MAGEEP Education Network

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Water System Adaptation To Hydrological Changes

Module 3
Consequences of Prolonged Drought on Urban Water System Resilience: Case Study from Las Vegas, Nevada, USA

Y. Jeffrey Yang, Ph. D.

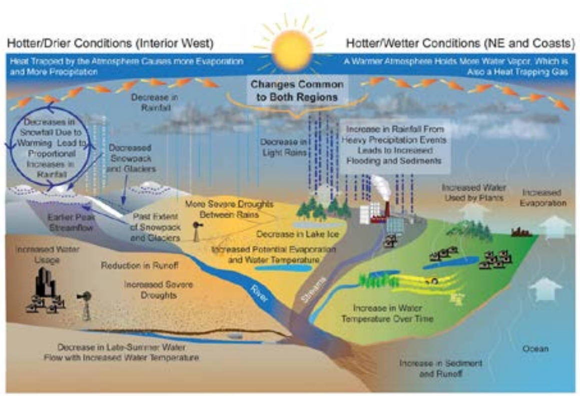
U.S. Environmental Protection Agency

Audrey Levine, Ph.D.

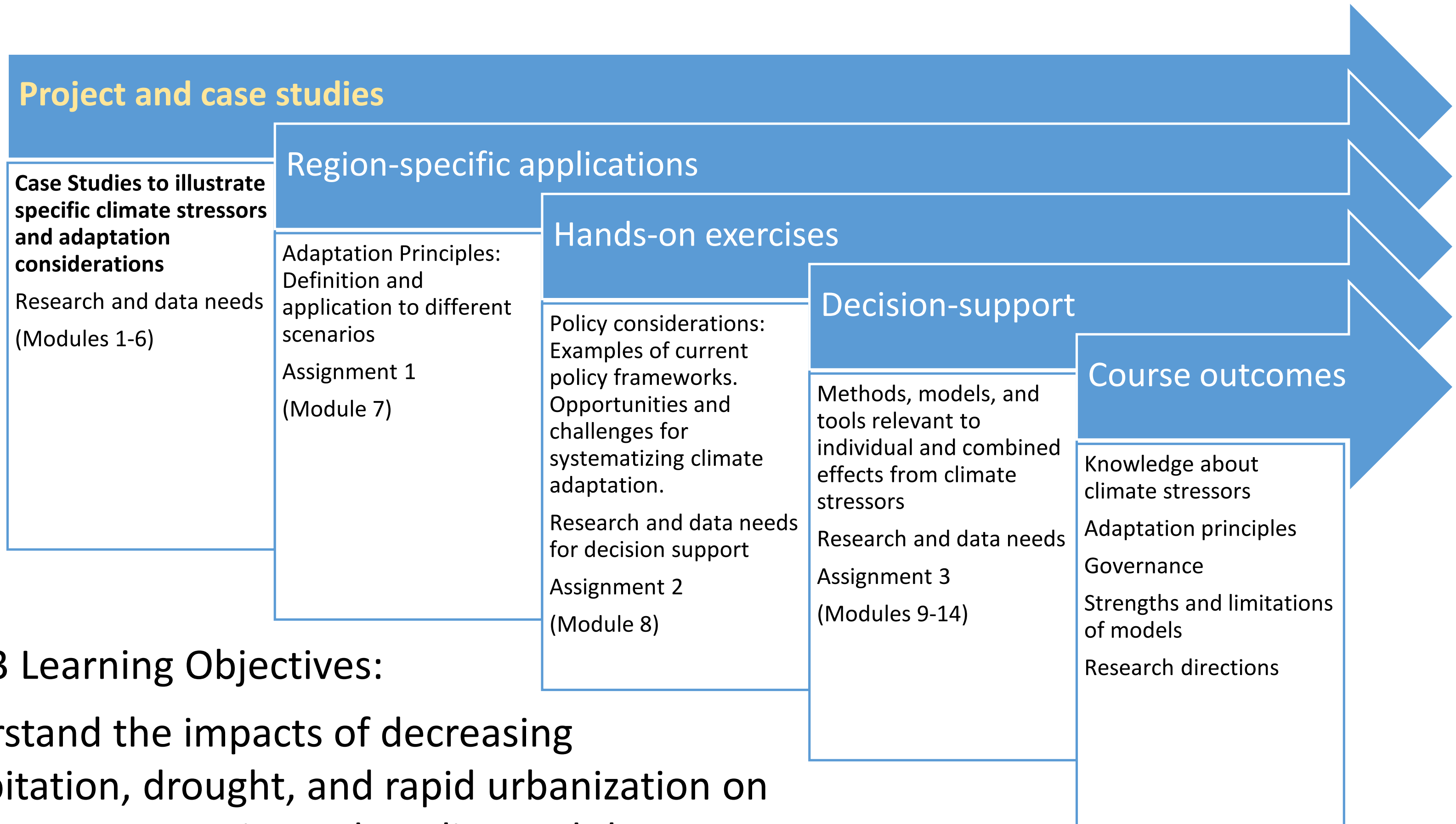
University of California, Santa Cruz

James A. Goodrich, Ph.D.

U.S. Environmental Protection Agency



Course Roadmap



Module 3 Learning Objectives:

- Understand the impacts of decreasing precipitation, drought, and rapid urbanization on source water quantity and quality, and thus water supply
- Illustrate location-specific total water management as an effective adaptation approach

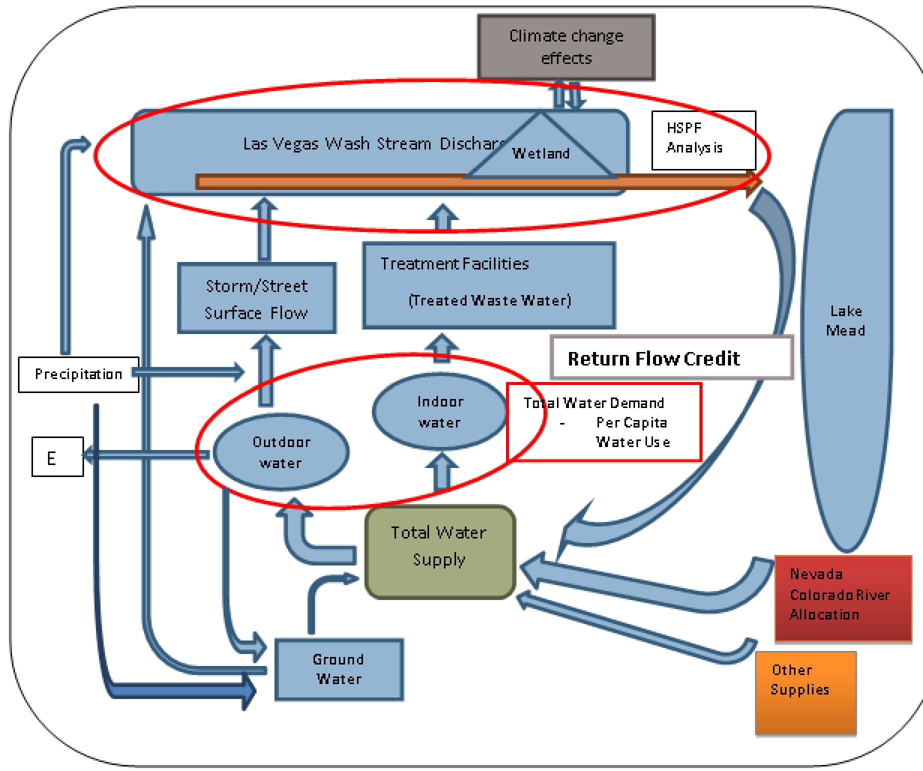
Droughts and Hydrological Impacts in a Changing Climate for Las Vegas, Nevada

- Las Vegas located in southern Nevada of the semi-arid southwestern U.S.
- Climate impacts are in form of precipitation decrease, changes in IDF and seasonality, hotter temperature, and evapotranspiration (ET). This past trend will continue
- At the same time, rapid urban sprawl has resulted in greater water demand, higher runoff, and less water availability
- Adaptation in master planning needed to mitigate significant water supply gap expected after 2024
- To characterize the future condition is key for planning of needed adaptation

Courtesy of Ranatunga et al. (2014)

Quantifying Impacts for Adaptation Planning

- Imbalance between water availability and water demand is the key
- The **approach in total water management** aims ay systematically evaluating options for **resilient water systems**



- For Las Vegas, water resources inventoried in future climate; water demand calculated using population and land use projections.
- Quantitative methods for modelling and calculations will be discussed in Modules #10 and #13.

Courtesy of Ranatunga et al. (2014)

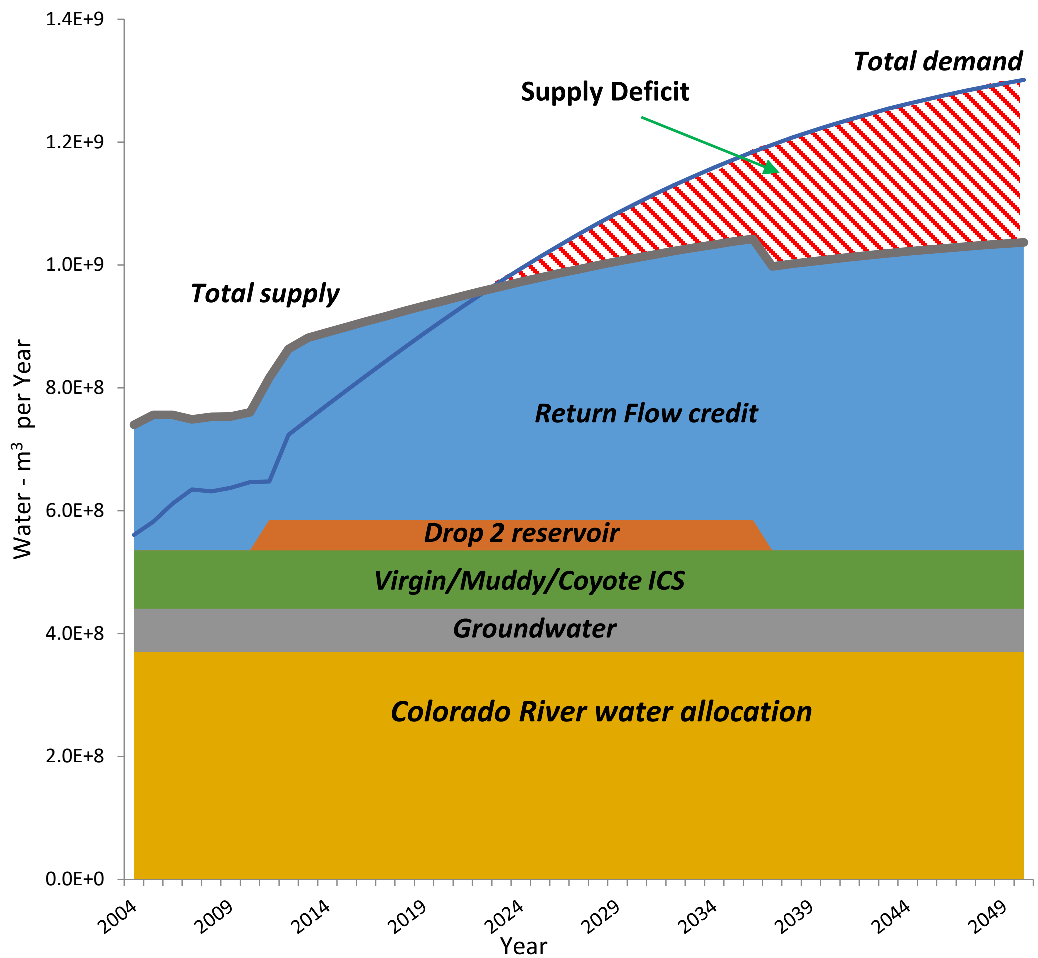
Case Study: Quantifying Impacts for Adaptation Planning

Total water supplies by inventory

- Colorado River water allocation: River flow available to the City is decreasing due to river flow decrease
- Return flow credit: Return flow from the city through Las Vegas Wash by water conservation and water reuse
- Flows from other areal rivers/streams such as Lower Virgin River and so on
- Groundwater through aquifer storage and recovery (ASR), and Drop 2 reservoir

Water demand in urban sprawl

- The tourist city had fast population growth at ~7% per year in 1970-2000 in a “S”-curve growth model forward
- Now ~2.0 million, and projected to be ~3.77 million by 2050



Courtesy of Ranatunga et al. (2014)

Case Study: Quantifying Impacts for Adaptation Planning

Quantifying Changes on Colorado River flow and water availability

- Historical Colorado River flow variations
- Consistent decrease in Lake Mead water volume
- Long-term precipitation changes
- Land use changes

Each examined subsequently

Enhancing adaptation measures

- Water conservation
- Water reuse and harvesting for higher return flow
- Use of aquifer storage and recovery for seasonal water supply imbalance

Drought and Hydrological Impacts for Las Vegas, Nevada

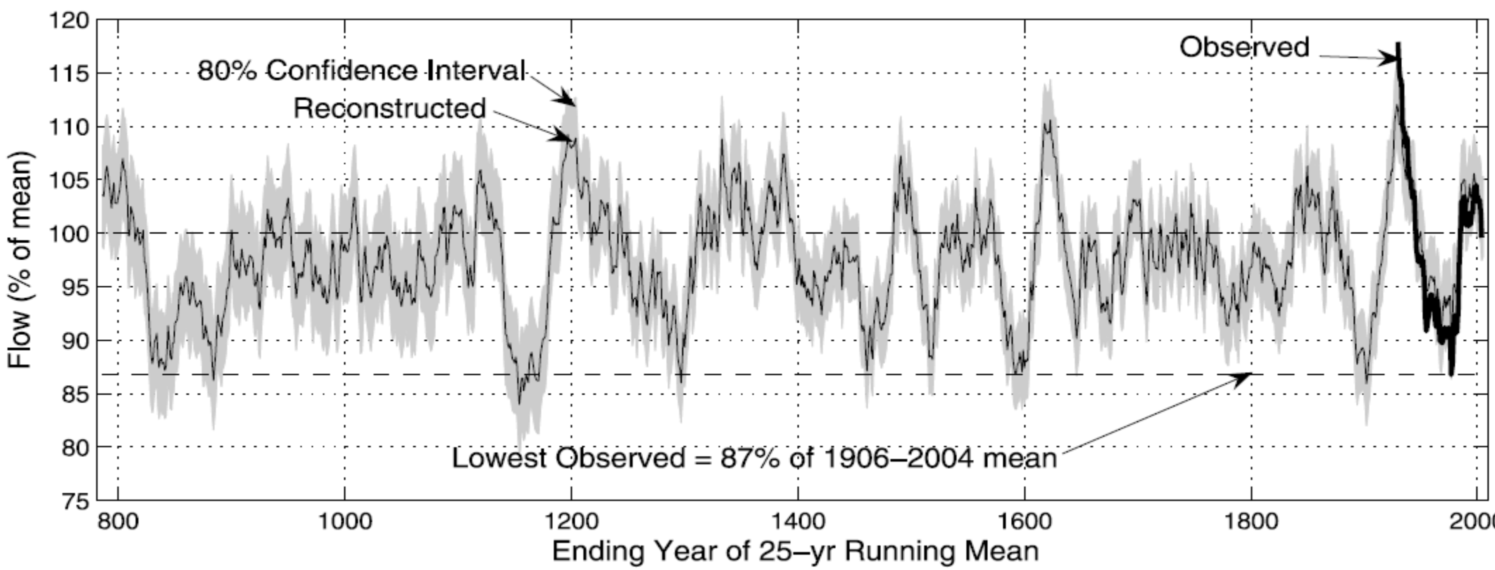
- Lake Mead on Colorado River is the only large reservoir of source water for the city
- Chronic droughts had decreased lake water level by ~100 ft from 2000 to 2009
- The City relocated th water intake to a deeper portion of the lake for water supply operations
- Source water quality changed as a result. Mussels and other opportunistic biological growth were extensive around the water intake

Courtesy of LVVWD

Historical Observations on Water Availability

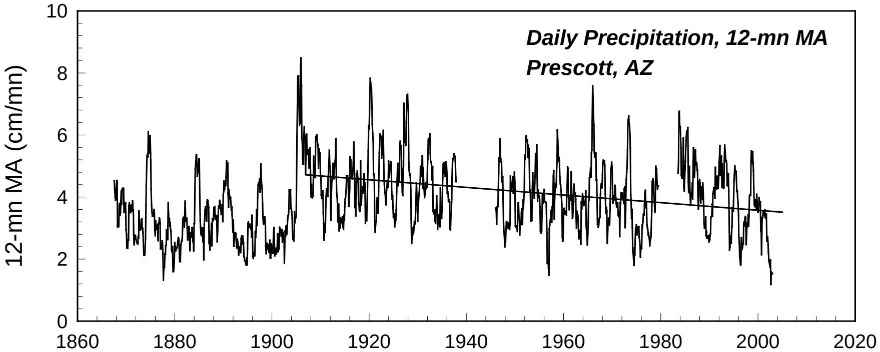
Historical tree-ring reconstructed river flow at Lees Ferry, Arizona (~327 km from Las Vegas to the east):

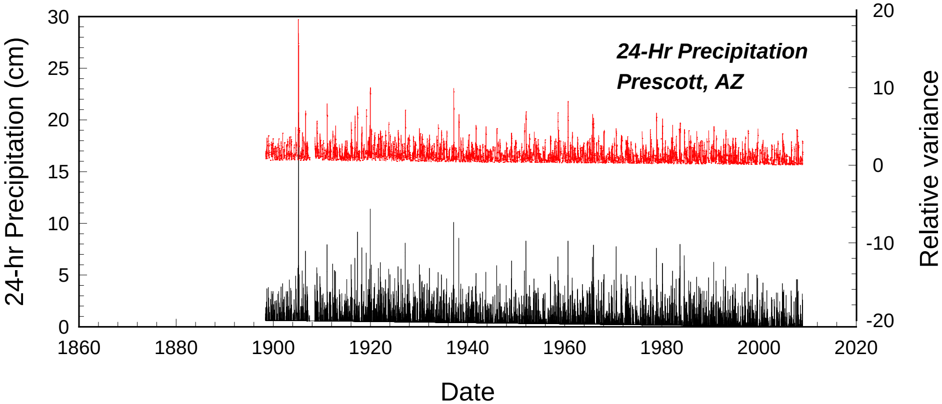
- Use age-dating of tree remnants found at 11 sites in the lower Colorado River basin
- Relative to 1906-2004 river flow average, reconstructed historical flow shows large decadal and millennial variations (See graph below)
- The Colorado River flow is likely in a declining phase in natural variation. Climate models shows worsening condition in the future



Colorado river flow change. Courtesy of Meko et al. (2007)

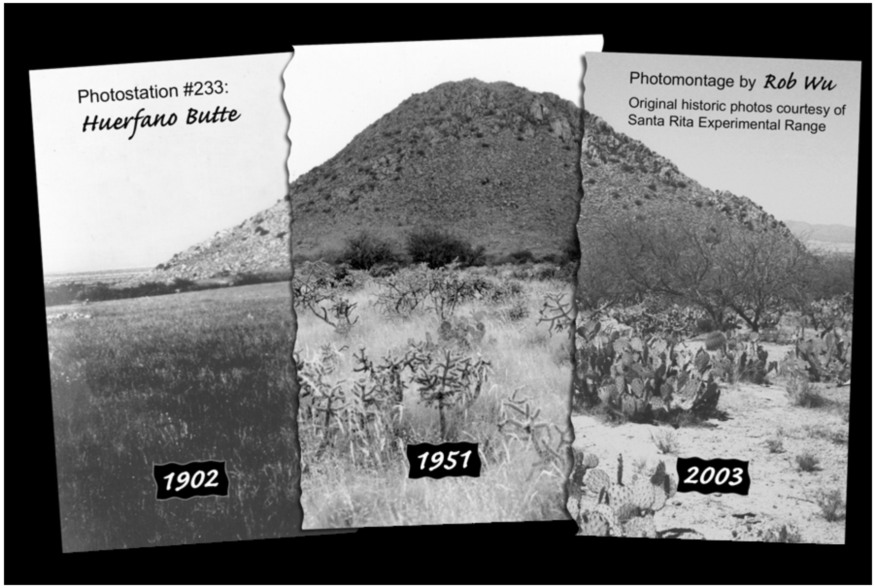
Historical Observations on Water Availability





- Precipitation in the region has been declining since the start of 1900s.

- The precipitation decline and areal arid hydrology are clearly shown by vegetation and land use changes.



(from USCCSP, 2009)

Case Study: Quantifying Impacts for Adaptation Planning

Quantifying Changes on Colorado River flow and water availability

- Historical Colorado River flow variations
- Consistent decrease in Lake Mead water volume
- Long-term precipitation changes: **Climate model Projections**
- Land use changes

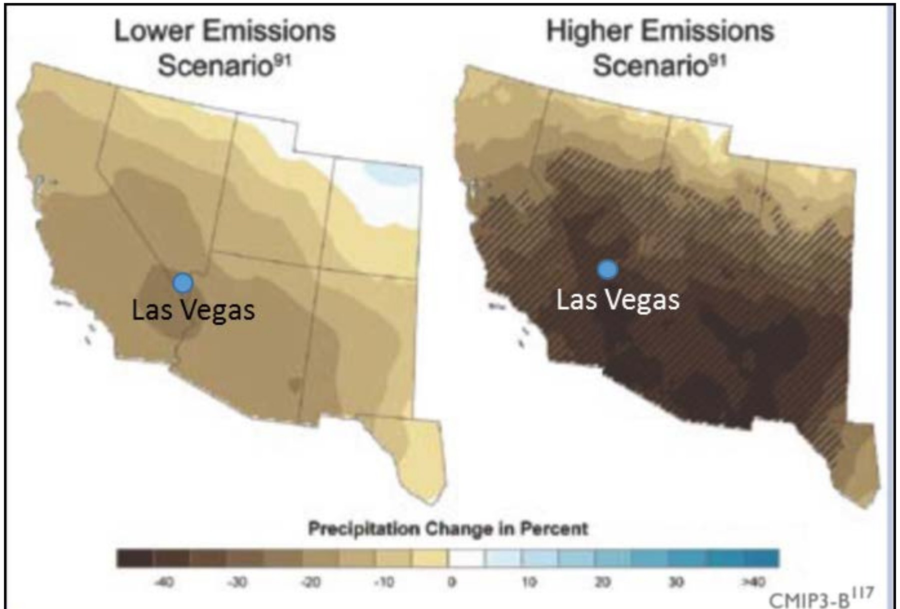
More details on climate models and land use models available in Module 11-13

Existing adaptation measures

- Water conservation
- Water reuse and harvesting for higher return flow
- Use of aquifer storage and recovery for seasonal water supply imbalance

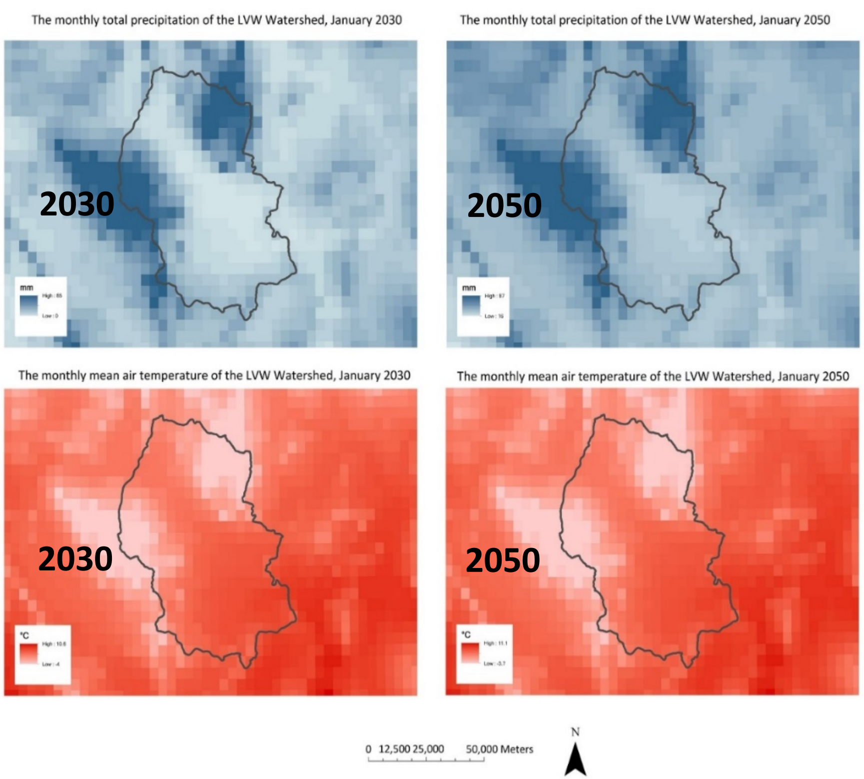
Future Precipitation Changes in US Southwest

- Total yearly precipitation is projected to decrease in the Las Vegas area and the regions to the south. The decrease is large under higher emission scenarios. See Figure on the right



Percentage change in March-April-May precipitation for 2080-2099 compared to 1961-1979 for a lower emissions scenario[91] (left) and a higher emissions scenario[91] (right). Confidence in the projected changes is highest in the hatched areas.

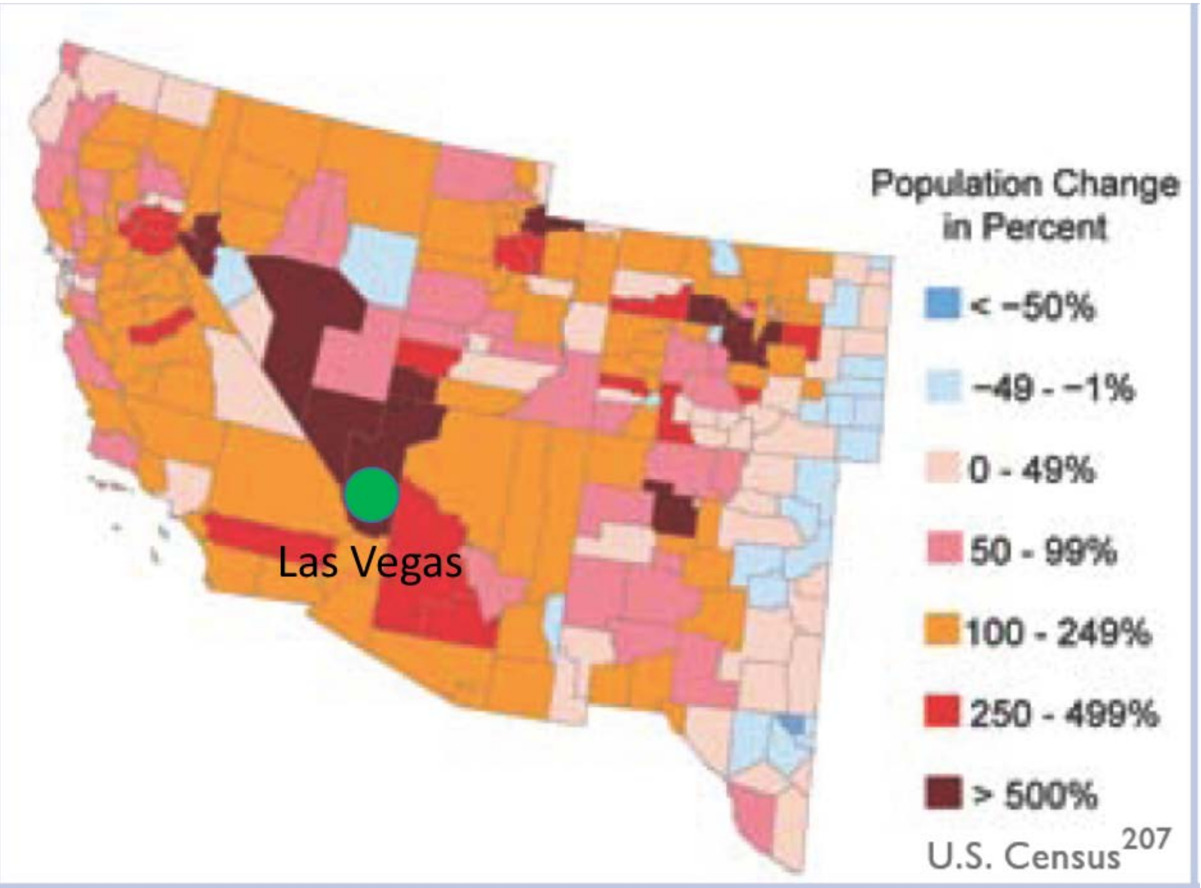
(from USCCSP, 2009 and references therein)



- In the Las Vegas region, climate models project spatial and seasonal changes in precipitation. See Figure on the left
- These projected values used for hydrological simulation of stream flows. Methods are described in Module #10

Case Study: Land Use and Population Projections

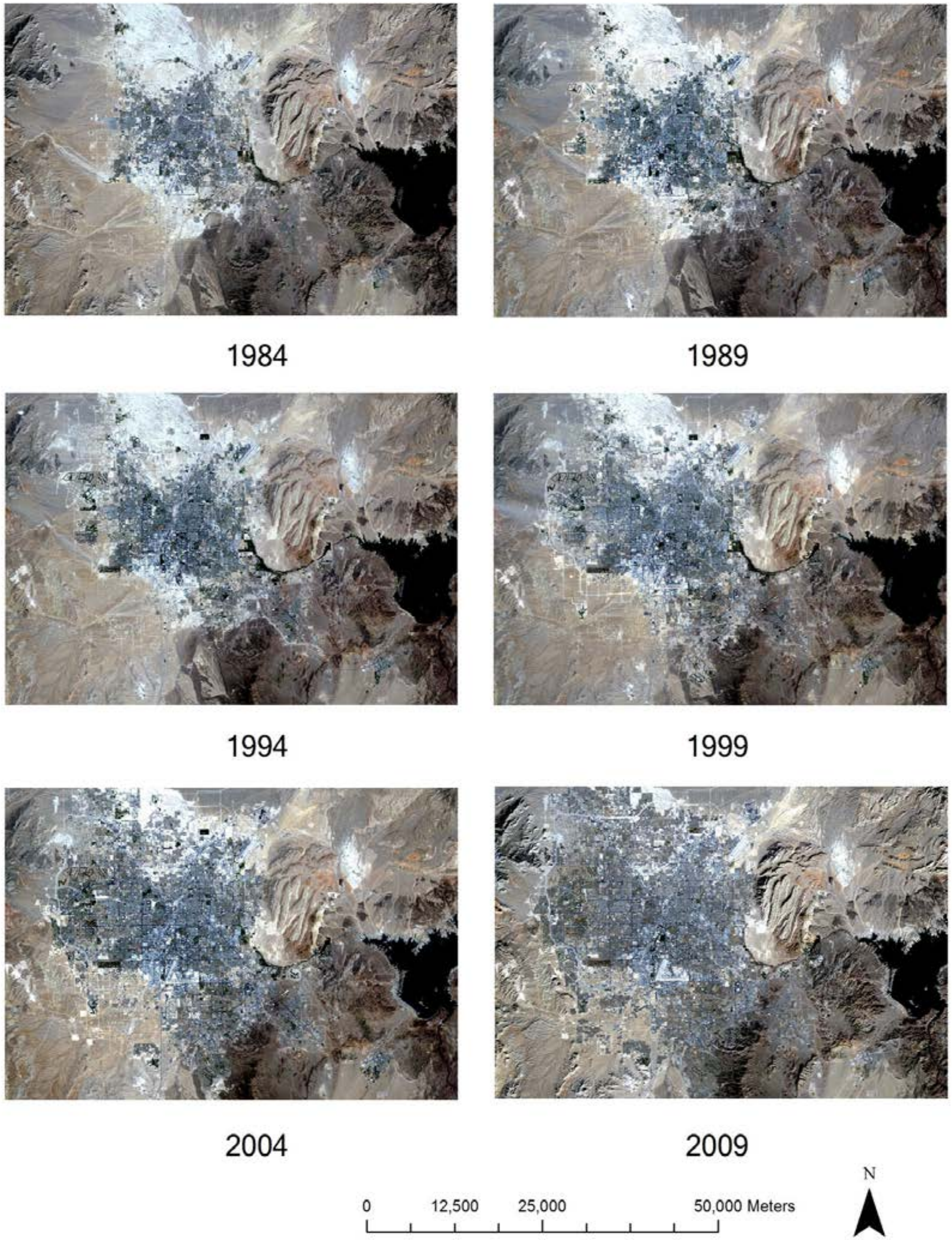
- Very rapid population increase in the recent decades
- High population growth common to most U.S. southwest



Courtesy of ESRI

Rapid Change in Urban Land Use and Land Covers

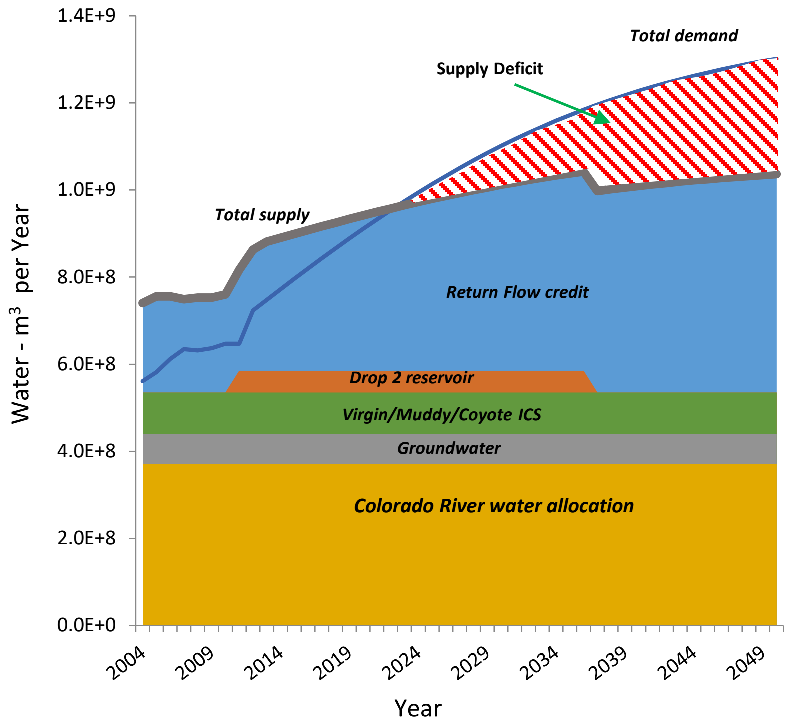
- At the same time rapid urban sprawl as shown by satellite photos
- Impervious surface in urban areas increases runoff, decreases infiltration to groundwater
- Combined hydrological consequence the reduced water availability and increased drought occurrence



Case Study: Quantifying Impacts for Adaptation Planning

Potential adaptation in total water management

- *Increasing return flow* for withdrawal credit from Colorado River
- *Enhancing infiltration* to enhance groundwater storage and decrease drought intensity
- *Aquifer storage and recovery (ASR) operation* against drought and flow imbalance
- *Other storage and water transfer options* such as the Drop 2 reservoir.
- *Water conservation*, including more use of artificial turf, intelligent irrigation, and policy for water use reductions.



Courtesy of Ranatunga et al. (2014)

Specific adaptation measures

Monitoring and forecasting

- Water availability forecasting for planning and operation
- Drought and climate monitoring;
- Real-time forecasting of Lake Mead water quality

Hydrology and water supply

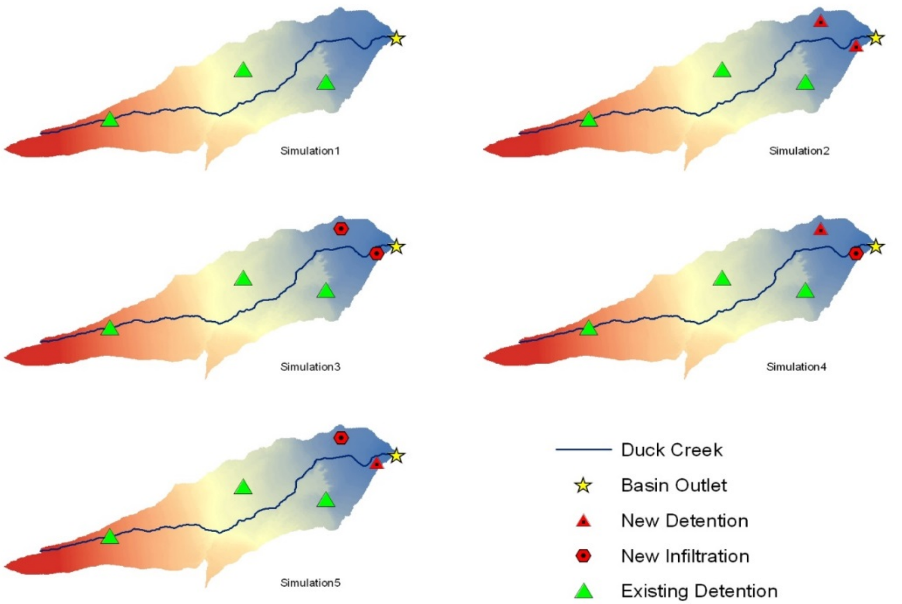
- Water storage and ASR operation
- Green infrastructures
- Water treatment and distribution optimization
- Policy toward water conservation

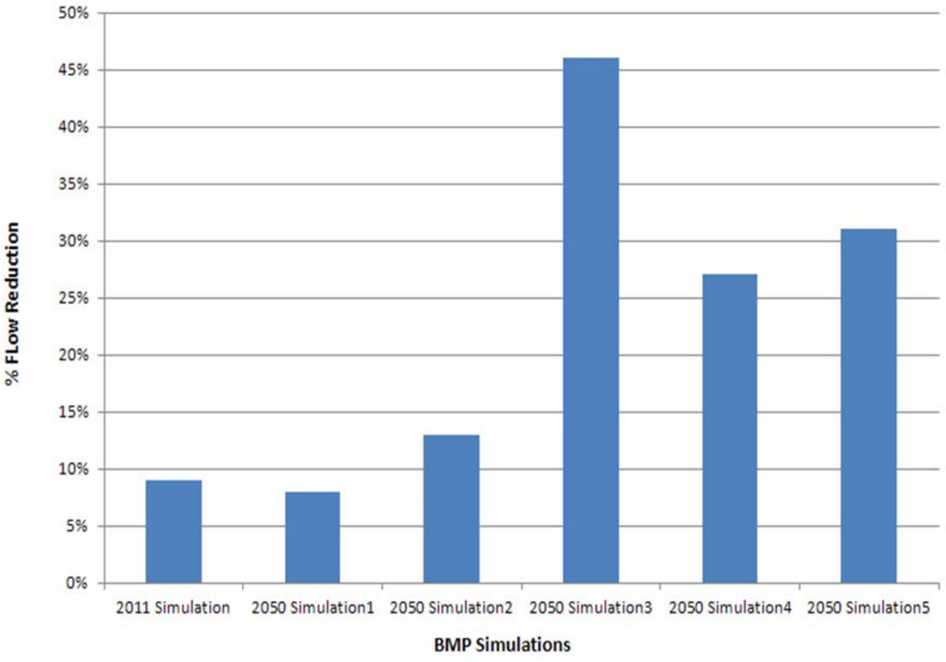
Las Vegas Case Study: Adaptation options

Issue	Adaptation Option	Mechanism	Feasibility
Drought and water availability for increasing water demand	Water reuse and increase of return flow to Lake Mead	• Wastewater treatment and reuse • Green infrastructure to reduce runoff • LID, water storage facilities, and water conservation	Very good
	Aquifer storage and recovery (ASR) and other large scale storage facilities	• Operate existing and expanding ASR • Water harvesting for storage including from high Colorado River flows	Good
	Water conservation	• Artificial lawn and water-less landscaping • Water saving measures and price incentives	Very good
Drinking water treatment and distribution	Source water quality nowcasting	• Satellite-based monitoring and short-term forecasting of water quality changes in Lake Mead	Very good, tested
	Increase water treatment efficiency and resilience	• Increase treatment efficiency in removal of TOC and other DBP precursors • Use EPANET-based modeling tools and SCADA system to control water age and DBP formation in water distribution	Very good, in practice

Adaptation Example: BMP Applications

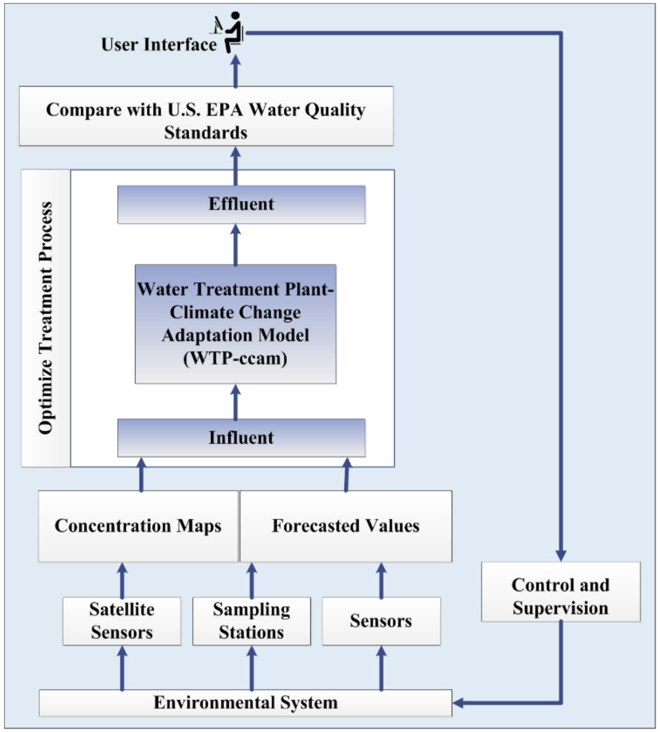
- Within the city, best management practice (BMP) applications such as retention pond can significantly reduce peak stream flow and overland runoff
- Green infrastructure such as green garden, green roof, can further enhance the adaptability against drought and climate impacts

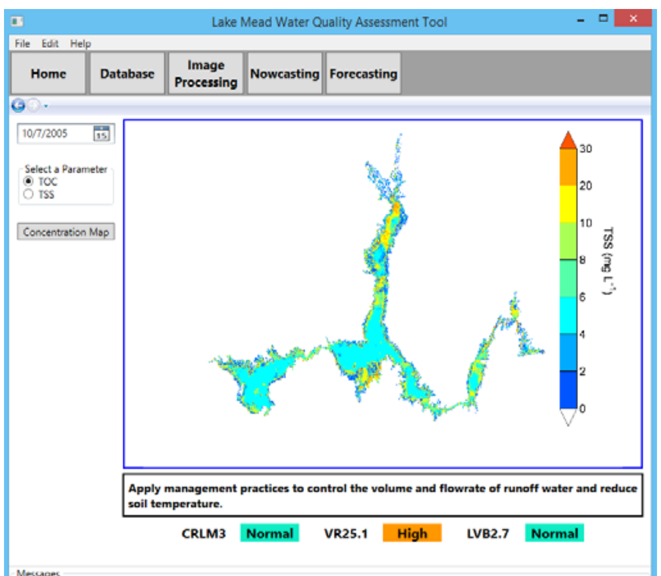




Courtesy of Sun et al. (2016)

Adaptation Example: Satellite-based Water Quality Monitoring for Water Treatment

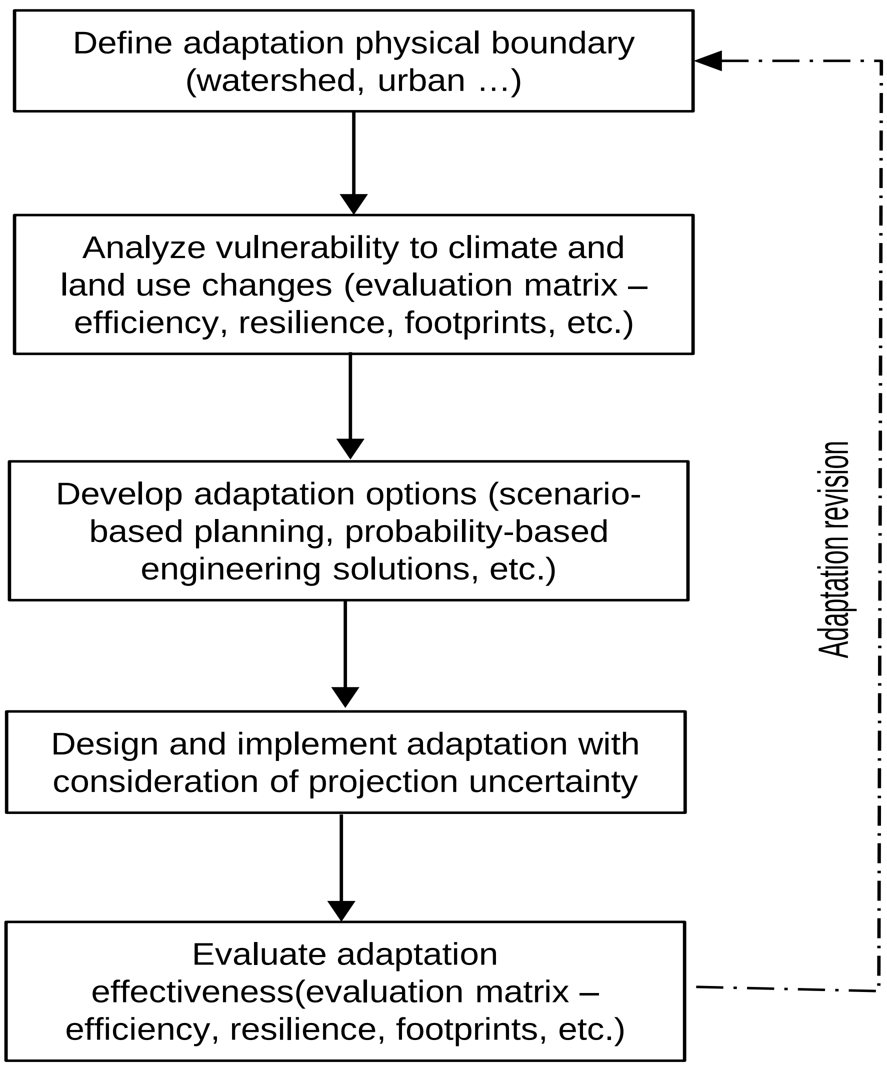




- Source water varies due to hydrological changes under the climate influences.
- Monitoring of the water quality in Lake Mead helps treatment plant operation and long-term planning.
- Adaptation measures to against disinfection by-products (DBPs), for example, can be implemented.
- The near real-time monitoring technique and nowcasting technique using satellites are developed.

Courtesy of Imen et al. (2016)

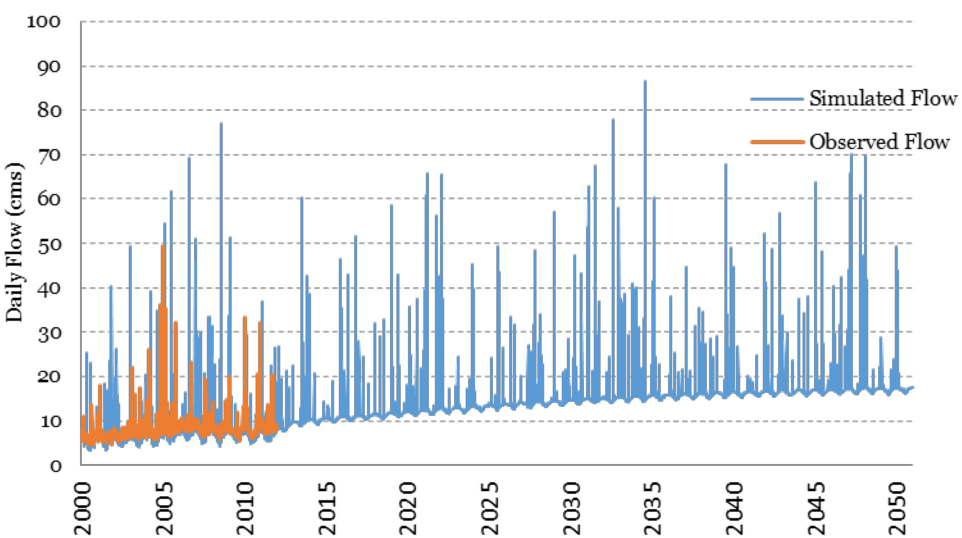
General Adaptation Approach

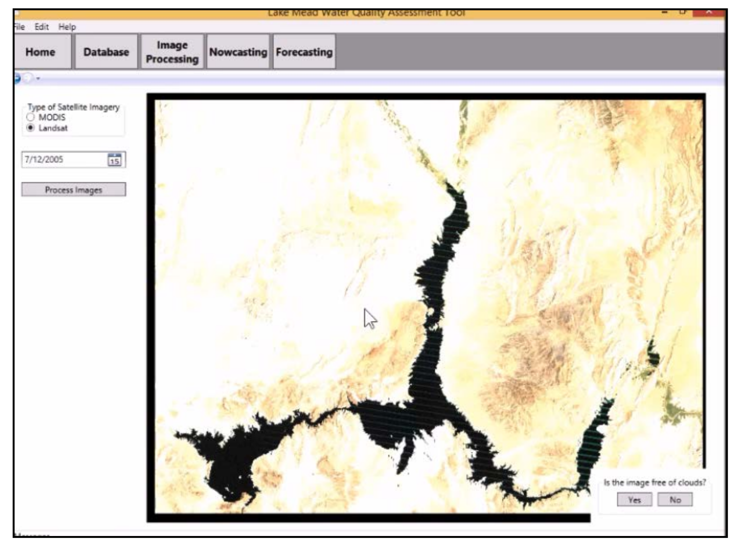


- General adaptation iterative steps:
  - ❖ Define impact for a climate scenario
  - ❖ Define land use factors
  - ❖ Design and model adaptation options
  - ❖ Implement and monitor adaptation effects
  - ❖ Re-evaluate adaptation planning
- The analysis sequence applicable for climate-related drought analysis in the Las Vegas study

Summary

- Drought and water availability in a changing climate is a major form of impacts in arid regions
- Drought occurrence due to multiple factors (e.g., land use, climate, population, etc.)
- Multiple adaptation approaches; they are location-dependent and require specific data and information
- Policy/governance considerations





Research Questions

- What kinds of data are needed to investigate short-term and long-term water supply gap?
- How are water quantity and water quality related to water availability in surface water?
- What are essential steps to conduct a comprehensive water supply analysis for now and 30 years into the future?
- As a city’s water manager, list your major factors you would consider to develop a total water management plan for your city.

Looking ahead to the next module…..

- Case study: Water quality response to climate and land-use changes
- Scoping of project topics