WISCONSIN'S SPRING RESOURCES: AN OVERVIEW

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ABSTRACT

Wisconsin's extensive spring resources make ecological, cultural, and economic contributions to the state's livelihood. Formal documentation of the variety and distribution of springs began as early as the mid-1800s; however, their abundance challenges resource managers to adequately characterize the full range and significance of spring resources in the state. With these challenges in mind, this case study of Wisconsin's springs aims to summarize their geologic and geomorphic context, the habitats that they create and support, their influence on Wisconsin culture over time, and the policies that affect their management and use.

INTRODUCTION

Wisconsin is home to thousands of springs, found across the state and in every major geologic setting. They support the state's vast wetlands, lakes, and world-class trout streams and sustain critical habitat for endangered and threatened species. Wisconsin's springs are part of a rich cultural history and contribute to agriculture and tourism, two of the largest economic enterprises in the state. Springs supplied water to the earliest homesteads and continue to support livestock and major fish hatcheries. Wisconsin spring water was also widely marketed as restorative water in the late 1800s and continues to appeal to the bottled water industry today. But regardless of their ecological, cultural, and economic contributions, Wisconsin's environmental laws failed to explicitly protect springs until 2003 when the Groundwater Protection Act (2003 WI Act 310) was passed. This act aims to prevent harm to trout streams and springs; however, challenges in crafting a legislative definition of a spring and balancing economic development with resource protection continue to test managers of Wisconsin's springs.

SPRING INVENTORIES

Except for a few recent studies, most of the information on the distribution of springs in Wisconsin stems from two statewide inventories. The first, the Wisconsin Land Economic Inventory (WLEI) (1927–1947), documented land use in nearly every county in the state, so that abandoned farms, cutover forests, and other "idle" land could be resettled, reforested, or otherwise put to wise use (Koch, 2006). Field workers would, in a single day, walk 3 miles along a section line, across ½ mile to the quarter section line, back 3 miles along that line, and then ½ mile back to their starting point. This allowed the surveyors to touch at least one side of every "forty" (40-acre quarter-quarter section) in the surveyed area. A forty was the area of land that was typically considered necessary for a small farm, preferably with another forty of pasture and another of woodland. Hand-drawn field maps were produced for sections or groups of sections in a township and included information on land use, land cover, wildlife, buildings, streams, lakes, and springs. These detailed maps, along with information from the original Federal General Land Office Survey of Wisconsin (1833–1866) and aerial photography, provided the raw material for the published WLEI maps (Koch, 2006).

The second statewide inventory was prepared by the Wisconsin Conservation Department (WCD), a precursor to the Wisconsin Department of Natural Resources (WDNR). The WCD conducted spring surveys for roughly 60 percent of the counties in the state from 1956 to 1962. These county-by-county spring surveys were designed to assess spring resources for fish management purposes. Springs were plotted on plat maps and the WCD recorded information on location, flow rate, substrate material, fish species

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present, and land use. Although the surveys are very detailed, there are inconsistencies among the county surveys, and the quality of some of the information is unknown. For example, spring locations are only accurate to about a quarter-section. In addition, spring flow was sometimes measured using the "floating stick" method or a V-notched weir, but other times it was probably visually estimated. Even so, the surveys represent the most detailed information on the distribution of springs in the state for this time period.

Aside from initiatives primarily aimed at documenting surface water features in Wisconsin (for example, WDNR Surface Water Inventories, 1961–1985), very little has been done since the WCD surveys to characterize springs on a statewide basis. However, following the highly publicized case involving a proposed Perrier bottling plant near Mecan Springs and Big Spring in Waushara and Adams Counties (Glennon, 2002) and the subsequent enactment of groundwater legislation in Wisconsin (2003 WI Act 310), there was renewed interest in the distribution and character of spring resources. In response, Macholl (2007) compiled a statewide springs database (fig. 1). It contains all springs that have been mapped by the WLEI, WCD, or WDNR; recorded in the U.S. Geological Survey Geographic Names Information System; or documented in another local source. In addition to the location of each spring, the database includes the historical information collected during the WCD surveys and, for a few springs, some more recent physicochemical data. Macholl's (2007) statewide springs database will serve as a critical tool in tracking and monitoring changes to Wisconsin's spring resources over time. It provides an estimate of the potential number and position of springs in the state and the range of expected flow rates. Nearly 11,000 individual springs are currently identified in the database, and most of these springs are fifth- or sixth-order springs, according to Meinzer's (1927) discharge classification. The mean flow of the springs in the database is approximately 90 gallons per minute (gpm), or 0.2 cubic feet per second (cfs), and the median flow is 15 gpm, or 0.03 cfs. However, because very few of the springs could be field-checked as part of the effort (less than 2 percent), the database may, for some regions, overestimate or underestimate the current distribution of spring resources.

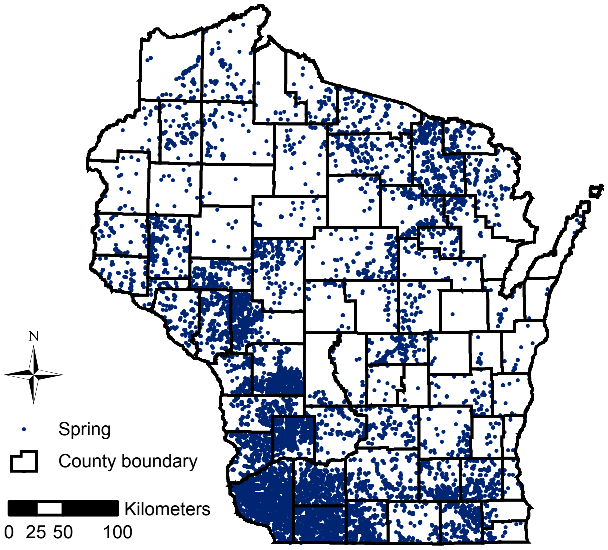

Figure 1. *Distribution of springs in Wisconsin. From Macholl (2007) and Swanson and others (2009).*

Studies specific to Brown, Calumet, Iowa, St. Croix, and Waukesha Counties were able to more thoroughly assess the accuracy of the historical sources of springs information and characterize the current state of spring resources in these areas (fig. 2) (Fermanich and others, 2006; Grote, 2007; Swanson and others, 2009). Results of work in Iowa and Waukesha Counties suggest that the positional

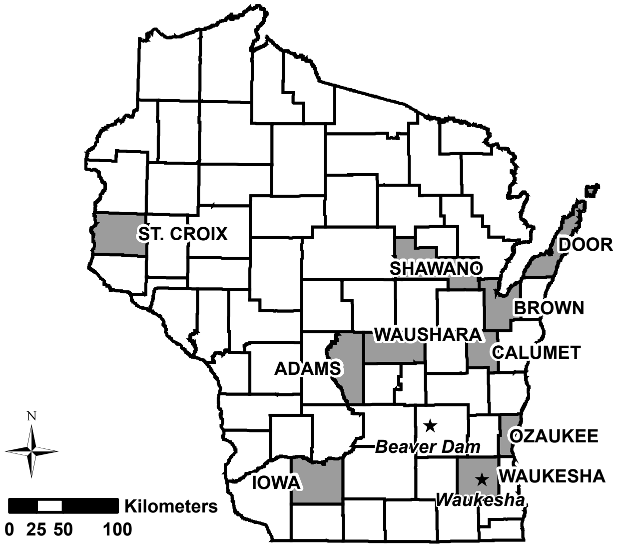

Figure 2. *Locations of cities and counties referred to in this report.*

accuracy of the springs in the WCD surveys is relatively high (at least to one quarter-section), but that the historical spring flow measurements can only be used as qualitative indicators of the size of a spring (first-order, second-order, etc., according to Meinzer, 1927). Because the positions of the springs are reliable, they can be used in association with regional data sets of geochemistry, topography, and geology to reveal important controls on groundwater flow or make initial assessments of the vulnerability of spring flow to groundwater withdrawals (Swanson and others, 2009). Furthermore, they serve as an important data set to which temporal changes in the distribution of springs can be compared. For example, very few of the springs documented in the 1958 survey of Waukesha County remain (WCD, 1958a; Swanson and others, 2009). The apparent loss of spring resources is attributed to urban development and groundwater withdrawals, which are known to have lowered groundwater levels and affected other surface water features in southeast Wisconsin (Feinstein and others, 2005; Swanson and others, 2009).

GEOLOGIC AND GEOMORPHIC CONTEXT

Wisconsin has a complex geologic past. Ancient Proterozoic and Archean sandstones, lava flows, and crystalline rocks underlie most of the state. Above that, mostly undeformed Paleozoic sedimentary rocks gently dip away from the Precambrian high (the Wisconsin Dome) in north-central Wisconsin. Pleistocene glacial deposits cover the bedrock over approximately three-quarters of the state (Mudrey and others, 2007).

The principal aquifers in Wisconsin are composed of Cambrian and Ordovician sandstones and dolomites, Silurian dolomite, and Quaternary sand and gravel deposits. Precambrian sandstone and lava flows are aquifers in northwestern Wisconsin, and the older crystalline rocks are also utilized for water supplies in limited areas (Kammerer and others, 1998).

Kammerer and others (1998) divide the state into four groundwater provinces on the basis of similarity of hydrogeologic regimes (fig. 3). These provinces (described below), along with local studies of spring systems, provide a useful framework for characterizing influences on groundwater flow to springs across the state.

Groundwater Province I

The largest of the four provinces, Groundwater Province I encompasses western and southwestern Wisconsin. Here, the Cambrian and Ordovician age strata generally thicken to the west and south and are overlain by glacial deposits only in the far north and east (Kammerer and others, 1998). Approximately half of the documented springs in the state occur in areas where the depth to bedrock is less than 5 feet, and

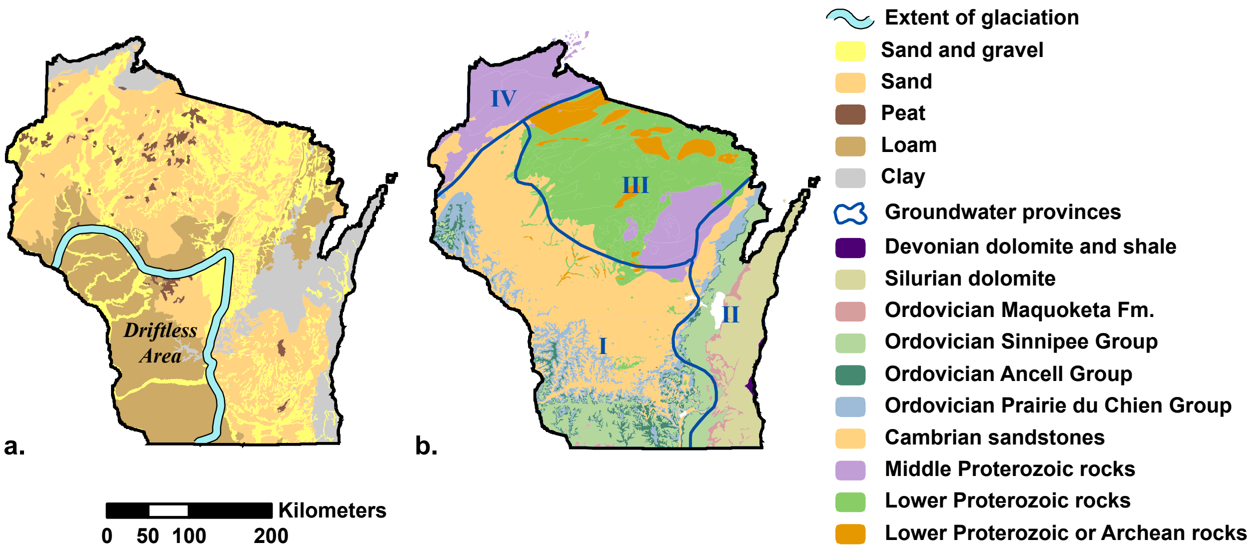

Figure 3. *General geology of Wisconsin.* **A.** *Distribution of surficial materials and extent of glaciation.* **B.** *Bedrock geology and major groundwater provinces. From WGNHS, 1989; Kammerer and others, 1998; Mudrey and others, 2007.*

nearly all of these springs are located in the Driftless Area (figs. 1 and 3). Glacial deposits are absent in the Driftless Area except for thin layers of loess and hillslope sediment on valley sides and stream sediment in valley bottoms, and Paleozoic rocks are deeply dissected and exposed in narrow valleys (Clayton and Attig, 1997).

In the Driftless Area, recharge primarily takes place along ridge tops and hillslopes, and local systems with short flow paths are common in the shallow bedrock aquifers. Perched water tables and local aquitards also occur throughout the region. In this complex setting, the relationship of springs to the groundwater flow system is often poorly understood (Krohelski and others, 2000; Hunt and others, 2003; Juckem and others, 2006; Carter and others, 2010). Groundwater is generally thought to flow preferentially along bedding plane fractures or along lithologic contacts with differences in hydraulic conductivity. The water emerges as contact springs where these features are intersected by stream valleys. Swanson and others (2009) found that springs are associated with every major stratigraphic unit in Iowa County; although most are associated with the heavily fractured Sinnipee Group (Platteville, Decorah, and Galena Formations), near the upper contact of the St. Peter Formation, or near the upper contact of the Cambrian sandstones. De Geoffroy and others (1967, 1970) similarly note that many of the springs in the historic lead-zinc mining district of southwest Wisconsin emanate from fractures and along zones of contrasting permeability in the Platteville, Decorah, and Galena Formations.

Several spring complexes in the eastern glaciated portion of Groundwater Province I have been studied in greater detail (for example, Domber, 2000; Hunt and Steuer, 2000; Anderson, 2002; Swanson and others, 2006). The bedrock surface is also deeply dissected in this area, but the valleys are filled with unlithified glacial deposits. Lakes formed in the low-lying areas during glacial retreat, and springs, composed of clusters of boiling sands, often emerge near the margins of wetlands that now occupy these low-lying areas. The springs are thought to form where high-permeability zones in the shallow sandstone aquifer are truncated by the buried bedrock valleys and where the hydraulic head exceeds the elevation of the land surface. These zones are attributed to erosional disconformities, limited cementation along bedding plane partings, and horizontal fractures in the sandstone aquifer (Swanson and others, 2006; Swanson, 2007).

Other notable patterns in the distribution of springs in Groundwater Province I include the concentrations of springs in the Baraboo Hills and those that coincide with the Johnstown moraine, which marks the farthest extent of late Wisconsin Glaciation in the state. Springs in the Baraboo Hills often emerge at the contact between the Precambrian Baraboo quartzite and the overlying Cambrian sandstones. Most of the springs in the vicinity of the Johnstown moraine are near streams, lakes, and wetlands that drain the hummocky glacial landscape. Groundwater flow paths to many of these springs are thought to be restricted to the sand and gravel aquifer and are not thought to intersect the underlying Cambrian or Ordovician bedrock (Conlon, 1996).

Groundwater Province II

Groundwater Province II covers the eastern part of the state. Here Paleozoic rocks gently dip towards Lake Michigan and are overlain by glacial deposits. Cambrian and Ordovician sandstones and dolomites are the uppermost rocks in the western half of the province. Silurian dolomite and Devonian dolomite and shale are the uppermost rocks elsewhere. The shaley Maquoketa Formation restricts vertical movement of groundwater between the Ordovician Sinnipee Group and the Silurian dolomite and confines the Cambrian-Ordovician sandstone aquifer throughout much of the province (Kammerer and others, 1998).

The spatial distribution of springs in this province is influenced by glacial features like drumlins and the Kettle Moraine, an irregular ridge of glaciofluvial material in southeastern Wisconsin that was formed during the retreat of the Green Bay and Lake Michigan Lobes (Clayton, 2001). In some areas, there is geochemical evidence that suggests that although flow paths originate in the sand and gravel aquifer, groundwater discharging to springs may also flow through shallow bedrock before discharging as depression springs in low-lying wetlands or near streams (Conlon, 1995; Gittings, 2005; Swanson and others, 2009). Elsewhere, flow is entirely within the sand and gravel aquifer (Newport, 1962; Swanson and others, 2009).

The Silurian dolomite aquifer occurs near the land surface throughout much of the central and northeastern part of the province, especially in the Door

County peninsula. The permeability of the dolomite is due primarily to secondary fractures and solution channels, so precipitation enters the groundwater system quickly. Once in the aquifer, groundwater flows laterally, through horizontal fractures, until it discharges to lakes, springs, or streams (Bradbury, 2003). Many small contact springs occur along the Niagara Escarpment near the contact of the dolomite with the underlying Maquoketa shale. These springs are often ephemeral, flowing only during the spring snowmelt (Newport, 1962; Johnson and Stieglitz, 1990).

Groundwater Provinces III and IV

Groundwater Province III extends across the Wisconsin Dome in north-central Wisconsin. Precambrian metasedimentary and metavolcanic rocks, granite, and gneiss are the uppermost rocks. Glacial deposits cover the area and range in thickness from 50 feet (15 m) to 200 feet (60 m).

Groundwater Province IV is located in northwesternmost Wisconsin. Here the uppermost bedrock is Middle Proterozoic volcanic and sedimentary rocks of the Keweenawan Supergroup. These rocks are overlain by glacial deposits that range in thickness from 50 feet (15 m) to over 400 feet (120 m) (Kammerer and others, 1998).

Like other areas of the state, the distribution of springs in both of these provinces is heavily influenced by the position of prominent glacial landforms, such as end moraines associated with the Green Bay, Langlade, Wisconsin Valley, Chippewa, and Lake Superior Lobes. Because the Precambrian rocks are dense and yield water only where fractures are present, most of the springs in these provinces are depression springs resulting from flow through the sand and gravel aquifer. Because some stream courses are influenced by faults in the Precambrian rocks (for example, the White River near Ashland in northern Wisconsin), the distribution of springs may be similarly influenced. However, more detailed research is needed to verify such relationships.

BIOLOGICAL CONTEXT

Springs in Wisconsin create unique habitat for rare and native species of plants and animals. They also support significant assemblages of coldwater organisms and diverse wetland communities, because springs often provide a stable physical and chemical environment (Webb and others, 1998; Epstein and others, 1999a, 1999b; Anderson and others, 2006). Springs can maintain stream flow during dry periods and provide refuge to organisms from heat in summer and cold in winter. Additional benefits may include increasing concentrations of dissolved oxygen and adding small amounts of nutrients that are essential to the health of organisms (Becker, 1983; Grannemann and others, 2000). A few examples of how springs contribute to important plant, insect, and fish habitat in Wisconsin follow.

Temperate zone fens, which are rare wetland plant communities, are frequently associated with springs. In Wisconsin, they most commonly occur in glaciated areas south of the vegetative tension zone between two distinct plant communities: the northern forest and the prairie-forest (Eggers and Reed, 1997; Amon and others, 2002). Amon and others (2002) conclude that Midwestern temperate zone fens are primarily differentiated from other wetlands not by fen indicator species, but instead by the source of the water and hydroperiod. Fens are dependent on continuous, and often focused, groundwater discharge, which allows for stable water levels and saturation of the root zone. Fens are supported by groundwater containing high levels of dissolved minerals, often rich in calcium and magnesium bicarbonates, and with a pH that ranges between 5.5 and 7.4.

Fen plant communities are known for their high botanical diversity. They host a disproportionately high number of rare, threatened, and endangered plant species compared to other plant communities in the Great Lakes Region (Eggers and Reed, 1997; Amon and others, 2002).

A few Wisconsin fens also provide habitat for the Hine's emerald dragonfly (*Somatochlora hineana*), which was listed as endangered by the U.S. Fish and Wildlife Service in 1995 and continues to remain on this list. Current populations are found only in isolated areas of Wisconsin, Illinois, Michigan, and Missouri. While adult Hine's emerald dragonflies are able to forage widely over open wetlands and meadows, their larvae require fen-type wetlands in association with dolomitic bedrock, groundwater seeps, marginal flow, shallow stream channels, and seasonal drying. A number of breeding sites have been identified and studied in Ozaukee and Door Counties, Wisconsin (fig. 2), several of which are spring fed (Soluk and others, 1999; Soluk and others, 2003; Bradbury and Cobb, 2008).

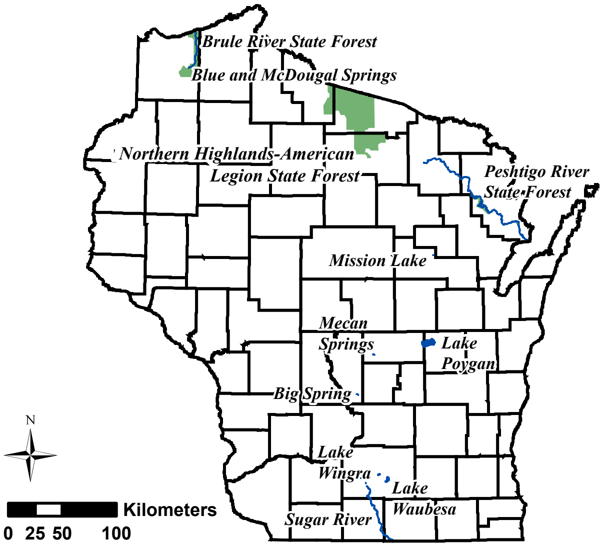

Figure 4. *Locations hydrologic features and state forests referred to in this report.*

Recent biotic inventories of Wisconsin's state forests also highlight the ecological significance of springs, particularly in northern Wisconsin (for example, Epstein and others, 1999a, 1999b; Anderson and others, 2006). The Brule River State Forest is known for its exceptionally rich biota and coldwater fishery (fig. 4). The upper Bois Brule River contains concentrations of soft water springs (for example, the Blue and McDougal Springs) and spring-fed streams, some of which support invertebrates that are very rare in Wisconsin, including two diamesin midges (*Pseudodiamesa pertinax* and *Protanypus* sp.), a bizarre caddisfly (*Lepidostoma libum*), a caenid mayfly (*Caenis youngi*), and a predaceous diving beetle (*Hydroporus pseudovilis*). A number of vascular plants that are listed at the state level as endangered, threatened, or of special concern also rely on the springs and spring-supported habitat in the Brule River State Forest. These include, but are not limited to, mountain cranberry (*Vaccinium vitis-idaea*), listed as endangered; and the fairy slipper (*Calypso bulbosa*) and large water-starwort (*Callitriche heterophylla*), both listed as threatened (Epstein and others, 1999a). The Peshtigo River and Northern Highlands–American Legion State Forests, both in northern Wisconsin, similarly contain ecologically significant spring-supported habitat (fig. 4) (Epstein and others, 1999b; Anderson and others, 2006).

Wisconsin is home to nearly 3,000 trout streams, which are highly valued for their recreational fishing opportunities. Forty percent of these streams are classified as Class 1, which means that they require no stocking because they have sufficient natural reproduction to sustain populations of wild trout at or near their carrying capacity (Becker, 1983; WDNR, 2002). Brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) both thrive in these waters, but brook trout are the only stream trout species native to Wisconsin. Brook trout require cold (≤ 68°F/20°C), well-oxygenated water and typically inhabit spring ponds and spring-fed streams (Becker, 1983). Although diffuse groundwater discharge can moderate stream temperatures over longer stream reaches, lower water temperatures are most consistent near springs. Therefore, springs are particularly effective at providing thermal refuge for fish, especially in extreme weather conditions (Gaffield and others, 2005). Brown trout often live in waters that are uninhabitable for brook trout, but both species spawn near springs. In addition to lowering stream water temperature, upwelling of groundwater at springs provides oxygen and prevents the deposition of silt on eggs (Carline, 1980; Becker, 1983; WDNR, 2002).

CULTURAL AND HISTORICAL CONTEXT

Generations of Wisconsin's residents have used, revered, and even fiercely protected the state's abundant spring resources. American Indian trails and evidence of villages or camping sites have been found near many springs, and some springs were considered sacred. In southern Wisconsin, the Grand Spring[2] was located along a trail leading from early Ho-Chunk villages along the Sugar River to Lake Waubesa (fig. 4) (Brown, 1943). The Blue Springs are located in northern Wisconsin near the Bois Brule River (fig. 4), and historic American Indian trails are on both sides of the river near these springs (Lucius, 1941). Legends surrounding sacred springs often refer to animal spirits, such as a spirit bear, that inhabit the waters and are worthy of offerings (Overton, 1928; Brown, 1928; Brown, 1938). Artifacts including flint spears, arrowheads, pipes, bone awls, shells, and pieces of deer

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[2] The Grand Spring was not identified in a 1958 survey of springs in Dane County (WCD, 1958b), so its precise location is unknown.

horn were recovered from several sacred springs in the Lake Poygan region of east-central Wisconsin. The Menominee tribe has occupied this region since about 1730, but many of these materials may also be associated with much earlier settlements (Overton, 1928). Other legends associated with springs involve spirits who were angered. A powerful spirit living in Mission Lake and Red Springs, in Shawano County (fig. 2, fig. 4), was offended and colored the spring water so that it was of no use to the Stockbridge–Munsee tribe who live in the region. A spirit who lived in a spring in the Menomonee River Valley was offended by the trampling of feet as children walked and sang in the spring. Without warning, the youngest child sank, but the others were able to pull the child out (Brown, 1938). Some American Indians also believed in the medicinal powers of spring water. For example, a spring on the south side of Lake Wingra in Madison was thought to possess medicinal values, and the Vita Spring[3] in Beaver Dam was known to the Ho-Chunk and Potawatomi tribes as a healing spring (fig. 2) (Brown, 1928).

European settlers also believed in the healthful benefits of mineral springs. Wisconsin spring water was widely marketed as restorative water in the late 1800s, and travelers from across the country came to the state's most famous springs in Waukesha (fig. 2). It was the Bethesda Spring that was first promoted for its healing properties by Colonel Richard Dunbar. Colonel Dunbar had apparently been cured by the spring water and began advertising and selling the water in 1869. Announcements of many other mineral springs soon followed, and bottled water became available from a variety of Waukesha springs including the Arcadian, Bethesda, Clysmic, Fox Head, Hygeia, Royal, and Silurian Springs. Waukesha was quickly transformed into a popular resort town with ornate structures built around the springs. By the 1880s elegant hotels were built, and Waukesha, also known as Spring City, became the summer destination of some of the nation's wealthiest families. A plan was even proposed by a Chicago entrepreneur, James McElroy, to pipe water from the Hygeia Spring to the World's Columbian Exposition in Chicago. However, Waukesha residents were vehemently opposed to the plan. They were concerned about the loss of World's Fair visitors to their own city if a pipeline were built and were sure that the pipeline would allow Chicago to demand their spring water in large volumes. Although the Village Board rejected the pipeline proposal, McElroy was persistent in his quest to bring Waukesha's famous spring water to the World's Fair. In May of 1892, he organized a group of over 200 workmen to travel to Waukesha by train in the middle of the night and construct the pipeline before Waukesha residents awoke the next day. However, when they arrived, the men were confronted by over 600 angry residents, many of whom were armed. By morning the workmen were on a return train to Chicago. Although water from the Hygeia Spring was not diverted, McElroy did finally manage to construct a pipeline from Big Bend, approximately 12 miles south of Waukesha, to Chicago (Schoenknecht, 2003; McDaniel, 2005).

Waukesha's springs continued to draw visitors until about 1905, but the advent of car travel coupled with skepticism regarding the benefits of spring water eventually took its toll on Spring City's popularity (McDaniel, 2005). Many of Waukesha's springs are now covered and forgotten, filled-in as development proceeded, or capped with metal covers and locked. Bethesda is one of the few springs that remains in a Waukesha City park, although the building that now houses the spring in no way resembles the ornate structure that stood in the 1890s (fig. 5) (Schoenknecht, 2003).

Wisconsin's spring water continues to appeal to the public and is bottled under labels like Chippewa Spring Water (Premium Waters, Inc.). However, like James McElroy, other bottlers have been met with great resistance from Wisconsin's residents. In 1999, the Perrier Group of America (Perrier) proposed bottling plants, first near Mecan Springs in Waushara County and later near Big Spring in Adams County (fig. 4). Perrier's initial plan was to install a well adjacent to Mecan Springs, which are located on state-owned land, and obtain an easement for access to the well. The proposed bottling plant would be located on privately held property (Seely, 2000, January 2). Although the Mecan Springs plant could eventually employ up to 250 people in this rural area of Wisconsin, residents and their state senator immediately expressed concern over the impacts of groundwater pumping on the state-owned springs and the trout stream fed by the springs (Associated Press, 1999, December 20; State Journal staff, 1999,

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[3] A spring house surrounding the Vita Spring still exists today in the Swan City Park, Beaver Dam.

December 24). Vocal opposition only intensified when Perrier began to consider installing the well on adjacent, privately held land. This would eliminate regulatory oversight by the WDNR, and although Perrier would still need approval for a high-capacity well, in other words, a well that pumps more than 100,000 gallons per day (gpd), the only way approval could be denied was if the well was not properly built or if it affected a municipal water supply (Seely, 2000, February 8).

Perrier eventually yielded to the opposition and announced that it would instead pursue a site near Big Spring in Adams County. The thought was that Big Spring would be a more palatable option because, in Perrier's view, the trout streams fed by Big Spring were degraded (Seely, 2000, February 26). They proposed to pump up to 150 gallons per minute (gpm), or just over 200,000 gpd, and voiced willingness to participate in environmental assessments prior to well approval (Seely, 2000, March 2; Seely, 2000, March 9). However, the Big Spring plan was met with similar resistance. Despite vocal opposition at town meetings, rejection of two referendums that asked residents to consider the idea of allowing Perrier to use the spring water or to build a plant to bottle that water, and backing of Perrier opponents by then-presidential candidates Ralph Nader and Al Gore, Perrier continued its pursuit for the high-capacity well approval (Seely, 2000, June 16; Milfred, 2000, September 22; Seely, 2000, October 17).

Because the pumping would not threaten nearby municipal wells (the only mechanism for denial), the WDNR granted approval. However, the WDNR did not set pumping rates. Instead, they negotiated an agreement with Perrier that allowed the agency to modify the company's well approval if environmental problems were to arise (Seely, 2000, September 22). The action sparked lawsuits filed against both Perrier and the WDNR by a group called Concerned Citizens of Newport and by the Ho-Chunk Nation, but plans to install a test well to help determine pumping levels continued. While awaiting the outcomes of the lawsuits and groundwater studies, Perrier announced that it would put their plans for the Adams County bottling plant on hold for up to 5 years and, in the interim, pursue opportunities in Michigan (Seely, 2001, May 11). Six months later, a judge ruled in favor of the Concerned Citizens of Newport, who argued that the WDNR violated the Wisconsin Environmental Protection Act when they issued the high-capacity well approval before the completion of environmental studies near the Big Spring site. The judge did not

Waukesha County Historical Society & Museum

Figure 5. *The Bethesda Spring House, c. 1898.*

revoke the well approval, but he did order the WDNR to conduct a complete environmental review and to hold public hearings prior to setting pumping rates for the wells (Seely, 2002, February 8). In late 2002, Perrier announced that they would let their high-capacity approval expire and that they had no plans to reapply (Gibson, 2002, September 18).

ADMINISTRATIVE CONTEXT, CHALLENGES, AND CONSERVATION

In 2005, Wisconsin's residents used approximately 983 million gallons of groundwater per day (mgd) for domestic, agricultural, and industrial uses (Buchwald, 2009). This is up from 804 mgd in 2000 (Ellefson and others, 2002). At these rates, even a water-rich state like Wisconsin starts to see the impacts of groundwater use on its lakes, rivers, wetlands, and springs. For example, in Madison where pumping has lowered groundwater levels in confined aquifers by approximately 60 feet, lakes that were once regional discharge areas now recharge aquifers near some municipal wells (Bradbury and others, 1999; Krohelski and others, 2000). In southeastern Wisconsin near Milwaukee, expanding communities pump at least 25 percent more groundwater than in 1979. This contributes not only to hundreds of feet of drawdown in the Cambrian-Ordovician aquifer, but also to increased groundwater withdrawals from aquifers with high levels of naturally occurring radium (Gaumnitz and others, 2004). Near Green Bay, municipal pumping has at times resulted in over 300 feet (90 m) of drawdown. In addition, the introduction of oxygen to deep oxygen-depleted aquifers through domestic well boreholes causes sulfide oxidation within a mineralized zone of the St. Peter sandstone, resulting in the release of arsenic to groundwater (Schreiber and others, 2000; Gaumnitz and others, 2004). However, it was the Perrier case concerning springs (discussed earlier) that highlighted the lack of legal protection for groundwater resources, including mechanisms to prevent companies from privatizing public waters. It prompted legislation (2003 Wisconsin Act 310, enacted in March 2004) that addresses groundwater quantity issues by controlling well location and pumping rates to protect sensitive surface water resources, including springs (Gaumnitz and others, 2004; Kwaterski Scanlan and others, 2006).

Wisconsin's groundwater protection law, 2003 WI Act 310, is limited to two primary functions. It created Groundwater Management Areas (GMAs) in southeast and northeast Wisconsin, where groundwater withdrawals have resulted in more than 150 feet (45 m) of drawdown since predevelopment. The drawdown raises concerns over impacts to surface water features and water quality, so the law mandated that plans to manage groundwater resources in a sustainable manner be written for these regions (WGAC, 2006). The second function is to expand the state's authority over new, privately owned high-capacity wells. Specifically, the law requires the WDNR to consider impacts to trout streams, outstanding and exceptional resource waters, and springs in the well-approval process (WGAC, 2007). However, the law does not protect all springs in the state; it defines a spring as "an area of concentrated discharge occurring at the surface of the land that results in a flow of at least one cubic foot per second at least 80 percent of the time (2003 WI Act 310, Wis. Stat. § 281.34(1)(f))." The number and location of springs that meet these criteria are unknown, but the historical records discussed previously suggest that it includes only a small fraction of the springs in the state. Furthermore, the definition as written fails to acknowledge the potential ecological significance of smaller springs.

The Wisconsin Groundwater Advisory Committee (WGAC) was established when the law was enacted to assess the effectiveness of its main elements. With respect to springs, the WGAC was directed to include recommendations regarding the definition as written in the law. In their 2007 report to the Legislature, the WGAC raised concerns with nearly every aspect of the springs definition including the flow rate criterion, the flow frequency criterion, and the language regarding "an area of concentrated discharge occurring at the surface of the land." They also noted the lack of a buffer zone, or distance criterion, although this type of protection measure was applied to surface water bodies, like trout streams, elsewhere in the legislation. The committee reached near-consensus over the need for an updated, statewide springs inventory, which would include all springs with a flow rate of 0.25 cfs or greater, but did not reach consensus on a revised definition of "springs." Instead, they developed two alternatives for the legislature to consider: maintain the existing definition or reduce the threshold flow requirement (WGAC, 2007; WGCC, 2009).

The groundwater protection law, which is now part of the Wisconsin Statutes (Wis. Stat. § 281.34), earned broad, bipartisan support, passing 99-0 in the Wisconsin Assembly and 31-1 in the Senate. Water professionals generally agree that it and the associated rule in the Wisconsin Administrative Code (Chapter NR 820) are significant steps in the protection of groundwater resources in Wisconsin (Gaumnitz and others, 2004; WGAC, 2007). Although disagreement over which springs are most deserving of protection persists, the fact that they are explicitly included in the law illustrates that Wisconsin residents agree that at least some springs are worthy of special recognition.

Subsequently, a decision issued by the Wisconsin Supreme Court in July 2011 also influenced when examination of impacts to springs may be warranted. The decision in the case of Lake Beulah Management District v. State Department of Natural Resources (2011) states that the WDNR's broad obligation to protect waters of the state may be triggered by a proposed high-capacity well permit application. "'Waters of the state' includes those portions of Lake Michigan and Lake Superior within the boundaries of this state, and all lakes, bays, rivers, streams, springs, ponds, wells, impounding reservoirs, marshes, watercourses, drainage systems and other surface water or groundwater, natural or artificial, public or private, within this state or its jurisdiction (Wis. Stat. § 281.01(18))." Although the decision was issued with respect to a lake, it may influence whether a broader range of springs, in other words, beyond those recognized by Wis. Stat. § 281.34(1)(f), receive attention in Wisconsin. Whether ecological and cultural contributions of springs, as well as hydrologic characteristics, are recognized, remains to be seen.

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