ADTA 5940 Section 003

Analytics Capstone Experience

Industry / Scholarly Review and References

Analyzing Public Water Systems in California

UNIVERSITY OF NORTH TEXAS

Chapter 2: Literature Review

The study examines California's current understanding of public water systems through systematic research about geographically unequal water provisions together with system classification patterns and water origin practices and hazard assessments and operator accreditation and support programs and predictive management approaches for water systems. This review directly supports studies using the Drinking Water Watch program dataset because it includes comprehensive details about water system locations and distribution areas as well as database information on water sources and governmental regulation and certified operator profiles and past assessment reports. This review organizes available research to sustain current academic initiatives focused on developing more sustainable and equitable water systems across California.

Geographic Inequality in Water Access

The state of California faces severe water accessibility disparities across different geographic regions and community areas. A study by Deitz and Meehan (2019) located racial and geographical hot spots of water insecurity throughout U.S. households that mainly affected northern California areas which displayed high percentages of minority and low-income residents (Geographic Inequality Study). Balazs et al. (2011) established social disparities in drinking water quality through their research on the San Joaquin Valley where affected communities received excessive nitrate exposure in their water sources (Water Quality Disparities).

A combination of historical and structural elements generates these inequalities through inadequate water governance structures and insufficient funding in various regions. Wescoat et al. (2007) explained that local decision-making regarding land use together with control preferences leads to decentralized water management resulting in increased inequalities (Water and Poverty). Environment experts advocate for fairer water policies alongside committed financial investments that center on serving communities that face marginalization. According to Mack and Wrase (2017) California needs specific interventions to counter water access tolls that affect its population (Water Affordability).

Water System Types and Their Implications

The United States EPA (Environmental Protection Agency) has divided water systems into three types. The three primary classifications of California public water systems consist of Community Water Systems (CWS), Non-Transient Non-Community Water Systems (NTNCWS) and Transient Non-Community Water Systems (TNCWS) which serve unique populations that require different regulatory compliance requirements. CWSs operate throughout the year to serve constant residents but follow the strictest rules whereas NTNCWSs support continuous residents for longer than six months per year and TNCWSs provide water services to temporary residents (System Classification).

The CWSs operate with superior water quality and consistent service delivery as they serve larger residential client groups rather than smaller utilities or provisional water systems. Research by Allaire et al. (2018) indicates that CWSs experience health-based rule violations at a rate exceeding 7% each year especially since smaller systems operate with reduced technical and financial resources (Drinking Water Violations). Hanak et al. (2014) highlighted how numerous CWSs and non-community systems total about 3,000 and 5,000 respectively lead to operational inequalities because smaller systems experience difficulties in complying with regulatory standards according to California Water Economy.

Water Source Utilization and Risks

The water sources of California comprise groundwater and purchased water alongside surface water although they present unique risks during administration. The vital groundwater source in arid regions gets contaminated because of agricultural practices together with industrial waste and natural geological structures as Schaider et al. (2019) pointed out in their examination of environmental justice related to arsenic pollution in the San Joaquin Valley (Environmental Justice). Repeated extraction depletes water sources to the point where the ground beneath can lower and produce long-term sustainability issues.

Surface water sources found in rivers and lakes remain exposed to pollution which enters through urban runoff and agricultural drainage and industrial discharge. The study conducted by Hanak et al. (2014) predicted precipitation pattern shifts from climate change that will produce degraded surface water conditions with heightened risks between droughts and floods (Climate Impact Study). Water purchases present benefits, but these systems become exposed to pricing instabilities while maintaining dependency according to PPIC water use reports (Water Use Analysis).

Identifying these potential risks enables proper development of resilient water management systems. Su et al. (2009) stressed that integrated methods should be used to manage water quality because communities of color face higher exposure to pollutants (Air and Water Pollution).

Operator Certification and System Performance

Operator certification remains an essential part for maintaining public water systems safety because the U.S. Environmental Protection Agency through Operator Certification Guidelines establishes certification and re-certification requirements (Operator Certification Guidelines). The State Water Resources Control Board in California operates the operator certification program after implementing the program transfer from the California Department of Public Health in 2014 (California Program).

Research indicates that operators who are certified by proper standards demonstrate superior capabilities to follow regulatory standards which produces excellent water quality with reduced violations. The EPA (2000) established specific instructions for implementation which state that certification defines basic operational standards for maintenance procedures (Implementation Guidance). Major barriers persist in obtaining sufficient certification among operators for systems across the board with particular focus on smaller systems. AWWA (American Water Works Association) provides training resources to operators which demonstrate how their professionalism maintains clean water supply for society (AWWA Resources).

dentifying and Supporting Disadvantaged Communities

In water systems disadvantaged communities refer to populations which encounter resistance when obtaining both inexpensive yet safe dependable drinking water supplies in places where minorities and low-income residents tend to live alongside rural and unincorporated areas. According to the California State Water Resources Control Board a system qualifies as Disadvantaged Small Community Water System (DAVCS) when it fails to afford improvement costs combined with weakened economic conditions within its community (DAVCS Criteria).

Studies demonstrate that these communities require specific financing support to create solutions for water quality problems and enhance their water system structures. According to Balazs et al. (2011) nitrate-contaminated drinking water adversely affects disadvantaged communities at higher levels (Water Quality Disparities). According to Brooks et al. (2018) water accessibility has caused health disparities and urgent resolution is needed (Health Disparities). The Safe and Affordable Funding for Equity and Resilience (SAFER) initiative distributes $130 million per year which serves to support small water systems present in low-income areas while connecting with other governmental funding programs (SAFER Initiative).

Predictive Modeling in Water System Management

The water system management sector adopts predictive modeling that utilizes data science methods together with machine learning tools to forecast system breakdowns and population changes along with compliance challenges. Predictive analytics stands as the standard approach to water main management according to BlueConduit (2023) since it evaluates both failure risk and impact potential for proactive resource allocation (Predictive Analytics). The paper by Lim (2023) reveals how agencies use predictive systems to monitor water while tracking the modifications in river elevation over time (Water Monitoring).

Predictive modeling proves essential for California utilities through its utility in identifying vulnerable assets and scheduling maintenance operations as well as forecasting water consumption projections. The paper titled Water Quality Modeling and Prediction (2017) presented its application as a method to forecast upcoming water quality states under different management approaches including new wastewater treatment plants (Modeling and Prediction). The study conducted by Khadr (2016) proved how the method generates accurate water quality simulations which qualify it for in-situ assessments (Case Study). The approach helps managers detect water quality inequities before they happen and promotes proactive strategies to reduce these flaws in water quality.

Complex modeling tools help California manage its water system by forecasting how wastewater connections impact groundwater and surface water relationships. Water resources in California undergo different hydrological modeling approaches for analysis through the California Department of Water Resources (Hanak & Chappelle, 2025). Simulation models allow utilities to study how population increases, climate change uncertainty and drought impact the water control infrastructure in California. The Arizona Water Quality Monitoring Program utilizes these models for water quality trend monitoring and future contamination risk predictions, as Archer et al. (2024) described. Predictive analytics systems at an advanced level must integrate with water management systems because they address current problems while forecasting future resource needs. Implementing predictive modeling becomes essential for California because it predicts water supply availability and upholds equal resource access across drought, urbanization, and climate change effects.

Summary

The extensive review explains how California faces numerous challenges in public water system management that calls for a combination of disciplinary expertise. The document analyzes location-based inequalities together with variations between different system types and identifies specific water source challenges while emphasizing operator certification requirements and providing support for underprivileged communities and leveraging predictive modeling methods in the field. Stakeholders can create better strategies to provide equal access to safe drinking water by combining these aspects while their ongoing sustainability research strengthens with such collaborative efforts.

References

Allaire, M., Wu, H., & Lall, U. (2018). National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences*, *115*(9), 2078–2083. https://doi.org/10.1073/pnas.1719805115

American Water Works Association. (n.d.). *Operators*. Retrieved from https://www.awwa.org/operators/

Balazs, C., Morello-Frosch, R., Hubbard, A., & Ray, I. (2011). Social disparities in nitrate-contaminated drinking water in California's San Joaquin Valley. *Environmental Health Perspectives*, *119*(9), 1272–1278. https://doi.org/10.1289/ehp.1002878

BlueConduit. (2023, March 14). *Why predictive analytics is the future of water main risk management*. Retrieved from https://blueconduit.com/post/why-predictive-analytics-is-the-future-of-water-main-risk-management/

Brooks, C. J., Gortmaker, S. L., Long, M. W., Cradock, A. L., & Kenney, E. L. (2017). Racial/Ethnic and Socioeconomic Disparities in Hydration Status Among US Adults and the Role of Tap Water and Other Beverage Intake. American journal of public health, 107(9), 1387–1394. https://doi.org/10.2105/AJPH.2017.303923

California State Water Resources Control Board. (n.d.). *California drinking water systems*. Retried from https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/california_water_systems.html

California State Water Resources Control Board. (2023). *Operator certification program*. Retrieved from https://www.waterboards.ca.gov/water_issues/programs/operator_certification/

California Water Blog. (2022, January 23). *Who governs California's drinking water systems?* Retrieved from https://californiawaterblog.com/2022/01/23/who-governs-californias-drinking-water-systems/

K. Meehan, J.R. Jurjevich, N.M.J.W. Chun, & J. Sherrill, Geographies of insecure water access and the housing–water nexus in US cities, Proc. Natl. Acad. Sci. U.S.A. 117 (46) 28700-28707, https://doi.org/10.1073/pnas.2007361117

Hanak, E., Lund, J., Dinar, A., Gray, B., Howitt, R., Mount, J., Moyle, P., & Thompson, B. (2014). *Water and the California economy*. Public Policy Institute of California. Retrieved from https://www.ppic.org/publication/water-and-the-california-economy/

Khadr, M. (2016). Water quality prediction using data-driven models: A case study. *Egyptian Journal of Aquatic Research*, *42*(4), 447–452. https://doi.org/10.1016/j.ejar.2016.09.004

Lim, S. (2023, April 12). *Predictive analytics in water monitoring*. Aquatic Informatics. Retrieved from https://aquaticinformatics.com/blog/hydrology/predictive-analytics-in-water-monitoring/

Mack, E. A., & Wrase, S. (2017). A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States. *PLOS ONE*, *12*(1), e0169488. https://doi.org/10.1371/journal.pone.0169488

Public Policy Institute of California. (2021). *Paying for California's water system*. Retrieved from https://www.ppic.org/publication/paying-for-californias-water-system/

Public Policy Institute of California. (n.d.). *Water use in California*. Retrieved from https://www.ppic.org/publication/water-use-in-california/

Schaider, L.A., Swetschinski, L., Campbell, C. *et al.* Environmental justice and drinking water quality: are there socioeconomic disparities in nitrate levels in U.S. drinking water? *Environ Health* **18**, 3 (2019). https://doi.org/10.1186/s12940-018-0442-6

U.S. Environmental Protection Agency. (2000). *Implementation guidance for the operator certification program*. Retrieved from https://www.epa.gov/sites/default/files/2015-11/documents/operator_certification_guidelines_-_implementation_guidance.pdf

U.S. Environmental Protection Agency. (n.d.). *About operator certification*. Retrieved from https://www.epa.gov/dwcapacity/about-operator-certification

Water Quality Modeling and Prediction. (2017). Water quality modeling and prediction. In M. B. Abbott & J. A. Cunge (Eds.), *Engineering hydrology today* (pp. 179–198). Springer. https://doi.org/10.1007/978-3-319-44234-1_10

Wescoat, J. L., Headington, L., & Theobald, R. (2007). Water and poverty in the United States. *Geoforum*, *38*(5), 801–814. https://doi.org/10.1016/j.geoforum.2006.08.007

Wikipedia (n.d.). *Water in California*. From https://en.wikipedia.org/wiki/Water_in_California

Shams, M.Y., Elshewey, A.M., El-kenawy, ES.M. *et al.* Water quality prediction using machine learning models based on grid search method. *Multimed Tools Appl* **83**, 35307–35334 (2024). https://doi.org/10.1007/s11042-023-16737-4

United States Environmental Protection Agency (n.d.). Information about public water systems. U.S. Environmental Protection Agency. https://www.epa.gov/dwreginfo/information-about-public-water-systems

Hanak, E., & Chappelle, C. (2025). California's Water Quality Challenges - Public Policy Institute of California. Public Policy Institute of California. https://www.ppic.org/publication/californias-water-quality-challenges/

Archer, H., Morello Frosch, R., Pace, C., Baehner, L., & Cushing, L. (2024, August). Drinking water arsenic contamination and COVID-19 outcomes in California, USA. In ISEE Conference Abstracts (Vol. 2024, No. 1). https://ehp.niehs.nih.gov/doi/abs/10.1289/isee.2024.0141