10-29-2020

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twj.media

An online, peer-reviewed journal
published in cooperation with the
Texas Water Resources Institute

Texas Water Journal

Volume 11 Number 1 | 2020

Texas Water Journal

Volume 11, Number 1
2020
ISSN 2160-5319

twj.media

THE TEXAS WATER JOURNAL is an online, peer-reviewed journal devoted to the timely consideration of Texas water resources management, research, and policy issues. The journal provides in-depth analysis of Texas water resources management and policies from a multidisciplinary perspective that integrates science, engineering, law, planning, and other disciplines. It also provides updates on key state legislation and policy changes by Texas administrative agencies.

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The Texas Water Journal is published in cooperation with the Texas Water Resources Institute, part of Texas A&M AgriLife Research, the Texas A&M AgriLife Extension Service, and the College of Agriculture and Life Sciences at Texas A&M University.

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Texas Water Resources Institute
Texas Water Journal
Volume 11, Number 1, October 29, 2020
Pages 133-151

Internet of Texas Water: Use Cases for Flood, Drought, and Surface Water–Groundwater Interactions

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Abstract: Experts representative of Texas' water sectors identified critical water data needs and described the design of a comprehensive open access data system that facilitates use of public water data in Texas at the April 2018 Connecting Texas Water Data Workshop as reported in the *Texas Water Journal.* Participants described potential use cases to initiate work on the most critical data hubs for connecting Texas water data. This note is an update to work on the Internet of Texas Water Data initiative that describes progress on a flood dashboard by the Texas Water Development Board and development of use cases by workgroups of stakeholders with expertise in water data for drought and for surface water–groundwater interactions.

Keywords: public water data, Texas water, internet of water, water management use case, water data management

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Terms used in paper

Acronym/Initialism	Descriptive Name
FAIR	Findable, Accessible, Interoperable, and Reusable
NASA	National Aeronautics and Space Administration
NRCS	Natural Resources Conservation Service
SCAN	Soil Climate Analysis Network
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United States Geological Survey

INTRODUCTION

The April 2018 Connecting Texas Water Data Workshop reported in the Texas Water Journal by Rosen et al. (2019) brought together experts representative of Texas' water sectors to engage in the identification of critical water data needs and discuss the design of a comprehensive, open access data system that facilitates the use of public water data in Texas. Workshop participants identified topics for use cases,[5] including data gaps, needs, and uses for water data in each scenario. They also answered questions on who needs data, what data they need, in what form they need the data, and the purposes for which data are most needed. Comprehensive information about the workshop and a full description of the purpose, development, and use of use cases as well as examples of their application can be found in Rosen and Roberts (2018). Review of the synthesis document by Rosen et al. (2019) will help the reader understand the general basis for the current work described in this update. However, for a full understanding of the expert stakeholder recommendations and recommendations for future work please refer to the full report by Rosen and Roberts (2018) covering the 2018 workshop. That workshop brought together 90 invited experts representative of Texas' government and water agencies, utilities, academia, businesses, industries, research institutes, water associations, and advocacy organizations. The recommendations of those stakeholders included having next steps guided by a small advisory group, with work on use cases conducted by small groups of water data experts relevant to each use case as it is formed. The full report further defines the goals of a Texas water data initiative or data hub(s), develops a model for the structure of data hubs, characterizes several use cases, and supports the development of the use cases to demonstrate the value of connected public water data for improved decision making (Rosen and Roberts 2018).

This program review summarizes the results of work by data experts meeting as advisory and use-case-specific work groups to define the goals of a Texas internet of water data initiative and to characterizes its first use cases. A full description of this work can be found in Rosen and Mace (2019), which should be referred to for comprehensive details.

[5] A use case is a short summary organizing, in a concise and consistent format, the data gaps, needs, uses, users, regulatory requirements, and workflow for a particular objective. Use cases serve as a tool for organizing and assessing stakeholder data needs and for communicating those needs to decision makers. Use cases are presented in Tables 1 and 2.

WATER DATA INITIATIVE ADVISORY COMMITTEE RECOMMENDATIONS

A Water Data Initiative Advisory Committee (hereafter referred to as Committee) was formed and selected three topics to focus on as use cases for beginning work on a Texas water data initiative: (1) flood data, (2) drought data, and (3) surface water–groundwater interactions. Members agreed that each use case should exhibit seven attributes: (1) be valuable, (2) involve known users, (3) be achievable, (4) be scalable/replicable, (5) be non-controversial,[6] (6) provide an opportunity for quick implementation, and (7) result in a viable product for users.[7] For greater detail on the process for use case selection and actions leading up to use case development workshops, please refer to the full report by Rosen and Mace (2019).

Flood data dashboard use case

The Texas Water Development Board (TWDB) received funding from the 86th Texas Legislature in 2019 to develop a water data hub with a flood data dashboard as the first area of focus. The Committee intends to provide comments or suggested guidance as appropriate to the TWDB as the water data hub project progresses. The TWDB's work on the flood dashboard reported herein describes initial and important steps forward for Texas to make important water data more accessible and usable.

Goals under consideration for the flood dashboard and water data hub include aggregating information housed across multiple platforms; providing access to data using an index with data sets identified by multiple factors, including frequency of use and key words; generating an index of authoritative, named data sources; and enabling output of data layers and statistics through a viewer that is customizable by the user.

Initial ideas discussed for design of the flood dashboard and water data hub include collaborating with holders of critical water data sets to coordinate efforts and providing users with the ability to link to data resources and viewers maintained by others. Committee members generally suggested data hub designers consider means to support uninterrupted access to all data hub services and use cloud infrastructure to ensure scalability over time to reduce the need for local servers and better ensure the continuation of service during heavy use.

Drought data dashboard use case

The Committee agreed that a drought data dashboard will be of great value to decision makers. The dashboard should be a forward-looking tool designed to use relevant public, accessible, and usable data (i.e., already collected). The Committee advised that the utility of a dashboard will be increased by identifying existing data sets lacking interoperability and making them usable and accessible and identifying, collecting, and adding relevant new data sets over time. The Committee formed a subcommittee of subject matter experts to initiate work on a use case for a drought data dashboard.

The use case developed by the subcommittee describes a collaborative effort between the TWDB and the Committee (Table 1). The use case details sharing resources, providing expertise, and— where feasible—supporting the TWDB in the design and development of a drought dashboard.

The Committee, as informed by the drought use case, will seek to provide support to the TWDB by delivering expert input and advice and by soliciting stakeholder input on the drought data dashboard design, development, and use through surveys and hands-on testing.

Surface water–groundwater interaction use case

The Committee believes that a system offering access to surface water–groundwater interaction data will provide information of great overall value to decision makers, including regional water planning groups, groundwater conservation districts, and elected officials. The Committee also recognizes that interaction data may be more difficult to assemble than flood and drought data, because far fewer interaction data sets exist (Table 2), and they may be difficult to locate, with some data residing in non-digital formats that must be converted to make them accessible. Despite these limitations, Committee members believe the assembly of these data to be critically important for use by Texas water managers. The Committee formed a subcommittee of subject matter experts to initiate work on a use case for surface water–groundwater interactions.

The Committee received the recommendations of the subcommittee and agreed to a use case that focused on adding available data sets to a data repository with a strong search function (Table 2). The interaction data repository is envisioned as evolving over time into a more robust data dashboard as interaction data sets are compiled and added, and as user needs become better defined.

[6] What is controversial also may vary by region and user (stakeholder group). As a result, what constitutes "controversy" may vary by use case topic, geographic coverage, and user (stakeholder).

[7] Users may be defined as all self-described or potential stakeholders, not just data management experts and water professionals.

Table 1. Texas drought dashboard use case details.

Title	Texas Drought Dashboard: An initiative to define and develop a drought data dashboard for Texas
Objective(s)	To initiate and complete development of a drought data dashboard collaboratively with the Texas Water Development Board (TWDB), to include support assembling and providing drought data expert stakeholder input in the design and build of the dashboard, and to include support assembling key end-user stakeholder group opinion and advice on dashboard design, needs for drought response decision support, and best use input, with design to include support for use by the general public.

Description	This use case is anticipated as a collaborative project with the TWDB to make a drought data dashboard for Texas by providing support to obtain expert advice and assembling key stakeholder group input to aid in the design and build of a data dashboard that may include the following characteristics:
	• Statewide and hyper-local applicability
	• Decision support tool for local decision makers and different levels of users, including decision support for the following as examples:
	  • Local and personal water conservation measures for use in the home and landscaping
	  • Media/public announcements and recommendations
	  • Business and industry water emergency planning
	  • Farming and ranching decisions
	• Scalable, multi-scale
	• Real-time data and historic trends
	• Means to verify and maintain data sets
	• Geographic or map-based interface
	• Robust visualization and graphic presentation capability
	• Functionality built in a sequence for different level users and advanced over time:
	1. Initial Development for the basic user: Entry level capabilities for basic functionality of dashboard:
	a) Basic level of decision support
	b) Accessible front-end site for viewing but no access to back end
	c) Easy to understand visuals and user experience/user interface (e.g., defined with specific user needs in mind)
	d) Built with accessible interoperable data
	e) Webpage for viewing/presentation/information sharing
	f) Data must be up to date
	2. Next Stage Development for the super user: Advanced level capabilities to meet greater level of functionality and robust decision support
	a) Simple back end for administrative and direct access by users
	b) Stable host/site where either the application lives and/or the digital objects are stored
	c) End user customizable interface
	d) Authentication standards
	e) Portable across regions and scales
	f) Modular for data entry-transformation-loading
	g) Model-based
	3. Future Development and capabilities
	a) Strategic problem solving and decision support
	b) Composable and reproducible
	c) Artificial intelligence assistance, recommendation support
	d) Facilitator and user support tools
	e) User-driven decision problem framing and diagnosis tools

Participants	• TWDB, along with collaborating Texas state and federal agencies • Key statewide stakeholders: major local and statewide water stakeholder groups in Texas • A representative group of the general public
Regulatory Context	There are no regulatory matters involved in development of an information dashboard. Development of public information portals is not subject to regulatory or statutory oversight. However, there will be interest by elected officials at all levels of Texas government and agency regulators in having drought status data and predictive data about water availability made more widely accessible and understandable to local and statewide decision makers and elected officials, water managers, water utility operators, regulated water users and permit holders, and the general public.
Workflow	Develop a proposal for funding (a quick operational plan of action linked to a realistic budget) and seek funding. Note: The following steps refer to anticipated potential operational and funded steps to be taken toward completion of the drought data dashboard use case project. The use case project may identify major key statewide and local stakeholder groups from which to solicit input and may identify a statewide or series of local (across the state) groups that can serve to represent general water-interest stakeholders. Work with the TWDB to help clearly define roles and responsibilities in a collaborative arrangement. In general, the use case project may serve as a community of experts to provide advice to the TWDB as requested and may manage multi-stakeholder input and review of the dashboard during the design-build phase of work. In general, any final decisions would have to be made by the TWDB. This would cover matters involving data sets and dashboard function, build of the dashboard interface, and populating the dashboard with data or real-time data feeds. The use case project is anticipated to convene stakeholder input sessions online and in workshops (perhaps at stakeholder conferences). These sessions may be aimed at identifying and managing the diversity or needs and complexity of the many different dashboard user groups. In addition to typical efforts to solicit stakeholder input based on the general concept of a drought dashboard, the use case project may use innovative means to solicit information on decision support needs desired by stakeholders and will seek input on innovative dashboard tools: 1. The use case project may seek to focus stakeholder learning about dashboards and enhance the usefulness of their response by developing and having stakeholders test-use simulated drought dashboards. Test dashboards should have realistic functionality that can provide stakeholders with high-level hands-on understanding of how a dashboard works and its use to support decision making. This can provide context for the stakeholders to understand the value of a dashboard as a decision support tool and make suggestions for improvement. Through input received during an iterative involvement process as the dashboard is built, stakeholders may help guide the design and functionality of the dashboard sequentially over time based on what they need, want, and are found to use, in part as a result of using the dashboard simulation. 2. The TWDB may choose to use information received through the use case project to help design the dashboard to accommodate the needs of multiple users. Users may range in level of technical training from expert to general public users. Users may range in the scope of decision support from decision making that affects water use by large populations to water use at an individual user's home. Users may also vary in geographic area of concern from statewide to hyper-local. 3. The use case project may help describe or design decision support visualization tools and graphic presentations or interfaces to determine best practices for delivering information to the various stakeholder groups. 4. The use case project can help support stakeholder feedback on potential innovative and enhanced dashboard design, such as use of artificial intelligence in decision support, virtual visualization tools, or 3D representations of data sets. Such innovation in dashboard design could be tested in advance of spending time and money to overbuild or add advanced functionality that may not be used or needed. This could help allow public funding to be focused on the best and most useful dashboard design.

Table 1 (Continued). Data Sources.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Weather, river stage	Real-time temperature, precipitation, wind chill, heat index, humidity, wind, soil moisture, soil temperature, river flow, and river stage	Accessible	TexMesonet	https://www.texmesonet.org/	Also used by watermaster programs to determine surplus water for requested diversions and may impact environmental flow determinations both during low and high flow periods. Should also determine other real-time monitoring systems that are relied upon by the Texas Commission on Environmental Quality (TCEQ) and others for similar determination, such as International Boundary and Water Commission stream flow stations.
Drought impacts	Quantifiable losses attributable to drought	Variable	• TWDB • TCEQ • The National Drought Resilience Partnership • United States Department of Agriculture (USDA) • Various other sources	• https://www.drought.gov/drought/states/texas • https://www.tceq.texas.gov/response/drought • https://www.waterdatafortexas.org/drought • https://droughtreporter.unl.edu/map/	• Difficult to quantify impacts, but no comprehensive reporting process • Annual agricultural statistics available for commodity crops, but no standardized process to separate drought impacts from other factors affecting the agricultural economy • Harder to justify resources for drought response when impacts are not comprehensively accounted for • The prolonged nature of a drought and its broad geographic distribution make it more difficult to assess impacts than in a discrete event, such as a flood.
Water use data	Real-time surface water and groundwater use	Accessible, but not real-time	• TWDB • TCEQ	• https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/wrwud • https://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/index.asp	TWDB water use data are annual and not available in real time. TCEQ data show monthly values but are only listed through 2014, except for watermaster areas, where near real-time diversion rate and authorizations are available.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Soil moisture	Remotely sensed soil moisture products (e.g., soil moisture active passive products) and modeled soil moisture from the North American Land Data Assimilation System suite of models.	Accessible, variable	• TWDB • Natural Resources Conservation Service (NRCS), Soil Climate Analysis Network (SCAN) • National Aeronautics and Space Administration (NASA)	• www.texmesonet.org • NRCS-SCAN sites	• Soil moisture data are currently available only from a few point measurements. The TexMesonet stations are collecting soil moisture. However, there needs to be a much wider spatial coverage of in-situ observations. • Remotely sensed soil moisture products (e.g., soil moisture active passive products) and modeled soil moisture from the North American Land Data Assimilation System suite of models. These are available from NASA's Distributed Active Archive Center and from Mirador, but it would be nice to collate the data and have it accessible as soil moisture maps and other value-added products (e.g., soil moisture anomalies for a given month or season). While these datasets are replacements for in-situ data, they can be used in tandem with in-situ data. The plus point for the remotely sensed or modeled products is that they provide continuous surfaces and may provide useful information on soil moisture variability across Texas.
Planning group boundaries	Regional water planning group boundaries	Accessible	TWDB	http://www.twdb.texas.gov/waterplanning/rwp/index.asp	
Population data (census or state water plan)	Population data from the census or state water plan	Accessible	TWDB	http://www.twdb.texas.gov/waterplanning/swp/index.asp	
Groundwater and reservoir level	Real-time groundwater, reservoir level	Accessible	TWDB	https://waterdatafortexas.org/reservoirs/statewide	
Groundwater extraction rates	Water extracted monthly for each aquifer	Variable	TWDB		
Topographic information	Digital elevation models and/or Lidar datasets	Accessible	Texas Natural Resources Information System	https://data.tnris.org/	The refined Lidar datasets are important for connecting various impact and vulnerability concerns.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Instream flow requirements	Adopted ecological flow standards for stream segments where values have been set	Accessible	TCEQ	https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/eflows/rulemaking	
Water discharge per day	Real-time water discharge rate per day	Variable	TCEQ	Public Information Request or direct request form to TCEQ and regional offices	If return flows from wastewater treatment plants, then utilities are required to measure and report this data to TCEQ.
U.S. Drought Monitor	Drought monitor (national, by state)	Accessible	• USDA • National Oceanic and Atmospheric Administration	https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?TX	
Drought calculator for ranch/farm production	Predictive tool for assessing potential drought impacts on forage production	Accessible	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/nd/technical/landuse/pasture/?cid=nrcs141p2_001670	
United States Geological Survey (USGS) dashboard for Texas	Stream gage data	Accessible	USGS	https://txpub.usgs.gov/txwaterdashboard/	
Streamflow	River streamflow statewide	Accessible	USGS	https://waterdata.usgs.gov/tx/nwis/current/?type=flow	

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Groundwater level monitoring	Static groundwater level measurements from different times of year, with data on impact of drought on those levels and groundwater availability	Accessible, variable	Groundwater conservation districts	Groundwater conservation districts	These data sets are variable, difficult to access in real time, and may not be readily interoperable.
Groundwater availability	Groundwater availability: How much water is available to be permitted and how much water has already been permitted	Accessible, variable	Groundwater conservation districts	Groundwater conservation districts	
Lithology-geological data	Drilling reports, electrical reports, seismic	Accessible, variable	• TWDB • Railroad Commission of Texas	Request	

Table 2. Surface water–groundwater interaction data use case details.

Title	Surface Water–Groundwater Interaction Data Repository and Dashboard for Texas: A use case to build a repository of existing surface water–groundwater interaction data and make the data available to users through a robust indexing system and by working to make the data available to users in a FAIR,[1] georeferenced data hub for interaction data to which data sets and new data can be added over time; there are means provided to hub users through a dashboard or viewer to access, view, and work with these data, along with user-added data to demonstrate interactions or other desired analysis; and means to allow users to add data or data sets where contributors' data are subject to review and verification. [1] FAIR: F=Findable, A=Accessible, I=Interoperable, and R=Reusable
Objective(s)	To design and build a surface water–groundwater interaction data repository, hub, and a dashboard viewer for Texas that thoroughly considers key stakeholder input in the design, build, and uses of the hub and dashboard, including input from the general public to aid in making the hub/dashboard universally valuable in enabling users to make better decisions about managing their water resources.
Description	• The use case may collect, index, and enable access to all available groundwater and surface water interaction data stratified by river basin, water planning region, groundwater management area, and groundwater conservation district. • The data may be housed first in a user-accessible repository or data hub that may contain all available interaction data sets, indexed at a minimum as described immediately above. • In a next step, an interaction data dashboard and viewer can build on a repository or hub using FAIR data. Over time, the dashboard may add the capacity for users to conduct basic data comparison work and view interaction display functions. The dashboard may allow for the addition of more water data over time that may enable display of more and better interaction information and help identify future data needs. • The dashboard may be initially populated with data sets that focus on high-priority areas (for conservation or public benefit purposes) or high-profile river basins or locations, such as San Felipe Springs, Devils River, Blanco River, Brazos River, Colorado River near San Saba, or Balmorhea/San Solomon Springs. • Initial work may define who is expected to use the dashboard. These stakeholders or stakeholder groups may be identified and asked to provide input on what they need and how they would use the dashboard. The project may also develop an example dashboard, or mock-up, to start the discussion with stakeholders and help define and test needs and desires. This can help in the development of multiple entry points to data sets for different levels of users or users with different needs, including delivery of information synthesized for public use.
Participants	• Groundwater conservation districts and other groundwater managers • River authorities and other surface water managers • Regional water planners • Water rights holders/owners • Counties and major cities government and elected officials • Water providers • Texas Water Development Board (TWDB) and collaborating Texas state and federal agencies • Texas Commission on Environmental Quality (TCEQ) • A representative group of the general public
Regulatory Context	There are no regulatory matters involved in development of a data repository or dashboard. The development of public information portals is not subject to regulatory or statutory oversight. However, there is likely to be interest by elected officials at all levels of Texas government and agency regulators in having surface water and groundwater interaction information and predictive data about interactions affecting water availability made more widely accessible and understandable to local and statewide decision makers, elected officials, water managers, water utility operators, regulated water users and permit holders, and the general public.

Suggested Workflow	Identify potential funders and make initial contact where possible and appropriate. Develop a framework work plan and budget for the use case. This plan may include items such as a detailed listing of sequential actions to be taken to develop the data repository and dashboard and to add data sets and tools that will turn these data sets into information displays about interactions and water availability described as useful and needed for decision making by water managers and stakeholders. Then, use the plan and budget as a guide to develop a proposal for funding by potential funders. Develop the technical work plan to design and build the repository and dashboard, including architecture, function, tools, interface, and back end. Develop a mock-up dashboard to provide a working example for stakeholder education, testing, and input. Identify initial examples to serve as initial subjects for populating the dashboard with FAIR data. Focus the following efforts on each basin or location as work proceeds. Repeat as new basins or locations area added, with data fit for each new specific purpose adding to the evolution and iterative building of a comprehensive dashboard. • Create and use a local stakeholder network or advisory group for project review and input on development of locally desired features and functionality of the dashboard by area, as opposed to relying only on technical experts and programmers. • Gather and add data sets relevant to each location, gradually building a comprehensive dashboard with capacity to display decision support information about surface water and groundwater interactions and availability. • Develop/adapt a mock-up dashboard for each new area to provide a working example for stakeholder education, testing, and input. • Develop a marketing plan to describe the benefits/results of better water management by users of the decision support tools available on the dashboard.

Table 2 (Continued). Data Sources.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Weather, river stage	Real-time temperature, precipitation, wind chill, heat index, humidity, wind, soil moisture, soil temperature, river flow, river stage	Accessible	• TWDB • TexMesonet	https://www.texmesonet.org/	
Groundwater levels	Daily water level (feet below ground surface) for 234 wells across the state	Accessible	TWDB	www.waterdatafortexas.org/groundwater/	Few, if any, of these wells are in alluvial aquifers. Priority could be placed on instrumenting at least some wells in alluvial aquifers in the future.
Field studies of Colorado River and Carrizo-Wilcox Aquifer in Central Texas	Report prepared to support the update of the groundwater availability model of the central portion of the Carrizo-Wilcox Aquifer	Accessible, data may not be readily interoperable	TWDB	http://www.twdb.texas.gov/groundwater/models/gam/czwx_c/Final_BBASC_083117.pdf?d=1566575514973	
Surface water and aquifer relationships in the Brazos River Alluvium Aquifer	Report prepared to document the conceptual model of the groundwater availability model of the Brazos River Alluvium Aquifer	Accessible	TWDB	http://www.twdb.texas.gov/groundwater/models/gam/bzrv/BRAA_AQUIFER_GAM_REPORT_ALL.PDF	

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Texas aquifers	Both major (9) and minor (22) aquifers as defined by the TWDB	Accessible	TWDB	http://www.twdb.texas.gov/mapping/gisdata.asp	Available shapefiles; website includes many other pertinent GIS data (e.g., river basins, rivers, reservoirs)
Summary report of surface water–groundwater interactions in Texas	Estimated groundwater flow to surface water based on historical baseflow data from nearly 600 USGS stream gauging stations.	Accessible	• TWDB • USGS	http://www.twdb.texas.gov/groundwater/docs/studies/TexasAquifersStudy_2016.pdf?d=1566575164951	• Base flow is from USGS stream gauges, TWDB aquifer properties and map. • Report prepared by the TWDB at the direction of the 84th Texas Legislature (House Bill 1232)
Spring discharge	Stage/discharge relationships and time series groundwater elevation and spring discharge records	Limited availability	Limited; some springs included in TWDB groundwater database	https://www.twdb.texas.gov/groundwater/data/index.asp	• Few spring discharge values are available. • Spring rating curves linking stage and discharge are generally not available.
Groundwater pumping data	Time series volume of water pumped by well (spatially explicit), covering all well types (including exempt wells)	Limited availability	• TWDB • Groundwater conservation districts • Others		• Pumping data are scarce • Estimates by different agencies are mixed and use a number of assumptions to estimate.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Soil moisture	Remotely sensed soil moisture products (e.g., soil moisture active passive products) and modeled soil moisture from the North American Land Data Assimilation System suite of models	Accessible	• TWDB • Natural Resources Conservation Service, Soil Climate Analysis Network (NRCS-SCAN)	• www.texmesonet.org • NRCS-SCAN sites	• Soil moisture data are currently available only from a few point measurements. The TexMesonet stations are collecting soil moisture. However, there needs to be a much wider spatial coverage of in-situ observations. • Remotely sensed soil moisture products (e.g., soil moisture active passive products products) and modeled soil moisture from the North American Land Data Assimilation System suite of models. These are available from National Aeronautics and Space Administration's Distributed Active Archive Center and from Mirador, but it would be nice to collate the data and have it accessible as soil moisture maps and other value-added products (e.g., soil moisture anomalies for a given month or season). While these datasets are replacements for in-situ data, they can be used in tandem with in-situ data. The plus point for the remotely sensed or modeled products is that they provide continuous surfaces and may provide useful information on soil moisture variability across the state.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Potential areas with surface water–groundwater interactions	Surface water–groundwater interaction evaluation for 22 Texas river basins	Accessible but generally not in a database; many numbers/ studies in published papers and reports	Texas Natural Resource Conservation Commission	https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/Surface-Groundwater_Interaction.pdf	• Assessment of surface water–groundwater interactions for river segments. Points out areas of the state where interaction is expected to occur (and relative degree of interaction). • Data is dated (circa 1999) and more qualitative than quantitative.
Streamflow gain/ loss	Streamflow measurements along a reach to define interaction between surface water and groundwater	Accessible, usability variable	USGS	https://pubs.usgs.gov/of/2002/ofr02-068/	• There are 366 streamflow gain-loss studies in 249 unique reaches. • Highly variable results • Snapshot in time measurements don't reflect groundwater dynamics. • Data does not address bank storage; existing methods are difficult and expensive; new methodologies needed. • Data doesn't include results from studies completed after 2000.
Stream and spring discharge	Real-time stream and spring discharge	Accessible	USGS	https://waterdata.usgs.gov/tx/nwis/current/?type=flow	• Stream flow at 640+ sites. Spring flows for 10 springs including Chalk Ridge Falls, Felps, Barton, San Marcos, Comal, Hueco, Jacobs Well, Giffin, San Solomon, and Las Moras. • Data does not exist for many springs in Texas.
Groundwater levels	Real-time groundwater elevations	Accessible	USGS	https://waterdata.usgs.gov/tx/nwis/current/?type=gw	• 15-minute data for water level for 35 wells across the state; few, in any, of these wells are in alluvial aquifers • Priority could be placed on instrumenting at least some wells in alluvial aquifers in the future.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Geodatabase	Geologic and hydrogeologic information for a geodatabase for the Brazos River Alluvium Aquifer	Accessible	USGS	• https://pubs.usgs.gov/of/2007/1031/ • https://pubs.usgs.gov/sim/2989/	• Data were compiled primarily from drillers and borehole geophysical logs from government agencies and universities, hydrogeologic sections and maps from published reports, and agency files. • Provides estimate of alluvial aquifer extent and thickness for one alluvial aquifer in Texas. Much less data available for other alluvial aquifers in the state.
Streamflow gain/loss	Gain/loss study for Colorado River in Burnett and San Saba counties	Accessible	USGS	https://pubs.er.usgs.gov/publication/sir20155098	• Traditional gain/loss study on about 10 miles of the Colorado River • Typical gain/loss study with use of an acoustic Doppler current profiler to make flow measurements. Example of study completed after #3 and #10 above.
Streamflow gain/loss	Gain/loss study for Guadalupe River in Gonzales County	Accessible	USGS	https://pubs.er.usgs.gov/publication/fs20183057	• Gaining and losing sections of river determined using floating geophysical methods • Methods provide an indication of gaining or losing, but don't quantify the amount. Map the length of segment (not just individual points)
Streamflow gain/loss	Gain/loss study for the Brazos River from McLennan County to Fort Bend County	Accessible	USGS	https://pubs.er.usgs.gov/publication/sir20075286	Base flow (1966–2005) and streamflow gain and loss (2006) of the Brazos River, McLennan County to Fort Bend County, Texas
Streamflow gain/loss	Gain/loss study for the Brazos River from New Mexico–Texas state line to Waco, Texas	Accessible	USGS	https://pdfs.semanticscholar.org/92e0/bbbaf13ceb477442ac9d9a2f966714151776.pdf?_ga=2.107396166.51329	Base flow (1966–2009) and streamflow gain and loss (2010) of the Brazos River from the New Mexico–Texas state line to Waco, Texas

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Spring locations	USGS database of Texas springs	Accessible	USGS	https://doi.org/10.3133/ofr03315	
Surface water–groundwater relationship	Estimate of groundwater outflow versus Medina Lake stage	Accessible, unknown usability	USGS	https://pubs.er.usgs.gov/publication/fs20173008	• Regression equations for groundwater outflow vs. stage based on measurements from 1955–1964, 1995–1996, and 2001–2002. • Example of the type of data that needs to be collected to estimate groundwater recharge from surface water bodies
Surface Water quantity/quality	Data related to surface water quality and quantity at field and watershed scales	Accessible	Texas Institute for Applied Environmental Research, Tarleton State University	Contact at Saleh@tarleton.edu	• Over 25 years of water quality and quantity data collected from number of watersheds in Texas for data analysis and modeling • Data related to interaction of surface and ground water quality and quantity; surface water quality and quantity data for many locations are of limited use
Overview of the impacts of surface water–groundwater interactions on water quality and quantity	Surface water–groundwater interactions in Texas	Accessible, use limited by location	Bureau of Economic Geology, University of Texas	http://www.beg.utexas.edu/files/publications/cr/CR2005-Scanlon-3_QAe6975.pdf	Data are limited to certain locations in state.
Streamflow/river Forecasts	Times series of river stage forecasts and streamflow at certain USGS gaging stations during certain conditions	Accessible, use limited	West Gulf River Forecast Center	https://www.weather.gov/wgrfc/obsfcst#	• Depending on conditions, forecasts of river stages, associated streamflow, and various USGS gaging stations • Currently, streamflow forecasts are not typically available for "normal" and "dry" conditions.

Data Category	Description	Availability	Data source	Access Method	Added Characteristics
Spring flow	Spring flow targets where already specified	Accessible, where specified as desired future conditions			May be policy-oriented target value, not collected data
Streamflow	Environmental flow targets	Available but not in a publicly accessible database	TCEQ	Database in development with Texas Parks and Wildlife Department	May be policy-oriented target values, not collected data
Groundwater management	Desired future conditions	Available but not in a publicly accessible database	TWDB	https://www.twdb.texas.gov/groundwater/management_areas/index.asp	May be policy-oriented target values, not collected data
Baseflow separation	Base flow separation using water chemistry and other tracers. Better data than simple flow-based separation.	Isolated case studies	e.g., Rhodes KA et al. Rhodes. 2017. The Importance of Bank Storage in Supplying Baseflow to Rivers Flowing Through Compartmentalized, Alluvial Aquifers. Water Resources Research. 53(12):10539-10557. Available from: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017WR021619		• Data not now generally available • More intensive monitoring required • A data need
Groundwater	Groundwater availability and water availability models outputs as well as inputs	Available but not wholly FAIR	• TWDB • TCEQ	https://www.twdb.texas.gov/groundwater/models/gam/index.asp	
Evapotranspiration rates	Remote sensing evapotranspiration data over a period of time	Not generally available	OpenET is developing a platform for remote-sensed evapotranspiration for the western United States	https://etdata.org/	• Data not now generally available • A data need • OpenET data products scheduled for release in 2021

NEXT STEPS

Committee members acknowledge and strongly support the TWDB's current work to develop a data hub and dashboards for flood and drought. They committed to assisting the agency when possible. The TWDB's work on data dashboards has the potential to serve as use cases that demonstrate the value of integrated Texas water data visualization tools to decision makers. A surface water–groundwater interaction data repository will add to this value demonstration. Future steps may be to link these efforts via a data hub, enabling an even more complete picture of Texas water data.

ACKNOWLEDGEMENTS

This work was supported by the Cynthia and George Mitchell Foundation, with assistance from Emily R. Warren and Farnaz Seddighzadeh. The outcomes and preceding text do not necessarily represent the views of individual committee members or of members' organizations. Committee and subcommittee members follow: Aaron Abel, Kathy Alexander, Bryan Anderson, Rob Bruant, Nelun Fernando, Tim Finley, Larry French, Marcus Gary, Ron Green, Karen Guz, Sam Marie Hermitte, Erin Keys, Ken Kramer, Michelle Lapinski, Cindy Loeffler, Glen Low, Leah Martinsson, Brooke McGregor, Justin Mcinnis, Suzanne Pierce, Daniel Pearson, Carlos Rubinstein, Ali Saleh, Rosario Sanchez, Bridget Scanlon, Sarah Schlessinger, Farnaz Seddighzadeh, Raghavan Srinivasan, Stephanie Moore, John Tracy, Darrel Tremaine, Richard Wade, Jennifer Walker, Emily Warren, Andy Weinberg, Mark Wentzel, and Gary Westbrook.

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