A HYDROGEOLOGICAL APPROACH TO TRANSBOUNDARY GROUND WATER RESOURCES AND INTERNATIONAL LAW

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INTRODUCTION

Over the last half century, ground water has emerged as a vital source of water for millions of people worldwide.[1] More than one-

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1. *See* Stephen McCaffrey, *Seventh Report on the Law of the Non-Navigational Uses of International Watercourses*, at 14, U.N. Doc. A/CN.4/436

half of the world's population today is dependent on ground water for its basic needs.[2] Among European nations, at least seventy-five percent of drinking water comes from ground water; in Austria, Croatia, Denmark, Hungary, Italy, Lithuania, and Slovenia, it exceeds ninety percent.[3] In the United States, ground water provides approximately one half of all drinking water; in rural areas of the country, the percentage is as high as ninety-seven percent.[4]

(1991), *reprinted in* [1991] 2 Y.B. Int'l L. Comm'n 45, 52 U.N. Doc. A/CN.4/SER.A/1991/Add.1 (Part 1) [hereinafter McCaffrey] (referring to a report prepared in 1990 by the United Nations Secretariat, and stating that in many arid and semi-arid regions, ground water is the only source of water); *see also* Payal Sampat, *Deep Trouble: The Hidden Threat of Groundwater Pollution, Worldwatch Paper*, 154 WORLDWATCH INST. 1, 10-13 (2000) (discussing the growing global dependence on ground water resources).

2. *See* McAffrey, supra note 1, at 52 (noting that a "majority of the world's population is currently dependant on groundwater"); *see also* WATER FOR PEOPLE, WATER FOR LIFE; THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT at 80, U.N. Sales No. 92-3-103881-8 (2003) [hereinafter WATER FOR PEOPLE] (identifying countries, like India, Iran, Bangladesh, and Saudi Arabia which rely heavily on ground water resources for agricultural irrigation and citing Africa's "sharp increase" in water demand as an example).

3. *See* E. ALMÁSSY & ZS. BUSÁS, U.N./E.C.E. TASK FORCE ON MONITORING & ASSESSMENT, GUIDELINES ON TRANSBOUNDARY GROUND WATER MONITORING, VOLUME 1: INVENTORY OF TRANSBOUNDARY GROUND WATERS at 21, U.N. Sales No. 9036952743 (1999) (identifying the percentage of ground water in various European countries' drinking water supplies: Austria (99%), Belarus (80%), Bulgaria (60%), Croatia (90%), Estonia (70%), Finland (57%), Germany (75-90%), Hungary (95%), Lithuania (100%), The Netherlands (67%), Portugal (60%), Slovak Republic (80%), Slovenia (90%), Switzerland (84%), Ukraine (65%)); *see also* McCaffrey, *supra* note 1, at 53 (claiming that the percentage is reported to be as high as 98% in Denmark); Stefano Burchi, *National Regulation for Groundwater: Options, Issues and Best Practices*, *in* GROUNDWATER: LEGAL AND POLICY PERSPECTIVES, PROCEEDINGS OF A WORLD BANK SEMINAR 55, 55 (Salman M.A. Salman ed., 1999) (reaffirming that the overwhelming majority of European water supplies comes from ground water sources).

4. *See* Burchi, *supra* note 3, at 55 (stating that while in many countries, including the United States, the primary use for ground water is drinking water, in other countries, other uses, such as irrigation, exist); *see also* Ludwik A. Teclaff & Eileen Teclaff, *Transboundary Ground Water Pollution: Survey and Trends in Treaty Law*, 19 NAT. RESOURCES J. 629, 629-30 (1979) (referring to information provided by the United States Environmental Protection Agency, and noting that "large cities around the world are increasingly dependent on ground water for public supply because of the pollution of surface bodies and the aquifers. . .[and because] [t]hese waters have become depleted as extraction exceeds the rate of natural replenishment.").

Expanded reliance on ground water as a chief source of fresh water is due in large part to the growth in industry, agriculture, and the global population.[5] In the past one hundred years, per capita global water consumption grew nine-fold; presently, human water use is increasing four to eight percent annually.[6] Coupled with improvements in ground water management technology, ground water use has escalated from meeting strictly local needs to providing for whole nations.[7]

Global ground water supplies dwarf, by a factor of one hundred to one (Figure 1) all of the supplies found in rivers, lakes and other surface freshwater.[8] Freshwater in lakes, streams, wetlands, and other surface bodies of freshwater comprise 1/125 of one percent of global water reserves, and less than 1/33 of one percent of the global volume of freshwater.[9] Fresh ground water, on the other hand, constitutes slightly more than thirty percent of global freshwater resources.[10] While not all ground water resources are easily

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5. *See* Robert Hayton & Albert E. Utton, *Transboundary Ground Waters: The Bellagio Draft Treaty*, 29 NAT. RESOURCES J. 663, 663, 674 (1989) (asserting that development and population expansion are causing cities throughout the world to become "critically dependent on ground water").

6. *See* Joseph W. Dellapenna, *The Evolving International Law of Transnational Aquifers*, *in* MANAGEMENT OF SHARED GROUND WATER RESOURCES: AN ISRAELI-PALESTINIAN CASE WITH AN INTERNATIONAL PERSPECTIVE 209, 209 (Eran Feitelson et al. eds., 2001) (finding that although the quantity of water available on the earth has remained unchanged and is unchangeable, there has been a huge increase in the consumption of water since 1900); *see also* WORLD RESOURCES INSTITUTE, UNITED NATIONS ENVIRONMENTAL PROGRAMME, UNITED NATIONS DEVELOPMENT PROGRAMME, WORLD RESOURCES 1992-93: A GUIDE TO THE GLOBAL ENVIRONMENT at 160-61 (1992) [hereinafter WORLD RESOURCES 1992-93] (discussing the amount of water used and consumed annually).

7. *See* WATER FOR PEOPLE, *supra* note 2, at 78 (discussing the "boom in groundwater resource exploitation"); *see also* Dellapenna, *supra* note 6, at 212 (finding that after World War II, the technology and demand for water made ground water a critical transnational resource).

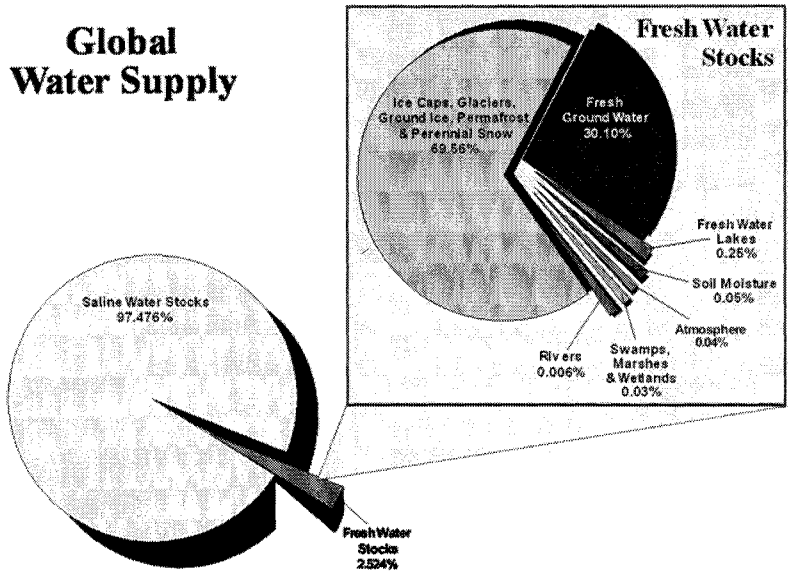
8. *See* McCaffrey, *supra* note 1, at 14 (reporting that, excluding polar ice and glaciers, ground water makes up nearly ninety-seven percent of the fresh water on Earth).

9. *See id.* at 13 (claiming that "[p]erhaps the most astonishing feature of groundwater is its sheer quantity in relation to surface water.").

10. *See* WATER FOR PEOPLE, *supra* note 2, at 78 (adding that certain aquifers can hold more water than the world's reservoirs and lakes).

accessible – due to the depth at which the ground water is found, or the geology of the surrounding strata – those resources that are technically and economically reachable still constitute more than thirty-three times the volume of water found in the world's lakes and streams.[11] The total volume of readily usable ground water, *i.e.*, accessible and not saline, is estimated at approximately 4.2 x 10^6 km^3, while lakes and streams contain only about 0.126 x 10^6 km^3 of fresh water.[12]

Figure 1. Global Water Supply (Note: Numbers do not add to 100% due to rounding)[13]



11. *See id.* (discussing ground water systems as the "predominant reservoir and strategic reserve of freshwater storage on planet Earth").

12. *See* HERMAN BOUWER, GROUNDWATER HYDROLOGY 2-3 (1978) (finding that, not including glaciers and ice caps, ground water reservoirs hold the largest amount of fresh water in the world's hydrologic cycle); *see also* MICHAEL PRICE, INTRODUCING GROUNDWATER 7 (1996) (comparing volumes of surface and underground water).

13. Compiled from: WORLD RESOURCES 1992-93, *supra* note 6; WATER FOR PEOPLE, *supra* note 2, at 68; BOUWER, *supra* note 12, at 2-3; C.W. FETTER, APPLIED HYDROGEOLOGY 4 (3d ed. 1994).

As dependence on ground water resources increases globally, a host of new questions and problems developed relating to ownership, use, access, protection, and development of ground water resources, especially in border areas where such water resources traverse international political boundaries.[14] These issues have become increasingly important in the transboundary context primarily because there is scarcely a country in the world (except for most island-nations) not linked hydrologically to another country.[15] As a result, there is now a growing need for the clarification and progressive development of international law as it applies to ground water resources.[16] In particular, with ground water consumption reaching and even exceeding sustainable withdrawals in many parts of the world, and in order to avoid future disputes and maximize beneficial use of this shared but finite resource, there is a need to clarify the rights and obligations that states enjoy *vis-à-vis* transboundary and international[17] ground water resources.

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14. *See* Hayton & Utton, *supra* note 5, at 663-64 (asserting that crises over ground water ownership may result from the uncertainty that currently exists over ground water rights).

15. *Cf.* Teclaff & Teclaff, *supra* note 4, at 630 (explaining further that, due to the pollution of surface water bodies, many interrelated aquifers are vulnerable to contamination). While the global number and scope of transboundary aquifers is still unknown, recent studies suggest that this is especially true for ground water resources. *Id.*; *see also* Almássy & Busás, *supra* note 3, at 64 (stating that a recent study identified eighty-nine aquifers traversing the borders of two or more states among the members of the Economic Commission for Europe); Stephen Mumme, *Minute 242 and Beyond: Challenges and Opportunities for Managing Transboundary Ground water on the Mexico-U.S. Border*, 40 NAT. RESOURCES J. 341, 344 (2000) (reporting that another study classified eighteen transboundary aquifers in the Mexico-United States border area, many of which are also related to international watercourses).

16. *See* Mumme, *supra* note 15, at 341 (using the United States and Mexico situation as an example).

17. This article focuses on ground water resources that traverse an international political boundary between two or more sovereign states or that are hydraulically connected to surface waters that traverse such a boundary. The phrases "transboundary aquifer" and "transboundary ground water" are used in this article to refer solely to ground water that traverses an international political boundary between two or more sovereign states. The term "international aquifer" is used to describe an aquifer that is part of a system that, at some point, traverses an international political boundary, like, for example, a purely domestic aquifer hydraulically linked to a transboundary river. *See* Chusei Yamada, *Shared Natural*

In a 1986 study for the United Nations ("U.N.") Food and Agriculture Organization ("FAO"), Julio Barberis offered four case models to demonstrate the various transboundary implications associated with ground water resources.[18] These case models attempted to illustrate transboundary and international aquifers found in nature and to serve as paradigms for the application of international water law.[19] Moreover, their purpose was to aid in clarifying the standards and principles of international law applicable to transboundary and international ground water resources.[20] While the underlying premise of Barberis' case models – that ground water resources can have substantial international implications – is correct, and although the FAO study has been widely cited (including in the proceedings of the International Law Commission ("ILC"), which drafted the 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses),[21] the models must be reconsidered. Two of the models are flawed, and the four case

Resources: Addendum to the First Report on Outlines, U.N. GAOR, 55th Sess., 533d mtg. at 5-6, para. 13 U.N. Doc. A/CN.4/533/Add.1 (2003) (discussing the definitions of transboundary and international aquifers), http://www.un.org/law/ilc/sessions/55/55docs.htm (last visited Oct. 21, 2003); *see also* Alberto Székely, *Transboundary Resources: A View from Mexico*, 26 NAT. RESOURCES J. 669, 674-76 (1986) (discussing the definition of "transboundary" and "shared" in the contexts of resources that traverse international political borders).

18. *See* Julio A. Barberis, *International Ground Water Resources Law*, *in* 40 FOOD AND AGRICULTURAL ORGANIZATION LEGISLATIVE STUDY NO. 36 (1986) [hereinafter Barberis 1986] (suggesting four models in which ground water forms part of an international water system); *see also* Julio Barberis, *The International Law of the Hydrologic Cycle: The Development of International Law of Transboundary Groundwater*, 31 NAT. RESOURCES J. 167, 168-69 (1991) [hereinafter Barberis 1991] (discussing instances where ground water may form a part of an international hydrologic system).

19. *See infra* note 162 and accompanying text (listing Barberis' descriptions of the four case models).

20. *Cf.* Barberis 1986, *supra* note 18 (defining the four models as a background to a discussion on the applicable international law).

21. G.A. Res. 51/229, U.N. GAOR, 51st Sess., U.N. Doc. A/RES/51/229 (1996) [hereinafter Watercourse Convention].

models do not fully account for all of the common aquifer types that exist in nature with transboundary implications.[22]

In this paper, we treat transboundary and international ground water resources under international law from a hydrogeologic perspective by considering the shortcomings of Barberis' four models and by offering six new conceptual models in which ground water resources have transboundary consequences. The models are intended to help assess the applicability and scientific soundness of existing and proposed rules governing transboundary and international ground water resources. Consequently, they should aid in developing clear, logical, and science-based norms of state conduct as they relate to transboundary and international ground water resources. Finally, this paper considers the development of international water law as it applies to ground water resources and makes recommendations based on the models and principles of hydrogeology.

As a backdrop to this discussion, we begin with a primer on the relevant concepts and principles of the science of ground water. In doing so, we identify those concepts and terms that are essential for any decision-maker whose actions might affect transboundary and international ground water resources.

I. GROUND WATER 101

A. THE HYDROLOGIC CYCLE

The hydrologic cycle (Figure 2) is the system in which water – solid, liquid, gas, or vapor – travels from the atmosphere to the Earth and back again in a constant cycle of renewal.[23] Generally, water falls from the atmosphere in the form of precipitation, such as rain, snow, and sleet.[24] Water that falls on land either runs over the land

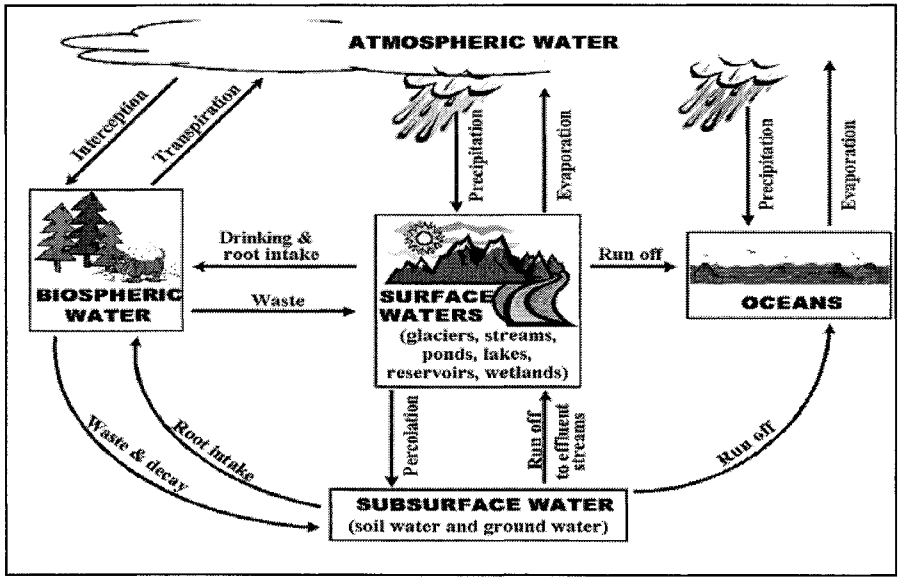
22. *See infra* Part IV.A (asserting that Barberis' models are defective because, among other things, they are scientifically imprecise and fail to differentiate between recharging and non-recharging aquifers, among others).

23. *See* FETTER, *supra* note 13, at 5-6 (describing the flow of water through the hydrologic cycle and noting that "the cycle actually has no beginning and no end").

24. *See* Barberis 1986, *supra* note 18, at 1 (stating that water falls as rain, snow, or hail from the atmosphere).

into streams, rivers and lakes, or it percolates into the earth.[25] Throughout its surface travels and especially when it reaches large bodies of water, it evaporates through the effects of solar energy and returns to the atmosphere where it continues in the cycle.[26] Plants consume or absorb some water, which they then transpire through their leaves back into the atmosphere.[27]

Figure 2. The Hydrologic Cycle



Water typically percolates into the earth vertically down until it reaches the ground water table, where it flows in a more lateral direction through the porous spaces in the geologic formation, thereby forming an aquifer. [28] Normally, such water emerges in natural discharge sites, such as springs, rivers, lakes, lagoons,

25. *See* PRICE, *supra* note 12, at 15-16 (describing how precipitation collects on and flows over the surface and the process in which water infiltrates into the ground).

26. *See* FETTER, *supra* note 13 (explaining in detail the different stages of the hydraulic cycle); *see also* PRICE, *supra* note 12, at 13-19 (diagramming the cycle of water); Barberis 1986, *supra* note 18, at 1-2 (describing the hydrological cycle).

27. *See* PRICE, *supra* note 12, at 15-16 (discussing the processes of interception and transpiration of water by foliage).

28. *See infra* note 38 (referring to Price's analysis of ground water movement).

swamps, and the sea.[29] While the rate of percolation into the subsurface and the flow of ground water within aquifers are considerably slower than surface water flow, they are relatively consistent processes.[30]

Ground water is a significant component of the hydrologic cycle.[31] This is especially evident given the exponentially vast quantity of water found under the ground.[32] From a hydrological point of view, however, one should view ground water as neither similar nor dissimilar to surface water resources.[33] Ground and surface waters are, in fact, part and parcel of the same thing; namely, water moving through the various stages of the hydrologic cycle.[34] Accordingly, it is inappropriate for optimal productivity and sustainable use, objectives espoused in the preamble of the U.N. Watercourse Convention,[35] to bifurcate the management and regulation of ground and surface water resources.

B. UNDERSTANDING GROUND WATER

The term *ground water* generally refers to subsurface water that is below the ground water table, *i.e.*, where the porous geologic formations are saturated completely with water, or where water occupies the entire porous space within a porous geologic

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29. *See* BOUWER, *supra* note 12, at 293 (noting that springs are the most conspicuous avenues for the natural return of ground water to the surface).

30. *See* PRICE, *supra* note 12, at 17 (remarking that percolation through aquifers is very slow).

31. *See id.* at 16-17 (demonstrating that ground water is an important element of the hydrologic cycle).

32. *See id.* at 2 (discussing the estimated distribution of the world's water resources).

33. *See* Thomas C. Winter et. al., *Ground Water and Surface Water, A Single Resource*, 1139 U.S. GEOLOGICAL SURV. CIRCULAR 1, 76 (1998) (emphasizing the importance of considering ground water and surface water collectively).

34. *See id.* at 3 (noting that "surface water commonly is hydraulically connected to ground water, but the interactions are difficult to observe and measure.").

35. *See* Watercourse Convention, *supra* note 21, pmbl. (advocating that a "framework convention will ensure the . . . promotion of the optimal and sustainable utilization [of international watercourses] for present and future generations").

formation.[36] Ground water, found in various types of aquifers around the world, comprises only 3/4 of one percent of the total volume of fresh and salt water found in nature, but it makes up nearly ninety-seven percent of the fresh water readily available for consumption.[37]

1. Aquifers

An *aquifer* is a relatively permeable geologic formation (such as sand or gravel) that has sufficient water storage and transmitting capacity to provide a useful water supply via wells and springs.[38] The upper limit of the saturated area is known as the *water table*.[39] All aquifers have an impermeable base layer that prevents water from seeping deeper to lower lying strata, thus creating a natural water reservoir within the porous geologic formation.[40] At any given location, the land surface may be underlain by one or more distinct aquifers separated by impermeable layers (like different apartments separated by floors in a multilevel apartment building), depending on the composition of the underlying strata.[41]

An *unconfined aquifer* (also known as water-table aquifer) is bounded by an impermeable base layer of rock or sediments, and

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36. *See* PRICE, *supra* note 12, at 7 (providing a basic explanation of the difference between surface and ground water); *see also* Ralph C. Heath, *Basic Ground-Water Hydrology* , 2220 U.S. Geological Survey Water-Supply Paper 1, 4 (1987) (explaining that only underground water found in the saturated zone is considered ground water), *available at* http://water.usgs.gov/pubs/wsp/wsp2220/ (last visited Oct. 15, 2003). *See generally* FETTER, *supra* note 13, at 5-7 (including a more advanced discussion of ground water resources and the science of hydrogeology).

37. *See* BOUWER, *supra* note 12, at 1-3 (explaining that humankind's supply of ground water is extremely limited and must be "wisely managed and protected").

38. *See* PRICE, *supra* note 12, at 9 (providing a definition and discussion of aquifers); *see also* S. Foster, *Essential Concepts for Ground Water Regulators*, *in* GROUNDWATER: LEGAL AND POLICY PERSPECTIVES, PROCEEDINGS OF A WORLD BANK SEMINAR, *supra* note 3, at 15, 15-16 (discussing the hydraulic properties of aquifers).

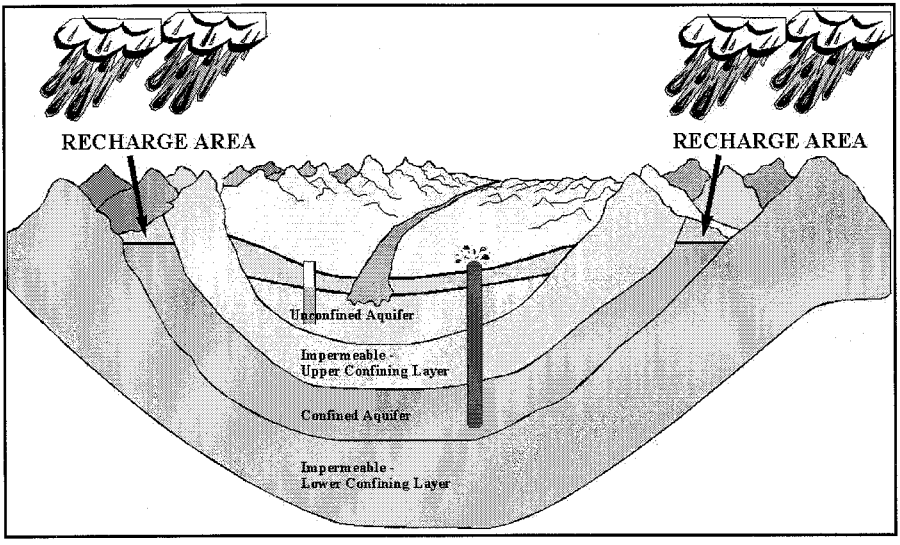
39. *See* PRICE, *supra* note 12, at 6 (providing the definition of a water table).

40. *See* BOUWER, *supra* note 12, at 4 (listing some of the materials that constitute the impermeable layer, including clays or "other fine-textured granular material, or of shale, solid limestone, igneous rock, or other bedrock").

41. *See* FETTER, *supra* note 13, at 511 (noting that a particular surface location may be underlain by several aquifers).

overlain by layers of permeable materials extending from the land surface to the impermeable base of the aquifer (Figure 3).[42] Although not always the case, unconfined aquifers are often directly related to a surface body of water, such as a river or lake.[43] Rivers, for example, tend to have interrelated unconfined aquifers located directly underneath and following the course of the riverbed.[44] Unconfined aquifers, however, can also exist independent of a surface body of water, as is evident in many arid climates, such as the Middle East.[45]

Figure 3. Confined and Unconfined Aquifers



42. *See* PRICE, *supra* note 12, at 10-11 (defining an unconfined aquifer through comparison with a confined aquifer); *see also* BOUWER, *supra* note 12, at 3-4 (describing the absence of clay or other material lying above the ground water to restrict its connection to the surface).

43. *See* BOUWER, *supra* note 12, at 4, 6 (explaining that seepage and draining from rivers and lakes connects unconfined aquifers to surface bodies of water).

44. *See id.* at 3-4 (noting that, depending on the strata underneath and beside the river, an unconfined aquifer hydraulically related to a river is generally spread out laterally on both sides of and below the river).

45. *See infra* note 55 (explaining that, for example, the Mountain or West Bank Aquifer traversing Israel and the West Bank is unconfined in its upper reaches and has no relationship to any surface body of water); *see also infra* note 73 (claiming that the Nubian Sandstone Aquifer, underlying Chad, Egypt, Libya, and Sudan in northeastern Africa, is another example of an unconfined aquifer that is unrelated to any surface body of water).

In contrast, a *confined aquifer* (also known as an artesian aquifer) is an aquifer contained between two impermeable layers – the base, or "floor," and the "ceiling" strata – that subject the stored water to pressure exceeding atmospheric pressure (Figure 3).[46] If a well is drilled through the impermeable upper layer of the aquifer, the confining or hydraulic pressure within the confined aquifer would propel water through the well toward the surface.[47] As an example, consider a U-shaped tube filled with water. If one were to attach a vertical pipe (or "well") anywhere between the two raised arms of the tube, water would be propelled upward into the vertical "well" at the point where it is attached.

Confined aquifers are not necessarily devoid of any connection to surface water or other water resources.[48] Such aquifers must have a source for their water and often are recharged through lateral flow of water from recharge zones located at distant higher elevations, such as mountains or high plateaus, where the aquifer crops out on the land surface.[49] In addition, confined aquifers can themselves discharge into rivers and lakes at lower elevations.[50] Hence, confined aquifers are very much a part of the hydrologic cycle.

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46. *See* PRICE, *supra* note 12, at 10-11 (providing a discussion on the difference between confined and unconfined aquifers); *see also* BOUWER, *supra* note 12, at 4 (stating that the impermeable layers are called "aquicludes"); Barberis 1986, *supra* note 18, at 4 (defining a confined aquifer as one that is subjected to exceeding amounts of pressure with an impermeable floor and roof).

47. *See* FETTER, *supra* note 13, at 110 (explaining that when tapped by a well, water pressure in a confined aquifer will force water to rise into the well). The water may rise a considerable distance above the top of the aquifer and may spout above the ground surface. *Id.*

48. *See* BOUWER, *supra* note 12, at 4-5 (relating that confined aquifers may transmit water vertically to the surface bodies, and vice versa, through an aquitard, a layer of strata less permeable than the aquifer, but not totally impermeable).

49. *See id.* at 5 (explaining with the aid of a diagram that water in confined aquifers is derived mostly from rainfall in higher elevations where the aquifer is exposed to the surface).

50. *See id.* at 6 ("Hillside seeps and springs occur where the aquifer and its lower impermeable boundary are exposed to the atmosphere at hillsides, canyons, etc.").

Confined aquifers often are confined in only a portion of the aquifer.[51] The San Pedro Basin Aquifer underlying Mexico and the United States, for example, is a mix confined/unconfined aquifer with transboundary implications.[52] Linked hydraulically to the San Pedro River, both the river and the related ground water flow northward into the United States.[53] While most of the aquifer is unconfined, in the border region of the basin in the Palominas-Hereford and the St. David-Benson areas, the aquifer becomes confined.[54]

Another example of a mixed confined-unconfined aquifer with transboundary implications is the Mountain, or West Bank, Aquifer underlying the foothills bordering the Israeli coastal plain and the Jordan-Dead Sea Rift Valley.[55] Beginning as an unconfined aquifer in the highlands of the Judean Mountains, which include the Palestinian Territory of the West Bank, the aquifer recharges solely from precipitation in the highlands.[56] As it slopes westward toward

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51. *See* Robert D. Hayton, *Observations on the International Law Commission's Draft Rules on the Non-Navigational Uses of International Watercourses: Articles 1-4*, 3 COLO. J. INT'L ENVTL. L. & POL'Y 31, 38 (1992) (noting that confined aquifers "may not be confined throughout, only locally").

52. *See* Hector M. Arias, *International Groundwaters: The Upper San Pedro River Basin Case*, 40 NAT. RESOURCES J. 199, 204 (2000) (describing the confined and unconfined characteristics of the San Pedro Basin Aquifer in the United States and in Mexico).

53. *See id.* at 199-200 (stating that the waters flow into Arizona).

54. *See id.* at 204 (describing the geographic location of the confined and unconfined portions of the aquifer).

55. *See, e.g.*, Eyal Benvenisti, *The Israeli-Palestinian Declaration of Principles: A Framework for Future Settlement*, 4 EURO. J. OF INT'L L. 542, 545 (1993) (noting how the Israelis and the Palestinians have different views over the proper allocation of their shared water resources), *available at* http://www.ejil.org/journal/Vol4/No4/art5-03.html (last visited Oct. 23, 2003). While the international political status of the West Bank and the Palestinian controlled territories may be debatable, the situation provides an interesting example of disputed waters in a political geography that could, at some point in the future, have possible international implications. *Id.*; *see also* Eyal Benvenisti & Haim Gvirtzman, *Harnessing International Law to Determine Israeli-Palestinian Water Rights: The Mountain Aquifer*, 33 NAT. RESOURCES J. 543, 543-67 (1993) (discussing the utilization of the Mountain Aquifer and the rights of both sides to its waters).

56. *See* Gabriel E. Eckstein, Hydrologic Reality: International Water Law and Transboundary Groundwater Resources, Address at the American University

the Mediterranean Sea and eastward toward the Jordan Rift Valley, following the downward curvature of the strata, it becomes confined in the lowland areas underneath impermeable rock formations.[57] Precipitation falling on the surface in the lowland areas does not reach the aquifer, making it absolutely reliant on recharge from the highlands.[58]

Surface water resources that are hydraulically linked to an aquifer are often described as *influent* or *effluent* bodies of water.[59] Where the ground water table is found below the bottom of a surface body of water, such as a stream or a lake, and where the soil is moderately permeable, water will percolate from the stream or lake downward, recharging the underlying aquifer—this is called an influent (or *losing*) stream or lake.[60] An effluent (or *gaining*) stream or lake results where the ground water table, lying at an elevation higher than the intersected stream channel or lake, recharges the surface water resource.[61] This differentiation is important, especially in the context of water quality and contamination. A polluted river that is effluent will not contaminate the related ground water on either side

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Center for the Global South Conference, "Water: Dispute Prevention and Development," Washington, D.C. (Oct. 12-13, 1998) [hereinafter Eckstein 1998] (indicating that the Mountain Aquifer is particularly interesting in that it is both an unconfined and a confined aquifer), *available at* http://www.internationalwaterlaw.org/Articles/GlobalSouth.htm (last visited Nov. 21, 2003).

57. *See id.* (noting that the aquifer begins as an unconfined aquifer in the highlands of the Judean Mountains where precipitation, mostly in the form of rain, recharges the aquifer); *see also* Haim Gvirtzman, *Ground Water Allocation in Judea and Samaria*, *in* WATER AND PEACE IN THE MIDDLE EAST 205, 208-12 (Jad Issac et al. eds., 1994) (describing the flow of ground water in the Mountain Aquifer).

58. *See* Eckstein 1998, *supra* note 56 ("Thus precipitation falling on the lowlands generally does not reach the aquifer, but flows toward another unconfined aquifer known as the coastal aquifer on the edge of the Mediterranean.").

59. *See* FETTER, *supra* note 13, at 58-59 (defining and describing influent and effluent streams).

60. *See* Barberis 1986, *supra* note 18, at 5 (defining the terms "influent" and "effluent" in relation to rivers and lakes).

61. *See id.* (defining the distinguishing characteristics between influent and effluent rivers and lakes); *see also* FETTER, *supra* note 13, at 58-59 (describing the relationship between an aquifer and an effluent stream).

of the river.[62] Ground water that is polluted on one side of an effluent river will contaminate the river, but will likely not affect the quality of the ground water on the other side of the river.[63]

Rivers that hydraulically link to an aquifer, however, can be influent at one point of the river and effluent at another point with the same or a different aquifer.[64] Moreover, a river that is normally effluent during normal climatic conditions may temporarily become influent during high rain and flood conditions.[65] Such changes can also be very localized, such as occurring on one side of a river but not the other, brought about by heavy ground water pumping in the vicinity of a river.[66] Well pumping could lower the water table in the immediate area around the pump well and, as a result, change the stream-aquifer relationship from an effluent to an influent relationship on only one side of a river.[67] Whether a river is influent or effluent at any particular point is dependent on factors such as topography, amount and rate of precipitation, soil permeability, and hydraulic conductivity of the soil underlying the river.[68]

Aquifers that do not recharge (*i.e.*, aquifers that are completely detached from the hydrologic cycle) often are described in legal literature as fossil aquifers.[69] Such aquifers do not have a source of

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62. An effluent river does not contribute to adjacent aquifers, therefore a polluted river will not pollute adjacent aquifers.

63. An effluent river receiving water from an aquifer section polluted on one side of the stream will receive all contaminants contained in the aquifer section, but will not transfer those contaminants to the aquifer section on the other side of the stream.

64. *See* Eckstein 1998, *supra* note 56 (differentiating between a losing and a gaining stream or lake and the ability of a stream to be losing and gaining at different points along its course).

65. *See* Barberis 1986, *supra* note 18, at 5 (noting that a river, lake, or lagoon can become influent during times of flooding, and effluent in times of low water).

66. *See infra* note 83-89 and accompanying text (relating more about the effects of ground water pumping).

67. *See* Heath, *supra* note 36, at 32-33 (describing the response of the ground-water systems to withdrawals from wells).

68. *See* Barberis 1986, *supra* note 18, at 6 (mentioning that, depending on the hydraulic potential of the flow, an effluent stream can become influent and vice versa).

69. *See id.* at 4 (noting that fossil waters are the type that "remain trapped at the time when geological accumulation occurred . . . "). The term "fossil" aquifer, as

recharge and do not discharge naturally. As a result, water in these aquifers is non-renewable, stagnant, and has little if any flow.[70] Such aquifers typically contain very old ground water that has been trapped in a geologic formation, either because of physical isolation of the aquifer from sources of recharge, impermeability of surrounding formations, or paucity of recharge in an arid region. Typically, water in aquifers that do not recharge may be hundreds (and may be thousands or millions) of years old.[71]

Often found in arid climates, fossil and other non-renewable ground water resources are important sources of water for many nations. An example of a transboundary, unconfined aquifer that has no recharge is the Nubian Sandstone Aquifer in northeastern Africa, which underlies the countries of Chad, Egypt, Libya, and Sudan.[72] Located at depths ranging from a few meters to hundreds of meters below the surface, the water in this aquifer is estimated to be at least 15,000, and as much as 35,000, years old.[73] While the overlaying strata is still relatively permeable, present-day recharge rates range from miniscule to nil, contingent on the occasional rain and flash

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used in the legal literature to describe all non-recharging aquifers, is a misnomer. A fossil aquifer is but one type of non-recharging aquifer. It describes an aquifer (whether confined or unconfined) containing water that was buried at the same time as the geologic formation in which it is trapped and that is non-renewable. Hence, the ground water in such aquifers is of the same age as the porous geologic formation in which it is found. A second type of non-recharging aquifer is a "connate" aquifer, which describes a confined aquifer which has been completely cut off from any recharge or discharge for an appreciable period of geologic time. In such aquifers, ground water once flowed freely through the aquifer from a recharge to a discharge zone, but has since become cut off from both. As a result, it has become stagnant within the porous geologic formation. *See* Fetter, *supra* note 13, at 288.

70. *Cf.* Barberis 1986, *supra* note 18, at 6 (adding that fossil waters are not part of the hydrologic cycle).

71. *See* BOUWER, *supra* note 12, at 7 (noting that connate water may have been isolated from the hydrologic cycle for millions of years); FETTER, *supra* note 13, at 364 (describing fossil aquifers in North Africa that have been determined to be more than 35,000 years old).

72. *See* Eckstein 1998, *supra* note 56 (describing the dynamics of this unique aquifer, which is not related or connected to any other water resource in the region).

73. *See id.* (tracing the origins of the water in this aquifer, which percolated down during the glaciation of northern and central Europe).

flood. Moreover, this aquifer is not related or connected to any other water resource in the region.[74]

2. *Ground Water Flow*

The lay community often misguidedly perceives aquifers and ground water as underground lakes or rivers. Yet, in reality they are neither. In most aquifers, water is rarely stagnant (except in aquifers with no recharge) and tends to flow toward natural discharge sites, such as springs, rivers, lakes, lagoons, swamps, and the sea.[75] Ground water in an aquifer resides in pore spaces in a similar way to water in a sponge where it fills up all the small holes, but with one distinction—that a sponge material is more elastic and pliable than the materials in a geological formation. Thus, the flow of ground water does not occur in the form of "underground rivers" or "veins," but rather in the form of water seeping like through a sponge.[76] Furthermore, the rate (or velocity) of ground water flow is far slower than any water flow perceived on the land surface, such as in rivers and streams – ground water velocities commonly range from one meter per day to one meter per year.[77]

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74. *See* UNESCO, INTERNATIONALLY SHARED (TRANSBOUNDARY) AQUIFER RESOURCES MANAGEMENT: THEIR SIGNIFICANCE AND SUSTAINABLE MANAGEMENT, A FRAMEWORK DOCUMENT, 41-44 (Shammy Puri et. al. 2001) (presenting a brief case study on the Nubian Sandstone Aquifer System).

75. *See* Barberis 1986, *supra* note 18, at 2 (explaining that water in aquifers flows toward surface water, such as rivers, springs, lakes, and the sea); *see also* Bouwer, *supra* note 12, at 36 (asserting that "[u]nderground water is almost always in motion.").

76. *See* Barberis 1986, *supra* note 18, at 2 (describing the movement of ground water and providing mathematical models for determining flow velocity, direction, and volume).

77. *See* W. KENNETH HAMBLIN AND E.H. CHRISTIANSEN, EARTH'S DYNAMIC SYSTEMS 325 (2001) (describing average flow velocities of ground water); *see also* Heath, *supra* note 36, at 25 ("The rate of movement of ground water is greatly overestimated by many people, including those who think in terms of ground water moving through "veins" and underground rivers at the rates commonly observed in surface streams."). "It would be more appropriate to compare the rate of movement of ground water to the movement of water in the middle of a very large lake being drained by a very small stream." *Id.*

Hydraulic potential governs the flow of water.[78] While hydraulic potential of surface water is primarily a function of gravity and the slope of the surface, hydraulic potential of ground water is a function of gravity as the dominant force, as well as soil porosity and permeability (the ability of the soil to transmit water), gradient, or slope of the ground water table, ambient air pressure, and temperature.[79] Ground water generally flows from areas of higher hydraulic potential to areas of lower hydraulic potential. As a result, it is possible to have a stream flowing down the side of a mountain in one geographical direction, while ground water in a connected underlying aquifer is flowing in another direction.[80] For example, surface water in the Danube River, as well as related ground water, generally flows toward a terminus in the Black Sea. In the upper region of the Danube, however, where the river emerges from the Black Forest in Germany, water from the river seeps on a seasonal basis into the fractured bedrock underlying the river and travels through the fractures into the Rhine River basin, thus flowing toward a terminus in the North Sea.[81] This scenario was the subject of a well-known case – *Donauversinkung* – brought by the German states of Württemberg and Prussia against Baden.[82]

78. *See* Heath, *supra* note 36, at 25 (adding that the thickness of the aquifers and confining beds affect the flow of ground water).

79. *See id.* at 20-25 (discussing the flow and velocity of ground water, methods for charting flow movement, and noting that gravity is the dominant force affecting ground water movement).

80. *See* FETTER, *supra* note 13, at 9 ("The boundaries of a surface-water basin and the underlying ground-water basin do not necessarily coincide.").

81. *See* Württemberg and Prussia v. Baden (the *Donauversinkung* case), 8 Ann. Dig. 128 (German Staatsgerichtshof 1927) (discussing the nature of the dispute, the facts and the holding of the case).

82. *See id.* at 129 (summarizing the holding of the case to be that Baden must refrain from causing an increase in the natural sinking of the waters of the Danube and that Württemberg must refrain from causing a decrease of the natural sinking of the waters of the Danube); *see also* McCaffrey, *supra* note 1, ¶¶ 40-45 (finding that the actions of one watercourse state with respect to its ground water may affect ground water or surface water in another watercourse state).

3. *Ground Water Pumping*

Production of water from water wells is usually accomplished through the use of a pump-intake lowered into a water well.[83] As a result of the pumping action, a pumping water well will typically generate a flow of ground water in the immediate vicinity of the well.[84] The water converges radially from all directions on the well's intake pipe thus resulting in a *cone of depression* – a curved funnel-shape depression in the ground water table – centered at the pumping well (Figure 4).[85] The largest drop in the ground water level occurs in the center of the "funnel", *i.e.*, at the pumping well, and diminishes with distance from the pumping well.[86] The shape and dimensions of the cone of depression, *i.e.*, the amount of drop in the ground water table at any given point around the pumping well, depend on the permeability of the aquifer material and the rate of pumping.[87] The radial distance from a pumping well at which the drop in the ground water table declines to nil is the *radius of influence* or the *radius of the cone of depression* for that particular water well at the specified rate of production.[88] Water outside the radius of influence (beyond the influence of the pumping well) will not flow toward the pump-intake, but rather in its normal flow pattern.

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83. *See* Heath, *supra* note 36, at 30 (relaying that the pump-intake action causes the water level of the well to fall).

84. *See id.* at 30 (describing the well-pumping process in detail).

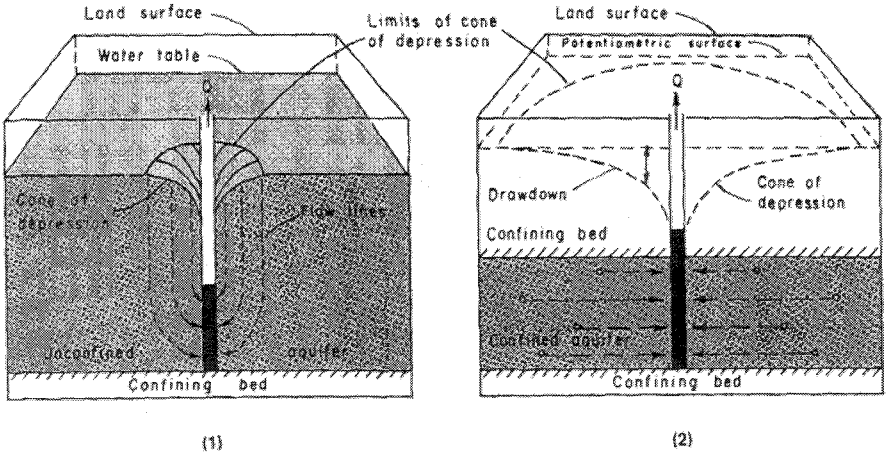
85. *See id.* (explaining how the water moves from the aquifer into the well).

86. *See id.* (showing how the area through which the flow occurs decreases toward the well, causing the hydraulic gradient to increase).

87. *See id.* at 32 (delineating the response of aquifers to well withdrawals).

88. *See* Heath, *supra* note 36, at 30 (explaining that "because water must converge on the well from all directions and because the area through which the flow occurs decreases toward the well, the hydraulic gradient must get steeper toward the well").

Figure 4. Diagram of a Cone of Depression for pumping wells in (1) an unconfined aquifer, and (2) a confined aquifer.[89]



4. Aquifer Recharge

Aquifers may recharge from rain-soaked ground, from lakes and streams, and, to some extent, from other aquifers.[90] Significantly, certain human activities, such as irrigation operations, dike and canal building, and damming projects, may also recharge aquifers.[91] Aquifer recharge is a function of both gravity and of the permeability of the strata lying between the aquifer and the source of the recharge. As a result, aquifers can also transmit to, and serve as, a source of water for lakes, streams, and other aquifers.[92]

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89. Heath, *supra* note 36, at 30.

90. *See* Barberis 1986, *supra* note 18, at 2 (adding that precipitation soaking through the ground contributes to aquifer recharge).

91. *See id.* (explaining the sources of aquifer recharge, including from human activity).

92. *See id.* at 5-6 (discussing possible aquifer recharge sources and the interrelation between ground water and surface water). An aquifer with ground water at a higher elevation than a nearby stream, lake, or other aquifer can serve as a source of recharge for that body of water. *Id.*

The Mimbres Basin Aquifer, which underlies the border-states of New Mexico in the United States and Chihuahua in Mexico, provides an example of a direct relationship between surface and ground water and of uneven distribution of recharge to a transboundary aquifer.[93] Due to the high level of evapotranspiration in this arid region, only a small percentage of basin-wide precipitation and surface runoff actually reaches the aquifer.[94] Most aquifer recharge occurs in the upland area in the northern part of the basin where temperatures and evapotranspiration are relatively lower.[95] Sources of recharge in the area include the only major perennial stream in the Mimbres Basin system, the Mimbres River, and a few intermittent streams, like the San Vicente Arroyo.[96]

This exchange between surface and subsurface water resources is not unique, and is important because the conditions affecting the quality and quantity of the water on one side of the relationship can have consequences on interrelated water resources.[97] Moreover, it is very common to have mutual relationships between surface and underground water resources that vary in time and space.[98] A river, for example, may discharge water into a related aquifer at one point of its course, and receive water from ground water at another; or a given stretch of a river may discharge into an aquifer during the autumn season and receive water in the spring.

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93. *See* J.W. HAWLEY ET. AL., N.M. WATER RES. RESEARCH INST., TRANS-INTERNATIONAL BOUNDARY AQUIFERS IN SOUTHWESTERN NEW MEXICO 30 (2000) (describing the location and setting of the Mimbres Basin system), http://wrri.nmsu.edu/publish/otherrpt/swnm/chap4.pdf (last visited Oct. 15, 2003).

94. *See id.* at 38 (noting that the ground water recharge of the Mimbres Basin system is typical of most arid and semiarid regions). Studies suggest that this contribution is less than two percent of average annual precipitation. *Id.*

95. *See id.* (adding that recharge also occurs in a narrow southern area of the Mimbres Valley).

96. *See id.* at 30, 36-38 (describing the major components of the Mimbres Basin ground water system, including surface water and intermittent streams). Notably, while the Mimbres Basin Aquifer is an international aquifer, the Mimbres River flows solely inside the United States. *Id.*

97. *See* HAMBLIN & CHRISTIANSEN, *supra* note 77, at 324 (stating that ground water is inextricably linked to surface water).

98. *See* WINTER, *supra* note 33, at 10-11, 16 (adding that storms and flooding can affect ground water and surface water exchange).

II. HISTORY OF GROUND WATER UNDER INTERNATIONAL LAW

Ground water resources historically have been omitted from, or neglected under, international law and cursorily misunderstood within the legal community.[99] While agreements focusing on transboundary rivers and lakes are relatively common,[100] there is a paucity of treaties and norms addressing transboundary and international ground water resources.[101] This, in turn, often causes a disregard for ground water resources in projects that have transboundary and ground water implications.[102]

English Common Law treated ground water either as part of the overlying land or as a commodity, subject to its capture (*i.e.*, via a well).[103] It was also subject to absolute ownership by the

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99. *See* Albert E. Utton, *The Development of International Groundwater Law*, 22 NAT. RESOURCES J. 95, 98 (1982) ("The laws governing ground water nationally are inadequately developed, and the law governing transboundary groundwaters is only at the beginning state of development."); *see also* Dante A. Caponera & Dominique Alhéritière, *Principles for International Ground Water Law*, 18 NAT. RESOURCES J. 589, 592-94, 612-13 (1978) (discussing the few references to ground water resources found in treaties and contending that most legal research, until recently, was directed towards surface water issues). Some publicists ascribe this neglect to a "hydroschizophrenia," a condition attributed to decision-makers who misunderstand the relationship of surface and ground water and seek to apply different regulatory schemes. *Id.* at 594; *see also* Robert D. Hayton, *The Ground Water Legal Regime as Instrument of Policy Objectives and Management Requirements, in* INTERNATIONAL GROUNDWATER LAW 57, 60 (Ludwik A. Teclaff et al. eds., 1981) (noting that the problem may also lie in the inability of the modern legal system to keep apace with scientific knowledge); North Sea Continental Shelf (F.R.G. v. Den.; F.R.G. v. Neth.), 1969 I.C.J. 3, 218 (Feb. 20) (dissenting opinion of Judge Lachs) (remarking that "the acceleration of social and economic change, combined with that of science and technology, have confronted law with a serious challenge: one it must meet, lest it lag even farther behind events than it has been wont to do.").

100. *See* DANTE A. CAPONERA, PRINCIPLES OF WATER LAW AND ADMINISTRATION: NATIONAL AND INTERNATIONAL, 186-87 (1992) (discussing sources of international water law).

101. *See* Caponera & Alhéritière, *supra* note 99, at 592-94, 612-13 (1978) (discussing the few references to ground water resources found in treaties).

102. *See* Utton, *supra* note 99, at 98 (explaining that states have ignored ground water resources because of lack of laws governing their management).

103. *See id.* (noting that traditional law treated ground water either as part of the land or as a commodity).

superadjacent property owner.[104] Under the French Civil Code, a landowner could make full use of springs located on his property so long as he did not affect the lands of his neighbors.[105] Spanish law, which influenced much of ground water law in Latin America and the Philippines, treated ground water similarly to the English Common Law, but added the more progressive concept that ground water underlying public lands constitutes public ground water.[106] Nevertheless, ground water under these legal regimes was rarely, if ever, considered in conjunction with related surface waters or made subject to the same regulatory or management scheme.[107]

Necessity being the mother of invention, Islamic legal tradition may have one of the richest traditions of law applicable to ground water resources.[108] Over the generations, an extensive priority of rights to water access and use developed, including a right to drink, to water domestic animals, to irrigate land, and to share for other needs.[109] Indeed Islam considers the sharing of water a holy duty.[110]

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104. *See id.* at 99 (noting that ground water was subject to ownership by superadjacent property).

105. *See* Caponera & Alhéritière, *supra* note 99, at 599 (restating the French Civil Code, in particularly the basic law of 1898, stating the legal regime of water resources which limited this ownership right whenever the spring waters were vital to the population of a nearby community).

106. *See* Robert D. Hayton, *The Ground Water Legal Regime as Instrument of Policy Objectives and Management Requirements*, 22 NAT. RESOURCES J. 119, 123 (1982) (discussing development of ground water law under different legal traditions).

107. *See* Hayton, *supra* note 100, at 62 (explaining that "groundwater is still a separate [legal] regime" in most countries).

108. *See* William S. D. Cravens, *The Future of Islamic Legal Arguments in International Boundary Disputes Between Islamic States*, 55 WASH. & LEE L. REV. 529, 567 (1998) (discussing the connection between the development of Islamic law as it pertains to water resources and the arid Middle East). The richness of Islamic law addressing water issues is likely related to the religion's proliferation in the arid Middle East and North Africa. *Id.*

109. *See* Caponera & Alhéritière, *supra* 99, at 596-97 (describing the Islamic water law tradition); *see also* Mélanne Andromecca Civic, *A Comparative Analysis of the Israeli and Arab Water Law Traditions and Insights for Modern Water Sharing Agreements*, 26 DENV. J. INT'L L. & POL'Y 437, 442 (1998) (finding that the Koran was similar to Jewish Talmudic law in its establishment of rights).

Like the Western legal systems, however, the Islamic legal tradition rarely considered ground water contemporaneously with surface waters and does not address transboundary ownership and allocation issues.[111]

References to ground water resources, in the form of wells and springs, can be found in international treaties dating in the nineteenth and early twentieth centuries, albeit typically only as a secondary (or even tertiary) issue: the 1888 Agreement between the United Kingdom (Somalia) and France (Djibouti) affords both parties common rights to use the Hadou well;[112] the Versailles Treaty ending World War I, in the delimitation of the common border between Germany and Belgium, refers to the use of springs and ground waters;[113] the 1923 exchange of notes between France (Syria) and the United Kingdom (Palestine) addresses the use of spring waters;[114] and the 1924 exchange of notes between France and the United Kingdom briefly addresses the use of surface and spring waters between the Central African Empire, Chad, and Sudan.[115] A number of early agreements dealing with mining activities in border regions also briefly refer to the use of ground water resources: the 1843 agreement between Belgium and Luxembourg concerning mining, and the 1934 agreement between Tanganyika and Ruanda Urundi concerning water rights on the boundary.[116]

Early in the twentieth century, as the importance of ground water resources began gaining recognition, treaties of cooperation and

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110. *See id.* (finding that, like Talmudic law, both Sunni and Shi'ite law recognizes a Right of Thirst, and both consider denying water to be an offense against God).

111. *See id.* at 451-52 (suggesting that current transboundary water, like Islamic and Jewish water law, emphasize communality).

112. *See* Caponera & Alhéritière, *supra* note 99, at 593 (listing agreements that mentioned the use of ground water in the form of wells and springs).

113. *See id.* at 593-94 (giving examples of treaties, which mention the use of ground water).

114. *See id.* at 594 (mentioning the treaty between Syria and Palestine with regard to the use of spring waters).

115. *See id.* (including the communication between France and the United Kingdom in the discussion).

116. *See id.* (noting that these agreements focused on mining activities; however, they sometimes referred to ground water).

resolutions of transboundary dispute began referencing aquifers and ground water in the border regions, but again only as a secondary issue and often in passing.[117] Among these: the 1925 agreement between Egypt and Italy on the Ramba Well;[118] the 1927 Convention and Protocol between the USSR and Turkey, which concerned the use of frontier waters;[119] and the 1947 treaty of peace between the Allies and Italy, which concerned the use of springs in the Commune of Gorizia and vicinity by Italy and Yugoslavia.[120]

As governments and policymakers became more knowledgeable about the science of water, international agreements began recognizing the interrelationship between surface and ground waters.[121] For example, the 1950 treaty between the German Federal Republic and Luxembourg provides that "in the event of damage caused by a rise or fall in the ground water on the west side of the Sauer in consequence of the construction of the dam, the government of the Grand Dutchy of Luxembourg undertakes to rectify such damage or pay appropriate compensation."[122] Recognition of

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117. *See* Utton, *supra* note 99, at 104 (discussing historical development of international ground water law).

118. *See* Accord Entre L'Égypte et L'Italie Concernant L'Établissement des Frontières entre La Cyrénaïque et L'Égypte, Dec. 6,1925, Egypt- Italy, *reprinted in* Legislative Texts and Treaty Provisions Concerning the Utilization of International Rivers for Other Purpose than Navigation, No. 1, at 99, U.N. Doc. ST/LEG/SER.B/12 (1963) [hereinafter Legislative Text and Treaty Provisions] (listing the provisions of Treaty No. 6 between Egypt and Italy).

119. *See* Convention Entre L'Union des Républiques Socialistes Soviétiques et La Turque pour la Jouissance des Eaux Limitrophes et Protocole Concernant la Rivière Araxe, Jan. 8, 1927, Turk.-U.S.S.R., *reprinted in* Legislative Text and Treaty Provisions, *supra* note 118, at 384 (outlining Treaty No. 106 concerning the use of former Soviet and Turkish frontier waters).

120. *See* Traité de Paix Entre les Puissance Alliées et Associées, d'Une Part, et L'Italie, d'Autre Part, Feb. 10, 1947, *reprinted in* Legislative Text and Treaty Provisions, *supra* note 118, at 415-21 (stating Treaty No. 120 concerning the utilization of springs in the Commune of Gorizia and vicinity).

121. *See* Utton, *supra* note 99, at 109 (explaining that in the nineteenth century many governments did not realize that surface water pollution could contaminate underground water resources).

122. *See* State Treaty Between the Grand Duchy of Luxembourg and the Land Rhineland-Palatinate in the Federal Republic of Germany Concerning the Construction of a Hydro-electric Ppower-plant on the Sauer (Sûre) at Rosport/Ralingen, Apr. 25, 1950, F.R.G.-Lux., art. 10, *reprinted in* Legislative

jurisdiction over transboundary aquifers by boundary commissions and boundary water institutions began appearing in international treaties. For example, such recognition appeared in a treaty between Yugoslavia and its neighbors;[123] between Poland and Czechoslovakia (1958) over the use of water resources in the frontier region;[124] between in Cameroon, Chad, Niger, and Nigeria (1964) over the development of the Chad Basin;[125] between in Finland and Sweden (1972) over water resources in the frontier;[126] between Italy and Switzerland (1972) regarding management of water pollution;[127] and

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Text and Treaty Provisions, *supra* note 118, at 721, 723 (agreeing to compensate Germany if Luxembourg damages the ground water source located on the west side of the Sauer).

123. *See, e.g.,* Agreement Between the Government of the Federal People's Republic of Yugoslavia and the Government of the Hungarian People's Republic Together With the Statute of the Yugoslav-Hungarian Water Economy Commission, Aug. 8, 1955, Yugoslavia-Hung., *reprinted in* Legislative Text and Treaty Provisions, *supra* note 118, at 830; Agreement Between the Government of the Federal People's Republic of Yugoslavia and the Government of the People's Republic of Albania Concerning Water Economy Questions, Together with the Statute of the Yugoslav-Albanian Water Economic Commission and With the Protocol Concerning Fishing in Frontier Lakes and Rivers, Dec. 5, 1956, Yugoslavia-Alb., *reprinted in* Legislative Text and Treaty Provisions, *supra* note 118, at 441; Agreement Concerning Water-economy Questions Between the Government of the Federal Republic of Yugoslavia and the Government of the People's Republic of Bulgaria, Apr. 4, 1958, Yugoslavia-Bulg., *reprinted in* Legislative Text and Treaty Provisions, *supra* note 118, at 558.

124. *See* Agreement Concerning the Use of Water Resources in Frontier Waters, Mar. 21, 1958, Czech Rep.-Pol., 523 U.N.T.S. 89 (addressing questions concerning the use of water resources in frontier waters).

125. *See* Convention and Statutes Relating to the Development of the Chad Basin, May 22, 1964, 13 NATURAL RESOURCES WATER SERIES 8 (preparing general regulations and making recommendations about the economic development inside the basin), *available at* http://ocid.nacse.org/qml/research/tfdd/toTFDDdocs/128ENG.htm (last visited Oct. 15, 2003).

126. *See* Agreement Concerning Frontier Rivers, Sept. 16, 1971, Fin.-Swed., 825 U.N.T.S. 191 (requiring the use of frontier waters in a manner that will not harm the two states).

127. *See* Convention Concerning the Protection of Italo-Swiss Waters Against Pollution, Apr. 20, 1972, Switz.-Italy, 957 U.N.T.S. 280 (establishing a mixed commission to protect against the pollution of surface and ground waters), *available at* http://ocid.nacse.org/qml/research/tfdd/toTFDDdocs/259ENG.pdf (last visited Oct. 15, 2003).

between the United States and Mexico (1973) over the salinity of the Colorado River.[128]

The agreement signed between the French Prefect de Haute-Savoie and the Swiss Canton of Geneva concerning ground water resources in the Lake Geneva basin is the only international agreement that directly addresses a transboundary aquifer.[129] This relatively simple agreement addresses both water extraction and artificial recharge for the rational management of the aquifer.[130] This agreement is especially unique because the parties arranged it at a local, rather than international, level.[131]

Despite these references and the growing acknowledgement of the significance of ground water resources, the experience pales in comparison with the recognitions afforded surface water resources and the development of international law applicable to transboundary surface waters.[132] While states are making greater efforts to address this situation, a lack of consensus regarding the applicable

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128. *See* Agreement Confirming Minute No. 242 of the International Boundary and Water Commission, Aug. 30, 1973, U.S.-Mex., 24 U.N.T.S. 1968 (discussing the problem of the salinity of the Colorado River).

129. *See* Arrangement on the Protection, Utilization, and Recharge of the Franko-Swiss Genevese Aquifer, Sept. 1977 Fr.-Switz. (agreeing on the management of the Genevese aquifer "in order to protect this natural resource and to preserve the quality of its waters"), *available at* http://www.internationalwaterlaw.org/RegionalDocs/Franko-Swiss-Aquifer.htm (last visited Oct. 19, 2003); *see also* BERNARD J. WOHLWEND, WORKSHOP ON HARMONIZATION OF DIVERGING INTERESTS IN THE USE OF SHARED WATER RES., *An Overview of Groundwater in International Law, A Case Study: The Franco-Swiss Genevese Aquifer* (2002) (analyzing the Franco-Swiss Aquifer under international law), *available at* http://www.bjwconsult.com/The%20Genevese%20Aquifer.pdf (last visited Oct. 19, 2003).

130. *See* WOHLWEND, *supra* note 129, at 17 (ordering the limitations of water extractions and discussing the construction and operation of the artificial recharge installation).

131. *See id.* at 6 (adding that the agreement is "remarkable" because it ignores historical concepts of international water law and follows a "purely pragmatic approach").

132. *See* Caponera, *supra* note 100, at Ch. 10 (discussing the sources of international water law); *see also* Caponera & Alhéritière, *supra* note 99, at 592-94, 612-13 (discussing the few references to ground water resources found in treaties).

international law to transboundary and international ground water resources still exists.[133]

The International Law Association ("ILA") Helsinki Rules of 1966[134] and Seoul Rules of 1986 represent some of the earliest efforts to formally and directly address the status of transboundary and international ground water resources under international law.[135] Article II of the Helsinki Rules defines an international drainage basin, the unit used to delineate the geographic scope considered under the Rules, as a transboundary geographic area defined by the extent of the watershed.[136] This definition includes "surface and groundwater."[137] The Seoul Rules reinforced and expanded the Helsinki Rule that ground water is a proper subject of international law by including *all* types of aquifers.[138] While the development of

133. *See* Ximena Fuentes, *The Utilization of International Groundwater in General International Law*, *in* THE REALITY OF INTERNATIONAL LAW: ESSAYS IN HONOR OF IAN BROWNLINE 177, 180 (Goodwin-Gill et al. eds., 1999) (questioning the existence of customary international law applicable to transboundary ground water resources); *see also* Dellapenna, *supra* note 6, at 214 (questioning the application of international water law principles to transboundary aquifers).

134. *See* INT'L LAW ASS'N, *Helsinki Rules on the Uses of the Waters of International Rivers and Comments*, *in* REPORT OF THE FIFTY-SECOND CONFERENCE 484 (1966) [hereinafter Helsinki Rules] (addressing general rules to the use of waters of an international drainage basin), *available at* http://www.internationalwaterlaw.org/IntlDocs/Helsinki_Rules.htm (last visited Oct. 15, 2003).

135. *See* INT'L LAW ASS'N, *The Seoul Rules on International Groundwaters*, *in* REPORT OF THE SIXTY SECOND CONFERENCE 251 (1987) (describing when international standards consider an aquifer international ground water), *available at* http://www.internationalwaterlaw.org/IntlDocs/Seoul_Rules.htm (last visited Oct. 15, 2003).

136. *See* Helsinki Rules, *supra* note 134, art. 2 (stating conditions for when an aquifer constitutes an international basin).

137. *See id.* (noting that a drainage basin includes surface and ground water); *see also* INT'L LAW ASS'N, *Comments to the Helsinki Rules on Uses of the Waters of International Rivers*, *reprinted in* Stephen McCaffrey, *International Organizations and the Holistic Approach to Water Problems*, 31 NAT. RESOURCES J. 139, 141 (1991) (commenting further on Article II that "[t]he drainage basin is an indivisible hydrologic unit which requires comprehensive consideration in order to effect maximum utilization and development of any portions of its waters.").

138. *See* Gabriel Eckstein, *Application of International Water Law to Transboundary Ground Water Resources, and the Slovak-Hungarian Dispute Over Gabcikovo-Nagymaros*, 19 SUFFOLK TRANSNAT'L L. REV. 67, 92-93 (1995)

these two Rules suggests progress in the evolution of international norms and principles for transboundary aquifers, their application has had limited influence on state practice and treaty development.[139]

The 1997 Convention on the Non-Navigational Uses of International Watercourses ("Watercourse Convention")[140] is a unique milestone in the development of international law related to ground water resources. While crafted to articulate the law of "international watercourses," the Convention defines watercourse as "a system of surface waters *and ground waters* constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus."[141] This definition supports the doctrine of hydrological unity and acknowledges the important interrelationship of surface and underground water within the hydrological cycle.[142] For the definition to apply in the international context, it is not necessary for an aquifer to traverse an international boundary so long

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[hereinafter Eckstein 1995] (explaining that the inclusion of ground water in the definition of drainage basin makes ground water a subject of international law).

139. *Cf.* Joseph Dellapenna, *Designing the Legal Structures of Water Management Needed to Fulfill the Israeli-Palestinian Declaration of Principles*, 7 PALESTINE Y.B. OF INT'L L. 63, 80 (1992/1994) (recognizing that work by the ILA, while significant, enjoys no official status in the development of international law). While the *raison d'etre* of the ILA is the interpretation and codification of international law, the organization operates as a private non-governmental organization. Accordingly, the work of the ILA has always been regarded as aspirational in nature and not as hard and fast rules of state conduct. *Id.*

140. *See* Watercourse Convention, *supra* note 21, art. 1 (discussing the rules of international law concerning the non-navigational uses of international watercourses).

141. *See id.* art. 2 (observing that the definition of watercourse includes surface and ground water).

142. *See* Gabriel Eckstein & Yoram Eckstein, *Ground Water Resources and International Law in the Middle East Process*, 28 WATER INT'L 154, 159-60 (2003) (stating that the doctrine of hydrological unity recognizes the interrelationship of surface and ground waters within the hydrologic cycle). It emphasizes that the most effective means to use, regulate, manage, and conserve transboundary water resources is through a comprehensive scheme that takes into account all interrelated water resources. *Id.* Thus, states must consider the watercourse and all hydraulically related surface and underground water resources as the unit of measure when implementing schemes for the use, management, and conservation of fresh waters. *Id.*

as a hydraulically related river traverses or flows along an international border.[143]

Thus, under the Watercourse Convention, the international norms and principles applicable to surface water resources also apply to all ground waters that fall within the definition of "international watercourse."[144] The most notable principles are reasonable and equitable utilization,[145] no substantial harm,[146] cooperation,[147] and good faith negotiations.[148]

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143. *See* Stephen McCaffrey, *International Ground Water Law: Evolution and Context*, *in* GROUNDWATER: LEGAL AND POLICY PERSPECTIVES, PROCEEDING OF A WORLD BANK SEMINAR, *supra* note 3, at 139, 155-56 (explaining the scope of the Watercourse Convention *vis a vis* ground water).

144. *See generally* Gabriel Eckstein, *Ground Water Resources Under the UN Watercourse Convention* (forthcoming 2004) (on file with author) [hereinafter Eckstein 2004] (analyzing the scope of the Watercourse Convention and its application to various transboundary and international ground water resources).

145. *See* Watercourse Convention, *supra* note 21, art. 5 (noting that the Watercourse Convention obliges states to use their transboundary water resources in an equitable and reasonable manner); *see also* Eckstein 1995, *supra* note 138, at 78-80 (explaining that the principle of equitable and reasonable use is a utilitarian concept that uses a cost-benefit analysis to maximize the beneficial use of limited water resources while minimizing the burdens). Riparian states, states with direct access to a transboundary river, must take into account the interests of all other riparian states and "the physical aspects of an entire water resource system" when implementing projects to use or develop the resource. *Id.*

146. *See* Watercourse Convention, *supra* note 21, art. 7 (explaining that states must use transboundary water resources in a manner that does not cause significant harm to the interests of other states relying on the resource); *see also* Eckstein 1995, *supra* note 138, at 75-78 (defining significant harm as injury that results or threatens consequential effects upon public health, economic productivity, the environment of another state, or when it materially interferes with or prevents a reasonable use of the water by another state). The principle of no significant harm, however, is considered subordinate to that of equitable and reasonable use. *Id.*

147. *See* Watercourse Convention, *supra* note 21, art. 8 (stating that in the use of an international watercourse, states must cooperate "on the basis of sovereign equality, territorial integrity, mutual benefit and good faith in order to attain optimal utilization and adequate protection of an international watercourse").

148. *See id.* art. 17 (noting that states have an obligation to employ good faith negotiations); *see also* Lake Lanoux (Fr. v. Spain), 24 I.L.R. 101 (NO.V 1957) (concluding that "the reality of the obligations thus undertaken is incontestable and sanctions can be applied in the event, for example, of an unjustified breaking off of the discussions, abnormal delays, disregard of the agreed procedures, systematic refusals to take into consideration adverse proposals or interests, more generally, in cases of violation of the rules of the rules of good faith."). *See generally* Brunson

Despite this progress, the Watercourse Convention is not a comprehensive elucidation of the status of ground water under international law.[149] In fact, the scope of the document may raise more questions than provide answers about the status of ground water resources under international law. Some unclear areas include the justification for differentiating between various aquifer types and the applicability of international law to particular aquifer types.[150] For example, the definition of "watercourse" imposes very specific limitations on the scope of the Convention.[151] Therefore, not all types of aquifers fall under the rubric of the Watercourse Convention.[152]

III. MODELS OF GROUND WATER RESOURCES WITH TRANSBOUNDARY IMPLICATIONS

Like surface water, ground water respects no political boundary.[153] Ground water in an aquifer can flow parallel to and across international boundaries and, often, form a part of a greater hydrologic system with the surface or ground water of neighboring

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MacChesney, *Judicial Decisions*, 53 AM. J. INT'L L. 156, 158 (1959) (stating that the case concerned France's proposal to divert the waters of Lake Lanoux for hydroelectric purposes). The Carol River flows across the border from France to Spain and feeds Lake Lanoux. *Id.*

149. *See* Eckstein 2004, *supra* note 144, at 15 (asserting that the Watercourse Convention excludes many types of ground water resources from the scope of the agreement).

150. *See, e.g., infra* Part V (arguing that the Watercourse Convention lacks a legitimate explanation for why its scope does not include non-recharging aquifers).

151. *See* Eckstein 2004, *supra* note 144, at 23 (explaining that the broad definition of watercourse restricts the Convention only to systems that have a physical relationship between inter-linked components). This suggests that an aquifer must be physically related to a surface body of water to be regarded as a component of a watercourse under the Convention. *Id.* Moreover, the definition limits the Convention's application to ground water that flows to a common terminus with the related surface waters. *Id.* Also, the Convention and the reports of the United Nations' International Law Commission suggest that the transboundary character of an aquifer-river system must be found in a river for the Convention to apply. *Id.*

152. *See generally id.* (explaining the gaps in analysis of ground water resources in the Watercourse Convention).

153. *See* Utton, *supra* note 99, at 113 (stating that ground water is similar to surface water because both do not respect political boundaries).

states.[154] From an international context, it is rare that a transboundary river is not linked to a domestic or transboundary aquifer.[155]

Spatial demarcations of frontiers and borders delineated by a sovereign serve as the basis for the sovereign's rights. For example, solid mineral deposits that extend across borders are divided based on these spatial demarcations.[156] However, this division of rights is inadequate in the case of fluid deposits, such as ground water, because none of the sharing states can determine the precise amount of ground water accruing to them without the assistance of the other riparian states.[157] Even with the assistance of other states, it is often difficult to reliably identify the exact dimensions and contents of an aquifer because of the fluid and dynamic nature of ground water.[158] When pumping water from a transboundary aquifer, it is practically impossible to predict the precise moment when the water being pumped is water from across the border.

In addition, with some exception, most aquifers regularly receive and transmit water as part of the hydrologic cycle, thus directly affecting both the quantity and quality of the water in the aquifer.[159]

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154. *See* Barberis 1991, *supra* note 18, at 168 (identifying four situations when states might share ground water with other states); *see also* Caponera & Alhéritière, *supra* note 99, at 590 (noting that many states currently share aquifers).

155. *See* Ludwik A. Teclaff & Eileen Teclaff, *supra* note 4, at 630 (1979) (noting that most international rivers are "connected with an underground water resource"). *See generally* Caponera & Alhéritière, *supra* note 101, at 590 (recognizing that most countries share a ground water system with other countries).

156. *Cf.* Rainer Lagoni, *Oil and Gas Deposits Across National Frontiers*, 73 AM. J. INT'L L. 215, 216 (1979) (discussing demarcation of sovereignty over transboundary oil and gas deposits).

157. *See id.* at 216-17 (conveying that no state can determine the precise amount of liquid deposits shared by multiple states without the cooperation of those states involved).

158. *See* Puri, *supra* note 74, at 16 (discussing ground water hydraulics with international implications). The flow of ground water across an international boundary cannot be measured directly, but can be estimated quite accurately through the use of parameters and mathematical models. *Id.*

159. *See* Edward A. Fitzgerald, *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers: Isolated Waters, Migratory Birds, Statutory and Constitutional Interpretation*, 43 NAT. RESOURCES J. 11, 37 (2003) (noting that water moves through the hydrologic cycle "so that pollution in any part of the

This is not to say that all aquifers are interconnected with surface water.[160] Nevertheless, there is an interdependent relationship between most surface and ground water resources that requires a comprehensive perspective for their use, management, and conservation.[161] Because of the transboundary and international characteristics of so many aquifers, ground water is a proper subject of international law.

A. BARBERIS' MODELS

Barberis, in his well-known 1986 study for the FAO, offers four case models to illustrate the transboundary and international nuances associated with ground water resources:

1) a confined aquifer is intersected by an international boundary, is not linked hydraulically with other groundwater or surface water, and, as such, it alone constitutes the shared natural resource;

2) an aquifer lies entirely within the territory of one state but is hydraulically linked with an international river;

3) the aquifer is situated entirely within the territory of a single state and is linked hydraulically with another aquifer in a neighboring state;

4) the aquifer is situated entirely within the territory of a given State but has its recharge zone in another state.[162]

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system will affect the quality of water that together forms the entire aquatic system").

160. *See supra* Part II.B.1 (describing non-recharging aquifers as disconnected from the hydrological cycle).

161. *See* McCaffrey, *supra* note 1, at 53 ("Because surface water and groundwater cannot be separated factually, these components of watercourse systems should not, in the view of water resource specialists, be treated separately for legal and planning purposes."); *see also supra* notes 32-33 and accompanying text (concluding that ground water and surface water are part of a whole; namely, the hydrologic cycle).

162. *See* Barberis 1986, *supra* note 18, at 36 (listing four situations in which ground water forms a part of an international water system); *see also* Barberis 1991, *supra* note 18, at 168 (containing a detailed description of all four Barberis models).

In presenting these models, Barberis sought to clarify both the international implications of transboundary and international ground water resources, and the legal status of this hidden resource under international law. Barberis intended the case models to illustrate transboundary and international aquifers found in nature and to be used as models for the application of international legal norms. While Barberis was correct in suggesting that ground water resources can have substantial international implications, two of the case models presented are scientifically imprecise and require further refinement and clarification.

Barberis' first example lacks precision in that it lumps together all unrelated confined aquifers under one example.[163] As we discuss below, unrelated confined aquifers must be subdivided into two categories based on their relationship to the hydrologic cycle: those that constitute a dynamic component of the hydrologic cycle (despite being unrelated to any other body of water), and those that are static bodies of water devoid of any connection to a source of recharge. The basis for this categorization is important to the extent that international law applicable to these two aquifer types may not necessarily be the same. The Watercourse Convention, for example, excludes unrelated confined aquifers from its scope and applies only to aquifers directly related to a surface body of water.[164] Moreover, as we will discuss below, a static body of water unconnected to the hydrologic cycle may not be subject to the same legal regime as is applicable to surface water.[165]

Furthermore, to the extent that this case model suggests that a substantial hydraulic link can exist between two distinct but adjacent aquifers, the case model is inconsistent with the science of ground

163. *See* Barberis 1986, *supra* note 18, at 36 (describing in the first model that a confined aquifer is disconnected hydrologically from other ground water and surface water).

164. *See* Watercourse Convention, *supra* note 21, art. 2 (defining "watercourse" as surface water and ground water that form a unitary whole through the nature of their physical relationship).

165. *See infra* note 195 (explaining why the Watercourse Convention's definition of a "watercourse" eliminates unrelated confined aquifers from its legal reach).

water.[166] Any "link" described between two adjacent aquifers is necessarily a component of both aquifers. Rather than two "linked" aquifers, the example would implicate one large transboundary aquifer. Even in the uncommon case where fractures spread laterally across an international boundary connecting two aquifer sections located on opposing sides of the border, the reality is that the aquifer sections are one heterogeneous aquifer composed of three interrelated lateral units (the two aquifer sections and the fractured rocks between). To the extent that Barberis' second case model also describes two separate but hydraulically linked aquifers, it too is scientifically inaccurate.

Barberis intended the four case models to be representative of the main cases in which ground water resources have transboundary implications.[167] As briefly noted above, the cases require reconsideration and refinement, in part, because of their scientific inaccuracy, but also because Barberis' list is incomplete. The four case models do not account fully for other common aquifer types that have possible transboundary implications, including aquifers that are unconfined and unrelated to other water resources, those that are confined and unrelated to other water resources, and those that do not recharge. However, one should not discount Barberis' models, as they still provide a useful starting point from which to develop more refined and precise models of transboundary and international aquifers that incorporate principles of hydrogeology and that are based on actual examples.

B. PROPOSED NEW MODEL STRUCTURE

The following six models are illustrative of the main scenarios in which ground water resources can have transboundary implications. While they do not encompass the entire realm of hydrogeological possibilities, the models are representative of the vast majority of

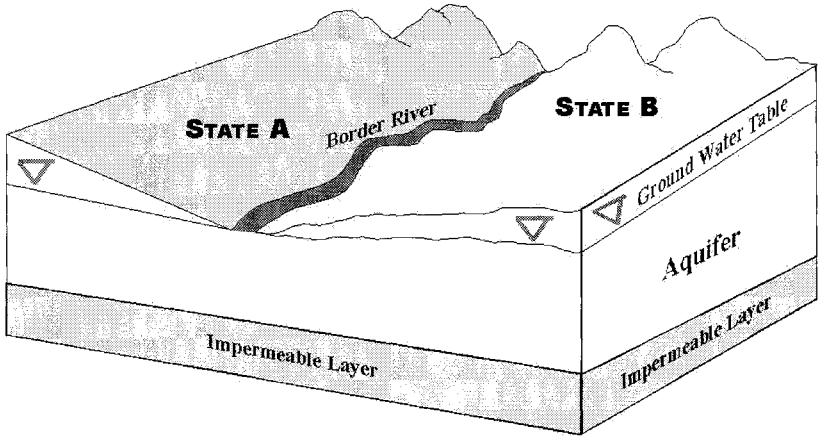
166. *See* BOUWER, *supra* note 12, at 3-6 (describing the main characteristics of aquifers).

167. *See* Barberis 1991, *supra* note 18 at 168 (stating that the four provided models depict cases in which ground water may be part of a system of international waters).

aquifers existing on Earth.[168] More importantly, they provide an opportunity to test, evaluate, and refine existing and proposed principles of international law on scientifically valid generic models.

1. Model A

Model A – An unconfined aquifer that is linked hydraulically with a river, both of which flow along an international border (*i.e.*, the river forms the border between two states).



Model A is defined by a uniform aquifer that is bisected by an interrelated river that forms a political boundary between two states. Because of the hydrologic connection between the transboundary aquifer and the transboundary river, the ground water in this model would be subject to the Watercourse Convention and the principles and norms contained therein.[169]

While the aquifer constitutes one body of water, the two related sections on either side of the border-river have little or no direct effect on each other. Regardless of whether the river is effluent (as shown in Model A) or influent, water flow between the two sections

168. *See* PURI, *supra* note 74, at 11, 15 (describing the main features of transboundary aquifers).

169. *See* Watercourse Convention, *supra* note 21, art. 2 (stating that the Watercourse Convention applies to physically interconnected surface water and ground water systems that are at least partially located in different states).

is limited by hydraulic potential.[170] Thus, any negative characteristic (such as pollution) found in one of the aquifer sections is unlikely to affect the other section, and, therefore, there is no transboundary relationship between the two aquifer sections. An exception to this, however, can occur when one of the nations sharing the aquifer over-pumps the section underlying its territory. If the resulting cone of depression extends to, and possibly even across, the river, the over-pumping state will also draw water from the aquifer section underlying the non-pumping state.[171] In addition to possible problems of depletion, any negative characteristic found in the section underlying the non-pumping state could flow to the section underlying the pumping state.[172]

Another transboundary consequence implicated by this model concerns the relationship of the aquifer to the border river. To the extent that the river is effluent (as depicted in Model A), water will flow from the aquifer into the river.[173] Thus, any negative characteristics found, or introduced, in one or both of the aquifer sections will impact the river, although, as noted above, not the other aquifer section.[174] Because the river forms the border between the two states, the impact is international. Similarly, any negative characteristic found in an influent river could impact both sections of the aquifer, again resulting in a transboundary consequence.

As discussed above, a river can be influent and effluent at different points in the river with the same aquifer based on topography, precipitation, and soil permeability and hydraulic conductivity. Moreover, the influent and effluent relationship between a river and

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170. *See supra* note 54 and accompanying text (discussing the dynamics of hydraulic potential).

171. *See supra* Part II.B.3 (explaining the physical results of pumping on ground water flow).

172. *See* Jacob Burke et al., *Groundwater and Society: Problems in Variability and Points of Engagement*, *in* GROUNDWATER: LEGAL AND POLICY PERSPECTIVES, *supra* note 3, at 31, 39-41 (discussing the sustainability issues related to ground water pollution and over-pumping).

173. *See supra* note 60 and accompanying text (relating that influent surface water will recharge its underlying aquifer).

174. *See supra* notes 56-61 and accompanying text (providing a detailed discussion of why an effluent polluted river will not contaminate ground water on the other side of the river).

underlying aquifer are subject to climatic conditions and can change with the weather, thus creating the potential for temporary international consequences.[175]

Examples of this model include: the Red Light Draw, Hueco Bolson, and Rio Grande aquifers underlying the United States and Mexico,[176] and the Danube alluvial aquifer underneath the portion of the Danube River flowing between Croatia and Serbia.[177]

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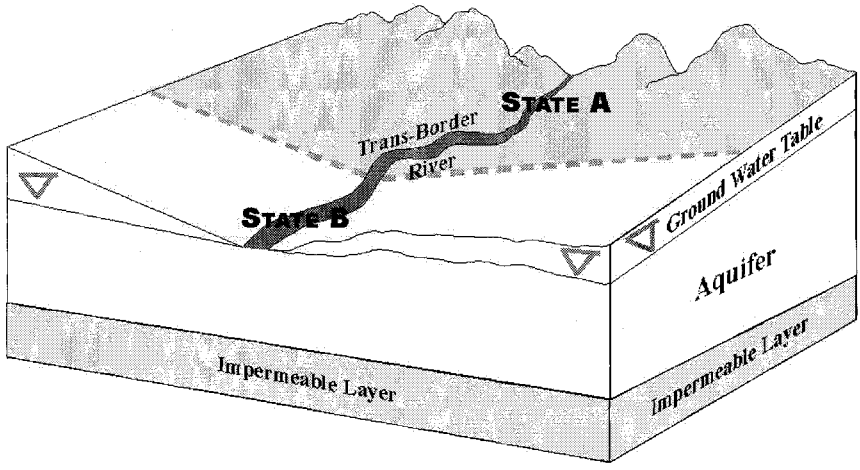
175. *See supra* notes 64-68 and accompanying text (detailing the possible impact of geographic and weather related changes on rivers hydraulically linked to aquifers).

176. All three of the aquifers are unconfined, directly related to the Rio Grande, and flow along the border between the state of Texas in the United States and the state of Chihuahua in Mexico. *See* Barry J. Hibbs et. al., *Hydrogeological Regimes of Arid-Zone Aquifers Beneath Low-Level Radioactive Waste and Other Waste Repositories in Trans-Pecos, Texas and Northern Chihuahua, Mexico*, *in* GAMBLING WITH GROUNDWATER – PHYSICAL, CHEMICAL; BIOLOGICAL ASPECTS PF AQUIFER-STREAM RELATIONS 311, 311-21 (Brahana, et. al., eds. 1998) (providing information on the Red Light Draw aquifer); *see also* International Boundary and Water Commission, *Transboundary Aquifers and Binational Ground-Water Data Base, City of El Paso/Ciudad Juárez Area* (1998) [hereinafter IBWC Report] (providing information on the Hueco Bolson and Rio Grande aquifers), *available at* http://www.ibwc.state.gov/html/body_body_binational_waters.htm (last visited Oct. 17, 2003).

177. *See* B.F. Mijatovic, *Prevention of Over-Exploitation of Deep Aquifers in Vojvodina, Northern Yugoslavia*, *in* GAMBLING WITH GROUNDWATER – PHYSICAL, CHEMICAL, BIOLOGICAL ASPECTS OF AQUIFER-STREAM RELATIONS, *supra* note 176, at 353 (providing information on the Danube alluvial aquifer). The Danube alluvial aquifer, which is linked hydraulically to the Danube River, flows below the Danube River along the border between Croatia and Serbia. *Id.*

2. Model B

Model B – An unconfined aquifer intersected by an international border and linked hydraulically with a river that is also intersected by the same international border.



Model B differs from the first model because the political boundary bisects both the river and the related aquifer rather than following the course of the river. Similar to the situation in Model A, this model also falls within the scope of the Watercourse Convention because of the hydrologic connection between the transboundary aquifer and the transboundary river.[178]

Generally, slope and gravity explain the transboundary consequences implied by this model. Water in the river and the related aquifers flows down-slope from State A to State B, therefore implying that most transboundary situations will result from pollution in State A flowing into State B (either in the river or the aquifer), or from over pumping in State A which reduces the flow into State B. Nevertheless, excessive pumping in either state could have limited local transboundary consequences. For example, depending on the size of the cone of depression surrounding a pumping well located in State A, in addition to problems of depletion, State A could inadvertently pump any negative

178. *See* Watercourse Convention, *supra* note 21, art. 2 (defining the scope of the Watercourse Convention).

characteristic found in the aquifer underlying State B (the non-pumping state) into State A.[179]

In addition, like the situation in Model A, the relationship between the two aquifer sections (on either side of the river) will be limited except to the extent that the river's effluent or influent relationship with the underlying aquifer changes along the course of the river. If the river is effluent upstream in State A, and influent downstream in State B, any negative characteristic (such as pollution) found in one of the aquifer sections in State A could flow into the river and then into the aquifer on both sides of the river in State B.[180]

Examples of this model include the Abbotsford-Sumas Aquifer traversing the border between Canada and the United States,[181] the Mures/Maros Aquifer underlying Hungary and Romania,[182] and the San Pedro Basin Aquifer traversing the border between Mexico and the United States.[183]

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179. *See supra* Part II.B.3 (relating effects of ground water pumping).

180. *See supra* notes 62-63 and accompanying text (explaining potential pollution consequences from influent and effluent bodies of water).

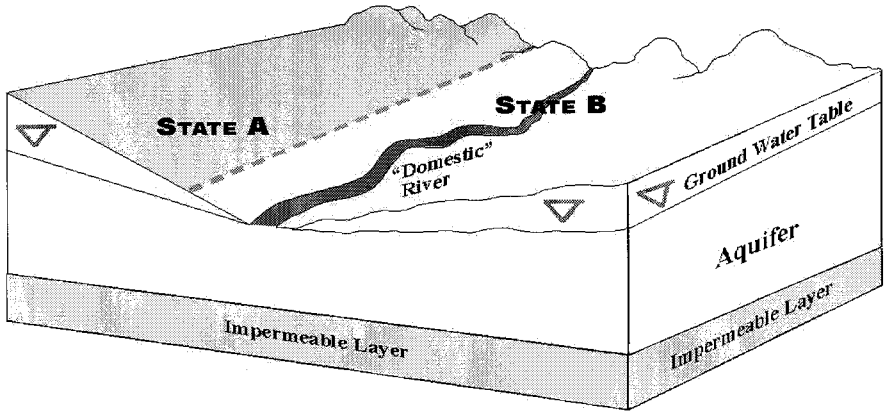
181. *See* ABBOTSFORD-SUMAS AQUIFER INTERNATIONAL TASK FORCE, WHAT IS THE ABBOTSFORD-SUMAS ACQUIFER? (providing information on the Abbostford-Sumas Aquifer), *available at* http://wlapwww.gov.bc.ca/wat/aquifers/absumas.html (last visited Oct. 17, 2003). The Abbotsford-Sumas Aquifer is an unconfined aquifer underlying southern British Columbia, Canada, and northern Washington in the United States. *Id.* The aquifer is related directly to the Sumas River, Bertrand Creek, and Fishtrap Creek, all of which flow from Canada into the United States. *Id.*

182. *See* Robert C. Anderson, *The Management of International Rivers and Lakes*, *in* ENVIRONMENTAL POLICY AND TECHNICAL PROJECT: NEW INDEPENDENT STATES 35 (1998) (on file with author) (providing information on the Mures/Maros Aquifier). The unconfined Mures/Maros Aquifer lies underneath Romania and Hungary, and is related directly to the overlying Mures/Maros River that flows into the Tisza River, a tributary of the Danube River. *Id.*

183. *See* Arias, *supra* note 52 (providing information on the San Pedro Basin Aquifer). The predominantly unconfined San Pedro Basin Aquifer underlies Mexico and the United States and is linked hydraulically to the San Pedro River, which flows northward into the United States and merges with the Gilo River, a major tributary of the Colorado River. *Id.*

3. Model C

Model C – An unconfined aquifer that flows across an international border and that is hydraulically linked to a river that flows completely within the territory of one state.



Model C describes an aquifer-river system in which one of the two components (here, the aquifer) traverses a political border. As noted above, it appears that for the Watercourse Convention to apply, the transboundary character of an aquifer-river system must be found in the river. Accordingly, this model does not fall within the scope of the Convention.[184]

The transboundary implications of this model rely solely on the distribution of hydraulic potential.[185] Model C shows an effluent river-aquifer relationship where ground water recharged in State A

184. *See supra* note 143 and accompanying text (interpreting the Watercourse Convention's transboundary characteristic requirement as only applicable to rivers and not the underlying aquifer). This type of aquifer-river system was actually considered, albeit briefly, by the ILC during their deliberations over the development of the Watercourse Convention. *See* 115th Meeting, *The Law of the Non-Navigational Uses of International Watercourses, in* Summary of record of the meetings of the thirty-first session,[1979] 1 Y.B. INTL L. COMM'N 119 ¶ 17, U.N. Doc. A/CN.4/SER.A/1979 (reporting on ILC Member Mr. Ushakov's comments that "a national watercourse that flowed through the territory of a single State could become an international watercourse if it was fed by underground water originating in the territory of another State.").

185. *See supra* notes 78-80 and accompanying text (clarifying the role of hydraulic potential in ground water flow).

flows into State B through the effluent river.[186] As noted above, this relationship can change at different points along the river based on topography, soil permeability and hydraulic conductivity, as well as on changes in precipitation rates.[187] Thus, depending on the proximity of such variations in relation to the international border, transboundary consequences could also manifest from State B to State A. Furthermore, excessive pumping in State A could result in a cone of depression that would locally reverse ground water flowing from State A to State B in the immediate area of pumping, thus causing any negative characteristic found underlying State B to flow toward the pump well in State A.[188]

An example of this model is the Mimbres Basin Aquifer traversing northern Mexico and the U.S. state of New Mexico.[189]

186. *See supra* note 60 and accompanying text (delineating how an effluent body of water is related to an aquifer).

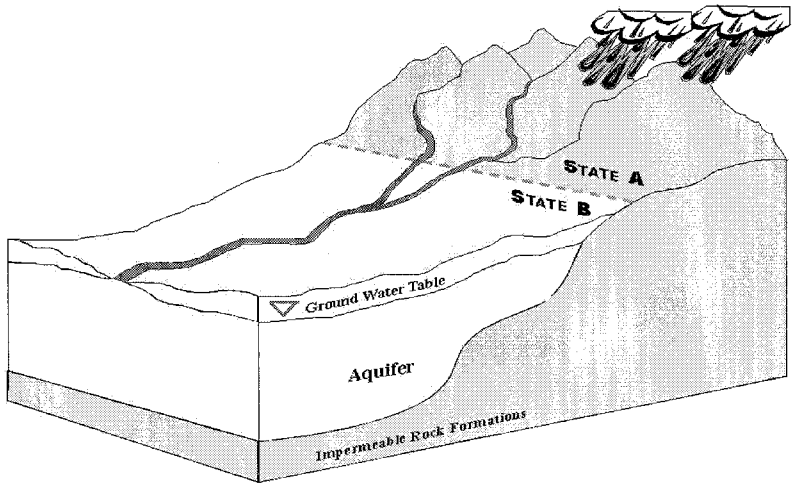
187. *See supra* notes 64-68 and accompanying text (elaborating on how these factors affect the river-aquifer relationship).

188. *See supra* Part II.B.3 (explaining the process and effects of ground water pumping).

189. *See* E.M. Hebard, *A Focus on a Binational Watershed With A View Toward Fostering A Cross-Border Dialogue*, 40 NAT. RESOURCES J. 281, 289-92 (2000) (providing general information on the Mimbres Basin Aquifer). The Mimbres Basin Aquifer is an unconfined aquifer in northern Mexico and the southern portion of New Mexico. *Id.* The Mimbres River, which flows solely inside the United States, recharges the Mimbres Basin Aquifer. *Id.*

4. Model D

Model D – An unconfined aquifer that is completely within the territory of one state but that is linked hydraulically to a river flowing across an international border (in such cases, the aquifer is always located in the "downstream" state).



Similar to Model C, Model D describes an aquifer-river system where one component of the system traverses a political border. In this model, the river is international while the aquifer is geographically domestic. As such, this river-aquifer system does fall within the scope of the Watercourse Convention[190] and is plainly described by Barberis' second case model.[191]

The transboundary implications for this model are solely dependent on river volume and quality flowing from State A to State B. In this model, State A has the singular opportunity and responsibility for ensuring the quantity and condition of water in the river.

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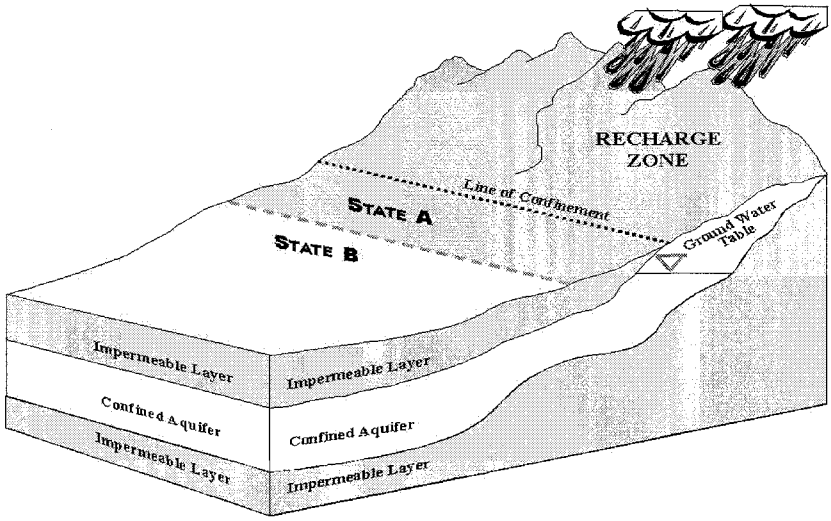
190. *See* Watercourse Convention, *supra* note 21, art. 2 (making the Watercourse Convention applicable to watercourses situated in different states).

191. *See supra* note 154 (describing a situation where an aquifer is entirely within one state but is linked hydraulically to a river that traverses two states).

An example of this model is the Gila River Basin Aquifer underneath parts of Arizona, California, Nevada, and New Mexico in the United States.[192]

5. *Model E*

Model E – A confined aquifer, unconnected hydraulically with any surface body of water, with a zone of recharge (possibly in an unconfined portion of the aquifer) that traverses an international boundary or that is located completely in another state.



Model E, conceptualized in Barberis' fourth case model, describes a solitary aquifer that is unrelated to any other body of water (such as a river or lake).[193] This type of aquifer, however, is still a dynamic component of the hydrologic cycle since it has an exposed zone that allows for recharge from precipitation.[194] Due to its solitary and unrelated characteristics, however, it is unlikely that the model could

192. *See* Hawley, *supra* note 93, ch. 8 (stating that the Gila River Basin Aquifer is an unconfined aquifer linked to the Gila River, which is a significant contributor to the Colorado River as it flows towards Mexico).

193. *See* Barberis 1986, *supra* note 18, at 36 (describing the model as an "aquifer [] situated entirely within the territory of a given State but [with a] recharge zone in another state").

194. *See supra* Part II.A (detailing the hydrologic cycle in which aquifers and precipitation play important roles).

fall within the scope of the Watercourse Convention. As discussed above, the definition of "watercourse" limits the scope of the Watercourse Convention only to "systems," and only to systems that have a "physical relationship" between the inter-linked components.[195] This begs the questions of whether a solitary aquifer can constitute a "system" in and of itself, and whether the aquifer's interaction within the hydrologic cycle (although not with any surface body of water) constitutes, by virtue of this interaction, "a unitary whole."[196]

Notwithstanding the ambiguous status of this model under international law, this type of aquifer can have transboundary consequences. Those consequences are, in large part, a function of the rate of pumping. Any excessive pumping in one or both states could have serious implications for the part of the aquifer along the border between the two countries.[197] Moreover, any negative characteristics found in the aquifer underneath one of the states could flow to the other as a result of natural flow (*i.e.*, from State A to State B) or as a result of a cone of depression locally reversing the natural flow (within a distance limited by the cone of depression).[198] In addition, the possibility that State A could divert surface runoff from recharging the aquifer or undertake activities that pollute surface waters in the recharge zone (*i.e.*, agricultural runoff, untreated municipal and industrial waste, etc.) also can implicate international consequences.

Examples of this model include the series of deep, confined aquifers in the Syr Darya River Basin,[199] the Mountain Aquifer

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195. *See* Watercourse Convention, *supra* note 21, art. 2 (defining "watercourse" for the purposes of the Convention as "a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus").

196. *See generally* Eckstein 2004, *supra* note 144 (discussing the scope of the Watercourse Convention and analyzing the "system" criteria of the definition of "watercourse").

197. *See* Burke, *supra* note 172, at 39-41 (reporting ground water issues concerning over-pumping).

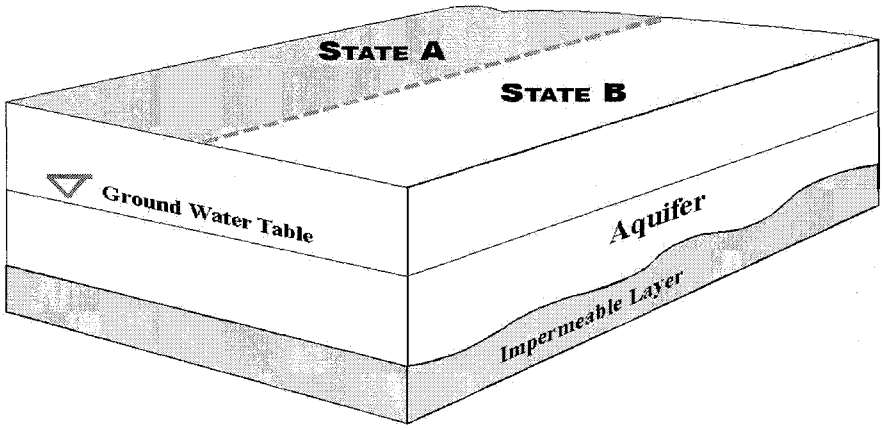
198. *See supra* Part II.B.3 (explaining how water within the zone of influence of a cone of depression is affected by ground water pumping).

199. *See* G.S Sydykov & V.V. Veselov, *Water Ecological Situation Changes of the Arial Sea Basin Under the Influence of Intensive Agricultural Development, in*

between Israel and the Palestinian Territories,[200] and the Guarani Aquifer underneath Argentina, Brazil, Paraguay and Uruguay.[201]

6. Model F

Model F – A transboundary aquifer unrelated to any surface body of water and devoid of any recharge.



Model F is unique from the other models in that the aquifer is both unrelated to any other body of water (like a stream or lake) and is

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ENVIRONMENTAL IMPACT OF AGRICULTURAL ACTIVITIES, PROCEEDINGS OF THE SECOND USA/CIS JOINT CONFERENCE ON ENVIRONMENTAL HYDROLOGY AND HYDROGEOLOGY 3 (Eckstein et al., eds. 1993) (providing information on the Syr Darya River Basin aquifers, which are not linked to the Syr Darya River, including the fact that the primary source of recharge for the aquifers is in the high mountains of Turkmenistan and Tajikistan).

200. *See supra* note 55 and accompanying text (providing a synopsis of the location, and operation, of the Mountain Aquifer).

201. *See* Eduardo Usunoff, *Web-Based Information for Integrated Water Resources Management of a Multi-National Aquifer: The Global Environmental Facility Project on the Guarani Aquifer* (2000) (providing detailed information on the Guarani Aquifer, specifically that it is a confined aquifer in ninety percent of its extent and is recharged primarily through rainfall infiltrating places where the confining layer is not present), *available at* http://www.waterweb.org/wis/wis3/presentations/30_Usunoff_paper.pdf (last visited Oct. 19, 2003); *see also* Puri, *supra* note 74, at 45-46 (providing a brief case study of the Guarani Aquifer System).

disconnected from the hydrologic cycle.[202] As such, this type of aquifer does not recharge, contains non-renewable ground water, and a state could never sustainably utilize the aquifer. Such aquifers contain paleo or ancient waters and may be confined or unconfined, as well as fossil or connate.[203] In the case that the aquifer is unconfined (as depicted in Model F), a lack of recharge generally implies a location in an arid zone where annual precipitation is inconsequentially small. Moreover, as there is neither a distinct recharge nor discharge zone, the ground water table in this type of aquifer is horizontal and the water is stagnant with little or no perceptible flow.[204]

Due to this unique geologic configuration, the transboundary consequences associated with aquifers that do not recharge are almost exclusively a function of pumping the aquifer in one or more of the riparian states. When a state commences production of ground water from a water well penetrating such an aquifer, the state will generate an ever-expanding cone of depression that will eventually encroach in the subsurface across the international border.[205] Any restrictions on the rates of pumping that international law or a treaty between the two (or more) riparian states claiming rights to the water in the aquifer may reduce the rate of the expansion of the cone of depression, but will never completely stop it from expanding. Of course, two competing wells on opposite sides of a border will create two cones of depression and their rates of expansion will depend on the particular rates of extraction. In either scenario, if the states do not completely stop pumping, the aquifer will eventually become fully depleted.

Note that such aquifers are uniquely susceptible to pollution because of their stagnant character and lack of recharge. Once aquifers become polluted, they are extremely difficult and expensive to clean. The absence of recharge and flow to, and within, the

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202. *See supra* note 69 and accompanying text (explaining that aquifers with no recharge are "completely detached from the hydrologic cycle").

203. *See generally supra* notes 69-71, and accompanying text (describing non-recharging aquifers and the non-renewable waters contained therein).

204. *See supra* note 70 and accompanying text (reporting that the water in non-recharging aquifers has little or no flow).

205. *See supra* Part II.B.3 (detailing the creation of a cone of depression).

aquifer, prevents any natural cleansing process and can make the aquifer unusable for decades or longer.[206] Additionally, any flow resulting from a pumping well could exacerbate the extent of the pollution and transfer the contaminants to other parts of the aquifer.

As a result of these distinctive qualities, it is unclear whether the principles and norms found in the Watercourse Convention would apply to this aquifer type.[207] Moreover, as we discuss below, questions arise as to whether any of the principles of contemporary international water law apply to such resources.[208]

Examples of this model include the Nubian Sandstone Aquifer underneath Chad, Egypt, Libya, and Sudan;[209] the Complex Terminal Aquifer underlying Algeria and Tunisia and possibly extending underneath Libya and Morocco;[210] the Continental Interclaire Aquifer underlying Algeria and Tunisia and possibly Libya and Morocco;[211] and the Qa-Disi Aquifer underlying southern Jordan and northern Saudi Arabia.[212]

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206. *Cf.* Yamada, *supra* note 17, at 3 (suggesting that a specific legal regime should cover fossil aquifers). This is primarily because of their vulnerability to pollution and inability to cleanse themselves.

207. *See* Watercourse Convention, *supra* note 21, art. 2 (setting forth the scope of the Watercourse Convention).

208. *See infra* Part V (discussing how international law considers aquifers that lack any recharge).

209. *See* Eckstein 1998, *supra* note 72 (defining the characteristics of the Nubian Sandstone Aquifer that it is an aquifer lacking in recharge and containing non-renewable ground water unrelated to any other water resource); *see also* Nubian Sandstone Aquifer System Programme (providing information on the Nubian Sandstone Aquifer), *available* at http://isu2.cedare.org.eg/nubian/ (last visited Oct. 23, 2003).

210. *See* Raj Krishna, & Salman M.A. Salman, *International Groundwater Law and the World Bank Policy for Projects on Transboundary Groundwater*, *in* GROUNDWATER: LEGAL AND POLICY PERSPECTIVES, PROCEEDINGS OF A WORLD BANK SEMINAR, *supra* note 3, at 163, 181 (describing the Complex Terminal Aquifer as an unrelated, non-recharging aquifer).

211. *See id.* (providing additional information on the Continental Interclaire Aquifer, including that it is an unrelated aquifer with no recharge).

212. *See id.* at 183-84 (providing information on the Qa-Disi Aquifer, including that it is a non-recharging aquifer unrelated to any other water resource); *see also* A. Macoun, & H. El Naser, *Groundwater Resources Management in Jordan: Policy and Regulatory Issues*, *in* GROUNDWATER: LEGAL AND POLICY

IV.NON-RENEWABLE TRANSBOUNDARY GROUND WATER RESOURCES AND INTERNATIONAL LAW

From the above models, it is clear that ground water resources are often transboundary and can have significant international consequences.[213] For the most part, transboundary and international aquifers should be subject to the same rubric of the international law applicable to surface waters.[214] In the case of non-renewable ground water, however, questions arise as to whether the same principles and norms can, and should, govern such aquifer types.

Non-renewable ground water, as discussed above, is water contained in an aquifer that is detached completely from the hydrologic cycle.[215] Such aquifers have little or no appreciable natural recharge and cannot discharge naturally.[216] By definition, a state cannot sustainably utilize such an aquifer, and any withdrawal from such an aquifer eventually will exhaust the resource. States utilizing a transboundary aquifer that does not recharge are slowly depleting, and will eventually exhaust, this resource.

One of the few articulations of international law that suggests applying to non-recharging aquifers the same international law applicable to surface water is the ILA's Seoul Rules.[217]

PERSPECTIVES, PROCEEDINGS OF A WORLD BANK SEMINAR, *supra* note 3, at 105, 111 (providing further information on the Qa-Disi Aquifer).

213. *See supra* Part IV.B (detailing six models of transboundary aquifers).

214. *See generally* Eckstein 1995, *supra* note 138, at 98 (advocating an integrated approach when contemplating transboundary water management and protection schemes).

215. *See supra* note 69 and accompanying text (defining non-renewable ground water).

216. *See* Robert Rosenstock, *Second Report on the Law of the Non-Navigational Uses of International Watercourses*, U.N. Doc. A/CN.4/462 (1994), *reprinted in* [1994] 2 Y.B. Int'l L. Comm'n 113, 123 U.N. Doc. A/CN.4/SER.A/1994/Add.1 (Part 1) (explaining that such unrelated aquifers are "completely enclosed . . . and they may for all practical purposes be independent of any identifiable inland surface water system").

217. *See* Seoul Rules, *supra* note 135 and accompanying text (making the Helsinki Rules applicable to non-recharging aquifers intersected by the boundaries of two or more states).

Supplementing the ILA's Helsinki Rules,[218] the Seoul Rules provide in Article II (2) that "[a]n aquifer intersected by the boundary between two or more States that does not contribute water to, or receive water from, surface waters of an international drainage basin constitutes an international drainage basin for the purposes of the Helsinki Rules."[219] The non-binding nature of the Rules as well as the absence of other similar enunciations, however, limit the authority and weight afforded to this pronouncement as a basis for the development of international law.[220]

The more recent, and possibly more authoritative, Watercourse Convention excludes aquifers that lack recharge from its scope. Non-recharging aquifers are, by definition, not part of any "system[s] of surface and groundwaters," do not have a "physical relationship" with any other water resources, and do not "flow[] into a common terminus."[221] Furthermore, in comments to the final Draft Articles of the Watercourse Convention, the ILC, which drafted the Convention, noted that, "[i]t follows from the unity of the system that the term 'watercourse' does not include 'confined' ground water, meaning that which is unrelated to any surface water."[222] While misapplying the hydrogeologic term "confined" to mean "unrelated,"[223] the ILC clearly indicated its position that solitary aquifers, such as non-recharging aquifers, are not subject to the norms and principles of the Watercourse Convention. The ILC rationalized this intentional exclusion on the unscientific and unsubstantiated basis that unrelated

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218. *See* Helsinki Rules, *supra* note 134 and accompanying text (containing no provision applicable to non-recharging aquifers).

219. Seoul Rules, *supra* note 135, art. II(2).

220. *See supra* note 139 and accompanying text (articulating that the ILA is a private organization and therefore lacks legitimacy as far as defining international law).

221. *See* Watercourse Convention, *supra* note 21, art. 2 (excluding non-recharging aquifers from the scope of the Convention).

222. *Report of the International Law Commission to the General Assembly on the Work of its Forty-Sixth Session, The Law of the Non-Navigational Uses of International Watercourses*, [1994] 2 Y.B. Int'l L. Comm'n 88, 90 U.N. Doc. A/CN.4/SER.A/1994/Add.1 (Part 2).

223. *See* Eckstein 2004, *supra* note 144, at 22-23 (discussing the etymology of "confined" ground water, as defined by the ILC and as used in hydrogeology); *see also* Hayton, *supra* note 51, at 38 (explaining why the term "confined" is a misnomer).

ground water could not have any untoward effects on any other watercourse.

It is noteworthy, however, that following the adoption of the text of the draft Watercourse Convention, the ILC adopted a Resolution on Confined Transboundary Groundwater.[224] In the Resolution, the ILC pressed states to apply the principles codified in the Watercourse Convention to ground water resources not related to an international watercourse.[225] The inconsistency of the Resolution with the Watercourse Convention, however, as well as the lack of definitiveness of the Resolution under international law, continues to leave this issue unresolved.

As discussed above, however, because of their lack of recharge and stagnant character, confined aquifers are uniquely susceptible to pollution.[226] The absence of recharge and flow to and within the aquifer makes any contamination extremely difficult and expensive to clean.[227] Moreover, the hidden quality of ground water, the lack of monitoring, and the fact that aquifer contamination often takes decades to manifest, brings into question whether states should apply even stricter standards than those found in the Watercourse Convention, especially those of no significant harm, and pollution prevention, reduction, and control.[228]

A number of authors, in a few brief sentences, have suggested that the law applicable to non-renewable ground water may be akin to the law applied to oil and gas deposits.[229] Like oil and gas, non-

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224. *Resolution on Confined Transboundary Groundwater*, 2 Y.B. Int'l L. Comm'n 135, U.N. Doc. A/CN.4SER.A/1994/Add.1 (Part 2).

225. *See id.* (stating that the ILC "[c]ommends States to be guided by the principles contained in the draft articles on the law of the non-navigational uses of international watercourses, where appropriate, in regulating transboundary groundwater").

226. *See supra* notes 69 and 73 and accompanying text (explaining the stagnant and easily polluted status of fossil waters); *see also*, Yamada, *supra* note 17, para. 20 (noting that ground water contamination may last for many years).

227. *See* Caponera, *supra* note 100, at 248 (declaring that once contaminants seep into an aquifer, the pollution is difficult, if not impossible, to erase).

228. *Cf.* Yamada, *supra* note 17, at 3 (suggesting that a more specific legal regime may be required for non-renewable ground water resources).

229. *See* Krishna & Salman, *supra* note 210, at 167 (suggesting that the principles of absolute territorial sovereignty and absolute territorial integrity may

renewable ground water is a static, fluid substance.[230] Accordingly, the argument goes, the legal regime for non-replenishable ground water should follow the model applicable to oil and gas deposits.[231] Generally, transboundary oil and gas resources are developed in the context of a cooperative and primarily commercial effort.[232] In some cases, the sharing states agree on joint management or joint ownership, and in other cases, some form of unitization.[233] Costs and

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be applicable to liquid mineral deposits); *see also* Caponera, *supra* note 100, at 247 (stating that states should treat non-renewable ground water like minerals because, like minerals, non-renewable ground water is no longer available after use). *But see* Krishna & Salman, *supra* note 210, at 167 (arguing that non-renewable ground water is not comparable to natural resources like minerals). Mineral law applies to solid, non-renewable resources like coal and salt, and is inadequate to deal with the fluid nature of water. *Id.*

230. *Cf.* Price, *supra* note 12, at 123 (asserting that the characteristics of fossil water make its exploitation "analogous to that of any other non-renewable mineral resource, such as oil, coal or copper").

231. *See* Caponera, *supra* note 100, at 247 (arguing that the legal regime for non-renewable water resources should be analogous to the law applicable to depletable minerals).

232. *See* Alberto Székely, *The International Law of Submarine Transboundary Hydrocarbon Resources: Legal Limits to Behavior and Experiences for the Gulf of Mexico*, 26 NAT. RESOURCES J. 733, 758-66 (1986) (reporting on an analysis of fifty-eight bilateral agreements on continental shelf delimitation to ascertain principles of law for the allocation and management of transboundary natural resources); *see also* W.T. Onorato, *Apportionment of an International Common Petroleum Deposit*, 17 INT'L & COMP. L.Q. 85, 93, 99 (1968); Albert E. Utton & Paul D. McHugh, *On An Institutional Arrangement for Developing Oil and Gas in the Gulf of Mexico,* 26 NAT. RESOURCES J. 717, 724-25 (1986) (noting that a majority of U.S. states impose compulsory unitization on the part of land owners). Among sovereign states, one-half of border delimitation agreements concluded since 1942, and nearly all agreements on continental shelf areas since 1970, include provisions calling for cooperation in the development of any transboundary resources discovered in the future. *Id.* at 727. The date 1970 is typically identified as a starting point because one year prior, the International Court of Justice came down with its decision on the North Sea Continental Shelf Cases. *See* North Sea Continental Shelf (F.R.G. v. Den.; F.R.G. v. Neth.), 1969 I.C.J. 3 (Feb. 20):

> [I]t frequently occurs that the same deposit lies on both sides of the line dividing a continental shelf between States, and since it is possible to exploit such deposit from either side, a problem immediately arises on account of the risk of prejudicial or wasteful exploitation by one or the other of the States concerned.

233. *See* Carmen Pedrazzini & Joaquin T. Teyssier, *Hydrocarbon Deposits of the Border Region Between Mexico and the United States and Potential Exploitation Problems in Transboundary Deposits: A Preliminary Report*, 26 NAT.

benefits are often allocated equally, in proportion to the resource located within each state at the time the agreement is concluded, or based on some other agreed-upon compromise.[234] Frequently, one company is hired to extract the resources as well as to allocate the costs, proceeds, and resources extracted.[235] The widespread acceptance of such cooperative efforts in the exploration and exploitation of transboundary oil and gas deposits, in some scholars' judgment, has given rise to a customary norm of international law.[236]

Given the physical similarities of non-renewable ground water and oil and gas deposits, the application of such a rule to non-renewable ground water resources is easily conceivable.[237] In some respects, one may argue that the rule is similar to the principle of reasonable and equitable utilization to the extent that both rules, by definition, mandate consultation, prior notification, and the exchange of data.[238] Moreover, to the extent that states with interests in transboundary oil and gas deposits reach an agreement over the development of these resources, such agreement is based on various and competing state

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RESOURCES J. 695, 709-10 (1986) (describing the most efficient method for exploiting transboundary oil and gas deposits); *see also* Utton & McHugh, *supra* note 232, at 724-25 (describing unitization as the policy of maintaining the unity of a transboundary resource by requiring that owners of the resource cooperate jointly in its development so as to maximize recovery by the most economical means). Under unitization, interested owners submit a unit development plan to the relevant state agencies, hold stakeholder hearings, establish a committee representing all owners, and appoint a unit operator. *Id.* Costs and revenues are allocated by formula to the various owners. *Id.* at 725-26. The municipal laws of most of the world's oil-producing nations, including the United States, have adopted unitization in the exploitation of oil and gas deposits that lie across property boundaries. *Id.* at 724-25.

234. *See* Utton & McHugh, *supra* note 232, at 726 (stating that states apply a formula to allocate the various costs and revenues).

235. *See id.* at 728-30 (describing the process of four types of cooperation agreements); *see also* Székely, *supra* note 232, at 760-65 (evaluating six types of transboundary resource agreements).

236. *See* Utton & McHugh, *supra* note 232, at 731 (noting that some authors have argued that cooperation in international practice has risen to the level of customary international law).

237. *See* Caponera, *supra* note 100, at 247 (arguing that water law applicable to non-renewable ground water should be similar to mineral laws).

238. *See* Krishna & Salman, *supra* note 210, at 168-69 (noting that recent water conventions include the principles of prior notification, consultation, and duty to negotiate, as well as concepts of equity).

interests and factors akin to those considered under equitable and reasonable utilization.[239]

Notwithstanding, water has often been described in relation to basic human necessity and even human rights that cannot be subjected solely to profit-based operations.[240] In a typical marketplace transfer, only the buyer and seller can have a legitimate interest in the commodity transferred.[241] However, in the market transfer of a particular water resource, the list of potential claimants with legitimate interests in the use of the resource could far exceed the number of those holding water rights.[242] As such, there are unique ethical considerations related to the commercialization and provision of fresh water resources.[243]

In interpreting the International Covenant on Economic, Social and Cultural Rights, the U.N. Committee on Economic, Social and Cultural Rights ("UNCESCR") formally declared that water is a human right.[244] It asserted that "[t]he human right to water entitles everyone to sufficient, affordable, physically accessible, safe and

239. *See* Watercourse Convention, *supra* note 21, art. 6 (listing factors relevant to equitable and reasonable utilization).

240. *See generally* Peter Gleick, *The Human Right to Water*, 1 WATER POLICY 5, 487 (1999) (arguing that access to water resources is a natural human right), *available at* http://www.pacinst.org/gleickrw.pdf (last visited on Oct. 16, 2003); Maude Barlow, *Globalization of Water as a Commodity is Destroying Resources*, U.S. WATER NEWS 9-10 (Feb. 2003) (asserting that "water must be declared a basic human right").

241. *See* U.C.C. § 1-201 (2002) ("party" means a person that has engaged in a transaction or made an agreement subject to the Code).

242. *See* Joseph L. Sax, *Understanding Transfers: Community Rights in the Privatization of Water*, 1 WEST-NORTHWEST 13, 15 (1994) (discussing the unique quality and value of water as well as the direct and indirect interests in the resource); *see also* Leticia M. Diaz & Barry Hart Dubner, *The Necessity of Preventing Unilateral Responses to Water Scarcity – The Next Major Threat Against Mankind This Century*, 9 CARDOZO J. INT'L & COM. L. 1, 12 (2001) (noting that water right holders are not the only claimants with legitimate interests in the water source).

243. *See* Puri, *supra* note 74, at 30-31, 36 (discussing ethical considerations in the provision of fresh water).

244. *See Substantive Issues Arising in the Implementation of the International Covenant on Economic, Social and Cultural Rights*, U.N. ECOSOC, 29th Sess., General Comment No. 15 at 1, U.N. Doc. E/C.12/2002/11 (2002) [hereinafter UNECOSOC Declaration] (noting the indispensability of water as a human right).

acceptable water for personal and domestic uses."[245] Moreover, it noted that states have the obligation to "fulfill" the right to water by undertaking measures that ensure the full realization of the right, including to those who are "unable, for reasons beyond their control, to realize that right themselves by the means at their disposal."[246]

While not necessarily barring the possibilities of commercialized extraction of non-renewable water resources, water regarded as a human right would significantly restrict the extent to which states could permit profit-oriented exploitation.[247] Each state would be bound to ensure that all of its citizens could realize their right to water, regardless of whether every citizen could afford that possibility.[248] Accordingly, exploration and exploitation would be driven more by state obligation to provide for its citizenry than by the free market of supply and demand.[249] In the case of a non-recharging transboundary aquifer, the principle of equitable and reasonable use theoretically could assist in ensuring this state obligation, if factors considered in the analysis include social and economic needs and populations dependent on the resource.[250]

Nevertheless, even from the UNCESCR declaration, it is unclear to what extent such a "right" applies.[251] Is the right to water an actual entitlement to a certain quantity of water, *i.e.*, to an amount necessary to sustain life, which would require the state to provide the

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245. *Id.* at 2.

246. *Id.* at 25.

247. *See, e.g.*, WATER FOR PEOPLE, *supra* note 2, at 12-13 (proposing that states impose responsibility for adverse health effects of specific water projects upon those particular sectors).

248. *See* Stephen McCaffrey, *A Human Right to Water: Domestic and International Implications*, 5 GEO. INT'L ENVTL. L. REV. 1, 13-15 (arguing that states must act with due diligence to provide a safe water supply to their populations).

249. *See id.* at 15 (noting that in addition to ensuring current water supplies, states must behave in a manner to ensure future water supplies).

250. *See* Watercourse Convention, *supra* note 21, art. 6(1) (listing a non-comprehensive list of factors watercourse states must consider in their analysis of what constitutes equitable and reasonable use).

251. *See* UNECOSOC Declaration, *supra* note 244 (failing to define the extent to which the human right to water applies).

water at all costs?[252] Or is it merely a right to have access to fresh water, which might suggest that the state could delegate the provision of water to a profit-motivated entity?[253] Furthermore, against whom would the right be enforceable? Would it be enforceable by a citizen only against that citizen's state, or could a citizen also enforce it against a co-riparian state, notwithstanding the citizen's nationality?[254]

The above discussion of the status of non-renewable ground water resources under international law clearly is far from definitive or comprehensive. It merely provides a starting point from which additional critical thought and dialogue may ensue. The need to delineate rules and norms to assist nations in the management and allocation of such resources, however, is clear. Although the extent of global reserves of fresh water stored in transboundary non-recharging aquifers is uncertain, suffice it to say that it constitutes a highly important water source for many nations and is often the only viable source of fresh water.[255]

CONCLUSIONS

In this paper, we considered transboundary and international ground water resources and international law from a hydrogeologic perspective. The purpose of this study was, in part, to consider the legal implications stemming from various circumstances when ground water resources traverse international political boundaries. A critical component of this discussion is the six conceptual models offered as illustrative of the main scenarios in which ground water resources can have transboundary consequences.[256] The models, which are based on principles of hydrogeology and actual examples,

252. *See id.* at 2 (noting that States Parties have an obligation to ensure the right to safe water).

253. *See* Puri, *supra* note 74, at 36 (arguing that the states should incorporate ethical principles in the development of transboundary aquifers).

254. *See* McCaffrey, *supra* note 248, at 17, 23 (discussing the right under international law of one state to receive water from a co-riparian country).

255. *See* WATER FOR PEOPLE, *supra* note 2, at 8-10 (describing the distribution of water resources).

256. *See supra* Part V.B (describing six conceptual models in which ground water resources have cross boundary consequences).

are intended to serve as generic templates against which to assess existing and proposed international norms for transboundary and international ground water resources. We hope that they will prove useful as tools in water management decision-making affecting transboundary and international ground water resources. To be fully understood, however, and if they are to provide useful information, their analysis and interpretation must be developed in the proper scientific context – based on a sound understanding of the science of ground water.

In addition, this study emphasized the need to further clarify the status of international law as it applies to transboundary and international ground water resources.[257] Ground water today is the single-most indispensable substance for sustaining growing populations as well as nourishing economic development.[258] And yet, the rules governing the use, allocation, conservation, and overall management of this resource across borders are still unclear. The Watercourse Convention is a significant milestone in the development of international law, especially to the extent that it supports the application of international water law principles, like the doctrine of hydrological unity, reasonable and equitable utilization, no substantial harm, cooperation, and good faith negotiations, to certain types of transboundary and international ground water resources.[259] While certainly a positive development, the Convention still leaves many questions unanswered. Most prominent of these is the question of which law to apply to aquifers unrelated hydraulically to any surface body of water, or to non-renewable ground water resources?

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257. *See supra* Part IV (describing the historical context of international law and water resources).

258. *See* TUSHAAR SHAH ET. AL., INT'L WATER MGMT. INST, THE GLOBAL GROUND WATER SITUATION: OVERVIEW OF OPPORTUNITIES AND CHALLENGES 6-8 (2000) (describing the various opportunities within ground water related industries, particularly in poor nations), *available at* http://www.iwmi.cgiar.org/pubs/WWVisn/GrWater.htm (lasted visited Nov. 20, 2003).

259. *See* Watercourse Convention, *supra* note 21, arts. 5-10 (stating the general principles of the Watercourse Convention, including "[e]quitable and reasonable utilization and participation," "[f]actors relevant to equitable and reasonable utlizilation," "[o]bligation not to cause significant harm," and "[g]eneral obligation to cooperate.").

Finally, this study was intended to infuse the science of ground water into the development, interpretation, and application of international legal concepts and norms relevant to transboundary and international ground water resources.[260] There is presently a dearth of scientific knowledge among government officials, legislators, policy-makers, jurists, and legal scholars about ground water. This is especially evident in the treatment afforded ground water resources in past international agreements and academic writings, and may be a principle reason for the incompleteness of the Watercourse Convention.[261]

Decision-makers and lawyers alike must develop a stronger understanding of hydrogeological terms and processes so as to overcome common misconceptions, mislabeling, and general misunderstanding about water resources. The absence or ignorance of this basic knowledge, in many respects, has resulted in the poor management of scarce water resources throughout the world; at times, it has resulted in serious harm to people and the environment.[262] While not a panacea, the inclusion and understanding of underlying science in the decision-making process can serve to achieve more balanced, scientifically based, and thoughtful decisions. Only through a full understanding of the various legal and policy issues, as well as the underlying science involved, can states use, manage, and protect their transboundary and international resources prudently and effectively, and in such a way that the resources provide adequately for both present and future generations.

260. *See supra* Part II (providing a background on the science of ground water).

261. *See supra* Part IV (analyzing the international laws applicable to ground water resources).

262. *See* Shah, *supra* note 258, at 3 (noting that in West Bengal and western Bangladesh, excessive withdrawals have resulted in increased concentrations of naturally occurring arsenic in the declining ground water). *See generally* Mumme, *supra* note 15 (stating that in the border region of Mexico and the United States, failure to cooperate in the management of transboundary aquifers has caused severe depletion and pollution problems).