GROUNDWATER GOVERNANCE – IMPACT OF AWARENESS-RAISING AND CITIZEN PRESSURE ON GROUNDWATER MANAGEMENT AUTHORITY IN THE UNITED STATES

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1. Chapter introduction

For this chapter, groundwater governance is considered to represent a dynamic and evolutionary process involving collective influences on policy and water management decisions with many different interests involved. Groundwater governance does not start from a blank page. Today's governance is built on the palimpsest of the past. This chapter shows some of the ways in which citizens, non-governmental organizations (NGOs), professional associations, and industry interest groups influence the way in which groundwater resources are managed. A key challenge for success in groundwater governance is to raise the level of scientific understanding of groundwater to help reconcile divergent values, interests and preconceptions. Information (data) that are the basis for decisions must be seen as credible with clear definition of hydrologic facts.

In addition to state and local agencies with responsibility and authority over water issues there are typically other agencies, for example forestry, transport, agriculture and health that have overlapping responsibilities that could also influence policy decisions about groundwater allocation and management. Stakeholders in groundwater governance outcomes include those directly involved as end-users (water utilities, irrigators) or as indirect economic beneficiaries in the community such as agricultural suppliers, engineering companies and developers. Stakeholders in groundwater management issues also include individuals and organizations with environmental, ecological, health related and socioeconomic priorities that could be affected by decisions about groundwater use and source protection priorities.

Decisions about the use of groundwater today are rooted in complex connections of political structure, historical precedent, hydrogeological conditions, legal rights, vested interests and perceptions of future need. The United States has diverse types of aquifer systems, regional differences in climate and topography, great variation in historical water use and regional differences in the evolution of water policy over the last 200 years.

The fifty states of the US each have independent political oversight of most natural resource issues. Water management strategies and the associated governance which provides management authority have typically developed in reaction to supply and demand concerns of major water users with resource competition and drought as major drivers.

It is only in the last few decades, that citizens have become active in water and environmental issues related to groundwater. The public, not just end-users, now have the power to influence policy. Public awareness of cause and effect in deteriorating water quality, the growth of strong citizen-based environmental organizations and the impact of demographic pressures have helped prioritize the need for political response to find solutions that will maximize the benefits of sustainable groundwater use among all citizens.

The devolution of authority from federal to state to local control over the use and protection of aquifers can be controversial if it generates "turf wars" over who has jurisdictional authority. Competing vested interests may clash over characterizing problems of overuse or deteriorating water quality and in proposing solutions. Promoting a science based understanding of groundwater has become a major education challenge for independent NGOs, agencies and academics striving for groundwater resources protection and sustainable use.

The chapter is organized under the headings of control of water, evolution of governance, informing the public, local authority, and concludes with examples of awareness raising and citizen pressure on groundwater decisions and policy.

2. Control of water

Control and authority over water resources is an evolutionary process, with groundwater management issues a relative late-comer as an essential part of overall water management. The political power that results from authority (given or taken) over the control of water is a well-documented phenomenon. For example Karl Wittfogel's thesis about the rise of "hydraulic societies" throughout history, (Wittfogel, 1957) and examples in Donald Worster's book, *Rivers of Empire*, subtitled Water Aridity & The Growth of the American West, (Worster, 1985).

Perhaps even more important as an influence of how groundwater is actually managed locally are the many elected and appointed boards, commissions, agencies and associations with direct or indirect authority over planning and environmental issues. In addition to direct citizen involvement with these officially recognized groups, there are many NGOs such as watershed associations with a focus on local or regional environmental issues. There are thousands of environmental organizations in the US. Most can be accessed via a web-portal provided by the US Environmental Protection Agency that has a state by state listing and provides links to environmental organizations for America's 43,000 postal zip code areas. (www.cfpub.epa.gov/surf). Some major environmental organizations such as the Sierra Club the Nature Conservancy, and the Environmental Defense Fund operate nationwide and have programs related to resource protection and have members and professional staff who exert powerful influence on shaping policy. Groundwater may not be a primary stated concern, but the broad environmental interest focus of these groups will often have an indirect influence of policies of groundwater resources use and aquifer protection.

There are professional membership groups such as the National Ground Water Association and the American Water Resources Association that do specifically exert influence on groundwater policy, and there are specialist non-profit groups not organized to represent any particular profession, such as the Groundwater Foundation and the American Ground Water Trust that have education about groundwater as the principal means of fulfilling their mission to protect resources and achieve sustainable use of groundwater.

Indirect impacts of groundwater governance are locally and nationally influenced by public pressure on decision makers arising from issues that have mobilized citizens to become actively involved. Other impacts come from groups that have economic interests tied to policy outcomes. Some specific examples are outlined in more detail later in this chapter. They show how groundwater management policy is directly or indirectly influenced by the involvement of NGOs in raising awareness, framing issues and in facilitating dialogue among stakeholders, groundwater professionals, agencies, regulators and political decision-makers. For example:

- Citizen and agricultural industry concern about drought impacts in California which have caused increased over pumping of aquifers for irrigation and dried domestic water wells.
- The loss of irrigated agricultural production in Colorado with urban water users buying agricultural water rights in so-called "buy and dry" deals leading to social impacts on rural communities because of reduced agricultural activity.
- Water quality concerns in states where there is oil and gas development involving hydraulic fracturing, pipeline construction and produce-water disposal via injection wells.
- Concerns that bottled water companies are depleting aquifers and making "profit" from local groundwater at the expense of local communities.
- Concerns about alterations to groundwater quality resulting from water recharged in Aquifer Storage Recovery projects.
- Litigation by water suppliers and end-users to assign responsibility and take action over legacy contaminants from past industrial activities.

3. Evolution of groundwater governance in the US

In any one place and in any one snapshot in time, management decisions such as groundwater pumping, source protection and water allocations are the result of past complex interactions among landowners, citizens and the legal authority vested in federal, state and local units of government.

The US Federal system distributes authority geographically among the fifty states. Each state claims jurisdiction over groundwater because they administer water law and water rights. The independence of state authority is complicated by laws related to federally funded reclamation projects, the interstate complications of transboundary aquifers and rivers, federal oversight of public lands, military bases and the commitment to treaty rights of Indian tribes. There is also federal legislation such as the Clean Water Act (1972), the Endangered Species Act (1973) and the Comprehensive Environmental Response, Compensation and Liability Act (1980) that may reduce the independence of state authority.

The historical record of the development of America's water resources in the 19th century and in first half of the 20th century, particularly in states west of the Mississippi, is one of federal government investment in structures to move water from where it occurs to where it is needed. The dams, diversions and canal structures were virtually all based on surface water. The implementation of large scale groundwater pumping for agriculture really began in the 1950s based on the completion of electrification of rural areas and the development of high capacity turbine pumps.

Citizen influence on groundwater governance has for most places in the US evolved over the centuries since early settlement. These influences include factors such as land ownership, water rights, perceptions of the economic value of groundwater, changing economic demands, environmental concerns, innovations in water technology, litigation and case-law and long and short-term changes in weather patterns. In recent years where groundwater scarcity has created a challenge for decision-making, the US has continued to vacillate over the conundrum of the sanctity of “water rights” and the need to make water allocation and management decisions in the public interest. An additional challenge, if economic value and costs are used as an element of governance, is that there are complex distortions in price because of the legacy of federal and state interference through subsidies, direct financing, interest forgiveness or by direct government construction of water storage and distribution systems.

Towards the end of the 20th century groundwater use was clearly established as a vital ingredient of the US economy with approximately half the nation’s drinking water and a third of irrigated agriculture from wells (Gollehon, 2000). The increasing importance of groundwater was recognized by the first Environmental Protection Agency Director, William Reilly, "Ground Water resources are of vital importance to this country - to the health of our citizens, the integrity of many of our ecosystems, and the vigor of the economy.” (US EPA, 1991).

Objectives of groundwater governance strategies are principally to achieve sustainability while protecting a diverse range of vested interests. When there is plenty of water to go around then controls are not an issue. When demands exceed supply (in reality or perception) then balancing economic, environmental and social issues within institutional political frameworks raises the issue of governance. Who has the authority at federal, state or local level to make policy decisions and develop regulations? What local units of government at county, parish, city or township level have authority that can influence resource management? Who has reliable groundwater data sets? What role is played by NGOs with environmental and social interests and groups with vested financial interests?

Public awareness can have an impact on the political process. While groundwater may not be the principal focus of citizen attention, there are contemporary issues where citizen pressure is directly or indirectly creating attention and political will for stronger and more consistent control of aquifers and groundwater pumping. There is a need to maintain citizen pressure on policy-makers. As David Sonnenfeld remarked in the context of environmental governance "Persistent efforts by interested parties are required to retain salience, maintain momentum, and extend effectiveness." (Sonnenfeld, 2002).

4. Informing the public

Water allocation and management policies work best with the support and cooperation of individuals and communities. A traditional top-down approach is that authorities know what is best and only need to inform the public what they are doing. A bottom-up approach requires that the public knows what it wants its elected representatives and state officials to achieve.

The key to achieving science based groundwater management policy is to make the sub-surface hydrologic system understandable to five principal groups:

- Policy-makers (elected representatives)
- Current and potential groundwater-user stakeholders
- The public in general and the myriad of citizen organizations and interest groups that have opinions and perspectives
- Journalists, publishers and broadcasters involved with radio, TV and print media
- Organizations and individuals active with social media via blogs and other postings.

Awareness, information and education are important elements that can assist all groups (politicians, groundwater end-users the media and citizens) better understand the important, allocation, protection, and sustainability issues that are involved with groundwater governance. Where the current system of water management and governance is not working, collaborative governance is critical for better decision-making.

Sustainability has moved from being a scientific exercise to becoming a political reality that recognizes the need to reduce stress between human population and natural resources. An informed public is better able to understand issues and recognize potential conflicts and can therefore voice support or opposition to decisions affecting the local use of resources. An informed public will have a basic level of hydrologic literacy and understand basic groundwater terminology such as aquifer, drawdown and recharge.

The first learning objective about groundwater should be the recognition that groundwater is that part of the hydrologic system that occurs in a geologic environment. Citizens informed about hydrology basics are empowered to demand and ensure that groundwater users, legislators, regulators and the news/communication media do not believe, receive, or dispense incorrect concepts or information. Education of all the constituent groups is essential to reduce the effects of incorrect information, "spin" from lobbyists and misinformed interest groups seeking to influence policy. To be effective, groundwater governance needs objective information and considered opinions from verifiable data sets, testable hypotheses and predictive models of water scientists. However, groundwater policy is not developed in academic isolation and there are many peripheral influences that result in groundwater management policy being a hybrid.

5. Local Authority impacting groundwater development, use and protection

In the US there is considerable local authority and control delegated at local town and county level regarding development and land use. There is a plethora of rules and ordinances that are in place to protect water resources, the application of which can have a major impact on whether or not groundwater resources may be developed. Groundwater regulation issues involving who can pump, where wells are sited, how much pumping, and resource protection needs etc. are much wider than the simple concept of managing aquifers for sustainability. Much of the regulatory oversight that is related to local planning, environmental concerns, building codes and land-use is administered by a complex web of state, county and local agencies, boards and government entities. These entities may not have aquifer management as a principal focus but never the less they may have regulatory oversight that on the local level affects groundwater management decisions. For example:

5.1 Boards that develop and oversee well construction standards.

The standards for well depth, diameter, casing materials and grouting requirements for different groundwater uses are typically regulated as a means of protecting aquifers. Design specifications are intended to prevent aquifer interconnection and to ensure that there is no possible conduit between surface water and groundwater. Siting requirements for new wells and protocols for well abandonment have cost implications that affect the economics of potential groundwater use and source protection.

5.2 Training and licensing standards for well contractors

Mandating that water wells can only be drilled by licensed contractors provides a means of maintaining professional standards. Continuing education requirements can enhance the contractors' knowledge of geology and local aquifers and the best-management practices that are effective in preserving groundwater integrity. Professional integrity and ethical standards are essential for well construction because of the costs and logistical challenges that would be required for regulatory supervision during the drilling process at every installation.

5.3 Zoning boards Planning Boards

Virtually all US towns have boards with the responsibility of controlling development. These boards provide an important element of groundwater governance by protecting aquifers and known groundwater recharge areas from industrial development and preventing land use changes that could impact hydrology. Local zoning boards generally have subdivision and site-plan review regulations. Determining housing density and setting the minimum area for property size can be important to ensure the sustainability of on-site wells. For municipal drinking water supply using groundwater there are requirements for protection zones and set-back distances from wells.

5.4 Building codes for onsite wastewater treatment and disposal systems

In the US, decentralized waste water systems (often called septic systems) collect, treat, and release about fifteen million cubic meters of effluent per day from an estimated 26 million facilities nationwide, (NEIWPCC, 2017). Although not designed specifically to do so, all of them, by design, are efficient aquifer recharge devices! Having siting criteria and codes for the correct design and construction of septic systems is important for reducing the risk of aquifer contamination. Virtually all of in-house water use for homes with on-site disposal is recharged to groundwater.

5.5 Building code design criteria for onsite water wells

There are an estimated 40 million people in the US with on-site private wells for drinking water supply, (Stone, 2013). The well is part of the equity value of the home and developers and home builders are often (although not always) required to prove a minimum well yield before an occupancy permit is issued. Typical minimum required yields are in the order of 10 to 20 liters per minute. In many instances where wells are obtaining water from bedrock fractures, actual yields may be accepted at a lower rate. (Two liters a minute gives close to three cubic meters a day). Of significance for overall groundwater protection is the permitted minimum property size allowed for each home. In places with low yielding aquifers, housing density of more than one home per hectare could result in over exploitation of groundwater.

5.6 Health requirement for water quality

Most community health authorities have jurisdiction over drinking water quality. Health authorities have the power to shut down municipal wells that supply public drinking water and issue advisories for private well owners. As for example in recent instances of aquifer contamination from perfluorochemicals, outlined in section 6.6 later in this chapter. In many jurisdictions, health authorities require full water quality testing for wells at the time of property transfer where there is an on-site source of water supply. To help achieve awareness of the importance of a safe and properly functioning water system the NGOs, Water Systems Council and American Ground Water Trust have developed education training programs about groundwater, wells and water treatment equipment specifically for real estate professionals, public health officials and home inspectors.

Some examples of other elements of local government and regulatory authority that impact decisions governing groundwater development and aquifer protection include conservation commissions that advocate for preservation of open-space, transport engineers that design detention ponds for storm water disposal and requirements from water utilities in northern states about restricting winter road-salt application in groundwater recharge areas.

As the public becomes more aware of groundwater and as groups such as health officials, real estate professionals and home inspectors are more involved with groundwater as a supply source, then the base of groundwater governance responsibility becomes wider. A wider base can provide more governance stability while retaining flexibility for changing local conditions.

6. Awareness-raising and citizen pressure on groundwater management authority

In this section, six examples are provided to show the ways in which citizen and NGO concerns are involved with the resolution of groundwater issues.

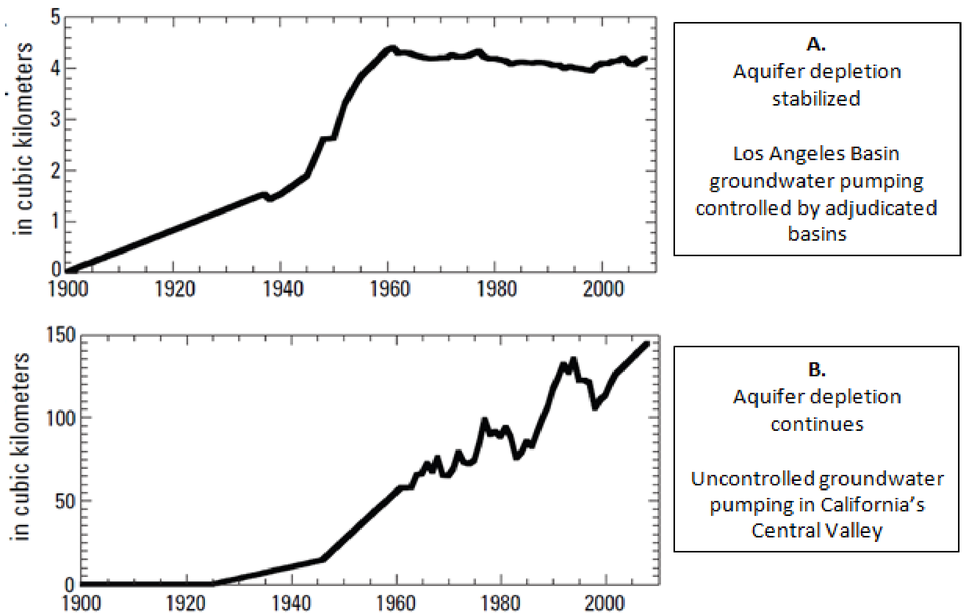
6.1 Citizen concern about drought impacts in California

California is in the process of trying to establish comprehensive groundwater governance that will apply to all 515 of its alluvial basins. The state has over one thousand regional and local water agencies operating complex storage and delivery systems. For decades the state did not have the political will to establish groundwater pumping controls despite evidence of continued aquifer depletions. However, from 2010 onward, a sustained drought stimulated political awareness from diverse pressure points. There has been ongoing involvement from environmental activists, anti-growth forces, and the farm lobby (with essential irrigation needs for tree and vine crops). There has been constant media coverage of aquifer declines, frenetic drilling, threats of farm bankruptcies water restrictions in cities, drying residential wells, damage from land subsidence caused by aquifer dewatering and concerns for potential declines in food production from the state’s multi-billion dollar agribusiness.

In addition to greatly decreased stream flows, surface water transfers to Central Valley farms from northern California via the state aqueduct system were reduced in order to maintain environmental flows to Chinook salmon and delta smelt, two fish species listed as “Endangered” in 1994. Because of the effects of drought and the associated reduction in spring and summer meltwater from mountain snowpack that traditionally provided surface water, between 2010 and 2014 irrigators increasingly supplemented their needs by pumping groundwater.

The California Sustainable Groundwater Management Act (SGMA), signed in 2014 has the intent of developing a state-wide uniform standard of sustainable management that will be applied at the local level. Unlike the Central Valley, in Southern California many of the groundwater basin and sub-basins have had some controls on pumping resulting from court adjudications, most of which occurred between 1960 and 1990. The limits on groundwater pumping stabilized groundwater levels. However over the same time period in the Central

Valley, groundwater levels continued to decline as water was “mined” from the aquifers. The graphs in figure one illustrate the differences in cumulative aquifer drawdown.



CUMULATIVE GROUNDWATER DEPLETIONS 1900 – 2008

A. Los Angeles Basin B. California Central Valley

Adapted from US Geological Survey Scientific Investigations Report 2013-5079 (Konikow, 2013)

Fig.1. Comparison of cumulative aquifer drawdown.

The basis for future California groundwater governance as proposed by SGMA is via a regulatory structure that gives local control of management, allocation and restrictions to achieve sustainability in identified groundwater basins. Stakeholders (a word which can have a wide inclusive interpretation) must get together and form a local groundwater agency with the responsibility to form a Sustainable Groundwater Management Plan for their basin by 2020. SGMA has statutory requirements for stakeholder engagement to encourage active involvement of social and cultural elements of the population. Most water agencies and local units of government have produced informational fact sheets and have held thousands of citizen meetings discussing the need for SGMA’s groundwater governance initiative. One of the major challenges is that the management strategies have to be harmonized with common law and this has the potential for conflict with water rights.

A 2014 initiative from the California Water Foundation, developed through stakeholder dialogue, provided recommendations for sustainable groundwater management to allow California’s diverse groundwater users and managers to balance supply and demand, protect private property rights, and meet the future needs of farms, cities, and the environment, (California Water Foundation, 2014). The Foundation also developed an online Information Bank available to the public to promote transparency and understanding about groundwater management in California.

With the opportunity to develop local control over California groundwater resources there are several NGOs that are actively involved in awareness raising and assistance by providing hydrologic and economic expertise, providing insight about data handling and management software, promoting open source code for groundwater models, helping coordinate stakeholders, and facilitating the interface of groundwater end-users with legal experts to ensure compliance with SGMA requirements while protecting established rights. Some of the NGOs actively involved with assisting California's new groundwater governance process are: Consensus Building Institute, Groundwater Resources Association, American Ground Water Trust, Clean Water Action, Public Policy Institute of California, and the Pacific Institute.

6.2 Urban water users and agricultural water rights

In Colorado, aquifers are defined as "tributary groundwater" if they have direct connection to surface water. The majority of senior water rights are for surface water and they are in most cases "senior" to groundwater rights. In essence, a water right gives the holder a right to apply the water to a beneficial use without waste. There are almost 180,000 decreed surface and groundwater water rights in Colorado. A "right" enables the right owner to use water from the state's rivers and aquifers in priority based on the date of the water right. "Injury" to surface rights is presumed to occur when pumping from aquifers reduces stream flow.

As part of the complex decision-making over groundwater management, downstream senior water right holders can make a "call" on the river and demand that upstream groundwater users cease pumping in order to be compensated for their past out of priority groundwater use. However, the augmentation water that the senior right holders then receive is not necessarily used by them for irrigation but may be sold to the metropolitan areas of Denver and the Front Range. Selling water can be more profitable than growing crops. Upstream farmers may be prevented from pumping (for drainage or for irrigation) while down-stream water right holders derive the benefit. This occurrence is "legal" under the existing water law but the augmentation requirements may be based on groundwater models which overestimate the required augmentation volumes, (Gates, et.al. 2012).

Colorado is a state with complex water rights, some going back to the 1860s. Groundwater governance, while officially under the aegis of the Colorado State Engineer, is in fact strongly influenced by decades of water litigation and court decrees. Colorado has one eighth of the population of California but has more law firms (16 compared with 13) specializing in water law, (U.S. News 2017). Denver is said to have the world's greatest concentration of water rights lawyers!

Meanwhile, rising groundwater levels where pumping is prohibited are causing flooded fields and crop failure, (D'Elgin 2016). The calculations made for restricting pumping and the time period required for augmentation are based on the volumes of past out of priority pumping by the junior right holder. Sticking rigidly to the replacement volume and timing calculations does not make hydrologic sense because the aquifers are demonstrably over-full but the augmentation law requirements in essence say "keep filling them up."

This abuse of common sense about this aspect of groundwater governance is having social and economic consequences in affected areas, (Fryar, 2012). Organizations such as the Lower Arkansas Valley Water Conservancy District, the Family Farm Alliance, and Weld County Farm Bureau, are working to overcome these results from a governance system that honours water rights while ignoring the basics of groundwater science. NGOs such as the American Ground Water Trust and the Colorado Water Education Foundation, have provided regular workshops and conferences that help frame the issues and highlight the challenges of effectively managing groundwater against the rigidity of the state's legal code.

6.3 Groundwater and oil & gas development

There are four aspects of fossil fuel extraction via drilled bores that have potential groundwater impact. Firstly, finding water to use in the process, (many fossil fuel deposits are in arid areas where groundwater is the only possible source). Secondly, there are potential contamination risks during drilling, well stimulation, and the operation processes which extract oil or gas. Thirdly, there are challenges for treatment and disposal of contaminated water (often accomplished by deep injection) and fourthly there are possible risks from accidents during transport of fuels away from the drill site by pipeline, road or rail. Hydraulic fracturing to stimulate the flow of oil and gas wells was first used in the United States in 1947. The process is now carried out on the horizontal portion of directionally drilled wells and typically requires thousands of cubic meters of water and results in the return of contaminated process water.

Over the last decade, public protests about oil & gas development using directional drilling and hydraulic fracturing have often focused on the risks (or perceived risks) to groundwater quality, although there may also be other concerns with climate change or globalization of energy companies. Whatever the protest reasons, the effect of consistent activism has forced authorities in affected areas to be more vigilant about groundwater protection rules and had resulted in increased regulatory oversight and reporting on drilling, well construction and the various chemicals that may be used. Examples of some of the local and national organizations that have been effective in exposing contamination, increasing awareness of possible risks to groundwater, making legal challenges and holding the industry and regulatory authorities accountable include: The Groundwater Protection Council, Living Rivers, Center for Biological Diversity, Marcellus Shale Coalition, Environmental Defense Center, and extensive independent reporting by ProPublica and recognized newspapers such as the New York Times and Wall Street Journal.

In practice, the deep zones where the gas or oil bearing rocks are actually fractured do not represent risks to groundwater because thick overlying rock units are a barrier to vertical propagation of fractures. Ensuring the integrity of the well casings and seals used in the upper portions of vertical bores has been shown to be important in reducing risks of methane migration into aquifers. However, the risks to freshwater aquifers and virtually all of the reported contamination issues result from problems on the surface from accidents and spills in the storage, handling, and treatment of fuels, chemicals and process water, or in the transport of the extracted product by road, rail or pipeline. The vast majority of gas wells do not have any reportable environmental violations, (Soeder, 2017). Additional disruptions in affected areas are disturbances associated with a noisy industrial process, road building, and truck traffic etc.

Benefits to groundwater science from well-orchestrated citizen pressure have been a plethora of research reports providing detailed knowledge of the potential aquifers for source water and detailed studies of the boundaries and properties of drinking water aquifers that require particular regulatory oversight vigilance. The Groundwater Protection Council has developed a publically accessible database for reporting of hydraulic fracturing in gas development. The data base includes information on water quality, the volumes of water used and the fracking additives. This independent data source can inform groundwater management decisions and provide a basis for science-based regulatory guidelines and will hopefully help the fossil fuel industry water utility managers and environmental organizations to cooperatively coexist.

Citizen activism has put fossil fuel companies in the spotlight. Citizen watch-dog groups have forced a high degree of operational transparency and environmental responsibility. It seems likely that it will be many decades before the use of fossil fuels can be phased out. Going forward, the citizen pressure has strengthened the hand of regulators responsible for groundwater protection and has resulted in increased research and technology investment in using saline water for fracking, developing non-water based hydraulic fracture options, and in the development of equipment for comprehensive on-site treatment of return flow (produce) water.

Improving groundwater governance by promoting objective science as the basis for safe oil & gas operations and development of groundwater protection policy has been assisted by the work of professional associations such as the American Institute of Professional Geologists, the National Ground Water Association, and the American Ground Water Trust. These organizations, and others, have helped frame issues at the water and energy interface and have facilitated meetings and conferences among land owners, environmental groups, regulators, the oil & gas industry and groundwater experts.

6.4 Concerns that bottled water companies are depleting aquifers

Public opposition to bottled water enterprises can result in demands for tighter controls over pumping permits. Such pressures can strengthen the hand of local regulatory authorities. The US ranks 6th in the world in per-capita annual consumption of bottled water (138 liters). Mexico is first with an annual average consumption of 247 liters, (Rodwan, 2016). According to the Beverage Marketing Corp., quoted in the Wall Street Journal, March 9, 2017, the US now consumes more bottled water per capita (39.3 gallons) than carbonated soft drinks (38.5 gallons). MANTA, a business directory firm, lists 628 companies the US with mineral and spring water bottling as their major enterprise.

The rise of bottled water consumption has produced great environmental controversy, much of which is related to concerns about disposal of containers and alleged misleading marketing. Opposition to the industry (for whatever reason) has given attention to the water sources used in bottling operations. In the US, 70% of all bottled water is from groundwater sources which may be a flowing spring, a well tapping the aquifer supplying the spring or a borehole that may have natural artesian flow or be pumped.

Local concerns, expressed in protest meetings, yard-signs and litigation, typically claim that bottling plants are drying up aquifers and disrupting aquatic ecology. In some instances, wider issues such as protecting the sanctity of water against any form of privatization are a driving force for opposition. The comments (below) from citizens in Michigan, (Cited in Business Insider, November 2016) show the passion that can be aroused by a bottled water facility, "The rape of our Michigan inland fresh water sources is a cause for concern, especially when it is done by a private company for profit." "Trying to privatize water is NOT acceptable. You're an evil corporation and just want you to know there isn't and will never again be a product of yours in our house."

Regulating agencies may run the risk of litigation unless they strictly follow laws and regulations. The focus of many of the opposition protests is to influence local units of government that have planning, zoning and permit oversight over development or water withdrawals and/or jurisdictional authority over environmental protection. A widely publicized case, Michigan Citizens for Water Conservation v. Nestlé Waters North America Inc., (Michigan, 2007), prompted the state legislature to make reforms in groundwater law. An example of how citizen pressure and legal action can bring legislative changes that impact groundwater governance.

Companies involved with or investing in a bottled water enterprise would presumably have source protection and sustainability as an important business criteria. The larger bottled water enterprises employ groundwater experts who present studies to demonstrate that their pumping will not deplete the resource or negatively impact springs or surface water. The fact that many of the plants have remained in operation for many years, apparently without any serious negative aquifer impacts, shows the importance of thorough initial hydrogeological investigations. It seems that for some people, it is the use to which the water is put that is more cause for concern that the use of the water. Although in the Michigan case the court did not treat the water bottler any differently than other commercial water users.

6.5 Concerns over impacts of Aquifer Storage Recovery projects.

Aquifer storage and recovery (ASR) systems are a sub-set of the many aquifer recharge technologies that are used to enhance groundwater storage. Engineered river diversions spreading basins and surface detention ponds are also used to increase the infiltration of surface water to groundwater storage. Water for recharge can be storm water, treated waste water or any other source where there is a surplus. Storing water underground has many economic and environmental benefits over the construction of surface impoundments. ASR is a particular technology where water (when available at time of surplus) is introduced via a well into a target storage zone in a receiving aquifer and then pumped for use via the same well when there is a demand. Books by Peter Dillon and David Pyne are frequently used references on aquifer recharge, (Dillon, 2002), (Pyne 2005).

The first ASR well in the US began operation at Wildwood, New Jersey in 1969 and there are now many states in the US with operating systems. The US EPA reports project sites with a total of 307 ASR wells, (US EPA, 2016a). The technology has had to overcome considerable public resistance, regulatory roadblocks and skepticism from some traditional water engineers. Much of the public resistance has centered on potential aquifer contamination from microbiota such as bacteria virus and protozoa; possible impacts of disinfection by-products if chlorinated water is used for recharge; potential leaching of metals such as arsenic mercury and uranium, and ownership and liability issues if the recharged water moves off site from the point of recharge. Politicians, sensitive to public concerns have been slow to accept the technology and management protocols. Regulatory guidelines for ASR have evolved project by project and state by state, often involving the need to resolve problems of overlapping jurisdictional authority among federal and state agencies.

Non-profits and professional organizations have helped alleviate environmental and health based concerns, interfaced scientists, end-users, legislators and regulators and facilitated information exchange about the progress of ASR projects among the US states. While several US professional groundwater organizations have been involved, in promoting aquifer recharge in the US there have also been international exchanges of technology via programs of the International Symposium on Managed Aquifer Recharge (ISMAR) and the International Association of Hydrogeologists. The NGO, American Ground Water Trust (AGWT) has been particularly active in promoting ASR solutions in the US.

Since 2001 the AGWT has regularly convened conferences in Florida, California, Texas and Colorado that have focused on aquifer recharge and ASR issues. A combined total of over 500 technical, scientific, engineering and policy presentations have been made at these AGWT events to audiences comprised of political and regulatory agency decision-makers, water district and utility managers and their scientific, engineering and legal advisors. These programs have become the de facto information exchange venue on aquifer recharge for water professionals, environmental groups and elected representatives. The issues presented have stimulated research, the results of which have incrementally led to a regulatory response at federal and state level that is now less restrictive about issuing project permits. Key research findings prompted by conference discussions that have led to regulatory changes include: natural attenuation with aquifer residence time of microorganisms in recharge water, lowering oxygen levels in recharge water by degasification to inhibit metals mobilization, and cycle testing of recharge and recovery to demonstrate progressive reduction of metal leaching to levels that comply with health standards.

6.6 Perfluorochemicals - legacy contamination from industrial activities

Perfluorochemicals (called PFCs) are a group of synthetic chemical compounds, not found naturally in the environment but which are of growing concern as a groundwater contaminant. PFC compounds have been used in the manufacture of products such as stain-resistant carpets and clothing, food packaging, non-stick cookware, cosmetics and cleaning products. In commercial use, PFCs have been used for photo imaging, semiconductor coatings, firefighting foam, plastics and hydraulic fluids. So ubiquitous has been their use over the last fifty years that virtually the whole US population carries in their blood some very small but measurable amount of a PFC compound, (CDC, 2016).

Citizen action, pressure from environmental groups and litigation are influencing regulatory and management responses to PFC contamination. Recent reports show impacts to private wells and public water supply wells. In 2015 the Environmental Working Group reported contamination in 94 public water systems in 27 states, (EWG, 2015). Although private wells are not directly regulated by state agencies, the health of all citizens is a state and local government responsibility. With increased public awareness and increased testing of groundwater quality over PFCs, governance for private wells has now become an issue for local and state government. The Federal Government has established 70 parts per trillion as a guideline threshold for PFCs (EPA 2016b). Local jurisdictions may have lower thresholds, for example the Vermont Department of Health's drinking water health advisory level is 20 parts per trillion, but many citizen groups are demanding even lower thresholds.

There are treatment technologies available that will remove PFOA compounds from drinking water, such as granular activated carbon; anion exchange, reverse osmosis and specialized membrane filtration. A policy dilemma is to choose between treating water pumped from affected wells or closing the wells and establishing a pipeline connection to a utility supply. Closing wells, sealing abandoned wells, de-designating aquifers as drinking water sources are decisions that impact groundwater management options.

Agency response in advising citizens with wells affected by PFCs has been swift and effective, and to date has been helped with tax dollars and in some cases with voluntary financial payments from former PFC industrial users. For example in New Hampshire, where the Department of Environmental Services has been proactive (NH DES, 2017), a former manufacturer that used PFC products has agreed to pay for a permanent treatment plant for town wells in Merrimack New Hampshire, (MVDWW, 2017). However, when it comes to long term financial redress for costs, litigants may have a vested interest in promoting the most expensive option. Independent objective information from NGOs about the extent and severity of the contamination may help moderate reaction.

7. Conclusion

Over forty years ago, in a paper on planning theory, Rittel and Webber outlined two types of problems, "Benign problems" which have a clear and logical definition and "Wicked problems" with multiple and conflicting criteria for defining solutions, (Rittel & Webber, 1973). There is little doubt that groundwater governance falls in the "wicked" category because of the complexities of the mix of historical precedent, vested interests, social and economic pressures, water allocation disputes, legal and political opinion and competing jurisdictional authority. Impacting every part of the "wicked" mix is ignorance and misunderstanding of the basics of groundwater science. NGOs and professional organizations can play an important role in framing issues, providing objective information, facilitating information exchange and helping technical, academic and engineering professionals integrate into the political process where "governance" is generated. Many different agencies and local units of government play a complicated role in creating, implementing and policing groundwater regulations which are the basic building blocks of groundwater governance. Citizen pressure and the interventions of associations and NGOs can have a major influence on regulations and policy. Acceptance by the regulated that there is a rational need for regulations is an important prerequisite to making rules workable and education needs to be a key element of regulation in order to achieve cooperation and compliance.

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