Engineering Methods for Precipitation Under a Changing Climate: Outline of the Problem

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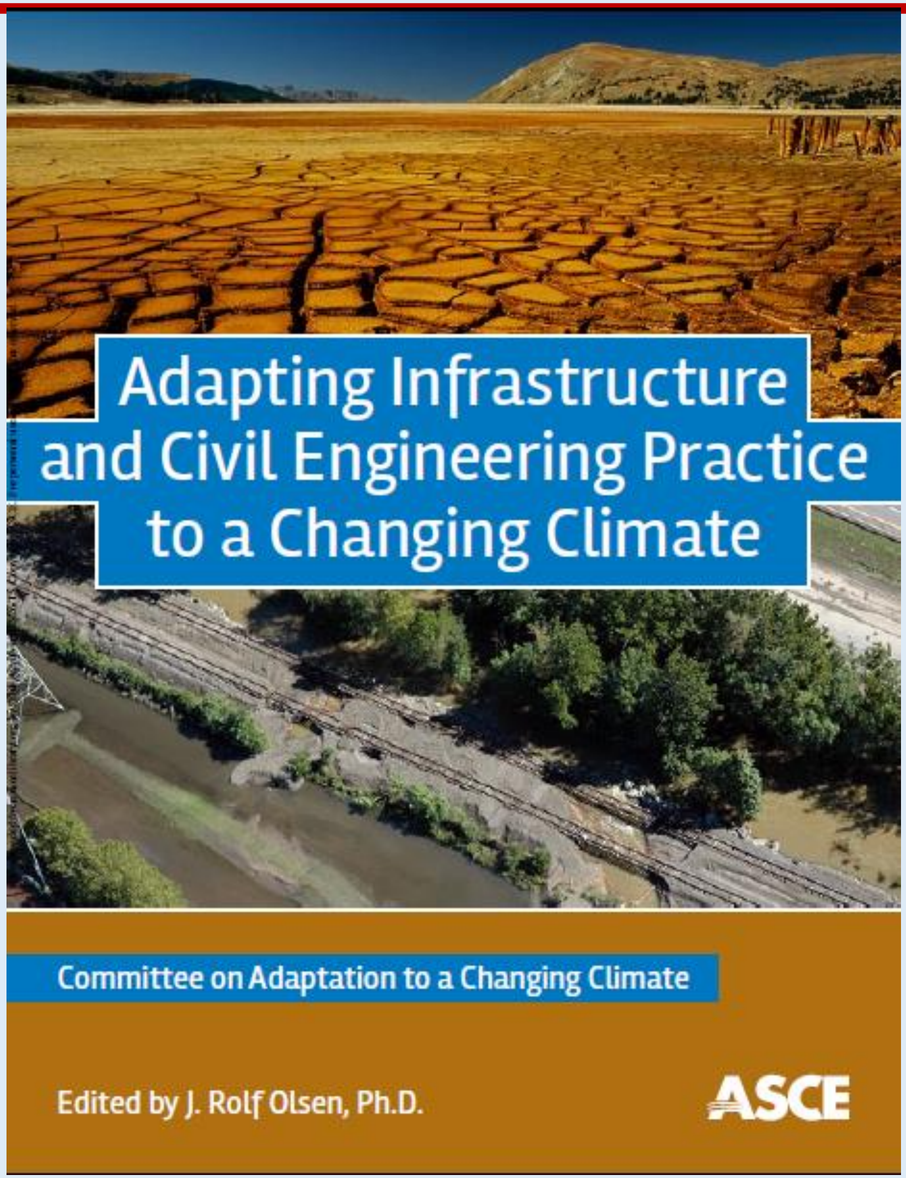
ASCE Committee on Adaptation to a Changing Climate (CACC)

- Purpose of CACC is identify and communicate the technical requirements and civil engineering challenges for adaptation to climate change.
- CACC published the white paper "Adapting Infrastructure and Civil Engineering Practice to a Changing Climate" in 2015
- It is available for free download at

http://dx.doi.org/10.1061/9780784479193



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Workshop Objectives

- Review engineering methods for designing for and managing precipitation extremes and floods throughout the life cycle of projects.
- Review approaches to uncertainty and how acceptable risk is determined.
- Communicate with climate scientists on engineering needs for climate information and receive status on climate trends, climate projections, and uncertainty.

Workshop Products

- ASCE technical report – all participants are encouraged to submit a paper
- Inform Manual of Practice on Adaptive Infrastructure Design and Risk Management for Climate Resilience
- Journal articles

Background

- Infrastructure is expected to remain functional, durable and safe for long service lives, typically 50 to more than 100 years.
- Infrastructure is exposed to, and potentially vulnerable to, the effects and extremes of climate and weather, such as droughts, floods, precipitation extremes, and accumulated ice and snow.
- Engineering practices and standards are intended to provide **acceptably low risks** of failures regarding **functionality, durability, and safety** over the service lives of infrastructure systems and facilities

From ASCE Committee on Adaptation to a Changing Climate (CACC), 2015, "Adapting Infrastructure and Civil Engineering Practice to a Changing Climate"

Approaches to Planning and Design

- Design events
  - Probable maximum precipitation or flood
  - Standard project hurricane or flood
  - 500-year or 0.2% probability flood
- Benefit-cost analysis
  - Requires a probability distribution of future conditions in order to calculate the expected future benefits and costs of a project.
- Risk-informed decision making

Highways

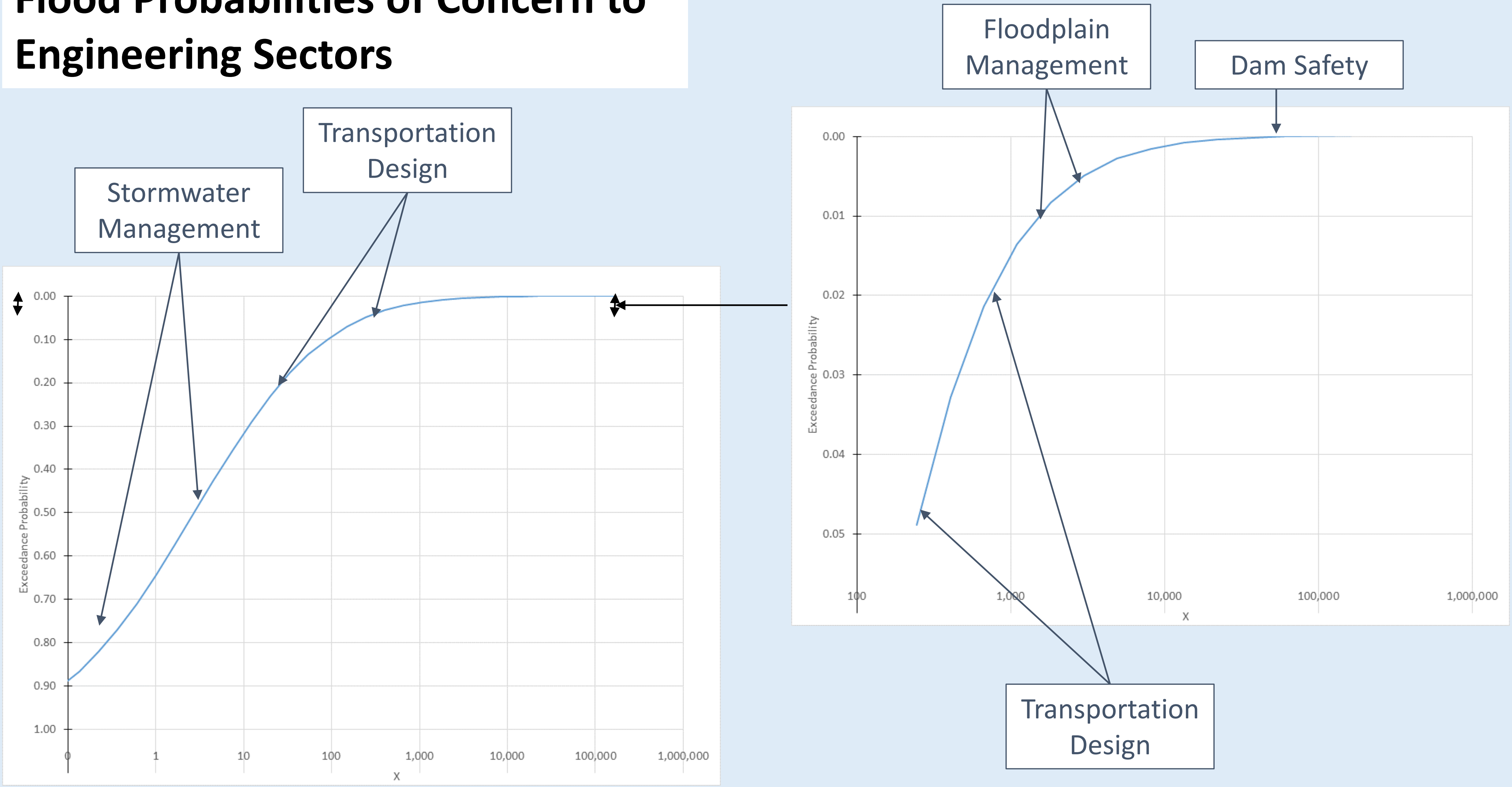
Some typical design frequencies for hydraulic structures associated with different roadway classifications, as identified in drainage guidance developed by the American Association of State Highway and Transportation Officials (AASHTO) (AASHTO, 1999).

Roadway Classification	Exceedance Probability	Return Period
Rural Principal Arterial System	2%	50-year
Rural Minor Arterial System	4% - 2%	25-50-year
Rural Collector System, Major	4%	25-year
Rural Collector System, Minor	10%	10-year
Rural Local Road System	20% - 10%	5-10-year
Urban Principal Arterial System	4% - 2%	25-50-year
Urban Minor Arterial Street System	4%	25-year
Urban Collector Street System	10%	10-year
Urban Local Street System	20% - 10%	5-10-year

Stormwater Management

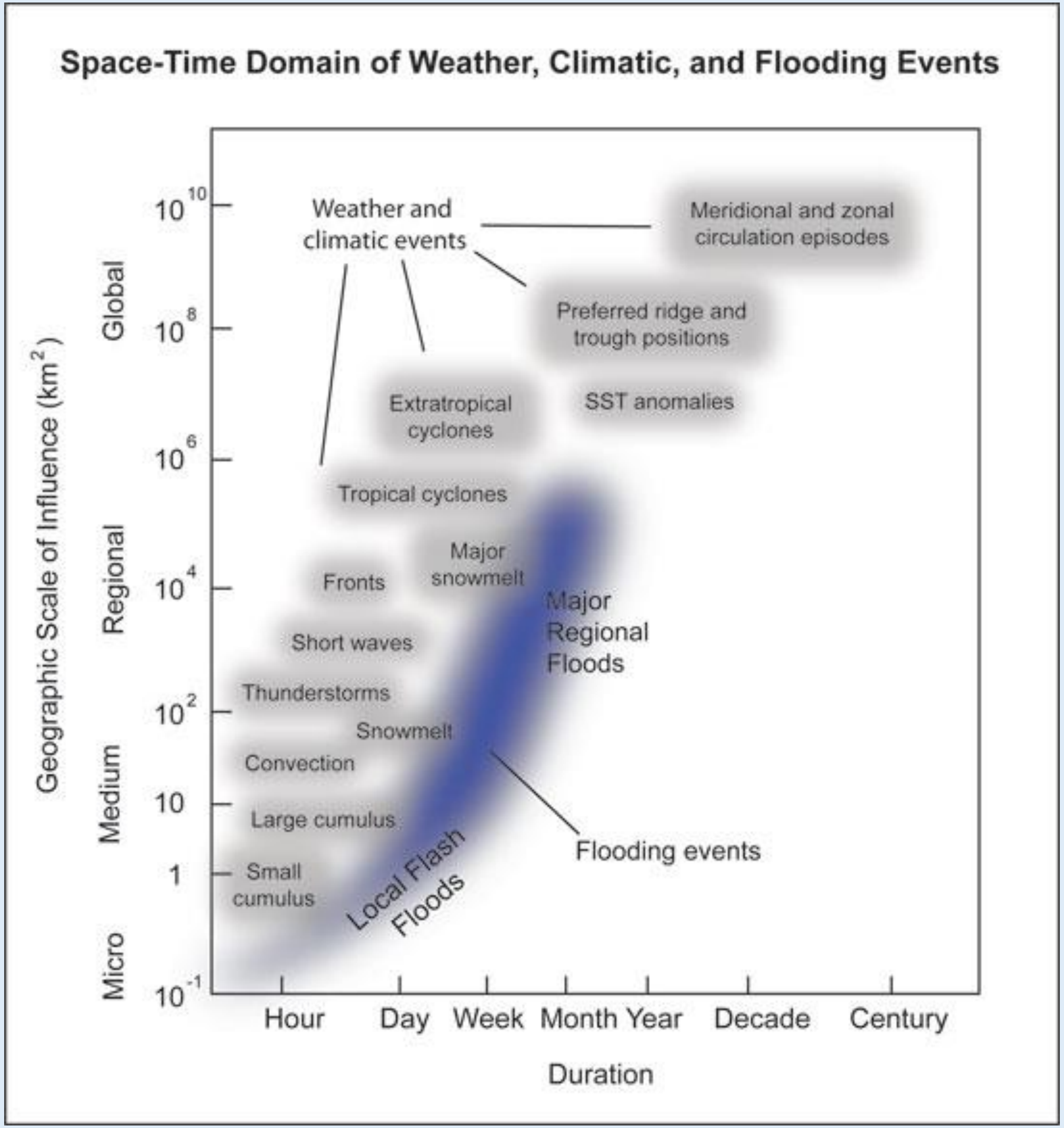
- From Virginia Stormwater Handbook
  - Alternative design criteria that has been found to be more effective in preventing *downstream channel erosion*: extended detention of the runoff from the 1-year frequency 24-hour storm.
  - *Adequacy of all channels and pipes* shall be verified in the following manner:
    - (a) Natural channels shall be analyzed by the use of a two-year storm to verify that stormwater will not overtop channel banks nor cause erosion of channel bed or banks; and
    - (b) All previously constructed man-made channels shall be analyzed by the use of a ten-year storm to verify that stormwater will not overtop its banks and by the use of a two-year storm to demonstrate that stormwater will not cause erosion of channel bed or banks; and
    - (c) Pipes and storm sewer systems shall be analyzed by the use of a ten-year storm to verify that stormwater will be contained within the pipe or system

Flood Probabilities of Concern to Engineering Sectors



Stationarity

- Most of our engineering standards and regulations for extreme events use “stationarity” as their basis for risk assessment.
- Stationarity means that statistical properties of variables in future time periods will be similar to past time periods.
- Climate change means that the past record may not be representative of the future.
- In truth, environment for engineered products and systems has never been stationary:
  - Societal demands and expectations change
  - Environmental conditions change – climate and land use



Each of these types of hazards may be affected by climate change differently.

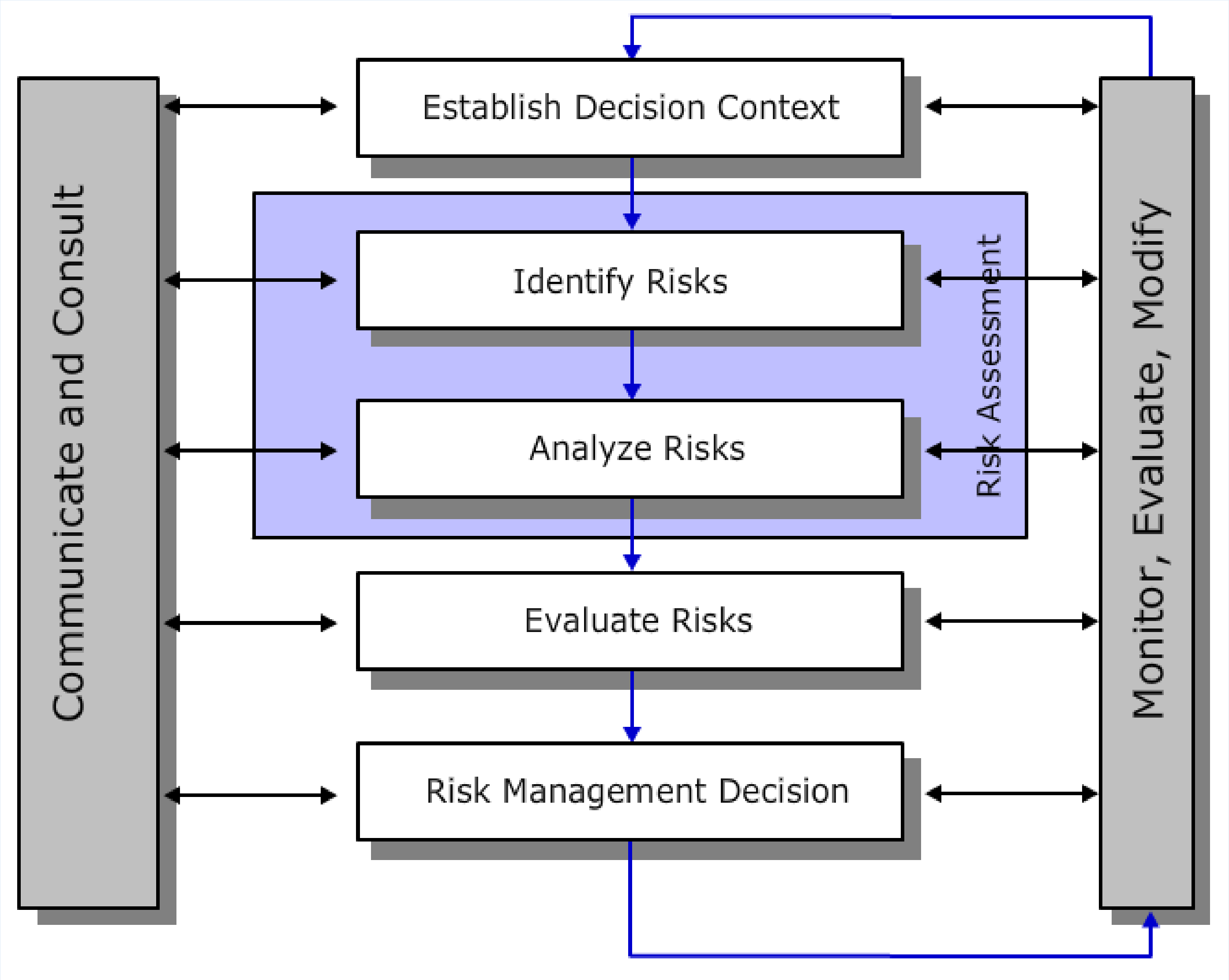
Climate Uncertainty and Probability

- Three main sources of uncertainty in projections of future climate:
  - Natural variability of climate
  - Uncertainty in climate model response, or sensitivity, to anthropogenic and natural forcing
  - Projection of future emissions and other natural and anthropogenic climate drivers
- Climate models represent an unknown fraction of potential future climate conditions
- Uncertainty associated with future climate is not completely quantifiable and will require engineering judgment in planning and design.

Risk Management

- Risk analysis and management is the primary approach engineers currently take to deal with future uncertainty.
- Risk management must consider potential consequences and likelihood of future events, including confidence in the information.
- There will generally be a tradeoff between designing to reduce risks for a larger range of uncertain events and minimizing project costs.
- With climate change uncertainty, estimates of the probabilities of future climate extreme events are uncertain.

Risk Management Framework



ISO (the International Organization for Standardization). 3100 Risk management - Principles and Guidelines (2009).

Dealing with Uncertainty

- Engineering practice has always recognized that there are uncertainties in future conditions and has developed methods to account for this uncertainty.
  - Future flood or precipitation with a specific magnitude or probability
  - Freeboard and safety factors
  - Probabilistic methods
  - Observational method and adaptive management
  - Low regret strategies and robust design

Executive Order 13690

- Executive Order – Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input
- The floodplain shall be established using one of the following approaches:
  - (1) Unless an exception is made under paragraph (2), the floodplain shall be:
    - (i) the elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. This approach will also include an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis;
    - (ii) the elevation and flood hazard area that result from using the freeboard value, reached by adding an additional 2 feet to the base flood elevation for non-critical actions and by adding an additional 3 feet to the base flood elevation for critical actions;
    - (iii) the area subject to flooding by the 0.2 percent annual chance flood; or

Thank you!

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