What if (Inland) Sea Levels are Falling…Then Rising…Then Falling…? Climate Change and Shoreland Management on the Laurentian Great Lakes

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The water levels of the Laurentian Great Lakes have recently been at historically law levels, possibly as a result of global climate change, but they have already begun to climb again as they always have in an ongoing pattern of seasonal, annual, and decadal fluctuations. Coupled with physical dynamics that are unique to the Great Lakes system, there are good reasons to believe that Great Lakes shorelines will continue to shift lakeward and landward dramatically over time, perhaps more so because of climate change. This pattern of shifting shores implicates legal doctrines that attempt to balance public interests and private property rights at the shore, complicating the Great Lakes state's efforts to effectively manage their Great Lakes shorelands. This paper describes Great Lakes shoreline dynamics and the application of the Public Trust Doctrine to those shorelines. It concludes by discussing the challenges that the Great Lakes states face especially in marking ordinary high water on their shores given global climate change.

Keywords: *Laurentian Great Lakes, shoreland management, climate change, sea level rise.*

In addition to their ocean coasts, the United States and Canada together enjoy substantial inland freshwater seas—the five Laurentian Great Lakes, including Lakes Superior, Michigan, Huron, Erie, and Ontario[1]. Sometimes referred to in the U.S. as the "north coast," these lakes constitute a substantial portion of the border separating the U.S. and Canada, extending some 750 miles (1,200 km) from west to east, and they provide a major natural resource for both countries for freshwater consumption, transportation (especially Great Lakes bulk carrier shipping), industry, power, tourism, and recreation. They represent about 84% of North America's

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surface freshwater supply and about 21% of the world's surface freshwater supply. And finally, they provide altogether over 10,000 miles (17,000 km) of coastal shoreline along their boundaries.

A number of international, national, and subnational governmental or quasi-governmental entities play various roles in managing different attributes of the Great Lakes—including most notably the International Joint Commission (IJC), the Great Lakes Commission (GLC), the U.S. Environmental Protection (USEPA), the U.S. Army Corp of Engineers (USACE), Environment Canada, and the eight U.S. states and two Canadian provinces bordering Great Lakes water[2]. For the most part, these international and national entities focus on resource management issues related to water quantity (especially withdrawal from the Great Lakes Basin), water quality (pollutant discharges), air quality (deposition of toxics), shoreland contamination (primarily on past and current industrial sites), water flow (primarily water levels and flows through the connecting rivers and St. Lawrence Seaway), and ecosystem impacts (primarily the introduction of invasive species through ocean-going ship ballast discharge). The USACE also plays an important role in the U.S. in terms of managing shoreland development to a limited extent, primarily by regulating potential impacts to coastal wetlands and especially by permitting activities that have the potential to affect navigable waters of the U.S[3].

Nonetheless, Great Lakes shoreland access, development, and use are managed for the most part—especially in the U.S.—by each of the several Great Lakes states and provinces through their own unique subnational constitutional and common law doctrines and corresponding legislative and administrative regimes. It is at this level that shoreland management in the face of constantly changing coastal dynamics has been addressed historically, and it will be at this level that the effects of climate change on Great Lakes coastal dynamics will be felt and addressed, particularly in terms of the effects that climate change will likely have on Great Lakes shoreline movement over time.

Focusing on the U.S. side of Great Lakes dynamics both physically and legally, this paper builds on recent work we have been conducting on integrating our knowledge of Great Lakes shoreline dynamics with the public planning, policy, and legal implications of those dynamics (Norton et al., 2011). We summarize the key findings from that earlier work through this paper while updating it by folding in more recent information on changing physical and policy-legal conditions. The paper first summarizes Great Lakes dynamics particularly with regard to how those dynamics differ from ocean coastal settings at the shore and how global climate change appears to be affecting those dynamics. It then describes the Public Trust Doctrine as it has been applied by the U.S. Great Lakes states, focusing on the challenge of demarcating the boundaries between public interests and private property rights along a Great Lakes shore. The paper concludes by contemplating the implications of these evolving physical and policy-legal dynamics for the long-term environmental and social sustainability of Great Lakes shorelands.

LAKE LEVEL DYNAMICS

As with the United States' ocean coastal states, all of the Great Lakes states hold title to the lands submerged beneath their jurisdictional portions of the Laurentian Great Lakes. As discussed more below, these submerged lands are held in trust for the people pursuant to each state's Public Trust Doctrine, and like most ocean coastal states, most of the Great Lakes states also hold a public trust interest in their Great Lakes shorelands up to the ordinary high water mark (OHWM). Finally, like the oceans, Great Lakes water levels also fluctuate over time, creating dynamic shoreline systems. Thus all of the coastal states—both oceanic and Great Lakes—confront the challenge of discerning the boundaries between public trust interests, on the one hand, and private property rights, on the other.

The Great Lakes states are unique, however, because they are not tidal. Rather, lake levels and shorelines fluctuate dramatically on longer seasonal, annual, and decadal timeframes because of changing climatic and geo-physical conditions. Those fluctuations create unique challenges for both understanding the effects that lake levels have on shoreline physical systems and determining where it is safe to build. These challenges have been further complicated by the advent of global climate change, which is exacerbating the dynamics of the Great Lakes physical systems and—we suspect—further complicating popular perceptions about those dynamics. Because of these changing physical systems, what appears to be happening with regard to Great Lakes shoreline movement, given recent trends, may be directly at odds with what may soon unfold.

Great Lakes Dynamics Historically and in General

A number of attributes of the Great Lakes system complicate discerning the OHWM along Great Lakes shorelines *in fact*, complicating in turn application of the OHWM concept *in law*. Before addressing the policy and legal challenges of managing Great Lakes shorelands, it is necessary to first understand these unique physical attributes. Four are especially relevant for purposes here, including morphological shoreline conditions, short- and long-term lake water level fluctuations, regional storm patterns, and the gradual geophysical tilting of the Great Lakes basin.

First, the Great Lakes were formed between roughly 10,000 to 20,000 years ago at the end of the last ice age as glaciers retreated from south to north, gouging out the lakes and filling them with glacial meltwater. They are geologically young features, with shorelines that are almost uniformly comprised of loose gravels and sands readily eroded away (Rovey and Borucki, 1994). Resistance to shoreline erosion is found in regions where bedrock is exposed at or near the lake margin, or at sites where the coast is sufficiently shallow-sloped to reduce wave action and form accretionary features such as spits and bars. These conditions are relatively limited, however, occurring primarily along the northern and western margins of Lake Superior and northwest Lake Michigan (Dorr and Eschman, 1970). Most of

Michigan's Great Lakes shorelines, therefore, are highly susceptible morphologically to ongoing water level fluctuations and other dynamic conditions.

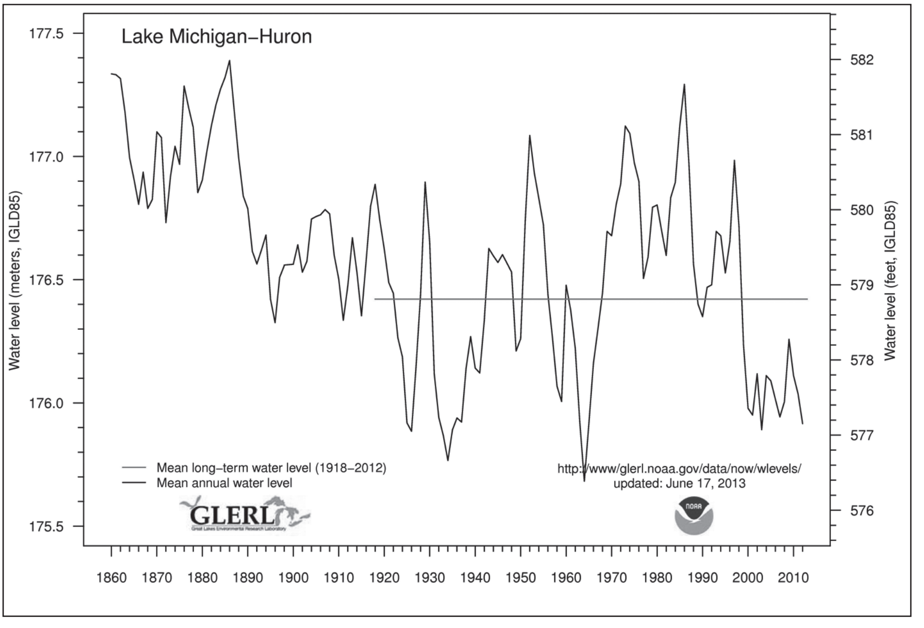
Second, in terms of water level fluctuations, Great Lakes water levels oscillate naturally on seasonal, decadal, and multi-decadal timeframes (i.e., smaller seasonal fluctuations nested within roughly decadal fluctuations nested within longer and larger multi-decadal fluctuations), as illustrated by Figure 1 for Lakes Michigan and Huron (hyrologically the same lake). These fluctuations are not the result primarily of the gravitational pull of the moon, as are ocean tidal fluctuations. Rather, Great Lakes water levels are influenced more by the hydrologic cycle, including especially ongoing changes in precipitation, evaporation, river outflow, and groundwater inflow (Meadows et al., 1997). Thus as Figure 1 illustrates, Great Lakes water level fluctuations follow a degree of periodicity, such that there are periods of "ordinary" high water, but those high water levels rise and then fall over much longer timeframes than tidal fluctuations.

A third unique attribute of the Great Lakes relates to the effects that regional storm patterns have on shoreline dynamics. Specifically, mid-latitude storms traversing the Great Lakes region strongly affect coastal characteristics in a variety of ways, particularly given the climatic relationship that exists between Great Lakes water levels and cumulative storm intensity (Meadows et al., 1997). Increases in storm frequency and severity have been found to lead to increases in water levels by approximately 18 months, resulting in the potential for greater landward migration of the shoreline on rising water levels than would be expected given those rising levels alone.

In addition, because the Great Lakes are bounded water bodies, high winds have the potential to induce not only wave setup characteristically found on open ocean coasts (i.e., an increase in local water elevation due to the presence of wind waves), but also basin seiching (i.e., the wind-induced piling of the water against the downwind shoreline and a corresponding sloshing back and forth when the wind subsides or shifts). This phenomenon can in turn force water levels at both the upwind and downwind ends of the lakes to fluctuate several meters above and below the existing mean water level over the course of several hours or a few days (Mortimer, 1987).

Storm patterns are particularly relevant because of the influence that storms have in producing wave action over time. Along all coastlines, coastal morphology changes seasonally in response to changing wave action on the shoreline. In ocean coastal settings, the near shore beach generally inflates through the dominant onshore transport of sand caused by constructive waves typical of the summer season (i.e., waves that transport sand from off-shore onto the beach). Conversely, destructive waves typical in the winter season bring about a deflation and offshore transport of beach sand into near shore sand bars (Komar, 1997).

Figure 1: Mean annual water levels of Lakes Michigan and Huron (hydrologically the same lake) above sea level in meters and feet from 1860 to 2011 (IGLD 1985).



Note: The horizontal curve represents mean long-term water level (1918-2012). The International Great Lakes Datum (IGLD) is an elevation reference system used to survey and study water levels in the Great Lakes relative to sea level. A separate IGLD is specified for each of the Great Lakes. These datum elevations are adjusted periodically to reflect the rise of the entire Great Lakes Basin relative to sea level over time. They were adjusted most recently in 1985. For more information on the IGLD, see: *http://www.lre.usace.army.mil/greatlakes/hh/newsandinformation/iglddatum1985/*.

Source: Great Lakes Environmental Research Laboratory, U.S. National Oceanic and Atmospheric Administration: http://www.glerl.noaa.gov/data/now/wlevels/levels.html (Hydrographs) (retrieved April 14, 2013).

Similar changes occur in the Great Lakes, but these dynamics are superimposed upon the seasonal fluctuations and the long-term variations in water levels and wave intensity just described. As a result, under conditions of falling water levels, the Great Lakes tend to experience less powerful storm systems, propagating constructive waves that tend to inflate the beach profile. When storm intensity increases, however, the beach deflates relatively quickly as sand is transported off and alongshore. Thus in contrast to the ocean environment, changes in the beach morphology of a Great Lakes shoreline—which occur over the period of years—often result in the appearance of broad beaches under lower water level conditions that appear to be stable and perhaps accreting but that in fact are ephemeral, quickly lost when water levels rise again—possibly even from a single storm event (Bennett et al., 1999).

Finally, in addition to shoreline morphology, water level fluctuations, and storm patterns, the entire Great Lakes Basin is also gradually rising as the earth slowly rebounds isostatically from the weight removed from the melting glaciers some 14,000 years ago, although it is decompressing unevenly and thus causing a shift in the pooling of the lakes generally from north to south (Bennett et al., 1999). This shift in the basin has resulted in variations in apparent erosion rates across the basin than might otherwise be expected. It also means that the entire Great Lakes system, including its surface water levels, has been gradually rising relative to sea level over time.

Great Lakes Dynamics in the Face of Climate Change

Although the target of significant research and evaluation, Great Lakes lake levels remain a challenge to predict, even on a short term basis (IJC, 2012). The probabilities used to model the likely future effects of climate on the Great Lakes into the 21st century increasingly lie outside the envelope of historically observed conditions (IPCC, 2007), making it difficult to use historical water level data sources to anticipate future water levels. In a recent study of the upper Great Lakes hydrodynamic system, the International Joint Commission found that regional climate models provide insights into the potential future dynamics of this system, but while this field is advancing, these insights are not sufficiently robust to serve as predictions.

For instance, in a comprehensive study of the response of Great Lakes water levels to climate change, Angel and Kunkel (2010) provide estimates of Lake Michigan-Huron water levels based on 565 model runs from 23 global climate models applied to the Great Lakes Environmental Research Laboratory Advanced Hydrologic Predication System for the Great Lakes. These runs were distributed over 3 future emission scenarios: low emission, moderate emission and high emission. Their findings reveal that although a majority of results (approximately 75% of realizations) indicate a modest decrease in lake levels over time, the possibility of higher levels at times cannot be dismissed. Morevoer, because of the complexities of the hydrologic system over the basin, changes in levels in the near-term future are likely to reflect existing fluctuations, remaining within the relatively narrow range historically experienced in the basin. In addition to uncertainty surrounding water levels, there is agreement among the models that the basin is likely to experience increasing severity of storm events and frequencies during the winter and spring months in response to global climate change. These changes in storm magnitude, frequency, and direction have the potential to alter nearshore sediment transport processes and increase shoreline erosion.

Implications for Shoreline Dynamics

Several important conclusions follow from this assessment. The first is that the high degree of variation in Great Lakes water levels occurring naturally or ordinarily over decadal and multi-decadal timeframes, in and of itself, translates to a dramatic degree of shoreline movement landward and lakeward on the Great Lakes over extended time periods. Great Lakes shorelands that were once submerged may be exposed for years at a time as lake levels decline, while shorelands that have been dry for years may again become inundated—sometimes from a single intense storm event—as lake levels again rise.

Second, as a result of these fluctuations and other dynamics, not only do lake levels shift dramatically over time, yielding dramatic shifts in the intersection of land and water landward and lakeward over time, but the profiles of the shoreline beaches themselves change dramatically in response to those changing lake levels. Specifically, low water-level beaches, particular during periods of water level decline, tend to inflate with sand. That phenomenon, in turn, tends to make the intersection of the beach with the lake further lakeward than would occur if the beach were comprised of a less moveable substrate. Nonetheless, because a sandy beach is highly erodible, that inflated beach quickly deflates as water levels rise again, in an historic cycle of water level fluctuations and corresponding shoreline shifts that will undoubtedly continue.

Third, as a result of these dynamics, the actual intersection of "ordinary high water" with the shoreline is unavoidably difficult to discern on the Great Lakes. For example, because the time scales of Great Lakes shoreline movements are relatively long when compared to the growth cycles of many shoreland vegetation species, the presence of vegetation like grasses and even shrubs—a reasonable indicator of more stable upland above ordinary high water in ocean-tidal settings—is a false indicator of stability on a normal Great Lakes coastline during prolonged lower lake levels. Similarly, the constantly changing profiles of Great Lakes shorelines both horizontally and vertically in response to changing water levels complicates the task of discerning the true (or at least a reasonably appropriate) mark of "ordinary high water" horizontally at any given time; that is, discerning the mark of how far landward water has extended in the past—or might be expected to extend in the future—when lake water elevations are close to their "ordinary" high levels, but doing so at a time when the lakes are in fact well below ordinary high levels.

Finally, while it is not yet clear how global climate change will affect the mean water levels of the Great Lakes over time, there is every reason to believe that lake water levels will continue to shift dramatically over time as they always have. There is also increasing evidence that global climate change could exacerbate the effects of fluctuating water levels at the shore through increased seasonal storm frequency and severity.

THE PUBLIC TRUST DOCTRINES OF THE GREAT LAKES STATES

The question of how far landward Great Lakes waters normally extend during periods of "ordinary" high lake levels is important mainly because that point on the beach has significant legal implications regarding the balance to be struck between public interests in Great Lakes shorelands and the private property rights of shorelands owners. This section briefly discusses key attributes of the Public Trust Doctrine in general, application of that doctrine by the Great Lakes states in particular, and the challenges of marking ordinary high water under that doctrine along a Great Lakes shore.

The Public Trust Doctrine in General

The Public Trust Doctrine has its historical roots in ancient Roman civil and English common law (see generally Frey and Mutz, 2007). The doctrine was incorporated as a sovereign power under common law by the original 13 colonies at the founding of the United States and by each of the remaining states as they subsequently entered the Union. It also applied originally to ocean tidal waters, but it has since been expanded in some form to include all freshwater inland lakes, ponds, rivers and streams—including all of the Great Lakes[4].

As it has evolved under U.S. law, the Public Trust Doctrine actually consists of separate doctrines unique to each coastal state.[5] While those doctrines vary somewhat across the coastal states, they consist uniformly of a core set of principles (Frey and Mutz, 2007; Titus, 1998). First and foremost, all distinguish between two property interests at the shore, including an ownership interest, or "*jus privatum*," and the public trust interest, or "*jus publicum*." In ocean coastal states and the Great Lakes states, the fee ownership of lands submerged by the oceans or Great Lakes is always held by the state, with certain limited exceptions, while ownership of uplands may be held either by the state (or other unit of government), or by private littoral shoreland property owners. Conversely, the *jus publicum* is always held by the state and it always encompasses all submerged lands, as well as some portion of the shorelands, depending on the particular state.

Second, all of the ocean coastal states in the U.S. have public trust doctrines establishing state ownership of submerged public trust lands to at least the low water mark (conventionally taken to mean the mean low water mark or that line generally dividing open water from mudflat at low tide), and in some instances above the low water mark. Similarly, all recognize public trust interest rights in one form or another for some portion of the shoreland above that low water mark, typically to the OHWM, conventionally defined as the *mean* high water mark (Titus, 1998).

Third, the public trust interest uniformly consists of the right of the citizens of the state to enter and use public trust shorelands for hunting, fishing, navigation, and recreation, although the precise formulation of those rights differ somewhat from state to state (Frey and Mutz, 2007). Fourth, the state always serves as trustee of the public trust interest and has a duty to safeguard the public trust interest in perpetuity, a duty that it cannot abdicate[6]. And finally, recognizing that shorelands are dynamic natural systems, the *jus privatum* is uniformly recognized as a "moveable freehold" ownership interest capable of both expanding and diminishing given the natural long-term movement of the shoreline[7]. To the extent that water levels increase and decrease over the long-term as well, and that shorelines correspondingly move landward and lakeward, the *jus publicum* is similarly capable of expanding and diminishing as the OHWM shifts over time, although in the Great Lakes this movement is generally less dramatic than the changing intersection of land and water over time.

The Public Trust Doctrine as Applied by the Great Lakes States

All of the eight Great Lakes states have recognized public trust interests in their Great Lakes submerged lands, and all but one have found those interests to extend onto the shorelands up to the OHWM (Frey and Mutz, 2007). The single state that has not done so, Ohio, has held through judicial decree that the state's public trust interest terminates, and private ownership begins, at the water's edge, thus using the "swash" zone as a coincident boundary[8]. Under this approach, except during periods of high lake water levels, the public rights secured by the Public Trust Doctrine stop short of the OHWM. Indeed, Ohio law places that boundary generally well below the line of ordinary high water however defined.

Three of the Great Lakes states appear to have taken the opposite approach, owning the shoreland as common property up to the OHWM and correspondingly excluding private ownership of that shoreland. Like Ohio, they appear to recognize a coincident boundary but they have set that boundary at the OHWM rather than the swash. This approach is consistent with that used by a number of the ocean coastal or tidewater states, which generally—although not universally—set the boundary for both the *jus publicum* and the *jus privatum* coincidentally at the OHWM (Slade, Kehoe, and Stahl 1997). Wisconsin, New York, and Indiana appear to have adopted this approach, based on review of somewhat ambiguous existing case law and statutory regimes (see Norton et al., 2011), although that case law and the administrative practices for each of these states could also be interpreted by a state court to establish boundaries according to yet a third, intermediate, approach.

The four remaining Great Lakes states—Illinois, Michigan, Minnesota, and Pennsylvania—appear to have adopted that intermediate approach, recognizing overlapping boundaries, interests, and rights. In these states, private ownership extends generally down to the water's edge or mean low water level on the Great Lakes shore, while the public trust interest extends up to the OHWM—which typically falls landward of the water's edge at any given time. Each of these four states thus owns in fee its permanently submerged Great Lakes bottomlands, which it holds in trust for the public. Each also owns a public trust interest in the shorelands that are only periodically submerged by Great Lakes water, up to the OHWM. Some refer to this periodically submerged shoreland, when it is not submerged, as the foreshore (e.g., Slade, Kehoe, and Stahl, 1997); we refer to it here as the public trust beach. Any private rights in the use of such waters, including the shorelands where *jus privatum* and *jus publicum* overlap, are held subject to the public trust. Thus on the public trust beach, the public's right to use the beach prevails over the littoral property owner's right to exclude.

Marking Ordinary High Water on a Great Lakes Shore

The seven Great Lakes states employing the OHWM have taken different approaches to using it relative to low water marks for demarcating the boundaries of *jus publicum* and *jus privatum* interests, and they have also taken different approaches to determining where exactly the OHWM itself falls. Of those seven, New York and Pennsylvania do not appear to have any case law or statutory provisions speaking directly on point to the question of how to determine where the OHWM falls on their Great Lakes shores (i.e., they merely refer to the concept without further explication). The five remaining states appear to have adopted one of two explicit approaches to discerning the OHWM, or in the case of Michigan, both of those approaches. One approach is to look for evidence on the shore of the presence of water for extended periods of time. Minnesota and Wisconsin appear to have adopted this approach in general. Thus, for example, Minnesota looks for evidence of "the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial."[9] Similarly, in a recent Michigan Supreme Court decision speaking to the reach of Michigan's Public Trust Doctrine, the court looked to Wisconsin law to define the ordinary high water mark as:

> …the point on the bank or shore up to which the presence and action of the water is so continuous as to leave a distinct mark either by erosion, destruction of terrestrial vegetation, or other easily recognized characteristic. And where the bank or shore at any particular place is of such character that it is impossible or difficult to ascertain where the point of ordinary high-water mark is, recourse may be had to other places on the bank or shore of the same stream or lake to determine where a given state of water is above or below ordinary high-water mark.[10]

Through that decision, Michigan has adopted this approach for the purpose of determining the reach of public trust access—specifically, for beach strolling. This standard is now referred to as the "natural ordinary high water mark" (NOHWM).

In contrast, a second approach being employed by Great Lakes states to mark OHW is to fix an elevation above sea level as the "ordinary high water level" for the relevant lake (i.e., the mean level above sea level to which the lake rises during high water periods) and then use the intersection of that elevation with the shore to mark ordinary high water. We refer to the horizontal point on the shore thus established as the "elevation ordinary high water mark" (EOHWM).

Both Illinois and Indiana appear to use this elevation-based approach to marking ordinary high water in general,[11] as does now Michigan for the purpose of determining the jurisdictional reach of the Michigan Department of Environmental Quality's (MDEQ) authority to regulate private shoreland development activities under the state's Great Lakes Submerged Lands Act (GLSLA).[12] In Indiana and Illinois, both of which abut Lake Michigan only, the states have adopted the IGLD elevation level used by the USACE to determine the EOHWM pursuant to its authorities to regulate shoreland activities within the federal government's navigation servitudes—581.5 feet above sea level (IGLD 1985).[13] Michigan, in contrast, has established by statute specific IGLD elevations to be used by state agencies in regulating shoreland management that differ slightly from the USACE standards.[14]

There are conceptual and administrative difficulties with both of these approaches to marking OHW, both stemming from the unique attributes of Great Lakes shoreline dynamics described above. In the best case, the NOHWM is discernable through the presence of a tree line, particularly one comprised of tree species that are water intolerant, or the presence of a steep bluff. These conditions are not always present, however. The primary difficulty in discerning that mark, particularly during low lake water level periods, occur when vegetative or topographical transitions are subtle, the natural shoreline morphology has been disrupted by shoreline armoring structures, or there is little long-lived vegetation because of sand dune movement rather than the presence of water.

Nonetheless, despite the challenges of discerning the NOHWM, research on Great Lakes shoreline dynamics conducted by Meadows and Meadows over the past 20 years (see Meadows et al., 1997; Norton et al., 2011) suggests that use of the EOHWM is even more difficult and problematic. Although there is no definitive legislative history, it is probably the case that the Michigan Legislature amended the GLSLA in the mid-1960s to fix 'ordinary high water levels' at given elevations for each of its Great Lakes and to define the EOHWM as the intersection of that elevation with the beach, given the extensive availability of lake water levels for an extended period of time.

In theory, this approach should be relatively straightforward because the ability to determine the point at which a given elevation above sea level intersects a given beach is relatively straightforward. In reality, however, the task is complicated because of the way in which shoreline profiles change with changing lake water levels. Most problematic is the tendency of a Great Lakes beach to inflate when lake water levels are low—making the EOHWM appear to be much more lakeward (and thus below the reach of the state's regulatory authorities) than it would be when lake levels are high, enticing shoreland property owners to build on shifting sands that will quickly erode once lake levels again rise.

The Great Lakes have recently experienced an extended period of historically low water levels, but they have already begun to rise this past year, and they will almost certainly rise again given historic patterns. Given current conditions, the difficulty in properly siting the EOHWM has already been highlighted by recent litigation in Michigan, where a shoreland property owner has proposed to build a house on a portion of beach that was under water as recently as two decades ago, asserting that his property is (and always has been) been above the EOHWM. As long as the Great Lakes remain at relatively low levels, the State of Michigan and possibly the States of Indiana and Illinois will face substantial difficulties employing the EOHWM as property owners seek to build lakeward on their temporarily inflated beaches, ignorant (whether intentionally or merely technically) of the rising waters and eroding beaches that will surely return.

CONCLUSIONS AND IMPLICATIONS

Like the ocean coastal states, the Laurentian Great Lakes states face significant shoreland management challenges in the face of global climate change. Their challenges are further complicated, however, by the fluctuating water levels, beaches, and shorelines that are unique to the Great Lakes system, and that counter-intuitively threat to lure shoreland property owners to the foreshore with the false promise of an accreting beach that will—nonetheless—quickly be scoured away when the lake levels begin to rise. Perhaps the best solution for the three states using the EOWHM would be to abandon that approach to marking OHW altogether. Short of that, there are good reasons to further explore application of that standard to ensure adequate protection of the state's interest in the public trust and minimal loss of private property to the Great Lakes shoreline dynamics.

NOTES

1. The label "Laurentian" is used here to distinguish this particular body of Great Lakes, which drain ultimately to the Atlantic Ocean through the St. Lawrence River and Seaway, from others worldwide. The Great Lakes system also includes a number of connecting waterways and small lakes (including most notably Lake St. Clair, which connects Lakes Huron and Erie via the Detroit River), although the term "Great Lakes" is generally used to refer only to the five largest lakes. The descriptive information provided here was obtained from http://www.epa.gov/greatlakes/basicinfo.html (accessed April 14, 2013).
2. Information on these international and national management programs can be found at: http://www.ijc.org/en_/ (IJC), http://www.glc.org/ (GCL), http://www.epa.gov/greatlakes/ (USEPA – Great Lakes), http://www.lre.usace.army.mil/ (USACE – Detroit Office), and http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=70283230-1 (Environment Canada – Great Lakes), respectively (all accessed April 14, 2013).

3. Information on these regulatory programs and requirements can be found at: http://www.lre.usace.army.mil/Missions/RegulatoryProgramandPermits.aspx (accessed April 14, 2013).
4. The United States Supreme Court adapted the public trust doctrine to apply specifically to the non-tidal waters of the Great Lakes in several now well-settled decisions (*Barney v. Keokuk*, 94 U.S. 324, 339 (1877) (extending the public trust doctrine beyond tidal waters to include navigable waters); *Ill. Cent. R.R. Co. v. Ill.*, 166 U.S. 387, 458 (1892) (applying the public trust doctrine to the Great Lakes)). All of the Great Lakes states have since incorporated the doctrine and adapted it within their own common, constitutional, and/or statutory law systems (Frey and Mutz, 2007).
5. *Shively v. Bowlby*, 152 U.S. 1, 26 (1894).
6. The Michigan Supreme Court, for example, held long ago that that the "State may not … surrender such public rights [in the use of the public trust] any more than it can abdicate the police power or other essential power of government" (*Nedtweg v. Wallace*, 237 Mich. at 16 (1926)).
7. *Shively,* 152 U.S. at 26. See also *Hilt v. Weber*, 252 Mich. 198, 219, 233 N.W. 159 (1930); *Glass v. Goekel,* 473 Mich. 667, 724, 703 N.W.2d 58 (2005) (Markman, J., dissenting).
8. See *Merrill v. Ohio Dept. Nat. Res.*, 130 Ohio St. 3d 30, 43; 955 N.E.2d 935, 949 (2011), which held, in part, that "the territory of Lake Erie held in trust by the state of Ohio for the people of the state extends to the natural shoreline, which is the line at which the water usually stands when free from disturbing causes." The line is roughly comparable to the mean low water mark on an ocean coastal shore.
9. See Minnesota's statutory definition of "ordinary high water level" at: https://www.revisor.mn.gov/statutes/?id=103G.005 (retrieved April 14, 2013)
10. *Glass v. Goekel,* 473 Mich. 667, 691, 703 N.W.2d 58 (2005), citing to *Diana Shooting Club v. Husting*, 156 Wis. 261, 272 (1914).
11. It is not clear where in statutory authority this approach originates for either state, but web-based publications suggest that this is the approach adopted by the states' Great Lakes shoreland management staff in practice. See http://www.in.gov/dnr/water/3658.htm, and http://www.glc.org/habitat/webinar/pdf/Casey-Lake-Michigan-Permitting.pdf, for Indiana and Illinois, respectively (accessed April 14, 2013).
12. A recent decision handed down by the Michigan Court of Appeals, *Burleson v. MDEQ*, 292 Mich. App. 544, 808 N.W.2d 792 (2011), *cert. denied*, 490 Mich. 917, 805 N.W.2d 438 (2011), clearly established that the reach of the MDEQ's authority to require permits for shoreland development under the Michigan Great Lakes Submerged Lands Act (GLSLA) extends only to the EOHWM, not the NOHWM, although the court specifically left unanswered the question of how exactly the precise location of the EOHWM on any given beach should be

determined.

13. See the note with Figure 1 regarding use of the IGLD for scientific and regulatory purposes.
14. See Section 32502 of the GLSLA. Michigan's standard for Lakes Michigan and Huron, for example, is currently set at 580.1 (IGLD 1985), one foot lower than the corresponding USACE standard.

REFERENCES

Angel, J.R. and K.E. Kunkel (2010) The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron. *Journal of Great Lakes Research*, 36: 51–58.

Bennett, T., Meadows, L. A., Meadows, G. A., Caufield, B. and Sansumeren, H.. (1999) Nearshore profile change and its impact on rates of shoreline recession. American Society of Civil Engineers (June 1999), Long Island, NY.

Dorr, J. A., and Eschman, D. F. (1970) *Geology of the Great Lakes*. Ann Arbor, MI: University of Michigan Press.

Frey, B. C., and Mutz, A. (2007) The public trust in surface waterways and submerged lands of the Great Lakes States. *University of Michigan Journal of Law Reform,* 40:907-993.

International Joint Commission (IJC), 2012, Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels: The International Upper Great Lakes Study, Final Report, Washington, DC.

International Great Lakes Datum (IGLD) (1985) http://www.ngs.noaa.gov/TOOLS/IGLD85/igld85.shtml

Intergovernmental Panel on Climate Change (2007) *Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change.* Geneva: IPCC.

Komar, P. D. (1997) *Beach Processes and Sedimentation*. 2nd edition. New York: Prentice-Hall.

Meadows, G. A., Meadows, L. A., Wood, W. L., Hubertz, J. M. and Perlin, M. (1997) The relationship between Great Lakes water levels, wave energies and shoreline damage. *Bulletin of the American Meteorological Society*, 78 (4):675-683.

Mortimer, C. H. (1987) Fifty years of physical investigations and related limnological studies on Lake Erie, 1928-1977. *Journal of Great Lakes Research*, 13:407-435.

Norton, R. K., Meadows, L.A. and Meadows, G.A.. (2011) Drawing lines in law books and on sandy beaches: Marking ordinary high water on Michigan's Great Lakes shorelines under the public trust doctrine. *Coastal Management*, 39(2):133-157.

Rovey, C. W. I., and M. K. Borucki. 1994. Bluff evolution and long-term recession rates, southwestern Lake Michigan. *Environmental Geology* 23:256-263.

Slade, D.C., Kehoe, R.K., & Stahl, J.K. (1997) *Putting the Public Trust to Work (2nd ed)*. Washington, D.C.: Coastal States Organization.

Titus, J. G. (1998) Rising seas, coastal erosion, and the Takings Clause: How to save wetlands and beaches without hurting property owners. *Maryland Law Review,* 57:1279-1399.