Literature Review of Solar in Wetlands

Photo credit: http://www.l-a-k-e.org/blog/2012/08/15mw-solar-field-near-philadelphia.html

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Executive Summary

Vermont's ambitious renewable energy goals, enacted in the Comprehensive Energy Plan, combined with the adoption of net metering and the decreasing cost of solar panels has resulted in a large influx of new solar photovoltaic permit applications each year. Many of these applications are sited for former agricultural sites on wet meadows- a form of wetland. The following literature review explores the relationship between solar photovoltaic projects on wetland ecosystems and the local community, with a focus on wet meadows. Recommendations are provided to assist the Watershed Management Division of the Vermont Department of Environmental Conservation in making permitting decisions.

Background

Solar Trends

In January of 2016, Governor Shumlin reaffirmed Vermont's goal of reaching 90% renewable energy by 2050 (Rutland Herald, 2016). The details for this plan are presented in the Vermont Department of Public Service's Comprehensive Energy Plan (CEP) and project a steady increase in solar development (Vermont DPS, 2016). Pressures for electric utilities to reach 75% by 2032 alongside strides in solar technology have pushed solar developers to take advantage of the economic opportunity. Green Mountain Power (GMP) is a major Vermont utility company that it working to increase in-state solar to meet Vermont's renewable energy goal. They are the first utility in the world to get a B Corp certification, indicating that their practices meet rigorous social, environmental, accountability and transparency standards (Green Mountain Power, n.d.). They are currently working on a new battery and grid system to increase storage capacity and reliability of solar power, which will make solar a more sustainable and viable option in the future (Green Mountain Power, n.d.).

New project proposals seek to develop on inexpensive marginal farmland which is sometimes found to be a regenerating wetland or wet meadow. As these companies apply for permits to develop on early successional wetlands, the Watershed Management Division of the Vermont Department of Environmental Conservation is given the role of deciding whether or not these projects can and should be implemented. The effects of solar fields on wetlands and the associated impacts on the greater area have not been extensively studied or understood in Vermont, so it is necessary to examine how wetlands and solar arrays behave in isolation and in conjunction. Wet meadows that are used as agricultural land have the potential of regenerating back to their original state when taken out of production, which may provide more ecosystem functions than they presently do. Although direct correlations have not been observed, adding solar arrays may impede on the ability for the wetland to recover to its natural condition.

The presence of solar photovoltaics (PV) in Vermont has seen tremendous increases partly due to the rapid decrease in the cost of solar PV panels and Vermont's adoption of net metering policies (Vermont DPS, 2016). For reasons stated above, solar has been the fastest growing renewable energy sector in Vermont by far (Vermont DPS, 2016). According to the US Energy Information Administration, "solar power produced less than 0.5% of Vermont's net electricity generation in 2014, but all new electricity generating capacity that went online during the year was solar powered" (2015). Currently, Vermont has around 120MW (840 acres) of solar photovoltaics in place with many more megawatts in some stage of the permitting process (Vermont DPS, 2016).

According to the 2016 CEP forecast, an additional 8,000 to 13,000 acres out of Vermont's total land area (~ 6 million acres) would need to be allocated for solar power. The intermediate model for the projected growth of solar can be seen in Figure 1. These estimates are based on the projected solar demand, solar efficiency, and availability of suitable rooftop sites. However, since rooftop construction is generally more expensive than constructing solar in open fields, compromises would have to be made in customer rate paying and/or environmental health. (Vermont DPS, 2016)

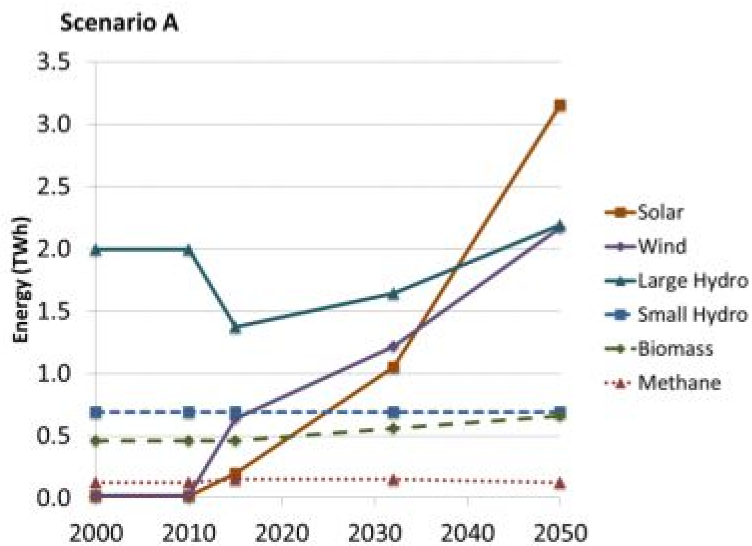

Figure 1: One of three scenarios from the Comprehensive Energy Plan showing the necessary growth of each renewable sector to meet Vermont's energy demand (Vermont DPS, 2016)

To monitor the actions of the solar industry, the Solar Siting Task Force was created by Act 56, which was signed by the Vermont Legislature in 2015 (Vermont DPS, 2016). This Task Force was given the responsibility to "study the design, siting, and regulatory review of solar electric generation facilities, and to provide a report in the form of proposed legislation with the rationale for each proposal" (Vermont DPS, 2016). An analysis of suitable solar PV land in Vermont was conducted by the Solar Siting Task Force using geographic information systems (GIS). Accounting for and ruling out "FEMA floodways, river corridors, federal wilderness areas, rare and irreplaceable natural areas, vernal pools, class 1, 2 and 3 wetlands, deer wintering areas, special flood hazard areas, conserved lands, hydric soils, habitat blocks of more than 2,000 acres, or local, prime, or statewide classified agricultural soils," it was determined that approximately 340,000 acres are available for siting solar PV (Vermont DPS, 2016).

Benefits of Solar Energy

Unlike many other energy sources, solar is a renewable, emissions-free energy source that can benefit local communities through job creation and energy independence. For instance, the 264-panel Stafford Hill project in Rutland provides 2.5 MW of power to the city and creates local jobs (Green Mountain Power, n.d.). Rutland's solar projects in total provide 7.87 MW of energy, or enough to power 1,600 homes year-round (Green Mountain Power, n.d.). The Stafford Hill array also provides an interactive educational resource for students and others interested in homegrown, emissions-free energy.

Many of the fields that solar arrays are being built in were previously used as hay fields. If these field were left uncut, they may turn into wet meadows and scrub-shrub. In reality, if these fields were not bought by solar developers they would continue to be used as farmland. In that sense, development of a solar farm can be considered a less intensive practice when compared to its agricultural counterpart. Although solar fields will undoubtedly have some negative effects on the environment they are located in, they can have a positive impact through the addition of features like bird feeders and wildflowers.

Bees and butterflies are essential pollinators for many of our agricultural products and the primary reason for their decline is habitat loss. Solar companies that develop on converted lands have the opportunity to plant their land with wildflowers and other beneficial native vegetation, which will provide vital habitat to bees and butterflies (Clancy, H., 2015). When comparing the price of vegetation to gravel (the more commonly used ground cover for solar sites), the costs are equal (Clancy, H., 2015). The vegetation will also help minimize the runoff from the site, which may be viewed as a benefit by the solar company. Solar sites have the potential to improve pollinator habitat and reduce runoff through the addition of wildflowers, maintaining healthy ecological function, at no extra cost to their project.

Wetlands in VT

There are 40 different kinds of wetlands located across the state of Vermont. The best way to visualize the distribution of the various types of wetlands is through the Vermont Agency of Natural Resources Wetlands Inventory Map. Using extensive data input into a user friendly GIS format, the Wetlands Inventory Map shows where wetland projects and inquiries are occurring, the location of protected species, impaired wetland information, and more (Figure 2).

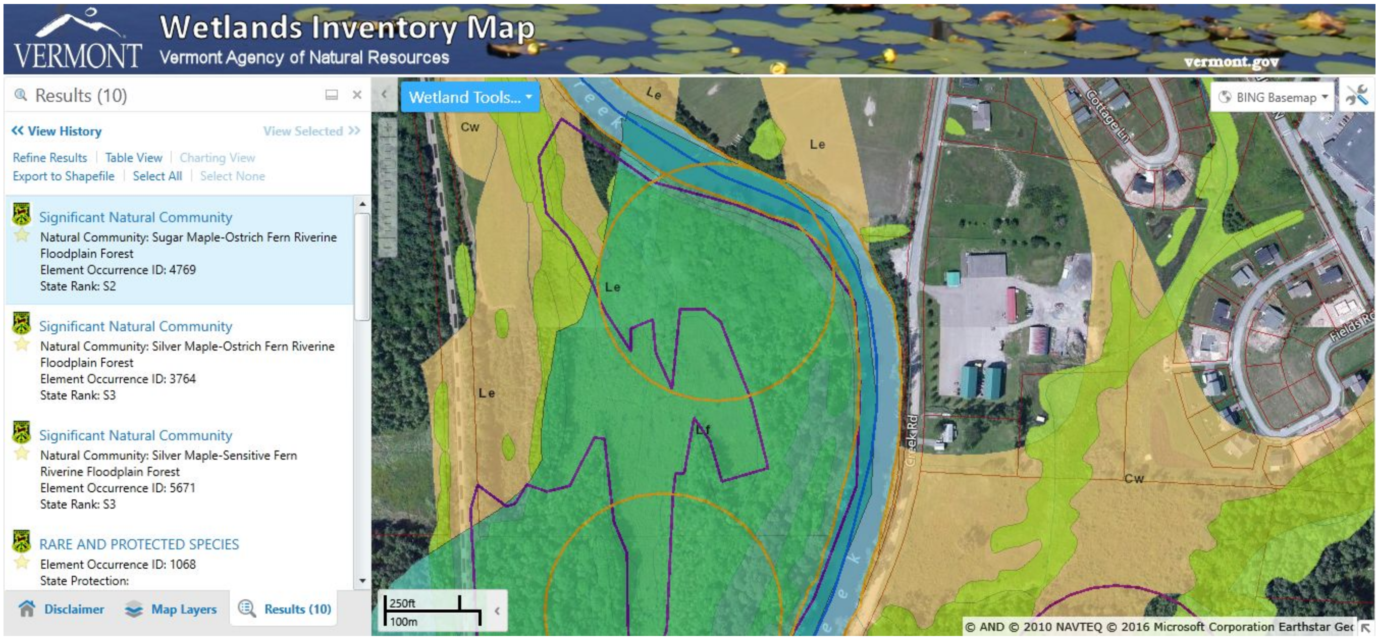

Figure 2: Wetlands inventory map along Otter Creek, just south of Middlebury, VT. The orange circles signify rare and threatened species/natural communities.

Although the Agency acknowledges that some significant wetlands remain unmapped, it is an excellent tool that the public and developers can use for determining if their project site coincides with a wetland. (Vermont ANR, 2010). Adding a "wet meadows" layer to this map would be a good resource that could be juxtaposed to the Solar Task Force's map of available land for solar development.

Wetland Importance

Wetlands are a diverse category of ecologically significant communities that offer many ecosystem services, but are also moderately/highly vulnerable systems (EcoAdapt). Too few of them are recognized as important ecosystems and thus many have been converted for agriculture or development. Within the wetland classification, deep brush marshes and cattail marshes, which are types of wet meadows, are considered "high quality examples of natural community types" (EcoAdapt). From Maine to Maryland spans a wetland type classified as Laurentian-Acadian wet meadows. This contiguous ecosystem is incredibly biodiverse and valuable, but due to land conversion it has a reduced ecosystem quality and functionality. Disrupted wet meadows may return to their former condition, as observed in beaver-disrupted wet meadows that regained former ecosystem functions, but that is dependent upon outside influences or lack thereof (EcoAdapt).

Animal and plant communities in wet meadows vary depending on the season, which contributes to rich biodiversity in this ecosystem type. Wet meadows usually occur as ecotones between fresh emergent wetlands and perennial grassland or mesic meadow types (California Department of Fish and Wildlife). Many species rely on this habitat during migration or for seasonal habitat. In late summer when the wet meadow has dried, small mammals are able to visit. Waterfowl, especially mallard ducks, frequent streams flowing through these areas. They often include native flowering plants, which are great habitat for insect pollinators such as bees and butterflies. Wet meadows have many associated reptiles, mammals, birds, insects and plants, of which dozens are in decline or in need of protection (see Table 1 in Appendix). The range of fauna and flora and seasonal variance makes wet meadows a valuable ecosystem type.

New England's wet meadows can also be home to some of our more unusual animals, including the Northern Leopard Frog, Spotted Turtle, Ribbon Snake, and butterflies such as the Bronze Copper and Baltimore Checkerspot (Hawthorne Valley Farmscape Ecology Program). Although these animals use wet meadows for food and shelter, it may not be sufficient habitat for their success nor the only places where they appear. These species may not be of highest consideration when looking at wet meadows, but their presence in wet meadows should be noted.

Aesthetics

In terms of aesthetics, a significant wetland is one that contributes substantially to the open-space and aesthetic character of the surrounding landscape (Vermont NRB, 2010). To put this into more tangible terms, several criteria that should be considered at a minimum include: "Can the wetland be readily observed by the public? Does it possess special or unique aesthetic qualities? Does it have prominence as a distinct feature in the surrounding landscape? Has it been identified as important open space in a municipal, regional or state plan?" (Vermont DEC, 2011, Vermont NRB, 2010).

In Vermont, there are rising concerns from municipalities regarding the rapidly expanding solar industry in greenfields. Although there are significant siting criteria for protecting natural resources, the criteria for addressing aesthetic value are lacking (Lougee, 2015). This being said, there are many best management practices (BMPs) that have been drafted to mitigate effects of solar projects on wetland aesthetics. Many of these BMPs which are presented in the recommendations section of this report have applications in all ecosystem types and should be taken into consideration when designing a solar plan.

Legislature/Regulations

There are several pieces of relevant legislation that dictate what types of electric energy and wetland development activities are permitted in Vermont including Section 248 of Title 30 and the Vermont Wetland Rules, respectively. Section 248 details the process and criteria required to permit the construction of electric generation or transmission facilities by the Public Service Board (VT Public Service Board, 2012). To be certified as a public good, the criteria in this legislation considers the impacts of new infrastructure on features of the land including water and air purity, habitat, geologic features, scenic areas, historic sites, recreation/education/research, natural communities and public safety (VT Public Service Board, 2012). The Vermont Wetland Rules from the Natural Resources Board define and classify wetlands, as well as control the activities that occur in wetlands through various exemptions, functional criteria, allowed uses, and by establishing the permitting process for wetlands in the state (Natural Resources Board). The Vermont Watershed Management Division categorizes wetland function by water storage, surface and groundwater protection, fish and wildlife habitat, exemplary wetland natural community, rare/threatened/endangered species habitat, education and research, recreational and economic value, open space and aesthetics, and erosion control (VT Department of Environmental Conservation, 2010). These laws overlap in their concern for protecting ecosystems that provide essential ecosystem services from degradation.

Discussion

Although the solar siting process should be examined with higher scrutiny to ensure the protection of wetlands, it is also important that the permitting process gravitates towards a more streamlined and effective direction that facilitates the development of renewable energy production. As solar continues to develop, best management practices need to be implemented.

Relationships Between Solar PV and Wetlands

Although there are few studies on solar fields' impacts on wetlands, there are many implications associated with installing, maintaining, and decommissioning solar technology. The duration of solar construction is typically between 2-3 years, and involves heavy equipment such as chainsaws, dozers, cranes, trucks, and other machinery, which is usually loudest in the beginning of construction (Patton, T., 2013). The initial noise level and associated vibrations would likely cause a mass emigration of resident species and prevent migrational species from using this space. The implications of losing wildlife in the area during the years of construction and onward are unknown. Furthermore, construction disturbances and the loss of species could cause shifts in plant communities.

Heavy machinery also poses the issue of compaction of spongy, delicate wetland soils, which would inhibit plant growth due to restricted nutrient and water flow through soils, increase runoff and flooding, and reduce groundwater recharge (Patton, T., 2013). In any construction project, there is the chance of water pollution from the various related wastes such as lubricating oils, hydraulic fluids, glycol-based coolants, and lead-acid storage batteries (Patton, T., 2013). There are also chemical byproducts that have the potential to leach into the environment. Considering wetland systems are rarely found in isolation, multiple bodies of water may be contaminated from development in wet meadows that are connected hydrologically.

Post-construction the solar project will continue to affect the wetland ecosystem. The solar panel itself will decrease the amount of light reaching the soil surface, which will decrease some plant productivity and reduce carbon sequestration (Patton, T., 2013). Another source presents conflicting information, stating that former agricultural land could benefit from solar implementation because it would provide a regenerative period for vegetation and soils and thus improve carbon storage (Parker, G., Greene, L., 2014). As part of maintaining any solar site, vegetation is controlled through mechanical and chemical techniques, which will cause disturbance, hurt vegetative populations, and create the potential for contamination due to pesticides. Furthermore, the site will see an increase in collision incidences, will decrease the carrying capacity of populations, and will disrupt species that are attracted to operational lighting.

Soils and Hydrology

Siting solar on converted farmland can be considered a “fallow period” for the land, where the soils will have a chance to replenish their nutrients. Over the course of the solar site’s 20 year lifespan, the hydrology will move towards its natural cycle. Planting a diversity of species would expedite the process of creating a healthy soil profile and create habitat for native mammals and pollinators. Compaction of soil is also of concern so the construction timing and protocol matters. Practices to reduce compaction include minimizing effects of heavy machinery by working when the ground is frozen, adding mats for the tires, and using continuous tracks instead of conventional tires.

In order for hydrology to best fit natural conditions, the spacing of panels and the slope of installation should be considered (Maryland Department of Environment, 2000). One way to do this is to space the panels far enough and to maintain healthy vegetation. The relationship between slope and vegetation cover should be examined. If slopes exceed 5% and ample meadow vegetation is absent, level spreaders should be put in place. The following diagram shows an example of row spacing to ensure proper hydrology (Figure 3).

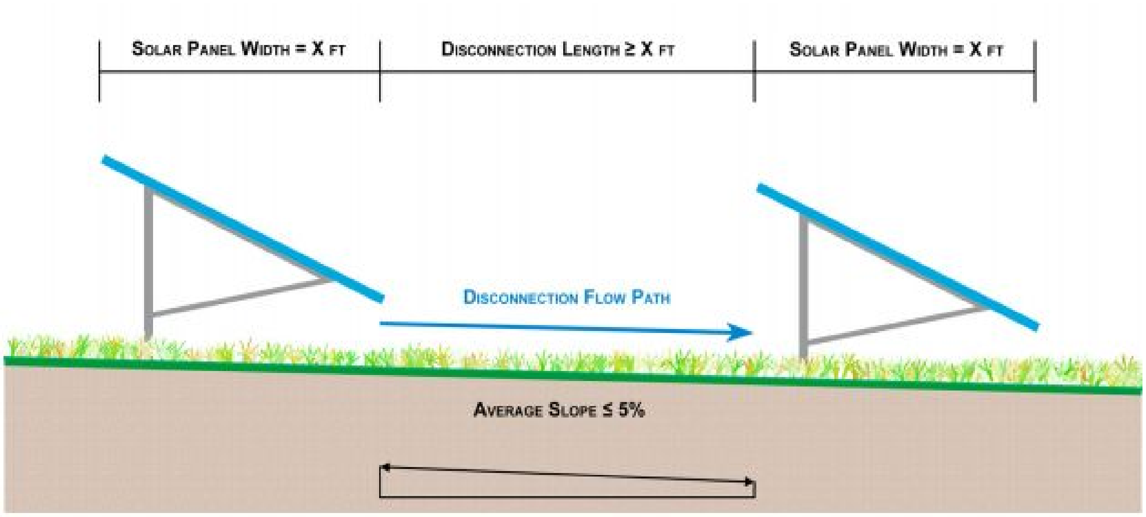

Figure 3: An example of row spacing to maintain natural hydrology. Not shown: level spreader (typically 1-2’ wide and 1’ deep (Maryland Department of Environment, 2000)

Biology

Solar panels offer shaded and protected habitat for the creation of nesting sites for birds and bees. Taking advantage of this can benefit the wetland ecosystem and can be enhanced by planting wildflowers, hedgerows, and adding bird and bee feeders. However, the abundance of birds can have a negative impact on the solar arrays as bird droppings can significantly degrade the performance of solar photovoltaics (Mondal, A.K., & Bansal, K., 2015).

The distance between rows of solar panels can affect flora and fauna mainly due to shading caused by the panels. In a series of short term studies conducted in Vermont looking at plant species composition in wet meadows with PV arrays, the shading of panels did not affect the species in the wet meadows. There was no significant decrease in vegetative coverage or species richness and no observed secondary effect on wetland parameters from solar panel structural support systems or panel shading where site grading was not required (Adam Crary and VHB). However, these were not long term studies so the impact over several years is still unknown. Furthermore, floristic quality will be affected by changes in management regimes, such as mowing, in either positive or negative ways depending on the site. Increased row spacing/rack heights on fixed array systems allow increased light penetration to vegetation and can improve floristic quality on PV array sites, allowing more natural vegetative growth.

Aesthetics

Perhaps the greatest area of concern for Vermont citizens in adopting solar projects is the concern over aesthetic degradation. There are several best management practices (BMPs) for siting solar seeking to preserve the aesthetic appeal of the surrounding landscape. One common theme is that solar projects should prioritize building in disturbed lands, parking lots, brownfields, and areas near industrial or commercial sites. The proposed S.230 bill in Vermont was created to incentivize solar projects in areas that the region found to be preferable, likely in areas such as the ones mentioned above. Another common theme among the BMPs is community involvement. Surveying the local community will allow solar developers to gain a better understanding of the scope, location, and shape of the solar farm that the community would like to see. Areas with upland development increase the aesthetic value of remaining wetlands that should be avoided for solar development. (Vermont DEC, 2011)

To mitigate aesthetic alterations, the Solar Siting Task Force has suggested that once a solar project has been established, a landscape architect or other professional should certify that aesthetic components such as plantings have been properly installed and maintained for at least a three year period (Solar Siting Task Force, 2016). Since solar PV arrays are south facing the north end of the project should be screened by a diversity of tall, native trees and plants in the absence of natural vegetation (Lougee, 2015). Solar projects should be close to topographical features that naturally screen the site from at least two sides. In addition, filling in hedgerows or in some cases creating new hedgerows adds an effective aesthetic barrier while simultaneously improving environmental conditions (Lougee, 2015). Viewshed analysis with GIS should be conducted for solar projects to minimize their aesthetic impact. It should be noted that the presence of many smaller solar projects may have a more significant impact on aesthetics than one large project. Alternatively, smaller arrays are more effectively shielded from sight using hedgerows that blend into the landscape. If larger projects are deemed necessary, their scale can be broken down through screening to better fit the surrounding landscape (Lougee, 2015). The shape of solar projects should follow natural features in the landscape to minimize visual impact; therefore, a rectangular configuration may not always be suitable. Keeping the solar panels as low to the ground as possible shields them from view. This can be troubling for solar tracking devices which are usually taller than fixed arrays.

Types of Structures

There are two general types of structures that may be effective for a wet meadow site. The first is an anchor system, which is commonly used for non-ideal soils with varying conditions. There are four different anchor systems available known as the h-weldment, foot (bearing plate), helical anchor or anchor rod (DCE Solar, n.d.). The downside is that they cannot be on a slope with more than a 10% grade, so they will only be useful on relatively flat sites. Another type of structure would be beneficial in unstable soils is the ballast system, but due to it's concrete footing it will likely be too disruptive to the wetland and cost even more than anchor systems (DCE Solar, n.d.).

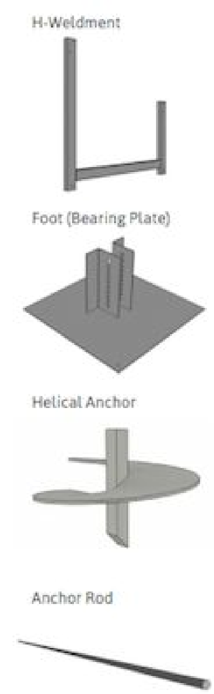

Figure 3. Anchor System Types. (DCE Solar, n.d).

The second option is a solar tracking device, which is effective in capturing more solar energy than an immobile array. Because they capture more solar energy per square foot, the number of panels put in place at the site could be reduced, thus reducing the impacts of shading on vegetation. A drawback of this option is that the arrays require a sturdier base than standard fixed solar arrays, which could mean drilling several feet into the ground and pouring a concrete base. If heavy, highly disruptive bases are needed for a particular site, then we would advise against using these structures. In cases where base structures have minimal ecosystem disturbance, these devices should be considered. Another consideration is that solar tracking devices are generally more elevated than fixed arrays, which can make them harder to blend into the landscape. This can be problematic if locals find solar fields aesthetically displeasing.

Recommendations and Best Management Practices:

- To reduce effects on the ecosystem, avoid or minimize pesticide use; plan the location of panels with consideration to rare/endangered species, species distribution, and ecosystem function; and avoid post-construction lighting altogether.
- To encourage repopulation of mammals and birds into the area, habitat enhancement should be implemented, including improved boundary and connectivity features and bird houses for nesting, roosting, and hibernating. (Parker, G., Greene, L., 2014).
- Structures for ground mounted solar should be minimized to encourage shade tolerant vegetation growth underneath panels in order to reduce effects of runoff.
- Wet meadow conditions can be improved by seeding wildflowers and native vegetation after construction.
- A plan should be approved for the post-decommission restoration of the site to either the prior condition or an improved condition (Lougee, 2015).
- Permit solar if the subsequent regeneration of a wet meadow will be more beneficial to the land than keeping the field as continuously mowed farmland.
- The effects of heavy machinery should be minimized by working when the ground is frozen, by adding mats for the tires, or by using continuous tracks instead of conventional tires.
- Strict regulations will be needed to prevent contaminants from entering the hydraulic system.
- Regardless of price, solar array structures with minimal impact should be used in wetland areas. Every site will differ, therefore structure types will need to be considered every time.
- Ecosystem inventories should be conducted at least 1 year prior to construction and monitored each year around the same time following project completion for several years.
- Collaborate with the Solar Siting Task Force and utilize the GIS data they have to determine if siting solar in wet meadows can be avoided.

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Appendix

Table 1. Species of concern in Laurentian-Acadian wet meadow/shrub swamps

Birds	American Bittern, Black Tern, Rusty Blackbird, Three-toed Woodpecker
Mammals	Southern Bog Lemming
Herptiles	Landing's Turtle, Bog Turtle, Jefferson Salamander, Pine Barrens Treefrog, Wood Turtle
Insects	Clayton's Copper Butterfly, Comet Darner, Don Skipper, Ebony Boghaunter, Elderberry Long-horned Beetle, Helicta Satyr, Incurvate Emerald, Mottled Darner, Mulberry Wing, Tomah Mayfly
Plants	Bead Pinweed, Branching Bur-Reed, Long's Bulrush, Ogden's Pondweed , Pursh's Goldenrod, Stout Smartweed, Walter's Paspalum