Integrating Groundwater Boundary Matters into Transboundary Aquifer Management

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ABSTRACT

With the UN General Assembly adopting a resolution on the law of transboundary aquifers, followed by the publication of the Atlas of Transboundary Aquifers by UNESCO-IHP, the transposition of the law into action and the need to move from policies to implementation is omnipresent. Political geographers have not extensively investigated the connection between groundwater resources to the metrics of space, scale and time common to the geographic study of natural resources. While it is well known that groundwater boundaries are different from surface water boundaries, and that the groundwater boundaries are both seen and unseen, the utilization of a transboundary aquifer in an equitable and reasonable manner requires taking into consideration the many boundaries associated with equitable and reasonable use without harm, resource protection, and the associated institutions.

A previously unrecognized typology for groundwater resources and user domains determined that (1) traditional approaches to defining groundwater domains focus on predevelopment conditions, referred to herein as a "commons" boundary; (2) groundwater development creates human-caused or a "hydrocommons" boundary where hydrology and hydraulics are meshed, and (3) the social and cultural values of groundwater users define a "commons heritage" boundary acknowledging that groundwater resources are part of the "common heritage of humankind". This typology helps define a fundamental unit of analysis to aggregate demographic, social, and economic data. Delineation of these boundaries is supremely political and morphs with changing social and cultural values.

Likewise, most of the emphasis regarding groundwater boundaries is two-dimensional; distinguishing between shallow and deeper groundwater systems is also important for governance. This presentation provides a starting point for differentiating between groundwater that may be governed under surface water regimes and deeper groundwater systems that may be governed by an aquifer State or as part of the global commons.

Boundaries can create competition between competing communities and institutions that do not promote the welfare of groundwater resources. Placing boundaries around user and resource domains (1) helps reduce the uncertainty within the groundwater "infosphere" and decreases reliance on knowledge entrepreneurs, (2) builds social identity and organization with groundwater resources, (3) localizes the institutional controls to promote fairness and trust regarding the use of groundwater, and (4) provides a roadmap to incentives to preserve the integrity of an aquifer or the associated ecosystem services. "Blurring the boundaries" promotes the philosophy that "we are all in this together".

Key words: Boundary typology, boundary spanning, dispute prevention

1. INTRODUCTION

Groundwater is a resource that is found everywhere. With dramatic changes in drilling technology, pumping technology and the availability of electrical and diesel power over the past 60 years, the number of wells has increased exponentially in many parts of the world (Moench, 2004; Shah, 2009). According to Zekster and Everett (2004) and Shah (2009), groundwater is the world's most extracted raw material, with withdrawal rates approaching 800 to 1,000 km^3 per year through millions of water wells. Pumping of groundwater is among the most intensive human-induced changes in the hydrologic cycle.

Information power or the "infosphere" of Lonsdale (1999) is perhaps the most important dimension of strategy in the geopolitics of groundwater. While groundwater monitoring networks have been in place in many intensively exploited regions of the world, few have been expanded since their inception (Moench, 2007). Groundwater data collection and information dissemination has created a large industry of "knowledge entrepreneurs" as described by Conca (2006).

And yet with 97% of the world's freshwater resources stored underground, the connection between groundwater resources to the metrics of space, scale and time common to the geographic study of natural resources has not been extensively investigated by political geographers.

2. OBJECTIVES

Despite the substantial body of geographic literature surrounding the historical, cultural and political development of boundaries (e.g., Anderson, 1999), it is ironic that few political geographers have addressed the problem of how boundaries are placed around common pool resources such as groundwater. Clearly, the new world order of groundwater will focus on the delineation of resource and user domain boundaries regardless if (1) the technological options to manage groundwater quantity and quality problems employ water transfers, managed recharge, or conjunctive use, or (2) the resource governance solutions include (a) collective or community action, (b) developing instrumental approaches such treaties, agreements, rights, rules and (c) prices or other incentives such as preserving the structural and ecological integrity of groundwater systems as summarized by Giordano (2009). The goal of this chapter is to provide an overview on groundwater boundaries within catchments, particularly the social and political boundaries, which do not necessarily line up with the technical or physical hydrologic boundaries.

3. THE BOUNDARIES OF GROUNDWATER

3.1 The Boundary Conundrum

Resource domains define the fixed spatial dimensions of resources (Buck, 1998). Spatial dimensions are used to define property rights that may be held by individuals, groups of individuals, communities, corporations, or nation-states. Rights to natural resource property are not a single right, but are rather composed of a "bundle of rights" such as rights of access, exclusion, extraction, or sale of the captured resource; the right to transfer rights between individuals, communities, corporations or nation-states; and the right of inheritance (Buck, 1998). Each "right" has an implied boundary.

The spatial extent of a resource affects both the ability of users to develop information and to assess their relative ability to capture the benefits of organization (Schlager, 2007). Yet with the assumptions associated with the bundle of rights and implied boundaries comes the fact that the assumptions, knowledge and understandings that underlie the definition of the rights and associated boundaries are uncertain and often contested (Adams *et al*., 2003). For example, the question of identity and its relation to the domains of natural resources is often overlooked (Dietz *et al*., 2002). Choices about water resources are value choices that involve distinct local communities of interest (Blomquist and Schlager, 2005). Defining boundaries around water resource domains is "a supremely political act" because they represent different interpretations of key issues such as water quality, water quantity, nature, economics and history (Blomquist and Schlager, 2005). The resulting boundaries may range from the international scale, to the national, regional, local, or even the individual scale. These come from the fact that water resources are coupled with the larger reality of a region, including its environmental, social, legal, and economic characteristics.

3.2 Why Boundaries Matter

Boundaries are "inner-oriented" or created by the will of a central government, or two or more states in an international setting, with the boundary indicating the limits of a political unit. All that falls within the confines of the boundary has a common bond. According to Casati *et al.* (1998), possession of a boundary is one mark of individuality in the ontology of geographic representation. Without a boundary, there can be no separation and control, and without control, it is doubtful where sovereignty in the full sense can be enjoyed (Bisson and Lehr, 2004). The existence of a boundary is the first criterion for the individuality of an autonomous entity.

Consideration of transdisciplinarity and a broad systems approach to exploring the geopolitics of groundwater yields a typology for groundwater boundaries. As depicted in Figure 1, this work found that traditional approaches used to defining groundwater domains focus on predevelopment conditions, referred to herein as a *bona-fide* "commons" boundary. Coastlines, rivers, watersheds or catchments, or rock outcrops are good examples of *bona-fide* boundaries for groundwater resource domains. At the global scale, the International Groundwater Assessment Center (IGRAC, 2009) developed a map of global groundwater regions that differentiated 35 regions on the basis of tectonic setting, present-day geomorphology, and the spatial extent of rock formations with contrasting hydraulic properties as part of the consortia of institutions undertaking WHYMAP (2008). Building upon the IGRAC mapping, the WHYMAP further refined the hydrogeologic regions into hydrogeologic units that form over 270 transboundary aquifers. The boundaries of the groundwater resources domains are based primarily on permeability architecture. The definitions of recharge and discharge zones in the Law of Transboundary Aquifers and the boundaries of aquifers in the Atlas of Transboundary Aquifers complied by Puri and Aureli (2009) fall under this category of boundary.

Groundwater development creates human-caused or *fiat* "hydrocommons" boundary. Focusing primarily on rivers and watersheds, Weatherford (2003) defined the "hydrocommons" as the convergence of hydrology and hydraulics yielding an area defined by the linkages of common water sources. *Fiat* boundaries are subjective boundaries demarcated by humans based on judgment and "ease" and represent groundwater user domains. Borders between countries are *fiat* boundaries. According to Anderson (1999), boundaries have no horizontal dimension, and that the crucial dimension of boundaries lies in the vertical plane or subsurface beneath the boundary. Three dimensional *fiat* objects are created by subterranean volumes of land assigned rights to minerals, the ocean, or groundwater. The capture area of a wellfield is an example of three-dimensional *fiat* boundaries in groundwater user domains (Casati *et al*., 1998). Likewise, large areas can be drained of groundwater by horizontal water "mines" such as qanats or karezes, found in the tens of thousands throughout the Middle East, which capture groundwater via gravity and drain towards portals. A body of groundwater within the EU Water Framework Directive refers to a distinct volume of groundwater within an aquifer or aquifers. Aquifer storage and recovery and aquifer replenishment programs that transmit surface water hundreds of kilometers from distant river basins to intensively exploited groundwater basins form a new hydrocommons. And unitization used by the oil industry to preserve the structural integrity of reservoir by "…government-mandated unitization of groundwater…is a solution to excessive access and drawdown … [where] a single "unit operator" extracts from and develops the reservoir. All other parties share in the net returns as share holders…" as suggested by Libecap (2005) may serve as one option to dealing with the emerging issue of overlapping jurisdictions or "values" related to groundwater.

The social and cultural values of groundwater users define a *fiat* "commons heritage" boundary acknowledging that groundwater resources are part of the "common heritage of humankind". The intensive use of groundwater is causing increased awareness of potential impacts to groundwater dependent ecosystems, spiritual resources, therapeutic resources, cultural and historical resources, and geothermal resources. These are natural and human boundaries associated with groundwater.

In order to protect deep confined aquifers, as well as spring waters and mineral waters used as therapeutic waters as part of a national or common heritage, de Marsily (1994) calls for the creation of "Hydrogeological Nature Reserves". Hydrothermal features are nature reserves that are not frequently considered within the context of groundwater resource domains. Yet, many have been used for thousands of years for therapeutic purposes, are World Heritage Sites, national and state parks, and are spiritually important to some cultures. And hydrothermal features are increasingly being explored as sources for renewable energy. Boundaries for groundwater user domains associated with common heritage sites vary from no protection to controlled areas.

The significance of this typology is that it focuses more on "problemsheds"—the boundaries of a particular problem defined by the issue-network—than on watersheds or catchments as recommended for water governance and management by Molden (2007). It also acknowledges that (1) groundwater systems are "boundary objects" shared by several different communities that are viewed or used differently by each of them, and (2) that groundwater scientists need to act as "boundary spanners" or persons that look across disciplinary, institutional, geographic, temporal, and sense-making (framing) boundaries for the exchange of information between an organization and groundwater system as described by Warner *et al.* (2010).

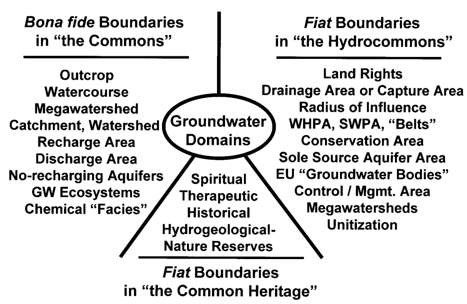

Figure 1. Inventory of groundwater domains. Adapted from Jarvis (forthcoming)

3.3 The Third Dimension

Up to this point, the discussion has focused on the planimetric boundaries associated with groundwater domains under both static and dynamic conditions. Lopez-Gunn and Jarvis (2009) synthesized the results of conceptual and numerical models of ideal groundwater systems, along with the mechanical limitations associated with pumping groundwater from great depths, to argue for a vertical dimension for distinguishing between shallow and deeper groundwater systems. Their work proposed a groundwater governance model that differentiates between shallow groundwater systems and deep groundwater systems. They found that shallow groundwater systems that are hydraulically connected to surface water resources may extend to depths approaching 305 meters. This boundary was proposed as a starting point for differentiating between groundwater that may be governed under surface water regimes and deeper groundwater systems that may be governed as part of the global commons.

4. DISCUSSION AND CONCLUSIONS

Changes in population, the world's climate, effectiveness of water treatment and conservation technologies, and social values all affect the rate of groundwater pumping, recharge, and ecological response with time. The types of spatial entities associated with groundwater resource domains not only occupy space, but also sometimes share space with other spatial entities. Governance, management, and use of shared resources such as groundwater cannot be treated independently and requires viewing the linkages between the user and resource domains as a problemshed rather than through the lens of the catchment (Molden, 2007).

Boundaries, either political or defining a resource or user domain, are obviously related to the control or the distribution of groundwater; boundaries are used to exclude some users while at the same time providing the appropriators an opportunity to develop information and capture the benefits of organizing within the boundaries (Schlager, 2004; 2007).

Social psychologist Mark van Vugt (2009) identified four conditions for the successful management of shared resources: information, identity, institutions, and incentives. Placing boundaries around user and resource domains (1) helps reduce the uncertainty within the groundwater "infosphere" and decreases reliance on knowledge entrepreneurs, (2) builds social identity and organization with groundwater resources, (3) localizes the institutional controls to promote fairness and trust regarding the use of groundwater, and (4) provides a roadmap to incentives to preserve the integrity of an aquifer or the associated ecosystem services. Clearly, boundaries can create competition and conflict between communities and institutions that do not promote the welfare of groundwater resources often times leading to "dueling expert" situations as described by Jarvis and Wolf (2010). Implementation of the Law of Transboundary Aquifers will require groundwater scientists and policy makers to become boundary spanners that acknowledge the many different ways a boundary entity like groundwater can be viewed and used. Van Vugt (2009) suggests that it is important to think of ways to "blur" the boundaries by promoting that "we are all in this together" to prevent disputes over the shared resources.

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