Minnesota Solar Farm

stormwater and erosion control Operations & Maintenance Manual

Version 1.0

Date 9/1/2016



Purpose 1

Audience 1

erosion control 1

Preventative Measures 1

Inspection 1

Ground Erosion 1

Dirty Panels 1

Animal Abatement 1

Leaks 1

vegetation 2

General Assumptions 2

Solar Farm Vegetation 2

Vegetation Screening 3

Pollinator Friendly and Native Plant Mix 3

Low Growing Mix 3

Decorative Plants 4

Incorporate Plant Diversity 4

Planting Specifications 4

Timeline 4

Seeding 4

Minimize Chemical Use 5

Storage 5

Establishment and Maintenance 5

Establishment Period 5

Mowing 5

Weed Control Sheets 6

Sheep/Solar Farm 6

Long-Term Maintenance 6

Re-Vegetate Disturbed Areas 6

storm water management 7

Stormwater Best Management Practices (BMPs) 7

Commonly Cited Operational and Maintenance Concerns: 7

Bioretention 7

Filtration 7

Stormwater Ponds 7

Preventative Measures 7

General 7

Bioretention and Filtration 7

Stormwater Ponds 8

Inspection 8

Maintenance 8

Routine Maintenance 8

Maintenance of Bioretention 8

Maintenance of Filtration 8

safety 9

Appendix A: Manual Approval 10

 Appendix B: References 11

Appendix C: SOLAR SITE POLLINATOR HABITAT ASSESSMENT FORM 12

**Disclaimer**

This document is provided as guidance only. It contains suggestions and recommendations that may not be applicable to every solar farm project.

# Purpose

The performance, reliability, and profitability of solar power plants are largely dependent on the proficiency of the Operations and Maintenance (O&M) team. For a solar farm to function as it was designed to, critical attention must be paid to operations and maintenance.

# Audience

This document was prepared for project owners who are responsible for ensuring that facilities installed on their property are properly maintained and that they function as designed long-term.

# erosion control

Naturally occurring erosion processes can affect the efficiency of a solar farm. Proper erosion control measures should be taken to ensure the system functions as it was designed, ultimately reducing future O&M costs.

## Preventative Measures

Controlling erosion can significantly reduce the amount of sedimentation and other pollutants transported by runoff from the site. A primary preventative measure that can be taken is maintaining healthy, uniform vegetation throughout the solar farm. See Section IV for vegetation alternatives.

## Inspection

Inspections should be performed quarterly by a qualified professional. Frequent inspections alert the O&M team to potential risks to operation and determine appropriate maintenance measures required for the system. Inspectors should observe the following:

### Ground Erosion

Natural erosion by wind and water, including loss of topsoil, can cause racking to shift. Moving panels from their optimal position will affect energy generation.

### Dirty Panels

Pollen, dust, snow, leaf fragments, and bird droppings can reduce the amount of light that reach the cells. Routine cleaning improves the performance and profitability of the modules.

### Animal Abatement

Wildlife would ideally be kept out of solar farms. However, some operating permits might require the owner to allow for land continuity for the passage of local fauna. Inspectors should look for signs of animals burrowing under fences, holes in fencing, or animal droppings around the panels. Equipment is at risk of damage, wires may be chewed through, and holes might result in destructive rack shifting.

### Leaks

Storage containers for fertilizer, herbicide and transformers should be checked for leaking fluid to prevent contamination of soil and water on site and ensure optimal effectiveness.

# vegetation

If properly and strategically maintained, vegetative groundcover can provide profitable benefits to the solar farm. Having grass present under the modules has proven to improve the long-term efficiency of the system, as it prevents the ground from radiating heat back up under the modules. In general, vegetation is preferred for solar projects for reasons including:

1. Reduced costs of fertilizer or herbicide applications
2. Greater ability to control weed growth.
3. Reduced erosion with root systems.
4. Increased pervious surfaces to reduce the need for on-site storm water treatment.

## General Assumptions

The following are general requirements project proposers must follow in order to use the stormwater credit for solar sites as described by the MPCA Stormwater Manual:

1. Pervious surfaces must have ninety percent (90%) or greater uniform vegetated cover. Gravel is impervious, so pathways and roads within the solar panel farm cannot be considered pervious area.
2. Photovoltaic panels within an array are arranged such that runoff passes between each module thereby minimizing the creation of concentrated runoff, and allows for vegetation growth beneath and between arrays.
3. Projects attempt to minimize earth disturbance and grading activities where natural vegetation cover is preserved and/or restored.
4. Structures or foundations for ground mounted solar panels are considered impervious surfaces.
5. The lowest vertical clearance of the solar array is ten feet (10’) or less from the ground, but an adequate height to promote vegetative growth below the array. At elevations greater than ten feet, Best Management Practices (BMPs) are necessary to prevent/control erosion along the drip line or otherwise provide energy dissipation.

## Solar Farm Vegetation

There are a number of alternatives for vegetation at solar farms. Recommended seed mixes include pollinator friendly plant and native plant mixes. It is recommended when choosing seed mixes to consider the following:

1. System size
2. Budget and seed cost
3. Maintenance Preferences
4. Seed/plants that match site conditions shall be used (soils, hydrology, precipitation, elevation, drainage, aspect, sun/shade, and climate).
5. Seed mix alternatives can be accessed at the following website: <http://www.bwsr.state.mn.us/native_vegetation/>

It is anticipated that typical Minnesota Department of Transportation (MnDOT) or Board of Water and Soil Resources (BWSR) seed mixes cannot be directly used without being customized to reach the desired outcome and, in particular, plant height, that may be associated with solar farms.

The Minnesota Department of Natural Resources (MnDNR) has recently developed guidance for the establishment and maintenance of prairies associated with solar projects and is referenced throughout this document. This document is referenced in Appendix B and can be found at the following website: <http://files.dnr.state.mn.us/publications/ewr/prairie_solar_tech_guidance.pdf>.

The following describes some of the common goals that may be desired for Solar Farms.

### Vegetation Screening

Vegetation screening can generally be accomplished with trees and shrubs. A visual impact assessment may be required to determine where screening needs to be implemented or enhanced. Screening is encouraged to mitigate potential visual impacts. Vegetative screening recommendations include:

1. Native flowering shrubs that act as both visual screen around the perimeter of the site and supplement early-blooming species. Suitable shrubs may include:
* Red-osier dogwood (Cornus sericea)
* Gray dogwood (Cornus racemosa)
* Pagoda dogwood (Cornus alternifolia)
* American wild plum (Prunus Americana)
* Chokecherry (Prunus virviniana)
* New Jersey tea (Ceanothus americanus)
1. Tree species as visual screening in open landscapes should be used only when required by a permit or in response to nearby landowner concerns. Consider native tree species, not including:
* Invasive species
* Eastern red cedar; this species competes with prairie vegetation and spreads aggressively

### Pollinator Friendly and Native Plant Mix

A pollinator friendly seed mix is a specialized seed mix that contains plant species that support pollinators such as bees, butterflies, and insects that pollinate flowering forbs and some agricultural crops. Native mixes often attract pollinators as well. Using local seeds protect native prairies from genetic contamination. If local seed is not available, refer to the seed sourcing sequence provided by the DNR on their website in the Seed Collection and Deployment Zones Document: <http://www.dnr.state.mn.us> Additional benefits of using pollinator friendly and native seed mixes include:

1. The Minnesota 2016 Legislature approved a policy that allows solar developers to certify their projects as “pollinator friendly.” Claiming pollinator or wildlife habitat benefits on solar sites serves as a good public relations opportunity. In order to claim that a solar project benefits pollinators, the project must:
* Score 70 points or greater on the Solar Site Pollinator Habitat Assessment Form. The 2016 Form is available in Appendix C.
* Make the vegetative management plan for the project publicly available and share it with a Minnesota nonprofit solar trade association (DNR, 2016, p. 2).
1. Minimal maintenance requirements once established.
2. Low cost of weed and invasive species management.
3. Restore soil health with added organic matter and reduce erosion with deep root systems.
4. Reduces wind and surface water erosion.
5. Provides permanent storm water control through infiltration, and treatment through filtration, and improving water quality.
6. Provides invaluable pollinator habitat, as well as food, cover, and nesting habitat for some species of mammals, birds, reptiles, and amphibians.

### Low Growing Mix

Prairie seed mixes can be adapted to include only low-growing species that will not shade or cause damage to the solar panels.

1. Certain types of grass are seeded to stay short.
2. Initial installation costs are low.
3. Ground maintenance is greatly reduced.
4. Provides permanent storm water control through infiltration and treatment through filtration, improving water quality.
5. Design requires a minimum of eighteen inches (18”) of clearance.

### Decorative Plants

1. Creates aesthetic appeal.
2. Recommended for small projects; regular maintenance such as weeding and watering is required.
3. Design clearance must allow for work under modules.
4. High initial costs.
5. Provides permanent storm water control through infiltration and treatment through filtration, improving water quality.

### Incorporate Plant Diversity

Diverse plantings are more likely to flourish long-term due to greater ability to adapt to changing environmental conditions, ultimately requiring fewer overall maintenance costs long-term. The MnDNR 2016 Prairie Establishment & Maintenance Technical Guidance for Solar Projects recommends that pollinator seed mixes include the following:

1. Total seeding rate of 40-60 seeds/ft2.
2. At least 40% of the total seeding rate should be composed of perennial forbs.
3. 7 or more native grass/sedge species with at least 2 species of bunchgrass.
4. 20 or more native forbs with at least 5 species in each bloom period:
* Early (April-May)
* Mid (June-August)
* Late (August-October)
1. Plant species under panel arrays should grow to a maximum height of 3 feet.
2. Plant taller species around perimeter or between panel rows.

Other recommendations include:

1. Grass-only seed mixes should include recommendations from a, c, and e listed above.
2. .
3. Tall warm season grasses should comprise no more than 5% of the total seed mix (it is recommended that these are not included at all)
4. State-listed species seed should not be included in any of the mixes, including endangered, threatened, or special concern species.

See the MnDNR’s Prairie Establishment and Maintenance Technical Guidance for Solar Projects (link provided in Appendix B, References) for native seed planting layout options and seed mix examples.

## Planting Specifications

The following measures should be taken to establish vegetation and to avoid damage to vegetation and plant loss:

### Timeline

Planting is recommended after construction and installation of the panels and racking is complete. Equipment and machinery maneuvering may impact seed contact and reduce growth efficiency. A temporary cover is required for erosion control and stabilization until seed mixes are planted. Planting dates vary depending on the seasonal weather patterns and location in the state.

### Seeding

The MNDNR recommends broadcast seeding grasses/sedges in grass only areas and drilling pollinator mix into remaining areas.

1. Seed beds shall be prepared so they are firm and smooth for drill seeding; however, sites that are recently disked will work for broadcast seeding.
2. Typically a solar site will need to undergo some preliminary grading with the seed bed prepared accordingly and a temporary seed mixed applied to provide erosion protection during construction.

### Minimize Chemical Use

Minimize use of pesticides, and herbicides, and other chemicals. More environmentally friendly maintenance alternatives are listed in Section V.5.

### Storage

Do not store materials outdoors unless properly protected from runoff.

## Establishment and Maintenance

Prairie plantings have both an establishment phase (1-3 years) and a long-term maintenance phase (years 4-5 and thereafter). The following alternatives should be discussed and designed for prior to construction to reduce O&M costs over many years of a solar project’s life:

### Establishment Period

This is the most critical period for establishing healthy vegetation. The following describes the general principles to be followed:

1. Once construction is completed, the permanent vegetation shall be installed. If the temporary cover is adequate, drill seeding might be the desired approach to establish vegetation with appropriate erosion protection applied such as a weed free mulch or hydro mulch in disturbed areas.
2. Consider the appropriate seeding timeframe:
* Fall dormant seeding is favorable for native vegetation establishment where winter conditions will naturally break seed coats (true for forbs and sedges). This would typically occur after October 15th in the northern half of the state and after November 1st for the southern half of the state.
* Spring plantings would be more favorable for grasses. These should be conducted prior to June 30th.
1. Mow at least twice the first season and at least once the second season with a flail mower or stalk chopper to prevent plant smothering. Mowing decreases competition and provides sunlight to seedlings. It is important that weeds are mowed before they go to seed (typically 12-14 inches in height).
2. Hand weeding and spot treatment will be necessary for weeds

### Mowing

When mowing the vegetation under large solar farms, both the geometric array and equipment to be used must be considered. This method is labor intensive and there exists the ongoing risk of projectiles from mowing equipment damaging the modules. Below are the design features of this alternative:

1. Mowing is a three-step process on the farm. First, the mower or bush hog trims the large areas. Second, trimmers are used to cut around structural elements and other places the mower couldn’t reach. Finally, any vegetation that was thrown and stuck to the modules should be cleaned.
2. The system must be designed such that machinery can fit between rows and clear the modules. Specific access points should be identified.
3. Spot-mowing is recommended for reducing invasive plants while native species are becoming established. Spot-mowing should be done at a raised height to avoid damaging native plants.
4. A list of invasive weed species that should be eliminated is available at the Minnesota Department of Agriculture’s website:

<http://www.mda.state.mn.us/plants/pestmanagement/weedcontrol/noxiouslist.aspx>

### Weed Control Sheets

Weed-control fabrics or sheets provide weed control by covering unwanted vegetation and blocking out light. They are particularly useful on areas where lawn mowing is particularly difficult, such as narrow or steep slopes. Design considerations are listed below:

1. Thin sheets can be used under the system, in shaded areas, and thicker sheets in sun-exposed areas to completely eliminate weed O&M.
2. Initial investment might be costly compared to other methods, but ongoing expenses are minimal.
3. The fabric should be covered with rock or soil to prevent the wind from picking them up.
4. No chemicals are used, a major environmental benefit.

### Using Sheep on Solar Farms

Sheep are ideal for large scale solar farms that wish to combine energy production with an agricultural business opportunity. Sheep are hardy and low cost. The solar project will naturally get its lawn mown for less than the cost of a single mow using a crew and machines. In addition, once the sheep reach a population that can sustain the area of the farm, excess flock can be sold for a profit. Below are the design features of this alternative:

1. Maintain a minimum clearance of thirty-one and one half inches (31.5”) so that animals can walk under the installation for grazing and shade (Huff)
2. Ensure wiring is protected from the sheep with a conduit.
3. Ensure the system is ammonia resistant, from the animal urine
4. Consider using a security measure other than motion sensors, as animal movements might trigger false alarms when the system is unattended
5. A professional shepherd must care for the sheep
6. Additional research might be required to make this option viable. The designer should consult with an agricultural specialist about specific site conditions.

### Long-Term Maintenance

Long-term maintenance is required of the vegetation, typically beginning in years 4-5. The following are recommendations provided by the MNDNR (DNR, page 8).

1. Rotate haying and mowing
* Perform at a raised height of 5” or higher
* Perform when prairie plants have gone dormant (usually in the month of October)
* No more than 1/3 of the site should be hayed or mowed each year. The same area should not be hayed or mowed in consecutive years.
* Approximately 10% of the site should be set aside as semi-permanent refugia that receives limited haying and mowing on a longer return interval of 15 years.
1. Repeat every 2 years, or as needed to prevent tree/shrub encroachment, noxious and invasive weeds, and retain overall plant health.

### Re-Vegetate Disturbed Areas

Areas of damaged vegetation should be restored to avoid exposing barren soil, which can result in the following:

1. Wind carries dust onto modules, reducing their energy production
2. Bare earth dries quickly and radiates absorbed heat back up under the modules, reducing their ability to shed heat, and ultimately reducing their efficiency.
3. Soil will erode more rapidly than vegetated areas, which might pose a structural risk to the racking and foundations of the modules if they are forced to shift.
4. Bare soil areas should be revegetated with the appropriate seed mix and a erosion control blanket or hydraulic soil stabilizer.

#

# storm water management

Effective long-term operation of storm water BMPs requires proper maintenance. Careful attention to site specific O&M will increase the life expectancy of these facilities and improve aesthetics of the area.

## Stormwater Best Management Practices (BMPs) For stormwater treatment

When designing storm water BMPs, considerable factors include minimizing O&M costs, available area, geographical setting, and topographical setting. While there is not one best option, storm water treatment may be accomplished through:

1. Constructed shallow depressions for infiltration
2. Natural depressions on the landscape that infiltrate
3. Swales with check dams to create storage and promote infiltration
4. Stormwater retention ponds, and
5. Stormwater filtration

More details regarding the siting and design of stormwater BMPs and the requirements of the NPDES permit can be found in the Minnesota Stormwater Manual:

<http://stormwater.pca.state.mn.us/index.php/Main_Page>.

Commonly Cited Operational and Maintenance Concerns:

### Bioretention

1. Standing water
2. Clogged filter surfaces
3. Inlet, outlet, or underdrain clogs

### Filtration

1. Standing water
2. Clogged filter surfaces
3. Inlet, outlet, or underdrain clogs

### Stormwater Ponds

1. Permanent pool elevations fluctuate
2. Debris blocks outlet structures
3. Pipe or riser damage
4. Invasive plants out-compete wetland plants
5. Sediment accumulates in the pond, reducing storage volume
6. Slope stabilizing vegetation loss

## Preventative Measures

Critical design considerations for future O&M procedures of BMPs are listed below:

### General

Provide access for inspection and maintenance, adequate for any necessary equipment and machinery.

### Bioretention and Filtration

1. Limit drainage area
2. Provide easy site access
3. Provide pre-treatment
4. Utilize native plants. Reference the MPCA’s *Plants for Stormwater Design* found at the link below:

<https://www.pca.state.mn.us/water/plants-stormwater-design>

### Stormwater Ponds

1. Design outlets and principal spillway to minimize clogging
2. Ponds should not be drained during the spring, as temperature stratification and high chloride concentrations at the bottom can occur, which could have negative effects downstream.
3. Avoid rapid release when draining ponds to minimize discharge of sediments and anoxic water.

Construction Checklists for many types of BMPs are available on the MPCA’s Minnesota Stormwater Manual.

## Inspection

The quality of stormwater entering public waters relies on proper operation and maintenance of permanent BMPs. Stormwater management facilities must be inspected once per year by a qualified individual to ensure that they function as designed. The inspection determines the appropriate maintenance measure that is required for the facility. All storm water management facilities on site should have a designated access location and a maintenance easement if required by the local jurisdiction. Inspectors should observe that the concerns listed in V1.1 through V1.3 are controlled. A collection of MPCA Field Operation and Maintenance Checklists for many types of BMPs are available on the MPCA’s Minnesota Stormwater Manual.

## Maintenance

Routine maintenance can help avoid more costly rehabilitative maintenance that may result when facilities are not adequately maintained.

### Routine Maintenance

Effective long-term operation necessitates a dedicated and routine maintenance schedule. Routine pond and BMP maintenance, such as mowing and removing debris or trash, may be required a couple of times of year to ensure quality vegetation is established and minimize the potential for trees or woody vegetation to grow within the stormwater BMPs.

### Maintenance of Bioretention

1. First year after planting: water is needed for plant survival unless they receive adequate and frequent rainfall.
2. For aesthetics: Prune and weed as needed, maintain stabilized mulch, remove trash and debris, mow filter strip, revegetate when percent cover falls below ninety percent (90%).

### Maintenance of Filtration

1. Sediment should be cleaned out of the pre-treatment chamber when it accumulates to a depth equal to the lesser of one-half (½) the total depth to the outlet or one and one-half feet (1.5’).
2. Sediment chamber outlet device should be cleaned or repaired when drawdown time exceeds thirty-six (36) hours.
3. Silt/sediment should be removed from filter bed when the accumulation exceeds one inch.
4. Top few inches of discolored material should be removed and replaced with fresh material when water ponds on the surface of the filter bed for more than forty-eight (48) hours. The removed material should be disposed of properly (i.e. in a landfill)
5. Grass covers should be mowed as needed to maintain maximum grass heights less than twelve inches (12”).
6. Trash and debris should be removed as needed.

# safety

Safety is a vital consideration of all inspection procedures. If any hazard is found within the facility area that poses an immediate threat to public safety, contact the local Sheriff’s Office immediately.

# Appendix A: Approval

The undersigned acknowledge they have reviewed the Solar Farm Operations & Maintenance Manual and agree with the approach it presents. Changes to this Operations & Maintenance Manual will be coordinated with and approved by the undersigned or their designated representatives.

|  |  |  |  |
| --- | --- | --- | --- |
| Signature: |  | Date: |  |
| Print Name: |  |  |  |
| Title: |  |  |  |
| Role: |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Signature: |  | Date: |  |
| Print Name: |  |  |  |
| Title: |  |  |  |
| Role: |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Signature: |  | Date: |  |
| Print Name: |  |  |  |
| Title: |  |  |  |
| Role: |  |  |  |

APPENDIX B: REFERENCES

The following table summarizes the documents referenced in this document.

|  |  |  |
| --- | --- | --- |
| **Author** | **Document / Article Name** | **Location** |
| James Huff, CEO Abakus Solar USA | Solar Farm Grounds Management Vegetation Control | <http://www.abakus-solar.us/blog/solar-farm-pv-power-plant-grounds-management-vegetation-control/>  |
| Macknick, JordanBeatty, BrendaHill, Graham | Overview of Opportunities for Co-Location of Solar Energy Technologies and Vegetation | <http://www.nrel.gov/docs/fy14osti/60240.pdf>  |
| Minnesota Board of Water and Soil Resources (BWSR) | Pollinator Initiative | <http://www.bwsr.state.mn.us/practices/pollinator/>  |
| Minnesota Department of Natural Resources | Prairie Establishment & Maintenance Technical Guidance for Solar Projects | <http://files.dnr.state.mn.us/publications/ewr/prairie_solar_tech_guidance.pdf>  |
| Minnesota Pollution Control Agency (MPCA) | Minnesota Stormwater Manual * Information for Determining Stormwater Management Impacts for Solar Sites
* Operation and Maintenance of Bioretention
* Operation and Maintenance of Stormwater Pond / Wetland
* Operation and Maintenance of Infiltration Trench
 | <http://stormwater.pca.state.mn.us/index.php/Main_Page>  |
| MPCA | Plants for Stormwater Design | <https://www.pca.state.mn.us/water/plants-stormwater-design>  |

APPENDIX C: SOLAR SITE POLLINATOR HABITAT ASSESSMENT FORM

As a part of BSWR’s Pollinator Initiative, the following form is provided for solar companies to claim pollinator/ wildlife habitat benefits on solar sites.

<http://www.bwsr.state.mn.us/practices/pollinator/Solar_pollinator_assessment_form.pdf>