Study of Issues Faced by Communities with Artificial Drainage Systems Lacking Topographic Relief, Slope, and Naturally Defined Floodways

Report to the 89th Texas Legislature

TEXAS WATER DEVELOPMENT BOARD

Study of Issues Faced by Communities with Artificial Drainage Systems Lacking Topographic Relief, Slope, and Naturally Defined Floodways

Report to the 89th Texas Legislature

Brooke T. Paup, Chairwoman

L'Oreal Stepney, Member

Tonya R. Miller, Member

Bryan McMath, Executive Administrator

January 1, 2025

TEXAS WATER DEVELOPMENT BOARD

Table of Contents

List of Figures

Acronyms and Key Terms/Definitions

Atlas 14: National Oceanic and Atmospheric Administration Atlas 14 contains precipitation frequency estimates for the United States and U.S. affiliated territories with associated lower and upper bounds of the 90 percent confidence interval and supplementary information on temporal distribution of heavy precipitation, analysis of seasonality, and trends in annual maximum series data, etc.

Atlas 15: An update to the National Oceanic and Atmospheric Administration Atlas 14 frequency standard while accounting for climate variability and includes precipitation frequency estimates for the entire U.S. and its territories.

Artificial drainage: Refers to a system designed to remove floodwater in a community lacking topographic relief, slope, and naturally defined floodways, per House Bill 4742.

Drainage area/watershed: The land area where precipitation collects and drains off into a common outlet, such as a creek, stream, river, lake, or reservoir. This area can be identified by tracing a line along the highest elevations between two points on a map, often following ridges.

Drainage density: The total length of channels found in an area, including natural channels and stormwater drainage infrastructure.

Natural drainage: The system of geomorphic features that allows water to flow on the Earth's surface.

Poorly drained: Soil that drains water slowly, causing it to remain wet for extended periods or periodically during the growing season.

Rational Method: Technique used to estimate the peak stormwater discharge of rainfall runoff from a small drainage area, typically less than 200 acres.

Slope: The incline of the ground surface and expressed as the elevation change that occurs between two different points, divided by the horizontal distance between those two points. It is calculated as the ratio of the vertical change (rise) to the horizontal change (run) between two points on the line.

Subsidence: When sinking land, especially in coastal areas, leads to higher sea level and increased flood risk.

Time of concentration: Hydrologic concept that refers to the time required for water to travel from the most distant point in a watershed to a specific point of interest, typically the watershed outlet.

Topographic relief: Broad measure of elevation variation across a larger area.

Executive Summary

In response to House Bill (HB) 4742, the Texas Water Development Board (TWDB) studied issues with communities in Texas that lack natural topographic relief, slope, or naturally defined floodways and therefore rely on artificial drainage systems for floodwater conveyance and removal.

The analysis focused on two main goals: (1) study issues faced by communities that predominantly rely on artificial drainage systems and (2) prepare a written report that contains possible recommendations relating to addressing identified issues facing those communities.

This report includes details about how communities with significant artificial drainage systems were identified, the outreach performed, and a synopsis of stakeholder feedback organized into two parts: (1) challenges and (2) potential solutions for communities reliant on artificial drainage.

Performed Analyses. To first identify areas across Texas most likely to rely on artificial drainage, the TWDB performed a literature review and conducted spatial analyses using two key components: low slope and low drainage density, or areas with few natural streams. The TWDB created a map intersecting the portions of Texas with a slope of 0.3 percent and a drainage density of ≤ 1 stream mile per square mile or less, which identifies areas of the state most likely to have artificial drainage systems**.**

Engaged in Outreach. The TWDB utilized the help of the 15 regional flood planning groups, asking for stakeholder contacts living in communities within the areas identified during analyses. Two roundtable interviews were held, and a 12-question survey was distributed to participants. The TWDB also conducted interviews with key contacts in the Rio Grande Valley area, the region instrumental in the creation of HB 4742.

Reported Challenges. Stakeholders interviewed for this report identified four general categories of issues faced by communities reliant on artificial drainage:

1. **Natural, topographical, and hydrologic issues**: Stormwater runoff in areas with very flat slopes spreads out across large areas and drains very slowly. When combined with areas that have very few natural streams and poorly draining soils, there is nowhere for the water to go unless more artificial drainage systems are built. Systems in these areas tend to be more numerous and larger, and thus are costly to build. Coastal communities are susceptible to storm surges that push against drainage systems, leaving no effective outlets for stormwater to travel.
2. **Reliance on built drainage infrastructure and their maintenance**: The more a community relies on artificial drainage systems, the greater the associated costs of constructing and maintaining systems to overcome the lack of topography. Regular upkeep and repairs can be expensive, especially as infrastructure ages and becomes less efficient at handling increased water flow from heavy rainfall or development.
3. **Funding and financial challenges:** Communities often struggle with securing sufficient funds for both new infrastructure projects and ongoing maintenance, as these systems require significant financial resources that many municipalities lack. Accessing additional

funding can be difficult due to budget constraints, limited tax bases, and competition for state and federal government grants or loans.

4. **Regulatory and environmental hurdles**: Regulatory and environmental requirements often pose significant challenges leading to delays and increased project costs. Balancing the need for efficient drainage with the protection of ecosystems, such as wetlands, further complicates compliance and can hinder the progress of infrastructure improvements.

Reported Possible Solutions. In addition to the significant challenges faced by communities, stakeholders reported several recommendations aimed to alleviate challenges. Interviewed individuals reported several possible solutions. These included the following:

1. Dedicated funding for additional artificial drainage projects to address community needs
2. Utilizing and/or restoring natural features into drainage strategies
3. Coordinating with property owners to utilize existing features
4. Creating and maintaining new regional detention ponds
5. Enhancing and maintaining conveyance, particularly in areas that do not have a nearby stream
6. Where possible, stronger floodplain management regulations
7. Creation of regional models to help guide development of floodplain regulations
8. Collaboration with local entities, including drainage districts and municipalities

TWDB Recommendations. The TWDB reviewed the responses from the community outreach efforts and prepared the following recommendations:

1. Study key cost drivers of developing flood infrastructure
2. Continue to fund regional models
3. Encourage regulatory consistency

Introduction and Background

During the 88th Legislative Session, the Texas Legislature enacted House Bill (HB) 4742 to address issues faced by communities with artificial drainage systems. Effective September 1, 2023, the bill authorized the Texas Water Development Board (TWDB) to conduct a study on the challenges experienced by Texas communities that predominantly rely on artificial drainage systems. The bill defines an *artificial drainage system* as “a system to remove floodwater in a community that lacks topographic relief, slope, and naturally defined floodway.”

The bill is as follows:

H.B. No. 4742

> *“AN ACT relating to a study by the Texas Water Development Board of issues faced by communities with artificial drainage systems.*
>
> *BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF TEXAS:*
>
> *SECTION 1. In this Act, "artificial drainage system" means a system to remove floodwater in a community that lacks topographic relief, slope, and naturally defined floodways.*
>
> *SECTION 2. The Texas Water Development Board, before January 1, 2025, may:*
>
> *(1) study issues faced by communities with artificial drainage systems; and*
>
> *(2) prepare a written report that contains possible recommendations relating to addressing identified issues facing those communities.*
>
> *SECTION 3. This Act takes effect September 1, 2023.”*

This legislation reflects the legislature's commitment to understanding and addressing the flood challenges faced by communities. It directs the TWDB to conduct a study aimed at identifying these challenges and formulating recommendations to address them.

Part I: Analyses to Identify Areas Lacking Topographic Relief, Slope, and Naturally Defined Floodways

The TWDB first performed a literature review (Appendix A) to (1) identify existing information on artificial drainage to help identify areas in Texas predominantly reliant on artificial drainage systems for further investigation and (2) identify documented effective solutions for issues experienced by Texas communities predominately reliant on artificial drainage systems. The literature review did not yield useful information for identifying artificial drainage areas in Texas, so the TWDB conducted its own analyses to locate flat, poorly drained areas in the state. Based on definitions from the bill, the analyses focused on two main factors: areas that lack topographic relief, or slope, and areas that lack naturally defined floodways.

Analysis of Areas Lacking Topographic Relief and Slope

The first factor examined was areas of Texas lacking topographic relief or slope, with an analysis conducted across the entire state to determine slope variations, as identified in Figure 1.

As a starting point, a slope of 1 percent or less was used to define flat terrain, taken from the Food and Agriculture Organization definition. However, this resulted in a classification that encompassed too much of the state's land area making it difficult to pinpoint specific areas of concern.

Several alternative thresholds were evaluated, with the TWDB ultimately opting to use 0.3 percent. This 0.3 percent threshold is derived from the Texas Department of Transportation Hydraulic Manual, where it is the cutoff indicating when a low slope adjustment may be necessary in a specific calculation. Although this number does not correlate directly with the study's definitions, its relevance in existing guidelines, particularly Texas guidelines, made it a suitable choice. Thus, the analysis concluded with the selection of 0.3 percent as the refined threshold, the results of which are shown in Figure 2.

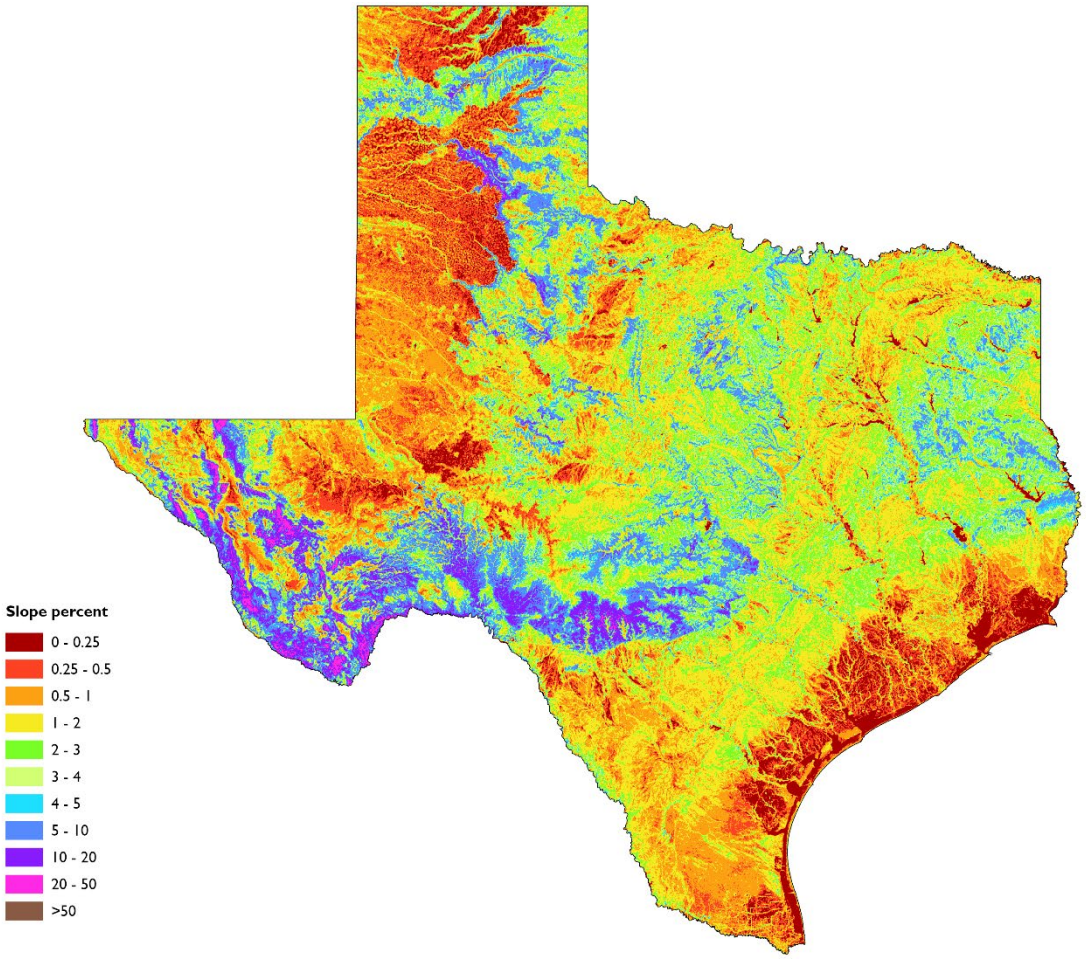

Figure 1. Topographic relief classification of Texas based on percent slope. The red colors, which represent a significant portion of the state, indicate a shallow slope (≤1 percent), whereas the purple color indicates a higher slope.

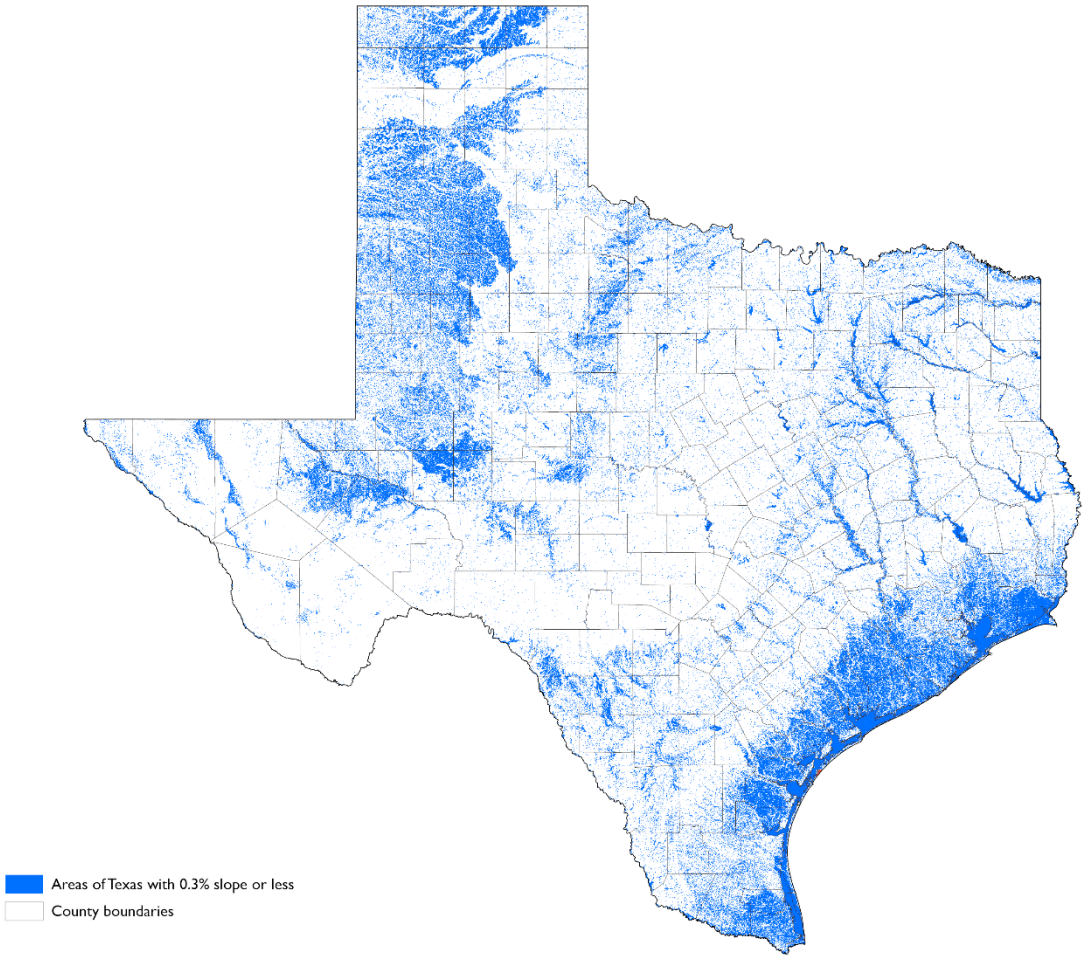

Figure 2. Area of Texas with 0.3 percent slope or less.

Analysis of Areas Lacking Naturally Defined Floodways

The second factor examined was areas in Texas lacking naturally defined floodways, or natural drainage features. This involved determining the drainage density across Texas by calculating the number of stream miles (based on the National Hydrology Dataset) per square mile, as shown in Figure 3. The analysis indicated that a threshold of 1 acre of stream mile per square mile or less served as an effective cutoff for identifying areas lacking defined floodways.

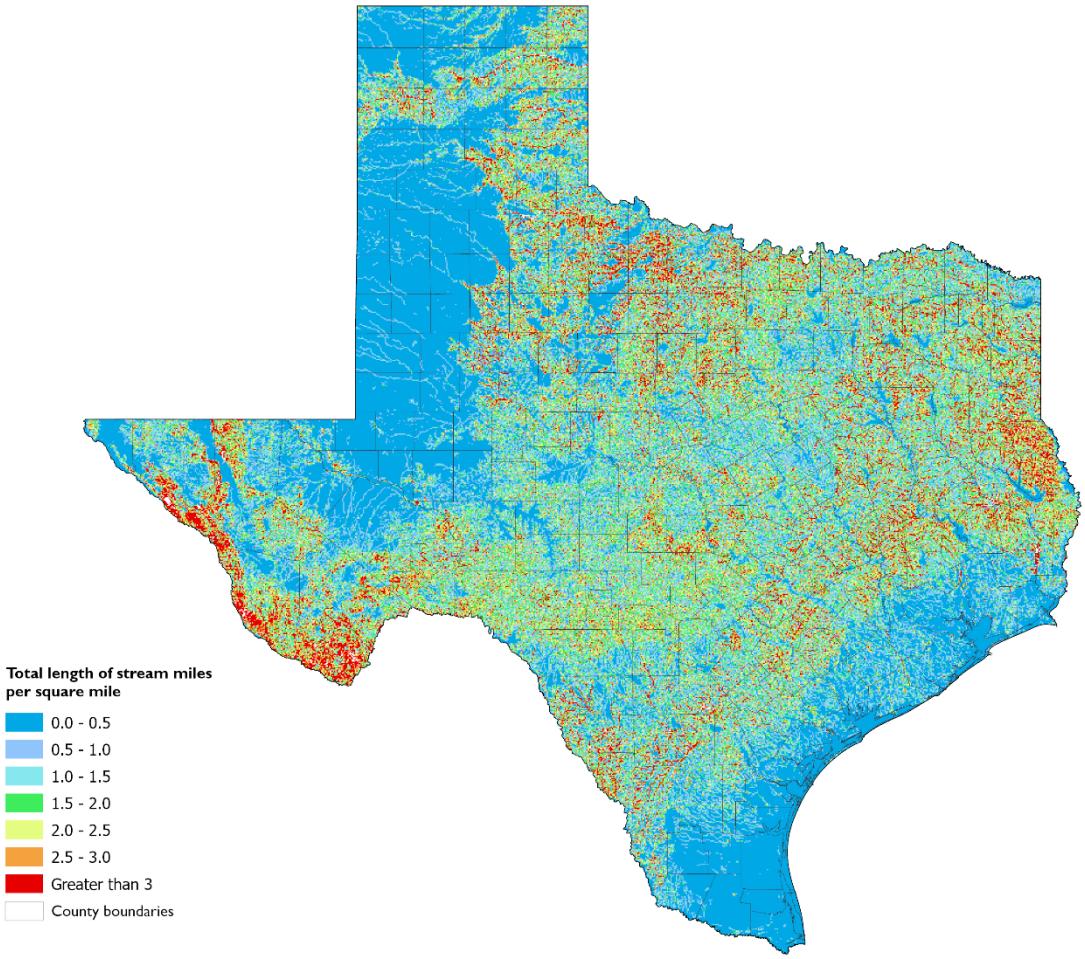

Figure 3. Map with hydro density in stream miles per square mile. Dark blue indicates a region with low stream density, whereas red indicates an area with high stream density.

Combination of Analyses

The two datasets previously identified were spatially combined to identify areas of Texas that are both lacking natural topographic relief or slope and lacking naturally defined floodways. This combination provided clarity on which Texas regions the TWDB should further investigate through discussions with communities that likely rely on artificial drainage systems to manage their floodwater, in line with the TWDB's directive to study issues faced by communities with artificial drainage systems, as per HB 4742.

Figure 4 illustrates the identified areas from areas that meet these criteria; however, they may not represent all areas of Texas experiencing artificial drainage challenges.

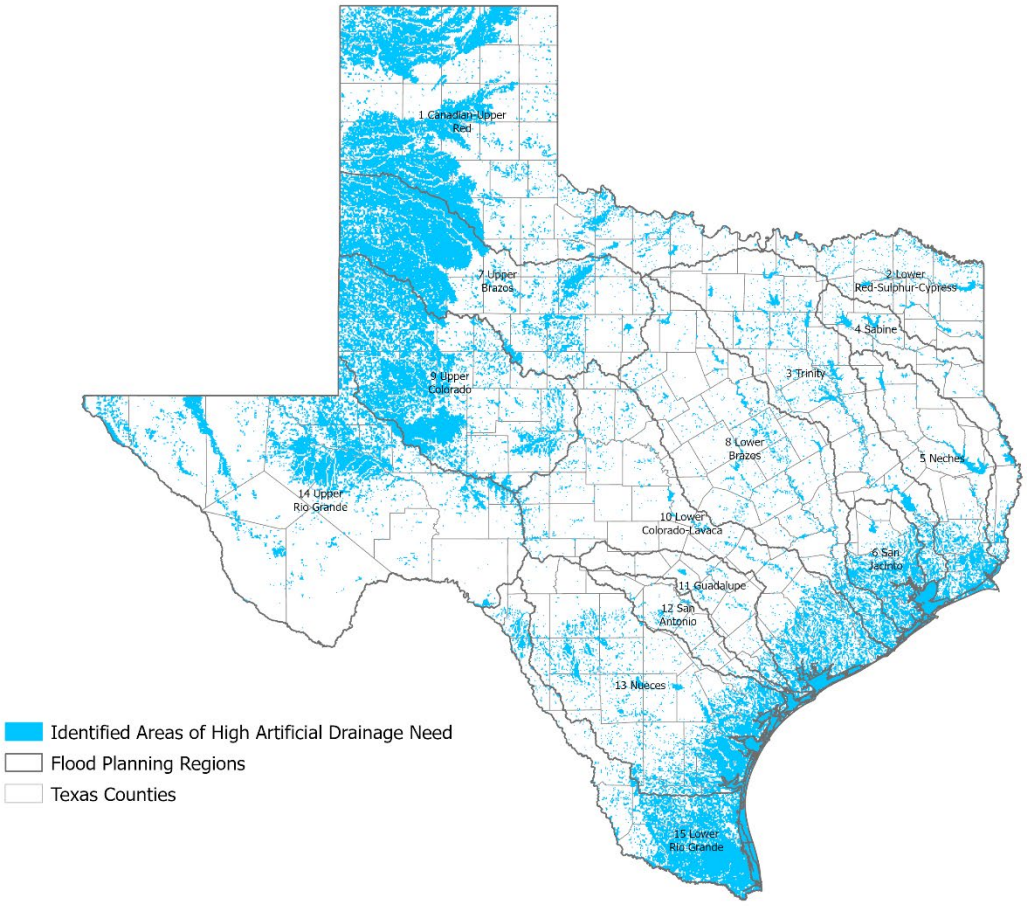

Figure 4. Areas identified as having high artificial drainage need (blue areas) overlayed by regional flood planning group boundaries.

Part II. Community Outreach Results

The results of the prior analyses identified areas in Texas lacking natural topographic relief, slope, and naturally defined floodways. To better understand drainage issues experienced by communities within these areas and to identify potential solutions, the TWDB contacted the regional flood planning groups and requested that they provide three contacts within the identified areas to interview. The TWDB then reached out to the contacts and conducted two virtual interviews to discuss drainage issues and potential solutions in these regions (see Appendix C, Interview Notes July Option 1 and July Option 2). Additionally, the TWDB conducted a focused interview with key stakeholders in the Rio Grande Valley (see Appendix C, Interview Notes Cameron County).

In addition to the roundtable interviews, a written survey consisting of 12 questions (Appendix B) was distributed to each interview invitee.

The results of these outreach efforts, including quoted examples from interviews, are presented in the following sections organized by (1) Challenges Faced and (2) Effective Solutions Identified by Communities. For a comprehensive overview of the feedback gathered, please refer to Appendix C. The following sections are taken specifically from community interview comments. In some cases, there is a specific reference, and in more general cases, the reference was left out.

Challenges Reported Through Community Interviews

Note that communities interviewed within the targeted areas lacking natural topographic relief, slope, and naturally defined floodways reported many important flood infrastructure-related issues that were not relevant only to areas with little natural slope but that impact other areas of the state that have greater natural topographic relief. These issues can have the effect of compounding and amplifying the problems that are directly associated with a lack topographic relief, slope, and naturally defined floodways.

Natural, Topographical, and Hydrologic Challenges

Flat Terrain

Communities that face extremely flat terrain will have impeded stormwater flow, leading to prolonged flooding and several issues. This includes slow water movement and high flood risk. The low slope causes low velocities resulting in water accumulating and remaining for long periods. Moreover, high intensity storms further exacerbate the flooding problem in flat areas. The flat terrain necessitates the construction of large, shallow artificial drainage systems for effective conveyance and detention of floodwater, which results in increased property acquisition, right-of-way costs, and higher maintenance costs due to pumping requirements.

Lack of Naturally Defined Floodways

The flat terrain and low density of natural relief create significant challenges for stormwater drainage. The substantial distance to natural drainage systems delays stormwater removal and heightens flood risk, causing reliance on artificial drainage systems to transport water over long

distances to reach a natural relief system. These artificial drainage systems require substantial right-of-way and ongoing maintenance, making the systems both difficult and expensive to implement and maintain (Regional Flood Planning Group 15, Interview Notes: Cameron County, Appendix C).

Soil Characteristics

Heavy clay soils are prevalent in some areas, contributing to poor infiltration and further exacerbating flooding. This soil type is often characterized by low permeability, leading to water pooling and extended flood durations.

Natural Detention Recovery

Efforts to restore the detention capacity of areas whose natural depressions have been filled. An example includes playa lakes, common to the Texas Panhandle.

Coastal Community Challenges

In low-lying, low-slope coastal communities, storm surges create high tides that push water in the opposite direction of drainage ditches, leaving no effective outlet for the water to flow out. This results in increased flood risk and land deformation. High tides and reverse water flow from storm surge hinder effective drainage, contributing to more severe flooding conditions.

Coastal communities are also affected by subsidence, which can lead to increased flooding in areas that might otherwise remain unaffected, or intensify flooding in regions already susceptible to it, particularly as sea levels rise along the coast (T. Pruski, Regional Flood Planning Group 13, Interview Notes: July Option 2, Appendix C).

Infrastructure and Maintenance Issues

Outdated, Undersized, or Lack of Infrastructure

Many existing drainage systems were designed prior to current regulations, resulting in infrastructure that is often undersized or outdated. Moreover, in numerous areas, essential drainage infrastructure is entirely absent, further worsening flooding concerns. Key issues identified include inadequate conveyance capacity, unmet maintenance needs, and fragmented detention strategies.

Conveyance systems, such as roadside ditches and storm sewer networks, struggle to manage current rainfall volumes effectively. Additionally, many systems were built without established maintenance plans or funding, leading to issues like clogging and diminished performance. Developments frequently implement detention solutions that lack proper maintenance strategies, resulting in small detention ponds that are often neglected over time (Regional Flood Planning Group 15, Interview Notes: Cameron County; E. Burden, Regional Flood Planning Group 6, Interview Notes: July Option 2, Appendix C).

Maintenance Challenges

Several maintenance challenges affect artificial drainage systems, including silt accumulation, restricted access, and lack of funding. Due to the low slopes and therefore relatively low flow velocities, channels and ditches often accumulate silt, reducing conveyance. Infrastructure near power lines and other obstructions complicates maintenance through restricted access.

Communities struggle to secure funding for the upkeep of their existing infrastructure, which leads to ineffective structures or failed systems.

Structural Damage on Existing Artificial Drainage Systems

Pumping water over levees, particularly in regions where federal regulations restrict natural flow, can lead to structural damage of the levees. One community identified challenges with the federal government's intent to keep the national border, the Rio Grande, in place and not shift. To accomplish this, manmade floodways to maintain border placement and levees are built, which act as dams that accumulate water and require pumping for water removal.

Damage from pumping requires frequent repairs, which complicates maintenance efforts and increases costs. The reliance on pumping systems to manage floodwater often strains the levees and associated infrastructure. In areas with flat terrain and extensive manmade drainage systems, pumps are essential but can exacerbate issues by overloading levees and often cause damage to levees (A. Sanchez, Regional Flood Planning Group 15, Interview Notes: July Option 1, Appendix C).

Funding and Financial Challenges

Higher Project Costs Due to Natural, Topographical, and Hydrologic Challenges

The need for large, shallow drainage systems results in a need for higher construction costs, larger drainage easement or right-of-way and ongoing maintenance costs. Areas with less natural slope may require wider channels to drain away the same volume of water that, in areas of greater slope, could be accomplished with smaller sized drainage channels. Additionally, prices can increase significantly between the scoping and bidding phases, often leading to underfunding. Rising land values and competition with revenue-generating development make it challenging and politically sensitive to acquire land for drainage purposes (G. Dagnino, Regional Flood Planning Group 14, Interview Notes: July Option 1, Appendix C).

Funding Constraints: High Community Match Requirements

Some projects may qualify for funding but for loan and/or grant terms that are insufficient for communities to be able to implement them. Specifically, with grant application requirements, communities expressed concern with using the Annual Mean Household Income instead of the Social Vulnerability Index in the Flood Intended Use Plan for determining Flood Infrastructure Fund grant ratios (Regional Flood Planning Group 15, Interview Notes: Cameron County, Appendix C). [1] Funding Constraints: Project Type Restrictions

Much of the existing infrastructure was built before modern drainage regulations, making improvements and maintenance costly and difficult. Entities have started exploring grant funding, but there is no funding available for ongoing maintenance costs.

---

[1] Several regional flood planning groups identified this issue in their 2023 regional flood plans. The TWDB included regional flood planning group policy recommendation 2.2.1, "Consider providing counties with authority to establish and collect drainage fees, at their own discretion, in unincorporated areas," in the 2024 State Flood Plan as one regional flood planning groupsconsidered necessary to facilitate floodplain management and flood mitigation planning and mitigation.

Funding Constraints: Benefit-Cost Ratio

Due to the flatness and distance to relief channels in these areas, projects are often large and expensive to build. This can lead to a lower benefit-cost ratio and may affect funding applications and opportunities.

Regulatory and Environmental Hurdles

Environmental Permitting Delays

Environmental permitting, especially under the Clean Water Act's Section 404 program administered by the U.S. Army Corps of Engineers, often takes a long time—requiring a long lead time for drainage projects and increases costs, partly due to the time required. Projects can be delayed for years due to this issue, and the stakeholders reported that the associated requirements are sometimes unclear.

Limited Authority of Drainage Districts

Drainage districts and irrigation districts have limited authority over construction and land use regulations. These entities are responsible for maintaining drainage systems but reported a lack of legal authority to review property plats, influence building permits, or impact construction practices. Because of this restriction they reported that they cannot affect how new developments are built or managed. For example, Cameron County Drainage District No. 5 expressed that they are "tasked with maintaining drainage systems but do not have [the] authority to affect how things get built" (Regional Flood Planning Group 15, Interview Notes: Cameron County, Appendix C).

Inconsistent Regulations Between Neighboring Communities

Differing regulations between neighboring communities can lead to significant impacts on drainage and development projects. Inconsistencies in regulatory standards often result in negative consequences for adjacent areas (E. Burden, Regional Flood Planning Group 6, Interview Notes: July Option 2, Appendix C).

Complexities Due to Multiple Drainage Authorities

With overlapping authorities, multiple drainage districts and authorities in some regions create confusion and inefficiencies in managing drainage projects and policies. The presence of numerous agencies with overlapping responsibilities complicates coordination and decision-making, leading to potential conflicts and ineffective flood management solutions.

Modeling Issues

A lack of regional integration can result in fragmented solutions that fail to address the broader, interconnected nature of flood risks. Federal Emergency Management Agency flood maps are often outdated and do not accurately reflect current flood risks. As a result, the 100-year

floodplain shown on these maps may no longer represent actual flood conditions, leading to regulatory and planning challenges.[2]

For artificial drainage modeling, the flat topography and extensive manmade drainage systems create challenges for accurate flood modeling. This makes it difficult to predict and manage flood events effectively.

Many existing flood models are localized and do not account for regional interdependencies and cumulative impacts. These models may overlook how upstream and downstream conditions affect flood risks across different areas, leading to incomplete or ineffective flood management strategies.

Atlas 14 and 15 Concerns

Atlas 14 has developed increased 100-year peak rainfall estimates by 3–4 inches in parts of Texas, creating new challenges for drainage system design and capacity. Atlas 15 is currently in development by the National Weather Service, and communities are concerned that the updated rainfall estimates will indicate that their drainage systems are even more inadequate. The updated estimates may lead to undersized infrastructure that cannot handle the higher rainfall, requiring costly upgrades to existing systems (T. Buscha, Regional Flood Planning Group 6, Interview Notes: July Option 1, Appendix C; E. Burden, Regional Flood Planning Group 6, Interview Notes: July Option 2, Appendix C).

Effective Solutions Reported Through Community Interviews

Note that these are not TWDB solutions but, rather, those that were provided by communities interviewed within the targeted areas lacking natural topographic relief. These communities reported many solutions to their flood concerns that were not only relevant to areas with little natural slope but that impact other areas of the state that have greater natural topographic relief.

Natural, Topographical and Hydrologic Solutions

Artificial Drainage Projects

Communities expressed that artificial drainage projects, such as increased conveyance and regional detention, are essential for managing floodwater and addressing their drainage challenges. These measures are viewed as the primary solution for their drainage problems (Regional Flood Planning Group 15, Interview Notes: Cameron County).[3]

Utilizing and/or Restoring Existing Natural Features

Incorporating natural features, such as resaca systems, which are typically dry or marshy oxbow features and oxbow lakes, into drainage strategies has proven beneficial. For example, cleaning

---

[2] The 2024 State Flood Plan includes TWDB policy recommendation 2.1.1 asking the Texas Legislature to consider allocating funding for flood risk modeling and mapping to support ongoing flood mitigation efforts.

[3] Recommendation 2.1.1 from the 2024 State Flood Plan recommends dedicated funding for ongoing flood mitigation efforts, including flood mitigation projects to address community drainage needs.

and repurposing oxbow and playa lakes as detention facilities can help manage excess water and reduce flooding.

Coordination with Property Owners to Utilize Existing Features
Working with property owners to manage water flow through existing systems, such as resaca systems, has proven effective. Incentives and conservation easements can facilitate cooperation and improve drainage outcomes.

Infrastructure and Maintenance

Regional Detention Facilities
Creating and maintaining large regional detention ponds has been effective in managing floodwaters by providing adequate storage capacity and reducing downstream flooding. Regional detention is preferred over piecemeal solutions for its efficiency in large-scale flood management. In addition to increased effectiveness, maintenance of regional detention facilities is also much easier than maintenance of many small detention facilities. Developers can utilize this regional detention instead of building their own (Regional Flood Planning Group 15, Interview Notes: Cameron County; E. Burden, Regional Flood Planning Group 6, Interview Notes: July Option 2, Appendix C).

Conveyance Infrastructure
Enhancing and maintaining conveyance, particularly in areas that do not have a nearby stream and rely on artificial drainage for conveyance needs, has been a practical solution for managing stormwater. Sometimes this means building new channels in wide, poorly drained expanses between sparsely located natural channels, and sometimes it means repairing existing channels. Ensuring these are kept clear of silt and debris helps maintain their effectiveness, as small detention ponds will silt up. Additionally, if feasible, armoring channels and restoring channels to their natural capacity to deliver flow to nearby streams has improved conveyance capacity. Streams are often degraded when development occurs, which leads to more stormwater in the drainage system because less is infiltrated. Stream restoration can enhance existing drainage systems' ability to handle higher volumes of water (E. Burden, Regional Flood Planning Group 6, Interview Notes: July Option 2, Appendix C).

Regulatory and Environmental

Floodplain Management
Floodplain management is key to reducing flood risk. Cities and counties can enforce this within their limited authority, but some drainage districts expressed that they do not have but need this authority to reduce flood risk.

Regional Models
Regional models to create a comprehensive approach to flood management have been effective in addressing drainage issues. Regional modeling allows for more holistic solutions that consider the interconnected nature of drainage systems. Additionally, it can help guide the development of floodplain regulations.

Engaging with Local Agencies

Collaboration between different local agencies, including drainage districts and municipalities, helps address overlapping responsibilities and improves the efficiency of drainage solutions.

Part III: Recommendations and Conclusions

Based on the literature review, geographic analyses and the problems and potential solutions reported to the TWDB as part of its outreach to communities experiencing challenges with artificial drainage systems, potential recommendations were developed. This section summarizes TWDB's recommendations to potentially address the identified issues, incorporating effective solutions that have been successfully implemented by these communities.

TWDB Recommendations: Consideration of the Following Potential Actions

There are several recommendations in the 2024 State Flood Plan that align with the recommendations made in this report and may help address some of the issues identified by communities all over Texas, including but not limited to communities who lack natural topographic relief, slope, and naturally defined floodways. Specific recommendations identified through this study are shown below.

1. Study key cost-drivers of developing flood infrastructure

A study could identify all the main factors that impact the cost of developing drainage infrastructure in Texas based on all relevant factors, including, but not limited to, the relative flatness and distance to natural drainage. This information could be used to develop a drainage infrastructure cost ”heat map” of Texas. Such a study should expand on factors in this study and identify and consider every key cost-driver, including, but not limited, to the local rainfall intensity, urban construction environments, land cost, and existing/conflicting infrastructure, etc. This map could visually represent the variation in relative costs of implementing drainage systems across Texas. It should be noted that this study did not have the resources to include every factor or quantify their impact on costs of flood infrastructure.

2. Continue to Fund Regional Models

The effectiveness of regional models for flood management was emphasized repeatedly during the interviews. It is recommended to maintain funding for regional models and studies to account for the interconnected nature of drainage systems and develop comprehensive solutions. Initiatives that are currently providing funding for regional models include, but are not limited, to flood-related programs at the TWDB, Texas General Land Office, and U.S. Army Corps of Engineers.

3. Encourage Regulatory Consistency

Having consistent floodplain regulations, especially at the local level and across watersheds, would help ensure more uniform drainage and flood management practices. Consistency across and within overlapping or adjacent jurisdictions would better mitigate flood risks and avoid conflicting requirements between neighboring areas. This could include drainage criteria manual templates that are optional for use but at least serve as a common starting point.

Conclusion

This study provides insights into some of the many challenges faced by communities that rely on artificial drainage systems to remove floodwater. It highlights several key issues encountered by these communities and solutions that communities reported as being effective at alleviating some of the reported problems. Notably, a number of the reported challenges and solutions appear to be addressed directly or indirectly by some of the recommendations already included in the adopted 2024 State Flood Plan, underscoring the relevance and importance of these prior recommendations in addressing flood infrastructure concerns.

Although this report provides additional insight into issues faced by certain communities with little natural topography, these are limited conclusions that may be drawn about the relative difficulties or cost of providing drainage in different areas across Texas. This is due to the subjective nature of the information gathered from the stakeholders, the simplified nature of the analysis, and the limited range of potential factors impacting flood mitigation that were evaluated. Areas lacking topographic relief, slope, and naturally defined floodways experience drainage challenges and may face higher costs of certain infrastructure components compared to areas with greater natural slope or nearby floodways.

There are a variety of factors that can make providing drainage difficult and/or expensive for those responsible for providing drainage, especially in populated areas. Consequently, it is difficult to draw meaningful conclusions about where in Texas drainage infrastructure may cost more or why or how to best compare drainage costs in different locations.

References

American Association of State Highway and Transportation Officials, 2007, Highway drainage guidelines (4th ed.): Washington, DC, American Association of State Highway and Transportation Officials.

Federal Emergency Management Agency, 2020, Guidance for flood risk analysis and mapping, Guidance document 106, Federal Emergency Management Agency, December 2020.

Food and Agriculture Organization, 1985), Irrigation water management: Training manual No. 1 - Introduction to irrigation, Food and Agriculture Organization of the United Nations, 1984, available at https://www.fao.org/4/r4082e/r4082e04.htm#3.1%20slopes

Texas Department of Transportation, 2019, Hydraulic design manual, Texas Department of Transportation, September 2019.

United States Department of Agriculture, 2017, Soil survey manual, Agriculture handbook no. 18, United States Department of Agriculture, 2017, available at www.nrcs.usda.gov/sites/default/files/2022-09/The-Soil-Survey-Manual.pdf

Appendix A: Literature Review

Literature Review

At the onset of the study, the TWDB conducted a literature review[1] to (1) identify existing information on artificial drainage to help identify areas in Texas predominantly reliant on artificial drainage systems for further investigation and (2) identify documented effective solutions for issues experienced by Texas communities predominately reliant on artificial drainage systems. The TWDB focused review on various national and state engineering guidelines and technical literature. The major literature sources reviewed are summarized in Table A1.

(1) The literature was first reviewed to ensure accurate and consistent definitions of the key topics outlined in the bill. However, no universally accepted definitions emerged, particularly for areas, as stated in HB 4742, “lack[ing] topographic relief [or] slope,” or are “lacking...naturally defined floodways.” Results of the literature review highlight inconsistencies across sources. For example, “flat” terrain is generally defined as having minimal elevation variation, but the specific amounts of elevation variation differ significantly between sources.

(2) Literature review similarly did not provide a clear definition of what constitutes an artificial drainage area, making the identification of possible solutions to issues related to artificial drainage systems challenging.

Given these challenges, the TWDB moved forward with analyses to identify flat, poorly drained areas of the state, with the intent of interviewing local stakeholders for additional insights and effective solutions to issues related to reliance on artificial drainage systems. Although the literature review did not provide clear definitions, it offered several starting points for analyses, which are discussed further below.

Review Summary

The major sources reviewed for this study were those identified to be most relevant to either agricultural drainage, transportation drainage, or flooding. Findings, including how terms are defined and classified across key sources, are summarized in Table A1. The summary highlights the inconsistencies and variations encountered in the literature, underscoring the complexity of achieving a unified definition of either artificial drainage or what slopes constitute “flat” terrain.

Table A1. List of major sources reviewed

Title	Publisher name	Published date
Highway Drainage Guidance	American Association of State Highway and Transportation Officials	2007
Geometric Design of Highways and Streets-The Green Book	American Association of State Highway and Transportation Officials	2018
Irrigation Water Management: Training Manual No. 1	Food and Agriculture Organization	1985
Guidance for Flood Risk Analysis and Mapping	Federal Emergency Management Agency	2020
Soil Survey Manual. Agriculture Handbook No. 18	United States Department of Agriculture	2017
Hydraulic Design Manual	Texas Department of Transportation	2019

The **American Association of State Highway and Transportation Officials** Highway Drainage Guidelines 2007 does not include a clear definition of "artificial drainage." Rather it identifies and considers the possible effects that highway construction may have on existing drainage patterns, river characteristics, potential flood hazard and the environment. Artificial drainage is mentioned on only two occasions throughout the guidance document, specifically dealing with the legal aspects of highway drainage. The American Association of State Highway and Transportation Officials Green Book, however, separates terrain into three classifications where level terrain is classified as anything less than 5 percent slope.

The **Food and Agriculture Organization of the United Nations** classified range of slopes commonly referred to in irrigated fields where fields less than 1 percent slope are considered flat. The Food and Agriculture Organization specifically classified 0.5 percent to -1 percent as flat, 0.2 percent to 0.5 percent as very flat, and < 0.2 percent as horizontal. In its Soil Survey Manual 1984, the United States Department of Agriculture Natural Resources Conservation Service classifies slopes into six categories based on slope gradient ranges. Level/flat slope is identified as slope between 0 and 3 percent, which is considered nearly flat terrain with minimal slope, generally suitable for various land use with minimum erosion risk.

In its guidance of shallow flow analyses and mapping (2020), the **Federal Emergency Management Agency** defined shallow flooding as flooding with an average depth limited to 3.0 feet or less where no defined channel exists, typically occurring in areas of low topographic relief and poorly established drainage systems. However, no proper definition or quantification of low topographic relief is established in the manual.

According to the **United States Department of Agriculture** (2017) slope refers to the extent that a soil surface has an incline relative to the horizontal. In percentage terms, slope represents the elevation difference that occurs between two different points. In a "flat" topographic area the absence of natural drainage may require additional engineering measures to manage stormwater effectively, such as an artificial drainage mechanism.

The **Texas Department of Transportation** Hydraulic Design Manual (2019) provides procedures for analyzing and designing effective highway drainage facilities. Multiple methods

use slope as a parameter for calculating the amount of water flow. For the rational method, which is used to estimate the peak discharge of runoff from small drainage areas, slopes less than 2 percent in urban watersheds and less than 5 percent in rural watersheds are considered flat for the purpose of calculating a runoff coefficient. For time-of-concentration calculations, slopes less than 0.2 percent are considered low/flat slope and slopes between 0.2 percent and 0.3 percent are considered transitional.

Given the absence of a clear, single definition, we proceeded with a sensitivity analysis approach related to topographic relief (slope). This involved exploring various threshold values for slopes and naturally defined floodways to determine their impact on the identification of communities with artificial drainage needs. Further discussion on this sensitivity analysis is provided in Task 2 of this report.

Appendix B: Community Questionnaire

HB No. 4742, Texas Artificial Drainage Systems

Community Interview Questionnaire

1. What do you consider "flat" terrain in your area? May define in technical terms, like slope of land, or provide relative descriptors for portions of your area that are much flatter than others.
2. What are the primary challenges you encounter with flooding in your area and your drainage systems? Examples include lack of topographic relief, soil issues, and lack of nearby natural drainage system.
3. Please provide specific examples and any available data or visuals illustrating flooding issues in your area.
4. Please also describe flooding in terms of type and number of structures flooded (houses, businesses, bridges/roadways) and how many inches of rain it takes to begin flooding.
5. Describe the drainage system for your area. For example, is it primarily curb and gutter streets that drain to inlets and storm drains that deliver it to creeks and rivers? Is it bar ditches along roadsides? Is it a canal system? Is there no formal drainage system?
6. Which agencies are typically responsible for ownership and maintenance of the drainage systems? What kinds of resources do they feel they need to better manage their assets? How are they currently obtaining the resources they have?
7. What factors primarily influence the costs of your drainage systems, both installation and operations and maintenance?
8. Do you perceive your drainage system costs to be higher compared to other regions?
9. What types of drainage solutions have proven effective or beneficial in addressing flooding issues in your community?
10. In cases where resources are limited, how do you prioritize and address drainage-related issues?
11. Considering the definition provided, to what extent does your community depend on artificial drainage systems?

a. *In this bill, Artificial Drainage has been defined as "a system to remove floodwater in a community that lacks topographic, relief, slope, and naturally defined floodways."*

12. If you have any additional information or insights you would like to share regarding artificial drainage systems, flooding issues, or effective mitigation strategies in your community, please feel free to provide them below.

Appendix C: Interview Notes

HB No. 4742, Texas Artificial Drainage Systems

Community Interview – Cameron County

04/29/2024

This meeting was a targeted meeting with professionals with experience in the Cameron County area. It focuses on the challenges faced in this area. The following notes combine responses taken during the meeting with additional insights gathered from follow-up survey responses. Feedback from the survey is marked as "Written Response" for clarity.

Attendees/Contributors:

Name	RFPG	Association
Jack Brown	**RFPG 15**	**Scheible Consulting LLC**
Eric Scheible	**RFPG 15**	**Scheible Consulting LLC**
Alan Moore	**RFPG 15**	**Former CCDD5 General Manger**
Rolando Vela	**RFPG 15**	**CCDD5**
Dustin Moore	**RFPG 15**	**Moore Land Surveying LLC**

This request is pursuant to HB No. 4742, which has tasked the TWDB to:

> *"(1) study issues faced by communities with artificial drainage systems; and*
> *(2) prepare a written report that contains possible recommendations relating to addressing identified issues facing those communities."*

In this bill, Artificial Drainage has been defined as *"a system to remove floodwater in a community that lacks topographic relief, slope, and naturally defined floodways.*

1. **What are the primary challenges you encounter with flooding in your area and your drainage systems? Examples include lack of topographic relief, soil issues, and lack of nearby natural drainage system.**

   Written Response: In Cameron Co., the main drainage systems are man-made drainage canals that were constructed in the early 1900's to convey farm runoff. Prior to these channels, natural drainage would collect in low depressions as there are no natural channels or swales formed, that are typical of a natural channel in other regions of the state. There is no natural floodplain valley, and thus when a road, railroad, or canal are elevated, they create a dam, as there is

no overtopping of the structures. Large areas flood when the man-made channel capacity is exceeded and the small outlet pipe under elevated structures drain very slowly.

- Harlingen-natural stream nearby however most of Harlingen does not drain to nearby creek
- Soil types-channel lining too expensive
    - Dispersible clay, water doesn't penetrate. "Sugar cube" loses strength when water hits. Drainage banks are not stable. Backs up water all the way to Harlingen.
- Low topo relief
    - Regional detention ponds must be shallow and big. Large quantity of real estate, very expensive
    - Drainage infrastructure is all manmade, difficulties w/ channel improvements
- FEMA maps do not come close to showing true flooding issues in area
    - Cannot regulate the river because maps are not updated. E.g. issues w/ railroad
    - BLE maps are more helpful than FEMA maps, still a little off
    - Playa lakes are not Zone AE on FEMA maps

2. **Describe the drainage system for your area. For example, is it primarily curb and gutter streets that drain to inlets and storm drains that deliver it to creeks and rivers? Is it bar ditches along roadsides? Is it a canal system? Is there no formal drainage system?**
    - Man made channels to creeks, supplemented w/ detention. Channel is just 2-year or so.
        - DD3 has some natural fall, but still all manmade channels
        - Once water is out of the channel, it just sits there for days because nowhere to go (sits in flooded houses etc.)
        - IBWC controls flow into arroyo Colorado from Rio Grande River,
            - some areas are not maintained and causes water to back up
            - Prevented by a few residents who want natural growth
        - Storm Drains are designed for 2-year flow. Half of it goes to the North Main Drain, half goes to the River
3. **Which agencies are typically responsible for ownership and maintenance of the drainage systems? What kinds of resources do they feel they need to better manage their assets? How are they currently obtaining the resources they have?**

    Written Response: Drainage Districts are the primary agency responsible for maintaining the open man-made ditches in Cameron Co. Cities are primarily responsible for stormsewer drainage. Drainage Districts are limited to bonding capacity and local tax revenue. In the poor areas of Cameron Co. there is a limit to how far funds can go. Outside State and Federal dollars are needed to meet the drainage needs of Cameron Co.
    - State Funding is Essential, because communities cannot increase tax rate. In order to make drainage improvements, they must apply for funding.

        - Funding Concerns: FIF grant ratio
        - is based on Annual Median Household Income, which gives them a high ratio they are responsible for. They believe SVI would be a better approach to give fair ratios.
            - Cameron County is one of lowest income areas in country, but not hitting lowest target level for highest match. ***Why***?
        - Because they do not get a high percentage, they are unable to pay for their portion of the grant because there are no available funds. They are maxed out on grants they can apply for because no more funds.

4. **What factors primarily influence the costs of your drainage systems, both installation and operations and maintenance?**

    Written Response: It is very costly to move water in Cameron Co. compared to other parts of the State due to the very flat terrain and lack of natural floodplain valleys. When flood water exceeds the capacity of a drainage channel, it just sits for days until it slowly drains.

    - Installation – cost is so high because improvements have to be carried such a long way due to low slope and length to receiving stream. No “pinch points,” the whole drain is the pinch point. ROW is also costly because the systems are so long.
    - Operations &Management: don’t want to create a channel that is so wide they cannot maintain
        - Catch 22, don’t want it to be so big you can’t maintain. Limitations on effectiveness
    - Power companies put transmission lines next to drainage. Restricts ROW amount and issues maintaining (powerline must be shut down to clean drain).
    - Need land for detention pond-competing against developers.
        - Most of cost is excavation
    - Loss of Natural Detention: Natural ponds have been covered up by development
        - Having to create detention ponds to mitigate problems from covering natural detention ponds
        - No FEMA flood map, so the Playa Lakes are hard to regulate

5. **Do you perceive your drainage system costs to be higher compared to other regions?**
    - Yes
6. **What types of drainage solutions have proven effective or beneficial in addressing flooding issues in your community?**
    - Creation of Cameron County DD5 after a severe flood in 1990. North Main is now maintained by DD5 instead of Irrigation district.
    - Construction of regional detention facilities is about all that’s left to help the community.
        - Some counties prefer conveyance over detention, but it’s hard to get ROW to do conveyance
        - Concrete lining
        - Widening channel

        - *Note, TWDB brought up concerns about draining extra water into receiving stream. Response:* Not an issue discharging extra water to river
    - Hildago County can release water into the arroyo, negatively affects Harlingen
7. **In cases where resources are limited, how do you prioritize and address drainage-related issues?**

    Written Response: Prioritization is typically based on what the District can afford, coupled with whether additional outside funding is available
8. **Considering the definition provided, to what extent does your community depend on artificial drainage systems?**

    Written Response: CCDD5 depends fully on artificial drainage systems. Artificial drainage channels lacking a natural floodplain valley and floodway are the only drainage system used in CCDD5, as all of the open channels were constructed through flat farmland and had no natural drainage path.
- *In this bill, Artificial Drainage has been defined as "a system to remove floodwater in a community that lacks topographic, relief, slope, and naturally defined floodways."*
9. **If you have any additional information or insights you would like to share regarding artificial drainage systems, flooding issues, or effective mitigation strategies in your community, please feel free to provide them below.**
    - **DD5** invites TWDB!
    - Eric Scheibe was involved in leg hearings/discussions
        - Challenge- everyone has "artificial drainage," but there is specific hardships in these areas. There is no natural conveyance, *everything* is manmade

Summary of issues/solutions/call

1. Can't take care of issues of just one location, as there will then be downstream effects
    a. Therefore, solutions need to be regional and connected
2. Regional issues, synthesize all the models
3. Improved conveyance and regional detention are main ways to solve drainage
    a. Because everything is manmade and flat, regional detention is not as effective.
        i. If money was no issue, communities would add more conveyance and more detention
        ii. Public education
            1. Raising homes is not viable as DD cannot regulate building codes. Cities can do this.
                a. Going forward this is an option. For existing structures, some buyouts.
                b. Cities and Counties need to enforce, flood maps are not accurate. BLE is being used by those who know, but not enforced.
                c. *No leg authority for DD to review property plats*
                    i. Applies to irrigation districts too
                    ii. Building permit process does not include DDs or irrigation districts

            iii. Tasked w/ maintaining drainage systems but don't have authority to affect how things get built
                1. Leg authority for DDs?
4. Need real estate and excavation for detention, which requires allocated funds for that.
5. SVI would be helpful for funding.
    a. Attempt to better address funding ratios.
6. Not a peak flow issue, but a volume issue. Volume management – V is very high, water inundation comes from multiple surrounding counties.

HB No. 4742, Texas Artificial Drainage Systems

Community Interview – July Option 1

7/17/2024

This meeting included contacts provided by the Regional Flood Planning Groups for the areas identified in Figure 4.

Attendees/Contributors*:

Name	RFPG	Association
Tim Buscha	RFPG 6	IDS Engineering Group
Gisela Dagnino	RFPG 14	El Paso Water
Cindy Engelhardt	Multiple (Consultant)	Halff
David Garza	RFPG 15	Cameron County
Mark Howard	RFPG 4	Sabine River Authority
Dawn Piltcher	Multiple (Consultant)	Tidewater Professional Services LLC
Travis Pruski	RFPG 13	Nueces River Authority
Augusto Sanchez	RFPG 15	Cameron County
Kyle Schniederjan	RFPG 1	City of Amarillo

This request is pursuant to HB No. 4742, which has tasked the TWDB to:

> *"(1) study issues faced by communities with artificial drainage systems; and*
> *(2) prepare a written report that contains possible recommendations relating to addressing identified issues facing those communities."*

In this bill, Artificial Drainage has been defined as *"a system to remove floodwater in a community that lacks topographic relief, slope, and naturally defined floodways.*

1. **What are the primary challenges you encounter with flooding in your area and your drainage systems? Examples include lack of topographic relief, soil issues, and lack of nearby natural drainage system.**

- K. Schniederjan, RFPG 1, City of Amarillo
    - Playa lakes, all AE.
        - 100-year boundary consistently exceeded. Someone is being flooded *annually*
        - No exit, water stays for 60-90 days
        - Rules /regulations don't protect for this condition

                - City rules higher than NFIP, but limit (especially on development side). Higher requirements don't meet "proportionality requirements"
        - 85/90% of emergency response and flooding calls are outside 100-year boundary. Lacking natural river/creek, water drains to playa lakes. The topography is flat, can't daylight pipes, streets become "rivers". Since outside of 100-year floodplain, difficult to write policy to make developer fix these things.
            - Fix would be to require detention inside existing playa lake, extremely hard to enforce
- A. Sanchez, RFGP 15, Cameron County
    - Region deals with very flat terrain, silt from coast, and infiltration is not good
        - Entire drainage system is manmade to drain to Colorado River
        - Hard to get ROW to expand ditches
        - 6 drainage districts, also many municipalities. Overlapping authorities make it difficult to manage the region. No real "head"
        - Federal govt-does not want Rio Grande to shift from its place. Built floodways to maintain border placement, levees and act as dams. Have to pump water over dams. Authority is limited
            - Pumping often causes damage to levees, then has to be fixed
    - Models are difficult due to topography
        - Natural levees in some fanned-out rivers (where river used to flow)
            - Complications when it comes to modeling
- T. Buscha, RFPG 6, IDS Engineering Group
    - A lot of manmade drainage, everything needs to be improved
        - Subsidence
        - Atlas 14 increased peak rainfall estimates by 3-4 inches

2. **Describe the drainage system for your area. For example, is it primarily curb and gutter streets that drain to inlets and storm drains that deliver it to creeks and rivers? Is it bar ditches along roadsides? Is it a canal system? Is there no formal drainage system?**

- T. Pruski, RFPG 13, Nueces River Authority
    - Mostly bar ditches. Bar ditches are silted in
        - Drain to major rivers nearby
        - Existing Bar ditches silted in
- T. Buscha, RFPG 6, IDS Engineering Group
    - Most drainage in state is rural w/ exception of urban areas
        - Rural areas dealing w/ inadequate drainage systems
            - Drainage ditches
            - Roadside bar ditch
- K. Schniederjan, RFPG 1, City of Amarillo
    - Most rural areas w/ bar ditch
    - No financial mechanism
        - No utility fees
        - Only way to fund is property taxes

3. **What factors primarily influence the costs of your drainage systems, both installation and operations and maintenance?**

- T. Pruski, RFPG 13, Nueces River Authority
    - Lacking drainage districts, so no funding for projects
- A. Sanchez, RFPG 15, Cameron County
    - ROW (Right Of Way) for expansion of waterways costly
    - Not necessarily cost of land, but cost to get land from citizens. Try to avoid using eminent domain
- G. Dagnino, RFPG 14, El Paso Water
    - Utility relocations because already urbanized
    - Large expensive projects
    - Lack of contractors
        - Drive cost up
    - Also ROW, project delay (which drives up cost)
        - Don't just use appraised value

4. **What types of drainage solutions have proven effective or beneficial in addressing flooding issues in your community?**

- T. Pruski, RFPG 13, Nueces River Authority
    - One specific Countywide DD, success story
        - Leaders in drainage, collect property taxes to move projects forward, collect FIF grants, etc.
- K. Schniederjan, RFPG 1, City of Amarillo
    - Success with improving playa systems, using tax dollars on excavating
        - Then development will pay for development
- A. Sanchez, RFPG 15, Cameron County
    - Working with existing natural features that they already have to utilize natural drainage pathways
    - Success story: working w/ property owners
        - Incentives for property owners to work w/ drainage
        - Resaca systems, Natural levee depressions
            - Work w/ property owners to convey water through existing resaca systems. Instead of getting ROW, property owners got conservation easements *tax break*, relieves flooding
        - Oxbow lake, dried
            - Clean up Oxbow Lake, make it a detention facility, connect it to drainage lateral.

5. **Considering the definition provided, to what extent does your community depend on artificial drainage systems?**

- A. Sanchez, RFPG 15, Cameron County
    - 60/70% of Cameron County drains through artificial ditches

HB No. 4742, Texas Artificial Drainage Systems

Community Interview – July Option 2

7/23/2024

This meeting included contacts provided by the Regional Flood Planning Groups for the areas identified in Figure 4.

Attendees/Contributors:

Name	Organization	Association
Erwin Burden	**RFPG 6**	**Harris County**
Doug Canant	**RFPG 5**	**DD6**
Patrick Frerich	**RFPG 9**	**City of San Angelo**
Travis Pruski	**RFPG 13**	**Nueces County**
Allen Sims	**RFPG 5**	**Port Arthur**
Michael Shannon	**RFPG 6**	**Galveston County**
Mark Vogler	**RFPG 6**	**Fort Bend County**
Allen Sims	**RFPG 10**	**Jefferson County Drainage District**
Dawn Piltcher	**Multiple (Consultant)**	**Tidewater Professional Services LLC**

This request is pursuant to HB No. 4742, which has tasked the TWDB to:

> *"(1) study issues faced by communities with artificial drainage systems; and*
> *(2) prepare a written report that contains possible recommendations relating to addressing identified issues facing those communities."*

In this bill, Artificial Drainage has been defined as *"a system to remove floodwater in a community that lacks topographic relief, slope, and naturally defined floodways.*

1. **What are the primary challenges you encounter with flooding in your area and your drainage systems? Examples include lack of topographic relief, soil issues, and lack of nearby natural drainage system.**

- D. Canant, RFPG 5, DD6
    - 25-5 elevation, very little fall
    - Will not runoff faster than rainfall
        - Channels/detention, etc. fills up extremely quickly. Impossible task w/ rain intensities
        - Never enough when it comes to drainage

        - Slope is so small, velocities are extremely slow
- T. Pruski, RFPG 13, Nueces County
    - Same issues as above
    - 2 additional: farmland-drainage ditches get silted in
    - Storm surge often pushes water in opposite direction of ditches, so no place for water to flow out
- M. Shannon, RFPG 6, Galveston
    - Ditto lack of topo relief
    - County was platted w/ no infrastructure. Now being built on. Road ditches not maintained by county. High tides inundating roads
    - Elevated irrigation canals, impede rainfall runoffs
    - Gulf of Mexico –high tides go over state highway 87
    - Undeveloped areas act like detention ponds, when they do become developed, lack of regulations and lack of understanding how existing conditions retain water, runoff is much greater than models anticipate
- M. Vogler, RFPG 6, Fort Bend County
    - Flat slopes
    - Ponding in rural areas
    - Developers have to come in w/ master drainage plan (if over 50 acres)
        - Provide some level of detention
        - Provide storage for areas built over
        - Conveyance, must provide conveyance if taken away from a stream
- P. Frerich, RFPG 9, City of San Angelo
    - Battle w/ developers
        - Models are not representative of actual runoff
        - Wanting to put small ponds that are ineffective
        - Maintenance long term is an issue
            - (no funds for city to take it over)
    - Flat, arid
    - Arroyo thru middle of town
        - Doesn't flow amount of water that comes thru it, improvement needed
        - Permitting not allowing improvement
            - 404 permit
- M. Shannon, RFPG 6, Galveston/ M. Vogler, RFPG 6, Fort Bend County
    - Developer model issues
        - Developers don't understand that there is natural detention in undeveloped property, difficult to address in a computer model
        - Infiltration is taken away
- E. Burden, RFPG 6, Harris County
    - Intensity of storms today, much more intense than they used to be
        - E.g. 7 in /2hrs
    - Floodplains weren’t mapped until 70s, lots of people in floodplains, no detention, etc., criteria outdated
    - Regional detention works, must be staged w/ development

        - Difficult
        - Maintenance issue long term is difficult
        - Small detention ponds will silt up, very little regulation for long term ownership
        - Retrofitting old subdivisions to current regulations because cheaper than buyouts
            - Not cheap
            - Requires federal assistance

2. **Describe the drainage system for your area. For example, is it primarily curb and gutter streets that drain to inlets and storm drains that deliver it to creeks and rivers? Is it bar ditches along roadsides? Is it a canal system? Is there no formal drainage system?**

- M. Shannon, RFPG 6, Galveston
    - Unicorp, roadside ditches then to drainage district ditch, to Galveston Bay
    - Pump over levees, storm pump stations
- A. Sims, RFPG 5, Port Arthur
    - Similar to Galveston
    - 50% road ditches, 50% curb and gutter
        - 80% pumped out
        - Dumps over levee
- E. Burden, RFPG 6, Harris County
    - Receiving water from somewhere
        - Regulations between counties
            - Need consistency between county to county
            - Harris receives lots of water from upstream from areas w/ less regulatory standards
        - Orange county told story about Harvey flooding twice, once due to Harvey, once due to downstream effects

3. **What factors primarily influence the costs of your drainage systems, both installation and operations and maintenance?**

- A. Sims, RFPG 5, Port Arthur
    - Pumping water out- DD7
- P. Frerich, RFPG 9, San Angelo
    - Location relative to existing development (vs greenfield development)
- M. Shannon, RFPG 6, Galveston
    - Cost of land, cost of easement aq, cost of materials/labor, cost of wetland permitting and mitigation (kills projects where $ has already been spent, no published policy on regulation required/what to expect in terms of mitigation)
        - Even roadside ditch in 1978 can be considered a wetland, keeps from piping
        - Ditto-from Alan at DD7
        - Regulations change because of lawsuits (in theory) but district office doesn't change policy

                - Harris County-referenced case of lawsuit but corps waiting on appeal, so law hasn't actually changed
                - Wetland mitigation is HUGE cost
                    - Finding land
                    - Creating the project
                    - Encumbering land, maintaining it
- Dawn Piltcher, Consultant, Tidewater Professional Services LLC
    - Ditto corps/wetlands
        - Getting funding from Federal Projects, these have timelines
            - If you don't execute w/in certain amount of time, lose funding
            - Endangered species as well
        - E.g. took 6 years to renew a permit that's only good for 5 years
        - Must have permitted project before they can even apply for a grant

4. **What types of drainage solutions have proven effective or beneficial in addressing flooding issues in your community?**

- M. Vogler, RFPG 6, Fort Bend County
    - Updating master drainage plan
        - Consultants figuring out max release rate from each development for regulations
- P. Frerich, RFPG 9, San Angelo
    - Putting in detention pond for entire neighborhood, extremely effective
    - Master Drainage Plan
        - Shows existing problems
        - Will expand using regional study
            - Where is future development? How can city be proactive, buy property for detention upfront
        - Question -How to ensure developers are able to get flows to detention?
- E. Burden, RFPG 6, Harris County
    - TRE
        - Bought the land, developers required to excavate, Harris maintains pond. Developers liked this solution. Set amount of ac/ft per ac development. Flood control district has its own tax to help, money from county as well
            - Dirt was used in development
        - New Atlas 15 coming out-large averaging
            - Penalizes watersheds because averaging, reality is high discharge in localized area
            - Elevated roads
                - "Borrow ditches", roads were built up like little berms
        - Home building
            - Slab on grade instead of crawl space
            - Sewer system issues because no fall w/o crawl space
            - Cannot prevent someone from building
        - Detention pond

                - Easy to maintain their own
                - Making sure the developers maintain their own, suing each gets expensive
- M. Shannon, RFPG 6, Galveston
    - After Harvey, 2000ft of large box culverts that drain directly into Galveston Bay
        - High elevation roads, development is in a “bowl”
- M. Vogler, RFPG 6, Fort Bend County
    - Did a “future” excavation project for future development
        - Issue: not as many people were able to use this as they thought
        - Atlas 14 used all the capacity
        - Concerned about investing in more capacity if developers can't use it because increased rainfall
- D. Canant, RFPG 5, DD6
    - Drainage projects alleviate flooding. Need more projects
        - Divert water out of flooded area to an area that can take it
        - Lots of water in area cannot reach main relief (Nueces River)
        - Detention basins
            - Counteract additional flows, instead of having to upsize all the infrastructure, reduce flows
        - Success: Larger channels, larger crossings, detention basins
            - Can maintain detention basins easily in this area
            - Mowing
        - In this area, soil is impervious so additional pavement not a huge deal, but decreased Tc makes a big deal.
        - Success in being strict in drainage criteria and calculations