MEMORANDUM

Jefferson County, West Virginia
Engineering, Planning & Zoning Department

TO: Mike Shepp, Planning Commission President
Alex Beaulieu, Zoning Administrator
Jennie Brockman, County Planner

FROM: Roger Goodwin, P.E., Director & Chief County Engineer
Jonathan Saunders, P.E, County Engineer
Joe Kent, Land Development Inspector

DATE: April 22, 2020

SUBJECT: Zoning Ordinance Amendments Project
Solar Farms - Stormwater Management & Bonding
SWM Text Revised Per 4/22/2020 Conference Call

This memorandum is the Office of Engineering's response to the proposed Zoning Ordinance amendment addressing requirements for solar farms, that we discussed during a conference call on Thursday, April 9th. We address the following two issues:

- Stormwater Management and Erosion & Sediment Control requirements; and
- Proposed requirement for a 30-year Decommissioning Bond.

1. Stormwater Management and Sediment & Erosion Control:

   A. It is our understanding that the intent of the proposed amendment to the Zoning Ordinance for Solar Farms is to eliminate the need to process a Site Plan and eliminate the requirement for stormwater management control. However, the intent is to require temporary construction sediment and erosion (S&E) control under the West Virginia Department of Environmental Protection's construction stormwater NPDES permitting requirements.

   B. We researched information on the impact of solar farms on stormwater runoff (pre-development conditions vs. post-development conditions) and best management practices for controlling storm water runoff and erosion. This includes the following attached information:

- <u>"Hydrologic Response of Solar Farms",</u> in the May 2013 ASCE Journal of Hydrologic Engineering; which looked at all the factors and conditions affecting stormwater runoff.

- <u>"A Rainy Day at a Solar Farm",</u> Kennedy Jenks consulting; which summarizes stormwater impacts and stormwater management practices in several states.

- "<u>Permiting for Solar Panel Farms – Frequently Asked Questions</u>", January 2, 2019, Pennsylvania Department of Environmental Protection; which provides conditions for exemption from traditional stormwater management control requirements.

C. Based on our findings, there can be a significant increase in stormwater runoff from solar farms. However, if solar farms can meet certain conditions as discussed in the study, and as adopted by the state of Pennsylvania, the post-development runoff versus pre-development runoff will be insignificant and no traditional stormwater management control facilities will be needed.

Therefore, we propose similar relatively simple conditions for solar farms, which if met, will exempt solar farms from having to provide traditional stormwater management control. These conditions are outlined in the attached proposed amendment to the Stormwater Management Ordinance, in Article 1, Section D(2)(h). By meeting these conditions, a solar farm will be exempt from providing traditional stormwater management control.

We believe all stormwater management requirements should be contained in the Stormwater Management Ordinance, not spread out across numerous unrelated ordinances. It is the logical place for these requirements and keeps the ordinances user friendly. Therefore, we recommend that the Zoning Ordinance reference the Stormwater Management Ordinance for solar farm requirements and that the conditions granting an exception be placed in the Stormwater Management Ordinance. Jonathan Saunders, county engineer, drafted language for the reference in the Zoning Ordinance (see attached).

In Summary, the ASCE hydrologic study indicates that stormwater runoff from solar farms can be significant. However, the hydrologic study, and stormwater management practices adopted by the by other jurisdictions, indicate that solar farms can be exempt from providing traditional stormwater management facilities if the conditions proposed in the Jefferson County Stormwater Ordinance are satisfied. These proposed conditions require low-impact methods for reducing post-construction runoff volumes and velocities.

If the Planning Commission agrees, then staff will prepare a county commission agenda item request for this purpose; and coordinate simultaneous approval of it with approval of the Zoning Ordinance amendment related to solar farm utilities.

2. 30-Year Decommissioning Bond:

With regard to the proposed requirement for a 30-year decommissioning bond, we offer the following comments:

A. West Virginia State Code, Chapter 8A, Article 6-1, Bond Requirements, addresses bonding requirements for land development projects. It says:

ARTICLE 6. METHODS OF SECURITY.

§8A-6-1. Bond requirements.

(a) If a bond is used as an acceptable method of security for infrastructure construction, then it shall meet the following requirements:

(1) Be in an amount to cover the infrastructure construction, as determined by the governing body;

(2) Be payable to the governing body;

(3) Have adequate surety and be satisfactory to the governing body;

(4) Specify the time for the completion of the infrastructure construction; and

(5) Specify the date and/or condition for when the bond will be released.

(b) The money from the bond shall only be used by the governing body to which the bond is payable, for the completion of the infrastructure construction, when the infrastructure construction is not completed as approved at the issuance of the bond.

In accordance with state code, the County Commission has a bonding policy which requires that the developer enter into an agreement with the County Commission to complete the site improvements (infrastructure) as required under a preliminary plat or site plan approval. The developer is required to post a bond/surety in the amount of 115% of the estimated cost to complete all the site improvements. The developer gets a limited amount of time to complete the site improvements. Upon satisfactory completion of all the site improvements, the bond is released. Upon release of the bond/surety, there are no further obligations between the County Commission and the developer.

The purpose of the bond authorized under Chapter 8A, Article 6-1, is for completion of site improvements. The proposed 30-year decommissioning bond is for the post-construction purpose of ensuring that the site is properly decommissioned upon cessation of operation of the solar farm. Which could extend as far out as 30-years.

It is our belief that the county does not have the authority under Chapter 8A, Article 6-1, to require a bond for the purpose of ensuring the proper decommissioning of a solar farm post-construction; which would typically occur decades later. However, we will defer to the Planning Commission's attorney for guidance on this matter.

B. We also discussed the need for a 30-year decommissioning bond and how difficult it will be to manage over a 30-year time period. We believe that holding and tracking a bond for 30 years will be difficult and impractical. Instead, we propose another option based on these two ownership scenarios:

- Solar Farm Utility owns the land; and
- Solar Farm Utility leases the land.

<u>In the first scenario</u>, the ordinance could require that, upon cessation of operations, the solar farm be decommissioned by fully dismantling and removing all the equipment and facilities from the site and disposing of it in a legal manner. If the utility fails to do so, it will be in violation of the ordinance and the county pursues enforcement under the ordinance, which could involve seeking an injunction and order in circuit court to enforce proper decommissioning and possibly imposing fines on the utility. You could borrow language from the Property Safety Enforcement Ordinance on how the enforcement process will work.

Whenever there is a violation of county land development ordinances and building codes, the county has always held the property owner to be the one in violation; not the developer or builder/contractor. <u>In the second scenario</u>, it seems the intent of the 30-year decommissioning bond is to protect the owner from the utility failing to properly decommission the solar farm upon cessation of operations and/or termination of the lease. If the utility abandoned the solar farm facility in place, this again would be a violation of the ordinance. However, the owner will be responsible for seeing that the utility properly decommissions the solar farm. If not, then the county will pursue enforcement under the ordinance, which could involve seeking an injunction and order in circuit court to enforce proper decommissioning by the property owner and possibly imposing fines.

Therefore, under the second scenario, it seems to us that the property owner needs to enter into a lease agreement that includes terms and conditions for the proper decommissioning of the solar farm. The property owner should be the one to require and hold a decommissioning bond or form of surety from the utility to ensure there is incentive for the utility to properly decommission the solar farm; which will be by demolishing it and disposing of it in a legal manner. It seems to us that in this scenario, it is a contractual civil matter between the property owner and the solar farm utility.

In summary, we believe that it will be difficult for the County Commission and staff to manage and track a bond over a 30-year time period. Putting language in the ordinance giving the county the ability to enforce decommissioning is an alternative to requiring a decommissioning bond. If the solar farm utility leases the property, then the property owner can enter into a lease agreement with the utility that requires the utility post a bond/surety with the property owner as incentive for proper decommissioning. In addition, we are not sure the county has the authority to require a decommissioning bond anyway. However, the property owner could require a bond/surety in the lease agreement. We will defer to the Planning Commission’s attorney for guidance on this matter.

Jefferson County, WV

Stormwater Management Ordinance
Department of Engineering

AUGUST, 2013

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ARTICLE I GENERAL PROVISIONS

A. STATUTORY AUTHORITY

(1) Short Title

(a) This Ordinance and Ordinances supplemental or amendatory thereto shall be known and may be cited as the "Stormwater Management Ordinance of Jefferson County" and hereinafter referred to as the "Ordinance."

(b) EFFECTIVE DATE:

(2) The provisions of this Ordinance are enacted pursuant to West Virginia Code:

- Chapter 7, County Commissions and Officers, Article 1, "County Commissions Generally"
- Chapter 8A, Land Use Planning, Article 4, "Subdivision and Land Development Ordinance"
- Chapter 8A, Land Use Planning, Article 5, "Subdivision or Land Development"
- Chapter 22, Environmental Resources, Article 11, "Water Pollution Control Act"
- Chapter 22, Environmental Resources, Article 12, "Ground Water Protection Act"

(3) The provisions of this Ordinance are also enacted pursuant to the Chesapeake Bay Restoration Act of 2000.

B. PURPOSE AND OBJECTIVES

This Ordinance has the following purpose:

(1) Protect, maintain, and enhance the environment of Jefferson County and the public health, safety, and general welfare of the citizens of Jefferson County by controlling discharges of pollutants to Jefferson County's stormwater system, and maintain and improve the quality of the receiving waters into which all stormwater flows, including, without limitation, lakes, rivers, streams, ponds, wetlands, and groundwater of the community

(2) Enable Jefferson County to comply with the West Virginia Department of Environmental Protection (WVDEP)-administered National Pollutant Discharge Elimination System (NPDES) stormwater permit program and applicable regulations (40 CFR, §122.26) for stormwater discharges

(3) Enable Jefferson County to comply with the Environmental Protection Agency's (EPA) Total Maximum Daily Loads (TMDLs) Water Quality Standards established for the Potomac River Basin

(4) Enable Jefferson County to comply with the West Virginia Water Pollution Control Act, West Virginia Code, Chapter 22, Article 11

(5) Allow Jefferson County to exercise the powers granted in West Virginia Code §8A-4, Article 4, "Subdivision and Land Development", Article 5, "Subdivision or Land Development," and §22, Article 12, "Ground Water Protection Act," which provide, among other powers that counties have with respect to stormwater systems and stormwater management programs, the power by ordinance or resolution, as the case may require, and by appropriate action based thereon to do the following:

(a) Establish standards for setback requirements, Lot sizes, streets, sidewalks, walkways, parking, easements, rights-of-way, drainage, utilities, infrastructure, curbs, gutters, street lights, fire hydrants, stormwater management, and water and wastewater facilities

(b) Adopt any rules and regulations deemed necessary to accomplish the purposes of this Ordinance, including the adoption of a system of fees for services and permits

(c) Establish standards to regulate the quantity of stormwater discharged and to regulate stormwater contaminants that may be necessary to protect water quality

(d) Establish standards for flood-prone or subsidence areas

(e) Review and approve plans and plats for stormwater management in proposed residential and nonresidential subdivisions as applicable under Subsection D below

(f) Issue permits for stormwater discharges, or for the construction, alteration, extension, or repair of stormwater facilities

(g) Suspend or revoke permits when it is determined that the permittee has violated any applicable ordinance, resolution, or condition of the permit

(h) Ensure that required improvements are installed and not avoided by a series of minor subdivisions or land developments

(i) Define control measures for drainage, erosion, and sediment

C. Administering Entity

(1) Pursuant to West Virginia Code §7, Article 1, "County Commissions Generally," any county commission in the State of West Virginia is hereby authorized and empowered to own, acquire, construct, equip, operate, and maintain within the respective county a stormwater system, stormwater works, and stormwater management program as defined herein.

(2) Jefferson County is the entity responsible for administering the provisions of this Ordinance.

D. APPLICABILITY

(1) This Ordinance shall be applicable to all activities as defined herein. A Stormwater Management Plan for any new development or redevelopment shall be required as described below. In addition to Stormwater Quantity and Quality Control Plans, stormwater Runoff conveyance systems, Erosion and Sediment Control Plans, and stormwater management facilities' maintenance requirements must be included in all Stormwater Management Plans. Stormwater management quantity and quality control shall be applicable as follows:

(a) *Quantity* control criteria for newly developed impervious surfaces and/or changes in land cover shall apply to

(i) Minor Site Developments, as defined by the Jefferson County Subdivision and Land Development Regulations, requiring a Limited Site Plan, and

(ii) Rural Site Plans, and

(iii) Any Site Development requiring a Full Site Plan, and

(iv) Any Major residential or commercial subdivision requiring a Preliminary Plat.

(b) In addition to the quantity control requirements noted above, *Quality* control criteria for newly developed impervious surfaces shall apply to

(i) Rural Site Plans involving the Development of 5,000 square feet or more of impervious surface or resulting in more than one acre of land disturbance, and

(ii) Any Site Development requiring a Full Site Plan, and

(iii) Any Major residential or commercial subdivision requiring a Preliminary Plat.

(2) The following activities are exempt from this Ordinance:

(a) Any emergency activity that is immediately necessary for the protection of life, property, or natural resources

(b) Projects that do not require Site Plans or Preliminary Plat Plans. This includes Minor Subdivisions as defined under the Subdivision and Land Development Ordinance.

(c) The construction of single-family or duplex residential structures or additions or modifications to existing single-family or duplex residential structures

(i) However, despite the exemption, minimal Erosion and Sediment control measures shall be required and include the following:

1. Installation and maintenance of a stone construction entrance during the entire construction phase to reduce the transport of sediment from the site by vehicles and equipment leaving the site, and

2. Installation of a Silt Fence during the entire construction phase to control erosion and sediment runoff from the Site, and

3. All disturbed areas on the Site shall be stabilized, within seven days of final grading or becoming inactive for more than 30 days, with permanent vegetation or protective ground cover suitable for the time of year.

(ii) The Erosion and Sediment control measures shall be constructed and installed according to the details and specifications as established by the Chief County Engineer.

(iii) The minimal stone construction entrance and Silt Fence shall be in place at the time of the footer inspection. Failure to meet minimal requirements will result in a failed footer inspection under the building code.

The final grading and stabilization of the Site shall be complete at the time of final inspection. Failure to meet this requirement will result in a failed final inspection and withholding of the Use and Occupancy Certificate issued under the building code.

(d) Any logging or Agricultural Activity that is consistent with an approved farm conservation plan or a timber management plan prepared or approved by the Eastern Panhandle Conservation District.

(e) Repairs to any Stormwater Management Facility.

(f) Subdivision Plats or Site Plans approved before the adoption date of this Ordinance. However, any and all Subdivision Plats and Site Plans approved prior to the adoption of this Ordinance shall still be required to meet the stormwater management requirements in effect at the time of their approval and under which they were approved.

(g) Any vested development that has an active application or submittal at the time of adoption of this ordinance and meets at least one of the following criteria, is exempt from this ordinance.

- An approved master planned development with a current CIS that has submitted at least the first phase of a multi-phased master planned development, or
- Any site plan within an approved non-residential subdivision that has existing central water quantity control structures shall be required to

provide stormwater management controls under the regulations, conditions and terms in effect at the time of the original approval.

However, if, after the adoption of this ordinance, there is any physical expansion to said exclusion listed above, this ordinance shall apply to the expanded area only.

(h) Solar Farms, provided all of the following conditions are met:

- Earth disturbance and grading activities shall be minimized and natural vegetal cover shall be preserved and/or restored.
- Vegetal cover shall have 90% or better uniform coverage and shall not be subject to chemical fertilization and herbicides/pesticides. A meadow condition is preferable, particularly for slopes between 5 and 10%. Mowed areas should be kept to a minimum of 4”.

  Individual Photo Voltaic (PV) modules within an array shall be arranged in a fashion that allows the passage of runoff underneath each module. The PV modules shall be arranged to allow the growth of vegetation beneath the PV modules and between the rows of PV arrays.

  If the width of the vegetative strip between rows of PV arrays is not a minimum of twelve feet (i.e. there is inadequate vegetated spacing between modules), then stormwater BMPs such as infiltration trenches (min. 12” wide by 12” deep) or infiltration berms shall be installed down gradient between each row.

- Ground-mounted solar PV modules shall be supported with structures/foundations occupying a maximum of 5% of the total project area. (not the parcel area, but that area within the boundary of the 100’ setback/buffer surrounding the solar farm equipment) This area shall be delineated, and dimensioned on the Concept Plan, along with a note of the total area and a calculation of the percent of impervious area occupied by the support structures/foundation.
- Solar PV modules shall be situated on mild slopes (10% max). If greater than 10% slopes are proposed, then stormwater BMPs such as infiltration trenches (min. 12” wide by 12” deep) or infiltration berms shall be installed down gradient between each row of PV arrays, in addition to providing the minimum 12-foot spacing between the rows of PV arrays.
- The lowest vertical clearance of the solar PV array shall be at an elevation of 10 feet or less from the ground, but is also at an adequate height to promote vegetative growth below the PV array.
- No erosion or transport of sediments shall be allowed. An Erosion and Sediment Control Plan shall be submitted as part of the Stormwater Report. Permanent Erosion and Sediment Control shall be provided to address the potential for erosion at the drip edge of solar panels. In addition, the West Virginia Department of Environmental Protection’s

temporary construction stormwater NPDES permit shall be submitted along with the Stormwater Report.

The developer shall submit documentation in the form of a Stormwater Report, which demonstrates all of the above conditions are satisfied, to the Jefferson County Engineer for review and approval. At the time of submission, the developer shall pay a non-refundable review fee in accordance with the established fee schedule. The Stormwater Report shall be prepared, signed, and sealed, by a professional engineer registered to practice in the State of West Virginia. The Stormwater Report shall be approved prior to the issuance of the building permit.

If all the above conditions cannot be met, then the project shall fall under the jurisdiction of this Ordinance and stormwater quantity and quality control shall be provided.

For the life of the project, the Jefferson County Engineering staff shall have the authority to visit the site, with 72-hours' notice, to determine if the above conditions are being maintained.

Failure to perpetually maintain and meet the conditions for this exemption shall be a violation of this Ordinance and enforceable under the law.

(3) Compatibility with Other Permits and Ordinance Requirements

(a) Compliance with the requirements herein does not create exclusion to permitting requirements from the WVDEP, the U.S. Army Corps of Engineers, or any other agency or reviewing body that has jurisdiction over the proposed project area.

(b) Whenever this Ordinance imposes a conflicting restriction regarding stormwater regulation, the provisions of the more restrictive ordinance shall control.

E. SEVERABILITY

If any section, clause, sentence, part, or provision hereof shall be held to be invalid, or unconstitutional, by any court of competent jurisdiction, such decision of the court shall not affect or impair the remaining sections, clauses, sentences, parts, or provisions of this Ordinance.

F. INCORPORATION BY REFERENCE

(1) For the purposes of this Ordinance, Jefferson County has adopted by reference the following published standards:

(a) *West Virginia Stormwater Management and Design Guidance Manual (2012)*

(c) *West Virginia Erosion and Sediment Control Best Management Practice Manual* (2006)

(d) *West Virginia Erosion and Sediment Control Handbook for Developing Areas*

(e) *Virginia Stormwater Best Management Practices Clearinghouse*

(f) *Maryland Stormwater Design Manual*

(g) *Pennsylvania Stormwater Best Management Practices Manual*

(2) All Stormwater Management Plans shall be consistent with the regulations and design standards established in the listed published standards.

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Hydrologic Response of Solar Farms

Lauren M. Cook, S.M.ASCE[1]; and Richard H. McCuen, M.ASCE[2]

Abstract: Because of the benefits of solar energy, the number of solar farms is increasing; however, their hydrologic impacts have not been studied. The goal of this study was to determine the hydrologic effects of solar farms and examine whether or not storm-water management is needed to control runoff volumes and rates. A model of a solar farm was used to simulate runoff for two conditions: the pre- and postpaneled conditions. Using sensitivity analyses, modeling showed that the solar panels themselves did not have a significant effect on the runoff volumes, peaks, or times to peak. However, if the ground cover under the panels is gravel or bare ground, owing to design decisions or lack of maintenance, the peak discharge may increase significantly with storm-water management needed. In addition, the kinetic energy of the flow that drains from the panels was found to be greater than that of the rainfall, which could cause erosion at the base of the panels. Thus, it is recommended that the grass beneath the panels be well maintained or that a buffer strip be placed after the most downgradient row of panels. This study, along with design recommendations, can be used as a guide for the future design of solar farms. **DOI:** 10.1061/(ASCE)HE.1943-5584.0000530. © *2013 American Society of Civil Engineers.*

CE Database subject headings: Hydrology; Land use; Solar power; Floods; Surface water; Runoff; Stormwater management.

Author keywords: Hydrology; Land use change; Solar energy; Flooding; Surface water runoff; Storm-water management.

Introduction

Storm-water management practices are generally implemented to reverse the effects of land-cover changes that cause increases in volumes and rates of runoff. This is a concern posed for new types of land-cover change such as the solar farm. Solar energy is a renewable energy source that is expected to increase in importance in the near future. Because solar farms require considerable land, it is necessary to understand the design of solar farms and their potential effect on erosion rates and storm runoff, especially the impact on offsite properties and receiving streams. These farms can vary in size from 8 ha (20 acres) in residential areas to 250 ha (600 acres) in areas where land is abundant.

The solar panels are impervious to rain water; however, they are mounted on metal rods and placed over pervious land. In some cases, the area below the panel is paved or covered with gravel. Service roads are generally located between rows of panels. Although some panels are stationary, others are designed to move so that the angle of the panel varies with the angle of the sun. The angle can range, depending on the latitude, from 22° during the summer months to 74° during the winter months. In addition, the angle and direction can also change throughout the day. The issue posed is whether or not these rows of impervious panels will change the runoff characteristics of the site, specifically increase runoff volumes or peak discharge rates. If the increases are hydrologically significant, storm-water management facilities may be needed. Additionally, it is possible that the velocity of water draining from the edge of the panels is sufficient to cause erosion of the soil below the panels, especially where the maintenance roadways are bare ground.

The outcome of this study provides guidance for assessing the hydrologic effects of solar farms, which is important to those who plan, design, and install arrays of solar panels. Those who design solar farms may need to provide for storm-water management. This study investigated the hydrologic effects of solar farms, assessed whether or not storm-water management might be needed, and if the velocity of the runoff from the panels could be sufficient to cause erosion of the soil below the panels.

Model Development

Solar farms are generally designed to maximize the amount of energy produced per unit of land area, while still allowing space for maintenance. The hydrologic response of solar farms is not usually considered in design. Typically, the panels will be arrayed in long rows with separations between the rows to allow for maintenance vehicles. To model a typical layout, a unit width of one panel was assumed, with the length of the downgradient strip depending on the size of the farm. For example, a solar farm with 30 rows of 200 panels each could be modeled as a strip of 30 panels with space between the panels for maintenance vehicles. Rainwater that drains from the upper panel onto the ground will flow over the land under the 29 panels on the downgradient strip. Depending on the land cover, infiltration losses would be expected as the runoff flows to the bottom of the slope.

To determine the effects that the solar panels have on runoff characteristics, a model of a solar farm was developed. Runoff in the form of sheet flow without the addition of the solar panels served as the prepaneled condition. The paneled condition assumed a downgradient series of cells with one solar panel per ground cell. Each cell was separated into three sections: wet, dry, and spacer.

The dry section is that portion directly underneath the solar panel, unexposed directly to the rainfall. As the angle of the panel from the horizontal increases, more of the rain will fall directly onto

[1]Research Assistant, Dept. of Civil and Environmental Engineering, Univ. of Maryland, College Park, MD 20742-3021.

[2]The Ben Dyer Professor, Dept. of Civil and Environmental Engineering, Univ. of Maryland, College Park, MD 20742-3021 (corresponding author). E-mail: rhmccuen@eng.umd.edu

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the ground; this section of the cell is referred to as the wet section. The spacer section is the area between the rows of panels used by maintenance vehicles. Fig. 1 is an image of two solar panels and the spacer section allotted for maintenance vehicles. Fig. 2 is a schematic of the wet, dry, and spacer sections with their respective dimensions. In Fig. 1, tracks from the vehicles are visible on what is modeled within as the spacer section. When the solar panel is horizontal, then the length longitudinal to the direction that runoff will occur is the length of the dry and wet sections combined. Runoff from a dry section drains onto the downgradient spacer section. Runoff from the spacer section flows to the wet section of the next downgradient cell. Water that drains from a solar panel falls directly onto the spacer section of that cell.

The length of the spacer section is constant. During a storm event, the loss rate was assumed constant for the 24-h storm because a wet antecedent condition was assumed. The lengths of the wet and dry sections changed depending on the angle of the solar panel. The total length of the wet and dry sections was set equal to the length of one horizontal solar panel, which was assumed to be 3.5 m. When a solar panel is horizontal, the dry section length would equal 3.5 m and the wet section length would be zero. In the paneled condition, the dry section does not receive direct rainfall because the rain first falls onto the solar panel then drains onto the spacer section. However, the dry section does infiltrate some of the runoff that comes from the upgradient wet section. The wet section was modeled similar to the spacer section with rain falling directly onto the section and assuming a constant loss rate.

For the presolar panel condition, the spacer and wet sections are modeled the same as in the paneled condition; however, the cell does not include a dry section. In the prepaneled condition, rain falls directly onto the entire cell. When modeling the prepaneled condition, all cells receive rainfall at the same rate and are subject to losses. All other conditions were assumed to remain the same such that the prepaneled and paneled conditions can be compared.

Rainfall was modeled after an natural resources conservation service (NRCS) Type II Storm (McCuen 2005) because it is an accurate representation of actual storms of varying characteristics that are imbedded in intensity-duration-frequency (IDF) curves. For each duration of interest, a dimensionless hyetograph was developed using a time increment of 12 s over the duration of the storm (see Fig. 3). The depth of rainfall that corresponds to each storm magnitude was then multiplied by the dimensionless hyetograph. For a 2-h storm duration, depths of 40.6, 76.2, and 101.6 mm were used for the 2-, 25-, and 100-year events. The 2- and 6-h duration hyetographs were developed using the center portion of the 24-h storm, with the rainfall depths established with the Baltimore IDF curve. The corresponding depths for a 6-h duration were 53.3, 106.7, and 132.1 mm, respectively. These magnitudes were chosen to give a range of storm conditions.

During each time increment, the depth of rain is multiplied by the cell area to determine the volume of rain added to each section of each cell. This volume becomes the storage in each cell. Depending on the soil group, a constant volume of losses was subtracted from the storage. The runoff velocity from a solar panel was calculated using Manning's equation, with the hydraulic radius for sheet flow assumed to equal the depth of the storage on the panel (Bedient and Huber 2002). Similar assumptions were made to compute the velocities in each section of the surface sections.

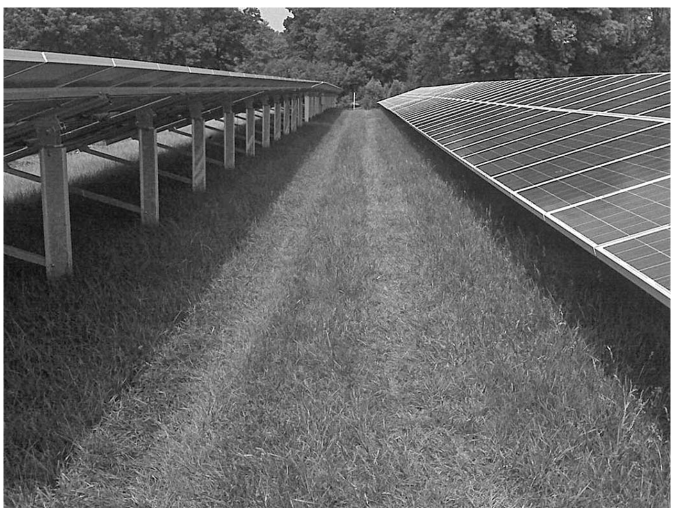

Fig. 1. Maintenance or "spacer" section between two rows of solar panels (photo by John E. Showler, reprinted with permission)

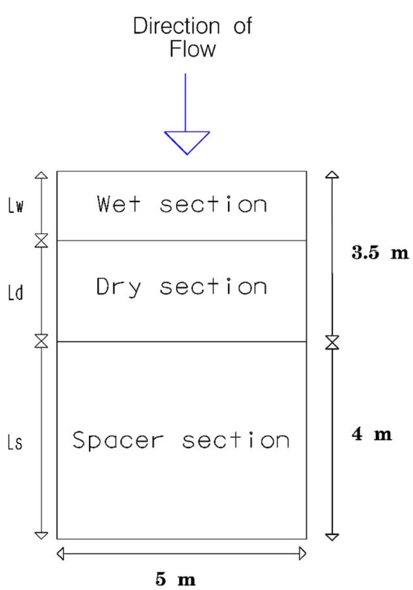

Fig. 2. Wet, dry, and spacer sections of a single cell with lengths *Lw*, *Ls*, and *Ld* with the solar panel covering the dry section

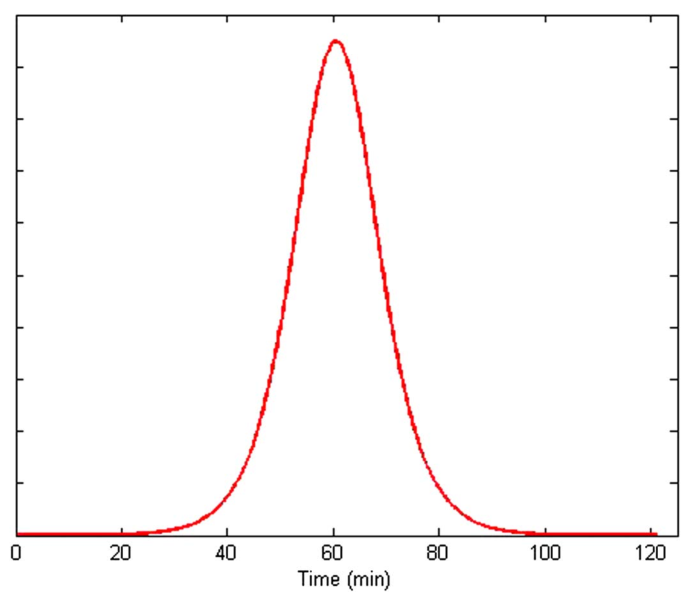

Fig. 3. Dimensionless hyetograph of 2-h Type II storm

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Runoff from one section to the next and then to the next downgradient cell was routed using the continuity of mass. The routing coefficient depended on the depth of flow in storage and the velocity of runoff. Flow was routed from the wet section to the dry section to the spacer section, with flow from the spacer section draining to the wet section of the next cell. Flow from the most downgradient cell was assumed to be the outflow. Discharge rates and volumes from the most downgradient cell were used for comparisons between the prepaneled and paneled conditions.

Alternative Model Scenarios

To assess the effects of the different variables, a section of 30 cells, each with a solar panel, was assumed for the base model. Each cell was separated individually into wet, dry, and spacer sections. The area had a total ground length of 225 m with a ground slope of 1% and width of 5 m, which was the width of an average solar panel. The roughness coefficient (Engman 1986) for the silicon solar panel was assumed to be that of glass, 0.01. Roughness coefficients of 0.15 for grass and 0.02 for bare ground were also assumed. Loss rates of 0.5715 cm/h (0.225 in./h) and 0.254 cm/h (0.1 in./h) for B and C soils, respectively, were assumed.

The prepaneled condition using the 2-h, 25-year rainfall was assumed for the base condition, with each cell assumed to have a good grass cover condition. All other analyses were made assuming a paneled condition. For most scenarios, the runoff volumes and peak discharge rates from the paneled model were not significantly greater than those for the prepaneled condition. Over a total length of 225 m with 30 solar panels, the runoff increased by 0.26 m^3, which was a difference of only 0.35%. The slight increase in runoff volume reflects the slightly higher velocities for the paneled condition. The peak discharge increased by 0.0013 m^3, a change of only 0.31%. The time to peak was delayed by one time increment, i.e., 12 s. Inclusion of the panels did not have a significant hydrologic impact.

Storm Magnitude

The effect of storm magnitude was investigated by changing the magnitude from a 25-year storm to a 2-year storm. For the 2-year storm, the rainfall and runoff volumes decreased by approximately 50%. However, the runoff from the paneled watershed condition increased compared to the prepaneled condition by approximately the same volume as for the 25-year analysis, 0.26 m^3. This increase represents only a 0.78% increase in volume. The peak discharge and the time to peak did not change significantly. These results reflect runoff from a good grass cover condition and indicated that the general conclusion of very minimal impacts was the same for different storm magnitudes.

Ground Slope

The effect of the downgradient ground slope of the solar farm was also examined. The angle of the solar panels would influence the velocity of flows from the panels. As the ground slope was increased, the velocity of flow over the ground surface would be closer to that on the panels. This could cause an overall increase in discharge rates. The ground slope was changed from 1 to 5%, with all other conditions remaining the same as the base conditions.

With the steeper incline, the volume of losses decreased from that for the 1% slope, which is to be expected because the faster velocity of the runoff would provide less opportunity for infiltration. However, between the prepaneled and paneled conditions, the increase in runoff volume was less than 1%. The peak discharge and the time to peak did not change. Therefore, the greater ground slope did not significantly influence the response of the solar farm.

Soil Type

The effect of soil type on the runoff was also examined. The soil group was changed from B soil to C soil by varying the loss rate. As expected, owing to the higher loss rate for the C soil, the depths of runoff increased by approximately 7.5% with the C soil when compared with the volume for B soils. However, the runoff volume for the C soil condition only increased by 0.17% from the prepaneled condition to the paneled condition. In comparison with the B soil, a difference of 0.35% in volume resulted between the two conditions. Therefore, the soil group influenced the actual volumes and rates, but not the relative effect of the paneled condition when compared to the prepaneled condition.

Panel Angle

Because runoff velocities increase with slope, the effect of the angle of the solar panel on the hydrologic response was examined. Analyses were made for angles of 30° and 70° to test an average range from winter to summer. The hydrologic response for these angles was compared to that of the base condition angle of 45°. The other site conditions remained the same. The analyses showed that the angle of the panel had only a slight effect on runoff volumes and discharge rates. The lower angle of 30° was associated with an increased runoff volume, whereas the runoff volume decreased for the steeper angle of 70° when compared with the base condition of 45°. However, the differences (~0.5%) were very slight. Nevertheless, these results indicate that, when the solar panel was closer to horizontal, i.e., at a lower angle, a larger difference in runoff volume occurred between the prepaneled and paneled conditions. These differences in the response result are from differences in loss rates.

The peak discharge was also lower at the lower angle. At an angle of 30°, the peak discharge was slightly lower than at the higher angle of 70°. For the 2-h storm duration, the time to peak of the 30° angle was 2 min delayed from the time to peak of when the panel was positioned at a 70° angle, which reflects the longer travel times across the solar panels.

Storm Duration

To assess the effect of storm duration, analyses were made for 6-h storms, testing magnitudes for 2-, 25-, and 100-year return periods, with the results compared with those for the 2-h rainfall events. The longer storm duration was tested to determine whether a longer duration storm would produce a different ratio of increase in runoff between the prepaneled and paneled conditions. When compared to runoff volumes from the 2-h storm, those for the 6-h storm were 34% greater in both the paneled and prepaneled cases. However, when comparing the prepaneled to the paneled condition, the increase in the runoff volume with the 6-h storm was less than 1% regardless of the return period. The peak discharge and the time-to-peak did not differ significantly between the two conditions. The trends in the hydrologic response of the solar farm did not vary with storm duration.

Ground Cover

The ground cover under the panels was assumed to be a native grass that received little maintenance. For some solar farms, the area beneath the panel is covered in gravel or partially paved because the panels prevent the grass from receiving sunlight. Depending on the

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volume of traffic, the spacer cell could be grass, patches of grass, or bare ground. Thus, it was necessary to determine whether or not these alternative ground-cover conditions would affect the runoff characteristics. This was accomplished by changing the Manning's n for the ground beneath the panels. The value of n under the panels, i.e., the dry section, was set to 0.015 for gravel, with the value for the spacer or maintenance section set to 0.02, i.e., bare ground. These can be compared to the base condition of a native grass ($n = 0.15$). A good cover should promote losses and delay the runoff.

For the smoother surfaces, the velocity of the runoff increased and the losses decreased, which resulted in increasing runoff volumes. This occurred both when the ground cover under the panels was changed to gravel and when the cover in the spacer section was changed to bare ground. Owing to the higher velocities of the flow, runoff rates from the cells increased significantly such that it was necessary to reduce the computational time increment. Fig. 4(a) shows the hydrograph from a 30-panel area with a time increment of 12 s. With a time increment of 12 s, the water in each cell is discharged at the end of every time increment, which results in no attenuation of the flow; thus, the undulations shown in Fig. 4(a) result. The time increment was reduced to 3 s for the 2-h storm, which resulted in watershed smoothing and a rational hydrograph shape [Fig. 4(b)]. The results showed that the storm runoff increased by 7% from the grass-covered scenario to the scenario with gravel under the panel. The peak discharge increased by 73% for the gravel ground cover when compared with the grass cover without the panels. The time to peak was 10 min less with the gravel than with the grass, which reflects the effect of differences in surface roughness and the resulting velocities.

If maintenance vehicles used the spacer section regularly and the grass cover was not adequately maintained, the soil in the spacer section would be compacted and potentially the runoff volumes and rates would increase. Grass that is not maintained has the potential to become patchy and turn to bare ground. The grass under the panel may not get enough sunlight and die. Fig. 1 shows the result of the maintenance trucks frequently driving in the spacer section, which diminished the grass cover.

The effect of the lack of solar farm maintenance on runoff characteristics was modeled by changing the Manning's n to a value of 0.02 for bare ground. In this scenario, the roughness coefficient for the ground under the panels, i.e., the dry section, as well as in the spacer cell was changed from grass covered to bare ground ($n = 0.02$). The effects were nearly identical to that of the gravel. The runoff volume increased by 7% from the grass-covered to the bare-ground condition. The peak discharge increased by 72% when compared with the grass-covered condition. The runoff for the bare-ground condition also resulted in an earlier time to peak by approximately 10 min. Two other conditions were also modeled, showing similar results. In the first scenario, gravel was placed directly under the panel, and healthy grass was placed in the spacer section, which mimics a possible design decision. Under these conditions, the peak discharge increased by 42%, and the volume of runoff increased by 4%, which suggests that storm-water management would be necessary if gravel is placed anywhere.

Fig. 5 shows two solar panels from a solar farm in New Jersey. The bare ground between the panels can cause increased runoff rates and reductions in time of concentration, both of which could necessitate storm-water management. The final condition modeled involved the assumption of healthy grass beneath the panels and bare ground in the spacer section, which would simulate the condition of unmaintained grass resulting from vehicles that drive over the spacer section. Because the spacer section is 53% of the cell, the change in land cover to bare ground would reduce losses and decrease runoff travel times, which would cause runoff to amass as it

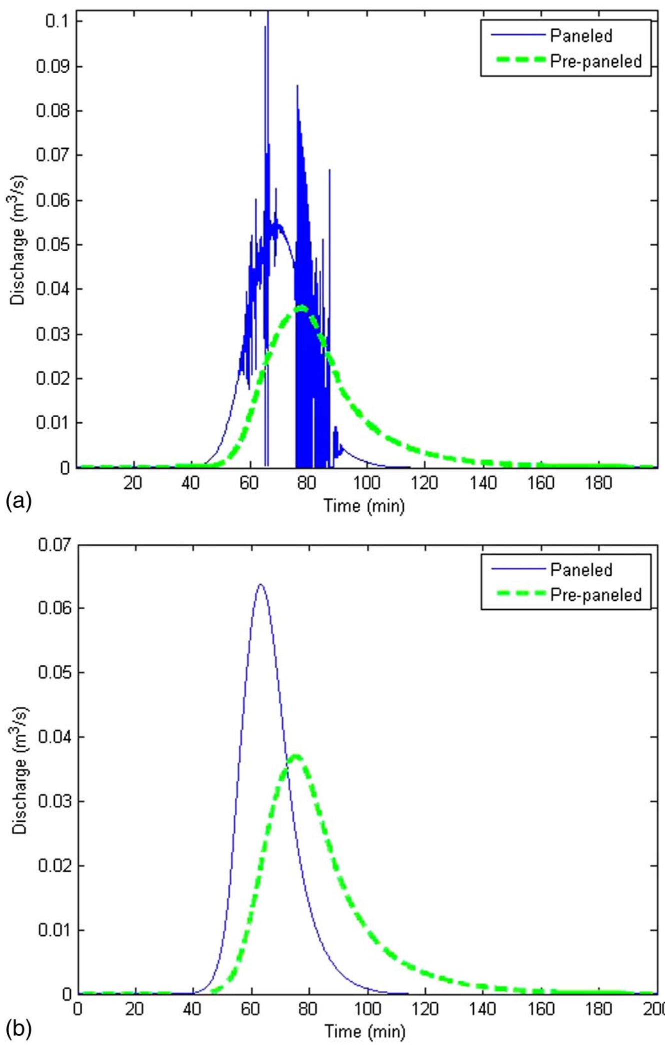

Fig. 4. Hydrograph with time increment of (a) 12 s; (b) 3 s with Manning's n for bare ground

Fig. 5. Site showing the initiation of bare ground below the panels, which increases the potential for erosion (photo by John Showler, reprinted with permission)

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moves downgradient. With the spacer section as bare ground, the peak discharge increased by 100%, which reflected the increases in volume and decrease in timing. These results illustrate the need for maintenance of the grass below and between the panels.

Design Suggestions

With well-maintained grass underneath the panels, the solar panels themselves do not have much effect on total volumes of the runoff or peak discharge rates. Although the panels are impervious, the rainwater that drains from the panels appears as runoff over the downgradient cells. Some of the runoff infiltrates. If the grass cover of a solar farm is not maintained, it can deteriorate either because of a lack of sunlight or maintenance vehicle traffic. In this case, the runoff characteristics can change significantly with both runoff rates and volumes increasing by significant amounts. In addition, if gravel or pavement is placed underneath the panels, this can also contribute to a significant increase in the hydrologic response.

If bare ground is foreseen to be a problem or gravel is to be placed under the panels to prevent erosion, it is necessary to counteract the excess runoff using some form of storm-water management. A simple practice that can be implemented is a buffer strip (Dabney et al. 2006) at the downgradient end of the solar farm. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the gravel and panels were installed. Alternatively, a detention basin can be installed.

A buffer strip was modeled along with the panels. For approximately every 200 m of panels, or 29 cells, the buffer must be 5 cells long (or 35 m) to reduce the runoff volume to that which occurred before the panels were added. Even if a gravel base is not placed under the panels, the inclusion of a buffer strip may be a good practice when grass maintenance is not a top funding priority. Fig. 6 shows the peak discharge from the graveled surface versus the length of the buffer needed to keep the discharge to prepaneled peak rate.

Water draining from a solar panel can increase the potential for erosion of the spacer section. If the spacer section is bare ground, the high kinetic energy of water draining from the panel can cause soil detachment and transport (Garde and Raju 1977; Beuselinck et al. 2002). The amount and risk of erosion was modeled using the velocity of water coming off a solar panel compared with the velocity and intensity of the rainwater. The velocity of panel

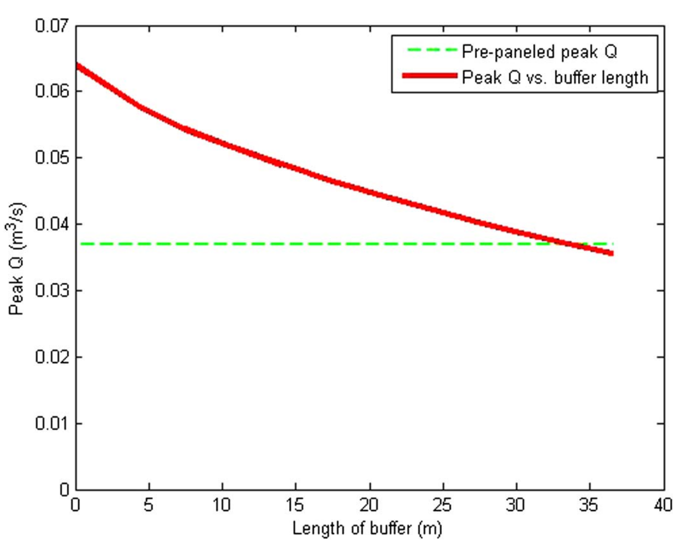

Fig. 6. Peak discharge over gravel compared with buffer length

runoff was calculated using Manning's equation, and the velocity of falling rainwater was calculated using the following:

$$V_t = 120\, d_r^{0.35} \tag{1}$$

where d_r = diameter of a raindrop, assumed to be 1 mm. The relationship between kinetic energy and rainfall intensity is

$$K_e = 916 + 330 \log_{10} i \tag{2}$$

where i = rainfall intensity (in./h) and K_e = kinetic energy (ft-tons per ac-in. of rain) of rain falling onto the wet section and the panel, as well as the water flowing off of the end of the panel (Wischmeier and Smith 1978). The kinetic energy (Salles et al. 2002) of the rainfall was greater than that coming off the panel, but the area under the panel (i.e., the product of the length, width, and cosine of the panel angle) is greater than the area under the edge of the panel where the water drains from the panel onto the ground. Thus, dividing the kinetic energy by the respective areas gives a more accurate representation of the kinetic energy experienced by the soil. The energy of the water draining from the panel onto the ground can be nearly 10 times greater than the rain itself falling onto the ground area. If the solar panel runoff falls onto an unsealed soil, considerable detachment can result (Motha et al. 2004). Thus, because of the increased kinetic energy, it is possible that the soil is much more prone to erosion with the panels than without. Where panels are installed, methods of erosion control should be included in the design.

Conclusions

Solar farms are the energy generators of the future; thus, it is important to determine the environmental and hydrologic effects of these farms, both existing and proposed. A model was created to simulate storm-water runoff over a land surface without panels and then with solar panels added. Various sensitivity analyses were conducted including changing the storm duration and volume, soil type, ground slope, panel angle, and ground cover to determine the effect that each of these factors would have on the volumes and peak discharge rates of the runoff.

The addition of solar panels over a grassy field does not have much of an effect on the volume of runoff, the peak discharge, nor the time to peak. With each analysis, the runoff volume increased slightly but not enough to require storm-water management facilities. However, when the land-cover type was changed under the panels, the hydrologic response changed significantly. When gravel or pavement was placed under the panels, with the spacer section left as patchy grass or bare ground, the volume of the runoff increased significantly and the peak discharge increased by approximately 100%. This was also the result when the entire cell was assumed to be bare ground.

The potential for erosion of the soil at the base of the solar panels was also studied. It was determined that the kinetic energy of the water draining from the solar panel could be as much as 10 times greater than that of rainfall. Thus, because the energy of the water draining from the panels is much higher, it is very possible that soil below the base of the solar panel could erode owing to the concentrated flow of water off the panel, especially if there is bare ground in the spacer section of the cell. If necessary, erosion control methods should be used.

Bare ground beneath the panels and in the spacer section is a realistic possibility (see Figs. 1 and 5). Thus, a good, well-maintained grass cover beneath the panels and in the spacer section is highly recommended. If gravel, pavement, or bare ground is

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deemed unavoidable below the panels or in the spacer section, it may necessary to add a buffer section to control the excess runoff volume and ensure adequate losses. If these simple measures are taken, solar farms will not have an adverse hydrologic impact from excess runoff or contribute eroded soil particles to receiving streams and waterways.

Acknowledgments

The authors appreciate the photographs (Figs. 1 and 5) of Ortho Clinical Diagnostics, 1001 Route 202, North Raritan, New Jersey, 08869, provided by John E. Showler, Environmental Scientist, New Jersey Department of Agriculture. The extensive comments of reviewers resulted in an improved paper.

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Kennedy Jenks

11.10.2017 | NEWS

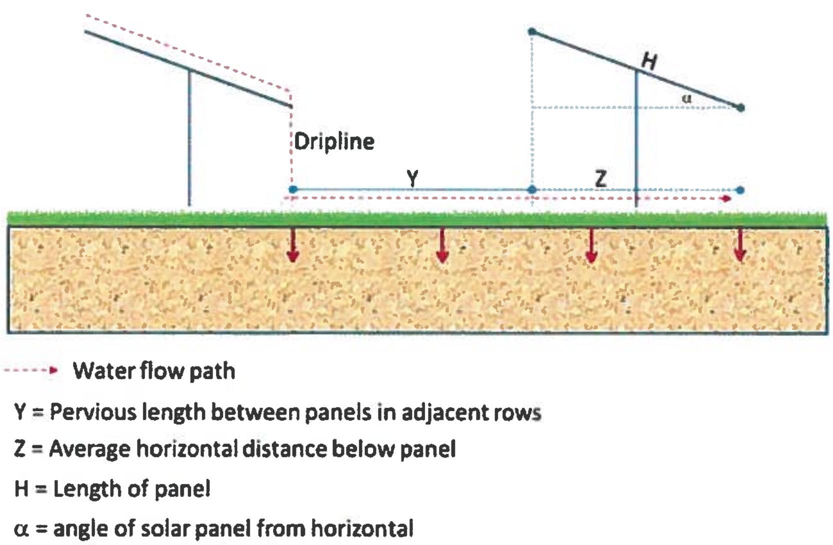
A Rainy Day at a Solar Farm

BY KENNEDY JENKS

Elevated ground-mount solar photovoltaic (PV) facilities present a unique situation for stormwater management because they usually involve an impervious surface elevated above a pervious vegetated surface. In this blog post, we will discuss the unique hydrologic processes at these solar PV facilities and the associated stormwater permitting requirements in various states across the country.

Hydrologic Processes at Solar PV Facilities

Stormwater runoff from solar PV facilities is generated primarily from rain that falls on access roads, inverter pads, and solar PV panels themselves. Water that falls on solar PV panels runs down the panel to the dripline, and eventually falls to the underlying surface, potentially causing localized erosion and/or scour. The primary factors that influence the potential for erosion and/or scour are shown on Figure 1. Some of the water falling on solar PV panels will infiltrate and some may run-off downslope and eventually to a collection basin or off site. [1]



There is some debate as to whether the solar PV panels themselves have a significant effect on runoff volumes, peak runoff or times to peak runoff. A 2011 study published by the American Society of Civil Engineers [2] found that solar PV panels themselves do not have a significant effect on these key stormwater characteristics. The study notes, however, that if the ground cover under the panels is gravel or bare ground, resulting from design decisions or lack of maintenance, the peak discharge may increase significantly. In addition, the study found that the kinetic energy of the sheetflow from the panels was greater than that of the rainfall, which could cause erosion at the base of the panels.

For more detailed information, the reader is directed to the Minnesota Pollution Control Agency's calculator (link) with detailed instructions for project proponents to estimate the hydrologic impacts of installing solar PV panels [1].

Approaches to Stormwater Permitting at Solar PV Facilities

Based on a brief internet search conducted in July 2017, the following state stormwater regulatory agencies have developed guidance or specific requirements for stormwater management at solar PV facilities. Most agencies do not count panels as impervious cover, reasoning that runoff can flow beneath the panel and infiltrate into the ground the same as it did before the panel was installed above it.

Maryland

Maryland's Department of the Environment guidance states that for the purposes of issuing a stormwater permit for a solar project, calculations relating to the impervious surface of the project must include only the foundation or base supporting the solar PV panel [3].

Maryland guidance further suggests that developers consider the following factors [4]:

- Vegetated area receiving runoff must be equal to or greater in length than the disconnected surface (e.g., width of the row of solar PV panels)
- Runoff must sheetflow onto and across vegetated areas to maintain the disconnection
- Disconnections should be located on gradual slopes (≤ 5%) to maintain sheetflow. Level spreaders, terraces, or berms may be used to maintain sheetflow conditions if the average slope is steeper than 5%. However, installations on slopes greater than 10% will require an engineered plan that ensures adequate treatment and the safe and non-erosive conveyance of runoff to the property line or downstream stormwater management practice.
- Construction vehicles and equipment should avoid areas used for disconnection during installation of the solar PV panels.
- Groundcover vegetation must be maintained in good condition in those areas receiving disconnected runoff. Areas receiving runoff should be protected from future compaction.

New Jersey

The New Jersey Department of Environmental Protection exempts solar PV panels in calculations of impervious cover for the purposes of stormwater permitting. [5]

Massachusetts

The Massachusetts Department of Environmental Protection has indicated that solar PV panels should not be considered

Pennsylvania

The Pennsylvania Department of Environmental Protection considers solar PV panels to be pervious cover and does not require additional Post Construction Stormwater BMPs, provided the following guidelines are followed [7]:

- Earth disturbance and grading activities must be minimized and natural vegetal cover must be preserved and/or restored.
- Vegetal cover must have 90% or better uniform coverage and must not be subject to chemical fertilization and herbicides/pesticides. A meadow condition is preferable, particularly for slopes between 5 and 10%. Mowed areas, where approvable, should be kept to a minimum of 4".
- Individual PV panels within an array must be arranged in a fashion that allows the passage of runoff between each module. If the width of the module exceeds 3 feet (i.e. there is inadequate spacing between modules), then BMPs such as infiltration trenches (min. 12" wide by 12" deep) or infiltration berms must be installed downgradient between each row. The panels must be arranged to allow the growth of vegetation beneath and between arrays.
- Ground-mounted solar PV panels must be supported with structures/foundations occupying a maximum of 5% of the total project area.
- Solar PV panels must be situated on mild slopes (10% max). If larger than 10% slopes are proposed, then BMPs such as infiltration trenches (min. 12" wide by 12" deep) or infiltration berms shall be installed downgradient between each row.
- The lowest vertical clearance of the solar PV array must be at an elevation of 10 feet or less from the ground, but is also at an adequate height to promote vegetative growth below the array.

North Carolina

North Carolina allows solar PV panels to be considered pervious if they are configured to promote sheetflow of stormwater from the panels and natural infiltration of stormwater into the ground beneath the panels. Other structures associated with the solar PV facility such as buildings, entrance roads, transformers, and footings are still considered impervious. [9]

Minnesota

The Minnesota Pollution Control Agency (MPCA) allows for the use of a volume credit for solar PV facilities that are vegetated beneath and between panels. This excludes sites that have rock bases [8]. The water quality volume calculation may be completed using the disconnected impervious credit method shown in the Solar Panel Calculator on the MPCA's webpage (link). The disconnected impervious credit method uses an Excel spreadsheet to calculate 1) the total water volume required credited and 2) the remaining water quality volume to be treated. Depending on site-specific conditions, solar PV facilities can expect a 50% – 85% reduction of required water quality volume. The remainder of the required water quality volume must be treated on site. [8]

Conclusions

Irrespective of state-specific permitting approaches, elevated ground-mount solar PV arrays may have the potential to alter the volume, velocity, and discharge pattern of stormwater runoff at a site during and after construction. According to MPCA, sites can expect a 15 – 50% increase in volume due to the installation of solar PV panels. Additionally, a solar PV is also at an adequate height to promote vegetative growth below the array.

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Conclusions

Irrespective of state-specific permitting approaches, elevated ground-mount solar PV arrays may have the potential to alter the volume, velocity, and discharge pattern of stormwater runoff at a site during and after construction. According to MPCA, sites can expect a 15 – 50% increase in volume due to the installation of solar PV panels. Additionally, a solar PV development site stripped of vegetation may result in erosive stormwater flows. Project proponents are advised to carefully consider the impacts of this additional runoff on their operations and overall compliance with environmental regulations.

KJ's Stormwater Community of Practice has assisted a number of solar industry clients with the complex world of stormwater management. We are well versed in state-specific requirements and guidance for permitting, and proficient in the development of hydrologic and hydraulic models that can be used to design effective stormwater management strategies. We also have experience in erosion and sedimentation controls during solar PV construction activities and in site-stabilization/restoration after construction activities are completed. Contact us for more information on how we can help you handle a rainy day at your solar PV facility.

If you are interested in more information on Kennedy Jenks, don't forget to subscribe to our blog!

KJ

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Clean Water

Chapter 102 Permitting for Solar Panel Farms

Frequently Asked Questions (FAQ)
January 2, 2019

Background

With renewed interest in development of clean, renewable energy in Pennsylvania, the development of solar photovoltaic installations is increasing in the state. This FAQ document was developed to clarify the Department of Environmental Protection's (DEP's) interpretations concerning applicability and implementation of National Pollution Discharge Elimination System (NPDES) permits for stormwater discharges associated with construction activities, including erosion and sediment control (E&S) and post-construction stormwater management (PCSM) for solar panel farms. This document refers to a solar panel farm as a large-scale application of solar panels to generate electricity.

Nothing in this document affects regulatory requirements. The interpretations herein are not an adjudication or a regulation. There is no intent on the part of DEP to give the interpretations in this document that weight or deference. This document provides a framework within which DEP and delegated county conservation districts (CCDs) will exercise administrative discretion in the future. DEP reserves the discretion to deviate from the interpretations in this document if circumstances warrant.

For additional information on solar energy use the following link:

http://www.dep.pa.gov/Citizens/Energy/Renewables/Pages/Solar.aspx

FAQ #1: Is NPDES permit coverage required for the development of a solar panel farm?

If the earth disturbance associated with the construction of a solar panel farm will be at least 1 acre, NPDES permit coverage is required (see 25 Pa. Code § 102.5(a)).

FAQ #2: What earth disturbance is associated with development of a solar panel farm?

Earth disturbance activities necessary to construct solar panel farms will vary depending on the topography, slopes, and soils of the proposed location of the solar panel farm, the layout of the solar arrays, and whether the arrays are fixed panel or dual tracking. In some instances, significant grading, including clearing and grubbing, of the site may be necessary. In other cases, minimal disturbance may be necessary to excavate the site to provide level ground for the installation of the solar modules. The total earth disturbance of the project would be the cumulative impacts of the earth disturbances associated with the installation of the support/mounting structures for each module, as well as any associated access roads and support building(s).

FAQ #3: What E&S BMPs are necessary for the installation of a solar panel farm?

A person proposing earth disturbance for the development of a solar panel farm must utilize appropriate E&S best management practices (BMPs) applicable to the size and scope of the proposed project. Acceptable E&S BMPs can be found in the *Erosion and Sediment Pollution Control Program Manual*, Department of Environmental Protection, No. 363-213-008. Persons proposing solar panel farms should minimize the extent and duration of the earth disturbance activity, maximize protection of the existing drainage features and vegetation, avoid soil compaction, and utilize any other measures or controls to prevent or minimize the generation of increased stormwater runoff.

FAQ #4: What are the PCSM requirements for a fixed-panel unit?

Many projects use mounting structures where the solar modules are mounted at a fixed inclination calculated to provide the optimum annual output profile. The modules are normally oriented towards the Equator, at a tilt angle slightly less than the latitude of the site. In some cases, depending on local climatic and topographical conditions or electricity pricing regimes, different tilt angles can be used, or the arrays might be offset from the normal East-West axis to favor morning or evening output.

All construction projects need to have some consideration of the impact that their project will have on stormwater runoff. With some solar panel farm projects these impacts will be minimal and may not require a detailed stormwater analysis to be completed. If the following conditions are met, then the project area of a fixed photovoltaic solar panel farm project can be considered pervious cover, a detailed stormwater analysis is not needed, and PCSM BMPs are not necessary:

1. Projects where earth disturbance and grading activities are minimized and where natural vegetative cover is preserved and/or restored. The utilization of low impact construction techniques must be used. Refer to BMP 5.6.1: Minimize Total Disturbed Area – Grading, BMP 5.6.2: Minimize Soil Compaction in Disturbed Areas, and BMP 5.6.3: Re-Vegetate and Re-forest Disturbed Areas, Using Native Species from the *PA Stormwater Best Management Practices Manual*, Department of Environmental Protection, No. 363-0300-002, (December 30, 2006).

2. The vegetative cover must have a minimum uniform 90% perennial vegetative cover with a density capable of resisting accelerated erosion and sedimentation. The 90% standard exceeds the 70% standard as in 25 Pa. Code § 102.22(a)(i), as the vegetation may be typically the primary and only BMP used for solar panel farms.

   (a) A meadow condition is preferable especially for projects located on slopes between 5-10%.
   (b) If areas under the solar panels must be mowed, then the vegetative cover should not be cut to less than 4 inches in height.

(c) Vegetated areas will not be subject to chemical fertilization or herbicide/pesticides application, except for those applications necessary to establish the vegetative cover and in accordance with an approved E&S Plan.

3. The individual photovoltaic panels within an "array" are arranged in a fashion that:

   (a) Allows the passage of runoff between each module, thereby minimizing the creation of concentrated runoff.
   (b) Allows for the growth of vegetation beneath the panel and between "arrays."

4. Ground mounted solar panels that are supported with structures/foundations require little earth disturbance for their installation/construction. Unless evidence is provided to the contrary, it will be assumed that for these ground mounted solar panels themselves (not including access drive, etc.) will disturb 5% of the total project area.

5. Solar panels must be situated on slopes of 10% or less.

6. The lowest vertical clearance of the solar "array" should be 10 feet or less from the surface of the ground but must be of adequate height to promote vegetative growth below the "array." Limiting the height of the solar "array" will minimize the potential for accelerate erosion to occur along the drip line of the solar "array".

Meeting these conditions will minimize the potential for accelerated erosion (by creating a stable flow condition under and around the solar panels) and provide for an uninterrupted hydrologic cycle (by creating pervious cover under the solar panels).

FAQ #5: What if I cannot meet the conditions outlined above as part of my project for PCSM planning?

If you cannot meet all the conditions listed above to have the project treated as pervious cover, the person proposing the earth disturbance activity will need to complete an analysis of how the proposed solar panel farm project will impact the amount and quality of stormwater runoff from the site, to determine the need for PCSM BMPs. The goal of stormwater management is to replicate the pre-development stormwater runoff condition after the construction project is finished. Post-development runoff conditions will dictate how much of a stormwater analysis must be provided for the project.

FAQ #6: Is there a difference for the PCSM requirements for a tracked-panel unit?

To maximize the intensity of incoming direct radiation, solar panels should be orientated normal to the sun's rays. To achieve this, arrays can be designed using two-axis trackers, capable of tracking the sun in its daily orbit across the sky, and as its elevation changes throughout the year. These arrays need to be spaced out to reduce inter-shading as the sun moves and the array orientations change, so they may need more land area. They also require more complex mechanisms to maintain the array surface at the required angle. This increase land area may result in additional earth disturbance for the project. However, the same PCSM requirements addressed for fixed panel units as outlined in FAQ #4, Items 1-6 would need to be addressed for tracked panel units as well. If the project area meets all 6 conditions as outlined in FAQ #4, then the project area of a tracked, two-axis photovoltaic solar panel farm would be considered pervious cover and will not require any additional PCSM BMPs.

FAQ #7: What if I proposed the use of gravel rather than vegetative cover under the solar panels?

The use of gravel under the solar panels is permissible; however, the use of gravel would not be considered pervious cover. PCSM is required for the use of the gravel under the solar panels, and the person proposing the project will need to provide a stormwater analysis in accordance with 25 Pa. Code §§ 102.8(g)(2) & 102.8(g)(3).

When calculating the stormwater analysis, projects that are utilizing a minimum of a 6-inch layer of clean, washed and uniformly graded gravel may utilize the void space as storage for stormwater purposes if the project site (e.g., slopes exceeding 10% are not applicable) and the underlying soil conditions allow for it. Sand layers (or another filter media, as approved by DEP) may be introduced into the stormwater design to help address water quality issues.

FAQ #8: What are the PCSM requirements for roadways and support buildings associated with the development of the solar panel farm?

All impervious areas associated with roadways and support buildings will need to follow normal protocols when performing the PCSM stormwater analysis.

FAQ #9: Are there any additional requirements if I need to re-grade the entire area?

Projects that are unable to minimize earth disturbance or grading activities should employ soil/landscape restoration and soil amendments in accordance with the recommendations of the *PA Stormwater BMP Manual*, BMP 6.7.1: Landscape Restoration and BMP 6.7.3: Soil Amendment and Restoration.

FAQ #10: If the width of my solar panels modules will exceed 3 feet are additional BMPs or design considerations necessary?

Yes, if the solar panels are too large, then an adequate vegetative cover may not be able to be established and maintained. Additional BMPs such as infiltration trenches or infiltration berms should be installed downgradient between each row (even if the conditions in FAQ #4 are met). See *PA Stormwater BMP Manual*, BMP 6.4.4: Infiltration Trench and BMP 6.4.10: Infiltration Berm and Retentive Grading for additional guidance.

FAQ #11: If the placement of the support structure/foundations result in these structures occupying more than 5% of the total project area, how is the PCSM stormwater analysis addressed?

Since greater than 5% of the total project area is occupied by the support structure/foundations, the impervious area is increased and the project cannot be treated as pervious cover. You will need to provide an analysis of the impact this will have on the amount and quality of stormwater runoff from the site. Additional drainage conveyances and PCSM BMPs will need to be used to address stormwater issues.

FAQ #12: The slope of my solar panel farm project is greater than 10%, are additional BMPs or design considerations necessary?

Yes, where the slope exceeds 10% additional BMPs such as infiltration trenches or infiltration berms should be installed downgradient between each row. See *PA Stormwater BMP Manual*, BMP 6.4.4: Infiltration Trench and BMP 6.4.10: Infiltration Berm and Retentive Grading for additional guidance.

FAQ #13: The elevation of my solar panels will be greater than 10 feet in height, are additional BMPs and design consideration necessary?

Yes, if the height of the solar panels exceeds 10 feet maximum additional controls are necessary to prevent and minimize accelerated erosion and scour along the drip line or provide some type of energy dissipation controls.

FAQ #14: Can agricultural crops be grown underneath the solar panels?

Yes, "agrivoltaics," the co-development of the same area of land for both solar photovoltaic power and conventional agriculture, may be used provided that:

1. Only shade tolerant crops may be used.

2. Crops must be no tilled in. Moldboard Plowing is not permitted.

3. A written erosion and sediment control plan must be developed for agricultural plowing or tilling activities or a portion of the overall farm conservation plan must identify BMPs used, in accordance with the requirements of Chapter 102.4(a) for the field(s) where the solar panel farm is located.

4. Any cutting or mowing of the agricultural crop is limited to a height of no less than 4 inches minimum.

5. Application of chemical fertilization or herbicides/pesticides is limited to the agronomic needs to the crop(s).

6. Additional BMPs may be used depending on site conditions, slopes and soil types.

7. The height of the solar panels from the ground will likely exceed 10 feet to allow for farm machinery to access the area, if so additional controls to address erosion and scour along the dripline and provide energy dissipation may be necessary.