Clear Creek Water Quality Data Collection and Trends Analysis Report

November 3, 2021

This document was prepared by the Houston-Galveston Area Council (H-GAC) for the stakeholders of the Clear Creek Watershed Partnership.

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1.0 Introduction

To support the development of a watershed protection plan (WPP) for Clear Creek Above Tidal (Segment 1102) and Clear Creek Tidal (Segment 1101), the project team conducted a series of water quality analyses. The purpose of this effort was to better understand water quality trends and variability that impact the ability of these waterways to meet state water quality standards and the water quality goals of local stakeholders.

This document discusses the:

- Analysis design and purpose for these analyses (2.0);
- Evaluations of data sources (3.0):
  - current and historical ambient water quality sampling data;
  - discharge monitoring reports (DMR) from wastewater treatment facilities (WWTFs)
  - sanitary sewer overflow (SSO) reports; and
- The outcome and implications of the analyses (4.0).

2.0 Analysis Purpose and Design

Purpose

This WPP development project is intended to address water quality issues in the waterways of the Clear Creek watershed. The main focus of the effort is to characterize and plan for the mitigation of water quality impairments and/or concerns listed for these segments and their tributaries[1]. The primary water quality issues identified as being of interest to this project are fecal waste and related pathogens (indicated by elevated levels of fecal bacteria species *E. coli* and Enterococcus) and depressed dissolved oxygen (DO). Additional concerns formally designated on the 2020 Integrated Report of Surface Water Quality (Integrated Report) produced by the Texas Commission on Environmental Quality included various nitrogen and phosphorus compounds (nutrients) and chlorophyll-a (an indicator of biotic activity

[1] The source for impairment or concern status is the 2020 Texas Integrated Report of Surface Water Quality, which describes the assessment process and results for these segments. The State of Texas assesses its waterways every two years, based on seven years of data. These assessments form the basis by which segments (defined portions of waterways) and their tributaries are classified as having impairments (inability to meet a state water quality standard for which a numerical or other specific limit exists) or concerns (levels of constituents which exceed screening levels or other criteria, but for which numerical or specific limits do not exist). The existence of an impairment is usually the primary driver for developing watershed-based plans for affected segments. More information on the2020 assessments can be accessed at https://www.tceq.texas.gov/waterquality/assessment/20twqi. This report was compiled prior to the approval of the 2022 Integrated Report. Data from that report and data from Clean Rivers Program monitoring in the watershed will be used to update this document prior to the conclusion of the WPP development project.

that may be linked to low DO). Additional local concerns raised by area stakeholders include waterway changes due to flooding, trash, and sediment from upstream development.

Analysis Project Design

Identifying the questions to be answered and the potential uses of the data produced by evaluations is the first step in developing an analysis project design. The following questions about the data and its uses were identified as being necessary for informing stakeholders and their subsequent project decisions:

- General understanding
    - Is there sufficient data to describe water quality conditions in the watershed?
    - What is the extent of the problem?
    - Is the problem spatially variable (i.e., do some areas have worse water quality than others?)
    - Are the issues seasonally variable?
- Specific Sources
    - Are permitted dischargers[2] meeting their permit limits?
    - Are there significant SSOs in the watershed?
        - If so, where are they located, and what is causing them?
- Model inputs[3]
    - Flow and bacteria data for load duration curves (LDCs)

H-GAC and TCEQ developed the water quality data acquisition and evaluation approach reflected in this document to satisfy these information and modeling input needs. Additional information about the data quality objectives, concerns, and methodologies used in these analyses can be found in the Clear Creek Modeling Quality Assurance Project Plan (QAPP)[4]. The general design for this evaluation project is:

1) Acquisition:
    a. Acquire at least five years[5] of quality-assured ambient water quality data[6] from the state's Surface Water Quality Monitoring Information System (SWQMIS) database for all monitoring stations active in the project watersheds.
    b. Acquire at least five years of DMRs from all WWTFs in the watershed.
    c. Acquire at least five years of SSO reports from all WWTFs in the watershed.

[2] For the purpose of this document, the permitted dischargers referred to are WWTFs operating under Texas Pollutant Discharge Elimination System (TPDES) water quality permits, whose discharges are evaluated through DMRs, and whose unintended releases are evaluated via SSO reports.
[3] The focus of this document is the general understanding of water quality in the watershed and specific potential pollutant sources that may shape modeling efforts. Model inputs are discussed in greater depth in the modeling documents available at www.clearcreekpartnership.com
[4] This document is available for review at www.clearcreekpartnership.com
[5] These analyses will be updated during year three of the project to include all available data from the project period itself.
[6] The constituents for these acquisition tasks are summarized in Table 1.

2) Evaluation
    a. Ambient data
        i. Determine if sufficient data exists for each station
        ii. Identify the historical trends for constituents of concern, by each station
        iii. Identify any seasonal trends, by constituent
        iv. Evaluate the relative character of water quality between stations
    b. DMRs
        i. Evaluate the constituents of concern for compliance with WWTF permit limits
        ii. Evaluate the general level of compliance for WWTFs
        iii. Evaluate the seasonality of exceedances
        iv. Evaluate the relationship between plant size and exceedance
    c. SSOs
        i. Evaluate the number, volume, and causes of SSOs by segment or tributary
    d. All sources – update the evaluations subsequent to the development of the WPP.

Table 1 - Constituents of concern by evaluation task

Constituent of Concern	Ambient	DMR	SSO
E. coli (bacteria)	X	X	
DO (grab)	X	X	
Temperature	X		
pH	X		
Chlorophyll-a	X		
Nitrate	X		
Flow (grab)	X		
Total Phosphorus	X		
Ammonia Nitrogen (NH3-N)	X	X	
TSS	X	X	
CBOD5		X	
Cause (SSO)			X
Number/Volume (SSO)			X

3.0 Evaluations

Overview

The initial evaluations were completed in October 2021 using the data available in SWQMIS (ambient) and the latest revisions to TCEQ databases (DMR and SSO) at that time. Statistical analyses were conducted in Statistical Analysis Software (SAS), and spatial evaluations were evaluated using Geographical Information Systems (GIS, specifically ArcGIS 10.6.). The outcomes of the evaluations were evaluated by project staff to translate the outputs into actionable implications for the WPP and characterization efforts. The full data and evaluation worksheets for these efforts are available on request but are not included in this report for sake of brevity. The information presented below is a summary of outcomes that have relevance for the project.

Ambient Data

Ambient water quality data are collected at over 400 sites in the 13-county Houston-Galveston region by H-GAC, local partners, and the TCEQ as part of the Clean Rivers Program (CRP)[7]. In general, most monitoring stations are sampled by CRP partners on a quarterly frequency for a suite of field, bacteriological, and conventional parameters[8]. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent on conditions at the time[9]. However, a history of samples provides a more representative view of the range of conditions that may be present in that waterway. Ambient data is important for characterizing waterways because it represents a range of conditions and has a historical aspect that allows for the identification of trends over time. The final determination of the regulatory status of each segment is based primarily on these ambient data. The goals and decisions for the WPP(s) are established in part due to the regulatory status, and therefore ambient data is an important source of information for informing stakeholder decisions. The current monitoring stations in Clear Creek are shown in Figure 1 and described in Table 2.

Assessed Status

Based on the 2020 integrated Report, elements of this segment have a series of water quality impairments (Table 3) and concerns (Table 4). Many of these water quality challenges are longstanding and appear on prior Integrated Reports.

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[7] More information about this state-wide water quality monitoring program can be found at https://www.tceq.texas.gov/waterquality/clean-rivers.
[8] More information about the specific monitoring and programmatic details of the local CRP can be found at http://www.h-gac.com/community/water/rivers/.
[9] For this report, 24-hour DO data is discussed in this section. In terms of technical terminology under CRP, 24-hour DO sampling is not considered "ambient" data, but rather, "biased sampling" because it is often collected during certain seasonal timeframes. Due to the nature of the 24-hour data for this project, and the basic categorization of this report, it is discussed as ambient data.

Table 2 - 2020 Integrated Report status of Clear Creek waterways - Impairments

Segment	AU(s)	Parameter	Category
1101	01, 02, 03	Enterococcus	4a
1101	01, 02, 03, 04	PCBs in edible tissue	5a
1101	01, 02, 03, 04	Dioxins in edible tissue	5a
1101A	01	Enterococcus	4a
1101B	01	Enterococcus	
1101C	01	Enterococcus	4a
1101D	01, 02	Enterococcus	4a
1101E	01	Enterococcus	4a
1101E	01	Dissolved oxygen 24hr. avg.	5c
1101E	01	Dissolved oxygen 24hr. min.	5c
1102	01, 02, 03, 04, 05	PCBs in edible tissue	5a
1102	02, 03, 04	*E. coli*	4a
1102A	01, 02	*E. coli*	4a
1102B	01	*E. coli*	4a
1102D	01	*E. coli*	4a
1102F	01	*E. coli*	4a
1102G	01	*E. coli*	4a

Table 3 - 2020 Integrated Report status of Clear Creek waterways - concerns

Segment	AU(s)	Parameter	Level of Concern
1101	02,03, 04	Total Phosphorus	CS
1101	02,03, 04	Nitrate	CS
1101	03,04	Chlorophyll-a	CS
1101	03	Depressed dissolved oxygen	CS
1101A	01	Nitrate	CS
1101A	01	Total Phosphorus	CS
1101C	02	Depressed dissolved oxygen	CS
1101D	01, 02	Depressed dissolved oxygen	CS
1101F	01	Depressed dissolved oxygen	CS
1102	05	Depressed dissolved oxygen	CS
1102	02, 03	Ammonia	CS
1102	02	Impaired habitat	CS
1102	02, 03, 04	Total Phosphorus	CS
1102	04, 05	Nitrate	CS
1102A	02	Ammonia	CS
1102B	01	Nitrate	CS
1102B	01	Total Phosphorus	CS
1102C	01	Depressed dissolved oxygen	CS
1102D	01	Depressed dissolved oxygen	CS
1102D	01	Nitrate	CS
1102D	01	Ammonia	CS
1102D	01	Total Phosphorus	CS
1102E	01	Depressed dissolved oxygen	CS
1102E	01	Nitrate	CS
1102F	01	Depressed dissolved oxygen	CS
1102F	01	Total Phosphorus	CS

As indicated in Table 3, all the assessment units of the segments in the system are impaired for fecal indicator bacteria and have concerns for total phosphorus and nitrate. Other constituents of concern are more sporadic.

Monitoring in Clear Creek

Clear Creek is the primary tributary system for the Clear Lake Watershed (Figure 1), which is directly adjacent to and connected with Galveston Bay. Clear Creek's drainage area is a mix of land uses from developing and legacy agricultural areas in its Fort Bend County headwaters to densely urban and suburban development along the majority of its length through Brazoria, southern Harris, and Galveston Counties. While much of the watershed is already developed, additional growth is expected to push further west into this watershed in the coming decades. The waterway is used for recreation, is a prominent flood management conveyance with repeat flooding events, and a great deal of community focus has been placed on its riparian corridor, which includes a string of park spaces and other public areas.

There are seventeen active monitoring stations in the watershed; 8 in the Clear Creek Tidal watershed (3 on the main stem, and 5 on its tributaries) and 9 in the Clear Creek Above Tidal watershed (3 on the main stem, and 6 on its tributaries.) Station 17928 on Cow Bayou (1101C) in Clear Creek Tidal was added for FY19 only, and has limited data, but is the only active site on this waterway. Station 18636 on Unnamed Tributary of Mary's Creek (1102G) in Clear Creek Above Tidal was added in FY21, and therefore also has limited data.

Table 4 - Monitoring station locations

Clear Creek Tidal (Segment 1101)		
Station ID	**Segment or Tributary Designation**	**Site Location**
11446	1101	Clear Creek Tidal at State Highway 3 near Webster
16573	1101	Clear Creek Tidal at the confluence with Clear Lake, League City
16576	1101	Clear Creek Tidal at Brookdale Drive, League City
16611	1101A	Magnolia Creek at West Bay Blvd., League city
16493	1101B	Chigger Creek at FM 528, Friendswood
17928	*1101C*	*Cow Bayou at NASA Road 1, Webster*
16475	1101D	Robinson's Bayou at FM 270
18591	1101F	Unnamed Tributary of Clear Creek Tidal at I-45, Webster

Clear Creek Above Tidal (Segment 1102)		
Station ID	**Segment or Tributary Designation**	**Site Location**
11450	1102	Clear Creek at FM 2351, Friendswood
11452	1102	Clear Creek at Telephone Road, South Houston
20010	1102	Clear Creek Above Tidal at Yost Road, Pearland
16677	1102A	Cowart Creek at Castlewood Drive, Friendswood
16473	1102B	Mary's Creek at Mary's Crossing, North Friendswood
17068	1102C	Hickory Slough at Robinson Drive, Pearland
21925	1102D	Turkey Creek at Beamer Road, Friendswood
18639	1102F	Mary's Creek Bypass at East Broadway Street, Pearland
18636	*1102G*	*Unnamed Tributary of Mary's Creek at Thalerfield Drive*

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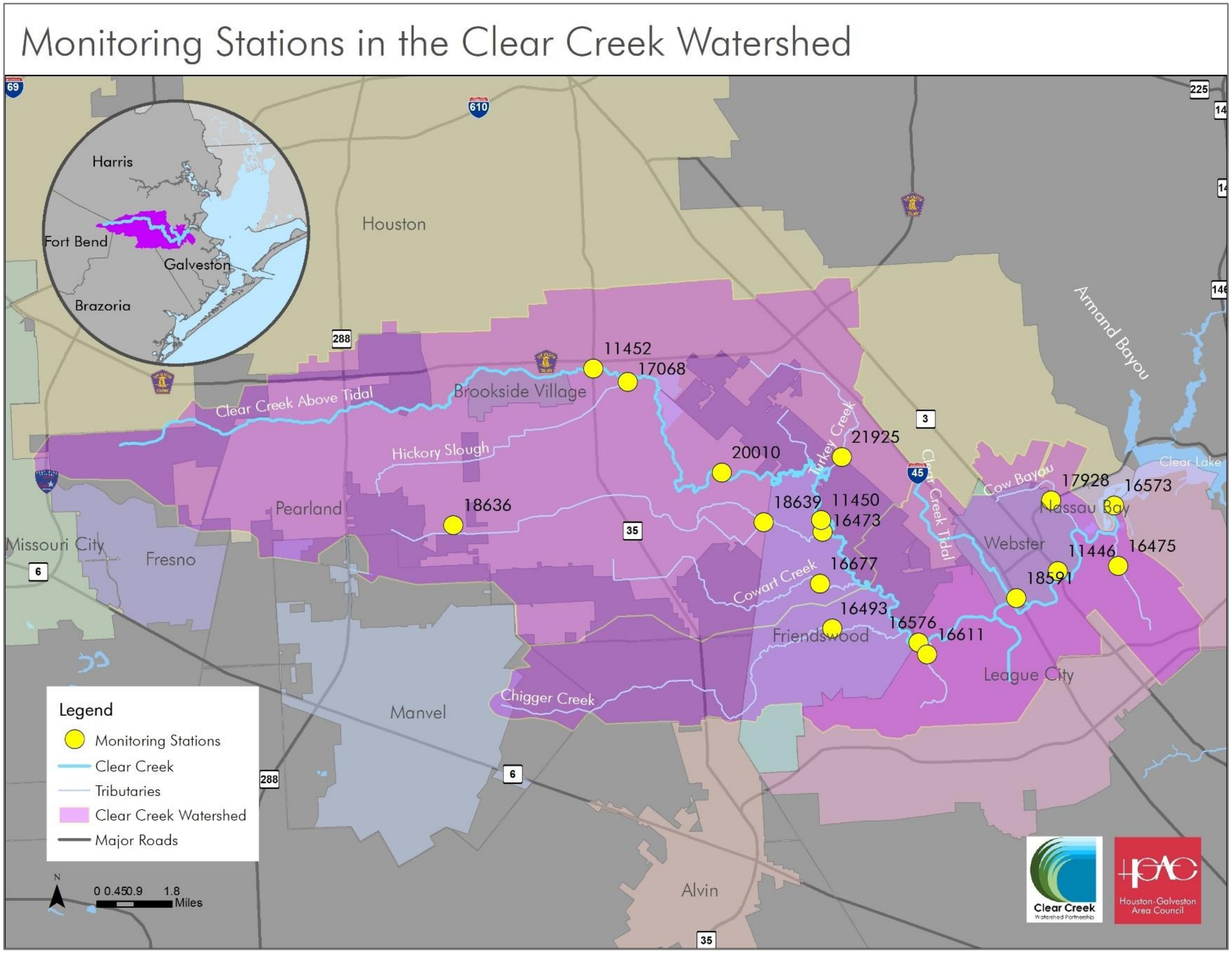

Figure 1 - Monitoring Stations in the Clear Creek Watershed

Water Quality Constituents

Routine ambient water quality monitoring under the CRP includes sampling for a suite of conventional, bacteriological, and field parameters[10]. For this evaluation, a subset of those parameters most closely related to the goals of the WPP, and characterization studies has been selected for in-depth analysis. The constituents reviewed are:

- *Escherichia coli (E. coli) and Enterococcus* – bacterial indicators of the presence of fecal wastes, and indicators of the safety of waterways for human recreation. *E. coli* is used for freshwater systems like Clear Creek Above Tidal, and Enterococcus is used for tidally influenced/marine systems like Clear Creek Tidal.
- *DO, grab* – an indicator of the ability of the waterway to support aquatic life.
- *DO, 24*-hour – an indicator of the ability of the waterway to support aquatic life throughout the daily cycle.
- *Temperature* – an indicator of a waterway's ability to hold oxygen, and a means for correlating other indicators to conditions in the waterways.
- *pH* – an indicator of the acidity or basicness of water, which may affect aquatic life and other uses.
- *Chlorophyll-a* – an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and thus potentially depressed DO.
- *Nitrate Nitrogen* – an indicator of nitrogen contribution to nutrient levels (and DO impacts).
- *Ammonia (NH3-N)* – a measure of specific nitrogenous compound that can impact aquatic life and is an indicator of nutrient levels and potentially of improperly treated sewage effluent.
- *Flow, grab* – a measure of water volume over time.
- *Total Phosphorus* – an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.

The data this effort reviewed included 3,825 samples from 17 stations between 2014-2020. Stations currently active under the Clean Rivers Program were included[11]. This time period is intended to show a historic data review, but one that does not obscure current trends with older data in a rapidly urbanizing watershed. The period of data, though not the specific years, was chosen to match the range approach taken by water body assessment under the Integrated Report. This report will be updated prior to the end of the WPP development project to include data acquired during the project term, and to provide a short-term view of the most current trends. The primary questions these evaluations sought to answer relate to: 1) the sufficiency of the data to characterize conditions; 2) the spatial component of variations in water quality conditions; 3) the extent of water quality issues; and 4) trends in water quality

[10] There are impairments for PCBs and Dioxins for Clear Creek Above Tidal. However, data for these impairments are not collected continually as part of the Clean Rivers Program. There are existing efforts addressing PCB/Dioxins in Galveston Bay and its tributaries, and the typical regulatory environment under which these contaminants are evaluated is outside the scope of this WPP.

[11] Three historical stations had data within this time period, but were representing assessment units also covered by current stations (i.e. stations 11425 and 16678 on 1102a, which are currently represented by station 16677, and staton 16486 on 1101D, which is currently represented by station 16475). Data from current stations on the AUs represented by historical stations was adequate to represent those AUs without issue.

conditions, including any observable seasonal patterns[12]. The assessment was completed on the segment level, with attention to any unclassified tributaries which have concerns or may be experiencing issues not common in the entire segment watershed. Full analysis of all the constituents for all stations is included as graphs in Appendix A[13].

Sufficiency of Data

Table 5 indicates the number of sampling events at each of the active monitoring stations during the period assessed and Table 6 indicates the number of samples per parameter per station. The data is generally sufficient enough to represent trends in water quality during this period. All but four of the 17 active stations, all of which were on tributary waterways, had monitoring throughout the entire 2014-2020 range. Station 16667 on 1102A replaced prior stations. Station 18636 is a new station on 1102G and had only 2 years of sampling. Stations 18629, 1102F, and 21925, 1102D, are relatively new stations but still have over four full years of monitoring events.

Table 5 - Number of Sampling Events by Station

Segment	Station	Segment or Tributary Name	Sampling Events	Sampling Range, in years
1101	11446	Clear Creek Tidal	24	2014-2020
1101	16573	Clear Creek Tidal	39	2014-2020
1101	16576	Clear Creek Tidal	27	2014-2020
1101A	16611	Magnolia Creek	47	2014-2020
1101B	16493	Chigger Creek	28	2014-2020
1101C	17928	Cow Bayou	27	2014-2020
1101D	16475	Robinson Bayou	28	2014-2020
1101F	18591	Unnamed Tributary of Clear Creek Tidal	28	2014-2020
1102	11450	Clear Creek Above Tidal	24	2014-2020
1102	11452	Clear Creek Above Tidal	24	2014-2020
1102	20010	Clear Creek Above Tidal	28	2014-2020
1102A	16677	Cowart Creek	13	2017-2020
1102B	16473	Mary's Creek/North Fork Mary's Creek	29	2014-2020
1102C	17068	Hickory Slough	27	2014-2020
1102D	21925	Turkey Creek	17	2016-2020
1102F	18639	Mud Gully	17	2016-2020
1102G	18636	Unnamed Tributary of Mary's Creek	8	2016-2017, 2020

[12] Throughout this ambient water evaluation, statistical significance is defined as a p-value of 0.0545 or less. Any significance not based on this statistical review (e.g. seasonal trends, qualitative comments) will be specifically described as not being related to this significance threshold. The quantitative analysis for the ambient conditions was conducted using Statistical Analysis System (SAS).

[13] Statistical analysis in the graphs of Appendix B are based on a LOESS curve rather than a straight regression curve to better indicate change in trend over time for disparate stations.

Table 6 - Samples per station per parameter

Station	Waterway	Total Records	*E. coli*	Entero-coccus	Tempe-rature	Flow	DO (grab)	pH	Nitrate	Ammonia	Total Phos-phorus	Chloro-phyll-a	24 hr. DO (Avg.)	24hr. DO (Min)
11446	1101	443	0	22	118	0	118	118	1	22	20	23	0	0
16573	1101	462	0	38	99	0	99	99	0	39	39	10	0	0
16576	1101	558	0	27	147	0	147	147	3	28	28	0	0	0
16611	1101A	333	26	15	28	38	28	28	6	28	28	0	13	13
16493	1101B	273	27	15	28	28	28	28	7	28	28	0	0	0
17928	1101C	355	0	26	77	0	71	77	0	26	26	0	0	0
16475	1101D	295	0	28	52	0	48	52	3	28	28	0	0	0
18591	1101F	273	27	15	28	28	28	28	7	28	28	0	0	0
11450	1102	170	22	1	27	0	27	27	1	21	20	23	0	0
11452	1102	177	23	0	25	12	25	25	1	21	21	23	0	0
20010	1102	268	27	15	34	28	34	33	7	28	28	0	0	0
16677	1102A	130	13	0	15	13	15	15	7	13	13	0	0	0
16473	1102B	300	27	15	37	28	37	37	7	28	28	0	0	0
17068	1102C	263	26	15	27	27	27	26	7	27	27	0	0	0
21925	1102D	164	17	4	17	17	17	17	7	17	17	0	0	0
18639	1102F	163	17	4	17	17	17	16	7	17	17	0	0	0
18636	1102G	53	5	4	5	8	5	5	1	5	5	0	0	0

Similar to the monitoring ranges in Table 5, the number of records per parameter in Table 6 indicates a good coverage for most parameters at most stations. However, there was limited nitrate, chlorophyll-a, and 24-hour DO data for most stations. Given the large number of monitoring stations in the system, and the generally good coverage of data time series and parameter-specific samples, the data is sufficient to characterize the impairments and concerns in the watershed.

Monitoring Results

While the primary focus of the analyses are the impairments noted in Table 3, analyses were conducted for all parameters of concern. Specific results and additional detail for each station are included in Appendix A.

Impairments

Tables 7 and 8 indicate the summary of bacteria monitoring results (*E. coli and Enterococcus, respectively*) over the time range of the data, by station, segment, and season. Data for either indicator species were evaluated wherever they were found. However, for the purpose of comparison to standards, *E. coli* results are of specific importance to the Clear Creek Above Tidal system (segment 1102 and its tributaries), and Enterococcus results are most pertinent for Clear Creek Tidal (1101 and its tributaries). Results shaded in red are geomeans in excess of the relative standard (126 MPN/100mL for *E. coli,* and 35 MPN/100mL for Enterococcus)[14].

Table 7 - E. coli monitoring summary, 2014-2020

Station ID	Total records	Segment	Max.	Min.	Geomean	Seasonal Geomeans			
						Summer	Winter	Fall	Spring
11446	*0*	*1101*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
16573	*0*	*1101*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
16576	*0*	*1101*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
1101 combined	0	1101	NA	NA	NA	NA	NA	NA	NA
16611	26	1101A	24000	52	405.47	597.31	476.68	230.11	441.33
16493	27	1101B	24000	16	219.85	224.67	609.50	152.87	111.95
17928	0	1101C	NA	NA	NA	NA	NA	NA	NA
16475	0	1101D	NA	NA	NA	NA	NA	NA	NA
18591	27	1101F	6500	1	56.87	31.19	79.77	56.93	67.75
11450	*22*	*1102*	*10000*	*10*	*267.31*	*124.04*	*259.23*	*433.24*	*429.97*
11452	*23*	*1102*	*1800*	*9*	*142.92*	*81.25*	*199.26*	*89.25*	*283.03*
20010	*27*	*1102*	*7300*	*10*	*170.36*	*155.57*	*579.44*	*73.76*	*125.05*
1102 combined	72	1102	10000	9	184.84	116.18	313.30	131.31	228.65
16677	13	1102A	16000	20	400.42	235.85	1172.72	240.47	458.11
16473	27	1102B	20000	38	449.62	296.63	1110.04	159.31	734.10
17068	26	1102C	6500	2	88.83	118.68	249.27	24.63	92.85
21925	17	1102D	24000	52	229.87	138.19	864.33	116.36	238.17
18639	17	1102F	14000	10	280.92	355.60	626.44	151.37	215.58
18636	5	1102G	24000	46	384.08	46.00	24000.00	288.44	91.00

[14] This should not be taken to indicate a formal impairment. It is only intended to indicate the geomean itself for this time period for that segment/station is in excess of the standard.

The *E. coli* data in Table 7 indicates that the majority of the waterways for which monitoring results were available were in excess of the *E. coli* criteria, based on their geomean for the full dataset. Two stations in the Tidal segment (1101) had both Enterococcus and *E. coli*, and were generally in excess of both indicators. In looking at seasonality, there was little differentiation in the Tidal segment, although fall geomeans were relatively lower on both stations with *E. coli* data. In the Above Tidal segment, winter was the period of highest geomeans for all waterways. Many waterways had their second highest seasonal geomeans in spring, but this was less universal (only 4 of 7 waterways followed this trend).

Table 8 - Enterococcus monitoring results, 2014-2020

Station ID	Total records	Segment	Max.	Min.	Geomean	Seasonal Geomeans			
						Summer	Winter	Fall	Spring
11446	*22*	*1101*	*20000*	*10*	*95.27*	*43.32*	*66.58*	*359.94*	*91.58*
16573	*38*	*1101*	*2800*	*10*	*30.28*	*11.49*	*65.00*	*32.65*	*27.40*
16576	*27*	*1101*	*4100*	*10*	*39.93*	*39.04*	*67.21*	*30.42*	*30.63*
1101 combined	87	1101	20000	10	44.09	28.09	66.26	54.01	35.61
16611	15	1101A	24000	110	491.44	1586.22	586.44	312.10	179.36
16493	15	1101B	24000	10	93.03	133.56	303.52	25.26	52.81
17928	26	1101C	24000	10	154.20	129.67	187.74	105.21	233.85
16475	28	1101D	24000	10	87.66	127.87	24.91	144.64	128.17
18591	15	1101F	24000	10	25.28	10.00	30.66	17.32	69.99
11450	*1*	*1102*	*180*	*180*	*180.00*	*NA*	*180.00*	*NA*	*NA*
11452	*0*	*1102*	*0*	*0*	*NA*	*NA*	*NA*	*NA*	*NA*
20010	*15*	*1102*	*2300*	*20*	*157.61*	*149.64*	*358.73*	*74.49*	*127.97*
1102 combined	16	1102	2300	20	158.93	149.64	312.51	74.49	127.97
16677	0	1102A	0	0	NA	NA	NA	NA	NA
16473	15	1102B	4000	41	221.77	233.72	586.79	85.79	162.14
17068	15	1102C	2900	10	117.05	77.36	144.42	80.56	189.95
21925	4	1102D	2300	39	158.34	73.00	2300.00	96.00	39.00
18639	4	1102F	1600	10	47.19	31.00	1600.00	10.00	10.00
18636	4	1102G	24000	41	268.63	84.00	24000.00	63.00	41.00

Similar to the *E. coli* results, 6 of the 8 stations in the Tidal segment (representing 5 of the 6 waterways of the system) have geomeans for Enterococcus in excess of the contact recreation criteria. Seasonally, the main channel of 1101 saw a significantly higher geomean in winter, its lowest geomean in summer, and then similar results in fall and winter. The tributary systems had some of the largest geomeans but showed less predictable variability by season.

As indicated in the 2020 Integrated Report, bacteria impairments continue as the most widespread water quality issue in the Clear Creek system. Both *E. coli* and Enterococcus levels remain elevated even in more recent data than that covered under the 2020 Integrated Report.

The 24-hour DO impairments listed for 1101E are based on data prior to the timeframe of these analyses, but within the timeframe of the Integrated Report assessment. No further data was collected during the intervening years. Therefore, it is not possible to assess current conditions with 24-hour DO as an impairment[15].. However, based on the general issues with DO (Tables 9 and 10) experienced in the waterways of the system, it is reasonable to assume that DO remains an issue in this waterway.

Concerns and Other Parameters

Although the primary focus of the WPP and these analyses are the impairments for fecal bacteria, a number of other water quality issues persists throughout the waterways, as reflected by the parameters designated as concerns in the Integrated Report. These parameters include DO (grab), nutrients, and chlorophyll-a. Additional water quality, hydrological, and related concerns expressed by stakeholders (e.g., trash, hydrologic modification of the channel by design or erosion, etc.) will be addressed as part of the WPP but are not examined in this report.

DO

The ability of the waterways of the Clear Creek system to support aquatic life, as measured by DO grab samples at screening or minimum levels, is noted in the Integrated Report as a widespread issue in both segments. Tables 9 and 10 summarize the results of the dissolved oxygen (grab) data by station, segment, and season.

Figure 2 - Clear Creek Above Tidal

[15] 24-hour data was only available for one station (16611 for tributary 1101A). the very limited data for this station indicated that the station was meeting the minimum and average criteria. The tributary for which there are impairments in the 2020 Integrated Report did not have data within the date range of this analysis and does not have an active CRP monitoring station.

Table 9 - Summary of Dissolved Oxygen (Grab) monitoring, 2014-2020

Station ID	Total records	Segment	Geomean	Criteria, Minimum	Exceedances, Minimum	Percent Exceedance, Minimum	Criteria, Screening Level	Exceedances, Screening Level	Percent Exceedances, Screening Level
11446	*118*	*1101*	*5.4547386*	*3*	*0*	*0.0%*	*4*	*21*	*17.8%*
16573	*99*	*1101*	*6.4150118*	*3*	*5*	*5.1%*	*4*	*10*	*10.1%*
16576	*147*	*1101*	*4.9363468*	*3*	*8*	*5.4%*	*4*	*29*	*19.7%*
1101 combined	364	1101	5.4753701	3	13	3.6%	4	60	16.5%
16611	28	1101A	6.0973975	3	0	0.0%	4	0	0.0%
16493	28	1101B	7.9315831	2	0	0.0%	3	0	0.0%
17928	71	1101C	4.6164025	3	14	19.7%	4	26	36.6%
16475	48	1101D	4.8401001	3	9	18.8%	4	18	37.5%
18591	28	1101F	6.1400205	3	0	0.0%	5	2	7.1%
11450	*27*	*1102*	*6.392768*	*3*	*0*	*0.0%*	*5*	*0*	*0.0%*
11452	*25*	*1102*	*6.3198417*	*3*	*1*	*4.0%*	*5*	*2*	*8.0%*
20010	*34*	*1102*	*6.3649017*	*3*	*1*	*2.9%*	*5*	*2*	*5.9%*
1102 combined	86	1102	6.3604874	3	2	2.3%	5	4	4.7%
16677	15	1102A	7.8181367	2	0	0.0%	3	0	0.0%
16473	37	1102B	6.988524	3	0	0.0%	4	0	0.0%
17068	27	1102C	5.930844	3	1	3.7%	5	4	14.8%
21925	17	1102D	5.2137862	3	0	0.0%	5	4	23.5%
18639	17	1102F	7.24334	3	0	0.0%	5	1	5.9%
18636	5	1102G	2.8069624	3	3	60.0%	5	4	80.0%

Table 10 - Seasonal assessment of minimum DO (grab) criteria, 2014-2020

Station ID	Total records	Segment	Criteria, Minimum	Minimum exceedances by Season Summer	Winter	Fall	Spring
11446	*118*	*1101*	*3*	*0*	*0*	*0*	*0*
16573	*99*	*1101*	*3*	*3*	*0*	*0*	*2*
16576	*147*	*1101*	*3*	*0*	*4*	*2*	*2*
1101 combined	364	1101	3	3	4	2	4
16611	28	1101A	3	0	0	0	0
16493	28	1101B	2	0	0	0	0
17928	71	1101C	3	6	0	5	3
16475	48	1101D	3	5	0	3	1
18591	28	1101F	3	0	0	0	0
11450	*27*	*1102*	*3*	*0*	*0*	*0*	*0*
11452	*25*	*1102*	*3*	*0*	*0*	*0*	*1*
20010	*34*	*1102*	*3*	*0*	*0*	*0*	*1*
1102 combined	86	1102	3	0	0	0	2
16677	15	1102A	2	0	0	0	0
16473	37	1102B	3	0	0	0	0
17068	27	1102C	3	0	0	0	1
21925	17	1102D	3	0	0	0	0
18639	17	1102F	3	0	0	0	0
18636	5	1102G	3	1	0	2	0
Total, all	**771**			**15**	**4**	**12**	**11**
1101	**567**			**14**	**4**	**10**	**8**
1102	**204**			**1**	**0**	**2**	**3**

In Table 9, the extent to which waterways are unable to support either the minimum criteria or the screening level criteria relative to their use designation varies throughout the system. An appreciable portion of the samples from 1101C, 1101D, and 1102G did not meet the minimum criteria. Inability to meet the screening level was more widespread. The seasonal analysis in Table 10 showed that for the whole system, the greatest number of samples that did not meet the minimum standard occurred in summer, with the fewest in winter. However, the effect was less pronounced for 1102, in part due to more limited data, which did not have a greater pattern for summer. Similarly, the Tidal segment did not reflect a pattern on the main channel but was heavily influenced by 1101C and 1101D. The combination of stations on the main 1101 segment of Clear Creek itself did not exhibit a seasonal bias. The Tidal segment It should also be noted that, while the majority of the samples not meeting the screening level were in the Tidal segment, this reflects that the majority of the overall numbers of samples were also in the Tidal. Overall, there was not a strong seasonal pattern outside of waterways 1101C and 1101D.

Other Parameters

In addition to DO, both the Tidal and Above Tidal systems have a significant number of concerns related to nutrients and other parameters (Table 3). This report also considered trends in general parameters (temperature and pH) and nutrients and potential indicators or precursors to low DO (nitrate, ammonia, total phosphorus, and chlorophyll-a).

The results summarized in Tables 11 (Tidal) and 12 (Above Tidal) represent a geomean of all data from the time period, by station and segment, and the percentage of samples that exceeded the screening level or other criteria. Specific results and additional detail for each station are included in Appendix A.

In the Tidal segment, temperature and pH are within acceptable ranges. Ammonia geomeans are generally below the screening level, but from 3.6-7.7% of samples exceed it. Nitrate levels in the main channel and 1101A have significant issues with nitrate limits, while other waterways of the system do not. While most of the waterways of the system exhibited geomeans under the screening level of total phosphorus, they all have at least 10% of their samples in exceedance, ranging as high as 92.9% in 1101A. Chlorophyll-a results in the main channel indicated about a fifth of the samples were in exceedance of the screening level. While nutrient levels were an issue throughout the system, the main channel and 1101A had the greatest degree of difficulty, suggesting additional investigation into sources in those areas should be prioritized.

In the Above Tidal segment, temperature and pH are within acceptable ranges. Ammonia geomeans are generally below the screening level, but from a large number (ranging from 22-47%) of the samples for the main channel and the majority of the tributaries exceeded it. Nitrate levels mirrors the ammonia levels, with only 1102C and 1102G not having more than roughly half the samples exceed the screening level. Total phosphorus results continued the spatial trend of relative issues throughout the system, but with relatively greater levels of exceedance, ranging as high as 76% in some waterways. Chlorophyll-a results in the main channel indicated only 2% of samples were in excess of the screening level and did not appear to be an appreciable challenge. While nutrient levels were an issue throughout the system, the main channel and 1102B,-D, and -F had the greatest degree of difficulty, suggesting additional investigation into sources in those areas should be prioritized.

Table 11 - Summary of analysis of other parameters in Clear Creek Tidal, 2014-2020

Parameter	Criteria	Units	Geomeans and Percent of Samples Exceeding Standards in the Tidal Segment (1101)					
			1101	**1101A**	**1101B**	**1101C**	**1101D**	**1101F**
			Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)
Temperature	35	Degrees Celsius	22.18 (0.0%)	20.62 (0%)	19.69 (0%)	21.74 (0%)	20.15 (0%)	19.81 (0%)
pH	9 (high)/ 6.5(low)	NA	7.77 (0.8%)	7.39 (0%)	7.84 (0%)	7.93 (0%)	7.84 (0%)	7.67 (0%)
Ammonia	0.33/0.46[16]	mg/L	0.16 (4.5%)	0.15 (3.6%)	0.13 (3.6%)	0.16 (7.7%)	0.15 (6.3%)	0.16 (3.6%)
Nitrate	1.95/1.10[17]	mg/L	1.64 (50.0%)	11.07 (100%)	0.08 (0%)	NA	0.24 (0%)	0.13 (0%)
Total Phosphorus	0.69/0.66[18]	mg/L	0.59 (41.4%)	1.44 (92.9%)	0.15 (10.7%)	0.35 (19.2%)	0.24 (15.6%)	0.22 (21.4%)
Chlorophyll-a	21	ug/L	8.52 (18.2%)	NA	NA	NA	NA	NA

[16] The 0.33 mg/L level applies to 1101A and 1101B. All other waterways use 0.46 mg/L.
[17] The 1.95 mg/L level applies to 1101A and 1101B. All other waterways use 1.10 mg/L.
[18] The 0.69 mg/L level applies to 1101A and 1101B. All other waterways use 0.66 mg/L.

Table 12 - Summary of analysis of other parameters in Clear Creek Above Tidal, 2014-2020

Parameter	Criteria	Units	Geomeans and Percent of Samples Exceeding Standards in the Above Tidal Segment (1102)						
			1102	**1102A**	**1102B**	**1102C**	**1102D**	**1102F**	**1102G**
Temperature	35	Degrees Celsius	21.54 (0%)	20.19 (0%)	20.25 (0%)	18.50 (0%)	20.71 (0%)	21.16 (0%)	21.99 (0%)
pH	9 (high)/ 6.5(low)	NA	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)
Ammonia	0.33	mg/L	0.18 (22.9%)	0.27 (31.3%)	0.19 (25.0%)	0.12 (3.7%)	0.35 (47.1%)	0.19 (23.5%)	0.12 (0%)
Nitrate	1.95	mg/L	1.95 (55.6%)	0.17 (0%)	1.86 (42.9%)	0.13 (0%)	3.29 (71.4%)	2.18 (57.1%)	1.18 (0%)
Total Phosphorus	0.69	mg/L	0.78 (60.9%)	0.16 (3.1%)	0.87 (67.9%)	0.24 (14.8%)	0.83 (76.5%)	0.90 (58.8%)	0.30 (20.0%)
Chlorophyll-a	14.1	ug/L	3.35 (2.2%)	NA	NA	NA	NA	NA	NA

Additional information on results over time at each station can be found in Appendix A.

Constituent Trends

Table 13 indicates the parameters in Segments 1101 and 1102 and the unclassified tributaries of the systems for which there are statistically significant trends[19]. The full data for all constituents for all stations can be found in Appendix A. Some trends, especially for the main channel, are not consistent across the whole segment, though the issues related to the constituents of primary concern (particularly *E. coli*) are relatively consistent. The broadest view of the system's trends is that there are few statistically significant trends in either improvement or degradation. Of the 120 instances (parameter by segment/tributary) reviewed, only 5 instances indicated a statistically significant improvement, and only 5 showed statistically significant degradation over the whole period of time represented by the dataset.

Most importantly, there were no statistically significant trends in either *E. coli,* Enterococcus, or DO. Additional information about this trends analysis is included in Appendix B.

Table 13 - Trends analysis by parameter, 2014-2020

Parameter	Improving	No Change	Deteriorating
Ammonia-N	4	9	.
Chlorophyll-a	.	1	.
Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	.	14	.
Dissolved Oxygen (24-hour Minimum / Grab Minimum)	.	2	.
E. Coli	.	11	.
Enterococci	.	3	.
Instantaneous Flow	.	10	1
Nitrate-N	.	13	.
Temperature	.	12	1
Total Phosphorus	.	13	.
Total Suspended Solids	.	11	2
pH	1	11	1

Relationship to Flow

As part of the ambient data analyses, staff considered the relationship of constituent levels to flow conditions. Further work on the relationship between flow, bacteria, and DO was completed as part of LDC model development[20]. In general, Clear Creek saw fairly consistent nonpoint source indications, as

[19] The trends represented here and in Appendix B do not consider stations for which there were less than 10 samples for any given parameter. These stations were excluded from the analysis for lack of sufficient data.
[20] Please refer to the Clear Creek Modeling Report available on www.Clearpartnership.com.

bacteria concentrations increased with flow fairly regularly throughout the stations of the waterway. Waterways with smaller flows showed more pronounced variability, although some (1101A) showed signs of consistent influence.

Ambient Analysis Summary

The Clear Creek watershed exhibits water quality challenges and trends that reflect a highly developed watershed still undergoing transition of land uses in some of its headwater areas.

Fecal bacteria remain an issue throughout the watershed, presenting a defensible case for the continued focus of the WPP on this parameter. Persistent dissolved oxygen and nutrients issues are also prevalent and should be strongly considered as stakeholders develop the WPP. Further modeling under this watershed projects will identify potential sources of fecal bacteria and the impacts of projected future growth. Opportunities to identify and implement solutions that benefit multiple water quality considerations will be an effective strategy for this watershed.

While water quality issues persist in these waterways since the 2016 assessment, they are not extraordinary in extent such that voluntary intervention through watershed-based plans would be fruitless. Targeted assessment and application of best management practices could be expected to reduce or remove impairments and concerns in these watersheds.

Figure 3 - Cattle and Cattle Egrets, Clear Creek Above Tidal

DMR Data

Discharges from wastewater treatment plants are regulated by water quality permits from the TCEQ which require stringent limits for effluent quality. In general, wastewater treatment plants in the Houston region are able to meet their permits with few excursions. However, because human waste has an appreciable pathogenic potential[21], identifying trends in permit exceedances for indicator bacteria by WWTFs is important in understanding overall impacts to waterways. Additionally, effluent (especially if improperly treated) can be a source of nutrient precursors to depressed DO. Discharges from WWTFs are monitored on a regular basis (with a frequency dependent on plant size and other factors). The data from these required sampling events is submitted to (and compiled by) the TCEQ and EPA as DMRs. As with any self-reported data, there is an expectation that some degree of uncertainty or variation from conditions may occur, but these DMRs are the most comprehensive data available for evaluating WWTFs in the watershed.

For this project, staff evaluated five parameters common to most WWTF permits, as reported in the last five years (2016-2021[22]) of DMRs available from TCEQ. Some parameters are themselves constituents of concern, while the others are indicators of the presence or potential presence of untreated/improperly treated waste[23]:

- Indicator bacteria (*E. coli* and Enterococcus*)* – this common gut bacterium indicates the presence of untreated fecal waste and related pathogens which can impact human health.
- TSS – this measure of the number of suspended particles in water indicates the efficiency of the WWTF process, and the potential of effluent to impact sedimentation and light transmission in the waterway. Excessive particles in the water quality can foster bacteria survival, among other impacts.
- NH3-N – this nitrogenous compound is specifically harmful to aquatic systems, can impact human health in high concentrations, contributes to algal blooms and low DO, and can indicate the efficiency of wastewater treatment processes.
- DO, grab samples – this indicator directly characterizes the ability of the effluent to support aquatic life and indicates the potential presence of nutrients and other oxygen-demanding substances (and thus the efficiency of treatment processes).
- CBOD5 – This indicator, which measures the depletion of oxygen over time by biological processes, indicates the efficiency of treatment.

[21] While the project considers many sources of fecal bacteria, recent research has indicated that human waste has a significantly higher risk of causing sickness in humans as compared to animal sources. Additional information about one research project illustrating this concept can be reviewed at http://oaktrust.library.tamu.edu/handle/1969.1/158640?show=full. (Gitter, 2017).

[22] 2021 data was not complete at the time of the analysis but was considered along with the previous 5 years.

[23] In consideration of the nutrient loading capacity of the plants, it should be noted that many nutrient parameters are not standard permit limits, and thus may not be tested. Based on review of correlations between nutrient parameters and flow for many stations the analyses did show a likelihood of plants as nutrient loading sources for non-permit limit parameters, particularly in effluent-dominated streams.

The parameter evaluations were based on the regulatory permit limits specific to each plant, and consider the number of exceedances by each plant, in each year, in each segment, and as a percentage of the total samples.

Indicator Bacteria (E. coli and Enterococcus)

E. coli and Enterococcus are indicator bacteria widely common to the guts of warm-blooded animals. While many strains of these bacteria are not themselves problematic, they are closely related to the presence of fecal waste and the various harmful pathogens they may contain. The water quality standard for indicator bacteria in ambient conditions in freshwater systems is 126 colony-forming units of *E. coli* per 100ml of water (for the geomean of samples) and 399 cfu/100ml (for single grab samples). For marine systems, Enterococcus is used, and its and these standards are generally applied as a permit condition for wastewater as well[24]. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, between category (average or maximum values), and by season. Ninety-one plants reported bacteria results for these segments in the data timeframe evaluated. The outcomes are summarized in Tables 7 through 11.

Table 14 – Fecal Bacteria Exceedance Statistics

Parameter	Number of Plants	Percentage of Plants
Plants in DMR	19	100%
Plants report bacteria	18	95%
Less than 1% violations	12	67%
1% to 5% violations	5	28%
5% to 10% violations	1	6%
Exceedances of geomean	1	6%
Exceedances of single grab	8	44%

As indicated in Table 14, the greater majority of plants have less than 1% of their samples in violation. However, roughly a third of all plants (6) have between 1 to 10% of their samples in violation, although the greater majority of this range is under 5%. The plants were generally more able to meet the geomean standard than the single grab standard indicating that conditions may have a high degree of variability, but the small size of the pool of exceedances limits meaningful extrapolation from this data.

[24] Several plants in the watershed have more stringent limits (e.g., 63 CFU/100mL) depending on site-specific conditions, or participation in TMDL projects like the Houston-area Bacteria Implementation Group (BIG). For all analyses, the actual limit for each plant was used in comparison with its plant-specific results. The range of limits applied to the average and maximum conditions ranges from 63 to 399 cfu/100ml.

Table 15 – Fecal Bacteria Exceedances by Season

Exceedance by Season by segment				
	Spring (Months 3-5)	Summer (6-8)	Fall (9-11)	Winter (12-2)
Total exceedances	9	12	4	4
Geomean exceedances	0	0	1	0
Single grab exceedances	9	12	3	4

There is not a strong relationship between season and violations of either the geomean or single grab criteria, given the relatively small number of violations overall (Table 15). However, historically, roughly three quarters of all violations happened in the spring and summer months.

Table 16 – Fecal Bacteria Exceedances by Year and Criteria

Exceedances by year, total							
	2016	2017	2018	2019	2020	2021	Total
Total Exceedances	9	6	7	2	1	4	29
Exceedances of Geomean	1	0	0	0	0	0	1
Exceedances of Single Grab	8	6	7	2	1	4	28

Table 16 shows that there is not a strong trend in exceedances from year to year[25], either in consideration of total exceedances, or in either the geomean or single grab criteria. Mirroring the data in Table 15, the greater majority of exceedances are due to the single grab criteria, which may indicate more variable conditions in plant effluent.

Table 17 demonstrates the distribution of plants and exceedances by size. Larger (1-5 million gallons per day (MGD)) plants had the most violations of the single grab criteria and total violations, representing over 85% of total exceedances in both cases. Over half the exceedances were represented by only two facilities, with almost a third represented by one facility alone. While the small number of exceedances overall makes any significant trend unsupportable, it is noteworthy that larger plants are disproportionately represented in the number of exceedances.

[25] It should be noted that the data for 2021 is not complete as of the initial publication of this report and will be included in a future revision at the end of the project period.

Table 17 – Fecal Bacteria Exceedances by Plant Size

Distribution of plants by size (permitted flow in million gallons a day)

Size	Number of plants	Percentage of plants
0>0.5 MGD	4	22%
0.5-1 MGD	2	11%
1-5MGD	5	28%
5-10 MGD	5	28%
> 10 MGD	2	11%

Exceedances by plant size

Plant Size	Number of exceedances (total)	Number of exceedances (geomean)	Number of exceedances (single grab)
0>0.5 MGD	1 (3.4%)	0 (0%)	1 (3.6%)
0.5-1 MGD	0 (0%)	0 (0%)	0 (0%)
1-5MGD	2 (6.9%)	1 (100%)	1 (3.6%)
5-10 MGD	25 (86.2%)	0 (0%)	25 (89.3%)
>10 MGD	1 (3.4%)	0 (0%)	1 (3.6%)

In general, the results indicated that a very small number of exceedances were noted, and two thirds of the facilities had less than 1% of their samples in exceedance of their relevant fecal bacteria standard. Maximum values were more commonly exceeded than average/geomean limits, indicating there is likely some variability in conditions even while the average values are within limits. Seasonality was not generally an issue, although there was a slight trend toward summer and spring months. Plant size was a significant indicator of potential to exceed limits[26] but the relatively small number of exceedances made this trend less meaningful overall. This may be in part due to relative frequency of monitoring, wherein large plants monitor more frequently and have more data to include in a geomean calculation, or it may be due to operational differences between larger manned plants and smaller unmanned plants. While WWTFs may be appreciable contributions under certain conditions, in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are likely still a point of concern for stakeholders.

Dissolved Oxygen

DO levels in WWTF effluent help indicate the efficiency of treatment processes. DO is generally more stable in effluent than it can be in ambient conditions because it is less subject to natural processes and

[26] It should be noted that self-reported data obscures underlying uncertainties about variability in conditions. This is exacerbated when comparing manned, larger facilities who are more likely to sample more frequently, and smaller facilities who sample less frequently and are generally unmanned.

variation in insolation. DO is measured in mg/L, and the permit limits with which results are compared vary based on the receiving water body and other factors. Unlike other contaminants, DO limits are based on a minimum, rather than maximum level, and represent a grab sample as opposed to a 24-hour monitoring event. Generally, permit limits for the data reviewed ranged between 4-6 mg/l. Evaluations for compliance with the permit limits were for all records, between years, and by season. 18 of the 19 plants in the watershed reported DO results for these segments during this period. Only one exceedance was observed, as shown in Table 19. Seasonal and inter-year comparisons are not included because no trend can be established from a single exceedance.

Table 18 - DO Monitoring Statistics, 2014-2019

Category	Number	Percentage of samples
Plants in DMR dataset	19	100%
Plants that report DO	18	95%
Total Records	1347	100%
Total Exceedances	1	<1%

Total Suspended Solids

TSS is generally an indication of wastewater treatment efficiency in removing solids. Substantial TSS levels in effluent can contribute to fostering bacterial regrowth as bacteria uses suspended particles as a protected growth medium. It can also decrease insolation in the water column and lead to deposition of particles on the substrate, etc. However, it can also be useful as an indicator that inefficient treatment may have led to other waste products (nutrients, etc.) being elevated in effluent.

Permit limits for TSS include a concentration based (average) limit (in mg/l) and a total weight-based limit (in weight/day). Both average and maximum monitored results exist for most plants. Evaluations for compliance with the permit limits were compared for all plants, between years, for both concentration and total volume, by season, and between category (average or maximum values). Eighteen plants reported TSS results for these segments during this period. The outcomes are summarized in Tables 19-21.

Table 19 - Monitoring Statistics for TSS, 2016-2021

Category	Number	% of samples
Plants in DMR dataset	19	100%
Plants reporting TSS	18	95%
Total Records	4,041	100%
Total Exceedances	42	1.0%
Total Exceedances, Concentration Average (mg/L)	21	50% of exceedances
Total Exceedances, Concentration Maximum (mg/L)	5	12% of exceedances
Exceedances, Weight Average (kg/d)	16	38% of exceedances

Table 20 - TSS Exceedances by Year, 2016-2021

Category	Total	2016	2017	2018	2019	2020	2021
Weight/Day, Average	16	0	1	0	1	2	12
Concentration/Day	26	1	1	0	6	4	11
Average	*21*	*1*	*1*	*0*	*6*	*4*	*9*
Maximum	*5*	*0*	*0*	*0*	*0*	*0*	*2*
Total	42	1	2	0	7	6	23
Average	*37*	*1*	*2*	*0*	*7*	*6*	*21*
Maximum	*5*	*0*	*0*	*0*	*0*	*0*	*2*

Table 21 - TSS Exceedances by Season, 2016-2021

Category	Winter (Months 12-2)	Spring (Months 3-5)	Summer (Months 6-8)	Fall (Months 9-11)
Weight/Day				
Average	8	4	4	0
Concentration	15	5	5	1
Average	10	5	5	1
Maximum	5	0	0	0
Total	26	13	13	1
Average	*18*	*9*	*9*	*1*
Maximum	*8*	*4*	*4*	*0*

Corresponding to other parameters, TSS violations were rare, making up approximately one percent of the total sample records. Exceedances have increased sharply in recent years, but a single facility[27] made up most of almost 75% of all permit violations. Removing that outlier leaves a set of exceedances too small to make meaningful comparisons on year or season. In general, TSS results indicate WWTFs are operating within their permit limits with little issue and that TSS inputs from WWTFs are not likely a chronic issue of importance for the waterways. However, it is likely that they are of concern to stakeholders on a localized basis and may be indicative of opportunities for WWTF improvement. Unlike other constituents, however, the exceedances occurred at a relatively smaller number of facilities.

Ammonia Nitrogen

NH3-N is a nitrogenous compound that can be toxic in concentration to people and aquatic wildlife and can also contribute to the deleterious impacts of elevated nutrient loadings. Additionally, excessive NH3-N levels in effluent indicate inefficient wastewater treatment and may correlate to the presence of improperly treated sewage.

Like TSS, permit limits for NH3-N include a concentration based (average) limit (in mg/l) and a total weight-based limit (in weight/day). Both average and maximum permit limit values exist for most plants. Evaluations for compliance with the permit limits were compared between plants, between years, between seasons, and between category (average or maximum values). Eighteen plants reported NH3-N results during the original analysis period. The outcomes are summarized in Tables 22 through 24.

[27] Permit TX0094226 represents 76% of exceedances, but has a permitted flow of only 0.035 MGD, limiting its impact to the system.

Table 22 - Ammonia Exceedances, 2016-2021

Category	Number	% of samples
Plants in DMR dataset	19	100%
Plants reporting TSS	18	95%
Total Records	4041	100%
Total Exceedances	154	3.8%
Total Exceedances, Concentration Average (mg/L)	40	26% of exceedances
Total Exceedances, Concentration Maximum (mg/L)	31	20% of exceedances
Exceedances, Weight Average (kg/d)	83	54% of exceedances

Table 23 - Ammonia Exceedances by Year, 2016-2021

Category	Total	2016	2017	2018	2019	2020	2021
Weight/Day							
Average	83	14	13	16	8	15	17
Concentration	71	12	6	15	0	8	11
Average	*40*	*10*	*4*	*9*	*0*	*6*	*11*
Maximum	*31*	*2*	*2*	*6*	*0*	*2*	*0*
Total	154	26	19	31	8	23	28
Average	*123*	*24*	*17*	*25*	*8*	*21*	*28*
Maximum	*31*	*2*	*2*	*6*	*0*	*2*	*0*

Table 24 - Ammonia Exceedances by Season, 2016-2021

Category	**Winter (Months 12-2)**	**Spring (Months 3-5)**	**Summer (Months 6-8)**	**Fall (Months 9-11)**
Weight/Day				
Average	19	19	24	21
Concentration	7	23	27	14
Average	4	12	16	8
Maximum	3	11	11	6
	3	7	5	4
Total	26	42	51	35
Average	23	31	40	29
Maximum	3	11	11	6

Corresponding to other parameters, Ammonia violations were more frequent, making up roughly one percent of the total sample records. However, 63% of all exceedances were from a single facility. There is no clear trend from year to year, and there was a slight trend toward exceedances in spring and summer month. However, the removal of the single facility outlier reduces the appearance of a trend. In general, ammonia results indicate WWTFs are operating within their permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for the waterways. The single facility with the lion's share of the exceedances has a permitted flow of only 0.035 MGD, reducing its potential impact on the system. However, it is likely that they are of concern to stakeholders on a localized basis and may be indicative of opportunities for WWTF improvement.

CBOD5

CBOD5 is not a pollutant itself, but is an indicator of biological oxygen demand, and thus potentially the presence of improperly treated effluent in a sample.

Like TSS and NH3-N, permit limits for CBOD5 include a concentration based (average) limit (in mg/l) and a total weight-based limit (in weight/day). For this evaluation, records for both were considered because of the nature of the test. Both average and maximum permit limit values exist for concentration limits for most plants. Evaluations for compliance with the permit limits were compared between plants, between seasons, between years, and between category (average or maximum values). Eighteen plants reported CBOD5 results for these segments during this period. The outcomes of these analyses are summarized in Tables 25 through 27.

Table 25 - CBOD5 Exceedances, 2016-2021

Category	Number	% of samples
Plants in DMR dataset	19	100%
Plants reporting TSS	18	95%
Total Records	4,041	100%
Total Exceedances	60	1.4%
Total Exceedances, Concentration Average (mg/L)	36	60% of exceedances
Total Exceedances, Concentration Maximum (mg/L)	3	5% of exceedances
Exceedances, Weight Average (kg/d)	21	35% of exceedances

Table 26 - CBOD5 Exceedances by Year, 2016-2021

Category	Total	2016	2017	2018	2019	2020	2021
Weight/Day							
Average	21	0	0	0	6	3	12
Concentration	39	2	2	2	8	8	15
Average	36	2	2	2	8	8	14
Maximum	3	0	0	0	0	0	1

Total	60	2	2	2	14	11	27
Average	57	2	2	2	14	11	26
Maximum	3	0	0	0	0	0	1

Table 27 - CBOD5 Exceedances by Season, 2016-2021

Category	Winter (Months 12-2)	Spring (Months 3-5)	Summer (Months 6-8)	Fall (Months 9-11)
Weight/Day				
Average	7	6	1	7
Concentration	13	13	7	5
Average	11	13	7	5
Maximum	2	0	0	0
	1	0	1	0
Total	20	19	8	12
Average	18	19	8	12
Maximum	2	0	0	0

Corresponding to other parameters, CBOD5 violations were relatively rare, making 1.4% of the total sample records. Again, a single facility accounted for 80% of the exceedances, leaving a very small set of exceedances from which to draw trends. The yearly rate of exceedance was variable and increasing in recent years, but due largely to the single outlier facility. Absent that outlier, there was not a meaningful seasonal trend. In general, CBOD5 results indicate most WWTFs are operating within their permit limits with little issue and that inputs that would be demonstrated by CBOD5 from WWTFs are not likely a chronic issue of importance for the waterways. The outlier facility's flow is 0.035 MGD, minimizing its potential impact on the system as a whole. However, it is likely that they are of concern to stakeholders on a localized basis and may be indicative of opportunities for WWTF improvement.

Overview of results

While there were exceedances for the evaluated constituents, the majority of plants met their permit limits the majority of the time without significant issue. Even allowing for variability in effluent conditions not reflected in the DMR results, it is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. However, the potential for localized inputs may be underrepresented by the overall impact of WWTFs for the watershed.

However, in interpreting these results, it should be noted that while WWTFs may not be the largest source of fecal indicator bacteria, they are likely one of the human fecal waste sources, and therefore have an inherently higher pathogenic potential than other sources. Additionally, unlike other source of natural and diffuse fecal waste in the watersheds, WWTF effluent has both regulatory controls and voluntary measures by which improperly treated wastewater may be addressed. Given the nature of WWTF effluent as a human pollutant, and our direct ability to influence its character, WWTF bacteria should be considered as a potential focus for some best management practices. While other constituents (e.g., nutrients) are not necessarily any more harmful than other sources in the watershed, the principle of direct control of effluent applies to their consideration as well. This is exacerbated for nutrients given the lack of permit limits for some nutrient parameters, and the likelihood that WWTFs may be appreciable nutrient loading sources in effluent dominated streams.

Sanitary Sewer Overflows

Unlike treated WWTF effluent, SSOs represent a high, if episodic risk, because they can have concentrations of bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal matter, making it a significant health risk where SSOs are sizeable and/or chronic issues. The causes of SSOs vary from human error to infiltration of rainwater into sewer pipes. Data used for these analyses is self-reported and may vary in quality. Even in the best of circumstances, the ability to accurately gauge SSO volumes or even occurrences in the field is limited by several factors. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges. SSO causes were broken into four broad categories with several subcategories each, to reflect the breakdown in the TCEQ SSO database. It should be noted, however, that this categorization depends on the accuracy of the data reported by the utilities. Additionally, while a single cause is typically listed on the SSO report, many SSOs are caused by a combination of factors[28].

This study considered six years of TCEQ SSO violation data for 2016-2021[29]. There were 338 SSO records from 12 of the 19 plants with collection systems considered for the watershed area (Table 28). Of those 12 plants, eight plants had more than five SSOs, and of those eight plants, six plants had 10 or more SSOs. Three plants had a 6-year total in excess of 75 SSOs each.

Table 28 – Summary of SSOs, 2016-2021

Category	Number of plants	Number of SSOs	% of SSOs	*Volume of SSOs*	*% of SSO Volume*
Plants in SSO dataset	12	338	100%	*3,010,610*	*100.0%*
Plants with <5 SSOs	4	10	3%	*30,050*	*1.0%*
Plants with 5-10 SSOs	2	17	5%	*76,250*	*2.5%*
Plants with 10-30 SSOs	3	68	20%	*1,295,407*	*43.0%*
Plants with 30-90- SSOs	3	243	71%	*1,608,453*	*53.4%*

Volume of SSOs corresponded roughly with numbers, but with the plants in the 10-30 SSO range represented with disproportionately large volumes (Table 29). Plants with the largest number of SSOs still made up the largest volume, but disproportionately smaller than the numbers they represented. On

[28] e.g., fats, oils, and grease collecting in lift station motors can cause overflows in high rain events when excess water is in a system. The event may be listed as lift station failure, but FOG and inflow and infiltration of rainwater were also causative elements.

[29] When the report was compiled, the 2021 dataset was not yet complete.

an individual plant scale, the percentages vary even more greatly. The top two plants whose number of SSOs represent roughly half of all SSOs by number, only represent 5% of the total SSO volume, whereas the plant with the third largest number of SSOs represented nearly half the total SSO volume. It should be noted that the period this assessment covers includes Hurricane Harvey in 2017, as well as other high profile flooding events, which impacted this area with storm surge and heavy flooding. Some portion of the volumes represented here are due to those storms, and it is likely a large volume of wastewater from SSOs during the storms is unaccounted for due to the conditions in the field.

Table 29 - Summary of SSO Volume, 2016-2021

Category	Number of plants	Volume of SSOs (in gallons)	% of SSO Volume
Plants in SSO dataset	12	3.010,610	100%
Plants with <10,000 gallons	3	8,900	0.3%
Plants with 10,000-50,000 gallons	4	128,771	4.3%
Plants with 50,000-500,000 gallons	3	363,674	12.1%
Plants with >500,000 gallons	2	2,509,265	83.3%

As shown in Table 30, the number of SSOs by year has not demonstrated a strong tend toward improvement or degradation, with the exception of the 2017 outlier year. While that outlier is an important consideration as to the impact of weather events on SSO frequency in a watershed with frequent flooding events, it should not be taken as an indicator of a normal year.

As noted previously, cause is an important consideration in SSO analysis. Finding patterns in trends of cause can point to the specifics of an issue in a watershed or subarea thereof. Causes reflected in this analysis (Table 30), show a fairly consistent pattern (again, with 2017 as an outlier.). Weather related issues cause about a quarter of SSO overall and range from 17-34% yearly. Malfunctions represent another quarter and range from 15-78% yearly. Blockages represent approximately 44% of the total on average and range from 20-60% yearly. Lastly, unknown or other causes typically represent the smallest portion, only 4% overall and ranging only as high as 7% yearly. Even though 2017 had a disproportionate number of weather events, it still did not entirely skew this range, as the largest reported category that year was actually blockages.

Table 30 - Summary of SSO Causes by Year and Number, 2016-2021

Cause	2016	2017	2018	2019	2020	2021	Total
Weather	**6**	**45**	**12**	**13**	**16**	**0**	**92**
Rain / Inflow / Infiltration	*5*	*9*	*9*	*10*	*16*	*0*	**49**
Hurricane/Force Majeure	*1*	*36*	*3*	*3*	*0*	*0*	**43**
Malfunctions	**6**	**20**	**13**	**18**	**16**	**11**	**84**
Human Error	*1*	*0*	*6*	*1*	*2*	*1*	**11**
Power Failure	*1*	*5*	*1*	*0*	*1*	*7*	**15**
Equipment Malfunction	*3*	*10*	*6*	*16*	*8*	*3*	**46**
Collection System Structural Failure	*1*	*5*	*0*	*1*	*5*	*0*	**12**
Blockages	**14**	**63**	**44**	**2**	**21**	**3**	**147**
Blockage in Collection System-Other Cause	*8*	*48*	*28*	*0*	*7*	*0*	**91**
Blockage in Collection System Due to Fats/Grease	*6*	*15*	*16*	*2*	*14*	*3*	**56**
Unknown or Other Cause	***2***	***4***	***2***	***6***	***1***	***0***	**15**
Total	**28**	**132**	**71**	**39**	**54**	**14**	**338**
% Total SSOs	*8.3%*	*39.1%*	*21.0%*	*11.5%*	*16.0%*	*4.1%*	*100.0%*

While the number of SSOs indicates the frequency with which sewage systems have events, and thus the chronicity of the load from those plants, the volume of SSOs (Table 32) indicates the extent of the impact they have (i.e., a small plant with 100 small SSOs may produce a more chronic, but smaller discharge than a large plant with a single SSO of a much larger volume). Malfunctions, as a broad category, remains the primary volumetric source of SSOs, accounting for 53.5% of all SSOs. Weather-related events are next at 38.9%, followed by blockages at 4.5%, with an unknown/other portion making up 2.9% of volume.

As Table 31 indicates, the examination of SSOs by cause and year for volume does not correlate well with the causes by number of SSOs over the 6-year period. The primary discrepancy is that while blockages make up an appreciable share of the number of SSOs, they are a relatively minor amount of actual reported volume, while malfunctions account for nearly double as much volume as they do number of SSOs.

Table 31 - Comparison of SSO Causes by Number and Volume, 2016-2021

Cause	% of SSOs by Number	% of SSO Volume
Weather	27.2%	38.9%
Malfunctions	24.8%	53.5%
Blockages	43.5%	4.5%
Other/Unknown	4.4%	2.9%

Table 32 - Summary of SSO Causes by Year and Volume in Gallons, 2016-2021

Cause	2016	2017	2018	2019	2020	2021	Total
Weather	**5,250**	**78,712**	**40,500**	**711,281**	**336,100**	**0**	1,171,843
Rain / Inflow / Infiltration	*4,950*	*45,201*	*18,000*	*709,231*	*336,100*	*0*	1,113,482
Hurricane/Force Majeure	*300*	*33,511*	*22,500*	*2,050*	*0*	*0*	58,361
Malfunctions	**15,472**	**318,085**	**124,415**	**830,769**	**290,925**	**33,700**	1,613,366
Human Error	*1,200*	*0*	*82,215*	*0*	*2,100*	*30,200*	115,715
Power Failure	*200*	*34,660*	*100*	*0*	*8,000*	*3,500*	46,460
Equipment Malfunction	*14,070*	*268,425*	*42,100*	*829,969*	*218,825*	*0*	1,373,389
Collection System Structural Failure	*2*	*15,000*	*0*	*800*	*62,000*	*0*	77,802
Blockages	**2,427**	**51,124**	**38,483**	**558**	**42,006**	**602**	135,200
Blockage in Collection System-Other Cause	*985*	*14,484*	*34,334*	*0*	*37,150*	*0*	86,953
Blockage in Collection System Due to Fats/Grease	*1,442*	*36,640*	*4,149*	*558*	*4,856*	*602*	48,247
Unknown or Other Cause	***5,600***	***27,500***	***5,060***	***16,041***	***36,000***	***0***	90,201
Total	**28,749**	**475,421**	**208,458**	**1,558,649**	**705,031**	**34,302**	**3,010,610**

Table 33 summarizes the consideration of seasonal impacts on SSOs. The number of SSOs is almost evenly distributed across the seasons, showing no trend. In volume, spring SSOs were predominant, followed by fall, both of which may be influenced by flooding events. However, the unequal distribution of number and volume across all reporting plants weighs against a broad seasonal trend, as issues may mor likely be specific to individual systems.

Table 33 - Seasonality of SSO occurrence

Season	Number	Volume (gallons)
Winter	86 (25.4%)	154,227 (5.1%)
Spring	76 (22.5%)	1,819,941 (60.5%)
Summer	86 (25.4%)	346,658 (11.5%)
Fall	90 (26.6%)	689,784 (22.9%)
Total	338 (100%)	3,010,610 (100%)

The breakdown of SSOs by cause over the entire watershed should not be taken as an accurate cause profile for individual areas in the watershed but reflects the general challenges to the area's wastewater infrastructure. In the spatial review of the SSO data, areas in the north and central east, areas that correspond generally to older systems and more dense development, had the greatest number of issues. This evaluation should be balanced against the consideration that identification and reporting of SSOs are likely more readily accomplished by larger manned systems in more populous areas, which may skew the data.

SSO Summary

SSOs are always a concern in watersheds with bacterial impairment and vulnerability to nutrient loading. Their concentrations of untreated human waste pose a disproportionately high risk to human health during recreation, and their episodic nature can make them an acute risk while they are ongoing. In terms of chronic loading, SSOs volumes in the project area are generally too small on an average basis to move conditions in the major waterways of the system in general. For comparison, a single plant of small to moderate size may have a discharge of 3 MGD, while the sum of all SSOs in the project area for a year is less than 3 million gallons. The SSOs are far greater in concentration, but their relatively minor volumes negate them to some degree as a primary source in average conditions.

However, given their pathogenic potential, inherently close proximity to urban populations, and the principle of focusing on those sources within our control, SSOs should remain as a consideration for best management practices (BMPs) in the watersheds. A specific point of interest for this data in Clear Creek is the impact and potential future implications for increasing high flow events, which can easily overwhelm even well-functioning sanitary collections systems.

4.0 Outcomes and Implications

The review of water quality data for the Clear Creek watershed provided a better understanding of the character of water quality issues in these systems and will inform subsequent stakeholder decisions. The primary questions answered were in regard to the sufficiency of the data, the extent and severity of water quality trends, seasonality of water quality issues, and the potential impact of wastewater effluent and SSOs.

In general, the review concluded that data was sufficient for all analyses.

As discussed in the individual analyses, the water quality issues facing this watershed are widespread in extent. Trends are mixed, with some positive trends, but increasing levels and ubiquity of issues with some other constituents. Compared to future growth projections, it is likely that increased development in the watershed will continue to alter the balance of pollutant sources and change the hydrologic processes and time frames by which pollutants reach the waterways in precipitation events.

Permitted wastewater effluent was generally of good quality and unlikely to be a widespread water quality issue except in limited scales and timeframes. The exception to this is the likelihood that nutrients without permit limits are source loads from plants, especially in effluent-dominated streams. There were few statistically significant relationships between exceedance of water quality standards and WWTF permit limits, or incidences of SSOs, and seasonal change other than expected relationships evident in DO levels in ambient conditions. SSOs were present in all areas of the watershed, in numbers that were relatively high for comparative areas, likely owing to the relative age of systems within some areas of the watershed and the relative vulnerability of much of the area to high rainfall events and periodic flooding.

Overall, water quality in these watersheds faces many challenges, but is within the range which may be successfully addressed through best management practices under a watershed-based plan. With continued growth of the watershed continuing to push west and south, while existing densely developed areas continue to age, the implication for future water quality is likely negative without intervention. Subsequent efforts should be made to identify causes and sources of the primary constituent of concern (indicator bacteria), and to characterize nutrient sources further to identify areas within the project watersheds most vulnerable to pollutant loadings and/or best suited for BMP siting.

Appendix A – Monitoring Site Data

Table 35 shows the results of trends analyses, by monitoring station, for all constituents evaluated. The period of data for the effort is 2014-2020, although data for each station may vary as indicated in the charts. Charts for each parameter evaluated for each station are available as a separate document (Clear Creek Water Quality Report Appendix B.pdf) available on the project website at www.clearcreekpartnership.com.

Station ID	Parameter	Trend
11425	Ammonia-N	No Change
11425	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
11425	E. Coli	No Change
11425	Instantaneous Flow	No Change
11425	Nitrate-N	No Change
11425	Temperature	No Change
11425	Total Phosphorus	No Change
11425	Total Suspended Solids	No Change
11425	pH	No Change
11446	Ammonia-N	Improving
11446	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
11446	Enterococci	No Change
11446	Nitrate-N	No Change
11446	Temperature	No Change
11446	Total Phosphorus	No Change
11446	Total Suspended Solids	Deteriorating
11446	pH	No Change
11450	Ammonia-N	No Change
11450	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
11450	E. Coli	No Change
11450	Nitrate-N	No Change
11450	Temperature	No Change

Station ID	Parameter	Trend
11450	Total Phosphorus	No Change
11450	Total Suspended Solids	No Change
11450	pH	No Change
11452	Ammonia-N	Improving
11452	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
11452	E. Coli	No Change
11452	Instantaneous Flow	No Change
11452	Nitrate-N	No Change
11452	Temperature	No Change
11452	Total Phosphorus	No Change
11452	Total Suspended Solids	No Change
11452	pH	Deteriorating
16473	Ammonia-N	No Change
16473	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16473	E. Coli	No Change
16473	Instantaneous Flow	No Change
16473	Nitrate-N	No Change
16473	Temperature	No Change
16473	Total Phosphorus	No Change
16473	Total Suspended Solids	No Change
16473	pH	Improving
16475	Ammonia-N	No Change
16475	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16475	Enterococci	No Change
16475	Nitrate-N	No Change
16475	Temperature	No Change
16475	Total Phosphorus	No Change
16475	Total Suspended Solids	No Change
16475	pH	No Change
16493	Ammonia-N	No Change

Station ID	Parameter	Trend
16493	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16493	E. Coli	No Change
16493	Instantaneous Flow	No Change
16493	Nitrate-N	No Change
16493	Temperature	No Change
16493	Total Phosphorus	No Change
16493	Total Suspended Solids	No Change
16493	pH	No Change
16573	Ammonia-N	No Change
16573	Chlorophyll-a	No Change
16573	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16573	Enterococci	No Change
16573	Nitrate-N	No Change
16573	Temperature	No Change
16573	Total Phosphorus	Improving
16573	Total Suspended Solids	No Change
16573	pH	No Change
16576	Ammonia-N	No Change
16576	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16576	Enterococci	No Change
16576	Nitrate-N	No Change
16576	Temperature	No Change
16576	Total Phosphorus	No Change
16576	Total Suspended Solids	No Change
16576	pH	No Change
16611	Ammonia-N	No Change
16611	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16611	E. Coli	No Change
16611	Instantaneous Flow	No Change
16611	Nitrate-N	No Change

Station ID	Parameter	Trend
16611	Temperature	No Change
16611	Total Phosphorus	No Change
16611	Total Suspended Solids	No Change
16611	pH	No Change
16677	Ammonia-N	No Change
16677	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
16677	E. Coli	No Change
16677	Instantaneous Flow	No Change
16677	Nitrate-N	No Change
16677	Temperature	No Change
16677	Total Phosphorus	No Change
16677	Total Suspended Solids	No Change
16677	pH	No Change
17068	Ammonia-N	Improving
17068	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
17068	E. Coli	No Change
17068	Instantaneous Flow	No Change
17068	Nitrate-N	No Change
17068	Temperature	No Change
17068	Total Phosphorus	No Change
17068	Total Suspended Solids	No Change
17068	pH	No Change
17928	Ammonia-N	Improving
17928	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
17928	Enterococci	No Change
17928	Nitrate-N	No Change
17928	Temperature	No Change
17928	Total Phosphorus	No Change
17928	Total Suspended Solids	No Change
17928	pH	No Change

Station ID	Parameter	Trend
18591	Ammonia-N	No Change
18591	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
18591	E. Coli	No Change
18591	Instantaneous Flow	No Change
18591	Nitrate-N	No Change
18591	Temperature	No Change
18591	Total Phosphorus	No Change
18591	Total Suspended Solids	Deteriorating
18591	pH	No Change
18639	Ammonia-N	No Change
18639	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
18639	E. Coli	No Change
18639	Instantaneous Flow	No Change
18639	Nitrate-N	No Change
18639	Temperature	No Change
18639	Total Phosphorus	No Change
18639	Total Suspended Solids	No Change
18639	pH	No Change
20010	Ammonia-N	No Change
20010	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
20010	E. Coli	No Change
20010	Instantaneous Flow	No Change
20010	Nitrate-N	No Change
20010	Temperature	No Change
20010	Total Phosphorus	No Change
20010	Total Suspended Solids	No Change
20010	pH	No Change
21925	Ammonia-N	No Change
21925	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
21925	E. Coli	No Change

Station ID	Parameter	Trend
21925	Instantaneous Flow	No Change
21925	Nitrate-N	No Change
21925	Temperature	No Change
21925	Total Phosphorus	No Change
21925	Total Suspended Solids	No Change
21925	pH	No Change

Appendix B – Segment/Tributary Trends Data

Table 35 shows the results of trends analyses, by segment or tributary, for all constituents evaluated. The period of data for the effort is 2014-2020, although data for each station may vary as indicated in the charts. Charts for each parameter evaluated for each segment/tributary are available as a separate document (Clear Creek Water Quality Report Appendix B.pdf) available on the project website at www.clearcreekpartnership.com.

Table 34 - Summary of parameter trends by segment or tributary

Segment	Parameter	Trend
1101	Ammonia-N	Improving
1101	Chlorophyll-a	No Change
1101	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101	E. Coli	No Change
1101	Enterococci	No Change
1101	Nitrate-N	No Change
1101	Temperature	Deteriorating
1101	Total Phosphorus	No Change
1101	Total Suspended Solids	Deteriorating
1101	pH	No Change
1101A	Ammonia-N	No Change
1101A	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101A	Dissolved Oxygen (24-hour Minimum / Grab Minimum)	No Change
1101A	E. Coli	No Change
1101A	Instantaneous Flow	No Change
1101A	Nitrate-N	No Change
1101A	Temperature	No Change
1101A	Total Phosphorus	No Change
1101A	Total Suspended Solids	No Change
1101A	pH	No Change
1101B	Ammonia-N	No Change

Segment	Parameter	Trend
1101B	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101B	E. Coli	No Change
1101B	Instantaneous Flow	No Change
1101B	Nitrate-N	No Change
1101B	Temperature	No Change
1101B	Total Phosphorus	No Change
1101B	Total Suspended Solids	No Change
1101B	pH	No Change
1101C	Ammonia-N	Improving
1101C	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101C	Enterococci	No Change
1101C	Nitrate-N	No Change
1101C	Temperature	No Change
1101C	Total Phosphorus	No Change
1101C	Total Suspended Solids	No Change
1101C	pH	No Change
1101D	Ammonia-N	No Change
1101D	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101D	Enterococci	No Change
1101D	Nitrate-N	No Change
1101D	Temperature	No Change
1101D	Total Phosphorus	No Change
1101D	Total Suspended Solids	No Change
1101D	pH	No Change
1101E	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101E	Dissolved Oxygen (24-hour Minimum / Grab Minimum)	No Change
1101E	Instantaneous Flow	No Change
1101F	Ammonia-N	No Change
1101F	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1101F	E. Coli	No Change

Segment	Parameter	Trend
1101F	Instantaneous Flow	No Change
1101F	Nitrate-N	No Change
1101F	Temperature	No Change
1101F	Total Phosphorus	No Change
1101F	Total Suspended Solids	Deteriorating
1101F	pH	No Change
1102	Ammonia-N	Improving
1102	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102	E. Coli	No Change
1102	Instantaneous Flow	No Change
1102	Nitrate-N	No Change
1102	Temperature	No Change
1102	Total Phosphorus	No Change
1102	Total Suspended Solids	No Change
1102	pH	Deteriorating
1102A	Ammonia-N	No Change
1102A	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102A	E. Coli	No Change
1102A	Instantaneous Flow	Deteriorating
1102A	Nitrate-N	No Change
1102A	Temperature	No Change
1102A	Total Phosphorus	No Change
1102A	Total Suspended Solids	No Change
1102A	pH	No Change
1102B	Ammonia-N	No Change
1102B	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102B	E. Coli	No Change
1102B	Instantaneous Flow	No Change
1102B	Nitrate-N	No Change
1102B	Temperature	No Change

Segment	Parameter	Trend
1102B	Total Phosphorus	No Change
1102B	Total Suspended Solids	No Change
1102B	pH	Improving
1102C	Ammonia-N	Improving
1102C	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102C	E. Coli	No Change
1102C	Instantaneous Flow	No Change
1102C	Nitrate-N	No Change
1102C	Temperature	No Change
1102C	Total Phosphorus	No Change
1102C	Total Suspended Solids	No Change
1102C	pH	No Change
1102D	Ammonia-N	No Change
1102D	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102D	E. Coli	No Change
1102D	Instantaneous Flow	No Change
1102D	Nitrate-N	No Change
1102D	Temperature	No Change
1102D	Total Phosphorus	No Change
1102D	Total Suspended Solids	No Change
1102D	pH	No Change
1102F	Ammonia-N	No Change
1102F	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102F	E. Coli	No Change
1102F	Instantaneous Flow	No Change
1102F	Nitrate-N	No Change
1102F	Temperature	No Change
1102F	Total Phosphorus	No Change
1102F	Total Suspended Solids	No Change
1102F	pH	No Change

Segment	Parameter	Trend
1102G	Ammonia-N	No Change
1102G	Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	No Change
1102G	E. Coli	No Change
1102G	Instantaneous Flow	No Change
1102G	Nitrate-N	No Change
1102G	Temperature	No Change
1102G	Total Phosphorus	No Change
1102G	Total Suspended Solids	No Change
1102G	pH	No Change