



Status Report: Implementing TMDLs to Reduce Phosphorus Improving Water Quality in the North Bosque River

Water Quality Impairment

Beginning in 1996, TCEQ identified excessive algal growth in the North and Upper North Bosque Rivers (Segments 1226 and 1255, Figure 1). High concentrations of nutrients can cause excessive growth of algae and other aquatic plants, which can impair water quality. Algae can also lead to taste and odor in drinking water and may reduce the dissolved oxygen in the water to support fish and other aquatic life.

The implementation of various nutrient control measures for the river segments has resulted in improved water quality (see “Environmental Progress”). This report summarizes progress and activities to improve water quality through fiscal year 2022; the state’s fiscal year is Sept. 1 through Aug. 31.

TCEQ developed total maximum daily loads (TMDLs) to reduce phosphorus in Segments 1226 and 1255. The commission adopted the TMDLs in 2001.¹ A TMDL is like a budget; it determines how much of a particular pollutant a water body can receive and still meet state standards for surface water quality. Discharges of the pollutant are then allocated to source categories within the watershed to stay within the overall budget—or total load—as defined in the TMDL.

In statewide assessment guidance, chlorophyll-*a* is measured to indicate whether concentrations of nutrients, which include phosphorus, nitrogen, and other substances—may be high enough to cause adverse conditions such as excessive algal growth. For the past 24 years, TCEQ and project partners have monitored concentrations of both phosphorus and chlorophyll-*a* at five monitoring sites, called index sites (Figure 2), to determine improvements in water quality.

In 2002, TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) developed a TMDL implementation plan (I-Plan) describing the regulatory and voluntary actions needed to reduce phosphorus and algal growth in the river segments, along with a schedule for implementing them.² In addition, stakeholders in the watershed have voluntarily undertaken measures not contained in the TMDL I-Plan to improve the water quality of the North Bosque River.

Water Quality Goal

The TMDL I-Plan is designed to reduce the annual average concentration of soluble reactive phosphorus in the North Bosque River. Soluble reactive phosphorus (SRP) has the highest correlation with algal growth in



Figure 1. Location within Texas of the North Bosque River Watershed, Segments 1226 and 1255

this watershed and is the most available form of the nutrient; therefore, SRP was selected as the target pollutant.³ Reduction goals are site-specific and range from 39% to 62%. The I-Plan sets specific water quality goals as measures of success at each of the five index sites.

Implementation Activities

The following list identifies regulatory and voluntary actions identified in the TMDL I-Plan to reduce phosphorus concentrations in the North Bosque River segments. Most of these activities have been completed (see Tables 1 and 2).

- *Regulatory Action*
 - Issuing new and amended permits for concentrated animal feeding operations (CAFOs) that require enhanced nutrient management plans for dairies.
 - Issuing new and amended permits for wastewater treatment facilities (WWTFs) that require phosphorus effluent limits.
 - Monitoring by TCEQ Regional Areas for compliance with permits.
 - Revising rules for all animal feeding operations (AFOs), and especially for CAFOs.

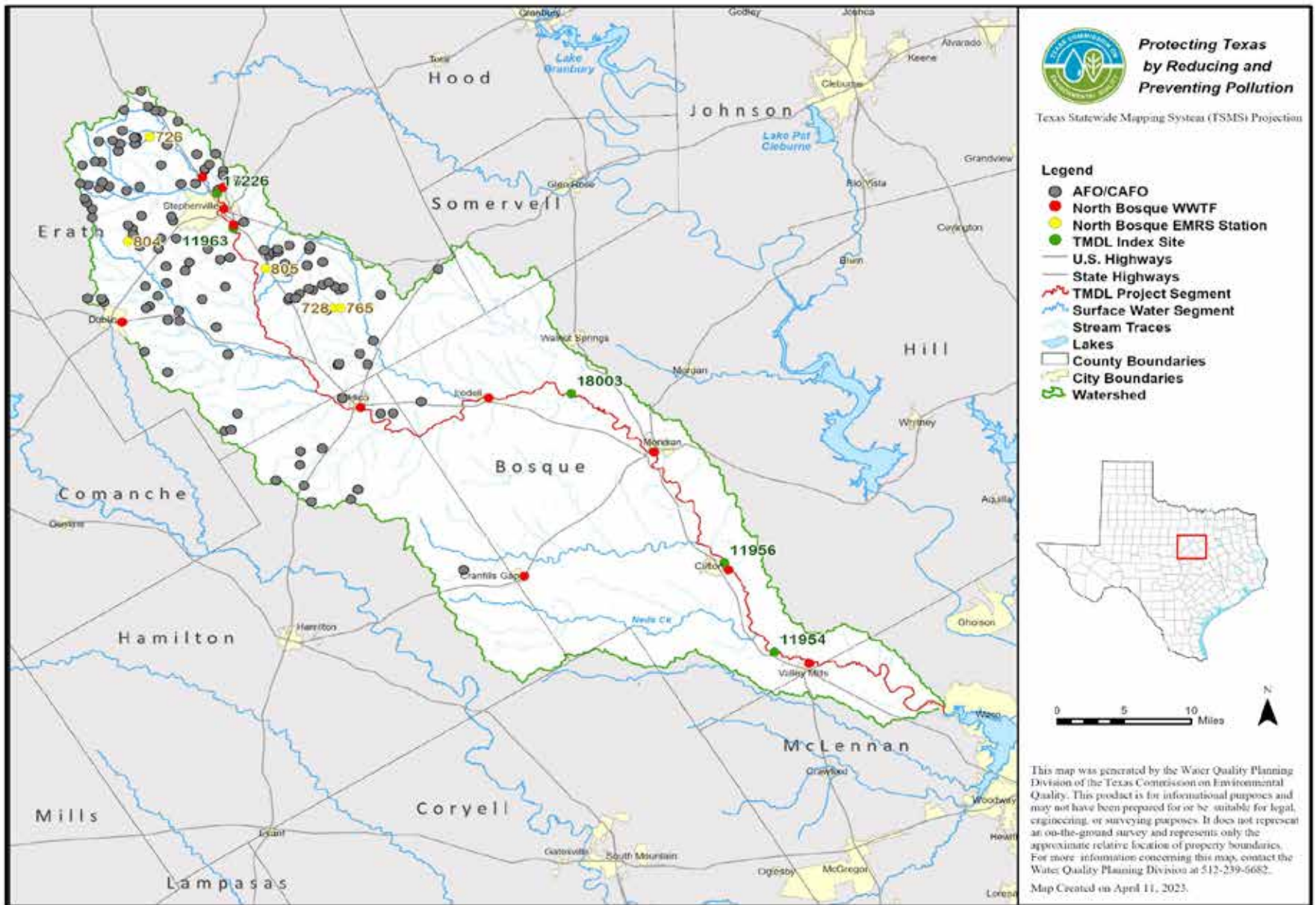


Figure 2. North Bosque River Watershed showing monitoring stations, CAFOs, and WWTFs

- Continuing education for facility operators.
- Developing and issuing a general permit for composting facilities.
- *Voluntary Actions*
 - Institutionalizing hauling and composting dairy manure for use in areas outside the watershed.
 - Applying improved land management practices through education, outreach, and implementation of comprehensive nutrient management plans (CNMPs) at all AFOs and CAFOs.
- *Tracking Results and Refining Plans*
 - Refining the model to verify target reductions.
 - Monitoring the rate of decline in phosphorus concentrations until water quality standards are met.
 - Inspecting regulated facilities and enforcing compliance as necessary.

Continuous Stream Monitoring

In addition to the five index sites where compliance with the TMDL is monitored, TCEQ maintains a local network of five Environmental Monitoring and Response System (EMRS) stations in the watershed (Figure 2). These five sites are part of the EMRS project that notifies TCEQ Stephenville Field Office staff when established trigger levels are exceeded.

Numerous field investigations by staff of the TCEQ Stephenville Field Office have resulted from EMRS station data since the inception of the EMRS in 2004. Several of those field investigations have resulted in enforcement actions.

Status of Implementation

Watershed stakeholders have made significant progress toward achieving the water quality goals in the I-Plan. Many regulatory and locally initiated phosphorus control measures have been implemented. Some of the measures have reduced the amount of phosphorus available in the watershed, notably manure management at CAFOs and AFOs, and effluent limits and upgrades for WWTFs.

Individual permits with more stringent requirements were implemented at dairies beginning in 2004, along with voluntary and regulatory nutrient management practices. The increased focus on preventing discharges and managing nutrients has been an important factor in improving water quality.

On July 2, 2014, TCEQ adopted a revised CAFO rule to incorporate changes in federal regulations. The rule changes imposed additional requirements in nutrient management plans for CAFOs in the watershed.

Tables 1 and 2 (pages 7 and 8) summarize specific activities implemented to reach the phosphorus reduction targets in the TMDL and I-Plan. Table 1 summarizes activities still in progress through August 2022. Table 2 identifies completed activities.

Environmental Progress

TCEQ and its partners monitor several sites each year under the state's coordinated monitoring schedule, including the five index sites identified in the TMDL I-Plan. Concentrations of SRP at these sites vary from year to year, often associated with the weather in the watershed. Figures 3 and 4 show average annual phosphorus concentrations at the five index sites since 1997.

Chlorophyll-*a* concentrations continue to be above statewide screening levels.⁴ Because chlorophyll-*a* is a measure of the green pigment contained in algae for use in photosynthesis, its concentrations may indicate whether a water body is likely to develop high concentrations of algae.

Analysis of data through December 2021 showed statistically significant decreasing trends for SRP at the lower four index stations (Stations 11963, 18003, 11956, and 11954). Although significant, the decreasing SRP trend at station 18003 is very slight, due to many values at the reporting limit routinely collected at that station.⁵ SRP concentrations at the three lowest index sites have generally been below or near their I-Plan targets since 2006 (Figure 4). There is a significant downward trend in chlorophyll-*a* at Station 11963.⁶

At the index site below the Stephenville WWTF (11963), SRP concentrations were reduced by more than 50% in 2006 after implementation of new phosphorus control practices by the city of Stephenville at their WWTF (Figure 3).⁷ Phosphorus concentrations at this site have since been trending gradually downward overall⁸.

However, between October 2021 and September 2022 Station 11963 did not meet the TMDL goal for the first time since September 2018 (Figure 3). This was likely due to the low flow conditions caused by drought in the watershed at the time. They have not yet met the water quality success measure in the I-Plan but have been near or very near to meeting it since fiscal year 2009 (Figure 3).⁹

At the site above Stephenville (Station 17226), SRP concentrations do not meet the TMDL goal (Figure 3). Data show a small but statistically significant downward trend in SRP concentrations after storms since 2017. In addition, concentrations of *E. coli*, ammonia-nitrogen, and total phosphorus are trending significantly downward at this station.¹⁰

Figure 3. Annual Average Concentrations of Soluble Reactive Phosphorus at the Two Upper Index Sites on the North Bosque River – October 1997 through September 2022

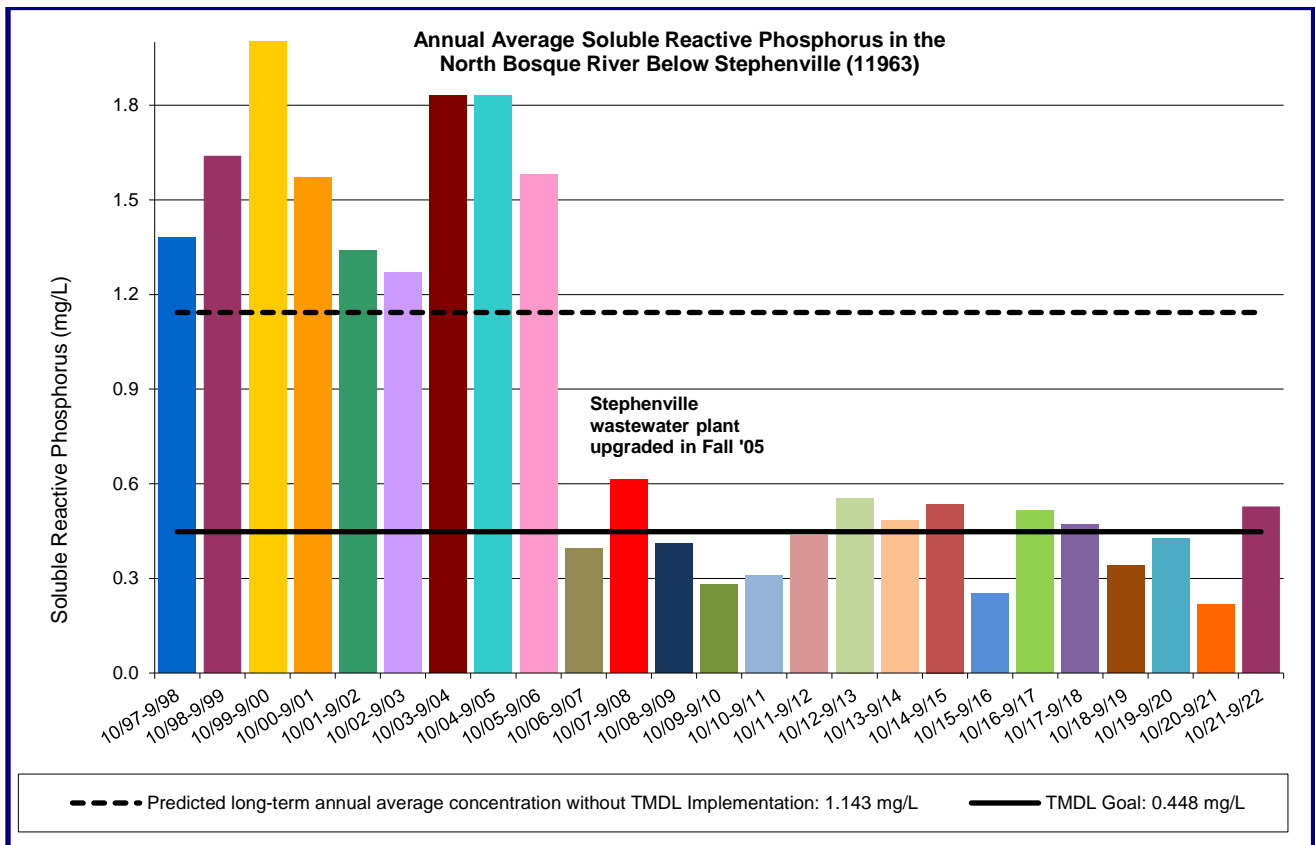
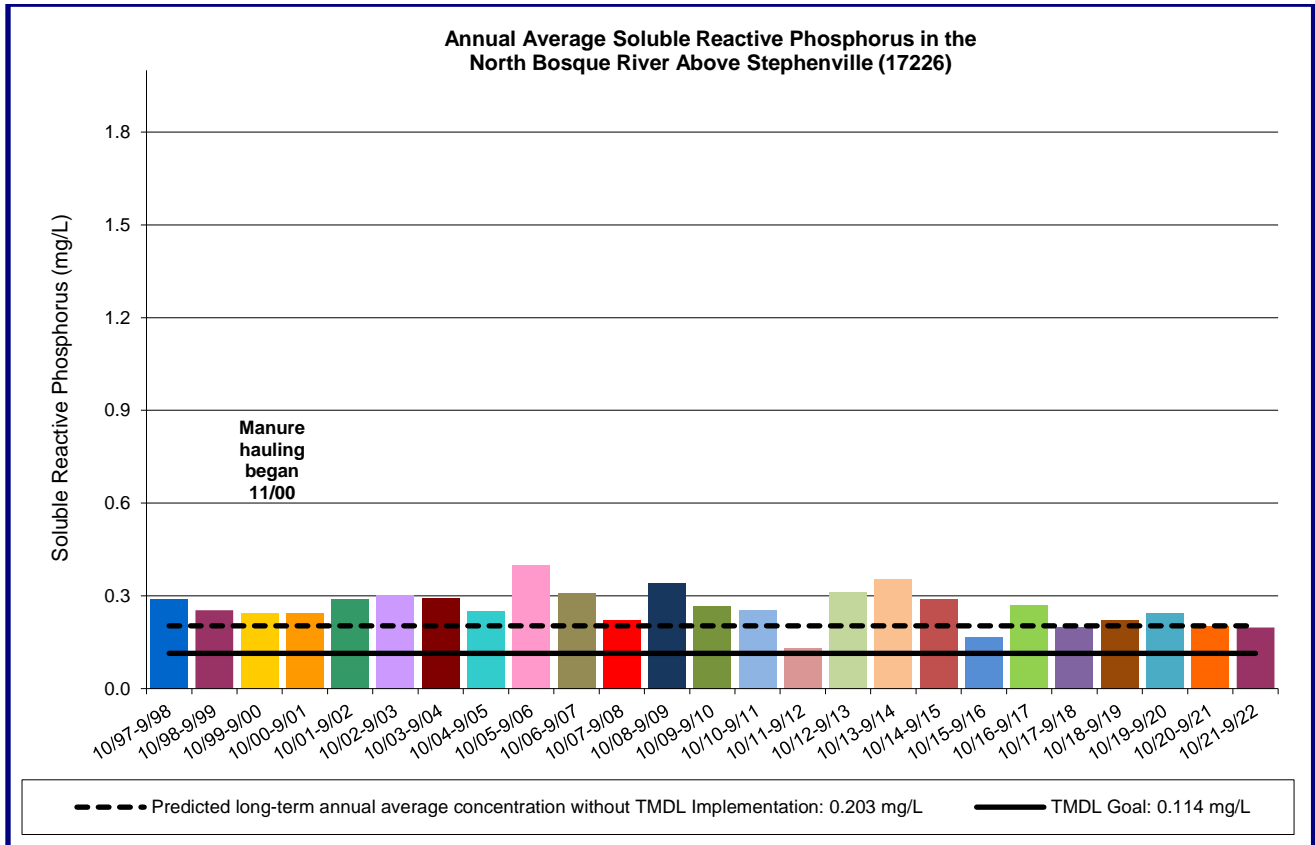
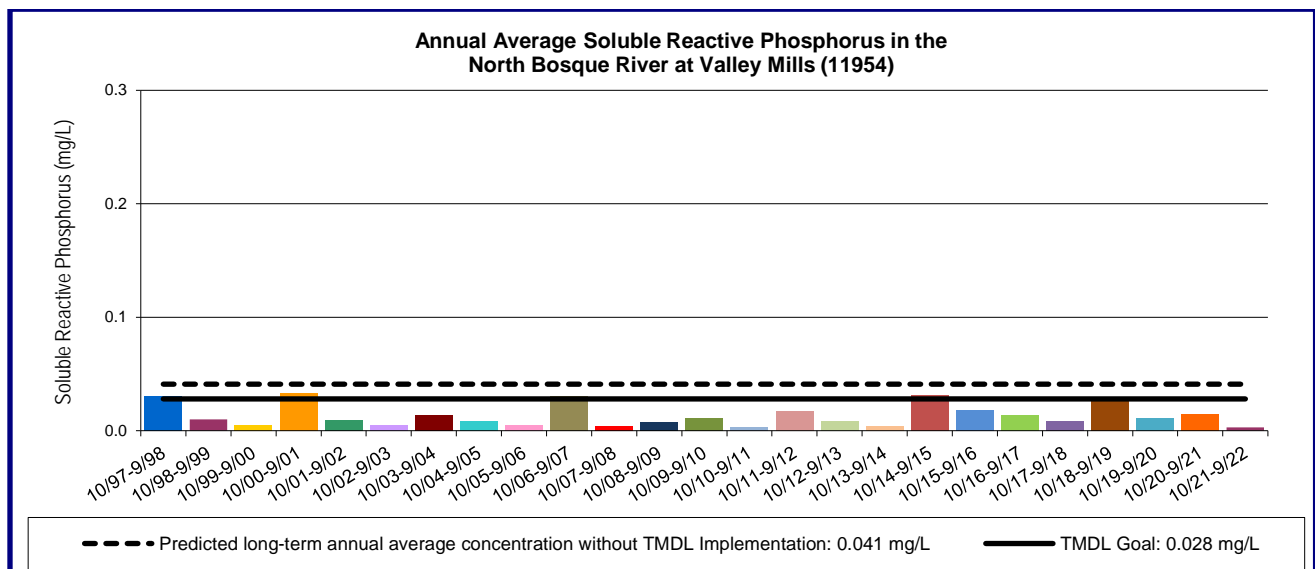
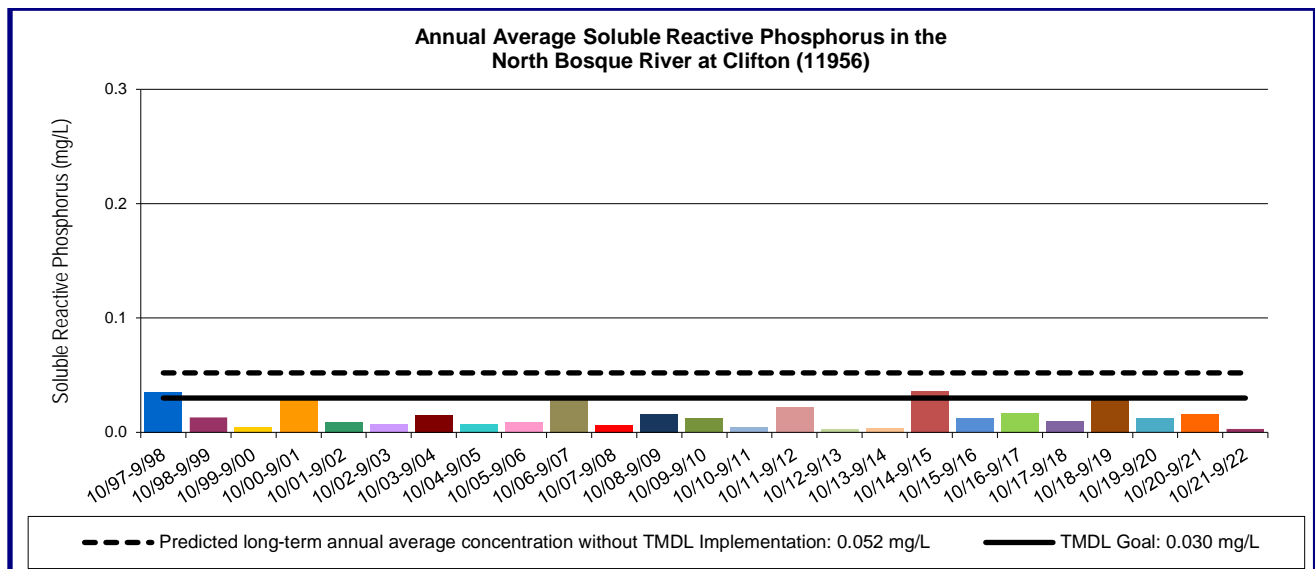
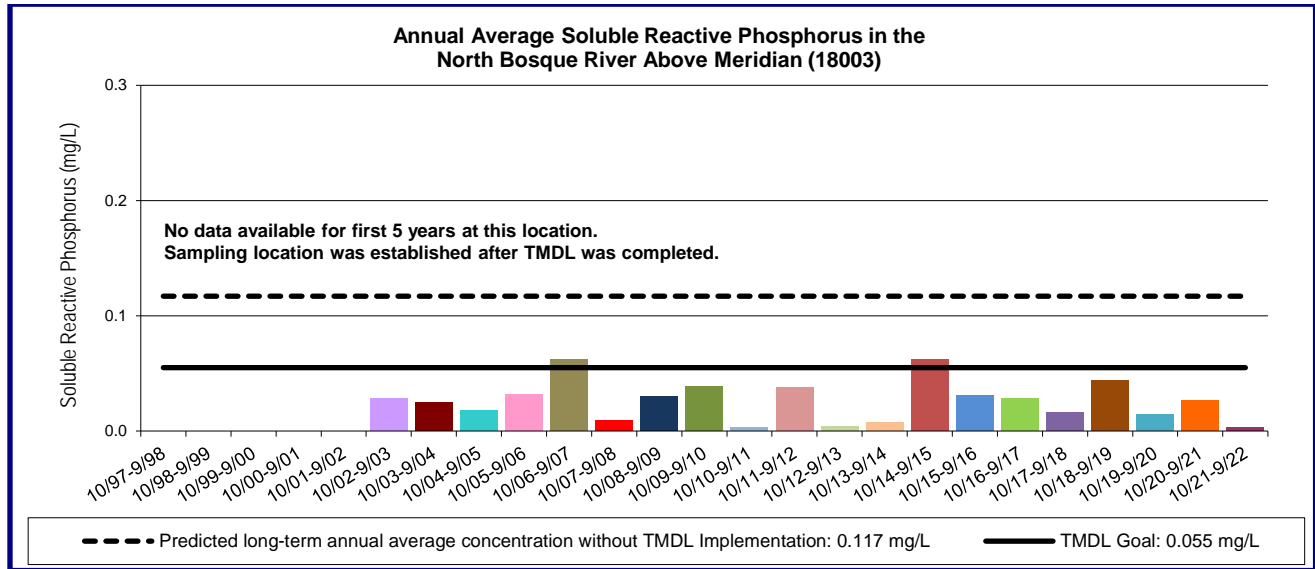


Figure 4. Annual Average Concentrations of Soluble Reactive Phosphorus at the Three Lower Index Sites on the North Bosque River – October 1997 through September 2022



Implementation Highlights

- TCEQ and EPA approved the TMDLs in February and December of 2001, respectively. TCEQ and TSSWCB approved the I-Plan in December 2002 and January 2003, respectively.
- By the beginning of 2006, all municipal WWTFs were on a compliance schedule consistent with the wasteload allocation in the TMDL. Permits continue to be issued, renewed, or amended consistent with TCEQ policies and rules.
- TCEQ Regional Offices developed and implemented regular schedules for compliance inspections of CAFOs, WWTFs, and composting facilities in the watershed.
- TCEQ assisted WWTFs with plans for remediation and prevention of sanitary sewer overflows.
- TCEQ adopted amendments to the Subchapter B rules for CAFOs on July 15, 2004.
- On July 2, 2014, TCEQ adopted a revised CAFO rule to incorporate changes in federal regulations. The primary effect of the rule changes for Bosque dairies is additional requirements related to nutrient management plans and recordkeeping.
- The TCEQ Region 4 satellite office in Stephenville conducts annual soil sampling of WAFs for Bosque CAFOs to comply with Texas Water Code Subsection 26.504(a). TCEQ provides the laboratory reports for the soil sampling to CAFO permittees for use in their annual nutrient management plan updates and application rates recalculations.
- The Composted Manure Incentive Plan and the Dairy Manure Export projects ended successfully in 2006 and 2007, meeting the I-Plan goal to remove approximately 50% of solid cattle manure from CAFOs during fiscal years 2003 through 2006. Performance monitoring indicated a positive correlation between participation in these programs and reductions in phosphorus in the river (Table 2).
- TCEQ developed markets for the use of composted manure from the watershed. The Texas Department of Transportation used large amounts of the compost in maintaining healthy vegetation along roadsides. Vegetative cover reduces the speed of stormwater runoff from roadways and acts as a filtering agent for suspended pollutants.
- TSSWCB assisted each of the 55 dairy CAFOs that were operating in the watershed in 2004 to develop and obtain certification for CNMPs by August 2010, adding substantive nutrient management practices at all the operations. New or amended plans are reviewed and certified annually, as appropriate.
- TIAER annually updates a Geographic Information System (GIS) inventory of all CAFO operations, along with CAFO and AFO WAFs in the watershed.
- TIAER continues to monitor water quality at the five index sites on the river and conducts annual assessments to track changes and trends in water quality.
- TIAER produces an annual Trends Report for the watershed in August of each year analyzing water quality trends through the previous December. The latest Trends Report is available on the TCEQ's TMDL project webpage.

Table 1. Progress on TMDL Implementation Activities in Fiscal Year 2022

Activity	Responsible Parties	Progress of Current Activities
<p>Inspect and Enforce Compliance</p> <ul style="list-style-type: none"> Perform inspections of CAFOs and AFOs. Report permit violations and levy fines as appropriate. <p>The TCEQ Region 4 satellite office in Stephenville conducts investigations of all CAFOs and AFOs in the five central Texas counties that are part of the eight-county Dairy Outreach Project Area (DOPA).</p> <p>The TCEQ Region 4 main office conducts biennial inspections at the Stephenville WWTF.</p> <p>The TCEQ Region 9 office conducts inspections following the normal compliance monitoring schedule at the six WWTFs in Hico, Iredell, Meridian, Cranfills Gap, Clifton, and Valley Mills. These WWTFs are considered minors and are inspected at least once during the life of their 5-year permit.</p>	<p>TCEQ Regional Offices 4 and 9</p>	<p>TCEQ Regional Area personnel continue to follow regular schedules for compliance inspections of CAFOs, AFOs, and WWTFs.</p> <p>Fiscal Year 2022</p> <p>CAFOs, AFOs, and WWTFs were inspected as required.</p> <p>CAFOs and AFOs</p> <ul style="list-style-type: none"> 78 compliance inspections 7 complaint investigations 14 notices of violation 6 enforcement actions 53 WAF soil sample tests <p>WWTFs</p> <ul style="list-style-type: none"> 3 compliance inspections 5 complaint investigations 8 notices of violation 1 enforcement actions
<p>Monitor Instream Water Quality</p> <ul style="list-style-type: none"> Monitor and assess instream water quality to determine status and trends in concentrations of soluble reactive phosphorus. 	<p>TCEQ</p>	<p>TIAER monitored instream water quality at seven sites in the North Bosque River watershed in fiscal year 22, including the five index sites identified in the North Bosque River I-Plan.</p>

Table 2. Completed Management and Improvement Activities

Completed Activity	Responsible Parties	Summary
<p>Municipal Permits</p> <ul style="list-style-type: none"> Initiate amendment actions for municipal wastewater treatment plants located in the watershed as of 2002, in order to make all the permits consistent with the TMDL. 	<p>TCEQ</p>	<ul style="list-style-type: none"> All municipal wastewater discharge permits were revised to a compliance schedule consistent with the wasteload allocation in the TMDL and I-Plan. Permits continue to be issued, renewed, or amended consistent with agency policies and rules. TCEQ issued amended permits to Stephenville and Clifton in mid-July 2003. The cities of Clifton and Stephenville completed facility upgrades in spring 2005 and fall 2005. Through August 2012, instream concentrations of phosphorus were reduced by more than 50% at the sampling site downstream of Stephenville after the 2005 facility upgrade.
<p>Update CAFO Permits</p> <p>Issue individual permits for all dairy CAFOs in the watershed.</p>	<p>TCEQ</p>	<ul style="list-style-type: none"> TCEQ issued new permits for CAFOs in the North Bosque watershed as existing permits expired. TCEQ continues to amend, issue, and renew individual permits as required.
<p>Implement Comprehensive Nutrient Management Plans for CAFOs</p> <p>Certify new or amended plans as appropriate.</p>	<p>TSSWCB</p>	<ul style="list-style-type: none"> New or amended plans are reviewed and certified annually, as appropriate.
<p>Develop and Implement Water Quality Management Plans for AFOs</p> <p>Dairy operations that run less than 200 cattle are called AFOs (animal feeding operations). They operate under authorizations set out in TCEQ rules.</p> <ul style="list-style-type: none"> Assist AFOs with the development of voluntary Water Quality Management Plans (WQMPs) and CNMPs, both of which help AFOs operate in a way that supports instream water quality. 	<p>TSSWCB</p>	<ul style="list-style-type: none"> TSSWCB reviews the status of AFOs that operate under certified WQMPs biennially. New or amended plans are reviewed and certified annually, as appropriate.
<p>Sanitary Sewer Overflow (SSO) Initiative</p> <ul style="list-style-type: none"> Develop voluntary SSO plans with cities in the watershed. <p>SSO plans are designed to reduce the number of SSOs that occur each year and to address them before they harm human health, safety, or the environment and before they become enforcement issues. Participants commit to a plan and schedule for rehabilitation of the collection system, development and implementation or improvements to operation and maintenance practices, and budgetary allocation of funding. Annual progress reports are required.</p>	<p>TCEQ Field Operations</p>	<p>The city of Stephenville is a current participant in the initiative and has submitted their SSO plan to TCEQ and is meeting the requirements. The cities of Meridian and Valley Mills are former participants who were removed from the program in 2017 and 2016, respectively. Both Meridian and Valley Mills submitted approved plans and completed improvements to their sewer systems while participating in the program.</p>

Completed Activity	Responsible Parties	Summary
<p>Implement Comprehensive Nutrient Management Plans for CAFOs</p> <ul style="list-style-type: none"> Complete guidance for CNMPs. Assist CAFO operators in developing CNMPs that are consistent with Nutrient Management Plan (NMP) requirements in permits. 	TSSWCB	<ul style="list-style-type: none"> CNMP guidance was completed in 2003. TSSWCB certified CNMPs for all dairy CAFOs in the watershed by 2010.
<p>Amend CAFO Regulations</p> <p>Amend rules for Chapter 321, Subchapter B as needed during 2004 to implement 2003 changes in federal regulations and to support implementation of the North Bosque River TMDL.</p> <p>Amend rules for Chapter 321, Subchapter B in 2014 to incorporate changes to the federal CAFO regulations that were finalized in July 2012.</p>	TCEQ	<p>Amendments to the Subchapter B regulations were adopted on July 15, 2004. Requirements of the amended rules became effective for each CAFO upon the issuance of its new or amended permit.</p> <p>The revised rules require NMPs and enhanced inspection, testing, and record-keeping elements. In addition, there are requirements specific to dairy CAFOs in the Bosque watershed.</p> <p>On July 2, 2014, TCEQ adopted additional amendments to the CAFO rule to incorporate changes in the federal CAFO regulations. The primary effect of the rule changes for Bosque dairies was additional requirements related to NMPs and recordkeeping.</p>
<p>CAFO Permits</p> <ul style="list-style-type: none"> Require all dairy CAFOs in the North Bosque River watershed to acquire an individual permit consistent with the 2004 amended rules for Subchapter B. <p>TCEQ has incorporated the CAFO rule changes into all active Bosque individual permits.</p> <p>In the Bosque watershed, TCEQ authorizes beef cattle CAFOs under a general permit, which was renewed on July 20, 2014, and incorporated the rule changes adopted on July 2, 2014. This CAFO general permit was renewed on July 20, 2019, and all beef cattle facilities in the Bosque watershed have since renewed their authorizations under the general permit.</p>	TCEQ and CAFO operators	<p>In 2005, TCEQ implemented an application review process for CAFO permits. All new and renewed CAFO permits issued since 2004 comply with the more stringent operating requirements set forth in the 2005 rule amendment, the TMDL load allocations, and the 2014 amended rules.</p>
<p>Conduct Dairy Waste Management Courses</p> <p>Subchapter B of the CAFO Rules requires all dairy operators to attend continuing education training to maintain knowledge of current practices.</p>	TCEQ and Texas A&M AgriLife	<p>In the first year of implementation, four training classes were held, and two special classes were offered.</p> <p>Continuing education classes have been institutionalized for this and other watersheds with numerous dairy operations. Texas A&M AgriLife now provides this training.</p>

Completed Activity	Responsible Parties	Summary
<p>Produce Compost from Manure</p> <ul style="list-style-type: none"> Annually remove 50% of collectable manure from dairy CAFOs and AFOs in the North Bosque River watershed from 2001 through 2006. <p>The amount of manure targeted for removal was based on the TMDL model, which estimated an average dairy cattle population of 40,450 head (and by extension, the associated manure) for the entire North Bosque River watershed.</p>	TCEQ	<p>The Composted Manure Incentive and Dairy Manure Export projects ended on August 31, 2006. At its conclusion, the projects had collected more than 650,000 tons of dairy manure at participating compost facilities and exported the equivalent of more than 329,000 tons of manure, removing more than 1.48 million pounds of phosphorus from the watershed.</p>
<p>Develop Regulations for Wastewater Discharges from Compost Facilities</p> <ul style="list-style-type: none"> Develop requirements for the design, construction, and management of manure composting facilities. Develop a permit to govern wastewater discharges from compost facilities. 	TCEQ	<ul style="list-style-type: none"> TCEQ issued a general permit for manure composting in October 2002. Three of the original facilities were allowed to use their wastewater for irrigation under specific restrictions. The remaining two facilities could not use wastewater for irrigation.
<p>Monitor the Effectiveness of Management Measures</p> <ul style="list-style-type: none"> Evaluate the effectiveness of the compost program in reducing instream phosphorus. 	TCEQ and TIAER	<ul style="list-style-type: none"> Information presented in the TIAER report, <i>Extending TMDL Efforts in the North Bosque River Watershed: Assessment Data through 2007</i>,¹¹ indicated a positive correlation between participation in the compost program and reductions in phosphorus in the stream through December 2007. Evaluation of smaller watershed areas supported a positive impact from the compost program.
<p>Monitor Micro-watersheds</p> <p>Monitor in-stream water quality of small tributaries to characterize the contribution of nutrients from waste application fields.</p>	TSSWCB	<p>Monitoring at 13 micro-watershed sites ended in July 2014. The final monitoring report, <i>Monitoring Effectiveness of Nonpoint Source Nutrient Management in the North Bosque River Watershed</i>, indicates small but measurable reductions of instream phosphorus.¹²</p>
<p>Validate and Improve the Phosphorus Index</p> <ul style="list-style-type: none"> Conduct field studies to quantify the effectiveness of the Phosphorus Index (PI) for predicting site vulnerability. <p>The PI is a reasonably rapid approach for identifying sites with the greatest potential to contribute to nonpoint source pollution. In addition, the PI enables comparison of alternative management practices used to reduce phosphorus losses.</p>	TSSWCB and Texas A&M AgriLife	<ul style="list-style-type: none"> In 2004, TSSWCB contracted with Texas A&M AgriLife to validate and/or modify the Texas PI as a predictive tool by conducting field studies in the dairy and poultry areas of Texas. All field and laboratory work for this project has been completed. The final project report, <i>Field Validation of the Texas Phosphorus Index</i>,¹³ is available online. Texas A&M AgriLife Extension Service recommended modifications to TCEQ's regulatory guidance based on results of the project, which TCEQ accepted. TCEQ published the revised guidance, <i>Soil Sampling for Concentrated Animal-Feeding Operations (CAFOs)</i>, RG-408,¹⁴ in 2009 and December 2017.

Completed Activity	Responsible Parties	Summary
<p>Improve and Standardize the Mehlich III Soil Test Method</p> <ul style="list-style-type: none"> Protect surface- and ground-water quality through the practice of soil testing. <p>Nutrient recommendations based on soil tests are a best practice for ensuring that nutrients are applied at agronomic rates. Soil testing is a prerequisite for participation in both state and federal regulatory cost sharing programs, issuance of land use permits, and compliance monitoring.</p>	<p>TSSWCB and Texas A&M AgriLife</p>	<ul style="list-style-type: none"> TSSWCB contracted with Texas A&M AgriLife to develop appropriate, standardized quality assurance, quality control, and standard operating procedures to provide a defined level of analytical assurance when using the Mehlich III soil test. The final report from the study, Improvement and Standardization of Laboratory Quality Assurance and Quality Control for Mehlich III Soil Test Methodology: Phase I and II,¹⁵ is available online.
<p>Construct Lake Waco Wetland</p> <p>In 1998 Waco City Council voted to raise the level of Lake Waco by seven feet, increasing the yield of the reservoir by over 20,000 acre/feet.</p> <ul style="list-style-type: none"> To provide habitat mitigation for the newly inundated land, the city constructed a 180-acre freshwater marsh, or wetland. 	<p>City of Waco</p>	<ul style="list-style-type: none"> The Lake Waco Wetland was completed in 2003 by the city of Waco, with help from the U.S. Army Corps of Engineers, Baylor University, and the U.S. Fish and Wildlife Service. The wetland is large enough to retain 11 million gallons of water for 7–10 days before returning it to the river, filtering out some of the nutrients and sediment in water that flows through it.
<p>Conduct an Aerial Survey of the Watershed</p> <ul style="list-style-type: none"> Conduct an aerial survey to document land uses that may be affecting water quality in the North Bosque watershed. 	<p>Brazos River Authority</p>	<ul style="list-style-type: none"> The Brazos River Authority conducted an aerial survey of the watershed around 2005 to obtain photographic and video-graphic records of land uses and of the riparian zones along the river. Interactive DVDs and an atlas were produced for each county in the watershed showing the flight path and points of interest.
<p>Apply and Refine the Bosque Model</p> <p>Incorporate new data and/or information related to model-simulated activities or features.</p> <ul style="list-style-type: none"> Refine and validate the original model using measured streamflow and water quality data. Use the refined model to reanalyze the TMDL allocation. 	<p>TCEQ and TIAER</p>	<ul style="list-style-type: none"> In 2003, TCEQ undertook work with TIAER to update the model associated with the original TMDL, at the request of the stakeholders. The Center for Research and Water Resources (CRWR) worked with TIAER on development of the refined model. Stakeholders were kept informed of the progress of this work at public stakeholder meetings. Ten stakeholder meetings were held from 2003 through 2007. TIAER submitted the final model report in March 2010. New data were acquired in 2004 and 2005 to support the model development. The updated model supported the validity of the original TMDL report and its load allocations. No midcourse correction in the plan was needed.
<p>Compliance and Enforcement</p> <ul style="list-style-type: none"> Perform inspections, report permit violations, and levy fines as appropriate. 	<p>TCEQ</p>	<p>Since fiscal year 2003, TCEQ has conducted compliance inspections and complaint investigations in the watershed and continues to do so (see Table 1).</p>

For More Information

Visit the TCEQ's [North Bosque River TMDL project webpage](#).¹⁶ Learn more about the activities to reduce bacteria from agricultural operations on the [TSSWCB website](#).¹⁷ Learn more about water quality standards, monitoring, TMDLs, and watershed-based plans by reading [Preserving and Improving Water Quality](#),¹⁸ available on TCEQ's website or in print. Or contact:

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Endnotes

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