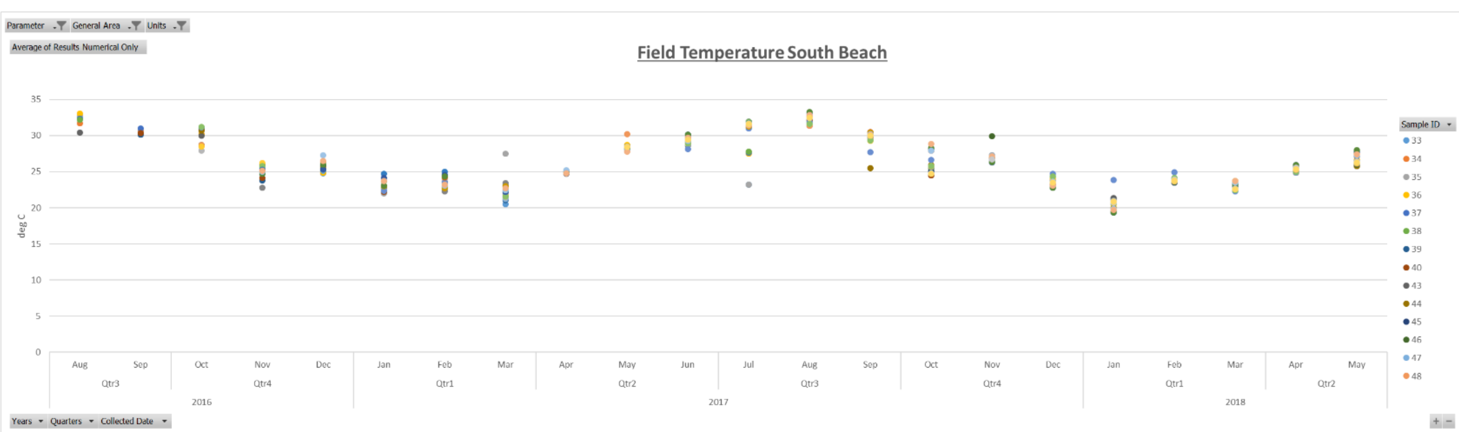
41
42
61
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field Temperature South Beach
deg C
35
30
25
20
15
10
5
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
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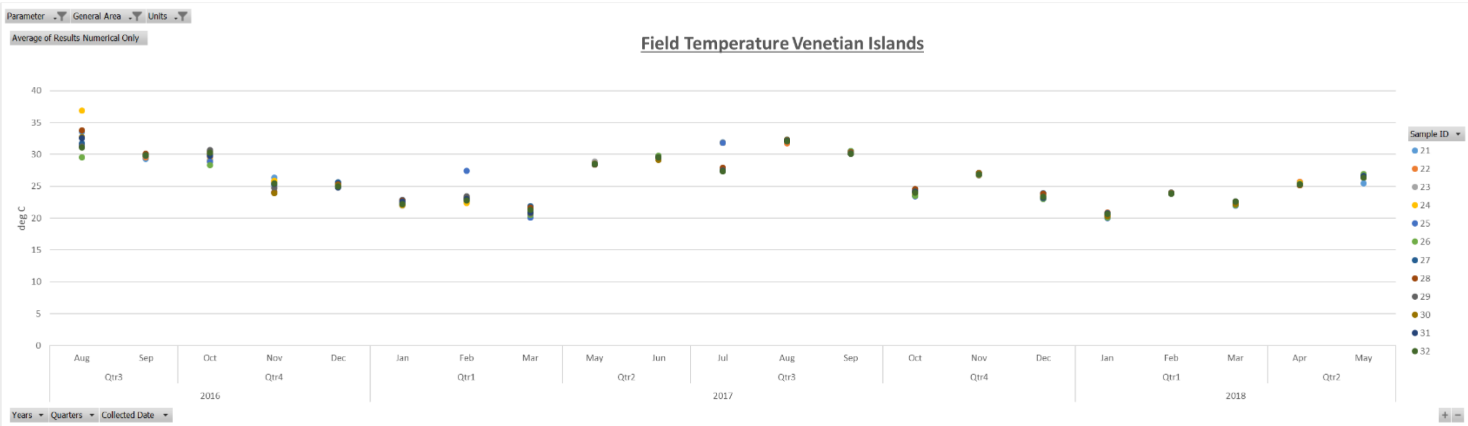
45
46
47
48
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Field Temperature Venetian Islands
deg C
40
35
30
25
20
15
10
5
0
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
21
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25
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27
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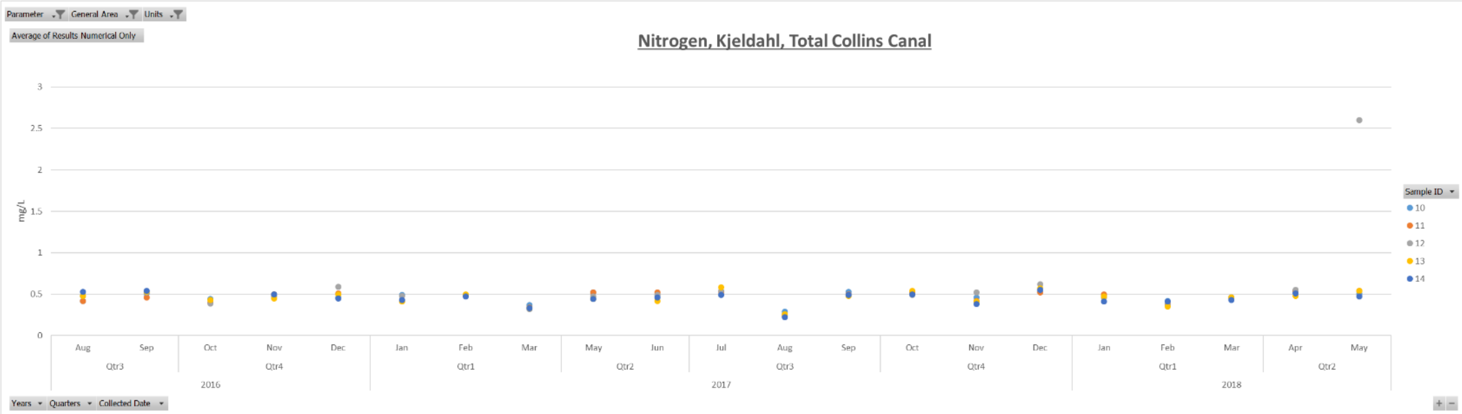
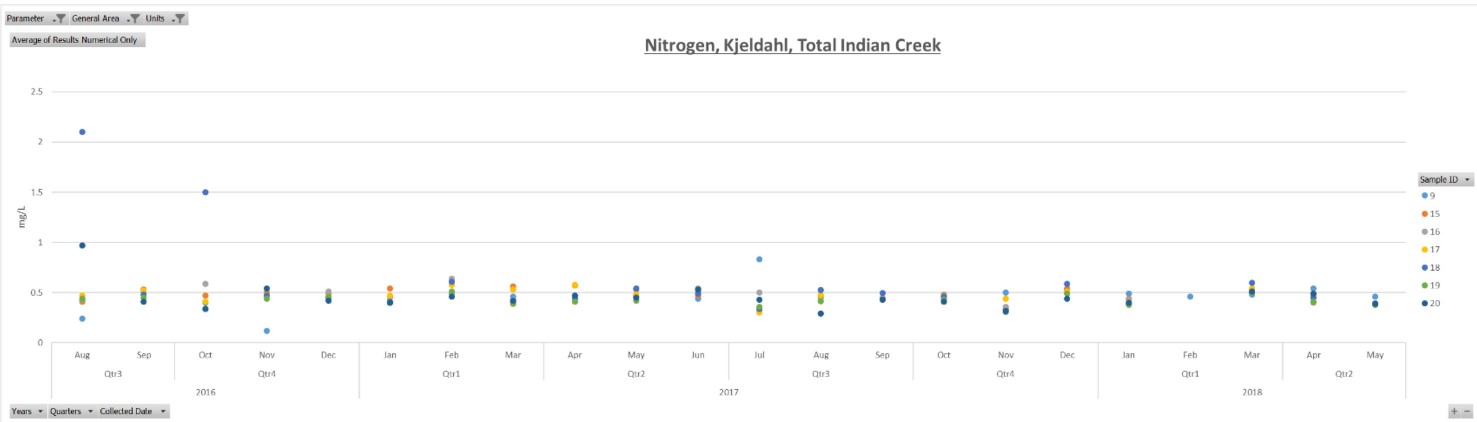
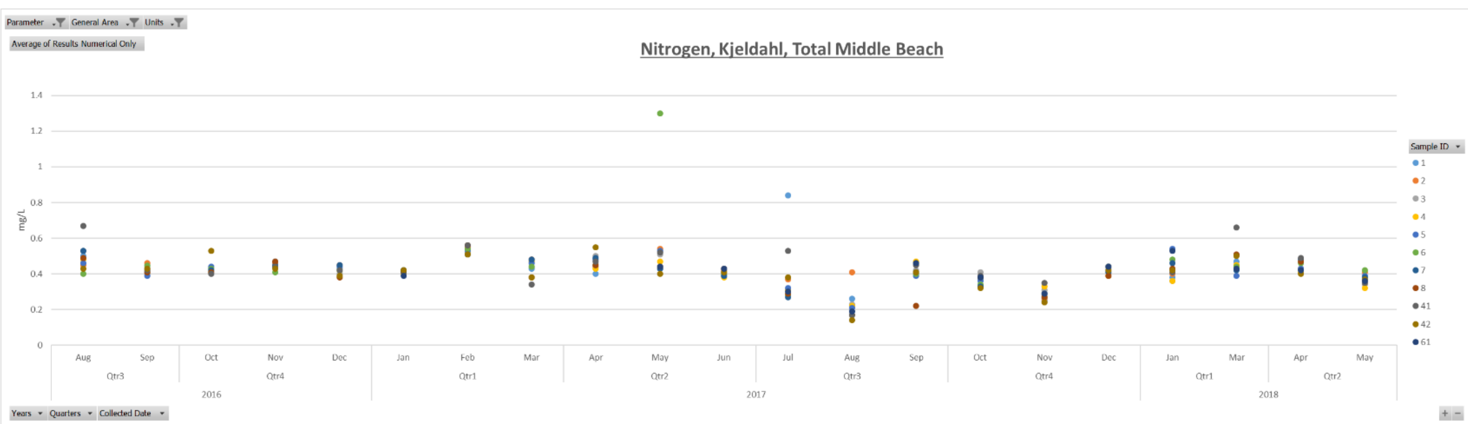
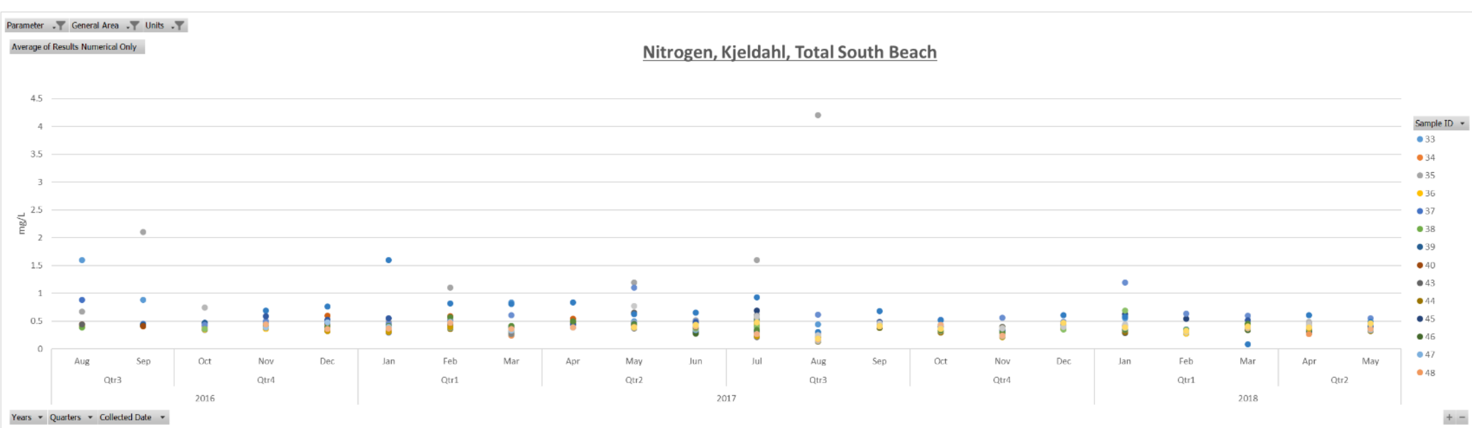
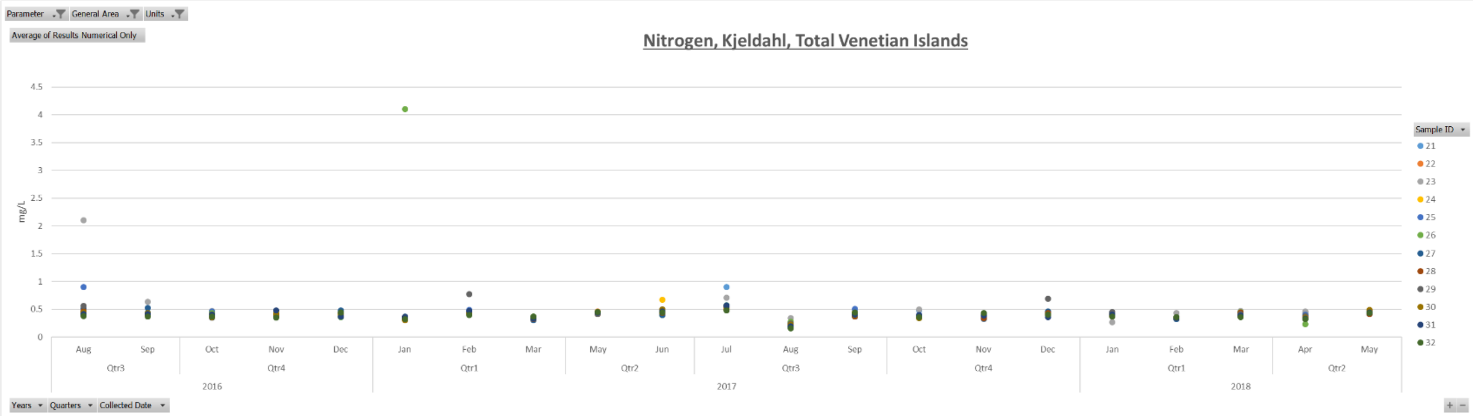
31
32
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Kjeldahl, Total Collins Canal
mg/L
Sample ID
10
11
12
13
14
Years
Quarters
Collected Date

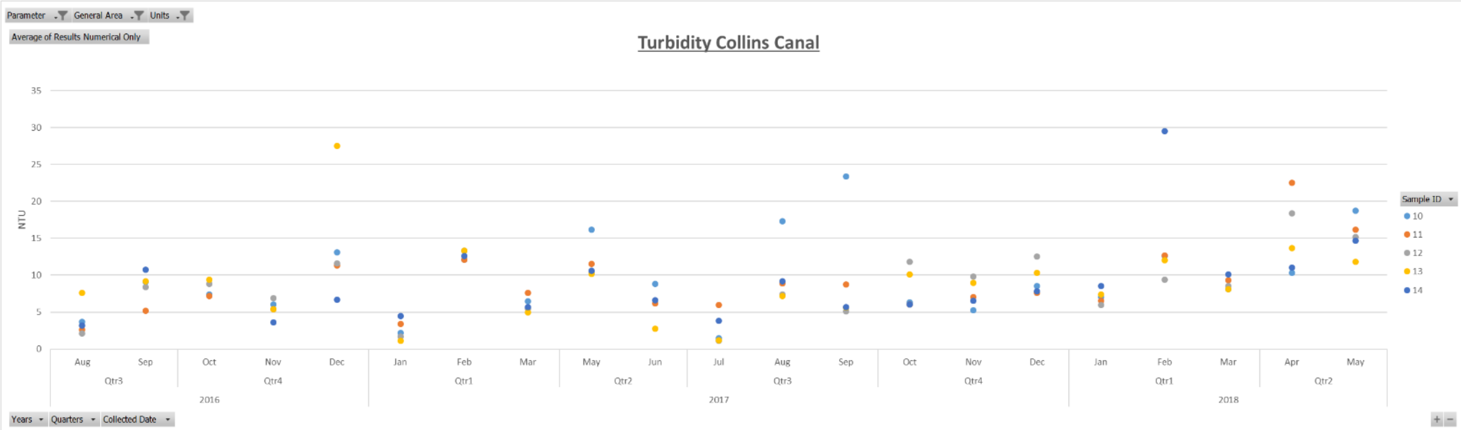

Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Kjeldahl, Total Indian Creek
mg/L
Sample ID
9
15
16
17
18
19
20
Years
Quarters
Collected Date

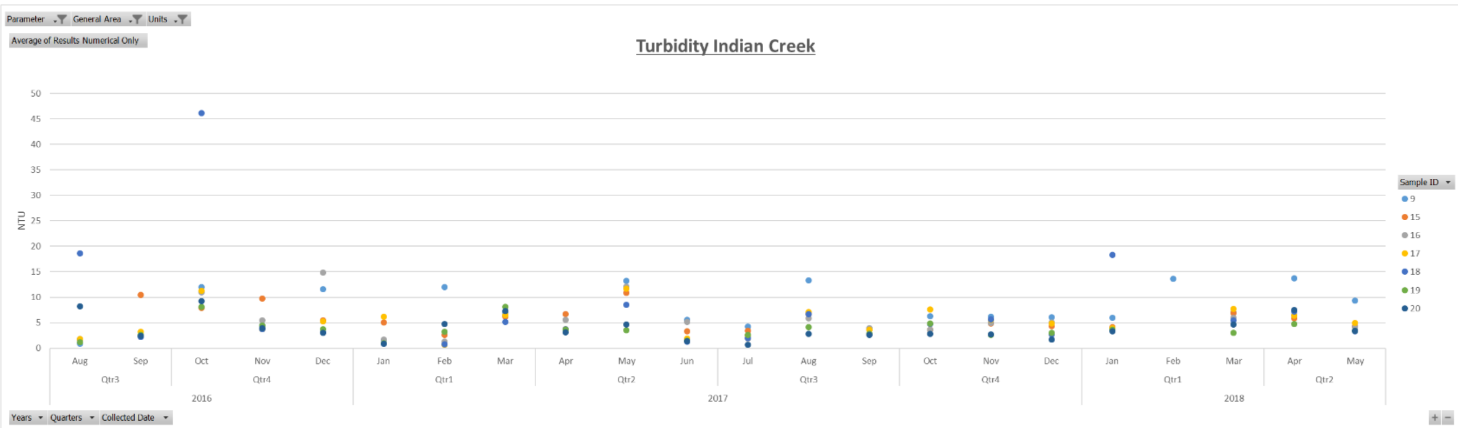

Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Kjeldahl, Total Middle Beach
mg/L
Sample ID
1
2
3
4
5
6
7
8
41
42
61
Years
Quarters
Collected Date

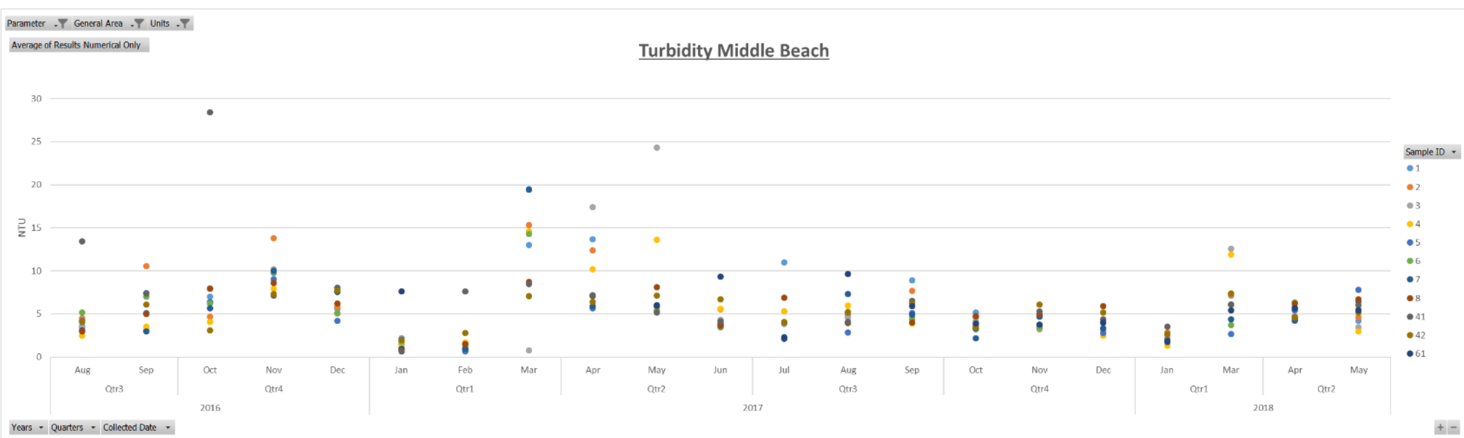

Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Kjeldahl, Total South Beach
mg/L
Sample ID
33
34
35
36
37
38
39
40
43
44
45
46
47
48
Years
Quarters
Collected Date

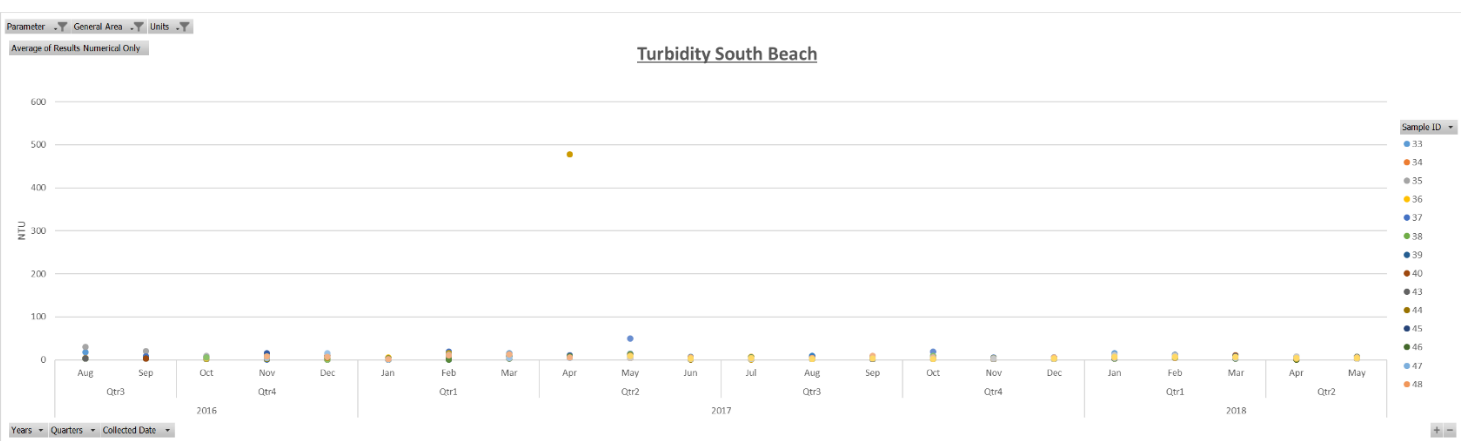


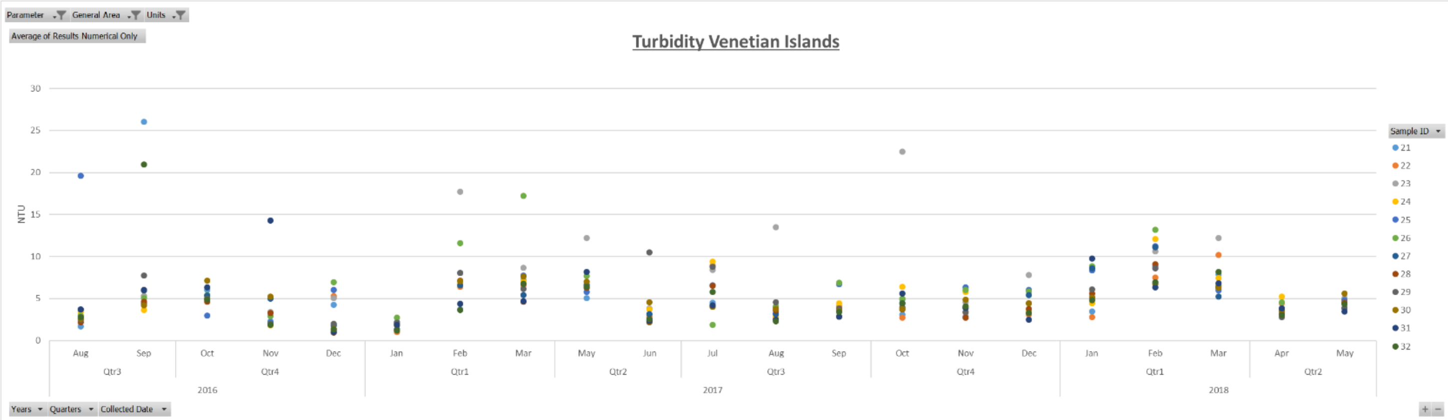
Parameter
General Area
Units
Average of Results Numerical Only
Nitrogen, Kjeldahl, Total Venetian Islands
mg/L
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Sample ID
21
22
23
24
25
26
27
28
29
30
31
32
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Turbidity Collins Canal
NTU
0
5
10
15
20
25
30
35
Aug Sep Oct Nov Dec Jan Feb Mar May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
10
11
12
13
14
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Turbidity Indian Creek
NTU
0
5
10
15
20
25
30
35
40
45
50
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
9
15
16
17
18
19
20
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Turbidity Middle Beach
NTU
0
5
10
15
20
25
30
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
1
2
3
4
5
6
7
8
41
42
61
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Turbidity South Beach
NTU
0
100
200
300
400
500
600
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Qtr3 Qtr4 Qtr1 Qtr2 Qtr3 Qtr4 Qtr1 Qtr2
2016 2017 2018
Sample ID
33
34
35
36
37
38
39
40
43
44
45
46
47
48
Years
Quarters
Collected Date


Parameter
General Area
Units
Average of Results Numerical Only
Turbidity Venetian Islands
NTU
30
25
20
15
10
5
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Qtr3
Qtr4
Qtr1
Qtr2
Qtr3
Qtr4
Qtr1
Qtr2
2016
2017
2018
Sample ID
21
22
23
24
25
26
27
28
29
30
31
32
Years
Quarters
Collected Date