Best management practices to minimize impacts of solar farms on landscape hydrology and water quality

A Proposed 'State of the Science' STAC Workshop

Workshop steering committee

Name	Position	Institution	Expertise
Lauren McPhillips	Assistant Professor Workshop lead	Penn State	Water quality; Stormwater management; Current field research on solar farm
Anthony Buda	Research Hydrologist STAC member	USDA ARS	Watershed hydrology; nutrients
Zachary Easton	Professor + Extension Specialist; STAC member	Virginia Tech	Watershed modeling and management
W. Lee Daniels	Professor	Virginia Tech	Land restoration, soil science
Siobhan Fathel	Asst. Teaching Professor	Penn State	Renewable energy; water quality management
John Ignosh	Extension Specialist	Virginia Tech	Renewable energy; nutrient management
Cibin Raj	Assistant Professor	Penn State	Water quality modeling
David Sample	Professor + Extension Specialist	Virginia Tech	Stormwater management and modeling

Topic background

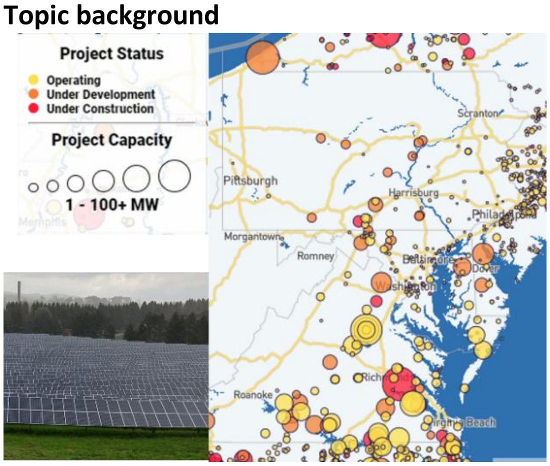

Figure 1. Map of existing and proposed major solar projects with example photo (Map/data source: SEIA 2022)

As solar energy becomes an increasingly cheap source of renewable energy, major utility-scale solar (USS) panel installations, which generate 1 MW or more and are often called solar farms, are rapidly growing in the US (US Energy Information Administration (EIA), 2020). There are over 5,300 major solar projects across the nation, with existing installations generating 74 GW, and projects under construction or in development generating 70 GW (Solar Energy Industries Association, 2022). In the Chesapeake Bay watershed, there are already over 100 existing or proposed projects (Figure 1).

Solar farms cover large areas of land (i.e. from tens of acres to greater than 1000 acres). Moreover, ground-mounted solar panels create a unique set of conditions with impervious surfaces elevated over pervious land. As such, there is potential to alter natural hydrologic and water quality processes, including runoff generation and erosion (Hernandez et al., 2014). These changes could have direct implications for the ability to achieve Total Maximum Daily Load reductions for the Chesapeake Bay. The extent of these impacts are dependent on prior land use (e.g. agricultural land, forest), other site conditions like slope and soils, and site management.

Current guidance on best management practices (BMPs) for minimizing negative environmental impacts of solar farms is highly variable across the Chesapeake Bay watershed. Only some states within the Chesapeake Bay watershed currently have solar farm-specific guidance for stormwater management; to our knowledge, that is currently Maryland and Pennsylvania (Maryland Department of Environment, 2013; PA Dept of Environmental Protection (DEP), 2021). Because of strong market conditions and an increased focus on reducing carbon footprint, some states have implemented expedited permits-by-rule for this activity. This has caused negative reaction in some local communities (VDEQ, 2012).

Existing guidance addresses issues such as minimizing compaction during the construction process, stipulating the amount of space needed between panel rows to facilitate infiltration, specifying optimal vegetation characteristics and management, and determining if post-construction structural stormwater management is needed under certain conditions. The diversity of landscapes in which solar farms could be installed and nascent BMP recommendations governing such installations limits our ability to understand and model the net effect of solar expansion on downstream water quality in the Chesapeake Bay watershed over the lifecycle cycle of USS projects (i.e., construction, operation, decommissioning).

There is a small but rapidly growing body of research addressing the question of how solar farms impact landscape conditions and processes. Existing field measurements from a few locations indicate redistribution of soil moisture around solar farms (Choi et al., 2020; Hassanpour Adeh et al., 2018; Lambert et al., 2021). Net impacts on runoff and erosion are less clear, and existing work largely comes from unvalidated modeling efforts (Cook & McCuen, 2013). Research focused on coupling solar farms with agriculture as 'agrivoltaics' demonstrates reduced evaporative water losses and associated crop stress, but runoff and water quality implications, particularly in more humid climates, are not clear (Marrou et al., 2013).

The land transitioned to this new use is growing rapidly within the Chesapeake Bay watershed, with Virginia alone anticipating more than 100,000 acres eventually needed for solar farms to meet renewable energy goals. Thus it is critical that we adequately understand the implications of this transition on hydrology and water quality, and how to best manage this transition to minimize adverse environmental impacts. There could be opportunities to prioritize certain types of land for conversion to solar farms that may facilitate nutrient and runoff reductions. Implications of certain conversions may merit further research, such as the conversion of conventional agricultural land with soils rich in legacy nutrients. The scale of parcels being converted to solar farms is also of great importance and uncertainty. Current erosion and stormwater control guidelines are not well adapted for the massive scale of some projects and it is unclear how the nature of impacts varies with the scale of solar farms.

The proposed workshop topic addresses issues that fall under the Chesapeake Bay Program's Management Strategies of Clean Water (e.g. Healthy Watersheds) and Conserved Lands (e.g. Land Use Methods and Metrics Development).

Rationale for workshop

It is a pivotal time to convene around this issue with an increasing push to transition towards renewable energy. Presently, there is very little knowledge on the potential impact of this land use transition for the Chesapeake Bay watershed, and our ability to meet TMDL goals. Current BMP recommendations are varied across the watershed, with only some states providing solar-specific stormwater management guidance. There is a need to ascertain the state of the science on solar farms and environmental quality that will inform field research and modeling in the Chesapeake Bay region. Given that the state of science in this topical area is rapidly evolving, relevant research is ongoing and not-yet-published, a facilitated discussion with invited experts would provide the best way forward. Thus a workshop would be an appropriate forum to address these issues and provide pointed guidance and recommendations for most sustainably managing this major land use transition in our region.

Proposed questions to answer at workshop

1) What is the state of science on how solar farms impact hydrology and water quality under a range of site and management conditions and project scales?
2) What are current best management practices and policies, and where in our region are there opportunities for improving recommendations and/or policies?
3) What are the key gaps with respect to research needs to better answer questions 1 and 2?

Name	Affiliation	Expertise
David Mulla	Professor, University of Minnesota + Co-PI of NREL PV-SMaRT research team	Modeling impact of solar farms on soil moisture and runoff
Sujith Ravi	Assoc. Prof., Temple University	Field evaluation of solar farm impacts on soil properties
Margaret Hoffman	Assistant Prof, Penn State University	Landscape contracting, vegetation selection for solar farm BMPs
Todd Walter or other TBD	Professor, Cornell University	Monitoring hydrology on solar farm in NY with grazing agri-voltaic management

Potential Additional Participants: Gary Shenk (CBP watershed model); Jordan Macknick (National Renewable Energy Lab); Tom Schueler (Chesapeake Stormwater Network); Richard Street (Street Development Solutions); Relevant staff from state agencies with stormwater management authority (e.g. PA DEP)

Workshop products

Workshop products will be provided within 90 days of the workshop's completion.

A STAC Report will provide a technical summary of the workshop, including synthesis of the existing body of science relevant to understanding how solar farms impact hydrology and water quality, associated management recommendations, and gaps and critical needs for new research. The report will include actionable recommendations to the Chesapeake Bay Program and allied agencies.

A STAC fact sheet will distill key findings from the technical report. We will Identify key recipients of the report and factsheets, such as Chesapeake Bay Program committees, Goal Implementation

Teams (GIT), workgroups, or other agencies or stakeholders who would be encouraged to adopt workshop outcomes.

References

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