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Articles

Key Investigators of the Binational Hueco Bolson Aquifer: 1897 to 2025

Investigadores Clave del Acuífero Binacional del Bolsón del Hueco: 1897 a 2025

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Abstract

The basin fill aquifer that spans the international boundary in the Paso del Norte region has been the focus of more than a century of scientific and technical work carried out by notable investigators in both the United States and Mexico. Their collective efforts responded to chronic water shortages, early dependence on groundwater, and the need to understand the behavior of a complex sediment-filled basin with limited natural recharge. As surface water supplies fluctuated, communities increasingly relied on groundwater, prompting the decline of freshwater zones and the recognition that better information on aquifer structure, recharge, and long-term availability was essential. Researchers from both countries

advanced this understanding by mapping basin geometry, assessing freshwater and saline-water distributions, and evaluating the relationship between the river and the underlying aquifer. Their work introduced quantitative field methods, developed early regional models, and later incorporated isotopic tracers, detailed stratigraphic studies, and numerical simulations that clarified the evolution and movement of groundwater. This paper profiles the most influential contributors from the United States and Mexico whose work collectively shaped modern interpretations of the aquifer. Their investigations created the scientific foundation used today to evaluate depletion trends, identify recharge pathways, plan managed aquifer recharge, and design brackish water recovery and desalination projects. The accumulated record of these binational efforts now provides a comprehensive framework for interpreting basin processes and supporting cooperative planning for a region that depends heavily on a shared and vulnerable groundwater resource.

Key Words: groundwater, aquifers, basins, water resources management, water supply, transboundary groundwaters, history of science, USA, Mexico.

Resumen

El acuífero de relleno de cuenca que se extiende a través de la frontera internacional en la región del Paso del Norte ha sido objeto de más de un siglo de trabajo científico y técnico realizado por destacados investigadores tanto en Estados Unidos como en México. Sus esfuerzos colectivos respondieron a la escasez crónica de agua, a la dependencia temprana del agua subterránea y a la necesidad de comprender el

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comportamiento de una cuenca sedimentaria compleja con recarga natural limitada. A medida que las fuentes de agua superficial fluctuaban, las comunidades dependieron cada vez más del agua subterránea, lo que provocó el abatimiento de las zonas de agua dulce y el reconocimiento de que era esencial contar con mejor información sobre la estructura del acuífero, la recarga y la disponibilidad a largo plazo. Investigadores de ambos países avanzaron este conocimiento mediante el mapeo de la geometría de la cuenca, la evaluación de la distribución de agua dulce y salina, y el análisis de la relación entre el río y el acuífero subyacente. Su trabajo introdujo métodos cuantitativos de campo, desarrolló modelos regionales iniciales y posteriormente incorporó trazadores isotópicos, estudios estratigráficos detallados y simulaciones numéricas que permitieron esclarecer la evolución y el movimiento del agua subterránea. Este artículo presenta a los contribuyentes más influyentes de Estados Unidos y México, cuyo trabajo en conjunto dio forma a las interpretaciones modernas del acuífero. Sus investigaciones establecieron la base científica que hoy se utiliza para evaluar tendencias de abatimiento, identificar vías de recarga, planificar la recarga gestionada de acuíferos y diseñar proyectos de recuperación de agua salobre y desalación. El conjunto acumulado de estos esfuerzos binacionales proporciona ahora un marco integral para interpretar los procesos de la cuenca y apoyar la planificación cooperativa en una región que depende en gran medida de un recurso de agua subterránea compartido y vulnerable.

Palabras clave: agua subterránea, capa acuífera, cuenca, gestión de los recursos hídricos, abastecimiento de agua, aguas transfronterizas, historia de la ciencia, Estados Unidos, México.

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1. Introduction

The Hueco Bolson is a broad Tertiary to Quaternary basin-fill aquifer system spanning the U.S.–México border and has long been central to water security in the Paso del Norte region. Its geologic complexity, early municipal dependence, and unique binational management context drew multiple generations of engineers and scientists whose work shaped modern understanding of this transboundary aquifer.

The basin fill consists of heterogeneous sediments derived from ancestral Rio Grande systems and erosion of surrounding uplands (Figure 1). These deposits form the principal water-bearing strata beneath El Paso, Texas, and Ciudad Juárez, Mexico. Fresh groundwater is concentrated along the Organ and Franklin Mountains and the Sierra Juárez, while central and eastern areas contain slightly saline water with limited freshwater pockets to the southeast (Audsley, 1959; Henry & Gluck, 1981). The Hueco Bolson is hydraulically connected to the Rio Grande alluvial aquifer through the floodplain, drains, and irrigation canals, except where channel lining restricts seepage (Land & Armstrong, 1985; Hutchison and Hibbs, 2008; Eastoe et al., 2010; White et al., 1997). This interconnected system made cross-border hydrogeologic data essential for understanding groundwater availability and movement.

Modern water development began in the late nineteenth century, when the Rio Grande frequently dried at the El Paso Narrows, leaving

farms in the Juárez Valley without reliable irrigation water (Sayre & Livingston, 1945; USBR, 1973). These shortages contributed to diplomatic tensions and ultimately to the 1906 Treaty, which guaranteed Mexico 60,000 acre-feet per year (74 Mm^3/yr), reduced proportionally during drought. The completion of the Elephant Butte Reservoir (1916) and the Caballo Reservoir (1938) stabilized flows and enabled the Rio Grande Project, providing regulated surface-water deliveries to irrigated lands in both countries (USBR, 1973; Bluntzer, 1975). These supplies were primarily reserved for agriculture, leaving municipal users, particularly in Ciudad Juárez, with little access to river water.

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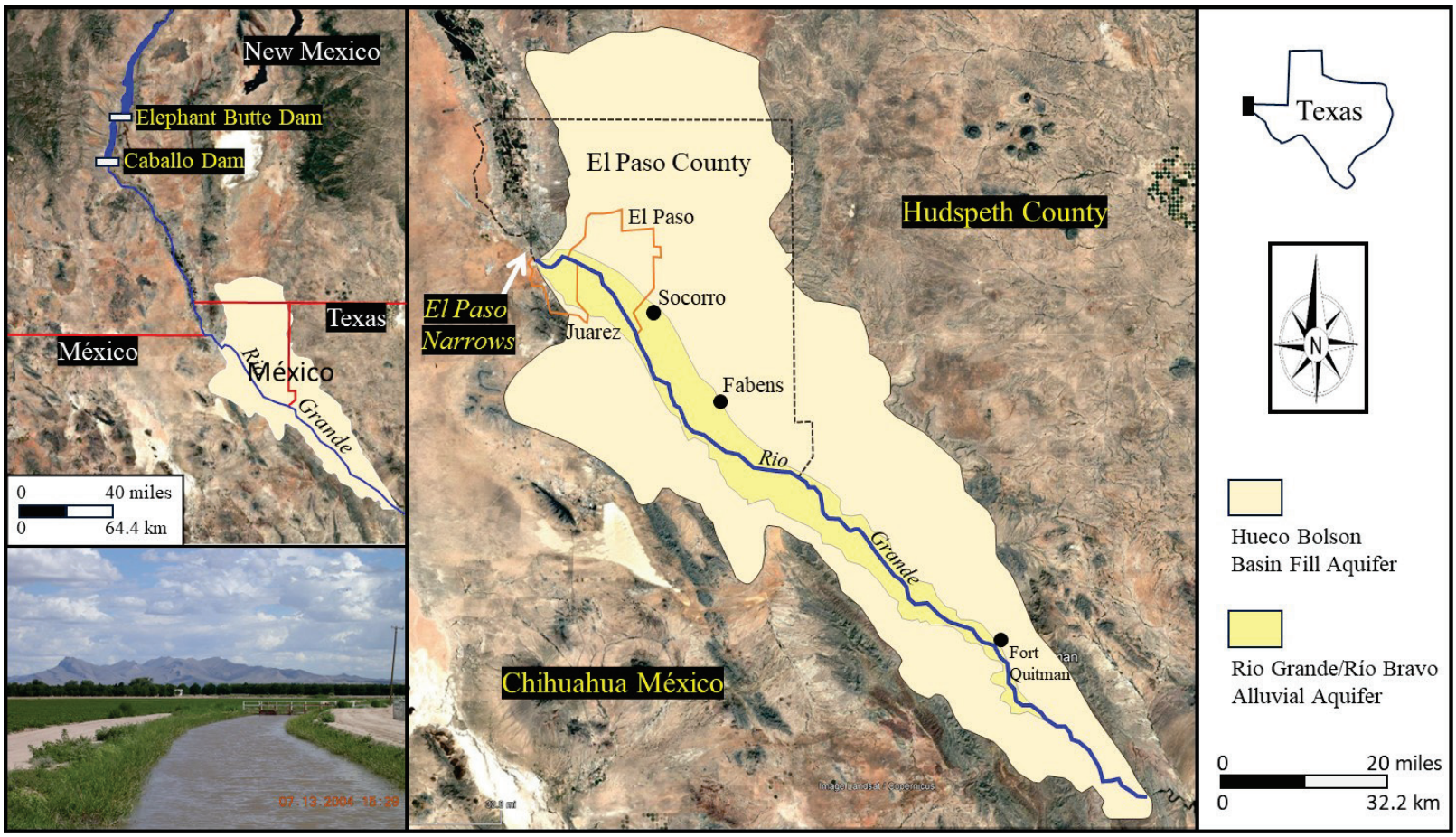

Figure 1. Basin fill in the Hueco Bolson consists of heterogeneous sediments derived from ancestral Rio Grande systems and erosion of surrounding uplands. These deposits form the primary water-bearing strata beneath El Paso, Texas, and Ciudad Juárez, Mexico.

Cities therefore turned increasingly to the Hueco Bolson aquifer. El Paso began pumping groundwater in 1892 and by the early twentieth century had committed to the bolson as its primary supply, expanding wellfields around the Mesa and Montana areas (Slichter, 1905a; Sayre & Livingston, 1945). By the 1920s, the city relied almost entirely on groundwater. Limited surface water rights acquired in the 1940s

increased Rio Grande use to 10 to 15% of annual demand by the 1970s and roughly 40% today (Bluntzer, 1975; El Paso Water, 2021).

Ciudad Juárez, whose 1906 Treaty allocation was committed to agriculture, became dependent on Hueco Bolson groundwater beginning in 1925. Rapid population growth, from 8,218 in 1900 to nearly 40,000 by 1930 (Roman, 2003), accelerated well development. Severe drought in the 1950s further increased pumping, with irrigation wells in the Juárez Valley expanding from one in 1935 to at least 470 by 1955 (de la O Carreño, 1957b). As extraction intensified on both sides of the border, declining water levels and increasing salinity underscored the need for more comprehensive hydrogeologic data.

Because the aquifer is continuous across the international boundary, neither country could plan sustainably without access to the other's data. Periods of accelerated binational cooperation, driven by groundwater modeling needs, treaty obligations, and rapid urban growth, became defining features of Hueco Bolson management and were later formalized through initiatives associated with the Rio Grande Environmental Research Project, NAFTA-era programs, and the Transboundary Aquifer Assessment Act.

By the late 1990s and early 2000s, numerical groundwater models, isotopic tracing studies, managed aquifer recharge projects, interbasin transfers supplying Ciudad Juárez, and large-scale desalination efforts transformed understanding of the Hueco Bolson. Against this backdrop, the contributions of the engineers, hydrologists, and groundwater specialists profiled below became indispensable, emerging directly from the basin's hydrogeologic complexity, municipal dependence, and the growing need for rigorous binational groundwater science.

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1.1. Key Historical Figures

This paper documents more than a century of work by hydrogeologists, geologists, engineers, and water-resource managers whose collective efforts shaped modern understanding of the Hueco Bolson. Investigations are broadly divided into an early period (1897 to 1960), a middle period (1960 to 1985), and a late period (1985 to 2025).

The earliest foundations were established by Charles Slichter, whose turn of the century measurements of groundwater underflow introduced quantitative methods applicable to the Hueco Bolson, and by Albert Sayre, whose pre- and post-World War II investigations provided the first rigorous hydrogeologic framework for the El Paso area. Mid-twentieth century contributions by Frank A. Scalapino, David Herrera Jordan, and Alfonso de la O Carreño refined basin geometry, aquifer properties, and early management concepts.

During the middle period, Rubén Chávez Guillén, Edward Leggat, and Thomas Cliett conducted detailed analyses using improved hydrogeologic mapping and monitoring methods. At the same time, Dr. William Strain's stratigraphic work on the Camp Rice and related formations supplied the geologic framework needed to distinguish permeable ancestral Rio Grande deposits from less transmissive bolson sediments. Subsequent investigators, including Robert Bluntzer, Henry Alvarez, Donald White, William Meyer, and the engineering team of C.I.E.P.S., expanded datasets, developed early digital models, and produced comprehensive groundwater and irrigation assessments.

From the mid-1980s to the present, a new generation of scientific and institutional leaders, including John B. Ashworth, Edmund G.

Archuleta, Luis Antonio Rascón Mendoza, Zhuping Sheng, Alfredo Granados Olivas, William Hutchison, and Chris Eastoe, integrated stratigraphy, isotopes, numerical modeling, desalination, and managed aquifer recharge into a coherent binational framework. Dr. John Hawley, active from the 1960s through 2014, provided stratigraphic and geomorphic reconstructions that remain central to modern interpretations.

Many additional contributors added critical elements at various scales and time periods. Together, those profiled here represent a cumulative transboundary effort that produced today's understanding of the Hueco Bolson. Their collective work continues to guide water resource development, international cooperation, and long term sustainability planning.

2. Methodology

The author has developed extensive biographical documentation on these contributors as part of a longstanding professional interest in the history of groundwater science in the region. The research draws upon rare and, in some cases, uniquely preserved historical documents, including translated reports by Alfonso de la O Carreño and archival materials produced by C.I.E.P.S., which are not widely available. The literature base also includes unpublished internal memoranda, government reports, peer-reviewed articles, and consulting reports. Together, these sources provide critical primary data for reconstructing the biographical history of key contributors to Hueco Bolson hydrogeology. The author's prior work in the region, including multiple peer-reviewed publications, reflects extensive familiarity with both the scientific literature and the broader

historical framework of groundwater investigations in the basin. In addition, the author has direct professional knowledge of, and collegial relationships with, many of the scientists and engineers active during the middle and modern periods, further supporting the accuracy and contextual depth of the biographical sketches.

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2.1. Early Period (1897–1960)

Figure 2. Upper row left to right, Charles Slichter, Albert Sayre, David Herrera Jordan. Lower figure, left to right, Left to right: Alfonso de la O Carreño; Jenaro Paz Reyes; and Ulrich Hungsberg. Photo sources are listed in the section entitled Photo Credits and Acknowledgments, before the references.

2.1.1. Charles S. Slichter

Charles S. Slichter was a pioneering hydrologist whose work laid the quantitative foundation for groundwater investigations in alluvial basin aquifers such as the Hueco Bolson. Trained as a mathematician at Cornell University and Northwestern University, he was among the first scientists to systematically quantify groundwater movement using field instrumentation. As a consulting engineer for the U.S. Geological Survey, Slichter conducted extensive studies of groundwater underflow in major valley fill aquifers, including those of the Rio Grande region. His most influential contribution was the development of electrical and chemical tracer techniques to measure groundwater velocity directly in wells. Described in publications between 1899 and 1906, these experiments used ammonium chloride injections and electrical detection of chloride pulses and represent early precursors to modern automated monitoring methods. Slichter's 1905a investigation of groundwater in the Rio Grande Valley provided some of the earliest quantitative insights into basin underflow and transmissivity, concepts directly applicable to the Hueco Bolson. His approaches to measuring gradients, characterizing transmissive sediments, and evaluating underflow beneath ephemeral channels influenced later USGS and Reclamation Service investigations and helped establish the Hueco Bolson as a municipal aquifer for El Paso and Ciudad Juárez. Selected pertinent references of his work includes Slichter (1899, 1902, 1905a; 1905b).

2.1.2. Albert N. Sayre

Albert N. Sayre was among the most influential early hydrogeologists to investigate the Hueco Bolson. After earning his Ph.D. in 1928, he joined the USGS Ground Water Branch and conducted extensive pre- and post-World War II studies of Texas aquifers, including the El Paso area.

His collaboration with Penn Livingston produced *The Ground-Water Resources of the El Paso Area* (1937, 1945), the first rigorous analyses of Hueco Bolson hydrostratigraphy, recharge, water chemistry, and sustainable yield. Sayre recognized the aquifer as a thick, coarse- grained basin fill system with limited natural recharge and strong transboundary linkages to Ciudad Juárez' concepts that remain foundational. During World War II, Sayre served in the USGS Military Geology Branch, expanding his expertise in groundwater supply under difficult conditions. After the war, he became Chief of the USGS Ground Water Branch, influencing national groundwater research priorities and supporting later studies in the Paso del Norte region. Selected references of his work includes Sayre and Livingston (1937, 1945).

2.1.3. David Herrera Jordan

David Herrera Jordan served as Mexican Commissioner of the International Boundary and Water Commission (CILA/IBWC) from 1947 to 1979 and played a central role in mid-twentieth-century binational water management in the El Paso–Ciudad Juárez region. His tenure coincided with rapid urban growth, rising water demand, and increasing diplomatic complexity. Herrera Jordan's work centered on implementation of the 1944 Water Treaty governing the Río Grande, including irrigation

deliveries, drought-time shortages, and flood-control infrastructure. He was instrumental in the diplomatic and technical processes leading to resolution of the Chamizal boundary dispute in 1963, relying on sustained cooperation with U.S. counterparts. Although IBWC authority focused on surface water treaty obligations, Herrera Jordan recognized growing groundwater depletion in the Hueco Bolson. He participated in binational discussions addressing the interdependence of river flows and declining aquifer reserves and conducted field reconnaissance in the Juárez Valley with Alfonso de la O Carreño. His leadership helped establish the principle that sustainable border region water management must integrate both surface water and groundwater. Selected references of his work includes Comisión Internacional de Límites y Aguas (1954); International Boundary and Water Commission (1958, 1965).

2.1.4. Alfonso de la O Carreño

Alfonso de la O Carreño was one of Mexico's most accomplished mid-century hydrogeologists, and his work in the Juárez Valley represents some of the earliest rigorous analyses of the Mexican portion of the Hueco Bolson. As Chief of the Bureau of Geology of the National Irrigation Commission and professor at UNAM, he integrated geophysics, geology, and field hydrology in a series of influential studies (1957a, 1957b, 1958). De la O Carreño conducted nearly all field reconnaissance himself, mapping well locations, correcting spatial errors, and inspecting outcrops and drill cuttings. His critiques of earlier data significantly improved aquifer characterization. His studies documented basin fill geometry, freshwater and saline water distribution, and structural controls on groundwater flow, providing essential insight into the transboundary

aquifer system. His broader scientific work, including publications on gravity anomalies, geohydrologic provinces, and electrical methods, advanced basin interpretation across northern Mexico. Despite limited circulation, his Juárez Valley studies remain critical to understanding the Mexican side of the Hueco Bolson. Selected references of his work includes De la O Carreño (1957a, 1957b, 1958).

2.2. Middle Period (1960–1985)

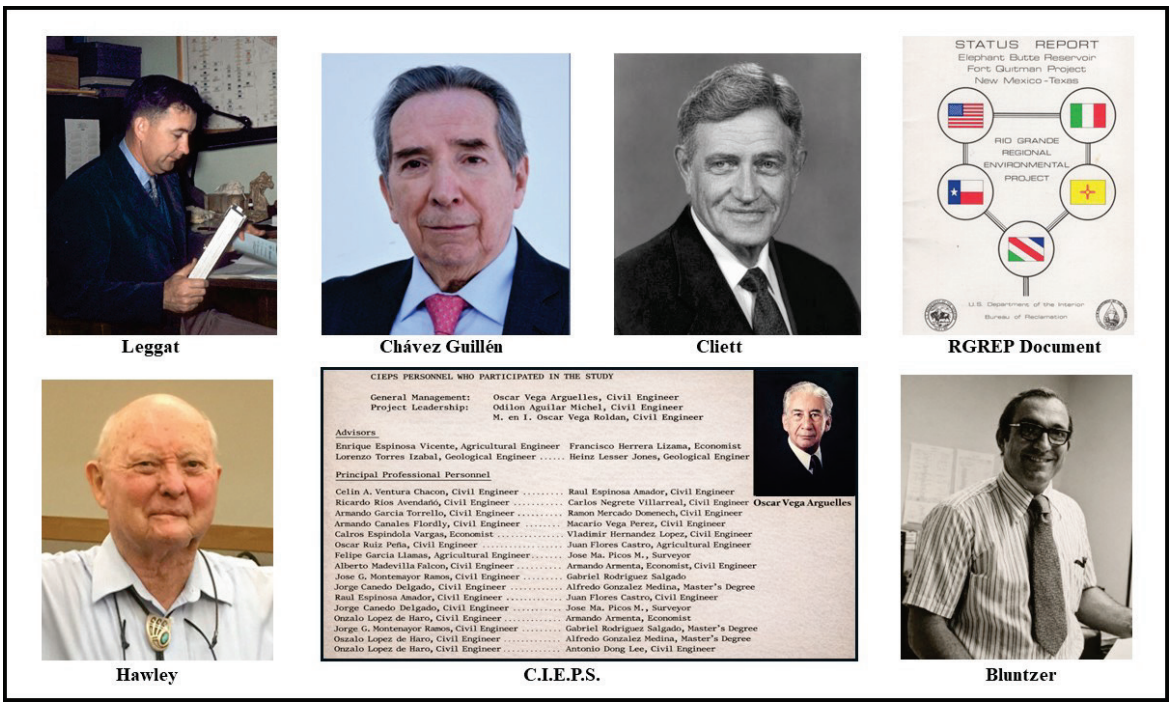

Figure 3. Upper row left to right, Edward Leggat, Rubén Chávez Guillén, Thomas Cliett, Rio Grande Regional Environment Project (RGREP) document cover. Lower row left to right, John Hawley, C.I.E.P.S. cover page from 1970 report, Robert Bluntzer. Not pictured, Donald White, Henry Alvarez, William Meyer, William Strain. Photo sources are listed in the section entitled Photo Credits and Acknowledgments, before the references.

2.2.1. Edward R. Leggat

Edward R. Leggat was a central figure in mid-twentieth century groundwater investigations in the Paso del Norte region, contributing essential assessments of both the Hueco and Mesilla Bolsons. Working with the Texas Water Commission and later the Texas Water Development Board, he documented aquifer behavior during a period of rapid pumping expansion in El Paso and Ciudad Juárez. His progress report *Development of Ground Water in the El Paso District, 1955–60* (1962) analyzed production trends, water-level declines, and aquifer responses during the early stages of large-scale municipal extraction. This work provided some of the first quantitative documentation of drawdown patterns in the Hueco Bolson and highlighted the vulnerability of the freshwater zone to over-pumping. Leggat also co-authored key studies of the lower Mesilla Valley aquifer system and collaborated with M.E. Davis on early analog model investigations of the Hueco Bolson (1967). These studies were important precursors to numerical modeling, helping define transmissivity distributions, freshwater depth, and potential future declines later refined by Meyer (1976) and subsequent modelers. Selected references of his work includes Leggat (1962); Leggat et al. (1962); Leggat and Davis (1967).

2.2.2. Rubén Chávez Guillén

Rubén Chávez Guillén was a long-time contributor to groundwater science and governance in northern Mexico, with work frequently intersecting the Hueco Bolson and adjacent transboundary aquifer systems affecting El Paso and Ciudad Juárez. He held a master's degree in hydraulics and

engineering from UNAM and worked from 1968 to 2018 within Mexico's federal water agencies, including SRH, SARH, and CONAGUA. As Director of the Office of Groundwater at CONAGUA, Chávez Guillén oversaw technical programs supporting scientific understanding of border-region aquifers, including the Conejos–Médanos and Bolsón del Hueco systems. He coordinated Mexico's participation in the ISARM initiative and contributed to binational studies addressing groundwater flow, recharge, and long-term sustainability relevant to the Hueco region. In addition to his technical work, Chávez Guillén taught hydrogeology at UNAM and other institutions. He is best recognized for strengthening groundwater governance and binational coordination, facilitating data exchange and regulatory context critical to shared aquifer management. Selected references of his work include Chávez Guillén (1976, 1981, 1984).

2.2.3. Thomas E. Cliett

Thomas E. "Tom" Cliett was a prominent geologist whose work had a lasting impact on groundwater management in the El Paso region. He earned his geology degree from Texas Western College (now UTEP) in 1958 and spent more than three decades as a groundwater geologist for El Paso Water Utilities. Cliett's work focused on the Hueco and Mesilla Bolsons. His 1969 report, *Ground-water Occurrence of the El Paso Area and Its Related Geology*, became an important reference for regional groundwater studies. He also collaborated with the USGS and Texas Water Development Board, helping compile and interpret critical groundwater datasets. Beyond technical studies, Cliett contributed to broader planning initiatives addressing artificial recharge, sustainable yield, and cross-border cooperation. After retirement, he continued

consulting on well design and groundwater development, reinforcing the long-standing emphasis on scientifically informed water management in El Paso. Selected references of his work includes Cliett (1969); Cliett and Hawley (1996); Knorr and Cliett (1985)

2.2.4. Dr. William S. Strain

Dr. William S. Strain, longtime UTEP geology professor and distinguished stratigrapher, made important contributions to the geologic framework underlying Hueco Bolson hydrogeology. Although best known for paleontological work, his greatest influence on groundwater science came through definition of the upper Santa Fe Group, particularly the Pliocene–Pleistocene Camp Rice Formation. Strain's field studies in the southeastern Hueco Bolson established type localities for the Camp Rice and Fort Hancock Formations. He demonstrated that Camp Rice deposits represent ancestral Rio Grande fluvial systems characterized by laterally extensive sand and gravel bodies with higher transmissivity than underlying bolson sediments, critical for identifying freshwater-bearing units. By documenting key chronostratigraphic markers, including Yellowstone derived ash beds, Strain enabled correlation of permeable basin-fill units across the international boundary. His work remains central to modern interpretations of transmissivity, freshwater saline water interactions, brackish water migration, and managed aquifer recharge potential in the Hueco Bolson. Selected references of his work include Strain (1966, 1970, 1971).

2.2.5. Donald E. White

Donald E. White of the U.S. Geological Survey played a major role in synthesizing the first 75 years of hydrologic information for the El Paso–Juárez region. His compilation, *Summary of Hydrologic Information in the El Paso Area, 1903–80* (1983), remains an indispensable reference for understanding long-term groundwater trends and aquifer development. White assembled decades of pumping records, water level data, water quality trends, drilling logs, and earlier investigations into a coherent historical framework. His analysis documented early warnings of limited recharge and accelerating depletion, as well as the transition from shallow freshwater production to deeper, more brackish zones. This synthesis directly influenced later USGS studies and binational investigations, providing the historical baseline for numerical modeling, desalination planning, and groundwater-quality assessment in the Hueco Bolson. Selected references of his work include Gates et al. (1980), White (1983), White et al. (1997)

2.2.6. Dr. John W. Hawley

Dr. John W. Hawley is one of the most influential geologists shaping modern understanding of the Hueco Bolson and adjacent basin systems. Over a career spanning more than five decades, he integrated stratigraphy, geomorphology, and basin-fill architecture to develop hydrogeologic frameworks used in nearly all contemporary studies of the region. Through collaborations with J.F. Kennedy, A. Granados Olivas, M.A. Ortiz, and others, Hawley defined the internal architecture of alluvial, lacustrine, and piedmont deposits governing groundwater storage and flow. His work included the *Hydrogeologic Framework of the Binational Western Hueco Bolson - Paso del Norte Area* (2009), one of the most

comprehensive characterizations of basin structure and hydrologic boundaries. Hawley's field reconnaissance, particularly mapping ancestral Rio Grande channels entering the Hueco Bolson provided critical evidence for paleo-recharge pathways. His work forms the geologic foundation for modern hydrologic, isotopic, and numerical modeling of the Hueco Bolson. Selected references of his work include Hawley et al. (1969, 2009, 2025).

2.2.7. C.I.E.P.S.

The C.I.E.P.S. study (1970) of the Juárez Valley Irrigation District stands as one of the most comprehensive groundwater and irrigation assessments produced for northern Mexico. Unlike other profiles in this paper, it is presented as a collective effort reflecting its scope, workforce, and technical sophistication. C.I.E.P.S. (Consultoría, Ingeniería, Estudios, Proyectos y Supervisión) was a multidisciplinary engineering firm capable of integrated field investigation, hydraulic modeling, engineering design, economic analysis, and project supervision. Its Juárez Valley study examined a 140-km reach of irrigated land along the Rio Grande, documenting crop patterns, groundwater extraction, surface water use, and irrigation efficiency across nearly 15,000 hectares. Led by General Manager Óscar Vega Argüelles, the project produced a landmark report whose clarity and rigor shaped groundwater and irrigation planning in the Juárez Valley for decades. Their work includes C.I.E.P.S. (1970).

2.2.8. Robert L. Bluntzer

Robert L. Bluntzer played a pivotal role in preserving and organizing transboundary groundwater data during a critical period of Hueco Bolson

development. After earning a geology degree from the University of Texas in 1960, he joined the Texas Water Commission and later rose to head the Water Level Division. Bluntzer was a principal figure in the Rio Grande Regional Environmental Project and the Texas - Mexico groundwater data exchange program (Buckner et al., 1976). His work ensured that Mexican well records, water-level measurements, and chemical analyses were preserved and incorporated into Meyer's (1976) digital model and later binational databases. He documented early binational cooperation in *Water Supply Problems in the El Paso Area, Texas* (1975b) and compiled widely used Ciudad Juárez groundwater datasets (1975a). His work remains foundational to modern transboundary modeling and water-management planning. Selected references of his work include Bluntzer (1975a, 1975b).

2.2.9. Henry J. Alvarez

Henry J. Alvarez was a key figure in groundwater monitoring and modeling for the El Paso–Ciudad Juárez region during the 1970s and early 1980s. As a hydrogeologist with the Texas Water Development Board, he led statewide water level and water quality monitoring programs and contributed directly to understanding Hueco Bolson conditions. His co-authored report with Buckner, *Groundwater Resources of the El Paso Valley, Texas* (1975; expanded 1980), compiled critical well, hydrochemical, and aquifer data used in regional planning. Alvarez also helped document the groundwater data exchange program with Mexico and co-authored the influential pumping simulation with Knowles (1979), projecting impacts through 2029. These studies shaped decades of water resource planning and articulated the risks of continued aquifer depletion

in the transboundary Hueco Bolson. Selected references for his work include Knowles and Alvarez (1979); Alvarez and Buckner (1980).

2.2.10. William R. Meyer

William R. Meyer served as a hydrologist with the USGS and made major contributions to quantitative groundwater analysis in the Hueco Bolson. His cooperative studies with the City of El Paso and TWDB compiled water budgets, aquifer characteristics, and withdrawal impacts. Meyer's most significant contribution was preparation of the first digital groundwater-flow model of the Hueco Bolson (1976). This pioneering effort documented aquifer geometry, hydraulic parameters, and historical pumping and simulated future declines. The model formed the foundation for all subsequent numerical modeling in the region and supported development of a binational database under the RGREP. Selected references of his work includes Meyer and Gordon (1973); Meyer (1976).

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2.3. Late Period (1985–2025)

Figure 4. Upper row left to right, John Ashworth, Edmund Archuleta, Luis Antonio Rascón Mendoza. Bottom row, left to right, Zhuping Sheng, William Hutchison, Alfredo Granados Olivas, Chris Eastoe. Photo sources are listed in the section entitled Photo Credits and Acknowledgments, before the references.

2.3.1. John B. Ashworth

John B. Ashworth is a Texas-based hydrogeologist who made important contributions to understanding the Hueco Bolson and related transboundary aquifers of West Texas. During his tenure at the Texas Water Development Board (TWDB), he authored major groundwater assessments, including *Evaluation of Groundwater Resources in El Paso County* (1990), *Public Supply Ground-Water Use in Western Texas*

(Ashworth, 1989), and *Aquifers of West Texas* (1995, with Hopkins). These publications updated hydrostratigraphy, pumping histories, and water quality trends critical to modern Hueco Bolson management. Ashworth initially served as head of the U.S. delegation for the first formal binational effort to compile a shared Hueco Bolson dataset, culminating in the *Transboundary Aquifers and Binational Ground-Water Data Base* (1998). This effort established an official cooperative framework that allowed regional groundwater models to incorporate data from both countries. After retiring from TWDB, Ashworth continued to influence regional planning as a senior consultant with LBG-Guyton Associates, leading the Far West Texas water-planning region. His career is distinguished by both technical contributions and sustained binational coordination. Selected references of his work includes Ashworth (1990, 2019); Hibbs et al. (1997).

2.3.2. Edmund G. Archuleta

As President and CEO of El Paso Water Utilities (EPWU) from 1989 to 2013, Edmund G. Archuleta directed one of the most comprehensive municipal groundwater management programs in the United States, centered on long-term sustainability of the Hueco Bolson. Under his leadership, El Paso became a national model for integrated water planning, conservation, recharge, and desalination. Archuleta strengthened binational cooperation with Ciudad Juárez through a Memorandum of Understanding with JMAS that enabled direct groundwater data exchange. This transparency improved numerical model accuracy and supported the transition to more responsive and updated modeling frameworks. His tenure included major investments in

artificial recharge, exploration drilling in the Hueco and Mesilla Bolsons, and development of the Kay Bailey Hutchison Desalination Plant. Archuleta also emphasized public education and conservation, reducing per-capita water use and delaying more costly supply alternatives. After retirement, he continued regional involvement through UTEP and private consulting and currently serves as Chairman of the Board of Las Cruces Utilities. Selected references for his work include Archuleta (2003, 2004, 2005).

2.3.3. Luis Antonio Rascón Mendoza

Luis Antonio Rascón Mendoza, Principal Engineer of the Mexican Section of the International Boundary and Water Commission (CILA), has been a key figure in modern binational groundwater management of the Hueco Bolson. Trained as a civil engineer with advanced specialization in hydraulic resources and arid-region water management, Rascón played a central role in formalizing binational groundwater cooperation. He served as lead negotiator and head of the Mexican delegation for the *Transboundary Aquifers and Binational Ground-Water Data Base* (1998), the first officially sanctioned transboundary groundwater database. At CILA, he held senior positions including Head of the Groundwater Department, Deputy Director of Engineering, and Interim Commissioner. Following the Hueco Bolson data exchange program that culminated in 1998, Rascón contributed to additional binational aquifer studies, including the Conejos-Médanos–Mesilla and Santa Cruz–San Pedro systems. His work established enduring institutional pathways for binational data sharing, monitoring, and cooperative management. Selected references of his work include International Boundary and Water

Commission (1992); U.S. Environmental Protection Agency and International Boundary and Water Commission (1994); US–Mexico Binational Report (1998).

2.3.4. Zhuping Sheng

Dr. Zhuping Sheng has produced an influential research portfolio on water resources in the Paso del Norte region, with substantial impact on scientific understanding of the Hueco Bolson. After joining EPWU in 1998, Sheng contributed to groundwater modeling, managed aquifer recharge studies, and development of operational databases guiding pumping and recharge. In 2001, Sheng joined Texas A&M AgriLife Research in El Paso, where he became a leading researcher on integrated hydrologic modeling, GIS-based databases, soil salinity, irrigation efficiency, reclaimed water systems, and basin- scale recharge. His work on river–aquifer interactions clarified the role of the Rio Grande floodplain in replenishing the Hueco Bolson. Sheng's 2005 paper with Devere framed the Hueco Bolson as a stressed transboundary system and promoted adaptive systems thinking in groundwater management. After retiring from Texas A&M in 2020, he joined Morgan State University, though his scientific legacy remains closely tied to Hueco Bolson hydrogeology. Selected references of his work include Sheng (2005); Sheng and Devere (2005); Talchabhadel et al. (2021).

2.3.5. Alfredo Granados Olivas

Dr. Alfredo Granados Olivas is a leading Mexican hydrogeologist at Universidad Autónoma de Ciudad Juárez (UACJ) whose binational

collaborations significantly refined conceptual models of the Hueco Bolson. His work integrates stratigraphy, geomorphology, recharge dynamics, and stable isotope hydrology. Granados co-led NSF-funded studies in the 2000s with U.S. colleagues, elucidating groundwater mixing, salinity sources, and paleo-recharge from ancestral Rio Grande channels south of the Sierra Juárez. His isotope work with Eastoe demonstrated that much of Ciudad Juárez's freshwater derives from pre-dam Colorado River snowmelt, overturning earlier recharge paradigms.

Beyond hydrogeology, Granados has contributed to soil salinity, land degradation, and watershed studies with implications for managed aquifer recharge and policy relevant hydrology. He has received numerous professional honors and continues to play a leadership role in Mexican water-resources science. Selected references for his work include Eastoe et al. (2016); Granados Olivas et al. (2016); Granados Olivas (2023).

2.3.6. William R. Hutchison

Dr. William R. Hutchison is one of the most prominent contemporary hydrogeologists working on the Hueco Bolson, combining municipal, academic, and consulting experience. He joined EPWU in 2001, later serving as Hydrogeology Manager and Water Resources Manager.

At EPWU, Hutchison led studies of aquifer properties, water chemistry, brackish water zones relevant to desalination, and long-term numerical modeling across Texas, New Mexico, and Chihuahua. His work substantially improved regional model accuracy and supported climate-change and supply-reliability evaluations. His Ph.D. dissertation, *Groundwater Management in El Paso, Texas* (2006), provided a

comprehensive synthesis of Hueco Bolson hydrology, regulation, and binational challenges. After serving as Director of the Groundwater Resources Division at TWDB, Hutchison returned to consulting and continues to contribute as a leading expert, including service as an expert witness. Selected references of his work include Hutchison et al. (2003, 2006); Hutchison and Hibbs (2008).

2.3.7. Chris J. Eastoe

Dr. Chris J. Eastoe, retired isotope geochemist at the University of Arizona, was responsible for major breakthroughs in understanding Hueco Bolson recharge, groundwater age, and salinity evolution. As former head of the Laboratory of Isotope Geochemistry, he analyzed hundreds of groundwater samples collected during NSF-funded binational studies.

Eastoe demonstrated that much of the freshwater beneath Ciudad Juárez originated from pre-dam Colorado River snowmelt infiltrated near the El Paso–Juárez Narrows, fundamentally revising recharge models for the basin. His collaborative publications with Hibbs, Hutchison, Hawley, Hogan, and Granados established a unified geochemical framework linking the Rio Grande, the Rio Grande alluvial aquifer, and the Hueco Bolson. Even after retiring in 2015, Eastoe has continued publishing groundwater-river interactions and salinity sources. His work remains central to modern interpretations of recharge timing, groundwater age, and mixing processes. Selected references include Eastoe et al. (2009, 2010, 2016).

2.4. Other Important Contributors

Several contributors worked on more limited portions of the Hueco Bolson or over shorter periods but made important technical contributions. Penn Livingston co-authored USGS reports with Albert Sayre (1937, 1945). Frank A. Scalapino conducted early federal investigations in the late 1940s, including a 1949 study of groundwater occurrence and basin stratigraphy. Pedro Picasso Tovar, President of JMAS in the 1950s, guided technical evaluations supporting municipal wellfield expansion.

Doyle B. Knowles and Richard A. Kennedy completed one of the earliest systematic USGS investigations of the Hueco Bolson in the 1950s. Joseph Gates contributed basin scale characterization and co-authored key USGS reports from the 1970s onward. Francisco Núñez supported groundwater management within JMAS during the 1990s. Dr. Bridget Scanlon and William Mullican advanced understanding of vadose zone processes, aquifer testing, and groundwater modeling in the Fort Hancock area.

At EPWU, Roger Sperka and Eric Bangs contributed hydrogeologic data and interpretation, while Scott Reinert leads long term groundwater planning and modeling. A. Wayne Buckner played a key role in early investigations and binational data exchange; his 1976 internal memorandum preserves information unavailable elsewhere.

Additional important contributors not already listed and listed in bold face type, with full citations in the references, include: **Lippincott** (1921); **De la Peña Porth** (1948); Scalapino and **Irelan** (1949); **Audsley** (1959); **Kernodle** (1992); **Orr and Risser** (1992); **Groschen** (1994); **Fisher** and Mullican (1990); Sheng, **Fahy, and Mace** (2001); **Anderholm and Heywood** (2003); and Heywood and **Yager** (2003).

3. Conclusions

More than a century of investigation in the Hueco Bolson reflects the cumulative work of hydrogeologists, geologists, engineers, and water planners who established the technical foundation for groundwater understanding in the Paso del Norte region. Early contributors such as Slichter, Sayre, and Livingston provided the first quantitative descriptions of basin geometry, groundwater movement, recharge limitations, and freshwater saline distributions.

Mid-century investigators expanded this framework through improved mapping, stratigraphic analysis, and hydrogeologic characterization as demands increased. Later investigators advanced understanding through expanded monitoring, isotopic studies, and numerical modeling, including evaluations of storage depletion, recharge, brackish water resources, and river-aquifer interactions. Many also participated in formal binational initiatives integrating U.S. and Mexican datasets.

Together, the contributors profiled here represent the principal participants known to the author in the development of Hueco Bolson hydrogeology. Their work provides the historical context, conceptual models, and data continuity required for evaluating trends and supporting modern groundwater-availability studies in a shared and increasingly stressed transboundary aquifer.

3.1. Author's Note

The author provides no autobiographical information regarding his work on the Hueco Bolson aquifer, aside from acknowledging peer-reviewed journal publications on which he is an author or co-author, as cited in the reference list. These studies have examined groundwater quality, aquifer processes, transboundary flow, salinity sources, recharge mechanisms, data limitations, and long-term aquifer behavior in the El Paso–Ciudad Juárez region (Hibbs, 1999; Hibbs and Boghici, 1999; Hibbs et al., 2003; Hibbs and Merino, 2006; Hutchison and Hibbs, 2008; Eastoe et al., 2009, 2010; Hibbs and Merino, 2020; Hibbs et al., 2024; Hibbs, 2025).

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- Slichter, University of Wisconsin public domain, pre-1931, https://digital.library.wisc.edu/1711.dl/HUADZ5DXIBOCK84
- Sayre, U.S. Geological Survey Public Domain Archival Photo
- Herrera Jordan, U.S. National Park Service Public Domain, https://www.nps.gov/cham/learn/historyculture/negotiation.htm
- De la O Carreño and others, Archivo Histórico CILA, Ciudad Acuña, Coahuila. Image originally published in La huella de un ingeniero geólogo en México, Revista Digital SMIG, Sociedad Mexicana de Ingeniería Geotécnica (SMIG), Núm. 270. Retrieved from https://smig.org.mx/revista-digital-smig/270/la-huella-de-un-ingeniero.php
- Leggat (photo provided by Bonnie Leggat)

- Chávez Guillén (photo provided by Comisión Nacional del Agua and Chávez Guillén)
- Cliett (photo provided courtesy of the New Mexico Water Resources Research Institute, in New Mexico Water Resources Research Institute Proceedings, https://nmwrri.nmsu.edu/publications/water-conference-proceedings/wcp-documents/w40/Cliett_Hawley.pdf)
- Hawley (photo provided by John Hawley)
- Vega Argüelles (photo from the public domain, https://es.wikipedia.org/wiki/Oscar_Vega_Arg%C3%BCelles)
- Bluntzer (photo provided by Peter Bluntzer)
- Archuleta (photo provided courtesy of the New Mexico Water Resources Research Institute, in New Mexico Water Resources Research Institute Proceedings, https://nmwrri.nmsu.edu/publications/water-conference-proceedings/wcp-documents/w53/archuleta.pdf)
- Rascón Mendoza (photo in U.S. Geological Survey, https://www.usgs.gov/media/images/signing-taap-agreement)
- Ashworth (photo provided by John Ashworth)
- Sheng (photo provided by Zhuping Sheng)
- William Hutchison (photo provided by William Hutchison)
- Granados Olivas (photo provided by Alfredo Granados Olivas)
- Eastoe (photo provided by Chris Eastoe)

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6. Statement of Conflict of Interest

The author declares no conflict of interest

7. Acronym List

C.I.E.P.S. = Consultoría, Ingeniería, Estudios, Proyectos y Supervisión

CILA = Comisión Internacional de Límites y Aguas

CONAGUA = Comisión Nacional del Agua

EPWU = El Paso Water Utilities

GIS = Geographic Information System

IBWC = International Boundary and Water Commission

ISARM = Internationally Shared Aquifer Resources Management

JMAS = Junta Municipal de Agua y Saneamiento

NAFTA = North American Free Trade Agreement

NSF = National Science Foundation

RGREP = Rio Grande Regional Environmental Project

SARH = Secretaría de Agricultura y Recursos Hidráulicos

SRH = Secretaría de Recursos Hidráulicos

TWDB = Texas Water Development Board

UACJ = Universidad Autónoma de Ciudad Juárez

UNAM = Universidad Nacional Autónoma de México

USBR = United States Bureau of Reclamation

USGS = United States Geological Survey

UTEP = University of Texas at El Paso

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