texaswaterjournal.org

An online, peer-reviewed journal published in cooperation with the Texas Water Resources Institute and the Bureau of Economic Geology

Texas Water Journal

Volume 16 Number 1 | 2025

Texas Water Journal

Volume 16, Number 1
2025
ISSN 2160-5319

texaswaterjournal.org

THE TEXAS WATER JOURNAL is an online, peer-reviewed, and indexed 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, a unit of Texas A&M AgriLife Research that brings together expertise from across the Texas A&M University System, the Bureau of Economic Geology in the Jackson School of Geosciences at The University of Texas at Austin, and the Water and Environment Research Center in the Department of Civil, Environmental and Construction Engineering at Texas Tech University.

The Texas Water Journal is indexed by Scopus, Google Scholar, and the Directory of Open Access Journals.

Cover photo:
Guadalupe River Nature Trail at Canyon Lake Dam.

Texas Water Journal
Volume 16, Number 1, July 28, 2025
Pages 80-92

Policy Review: How Texas Could Lead the Nation in Addressing a Growing Water Workforce Problem

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Abstract: The water sector has been experiencing an aging workforce where retirements are outpacing recruitment of new, job-readied workers. The resulting workforce shortage threatens the ability of the water industry to protect the nation's public health and environment and the sustainability of critical water infrastructure investments. While working on the frontline of water and wastewater system operations traditionally required an education level equal to or less than a high school diploma, the increased complexity of our water system will entail increased levels of education and professional training. In the meantime, colleges must reinvent themselves quickly to accommodate the needs of the water industry and a new generation of students seeking different options to maximize their investments in education and professional development. We examined the water workforce landscape and the emerging challenges of working in water and wastewater utilities. We then outlined the role of higher education programs in developing a competent workforce ready to tackle these challenges, such as the treatment of emerging water contaminants and modernizing an aging system vulnerable to extreme weather and cyberattacks. While college degrees remain valuable for educational credentialing and career development, programs offered in colleges and universities must be made accessible to in-service professionals and curricula must reflect the challenges faced by workers in today's water systems.

Keywords: Water sector, workforce development, postsecondary education, water license

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Received 13 July 2024, Accepted 18 March 2025, Published online 28 July 2025.

Citation: Den W, Smyth DS. 2025. Policy Review: How Texas Could Lead the Nation in Addressing a Growing Water Workforce Problem. Texas Water Journal. 16(1):80-92. Available from: https://doi.org/10.21423/twj.v16i1.7194.

Terms used in paper

Acronym/Initialism	Descriptive Name
AS	Associate of Science
AAS	Associate of Applied Science
A&M-SA	Texas A&M University-San Antonio
AWWA	American Water Works Association
BAAS	Bachelor of Applied Arts and Sciences
BLS	U.S. Bureau of Labor Statistics
BS	Bachelor of Science
CISA	Cybersecurity and Infrastructure Security Agency
CTE	Career and Technical Education
CWS	community water systems
GAO	U.S. Government Accountability Office
GED	General Education Diploma
GIS	geographic information system
IIJA	Infrastructure Investment and Jobs Act
IT	information technology
MS	Master of Science
NPDWR	National Primary Drinking Water Regulations
PFAS	per- and polyfluoroalkyl substances
PPCP	pharmaceutical and personal care products
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
STEM	science, technology, engineering, mathematics
TCEQ	Texas Commission of Environmental Quality
TEEX	Texas A&M Engineering Extension Service
TEKS	Texas Essential Knowledge and Skills
UCMR	Unregulated Contaminant Monitoring Rule
EPA	U.S. Environmental Protection Agency
WATR	Water Resources Science and Technology

THE WATER WORKFORCE LANDSCAPE

America's water utility sector is facing enormous challenges. These include aging infrastructure, rapid population growth, chemical and biological pollutants, challenges with affordability, and climate change impacts. This paper describes the challenge of increasing the diversity of and replacing an aging water workforce, while ensuring that new workers are prepared with the technical skills, soft skills, and content knowledge needed to protect natural water resources, public health, and the environment. The workforce shortage in the water utility sector is hardly a new concern to industry and public safety officials responsible for ensuring water security. It is an issue that has become a focus of attention in recent years when numerous public water supply safety incidents (Lloyd, 2022; Martinez, 2024) and cyberattack incidents were reported (EPA, 2024).

In 2018, a U.S. Government Accountability Office (GAO) report (GAO, 2018) and Senate Bill 2346 described workforce demographic information that is commonly cited as evidence of a coming crisis for the water industry (S. 2346, 2018). Key statements in the bill revealed that the median age of water sector workers was 48 years old—6 years older than the national median age of workers—and that 37% of water and 31% of wastewater workers would retire in the next 10 years, at the time of the bill's writing. That same year, an investigative report by the Metropolitan Policy Program at the Brookings Institution stated that:

> The water sector is aging, while employers are struggling to attract and hold onto skilled workers, particularly younger and more diverse workers … A lack of public visibility, combined with declines in career and technical education (CTE), has reduced interest and experience among prospective workers who could fill water-related positions. (Kane & Tomer, 2018, p. 10)

These reports validated the national concern over high rates of retirement eligibility and difficulties finding and attracting skilled and trained workers to fill job openings.

Employment projections released in July 2024 by the U.S. Bureau of Labor Statistics (BLS; BLS, 2024a) forecast a decline of 6.3% in employment for water and wastewater treatment plant and system operators over the next 10 years (2022–2032). Despite the projected declining employment, the outlook for job demand is strong, as 10,500 job openings are projected annually due to the need to replace workers exiting the workforce due to retirement and career changes. Meanwhile, employment of environmental engineers, scientists, geoscientists, hydrologists, geographers, and chemical technicians—all water-related professions requiring postsecondary education credentials, often a college degree—is projected to increase. Kane and Tomer (2018) reported that many of these occupations are slated to grow, with the number of software developers, information security analysts, environmental engineering technicians, paralegals, legal assistants, and market research analysts all projected to increase (Table S1). Kane and Tomer (2018) described 212 different positions associated with the water workforce. Figure 1 shows a selection of these positions, and the levels of educational attainment associated with the workers in those positions.

Kane and Tomer (2018) also revealed insights into the demographics of the water workforce. Water workers tended to be older and lacked gender and racial diversity in certain occupational categories. Nearly 85% were male and two-thirds were White, with women making up only a fraction of employment in some of the largest water occupational categories in 2016. Women often occupied primarily administrative positions, such as receptionists. Only 1.4% of plumbers were female. Black and Asian people were also underrepresented in the water workforce, together making up 11.5% of the water workforce, compared with 18% of the overall workforce nationally.

Kane and Tomer (2018) identified several additional key challenges for the water workforce:

- Recognizing the varying scale and capacity of different communities, from urban to rural, when expanding the workforce;
- Attracting younger and more diverse workers, and increasing the public visibility of the water workforce;
- Identifying barriers to recruiting workers;
- Developing strategies to proactively and effectively recruit skilled workers; and
- Offering professional development opportunities to help retain skilled workers and grow new competencies and skills in response to new challenges.

The last point here is typically the domain of postsecondary education, where hard skills (e.g., technical, analytical, and writing skills) and soft skills (interpersonal and communication skills) are developed during academic preparation. Many university curricula are designed to help develop a lifelong-learning mindset and the ability to learn new skills, critical thinking, and problem solving.

The implementation of the Infrastructure Investment and Jobs Act (IIJA), introduced by H.R. 3684 (Infrastructure Investment and Jobs Act, 2021) and commonly referred to as the Bipartisan Infrastructure Law, significantly boosted the water job market (The White House, 2022). The law urges water and wastewater utilities to invest in and develop a pipeline of skilled and diverse workers.

Recognizing the challenges in the workforce gap, Congress authorized the U.S. Environmental Protection Agency (EPA), under the American Water Infrastructure Act of 2018, to develop programs to accelerate career pipelines in the water utilities sector and provide access to water utility workforce opportu-

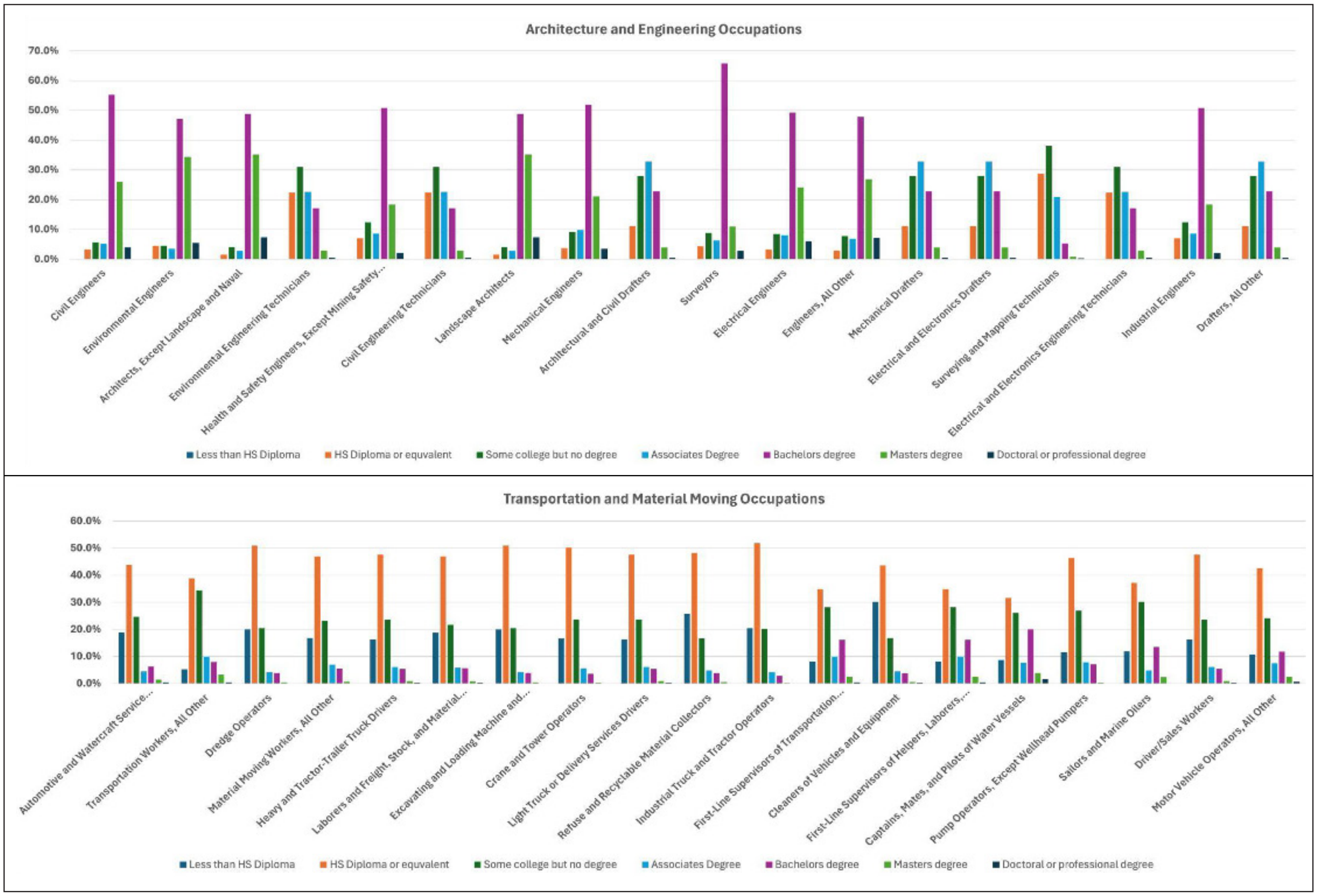


Figure 1. Educational attainment of water workforce personnel from Kane and Tomer (2018). A. These data describe the education levels of those in architecture and engineering occupations (Kane and Tomer, 2018). The majority of personnel in these positions have at least some college education. In May 2023, BLS data showed the average salary for these jobs was $86,100 (minimum $54,900 for "surveying and mapping technicians," maximum $124,190 for "electronic engineers, except computer"). B. These data are for occupations in transportation and material moving, most of which require a high school diploma. In May 2023, BLS data showed the average salary for these jobs was $50,264 (minimum $34,530 for "automotive and watercraft service attendants," maximum $97,820 for "captains, mates, and pilots of water vessels").

nities. In late 2020, EPA launched its America's Water Sector Workforce Initiative (EPA, 2020). The initiative states that:

> The necessary technologies required to run today's water utilities are wide-ranging and complex. They include advanced monitoring and treatment technologies and sophisticated information management systems … Smart Systems (water quality sensing, remote sensing, and satellite imagery), Treatment Technologies/Processes (advancements in treatment technologies and processes to help eliminate legacy and emerging water contaminants), Information System Management (operations, asset management, and cybersecurity) (EPA, 2020, p. 3).

The water workforce initiative is organized around three interrelated action areas and associated strategies:

- Action Area 1: Provide federal leadership to create national momentum and coordinate efforts, via successful collaboration with the federal government.
- Action Area 2: Partner to build the water workforce of the future via collaboration with associations and utilities, tribes, and states.
- Action Area 3: Bolster education and outreach to make water a career of choice by (i) administering new grant programs, (ii) engaging schools and educational organizations to bolster student awareness, and (iii) focusing on underserved communities and water workforce diversity.

It is not yet clear what impact these federal initiatives are having on the workforce and what utilities are doing in response to IIJA.

A FOCUS ON THE TEXAS WATER WORKFORCE

Background Context

There are more than 7,000 public water systems in Texas, of which 771 are publicly owned wastewater treatment facilities (La Caille, 2019). Recent survey data released by the Texas Water Infrastructure Network and Water Opinions showed that 82% of water utilities surveyed were very concerned about their current or future workforce capacity (Texas Water Infrastructure Network, 2022). This applied to both small (about 60% of the responding entities serve communities with less than 20,000 people) and large (10%, serve more than 1 million people). In October 2023, the Texas Water Foundation published a statewide survey of the state's water industry. Respondents expressed widespread concerns about attracting and retaining workers, the need to provide competitive wages, and current and future staffing shortages (Houston Advanced Research Center, 2023). Respondents included water/wastewater providers, municipalities, and groundwater and river management agencies. Half of the respondents came from small organizations with less than 10 employees.

Despite the challenges in attracting and retaining talent, Houston Advanced Research Center (2023) revealed that many of the respondents' organizations did not monitor retention and retirements (31% of responses) or track leadership and development accomplishments (38% of responses). Most respondents stated that their organizations offered employee development and training opportunities as well as job advancement or rewards for completing additional training or certifications, suggesting that such endeavors are valued by the organization. An additional finding from the survey was a reliance on external expertise by the respondents for help in several professional occupational categories (i.e., surveyors, engineers, and hydrologists) and technical occupations (e.g., information technology [IT] and geographic information system [GIS] services, grant writers, and project managers; Houston Advanced Research Center, 2023). Many of these external specializations are among those identified by Kane and Tomer (2018) as future areas of job growth.

Education Level

Kane and Tomer (2018) revealed that more than half (53%) of the water workers they surveyed had a high school diploma or less, outnumbering all other occupations by 20%. Conversely, the fraction of water workers with a bachelor's degree or higher was less than half as compared to all other occupations. Water workers rely more on on-the-job training in relevant skills to improve their opportunities for advancement and higher wages than formal education. For example, it would generally take at least 10 years for an individual with only a high school diploma or GED to progress from a Class D license to a Class A license—the highest license level, which qualifies holders for supervisory responsibility in both water and wastewater operation (Purpose and Applicability, 2001a, 2001b).

Per BLS (U.S. Bureau of Labor Statistics, 2024a), as of 2022, most of the water and wastewater treatment plant and system operators have a high-school diploma or less (40.2%) or some college credits (30.5%). Less than 26% possess a college degree, and only 2% have a master's degree (BLS, 2024b). Despite the discrepancies in the statistics from those reported by Kane and Tomer (2018) attributed to the different methodologies applied to scope water jobs, both data reflect that the relatively lower education level for workers in the water industry. The majority of water workforce employees with master's degrees are employed in technical or managerial services, such as environmental scientists and specialists, geoscientists, hydrologists, and managers. These positions are particularly in demand for large water supply organizations.

Solutions to education level issues

Water resource agencies and professional groups in Texas are working to improve and expand training and educational opportunities related to the water workforce. Regulatory agencies, such as the Texas Commission on Environmental Quality (TCEQ), and professional associations, such as the Texas Water Utilities Association, Texas Rural Water Association, and the Water Environment Association of Texas, have been actively working to develop courses and deliver training programs to help qualified applicants become licensed water operators (Gerfers, 2024). Many of these programs coordinate with water and wastewater utilities to offer apprenticeship opportunities for people with a high school or general education diploma (GED; Carver & Salhotra, 2023). TCEQ certifies individuals or organizations to provide water licensure training courses. Texas A&M Engineering Extension Service (TEEX) offers a water and wastewater program that provides basic and advanced technical training to industry professionals across Texas. The program also delivers federally funded critical infrastructure safety training to water treatment plant personnel (TEEX, n.d.).

Texas House Bill 1845, which became effective in September 2023, allows high school students to work toward becoming water or wastewater operators while still in high school (Tex. H.B. 1845, 2023). This bill, which establishes a provisional certification opportunity prior to high school graduation, is intended to accelerate recruitment to the water workforce and attract early career workers to enter the water sector. However, workers who enter water jobs directly from high school—or even without completing formal high school education—would have limited educational preparation and background.

Table 1. Selected salary data for water and wastewater treatment plant personnel at medium-sized* utilities in the United States and Texas (American Water Works Association [AWWA], 2023a).

Category	Level of experience	U.S. average salary range (USD, $)			Texas salary range (USD, $)		
		Min	Mid	Max	Min	Mid	Max
Water /wastewater distribution operator	Associate	44,057	51,750	59,658	38,762	46,254	53,919
	Intermediate	49,573	57,882	66,571	40,311	47,267	54,968
	Senior	59,197	69,214	79,260	49,678	63,007	74,394
Water /wastewater treatment plant operator	Associate	44,457	52,680	61,914	41,238	49,387	58,011
	Intermediate	50,261	59,454	69,274	47,423	55,674	64,526
	Senior	57,563	67,719	78,506	54,510	65,273	78,256
Water/wastewater treatment manager	All	75,485	90,988	106,320	71,151	88,199	105,695

* Water and wastewater utilities serving a population between 10,000 and 99,999. AWWA also published data for small (<10,000) and large (>100,000) utilities separately. Medium-sized utilities had the largest share of the survey response (45%) in the report.

While workers will be able to earn a competitive salary, without at least some college education and training, they may be limited in their ability to move into new positions, attain desired increases in salary, or enter management roles that require an associate or bachelor's degree. In addition, they will have limited opportunity to move out of the water workforce into other industries that require a college education as an entry point. Such workers would need to perhaps complete their GED at night, which would open up options to attend a vocational school or to enter community college to gain an associate's degree. Attainment of these education credentials would likely increase the earning potential of the workers.

Salaries

In 2023, the American Water Works Association (AWWA) published its national compensation survey for the water sector based on the population size for which a utility served. The report shows that the median annual salaries for job titles under "treatment operation" increased by 4.5% between 2022 ($66,261) and 2023 ($69,100), and those under "distribution/collection operation" increased by 4.4% during the same timeframe (AWWA, 2023b). These 1-year salary increases represent, by far, the largest jump in the past 10 years and are above the national composite average of about 4%. Table 1 lists salary range data for water distribution, wastewater collection, and water/wastewater plant operation (AWWA, 2023a). Observations from these data are:

1. Salaries in Texas are lower than the national average across all experience levels for the operator positions. The disparity is wider at the lower spectrum of the salary ranges, but the gaps narrow as salary level increases.
2. Salaries for senior positions are roughly 30%–40% higher than associate (entry-level) positions for the same job categories. The national average salary level for managerial positions is roughly 70% more than that of associate positions; in Texas, that salary difference further widens to 84%–96%. These managerial positions likely require education credentials of at least a college degree to qualify.

According to BLS, 120,710 people in the occupation category "water and wastewater treatment plant and system operators" were employed nationally in May 2023, with Texas, California, and Florida having the greatest share of those employed (BLS, 2024c). However, the median salary for Texas operators ($45,900) lags behind salaries in California ($79,130), Florida ($52,120), and the national average ($54,890) (Salary.com, n.d.). Median salaries also vary across Texas: They are higher in population centers and urban areas, such as Austin ($64,772) and San Antonio ($61,893), than in smaller cities, such as Midland ($49,444) and Brownsville ($56,398) (Salary.com, n.d.).

Using San Antonio, Texas, as an example, we compared the increase in salary associated with experience and education levels (Table 2), using the overall median (50% percentile) salary of $61,893 for a water treatment plant operator, reported by Salary.com (n.d.), as the baseline for all comparisons (i.e., experience and education). We observed the following trends:

- It takes 5–6 years for an entry-level person with a high school diploma to reach the mean median salary. The time to reach this salary gradually shortens with increasing levels of education (i.e., associate, bachelor, and master's degrees). For a person with a master's degree, the time decreases to about 3 years.
- While the salary growth for individuals with only a high school diploma was competitive with those with higher educational credentials, the potential for salary growth with the accumulation of on-the-job experience begins to diminish after 5 years.
- Salary levels for water workers at higher earning brackets (70 percentile and 90 percentile) generally lag behind those

Table 2. Salary discrepancies (%) as compared to the median salary ($61,893) by experience and education level for water plant operators (Salary.com, n.d.).

Degree	Experience (years)				
	<1	1–2	3–4	5–6	7–9
High School	–8.3	–7.2	–2.6	0.0	2.8
Associate	–7.6	–5.9	–2.2	1.4	3.4
Bachelor	–6.5	–5.4	–2.0	2.0	4.8
Master	–5.9	–4.8	–0.4	2.8	5.7

for all occupations in the same brackets, implying that the value of education credentials and the ability to develop professionally become increasingly crucial to maintaining competitive earnings for experienced water workers.

Greater levels of education increase a worker's capacity and opportunity to pivot to a supervisory and management role or migrate to another sector requiring similar skill sets and experience. Many utilities offer financial assistance to support their employees in earning a bachelor's degree. While workers can enter the water workforce with a high school diploma, they face barriers to career advancement if they lack a higher degree or credential as they progress in their profession.

HIGHER EDUCATION AND THE WATER WORKFORCE

While industry-level and on-the-job training delivers licenses required for employment in many water operation jobs, it does not equip workers with the technical and soft skills needed for promotion to managerial roles or many emerging careers in the water workforce today. Nor does industry training alone provide a means for employment in a company where a university degree is an entry-level position requirement. The difference between industry-level and on-the-job training versus post-secondary education level degrees is also reflected by the salary level across the water sector-competitive wages at the entry and intermediate levels (workers with 5 years or less experience), but salary hits the ceiling at the senior and management levels.

College degrees offer an education beyond just the skill sets to perform a technical job. A college degree often offers the career-enhancing ability to understand the complexity of the water industry. To illustrate this point, here are examples of skills that would be advantageous for a water worker to have, but that training for an advanced-level license would not provide:

1. GIS: GIS is a powerful visualization and spatial analysis tool that aggregates, maps, and layers data. Many utilities have adopted GIS to help plan, operate, and maintain their facilities, especially if their infrastructure is distributed across a large area (e.g., a city's water distribution or sewer collection system). For example, equipping GIS skills to develop and maintain GIS databases would greatly enhance the marketability of a water professional. Not typically covered in high school, GIS certificates can be provided by 2- and 4-year institutions or readily obtained after a few GIS courses at the college level.
2. Information management and database management systems: Data acquisition, analysis, and management skills are increasingly critical to operating a facility or system of facilities. Reliance on Supervisory Control and Data Acquisition (SCADA) systems, a network of computerized systems which allow operators to control equipment remotely, is currently standard practice in facility automation. There is high demand for water workers who can perform data analytics to help enhance the technical (e.g., fine-tuning operating parameters), economic (cost-effectiveness), and environmental (carbon emissions) performance of water facilities. User-friendly tools available in today's IT world have made data analytics in the context of water utility operations much more accessible. Not typically found in high school curricula, courses on data analytics relevant to water resources management are often offered in a variety of degree plans across colleges and universities.
3. Cybersecurity: Cybersecurity threats to critical infrastructure, such as hospitals, power and water utilities, police departments, courts, schools, and local governments, are increasingly recognized as national security concerns. The Cybersecurity and Infrastructure Security Agency (CISA) has specifically identified water and wastewater infrastructure as a vulnerable target of cyberattacks. While large utilities usually have adequate resources to safeguard their cyber system, small utilities are typically ill-prepared for cyberattacks. Students can enroll in cybersecurity certificate or minor programs at colleges or universities, some of which may already have water-related programs.
4. Emerging contaminants: Water and wastewater systems are currently designed to remove "legacy" contaminants.

These are contaminants regulated by the Safe Drinking Water Act (SDWA) and the National Primary Drinking Water Regulations (NPDWR). In contrast to legacy contaminants, emerging contaminants are chemicals of concern that are not currently regulated by EPA. The Unregulated Contaminant Monitoring Rule (UCMR) empowers EPA to collect data from public water suppliers about contaminants that are suspected to be present in drinking water and do not yet have health-based standards set under the SDWA (EPA, 2015). Examples of these unregulated contaminants include compounds derived from cyanotoxins, per- and polyfluoroalkyl substances (PFAS), pesticides, pharmaceutical and personal care products (PPCPs), and industrial chemicals or processes. The ability to keep up with new knowledge on the regulatory, analytical, and treatment of these emerging contaminants is a highly desirable skill for young professionals. College-level courses are increasingly incorporating elements about emerging contaminants, such as their widespread presence, ecological and health impacts, and analytical methods. From that perspective, a minor in biology or chemistry would be a valuable addition to any water-related STEM degree.

According to Universities.com (n.d.), the United States has 48 institutions of higher education—including two community colleges—that offer degrees in hydrology and water resources. Most of these programs focus on watershed science and management. In 2019, Texas A&M University-San Antonio (A&M-SA) launched the Water Resources Science and Technology (WATR) degree program with a vision to respond to the widening workforce gap in the water supply and wastewater management industry across the country. The program offers various online degree pathways, which provides the flexibility valued by water industry managers and operators to meet the needs of the industry. The program's degree pathways include a Bachelor of Science (BS), a Bachelor of Applied Arts and Sciences (BAAS), and a Master of Science (MS). The BAAS offers an accelerated pathway for licensed operators through TCEQ. These programs align with the A&M-SA mission to develop talents and elevate the competency of practicing professionals in the water industry.

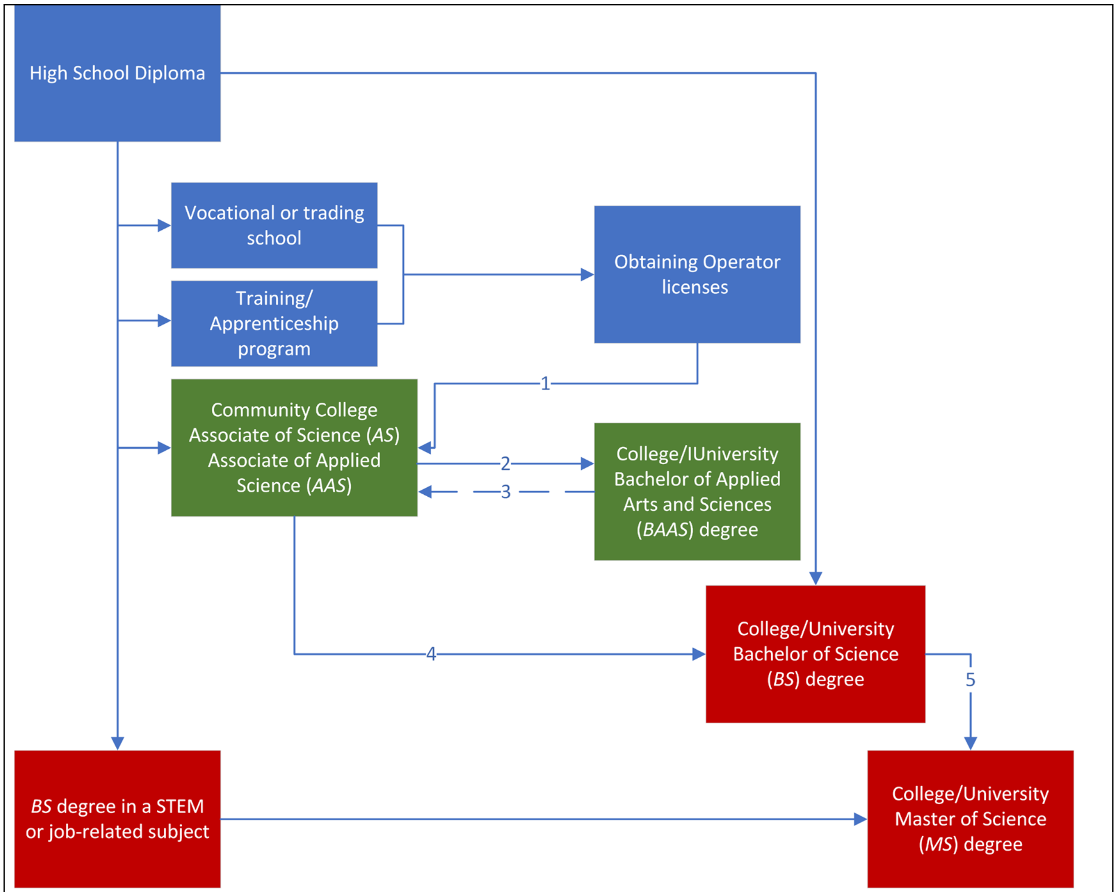
College degree attainment models are summarized in Figure 2. An individual with a high school diploma can choose either one or a combination of three pathways:

- Vocational training for professional license acquisition (Figure 2, blue boxes). This is a pathway that will build a career on licensure level and time of service. This pathway typically has the greatest likelihood that the recipient will encounter a career ceiling.
- Matriculation through a 2-year institution to earn an AS or AAS. An AAS can lead to a BAAS through limited transfer rules† (Figure 2, green boxes). This is usually considered a terminal degree. Similarly, an AS degree can lead to a BS degree (Figure 2, red boxes). This may be the most economic and flexible pathway for new and seasoned workers to earn their bachelor's degree and fast-track their career development. Furthermore, while 4-year institutions are normally reluctant to accept vocational credits for their degree requirements, a 2-year community college AAS program in water science that accepts water-related license credentials as part of its degree requirements can still shorten the time needed for students to earn a BAAS in water science and technology, should they decide to pursue one.
- Matriculation through a 4-year institution to earn a BS degree (Figure 2, red boxes). While a degree in STEM (science, technology, engineering, mathematics) fields is desirable, graduate degree programs such as those offered by A&M-SA's water resources program do not require enrolling students to have a STEM bachelor's degree, especially when a student seeks to develop a career in a nontechnical area of the water industry.

These three pathways are not mutually exclusive. For example, licensed professionals may enroll in a water-related program at a 2-year institution, eventually leading to a BAAS degree from a 4-year institution. Alternatively, an individual with a BAAS degree can reverse-transfer to a 2-year institution to fulfill the general education requirement and earn a BS degree, which can then lead to a graduate degree.

As noted by Rosen and colleagues (2018), access to a combination of distance education, extension education, mobile laboratories, competency-based education credits, industry training, community colleges, and regional universities ensure local opportunities for training and degrees for students throughout Texas. The model adopted by A&M-SA's WATR program addresses requirements for licensing and long-term employment of graduates. It includes an option for the first 2 years of academic work to be completed at a community college and the last 2 years to be completed at a 4-year degree-granting regional university. Practicing industry professionals who have completed certifications and training through industry, government, or university extension programs can earn competency-based credit toward a degree at a participating community college or university, including A&M-SA. Internships or work-study arrangements in water-related industries are compulsory for students without prior relevant experience to gain onsite training and exposure to water workforce personnel. These internships, often expected by potential employers, can lead to enhanced job placement opportunities for students.

† Some AAS courses are not granted transfer equivalency credit, nor will they fulfill the general education requirements of a bachelor's degree program. Typically, a transfer agreement between a 2-year and a 4-year institution must be established.



Notes:
1. Students with an operator license can apply for credit hour reduction based on competency and equivalency.
2. AAS degree plans contain various vocational hours that can be transferred en bloc. Licensed professionals can take advantage of this pathway via an AAS degree to eventually obtain a BAAS degree.
3. Reverse transfer is possible to complete the general education requirements for AS and BS degrees.
4. It typically takes 60 semester hours to earn an AS degree and be eligible to enter a 2+2 transfer.

Figure 2. Degree attainment pathway map for an individual with high school diploma or professional licenses to obtain a college degree in water resources.

THE CHALLENGE OF OFFERING UNIVERSITY WATER PROGRAMS

Despite the above, A&M-SA's WATR program has experienced low enrollment since its inception in 2019, especially for the BS and BAAS degree programs. Enrollment totals have hovered at around 15 students, with about five new students (first year and transfers) entering the undergraduate program each year. Enrollment at the graduate level has been slightly higher. Northwest Vista College (one of five community colleges collectively known as the Alamo Colleges) in the San Antonio area recently terminated an AAS degree program in water resource science due to persistent low enrollment.

Two issues appear as constraints:

- The study of water resources is not sufficiently visible as an academic discipline that can lead to a high-demand career. This is despite concerted efforts to incorporate water science in Texas Essential Knowledge and Skills (TEKS) for 6th–12th grade students (Rosen, 2019), including curriculum explicitly introducing water treatment-related subject matter and careers in water industries (Rosen, 2014). More should therefore be done to engage K–12 students about future careers in water. ‡
- There appears to be a misconception that working professionals without college degrees can enroll in college and

‡ TEKS water-related instruction is listed under the term "aquatic science." The water science curriculum textbook and teachers guide have been titled "Texas Aquatic Science" (TAS; Rosen, 2014). The TAS curriculum's alignments with TEKS maps water-related content across major categories of instruction in the textbook and activities in the teacher's guide (Implementation of Texas Essential Knowledge and Skills for Science, High School, 2020; Implementation of Texas Essential Knowledge and Skills for Science, Middle School, 2021).

receive immediate additional salary and career growth to justify the cost and time involved in getting a college degree. A college degree can significantly impact long-term career trajectory with greater employment opportunities and increased career advancement opportunities.

The authors recently conducted focus groups with practicing professionals in the water industry in San Antonio to gather opinions and attitudes about issues related to their work experiences. The groups included water industry workers who have held positions for less than 3 years and workers who have more than 3 years of experience. The groups also included both workers who have already earned their college degrees and workers who are still deciding whether a college degree is worth their investment. Most interviewees expressed that their motivation to enter the water industry was driven by their desire to help the environment and community, the satisfaction of seeing the effects of their work, and job security. Those who were already utility operators stated that the primary consideration in investing in earning a college degree hinged on the time they must spend earning their degrees. Many of those surveyed cited an opinion that professional licenses holders are valued as water/wastewater utility operators much more than workers with a college degree. Many also thought that the length of time to complete a college degree (at least 4–6 years) does not translate well into the time to obtain advanced-level licenses. They felt that the licenses are more valuable to their short and mid-term career advancement goals. Other factors, such as the difficulty of finding the right program, limited financial resources, and the challenge of juggling the time and financial demands of work, family, and school, were also mentioned as impediments. Interviewees who had a bachelor's degree mentioned that while a degree was not always a field requirement, they valued having it because they aspired to advance to management positions. This point of view holds whether the interviewee works in a water utility, regulatory agency, or within a municipality.

Despite future or current water workers' perceptions of the value of and impediments to attaining a college degree, they will need post-secondary education if they desire to advance to management positions at workplaces that require degrees for such jobs. Entering the workforce without college-level preparation will limit their ability to quickly or possibly ever attain managerial or upper-level role. Similarly, if a water worker decides to change direction from operation to marketing or sales, or enter another unrelated STEM career, not having a post-secondary level degree could be an impediment.

FUTURE DIRECTIONS FOR HIGHER EDUCATION

While 2-year or 4-year degree-granting programs—especially those that align their degree plans with licensing credentials—provide an excellent pathway for practicing professionals to earn a college degree, the strategy has unfortunately not been successful in attracting enough students to sustain these programs. College-level curricula should focus on marketable, transferable, technical, and soft skills relevant to water industry positions. This should include pathways for students to attain skills required by advanced-level technologists, cyber security experts, and project managers rather than only those needed by entry-level operators. This will require a recalibration of existing programs. While a successful water industry career does not require an engineering degree, developing skills in project management, GIS analysis, and at least basic cybersecurity, as well as skills in critical thinking, problem solving, effective communication, and teamwork, will better prepare graduates for effective and rewarding careers. This, in turn, will promote recruitment to and retention in the workforce.

The visibility and attractiveness of the water treatment sector remains a major concern. There is a need for greater public visibility, especially for utilities and companies that are trying to attract younger, more diverse workers. Utilities should consider expanding digital recruitment strategies, such as by improving social media use to engage prospective workers. New recruitment approaches using social media platforms could serve as effective channels to engage with Millennials (the demographic of people born after 1990s) through platforms such as Reddit, Instagram, Facebook, and YouTube. These are recruiting outlets that have not traditionally been used by the water sector. Additionally, while traditional apprenticeships remain effective in providing new workers with on-the-job training, companies need to develop robust career development programs for their employees to retain and maximize talents.

Closer collaboration of companies and utilities with academic institutions in the water sector is a win-win situation—academic institutions offer programs (degrees, certificates, credentials, etc.) desired by the industry, and employers endorse their employees' professional growth by financially supporting their education. This collaboration will help sustain both the operation of the water systems and the college educational and training programs.

Texans urgently need to maintain the integrity of the state's water supply and wastewater management systems. We will need to become more effective in recruiting high school students to enter the water workforce and provide opportunities for future water workers to have a successful and fulfilling career. Today's higher education programs need to align themselves with the need for professional development, in order to be compatible with and complement the water industry's license-heavy market. These programs could provide flexible pathways to elevate the competence of the water utility workforce and demonstrate the value of continuous education to its in-service water workers.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant No. DUE-2247898.

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Table S1. Projections from the U.S. Bureau of Labor Statistics on job growth from 2022 to 2032, categorized by water work force occupations defined in Kane and Tomer (2018). The numbers reported are averaged and presented in the thousands.

Standard Occupational Classification (SOC) code category	Employment, 2022	Employment, 2032	Employment distribution, percent, 2022	Employment distribution, percent, 2032	Employment change, numeric, 2022–2032	Employment change, percent, 2022–2032	Occupational openings, 2022–2032 annual average
Management occupations	624.4	659.5	0.4	0.4	35.1	5.3	50.6
Business and financial operations occupations	592.9	633.3	0.3	0.4	40.5	6.8	53.4
Architecture and engineering occupations	106.4	112.1	0.1	0.1	5.7	2.8	7.7
Life, physical, and social science occupations	56.6	59.3	0.0	0.0	2.8	4.3	5.6
Legal occupations	590.3	628.9	0.4	0.4	38.6	5.9	38.6
Arts, design, entertainment, sports, and media occupations	137.4	143.9	0.1	0.1	6.5	4.3	11.7
Protective service occupations	424.8	421.4	0.3	0.3	–3.4	2.1	58.1
Building and grounds cleaning and maintenance occupations	593.0	605.6	0.3	0.3	12.6	2.5	80.3
Sales and related occupations	1,137.6	1,088.9	0.7	0.7	–48.7	–0.4	151.1
Office and administrative support occupations	700.1	653.2	0.4	0.4	–46.9	–7.8	73.4
Farming, fishing, and forestry occupations	11.2	11.4	0.0	0.0	0.2	1.8	1.7
Construction and extraction occupations	198.0	202.9	0.1	0.1	4.9	0.7	17.3
Installation, maintenance, and repair occupations	257.3	267.1	0.2	0.2	9.8	2.6	23.5
Production occupations	215.3	211.9	0.1	0.1	–3.4	–3.8	21.9
Transportation and material moving occupations	535.6	565.7	0.3	0.3	30.1	3.9	65.9

* Data for some SOC codes included in the 212 professions described in the Kane and Tomer (2018) were not presented in the 2022 BLS data (BLS, 2024b), due to their removal or deletion.