GREAT PLAINS INSTITUTE

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# Photovoltaic Stormwater Management Research and Testing (PV-SMaRT)

## Barriers and Best Practices

Photo from Great Plains Institute by Katharine Chute

# Acknowledgments

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**Disclaimer**

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# PV-SMaRT Barriers and Best Practices

## About the PV-SMaRT Project

The Photovoltaic Stormwater Management Research and Testing (PV-SMaRT) project seeks to develop and disseminate research-based, solar-specific resources for estimating stormwater runoff at ground-mounted PV facilities as well as stormwater management and water quality permitting best practices. The Great Plains Institute (GPI) identified existing permitting practices and standards for solar development in the five PV-SMaRT case study states (New York, Georgia, Minnesota, Colorado, and Oregon) and other states across the nation. From this assessment GPI completed the *Potential Stormwater Barriers and Opportunities* document.

The *Barriers and Opportunities* document is the foundation for this document, which identifies permitting best practices and solar project best management practices. The Best Practices document identifies practices to reduce barriers and realize opportunities for a transparent and predictable permitting process for large scale solar development that also improves water quality and stormwater management outcomes.

The Best Practices document is a final draft for public use and review. It will be modified to reference additional technical information (validated modeling results, lookup tables for runoff coefficients) in the next phase of the project. Users are invited to provide comments and suggest changes for the next phase.

## Introduction

Stormwater permitting standards are designed to protect surface and ground waters from the effects of land development or redevelopment. These land use changes typically modify stormwater flow, infiltration, evapotranspiration, and pollutant loading from what occurs in an undeveloped or natural landscape. Removing native vegetation and increasing the amount of impervious surface can significantly change the hydrologic function of a watershed, resulting in higher levels of surface water flow and decreased infiltration of subsurface water flow.

> **"Impervious Surface** – for the purpose of this permit, any land surface with a low or no capacity for soil infiltration including, but not limited to, pavement, sidewalks, parking areas and driveways, packed gravel or soil, or rooftops.."
>
> Source: US Environmental Protection Agency, *2017 Construction General Permit*, Appendix A, Definitions (emphasis added).

Stormwater regulations were not developed to account for the unique characteristics of large-scale photovoltaic (PV) solar installations (large scale meaning standalone solar projects ranging from 10–5,000 acres). Most of the stormwater standards are designed for urban watershed and development use cases.

Permitting authorities must either develop processes and standards for large-scale solar development projects or apply existing standards that were not designed for such projects. Authorities having jurisdiction (AHJs) over solar developments include those at the federal, state, and local levels. Consequently, permitting standards and processes can be unpredictably variable across jurisdictions for solar developments. The result can include the following:

- higher development and management costs (soft costs and infrastructure costs)
- inability to standardize site designs
- unclear and inconsistent water quality outcomes that may not be commensurate with water quality risks or permit-related costs and practices

> "**Solar soft costs** include all non-hardware costs that directly affect the prices of installed systems. Key categories of soft costs include installation labor, permitting costs, interconnection costs, land acquisition, customer acquisition, and installer profits."
>
> Source: US Department of Energy, *Solar Futures Study* (September 2021), 132 (emphasis added).

The Photovoltaic Stormwater Management Research and Testing (PV-SMaRT) team has identified inadvertent barriers to solar development within existing permitting practices. The team also identified missed opportunities to improve water quality outcomes and add value to solar development. These barriers fall into four categories that address both:

1. permitting structures and processes (administered by AHJs), and
2. design and operating practices managed by solar developers and solar site managers.[1]

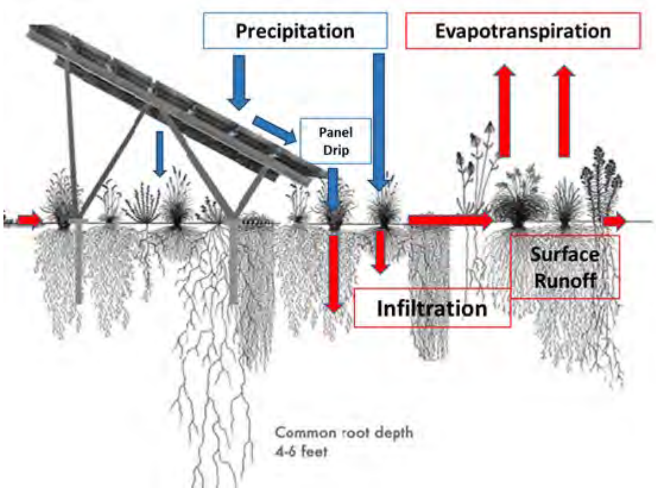
> **Four Barrier Categories**
>
> #1 Existing stormwater standards and best practices were not designed or tested for solar installations.
>
> #2 Different post-construction and construction permit goals lead to suboptimal water quality results.
>
> #3 Solar projects face varying expectations and standards across jurisdictions.
>
> #4 Lack of consistent, data-driven best management practices about array design, layout, and site standards to minimize water quality risks and maximize benefits.

Creating permitting best practices for these barriers offers an opportunity to increase consistency and transparency of water quality permitting processes and reduce solar development costs. The PV-SMaRT field research and modeling activities provide a data-driven foundation to support the creation of permitting and development best practices that can:

1. reduce permitting uncertainty (soft costs),
2. limit unnecessary infrastructure costs,
3. promote more consistency across jurisdictions in terms of permitting procedures and practices for large-scale PV projects, and
4. improve water quality outcomes.

[1] See the accompanying *Photo Voltaic Stormwater Management Research and Testing (PV-SMaRT), Barriers and Opportunities for Large-Scale PV Great Plains Institute* September 2021 for a detailed assessment of existing practices and case study examples.

**PV-SMaRTStormwater Modeling  Components**




The PV-SMaRT field testing and modeling of stormwater runoff under 2-, 10-, and 100-year frequency design storm conditions tests the viability of disconnection as a best management practice for mitigating stormwater risks.

Image source: PV-SMaRT interim results presentation, unpublished.

**What are "permitting best practices"?**

The term "best management practice" emerged from the federal Clean Water Act and is widely used in water quality permitting, including stormwater management, to refer to structural devices or stormwater management practices that avoid, minimize, or abate water quality risks. The Minnesota Stormwater Manual, for instance, offers the following definition:

> "Best Management Practice (BMP) - one of many different structural or non–structural methods used to treat runoff, including such diverse measures as ponding, street sweeping, filtration through a rain garden and infiltration to a gravel trench."[2]

As such, BMPs refer to actions taken ***by the permittee*** to mitigate water quality risk or achieve desired water quality outcomes.

**"The types of mitigation** enumerated by (the Council on Environmental Quality) are compatible with the requirements of the (Section 404) Guidelines; however, as a practical matter, they can be combined to form three general types of mitigation: avoidance, minimization, and compensatory mitigation.."

Source: "Section 404 of the Clean Water Act, Types of Mitigation under CWA Section 404: Avoidance, Minimization and Compensatory Mitigation," US EPA (website), https://www.epa.gov/cwa-404/types-mitigation-under-cwa-section-404-avoidance-minimization-and-compensatory-mitigation.

The PV-SMaRT project uses the term "permitting best practice," in contrast, to refer to practices taken ***by the permitting AHJ*** to achieve desired water quality outcomes specific to large-scale solar development. The PV-SMaRT project provides information that water quality permitting authorities can use at the federal, state, and local level that may improve water quality outcomes (protection, enhancement, restoration) laid out in water quality permits.

[2] Minnesota Pollution Control Agency, Minnesota Stormwater Manual Wiki, Appendix E. Definitions. https://stormwater.pca.state.mn.us/index.php?title=APPENDIX_E._DEFINITIONS_and_ABBREVIATIONS

Permitting best practices ensure that the standards and processes used by the permitting AHJ achieve the permitting goals in a predictable and transparent manner that can reduce solar development soft costs.

**Best Practice**

"A procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread adoption."

Source: "Best practice," Merriam-Webster Dictionary, https://www.merriam-webster.com/dictionary/best%20practice.

Permitting best practices include explicitly recognizing BMPs used by the permittee to meet permit requirements. Recognizing solar-specific BMPs in the permitting process will make the permit process more predictable and help reduce time and effort by both the AHJ and permittee, reducing the soft costs of development. Recognizing the solar-specific BMPs also has the potential to reduce costs associated with expensive or redundant BMPs and additional land needs to site them.

**Barrier Category #1 - Existing stormwater standards and best practices were not designed or tested for solar installations**

The barriers and opportunities assessment found that most AHJs used stormwater and water quality standards that were designed for non-solar, typically urban kinds of development. Even those AHJs that created solar-specific guidance did not use solar-specific research (largely because it did not exist). Consequently, solar projects face considerable uncertainty and variability in water quality permitting.

The types of variability in permitting processes and mitigation strategies that affected solar development are listed below.

| Barrier Category |
| --- |
| **Existing stormwater standards and best practices were not designed or tested for solar installations** |
| **Impervious Surface -** Definitions used for "impervious surface" in post-construction requirements are frequently not defined in the context of solar development projects, where the ground beneath the impervious surface of the panel can be used for infiltration (unlike a roof or parking lot). |
| **Final Stabilization -** Definitions of "final stabilization" in many state construction general permits create an inadvertent barrier to the use of deep-rooted and native vegetative ground cover that provides a sustainable final stabilization, creates co-benefits, and enhances disconnection as a BMP. |
| **Runoff Coefficients -** Permit officials relied on non-solar runoff coefficients or ground cover categories to guide the extent of required post-construction best management practices. |
| **Qualitative or Narrative Standards** - A few states and local governments developed solar-specific stormwater standards but used a narrative standard and generally no distinction for ground cover types. |

The following AHJ permitting best practices are designed to address the solar-specific considerations of stormwater and water quality permitting practices and standards.

These best practices recharacterize terms to recognize the three-dimensional nature of stormwater management on solar farms and to remove inadvertent barriers to disconnection as a BMP. These permitting best practices are based on the following research: (1) the interim findings of the field research and modeling; (2) review of existing permitting practices and standards; and (3) input from water quality professionals, permit officials, solar industry stakeholders, and land use professionals.

| Permitting Best Practices for AHJs | |
|---|---|
| **Define impervious surface for solar farms** to recognize ground under the panel, if vegetated, to be pervious. Incorporate into stormwater manuals, construction general permit guidance documents for solar development, and local ordinances. | |
| E X A M P L E | **“**Solar farms that use traditional elevated solar panels are unique because they contain an impervious surface (elevated solar panel) that often have a pervious surface (vegetation) underneath the panel. . . . DEMLR [Dept of Energy, Mineral, and Land Resources] allows solar panels associated with ground-mounted solar farms to be considered pervious if they are configured in accordance with the recommendations in this chapter. . .”<br>Source: North Carolina Department of Environmental Quality website, Stormwater Design Manual E.6 Solar Farms. |
| **Clarify final stabilization standards** to prevent the longer establishment time for native or deep-rooted vegetation from becoming a disincentive to its use as a permanent ground cover:<br>1. include vegetative stabilization under arrays,<br>2. include a standard for decompaction of soil, both between and under the array, and<br>3. create a plan or obligation for the establishment of native or naturalized optimal vegetative cover that allows interim use of an appropriate cover crop. | |
| E X A M P L E | “To incentivize a native or pollinator ground cover, which can take longer to establish than basic turf grass, the permittee can submit a Notice of Termination (NOT) upon achieving 70% vegetative cover when a native ground cover is established and there is a clear plan for achieving 90% establishment, or other provisions are employed until the ground cover meets the 90% threshold. If there is a sale of the property and the NOT has been acknowledged, the new owner will assume the responsibility of achieving and maintaining the 90% standard as part of the [Post-Construction Stormwater Management] Operation and Maintenance Plan.”<br>Source: Pennsylvania Dept. of Environmental Protection Chapter 102 Permitting for Solar Panel Farms FAQ, Version 1.1, Revised April 30, 2021 |
| **Use PV-SMaRT runoff coefficients** (or similar solar-specific modeled coefficients) to supplement Natural Resource Conservation Service or other accepted curve numbers included in stormwater management design or performance manuals used by permitting authorities. Include conditions (decompacted soils, slope limitations, sheet flow characteristics, or devices) under which the coefficients are valid. | |
| **Recognize different vegetative covers** in defining BMPs or modeling impacts where research has established a basis for distinguishing among vegetative types) (PV-SMaRT runoff coefficients provide multiple ground cover coefficients). | |
| E X A M P L E | “DEP recommends the measures below to control the peak runoff rate, provide recharge, and treat [Total Suspended Solids], provided the following are also met. . . construction and post-construction phase stormwater management plans include sub-catchments under the [Photovoltaic solar] arrays which include stormwater BMPs such as infiltration trenches, water bar/log bars, and **natural vegetative cover consisting solely of native grass and plant species**.”<br>Source: Massachusetts Dept. of Environmental Protection (DEP), Wetlands Program Policy 17-1: Photovoltaic System Solar Array Review, Stormwater Management, 9/23/2017 [emphasis added]. |

**Barrier Category #2 - Different post-construction and construction permit goals lead to suboptimal water quality results**

The PV-SMaRT interim field testing and modeling results indicate that projects can achieve significant improvements in water quality outcomes if certain standards were used in the solar project. The barriers and opportunities assessment identified that solar projects had, in most stormwater permitting, little incentive to meet such standards once minimum construction general permit compliance was achieved. Mechanisms exist in a handful of jurisdictions and in some circumstances for "over-compliance" in post-construction to benefit the solar project. But most stormwater permitting had no means of incentivizing actions to optimize water quality outcomes.

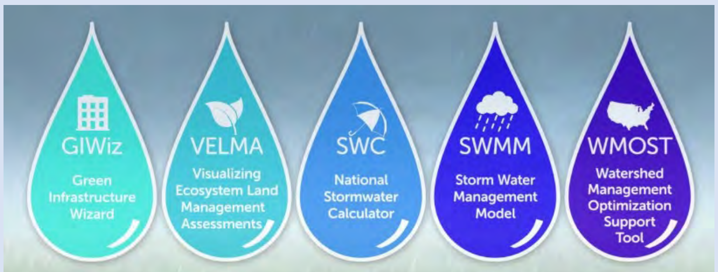
Barriers to optimal performance that affect solar development are presented below.

| **Barrier Category #2 - Different post-construction and construction permit goals lead to suboptimal water quality results** |
| --- |
| **No green infrastructure standards** for large-scale PV in typically rural watersheds. Green infrastructure standards are designed for urban watersheds. |
| **Disincentive for optimal ground cover.** Final stabilization standards disadvantage optimal ground cover, where full establishment takes longer than turf grasses or similar shallower-rooted, non-native vegetation. |
| **No credit for multi-benefit projects**. There is no regulatory credit in the construction general permit for multi-benefit projects, such as projects that create habitat, restore degraded watershed function, co-locate agriculture, or provide other ecosystem services. |

The following AHJ permitting best practices are designed to enable the capture of water quality opportunities and encourage optimal water quality outcomes in solar development. These permitting best practices are based on (1) the interim findings of the field research and modeling; (2) review of existing permitting practices and standards; and (3) input from water quality professionals, permit officials, solar industry stakeholders, and land use professionals.

**Permitting Best Practices for AHJs**

**Create green infrastructure best practices for solar projects**, recognizing conditions that allow native and naturalized ground cover to maximize water quality performance and to provide co-benefits after meeting required mitigation for post-construction design storms. Enable modeling tools that use green infrastructure such as the Stormwater Management Model (SWMM), Stormwater Calculator (SWC), or Community-enabled Lifecyle Analysis of Stormwater (CLASIC) model to be used with solar facilities.




"EPA has developed innovative models, tools, and technologies for communities to manage water runoff in urban and other environments. The resources in this toolkit incorporate green or a combination of green and gray infrastructure practices to help communities manage their water resources in a more sustainable way, increasing resilience to future changes."

Source: US EPA website, Green Infrastructure Modeling Toolkit, https://www.epa.gov/water-research/green-infrastructure-modeling-toolkit.

**Remove inadvertent barriers to co-benefit/multi-benefit ground covers** in the construction stormwater permit. Provide a construction general permit final stabilization pathway or an accompanying guidance document that allows habitat- and pollinator-friendly or native ground cover to reach final stabilization in the same time frame as turf or other stabilization methods.

EXAMPLE

"**(Final stabilization)** requirement does not apply to: . . . Projects or specific stormwater measures that utilize native vegetation and/or special vegetative plantings that are either required by a water quality permit/authorization or part of the design and functionality of a stormwater measure provided the activity does not pose a threat that will result in off-site sedimentation."

Source: Indiana Dept of Environmental Management, *Draft Construction Stormwater General Permit*, November 12, 2020.

**Develop and apply standards for quantifying full water quality benefits** that create value for exceeding design storm minimums or improvement from existing land use for those AHJs that have a water quality trading program. Alternatively, a quantified benefit can be incorporated into a value-added component to the energy off-taker, as with renewable energy credits.

**"What is Water Quality Trading (WQT)?**

EXAMPLE

- A compliance option that provides point sources with the flexibility to acquire pollutant reductions from other sources in the watershed to offset their point source load to comply with a permit limit (WQBEL)
- A strategy built on partnerships between point source facilities and their trading affiliates including other point sources, landowners, municipalities, private or public entities
- A compliance approach that must result in an overall reduction in pollutant load"

Source: Wisconsin Dept of Natural Resources website, *Water Quality Trading Factsheet*, accessed September 2021, https://dnr.wisconsin.gov/sites/default/files/topic/Wastewater/WQT_Factsheet_432013.pdf

**Barrier Category #3 - Solar projects face varying expectations and standards across jurisdictions**

The barriers and opportunities assessment identified that solar development faces a wide range of stormwater and water quality goals, policies, and permitting standards across jurisdictions (federal, state, and local). Some variability is to be expected given different ecosystems, hydrologic regimes, and protection priorities as expressed in state or local policy. However, much of the variability could also be attributed to inadvertent barriers due to the use of non-solar land use assumptions and to the lack of foundational, science-based evidence on the risks and opportunities attributable to solar development.

The types of variability in permitting processes and mitigation strategies that affected solar development are presented below.

| **Barrier Category #3 – Solar projects face varying standards across jurisdictions** |
|---|
| **Variability in water quality priories and policies that affect required BMPs -** Water quality or resource protection policies and standards vary significantly between state jurisdictions and within states between local jurisdictions. These differences can lead to community-specific protection thresholds and variability in required BMPs. |
| **Local capacity for permitting -** Local AHJs have limited capacity for managing permit processes, modeling, and best practice innovations. For an unfamiliar land use, for which little guidance is available, permitting can be slow and outcomes uncertain. |
| **Jurisdictional uncertainty -** Overlapping local jurisdictions, such as watershed districts or drainage districts that overlap with county or city land use authority, have conflicting standards. Jurisdictional uncertainty contributes to permitting uncertainty and project risk. |
| **Lack of centralized guidance -** Some states lack centralized stormwater guidance or assessment tools for local regulators, leading to a wider variety of local government interpretations, particularly with new land uses such as solar development. |
| **Perception of risk -** Unfamiliarity with large-scale solar as a land use leads to perceptions that a community should limit its deployment and assign a higher risk to solar than to more familiar land uses. |

The following AHJ permitting best practices are designed to reduce interjurisdictional variability in permitting processes and standards. These permitting best practices are based on (1) the interim findings of the field research and modeling, (2) review of existing permitting practices and standards, and (3) input from water quality professionals, permit officials, solar industry stakeholders, and land use professionals.

| **Permitting Best Practices for AHJs** |
|---|
| **Develop national or regional (cross-state) guidance** on solar-specific research, modeling, best practices. Enable nationally available tools such as the National Stormwater Calculator and CLASIC to be used with solar facilities. |
| **Develop state-level guidance** to inform regional and local solar stormwater permitting. Options for state AHJs include the following:<br>1. **Incorporate solar-specific standards in the construction general permit**. States can consider changes to the construction general permit at the five-year renewal interval.<br>2. **Modify statewide guidance, such as the statewide stormwater manual or guidance** or a standalone solar-specific guidance document that incorporates new research and scientific findings for solar development. |

3. **Create state model water quality permitting standards** that address solar land uses for the different types of permits managed by each local AHJ. Different local jurisdictions include city or county, watershed district, drainage district, conservation district. Different permit types include land use/zoning, stormwater, shoreland, TMDL (via MS4), wetland, and special waters permits.

EXAMPLE

"**Stormwater management for solar projects and determining compliance with the [National Pollution Discharge Elimination System] construction stormwater permit.**

Construction projects need to have consideration of the quantity of stormwater retained at the construction site. Estimating stormwater retained for a photovoltaic solar farm project can be challenging because the panels are impervious but the area beneath the panels is often pervious. The following methodology and guidelines are recommended for determining the quantity of stormwater retained at these types of solar panel projects."

Source: "Minnesota Stormwater Manual Wiki," Minnesota Pollution Control Agency, https://stormwater.pca.state.mn.us/index.php/Stormwater_management_for_solar_projects_and_determining_compliance_with_the_NPDES_construction_stormwater_permit.

**Model ordinance (local AHJs) guidance –** Develop, educate, and promote model ordinance language for local government AHJs. For example, provide sample text and explain lot coverage standards: (1) treat vegetated uncompacted ground under the arrays as pervious, (2) tie coverage standards to array spacing that meets disconnection thresholds, and (3) provide language for using large-scale solar as green infrastructure in rural watersheds.

EXAMPLE

"**Agricultural Resources.** For projects located on agricultural lands: … Tier 3 Solar Energy System owners shall develop, implement, and maintain native vegetation to the extent practicable pursuant to a vegetation management plan by providing native perennial vegetation and foraging habitat beneficial to game birds, songbirds, and pollinators. To the extent practicable, when establishing perennial vegetation and beneficial foraging habitat, the owners shall use native plant species and seed mixes."

Source: New York State Energy Research and Development Authority, *Solar Guidebook for Local Governments*, New York Model Solar Energy Local Law [August 2021]

**Provide training for local officials** on the following:

- the scientific foundation for solar-specific standards
- model ordinances that directly address lot coverage and science-based standards
- statewide guidance documents for different permits
- case study examples to help communities become more comfortable with large-scale solar arrays

EXAMPLE

"**SolSmart Workshops:** SolSmart Workshops are intensive, action-oriented sessions designed to empower communities to make significant progress toward achieving designation. Workshops are single or multi-day events, the duration of which are driven by the capacity, needs, and priorities of community hosts. During SolSmart Workshops, technical assistance providers meet with departmental staff in prearranged sessions to assist in the deployment of best practices."

Source: SolSmart.org, https://solsmart.org/how-we-help/types-of-assistance/

**Barrier #4 - Lack of consistent, data-driven best management practices about array design, layout, and site standards to minimize water quality risks and maximize benefits**

PV-SMaRT field research and interim modeling results, supplemented by external input, identified potential barriers in solar project development to achieving stormwater and water quality permitting outcomes. The external input came from water quality professionals, permit officials, solar industry stakeholders, and land use professionals.

<table>
<tr><th>Barrier #4 - Lack of consistent, data-driven best management practices</th></tr>
<tr><td>Array layout and spacing rarely incorporate considerations to create disconnection areas that can serve as BMPs. Disconnection as a BMP must also consider slope direction relative to array orientation (affecting sheet flow), soil types (affecting infiltration), and gradient (affecting velocity).</td></tr>
<tr><td>Choices on array design, panel choice, and racking height affect the efficacy of the vegetation and, therefore, the disconnection BMP. For instance, lower array heights increase shading and reduce the sustainability of vegetation under arrays, limit seed mix diversity across the site, and complicate vegetation establishment and post-construction maintenance. Similarly, racking and panel selection affects sheet flow, drip edge water volume, and viability of vegetation under the array.</td></tr>
<tr><td>Choice of construction practices and site closure methods affect the post-construction stormwater performance of the site. Practices include the following:<ul><li>Grading or soil removal affects site hydrology and vegetative establishment.</li><li>Retaining or removing existing vegetation affects construction and post-construction stormwater performance.</li><li>Soil compaction from construction activity limits infiltration and slows re-vegetation, both between arrays and under arrays.</li><li>method and frequency of establishing temporary vegetative cover affects speed of establishment and density of final perennial cover..</li></ul></td></tr>
<tr><td>Final ground cover choices affect post-construction infiltration capacity of the disconnection area, viability of co-benefit or multi-benefit outcomes, and post-construction maintenance costs and practices. Choices must consider uncertainty about the efficacy and cost of different ground covers, the availability of some seed mixes, and the definition of habitat or conservation goals.</td></tr>
</table>

The PV-SMaRT field research and interim modeling results provide a science-based foundation for the following BMPs or project practices. The BMPs are also consistent with most of the solar-specific guidance adopted by AHJs that have developed solar guidance. The BMPs were reviewed by AHJs, solar developers, water quality professionals, or engineering procurement construction contractors.

<table>
<tr><th colspan="2">Best Management Practices for Solar Project Permittees</th></tr>
<tr><td colspan="2">Practice site design for disconnection. Incorporate infiltration areas into array layout and design, particularly for areas with class C or D soils (tight soils, clay) where additional infiltration area may be needed to address some design storms. Recognize that larger panels require both additional separation or disconnection due to more volume at the drip edge (primarily for fixed rather than tracking arrays) and increases the need for dissipation BMPs to ensure sheet flow.</td></tr>
<tr><td colspan="2">Take a green infrastructure approach - Maximize, to the extent possible, use of native and deep-rooted naturalized vegetation in a diverse mix of vegetative cover across the site that can become self-sustaining (a minimum of maintenance needed) upon establishment:<ul><li>Use habitat- or pollinator-friendly solar standards where available (currently available in 12 states) or similar deep-rooted vegetative ground covers that create co-benefits (agrivoltaics, ecosystem services).</li><li>Include a post-construction vegetation establishment and maintenance plan in Stormwater Pollution Prevention Plan.</li><li>Incorporate the staged use of compatible cover crop with the final vegetative mix to bridge the time between the end of construction and establishment of final vegetative cover.</li><li>Use appropriate vegetative cover under the array that can be self-sustaining and sufficient to maintain the vegetative root system and infiltrative capacity.</li></ul></td></tr>
<tr><td>E<br>X<br>A<br>M<br>P<br>L<br>E</td><td>“To achieve a native deep-rooted vegetative cover, a mixture of perennial grasses and wildflowers is recommended with a diversity of forbs or flowering plants that bloom throughout the growing season. Blooming shrubs may also be used in buffer areas as appropriate for visual screening. Perennial vegetation (grasses and forbs) should be native to Pennsylvania, but where appropriate to the vegetative management plan goals, may also include other naturalized and non-invasive species which provide habitat for pollinators and wildlife and/or other ecosystem services.”<br><br>Source: Pennsylvania Dept. of Environmental Protection, Chapter 102 Permitting for Solar Panel Farms FAQ, Version 1.1, Revised April 30, 2021.</td></tr>
<tr><td colspan="2">Use low-impact development (LID) construction techniques and mitigate for soil compaction from construction. LID techniques include the following:<ul><li>Minimize to the extent practical, or eliminate, grading of the site</li><li>During construction, use LID practices to limit soil compaction, and till and aerate (or equivalent) areas between arrays to a minimum of six inches and under arrays to a minimum of four inches at the end of construction</li><li>Prevent soil removal unless there is a need for remediation of contamination</li><li>Maximize preservation of pre-construction vegetation</li><li>Ensure continued viability of ecosystem services and watershed functions</li></ul></td></tr>
</table>

| E X A M P L E | **“**Apply the principles of Environmentally Sensitive Site Design and Low Impact Development (LID) Techniques (310 CMR 10.04) in the design and monitoring of stormwater controls (during both construction and post-construction).”<br><br>Source: Massachusetts Dept. of Environmental Protection (DEP), Wetlands Program Policy 17-1: Photovoltaic System Solar Array Review, 9/23/2017 |
|---|---|

**Design array to sustain vegetative cover and infiltration -** Use array design to allow self-sustaining vegetation cover under and between arrays. Consider

- how the racking system height affects vegetation management under and between arrays,
- how the array layout and design affect the ease of post-construction maintenance,
- interaction between vegetation management and use of bifacial panels, and
- how landscape panel orientation (internal array disconnection) can be used to reduce volume at the drip edge, encourage sheet flow, and support vegetation under the array.

Include internal array disconnection as a component of disconnection BMP in Stormwater Pollution Prevention Plan or post-construction plan.

**Adopt solar-specific mitigation of runoff under special (more challenging) site conditions.**

- Steep slopes or clay soils – Effectiveness of disconnection as a BMP can be affected by slope and may require a larger disconnection area between arrays or the use of additional BMPs. Areas with tighter soils (class C or D) similarly reduce the disconnection BMP’s effectiveness and may require a larger disconnection area or the use of additional BMPs.
- Slope orientation relative to array – design array to ensure a perpendicular layout of drip edge to slope direction or install devices to ensure sheet flow from the drip edge.
- Forested sites (cleared for solar) – minimize tree clearing or mitigate vegetation removal, adopt low-impact development standards, add BMPs to the disconnection to achieve post-construction outcomes equivalent to the forested pre-development standard.

**Look beyond the design storm** – Where modeling is required for post-construction standards, include estimates of stormwater infiltration capacity in excess of AHJ minimum standards for design storms.

# ABOUT THE GREAT PLAINS INSTITUTE

GREAT PLAINS INSTITUTE

Better Energy. Better World.

A nonpartisan, nonprofit organization, the Great Plains Institute (GPI) is transforming the energy system to benefit the economy and environment. Working across the US, we combine a unique consensus-building approach, expert knowledge, research and analysis, and local action to find and implement lasting solutions. Our work strengthens communities and provides greater economic opportunity through creation of higher paying jobs, expansion of the nation's industrial base, and greater domestic energy independence while eliminating carbon emissions.

www.betterenergy.org

To learn more about the PV-SMaRT project, and to stay up to date on the research and analysis, visit https://www.nrel.gov/solar/market-research-analysis/pv-smart.html.