Journal of Hydrology 535 (2016) 101–119

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Identifying and characterizing transboundary aquifers along the Mexico–US border: An initial assessment

Rosario Sanchez [a,*], Victoria Lopez [b], Gabriel Eckstein [c]

[a] Water Management and Hydrological Sciences Program, Texas A&M University, MS 3408 TAMU, College Station, TX 77845, United States
[b] Water Management and Hydrological Sciences Program, Texas A&M University, United States
[c] Texas A&M University School of Law, International Water Law Project, United States

ARTICLE INFO

Article history:
Received 29 October 2015
Received in revised form 15 December 2015
Accepted 26 January 2016
Available online 3 February 2016
This manuscript was handled by Geoff Syme, Editor-in-Chief, with the assistance of Craig T. Simmons, Associate Editor

Keywords:
Transboundary
Aquifer
Mexico
United States
Management

SUMMARY

The transboundary nature of water dividing Mexico and the United States (U.S.) transforms the entire border region into an instrument of cooperation, a source of conflict, a national security issue, and an environmental concern. Reasonable data collection and research analysis have been conducted for surface waters by joint governmental institutions and non-governmental bodies. However, with the exception of the U.S. Transboundary Assessment Act Program (TAAP) (focusing on the Hueco Bolson, Mesilla Bolson, San Pedro and Santa Cruz aquifers), there is no comparable research, institutional development, or assessment of transboundary groundwater issues on the frontier. Moreover, data collection and methodologies vary between the two countries, there is no broadly accepted definition of the transboundary nature of an aquifer, and available legal and policy frameworks are constrained by non-hydrological considerations. Hence, there is a conceptual and institutional void regarding transboundary groundwater resources between Mexico and the U.S. The purpose of this paper is to bridge this void and characterize transboundary aquifers on the Mexico–US border. It reviews existing international frameworks for identifying hydrological and social criteria that characterize an aquifer as transboundary. It then assesses data from both countries to propose where and which aquifers could be considered transboundary. Finally, the paper proposes an agenda for assessing Mexico–US transboundary aquifers as a means for improving groundwater management in the border region.

1. Introduction

The transboundary nature of water dividing Mexico and the United States (U.S.) transforms the entire border region into an instrument of cooperation, a source of conflict, a national security issue, and an environmental concern. Reasonable data collection and research analysis have been conducted for surface waters by joint governmental institutions and non-governmental bodies. However, with the possible exception of the U.S. Transboundary Assessment Act Program (TAAP) (focusing on the U.S. sections of the Hueco Bolson, Mesilla Bolson, San Pedro and Santa Cruz aquifers), there is no comparable research, institutional development, or assessment of transboundary groundwater issues on the frontier. Overall, joint groundwater management practices are non-existent and unlikely in the near term.

The Mexico–U.S. case is not unique. Globally, over 600 transboundary aquifers have been mapped since 2003 by the International Groundwater Resources Assessment Centre (IGRAC), an initiative of UNESCO and the World Meteorological Organization. Yet, of these, only one is managed collaboratively (Genevese Aquifer shared by France and Switzerland), one has rudimentary extraction controls (Al-Sag/Al-Disi Aquifer shared by Jordan and Saudi Arabia), and two others in northern Africa (Nubian Sandstone Aquifer and Northwestern Sahara Aquifer) have data sharing arrangements (IGRAC, 2012, 2014).

According to the United Nations International Decade for Action 'Water for Life' 2005–2015 Program (UNDESA, 2014), research and data exchange has increased considerably for the 276 transboundary river basins found around the world. Moreover, after the entry into force of the 1997 U.N. Watercourse Convention (Watercourse Convention) in August 2014, a more rigorous effort for transboundary surface water management is expected to develop as water scarcity continues to challenge transboundary water systems internationally.

In contrast, the expectations for transboundary aquifers are more modest. Apart from the mapping program pursued by IGRAC, transboundary data exchange and cross-border research

* Corresponding author. Tel.: +1 979 845 2027.
E-mail address: rosario@geos.tamu.edu (R. Sanchez).

http://dx.doi.org/10.1016/j.jhydrol.2016.01.070
0022-1694/

development are not common. Additionally, while the Watercourse Convention does apply to some transboundary aquifers, its primary focus is on transboundary rivers and lakes (Eckstein, 2005). Moreover, the development of an international legal framework focusing on all shared groundwater resources is limited to a set of draft general principles proposed by the United Nations – the 2008 Draft Articles on the Law of Transboundary Aquifers.

While the existence of these instruments may appear promising, both the 1997 U.N. Watercourse Convention and the 2008 Draft Articles on the Law of Transbounday Aquifers are limited to 'general' principles that do not necessarily encompass the diversity or complexity of transboundary groundwater systems around the world. Numerous concerns related to the unique geological, climatic, and other natural conditions that characterize various transboundary aquifers, as well as the 'functioning' of different aquifers (e.g., disparate capacities to store and transport water, dilute contaminants, transmit geothermal heat, and serve as a habitat or water source for aquifer-dependent species) (Eckstein, 2011a), marginalize the countless hydrogeological conditions of groundwater resources around the world. There are also no international recognized guidelines for defining the boundaries of a transboundary aquifer system, and methodologies and principles for data-sharing tend to be decided by sovereign priorities, which might not necessarily be compatible with a holistic basin approach for groundwater management.

These conditions are also present in the Mexico–U.S. border. There is no consensus on the number of transboundary aquifers between Mexico and the U.S. At the international level, the International Shared Aquifer Resources Management Agency (ISARM) recognizes 11 transboundary aquifer systems (IGRAC, 2014); in Mexico, the National Water Commission (CONAGUA) reports 36 aquifers bordering the U.S, but officially only identifies the same as ISARM (CONAGUA, 2014). In contrast various research from the U.S. suggests that there may be as many as 38 (12 on Mexico's border with California, 9 with Arizona, 8 with New Mexico, and 9 with Texas) (ADWR, 2013; CDWR, 2014; George et al., 2011; Hawley et al., 2000). Although there is no official number recognized by the United States federal government (GNEB, 2010), the 15th report of the GNEB (Good Neighbor Environmental Board) mentions 20 transboundary aquifers but offers no additional information (GNEB, 2012). Other studies suggest a range of between 8 and 20 transboundary aquifers in the Mexico–U.S. border region (Eckstein, 2013; Mumme, 1988, 2000).

In addition, data collection and methodologies vary considerably between the two countries. Among the international community, as well as between Mexico and the United States, there is no broadly accepted definition of the transboundary nature of an aquifer or agreement on defining the boundaries of aquifers. Moreover, available legal and policy frameworks are constrained by non-hydrological considerations. The "blank map" syndrome, a condition in which researchers on either side of the border only describe the portion of the aquifer located within their side and leave the other side blank or delineate the border of the aquifer in relation to the international boundary (GNEB, 2010), still governs the interaction of transboundary hydrological systems in the border region, leading to incomplete and bias assessments in both countries. Hence, there is a conceptual and institutional void regarding transboundary groundwater resources between Mexico and the U.S. It is worth mentioning that challenges related to data collection and agreement on methodologies as well as lack of literature on characterization transboundary aquifers in the United States was first documented in the early 1970s by Bittinger (1972). The study characterized the severity of international and interstate aquifer problems for the United States' as 'major' or 'minor' based on survey responses from State water agencies and university personnel. Bittinger's work, however, did not seek to identify, delineate, or classify transboundary aquifers on the Mexico–U.S. border (Bittinger, 1972).

The purpose of this paper is to bridge the void in practice and in the literature and identify and characterize transboundary aquifers that cross the Mexico–U.S. border. It assesses data from both countries to propose, at various levels of confidence in relation to the available information, where and which aquifers could be considered transboundary. The analysis is intended to develop a foundation upon which further efforts could begin to characterize, categorize, and prioritize transboundary aquifers on the Mexico–U.S. border for purposes of enhancing groundwater management and decision making.

2. Methods

The approach used for this project included an array of targeted research to identify and analyze the data and information sought so as to provide as complete a foundation as possible for further study. Data collection included reviewing all available technical studies and raw data related to aquifers located on or near the Mexico–U.S. border that were generated by state and federal agencies, non-governmental organizations, and private researchers in both countries. It also included technical studies and publications discussing the governance framework administering transboundary aquifers on the border.

Building on the data collection effort, the study reviewed and analyzed the international, binational, and national efforts to characterize and classify aquifers as transboundary in the border region. It also assessed the hydrogeologic data related to frontier aquifers and identified gaps and inconsistencies in the information in an effort to begin characterizing the aquifers.

The analysis used ISARM's boundaries categorization as a reference for identifying aquifer boundaries in the border region. The *true/system aquifer boundary* refers to the limits of groundwater bodies with relatively high transmissivity and storage capacity, usually referred as the saturated zone. The *basin aquifer boundary* relates to the boundaries of the whole hydrological basin, which includes hydraulically connected groundwater systems. The *geological aquifer boundary* delimits the extension of the geological formation, which can potentially include aquifers but not necessarily across the entire unit. According to specific data, aquifer boundaries are sometimes defined by the funding available for the research project, therefore the aquifer extent could also be limited by budget considerations (Boghici, 2002; Timmons, 2014). Because Mexican and U.S. approaches for aquifer delimitation differ (Mexico uses basin aquifer boundary methodology exclusively, while the U.S. uses different approaches for different aquifers), Mexican data was used as the guiding reference for identifying and counting potential transboundary aquifers on the border. Where Mexican and U.S. data for a particular location conflicted, the Mexican data was used.

Based on the analysis, the study developed a new methodology to categorize transboundary aquifers based on available hydrological and institutional data. Three categories were created in relation to levels of confidence of the existence of a transboundary relationship: "reasonable," "some," and "limited." "*Reasonable*" level of confidence applies to aquifers for which the technical and related data evidencing a transboundary character was convincing. "*Some*" level of confidence applies to aquifers for which technical and related evidence was available but not definitive. "*Limited*" level of confidence refers to aquifers for which there is no technical data of a transboundary nature, but where some hydrological elements mentioned in technical studies, usually from only one side of the border, suggest the possibility of a transboundary aquifer. GIS is used to present the study's preliminary results for the entire border region.