Lauren Ross

I am a professional engineer licensed to practice by the State of Texas. I am submitting the attached comments on behalf of the Greater Edwards Aquifer Alliance and Save Our Springs Alliance.

Proposed Rulemaking on Land Application of Produced Water
Rule Project Number 2026-006-309-OW

Prepared for
Greater Edwards Aquifer Alliance
and
Save Our Springs Alliance

D. Lauren Ross

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Introduction

Texas Commission on Environmental Quality (TCEQ) Rule Project Number 2026-006-309-OW proposes to edit administrative rules to address regulation of oil and gas produced water. Rule changes are necessary because legislation in the 89th Regular Legislative Session transferred permitting authority for land application of produced water treated for beneficial use from the Railroad Commission of Texas to TCEQ. This report examines the proposed rule changes in terms of their effectiveness to protect surface water, groundwater, human and environmental health.

Produced Water

"Produced water" is an unavoidable part of hydrocarbon extraction. For every barrel of crude produced from Texas' Permian Basin, for example, three to five barrels of produced water also flow to the surface. In some areas, the ratio of produced water to crude can reach as high as 12 to one.[1]

A 2020 report compiled information on U.S. produced water volumes and management practices in 2017.[2] Data in the report from Texas was based on information provided by the Railroad Commission. Table 1 is estimated volumes of produced water managed using alternative practices. The total 2017 volume for Texas was 9.9 billion barrels. 41% of all produced water for that year in the United States.

The largest reported volumes for Texas were either injected for enhanced recovery or injected for disposal. This combined injection accounted for 82% of the total estimated produced water volume. Offsite commercial disposal accounted for another 17%. Surface discharge accounted for only 0.3%. Although produced water reuse occurred both within

[1] https://www.b3insight.com/permian-produced-water-recycling/
[2] Veil, John, *U.S. Produced Water Volumes and Management Practices in 2017,* prepared for the Ground Water Research and Education Foundation, February 2020.

and outside oil and gas facilities in 2017, the Railroad Commission was unable to quantify these volumes..

Table 1. Produced Water Management In Texas in 2017

Produced Water Management Practice	2017 Volume (bbl/yr)
Injection Enhanced Recovery	4,557,819,641
Injection for Disposal	3,586,674,633
Offsite Commercial Disposal	1,716,310,350
Surface Discharge	34,279,995
Evaporation	0
Beneficial Reuse in Oil Field	?
Beneficial Reuse outside Oil Field	?
Total Produced Water Managed	**9,895,084,619**

As Texas oil and gas production has increased, the volume of produced water has also increased. Furthermore, Permian Basin produced water is predicted to increase by 39 percent by 2035.[3]

Produced water includes formation water, injection water, and any chemicals added downhole during oil and gas well development, maintenance, or production. Its mixture of organic and inorganic chemicals varies depending on the geologic formation and on development, production and maintenance processes. Organic chemicals from dissolved and dispersed hydrocarbons, hydraulic fracturing components, polycyclic aromatic hydrocarbons, phenols, organic acids, scale inhibitors, corrosion inhibitors, biocides, flocculants, and dissolved gases like carbon dioxide, hydrogen sulfide, and methane are all potentially present in produced water. Produced water may also contain clays, waxes, sands, metals like barium, iron, zinc, lead, and mercury, and naturally occurring radioactive material. Attachment 1 is a table of additives commonly used in oil and gas well development, stimulation, and maintenance.

[3] https://www.bloomberg.com/graphics/2025-permian-basin-geyser/.

The U.S. Geological Survey maintains a nationwide database for produced water quality. Figure 1 is a map of Texas produced water wells in the database. The database stores available information regarding concentrations of major elements, trace elements, isotopes, organic chemistry, and radionuclides, Attachment 2 to this report is a summary of available Texas produced water quality data from the database. The table reports the number of samples for each parameter, its reported low and high values, and the median of all reported values.

There are several U.S. Geological Survey database parameters for which there are no reported data for Texas wells. These parameters are listed in Attachment 3. Parameters missing from the database for Texas wells include oil and grease, naturally occurring radionuclides, cyanide, biochemical oxygen demand, benzene, ethylbenzene, naphthalene, tetrachlorethylene and toxic metals like arsenic, beryllium, and vanadium, This list of parameters for which there is no Texas data includes several parameters that would significantly degrade surface and groundwater, human health and environmental health.

30 TAC Chapter 210 Use of Reclaimed Water

The proposed rulemaking would make the following substantive changes to 30 TAC Chapter 210 Use of Reclaimed Water.

- ***Add 30 TAC §210.54(a)(5)(J) Part 435 – oil and gas extraction.*** This rule addition would allow authorization of beneficial reuse under 30 TAC Chapter 210 for processed wastewater generated by facilities engaged in field exploration, drilling, well production and well treatment in the oil and gas industry.
- ***Add 30 TAC §210.54(a)(5)(L) Part 437 – centralized waste treatment, in accordance with requirements, conditions, and prohibitions in Part 437.*** This rule addition would allow authorization of beneficial reuse under 30 TAC Chapter 210 for wastewater discharged from treatment and recovery of hazardous or non-hazardous industrial metal-bearing wastes, oily wastes, and organic-bearing wastes received from off-site and from the treatment of a centralized waste treatment

(CWT) facility wastewater, with limitations excluding wastewater from treatment of wastes generated on-site if those wastes would otherwise be subject to another part of Code of Federal Regulations Title 40 Chapter I Subchapter N Effluent Guidelines and Standards.

Limitations and Inadequacies of the Proposed 30 TAC Chapter 210 Rulemaking

The proposed substantive rulemaking for 30 TAC Chapter 210 involves the addition of only twenty words. The consequences of adding these twenty words, however, would be to extend eligibility for beneficial reuse authorization to wastewater effluents with chemical characteristics vastly different than those of the domestic and municipal effluents mostly commonly authorized for beneficial use under the provisions of this chapter.

These effluent characteristic differences are illustrated in Table 2, which compares the range of produced water quality with corresponding chemical concentration ranges for highly treated municipal effluent.

An examination of concentrations in Table 2 makes it clear that produced water exhibits much higher concentrations of total dissolved solids, nutrients, and relevant measures of organic compounds: total organic carbon and chemical oxygen demand than treated domestic effluent. Beneficial use of produced water with these different pollutant concentrations represent potentially significant impacts to Texas surface water, groundwater, soils, crops, and human and environmental health.

Sections below provide additional perspectives regarding why the proposed rulemaking changes to 30 TAC Chapter 210 would be inadequate to regulate such profound changes in the character of effluent that could be authorized for reuse and/or land-applied for disposal in Texas.

Table 2. Comparison of Produced Water and Treated Domestic Wastewater Effluent

	Texas Produced Water Concentrations (1)		High Quality Domestic Wastewater Effluent (2)	
Parameter	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Total Dissolved Solids, mg/L	60	403,299	500	700
Total Suspended Solids, mg/L	2,240	6,660	<1	15
Chloride, mg/L	2.00	250,224	no data	no data
Potassium, mg/L	0.10	33,962	no data	no data
Nitrate, mg/L	0.10	10	2	10
Ammonia, mg/L	2.00	3,488	0.7	3
Phosphorus, mg/L	0.30	0	0.5	2
Sulfate, mg/L	0.10	16,348	no data	no data
Total Organic Carbon, mg/L	24	1,033	5	10
Chemical Oxygen Demand, mg/L	950	1,075	15	30

(1) Based on the U.S. Geological Survey Produced Water Database for Texas wells.

(2) From Metcalf & Eddy | AECOM, Wastewater Engineering: Treatment and Resource Recovery, 2014, Table 4-5 Typical range of effluent quality after secondary treatment.

Expansion of Rulemaking to Industrial Wastewater Beyond Produced Water

The stated purpose of the proposed rule changes is to create an authorization process for beneficial reuse of produced water. But the addition of *30 TAC §210.54(a)(5)(L) Part 437 – centralized waste treatment, in accordance with requirements, conditions, and prohibitions in Part 437* would extend potential authorizations to include hazardous and non-hazardous wastewater from metals treatment, oily waste treatment and recovery, organics treatment and recovery, and mixed wastewater effluent from more than one of the above sources. In addition to providing an inadequate basis for authorizing beneficial reuse of produced water, the proposed rule changes are inadequate to regulate the reuse, reclamation, and irrigation of this wider class of industrial effluents.

Level I Versus Level II Authorization for Beneficial Reuse of Industrial Wastewater

30 TAC Chapter 210 Subchapter E divides reclaimed industrial effluent authorizations into Levels I and II. Different standards apply to each level. For produced water to be eligible for

Level I authorization, effluent concentrations must be at or below threshold levels in 30 TAC §210.53(a)(9) ***and*** all other priority pollutants in 40 CFR Part 122 Appendix D, Tables II and III must be at concentrations lower than the minimum analytical level.

Based on data in the U.S. Geological Survey Produced Water Database for Texas oil and gas wells, produced water would generally fail to meet minimum requirements for Level I authorization. See Table 3. More than 99% of 18,823 samples of produced water from Texas oil and gas wells exceeded the total dissolved solids threshold level of 2,000 mg/L. Although the database for parameters other than total dissolved solids is fewer than 18,000 samples, based on available data most produced water would also fail to meet minimum requirements for Level I authorization based on concentrations of total organic carbon, barium, copper, manganese, silver, thallium, and zinc. High concentrations of these toxic metals and of organic chemicals represented in the database only by total organic carbon (other relevant measures are not reported) represent a threat to surface water, groundwater, soil, vegetation, and human and environment health. Furthermore, treatment cost of treatment to reduce high total dissolved solids concentrations in produced water to below 2,000 mg/L, mean that produced water would likely be authorized for beneficial reuse only under industrial wastewater Level II requirements.

Table 3. 30 TAC §210.53(a)(9) Threshold Levels for Industrial Reclaimed Water and Proportion of Texas Produced Water Samples that Would Fail to Meet the Standards

30 TAC §210.53(a)(9) Threshold Levels for Industrial Reclaimed Water			Proportion of Texas Produced Water Samples Meeting Criteria[4]		
Parameter	Threshold (mg/l)	MAL (mg/l)	# of Produced Water Samples	# Meeting Criteria	% Failing to Meet Criteria
Conventionals & Nonconventionals					
Total Organic Carbon	55	---	66.00	19	71%
Oil and Grease	10	---	no data	no data	
Total Dissolved Solids	2000	---	18823	172	99%
Nitrate Nitrogen	10	---	9	7	22%
Metals					
Antimony, total	0.09	0.03	2	1	50%
Arsenic, total	0.03	0.01	28	25	11%
Barium, total	0.03	0.01	2612	1	100%
Beryllium, total	0.015	0.005	no data	no data	
Cadmium, total	0.003	0.001	33	30	9%
Copper, total	0.03	0.01	90	37.00	59%
Lead, total	0.015	0.005	41	38	7%
Manganese	0.05	---	239	3	99%
Mercury, total	0.0002	0.0002	no data	no data	
Nickel, total	0.03	0.01	41	40	2%
Selenium, total	0.03	0.01	19	19	0%
Silver, total	0.006	0.002	22	0	100%
Thallium, total	0.03	0.01	1	0	100%
Zinc, total	0.015	0.005	148	29	80%
Cyanide, free	0.2	---	no data	no data	

Minimum Effluent Testing Requirements

For Level II authorization, an application must include ***"effluent testing results"*** (30 TAC §210.55(b)(9)). Regulations do not specify, however, what parameters must be tested. At a

[4] Based on data from the U.S. Geological Survey Produced Water Database, version 3.0.

minimum, testing parameters should include the suite of tests included in the U.S. Geological Survey Produced Water Database. See Attachment 4.

Adequate Effluent Limitations

Required regulatory limitations for Level II industrial wastewater beneficial reuse authorizations are only the following: total organic carbon limited to 55 mg/L, monitored once each month by grab sample, and pH limited to a minimum of 6.0 standard units and a maximum of 9.0 standard units and monitored once per week by grab sample.[5] While the executive direct may include additional limitations or increased monitoring frequencies based on information provided by the application or any other available information, there is no assurance that either relevant produced water quality data will be required of the applicant or that the executive director will use any available information to specify additional limitations.

At a minimum, produced water effluent limits for beneficial use land application should meet the requirements of the Level I threshold values, including concentrations of all priority pollutants lower than minimum analytical limits. Furthermore, effluent limitations are also required to prevent human health and environmental degradation from radioactive material in produced water.

Groundwater Protection from Produced Water Contamination

[1] 30 TAC §210.24(d) General irrigation requirements would apply to industrial reclaimed water use. This section requires the reclaimed water provider or user to ensure that reclaimed water does not stress crops or result in undesirable soil contamination by salt. Where total dissolved solids concentrations in the reclaimed water present the potential for excessive soil salinity buildup, leaching is required.

Because of their high salinity, produced water, even if treated before land application, is likely to require leaching to prevent soil salinity buildup. The result of a leaching requirement, however, is to transport produced water chemicals, including salts, toxic

[5] 30 TAC §210.56(d)(1).

metals, nutrients like nitrate, potentially transmissive organic chemicals and naturally occurring radionuclides into groundwater, representing a significant risk of groundwater contamination. Nothing in the proposed regulations would protect groundwater from such contamination.

The proposed rulemaking should limit pollutants in produced water used for beneficial irrigation to concentrations that do not require leaching to groundwater to maintain healthy soil and crop conditions. Soil and groundwater monitoring on a quarterly basis should be required to demonstrate no degradation from beneficial use.

Adequate Irrigation Setback Requirements

Irrigation setback requirements for industrial reclaimed water are specified in 30 TAC §210.56(f), requiring a minimum buffer of 250 feet from a private water well used for domestic or irrigation and 500 feet from a public water supply well. These setbacks are, however, insufficient to protect water supplies from highly mobile salts, chlorides, metals, and organic chemicals that are potentially present in the applied water.

Quarterly groundwater and soil monitoring should be required between land application and any wells within a distance that could be contaminated within fifty years, based on the best available groundwater modeling for the potentially contaminated aquifer. To protect waters of the state and maintain Texas Surface Water Quality Standards, produced water irrigation should be prohibited within 100 feet of a 100-year floodplain, wetland, or critical environmental features.

Unsuitability for Subsurface Drip Disposal

For total dissolved solids concentrations above 5,000 mg/L, calcium and silica fouling of emitters accelerates significantly. At this level, standard emitters are non-functional without aggressive acid treatment. Rulemaking should be expanded to prohibit the use of subsurface drip disposal for any reclaimed water, including produced water, with total dissolved solids higher than 5,000 mg/L.

Disposal on Saturated or Frozen Soil

30 TAC §210.56(f)(3) prohibits land application of industrial reclaimed water *"when the ground is frozen or saturated or during rainfall events."* There is, however, no regulatory enforcement mechanism for this prohibition and records that I have reviewed indicate that effluents have been applied during saturated soil conditions. Given the uniquely toxic characteristics of produced water and potentially other industrial effluent that could be authorized under the proposed rulemaking, failure to enforce the prohibition of application to saturated or frozen soil presents a unique threat of surface water, groundwater, human and environmental health degradation. At a minimum, irrigators should be required to report daily effluent application volumes, application areas, and rainfall amounts.

30 TAC Chapter 309 Domestic Wastewater Effluent Limitation and Plant Siting

TCEQ Rule Project Number 2026-006-309-OW proposes the following substantive changes to 30 TAC Chapter 309.

- ***Amend 30 TAC §309 title to "Wastewater Effluent Limitations and Plant Siting."*** Removing the word "Domestic" from the title expands the coverage of the chapter to encompass all wastewater effluent, including industrial and/or produced water effluent.
- ***In 30 TAC §309.1(a) substitute "effluent" for "domestic sewage" and "treated effluent" for "domestic sewage."*** This change expands the subchapter purpose beyond just domestic sewage to set effluent quality limitations for all wastewater effluent, including industrial and/or produced water effluent.
- ***Amend 30 TAC §309.10(a) to add "and land application of industrial wastewater, including produced water under Tex. Water Code §26.131."*** This language expands the scope of minimum locations standards to include land application of industrial wastewater, including produced water.

- ***Amend 30 TAC §309.10(a)(2) by deleting "domestic" and insert "and land application."*** The effect of this change is to expand the range of these regulations beyond domestic wastewater to encompass any wastewater or land application permit applications.
- ***Amend 30 TAC §309.11 to add "(5)Industrial wastewater as defined in 30 Tex. Admin. Code §210.52(9)."*** Defines industrial wastewater, for the purposes of this subchapter to include all non-domestic or non-municipal wastewater.
- ***Amend 30 TAC §309.11 Definitions to add "(9) Produced water – as defined in 30 Tex Admin. Code §305.541(b)."***
- ***Amend 30 TAC §309.13(c) to add "and industrial wastewater, including produced water under Tex. Water Code §26.131."*** Expands the prohibition of wastewater treatment plant units closer than 500 feet from a public well or 250 feet from a private well to include facilities used for the storage, processing, or application of industrial wastewater, including produced water.
- ***Add 30 TAC §309.13(c)(6) A wastewater treatment plant unit, or land where irrigation using wastewater effluent occurs, must be located a minimum horizontal distance of 100 feet from a water in the state."*** Prohibits all wastewater treatment plant units or effluent land disposal within 100 feet of surface waters of the state.
- ***Amend 30 TAC §309.13 (d)to add "Additional requirements under §217.203 of this title (relating to Design Criteria for Natural Treatment Systems) may apply."***
- ***Amend 30 TAC §309 Subchapter C and §309.20 titles to "Land Application of Treated Effluent."*** Expands the land application requirements to include industrial wastewater effluent.

Proposed changes to 30 TAC Chapter 309 would remove and/or replace language that limits this chapter to regulate only domestic or municipal sewage and expand its scope to include effluent limits and plant siting requirements for facilities treating and/or disposing of anything characterized as "treated effluent." The term "treated effluent" is not defined in the chapter but could theoretically include the product of any treatment process, including the treatment of wastewater containing industrial or hazardous material.

The apparent simplicity of these proposed rule changes to expand the applicability of 30 TAC Chapter 309 from just domestic wastewater to encompass treated effluent from any source disguises the lack of suitable standards within this chapter to address an expanded set of concerns associated with oil and gas activity produced water or broader concerns associated with an expansion of the applicability of this chapter to encompass any wastewater other than wastewater from domestic sources.

Failure to Address Fundamentally Different Wastewater Characteristics

Primary pollutants of concern in domestic wastewater are biochemical oxygen demand, total suspended solids, nutrients, and pathogens. 30 TAC §309.4 addresses this limited set of parameters with effluent limitations for biochemical oxygen demand, total suspended solids, ammonia, and dissolved oxygen.

The character of produced water, however, is significantly different from that of domestic effluent. Table 4 compares total dissolved solids, suspended solids, chloride, ammonia, potassium, phosphate, and sulfate concentrations in produced water to those in high-strength domestic wastewater. Produced water concentrations are 5.7 to more than 300 time higher. Differences would be even larger for medium or low-strength domestic sewage. Furthermore, produced water and industrial effluents contain a wide range of total dissolved solids, toxic metals, oil and grease, and organic and inorganic priority pollutants and naturally occurring radioactive materials for which 30 TAC Chapter 309 provides no effluent limitations.

At a minimum, 30 TAC Chapter 309 should be amended to adopt effluent limitations that encompass the range of oil and gas produced water, as well as other effluent characteristics that threaten degradation to surface and groundwater, human health and the environment.

Table 4. Comparison of Constituent Concentrations in Produced Water to Typical High-Strength Domestic Wastewater

Parameter	Texas Produced Water Median Concentrations (1)	High Strength Untreated Domestic Wastewater (2)	Difference Factor
Total Dissolved Solids, mg/L	66,161	1,121	59.0
Total Suspended Solids, mg/L	4,450	389	11.4
Chloride, mg/L	39,130	118	331.6
Potassium, mg/L	220	32	6.9
Nitrate, mg/L	0.40	0	---
Ammonia, mg/L	235	41	5.7
Phosphorus, mg/L	0.30	11	0.027
Phosphate, mg/L	318	4.7	67.6
Sulfate, mg/L	538	72	7.5
Total Organic Carbon, mg/L	96	328	0.293
Chemical Oxygen Demand, mg/L	1,013	1016	0.997

(1) Based on the U.S. Geological Survey Produced Water Database for Texas wells.

(2) From Metcalf & Eddy | AECOM, Wastewater Engineering: Treatment and Resource Recovery, 2014, Table 3-18 Typical composition of untreated domestic wastewater, high strength.

30 TAC Chapter 213 Edwards Aquifer

The Edwards Aquifer is a highly productive karst limestone aquifer providing critical water supplies to 2 million Texans from Belton to the Rio Grande. It supports significant agricultural, industrial, and recreational activities in otherwise dry and drought-prone areas. The karst limestone of the Edwards Aquifer recharges rapidly through fractures and fissures in limestone stream bottoms and through upland sinkholes, fractures, fissures, and cave openings, with little filtration. Its vulnerability to pollution is recognized by the State of Texas in the geographically unique restrictions of 30 TAC Chapter 213 Edwards Rules. These rules regulate activities with the potential to pollute the Edwards Aquifer and its hydrologically connected surface streams. The proposed rulemaking for produced water should be expanded to protect these unique water resources.

Remove Exemption for Activities Associated with Exploration, Development, and Production of Oil or Gas.

30 TAC §213.3(28)(B)(iii) exempts activities associated with the exploration, development, and production of oil, gas, or geothermal resources under the jurisdiction of the Railroad Commission of Texas. This section should be amended to clarify that land application of produced water associated with the exploration, development, and production of oil, gas, or geothermal resources for either disposal or beneficial use is a regulated activity under 30 TAC §213.

Land Application Systems

30 TAC §213.6(b)(2) requires wastewater disposal systems on the recharge zone to attain, at a minimum, secondary treatment as defined in 30 TAC Chapter 309. Secondary treatment standards defined in 30 TAC Chapter 309, however, fail to address the total dissolved solids, suspended solids, chloride, ammonia, potassium, phosphate, sulfate, toxic metals, oil and grease, and organic and inorganic priority pollutants present in produced water.

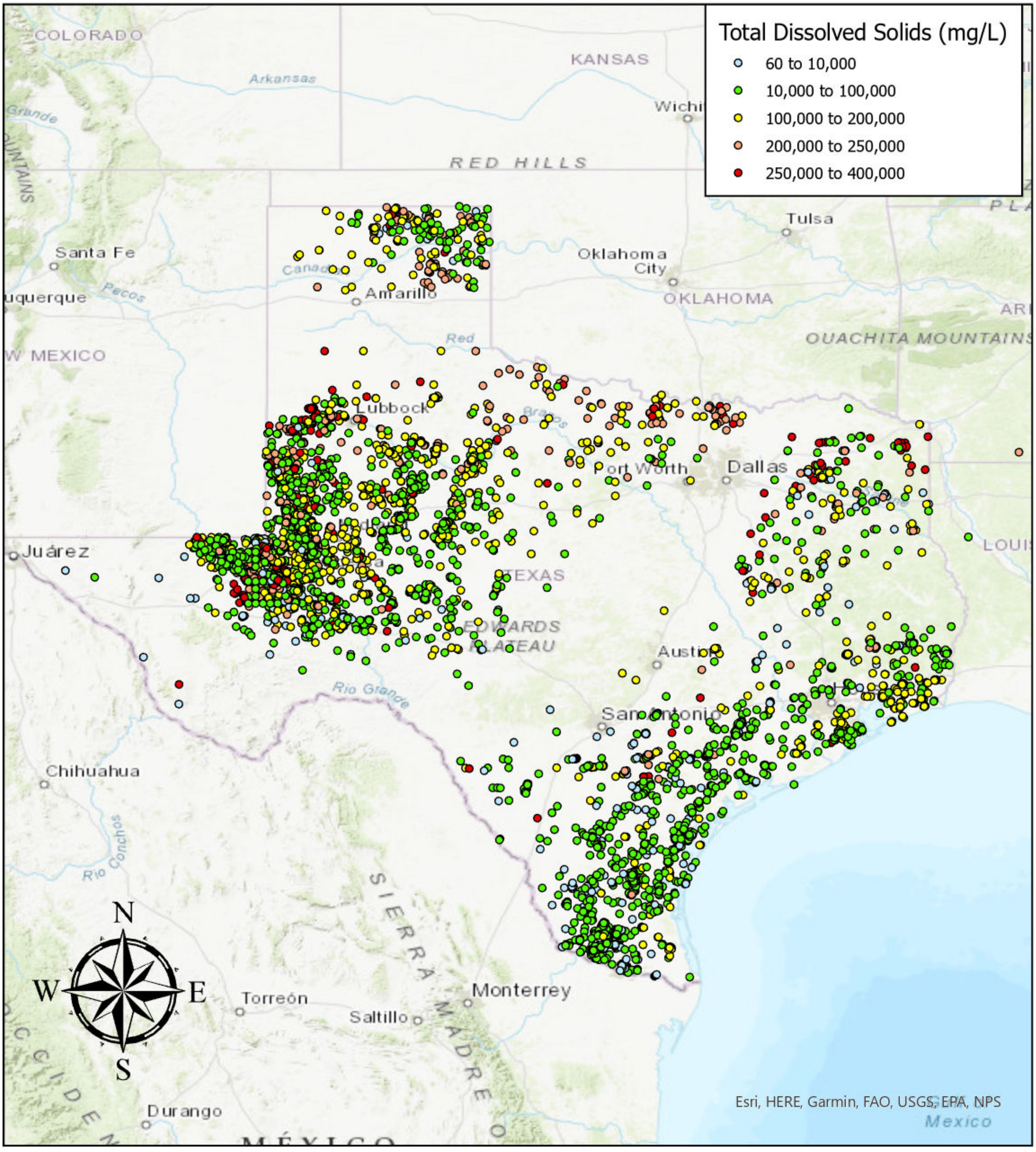
Similarly, 30 TAC §213.6(b) addresses effluent limitations for industrial wastewater discharges within zero to five miles upstream from the Edwards Aquifer recharge zone in terms of carbonaceous biochemical oxygen demand, total suspended solids, ammonia nitrogen and phosphorus. These parameters also do not represent the significant pollutants present in produced water.

Given the inadequacy of regulations and lack of suitable, cost-effective treatment methods for produced water, 30 TAC Chapter 213 should be amended to prohibit produced water beneficial use within the Edwards Aquifer contributing, transition, or recharge zones.

Qualifications

I have a Bachelor of Science degree in civil engineering from the University of Texas, awarded with highest honors, a Master of Science degree in civil engineering from Colorado State University, and a Doctor of Philosophy degree in civil engineering from the University of Texas. My master's degree research was water and solute movement into and through unsaturated soils. My doctoral research was multivariate statistical methods for analyzing environmental monitoring data.

I have worked as a civil and environmental engineer since 1977 and have been registered to practice engineering in Texas since 1984. My areas of expertise include water resources engineering, water quality protection and engineering design, groundwater fate and transport, stormwater management, erosion and sedimentation controls, solid waste and wastewater management and disposal, statistical methods, and environmental monitoring. I have served as a testifying expert in legal proceedings regarding these matters. Attachment 5 is my resume.



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Data from the U.S. Geological Survey Produced Waters Geochemical Database version 3.0.

Figure 1. Total Dissolved Solids in Texas Oil and Gas Produced Water

Attachment 1. Additives Used in Well Development, Stimulation and Maintenance

Category of Additive a	Example Constituents b	Purpose
Acid	Hydrochloric acid; muriatic acid	Removes cement and drilling fluid from casing perforations prior to fracturing fluid injection.
Biocide	Glutaraldehyde; 2,2-dibromo-3-nitrilopropionamide	Inhibits growth of organisms that could produce gases (particularly hydrogen sulfide) that could contaminate methane gas; prevents the growth of bacteria that can reduce the ability of the fluid to carry proppant into the fractures by breaking down the gelling agent.
Breaker	Peroxydisulfate salts	Reduces the viscosity of the fluid by breaking down the gelling agents to release proppant into fractures and enhance the recovery of the fracturing fluid.
Clay Stabilizer	Potassium chloride	Creates a brine carrier fluid that prohibits fluid interaction (e.g., swelling) with formation clays; interaction between fracturing fluid and formation clays could block pore spaces and reduce permeability.
Corrosion Inhibitor	Acetaldehyde; formic acid	Reduces rust formation on steel tubing, well casings, tools, and tanks.
Crosslinker	Borate salts; potassium hydroxide	Increases fluid viscosity to allow the fluid to carry more proppant into the fractures.
Friction Reducer	Polyacrylamide	Minimizes friction, allowing fracturing fluids to be injected at optimum rates and pressures.
Gel	Guar gum; hydroxyethyl cellulose	Increases fracturing fluid viscosity, allowing the fluid to carry more proppant into the fractures.
Iron Control	Citric acid	Sequestering agent that prevents precipitation of metal oxides, which could plug the formation.
pH Adjusting Agent	Acetic acid; potassium or sodium carbonate; sodium hydroxide	Adjusts and controls the pH of the fluid to maximize the effectiveness of other additives such as crosslinkers.
Proppant	Quartz; sand; silica	Used to hold open the fractures created in the formation, allowing the natural gas or crude oil to flow to the production well.
Scale Inhibitor	Methylene phosphonic acid, polyacrylate	Prevents the precipitation of carbonate and sulfate scales (e.g., calcium carbonate, calcium sulfate, barium sulfate) in pipes and in the formation.
Surfactant	Ethoxylated glycols; alcohol ethoxylates	Reduces the surface tension of the fracturing fluids to improve fluid recovery from the well after fracture is completed.

Sources: U.S. EPA, 2015; Acharya, 2011; FracFocus, 2014; CCST, 2014; ExxonMobil Corporation, 2014.
a Operators do not use all of the chemical additives in hydraulic fracturing fluid for a single well: they decide which additives to use on a well-by-well basis.
b The specific compounds used in a given fracturing operation will vary depending on company preference, base fluid quality, and site-specific characteristics of the target formation.

Attachment 2. U.S. Geological Survey Produced Water Database
Summary of Reported Parameters in Texas Wells

Code	Parameter	Data Type	Number of Samples	Minimum	Maximum	Median
TDS	Total Dissolved Solids, mg/L	Inorganic Chemistry	18,823.00	60.00	403,299.00	66,161.00
PH	pH	Physical Parameters	15,781.00	0.13	13.95	7.00
TSS	Total Suspended Solids, mg/L	Inorganic Chemistry	2.00	2,240.00	6,660.00	4,450.00
Ag	Silver, mg/L	Inorganic Chemistry	22.00	0.00	0.01	0.00
Al	Aluminum, mg/L	Inorganic Chemistry	47.00	0.00	668.00	3.08
As	Arsenic, mg/L	Inorganic Chemistry	28.00	0.00	0.06	0.00
B	Boron, mg/L	Inorganic Chemistry	961.00	0.20	515.00	41.80
BO3	Borate, mg/L	Inorganic Chemistry	6.00	1.00	14.00	7.50
Ba	Barium, mg/L	Inorganic Chemistry	2,612.00	0.01	3,740.00	19.00
Br	Bromide, mg/L	Inorganic Chemistry	1,073.00	0.50	6,535.00	201.00
CO3	Carbonate, mg/L	Inorganic Chemistry	1,256.00	0.01	169,123.00	56.06
HCO3	Bicarbonate, mg/L	Inorganic Chemistry	17,473.00	0.20	13,926.12	336.24
Ca	Calcium, mg/L	Inorganic Chemistry	18,755.00	0.08	70,700.00	2,130.00
Cd	Cadmium, mg/L	Inorganic Chemistry	33.00	0.00	0.08	0.00
Cl	Chloride, mg/L	Inorganic Chemistry	18,800.00	2.00	250,224.00	39,129.56
Co	Cobalt, mg/L	Inorganic Chemistry	38.00	0.00	0.00	0.00
Cs	Cesium, mg/L	Inorganic Chemistry	66.00	0.01	30.00	0.39
Cu	Copper, mg/L	Inorganic Chemistry	90.00	0.00	133.00	0.14
F	Fluoride, mg/L	Inorganic Chemistry	115.00	0.05	22,400.00	2.70
FeTot	Iron, total, mg/L	Inorganic Chemistry	3,237.00	0.01	4,160.00	21.10
FeIII	Iron, 3+, mg/L	Inorganic Chemistry	238.00	0.10	8,800.00	1.00
FeII	Iron, 2+, mg/L	Inorganic Chemistry	201.00	0.01	3,528.00	20.00
FeS	Iron sulfide, mg/L	Inorganic Chemistry	2.00	63.59	1,585.00	824.30
FeAl	Iron plus Aluminum, reported as elements, m	Inorganic Chemistry	61.00	1.00	1,110.00	34.92
FeAl2O3	Iron plus Aluminum, reported as oxides, mg/L	Inorganic Chemistry	86.00	1.00	3,448.00	51.60
I	Iodine, mg/L	Inorganic Chemistry	700.00	0.40	423.00	15.00
K	Potassium, mg/L	Inorganic Chemistry	2,488.00	0.10	33,962.00	220.44
KNa	Potassium plus Sodium, mg/L	Inorganic Chemistry	2,232.00	33.00	151,000.00	34,980.00
Li	Lithium, mg/L	Inorganic Chemistry	941.00	0.01	1,001.00	10.00
Mg	Magnesium, mg/L	Inorganic Chemistry	18,610.00	0.05	39,851.00	515.90
Mn	Mangansese, mg/L	Inorganic Chemistry	239.00	0.01	440.48	1.00
Mo	Molybdenum, mg/L	Inorganic Chemistry	14.00	0.00	1.32	0.03
NO3	Nitrate, mg/L	Inorganic Chemistry	9.00	0.10	10.40	0.40
NH4	Ammonia, mg/L	Inorganic Chemistry	305.00	2.00	3,488.00	235.00
Na	Sodium, mg/L	Inorganic Chemistry	16,578.00	0.30	146,769.57	20,800.00
Ni	Nickel, mg/L	Inorganic Chemistry	41.00	0.00	0.03	0.00
OH	Hydroxide, mg/L	Inorganic Chemistry	50.00	1.16	1,108.00	50.66
P	Phosphorus, mg/L	Inorganic Chemistry	2.00	0.30	0.30	0.30
PO4	Phosphate, mg/L	Inorganic Chemistry	4.00	1.05	799.00	317.60
Pb	Lead, mg/L	Inorganic Chemistry	41.00	0.00	8,187.00	0.00
Rh	Rhodium, mg/L	Inorganic Chemistry	1.00	8.00	8.00	8.00
Rb	Rubidium, mg/L	Inorganic Chemistry	113.00	0.02	18.15	0.30
S	Sulfide, mg/L	Inorganic Chemistry	56.00	0.26	71,680.00	28.00
SO4	Sulfate, mg/L	Inorganic Chemistry	16,505.00	0.10	16,348.00	538.32
Sb	Antimony, mg/L	Inorganic Chemistry	2.00	0.00	0.27	0.14
Se	Selenium, mg/L	Inorganic Chemistry	19.00	0.00	0.01	0.00
Si	Silica, mg/L	Inorganic Chemistry	948.00	0.42	5,555.00	28.90
Sr	Strontium, mg/L	Inorganic Chemistry	1,984.00	0.01	8,794.00	154.05
Tl	Thallium, mg/L	Inorganic Chemistry	1.00	0.06	0.06	0.06
Zn	Zinc, mg/L	Inorganic Chemistry	148.00	0.00	74.00	0.50
Zr	Zirconium, mg/L	Inorganic Chemistry	17.00	0.00	0.00	0.00
ALKALINITY	Alkalinity as HCO3, mg/L	Inorganic Chemistry	440.00	30.00	2,870.00	536.50
DIC	Dissolved Inorganic Carbon, mg/L	Inorganic Chemistry	78.00	0.40	172.00	29.17
DOC	Dissolved Organic Carbon, mg/L	Organic Chemistry	86.00	3.50	5,080.23	195.50
TOC	Total Organic Carbon, mg/L	Organic Chemistry	66.00	24.00	1,033.00	96.00
COD	Chemical Oxygen Demand, mg/L	Organic Chemistry	2.00	950.00	1,075.00	1,012.50
ACETATE	Acetate, mg/L	Organic Chemistry, Organic Acid Anion	87.00	11.80	3,224.83	290.00
BUTYRATE	Butyrate, mg/L	Organic Chemistry, Organic Acid Anion	11.00	4.00	12.00	8.00
PROPIONATE	Propionate, mg/L	Organic Chemistry, Organic Acid Anion	11.00	13.00	48.00	27.00
VALERATE	Valerate, mg/L	Organic Chemistry, Organic Acid Anion	8.00	1.00	13.00	3.00
ORGACIDS	Total Organic Acids, mg/L	Organic Chemistry, Organic Acid Anion	4.00	9.00	49.00	21.00
Ar	Argon gas, dissolved, mg/L	Dissolved Gases	4.00	0.05	0.10	0.07
CH4	Methane gas, dissolved, mg/L	Dissolved Gases	4.00	1.00	11.00	3.10
C2H6	Ethane gas, dissolved, mg/L	Dissolved Gases	4.00	0.07	4.20	0.68
CO2	Carbon Dioxide gas, dissolved, mg/L	Dissolved Gases	53.00	6.64	4,772.00	160.00
H2S	Hydrogen Sulfide gas, dissolved, mg/L	Dissolved Gases	316.00	0.02	23,600.00	55.00
N2	Nitrogen gas, dissolved, mg/L	Dissolved Gases	4.00	0.35	21.00	2.10
NH3	Ammonia gas, dissolved, mg/L	Dissolved Gases	117.00	1.20	90.00	13.00
O2	Oxygen gas, dissolved, mg/L	Dissolved Gases	3.00	0.04	0.76	0.06
dD	δH, per mil	Isotopes	567.00	(55.00)	12.10	(18.37)
d7Li	δ7Li, per mil	Isotopes	168.00	2.93	39.28	13.24
d11B	δ11B, per mil	Isotopes	149.00	11.00	46.00	21.00
d13C	δ13C, per mil	Isotopes	62.00	(20.94)	5.10	(5.90)
C14	14C, pCi/L	Isotopes	3.00	0.70	1.10	0.80
d18O	δ18O, per mil	Isotopes	779.00	(10.87)	18.00	5.39
d34S	δ34S, per mil	Isotopes	7.00	30.00	42.10	32.30
Sr87Sr86	87Sr/86Sr	Isotopes	367.00	0.71	0.72	0.71

Attachment 4.
U.S. Geological Survey Produced Water Database
Parameter List

Name	Data Type	Description
IDUSGS	ID	Unique ID in this database. Note that these values will change between database versions.
IDORIG	ID	ID in original database or publication
PLAYTYPE	Well Info	Samples are classified by the play type / reservoir type of the sampled formation. "Shale" are shale and mixed-shale plays as defined by the EIA in 2016 (https://www.eia.gov/maps/images/shale_gas_lower48.pdf), as well as other shale reservoirs. "Coal" plays are those described as coal bed methane production wells, as well as conventional production from coal. "Sedimentary" plays include production from all other sedimentary lithologies, including sandstones, limestones, conglomerates, and evaporites. Nearly all conventional hydrocarbon production falls into this category, yet it also includes some tight reservoirs that are not dominantly shale-bearing. "Geothermal" wells are geothermal wells. "Injection" samples are those used for wastewater injection or hydraulic fracturing.
WELLTYPE	Well Info	One of seven well type designations (Conventional Hydrocarbon, Shale Gas, Tight Oil, Tight Gas, Coal Bed Methane, Geothermal, and Groundwater), which were defined using a combination of geologic and engineering-based parameters. This variable was not updated from version 2.3 but was retained for consistency. PLAYTYPE is the preferred well categorization for version 3.0.
BASIN	Location	Geologic basin as reported, and modified for consistency between data sources. Basins do not have strict outlines and data may overlap. The reported basin name was kept unless there was information suggesting it was mislabeled, or to standardize the names.
FORMSIMPLE	Geology	Geologic formation name simplified and standardized. All entries that were assumed to represent the same formation were reported as the simplest version of the name without any age or lithologic qualifiers. For example, "Clinton Sandstone", "Clinton Ss", "Silurian Clinton Fm." and "Clinton" are all labeled "Clinton." For entries where only geologic age descriptors were used instead of formation names (e.g. "Devonian"), the geologic age descriptor was used as the formation name. Age descriptors were also used where the lithology is necessary to differentiate from other formations (e.g. "Devonian Shale" was retained to differentiate it from "Devonian"). If multiple formations were listed, the first formation listed was used.
TDS	Inorganic Chemistry	Total Dissolved Solids, in mg/L. Value is the reported measured value (1), reported calculated value (2), or the value calculated using major ion chemistry (3), in that order. If not already in mg/L, TDS was converted from ppm using the specific gravity (1) or an empirical relationship of total dissolved solids in ppm to specific gravity to estimate specific gravity, and then convert from ppm to mg/L.
LATITUDE	Location	Latitude. Uses latitude of the source information (where available). If the source dataset is missing location information, then latitude is approximated using the following order: latitude of county centroid (where the county of the well is known), latitude of the approximate center of the field based on wells in the same field (where information is available), latitude of the centroid of the basin within the state of the well location (where information is available), or the state centroid (if all other information is missing).
LONGITUDE	Location	Longitude. Uses longitude of the source information (where available). If the source dataset is missing location information, then longitude is approximated using the following order: longitude of county centroid (where the county of the well is known), longitude of the approximate center of the field based on wells in the same field (where information is available), longitude of the centroid of the basin within the state of the well location (where information is available), or the state centroid (if all other information is missing).
FIPCODE	Location	FIP (Federal Information Processing) Code, a 5 digit code indicating a US state or territory, as well as county.
COORDAPX	Location	Description if LATITUDE or LONGITUDE are approximate
COORDNEW	Location	Description of updated location information compared to version 2.3; orig = original location from source data used and location the same as v2.3; new latlon = new latitude and longitude; new county centroid = updated location using county centroid; new field centroid = updated location using field centroid; state basin centroid = updated location using centroid of basin with state; new state centroid = updated location using state centroid; missing = location missing
STATE	Location	Name of state (for U.S. wells), province for Canadian wells, or "Offshore" for wells outside of U.S. state boundaries.
STATEFIP	Location	State FIP code
COUNTY	Location	Modified county name from GIS analysis. Workflow uses COUNTYORIG (as available), modifies COUNTYORIG where the name is incorrect, uses the county of the updated well location (if latitude or longitude were modified from the source dataset), or uses a county centroid if location (latitude / longitude) are available and COUNTYORIG is missing. COUNTYNAME is -9999 if location information is missing or a state centroid is used for the well location.
COUNTYFIP	Location	County FIP code
COUNTYORIG	Location	Name of county from dataset source.
FIELD	Location	Field name, as reported
FIELDCODE	Location	Field Code, as reported
PROVINCE	Location	USGS 1995 National Oil and Gas Assessment Province Boundaries (https://certmapper.cr.usgs.gov/data/noga95/natl/spatial/doc/pr_natlg.htm)
REGION	Location	USGS 1995 National Oil and Gas Assessment Region Boundaries
TOWNRANGE	Location	Township, Range, Section, Quarter
LOC	Location	Location information not otherwise recorded
WELLNAME	Well Info	Well name
API	Well Info	API well number, 14 digits
OPERATOR	Well Info	Well operator
WELLCODE	Well Info	Well code
PERMIT	Well Info	Well permit holder
DATECOMP	Well Info	Date of well completion, in format YYYY-MM-DD
ELEVATION	Well Info	Elevation of well, ft
DEPTHUPPER	Well Info	Upper perforation depth of sampled interval, ft. Depth added here if non-specific.
DEPTHLOWER	Well Info	Lower perforation depth of sampled interval, ft
NWIS	Well Info	USGS National Water Information System (NWIS) Site Number
GROUP	Geology	Geologic group name
FORMATION	Geology	Geologic formation name as reported, and modified for consistency for some high priority formations.
MEMBER	Geology	Geologic member name
ERA	Geology	Geologic Era name, if not given, determined by GEOLEX from FORMATION
PERIOD	Geology	Geologic Period name, if not given, determined by GEOLEX from FORMATION
EPOCH	Geology	Geologic Epoch name, if not given, determined by GEOLEX from FORMATION
LITHOLOGY	Geology	Lithology
POROSITY	Geology	Porosity, % reported
TIMESERIES	Time	Order of time-series data
DAY	Time	Sample day of time-series data
DATESAMPLE	Time	Date of sample collection, in format YYYY-MM-DD
DATEANALYS	Time	Date of analysis, in format YYYY-MM-DD
METHOD	Method	Sample Method
LAB	Method	Laboratory that analyzed the results
TEMP_R	Physical Parameters	Temperature, deg F reported
PRESSURE	Physical Parameters	Formation pressure, psi reported
SG	Physical Parameters	Specific Gravity, reported or calculated
SPGRAV	Physical Parameters	Specific Gravity, reported
SPGRAVT	Physical Parameters	Temperature of Specific Gravity measurement, deg F
RESIS	Physical Parameters	Resistivity, Ohm m
RESIST	Physical Parameters	Temperature of Resistivity measurement, deg F
PH	Physical Parameters	pH
PHT	Physical Parameters	Temperature of pH measurement, deg F
EHORP	Physical Parameters	Eh / Oxidation Reduction Potential, mV
COND	Physical Parameters	Conductivity, µS/cm
CONDT	Physical Parameters	Temperature of Conductivity measurement, deg F
TEMP	Physical Parameters	Combined temperature column, using TEMP > PHT > CONDT > RESIST
TURBIDITY	Physical Parameters	Turbidity
HEM	Physical Parameters	Oil and Grease (Hexane Extractable Material)
MBAS	Physical Parameters	Surfactants and Detergents
UNITSORIG	Metadata	mg/L or ppm, reported. All ppm data were converted to mg/L.
TDSLAB	Inorganic Chemistry	Total Dissolved Solids, measured, as reported in reference, mg/L
TDSCALC	Inorganic Chemistry	Total Dissolved Solids, calculated, as reported in reference, mg/L

Attachment 4.
U.S. Geological Survey Produced Water Database
Parameter List

Name	Data Type	Description
TDSDESC	Inorganic Chemistry	Description of TDS measurement; either "reported measured", "reported calculated", or "calculated" the value calculated using major ion chemistry
TSS	Inorganic Chemistry	Total Suspended Solids, mg/L
Ag	Inorganic Chemistry	Silver, mg/L
Al	Inorganic Chemistry	Aluminum, mg/L
As	Inorganic Chemistry	Arsenic, mg/L
Au	Inorganic Chemistry	Gold, mg/L
B	Inorganic Chemistry	Boron, mg/L
BO3	Inorganic Chemistry	Borate, mg/L
Ba	Inorganic Chemistry	Barium, mg/L
Be	Inorganic Chemistry	Beryllium, mg/L
Bi	Inorganic Chemistry	Bismuth, mg/L
Br	Inorganic Chemistry	Bromide, mg/L
CO3	Inorganic Chemistry	Carbonate, mg/L
HCO3	Inorganic Chemistry	Bicarbonate, mg/L
Ca	Inorganic Chemistry	Calcium, mg/L
Cd	Inorganic Chemistry	Cadmium, mg/L
Cl	Inorganic Chemistry	Chloride, mg/L
Co	Inorganic Chemistry	Cobalt, mg/L
Cr	Inorganic Chemistry	Chromium, mg/L
Cs	Inorganic Chemistry	Cesium, mg/L
Cu	Inorganic Chemistry	Copper, mg/L
F	Inorganic Chemistry	Fluoride, mg/L
FeTot	Inorganic Chemistry	Iron, total, mg/L
FeIII	Inorganic Chemistry	Iron, 3+, mg/L
FeII	Inorganic Chemistry	Iron, 2+, mg/L
FeS	Inorganic Chemistry	Iron sulfide, mg/L
FeAl	Inorganic Chemistry	Iron plus Aluminum, reported as elements, mg/L
FeAl2O3	Inorganic Chemistry	Iron plus Aluminum, reported as oxides, mg/L
Ga	Inorganic Chemistry	Gallium, mg/L
Ge	Inorganic Chemistry	Germanium, mg/L
Hf	Inorganic Chemistry	Hafnium, mg/L
Hg	Inorganic Chemistry	Mercury, mg/L
I	Inorganic Chemistry	Iodine, mg/L
K	Inorganic Chemistry	Potassium, mg/L
KNa	Inorganic Chemistry	Potassium plus Sodium, mg/L
Li	Inorganic Chemistry	Lithium, mg/L
Mg	Inorganic Chemistry	Magnesium, mg/L
Mn	Inorganic Chemistry	Mangansese, mg/L
Mo	Inorganic Chemistry	Molybdenum, mg/L
N	Inorganic Chemistry	Nitrogen, total, mg/L
NO2	Inorganic Chemistry	Nitrite, mg/L
NO3	Inorganic Chemistry	Nitrate, mg/L
NO3NO2	Inorganic Chemistry	Nitrate plus Nitrite, mg/L
NH4	Inorganic Chemistry	Ammonium, mg/L
TKN	Inorganic Chemistry	Kjeldahl Nitrogen, mg/L
Na	Inorganic Chemistry	Sodium, mg/L
Ni	Inorganic Chemistry	Nickel, mg/L
OH	Inorganic Chemistry	Hydroxide, mg/L
P	Inorganic Chemistry	Phosphorus, mg/L
PO4	Inorganic Chemistry	Phosphate, mg/L
Pb	Inorganic Chemistry	Lead, mg/L
Rh	Inorganic Chemistry	Rhodium, mg/L
Rb	Inorganic Chemistry	Rubidium, mg/L
S	Inorganic Chemistry	Sulfide, mg/L
SO3	Inorganic Chemistry	Sulfite, mg/L
SO4	Inorganic Chemistry	Sulfate, mg/L
HS	Inorganic Chemistry	Bisulfide, mg/L
Sb	Inorganic Chemistry	Antimony, mg/L
Sc	Inorganic Chemistry	Scandium, mg/L
Se	Inorganic Chemistry	Selenium, mg/L
Si	Inorganic Chemistry	Silica, mg/L
Sn	Inorganic Chemistry	Tin, mg/L
Sr	Inorganic Chemistry	Strontium, mg/L
Th	Inorganic Chemistry	Thorium, mg/L
Ti	Inorganic Chemistry	Titanium, mg/L
Tl	Inorganic Chemistry	Thallium, mg/L
U	Inorganic Chemistry	Uranium, mg/L
V	Inorganic Chemistry	Vanadium, mg/L
W	Inorganic Chemistry	Tungsten, mg/L
Y	Inorganic Chemistry	Yttrium, mg/L
Zn	Inorganic Chemistry	Zinc, mg/L
Zr	Inorganic Chemistry	Zirconium, mg/L
La	Inorganic Chemistry, Rare Ear	Lanthanum, mg/L
Ce	Inorganic Chemistry, Rare Ear	Cerium, mg/L
Pr	Inorganic Chemistry, Rare Ear	Praseodymium, mg/L
Nd	Inorganic Chemistry, Rare Ear	Neodymium, mg/L
Sm	Inorganic Chemistry, Rare Ear	Samarium, mg/L
Eu	Inorganic Chemistry, Rare Ear	Europium, mg/L
Gd	Inorganic Chemistry, Rare Ear	Gadolinium, mg/L
Tb	Inorganic Chemistry, Rare Ear	Terbium, mg/L
Dy	Inorganic Chemistry, Rare Ear	Dysprosium, mg/L
Ho	Inorganic Chemistry, Rare Ear	Holmium, mg/L
Er	Inorganic Chemistry, Rare Ear	Erbium, mg/L
Tm	Inorganic Chemistry, Rare Ear	Thulium, mg/L
Yb	Inorganic Chemistry, Rare Ear	Ytterbium, mg/L
Lu	Inorganic Chemistry, Rare Ear	Lutetium, mg/L
ALKALINITY	Inorganic Chemistry	Alkalinity as HCO3, mg/L
ACIDITY	Inorganic Chemistry	Acidity as CaCO3, mg/L
DIC	Inorganic Chemistry	Dissolved Inorganic Carbon, mg/L
DOC	Organic Chemistry	Dissolved Organic Carbon, mg/L
TOC	Organic Chemistry	Total Organic Carbon, mg/L
CYANIDE	Organic Chemistry	Cyanide, mg/L

Name	Data Type	Description
BOD	Organic Chemistry	Biochemical Oxygen Demand, mg/L
COD	Organic Chemistry	Chemical Oxygen Demand, mg/L
BENZENE	Organic Chemistry, Volatile O	Benzene, mg/L
ETHYLBENZ	Organic Chemistry, Volatile O	Ethybenzene, mg/L
NAPHTH	Organic Chemistry, Aromatic	Napthalene, mg/L
PERC	Organic Chemistry, Volatile O	Tetrachloroethylene, mg/L
TOLUENE	Organic Chemistry, Volatile O	Toluene, mg/L
XYLENE	Organic Chemistry, Volatile O	Xylene, mg/L
PHENOLS	Organic Chemistry	Phenols, mg/L
ACETATE	Organic Chemistry, Organic A	Acetate, mg/L
BUTYRATE	Organic Chemistry, Organic A	Butyrate, mg/L
FORMATE	Organic Chemistry, Organic A	Formate, mg/L
LACTATE	Organic Chemistry, Organic A	Lactate, mg/L
PROPIONATE	Organic Chemistry, Organic A	Propionate, mg/L
PYRUVATE	Organic Chemistry, Organic A	Pyruvate, mg/L
VALERATE	Organic Chemistry, Organic A	Valerate, mg/L
ORGACIDS	Organic Chemistry, Organic A	Total Organic Acids, mg/L
Ar	Dissolved Gases	Argon gas, dissolved, mg/L
CH4	Dissolved Gases	Methane gas, dissolved, mg/L
C2H6	Dissolved Gases	Ethane gas, dissolved, mg/L
CO2	Dissolved Gases	Carbon Dioxide gas, dissolved, mg/L
H2	Dissolved Gases	Hydrogen gas, dissolved, mg/L
H2S	Dissolved Gases	Hydrogen Sulfide gas, dissolved, mg/L
He	Dissolved Gases	Helium gas, dissolved, mg/L
N2	Dissolved Gases	Nitrogen gas, dissolved, mg/L
NH3	Dissolved Gases	Ammonia gas, dissolved, mg/L
O2	Dissolved Gases	Oxygen gas, dissolved, mg/L
ALPHA	Isotopes	Alpha particles, pCi/L
BETA	Isotopes	Beta particles, pCi/L
dD	Isotopes	δH, per mil
H3	Isotopes	Tritium, 3H, tritium units
d7Li	Isotopes	δ7Li, per mil
d11B	Isotopes	δ11B, per mil
d13C	Isotopes	δ13C, per mil
C14	Isotopes	14C, pCi/L
d18O	Isotopes	δ18O, per mil
d34S	Isotopes	δ34S, per mil
d37Cl	Isotopes	δ37Cl, per mil
K40	Isotopes	40K, pCi/L
d81Br	Isotopes	δ81Br
Sr87Sr86	Isotopes	87Sr/86Sr
I129	Isotopes	129I/I, parts per quadrillion
Rn222	Isotopes	222Rn, pCi/L
Ra226	Isotopes	226Ra, pCi/L
Ra228	Isotopes	228Ra, pCi/L
MICROBES	Microbial Data	Link to genomic data
CHARGEBAL	Data Quality	Charge balance of major ions, %, calculated
REMARKS	Metadata	Remarks or comments
IDDB	ID	Name of input data or database
SOURCE	Reference	Source of data, often a database or a compilation paper. SOURCE may also be the same as REFERENCE.
REFERENCE	Reference	Source of data, first level source where data were published or shared.

Attachment 3. U.S. Geological Survey Produced Water Database: Parameters Not Reported for Texas

Code	Description	Data Type
TURBIDITY	Turbidity	Physical Parameters
HEM	Oil and Grease (Hexane Extractable Material)	Physical Parameters
MBAS	Surfactants and Detergents	Physical Parameters
As	Arsenic, mg/L	Inorganic Chemistry
Au	Gold, mg/L	Inorganic Chemistry
Be	Beryllium, mg/L	Inorganic Chemistry
Bi	Bismuth, mg/L	Inorganic Chemistry
Cr	Chromium, mg/L	Inorganic Chemistry
Ga	Gallium, mg/L	Inorganic Chemistry
Ge	Germanium, mg/L	Inorganic Chemistry
Hf	Hafnium, mg/L	Inorganic Chemistry
Hg	Mercury, mg/L	Inorganic Chemistry
N	Nitrogen, total, mg/L	Inorganic Chemistry
NO2	Nitrite, mg/L	Inorganic Chemistry
NO3NO2	Nitrate plus Nitrite, mg/L	Inorganic Chemistry
TKN	Kjeldahl Nitrogen, mg/L	Inorganic Chemistry
SO3	Sulfite, mg/L	Inorganic Chemistry
HS	Bisulfide, mg/L	Inorganic Chemistry
Sc	Scandium, mg/L	Inorganic Chemistry
Sn	Tin, mg/L	Inorganic Chemistry
Th	Thorium, mg/L	Inorganic Chemistry
Ti	Titanium, mg/L	Inorganic Chemistry
U	Uranium, mg/L	Inorganic Chemistry
V	Vanadium, mg/L	Inorganic Chemistry
W	Tungsten, mg/L	Inorganic Chemistry
Y	Yttrium, mg/L	Inorganic Chemistry
La	Lanthanum, mg/L	Inorganic Chemistry, Rare Earth Elements
Ce	Cerium, mg/L	Inorganic Chemistry, Rare Earth Elements
Pr	Praseodymium, mg/L	Inorganic Chemistry, Rare Earth Elements
Nd	Neodymium, mg/L	Inorganic Chemistry, Rare Earth Elements
Sm	Samarium, mg/L	Inorganic Chemistry, Rare Earth Elements
Eu	Europium, mg/L	Inorganic Chemistry, Rare Earth Elements
Gd	Gadolinium, mg/L	Inorganic Chemistry, Rare Earth Elements
Tb	Terbium, mg/L	Inorganic Chemistry, Rare Earth Elements
Dy	Dysprosium, mg/L	Inorganic Chemistry, Rare Earth Elements
Ho	Holmium, mg/L	Inorganic Chemistry, Rare Earth Elements
Er	Erbium, mg/L	Inorganic Chemistry, Rare Earth Elements
Tm	Thulium, mg/L	Inorganic Chemistry, Rare Earth Elements
Yb	Ytterbium, mg/L	Inorganic Chemistry, Rare Earth Elements
Lu	Lutetium, mg/L	Inorganic Chemistry, Rare Earth Elements
ACIDITY	Acidity as CaCO3, mg/L	Inorganic Chemistry
CYANIDE	Cyanide, mg/L	Organic Chemistry
BOD	Biochemical Oxygen Demand, mg/L	Organic Chemistry

Code	Description	Data Type
BENZENE	Benzene, mg/L	Organic Chemistry, Volatile Organic Compound
ETHYLBENZ	Ethybenzene, mg/L	Organic Chemistry, Volatile Organic Compound
NAPHTH	Napthalene, mg/L	Organic Chemistry, Aromatic Hydrocarbon
PERC	Tetrachloroethylene, mg/L	Organic Chemistry, Volatile Organic Compound
TOLUENE	Toluene, mg/L	Organic Chemistry, Volatile Organic Compound
XYLENE	Xylene, mg/L	Organic Chemistry, Volatile Organic Compound
PHENOLS	Phenols, mg/L	Organic Chemistry
FORMATE	Formate, mg/L	Organic Chemistry, Organic Acid Anion
LACTATE	Lactate, mg/L	Organic Chemistry, Organic Acid Anion
PYRUVATE	Pyruvate, mg/L	Organic Chemistry, Organic Acid Anion
H2	Hydrogen gas, dissolved, mg/L	Dissolved Gases
He	Helium gas, dissolved, mg/L	Dissolved Gases
ALPHA	Alpha particles, pCi/L	Isotopes
BETA	Beta particles, pCi/L	Isotopes
H3	Tritium, 3H, tritium units	Isotopes
d37Cl	δ37Cl, per mil	Isotopes
K40	40K, pCi/L	Isotopes
d81Br	δ81Br	Isotopes
I129	129I/I, parts per quadrillion	Isotopes
Rn222	222Rn, pCi/L	Isotopes
Ra226	226Ra, pCi/L	Isotopes
Ra228	228Ra, pCi/L	Isotopes

D. Lauren Ross, Ph. D., P. E. – Principal Engineer

Dr. Lauren Ross is an environmental engineer and owner of Glenrose Engineering, Inc. in Austin, Texas since 1987.

Education

Ph. D. Civil Engineering, University of Texas at Austin; 1993
M. S. Civil Engineering, Colorado State University, Fort Collins, Colorado; 1982
B. S. Civil Engineering, University of Texas at Austin; 1977, *summa cum laude*

Registration, Certification, and Training

Registered Professional Engineer: State of Texas, 1984
OSHA 40-hour Hazardous Waste Health and Safety Training, 1993
Certified Professional in Erosion and Sediment Control, 2009
U. S. E.P.A. 5-Day Water Quality Analysis Simulation Program (WASP), 2016

Experience

Wastewater Engineering and Permitting

- Design of a constructed wetland system to treat high biochemical oxygen demand and concentrated nutrient wastewater from a tofu production facility.
- Soil, spring, and groundwater monitoring system recommendations for Texas land application systems: Barton Creek West Water Supply Corporation, Rocky Creek Wastewater Utility, Austin Highway 290 (Headwaters), City of Dripping Springs, Travis County Municipal Utility District No. 4, Scenic Greens, Hays County Water Control and Improvement District No. 1, Prentiss Properties Acquisition Limited Partnership.
- Water balance modeling for septic systems in the Barton Springs Edwards Aquifer Recharge and Contributing Zones.
- Water balance modeling for Three Rivers Refinery wastewater effluent irrigation.
- Environmental sampling and/or data analysis associated with wastewater effluent irrigation at Barton Creek West WSC, Hays County Water Control and Improvement District No. 1 (Belterra), Hays County Municipal Utility District No. 5 (Highpointe) Three Rivers Refinery, and West Cypress Hills wastewater effluent irrigation.

Ground Water

- Pollution concentration predictions in Barton Springs from a pipeline leak using a numerical model based on field dye trace data.
- Evaluation of environmental data to determine coal combustion waste disposal impacts in the Four Corners region.
- Groundwater contamination study, waste evaluation, sampling, and analysis for petroleum refinery.
- Closed landfill study: field investigation, compiled and reviewed historical records, assessed potential environmental consequences, installed, sampled, and evaluated data from monitoring wells.
- Conducted geologic assessment, designed and installed groundwater monitoring well system for municipal landfills.
- Designed a system to limit methane and leached organic chemical migration from a closed municipal landfill into a karst limestone sole-source drinking water aquifer.

D. Lauren Ross, Ph. D., P. E. – Principal Engineer

- Developed groundwater management alternatives to limit withdrawal and related land subsidence.

Environmental Assessment

- Baseline and impact assessment for wastewater line remediation project including evaluation of soils, geology, topography, and flow regimes.
- Environmental Assessment evaluation for a proposed project to convert an inactive crude oil pipeline, largely constructed in 1950, into active service as a high-pressure fuel transmission line. Work included: evaluating historical spill records; calculating statistical failure probabilities for different pipeline reaches and spill sizes; predicting time and concentrations of toxic and carcinogenic constituent migration through and discharge from a karst limestone aquifer; and evaluating the Operational Reliability Assessment performed for the pipeline.

Solid Waste

- Investigated waste metal migration in soil for petroleum land treatment unit.
- Investigated geologic setting and groundwater contamination and designed recovery well system for groundwater remediation at a commercial RCRA waste storage impoundment.
- Designed petroleum waste land treatment units: baseline soil and groundwater characterization; monitor well system design and installation; lysimeter systems; and land treatment demonstrations to determine maximum waste capacity and loading rates.
- Developed sampling procedures and in-place treatment for RCRA waste at electrical generation power plants.
- Managed and prepared technical phases of Industrial Solid Waste Permit Applications under RCRA and Texas Natural Resource Conservation Commission regulations for waste management facilities: land treatment units, surface impoundments, container storage areas.
- Designed closure plans for RCRA waste impoundments to store, treat and dispose of inorganic acids, spent pickle liquor, and organic chemicals.
- Review of proposed municipal solid waste landfill applications.

Water Quality and Engineering Design

- Gravity-flow retention and irrigation water pollution control system for a large hospital complex within the contributing watershed of the karst Barton Springs Aquifer.
- Design of an innovative bioretention water quality control system for a municipal complex located on the Barton Springs Edwards Aquifer Recharge Zone and permitting under Texas Commission on Environmental Quality Edwards Aquifer protection rules.
- Design of an innovative pervious pavement storm runoff detention and treatment system for a proposed parking lot to be located on the Northern Edwards Aquifer Recharge Zone and permitting under stringent City of Austin and Texas Commission on Environmental Quality water quality protection rules.
- Wet pond design and detention basin retrofit to treat stormwater from existing residential and commercial development in the Oak Springs neighborhood in East Austin.
- Combined wet pond and bioretention design for commercial storm runoff.
- Combined wet pond and retention/irrigation design for an existing 162-acre residential development over the sensitive Barton Springs recharge zone in the City of Austin, Texas.

D. Lauren Ross, Ph. D., P. E. – Principal Engineer

- Municipal engineer responsible for all water quality design, review, inspection, rules, and ordinances for the City of Sunset Valley, Texas.
- Analyzed nonpoint pollution sources and structural and non-structural retrofit controls for recharge and contributing zone of a sensitive karst aquifer.
- Analyzed nonpoint pollution sources and structural and non-structural retrofit controls as water quality engineer for the City of Sunset Valley, Texas.
- Technical consultant to the City of Austin on implementation of the 1991 Comprehensive Watersheds Ordinance and associated water quality monitoring system.
- Analyzed stormwater conveyance and flooding potential, designed regional detention basin to protect natural ecological systems for Armand Bayou Master Drainage Study.
- Estimated long-term groundwater yields based on rainfall rates, soil type, and river losses for Chisumbanje region of Zimbabwe, Africa.
- Evaluated land use, soils, agricultural and silvicultural practices to assess non-point pollution potential in the San Jacinto River Basin.
- Designed storm water drainage for subdivisions and regional water detention facilities.

Teaching and Presentations

- Semester Course in Statistics for Environmental Monitoring; University of Texas at Austin; Fall 1995.
- Semester Course in Water Resources, University of Texas at Austin.
- Land Development Seminar; Travis County Bar Association, 12 July 1996.
- Water Quality Protection Programs to Reduce Nonpoint Source Pollution, a presentation to the Barton Springs/Edwards Aquifer Conservation District's Watershed Management: Challenges and Innovations—A Nonpoint Source Pollution Conference, 25 July 1996.
- Presenter at Emerging Issues in Groundwater Regulation panel discussion, Key Environmental Issues in U.S. EPA Region VI conference, hosted by U.S. EPA and the American Bar Association, May 12-13, 1997.
- Short Courses in Statistics for Environmental Monitoring; University of Texas Continuing Engineering Studies Program: Spring 1995, Fall 1995, Spring 1996, Spring 1997, Spring 1998.
- Short Courses in Statistics for Environmental Monitoring; Louisiana Department of Environmental Quality. Focus on surface water sampling considerations, trend analysis and methods to assess the achievement of data quality objectives.

Statistics

- Evaluated surface and groundwater measurements for normality, differences in mean, spatial variability, and time series analysis. Techniques used include Student's t-test, Wilcoxon test, parametric and non-parametric ANOVA, Fourier series decomposition, Shapiro-Wilkes test, and Chi-squared tests.
- Geostatistical analysis and kriging of groundwater transmissivity data.
- Statistically-based sampling design including optimum sample number, stratified random sampling, and assessment of monitoring parameters to achieve efficient sampling designs.

Field/ Laboratory Experience

D. Lauren Ross, Ph. D., P. E. – Principal Engineer

- Field supervision of auger drilling, rotary-bit drilling, well installation, Shelby-tube core and split-spoon sampling, and soil type identification using the Unified Soils Classification System
- Surface, groundwater and hazardous waste sampling for a variety of constituents, including volatile organic constituents, dioxins, nutrients, metals, anions, cations, and other collection-sensitive parameters.
- Laboratory experiments to measure unsaturated hydraulic conductivity, water content versus soil water pressure, and other geophysical soil properties.

Reports and Publications

- *Wastewater Discharge Impacts to Wilbarger Creek Water Quality,* for Wilbarger Creek Conservation Alliance, June 2026.
- *Review letter: TCEQ Proposed Renewal with Amendment of General Permit TXG110000 Authorizing Wastewater and Storm water Discharges from ready-Mixed Concrete Plants, Concrete Products Plants and Associated Facilities;* for Earth Justice, April 27, 2026.
- *Review letter: Revisions to City of Austin Environmental Criteria Manual: Retention Irrigation Criteria,* for Save Our Springs Alliance, February 25, 2026.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application by The Village of Grape Creek, LLC for TPDES Permit No. WQ0016363001 on behalf of Pedernales River Alliance and Greater Edwards Aquifer Alliance, submitted on August 7, 2025, 2025.
- *Underground Injection Control Class VI Draft Permit ID Nos: R6-TX-245-C6-0001, R6-TX-245-C6-0002, R6-TX-245-C6-0003, Preliminary Permit Review* for EarthJustice, August 4, 2025.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Cullen RV Resort, LLC for TPDES Permit No. WQ0016309001 on behalf of Brazoria County, submitted on May 9, 2025.
- *Total Petroleum Hydrocarbons: Absher Equine Center; Flatonia, Texas,* prepared for Phillip Poplin, attorney, March 10, 2025.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application of Municipal Operations, LLC for TPDES Permit No. WQ0016171001 on behalf of Greater Edwards Aquifer Alliance and the City of Grey Forest, submitted on January 3, 2025 and amended on February 18, 2025.
- *Evaluation of Draft Permit WQ0005462000 for Space Exploration Technologies Corporation Deluge Wastewater,* prepared for Marisas Perales, attorney and Lauren Ice, attorney, December 27, 2024.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application of Corix Utilities (Texas) Inc. for TPDES Permit No. WQ0013977001 on behalf of Environmental Stewardship, December 19, 2024.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application of Clancy Utility Holdings, LLC for an Operating Permit from the Hays Trinity Groundwater Conservation District on behalf of Save Our Springs Alliance and Save the Pedernales, September 16, 2024.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application by San Miguel Electric Cooperative, Inc. for Renewal and Major Amendment to Texas Pollutant Discharge Elimination System Permit No. WQ0002043000 on behalf of Swaim, Lively & Shorty, Owners, July 3, 2024.

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- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application by City of Kyle for a Major Amendment to Texas Pollutant Discharge Elimination System Permit No. WQ001041002, on behalf of San Marcos River Foundation, Inc, May 29, 2024.
- *Total Petroleum Hydrocarbons Present in Soils at the Absher Equine Center, Flatonia, Texas,* prepared for Phillip Polin, attorney, February 19, 2024.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application of San Miguel Electric Cooperative, Inc. for Renewal/Revision of Permit No. 60, San Miguel Lignite Mine, Areas F, G & H, McMullen County, Texas before the Railroad Commission of Texas, on behalf of Protestants Swaim, Lively, and Shorty Owners, October 9, 2023.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application by Undine Texas Environmental, LLC for New Texas Pollutant Discharge Elimination System Permit No. WQ0016046001, on behalf of Brazoria County, December 14, 2023.
- *Prefiled Direct Testimony of D. Lauren Ross, PH. D., P.E.,* regarding Application by SJWTX, Inc. and Mary Jane Cielencki for New Texas Pollutant Discharge Elimination System Permit No. WQ0016052001, on behalf of Protestants Annette Gass, Rita Acker, and Rhonda Luman, July 19, 2023.
- *Prefiled Direct Testimony of D. Lauren Ross, Ph.D., P.E. on Remand,* regarding Application by City of Liberty Hill for Renewal of Texas Pollutant Discharge Elimination System Permit No. WQ0014477001, on behalf of Protestant Stephanie Morris, June 7, 2023.
- *Warrior Oil Tank Well Tank Battery and Associated Contamination,* prepared for Phillip Poplin, attorney, January 2, 2023.
- *Pre-Filed Direct Testimony of D. Lauren Ross, Ph.D., P.E. on Behalf of the Swaim, Lively & Shorty Protestants, regarding San Miguel Electric Cooperative, Inc.'s Application for New Permit, X, Y, and Z Area Lignite Mine, McMullen County, Texas,* Railroad Commission of Texas Docket No. MR-21-00006257, October 11, 2022.
- *Prefiled Direct Testimony of D. Lauren Ross, Ph.D., P.E.* regarding Application by City of Liberty Hill for Renewal of Texas Pollutant Discharge Elimination system Permit No. WQ0014477001, on behalf of Protestant Stephanie Morris, July 20, 2022.
- *Stormwater Control Measures Audit: Water Conservation Supply and Ecosystem Benefits,* memorandum for City of Austin, January 31, 2022.
- *Direct Prefiled Testimony in Application from Kendall West Utility, LLC for a new TPDES Permit WQ0015787001* for Save Our Springs Alliance, January 28, 2022.
- *Storm Water Pollution Prevention Plan for Country Club Creek West; Roy G. Guerrero Park Channel Stabilization, City of Austin C.I.P. No. 5848.026,* for City of Austin, November 2021.
- *Review of Houston Tradeport Municipal Setting Designation Application* for EarthJustice, April 2021.
- *Prefiled Testimony in Application by Silesia Properties, LP for TCEQ Permit WQ0015835001,* for Greater Edwards Aquifer Alliance, Mary 31, 2021.
- *Prefiled Testimony for Application of Cherryville GP, Inc. and Cherryville #5 LTD for new TPDES Permit No. WQ0015738001,* for Save Our Springs Alliance, January 15, 2021.
- *Review of Application to Register Domestic Septage Beneficial Use Site; Jack County, Texas for the Two Bush Community Action Group, October 15, 2020.*

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- *Prefiled Testimony in Application of Texas Regional Landfill Company, LP, for MSW Permit No. 1841B* for Marisa Perales, attorney, August 25, 2020.
- *Review of Proposed City of Liberty Hill Sewage Effluent Discharge to the South Fork San Gabriel River,* prepared for Texas RioGrande Legal Aid, August 12, 2020.
- *Urban Sinkhole Evaluation and Mitigation Preliminary Engineering Report* with Geosyntec Consultants, January 31, 2020.
- *Prefiled Testimony in Application by Aqua Texas, INC> for TPDES Permit No. WQ0015642001,* for Mary Conner, attorney, June 21, 2019.
- *Black Mountain Sand Mine Review,* Wintergarden Groundwater Conservation District, January 2019.
- *Soils, Surface Water and Groundwater Hydrology in the Vicinity of the Peeler Ranch in Atascosa County, Texas,* Mary Whittle, attorney, August 2018.
- *June 28 to 29, 2018 Field Investigation Report for Peeler Ranch, Atascosa County, Texas,* Mary Whittle, August 2018.
- *Direct Testimony in Application by the City of Dripping Springs for New TPDES Permit No. WQ0014488003,* for Save Our Springs Alliance, July 24, 2018.
- *Sampling Plan for June 28 to 29, 2018 Peeler Ranch Atascosa County, Texas,* Mary Whittle, June 2018.
- *City of Houston Sanitary Sewer Overflow Data Summary: Preliminary Report,* Eric Allmon, attorney, June 2018.
- *Water Quality Control Concept Design; Courtyard Park @ 5811 Southwest Parkway; Austin, Texas* for RealTex Ventures LP, April 11, 2018.
- *Arrowhead Landfill Protestant's Field Protocols,* for EarthJustice, May 26, 2017.
- *Review of Proposed City of Dripping Springs Wastewater Effluent Discharge to Onion Creek,* Protect Our Water, November 2016.
- *Prefiled Testimony on Application of 130 Environmental Park, LLC for Proposed TCEQ Municipal Solid Waste Permit No. 2383,* attorney Marisa Perales, June 2016.
- *Barnes Family Farm Water Availability Report*, Barnes Family Farm, Inc., April 2015.
- *Preliminary Engineering Design of Storm Runoff Treatment System,* Parkside Montessori Community School, February 2015.
- *Declaration regarding Wetlands Development in Galveston Baykeeper, Inc. vs. Trendmaker Homes, Inc.,* Galveston Baykeeper, Inc., November 2014.
- *Prefiled Testimony on Application of DHJB Development, LLC for a Major Amendment to TPDES Permit No. WQ 0014975001,* attorney Mary Conner, October 2014.
- *Potential Improvements to the Join Task Force Municipal Separate Storm Sewer MS4 Permit,* Houston Parks Board, Galveston Bay Foundation, Buffalo Bayou Partnership and Bayou Preservation Association, March 2014.
- *Asher Property Water and Soil Sampling Results* for Phillip Poplin Law Office, 23 January 2014.
- *Circle Acres Environmental Sampling Report*, Ecology Action, January 2014.

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- *Potential Improvements to the Harris County Municipal Separate Storm Sewer MS4 Permit*, Houston Parks Board, Galveston Bay Foundation, Buffalo Bayou Partnership, and Bayou Preservation Association, January 2014.
- *Circle Acres Preliminary Engineering Biofilter Design*, Ecology Action, August 2013.
- *Circle Acres Storm Water Management Concept Plan*, Ecology Action, May 2013.
- *Comments on Draft Environmental Assessment of the Proposed Longhorn Pipeline Reversal*, City of Austin, September 2012.
- *Water for Coal-Fired Power Generation in Texas: Current and Future Demands,* for Sierra Club, February 2012.
- *Land-Applied Wastewater Effluent Impacts on the Edwards Aquifer,* for Greater Edwards Aquifer Alliance and Save Our Springs Alliance, November 2011.
- *Proposed White Stallion Coal-Fired Power Plant Water Demands and the Highland Lakes Water Supply,* for Sierra Club, June 2011.
- *Water Treatment Plant #4 Environmental Monitoring Program,* for City of Austin, with INTERA, Inc., June 2011.
- *Remediation to Protect the Conemaugh River from Acidic Groundwater,* for Environmental Integrity Project, Lisa Widawsky, attorney, March 2011.
- *What Would You Drink if the Well Ran Dry? Nolan County Water and the Proposed Tenaska Coal-Fired Power Plant,* for Lone Star Chapter of the Sierra Club, November 2010.
- *A Unique Water Quality Retrofit Project in Austin, Texas,* with Scott Muchard, Rebecca Batchelder, and Tom Franke, StormCon; The North American Surface water Quality Conference & Exposition, August 5, 2010, San Antonio, Texas.
- *Potential Stormwater Impacts from Sand and Gravel Excavation on the Llano River, Texas,* for Brad Rockwell, attorney, February 2010
- *Engineering Analysis of Jeremiah Ventures L.P. Propose Wastewater Irrigation Areas,* submitted to City of Austin, December 2009.
- *Pease Park Water Quality and Stream Restoration: Preliminary Engineering Report*, with PBS&J, Inc., for City of Austin, August 2009.
- *Fort Branch Watershed Management Area Reaches 6 and 7; Final Environmental Assessment,* for City of Austin, August 2009.
- *Tannehill Branch Wastewater Line Environmental Assessment,* for City of Austin, August 2009.
- *Water Quality and Quantity Impacts from Proposed South Texas Plant Expansion,* submitted to Sustainable Energy and Economic Development (SEED) Coalition, April 2009.
- *City of Sunset Valley Environmental Monitoring Program: Air Quality,* submitted to the City of Sunset Valley, Texas, November 2008.
- *Recommendations to Stabilize Construction at Ranches at Hamilton Pool,* submitted to Brad Rockwell, attorney, October 2008.
- *Williamson Tributary 2 Water Quality Retrofit: Preliminary Design,* prepared for the City of Austin, October 2008.

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- *Twin Oaks Community: Conceptual Design for Tofu Wastewater Treatment,* submitted to Twin Oaks Intentional Community, June 2008.
- *City of Sunset Valley Surface Water Quality Monitoring Program,* for the City of Sunset Valley, Texas, June 2008.
- *Storm Sewer Retrofit Alternatives to Improve Water Quality in Fort Branch Creek Reaches 6 and 7,* for City of Austin, December 2007.
- *Lundelius-McDaniel Water Quality Retrofit Project: Phase I Environmental Assessment* for HDR Engineering, Inc., September 2007.
- *Effects of Four Corners Power Plant Coal Combustion Waste Disposal on Surface and Groundwater Quality,* submitted to Lisa Evans, Earth Justice Attorney, August 2007.
- *Preliminary Review of the McCarty Road Landfill Proposed Major Permit Amendment*, submitted to Monica Jacobs, Attorney, August 2007.
- *Surface Water and Sediment Sample Results Associated with the Walsh Cresson Ranch and Walsh West Ranch,* submitted to Mary Sahs, attorney, May 2007.
- *Biofiltration Water Quality Control Design Standards,* submitted to the City of Sunset Valley, Texas, 2007.
- *Review of Proposed XTO Energy, Inc. Centralized Landfarm Facility, Jack County, Texas,* submitted to Robert Thompson, Ph.D., July 2006.
- *Carson Creek Watershed Flood Mitigation Project: Impacts on Erosion and Water Quality,* submitted to PBS&J, Inc., December 2005.
- *Water, Mud, Mold, and More: Toxic Chemicals and Staying Safe When Returning to Coastal Louisiana*, Common Ground Relief, December 2005.
- *West Lamar Wastewater Replacement Line: Phase I Environmental Assessment,* prepared for City of Austin, December 2005.
- *Lundelius-McDaniels Water Quality Retrofit Project Preliminary Engineering Report,* submitted to City of Austin with HDR Engineering, Inc., October 2005.
- *Surface Water and Sediment Sample Results Associated with the Diamond Shamrock Three Rivers Refinery Wastewater Irrigation Fields,* submitted to: Ms. Mary Sahs, attorney, September 2005.
- *Diamond Shamrock Three Rivers Refinery Wastewater Irrigation Water Balance* submitted to: Ms. Mary Sahs, attorney, June 2005.
- *Intrawell Comparisons for Arsenic and Benzene Concentration Measurements in Maxwell Landfill Monitoring Well 4.* Submitted to: Robert S. Kier Consulting, Inc., June 2005.
- *Groundwater Sampling Protocols: Ruby Ranch Subdivision.* Submitted to Neighbors Organized in Defense of the Environment. May 2005.
- *Oak Springs Detention Pond Retrofit for Water Quality,* for the City of Austin, February 2005.
- *TR-20 Computer Simulations to Determine Runoff Detention Stage/Storage/Discharge Relationships Meeting Specified Erosion Control Criteria* for City of Austin, January 2005.
- *Potential for Surface and Groundwater Contamination at the Waste Management of Texas, Inc. Westside Landfill,* submitted to Mary K. Sahs, attorney, September 2004.

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- *Recommendations for Edwards Aquifer Authority Water Quality Regulations.* Presented to the Edwards Aquifer Authority Water Quality Task Force in San Antonio, Texas, 17 February 2004.
- *Tanglewood Forest Regional Detention Pond: Phase I Environmental Assessment,* prepared for City of Austin, October 2003.
- *Effects of Impervious Cover Limits to Improve Water Quality*, submitted to City of Sunset Valley, January 2003.
- *EcoCreto ™ Pervious Pavement Water Quality & Flood Control Design.* January 2003.
- *Sampling at the Alcoa Sandow Lignite Mine.* For Neighbors for Neighbors, Inc. December 2002.
- *Preliminary Review of Northern Hays and Southwestern Travis Counties Water Supply System Project Environmental Impact Study; October 2001,* 15 January 2002.
- *Water Quality Design Calculations Wells Branch Church of Christ Austin, Texas* for EcoCreto, Inc. September 2001.
- *Product Pipeline Hazards over Karst Aquifers.* American Society of Civil Engineering Environmental and Pipeline Engineering Convergence 2000. July 23 – 26, 2000, Kansas City, Missouri.
- *Review of the Environmental Assessment of the Proposed Longhorn Pipeline System.* January 2000.
- *Comments on the Final Environmental Assessment of the proposed Longhorn Pipeline System.* January 2001.
- *Water Fights: Citizens Struggle to Shape a City in Central Texas.* From *Under the Blade: The Conversion of Agricultural Landscapes,* Westview Press, Boulder, Colorado. 1999.
- *Hydrogeologic Setting and Potential Contamination of Barton Springs from a Longhorn Pipeline Discharge.* September 1998.
- *Watershed Protection Utility Master Plan: Integrated Solutions Regulatory Inventory.* Prepared for the City of Austin. August 1998.
- *Watershed Protection Utility Master Plan: Integrated Solutions Regulatory Protocols.* Prepared for the City of Austin. July 1998.
- *Statistical Analysis of Soil Samples for Quanex Land Treatment Unit.* Prepared Quanex Gulf States Tube Division. December 1997.
- *A Scientific Basis for Edwards Aquifer Protection,* prepared for the American Bar Association Conference: Key Environmental Issues in U.S.EPA Region VI, May 1997.
- *Robert Mueller Municipal Airport Phase II Environmental Assessment Work Plan, w*ith Geomatrix, Inc., prepared for the City of Austin. April 1997.
- *Water Quality Protection Programs to Reduce NPS Pollution.* Presented at Barton Springs/Edwards Aquifer Conservation District Conference: Watershed Management: Challenges and Innovations. July 1996.
- *Water Quality Ordinance Amendments to the City of Sunset Valley Land Development Code.* Prepared for the City of Sunset Valley. April 1996.

D. Lauren Ross, Ph. D., P. E. – Principal Engineer

- *Soil and Water Quality Monitoring Plan for the City of Austin Municipal Golf Courses.* Prepared for the City of Austin. January 1996.
- *D. C. Reed Estate Water Quality Protection Zone Monitoring Program.* January 1996.
- *Soil Monitoring Plan for Utility Trench Segment through SWMU 216.* Prepared for the City of Austin. January 1996.
- *Waller Creek Flood Control Master Plan.* Prepared with Loomis and Associates for the City of Austin. December 1995.
- Barton Springs Water Protection Efforts Challenged *Nonpoint Source News-Notes,* published by U. S. EPA. . August/September 1995.
- *Statistical Methods for Environmental Monitoring*. Lecture notes for Continuing Engineering Studies Short Course, University of Texas at Austin. 5 to 7 April 1995.
- *"Don't Mess with Texas" Litter Survey.* Prepared for GSD&M Associates, Inc. With Capitol Environmental Services. April 1995.
- *Long Term Viability of the Edwards Aquifer for the City of Sunset Valley Water Supply.* Report prepared for the City of Sunset Valley. February 1995.
- *Character and Magnitude of Degradation in* the *Barton Springs Zone* Report prepared for Loomis and Associates as part of the Barton Springs Zone Retrofit Project, Austin, Texas. . December 1994.
- *Report on Septic Systems in* the *Barton Springs Zone.* Report prepared for Loomis and Associates as part of the Barton Springs Zone Retrofit Project, Austin, Texas. December 1994.
- *"Don't Mess with Texas" Litter Survey Work Plan.* Report prepared for GSD&M Associates, Inc. With Capitol Environmental Services. October 1994.
- *Statistical Analyses to Establish Constituent Action Limits for Detection Monitoring: Industrial Waste Control Site, Sebastian County, Arkansas.* Prepared for IT Corporation. June 1994.
- *Review of Environmental Information Document for Proposed Lacey Pig Operation.* Letter report prepared for Mr. Michael J. Hobbs. April 1994.
- *Barton Creek and Barton Springs: Petition to Texas Natural Resource Conservation Commission for Designation as Outstanding National Resource Waters.* (with others). April 1994.
- *Base Flow in Barton Creek and Statistical Analysis of Water Quality Data for Barton Creek and Barton Springs, Austin, Texas.* Report prepared for Loomis, Santos and Associates. March 1994.
- *Statistical Analysis: Background Sampling Investigation at Bergstrom Air Force Base, Texas.* Prepared for Southwest Laboratories. January 1994.
- *Multivariate Statistical Analysis of Environmental Monitoring Data.* Petroleum Hydrocarbons Conference sponsored by the National Ground Water Association and American Petroleum Institute, Houston, Texas. November 1993.
- *An Environmentalist's Perspective on Pump-and-Treat Groundwater. Ground Water Monitoring and Remediation*, Vol. XIII, No. 4. 1993.

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- *The Importance of the SOS Water Quality Ordinance to the Protection of the Barton Springs Segment of the Edwards Aquifer.* Prepared for the Texas Natural Resource Conservation Commission. September 1993.
- *Statistical Analyses to Establish Constituent Action Limits for Detection Monitoring.* Report prepared for IT Corporation for IWC Site in Fort Smith, Arkansas. June 1993.
- *Multivariate Statistics for Environmental Monitoring Data.* Doctoral Dissertation for the University of Texas at Austin. May 1993.
- *Statistical Analyses to Establish Constituent Action Limits for Detection Monitoring.* Prepared for IT Corporation. May 1993.
- *Statistical Analysis of Phase I and Phase II Background Soil Measurements.* Report prepared for Quanex Corporation. February 1993.
- *Sampling Recommendations to Detect Chromium Contamination in Soils.* Letter report to Mr. Phil Bullock, Southwest Laboratories. 16 August 1993.
- *Recommendations for Sampling: West Dallas Lead Project.* Prepared for International Technology Corporation. August 1992.
- *Implementation Strategy for the Pollution Reduction Standard of the SOS Water Quality Referendum.* Prepared for Save Our Springs Coalition (SOS). July 1992.
- *Statistical Determination of Background Values for Groundwater Based on Student's T-Test, Tolerance Interval and Mann-Whitney Analysis.* Prepared for Quanex Corporation. September 1991.
- *Phase I Environmental Site Assessment: Jollyville/360 Tract; 9401 Capitol of Texas Highway; Austin, Texas.* (with others). June 1991.
- *Statistical Analysis: Koch East Plant Soil Samples.* (with others). May 1991.
- *Soil Metal Evaluation Final Report*. Prepared for Chevron USA, Inc. (with others). October 1990.
- *Review of Hydrogeology and Potential Contamination of Ramada Inn Site.* Report prepared for Capitol Environmental Services. September 1990.
- *Malone Service Company Compliance Plan.* Prepared as part of a RCRA hazardous waste facility permit application. October 1989.
- *Malone Service Company Geology Report.* Prepared as part of a RCRA hazardous waste facility permit application. October 1989.
- *HST3D Groundwater Model to Predict Waste Migrations.* November 1988. Report for Union Carbide Corporation.
- *Statistical Issues in Monitoring Groundwater Quality.* (with others). Prepared for Texas Water Commission. Fall 1987.
- *Land Treatment of Sugar Cane/Ethanol Process Waste.* (with others). May 1987.
- *Phase 1: Feasibility Study for the Development of Groundwater for Irrigation in the Chisumbanje Area*. Prepared for the Zimbabwe Regional Water Authority. (with others). January 1987.
- *Morton Thiokol, Inc. RCRA Hazardous Facility Part B Permit Application*. (with others). 1985.

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- *Air Products Company RCRA Hazardous Facility Part B Permit Application*. (with others). 1985.
- *Quanex Corporation: Gulf States Tube Division RCRA Hazardous Facility Part B Permit Application*. (with others). 1985.
- *Union Carbide Corporation RCRA Hazardous Facility Part B Permit Application*. (with others). 1985.
- *Koch Refining Company RCRA Hazardous Facility Part B Permit Application*. (with others). 1984.
- *Evaluation of Proposed Waste Disposal in Salt Caverns in the Boling Dome.* Prepared for the County of Wharton, Texas. (with others). February 1985.
- *Closure Plans for Two Cooling Tower Blow-Down Impoundments.* Prepared for Houston Lighting and Power. 1984.
- *Landfills in the Vicinity of Austin, Texas.* Prepared for the City of Austin. (with others). November 1984.
- *Maximizing the Statistical Performance of Groundwater Monitoring Systems.* Prepared for Petroleum Hydrocarbons and Organic Chemicals in Groundwater Conference, sponsored by the National Water Well Association. November 1984.
- *Applicability of Student's t-test to Groundwater Monitoring.* American Geophysical Union Conference, Fort Collins, Colorado. April 1984.
- *An Analytical Model to Predict Soil Water Profiles.* Master's Thesis, Colorado State University, Fort Collins, Colorado. June 1982.
- *Groundwater Management Options for the Harris/Galveston Coastal Subsidence District.* (with others). 1979.
- *Armand Bayou Master Drainage Study*. Espey Huston and Associates, Inc. (with others). August 1979.
- *Non-Point Source Pollution Assessment for the San Jacinto Watershed.* Espey Huston and Associates. 1978.