How is Groundwater Quality Affected by Failing On-Site Sewage Facilities (OSSFs)?

White Paper Prepared by the Texas Groundwater Protection Committee (TGPC) Groundwater Issues (GWI) Subcommittee

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Executive Summary

Approximately one out of five homes (20%) in Texas uses an On-Site Sewage Facility (OSSF) for wastewater treatment and disposal. The most common type of OSSF has a conventional septic tank and drain field; however, since early 2000, the use of an aerobic treatment and surface spray disposal system has become more common in Texas. Use of OSSFs (aka, septic systems) is regulated by the Texas Commission on Environmental Quality (TCEQ) Title 30, Texas Administrative Code (30 TAC), §285 and by local contract orders that are implemented and enforced by more than 350 Authorized Agents (AAs).

The number of OSSFs in Texas has increased from about 1.3 million in 1990 to about 2.2 million in 2016 (Bonaiti, et. al., 2017-a). Prior to 1995, aerobic systems accounted for less than 10% of the new installations; however, in 2016 they accounted for 55% of the new installations. The Texas A&M AgriLife Extension Service (AgriLife Extension) OSSF program maintains a state map showing the approximate number and type of OSSFs in each of the 254 counties in Texas. Approximately 20,000 to 30,000 permits are issued per year to install new OSSFs in the state, thus it is safe to assume the number of OSSFs in the state will continue to increase. Currently there is no state-wide mechanism to determine the number of old, private OSSFs replaced by new, public sewer connections. The fact remains that approximately 20% of the dwellings in Texas will be served by OSSFs in the future.

A properly designed, permitted, installed, and maintained OSSF does not adversely impact groundwater quality because wastewater is adequately treated before entering groundwater. However, an OSSF that is not properly designed, permitted, installed, or maintained has the potential to cause an adverse impact on groundwater quality by allowing inadequately treated wastewater to enter groundwater. A failing OSSF may create a "nuisance", which is defined in TAC Chapter §285.2(43)(B) as "*... an overflow from a septic tank or similar device, including surface discharge from or groundwater contamination by a component of an on-site sewage facility...*" Typically, groundwater contamination is due to coliform bacteria, nitrate, or other bio-chemical pollutants present in untreated wastewater that are not removed before they mix with groundwater. This white paper gives an overview of how groundwater quality could be adversely affected by failing OSSFs with examples from Texas and other states, and it presents concepts for ensuring groundwater quality protection from OSSFs operating in Texas.

Acronym List

AA	Authorized Agent
AgriLfe Extension	Texas A&M AgriLife Extension Service
ATU	Aerobic Treatment Unit
BOD	Biological Oxygen Demand
CFU	Colony Forming Unit
COSSI	Coastal Zone OSSF Inventory
CSM	Colorado School of Mines
EDTA	Ethylenediaminetetraacetic Acid
EOCs	Emerging Organic Contaminants
E. coli	*Escherichia coli*
FC	Fecal Coliform
ft	feet
GIS	Geographic Information System
GWI	Groundwater Issues
ml	milliliter
NE	New England
NELAC	National Environmental Laboratory Accreditation
NO_3-N	Nitrate Nitrogen
NP1EO	4-nonylphenolmonoethoxylate
NY	New York
OARS	On-Site Activity Reporting System
OSSF	On-Site Sewage Facility
pH	potential Hydrogen (i.e., measure of the acidity or alkalinity)
STE	Septic Tank Effluent (sewage)
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TDLR	Texas Department of Licensing and Regulation
TGPC	Texas Groundwater Protection Committee
TOWA	Texas Onsite Wastewater Association
TSS	Total Suspended Solids
TWDB	Texas Water Development Board
TWON	Texas Well Owner Network
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WREF	Water Environment Reuse Foundation

Introduction

A conventional OSSF relies on septic tanks for the primary treatment of raw wastewater followed by discharge of primary treated effluent (i.e., Septic Tank Effluent, STE) to the subsurface soils for further treatment and possible recharge of underlying groundwater. Figure 1 shows the operation of a conventional OSSF (United States Environmental Protection Agency, (USEPA), February 2002).

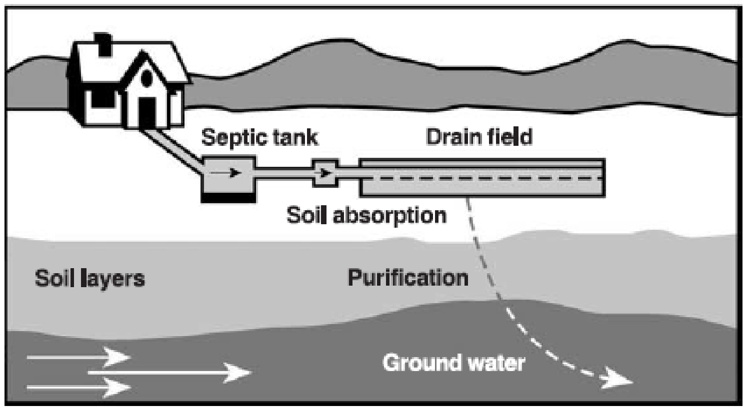

Figure 1: Conceptual drawing of a conventional septic tank soil absorption system.

Septic tanks remove most material that can settle or float (achieving partial reduction of Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS)) and function as anaerobic bioreactors that promote partial digestion of retained organic matter. STE contains significant concentrations of pathogens, nutrients, and chemicals. Soil layers underneath the drain field purify STE through biological processes, adsorption, and filtration before mixing it with groundwater.

Conventional septic tank drain field systems work well if they are:

- Installed in areas with appropriate soil characteristics;
- Designed to treat the incoming waste load so that it meets both the public health and groundwater quality standards;
- Installed properly; and,
- Maintained to ensure long-term performance.

Aerobic systems are used when soil characteristics are not appropriate for treating STE; in those instances, an Aerobic Treatment Unit (ATU) is used for treating raw wastewater to significantly higher quality levels before discharge into soil. Effluent from an ATU, when disinfected using chlorine or other disinfection processes, is adequate for spraying on top of the ground surface where soil and vegetation provide polishing effects and the effluent either evaporates, runs off as surface water, or infiltrates into groundwater, depending on the location and weather conditions. Figure 2 shows an OSSF using an ATU and spray system (AgriLife Extension publication L-5302, 9-08).

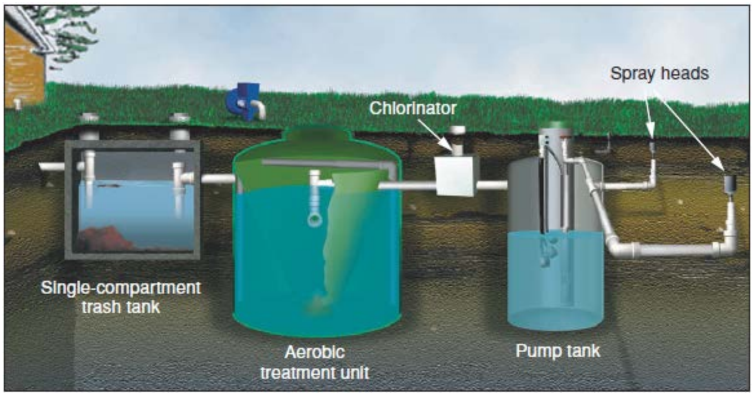

Figure 2: Conceptual drawing of an aerobic treatment unit and spray system.

Full Issue Information and Discussion

Treated wastewater from OSSFs may ultimately be mixed with groundwater as a nonpoint source discharge as shown in the Figure 1. Thus, a complete treatment of the wastewater (i.e., removal of all contaminants) is necessary before it mixes with the groundwater. An OSSF that is discharging untreated wastewater directly into groundwater or on top of the ground surface is a “Failing OSSF” for discussion in this paper. While it is easy to detect discharge of untreated wastewater on top of the ground surface (as shown in Figure 3), it is difficult to detect the discharge of untreated wastewater into groundwater.

Figure 3: Surfacing of untreated wastewater around a failing OSSF.

Frequently, polluted groundwater is detected from contamination found in well water, such as high levels of Fecal Coliform (FC) bacteria, *Escherichia coli* (*E. coli*), or viruses. Humphrey et al. (2011) monitored *E. coli* levels at 16 homes with gravity flow and conventional OSSFs in coastal North Carolina. They found that 23% of all groundwater samples near OSSFs had *E. coli* concentrations exceeding the USEPA fresh water contact standard (single sample 235 Colony Forming Units (CFU) per 100 milliliter (ml) for surface water). They also reported that the groundwater *E. coli* concentrations near OSSFs were highest during shallow water table periods (i.e., during wet seasons). Scandura and Sobsey (1997) studied the survival and transport of a model enterovirus (BE-1) and FC bacteria in four OSSFs installed in the sandy soil of coastal North

Carolina. They dosed septic system wastewater with BE-1. Samples were taken from a septic tank, distribution box, and monitoring well. They found that groundwater contained more viruses in winter than in summer. Other factors influencing the virus detection were proximity to septic effluent distribution lines, soil type, and elevated groundwater potential Hydrogen (pH). Borchardt et al. (2002) studied 50 water wells located in seven hydrogeological areas near septage land application sites or in rural subdivisions on septic systems in Wisconsin. Water samples were collected four times over a year representing the four seasons. Testing detected enteric viruses, rotavirus, hepatitis A virus, and Norwalk-like viruses. Among the 50 water wells, they found four (8%) to be positive for viruses. They reported that the contamination was transient, since none of the wells were virus positive for two sequential samples. They also reported that, although the water quality indicators were not statistically associated with virus occurrence, some agreement was noted for chloride.

Morrison et al. (2017) conducted a study in the Dickinson Bayou watershed in southeast Texas to investigate *E. coli* contamination in surface water. They installed two monitoring stations about five miles apart: one in a neighborhood with OSSFs (the test site), and the other on a centralized sewer system (the control site). Water samples were taken during pre-peak, peak, and post-peak stormwater runoff time periods. Representative samples showed no statistically significant difference between the two sites in *E. coli* concentrations. Even though human fecal presence was observed at both sites, failing OSSFs were not confirmed as the contributor in the test neighborhood.

Scott et al. (2018) reported on the spatial and temporal influence of OSSFs, centralized effluent discharge, and tides on aquatic hazards of nutrients, indicator bacteria, and pharmaceuticals in Dickinson Bayou. Surface water quality samples were collected from 12 sampling points – seven were located upstream of a centralized effluent discharge (near a high density of OSSFs), four were located downstream of this discharge (near a low density of OSSFs), and one was located directly at the centralized effluent discharge. Samples were analyzed for nutrients (nitrogen and phosphorus), indicator bacteria (*E. coli* and *Enterococci*), pharmaceuticals, and effluent tracers (e.g., acetaminophen, caffeine, and sucralose). The study reported higher levels of indicator bacteria and ammonia in upstream samples than samples collected from downstream, suggesting the influence of high OSSF densities on surface water quality. The authors claim that this study provides a diagnostic approach for future studies of emerging water quality challenges in rapidly urbanizing coastal bays and estuaries.

The Texas Well Owner Network (TWON, http://twon.tamu.edu/) offers education programs and materials related to groundwater resources, well maintenance, OSSF maintenance, water conservation, water quality, and water treatment. The program includes a citizen science component where water well owners are offered an opportunity to collect and bring their own well water samples to be screened by a mobile lab (non- National Environmental Laboratory Accreditation (NELAC) accredited) for common contaminants including total coliform and *E. coli* bacteria, nitrate-nitrogen, and salinity. Results are returned directly to the water well owner and are for educational purposes only. However, the concept of conducting well water analyses for private water wells in close proximity to OSSFs, especially if bacterial source tracking which identifies the source group (e.g., human, livestock, wildlife, etc.) is included, provides an approach for estimating the impact of OSSFs on groundwater quality.

Besides bacteriological contamination, inadequately treated STE can also adversely impact groundwater quality by adding organic/chemical contaminants such as nitrogen and pharmaceutically-active compounds (e.g., antibiotics). The United States Geological Survey (USGS) conducted a study of 26 shallow water wells covering 300 square miles in Eastern Nebraska (Verstraeten, et. al. 2004). The water wells were less than 120 feet (ft) deep and within 250 ft of a septic tank. Water samples were tested for bacteria, viruses, nitrogen, oxygen, boron isotopes, drugs, and organic compounds. Bacteria were not detected, but two out of 19 samples had viruses, four out of 26 wells exceeded the USEPA limit for nitrogen, eight non-prescription drugs were detected in 12 of 19 water wells, and antibiotics were detected in three of 26 water wells. USGS also conducted a study in the La Pine area, Oregon which found that nitrate levels in the underlying aquifer were increasing due to contamination from residential septic systems (Williams, et. al. 2007). Elevated nitrate concentrations in groundwater were attributed to contamination from a high density of conventional septic systems resulting from the concentrated development within the La Pine area. It is important to note that conventional OSSFs and most ATU systems are not designed to remove nitrogen from wastewater, thus the only way to limit nitrogen overload into groundwater is by controlling their density. A USGS study conducted in Texas measured nitrate in water samples collected from five streams recharging the Barton Springs segment of the Edwards Aquifer (Mahler, et. al., 2011). The study found that an increase in nitrate concentration coincided with a rapid increase in the number of OSSFs and the volume of treated wastewater applied to the land in the area contributing recharge to Barton Springs.

Since some of the treated wastewater from OSSFs could potentially enter groundwater, it is important to ensure that OSSFs are designed and maintained properly in order to minimize the adverse impact on groundwater quality. Waste streams to be treated by OSSFs have changed in recent years due to changing lifestyles including the increasing use of personal care and home cleaning products, the increasing use of pharmaceutically-active compounds (e.g., antibiotics), and the use of low-flow fixtures for water conservation. A research team from the Colorado School of Mines (CSM) conducted a multiyear study to characterize modern single source raw wastewater and STE composition to aid in OSSF system design and management (Lowe, et al., 2009). The researchers found that the range of constituent concentrations was higher for raw wastewater compared to STE, confirming septic tank ability to partially treat raw wastewater. The consumer product chemicals caffeine, Ethylenediaminetetraacetic Acid (EDTA), nonylphenol monoethoxylate (NP1EO), and triclosan, as well as the pharmaceutical residues ibuprofen, naproxen, and salicylic acid, were detected in raw wastewater and STE, indicating potential discharge of these chemicals into groundwater in the absence of adequate treatment by a soil absorption system. USGS scientists conducted a study at two septic system sites, one in New England (NE) and one in New York (NY) state (Phillips, et. al., 2011). In the NE area, the research found numerous pharmaceuticals and a floor cleaner in groundwater samples collected downgradient from a septic system serving an extended health care facility. In the NY area, the researchers found hormones, detergent, fragrances, insect repellent, sunscreen additive, floor cleaner, and pharmaceuticals in groundwater samples collected downgradient of septic systems used seasonally in a densely populated (five dwellings per acre) portion of a Fire Island beach.

Oosting and Joy (2011) developed a Geographic Information System (GIS)-based model to calculate the potential cumulative risk related to OSSFs for a specific area in Ontario, Canada, which has 1.2 million OSSFs. They divided nine risk parameters in two groups: terrain and geological risk factors (soil type, land slope, floodplain, groundwater intrinsic susceptibility index, and recharge area), and on-site system design risk factors (lot size, surface water proximity, system age, and water supply proximity). The authors used a 5-point scale (1 low-5 high) for each of the nine parameters. They conducted a survey of experts such as building officials, public health officials, and researchers in the OSSF field in order to develop parameter weightings. The GIS model used the risk score values, where risk score = $\sum$ (risk rating x weighting). The study involved the Huron-Kinloss Township which has 2,800 OSSFs on Lake Huron. The authors used a GIS model to map at-risk areas in order to help with watershed planning, as well as the creation and enforcement of regulatory policies, and concluded that this approach would be useful for developing and applying inspection, re-inspection, and maintenance programs to reduce potential risks from the use of OSSFs in a given area.

The number of OSSFs used in Texas has increased from less than 1.5 million in 1990 (US Census data) to more than 2 million in 2016. Before 1990, permitting activities were not reported to TCEQ by the localities. An estimate of permits issued before 1990 is based on 1990 census responses to the question, "Is this building connected to the public sewer?" Since then, an annual summary of total of permits issued is reported by local AAs to the TCEQ On-Site Reporting System (OARs) database (https://www.tceq.texas.gov/permitting/ossf/on-site-activity-reporting-system/OARS.html). The AgriLife Extension OSSF team used the 1990 census data and the OARs database to develop a map showing OSSFs per county as show in Figure 4. The AgriLife Extension OSSF team is also involved with GIS mapping of OSSF locations in the Texas General Land Office defined Coastal Zone. In October 2017, the team completed the Coastal Zone OSSF Inventory (COSSI) database for all 19 counties within the Coastal Zone. The database estimates 63,374 OSSFs in the Coastal Zone and includes locations and information such as system type, install date, and permit date (Bonaiti, et. al., 2017).

Figure 5 shows an example of a GIS map for the area within the coastal zone of Jefferson County. Information associated with each OSSF data point is collected from the permit records when they are available from the local AAs. Funding for additional work is needed for further refinement of the estimated OSSF locations and attributes including: adding newly permitted OSSFs, removing OSSFs where the building has been connected to a sewer system, and research into potential failure rates of OSSFs. State-wide implementation of this approach will require additional funding as well as a legislative mandate requiring OSSF license holders to electronically report certain information for future data entry and validation.

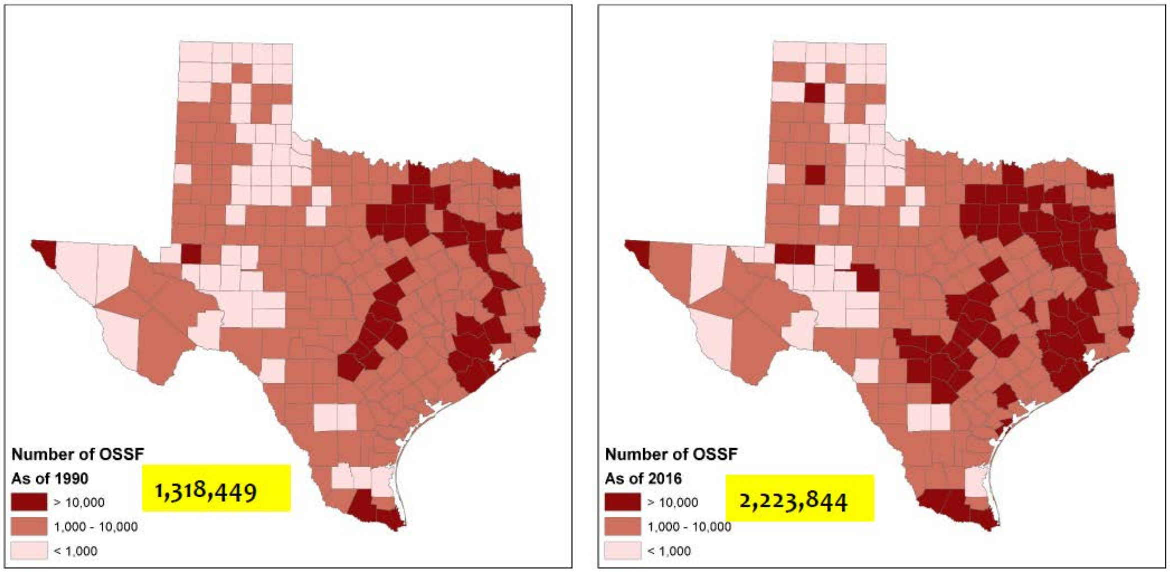

Figure 4: Changes in the number of OSSFs in Texas Counties based on the data compiled from the 1990 Census and TCEQ OARS Database.

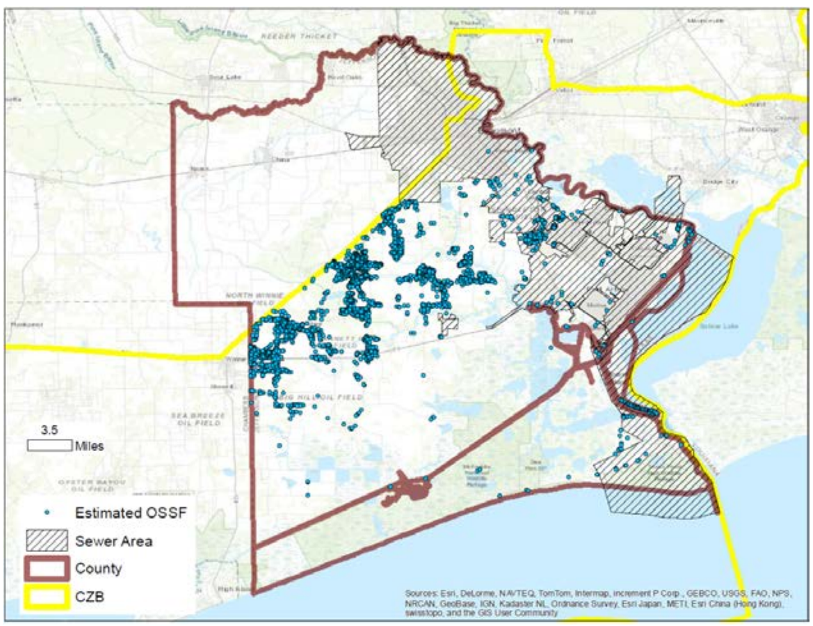

Figure 5: OSSF locations for the Texas Coastal Zone area in Jefferson County.

Conclusion

- Failing OSSFs have the potential to adversely impact groundwater quality by adding microbial and/or chemical contaminants that are not adequately removed by either a pre-treatment unit before discharge and/or by a soil treatment unit after discharge.
- Studies documenting groundwater contamination from OSSFs support the notion that failing and/or improperly designed or inadequately maintained OSSFs can raise bacteriological (FC, *E. coli*, viruses, etc.) and chemical (Nitrate Nitrogen (NO3-N), Emerging Organic Contaminants (EOCs), etc.) concentrations in groundwater.

- Monitoring groundwater quality from private water wells located on properties with OSSFs is the best way to know the effects of OSSFs on groundwater quality; however, such monitoring is expensive and presently it is not formally done at the state level.
- GIS mapping of OSSFs in conjunction with private water wells offers an effective and relatively inexpensive way to assess the risk of groundwater contamination by failing OSSFs.
- The state of Texas would benefit from establishing a formal protocol to:
  - Develop and maintain an accurate inventory and map of OSSFs and private water wells;
  - Develop and maintain a database on groundwater quality results reported by private water well owners;
  - Gather information from localities related to groundwater quality impacts from failing OSSFs;
  - Use GIS maps and the groundwater quality database in order to model the long-term impacts of OSSFs on groundwater; and,
  - Develop funding sources for homeowners to repair or replace failing OSSFs that are determined to adversely impact groundwater and surface water quality. Some states use a Revolving Fund to provide financial assistance to homeowners with these repairs or replacements.

Continuing Research Needs

- How best to maintain a state-wide inventory and GIS map of all OSSFs;
- Determine the cost-effective approach for evaluation of an OSSF's operational status – functioning or failing – and the optimum frequency for conducting such an evaluation;
- Data collection and reporting of groundwater quality impacts from OSSFs (locally, regionally, and state-wide from users and licensed professionals);
- A cost-effective method to determine if groundwater contamination is due to failing OSSFs or something else; and,
- A systematic approach to the routine revision of state-wide rules (30 TAC, Chapter 285) regulating the use of OSSFs in order to provide stronger measures to protect groundwater quality by assuring proper OSSF design, installation, and maintenance, thus minimizing OSSF failures.

Recommendations

- Legislation requiring TCEQ, authorized agents, and/or their designated representatives to electronically report the location of all new OSSFs at the time of installation, and OSSF licensed professionals to report the location of all existing OSSFs at the time of servicing;

- Inspections of OSSFs on a regular basis, especially those nearest to water resources and sensitive aquifers;
- Require maintenance contractors and homeowners maintaining an OSSF to report annually to an AA;
- Development of a state-wide GIS to collect and record the location and detailed permit and design information on all OSSFs (similar to the current Texas Department of Licensing and Regulation (TDLR) and Texas Water Development Board (TWDB) system for water wells);
- Funding for formalizing the TWON approach to well water quality analysis and data analysis in order to determine the OSSF impact on groundwater;
- A state-wide policy on data collection and reporting of groundwater quality contamination from a failing OSSF;
- A state-wide procedure to effectively repair or replace failing OSSFs that are adversely affecting groundwater and surface water quality; and,
- Develop a sustainable source of funding or low-cost loans for homeowners to fund OSSF replacement.

The above recommendations represent the opinion of the TGPC GWI Subcommittee and do not necessarily reflect the views and policies of each participating organization. The United States Geological Survey (USGS) may have contributed scientific information.

TGPC GWI Subcommittee members include, but are not limited to:

- Texas Commission of Environmental Quality (TCEQ);
- Texas Water Development Board (TWDB);
- Railroad Commission of Texas (RRC);
- Texas Department of State Health Services (DSHS);
- Texas Department of Agriculture (TDA);
- Texas State Soil and Water Conservation Board (TSSWCB);
- Texas Alliance of Groundwater Districts (TAGD);
- Texas A&M AgriLife Research (AgriLife Research);
- Bureau of Economic Geology of The University of Texas at Austin (UTBEG);
- Texas Department of Licensing and Regulation (TDLR);
- Texas Parks and Wildlife Department (TPWD);
- Texas Tech University (TTU);
- Texas A&M AgriLife Extension Service (AgriLife Extension); and,
- United States Geological Survey (USGS).

The primary goals of the TGPC GWI Subcommittee are to:

- Facilitate interagency communication for assessment programs addressing groundwater contamination;
- Coordinate and assist member agencies with monitoring programs for:
  - Ambient groundwater conditions;
  - Pesticides; and,
  - Emerging contaminants or constituents of concern;
- Review published data reports and evaluate data independent of reports to assist in the determination of the effectiveness of existing regulatory programs;
- Review published data reports and evaluate data independent of reports for potential contaminants not addressed by existing regulatory programs; and,
- Develop recommendations for consideration by the TGPC to address potential groundwater contamination identified through monitoring and data review.

For more information about this white paper, please contact the TGPC (https://tgpc.texas.gov/contact-us/).

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