Petition No. 1328
Interrogatories
October 11, 2017

Notice

CSC AS 1. Please submit a clearly labeled abutters map identifying each parcel owner corresponding to the names listed on the abutters list behind Tab D of the petition.

Please refer to the map marked Exhibit AS-1, which now includes the names for each parcel owner corresponding to the names listed on the abutters list.

Project Development

CSC AS 2. What is the relationship between the petitioner and the developer? If the project is approved, which entity will hold which permits?

Ecos Energy LLC is the entity that will be providing development services to Windham Solar LLC. Windham Solar LLC will be the owner of the project and the entity that will hold the permits. Ecos Energy LLC is owned by Allco Renewable Energy Limited, and Windham Solar LLC is owned by Allco Finance Limited.

CSC AS 3. Was the project selected through a Department of Energy and Environmental Protection (DEEP) RFP process? If so, which RFP? What entity submitted the proposal? When was the project submitted? When was the project selected?

The project was not selected through a DEEP RFP solicitation.

CSC AS 4. Page 16 of the petition filing states that the petitioner does not have a contract to sell the energy or capacity from the project. Is the petitioner negotiating a contract? When would a contract be expected to be negotiated?

It is Petitioners hope that it will be able to secure a long-term power purchase agreement (PPA) to sell the energy and capacity through either the virtual net metering program or the public utility regulatory policy act (PURPA). If the Petitioner is unsuccessful in obtaining a long-term PPA through either of these avenues, then Petitioner would likely sell the energy and capacity on a wholesale basis until a PPA could be secured.

Proposed Site

CSC AS 5. Page 4 of the petition states "The Site is currently being used as un-cleared vacant land, light agriculture, commercial and there are a small number of residences to the west and south of the Site across Mashamoquet Road." Is that the current land use of the property or the existing surrounding land uses? What is the host property currently used for?

The above description was intended to describe the surrounding land use. The site is not currently being used for any purpose and is vacant land.

CSC AS 6. Have there been any photographic simulations of the solar facility prepared from area vantage points? If so, please submit.

Petitioner has not prepared any photographic simulations for the solar facility. A cross sections and key observation point plan was included with the original petition submission.

CSC AS 7. Where is the nearest recreational area from the proposed site? Describe the visibility of the proposed project from nearby recreational areas.

Please see the attached Exhibit AS-7 for a map of the location of all recreation areas with respect to the proposed site. Petitioner has not performed a view shed analysis of the solar farm from nearby recreation facilities, however, based upon our site visit, the view of the solar facility from the nearest state park (Mashamoquet Brook State Park) would be screened 100% by existing vegetation and topography. The only other recreation area in close proximity to the proposed solar projects is the Airline North State Park Trail, which is located approximately 900 feet east of the proposed projects. In the case of this trail, there is also heavy vegetation between the trail and the solar projects. Where the trail crosses Mashamoquet Road is the only possible place where the solar projects may be visible and in this location the elevation is 521 feet whereas the solar projects' site is at approximately 600'. The lower elevation of the trail and existing vegetation would make it impossible to see the proposed solar projects from the trail.

CSC AS 8. Is the site parcel, or any portion thereof, part of the Public Act 490 Program? If so, how does the town land use code classify the parcel(s)? For example, is/are the parcel(s) classified as "Tillable D – good to fair"?

The site parcel is not enrolled in the Public Act 490 Program. Evidence of this has been confirmed in the title commitment Petitioner obtained, which is included as Exhibit AS-8.

CSC AS 9. Has the State of Connecticut Department of Agriculture purchased any development rights for the proposed site as part of the State Program for the Preservation of Agricultural Land?

Petitioner has obtained a title commitment for the property and the title search did not reveal any conservation easements or any other documents of record conveying any of the development rights for the property. Please reference Exhibit AS-8.

CSC AS 10. Is any portion of the site currently in productive agricultural use? If so, how many acres and is it used by the property owner or is it leased to a third party? Could the project qualify under the Agricultural Virtual Net Metering Program or other agriculturally-friendly renewable energy program?

None of the land is currently in agricultural use.

CSC AS 11. Does the proposed site contain any Connecticut Prime Farmland and/or Important Agricultural Soils? If so, what acreage of prime and important soils would the solar panels and associated equipment be located on?

Yes. The site parcel contains 8.42 acres of prime farmland soils. 5.03 acres of the solar arrays would encumber prime farmland soils. Please reference the map attached as Exhibit AS-11.

CSC AS 12. What impacts, if any, would the proposed project have on the soil productivity of the site? Would the project developer be willing to discuss and/or implement any potential restoration methods to be employed at the end of the project's useful life with the property owner? How would the petitioner decompact the soil as described in the decommissioning memo included with the

petition? Has this soil decompaction previously been found to be adequate to restore soil productivity?

Soil decompaction is a common practice to restore compaction due to construction activities. It's most often performed in proposed infiltration/BMP basins that may have been compacted during construction of these basins. The same principal, may be implemented into the solar array field to uniformly decompact the site. Compacted layers typically develop 12 to 22 inches below the surface when heavy equipment is used. Subsoilers (rippers) can break up the compacted layer without destroying soil aggregate structure, surface vegetation, or mixing soil layers. The attached report in Exhibit AS-12 explains in detail the process of soil ripping and decompaction. If these decompaction methods are employed, then the proposed solar projects would not have any impact on the soil productivity after the solar projects are decommissioned.

CSC AS 13. Have any residential subdivisions or other land use plans been approved by the town for the site in the past? If so, please submit the approved plans. If not, could a residential subdivision or other land use plan be constructed at the site? If so, please provide an overlay map depicting the details of a potential residential subdivision or other land use plan for the site using maximum development potential allowed by the town's zoning regulations.

To our knowledge, no residential subdivisions or other land use plans have been approved by the town for the site in the past. The current landowner is also not aware of any previous plans and there are no approvals of record that were discovered in the title search performed by Petitioner.

Regarding the request to overlay a residential subdivision on the property, we fail to understand how this is relevant to the proposed solar projects. Preparing a subdivision map would require Petitioner to engage an engineer and incur significant costs in preparing residential subdivision plans, which ultimately have nothing to do with the Petition at hand. We object to this request based upon relevance to the proposed projects.

Energy Production

CSC AS 14. Is this electrical output of each facility provided in direct current (DC) or alternating current (AC)?

The nameplate capacity of each facility is 1.0 MW AC / 1.201 MW DC and 0.99 MW AC / 1.195 MW DC. The direct current nameplate capacity of the projects is based upon the use of a 345 watt module, however, Petitioner may elect to use a different size module depending on availability, which could slightly impact the direct current rating of the facility. The output of the facility stated in the Petition is based upon the project sizes listed above. The projects will deliver energy to the grid using alternating current.

CSC AS 15. What are the percent losses associated with the inverters?

Petitioner anticipates 1.6% losses due to inverter efficiency and 0.5% losses due to inverter clipping.

CSC AS 16. On page 19 of ISO-New England, Inc.'s (ISO-NE) Final 2017 Solar PV Forecast, ISO-NE utilizes an AC MW to DC MW (AC/DC Ratio) of 0.83. Is it correct to say that the actual AC/DC Ratio can vary from one solar PV project to the next? Generally, which design considerations were used to determine the AC/DC Ratio of the proposed project?

It is absolutely correct to say that the AC/DC ratio can vary from one solar PV project to the next. The AC to DC ratio is typically chosen by developers to maximize production during shoulder periods (i.e. early-mid morning and mid-late afternoon), while minimizing losses from inverter clipping during peak production periods in the late morning through early afternoon. Petitioner has found that an AC to DC ratio of 1.4 to 1.5 typically provides the best economic returns for a solar project, however, there are many factors that can influence the selection of this ratio. These factors include land constraints, time of use rates, contract constraints, inverter constraints and location.

In the case of the Abington Solar projects, a lower AC to DC ratio of approximately 1.20 was selected due to contractual constraints in the ZREC contracts with Eversource. The ZREC contracts limit the amount of RECs that can be sold on an annual basis, which influenced the DC size of the project. If a higher AC/DC ratio was selected, the projects would produce excessive RECs that would not receive compensation under the ZREC contracts.

CSC AS 17. Could a battery or other type of energy storage system be used to store power from the proposed facilities to be used at other times?

Yes. Battery Energy Storage Systems (BESS) could be installed during initial construction or retrofitted after commercial operation. Although the price of BESS continues to decline at a rapid pace, the technology is still expensive and needs the appropriate applications and compensation to make economic sense. Petitioner has no plans to install a BESS on either of the proposed projects at this time.

CSC AS 18. Would the impact of bird droppings, bird feeding habits (ex. Dropping food items such as clams or other prey on the solar panels) or weather events (ex. Snow or ice accumulation, hail, dust, pollen, etc.) reduce the energy production of the proposed project? If so, approximately how much and for how long? Would any of these expose the solar panels to ballistic or other damage? If applicable, what type of methods would be employed to clear the panels of the bird droppings, prey shells, snow and ice accumulation, hail, dust or pollen?

Bird droppings, dust, pollen and other external elements that cover the solar panels is referred to as "soiling". Soiling can impact the production of a solar array, particularly in areas that don't receive a lot of precipitation or during times of drought. In Connecticut, we don't anticipate excessive soiling because the location of the project receives adequate annual precipitation, which naturally cleans the solar modules. During times of drought or if there are excessive bird droppings on the panels, Petitioner would simply clean the solar modules. Cleaning solar modules can be performed by hand or with machinery and there are a number of contractors that have cropped up over the years that perform these cleaning services throughout the country.

Regarding ballistic damage, hail is the major concern for solar projects. Solar panel manufacturers typically design their panels to be able to withstand most normal hail events up to golf ball sized hail events. Petitioner will carry property insurance to cover the loss of any panels that are damaged from hail or other ballistic events.

CSC AS 19. Would voltage and current be impacted by soft shading of the solar panels, such as air pollution, or hard shading of the solar panels, such as an accumulated solid? If so, would energy production be reduced and by what percent?

The voltage and current of a solar project can be impacted by any shading event. A "soft shading" event would limit the output of a particular solar panel, where as a "hard shading" event of an entire solar module would eliminate the output of a particular solar panel. Calculating the reduced output of a solar panel from a soft shading event would depend on a number of factors including the transparency of the shading event, the time of day and the day of the year. There is not a standard answer to provide in response to this question without these additional details.

CSC AS 20. On page 7 of the petition, it states the facility equipment has an expected useful life of 45 years. Is it the petitioner's intent to operate the facility for 45 years with the original equipment? Would the petitioner consider a change in equipment if technology allowed greater improvements of electric output?

It is Petitioner's intent to operate the solar facility for 45 years with the original equipment, however, given the rapid advancement of photovoltaic and other technologies, Petitioner would consider a change in equipment if the technology allowed greater improvement of electrical output and such a change made economic sense.

Site Components and Solar Equipment

CSC AS 21. What would be the benefit of using a string inverter design rather than a centralized inverter design? If the petitioner elects to use a string inverter design of thirty-three 60 kilowatt inverters, where would those inverters be installed within the project area? What size concrete pad would be necessary for the installation of each inverter using a string inverter design? When would the decision on inverters be made?

The key benefit of a string inverter design has to do with the number of "strings" of solar panels that are dependent upon the operation of a single inverter and thus how much of the solar array is dependent upon the operation of that inverter. In the case of the projects being proposed, a 60 kW inverter would have approximately 11 to 12 strings of solar modules (18 modules per string) connected to it. Alternatively, a centralized 500 kW inverter would have approximately 95-100 strings connected to it. In the event of a mechanical failure of an inverter, the string inverter design would only lose production from 11-12 strings of solar modules, whereas if a central inverter fails, a much larger portion of the array would stop producing energy. The idea behind string inverter architecture is to limit the amount of energy lost due to an inverter failure. There are certainly benefits to a central inverter as well, however, Petitioner has initially selected a string inverter for this design because Eversource requires the interconnecting voltage to their transformer to be 480V. Most string inverters have a 480V output, whereas a central inverter is typically around 390V. The only way to use a centralized inverter with the Eversource provided transformers is to use a secondary transformer, which would result in energy losses of around 2-3%.

String inverters are small enough that they can be mounted onto a driven pier and don't require concrete pads or skids like a centralized inverter would.

The final inverter architecture will be selected once the electrical engineering has commenced, which would take place after discretionary permits for the project are approved.

CSC AS 22. What is the design wind speed of the solar panel H-beam mount? How are the panels adhered to the mount? What prevents the solar panels from separating from the racking during high winds?

The structural components of the solar projects will be designed and stamped by a Connecticut licensed structural engineer. The solar projects will be designed to withstand wind speeds up to 120 mph.

The solar modules are adhered to the racking tables using metal clips. These clips prevent the modules from separating from the racking during high winds.

CSC AS 23. What is the length of the proposed access road?

875 feet

CSC AS 24. What is the color of the solar panels? Are other colors available? Is the glass casing reflective? Are there solar panels available with non-reflective glass? If so, what are the costs and benefits of each type?

Most utility scale solar modules are manufactured with cells that are dark blue in color, with a white back sheet and a silver frame. This would be the color of the modules being proposed for these projects.

Some manufacturers produce modules that are all black, meaning they have a black cell, black backsheet and black frame. These all black modules are more typically manufactured for residential rooftop applications and are more expensive to produce and more difficult to purchase.

Solar modules are designed to capture light and irradiance, not reflect it. Nearly all manufacturers use some type of anti-reflective coating on the glass, however, there is always going to be some level of reflection of light. Petitioner is not aware of a glass technology that eliminates reflection all together.

Interconnection

CSC AS 25. Several locations in the petition state that the project would be located on the customer-side of the meter, including pages 1 and 5. Please confirm that the energy produced by the proposed facilities would be used to provide power on-site rather than to the electrical grid. If this is true, what would the power generated be used for?

The project would be located on the customer side of the meter. Energy will first be used for on-site load which would be a small amount. Almost all the energy would be fed back into the electric distribution grid.

CSC AS 26. Would any of the power produced go to the grid? If so, would the power produced by the project be used regionally, locally or both?

All of the energy that is not consumed on-site would be delivered into the distribution grid for local consumption. The projects would act as a load reducer in ISO-NE and thus would reduce the local utility's regional capacity requirements.

CSC AS 27. Would the proposed facilities have one electrical interconnection to the electric distribution system for both solar arrays?

No. Each facility/project will have its own independent point of interconnection into the distribution system.

Public Safety

CSC AS 28. Would the solar plant have a protection system to shut the plant down in the event of a fault within the facility or isolate the facility during abnormal grid disturbances or during other power outage events?

There are a number of protection devices that will be installed for each facility. Internal to the system, there will be breakers installed in both the panelboards and the switchboards which will protect the system in the event of a fault. On the utility side, reclosers will be installed which will detect outages and prevent the solar facilities from delivering power during any outage (anti-islanding protection). In addition, the reclosers are capable of detecting abnormal grid conditions on the utility/system side and will open during any event that would potentially harm the solar facility or the grid. Eversource also may require a transfer trip to be installed, which is a communication line between the substation and the recloser, if certain electrical conditions are met.

CSC AS 29. Would the project comply with the National Electric Code, the National Electrical Safety Code and any applicable National Fire Protection Association codes and standards?

The projects will comply with the National Electric Code (NEC), the National Electric Safety Code and the National Fire Protection Association codes and standards.

CSC AS 30. Would the proposed fencing be installed around the entire project areas? Would there be any physical division between the 1 megawatt area and the 0.99 megawatt area? Could there be a gap in the fence at the bottom for wildlife? Would the fence utilize any anti-climb measures?

The fence is currently proposed to surround the boundaries of both projects.

It's possible to install a gap at the bottom of the fence for wildlife (wildlife friendly fence), however, such gap would need to be small enough so that a person or small child couldn't crawl underneath the fence.

Petitioner is not proposing to utilize any anti-climb measures. These types of fences are known as wildlife exclusion fences and would prevent wildlife from using the project's land as any type of habitat. Petitioner sees no reason to install this type of fence. Wildlife exclusion fences tend to consist of a chain link fence surrounded by a mesh fabric that's partially buried and attached to the fence. The end product looks like a sild fence attached to the bottom of a chain link fence and creates a visual blight.

CSC AS 31. What are the requirements for fencing the proposed project in accordance with the 2017 National Electric Code, including but not limited to, location, fence height, mesh size, barbed wire.

Article 490 (over 1000 volts) of the National Electric Code references Article 110.31. A wall, screen or fence shall be used to enclose an outdoor electrical installation (over 1000 volts) to deter access by persons who are not qualified. A fence shall not be less than 7 feet in height or a combination of 6 feet in ore more of fence fabric and a 1 foot or more extension utilizing three or more strands of barbed wire or equivalent.

The solar projects which the petitioner is proposing would operate at 1500 volts and therefore it is proposing to construct 7 feet in height.

CSC AS 32. Would glare from the solar panels attract birds (ex. Appear as water) and create a collision hazard?

There is a theory that large solar farms can be mistaken by waterfowl and other birds for bodies of water, not because of the glare but because of the color of the panels. This theory is known as the "lake effect" and some people claim that it can put waterfowl in particular risk because some species can't take off from the ground; they require a running start on the water's surface. This theory, if correct, would only be a problem for locations where there is no body of water nearby. In the case of the site for the solar projects, there is a wetland and brook on the easterly portion of the property which would eliminate this risk. Also, the "lake effect" theory is limited mainly to desert regions where there are no bodies of water nearby. It should be noted that Petitioner is not aware of any evidence to support the "lake effect" theory.

Petitioner is not aware of any evidence to support the notion that solar panels attract birds and thus create a collision hazard.

CSC AS 33. Where is the nearest airport and/or airfield? Would glare from the solar arrays have any impact on air navigation? Has a glare analysis been conducted?

The nearest airport to the projects' site is the Woodstock Airport, which is located 4.9 miles to the north/northeast. The Danielson Airport is located 5.7 miles to the southeast. Please refer to Exhibit AS-33.

A glare analysis of the solar projects has not been performed, however, Petitioner has reviewed the FAA's Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports.[1] This policy establishes guidelines for constructing solar energy systems on airport property, which solar facilities would be held to a higher standard than off-site solar generation. The FAA has established a standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport. Applicants must demonstrate that the proposed solar energy system meets the following standards: "(i) No potential for glint or glare in the existing or planned airport Traffic Control Tower (ATCT) cab, and (ii) No potential for glare or "low potential for after-image" (shown in green in Figure 1) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath."

Since each of the solar projects are more than 2 miles from any airport, there would be no ocular impact under this policy.

CSC AS 34. Would the proximity of any existing or proposed outbuildings, structures, etc. present a fire safety or other hazard (ex. Lightning strike)? Would the proximity of any existing or proposed outbuildings, structures, etc. present a hazard in relation to the electric generating equipment?

Petitioner is not aware of any existing or proposed outbuildings, structures, etc that present a safety or other hazard.

CSC AS 35. In the event of a brush or electrical fire, how would the Petitioner mitigate potential electric hazards that could be encountered by emergency response personnel?

In the unlikely even of a brush or electrical fire, the most important first step is to shut the system down at the main disconnect. Petitioner proposes to install a sign at the entrance to the facilities that will contain a map depicting the location of each systems disconnect switch. The sign will contain the message: "In the event of emergency, the solar facilities can be shut down in these locations".

Petitioner is also willing to provide a copy of the systems' operation and maintenance manuals to the local fire department and police department and also provide a training session to local emergency responders to show them the location of the disconnects. Lastly, Petitioner is willing to provide emergency personnel with the gate code to access the site at any time.

Environmental

CSC AS 36. Provide the carbon debt payback period based on Environmental Protection Agency calculations, including the acreage of tree clearing. How long would it take for the facilities to reach a point where carbon dioxide emissions reductions would equal sequestration loss?

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[1] https://www.federalregister.gov/documents/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports

The EPA estimates that one acre of trees sequesters 1.22 tons of CO_2 [2]per year. The projects are proposing to remove 15.5 acres of trees, which would equate to a total sequestration loss of 18.91 tons of CO_2 per year.

It is anticipated that the solar projects will generate approximately 1,326.2 kWh per kW or approximately 3,179,896 kWs in the first year. The EPA's Greenhouse Gases Equivalencies Calculator estimates that 1 kWh hour of electricity is equal to 1.488 lbs of CO_2 [3] emissions from a coal power plant. Using the EPA's estimate, Petitioner calculates that the solar projects would offset 2,366 tons of CO_2 per year or 6.48 tons of CO_2 per day. Therefore, the carbon payback period would equal 2.92 days for each year of generation or 131.28 days over a 45 year period.

CSC AS 37. Is there any environmental contamination on the proposed site from any previous agricultural use or other land disturbance (ex. Soil and/or water contamination)? If so, how would the petitioner remediate the pre-existing soil and/or water contamination?

A Phase I environmental assessment was submitted with the initial Petition. The Conclusions Section (8.0) of the Phase I did not reveal any recognized environmental conditions (RECs). RECs would include any environmental contamination on the proposed site from any previous agricultural use or other land disturbance.

CSC AS 38. Would any proposed tree clearing occur within .25 miles of a known Northern Long-eared Bat hibernaculum?

No. It is not anticipated that there is any Northern Long Eared Bat (NELB) hibernacula, based on the Feb 1, 2016 NLEB areas of Concern in Connecticut. The removal and cutting of all trees greater than 3" in diameter, is prohibited under a time of year restriction by the USFWS during the bat active season from April 15th through October 31st, for any project within 1 mile of a designated hibernacula. Depending on the time of approval for the project, the developer will attempt to adhere tree removal outside these clearing dates, if trees need to be cleared within that timeframe, a bat hibernacula survey will be performed and consultation with the USFWS will occur. Please reference Exhibit AS-38 for a map of Northern long-eared bat areas of concern in Connecticut.

CSC AS 39. If applicable, would the petitioner comply with any seasonal construction restrictions due to the presence of any protected species on the site (ex. Northern Long-eared Bat)?

Please see the response to CSC AS 38.

CSC AS 40. Are residences near the site served by private wells? Assuming some areas are served by private wells, can vibrations caused by the installation of the racking posts cause sediment buildup in adjacent wells? What measures will the petitioner undertake to ensure there is no disruption or effect on private well water?

The area surrounding the proposed solar projects are not served by town/city sewer and water, so the residents nearby would be served by private wells. Petitioner has installed 17 solar projects throughout the country, many of which have been constructed in close proximity to homes with wells and we have never experienced an

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[2] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-revision-history

[3] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references#coalplant

impact to the well water quality caused by the machinery used to install the piers. We do not plan to undertake any measures to ensure that there is no disruption or effect on private well water because Petitioner is not aware of any evidence to support that this is a risk. If Petitioner is provided with documentation to support this assumed risk, then Petitioner would be open to revisiting this concern.

CSC AS 41. Page 12 of the petition states that views of the solar facilities from the south, north and west would be screened by trees and natural vegetation that would be left in place; however, the site plans and Key Observation Point Plans included show that most or all vegetation along Mashamoquet Road and along the western boundary would be within the facilities project area and, therefore, removed. Please provide information as to where the robust buffer of trees and vegetation would remain to provide screening of the facilities.

The statement in the petition regarding the screening was an error. It should've read that the views of the solar facilities from the east and north would be screen by trees and natural vegetation that would be left in place. In order to enhance the screening from the existing vegetation, Petitioner is proposing to install screening vegetation as shown in the landscape plan attached as Exhibit AS-41-42.

CSC AS 42. Page 12 of the petition discusses planting trees to screen the views of the facilities from the property to the east; however, the Overall Landscape Plan shows only areas of hydroseeding. Where and what type of vegetation would be installed. Please provide an updated landscaping plan depicting these areas.

Please refer to the landscape plan attached as Exhibit AS-41-42. Approximately 250 Green Giant Arborvitaes (Thuja plicata) will be installed along the west and south fence line planted 10' on center, staggered in two rows to create a robust screening hedge. The Green Giant Arborvitaes are deer resistant as well.

CSC AS 43. What effect would runoff from the drip edge of each row of solar panels have on site drainage patterns? Would channelization along the drip edge be expected? If not, why not?

The runoff from the drip edge of each row of solar panels will have no impact on site drainage patterns and channelization along the drip edge is not expected. Petitioner has extensive experience developing, constructing and operating several existing solar projects in the Northeast portion of the United States with similar site characteristics (soil type and topographic slope) and channelization has not occurred. The project sites are proposed to be seeded with a clover/fescue seed mix, and the groundcover establishment is hearty enough to eliminate erosion caused by water sheathing off the lip of the solar modules. The modules are also separated in the racking, so there is not a uniform plane for the water to sheath off of. The proposed layout is 4 modules in landscape, thus allowing for 4 separate drip locations, from an approximate 3.25' long plane (module width), at 15 degrees.

<u>Construction Questions</u>

CSC AS 44. What is the anticipated sequence of construction? During what time of year would each sequence ideally occur?

Construction of a solar project typically occurs in the following sequence, but in our experience this schedule can be shifted around significantly.

1. Site clearing

2. Erosion control measures installed
3. Site grading
4. Fence installation
5. Pier installation
6. Conduit and cable installation
7. Concrete pads poured
8. Racking installation
9. Module installation
10. Interconnection Upgrades (ongoing throughout construction phase)
11. Major equipment such as transformer, inverters and panelboards, switchboards and disconnect switches installed.
12. Site restoration/hydroseeding

Ideally the project would be constructed when there is no frost in the ground and the site would be cleared outside the pup season for the Northern long-eared bat.

CSC AS 45. Page 9 of the petition filing states that provisions for the wood turtle have been implemented on the project plans; however, there is no mention of the wood turtle on the DEEP response letter for the project or on the project plans included with the petition. Please clarify and identify where the provisions for wood turtle protection are located on the project plans.

This was stated erroneously in the Petition. Petitioner has no evidence that the wood turtle is present on the site and DEEP did not find any evidence in performing a review of the natural diversity data base (NDDB) maps.

CSC AS 46. Are the areas identified as being Hydroseeded and the proposed access road as shown on the "Overall Landscape Plan" drawing in the petition filing, the only areas that would require grading on the property? Would ground cover on the areas outside the hydroseeded areas remain as it exists today?

This assumption is correct. The areas shown to be hydroseeded on the original landscape plan constitute the grading envelope of the project. The areas outside the hydroseeded areas remain as it exists today, however, those areas that are not designated to be hydroseeded *and* are within the fence/project boundary will be impacted by construction activity. It's always Petitioner's goal to minimize the impact to existing ground cover vegetation whenever possible.

CSC AS 47. Are any impacts to groundwater anticipated as a result of construction of the proposed project? If so, how would the petitioner manage and/or mitigate these impacts?

No.

CSC AS 48. Is the Hydrology Report included in Exhibit I of the petition consistent with the *2004 Connecticut Stormwater Quality Manual*?

Yes.

Maintenance Questions

CSC AS 49. Would any mowing be required under or around the proposed solar panels/modules, and if so, approximately when and how often would mowing occur?

Yes. Mowing is required to keep the vegetation and ground cover from growing above the drip edge of the solar modules so that the vegetation doesn't shade the solar panels. In the location of the proposed projects, Petitioner anticipates that 4 mowings will be required each year, however, this will entirely depend on the amount of precipitation the site receives each year.

CSC AS 50. Would the installed solar panels require regular cleaning or other, similar, maintenance? How would this be accomplished? Would this maintenance activity have any impacts to water quality?

Cleaning of solar modules in the northeast part of the country is not standard practice. Mother nature typically provides sufficient precipitation to clean the modules on a regular basis. In the event of drought or excessive soiling, Petitioner may wash the modules using a non-toxic soap which is safe to the environment and the ground water.

CSC AS 51. How would the grass/vegetative growth be controlled to keep the solar panels clear? Describe the maintenance of the grass/vegetative surface in the fenced solar field area.

The vegetation would be mowed as described in CSC AS 49.

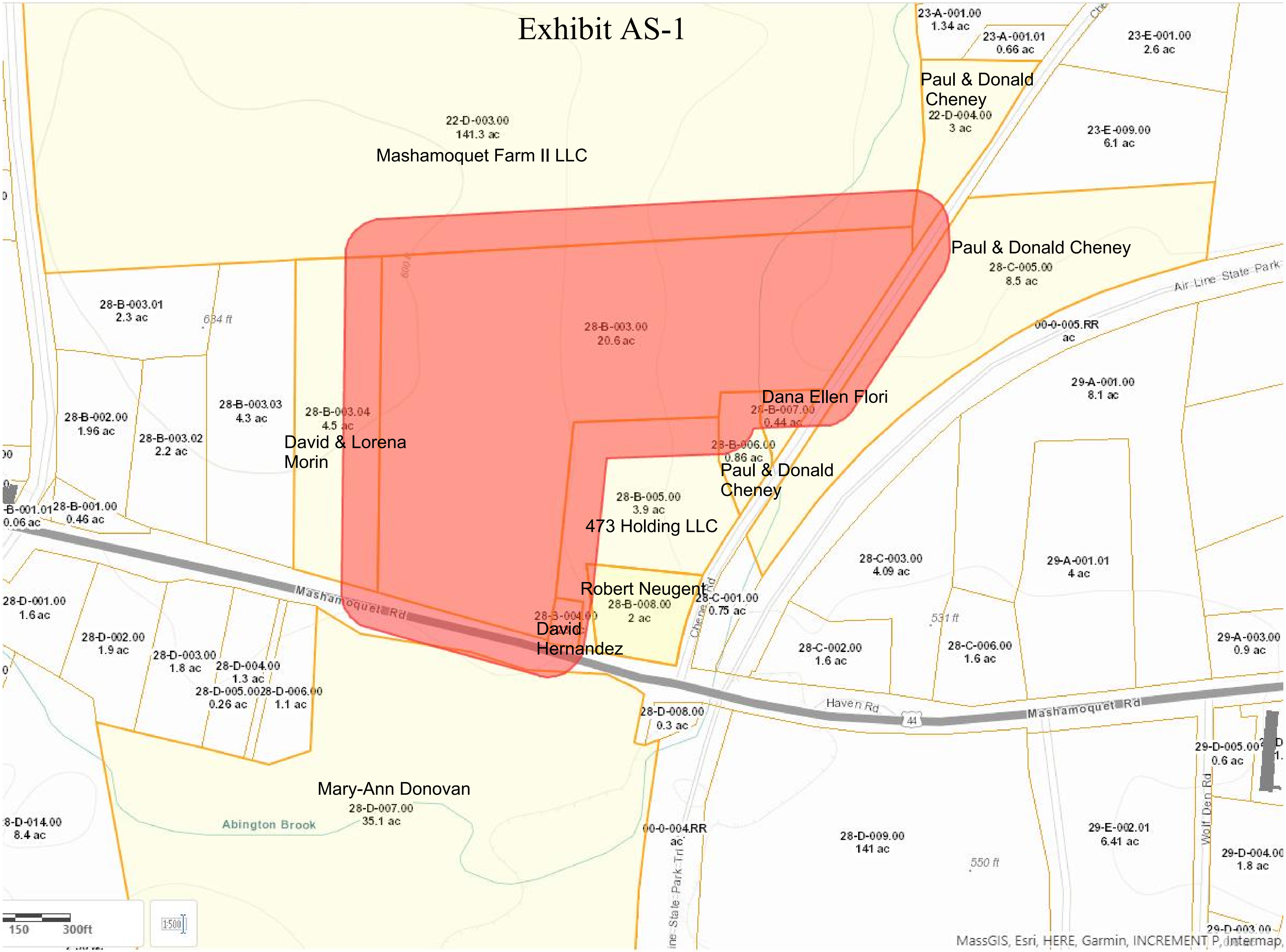
CSC AS 52. What are the impacts of the grass on erosion?

Grass roots offset and minimizes erosion.

CSC AS 53. Could the petitioner establish post-construction site restoration/revegetation that includes the incorporation of model pollinator habitat?

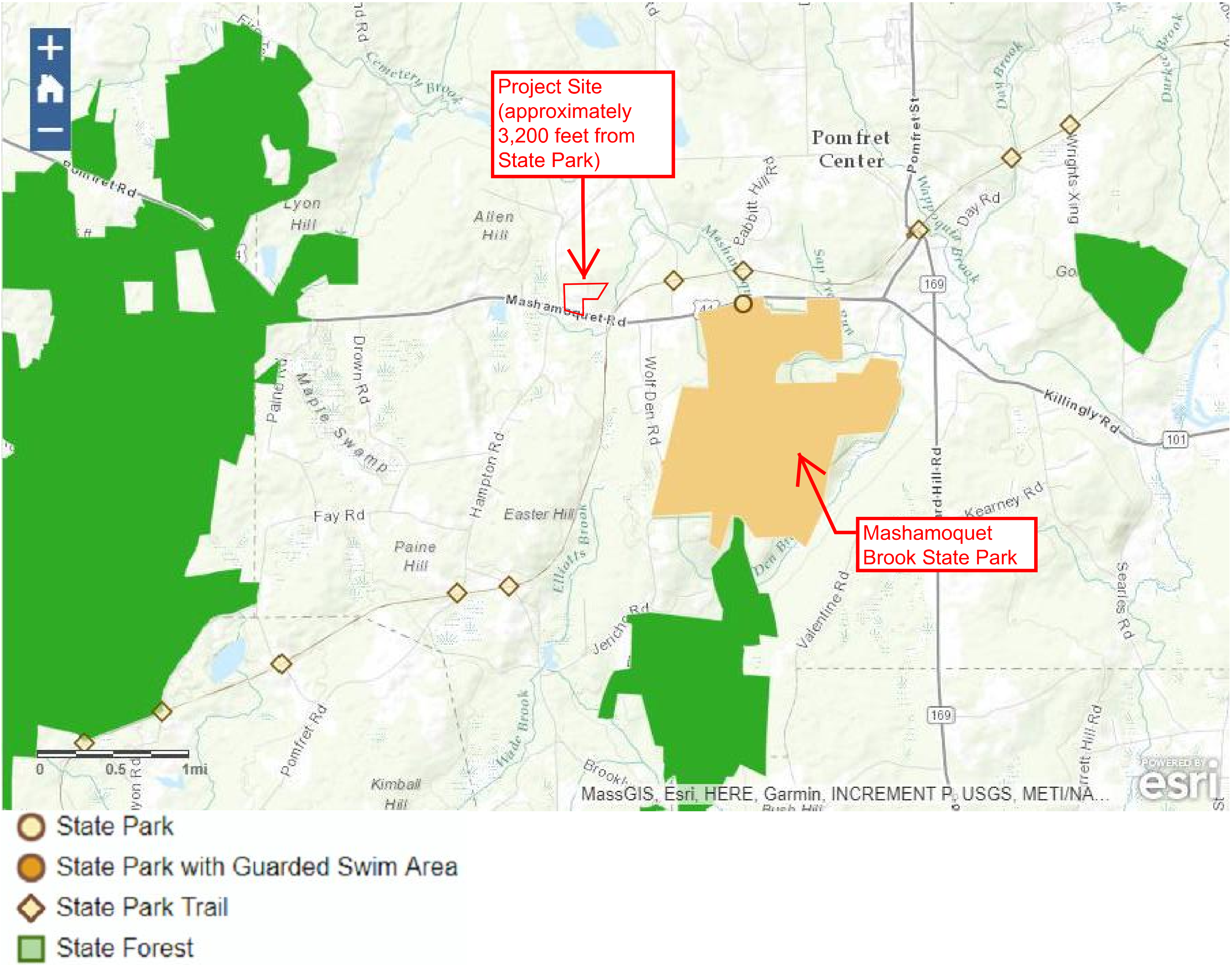
Petitioner is not proposing to incorporate any pollinator habitat vegetation in its restoration plan.

Exhibit AS-1



22-D-003.00
141.3 ac
Mashamoquet Farm II LLC
23-A-001.00
1.34 ac
23-A-001.01
0.66 ac
23-E-001.00
2.6 ac
Paul & Donald Cheney
22-D-004.00
3 ac
23-E-009.00
6.1 ac
Paul & Donald Cheney
28-C-005.00
8.5 ac
Air Line State Park
00-0-005.RR
ac
28-B-003.01
2.3 ac
634 ft
28-B-003.00
20.6 ac
29-A-001.00
8.1 ac
Dana Ellen Flori
28-B-007.00
0.44 ac
28-B-002.00
1.96 ac
28-B-003.03
4.3 ac
28-B-003.04
4.5 ac
28-B-003.02
2.2 ac
David & Lorena Morin
28-B-006.00
0.86 ac
Paul & Donald Cheney
28-B-005.00
3.9 ac
473 Holding LLC
-B-001.01
0.06 ac
28-B-001.00
0.46 ac
28-C-003.00
4.09 ac
29-A-001.01
4 ac
Robert Neugent
28-B-008.00
2 ac
28-C-001.00
0.75 ac
Cheney Rd
28-D-001.00
1.6 ac
Mashamoquet Rd
28-B-004.00
David Hernandez
531 ft
28-D-002.00
1.9 ac
28-D-003.00
1.8 ac
28-D-004.00
1.3 ac
28-C-002.00
1.6 ac
28-C-006.00
1.6 ac
29-A-003.00
0.9 ac
28-D-005.00
0.26 ac
28-D-006.00
1.1 ac
Haven Rd
44
Mashamoquet Rd
28-D-008.00
0.3 ac
29-D-005.00
0.6 ac
Mary-Ann Donovan
28-D-007.00
35.1 ac
Abington Brook
8-D-014.00
8.4 ac
00-0-004.RR
ac
28-D-009.00
141 ac
29-E-002.01
6.41 ac
Wolf Den Rd
29-D-004.00
1.8 ac
550 ft
Air Line State Park Trl
150
300ft
1:500
29-D-003.00
MassGIS, Esri, HERE, Garmin, INCREMENT P, Intermap,

Exhibit AS-7



Project Site (approximately 3,200 feet from State Park)
Mashamoquet Brook State Park
Pomfret Center
Mashamoquet Rd
Killingly Rd
Pomfret Rd
Lyon Hill
Allen Hill
Paine Hill
Easter Hill
Kimball Hill
Maple Swamp
Fay Rd
Hampton Rd
Drown Rd
Paine Rd
Wolf Den Rd
Babbitt Hill Rd
Pomfret St
Day Rd
Wrights Xing
Kearney Rd
Valentine Rd
Searles Rd
Day Brook
Cemetery Brook
169
101
0
0.5
1mi
MassGIS, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NA...
State Park
State Park with Guarded Swim Area
State Park Trail
State Forest

Exhibit AS-8

COMMITMENT FOR TITLE INSURANCE
Issued by
FIRST AMERICAN TITLE INSURANCE COMPANY

FIRST AMERICAN TITLE INSURANCE COMPANY, herein called the Company, for valuable consideration, hereby commits to issue its policy or policies of title insurance as identified in Schedule A, in favor of the proposed insured named in Schedule A, as owner or mortgagee of real estate or interest covered hereby in the land described or referred to in Schedule A, upon payment of the premiums and charges therefor; all subject to the provisions of Schedules A and B and to the Conditions and Stipulations hereof.

This commitment shall be effective only when the identity of the proposed insured and the amount of the policy or policies committed for have been inserted in Schedule A hereof by the Company, either at the time of the issuance of this Commitment or by subsequent endorsement.

This Commitment is preliminary to the issuance of such policy or policies of title insurance and all liability and obligations hereunder shall cease and terminate six (6) months after the effective date hereof or when the policy or policies committed for shall issue, whichever first occurs, provided that the failure to issue such policy or policies is not the fault of the Company. This Commitment shall not be valid or binding until countersigned by an authorized officer or agent of the Company.

CONDITIONS AND STIPULATIONS

1. The term "mortgage", when used herein, shall include deed of trust, trust deed or other security instrument.

2. If the proposed insured has or acquires knowledge of any defect, lien, encumbrance, adverse claim or other matter affecting the estate or interest or mortgage thereon covered by this Commitment other than those shown in Schedule B hereof, and shall fail to disclose such knowledge to the Company in writing, the Company shall be relieved from liability for any loss or damage resulting from any act of reliance hereon to the extent the Company is prejudiced by failure to so disclose such knowledge. If the proposed insured shall disclose such knowledge to the Company, or if the Company otherwise acquires actual knowledge of any such defect, lien, encumbrance, adverse claim or other matter, the Company at its options may amend Schedule B of this Commitment accordingly, but such amendment shall not relieve the Company from liability previously incurred pursuant to paragraph 3 of these Conditions and Stipulations.

3. Liability of the Company under this Commitment shall be only to the named proposed Insured and such parties included under the definition of Insured in the form of policy or policies committed for and only for actual loss incurred in reliance hereon in undertaking in good faith (a) to comply with the requirements hereto, or (b) to eliminate exceptions shown in Schedule B, or (c) to acquire or create the estate or interest or mortgage thereon covered by this Commitment. In no event shall such liability exceed the amount stated in Schedule A for the policy or policies committed for and such liability is subject to the insuring provisions, exclusions from coverage, and the conditions and stipulations of the form of policy or policies committed for in favor of the proposed insured which are hereby incorporated by reference and are made a part of this Commitment except as expressly modified herein.

4. Any claim of loss or damage, whether or not based on negligence, and which arises out of the status of the title to the estate or interest or the lien of the insured mortgage covered hereby or any action asserting such claim, shall be restricted to the provisions and conditions and stipulations of this Commitment.

IN WITNESS WHEREOF, the Company has caused this Commitment to be signed and sealed, to become valid when countersigned by an authorized officer or agent of the Company, all in accordance with its By-Laws. This Commitment is effective as of the date shown in Schedule A as "Effective Date".

NICHOLAS R. SCOLA, LLC

By: ______________________
NICHOLAS R. SCOLA, MANAGER

(PLH_481&505MASH.PFD/PLH_481&505MASH/20)

SCHEDULE A

Agent: PLH_481&505MASH

1. Effective Date: June 26, 2017 at 08:00 AM

2. Policy or policies to be issued: AMOUNT OF INSURANCE

   (a) [X] ALTA [ ] EAGLE - OWNER'S POLICY $ 170,000.00

   Proposed Insured:
   PLH, LLC

   (b) [ ] ALTA [ ] EAGLE - LOAN POLICY

   Proposed Insured:

3. The estate or interest in the land described or referred to in this commitment and covered herein is Fee Simple and title thereto is at the effective date hereof vested in:

   David V. Morin and Lorena C. Morin acquired title from Lorena Morin by virtue of a Warranty Deed dated November 13, 1989 and recorded November 15, 1989 in Volume 83 at Page 258 of the Pomfret land records.

4. The land referred to herein is located at 481 Mashamoquet Road (Lot 3.00) and 505 Mashamoquet Road (Lot 505) in the city/town of Pomfret, State of Connecticut and is described as set forth in Exhibit "A" attached hereto and made a part hereof.

This Commitment is valid only if this Commitment includes a Schedule A description and Schedule B, Section 1, and Schedule B, Section2.

NOTE: Unless a specific amount of insurance is stated on this schedule A, or set forth in an Endorsement to this Commitment, the liability of the company shall not exceed $1,000.00.

This Commitment is issued solely for the purpose of facilitating the issuance of a policy or policies of title insurance by First American Title Insurance Company's liability shall be limited to the terms of its policy or policies.

SCHEDULE B, SECTION 1
REQUIREMENTS

The following are the requirements to be complied with:

General Requirements:

a. Payment to or for the account of the grantors or mortgagors of the full consideration for the estate or interest to be insured.

b. Proper instrument(s) creating the estate or interest to be insured must be properly executed and duly filed for record.

c. If the insured property is an existing one to four family residence, seller/borrower must execute the company's "affidavit in lieu of mortgage survey."

d. If the insured property is commerical property or new construction, A class A-2 survey with long form certification must be submitted, and any adverse matters shown on the survey must be excepted on schedule B; and the Seller/borrower must execute the company's owners affidavit.

e. If the insured property is a condominium unit, the seller/borrower must execute the company's condominium affidavit of owner.

f. If there are tenants or parties in possession other than recorded leases shown in Schedule B, rights of those tenants and parties in possession must be excepted on schedule B.

g. If labor and/or materials have been supplied to the premises within the 90 days prior to and including the date of policy, or if labor and/or materials have been contracted for future construction or if any contractor has been hired for contemplated work, service or materials, the company mechanics lien waiver/affidavit/indemnity form must be fully executed and submitted prior to closing.

h. All municipal taxes, special tax district taxes, water and sewer use charges, and municipal and private association charges including common interest community common charges and special assessments must be paid current to date of policy.

SPECIAL EXCEPTIONS: Matters to Pay or Release

The matters set forth in the following special exceptions must be paid and released of record at or prior to date of policy:

SCHEDULE B, SECTION 1
SUBORDINATE REQUIREMENTS

The matters set forth in the following special exceptions must be filed of record subsequent to the date and time of recording of any mortgage to be insured based on this commitment or must be subordinate of record to the lien of any mortgage to be insured:

SCHEDULE B, SECTION 2
EXCEPTIONS

The policy or policies to be issued will contain exceptions to the following unless the same are disposed of to the satisfaction of the Company:

1. Any state of facts which an accurate survey or personal inspection of the premises would disclose. (To be omitted from Loan Policy upon compliance with general requirements in Schedule B, Section 1.)

2. Unrecorded Mechanics Liens. (To be omitted from Loan Policy upon compliance with general requirements in Schedule B, Section 1.)

3. OMITTED

4. Real estate taxes and municipal charges as follows: Real estate taxes and municipal charges which may constitute liens.

SPECIAL EXCEPTIONS:

a. SUBJECT TO ANY AND ALL ENCUMBERANCES REFERENCED ON THE LEGAL DESCRIPTION ATTACHED HERETO AND MADE A PART HEREOF.

b. As to 481 Mashamoquet (Lot 3.00), Real Estate taxes payable to the Town of Pomfret on the Grand List of 2015 in the yearly amount of $175.24 payable Semi-Annually in July and January each year. Currently taxes are paid through June 30, 2017. Next installment is estimated to be $87.62 due July 1, 2017.

c. As to 505 Mashamoquet (Lot 3.04), Real Estate taxes payable to the Town of Pomfret on the Grand List of 2015 in the yearly amount of $38.32 payable Annually in July each year. Currently taxes are paid through June 30, 2017. Next installment is estimated to be $38.32 due July 1, 2017.

NOTE: The matters set forth as subordinate matters in Schedule B, Section 1, will be excepted on Schedule B of the Owner's Policy, and will be shown on Schedule B, part II, of the loan policy.

SCHEDULE A

DESCRIPTION

A certain tract or parcel of land with the buildings thereon situated in the Town of Pomfret, County of Windham and State of Connecticut, and more particularly bounded and described as follows:

The Home Place with the buildings thereon situated on the northerly side of Highway Route U.S. #44, on the easterly side of State Highway Route #97, and on the northwesterly side of Cheney Road; Beginning at a concrete highway bound in the northerly line of Highway Route U. S. #44, said concrete highway bound marking a southeasterly corner of the within described tract of land and being in the westerly line of land now or formerly of Reuel E. Young; thence N 15 36' E 112.5 feet, along wall adjoining said Young land, to a corner of land now or formerly of Orren A. Weeks; thence N 15 31' E 468 feet, along wall adjoining said Weeks land, to a corner of wall; thence S 81 36' E 404 feet, along wall adjoining said Weeks land, to a corner of wall and fence in the westerly line of land now or formerly of William T. Cheney; thence N 13 11' E 65.3 feet, along fence adjoining said Cheney land, to an iron bound; thence S 80 10' E 239.6 feet, along fence and wall adjoining said Cheney land and adjoining land now or formerly of David M. Robbins, to an iron bound at a corner of wall on the northwesterly side of Cheney Road; thence N 43 44' E 438.4 feet, along wall on the northwesterly side of Cheney Road, to an iron bound at a corner of wall at a corner of land now or formerly of William Cheney; thence N 9 01' E 85 feet, along wall adjoining said Cheney land to a corner of wall and fence, a corner of land now or formerly of Alfred L. Arnold and Gertrude S. Arnold; thence N 84 30' W 354 feet, along fence and crossing a brook adjoining said Arnold land; thence N 82 45' W 392 feet, along wall adjoining said Arnold land; thence N 82 15' W 127 feet, along wall adjoining said Arnold land; thence N 82 30' W 171 feet along wall adjoining said Arnold land; thence N 82 45' W 213 feet, along wall adjoining said Arnold land; thence N 82 15' W 761 feet, along wall adjoining said Arnold land; thence N 81 00' W 363 feet, along wall adjoining said Arnold land, to a drill hole in a rock in a corner of wall in the easterly line of the before mentioned State Highway Route #97; thence s 5 00' W 220.7 feet, along wall on the easterly line of said State Highway Route #97, to a drill hole in a rock in a corner of wall at a corner of land now or formerly of Edna B. Sharpe; thence S 72 35' E 239.4 feet, along wall adjoining said Sharpe land, to a corner of wall; thence S 16 35' W 436.2 feet, partly along wall adjoining said Sharpe land, to a drill hole in a rock in the line of remains of wall in the northerly line of land now or formerly of the Town of Pomfret; thence S 57 43' E 72.99 feet, along remains of wall adjoining said Town land, to a concrete highway bound in the northerly line of Highway Route U.S. #44; thence S 64 09' E 670.75 feet, along the northerly line of said Route #44, to a concrete highway bound; thence S 67 07' E 468.68 feet, along the northerly line of said Route #44, to the place of beginning.

Containing 34.6 acres of land more or less.

For further reference see a certain plan entitled "Plan of the Home Place of the Estate of John R. Stromberg in the Town of Pomfret, Conn. Scale 1"= 100', Feb. 1, 1962 William W. Pike, Surveyor".

Being the same premises described in a certain Fiduciary Deed from the Estate of John R. Stromberg to Victor J. Howe and Isabel B. Howe, dated June 28, 1962 and recorded in Vol. 38 at Page 335 of the Pomfret Land Records.

Said Isabel F. Howe a/k/a Isabel B. Howe died on July 26, 1985 and reference may be had to a Probate Tax Certificate dated May 21, 1986 and recorded in Vol. 59 at Page 48 of the Pomfret Land Records.

EXCEPT the following tracts or parcels of land which have been conveyed from the aforesaid premises:

1. A certain tract or parcel of land situated on the easterly side of Route #97 in the Abington section of said Town of Pomfret and being more particularly bounded and described in a certain Warranty Deed from Victor J. Howe and Isabel B. Howe to John E. West and Rita A. West, dated January 4, 1985 and recorded in Vol. 55 at Page 20 of the Pomfret Land Records.

2. A certain piece or parcel of land located on the northerly side of Route #44, so-called, in said Abington section of the Town of Pomfret and being the same premises described in a certain Warranty Deed from Victor J. Howe to Walter J. Rucki and Lillian A. Rucki, dated April 30, 1986 and recorded in Vol. 58 at Page 245 of said land records.

3. A certain piece or parcel of land located on the northerly side of said Route #44, containing by estimation 4.34 acres of land, more or less, and known as Lot #2 on a certain map or plan entitled, "Subdivision Map Remaining Land of Victor & Isabella (sic) Howe Conn. Rte 44 and Cheney Road Pomfret, Conn.", and being more particularly bounded and described in a certain Executrix Deed from Lorena Morin, Executrix of the Will of Victor J. Howe to Walter A. Bankowski and Deborah J. Bankowski, dated November 9, 1988 and recorded in the Pomfret Land Records.

Being the same premises described in a certain Certificate of Devise from the Estate of Victor J. Howe to Lorena Morin, dated October 12, 1989 and recorded in the Pomfret Land Records.

NICHOLAS R. SCOTT, ESQ.
286 MAIN STREET
DANIELSON, CT 06239

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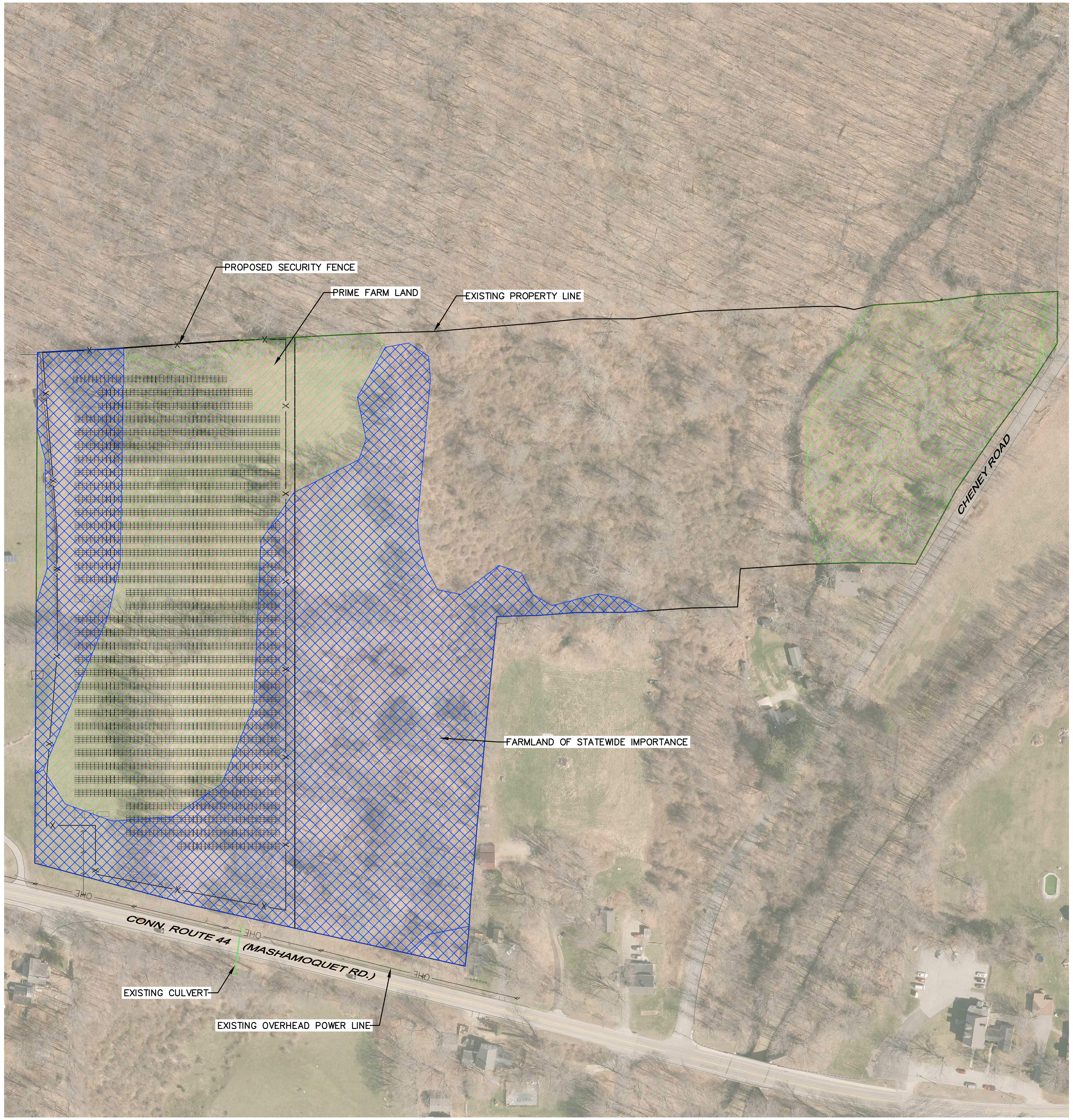
Exhibit AS-11



LEGEND:

- EXISTING PROPERTY LINE
- PROJECT FOOTPRINT
- PRIME FARM LAND
- FARM LAND OF STATEWIDE IMPORTANCE
- PROPOSED SOLAR ARRAY

Soils Data

Item	Site Area	Percent of Site	Percent of Footprint
Prime Farmland	8.42 acres	33.45%	59.73%
Not Prime Farmland	9.84 acres	39.10%	0%
Farmland of Statewide Importance	6.91 acres	27.45%	40.27%
Total	25.17 acres	100%	100%

Westwood

7699 Anagram Drive
Eden Prairie, MN 55344

PHONE (952)-937-5150
FAX (952)-937-5822
TOLL FREE (888)-937-5150

Westwood Professional Services, Inc.

Designed: BTB
Checked: ADC
Drawn: JLB
Record Drawing by/date:

Revisions:

#	DATE	DESCRIPTION
-	09/08/2017	CT SITING BOARD SUBMISSION

Prepared for:

ecos ENERGY
222 SOUTH 9TH STREET
SUITE 1600
MINNEAPOLIS, MN 55402

0' 100' 200' 300'

ABINGTON SOLAR

481 MASHMOQUET ROAD
POMFRET, CT 06259
TOLLAND COUNTY

PRIME FARMLAND EXHIBIT

SITING BOARD REVIEW

DATE: 09/08/2017

REPORT for OBJ2.TASK 6: SOIL RIPPING FOR INFILTRATION

To: MPCA
From: The Kestrel Design Group Team (The Kestrel Design Group Inc, with Dr. William Hunt, PE, Ryan Winston, PE, Dwayne Stenlund – Minnesota Department of Transportation, Dr. John Gulliver, PE – University of Minnesota
Date: July 31, 2013
Re: Contract CR5332 Objective 2 Task 6

SCOPE

Develop guidance and recommendations on the use of soil ripping to increase infiltration capacity of infiltration and bioretention BMPs.

a. Review literature information on soil ripping. Identify case studies and associated changes in soil infiltration rates resulting from use of soil ripping. Include a review of long-term effects of soil ripping on infiltration.
b. Prepare and submit a Technical memo summarizing the principles of soil ripping and conditions under which soil ripping is or is not recommended. Include a discussion of the effect of different soil types (e.g. clay, silt, sand) including amendments that may be needed for certain soil types. Include a discussion of effects from soil ripping over time (e.g. initial impact on soil infiltration rate and changes in infiltration rate over time following soil ripping). Cost information shall be included. Include appropriate graphics. As part of the memo, Kestrel shall provide recommendations regarding the feasibility of developing specifications for conducting soil ripping.
c. Prepare and submit a report summarizing information contained in the Technical memo, including life cycle properties, long-term benefits, and maintenance needs for bioretention and infiltration BMPs in which soil ripping has occurred. If development of specifications were recommended in the Technical memo associated with Task 6.b, the report shall include specifications for soil ripping, including CAD drawings and other graphics.

Report Table of Contents:

I. List of Figures

II. List of Tables

III. Effects of Development on Soil Properties Relevant to Stormwater Management

A literature review by Schueler (2000) found that construction increases the bulk density of surface soils on the order of 0.35 gm/cc over the predevelopment land use. The compaction can extend up to two feet down into the soil profile. Urban lawn and turf areas are just as compacted as sites that have been subjected to construction traffic or that have been mass graded. Athletic fields appear even more compacted. Schueler (2000) summarized his literature review on increases in soil bulk density from various land uses (Table 1).

Land Use or Activity	Increase in Bulk Density (gm/cc)	Source:
Grazing	0.12 to 0.20	Smith, 1999
Crops	0.25 to 0.35	Smith, 1999
Construction, mass grading	0.34	Randrup, 1998
Construction, mass grading	0.35	Lichter and Lindsey, 1994
Construction, no grading	0.2	Lichter and Lindsey, 1994
Construction traffic	0.17	Lichter and Lindsey, 1994
Construction traffic	0.25 to 0.40	Smith, 1999; Friedman 1998
Athletic fields	0.38 to 0.54	Smith, 1999
Urban lawn and turf	0.30 to 0.40	Various Sources

Table 6.1: Increase in Soil Bulk Density by Land Use or Activity (Schueler 2000)

The compaction that results from development acutely impacts stormwater management, as it increases runoff and severely decreases infiltration rates as well as the ability for plants to grow. While infiltration rates of soils of all textures are significantly reduced when compacted, Pitt et al (2008) found that:

- Sandy soils can still provide substantial infiltration capacity even when greatly compacted.
- Clay soils are less able to withstand low levels of compaction compared to sandy soils.
- Dry, uncompacted clay soils can have relatively high infiltration rates
- Saturated clay soils and compacted clay soils have very low infiltration rates.

To put in perspective the typical magnitude of the impacts of compaction from development, Tables 6.2 and 6.3 show a comparison of bulk density for undisturbed soils and common urban conditions, and root limiting soil bulk densities. Note even some urban lawns are compacted beyond root limiting bulk densities.

According to the 2006 Pennsylvania Stormwater Best Management Practices Manual's chapter on soil amendment and restoration, axle loads >10 tons can compact up to 1' deep, while axle loads > 20 tons can compact up to 2' deep. These large loads are commonly applied during construction in "large areas compacted to increase strength for paving and foundation with overlap to "lawn" areas."

Undisturbed Soil Type or Urban Condition	Surface Bulk Density (grams/cubic centimeter)
Peat	0.2 to 0.3
Compost	1.0
Sandy Soil	1.1 to 1.3
Silty Sands	1.4
Silt	1.3 to 1.4
Silt Loams	1.2 to 1.5
Organic Silts/Clays	1.0 to 1.2
Glacial Till	1.6 to 2.0
Urban Lawns	1.5 to 1.9
Crushed Rock Parking Lot	1.5 to 2.0
Urban Fill Soils	1.8 to 2.0
Athletic Fields	1.8 to 2.0
Rights of Way and Building Pads (85% Compaction)	1.5 to 1.8
Rights of Way and Building Pads (95% Compaction)	1.6 to 2.1
Concrete Pavement	2.2
Quartzite (Rock)	2.65

Table 6.2: a comparison of bulk densities for undisturbed soils and common urban conditions (Schueler 2000)

Soil texture	Ideal bulk densities (g/cm3)	Bulk densities that may affect root growth (g/cm3)	Bulk densities that restrict root growth (g/ cm3)
Sands, loamy sands	<1.60	1.69	>1.80
Sandy loams, loams	<1.40	1.63	>1.80
Sandy clay loams, loams, clay loams	<1.40	1.60	>1.75
Silts, silt loams	<1.30	1.60	>1.75
Silt loams, silty clay loams	<1.10	1.55	>1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	>1.58
Clays (>45% clay)	<1.10	1.39	>1.47

Table 6.3: A Comparison of Root Limiting Bulk Density for Different Soil Types (NRCS 1998 in Dallas and Lewandowski, 2003)

IV. Alleviating Soil Compaction Caused by Development

Alleviation of compaction of disturbed soil is clearly crucial to the installation of successful vegetated stormwater infiltration practices.

While natural processes can alleviate soil compaction, additional techniques to alleviate soil compaction are often desirable because:

(1) It can take many years for natural processes to loosen up soil
(2) Natural processes operate primarily within the first foot or so of soil, and compaction from development can extend to two feet deep
(3) Once soil compaction becomes so severe that plants and soil microbes can no longer thrive, they are no longer able to reduce soil compaction

Schueler (Technical Note 108) summarizes natural processes that can alleviate soil compaction as follows: “Once soil is compacted, is there anything that can be done to reverse the process? Many natural processes act to loosen up soil, such as freezing/thawing, particle sorting, earth worm activity, root penetration and the gradual buildup of organic matter. Often, however, these processes take decades to work, and operate primarily within the first foot or so of soil. In addition, many of these natural processes are effectively turned off when soil compaction becomes severe because water, plant roots and soil fauna simply cannot penetrate the dense soil matrix and get to work.”

One example of how easily soil becomes compacted and how long it can take to recover is the Oregon trail. Ruts are still visible today on the Oregon Trail from large wheeled covered wagon traffic between 1840 and 1869!

In a literature review of techniques to alleviate soil compaction, Schueler (Technical Note 108) concludes that “Based on current research, it appears that the best construction techniques are only capable of preventing about a third of the expected increase in bulk density during construction.”

From his literature review, summarized in Table 6.4, it appears that compost amendment and reforestation are the most effective techniques to reduce soil bulk density. Tilling (ripping) of soil alone did not appear to significantly reduce bulk density according to Schueler’s literature review.

Land Use or Activity	Decrease in Bulk Density (gms/cc)	Source:
Tilling of Soil	0.00 to 0.02	Randrup, 1998, Patterson and Bates, 1994
Specialized Soil Loosening	0.05 to 0.15	Rolf, 1998
Selective Grading	0.00	Randrup, 1998 and Lichter and Lindsey, 1994
Soil Amendments	0.17	Patterson and Bates, 1994
Compost Amendment	0.25 to 0.35	Kolsti *et al.*, 1995
Time	0.20	Legg *et al.*, 1996
Reforestation	0.25 to 0.35	Article 36

Table 6.4: Reported Activities that Restore or Decrease Soil Bulk Density (Schueler, Technical Note 108)

A more detailed review of literature on the effects of ripping and compost amendment on soil infiltration rates follows below.

A. Effect of Ripping on Soil Compaction

1. Principles of Soil Ripping (subsoiling)

The goal of subsoiling is to fracture compacted soil “without adversely disturbing plant life, topsoil, and surface residue. Fracturing compacted soil promotes root penetration by reducing soil density and strength, improving moisture infiltration and retention, and increasing air spaces in the soil” (Kees 2008).

According to Kees (2008), “compacted layers typically develop 12-22 inches below the surface when heavy equipment is used. Conventional cultivators cannot reach deep enough to break up this compaction. Subsoilers (rippers) can break up the compacted layer without destroying soil aggregate structure, surface vegetation, or mixing soil layers.

How effectively compacted layers are fractured depends on the soil's moisture, structure, texture, type, composition, porosity, density, and clay content. Success depends on the type of equipment selected, its configuration, and the speed with which it is pulled through the ground. No one piece of equipment or configuration works best for all situations and soil conditions, making it difficult to define exact specifications for subsoiling equipment and operation.”

Based on their previous research, Spoor (2003) similarly defines the goal of soil compaction reduction where a strong pan layer is present as follows:

"*to improve conditions with minimal loss of soil support, leaving the natural and biological processes to complete the remediation and stabilise the resulting soil condition. Subsoiling operations to alleviate soil compaction are frequently associated with considerable loosening, soil rearrangement and loss of bearing capacity. Such a type of disturbance is most inappropriate for future subsoil protection from loading stresses. The prime aim in compaction alleviation operations must, therefore, be the creation of fissures or cracks through the damaged zone to restore rooting and drainage, but with minimum disturbance to the remaining bulk of the soil profile. This disturbance is in effect, "fissuring without loosening", allowing the bearing capacity of the soil to be maintained. Such an aim can best be achieved by generating a tensile soil failure within the damaged area, where fissures are generated, leaving the soil mass between the fissures largely intact, unbroken and strong.*
Tensile failure can be generated by lifting the soil mass with a subsurface blade and allowing it to flow over the blade so that soil bending occurs, the bending action placing the soil in tension and creating fissures (Fig. 2). Appropriate cultivation tools for inducing this type of failure (Fig. 3) are winged subsoilers, subsurface sweeps and Paraplow type angled leg subsoilers (Spoor and Godwin, 1978)"- bold added.

Urban (2008) concurs that the best soil compaction reduction methods leave soil peds intact, and if "soil is broken into overly fine particles, it will re-compact as gravity and water settle the soil…" He also adds that "adding organic or mineral amendments to the soil can help reduce this re-compaction…High-lignin compost or ESCS products are most commonly used".

Subsoilers are available with a wide variety of shank designs (Figure 6.1). Shank design affects subsoiler performance, shank strength, surface and residue disturbance, effectiveness in fracturing soil, and the horsepower required to pull the subsoiler. According to Kees (2008), "Parabolic shanks require the least amount of horsepower to pull. In some forest applications, parabolic shanks may lift too many stumps and rocks, disturb surface materials, or expose excess subsoil. Swept shanks tend to push materials into the soil and sever them. They may help keep the subsoiler from plugging up, especially in brush, stumps, and slash. Straight or "L" shaped shanks have characteristics that fall somewhere between those of the parabolic and swept shanks."

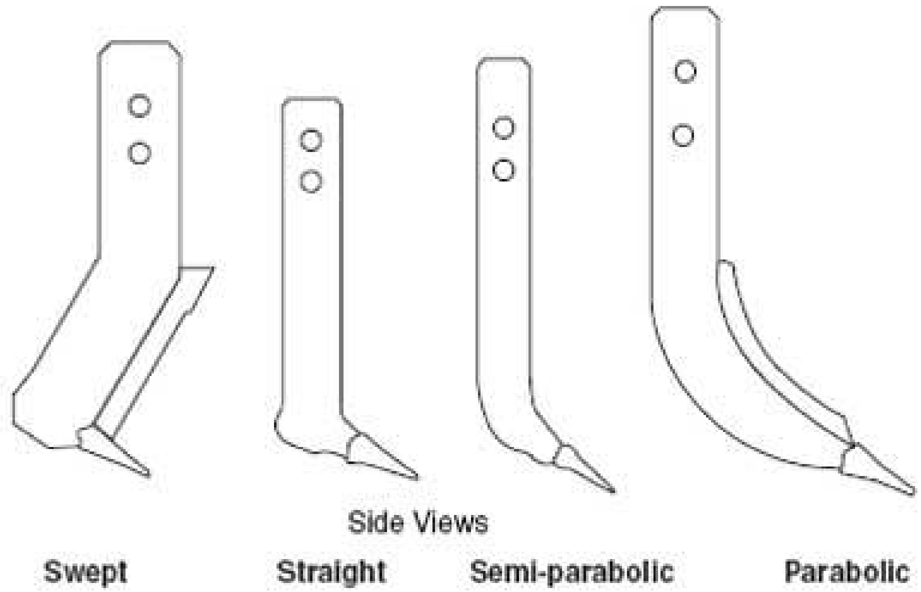


Figure 6.1: Examples of various agricultural shank designs (Kees 2008)

Figure 6.2: A winged tip and a conventional tip subsoiler (Kees 2008)

Shanks are available with winged tips and conventional tips (Figure 6.2). Winged tips cost more than conventional tips and require more horsepower, but can often be spaced farther apart (Figure 6.3). Increasing wing width also increases critical depth – the depth below which little soil loosening occurs (Owen 1987, Spoor 1978). Using shallow leading tines ahead of deeper tines also increases required shank spacing (Spoor 1978).

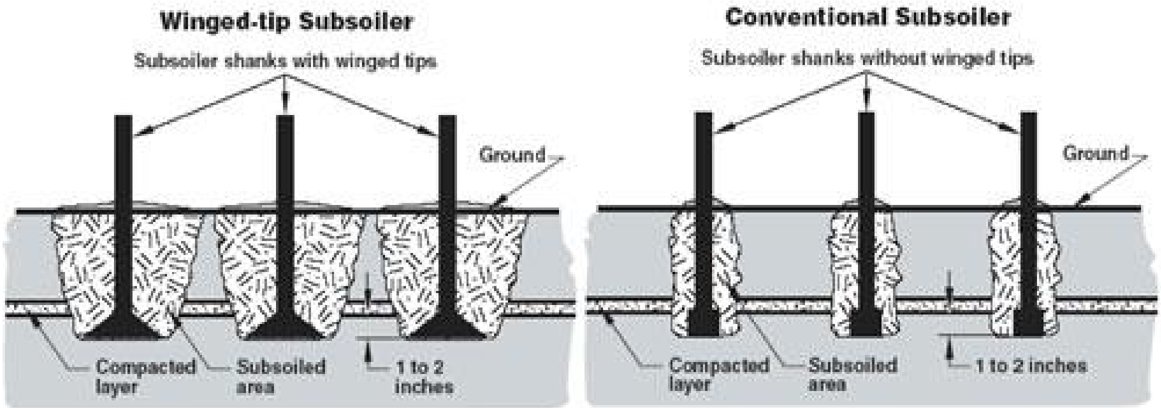


Figure 6.3: Comparison of soil disturbance from a winged tip vs. a conventional tip: winged tips can typically be spaced farther apart because they fracture more of the soil than conventional tips (Kees 2008)

Several researchers have found that there is a "critical depth", and according to Spoor and Godwin (1978) this "critical depth is dependent upon the width, inclination and lift height of the tine foot and on the moisture and density status of the soil." Spoor and Godwin (1978) explain that tine depth is crucial because "At shallow working depths the soil is displaced forwards, side-ways and upwards (crescent failure), failing along well defined rupture planes which radiate from just above the tine tip to the surface at angles of approximately 45" to the horizontal. Crescent failure continues with increasing working depth until, at a certain depth, the critical depth, the soil at the tine base begins to flow forwards and sideways only (lateral failure) creating compaction at depth." They found that below the critical depth "compaction occurs rather than effective soil loosening." They also found that "The wetter and more plastic a soil is, the shallower is the critical depth."

Spoor 2006 explains as follows why it is so crucial to tailor shank depth to site conditions: "When soil is loaded by cultivation implements, it can deform and move in three distinct ways, often referred to as brittle, compressive (ductile) and tensile disturbances (Hettiaratchi, 1987)…Brittle and tensile types of disturbance are the only two modes of disturbance capable of alleviating compaction. Cracks and fissures are generated through the compacted area in both cases, with little disturbance between the cracks. Both brittle and tensile disturbances require an upward component of soil movement to allow the soil to dilate. In a field situation this upward movement is resisted by the overburden load and strength of the soil above implement working depth. If this resistance, usually termed the confining resistance, becomes too great, it becomes easier for the soil to move laterally rather than upwards and a compressive rather than brittle or tensile disturbance occurs. The confining resistance increases with increasing working depth and it is also dependent on moisture content and density."

According to Kees (2008), the shank's tip should run to a depth of 1-2 inches below the compacted layer (see Figure 6.4).

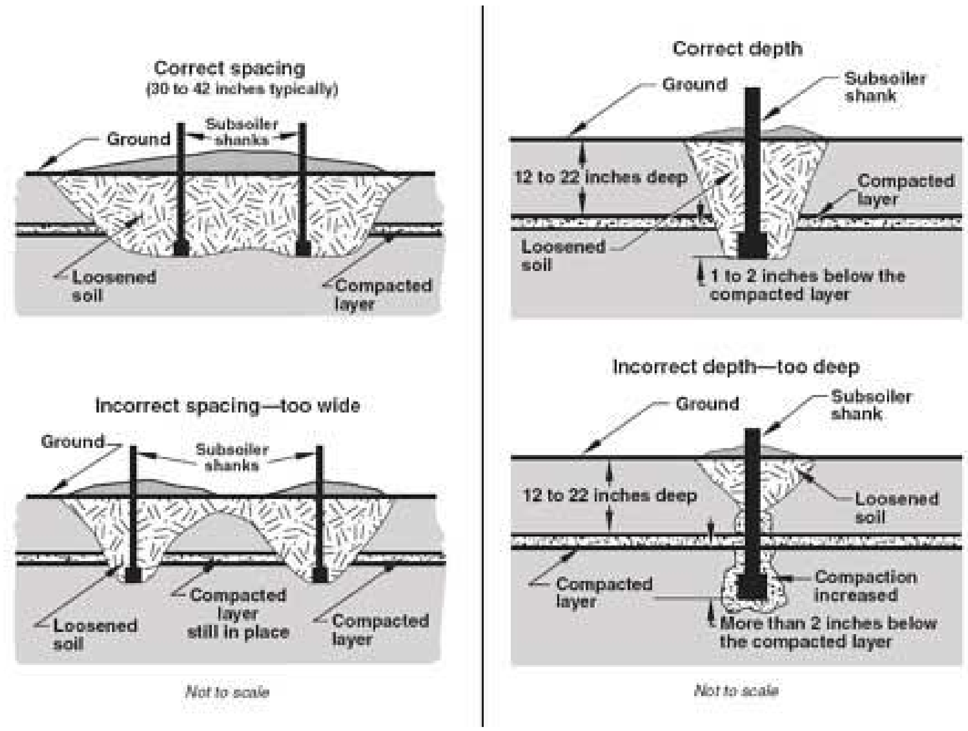


Figure 6.4: Impacts of having subsoiler shanks spaced correctly (top left) vs. spaced too widely apart (bottom left) and having shanks at correct depth (top right) vs. too deep (bottom right) (Image from Kees 2008). Note: compaction on a construction site can be much more severe than just the plow layer shown in the above agricultural or forestry images.

Ideal shank spacing will depend on soil moisture, soil type, degree of compaction, and the depth of the compacted layer. Spacing should be adjustable so the worked area can be fractured most efficiently (see figure 6.4).

Because ideal shank configuration will vary with varying soil textures and moisture, shank spacing and height should be adjustable in the field (Kees 2008).

Travel speed of the subsoiler also affects subsoiling disturbance. “Travel speed that is too high can cause excessive surface disturbance, bring subsoil materials to the surface, create furrows, and bury surface residues. Travel speed that is too slow may not lift and fracture the soil adequately” (Kees 2008).

Kees (2008) also recommends making sure that the shanks on the subsoiler are spaced so that they run in the tracks of the tow vehicle, because the equipment used to pull subsoilers is heavy enough to create compaction itself.

Direction of travel and number of passes

Multiple passes are generally required to alleviate compaction on severely compacted sites.

According to Spoor (2006), on “sites where compaction is frequently excessive and deep (densities up to 1.9–2.0 t /m^3 [tons per cubic meters]), to depths of >0.8 m), it is virtually impossible, even with very large power units, to achieve the desired degree of soil break-up to the required working depth within a single or double pass. Using toolframes fitted with both shallow leading and deeper following tines can assist, with further improvements by fitting tines at three working depths. With these tine configurations the soil is disturbed progressively from the surface downward, thus reducing the size of soil unit produced. It is imperative to achieve the desired sized soil unit on the first pass, as subsequent passes at the same depth only stir the loosened medium, with little further soil unit break-up. An approach developed by Silsoe College, Cranfield University, in collaboration with Transco UK, for use on pipeline sites, was to work progressively deeper with repeated passes, up to 5 or 6 under extreme conditions, with the tractor operating on the same tramline/traffic lane on each pass (Spoor & Foot, 1998)." Much more detail on this approach is provided in their paper.

Kees (2008) recommends following ground contours whenever possible when subsoiling to "increase water capture, protect water quality, and reduce soil erosion." He also states that "in some cases, two passes at an angle to each other may be required to completely fracture compacted soil."

Spoor and Godwin (1978) also found that "Relatively closely spaced tines, staggered to prevent blockage, are more efficient at producing complete loosening than repeated passes with tines at wider spacings."

Need to field adjust

According to Spoor and Godwin (1978) "The number of variables involved and soil variation make the accurate prediction of the critical depth for field conditions impractical. Simple field modifications are available, however, such as increasing tine foot width and lift height or loosening the surface layers, to allow rapid implement adjustment to satisfy a range of field conditions."

If subsoiling was effective, "The ground should be lifted slightly and remain relatively even behind the subsoiler, without major disruption of surface residues and plants. No more than a little subsoil and a few rocks should be pulled to the surface. If large furrows form behind the subsoiler, the shanks may not be deep enough, the angle on winged tips may be too aggressive, or the travel speed may be too high" (Kees 2008).

2. Where Ripping is Not Feasible

Always know where utilities are buried prior to subsoiling. Avoid subsoiling in area that have buried utilities, wires, pipes, culverts, or diversion channels (Kees 2008, Urban 2008).

3. Suitable conditions for Ripping

According to Kees, 2008, "Soils should be mostly dry and friable. If the soil is too wet, subsoiler shanks will slide through the ground without breaking up the soil. The shank can actually glaze the soil and compact it even more. If the soil is extremely dry, getting the subsoiler into the ground can be difficult, requiring larger, more powerful tractors to pull the shanks through compacted areas. Soils, especially those with more clay content, can actually break into large clods or slabs if conditions are too dry.
For most areas, ideal subsoiling conditions are during summer months before the soils are completely dry. Soils should crumble without sticking together, yet not be so dry and hard that they can't be broken up easily."

Urban (2008) describes ideal conditions for compaction reduction as follows: "soil moisture must be between field capacity and wilt point during compaction reduction for maximum effectiveness. This soil is considered friable, meaning it has adequate moisture to break into clods when lifted and turned with a shovel. Friable soil will make the hand dirty but not muddy when squeezed. If the soil is so wet that it makes a mud stain on the hand, compaction reduction efforts may be ineffective or even make things worse. If the soil is so dry that it does not break easily into clods, compaction reduction will also be limited. In most soil, "too wet" is defined as within several days after enough rain has fallen to saturate the soil profile. If the soil is heavily compacted or in an area of poor drainage, this may take much longer. If the soil is dry, it will take several inches of water to hydrate the soil. One rainy day may not provide enough water."

4. Summaries of Selected Studies and Publications on the Effects of Ripping on Soil Compaction

While some studies did not find ripping to significantly alleviate soil compaction (e.g. Randrup 1998 and Patterson and Bates 1994 in Schueler Technical Note #108, Chaplin et al 2008 – clay soil site, Meek et al 1992 in Olson 2010, Olson 2010), others found very significant increases in infiltration rates after ripping (e.g. Tyner 2010, Chaplin et al 2008 – sandy soil site, Meek et al 1992 in Olson 2010).

Ripping is sometimes not effective to increase infiltration rates if:

- Equipment is not adequately tailored to meet project conditions
- Soil still had good structure and ripping destroyed remaining soil structure

In general, it appears as if ripping is effective for alleviating compaction where soils are severely compacted and ripping equipment is tailored to meet project goals and conditions.

According to Kees (2008), "Under ideal conditions, subsoiling should be 75 to 80 percent successful in breaking up compacted layers. In some cases, two passes at an angle to each other may be required to completely fracture compacted soil (Kees 2008)." Other studies have found in some conditions, 5 to 6 passes may be needed to alleviate compaction (Spoor 2006).

Olson 2010

A local study of the effects of ripping and amending soils with compost on soil compaction and infiltration rates was conducted by Olson (2010) at three sites in the Twin Cities Metropolitan area. At each site, he compared soil saturated hydraulic conductivity, bulk density, and soil strength of 3 treatments:

(1) Ripped
(2) Ripped and amended with compost
(3) Control

"Deep tillage was effective at reducing the level of soil strength. Soil strength was approximately half that of the control plot in the first six inches of soil. However, tilling did not significantly improve the bulk density of the soil. At two of the sites, tilling was ineffective at improving that infiltration capacity of the soil. Tilling may have damaged natural pathways in the soils, thus reducing the permeability.

Tilling was effective at remediating the soil at one site, which was not as well-established at the previous two sites. The geometric mean of K_{sat} was 2.1 to 2.3 times that of the control plot."

See section on ripping with compost amendment for results from those plots.

Tyner:

- Studied effect of various de-compaction techniques on pervious concrete installed on compacted clay soils: 1) control – no treatment; 2) trenched – soil trenched and backfilled with stone aggregate; 3) ripped – soil ripped with a subsoiler; and 4) boreholes – placement of shallow boreholes backfilled with sand.
- Initial infiltration rate was VERY low:

"Initially, the site was covered by poorly manicured grass…A 16.6 metric ton track loader removed the surface grass and root structure and graded the site: removing approximately 90 cm of soil from the northern end of the site and approximately 30 cm from the southern end. Although not in a purposeful manner, the cut surface was compacted and smeared by the track loader during grading. Also, several heavy rain showers fell on the bare clayey subsoil, which further sealed the surface. Shallow puddles of water from rain showers took more than 24 h to infiltrate suggesting that the infiltration capacity of the subgrade had deteriorated. Instead of a percolation test, which would bypass the compacted sealed surface, a double ring infiltrometer at 30 cm of head was used to measure the infiltration rate of the graded pad (ASTM D3385, 2003). After a 24 h wetting period, the infiltration rate was less than 0.3 cm d^{-1}."

- Found that ripping subsoil to a depth of 17.7 inches significantly increased pervious pavement infiltration rates compared to control: average 4 inches/day for ripped vs. only 0.32 inches/day for control: more than a 10 fold increase!
- Clean coarse sand was poured across the ripped soil surface and allowed to penetrate into the fissures and cracks to help keep the fissures open and free flowing.
- Trenching resulted in even greater infiltration rates than ripping (110.2 inches/day for trenching vs 4 inches/day for ripped subsoils). Trenching is, however, significantly more costly than ripping.
- Measured infiltration rates 3 times over the course of 1 year, infiltration rates did not significantly change over the course of the year.

Chaplin 2008:

- Compared effects of subsoiling with several types of equipment on several soils at various slopes.

- Soil types tested included:

  - Clay Loam (Janesville and Belle Plaine)
  - Sandy Loam (Brainerd)
  - Silty Loam (MnROAD)

- The tillage treatments applied in this study consisted of:

- DMI Ecolotill 5 tines 30” spacing 12” operational depth (DMI)
- Kongskilde Paraplow 4 tines 36” spacing 18” operational depth (KSK)
- Caterpillar Subsoiler 2 tines 36” spacing 24” operational depth (RIP)
- Control no tillage

- Data was collected from each site during the two summers that followed the application of the tillage treatment.

- Found subsoiling to significantly increase infiltration rate in sandy soil after a single pass, but not in clayey soil. However, from other references, it appears that multiple passes can be effective on sites where just one pass was not effective (e.g. Spoor 2006, Kees 2008)

- No significant differences were detected between the three tilling methods.

- “The post-tillage aesthetic appeal when using a non-inverting plow (Kongskilde Paraplow) was apparent in this study. The vegetation was largely undisturbed following tillage, and this would be beneficial in preventing erosion on slopes. The ripper and the DMI inverted more soil, and therefore the tillage operation was less appealing to motorists.”

- “… one third of the tilled ROW area (sandy loam) would have the capacity to infiltrate the same volume of water for a given rainfall event when compared to the same situation with untilled soil.”

Spoor and Godwin 1978

- Includes detailed description of effects of a range of rigid deep loosening tines at different working depths on soil compaction. Variations include, for example, implement shape (chisel tine, conventional subsoiler, mole plow, slant subsoiler), varying tine depths, angles, widths, and spacing, the effects of using shallow tines to loosen surface layers ahead of the deep tine, as well as the effects of using multiple passes vs. just a single pass.

- Includes many figures that visually illustrate the effects of varying tine geometry.

Owen 1987

The experiment was performed in both a Fundy clay soil and a Fredericton Research Station sandy loam. The results confirm the existence of a critical depth, below which little soil loosening occurs, in both soil types and a difference in the critical depths in the two soils.

The study examined the soil disturbance and loosening that resulted from deep subsoiling in compacted soils with and without wings at 0.32, 0.52 and 0.72 m (2.6, 20.5, and 28.4 inches) deep in both a clay and sandy loam soil.

They concluded:

1) “There is a critical depth of operation for subsoiling in compact soils and this critical depth is greater in the clay soil tested than in the sandy loam.

2) In terms of the area disturbed, the major benefit achieved by using an increased wing width is through an increase in the critical depth, and hence in disturbed area and soil density reduction. When operating above the critical depth, the wings provided no benefit.
3) A greater volume of soil is disturbed when operating in the clay soil tested than in the sandy loam.
4) The wide wings improve the subsoiler's ability to reduce the dry bulk density in the clay soil."

Brown and Hunt 2010

- This study did not look at the effects of ripping soil, but investigated a lower cost, less intensive method of reducing compaction on bioretention sites. They investigated the effect of using a backhoe bucket with teeth (as opposed to smearing the soil with the bottom of the bucket) to excavate the last 12 inches of a bioretention practice in wet vs dry and clayey vs sandy soils.
- The authors concluded:
    - "Based on the data collected, it was determined that excavating the final 30 cm (12 in.) using the teeth on the bucket to rake the surface, instead of using the bucket to scoop and make the surface smooth, improved the soil properties that govern infiltration."
    - "Prior to backfilling the cell with gravel and sand, the impact of using the rake method for excavation in dry loamy sand and in wet clay can allow for the infiltration rate to be two and four times greater, respectively, than when the scoop method is used."
    - "The rake method scarified the bottom layer in the bioretention cell and created more pore spaces which is evidenced by a lower bulk density. This helped promote the underlying soil's ability to exfiltrate water from bioretention cells to the underlying soils."
    - "The potential for exfiltration was reduced when using the scoop method because it compacted the soils to a greater extent, as evidenced by higher bulk densities."
    - "In particular, when excavating in wet conditions, the hydraulic conductivity and infiltration rate associated with the scoop method were significantly less than that of the rake method (p-values=0.005 and 0.034, respectively)."
    - "Under dry conditions, there was no statistical significance associated with excavation technique, but the trend showed improved infiltration and hydraulic conductivity when using the rake method."
    - "The hydraulic conductivity associated with the scoop method of excavation were significantly less at the sandy soil sites, and the infiltration rate associated with the scoop method of excavation was significantly less at the clay soil sites. Based on the results of this study and because there is no extra cost associated with the rake method, it is recommended to use the rake excavation technique in preference to the "conventional" scoop method for future bioretention or other infiltration BMP projects to decrease outflow volume and pollutant loads. The same recommendation of scarifying the soil surface with the teeth of the bucket can also be applied to the side walls of the excavated pit to promote exfiltration from the sides of bioretention cells."

- “For pure sand environments, because of extremely high infiltration rates and hydraulic conductivities, excavation may take place under wet or dry soil conditions.”
- “For clay to loamy sand, however, excavation during a dry soil condition is recommended. The infiltration rates were less impacted in dry soil compared to wet soil.”
- “In general, excavation should be avoided during or immediately following a rainfall event, or if a rainfall event will occur before the cell’s media can be replaced.”

B. Effect of Ripping PLUS Compost Amendment on Soil Compaction

1. How Compost Reduces Soil Compaction

“Compost works by aggregating soil particles (sand, silt, and clay) into larger particles (Cogger, 2005). Organic mineral complexes in the compost create water-soluble cement that binds the soil particles together (Craul, 1994). Aggregation of soil particles creates additional porosity, which reduces the bulk density of the soil (Cogger, 2005). Compost can also reduce the bulk density of a soil by dilution of the mineral matter in the soil (Cogger, 2005). When the porosity of the soil increases and the particle surface area increases, water holding capacity is also increased (Cogger, 2005). Increases in macropore continuity have been found as well (Harrison et al., 1998)… Studies have cited numerous beneficial abilities of compost: increased water drainage, increased water holding capacity, increased plant production, increased root penetrability, reduction of soil diseases, reduction of heavy metals, and the ability to treat many chemical pollutants (EPA, 1997; Harrison et al., 1998; WDOE Stormwater Management Manual, 2007).” (Olson 2010).

2. Summaries of Selected Studies on the Effects of Ripping PLUS Compost Amendment on Soil Compaction

Similar to the studies reviewed in Schueler’s literature review (Technical Note # 108), many other studies have also found that tilling in compost is an effective technique to alleviate soil compaction (e.g. Harrison et al 1998 in Olson 2010; Olson 2010, Virginia Tech Rehabilitation study). A sampling of those studies is described in more detail below.

Olson 2010

A local study of the effects of <u>ripping and compost amendment</u> on soil compaction and infiltration rates was conducted by Olson (2010) at three sites in the Twin Cities Metropolitan area. At each site, they compared soil saturated hydraulic conductivity, bulk density, and soil strength of 3 treatments:

(1) Ripped
(2) Ripped and amended with compost
(3) Control

Each of the sites had sandy clay loam soil. Tilling and compost addition occurred during Fall 2008, and measurements were made in Spring 2009, and Spring and Summer of 2010. Compost addition was the most effective soil remediation technique. More specifically, on the plots that were ripped AND amended with compost:

- Soil strength was reduced
- Soil bulk densities on the compost plots were 18-37% lower than the control plot.
- The geometric mean of K_{sat} on the compost plots was 2.7 to 5.7 times that of the control plot.

According to the authors of this study "the effects of compost addition are…expected to outlast tillage alone".

Virginia Tech Soil Rehabilitation Study

A study at Virginia Tech's Soil Rehabilitation Experiment Site (SRES) found subsoiling and compost amendment to reduce soil bulk density. The study compared soil characteristics and tree growth in the following 4 soil treatments:

1) Undisturbed (UN) - was not graded or compacted. Existing vegetation was sprayed with herbicide.

In treatments 2-4, the plots were compacted to match standard urban post-construction soil conditions: topsoil was removed and subsoil was compacted to 2 g/cm^3 bulk density.

2) Minimum Effort (ME) - 4 inches of soil added to the top of graded, compacted soil. It represents a low effort level of rehabilitation of compacted and low organic soils. This is a common practice among many contractors and landscapers.

3) Enhanced Topsoil (ET) - 4 inches of topsoil tilled to an 8 inch depth. Represents a moderate level of soil rehabilitation. Topsoil is rototilled to scarify the interface between the topsoil and existing compacted soil.

4) Profile Rebuilding (PR) - 4 inches of compost incorporated into the soil at a depth of 2 feet and 4 inches of topsoil tilled to an 8 inch depth. This treatment involves the highest degree of rehabilitation and is intended to address both the low organic matter of the compacted soil as well as the high bulk density.

Two years into the experiment, the PR soil has decreased bulk density in the subsoil and is accelerating the process of soil formation and long-term carbon storage. Trees growing in the PR treatment are not only growing faster (tree height, canopy, and trunk diameter are measured) than those in the compacted treatments without compost, they are even growing faster than those in the undisturbed treatment (Virginia Tech Rehabilitation study website, accessed July 10, 2013, from http://urbanforestry.frec.vt.edu/sres/index.html).
Based on the results of this research, Susan Day et al have created a "Soil Profile Rebuilding" specification (available from the Virginia Tech Rehabilitation study website, accessed July 10 from http://urbanforestry.frec.vt.edu/sres/index.html).

3. Where Not to Use Compost to Alleviate Soil Compaction

While it is effective in reducing compaction, tilling in compost amendment may not be desirable on sites with steep slopes, a high water table, wet saturated soils, or downhill slope toward a house foundation (Schueler Technical Note #108) or where there are tree roots or utilities, or where nutrients leaching from compost would pose a problem.

V. Precedent Specifications

Since soil restoration techniques will need to be tailored to site conditions, a prescriptive soil restoration specification is not recommended.

The 2006 Pennsylvania Stormwater Best Management Practices Manual's chapter on soil amendment and restoration provides a sample specification for soil restoration. Their specification is not prescriptive, but does provide guiding principles, compost material specifications, and performance requirements. They require sub-soiling to loosen soil to less than 1400 kPa (200 psi) to a depth of 20" below final topsoil grade to reduce soil compaction in all areas where plant establishment is planned in areas where subsoil has become compacted by equipment operation, or has become dried out and crusted, or where necessary to obliterate erosion hills.

The Virginia Tech Rehabilitation study website also provides a "Soil Profile Rebuilding Specification" based on their research. The basic steps in their specification are:

- Spread mature, stable compost to a 4 inch depth over compacted subsoil.
- Subsoil to a depth of 24"
- Replace topsoil to 4" (6-8 if severely disturbed)
- Rototill topsoil to a depth of 6-8"
- Plant with woody plants

Washington State's Department of Ecology's "Stormwater Management for Western Washington", Volume V: Runoff Treatment BMPs, Chapter 5, pages 5-7 to 5-10 also includes a very detailed soil restoration specification at:

http://www.ecy.wa.gov/programs/wq/stormwater/manual.html

The basic outline for their specification is:

"1. A topsoil layer with a minimum organic matter content of 10% dry weight in planting beds, and 5% organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the undisturbed soil. The topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer should be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.
2. Mulch planting beds with 2 inches of organic material.
3. Use compost and other materials that meet these organic content requirements:

a. The organic content for “pre-approved” amendment rates can be met only using compost that meets the definition of “composted materials” in WAC 173-350-100. This code is available online at: http://apps.leg.wa.gov/wac/default.aspx?cite=173-350

The compost must also have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.

The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.

c. Calculated amendment rates may be met through use of composted materials meeting (a.) above; or other organic materials amended to meet the carbon to nitrogen ratio requirements, and meeting the contaminant standards of Grade A Compost.

The resulting soil should be conducive to the type of vegetation to be established.

• Implementation Options: The soil quality design guidelines listed above can be met by using one of the methods listed below:

1. Leave undisturbed native vegetation and soil, and protect from compaction during construction.
2. Amend existing site topsoil or subsoil either at default “pre-approved” rates, or at custom calculated rates based on tests of the soil and amendment.
3. Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, either at a default “pre-approved” rate or at a custom calculated rate.
4. Import topsoil mix of sufficient organic content and depth to meet the requirements.

More than one method may be used on different portions of the same site. Soil that already meets the depth and organic matter quality standards, and is not compacted, does not need to be amended.”

VI. Precedent Stormwater Credits for Soil Restoration

The 2006 Pennsylvania Stormwater Best Management Practices Manual’s chapter on soil amendment and restoration gives volume credits for soil restoration as follows:

For soils that have either been compost amended according to the recommendations of their BMP manual, or subject to restoration such that the field measured bulk densities meet the ideal bulk densities, the following volume reduction may be applied:

Amended Area (ft^2) x 0.50 in x 1/12 = Volume (cf)

Ideal Bulk Densities (same as table 6.3):

Table 4. General relationship of soil bulk density to root growth based on soil texture.			
Soil texture	Ideal bulk densities (g/cm^3)	Bulk densities that may affect root growth (g/cm^3)	Bulk densities that restrict root growth (g/cm^3)
sands, loamy sands	< 1.60	1.69	> 1.80
sandy loams, loams	< 1.40	1.63	> 1.80
sandy clay loams, loams, clay loams	< 1.40	1.60	> 1.75
silts, silt loams	< 1.30	1.60	> 1.75
silt loams, silty clay loams	< 1.40	1.55	> 1.65
sandy clays, silty clays, some clay loams (35-45% clay)	< 1.10	1.49	> 1.58
clays (> 45% clay)	< 1.10	1.39	> 1.47

VII. Cost Estimates

Cost for subsoiling varies significantly from project to project. Table 6.5, for example, shows average costs for subsoiling for MnDOT projects from 2002-2012 (source: Stenlund, 2013):

Year	Spec No.	Acres	Ave Bid Price	No. Projects
2002	2105.55	200	$ 61.26	3
2003		14	$ 646.87	3
2004		501	$ 62.72	5
2005		73	$ 153.48	7
2006		1	$ 2,500.00	1
2007		231	$ 90.87	4
2008		69	$ 245.65	2
2009		70	$ 450.09	9
2010		117	$ 344.09	7
2011		73	$ 329.23	2
2012		34	$ 420.99	4

Table 6.5: Average costs for subsoiling for MnDOT projects from 2002-2012 (source: Stenlund, 2013)

The 2006 Pennsylvania Stormwater Best Management Practices Manual's chapter on soil amendment and restoration provides the following cost estimates:

"Tilling costs, including scarifying sub-soils, range from $800/ac to $1,000/ac
Compost amending of soil ranges in cost from $860 to $1,000/ac"

VIII. Recommendations

Infiltration Basins:

If compaction is above the bulk density that may affect root growth per Table xxx, soil must be remediated as follows:

- Spread 4” compost in accordance with MNDOT Grade 2 Compost or sand over ripped subsoil.

- Rip to a depth of 18” where feasible (see II.A.3 “Where Ripping is Not Feasible”)

- If compaction is still above the bulk density that may affect root growth per Table xxx, rip again at a 90 degree angle to first pass.

- If compaction is still above the bulk density that may affect root growth per Table xxx, rip again until compaction is below the bulk density that may affect root growth per Table xxx.

Note: Maintain a 2’ minimum separation distance between bottom of infiltration practice and the elevation of the seasonally high water table and bedrock. If there is only a 3’ separation distance between the bottom of the infiltration practice and the elevation of the seasonally high water table or bedrock, limit ripping depth to 12”.

Bioretention Basins:

For basins larger than 1000 s.f., if compaction is above ideal bulk density per Table x, soil must be remediated as follows:

- Rip to a depth of 18” where feasible (see II.A.3 “Where Ripping is Not Feasible”)
- For clay subsoil, incorporate 2” of sand. For bioretention without an underdrain, MnDOT Type 2 compost may be incorporated instead of sand.

Note: Maintain a 2’ minimum separation distance between bottom of bioretention practice and the elevation of the seasonally high water table and bedrock. If there is only a 3’ separation distance between the bottom of the bioretention practice and the elevation of the seasonally high water table or bedrock, limit ripping depth to 12”.

IX. References

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Exhibit AS-33

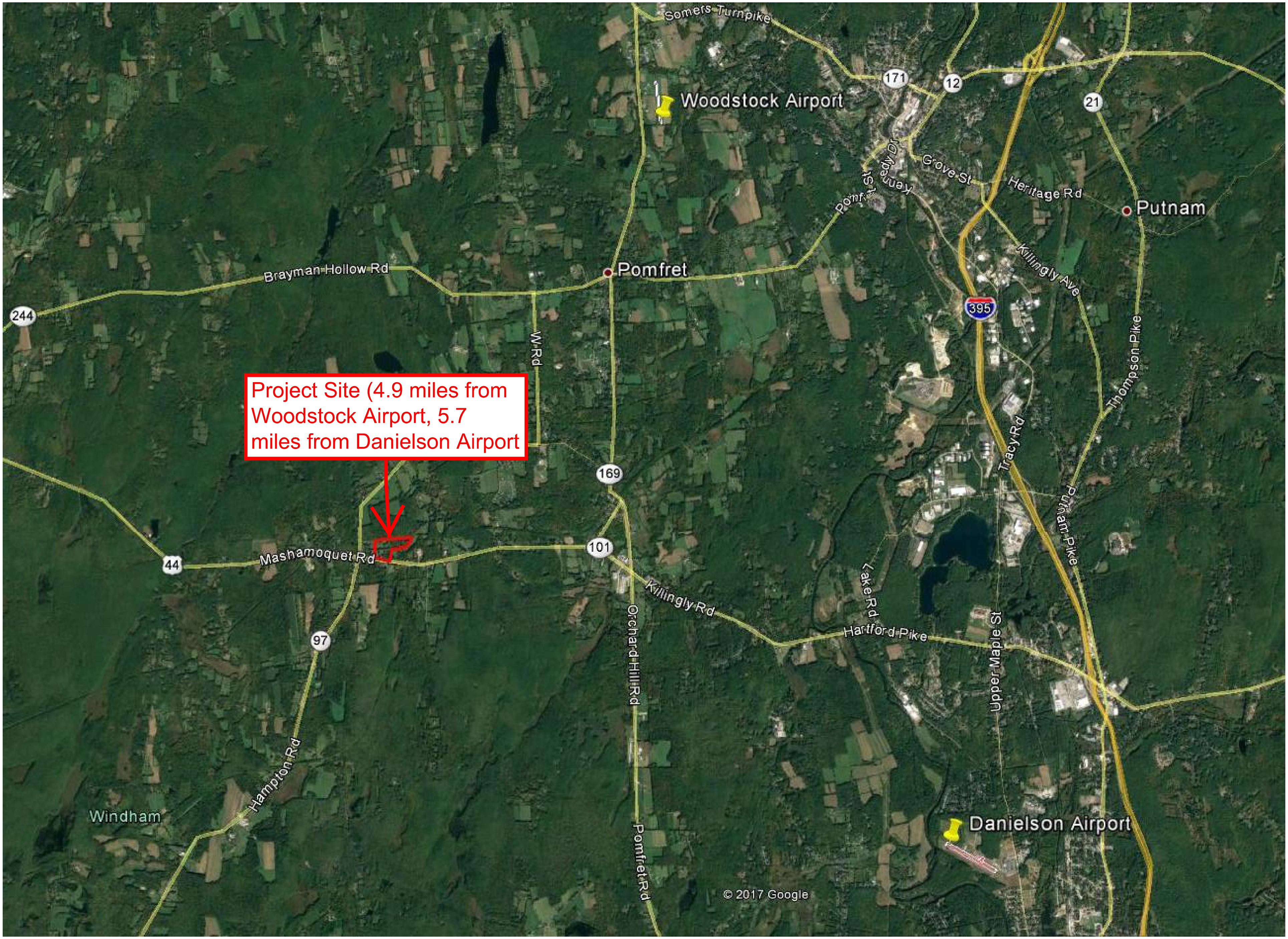
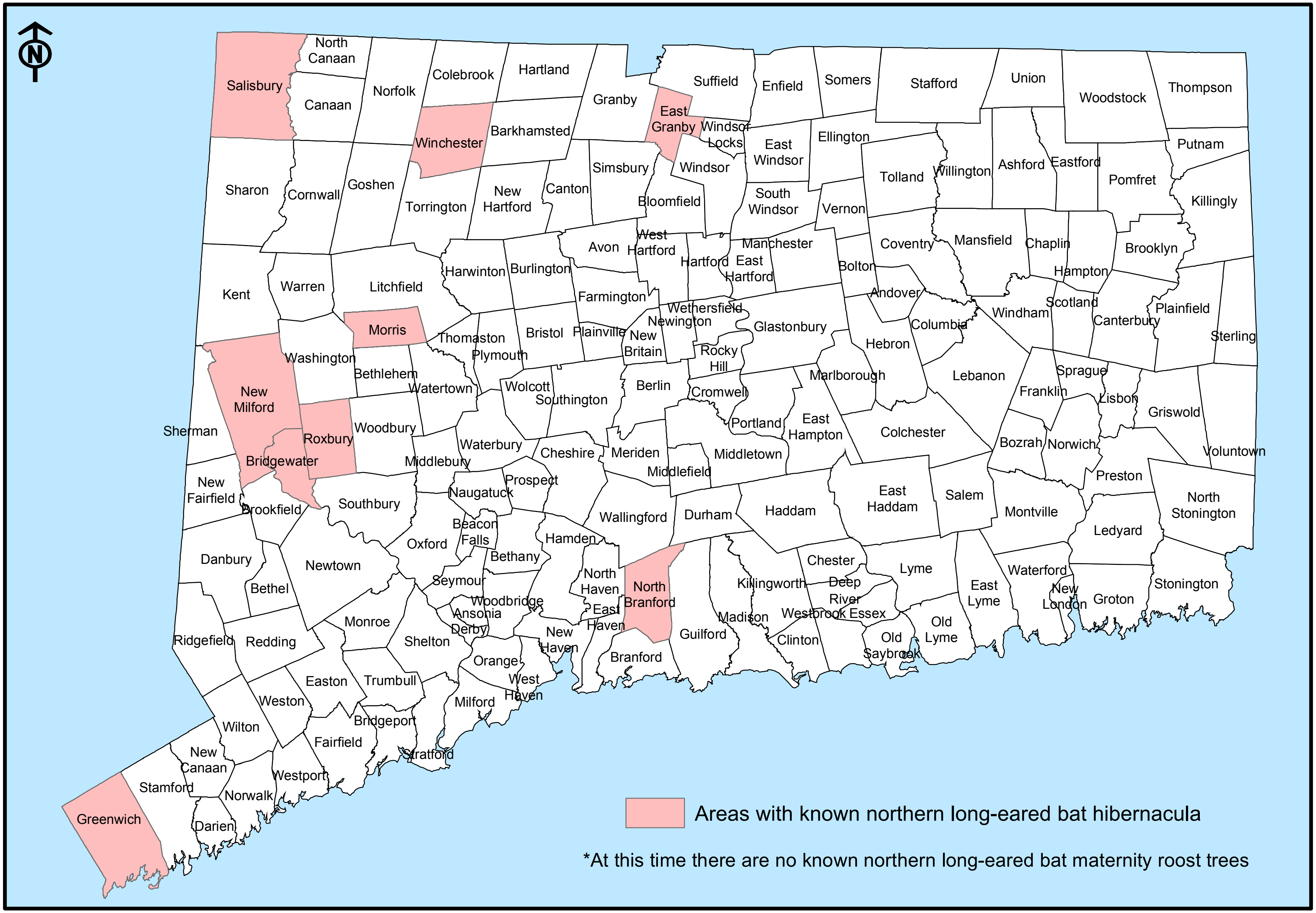


Exhibit AS-38

Northern long-eared bat areas of concern in Connecticut to assist with Federal Endangered Species Act Compliance



February 1, 2016

For information on federal requirements visit http://www.fws.gov/midwest/endangered/mammals/nleb/

The Federally Threatened and State Endangered species northern long-eared bat (NLEB) (*Myotis septentrionalis*), may be present within the Project Limits**.** If federal funds and / or a federal permit (See Army Corps General Permit Condition Number 9) are required for this project you must consult with the United States Fish & Wildlife Service's (USFWS) mapping database IPaC at http://ecos.fws.gov/ipac/ to see if the NLEB is present and further consultation is needed for your project. **It is the Towns responsibility to comply with Section 7 of the Endangered Species Act.** In Connecticut, during the winter, northern long-eared bats hibernate in caves and mines, called hibernacula. They use areas in various sized caves or mines with constant temperatures, high humidity, and no air currents. During the summer, northern long-eared bats roost singly or in colonies underneath bark, in cavities or in crevices of both live trees and snags (dead trees). Males and non-reproductive females may also roost in cooler places, like caves and mines. NLEB seem to be flexible in selecting roosts, choosing roost trees based on suitability to retain bark or provide cavities or crevices. The removal and cutting of all trees $\geq$ 3" in diameter is prohibited under a time-of-year (TOY) restriction by the USFWS during the bats active season which are as follows. These dates are inclusive unless determined otherwise through consultation with the USFWS.

a. April 15th – August 31st for all Connecticut Towns that do not front Long Island Sound and are not within 1 mile of a designated hibernacula.

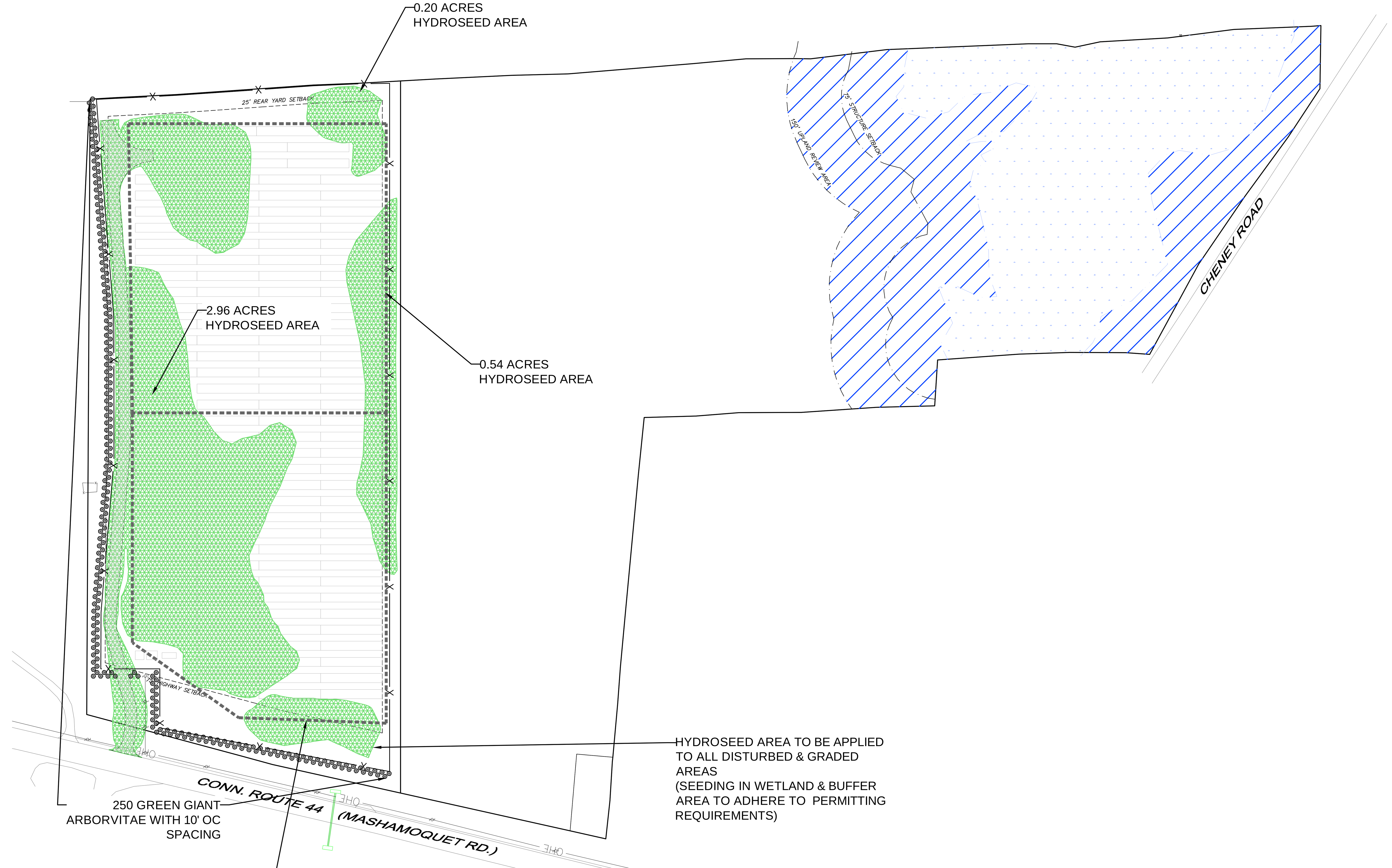
b. April 15th – September 30th for Connecticut Towns that front Long Island Sound and are not within 1 mile of a designated hibernacula.

c. April 15th – October 31st for any project within 1 mile of a known hibernacula. Consultation through the Department of Energy and Environmental Protection's (DEEP) Natural Diversity Data Base (NDDB) will determine this.

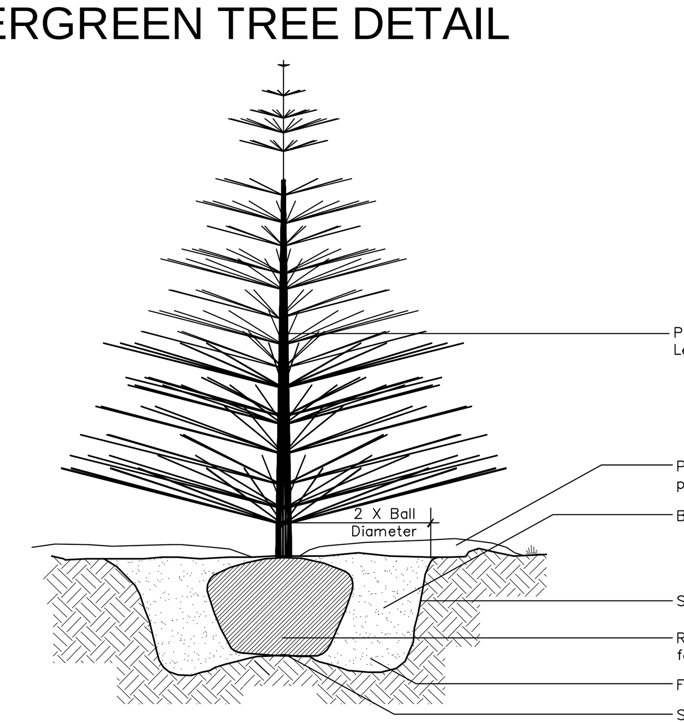
This species is protected by state and federal laws which prohibit killing, harming, taking, harassing or keeping them in your possession. Workers shall be notified of the existence of northern long-eared bat in this area and be apprised of the laws protecting them. Observations of any bat species are to be immediately reported to the Department of Energy and Environmental Protection at 860-424-3011.

SEEDING NOTES:

1. THE CONTRACTOR SHALLHYDROSEED ALL DISTURBED AREAS ASSOCIATED WITH THE CONSTRUCTION OF THE SOLAR FACILITY. CONTRACTOR SHALL USE AN APPROVED LOW GROWTH LOW MAINTENANCE SEED MIX APPROVED BY THE APPROPRIATE GOVERNING AUTHORITY.

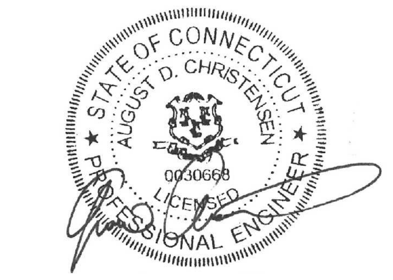


EVERGREEN TREE DETAIL



PLANT SCHEDULE					
CODE	QTY.	COMMON NAME	BOTANICAL NAME	SIZE	ROOT
GGA	250	Thuja Plicata	Green Giant Arborvitae	4ft-6ft	10 GAL

Westwood
7699 Anagram Drive
Eden Prairie, MN 55344
PHONE (952)-937-5150
FAX (952)-937-5822
TOLL FREE (888)-937-5150
Westwood Professional Services, Inc.



9-12-17

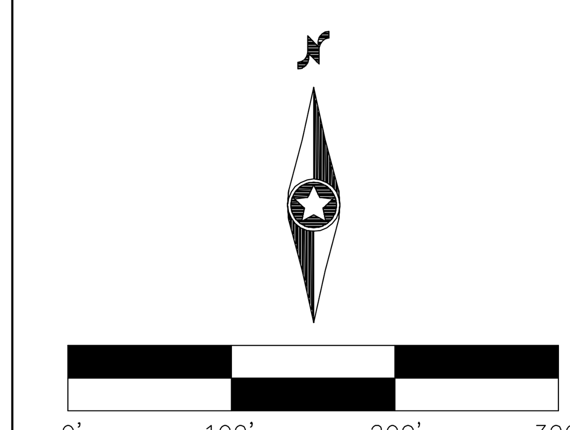
Designed: BTB
Checked: ADC
Drawn: JLB
Record Drawing by/date:

Revisions:

#	DATE	DESCRIPTION
-	09/12/2017	CT SITING BOARD SUBMISSION

Prepared for:

ecos ENERGY
222 SOUTH 9TH STREET
SUITE 1600
MINNEAPOLIS, MN 55402



ABINGTON SOLAR

481 MASHMOQUET ROAD
POMFRET, CT 06259
TOLLAND COUNTY

OVERALL LANDSCAPE PLAN

SITING BOARD REVIEW

DATE: 09/19/2017

SHEET: 8 of 12