LOCAL ENVIRONMENTAL BENEFITS OF SOLAR FARMING IN WISCONSIN

APPENDIX B1: ANALYSIS OF PHOSPHORUS RUNOFF REDUCTION FROM A SOLAR FARM SITED ON FORMER CROPLAND AT THE PROPOSED ONION RIVER SOLAR FARM

CLEAN WISCONSIN

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1. Introduction and Methodology

This analysis was originally submitted Paul Mathewson, PhD, on behalf of Clean Wisconsin to Wisconsin Public Service Commission docket 9805-CE-100, Application for a Certificate of Public Convenience and Necessity of Onion River Solar, LLC to Construct a Solar Electric Generation Facility.

To obtain an estimate of how much phosphorus surface runoff to local waterways could be saved by replacing existing row crops with the planned solar fields at the proposed Onion River solar farm, I used SnapPlus 20.0 software. SnapPlus is Wisconsin's nutrient management planning software, developed by researchers at the University of Wisconsin with a well-established history of use and vetting (Panuska et al. 2007, Good et al. 2012, Vadas et al. 2015). Of interest for this analysis, the software calculates phosphorus runoff, based on a field's soil test phosphorus concentration, predominant soil type, slope, proximity to waters, and cropping, tillage, and nutrient management practices.

Onion River Solar Farm project boundaries were intersected with field boundaries from the Agricultural Conservation Planning Framework (ACPF) database. The ACPF database contains a history of crop rotations on individual fields, which in turn are based on USDA's National Agricultural Statistics Service's Cropland Data Layer. For this analysis, I used the most recent 6-year crop rotation (2014-2019) as baseline crop rotations on each field and assumed this rotation would continue into the future. One important limitation of this crop history dataset for the purposes of this analysis is that it does not distinguish between corn grown for grain and corn grown for silage. SnapPlus distinguishes between corn for grain and corn for silage, with fields growing corn for silage having more soil and phosphorus loss. To bound this uncertainty, I performed calculations assuming all corn was corn for grain and assuming all corn was corn for silage.

I imported shapefiles of the fields within the Onion River project area to SnapMaps within the SnapPlus software to obtain the predominant soil types, slopes and distances from waters. Soil phosphorus concentrations were based on data from nutrient management plans from two farmers leasing approximately half of the fields used by the project (Fig. 1). For fields included in these plans I used most recent soil P test from the nutrient management plans. For fields not covered by the nutrient management plans I was able to obtain, I used the average P test for known fields of the same soil type and general crop history. For fields without similar soil type

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and crop history, I used the Sheboygan county average value from DATCP's summary of all soil tests from 2010-2014 (the most recent summary available).

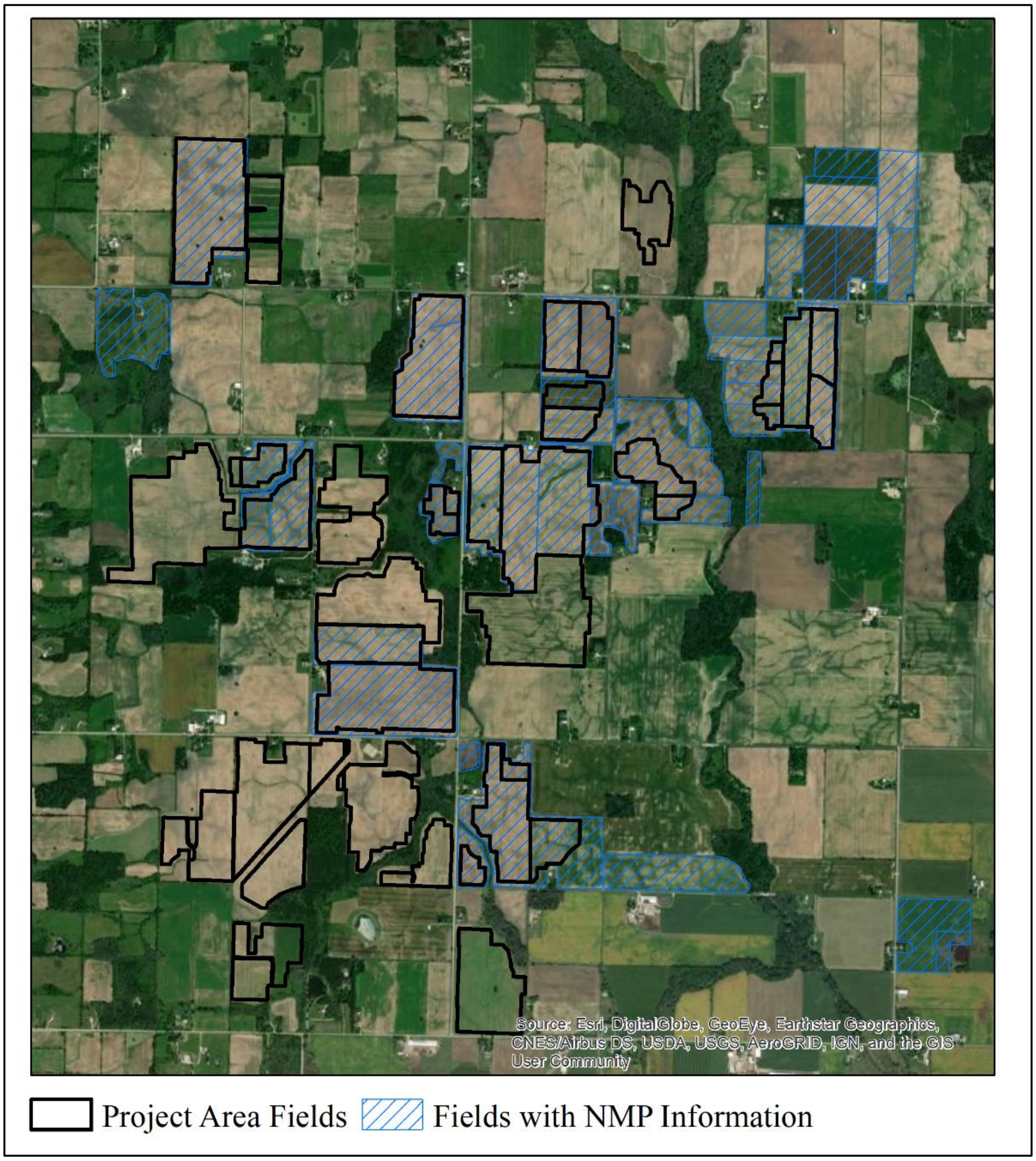

Figure 1. Map of fields within the Onion River Project area (black outlines) and fields in the area for which specific cropping and nutrient management plans were available (blue hatching).

Tillage practices and target yields for various crops were estimated based on common practices listed in nutrient management plans for fields being leased for the proposed project that I was able to obtain (Table 1). Specifically, most corn, soybean, and winter wheat fields were chisel tilled in the fall and most alfalfa was no till. Typical yields used in this analysis are summarized in Table 2

Table 1. Summary of crop fields listed as no-till in nutrient management plans for fields in and around the project area.

Crop	Total Crop Years Found in NMPs	Years No Till
Corn[1]	91	22
Soybeans	110	24
Winter Wheat	42	9
Other	43	0

For the purposes of this analysis, I assumed that all the fields were fertilized with phosphorus at UW recommended levels. To simulate this in SnapPlus, I used the Fertilizer Allocator Tool to apply Triple Superphoshate fertilizer as close as possible to the UW recommended level for each field. There are several application methods available in the Fertilizer Applicator Tool, including unincorporated (broadcast), incorporated, and subsurface application. Unincorporated application results in the highest calculated phosphorus (P) runoff, and subsurface application results in the lowest calculated P runoff. To address the uncertainty as to how fertilizers are applied on any given field, I ran simulations assuming different application methods, as summarized in Table 2.

In total, three different crop/management scenarios were assumed. First a high P runoff scenario in which all corn crops were assumed to corn for silage, fall tillage (chisel, disked) was assumed for all crops other than alfalfa, and fertilizer application was assumed to be unincorporated. Second, a low P runoff scenario assumed that all corn crops were corn for grain, no till was practiced on all fields, and fertilizer was applied in an unincorporated manner (forced by the assumed no-till practice on the fields). Third, a “best estimate” scenario was conducted based on the most common crops/practices listed in the nutrient management plans for fields included in the project area. All corn was assumed to be corn for grain (69 of 91 corn cropping years were listed as corn for grain), all crops except alfalfa were assumed to be tilled in the fall, and fertilizer was assumed to be incorporated upon application (the moderate P runoff choice).

Table 2. Summary of the crop, tillage, and nutrient management inputs used in SnapPlus phosphorus runoff calculations. The High P Runoff inputs were chosen to result in the highest P runoff calculations; low P Runoff inputs were chosen to minimize P runoff calculations. Best estimate inputs are chosen based on the most common practices observed in the nutrient management plans for fields included in the project area. Corn, soybean, winter wheat, and alfalfa were by far the primary crops identified in

these fields so only those are summarized here, but a few other crops were included on some fields (e.g., dry beans, peas, sweet corn, pasture, idle land).

		High P Runoff	**Best Estimate P Runoff**	**Low P Runoff Estimate**
	Corn Assumption	Corn for silage	Corn for grain	Corn for grain
Tillage	Corn	Fall, chisel	Fall, chisel	No till
	Soybean	Fall, chisel	Fall, chisel	No till
	Winter wheat	Fall, chisel	Fall, chisel	No till
	Alfalfa	No till	No till	No till
Yield Goal	Corn for grain	150-170	150-170	150-170
	Corn for silage	20-25	20-25	20-25
	Soybean	46-55	46-55	46-55
	Winter wheat	81-100	81-100	81-100
	Alfalfa	4.6-5.5	4.6-5.5	4.6-5.5
	Fertilizer application	Unincorporated	Incorporated	Unincorporated[1]

[1]Incorporated or subsurface application would provide a lower runoff, but those applications are not compatible with no till, and tillage/no till has a substantially greater effect on calculated runoff than fertilizer application choice.

To simulate the effect of replacing crops on these fields with solar panels over a permanently grassed surface, I set all fields to be “Grassland, permanent, not harvested” with no fertilizer application for 30 years, the expected lifespan of the proposed solar farm.

Summaries of annual pounds of phosphorus in surface runoff from the fields entering surface waters were obtained by generating Phosphorus Trade reports in SnapPlus. Total phosphorus runoff for five 6-year crop rotations was compared to total phosphorus runoff from 30 years of permanent grassland following the current cropping regime to quantify the effect of converting these fields from row crops to a solar farm.

Finally, I performed some analyses examining how well using the ACPF crop history database and generic input for target yields, tilling practices, and nutrient applications reflected the more field-specific details available in the nutrient management plans for some of the fields. For fields in the project area with detailed nutrient management plan information including at least six years of crop rotation, I performed SnapPlus phosphorus runoff calculations with the field inputs exactly as they are found in the NMP, followed by 30 years of an unharvest grassland land cover approximating a solar farm. I then compared those calculations to the SnapPlus phosphorus runoff calculations made as described above for the main solar farm phosphorus reduction analysis using the ACPF crop history database and generic target yield, tilling practices, and nutrient application inputs. All comparisons are made on a per-acre basis since the solar project boundaries only comprise a subset of a field boundary for some fields.

2. Results

This analysis indicates that replacing existing crop rotations with solar panels over permanently grassed fields would reduce phosphorus runoff by 85-98%, with a best estimate of 97% (Table 2). Based on the analysis discussed below on the effect of the generic inputs used in this modeling, the true runoff values likely lie between the low and best estimate, closer to the best estimate. Tillage input accounts for most of the difference between the low (all fields assumed to be no till) and best estimate (all fields except alfalfa assumed to be tilled). In reality, there is a mix of no-till and tilled fields, so it makes sense that the "true" value would lie between the low and best estimate.

Table 2. Total pounds of phosphorus runoff into surface waters over 30-year period from fields leased by the Onion River project assuming that crop rotations continue similar to the past 6 years or if the crops are replaced with solar panels. Under each alternative (continued crops or solar panels), three scenarios were modeled assuming high P runoff, low P runoff, and a best estimate.

		Crop Rotations Continue			Crops Replaced with Solar Panels		
	Acres	High	Best Estimate	Low	High	Best Estimate	Low
ALL FIELDS	1,082	233,079	128,793	21,241	4,156	3,838	3,350
PRIMARY FIELDS	885	183,398	106,629	18,046	3,364	3,133	2,732
ALTERNATE FIELDS	196	49,681	22,164	3,196	791	705	618

Comparing phosphorus runoff calculations to calculations made using the field-specific information contained in the NMPs indicates that the estimated range of runoff modeled in this analysis encompasses the "true" runoff. The runoff calculated using the field-specific NMP information is generally between the low and best estimates, closer to the best estimate than the low estimate (Fig. 2). Comparing runoff reductions when the current cropping rotation is replaced with the simulated solar farm, using the field-specific crop information results in a 96% reduction in phosphorus runoff across all fields included in the Onion River project area (Fig. 3). This is similar to the 97% reduction assumed by the best estimate in my more generic modeling, and within the estimated 85-98% reduction range.

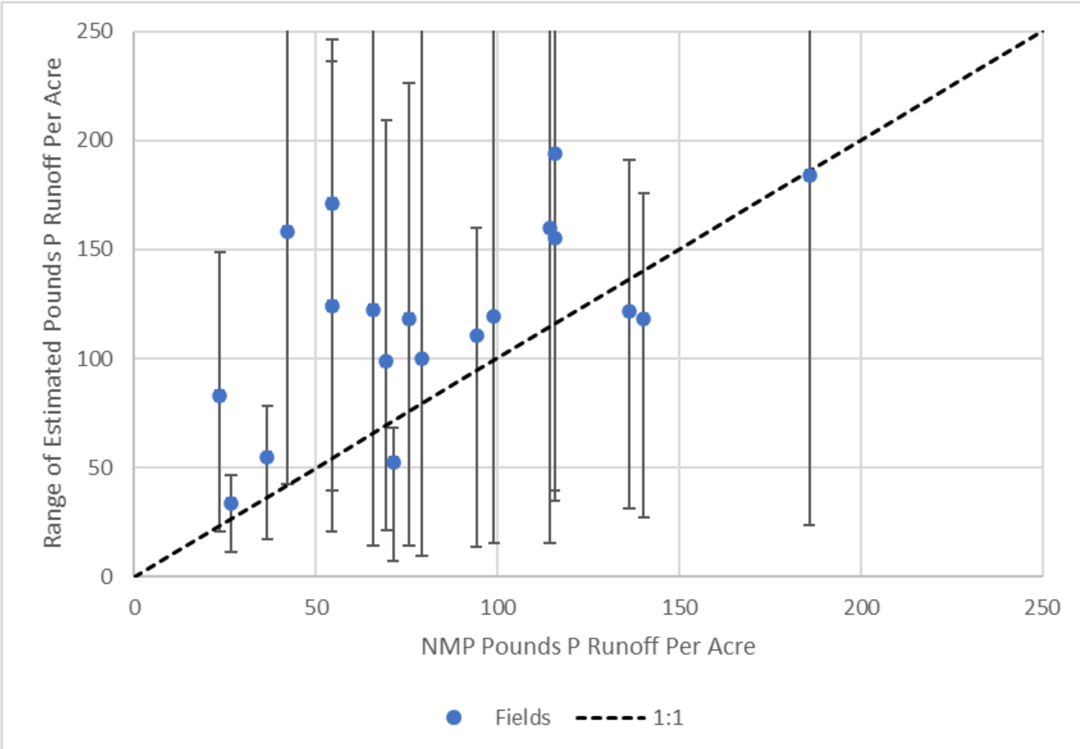

Figure 2. Pounds of phosphorus runoff per acre over the course of five, 6-year crop rotations calculated in SnapPlus using field-specific information available from nutrient management plans compared to calculations made with crop history information from the ACPF database and generic yield targets, tillage, and nutrient management inputs. The blue symbol represents the best estimate, with the vertical error lines extending to the upper and lower estimates. The dashed line indicates a 1:1 relationship; with a perfect fit all points would lie right on the 1:1 line. Notably, most points are close to the 1:1 line, and for all but two of the fields, the range of estimated values intersects with the 1:1 line, indicating the value calculated with the field-specific NMP information is within the estimated range. This plot does not contain the comparison for one field where the best estimate value is significantly higher than for other fields (662 pounds per acre; range: 99-978). The runoff calculated for this field using the field-specific NMP information is 89 pounds per acre.

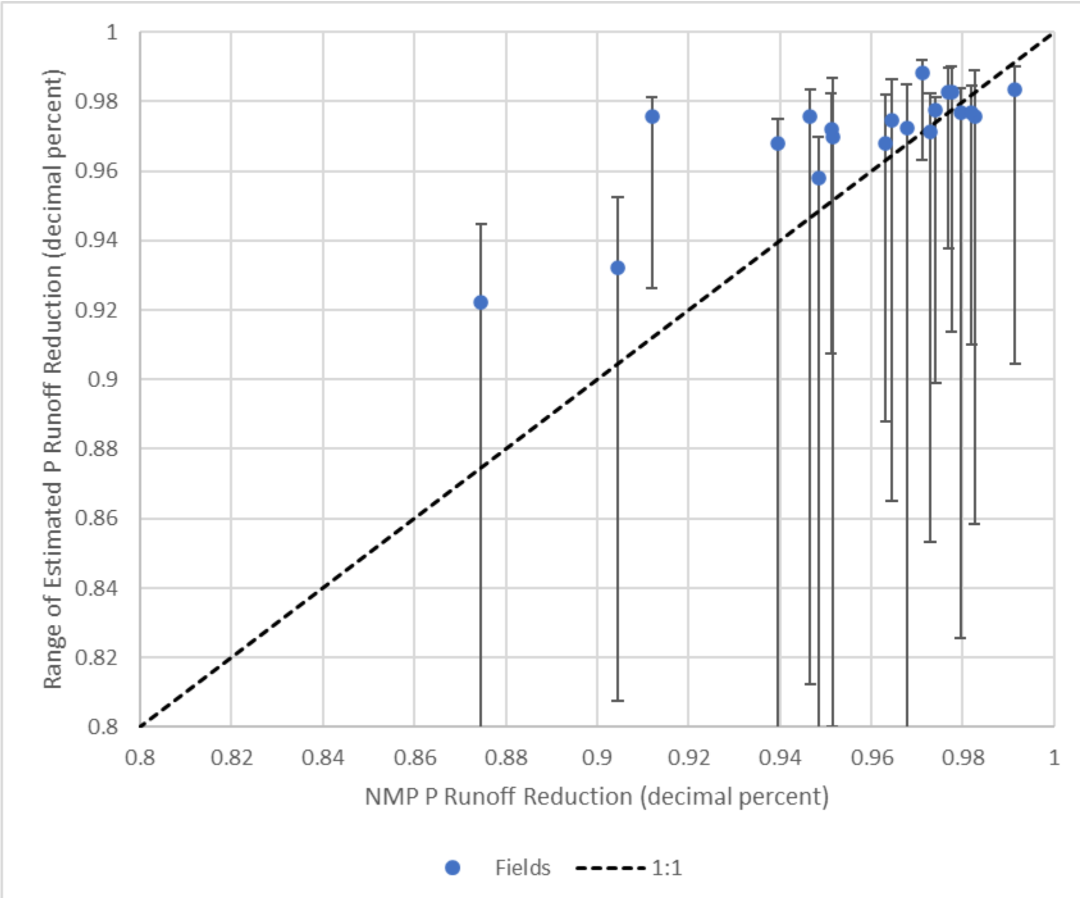

Figure 3. Reduction in phosphorus runoff per acre when solar farms are simulated for 30 years vs. five, 6-year crop rotations calculated in SnapPlus using field-specific information available from nutrient management plans compared to calculations made with crop history information from the ACPF database and generic yield targets, tillage, and nutrient management inputs. The blue symbol represents the best estimate, with the vertical error lines extending to the upper and lower estimates. The dashed line indicates a 1:1 relationship; with a perfect fit all points would lie right on the 1:1 line. Notably, most points are close to the 1:1 line, and for all but one of the fields, the range of estimated values intersects with the 1:1 line, indicating the value calculated with the field-specific NMP information is within the estimated range.

3. *Limitations*

There are several limitations of this analysis that are important to be recognized:

- This analysis assumes that solar panels do not substantially alter the volume of stormwater runoff from the field or velocity of stormwater hitting the field surface (and thus alter the stormwater-induced erosion from different soils assumed by SnapPlus). The only study examining this that I am aware of suggests that this is a reasonable assumption (Cook & McCuen 2013, but see MPCA 2019 indicating that solar panels may increase stormwater volume). If stormwater-induced erosion is increased by the presence of solar panels, these calculations would underestimate the phosphorus runoff from the simulated solar farm fields and thus overestimate the phosphorus reduction benefits of the project.
- Similarly, this analysis assumes that grassland vegetation planted under and around solar panels develops and holds soil in place in an equivalent manner to grassland vegetation on a field without solar panels. Shading from the panels could reduce plant density compared to a field without solar panels, which might increase erosion and phosphorus runoff. A scenario with solar panels over native plants has not been modeled or included in SnapPlus yet, so we used the unharvested grassland option in the program as a proxy.
- This analysis does not consider any increased runoff during the construction phase. It assumes the field immediately goes from cropland to a permanently grassed surface. However, required construction stormwater best management practices likely capture most of this increased runoff. Furthermore, over the course of the 30-year analysis, a small increase in the first year or two would not alter the overall conclusions.
- As described above, I only had soil P test values for about half of the fields in the project area, and the soil P values for the remaining fields were based on the known P soil values or county average values. If true soil P values on the fields without test results are significantly different than the estimated value, the runoff calculations could either be overestimates or underestimates, depending on how true soil P values differ from the estimated soil P values.

- This analysis assumes that all nutrients are added as fertilizer and thus does not include any manure applications. However, since the majority of phosphorus runoff calculated in SnapPlus is from particulate-bound phosphorus rather than soluble phosphorus, this simplifying assumption is not expected to have much of an effect.
- SnapPlus does not account for the effect of concentrated flow channels or tile drainage. If any such features are present on these fields, the calculated phosphorus runoff will underestimate phosphorus losses, particularly under a cropping regime. Thus, presence of these features would suggest that this analysis underestimates the phosphorus runoff reduction benefit of a solar farm.

4. References

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