Climate Impacts to Restoration Practices

Joint Meeting of the Urban Stormwater Workgroup and Climate Resiliency Workgroup
October 19, 2021

Jon Butcher, Tetra Tech,
with support from:

Two CBT grants to investigate future changes in storm intensity and potential effects on infrastructure in MD

- Grant # 16928 (Sept 2019 – January 2021)
  - Build on theoretical work sponsored by EPA ORD to develop climate-modified IDF curves consistent with NOAA Atlas 14
  - Develop mid and late-century IDF and runoff relationships for all MD Atlas 14 stations
- Grant # 19278 (July 2021 – December 2022)
  - Explore methodological questions raised in first phase
  - Required QAPP, signed 9/16/2021

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Premises:

- Need analyses that present the range of reasonably possible future events to which adaptation may be needed
- Desire consistency with NOAA Atlas 14
- Want methods that can rapidly ingest new climate projections (e.g., CMIP6 experiments, new dynamical downscaling results) so that results are not tied to a limited set of experiments
- Should provide conversion of storm-event precipitation to runoff time series that will determine impacts on infrastructure

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Technical Approach

- Our Phase 1 approach differs from many other IDF efforts
  - Don’t rely directly on GCM or RCM-based prediction of extreme events
  - Replicate NOAA Atlas 14 IDF methods (AMP-based)
  - Use LOCA statistically downscaled daily GCM output
  - Map relative change in AMP distribution functions between historic and future conditions in downscaled GCM output to NOAA maxima series and recalculate IDF

Climatic Change (2021) 164: 3
https://doi.org/10.1007/s10584-021-02963-y

Check for updates

Efficient statistical approach to develop intensity-duration-frequency curves for precipitation and runoff under future climate

Jonathan B. Butcher[1] · Tan Zi[2] · Brian R. Pickard[1] · Scott C. Job[1] · Thomas E. Johnson[3] · Bryan A. Groza[4]

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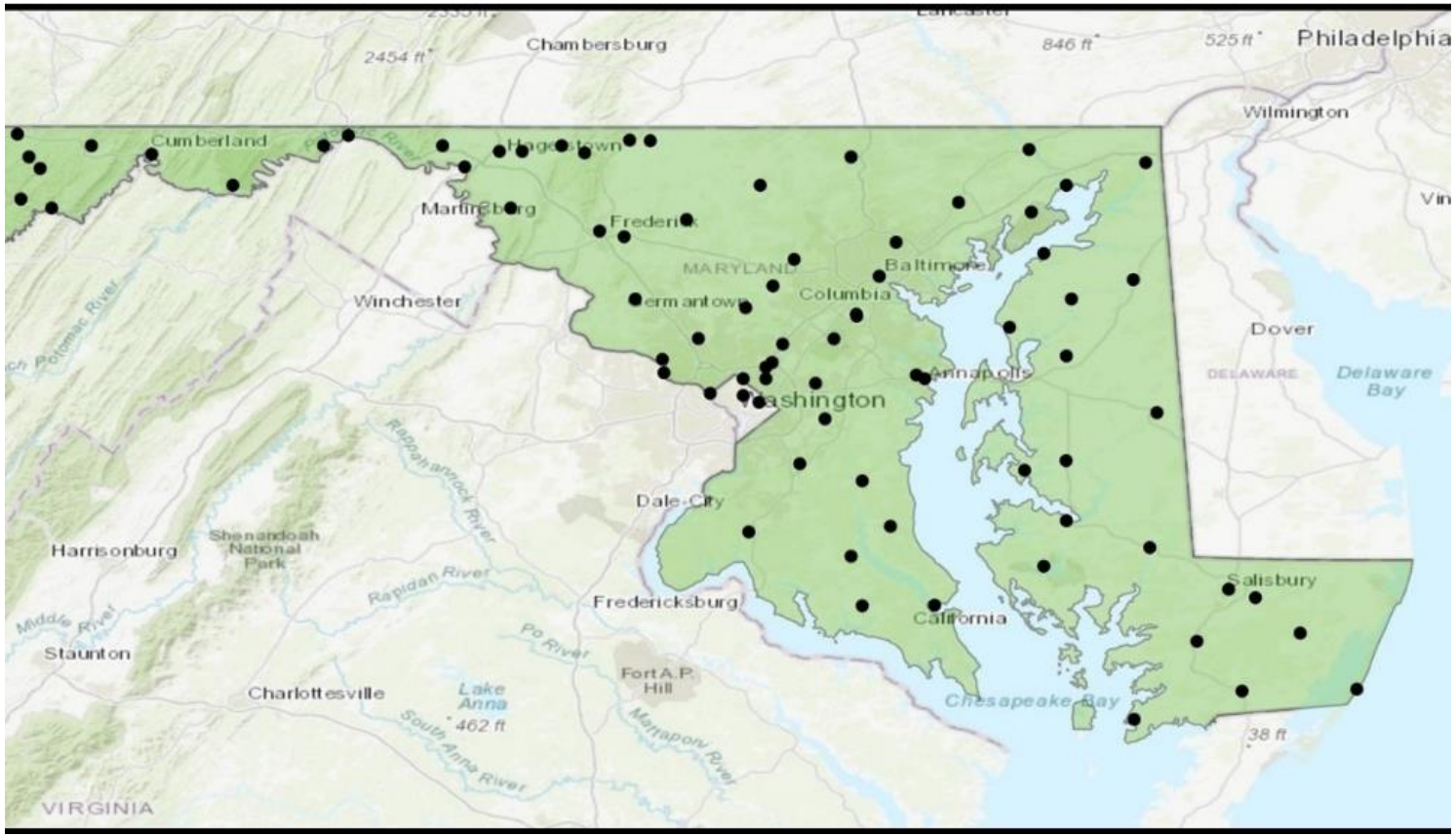
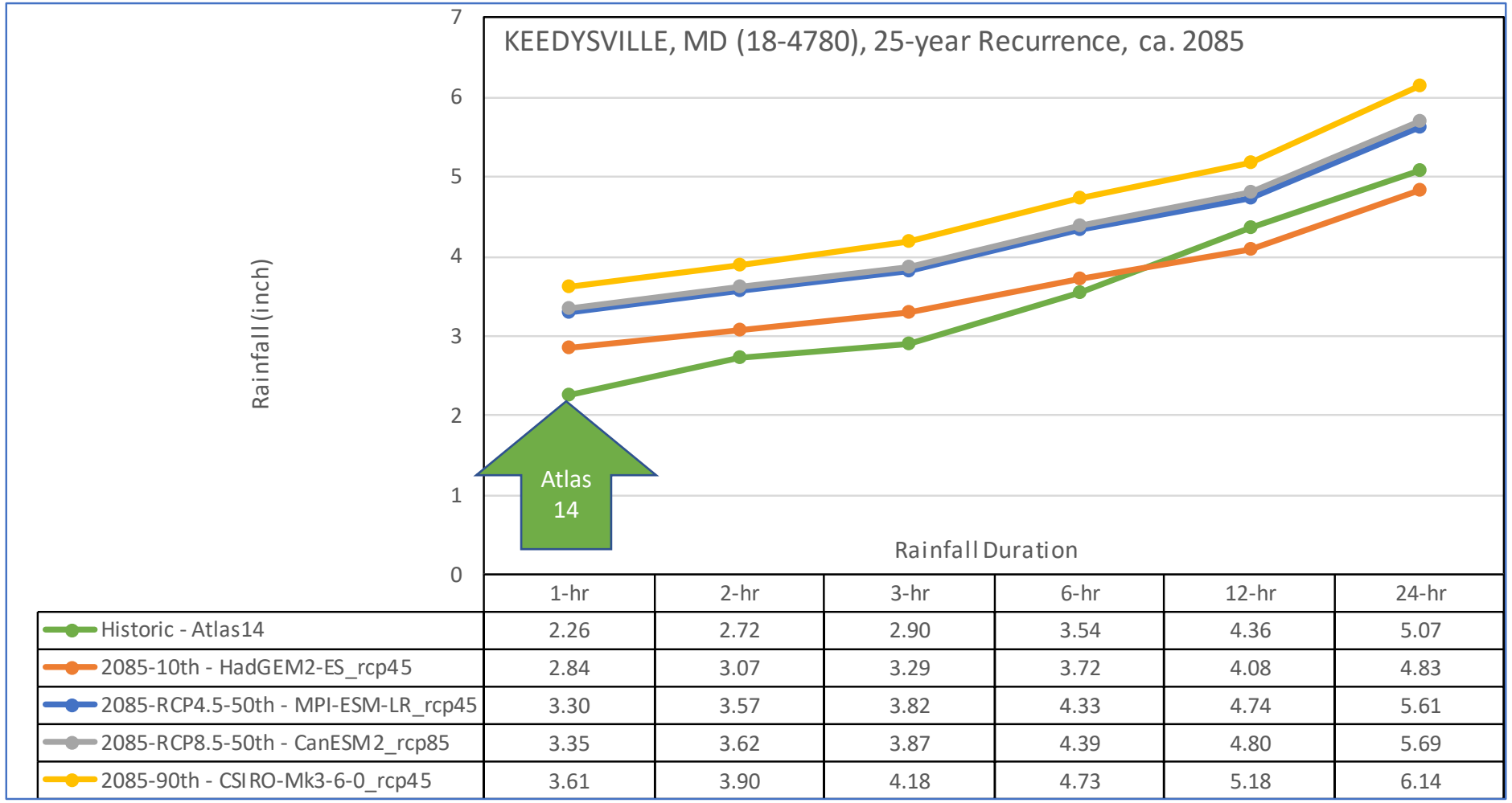


Efficient Methods Enable Climate-adjusted Estimates of Precipitation and Runoff throughout MD

- 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

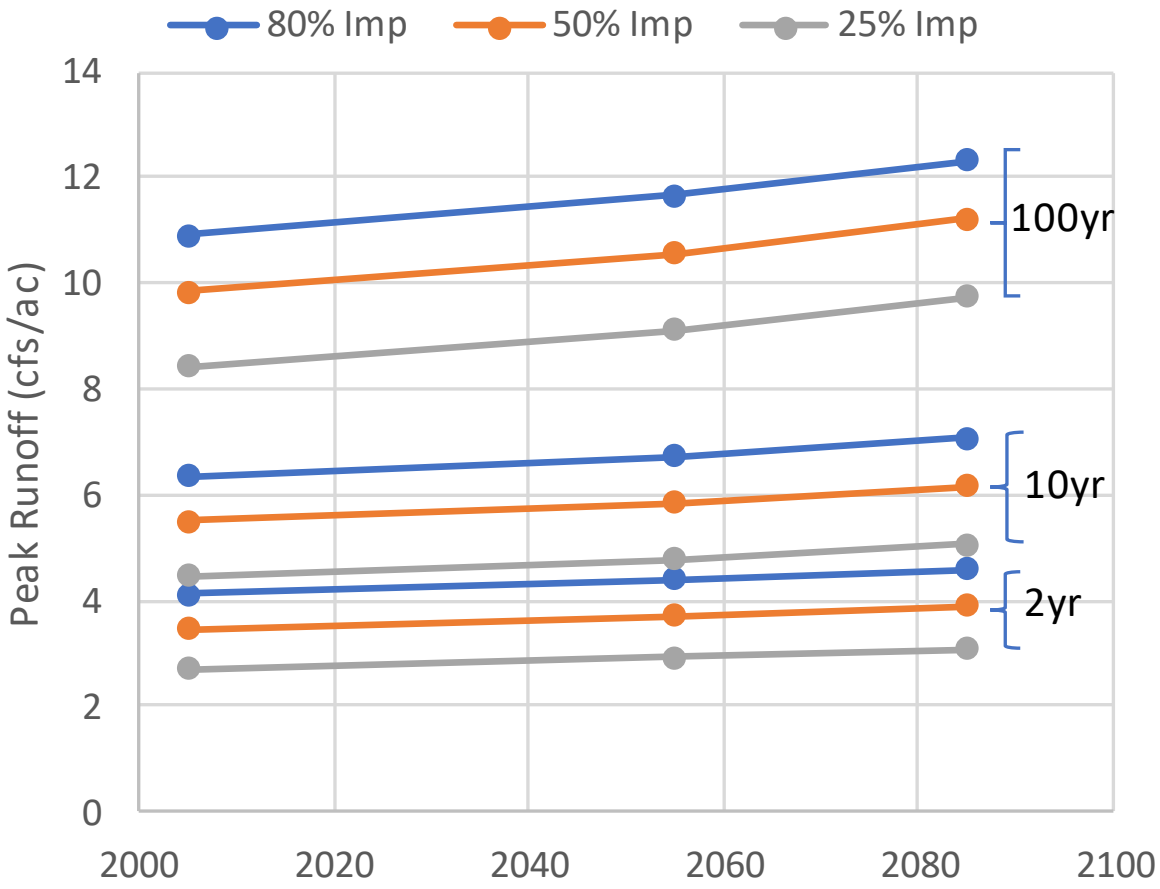
Future IDF Curves Show a Range of Possible Conditions, with a Tendency toward More Intense Storms



	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

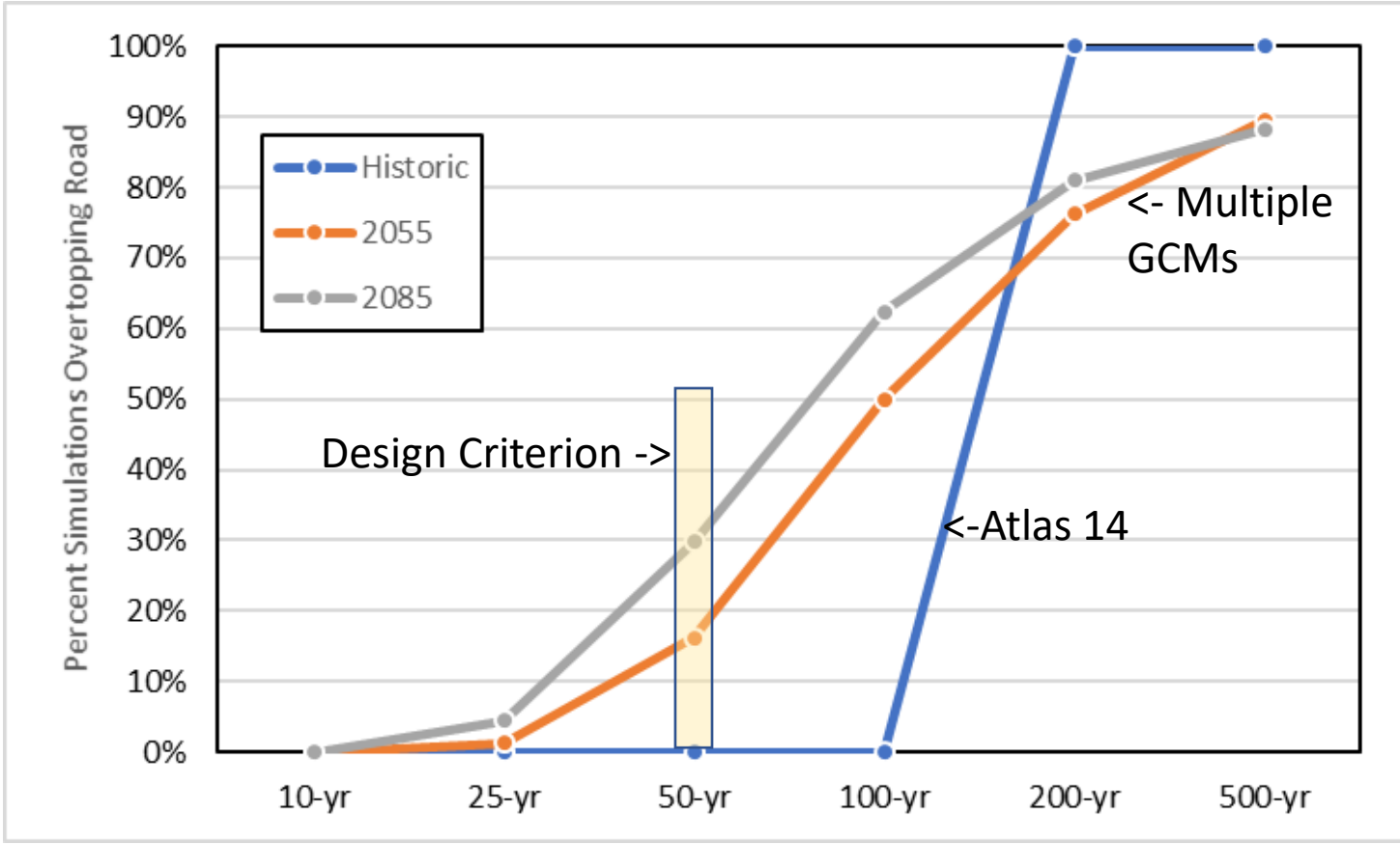
Runoff Depends on Rainfall and Site Conditions – but the General Trend is Up

- 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

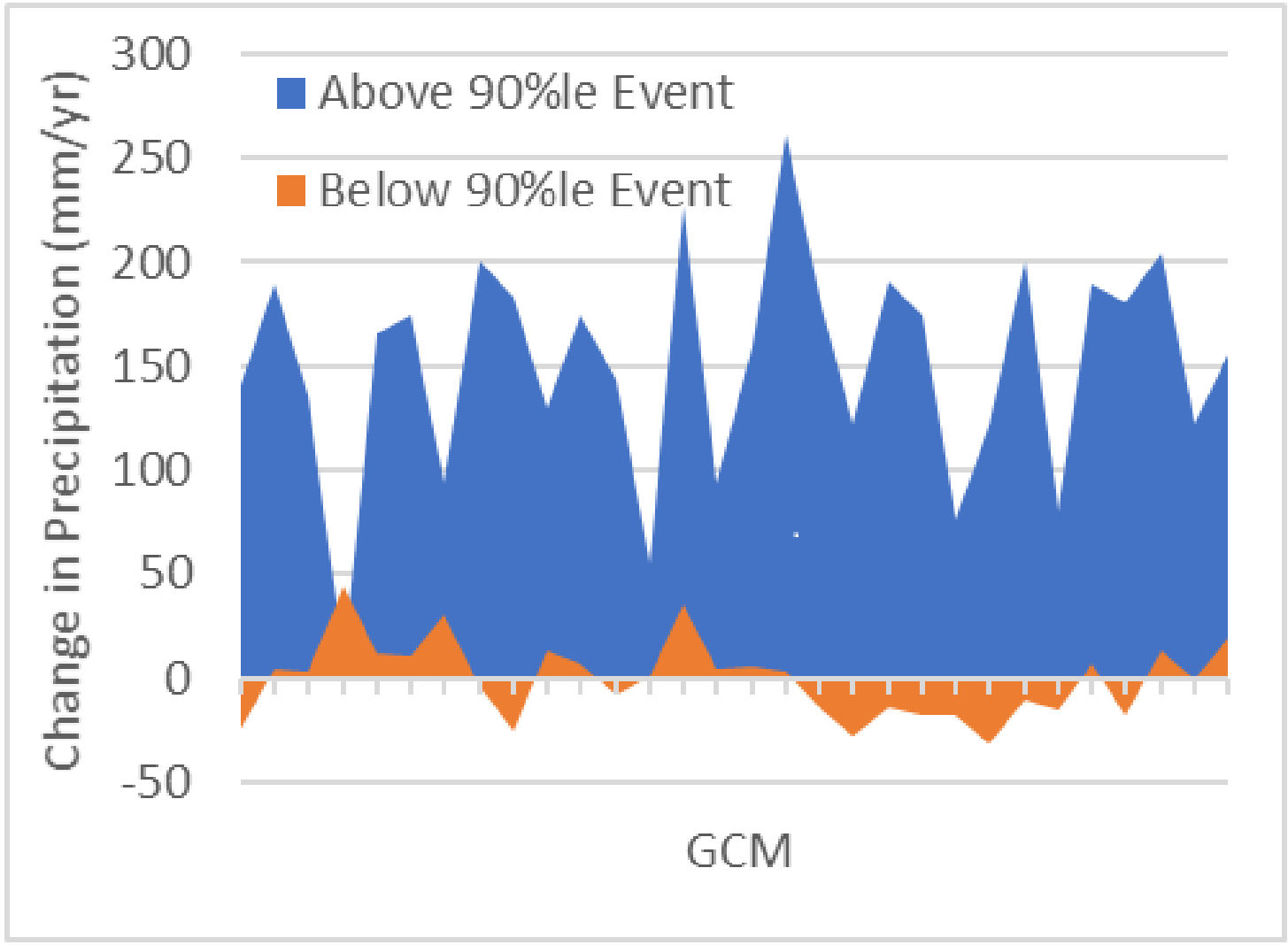
- Road culvert designed to pass runoff from 50-year 24-hr storm (minor arterial road)
- Large potential increases in low-recurrence events = greater flood risk



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)

Water Quality BMPs

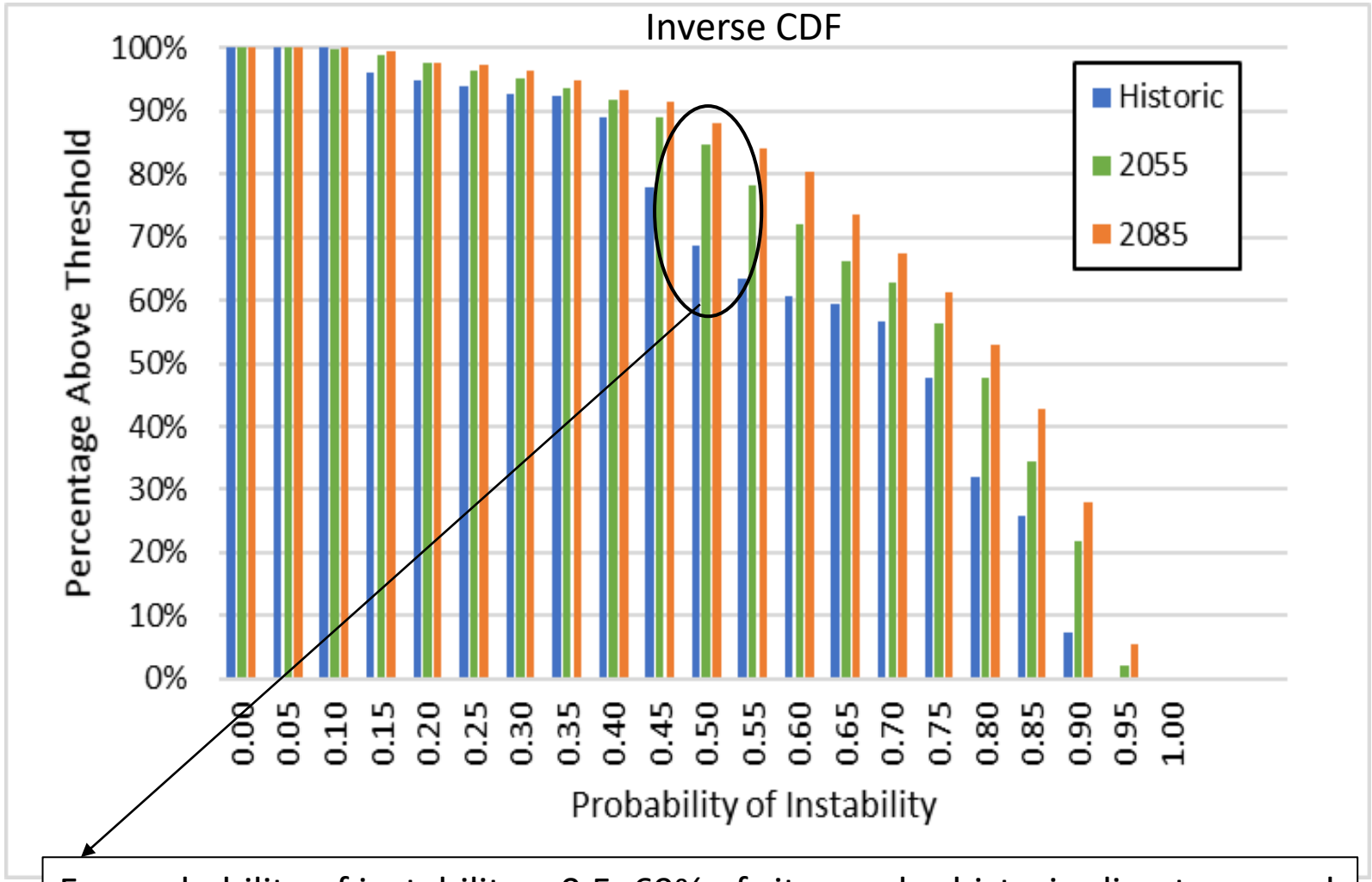
- Typically designed to maximize treatment of 90th or 95th percentile event that occurs multiple times in an average year
- Prediction with peaks-over-threshold method and Generalized Pareto Distribution estimates smaller changes in the magnitude of these events



Maryland Environmental Site Design

- Based on matching runoff from forest in good condition for 1-year storm
- Relatively minor changes in runoff for events ≤ 1-year recurrence
- ESD is likely to continue to continue to perform well
- Pollutant removal functions of most BMPs likely to be maintained

Predicted Probability of Channel Instability at 25% Imperviousness for Runoff from a 1 Acre Site with $S/\sqrt{d_{50}}$ = 1.75 using the Logistic Regression of Bledsoe and Watson (2001)



For probability of instability = 0.5, 69% of sites under historic climate exceed threshold; increasing to 85% and 88% under mid and late-century climate

Channel Stability

- Depends on site-specific factors such as slope and grain size
- Risk of crossing threshold for instability is likely to increase
- Restoration designs should consider resilience

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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

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

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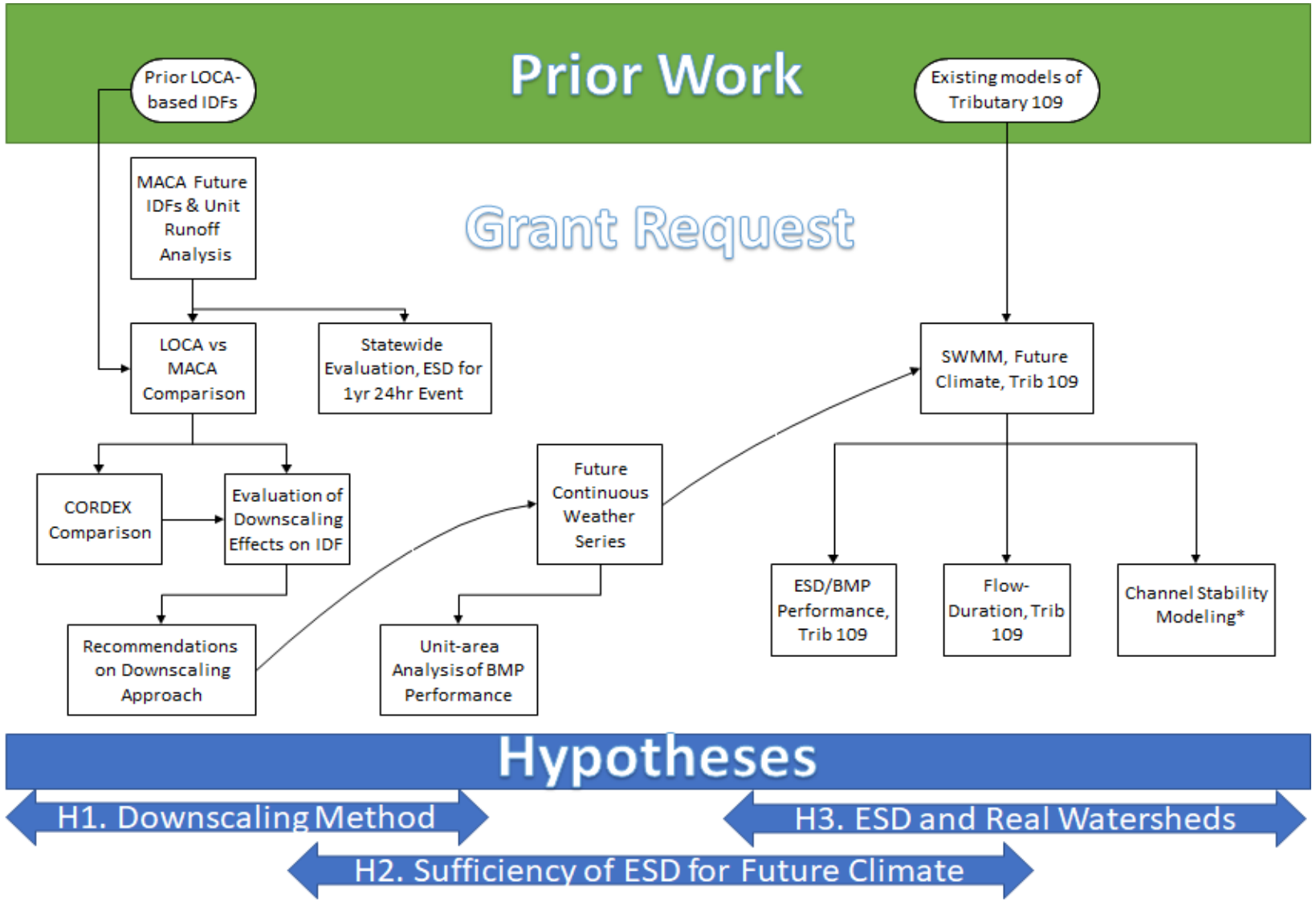
All results are conditional on the data and methods used

Phase 1 Caveats

- LOCA statistically downscaled climate scenarios may contain inherent biases relative to prediction of extreme events
- Common methods of identifying representative median, dry, and wet scenarios may be misleading
- Analysis based on IDF curves and simplified runoff models may differ from real world responses

Phase 2 CBT Grant

- Joint proposal from Tetra Tech and Virginia Tech to investigate the caveats raised on previous slide
- **H1**. Problems in the LOCA methodology introduce biases in the estimation of future 1-year, 24-hour rainfall events used to calculate ESD. If the null hypothesis of no significant differences is not supported, analysis based on LOCA alone is not sufficient to address H2.
- **H2**. Despite changes in precipitation by mid-century, current ESD requirements will be sufficient to mitigate effects associated with anthropogenic development. Note that this focuses on anthropogenic stresses, which are the result of the difference between post-development and good condition forest. There will still be climate effects because the forest baseline will also move.
- **H3.** ESD concepts and requirements are applicable and appropriate to management of real watersheds under future climate. Most conclusions to date are based on simplified analyses using design storms and estimates of runoff from unit-area runoff models. To what extent do those conclusions remain applicable under continuous simulation with complex real watersheds? How will channel stability respond to forecast changes in hydrology?

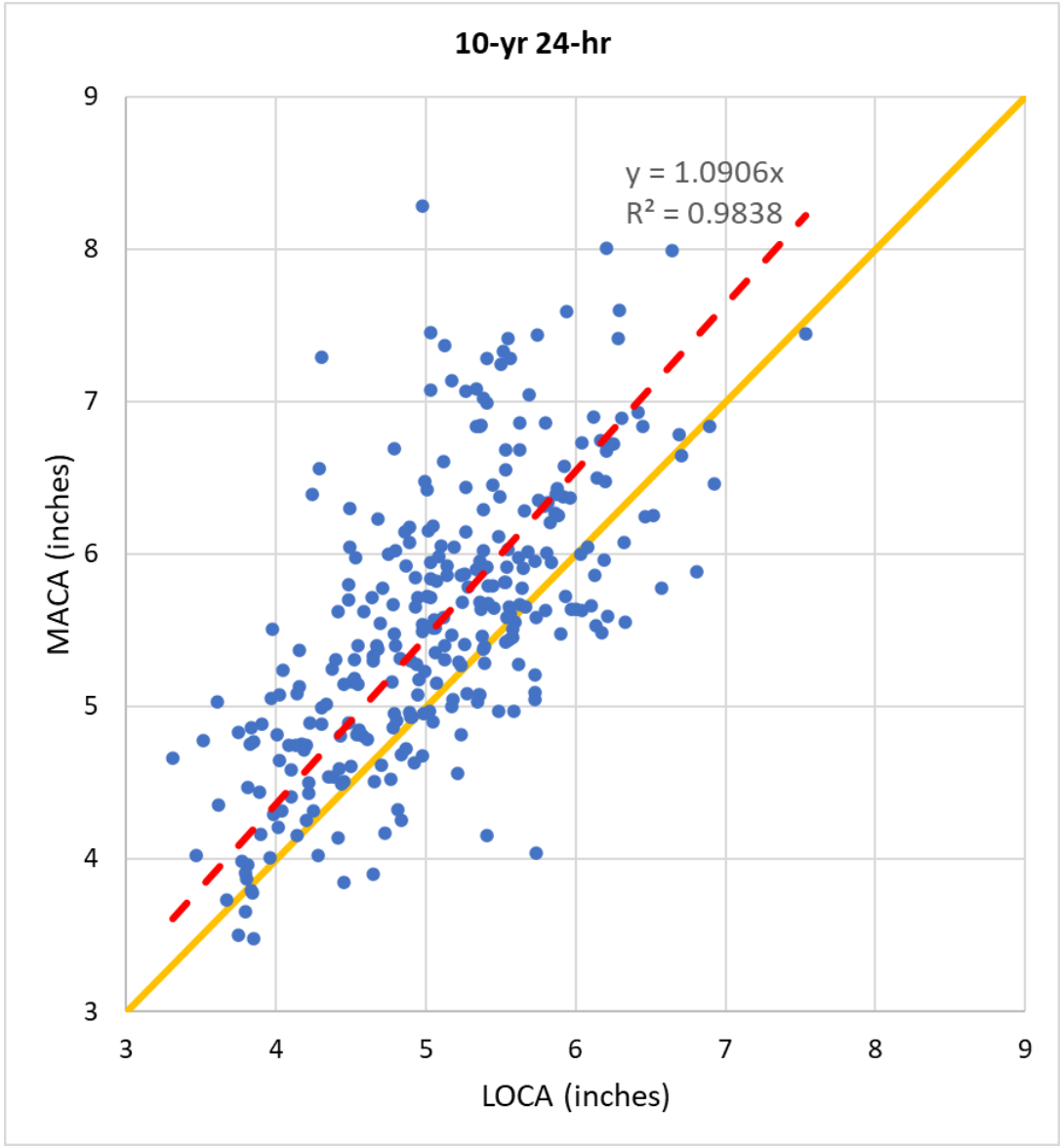

Prior Work
Prior LOCA-based IDFs
Existing models of Tributary 109
Grant Request
MACA Future IDFs & Unit Runoff Analysis
LOCA vs MACA Comparison
Statewide Evaluation, ESD for 1yr 24hr Event
SWMM, Future Climate, Trib 109
CORDEX Comparison
Evaluation of Downscaling Effects on IDF
Future Continuous Weather Series
ESD/BMP Performance, Trib 109
Flow-Duration, Trib 109
Channel Stability Modeling*
Recommendations on Downscaling Approach
Unit-area Analysis of BMP Performance
Hypotheses
H1. Downscaling Method
H3. ESD and Real Watersheds
H2. Sufficiency of ESD for Future Climate

Role of Downscaling Methods

- Recent research by G. Wang et al. suggests LOCA estimates of extreme events from CMIP5 could be biased low due to the way the training data set was constructed (*J. Hydrometeorol*., DOI:10.1175/JHM-D-19-0275.1.)
- MACA (another constructed analog method) not subject to same methodological issues
- Statistical downscaling with analog methods also makes assumptions that local weather patterns in the future can be inferred from characteristics of past events; this may create biases relative to dynamical downscaling

Role of Downscaling Methods

- Comparison of IDF estimates obtained from MACA vs. LOCA suggests MACA is about 10% higher for the 10-year 24-hr event across MD for mid-century
- Discrepancy increases for larger events
- Comparison to NA-CORDEX dynamically downscaled GCMs is currently underway

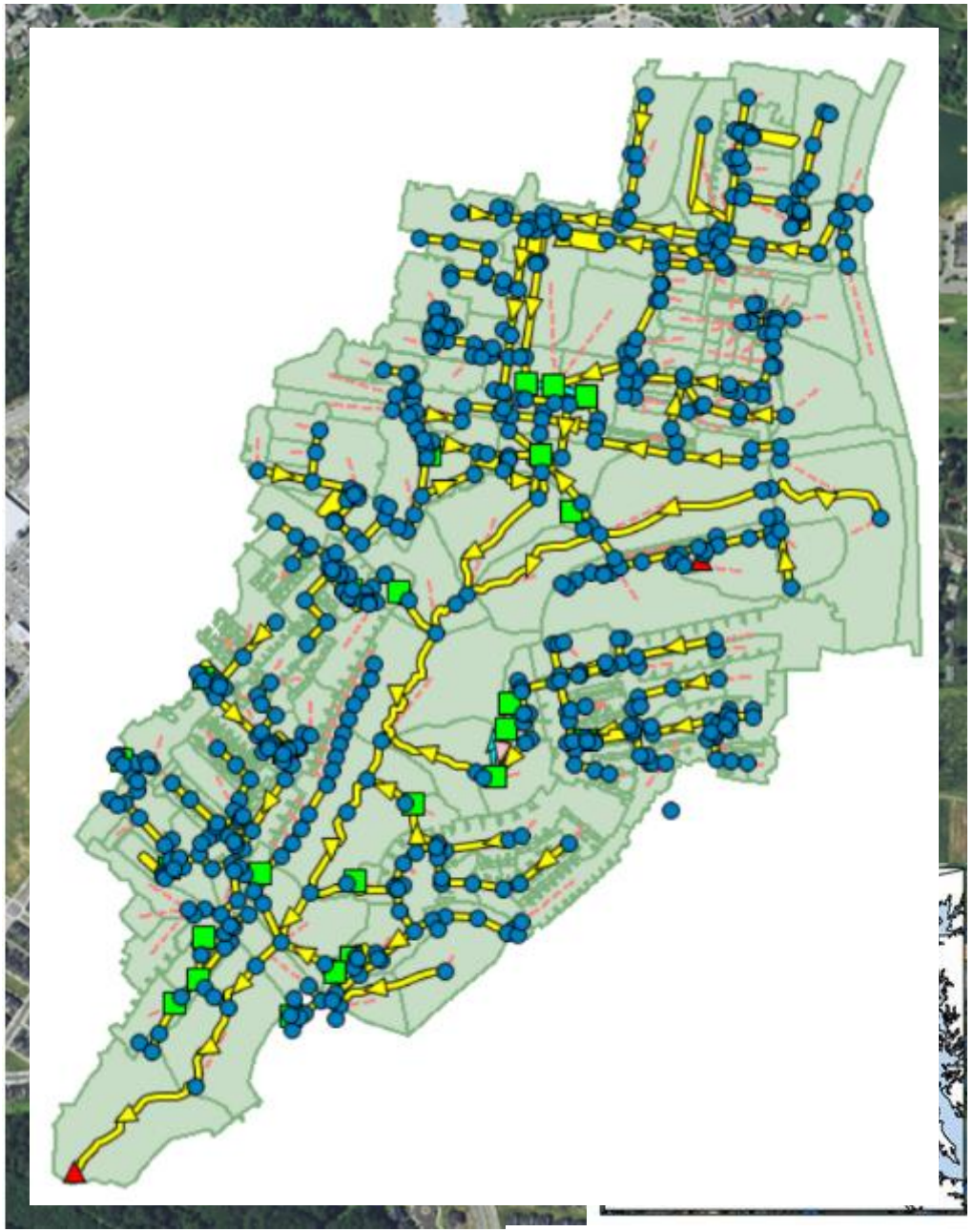


Identifying Representative Scenarios

- Selecting GCMs based on low, medium, and high annual precipitation volume does not reliably identify IDF changes
- Selecting GCMs based on magnitude of highest AMP also does not
- Solution: Generate 10-yr, 24-hr IDF estimates from all available GCMs (for both RCP 4.5 and 8.5) and pick bounding scenarios from full set

Real Sites

- Combine climate projections with detailed watershed study
- Tributary 109 to Little Seneca Creek, Montgomery Co., MD, trib to Anacostia River
- Subject of existing CBT grant to VT, detailed SWMM model
- Developed 2006-2017 with extensive emphasis on ESD BMPs
- Use HEC-RAS 6 capabilities for detailed simulation of sediment transport response to changing climate



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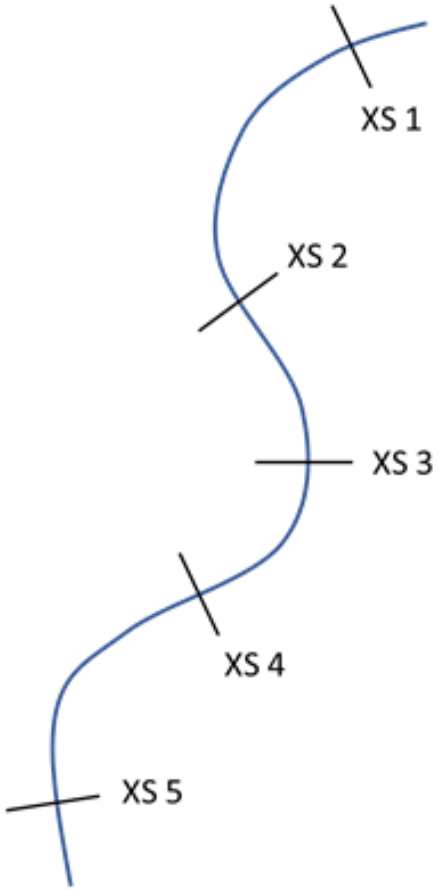
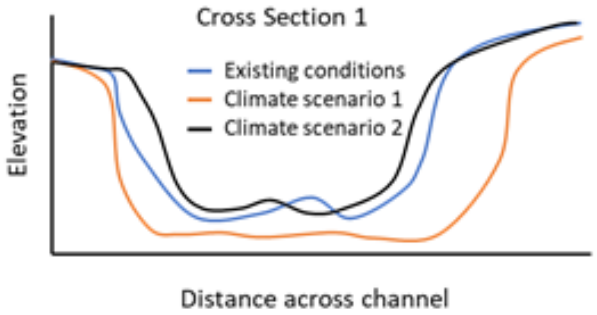
Trib 109 Study Questions

- Ability of ESD to protect channel stability
- Difference in development impact under alternative management
- Applicability of simplified measures of stream stability to real sites





Cross Section	Current XS Area (ft^2)	Scenario 1 XS Area (ft^2)	Scenario 2 XS Area (ft^2)
1	30.5	33.6	28.2
2	24.6	29.4	21.6
3	33.8	39.3	30.7
4	29.8	31.4	28.9
5	38.1	41.6	33.8

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Forthcoming Deliverables

- 11/1/2021 CORDEX analyses
- 12/1/2021 Variance decomposition and analysis of LOCA vs. MACA vs. CORDEX
- 1/15/2022 Reanalysis of adequacy of ESD guidelines for future climate (non-inferiority test); Full sets of timeseries for SWMM
- 4/1/2022 Evaluation of ESD hydrology with MACA and CORDEX: Statewide results
- 6/1/2022 SWMM evaluation of ESD hydrology: Clarksburg Trib. 109
- 6/30/2022 White Paper on Applicability of Downscaling Methods, Presentations at Restoration Research Conference
- 10/15/2022 SWMM analysis of channel stability, Clarksburg Trib. 109
- 12/15/2022 Final Project Report

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