**FIELD PARAMETERS** are water quality constituents that can be collected on-site and generally include: temperature, pH, conductivity, dissolved oxygen, stream flow, and secchi disc.

**Temperature** of the water affects its ability to hold dissolved oxygen. It can also impact the biological functions of aquatic organisms.

**Conductivity** is the measurement of dissolved salts such as chloride, sulfate, and sodium in the stream as well as the streams capacity to conduct electricity. Elevated concentrations of these dissolved salts can impact aquatic life and drinking water sources.

**Dissolved Oxygen (DO)** is the amount of oxygen readily available in the streams to support aquatic life. DO can be suppressed by the decomposition of organic material or excess of bacteria within the water body.

**pH** is the measure of hydrogen ion concentration in an aqueous solution. It is a measure of acidity or alkalinity of the water body. Chemical and biological processes can be affected by changes in pH. Changes in pH can be affected by nonpoint and point source pollution, dissolved carbon dioxide, and dissolved constituents.

**Stream Flow** is an important parameter that affects water quality. Low flow conditions that are more common during the summer months create less than ideal conditions for aquatic organisms. Under these conditions, streams have a lower assimilative capacity for waste inputs from point and nonpoint source pollutants.

**Secchi Disc Transparency** is the measure of depth that light penetrates through the water column, thus the depth at which aquatic plants can grow.

**CONVENTIONAL PARAMETERS** are typical water quality parameters that require laboratory analysis and generally include: nutrients, chlorophyll-a, total suspended solids, turbidity, hardness, chloride, and sulfate. These parameters and their effect are explained in the table below.

**Nutrients** include the various forms of nitrogen and phosphorus. Elevated nutrient concentrations may result in excessive aquatic plant growth and can make a water body unfit for its intended use(s).

**Total Hardness** is a total measure of certain ions in the water, primarily calcium and magnesium. Typically, higher concentrations in the stream can reduce the toxicity of heavy metals.

**Total Dissolved Solids** is the measure of inorganic and organic material combined in the water column.

| Parameter | Description | Impacts/Concerns |
| --- | --- | --- |
| Bacteria | Specifically, the *Escherichia coli bacteria*, is used as an indicator of possible presence of disease-causing organisms. *E. coli* is reported as Most Probable Number per 100 milliliters (MPN/100mL). It is directly relatable to the units used for the primary contact recreation 1 standard of 126MPN/100mL. | Indicates that the water body is possibly contaminated by animal and or human fecal matter. Contact with contaminated water can cause illness when exposed or ingested. It can cause severe disease and can be fatal for weakened immune systems. |
| Total Suspended Solids | Indicates the amount of particulate matter suspended in the water column. | Can prevent light from penetrating for effective plant growth. With the additional surface area in the water column, gives toxicants a surface to cling to and distribute. |
| Ammonia Nitrogen | Ammonia is one of several forms of nitrogen that exists in aquatic environments. It can enter a stream through direct means such as wastewater effluent, runoff, nitrogen fixation, and animal excretion. | Can have direct toxic effects on aquatic life. In high enough levels, organisms struggle to get rid of the toxicant causing a buildup in tissues and regulatory systems. External factors such as temperature and pH can cause higher toxicity. |
| Nitrates | A form of nitrogen that can be found in aquatic environments. It is an essential plant nutrient that is a natural part to the aquatic environment. | Nitrates when in excess can cause a large increase in plant growth (native or non-native) and increase eutrophication within the water column. A rapid increase of plant growth can lower the dissolved oxygen causing hypoxia which is toxic to aquatic organisms. |
| Total Kjeldahl Nitrogen | The sum of organic nitrogen compounds and ammonia nitrogen. | Higher concentrations can indicate algal blooms as well as eutrophication and depressed dissolved oxygen. |
| Total Phosphorus | Is an essential nutrient for plants and animals that is a natural part to the aquatic environment. Both organic and inorganic phosphorus can be suspended and dissolved in the water column. | Naturally low in freshwater streams, an increase in concentration can cause large algal blooms, and overgrowth in aquatic plants, death of some fish and invertebrates, as well as the depression of dissolved oxygen. |
| Chloride | One of the major components in total dissolved solids. | In high enough concentrations, can be toxic to aquatic life and cause a higher corrosive potential of water. This in turn can affect the quality of drinking water. |
| Sulfate | One of the major components in total dissolved solids and is found naturally in water. | Can cause illness when ingested in higher concentrations and can contribute to acidification of surface water. |
| Chlorophyll *a* | Is a plant pigment in which concentrations of this compound is an indicator for the amount of algal biomass and growth in the water. | Can cause streams to be aesthetically unpleasing and depress dissolved oxygen. |
| Turbidity | Is the measure of clarity and light transmitting properties in water. An increase in turbidity is usually caused by suspended solids, clay, microscopic organisms, and finely divided inorganic and organic matter. | Due to the suspension of particles in the water column, this can increase the temperature of water and suppress dissolved oxygen concentrations. Higher turbidity can block light for aquatic plants reducing the production of dissolved oxygen. It can also be harmful to fish and their growth rates. |

## OTHER PARAMETERS

**Biological and Habitat Assessment** includes a collection of fish community data, benthic macroinvertebrate (insect) data, and the measurement of physical habitat parameters. This information is used to determine whether the stream adequately supports a diverse and desirable biological community. The physical, chemical, and biological data are used together to provide an integrated assessment of aquatic life use designation.

**24-Hour DO** studies perform measurements of DO in frequent intervals in a 24-hour period. The average and minimum concentrations in the 24-hour period are compared to corresponding criteria. This type of monitoring considers the diurnal variation of DO and avoids the bias in samples taken only at certain times of the day.

**Metals in Water**, such as mercury or lead, typically exist in low concentrations, but can be toxic to aquatic life or human health when certain levels are exceeded. To obtain accurate data at low concentrations, GBRA uses special clean methods that minimize the chance for sample contamination and provide high quality data.

**Organics and Metals in Sediment** could be a source of toxicants for the overlying water, though currently there are no numeric sediment standards.

**Organics in Water**, such as pesticides or fuels, can be toxic to aquatic life or human health when certain levels are exceeded.

This Basin Summary Report includes an overview of general water quality conditions in the Guadalupe River Basin, a discussion of TCEQ's latest biennial assessment of the surface water quality, and a review of significant trends in water quality over time in this basin. Relevant supporting information, such as land use, soil and vegetation, point source discharges, and results of biological analyses, if any, are also considered and included in the discussion as appropriate. The goal of this report is to highlight and prioritize concerns or impairments, explain probable causes of water quality issues, and recommend and inform future actions (e.g. future monitoring activities, implementation of control or remediation actions, public outreach) to address these concerns.

Water quality conditions and analyses in this Basin Summary Report are organized by sub-watershed, segment, and station. A watershed is the total area drained by a particular stream. The Guadalupe River Basin is broken into 15 sub-watersheds for this report. For assessment and trend analysis, the watersheds were broken down further into segments. Segments and unclassified segments are water bodies or specific portions of a water body with a specific location, defined dimensions, and designated or presumed uses. Segments are contiguous reaches that exhibit similar physical, chemical, and biological characteristics for which a uniform set of standards apply.

## Segment Impairments and Concerns

Segment impairments and concerns discussed in this report are determined by TCEQ and documented in their 2022 Integrated Report. In compliance with sections 305(b) and 303(d) of the Federal Clean Water Act, TCEQ evaluates water bodies in the state and identifies those that do not meet the uses and criteria defined in the Texas Surface Water Quality Standards. EPA has established guidance that directs TCEQ to document and submit the assessment results to EPA biennially in even numbered years. The 2022 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d) summarizes the condition of the state's surface waters, including concerns for public health, fitness for use by aquatic species and other wildlife, and specific pollutants and their possible sources (TCEQ, 2022). It describes the status of water quality in all surface water bodies in the state that were evaluated for the assessment period. The data used in the assessment comes from various sources, including the Guadalupe River Basin CRP partners, TCEQ's Surface Water Quality Monitoring program, and other contributors.

A variety of data are included in TCEQ's assessment process, including water quality grab sample data, data collected over a 24-hour period, and biological data. Water quality data are collected according to Surface Water Quality Monitoring Procedures Volume 1 sampling procedures. TCEQ utilizes an Index of Biotic Integrity (IBI) tool that was developed from multiple biological statistics to quantitatively assess the health of a biological community in an ecological region. Separate habitat, nekton (fish), and benthic (macroinvertebrate) indices of biotic integrity (IBIs) are calculated based on biological sampling procedures following Surface Water Quality Monitoring Procedures Volume 2 methods.

Given the regulatory implications associated with the use of the water quality data, the data used in the assessment process must be collected using consistent and scientifically rigorous sampling and laboratory methods. Data collected under an accepted quality assurance project plan that describes the integrated system of management activities ensures that data generated is of the type and quality needed for its intended use. The 2022 Guidance for Assessing and Reporting Surface Water Quality in Texas dictates which data will be evaluated in the biennial Texas

Integrated Report. Data that are not collected under a TCEQ-approved quality assurance plan, if submitted, must be accompanied by documentation of quality assurance for evaluation by TCEQ water quality staff. Data without appropriate quality assurance documentation will be considered as anecdotal evidence to support or refute assessment results, but will not be used in statistical evaluations. Additionally, all data must comply with the National Environmental Laboratory Accreditation Conference (NELAC) standard to be used to generate the Integrated Report (See 30 TAC, Chapter 25). Both the GBRA and UGRA laboratories are accredited by the Texas Environmental Laboratory Accreditation Program administered by TCEQ.

The quality of water described in TCEQ's assessment report is a snapshot of conditions during the specific time period considered in the assessment. The 2022 assessment covers the period of record from 12/1/2013 to 11/30/2020. If the minimum number of samples are not available within this seven-year period of record, the most recent samples collected between 12/1/2010 and 12/1/2013 may be used to make up the minimum sample number for assessment. The TCEQ assessment process has been developed by TCEQ staff through a stakeholder process. River Authorities and CRP partners are invited to participate in the development and review of the assessment guidance.

TCEQ designates segments as impaired or as a concern in the Integrated Report based on whether the assessed data meet relevant water quality standards or screening levels. Water quality standards are comprised of two parts: designated uses and their associated criteria for stream conditions necessary to support that use. The uses of a water body include aquatic life use, providing a suitable environment for fish and other aquatic organisms, and contact recreation use. The criteria for each use may be described numerically or expressed narratively in terms of desirable conditions. Uses and criteria are assigned to a segment or unclassified waterbody. If the criteria of a segment or unclassified waterbody are not met, then the water body is designated as impaired. If nonattainment of the criterion is imminent, then the water body is designated as having a concern. Overall, the quality of the Guadalupe River Basin is good. According to the 2022 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d), thirteen segments in the Guadalupe River Basin were found to be impaired for recreational use, aquatic life use, or fish consumption use (Table 1). Eighteen segments were found to have at least one concern for general use, aquatic life use, or recreational uses (Table 2). The most common impairments and concerns in the basin were for bacteria, depressed dissolved oxygen, and nitrate nitrogen concentrations.

## Table 1: Impaired segments in the Guadalupe River Basin

| Segment Number | Segment Name | Impairments |
|---|---|---|
| 1801 | Guadalupe River Tidal | Bacteria in Water (Recreation Use) |
| 1803A | Elm Creek | Depressed Dissolved Oxygen in Water |
| 1803B | Sandies Creek | Bacteria in Water (Recreation Use), Depressed Dissolved Oxygen in Water |
| 1803C | Peach Creek | Bacteria in Water (Recreation Use), Depressed Dissolved Oxygen in Water |
| 1804A | Geronimo Creek | Bacteria in Water (Recreation Use) |
| 1805 | Canyon Lake | Mercury in Edible Tissue |
| 1806 | Guadalupe River Above Canyon Lake | Bacteria in Water (Recreation Use) |
| 1806A | Camp Meeting Creek | Bacteria in Water (Recreation Use) |
| 1806D | Quinlan Creek | Bacteria in Water (Recreation Use) |
| 1806E | Town Creek | Bacteria in Water (Recreation Use) |
| 1810 | Plum Creek | Bacteria in Water (Recreation Use) |
| 1811 | Comal River | Bacteria in Water (Recreation Use) |
| 1811A | Dry Comal River | Bacteria in Water (Recreation Use) |
| 1815 | Cypress Creek | Impaired Fish Community, Impaired Macrobenthic Community in Water |
| 1817 | North Fork Guadalupe River | Impaired Fish Community, Impaired Macrobenthic Community in Water |
| 1818 | South Fork Guadalupe River | Impaired Fish Community, Impaired Macrobenthic Community in Water |

## Table 2: Segments containing concerns in the Guadalupe River Basin

| Segment Number | Segment Name | Concern |
|---|---|---|
| 1801 | Guadalupe Tidal | Nitrate in Water |
| 1802 | Guadalupe River Below San Antonio River | Nitrate in Water |
| 1803 | Guadalupe River Below San Marcos River | Nitrate in Water |
| 1803A | Elm Creek | Chlorophyll-a in Water, Depressed Dissolved Oxygen in Water |
| 1803B | Sandies Creek | Depressed Dissolved Oxygen in Water |
| 1803C | Peach Creek | Chlorophyll-a in Water, Impaired Macrobenthic Community in Water, Total Phosphorous in Water |

## Table 2 Continued

| Segment Number | Segment Name | Concern |
|---|---|---|
| 1804A | Geronimo Creek | Nitrate in Water |
| 1804D | Bear Creek | Bacteria in Water (Recreation Use) |
| 1806 | Guadalupe River Above Canyon Lake | Impaired Fish Community in Water, Impaired Habitat in Water |
| 1806A | Camp Meeting Creek | Depressed Dissolved Oxygen in Water |
| 1807 | Coleto Creek | Chlorophyll-a in Water |
| 1808 | Lower San Marcos River | Bacteria in Water (Recreation Use) |
| 1810 | Plum Creek | Ammonia in Water, Fish Kill in Water, Impaired Fish Community in Water, Impaired Habitat in Water, Impaired Macrobenthic Community in Water, Nitrate in Water, Total Phosphorus in Water |
| 1810A | Town Branch | Bacteria in Water (Recreation Use), Depressed Dissolved Oxygen in Water, Nitrate in Water |
| 1815 | Cypress Creek | Depressed Dissolved Oxygen in Water, Impaired Habitat in Water |
| 1816 | Johnson Creek | Impaired Habitat in Water |
| 1817 | North Fork Guadalupe River | Impaired Habitat in Water |
| 1818 | South Fork Guadalupe River | Impaired Habitat in Water |

## Trend Analyses

When looking for potential changes in water quality conditions, water quality parameters are compared over time. The statistical comparisons and graphs of these comparisons can show if there are overall increasing or decreasing trends at a location or in a segment. Water quality data for trend analyses were obtained from the TCEQ's Surface Water Quality Monitoring Information System. Data were divided by station and then by parameter. The data used for trend analyses adhere to the same quality control guidelines as data used by TCEQ to identify impairments and concerns as described above. The historical period of data examined varied by station, but generally encompassed all available data collected between September 1, 2012 and August 31, 2022. This time frame was examined in order to include the data used from the previous 2018 Basin Summary Report in the evaluation of trends. The historical period examined utilized substantially similar collection and laboratory methodologies. For a given station and parameter, only datasets that contained at least 20 sampling points over a period of at least 10 years were analyzed. Datasets with over 50% censored data were not analyzed. Censored data are data that are reported only as above or below some threshold. For example, concentrations of chemicals that are below a laboratory reporting limit are typically reported as being less than the reporting limit concentration rather than reporting a specific value. Because the exact values of censored data are not known, datasets with a high proportion of censored data require specialized statistical techniques that are outside the scope of this report.

Some datasets had gaps where data were not collected. In particular, the COVID-19 pandemic prevented some partners from collecting data during portions of this basin assessment period, which resulted in substantial data gaps. Best professional judgement was used to determine whether data gaps were large enough to prohibit effective trend analyses at those sites, but generally datasets that had 11 months or more between sampling points were not analyzed for trends over time. Datasets that met the data criteria were compared over time to observe any trends using statistical tools in Excel. Linear regressions were performed to confirm the significance of the trend. Additionally, a graph and narrative were created to explain any significant trends. Datasets were evaluated for normality by comparing skewness and kurtosis to a normal distribution using the Jarque-Bera goodness- of-fit test. A log10 base transformation was added prior to the analysis for E. coli. The flow and E. coli data assessed in this report have positively skewed data with outliers, which would not fit the assumptions required by linear regression analyses without transformation. A logarithm-based transformation is the most commonly used transformation for analyses related to water resources and is often used to address issues with positively skewed data (Helsel et al. 2020). If the assumption of normality or equal variance was still not met after transformation, the analysis of variance (ANOVA) is considered robust enough within the regressions to be valid as long as one of the assumptions is met (Glass et al., 1972). A trend was identified as significant by evaluating the F-test of overall significance for each regression model. The probability value or "p-value" generated by the F-test was compared to a predetermined p-critical value. A critical p-value of 0.10 was used for these analyses. If the "p-value" was less than the predetermined p-critical value then the regression model was determined to be significant. A "p-value" less than the p-critical value indicates that there is a high chance that at least some of the regression coefficients for the model are not equal to zero and that the regression model has some degree of validity. Some trend analyses with significant p-values had extremely low coefficient of determination, or $r^2$ values, indicating that the analysis did not explain a lot of the variation in the data. The coefficient of determination is the proportion of the variation in the dependent variable that is explained by the independent variable, with higher values indicating a better fit. This report generally only discusses significant trends that also have $r^2$ values above 0.1. Significant trends with lower $r^2$ values were included in the report in certain cases based on best professional judgement, such as if the analysis involved a parameter of concern for that waterbody.

Although many waterbodies only contain one monitoring station, some waterbodies contained multiple sampling stations. Data from these stations were kept separate during analyses. Although it is permissible to combine data from multiple stations within the same waterbody, doing so generally worsened the model fit considerably. In cases where multiple stations within a waterbody shared a common, significant trend for a parameter, model statistics were reported separately for each station. Significant trends that were selected for inclusion in the Basin Summary Report were graphed using Excel. Graphed data can be represented with or without a line that connects the data points. The line may make it easier to see seasonal patterns in the water quality data. It should be recognized that if the data points are connected by a line in time comparisons, the line between the points does not represent the true conditions of the stream between the times that the data was actually collected. In cases where multiple stations in the same waterbody shared a common significant trend, only the graph of the station with the best fit was included in the report. Statistics from other stations were discussed in the report text where applicable.

Parameters that exhibited a significant increase or decrease over time were also statistically compared with flow to provide useful supplementary information. A linear regression was performed between the parameter of interest and flow using a linear regression analysis. Linear regressions were performed using the same techniques and with the same statistical programs as trend analyses. F-values and p-values for these analyses were not typically reported in the Basin Summary Report, although significant trends were mentioned in the narrative text where it provided a relevant explanation for fluctuations in a parameter over time. In some cases where flow was significantly correlated with a parameter, a flow trendline or flow data points were shown on the graphs of parameters over time for visual reference. Flow was only generally included on these trends over time if the $r^2$ value of the parameter vs flow analysis was at least 0.2. Flow trendlines and flow datapoints added visual clutter to the trend graphs, and so they were only added in cases where they provided helpful information to explain trends.

In certain cases, additional data were pulled from other external data sources and used for comparison to datasets used for trend analyses. Daily mean specific conductivity data were retrieved from the United States Geological Society (USGS) station located at Jacob's Well (station 08170990) for comparison with Clean Rivers Program data at the same site. USGS data were downloaded from the United States Geological Society (USGS) using the data retrieval package in R version 4.2.2 (R Core Team 2021, De Cicco et al. 2022). Total dissolved solids (TDS) values were calculated by multiplying specific conductivity with the statewide conversion factor (0.65) between conductivity and TDS (TCEQ 2022). USGS data were graphed alongside CRP data for visual comparison using Excel.

Daily mean reservoir stage data were retrieved from the Texas Water Development Board's "Water Data for Texas" website for Coleto Creek. Reservoir stage height data were statistically compared with selected Coleto Creek parameters using a linear regression. Reservoir stage data were included on trend graphs where they explained additional fluctuations in parameter values.

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