Climate Impacts to Restoration Practices

Restoration Research Question B.4 (Grant # 19278)

Chesapeake Bay Trust Pooled Monitoring Forum

June 16, 2022

Jon Butcher, Tetra Tech,

In conjunction with:

Dr. David Sample, Dr. Tess Thompson, Sami Towsif Khan, Virginia Tech

Follow on to prior grant on future changes in storm intensity and potential effects on infrastructure in MD

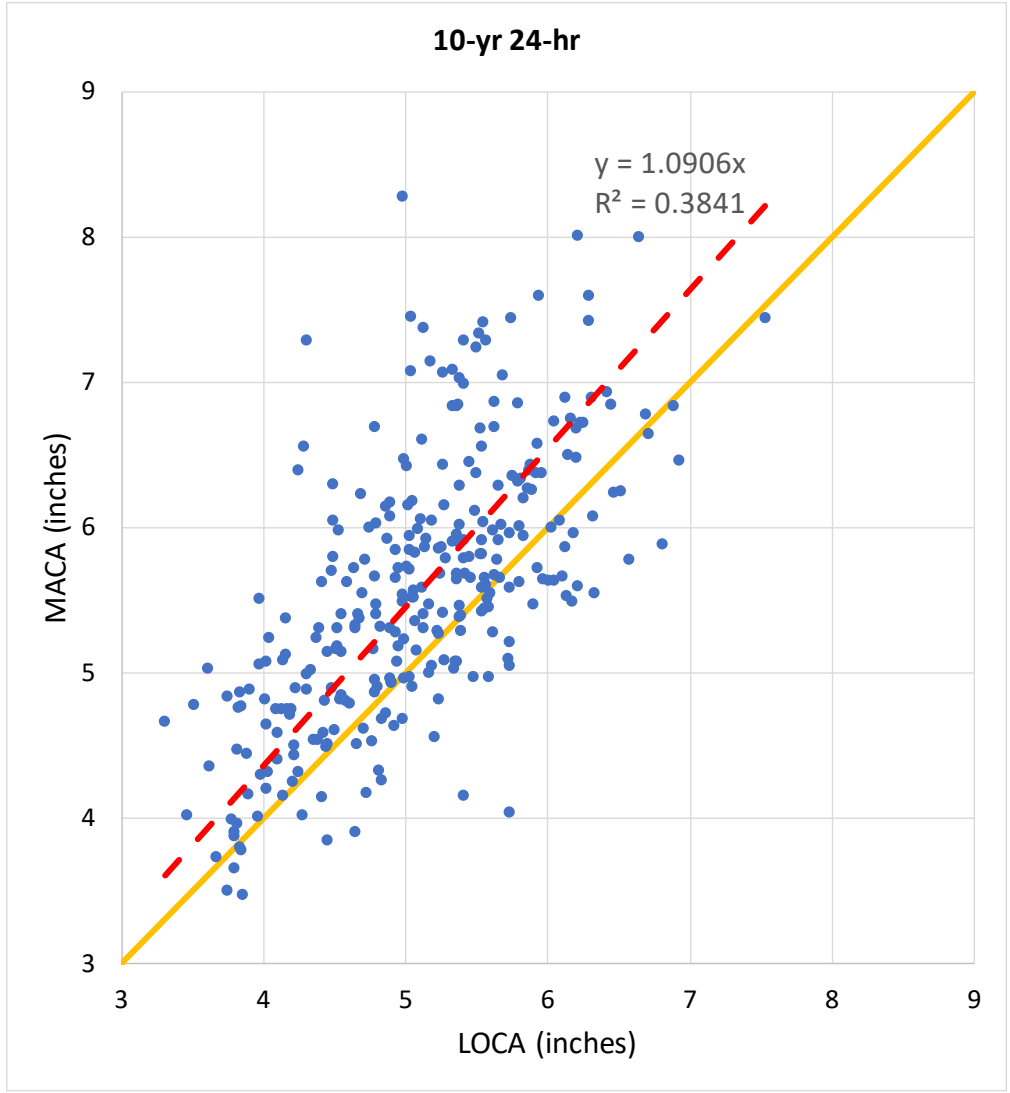
- Grant # 16928 (Sept 2019 – January 2021):
- Developed methods and estimated climate-modified intensity-duration-frequency (IDF) curves for all MD NOAA Atlas 14
- Evaluated impacts on infrastructure, BMPs, channel restoration stability
- Hypothesis: Designs based on historic weather may be inadequate to achieved desired levels of service under future climate
- Conclusions
  - Infrastructure such as road culverts likely inadequate to address future large storm events
  - Risk to channel stability will increase, should be a factor in restoration design
  - Smaller storms (e.g., current 90th percentile event will likely not increase in frequency; Environmental Site Design adequate to address future water quality
- Caveats:
  - Results depend on downscaled climate product (LOCA)
  - Analyses based on design storms may not yield a complete picture

Hypotheses for Current Grant:

- **H1**. Problems in the LOCA methodology introduce biases
  - Test against alternative sources
- **H2**. Current ESD requirements will be sufficient to meet management objectives under future climate
  - Continuous analyses with LOCA and alternative sources
- **H3.** Conclusions based on IDF analysis hold up under continuous simulation on real watersheds
  - Detailed simulations with calibrated flow and sediment transport models

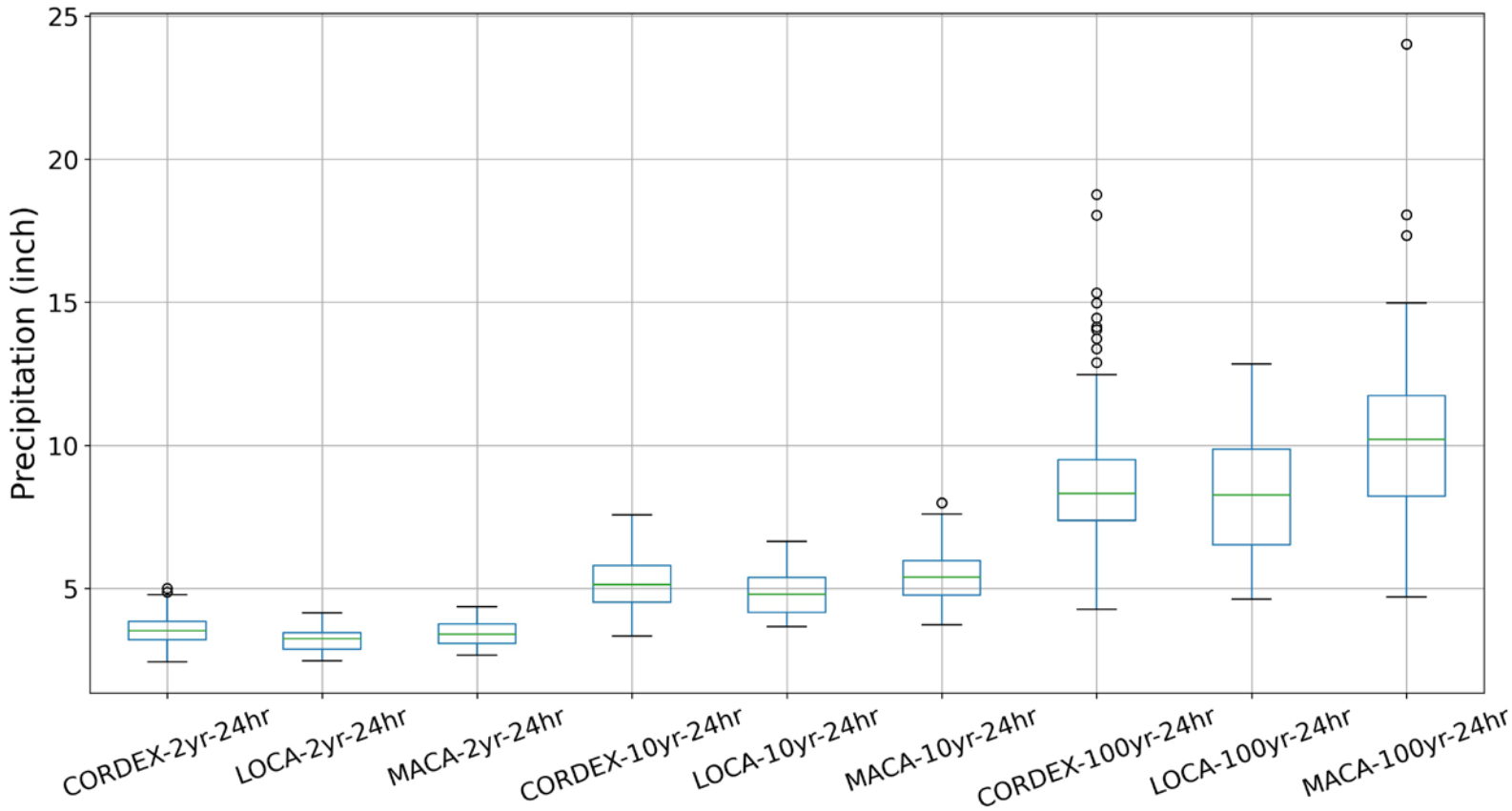
Does LOCA Downscaling Introduce Biases?

- Raw GCM output needs to be downscaled to shorter timestep with local bias correction for IDF analysis
- Training method for LOCA statistical downscaling may underestimate large events
- MACA is an alternative statistical downscaling product that covers most of the same GCMs but uses different training data
- CORDEX experiments with dynamic downscaling using regional climate models (available for a limited number of GCMs)



MACA results for future 10-yr, 24-hr event average 10% higher

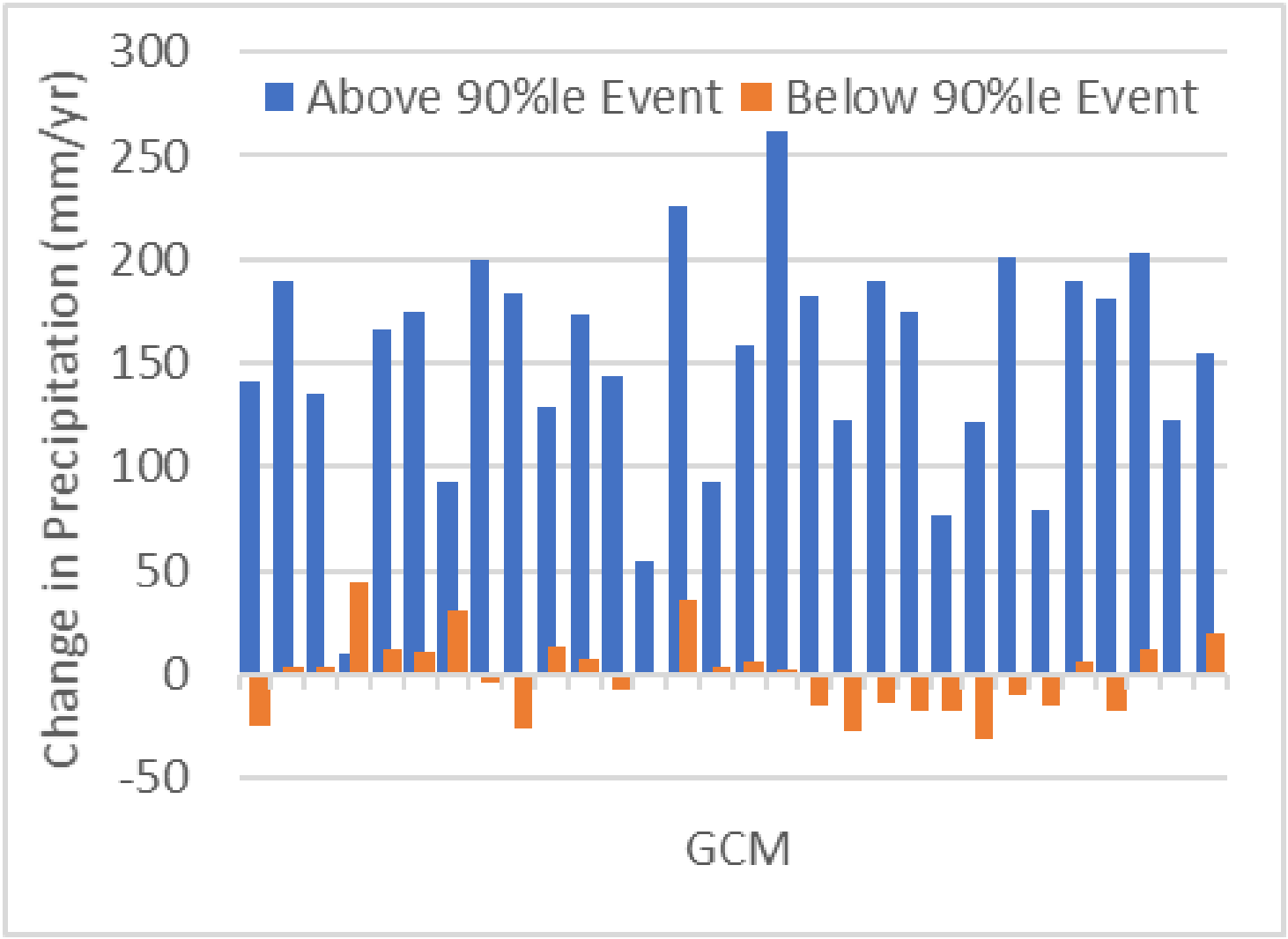
Does Downscaling Method Introduce Biases?



- Comparison to CORDEX dynamic downscaling (limited sample) shows LOCA < MACA; CORDEX tends to be in between
- Hierarchical ANOVA shows downscaling effect is statistically significant
- Variance components: Site > GCM > Downscaling
- Downscaling contributes about 10% of variance

H2: Current ESD Sufficiency for Future Climate

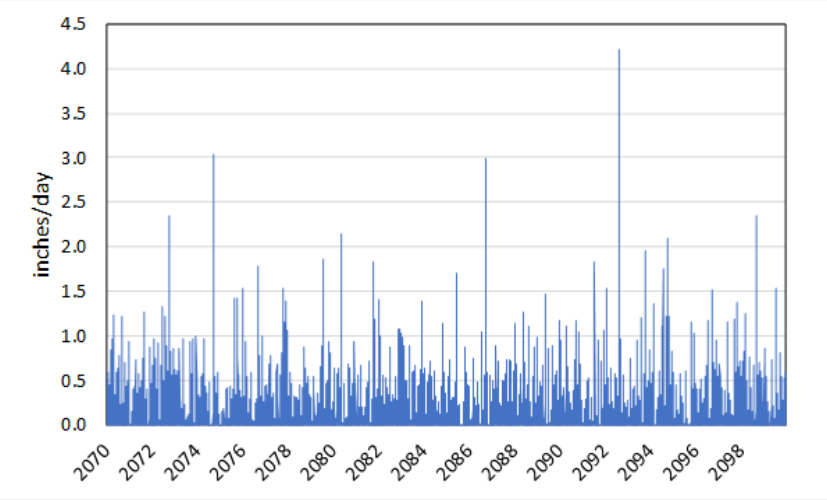
- BMPs designed to maximize treatment of 90th percentile 24-hr event that occurs multiple times per year
- Both LOCA and MACA estimate smaller changes in these events
- ESD excess runoff volume target generally achieved in both analyses
- Hypothesis confirmed with non-inferiority test with tolerance of 0.1 inch increase per event

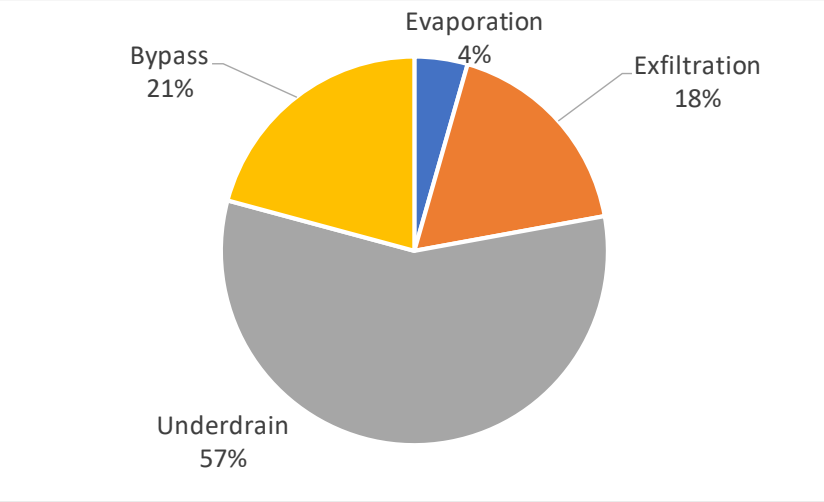


Example results for 30 GCMs, LOCA downscaling, Baltimore, RCP 8.5

Continuous Analyses of Bioretention Performance

- Statewide analysis: Use quantile mapping to modify historic 1-hr rainfall series and unit-area SWMM simulations to evaluate performance across all sites and scenarios

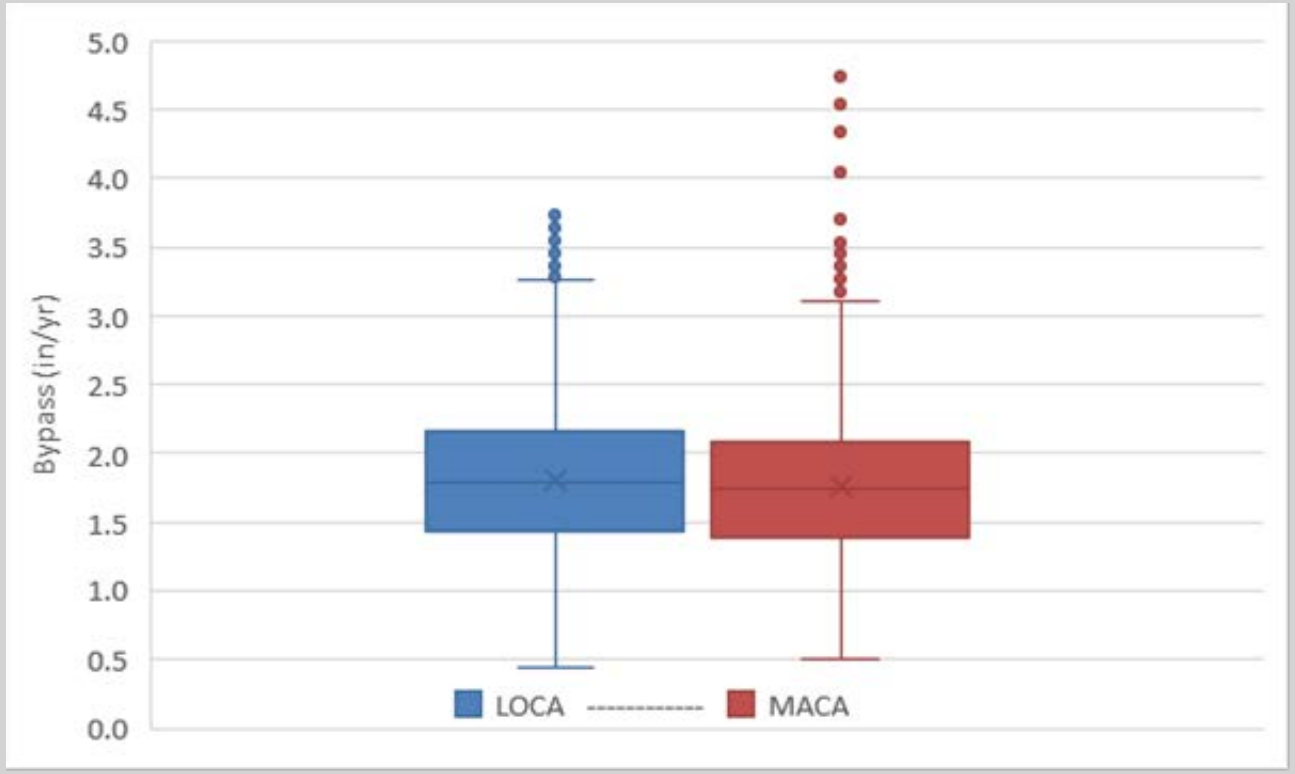




- Detailed analysis: Created future climate 5-minute time series for use by Virginia Tech collaborators in calibrated SWMM and HEC-RAS models of Tributary 109, Clarksburg, MD

Statewide Analysis of Bioretention Performance

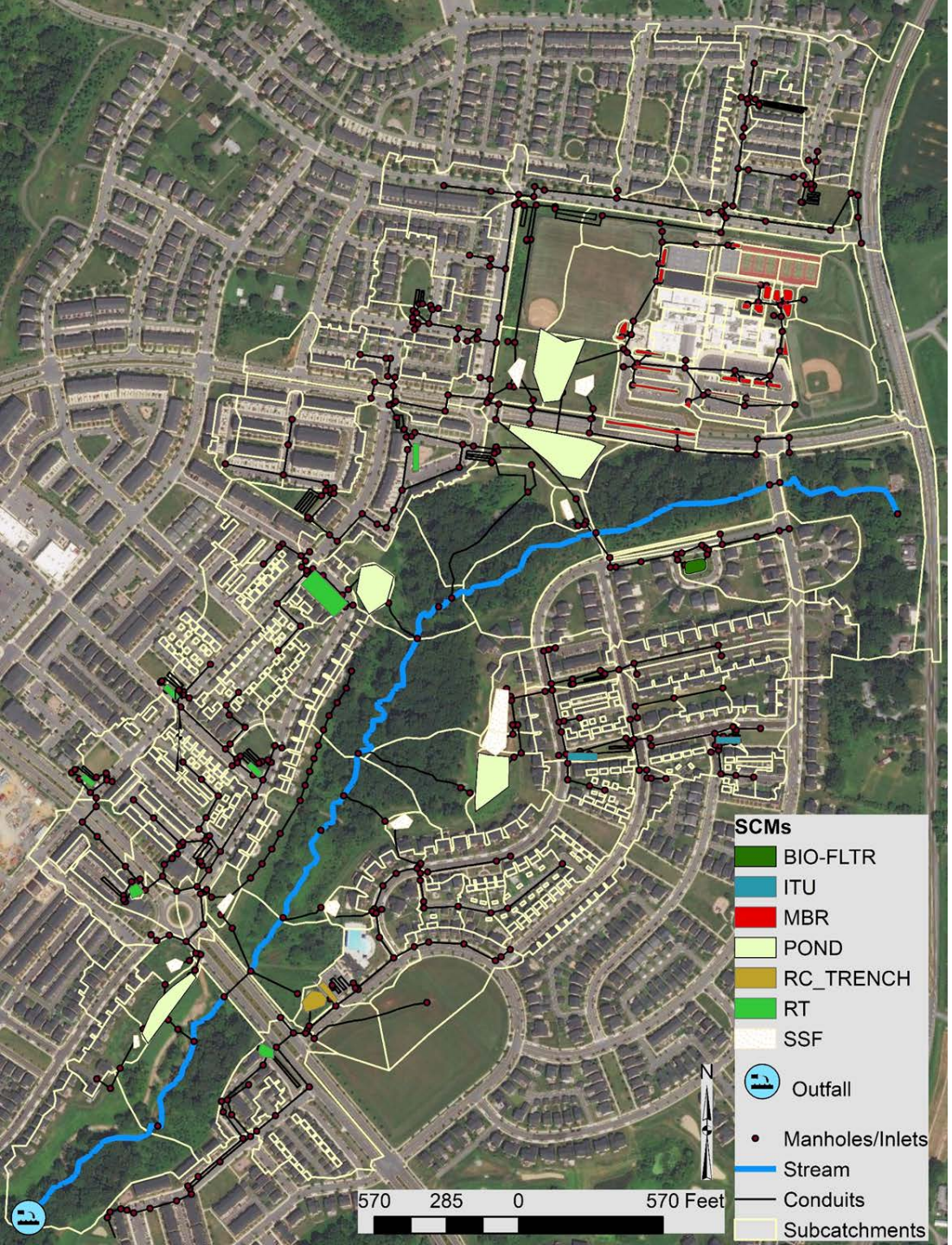
- Based on continuous simulation for all GCMs at all MD Atlas 14 sites, LOCA and MACA provide similar distribution of untreated bypass from bioretention through end of century



H3: Response of watershed equipped with ESD under future climate: Null Hypotheses

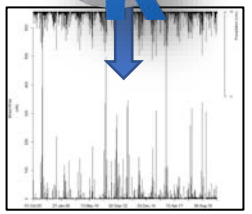
- Historical duration curve will not change
- Stream will not experience increased channel erosion
- Retrofitting existing stormwater management will protect channel stability for all CC scenarios

H3a: Continuous SWMM Simulation with Future Climate



SWMM
Storm Water Management Model

R

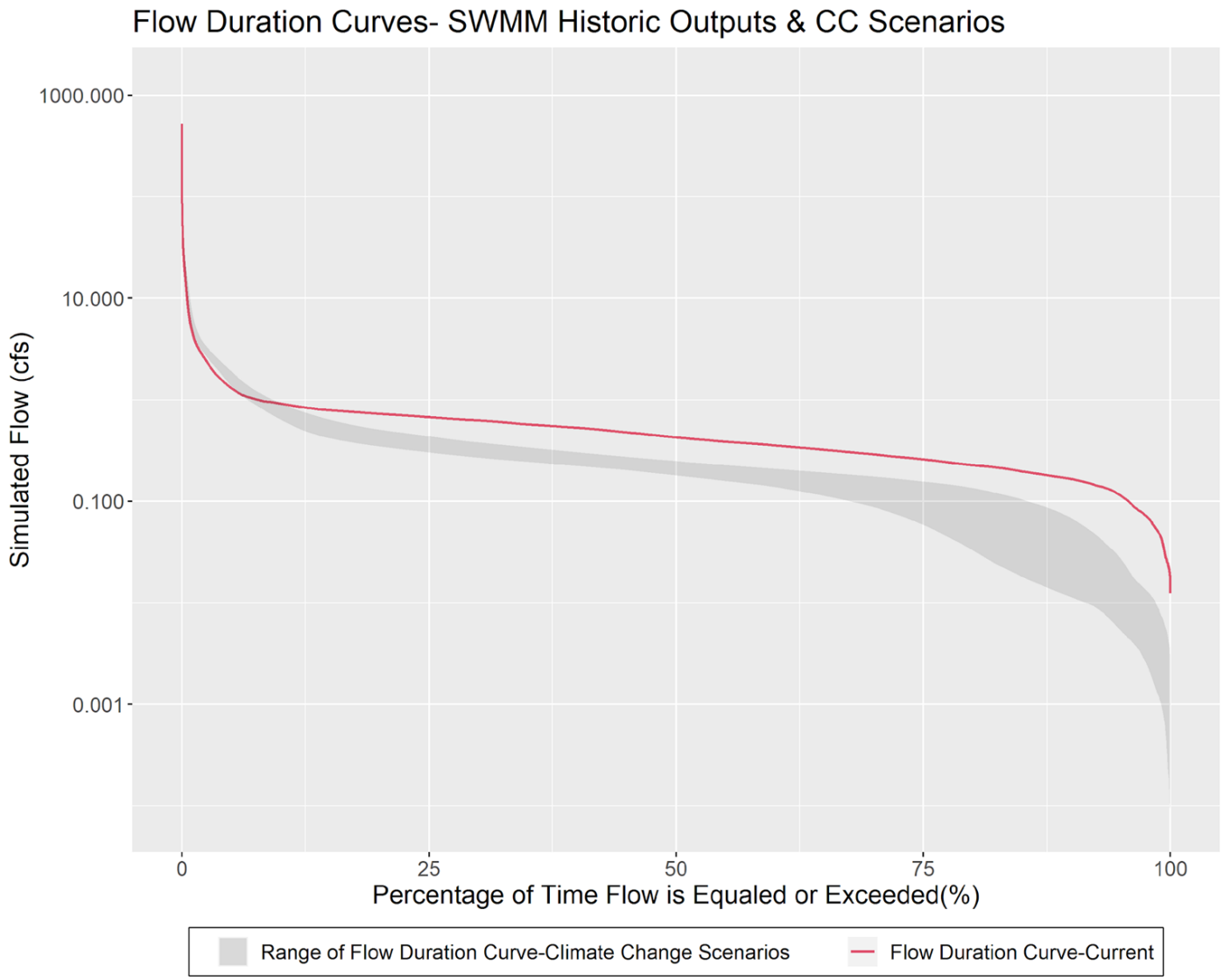


All 5-minute flows

Flow Duration Curve

Annual maximum flows

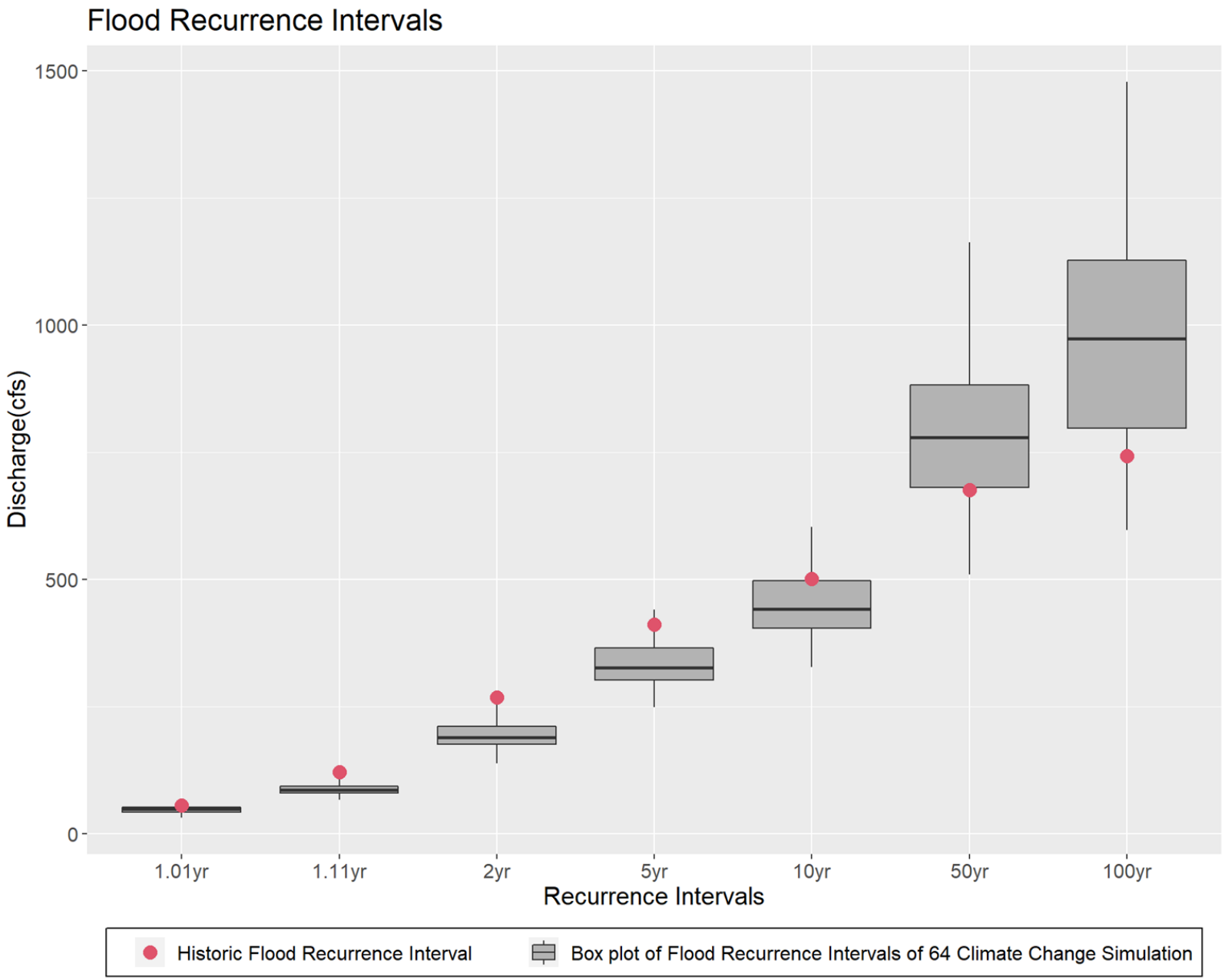
Flood Frequency



Stream discharge will be greater than current conditions for 4% of all flows in Tributary 109

* Flood peak discharges will likely decrease for recurrence intervals <10 yrs and increase for recurrence intervals > 20 yrs

* Ongoing work by VT: simulating channel stability with HEC-RAS for continuous future-climate time series



Summary

Downscaling methods concur in predicting strong increases in extreme events; small changes in more common events

Maryland ESD requirements are likely robust against predicted changes

Infrastructure and stream restoration projects appear at greater risk from extreme events

Downscaling method does affect results, with intensities on average MACA > CORDEX > LOCA

Only the more extreme flood events (Recurrence Interval > 20 yrs) will likely increase due to climate change; average stream flows will generally decrease for Clarksburg Tributary 109

Advice to Regulators and Practitioners

- Future is uncertain, but increase in high intensity storms is likely
- How to adjust design standards depends on risk aversion – cost versus risk from potential future conditions

➢ Encourage designs that are adaptable to an uncertain future

➢ Seek resilient solutions in which adaptations provide co-benefits (e.g., green space, urban heat island mitigation, carbon sequestration) even if the future turns out different than projected by models

Acknowledgments

- We thank the many partners who support the Restoration Research program for their funding and interest. Major funding for this phase of the work was provided by the U.S. Environmental Protection Agency

Translation Slides

What are the take home points?
What does this mean for me?

Translation Slides by Guido Yactayo

What does this mean for me?

- Downscaling choice matters
- ESD will still meet design objectives

What does this mean for me?

What do I take from this if I am a practitioner: ~2 ideas here

- Downscaling methods can be a source of bias in climate assessments.
- Need for synthesis of research

What do I take from this if I am a regulator: ~2 ideas here

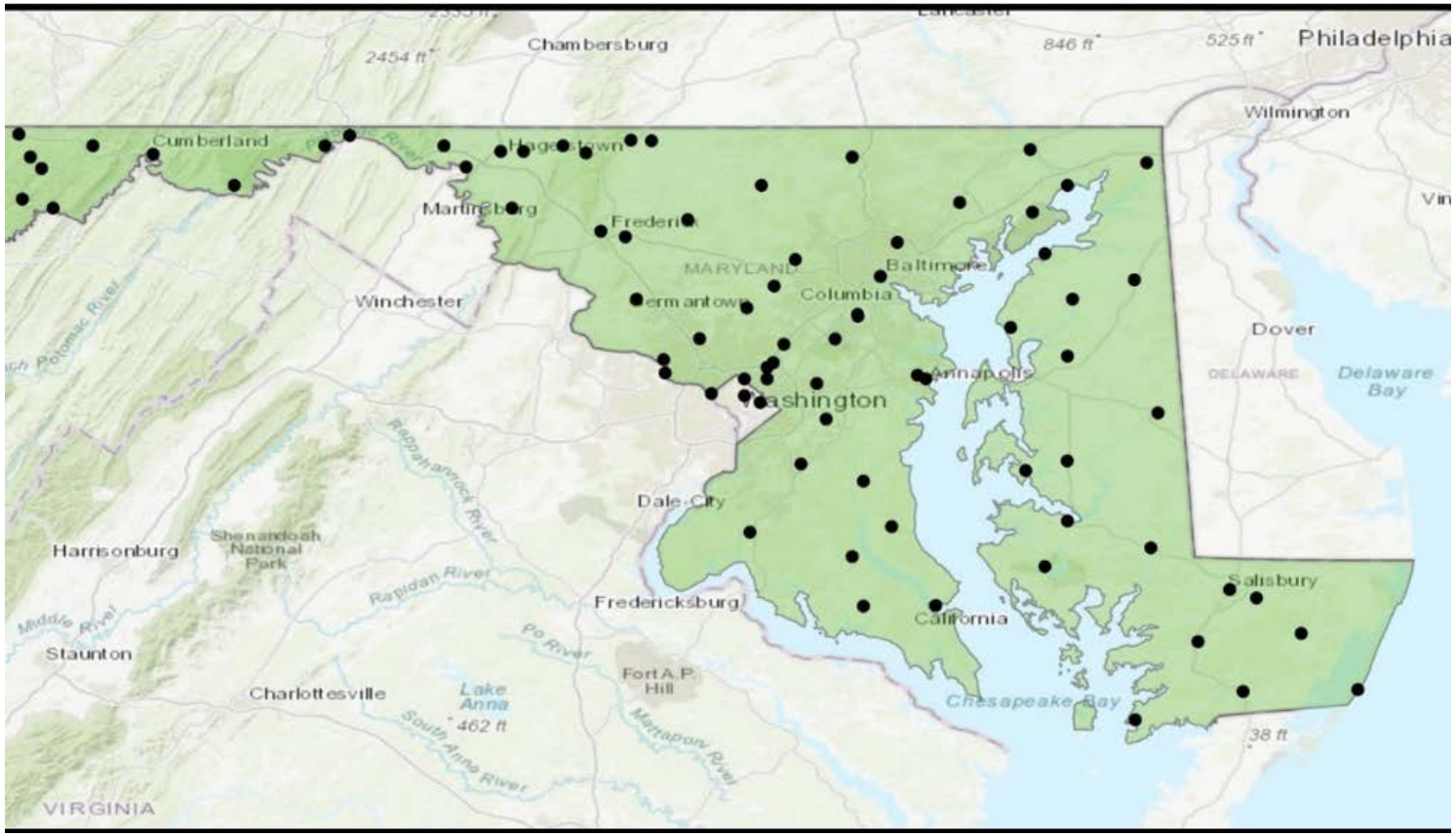
- MDE's plans to update stormwater management regulations.
- Incorporate resilient design to restoration projects to minimize risk in vulnerable communities.

You are done!

Thank you for your hard work to do the research, communicate it clearly to the audience, and translate this into something the audience can do with the information in their work tasks.

Backup Slides

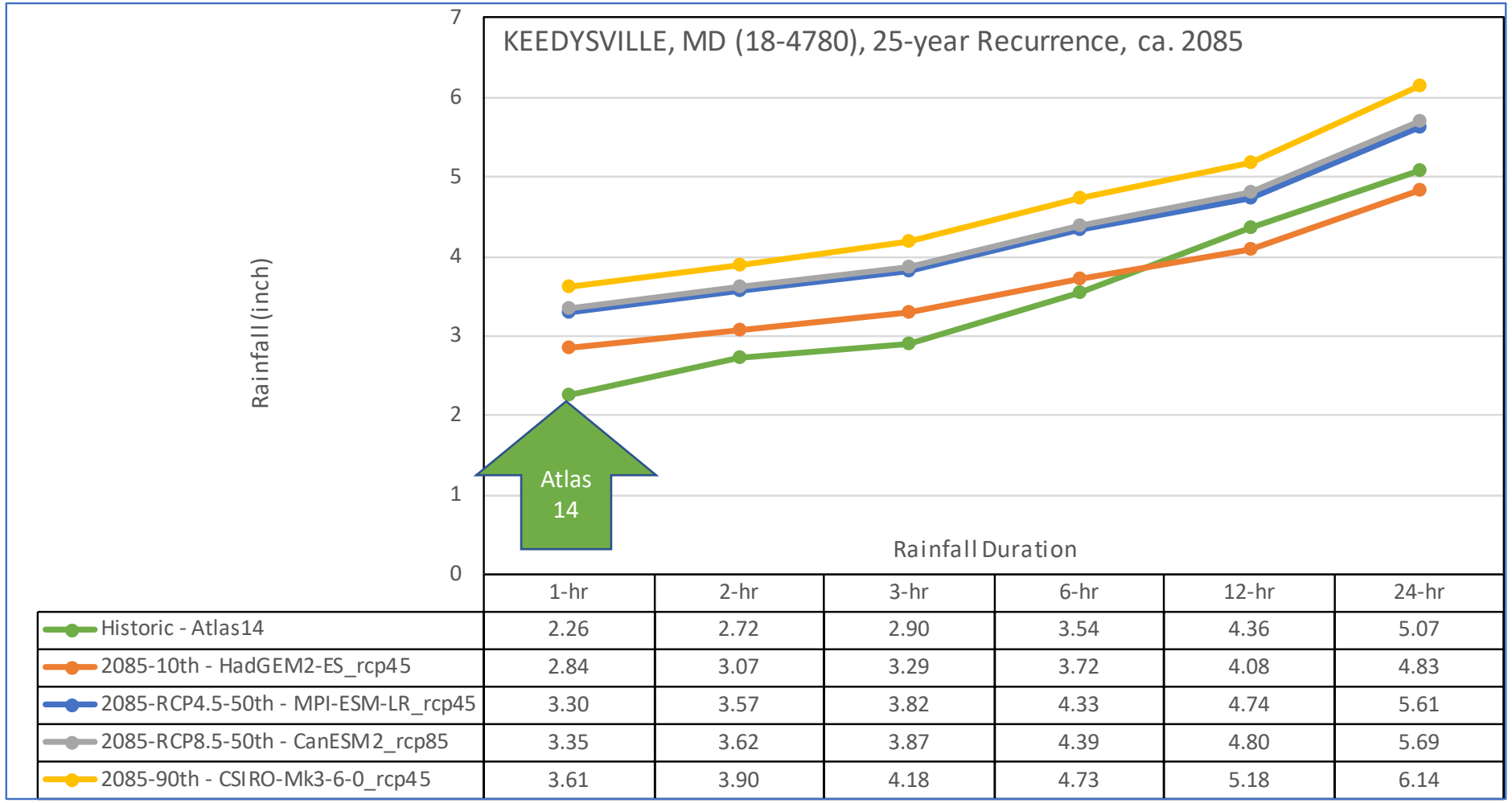
Use only if needed to answer questions



Efficient Methods Enable Climate-adjusted Estimates of Precipitation and Runoff throughout MD

- Statistical approach to update NOAA Atlas 14 IDF curves based on change in climate models (EQM)
- Application of SWMM5 to convert rainfall to runoff and simulate BMP performance
- Estimate range of futures to which adaptation may be needed
- Database of results for 79 MD stations, mid and late century

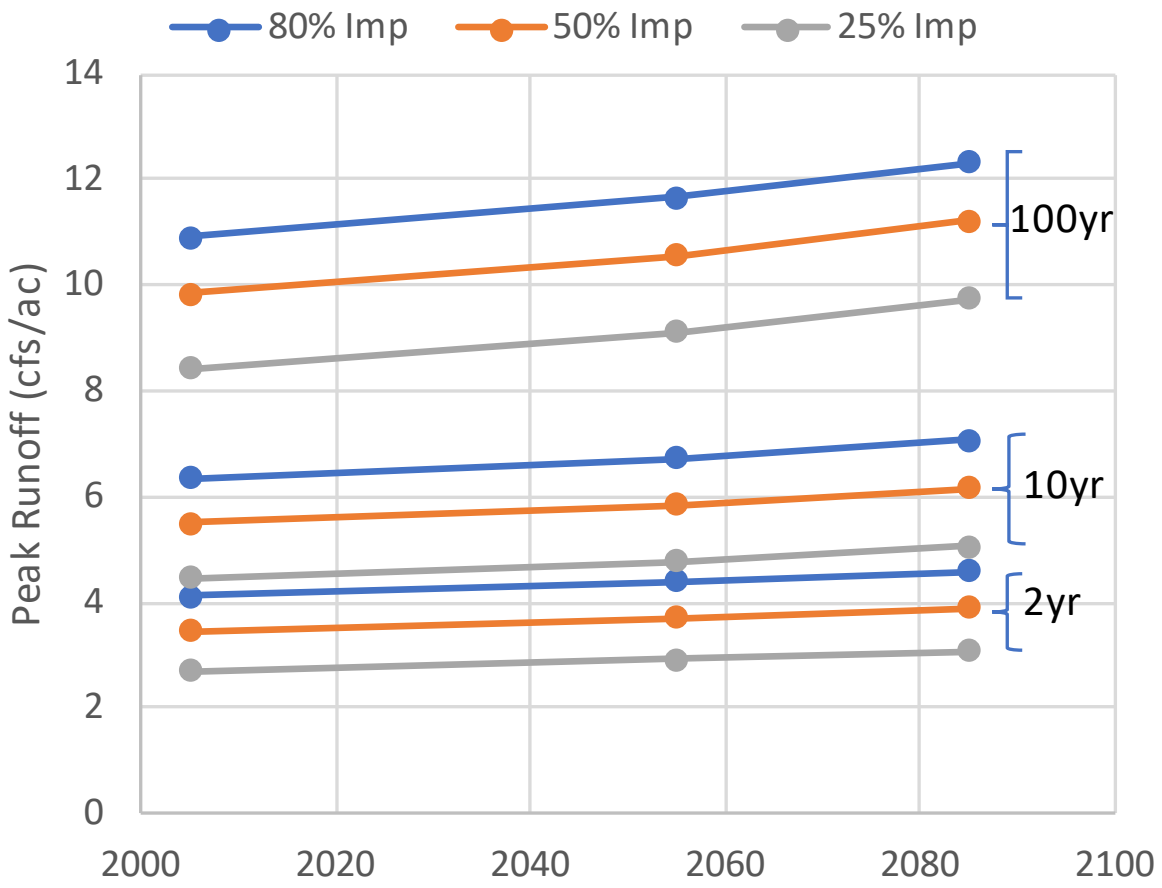
Future IDF Curves Show a Range of Possible Conditions, with a Tendency toward More Intense Storms



	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Historic - Atlas14	2.26	2.72	2.90	3.54	4.36	5.07
2085-10th - HadGEM2-ES_rcp45	2.84	3.07	3.29	3.72	4.08	4.83
2085-RCP4.5-50th - MPI-ESM-LR_rcp45	3.30	3.57	3.82	4.33	4.74	5.61
2085-RCP8.5-50th - CanESM2_rcp85	3.35	3.62	3.87	4.39	4.80	5.69
2085-90th - CSIRO-Mk3-6-0_rcp45	3.61	3.90	4.18	4.73	5.18	6.14

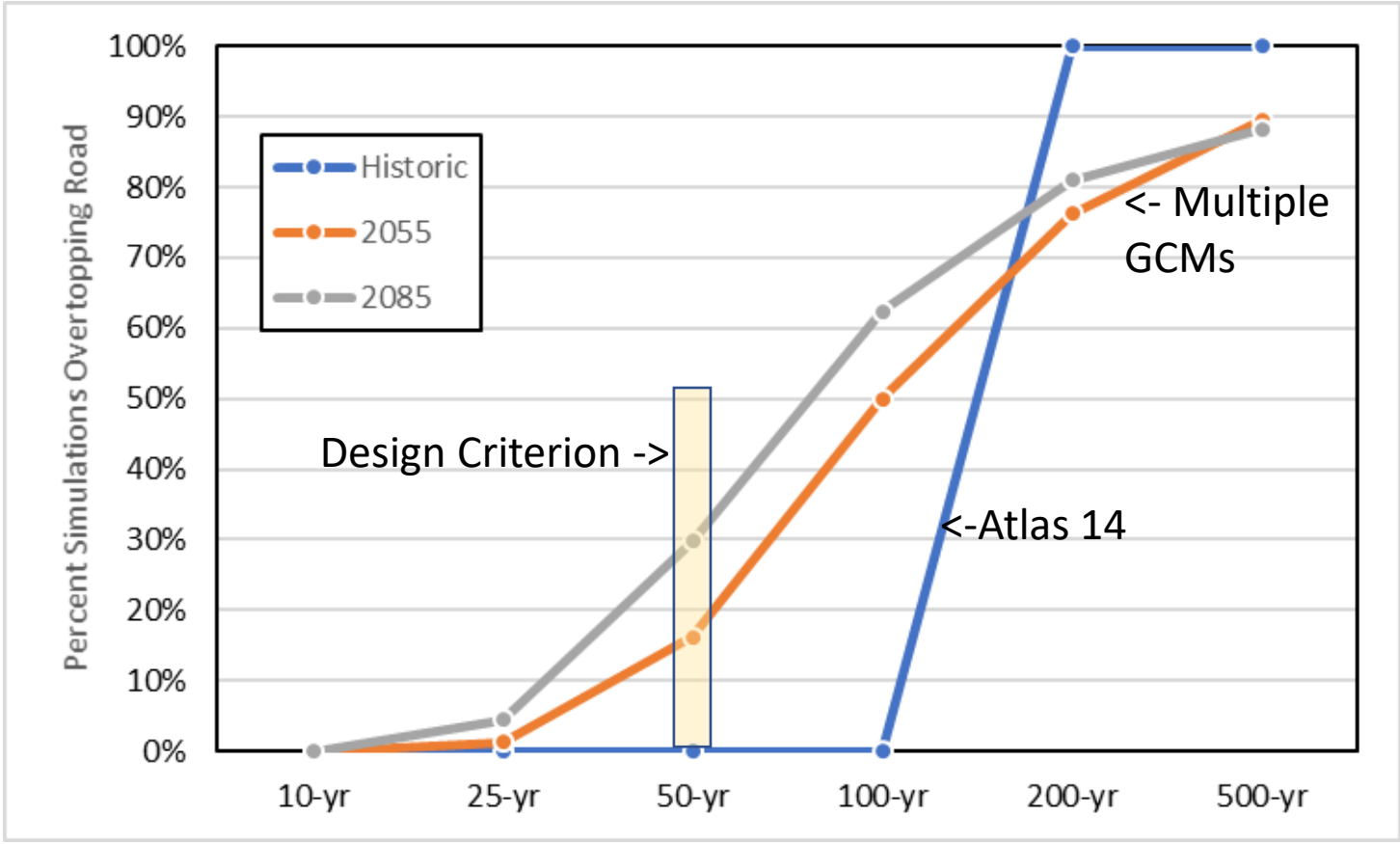
Runoff Depends on Rainfall and Site Conditions – but the General Trend is Up

- Averages over 20,576 combinations of sites, GCMs, recurrence intervals, imperviousness
- ~14% increase in storm peak runoff rates by late century
- Larger increases for more extreme events



Increasing Flood Risk for Current Designs

- Road culvert designed to pass runoff from 50-year 24-hr storm (minor arterial road)
- Large potential increases in low-recurrence events = greater flood risk



1% slope, 100 ft round culvert, 4.5 ft diameter, 200 cfs design flow, 2 ft freeboard at design flow (matches FHWA Design Guideline 1)

Journal of Water Resources Planning and Management / Volume 147 Issue 10 - October 2021

Technical Papers

Storm Intensification: Implications for Environmental Design in Maryland

Jonathan B. Butcher, Ph.D., P.H., M.ASCE

Abstract

Extreme precipitation is predicted to increase over the 21st century. Stormwater infrastructure designs based on historic climate experience will have reduced margins of safety and could fail to provide intended levels of services. Climate-adjusted rainfall intensity-duration-frequency curves were estimated at locations throughout Maryland for multiple climate models and land cover assumptions and linked to rainfall-runoff models with green and gray stormwater control measures (SCMs). These data are used to evaluate three classes of responses: highway

Author

Jonathan B. Butcher, Ph.D., P.H., M.ASCE

Senior Hydrologist, Tetra Tech, Inc., Research Triangle Park, NC 27709. ORCID: https://orcid.org/0000-0002-1894-4419. Email: Jon.Butcher@tetratech.com

https://doi.org/10.1061/(ASCE)WR.1943-5452.0001448

Received: December 03, 2020

Accepted: May 09, 2021

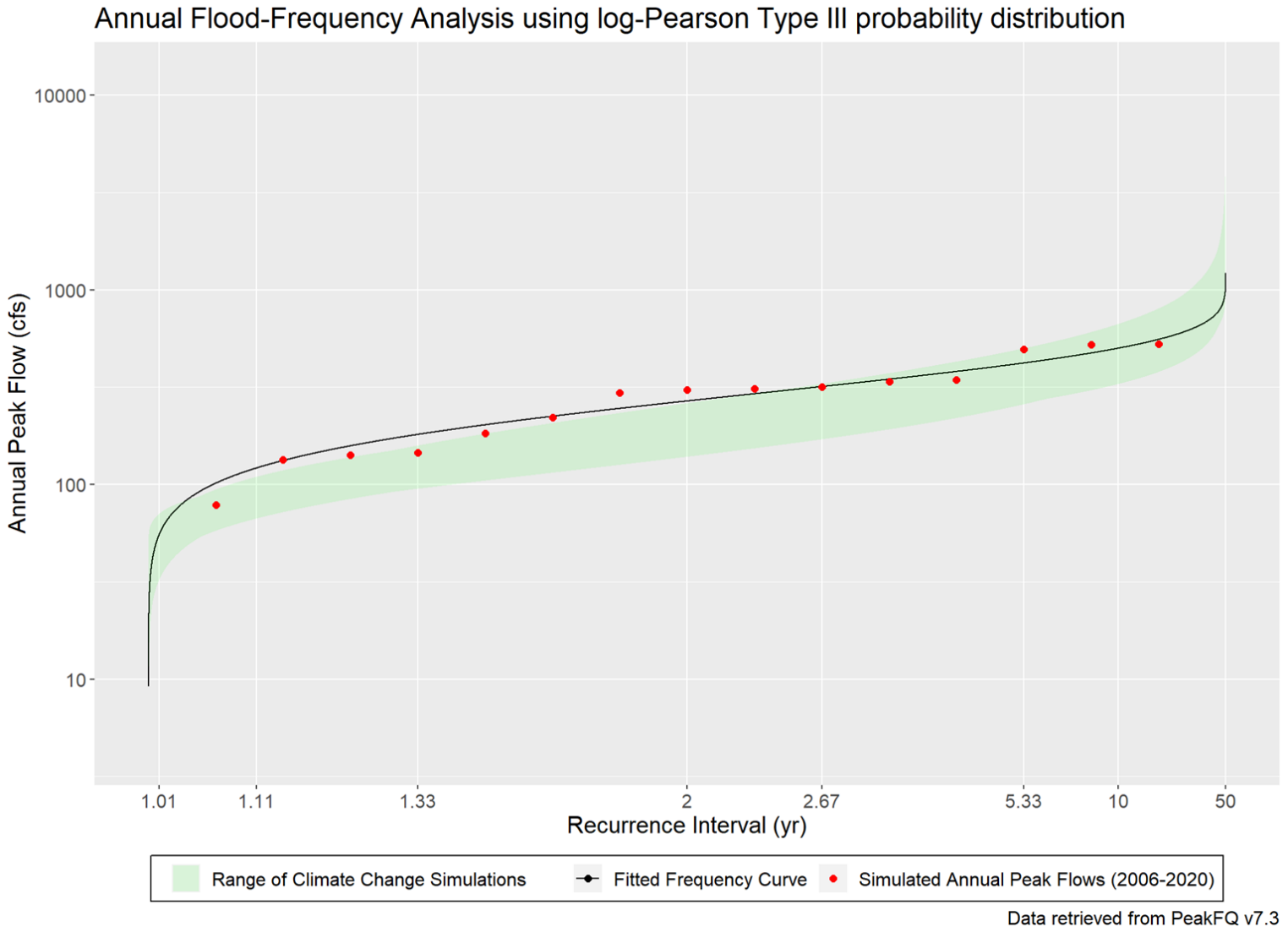
Published online: August 16, 2021

ASCE Subject Headings: Precipitation, Storms, Stormwater management, Floods, Climates, Rainfall intensity, Highway and road design, River bank stabilization, Maryland

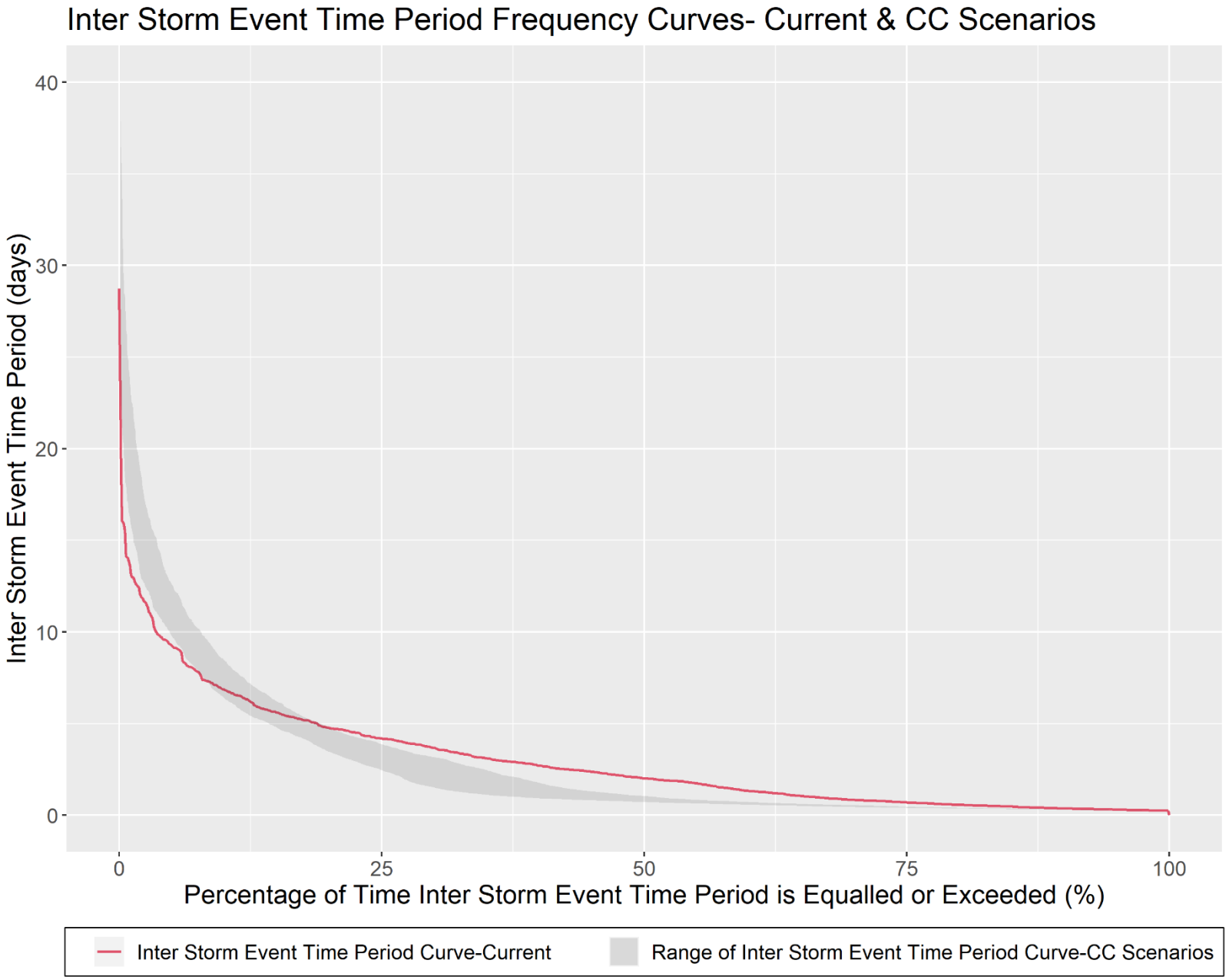
Journal of Water Resources Planning and Management

Vol. 147, Issue 10 (October 2021)

Flood Frequency Analysis – Tributary 109



Droughts (Inter Storm Event Time Period> **5** days) most likely to increase in future. Median Dry Duration to decrease in future – Storms likely to happen more frequently



For Clarksburg Tributary 109: Total rainfall depth of extreme storm events increases.
For 99% of storm events total rainfall depth will decrease