New York's Offshore Wind Energy Development Potential In The Great Lakes: Feasibility Study

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Foreword

This feasibility study was prepared by AWS Truewind on behalf of the New York State Energy Research and Development Authority (NYSERDA) under the PON 995, Agreement 9998. NYSERDA is a public benefit corporation created in 1975 under Article 8, Title 9 of the State Public Authorities Law through the reconstitution of the New York State Atomic and Space Development Authority.

This publication assesses the feasibility of offshore wind development in New York's Great Lake waters, and identifies the major areas of study associated with development. AWS Truewind would like to acknowledge the New York Power Authority for supporting the effort to make this study more comprehensive than originally planned.

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Executive Summary

This report, which was prepared on behalf of the New York State Energy Research and Development Authority (NYSERDA), assesses the technical and economic feasibility of future offshore wind development in New York's Great Lake waters. These waters are comprised of over 9200 sq. km in Lake Ontario and 1500 sq. km in Lake Erie, and form a coastline that extends for a combined 980 km. Interest in the potential for offshore wind energy development in the Great Lakes has grown sharply in recent years. This is due to a number of factors, including public demand for more sources of clean and renewable energy, state policy initiatives and incentives, and the prospect of new economic development opportunities. In addition, the wind resource over the lakes is much more energetic than over most of the state's land area. As a response to the heightened interest in Great Lakes offshore wind development, this report's intent is to provide background information and analysis on a broad range of relevant state-specific issues for the benefit of a variety of potential stakeholders.

This report's approach consisted of a desktop investigation of parameters affecting the feasibility of offshore wind development in New York's Great Lake waters. The investigation relied on existing data sources describing the state's coastal and offshore resources, the documented experiences of others with offshore development, and the characteristics of offshore wind energy technology. The study is intended to assess the general feasibility of offshore wind energy development in the vicinity of the Great Lakes coastline, addressing various physical, technical, environmental, regulatory, and commercial considerations. The assessment acknowledges some of the lakes' unique characteristics relative to offshore experience elsewhere, such as lake ice development in winter and construction vessel size limitations. Specific topics include:

- Global offshore wind development activity and technology, including wind turbine and foundation types
- Geophysical lake conditions, including winds, waves, water depths, ice, and bottom geology
- Wildlife
- Existing lake uses such as vessel traffic and commercial/recreational fishing
- Existing adjacent land uses and infrastructure availability to support offshore wind development
- Siting considerations
- Legal jurisdictions, including a summary of federal and state approvals, reviews, and permits
- Economics

Many water and land use considerations are presented as maps. These and other considerations were analyzed to identify preliminary offshore wind development areas in both lakes. Screening factors included in this preliminary siting assessment included minimum annual average wind speed (7.5 m/s at 80 m), maximum water depth (45 m), and avoidance of shipping lanes.

Recommendations for more in-depth investigations are given to fully assess the feasibility of offshore wind energy development in New York's Great Lake waters.

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1.0. Introduction

1.1. Objective and Scope

Interest in wind energy development in New York has risen sharply in recent years, as it has both nationally and globally. The public's increasing demand for clean, renewable energy sources, supported by New York State's renewable energy portfolio standard, is a driving factor behind wind energy's growth. Wind energy is one of the lowest cost renewable technologies and has been the world's fastest growing energy source on a percentage basis for more than a decade. Wind energy development enhances diversification of the power generation mix without fuel cost or long-term supply risks. An added benefit is the net reduction of greenhouse gases and other environmentally polluting emissions per unit of electricity produced by a fossil fuel-dominated power generation base.

All wind generation in the United States (U.S.) has been installed on land, with most of the installed capacity located in rural or remote areas where average wind speeds at wind turbine hub height exceed 7 m/s. This speed roughly defines the current threshold above which large-scale onshore wind projects have a good opportunity for being economically feasible, depending on a host of local market factors.

Interest in offshore wind development in New York's Great Lake waters has been supported by energy portfolio goals. In 2007, approximately 17% of New York's energy supply came from renewable sources, with 15% of this from hydropower.[1] In order to meet New York's renewable energy goal of 30% by 2015, substantial wind, solar, and biomass development will be necessary, considering that opportunities for hydroelectric development are mostly exhausted. While energy sources like onshore wind, solar, and biomass will contribute to meeting this objective, the significant amount of growth necessary to meet this energy goal may require other options to be considered as well. Offshore wind has the potential to be part of the solution, as wind speeds over New York's jurisdictional waters are even greater than those over its land area, maximizing the potential for energy generation offshore. Although turbines are generally more expensive to install offshore, the significant amount of water area with high wind speeds and the location of large load centers (i.e. Buffalo, New York City) near the coast brings offshore wind development into consideration.

While offshore wind development in the New York's Atlantic waters has been previously explored over the last decade, interest in offshore wind development in the Great Lakes has increased significantly only recently.[2,3] The level of interest in offshore wind development in this region warrants research into the feasibility of such activity and the collection of preliminary information to determine the next steps to making offshore wind projects in the Great Lakes a reality. This report presents the results of a preliminary study commissioned by NYSERDA to investigate the feasibility of wind energy development in the New York waters of Lake Erie and Lake Ontario.

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[1] Source: New York State Energy Plan. Data obtained January 5, 2010 from Web site http://www.nysenergyplan.com/final/Renewable_Energy_Assessment.pdf

[2] The Long Island Power Authority (LIPA) has been exploring an Atlantic-based offshore project since before 2004. Source: LIPA, ConEd Plan Offshore Wind (April 8, 2009). *Project Finance International,* Issue 406. Obtained February 2010 from Project Finance International Web site http://www.pfie.com/lipa-coned-plan-offshore-wind/412150.article

[3] Recent interest in Great Lakes offshore development includes the New York Power Authority's (NYPA's) Request for Proposals released December 1, 2009. Source: NYPA press release, obtained February 8, 2010 from NYPA Web site http://www.nypa.gov/press/2009/091201.htm

The following material represents the results of a desktop assessment of the technical and economic feasibility of large-scale wind energy development in Lake Erie and Lake Ontario. Specific issues addressed include:

- Current offshore development activity, technology, benefits and challenges
- The lakes' geophysical environments
- Shoreline land uses and available support infrastructure
- Existing uses of offshore areas
- Siting considerations
- Jurisdictional and regulatory oversight
- Economics.

The selected issues in this report were addressed at a level appropriate for understanding primary siting and feasibility considerations. A more complete and comprehensive treatment of issues, including biological and ecological impacts, will be called for when addressing specific offshore development proposals.

The study area was defined as New York's territorial waters of Lake Erie and Lake Ontario. This area is composed of approximately 9,230 km^2 of water area and 847 statute km (526 statute mi) of the state's coastline for Lake Ontario, and 1516 km^2 of water area and 132 statute km (82 statute mi) of the coastline for Lake Erie. Neighboring water areas in Michigan, Pennsylvania and Canada were not considered in this report.

1.2. Approach

This report's approach involved a desktop investigation of parameters affecting the feasibility of offshore wind development in New York's Great Lake waters. The investigation relied on existing data sources describing the state's coastal and offshore resources, the documented experiences of others with offshore development, and the characteristics of offshore wind energy technology. The study is intended to assess the general feasibility of offshore wind energy development in the vicinity of the Great Lakes coast, addressing various physical, technical, environmental, regulatory, and commercial considerations. It is not intended to substitute for an environmental review for any permit application for any particular project. The scope and impact of such a project would require that all technical, economic and environmental factors at the proposed site be thoroughly investigated in collaboration with all appropriate regulatory bodies and public stakeholders.

To facilitate understanding, many attributes of the Great Lakes are depicted in this report in a complementary blend of text, graphic, and tabular formats. To assist in the management of the large number of databases, electronic versions were obtained and incorporated into a geographical information system (GIS). A GIS is a system of hardware and software that manages, analyzes and maps geographically referenced data. A benefit of GIS is the ability to display multiple data layers on a single map, thus facilitating the assessment of several siting factors at once, which is helpful in illustrating relative siting attributes across a large geographical area.

Table 1.1 lists the types and sources of databases utilized by this study. Exclusionary data layers denote areas that are effectively undevelopable due to siting constraints, while precautionary data layers indicate zones where there is only a possibility that development may be precluded. Data layers marked as requiring consideration will require additional follow-on work, research, and site-specific data collection in order to determine their affect on a wind project. The obtained GIS data were used to quantify the development potential of offshore development for a handful of scenarios in the Siting Analysis portion of the report (Chapter 8.0).

In addition to the presentation of siting-related information, this study compares factors influencing the relative feasibility of wind energy development among different portions of the study area. Associated development and logistical issues are discussed, including: interconnection to the existing transmission system on land; legal and jurisdictional issues associated with the likely permitting process; the availability of ports for construction and maintenance vessels; and project economics. In some cases, information from existing projects in Europe is used to illustrate current site evaluation and engineering practices.

1.3. Chapter Summary

The remaining chapters, as summarized below, present the various considerations, recommendations and conclusions addressed by this feasibility study.

Chapter 2: Background – This chapter provides an overview of state-of-the-art offshore wind energy development. Topics of discussion include the recent history of offshore wind energy, the status of the current wind industry, the future outlook, and benefits and challenges of wind energy, both generally and in the offshore context.

Chapter 3: Offshore Wind Technology – This chapter provides an overview of the technical aspects of offshore wind development. Topics of discussion include wind resource assessment, state-of-the-art offshore technology, and technical considerations and challenges generally associated with offshore projects, with consideration to Great Lakes applications.

Chapter 4: Physical and Climatic Parameters of Lake Erie - This chapter characterizes the physical and meteorological environment of Lake Erie. General topics of discussion include seabed geology, oceanography, and climatology.

Chapter 5: Physical and Climatic Parameters of Lake Ontario - This chapter covers the same general topics as those for Lake Erie.

Chapter 6: Offshore Considerations - This chapter identifies lake uses that could be impacted by an offshore wind project. Topics addressed include vessel traffic, commercial and recreational fishing, obstructions, and wildlife.

Chapter 7: Onshore Considerations - This chapter identifies coastal land uses that could be impacted by an offshore wind project in either lake. Land-based facilities and activities may also affect the siting of a project. Topics addressed include coastal land use, locations of ports, aviation, and the electrical transmission system.

Chapter 8: Siting Analysis - The foregoing information is collectively analyzed in this chapter to make preliminary qualitative and quantitative assessments of offshore wind energy in both lakes.

Chapter 9: Legal and Jurisdictional Evaluation - The legal and jurisdictional requirements of siting and permitting offshore wind projects are addressed in this chapter. Federal, state, and local jurisdictions, together with application process overviews, are presented.

Chapter 10: Economic Overview - This chapter presents the leading cost variables comprising a wind project investment and illustrates the installed cost experienced to date by European offshore projects. A cost of energy analysis for a hypothetical New York offshore project is included, together with a discussion of financial incentives available to wind projects.

Chapter 11: Conclusions - A set of study conclusions is presented in this chapter.

Chapter 12: Recommendations – Recommendations for the next steps in the development process are presented. Categories with sparse data availability and areas for future study are addressed.

Table 1.1: Types and Sources of GIS Databases

Physical and Environmental Parameters		
Parameters	**Description**	**Source**
Bathymetry	Exclusionary	National Oceanic and Atmospheric Administration (NOAA), National Geophysical Data Center, Boulder, CO, 2006. http://www.ngdc.noaa.gov/ngdc.html
Ice Cover	Precautionary	Digitized From NOAA Great Lakes Ice Atlas http://www.glerl.noaa.gov/data/ice/atlas/ice_duration/duration.html
Wind Resource	Exclusionary	AWS Truewind National Map at 80 Meters (200m resolution) AWS Truewind, LLC, Albany, NY, 2009 http://www.awstruewind.com
Lake Erie Surficial Geology	Consideration	U.S. Geological Survey; Quaternary Geologic Atlas of The United States, 1991 http://pubs.usgs.gov/imap/i-1420/nk-17/lakeerieAV.zip
Lake Ontario Surficial Geology	Consideration	U.S. Geological Survey; Digital Data Series DDS-38, 1998 http://pubs.usgs.gov/dds/dds38/shape.html
Natural Resources / Wildlife		
Parameters	**Description**	**Source**
Federal Lands	Consideration	ESRI, Data and Maps Media Kit; Redlands, CA, 2008 http://www.esri.com/
Important National Areas	Consideration	WDPA Consortium. "World Database on Protected Areas" 2004. Copyright World Conservation Union (IUCN) and UNEP-World Conservation Monitoring Centre (UNEP-WCMC), 2004. http://glcf.umiacs.umd.edu
DEC Lands	Consideration	DEC Lands, NYS GIS Clearinghouse, 2009, http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=1114
The Nature Conservancy Lands	Consideration	The Nature Conservancy Lands, 2009 http://maps.tnc.org/#gisdata
Zebra Mussel Distribution	Consideration	Great Lakes Information Network, 2008 http://gis.glin.net/ogc/services.php?by=topic
Critical Fish Habitat Areas	Precautionary	New York State Department of Environmental Conservation, 2007 http://dec.ny.gov/
Fish Netting Areas	Precautionary	Digitized from historical NOAA maps, 2000
Significant Coastal Fish and Wildlife Boundaries	Precautionary	NYS GIS Clearinghouse, 2006 http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=318
Bird Conservation Areas	Precautionary	NYS GIS Clearinghouse, 2005 http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=1129
Hawk Watch Sites	Precautionary	Hawk Migration Association of North America http://www.hmana.org/sitesel.php?country=USA&stateprov=New%20York
Important Bird Areas	Precautionary	Audubon New York. August 2007. Important Bird Areas Database, Boundary Digital Data Set. Ithaca, New York.
Parks	Consideration	Detailed Parks ESRI, Data and Maps Media Kit; Redlands, CA, 2008 http://www.esri.com/
Areas of Concern	Consideration	Great Lakes Information Network, 2007 http://gis.glin.net/ogc/services.php#boundaries

Marine Considerations		
Parameters	**Description**	**Source**
Tracklines / Shipping Routes	Exclusionary	Digitized from historical NOAA maps, 2000
Anchorage Areas	Exclusionary	Digitized from historical NOAA maps, 2000
Cables	Exclusionary	Digitized from historical NOAA maps, 2000
Dumping Grounds	Exclusionary	Digitized from historical NOAA maps, 2000
Submerged Pipelines	Exclusionary	Digitized from historical NOAA maps, 2000
Shipwrecks and Obstructions	Exclusionary	NOAA, Automated Wreck and Obstruction Information System (AWOIS) Silver Springs, MD, 2009 http://www.nauticalcharts.noaa.gov/hsd/awois.html
Ports and Waterway Facilities	Consideration	Great Lakes Information Network, 2007 http://gis.glin.net/ogc/services.php#boundaries
Military Practice Area	Precautionary	Digitized from historical NOAA maps, 2000
Onshore Considerations		
Parameters	**Description**	**Source**
Airports	Precautionary	U.S. Bureau of Transportation Statistics National Transportation Atlas Database, 2008
Air Traffic Exclusion Zones	Precautionary	Aviation Systems, Inc. http://www.aviationsystems.com
Military Operation Areas	Precautionary	Aviation Systems, Inc. http://www.aviationsystems.com
Transportation	Consideration	Interstates, Railroads ESRI, Data and Maps Media Kit; Redlands, CA, 2008 http://www.esri.com/
Transmission	Consideration	Ventyx Velocity Suite, January 2009
Substations	Consideration	Ventyx Velocity Suite, January 2009
Wind Farms	Consideration	Ventyx Velocity Suite, January 2009
Power Plants	Consideration	Ventyx Velocity Suite, January 2009
Other		
Parameters	**Description**	**Source**
Political Boundaries	Consideration	Country, State and County Boundaries ESRI, Data and Maps Media Kit; Redlands, CA, 2008 http://www.esri.com/
Major Cities	Consideration	ESRI, Data and Maps Media Kit, Redlands, CA, 2008 http://www.esri.com/
Population Per Square Mile	Consideration	Census Tracts ESRI, Data and Maps Media Kit; Redlands, CA, 2008 http://www.esri.com/

2.0. Background

Interest in wind energy development in New York has risen sharply in the recent years, much as it has throughout the United States and Europe. This is due in part to the public's increasing interest in expanding the use of clean, renewable energy sources. Wind is one of the lowest cost renewable technologies, and allows diversification of the power generation mix without fuel costs or long-term supply risks.

Indigenous wind resources off of New York's coast offer the potential for large amounts of wind-based energy production while likely displacing pollutants produced by conventional power plants. However, significant tradeoffs and challenges associated with offshore wind power development also exist. This chapter discusses the potential benefits and challenges of offshore wind energy based on worldwide experiences, and illustrates the major components comprising an offshore wind energy facility.

2.1. Recent History

Since the early 1990s northern Europe has pioneered offshore wind technology. Over 1,500 MW of offshore wind capacity have been installed in over 35 different projects, with over 25 more projects currently financed or under construction, totaling to almost 4,500 additional MW soon to be available (see Table 2.1).

Strong offshore winds, relatively shallow waters offshore, diminished development opportunities on land, and strong government support are all spurring this growth. In terms of available coastal areas, it has been estimated that in the long term the United States has the second greatest potential for offshore wind power production in the world, behind China.[4,5]

In the United States, serious interest in offshore wind development has been a more recent trend. Multiple offshore projects are planned in United States waters, including projects off the coasts of Massachusetts, New York, New Jersey, Rhode Island, Delaware, Virginia, the Carolinas, Georgia, Ohio, and Texas, as well as some projects being considered for the West Coast. The objective of these projects is to deliver wind energy to major coastal electric load centers. Most wind energy in the United States is generated in the Midwest, far from the significant energy users along the nation's coasts. Offshore wind projects would create renewable energy generation in close geographic proximity to large cities.

Offshore development in the Great Lakes has also been an area of recent interest and growth. For example, a 710 MW project, known as Trillium Power Wind 1, is proposed in Canada's Lake Ontario waters off the coast of Prince Edward County in Ontario.[6] In April 2009, the New York Power Authority (NYPA) announced a Request for Expressions of Interest for offshore development in New York's Lake Erie and Lake Ontario waters. NYPA released a more formal Request for Proposals on December 1, 2009 for the development of a 120 to 500 MW wind project in the lakes, with plans to "purchase the full

[4] Offshore Wind Energy Potential Outside the European Union (2001). *Aerodyn Engineering GmbH*.

[5] Renewable Energy Country Attractiveness Indices (February 2003). London, UK: Retrieved from Ernst & Young Structured Finance Documents.

[6] *Great Lakes Offshore Wind Energy Project Could Surpass 700 MW*. (June 5, 2006). Retrieved October 9, 2009 from Renewable Energy World Web site: http://www.renewableenergyworld.com/rea/news/article/2006/06/great-lakes-offshore-wind-energy-project-could-surpass-700-mw-45079

output of the project under a long term Power Purchase Agreement ('PPA')."[7] With intentions to have a PPA in place by the end of May, 2011, NYPA's support has brought increased attention to New York's Great Lake waters as an area for potential offshore development.

In the last year, multiple offshore wind projects have made substantial strides toward becoming a reality in the United States. The proposed Cape Wind project in Nantucket Sound of Massachusetts has reached advanced stages of permitting. After a lengthy Environmental Impact Statement (EIS) review process, the 130 turbine 468 MW project received a favorable EIS, with a tentative timeline to begin construction within the next few years.[8] The Bluewater project off the coast of Delaware and the Deepwater project off the coast of New Jersey also have potential to be two of the first wind projects in United States waters.

To date, offshore wind has been developed almost exclusively in ocean waters, but discussions about multiple freshwater projects have emerged in recent years. The Lake Vanern Wind Park in southern Sweden, consisting of ten 3-MW turbines, is the most advanced freshwater project to date, with plans to become operational within a year. Offshore wind energy in the Great Lakes has received substantial attention at offshore wind conferences, and multiple task groups have been formed to support research and development efforts for offshore wind installations specifically within the Great Lakes. On February 6, 2009, Michigan Governor Jennifer M. Granholm ordered the creation of the Great Lakes Wind Council, a committee devoted to identify potential project sites within the Great Lakes.[9] It is clear from these events that the wind energy industry is likely to focus an increasing amount of attention on offshore wind projects in the Great Lakes during the years to come.

2.2. Benefits and Advantages of Offshore Wind

There are numerous benefits and advantages to offshore wind development. The United States Department of Energy's Wind Energy Program has stated that "wind energy diversifies the nation's energy supply, takes advantage of a domestic resource, and helps the nation meet its commitments to curb emissions of greenhouse gases, which threaten the stability of global climates."[10] In the draft Environmental Impact Study for the Cape Wind Project released in November 2004, the United States Army Corp of Engineers found that the project would "produce important energy, environmental and economic benefits for the region."[11] This statement was supported in January 2009, when the Minerals Management Service released a favorable Final Environmental Impact Statement for the Cape Wind project, noting that the project would "make a substantial contribution to enhancing the region's electrical reliability and achieving the renewable energy requirements under the Massachusetts and regional renewable portfolio standards."

[7] *Request for Proposals to Provide Electric Capacity and Energy from a Great Lakes Offshore Wind Generating Project.* (December 1, 2009). Retrieved December 17, 2009 from NYPA Web site: http://www.nypa.gov/NYPAwindpower/REQUEST%20FOR%20PROPOSALS.htm

[8] *Cape Wind Final Environmental Impact Statement (January 2009)*. Retrieved October 9, 2009 from, Cape Wind Web site: http://www.mms.gov/offshore/AlternativeEnergy/PDFs/FEIS/Cape%20Wind%20Energy%20Project%20FEIS.pdf

[9] Brown, M. (February 6, 2009). *Governor Granholm Signs Executive Order Creating Great Lakes Wind Council.* Retrieved October 9, 2009 from, Office of the Governor of the State of Michigan Web site: http://www.michigan.gov/gov/0,1607,7-168--208364--,00.html

[10] Retrieved November 2009 from Wind Energy and Rural Development in North Dakota V Web site: http://www.undeerc.org/aboutus/pastevents/conferences/windv/sponsors.asp

[11] Retrieved from Cape Wind Web site: www.capewind.org

2.2.1 General Benefits of Wind Energy

Some specific benefits of wind power (both offshore and onshore) include:

- Clean and inexhaustible source of energy - A single offshore-scale turbine can generate nearly 14,000 MWh of net energy annually, displacing 9,500 tons of carbon dioxide emissions that would otherwise be produced annually from conventional power plants.[12]
- Promotes local economic development - Wind energy provides more jobs per dollar invested than most other energy technologies. Besides the creation of jobs during both the construction and operational phases of the project, economic benefits include the improvement of infrastructure and the revitalization of cities within the region, as well as meeting Renewable Portfolio Standards.
- Scalable project size - Wind energy projects can be built as single turbine installations or as large turbine arrays known as wind farms or wind plants. In general, economies of scale favor large projects.
- Promotes energy price stability - By further diversifying the energy mix, wind energy reduces dependence on conventional fuel sources (such as oil and natural gas) that are subject to price and supply volatility.

2.2.2 Additional Advantages of Offshore Wind Energy

Although additional challenges also exist, offshore wind projects have some clear advantages when compared to onshore projects that make them an attractive selection for developers. Specific advantages of offshore wind power include:

- A stronger wind resource - Offshore wind speeds increase with distance from land as the impacts of topography and surface roughness decrease, and have been estimated to be between 25 and 40 percent higher than on land. This speed advantage yields a 50 to 75 percent gain in energy production from a wind turbine.[13]
- Less turbulent winds - Lower turbulence results in more efficient energy production. It also translates into less wear and tear on turbines and components.
- Lower wind shear - The boundary layer of slow-moving air near the sea-surface is much thinner than what exists on land. This allows for the use of shorter towers offshore to reach a desired hub-height average wind speed.
- Economies of scale - Potentially achieved for large, contiguous developments. Open water offers the space for large turbine arrays to be constructed in portions of the country where large onshore arrays are often more difficult to develop. Additionally, offshore turbines tend to have larger capacities (2-5 MW) compared to some onshore models. This is beneficial because of the greater infrastructure cost for each offshore unit (i.e. foundations, collection system, interconnection). Larger offshore turbines allow for the development of large MW-rated farms with less turbine installations than onshore.

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[12] Based on the 5 MW Repower 5M offshore turbine production estimates (8.0 m/s wind regime, 31.7% net capacity factor) and NY average utility generation fuel mix. *Green Power Equivalency Calculator*. Retrieved October 9, 2009 from, U.S. EPA Web site: http://www.epa.gov/greenpower/pubs/calculator.htm

[13] The power extracted from the wind is a cubic function of wind speed.

- Location near primary load centers – Densely populated areas are usually primary energy consumers; however, generating renewable energy in close proximity to an urban environment is often challenging, as large amounts of open land area may be necessary for solar and onshore wind installations. Offshore wind projects strategically placed near urban areas can provide renewable energy to these load centers.
- Reduced land use conflicts – While some proposed onshore wind projects can have conflicts with existing land uses, offshore wind development may affect fewer stakeholders than onshore wind, potentially reducing community opposition to development.
- Renewable energy goals – Offshore wind development helps to meet local, state, and national renewable energy goals, mitigate pollution, and comply with any potential greenhouse gas regulations established by the Environmental Protection Agency.[14]

2.3. Challenges and Considerations of Offshore Wind

Offshore wind development creates challenges and considerations uncommon to onshore projects. These challenges include:

- Limited experience - The siting, permitting, construction, and operation of offshore wind projects are still undergoing development. Equipment, techniques and infrastructure have yet to be developed or adapted in the United States for all aspects of offshore wind development. The first offshore project to become operational in the United States will set a precedent for other projects regarding legal, jurisdictional, political, environmental, and stakeholder concerns, making entry into the industry easier for other projects; however, until United States experience is gained, project development will continue to be slowed by these concerns. The Cape Wind EIS, for example, was the first of its kind in the United States, and took over seven years to complete,[15] due to the need to determine appropriate processes and regulations for this type of review in the offshore environment.
- Aquatic environment - Hydrodynamic structure and foundation loading, water depth, siting conflicts with air and water-borne vessels, waves, severe weather and lake states, logistics (of installation and operation and maintenance), marine growth – these are all issues unique in an offshore environment.
- Freshwater ice - The consideration of lake ice is unique to freshwater environments, and is an area of ongoing research within the industry. Challenges posed by freshwater ice include increased loading on the foundation structure and limited accessibility to the turbines for maintenance.
- Infrastructure - An extensive on- and offshore infrastructure is required to construct and operate an offshore project. Some of the necessary items include: a port with deep draft facilities, large staging area with appropriate loading equipment, dedicated fleet of maintenance

[14] Quote from the Huffington Post: "Under the Clean Air Act, EPA is now obligated to issue rules regulating global warming pollution from all major sources, including cars and coal-fired power plants. The law specifically states that EPA 'shall' (i.e. must, not may) regulate dangerous pollutants once they are found to endanger public health or welfare."
EPA to Propose Greenhouse Gas Regulation Under Clean Air Act (2009, April 17). Retrieved December 17, 2009 from, the Huffington Post Web site: http://www.huffingtonpost.com
[15] *Cape Wind Project Draws Near As Final Report Released.* Retrieved October 9, 2009 from, Cape Wind Web site: http://www.capewind.org/news940.htm

and construction vessels (possibly including a helicopter), reliable communication system, appropriate safety and rescue provisions, and skilled personnel.

- Environmental impact - Although research into wind project impacts on marine habitats, avian use and fisheries is ongoing, site-specific concerns require additional attention. Concerns arise when a proposed offshore project has the potential to significantly affect local or migratory avian or aquatic populations. The environmental impact of a project is assessed through an EIS, which may take years to complete.
- Aesthetics - A common concern regarding any wind project is its visibility. Depending on weather and sea conditions, offshore turbines can be seen up to 30 km from the coast. Aesthetic impact is an issue that has led to some offshore project permit applications in Europe being declined, and other United States based projects to be delayed.
- Foundations - Foundation design is a site-specific design consideration that represents a much larger portion of a project's installed cost compared to land-based installations. Water depth, maximum loads experienced by the structure, and lakebed geology dictate the foundation design.
- Costs - The installed cost of an offshore wind plant can be twice as expensive as an equivalent onshore plant. Offshore costs are much more dependent on site-specific factors than land-based projects. Factors affecting offshore costs include the project's water depth, distance from shore, geologic conditions, and the complexity of the installation procedure, which varies from site to site. Balance-of-plant costs (foundations, electrical system, etc.) are much more expensive offshore than onshore, and acquiring the infrastructure for installation procedures is both costly and challenging. Access to financing is typically more difficult to obtain due to the higher perceived investment risk and limited experience in the United States.
- Maintenance and availability - Early experiences in Europe have shown that ocean offshore wind turbines may be accessible by boat 80% of the time.[16] This is due to variable weather conditions and sea states, which can limit safe access to a wind project by work crews. As a result, turbine maintenance needs may take longer to address, potentially leading to longer down times and lost production. Freshwater wind turbine access is more likely to be limited by lake ice conditions than by rough sea states, with possible site access by boat reaching as low as 65% of the calendar year. Offshore wind turbine availability may be lower than onshore projects due to limited maintenance experience in the United States for offshore turbines and the harsh offshore operating environment, but little operational data is publicly available to quantify the significance of this parameter.

The complex nature of offshore wind power siting and development necessitates extensive preparation. Thorough project planning helps mitigate challenges associated with the lack of offshore wind experience in the United States, the site-specific nature of each project and the scope of the overall effort.

[16] *Wind Turbine Technology for Offshore Locations.* Retrieved October 9, 2009 from, *Wind Energy: the Facts* Web site: http://www.wind-energy-the-facts.org/en/part-i-technology/chapter-5-offshore/wind-turbine-technology-for-offshore-locations/

Table 2.1: Installed Offshore Wind Energy Projects (Data Verified by AWS Truewind Research, December 2009)

Project Name	Country	Capacity (MW)	Operating Year	Status	No. Turbines	Turbine Size (MW)	Turbine Model	Water Depth (m)	Distance from Shore (km)	Foundation Type
Vindeby	Denmark	5	1991	Commissioned	11	0.45	Siemens 450	3 to 5	1.5	Gravity
Lely	Netherlands	2	1994	Commissioned	4	0.5	NEG Micon	5 to 10	1	Monopile
Tuno Knob	Denmark	5	1995	Commissioned	10	0.5	Vestas 500 kW	3 to 5	6	Gravity
Dronten/Irene Vorrink	Netherlands	16.8	1996	Commissioned	28	0.6	Nordtank	5	0	Monopile
Bockstigen	Sweden	2.75	1997	Commissioned	5	0.55	NEG Micon 550 kW	6	3	Monopile
Blyth	United Kingdom	4	2000	Commissioned	2	2	Vestas V66	9	1	Monopile
Middelgrunden	Denmark	40	2001	Commissioned	20	2	Bonus 2 MW	5 to 10	2 to 3	Gravity
Yttre Stengrund	Sweden	10	2001	Commissioned	5	2	NEG Micon 2 MW	8	5	Monopile
Horns Rev	Denmark	160	2002	Commissioned	80	2	Vestas V80	6 to 14	14 to 17	Monopile
Samsoe	Denmark	23	2002	Commissioned	10	2.3	Siemens 2.3	11 to 18	3	Monopile
Utgrunden	Sweden	11.4	2002	Commissioned	8	1.425	Enron 1.425	7 to 10	8 to 12	Monopile
Frederikshavn	Denmark	10.6	2003	Commissioned	2 1 1	3 2.3 2.5	Vestas V90 Bonus 2.3 Nordex N90	1	1	Monopile, Bucket
North Hoyle	United Kingdom	60	2003	Commissioned	30	2	Vestas V80	5 to 12	8	Monopile
Emden Nearshore	Germany	4.5	2004	Commissioned	1	4.5	Enercon	3	0	#N/A
Rodsand I/Nysted	Denmark	165.6	2004	Commissioned	72	2.3	Siemens 2.3	6 to 10	6 to 10	Gravity
Ronland	Denmark	17.2	2004	Commissioned	8	2	Vestas V80	1	0	Monopile
Scroby Sands	United Kingdom	60	2004	Commissioned	30	2	Vestas V80	2 to 10	3	Monopile
Setana	Japan	1.32	2004	Commissioned	2	0.66	Vestas V47	13	1	#N/A
Arklow Bank	Ireland	25	2005	Commissioned	7	3.6	GE 3.6	2 to 5	10	Monopile
Kentish Flats	United Kingdom	83	2005	Commissioned	30	3	Vestas V90	5	9	Monopile
Barrow	United Kingdom	90	2006	Commissioned	30	3	Vestas V90	15	7	Monopile
Beatrice (Moray Firth)	United Kingdom	10	2006	Commissioned	2	5	REpower 5M	43	25	Jacket
Rostock	Germany	2.5	2006	Commissioned	1	2.5	Nordex 2.5 MW	2	1	#N/A
Blue H Puglia (Pilot)	Italy	0.08	2007	Commissioned	1	0.08	WES18 mk1	108	20	Floating
Bohai Bay	China	1.5	2007	Commissioned	1	1.5	Goldwind	#N/A	70	Jacket
Burbo Bank	United Kingdom	90	2007	Commissioned	25	3.6	Siemens 3.6	10	5.2	Monopile
Egmond aan Zee (Nordzee Wind)	Netherlands	108	2007	Commissioned	36	3	Vestas V90	17 to 23	8 to 12	Monopile
Kemi Ajos Phase I	Finland	15	2007	Commissioned	5	3	WindWinD 3 MW	#N/A	0 to 1 km	Artificial Islands
Hooksiel (Demonstration)	Germany	5	2008	Commissioned	1	5	BARD 5 MW	2 to 8	1	Tripile
Inner Dowsing	United Kingdom	97.2	2008	Commissioned	27	3.6	Siemens 3.6	10	5	Monopile
Kemi Ajos Phase II	Finland	15	2008	Commissioned	5	3	WindWinD 3 MW	#N/A	0 to 1 km	#N/A
Lillgrund Oresund	Sweden	110	2008	Commissioned	48	2.3	Siemens 2.3	2.5 to 9	10	Gravity
Lynn	United Kingdom	97.2	2008	Commissioned	27	3.6	Siemens 3.6	10	5	Monopile
Princess Amalia (Q7-WP)	Netherlands	120	2008	Commissioned	60	2	Vestas V80	19 to 24	> 23	Monopile
Alpha Ventus/Borkum West	Germany	60	2009	Commissioned	6 6	5 5	Multibrid M5000 REpower 5M	30	45	Tripod Jacket
Gasslingegrund (Lake Vanern)	Sweden	30	2009	Commissioned	10	3	(DynaWind AB)	4 to 10	4	#N/A
Gunfleet Sands Phase I	United Kingdom	108	2009	Commissioned	30	3.6	Siemens 3.6	2 to 15	7	Monopile
Horns Rev Expansion	Denmark	210	2009	Commissioned	91	2.3	Siemens 2.3	9 to 17	30	Monopile
Hywind/Karmoy (Floating Pilot)	Norway	2.3	2009	Commissioned	1	2.3	Siemens 2.3	120 to 700	10 km initially	Floating
Rhyl Flats/Constable Bank	United Kingdom	90	2009	Commissioned	25	3.6	Siemens 3.6	8	8	Monopile
Robin Rigg (Solway Firth)	United Kingdom	180	2009	Commissioned	60	3	Vestas V90	>5	10	Monopile
Sprogo	Denmark	21	2009	Commissioned	7	3	Vestas V90	6 to 15	1	Gravity
Thornton Bank	Belgium	30	2009	Commissioned	6	5	REpower 5M	25	30	Gravity
Avedore/Hvidovre	Denmark	15	2010	Financed/Under Construction	3	5	#N/A	#N/A	20 to 100	#N/A
Baltic I	Germany	48.3	2010	Financed/Under Construction	21	2.3	Siemens 2.3	18	16	#N/A
Bard Offshore I	Germany	400	2010	Financed/Under Construction	80	5	BARD 5 MW	39 to 41	100	Tripile
Greater Gabbard Phase I	United Kingdom	150	2010	Financed/Under Construction	140	3.6	Siemens 3.6	24 to 34	25	Monopile
Gunfleet Sands Phase II	United Kingdom	64	2010	Financed/Under Construction	18	3.6	Siemens 3.6	2 to 15	7	Monopile
Nordergrunde	Germany	90	2010	Financed/Under Construction	18	5	REpower 5M	4 to 20	30	Monopile or Jacket
Rodsand II	Denmark	207	2010	Financed/Under Construction	90	2.3	Siemens 2.3	5 to 12	6 to 10	Gravity
Sea Bridge	China	102	2010	Financed/Under Construction	34	3	Sinovel 3 MW	8 to 10	8 to 14	#N/A
Walney Island Phase I	United Kingdom	183.6	2010	Financed/Under Construction	51	3.6	Siemens 3.6	20	15	#N/A
Belwind	Belgium	165	2011	Financed/Under Construction	55	3	Vestas V90	20 to 35	46	Gravity
Borkum West II	Germany	400	2011	Financed/Under Construction	80	5	Multibrid M5000	22 to 33	45	Tripod
Ormonde	United Kingdom	150	2011	Financed/Under Construction	30	5	REpower 5M	17 to 22	10	Jacket
Thanet	United Kingdom	300	2011	Financed/Under Construction	100	3	Vestas V90	20 to 25	7 to 9	Monopile
Borkum Riffgat	Germany	264	2012	Financed/Under Construction	44	5	#N/A	16 to 24	15	#N/A
London Array Phase I	United Kingdom	630	2012	Financed/Under Construction	175	3.6	Siemens 3.6	23	>20	Monopile
Sheringham Shoal	United Kingdom	316.8	2012	Financed/Under Construction	88	3.6	Siemens 3.6	16 to 22	17 to 23	Monopile
Walney Island Phase II	United Kingdom	183.6	2012	Financed/Under Construction	51	3.6	Siemens 3.6	20	15	#N/A

3.0. Offshore Wind Technology

Offshore wind energy development has been an almost exclusively European phenomenon since the early 1990s. More than 35 wind projects totaling over 1,500 MW of capacity are now operating off the shores of five countries, most within northwest Europe in the Baltic and North Seas. Another 2,500 MW of capacity are under construction in 16 projects. Overall, the European Union predicts there will be at least 40,000 MW of offshore wind energy in Europe by the year 2020. China has also begun construction on the Sea Bridge Wind Farm in the Bohai Sea, its first offshore wind project scheduled to be completed in 2010.

This large body of offshore experience provides an excellent basis to understand the wind turbine technologies and foundation designs likely to be applicable to a Great Lakes project for a wind facility built in the next five to ten years. The objective of this section is to provide an overview of offshore wind turbine technologies, foundation designs and design drivers, balance-of-plant components, and construction and maintenance logistics.

3.1. Design Requirements

The design of an offshore wind project is based on the environmental conditions to be expected at a proposed site over the project's lifetime (typically 20 or more years). These environmental conditions are primarily defined by the wind, wave, current, water depth, soil and sea/lake bed characteristics. Figure 3.1 illustrates the various dynamic factors impacting a wind turbine's external environment. Different project components are more sensitive to some of these characteristics than others. For example, a wind turbine's rotor and nacelle assembly are most sensitive to wind and other atmospheric conditions while the support structure (tower and foundation) design is more dependent on hydrodynamic and sea/lake bed conditions. Wind turbine models tend to be designed for applicability for a specified range of wind conditions whereas turbine support structures are usually engineered for on-site conditions. This section provides additional insight into the design parameters relevant to the entire project.

3.1.1 Winds

Wind conditions are important in defining not only the loads imposed on all of a turbine's structural components, but also in predicting the amount of future energy production at different time scales. The measured on-site wind resource strongly influences the layout of turbines within a defined area as a function of the prevailing wind direction(s). Desired wind data parameters include the following:

- Wind speed – annual, monthly, hourly, and sub-hourly; preferably at hub height
- Speed frequency distribution – number of hours per year within each speed interval
- Wind shear – rate of change of wind speed with height
- Wind veer – change of wind direction with height, especially across the rotor plane
- Turbulence intensity – the standard deviation of wind speeds sampled over a 10-minute period as a function of the mean speed
- Wind direction distribution
- Extreme wind gusts and return periods (50- and 100-year).

Air temperature, water surface temperature and other meteorological statistics (icing, lightning, humidity, etc.) are also desired when evaluating a proposed site.

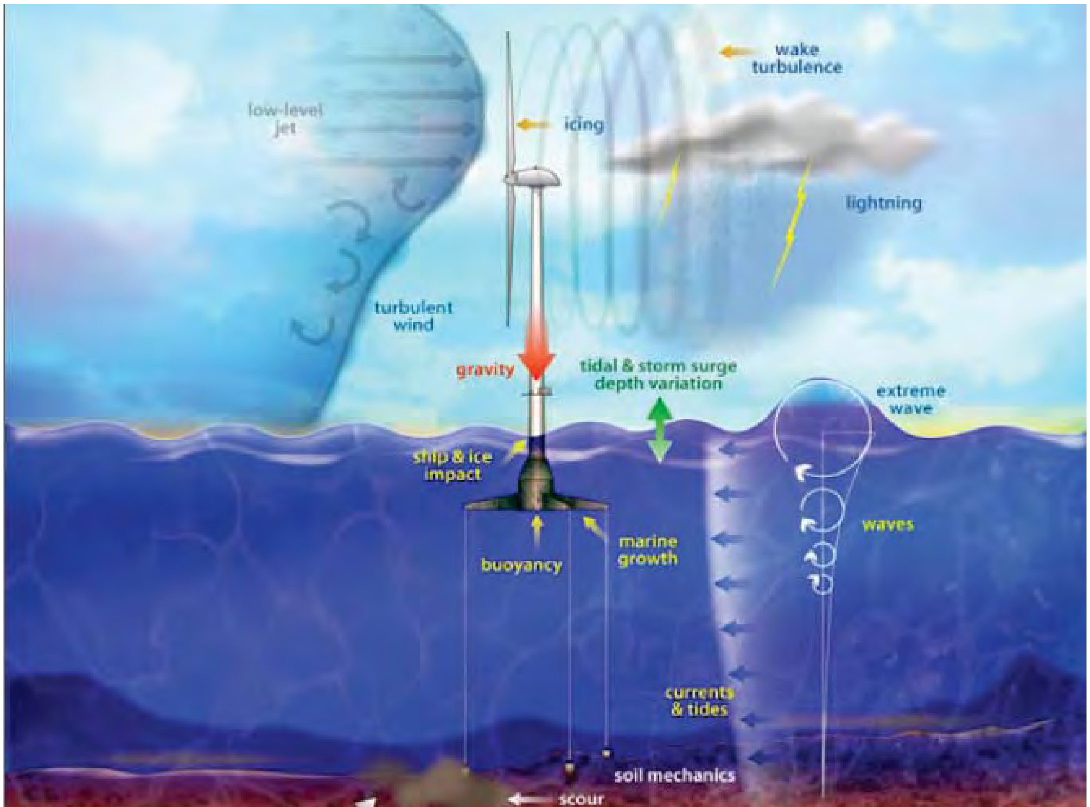


Figure 3.1: Site Conditions Affecting an Offshore Wind Project[17]

3.1.2 Waves

In addition to the loading forces imposed on a turbine's support structure, waves also determine the accessibility of offshore projects by vessels during construction and operations. Desired wave data parameters include the following:

- Significant wave height – average height of the third highest waves
- Extreme wave height – average height of the highest 1% of all waves
- Maximum observed wave height
- Wave frequency and direction spectra
- Correlation with wind speeds and direction

Waves tend to be irregular in shape and height and may approach a wind turbine from more than one direction simultaneously. The probability and characteristics of breaking waves is also important. The correlation of wind and waves is a critical design criterion for an offshore wind turbine. This correlation is normally expressed as a joint probability of wind speeds and wave heights, and may include wave frequency as well. In addition to defining extreme aerodynamic and hydrodynamic loads, it is important

[17] Source: Robinson & Musial, National Renewable Energy Laboratory. (2006, October). Offshore Wind Energy Overview. Webinar. Used with permission.

to assess the dynamic vibrations induced upon the entire turbine structure. The effects of resonant motion from certain wind and wave loads may be a primary design driver.

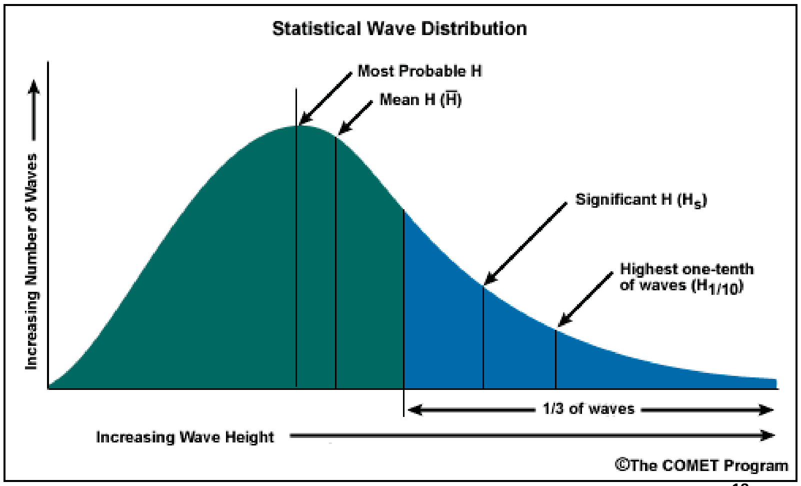


Figure 3.2: Statistical Wave Distribution and Data Parameters[18]

3.1.3 Currents

Currents are generally characterized either as sub-surface currents produced by tides, storm surges, and atmospheric pressure variations, or as near-surface currents generated by the wind. Currents can drive sediment transport (e.g. sand waves) and foundation scouring. They can also affect lake bottom characteristics and vessel motion during construction or service visits.

3.1.4 Integrated Onsite Data Collection

As accurate estimations of energy production potential are requirements by the financial community for offshore wind projects, precise definition of all of these atmospheric and aquatic parameters is critical. These parameters can be derived from various sources depending on the stage of project development. Early stage conceptual planning relies mostly on existing climatological data and model results (such as wind maps). Advanced stages rely on on-site measurement campaigns lasting one to three years.

Meteorological, wave and current data are monitored using a variety of instrumentation (see Figure 3.3, Figure 3.4, and Figure 3.5). Atmospheric data is measured by tall meteorological masts installed on offshore platforms to assess the site's wind resource for both energy assessment and maximum loading purposes. These measurements can be complemented by remote sensing devices (such as lidar and sodar), weather buoys, and regional weather observations to assess atmospheric conditions throughout and surrounding the project area. Wave and current data are collected by instrumented buoys and acoustic Doppler current profilers (ADCPs). Additional information acquired from specialized radar and satellite data, as well as regional and historic surface data sources, can further characterize the offshore environment.

[18] Source: Cooperative Program for Operational Meteorology, Education and Training (COMET). Used with permission.

Figure 3.3: ZephIR and Windcube Lidars for Wind Resource Assessment[19]

Figure 3.4: Three-Meter Disc Weather Buoy[20]

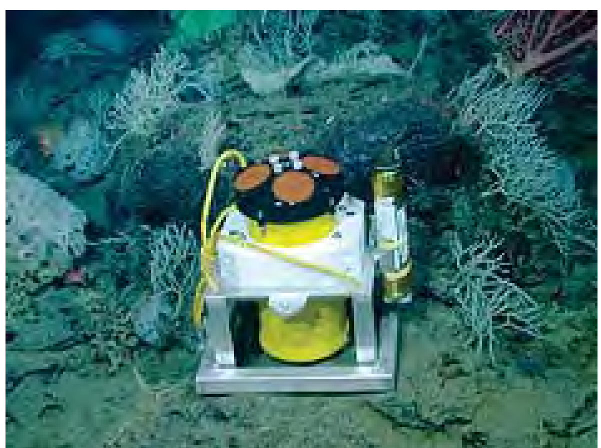


Figure 3.5: Bottom-Mounted ADCP[21]

[19] Source: AWS Truewind, LLC.
[20] Source: Carl Schoch, Alaska Ocean Observing System. Retrieved November 19, 2009 from Alaska Ocean Observing System Web site: http://ak.aoos.org. Used with permission.
[21] Source: Copyright 2006 Monterey Bay Aquarium Research Institute (MBARI)/NOAA. Retrieved November 19, 2009 from MBARI Web site: http://www.mbari.org. Used with permission.

3.1.5 Freshwater Ice

A significant design consideration for offshore wind energy projects in a freshwater environment is lake ice. Freshwater ice has multiple implications, including site access restrictions, cable scouring, and structural loading on the turbine foundation. Both static loading on turbine structures from ice compression and dynamic loading from ice floes influence structure design, in conjunction with traditional loading considerations such as wind, waves, and currents. All these loads are assessed for both the maximum load scenario as well as for resistance to resonance and fatigue.

Research into ice loading on offshore structures is ongoing across several North American and European industries. Regional assessments of lake ice effects on wind turbine structural design have also been examined. For example, juwi GmbH recently released an offshore wind feasibility report for the Great Lakes Wind Energy Center that assessed ice cover on Lake Erie in the vicinity of Cleveland and potential design solutions to mitigate ice concerns. While additional research is necessary, studies of this nature provide an initial assessment of how to treat ice considerations in the Great Lakes.

Figure 3.6: Turbine from Utgrunden Wind Project in Sweden Under Ice Pressure[22]

Technologies addressing the challenges associated with floating and rafted ice have been developed by other industries, including the bridge industry; some of which have been implemented on existing offshore wind structures in marine icing environments. For example, supports in freshwater environments are often outfitted with cones. These cones take advantage of ice's relatively low bending strength and break up the sheet as it pushes up against the support structure, minimizing the ice loads.

[22] Source: Gunnar Britse, Wind Power Photos. Retrieved November 19, 2009 from Web site: http://www.windpowerphotos.com. Used with permission.

Figure 3.7: Upward Breaking Cone Fails the Ice, Minimizing its Load on the Foundation Structure[23]

The cone design has both advantages and disadvantages: while cone structures are effective in mitigating the static and dynamic loading effects of lake ice, the geometry of a cone structure is likely to increase the loads experienced from waves. Additionally, some cone designs may create unfavorable loading conditions on certain foundations, e.g. upward lifting forces on gravity foundations with outward and upward flaring cones. Therefore, a preventative technology design accounts for both ice loading and wave loading simultaneously, balancing these factors appropriately according to site-specific conditions.

Another lake ice concern is cable scouring. During the course of a winter, large ice compilations can develop and may reach the bottom of the lake bed. These ice formations continue to move along the lake's floor, scouring the submerged land. Electrical collection system cables, buried underneath the lakebed, have the potential to be unearthed, damaged, or even severed by these massive ice features scraping along the lake bottom.

While structural loading and cable scouring represent engineering design challenges associated with lake ice, a logistical issue is the limitation of site access by boat due to lake ice accumulation. When a turbine requires maintenance, timely repair is necessary to resume operation and mitigate energy losses. Although typical O&M boat access may be severely limited by lake ice in the Great Lakes region, other accessibility options may be available. Icebreaker vessels[24] and/or helicopters may be used to achieve access to turbine locations during ice cover periods; alternatively, vehicular access to the project may be possible during suitable ice conditions in the winter months. While these site access and maintenance techniques have the potential to be more expensive than traditional boat access, they can increase the percentage of time that the turbines can be reached. Using a helicopter to access offshore turbines has been successfully implemented at multiple offshore monitoring stations and wind projects in Europe, as some offshore wind turbine designs (i.e. GE 3.6, Vestas V90, Siemens 3.6, and REpower 5M) have provisions for helicopter access atop the nacelle.

[23] Source: Brown, T.G., University of Calgary. 2006: "Confederation Bridge – An Innovative Approach to Ice Forces." Used with permission.

[24] Ice breaker vessels, while potentially useful for breaking up ice near the shore in order to reach turbines in open water, may not be economic and may cause a risk of damage to turbines when used to break up ice in close proximity to the structures. Source: Driedger-Marschall, B., & Endres, P. of juwi GmbH. *Great Lakes Wind Energy Center Feasibility Study* (April 2009). Page 5-9.

Figure 3.8: United States Coast Guard Icebreaker Vessel[25]

3.1.6 Lakebed Characteristics and Water Depth

The geologic and bathymetric characteristics of a project site are significant design parameters for offshore wind turbines. While the entire system – turbine, tower, substructure, and foundation – is affected by these parameters, the foundation is particularly sensitive to the site conditions. The site bathymetry (water depth) will primarily drive the size of the underwater structure and its exposure to hydrodynamic forces. The lakebed soil properties and profiles will influence the suitable foundation types. From a system perspective, the geologic and bathymetric characteristics help determine the axial and lateral pile responses, load-carrying capabilities, resonant frequencies, ultimate strength, fatigue strength, and acceptable deformation of the offshore support structure.

A geologic survey of the site often begins with a desktop review of available data to understand conditions likely found on-site. Detailed design and engineering work involves a multi-step on-site investigation process, including seismic reflection methods combined with soil sampling and penetration tests. These techniques obtain information about sediment characteristics and stratification to depths of at least 60 meters (200 feet) below the lake floor. Sediment and subsurface descriptors include the following:

- Soil classifications
- Vertical and horizontal strength parameters
- Deformation properties
- Permeability
- Stiffness and damping parameters – for prediction of the dynamic behavior of the wind turbine structure.

[25] Source: Defense Image Digest Collection, VIRIN DF-ST-87-08205. Retrieved December 2009 from Web site: http://www.au.af.mil/au. Used with permission.

The first phase of on-site investigation, commonly referred to as the geophysical survey, employs remote sensing technology, often multi-beam sonar and/or high-resolution seismic reflection. This phase, known as hydrographic surveying, generally provides a detailed bathymetric map of the sea/lake bottom as well as general soil characteristics. Both techniques rely on a vessel-mounted array of energy emitters and receivers that can carry out the initial site investigation in a relatively short period of time (see Figure 3.9). Advanced design work usually requires direct sampling of bottom soils, typically at each foundation location. This phase of investigation involves vibracore sampling to depths of up to 10 m (33 ft) or conventional borings to much greater depths. Retrieved soils are analyzed to determine their textural and engineering properties.

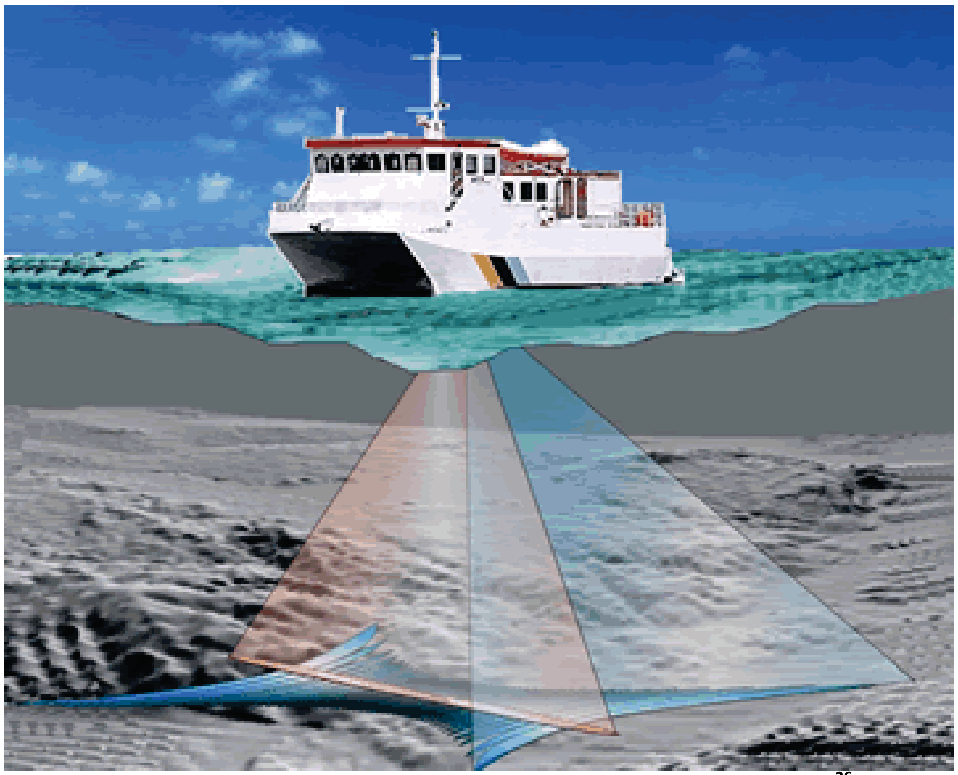


Figure 3.9: Hydrographic Surveying Using Multi-Beam Bathymetry[26]

[26] Source: Hong Kong Hydrographic Office. Courtesy: HKHO. Retrieved April 2010 from HKHO Web site http://www.hydro.gov.hk/service/survey.htm. Used with permission.

3.2. *Overview of Wind Plant Components*

An offshore wind plant's principal components, shown in Figure 3.10, are the turbines, towers, foundations, electric collection and transmission system (including substations), and other balance of plant items. These components are described in detail in this section.

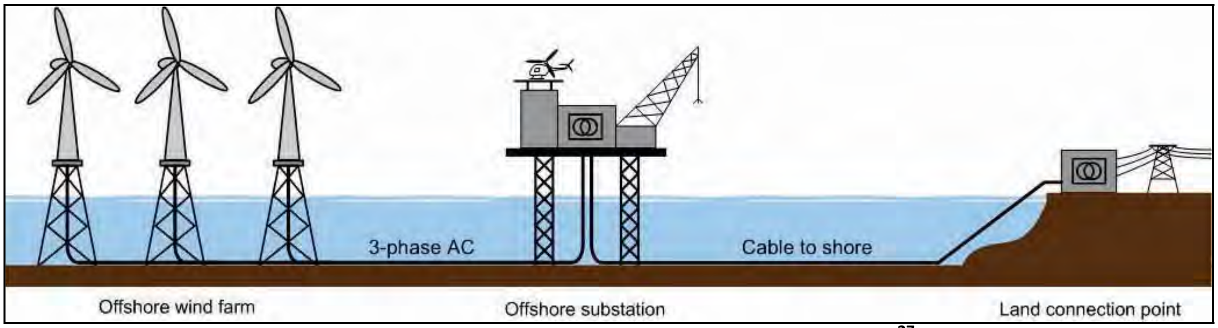


Figure 3.10: System View of an Offshore Wind Project[27]

3.2.1 Wind Turbines

Wind turbines are the electricity generating component of an offshore wind plant. As shown in Figure 3.11, the turbine sits atop the support structure, which is comprised of the tower and foundation. The standard turbine design consists of a nacelle housing the main mechanical components (i.e. gearbox, drive shaft, and generator), the hub, and the blade-rotor assembly (see Figure 3.12).

Offshore wind turbines have historically been adaptations of onshore designs, although some manufacturers are now developing new models designed specifically for the offshore environment. International standards for wind turbine classes have been defined to qualify turbines for their suitability in different wind speed and turbulence regimes. Since all of the existing standards treat either onshore or marine offshore turbine designs, close cooperation with the manufacturer and other project stakeholders (e.g. funding and/or insurance entities) will be required during turbine model selection.

Early offshore installations deployed small (less than 1 MW) wind turbines, which was the typical land-based turbine size at the time. To date, Vestas and Siemens have been the most prominent offshore wind turbine suppliers. These two suppliers were among the first to offer offshore technology, entering the market in 2000 and 2003, respectively. Consequently, Vestas' V80 2 MW and V90 3 MW models have been installed predominantly throughout Europe, as have Siemens' 2.3 MW and 3.6 MW models. These turbines have rotor diameters of between 80 and 107 m, and hub heights between 60 and 105 m, which are significantly larger than the turbines deployed in the earliest projects.

In recent years, larger offshore turbines have been developed by BARD Engineering, AREVA Multibrid, and REpower. These 5 MW machines stand at a 90 meter or greater hub height, with rotor diameters of 116 to 122 m. These "next generation" turbines are the first batch of machines designed more specifically for offshore applications, as exhibited by their greater rated capacity and offshore-specific design features. Vestas is also designing a 112 rotor diameter version of its 3 MW machine, which may be available for offshore installations within the next few years.

[27] Source: Troll Wind Power (www.trollwindpower.no). Used with permission.

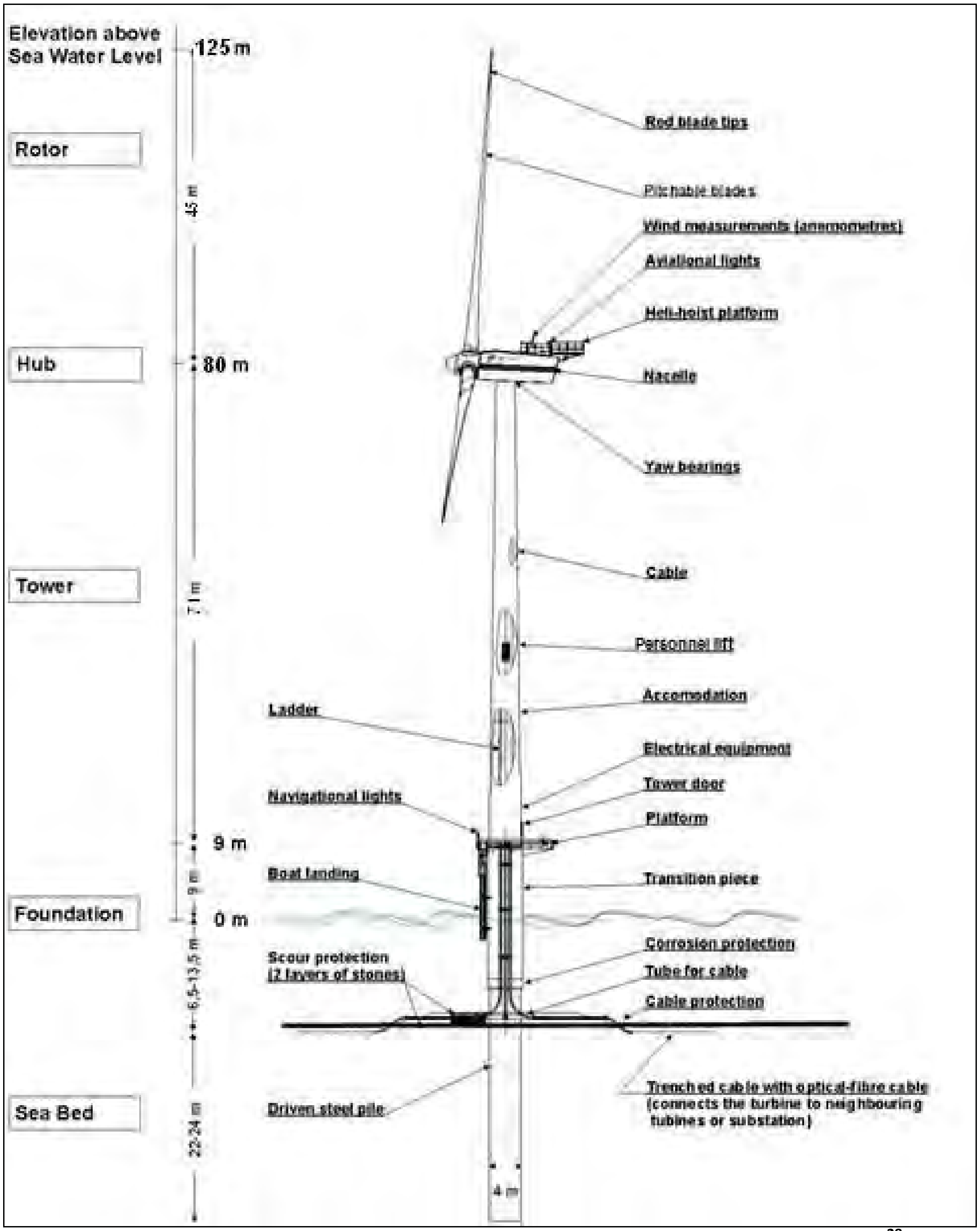


Figure 3.11: Principal Components and Dimensions of an Offshore Wind Structure[28]

Other manufacturers are also in the process of developing offshore turbine models, including Clipper and Enercon, but these designs have not reached the same level of commercial development as the turbines offered by Vestas, Siemens, BARD, AREVA Multibrid, and REpower. General Electric formerly offered a 3.6 MW offshore turbine, but has since exited the offshore market in order to focus on its onshore product line.

[28] Source: Modified from the Horns Rev wind project, Vattenfall AB. Used with permission.

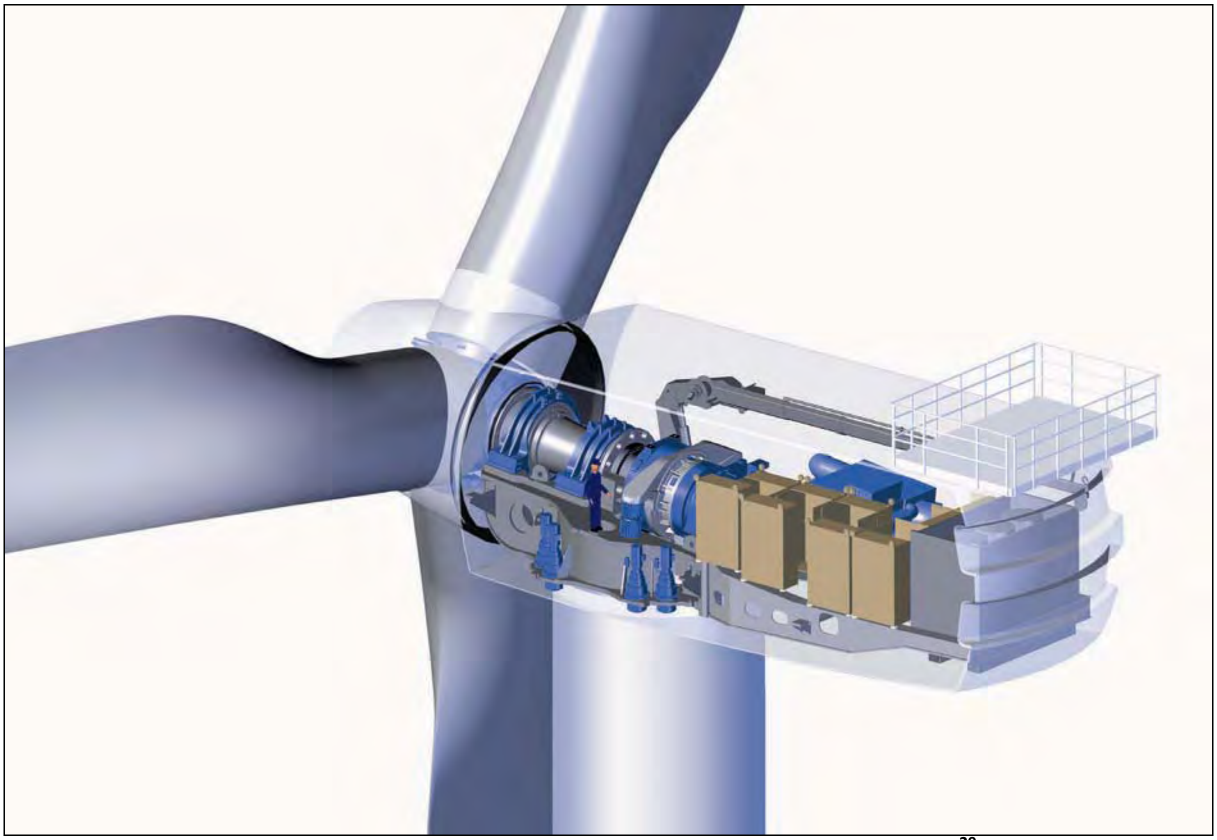


Figure 3.12: Main Components of a Horizontal Axis Wind Turbine[29]

Turbines specially designed and/or type-certified for offshore operation have components and characteristics suited for long-term operation in their environments. Among the systems unique to offshore-specific turbines are special climate control systems for the nacelle and other sensitive components and enhanced corrosion protection.

Several design guidelines and standards have been developed nationally and internationally that apply to wind turbines, wind turbine foundations and offshore structures. While the United States does not currently have any specific standards for offshore wind turbine design and construction, several European institutions do. Germanischer Lloyd (GL), Det Norske Veritas (DNV), and TUV Nord are among the bodies that offer type certification and guidelines for offshore wind turbines and related components and processes. Additionally, the IEC 61400-3 International Standard *Design Requirements For Offshore Wind Turbines* (2008) provides criteria for offshore site conditions assessment, and establishes five critical design requirements for offshore wind turbine structures.[30] These guidelines were developed to ensure that type-certified wind turbines, support structures and related processes meet the requirements dictated by the site conditions. In the United States there are ongoing efforts to establish guidelines that integrate the American Petroleum Institute's (API) recommended practices (API RP-2A) for offshore platforms into the offshore wind industry's practices.[31]

[29] Source: REpower Systems AG. Used with permission.
[30] *Offshore Wind Turbines* (September 2007). IEC Web site: http://www.iec.ch/online_news/etech/arch_2007/etech_0907/prodserv_2.htm.
[31] Comparative Study of OWTG Standards (June 29, 2009). MMI Engineering.

Table 3.1 summarizes today's commercially available offshore wind turbine technologies. The availability of some models is limited, however, either due to supply constraints or due to the lack of a 60 Hz version required for installations in North America (European versions are 50 Hz). These limitations narrow the list of turbine models available today for installation in the United States to five: the Vestas V80, V90, and V112, and the Siemens SWT-2.3 and SWT-3.6. Manufacturers without 60 Hz versions of their product today are likely to build United States compatible units in the future once they become confident that a sustainable offshore market is established. Siemens, for example, has tentative plans to release a 60 Hz version of their 3.6 MW machine at the end of 2010.

While the offshore-specific turbines do have certain advantages for both salt- and fresh-water projects, there is merit in considering land-based turbines for use in the Great Lakes. Doing so significantly increases the list of 60 Hz wind turbines available for use in the Lakes' IEC Class I and II wind regimes. Employing land-based turbine technology may also facilitate construction and logistics as United States installers are already familiar with these models, and many of the components are smaller and lighter than the large 5 MW turbines. The installation of onshore turbine models in a Great Lakes wind project may, however, cause concerns with IEC safety class requirements. Onshore turbine designs modified for the offshore environment are required to meet the load requirements and safety standards for the offshore environment, as specified in documents such as IEC 61400-3, which may differ from onshore requirements. Final turbine selection will ultimately be based upon observed site conditions, adherence to safety standards, manufacturer support, and project economics.

Table 3.1: Commercially Available Offshore Wind Turbines Looking Forward

Manufacturer	Model	Estimated Date of Availability	Rated Power (MW)	Grid Frequency (Hz)	Rotor Diameter (m)	Hub Height (m)	No. Turbines Installed[32]
BARD	5.0	2008-2009	5	50	122	90	1
AREVA Multibrid	M5000	2005	5	50	116	90	6
REpower	5M	2005	5	50	126	90	15
Siemens	3.6	2005/2011	3.6	50/60	107	80, 83.5	134
Siemens	2.3	2003	2.3	50, 60	82, 93	60-80	221
Vestas	V80	2000	2	50, 60	80	67, 80	208
Vestas	V90	2004	3	50, 60	90	80, 105	163
Vestas	V112	2011	3	50, 60	112	84, 94, 119	0

3.2.2 Towers and Foundations

Offshore wind turbines are typically mounted on tubular towers that range from 60 to 105 meters above the water surface. Lattice-type towers can also be used. The towers are fixed to the foundation, often employing a transition piece as an interface between the tower and foundation. These towers allow for the turbine to capture winds at heights far above the water's surface, where the wind resource is

[32] Not including prototypes. Based on Table 2.1; only includes data from projects already commissioned at the time of the report.

generally more energetic and less turbulent.

Foundation technology is designed according to site conditions. Maximum wind speed, water depth, wave heights, currents, and soil properties are parameters that affect the foundation type and design. While the industry has historically relied primarily on monopile and gravity-based foundations, the increasing number of planned projects in deeper water has motivated research and pilot installations for more complex multimember designs with broader bases and larger footprints, such as jackets, tripods, and tripiles, to accommodate water depths exceeding 20 to 30 meters. These designs, some of which were adapted from the offshore oil and gas industry, are expected to accommodate projects installed in deep water. These basic designs, along with their pros and cons, are discussed below.

Monopile Foundation

The monopile has historically been the most commonly selected foundation type due to its lower cost, simplicity, and appropriateness for shallow water (less than 20 m). The design is a long hollow steel pole that extends from below the sea/lakebed to the base of the turbine. The monopile generally does not require any preparation of the sea/lakebed and is installed by drilling or driving the structure in to depths of up to 40 meters. The monopile is relatively simple to manufacture, keeping its cost down despite reaching weights of over 500 tons and diameters of up to 5.1 m, which can be heavier than some more complex foundation designs.

While the monopile is an appropriate foundation choice for many projects, it can be unsuitable in some applications. Although monopiles may be preferable to multi-legged or lattice foundation structures for project areas prone to ice cover, these foundations are not well suited for soil strata with large boulders. Additionally the required size of an acceptable monopile increases disproportionately as turbine size increases and site conditions become more challenging. Therefore, sites with deeper water, harsh waves and currents, and larger turbines may require the implementation of more complex and sturdier designs, such as the jacket, the tripod, or the tripile.

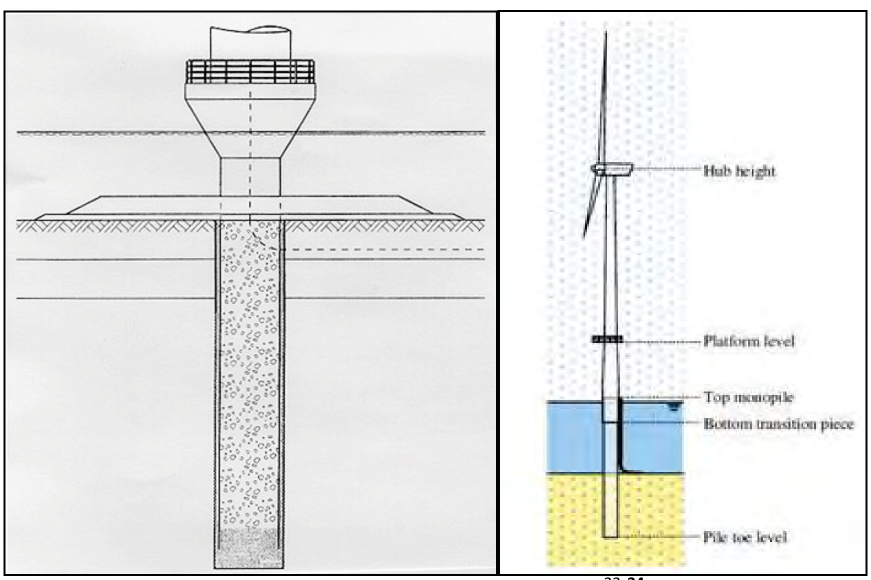


Figure 3.13: Monopile Foundation[33,34]

[33] Source: Grontmij-Carlbro. Retrieved August 2009 from Middelgrunden Web site: http://www.middelgrunden.dk. Used with permission.

Gravity Base Foundation

An alternative to the monopile foundation is the gravity base foundation. Historically deployed in shallow waters (usually less than 15 meters), the gravity foundation is now installed at depths of up to 29 meters. This technology relies on a wide footprint and massive weight to counter the forces exerted on the turbine from the wind and waves. Gravity foundations may be preferable to lattice and multi-legged structures for resisting ice loads. The gravity foundation differs from monopile in that it is not driven into the sea/lakebed, but rather rests on top of the floor. Depending upon site geologic conditions, this foundation may require significant site preparation including dredging, filling, leveling, and scour protection.

These structures are constructed almost entirely on shore of welded steel and concrete. It is a relatively economical construction process, but necessitates very robust transports to deploy on-site. Once complete, the structures are floated out to the site, sunk, and filled with ballast to increase their resistance to the environmental loads. While these structures can weigh over to 7,000 tons, they can be removed completely during decommissioning phase of the project.

Figure 3.14: Gravity Base Foundation[35]

Jacket Foundation

The jacket foundation design is commonly employed by the oil and gas industry for offshore structures. Jacketed turbine foundations that are currently deployed are four-sided, A-shaped truss-like lattice structures that support large (5 MW) offshore wind turbines installed in deep water (40+ meters). The legs of the jacket are set on the sea/lake bed and a pile is driven in at each of the four feet to secure the structure. This foundation design has a wider cross-section than the monopile, strengthening it against momentary loads from the wind and waves. However, in ice prone environments, the larger cross-sectional area could possibly make the structure more susceptible to ice loads, as ice may become packed between the legs of the structure. Despite this consideration, jacketed foundations remain a viable design alternative for a Great Lakes project, but the structures will need to be designed appropriately for onsite ice conditions. Due to its geometry, the jacket foundation is able to be relatively

[34] Source: de Vries, W.E. (2007). Effects of Deep Water on Monopile Support Structures for Offshore Wind Turbines. In Conference Proceedings European Offshore Wind 2007. Berlin. Used with permission.
[35] Source: COWI A/S for Thornton Bank Wind Project. Used with permission.

lightweight for the strength that it offers, weighing approximately 600 tons. Although its design is more complex than that of a monopile, the manufacturing process is generally well understood from the offshore oil and gas industry. The necessary materials (i.e. pipes) are already available due to their prevalent use in this same industry. Once manufacturing and deployment practices can be scaled up to economically meet the needs of large projects, these foundations will likely become the predominant foundation type for deployments in deeper waters.

Figure 3.15: Jacket Foundation[36,37]

Developing Foundation Types

While the previously described designs (monopile, gravity base, and jacket) are the most likely to be considered for Great Lakes installation, additional foundation types for offshore wind turbines are currently in the concept development and prototype phase. These foundation designs are relatively new, and their usefulness for large scale deployment is currently being assessed through pilot projects and prototype demonstrators in favorable conditions. Foundation concepts such as the tripod and tripile foundations allow for installation in deep water, and are adaptations of the monopile design. Other concepts, such as the bucket and floating foundation, attempt to mitigate issues with sea/lake bed geology characteristics and extreme water depths, respectively. Some of the more prominent design concepts are discussed in more detail below.

Tripod Foundation: For deep water installations, the tripod foundation adapts the monopile design by expanding its footprint. The three legs of the structure are seated on the sea/lake bed, and support a central cylindrical section that connects to the wind turbine's base. Piles are driven through each of the three feet to secure the structure to the bed. The three supportive legs resist momentary loads exerted on the turbine. Tripod foundations are relatively complex and time consuming to manufacture, and also are more massive than jackets. In cases when using a traditional monopile becomes unwieldy for size reasons, a tripod design can reduce the amount of material needed by broadening the foundation's base.

[36] Source: Seidel. M. (2007). Jacket Substructures for the REpower 5M Wind Turbine. In Conference Proceedings European Offshore Wind 2007. Berlin. Used with permission.
[37] Source: Scaldis Salvage & Marine Contractors. Photo from Beatrice Wind Project. Used with permission.

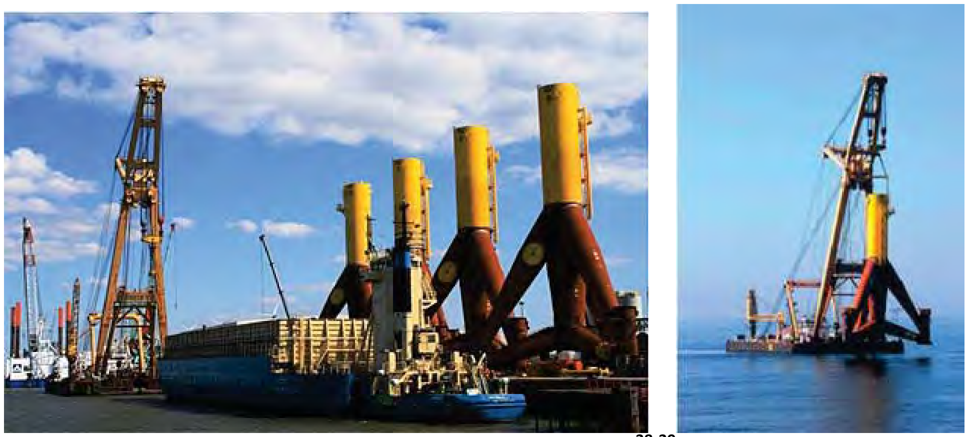


Figure 3.16: Tripod Foundation[38,39]

Tripile Foundation: The tripile foundation is also a relatively new adaption of the traditional monopile foundation. Instead of a single beam, three piles are driven into the sea/lake bed, and are connected just above the water's surface to a transition piece using grouted joints. This transition piece is connected to the turbine tower's base. The increased strength and wider footprint created by the three piles is expected to allow for turbine installation in water up to 50 meters in depth. The tripile design is easily adaptable to a variety of bottom-type conditions, as each or all of the piles can be manufactured appropriately to match site-specific conditions while still being connected to the standard transition piece.

Figure 3.17: Tripile Foundation[40,41]

Suction Bucket Alternative to Piles: Suction bucket foundations can conceivably be applied to any of the foundation types previously described as an alternative to driving piles deep into the sea/lake bed. Although research continues, the development of bucket foundations was set back by a significant failure in 2007 during a demonstration phase. Instead of a slender beam being driven deep below the surface, bucket foundations employ a wider based cylinder, which does not extend as far below the floor, but still adequately resists loading due to its greater diameter and reactive soil forces. Because of

[38] Source: AREVA Multibrid 2009. Used with permission.
[39] Source: AREVA Multibrid/Jan Oelker 2009. Used with permission.
[40] Source: de Vries, E. (November 18, 2008). 5-MW BARD Near-shore Wind Turbine Erected in Germany. *Renewable Energy World*. Retrieved July 2009 from www.renewableenergyworld.com. Used with permission.
[41] Source: Copyright BARD-Group (www.bard-offshore.de). Used with permission.

their greater width, the cylinders are not driven under the surface, but rather are vacuum-suctioned into position under the sea/lake bed. Depending on soil conditions encountered at a site, the suction bucket alternative may be preferable to deep, slender piles for economic reasons and for ease of installation.

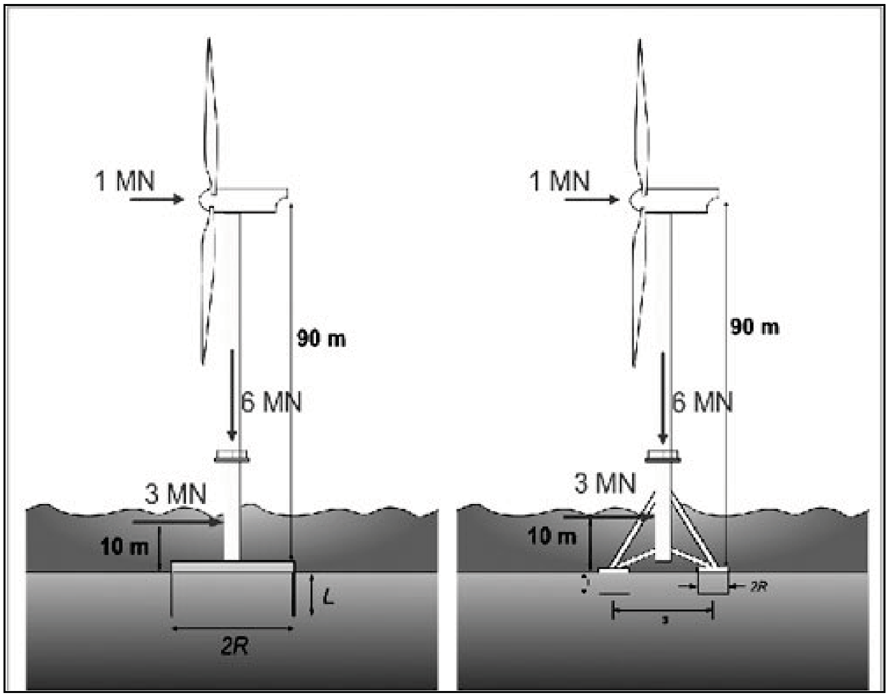


Figure 3.18: Suction Bucket Alternatives for the Monopile and Tripod Foundations[42]

3.2.3 Electrical System and Balance of Plant

Additional components of an offshore wind project include the electrical cabling, the substations, and the meteorological mast. The electrical cabling serves two functions: collection within the project, and transmission to shore. Both types of cable may have trenching requirements and specifications for armoring. Each substation typically includes one or more step-up transformers, switchgear, and remote control and communications equipment for the project. Procurement and coordination of equipment, crews, and materials for the balance-of-plant installation is a nontrivial task, due to the specialized nature of the installation and the limited number of experienced companies in the arena. Therefore, the balance-of-plant portion of development has the potential to drive project scheduling and can be a significant portion of the overall project price.

Electrical System

The typical offshore wind project's electrical system consists of the individual turbine transformers, the collection system, the offshore substation, the transmission line to the mainland, and the onshore transmission components. Each of these components can impose an electrical loss on the gross energy production collected by the plant, so electrical system design is an important aspect of the overall system.

Pad Mount/34.5 Kilovolt Transformers: Individual turbine transformers for offshore turbines differ from those for onshore turbines. Rather than being mounted on the ground, the individual turbine

[42] Source: Villalobos, A. (2009). Foundations for Offshore Wind Turbines. *Revista Ingeniería de Construcción*, v.24 n.1. Retrieved July 2009 from http://www.scielo.cl. Used with permission.

transformer is either located up tower in the nacelle, or at the base of the turbine (down tower) where it is enclosed to protect it from the harsh elements. Each transformer takes the energy generated by the turbine and converts it to approximately 34.5 kilovolts for connection with the collection system.

Collection System: The collection system is a series of submarine conductors that are laid using trenching technology, such as utilizing high pressure water jets. As shown in Figure 3.19, the collection system is designed to connect multiple turbines in each string before delivering power to the offshore substation. This design minimizes cost while maintaining the electrical reliability of the lines.

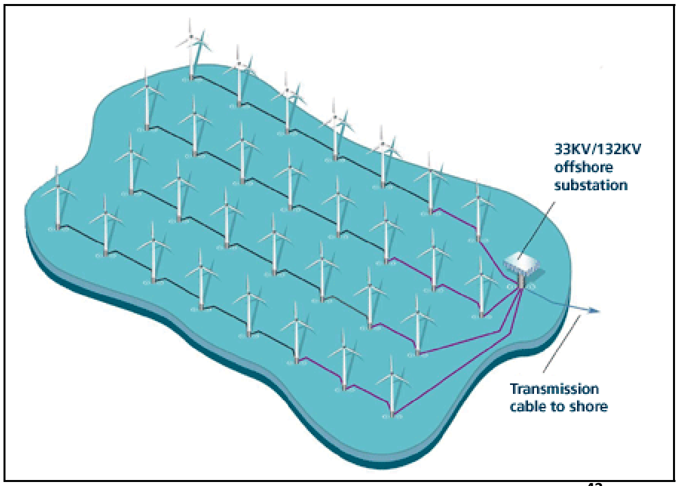


Figure 3.19: Optimal Collection System Design[43]

Offshore Substation: Lines from the collection system typically come together at the on-site offshore substation, where the power is transferred to high voltage submarine lines for transmission back to shore. The offshore substation is sized with the appropriate power rating (MVA) for the project capacity, and steps the line voltage up from the collection system voltage to a higher voltage level, which is usually that of the point of interconnection (POI). This allows for all the power generated by the project to flow back to the mainland on higher voltage lines, which minimizes the electrical line loss and increases the overall electrical efficiency.

Figure 3.20: Nysted Offshore Substation and Wind Farm[44]

[43] Source: Barrow Offshore Wind/DONG Energy. Web site: http://www.bowind.co.uk/project.shtml. Used with permission from DONG Energy.
[44] Source: Nysted Offshore Wind Project/DONG Energy. Web site: http://www.dongenergy.com. Used with permission from DONG Energy.

Transmission to Shore: Transmission lines back to shore are specified at an appropriate voltage and power rating (MVA). The size of these cables is dependent on the project's capacity and the amount of power that will be transmitted to the shore, as shown in the table below. The transmission connects the offshore system (turbines, collection system, and offshore substation) to the mainland. Like the collection system, trenching and scour protection technologies are employed to install transmission lines.

Table 3.2: Required Line Voltage for Various Project Sizes

Project Size	Minimum Line Voltage (AC)
35 MW	35 kV
70 MW	69 kV
135 MW	115 kV
160 MW	138 kV
210 MW	161 kV
300 MW	230 kV
1000 MW	345 kV
2000 MW	500 kV

High voltage underwater transmission cabling is an important design and contracting consideration during the offshore wind development process. There are few manufacturers of the appropriate cable and the fabrication and lead time is significant. The specialized installation vessels are relatively rare, costly and in high demand. These factors contribute to an installed cost for underwater transmission of around two to three times more than an equivalent voltage for land-based transmission.

Onshore Transmission Components (Point of Interconnection): Depending upon where the underwater cabling makes landfall, it may be necessary to construct traditional buried or overhead transmission lines on shore. At the onshore substation or switchyard, energy from the offshore wind project is injected into the electric power grid. If the point-of-interconnection voltage is different than that of the submarine transmission, a substation using appropriately sized transformers is used to match the point of interconnection (POI) voltage; otherwise, a switchyard is used to directly interconnect the wind project. Either the offshore or onshore substation acts as the power off-take point, where power generated by the project is metered and purchased, via Power Purchase Agreement (PPA), by a local utility or enters the Independent System Operator's merchant market.

For projects close to shore, it sometimes is not economical to construct both an offshore and an onshore substation. In these cases, the collection system is tied into a single substation (typically onshore), which also functions as the point of interconnection with the local electric grid.

AC versus DC Transmission

Traditionally, transmission of power from the project area to the electric grid has utilized high-voltage alternating current (AC) transmission lines; however, the construction of high-voltage direct current (DC) transmission lines to transmit power has become a feasible option in some cases. Although DC systems, including conversion stations and transmission lines, are significantly more expensive than an AC infrastructure, there are some advantages to DC transmission.

One advantage is lower electrical losses. AC transmission will have impedance-based line losses that limit the "reach" of the line for delivering power. DC systems have losses associated with the conversion station, but will have limited electrical line losses associated with the line impedance. The limited line losses makes DC transmission an economic option for projects that require power to be transmitted long distances to interconnect with the grid. Additionally, if the electric grid in the project's vicinity has limited availability due to a lack of lines or high congestion, a DC line can be used to transport power to a more distant, stronger point of interconnection, such as a primary load center or large generation facility. This option can be more cost effective than completing the necessary onshore network upgrades or decreasing the project capacity to interconnect to the existing transmission system. Of further interest for offshore wind projects, the use of DC transmission would allow 50 Hz turbine models to be connected to the 60 Hz North American grid, increasing the compatible turbine technology to include European offshore wind turbine models.

From an economic perspective, DC transmission becomes a financially feasible option when the revenue lost from the AC transmission system electrical line losses or the cost of the network upgrades required for project interconnection is greater than the increased cost of building a DC transmission system to a suitable substation. The existing electric infrastructure surrounding Lake Erie and Lake Ontario has multiple 115 kV to 345 kV lines and substations. AC transmission lines in this kV range are capable of transmitting up to 1000 MW of power. Based on the distance to a suitable point of interconnection, and the existing infrastructure in the region it is unlikely that a DC transmission line will be necessary to connect the project to the electric grid.

Meteorology-Lake (Met-Lake) Monitoring System

While standard practices for offshore wind development are still evolving, the installation of an offshore meteorology and lake property monitoring system prior to project construction is becoming more common, and is strongly recommended. If sited properly, the monitoring station will also bring added value through the entire operating life of the project. The purpose of the monitoring platform is to provide continuous, real-time characterization of the weather and wave conditions within the project area. It can also serve as a platform for environmental monitoring (e.g. bird and bat, lake organisms, etc.) and other related programs. An offshore monitoring platform (or platforms) is an important component to the balance of plant for an offshore wind project, as it will ultimately provide the data necessary for characterizing the site conditions, performance, and environmental impact of the project.

The platform typically accommodates an offshore meteorological mast, which has multiple uses during the project's lifetime. In the planning stage of the project, data from the mast is used for wind resource assessment. Often the platform used to qualify a site during the development phase is retained after installation to extend the climatologic record already initiated. This information is useful for verifying on-site conditions, turbine power performance testing, operational performance assessment, due diligence evaluation, and O&M management. For these purposes, the ideal location for the monitoring platform and meteorological tower is immediately upwind of the project area in the prevailing wind direction: its use for power performance testing, for example, is dependent on its unwaked placement within two to four rotor diameters of the test turbine(s).

The monitoring station can also provide valuable input data for wind forecasting and generation scheduling in the next-hour and next-day markets. Forecasting is a beneficial tool for market bidding strategy and transmission system reliability. In May 2009, NYISO enacted a Wind Management Plan, which requires all wind projects to supply meteorological data to the NYISO, and in turn to the NYISO's Forecasting Vendor. The offshore meteorological mast can be used to supply the necessary resource and climatologic information to comply with the Wind Management Plan requirements.

Figure 3.21: High-Atmosphere Monitoring Stations: Offshore Met Tower[45]

O&M Facility and Equipment

The design of the operations and maintenance (O&M) facility and the equipment procured for offshore turbine access is dictated by site-specific and environmental conditions. A well developed O&M service plan based on these parameters is essential to minimize turbine downtime, which results in lost revenue. The O&M facility, usually housed at a nearby port, provides rapid access to the project area for turbine maintenance and repairs; however, in cases where the project area is a greater distance from shore, O&M operations can conceivably be housed out of an expanded substation facility, where spare parts could be stored for immediate installation. This would allow for a quicker response time to turbine failures.

The O&M staff is outfitted with vessels to support repair efforts. Accessibility is a prime driver for availability, so vessels capable of operating safely even in slightly higher seas or more adverse conditions can improve project performance.

[45] Source: Horns Rev wind project, Vattenfall AB. Retrieved November 19, 2009 from Web site: http://www.hornsrev.dk. Used with permission from Vattenfall AB.

Figure 3.22: O&M Service Vessel[46]

In situations where site access may be precluded by lake ice and rough water conditions, helicopter access may provide a more costly but speedy alternative to get turbines up and running as soon as possible. Helicopter access from an oversized substation may prove to be more effective than from onshore, especially if the project is a great distance from shore, due to the cost and complexity of flying a helicopter a great distance while carrying turbine repair parts.

Figure 3.23: Helicopter Dropdown Access to Vestas Turbine[47]

[46] Source: South Boats SP/Mercator Media 2009. Retrieved September 2, 2009 from Web site: http://www.seawork.com. Used with permission.
[47] Source: Nicky Plok/UNI-FLY A/S. Used with permission.

3.3. Layout Considerations

Wind project layout and spacing are design considerations that can have a significant effect on project performance, size and cost. A number of factors can drive how a wind project is spatially configured. One factor is the potential constraint of limiting the project's size dimensions due to boundary issues imposed by legal, regulatory, or geophysical reasons.

Other factors, such as facility performance and production efficiency, influence turbine spacing and arrangement relative to the prevailing wind direction(s). As general practice, spacing between turbines aligned in a row is on the order of 5 to 10 rotor diameters, and spacing between rows is between 7 and 12 rotor diameters. Rows tend to be aligned perpendicular to the prevailing wind direction. The spacing goal is to reduce the impacts of wind flow disturbances (wakes) created by wind turbines in the upwind portions of a project area on the rest of the turbine array. These flow disturbances can reduce the energy output of individual turbines by 50% or more compared to unaffected turbines. They also create added turbulence to the flow field, thereby increasing mechanical loading on impacted turbines and decreasing component fatigue life. As future offshore projects become larger in size, the significance and potential impact of these "deep array" effects becomes greater. While the magnitude of losses due to turbine wakes is dependent on site-specific atmospheric conditions, wake losses will be a significant factor in determining a project layout.

Project economics also is a driving factor for turbine spacing and layout design. The wake losses described above from compact turbine spacing can be mitigated by increasing the distance between turbines; however, this action increases the balance of plant costs, since additional cabling is needed to accommodate the greater distance between machines. Non-uniformity in soil conditions and increasing water depths may also impose additional expenses as the project area is expanded. Therefore, turbine spacing is optimized to minimize wake losses, while keeping balance of plant costs at a reasonable level; the additional revenue obtained by increasing turbine spacing must be more than the additional expense of increasing the turbine spacing.

Other layout factors can include sensitivity to environmental and aesthetic impacts and to existing uses (such as vessel traffic, fishing, air space usage, etc.) within the project area. The aerial photo and project layout of the 160 MW Horns Rev wind project in Denmark (Figure 3.24 and Figure 3.25) illustrate an offshore wind project array having a turbine spacing of 7 by 7 rotor diameters. Due to wake loss considerations, the 7 rotor diameter spacing between rows at Horns Rev represents the minimum spacing that is likely to be recommended for an offshore wind project installed in the Great Lakes.

Figure 3.24: Aerial Photograph of Horns Rev Wind Project in Denmark[48]

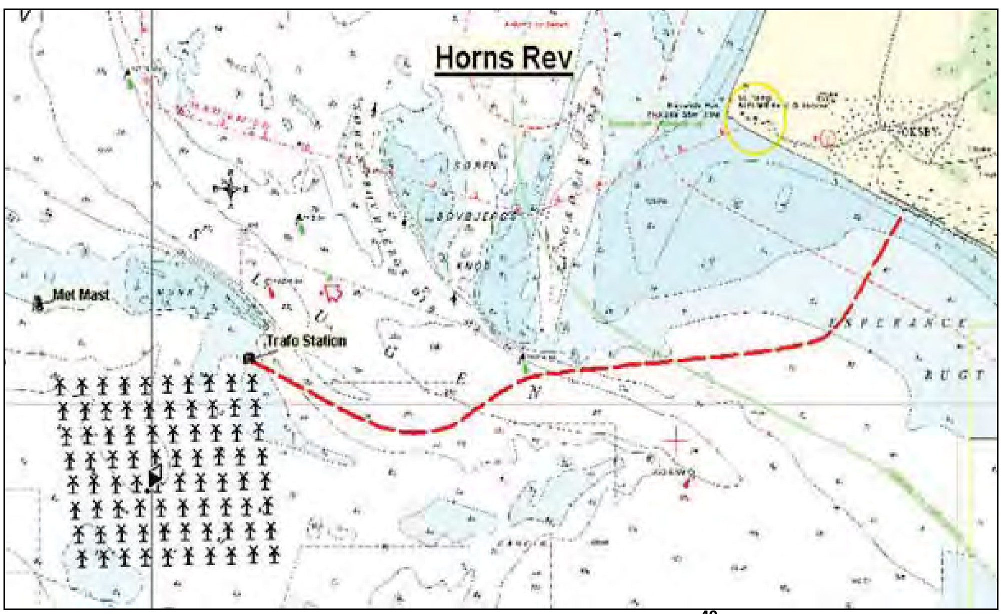


Figure 3.25: Horns Rev Project Layout[49]
(Scale: 1.0 cm to 1.7 km)

[48]Source: Horns Rev wind project/DONG Energy. Retrieved from *New Energy Focus* article: November 8, 2009. DONG Profits Down by 56% as Generation Revenue Takes Hit. *New Energy Focus*. Retrieved September 2, 2009 from Web site: http://www.newenergyfocus.com. Used with permission from DONG Energy.
[49] Source: Horns Rev wind project, Vattenfall AB. Used with permission.

3.4. Summary

This chapter has provided an overview of offshore wind system technologies and design criteria that are likely to be relevant to a proposed offshore project in the New York State waters of Lake Erie or Lake Ontario. Key considerations include the following:

- The ultimate selection of suitable wind turbine models and foundation designs will be influenced by a site-specific evaluation of the external environmental conditions of the project area, which include winds, weather, waves, currents, ice, water depths, and lakebed characteristics.
- There are a limited number of commercially available offshore-specific turbine models available today for use in the United States. Additional turbine selections may be available if onshore turbines are considered. The capacity rating of individual units is between 2 MW and 5 MW.
- Given the range of water depths and variety of soil conditions in the lakes, there is no clear preferred foundation type. Gravity, monopile, and multimember foundations may all be feasible for certain site conditions found in the Lakes.

4.0. Physical and Climatic Parameters of Lake Erie

Environmental conditions significantly affect the feasibility of offshore wind development. This chapter introduces parameters that influence project siting and feasibility based on technical constraints and economic feasibility. Key geophysical characteristics of Lake Erie are presented and their relevance to wind development is explained. Areas of particular concern requiring further research are identified. Ultimately, site-specific climatic and environmental conditions may influence costs through equipment design requirements and project engineering expenditures.

The local geology and sediment type of the lakebed are significant considerations in the turbine base structure design. A strong understanding of the geology of the Lake Erie lakebed will drive the selection of turbine foundation structural properties. Geologic information about Lake Erie's lakebed has not been well documented. A more substantial geophysical survey is recommended to better understand the local geology in potential project areas, applying methods such as soil sampling, seismic refraction, and the use of other tools such as side-scan and swath sonar.

4.1. Geology and Bottom Types

The Great Lakes Basin, including Lake Erie and Lake Ontario, were formed roughly three billion years ago during the Precambrian time. This was a time of great volcanic activity that resulted in the creation of the granite rock of the Canadian Shield. The Great Lakes Basin was flooded several times during the Paleozoic Era, which deposited lime silts, clays, sand, and salt that eventually consolidated into the limestone, shale, sandstone, halite, and gypsum bedrock that exists today.[50,51]

The most recent restructuring occurred 7,000 to 32,000 years ago during the Pleistocene Epoch, which is better known as the Ice Age. During this period, large glaciers carved the basin out of the existing bedrock. The bedrock in the shallow western basin of Lake Erie consists of hard limestone, while the bedrock in the eastern basin consists of softer shale, shaly limestone, and shaly sandstone. The softer bedrock in the eastern basin lead to more substantial glacial gouges and resulted in deeper water depths. Preglacial streams and post-glacial lake processes also contributed to the weathering of the soft eastern basin bedrock.[52]

Sediment above the underlying bedrock can be distinguished as one of two types: glacial deposits or recent sediments. Glacial deposits can be further classified into three categories: glacial till, glacio-lacustine, and glacial outwash. Glacial till consists of clay, silt, sand, pebbles, and boulders that were deposited directly by the melting ice sheet. Glacio-lacustrine deposits consist of finer sediments including sand, silt, and clay that were deposited in lakes as the glacial ice melted. Glacial outwash includes sediments deposited by flowing waters from melting glaciers and consists of coarser material, including sand and gravel.[53] Recent sediment is defined as material that was deposited after the retreat

[50] EPA and Government of Canada, 1995, *The Great Lakes: An Environmental Atlas and Resource Book*, 3rd ed., EPA 905-B-95-0001, K. Fuller et. Al. (editors), joint publication of EPA Great Lakes

[51] U.S. Army Corps of Engineers, 2005, *Known and Potential Environmental Effects of the Oil and Gas Drilling Activity in the Great Lakes*, Chicago, Ill. Available at http://www.lrc.usace.army.mil/GrtLakes/OilGas/FinalReport.pdf.

[52] Bolsenga, S.J., and C.E. Herdendorf (editors), 1993, Lake Erie and Lake St. Clair Handbook, Wayne State University Press, Detroit Mich.

[53] Cuyahoga County Great Lakes Energy Development Task Force, 2008, *Great Lakes Wind Energy Center Feasibility Study: Geological and Geotechnical Desktop Study*, Available at http://development.cuyahogacounty.us/pdf_development/en-US/GeologicalStudy.pdf.

of the last glaciers. These sediments originate from the weathering of existing rock through physical and chemical processes. Rivers and streams feeding into Lake Erie also contribute to the lakebed sediment. In general, the deep water areas contain fine grain sediments, such as silt and clay, while shallower areas with water depths of less than 10 m near the shore consist of coarser material, such as sand and gravel. The type of sediment is dependent on the energy in the waves and currents: the greater the energy, the coarser the sediment, as finer materials are swept away by the waves and currents and are deposited in deeper waters. Large boulders are not typically found in recent sediment.

Map 4.1 depicts the Lake Erie sediment types. Within a few kilometers of the coast, the sediments consist of loamy till. The loamy till is comprised of loam, silt loam, clay loam, and silty clay loam, with some pebbles, cobbles, and small boulders. Further from the coast, in the southeast portion of the study area that includes deeper water depths, the sediment consists of lake clay, silt, sand, and gravel. The sediment is generally 1 – 5 m thick, with local thicknesses up to 15 m. To the northeast, where the water depth decreases and the lake bed is more susceptible to waves, the sediment consists of coarser material including sand and gravel. The sediment in this area is generally 1 – 10 m thick, with local thicknesses up to 30 m.

Lakebed geology is an important consideration for foundation design and installation procedure, cable entrenchment methodology, and construction cost estimation. The type and depth of sediment and bedrock composition are important considerations for choice of turbine base, the level of effort to bury the cables, and depth of cable burial. For example, large boulders in the lakebed sediments could hinder turbine base installation and the lakebed composition will, in part, dictate the extent of lake ice gouging, which impacts the required depth of cable burial. Further study, including geological field data, is required to completely assess the impact of the lakebed geology on a proposed project.

4.2. Physical Lake Characteristics

Lake Erie's physical characteristics define the areas that are most feasible for development, and significantly affect the selected technology and installation procedures. Bathymetry, waves, and lake ice affect foundation design in particular. Site access and installation schedules will be affected by seasonal and extreme lake conditions. These sections outline the physical lake characteristics for Lake Erie.

4.2.1 Bathymetry

Bathymetry is the measure of a water body's depth and is an important factor in siting and designing an offshore wind project. A site's water depth affects both installation and engineering costs, which increase with deeper water. Until recent years, foundation designs limited installations to water depths of no more than approximately 30 m (100 ft); however, some pending technologies may increase the maximum depth to greater than 45 m (about 150 ft).

Lake Erie is divided into three basins, with the eastern basin being on average the deepest of the three. Map 4.2 provides a map of the bathymetry of New York's Lake Erie jurisdictional waters. These waters have an average depth of 26 m (84 ft) and a maximum depth of 59 m (194 ft). These moderate water depths make current foundation technology (described in 0) feasible over a broad area, about 92% of New York's Lake Erie waters. The steep gradient in water depth in the offshore area southwest of Dunkirk will restrict development close to the New York-Canada border. The 45 m (about 150 ft) depth contour runs from southwest to northeast then turns north into Canadian waters just to the north of Dunkirk. The lakebed becomes less steep moving northeast of Dunkirk up to Buffalo, resulting in lake depths of less than 30 m (100 ft) all the way from the New York coast to the Canadian border. This is a large area for consideration that has modest water depths well off the coast that will help limit construction costs and visual impacts from shore.

Table 4.1 summarizes the bathymetric characteristics of Lake Erie and breaks down the percentage of the study area (New York's jurisdictional Lake Erie waters) by 5 m (16.4 ft) depth increments. About 92%, or 1397 km^2, of New York's Lake Erie waters have depths of less than 45 m (about 150 ft).

Table 4.1: New York's Lake Erie Water Depth Area

Depth Bin	Area	
	(km^2)	(%)
0 – 5 m	58	3.8
5 – 10 m	95	6.3
10 – 15 m	152	10.0
15 – 20 m	269	17.7
20 – 25 m	219	14.4
25 – 30 m	168	11.1
30 – 35 m	118	7.8
35 – 40 m	119	7.8
40 – 45 m	199	13.1
45+ m	122	8.0
Total	**1519**	**100**

4.2.2 Waves

Wave loading and coupled wind-wave loading scenarios provide a basis for foundation and wind turbine system design. Turbine manufacturers and foundation designers use average and maximum wave statistics for extreme and cyclic load analyses. Loading from both breaking and non-breaking waves are included in the turbine structure design. Non-breaking waves are more prevalent at greater distances from shore and begin to break as the wave approaches shallower water near the shore. Non-breaking waves are accounted for in the fatigue loading design of the structure, while breaking waves result in higher impact loads. Larger waves typically translate into higher costs due to increased design efforts and more robust system components. Waves and sea state also have a direct impact on project installation, operational logistics, and post-construction site access for repairs and maintenance, as access to the site may be limited during rough seas.

Waves in Lake Erie are primarily wind driven, due to its orientation. The lake is very susceptible to large waves during southwest and northeast wind events. Strong winds from these directions have the longest fetch (length of water over which a wind has blown) and can drive up the sea state considerably. Seas of 1.5 m (5 ft) can be expected 30% of the time lake-wide, and 3 m (10 ft) seas can be expected three percent of the time, with the deeper eastern part of the lake being more prone to larger waves. These conditions are accounted for when designing foundations and will occasionally limit access via water vessel in case of maintenance need. Thunderstorms are responsible for some of the largest waves and are discussed further in Section 4.3.3. Wave activity follows the annual wind patterns, and as a result, the roughest conditions will occur during the fall and early winter. This can be seen in Table 4.2, which provides a monthly summary of significant wave height data from an eastern Lake Erie Buoy (Environment Canada Buoy 45142). Significant wave height is defined as the average of the highest one-third of the waves from a given wave group and is computed by applying a Beta-Rayleigh distribution.

Table 4.2: Significant Wave Heights in Eastern Lake Erie

Buoy 45142[54] (1994-2008)	Significant Wave Heights (Measured in meters)	
Month	**Average**	**Maximum**
January	-	-
February	-	-
March	-	3.2
April	0.2	2.8
May	0.3	2.8
June	0.4	2.0
July	0.4	3.1
August	0.4	2.6
September	0.6	4.4
October	0.8	5.5
November	0.8	5.2
December	-	-
Annual	**0.4**	**5.5**

Wave heights in the eastern portion of the Lake Erie are comparable to those of offshore wind projects in Europe and are not expected to be limiting factors in site selection. Depending on the vessels employed, periodically rough seas may limit access to a project site by surface construction and maintenance crafts. Current maintenance vessels can safely operate in 1-1.5 m (3-5 ft) seas to perform scheduled maintenance inspections, which are required once or twice per year per turbine, and other required maintenance. Adverse sea conditions will decrease turbine accessibility and yield lower availability for offshore turbines. Access in rougher seas may be accomplished by purpose-built maintenance vessels or helicopter, as these conditions may still be suitable for helicopter access.

4.2.3 Lake Ice

Ice imposes another set of loading criteria to be considered for foundation and system design. The effects of lake ice on the turbine design are twofold: the increased loading on the turbine structure applied directly by the ice and lower accessibility of wind project for routine and other maintenance. Depending on the nature of the ice, it can impose static and dynamic loads on structures that may be

[54] December through February data are not presented, as the data buoys are removed from service annually at the end of navigation season due to lake ice.

coupled with wind and/or water loads. These stresses are taken into account when designing the turbine base structure. In Lake Erie, ice can effectively stop waterborne traffic for months, limiting access to projects via surface vessels. The limited access will likely result in lower turbine availability and increased cost to find alternative transport modes (e.g., helicopter, hovercraft, tracked vehicle, or other vehicular access on frozen ice at the discretion of the O&M supervisor).

Formation of ice on Lake Erie begins in the west and slowly progresses east throughout the early winter. The eastern basin is typically the last portion to freeze due to the deeper water. The date of ice formation depends on the severity of the winter, but the eastern basin typically begins to freeze in mid-January (90% coverage). The maximum thickness occurs during mid-February, with ice ranging from 40 to 51 cm (16 to 20 in) thick; the ice may be thicker in bays and restricted passages. Severe winters can increase the ice thickness to 61 cm (24 in), while rafting, ridging and windrows can aggregate ice thickness in excess of 1.5 m (5 ft). As the ice pack begins to melt, prevailing westerly winds force the ice toward the east end of the lake and Buffalo Harbor can become completely blocked off. The ice flows from the wind-ice interaction will have the biggest impact on the structural design of the turbines. The ice ridges can last through the end of April and can cause considerable navigation problems, which will impact the ability of maintenance crews to quickly repair malfunctioning turbines. The last date of ice with 90% coverage, as shown in Figure 4.1, typically occurs between late March and early April, resulting in an average ice duration of about 90 days. Average ice duration for eastern Lake Erie is included in Map 4.3.

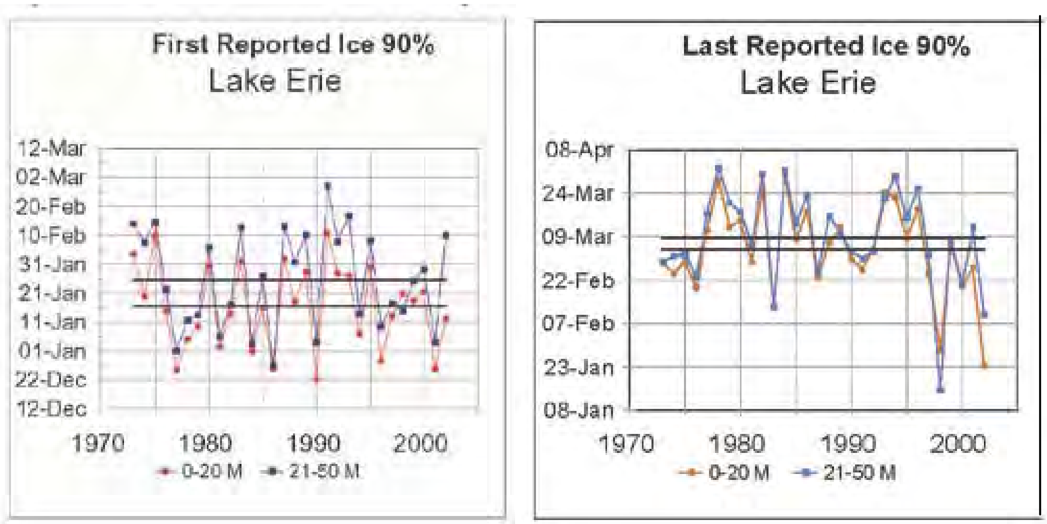


Figure 4.1: Lake Erie First and Last Date of Reported Ice > 90% Coverage [55]
The horizontal black lines represent 30 year averages.

The lack of experience in freshwater offshore wind development makes the actual impact of ice on Lake Erie difficult to quantify. Existing projects (in the Baltic Sea) and studies in Europe have shown that turbine foundations can be designed to be capable to withstand certain types of ice. Experience in European markets has also shown that offshore structures can survive in icy conditions, although fresh water ice will be somewhat harder than salt water ice. While offshore wind development in icy waters requires further study, it is technically feasible, although there will be cost implications for the

[55] Source: Assel, R. A. Great Lakes Ice Cover, First Ice, Last Ice, And Ice Duration: Winters 1973-2002. NOAA Technical Memorandum GLERL-125. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, pp. 25, 29 (2004). Retrieved from FTP site ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-125. Used with permission.

foundation design.

4.3. Climatology

A region's climatology will have an influence on the design and operation of offshore wind projects. Wind and temperature variations will affect project energy production while extreme weather events will drive the project's structural design. Project installation and operation activities are heavily weather dependent. While storms and sustained high winds may limit access to a project site during installation or operation, these conditions also yield favorably high levels of energy production. The following sections will discuss the primary climatic components that drive the structural design and energy production in the Lake Erie environment.

4.3.1 Temperature

The temperature distribution and annual variation are important contributors to how quickly the lake freezes and the corresponding ice thickness. Colder winters will result in thicker ice and longer duration of ice coverage. Table 4.3 presents a summary of the average, maximum, and minimum temperature distributions recorded at Buoy 45142, which is located near the center of the lake, and at Station DBLN6, located on the shore near Dunkirk. The coldest temperatures will occur during January and February, while the warmest temperatures will occur in June and July.

Temperatures below freezing can lead to ice accumulation on turbine blades and other components during inclement weather, which can temporarily reduce turbine output. Blade icing occurs when precipitation freezes on the turbine blades, and can also occur more often in the offshore environment due to lake spray and the increased humidity from the lake itself. The more humid environment results in increased condensation on turbine blades. When this condensation freezes, turbine performance is affected; however, in Lake Erie, where the lake is completely frozen for a good portion of the winter, ice cover limits the effect of humidity and inhibits lake spray.

Extreme cold temperatures can damage the turbine components unless properly addressed (e.g., heaters in the turbine nacelle). Both extreme high and extreme low temperatures can cause turbines to shut down to protect system components, resulting in lost production. While the magnitude of these losses is dependent on the operable range of the turbine technology, the usual operable range is from -20°C to +40°C.

Table 4.3: Temperature Distribution in Eastern Lake Erie

	Buoy 45142[56] Temperature (°C)			Station DBLN6 (Dunkirk) Temperature (°C)		
Month	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
January	-	-	-	-2.0	20.6	-18.1
February	-	-	-	-2.0	21.8	-18.3
March	2.2	25.8	-12.6	1.0	25.6	-18.3
April	5.4	28.0	-6.9	6.4	26.1	-6.6
May	10.6	23.9	2.3	12.5	29.9	1.8
June	17.5	27.0	4.9	18.8	32.2	7.7
July	21.4	28.5	11.4	21.6	31.3	10.9
August	21.7	28.2	8.0	21.5	30.2	10.1
September	18.7	28.0	7.3	18.1	31.7	3.5
October	12.6	24.7	2.3	12.2	27.5	-0.4
November	7.4	18.9	-6.1	6.4	21.5	-6.9
December	-	-	-	0.9	20.9	-15.2
Annual	**13.8**	**28.5**	**-13.6**	**9.6**	**32.2**	**-18.3**

[56] December through February data are not presented, as the data buoys are removed from service annually at the end of navigation season due to lake ice.

4.3.2 Winds

The prevailing wind direction in the eastern portion of Lake Erie is from the southwest and west-southwest as shown by the observed wind roses in Figure 4.2. The small increase in percentage of time to the south-southeast at Dunkirk is most likely due to the periodic lake breeze that is present during the summer months. The prevailing wind direction will be an important factor to account for in the turbine layout design.

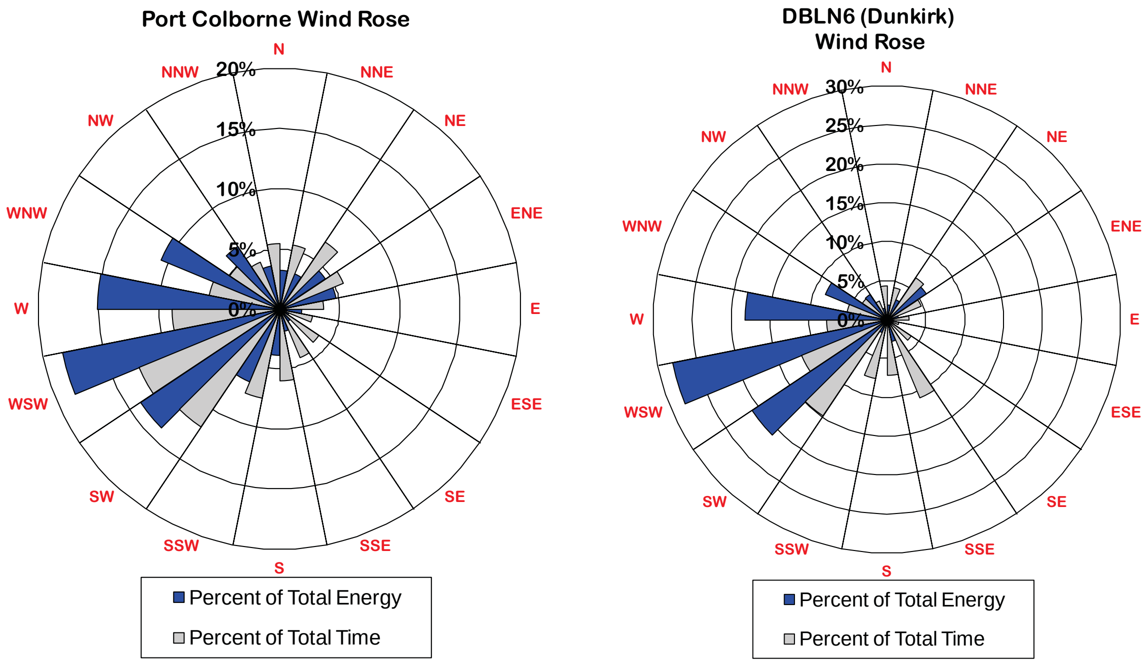


Figure 4.2. Wind Roses for Lake Erie[57]

To be financially feasible, large-scale offshore wind development typically requires annual average wind speeds of at least 7.5 m/s (16.8 mph); most of the offshore projects operating or planned in Europe and the eastern United States are in locations where winds average between 8.5 and 9.5 m/s (19.0 and 21.3 mph) at hub height.

Using atmospheric data and mesoscale modeling, AWS Truewind has mapped the whole Great Lakes region. A color coded depiction of the predicted average wind speeds at a height of 80 m over New York's Lake Erie waters is included in Map 4.4. In general, the offshore wind speeds close to the Erie coast average between 7 and 8 m/s, while slightly higher speeds of slightly over 8 m/s (17.9 mph) occurring 3 to 5 km (1.9 to 3.1 mi) off the coast up to about the Erie County border. The slight acceleration in the near-shore average wind speeds is due to the orientation of the coastline (parallel to the prevailing wind direction) and the relatively steep drop-off in elevation from the Alleghany Plateau down to the water. This could result in a slight local acceleration, but it is important to note that these wind speeds are only marginally higher than the surrounding area. The wind speeds pick up again in the open waters near the Canadian border, but this area is largely undevelopable within the foreseeable future due to the design limitation of water depths of greater than 45 m (148 ft). The wind speeds drop off somewhat to the northeast near Buffalo in areas that are slightly more sheltered by the coast.

[57] Source: AWS Truewind, LLC.

Table 4.4 contains a breakdown of the lake's area by wind speed range. The majority of New York's Lake Erie waters fall in the 7.75 m/s (17.3 mph) to 8.0 m/s (17.9 mph) speed range. Ninety-four percent of the lake experiences mean wind speeds of greater than 7.5 m/s (16.8 mph) and 28% of the lake experiences mean wind speeds of greater than 8.0 m/s (17.9 mph). Eighty-seven percent (1323 km^2) of New York's Lake Erie waters have mean wind speeds greater than 7.5 m/s (16.8 mph) and depths of less than 45 m (148 ft).

Table 4.4: Lake Erie Wind Resource Breakdown

Speed Bin (70 m)	**Area**	
	(km^2)	**(%)**
< 7.5 m/s	88	5.8
7.5 – 7.75 m/s	95	6.3
7.75 – 8.0 m/s	913	60.1
8.0 – 8.25 m/s	423	27.8
Total	**1519**	**100**

Table 4.5 provides a summary of the seasonal distribution of wind variations and extremes at two sites: one offshore and one on the coast near Dunkirk. The strongest winds will typically occur in the fall into early winter due to strong pressure gradients in the area during the fall/winter. The uncertainty in the offshore wind resource remains relatively high due to the lack of a consistent, wide-spread monitoring campaign in Lake Erie. There are only a handful of mid-lake buoys that monitor the wind at approximately 5 m (16 ft) above the lake surface. This uncertainty could be minimized with a structured mast-based measurement program near the developable areas, at a height closer to the hub height of offshore wind turbines. Measurements using alternative methods, including sodar and lidar, would also be very beneficial for characterizing the wind resource on the lake.

Table 4.5: Wind Variations at Lake Erie Coastal and Offshore Stations

	NDBC Buoy 45142 (1994 – 2008)		NDBC Station DBLN6 (1995-2008)	
	Average Speed (m/s)	**Peak Gust (m/s)**	**Average Speed (m/s)**	**Peak Gust (m/s)**
January[58]	-	-	7.4	34.4
February	-	-	6.5	31.1
March	2.9	21.0	6.0	31.2
April	3.8	17.9	5.7	23.2
May	4.5	26.3	5.0	25.3
June	4.3	22.3	4.0	20.7
July	4.8	20.2	4.1	22.2
August	4.8	19.2	3.7	18.7
September	5.7	21.1	4.3	24.7
October	6.7	25.2	5.3	30.7
November	6.4	27.4	6.5	32.6
December	-	-	7.2	33.4
Annual	**4.9**	**27.4**	**5.5**	**34.4**

While storms and extreme events can impart significant, prolonged loads on wind project system components, offshore turbines are designed to safely withstand severe wind events (e.g., 70 m/s (157 mph) gusts and 50 m/s (112 mph) sustained speeds[59]). Wind turbines will automatically shut down in some circumstances (i.e. winds over 25 m/s (56 mph), unbalanced ice loads) to limit loading on the structure and components. The ranges of wind and temperature values occurring on Lake Erie are comparable to those of existing offshore wind projects and do not represent significant barriers to development.

4.3.3 Extreme Events

The most frequent severe weather occurs during the fall over Lake Erie. Thunderstorms are responsible for the strongest winds and most hazardous lake conditions. Thunderstorms can occur all year, but are most frequent from April to September, with maximum frequency in June. On or near shore, thunderstorms will occur about 25 to 35 days of the year. During the peak thunderstorm season, this area averages about five to eight thunderstorm days per month. While most turbine designs include lightning protection, a high incidence of thunderstorms has the potential to affect turbine availability in the event of lightning damage to a wind turbine's physical and electrical components.

[58] December through February data are not presented, as the data buoys are removed from service annually at the end of navigation season due to lake ice.
[59] Source: Specifications for GE 3.6 Offshore Turbine, IEC 61400-1 Safety Class IB.

The orientation of the lake parallels the prevailing wind direction. During prolonged strong wind events from the southwest (or northeast) water will be forced from one end of the lake to the other. This phenomenon is known as wind set-up. Wind set-up can cause differences in water depth as large as 4 m (14 ft) between Toledo and Buffalo. When wind set-up is combined with a sudden drop in wind speed or change in atmospheric pressure the resulting storm surge will slosh back and forth in tide-like fashion. This phenomenon is known as a seiche and can cause large fluctuations in water levels over short time periods (wave period of about 14 hours). Besides the additional loading associated with wind set-up events, these fluctuations alter the effective turbine hub height above the water, which is a consideration for energy production estimation.

4.4. Physical Lake Parameter Comparison Table

A summary of Lake Erie's physical parameters compared to Lake Ontario is included in Table 5.6 in Section 5.4 of the report.

4.5. Maps

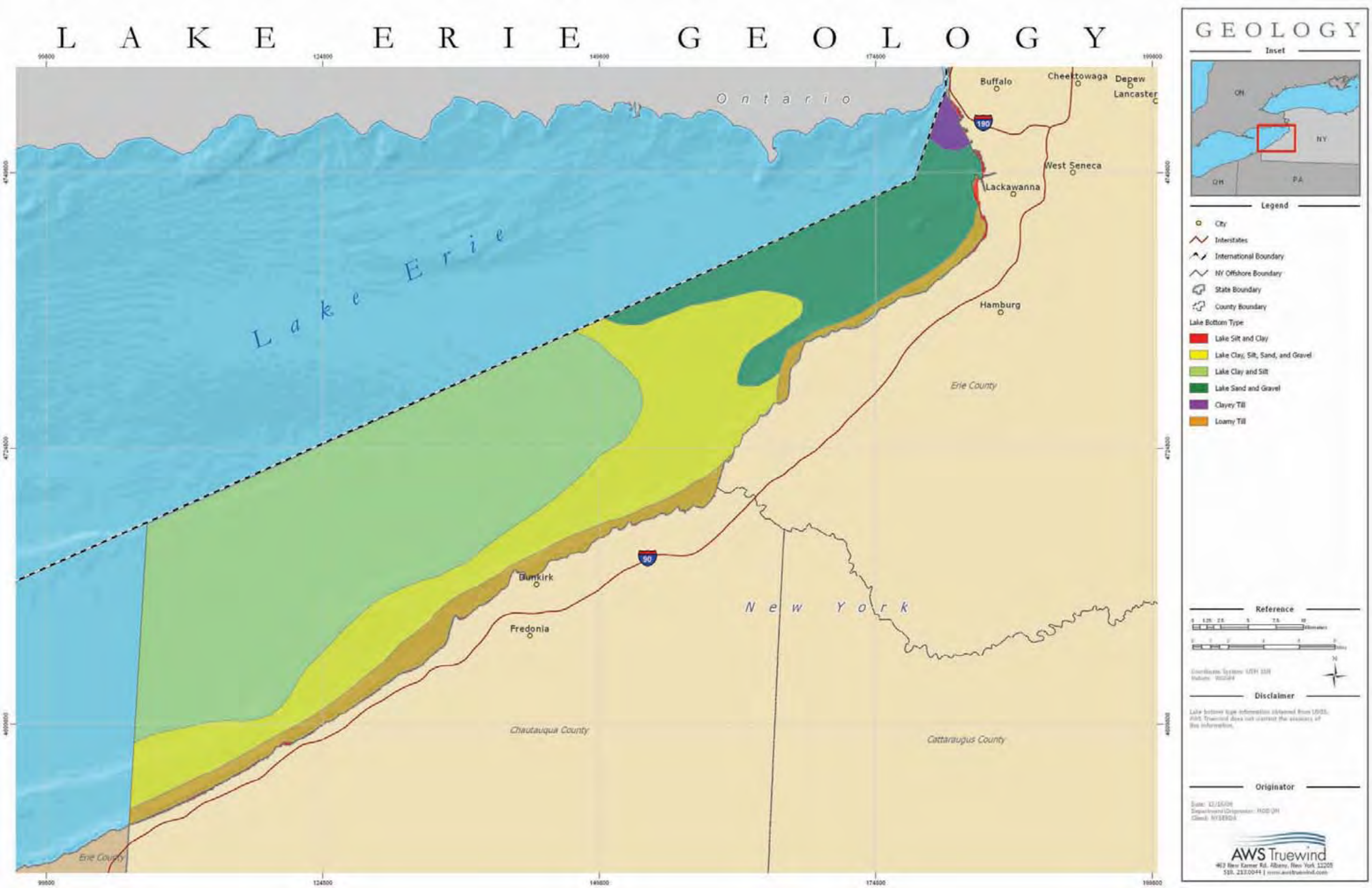
Map 4.1: Lake Erie Geology

Map 4.2: Lake Erie Bathymetry

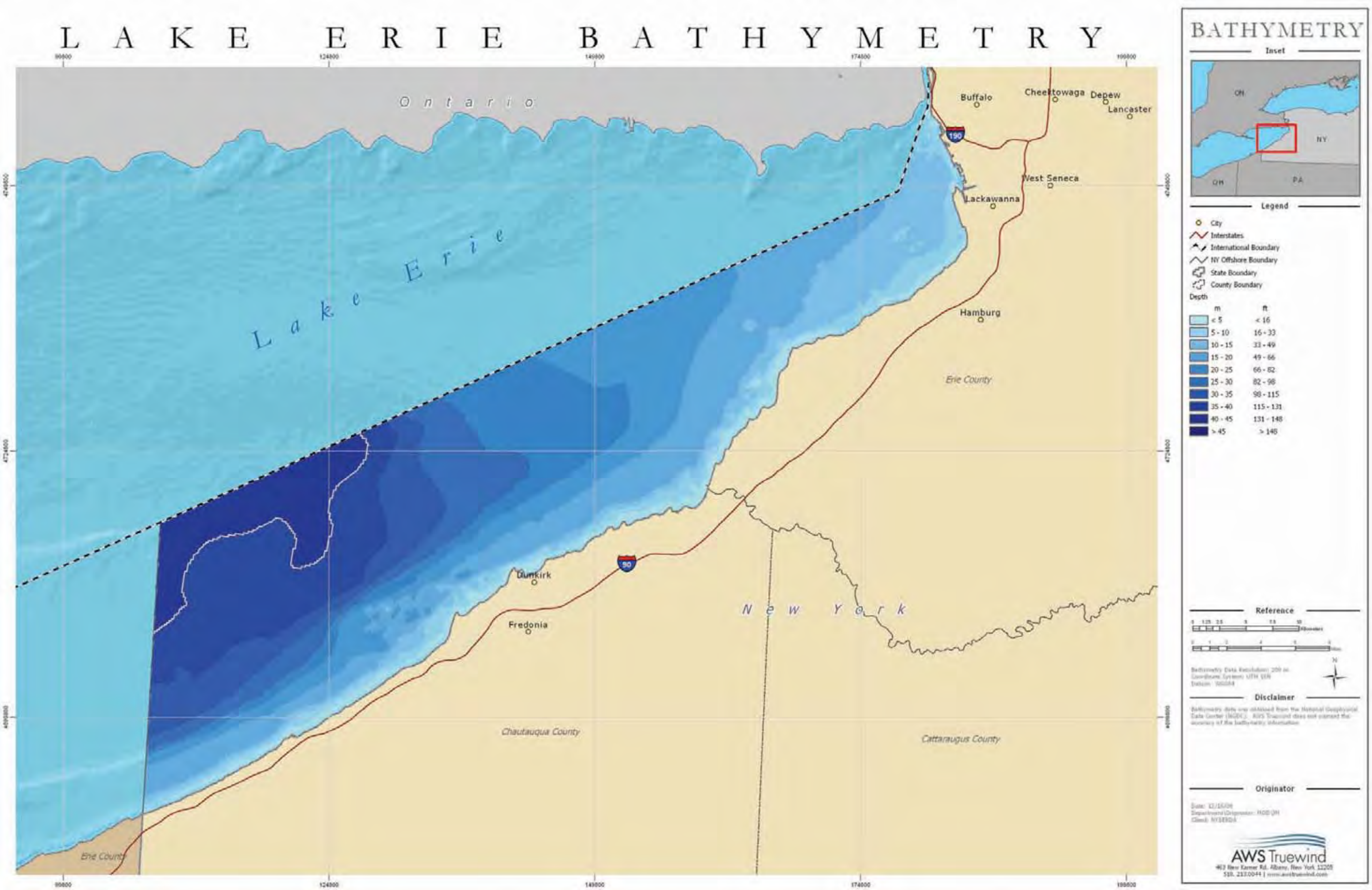
Map 4.3: Lake Erie Average Ice Duration Winters 1973-2002

Map 4.4: Lake Erie Wind Resource at 80 m

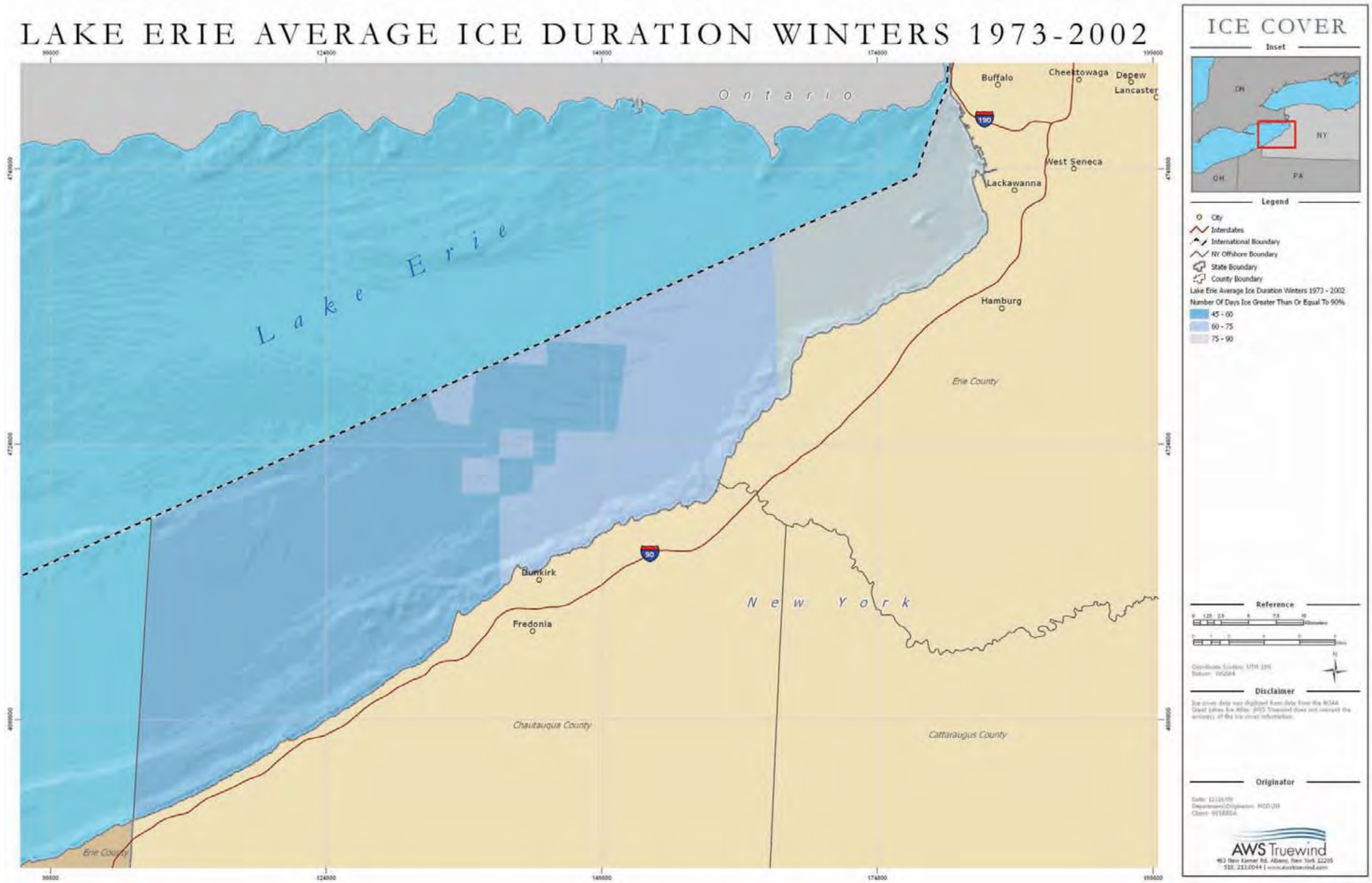
Map 4.1: Lake Erie Geology



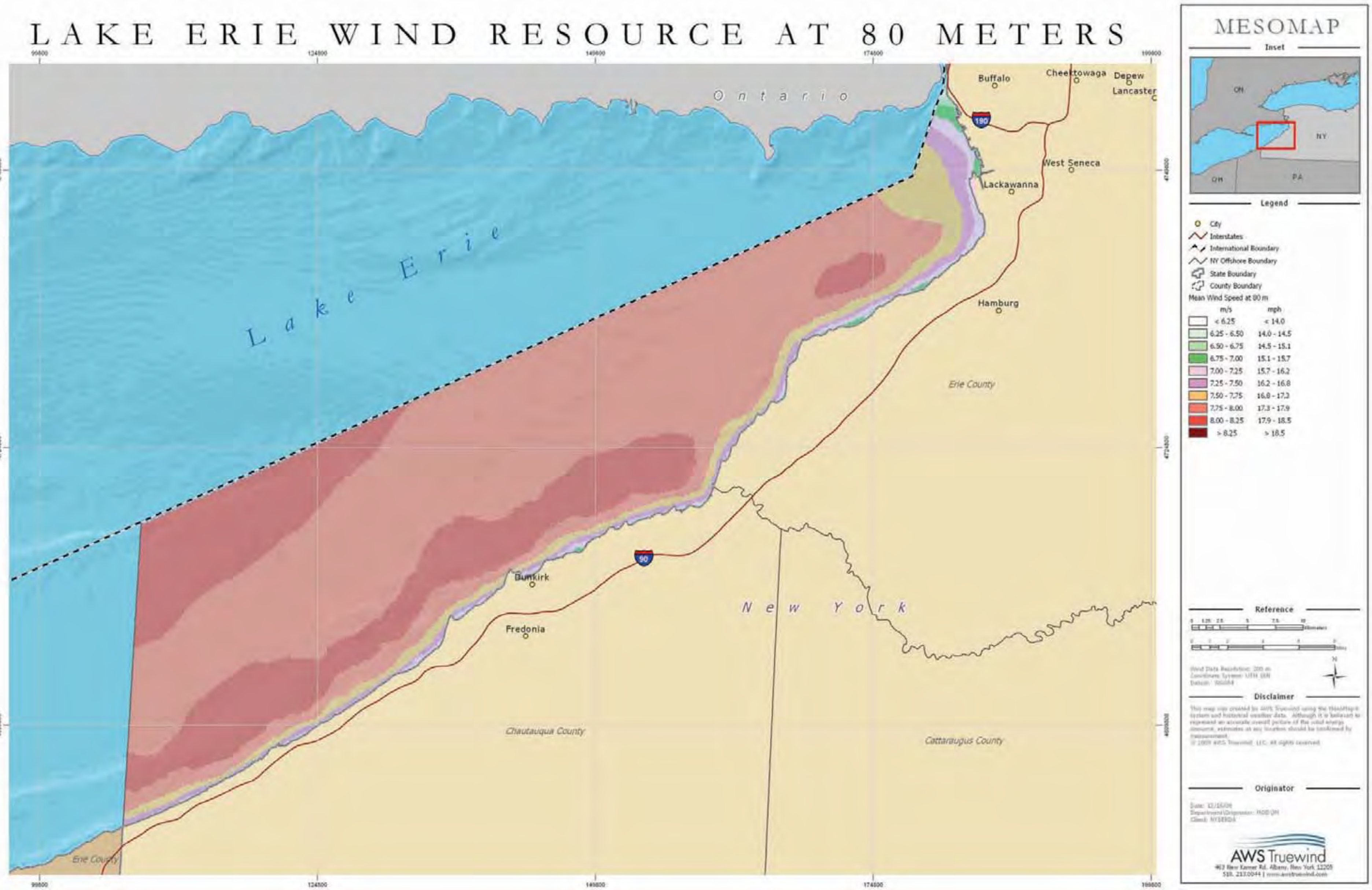
Map 4.2: Lake Erie Bathymetry



Map 4.3: Lake Erie Average Ice Duration Winters 1973-2002



Map 4.4: Lake Erie Wind Resource at 80 m



5.0. Physical and Climatic Parameters of Lake Ontario

Environmental conditions significantly affect the feasibility of offshore wind development. This chapter introduces parameters that influence project siting and feasibility based on technical constraints and economic feasibility. Key geophysical characteristics of Lake Ontario are presented and their relevance to wind development is explained. Areas of particular concern requiring further research are identified. Ultimately, site-specific climatic and environmental conditions may influence costs through equipment design requirements and project engineering expenditures.

The local geology and sediment type of the lakebed are significant considerations in the turbine base structure design. A strong understanding of the geology of the Lake Ontario lakebed will drive the selection of turbine foundation structural properties. Geologic information about Lake Ontario's lakebed has not been well documented, even less so than Lake Erie. A more substantial geophysical survey is recommended to better understand the local geology in potential project areas, applying methods such as soil sampling, seismic refraction, and the use of other tools such as side-scan and swath sonar.

5.1. *Geology and Bottom Types*

The Great Lakes Basin, including Lake Erie and Lake Ontario, were formed roughly three billion years ago during the Precambrian time. This was a time of great volcanic activity that resulted in the creation of the granite rock of the Canadian Shield. The Great Lakes Basin was flooded several times during the Paleozoic Era, which deposited lime silts, clays, sand, and salt that eventually consolidated into the limestone, shale, sandstone, halite, and gypsum bedrock that exists today.[60,61]

The most recent restructuring occurred 7,000 to 32,000 years ago during the Pleistocene Epoch, which is better known as the Ice Age. During this period, large glaciers carved the basin out of the existing bedrock. The bedrock of Lake Ontario principally consists of Dolostone and Limestone.[62]

Sediment above the underlying bedrock can be distinguished as one of two types: glacial deposits or recent sediments. Glacial deposits can be further classified into three categories: glacial till, glacio-lacustine, and glacial outwash. Glacial till consists of clay, silt, sand, pebbles, and boulders that were deposited directly by the melting ice sheet. Glacio-lacustrine deposits consist of finer sediments including sand, silt, and clay that were deposited in lakes as the glacial ice melted. Glacial outwash includes sediments deposited by flowing waters from melting glaciers and consists of coarser material, including sand and gravel.[63] Recent sediment is defined as material that was deposited after the retreat of the last glaciers. These sediments originate from the weathering of existing rock through physical and chemical processes. Rivers and streams feeding into Lake Ontario also contribute to the lakebed sediment. In general, the deep water areas contain fine grain sediments, such as silt and clay, while shallower areas with water depths of less than 10 m near the shore consist of coarser material, such as

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[60] EPA and Government of Canada, 1995, *The Great Lakes: An Environmental Atlas and Resource Book*, 3rd ed., EPA 905-B-95-0001, K. Fuller et. Al. (editors), joint publication of EPA Great Lakes.
[61] U.S. Army Corps of Engineers, 2005, *Known and Potential Environmental Effects of the Oil and Gas Drilling Activity in the Great Lakes*, Chicago, Ill. Available at http://www.lrc.usace.army.mil/GrtLakes/OilGas/FinalReport.pdf.
[62] Preliminary integrated geologic map databases for the United States: Delaware, Maryland, New York, Pennsylvania, and Virginia. Available at http://pubs.usgs.gov/of/2005/1325/.
[63] Cuyahoga County Great Lakes Energy Development Task Force, 2008, *Great Lakes Wind Energy Center Feasibility Study: Geological and Geotechnical Desktop Study*, Available at http://development.cuyahogacounty.us/pdf_development/en-US/GeologicalStudy.pdf.

sand and gravel. The type of sediment is dependent on the energy in the waves and currents: the greater the energy, the coarser the sediment, as finer materials are swept away by the waves and currents and are deposited in deeper waters. Large boulders are not typically found in recent sediment.

Map 5.1 depicts the Lake Ontario sediment types. Much less data is available for Lake Ontario as compared to Lake Erie and the data that does exist is less complete. The section of missing data in the map exists due to differences between on- and off-shore sedimentary detection techniques. The missing data happens to overlap a good portion of the developable area due to water depth restrictions. Most of the sediments in the deeper areas of the lake consist of fine-grained stratified sediment, with typical thicknesses of 1 m to 30 m, with the thicker areas of sediment located in deeper waters. These sediments consist primarily of clay, silt and very fine sand, with some fine sand and coarser grained sediment. Sediments closer to the coast consist primarily of coarse-grained sediment and till. The coarse grained sediments include sand and gravel, with some silt and clay. The till consists of poorly sorted sediment deposited by retreating glaciers, including grainy sediment with sizes ranging from clay to boulders (millimeters to 3+ meters in size). The depth of this sediment ranges from 1 m to 15 m. Deeper sediments can be found near Irondequoit Bay near the inlet of the Genesee River, where coarse-grained material in transported from the river into the near-shore lake area. The lakebed in this area consists mostly of coarse-grained sediment and has thicknesses of up to 120 m. As mentioned previously, data closer to the coast is largely unavailable and will require further research to fully define the sediment type and thickness.

Lakebed geology is an important consideration for foundation design and installation procedure, cable entrenchment methodology, and construction cost estimation. The type and depth of sediment and bedrock composition are important considerations for choice of turbine base, the level of effort to bury the cables, and depth of cable burial. For example, large boulders in the lakebed sediments could hinder turbine base installation and the lakebed composition will, in part, dictate the extent of lake ice gouging, which impacts the required depth of cable burial. Further study, including geological field data, is required to completely assess the impact of the lakebed geology on a proposed project.

5.2. Physical Lake Characteristics

Lake Ontario's physical characteristics define the areas that are most feasible for development, and significantly affect the selected technology and installation procedures. Bathymetry, waves, and lake ice affect foundation design in particular. Site access and installation schedules will be affected by seasonal and extreme lake conditions. These sections outline the physical lake characteristics for Lake Ontario.

5.2.1 Bathymetry

Bathymetry is the measure of a water body's depth and is an important factor in siting and designing an offshore wind project. A site's water depth affects both installation and engineering costs, which increase with deeper water. Until recent years, foundation designs limited installations to water depths of no more than approximately 30 m (100 ft); however, some pending technologies may increase the maximum depth to greater than 45 m (about 150 ft).

In contrast to Lake Erie, Lake Ontario is a much deeper lake with a significantly steeper lake depth gradient. Map 5.2 provides a map of the bathymetry of New York's jurisdictional Lake Ontario waters. These waters have an average depth of 111 m (363 ft) and a maximum depth of 241 m (790 ft). Considering the limits of current turbine foundation technology, only about 25% of the study area would be feasible for wind development. Along the southern coast, the 45 m depth contour roughly parallels the coast anywhere from 2 to 7 km from shore. Along the eastern coast, the 45 m depth contour is slightly farther from the coast. There is a fair amount of feasible area in the bays near Jefferson County. These areas will present other challenges due to lake ice, which is much less of a factor in the main body of the lake.

Table 5.1 summarizes the bathymetric characteristics of Lake Ontario and breaks down the percentage of the study area (New York's jurisdictional Lake Ontario waters) by 5 m (16.4 ft) depth increments. About 25%, or 2305 km^2, of New York's Lake Ontario waters have depths of less than 45 m (about 150 ft).

Table 5.1: New York's Lake Ontario Water Depth Area

Depth Bin	Area	
	(km^2)	(%)
0 – 5 m	292	3.2
5 – 10 m	316	3.4
10 – 15 m	298	3.2
15 – 20 m	256	2.8
20 – 25 m	270	2.9
25 – 30 m	266	2.9
30 – 35 m	234	2.5
35 – 40 m	183	2.0
40 – 45 m	190	2.1
45+ m	6926	75.0
Total	**9231**	**100**

5.2.2 Waves

Wave loading and coupled wind-wave loading scenarios provide a basis for foundation and wind turbine system design. Turbine manufacturers and foundation designers use average and maximum wave statistics for extreme and cyclic load analyses. Loading from both breaking and non-breaking waves are included in the turbine structure design. Non-breaking waves are more prevalent at greater distances from shore and begin to break as the wave approaches shallower water near the shore. Non-breaking waves are accounted for in the fatigue loading design of the structure, while breaking waves result in higher impact loads. Larger waves typically translate into higher costs due to increased design efforts and more robust system components. Waves and sea state also have a direct impact on project installation, operational logistics, and post-construction site access for repairs and maintenance, as access to the site may be limited during rough seas.

The long axis of Lake Ontario is oriented roughly east-west resulting in the roughest seas expected during strong wind events from the east or west direction sectors. Seas of 1.5 m (5 ft) can be expected 10 to 20 percent of the time lake wide, while 3 m (10 ft) seas can be expected two percent of the time. The calmest seas can be expected from May through July with waves of less than 0.3 m (1 ft) occurring 50% of the time. These conditions are accounted for when designing foundations and will occasionally limit access via water vessel in case of maintenance need. Thunderstorms are responsible for some of the largest waves and are discussed further in Section 5.3.3. Wave activity follows the annual wind patterns, and as a result, the roughest conditions will occur during the fall and early winter. This can be seen in Table 5.2, which provides a monthly summary of significant wave height data from a Lake Ontario buoy (NDBC Buoy 45012). Significant wave height is defined as the average of the highest one-third of the waves from a given wave group and is computed by applying a Beta-Rayleigh distribution.

Table 5.2: Significant Wave Heights in Eastern Lake Ontario

Buoy 45012[64] (2002-2008)	**Significant Wave Heights (Measured in meters)**	
Month	**Average**	**Maximum**
January	-	-
February	-	-
March	-	-
April	0.46	2.67
May	0.33	2.71
June	0.25	2.36
July	0.36	2.24
August	0.45	3.04
September	0.58	3.52
October	0.86	5.86
November	1.00	7.57
December	-	-
Annual	**0.54**	**7.57**

Wave heights in the eastern portion of the Lake Ontario are comparable to those of offshore wind projects in Europe and are not expected to be a limiting factor in site selection within the lake. Depending on the vessels employed, periodically rough seas may limit access to a project site by surface construction and maintenance crafts. Current maintenance vessels can safely operate in 1-1.5 m (3-5 ft) seas to perform scheduled maintenance inspections, which are required once or twice per year per turbine, and other required maintenance. Adverse sea conditions will decrease turbine accessibility and yield lower availability for offshore turbines. Access in rougher seas may be accomplished by purpose-built maintenance vessels or helicopter, as these conditions may still be suitable for helicopter access.

[64] December through March data are not presented, as the data buoys are removed from service annually at the end of navigation season due to lake ice.

5.2.3 Lake Ice

Ice imposes another set of loading criteria to be considered for foundation and system design. The effects of lake ice on the turbine design are twofold: the increased loading on the turbine structure applied directly by the ice and lower accessibility of wind project for routine and other maintenance. Depending on the nature of the ice, it can impose static and dynamic loads on structures that may be coupled with wind and/or water loads. These stresses are taken into account when designing the turbine base structure. Unlike Lake Erie, Lake Ontario is much deeper and remains largely ice-free except for some small areas of thin or slushy ice during cold snaps. The most significant ice is confined to the northeast section of Lake Ontario, from Stony Island north into the Thousand Islands region. Seventy to ninety percent coverage usually occurs by the end of January, with nearly one-hundred percent coverage and the maximum ice thickness of 50 to 65 cm (20 to 25 inches) occurring during February.[65] Depending on the location of the project and the severity of the winter, access will be limited to some extent that will lead to lower turbine availability and increased cost to find alternative transport modes (e.g., helicopter, hovercraft, tracked vehicle, or other vehicular access on frozen ice at the discretion of the O&M supervisor).

Average ice duration for New York's Lake Ontario waters is included in Map 5.3. Lake Ontario's open waters are essentially ice-free, with some ice buildup within 5 to 15 km of the coast; therefore, project siting and distance from shore will determine the effect of lake ice. The average first and last day of 90% ice coverage is presented graphically in Figure 5.1. The average duration of ice cover ranges from about 10 days in the open lake waters to about 40 days in the northeast bays.

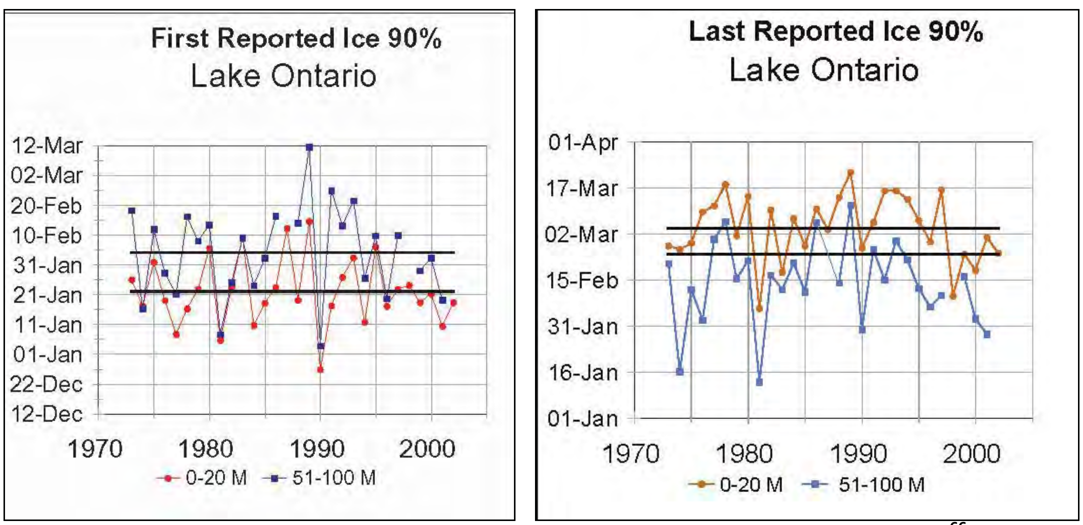


Figure 5.1: Lake Ontario First and Last Date of Reported Ice > 90% Coverage[66]
The horizontal black lines represent 30 year averages.

The lack of experience in freshwater offshore wind development makes the actual impact of ice on Lake Ontario difficult to quantify. Existing projects (in the Baltic Sea) and studies in Europe have shown that

[65] Source: *United States Coast Pilot 6: Great Lakes and their Connecting Waterways, 33rd Ed.* (2003). Washington, D.C., U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Ocean Service.

[66] Source: Assel, R. A. Great Lakes Ice Cover, First Ice, Last Ice, And Ice Duration: Winters 1973-2002. NOAA Technical Memorandum GLERL-125. NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, pp. 25, 29 (2004). Retrieved from FTP site ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-125. Used with permission.

turbine foundations can be designed to be capable to withstand certain types of ice. Experience in European markets has also shown that offshore structures can survive in icy conditions, although fresh water ice will be somewhat harder than salt water ice. While offshore wind development in icy waters requires further study, it is technically feasible, although there will be cost implications for the foundation design.

5.3. Climatology

A region's climatology will have an influence on the design and operation of offshore wind projects. Wind and temperature variations will affect project energy production while extreme weather events will drive the project's structural design. Project installation and operation activities are heavily weather dependent. While storms and sustained high winds may limit access to a project site during installation or operation, these conditions also yield favorably high levels of energy production. The following sections will discuss the primary climatic components that drive the structural design and energy production in the Lake Ontario environment.

5.3.1 Temperature

The temperature distribution and annual variation are important contributors to how quickly the lake freezes and the corresponding ice thickness. Colder winters will result in thicker ice and longer duration of ice coverage. Table 5.3 presents a summary of the average, maximum, and minimum temperature distributions recorded at Buoy 45142, which is located near the center of the lake, and at Station DBLN6, located on the shore near Dunkirk. The coldest temperatures will occur during January and February, while the warmest temperatures will occur in June and July.

Temperatures below freezing can lead to ice accumulation on turbine blades and other components during inclement weather, which can temporarily reduce turbine output. Blade icing occurs when precipitation freezes on the turbine blades, and can also occur more often in the offshore environment due to lake spray and the increased humidity from the lake itself. The more humid environment results in increased condensation on turbine blades. When this condensation freezes, turbine performance is affected; however, in the proposed project areas on Lake Ontario, where the lake is completely frozen for a good portion of the winter, ice cover limits the effect of humidity and inhibits lake spray.

Extreme cold temperatures can damage the turbine components unless properly addressed (e.g., heaters in the turbine nacelle). Both extreme high and extreme low temperatures can cause turbines to shut down to protect system components, resulting in lost production. While the magnitude of these losses is dependent on the operable range of the turbine technology, the usual operable range is from -20°C to +40°C.

Table 5.3: Temperature Distribution in Eastern Lake Ontario

	Buoy 45012[67] Temperature (°C)			Station OSGN6 (Oswego) Temperature (°C)		
Month	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
January	-	-	-	-2.8	18.6	-24.8
February	-	-	-	-3.4	13.9	-17.7
March	-	-	-	0.2	24.6	-18.5
April	5.6	13.9	0.4	7.2	28.4	-6.8
May	7.4	22.3	1.4	11.9	29.5	1.9
June	15.3	26.7	4.8	19.5	32.9	7.1
July	20.6	28.2	13.3	22.1	32.4	13.1
August	21.5	29.5	13.1	21.5	33.3	12.3
September	18.5	26.5	8.7	17.4	34.3	6.2
October	11.7	22.7	1.6	11.5	27.0	0.3
November	6.5	16.3	-5.5	5.7	22.9	-8.2
December	-	-	-	-0.4	15.2	-18.7
Annual	**14.9**	**29.5**	**-5.9**	**8.5**	**34.3**	**-24.8**

[67] December through March data are not presented, as the data buoys are removed from service annually at the end of navigation season due to lake ice.

5.3.2 Winds

The prevailing wind direction in Lake Ontario is west and west-southwest as shown by the observed wind roses in Figure 5.2. The small increase in percentage of time to the south-southeast at Oswego is most likely due to the periodic lake breeze that is present during the summer months. The prevailing wind direction will be an important factor to account for in the turbine layout design.

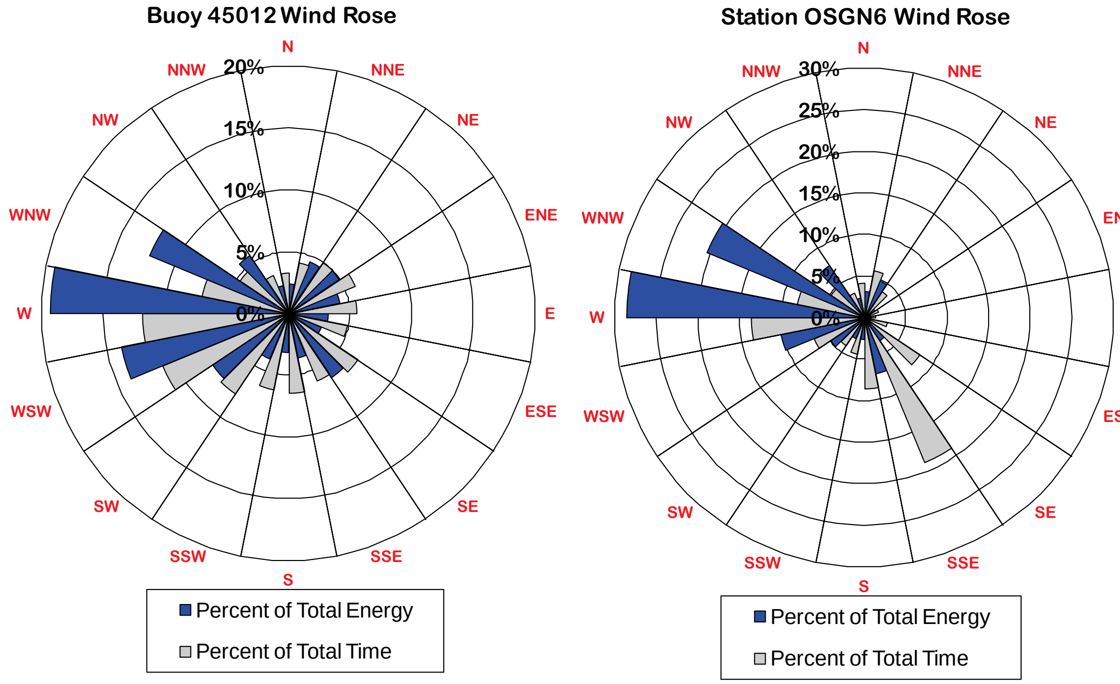


Figure 5.2. Wind Roses for Lake Ontario[68]

To be financially feasible, large-scale offshore wind development typically requires annual average wind speeds of at least 7.5 m/s (16.8 mph); most of the offshore projects operating or planned in Europe and the eastern United States are in locations where winds average between 8.5 and 9.5 m/s (19.0 and 21.3 mph) at hub height.

Using atmospheric data and mesoscale modeling, AWS Truewind has mapped the whole Great Lakes region. A color coded depiction of the predicted average wind speeds at a height of 80 m over New York's Lake Ontario waters is included in Map 5.4. In general, the offshore wind speeds within a few kilometers of the southern coast average between 7.0 and 8.0 m/s (15.6 mph and 17.9 mph). Moving farther from the coast, the average wind speed increases to just over 8 m/s (17.9 mph) and remains relatively constant over a significant portion of the lake. The maximum average speeds can be expected near the center of the lake where the frictional influences of the land are at a minimum. Slightly lower speeds can be expected near the eastern coast north of Oswego due to the influence of the coast.

[68] Source: AWS Truewind, LLC.

Table 5.4 contains a breakdown of the lake's area by wind speed range. The majority of New York's waters fall in the 8.0 m/s (17.3 mph) to 8.25 m/s (17.9 mph) speed range. Ninety-four percent of the New York's Lake Ontario waters experience mean wind speeds of greater than 7.5 m/s (16.8 mph) and seventy percent of this area experiences mean wind speeds of greater than 8.0 m/s (17.9 mph). Twenty percent (1811 km^2) of New York's Lake Ontario waters have mean wind speeds greater than 7.5 m/s (16.8 mph) and depths of less than 45 m (148 ft).

Table 5.4: Lake Ontario Wind Resource Breakdown

Speed Bin (70 m)	**Area**	
	(km^2)	**(%)**
< 7.5 m/s	523	5.7
7.5 – 7.75 m/s	414	4.5
7.75 – 8.0 m/s	1865	20.2
8.0 – 8.25 m/s	5635	61.0
8.25 – 8.5 m/s	794	8.6
Total	**9231**	**100**

Table 5.5 provides a summary of the seasonal distribution of wind variations and extremes at two sites: one offshore and one on the coast near Oswego. The strongest winds will typically occur in the fall into early winter due to strong pressure gradients in the area during the fall/winter. The uncertainty in the offshore wind resource remains relatively high due to the lack of a consistent, wide-spread monitoring campaign in Lake Ontario. There are only a handful of mid-lake buoys that monitor the wind at approximately 5 m (16 ft) above the lake surface. This uncertainty could be minimized with a structured mast-based measurement program near the developable areas at a height closer to the hub height of offshore wind turbines. Measurements using alternative methods, including sodar and lidar, would also be very beneficial for characterizing the wind resource on the lake.

Table 5.5: Wind Variations at Lake Ontario Coastal and Offshore Stations

	NDBC Buoy 45012[69] (2002 – 2008)		NDBC Station OSGN6 (2004-2008)	
	Average Speed (m/s)	Peak Gust (m/s)	Average Speed (m/s)	Peak Gust (m/s)
January	-	-	5.8	28.6
February	-	-	6.1	36.0
March	-	-	6.0	28.6
April	5.4	18.6	4.8	20.9
May	4.5	17.0	4.0	18.1
June	4.0	21.1	3.8	39.8
July	4.6	19.5	3.9	18.6
August	5.1	23.8	4.2	28.6
September	5.8	27.7	4.3	28.6
October	7.1	26.4	5.0	28.6
November	7.5	30.3	5.5	40.7
December	-	-	6.2	28.6
Annual	**5.5**	**30.3**	**5.0**	**40.7**

While storms and extreme events can impart significant, prolonged loads on wind project system components, offshore turbines are designed to safely withstand severe wind events (e.g., 70 m/s (157 mph) gusts and 50 m/s (112 mph) sustained speeds[70]). Wind turbines will automatically shut down in some circumstances (i.e. winds over 25 m/s (56 mph), unbalanced ice loads) to limit loading on the structure and components. The ranges of wind and temperature values occurring on Lake Ontario are comparable to those of existing offshore wind projects and do not represent significant barriers to development.

5.3.3 Extreme Events

Similar to Lake Erie, the most severe weather occurs during the fall over Lake Ontario. Thunderstorms are responsible for the strongest winds and most hazardous lake conditions. Thunderstorms can occur all year, but are most frequent from May to September, with maximum frequency in June. During the peak thunderstorm season, areas along the shore will average about five to eight thunderstorm days per month. Over the open water thunderstorms are less frequent and are most likely to occur overnight. While most turbine designs include lightning protection, a high incidence of thunderstorms has the

[69] January and February data are not presented, as the data buoys are removed from service annually at the end of navigation season due to lake ice.
[70] Source: Specifications for GE 3.6 Offshore Turbine, IEC 61400-1 Safety Class IB.

potential to affect turbine availability in the event of lightning damage to a wind turbine's physical and electrical components.

The winds in the northeast section of the lake near the Thousand Islands may become channeled by the land during west and southwest wind events. The channeling will cause a local acceleration that could transform a moderate wind into a strong gale in this region.

Seiches are less prevalent in Lake Ontario than Lake Erie due to the deeper water and fewer pressure centers passing directly over the lake. The oscillations in water level of Lake Ontario are therefore less pronounced and will have less impact on the turbine design.

5.4. Physical Lake Parameter Comparison Table

A summary of Lake Ontario's physical parameters compared to Lake Erie is included in Table 5.6 on the following page.

5.5. Maps

Map 5.1: Lake Ontario Geology

Map 5.2: Lake Ontario Bathymetry

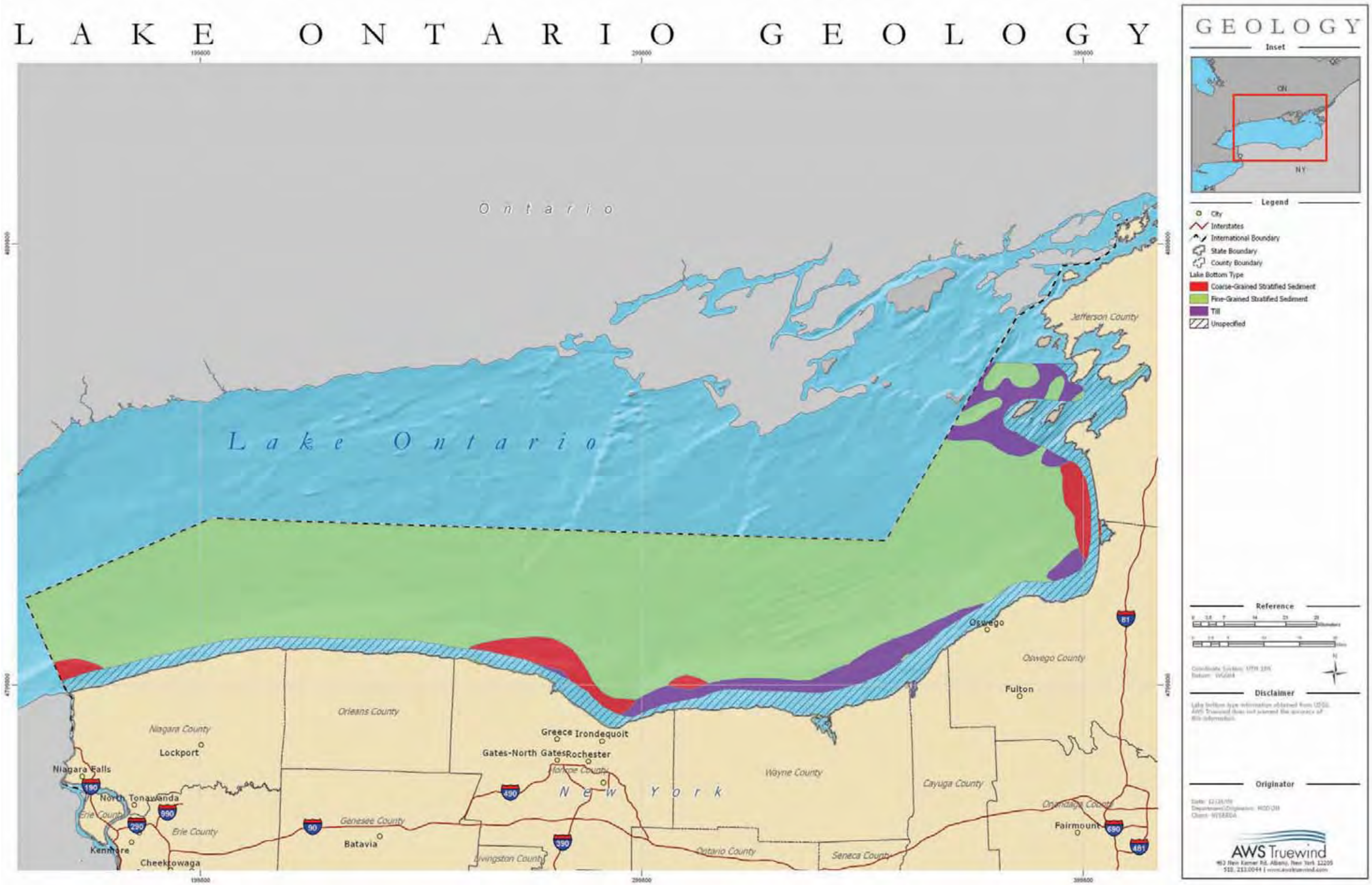
Map 5.3: Lake Ontario Average Ice Duration Winters 1973-2002

Map 5.4: Lake Ontario Wind Resource at 80 m

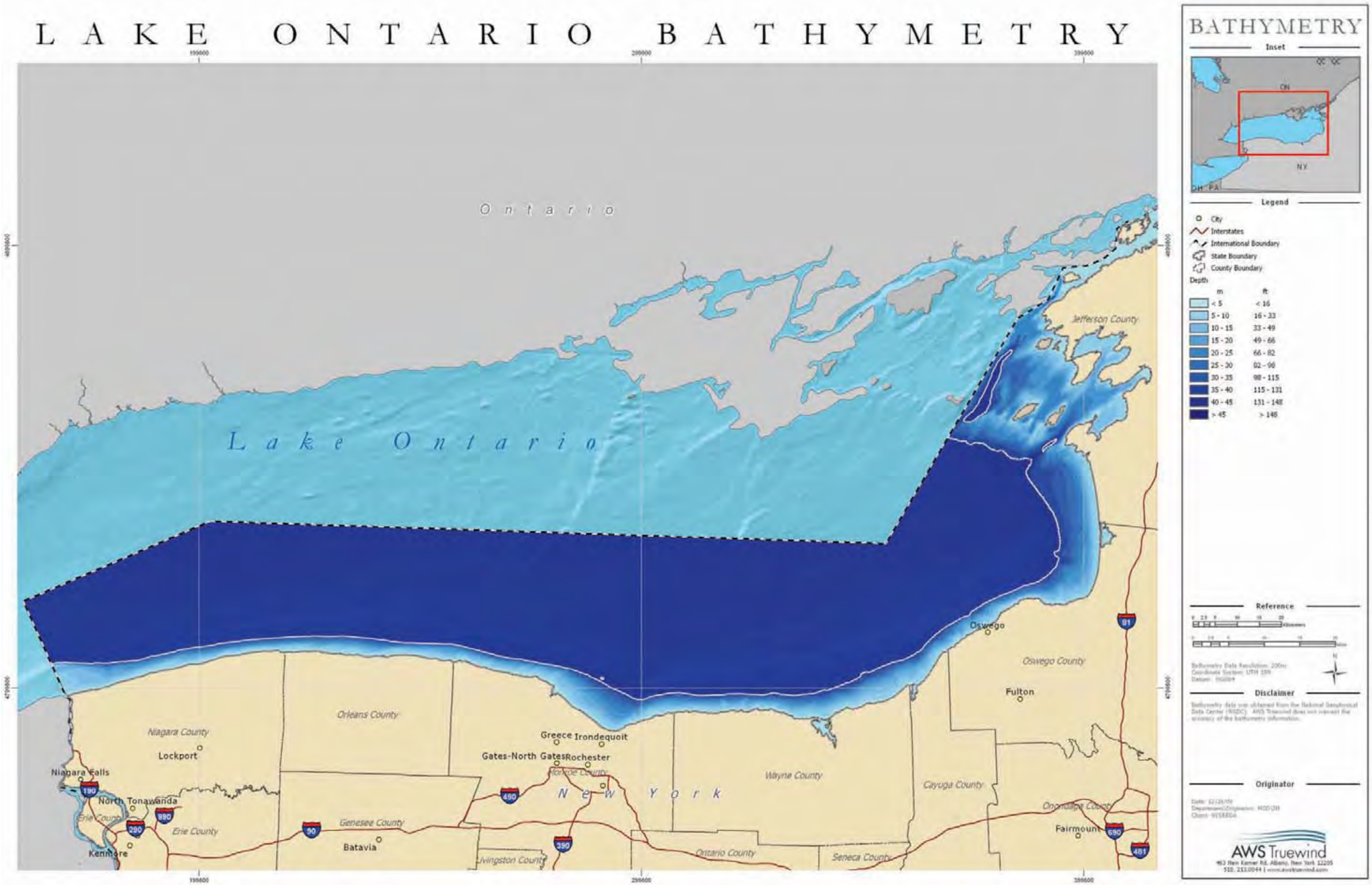
Table 5.6: Physical Lake Characteristics of Lake Erie and Lake Ontario

Design Parameter	Lake Erie	Lake Ontario
50-Year Extreme Wind Speed (m/s)	36	40
Annual Average Wind Speed (m/s)	7.5-8.5	7.5-8.5
Shape Parameter – k	1.7	1.8
Characteristic TI	12%	12%
Wind Shear During Normal Conditions	0.10	0.10
Mean Air Density (kg/m^3)	1.24	1.25
Mean Air Temperature (C)	~10	~9
Mean Water Depth (m)	26	111
Maximum Water Depth (m)	59	241
Water Density (kg/m^3)	1.0	1.0
Mean Wave Period (s)	4.2	3.4
50-Year Wave Period Max (s)	10.7	9.5
Mean Significant Wave Height (m)	0.70	0.60
50-Year Significant Wave Height (m)	5.5	6.2
1-Year Significant Wave Height (m)	3.5	4.0
Average Level Ice Thickness (cm)	40-50	Slush (open water) 50 (northeast bays)
Maximum Level Ice Thickness (cm)	60	65 (northeast bays)
Maximum Expected Rafted Ice Thickness (cm)	150	Little rafting expected
Average Ice Cover Duration (days)	45	10 (open water) 40 (northeast bays)
Minimum Ice Cover Duration (days)	0	0
Maximum Ice Cover Duration (days)	90	15 (open water) 40 (northeast bays)
Bending Strength (kPa)	750	750
Compressive Strength (MPa)	2-3	2-3

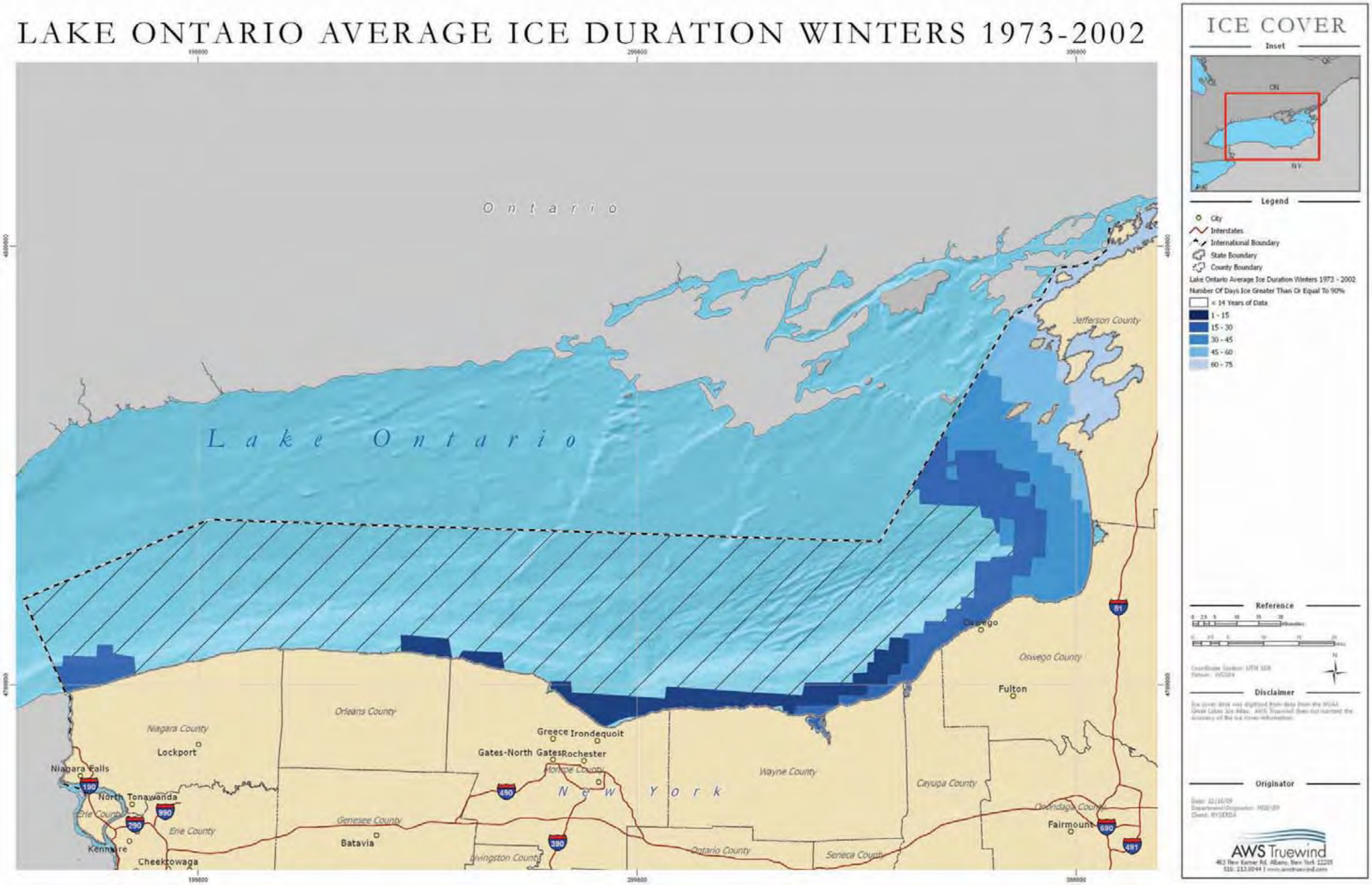
Map 5.1: Lake Ontario Geology



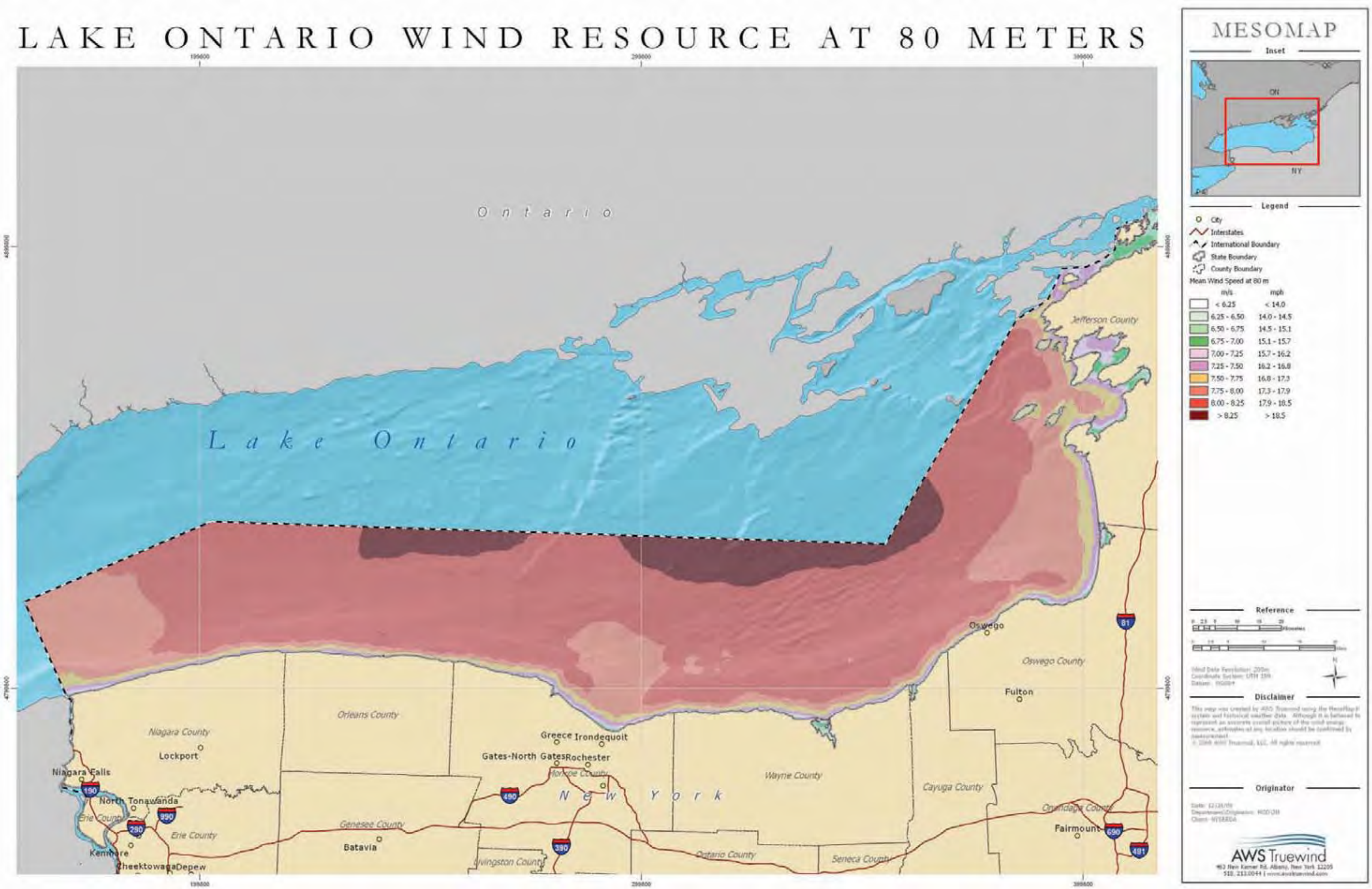
Map 5.2: Lake Ontario Bathymetry



Map 5.3: Lake Ontario Average Ice Duration Winters 1973-2002



Map 5.4: Lake Ontario Wind Resource at 80 m



6.0. Offshore Considerations

Existing water uses require consideration when determining the feasibility of an offshore wind project. Vessel traffic, commercial and recreational fishing, obstructions, and wildlife may all influence the feasibility of project development. While the presence of these existing uses in a particular area may not automatically preclude development, a preliminary assessment of the current offshore stakeholders in the area adds significant insight to the siting process.

6.1. Vessel Traffic

Established vessel traffic routes may affect potential wind project siting. Transportation routes in New York's Lake Erie waters, shown in Map 6.1, typically run parallel to the coast at varying ranges from the shore and converge near the Port of Buffalo. Traffic patterns also extend latitudinally from the city of Dunkirk, NY. The development of a wind project within these waters will require sensitive planning to ensure that all established transportation routes are not interrupted or inhibited.

Lake Ontario is used extensively by commercial shipping traffic, as it is the link between the upper Great Lakes and the Atlantic Ocean as part of the St. Lawrence Seaway. This provides both advantages and challenges to siting an offshore wind park. The benefit of the high traffic is the infrastructure for moving and handling goods on the water. Oswego and Rochester are two of the primary ports on the lake. Both have deep-draft vessel facilities, are equipped to handle bulk cargo, and are serviced by road and water. Major ports in Canada – Toronto and Hamilton – are available, and may be able to offer resources during the construction period. The shipping lanes that service these ports, however, provide a challenge to locating a project site. Avoiding designated routes for vessel traffic minimizes collision dangers and shipping interference. The effects of this lake use are illustrated in Map 6.2, which shows the location of primary ports, vessel traffic patterns, land use areas, and transmission lines.

Lake Ontario recreational boating, specifically boat tours in the St. Lawrence River inlet region, are common during the summer months, and will be part of siting considerations. These tours are popular due to the scenic natural (i.e. undeveloped) views in the area. If a wind project were constructed in nearby vicinity to these waters, the viewshed implications for these stakeholders could be significant. Other locations where boat tourism is prevalent include the Thousand Islands and the southwest corner of the lake near the Niagara Falls region.

6.2. Commercial and Recreational Fishing

Commercial and recreational fishing thrive in Lake Erie. The lake produces more fish for human consumption than the other four Great Lakes combined. The western end of the lake produces more walleye per square kilometer than anywhere else in the world. Between 1915 and 1980, an average of 13 to 30 million kg (about 29 to 66 million pounds) of fish were extracted annually by commercial fishermen in the United States and Canada.[71] Sport fishermen in New York annually spend over 10 million labor-hours fishing Lake Erie. The lake continues to be fished at the present date. In 2009, Lake Erie total allowable catch totals for yellow perch and walleye alone were set to approximately 6.5 million kg (about 14.5 million pounds).[72]

[71] *Lake Erie.* Retrieved March 2009 from International Lake Environment Committee Web site: http://www.ilec.or.jp/database/nam/nam-06.html.

[72] Ripple Outdoors MNR Press Release, March 2009. Retrieved March 2009 from Web site: http://www.rippleoutdoors.com/recommended-lake-erie-yellow-perch-and-walleye-catch-limits-for-2009/.

Specific locations along the New York Lake Erie shoreline where fishing is especially prevalent are Barcelona, near the town of Westfield, NY, and Sunset Bay, near the mouth of the Cattaraugus Creek. The port cities of Barcelona, Dunkirk, Irving, and Buffalo are centers for fishing activity.[73] Recreational fishing is prevalent all along the shoreline at various beaches and parks.

The fishing community is one of the largest existing users on the lake and would be a significant stakeholder in offshore wind development for Lake Erie. Real and perceived impacts by wind projects on this activity, as well as collaboration with these stakeholders, will warrant being addressed during project planning and siting. Experience in Europe has shown minimal to positive effects (due to increased hard structures and reef effects) on fishing in the proximity of carefully sited offshore wind projects. While development in fishing areas may be possible, potential impacts to stakeholders in these areas merit attention.

Commercial and recreational fishing in Lake Ontario is far less prevalent than in Lake Erie. While a degree of Canadian commercial fishing occurs to accommodate the population centers located along the Province of Ontario's coast, New York's commercial fishing in Lake Ontario is comparatively minimal. The annual fish catch per year in Lake Ontario is approximately 2.3 million kg (5.1 million pounds), only a fraction of that in Lake Erie.[74] United States fishing in Lake Ontario has been further discouraged by governmental advisory notices from both the New York State Department of Health and the United States Environmental Protection Agency, siting the lake as an area of concern due to pollution.

Nevertheless, fishing in Lake Ontario occurs all along the New York shoreline, but is especially prevalent along the eastern shore from Alcan Point (just east of the city of Oswego) to Montario Point (just north of North Sandy Pond).

Although less fished than Lake Erie, the fishing community on Lake Ontario would be a significant stakeholder in offshore wind development. Real and perceived impacts by wind projects on this activity, as well as collaboration with these stakeholders, will need to be addressed during project planning and siting. Experience in Europe has shown minimal to positive effects (due to increased hard structures and reef effects) on fishing in the proximity of carefully sited offshore wind projects.

6.3. Obstructions

Non-geologic occurrences and man-made structures in the water can pose concern to navigation and turbine siting. Artificial reefs, sewer outfalls, dump sites, wrecks, danger areas, and other similar hazards may affect turbine placement. The historic high use of the lakes has resulted in a significant number of obstructions and areas of concern.

A number of these obstructions warrant the attention of Lake Erie navigators and potential wind developers. Map 6.3 illustrates the potential known obstructions in the lake. In the northeastern portion of the lake, various obstructions exist that warrant consideration. A handful of shipwrecks occur throughout the region and are clustered near the coastal waters of the city of Buffalo. Additional anchorage areas, dumping grounds, and other obstructions exist in this area just off the coast of Buffalo Harbor, usually within five ten km of shore. Occasional submerged pipelines extend from the shore into Lake Erie at various points along the coast.

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[73] *Eastern Lake Erie Marinas.* Retrieved March 2009 from Lake Erie Walleye Online Magazine Web site: http://www.walleye.com/lakeeriemarinas-eastern.htm.

[74] *Lake Ontario*. Retrieved March 2009 from International Lake Environment Committee Web site: http://www.ilec.or.jp/database/nam/dnam07.html.

A number of these obstructions warrant attention in Lake Ontario as well. Map 6.4 illustrates the potential known obstructions in the lake. Numerous marine cables and submerged pipelines extend out from the coast and connect between the islands. Offshore dumping grounds of various sizes also exist throughout the region, most within ten km of shore. A military practice area exists in the center of New York's waters on Lake Ontario from the town of Morton to the town of Fair Haven, which is recommended to be excluded from development. Submerged shipwrecks occur throughout the lake, interspersed along New York's southern shoreline and concentrated at the inlet of the St. Lawrence River in Canada's waters. Although out of New York's jurisdiction, these wrecks at the river inlet may pose a concern for navigation if equipment is expected to be transported in and out of the region by this waterway.

Not all of these obstructions necessarily preclude siting in their immediate area. Shipwrecks are small compared to turbine spacing, and thus they may be located inside a wind project without being disturbed; however, the charted military zone and dumpsites are not recommended for development. The implications of underwater obstructions warrant further investigation during the siting process, but are recommended to be avoided in general.

6.4. Wildlife

A preliminary review of wildlife considerations within Lake Erie and Lake Ontario was conducted to call attention to specific areas of concern where more investigation is warranted. The review is not intended to be all inclusive, nor is it meant to be supplementary to an environmental impact study. Rather, this natural resource review intends to call out obvious areas of significance from a high level, and recommend potential paths for further study. Map 6.5 and Map 6.6 demonstrate areas of consideration in the lakes. In most cases, impacts on local species must be statistically significant to affect project development; therefore a low level of environmental impact is likely acceptable.

Many species of North American birds migrate to through the Great Lakes region during their biennial treks. Migration patterns vary in route, time of day, and flight altitude depending on the species; thus, only some species may potentially be affected by offshore wind development. Land birds tend to avoid crossing large bodies of water, staying close to their resources along the shore. Birds that do cross the open water tend to fly at higher altitudes than those over land, in most cases above the height of wind turbines.[75] Bird migration patterns are also dependent on topography (i.e. mountain ranges and coastlines) and weather events at the time of migration.

The development of a wind project in the path of a migration flyway may be a concern for bird species that fly through that location. Studies at European offshore wind projects have attempted to capture the significance of impacts on bird species, with results thus far indicating that impacts are not significant. One study conducted at the Nysted wind project in Denmark showed that migratory birds tended to alter their flight path around the wind project (see Figure 6.1); however, whether a bird flies around or through an offshore project is often species-dependent.[76] Impact assessments are recommended prior to and following the construction of an offshore wind energy project in the Great Lakes.

[75] Source: Driedger-Marschall, B., & Endres, P. of juwi GmbH. *Great Lakes Wind Energy Center Feasibility Study* (April 2009). Page 6-2.
[76] Source: Driedger-Marschall, B., & Endres, P. of juwi GmbH. *Great Lakes Wind Energy Center Feasibility Study* (April 2009). Page 6-6.

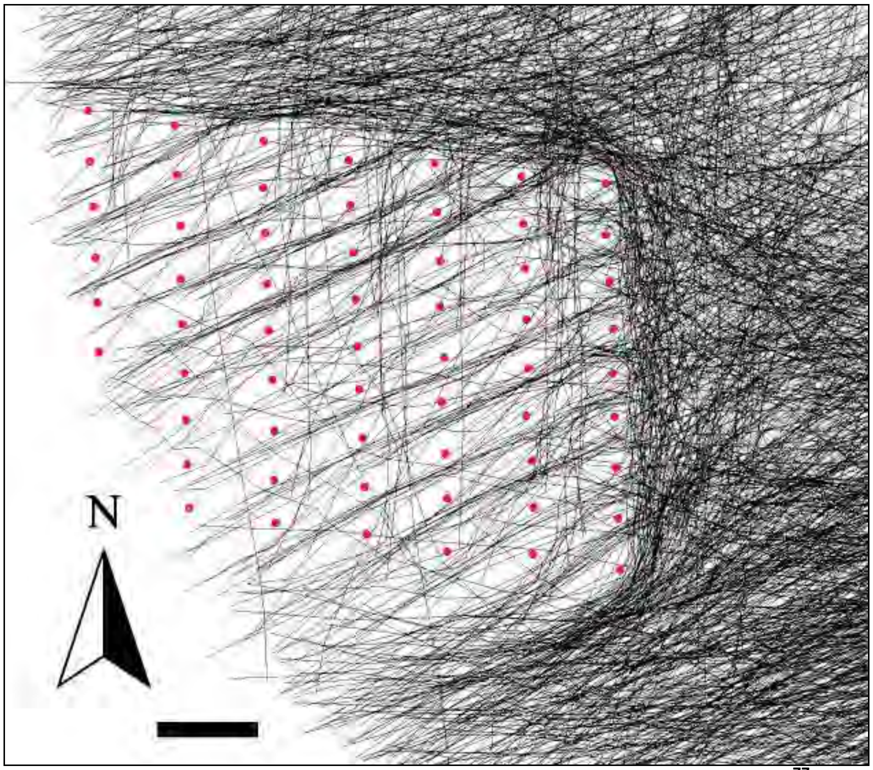


Figure 6.1: Bird Flight Paths Around Nysted Offshore Wind Project[77]

The lakes' coastlines have a significant population of local and migratory birds. A map of principle migration flyways in North America (Figure 6.2) implies that, from a high level, New York's Lake Erie and Lake Ontario waters are likely to be clear of principle hawk migration routes. Nevertheless, additional environmental studies are recommended to ensure that the development of an offshore wind project on Lake Erie does not interfere with supporting less-trafficked migration flyways.

Another avian consideration is the possibility of habitat loss in the vicinity of the project. Research from offshore wind projects in Europe indicates that some species of birds tend to avoid wind turbines.[78] Habitat loss for these species may encompass more area than just the proposed project area, due to displacement distances from turbines. Populations of other species, such as gulls, were found to increase within the project footprint. Potential habitat loss will require additional attention once a specific project area is selected.

[77] Source: Desholm and Kahlert (2005). Avian Collision Risk at an Offshore Wind Farm. *Biology Letters* 2005 1, 296-298, Figure 1, Page 297. Published by The Royal Society. Retrieved March 2009 from PubMed Central Web site: http://www.pubmedcentral.nih.gov. Used with permission.

[78] Source: Driedger-Marschall, B., & Endres, P. of juwi GmbH. *Great Lakes Wind Energy Center Feasibility Study* (April 2009). Page 6-5.

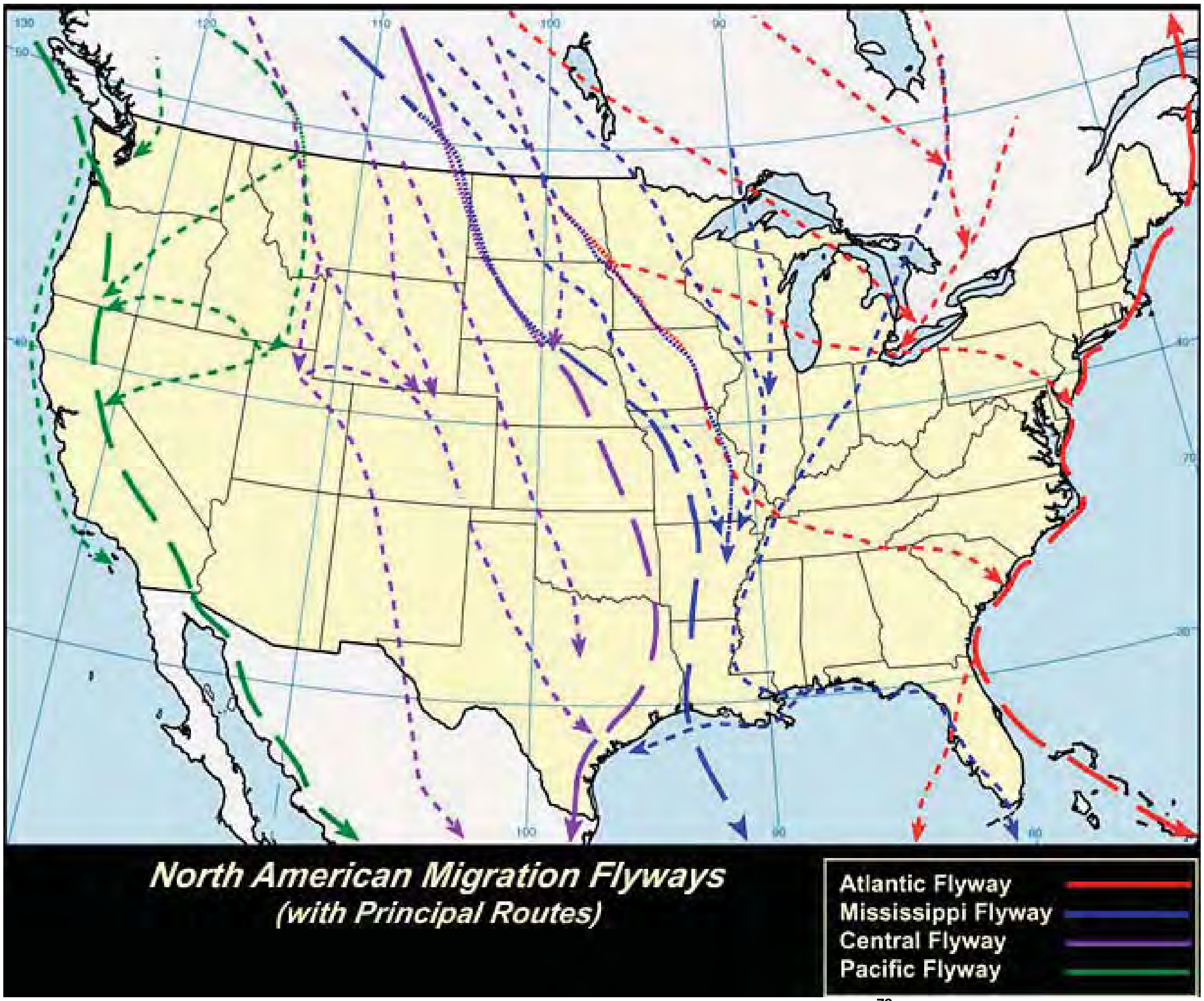


Figure 6.2: Principal Migration Flyways in North America[79]

In addition to avian considerations, endangered and threatened fish species may exist in the waters of the lakes, such as the Shortnose Sturgeon (endangered). These species may be present within the project vicinity and require separate attention.

Other wildlife such as mammals (bats), reptiles, amphibians, crustaceans, insects, invertebrates, snails, clams and plants may be affected by a wind project on Lake Erie or Lake Ontario. While this investigation is outside the bounds of this study, it is recommended that attention be given to endangered and threatened wildlife in these groups.

Another wildlife concern is the effect of invasive species on the project. The zebra mussel is a non-native species to the great lakes that was introduced in the 1980s.[80] These small mollusks are able to latch onto any hard surface, including rock formations, boat hulls, wood, and steel. The presence of these creatures in the Great Lakes is generally considered to be a nuisance. This organism has the potential to negatively

[79] Source: Image courtesy of the U.S. Geological Survey. Retrieved March 2010 from National Park Service Web site: http://www.nps.gov. Used with permission.

[80] Source: *Zebra Mussels* (2008). Retrieved April 2009 from National Atlas Web site: http://www.nationalatlas.gov/articles/biology/a_zm.html

affect a wind project in the Great Lakes. During the measurement collection period, zebra mussels may interfere with offshore equipment operation and data collection. If a large population of zebra mussels attaches to a monitoring buoy, there is a possibility that the buoy could sink. Additionally, zebra mussels may block transmitters and receivers on optical underwater equipment such as an ADCP. Once a wind project in the Great Lakes is constructed, zebra mussels may attach themselves to the underwater foundations, potentially causing material damage to the steel structures, and increasing the drag force exhibited on the structure surfaces, causing them to experience greater-than-expected loads. Removal of zebra mussels from turbine structures and monitoring equipment would require regular upkeep, and may be costly.

Figure 6.3: Retrieval of Zebra Mussel-Encrusted Vector Averaging Current Meter (Similar to an ADCP)[81]

It is possible that submerged turbine foundation structures may provide a suitable habitat for the continued development of another Great Lakes invasive species, the bloody red shrimp.[82] The bloody red shrimp prefers shadowed environments with hard structures and rocky bottoms. The introduction of turbine foundations to the lakes may create an environment conducive to bloody red shrimp populations. While there is no apparent negative effect of this creature on the wind turbine structure, its propagation in the Great Lakes is undesirable.

[81] Source: NOAA, Great Lakes Environmental Research Laboratory. Taken near Michigan City, IN, on Lake Michigan, June 1999. Retrieved March 2009 from Web site: http://www.glerl.noaa.gov. Used with permission.
[82] *Great Lakes New Invader: Bloody Red Shrimp (Hemimysis Anomala)*. Retrieved March 2009 from Web site: http://seagrant.wisc.edu/AIS/Portals/7/hemimysis.pdf.

Additional study on the interaction between Lake Erie's offshore natural resources/wildlife and a potential offshore wind energy project is recommended. Comprehensive lists of endangered species, threatened species, and species of special concern are available from the New York State Department of Environmental Conservation.[83] A list of potential organizations and institutions for assistance in this review is presented below:

- Great Lakes Sea Grant Network
- Great Lakes Commission
- Great Lakes Program at Buffalo
- University of Wisconsin Sea Grant Institute
- Great Lakes Waterbird Research Program
- Case Western Great Lakes Institute for Energy Innovation
- Great Lakes Wind Energy Center

6.5. Maps

Map 6.1: Lake Erie Ports and Logistics

Map 6.2: Lake Ontario Ports and Logistics

Map 6.3: Lake Erie Obstructions and Exclusions

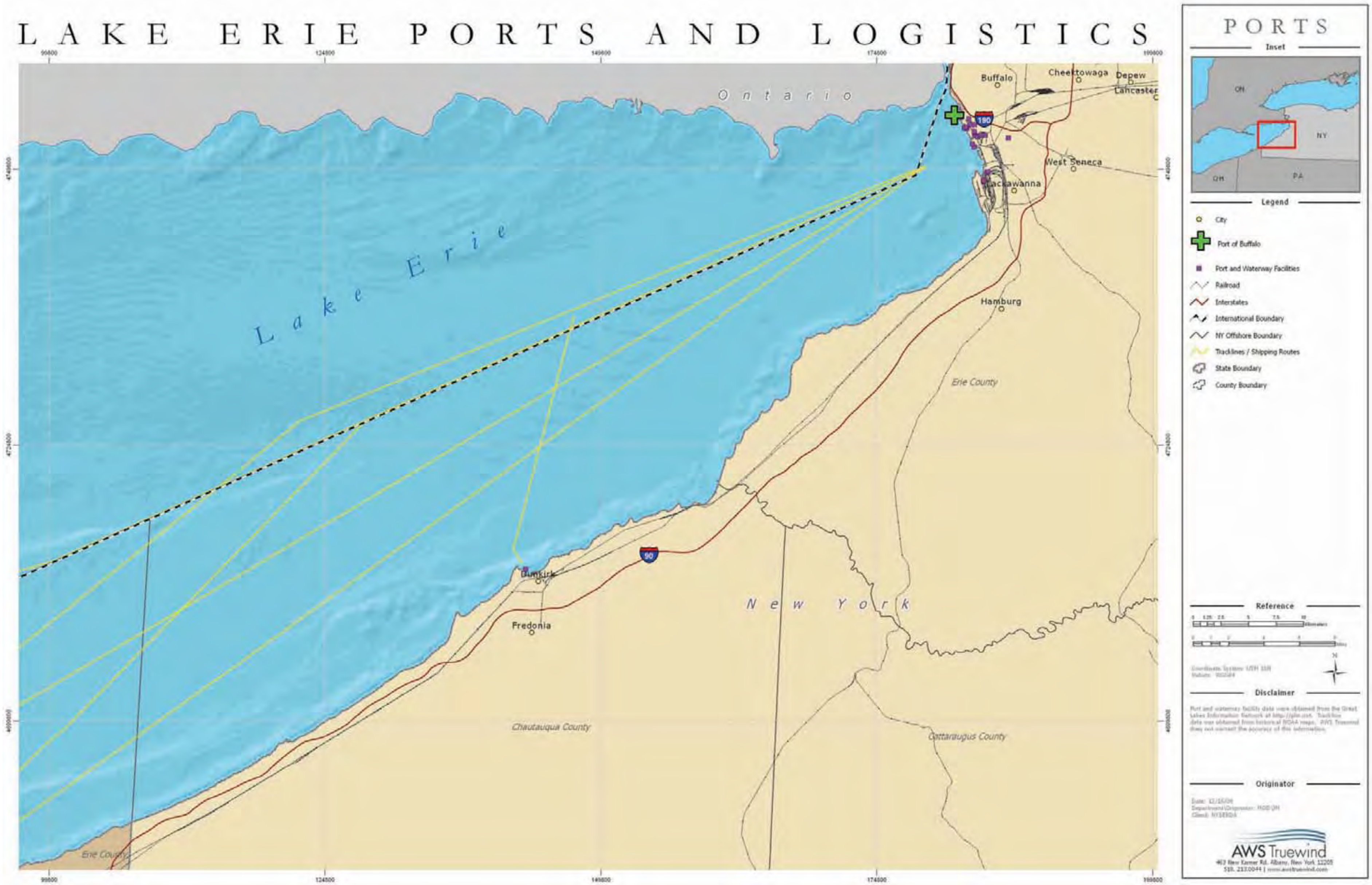
Map 6.4: Lake Ontario Obstructions and Exclusions

Map 6.5: Lake Erie Offshore Natural Resources

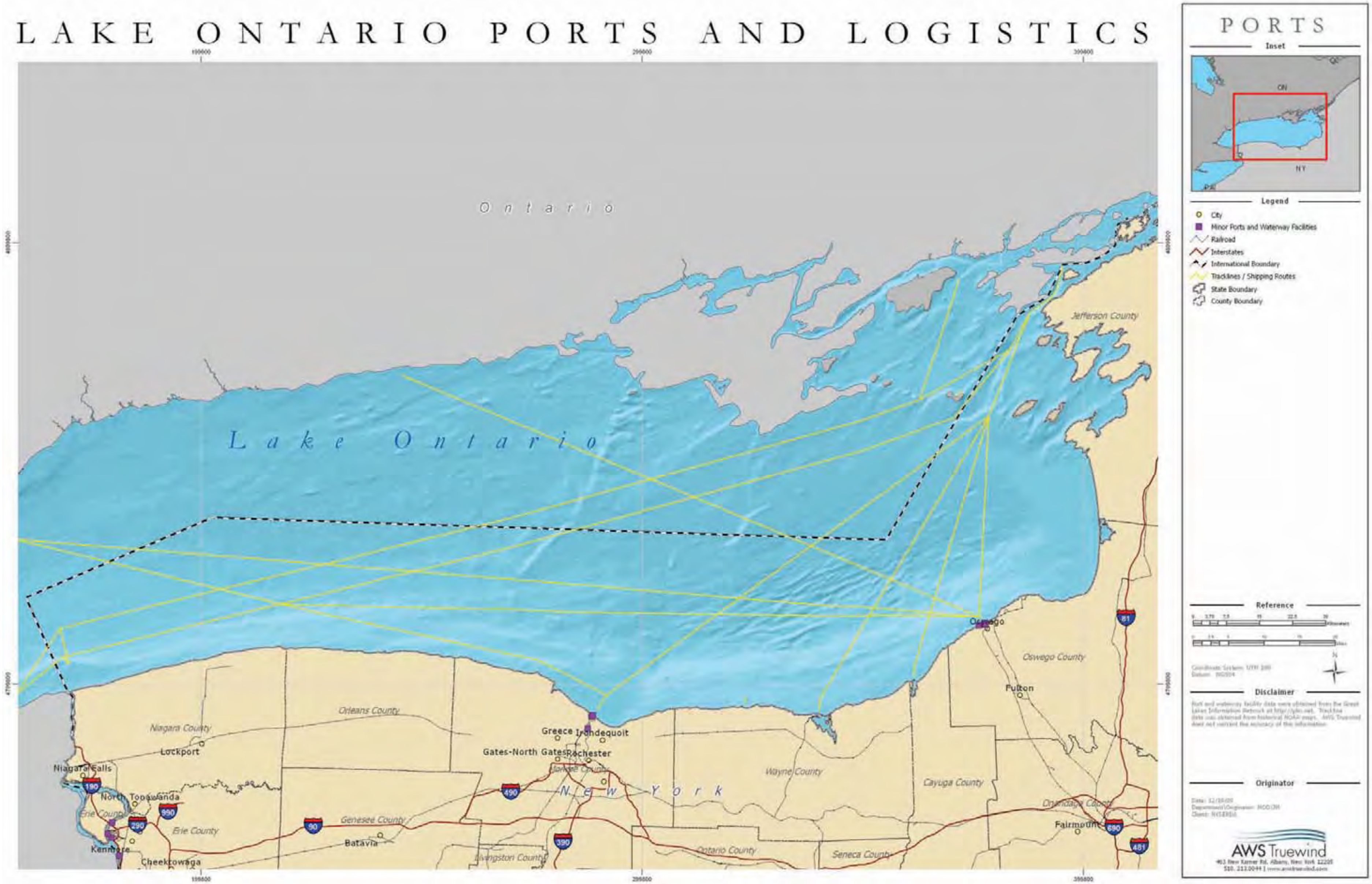
Map 6.6: Lake Ontario Offshore Natural Resources

[83] More information available at http://www.dec.ny.gov/animals/7494.html.

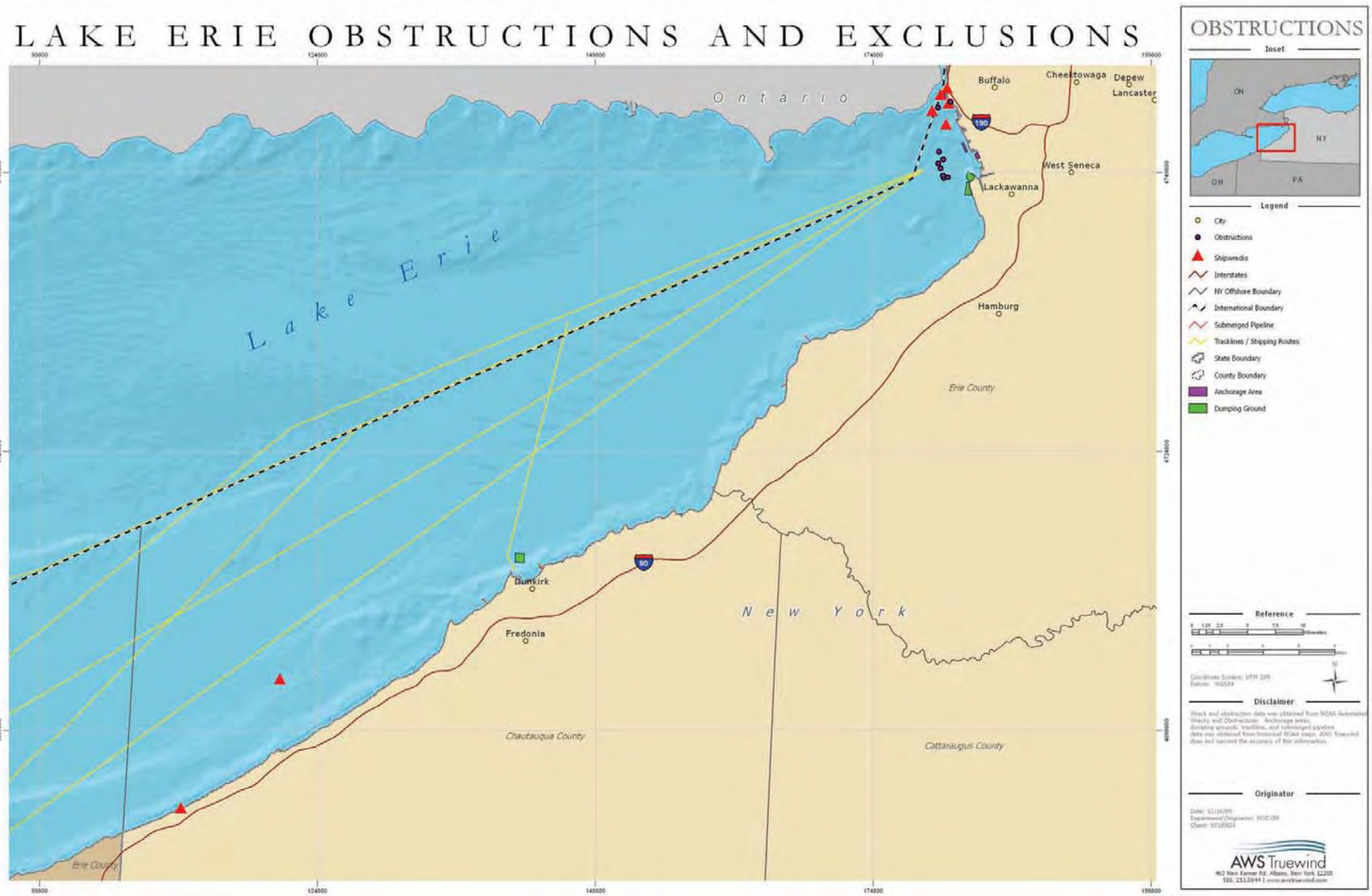
Map 6.1: Lake Erie Ports and Logistics



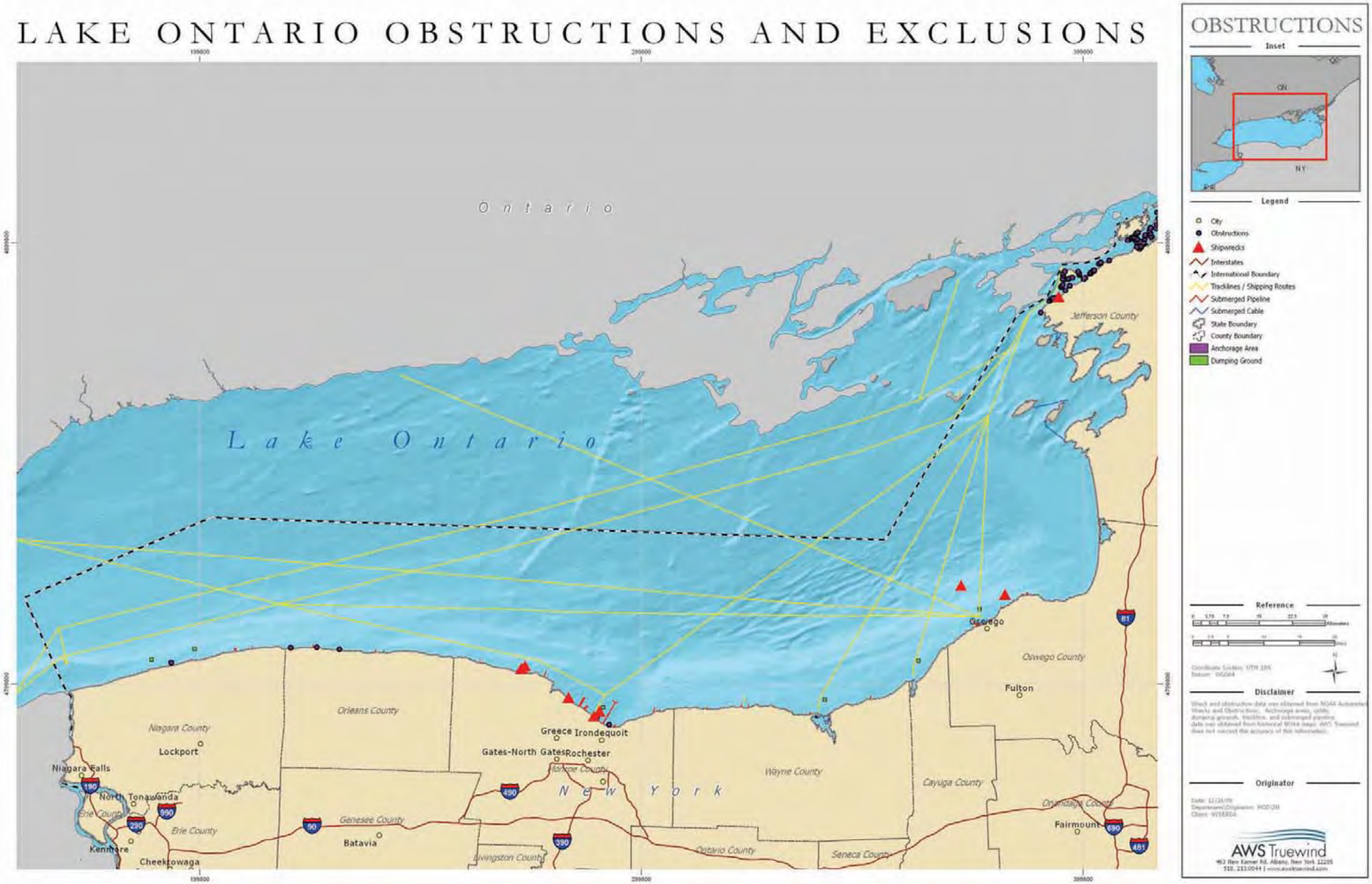
Map 6.2: Lake Ontario Ports and Logistics



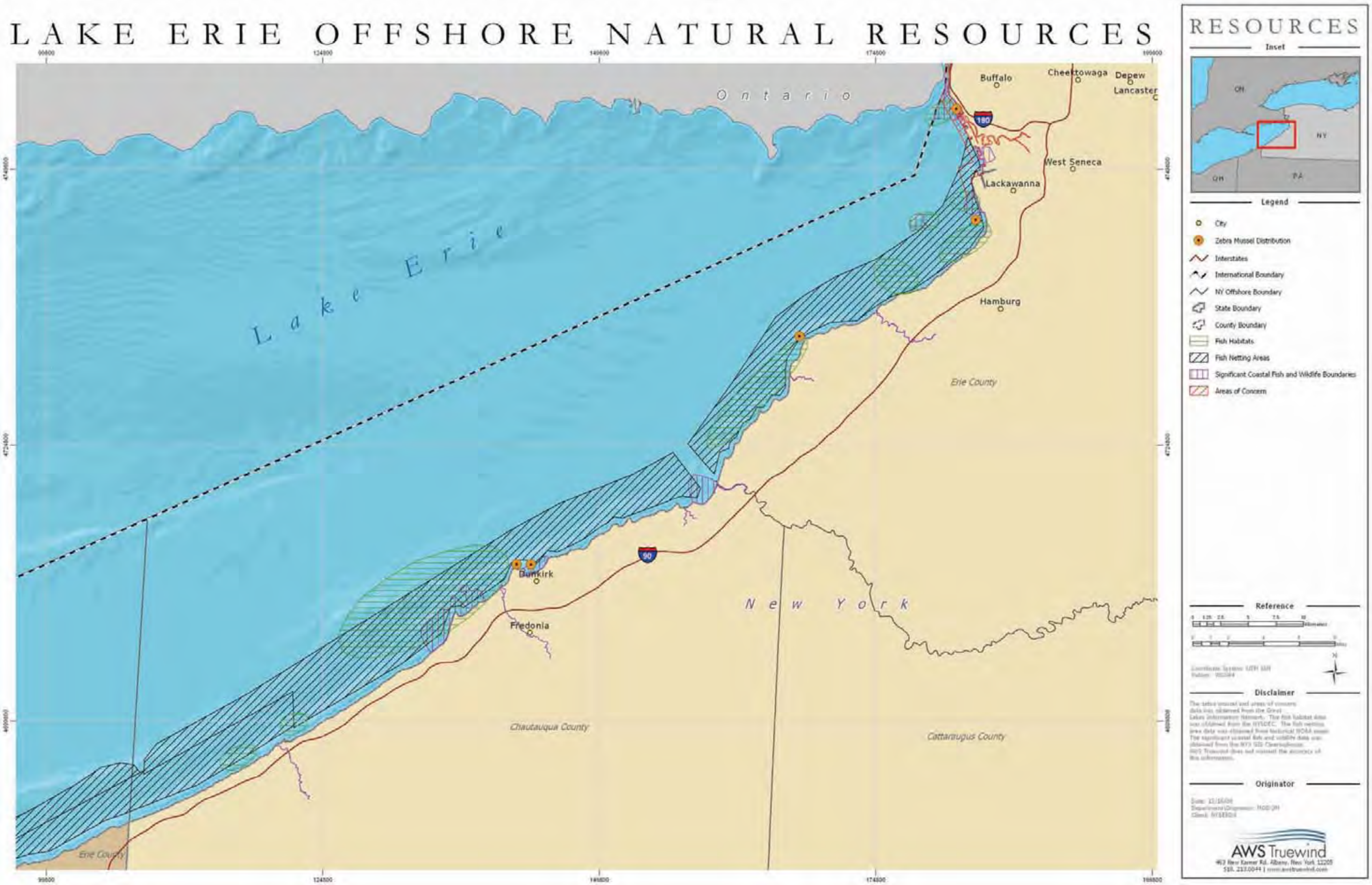
Map 6.3: Lake Erie Obstructions and Exclusions



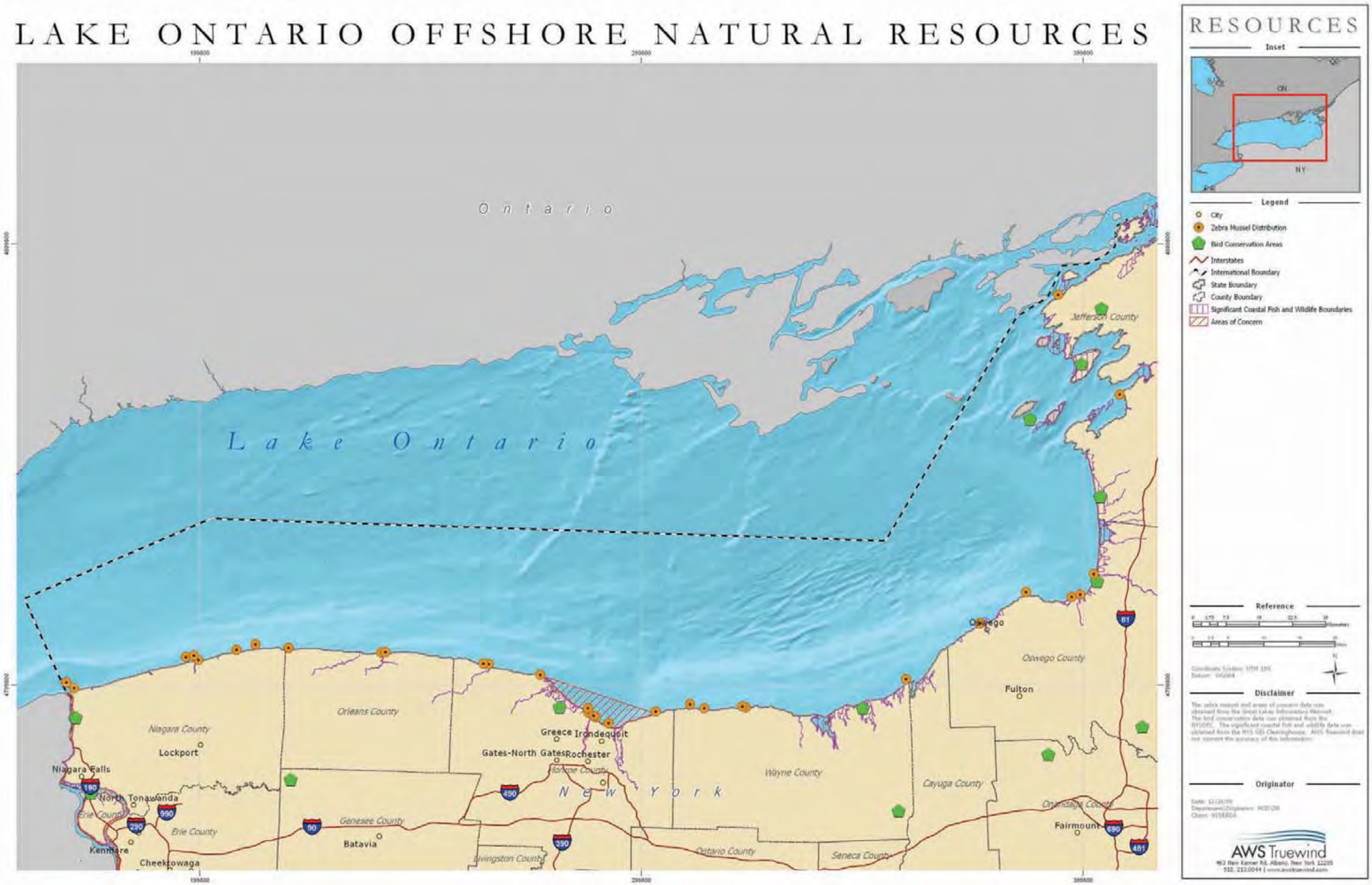
Map 6.4: Lake Ontario Obstructions and Exclusions



Map 6.5: Lake Erie Offshore Natural Resources



Map 6.6: Lake Ontario Offshore Natural Resources



7.0. Onshore Considerations

Both designated and existing land use may affect project siting and proposed transmission pathways. Population centers near the project may positively affect siting by providing load centers for energy produced by the project, but may also result in viewshed implications. Existing port availability capable of supporting wind project construction and maintenance is essential for development. Aviation, nuclear plant regulations, availability of high-voltage transmission, and onshore wildlife merit consideration.

7.1. Land Use

Land use along the New York shoreline on Lake Erie and Lake Ontario is very diverse. Adjacent land usage changes from rural agricultural to commercial and industrial over very short distances. The coastline is interspersed with ports, parklands, important bird areas, power plants, American Indian lands, and a variety of other uses. Detailed analysis will be covered in the site-specific sections.

7.1.1 Population

A 2007 United States Census Bureau estimate for the two New York counties bordering Lake Erie (Chautauqua and Erie) projected a total population of 1.0 million. This coastal zone represents approximately 5.4% of New York's total population and 4.5% of its total land area. Within these counties, the population and development are concentrated near the shore, particularly in the metropolitan area of Buffalo. Map 7.1 and Map 7.3 depict population density, highways, and cities along New York's Lake Erie coast.

Large coastal populations (both resident and tourist) have a variety of effects on offshore wind development. Large load centers near the coast facilitate interconnection and provide a driver for additional clean power generation. Numerous existing land and water uses accompanying high populations may influence the siting process. Project aesthetics become more significant as more residents' viewsheds are affected. Map 7.2 and Map 7.4 depict population density, highways, and cities along New York's Lake Ontario coast.

7.1.2 Existing Uses

Offshore wind development can have both real (transmission cable landfall) and perceived (viewshed) effects on the land adjacent to the project. The significance of these effects can vary greatly, and they can influence many aspects of project planning. Identifying and understanding adjacent land uses can facilitate the entire development process.

Land use varies significantly along New York's coast, from protected parklands to extensive commercial/industrial development. While characterizing the entire coastline is beyond the scope of this study, several noteworthy land uses are shown in Map 7.5 and Map 7.6.

The city of Buffalo is the prominent land user adjacent to Lake Erie. The urban and industrial development from Buffalo stretches south along the shore line and gives way to residential development and small towns. The 20 MW Steel Winds Wind Farm is sited along Lake Erie's coast near Lackawanna, NY. Significant natural areas, as designated by state and national entities, exist in several locations along the coast, most notably three state parks (Lake Erie, Evangola, and Woodlawn Beach), with numerous coastal areas as tourist attractions, most notably lake beaches. The Cattaragaus Indian Reservation occupies a large area of adjacent land as well as a portion of the lakeshore.

Extensive waterborne commerce is based on the lake's shore, including fishing, and recreational uses are carried out on Lake Erie. This heavy usage will provide opportunities and challenges to offshore wind development. Parks, beaches and public boating access points mark the coast. There is a significant amount of private recreational boating along the shore as well.

New York shoreline of Lake Ontario is several hundred miles long. The adjacent land use is thus quite varied. The southern shoreline is principally farmland and rural residential areas with growing commercial and industrial development near Rochester. Several state parks are located along this area as well. Further east and north along the coast, the same mixed use of the shoreline can be seen. North of Nine Mile Point the land is much less populated and the area adjacent to the water is primarily parkland and undeveloped land.

Some of these land uses may directly affect the siting of a wind project in the lakes, such as avoiding development in and cable transit through protected natural areas. Other existing land uses and designations will influence the siting and permitting of a project. These issues are often site-specific and will require further study when specific project locations are better defined.

7.2. Ports and Logistics for Installation and Maintenance

Logistics for offshore wind project installation are far more complex than those for onshore projects. This is compounded by the lack of an experience base or installation infrastructure in the United States. This section provides an overview of some logistical factors to consider when developing an offshore wind project.

Unfavorable weather and sea states are a leading cause of construction delays and installation cost risks. The safety of crews, vessels and equipment takes precedence over construction schedules. It is anticipated that the "weather window" for installing wind turbines in the Great Lakes will be limited to the mid-spring to mid-autumn seasons. Even within these more favorable seasons, there will be periods of unsuitable conditions for work on the water or at hub height. Strategies have been employed in Europe to minimize the number of vessel transits from ports to offshore sites, thereby reducing the sensitivity of transportation to foul weather.

7.2.1 Port Availability

Nearby ports for wind project installation capable of accommodating deep draft vessels and supporting large equipment offloading will be necessary for development. In addition, these ports will be required to have an adequate laydown area for turbine components. Typically, the available port laydown space is roughly three-quarters to one acre of land area per turbine.[84] Ideally, if adequate space is available at the installation port, hub and blade assemblies can be constructed onshore, minimizing the number of offshore crane operations per turbine installed. This makes the construction schedule less sensitive to weather delays.

[84] For example, Burbo Bank employed 20 acres of lay down area for 25 turbines; and the Port of Romoe near Butendiek is planning to create 60 acres of lay down space for the 80 turbine project. This metric is also dependent on turbine size.
Sources: *Bank Offshore Windfarm Construction Project* (June 2007). Retrieved June 2009 from PTI Online Web site: http://www.porttechnology.org/article.php?id=2777; *Airtricity and Port of Romoe Join Forces for Offshore Wind steeService and Maintenance Centre* (June 2009). Retrieved June 2009 from Green Jobs Web site: http://www.greenjobs.com/Public/IndustryNews/inews06092.htm

Figure 7.1: Port of Mostyn Construction Base for Burbo Bank Offshore Wind Project (UK) [85]

A nearby port is also essential to accommodate the O&M activity during the operational phase of the project. However, the requirements for port specifications are far less demanding because of the much smaller size of service vessels and the limited requirements for any laydown area. A landing location for a service helicopter may be desirable if this mode of transport is used as an alternative to surface vessels, especially when sea states frequently limit the use of surface vessels.

The nearby ports of Buffalo (shown in Figure 7.2) and Erie, Pennsylvania provide a significant advantage for a wind project sited on Lake Erie. These ports, as well as nearby ports in Ohio, have deep draft vessel accommodations, facilities to manage bulk materials, and are serviced by air, sea, rail, and highway. Heavy shipping and construction fleets are available in the area as well. Map 6.1 illustrates the locations of existing ports and vessel traffic patterns in the eastern end of Lake Erie.

Figure 7.2: Port of Buffalo[86]

[85]Source: Port of Mostyn. Offshore Renewables Boost Ports Industry (July 2008). *Maritime Journal*. Retrieved April 2009 from Web site: http://www.maritimejournal.com. Used with permission.
[86] Source: Buffalo Crushed Stone, Inc. Retrieved April 2009 from Port of Buffalo Web site:

Two of the primary ports on Lake Ontario are the ports of Oswego (shown in Figure 7.3) and Rochester.[87] Both have deep-draft vessel facilities, are equipped to handle bulk cargo, and are serviced by road and water. Major ports in Canada—Toronto and Hamilton—are also available, and may be able to offer resources during the construction period. While no vessels specifically suited for turbine construction exist in the United States, heavy transport and construction-capable fleets are available out of Montreal and the adjacent Great Lakes. Due to New York's expansive water area on Lake Ontario and the limited number of ports capable of supporting a wind project installation, a potential site's distance from major ports may pose a challenge for development. Map 6.2 illustrates the locations of existing ports and vessel traffic patterns on Lake Ontario.

Figure 7.3: Port of Oswego[88]

7.2.2 Construction Vessels

Heavy construction vessels are employed to install an offshore wind project. Special purpose vessels, such as the Jumping Jack Barge shown in Figure 7.4, now exist in Europe for the purpose of wind project construction. Access to existing European installation vessels for use in the United States may be barred by the Merchant Marine Act of 1920, which is also known as the Jones Act. According to this act, energy-related projects being constructed in United States waters are typically required to employ United States vessels, although an allowance may be made if no suitable vessel exists.[89] This jurisdiction may restrict the use of a foreign offshore liftboat for construction of an offshore wind project in the New York waters of the Great Lakes. It is estimated that the construction of a new purpose-built United

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http://www.portofbuffalo.com. Used with permission.

[87] More information on available ports on Lake Erie and Lake Ontario can be obtained from the Great Lakes Group (http://www.thegreatlakesgroup.com/index.php), the *United States Coast Pilot* (book 6), and *Greenwood's Guide to Great Lakes Shipping*.

[88] Source: Syracuse Post-Standard. Retrieved April 2009 from Web site: http://blog.syracuse.com. Used with permission.

[89] Eisenhower, Brian. 2007. "Memorandum: U.S. Cabotage Laws and Offshore Energy Projects." June 15. http://law.rwu.edu/sites/marineaffairs/content/pdf/Eisenhower.pdf.

States liftboat could cost between $150 and $250 million.[90] Since the Jones Act restricts a non- United States liftboat from picking up equipment from a United States dock, complications with the Jones Act may be avoided by using a United States owned feeder barge to transport installation equipment from the dock to a European liftboat on-site. Additional investigation is recommended to assess the implications of the Jones Act on offshore wind project construction in the United States.

Figure 7.4: Jumping Jack Barge for Offshore Wind Project Installation[91]

Figure 7.5: Heavy Construction Vessels Installing Wind Turbines[92,93]

[90]Range based on correspondence with industry experts and literature review (see "How to Keep Up With the Jones Act." *North American WindPower*, Vol. 6, No. 5: June 2009).
[91] Source: Jumping Jack Goes Down (July 31, 2007). Vertical Press News Archive. Retrieved July 2009 from Web site www.vertikal.net. Used with permission.

Another constraint on construction vessels within the Great Lakes is the ability for such a vessel to traverse between the lakes. Both the Saint Lawrence Seaway and Welland Canal have size restrictions of a maximum length of 222.5 meters, breadth of 23.2 meters, draft of 8 meters, and air draft (height above water level) of 35.5 meters.[94] While most O&M vessels will be able to traverse these waterways, these constraints are smaller than the dimensions of most of the vessels that have been utilized for offshore wind project installation in Europe. Therefore, obtainment of an adequate construction vessel that can traverse between open ocean waters and the Great Lakes could prove to be a challenge. However, access points between Lake Erie and the upper Great Lakes through the Detroit River, Lake Saint Claire, the Saint Claire River, and the Straits of Mackinac are more expansive, although these waterways do not access the open ocean.

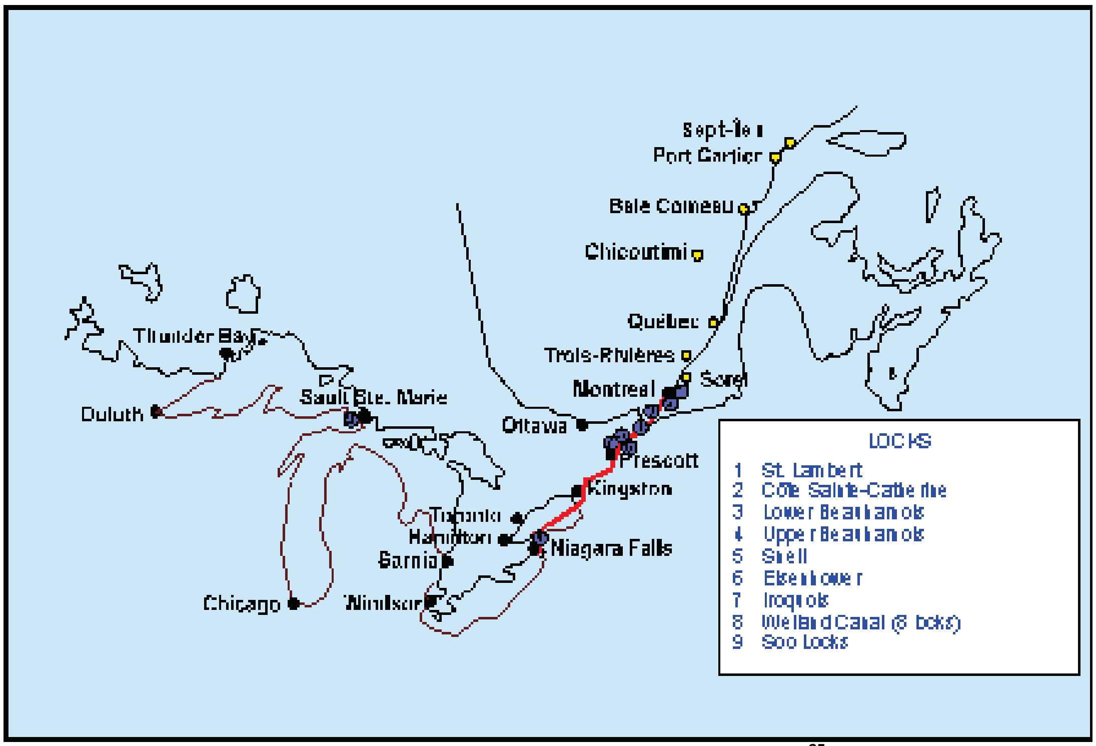

Figure 7.6: Locks Along the St. Lawrence Seaway[95]

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[92] Source: Scaldis Salvage & Marine Contractors. Retrieved March 2010 from Web site: http://www.scaldis-smc.com. Used with permission.

[93] Source: Siemens Energy. Retrieved from *Power Magazine* article: Peltier, R. (December 15, 2007). Burbo Bank Offshore Wind Farm, Liverpool Bay, UK. *Power Magazine*. Retrieved March 2010 from Web site: http://www.powermag.com. Used with permission.

[94] Source: The St. Lawrence Seaway Management Corporation (2008). *The Seaway Handbook.* Retrieved June 2009 from Web site: www.greatlakes-seaway.com/.

[95] Source: Great Lakes S. Lawrence Seaway Study. Retrieved March 2010 from Web site: http://www.glsls-study.com/English%20Site/waterway.html. Used with permission.

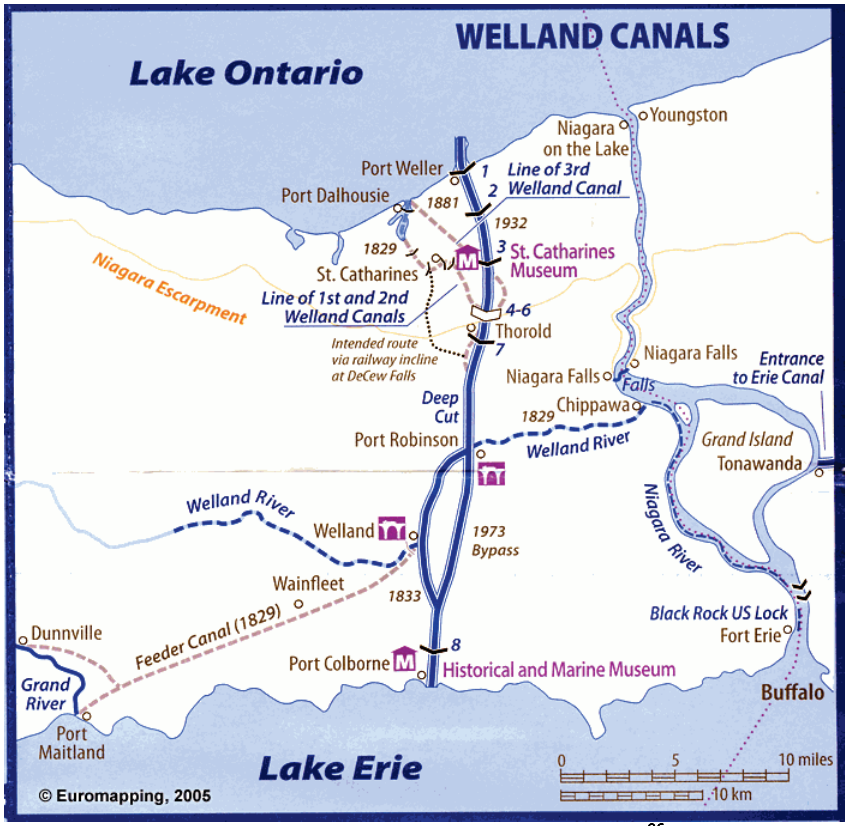


Figure 7.7: Locks Along the Welland Canal[96]

In summary, while special vessels exist worldwide for wind project installation, their availability in the Great Lakes may be limited by jurisdictional concerns (i.e. the Jones Act), as well as by passageway size through the Saint Lawrence Seaway and the Welland Canal. A candidate plan to remedy this issue could be the construction of one or more vessels specifically suited for offshore wind installation on the Great Lakes, as well as access to and from the lakes. There are adequate ship-building facilities and expertise available in the Great Lakes region and along the East Coast. Alternatively, creative logistics plans for employing existing equipment on the Great Lakes may also prove adequate for some projects and turbine/foundation designs. Ultimately, continued interest and growth in offshore wind in the United States may stimulate the construction of installation vessels and procedures to help facilitate the needs of the industry independent of a specific project or regional interest. While vessel access is a current concern, it is a challenge that can be addressed and overcome to make offshore wind energy development in the Great Lakes a reality.

7.3. Aviation

The location, height, and breadth of an offshore wind project will affect the navigable airspace around it. Wind turbine structures, including the rotor blades, can extend beyond 150 m (about 500 ft) above mean water level (see Table 7.1). The Federal Aviation Administration (FAA) regulates the siting of such structures near public use airfields and in certain navigable airspace. The criteria set forth in Federal Aviation Regulation (FAR) Part 77 (14 CFR 77) *Objects Affecting the Navigable Airspace*, FAA Order

[96] Source: David Edwards-May, Euromapping (2005). *North America Inland Waterways Map and Index*. Seyssinet, France: Euromapping. Used with permission.

8260.3B *United States Standard for Terminal Instrument Procedures* (TERPs), and FAA Order JO 7400.2G *Procedures For Handling Airspace Matters* will be used by the FAA in evaluating the aeronautical compatibility of a project when it is submitted for official regulatory review.

7.3.1 General Considerations

Multiple types of aviation patterns and procedures may affect a proposed wind project on Lake Erie or Lake Ontario. Aviation and FAA-related parameters pertinent to development include:

- Minimum Vectoring Altitude (MVA) thresholds
- Existing flight vectors
- Minimum En-Route Low Altitude Airways (MEAs), i.e. takeoff and landing approach paths to airports
- Minimum Obstacle Clearance Altitudes (MOCAs)
- Military Operation Areas (MOAs)
- Military Training Routes (MTRs)
- Long-Range and Doppler (WSR-88RD) Radar

While both major airports and smaller airports were considered for projects on both lakes, areas of concern typically are associated with smaller airports. This is because small airports usually have lower approach segments than major airports.

Table 7.1: Maximum Heights of Commercially Available Offshore Wind Turbines

Manufacturer	Model	Rotor Diameter (m)	Hub Height (m)	Max. Height (m)	Max. Height (ft)
AREVA Multibrid	M5000	116	90	148	486
REpower	5M	126	90	153	502
Siemens	2.3-93	93	80	126.5	415
Siemens	3.6-107	107	80	133.5	438
Vestas	V90-3	90	80	125	410
Vestas	V112-3	112	84	140	459

Air traffic restrictions are typically referenced in feet above mean sea level (AMSL). When treating inland projects and rules, the local terrain/water body elevation is subtracted from the AMSL to give the clearance above ground level (AGL). The elevation of Lake Erie is given by the United States Army Corp of Engineers as approximately 571 ft (174 m) AMSL.[97] Assuming an 80 m hub height, current and near-term turbine technology will likely have a total structure height in the range of 410-438 ft (125-133.5 m), considering the Vestas V90 and the Siemens 3.6, respectively (see Table 7.1). For each sector identified for Lake Erie and Lake Ontario, maximum buildable heights above the water level were obtained by

[97] Source: U.S. Army Corps of Engineers (2009). *Great Lakes Water Levels.* Retrieved August 2009 from U.S. Army Corps of Engineers Web site: http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/.

subtracting the lake's elevation from the regulated FAA threshold (see Table 7.2 and Table 7.3). The restrictions are height-sensitive and may allow construction of some current and near-term turbine models.

Situations where the planned turbine height would exceed a sector's specified limit can have differing implications. In most circumstances, objects exceeding the height restrictions defined by that area's procedures are issued a Notice of Presumed Hazard (NPH) and are subject to extended study by the FAA. The studies are very site-specific and assess the potential impact of specific turbine heights and locations on all air traffic in the region. In many cases, turbines sited far (3 nautical miles or greater) from airports are given a determination of No Hazard. However, if after study a proposed project is still determined to be a hazard to navigation then the FAA and developer/project proponent negotiate potential variations to project layout and/or height. These decisions are carried out on a case-by-case basis. In certain circumstances, the FAA and the local airport may alter approach patterns to accommodate projects, or the FAA may allow variances on the order of 100-150 ft to the MEA floor. In many sectors, modifying the current height restriction by this amount would allow for most current and near-term wind turbine heights to be within the adjusted guidelines. The relative importance of the project and/or its regional support may influence the FAA's determination or relative stance during negotiations. Since the determination is site and turbine-specific and there is an opportunity to negotiate a resolution with the FAA, development within these sectors cannot be wholly excluded from consideration.

7.3.2 Lake Erie Aviation

There is extensive commercial and private use of the air space over Lake Erie and the adjacent shoreline. Numerous air facilities are located in proximity to the lake and a complex airway structure exists to facilitate navigation in the area. The air traffic-related structure restrictions in Lake Erie fall into two general categories. The first category is defined by the VHF Omni-directional Radio (VOR) approaches to the Dunkirk Airport (FAA ID: DKK), a small public-use airport consisting of four approaches oriented approximately perpendicular and parallel to the Lake Erie shoreline.[98] Sectors A, B, C, D and E are defined in part by the Federal Aviation Regulation (FAR) part 77, and are configured based upon the orientation of the airport's primary runways. The second category, defining Sector F, is driven by the Minimum En-Route Low Altitude Airway (MEA) V-265, which is a point-to-point navigation path set by the FAA. These restrictions are buffers below the minimum navigation altitudes for the area: aircraft operating in these sectors are between 1000 and 2000 ft (305 and 610 m) above the thresholds described. Map 7.7 depicts the seven sectors for aviation consideration within Lake Erie. These sectors (A through F) are areas where development would be conditionally feasible, assuming potential conflicts with existing flight patterns and regulations are resolved with the FAA. The rest of New York's Lake Erie waters have a maximum developable height of 609 ft (186 m) above the water level, which exceeds the heights of turbines being considered for this study. Specific height restrictions for each of the sectors are defined below.

[98]Source: Retrieved April 2009 from AirNav.com Web site: http://www.airnav.com/airports/

Table 7.2: Lake Erie Aviation Sectors

Sector	Potential Conflict	Maximum Height Above Water
A	DKK VOR Rwy 24 Final Approach Stepdown Area	269 ft (82 m)
B	DKK VOR Rwy 24 Final Approach Primary Area	429 ft (131 m)
C	DKK VOR Rwy 24 Final Approach Secondary Area	429 to 609 ft (131 to 186 m)
D	DKK VOR Rwy 6 Final Approach Primary Area	349 ft (106 m)
E	DKK VOR Rwy 6 Final Approach Secondary Area	349 to 609 ft (106 to 186 m)
F	MEA V-265	329 ft (100 m)
NY Waters	No conflict - 1180 ft AMSL target height	609 ft (186 m)

In addition to the airport procedures, there is a complex, low-altitude Victor airway system that extends over Lake Erie as well as two FAA radar facilities that service the Lake Erie airspace area. The protected airspace for each of the airways is eight nautical miles (14.8 km) wide, within which there is a vertical obstruction clearance requirement of at least 1000 ft (305 m) below the prescribed Minimum En-Route Altitude (MEA). The heights of the structures (440 to 490 ft, or about 135 to 150 m) have to be considered in addition to the elevation of the lake (571 ft, or 174 m) when determining clearance for each airway. The minimum vertical obstacle clearance for the radar procedures is also 1000 ft (305 m). Further review of the en-route airway charts and radar vectoring charts is necessary to determine specific effects of turbine siting. The initial survey of the airway and radar vectoring systems indicated little potential impact on development. The volume and complexity of the existing airspace use around the Lake Erie study area necessitates further research and early involvement of the FAA and/or a qualified consultant to identify and mitigate any airspace infringements.

7.3.3 Lake Ontario Aviation

There is also extensive commercial, military, and private use of the air space over Lake Ontario and the adjacent shoreline. As for Lake Erie, maximum buildable heights were calculated by subtracting the FAA's AMSL requirements from Lake Ontario's elevation (245 ft, or 75 m).[99] The restrictions are height-sensitive and may allow construction of some current and near-term turbine models. For situations where the planned turbine height would exceed a sector's specified limit, discussions with the local airport and FAA regarding variances to the local procedures would a necessary early development step.

Three Military Operation Areas (MOAs), Misty 1, Misty 2, and Misty 3, are sited within Lake Ontario. Misty 1 and Misty 3 are above the project's threshold, and are not a concern for development. Misty 2 has a floor of 200 ft (61 m), which is lower than the height of a typical utility-scale wind turbine, making this area only conditionally feasible for development; however, this area is already mostly excluded due to water depth requirements.

Numerous air facilities are located in proximity to Lake Ontario and a complex airway structure exists to facilitate navigation in the area. There are three public use airports that will potentially affect offshore wind development in the lake. Map 7.8 depicts sectors for aviation consideration with respect to these airports. St. Catharines Niagara District Airport (ID: CYSN) in Ontario, CA, just west of the Federal border in the western portion of the lake, is a three-runway certified airport, making Sectors A and B

[99] Source: Retrieved October 2009 from Web site:
http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/.

conditionally feasible.[100] Olcott-Newfane Airport (FAA ID: D80) near Burt, NY is a small public airport consisting of four approaches. When in operation, an average of 23 operations were conducted per day, but the airport has been closed indefinitely at the current time.[101] Although the Olcott-Newfane Airport is not currently operational, the surrounding airspace, including Sector C, remains protected until its status is listed as permanently closed. Watertown International Airport (FAA ID: ART) in Jefferson County is a four-approach publicly-owned airport with an average of 142 daily operations, having the protected airspace indicated by Sectors D and E.[102]

MOA Misty 2 and Sectors A, B, C, and E are all areas where development would be conditionally feasible, assuming conflicts with existing flight patterns and regulations are resolved with the FAA. Sector D in Lake Ontario, defined by an approach to Watertown International Airport, is unique within the region, as it has no minimum clearance: the floor of the restricted area follows the surface of the ground and then the lake. As such, new structures of any height within that region will likely require a special variance from the airport and FAA. This type of restriction is very uncommon in the region and is expected to be difficult to modify. Allowances for wind turbine-sized structures (approximately 135 to 150 m, or about 440 to 490 ft) are considered unlikely. Thus, development within Sector D faces sufficient known obstacles, and development would only be feasible if the FAA were to significantly modify the current restriction. The rest of New York's Lake Erie waters have a maximum developable height of 755 ft (230 m) above the water level, which exceeds the heights of turbines being considered for this study.

Table 7.3: Lake Ontario Aviation Sectors

Sector	Potential Conflict	Maximum Height Above Water
A	St. Catharines Initial Approach Primary Area	455 ft (139m)
B	St. Catharines Initial Approach Secondary Area	455 to 755 ft (139 to 230 m)
C	Olcott-Newfane Cat B Traffic Area	420 ft (128 m)
D	Surface - Watertown International Transition Route to VOR Approach Rwy 7 Primary Area	0 ft (0 m)
E	Watertown International Transition to VOR Approach Rwy 7 Secondary Area	455 to 755 ft (139 to 230 m)
Misty 2	Military Operation Area	200 ft (60.9 m)
NY Waters	No conflict - 1000 ft AMSL target height	755 ft (230 m)

In addition to the airport procedures, there is a complex, low-altitude Victor airway system over the eastern portion of Lake Ontario and the surrounding land, as well as two long-range radar facilities located in Niagara and Rochester that service the Lake Ontario airspace area. The protected airspace for each of the airways is eight nautical miles (15.8 km) wide, within which there are vertical obstruction clearance requirements ranging from 600 to 1000 ft (183 to 305 m) below the prescribed Minimum En-Route Altitude (MEA). The heights of the structures (450-600 ft, or about 140-180 m) have to be considered in addition to the elevation of the lake (approximately 245 ft, or 75 m) when determining clearance for each airway. The minimum vertical obstacle clearance for the radar procedures is also 1000 ft (305 m). Further review of the en-route airway charts and radar vectoring charts is necessary to determine specific effects of turbine siting. The initial survey of the airway and radar vectoring systems

100 Source: Retrieved April 2009 from Niagara District Airport Web site: http://www.niagaradistrictairport.ca/.
101 Source: Retrieved April 2009 from AirNav.com Web site: http://www.airnav.com/airports/.
102 Source: Retrieved April 2009 from AirNav.com Web site: http://www.airnav.com/airports/.

indicated little potential for impact on development. The volume and complexity of the existing airspace use around the study area necessitates further research and early involvement of the FAA and/or a qualified consultant to mitigate any airspace infringements.

7.3.4 Further Research

For both lakes, the review determined that there are numerous approach procedures, transition routes, holding patterns, missed approach tracks, radar vector procedures, and other traffic pattern airspace areas (some directly over or in close proximity to the lakes) that may be affected by offshore development. Given the complexity and extent of this facility's influence on the region's airspace, further research will be required to determine specific impacts on project development.

The FAA makes changes to the National Aviation Systems every day. For example, new approaches are published, departure procedures are changed, new runways are planned, and MVAs are modified. Therefore, it is possible for the study's findings to become obsolete in a relatively short time period. It is recommended that, prior to filing for specific sites within the study area, the study findings be reviewed for currency. Studies more than 12 months old automatically require revisiting to confirm their findings.

These findings are intended as a planning tool in conjunction with the resolution of other pertinent issues. Actual construction activities are not advisable until the FAA Determinations of No Hazard are issued. Federal Aviation Regulation (FAR) Part 77 states that all proposed turbines locations require prior notice to the FAA. Most turbines submitted for approval are accepted, and very few are considered to be a hazard: from 2004 to 2006, almost 18,000 proposals were approved, and only eight were declined.[103] Depending on project size and siting, further requirements such as lighting schemes and aids to air navigation may be imposed. Any structure over 200 ft (61 m) above ground/water level requires notice to the FAA, and also requires lighting in accordance with FAA Advisory Circular (AC) 70/7460-1K, change 2. Any structure over 500 ft (152 m) above ground level would exceed obstruction standards, requiring the FAA to conduct an extended study.

7.4. Nuclear Plant Implications

Nuclear power generation on Lake Ontario may be a factor affecting potential wind development. Nuclear generation facilities are often sited along the coast, using the nearby water source to cool the condenser. The existence of a nuclear generation facility near a proposed project site would introduce a potential interconnection point along the coast. Jurisdictional and Homeland Security restrictions have the potential to inhibit or prevent wind project development in the area immediately surrounding the facility. While nuclear buffer zones may exist, these requirements vary on a plant-by-plant basis.

Although a review of Lake Erie's New York shoreline indicates that there are presently no planned or existing nuclear generation facilities in the region, Lake Ontario's shore is the site for three nuclear generation facilities. Nine Mile Point Nuclear Station (1,140.8 MW) and James A. Fitzpatrick Nuclear Reactor (852.2 MW) reside on the tip of Nine Mile Point, seven miles northeast of the city of Oswego along the shoreline. Robert E. Ginna Nuclear Power Plant (570 MW) is located on the lake's coast east of the city of Rochester. The presence of these facilities warrants additional investigation of the potential siting issues described above.

[103] Swancy, H. 2006. "Wind Power and Aviation." Presented at the AWEA 2006 Fall Symposium, December 6-8, Phoenix, AZ.

7.5. *Transmission System Assessment*

An analysis of the local electric infrastructure in the vicinity of the proposed project is influential in determining potential project size and viable points of interconnection. The local utility grid must be capable of transmitting the offshore wind energy production to consumers. A weak utility grid or high congestion on the local transmission system may limit project size. Although network upgrades can be completed to alleviate these concerns, system upgrades may affect the overall project cost. Distance to a viable point of interconnection will also affect balance-of-plant costs. While the details of permitting, interconnection, regulation, and other transmission issues are beyond the scope of this study, the following sections provide an initial assessment of the transmission systems along the shores of Lake Erie and Lake Ontario.

7.5.1 Lake Erie Transmission

Transmission along Lake Erie's southeastern shore is well developed close to the shoreline. Two high-voltage transmission lines (one 230 kV and one 115 kV) run parallel to Lake Erie's shore approximately five to eight km (three to five mi) from the coast. Multiple existing substations can be found along this path, which could be considered for financially feasible points of interconnection (POIs). Large cities such as Erie, Pennsylvania and Buffalo, NY have established infrastructure and large load demand, which are necessary elements for the off-take of wind energy. Also, large operational power plants in Dunkirk and Buffalo have strong electrical infrastructure. For additional transfer capability, PJM's Lake Erie Project, proposed in 2003, will link the United States to Ontario, Canada via two proposed submarine HVDC transmission lines, one in Pennsylvania and one in Ohio. This project would allow for international transfer of power from a Lake Erie wind project to Canadian load centers. While a more detailed analysis is necessary to determine the existing capacity on the transmission lines, access to high voltage transmission and interconnection seems readily available on Erie's southeast shore.

For the purpose of this study, New York's Lake Erie waters were divided into three regions of interest (Pennsylvania border to Dunkirk, Dunkirk to Lackawanna, and the Buffalo region). Potential POIs were determined for each region for various project size ranges: 150 MW or less, 150 to 300 MW, and 300 MW or greater. These POIs, presented in Table 7.4, Table 7.5, and Table 7.6, were listed in order of economic feasibility, assuming the potential project is sited in the center of the region.

Table 7.4: Potential POIs for Various Project Sizes – Pennsylvania Border to Dunkirk

Point of Interconnection	Voltage (kV)
0 -150 MW	
Near Barcelona	115
Westfield	115
West of Fredonia	115
Near Barcelona - Near West Portland (New Tap)	115
Dunkirk - Near Fredonia (New Tap)	115
Dunkirk	230
150 - 300 MW	
Dunkirk	230
Dunkirk - South Ripley Line (New Tap)	230
South Ripley Tap	230
300 MW +	
Lines greater than 230 kV will be required to support a project of this magnitude	

Table 7.5: Potential POIs for Various Project Sizes – Buffalo Region

Point of Interconnection	Voltage (kV)
0 - 150 MW	
Near Angola	115
Near Lake View	115
Silver Creek	115
Near Clover Bank	115
Tap East of Dunkirk	115
Near East Blasdell	115
150 - 300 MW	
Dunkirk - Gardenville Line (New Tap)	230
Dunkirk	230
Gardenville	230
300 MW +	
Lines greater than 230 kV will be required to support a project of this magnitude	

Table 7.6: Potential POIs for Various Project Sizes – Buffalo Area

Point of Interconnection	Voltage (kV)
0 - 150 MW	
Near East Blasdell	115
Near Union Ship Canal	115
Buffalo River	115
Near Lakawanna	115
Elm Street	230
150 - 300 MW	
Elm Street	230
Kensington	230
Gardenville	230
300 MW +	
Lines greater than 230 kV will be required to support a project of this magnitude	

7.5.2 Lake Ontario Transmission

Access to high-voltage transmission lines along New York's Lake Ontario coast is limited; however, there is adequate infrastructure for injection of wind energy farther inland. Transmission lines near the shoreline can be found near the cities of Rochester and Oswego. Multiple generation facilities exist along the coast line, including several in the Oswego area, which could be potential points of interconnection. With the exception of these few locations, the nearest high-voltage lines for potential interconnection are typically 25 to 50 km (about 15 to 30 mi) inland. Although these lines have potential for interconnection, injection will be costly, and obtaining necessary rights of way will be more difficult. Cities such as Buffalo and Rochester have established infrastructure and large load demand: two necessary elements for the off-take of wind energy. For additional transfer capability, NYISO's St. Lawrence tie with Ontario allows for international transfer of power from a Lake Ontario wind project to Canadian load centers; however, the transfer capabilities at St. Lawrence are limited to 200 MW. Therefore, load demand is limited, and finding nearby access to high-voltage lines for grid interconnection may be difficult for a project sited on Lake Ontario.

For the purpose of this study, New York's Lake Ontario waters were divided into three regions of interest (Buffalo to West Hamlin, West Hamlin to Station 216 (just West of Sodus Bay), and Station 216 to Dexter, NY). Potential POIs were determined for each region for various project sizes. These POIs, presented in Table 7.7, Table 7.8, and Table 7.9, were listed in order of economic feasibility, assuming the potential project is sited in the center of the region.

Table 7.7: Potential POIs for Various Project Sizes – Buffalo to West Hamlin

Point of Interconnection	Voltage (kV)
0 -150 MW	
Telegraph Road	115
Shelby	115
Somerset	345
Lockport	115
Robinson Road	115
W. Hamlin	230
150 - 300 MW	
Somerset	345
Robinson Road	230
Moses Niagara	345
Robinson Road - Stolle Road (New Tap)	230
Moses Niagara - Robinson Road (New Tap)	230
300 MW +	
Somerset	345
Moses Niagara	345
Moses Niagara - Rochester (New Tap)	345

Table 7.8: Potential POIs for Various Project Sizes – West Hamlin to Station 216

Point of Interconnection	Voltage (kV)
0 - 150 MW	
Ginna	115
Station 3	115
Spencerport	115
Station 216	115
W. Hamlin	115
Pannell	345
150 - 300 MW	
Pannell	345
Rochester	345
Pannell - Clay (New Tap)	345
Moses Niagara - Rochester (New Tap)	345
Somerset - Rochester (New Tap)	345
300 MW +	
Pannell	345
Rochester	345
Pannell - Clay (New Tap)	345

Table 7.9: Potential POIs for Various Project Sizes – Station 216 to Dexter

Point of Interconnection	Voltage (kV)
0 - 150 MW	
Alcan	115
Scriba	115
Hammerhill	115
South Oswego	115
Scriba	345
Oswego	345
150 - 300 MW	
Scriba	345
Oswego	345
Volney	345
300 MW +	
Scriba	345
Oswego	345
Volney	345

7.6. Wildlife

A preliminary review of wildlife considerations along the shoreline of Lake Erie and Lake Ontario was conducted. The purpose of this review is to call attention to specific areas of concern where more investigation is warranted. The review is not intended to be all inclusive, nor is it meant to be supplementary to an environmental impact study. Rather, this natural resource review intends to call out obvious areas of significance from a high level, and recommend potential paths for further study.

An important land use consideration along Lake Erie's shoreline is the presence of bird habitats. Audubon New York designates Chautauqua Lake, Dunkirk Harbor and Point Gratiot, Ripley Hawk Watch (Ripley, NY), and Wheeler's Gulf as important bird areas in Chautauqua County that may be impacted by a potential wind project on Lake Erie. In Erie County, Tifft Nature Preserve, located in the city of Buffalo on the lake's shore, is an important bird area meriting consideration. Designated important bird areas are located at various points along Lake Ontario's shore, most prominently near Rochester and along the lake's eastern coast. Additional areas of importance exist inland, particularly in the lands northeast of the lake and along the St. Lawrence River. The double-crested cormorant, which is listed by the United States Fish and Wildlife Service as a species of concern, is found in abundance on Galloo Island. Avian considerations will merit additional attention, particularly for potential project locations in the northeastern and eastern portion of the lake.

Numerous endangered and threatened species exist in both New York and along the lakes' shorelines. The Piping Plover, a beach dweller, is an endangered species in the Great Lakes region. The Piping Plover, shown in Figure 7.8, has a designated critical habitat along the eastern shore of Lake Ontario, spanning Oswego and Jefferson counties. The presence of this bird may cause environmental considerations for projects proposed in the northeastern and eastern portions of the lake. The Piping Plover also has a designated critical habitat on Lake Erie's southern shore near the city of Erie, PA, although this region is likely to be outside of the area of impact for a New York offshore wind project. Another species to consider in the Lake Erie and Lake Ontario region is the Bald Eagle (threatened).

Figure 7.8: Piping Plover[104]

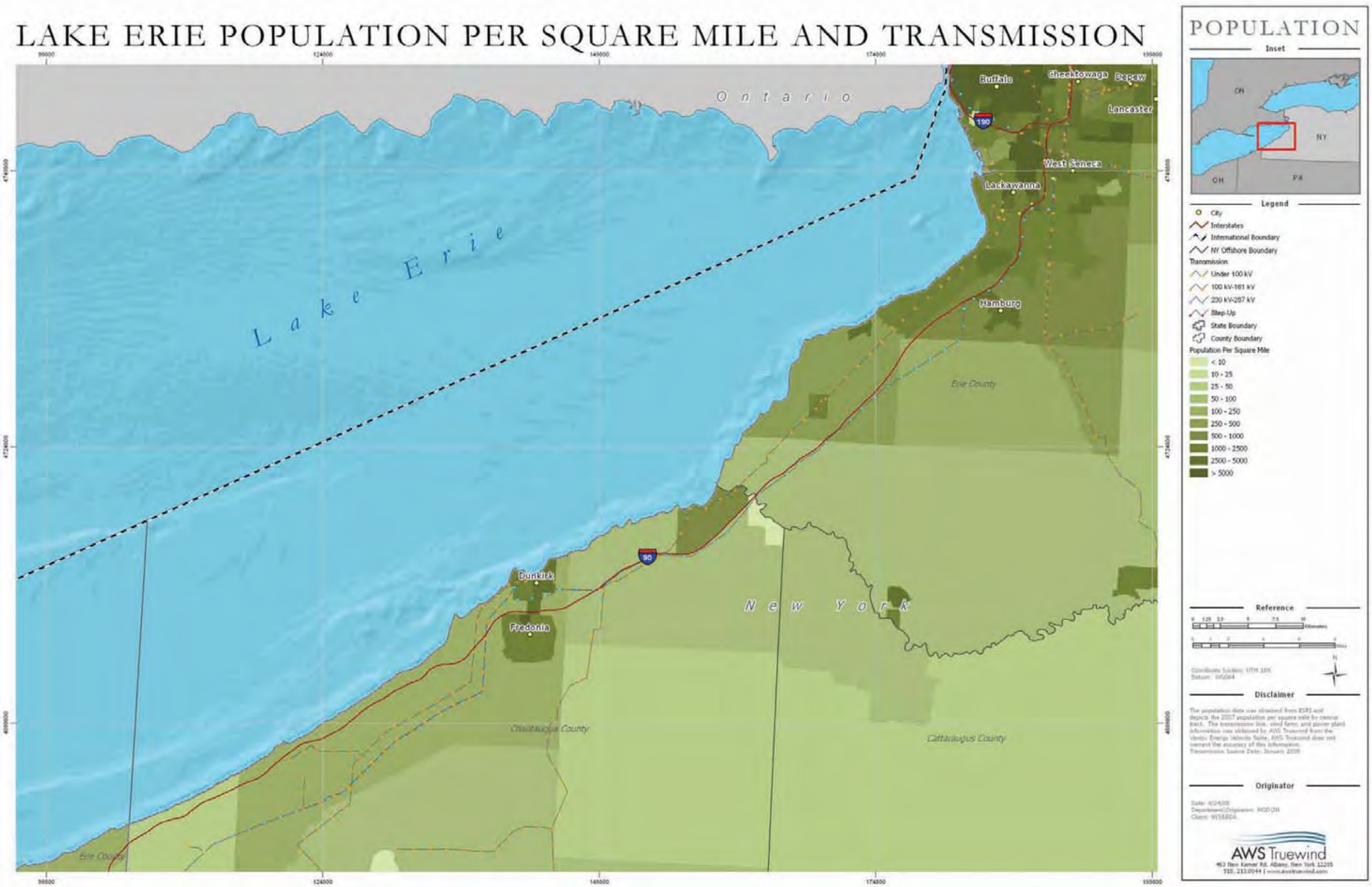
Additional study on the interaction between onshore wildlife in the Lake Erie and Lake Ontario region and a potential offshore wind energy project is recommended. Comprehensive lists of endangered species, threatened species, and species of special concern are available from the New York State Department of Environmental Conservation.[105] A list of potential organizations and institutions for assistance in this review is presented below:

- Great Lakes Sea Grant Network
- Great Lakes Commission
- Great Lakes Program at Buffalo
- University of Wisconsin Sea Grant Institute
- Great Lakes Waterbird Research Program
- Case Western Great Lakes Institute for Energy Innovation
- Great Lakes Wind Energy Center

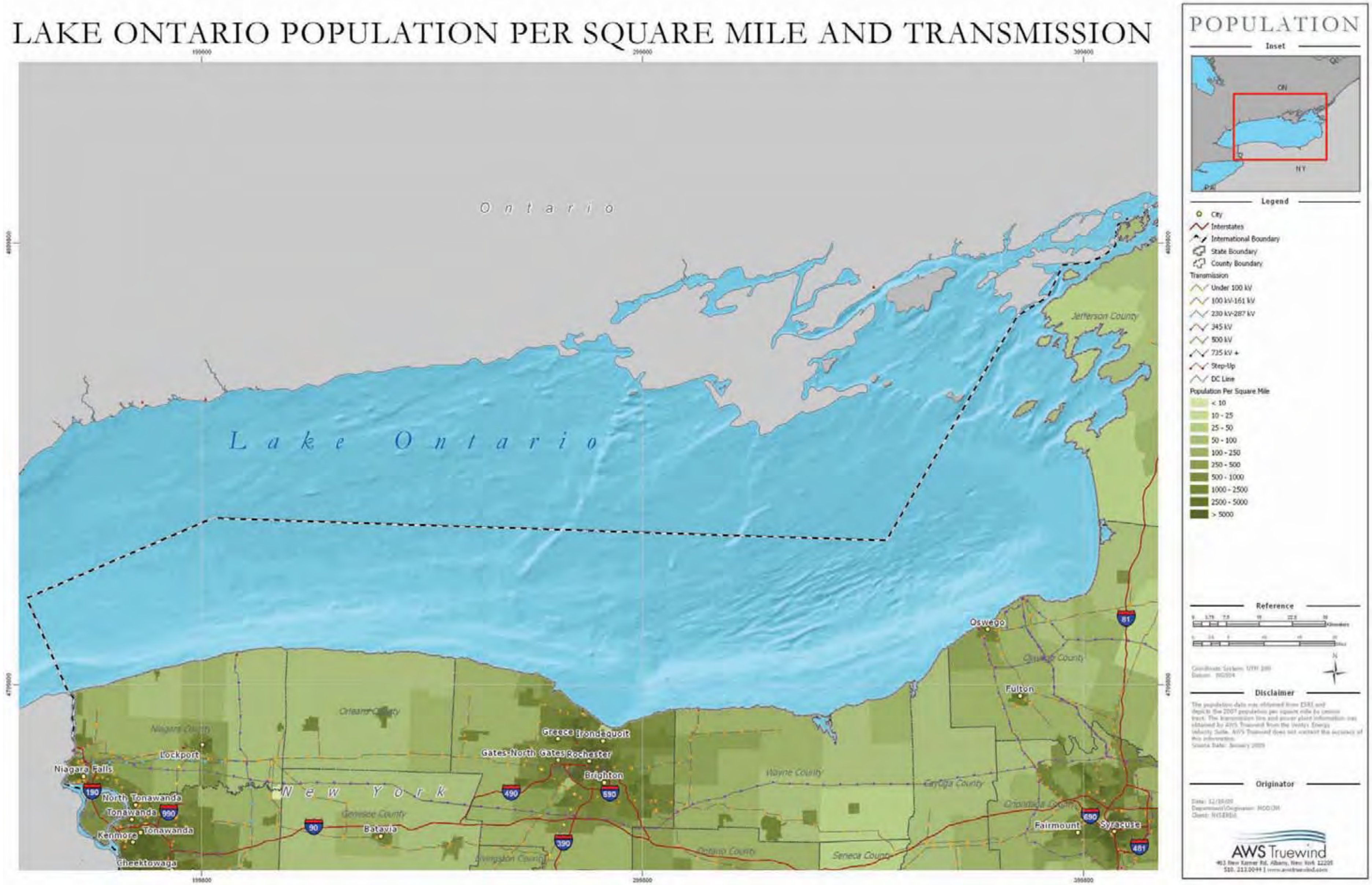
[104] Source: Courtesy of the Tern and Plover Conservation Partnership, Wayne Hathaway, photographer. Retrieved February 2010 from Web site: http://ternandplover.unl.edu. Used with permission.
[105] More information available from the Department of Environmental Conservation at http://www.dec.ny.gov/animals/7494.html

7.7. Maps

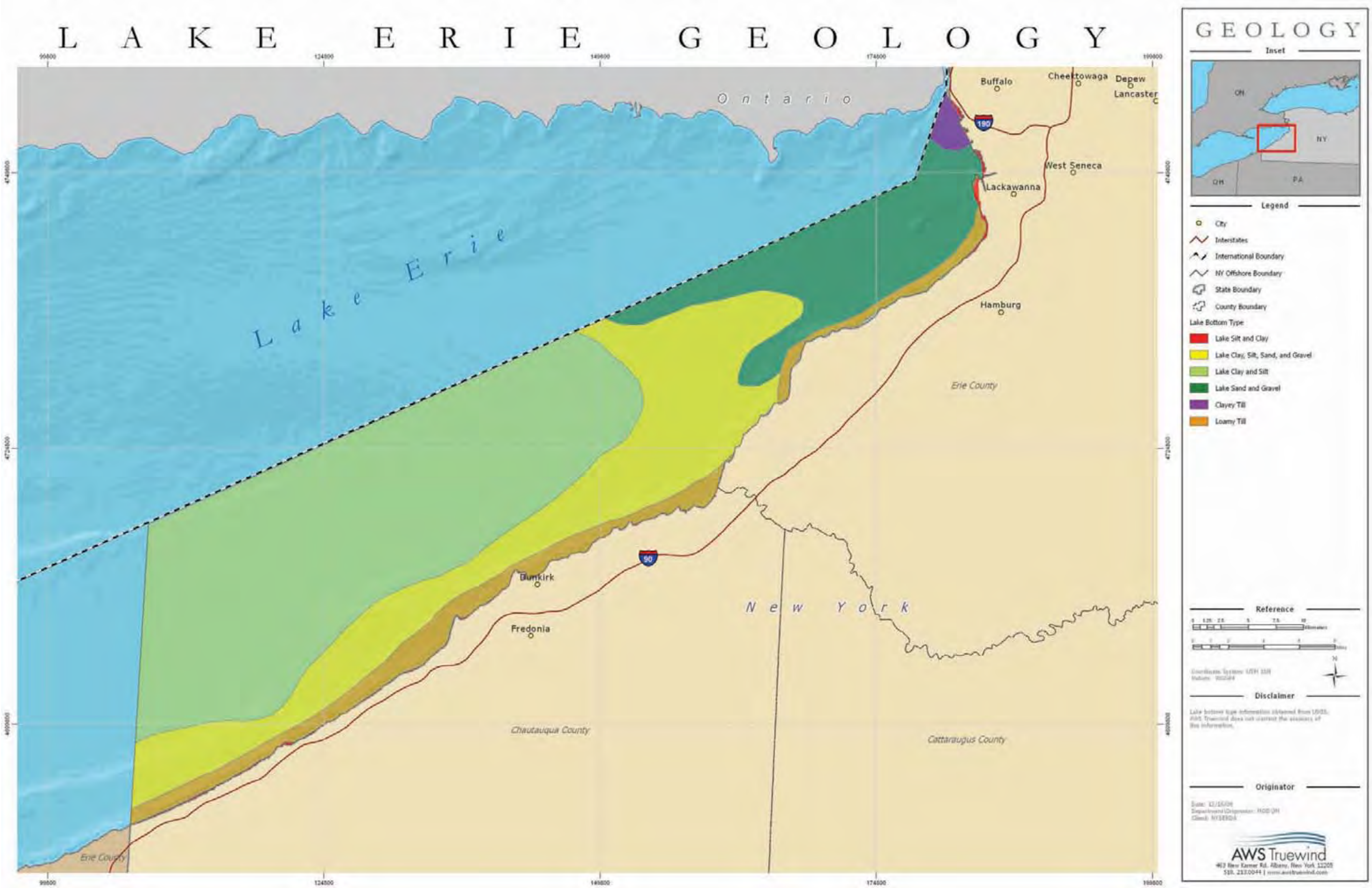
Map 7.1: Lake Erie Population per Square Mile and Transmission



Map 7.2: Lake Ontario Population per Square Mile and Transmission

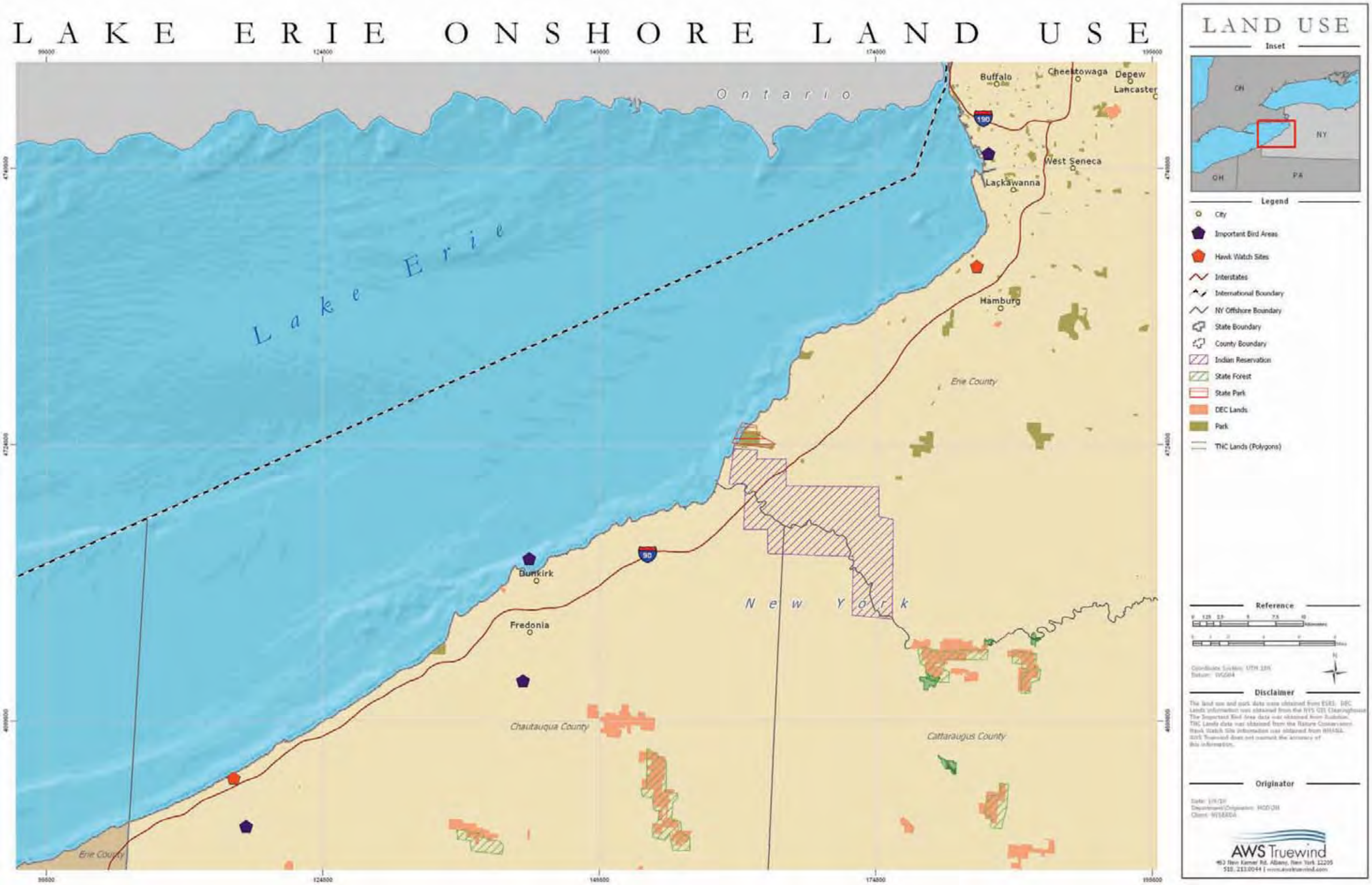


Map 4.1: Lake Erie Geology

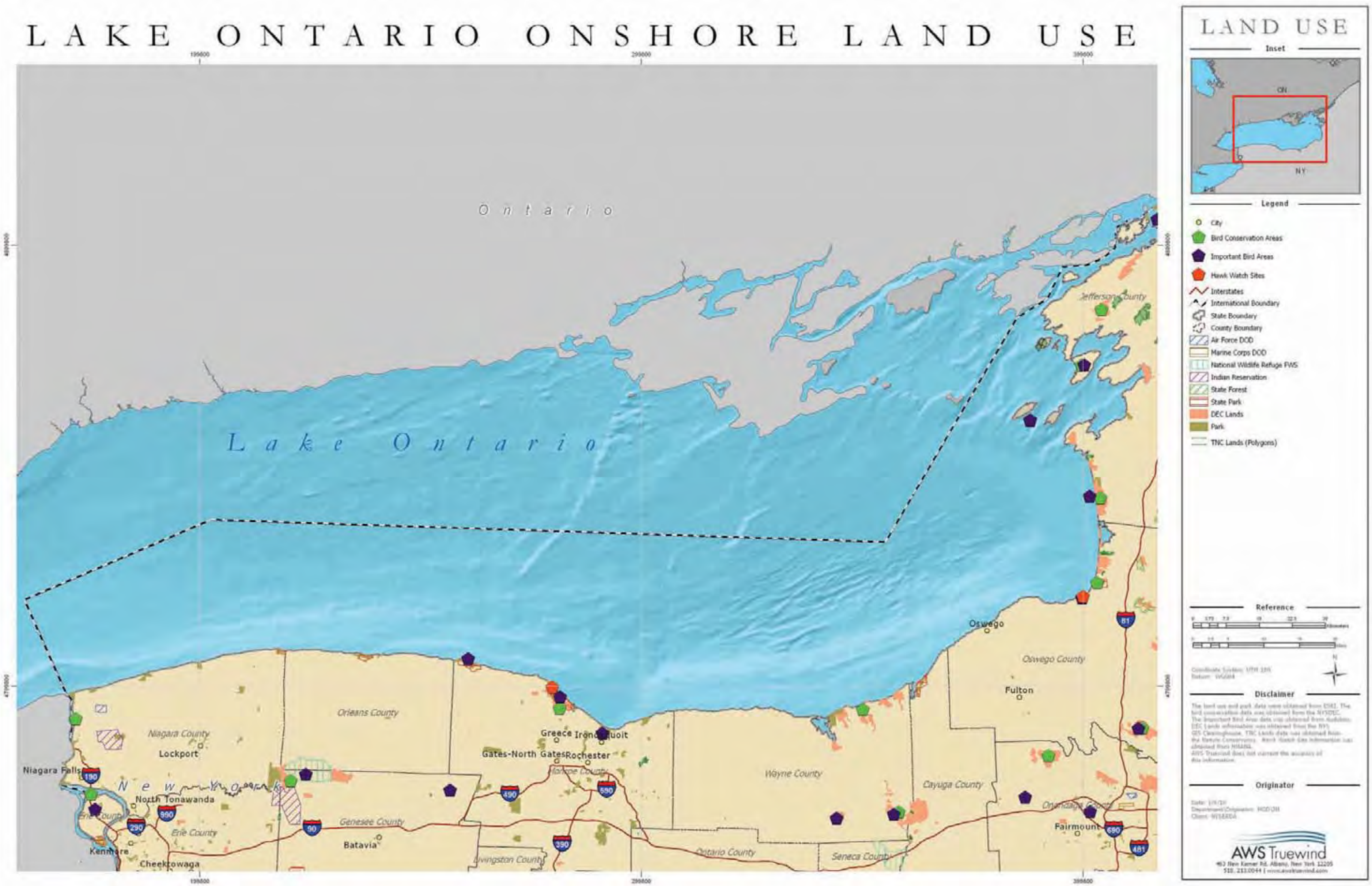


Map 7.4: Lake Ontario Highways and Cities

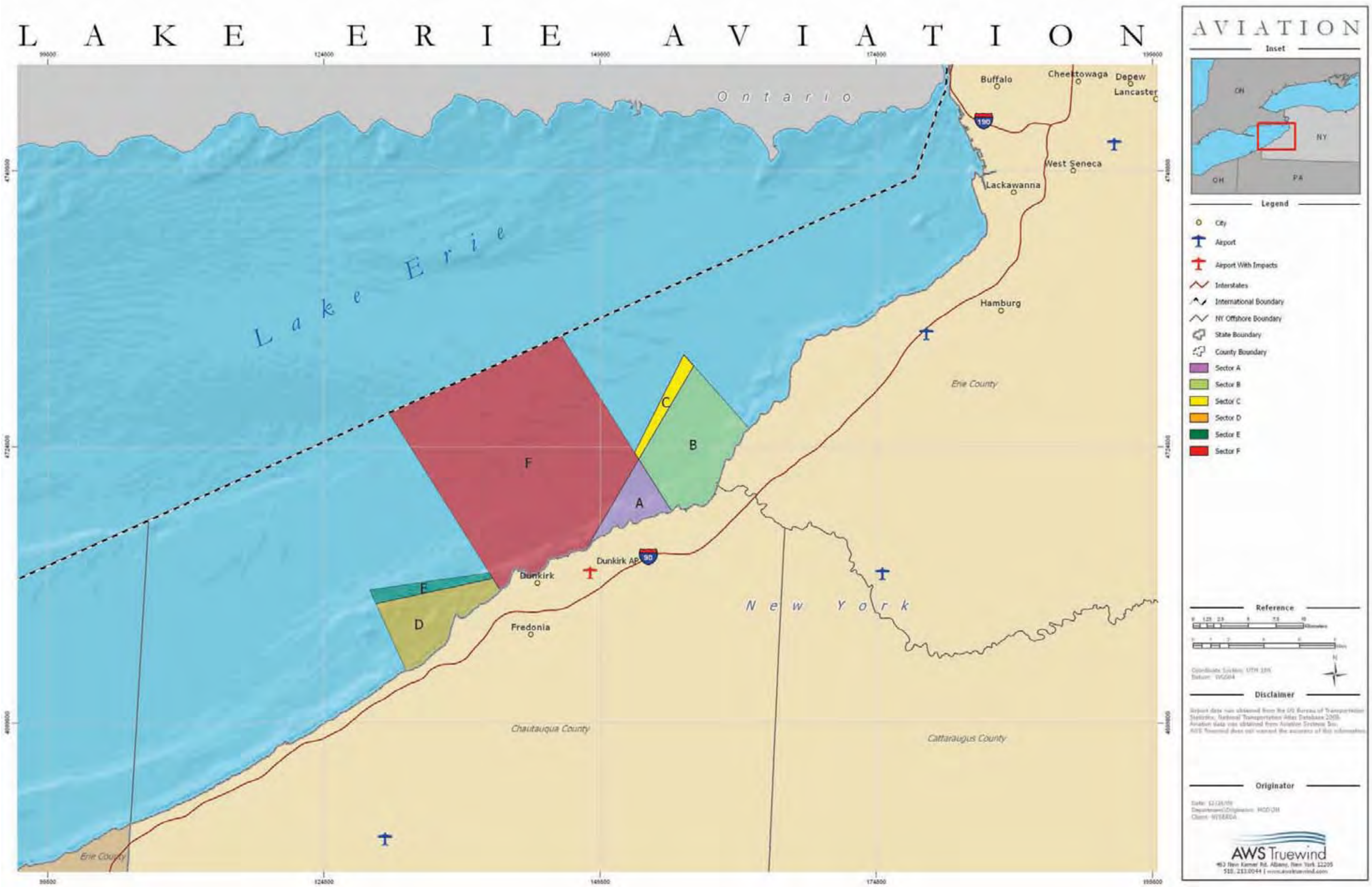
Map 7.5: Lake Erie Onshore Land Use



Map 7.6: Lake Ontario Onshore Land Use

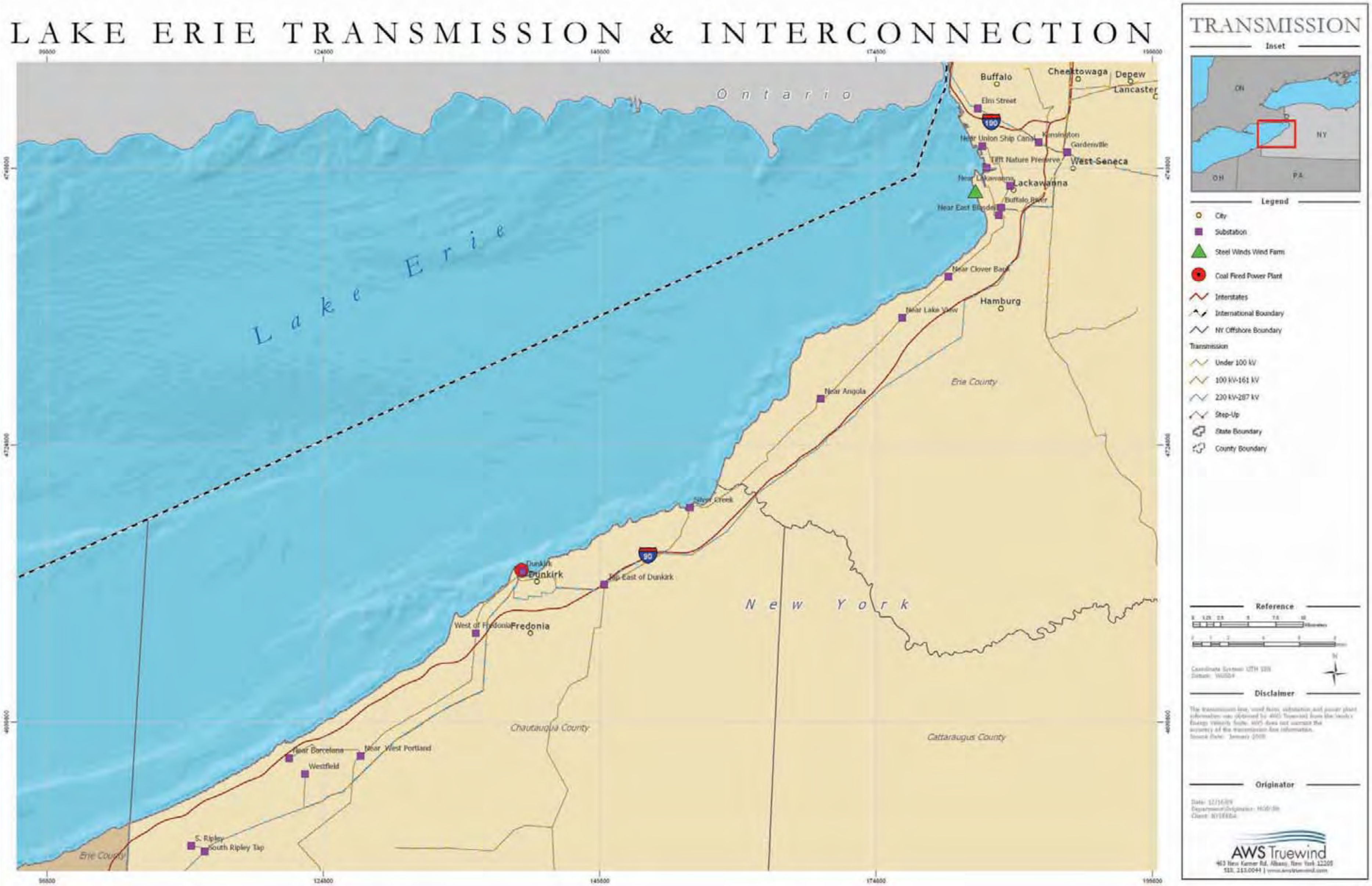


Map 7.7: Lake Erie Aviation

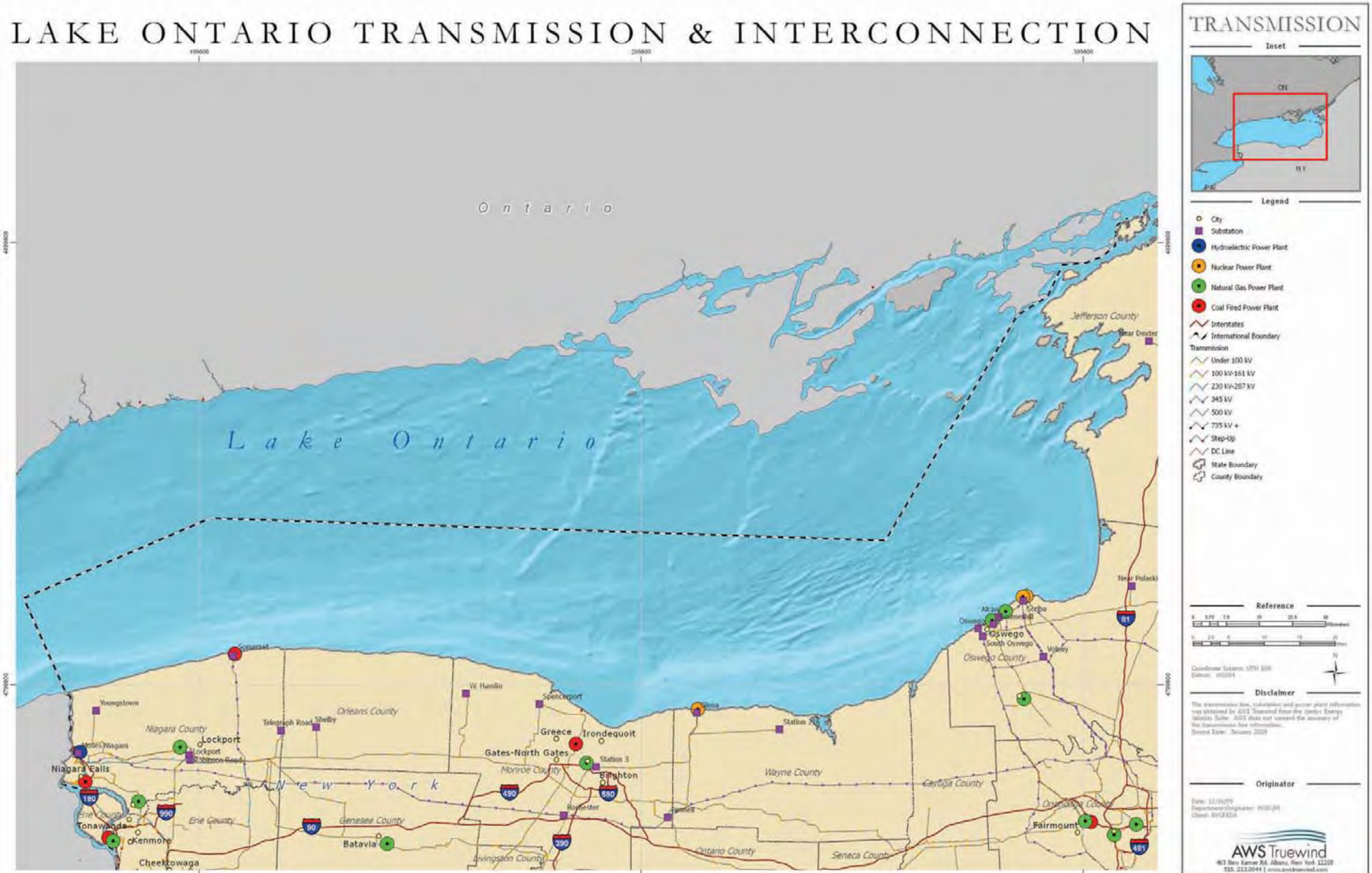


Map 7.8: Lake Ontario Aviation

Map 7.9: Lake Erie Transmission and Interconnection



Map 7.10: Lake Ontario Transmission and Interconnection



8.0. Siting Analysis

8.1. Introduction

Development of an offshore wind project in the New York State waters of Lake Erie or Lake Ontario is to date unprecedented. Brought to fruition, such a project would be one of the first offshore projects in the United States and among the first in the world as a freshwater venture.[106] Integrating local and regional data, as well as European offshore wind experience, this study has reviewed a variety of technical, logistical, and environmental siting considerations relevant to the feasibility of offshore wind development in the New York waters of Lake Erie and Lake Ontario. The significance and impact of these parameters will have a bearing on wind project siting, sizing, engineering, and economics.

In this chapter, the relative attractiveness of various portions of New York State's coastal zone is evaluated by applying a set of specific screening criteria. The resulting areas tentatively eligible for wind project development are referred to as "conditionally feasible" areas, meaning that their actual feasibility will be contingent on more comprehensive site screening investigations in the future. This study's aim is to define a first-order set of areas where future investigations should focus.

The screening criteria employed in this section were principally selected for the siting of large-scale (greater than 100 MW) commercial wind projects. They were chosen to identify sites with the highest energy yield, considering technical and environmental constraints. This screening process is not meant to exclude the feasibility of smaller project ventures, erected with public or private support as pilot and/or research projects, which may not necessarily be held to the same requirements.

8.2. Approach

The parameters addressed by this study were selected based on known technical and non-technical constraints. Based on these parameters, areas presenting greater challenges to wind development and lower apparent feasibility were removed from consideration. Table 8.1 presents the site screening criteria used for this analysis. The developable area in each lake by water depth and wind speed and corresponding potential MW build-outs are presented at the end of the chapter in Table 8.2 and Table 8.3.

For this site screening process, the study was split into three parts—Lake Erie, Lake Ontario, and Pilot Project Locations—based on similarity of features. The analysis process examines these areas according to the criteria described above and detailed in the sections below. Maps illustrating the combined effects of these parameters are presented at the end of this chapter.

[106] *AWEA Applauds NYPA Plans to Proceed With First Freshwater Offshore Wind Projects.* April 23, 2009. Retrieved November 2009 from AWEA Web site: http://www.awea.org/newsroom/releases/AWEA_applauds_NYPA%20_Offshore_plans_23Apr09.html

Table 8.1: Lake Erie Site Screening Criteria

Parameter	Description	Specified Constraint
Wind Resource	Exclusionary	Mean annual wind speed <=7.5 m/s at 80 meters (16.8 mph at 262 ft)
Bathymetry	Exclusionary	Depths >= 150 ft
Shipping Lanes	Exclusionary	Track lines plus 0.5 nautical mile buffer
Shipwrecks & Obstructions	Exclusionary	Plus 30 m buffer
Dumping Grounds	Exclusionary	Plus 300 m buffer
Anchorage Areas	Exclusionary	Plus 300 m buffer
Cables/Pipelines	Exclusionary	Plus 300 m buffer
Political Boundaries	Exclusionary	0.25 nautical mile buffer from international boundary
Air Traffic Restrictions	Precautionary	No additional buffer applied
Ice Cover (No. of days at 90% or greater)	Precautionary	TBD
Significant Coastal Fish and Wildlife Habitat	Precautionary	No additional buffer applied. Obtain guidance from active user
Airports	Precautionary	Reference Air Traffic Restrictions above
Bird Conservation Areas	Precautionary	TBD
Important Bird Areas	Precautionary	TBD
Hawk Watch Sites	Precautionary	TBD
Ports	Consideration	Proximity to ports; access to construction materials
Transmission/Substations	Consideration	Proximity to substations; capacity availability
Railroads and Major Highways	Consideration	Proximity to transportation
Federal Lands	Consideration	TBD
Parks and Other Protected Areas	Consideration	TBD
National Register Sites	Consideration	TBD
Coastal Land Cover/Land Use	Consideration	Visual and environmental impact
Rivers/Streams	Consideration	Sediment deposits at the mouth of the river
Population Density/Major Cities	Consideration	Proximity to load center
Wind Farms	Consideration	Impact on performance, transmission load or siting
Power Plants	Consideration	Impact on transmission load or siting

8.3. Lake Erie

Evaluation of New York's Lake Erie waters resulted in two primary areas of interest, divided roughly by the north-south track line entering Dunkirk. The first is located southwest of the city of Dunkirk and stretches to the Pennsylvania border. It extends from the coast of Chautauqua County out to approximately 8 km (5 mi) from shore. The second is located northeast of Dunkirk and reaches roughly to the city Buffalo. This area is also adjacent to the coasts of Chautauqua and Erie Counties and varies from 5 to 11 km (3 to 7 mi) in width. Both these locations have characteristics attractive for commercial-scale offshore wind energy development.

The screening process also resulted in several smaller, discontinuous areas farther offshore of the regions identified above. These were not explicitly excluded from consideration, but their limited size and additional challenges to development (including greater distance from shore, greater water depth, and potential increases in the shipping lane buffers) did not warrant separate discussion. The primary considerations for Lake Erie are described below.

8.3.1 Water Depth

The slope of the Lake Erie lakebed is relatively gentle, with only a small portion of the New York State waters having depths over 45 m. This allows project siting to be considered along the State's entire coast. The eastern end of the lake has the additional benefit of shallow water farther off shore. From Buffalo to northwest of Dunkirk, sub-45 m depths extend from shore to the Canadian Border. Farther south from Dunkirk to the Pennsylvania border, shallow United States waters exist out to distances of 13 to 19 km (8 to 12 mi) from shore. While not exclusionary criteria, it should be noted that design conditions associated with shallow water – namely, ice and storm surge - are expected to be prevalent at this end of the lake.

8.3.2 Wind Resource

The southern shore of Lake Erie along the New York border exhibits relatively high expected annual average wind speeds for the region, 7.5 to over 8.0 m/s (17 to 18+ mph). The high-speed winds are expected to come very close to the shoreline and suffer little attenuation, establishing several large areas that meet both the depth and resource siting criteria. The size of the areas with predicted speeds of over 7.5 m/s (18 mph) allows considerable siting freedom.

8.3.3 Weather, Waves, and Ice

Seasonal variations of weather and sea state on the lake will affect numerous development parameters. Among these are the overall project timetable, installation logistics, O&M, and annual energy production. Autumn and winter will prove to be the most challenging seasons for construction and site access on Lake Erie. High winds in the fall months tend to bring rough seas and large, breaking waves; however, these winds will also be the strongest contributors to annual energy production. The southwest and northeast winds also lead to dramatic water level changes at the lake extremities. Depending on the strength and direction of the winds, areas near Buffalo may see water levels as much as ten feet above or below normal for as long as twelve hours, potentially limiting site access during these periods.

Ice effects in Lake Erie are more prevalent in the eastern end of the lake. Both pack ice and fast ice are regularly present within developable areas in Lake Erie as the lake's strong wind resource also brings ice floes and drifts. These ice effects continue into the spring as loose ice is blown eastward and packed into the Buffalo area, forming pressure ridges, sometimes extending more than 20 feet out of the water and anchoring themselves to the lake floor. While the weather, wave, and ice conditions on the lake merit attention during subsequent investigation – and, in the case of ice, additional detailed study – none were deemed significant obstacles to offshore wind development in Lake Erie and no regions of the lake were excluded based upon them.

8.3.4 Transmission

Transmission access and interconnection are not expected to limit development opportunities within the areas of Interest in Lake Erie. An extensive electrical infrastructure exists at Buffalo for a project sited in the northeast portion of the lake, while the coal generation station at Dunkirk, NY could be a feasible point of interconnection for a project sited along the Chautauqua County coast. There are several high voltage lines running parallel to the coast all along the Lake Erie's New York shoreline. Though detailed interconnection analysis is still required, there appear to be no obvious transmission roadblocks at this stage of evaluation.

8.3.5 Existing Uses and Transportation

Existing land and water usage and transportation infrastructure along Lake Erie's New York shoreline is diverse. Highly urban and industrial areas, residential areas and small towns, recreational and agricultural areas, and reserved American Indian and State lands all exist along and adjacent to the lake's shore. There is extensive air, water, and land transportation usage over, on, and adjacent to the lake. While few explicit exclusions to development were identified, the implications of these uses are varied and potentially significant (particularly as related to permitting). Prominent existing land use and transportation topics are identified below.

An important land use consideration along Lake Erie is bird activity. Designated important bird areas are located along the coast, most predominantly just north of Buffalo and adjacent to the southernmost portion of New York's Lake Erie waters. Farther south and inland are more areas of importance. The Lake Erie coastline has a significant population of local and migratory birds and bird watchers. Although some bird activity may extend over portions of the lake, no specific exclusion areas were identified for this study. The sites' proximity to these sensitive areas certainly merit further attention in follow-on studies.

Transportation in the vicinity of the lake will affect potential siting and layout. Water-borne traffic on Lake Erie will both facilitate and restrict potential development. The proximity of the Port of Buffalo has logistical advantages to development. Deep draft vessel berths and heavy cargo handling facilities are available. The port is serviced by air, rail, water and highway connections. Heavy shipping and construction companies operate in the area and many have bases on eastern Lake Erie. It will be a likely candidate port to base project installation and O&M activities for Lake Erie projects.

High-traffic areas on the lake, such as the Port of Buffalo, and prescribed track lines between major lake ports were excluded from consideration. The track lines were given a buffer of 0.5 approximately 1 km (0.5 nautical miles); however, the United States Coast Guard indicated that actual buffers from traffic lanes would be determined during project-specific evaluation. While these exclusions are not large, they significantly segment the attractive areas and may limit the feasibility of development north of the Buffalo-Conneaut route.

Fishing is another existing water use that exists within the conditionally feasible area. Commercial, recreational, and sport fishing all exist to varying degrees on the lake. While no specific fishing-related exclusions were found for this study, this topic merits further study and outreach as a stakeholder.

Air traffic routes in the vicinity of Dunkirk Airport (DKK) may affect development. Several regions with various air space related height restrictions were identified over Lake Erie. While the height restrictions listed for nearly all these areas are lower than the expected turbine structure height, development within the regions is not necessarily precluded. This topic merits follow-on study to both further characterize specific areas of the lake and to engage the FAA as an important stakeholder in development.

8.4. Lake Ontario

Evaluation of New York's Lake Ontario waters resulted in characterizing the lake in separate eastern and western geographical regions, split approximately at the city of Rochester. The eastern portion of the lake has the largest concentration of contiguous, technically feasible and conditionally feasible area on the lake. The portions most attractive for commercial wind development reach north and east from Oswego, through Mexico Bay and into the northeast portion of the lake near Galloo Island and Cape Vincent. The area of interest roughly follows the coastlines of Oswego and Jefferson Counties, stretching farther from shore near the entrance to the Saint Lawrence River.

The screening process also identified a long, narrow band of conditionally feasible area along the lake's southern shore. While likely not feasible for a commercial project of 100 MW or larger, this area was not explicitly excluded from development consideration. Portions of this area are discussed in a following section on Pilot Projects (8.5). The primary considerations for Lake Ontario are described below.

8.4.1 Water Depth

The overall depth of Lake Ontario and the relatively steep slope of its lakebed near the southern shore were the most significant screening criteria for this region. For most of the lake, the 45 m (approximately 150 ft) bathymetric contour generally restricted the eligible area to a narrow band, approximately 2 to 7 km (1 to 4 mi) from shore. While this does not necessarily preclude offshore wind development across that area, it may significantly limit project size and necessitate that turbines are sited relatively close to shore.

The eastern and northeastern ends of Lake Ontario, identified as attractive regions for commercial wind development, are unique in that they contain shallow water well offshore; depths of less than 45 m (approximately 150 ft) can be found up to 35 km (22 mi) offshore. The region from Mexico Bay north to Stony Point has technically feasible area roughly 10 to 14 km (six to nine mi) away from shore. The moderate water depths continue north and west of Stony Point, resulting in a large, nearly contiguous region of technically feasible area from Oswego north and east to the entrance of the Saint Lawrence river. Current and near-term offshore wind turbine foundation technology can be used here and the benefits of offshore development can be considered.

8.4.2 Wind Resource

The wind resource in the eastern and northeastern waters of Lake Ontario is enhanced by several physical aspects of the lake. The prevailing winds through the year are out of the northwest to the southwest, resulting in a long open-water fetch that favors relatively strong winds. In the northeastern portion of the lake, southwestern winds are expected to be further channeled by the converging landmasses at either side of the entrance to the St. Lawrence. These features are expected to yield a favorable wind resource in the eastern and northeastern sectors of the lake. The orientation of the shoreline and shallow water regions also allow for optimization of exposure to prevailing wind directions and potentially limiting wake-induced array losses. Relatively large portions of the lake from Oswego east and north to the Saint Lawrence have access to expected annual average speeds of at least 7.5 m/s (16.8 mph) over feasible water depths.

Similar to the water depth, the wind resource along Lake Ontario's southern coastline exhibits a steep gradient from the shore. While relatively attractive annual average wind speeds – 7.5 m/s (16.8 mph) and above – are predicted to exist within close proximity to shore (roughly 2-5 km, 1-3 mi), access to much of this resource is limited by water depth. It is addressed further in Section 8.5.

8.4.3 Weather, Waves and Ice

There were no exclusion areas identified in Lake Ontario that resulted from expected climate or sea state conditions. While the eastern region of the lake experiences weather and wave events of increased severity with respect to other coastal areas, it is anticipated that these conditions can be effectively treated in subsequent siting and development efforts.

Similarly, there were no exclusion areas defined for the lake based upon expected icing conditions. The eastern end of the lake does experience more frequent and often thicker icing than the rest of the lake; however, these conditions are not expected to preclude development within the identified areas. Additional technical study into cost effective solutions to ice-related challenges is both anticipated for the near-term and recommended for this lake.

8.4.4 Transmission

Transmission and interconnection options in the vicinity of prospective eastern regions are limited. There is not a great population density along the eastern end of the lake and thus the electrical infrastructure is not as developed as other shoreline areas (e.g. Rochester). Oswego and the nearby generating stations (fossil and nuclear) are the exception to this, and do provide potential interconnection options; however, these are at the far southern end of the screened region. In the immediate siting area, there are buried cables to supply power to the islands: Galloo and Stony Islands in the south, and Grenadier and Fox Islands in the north, have electricity supplied from the mainland via buried cable. High voltage transmission exists farther inland, primarily in the vicinity of Watertown. Interconnection of a project in the eastern end of the lake will require further analysis of the shoreline power grid.

8.4.5 Existing Uses and Transportation

The existing land and water use near the eastern portion of Lake Ontario will affect potential project feasibility. Similar to Lake Erie, these uses resulted in only a few development exclusion zones, but the implications of these uses can still be significant (particularly as related to permitting). Prominent existing land use and transportation topics are identified below.

Local and transient bird activity is pertinent along the eastern end of Lake Ontario. Important Bird Areas and bird conservation areas exist along the coasts of both Jefferson and Oswego counties. More areas of importance are located farther south and inland. Although some bird activity may extend over portions of the lake, no specific exclusion areas were identified for this study. The sites' proximity to these sensitive areas certainly merits further attention in follow-on studies.

Similar to Lake Erie, transportation on and in the vicinity of the lake will affect potential wind project siting and configuration. The buffered track lines in the eastern end of the lake excluded little feasible area. The Port of Oswego is an asset to development; it is serviced by air, rail, water and highway connections. Heavy rigging and construction companies also operate in the area and can work onsite at the port. Additionally, the staff have experience handling wind turbine components. It will be a likely candidate port to base project installation and O&M activities for Lake Ontario projects.

Fishing is another existing water use that exists within the conditionally feasible area. While commercial fishing on Lake Ontario is limited, recreational and sport fishing are both very common throughout the lake. No specific fishing-related exclusions were found for this study, but this topic merits further study of the participants engaged as stakeholders.

Air traffic routes in the vicinity of Watertown (ART) Airport may affect development. Several regions with various air space related height restrictions were identified over the eastern end of Lake Ontario. While the height restrictions listed for nearly all these areas are lower than the expected turbine structure height, none of the regions were removed from consideration on the basis of known challenges. This topic merits follow-on study to both further characterize specific areas of the lake and to engage the FAA as an important stakeholder in development.

8.5. Lake Ontario Pilot Project Locations

Preliminary installation of one or a few turbines as a demonstrator project is not an uncommon development strategy. Therefore, areas too small for utility-scale development, but with sufficient site characteristics were identified. The criteria used to determine the feasibility of pilot or demonstrator projects are generally less stringent that those used for commercial projects. The screening parameters can vary based on the goals for the project(s), and with adequate support, nearly any technically feasible location could be a candidate pilot project location. The developable areas along Lake Erie's shoreline large enough for utility development would also be available for potential pilot projects. Site considerations have already been discussed for these areas in Section 8.3. Two potential pilot project areas, besides the utility-scale areas described in Section 8.4, were identified on the south shore of Lake Ontario. These locations have adequate predicted wind speeds, moderate water depths, and reasonably attractive site conditions based on the other previously employed screening criteria. They also have fewer obvious siting challenges (e.g. limited existing use impacts, fewer ice risks, etc.), but will likely still require additional work (e.g. natural resource studies, interconnection studies, outreach).

These characteristics make the identified sites feasible for a potential small-scale test projects, but are not meant to exclude explicitly exclude other areas that may also be attractive to demonstrator projects. The first potential pilot site is located along the coast of eastern Orleans County, and the second site is located along the coast of eastern Wayne County.

8.6. Siting Analysis Summary

Offshore wind power has the potential to become a commercial power source on the Great Lakes. The New York waters of Lake Erie and Ontario were evaluated for wind development potential. Criteria stipulating maximum water depth, minimum wind resource, project area size, and other siting characteristics were applied with the goal of identifying the most attractive candidate offshore development areas.

Offshore wind energy development was deemed conditionally feasible within regions of Lake Erie. While existing uses and ice require further study, no major roadblocks to development were identified. The relative shallowness of Lake Erie, combined with its strong winds close to shore, offer numerous siting opportunities. Two primary candidate areas were identified: one to the southwest of the city of Buffalo, and the other along New York's shoreline southwest of the city of Dunkirk. Additional siting criteria may shrink the perspective sites if stand-off distances from shipping lanes are needed.

Evaluation of Lake Ontario resulted in identification of conditionally feasible regions for offshore wind development. With its great depth and steep sides, Lake Ontario's commercial siting opportunities are focused at the shallower eastern end of the lake. The developable area in this region is composed of a contiguous swath of sub-45 m deep water that follows the shore line from Oswego north and east to the entrance of the St. Lawrence River. In addition to existing uses and ice, transmission and interconnection studies in this lake will be necessary to further assess the implications of a less developed coastal grid at the eastern end of the lake.

Two regions on the south coast of Lake Ontario exhibited sufficient attractive qualities that they were identified as potential pilot project areas. Too small to be considered for commercial projects, these locations have the benefits of adequate wind resource and lower expected ice and wildlife risks. While transmission from these areas is less accessible than the Lake Erie project areas, their relative proximity to infrastructure near Oswego and Rochester, compared to the northeastern portion of Lake Ontario, makes them attractive pilot project locations.

8.7. Tables[107]

Table 8.2: Lake Erie Area by Wind Speed at Specific Depths

Depth	7.5 - 7.75 m/s			7.75 - 8.0 m/s			8.0 + m/s		
m	Total km^2	Developable Area km^2	MW	Total km^2	Developable Are km^2	MW	Total km^2	Developable Area km^2	MW
0 - 5	22	21	105	2	2	10	0	0	0
5 - 10	35	35	173	31	30	152	1	1	4
10 - 15	36	31	153	83	82	411	21	21	104
15 - 20	3	0	0	159	108	538	107	101	503
20 - 25	0	0	0	143	73	365	75	72	360
25 - 30	0	0	0	147	83	414	21	21	106
30 - 35	0	0	0	94	60	298	25	24	119
35 - 40	0	0	0	110	50	252	9	6	31
40 - 45	0	0	0	139	107	536	60	27	134
45 +	0	0	0	13	0	0	109	0	0
Total	**96**	**86**	**431**	**921**	**595**	**2977**	**428**	**272**	**1361**

[107] MW calculation assumes 5 MW per square km. This assumption is dependent on turbine spacing, turbine capacity, and rotor diameter.

Table 8.3: Lake Ontario Area by Wind Speed at Specific Depths

Depth	7.5 - 7.75 m/s			7.75 - 8.0 m/s			8.0 + m/s		
m	Total km^2	Developable Area km^2	MW	Total km^2	Developable Area km^2	MW	Total km^2	Developable Area km^2	MW
0 - 5	30	30	150	4	3	15	0	0	0
5 - 10	120	111	555	35	34	170	2	2	10
10 - 15	119	108	540	115	103	515	15	13	65
15 - 20	55	51	255	132	114	570	50	42	210
20 - 25	44	40	200	133	116	580	87	69	345
25 - 30	24	21	105	128	110	550	112	79	395
30 - 35	7	7	35	92	87	435	133	92	460
35 - 40	2	2	10	75	72	360	106	73	365
40 - 45	2	2	10	78	76	380	111	79	395
45 +	0	0	0	1074	0	0	5852	0	0
Total	**403**	**372**	**1860**	**1866**	**715**	**3575**	**6468**	**449**	**2245**

8.8. Maps

Map 8.1: Lake Erie Exclusion Zones

Map 8.2: Lake Erie Developable Area

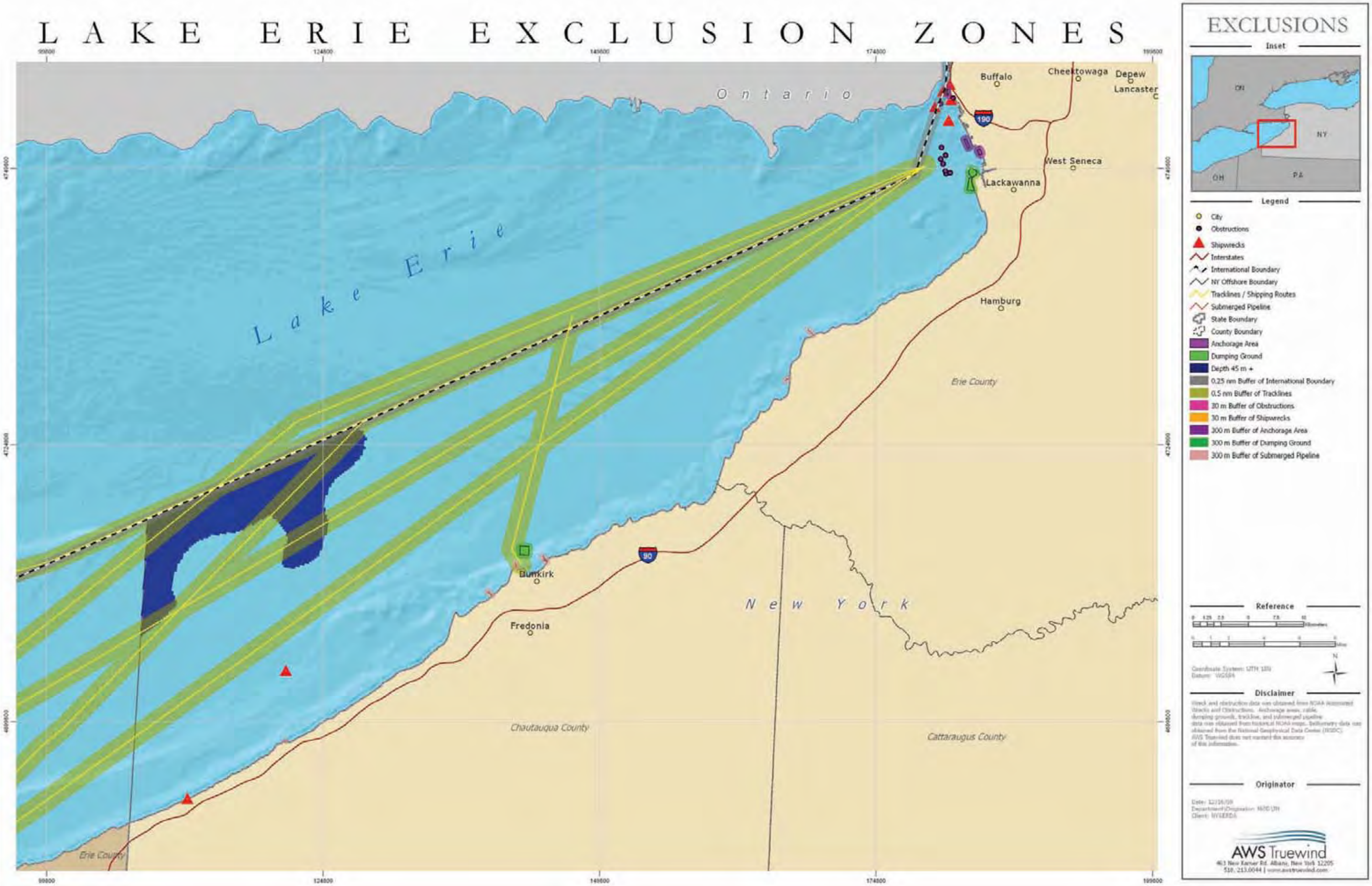
Map 8.3: Lake Ontario Exclusion Zones

Map 8.4: Lake Ontario Developable Area

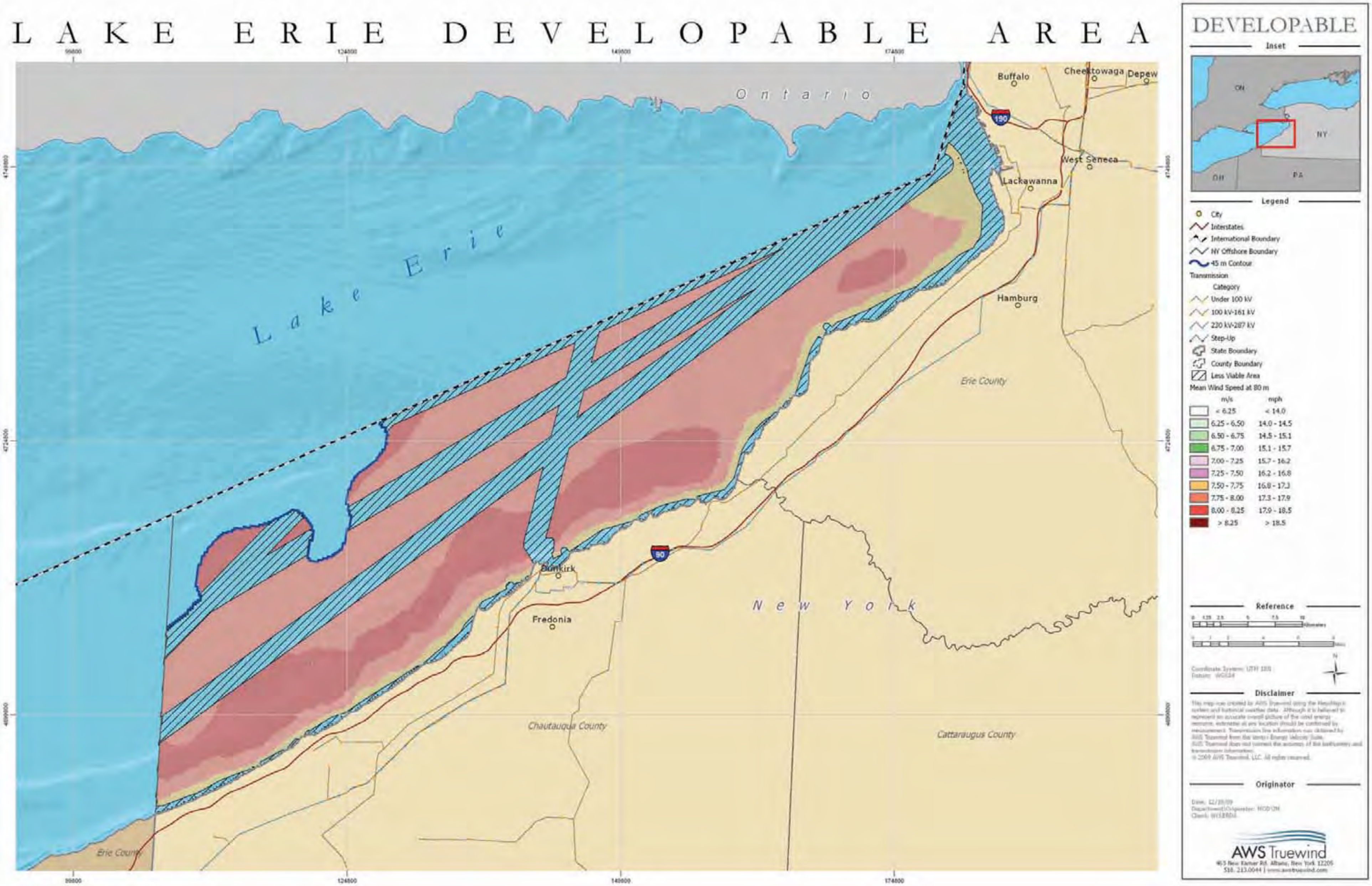
Map 8.5: Lake Ontario Developable Area East

Map 8.6: Lake Ontario Developable Area West

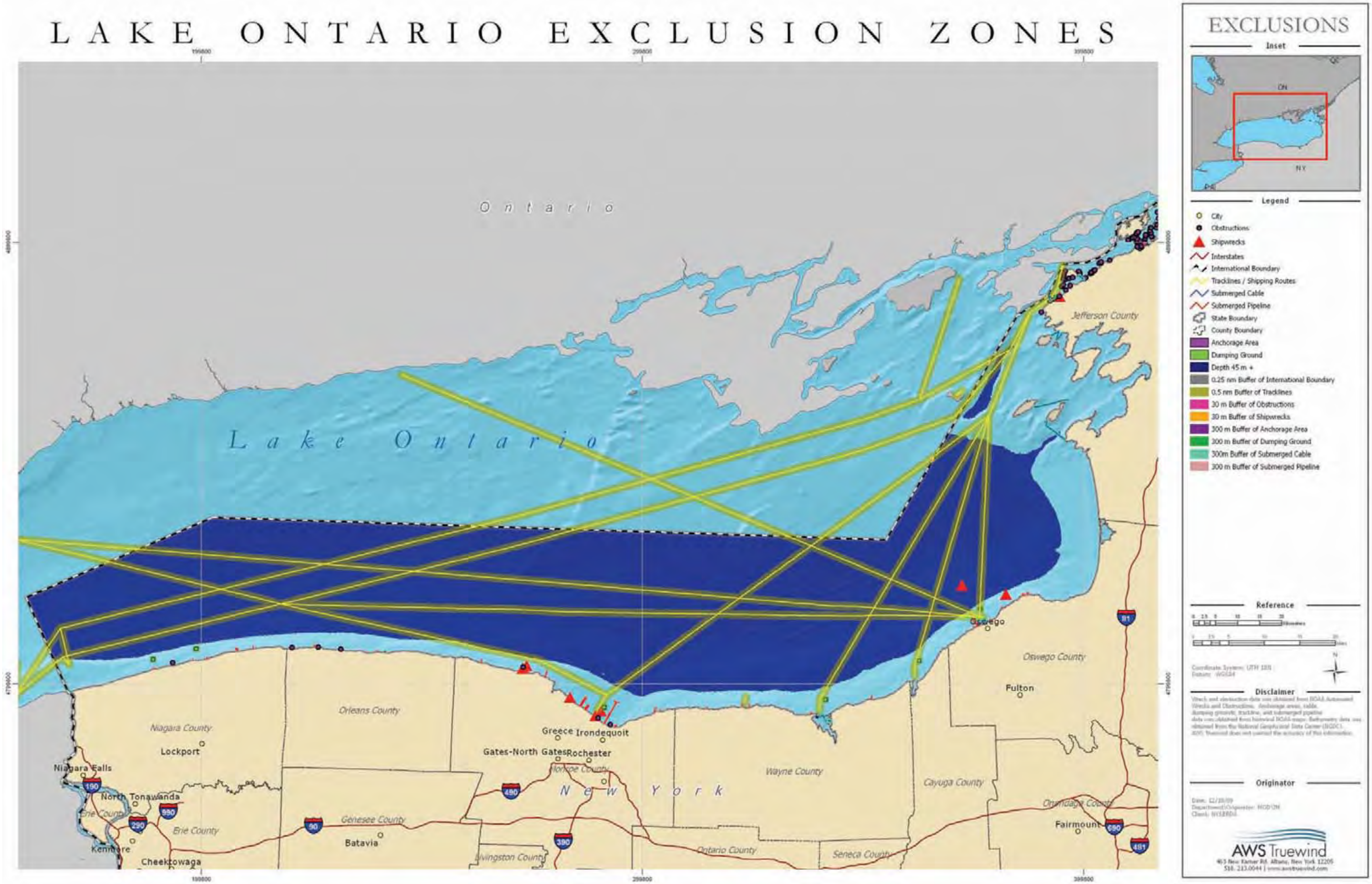
Map 8.1: Lake Erie Exclusion Zones



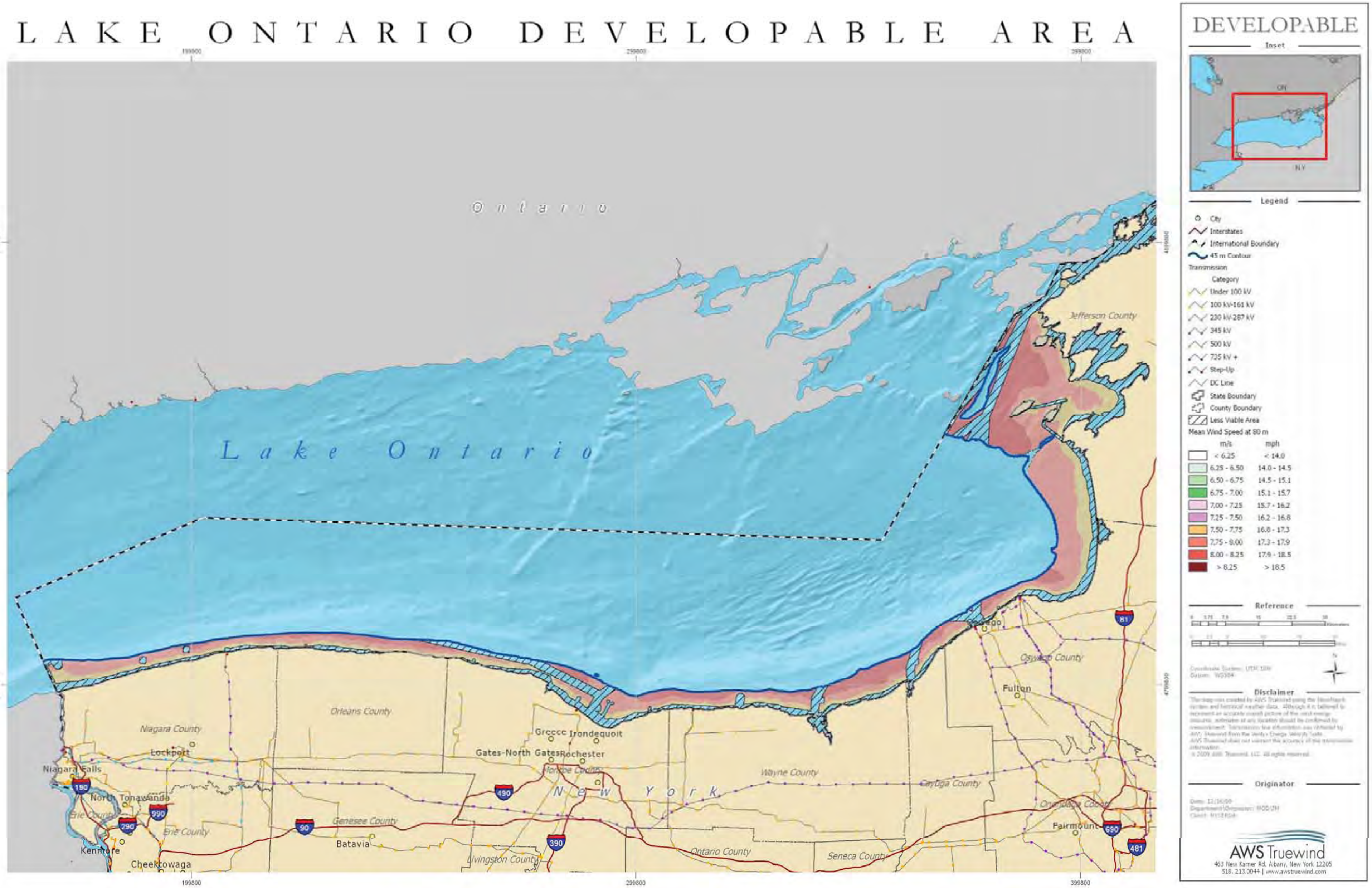
Map 8.2: Lake Erie Developable Area



Map 8.3: Lake Ontario Exclusion Zones

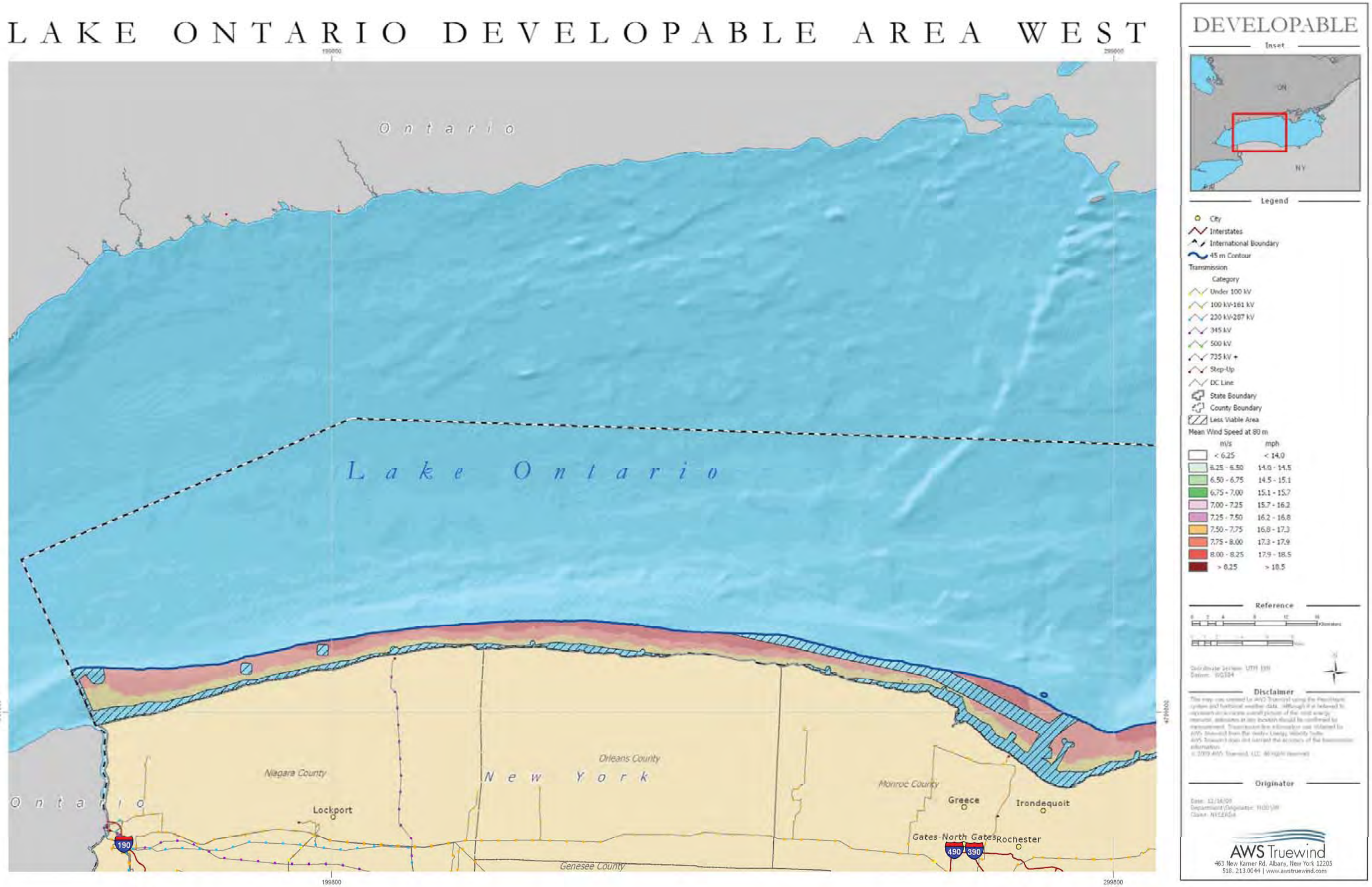


Map 8.4: Lake Ontario Developable Area



Map 8.5: Lake Ontario Developable Area East

Map 8.6: Lake Ontario Developable Area West



9.0. Legal and Jurisdictional

9.1. *Introduction*

The purpose of this chapter is to provide legal guidance on the jurisdictional and procedural issues relating to the siting of an offshore wind energy project in the Lake Erie and Lake Ontario territorial waters of New York. As no such project has ever been formally approved or sited in the waters of the Great Lakes, historical case law, statutory interpretation, and administrative guidance are virtually non-existent. Thus, the analysis is based upon interpretation of current federal, state, and local regulatory schemes, assessment of the Cape Wind project in Nantucket Sound,[108] preparatory work for the Long Island Power Authority's Offshore Wind Energy Facility, and communications with personnel from appropriate regulatory authorities. Any conclusions or representations offered here are provisional; that is, until actual permit applications and environmental assessments are submitted to participating agencies, the analysis presented below is intended to serve only as guidance.

It is assumed that an offshore wind energy project consists of multiple wind turbines with accompanying infrastructure (i.e. moored or anchored platforms, transmission lines from platform to onshore facilities) located somewhere in New York state territorial waters. Depending upon the exact location and size of the facility, there are a multitude of federal, state, and local agencies and authorities that can assert jurisdiction over the project. As such there will be overlapping jurisdiction among regulatory authorities.

The analysis is presented as follows: a summary of 1) federal permits, approvals, and other reviews; 2) New York State permits and approvals; and 3) international treaties and agreements. Project applicability to each permit/approval is given following the analysis and discussion of the regulating authority.

9.2. *Governing Authorities*

9.2.1 Federal Regulations—Permits and Approvals

Federal jurisdiction of underwater lands. The Submerged Lands Act affirms that Federal Jurisdiction begins 3 nautical miles off of America's coast, except in the waters off of Texas where jurisdiction begins 9 nautical miles from the coast.[109] However in the Great Lakes, state jurisdiction extends from the coast to international boundaries.[110] There is no lead agency designation made for development in the Great Lakes.

[108] On January 16, 2009 the MMS announced the release of the Final Environmental Impact Statement (FEIS) for the Cape Wind Energy Project.

[109] *Note on the Energy Policy Act of 2005 (Pub L. 109-58).* Section 388 of the Act amended Section 8 of the Outer Continental Shelf Lands Act (OCSLA) (43 USC 1337) in an effort to address legal questions that have arisen concerning (1) which federal agency could authorize an applicant to occupy the submerged lands of the U.S. Outer Continental Shelf (OCS) for the purpose of wind energy development and (2) what process should be followed by that federal agency in granting such authorization. Specifically, Section 388 added section 8(p) to the OCSLA authorizing the Department of the Interior (DOI) to grant, in consultation with other federal agencies, leases, easements, or rights of- way on the OCS for certain energy-related activities.

[110] Each Great Lakes State holds title to submerged lands underlying the Great Lakes in trust for the benefit of the public. See Illinois Central Railway Commission v. Illinois, 146 U.S. 387, 452 (1892). Codified under 43 U.S.C. §1312.

1. Coastal Zone Management Act of 1972, as amended through Public Law 104-150, The Coastal Zone Protection Act of 1996 (16 U.S.C. §1451 *et seq*)

The Coastal Zone Management Act (CZMA) of 1972 requires that federal activities (including the granting of permits) affecting land or water resources located in the coastal zone be fully consistent with federally approved State coastal zone management plans. The Coastal Zone Act Reauthorization Amendments of 1990 strengthened the Act by requiring state programs to focus more on controlling land use activities and the cumulative effect of activities in coastal zones. The CZMA encourages development of state Coastal Management Plans (CMPs) to balance wise use and protection of coastal resources. The Act defines a "coastal zone" as coastal waters and adjacent shorelands, including islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. In the five Great Lakes, the coastal zone extends to the international boundary. 16 U.S.C.A. § 1453(1).

For Lake Ontario and Lake Erie, the CZMA (through an approved CMP) is implemented by the State of New York's Department of State's (NYDOS) Division of Coastal Resources. An offshore wind energy project located adjacent to the waters of Pennsylvania may require approvals from the Pennsylvania Department of Environmental Protection's (PADEP) Office for River Basin Cooperation.

To implement the CZMA, the New York Legislature passed the Waterfront Revitalization and Coastal Resources Act (WRCRA) in 1981. Coastal waters and lands subject to WRCRA include Lakes Erie and Ontario. N.Y. EXEC. LAW § 911. In addition to the waterbodies themselves, WRCRA defines the coastal areas of New York, and includes adjacent shorelands, such as islands, wetlands, beaches, dunes, barrier islands, cliffs, bluffs, inter-tidal estuaries and erosion prone areas. Discussion of New York's WRCRA and applicable regulations is given in section II.c below.

2. Rivers and Harbors Acts of 1890 (superseded) and 1899 (33 U.S.C. §401. *et seq*)

Various sections of the Rivers and Harbors Acts establish permit requirements to prevent unauthorized obstruction or alteration of any navigable water of the United States. Section 10 of the Act regulates construction, excavation, or deposition of materials in, over, or under such waters, or any work that would affect the course, location, condition, or capacity of those waters. 33 U.S.C. §403. A permit from the United States Army Corps of Engineers (USACE) must be obtained prior to the construction of any "wharf, pier…or other structures" in the navigable waters of the United States. 33 C.F.R. §322.2(b). A tunnel or other structure under or over the navigable waters of the United States, such as power transmission lines, must also have a Section 10 permit. 33 C.F.R. §322.3(a); 322.5(i).

The geographic jurisdiction of the Rivers and Harbors Act of 1899 includes all navigable waters of the United States "Navigable waters" are defined as "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce." 33 C.F.R. Part 329. This jurisdiction includes "all interstate waters including interstate wetlands." On the Great Lakes, these structures or work are "in" these waters if they are conducted "waterward" of a line on the shore known as the Ordinary High Water mark (OHWM). The OHWM is a fixed height contour. For Lake Erie, the OHWM is 174.8 m (573.4 ft); for Lake Ontario, the OHWM is 75.4 m (247.3 ft).

Project applicability: As the offshore wind energy project will be sited in "navigable waters of the United States" as defined in 33 C.F.R. Part 329, and will involve the construction of "structures" such as wind turbines and accompanying platforms in such waters, the USACE has clear jurisdiction and permitting authority. Furthermore, jurisdiction and permitting authority may also be triggered by the laying of power transmission lines across navigable waters, as set forth in 33 C.F.R. §322(i)(1), although 33 C.F.R.

§322(i)(2) only refers to overhead lines (it would certainly apply to burying of the transmission cable from the offshore wind energy project shoreward).

3. Clean Water Act of 1977, as amended (33 U.S.C. §1251 *et seq*)

Under Section 404 of the Clean Water Act (CWA), a permit from the USACE[111] is required for the discharge of dredged or fill material "into the waters of the United States." For the purpose of this section, "discharge of dredged material" includes "redeposit of dredged material, *including excavated material,…incidental to any activity, including…excavation* (emphasis added). 33 C.F.R. § 323.2(d)(1)(iii). In 1997 a court decision[112] made it clear that §404 does not require a permit for the "incidental fallback" from dredging. After a lengthy rule-making process, the USACE promulgated a final rule on the meaning of "incidental fallback" on December 30th, 2008 (see 73 F.R. 79641). Under the new rule the Corps will decide on a case-by-case basis whether a project will cause only non-regulated incidental fallback – i.e. material that is incidentally re-deposited into a wetland during dredging or clearing operations – or will cause redeposit of dredged material that amounts to a discharge subject to regulation under the Clean Water Act. Such determinations will now be made by reference to case law and agency guidance rather than to an express definition in the Corps regulations.

Project applicability: Whether the offshore wind energy project will require a USACE dredge and fill permit will be decided by the USACE on a case-by-base basis.

4. Navigation and Navigable Waters (33 C.F.R. Parts 62, 64, 66 *et seq*.)

Under these regulations, the District Commanders of the United States Coast Guard[113] have the authority to determine "whether an obstruction is a hazard to navigation" and what markings, lights, fog signals etc. are required. Under 33 C.F.R. §64.21, "[b]efore establishing a structure, the owner or operator shall apply for Coast Guard authorization to mark the structure in accordance with §66.01-5 of this chapter." The appropriate District Commander will determine the marking requirements. The application procedure is given in 33 C.F.R. §66.01-5.

Project applicability: Authorization from the Coast Guard will be needed as almost any proposed wind turbine platform will be in "navigable waters" and will likely pose "an obstruction or hazard to navigation." The District Commander (the 9th District covers the Great Lakes) cannot proceed on a navigation aid permit until the USACE (and other state agencies, see below) has issued its permit.

5. Federal Aviation Administration (Objects Affecting Navigable Airspace, 14 C.F.R. Part 77*)*

These regulations 1) establish standards for determining obstructions in navigable airspace; 2) set forth the requirements for notice to the FAA Administrator of certain proposed construction or alteration; 3) provide for aeronautical studies of obstructions to air navigation, to determine their effect on the safe and efficient use of airspace; and 4) provide for public hearings on the hazardous effect of proposed

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[111] Section 404 permitting authority has not been transferred to the New York State Department of Environmental Conservation.

[112] American Mining Congress v. United States Army Corps of Engineers, 951 F. Supp. 267 (D.D.C. 1997), *aff'd sub nom*. National Mining Ass'n v. United States Army Corps of Engineers, 145 F.3d 1399 (D.C. Cir. 1998).

[113] Under 14 U.S.C. 89 the Coast Guard is authorized to enforce the laws of the United States upon the "high seas" and waters over which the United States has jurisdiction. High seas, as used in 18 U.S.C. 7(1), means the Great Lakes and waters seaward of the low water line along the coast, except waters within harbors or narrow coastal indentations enclosed by promontories.

construction or alteration on air navigation. The kinds of objects affected include "[a]ny object of natural growth, terrain, or permanent or temporary construction or alteration, including equipment or materials used therein, and apparatus of a permanent or temporary character." 14 C.F.R. §77.5(a). Notice to the FAA regional office (in this case, the Eastern Region, which includes New York) is required for "[a]ny construction or alteration of more than 200 feet in height above the ground level at its site" or some calculated height a given distance from an airport runway, and for a waterway, "an amount equal to the height of the highest mobile object that would normally traverse it." 14 C.F.R. §77.13(a). This would presumably include offshore platform-based wind turbines. Timeliness and notice form requirements are set forth in 14 C.F.R. §77.17. Section 77.23 sets forth standards for determining obstructions, and according to 14 C.F.R. §77.23(a)(2) or (b)(5), an offshore platform with wind turbine would likely qualify as an obstruction.

The Regional Manager of the FAA Air Traffic Division initiates an aeronautical study to determine whether such an obstruction is a hazard upon request of the sponsor or if the FAA determines it to be appropriate. 14 C.F.R. §77.33. The study can lead to a positive or negative determination of whether the proposed construction constitutes an air hazard, or more formal hearings may be held to decide the issue. In November 2005, the FAA developed lighting standards specifically for wind turbines.[114]

Project applicability: Since any proposed platform-based wind turbine will likely exceed the height thresholds established under the above-referenced regulations, notice must be given to and obstruction determination will have to be sought from the FAA. The FAA will also make recommendations as to the appropriate lighting (i.e. How many and which turbines would require lighting) to be placed on the facility for visibility purposes.

6. National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. §4341 *et seq.)*

This Act requires that environmental consequences and project alternatives be considered before a decision is made by an agency to implement a federal project. NEPA establishes requirements for the preparation of an Environmental Impact Statement (EIS) for projects potentially having significant environmental impacts.

Under NEPA, an EIS is required for "major federal actions significantly affecting the quality of the human environment." 42 U.S.C. §4332. In order to determine the necessity of an EIS, agencies may define certain types of actions as "categorically excluded," or else usually requiring an EIS. 40 C.F.R. §1501.4(a). Otherwise, an environmental assessment ("EA") must be prepared. 40 C.F.R. §1501.4(b). Any federal agency involved in a proposed action must make a "determination of significance," 40 C.F.R. §1508.4(c), and either make a Finding of No Significant Impact ("FONSI"), 40 C.F.R. §1508.13, or else determine that an EIS will be required. Mitigation measures can be considered when making this determination. A threshold determination must be made, and a FONSI issued or an EIS completed, before a decision can be made by a federal agency on a proposed action. If required, an EIS must address:

(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action,

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and

[114] See http://www.airtech.tc.faa.gov/safety/Downloads/TN05-50.pdf

(v) any irreversible and irretrievable commitments of resources which should be involved in the proposed action should it be implemented.

42 U.S.C. §4332. A draft EIS must first be circulated for public comment, followed by a final EIS which addresses substantive public comments. 40 C.F.R. §1502.9.

Project applicability: Potential federal authorities with NEPA involvement include (but may not be limited to) the USACE, the FAA, the United States Coast Guard, the United States Fish and Wildlife Service, the National Marine Fisheries Service, and the United States Environmental Protection Agency. Coordination as to lead/cooperative agency status will have to be made by the above authorities. The majority of wind projects that have been subject to NEPA have required only a FONSI. However, for the only United States offshore wind energy project to have completed a formal review (Cape Wind), the USACE (and now, given the jurisdictional requirements set forth in the Energy Act of 2005, the MMS) has required a full EIS. The location and magnitude of an OWEF in the Great Lakes waters will be key determinants as to whether a full EIS is required.

9.2.2 Other Federal Reviews

1. Archaeological and Historic Preservation Act of 1974; National Historic Preservation Act (16 U.S.C. §469 *et seq.;* §470 *et seq)*

The Archaeological and Historic Preservation Act (AHPA) amended the Reservoir Salvage Act of 1960. The AHPA provides for the preservation of historic and archaeological data that might otherwise be lost or destroyed as a result of any federal construction project or federally licensed or assisted undertaking. The AHPA authorizes the lead federal agency of a project, or the Secretary of the Interior, to undertake recovery or preservation of such data. Federal project funds, up to one percent of the project cost, may be used, or the agency may request the Secretary of the Interior to conduct the desired measures.

The National Historic preservation Act (NHPA) provides funding for the State Historic Preservation Officer (SHPO) and his or her staff to conduct surveys and comprehensive preservation planning. The act establishes standards for state programs and requires states to establish mechanisms for Certified Local Governments to participate in the National Register nomination and funding programs. In New York, the SHPO operates out of the Department of Parks, Recreation and Historic Preservation.

2. Fish and Wildlife Coordination Act of 1958 (16 U.S.C. §661 *et seq.)*

The Fish and Wildlife Coordination Act requires that whenever any body of water is proposed or authorized to be impounded, controlled (i.e., diverted), or modified (i.e., deepened), the lead federal agency (here, most likely the USACE) must consult with the United States Fish and Wildlife Service (USFWS) and with the State agency exercising administrative authority over wildlife resources. In New York, the State agency would be NYSDEC. For projects affecting marine fisheries, the National Marine Fisheries Service (NMFS) should also be consulted. Section 662(b) of the Act requires the lead federal agency to consider the recommendations of USFWS and other agencies. The recommendation may address wildlife conservation and development, any damage to wildlife attributable to the project, and any measures proposed for mitigating or compensating for these damages.

In 2003, the Service published its Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines.[115] After reviewing the comments received, the Secretary of the Interior established a Wind

[115] See http://www.fws.gov/habitatconservation/Service%20Interim%20Guidelines.pdf

Turbine Guidelines Advisory Committee,[116] composed of 22 members appointed by the Secretary to achieve balanced representation of wind energy development, wildlife conservation, and government. The Committee provides advice and recommendations to the Secretary on developing effective measures to avoid or minimize impacts to wildlife and their habitats related to land-based wind energy facilities.

3. Endangered Species Act of 1973, as amended (16 U.S.C. §1531 *et seq.)*

The Endangered Species Act protects threatened and endangered species by prohibiting Federal actions that would jeopardize the continued existence of such species or that would result in the destruction or adverse modification of any critical habitat of such species. Section 7 (a) of the Act requires consultation with the Secretary of the Interior (through the USFWS and/or the NMFS), prior to project implementation, to determine if any endangered or threatened species may be present in the area of a proposed USACE action, and to ensure that the action will not jeopardize the continued existence of a species or destroy or adversely modify the designated critical habitat of such species. During the project planning process, the FWS and NMFS evaluate the potential impacts of all aspects of the project on threatened or endangered species. Their findings are contained in letters that provide an opinion on whether a project will jeopardize the continued existence of endangered species or modify critical habitat. Such letters must provide reasonable and prudent alternatives, if any, that will avoid jeopardy.

4. Migratory Bird Treaty Act of 1918 (16 U.S.C. §§ 703-712)

The original 1918 statute implemented the 1916 Convention between the United States and Great Britain (for Canada) for the protection of migratory birds. Later amendments implemented treaties between the United States and Mexico, the United States and Japan, and the United States and the Soviet Union (now Russia). Unless permitted by regulations, the Act provides that it is unlawful to pursue, hunt, take, capture or kill; attempt to take, capture or kill; possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product, manufactured or not. Subject to limitations in the Act, the Secretary of the Interior may adopt regulations determining the extent to which, if at all, hunting, taking, capturing, killing, possessing, selling, purchasing, shipping, transporting or exporting of any migratory bird, part, nest or egg will be allowed, having regard for temperature zones, distribution, abundance, economic value, breeding habits and migratory flight patterns. Regulations are effective upon Presidential approval. §§ 703 and 704

5. Abandoned Shipwreck Act of 1987 (43 U.S.C. 2101-2106)

Under this Act, the United States Government asserts title to three categories of abandoned shipwrecks: abandoned shipwrecks embedded in a State's submerged lands; abandoned shipwrecks embedded in coralline formations protected by a State on its submerged lands; and abandoned shipwrecks located on a State's submerged lands and included in or determined eligible for inclusion in the National Register of Historic Places.

The United States Government has transferred its title to the majority of shipwrecks to the respective States to manage. The United States retained its title to shipwrecks located in or on public lands while Indian tribes hold title to shipwrecks located in or on Indian lands.

The Act directs the National Park Service to prepare the guidelines to assist the States and federal

[116] See http://www.fws.gov/habitatconservation/windpower/wind_turbine_advisory_committee.html

agencies in developing legislation and regulations to carry out their responsibilities under the Act. In accordance with the Act, the guidelines are intended to maximize the enhancement of cultural resources; foster a partnership among sport divers, fishermen, archeologists, salvors, and other interests to manage shipwreck resources of the States and the United States; facilitate access and utilization by recreational interests; and recognize the interests of individuals and groups engaged in shipwreck discovery and salvage.

6. Nuclear Regulatory Commission--Energy Reorganization Act of 1974 (Pub.L. 93-438)

Set back requirements in the regulations seem to apply only to radiation doses. These regulations will likely be monitored by the United States Coast Guard.

9.2.3 New York Regulations—Permits and Approvals

1. Waterfront Revitalization of Coastal Areas and Inland Waterways Act (Article 42 NYS EXEC. LAW §910 *et seq*.)

Under this Act implementing the CZMA, the New York Department of State (NYSDOS) administers the coastal program (through 19 N.Y.C.R.R. Parts 600-603) that contains legislatively enacted coastal area policies to which state agencies must conform. The Act also authorizes the state to encourage local governments to adopt local waterfront revitalization programs (LWRPs) that are consistent with the state's coastal area policies. These policies in general require a balance between economic development and preservation that prevents the loss of natural resources as well as encourages the use of existing infrastructure and public services. (There are 44 enumerated policies.) Under the Act, the State also established the Significant Coastal Fish and Wildlife Habitats Program to identify and give additional protection to designated habitats. There are dozens of such sites within the Lake Erie and Lake Ontario basins.[117]

i) LOCAL WATERFRONT REVITALIZATION PROGRAM (LWRP)

As the CZMA is geared towards state and local control, New York provides coastal municipalities with the opportunity to adopt and implement their own coastal policies through LWRPs. LWRPs refine and supplement New York's Coastal Management Program (CMP) by defining area-specific needs and objectives at the municipal level. The legal authority to implement an LWRP is derived from Article 42 of the Executive Law and a municipality's comprehensive planning and zoning power delegated by the state through the Town, Village, or General City Laws. *See* N.Y. GEN. CITY LAW §28-a; N.Y. TOWN LAW §272-a; N.Y. VILLAGE LAW §7-700 *et seq*. Towns may appoint an existing entity when administering a program, or may establish a special board overseeing a LWRP. The local authorities are required to adopt appropriate legislation necessary to fully implement Article 42 and 19 N.Y.C.R.R. Part 600. There are currently several approved LWRPs along the shores of Lake Erie and Lake Ontario.

ii) CONSISTENCY REQUIREMENTS

Projects and activities which affect the coastal area of New York and are directly undertaken, authorized, or financially assisted by federal and state agencies, must be consistent with the enforceable policies and purposes of the State's CMP. Where an LWRP is in effect, the agencies' projects and activities must be consistent with the local program.

[117] See http://www.nyswaterfronts.com/waterfront_natural_narratives.asp#GreatLakes

A) FEDERAL

The CZMA requires that any federal agency activity in a coastal area must be consistent with the State's coastal management program. 16 U.S.C. §§ 1452, 1455, 1456. If a municipality adopts a LWRP, it becomes the State's coastal policy for that geographically specific area, and all federal actions must then conform to the LWRP. In addition, any other agency, company or individual that is funded, permitted or authorized by a federal agency must also adhere to the consistency requirements established by CZMA and WRCRA. 16 U.S.C. § 1456.

Applicants seeking federal permits within New York's coastal zone must submit a Federal Consistency Assessment Form (FCAF), along with a copy of any necessary federal application (including a summary of the affect of the proposal on state policies) for authorization, to the NYSDOS. The Department of State then reviews the FCAF to ensure that the proposal will be consistent with New York's coastal management polices. If NYSDOS finds that the activity as proposed is contrary to these policies, it objects to the consistency determination, and the federal agency may not fund or approve the project. Federal agencies may, however, seek an exemption by the president if the "activity is in the paramount interest of the United States." 16 U.S.C. §1456.

B) STATE

State agency actions must be consistent with WRCA's guidelines (or a state approved LWRP) as set forth in the corresponding rules and regulations. See 19 N.Y.C.R.R. §600.1 *et seq.* First, a state agency must classify the proposed action under the State Environmental Quality Review Act (SEQRA; see below). Whether or not an environmental assessment form (EAF) is filed, however, the agency must submit a Coastal Assessment Form (CAF) to the NYS Secretary of State prior to determining the action's significance under SEQRA. The CAF is used to ensure consistency with the State's coastal policies (or the policies established in a LWRP, if applicable) and to aid state agencies in making determinations under SEQRA. If, pursuant to SEQRA, it is determined that the action will have a significant impact on the environment, that impact must be mitigated. Only after mitigation will the action be considered consistent with WRCRA. If the action will not have a significant impact on the environment, the state agency must then notify the Secretary of State that the action is consistent with, and in fact advances New York's coastal policies or the policies of a LWRP. 19 N.Y.C.R.R. §600.4. If the action is not fully consistent with one or more of the State policies, the agency must then satisfy at least one or more of the following to meet WRCRA's consistency requirements:

- No reasonable alternatives exist which would permit the action to be taken in a manner which would not substantially hinder the achievement of such a policy;
- The action taken will minimize all adverse effects on such policies to the maximum extent practicable;
- The action will advance one or more of the other coastal policies;
- The action will result in an overriding regional or statewide public benefit.

Project applicability: As the siting of an offshore wind energy project and accompanying infrastructure will likely be in designated coastal zones, and federal (e.g. USACE and FAA) and state (e.g. NYSDEC) approvals will be necessary, FCAFs and CAFs will have to be filed with NYSDOS prior to permit approvals. Furthermore, as certain local authorities have adopted local ordinances pursuant to their LWRPs governing construction or alterations in the coastal zone, federal and state adherence to these regulations and policies will be required.

2. Protection of Waters Program (NYS ECL Article 15, Title V)

This program regulates activities occurring in or near designated protected waters. This includes the excavation and/or filling in of or construction of platforms within the navigable waters of the State. ECL §§15-0503, 15-0505. The intent of the Protection of Waters program is to prevent undesirable activities on water bodies by establishing and enforcing regulations that are compatible with the preservation, protection, and enhancement of the present and potential values of the water resources, protect the public health and welfare, and are consistent with the reasonable economic and social development of the state.

The term "navigable waters of the State" includes "[a]ll…bodies of water in the State which are navigable in fact or upon which vessels with a capacity of one or more persons can be operated." 6 N.Y.C.R.R. §608.1(l).

Project applicability: If an offshore wind energy project is constructed in the "navigable waters" of New York, a state dredge and fill permit may be needed. However, a permit is NOT required for platforms, moorings, or other structures for which a lease or conveyance authorizing use and occupancy has been obtained from the Commissioner of General Services. ECL §15-0503(1)(b); 6 N.Y.C.R.R. §608.4(c)(1). Thus, if the project is to be located on underwater lands owned by the State (see section II(c)(5) below), then it is exempt from at least part of the Article 15 permitting requirements.

3. Coastal Erosion Hazard Areas (NYS ECL Article 34)

This law recognizes that "certain sections of the coastline of the state of New York are prone to erosion from action of the adjacent water bodies" and that "any activities, development or other actions in such erosion hazard areas should be undertaken in such manner as to minimize damage to property, and to prevent the exacerbation of erosion hazards." ECL § 34-0102. ECL Article 34 and 6 N.Y.C.R.R. Part 505 establishes a scheme for regulation of designated "coastal erosion hazard areas," which requires New York State Department of Environmental Conservation (NYSDEC) permits for even minor activities, and often totally prohibits permanent construction on fragile beaches or cliff areas. The program is based upon NYSDEC maps that specify the location of coastal erosion hazard areas subject to regulation.

There are two categories of regulated areas: Natural Protective Features and Structural Hazard Areas. Natural Protective Features (NPFs) include: the nearshore, beaches, bluffs, primary dunes, and secondary dunes. "Structural Hazard Areas (SHAs) are located landward of the NPFs and are found on shorelines which have a demonstrated long-term average annual recession rate of one foot per year or greater.

The actual regulation of coastal erosion hazard areas may be performed by localities. If a locality has not submitted laws for NYSDEC approval, counties may do so. Many local jurisdictions have approved programs. If no local authority has asserted jurisdiction, NYSDEC must regulate the erosion hazard area directly. Permit applications are to be coordinated with whatever other permits are required by state or local law. ECL § 34-0105(6), 34-0106(9), 34-0107(6). The act specifically provides that activities in erosion hazard areas are actions likely to require an EIS pursuant to SEQRA.

Project applicability: There are NYSDEC mapped coastal erosion hazard areas along the shores of both Lake Erie and Lake Ontario. It is strongly recommended that the proposed project avoid the jurisdiction of ECL Article 34. It may present additional obstacles to project approval if the offshore wind energy project or associated infrastructure (transmission lines) is to be located in coastal erosion hazard areas.

4. Grants of Lands Underwater (NYS Public Lands, Article 6)

Most navigable bodies of water in the New York are State-owned, including the beds of lakes Erie and Ontario. Various activities relating to the use of this land under water, such as construction of commercial docks, wharves, moorings and permanent structures, such as piers and breakwaters or occupation of previously filled in lands, require permission from the State. In order to obtain permission for the use of these lands underwater, an application must be made to the Office of General Services (NYSOGS). NYSDEC and the Secretary of State must review any proposed leases, easement, or permit. 9 N.Y.C.R.R. §§270-3.2(a)(b). NYSDEC is to make recommendations to protect the environment and natural resources, the Secretary of State to make recommendations with regard to coastal management (see section II.c(1) above). The application process and service requirements are set forth in 9 N.Y.C.R.R. Subpart 270-5.

The fee schedule for commercial users is based upon estimated income potential from their docks and moorings. 9 N.Y.C.R.R. Subpart 270-6. NYSOGS conducts appraisals to establish regional market rates. Based upon this rate and a review of the dockage and moorings, a potential income is derived for a specific facility. The user who established rights after June 17, 1992 will be required to pay an annual fee "not to exceed two percent of net annual income." 9 N.Y.C.R.R. §270-6.1. Terms normally run for a period of ten years. Intake and discharge pipes, pipelines, cables and conduit lines for commercial purposes are required to be issued easements for the use and occupation of land underwater. Pending issuance of any other required State and federal permits, NYSOGS will issue an easement for these uses through an application, normally for a twenty-five year term.

Project applicability: Any offshore platforms sited on underwater lands owned by New York will need a lease, easement, or license from NYSOGS.

5. Certificate of public convenience and necessity (CPCN) NYS Public Service Law Section 68.

PSL §68 requires that no electric corporation shall begin construction of an electric plant without first obtaining a CPCN. Project developers (if it is an electric corporation as defined in Section 2(13) of the Public Service Law) must obtain a certificate of public convenience and necessity (CPCN), pursuant to Section 68 of the Public Service Law.

6. Environmental Compatibility and Public Need for Electric and Gas Transmission Facilities (NYS Public Service Law, Article VII).

An Article VII Certificate may be required for the construction and operation of major electric transmission facilities. "Major utility transmission facility" means "…an electric transmission line of a design capacity of one hundred twenty-five kilovolts or more extending a distance of one mile or more, including associated equipment…." PSL Article VII, §120.2; 16 N.Y.C.R.R. §70.2(k).The certification and hearing process usually adheres to the permitting requirements that normally would fall under those particular jurisdictions (e.g. Tidal Wetlands).

Project applicability: If transmission lines extending from offshore wind energy projects to onshore facilities are a mile or more in length, then a certificate of environmental compatibility will be needed. These facilities would be exempt from most other New York State agency reviews.

7. State Environmental Quality Review Act (SEQRA: ECL §§ 8-0101-8-0117; 6 N.Y.C.R.R. part 617)[118]

SEQRA requires the environmental review of virtually all discretionary acts taken by state agencies and local governments in New York. Thus, almost every unit of government in New York must conduct a SEQRA review[119] in conjunction with permits or approvals they are empowered to issue. The provisions of the Uniform Procedures Act (6 N.Y.C.R.R. Part 621) require that applications for NYSDEC permits cannot be considered complete unless certain requirements of SEQRA (6 NYCRR Part 617) have been satisfied. This initially involves the filing by the applicant of a completed environmental assessment form (EAF). More complex projects or those having a potentially significant impact may require a more lengthy and detailed EIS.

Review of an action is to begin "[a]s early as possible in an agency's formulation of an action it proposed to undertake, or as soon as an agency receives an application for funding or for approval of an action." 6 N.Y.C.R.R. § 617.6(a)(1).

SEQRA is modeled after NEPA, and requires that "[s]ocial, economic and environmental factors shall be considered together in reaching decisions on proposed activities," ECL §8-0103(7), and that public agencies will give "due consideration... to preventing environmental damage." ECL § 8-0103(9).

The heart of SEQRA is ECL §8-0109(4), which requires "agencies" (including state and municipal, boards, agencies and authorities), "[a]s early as possible in the formulation of a proposal for action" to "make an initial determination whether an environmental impact statement need be prepared," and ECL §8-0109(2), which requires all state agencies and municipalities to prepare or cause to be prepared "an environmental impact statement on any action they propose or approve which may have a significant effect on the environment."

The sequence of events under SEQRA can be broken down into four general phases where:

1) threshold questions concerning whether the agencies activity is subject to the environmental review mandates of the statute are addressed;
2) preliminary information is submitted, a lead agency is selected, and a determination is made as to whether an EIS will be required;
3) a draft EIS is scoped out, prepared and subjected to agency and public review;
4) a final EIS is prepared and accepted and findings are issued.

The first step in the SEQRA process is to determine whether an action is subject to SEQRA. Actions involving federal agencies are subject to SEQRA unless a federal EIS is compiled. 6 N.Y.C.R.R. §617.15. If an action is classified as a "Type II action," no further SEQRA review is required. 6 NYCRR §617.6(a). One Type II action relevant to a potential approval required here is "[a]ctions requiring a certificate of environmental compatibility and public need under Articles VII…or X of the Public Service Law (see above) and the consideration of, granting or denial of any such certificate." 6 N.Y.C.R.R. §617.5 (c)(35).

Otherwise, actions are either classified as "Type I actions" if listed in §617.4 (which are more likely to require an EIS), or unlisted actions not specifically listed. Following classification of an action, an environmental assessment form ("EAF") must be completed. 6 NYCRR §617.6(a). For a "Type I action," use of the lengthy "full EAF" is mandatory. 6 NYCRR §617.6(a)(2). However, unlisted actions only require the "short EAF," although the full EAF may still be required. 6 NYCRR §617.6(a)(3).

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[118] It is assumed here that the proposed project is under 80 MW, and therefore does not fall under the jurisdiction of Article X of the PSL.

[119] See SEQRA flowchart, Fig. 2.

If more than one agency is an "involved agency" which makes a decision on the action, a lead agency must be selected by agreement of the agencies through the "coordinated review process." 6 NYCRR §617.5(b)(2). If only one is involved, it automatically acts as "lead." 6 NYCRR §617.5(b)(1). Unlisted actions do not have to go through coordinated review, so each involved agency can make its own separate SEQRA review. 6 NYCRR §617.6(d).

In most cases a wind farm will be considered a Type 1 Action as turbine heights are well above 100 feet (see 6 NYCRR §617.4(b)(7)). However, where local zoning includes code regulating wind farm development or any structure pertaining to height, a wind farm may be considered an Unlisted Action, so long as it doesn't fall under the purview of §§617.4(b)(8 - 11). However, for all individual actions which are Type I or Unlisted, the determination of significance must be made by comparing the impacts which may be reasonably expected to result from the proposed action with the criteria listed in 6 NYCRR 617.7(c).

The lead agency then reviews the EAF, and makes the "determination of significance" by determining whether the proposal "may include the potential for at least one significant environmental effect." 6 NYCRR 617.7(a)(1). If so, a positive declaration is made, and an EIS is required. 6 NYCRR §617.7(a)(1). If not, the lead agency must make a negative declaration that the project will not have a significant adverse environmental impact. 6 NYCRR §617.7(b)(2).

If an EIS is required, the "scoping" process may be used to define the issues to be addressed. 6 NYCRR §617.8. A draft EIS is circulated, and after public comment and an optional public hearing, a final EIS is then compiled which addresses public comments. 6 NYCRR §617.9. The lead agency may require a private applicant to prepare an EIS. 6 NYCRR §617.9(a)(1). No final EIS is necessary if, after analysis, the draft EIS allows the lead agency to make a negative declaration that the action will not have a significant effect on the environment. 6 NYCRR §617.9(a)(5)(i)(b).

An EIS must also contain an evaluation of "alternatives to the propose action," ECL §8-0109(2). The "range of alternatives must include the no-action alternative," and "may also include, as appropriate, alternative: (a) sites; (b) technology; (c) scale or magnitude; (d) design; (e) timing; (f) use; and (g) types of action." 6 NYCRR §617.9(b)(5)(v).

Prior to taking action on an action subject to final EIS, an additional public comment period of at least 10 days must take place after the final EIS is filed. 6 NYCRR §617.11(a). Each involved agency must then make findings that:

(1) consider relevant environmental impacts, facts and conclusions disclosed in the final EIS;
(2) weigh and balance relevant environmental impacts with social, economic and other considerations;
(3) provide a rationale for the agency's decision;
(4) certify that the requirements of [SEQRA] have been met; and
(5) certify that consistent with social, economic and other essential considerations from among the reasonable alternatives available, the action is one that avoids or minimizes adverse environmental effects to the maximum extent practicable, and that adverse environmental impacts will be avoided or minimized to the maximum extent practicable by incorporating as conditions to the decision those mitigative measures that were identified as practicable. 6 NYCRR §617.11(d); see also ECL §8-0109(8).

Application to the proposed project: If the offshore wind energy project is not subject to NYS PSL Article X jurisdiction, an EIS will most likely be needed, especially as the size of the project scales upward. Also, if an EIS is prepared under NEPA, an EIS under SEQRA is not required, so long as the agency can comply with the findings requirements under §617.11. 6 N.Y.C.R.R. §617.15(a). However, a FONSI issued by a federal agency does not automatically constitute compliance by the relevant state agencies. 6 N.Y.C.R.R. §617.15(b).

9.3. Great Lakes Laws and Agreements

The following is a summary of treaties, compacts and agreements that may be relevant to the siting of an offshore wind energy project in lakes Erie and Ontario. Much of this information is contained in the NYSDEC's Great Lakes Directory 2001.[120]

9.3.1 Boundary Waters Treaty of 1909

The treaty between the United States and Great Britain (Canada) on the use of the Great Lakes boundary waters is the basis for establishing the International Joint Commission (IJC) and the Great Lakes Water Quality Agreement (GLWQA).

9.3.2 Convention on Great Lakes Fisheries

This Convention established the Great Lakes Fisheries Commission, which coordinates fisheries research, controls the invasive sea lamprey, and facilitates cooperative fishery management among the state, provincial, tribal, and federal management agencies. The Commission has two major responsibilities:

- To develop coordinated programs of research on the Great Lakes, and, on the basis of the findings, to recommend measures which will permit the maximum sustained productivity of stocks of fish of common concern; and
- To formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.

9.3.3 Great Lakes Basin Compact--Establishment of the Great Lakes Commission

The Great Lakes Commission is the only regional organization with a statutory mandate to represent the nine Great Lakes states on a variety of environmental and economic issues.

The Great Lakes Basin Compact (Public Law 90-419) established five general areas of responsibility for the Great Lakes Commission:

- To promote the orderly, integrated, and comprehensive development, use, and conservation of the water resources of the Great Lakes Basin (hereinafter called the Basin).
- To plan for the welfare and development of the water resources of the Basin as a whole as well as for those portions of the Basin which may have problems of special concern.
- To make it possible for the states of the Basin and their people to derive the maximum benefit from utilization of public works, in the form of navigational aids or otherwise, which may exist or which may be constructed from time to time.
- To advise in securing and maintaining a proper balance among industrial, commercial, agricultural, water supply, residential, recreational, and other legitimate uses of the water resources of the Basin.
- To establish and maintain an intergovernmental agency so that the purposes of this compact may be accomplished more effectively.

[120] See http://www.dec.ny.gov/docs/regions_pdf/gldir.pdf

9.3.4 Great Lakes Charter of 1985

Signed by the nine Great Lakes states,[121] and the Canadian Provinces of Ontario and Quebec, the Charter embodies the policies and programs that must be put in place by the Great Lakes states and provinces to protect the lakes for the benefit of the citizens of the region. It consists of five principles:

0.0. Integrity of the Great Lakes Basin - In planning and management of the basin, the natural resources and the ecosystem of the basin should be considered as a unified whole.
1.0. Cooperation Among Jurisdictions - There is a commitment for cooperation among local, state and provincial agencies, the federal governments of Canada and the United States, and the International Joint Commission (IJC) in the study, monitoring, planning and conservation of the basin's water resources.
2.0. Protection of Water Resources - It is the intent of the signatory representatives that no new or increased diversions will be allowed if individually or cumulatively, they would have any significant adverse impacts on lake levels, in basin uses, and the lakes system.
3.0. Prior Notice and Consultation - No Great Lakes state or province will approve or permit any major new or increased diversion or consumptive use in excess of five million gallons per day average without notifying and consulting with and seeking the consent and concurrence of all affected Great Lakes states or provinces.
4.0. Cooperative Programs and Practices - The governors and premiers commit to pursue the development and maintenance of a common base of data and information regarding the use and management of basin water resources, the information, and the creation of a Water Resources Management Program and for additional concerted and coordinated research efforts.

Great Lakes Water Quality Agreement of 1972; amended by Protocol 1978 and 1987 (GLWQA)

Agreement between United States and Canada committing to restoring and maintaining the chemical, physical and biological integrity of the waters of the Great Lakes Basin. This agreement reaffirms the commitment of the Boundary Waters Treaty of 1909. The amendments also aim to strengthen the programs, practices and technology described in the 1978 Agreement and to increase accountability for their implementation. Timetables are set for implementation of specific programs. The 1987 amendments address atmospheric deposition, contaminated sediments, groundwater and nonpoint sources of pollution. These amendments also called for the development of the Remedial Action Plans (RAPs) and the Lakewide Management Plans (LaMPs) to reduce toxic substances.

9.3.5 Great Lakes Fishery Act of 1956

This Act authorizes the Secretary of the Interior to act for and on behalf of the United States in the exercise of the powers granted by the 1954 Convention on Great Lakes Fisheries as amended. The Act sets forth the procedures for carrying out programs under the Convention of Great Lakes Fisheries. It also provides authority for the appropriation of such sums as may be necessary to carry out the provisions of the Convention and the Act. In 1986, increased the number of Commissioners in the Great Lakes Fishery Commission (GLFC) from three to four.

[121] Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin

9.3.6 Great Lakes Fish and Wildlife Restoration Act of 1990

This Act was established to:

- carry out a comprehensive study of the status, assessment, management and restoration needs, of the fishery resources of the Great Lakes Basin;
- develop proposals to implement recommendations resulting from the study; and
- provide assistance to the Great Lakes Fishery Commission (GLFC), states, Native Americans and other interested entities to encourage cooperative conservation, restoration and management of the fish and wildlife resources and habitats in the Great Lakes Basin.

9.3.7 Joint Strategic Plan for the Management of Great Lakes Fisheries

This plan was adopted in 1981 as a commitment to interjurisdictional coordinated fishery management based upon an ecosystem approach. It provides institutional frameworks for coordination of fishery management on the Great Lakes and linkages to environmental management of the Great Lakes. The 1997 revisions were intended to strengthen the plan. The plan was revised in 1986 and then again in 1997. A common goal statement for Great Lakes Fishery Agencies was formed in the 1997 revision:

> To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic ecosystem.

Great Lakes Regional Collaboration Strategy

The Governors of the Great Lakes States identified priorities for restoring and protecting the Great Lakes, supported by the Great Lakes and St. Lawrence Cities Initiative, the Great Lakes Commission, and other groups committed to the preservation of the Great Lakes. President George W. Bush signed executive order 13340 on May 18, 2004, acknowledging the national significance of the Great Lakes and helping establish a "Great Lakes Regional Collaboration." The Great Lakes Regional Collaboration convened in Chicago, Illinois, on December 3, 2004 and included representatives of the federal government, the Great Lakes States, the Great Lakes Cities, the Tribes and the Region's Congressional delegation. The Great Lakes Regional Collaboration Strategy was released on December 12, 2005.[122]

9.4. Summary and Recommendations

Given the uniqueness and potential environmental impacts (i.e. viewsheds) of the offshore wind energy project, and its multi-jurisdictional coverage, it is strongly recommended that all federal, state, and local authorities with potential approvals or lessor party status be informed and included prior to and at the earliest stages of the review process. This will facilitate the coordinated review necessitated by the overlapping jurisdictional and regulatory schemes described above. The potential involved agencies for decision-making purposes are listed in Table 1.

NYSDEC has adopted a joint application with the USACE for various permits and approvals, but do not issue joint permits. The same application is submitted to each agency, and the separate review procedures of the two (or more) agencies result in separate permits.

[122] See http://glrc.us/documents/strategy/GLRC_Strategy.pdf

NYSDEC permits are subject to the Uniform Procedures Act (UPA) which requires, in the absence of extenuating circumstances, that applications for all relevant permits be submitted at one time and that NYSDEC review be completed within specified time limits. ECL Article 70 and 6 N.Y.C.R.R. Part 621.

Compliance with NEPA and SEQRA, the multiple reviews likely required under other New York State and local regulatory programs, the extensive public participation requirements set forth in SEQR and Article VII, and the difficulty in coordinating a multi-jurisdictional review will most likely result in approval and certification taking at least 2 – 3 years.

Table 9.1: Permits, Actions, and Authorities

Permit or Action	Agency	Regulatory Authority	Timeframe
Federal			
NEPA	Lead: Likely USACE	40 C.F.R. Part 1500	2 years
Navigable Waters of United States*	USACE	33 C.F.R. Part 322	60 - 180 days (No NEPA EIS)
Dredge or Fill*	USACE	33 C.F.R. Part 323	60 - 180 days (No NEPA EIS)
Obstruction to Navigation	FAA	33 C.F.R. Parts 62, 64, 66	60 - 180 days (No NEPA EIS)
Private Aid to Navigation	United States Coast Guard	33 C.F.R. Part 66	30 - 60 days (No NEPA EIS)
Federal Consistency Assessment Form	NYSDOS	15 C.F.R. Part 930	Permit submission complete (up to 180 days)
New York State			
Coastal Erosion Hazard Areas*#	NYSDEC	6 NYCRR Part 505	Same as above
Protection of Waters*#	NYSDEC	6 NYCRR Part 608	Same as above
Grants of Lands Underwater*	NYSOGS	9 NYCRR Subdivision G, Part 271	Upon issuance of all permits and approvals
Certificate of Environmental Compatibility (Transmission)	NYSPSC	NYS PSL Article VII	420 days
SEQRA#	Lead: Likely NYSDEC	6 NYCRR Part 617	180+ days - 3 years+
Coastal Assessment Form	NYSDOS	16 U.S.C. 1456; NY EXEC LAW 911	Up to 180 days

***** Submitted as joint application, but separate permits must be issued.

[#] Not applicable under Article VII procedures.

10.0. Economic Overview

Economics plays a critical role when assessing the feasibility of offshore wind energy. This section identifies the major cost variables comprising a wind project investment and estimates the cost of energy derived from a hypothetical offshore wind project. For comparison purposes, costs are given for conventional wind projects on land as well. Financial incentives for wind development are also discussed.

10.1. Offshore Project Costs

Offshore wind energy projects cost approximately twice as much per MW than land-based projects. Installed costs result from offshore turbine foundations, specialized installation processes and equipment for turbines and balance-of-plant infrastructure, and higher development costs associated with offshore planning.

To date, offshore wind development has taken place almost exclusively in Europe, with the first project emerging in the Far East in 2009. At this time, a reasonable approach to project the cost of a United States based offshore project is to analyze the European wind market experience and cost information that is publicly available. Therefore, in order to assess the potential cost of an offshore wind energy project in the Great Lakes, international offshore wind project cost data was retained and analyzed.

Sources of project cost information for this analysis include a variety of trade publications and industry Web sites (such as www.offshorewindenergy.org), a clean energy financial research database (New Energy Finance), expert opinions expressed in recent reports and conference presentations, and personal communications. In cases where sources gave differing costs for the same project, the higher figure was used based on our assumption that it represented the more inclusive value. It is possible that some published costs are not fully inclusive (especially with regard to interconnection); however, this could not be verified for every project for this analysis.

Figure 10.1 illustrates the published installed costs of 25 offshore projects, 18 of which have been commissioned or are under construction in Europe and China. Projected costs are included for 7 projects due to be commissioned between 2010 and 2012 that have already secured financing. Table 10.1 gives vital statistics for the 25 projects, including MW capacity, distance from shore, and water depth.

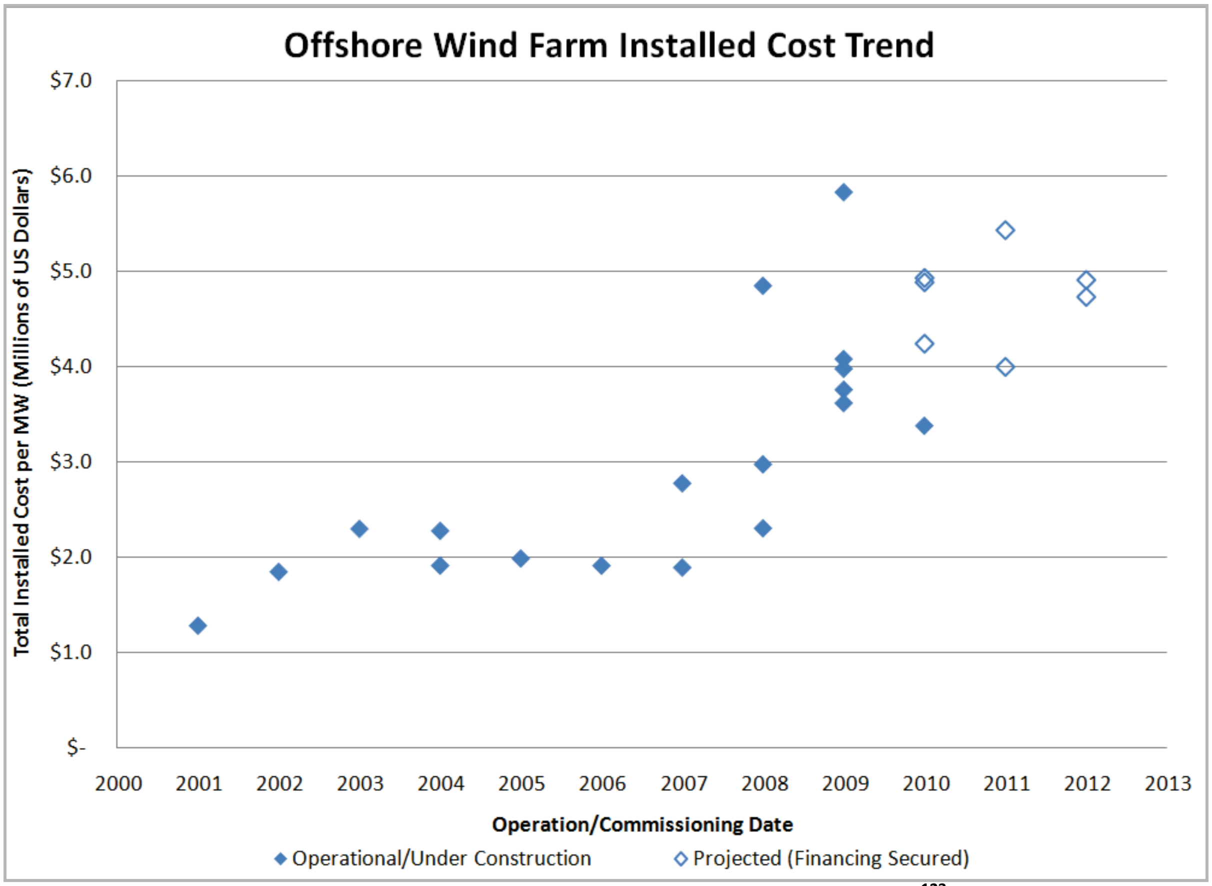

Figure 10.1: Offshore Wind Project Cost per MW Over Time[123]

Up through 2007, the total installed cost of projects ranged between $1.3 and $2.8 million per MW (i.e., mean of $2.1 million/MW + 38%).[124] In 2008, higher costs began to be realized. For several projects now under construction and others scheduled to be built within the next three years, costs are in the range of $3.4 – $5.8 million per MW (i.e., mean of $4.6 million/MW ± 26%). This rise in mean cost of 119% is attributable to several factors:

- The increase in commodity and fuel prices, which affected many equipment and construction intensive industries, not just the wind sector. The costs of land-based wind projects increased 60-100% over the same period.
- Turbine supply chain shortages and bottlenecks
- Higher profit margins on turbine sales
- Better understanding of project risks after learning from earlier projects
- Fluctuations in currency exchange rates
- Increasing distance from shore and water depth.

Thus, data was separated into two subsets prior to and after the cost increase that occurred in 2008.

[123] Source: AWS Truewind, LLC.
[124] Dollar values were converted from European currencies using the average exchange rates for the given year.

Total installed cost was plotted against project nameplate capacity to determine the effect of project size on cost. Based on the data shown in Figure 10.2, it is not conclusive whether larger offshore wind projects will benefit from economies of scale with lower per MW costs. This is due to the limited number of projects built thus far and the fact that the project characteristics (location, water depth, distance from shore, foundation type) differ significantly from site to site. Figure 10.3 demonstrates, for example, that variation in water depth tends to affect project economics. Customized approaches to project financing, materials handling, transport, and installation is also a factor contributing to economies of scale. As more projects are built using standardized practices, economies of scale may become more evident.

Figure 10.2 indicates that later projects tend to exhibit a larger project size, and depicts the significance in the increased installed costs beginning in 2008. Industry projections for future cost trends are mixed partly because of the current recession and the uncertainty over the timing and pace of a recovery. But the general consensus is that costs will either hold roughly steady or increase further. Installed cost estimation for a potential Great Lakes project was based on the post-2007 data set, assuming costs will continue at the current level

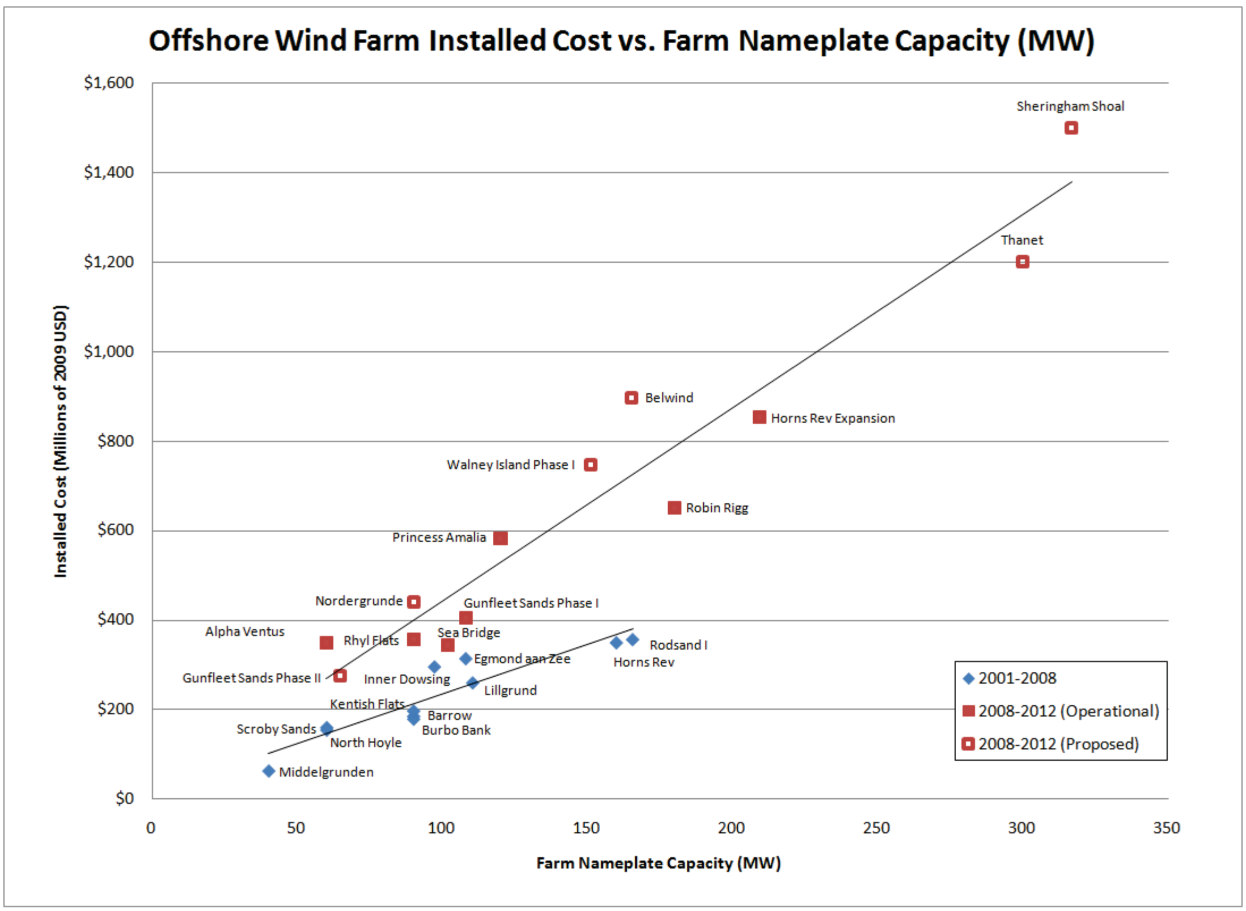

Figure 10.2: Installed Cost of Offshore Projects, 0 to 350 MW[125]

[125] Source: AWS Truewind, LLC.

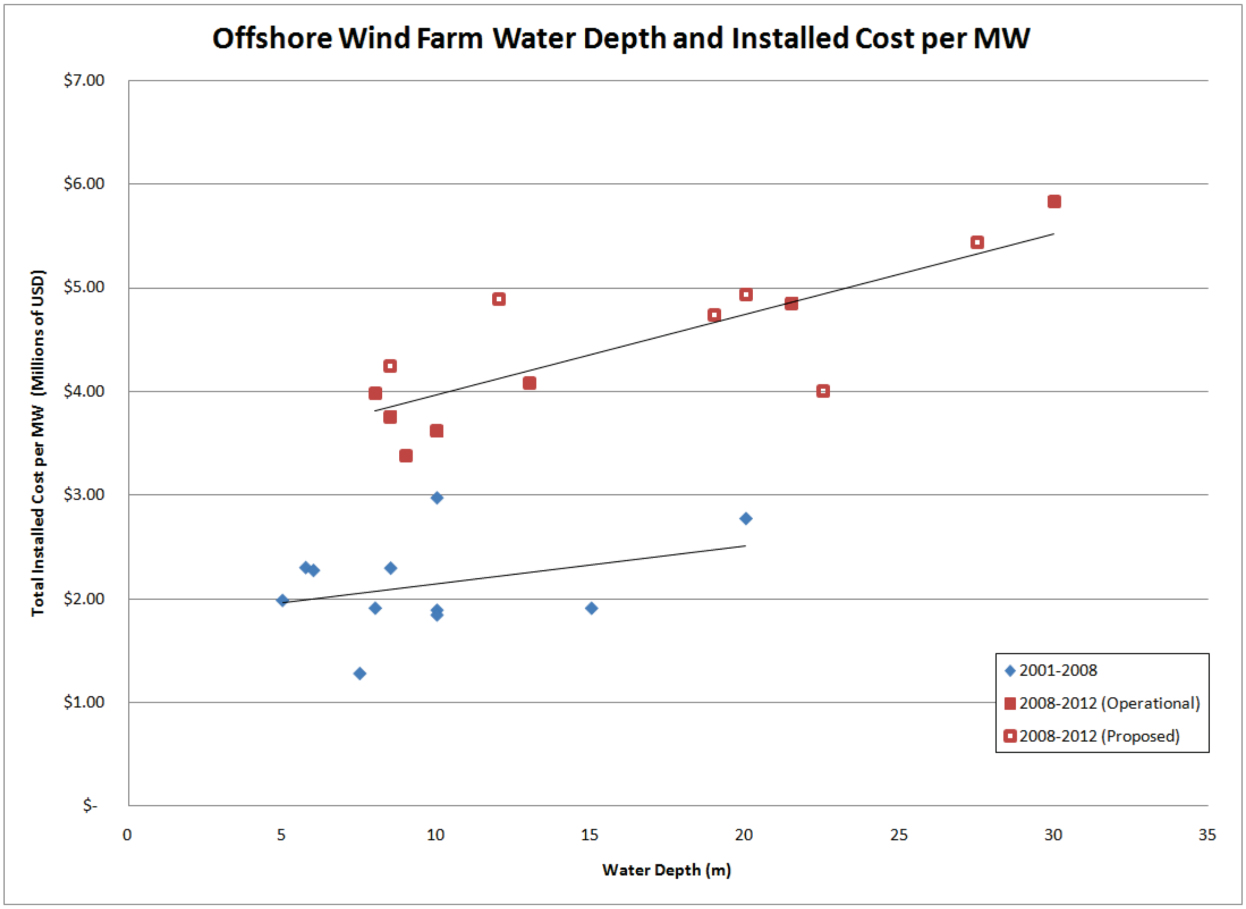

Figure 10.3: Installed Cost per MW and Water Depth for Offshore Projects, 0 to 350 MW[126]

[126] Source: AWS Truewind, LLC.

Table 10.1: Offshore Wind Project Installed Costs and Statistics

Project Name	Country	Status	Operating Year	Project Cost ($M)	Project Capacity (MW)	Project Cost per MW ($M)	No. Turbines	Turbine Size (MW)	Turbine Model	Water Depth (m)	Distance from Shore (km)
Middelgrunden	Denmark	Commissioned	2001	$ 51	40	$ 1.28	20	2	Bonus 2 MW	5 to 10	2 to 3
Horns Rev	Denmark	Commissioned	2002	$ 295	160	$ 1.84	80	2	Vestas V80	6 to 14	14 to 17
North Hoyle	United Kingdom	Commissioned	2003	$ 138	60	$ 2.30	30	2	Vestas V80	5 to 12	7.5
Nysted	Denmark	Commissioned	2004	$ 316	165.6	$ 1.91	72	2.3	Siemens 2.3	6 to 10	6 to 10
Scroby Sands	United Kingdom	Commissioned	2004	$ 136	60	$ 2.27	30	2	Vestas V80	2 to 10	3
Kentish Flats	United Kingdom	Commissioned	2005	$ 179	90	$ 1.98	30	3	Vestas V90	5	8.5
Barrow	United Kingdom	Commissioned	2006	$ 172	90	$ 1.91	30	3	Vestas V90	15	7
Burbo Bank	United Kingdom	Commissioned	2007	$ 170	90	$ 1.89	25	3.6	Siemens 3.6	10	5.2
Egmond aan Zee	Netherlands	Commissioned	2007	$ 300	108	$ 2.77	36	3	Vestas V90	17 to 23	8 to 12
Inner Dowsing	United Kingdom	Commissioned	2008	$ 289	97.2	$ 2.97	27	3.6	Siemens 3.6	10	5.2
Lillgrund	Sweden	Commissioned	2008	$ 254	110.4	$ 2.30	48	2.3	Siemens 2.3	2.5 to 9	10
Princess Amalia	Netherlands	Commissioned	2008	$ 582	120	$ 4.85	60	2	Vestas V80	19 to 24	> 23
Alpha Ventus	Germany	Commissioned	2009	$ 350	60	$ 5.83	12	5	Multibrid & REpower	30	45
Gunfleet Sands I	United Kingdom	Commissioned	2009	$ 406	108	$ 3.76	30	3.6	Siemens 3.6	2 to 15	7
Horns Rev Expansion	Denmark	Commissioned	2009	$ 854	209.3	$ 4.08	91	2.3	Siemens 2.3	9 to 17	30
Rhyl Flats	United Kingdom	Commissioned	2009	$ 358	90	$ 3.98	25	3.6	Siemens 3.6	8	8
Robin Rigg	United Kingdom	Commissioned	2009	$ 651	180	$ 3.62	60	3	Vestas V90	>5	9.5
Sea Bridge	China	Under construction	2010	$ 345	102	$ 3.38	34	3	Sinovel 3 MW	8 to 10	8 to 14
Gunfleet Sands II	United Kingdom	Financing secured	2010	$ 275	64.8	$ 4.24	18	3.6	Siemens 3.6	2 to 15	7
Nordergrunde	Germany	Financing secured	2010	$ 440	90	$ 4.89	18	5	REpower 5M	4 to 20	30
Walney	United Kingdom	Financing secured	2010	$ 746	151.2	$ 4.93	42	3.6	Siemens 3.6	20	7
Belwind	Belgium	Financing secured	2011	$ 897	165	$ 5.44	55	3	Vestas V90	20 to 35	46
Thanet	United Kingdom	Financing secured	2011	$ 1,200	300	$ 4.00	100	3	Vestas V90	20 to 25	7 to 8.5
London Array	United Kingdom	Financing secured	2012	$ 3,095	630	$ 4.91	175	3.6	Siemens 3.6	23	>20
Sheringham Shoal	United Kingdom	Financing secured	2012	$ 1,500	316.8	$ 4.73	88	3.6	Siemens 3.6	16 to 22	17 to 23

10.2. Cost Breakdown

Figure 10.4 compares the installed cost components of offshore and land-based projects. The support structure (foundation and tower) and electrical collection and transmission system of an offshore project constitute larger fractions of the installed cost relative to land projects. Wind turbines constitute less than half the cost of an overall offshore project investment.

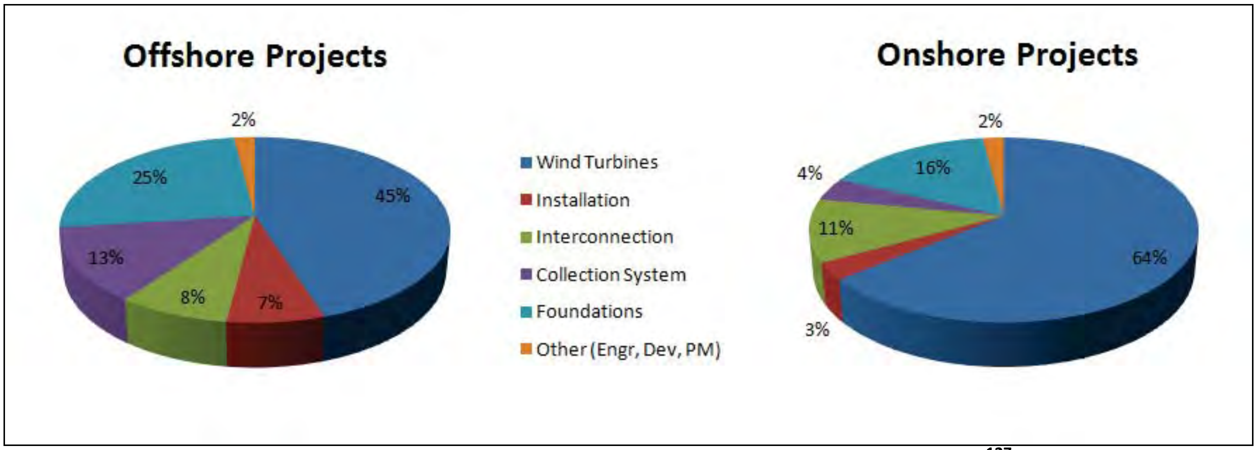

Figure 10.4: Breakdown of Costs for Onshore and Offshore Projects[127]

Table 10.2 lists cost components found within different phases of project development, from permitting to commissioning. Construction costs and schedules are very dependent on weather, waves, geotechnical conditions, foundation types and installation technique, and on the availability of specialized vessels. At the 160 MW Horns Rev project in Denmark, which uses monopile foundations, approximately one day was required to install a foundation, one day to install the transition piece, and one day to install the turbine (load, transport and erect).

[127] Source: AWS Truewind, LLC. Data modified April 2009 based on AWST research of industry journals and conference proceedings. Original data taken from "Offshore Wind Energy in Europe—A Review of the State-of-the-Art," Wind Energy, Vol. 6, No. 1, January-March 2003, Wiley, pg. 42.

Table 10.2: Project Cost Components

Development	Engineering	Equipment Procurement and Delivery	Construction
Site permitting	Foundations, scour protection	Meteorological equipment	Foundation piles, transition piece, tower erection
Meteorological studies including monitoring	Electrical facilities	Turbines	Turbine erection
Environmental studies	Operation and maintenance facilities	Tower	Plant start up and commissioning
Geotechnical studies	Site surveying	Supervisory Control and Data Acquisition (SCADA)	Construction contracting, project management and administration
Public outreach	Preparation of drawings	Electrical cable and collection system	FAA lighting
Power purchase agreement	Inspections/approvals	Offshore substation	Bonding

10.3. *Cost of Energy*

The cost of energy from a wind project includes several factors besides those constituting the initial installed cost. In basic terms, the total expenses required to build and operate a project over its effective lifetime divided by the total energy generated by the project yields the cost of energy (i.e., dollars per kWh). Lower energy costs are therefore attainable at windier sites when installed and operating costs among sites are comparable. The cost of energy is affected by a variety of inputs, including:

- A capital structure consisting of both equity and debt portions
- Operations and maintenance (O&M) costs
- The life span of the wind turbines (assumed to be 25 years)
- The annual inflation rate
- The debt service coverage ratio
- The loan terms (payback period and interest rate)
- The target project rate of return (influenced by the equity/debt ratio)
- Government incentives, including the Production Tax Credit (PTC), the Investment Tax Credit (ITC), and the Federal Cash Grant (explained in more detail below)
- Depreciation of the plant's value over time
- Net annual energy production generated by the project

In order to gain a better perspective on the potential costs of a utility-scale (100 to 300 MW) offshore wind project in the Great Lakes, a hypothetical cost of energy analysis was performed for an offshore facility. This analysis utilized a range of representative values for the cost variables listed above, and assessed the sensitivity of the cost of energy to each input assumption.

Government Incentives

The selected government incentive affects the cost of energy. Three alternatives are available: the Production Tax Credit (PTC), the Investment Tax Credit (ITC), or the Federal Cash Grant. (These incentives are explained in detail in Section 10.4) The PTC currently offers $0.021 per kWh of wind generation, and is adjusted annually for inflation. The ITC and the Federal Cash Grant offer 30% credit toward the project's qualifying costs, which is typically 95% of the installed project cost.[128] Although quantitatively equivalent, the Federal Cash Grant differs from the ITC in that it is provided up front, where the ITC is apportioned over a five year period.

The PTC is favorable for projects with high capacity factors, since incentives are awarded per unit of generation. Alternatively, the ITC and the Cash Grant are favorable for projects with a high installed cost, since incentives are offered as a percentage of the qualifying installed project cost. The analysis was run for both the PTC and ITC scenarios (the economics for the Cash Grant scenario are the same as the ITC scenario).

Net Annual Energy Production and Capacity Factor Range

Multiple variables affect the net annual energy production estimate, including the wind resource, turbine selection, and loss assumptions. A range of typical capacity factors was determined based on the parameters described below:

- Wind resource: energy production estimates were based on wind speeds of 7.5 to 8.25 m/s, which represent a range of wind speeds available for offshore wind development on New York's Great Lakes. The assumed wind speed frequency distributions were also representative of those within the proposed project area.
- Turbine selection: four utility-scale turbine types were selected that could feasibly be installed in a Great Lakes project. The turbine models selected were the REpower 5M, Siemens 2.3, Siemens 3.6, and Vestas V90.
- Loss assumptions: typical losses for a freshwater offshore project are dependent on a variety of factors. For this analysis, a range of 20 to 24% was assumed.

Based on the wind resource, turbine selection, and loss assumptions described above, the typical capacity factor range was determined to be between 30% and 36%. This corresponds to an annual energy production range of 263.0 to 315.6 GWh a year for a 100 MW wind project.

[128] NREL Report: "PTC, ITC, or Gash Grant?" March 2009. Web site: http://eetd.lbl.gov/ea/emp/reports/lbnl-1642e.pdf

Economic/Financial Inputs

Economic and financial inputs drive the cost of energy. The analysis assessed the sensitivity of the cost of energy to a range of economic and financial input parameters, as described in Table 10.3.

Table 10.3 Economic/Financial Input Ranges

Input	Units	Low	Typical	High
Installed cost	$/kW	3680	4600	5750
O&M costs	$/kWh	0.03	0.04	0.05
Tax depreciation (MACRS, 5 year property)	%	90	90	90
Tax depreciation (MACRS, 15 year property)	%	5	5	5
Non-depreciable costs	%	5	5	5
Effective income tax rate (New York State)	%	40	40	40
PTC (inflated annually)	$/kWh	0.021	0.021	0.021
PTC term	Years	10	10	10
ITC subsidy on qualifying capital	%	30	30	30
Annual inflation rate	%	2.5	2.5	2.5
Debt service coverage ratio	-	1.5	1.5	1.5
Equity	%	20	30	40
Debt	%	80	70	60
Project rate of return	%	17	15	13
Term	Years	16	14	12
Interest rate	%	5.5	6.0	6.5

Cost of Energy Range and Sensitivity Analysis

The cost of energy (COE) was computed by optimizing the cash flow model to the project's target rate of return. The input assumptions were set for three distinct cases to calculate the low cost of energy, typical cost of energy, and high cost of energy using the ranges presented in Table 10.3. The results of the cost of energy analysis are presented in Table 10.4. Because of the high installed cost associated with offshore wind development, the ITC/Cash Grant scenario is likely the more favorable incentive option, with a typical cost of 18.0 cents per kWh, compared to 18.7 cents per kWh for the PTC scenario.

Table 10.4: Anticipated Costs of Energy for Great Lakes Projects in New York

Incentive	Low ¢/kWh	Typical ¢/kWh	High ¢/kWh
PTC	15.8	18.7	22.4
ITC/Cash Grant	15.4	18.0	21.2

The sensitivity of the cost of energy to each individual input was computed. The cost of energy was most sensitive to ten of the inputs, while less sensitive to the others. Table 10.5 shows how the cost of energy varies with respect to the input ranges for both the PTC and the ITC/Cash Grant scenarios.

Table 10.5: Input Assumptions and COE Sensitivity Analysis

Input	Cost of Energy Assumptions			PTC Cost of Energy			ITC Cost of Energy		
	Low COE	High COE	Units	Low ¢/kWh	High ¢/kWh	Range ¢	Low ¢/kWh	High ¢/kWh	Range ¢
Turbine Type	(Type X)	(Type Y)	MFG	16.8	21.1	4.4	16.5	19.9	3.4
Wind Speed	8.25	7.5	m/s	18.6	21.1	2.6	17.9	19.9	2.0
Losses	20	24	%	18.7	19.6	0.9	18.0	18.7	0.7
Capacity Factor	36	30	%	17.3	20.4	3.1	16.9	19.3	2.4
Installed Cost	3680	5750	$/kW	15.3	23.0	7.7	15.3	21.3	6.0
O&M Cost	0.03	0.05	$/kWh	17.6	19.9	2.3	16.8	19.2	2.3
Equity/Debt/Return	20/80/17	40/60/13	%	17.3	19.3	2.0	17.1	18.2	1.1
Term	16	12	Years	18.0	19.5	1.6	17.5	18.7	1.2
Interest Rate	5.5	6.5	%	18.4	19.0	0.7	17.8	18.2	0.4

The analysis demonstrates that installed cost, equity/debt ratio, and turbine type are the most significant inputs to the cost of energy. Capacity factor and O&M expenses will also significantly affect the cost of energy. The analysis indicates that the selection of the ITC or Cash Grant is likely to offer more economic benefits than the PTC.

The cost of energy estimates included in this section do not account for revenue that may be generated by selling Renewable Energy Certificates (RECs). Although RECs may be a significant source of revenue for renewable energy projects, RECs may not be long-term or creditworthy enough to be included as a guaranteed source of revenue for project financing.

The analysis did not account for any potential expense for royalty fees or submerged land leases; neither did the analysis consider how capacity markets would affect the purchase price of energy.

The analysis assumes that the project will be able to take full advantage of the accelerated depreciation schedule. If project revenues are such that that depreciation is deferred to a later date, then the full value of the accelerated depreciation schedule will not be realized, potentially affecting the cost of energy.

These estimates are sensitive to project-specific site conditions, design decisions, and financing parameters. Furthermore, the uncertainties associated with offshore development costs are higher than for land-based projects. However, these cost-of-energy estimates provide a useful benchmark for future planning and evaluation purposes.

Comparison to European Energy Costs

It is appropriate to compare the hypothetical cost of energy for a Great Lakes project to the cost of energy for existing projects in Europe and cost of energy estimates from other sources. Reported energy purchase prices vary significantly from source to source: a recent article in *WindPower Monthly* cites the contracted power purchase price for the Rodsand II project as 11.8 ¢/kWh;[129] however, Ernst & Young

[129] WindPower Monthly Offshore Edition, September 2009: "No Consensus on Offshore Costs." Article sites €84/MWh and €2,100/kW, which is equivalent to 11.8¢/kWh and $2,940/kW, assuming an exchange rate of 1.4 euro per dollar.

Foreword

This feasibility study was prepared by AWS Truewind on behalf of the New York State Energy Research and Development Authority (NYSERDA) under the PON 995, Agreement 9998. NYSERDA is a public benefit corporation created in 1975 under Article 8, Title 9 of the State Public Authorities Law through the reconstitution of the New York State Atomic and Space Development Authority.

This publication assesses the feasibility of offshore wind development in New York's Great Lake waters, and identifies the major areas of study associated with development. AWS Truewind would like to acknowledge the New York Power Authority for supporting the effort to make this study more comprehensive than originally planned.

The principal authors were Matthew Filippelli, Jeffrey Freedman, Esq., PhD , Steven Hatlee, and Peter Johnson of AWS Truewind. Contributing authors were Bruce Bailey, PhD, Jennifer Manley, Marie Schnitzer, and Whitney Wilson, also of AWS Truewind. The aviation analysis was conducted by Gary M. Allen and Kevin Justis of Aviation Systems, Inc.

Highest level of scrutiny

10.4.1 Production Tax Credit

Utilization of tax benefits, such as the federal Renewable Energy Production Tax Credit, can improve project economics and stimulate development activity. This tax credit, also referred to as the Production Tax Credit (PTC), is a per kilowatt-hour (kWh) corporate tax credit for electricity generated by qualified energy resources, including wind. The PTC is available for the first ten years of operation and provides 1.5 cents per kWh credit, which is adjusted annually for inflation. The adjusted credit amount for 2008 was 2.1 cents per kWh.

The PTC was originally enacted as part of the Energy Policy Act of 1992. Since then, the PTC has expired and been reinstituted multiple times. The latest extension of the PTC was included in The American Recovery and Reinvestment Act of 2009 (ARRA 2009). The act extended the PTC for wind energy through 2012.

10.4.2 Investment Tax Credit

The American Recovery and Reinvestment Act of 2009 includes the option for wind projects installed from 2009 through 2012 to take advantage of an Investment Tax Credit (ITC) in lieu of the PTC. The ITC provides a 30% credit of the project's qualifying costs which are paid in the first year of operation and vested linearly over a five-year period. The ITC will be available to facilities installed in 2009 through 2012. Selection of the ITC requires the project to reduce its depreciable basis by half the value of the ITC, or 15%.

10.4.3 Cash Grant

The American Recovery and Reinvestment Act of 2009 offers a 30% cash grant in place of the ITC for facilities placed in service in 2009 and 2010, or facilities that have started construction during 2009 and 2010 and are operating prior to 2013. The Cash Grant is paid by the United States Treasury within 60 days after receiving the grant application and the project becoming operational. Selection of the Cash Grant requires the project to reduce its depreciable basis by half the value of the grant, or 15%.

10.4.4 Renewable Energy Certificates

Renewable Energy Certificates (RECs) represent the separable bundle of non-energy attributes (environmental, economic and social) associated with the generation of renewable power. RECs are sometimes also referred to as tradable renewable certificates, green tags, green tickets, renewable certificates, and renewable energy credits. RECs are generally sold separately from their associated energy in wholesale markets. In retail markets they may be sold separately as an independent product or may be combined with electrical energy at the point of sale to create a renewable electricity offering. RECs are sold in compliance markets to meet RPS goals, as well as in voluntary markets to accommodate consumer desires to purchase renewable energy. The market rate and revenue generated by RECs varies depending on project location and the availability of RECs. In New York State, REC rates from the State Renewable Portfolio Standard Program have ranged from $14.94 to $22.90 per MWh in recent years, potentially offering developers 1.5 to 2.3 more cents of additional revenue per kWh (see Figure 10.5).[133]

It is possible that a REC market may develop in New York similar to the markets available in other states; however, there is no certainty that RECs will be available in the timeframe of an offshore project's development in New York's Great Lakes waters. If RECs are available, rates will reflect current market

[133] Nemore, Carole, of Summit Blue Consulting, LLC (November 14, 2008). *Renewable Energy Credit Prices – the Market Signal from the State Renewable Portfolio Standard Program.* Available from NYSERDA Web site: http://www.nyserda.org/rps/SB%20EXH%20C%20REC%20Price%20Report_11-14-08.pdf.

conditions at the time of development, and historical rates may not be indicative of the future value of these credits. Therefore, although RECs may be a significant source of revenue for renewable energy projects, RECs may not be long-term or creditworthy enough to be included as a guaranteed source of revenue for project financing.

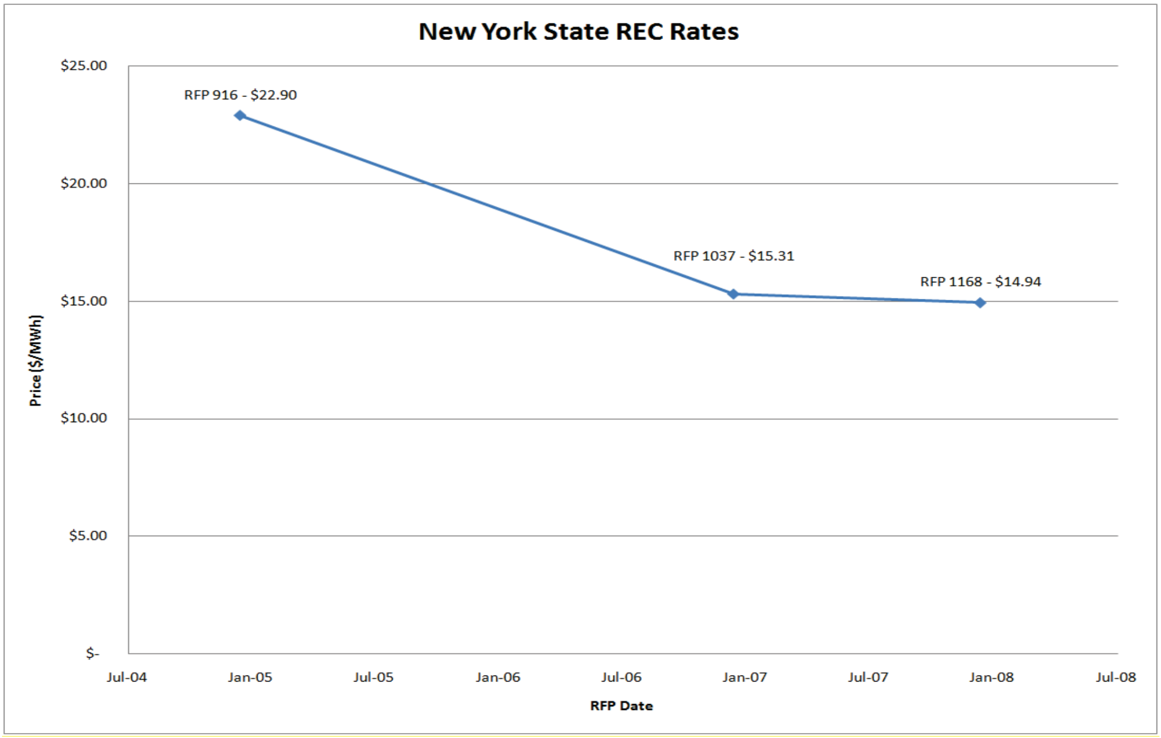

Figure 10.5: Recent New York State REC Rates[134]

10.5. Regional Economic Benefits

While the projected cost of a United States offshore project may appear to be high, it is necessary to consider how this cost projection compares with alternatives to offshore wind. Economic benefits to offshore wind development extend beyond the generation of environmentally friendly energy by supporting Renewable Portfolio Standard (RPS) goals and by bolstering economic development within a region.

Offshore development in New York's Great Lake waters would contribute to RPS goals. To achieve the levels proposed in New York State's renewable portfolio standards goals of 30% by 2015, a substantial amount of new renewable supply is necessary. Offshore wind development would contribute to meeting these renewable energy needs. It is unlikely that solar alone will meet this goal, as substantially more solar capacity would be required compared to wind capacity. Onshore wind development in northern New York and Canadian hydro power could meet this need, but these resources are remote from the State's major load centers, thus requiring major transmission additions to integrate these resources to the electric grid. Offshore wind development near load centers such as of Buffalo, Oswego, and Rochester would require less transmission upgrades that renewable energy from these other sources.

Additional economic benefits to offshore wind development include the creation of jobs, revitalization

[134] Source: AWS Truewind, LLC.

of cities, and the development of infrastructure within a region. The development of offshore wind infrastructure in the Great Lakes would lead the way for other Great Lakes projects to be installed, further supporting RPS goals. A region developing an offshore wind project would benefit from opportunities for local economic growth to support construction efforts and O&M tasks during the project's lifetime. These considerations must be included when assessing the overall costs and benefits of an offshore wind facility.

10.6. Economic Outlook

In order to meet New York State's RPS goals, a variety of additional renewable energy generation facilities will need to be constructed. As Europe is realizing, offshore wind development has the potential to be a viable new option to help reach ambitious renewable energy goals.

An important consideration to enable progress on offshore development in New York is the availability of U.S.-based infrastructure (i.e. installation vessels, cable-laying companies, crews, etc.) capable of supporting project construction. While the cost of obtaining this infrastructure may be relatively expensive for any of the first offshore projects, the expense could potentially be shared among multiple projects. There are numerous proposed projects along the east coast and throughout the Great Lakes that would have similar infrastructure needs. The ability to share installation equipment and services among offshore projects could be advantageous for all. Coordination between project developers regarding timelines and specific infrastructure needs may be necessary, and would benefit the United States offshore wind industry as a whole.

The installed cost for United States development may reflect the prices of projects recently installed overseas, following the trend beginning in 2008 (shown in Figure 10.1 and Table 10.1). However, prices will remain uncertain until market conditions stabilize. The installed cost may be further influenced by the unprecedented nature of a United States based offshore wind industry. Offshore projects installed in Europe offer some industry knowledge that will benefit United States based projects;[135] however, the experience from initial United States based projects will provide valuable information for subsequent ones in terms of the permitting process and construction, potentially streamlining future project timelines and reducing costs.

Project financing for offshore projects may come from public and/or private sources. While the earliest European offshore projects were publicly supported, some recent projects installed since 2008 have received private funding as the industry has matured. Long-term power purchase agreements from creditworthy entities can facilitate offshore project financing. Such agreements have been a catalyst for new project proposals in several states, including New York.

Government support of offshore wind projects can play a significant role in their development as well. Both federal and state governments may assist offshore wind development through the establishment of supportive policies and financial incentives, and by raising public awareness. In particular, the need for a well-defined regulatory and permitting path would help streamline the offshore development process and reduce financial risks. As has been demonstrated in Europe, strong government support of offshore wind can positively influence the economic outlook and timeline for significant levels of new development.

[135] The report *Case Study: European Offshore Wind Farms – A Survey for the Analysis of the Experiences of Lessons Learnt by Developers of Offshore Wind Farms* summarizes the knowledge obtained from the first round of European offshore wind farms. This report is publically available at http://www.offshore-wind.de/page/fileadmin/offshore/documents/Case_Study_European_Offshore_Wind_Farms.pdf.

11.0. Conclusions

This report assessed the feasibility of offshore wind development in New York's Great Lake waters, and identified the major areas of study associated with development. Key conclusions from the study are presented in this section.

11.1. Technology

A review of current offshore wind energy technology was conducted to provide background and to address design considerations specific to development in a freshwater environment. Design considerations specific to Lake Erie and Lake Ontario include site conditions, water depth, and turbine compatibility with the 60 Hz electric grid.

Site conditions such as winds, weather, waves, currents, and ice will influence wind project design. Specifically for a project in Lake Erie or Lake Ontario, freshwater ice will affect site access and contribute to structure loading on the turbine and foundation. While cone structures can be installed around the turbine foundation at the water level to mitigate structure loading, limited site access during winter months may be mitigated by helicopter access, which is available for a few turbine types (GE 3.6, Vestas V90, Siemens 3.6, and REpower 5M).

Current offshore foundation technology allows turbines to be installed in waters up to a depth of 30 m, but developing foundation types (i.e. jackets) may allow installations in waters up to 45 m deep. The ability to install turbines in water with depths up to 45 m greatly increases the potentially developable area on Lake Erie and Lake Ontario. Given the range of water depths and variety of soil conditions in the lakes, there is no clear preferred foundation type. Gravity, monopile, and multimember foundations may all be feasible for certain site conditions found in the lakes.

Compatibility with North America's 60 Hz grid will require turbine manufacturers to develop offshore technology adapted specifically for North American development. Vestas (V80 and V90) and Siemens (SWT-2.3) have onshore versions of 60 Hz turbines that could be marinized for an offshore project—the 50 Hz versions of these turbines have been installed in offshore applications in Europe.

The results of this work indicate that offshore development is technically feasible in New York's Great Lake waters. While some design challenges exist for Lake Erie and Lake Ontario, these issues are not expected to be major obstacles to development.

11.2. Site Selection

The New York waters and adjacent shorelines of Lake Erie and Lake Ontario were evaluated to determine potential sites for offshore wind development. Criteria stipulating maximum water depth (<45 m), minimum wind resource (>=7.5 m/s at 80 m), and buffers from shipping lanes and known obstacles were applied to determine areas on the lakes available for potential wind development. Air traffic routes, winter ice coverage, and natural resources were addressed as precautionary concerns when selecting potential development zones. Proximity to ports, electric transmission, population/load centers, and regional stakeholders were also considered in the site selection process.

Site selection on Lake Erie is summarized below:

- Approximately 954 km^2 (66.0%) of New York's Lake Erie waters are developable, having a wind speed of 7.5 m/s or greater, a water depth of less than 45 m, and no exclusionary obstacles to development. Important siting considerations exist in these conditionally feasible areas that must be investigated in greater detail if specific projects are contemplated. It is likely that more in-depth study of environmental constraints would exclude additional offshore areas from consideration.

- Evaluation of New York's Lake Erie waters resulted in two primary areas of interest, divided roughly by the north-south track line entering Dunkirk. The first is located southwest of the city of Dunkirk and stretches to the Pennsylvania border. It extends from the coast of Chautauqua County out to approximately 8 km (5 mi) from shore. The second is located northeast of Dunkirk and reaches roughly to the city Buffalo.
- While the weather, wave, and ice conditions on the lake merit attention during subsequent investigation – and, in the case of ice, additional detailed study – none were deemed significant obstacles to offshore wind development in Lake Erie.
- Though detailed interconnection analysis is still required, there appear to be no obvious transmission roadblocks at this stage of evaluation, as several high voltage lines run parallel to the selected sites along the New York shoreline, and load centers such as Buffalo and Dunkirk are in nearby proximity to the selected sites.
- Diverse uses of the land and water adjacent to the selected sites merit attention and further study, as local stakeholders will be affected by offshore wind development.

Site selection on Lake Ontario is summarized below:

- Approximately 1536 km^2 (17.6%) of New York's Lake Ontario waters are developable, having a wind speed of 7.5 m/s or greater, a water depth of less than 45 m, and no exclusionary obstacles to development. Important siting considerations exist in these conditionally feasible areas that must be investigated in greater detail if specific projects are contemplated. It is likely that more in-depth study of environmental constraints would exclude additional offshore areas from consideration.
- The portions of Lake Ontario most attractive for commercial wind development reach north and east from Oswego, through Mexico Bay and into the northeast portion of the lake near Galloo Island and Cape Vincent. The area of interest roughly follows the coastlines of Oswego and Jefferson Counties, stretching farther from shore near the entrance to the Saint Lawrence River.
- The selected region experiences more frequent and often thicker icing than the rest of the lake; however, these conditions are not expected to preclude development within the identified areas.
- Transmission and interconnection options in the vicinity of prospective eastern region are limited. High voltage transmission exists farther inland, primarily in the vicinity of Watertown. Interconnection of a project in this area will require further analysis of the shoreline power grid.
- Two potential pilot project areas were identified on the south shore of Lake Ontario. The first potential pilot site is located along the coast of eastern Orleans County, and the second site is located along the coast of eastern Wayne County. These locations, though too small for commercial development, have adequate predicted wind speeds, moderate water depths, and reasonably attractive site conditions based on the screening criteria.
- Diverse uses of the land and water adjacent to the selected sites merit attention and further study, as local stakeholders will be affected by offshore wind development.

Besides the siting considerations described above, legal and jurisdictional regulations will affect a potential project's siting and timeline. A preliminary review of relevant laws and regulations was undertaken to provide initial guidance in this sector.

11.3. Economics

Project economics were studied for offshore wind energy projects installed in Europe. The total installed cost of offshore projects increased from between $1.3 and $2.8 million per MW prior to 2008 to between $3.4 and $5.8 million per MW in recent years. This 119% increase in mean cost ($4.6 million compared to $2.1 million) can be attributed to a variety of market influences and to project siting in more challenging environments. Although uncertainty exists as to how prices will change going forward, it is reasonable to expect that a project installed in Lake Erie or Lake Ontario will have a total installed cost in this range.

A preliminary cost of energy assessment was conducted for an offshore wind project in Lake Erie or Lake Ontario. The cost of energy is affected by a number of technical and economic assumptions, including turbine type, net annual energy production, installed project cost, and financing criteria. The sensitivity of the cost of energy to these assumptions was evaluated, resulting in the ranges presented in Table 11.1. The cost of energy is most sensitive to the installed cost and factors affecting net annual energy production assumptions.

Government incentives such as the PTC and the ITC/Cash Grant were included in the economic analysis (the Cash Grant has the same quantitative value as the ITC). It was determined that the ITC/Cash Grant incentive would result in a lower cost of energy for a potential project in Lake Erie or Lake Ontario, due to the high installed cost of an offshore wind project.

Table 11.1: Anticipated Costs of Energy for Great Lakes Projects in New York

Incentive	Low ¢/kWh	Typical ¢/kWh	High ¢/kWh
PTC	15.8	18.7	22.4
ITC/Cash Grant	15.4	18.0	21.2

Although the cost of offshore wind energy is greater than energy from other fossil fuel sources, wind energy has environmental benefits that other fuel sources do not. Economic benefits to offshore wind development extend beyond the generation of clean energy by supporting RPS goals and by bolstering economic development within a region.

11.4. Follow-on Work

Additional guidance and follow-on work will be necessary to acquire data and further assess the feasibility of offshore development in Lake Erie and Lake Ontario. Specific areas for follow-on work include technical studies, meteorological and lake condition assessment, confirmation of the legal and regulatory framework, and stakeholder outreach. Recommended follow-on work is discussed further in Chapter 12.0.

12.0. Recommendations

This study addressed many of the key technical and regulatory parameters affecting the feasibility of offshore wind development in the New York State waters of Lake Erie and Lake Ontario. The results of this report indicate that both Great Lakes have areas that are conditionally viable for offshore wind energy. This section outlines follow-on work and technical studies that may be useful for potential project sponsors, developers, or other stakeholders in the region.

12.1. Technical Studies

Additional technical investigations are recommended to further characterize specific parameters affecting wind development on Lake Erie and Lake Ontario. Below are candidate next steps to advance the development process and refine site selection in the lakes. The list is not comprehensive, but identifies pertinent technical parameters that can be investigated in parallel.

12.1.1 Geology

A phased approach to the investigation of lake bed geology is recommended. For the first phase, an initial seismic and/or multi-beam sonar survey will help characterize the lake beds and soil composition. These results will inform subsequent site selection in both lakes as well as aid in foundation choice and initial project engineering. The second phase, a detailed geotechnical survey with multiple soil borings, is an advanced task and is likely not necessary until site selection is completed and project development is in progress.

12.1.2 Natural Resources and Wildlife

Further investigation into the natural resources of the lakes will be instrumental in both ensuring environmental compatibility of any proposed offshore wind project and facilitating the expected regulatory and permitting processes. These investigations should identify current conditions and trends in lake and adjacent land ecosystems, identify potential environmental changes, impacts and benefits from offshore wind energy development, and identify appropriate and effective avoidance and mitigation strategies for natural resource impacts and conflicting uses. Among the studies should be investigations into endangered and threatened species, characterization of bird and bat activity over and adjacent to the lakes, and examinations of other lake dwelling species. This work will help in advancing site selection as well as supporting any subsequent development efforts.

12.1.3 Aviation

The extensive use of airspace over the Great Lakes and the dynamic nature of the FAA regulations warrant detailed investigation into any site selected for development consideration. Additional detailed aviation studies are recommended to refine site selection and determine the feasibility of specific project areas and turbine configurations. If development is considered within one of the areas affected by airport procedures, the FAA should be engaged early in the planning process.

12.1.4 Transmission and Interconnection

Additional transmission studies will facilitate advanced site selection, refine candidate points of interconnection, and characterize the need for any grid upgrades. Initial thermal screenings of shoreline transmission lines and evaluation of currently queued generation facilities are recommended as follow-on work. As development activities proceed, detailed interconnection studies will likely become necessary, including contingency studies and collection and interconnection system design.

12.1.5 Freshwater Ice

Further research into the implications of freshwater ice on offshore wind development is recommended. In particular, the effects of ice on foundation design, system dynamics, and operations and maintenance should be examined. Awareness of, and potential collaboration with planned and ongoing Scandinavian research on this topic will add value as well. While ice is not expected to significantly affect feasibility of offshore wind development, studying its effects will help characterize implications on project performance, expected life span and overall economics.

12.1.6 Logistics and Infrastructure

A detailed assessment of the logistics of offshore wind in the context of Lake Erie's and Lake Ontario's existing infrastructure is recommended as a valuable follow-on task. Since the equipment and procedures to assemble, deploy, and maintain offshore wind turbines, foundations, and balance of plant equipment do not exist in North America as they do in Europe, this work will help reduce uncertainty in development costs and identify opportunities for economic development in New York. This work should define the minimum requirements for New York ports to support installation and maintenance of an offshore wind project, characterize the current conditions of and necessary upgrades to the lakes' primary port facilities, assess construction vessel requirements and availability, identify strategies to acquire, build or retrofit suitable vessels, and assess the specific implications of the Jones Act on project development and operation.

12.2. Meteorological and Lake Condition Assessment

There is a need for additional monitoring programs and stations to provide atmospheric and limnological data pertinent to offshore wind development. Implementation of one or more multi-year measurement campaigns, including station deployment on or adjacent to the lakes, is recommended to help enhance the understanding of the operating environment for offshore wind turbines (and associated infrastructure) and to further refine the estimation of the wind resource across New York's Lake Erie and Lake Ontario waters. Whether the measurements are carried out directly on the lakes, remotely from the adjacent shorelines, or some combination thereof, a robust and integrated monitoring program will greatly facilitate project siting, engineering and ultimately operation. The data collected will also help satisfy desired targets of long-term project performance, reliability, safety, and longevity, as well as help define economic viability and transmission grid compatibility.

12.3. Legal and Regulatory

This report has outlined the expected legal and regulatory framework in which an offshore wind project would be developed in New York State's Great Lakes' waters. Consultation should continue with the departments and agencies responsible for permitting and otherwise regulating each component of the project development. In particular, these consultation efforts should facilitate approval of the site screening and selection processes, confirm the approaches to necessary pre- or post-construction studies, and establish a clear application and permitting procedure.

12.4. Stakeholder Outreach

Engagement of the public, industry, and other stakeholders will be vital to the success of offshore wind development in the Great Lakes. This work should include outreach to existing lake users, local and regional communities, and any other parties concerned with site selection, environmental impact, and economic considerations associated with development in Lakes Erie or Ontario. In particular, these efforts should also incorporate public education on offshore wind and consultation with stakeholders throughout the siting and development processes. Outreach programs on the part of potential project sponsors, developers, and other involved stakeholders are expected to increase public support offshore wind and ultimately increase the chances of successfully deploying one or more projects in New York's Great Lakes waters.

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