WATER INFRASTRUCTURE RESILIENCY AND SUSTAINABILITY ACT OF 2011

H.R. 2738

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EXECUTIVE SUMMARY

Although water is plentiful on the planet, less than 1% of freshwater is readily available for human use. The total available amount in a given location fluctuates based on annual precipitation and other hydrologic processes. As climate change increases sea level rise and the regional unpredictability of precipitation, the ability of systems that transport, store and treat freshwater in the U.S. will be critically affected. This is evidenced by the current national drought situation, which led to increased crop prices and destructive wildfires, as well as the failure of water infrastructure in the Northeast to manage stormwater runoff during Tropical Storm Irene in 2011.

Much of the U.S. water system was built in the 1950's and is now nearing the end of its planned lifespan, demonstrated by water main breaks across the country. Since that time, population increases have led to increased demand for water. Postponed maintenance has led to budget shortfalls estimated at $11 billion each year.[1] Investment in water infrastructure is clearly needed, but current stopgap measures do not address the full present and future needs of water managers. The Water Infrastructure Resiliency and Sustainability Act of 2011 (H.R. 2738) proposes to fund a suite of innovative solutions that would be administered through an Environmental Protection Agency (EPA) grant program. The goals of the program are to increase water quantity, water quality, disaster risk reduction, and ecosystem protection. The program offers a broad approach that allows owners or operators of water systems to apply for a grant that would address the impacts changing hydrologic conditions will have on water infrastructure in any region of the United States. Grant funds are intended to encourage innovative pilot programs that incorporate cutting-edge technology and research into water infrastructure system design and operations.

Examples of projects that could be funded under this program range from the use of green infrastructure in urban neighborhoods to advanced water metering on agricultural land. The solutions presented in the bill represent the geographic diversity of water challenges facing the country. Climate change models predict a changing probability of extreme weather events and a shifting mean in climate conditions. Therefore, common to all solutions presented in the bill, are the principles of increasing resiliency and decreasing vulnerability of water systems.

With clear goals in mind, the program lends itself to rigorous measurement and evaluation. Metrics such as total gallons of water saved, reduction in electricity use, and decreased contaminant levels would measure the effectiveness of grant projects and determine which solutions are the most promising for replication. Case studies have already shown successful examples of innovative and sustainable water management. H.R. 2738 would assist in propagating these strategies and technologies across the country and finding the right mix of solutions that allow for the efficient and effective functioning of future water systems.

1. H.R. 2738 INTRODUCTION

The Water Infrastructure Resiliency and Sustainability Act of 2011 (U.S. House Resolution 2738) seeks to address vulnerabilities of current water systems from changing hydrologic conditions caused by changing climate and human impacts. The policy proposes a grant program with the goal of funding pilot projects that increase the resiliency and adaptability of U.S water systems to hydrologic changes. The bill would authorize funds in the amount of $50 million for each of five fiscal years between 2012 and 2016 to be distributed through a program entitled 'The Water Infrastructure Resiliency and Sustainability Program.' This EPA program would be a competitive process in which owners or operators of water systems apply for partial funding to create or enhance some aspect of their operation. The highest priority would be granted to water systems at most immediate risk and highest vulnerability to hydrologic changes.

H.R. 2738 is grounded in the concept of sustainability with a focus on long-term preparedness. The list of eligible project types is broad in scope and allows for innovations related to water use and management across many areas of the public and private sectors. The following schematic depicts the combined impacts of global climate change and local human modifications to the hydrologic cycle. Changing hydrologic conditions affect the ability of water systems to provide the desired quantity and quality of water, the necessary protection against the effects of severe weather events, and the necessary maintenance of ecosystems.

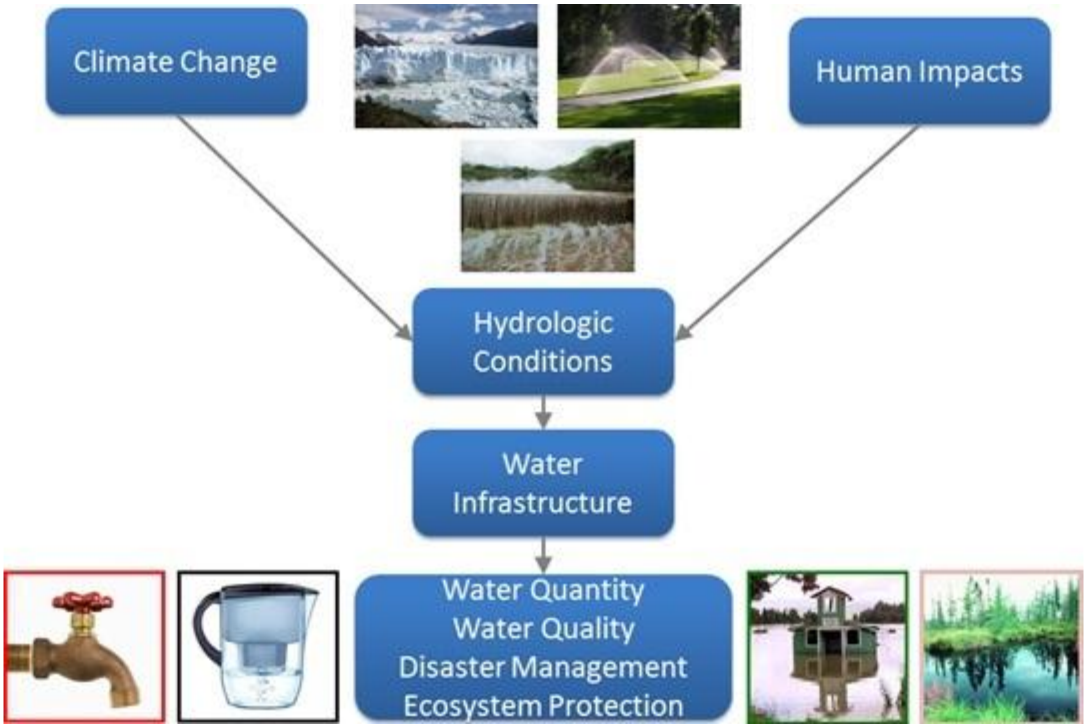


Figure 1. Main Components of the Environmental Problem for H.R. 2738.

2. H.R. 2738 LEGISLATIVE BACKGROUND

2.1 Legislative Background

H.R. 2738 was introduced during the 112th Congress, 2011-2012 on August 1, 2011 by Representative Lois Capps [D-CA23] in the House of Representatives. It was immediately referred to several committees: House Committee on Energy and Commerce, House Committee on Natural Resources, and House Committee on Transportation and Infrastructure. The bill is supported by 22 Democrats in the House and Senate, mainly from coastal states (Figure 2).

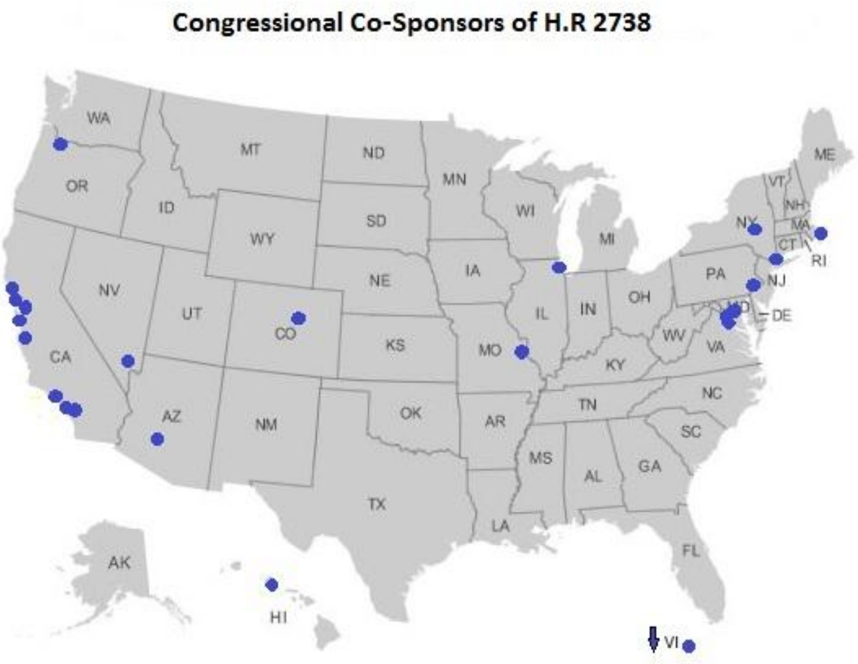


Figure 2. Congressional co-sponsors of H.R. 2738 represented by blue dots.

While the term 'climate change' is never explicitly stated in the text of the bill, much of the science behind increasing resiliency and adaptability is tied to the effects of climate change. The bill uses the term 'ongoing and projected hydrologic conditions' in order to avoid opposition and instead focuses on climate adaptation as it relates to water resources.

2.2 The Current State of Climate Science

While the science of water extraction in local systems is well understood, the projected changes caused by global warming are less certain, especially in local areas. Although climate change has been proven by observed data and is accepted by the scientific community, the exact rates of change and consequences are dependent on future human impacts and policies. Figure 3 shows the United Nations Intergovernmental Panel on Climate Change (IPCC) observed global surface temperatures from 1900 to 2000, alongside four different future projections based on economic growth. IPCC also states, "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."[2]

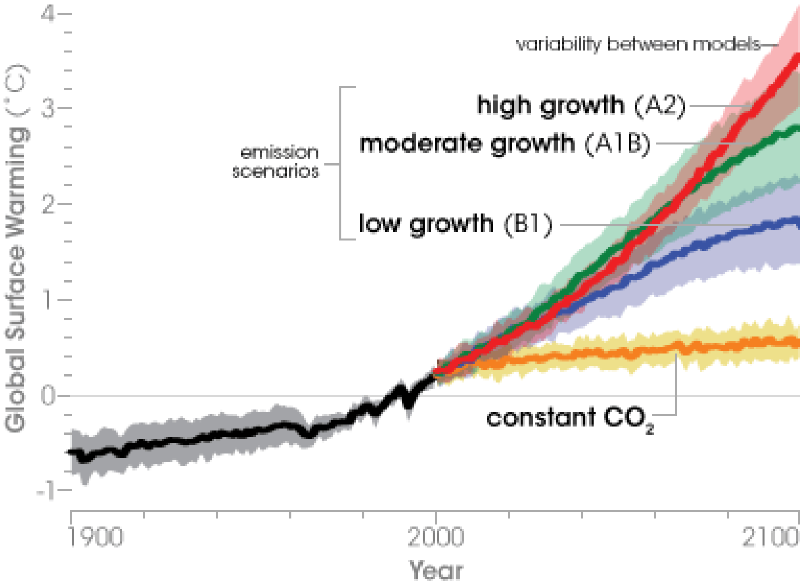


Figure 3. Observed global surface temperature (20th century) and future scenario projections (A2, A1B, B1, constant composition commitment) from 1900 to 2100. *Source: IPCC, 2007.*

Table 1. Estimates of confidence by IPCC: *very likely = 90-99% chance, likely = 66-90% chance. *Source: IPCC SREX 2011.*

Change in Phenomenon	Confidence in projected change*
Higher maximum temperatures (more hot days)	Very likely
Higher minimum temperatures (fewer cold days)	Very likely
More intense precipitation events	Likely, over many areas
Anthropogenic influence on increasing extreme coastal high water	Likely

As a function of the Earth's warming climate there is also a projected increase in extreme climate events such as flooding, droughts, and severe temperatures. Although it is difficult to say that global warming directly causes any given extreme event, there has been a 'likely' (66-90% chance) increase in droughts and heavy precipitation events (e.g. 95th percentile) since the 1970's, which is consistent with a warming climate (Figure 3).

3. THE HYDROLOGIC CYCLE

Water on earth is stored in three main reservoirs, which collectively make up the hydrologic cycle. The largest reservoir is the ocean, comprising 97% of the earth's surface. The atmosphere, which has a capacity of 0.001%, is the smallest reservoir, but is still largely influential on the hydrologic cycle due to its interactions with the ocean. The last reservoir is land, which holds 2.5% of the earth's water in the form of ice caps, vegetation, soil moisture, and surface waters such as rivers, lakes, and water runoff.

The main transport processes of the hydrologic cycle include evaporation and transpiration of water into the atmosphere, condensation and precipitation which returns water vapor into a liquid, and infiltration and runoff, which flows water into either the groundwater or ocean reservoir (Figure 4). These processes occur at varying rates, or fluxes. The interactions between the ocean and atmosphere, via evapotranspiration and precipitation, are the largest annual fluxes.

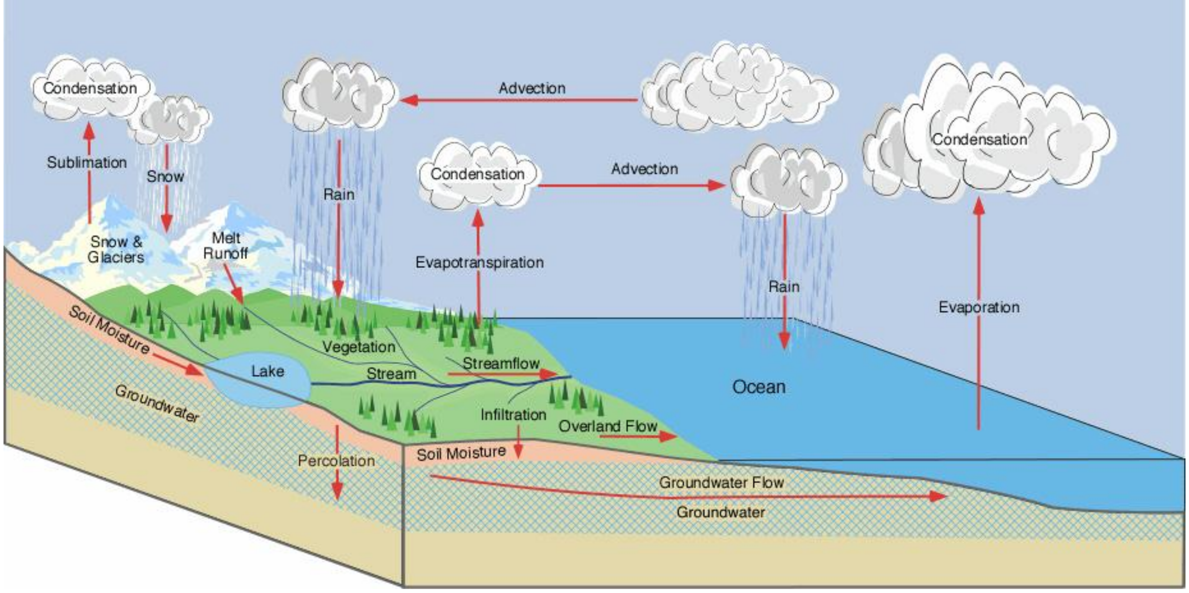


Figure 4. Summary of the hydrologic cycle. ***Source: www.physicalgeography.net/fundamentals/8b.html.***

Although water is plentiful, only 3% of Earth's water is drinkable since the remaining 97% is in the form of highly saline oceans. Additionally, most freshwater sources are not readily accessible, as 99% is sequestered in polar ice caps and groundwater. The latter is often accessed from underground aquifers and wells, a fairly inexpensive water extraction method. Consequently, less than one percent (~0.007%) of water is easily available and economically feasible for human consumption. These resources, mainly freshwater bodies (e.g. lakes, rivers, and streams) and shallow groundwater, are replenished and sustained through annual precipitation patterns.[3] Therefore, the hydrologic cycle is not a fixed process and is strongly influenced by climate patterns and anthropogenic withdrawal.

4. HUMAN IMPACTS

4.1 Overwithdrawal

Global water consumption has grown exponentially with human population, especially since the industrial age. To put into perspective, the long-term average of continent runoff totals 45,000 cubic kilometers per year, while human withdrawals are approximately 5,000 cubic kilometers/year.[4] Although overwithdrawal consumes roughly one-ninth of global availability, it is significant because water is spatially and temporally limited. Global water availability has decreased from 16,000 cubic meters/year per capita in 1950 to 6,700 cubic meters in 1998. If existing trends continue, yearly capita supplies will decline to 5000 cubic meters by 2025.[5]

4.2 "Hard" Infrastructure, Dams and Flood Control

Urbanized "hard" infrastructure includes impervious surfaces and structures such as sidewalks and paved roads. These types of infrastructure channel about 50% of rainwater into surface runoff, whereas natural ground produces only 10%. Storm sewers are an example of hard infrastructure designed to redirect large quantities of water into distant water bodies. During storms, impervious surfaces increase water volume, velocity and flow duration, which intensifies erosion and sediment transport. In an attempt to manage flow rates, cities often build drainage channels lined with concrete to reduce flooding and erosion.[6] However, this can exacerbate cases of flash flooding.

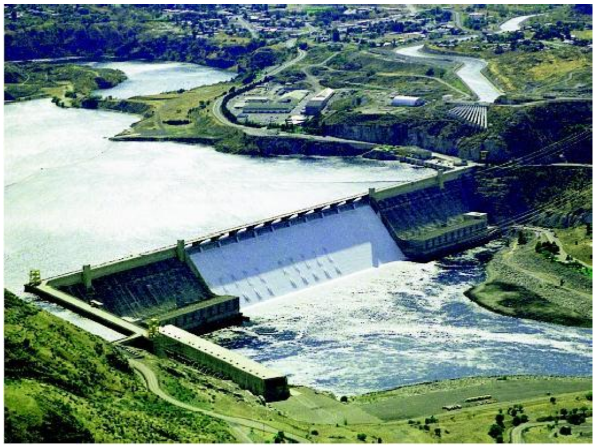


Figure 5. Grand Coulee Dam in Washington State. ***Source: Water Encyclopedia, 2012.***

Dams are constructed for crop irrigation, hydroelectric power generation or municipal drinking water (Figure 5). However, building dams can lead to an increased loss of available water through evaporation from reservoirs. Artificially impounding river flow alters the overall water budget of drainage basins, altering timing of river discharge and continental runoff.[7] While dams may decrease the frequency and average size of flood peaks during flood events, in the long-term they can also increase unpredictability and magnitude of large flood events.[8]Another destructive effect of dams is on the downstream ecology (e.g. migratory fish species, nutrient transport, oxygen levels, and water temperature) of the rivers and streams.

Seawalls, levees, dikes, and bulkheads are rigid barriers built to control floods and stabilize water flows. However, these structures can fail thereby increasing the frequency and magnitude of flood events outside of and sometimes within the areas they are designed to protect. Jetties are designed to reduce coastal erosion, but sand can get trapped between jetties, causing further sand loss from beaches, leaving coastlines even more vulnerable.

4.3 Wetland and Floodplain Development

Undeveloped wetlands control water levels in natural watersheds, improve water quality through natural filtration, and reduce flood damages. Besides hydrologic services, protected wetlands also provide wildlife habitat and support recreational activities. The US Department of Agriculture (USDA) estimates 58% of total wetland loss and 96% of wetland loss in watersheds are due to human development. Figure 6 depicts national wetland loss from 1780 to 1980. The major causes of wetland loss are filling, ditching, diking, draining, and damming wetlands for the purposes of industrial development, real estate expansion, and agricultural irrigation.[9]

Floodplains are adjacent areas of channels, rivers, streams, and wetlands that are often defined by their probability of inundation. Undeveloped floodplains provide ecosystem and hydrologic benefits including water quality enhancement via nutrient sinks for upland runoff, habitat provision, flood mitigation, and groundwater recharge.[10] The most common type of floodplain development and flood risk management is through construction of bunds, levees, dykes, weirs, and embankments. Development of floodplains increases both the probability of coastal flooding and the scale of anticipated flood damage.[11]

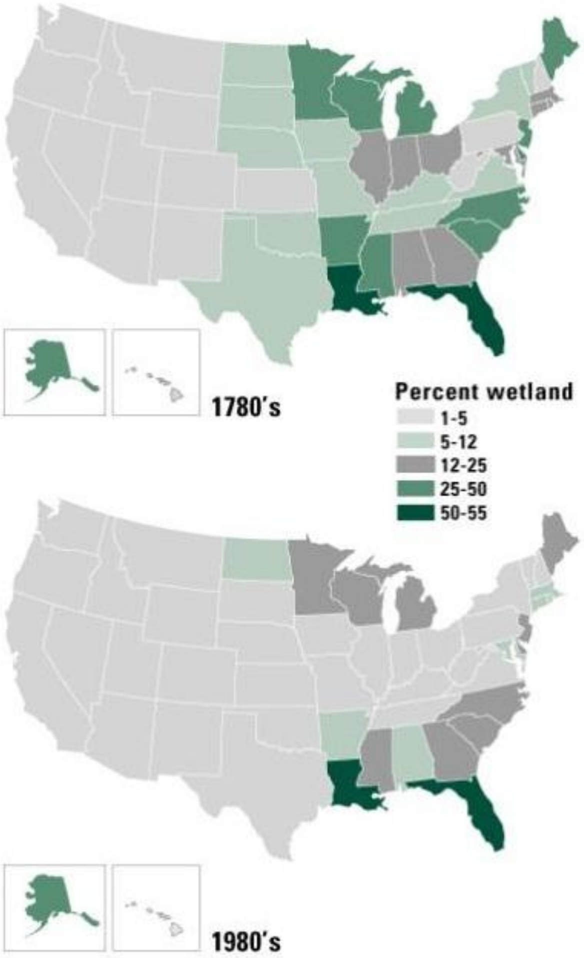


Figure 6. Total wetland cover in the 1780's and 1980's. ***Source: USFS, 2001.***

5. CLIMATE CHANGE IMPACTS

5.1 Precipitation Changes

Climate change is rapidly altering the earth's hydrologic cycle. Increased greenhouse gas emissions in the atmosphere are raising the earth's annual average surface temperatures, which increase water vapor saturation in the atmosphere. This effect is likely to increase flooding in some regions, while increased evaporation due to warmer temperatures is likely to increase droughts in other regions.

In the past 50 years in the United States, scientists have observed a wide variability in precipitation patterns (Figure 7). The West and Southwest regions are typically dry and periodically experience water shortage. Due to climate change and human impacts, the severity of droughts is increasing and is projected to increase in intensity with time. However, in the Northeast and Midwest, increased precipitation is affecting water infrastructure through increased surface runoff and more frequent combined sewer overflow (CSO) events.

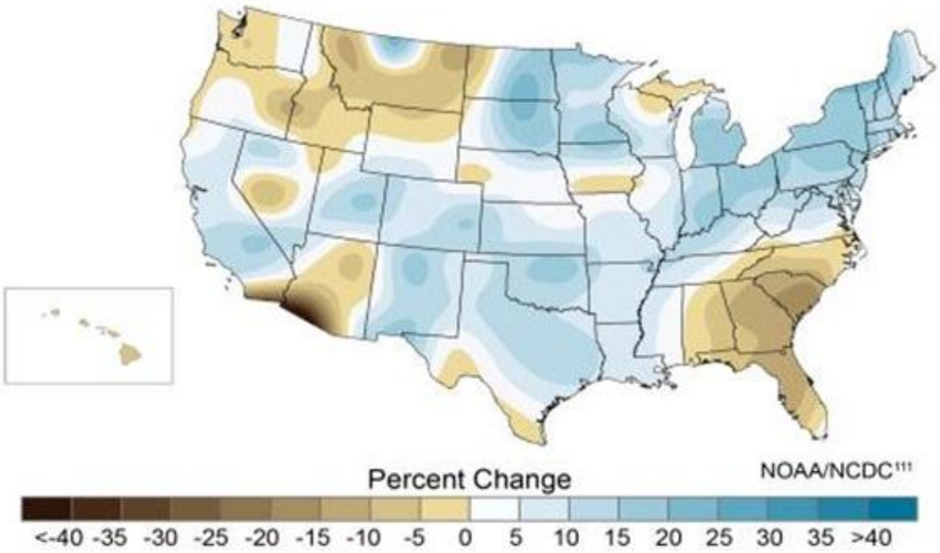


Figure 7. Observed annual average precipitation changes in the United States between 1958 and 2008. Blue indicates areas where precipitation has increased, and brown indicates areas where precipitation has decreased. *Source: NOAA/NCDC, 2008.*

In older American cities that were built with combined sewer systems, heavy precipitation causes the direct, untreated release of sewage into the river, lake, or ocean. Increased incidence of heavy rainfall events will result in more frequent overflows of combined sewer systems and affect the quality of water systems.

5.2 Probability and Distribution of Extreme Events

The Intergovernmental Panel on Climate Change (IPCC) states “a changing climate leads to changes in the frequency, intensity, special extent, duration, and timing of extreme weather.” [12] The current water infrastructure was predominantly designed on the assumption that the range of conditions and the probabilities of extreme events in a given area were both known and consistent. Figure 8 below illustrates how climate change may shift probabilities of average conditions (peak of curve) and extreme events, such as droughts or floods (tails of curve).

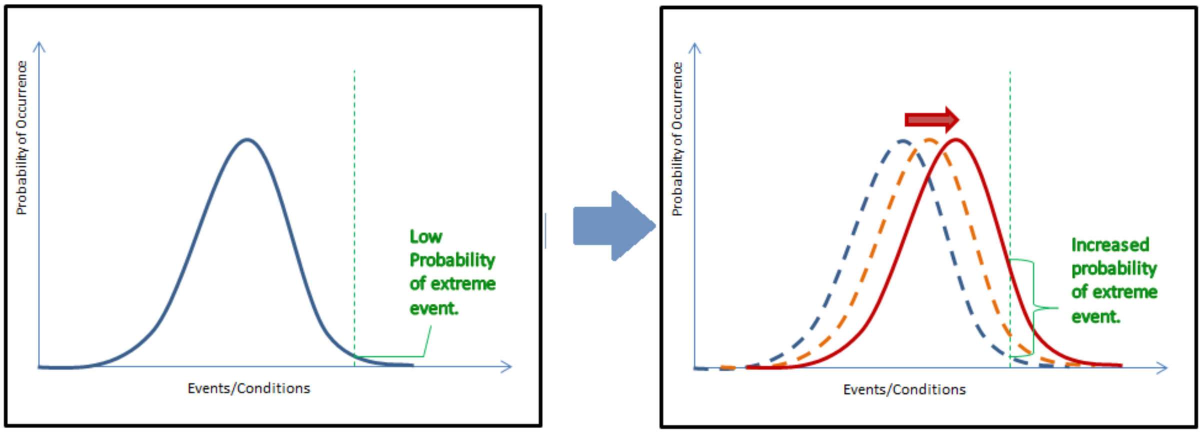


Figure 8. Modified probability distributions showing the increased probability of extreme events over time.

IPCC projects that extremes at either end of the probability distribution will become more frequent and more intense; however, it is unknown exactly how these probabilities will shift and by how much. As climate and the probability curve continue to change over time, current water systems designed for a more stable climate may be unable to respond, resulting in system degradation and failure.

5.3 Global Sea Level Rise

In the U.S. over 50% of the population lives in coastal counties and large cities on the coast.[13] Climate change is projected to result in worldwide sea level rise. Figure 9 shows observed sea level change in the U.S. from 1958 to 2008. The entire east coast was especially affected, with an average sea level rise of four to six inches over the past 50 years.

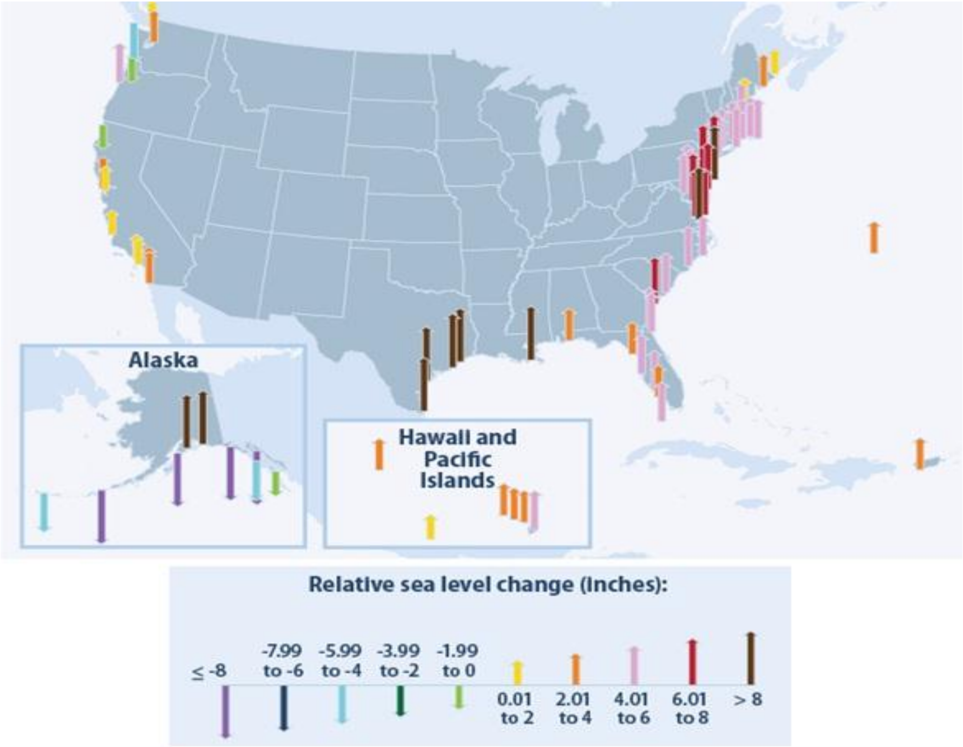


Figure 9. Sea level trends of coastal cities in the United States from 1958-2008. ***Source: National Oceanic and Atmospheric Administration, 2009.***

Rising sea levels affect water infrastructure through salt water intrusion, higher water tables, and decreased gravity drainage. Salt water intrusion in groundwater reservoirs renders water unsuitable for human consumption. Higher water tables also result in decreased groundwater recharge and increased runoff during heavy rainfall events, leading to frequent and severe flooding events.[14] A decrease in gravity drainage due to higher sea levels causes an increased likelihood of backflow up rivers and drain lines. Additionally, infrastructure overwhelmed by storm surge events releases untreated sewage and waste into nearby rivers and ocean.

6. EXISTING WATER MANAGEMENT

6.1 Allocation

Americans use approximately 410 billion gallons of water per day.[15] The largest allocation of water, or 49%, is utilized for thermoelectric power, followed by 31% that is used for irrigation, and 11% for public supply. Together, these three categories comprise over 90% of the nation's water supply with the remaining 10% distributed among aquaculture, mining, domestic, livestock, and industrial purposes (Figure 10).

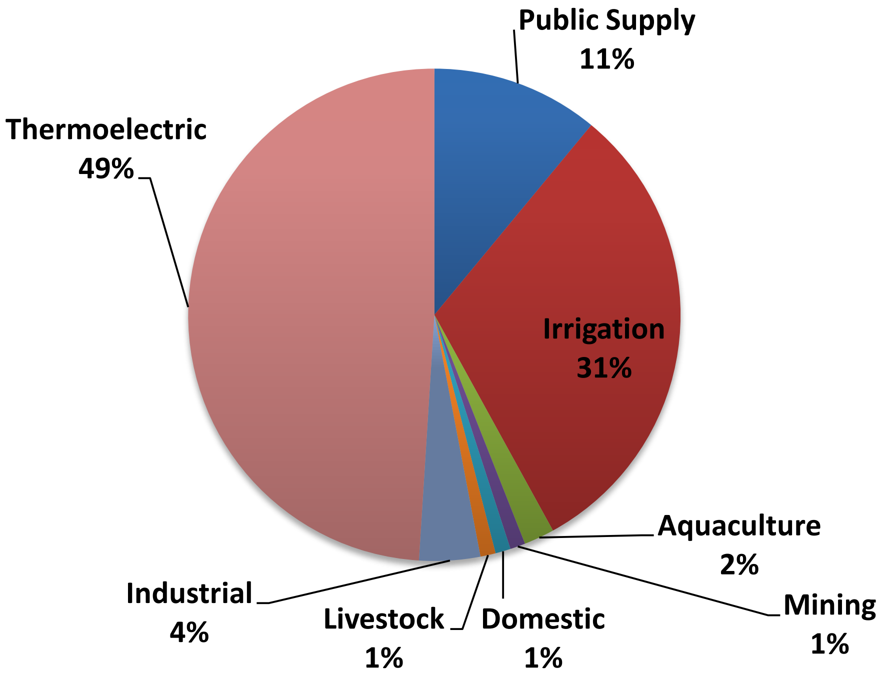


Figure 10. U.S. water use allocation by industry. *Source: U.S. Geological Survey, 2005.*

6.2 Infrastructure

Much of the U.S. water system, including treatment plants, pumping stations, water mains, reservoirs and dams, was constructed post-WWII. While each of these structures has a different useful lifespan, on average water infrastructure is expected to last up to 80 years. Thirty percent of large water systems have water pipes that are 40-80 years old, causing a national average of 700 water main breaks per day. The estimated cost for repairing the nation's water infrastructure over the next 20 years has increased from about $198 billion in 1999 to the current estimate of $335 billion.[16]

6.3 Funding

The majority of existing U.S. water infrastructure funding comes from two EPA programs – the Clean Water State Revolving Fund (CWSRF) and the Drinking Water State Revolving Fund (DWSRF), first implemented in 1987 and 1997, respectively. CWSRF allocates over $5 billion a year to finance water quality protection projects for wastewater treatment, nonpoint source pollution control, and watershed management. The mechanism is primarily low interest loans, partnerships with other funding sources, and borrowing assistance programs. DWSRF funds vary each year, but in 2010 $1.3 billion was awarded to states for infrastructure installations, upgrades, and replacements to ensure safe drinking water and reduce contamination. Preference is given to underrepresented or disadvantaged communities to improve pollution prevention programs.[17]

H.R. 2738 proposes a new grant program that addresses unique infrastructure challenges to respond to hydrologic changes and would not replace or affect Clean Water and Drinking Water State Revolving Funds. Figure 11 below shows that the CWSRF and DWSRF basic funding alone is not enough to sustain water infrastructure in the future.

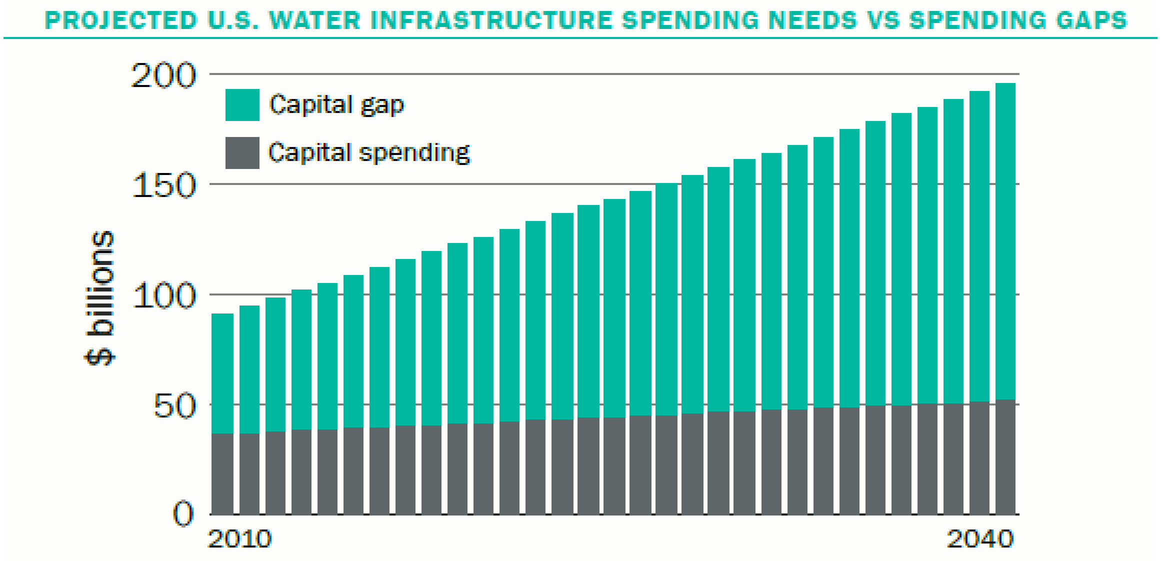


Figure 11. Projected U.S. water infrastructure spending needs vs. spending gaps. *Source: American Water Intelligence, 2012.*

The increasing backlog of projects to replace aging infrastructure restricts funding for systems experiencing new stresses from hydrologic changes. Funding authorized by H.R. 3728 would create a mechanism for funding innovative, long-term strategies that might not otherwise be given priority by the basic maintenance goals of CWSRF and DWSRF.

7. THE NEED FOR RESILIENT AND SUSTAINABLE INFRASTRUCTURE

7.1 Agriculture and Food Security

Agriculture and food production relies on the availability of water more than any other product, and is therefore extremely vulnerable to climate change. Increasing temperatures and correlated drought events may reduce crop yields while encouraging the proliferation of pests. Changes in precipitation patterns could increase the likelihood of short-term crop failures and affect long-term production declines. While there may be gains in certain crops parts of the world, the overall impact of climate change on agriculture is expected to be negative, with severe consequences on global food security. For example, the U.S. produces 41% of the world's corn and 38% of the world's soybeans. These crop yields are predicted to decrease 31-43% under the slowest warming scenario and 67-79% under the most rapid warming scenario by the end of the century.[18]

7.2 Public Health

Regions that experience an increase in precipitation may experience water quality issues as sewage systems and water treatment plants are unable to cope with increased volumes of water. Heavy rainfall can increase the amount of harmful runoff containing waste and sediment accumulating in water supplies, making them unsafe or in need of additional treatment. Increased precipitation can also increase the likelihood of water-borne parasites such as Cryptosporidium and Giardia, which affect drinking water reservoirs.[19]

7.3 Energy

Some regions of the United States such as the Northwest rely on hydropower. If hydrologic changes alter the timing or decrease the volume of stream flows in these areas, it will reduce the amount of energy that can be produced. For example, along the Colorado River, a 1% reduction in stream flow can reduce electricity output by roughly 3%, as water flows through multiple power plants in the river basin.[20]

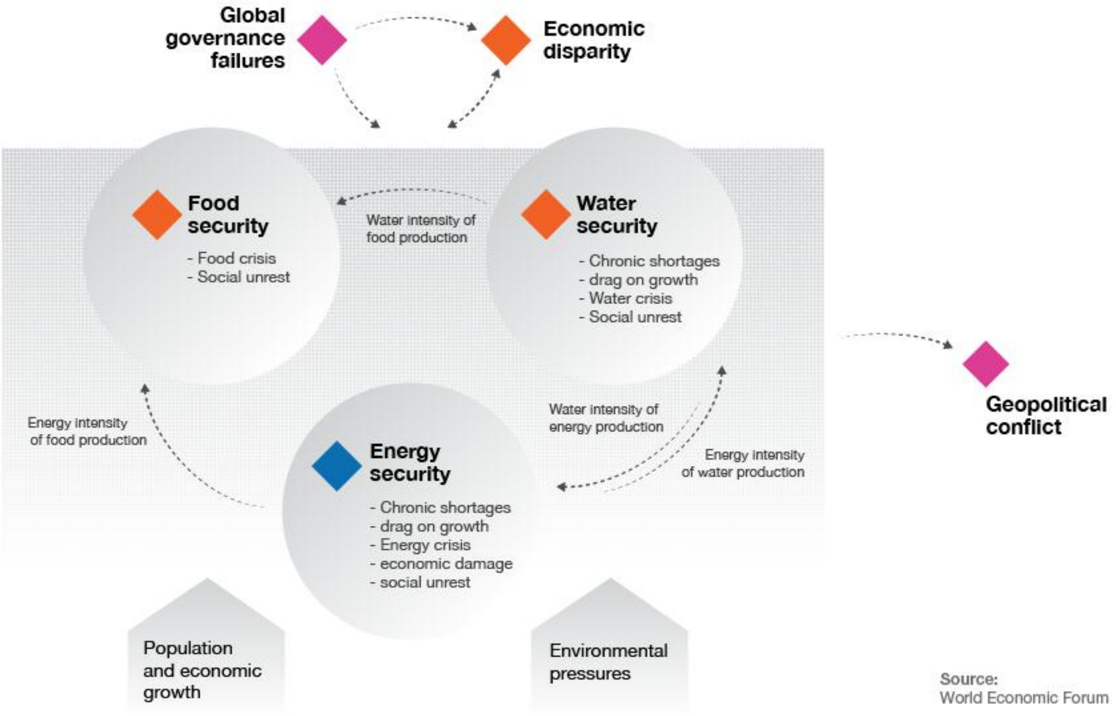
Hydroelectric and nuclear plants require large quantities of water for cooling. One kilowatt-hour of electricity (enough power to run 400 typical compact-fluorescent light bulbs for an hour) requires 25 gallons of water to be extracted from rivers or lakes.[21] An increasingly popular method of extracting natural gas from underground shale, called hydraulic fracturing, utilizes 2-5 million gallons of freshwater.[22] Regions that face declining water resources may be forced to curtail power plant or energy extraction productions, or alter designs for power plants if sufficient water is not made available.

7.4 Business and Economy

A majority of consumer products require water for their manufacturing processes. Consequently, the global availability and quality of water has direct and immediate impacts to consumption patterns in the U.S. Water shortages and water quality issues may cause supply chain disruptions that impact sales of goods and services. Additionally, tourism and recreation industries rely heavily on the aesthetic value and quality of water.

7.5 Water Conflicts

Watersheds and directions of water flow do not follow county, state or political lines. This often leads to fierce political conflict. The Colorado River Basin provides an example of a water resource that serves multiple states — Colorado, New Mexico, Utah, Wyoming, Arizona, California, and Nevada (and Mexico). In the early 20th century, "The Law of the River" Compact was a compromise on water rights between the territories. As a result of this agreement, California's water allocation was greatly reduced and to this day California is still operating at a deficit. The increasing scarcity of food, water, and energy and their subsequent interactions is referred to as the 'water-food-energy nexus,' which can cause geopolitical conflict not just in the states, but also around the world (Figure 12). Reliable water infrastructure is essential to avoiding conflicts that arise from water scarcity.



Source:
World Economic Forum

Figure 12. Water-food-energy nexus. *Source: World Economic Forum Report, 2011.*

8. PROPOSED SOLUTIONS OF H.R. 2738

8.1 Goals of H.R. 2738

The Water Infrastructure Resiliency and Sustainability Act of 2011 would fund solutions that alleviate stresses on U.S. water infrastructure through competitive grant allocations to owners or operators of water systems. The bill language establishes a broad range of potential strategies which addresses water conservation, the exploration of new technologies to manage water systems, management of floodwater, and enhanced storm water and wastewater treatment. The overarching goals of H.R. 2738 are summarized in the following four main categories:

Water Quantity: Supply Enhancement or Demand Reduction

Water Quality: Quality Protection or Improvement

Disaster Risk Reduction

Ecosystem Protection and Improvement

In general, the main strategies that are considered for adapting to changing hydrologic conditions involve decreasing water system vulnerability and increasing system resiliency.[23] The definitions of resiliency and vulnerability as they relate to changing climate according to the IPCC are:

> ***Resilience***: *"The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structure and functions"*
>
> ***Vulnerability***: *"The propensity or predisposition to be adversely affected"*[24]

One way to describe the difference between resilience and vulnerability is that low vulnerability means the system is being less impacted by changing conditions. Increased resilience means that the system is still being impacted by changing conditions, but these impacts do not cause adverse effects (or the adverse effects are more short-lived). These strategies are intertwined and can be considered opposite ends of a spectrum, as low resiliency typically leads to more vulnerable systems. Therefore, a resilient system will be better prepared to respond to changing baseline conditions.

8.2 H.R. 2738 Solution Analysis and Examples

In order to reach the four goals listed above, the bill lays out a specific set of potential solutions that would qualify for grant funding from the EPA. The suggested solutions from the bill language are summarized below in Table 3, followed by a brief description, possible applications, and pertinent case studies.

Table 3. Simplified Environmental Goal and Solution Matrix for H.R. 2738.

H.R. 2738 Outlined Solutions:	Water Quantity	Water Quality	Disaster Risk Reduction	Ecosystem Protection & Improvement
1a. Water metering	x			
1b. Electronic sensing and control systems	x	x		
2. Modify or relocate existing water infrastructure that may be impaired by changing hydrologic conditions			x	
3a. Improve stormwater management		x	x	
3b. Improve municipal wastewater treatment		x		
4a. Develop groundwater remediation systems		x		
4b. Develop water recycling or reuse systems	x			
4c. Develop desalination facilities	x			
5. Natural or engineered green infrastructure		x		x
6. Renewable energy generation				x
7a. Water supply management: Reservoir reoperation	x			x
7b. Water supply management: Water banking	x		x	
7c. Water supply management: Adaptive conservation pricing	x			
8a. Agricultural land: Improve irrigation systems	x		x	
8b. Agricultural land: Groundwater recharge	x			x
8c. Agricultural land: Groundwater conjunctive use	x			
9a. Restore floodplains, wetlands, and uplands			x	x
9b. Modify levees, floodwalls, and other structures through setbacks, notches, gates, and removal			x	
9c. Acquire flood-prone lands and properties			x	
9d. Promote land use planning that prevents future floodplain development			x	
10. Conduct studies to project how changing hydrologic conditions may impact the future operations and sustainability of water systems	x	x	x	x

Solution 1a: Water metering
Goal: Quantity
Areas of Applicability: Agricultural, Residential, Industrial
Description: Upgrading to automated water metering provides real-time feedback, increased metering accuracy, remote meter reading, and increased leak detection efficiency. Coupling water metering with education and conservation pricing can also reduce water usage substantially; Palo Alto, CA reduced usage by 27% in drought season with these techniques.[25]

Solution 1b: Electronic sensing and control systems
Goals: Quantity, Quality
Areas of Applicability: Agricultural, Residential
Description: Similar to water metering, electronic sensing and control systems provide more precise feedback on different aspects of water quantity and quality and allow consumers to adjust accordingly. For example, inexpensive underground gypsum and wire sensors that measure soil moisture in crops allowed for water saving of 33%-66% in Lubbock, TX, as farmers no longer unintentionally overwatered crops.[26]

Solution 2: Modify or relocate existing water infrastructure that may be impaired by changing hydrologic conditions
Goals: Disaster Risk Reduction
Areas of Applicability: Agricultural, Residential, Wetlands
Description: Water infrastructure can be threatened by rising sea levels and inundation from storms. Relocating existing infrastructure in New York is estimated at over $12 million per mile to relocate a sewer outfall for a million gallons per day.[27] This cost would need to be compared to potential infrastructure damages and service failures if infrastructure was not modified or relocated.

Solution 3a: Improve stormwater management
Goals: Quality, Disaster Risk Reduction
Areas of Applicability: Municipal, Residential
Description: Low impact development and green infrastructure address stormwater runoff concerns by minimizing the amount of stormwater that reaches sewers. The cost of stormwater management includes pre-construction, land, post-construction and annual county implementation. The stormwater best management practices in Maryland counties totaled over $2 million over a span of 20 years.[28] Other improvements could address efficiency of existing sewer systems.

Solution 3b: Improve municipal wastewater treatment
Goals: Quality, Quantity
Areas of Applicability: Municipal
Description: Wastewater is treated at the municipal level through a combination of physical, chemical, and biological processes. Energy-saving techniques or new technologies could be utilized to improve system efficiency. In New York City, methane gas (a byproduct from anaerobic digesters) is used to run 20% of the city's wastewater treatment plants.[29]

Solution 4a: Develop groundwater remediation systems
Goal: Quality
Areas of Applicability: Agricultural, Industrial, Wetlands
Description: Groundwater remediation is the process of removing contaminants from groundwater sources. Methods include chemical, biological, and physical remediation of polluted water. In Park City Utah, arsenic and antimony contamination was a result of abandoned silver mines. Reverse osmosis was used as an effective groundwater remediation technique to restore drinking water to EPA standards.[30] There are three main ground water protection activities run by EPA: the Underground Injection Control (UIC) regulatory program, the Sole Source Aquifer (SSA) designation program, and the Source Water Assessment and Protection (SWP) program.[31]

Solution 4b: Develop water recycling or reuse systems
Goal: Quantity
Areas of Applicability: Residential, Industrial, Commercial, Agriculture
Description: Recycled water is an ideal conservation strategy for arid climates such as the Southwest U.S. for non-potable purposes including agriculture, landscaping, and park/golf course irrigation. Recycled water is also used as cooling water for power plants, oil refineries, dust control and concrete mixing in construction. The Irvine Ranch Water District (IRWD) in California meets an estimated 21% of their demands with recycled water. Every building in IRWD with more than seven stories is required to install pumping systems for the use of recycled water in toilet flushing. California, Virginia, and New Mexico recycle wastewater through a combination of various techniques (e.g. reverse osmosis and ultraviolet lighting) to produce potable water.[32]

Solution 4c: Develop desalination facilities
Goal: Quantity
Areas of Applicability: Industrial, Commercial
Description: Desalination plants offer system reliability and water quality advantages, but large-scale desalination is an energy (often fossil fuel) intensive process and requires expensive infrastructure. Desalination produces highly concentrated salt brine that may contain other chemical pollutants. Since the grant program offers limited funds and would not cover the cost of a new desalination facility, it may have potential to fund programs that develop effective technologies for environmentally safe brine disposal.

Solution 5: Natural or engineered green infrastructure
Goals: Quality, Disaster Risk Reduction, Ecosystem Protection and Improvement
Areas of Applicability: Urban, Residential
Description: Examples of green infrastructure include green roofs, bioswales, permeable pavements, and engineered wetlands. Green infrastructure mimics natural processes of water management. In 2012, New York City awarded $4 million to its Green Infrastructure Grant Program to build green roofs, rain gardens, rainwater harvesting, and bioswales on private and public sidewalks in areas affected by CSO events.[33]

Solution 6: Renewable energy generation
Goals: Ecosystem Protection and Improvement
Areas of Applicability: Commercial, Industrial, Agricultural
Description: Combined heat and power (CHP) is a reliable and cost effective option for wastewater treatment facilities that use anaerobic digesters. Biogas from these digesters is used as 'free fuel' to generate electricity and power. CHP systems produce power at a lower cost (compared to retail electricity), enhance power reliability and reduce greenhouse gas emissions.

Solution 7a: Water supply management through reservoir reoperation
Goals: Quantity, Ecosystem Protection and Improvement
Areas of Applicability: Wetlands, Agriculture, Municipal
Description: Reservoir reoperation is the redesign of a system to achieve a balance between the original purposes of a reservoir and emerging concerns such as the restoration of natural flow regimes.[34] The costs of reservoir reoperation might include developing monitoring systems, hydrologic models, decision support systems, and collecting data to evaluate benefits and impacts of proposed changes. Other costs are associated with conducting feasibility studies, such as completing CEQA/NEPA analyses, modifying or constructing new facilities, or removing existing facilities.[35] For instance, The Detention Dam Plan in California would increase water storage over the current Folsom Reservoir Reoperation Plan by alleviating water demand. The Army Corps of Engineers has calculated this increase in water, power, and recreation at Folsom to be $2.6 million each year or $58.5 million over the life of reoperation.[36]

Solution 7b: Water supply management through water banking
Goals: Quantity
Areas of Applicability: Municipal
Description: Water banking is an institutional mechanism that facilitates the legal transfer and market exchange of various types of surface, groundwater, and storage entitlements. The goal of a water bank is to treat water as a commodity and allow operators to sell and purchase quantities to meet consumer needs. For example, the Irvine Ranch Water District's water banking program aims to provide enough water to meet approximately 15% of IRWD customer needs during critically dry years by purchasing groundwater from a neighboring county.[37] The cost of the water banking facilities (including the land acquisition) is currently estimated to be approximately $19 million, which was cost effective for the county and had negligible impacts on environmental resources, compared to the alternative of surface storage reservoirs.[38]

Solution 7c: Water supply management through adaptive conservation pricing
Goal: Quantity
Area of Applicability: Municipal
Description: Excess demand has resulted in depleted aquifers. To relieve stresses on water systems, utility prices can be adjusted to discourage overuse. Adaptive conservation pricing can incorporate costs to cover additional infrastructure needs that would be managed at the state level.[39]

Solution 8a: Groundwater recharge on agricultural land
Goals: Quantity, Ecosystem Protection and Improvement
Areas of Applicability: Agricultural
Description: Artificial groundwater recharge creates a route for surplus surface water to replenish aquifers, accelerating the natural recharge process. Specific methods include infiltration basins and canals, which collect surplus water near the surface. Drainage wells are used as deeper constructions that penetrate aquifers directly.

Solution 8b: Improve irrigation systems on agricultural land
Goal: Quantity
Area of Applicability: Agricultural
Description: Irrigation used for agricultural purposes is the second largest category of water allocation in the U.S. More efficient irrigation systems would allow water managers to adapt to changes in water availability, especially in drought-prone regions.

Solution 8c: Groundwater conjunctive on agricultural land
Goal: Ecosystem Protection and Improvement
Area of Applicability: Agricultural
Description: Conjunctive use of groundwater and surface water on agricultural land helps achieve greater water security by taking advantage of natural groundwater storage in aquifers. Conjunctive use of water relies on surface water during wet years and groundwater during dry years in order to optimize productivity and environmental sustainability.[40]

Solution 9: Flood control

- **a.** Reduce flood damage, risk, and vulnerability by restoring floodplains, wetlands, and uplands
- **b.** Modify levees, floodwalls, and other structures through setbacks, notches, gates, removal, to facilitate reconnection of rivers to floodplains, and reduce flood stage height
- **c.** Acquire flood-prone lands and properties
- **d.** Promote land use planning that prevents future floodplain development

Goal: Disaster Risk Reduction, Ecosystem Protection and Improvement
Area of Applicability: Wetlands, Agricultural
Description: Floodplain restoration can consist of the construction or reinforcement of existing levees, restoring natural flow of rivers and streams, and minimizing encroachment in the floodplain area. Proper management of floodplains and levees will both lower risk and reduce damage from floods.

Solution 10: Conduct studies to project how changing hydrologic conditions may impact the future operations and sustainability of water systems
Goals: Quantity, Disaster Risk Reduction
Areas of Applicability: Industrial, Agricultural, Wetlands
Description: Climate change will affect water supplies through quantity, variability, timing, and intensity of precipitation and sea level rise. Further studies and models are needed to understand how climate change will affect the exact rates of projected extreme weather events and sea level rise, and how infrastructure will respond.

9. ASSESSING THE RESULTS OF H.R. 2738

9.1 Measures of Water Infrastructure Sustainability and Resilience

H.R. 2738 proposes a grant program with specific and attainable goals of achieving increased quantity, quality, risk reduction, and ecosystem protection. The process of measuring success supplies the bill with direction and accountability. Due to the broad nature of the different solution strategies, the metrics used for measuring success may vary depending on which solutions are chosen. For example, where some regions are susceptible to floods or heavy storm events, others are prone to droughts or other shortages. Figure 13 outlines the key indicators that relate to each goal.

Water Quantity: Supply Enhancement or Demand Reduction	Water Quality: Quality Protection or Improvement	Disaster Risk Reduction	Ecosystem Protection and Improvement
Total Water Consumed Per Year	Turbidity	Annual Non-Routine Water Infrastructure Repair Costs	% Cover of Native Plant Species
Total Water Consumed Per Capita Per Year	Nitrates	Climate Resilience and Awareness Tool	Average Wetland Buffer Width
System Capacity ÷ Volume Consumed Per Day	E Coli	Peak Flow Rate	Reduction in Electricity Used by Water Infrastructure
Volume Water Recycled Per Year ÷ Volume Water Consumed Per Year	Arsenic		
	Chlorine		
	Combined Sewer Overflow		

Figure 13. Key indicators grouped by goal. Operators of water systems use these indicators to link solutions to each goal.

In cases where pre-implementation data is not available for comparison with post-implementation data, operators can compare post-implementation metrics to those of a control system. In many cases, success cannot be defined in quantitative terms. Instead operators would apply qualitative feedback informed by self-assessment, expert elicitation and EPA analysis to measure success. Assessors can then weigh these quantitative and qualitative elements to produce a final success rate or grade for each relevant goal. Setting objectives and measuring disaster risk reduction is challenging given changing climate conditions. In many cases, operators must measure risk reduction without the actual occurrence of extreme weather events. These types of metric indicators are necessary to determine the best approach for each water system, as well as to measure success of the implemented solution.

Below are descriptions and units of each key indicator by goal:

Water Quantity: Supply Enhancement or Demand Reduction

Total Water Consumed per Year (gallons) provides an overview of the quantity of water that a particular system produces in a given calendar year. Total Water Consumed per Capita per Year (gal) allows managers to examine the average demand of each user with respect to a particular water system. System Capacity ÷ Volume Consumed per Day (days) indicates the number of days that current water supply could meet daily demand. Volume Water Recycled per Year (gal) ÷ Volume Water Consumed per Year (%) allows a water systems manager to track the effectiveness of the water reuse solution.

Water Quality: Quality Protection or Improvement

EPA currently regulates approximately 90 contaminants for drinking water, of which operators measure both the quality of incoming consumable water and outgoing wastewater. Nitrates (ppm) are correlated with Biological Oxygen Demand (the amount of oxygen needed to decompose suspended organic matter) and acidification, other detriments to overall water quality. Turbidity (Nephelometric Turbidity Unit) measures the amount of suspended particles in water. Low turbidity is associated with healthy water quality, filtration effectiveness, and lower presence of harmful microorganisms. Arsenic (ppm), a metalloid, is one of several metals and metalloids that are toxic to humans. E coli (ppm) indicates freshwater contamination by microorganisms. Chlorine (ppm) can be measured during the process of drinking water treatment or wastewater treatment to ensure adequate decontamination. Volume of Combined Sewer Overflow per Year (gal) indicates water infrastructure's ability to handle storms and floods.

Disaster Risk Reduction

Annual Non-Routine Water Infrastructure Repair Cost ($) is the total irregular infrastructure repair cost each year, which gauges overall infrastructure resilience. The EPA Climate Resilience and Awareness Tool (unit of risk reduction) helps managers assess risks associated with climate change and how infrastructure would likely respond. Peak Flow (cubic feet per second) examines the rate of water runoff of a given area during a particular precipitation event, and is also a helpful measurement of resiliency.

Ecosystem Protection and Improvement

Cover of Native Plant Species (%) is a core indicator of ecological integrity, as it focuses on biotic quality which supplements output quantity measures of wetlands acreage. Average Wetland Buffer Width (meters) describes the width of the tract of land surrounding a wetlands area, which relates ecosystem health to anthropogenic land use. Intact ecosystems, such as wetlands, provide services of food abatement and water filtration of nutrients and sediments. Reduction in Electricity Used by Water Infrastructure (kilowatt hours) such as green infrastructure innovations can reduce energy consumption. This is one method of calculating a financial price on valuable ecosystem services.

9.2 Example Logic Model: Natural or Engineered Green Infrastructure

Figure 14 below illustrates a logic model for a hypothetical water system aiming to install green infrastructure, a category of solutions in H.R. 2738. In this example, the implementers chose to use greywater recycling, green roofing, and wetlands engineering, three of the specific strategies outlined in the bill.

In the left-hand column are the solutions, or outputs (see Table 3). The middle column shows the outcomes, which comprise some of the indicators listed in Section 9.1 (see Figure 13). The right-hand column displays the goals – the ultimate impact that the implementer seeks to achieve. The green arrows from the outputs to the indicators show which key indicators are used for each solution. The blue arrows from the indicators to the goals show which goals the indicators measure.

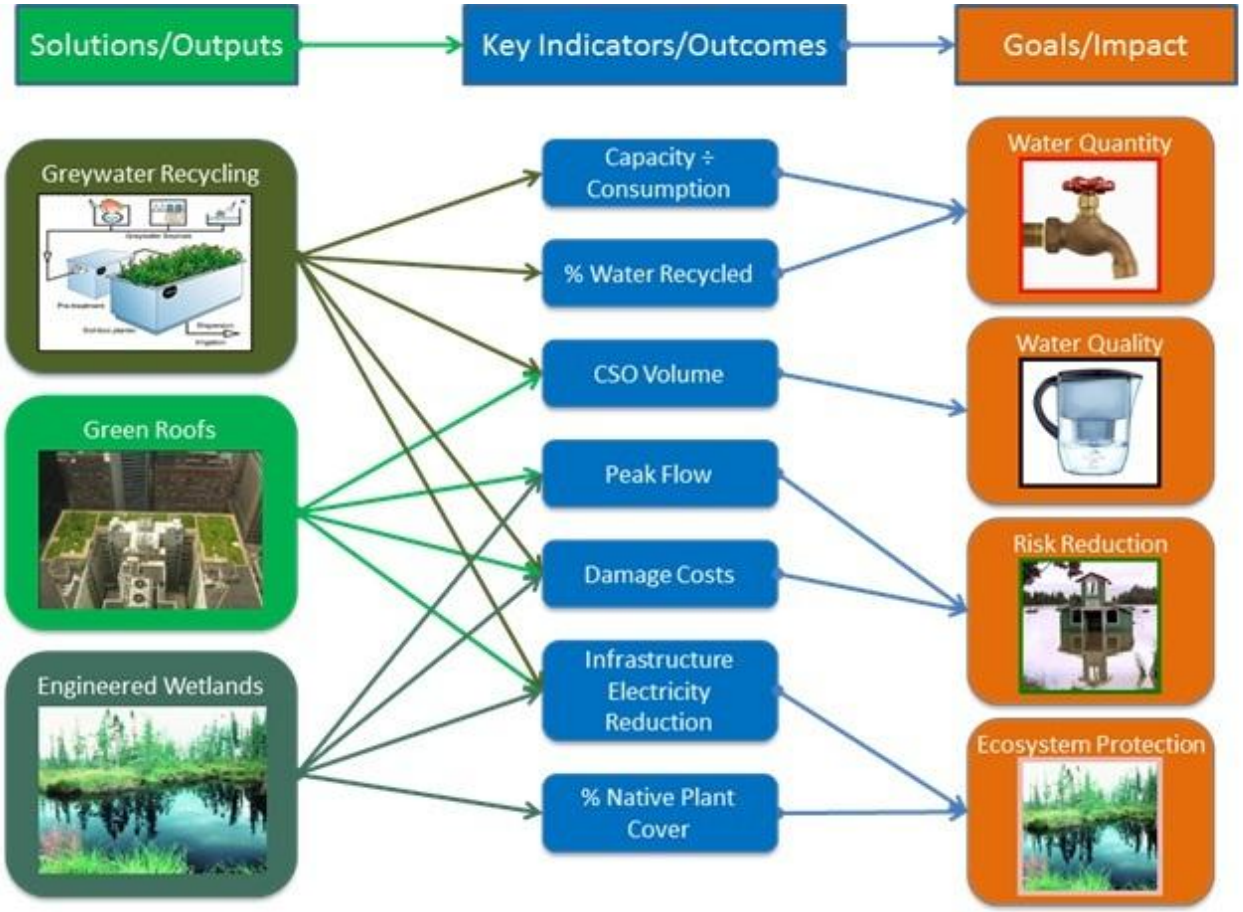


Figure 14. A logic model for a hypothetical green infrastructure implementation showing links between solutions and indicators (green arrows on left), and links between indicators and goals (blue arrows on right).

For example, operators would measure success of greywater recycling by its performance in the Capacity ÷ Consumption, % Water Recycled, CSO Volume, Damage Costs and Infrastructure Electricity Reduction indicators. Green roofs would aim to improve scores in CSO Volume, Peak Flow, Damage Costs, and Infrastructure Electricity Reduction. Operators would gauge performance of engineered wetlands by performance in Peak Flow, Damage Costs, Infrastructure Electricity Reduction, and % Native Plant Cover. Analysis could incorporate qualitative feedback as well.

CONCLUSION

A combination of anthropogenic and climate factors is ultimately changing the natural hydrologic cycle. The Water Infrastructure Resiliency and Sustainability Act of 2011 proposes to fund a multitude of potential strategies for water system owners and operators to not only face these changing hydrological conditions, but also to become more resilient against future changes. The four goals of improving water quality and quantity, reducing disaster risk, and protecting ecosystems express the larger issue of sustaining water resources for human use and the environment. The potential strategies, or solutions, must be considered on a case-by-case approach, since many water infrastructure issues are either region or scale-specific. H.R. 2738 covers a broad scope of applications, such that any water manager could potentially benefit from this bill. The emphasis on innovation and sustainability in water system design and management is a response to sophisticated scientific understanding of the environmental problem and the desire to provide solutions for the future.

Glossary

Acronyms:

CEQA/NEPA	California Environmental Quality Act/National Environmental Policy Act
CHP	combined heat and power
CWSRF	Clean Water State Revolving Fund
CSO	combined sewer overflow
CSS	combined sewer system
DWSRF	Drinking Water State Revolving Fund
EPA	Environmental Protection Agency
IPCC	Intergovernmental Panel on Climate Change
NOAA	National Oceanic and Atmospheric Administration
ppm	parts per million
SSA	Sole Source Aquifers Designation Program
SWP	Source Water Assessment and Protection Program
UIC	Underground Injection Control Regulation Program
USDA	United States Department of Agriculture

Key Terms:

biomimicry	designs that imitate natural processes and models to solve human problems
bioswale	a shallow depression created in the earth to accept and convey stormwater runoff; utilizes natural means (e.g. vegetation and soil) to filter stormwater
conjunctive use	combined usage of groundwater and surface water
desalination	any of several processes that remove some amount of salt and other minerals from saline water
engineered wetlands	wastewater treatment method that mimics natural processes to cleanse water
fertigation	application of fertilizers, soil amendments, or other water-soluble products through an irrigation system
floodplain	adjacent areas of channels, rivers, streams, and wetlands that are often defined by their probability of inundation
green roof	abuilding partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane; may also include additional layers such as a root barrier and drainage and irrigation systems
greywater	wastewater generated from domestic activities (e.g. laundry, dishwashing, bathing); differs from blackwater, which contains human waste
land subsidence	the gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials
sullage	see **greywater**
wastewater	water that has been adversely affected in quality by anthropogenic influence; can encompass a wide range of potential contaminants
wetlands	areas inundated or saturated by surface or groundwater; includes swamps, marshes, and bogs

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