MAGEEP Education Network

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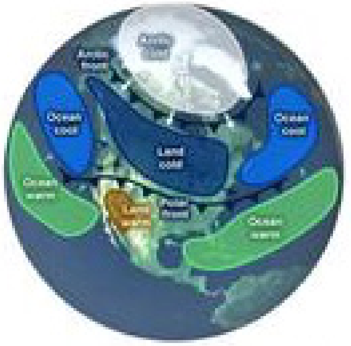

Water System Adaptation To Hydrological Changes

Module 12
Models and Tools for Stormwater and Wastewater System Adaptation

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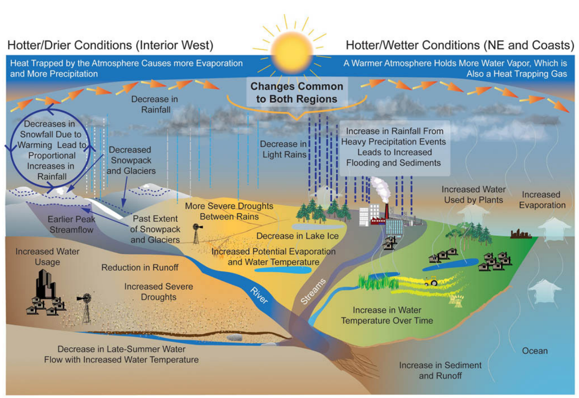
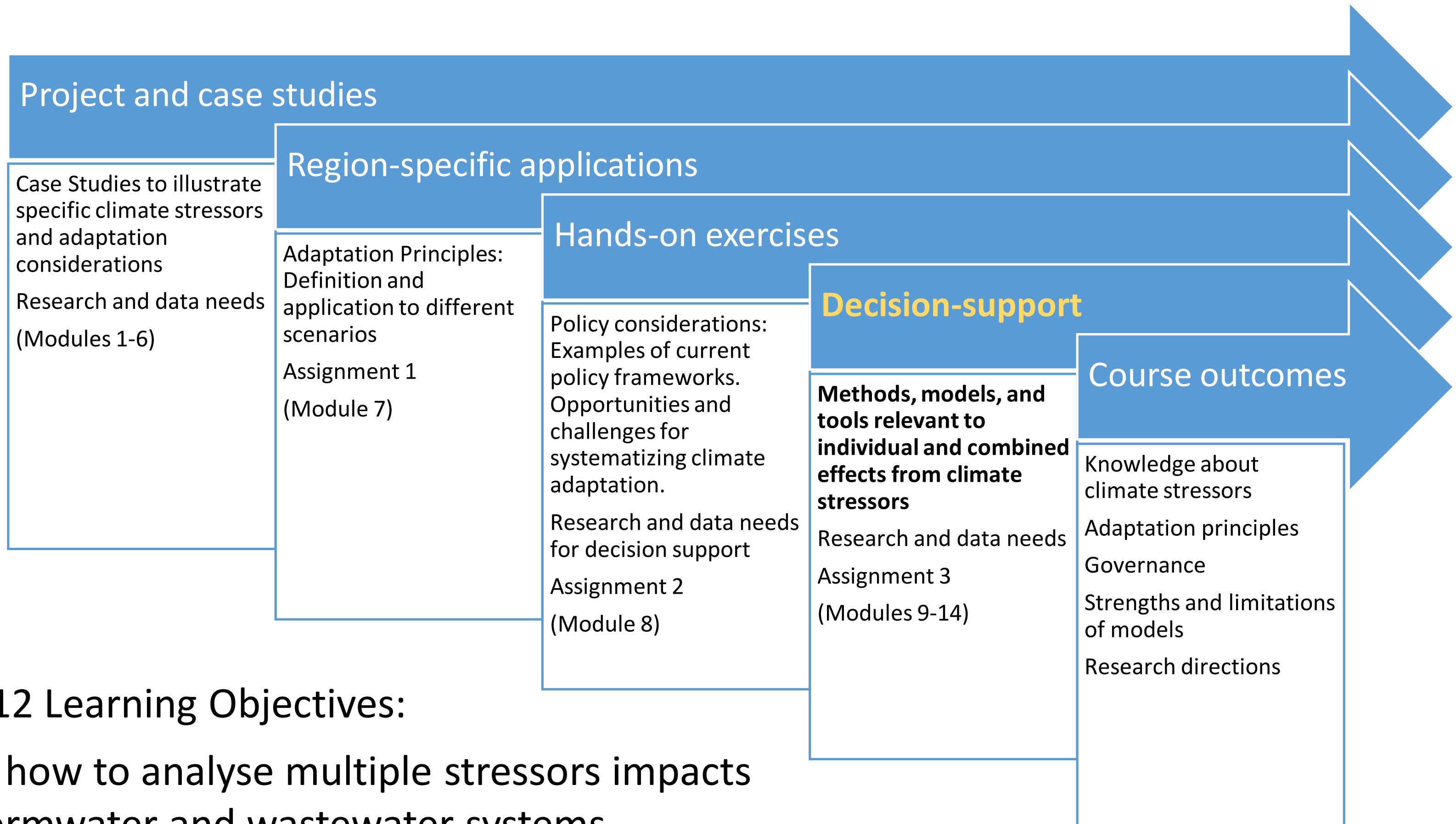


Course Roadmap



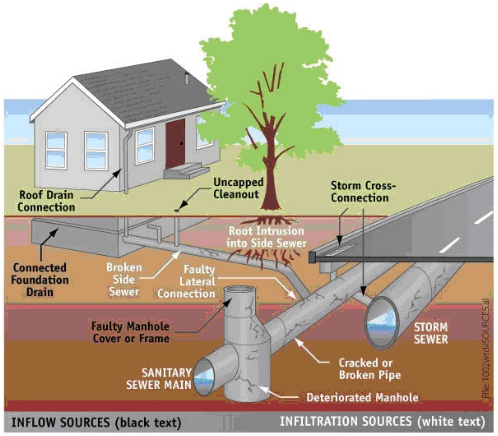
Module 12 Learning Objectives:

- Learn how to analyse multiple stressors impacts on stormwater and wastewater systems
- Describe models and tools to design water system adaptation for water qualtiy objectives

Key Topics: Module 12

Modeling and Quantitative Analysis for Adaptation

- Precipitation change leading to watershed and catchment basin hydrological changes (runoff, pollutant transport, etc.)
- Modeling methods are available to quantify the change and thus develop adaptation accordingly
- Major topics for modeling analysis:
  - ✓ ***Stormwater runoff and impacts on stormwater infrastructure hydraulic capacity***
  - ✓ ***Changing stormwater runoff and combined sewer overflow (CSO) in CSS infrastructures***
  - ✓ Changes in surface water quality of a watershed and thus the stream carrying capacity for discharges
- Modeling methods and tools



Drivers affecting stormwater, wastewater infrastructure, combined sanitary sewers (CSS):

- Precipitation/runoff changes in future
- Land use changes, particularly urbanization
- Aging infrastructure
- Application of green infrastructure and stormwater BMPs

Also in coastal area:

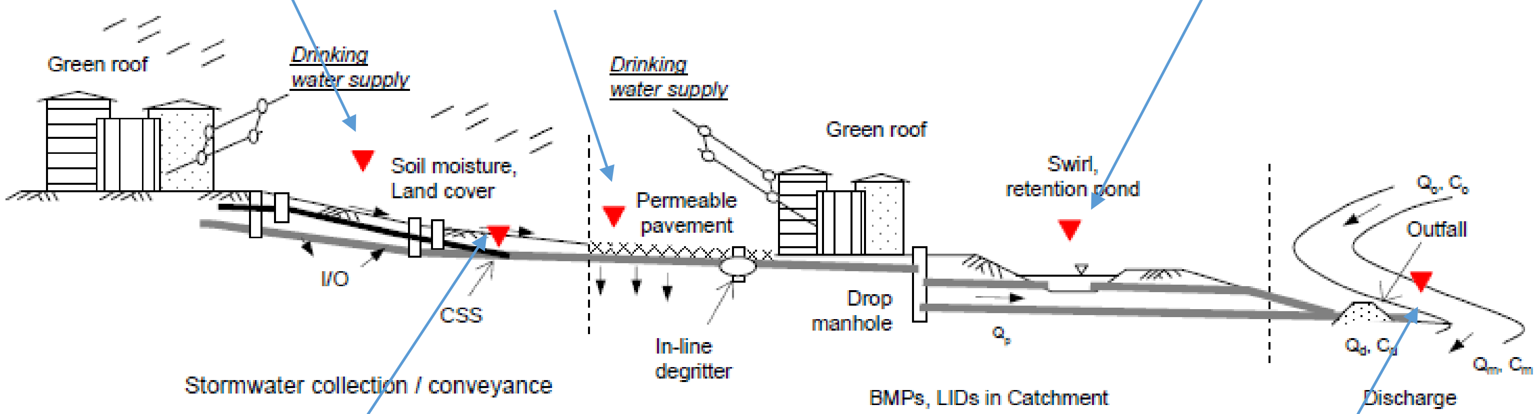
- Sea level rise, resulting in less hydraulic gradient
- Storm surge and wind damage, impacting physical integrity and operation

Impacts on Stormwater Infrastructure and Wastewater Discharges

Changes in precipitation and land cover can significantly affect surface runoff properties

Changes in precipitation can affect green infrastructure designs (e.g., permeable pavement, green roof, etc.)

Changes in precipitation and hence runoff can significantly impact BMP designs, such as swirl and retention ponds

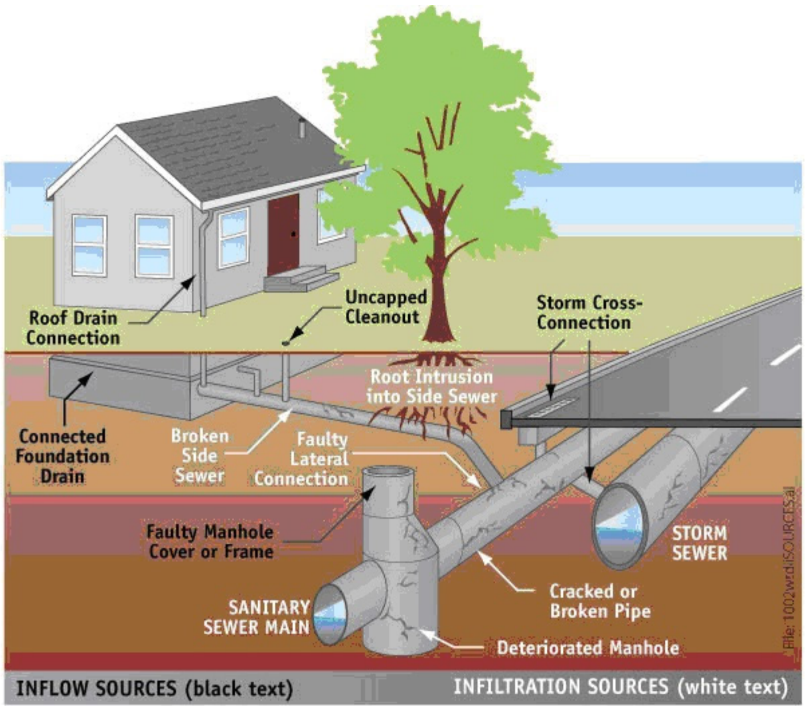


Changes in precipitation and land cover can impact combined sewer system (CSS) in combined sewer overflows (CSO)

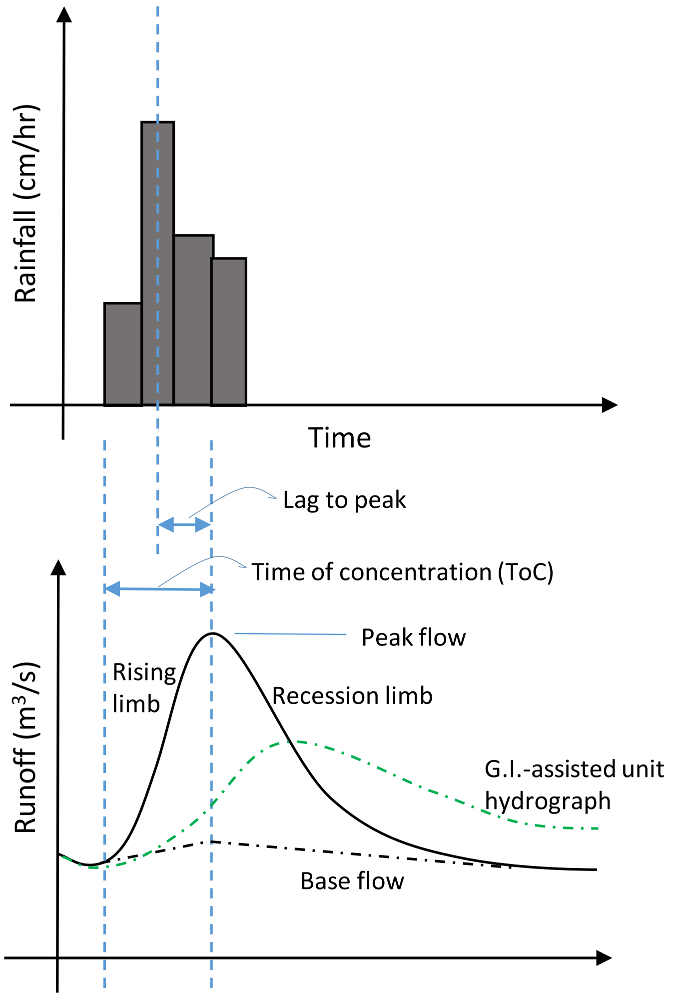
Permits for stormwater and treated wastewater effluent discharge may change due to stream's carrying capacity in future climate

Stormwater and CSS Adaptation Planning and Design

- Design Storm: Historical data are used to calculate peak flow from a maximum precipitation over a specific time return interval (RI)
  - 100-year RI (e.g., large reservoirs)
  - 25-year RI (e.g., water mains)
  - 5-year RI (e.g., street drains)
- Collection pipe, pump station, diversion structure in CSS, stormwater best management practices or BMPs (e.g., retention pond, green garden, etc.) are directly dependent upon design precipitation
- CSO events occur in high-intensity runoffs



Adaptation for Urban Runoff



Runoff (SCS CN method) – Accumulative runoff (in)

Design storm, total (in)

$$R = \frac{(\boldsymbol{I} - la)^2}{\boldsymbol{I} - la + S} \qquad S = \frac{1000}{\boldsymbol{CN}} - 10$$

Curve #

Initial abstraction

Soil moisture storage (in)

- Rainfall-runoff hydrograph on right follows important hydrological properties:
  - ✓ The runoff shape (peak flow and ToC) depends on rainfall intensity and ground curve number (CN)
  - ✓ More intense rainfall, higher peak flow and steeper rising limb
  - ✓ Impervious ground with greater CN yields greater runoff, higher peak flow, shorter ToC, and large runoffs
- These relations are described by runoff models such as those using SCS CN method
- Use of green infrastructure (G.I.) and best management practices (BMPs) flattens the runoff curve, reduce runoff volume and peak flow

Adaptation for Urban Runoff

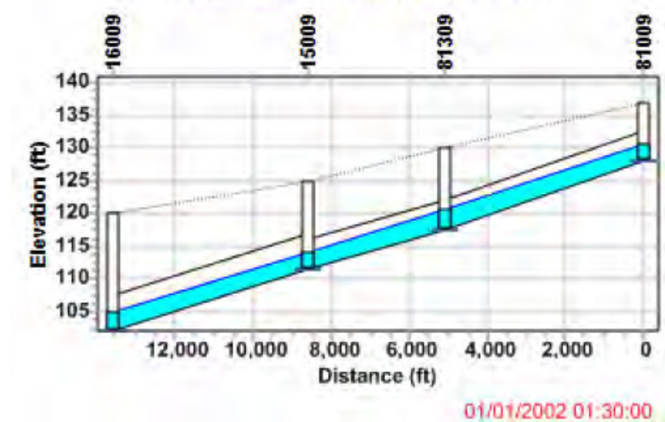
Sizing the pipe, pump, and conveyance systems:

- Pipe flow (Hazen-Williams equation):
  Velocity (ft/s)

$$V = 1.318 C\, R^{0.63}\, S^{0.54}$$

Roughness coefficient (C); Hydraulic radius (R); Slope (S)

Sewer pipe design (hydraulic profiles)

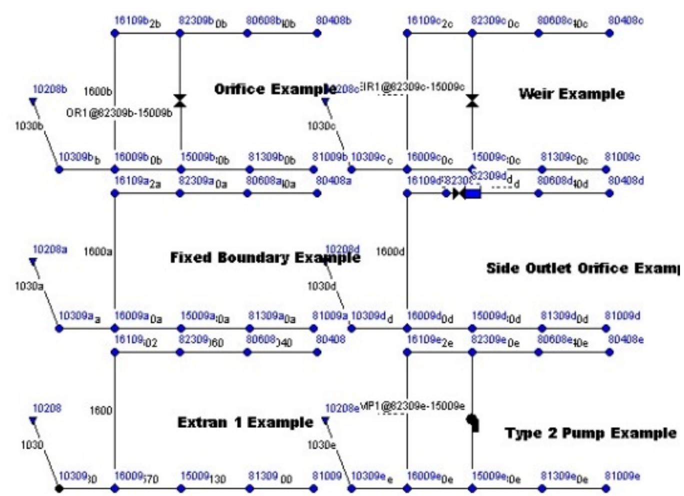


- Open channel flow (Manning's equation):
  Flow rate (ft^3/s)

$$Q = \frac{1.49}{n} A R^{0.75}\, S^{0.5}$$

Flow area (A); Hydraulic radius (R); Slope (S)

Routing design



Adaptation for Urban Runoff

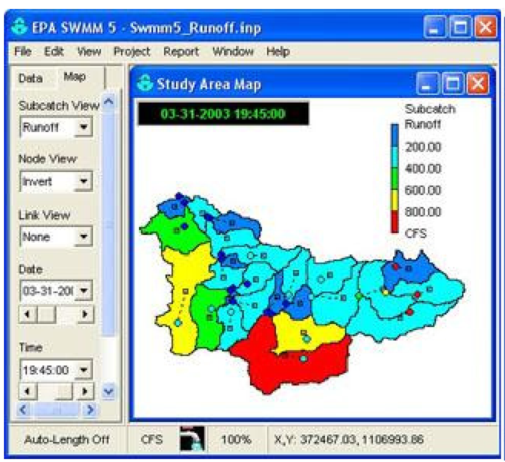
Using software to assist planning and design

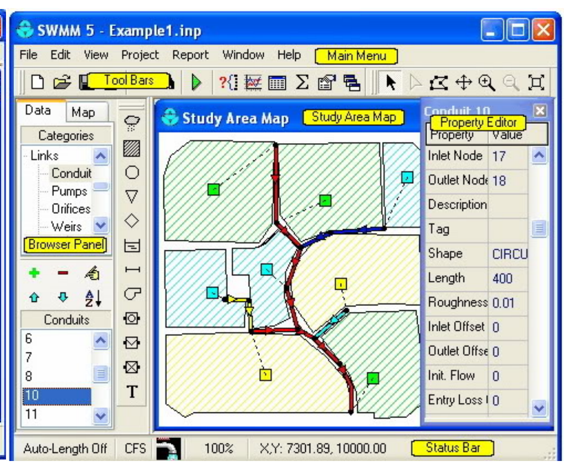
EPA National Stormwater Calculator – Climate Assessment Tool

To Install the Calculator on Your Computer:

1. Download the National Stormwater Calculator Version 1.1.0.2 (EXE) (17 MB)
2. If your browser offers the option to run the setup program then do so.
3. Otherwise have your browser display its list of recent downloads and select the setup file to run it.
4. If you have problems installing the calculator contact your system administrator or try the alternative method described below.

Storm Water Management Model (SWMM)

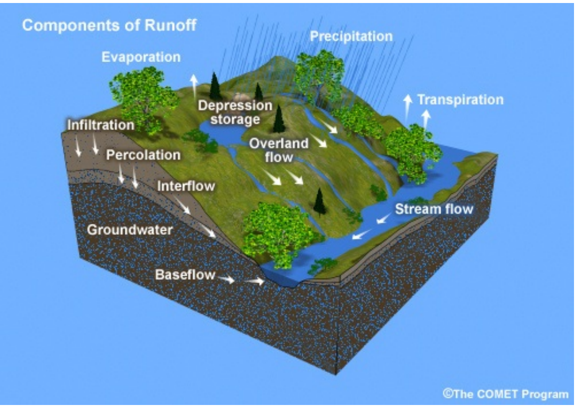




To download the SWMM

Date	Description
01/29/2016	Storm Water Management Model Reference Manual Volume 1 - Hydrology (PDF) (235 pp, 3.8 MB) January 2016 Revised, EPA No. 600/R-15/162A.
09/08/2016	Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)(161 pp, 1.6 MB) July 2016, EPA No. 600/R-16/093
09/07/2016	Self-extracting installation program for SWMM 5.1.011 (EXE)(5 MB)
09/07/2016	SWMM 5.1.011 Interface Guide (ZIP)(47 K)
09/30/2015	SWMM 5.1 User’s Manual (PDF) (353 pp, 10.2 M)
07/06/2010	SWMM Applications Manual (ZIP)(7 MB)
09/19/2006	Quality Assurance report for dynamic wave flow routing (ZIP)(3 MB)
05/25/2005	Utility for converting SWMM 4 data files to SWMM 5 files (EXE) Version 1.2(2 MB)

Adaptation for Urban Runoff: Green Infrastructure



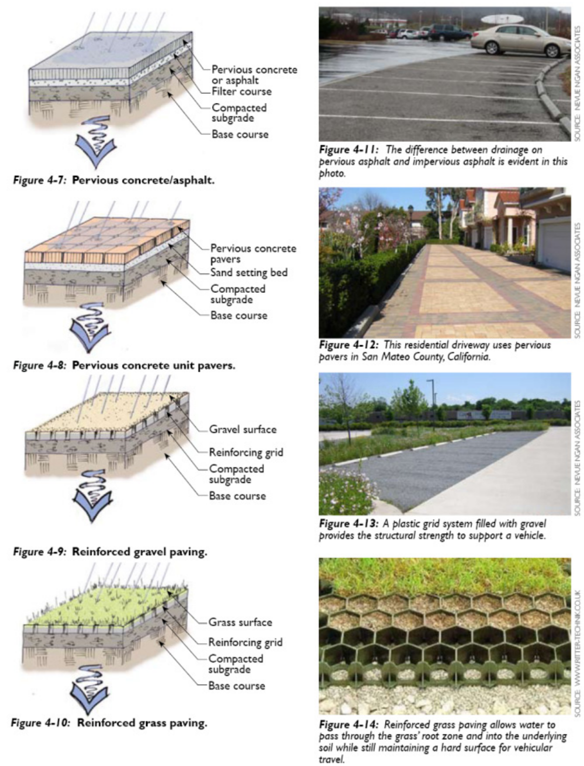


Figure 4-7: **Pervious concrete/asphalt.**

Figure 4-8: **Pervious concrete unit pavers.**

Figure 4-9: **Reinforced gravel paving.**

Figure 4-10: **Reinforced grass paving.**

Figure 4-11: *The difference between drainage on pervious asphalt and impervious asphalt is evident in this photo.*

Figure 4-12: *This residential driveway uses pervious pavers in San Mateo County, California.*

Figure 4-13: *A plastic grid system filled with gravel provides the structural strength to support a vehicle.*

Figure 4-14: *Reinforced grass paving allows water to pass through the grass' root zone and into the underlying soil while still maintaining a hard surface for vehicular travel.*

Water partitioning in urban area: evapotranspiration, infiltration, surface runoff, water diversion for human use

- Agent-based modeling
- Soil conservation method

Landscape alteration and mitigation

- Land use → local climate → urban hydrology
- Role of green infrastructure

Modeling and Monitoring Surface Water Impacts

Modeling and Quantitative Analysis for Adaptation

- Precipitation change leading to watershed and catchment basin hydrological changes (runoff, pollutant transport, etc.)
- Modeling methods are available to quantify the change and thus develop adaptation accordingly
- Major topics for modeling analysis:
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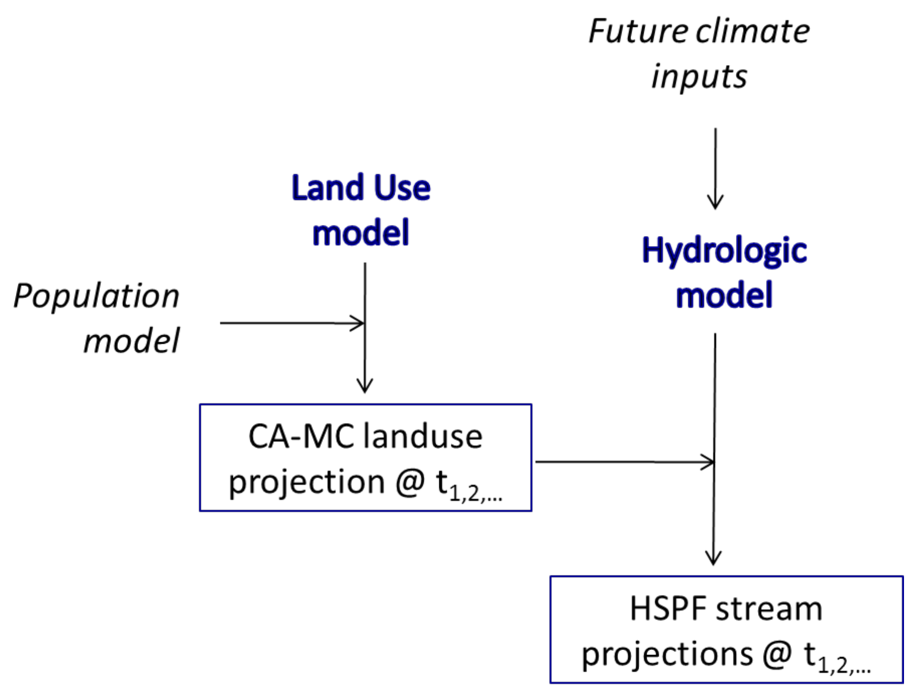
- Modeling methods and tools

Modeling and Monitoring Surface Water Impacts

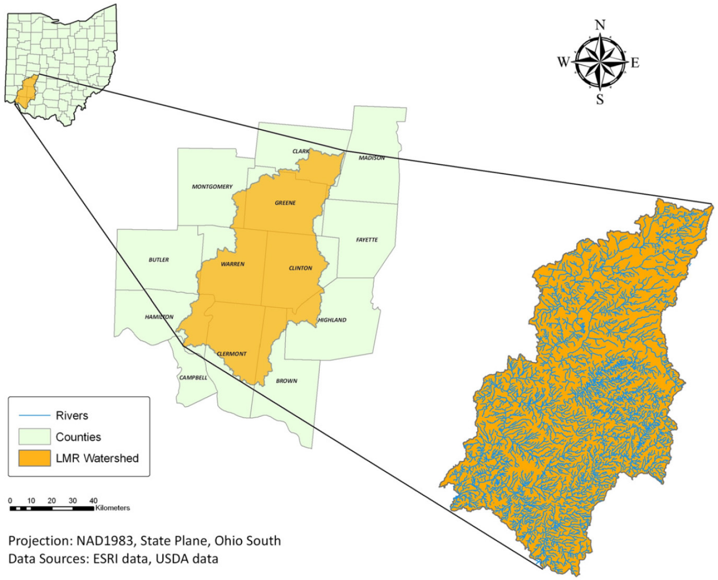
Integrated Land Use and Hydrological Simulation for Water Qualtiy Impacts in a Watershed

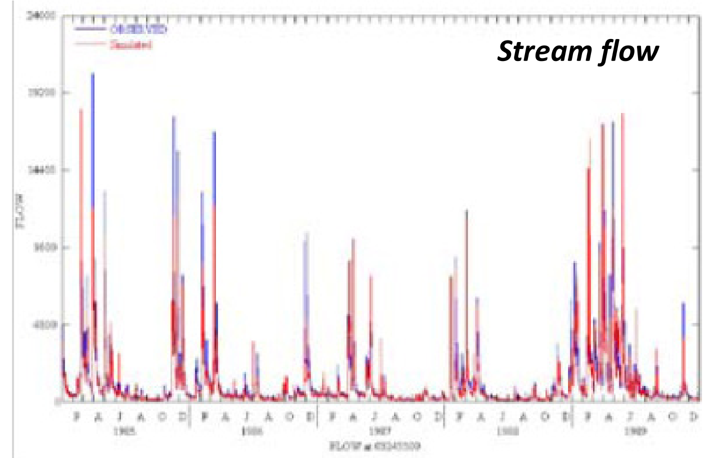
- **Climate impact modeling:** Precipitation changes by climate models or planning scenarios
- **Population modeling:** Often based on population census model and results
- **Land use modeling**: by either mechanistic models (e.g., CA-Markov) or statistical models (e.g., ICLUS)
- **Hydrological modeling**: Based on hydrological models (e.g., HSPF) to simulate stream flow and water quality response

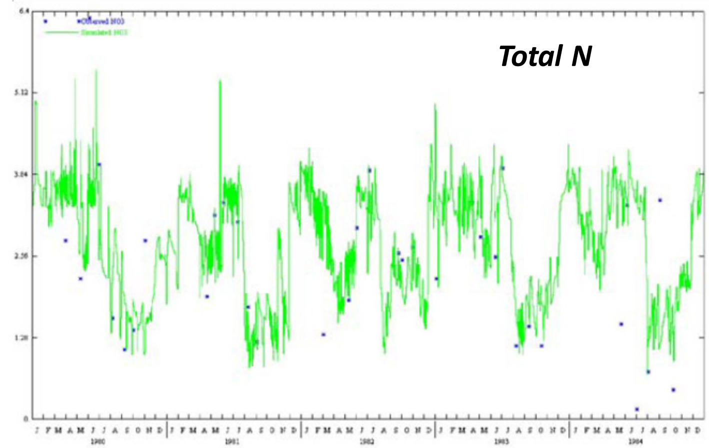


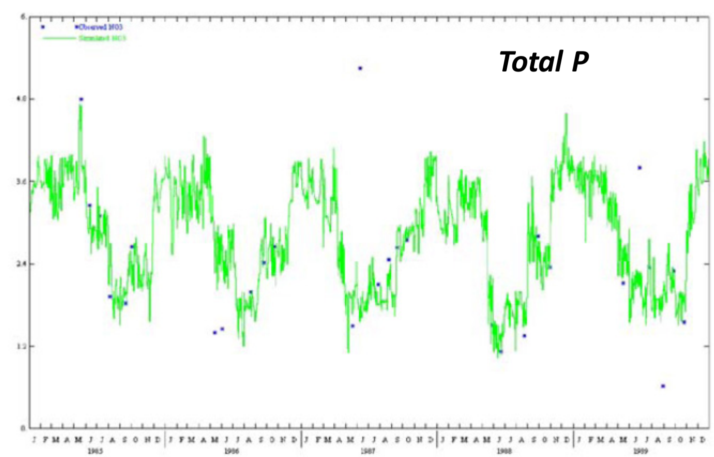
The models are coupled together for future hydrological changes. Note that model calibration and validation in both stream flow and water quality are essential

Modeling and Monitoring Surface Water Impacts – Example in Little Miami River Watershed, U.S.A.

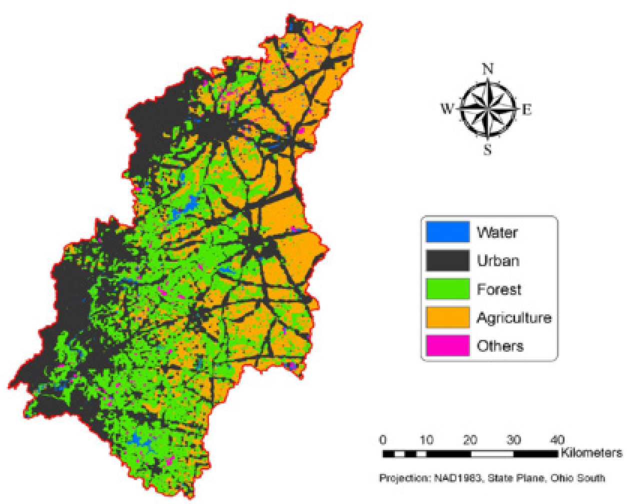








Yr 2050



Models calibrated for observed land use changes, and changes ir flow and water qualitie: (total N and P).

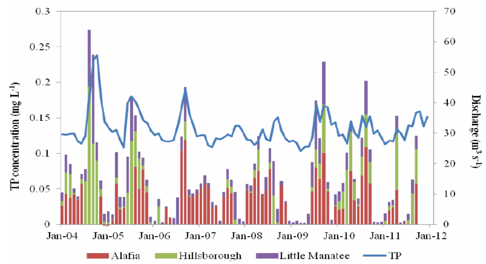
Modeling and Monitoring Surface Water Impacts – Example in Little Miami River Watershed, U.S.A.

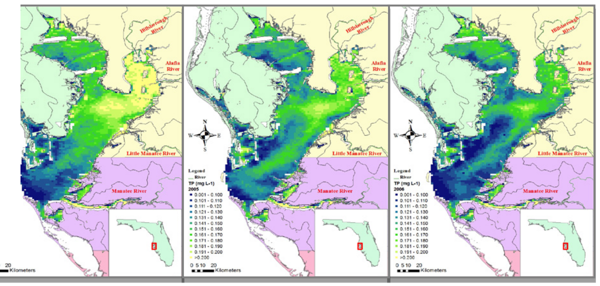
Scenario	Mean daily flows (m^3/s)	% difference from NO CHANGE*	Mean daily TP concentration (mg/L)	% difference with NO CHANGE*	Mean daily N concentration (mg/L)	% difference with NO CHANGE*
No change (NO CHANGE)	32.31		0.342		2.77	
Land use change only (LU)	41.71	29.09%	0.356	4.09%	2.86	3.25%
Wettest precipitation change only (W2)	42.20	30.61%	0.391	14.33%	2.99	7.94%
Wettest precipitation and land use changes (W2 + LU)	46.47	43.83%	0.415	21.35%	3.09	11.55%
Wet precipitation change only (W4)	36.46	12.84%	0.362	5.85%	2.91	5.05%
Wet precipitation and land use changes (W4+ LU)	37.55	16.22%	0.370	8.19%	2.97	7.22%
Dry precipitation change only (D2)	16.00	-50.48%	0.368	7.60%	2.81	1.44%
Dry precipitation and land use changes (D2+ LU)	18.12	-43.92%	0.383	11.99%	2.85	2.89%
Driest precipitation change only (D4)	10.00	-69.05%	0.351	2.63%	2.83	2.17%
Driest precipitation and land use changes (D4 + LU)	15.16	-53.08%	0.365	6.73%	2.88	3.97%

- 2050 land use – Model projected using CA-MC
- 2050 Climate scenario: +2 ^{o}C or 4 ^{o}C temperature increase
- 2050 Climate scenario: + 20% or -20% precipitation change

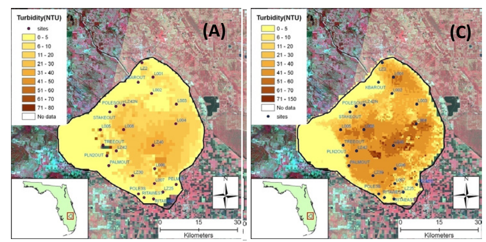
Modeling and Monitoring Surface Water Impacts – Monitoring Methods and Techniques

- Satellite-based daily high-resolution monitoring of climate and impacts
- For monitoring water quality changes both short-term and long-term
  - Daily, high-resolution (250m)
  - Several water quality parameters related to climate: TOC, turbidity, chlorophyll-a, TN, TP, TSS, DSS, microcystin
  - Applicable to large and small water bodies

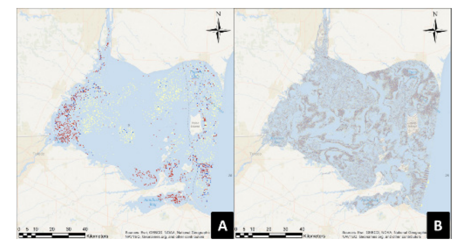




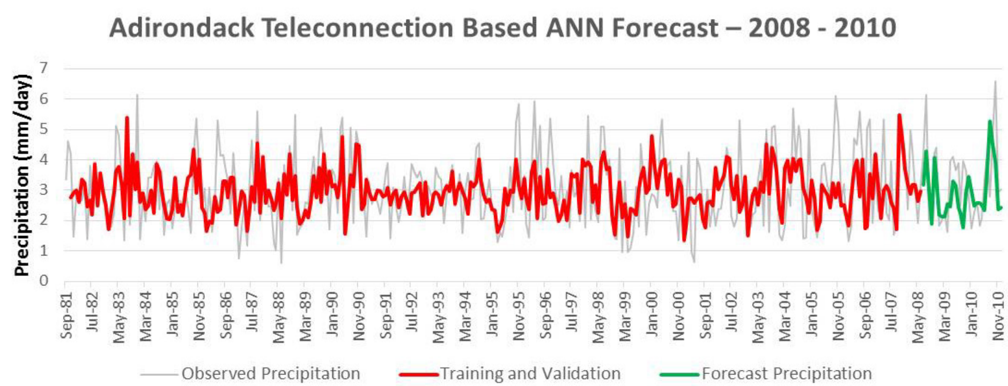
TP in Tampa Bay (hydrol. response)



Turbidity in Lake Okeechobee (hurricane)



Microcystin in western Lake Erie



Summary and Research Questions

- Hydroclimatic change affects surface runoff properties and surface water quality in streams.
- Land use change in urbanization further exacerbates the precipitation change impacts
- These changes can impact the design and operation of stormwater, CSS and wastewater infrastructures
- Models are available to simulate the hydraulic and water quality impacts for both urban catchment and watersheds.
- Models for climate, land use, and population are often integrated in projections

Research Questions

- List uncertainty sources in runoff projections, and describe how they impact the evaluation and adaptation design of a CSS pipe system
- How would the frequency and intensity of heavy precipitation affect the design and sizing of a stormwater conveyance pipe? What if the 10-year design 24-hour precipitation will increase by 15%?
- List the major variables in simulating stream flow for now and 30 years in the future. The urban catchment will be developed into predominant residential area in 30 years.
- Assuming your city is located at ocean shore, what are the major hydrological impacts from a class 4 hurricane and associated storm surge? (Hint, list <u>all</u> major threats)

Looking ahead to the next module.....

- Next module: Models and Tools for Drinking Water System Adaptation
- Scoping of project topics

Project and case studies

Case Studies to illustrate specific water system stressors and adaptation considerations

Research and data needs

(Modules 1-6)

Region-specific applications

Adaptation Principles: Definition and application to different scenarios

Assignment 1

(Module 7)

Hands-on exercises

Policy considerations: Examples of current policy frameworks. Opportunities and challenges for systematizing water system adaptation.

Research and data needs for decision support

Assignment 2

(Module 8)

Decision-support

Methods, models, and tools relevant to individual and combined effects from water system stressors

Research and data needs

Assignment 3

(Modules 9-14)

Course outcomes

Knowledge about water system stressors

Adaptation principles

Governance

Strengths and limitations of models

Research directions