Summary of CRWP Code Updates and Rationale Resulting from "Increasing Climate Resiliency in Coastal Ohio Using Green Infrastructure" NOAA Coastal Storms Grant through The Ohio State University

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Precipitation and Flood Predictions for Ohio

Total annual precipitation in Cleveland has increased by 25.8% during the period of 1956 to 2012 (GLISA 2016). Cleveland has also experienced a 16.3% increase in the number of days with precipitation in the top 1% of the daily total precipitation and an increase of 22.2% in the amount of rain falling in these very heavy precipitation events in 1981-2010 compared to 1961-1990 (GLISA 2016).

Global climate models indicate 10 -20% increases in average winter and spring precipitation in the Midwest in 2071- 2099 compared to 1971-2000 under increased emission scenarios (Pryor et al. 2014). Changes in annual precipitation are expected to be larger for the northern Midwestern states than the southern ones (Pryor et al. 2014). The average number of days without precipitation is expected to increase in the future (Pryor et al. 2014). .

The National Climate Assessment reports that very heavy precipitation events are expected to increase nationwide, and that storms with a historic return interval of 20 years may occur every 5 to 15 years by 2100 (Georgakakos et al. 2014). Regional climate models indicate that the southern Midwestern states can expect an 8% decrease in summer precipitation and a 9% increase in spring precipitation for 2041-2062 compared to 1979-2000 under an increased emissions scenario (Pryor et al. 2014). Both global climate models and regional climate models indicate increases in frequency and intensity of heavy precipitation across the Midwest (Pryor et al. 2014). A global Community Earth System Model 1 simulation using the Representative Concentration Pathways 8.5 scenario dynamically downscaled with the Weather Research and Forecasting (WRF) model for the Great Lakes Basin indicates that both mean and extreme daily precipitation (defined as the 24-hour storm) amounts are predicted to increase in 2045-2060 compared to 1979-1994 (d'Orgeville et al. 2014). The amount of precipitation in the 50-year 24-hour storm is expected to increase by 14-29% in 2045-2060 compared to 1979-1994 (d'Orgeville et al. 2014). However, high resolution climate projection data for the eastern United States using dynamic downscaling of the Weather Research and Forecasting model (WRF) by Gao et al. 2012 on a 4 km x 4 km high resolution scale with the Community Earth System Model version 1.0 (CESM v1.0) serving to establish boundary conditions for the WRF model suggested lower annual average rainfall depths, longer dry periods, and hotter temperatures for northern Ohio for 2055-2059. This climate modeling data indicates that some areas in northern Ohio will experience increases in the rainfall depth of the 90th percentile of storms, while other sites will experience decreases in the size of extreme precipitation events (Smolek et al. 2015)

Georgakakos et al. (2014) predict that urban floods and flash floods will increase in frequency since these events are closely related to heavy precipitation. Floods in many riverine systems are also influenced by land cover, water supply management, antecedent soil moisture, channel conditions, basin topography, and precipitation patterns over larger areas, so floods in these systems are harder to predict and may not increase with increases in heavy precipitation events (Georgakakos et al. 2014). Predicting future flood intervals and intensity is also inherently difficult because floods are rare events (Georgakakos et al. 2014). Between 1920 and 2008, annual flood magnitude has increased substantially in the western Midwest and decreased substantially in the southwest (Georgakakos et al. 2014). Change in Ohio has been much more muted (Georgakakos et al. 2014). Georgakakos et al. (2014) also states that there are large uncertainties about how well climate models forecast extreme precipitation, which further complicates future flood forecasting.

Great Lakes Integrated Sciences + Assessments (GLISA) climatologists are currently exploring the feasibility of developing intensity-duration-frequency curves for the Great Lakes region that consider future climate projections (personal communication 2016). This information would be extremely helpful to stormwater and floodplain managers in sizing infrastructure and evaluating flood risk.

Comprehensive Stormwater Code

In 2015, CRWP updated its comprehensive model code to include the following requirements that promote flood resiliency: stormwater management for all commercial and industrial site development, soil preservation and post-construction soil restoration, incentivizing infiltration-based infiltrating stormwater control measures (SCMs) for redevelopment, and requiring the use of infiltrative SCMs in coldwater habitat watersheds. These recommendations are designed to promote infiltration of stormwater and catch smaller developments not regulated by state law. CRWP has discussed these recommendations with 15 communities in Lake and Cuyahoga Counties. The City of Willoughby Hills in Lake County updated its stormwater ordinance on May 26, 2016 to include all of CRWP's recommended higher standards.

CRWP's model stormwater code recommends the use of NOAA Atlas 14 rainfall data because it is constantly updated. We expect this to provide greater resiliency over time than the use of older, static datasets. The Wisconsin Initiative on Climate Change Impacts Stormwater Working Group (2011) also recommends the use of NOAA Atlas 14 data and extending regulatory control to the 100-year storm. CRWP's code states that the stormwater system shall be designed to prevent structure-flooding during the 100-year, 24 hour storm and that the peak discharge rate from the 100-year, 24 hour storm after development shall not exceed the predevelopment rate.

CRWP's recommendations regarding incentivizing infiltration over capture-treat-and-release SCMs for redevelopment and promoting infiltrative SCMs in coldwater habitat watersheds can help communities reduce urban flooding. Monitored bioretention cells on clayey soils in northern Ohio reduced outflow volume by 36 - 60% through exfiltration and evapotranspiration. Additionally, the monitored bioretention cells reduced 90th percentile peak flow rates by 83 – 93% (Winston et al. 2015). Orange Village in northeastern Ohio stopped experiencing street and yard flooding along a residential street called Sterncrest Drive after bioswale installation (Darner and Dumouchelle 2011). Monitored permeable pavement applications on poorly draining soils reduced outflow by 16 – 99% and reduced 90th percentile peak flow rates by 30 – 97% (Winston et al. 2015). A subdivision in Connecticut designed with LID features including permeable pavement, bioretention, rain gardens, swales, and shared driveways and open space did not increase runoff volumes after development. A nearby traditional subdivision developed at the same time had substantial and significant increases in runoff volumes (Dietz and Clausen 2008). Stack et al. (2010) predicted that the use of LID (retaining the first inch of precipitation on-site) for new development in the Oyster River watershed in New Hampshire would reduce the number of culverts that would need to be replaced due to future increases in precipitation.

Other research indicates that low impact development (LID) stormwater control measures such as permeable pavement, green roofs, and rainwater harvesting are effective at reducing peak flow rates and runoff volumes from small storms and are less effective at managing larger storms (Damodaram et al. 2010). At a large watershed scale in the Lamprey Watershed in New Hampshire, Scholz (2011) predicted that the use of LID in would only decrease the 100-year flood flow by an average of 1.4%, although decreases were much larger in smaller drainage areas with more impervious surface. However, Atkins (2015) found that SCMs that reduce runoff volume may help reduce riverine flood losses throughout the United States.

CRWP's recommendation of post-construction soil restoration also promotes runoff reduction and therefore reduction of urban flooding problems. Carmen (2015) found that two of four filter strips amended with compost, lime, tillage, and a local turf seed blend provided significantly more volume reduction and peak flow mitigation than non-amended filter strips. The author credited the fact that only half of the amendments improved filter strip hydrology to the existing, long-established lawns (50 years or more) with deep topsoil layers. Amendments with sand increased soil infiltration rate by two factors of ten in a filter strip built on a clay loam soil (Knight et al. 2013).

Flood Damage Reduction Code

CRWP encourages its member communities to adopt the higher standards in the model code developed by the Ohio Department of Natural Resources (ODNR) – Division of Water Resources Floodplain Management Department (Ohio Department of Natural Resources 2013). These higher standards include the following restrictions on development within the special flood hazard areas (100-year floodplain) delineated by the Federal Emergency Management Agency: new structures must be built at least 2 feet above the base flood (100-year) elevation, new structures in special flood hazard areas where base flood elevations have not been established shall be at least 2 feet above the highest adjacent natural grade, cumulative consideration of substantial damage and/or substantial improvements for structures existing prior to the adoption of floodplain development regulations, access routes to and from special flood hazard areas shall be at or above flood protection elevation, filling in the floodplain shall be compensated by removing an equal amount of material from a nearby floodplain area, requiring structures critical to community function or housing people with limited mobility to be elevated to the 500-year elevation or highest historic flood elevation, quality standards for fill and foundation design, prohibition of storing hazardous, flammable, explosive, or buoyant material in special flood hazard area.

The new Federal Flood Risk Management Standard resulting from Executive Order 13690 calls for avoiding building federally funded projects within a floodplain when practicable, and elevating or floodproofing federally funded projects to at least 2 ft. above the base flood elevation (3 ft. for critical infrastructure) or building them at or above the 500-year floodplain elevation when structures must be located in a floodplain. This Standard also instructs federal agencies affected by it to use these higher elevations when evaluating the width of the floodplain.

Agencies may also use "the best available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science;" however, the guidance acknowledges that such data are not readily available for riverine systems. In fact, it points out that the direction of future precipitation trends are uncertain in many areas of the country. Agencies that use the climate-informed science approach are also encouraged to consider the impact of erosion, subsidence, land use change, wildfires, and other potentially confounding factors on future flood risk (United States Government 2015).

CRWP did a qualitative GIS review comparing the elevations for the 100-year and 500-year floodplains for the Chagrin River watershed to determine what impact this guidance might have on building standards within the watershed. In many areas, the 100-year and 500-year floodplains are at the same or very close elevations, but in some areas, there is more than 4 feet difference between these elevations. However, since advocating the higher of the 500-year elevation or 2 feet above the base flood elevation would not be different than 2 feet above the base flood elevation for most of the floodplain areas in the Chagrin River watershed, CRWP decided to maintain our previous recommendation of 2 feet above the base flood elevation.

CRWP also reviewed the literature for examples of communities that have adopted higher standards than those in the ODNR model. At least forty-two communities nationwide, including seven in the Great Lakes states, require 3 foot freeboard (Association of State Floodplain Managers 2015).

The City of Cedar Falls, Iowa requires flood damage reduction measures within the 500-year floodplain. The City requires that new construction or substantially damaged structures within the 500-year floodplain be elevated at least 1 ft. above the 500-year elevation (Section 29-156 of City Ordinances). Additionally, no new lots are allowed within the 500-year floodplain unless they have sufficient buildable area outside the 500-year floodplain and critical facilities including hospitals, municipal government buildings, schools, and residential facilities for elderly or disabled persons must be located outside of the 500-year floodplain (Section 29-156 of City Ordinances). The City's decision to regulate development within the 500-year floodplain was influenced by the area of damages the City experienced during the 2008 flood event in order to reduce future flood risk (U.S. Environmental Protection Agency 2011).

The Town of Chapel Hill, North Carolina requires new structures within a resource conservation district to be elevated 4.5 feet above the 100-year flood elevation (Town Ordinances Appendix A Section 3.6.3). The resource conservation district is an overlay district that includes the land adjacent to streams and other water bodies that is at or below 3 ft. above the 100-year flood elevation or a minimum of 150 feet from perennial streams. The overlay district also imposes use restrictions on activities within certain distances from streams, with most developed land uses not permitted within 50 feet of the water body. The Town adopted this regulation to maintain water quality, wildlife, and greenspace benefits in addition to the flood reduction benefits it provided (American Planning Association 2010).

Riparian Setback Code

CRWP's model riparian setback code includes 25 ft. setbacks for streams draining less than 0.5 square miles, 75 ft. setbacks for streams draining 0.5 to 20 square miles, 120 ft. setbacks for streams draining 20 to 300 square miles, and 300 ft. setbacks for streams draining more than 300 square miles. Setbacks are extended to include the outer edge of the 100-year floodplain and the outermost boundary of any wetlands that are within the riparian setback. Construction of buildings, parking spaces, fences, roads, and dredging or dumping are prohibited within the riparian setback.

Keene, New Hampshire's Climate Adaptation Plan sets a goal of identifying the 200-year floodplain and preventing new development within it (City of Keene New Hampshire and ICLEI 2007), but that community does not seem to have made any progress towards this goal. Wu (2010) used precipitation output from 14 global climate models to predict that the 100-year flood peak flow of the Great Miami River at Dayton will be 10-20% greater in the future. This increase in peak flow may increase the inundation area. In contrast, Scholz (2011) found that current rainfall data was similar enough to future climate model predictions to use the current rainfall data for analyzing the impact of buildout on future flood risk in the Lamprey River in New Hampshire.

Because CRWP was able to find any resources that indicate a likely quantitative increase in 100-year floodplain size, CRWP did not make any updates to our model riparian setback code.

Conclusions

Northeastern Ohio currently lacks reliable, quantitative predictions of increases in extreme precipitation events expected under future climate conditions. In many areas of the world, professionals seeking to incorporate future climate predictions into water infrastructure decisions face similar challenges (García et al. 2014). Under these situations, emphasizing low regret solutions that would function well over the range of precipitation changes that could occur in a changing climate is a recommended adaptation strategy (García et al. 2014). The qualitative data currently available indicate that flood risk will most likely increase, meaning that strategies to promote flood resiliency will only increase in importance in the future. Adoption of riparian setbacks and higher building standards for flood risk areas and incorporation of LID are tried and true methods for increasing resilience from extreme precipitation events.

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