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## U.S. GLOBAL CHANGE RESEARCH PROGRAM

### Adaptation Science Interagency Working Group (ASIWG)

*Sub-Work Group: Federal Architects & Engineers on Buildings & Infrastructure Design (Climate Risks)*

## **“Focusing on the Challenge and the Path Forward”**

Presentation by --  
**Sam Higuchi<sup>1</sup>**

Chair, Sub-Work Group of Federal Architects & Engineers on  
Buildings & Infrastructure Design (Climate Risks)  
*(Staff Engineer, NASA-HQ, Office of Strategic Infrastructure)*

**11 January 2018**

National Institute of Building Sciences (NIBS)

6<sup>th</sup> Conference – “Building Innovation Conference & Expo: Sustain – Strengthen – Secure”

10:10 – 11:45 AM; Panel on: “Climate Resilience: Adaptive Design and Risk Management”

8-11 January 2018; Mandarin Oriental Hotel, 1330 Maryland Ave SW Washington DC

Contact Persons: [Dr Richard Wright](#), ASCE

<sup>1</sup> This presentation does not represent the official position of NASA or the United States government. This presentation reflects only the personal views of the presenter.



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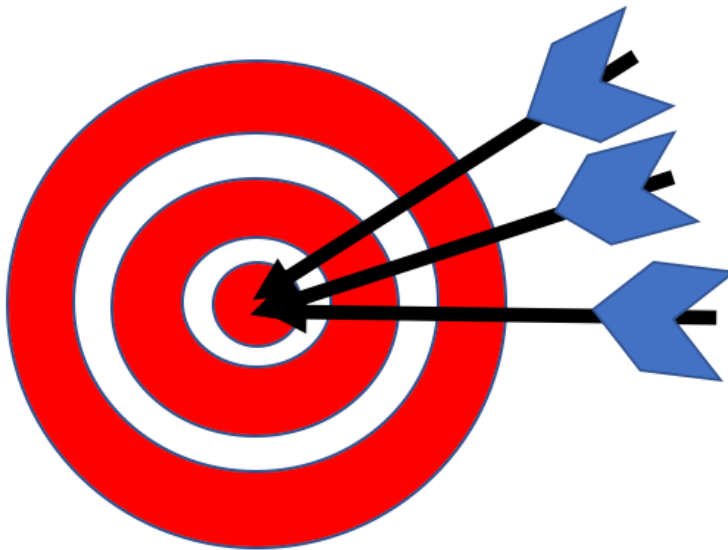
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## *Federal Agencies* **SAFEGUARDING ASSETS**

*31 U.S.C. §3512*



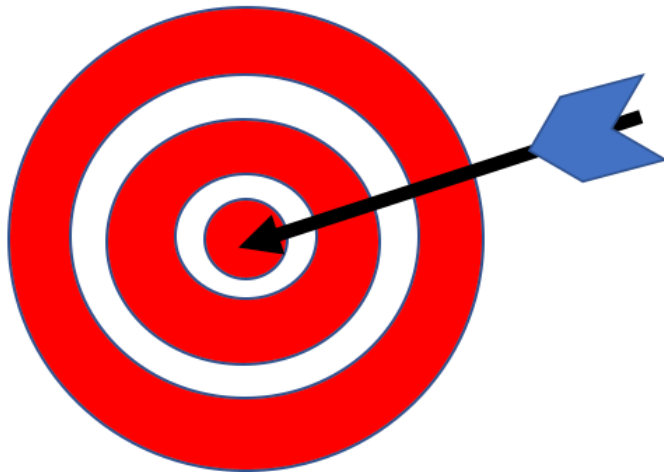
- **Funds**
- **Property**
- **Other Assets**



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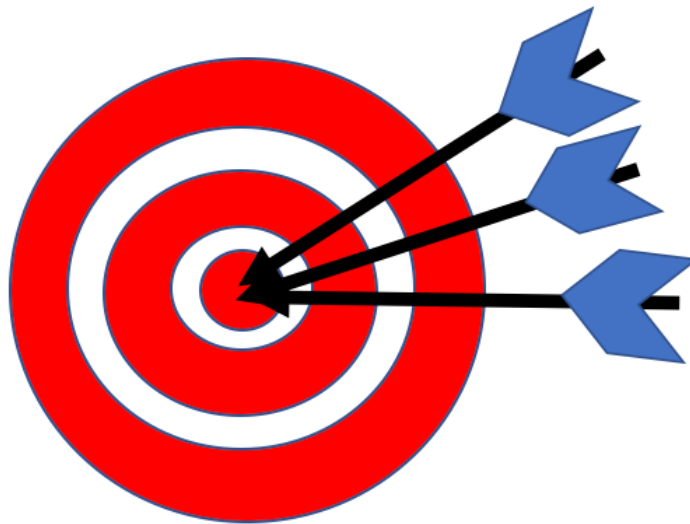
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## PROFESSIONAL LICENCES

- *Professional Architect*
- *Professional Engineer*

*POWERS LEFT TO THE STATES: Police Powers*



- **Public Safety**
- **Public Health**
- **Public Welfare**



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## CLIMATE SCIENCE SPECIAL REPORT

- 1) *Temperature & Precipitation Changes*
- 2) *Drought, Floods & Wildfires*
- 3) *Extreme Storms*

Public Release: 3 Nov 2017  
63 Key Findings



[https://science2017.globalchange.gov/downloads/CSSR2017\\_FullReport.pdf](https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf)

## TABLE OF CONTENTS

### Front Matter

About This Report .....	1
Guide to the Report .....	3
Executive Summary .....	12

### Chapters

1. Our Globally Changing Climate .....	35
2. Physical Drivers of Climate Change .....	73
3. Detection and Attribution of Climate Change .....	114
4. Climate Models, Scenarios, and Projections .....	133
5. Large-Scale Circulation and Climate Variability .....	161
6. Temperature Changes in the United States .....	185
7. Precipitation Change in the United States .....	207
8. Droughts, Floods, and Wildfires .....	231
9. Extreme Storms .....	257
10. Changes in Land Cover and Terrestrial Biogeochemistry .....	277
11. Arctic Changes and their Effects on Alaska and the Rest of the United States .....	303
12. Sea Level Rise .....	333
13. Ocean Acidification and Other Ocean Changes .....	364
14. Perspectives on Climate Change Mitigation .....	393
15. Potential Surprises: Compound Extremes and Tipping Elements .....	411

### Appendices

A. Observational Datasets Used in Climate Studies .....	430
B. Model Weighting Strategy .....	436
C. Detection and Attribution Methodologies Overview .....	443
D. Acronyms and Units .....	452
E. Glossary .....	460





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## 15 USC §2938

(b) Availability of [U.S. Global Change Research Program and of Federal agencies and departments] Research Findings.

\*\*\*

Agencies and departments ... shall ensure that the research findings [of U.S. Global Change Research Program and of Federal agencies and departments] ... are available to ---

(2) All Federal agencies and departments for use in ... responding to ... global change pursuant to ... statutory responsibilities and obligations.

(c ) Consistent with this subchapter, there is to be no delays in implementing Federal response actions designed to address the threats of global climate change.

### **AGENCIES ARE MANDATED BY STATUTE TO USE USGCRP RESEARCH FINDINGS: THIS INCLUDES CLIMATE DATA AND CLIMATE INFORMATION<sup>1,2</sup>**

15 USC §2938					
RESEARCH FINDINGS OF:		USE RESEARCH FINDINGS PURSUANT TO:			
		AGENCY (Authorization) STATUTES & LAWS:		OTHER FEDERAL STATUTES & LAWS (includes Sovereign Immunity Waivers):	
		Responsibilities	Obligations	Responsibilities	Obligations
1) U.S. Global Change Research Program (USGCRP):		X	X	X	X
2) USGCRP Member Agencies:	a) U.S. Department of Agriculture	X	X	X	X
	b) U.S. Department of Commerce (includes NOAA)	X	X	X	X
	c) U.S. Department of Defense (includes USACE)	X	X	X	X
	d) U.S. Department of Energy	X	X	X	X
	e) U.S. Department of the Interior (includes USGS)	X	X	X	X
	f) U.S. Department of State	X	X	X	X
	g) U.S. andepartment of Transportation	X	X	X	X
	h) U.S. Environmental Protection Agency	X	X	X	X
	i) National Aeronautics & Space Administration	X	X	X	X

<sup>1</sup> USGCRP (May 2015) Principals decided to focus on CMIP5 scenarios RCP 8.5 and 4.5 for National Climate Assessment #4, and for the framing of impacts, vulnerability and adaptation research findings.

<sup>2</sup> Several USGCRP member agencies have created and maintained a climate data portal ("Downscaled CMIP3 & CMIP5 Climate and Hydrology Projects") relevant to the scope of architects & engineers involved with Federal buildings and infrastructure projects and assets.



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## CHAPTER 7:

# "KEY FINDINGS" - PRECIPITATION CHANGES IN THE UNITED STATES:

### OBSERVATIONS

7-2 {25} **Heavy precipitation events** in most parts of the United States **have increased in both intensity and frequency** since 1901 (high confidence).

\*\*\*

[L]argest increases occurring in the northeastern United States (high confidence).

\*\*\*

[Organized clusters of thunderstorms] for warm season precipitation in [central U.S.] have increased in occurrence and ... amounts since 1979 (medium confidence).

### PROJECTIONS

7-3 {26} The **frequency and intensity of heavy precipitation events are projected** to continue **to increase** over the 21st century (high confidence).

Mesoscale convective systems in the central United States are expected to continue to increase in number and intensity in the future (medium confidence).



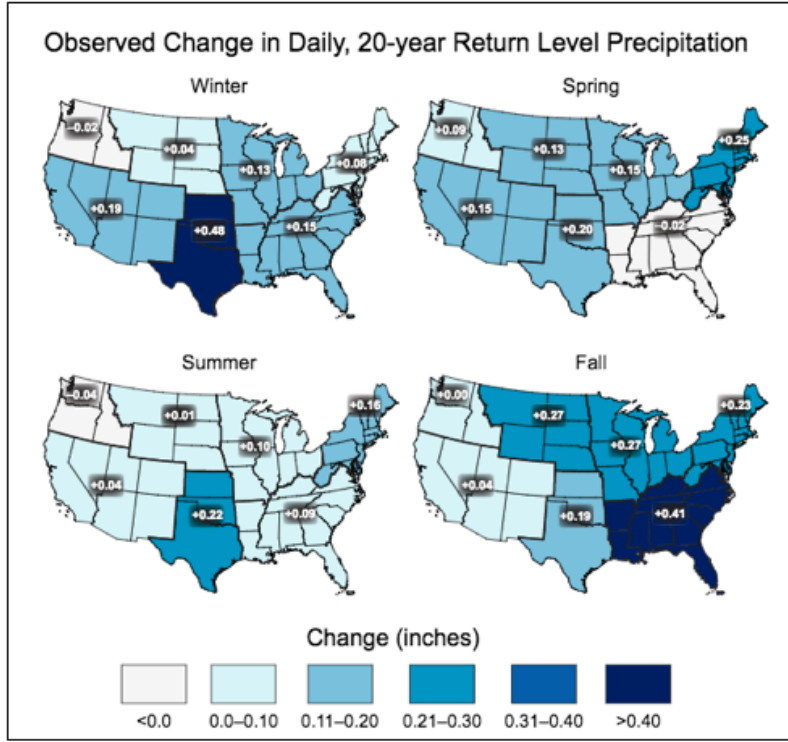
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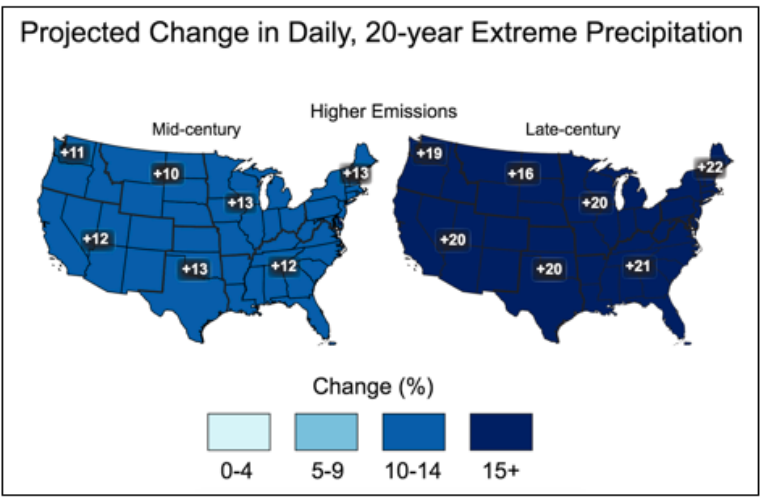
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## Observations and Projections

### Observations 1948-2015



### Projections RCP 8.5 (LOCA data)



[https://science2017.globalchange.gov/downloads/CSSR2017\\_FullReport.pdf](https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf)





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## Climate Risks

**Wallops Flight Facility, VA**



**Kennedy Space Center, FL**



**Johnson Space Center, TX**







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## 42 USC §17094 – Storm water runoff requirements for Federal development projects.

Any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site

- **planning,**
- **design,**
- **construction, and**
- **maintenance strategies**

for the property to maintain or restore, to the maximum extent technical feasible, the predevelopment hydrology of the property with regard to the

- **temperature,**
- **rate,**
- **volume, and**
- **duration of flow.**

### 42 USC §17094 – Storm water runoff requirements (Federal Facilities = 5,000 square feet)

#### *Challenge – Precipitation Non-Stationarity*

	Use Strategies for ...			
To Maintain or Restore Hydrologic Property of ...	Planning	Design	Construction	Maintenance
Temperature	X	X	X	X
Rate	X	X	X	X
Volume	X	X	X	X
Duration of Flow	X	X	X	X



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**Table 1. Guidelines for the selection of return period.**

No.	Type of project or feature	Return period (yr)
1	Urban drainage [low risk] (up to 100 ha)	5 to 10
2	Urban drainage [medium risk] (more than 100 ha)	25 to 50
3.	Road drainage	25 to 50
4	Principal spillways (dams)	25 to 100
5	Highway drainage	50 to 100
6	Levees [medium risk]	50 to 100
7	Urban drainage [high risk] (more than 1,000 ha)	50 to 100
8	Flood plain development	100
9	Bridge design (piers)	100 to 500
10	Levees [high risk]	200 to 1000
11	Emergency spillways (dams)	100 to 10,000 (PMP)
12	Freeboard hydrograph [for a class (c) dam]	10,000 (PMP)

[http://ponce.tv/return\\_period.html](http://ponce.tv/return_period.html)

**Table 1.1. Design Storm Selection Guidelines (AASHTO, 1999)**

Roadway Classification	Exceedence 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

Note: Federal regulations require interstate highways to be provided with protection from the 2 percent flood event. AASHTO recommends that facilities such as underpasses, depressed roadways, etc., where no overflow relief is available should also be designed for the 2 percent flood event (AASHTO, 1999).

<http://isddc.dot.gov/OLPFiles/FHWA/013248.pdf>



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## Precipitation Non-Stationarity

Was:

**Average Return Interval (ARI) = 100-Years**

*24-hour Extreme Precipitation Events*

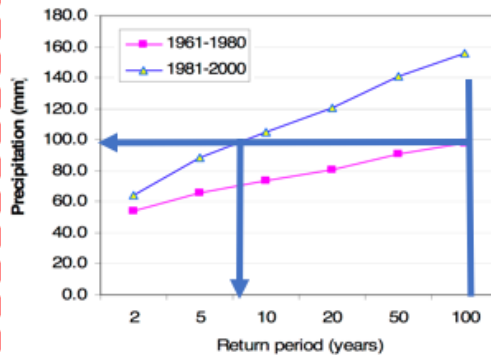
### 6-Years

**Woodstock, Ontario, Canada**

Meteorological Station G6149625  
(near Niagara Falls/ Buffalo, NY)

URL:

[http://www.cspl.ca/sites/default/files/download/Final\\_MTO\\_Report\\_June2005rv.pdf](http://www.cspl.ca/sites/default/files/download/Final_MTO_Report_June2005rv.pdf)



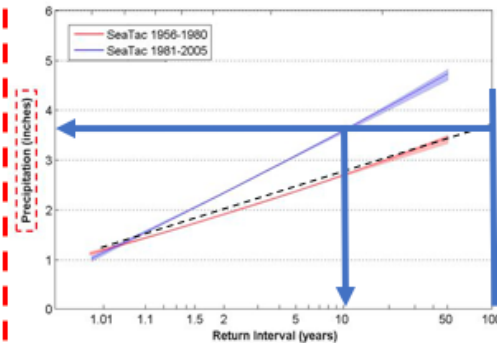
### 10-Years

**SeaTac, WA**

Station: 457473  
(near Seattle, WA)

URL:

[http://www.stillwatersci.com/resources/2010stormwater\\_infrastructure\\_climate\\_change.pdf](http://www.stillwatersci.com/resources/2010stormwater_infrastructure_climate_change.pdf)



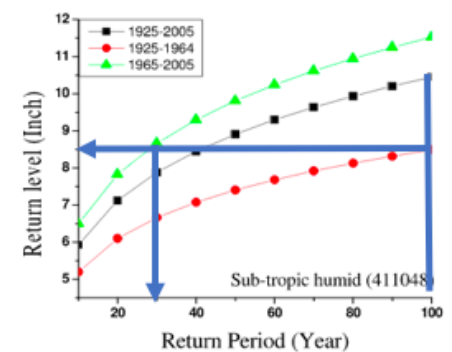
### 30-Years

**Brenham, TX**

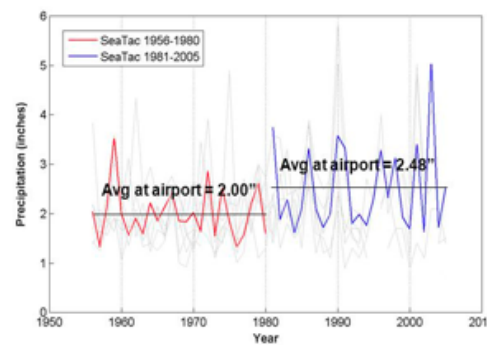
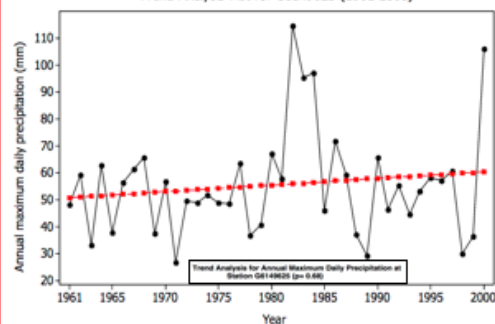
Station: 411048  
(near Houston/ Galveston, TX)

URL:

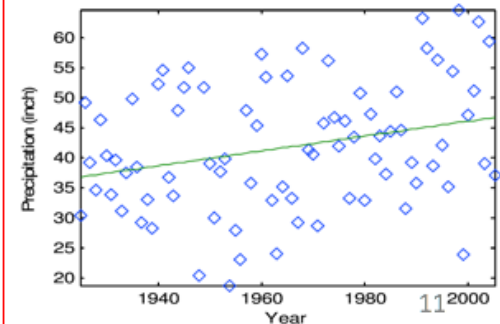
<http://onlinelibrary.wiley.com/doi/10.1029/2009JD013398/epdf>



Trend Analysis Plot for G6149625 (1961-2000)



411048



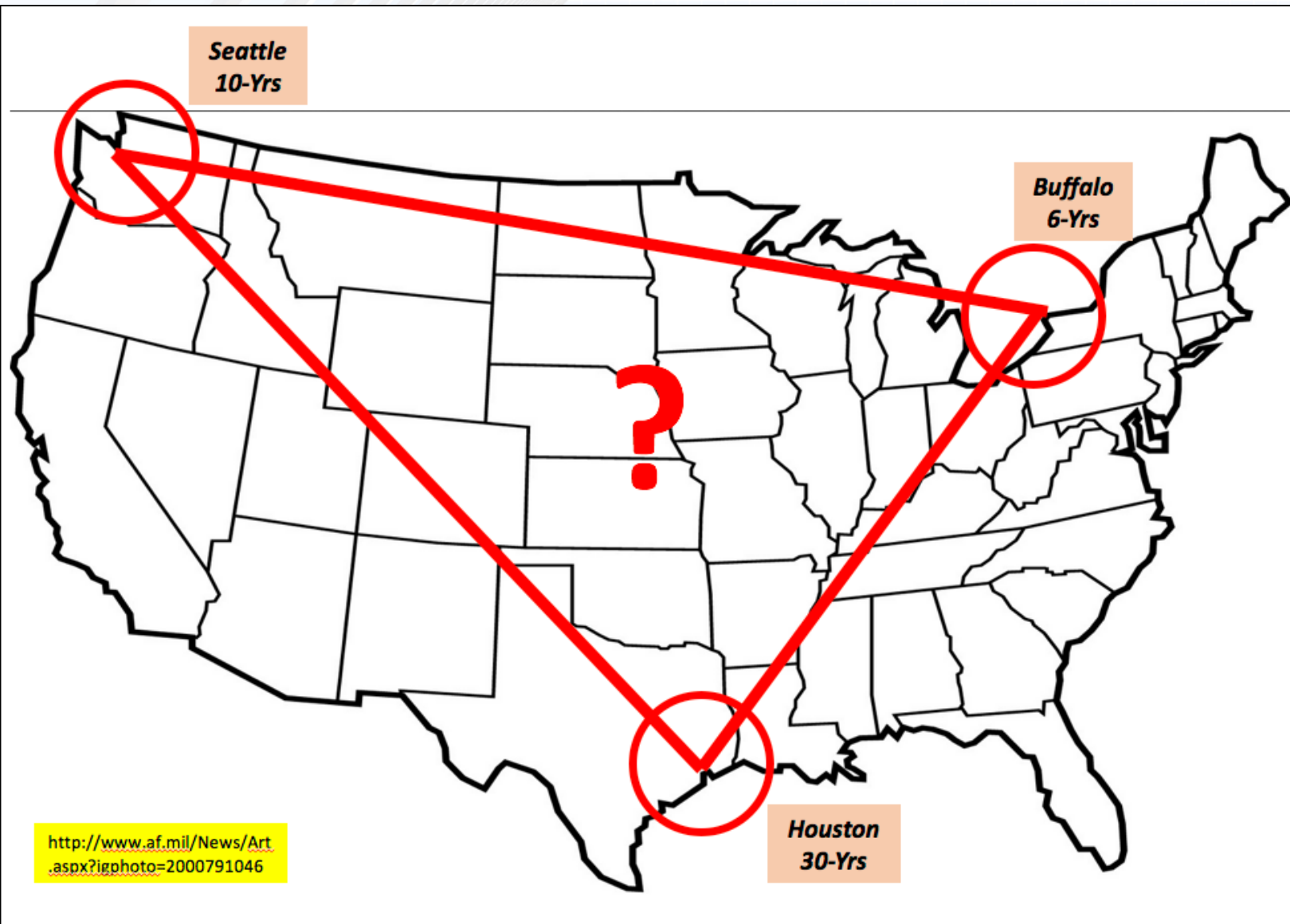




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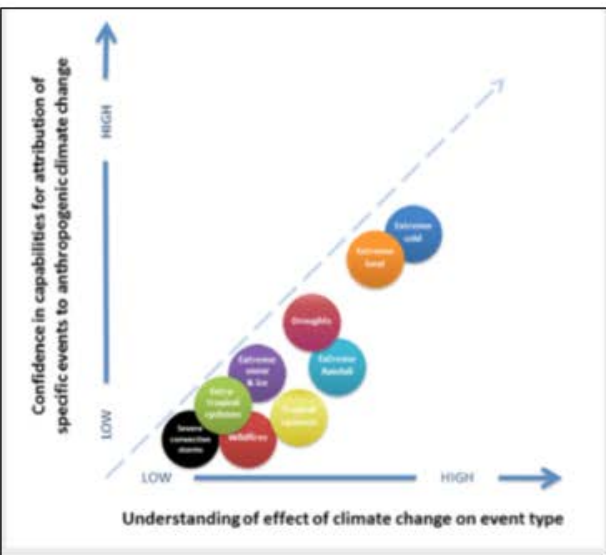
<http://www.af.mil/News/Art.aspx?igphoto=2000791046>



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### Research Agenda:

- 1) Observational Record Analysis
- 2) Physical Mechanisms Understanding
- 3) Models to Simulate Event

**Box 1. Current Scientific Confidence in Attribution Results Varies for Different Types of Extreme Event**

	Capabilities of Climate Models to Simulate Event Class	Quality/Length of the Observational Record	Understanding of Physical Mechanisms that Lead to Changes in Extremes as a Result of Climate Change
● = high ◐ = medium ○ = low			
Extreme cold events	●	●	●
Extreme heat events	●	●	●
Drought	◐	◐	◐
Extreme rainfall	◐	◐	◐
Extreme snow	◐	○	◐
Tropical cyclones	○	○	◐
Extratropical cyclones	◐	○	○
Wildfire	○	●	○
Severe convective storms	○	○	○

<https://www.nap.edu/catalog/21852/attribution-of-extreme-weather-events-in-the-context-of-climate-change>



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## 31 USC §3512

*(c)(1) Each executive agency shall ... ensure that --*

**\*\*\***

*(B) All assets\* are safeguard against waste, loss, unauthorized use, and misappropriation*

- Public Law 97-255 specifically states and lists & identifies: "funds, property and other assets" (= all assets)

• {for DOD 10 USC §383(b)(2)}

## 31 USC §3512

*Each executive agency is to ensure all assets\* are safeguarded against loss.*

<b>ENSURE AGAINST ... :</b>	<b>TYPE OF ASSET**:</b>		
	<b>"FUNDS"</b>	<b>"PROPERTY"</b>	<b>"OTHER ASSETS"</b>
<b>"... Loss"</b>	<b>X</b>	<b>X</b>	<b>X</b>
<b>"... Misappropriation"***</b>	<b>X</b>	<b>X</b>	<b>X</b>
<b>"... Waste"</b>	<b>X</b>	<b>X</b>	<b>X</b>
<b>"... Unauthorized Use"</b>	<b>X</b>	<b>X</b>	<b>X</b>

\* For example: buildings & infrastructure (or capital assets), and natural resources

\*\* See Federal Accounting Standards Advisory Board concerning definition of "assets"; assets include: property plant and equipment, and heritage assets

\*\*\* See OMB Circular A-11 concerning "capital assets"; failure to use the appropriate "design life" (for example due to risks related to a changing climate) in justifying invest of a capital asset project to Congress





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## Engaging Stakeholders on Climate Risk Management through Statutory Chartered Entities

- 1) National Institute of Building Sciences (buildings & Infrastructure) 12 USC §1701j-2
- 2) National Academies of Science, Engineering & Medicine 36 USC §150301 et seq
- 3) National Academy of Public Administration (Federal-Tribes-State-Local) 36 USC §1501 et seq



### ***“Establishing a long-term dialogue between climate scientists and building scientists ....”***

The built environment will play a significant role when it comes to changes in climate. It is essential that the nation's communities have information that is actionable and easily understood in order to prepare buildings before and in response to events. Establishing a long-term dialogue between climate scientists and building scientists would help bridge the gap between the current uncertainty in climate and the design criteria required by the building industry. The structure of the Institute's Building Seismic Safety Council (BSSC), which brings together experts from a number of different fields, can serve as a model.<sup>2</sup> Such a dialogue would improve the relevance of climate modeling for use in the planning, design, operation, maintenance and renewal of the built and natural environment.

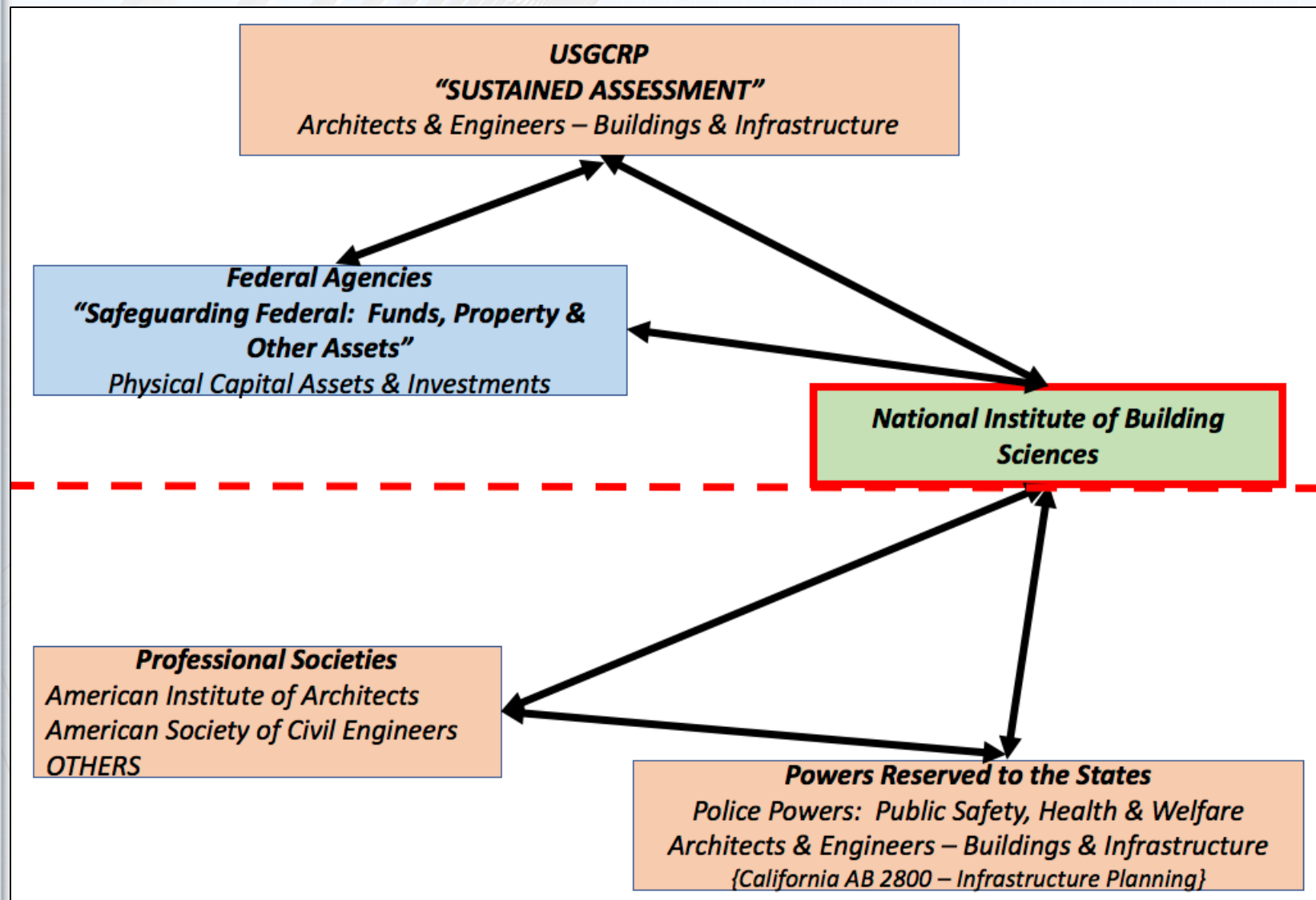
<http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/CC/MovingForward-Final.pdf>



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## California AB 2800; Public Resources Code – Section 71155

A) Create “Climate Safe Infrastructure Working Group” - consisting of:

- 1) Engineers with expertise in infrastructure design
- 2) Scientists from Universities with expertise in climate change projections and impacts
- 3) Architects with experience in infrastructure design

B) Establish by 1 July 2017, working group to work with other organizations that advance sustainability in infrastructure

C) Investigate the following issues:

- 1) Current informational and institutional barriers to integrating projected climate change impacts into infrastructure design
- 2) Critical information that engineers responsible for infrastructure design and construction need to address climate change impacts
- 3) How to select an appropriate engineering design for a range of future climate scenarios as related to:
  - a) Infrastructure planning, and
  - b) Investment

D) By 1 July 2018, make recommendations:

- 1) Integrate scientific knowledge of projected climate impacts into infrastructure design
- 2) Addressing critical gaps identified
- 3) Process to facilitate communications between climate scientists and infrastructure engineers





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**AB 2800 (Quirk) Climate-Safe Infrastructure Working Group**

If you wish to be included in the Climate-Safe Infrastructure Working Group distribution list, please email [climate-safe-infrastructure@resources.ca.gov](mailto:climate-safe-infrastructure@resources.ca.gov) with "distribution list" in the subject line.

**Brief description of Bill**

**LEGISLATIVE COUNSEL'S DIGEST**  
AB 2800, Quirk. Climate change: infrastructure planning.

Existing law requires the Natural Resources Agency, by July 1, 2017, and every 3 years thereafter, to update the state's climate adaptation strategy to identify vulnerabilities to climate change by sectors and priority actions needed to reduce the risks in those sectors.

This bill, until July 1, 2020, would require state agencies to take into account the current and future impacts of climate change when planning, designing, building, operating, maintaining, and investing in state infrastructure. The bill, by July 1, 2017, and until July 1, 2020, would require the agency to establish a Climate-Safe Infrastructure Working Group for the purpose of examining how to integrate scientific data concerning projected climate change impacts into state infrastructure engineering, as prescribed. The bill would require the working group to consist of registered professional engineers with specified relevant expertise from the Department of Transportation, the Department of Water Resources, the Department of General Services, and other relevant state agencies; scientists with specified expertise from the University of California, the California State University, and other institutions; and licensed architects with specified relevant experience. The bill would require the working group, by July 1, 2018, to make specified recommendations to the Legislature and the Strategic Growth Council.

[Link to text of Bill](#)

**Appointees**

**Dr. Amir Aghakouchak, P.E., University of California, Irvine**

Amir Aghakouchak is an Associate Professor of Civil and Environmental Engineering at the University of California, Irvine. His research focuses on climate extreme and crosses the boundaries between hydrology, climatology, remote sensing. Amir is the principal investigator of several research grants funded by the National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), and the United States Bureau of Reclamation (USBR). Website: <http://amir.eng.uci.edu/>

<http://resources.ca.gov/climate/climate-safe-infrastructure-working-group/>

## California AB2800 "Climate-Safe Infrastructure Working Group"

Appointees include:

<u>Name</u>	<u>Affiliation</u>
Dr. Amir Aghakouchak, P.E.	University of California, Irvine
Bruce Swanger, P.E.	California Department of Transportation
Chester Widom, FAIA	California Department of General Services: Division of State Architect
Dr. Chris Liban, P.E., ENV SP	Los Angeles County Metropolitan Transportation Authority; City of Los Angeles; National Council for Environmental Policy and Technology, USEPA
Dr. Dan Cayan	University of California, San Diego: Scripps Institution of Oceanography
Dr. David Groves	RAND Water and Climate Resilience; Pardee Rand Graduate School
Dr. Deb Niemeier, P.E, NAE	University of California, Davis
James Deane AIA, CDT, LEED AP, PMP	California High Speed Rail Authority; Parsons Brinckerhoff
John Andrew, P.E.	California Department of Water Resources
Dr. Kristin Heinemeier, P.E.	University of California, Davis: Energy Efficiency Center
Dr. Kyle Meng	University of California, Santa Barbara: Bren School of Environmental Science and Management
Martha Brook, P.E.	California Energy Commission
Nancy Ander, P.E.	California Department of General Services
Dr. Noah Diffenbaugh	Stanford University: Stanford Woods Institute for the Environment

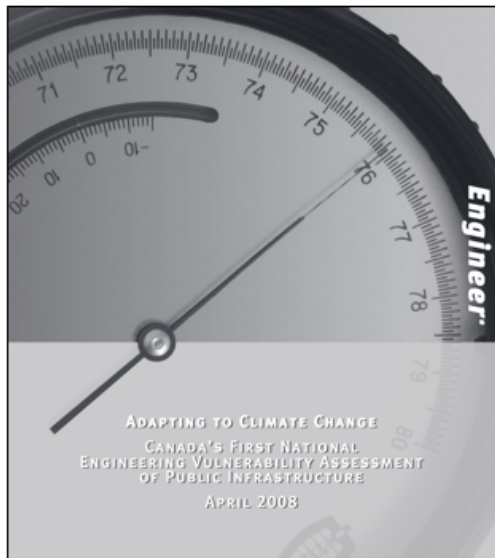
<https://yubanet.com/california/secretary-laird-announces-establishment-of-climate-safe-infrastructure-working-group/>



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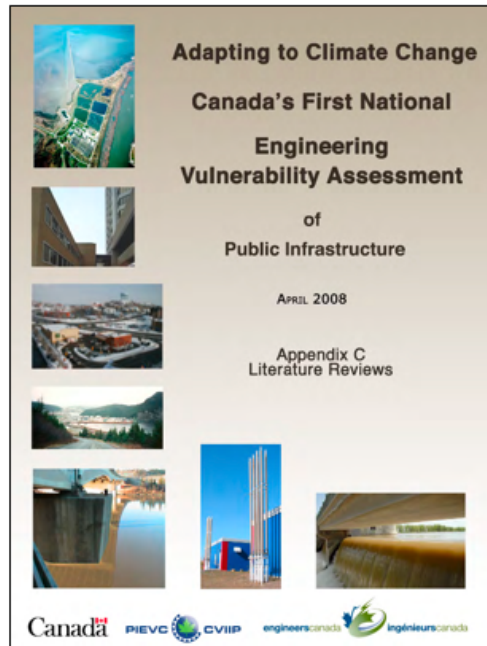
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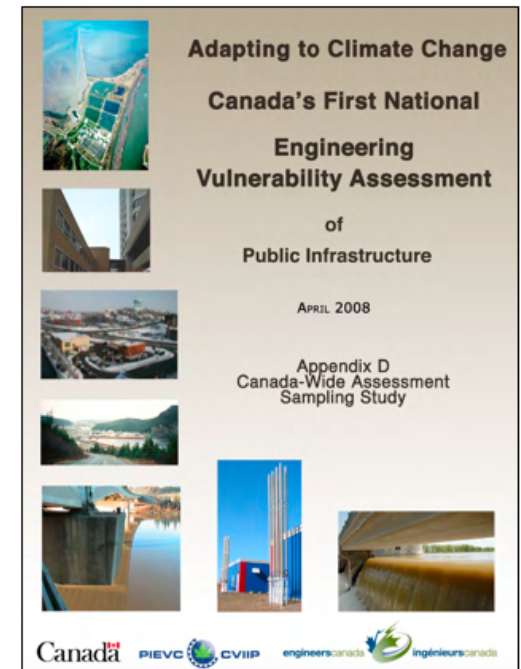
[https://pievc.ca/sites/default/files/adapting\\_to\\_climate\\_change\\_report\\_final.pdf](https://pievc.ca/sites/default/files/adapting_to_climate_change_report_final.pdf)

## CANADA 1<sup>st</sup> National Engineering Vulnerability Assessment of Infrastructure 2008



[https://pievc.ca/sites/default/files/appendix\\_c\\_literature\\_reviews.pdf](https://pievc.ca/sites/default/files/appendix_c_literature_reviews.pdf)

Transportation Infrastructure – Climate Change Issues  
Buildings Infrastructure – Climate Change Issues  
Water Resources Infrastructure – Climate Change Issues  
Stormwater & Wastewater Infrastructure – Climate Change Issues



[https://pievc.ca/sites/default/files/appendix\\_d\\_final\\_report\\_canada\\_wide\\_assessment\\_sampling\\_strategy.pdf](https://pievc.ca/sites/default/files/appendix_d_final_report_canada_wide_assessment_sampling_strategy.pdf)



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## Principles of Climate Change Adaptation for Engineers

Canadian Engineering Qualifications Board

[https://engineerscanada.ca/sites/default/files/01\\_national\\_guideline\\_climate\\_change\\_adaptation.pdf](https://engineerscanada.ca/sites/default/files/01_national_guideline_climate_change_adaptation.pdf)

## CANADA

*Canadian Engineering Qualifications Board  
October 2014*

### Professional Judgment

Guideline Element # 1: Integrate Adaptation Into Practice

Guideline Element # 2: Review Adequacy of Current Standards

Guideline Element # 3: Exercise Professional Judgement

### Integrating Climate Information

Guideline Element # 4: Interpret Climate Information

Guideline Element # 5: Work with Specialists and Stakeholders

Guideline Element # 6: Use Effective Language

### Practice Guidance

Guideline Element # 7: Plan for Service Life

Guideline Element # 8: Use Risk Assessment for Uncertainty

Guideline Element # 9: Monitor Legal Liabilities





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*Environmental Engineers: ... address global issues, such as ... :*

- 1) Climate change and*
- 2) environmental sustainability*

## OCCUPATIONAL OUTLOOK HANDBOOK

Occupational Outlook Handbook > Architecture and Engineering >

### Environmental Engineers

Summary

**What They Do**

Work Environment

How to Become One

Pay

Job Outlook

### What Environmental Engineers Do

Environmental engineers use the principles of engineering, soil science, biology, and chemistry to develop solutions to environmental problems. They work to improve recycling, waste disposal, public health, and water and air pollution control. They also address global issues, such as unsafe drinking water, climate change, and environmental sustainability.

<https://www.bls.gov/ooh/architecture-and-engineering/environmental-engineers.htm#tab-2>





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**STOP**



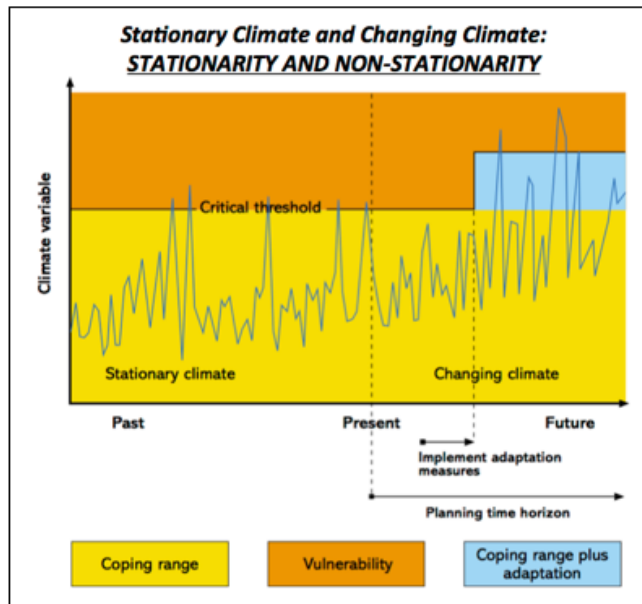
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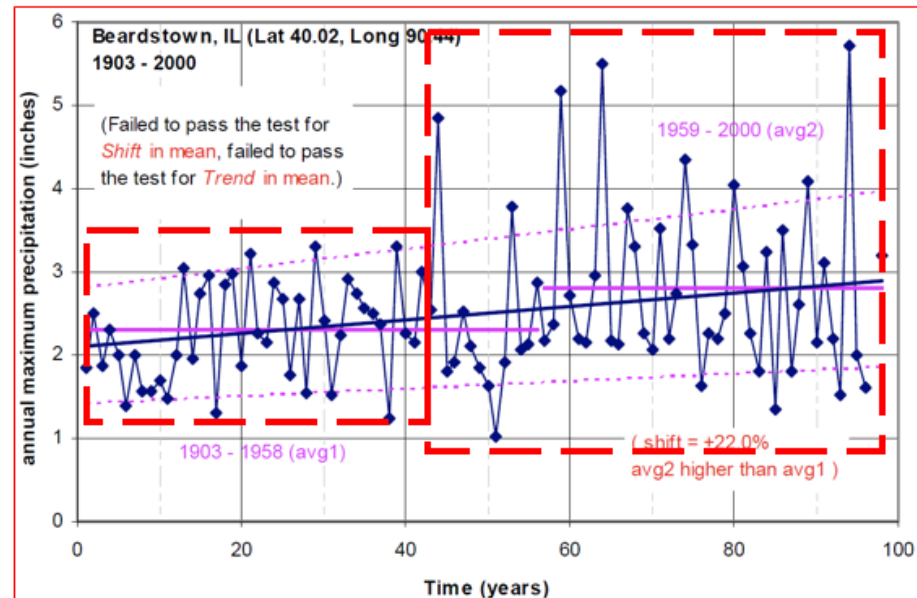
## NON-STATIONARITY

### Concept



<http://www.ukcip.org.uk/wp-content/PDFs/UKCIP-Risk-framework.pdf>

### Observational Data



[http://www.nws.noaa.gov/oh/hdsc/PF\\_documents/Atlas14\\_Volume2.p](http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume2.p)



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# "OLD SCHOOL" – ASSUMPTION OF "STATIONARITY": Science and Engineering

## Storm Water Management: pipe culvert design (Historical Data)

**Science**

**"Location Specific Observations"**

**Step: S-1**

**Interpretation of IDF Curves**

**Step: S-2**

**Intensity-Duration-Frequency (IDF) Curves**

The average 1-hour rainfall intensity expected to be equal or exceeded, on average, once every 25 years is 3.0 in/hr

**Step: S-3**

Figure 3. Intensity pattern based upon long term average (historical data).

[http://www.ces.scf.edu/~mark/cvwr4542/CWR4542\\_Packet\\_03\\_student.pdf](http://www.ces.scf.edu/~mark/cvwr4542/CWR4542_Packet_03_student.pdf)

**Engineering**

**"Design Manual"**

**Step: E-1**

**"Location Specific"**

**Step: E-2**

Chapter Six  
Drainage and Stormwater Management

6.1 INTRODUCTION

Adopting drainage is essential in the design of highway sites to affect the highway's vulnerability and safety, including the pavement's structural strength, its loading on the subgrade, and its resistance to hydroplaning, rutting, and cracking.

Figure 6-1  
Design Criteria - Frequency (Return Period in Years)

Functional Classification	Pipe Culverts	Storm Drains	Roadside Ditches	Median Drains
Interstate	100	10 <sup>1</sup>	10	10
Arterial	100	10 <sup>1</sup>	10	10 <sup>1</sup>
Collector	10 <sup>1</sup>	10 <sup>1</sup>	10 <sup>1</sup>	10 <sup>1</sup>
Local Road and Residential Streets	10	10	10 <sup>1</sup>	10 <sup>1</sup>

Figure 6-2  
Rainfall Intensity Estimates (in/hr) for Rational Method - New Castle County

Frequency (yr)	1	10	17	30	50	100	200	500	1000
1	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
10	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
17	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
30	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
50	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
100	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
200	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
500	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
1000	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57

Figure 6-3  
Rainfall Intensity Estimates (in/hr) for Rational Method - Kent County

Frequency (yr)	1	10	17	30	50	100	200	500	1000
1	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
10	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
17	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
30	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
50	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
100	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
200	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
500	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
1000	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57

Figure 6-4  
Rainfall Intensity Estimates (in/hr) for Rational Method - Sussex County

Frequency (yr)	1	10	17	30	50	100	200	500	1000
1	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
10	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
17	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
30	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
50	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
100	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
200	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
500	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
1000	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57

[http://deldot.gov/information/pubs\\_forms/manuals/road\\_design/pdf/06\\_drainage\\_stormwater\\_mgmt.pdf](http://deldot.gov/information/pubs_forms/manuals/road_design/pdf/06_drainage_stormwater_mgmt.pdf)



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## Chapter Six Drainage and Stormwater Management

### 6.1 INTRODUCTION

Adequate drainage is essential in the design of highways since it affects the highway's serviceability and usable life, including the pavement's structural strength. If ponding on the traveled way becomes an important factor, drainage design involves that collect, transport and discharge from the highway. The designer must consider the stormwater embankment through manmade ditches.

This chapter deals with procedures and guidelines for achieving cost-effective construction within the System. The information compiled from various publications, textbooks, and the information provided with the inclusion and references specific to DelDOT projects.

Source documents introduction to each section that the designer is familiar with theory and methods of both hydrology and information provided to supplement with the access to the referenced.

The regulatory drainage design is continues to grow in responsible for the proper drainage facilities must

Federal, state, county and local regulations, laws, and ordinances that may impact the design of storm drain systems.

Many federal laws have implications that affect drainage design. These include laws

**Figure 6-1  
Design Criteria — Frequency  
(Return Period in Years)**

Functional Classification	Type of Drainage Installation <sup>1</sup>			
	Pipe Culverts	Storm Drains	Roadside Ditches	Median Drains
Interstate, Freeways and Expressways	50	10 <sup>2</sup>	50	50
Arterials	50	10 <sup>2</sup>	25	25 <sup>2</sup>
Collectors	50 <sup>3</sup>	10 <sup>2</sup>	25 <sup>4</sup>	10 <sup>2</sup>
Local Roads and Streets including Subdivision Streets	25	10 <sup>5</sup>	10	10 <sup>5</sup>

<sup>1</sup> For Stormwater Management see Section 6.10.

<sup>2</sup> Use a 50-yr frequency at sag points, i.e. underpasses or depressed roadways, where ponded water can be removed only through the storm drain system.

<sup>3</sup> Use a 25-yr frequency for rural collectors.

<sup>4</sup> Use a 10-yr frequency for rural collectors.

<sup>5</sup> Use a 25-yr frequency at underpasses or depressed roadways where ponded water can be removed only through the storm drain system.

July 2008

[https://www.deldot.gov/Publications/manuals/road\\_design/pdfs/06\\_drainage\\_stormwater\\_mgmt.pdf](https://www.deldot.gov/Publications/manuals/road_design/pdfs/06_drainage_stormwater_mgmt.pdf)

**Figure 6-5  
Rainfall Intensity Estimates (in/hr) for Rational Method - New Castle County**

Frequency (yr)	Duration (min)									
	5	10	15	30	60 (1 hr)	120 (2 hr)	180 (3 hr)	360 (6 hr)	720 (12 hr)	1440 (24 hr)
2	4.97	3.97	3.33	2.30	1.44	0.87	0.62	0.38	0.23	0.13
5	5.83	4.67	3.94	2.80	1.79	1.08	0.78	0.48	0.29	0.17
10	6.42	5.13	4.33	3.13	2.04	1.24	0.89	0.55	0.34	0.20
25	7.13	5.68	4.80	3.55	2.37	1.45	1.05	0.66	0.41	0.25
50	7.60	6.05	5.10	3.84	2.60	1.61	1.18	0.74	0.47	0.29
100	8.06	6.40	5.40	4.13	2.85	1.77	1.30	0.83	0.53	0.34
200	8.44	6.69	5.63	4.38	3.07	1.93	1.43	0.92	0.60	0.39
500	8.88	7.02	5.89	4.69	3.36	2.14	1.60	1.05	0.70	0.46

**Figure 6-6  
Rainfall Intensity Estimates (in/hr) for Rational Method - Kent County**

Frequency (yr)	Duration (min)									
	5	10	15	30	60 (1 hr)	120 (2 hr)	180 (3 hr)	360 (6 hr)	720 (12 hr)	1440 (24 hr)
2	5.06	4.05	3.40	2.34	1.47	0.90	0.65	0.40	0.24	0.14
5	6.01	4.81	4.06	2.88	1.85	1.13	0.82	0.50	0.30	0.18
10	6.68	5.35	4.51	3.27	2.13	1.31	0.95	0.59	0.36	0.21
25	7.54	6.01	5.08	3.76	2.50	1.56	1.14	0.71	0.44	0.27
50	8.15	6.49	5.48	4.13	2.79	1.76	1.29	0.81	0.51	0.32
100	8.76	6.96	5.86	4.49	3.09	1.96	1.45	0.92	0.59	0.37
200	9.92	7.39	6.22	4.84	3.39	2.17	1.62	1.04	0.67	0.43
500	10.02	7.93	6.65	5.29	3.80	2.45	1.85	1.21	0.80	0.52

**Figure 6-7  
Rainfall Intensity Estimates (in/hr) for Rational Method - Sussex County**

Frequency (yr)	Duration (min)									
	5	10	15	30	60 (1 hr)	120 (2 hr)	180 (3 hr)	360 (6 hr)	720 (12 hr)	1440 (24 hr)
2	5.06	4.04	3.39	2.34	1.47	0.91	0.66	0.40	0.24	0.14
5	6.02	4.83	4.07	2.89	1.85	1.16	0.84	0.52	0.30	0.19
10	6.76	5.40	4.56	3.30	2.15	1.35	0.99	0.61	0.36	0.22
25	7.67	6.11	5.15	3.82	2.54	1.61	1.19	0.74	0.45	0.28
50	8.32	6.62	5.59	4.21	2.85	1.83	1.35	0.85	0.52	0.33
100	8.96	7.12	6.00	4.59	3.16	2.05	1.53	0.97	0.61	0.38
200	9.60	7.61	6.40	4.98	3.49	2.28	1.71	1.10	0.70	0.45
500	10.38	8.21	6.88	5.48	3.93	2.59	1.97	1.28	0.84	0.54

Note: Interpolation shall be used for rainfall for intermediate durations.





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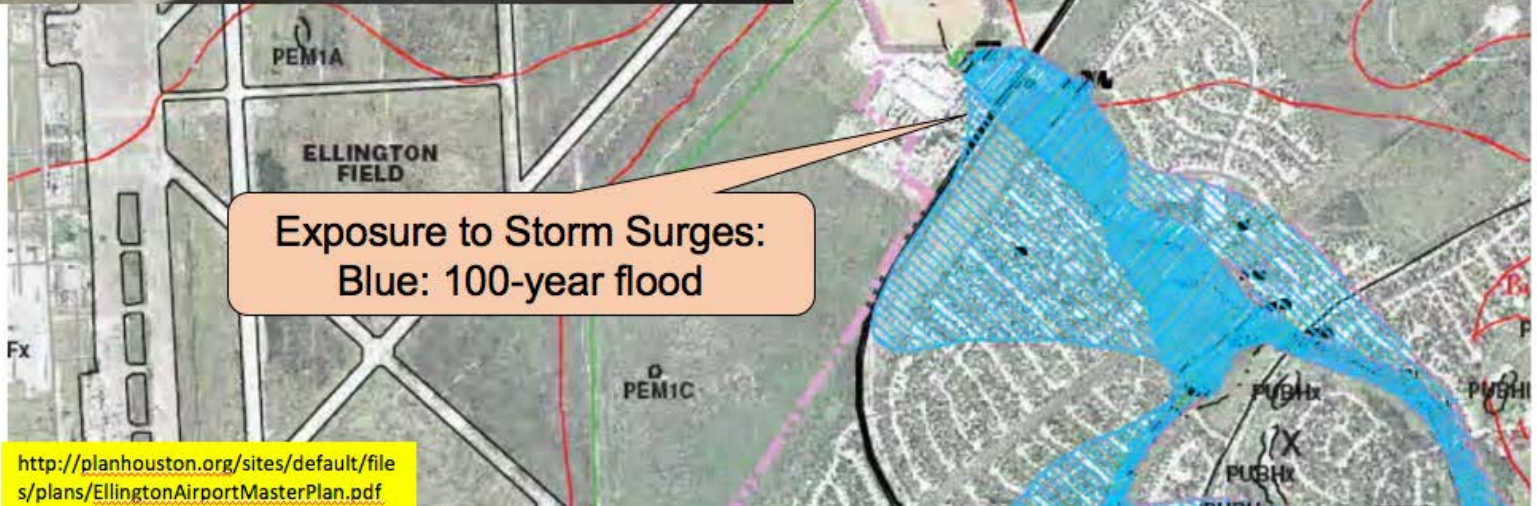


<http://saturn500f.com/sonny-carter-training-facilityneutral-buoyancy-laboratory>

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<http://planhouston.org/sites/default/files/plans/EllingtonAirportMasterPlan.pdf>



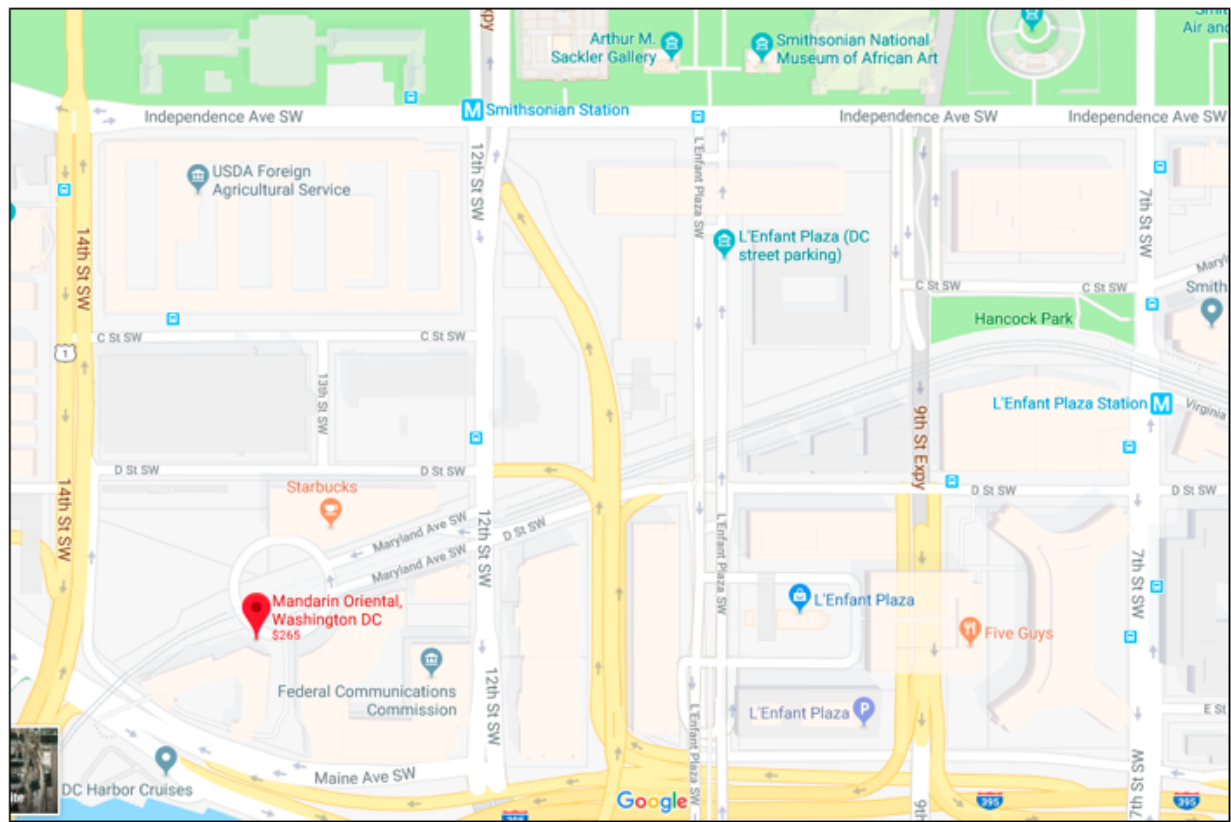
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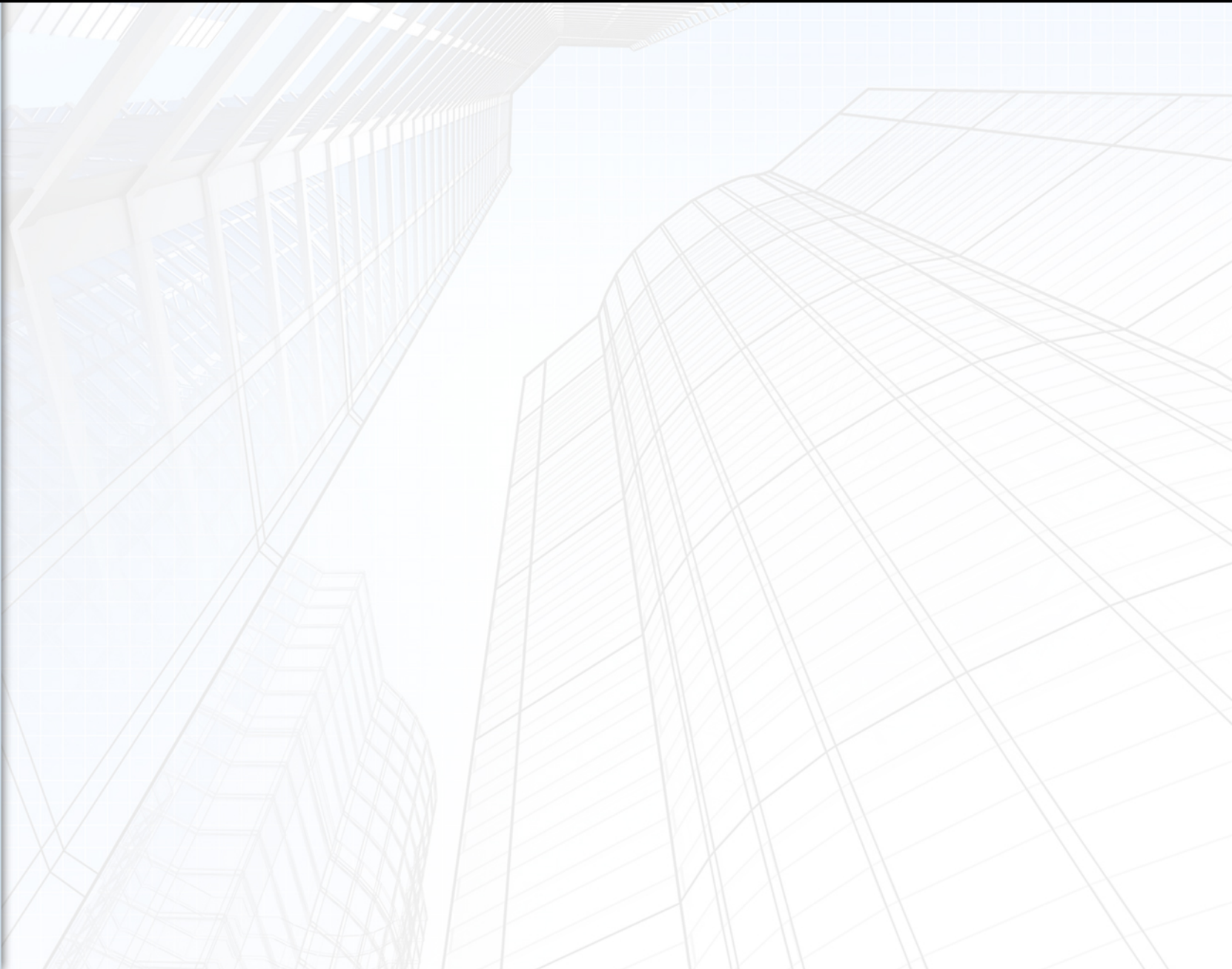




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INTERAGENCY FORUM ON CLIMATE RISKS, IMPACTS & ADAPTATION

## **CLIMATE RISK MANAGEMENT:** **Best Available Science and** **Best Management Practices**

Presentation by --

**Sam Higuchi<sup>1</sup> {for Dr. Tom Fish}**

Co-Chair, Interagency Forum on Climate Risks, Impacts & Adaptation

(NASA-HQ, Office of Strategic Infrastructure)

*{National Coordinator, Cooperative Ecosystem Studies Units (CESU), U.S. Department of the Interior}*

**11 January 2018**

National Institute of Building Sciences (NIBS)

6<sup>th</sup> Conference – "Building Innovation Conference & Expo: Sustain – Strengthen – Secure"

10:10 – 11:45 AM; Panel on: "Climate Resilience: Adaptive Design and Risk Management"

8-11 January 2018; Mandarin Oriental Hotel, Washington DC

Contact Persons: Dr Richard Wright, ASCE

<sup>1</sup> This presentation does not represent the official position of NASA or the United States government. This presentation reflects only the personal views of the presenter.



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*11<sup>th</sup> Year (Established 2007)*

# Interagency Forum

## On Climate Risks, Impacts, and Adaptation



The Forum's scope includes but is not limited to aspects of the following:

### A Federal Agency is mandated to

**31 U.S.C. §3512**

#### **Safeguard: Funds, Property, and Other Assets**

Exposure to "Material Weakness" requirements; with statutory related "Disclosure" to Congress, and to taxpayers and the public, unless a specific statutory exemption applies

### Further, an Agency is mandated to

**31 U.S.C. §1115**

#### **Manage High Risk Management Challenges, Identified by GAO\* or IG**

\* "Limiting the Federal Government's Fiscal Exposure by better managing climate change risks" URL: [http://www.gao.gov/highrisk/limiting\\_federal\\_government\\_fiscal\\_exposure/why\\_did\\_study](http://www.gao.gov/highrisk/limiting_federal_government_fiscal_exposure/why_did_study)



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## ***“Knowledge Networks” = Interagency Forum***

### **CONNECTING PRODUCERS & USERS OF CLIMATE SCIENCE: PROVEN INSTITUTIONAL ARRANGEMENTS & MECHANISMS\***

\* L DILLING & M C LEMOS (2011) “CREATING USABLE SCIENCE: OPPORTUNITIES AND CONSTRAINTS FOR CLIMATE KNOWLEDGE USE AND THEIR IMPLICATIONS FOR SCIENCE POLICY”; GLOBAL ENVIRONMENTAL; CHANGE, PAGES 680-689

<b><i>Institutional Arrangements &amp; Mechanisms</i></b>	<b>Description</b>	<b>Remarks: NASA’s Approach</b>
<i>1) Information Brokers</i>	Broker is an intermediary between the user and the scientists	<i>NASA’s contractor consultant is currently SAIC</i>
<i>2) Collaborative Group Processes</i>	Many groups with a vested the outcome and where decision making is highly distributed	<i>NASA “Oversight Steering Group”: Directorate level stakeholders that coordinate efforts</i>
<i>3) Embedded Capacity</i>	Local climate scientists available to provide information and advice	<i>NASA Climate Adaptation Science Investigators (CASI) are NASA climate scientists at NASA Centers doing local applied research</i>
<i>4) Boundary Organizations</i>	Functions between the world of research and use of science to tailor information and produce value-added products; translation and customization of climate information to specific users	<i>NASA “Core Team” on Climate Risks &amp; Adaptation: implementation team that designs workshops and information products</i>
<i>5) Knowledge Networks</i>	Comprised of policy makers, scientists, government agencies, and non-government organizations that communicate and share information across areas of practice	<i>Interagency Forum on Climate Change Impacts &amp; Adaptations: (NASA, USACE, and others) NASA is Forum Co-Chair and uses the Forum to spin-in best practices.</i>





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## **FORUM SEEKS OUT:**

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- ***BEST AMANGEMENT PRACTICES***
- ***LESSONS LEARNED***





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U.S. Department of Justice	U.S. Department of Transportation (including Federal Aviation Administration)
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U.S. Army (including U.S. Army War College, Army Environmental Policy Institute)	General Services Administration
U.S. Navy	U.S. Air Force
U.S. Department of Commerce (including National Oceanic and Atmospheric Administration)	National Academies (including National Academy of Sciences, National Research Council)
U.S. Department of Energy	Office of Secretary of Defense
U.S. Global Change Research Program	National Institutes of Health



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**Climate Change Adaptation**

The Climate Change Adaptation Program Area supports Federal agency climate adaptation planning. Please check in periodically for new information.

- What is climate change adaptation & why do Federal agencies need to adapt?
- Background on the Implementing Instructions for Federal Agency Climate Change Adaptation
- Federal Framework for adaptation planning and guiding principles

**What is Climate Change Adaptation & Why is it Important?**

Climate change adaptation means adjusting to a changing climate to minimize negative effects and take advantage of new opportunities. Climate change directly affects a wide range of Federal services, operations, programs, assets, and our national security. Through adaptation planning, an agency can identify how climate change is likely to impact its ability to achieve its mission, operate, or meet its policy and program objectives. By integrating climate change adaptation strategies into its planning, the Federal Government can ensure that resources are invested wisely and Federal services and operations remain effective in current and future climate conditions.

**Background on the Implementing Instructions for Federal Agency Climate Change Adaptation**

Executive Order 13524, Federal Leadership in Environmental, Energy, and Economic Performance, establishes an integrated strategy for sustainability within the Federal Government. Under the Executive Order, each agency is required to evaluate their climate change risks and vulnerabilities to manage the effects of climate change on the agency's mission and operations in both the short and long term as part of the Federal Strategic Sustainability Performance Planning process. In its October 2010 Progress Report, the Interagency Climate Change Adaptation Task Force recommended that CIO issue climate change adaptation planning implementing instructions. The Implementing Instructions for Federal Agency Climate Change Adaptation Planning identify how agencies should respond to the adaptation requirements under the Executive Order.

**Federal Framework for Adaptation Planning, and Guiding Principles**

CIO based its adaptation planning requirements on a six-step, flexible planning framework and eight guiding principles, as recommended by the Interagency Climate Change Adaptation Task Force. The planning framework is not meant to be prescriptive or to provide detailed recommendations for project-level adaptation; those detailed options will be developed over time by each agency with the help of a growing set of planning tools, illustrative case studies, and lessons learned. In addition, climate change adaptation planning is an iterative process; our knowledge of climate change is evolving, as is our understanding of different types of adaptive actions.

Please click on the links below for more information on specific planning actions.

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## *(Past) SPECIAL EVENTS*

- *2<sup>nd</sup> International Technical Workshop on Climate Risks*
- *Special Training Event: Climate Change - Installation Adaptation & Resilience*
- *Special Training Event: Climate Risks Management*
- *Special Training Event: Climate Adaptation and Infrastructure Engineering*
- *Climate and Energy: Extreme Weather & Climate Events*
- *Special Session: Climate Change and Adaptation*





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