Revisions to the Implementation Plan for Three Total Maximum Daily Loads for Chloride, Sulfate, and TDS in Petronila Creek Above Tidal

Segment 2204, Petronila Creek Above Tidal

Prepared by **Nueces River Authority** for:

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON EVIRONMENTAL QUALTIY

Distributed by the
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TMDL implementation plans are also available on the TCEQ website at
<www.tceq.texas.gov/implementation/water/tmdl/>

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This report is modeled after the report titled
"Implementation Plan for Two Total Maximum Daily Loads for Dissolved Oxygen and One Two Total Maximum Daily Load for Bacteria in Upper Oyster Creek."

The plan is based in large part on the recommendations of the two stakeholder Work Groups organized by the Nueces River Authority.

Acknowledgements

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Acronyms and Abbreviations

BHR	Basin Highlights Report
BMP	Best Management Practice
BSR	Basin Summary Report
CAMS	Continuous Ambient Monitoring Station
CRP	Clean Rivers Program
CWQM	Continuous Water Quality Monitoring
DO	Dissolved Oxygen
FY	Fiscal Year
I-Plan	Implementation Plan
m	meter
mg/L	milligrams per Liter
NRA	Nueces River Authority
RRC	Railroad Commission of Texas
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TRC	The Research Corporation
TSSWCB	Texas State Soil and Water Conservation Board
µS/cm	micro Siemens per centimeter

Executive Summary

On October 10, 2007, the Texas Commission on Environmental Quality (TCEQ) approved the *Implementation Plan for Three Total Maximum Daily Loads for Chloride, Sulfate, and Total Dissolved Solids in Petronila Creek Above Tidal*. This implementation plan (I-Plan):

- described the steps the TCEQ and its stakeholders would take to achieve the pollutant reductions identified in the original Total Maximum Daily Load (TMDL) report for chloride, sulfate, and total dissolved solids (TDS), and
- outlined the schedule for implementation activities.

This report, Revisions to the I-Plan:

- documents the implementation activities that have been accomplished,
- documents the data analyses that have been conducted, and
- updates the steps and schedule for continued implementation activities.

The implementation activities that have been completed include:

- the identification of areas of soils with a high chloride content,
- the removal of these soils, where feasible,
- analysis of groundwater and surface water interaction,
- installation of a continuous water quality monitoring station (CWQM), and
- analysis of data collected at the CWQM site.

These activities are discussed in detail in the following sections of this report.

Continued sampling at appropriate locations and frequencies will allow tracking and evaluation of progress toward the interim and final endpoints of the TMDL.

The project information for Petronila Creek Above Tidal is available on the TCEQ's web site at www.tceq.texas.gov/waterquality/tmdl/nav/32-petronila/32-petronila-tds.

Implementation Progress

This section provides a brief description and summary of activities implemented since the development of the TMDL and I-Plan addressing the chloride, sulfate, and TDS impairment in Petronila Creek Above Tidal.

Control Action 1: Investigation and Abatement of Produced Water Impacts and Seeps to Surface Water

This Control Action focused on the reach of Petronila Creek from US 77 downstream to the tidal boundary near FM 70.

In 2006, during development of the original I-Plan, the Railroad Commission of Texas (RRC) was awarded a nonpoint source grant to investigate the nature and extent of known salinity contamination associated with oil and gas production, the development of abatement alternative or best management practices (BMP), and the construction and placement of BMPs to reduce water pollution in the area of the Clara Driscoll oil fields.

The project management team included personnel from the RRC's Site Remediation section in Austin and personnel from the District 4 office in Corpus Christi. The project team contracted with The Research Corporation (TRC) Customer-Focused Solutions to investigate the Clara Driscoll oil fields and identify and evaluate effective BMPs.

RRC and TRC were tasked with six activities:

- review the Bureau of Economic Geology airborne geophysical survey and land-based confirmation sampling project for the Petronila Creek TMDL project and determine the most effective approach for source investigation,
- determine locations using the geophysical survey data and selected soil borings to install monitoring wells up-gradient and downstream of saltwater seepage into Petronila Creek, its tributaries, and downstream of known or suspected discharge points,
- select soil-boring locations in abandoned pits and suspected release areas and collect samples for analysis,
- sample newly installed monitoring wells and sample surface water at strategic points along Petronila Creek, its watershed, and hurricane canals that flow into the creek,
- conduct a study to choose BMPs to reduce the TDS loading, and
- implement BMPs to reduce the TDS loading.

The first five tasks were completed by August 2009. The results are documented in five reports available on the RRC website (http://www.rrc.state.tx.us/environmental/environsupport/nps/petronila/index.php):

- Petronila Creek Records Review, Site Reconnaissance Results, and Recommendations – August 2006
- Final Phase III Investigative Report on Petronila Creek – May 2008
- Soil Feasibility Study Petronila Creek Nueces County, Texas – September 2008
- Soil Feasibility Study Addendum Petronila Creek Nueces County, Texas – August 2009
- Conceptual Site Model Petronila Creek Nueces County, Texas – August 2009

The RRC/TRC studies concluded that the most likely source of the highly elevated salinity levels is from produced water associated with oil and gas activities.

Some of the produced water was discharged into ditches, referred to as tidal disposal, and into evaporation pits. The RRC discontinued the use of evaporation pits in 1969 and ended the practice of tidal disposal in 1987.

Hydrogeologic and salinity data suggest interconnection between soil, groundwater, and surface water. This has resulted in salinity loading to Petronila Creek. It is likely that the primary loading mechanism to portions of the creek is base flow, which is enhanced following significant precipitation events.

The soil studies identified seven areas of high chloride concentrations (Figure 1) and provided BMP recommendations where feasible.

- Area 1: No BMP was recommended because the chloride concentrations in the soils were relatively low compared to the other areas.
- Area 2: Soil removal to reduce continued contamination from the area was recommended. The RRC was able to identify the operator who removed the contaminated soil and replaced it with clean soil in September 2013.
- Areas 3 & 4: Soil removal to reduce continued contamination from the areas was recommended. If the RRC can identify the operator(s), they will be held liable for cleanup. If not, the RRC will do the cleanup when funding becomes available.
- Area 5: Soil removal to reduce continued contamination from the area was recommended. In addition, the chloride distribution data showed that a high chloride plume, > 10,000 mg/L, emanates from this area and flows to the south towards the creek and to the southeast. The plume continues further downgradient, to the southeast, running parallel to the creek. However, the conclusion was that it would not be cost or time effective to implement a recovery and disposal BMP that directly addresses the impacted groundwater. Implementation would consume large amounts of energy and monetary resources over a long period of time as it would also require the disposal of the saline-impacted groundwater.
- Areas 6 & 7: Soil removal to reduce continued contamination from the areas was recommended. The top 2’ of soil was removed from these areas during the spring and summer of 2012.

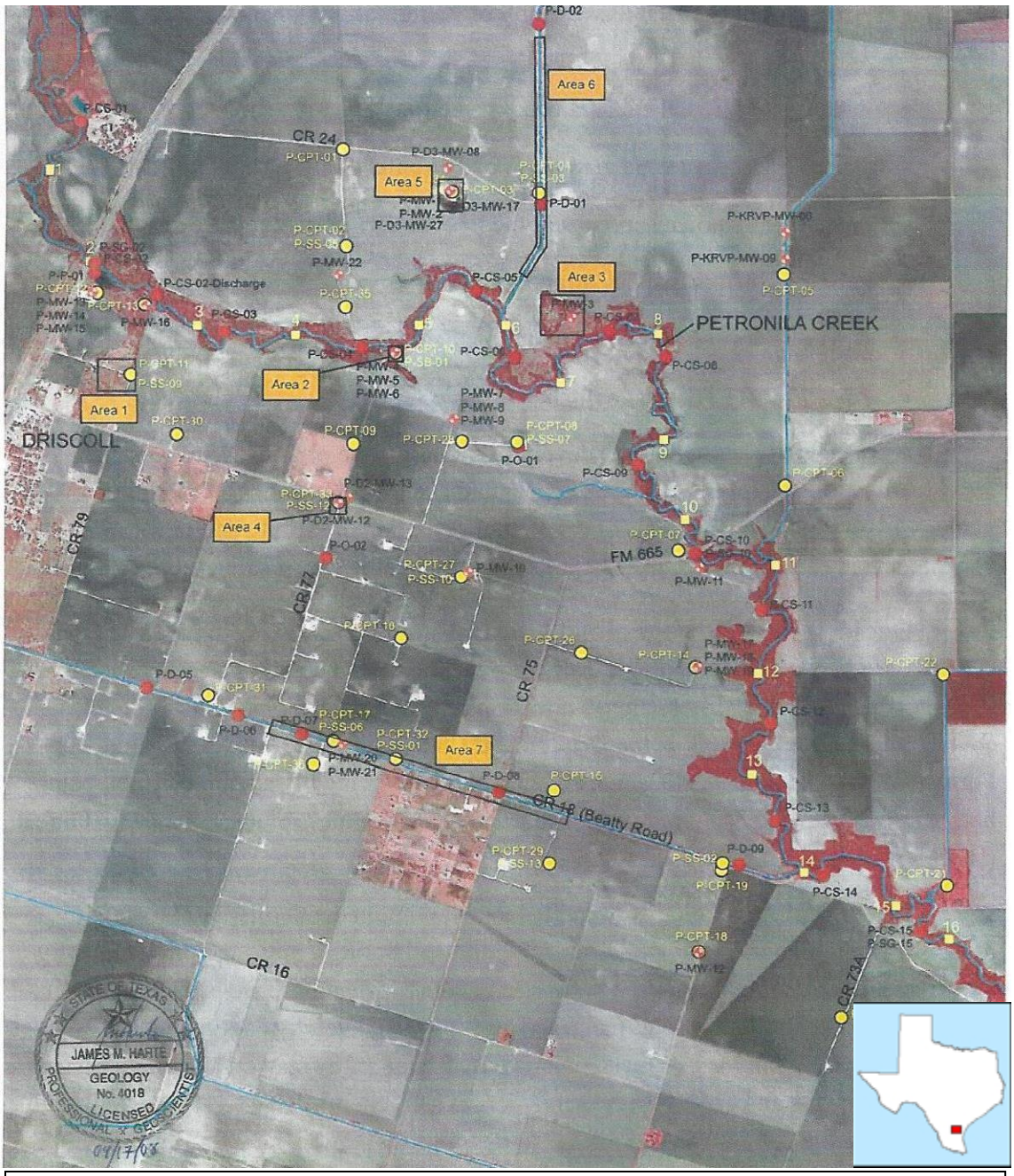

Figure 1: Areas of High Chloride Concentrations (Taken from Soil Feasibility Study Petronila Creek Nueces County, Texas- September 2008)

Control Action 2: Routine and Continuous Water Quality Monitoring

Under the TCEQ Clean Rivers Program (CRP), Nueces River Authority (NRA) conducts quarterly, routine monitoring at three Surface Water Quality Monitoring (SWQM) locations on Petronila Creek below US 77. Station 13093 is located at FM 70, Station 13094 is located at FM 892, and Station 13096 is located at FM 665 (Figure 2).

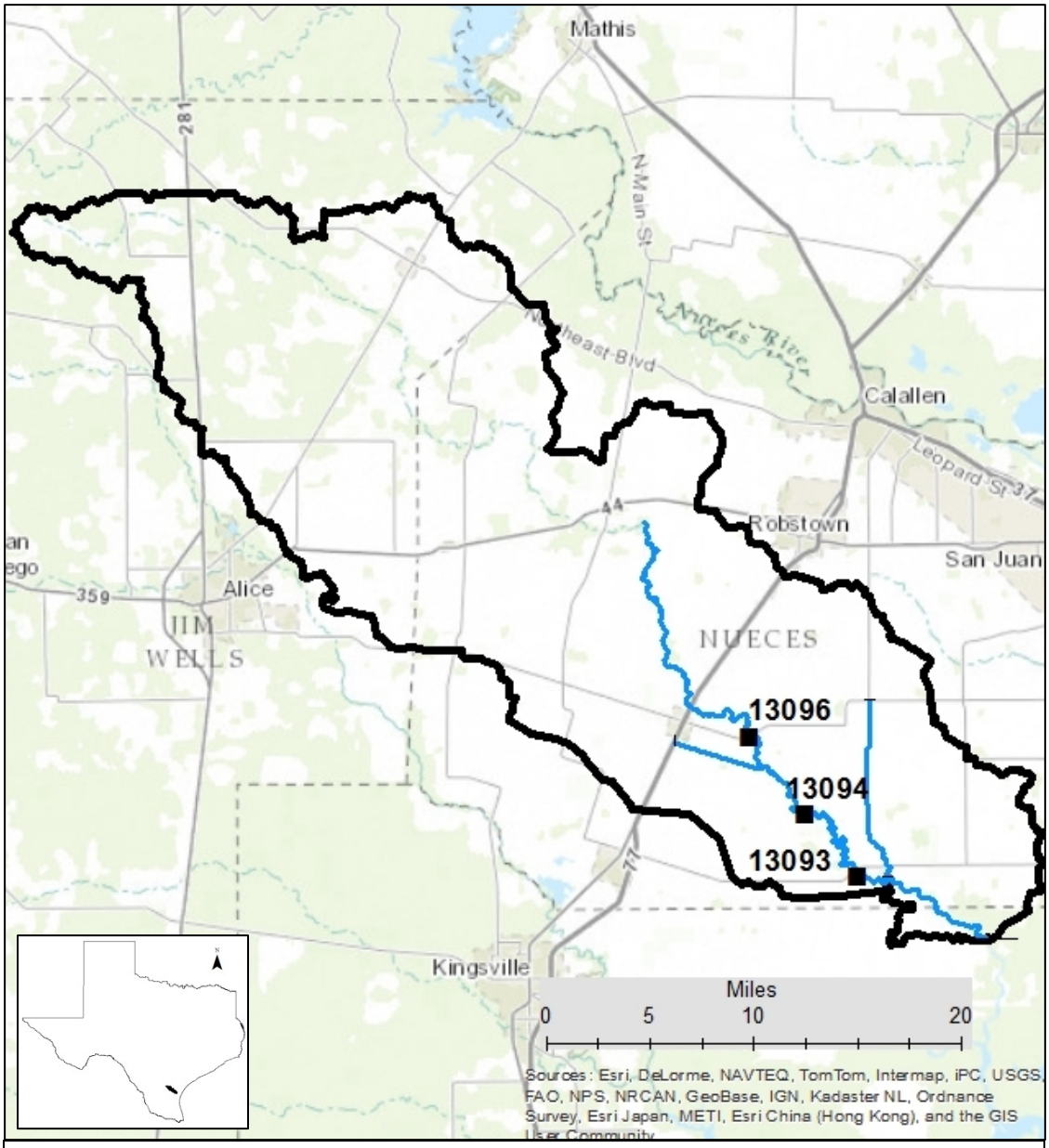

Figure 2: SWQM Locations Within Petronila Creek Implementation Plan Project Area

Routine field parameters include water and air temperature, transparency, flow, 1-day and 7-day rainfall totals, days since last rainfall, wind direction and intensity, turbidity, dissolved oxygen (DO), and specific conductance.

Routine water samples are analyzed for alkalinity, ammonia, nitrite and nitrate, total Kjeldahl nitrogen, total organic carbon, chloride, sulfate, TDS, *E. coli*, total suspended solids, total phosphorus, hardness, pheophytin-*a*, and chlorophyll-*a*.

Beginning in fiscal year (FY) 2011, additional monthly sampling for TDS, chloride, sulfate, and field data was added for the months not sampled during routine sampling.

The CWQM site at Station 13093 was installed in February 2009. Its operation is coordinated by the Monitoring Operations Division of the TCEQ and is operated and maintained by NRA staff. This monitoring site is also referred to as Continuous Ambient Monitoring Station (CAMS) 731.

Data collected under the routine and continuous monitoring were analyzed to determine if any trends and / or correlations existed.

Trend analysis was conducted on TDS, chloride, and sulfate measurements based on routine sampling results from Stations 13093, 13094, and 13906. All available data through 2012 were used. Averages were calculated, by year, for each site. See Appendix A for data values used to generate the following graphs.

The data show a significant decrease in measured TDS values after the RRC discontinued the practice of tidal disposal in 1987 (Figure 3). However, there appears to be little difference in the measured values since 2007 when the TMDL and I-Plan were approved (Figure 4). The chloride analysis is similar (Figures 5 and 6). Sulfate values, however, increased after tidal disposal was discontinued, but very little change since 2007 (Figures 7 and 8).

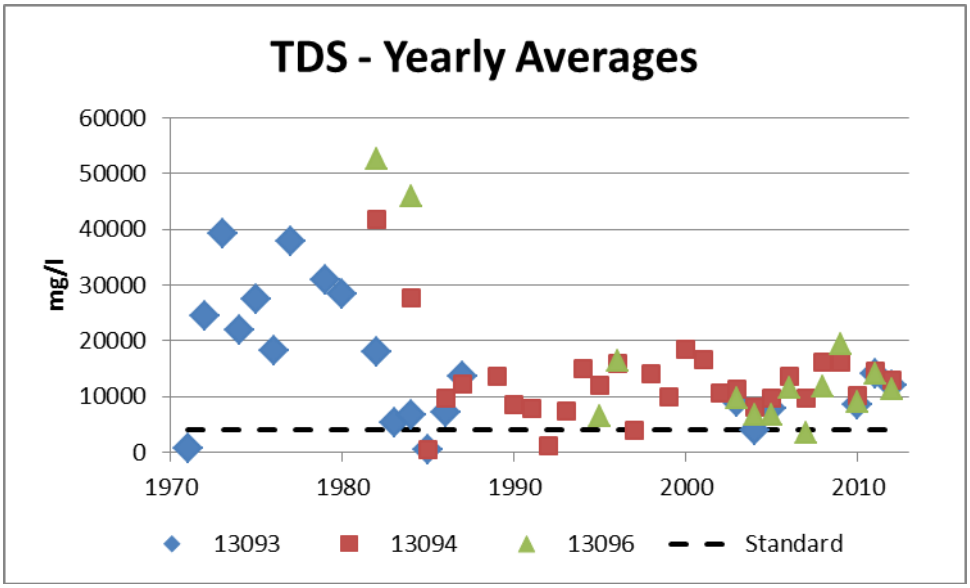

Figure 3: 1971 – 2012 Yearly Averages of TDS Data

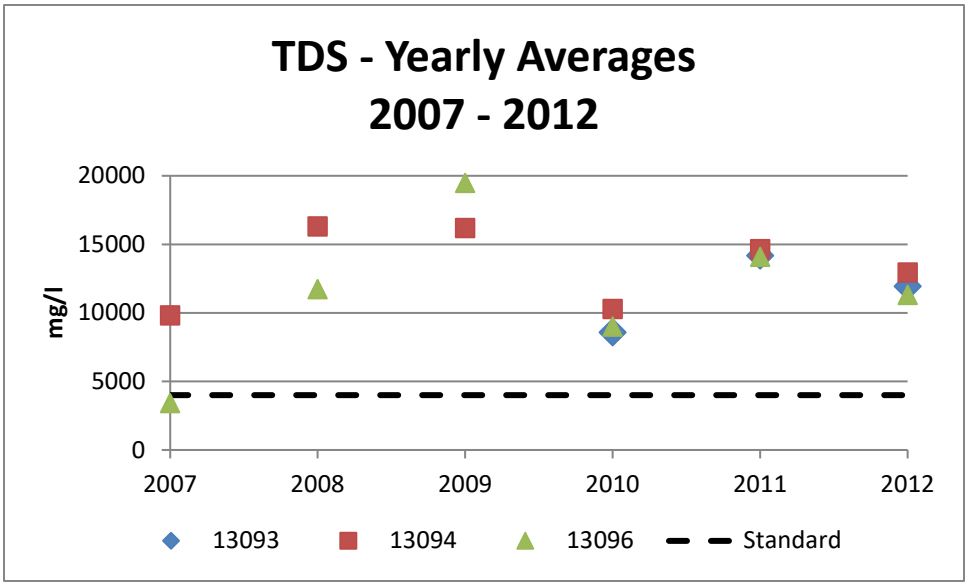

Figure 4: 2007 – 2012 Yearly Averages of TDS Data.

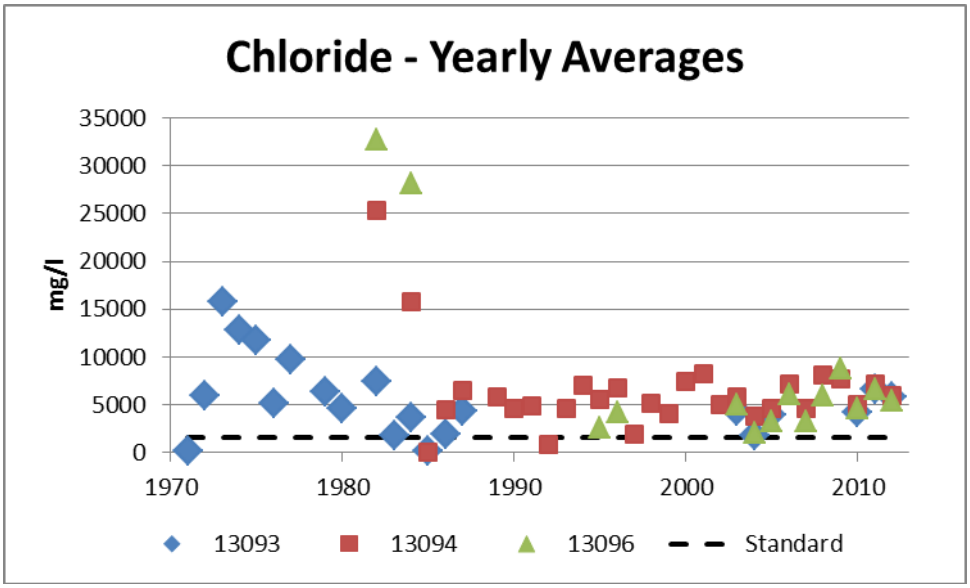

Figure 5: 1971 – 2012 Yearly Averages of Chloride Data.

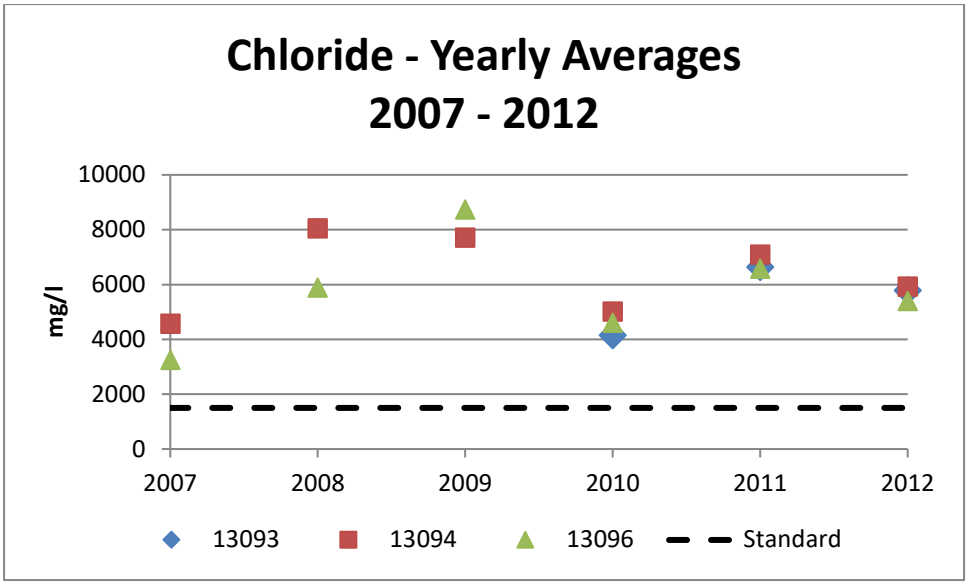

Figure 6: 2007 – 2012 Yearly Averages of Chloride Data

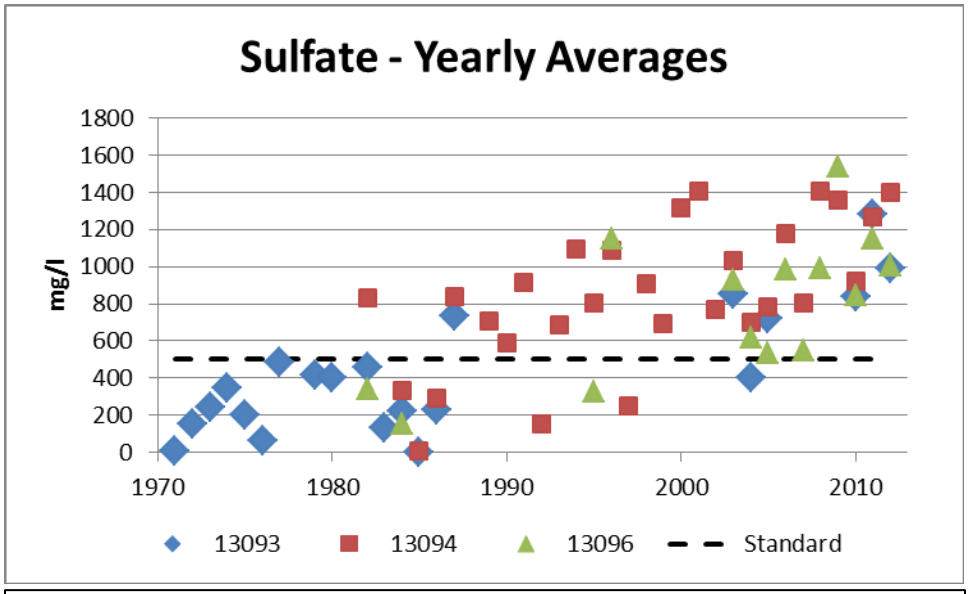

Figure 7: 1971 – 2012 Yearly Averages of Sulfate Data

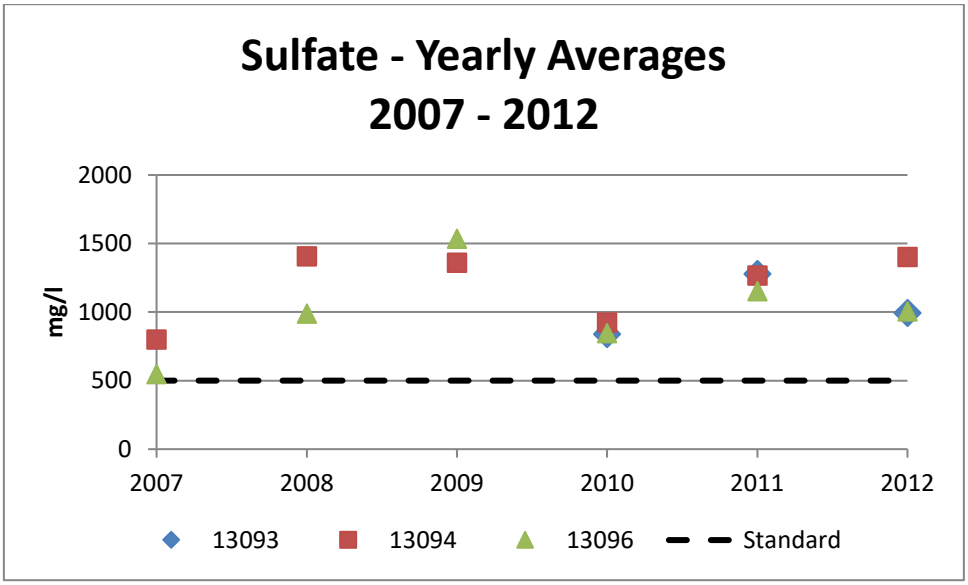

Figure 8: 2007 – 2012 Yearly Averages of Sulfate Data

In an effort to determine the reason for the increase in sulfate values, the possibility of anoxic conditions contributing to the release of sulfate was investigated. The Excel correlation function was run on DO data collected at the same time as the sulfate samples were taken. The closer the calculated correlation is to |1|, the higher the probability a relationship exists. The correlation results for Stations 13093, 13904, and 13906 were -0.221, 0.004, and 0.165, respectively. Based on this analysis, it was concluded that there was no correlation between DO and sulfate values.

Correlation with rainfall data was also analyzed. Rainfall data for 1971 – 2012 were downloaded from the National Oceanic and Atmospheric Administration National Climatic Data Center from 12 locations. The locations were prioritized based on the proximity to the watershed. Not all stations had data for all days. Only two locations where within the watershed, and only had data for 3% of the days during this time frame.

Again using the Excel correlation function, sulfate concentrations and the previous 1-day, 7-day, 14-day, and 21-day rainfall totals correlations were calculated. The highest correlations were associated with the 21-day rainfall totals (Table 1). These results suggest that there could be correlation, but the uncertainty is great since the recorded rainfall is primarily outside the watershed. The negative values do support the conclusion by TRC of a connection between groundwater and surface water: the values decrease with greater amounts of fresh water from rain, but rebound quickly which suggests that there is an influx of high salinity groundwater into the creek when there is little to no rain.

Table 1: Correlation Analysis: Sulfate Levels vs Rainfall Amounts

	1-day	7-day	14-day	21-day
13093	-0.158	-0.239	-0.315	-0.456
13904	-0.196	-0.425	-0.472	-0.478
13096	-0.238	-0.464	-0.454	-0.489

Unfortunately, neither the DO nor the rainfall analyses provided an explanation as to why the sulfate values increased after 1987.

The Meadows Center for Water and the Environment at Texas State University conducted analysis on data collected at the CWQM site. They analyzed the specific conductivity values (measured in micro Siemens per centimeter (µS/cm)), as they relate to sample depth. The conclusions from their analysis were:

- The average sample depth for the CAMS 731 sensor was 0.76 meters (m), and the depth ranged from 0.17 m to 2.71 m 95% of the time. There was a 2 order magnitude of variation in the conductivity measurements during this time period. Conductivity ranged from169 µS/cm to 33,685 µS/cm.
- The depth of the CAMS 731 sensor was greatest during large rainfall events. These events lowered the conductivity of the water but were episodic and ephemeral in nature. A large amount of variation in the conductivity occurred when the sample depth was around the mean.
- A significant correlation between conductivity and depth was determined. Conductivity had a negative relationship with sample depth. However, even with a root transformation of the data and a removal of outliers, the relationship only explained up to 19.6% of the variation in the data. Although the relationship between conductivity and depth is significant, other variables likely contribute to the variation in conductivity.

The full report, *Petronila Creek: Specific Conductivity versus Sample Depth, January 30, 2014*, is included as Appendix B.

Implementation Strategy for the Revised I-Plan: Revised Control Actions / Management Measures

This section provides a brief description and summary of activities that can be implemented to address the chloride, sulfate, and TDS impairment in Petronila Creek Above Tidal. Appendix C contains an implementation matrix of the control actions and implementation activities.

Control Action 1: Investigation and Abatement of Produced Water Impacts and Seeps to Surface Water

Based on the results of the TMDL and studies conducted as part of the I-Plan, additional chloride, sulfate, and TDS contamination continues from saturated soils and affected groundwater.

Implementation Activity 1.1: Soil remediation at Areas 2A, 3, 4 and 5

The removal of saturated soils will help reduce the amount of chlorides, sulfates, and TDS that runoff the land into the creek and leach into the groundwater.

Implementation Schedule: RRC will attempt to identify/hold liable the companies that operated in these areas. If the operator cannot be found, RRC will conduct the cleanup when funding becomes available.

Funding Requirement: If the operator(s) are identified, they will be held financial responsible for the cleanup. Otherwise, approximately $400,000 - $500,000 per area ($1.2M - $1.5M total) will be needed for the RRC to conduct the cleanup.

Implementation Activity 1.2: Investigate the old saltwater disposal wells and tanks near the US 77 crossing north of Driscoll

Approximately nine empty tanks and one or two wells are located at this site. The threat of pollution from this site needs to be determined in order to prioritize the need for cleanup. The RRC has previously visited this area and violations have been found. However, they have been unable to locate the operators to hold them liable.

Implementation Schedule: RRC will not be able to address this site prior to FY 2015. The exact timing will depend on when funding becomes available.

Funding Requirement: Approximately $30,000 per well to properly plug the wells plus approximately $250,000 to remove and dispose of the tanks will be needed.

Control Action 2: Water Quality Monitoring and Data Analysis

Monitoring provides a basis for evaluating segment conditions and measuring progress.

Implementation Activity 2.1: Continue routine and continuous monitoring

The RRC cleanups occurred in 2012 and 2013, so probably not enough time has passed to see results.

Implementation Schedule: Both routine and continuous monitoring have been implemented. The routine monitoring is conducted by NRA under the TCEQ's CRP. The CWQM site is operated by the Water Quality Division of the TCEQ and maintained by NRA.

Funding Requirement: No additional funding is required since the routine monitoring and maintenance of the CWQM site are covered by CRP.

Implementation Activity 2.2: Conduct data analysis yearly and report in the CRP reports
CRP deliverables include yearly Basin Highlights Reports (BHR) and every 5th year a Basin Summary Report (BSR). The BSR contains detailed analysis of every segment within the CRP area. NRA also provides quarterly updates to the CRP stakeholders. Data analysis and project updates will be included in the BHRs and BSRs. Quarterly updates will include project updates when applicable.

Implementation Schedule: BHRs and BSRs are generally published in the spring or summer of each year. The next BSR is due in 2018.

Funding Requirement: No additional funding is required since the reports are covered by CRP.

Implementation Activity 2.3: Install a flow meter at the CWQM site
The concentration of many water quality parameters are related to flow. The CWQM site does have a depth sensor which was used to estimate relative flow in the data analysis conducted for this I-Plan Revision. Measured flow values would enhance data analysis.

Implementation Schedule: TCEQ and NRA will submit applications for funding when opportunities arise.

Funding Requirement: $14,000 - $17,000 per year for a United States Geological Survey maintained flow gauge.

Implementation Activity 2.4: Establish a Texas Stream Team volunteer monitoring group
Volunteer monitoring, comprised of local stakeholders with a vested interest in their river or creek, is an efficient and inexpensive way to conduct water quality monitoring. The data collected, while not used for official assessment by the TCEQ, can be used to screen for water quality problems and/or improvements on a more frequent basis than routine CRP monitoring.

Implementation Schedule: TCEQ and NRA will work with the Texas Stream Team, a program of The Meadows Center for Water and the Environment at Texas State University, to establish a volunteer monitoring group in FY 2015.

Funding Requirement: The training to become a water quality monitor is a 3-phase program provided by the Texas Stream Team. $2,140 for two monitoring kits and one year of supplies and $169 per year to restock consumable supplies.

Implementation Activity 2.5: Conduct targeted monitoring in tributaries
The routine monitoring and CWQM sites are located in the main stem of the creek. Targeted monitoring in the tributaries can help identify more localized sources of chloride, sulfate, and TDS, allowing for more site specific BMPs to address these sources.

Implementation Schedule: TCEQ intends to contract with NRA for FY 2015 to conduct monitoring at up to nine sites: 1 – Petronila Creek at US 77; 2 – Drainage Ditch at US 77 / CR 233; 3 – Drainage Ditch at CR 24; 4 – Drainage Ditch at FM 665; 5 – Petronila Creek at CR 232 (Willoughby Farms); 6 – Tributary at FM 892; 7 – Tributary at FM 892 / CR 373; 8 – Tributary at FM 70; 9 – Outlet for Drainage Ditch from Cefe Valenzuela Landfill (Figure 9).

Funding Requirement: Monthly monitoring at all nine sites, including some administrative costs, will be approximately $35,000 - $40,000 for one year.

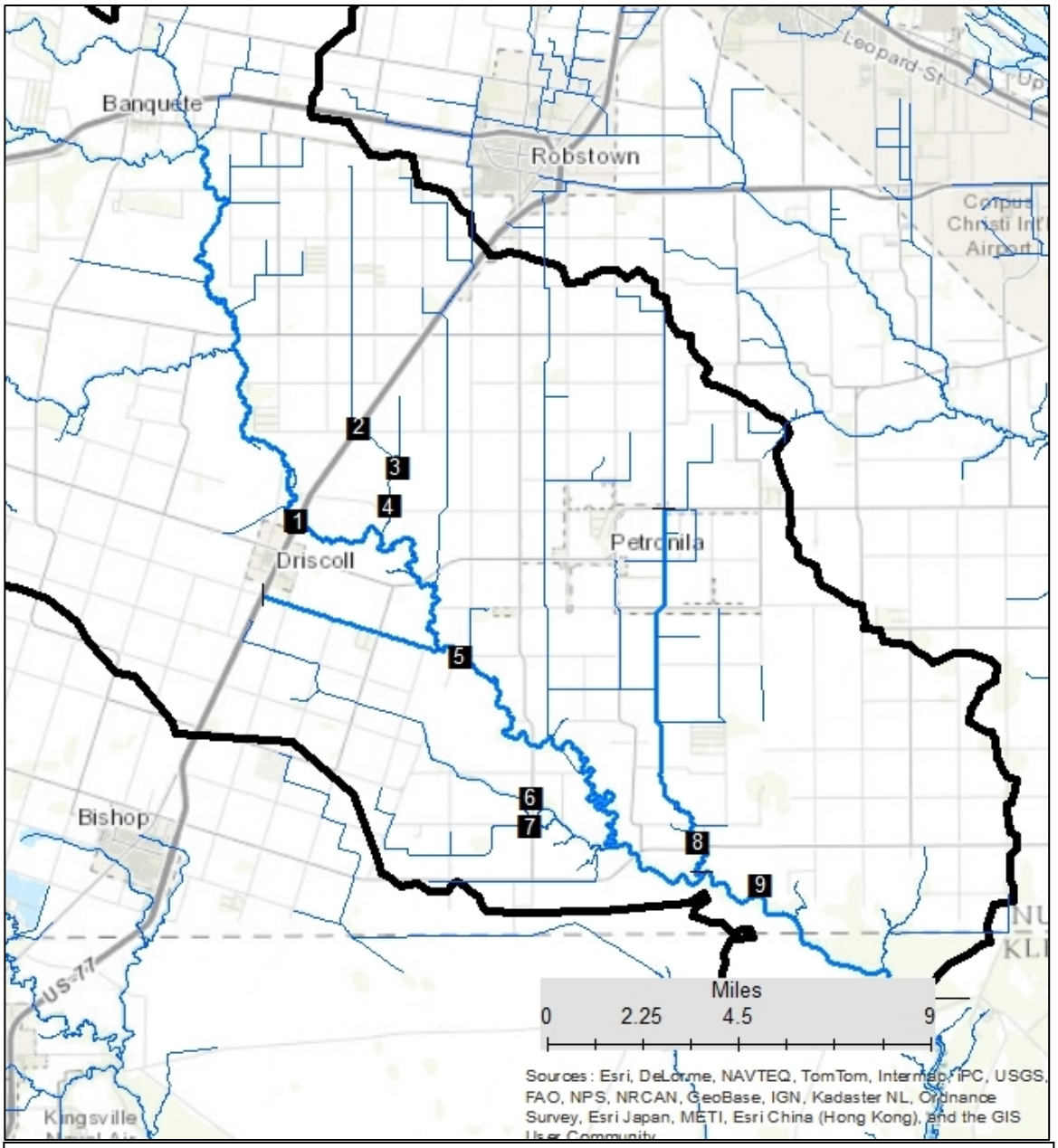

Figure 9: FY 2015 Targeted Monitoring Sites

Implementation Activity 2.6: Intensive monitoring program to identify "hot spots" within the creek
One method to identify the exact locations of input into the creek is to travel the entire creek, taking water quality measurements continuously or at very small increments all along the way.

Implementation Schedule: TCEQ and NRA will coordinate with Texas A&M University– Corpus Christi to submit applications for funding when opportunities arise.

Funding Requirement: Estimate of $25,000 – $40,000.

Control Action 3: Education and Outreach

Education and outreach are critical components to any restoration effort. They raise awareness and promote stewardship of the environment.

Implementation Activity 3.1: Conduct riparian workshops for landowners

NRA and the Texas State Soil and Water Conservation Board (TSSWCB) have developed riparian workshop programs to educate landowner about the benefits of properly functioning riparian areas.

Implementation Schedule: NRA will coordinate a workshop for landowners for FY 2015.

Funding Requirement: No additional funding is required for workshops since they are covered by other programs.

Implementation Activity 3.2: Conduct riparian workshops for school children

The riparian workshops are also excellent outreach and education opportunities for schools. School districts that may be willing to participate are Agua Dulce, Alfred, Banquete, Bishop, Driscoll, Orange Grove, Petronila, and Robstown.

Implementation Schedule: NRA will contact the schools in FY 2015 – FY 2016 and offer these workshops in coordination with their curriculums and as funding for transportation is available.

Funding Requirement: No additional funding is required for workshops since they are covered by other programs. However, transportation expenses for schools will most likely be needed. Estimated cost of $500 per school for a total of $4,000.

Implementation Activity 3.3: CRP Education and Outreach

NRA conducts numerous education and outreach activities throughout its CRP area of responsibility. These include the use of NRA's watershed, rainwater, and groundwater models in schools, ag fairs, Earth Day Bay Day, and other community events.

Implementation Schedule: NRA conducts these activities on an ongoing basis

Funding Requirement: No additional funding is required since these events are covered by CRP.

Potential Funding Sources

While many of the activities described under this I-Plan require no additional funding, or minimal additional funding, full implementation will require some additional funding, particularly for remediation and monitoring measures. The following is a brief list of potential funding sources. Implementation under this I-Plan may make use of a mix of these sources, or other sources as available. It is the intent of this I-Plan to be compatible with the widest array of potential grant program requirements possible in order to provide greater flexibility for its stakeholders.

Federal Grants – Federal money, administered through grants from the TCEQ and TSSWCB, is available under several grant programs, including Section319(h)[1], Section 604(b)[2], and Section 106[3]. These grants are competitive, and often require matching funds or in-kind value.

[1] This funding source, available in grants from the EPA, as administered through the TCEQ and TSSWCB, funds nonpoint source reduction efforts needed to implement Watershed Protection Plans and TMDLs.

[2] This funding source is related to water quality management planning and the State Water Quality Management Plan (TCEQ only).

[3] Section 106 covers water pollution control grants that are used for a variety of research, monitoring, and related activities (TCEQ only).

State grant/loan programs – Aside from federal monies administered by the state, some state programs exist to fund water and wastewater infrastructure, such the Texas Water Development Board's Clean Water State Revolving Fund and Drinking Water State Revolving Fund, and related programs specific to certain circumstances like the Economically Disadvantaged Area Program.

Volunteer/in-kind – Some of the activities identified will rely on the participation of the general public through volunteer efforts. Texas Stream Team volunteer monitoring will play a large role in implementation.

Implementation Tracking

Implementation tracking provides information used to determine if progress is being made toward meeting goals. Tracking also allows stakeholders to evaluate actions taken, identify those which may not be working, and make any changes that may be necessary to get the plan back on target. The RRC, NRA, and TCEQ will work collaboratively to ensure monitoring data are assessed to track progress.

This I-Plan revision includes essentially the same provisions to track the progress of the plan as found in the original I-Plan. It uses both programmatic and water quality indicators defined as:

- **Programmatic Indicator** – A measure of administrative actions undertaken that result in an improvement in water quality.
- **Water Quality Indicator** – A measure of water quality conditions for comparison to pre-existing conditions, constituent loadings, and water quality standards.

Programmatic Indicators

The TCEQ will further evaluate the need for, and effectiveness of, the various mitigation and remediation options based on periodic evaluation of monitoring results. Additional monitoring and/or implementation of any BMPs will be further developed as the results of the ongoing monitoring become known. Interim evaluations will be made as appropriate, with final evaluations to be performed following completion of all scheduled efforts.

Water Quality Indicators

Verification that designated uses have been restored requires the measurement of applicable water quality indicators. The measurable outcome of all phases of this Revised I-Plan shall be the attainment of the TMDL endpoints for chloride, sulfate, and TDS in Petronila Creek Above Tidal.

Throughout the implementation schedule, continuous and routine quarterly monitoring will occur at water quality station 13093, Petronila Creek at FM 70. Routine quarterly monitoring will occur at station 13094 at FM 892 and station 13096 at FM 665. Additional monthly chloride, sulfate, and TDS measurements will be taken and at all three locations. Achievement of the endpoints will be measured through the analysis of data collected by NRA and TCEQ. Updates on progress toward the endpoints will be provided to stakeholders via the project web page and the NRA's annual assessment report.

Review Strategy

The TCEQ and stakeholders in TMDL implementation projects periodically assess the results of the planned activities and other sources of information to evaluate the effectiveness of the I-Plan implementation. Stakeholders evaluate several factors, such as the pace of implementation, the effectiveness of BMPs, load reductions, and progress toward meeting water quality standards. The TCEQ will document the results of these evaluations and its rationale for maintaining or revising elements of the I-Plan, and will present them as part of the state's normal reporting process summarized in the following section.

Communication Strategy

Communication is necessary to ensure that stakeholders understand the I-Plan and its progress in restoring water quality conditions. The TCEQ will disseminate the information derived from tracking I-Plan activities to interested parties, including watershed stakeholders, state leadership, government agencies, nongovernmental organizations, and individuals.

Throughout the implementation process, general updates will be provided to the stakeholders in the basin via the project web page. The results of TCEQ's bi-annual water quality assessment of surface waters are reported in NRA's annual assessment report. At annual meetings hosted by the TCEQ, the stakeholders will periodically assess progress using the schedule of implementation, interim measurable milestones, and water quality data. If periodic assessments find that insufficient progress has been made in improving water quality, the implementation strategy will be adjusted.

References

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Appendix A

Yearly Average Data Values

TDS (mg/L)

Year	13093	13094	13096
1971	750		
1972	24,602		
1973	39,345		
1974	21,890		
1975	27,533		
1976	18,367		
1977	37,945		
1978			
1979	31,000		
1980	28,367		
1981			
1982	17,937	41,900	52,700
1983	5,380		
1984	6,627	27,672	46,000
1985	470	431	
1986	7,200	9,750	
1987	13,690	12,311	
1988			
1989		13,696	
1990		8,678	
1991		7,919	

Year	13093	13094	13096
1992		1,210	
1993		7,456	
1994		15,133	
1995		12,087	6,550
1996		15,874	16,500
1997		4,052	
1998		14,043	
1999		9,911	
2000		18,600	
2001		16,575	
2002		10,722	
2003	9,015	11,395	9,640
2004	3,953	8,048	6,775
2005	7,920	9,704	6,659
2006		13,623	11,663
2007		9,820	3,420
2008		16,300	11,733
2009		16,188	19,473
2010	8,573	10,274	8,994
2011	14,174	14,638	14,082
2012	11,928	12,928	11,298

Chloride (mg/L)

Year	13093	13094	13096
1971	153		
1972	5,981		
1973	15,749		
1974	12,832		
1975	11,793		
1976	5,100		
1977	9,645		
1978			
1979	6,387		
1980	4,620		
1981			
1982	7,407	25,300	32,700
1983	1,810		
1984	3,621	15,753	28,100
1985	88	69	
1986	1,883	4,500	
1987	4,300	6,428	
1988			
1989		5,820	
1990		4,587	
1991		4,850	

Year	13093	13094	13096
1992		868	
1993		4,529	
1994		7,080	
1995		5,507	2,560
1996		6,810	4,197
1997		1,922	
1998		5,080	
1999		4,100	
2000		7,403	
2001		8,208	
2002		4,953	
2003	4,352	5,847	5,063
2004	1,815	3,801	2,058
2005	3,856	4,608	3,293
2006		7,115	6,010
2007		4,573	3,246
2008		8,045	5,893
2009		7,710	8,733
2010	4,150	5,011	4,605
2011	6,635	7,088	6,582
2012	5,783	5,928	5,398

Sulfate (mg/L)

Year	13093	13094	13096
1971	6		
1972	151		
1973	243		
1974	348		
1975	199		
1976	66		
1977	487		
1978			
1979	416		
1980	400		
1981			
1982	457	830	340
1983	130		
1984	225	337	150
1985	3	5	
1986	228	292	
1987	738	842	
1988			
1989		710	
1990		589	
1991		918	

Year	13093	13094	13096
1992		151	
1993		685	
1994		1,098	
1995		803	329
1996		1,088	1,151
1997		247	
1998		906	
1999		695	
2000		1,314	
2001		1,408	
2002		770	
2003	854	1,032	925
2004	406	700	620
2005	718	781	536
2006		1,180	984
2007		801	548
2008		1,408	990
2009		1,361	1,536
2010	839	925	847
2011	1,280	1,268	1,152
2012	994	1,403	1,006

Appendix B

Petronila Creek: Specific Conductivity versus Sample Depth, January 30, 2014

Prepared by The Meadows Center for Water and the Environment

Appendix C

Implementation Matrix

Table C.1 Implementation Matrix

Control Action	Implementation Activity	Estimated Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators to Measure Progress	Monitoring Component	Responsible Party
1. Investigation and Abatement of Produced Water Impacts and Seeps to Surface Water	1.1 Soil remediation at Areas 2A, 3, 4, 5.	Need several more years of water quality data to determine how much of an impact the removed soils have	$400k - $500k per site	N/A	FY 2015 for Areas 2A, 3, and 4. Earliest FY 2016 - 2017 for Area 5.	Identification of operators and scheduled remediation	Completion of soil remediation at each site	N/A	RRC
	1.2 Investigate the old saltwater disposal wells and tanks near US 77 crossing north of Driscoll	Need several years of water quality data after well P&As and tank removal to determine how much this area was contributing	$250k	N/A	Earliest FY 2016 - 2017	Identification of operators and scheduled cleanup	Completion of well P&As and removal of tanks	N/A	RRC
2. Water Quality Monitoring and Data Analysis	2.1 Continue routine and continuous monitoring	Need several more years of water quality data to determine impact	N/A – expenses are covered under CRP and CWQM programs	Include in CRP Education and Outreach activities	Ongoing	Decreasing measured TDS, chloride, and sulfate concentrations	Decreasing trend in TDS, chloride, and sulfate values	Routine CRP and TCEQ continuous monitorin	NRA and TCEQ
	2.2 Conduct analysis yearly and report in the CRP reports	N/A	N/A – expenses are covered under CRP	Include updates in CRP reports	Yearly	N/A	Inclusion in CRP reports	N/A	NRA
	2.3 Install a flow meter at the CWQM site	N/A	$14k - $17k per year	N/A	Dependent on funding	Identification and securement of funding	Installation of flow meter	Addition of flow measurements to continuous data	NRA and TCEQ

Control Action	Implementation Activity	Estimated Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators to Measure Progress	Monitoring Component	Responsible Party
	2.4 Establish a Texas Stream Team volunteer monitoring group	N/A	$2,140 for first year, then $169 per year	Landowner responsibility and student education	FY 2015	Organization of Stream Team group	Submittal of monitoring information	Volunteer monitoring	NRA, TCEQ, and Texas Stream Team
	2.5 Conduct targeted monitoring in tributaries	May narrow geographic area of source and identify additional areas for remediation	$35k - $40k	Include updates in CRP reports	FY 2015	Monthly data review	Identification of point source loading from tributaries	Monthly monitoring	NRA
	2.6 Intensive monitoring program to identify “hot spots” within the creek	May narrow geographic area of source and identify additional areas for remediation	$25k - $40k	Include updates in CRP reports	Dependent on funding	Identification and securement of funding	Contract with TAMUCC and project report	Water quality measurements at specific intervals, to be determined, for the entire length of the project area	NRA, TCEQ, and TAMUCC
3 Education and Outreach	3.1 Conduct riparian workshop for landowners	N/A	N/A – the workshops are provided by other programs	Landowner responsibility	FY 2015	Scheduling of the workshop	Completion of workshop	N/A	NRA, TCEQ, and TWRI
	3.2 Conduct riparian workshop for school children	N/A	$500 per school for transportation	Compatible with State requirements	FY 2015	Scheduling of the workshop	Completion of workshop	N/A	NRA, TCEQ, and TWRI
	3.3 CRP Education and Outreach	N/A	N/A – expenses are covered under CRP	Multiple education and outreach activities in schools and community events	Ongoing	Scheduling of the events	Inclusion of summary of events in annual CRP reports	N/A	NRA