Developing Credits and Incentives for Innovative Stormwater Management
Collaborative Learning Group Meeting
April 22, 2015, 9:00am-3:30pm
Meeting & site tour at West Creek Watershed Stewardship Center, Parma, OH

Meeting Summary

CLG Members, and Observers: Dan Bogoevski (Ohio EPA), Amy Brennan (TNC), Justin Czekaj (City of Aurora), Eric Dodrill (Erie SWCD), Jennifer Grieser (Cleveland Metroparks), Kevin Grieser (Biohabitats), Lynette Hablitzel (Ohio EPA), Clyde Hadden (CT Consultants), Anne Jefferson (KSU), Dave Ritter (NEORSD), Rachel Webb (NEORSD), Betsy Yingling (NEORSD)

Project Team & Staff: Keely Davidson-Bennett (CRWP), Jay Dorsey (ODNR), Heather Elmer (CRWP), Ona Ferguson (CBI), Breann Hohman (Erie SWCD/OWCNERR), Frank Lopez (OWCNERR), Alessa Smolek (NCSU), Ryan Winston (NCSU)

Welcome, Introductions & Meeting Overview

Ona Ferguson welcomed everyone and reviewed the meeting objectives to present preliminary project results and products, provide recommendations on ways to credit the contribution of LID stormwater control measures toward state and local stormwater requirements, and gather feedback on how project results may be used by stormwater professionals for plan review, design and construction, and how to best communicate results through trainings and outreach. Keely Davidson-Bennett provided an overview of products produced by the project including runoff reduction credits in CRWP's model stormwater codes, crediting mechanism for LID SCMs, updated guidance in state stormwater manual, training for stormwater professionals, monitoring and modeling reports, case studies, collaboration evaluation, rainwater harvesting tool, and permit language for Ohio EPA.

Bioretention Performance

Ryan Winston presented bioretention monitoring and modeling results.

Bioretention Monitoring
The project monitored three bioretention cells at Holden Arboretum and Ursuline College, all with internal water storage zones of 15-24 inches. For all three cells, post-construction drawdown rates were higher than pre-construction saturated hydraulic conductivity, possibly because the single ring test measures vertical soil hydraulic conductivity while measured SCM drawdown rates include lateral exfiltration and evapotranspiration. Hydrologic fate for all cells: 9-11% evapotranspiration, 29-49% exfiltration, 26-47% treated underdrain flow, 12-15% overflow. Vegetation in the watershed may help mitigate large peaks and reduce overflow. Discharge thresholds (amount of rainfall before observing outflow from underdrain) were 0.25-0.63 inches. A higher percentage of events had no outflow for Ursuline than for Holden owing to underlying soil types. Bioretention reduces the curve numbers and may be able to reduce the size of stormwater ponds. Significant peak flow mitigation was observed: 29-95% at Holden and 72-93% at Ursuline.

Northeast Ohio Regional Sewer District provided in kind assistance for water quality monitoring of the Ursuline bioretention cell. The team was only able to collect 4 water quality samples from Ursuline in 2014. Those limited results indicate 70% reduction in TSS concentration. This is the low end of

literature reported values, which could be due to sampled storms being among the largest events. The bioretention cell reduced concentrations and load for some metals but chloride increased. Effluent nitrogen concentrations were elevated 3-5 fold, which could be attributed to soil media within the IWS zone, high exfiltration rate reducing retention time, small plants, mobilization of particulate nitrogen or type of organic matter in the media mix. The cell was also a source of total and dissolved phosphorus, possibly due to the soil media which exceeded the Rainwater and Land Development specification of 60mg/kg. *Because of infiltration, the team estimates that the cell reduced overall loading for total phosphorus, total suspended solids and some metals.*

CLG member discussion included the following feedback and questions:

- Project results support the use of a treatment train approach since it is unlikely that bioretention alone is able to infiltrate the water quality volume on sites with C and D soils. Ryan noted on sites with A and B soils bioretention can infiltrate the water quality volume and on C and D soils bioretention cells will still filter the water quality volume. LID SCMs result in significant lag time even if not able to retain the water quality volume.
- Consider looking at the impact of plants on water quality performance with future research. A cell with immature plants may act more like a sand filter.
- At Ursuline College, the forebay is about ¾ full of sediment one year after construction, so limiting the size of contributing drainage area is likely important for long-term performance.
- Suggestions for trainings and presentations of these results:
    - This information is good for engineers but less useful for MS4 managers and developers who are interested primarily in the costs and potential cost savings of LID. In trainings for developers/contractors, focus more on design and construction and less on water quality and runoff reduction performance.
    - O&M training is very important for LID SCMs, certification needed for landscapers and other professionals.
- Water quality:
    - Manufacturer claims Osorb improves nutrient removal and observed project results call this into question.
    - More research is needed to refine the soil media specification for *Rainwater and Land Development* and that a certification/testing program for soil media could be developed.
    - TSS reduction points out the importance of maintenance
    - Some CLG members expressed concern regarding nutrient export. Ryan reiterated that although elevated effluent pollutant concentrations were observed, the cell *decreased* pollutant loads, which is the more relevant measure of the SCM's impact on receiving waters. Pollutant load reduction and *not* efficiency ratio should be stressed in project reports and training. CLG members suggested not sharing water quality results with larger audiences if sample sizes were too small. If results are shared, they should be placed in the context of the literature on the water quality performance of LID SCMs especially because of the small sample size leading to these particular conclusions.
- Although bioretention cells are more susceptible to clogging than wet ponds, plant roots create macropores that help keep cells functional even with lower maintenance. With permeable pavement this is not the case which likely contributes to higher maintenance burden.

DRAINMOD and SWMM Bioretention Modeling

Ryan shared bioretention performance modeling results using DRAINMOD, a long-term agricultural drainage model for evaluating long-term hydrology. DRAINMOD calculates the change in water depth in the soil as a function of drainage, evaporation, deep seepage, and infiltration at hourly time steps. Calibration and validation for the Ursuline cell showed very high agreement with monitoring data. Modeling the Holden Arboretum cells was a little more challenging because of the perviousness of the watershed, and two inflow files had to be created and merged. These had slightly lower NSE coefficients for calibration and validation, but they were still acceptable. The percent error for total volume in the validation period was 0.2% for the north cell and 0.6% for the south cell. The model generally under-predicted overflow at both Holden cells. Ryan has more confidence in the Ursuline model because there is better agreement with measured data likely due to the imperviousness of the watershed. Overall, the models are within 2% of monitored hydrologic fate for drainage, overflow, exfiltration/ET.

Jay Dorsey presented SWMM modeling results for the Holden Arboretum bioretention cells. Developing a winter/spring model and summer model and putting them together improved model performance. Jay discussed model limitations including uncertainty with increasing pervious areas, seasonality, and LID control issues including sub-area routing, overflow height/bowl volume, inability to locate drain outlets in filter media (IWS), single constant seepage rate, inability to adjust seasonal performance, and drainage equation.

In summary, concurrent modeling and monitoring helps improve understanding and the quality of results for both endeavors. Having models calibrated to field measured data enhances the value and credibility of performance information. Modeling seasonal performance is a challenge, variability in seasonal performance should be taken into consideration for SCM design. Any volume captured below surface basin overflow achieves water quantity and water quality goals. SWMM is better for urban hydrology, and DRAINMOD is a robust and reliable method of measuring soil drainage.

CLG feedback and discussion included the following:

- Identify relevant modeling take home messages for stormwater professionals.
- Modeling is useful to inform SCM design standards.
- Model strengths and limitations should be emphasized in all reports.
- Model outputs should be translated into simple, easy to use tools, specifications and guidance.
- Seasonality in performance may have implications for design, e.g. rain over snow/frozen ground. ODNR DSWR is open to suggestions regarding how to address this in design guidance.
- In a side conversation, Dave Ritter suggested that the project team might look into the work of the Coshocton Experimental Station – USDA Ag Research Center.

Permeable Pavement Performance

Permeable Pavement Monitoring Results

Ryan presented monitoring results from permeable pavement installations at Willoughby Hills, Perkins Township, and Orange Village and reminded the group of key attributes for each site and SCM. All installations include 15-30” of aggregate and 6” internal water storage zones. At Perkins, open graded aggregate is beneath the entire parking area, not just the pervious concrete. Orange Village includes a subdrain 3’ beneath the cross-section, which affects site drainage. The Willoughby Hills large bay includes a stepped subgrade. Hydraulic loading ratios vary from 1.0-8.2. Pre- and post-construction drawdown rates were similar for all sites. Single ring infiltration tests completed pre-construction were more consistent with permeable pavement draw down rates than with bioretention, possibly because

permeable pavement installations have a lower surface area available for lateral exfiltration than bioretention.

Annual Fate of Water

	ET/Abstraction	Exfiltration	Drainage	Overflow
Perkins Twp	5%	42%	53%	0%
WH Small	13.2%	3.5%	75.3%	8%
WH Large	10.5%	21.5%	44%	24%
Orange Village	98.8%		1.2%	0%

Clogging caused surface runoff from the Willoughby Hills large bay. An estimated 4000 sf of contributing area bypassed the system. Alessa Smolek determined the effective runoff area by adjusting the contributing area and respective drain spacing in DRAINMOD until the drainage matched and estimated approximately 550 square feet (approximately 13%) of the PICP surface area was clogged, which corresponds to approximately 24% of surface runoff.

Key contributors to permeable pavement performance include the level of clogging, internal water storage zone and underlying soils. Permeable pavement reduced runoff volume by 17-99% (factors– underlying soils, hydraulic loading ratio, curtain drains). Curve numbers were reduced from 98 to 93.3-94.3 for hydrologic loading ratios of 3.4-8.2. Peak ratio was <0.33 for 55-100% of events, peak flow mitigation was observed even for relatively infrequent design storms.

Permeable Pavement Water Quality Performance

Ryan presented water quality monitoring results for Willoughby Hills and Old Woman Creek. Willoughby Hills nutrient removal performance was low, and leaching of sediment and metals was observed, but observed trends suggest a possible maturation period due to disturbed subgrade or aggregate. Monitoring continues in spring 2015 to determine if the trend continues. Leaching of Ca and Mg was also observed. The permeable pavers and cistern at Old Woman Creek NERR reduced concentrations of nitrogen, phosphorus and sediment. This was the best performing site from a water quality perspective, with excellent capture of particulate nitrogen (ON, TKN >60%), particulate P (87%), and TSS (99%). Coupling the pavers and cistern increases hydraulic retention time and may support transformation of ammonia to $NO_{2\text{-}3}$. The system is also excellent at capturing dissolved phosphorus (90%), perhaps due to binding cations in limestone.

CLG discussion included the following:

- Pervious concrete and PICP should have similar water quality performance if not clogged. Underlying soils and hydraulic loading ratio appear to be the most significant contributors to performance. The difference between Perkins and other sites is likely not attributable to the permeable pavement surface.
- Has there been a problem with frost heave during the recent very cold winters with 40-42 inch frost depth? Jay noted the design recommendation of 2/3 frost depth has been reduced to 1/2. Ryan has not seen temperatures below 32 degrees in cross sections, and noted that a 40% void provides ample room for expansion. Ryan estimates 20” cross section should be sufficient for most locations in Ohio. Industry groups recommend 15” of section above sump.
- A permeable paver parking lot in University Circle that does not receive direct sunlight had ice build-up in joints. Perkins Township had similar experience. Consider challenges from extensive shading when designing and siting systems.
- The group discussed lessons learned regarding installation of permeable pavement on sloped sites. Keely recommended excavating to a flat bottom, Jay suggested a stepped subgrade could

be implemented effectively, Ryan mentioned that he thought the 1' of additional excavation would have been required for a level subgrade at Willoughby Hills would not have added that much to the cost.

- Some CLG members asked what the implications of calcium and magnesium leaching were for water quality, and the project team replied that since these minerals are not toxic and are not at very high levels, they would not be expected to negatively affect water quality.
- Has sediment built up in the Old Woman Creek cistern? Sediment did get into the cistern from a storm during construction, but Ryan has not noticed additional significant build up.

Permeable Pavement Modeling

Alessa Smolek presented DRAINMOD permeable pavement modeling results. Modeling permeable pavement with DRAINMOD is similar to modeling bioretention, but the soil water characteristic curve must be adapted for aggregate. Nash-Sutcliffe Efficiencies (NSEs) were good for the Willoughby Hills small bay. The large bay was not a perfect fit due to variability of surface runoff, but NSE was still acceptable given circumstances at the site. There was good agreement for the large bay cumulative volume (within 2%) for drainage, outflow and exfiltration/evaporation. A sensitivity analysis for the Willoughby Hills small bay was completed using 30 years of historic rainfall data to simulate baseline models for four different soil exfiltration rates using existing design parameters and varying contributing area, IWS depth and aggregate depth. This analysis indicated that combination of depth of IWS and contributing drainage area ratio were the most sensitive design elements affecting draining and overflow was most influenced by aggregate depth. However, aggregate depth is less of an issue for SCMs with lower HLR. Evaporation varies based on the ratio of contributing drainage area to permeable pavement surface area. Exfiltration was most sensitive to the depth of the IWS zone.

Perkins Township was modeled based on the entire infiltrative surface under both the permeable and impermeable pavement. This model showed good agreement for exfiltration/ET and depth to water table. Lessons learned from this include that modeling can help identify and remedy monitoring issues, pervious contributing areas cause more uncertainty but can still be modeled within acceptable limits, Nash Sutcliffe Efficiency (NSE) is more sensitive to variability when exfiltration volumes are low, and inflow can be modeled better for higher hydraulic loading ratios.

Jay Dorsey presented SWMM modeling for Perkins Township pervious concrete. Pavers were modeled as storage with bottom seepage in this hydraulic model. Roof runoff was modeled with a pipe draining to storage. This approach yielded an excellent fit with well data and a reasonable fit to flow data. Flow is very sensitive to depth; but not consistently correlated. Performance is sensitive to soil moisture and evaporation. Jay noted that this is a reasonable model for the site, though there is room for improvement. The system was also modeled using the LID sub-routine where roof runoff is applied as runoff to pavers. The storage model matched the water table well data better than the LID sub-routine model.

CLG member discussion

- CLG members requested "if, then" scenarios based on modeling results be included in trainings.
- Use models to describe how varying the underdrain level affects performance.
- Modeled LID designs should be practical and feasible.

Permeable Pavement Maintenance

Ryan presented results of a study to determine how clogging progresses over time, how surface clogging can best be managed, and identify maintenance needs/frequencies. This study includes 5 SCMs installed under trees, with concentrated flows and run on from pervious landscaped areas. Results

indicate significant clogging at the permeable impermeable interface (PII) and in areas with trees, concentrated flow, and run on from pervious areas. Concrete raveling does not have a significant impact on surface infiltration rates. For pervious concrete, infiltration rates were statistically significantly lower in heavy use areas such as in tire tracks from vehicle parking than in surrounding areas, but the median infiltration rate for the tire track was still 874 in/hr. Perkins Township has not been maintained and is the best performing site, owing at least in part to a lower hydraulic loading ratio. Clogging at the PII was the most significant predictor of overall system clogging. The already-high HLR to the Willoughby Hills large bay was multiplied by up to 100 fold in one area by the parking lot island causing shallow concentrated flow greatly increasing maintenance requirements.

Pre- and post-maintenance simple infiltration tests indicated that bristle sweepers are not that effective. A regenerative air street sweeper with suction (which applies suction across whole width of truck) is needed to address clogging. Vacuum trucks can apply more suction than a regenerative street sweeper. Multiple passes may be required. Maintenance improved infiltration rates, but a downward trend of infiltration rates at the PII was still observed. Designers can decrease the hydraulic loading ratio to permeable pavement systems to keep maintenance frequency down. Conclusions include that high run-on ratios (2:1 or greater) lead to quick clogging and more frequent maintenance intervals near the PII (first 3-6 months), trees contribute to clogging, and designs should avoid concentrated or shallow concentrated flow. Vacuum truck performs best for maintenance at the PII.

CLG discussion included:

- Small-scale permeable pavement installations compound maintenance problems because of physical constraints on equipment and the likelihood of higher loading ratios.
- Being able to use or adapt equipment, e.g. vactor trucks, would be helpful for communities.

Policy Implications: Crediting Runoff Reduction in Ohio

Jay provided background on the critical storm method and an example of how it can be used to credit runoff reduction. Using the CSM volume reduction credit for permeable pavement, for a 5 acre site that is 91% impervious on C soils with an infiltration area of 3 acres, the critical storm is reduced from 25 year, 24-hour to 1-year, 24 hour and the WQv is fully infiltrated. Peak discharge was managed in the aggregate storage layer under the parking lot without the need for a surface detention basin. Jay noted that he is designing the crediting framework so that storage must be opened up within 24 hours for the next event. Ryan noted the antecedent dry period in OH is likely longer than 24 hours and asked why this threshold. Jay explained that ODNR is taking a conservative approach. Jay also demonstrated a draft calculator for determining volume and retention depth credit for bioretention. Designers can use this calculator to figure out how to design LID SCMs to decrease the critical storm. Outstanding questions for finalizing the calculator include how to guarantee long-term hydrologic performance, how simple to make the crediting method, how conservative the method should be, whether credit for green roofs or other practices should be enhanced to promote their use, and how can communities that do not use CSM credit LID.

CLG discussion included the following:

- The crediting tool needs to be very simple and set the minimum.
- There was a lot of discussion about how to guarantee hydrologic performance for LID SCMs and about whether it needs be guaranteed, given no or very limited mechanisms to guarantee performance of conventional SCMs. Ohio EPA staff noted that problems with conventional SCM performance are addressed through a compliance and investigation process which could also be

used for LID. Many people indicated that they do not think it is reasonable to hold LID to higher design and construction standards than those to which conventional SCMs are held.

- Ideas about how certification might work, if it were needed, included:
    - Design engineers should be required to certify that SCMs are installed per design to receive credit.
    - Credit policies should be cautious but not overly restrictive.
    - Consider including a mechanism to revoke credits based on negligence? This would be possible with utility fee credits. In North Carolina, liens are placed on properties if SCMs not maintained.
    - Credits should require approval for alterations to SCMs.
- One CLG member indicated that green roof performance data is inadequate. Jay indicated that research has shown good performance in the mid-Atlantic and Midwest. Ryan mentioned green roofs work differently depending on climate and that they work well in Ohio. Hydrologic performance is a function of media depth and plant available water.

CRWP Model Stormwater Code

Heather presented draft revisions for CRWP's model comprehensive stormwater management code including: crediting runoff reduction toward peak discharge and water quality volume requirements, adopting a less than one acre threshold for comprehensive stormwater management, requiring SCMs that infiltrate WQv or reduce runoff temperature for sites discharging to cold water habitat streams, requiring soil preservation and post-construction soil restoration, and incentivizing impervious area reduction and infiltration for redevelopment projects.

Participant discussion included the following:

- Participants recommended using "recommended" instead of "higher standard" to increase chance of adoption.
- One participant stated there is no need for language related to the water quality volume because the permit already allows bioretention and permeable pavement as ways to meet the water quality volume.
- One participant recommended checking the language in the TMDL because she thought the recommendation is for sites in coldwater habitat watersheds, not just sites discharging directly to coldwater habitat streams.
- One participant suggesting creating coldwater habitat maps, providing a list of coldwater habitat friendly SCMs, explaining why this code language is recommended, listing communities that adopt recommendations, creating a presentation template, and linking recommendations as a means of demonstrating compliance with TMDLs to encourage adoption.
- Someone suggested separating new development and redevelopment for soil preservation and considering a decompaction level based on hydrologic code for redevelopment.
- Someone suggested that it would be most effective for each community to determine what an appropriate less than one acre threshold would be for it, rather than recommending the same threshold for all communities. Communities could look at past building permits to determine what the typical size of a commercial development and what the typical size of a residential development project is in the community. Many communities will not want to deal with residential development, but will want to catch commercial developments that are less than one acre. Many people have difficulty relating to square footage, so it might be more effective to phrase this as wanting to require post-construction stormwater management for anything bigger or equal to the size of a McDonald' s.
- Someone else mentioned that some communities might want to catch residential development.

Potential state policy language recommendations

The group discussed the following potential state policy recommendations:

- Where physical constraints such as water table or slopes do not preclude their implementation, require bioretention and/or permeable pavement in watersheds where TMDLs indicate impairment due to hydrologic or thermal impacts. Someone asked if this could be included in the MS4 permit. An Ohio EPA staff member indicated this could be done this way but that TMDLs might be more appropriate.
- Require 1-5 acre sites treat WQv in the next construction general permit.
- Determine how many acres of bioretention and/or permeable pavement would be needed to meet wasteload allocations.
- The group also discussed that letters of support to Ohio EPA's Chief of Surface Water would increase the odds of the agency making these kinds of policy changes.

Outstanding Research Questions and Next Steps

Keely and Ona reminded the group that project results will be shared at the Ohio Stormwater Conference and at two full-day trainings in early June. Ona reviewed a list of national stormwater needs identified by participants at a two-day workshop held in late March/early April to discuss outcomes and next steps from three NERRS Science Collaborative projects focused on LID and green infrastructure. Several of the research priorities identified at that workshop are included in a proposal for a second phase of work on this project. Keely reviewed the contents of this team's NERRS Science Collaborative pre-proposal and invited the CLG to provide input to help shape the invited full proposal due May 18th. Participants suggested the following regarding the proposal:

- Incorporating professional exchange with an Arizona watershed management greywater use program
- Broadening end users related to rainwater harvesting and use (including commercial and industrial uses)
- Assessing the co-benefits of LID and green infrastructure
- Looking at long-term performance and maintenance requirements for permeable pavement and bioretention systems
- Bringing in additional partners and expanding the geographic area of focus beyond the watersheds targeted in the current proposal
- Investigating dry extended detention basin retrofits, as there are many in northern Ohio.
- Leveraging other regional monitoring efforts such as the Cleveland Metroparks West Creek project ad developing partnerships and standard methods for applied stormwater research.
- Some end users will be invited to advocate for the project if the team is invited to the panel review stage. The team is planning to ask Jay Dorsey to serve this role, but other suggestions are welcome.

Ona asked participants to share their final thoughts about the project. These included:

- I'm grateful for the opportunity to participate with this group, I've learned a lot that I've been able to take back to Ohio EPA.
- Final products need to be easy to use and transferable to the real world. Research is great but the final project needs to be translated to move things forward.
- The results have been eye opening. I would like a broader group for the CLG, but recognize it's hard to get people to come to multiple all-day meetings.

- This project has helped me do my job better, and I appreciated being part of this group. The results need to be put in a form that is more accessible to everyone.
- This project has created a roundtable discussion for these types of stormwater issues. From a network and collaborative sense, this group has been wonderful. The value of the collaboration is an important part of the project.
- I have gotten a ton out of this project, including hopefully my PhD. The thing I enjoy most is seeing the research applied on a statewide level.
- I'm looking forward to packaging the modeling results into a digestible form for regulators and other users.
- Looking at my notes from early discussions regarding questions about LID performance in Ohio, it is great to realize this project made progress in many of these areas. Thanks to the collaborative learning group. I was skeptical, but it was worth getting everyone in the room.
- There were some panicked calls early on when we did not have the monitoring contractor on board, and recognizing that planned designs for some sites were not viable. I've enjoyed working toward changing the landscape of stormwater management in Ohio.
- I heard that getting a group of end users and scientists together doesn't work, but in our case it worked beautifully.
- This will help inform other research efforts such as the upcoming project led by Cleveland Metroparks.

Jenn Grieser described a Cleveland Metroparks effort to monitor a swale, wetland and green roof at the West Creek Watershed Stewardship Center. The team and CLG members are invited to advise this two-year study, which will include development of design guidance and tools.

Ona concluded the meeting and reminded everyone they were invited to an optional tour of the West Creek Stewardship Center and to the happy hour celebration in honor of the CLG's work together.