9. Monitoring for BMP Effectiveness and Adaptive Management

In order to determine if management measures are keeping Cypress Creek clean, clear and flowing, the Stakeholder Committee determined target levels for six pollution constituents, impervious cover levels and flows from the springs feeding Cypress Creek (Table 12).

The Cypress Creek Watershed Protection Plan implements best management practices and other actions to attain and maintain water quality in the creek and its tributaries. The implementation of management measures throughout the watershed over time will result in pollutant loading reductions and established pollutant targets will serve as benchmarks of progress and indicators for adaptive management activities. Tracking the effectiveness of these management measures will be required to ensure that water quality goals are being achieved.

Water quality monitoring will detect the longitudinal increases of pollution contributed by tributaries as water flows into the creek. This stormwater, baseflow and routine monitoring, along with biological and bmp effectiveness monitoring, will determine if desired pollutant load reductions are being met and will highlight management activities and measures that require adjustments.

As of 2012, according to the Texas Integrated Report, which describes water quality conditions for water bodies in the state, Cypress Creek meets water quality standards. However, with the watershed facing rapid growth, the water quality in Cypress Creek is expected to degrade in the coming years. The Stakeholder Committee held a series of meetings to determine practicality and feasibility of standards set at or above the state's levels for the constituents mentioned below, and chose target levels based on monitoring results. Based on detailed review of modeling results and water quality monitoring data, these targets were refined in the summer of 2013. Target levels were established for six pollution constituents (nitrogen, phosphorus, TSS, bacteria, oil & grease and dissolved oxygen), impervious cover levels and flows from the springs feeding Cypress Creek (Table 12).

Components of the stakeholder approved monitoring plan include the coordination of all existing monitoring efforts, increased surface water quality monitoring, groundwater monitoring, the continuation of USGS gage collection of stream flow and water quality parameters, as well as the implementation of monitoring of:

- water quality related to stormflow, baseflow and rain events,
- biological and environmental components (including dissolved oxygen),
- demonstration best management practices (BMPs),
- implemented and existing BMPS, and

- bacterial source tracking.

As the watershed continues to urbanize, water modeling results will be used as a guide for detecting early signs of potential pollution concerns. Routine water quality monitoring data will be disseminated to the Stakeholder Committee and will help to identify any new concerns. If target levels are exceeded regularly, the Stakeholder Committee will utilize adaptive management to address new concerns (25).

Selected Targets for Reduction in Pollution

Targets for reduction in pollutant concentrations were established with the understanding that some management measures are preventative and that as development increases in the watershed, pollution reductions must increase (via implementation of additional management measures). Staggered implementation of these management measures will accomplish total required pollutant load reductions by the end of the 10-year project period and many years into the future. Management measures that are relatively simple and cost efficient to implement early in the WPP, will address initial targeted load reductions. These measures were prioritized as "highest" by the Stakeholder Committee and include structural and non-structural measures and varied sources of funding (shown in Table 12.) These measures selected by the Stakeholder Committee will initially focus on demonstration BMPS implemented in the first 3 Years of the WPP to address critical concerns in the watershed (i.e. keeping water quality above target levels).

Implementation of some additional measures will require greater investments of time, planning, effort, and financial resources and will mitigate the increased pollution loads associated with continued development. The Stakeholder Committee will determine, based on monitoring results and updated modeling outcomes, which of these management measures require adoption, as well as when and where they should be implemented. Table 25 shows the management measures to be utilized as adaptive management strategies.

Reductions in concentrations (and associated pollutant loads) initially will be gradual, but will increase over time, as both sources of pollution and implementation of BMPs in the watershed increase. Activities and measures implemented will maintain water quality sufficient to meet selected target loads in years 1-10, but it is recommended that target loads be reassessed as additional BMPs are implemented and development in the watershed continues, including conversion of land uses. Further, results from ground/source water assessment and preservation of flows study results and additional monitoring data will contribute to knowledge regarding non-point source pollution. This will assist with updating load reductions during the adaptive management review process, as necessary.

However, in the case of TSS, targets will become more stringent over time and are tailored for certain levels of development and land uses in the watershed. Quantities of TSS are expected to increase during periods of increased development, but reduce over time as open land becomes developed and BMPs are implemented.

Load Reduction Modeling

While actual water quality conditions will not precisely follow the models and projections utilized to determine pollutant loadings, these estimates and targets facilitate stakeholder identified adaptive management strategies to keep Cypress Creek clean, clear and flowing (Table 23).

Table 23. Examples of Performance Indicators

A Quick Guide to Developing Watershed Plans to Restore and Protect Our Water (EPA April 2013, p.12).

Environmental	Programmatic	Social
• Number (or percentage) of river/stream miles that fully meet all water quality standards. • Reduction in pollutant loadings from nonpoint sources	• Number of public water systems with ground/source water protection plans • Number of management measures implemented in a watershed (e.g., number of acres under nutrient management, number of riparian buffers created)	• Increase the number of residents signing watershed stewardship pledge • Rates of participation in education programs specifically directed toward solving particular nonpoint source pollution problems

Plan to Measure Effectiveness of Management Measures in Load Reductions

The plan to measure effectiveness of management measures is based on a combination of the Implementation Schedule (Element F), modeled outcomes of measures (Element B), and identified management objectives (Element C). In order to evaluate effectiveness of the measures, a monitoring component outlined below will be engaged alongside the implementation schedule (Table 24).

Table 24. Monitoring Plan Components and Communication of Monitoring Results.

Component	Tasks	Notes
Texas Stream Team proposed monitoring plan/Citizen scientist monitoring group	TST - Develop plan and coordinate with monitoring group. Monitoring Group – conduct monitoring, submit data and email results to stakeholder/workgroup contact.	Data collected is quality assured through TCEQ
Texas Stream Team and US Fish and Wildlife's San Marcos Aquatic Resources Center long term macroinvertebrate sampling	TST and USFWS will monitor and analyze macroinvertebrate assemblages at several sites along the creek as indicators of potential water quality concerns. Results will be	

Component	Tasks	Notes
program	provided to stakeholder/workgroup contact.	
Clean Rivers Program Monitoring	Clean Rivers Program, TCEQ, USGS. Appoint 1 person from stakeholder committee/workgroup to compile results and email to stakeholder committee/workgroup.	Data is quality assured through various sources; TST, WVWA and GBRA are currently conducting monitoring
Stakeholder committee/workgroup assessment of monitoring results.	Coordinate with monitoring efforts and review results on a regular basis (at least quarterly).	
Wimberley Valley Advisory Group	Collect *E. coli* samples on a monthly basis, and report the results to the appointed representative on the stakeholder committee.	Samples are processed in a NELAP accredited lab
Hays County Citizens Alliance for Responsible Development	Results and recommendations will be reported to the stakeholder committee as they are completed. If necessary, ad hoc committees will be formed to plan for implementation activities and adaptive management.	

Coordinating Existing and Future Monitoring Efforts

The Stakeholder Committee determined it is best to coordinate all the concurrent monitoring activities (Figure 32 shows existing USGS, CRP, Cypress Creek Project/TST monitoring sites and LCRA rain gages.) occurring in the watershed throughout implementation. Many of the volunteer monitoring groups are represented on the Stakeholder Committee already work together to collect data and partner with an organization that can formally analyze monitoring results for them. The technical committee will also play a role in analyzing the data collected through monitoring efforts. See the Cypress Creek Stakeholder Committee section above for information about how the committee will coordinate monitoring efforts during implementation (Page 26).

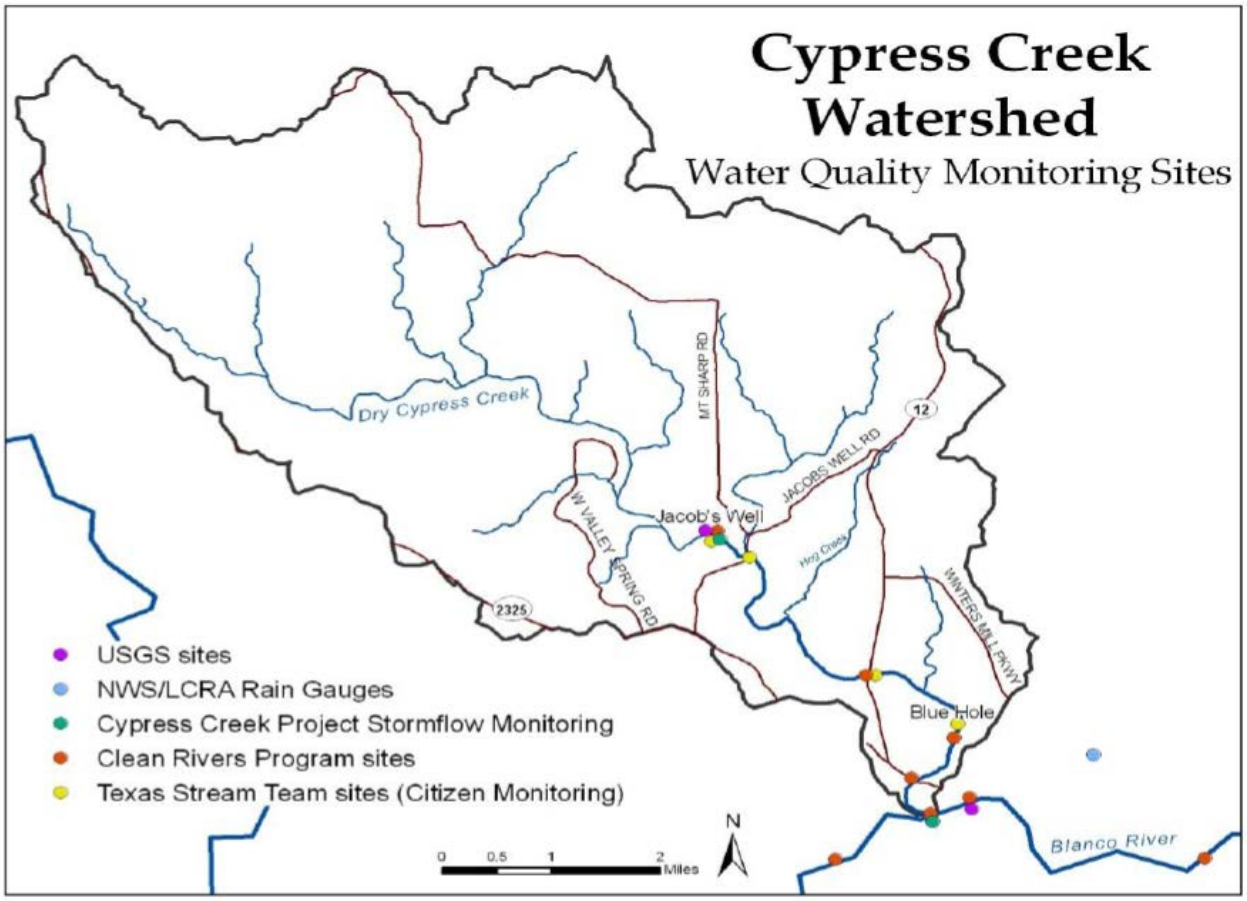

Figure 32. Existing Water Quality Monitoring Sites Rain Gages.

Baseflow Monitoring - The Texas Clean Rivers Program (GBRA and WVWA)

The Texas Clean Rivers Program is a partnership between the TCEQ and regional water authorities to coordinate and conduct water quality monitoring, assessment, and stakeholder participation to improve the quality of surface water within each river basin in Texas. The Guadalupe Blanco River Authority (GBRA) is the partner responsible for administrating The Clean Rivers Program in the Guadalupe River Basin, to which Cypress Creek belongs.

The Wimberley Valley Watershed Association (WVWA) is a non-profit organization dedicated to preserving the water quality of Cypress Creek, and contributes to the Clean Rivers Program by monitoring several sites on Cypress Creek in accordance with The Clean Rivers Program QAPP. Water quality data that is collected for Cypress Creek as part of the Clean Rivers Program includes: water temperature, specific conductivity, dissolved oxygen, and pH. Samples are collected and brought to GBRA's NELAP accredited lab where they are analyzed for total suspended solids, nitrates, ammonia, phosphorus, and *E. coli*.

There are five sites on Cypress Creek that are monitored for The Clean Rivers Program on a quarterly basis. GBRA monitors one location at the Ranch Road 12 crossing in downtown Wimberley. The WVWA monitors four sites on Cypress Creek that include: Jacobs Well, the

upstream Ranch Road 12 crossing, the Blue Hole, and the confluence with the Blanco River. Data collected for the Clean Rivers Program can inform the Stakeholder Committee the quality of the water of Cypress Creek before and during the implementation phase of the Watershed Protection Plan.

Stormflow Monitoring

In general, ambient monitoring data are collected under baseflow conditions and occasionally following storm events when flows are elevated. Data are never collected when flows are elevated to a point that would compromise the safety of monitoring teams, nor are daily streamflow measurements routinely collected. However, proper characterization of the hydrology and water quality of the creek requires reliable data on streamflow, and this information is also necessary to calculate average pollutant loads using ambient data. In addition data on both streamflow and water quality should characterize the range and temporal variability of water quantity and quality under the full range of natural conditions. Because water quality parameters are highly influenced by flow rates, it is important to understand the hydrologic response of the watershed to identify causes and sources of NPS pollution, in addition to identifying and developing appropriate best management practices (BMPs) to address pollution issues of concern. Modeling efforts of the Cypress Creek Project are also dependent on accurate flow estimates to ensure the greatest possible accuracy when evaluating potential impacts of future development (Please refer to 4.2.3 Stormflow Monitoring Section of the WCR found in the Technical Reference Document.

The ISCO automatic sampler (20828) located several hundred feet above Jacobs Well in Cypress Creek will be used to monitor stormflows from the dry portion of the creek. Samples will be processed at the GBRA's NELAC certified lab used during the project. Monitoring stormflows at this site will differentiate pollutant loads from the dry portion of the creek and Jacobs Well during storm events.

Rain Event Monitoring

Precipitation accounts for a portion of the water in Cypress Creek and all of the water in the dry portion above Jacobs Well. In order to better understand how much rain falls over the Cypress Creek Watershed, the Cypress Creek Project installed a network of rain gauges within the watershed to collect precipitation data and compared it with surface flow data which to improve the accuracy of the SWAT model. Prior to the rain gauge network, only one long term rain gauge was measuring rainfall near Cypress Creek in Wimberley, TX (NCDC). Other gauges that lie in close proximity to the watershed (<10 km) include Fisher Store (NCDC) and Dripping Springs (LCRA), however rainfall recorded at these do not correlate with one another. One gauge may measure an inch and the other no rain at all. The three additional gauges at or near the points presented on the map will further characterize spatial climate variability in the watershed. The portion of the watershed represented by a rain gauge was determined by utilizing a theissen polygon analysis in ArcMap (Figure 33). Rainfall amounts measured from each gauge will be multiplied by the percentage of the watershed it covers and totaled with

the others to give a more accurate measure of rainfall over the 38 square mile area. With Onset Computer Company's RG3 self-tipping rain gauges, data is electronically stored on a data logger within the gauge to be read at the first of every month for at least 12 months. The tipping mechanism is calibrated to tip when filled with 1/100th of an inch, and by multiplying the number of tips by 1/100, you get rainfall measured to the nearest 100th of an inch.

The Interim Stakeholder Committee will collect the data and determine who will analyze and incorporate it into the Cypress Creek DSS during the interim.

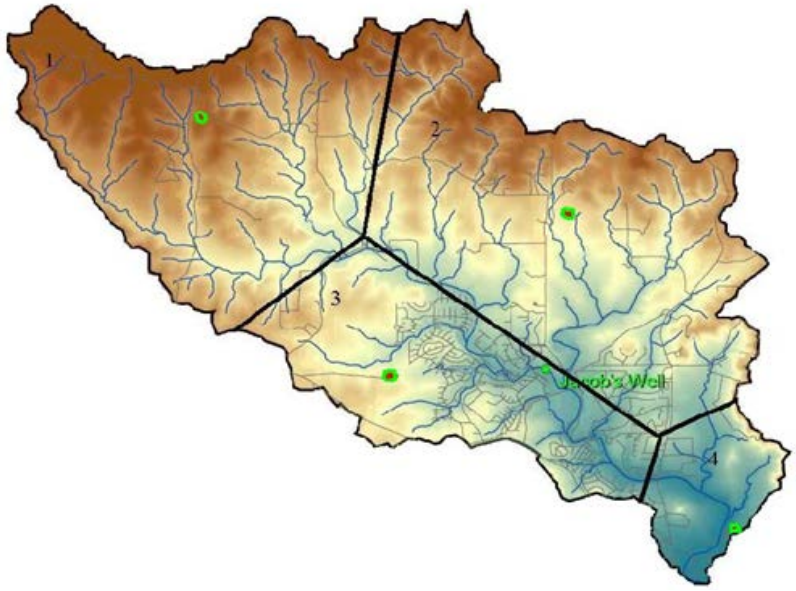

Figure 33. Rain Gauge sites in Cypress Creek Watershed

Supplemental Surface Water Monitoring

Texas Stream Team

Texas Stream Team is a program at The Meadows Center for Water and the Environment and is primarily funded by a Section 319(h) grant from The U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality. The Texas Stream Team program supports a network of citizen scientists and partner organizations such as municipal government environmental divisions, river authorities, and non-profit organizations, who collaborate on projects related to improving or protecting water quality.

Citizen scientists who join Texas Stream Team are trained to collect water quality data in accordance with Texas Stream Team's TCEQ approved Quality Assurance Project Plan (QAPP). The parameters collected by Texas Stream Team Citizen Scientists include: water temperature, specific conductivity, pH, dissolved oxygen, water clarity, and field

observations. Citizen Scientists collect nitrates, phosphates, *E. coli*, turbidity, and stream flow.

Once trained, these citizen scientists are assigned a site and expected to monitor on a monthly basis. The data is submitted to Texas Stream Team where it undergoes quality assurance according to Texas Stream Team's QAPP. The verified data is then uploaded to the Data Viewer, an interactive map/database that projects citizen scientists' data for public consumption.

Texas Stream Team can increase stakeholder involvement in the Cypress Creek Watershed Protection Plan by training local stakeholders to collect water quality data. The data can then be presented to stakeholder committees and the public to get a better understanding of current water quality conditions on Cypress Creek. This data can help supplement the other water quality data that is collected in the watershed, such as The Texas Clean Rivers Program monitoring, which is collected from five sites along the creek quarterly basis.

The Texas Stream Team (TST) is currently reaching out to the Cypress Creek community to reestablish citizen scientist water quality monitoring efforts. As part of the plan TST recommends a structured group to carry out monitoring activities. Groups ensure continuity of monitoring activities, increased numbers of monitoring sites and more effective communication among monitors and community members.

In addition to its traditional water quality monitoring programs, TST will partner with USFWS staff to routinely monitor aquatic macroinvertebrate assemblages in several sites along Cypress Creek. TST staff and citizen scientists will collect samples in conjunction with water quality sampling parameters and an identified and widely accepted protocol. USFWS experts will classify and categorize the samples, and analyze assemblage structures as indicators of water quality and environmental health. TST and USFWS will provide results to the Cypress Creek Community and Stakeholder Committee as part of the biological monitoring efforts outlined below.

The Wimberley Valley Advisory Group

The Wimberley Valley Advisory Group is a local Citizen Scientist Group that has been collecting *E. coli* samples from Cypress Creek for 20 years. These samples are sent to a NELAP accredited Lab and are very useful in analyzing and monitoring bacterial issues in the creek.

Hays County Citizens Alliance for Responsible Development

CARD supports and encourages sustainable development and practices that protect local natural resources, including Blue Hole, Jacob's Well, Cypress Creek, the Blanco River and local aquifers. CARD members also participate in a volunteer advisory group composed of regional scientists whose goal is to identify ground/source water that comprise flow in

Jacob's Well. Their activities include groundwater monitoring. Better understanding ground/source water in Jacob's Well is critical to preserving flows in Cypress Creek.

Increased Surface Water Quality Monitoring

GBRA can process samples for oil and grease in their accredited lab. Presence is measured as mg/L and is typically only done when there is a sewage/septic spill. Total hydrocarbon tests also could be performed, which would test for oil and grease, as well as other pollutants such as gasoline. Currently, the oil and grease levels in the watershed are too low to justify testing and sampling expenditures, but as development in the watershed continues the Stakeholder Committee would like to implement oil and grease testing as an indicator for faulty or improperly functioning septic systems in the watershed.

Groundwater Monitoring

Most of the water quality data collected for Cypress Creek is focused on surface water quality. Groundwater monitoring is needed to better understand what pollution is contributed to Cypress Creek in flows from Jacobs Well. Jacobs Well can be seen as a point source of pollution to Cypress Creek. When it is determined what type of pollution, if any, flows from Jacobs Well work can begin to determine the source of that pollution. This will help the Stakeholder Committee determine the source of the pollution and water in Jacobs Well. The monitoring efforts coupled with the SWAT model results and EMC source identification calculations will help the committee determine the most appropriate BMPs from their toolbox for adaptive management and which karst features are priorities for protection measures. Monitoring will include continued operation of the USGS stream gage 08170990 in Jacobs Well and Clean River Program water quality monitoring site 12677 (Please refer to Table 4.1 in the WCR found in the Technical Reference Document). While the amount of water quality data for Jacobs Well and Cypress has increased there is still much analysis needed. Continued groundwater monitoring coupled with current data sets will allow for analysis into correlations that exist for pollutants as was done for dissolved oxygen. As pollutants are detected the Stakeholder Committee and project partners can work to identify the source of pollution flowing from Jacobs Well which will also help define the Cypress Creek recharge zone.

Preferred flows from Jacobs Well and in Cypress Creek are threatened by water demand from the aquifer feeding the creek. In order to determine the link between streamflow and wells the Stakeholder Committee will coordinate with project partners to follow approaches laid out in USGS Circular 1376 Streamflow Depletion by Wells-Understanding and Managing the Effects of Groundwater Pumping on Streamflow (Barlow and Leake, 2012).

Biological/Environmental Monitoring

Cypress Creek is classified in the Texas Administrative Code as being and Exceptional Aquatic Habitat. Biological monitoring will provide many indicators and a big picture view of water

quality in Cypress Creek including flow regimes and water quantity. This monitoring can also provide early indicators of water quality issues and imbalances in the system. Looking holistically at the Cypress Creek the stakeholder committee will be able to see changes over time, overall ecosystem health and water quality water quantity conditions.

Current biological monitoring efforts from the USFWS, TPWD, GBRA and the Meadows Center should be a coordinated to ensure the data and conclusions reached from analysis are available to the stakeholder committee.

Monitoring of Demonstration BMPs

Demonstration BMPs implemented in the first 3 years of implementation will be monitored for effectiveness of mitigating pollution entering Cypress Creek. The Stakeholder Committee will work with the technical committee to determine if BMPs are operating effectively. If it is determined that a BMP may not be operating effectively the Stakeholder Committee will work with project partners to help determine what changes are needed. Demonstration BMPs that are working effectively will be presented to the community and encouraged for implementation where appropriate across the watershed.

Monitoring of Existing and Implemented BMPs

Existing BMPs installed by Wimberley, Woodcreek and Hays County need monitoring to determine their effectiveness at protecting water quality in Cypress Creek.

Bacterial Source Tracking

Monitoring for bacteria source only shows the amount of fecal bacteria in the creek. Bacterial Source Tracking identifies sources of fecal matter allowing targeted management strategies. Identification and assessment of sources is a key component for effective abatement programs (TWRI, 2012). Additionally, bacterial source tracking will provide valuable information about potential water quality impacts from the permitted discharges in the watershed.

Cypress Creek Decision Support System

The CC-DSS was developed to assist the Stakeholder Committee and decision makers with assessing the effects of increased urbanization in the watershed. As new data is collected and model accuracy increases, the CC-DSS will be used to model the effect of new development on water quality. Because this plan is preventative the Stakeholder Committee decided that water quality modeling results can be used as a proxy for monitoring instream concentrations in future development/urbanization scenarios and assist in determining the most appropriate location for BMPs. Improved monitoring data, and land use/land cover data is required to update the DSS and increase its functionality as a tool for City and County staff to utilize it as a planning tool.