Final Report

Innovative Drought and Flood Mitigation Projects

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FEMA

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ACRONYMS AND ABBREVIATIONS

ACB	Articulating Concrete Block
ACEP	Agricultural Conservation Easement Program
AMA	Agricultural Management Assistance
ARAR	Aquifer Recharge and Recovery
ASR	Aquifer Storage and Recovery
AWWA	American Water Works Association
AwwaRF	American Water Works Association Research Foundation (now Water Research Foundation)
BCA	Benefit-Cost Analysis
BCR	Benefit Cost Ratio
bls	Below Land Surface
BMP	Best Management Practice
CatEx	Categorical Exclusion
CBP3	Community-Based Public-Private Partnership
CBRA	Coastal Barrier Resources Act
CDBG	Community Development Block Grant
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERP	Comprehensive Everglades Restoration Plan
CFR	Code of Federal Regulations
CLOMR	Conditional Letter of Map Revision
CNT	Center for Neighborhood Technology
CO_2	Carbon Dioxide
CPC	Climate Prediction Center
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund

CZMA	Coastal Zone Management Act
DARRP	Damage Assessment, Remediation and Restoration Program
DEP	Department of Environmental Protection
DOP	Duplication of Programs
DWQ	Division of Water Quality
DWSRF	Drinking Water State Revolving Fund
EA	Environmental Assessment
E&SC	Erosion and Sediment Control
ECP	Emergency Conservation Program
ECWAG	Emergency Community Water Assistance Grant
EHP	Environmental and Historic Preservation
EIS	Environmental Impact Statement
EO	Executive Order
EPWU	El Paso Water Utilities
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
EWP	Emergency Watershed Protection
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
FIMA	Federal Insurance and Mitigation Administration
FISRWG	Federal Interagency Stream Restoration Working Group
FPPA	Farmland Policy Protection Act
FRS	Flood Retaining Structure
GI	Green Infrastructure
GPB	Grants Policy Branch
gpd	Gallons per Day
HEC	Hydrologic Engineering Center
HMA	Hazard Mitigation Assistance

HMS	Hydrologic Modeling System
HMGP	Hazard Mitigation Grant Program
KRASR	Kissimmee River Aquifer Storage and Recovery
L	Liter
LID	Low Impact Development
LUNKERS	Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids
µg/L	Micrograms per Liter
M	Million
mg/L	Milligram per Liter
MG	Million Gallons
mgd	Million Gallons per Day
NAGPRA	National American Graves Protection and Repatriation Act
NARC	National Association of Regional Councils
NASS	National Agricultural Statistical Service
NDMC	National Drought Mitigation Center
NEPA	National Environmental Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service
NHPA	National Historic Preservation Act
NIDIS	National Integrated Drought Information System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NORA	New Orleans Redevelopment Authority
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service (formerly Soil Conservation Service)
NRDA	Natural Resource Damage Assessment
NWP	Nationwide Permit
NYC	New York City
OFA	Other Federal Agency

OGSI	Opportunity, Growth, and Security Initiative
O&M	Operations and Maintenance
PL	Public Law
PDM	Pre-Disaster Mitigation
PDSI	Palmer Drought Severity Index
PSAT	Puget Sound Action Team
RAS	River Analysis System
RCA	Soil and Water Resources Conservation Act
RCRA	Resource Conservation and Recovery Act
RRD	Risk Reduction Division
SJRWMD	St. Johns River Water Management District
SFWMD	South Florida Water Management District
SWMM	Storm Water Management Model
SPI	Standard Precipitation Index
SRF	State Revolving Fund
TDS	Total Dissolved Solids
TNC	The Nature Conservancy
TOC	Total Organic Carbon
TS	Total Solids
TSS	Total Suspended Solids
UIC	Underground Injection Control
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDM	U.S. Drought Monitor
USDOE	United States Department of Energy
USDOI	United States Department of Interior
USDOT	United States Department of Transportation

USDW	Underground Source of Drinking Water
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USHUD	United States Department of Housing and Urban Development
UV	Ultraviolet
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WFPO	Watershed and Flood Prevention Operations
WQCE	Water Quality Criteria Exemption
WRP	Water Reclamation Plant
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

ES.1 BACKGROUND AND SCOPE OF WORK

The Federal Emergency Management Agency (FEMA) recognizes the increased risk posed by climate change and is committed to promoting resilience as demonstrated by the *FEMA Climate Change Adaptation Policy Statement* (Administrator Policy 2011-OPPA-01) and the *2014-2018 FEMA Strategic Plan.* The Opportunity, Growth and Security Initiative (OGSI), provides a unique opportunity for the Hazard Mitigation Assistance (HMA) grants to further support these efforts. FEMA's focus on risk management has expanded to anticipate climate changes and to plan and implement strategy for program development in support of climate resilient infrastructure. FEMA now integrates climate change adaptation into planning for future risk, programs, policies, and operations to strengthen the nation's resilience. The Federal Insurance and Mitigation Administration (FIMA), Hazard Mitigation Assistance (HMA) Division, Grants Policy Branch (GPB) evaluates potential Climate Resilient Mitigation Activities (CRMA) for HMA that may reduce the risk of climate change induced weather extremes on people, and the built environment and that could potentially be funded under OGSI.

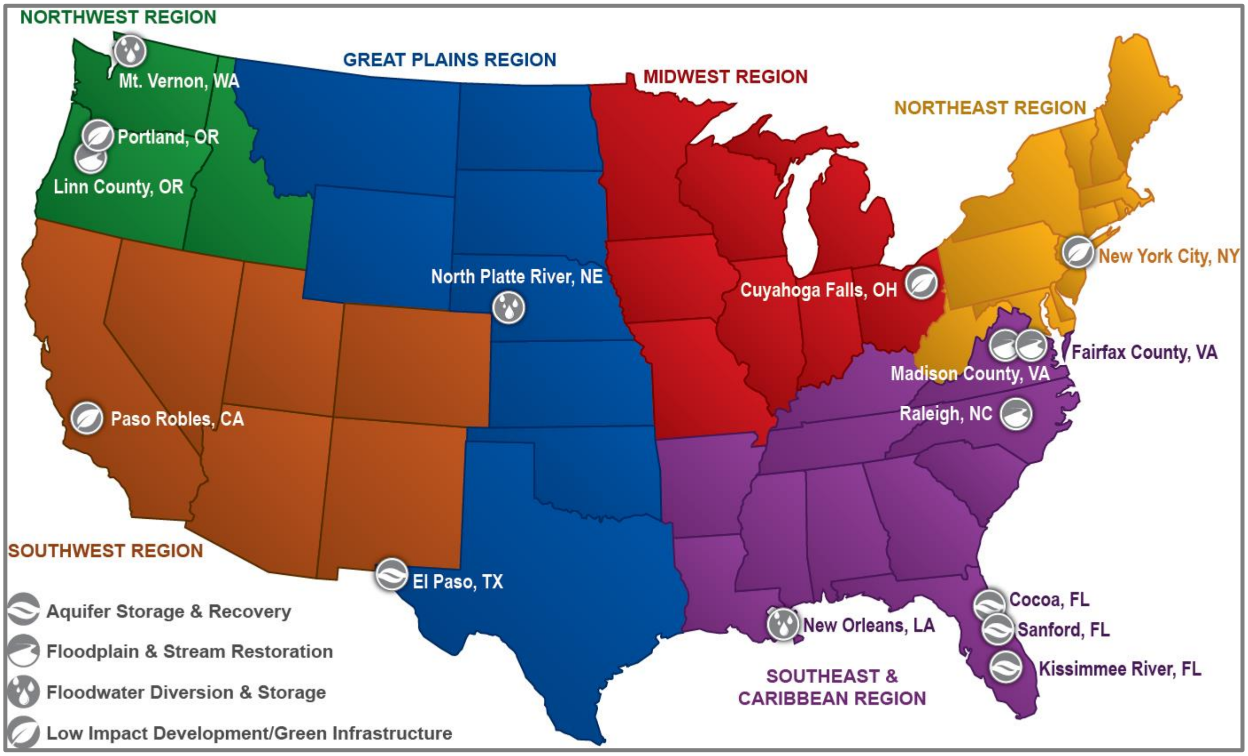
FEMA commissioned a report titled *FEMA Mitigation Support for Planning and Implementation of Climate Resilient Infrastructure* (CDM Smith, 2015a) in February 2015. In this report, over 70 climate resilient project options were identified that may reduce the risk of impacts to people and infrastructure attributed to climate change weather extremes. This list was reduced to 14 project types for further evaluation and analysis of various technical, economic-financial, implementation, and environmental considerations. Of the14 project types 4 of these projects were selected based on their high performance related to the aforementioned criteria and their ability to meet basic requirements consistent with HMA Guidance.

This document evaluates the four project types from the standpoint of HMA program requirements: technical feasibility and effectiveness, cost effectiveness, Environmental and Historic Preservation (EHP) requirements and identifies areas of potential overlap with other Federal Agencies to support FEMA's evaluation of Duplication of Programs (DOP) while also considering areas where Federal agencies could successfully coordinate to fund these project types from multiple Federal programs.

The project types explored further in this evaluation include Aquifer Storage and Recovery (ASR), Floodwater Diversion and Storage, Floodplain and Stream Restoration, and Low Impact Development (LID)/Green Infrastructure (GI). For each of these four project types, the following information is presented:

- A detailed description of each project type
- Technical feasibility and effectiveness considerations
- An evaluation and summary of benefits and costs, as a project must be shown to be cost-effective, typically demonstrated through a benefit-cost analysis (BCA)
- EHP considerations, as the project must comply with all applicable EHP laws, implementing regulations, and Executive Orders, including but not limited to the National Environmental Policy Act (NEPA), the National Historic Preservation Act (NHPA) and Title 44 of the Code of Federal Regulations (CFR) Parts 9 and 10.

- A discussion of the availability of funds from other Federal agencies (OFAs) for the project type to support DOP evaluation and potential coordination of funds
- A summary of programmatic considerations to ensure that the project is:
    - Likely feasible and effective at reducing risk to people, structures, or infrastructure
    - A stand-alone mitigation project that solves a problem independently
    - Not under the specific authority of another Federal agency or program
    - Possible to be implemented within a 3-year period of performance
- Example implementation success stories project sizes in the $1 to $5 million range that provide geographic diversity and ranges of scale and cost. (**Figure ES-1**)



Note: Climate Regions as defined in the 2014 U.S. National Climate Assessment (Melillo et al. 2014).

Figure ES-1. Locations of Implementation Success Stories

ES.2 AQUIFER STORAGE AND RECOVERY

By definition, ASR is taking water when it is abundant, storing the water in the subsurface in aquifers, and recovering the water when needed. ASR is a drought management tool that has all of the benefits of a surface reservoir but does not have evaporative or seepage losses and provides better protection of the injected water quality than a surface reservoir. ASR has been used since the late 1960s and has been applied across the United States and around the world. Source waters for injection into ASR wells range from potable water, reclaimed water, partially treated surface water, and more recently raw groundwater. Projects range in size from single ASR well projects, storing relatively small volumes of water, to multi-well projects, storing billions of gallons (thousands of acre-feet) of water in the ground. A subset of ASR is Aquifer Recharge and Recovery (ARAR), where water is recharged to an aquifer either under gravity (spreading basins) or injected (wells) for the purpose of recharging the aquifer. Recovery of the recharged water mixed with native groundwater is accomplished with a separate set of production or extraction wells.

Feasibility and Effectiveness: Challenges for implementing ASR include reduced recovery efficiency due to improper selection of the storage zone, arsenic leaching from the storage zone, and elevated arsenic concentrations in the recovered water. There have been advances in the last 10 years for minimizing arsenic leaching (pretreatment of the source water and conditioning) for the utility-scale ASR projects and regulatory relief mechanisms on larger projects such as water quality criteria exemptions, mixing zones, and buffer zones. Technical considerations for successfully implementing ASR projects include clearly understanding the goals and objectives of the project, proper site selection, utilization of all available tools for appropriate storage zone selection, and hydrogeochemical characterization and modeling of interactions between the target storage zone aquifer matrix, native groundwater, and the injected fluid. Further guidance is provided in the report and **Attachment 2** quantifies some of these metrics.

Evaluation and Summary of Benefits and Costs: As a hazard mitigation project, ASR primarily enhances water supply resiliency during times of drought. If surface water is the source of water to be redirected to the aquifer, the project may also mitigate impacts of flooding by reducing peak stormwater flows. The increased groundwater baseflow provided by ASR may also reduce subsidence and therefore structural damage to facilities in the vicinity. Although it may be difficult, an Applicant could quantify the benefits and provide proper documentation for inclusion in the BCA. The benefits related to increased water supply capacity can be captured based on the two values presented in **Section 2.3.2**. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation. According to rates developed by Pyne (2014) construction costs for ASR projects range from $0.50 to $2.00 per gallon per day ($0.5 to $2.0 Million per mgd of total ASR system capacity), which is on the low end of the range for water supply projects and other surface storage technologies such as reservoirs and ground storage tanks of comparable capacity. The implementation costs of an ASR project can vary based on existing conditions of the site and should be examined closely for on a project by project basis.

EHP Requirements: All recharge or injection of fluids directly into aquifers in the U.S. are regulated by the USEPA under 40 CFR Part 144 titled Underground Injection Control (UIC) Program. As part of the USEPA UIC permit process, an applicant must demonstrate that the activity does not impact other users of the aquifer.

An exploratory test well should be drilled to confirm that the hydrogeology is favorable for a successful ASR project. If there is evidence that the site is a historic or archaeological significant site, then the location of the ASR site should be relocated. Similarly, facilities may be sited to avoid sensitive fish and wildlife and designated critical habitats, thereby reducing potential impacts and the necessary level of EHP review. ASR facilities would not typically qualify for a categorical exclusion (CatEx) because they do not fit into the categories of actions described in 44 CFR 10.8. Most local-scale ASR facilities and those closely associated with an existing municipal treatment facility would likely be covered by an environmental assessment (EA).

Potential Coordination with Other Federal Agencies: Since ASR is often considered a sustainable, environmentally friendly, alternative water supply option, there are currently several Federal programs that have or could potentially fund ASR projects such as U.S. Bureau of Reclamation, U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers (USACE), U.S. Department of Agriculture (USDA), and U.S. Department of Housing and Urban Development (USHUD). While the availability of funding from other Federal agencies may present a potential DOP issue, it may also present an opportunity for FEMA to leverage grant funding to implement cost effective mitigation projects that are also fundable under other programs.

Summary of Programmatic Considerations: Overall, ASR enhances water supply resiliency during times of drought, can reduce impact from flooding by reducing peak stormwater flows, and provides an ecosystem service through avoided stormwater mitigation and filtration costs. Therefore, while there are multiple benefits for a project of this type, it may be eligible as an HMA project as it has the potential to reduce losses to infrastructure and protects the health and safety of the people in a community during a drought. The size of ASR projects can vary significantly, therefore sizing and planning of the project should be tailored to meet the HMA 3-year implementation time frame required by HMA guidance. It is not likely that a CatEx can be applied to reduce the EHP requirements for review of the project, therefore early screening of the site is recommended to determine if an EA or and Environmental Impact Statement (EIS) would be likely based on project complexity. While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing implementation and drought resiliency throughout the U.S.

ES.3 FLOODWATER DIVERSION AND STORAGE

Every year, communities face significant damages from flooding. Diverting floodwaters from a stream, river, or other body of water into a wetland, floodplain, canal/ditch, pipe, or other conduit (e.g., tunnels, wells) and storing them in reservoirs, floodplains, wetlands, or other storage facilities allows for a controlled base flow release and attenuates peak flows, stages, and velocities to mitigate flooding. Actively managing floodwaters by diversion, storage, and infiltration can also replenish water supply aquifers and enhance usable water supply to mitigate the effects of drought. Floodwater diversion also can help maintain healthy ecosystems.

Feasibility and Effectiveness: The concept of floodwater diversion and storage is applied nationwide at multiple scales: large, regional efforts like the network of major flood control diversions along the Mississippi River; moderate-sized diversion and storage efforts that occur in relatively smaller rivers and tributaries; and at a site-specific or neighborhood scale that utilize stormwater infrastructure to divert flows and store water on a parcel-by-parcel basis. Depending on the scope, scale, and location of potential sites, floodwater diversion and storage projects vary in complexity and the scale of these projects must be considered when evaluating if the projects are consistent with HMA Guidance regarding Flood Risk Reduction Projects. Proper planning, siting, sizing, and construction are required to implement successful floodwater diversion and storage systems. Types of flood storage (online, offline, dry, wet, or wet/dry), planning constraints, and design considerations (land acquisition, siting, and adaptability) are key elements of technical implementation.

Evaluation and Summary of Benefits and Costs: The primary benefit of floodwater diversion and storage projects is to reduce flooding by attenuating peak flows and velocities, allowing them to slowly be released or infiltrate into the ground, therefore, potentially reducing flood damages to infrastructure such as roads, residential and commercial structures, or other property downstream and upstream.

The reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project. If a Floodwater Diversion and Storage project results in new or restored Wetlands, Estuaries, Riparian or Green Open Space, the total annual benefits for these categories can be included in the BCA. The subapplicant would need to quantify the area (in acres) of restored ecosystem and the land use type. If applicable, benefits related to increased water supply capacity can be captured based on the two values presented in **Section 2.3.2**. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

Costs for floodwater diversion and storage projects are site specific and vary, depending on the scope, scale, and location of the floodwater diversion and storage project. Some costs that may be incurred include land acquisition; feasibility analyses; environmental impact, habitat assessment, and cultural significance analyses; hydrologic and hydraulic analyses; subsurface and foundation investigations; consulting services for the design, permitting, project management, and supervision of the construction; demolition, construction, and mobilization costs (e.g., channels, pipes, detention basins, stormwater interventions, floodgates, levee realignment, utility realignment); pre- and post-project monitoring; and Operations and Maintenance (O&M)costs.

EHP Requirements: There are numerous permits and supporting documentation that may be required as part of any floodwater diversion and storage project and may be required to show compliance with EHP requirements. Many of these permits relate to environmental habitat considerations, wetland delineation, water quality, and additionally, tribal community reviews. Neighborhood scale projects that utilize stormwater infrastructure to divert flows and store water on a parcel-by-parcel basis would likely be eligible for a CatEx. The CatEx would not apply if a project would change downstream flow patterns to the extent that land use, delineated special flood hazard, stream functions, stream habitat, erosion or sedimentation rates are affected. Moderate, large or regional scale projects would not be covered by a CatEx and would need to be reviewed under an EA or an EIS.

Potential Coordination with Other Federal Agencies: A critical piece of a floodwater diversion and storage project plan is to have a transparent and inclusive approach to outreach and collaboration. In addition to local stakeholders, there may be an opportunity to coordinate with other Federal agencies such as the USDA-Natural Resources Conservation Service (NRCS), U.S. Bureau of Reclamation, USEPA, National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (USFWS), USACE, and USHUD. In many of these cases, coordination is required for permitting, cost-sharing, and for multi-benefit, multi-goal objectives such as using floodwater diversion and storage projects as a means for providing a wealth of ecosystem goods and services, recreational opportunities, and regional sediment management for beneficial reuse.

Several Federal agencies are already engaged in floodwater diversion and storage activities, and many agencies help support and provide funding for restoration activities. While the availability of funding from other Federal agencies may present a potential DOP issue, it may also present an opportunity for FEMA to leverage grant funding to implement cost effective mitigation projects that are also fundable under other programs.

Summary of Programmatic Considerations: The primary benefit of a floodwater diversion and storage project is the reduction in flood damages. Therefore, the project is likely to be an effective, stand-alone mitigation activity to reduce losses to infrastructure. The project must not duplicate flood prevention activities of other Federal agencies and may not constitute a section of a larger flood control system. While the project can be sized based on the risk in the project area, HMA requirements of a 3-year period of performance for implementation should be considered. While a CatEx may be applied in some cases to reduce the EHP requirements for review of the project, early screening of the site is recommended to determine if an EA or an EIS would be likely based on project complexity and site conditions. While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing implementation and drought resiliency throughout the U.S.

ES.4 FLOODPLAIN AND STREAM RESTORATION

The U.S. has more than 3.5 million miles of rivers and streams that, along with closely associated floodplain and upland areas, comprise corridors of great economic, social, cultural, and environmental value (Federal Interagency Stream Restoration Working Group [FISRWG] 1998). When healthy, these systems can provide stream flood mitigation, mitigate bank erosion concerns, and provide ecological benefits.

Many natural events and human activities can contribute significantly to changes in the dynamic equilibrium of stream systems across the country. Stream degradation ultimately results in water quality issues, loss of water storage and conveyance capacity, loss of habitat for fish and wildlife, and decreased recreational and aesthetic values (National Research Council 1992) while risks to flooding and erosion increase.

Restoration of disturbed river systems is accomplished by adjusting the physical stability and biological function of an impaired river to that of a natural stable river. Channel improvements generally involve alterations to degraded channel floodplain storage, side slopes, sinuosity (degree of meandering), vegetation, bed slope, and roughness. The floodplain of a riverine or stream system provides capacity for storing stormwater runoff, reducing the number and severity of floods, and minimizing non-point source pollution. Restoring floodplains and wetlands and their native vegetation are integral components of stream restoration efforts. Comprehensive considerations of the streams at a watershed scale are also a component of stream restoration efforts.

Feasibility and Effectiveness: A wide variety of techniques can be applied to stream restoration planning and channel design. It is important to note that there are no one-size-fits-all approaches, and stream restoration requires a site-specific approach based on sound stream restoration analysis and design. A successful stream restoration project must incorporate multi-disciplinary techniques from hydrology and hydraulics, fluvial geomorphology, engineering, and stream ecology. Clearly defining the objectives of the stream restoration project reduces ambiguity for all parties involved. Objectives should not only be specific, but also realistic, achievable, and measureable (USACE 2007). Project scale is a major consideration for stakeholders and the design team in setting objectives. Project scope and scale control the breadth of restoration options (Smith and Klingeman 1998). Channel design is a critical portion of the overall stream restoration process and constructability and environmental impacts are two critical items to consider during the design phase. Flood damage reduction techniques should simultaneously provide flood protection benefits while restoring natural environmental functions while considering FEMA authorized Localized and Non-Localized Flood Risk Reduction Projects. Sedimentation analysis is a key aspect of design since many projects fail due to excessive erosion or sediment deposition. Implementing a successful stream restoration solution requires detailed planning, analysis, and design phases. Once the restoration plan is designed, it is important to carefully execute the construction, maintenance, and monitoring phases.

Evaluation and Summary of Benefits and Costs: The primary benefit of floodplain and stream restoration is to reduce flood damages to structures and infrastructure while restoring natural and beneficial function of the floodplain. The benefits due to a reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool and erosion control benefits can be similarly quantified. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project. If a Floodplain and Stream Restoration project results in new or restored Wetlands, Estuaries, Riparian or Green Open Space, the total annual benefits for these categories can be included in the BCA. The subapplicant would need to quantify the area (in acres) of restored ecosystem and the land use type. If applicable, benefits related to increased water supply capacity can be captured based on the two values presented in Section 2.3.2. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

The costs of floodplain and stream restoration measures are very site specific and depend on numerous factors such as tributary area, size and condition of floodplain, depth, width, sinuosity, and flow of the stream. These factors, along with bank slopes, access, existing and proposed vegetation, extent of erosion, type of soil/rock comprising the streambed and stream bank, and the amount of land required for easement or acquisition, all result in a complex array of costs. Some costs that may be incurred include land acquisition; feasibility analyses; environmental impact, habitat assessment, and cultural significance analyses; geotechnical investigations; hydrologic and hydraulic analyses; consulting services for the design, permitting, project management, and supervision of the construction; demolition, construction, and mobilization costs (e.g., erosion and sediment control, channel clearing and shaping, riprap, restoration structures, seeding and mulching, earthfill and drainfill, etc.); pre- and post-project monitoring; and O&M costs.

EHP Requirements: Legal compliance, permits, and supporting documentation may be required as part of any floodplain and stream restoration project and may be required to show compliance with EHP requirements. Many of these permits relate to environmental habitat considerations, wetland delineation, water quality, and additionally, tribal community reviews. A simple floodplain restoration project that only involves land acquisition, removal of structures, and planting of indigenous vegetation might be covered under CatExs (d)(2)(vii), property acquisition and demolition and (d)(2)(xi), planting of vegetation. A more complex project that involves construction activities such as setback and reconstruction of levees, regrading stream beds and banks, or armoring countermeasures would likely not be eligible for a CatEx and would need to be analyzed in an EA.

Potential Coordination with Other Federal Agencies: Several Federal agencies are already engaged in floodplain and stream restoration activities, and many agencies help support and provide funding for these activities. The following Federal agencies currently support stream restoration projects: USDA-NRCS, USFWS, USACE, and NOAA - National Marine Fisheries Service (NMFS). While the availability of funding from other Federal agencies may present a potential DOP issue, it may also present an opportunity for FEMA to leverage grant funding to implement cost effective mitigation projects that are also fundable under other programs.

Summary of Programmatic Considerations: The benefits of a floodplain and stream restoration project vary greatly based on the design and site conditions. While there are many environmental and ecological benefits, the project must act as an effective, stand-alone mitigation activity to reduce losses to infrastructure or people. From an HMA program standpoint, it will be important to establish the benefits during the project design phase to be able to justify it as a mitigation project. The project must not duplicate flood prevention activities of other Federal agencies and may not constitute a section of a larger flood control system. While the project can be sized based on the risk in the project area, HMA requirements of a 3-year period of performance for implementation should be considered. While a CatEx may be applied in some cases to reduce the EHP requirements for review of the project, early screening of the site is recommended to determine if an EA or an EIS would be likely based on project complexity and site conditions.

While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing resiliency throughout the U.S.

ES.5 LOW IMPACT DEVELOPMENT/GREEN INFRASTRUCTURE

LID is a sustainable approach to natural landscape preservation and stormwater management (USEPA 2013). This approach emphasizes conservation and the use of onsite natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions (Puget Sound Action Team [PSAT] 2005). Implementation of LID/GI practices can help mitigate flood events by increasing the ability of the landscape to store water on site. Infiltration of these stored waters can also mitigate the effects of drought by replenishing water supply aquifers and enhancing usable water supply.

GI can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID (USEPA 2014c). Both LID and GI utilize best management practices (BMPs) that can be combined in a BMP Treatment Train to enhance benefits and reduce costs. In the last decade, LID and GI often have been used interchangeably; however, LID focuses specifically on water management issues while GI's scope can be broader and used to mitigate issues such as air pollution, urban heat island effects, wildlife conservation, and recreational needs (Chau 2009). In this report, when possible, more focus will be given to the stormwater management and flood control/management aspects offered by using LID/GI practices.

Feasibility and Effectiveness: Instead of large, centralized treatment plants and water storage facilities, LID/GI emphasizes local, decentralized solutions that capitalize on the beneficial services that natural ecosystem functions can provide. LID/GI is most effective when applied on a wide scale and encompasses much more than just water infiltration, as it can be used to mitigate floods downstream, filter pollutants, and capture and store water for use at a later time. Storing potential floodwaters on site in LID/GI practices allows for a controlled base flow release and attenuates peak flows, stages, and velocities to mitigate flooding. The diversion, storage, and infiltration of these waters also can replenish water supply aquifers and enhance usable water supply to mitigate the effects of drought.

One of the primary motivations for LID/GI for a number of communities in the U.S. is to reduce stormwater runoff, which may contribute to combined sewer overflow (CSO) events. Overflow occurs in cities with combined sewer systems (CSS) where wastewater (i.e., sanitary sewage), stormwater, and urban runoff water are collected in the same pipe network and routed to a treatment plant (Economides 2014). If the capacity of the downstream treatment plants cannot handle the amount of water collected, excess flows, inclusive of sanitary sewage, are often routed directly to the nearest body of water. LID/GI is an ecosystem-based approach that is used to replicate a site's predevelopment hydrologic function. The primary goal of LID/GI is to design each development site to protect, or restore, the natural hydrology of the site so that the overall integrity of the watershed is protected (Maimone et al. 2007). This is done by creating a "hydrologically" functional landscape.

In the face of a changing climate, LID/GI can potentially play an increasingly important role to reduce local impacts for community resources and waters. By reducing the volume of runoff entering sewer systems and increasing natural features that can reduce the effects of flooding, LID/GI can add resiliency to climate change adaptation planning (American Rivers et al. 2012). Scales of implementation, site design considerations, design guidance and technical manuals, and LID/GI practice selection guidance are key considerations and guidance to be used in planning and design of any LID/GI project.

Evaluation and Summary of Benefits and Costs: The primary benefit for many LID/GI projects is the reduction of flood damages to structures and infrastructure through stormwater detention and infiltration. The reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project. If a GI/LID project results in new or restored Wetlands, Estuaries, Riparian or Green Open Space, the total annual benefits for these categories can be included in the BCA. The subapplicant would need to quantify the area (in acres) of restored ecosystem and the land use type.If applicable, benefits related to increased water supply capacity can be captured based on the two values presented in Section 2.3.2. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

There are some cases where LID project costs have been higher than those for conventional stormwater management projects, but in the majority of these cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping (USEPA 2007). On average, total capital cost savings ranged from 15 to 80 percent when LID methods were used (USEPA 2007). O&M costs for LID/GI practices vary, depending on site-specific conditions; however, ongoing maintenance need diminishes as plant materials establish and the site stabilizes. Cost of LID/GI practices vary widely, depending on site-specific site conditions and the type of GI techniques being used.

EHP Requirements: Water quality certification, hydraulic project approval, no-rise certification or a conditional letter of map revision, and a general construction permit may be required as part of any LID/GI project and may be required to show compliance with EHP requirements. Many types of LID/GI projects may be covered under existing CatExs when they are replacing existing structures resulting in the same developed footprint and similar form and function. However, it is important to note that while most LID/GI projects would be expected to meet the general criteria for a CatEx found in 40 CFR 1508.4, unless the activity would be covered under a specific CatEx in 44 CFR 10.8, it would require an EA.

Potential Coordination with Other Federal Agencies: Given the potential of GI to support a wide range of purposes, a number of agencies, including USEPA, U.S. Department of Transportation (USDOT), USHUD, USDA, U.S. Department of the Interior (USDOI), and the U.S. Department of Energy (USDOE) offer expertise and resources that can be used to help communities, plan, design, and then implement GI practices (USEPA 2014). In addition, USEPA states in their *Green Infrastructure Strategic Agenda 2013* that one of their five major focus areas is Federal coordination. This includes objectives such as leveraging existing Federal partnerships, continuing Federal dialogue on critical GI barriers and knowledge gaps, demonstrating commitment to GI through Federal projects, developing information on large-scale GI systems as a component of community resiliency and disaster relief, and continuing to integrate source water protection into stormwater management practices (USEPA 2013). There are also several documents on possible funding mechanisms for LID/GI projects presented in the report.

Summary of Programmatic Considerations: The benefits of a LID/GI project vary greatly based on the design and site conditions. While there are many environmental and ecological benefits, the project must act as an effective, stand-alone mitigation activity to reduce losses to infrastructure or people. From, an HMA program standpoint, it will be important to establish the benefits during the project design phase to be able to justify it as a mitigation project. The project must not duplicate flood prevention activities of other Federal agencies and may not constitute a section of a larger flood control system. While the project can be sized based on the risk in the project area, HMA requirements of a 3-year period of performance for implementation should be considered. While a CatEx would likely apply in many cases to reduce the EHP requirements for review of the project, early screening of the site is recommended to determine if an EA or an EIS would be likely based on project complexity and site conditions. While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing resiliency throughout the U.S.

ES.6 RECOMMENDATIONS

To date, FEMA's mitigation funding efforts have been in response to natural and manmade disasters; however, FEMA's focus on risk management is expanding to include proactively anticipating climate changes and planning for additional new funding programs in support of climate resilient infrastructure. With these two OGSI reports and guidance on incorporating sea level rise estimates in HMA grant applications (December 2013), FEMA continues to integrate climate change adaptation into programs, policies, and operations to strengthen the nation's resilience by addressing current needs while planning for future risk.

One of the goals of the OGSI is to achieve long-term climate resiliency. A portion of the proposed OGSI funding would support competitive grants to local, Tribal, and State governments through the Pre-Disaster Mitigation (PDM) program. The OSGI funding would be applied to cost-effective project grants to reduce flood losses and other eligible hazard mitigation activities that reduce disaster losses and protect life and property from further disaster damages. Projects that best address climate change weather extremes may receive additional funding consideration by FEMA.

All four climate change adaptation project options presented in this report are consistent with FEMA's HMA programmatic requirements and guidelines. They are feasible and effective measures for independently addressing issues, can be shown to be cost effective and meet EHP requirements.

Additional areas that will require further exploration to facilitate the funding of these climate resilient projects include:

- **Cost Effectiveness –**While benefits such as ecosystem services and water supply have been identified for the project types, tying these projects to quantifiable hazard mitigation is critical to ensure the availability of FEMA funds. If other Federal agencies have a funding mechanism, FEMA should consider ways to leverage available funding sources to implement mitigation actions that have other benefits.

- **Duplication of Programs** – Projects considered for funding under OGSI will need to be further evaluated by FEMA to determine if duplication of programs exists. While other Federal Agencies have authorities related to these project types, when possible, FEMA may consider these opportunities to leverage funding, technical resources and best practices, rather than view them as duplication of programs.

- **Guidance and Tools** – As subapplicants and Applicants begin to apply for funding for new project types, there will be a need for additional guidance and tools to facilitate the development of complete and technically sound subapplications. FEMA will also benefit from these products by having a clear set of evaluation metrics to ensure consistency across Regions. Because PDM does not fund 5 percent initiative projects, well documented BCAs, quantifying both traditional and environmental benefits of these projects, will be needed.

- **Environmental Benefits** – Continued evaluation and quantification of environmental benefits such as regional variation of per capita water consumption, water demand reduction projects, ecological health, and proximity to urban areas, will allow for a more holistic evaluation of drought mitigation and disaster risk reduction benefits for inclusion in a future update of the FEMA BCA Tool.

The funding of climate resilient projects and enhanced land/floodplain development regulations are critical to building stronger, more resilient communities. Climate resilient planning and infrastructure projects allow communities to be better prepared for climate change related disasters in order to minimize, or avoid, damage. Climate change mitigation planning results in less post-disaster damage and, therefore, reduced costs to rebuild communities post-disaster. Strategic funding by FEMA of climate resilient projects will help communities proactively plan and be better prepared for impacts related to climate change weather extremes.

SECTION ONE INTRODUCTION

1.1 BACKGROUND AND PURPOSE

To date, the Federal Emergency Management Agency (FEMA) funding efforts for mitigation has been in response to natural and manmade disasters. FEMA now addresses the effects of climate change in response in response to the 2014 Opportunity, Growth, and Security Initiative (OGSI), Executive Order 13653 Preparing the United States for the Impacts of Climate Change (Executive Office of the President, 2013a), The President's Climate Action Plan (Executive Office of the President, 2013b), and FEMA's Climate Change Adaptation Policy (2011-OPPA-01) (FEMA, 2011). FEMA's focus on risk management has expanded to anticipate climate changes and to plan and implement strategy for program development in support of climate resilient infrastructure. In particular, Hazard Mitigation Assistance (HMA) is being expanded to meet the goals of long-term climate resilience. Projects that best address climate change weather extremes receive additional funding consideration by FEMA.

This report consolidates a report titled FEMA Mitigation Support for Planning and Implementation of Climate Resilient Infrastructure (CDM Smith, 2015), prepared in February 2015, and a report titled Supplement to FEMA Mitigation Support for Planning and Implementation of Climate Resilient Infrastructure (CDM Smith, 2015), prepared in August 2015. In the earlier report, over 70 climate resilient project options were identified that may reduce the risk of impacts to people and infrastructure attributed to climate change weather extremes. This list was then collaboratively reduced to 14 project types for further evaluation and analysis of various technical, economic-financial, implementation, and environmental considerations. Four of these projects were selected based on comparatively high risk reduction-related performance and ability to meet basic requirements consistent with HMA Guidance.

The four hazard mitigation project types are evaluated from the standpoint of HMA program requirements: technical feasibility and effectiveness, programmatic considerations, cost effectiveness, Environmental and Historic Preservation (EHP) requirements; and identifies areas of potential overlap with other Federal Agencies to support FEMA's evaluation of duplication of programs (DOP) while also considering areas where Federal funds from multiple Federal agencies could fund these project types. The hazard mitigation project types and practices explored in this evaluation are Aquifer Storage and Recovery (ASR), Floodwater Diversion and Storage, Floodplain and Stream Restoration, and Green Infrastructure (GI) hazard mitigation practices. FEMA continues to integrate climate change adaptation into programs, policies, and operations to strengthen the nation's resilience by considering and planning for future risk.

1.2 ORIGINAL CLIMATE RESILIENT PROJECT OPTIONS

The initial report in February 2015 classified, identified, and evaluated potential project types that reduce the elevated risk from natural hazards and the risk of impacts attributed to climate change weather extremes, through a methodical step by step process: The regional climate change impacts and associated risk factors throughout the United States were investigated and identified, from increased temperatures and the escalating frequency and intensity of storms, to rising sea levels and storm surge; Methods, tools, and resources to assess the potential risk posed to public safety and property, infrastructure, and the environment were identified; Assessment methods were developed for three key strategic areas: water supply, water quality and ecosystem, and flood control; The key strategic areas of water supply, water quality and ecosystem and flood control, were expanded to include green infrastructure; and, Potential hazard mitigation projects to increase climate resiliency (climate resilient projects) were identified and organized based on these strategic areas.

More than 70 project types that could be capable of addressing climate change uncertainty were initially compiled and evaluated. The list was reduced to 14 project types through a collaborative process of qualitative analysis and evaluation of technical, economic-financial, implementation, and environmental factors and considerations: Brackish Groundwater Desalination; Seawater Desalination; Aquifer Storage and Recovery; Reclaimed Water; Water Conservation; Freshwater Wetland Enhancement, Restoration, or Creation; Coastal Wetland Restoration and Construction; Low Head Dams or Sills; Floodwater Storage and Diversion; Floodplain and Stream Restoration; Breakwaters and Wave Attenuation Features; Adaptive Groundwater Management Regime; and, Low Impact Development/Green Infrastructure.

Three of these 14 project types were selected based on analysis and evaluation of ability and expected performance to meet basic requirements consistent with HMA Guidance, and the following criteria:

- Climate Change Risk Factor (Consequence of climate change impact);
- Additional Benefits (Climate change risk factor that may be additionally addressed as a result of project implementation);
- Project Type (Type of proposed project for implementation);
- Project Timeframe (Timeframe for project implementation);
- Effectiveness Timeframe (Timeframe for project to start mitigating impacts once implemented);
- Technical Feasibility (Feasibility of project implementation and ability of project to independently mitigate identified risk);
- Environmental Consistency (Level of consistency with existing and potential Federal, State, and local regulatory programs);
- Economic Reasonability (Qualitative likelihood of project being considered cost effective);
- Social and Political Acceptability (Level of community and institutional understanding and -acceptance of the project);
- Sustainability (Benefits to multiple infrastructure sector and/or jurisdiction); and
- Financial Need (Ability of jurisdictions to fund projects without Federal assistance).

1.3 OBJECTIVES

This report evaluates potential projects and identifies effective mitigation actions consistent with the HMA programs and identifies examples of successful implementation as case studies to inform FEMA decisions regarding the funding of additional project types to mitigate the risks associated with climate change. The projects evaluated under this effort are:

1. **Aquifer Storage and Recovery (ASR)**: ASR involves injecting surface water or groundwater when it is available into an aquifer through a well, to be stored for a period of time until it is

needed, and then recovered for use (referred to as a cycle) through the same well. Implementation of ASR increases climate resiliency for periods of low rainfall or extended periods of drought by taking advantage of seasonal variations in surface water runoff or groundwater surpluses. ASR does not typically provide flood hazard reduction independently due to the relatively low injection volumes (compared to flood flows); however, it can be used to "free up" storage in regional stormwater management facilities and reservoirs if pumped at a constant maximum rate.

2. **Floodwater Diversion and Storage:** This project type includes the transfer of floodwater from a stream, river, or other body of water into a wetland, floodplain, canal/ditch, pipe, or other conduit (e.g., tunnels, wells). Storage of these floodwaters provides for a controlled base flow release and reduces downstream peak flows, stages, and velocities. Water can be impounded in surface reservoirs, floodplains, and wetlands along with retention and detention facilities. By actively managing floodwaters by diversion, storage, and infiltration and allowing for a controlled base flow release, the project would mitigate flooding impacts. In addition, floodwater diversion and storage can replenish water supply aquifers and enhance usable water supply to mitigate the effects of drought. Floodwater diversion can also help maintain healthy ecosystems.

3. **Floodplain and Stream Restoration:** Natural events and human activities can change the dynamic equilibrium of stream and floodplain systems. Restoration is the re-establishment of the structure and function of floodplains, stream morphology, and ecosystems. Typical projects include improvements to floodplains and floodways, wetlands, streambeds, flow area, natural channel form, and sinuosity. When healthy, these systems can provide stream flood mitigation, mitigate bank erosion concerns, and provide ecological benefits. Additional benefits include habitat for fish and wildlife, improvement of water quality, water supply benefits, and recreation opportunities.

4. **Low Impact Development (LID)/Green Infrastructure (GI):** LID is a sustainable development and re-development approach to natural landscape preservation and stormwater management. It emphasizes conservation and use of onsite natural features integrated with engineered, hydrologic controls to more closely mimic pre-development hydrologic functions. GI can be used at a wide range of scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID. These approaches are also termed Best Management Practices (BMPs). Implementation of LID/GI practices can help mitigate flood events by increasing the ability of the landscape to store water on site. Infiltration of these stored waters can also mitigate the effects of drought by replenishing water supply aquifers and enhancing usable water supply.

To support FEMA's evaluation of project eligibility for the implementation of climate resilient infrastructure under the HMA grant programs, the following areas specific to each project type were further explored: technical feasibility and effectiveness, cost effectiveness, compatibility with FEMA's EHP process, and coordination opportunities with other Federal agencies (OFAs) currently financing water resources development projects (e.g., U.S. Environmental Protection Agency [USEPA], U.S. Army Corps of Engineers [USACE], Natural Resources Conservation Service [NRCS], U.S. Bureau of Reclamation [USBR]). Definitions of commonly used terms related to each project type can be found in **Attachment 1** of this report.

1.4 PROJECT APPROACH

The following two-step approach in preparing this exploratory report was implemented:

Step 1: Gather and Evaluate Data:

- Review technical literature specific to each project type and FEMA programmatic guidance, including EHP and Benefit-Cost Analysis (BCA) to identify best practices and recommendations for project evaluation and implementation

Step 2: Develop Requirements and Guidance Document:

- Link measure/activity to loss/risk reduction and identify benefits
- Identify other potential benefits (e.g., social, environmental, and economic) and methods for quantifying
- Identify timeframe, costs, and technical feasibility for implementation and consistency with HMA program
- Consider EHP requirements for each activity
- List agencies for potential OFA coordination to leverage resources and funds
- Identify and discuss programmatic considerations
- Include examples of implementation success stories with project sizes in the $1 to $5 million range that provide geographic diversity and ranges of scale and cost.

1.5 REPORT STRUCTURE

In addition to **Section 1 (Introduction)**, this report is organized as described below:

Section 2 – Program and Project Evaluation Considerations - This section provides background information that FEMA may use when considering future policy and guidance regarding these project types, and some information that will support the evaluation of individual projects FEMA may fund in the future.

Section 3 – Climate Change Adaptation Project Options – the four climate resilient project types (ASR, Floodwater Diversion and Storage, Floodplain and Stream Restoration, and LID/GI) are evaluated in terms of technical feasibility and effectiveness, programmatic considerations, cost effectiveness, consideration of FEMA's EHP process, and potential coordination opportunities with OFAs. This evaluation considers the project types in the context of FEMA's basic HMA programmatic requirements for implementation and consistency as follows:

- **Technical Feasibility and Effectiveness:** The paper considers the feasibility of each project and conditions for consideration during implementation to ensure feasibility. It also examines their ability to effectively reduce risk from hazards and independently solve a problem.
- **Evaluation and Summary of Benefits and Costs:** Mitigation activities funded through HMA grants are required by statute and regulation to be cost effective. This is demonstrated through

a BCA and the calculation of a Benefit Cost Ratio (BCR), which divides total discounted annualized project benefits by total annualized project cost. Projects where benefits exceed costs are considered cost effective. Benefits typically include avoided damages, loss of function, and displacement in relation to protection of infrastructure and people. However, the projects analyzed in this paper provide additional benefits that require additional analysis and consideration. Information is provided under each project type for these considerations.

- A list of the expected line items for a project cost estimate and operations and maintenance (O&M) activities are also included for each project type. Although the O&M costs will not be funded by FEMA, they are required to be included in the BCA and therefore should be considered.
- **EHP Requirements:** HMA grants must comply with all Federal, state, and local EHP laws, including the National Environmental Policy Act (NEPA) and Title 44 of the Code of Federal Regulations (CFR) Part 10. EHP compliance may have cost and schedule implications for a project, and EHP consideration should begin during the initial scoping phase of the project. NEPA may require a subapplicant to consider project alternatives, typically when the proposed scope has the potential to significantly impact environmental and human resources. Common considerations include impacts to historic or cultural resources, floodplains, wetlands, and threatened and endangered species or their critical habitat. Federal EHP laws and Executive Orders (EOs) include:
    - NEPA
    - National Historic Preservation Act (NHPA)
    - Endangered Species Act (ESA)
    - Clean Water Act (CWA)
    - Rivers and Harbors Act (Section 10)
    - EO 11988 (Protection of Floodplains), May 24, 1977
    - EO 11990 (Protection of Wetlands), May 24, 1977
    - Coastal Zone Management Act (CZMA)
    - Coastal Barrier Resources Act (CBRA)
    - Farmland Policy Protection Act (FPPA)
    - Resource Conservation and Recovery Act (RCRA)
    - Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
    - 36 CFR Part 800, Protection of Historic Properties
    - EO 12898 (Environmental Justice for Low Income and Minority Populations), February 16, 1994
    - Others as appropriate

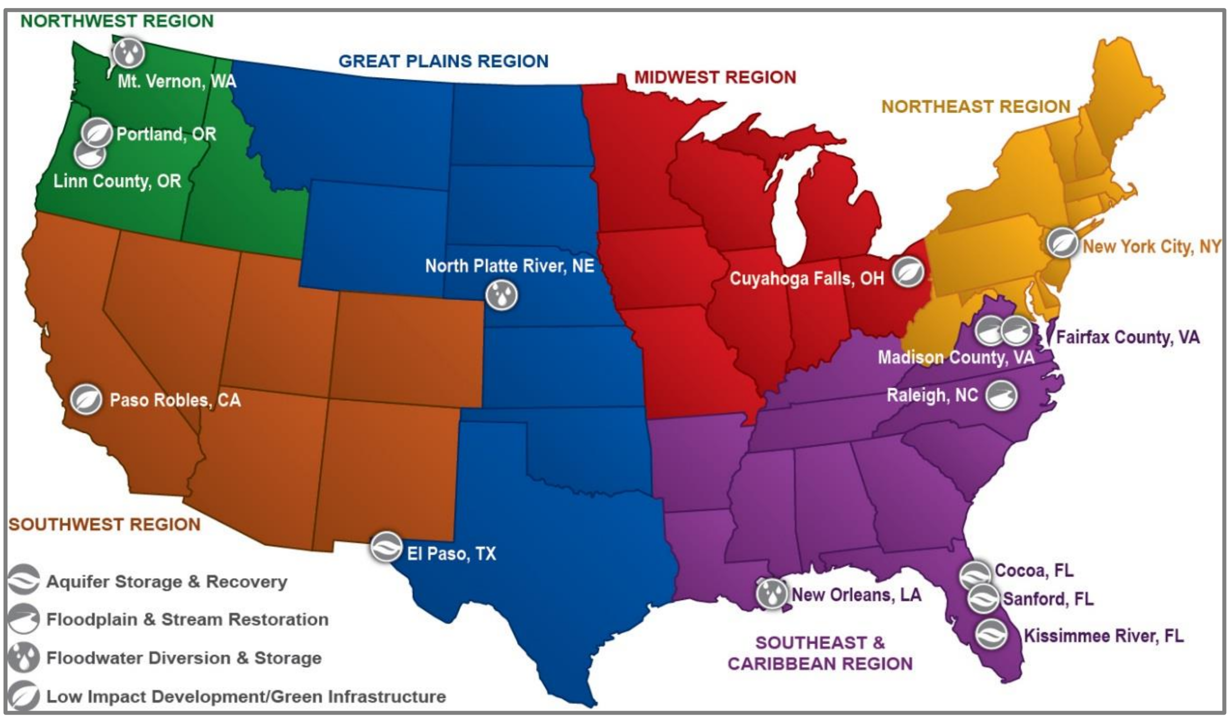
This paper analyzes the potential impacts of the projects and provides a discussion on the potential EHP review required to meet ensure compliance.

- **Summary of Programmatic Considerations:** The paper provides a summary of the programmatic considerations for project implementation, such as the ability for the project to be implemented in 3-years, conditions for localized vs. non-localized flood reduction projects, and duplication of programs as other Federal agencies have programs in place that could fund these types of projects.

Section 3 also provides examples of implementation success stories with project sizes in the $1 to $5 million range (a feasible size for HMA programs) that provide geographic diversity and ranges of scale and cost (**Figure 1-1**).

Section 4 – Summary and Recommendations – this section presents the summary of the evaluation of the four climate resilient project types considered along with recommendations for future HMA program considerations.

Section 5 – References – this section provides the references used in the development of this report.



Note: Climate Regions as defined in the 2014 U.S. National Climate Assessment (Melillo et al. 2014).

Figure 1-1. Locations of Implementation Success Stories

SECTION TWO PROGRAM AND PROJECT EVALUATION CONSIDERATIONS

The four projects evaluated in this paper were selected based on a number of conditions, including their ability to address risk due to climate change conditions and their ability to meet HMA funding requirements This section provides background information that FEMA may use when considering future policy and guidance regarding these project types, and some information that will support the evaluation of individual projects FEMA may fund in the future.

2.1 CLIMATE CHANGE AND DROUGHT

Historically, the bulk of mitigation funded through FEMA's HMA programs has been related to flood mitigation. However, with increased frequency and duration of water shortages related to drought and magnified by impending climate change, FEMA is expanding its role into the area of drought mitigation. Three of the four project types discussed and explored in this report provide benefits for drought mitigation.

The National Weather Service (2012) defines drought, as follows:

> *Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people. It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry. Drought is a temporary aberration from normal climatic conditions, thus it can vary significantly from one region to another.*

The U.S. Drought Monitor (USDM), produced through a partnership between the National Drought Mitigation Center (NDMC), U.S. Department of Agriculture (USDA), and National Oceanic and Atmospheric Administration (NOAA), provides a weekly summary of current national drought conditions. The USDM map produced as of July 28, 2015 is presented on **Figure 2-1** (NDMC, 2015a). The USDM is part of the National Integrated Drought Information System (NIDIS), which was established by Congressional Act in 2006 to implement an integrated drought monitoring and forecasting system at Federal, state, and local levels. More information is available on the U.S. Drought Portal http://www.drought.gov.

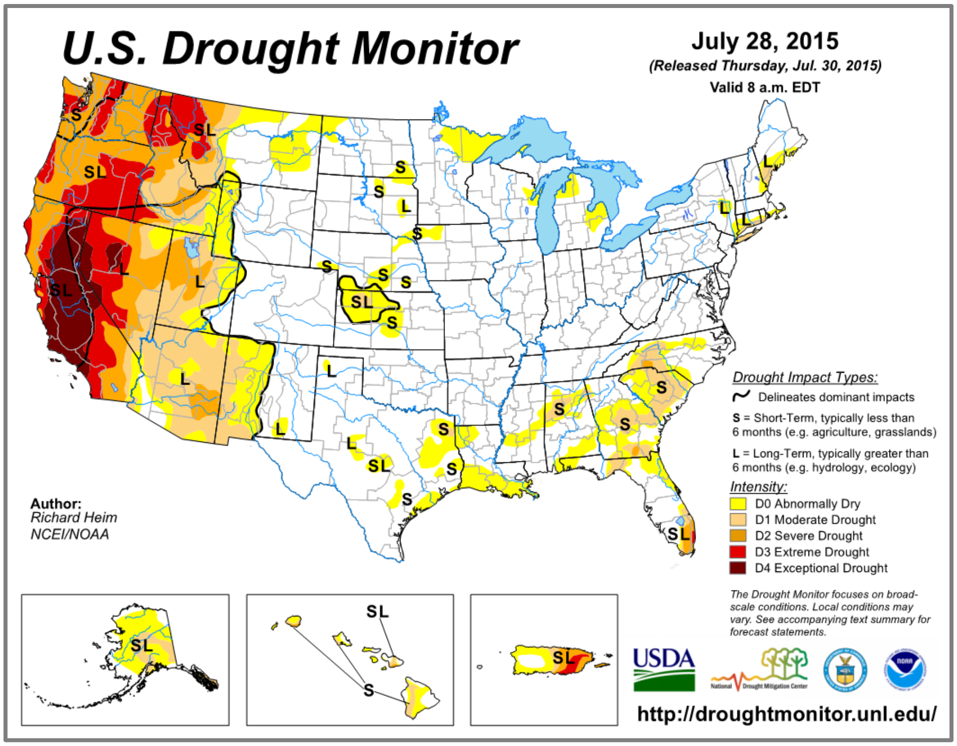


Figure 2-1. July 28, 2015 U.S. Drought Monitor Map

As shown on Figure 2-1, a large part of the western U.S. is under a moderate to an exceptional drought. The USDM identifies general drought areas, labelling droughts by intensity, with D1 being the least intense and D4 being the most intense. D0 are drought watch areas that are either drying out and possibly heading for drought or are recovering from drought, but not yet back to normal, suffering long-term impacts such as low reservoir levels. Table 2-1 shows Drought Severity Classification used in the development of Figure 2-1 and presents the ranges for each indicator for each dryness level. Because the ranges of the various indicators often do not coincide, the final drought category is based on what the majority of the indicators show and on local observations. The analysts producing the USDM also weigh the indices based on their applicability to various regions of the country, taking into account seasonal variability. Additional indicators are often needed in the West, where winter snowfall in the mountains has a strong bearing on water supplies.

Table 2-1. Drought Severity Classification[1]

Category	Description	Possible Impacts	Palmer Drought Index	Climate Prediction Center Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short- and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops, or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low; some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells, creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

[1] National Drought Mitigation Center 2015b.

Per the USDM "Short-term drought indicator blends focus on 1-3 month precipitation. Long-term blends focus on 6-60 months. Additional indices used, mainly during the growing season, include the USDA/ National Agricultural Statistical Service (NASS) Topsoil Moisture, Keetch-Byram Drought Index, and NOAA/ National Environmental Satellite, Data, and Information Service (NESDIS) satellite Vegetation

Health Indices. Indices used primarily during the snow season and in the West include snow water content, river basin precipitation, and the Surface Water Supply Index. Other indicators include groundwater levels, reservoir storage, and pasture/range conditions."

Historically, a recurrence interval has been determined by calculating frequency of occurrence using many years of past data and assuming that the past was a good predictor of future conditions. However, in more recent times, a slightly better understanding about natural and man-induced global warming has altered this paradigm. Numerous factors such as air temperature increases, land surface temperature increases, ocean temperature increases, and carbon dioxide emissions affect the future recurrence of extreme weather conditions such as storm and drought intensity and occurrence.

Unlike storm events that cause flood conditions, the recurrence interval for droughts is hard to predict. The recurrence of drought is very complex and there are many variables to be understood in predicting drought. Global climate factors that influence extreme weather conditions, such as El Niño in the Pacific Ocean and the Atlantic Multidecadal Oscillation, are being studied, and their influences are not yet fully understood. For drought, the focus has been on predicting the risk of occurrence and intensity over the next 100 years in the U.S. (Wehner et al. 2011; Strzepek et al. 2010; Hoerling et al. 2012) and the world (Dai 2013).

In one study (Wehner et al. 2011), 19 climate models were used to simulate the Palmer Drought Severity Index (PDSI) for the period 1950-2009. Corrections were made to the models and then they were used to predict future PDSI changes over the 21st century. Figure 2-2 shows the PDSI over the 10 year period of 2089-2098 from the corrected 19 climate models. As indicated on this figure, severe to extreme drought conditions would be the normal climatological state over much of the continental U.S. and Mexico. Approximately two-thirds of the area in this region's normal state would be considered moderate drought conditions today and a tenth would be considered extreme drought conditions. As stated by the principal investigators of this study, even in areas where precipitation is projected to increase by all models, moderate drought or mild drought conditions are projected to be the normal state. The increased precipitation does not offset the increase in evapotranspiration due to warmer surface temperature. This leads to a reduction in soil moisture that is reflected in negative values of PDSI.

A changing climate, particularly in areas projected to be warmer and drier, is expected to lead to more drought and stresses on water supply (Melillo et al. 2014). Figure 2-3 shows the Water Supply Stress Index for the U.S. (1900-2008) based on historical observations. As indicated on this figure, there has been widespread stress in much of the southwest, western Great Plains, and part of the northwest (Averyt et al. 2011). Ground watersheds are considered stressed when water demand exceeds 40 percent of available supply (i.e., Water Supply Stress Index ≥ 0.4). Another study (Figure 2-4) completed by the U.S. Geological Survey (Konikow 2013), showed cumulative groundwater depletion from 1900-2008 in 40 assessed aquifers due to several factors including increased pumping and increased natural discharge rates, physical properties of the aquifer, and natural and changes to human-induced recharge rates.

Based on current FEMA BCA guidance and practices, to evaluate a project that reduces the risk from drought, it would be necessary to determine the frequency (or recurrence interval) associated with the severity of scenario drought events. As explained, this may prove to be a very complicated task. Therefore, to include the benefit in a BCA, the subapplicant should use the best available data and methodology deemed appropriate by the design engineer. Alternatively, consideration of Federally produced analyses such as the U.S. Drought Monitor may provide FEMA with a qualitative criteria for the prioritization of mitigation actions that have a drought benefit.

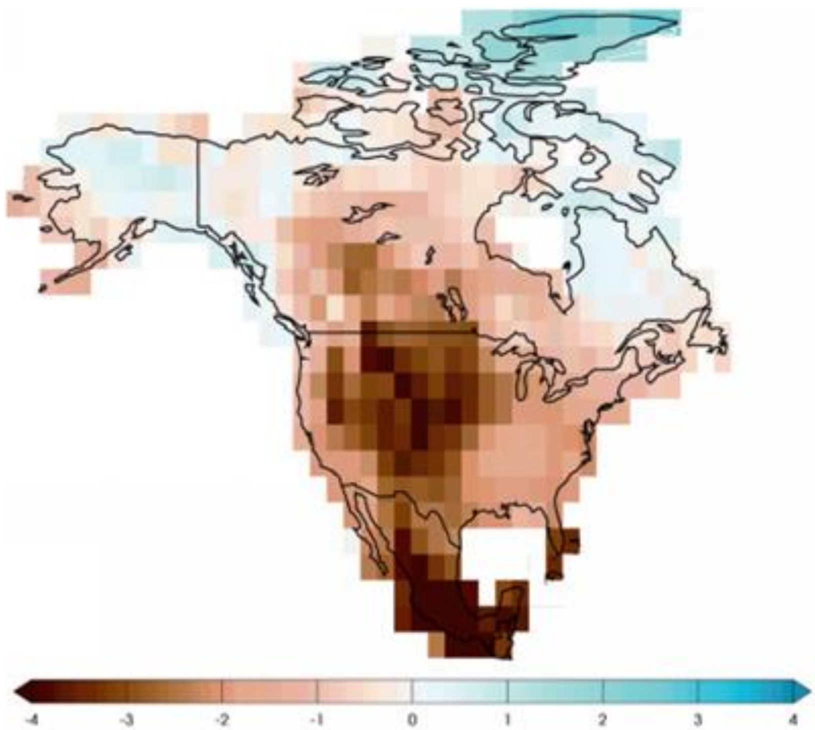


Figure 2-2. Projected Multimodel Mean PDSI averaged over the period 2089-2098 for North America from 19 Climate Models (Wehner et al. 2011)

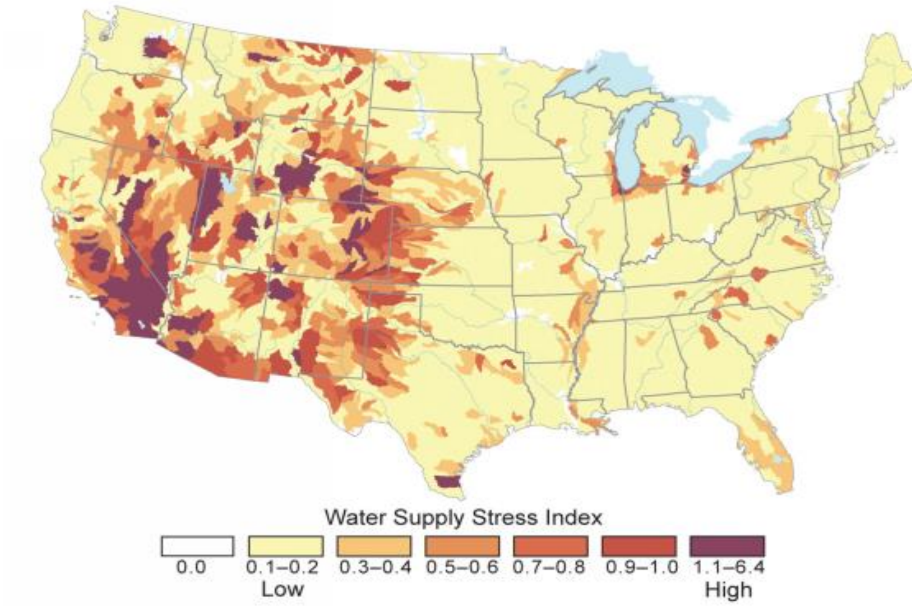


Figure 2-3. Water Supply Stress Index in the United States 1900-2008 (Averyt et al. 2011)

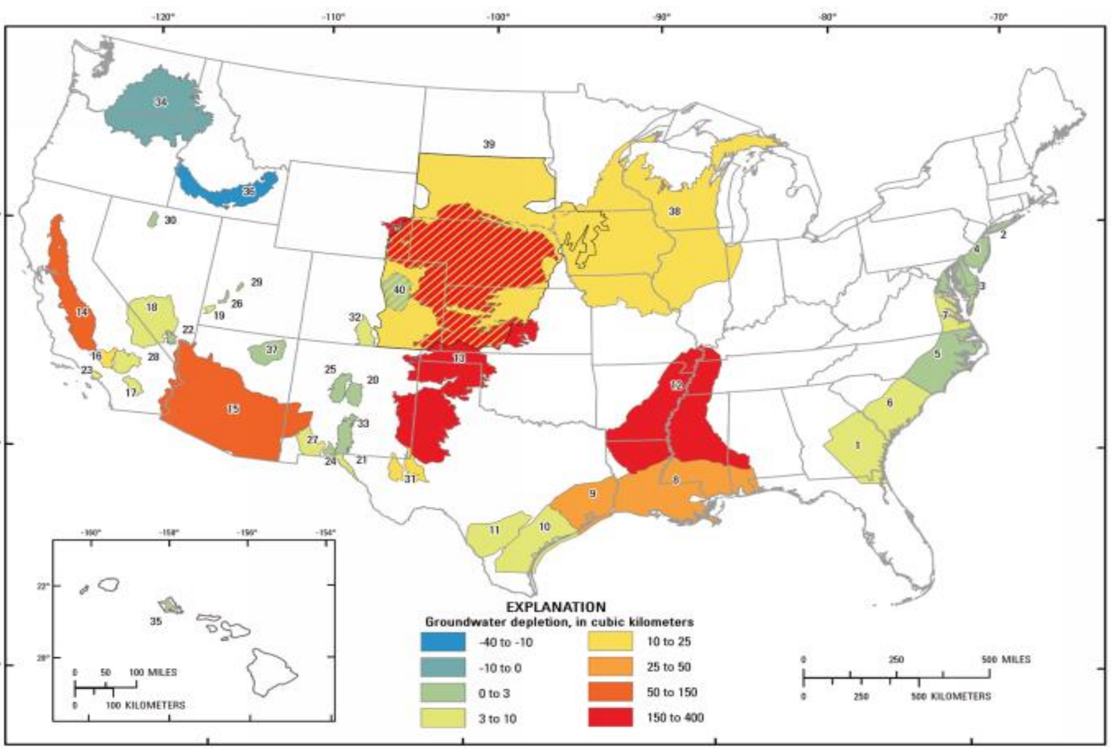


Figure 2-4. Cumulative Groundwater Depletion, 1900-2008 in 40 Assessed Aquifers in the United States (Konikow 2013).

2.2 PROGRAMMATIC CONSIDERATIONS

FEMA is currently evaluating projects for consistency with the HMA programs to mitigate risks associated with climate change, including drought conditions, in addition to the traditional (flood, wildfire, high wind events) hazards traditionally funded through the HMA programs. The project types explored in this paper address flooding and drought, but also may have benefits beyond hazard mitigation including water quality and supply as well as ecosystem services which are defined and discussed in **Section 2.3**. This fact will require FEMA to make programmatic considerations in regards to funding.

Mitigation activities funded through HMA grants are required by statute and regulation to be cost effective. This is demonstrated through a BCA and the calculation of a Benefit Cost Ratio (BCR), which divides total discounted annualized project benefits by total project cost, including annual O&M costs. Projects where benefits exceed costs are considered cost effective. Traditionally, FEMA evaluates potential mitigation projects based on their ability to reduce impacts from natural hazards. As a minimum, projects funded through HMA must demonstrate an ability to reduce risk to people, structures, or infrastructure. Each of the projects evaluated in this paper provide additional benefits in two ways:

1. All of the projects provide benefits related to a reduced risk to elements outside of people and infrastructure, such as to the environment, from natural hazards

2. Some of the projects provide benefits unrelated to hazard mitigation, such as an increase in water supply capacity for day-to-day conditions.

For example, ASR can provide for additional water supply both to meet the basic needs of a community and for drought conditions. Floodwater diversion and storage provides environmental benefits through the creation of open space, riparian habitat or wetlands. Based on FEMA's current practices for inclusion of environmental benefits in a BCA (at least 75 percent of the benefits have to be related to a reduction in risk to people or infrastructure), FEMA may want to evaluate the ratio of hazard mitigation benefits provided by each project to people and infrastructure to the benefits provided to the environment or non-hazard mitigation benefits for eligibility purposes.

For all project types, other Federal agencies (OFAs) have programs that support the funding of these project types, though often for water quality or supply purposes. Coordination between FEMA and the OFAs to identify approaches to coordinate and align HMA funding or, at a minimum, to avoid a duplication of programs will be needed.

When performing a BCA for a project funded by multiple agencies, it would likely be performed to evaluate all benefits, not just those considered programmatically acceptable by FEMA. Therefore, if FEMA determines that it will fund these projects in conjunction with an OFA, the ratio of hazard mitigation benefits may provide a way to evaluate funding contributions. For example, a project that primarily improves water supply capacity may both support the community's water supply under normal conditions, as well as provide for additional supply during times of drought. FEMA may want to contribute funds based only on the amount of additional water supply needed for drought. One challenge to this approach would be the difficulty in establishing a recurrence interval for drought, as discussed above. However, several methodologies may be utilized to provide a reasonable estimate for the BCA including: analyzing stream flow records, precipitation, Standardized Precipitation Index (**Table 2-1)** through climate models, or other methodologies justified as appropriate by the subapplicant. The analysis to isolate the benefits due to the need for water supply during drought would require a technical professional, such as an engineer, and sufficient support data. Therefore, not all communities may be equipped to perform this analysis. Programmatically, FEMA may want to consider a phased-project approach in this situation. The evaluation of each of the projects included in this report was performed based on the assumption that a recurrence interval of the drought will be determined.

There may be another option to demonstrate cost-effectiveness. If FEMA agrees that a project shown to be cost-effective in general (not based only on the benefits related to hazard mitigation) is eligible, then the need for a hazard mitigation project could be further justified based on qualitative criteria, such as the water stress maps or drought severity. For example, as ASR project might be shown to be cost-effective based on the additional amount of water supply made available to the community for all of its needs. If such a project were shown to be in an area of high drought risk, FEMA may consider funding the project (or contributing funds in conjunction with another Federal agency). If the phased project approach is used, it may also be possible that this method be used for initial application until a more detailed analysis could be completed.

The scale (size and cost) of the projects evaluated in this paper can be adjusted based on a community's needs as well as the natural hazard risk, but the HMA requirements of a 3-year period of performance for implementation must also be considered. The scale of the projects affects the timeframes for implementation and effectiveness to be realized, therefore consideration of HMA programmatic requirements are necessary to ensure a project is completed within the grant specified time frames (36 months). While the PDM program allows non-localized flood reduction projects, the scale should also be considered in terms of programmatic eligibility for Floodwater Diversion and Storage and Floodplain and Stream Restoration and Low Impact Development / Green Infrastructure. It must also be confirmed that the projects do not constitute a section of a larger flood control system or duplicate the flood prevention activities of other Federal agencies on the same site.

The scale of the project can also greatly impact the level of EHP review required and this consideration should be evaluated early in the grant application and review process. Depending on the scale of the projects related to Floodwater Diversion and Storage, Floodplain and Stream Restoration, and Low Impact Development / Green Infrastructure, a Categorical Exclusion (CatEx) may be appropriate. However, for larger scale projects, and Environmental Assessment (EA) or Environmental Impact Statement (EIS) may be required. ASR projects typically require an EA, but projects where special studies are required to evaluate potential impacts may require an EIS.

2.3 ECOSYSTEM SERVICES BENEFITS

As explained in Section 2.2, the projects evaluated in this paper provide benefits to elements other than people or infrastructure that could be considered in a BCA, such as ecosystem services. Environmental economists interpret ecosystem services as market and nonmarket goods and services. The market value of environmental goods is easily derived through data collected on price and quantity. Potable water, fish production, or agricultural products fall within this category of goods that are sold in markets. Many other important services, such as hurricane buffering, flood protection, recreation, aesthetic value, and water quality, are not physical goods, but services and, because of their non-physical nature, they cannot be (or cannot easily be) traded in markets. Measuring these nonmarket services presents a more complicated task, but these values can be estimated.

2.3.1 Benefits for Restoration of Natural Land Uses

The total annual value of ecosystem services for Green Open Space and Riparian land use areas are currently in use in the FEMA BCA Tool. Updated and new values and a detailed discussion of the methodology used can be found in the *Update to FEMA Ecosystem Services Values* (CDM Smith 2015b) prepared in conjunction with Earth Economics, and are presented in **Table 2-2**. Ecosystem values can be used when a mitigation project creates or restores an area of land to the land-use types listed in **Table 2-2** and can be included in a FEMA BCA if the traditional benefits (based on a reduction of risk to infrastructure or people) of the proposed mitigation project produce a BCR of 0.75 or higher.

Table 2-2. Updated Ecosystem Service Matrix per Acre per Year (US$ 2014)

Ecosystem Service	Green Open Space	Riparian	Forest	Wetland	Marine and Estuary
Aesthetic Value	$1,707	$612		$3,640	
Air Quality	$215	$226			
Biological Control		$173			
Climate Regulation	$61	$81	$153	$136	$63
Erosion Control	$68	$12,042			
Flood Hazard Reduction		$4,215	$321		
Food Provisioning		$641			
Habitat		$878			$1,214
Nutrient Cycling				$536	$522
Pollination	$305				
Recreation/Tourism	$5,644	$15,967			
Stormwater Retention	$308				
Water Filtration		$4,473		$1,406	
Water Supply		$237	$80	$292	
Total Annual Value	$8,308	$39,535	$554	$6,010	$1,799

Source: CDM Smith 2015c.

2.3.2 Benefits for Water Supply and Drought Resiliency

The project types analyzed in this paper may also provide ecosystem services associated with increased water supply, including drought resiliency. A value has been calculated for two related benefits:

1. $101 per 1 million gallons of water in avoided costs of stormwater conveyance and treatment infrastructure

2. $3,455 per 1 million gallons of water for which there is an avoided cost of building infrastructure of alternative public drinking water supplies;

These values can be used for mitigation actions that result in more groundwater infiltration and/or aquifer recharge as reduced stormwater runoff may help avoid investment in expensive stormwater systems. Additionally, this recharged water becomes available for human consumption and the benefit reflects the value of the avoided costs associated with compromised potable water supply through the availability of alternative water supplies.

The value of water is relatively inelastic, therefore the value presented for potable water supply does not incorporate the variation of per capita consumption by region or the likely increased value of water in areas with a higher water supply stress index. Further study would be necessary to incorporate regional adjustments to the current FEMA loss of function value if desired. This would include modifying the FEMA standard value of potable water supply based on a water supply stress index. Potential datasets that would be evaluated include data from the NOAA National Climatic Data Center and American Water Works Association water supply data (NOAA 2014b, AWWA 2013). Additionally, it is currently unknown how the immediate scarcity of water supply would directly affect the value of potable water supply and it is believed that, in general, the value of water does not increase in the short-term (this could include seasonal variations or droughts that may only last one or two years). Currently, data available with respect to droughts is related to short-term drought, and in general water supply rates will not change because the conditions return to normal in the short-term, before water supply rate adjustments can be implemented to reflect the shortage. Alternatively, further study related to drought surcharge rates could provide information on the increased value of water supply during periods of water restrictions. Water utility rate surcharges are used relatively infrequently, but in certain circumstances can be placed into effect for limited periods of time to manage demand or provide revenue (AWWA 2012).

A further discussion of the methodology used to estimate the values is available in the Ecosystem Services of Drought Mitigation report prepared by CDM Smith in collaboration with Earth Economics (CDM Smith 2015b). However, it is important to note that the use of these values is currently under consideration by FEMA and a determination that they are appropriate for use in the BCA is needed before they can be applied for any project type.

SECTION THREE CLIMATE CHANGE ADAPTATION PROJECT OPTIONS

Each of the four project types is summarized in a "Climate Resiliency Snapshot" to provide an overview of the implementation considerations, costs, and benefits, as previously presented in the first phase of the OGSI evaluation (CDM Smith 2015a). **Table 3-1** provides a guide to the snapshot components.

CLIMATE RESILIENCY SNAPSHOT GUIDE		
Criteria	**Description**	**Features and Attributes**
Climate Change Risk Factor	Consequence of climate change impact	Flooding, Sea Level Rise, Storm Surge, Extreme Precipitation, Drought, Water Quality
Additional Benefits	Climate change risk factor that may be additionally addressed as a result of project implementation	Flooding, Sea Level Rise, Storm Surge, Extreme Precipitation, Drought, Water Quality
Project Type	Type of project proposed for implementation	Policy, Research/Study, Ordinance/Zoning, Program, Outreach/Education, Planning, Design, Construction, Operations
Project Timeframe	Timeframe for project implementation	Short-term *(within 3 years)* Mid-term *(3-5 years)* Long-term *(more than 5 years)*
Effectiveness Timeframe	Timeframe for project to start mitigating impacts once implemented	Short-term *(within 3 years)* Mid-term *(3-5 years)* Long-term *(more than 5 years)*
Technical Feasibility	Feasibility of project implementation and ability of project to independently mitigate identified risk	**Low:** Unproven implementation and only provides a partial solution to identified problem **Medium:** Proven implementation but only provides a partial solution to identified problem **High:** Proven implementation and provides significant solution to identified problem
Environmental Consistency	Level of consistency with existing and potential Federal, State, and local regulatory programs	**Low:** May not be consistent with regulatory programs or risky permit process **Medium:** May not be consistent with regulatory programs, but good case exists for update, and is otherwise a low-risk permit process **High:** Consistent with regulations and low-risk permit process
Economic Reasonability	Qualitative likelihood of project being considered cost effective	**Low:** Costs exceed benefits **Medium:** Costs equal benefits **High:** Benefits exceed costs
Social and Political Acceptability	Level of community and institutional understanding and acceptance of the project	**Low:** Not likely to be locally supported without focused public outreach and education **Medium:** Likely to be supported, but would benefit from public education component **High:** Generally understood and supported, but should include outreach component
Sustainability	Benefits to multiple infrastructure sectors and/or jurisdictions	**Low:** Project may only benefit one community or infrastructure sector **Medium:** Limited to one infrastructure sector but has potential to benefit multiple communities **High:** Benefits more than one sector and potentially more than one community
Financial Need	Ability of jurisdictions to fund projects without Federal assistance	**Low:** Funding mechanisms already in place among other grant programs or local revenue sources **Medium:** Need for Federal government to leverage other funding mechanisms **High:** Clear role for the Federal government to fill funding needs among jurisdictions

Table 3-1. Climate Resiliency Snapshot Guide

3.1 AQUIFER STORAGE AND RECOVERY

3.1.1 Description

ASR is taking water when it is abundant, storing the water in the subsurface in brackish aquifers, and recovering the water when needed. ASR is a drought management tool that has all of the benefits of a surface reservoir but does not have evaporative or seepage losses and provides better protection of the injected water quality than a surface reservoir. Once implemented, ASR systems help to supplement water supplies and mitigate the effects of drought. In addition, ASR systems can provide flood control and water quality benefits. A Climate Resiliency Snapshot for ASR is provided on **Figure 3-1**. **Figure 3-2** is a schematic of a single ASR well operation. During times of abundant or excess water availability, fresh water is pumped (injected) into the aquifer storage zone, deep below the ground surface, to create a "bubble" of stored fresh water. Due to differences in water quality (e.g., chlorides) a "mixing zone" is created between the injected water and native groundwater. During periods of drought, high demand, or when additional water supply is required, the stored water is pumped out of the aquifer (recovered), treated, and utilized as a freshwater supply. Typically, in ASR systems, water is pumped and recovered from the same ASR well.

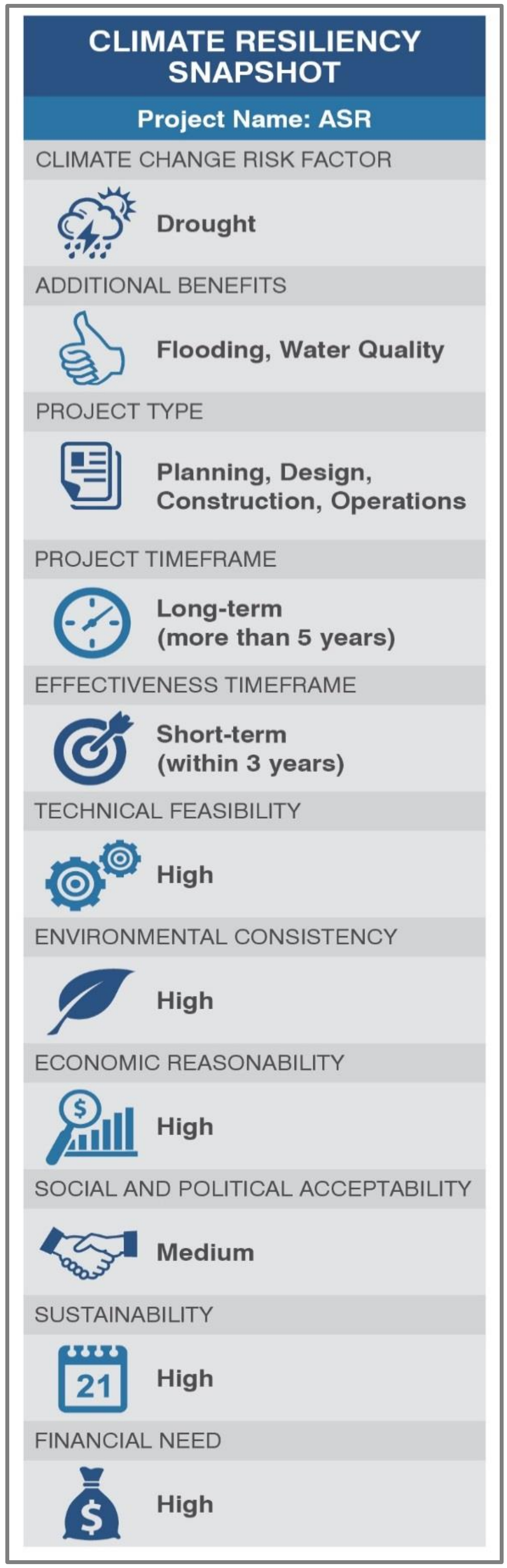
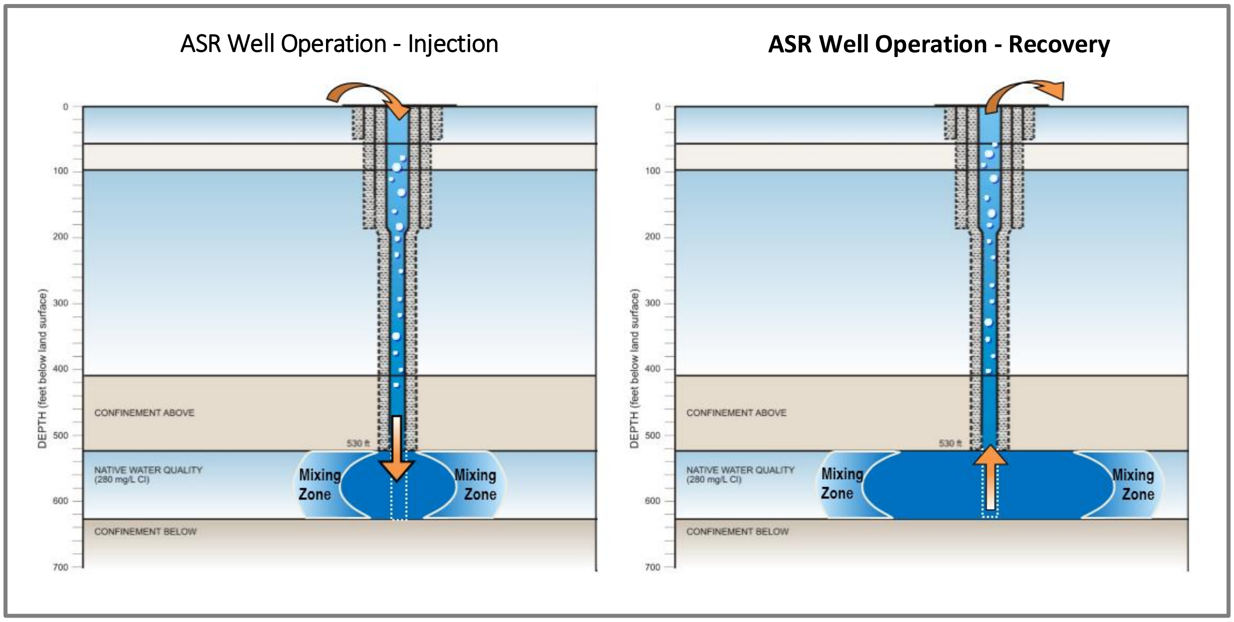


Figure 3-1. ASR Snapshot

ASR has been used in the United States for over 30 years (Muniz et al. 2003). The oldest operating system in the U.S. is located in Wildwood, New Jersey and has been operational since 1967 (Bloetscher et al. 2014). According to a 2013 survey of the status of ASR in the U.S., over 50 sites in at least 26 states have either used or investigated the use of ASR, and worldwide, there are over 100 operational ASR facilities (USGS 2015). **Figure 3-3** shows the locations of ASR sites in the U.S. as of 2013 (Bloetscher et al. 2014). Different source waters have been injected into the various aquifers in the U.S, including finished drinking water, raw and partially treated surface water, raw groundwater, and reclaimed water. ASR systems can be operated such that the recovered water is used to satisfy seasonal demands or water can be stored over several years, recovering only a portion of the water but leaving a significant quantity of stored water to meet demands during drought conditions. Given the ability to utilize multiple types of source water for implementation, ASR systems can be designed and operated to help mitigate the effects of increased demand and drought in a variety of communities across the country, all which have different needs and constraints.

Aquifer Recharge and Recovery (ARAR) is considered a subcategory of ASR. Instead of a single well for injection and recovery, ARAR involves using one well for aquifer recharge and a second, downgradient well for recovery. Alternatively, infiltration via a surface water basin can be used as the source of aquifer recharge instead of an injection well. **Figure 3-4** is a schematic of an ARAR system (Archuleta 2014). In an ARAR system, the water source is directly injected (for unconfined or confined aquifers) or allowed to infiltrate through the unsaturated zone for unconfined aquifers. Infiltrated water helps replenish groundwater supplies, mixes with native groundwater, and slowly flows through the aquifer. At some downgradient location, the groundwater is extracted from the aquifer by production/recovery wells and utilized as a freshwater supply.



Source: CDM Smith.

Figure 3-2. Typical ASR Well Operation

Source: Bloetscher et al. 2014.

Figure 3-3. Operational ASR Sites in the United States in 2013

Source: Archuleta 2014.

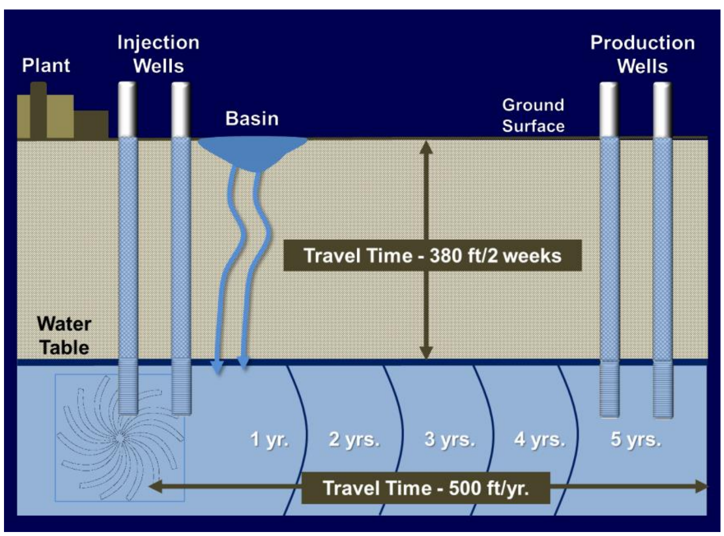


Figure 3-4. Typical ARAR System Operation

3.1.2 Feasibility and Effectiveness

While widely used in the U.S. and around the world, there are potential challenges that can be associated with ASR, including less than desirable recoverable efficiencies due to improper selection of the storage zone and arsenic leaching from the aquifer storage zone matrix upon recovery of the injected water. However, better hydrogeologic assessment techniques have improved proper selection of storage zones. The more saline the native groundwater in the aquifer storage zone is relative to the injected fluid, the lower the recovery efficiency due to mixing; therefore, there are some tradeoffs to be considered in this regard.

Arsenic leaching has been a challenge to some ASR projects in the U.S. Two factors have influenced this. Arsenic is commonly part of a naturally occurring mineral called pyrite in many unconfined and confined aquifers. Under natural conditions, groundwater exists under reduced conditions, and arsenic is bound up in the pyrite matrix. However, potable water, partially treated surface water, and reclaimed water are typically highly oxidized due to the treatment and disinfection process. When these waters are injected into aquifers and pyrite is present, arsenic is released into the stored water, and when recovered, the arsenic concentrations are sometimes elevated, exceeding the drinking water limit of 10 micrograms per liter (μg/L). Over the last 10 years, technologies and strategies have been implemented to minimize or prevent the arsenic leaching altogether when using potable water, partially treated surface water, and reclaimed waters as a source of supply. Also, recent regulatory relief under certain settings from the USEPA has helped with this issue. The USEPA has been supportive of ASR and allows for arsenic leaching in the Underground Source of Drinking Water (USDW) if the stored water is wholly contained within the ASR project owner's property and the stored volume is controlled by the owner. If the recovered water has elevated arsenic concentrations, the recovered water can be blended with a secondary source (potable water or reclaimed water) to meet the regulatory limit for arsenic prior to using the water.

Since ASR is a subsurface storage technology, it is more resilient and better able to mitigate the effects of climate change than alternative and more traditional storage technologies such as reservoirs or surface impoundment. The stored water in an ASR system is protected from evaporation, potential pollution from atmospheric deposition and animals, and protected during extreme weather conditions such as droughts and hurricanes. ASR application can be beneficial to the environment and significantly cost effective relative to alternative storage technologies by eliminating or reducing the land area that would be required. Also, unlike surface reservoirs, there is no potential for levee failure and downstream catastrophic flooding, which could occur during periods of extreme rainfall. ASR also has the benefit of aquifer recharge and can be used as a barrier for saltwater intrusion to protect freshwater supplies along coastal areas.

3.1.2.1 ASR Systems

Depending on the location of the injection/storage zone relative to the USDW, defined as having groundwater with a total dissolved solids (TDS) concentration of 10,000 milligrams per liter (mg/L) or less, the quality of the source water to be injected (finished water, raw groundwater, untreated or partially treated surface water, or reclaimed water) influences the technical considerations. For most ASR projects, either finished treated water, untreated, or partially treated surface water is injected into a brackish (TDS concentration >10,000 mg/L) groundwater aquifer above the USDW. There are very few ASR projects using untreated groundwater or reclaimed water as the source of recharge for an ASR well. For ASR projects injecting above the USDW, the goal is to store and recover the injected fluid with minimal mixing with native groundwater. The following criteria define the technical considerations for these types of ASR systems, and **Attachment 2** provides guidance on quantification of these metrics:

- There is good hydrogeological confinement above and below the target storage zone to minimize vertical flow.

- There is a sufficient density contrast between the injected fluid and the native groundwater in the target storage zone to keep the injected fluid close to the ASR well for later recovery and minimize the "mixing zone".
- Flow into and out of the storage zone is by matrix flow (i.e., water flow through permeable rock) rather than fracture flow (i.e., water flow through fractures or open voids in the aquifer) so that the storage zone can accept the recharged water at a reasonable rate but not so fast that the injected fluid quickly travels too far away from the ASR well.
- There are no nearby water supply wells that would induce movement or pull the injected fluid away from the ASR well.
- Native groundwater and aquifer matrix geochemistry is compatible with the injected fluid so that there are no adverse geochemical reactions that result in violation of drinking water standards or lead to aquifer clogging.

Typical pre-construction activities related to implementation of ASR projects are summarized in **Table 3-2**.

Table 3-2. Typical Pre-Construction Activities for Aquifer Storage and Recovery Projects

Phase	Components	Definition	Remarks
Planning	***Scope of Work***	Identify climate change risk factor (consequence of climate change) and effects related to degradation	Drought, Water Quality Improvement, and Flood Control
		Conduct Initial Assessment	Identify need for the mitigation project (scale and severity), describing work to be done and where the ASR Project will be located.
			Identify target aquifer and storage zone and volume of water to be stored
			Identify range of alternative solutions that are both feasible and acceptable to stakeholders
		Set goals and define objectives/benefits	Water supply augmentation and resiliency, can also be used for water quality protection (e.g., barrier for salt water intrusion)
		Identify risks and constraints for Implementation	Permitting requirements, land ownership and site access, water availability for storage, tolerance for risk/uncertainty, underground and overhead utilities, threatened and endangered species, public acceptance and potential for adverse water quality interactions between injected water and aquifer matrix.
	Data Collection	Major data types that are needed to conduct initial assessment and engineering evaluation of alternative solutions	Existing and future land use in and around the ASR site(s) including property setbacks
			An evaluation of supply versus demand under average conditions and high demand conditions including drought
			Topographic and Surveying data (Specific to the project extents, identifying utilities and other avoidance areas)
			Regional and site-specific hydrogeological Data (i.e., Aquifer properties and confinement)

Phase	Components	Definition	Remarks
			Source water quality data, native groundwater data and Aquifer matrix geochemical data
			An inventory of other users of the aquifer within a 1 mile radius of the proposed ASR Project
			Historical Streamflow and Stage (USGS) http://waterdata.usgs.gov/nwis/sw for projects using surface water as the source of supply for ASR
Assessment	***Data Evaluation***	Determine modeling tool(s) for use in engineering evaluation (pre- and post-project conditions)	Groundwater modeling tools may include: MODFLOW, SEAWAT and/or PHREEQC
			Hydrogeological evaluation
		Manuals and Guidance Documents	*Aquifer Storage and Recovery - A Guide to Aquifer Recharge through Wells* (Pyne, 2005); *Aquifer Storage and Recovery Manual of Water Supply Practices M63* (AWWA, 2015).
		Identify alternatives	Project scale and target storage volumes
		Establish design criteria	Define storage volume, injection rates, recovery rates, and number of wells
		Analyze compatibility of injected fluid with target aquifer storage interval	Characterize source water quality
			Characterize ambient aquifer hydrogeochemical conditions
			Complete geochemical modeling and determine the need for source water pretreatment
		Develop recommendations	Project alternatives
			Future data collection and analysis to support design
	ASR Feasibility Report	Conduct Desktop Feasibility of ASR Implementation	Evaluate and compare alternatives and make recommendation for selected alternative
	Confirm ASR Feasibility	Drill Exploratory/Test Well at Selected Site	Confirm Feasibility from Desktop Study
Design	***Basis of Design Report***	Document model methodology, results, and design recommendations	
	Construction Drawings and Specifications	Describe work to be performed, providing specific implementation strategies, construction details, and construction materials and equipment	Includes a 30%, 60%, 90%, and Final design process for selected alternative
	Create Bid Schedule (Cost Estimate)	List of pay items, their units of measurement, and estimated quantities for	

Phase	Components	Definition	Remarks
		proposed scope of work	
	Estimate Construction Schedule	Listing of a project's milestones, activities, and deliverables, with intended start and finish dates	
Environmental Planning and Historic Preservation (EHP)	***EHP Coordination and Compliance***	Coordinate efforts throughout each stage of design with FEMA and demonstrate compliance with EHP requirements	Conduct initial screening of current environmental and historic conditions to identify design constraints
			NEPA Determination (Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement)
			Meet with FEMA at 30%, 60%, and/or 90% design stages to discuss EHP considerations
			Provide copies of all documentation to FEMA of any environmental, historic, and archaeological consultation and permitting
Cost Effectiveness	***Project Cost Effectiveness***	Demonstrate project cost effectiveness using BCA methodology	Prepare BCA using data developed in the design process. Provide supporting documentation (figures and narrative) related to this analysis. Cost effectiveness is demonstrated when the benefits of a project exceed the costs (i.e., Benefit Cost Ratio > 1.0).
Permitting and Site Access	***Permitting Requirements***	List of permits to be acquired prior to initiation of construction and operation of project	Underground Injection Control Permit for a Class V Well; Water Use Permit from the appropriate State Agency for the source water withdrawal allocation; See Section 3.1.4 for a complete list of permits for ASR projects.
	Ownership/Land Rights/Site Access	Obtain site access and easements (acquire land as necessary) prior to initiation of construction	
Potential Challenges to Implementation	***Project Challenges and Resolutions***	Describe challenges and potential resolutions	Recovery efficiency, potential for adverse water quality interactions between source water quality and ambient aquifer conditions, and recovered water quality. Proper selection of the target storage interval and associated native water quality can help improve recovery efficiency. Pretreatment can be implemented to help control adverse water quality reactions. Planning on having sufficient property buffer around the ASR system to contain the injected storage volume entirely within the property owned by the utility or agency is very desirable in terms of managing adverse water quality interactions. Water Quality Criteria Exemptions are a good regulatory relief mechanisms and treatment of the recovered water for recovered water.

3.1.2.2 ARAR Systems

The goal of ARAR projects is to recharge or augment the quantity of water available from an aquifer that typically has been depleted of groundwater. For ARAR projects, the source water is typically an untreated or partially treated surface water or reclaimed water. The injected fluid then travels in the aquifer some distance and is recovered downgradient by separate production or extraction wells. The travel time in the aquifer is used to help improve the water quality and allow for mixing of the injected fluid and the native groundwater prior to extraction. Aquifers targeted for ARAR projects usually contain, freshwater with TDS concentrations of less than or equal to 500 mg/L. The following are technical and implementation considerations for ARAR systems:

- In confined aquifers, source water must be recharged through injection wells. However, for unconfined aquifers, either injection wells or spreading over infiltration basins can be used to recharge the water.
- Adequate travel time needs to be provided between the injection wells and spreading basins and the production or extraction wells.
- Native groundwater and aquifer matrix geochemistry must be compatible with the injected fluid so that there are no adverse reactions potentially resulting in violations of drinking water standards or leading to aquifer clogging.
- There are no nearby water supply wells that would induce movement or pull the recharged fluid away from the targeted production or extraction wells.

A 2003 American Water Works Association (AWWA) Research Foundation collaboration project with El Paso Water Utilities (EPWU) compared the efficiency and costs of injection wells and spreading basins for recharging fluids for an existing ARAR project. This study found that for unconfined aquifers spreading basins can be more efficient and economical to operate than injection wells. However, both technologies are still being used by EPWU.

The primary goal of a typical ASR and ARAR projects is augmentation of available water supply. However, the secondary goal of some ASR and ARAR projects is aquifer recharge. The primary differences between ASR/ARAR projects and floodwater diversion and storage projects is that the storage for ASR/ARAR projects occurs in the subsurface where storage prior to recharge for floodwater diversion and storage projects occurs at the land surface. Subsurface storage of the recharge water affords several advantages over surface storage such as no losses of water to evaporation and better protection of water quality.

3.1.3 Evaluation and Summary of Benefits and Costs

While ASR/ARAR may have water supply benefits for day-to-day use, it may be necessary to identify the hazard mitigation benefits of the project to ensure eligibility for FEMA funding. The BCA should be prepared defining and quantifying the severity of drought the project is designed to mitigate and then estimating the probability of the drought events. While estimating the probability of a drought can be difficult several methodologies may be utilized to provide a reasonable estimate for the BCA including: analyzing stream flow records, precipitation, SPI, through climate models, or other methodologies justified as appropriate by the subapplicant. Any climate projections incorporated into the probability analysis should have timelines consistent with the project useful life, which is expected to range from 30 to 40 years depending on individual site conditions and construction materials. Additionally, the methodologies utilized in the BCA should be consistent with the design criteria, that is, if the estimate is for 500 million gallons of water supply to be utilized in a severe drought, the design criteria should support the availability of the water and the system’s capacity to withdraw it.

3.1.3.1 Benefits

As a hazard mitigation project, ASR primarily enhances water supply resiliency during times of drought. If surface water is the source of water to be redirected to the aquifer, the project may also mitigate impacts of flooding by reducing peak stormwater flows.

The benefits due to a reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project.

The benefits related to increased water supply capacity can be captured based on the two values presented in Section 2.3.2. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

The increased groundwater baseflow provided by ASR may also reduce subsidence and therefore structural damage to facilities in the vicinity. There are many variables in the calculation of this benefit, and therefore it is not possible to create a standard value. Although it may be difficult, a subpplicant could quantify the benefits and provide proper documentation for inclusion in the BCA.

3.1.3.2 Costs

In the article *Economics of Managed Aquifer Recharge* (Maliva 2014), typical costs associated with ASR and ARAR projects are summarized, including implementation and O&M costs. The fixed, one-time implementation costs incurred during the design and construction of the ASR system include but are not limited to:

- Land acquisition
- Testing costs, feasibility analyses
- Consulting services for the design, EHP review and permitting, and supervision of the construction
- Construction costs (e.g., roads, piping, instrumentation, controls, and pretreatment systems)
- Regulatory testing requirements during construction and operational testing
- Although the O&M costs will not be funded by FEMA, they are required to be included in the BCA and therefore should be considered. O&M costs include the following:
- Labor (system operation, regulatory requirements, administration)
- Electricity
- Consulting services
- Regulatory testing requirements (e.g., water quality testing)
- Maintenance costs (e.g., parts replacement, well and basin rehabilitation)

- Pre-treatment costs (additional treatment prior to recharge)
- Post-treatment costs (e.g., chlorination)
- Raw water costs

According to rates developed by Pyne (2014) construction costs for ASR projects range from $0.50 to $2.00 per gallon per day ($0.5 to $2.0 Million per mgd of total ASR system capacity), which is on the low end of the range for water supply projects and other surface storage technologies such as reservoirs and ground storage tanks of comparable capacity. Engineering design and permitting costs for ASR projects will vary based on the scale and complexity of each project and typically range from 8 to 15 percent of the construction cost. For new ASR systems, the engineering design and permitting costs would tend to be on the higher end of the scale (i.e., closer to 15 percent of the construction cost) because an exploratory test well would need to be constructed to demonstrate that the selected storage zone is suitable and additional monitoring zone wells may be required. For existing, successfully operational ASR systems, the exploratory test well and associated data collection would not be required for a system expansion to enhance water recharge and the engineering design and permitting costs would be on the lower end of the scale. O&M costs for ASR projects range from $0.04 to $0.08 per 1,000 gallons of water produced (Black and Veatch 2008).

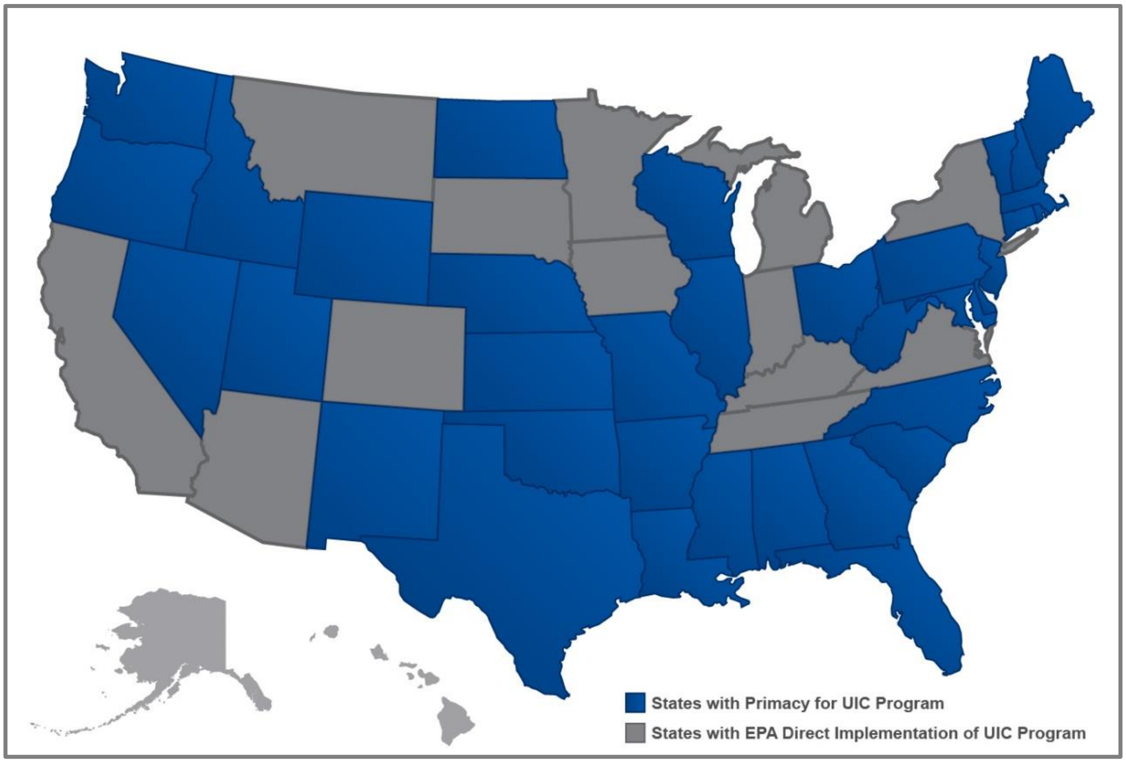
The implementation costs of an ASR project can vary based on existing conditions of the site and should be examined closely for HMA grant applications. For example, the project may leverage the use of existing wells, intakes and piping, which would reduce implementation costs. Also, hydrogeological investigations are required to accurately design the system. These could have a large impact on the project cost based on whether they are performed prior to a grant application period, or included in the grant application after the grant opening period. Environmental permitting as well as the documentation required to demonstrate EHP compliance may be prohibitive based on a variety of issues, as explained in Section 3.1.4. These should be considered early in the process.

Compared to other comparable scale water supply storage alternatives like reservoirs, ASR is more likely to be cost-effective. Reservoirs typically require a large land footprint and receive considerable opposition from the public and environmental groups during the planning and siting phase of the project. It is common to take anywhere from 10 to 30 years from project conception to the start of operation of a reservoir. Ongoing environmental monitoring and Environmental Impact Statements can take years for surface reservoir projects. Based on data from Pyne (2014), ASR implementation costs are competitive with typical costs for conventional water supply/treatment alternatives and lower than the cost for alternative water supply and surface storage, as noted below:

- Conventional Supply/Treatment – $0.50 to $5.00/gallons per day (gpd)
- ASR - $0.50 to $2.00/gpd
- Brackish Desalination – $2.00 to $5.00/gpd
- Seawater Desalination – $7.00 to $12.00/gpd
- Surface Reservoirs – $3.00 to $30.00/gpd
- Indirect Potable Reuse – $7.00 to $25.00/gpd

3.1.4 EHP Requirements

All recharge or injection of fluids directly into aquifers in the U.S. are regulated by the USEPA under 40 CFR Part 144 titled Underground Injection Control (UIC) Program. USEPA may delegate authority of this program to a state environmental agency as long as it develops rules and regulations that are at least consistent with USEPA rules. Title 40 CFR Part 145 presents the requirements for state UIC programs to have Primacy. Individual states may even have UIC programs more stringent than the USEPA's program. A listing of states that have Primacy is provided in Section 144.83, Federal Statutes. As of 2014, 34 states have Primacy, and 16 states have Direct Implementation Programs, where USEPA runs the Class V UIC Program. **Figure 3-5** shows the states that have Primacy and the states that have Direct Implementation. Even in states that have Primacy, USEPA is still copied on all UIC permit applications and given the opportunity to comment.



Source: 40 CFR. §144.83 2014.

Figure 3-5. Authority to Implement Underground Injection Control Program

As part of the USEPA UIC permit process, an applicant must demonstrate that the activity does not impact other users of the aquifer. A well inventory must be conducted within a certain radius of the proposed ASR system referred to as the "potential zone of endangering influence". Title 40 CFR Part 146 contains the UIC Program criteria and standards. A UIC Permit holder for an ASR project is not allowed to cause a water quality criteria violation for any user within the zone of endangering influence within the USDW. The UIC Program is focused on injection and storage of fluids in underground aquifers. The withdrawal of source water from aquifers and surface waters for injection or recharge is not regulated under the UIC Program. State agencies that issue water use permits typically have programs that evaluate withdrawals against water resources or environmental constraints such that the withdrawal cannot impact wetlands; other users; minimum levels or flows established for aquifers, surface waters, and springs; and cannot induce the movement of pollution and other criteria. As discussed in Section

3.1.2, one of the challenges with ASR systems is arsenic leaching, which can cause arsenic concentrations in the recovered water to exceed the drinking water limit of 10 μg/L.

A due diligence evaluation is typically performed during a preliminary desktop feasibility study for siting of an ASR project. As with any development project, early screening for natural and cultural resources and avoidance through design may reduce potential impacts and allow for a lower level of EHP review (i.e. an EA rather than an EIS). Then, an exploratory test well is drilled to confirm that the hydrogeology is favorable for a successful ASR project. If there is evidence that the site is a historic or archaeological significant site, then the location of the ASR site should be relocated. Similarly, facilities may be sited to avoid sensitive fish and wildlife and designated critical habitats, thereby reducing potential impacts and the necessary level of EHP review. ASR facilities are typically located near water treatment plants but can also be located remotely near the potable water or reclaimed water distribution system, depending on the type of source water.

ASR facilities would not typically qualify for a CatEx because they do not fit into the categories of actions described in 44 CFR 10.8. Most local-scale ASR facilities and those closely associated with an existing municipal treatment facility would likely be covered by an EA. However, proposals that are regional in scope that may adversely affect natural or cultural resources, or where special studies are required to evaluate potential impacts may require an environmental impact statement (EIS). For example, an EIS was prepared for the Kissimmee River project described below in Section 3.1.7.2 because of the large scope of the project and the number of unknown factors requiring special studies. ASR projects may also be controversial due to the potential for water quality impacts. If there is a high degree of public controversy an EIS may be recommended because of the more extensive public process associated with an EIS.

Because the scope of an ASR project may vary widely from a minimum of two wells close to a developed facility to a large regional project encompassing multiple wells and spreading basins in previously undeveloped lands, the costs associated with EHP reviews may also vary widely. The EHP review for a small project for which potential concerns are easily reviewed through online or desktop resources may cost as little as $20,000. Average costs for an EA of moderate complexity tend to be approximately $50,000. Average costs for an EIS vary widely depending on the variety of special studies and field surveys required and the level of controversy and they can range from $1M to $5M or more. A careful screening process conducted early in the project review can identify potential issues for consideration in an EIS and help to define potential costs before a commitment is made to fund project development.

3.1.5 Potential Coordination with Other Federal Agencies

Since ASR is often considered a sustainable, environmentally friendly, alternative water supply option, there are currently several Federal programs that have or could potentially fund ASR projects. This presents an opportunity to coordinate and align HMA funding, but may also require consideration of duplication of program concerns.

3.1.5.1 U.S. Department of the Interior - Bureau of Reclamation

Operating in the Western United States, the U.S. Department of Interior's Bureau of Reclamation's mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. The Bureau of Reclamation offers several grant opportunities that may be available for utilities or other entities interested in implementing ASR projects.

WaterSMART

Through the WaterSMART (Sustain and Manage America's Resources for Tomorrow) Grants (formerly Challenge Grants), the Bureau of Reclamation provides 50/50 cost share funding for sustainable water supply projects, including those that address climate-related impacts on water or prevent any water-related crisis or conflict. To participate in the WaterSMART program, applicants must provide at least 50 percent of the total project costs from non-federal sources, either in cash or as in-kind contributions. Total Federal funding (Bureau of Reclamation and all other Federal sources) cannot exceed 50 percent of the total estimated project cost. Additional information can be found at http://www.usbr.gov/WaterSMART/weeg/index.html

Title XVI

Through the Title XVI program, the Bureau of Reclamation identifies and investigates opportunities to reclaim and reuse wastewaters and naturally impaired ground and surface water. Title XVI includes funding for the planning, design, and construction of water recycling and reuse projects on a project-specific basis in partnership with local government entities. Through the Title XVI program, Applicants must be willing to cost share 75 percent or more of the total project costs. The cost or value of in-kind contributions that have been or will be relied on to satisfy a cost-sharing or matching requirement for another Federal financial assistance agreement, a Federal procurement contract, or any other award of Federal funds may not be relied on to satisfy the cost-share requirement for Title XVI projects. Although these grants focus on water reclamation and water reuse, ASR and ARAR projects could be implemented into these projects as well. Additional information can be found at http://www.usbr.gov/WaterSMART/title/index.html

Drought Response Programs – Resiliency Projects

The Bureau of Reclamation's Drought Response Program supports a proactive approach to drought. It provides assistance to water users for drought contingency planning, including consideration of climate change information and to take actions that will build long-term resiliency to drought. Drought resiliency projects, also referred to as "mitigation actions," help communities prepare for and respond to drought. To be eligible, projects must be supported by an existing drought contingency plan. The Bureau of Reclamation provides funding (up to $300,000 per Applicant) on a 50/50 cost-share basis. The Federal share (the Bureau of Reclamation's share in addition to any other sources of Federal funding) of any one proposed project shall not exceed 50 percent of the total project costs. Projects identified must result in long-term benefits that will build resiliency in the future and meet one of the following goals: increase the reliability of water supply and sustainability; improve water management; implement systems to facilitate voluntary sale, transfer, or exchange water; and provide benefits for fish, wildlife, and the environment. Additional information can be found at http://www.usbr.gov/drought/

3.1.5.2 U.S. Environmental Protection Agency

The USEPA offers several grant opportunities that may be available for utilities or other entities interested in implementing ASR projects.

USEPA Drinking Water State Revolving Fund

The Safe Drinking Water Act, as amended in 1996, established the Drinking Water State Revolving Fund (DWSRF) to make funds available to drinking water systems to finance infrastructure improvements.

Through the DWSRF program, each state and Puerto Rico maintain revolving loan funds to provide independent and permanent sources of low-cost financing for a wide range of public health protection projects, including water supply resiliency. The program also emphasizes providing funds to small and disadvantaged communities and to programs that encourage pollution prevention as a tool for ensuring safe drinking water. Since the program is managed by the states, project funding varies according to the priorities, policies, and laws within each state. Eligible applicants also vary by state. Additional information can be found at http://water.epa.gov/grants_funding/dwsrf/index.cfm

3.1.5.3 U.S. Army Corps of Engineers

Under its civil works program, the USACE plans, builds, operates, and maintains a wide range of water resource facilities. Its civil works responsibilities are principally to support navigation, reduce flood and storm damage, and protect and restore aquatic ecosystems. Since 1992, Congress also has authorized USACE participation in select environmental infrastructure projects (e.g., municipal water and wastewater treatment systems) and other nontraditional activities. Because environmental infrastructure projects fall outside the typical USACE missions, there are no clear general eligibility requirements. Typically, Congress has authorized USACE assistance for projects in a specific geographic location (e.g., city or county). Most environmental infrastructure projects are financed 75 percent Federally and 25 percent locally (Carter et al. 2015). The Federal portion is typically provided or authorized by Congress to the USACE while specifics of the management of the non-federal portion varies by project. A project will be approved only if there is Congressional authorization for work in the specified area and the activity undertaken is covered by that authorization. The USACE has been evaluating ASR options with the South Florida Water Management District (SFWMD) as part of Everglades restoration to enhance water storage in and around Lake Okeechobee.

3.1.5.4 U.S. Department of Agriculture

The USDA Rural Development program's mission is to help improve the economy and quality of life in rural America and offers funding opportunities to rural communities that may be interested in implementing ASR projects to provide water supply resiliency.

Water and Environmental Program

The USDA Rural Development Water and Environmental Program provides loans, grants, and loan guarantees for drinking water and other public utility facilities in rural areas and cities and towns of 10,000 or less. In addition, the Program provides Emergency Community Water Assistance Grants of $500,000 to assist rural communities that have experienced a significant decline in quantity or quality of drinking water due to an emergency, including drought, or in which such decline is considered imminent to obtain or maintain adequate quantities of water that meet the standards set by the Safe Drinking Water Act. Example projects that have been funded include new wells, reservoirs, transmission lines, treatment plants, and/or other sources of water. Additional information can be found at http://rurdev.sc.egov.usda.gov/UWEP_HomePage.html

3.1.5.5 3.1.5.5 U.S. Department of Housing and Urban Development

The U.S. Department of Housing and Urban Development (USHUD) several grant opportunities that may be available for communities interested in implementing ASR projects for the purpose of long-term water supply security.

Community Development Block Grant Program

USHUD Community Development Block Grants (CDBGs) are programs that may provide grants for long-term needs to rehabilitate, construct, or buy public facilities/infrastructures such as water and sewer systems. In the past, these grants have been used to develop new water sources, improve treatment, and replace distribution pipes; therefore, it is feasible that development of an ASR project would qualify. Recipient communities must spend at least 70 percent of their funds for activities that benefit low- and moderate-income persons. Grantees may fund activities that meet community development needs of particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community and other financial resources are not available to meet such needs. CDBGs may be used to match FEMA grants.

In addition, in response to specific disasters, Congress may appropriate additional funding under CDBG Disaster Recovery grants to rebuild in Presidentially Declared Disaster areas and provide crucial seed money to start the recovery process. Among eligible activities used for recovery efforts under CDBG Disaster Recovery funds are several relating to infrastructure, including construction/reconstruction of water systems.

CDBG Section 108 loan guarantees provide communities with a source of financing for public facilities, economic development, housing rehabilitation, and large-scale physical development projects. It allows local governments to transform a small portion of their CDBG funds into Federally guaranteed loans large enough to pursue physical and economic revitalization projects.

Additional information on the CDBG programs can be found at http://water.epa.gov/infrastructure/watersecurity/funding/fedfunds/hudcgrants.cfm and http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs

3.1.6 Summary of Programmatic Considerations

The primary benefit of an ASR/ARAR project is the increased availability of water supply, which from a hazard mitigation perspective, is beneficial in terms of drought resiliency. If surface water is captured and used as a source for the aquifer, the project may also result in reduction in flood damages. Therefore, the project may be an effective, stand-alone mitigation activity to reduce losses to infrastructure and protect public health and safety. However, from a HMA program standpoint, it may be important on a project-by-project basis to establish the need for the additional water supply (to meet demands under normal conditions versus drought). Although there are challenges to determining recurrence intervals for drought scenarios in a specific location, FEMA may consider some requirements to demonstrate the risk of drought to justify an ASR project as mitigation. This may also prove to be a challenge for the BCA if FEMA would prefer to quantify the benefits due only to hazard mitigation.

While the project can be sized based on needs of the community, HMA requirements of a 3-year period of performance for implementation should be considered. Also, the siting of the ASR project depends greatly on the source water. If surface water is used to also align the project with flood mitigation objectives, there may be floodplain regulations to consider. It is not likely that a CatEx can be applied to reduce the EHP requirements for review of the project, therefore early screening of the site is recommended to determine if an EA or and EIS would be likely based on project complexity.

While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing implementation and drought resiliency throughout the U.S.

3.1.7 Example Implementation Success Stories

3.1.7.1 City of Cocoa, Florida ASR System

The City of Cocoa has one of the longest operating ASR projects in Florida (**Photo 3-1**). Initially (1991-1999), the city was using groundwater treated to potable standards as the source of supply for the ASR system. In 2000, the city began augmenting their groundwater supply with surface water from the Taylor Creek Reservoir, treating this supply to potable standards and blending the water. From 2000 through the current time, treated and blended water from both sources has been recharged, stored, and recovered from the city's ASR System. The city's operational concept for their ASR system was to store finished water during periods of low demand and recover during periods of high demand.

Photos of the ASR wells in the City of Cocoa, Florida.

Photo 3-1. City of Cocoa, FL ASR Wells

Six ASR wells, each capable of pumping 1 million gallons per day (mgd) were constructed around the Claude H. Dyal Water Treatment Plant (WTP) between 1984 and 1989. The storage zone for the wells is the Upper Floridan aquifer, occurring at depths between 300 and 370 feet below land surface (bls). The Upper Floridan aquifer at the WTP site contains brackish groundwater, and vertical confinement above the storage zone is provided by the regional Intermediate Confining Unit (Hawthorn Group Formation). The six ASR wells began storing and recovering water in 1991. The recovery efficiency from these six wells was high and proved to be very valuable in helping the city meet high demands. In 1998, the city added four new ASR wells to their existing ASR wellfield. Construction cost information was not readily available for the first six ASR wells because of the age of those projects; however, construction costs for the four ASR wells added in 1998 were available. The construction cost for these four wells was approximately $921,000 (in 1996 dollars), including site work, well equipment, structural and electrical components, and well drilling. Since the components and construction details for all four wells were very similar, the construction cost for a single well can roughly be estimated as a quarter of the total construction cost, or approximately $230,000 (in 1996 dollars). Also, because these wells were constructed as an expansion of an operational and successful ASR system, some activities (e.g., test well and associated data collection) were not required and the total costs were lower than average. Piping costs from the WTP to the ASR sites varied based on distance and pipe diameter and ranged from $8,800 to $69,650 (in 1996 dollars) per well. Construction costs for a control valve station at the WTP for the four ASR sites cost $70,200 (in 1996 dollars).The combined subsurface water storage capacity of the 10 ASR wells is 1 to 2 billion gallons. In 2014, the City of Cocoa provided potable water to approximately 75,000 customers.

3.1.7.2 Kissimmee River, Florida Pilot ASR Project


KISSIMMEE RIVER, FL

The Florida Everglades was greatly altered over the past century by water management intended to provide flood control, increase urban water supply, and enhance agricultural production. The Comprehensive Everglades Restoration Plan (CERP), launched in 2000, is a joint effort led by the state and Federal government to reverse the decline of the ecosystem. The CERP is designed to capture, store, and redistribute freshwater and improve the quality, quantity, timing, and distribution of water flows. To help restore the Everglades, there is a need for new water storage because 130 years of canal drainage and water management practices have resulted in extensive losses of natural storage. In addition to surface reservoirs, the CERP included a project that would drill over 330 ASR wells. Per the *Everglades Aquifer Storage and Recovery Regional Study* (USACE 2014), the ASR wells would be located along the north shore of Lake Okeechobee, Caloosahatchee River, L-8 Canal, C-51 Canal, and Hillsboro Canal, all referred to as the Regional System as shown on **Figure 3-6**. The CERP feasibility study proposed that up to 1.7 billion gallons per day could be stored in porous and permeable units in the Upper Floridan aquifer during wet periods and recovered during seasonal or longer-term dry periods.

Although ASR technology has been employed successfully in Florida since 1983, concerns were expressed about this large-scale application of ASR in the Everglades. Two pilot ASR demonstration projects, one at the confluence of the Kissimmee River with Lake Okeechobee and one on the Hillsboro Canal, were developed and implemented by the USACE and the SFWMD. Both ASR pilots have been successful, but only the Kissimmee River ASR (KRASR) pilot project will be discussed herein.

The KRASR pilot project was built and operated by the USACE. The pilot facility is located on 2 acres of land immediately adjacent to the Kissimmee River. A 24-inch diameter ASR well was installed in the Upper Floridan aquifer in 2007. A combination of existing and new monitor wells were used to evaluate water quality in the Upper Floridan aquifer during injection, storage, and recovery. The target storage interval in the Upper Floridan aquifer is 572 to 880 feet bls, and native groundwater in this interval is brackish. The target injection and recovery rate for the ASR well was 5 mgd.

Source: USACE 2014.

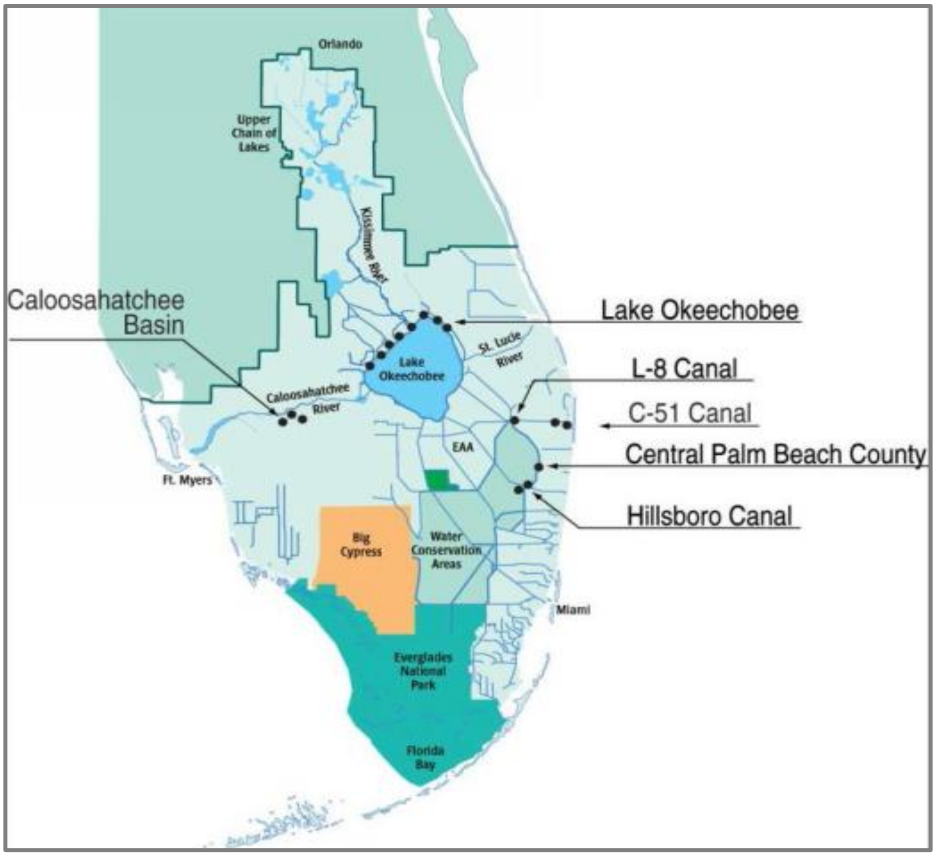


Figure 3-6. Generalized ASR Well Locations from Original CERP Plan (333 ASR wells)

The source of supply for the ASR pilot project was surface water from the Kissimmee River, which is high in color, total organic carbon (TOC), turbidity, iron, phosphorus, and fecal coliforms. Since the target storage interval in the Upper Floridan aquifer is above the USDW, and there are Secondary drinking water standards for iron and color along with Surface Water Treatment Rule requirements for coliforms and turbidity, treatment of the source water was needed. Additionally, turbidity and TOC are related to the ability to disinfect water. Treatment of the source water consisted of pressure media filtration followed by ultraviolet (UV) disinfection. The media filters were intended to help reduce TOC, turbidity, iron, phosphorus, and fecal coliforms prior to disinfection with UV light. Because the treatment processes could not lower color and iron sufficiently such that the injected water met the Secondary drinking water standards, Water Quality Criteria Exemptions (WQCEs) were obtained for these parameters from the Florida Department of Environmental Protection (FDEP).

A cycle testing strategy involving short and long recharge, storage, and recovery periods was developed and implemented at KRASR. When stored water is recovered and retreated, it is discharged through a constructed cascade to aerate the water to make it compatible with surface water before it enters the river. Four cycles of recharge, storage, then recovery were conducted over 4 years (January 2009-July 2013). Injection volumes for Cycle Tests 1 through 4 were 129 million gallons (MG), 334 MG, 93 MG, and 998 MG, respectively (USACE and SFWMD 2013). Given the mildly brackish native groundwater quality in the target storage interval, 100 percent recovery efficiency was realized for all four cycles.

Provided below are the findings from the cycle testing:

- Successfully injected and recovered large quantities of partially treated surface water during cycle testing.
- Demonstrated high capacity wells (5 mgd) are possible under certain conditions.
- Initially, there was some arsenic release in the storage zone near the ASR well, but concentrations attenuated to below the Primary Drinking Water Maximum Contaminant Level of 10 µg/L over time and distance from the ASR well.
- Even after UV disinfection, the recharge water still commonly contained coliforms, *Giardia,* and *Cryptosporidium*.
- Arsenic leaching is much less of an issue with lightly treated surface water than finished drinking water.
- ASR wells may be prone to plugging if total suspended solids (TSS) concentrations are high.
- Statistically significant reductions in phosphorus from the source water occurred during storage.

Findings from the KRASR pilot study were used to develop the revised regional ASR system as part of CERP. Groundwater modeling completed as part of the Regional Study indicated that 131 ASR wells, each pumping 5 mgd each, planned around Lake Okeechobee and the regional canal system will help manage the timing and volume of flows from Lake Okeechobee into the Regional System. The total project cost for the KRASR pilot project surface facility, including intake structures, piping, and the water treatment system, was $6.1 million. The KRASR pilot system was constructed among several pre-existing wells, including a well with a nominal 22-inch diameter borehole which was suitable for use as an ASR well. The pre-existing wells were constructed by SFWMD, and no construction cost information was available. However, additional monitoring wells which were required by the UIC permit were constructed or pre-existing wells were modified at a total cost of $1.7 million. In the report *CERP ASR Pilot Project Technical Data Report* (USACE and SFWMD 2013), O&M cost data (labor, electricity, and parts supplies and services) for three cycle tests were used to determine O&M costs normalized to the volume of water stored for the various phases of well operation. The average O&M cost during recharge/injection was $401/MG ($148/acre-ft) and the average O&M cost during the recovery phase was $256/MG ($79/acre-ft). Since there is no water injected or recovered during the storage phase, a normalized O&M cost is not relevant. However, the O&M cost during the storage phase was provided as an average monthly cost of $24,250.

This project is a large regional project that is focused on flow management for environmental restoration. However, water from Lake Okeechobee is also delivered into a regional system for water supply purposes, necessitating a balanced approach. Many utilities count on these water deliveries to help maintain groundwater levels in the surficial aquifer to prevent saltwater intrusion in water supply aquifers. While the scale of the KRASR project is much larger than most utility or community-based projects, it was determined from this study that partially treated surface water can be cost effectively used as a source of supply for ASR but still has a few challenges.

3.1.7.3 El Paso Water Utilities, Texas ARAR System

The EPWU ARAR project in Texas is one of the oldest operating systems in the U.S. using reclaimed water as the source of supply. Since 1985, EPWU has been using reclaimed water meeting drinking water standards for aquifer recharge. The Fred Hervey Water Reclamation Plant (WRP), which provides reclaimed water to the ARAR project, has a treatment capacity of 12 mgd. The Fred Hervey WRP is located approximately 20 miles from the Rio Grande River, and effluent discharge to the river was not economical. The City of El Paso is located in the Chihuahua Desert and receives on average 8 inches of rainfall annually, with an average evaporation rate of 80 inches per year (Sheng 2005). El Paso's historic water supply was surface water from the Rio Grande River and groundwater from the Hueco Bolson Aquifer, a thick unconfined aquifer. Since pumping began in the early 20th century, groundwater levels in the Hueco Bolson aquifer have declined up to 200 feet.

During the 1980s, EPWU started to explore alternative water resources to augment future water supply. One of the alternative water resources discovered was the reuse of reclaimed wastewater, injected through recharge wells into the Hueco Bolson aquifer and recovered by neighboring wells for municipal and industrial water supply. Initially, reclaimed water was injected into the aquifer using recharge wells located within a water production wellfield. The injected reclaimed water was spaced sufficiently far enough away from the production wells to provide further treatment of the water in the aquifer. In 2003, EPWU collaborated with the American Water Works Association Research Foundation (AwwaRF) and the U.S. Bureau of Reclamation in comparing surface spreading basins with injection wells for recharging the reclaimed water to the aquifer. From this study, the spreading basins were found to be more economical and efficient in recharging the aquifer than the recharge wells. However, EPWU continues to use both technologies for recharging the aquifer.

Ten injection wells and three spreading basins deliver the reclaimed water to the Hueco Bolson aquifer. After appropriate time in the aquifer, the blended groundwater and reclaimed water is extracted through numerous production wells surrounding the injection wells and spreading basins, treated at the Fred Hervey WRP, and blended with finished surface water from the Rio Grande River (**Figure 3-7**). **Figure 3-8** shows the distribution of groundwater and surface water use by EPWU between 1967 and 2012. Continued withdrawals from the Hueco Bolson aquifer would not have been possible without the aquifer recharge with reclaimed water from the Fred Hervey WRP, which is also one of the longest operating indirect potable reuse projects in the U.S.

In 2012, reclaimed water from the Fred Hervey WRP was distributed as follows: 3,401 acre-feet (3.04 mgd) to El Paso Electric for cooling water, 732 acre-feet (0.65 mgd) for golf course irrigation, 1,652 acre-feet (1.47 mgd) for aquifer recharge in the spreading basins, and 718 acre-feet (0.64 mgd) for aquifer recharge through the injection wells (Archuleta 2014). In 1985 dollars, the approximate capital cost for the injection wells is $0.5 million per well, and the reclaimed water distribution main capital cost is $1 million. The approximate 2014 population served by EPWU is 860,000.

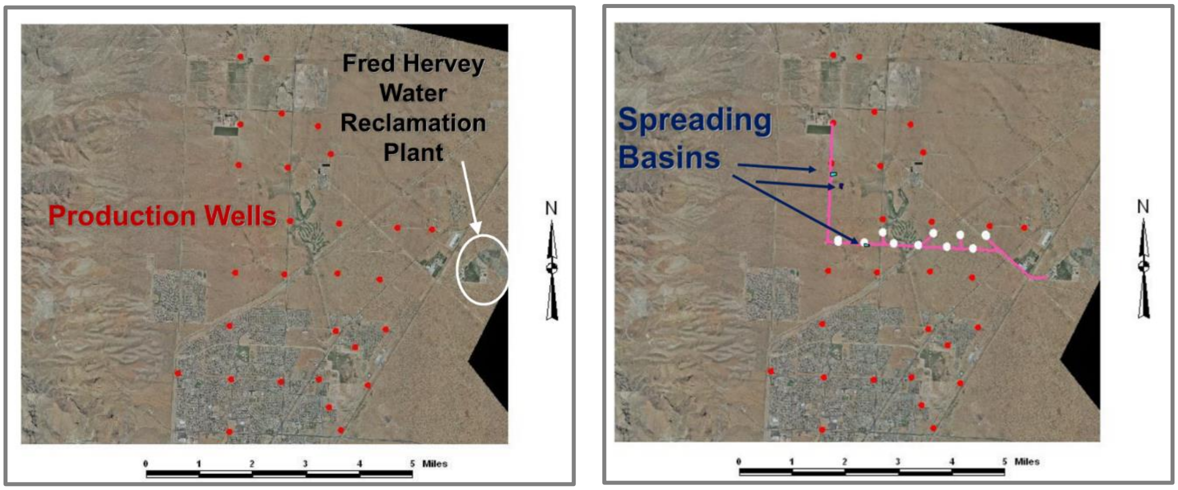


Figure 3-7. Injection Wells and Spreading Basins Interspersed in El Paso, Texas Water Supply Well field

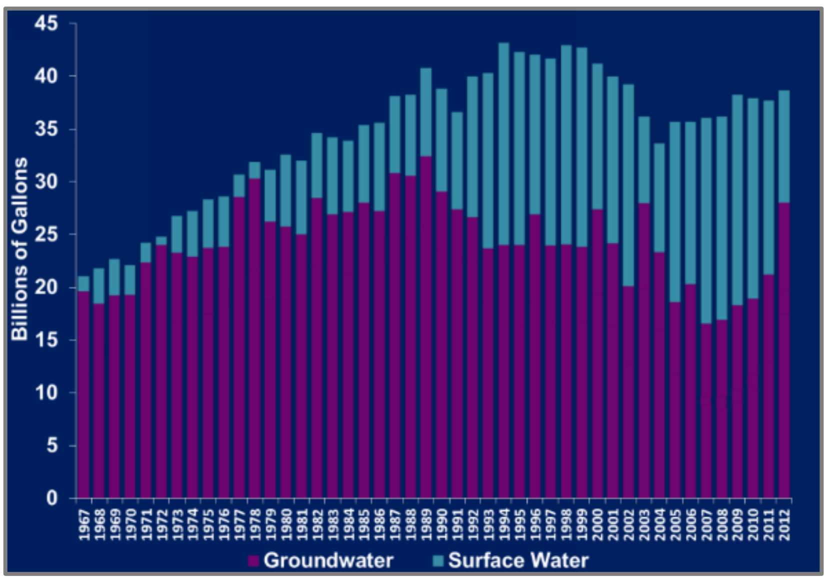


Figure 3-8. Annual Water Production for El Paso Water Utilities (1967-2012)

3.1.7.4 City of Sanford, Florida ASR System

The City of Sanford, Florida has a one-well ASR system (**Photo 3-2**) that was installed under the local water management district's ASR Construction and Testing program for a capital cost of approximately $4.0 million. Sanford was selected by the St. Johns River Water Management District (SJRWMD) as a Cooperator in the program because they likely would have a surface water treatment plant on the St. Johns River in the future to meet alternative water supply needs. Surface water from the river is only seasonally available due to elevated total dissolved solids and chloride in the water during the traditional dry season (October-May) but is fresh during the traditional wet season (June-September).

Source: CDM 2011.

Photo 3-2. (L) City of Sanford, FL ASR Well; (R) City of Sanford, FL ASR Wellhead

Until the surface water plant on the St. Johns River is constructed in the future, the city has been using finished potable water to inject into the Upper Floridan aquifer, store the water, and recover it to meet peak demands. The city withdraws quantities of groundwater from the Upper Floridan aquifer that are not used to supply demand but within their Consumptive Use Permit allocation, pretreats the water to help control arsenic leaching, and injects and stores this water in a different zone than their production interval in the Upper Floridan aquifer. The City has conducted five cycles of injection, storage, and recovery and has successfully recovered 100 percent of the injected fluid from four of the five cycles and sent the water into their potable water distribution system for consumption by their customers. The city has a chemical pretreatment system at the wellhead to help minimize arsenic leaching from the ASR storage zone during injection and storage. The city is still cycle testing using larger volumes of injection and recovery. The total capital cost of this project ($4.0 million) included $495,000 for an exploratory well program and feasibility analysis, approximately $140,000 for design services and $50,000 for permitting. The test well and ASR system cost approximately $2.1 million to construct and the pretreatment system cost approximately $1.2 million to construct. System startup costs were approximately $73,000. Annual O&M costs for this project such as well acidification, well head maintenance, pretreatment system maintenance, pretreatment chemicals, electricity, water quality testing, additional labor are estimated to be $53,000 per year. As of 2011, the City of Sanford Utilities provided water to an estimated 61,000 customers.

3.2 FLOODWATER DIVERSION AND STORAGE

3.2.1 Description

Every year, communities face significant damages from flooding. Diverting floodwaters from a stream, river, or other body of water into a wetland, floodplain, canal/ditch, pipe, or other conduit (e.g., tunnels, wells) and storing them in reservoirs, floodplains, wetlands, green infrastructure elements, or other storage facilities allows for a controlled baseflow release and attenuates peak flows, stages, and velocities to mitigate flooding. Actively managing floodwaters by diversion, storage, and infiltration also can replenish water supply aquifers through groundwater recharge, increasing baseflows, and enhancing usable water supply to mitigate the effects of drought. Floodwater diversion also can help maintain healthy ecosystems.

The concept of floodwater diversion and storage is applied nationwide at multiple scales: large, regional efforts like the network of major flood control diversions along the Mississippi River; moderate-sized diversion and storage efforts that occur in relatively smaller rivers and tributaries; and at a site-specific or neighborhood scale that utilize stormwater/green infrastructure to divert flows and store water on a parcel-by-parcel basis. These projects typically operate above ground surface unlike ASR projects, which typically store water below ground. Additional discussion regarding green infrastructure is found in Section 3.4. In the success stories presented in this section, existing facilities and open space were modified to serve multiple uses and purposes and have proven to provide a variety of benefits, without a significant increase in the capital, operational, and management costs of the facility (Tipping Points and Indicators 2015).

Floodwater diversion and storage is just one of the options that can be used to manage flood risk and drought effects. As appropriate, it can be coupled with other techniques such as land use planning, watershed management, green infrastructure, and engineering efforts to provide an adaptable, holistic approach that can further reduce future damages from both floods and droughts. A Climate Resiliency Snapshot for floodwater diversion and storage is provided on **Figure 3-9**.

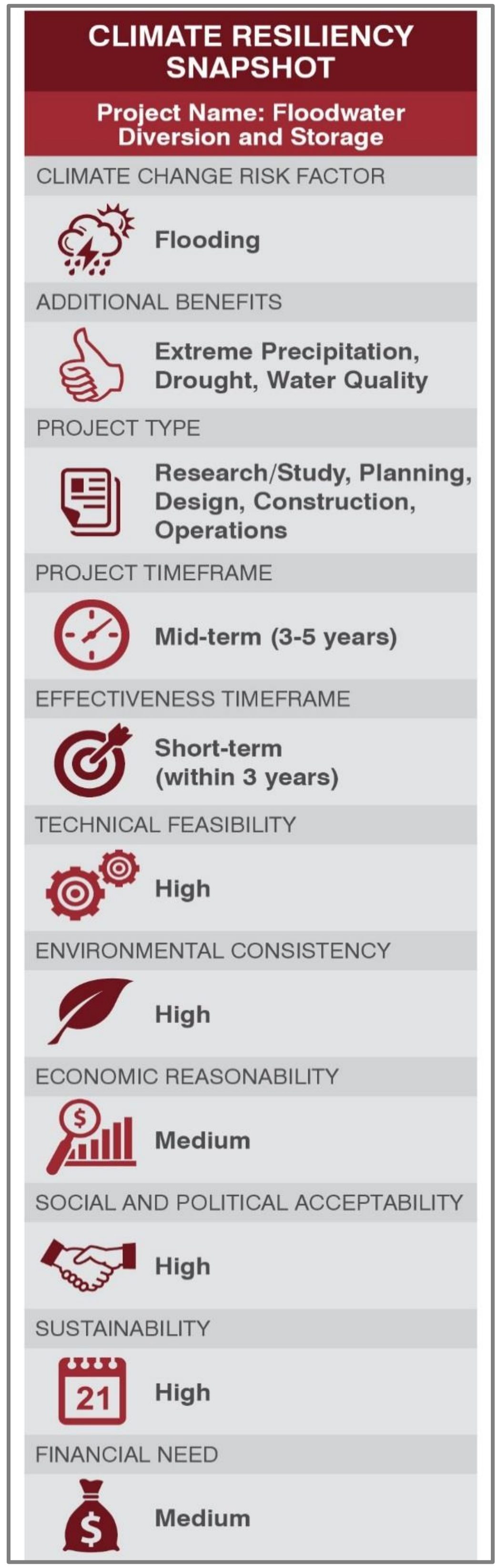


Figure 3-9. Floodwater Diversion and Storage Snapshot

3.2.2 Feasibility and Effectiveness

Depending on the scope, scale, and location of potential sites, floodwater diversion and storage projects vary in complexity. Proper planning, siting, sizing, and construction are required to implement successful floodwater diversion and storage systems. The fundamental concepts along with technical and implementation considerations for flood diversion and storage projects are described in this section.

3.2.2.1 Types of Flood Storage

In general, flood storage areas/reservoirs can be categorized into five different categories as summarized in Table 3-3 (Ackers and Bartlett 2009). Online storage allows for water to be temporarily stored within the river channel and its floodplain and can include elements such as an impounding structure, flow control structure, or spillway. Offline storage diverts water from the river channel to be stored in a separate area (which may be part of the floodplain such as a marsh) and is then subsequently released back to the river or to another channel. Elements of an offline storage diversion include an intake structure, a storage area, an outlet structure, and a spillway. These types of flood storage options require additional infrastructure and land use planning. As previously stated, the primary differences between ASR/ARAR projects and floodwater diversion and storage projects is that the storage for ASR/ARAR projects occurs in the subsurface, whereas storage prior to recharge for floodwater diversion and storage projects occurs at the ground surface. Both types of projects can divert, capture, and store waters to enhance water supply for drought mitigation.

Depending on the type of storage reservoir, the inlet and outlet of the structure may be controlled by gravity, pumping, or a combination of the two. The outlet capacity depends on the volume stored and the time allowed for the system to fully drain. In addition, if the outlet is on a tidal river, it may only be possible to fully drain the storage location during low tide. Other considerations include the physical infrastructure required to divert the floodwater to the storage locations, gates to control flow, and other mechanical devices such as screens or racks to control debris. Green infrastructure principles and practices may be considered during design and construction of the floodwater diversion and storage project.

Table 3-3. Types of Flood Storage Areas/Reservoirs

Type of Flood Storage Area/Reservoir	Description
Online	Both dry and wet weather flows pass through the flood storage area.
Offline	Dry and first-flush wet weather flows pass through the flood storage area. Larger flows bypass the facility.
Dry	The flood storage system is kept essentially dry due to infiltration and evapotranspiration
Wet	The flood storage area contains water under all flow conditions.
Wet/Dry	Part of the flood storage area contains water and part is dry during various flow conditions.

3.2.2.2 Planning Constraints and Design Considerations

A key objective in implementing flood storage and diversion projects is to ensure that the project does not induce negative effects to upstream or downstream communities and areas. For projects that need a staging area or areas that are purposefully inundated as floodwater storage, changes to the floodplain may affect neighboring parcels and landowners – therefore land acquisition is often a project component. Within the watershed, the siting of the flood storage location also needs to be strategically placed in order to be effective in capturing flood flows. In addition to location, the storage area needs to be sufficient to capture and store the total volume of excess floodwaters. If stored, the excess volume of water will need treatment and/or an additional conveyance system either by gravity or by pumping to water supplies. For flood storage systems that utilize impoundment structures, suitable access for construction, operation, and maintenance is another consideration.

Early consideration needs to be given to practical issues associated with the construction of flood storage locations. These include the need for a site investigation to inform the design of the project and establish suitable topographic elevations for gravity systems, groundwater levels and soil-geotechnical characteristics, suitability of materials for reuse, availability of suitable construction materials on site, whether the site involves contaminated land that might require remediation or special precautions and design features, the presence of other utilities and services that may hinder construction, and other potential issues, such as environmental impacts, to surrounding land and habitat.

Other more specific environmental issues include the presence of potential hazardous, toxic, or radioactive waste materials. The project could be sited on potentially historic or culturally significant sites, some of which are commonly found near riverbanks. Federally designated threatened species may have habitat in the project area, and fish passage is also an important issue for many agencies involved. For areas requiring large storage or staging locations, land acquisition and compensation may be required.

Typical pre-construction activities related to implementation of floodwater diversion and storage projects are summarized in **Table 3-4**.

Table 3-4. Typical Pre-Construction Activities for Floodwater Diversion and Storage Projects

Phase	Components	Definition	Remarks
Planning	***Scope of Work***	Identify climate change risk factor (consequence of climate change) and effects related to degradation	May include: Flooding, Extreme Precipitation, Drought, Water Quality
		Conduct Initial Assessment	Identify need for the mitigation project (scale and severity), describing work to be done and where the Floodwater Diversion and Storage Project will be located. These types of projects may range from site-specific elements to large, regional-scale efforts.
			Identify target capture/storage volume or peak flow to be attenuated.
			Identify range of alternative solutions that are both feasible and acceptable to stakeholders. Engage, coordinate and communicate with partners, stakeholders, public, funding and permitting agencies.

Phase	Components	Definition	Remarks
		Set goals and define objectives/benefits	May include: flood mitigation, water supply/water quality improvements, bank stability, habitat restoration, increased conveyance/storage, and recreational and aesthetic benefits
		Identify risks and constraints	May include: cost, funding, permitting Permitting requirements, land ownership and site access, water availability for storage, hydrologic and hydraulic constraints, tolerance for risk/uncertainty, underground and overhead utilities, threatened and endangered species, public acceptance, constructability, infrastructure alignment issues
	Data Collection	Major data types that are needed to conduct initial assessment and engineering evaluation of alternative solutions	Existing and future water use projections to include both upstream and downstream users that may be affected by floodwater diversion and storage projects (agricultural, domestic, manufacturing and industrial, hydropower generation, recreation, instream flow, etc.)
			Other considerations may include evaluation of T&E species, fish and wildlife habitat, invasive species, wetlands, historical resources, cultural resources, air quality, water quality, prime farmland, irrigation canals, irreversible use of resources, public safety, real estate tax base, and other existing infrastructure or recharge facilities, etc. Soil Type (National Resource Conservation Service) http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/
			Topographic and Surveying data (Specific to the project extents, identifying utilities and other avoidance areas)
			Consideration of the availability and reliability of water supplies in the region, under average conditions and during high demand conditions including drought.
			Geotechnical and/or Hydrogeological data (historical and current)
			Historical Rainfall Data (NOAA) https://www.ncdc.noaa.gov/cdo-web/ Some states have state-specific hydrologic data available. In addition, precipitation frequency estimates (NOAA/NWS) http://hdsc.nws.noaa.gov/hdsc/pfds/ for hydraulic studies.
			Historical Stream flow and Stage (USGS) http://waterdata.usgs.gov/nwis/sw, or best estimates based on engineering analyses
			National Wetland Inventory (NWI) http://www.fws.gov/wetlands/
Assessment	***Data Evaluation***	Determine modeling tool for use in engineering evaluation (pre-and post-project conditions)	For hydraulic studies, modeling tools such as FLOW2-D, MIKE-11, SWMM, HEC-RAS have been used to evaluate engineering alternatives. Other regional approaches using STELLA, or spreadsheet based tools have been used for water balances.

Phase	Components	Definition	Remarks
			Hydrogeological evaluation for potential soil suitability for infrastructure or material reuse.
			Perform additional engineering analysis (scour analysis, sediment transport, ecological viability assessments, as needed).
		Manuals and Guidance Documents	N/A (due to the broadness of the project type).
		Identify alternatives	Project scale and target diversion and storage volumes. Evaluate different strategies for either passive or active approaches to floodwater diversion and storage.
		Establish design criteria	Define level of service, volume of diverted and stored floodwater, reduction of flood surface elevation
		Analyze performance of infrastructure elements (% full, storage volume, flood elevations)	Evaluate passive and active alternatives under different conditions
			Confirm flood storage volumes, final evaluation of any flow depths or spillway conditions
			Evaluate areas for erosion protection, or of any potential water quality impacts.
		Develop recommendations	Project alternatives that satisfy and maximize project goals and objectives.
			Future sampling data collection and analysis to support design and adaptive management
Design	***Basis of Design Report***	Document modeling methodology, results, and design recommendations	Methodology should be based on a sound scientific approach, results should present values for key flood reduction parameters and recommendations should be supported by the results provided.
	Construction Drawings and Specifications	Describe work to be performed, providing specific implementation strategies, construction details, and construction materials and equipment	Includes a 30%, 60%, 90%, and Final design process for selected alternative
	Create Bid Schedule (Cost Estimate)	List of pay items, units of measurement, and estimated quantities for proposed scope of work	Consider maintenance as part of cost estimations.
	Estimate Construction Schedule	List project's milestones, activities, and deliverables, with intended start and finish dates	-
Environmental Planning and Historic Preservation (EHP)	***EHP Coordination and Compliance***	Coordinate efforts throughout each stage of design with FEMA and demonstrate compliance with EHP requirements	Conduct initial screening of current environmental and historic conditions to identify design constraints
			NEPA Determination (Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement)
			Meet with FEMA at 30%, 60%, and/or 90% design stages to discuss EHP considerations

Phase	Components	Definition	Remarks
			Provide copies of all documentation to FEMA of any environmental, historic, and archaeological consultation and permitting
Cost Effectiveness	***Project Cost Effectiveness***	Demonstrate project cost effectiveness using BCA methodology	Prepare BCA using data developed in the design process. Provide supporting documentation (figures and narrative) related to this analysis. Cost effectiveness is demonstrated when the benefits of a project exceed the costs (i.e., Benefit Cost Ratio > 1.0).
Permitting and Site Access	***Permitting Requirements***	List of permits to be acquired prior to initiation of construction and operation of project	Potential permits may include Federal T&E species USFWS permits, USACE dredge and fill, rivers and harbors act permits, State project approval and construction permits, MS4 permits, or surface water/groundwater appropriation permit; Local shoreline, special use, grading, right-of-way, utility permits.
	Ownership/Land Rights/Site Access	Obtain site access and easements (acquire land as necessary) prior to initiation of construction	
Potential Challenges to Implementation	***Project Challenges and Resolutions***	Describe challenges and potential resolutions	Varies geographically and project-to-project, but may include project location and siting, upstream/downstream effects, instream-flow requirements – resolved with proper design and planning.

3.2.2.3 Adaptability

Changes to upstream drainage conditions may affect downstream flood diversion and storage elements. Adaptability of flood storage projects could include features such as the ability to raise the impounding element (dam or weir) to increase flood storage capacity, adjusting the setting of gates or orifices to control downstream releases, and/or controls to water supply reservoirs or storage tanks. Green infrastructure practices and principles may be implemented during the planning and design phase in order to improve the project's performance and level of adaptability. Additional information on Low Impact Development and Green Infrastructure can be found in Section 3.4. It is also important to consider future conditions and whether or not design of current projects account for potential changes in development, floodplain, and whether or not flexibility or capacity can be built into the design.

3.2.3 Evaluation and Summary of Benefits and Costs

Since floodwater diversion and storage has a primary benefit of reducing peak flows, and therefore a reduction of flood damages, this project type is consistent with HMA requirements for a reduction in risk to infrastructure or people. The project may also provide benefits related to increased water supply and ecosystem services. As some of the water supply benefits may be for day-to-day use rather than specifically for drought conditions, it is be important to identify the hazard mitigation benefits of the project to ensure eligibility for FEMA funding.

The BCA should be prepared defining and quantifying the severity of drought the project is designed to mitigate and then estimating the probability of the drought events. As previously discussed, estimating the probability of a drought can be difficult but, the sub-applicant should use the best available data and methodology deemed appropriate by the design engineer. Any climate projections incorporated into the probability analysis should have timelines consistent with the project useful life, which is expected to be 50 years but may vary depending on individual site conditions and construction materials. Additionally, the methodologies utilized in the BCA should be consistent with the design criteria, that is, if an estimate of 500 million gallons of water supply will be utilized in a severe drought, the design criteria should support the availability of the water and the system's ability to utilize it.

3.2.3.1 Benefits

The primary benefit of floodwater diversion and storage projects is to reduce flooding by attenuating peak flows and velocities, allowing them to slowly be released or infiltrate into the ground. The project, therefore, would potentially reduce flood damages to other types of infrastructure such as roads, residential and commercial structures, or other property downstream and upstream.

The reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project.

As described in Section 2.3.1, CDM Smith (2015c) in collaboration with Earth Economics provided standard values for ecosystem service benefits per acre for various land types as shown in Table 2-2. If a Floodwater Diversion and Storage project results in new or restored Wetlands, Estuaries, Riparian or Green Open Space, the total annual benefits for these categories can be included in the BCA. The subapplicant would need to quantify the area (in acres) of restored ecosystem and the land use type.

If applicable, benefits related to increased water supply capacity can be captured based on the two values presented in Section 2.3.2. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

There are often several additional benefits to floodwater diversion and storage projects, such as reduced flooding in agricultural areas which result in a decrease in damages to crops from rot, washouts, and pests. Additionally, aquifer recharge and water table stabilization can help slow or lessen land subsidence and therefore potentially reduce structural damage to facilities in the vicinity. Although FEMA does not currently have standard values for benefits such as these, a subapplicant could quantify the benefits and provide proper documentation for inclusion in the BCA. There are many variables in the calculation of such benefits, and efforts to do so may prove to be challenging. Therefore, these benefits should only be considered if needed to demonstrate cost-effectiveness.

3.2.3.2 Costs

Costs may vary depending on the scope, scale, and location of the floodwater diversion and storage project. Hydrologic and hydraulic investigations are required to accurately design the system and ensure a reduction in flood risk. These could have a large impact on the project cost based on whether they are performed prior to a grant application period, or included in the grant application after the grant opening period.

- Feasibility analyses
- Land acquisition
- Environmental impact, habitat assessment, and cultural significance analyses
- Hydrologic and hydraulic analyses
- Subsurface and foundation investigations
- Consulting services for the design, permitting, project management, and supervision of the construction
- Demolition, construction, and mobilization costs (e.g., channels, pipes, detention basins, stormwater interventions, floodgates, levee realignment, utility realignment)
- Pre- and post-project monitoring

Although the O&M costs will not be funded by FEMA, they are required to be included in the BCA and therefore should be considered. O&M costs generally range from 0.5% to 1% of construction costs and can include the following:

- Labor (system operation and maintenance, regulatory requirements, administration)
- Material and equipment costs (e.g., fencing, trails, equipment, parts replacement, inlet/outlet controls, scour protection)

3.2.4 EHP Requirements

Neighborhood scale projects that utilize stormwater infrastructure to divert flows and store water on a parcel-by-parcel basis would likely be eligible for a CatEx. Improvements to existing facilities and the construction of small scale hazard mitigation measures in existing developed areas with substantially completed infrastructure, when the immediate project area has already been disturbed, and when those actions do not alter basis functions, do not exceed the capacity of other system components, or modify the intended land use may be covered (44 CFR 10.8(d)(2)(xvi). The operation of the small scale project would still need to be screened to ensure that it would not have an adverse effect on the quality of the human environment.

The FEMA NEPA Desk Reference clarifies that this CatEx is intended to cover such things as upgrading the size of an existing culvert, constructing a small culvert under a road, upgrading or construction of a small-area urban storm drainage system, or installation of small floodwalls. It is intended to cover activities with no disturbance or adverse effects outside the currently disturbed area or the footprint of an existing facility.

Because a flood diversion project is intended to control baseflow release and attenuate peak flows, stages, and velocities to mitigate flooding, it would not be expected to have adverse effects on flood levels, local hydrology, or drainage patterns (i.e., lowering water tables; increasing flooding elsewhere that would affect residences, facilities, or other resources; creating erosion at the next bend in the stream; or affecting the mapped 100-year flood level), but projects should be evaluated to ensure that adverse effects would not occur. The CatEx would not apply if a project would change downstream flow patterns to the extent that land use, delineated special flood hazard, stream functions, stream habitat, erosion or sedimentation rates are affected.

Each Federal agency identifies the categories of activities that it most frequently engages in that may qualify for a CatEx. Because each agency has identified different activities that it may cover with a CatEx, a project funded by FEMA may not qualify for a CatEx even though the same project might if it were funded by a different agency. Activities that another agency may cover with one of its CatExs may not fit under a CatEx authorized by FEMA. Therefore, the type of NEPA documentation applied to the various case studies described below may not be the same as would need to be developed for a similar project funded by FEMA.

Moderate, large or regional scale projects would not be covered by a CatEx and would need to be reviewed under an EA or an EIS. Projects larger than a neighborhood scale are more likely to affect wetlands, coastal zones, cultural resources, or habitat for listed species and these issues will need to be carefully evaluated during design. Because flood diversion and storage projects generally rely on gravity to function, they may be somewhat less flexible in location as compared to other types of projects. This may reduce the ability of the project to avoid adverse impacts on natural and historic resources or the human environment. If it is not possible to mitigate adverse impacts, then an EIS may need to be prepared. This type of project also has the potential for considerable beneficial effects, which may mitigate some of the potential adverse effects on natural resources such as wetlands or fish and wildlife habitat. Costs for each type of EHP document would be similar to those described under Section 3.1.4.

3.2.5 Potential Coordination with Other Federal Agencies

A critical piece of a floodwater diversion and storage project plan is to have a transparent and inclusive approach to outreach and collaboration. In addition to local stakeholders, there may be an opportunity to coordinate with other Federal agencies such as the USDA-NRCS, U.S. Bureau of Reclamation, USEPA, NOAA, USFWS, USACE, and USHUD.

In many cases, coordination is required for permitting purposes, cost-sharing, and for multi-benefit, multi-goal objectives such as using floodwater storage and diversion projects as a means for providing a wealth of ecosystem goods and services, recreational opportunities, and regional sediment management for beneficial reuse. Several Federal agencies are already engaged in stream and floodplain restoration activities, and many agencies help support and provide funding for restoration activities. A list of Federal agencies that currently support stream restoration projects are listed below. The need for this coordination among multiple (including Federal) stakeholders presents an opportunity to coordinate and align HMA funding, but may also require consideration of duplication of program concerns.

3.2.5.1 U.S. Department of Agriculture - Natural Resources Conservation Service

For 80 years, NRCS and its predecessor agencies have worked in close partnerships with farmers and ranchers, local and state governments, and other Federal agencies to maintain healthy and productive working landscapes. The NRCS provides many services, including technical and financial assistance to farmers, ranchers, and landowners, to make improvements to their land. Most of these programs are under the 2014 Farm Bill. More information on the programs can be found at www.nrcs.usda.gov/getstarted

Emergency Watershed Protection (EWP)

The NRCS administers the Emergency Watershed Protection (EWP) Program, which responds to emergencies created by natural disasters. It is not necessary for a national emergency to be declared for an area to be eligible for assistance. This is a viable local match funding source, where the NRCS may pay up to 75 percent of the construction costs of emergency measures. Up to 90 percent may be paid for projects within limited-resource areas as identified by U.S. Census data. The remaining costs must come from local sources and can be made in cash or in-kind services.

EWP is an emergency recovery program that provides assistance to project sponsors (State, local, general improvement district, and conservation district) and individuals in implementing emergency recovery measures. The program is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, windstorms, and other natural occurrences that cause a sudden impairment of a watershed. In recent disasters, flood retarding structures (FRSs) were built by the USDA-NRCS to store rainfall runoff caused by heavy storms. In February 2015, NRCS invested $84 million in EWP to fund more than 150 recovery projects in 13 states. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program (EQIP) provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation along with improved or created wildlife habitat. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Watershed and Flood Prevention Operations (WFPO)

The Watershed and Flood Prevention Operations (WFPO) Program provides technical and financial assistance to States, local governments, and Tribes (project sponsors) to plan and implement authorized watershed project plans for the following purposes:

- Watershed protection
- Flood mitigation
- Water quality improvements
- Erosion reduction and sediment control
- Rural, municipal, and industrial water supply
- Irrigation
- Fish and wildlife enhancement
- Hydropower

The program provides cost-share funds for engineering and construction costs. Under the Watershed Program, NRCS cooperates with States and local agencies to carry out works of improvement for soil conservation and for other purposes, including flood prevention; conservation, development, utilization and disposal of water; and conservation and proper utilization of land. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/

Emergency Community Water Assistance Grants (ECWAG)

The USDA Emergency Community Water Assistance Grants program helps eligible rural communities recover from or prepare for emergencies that result in a decline in their capacity to provide safe, reliable drinking water for households and business. These grants are available to communities that are experiencing a significant decline in the quality or quantity of drinking water due to drought or ability to maintain water sources of sufficient quantity and quality. Additional information can be found at http://www.rd.usda.gov/files/rdECWAG_Feb2014.pdf

3.2.5.2 U.S. Department of the Interior - Bureau of Reclamation

Operating in the Western United States, the U.S. Department of Interior Bureau of Reclamation's mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. The Bureau of Reclamation offers several grant opportunities that may be available for utilities or other entities interested in implementing flood diversion and storage projects.

WaterSMART

Through the WaterSMART (Sustain and Manage America's Resources for Tomorrow) Grants (formerly Challenge Grants), the Bureau of Reclamation provides 50/50 cost share funding for sustainable water supply projects, including those that address climate-related impacts on water or prevent any water-related crisis or conflict. To participate in the WaterSMART program, applicants must provide at least 50 percent of the total project costs from non-federal sources, either in cash or as in-kind contributions. Total Federal funding (Bureau of Reclamation and all other Federal sources) cannot exceed 50 percent of the total estimated project cost. Additional information can be found at http://www.usbr.gov/WaterSMART/weeg/index.html

Drought Response Programs – Resiliency Projects

The Bureau of Reclamation's Drought Response Program supports a proactive approach to drought. It provides assistance to water users for drought contingency planning, including consideration of climate change information and to take actions that will build long-term resiliency to drought. Drought resiliency projects, also referred to as "mitigation actions," help communities prepare for and respond to drought. To be eligible, projects must be supported by an existing drought contingency plan. Reclamation provides funding (up to $300,000 per Applicant) on a 50/50 cost-share basis. The Federal share (Bureau of Reclamation's share in addition to any other sources of Federal funding) of any one proposed project shall not exceed 50 percent of the total project costs. Projects identified must result in long-term benefits that will build resiliency in the future and meet one of the following goals: increase the reliability of water supply and sustainability; improve water management; implement systems to facilitate voluntary sale, transfer, or exchange of water; and provide benefits for fish, wildlife, and the environment. Additional information can be found at http://www.usbr.gov/drought/

3.2.5.3 U.S. Environmental Protection Agency

The USEPA offers grant opportunities that may be available for utilities or other entities interested in implementing flood storage and diversion projects. One of those is the USEPA Clean Water State Revolving Fund (CWSRF). This program has provided more than $4.5 billion annually in recent years to fund water quality protection projects for wastewater treatment, stormwater management, nonpoint source pollution control, and watershed and estuary management. Additional information can be found at http://water.epa.gov/grants_funding/cwsrf/cwsrf_index.cfm

3.2.5.4 National Oceanic and Atmospheric Administration

Coastal Wetland Planning, Protection and Restoration Act

NOAA works through the Coastal Wetland Planning, Protection and Restoration Act to restore Louisiana's coastal habitat, which is the state's first line of defense during storms, reducing the devastating effects of wind, waves, and flooding. The act works to fund and implement large-scale restoration projects to ensure healthy and sustainable coastal habitat for Louisiana's fisheries. These projects are significant at the local and national scale for their role in improving marine fisheries and their ability to protect communities and vital oil and gas infrastructure from storm damage. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/cwppra.html

Community-based Restoration Program

The NOAA Restoration Center's Community-based Restoration Program invests funding and technical expertise in high-priority habitat restoration projects that instill strong conservation values and engage citizens in hands-on activities. The program invests millions of dollars annually in restoration, leveraging double and triple the outcome by working with partner organizations. The program also provides restoration science and technical guidance, including assistance with environmental compliance, and monitoring. Federal funds awarded under this program must be matched with non-Federal funds (cash or in-kind services) at a 2:1 ratio of Federal to non-federal contributions. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/crp.html

Coastal Restoration through the Recovery Act

NOAA received $167 million from the American Recovery and Reinvestment Act of 2009 to restore coastal habitat and help jump-start the nation's economy by supporting thousands of jobs. NOAA's Recovery Act restoration efforts are spread over 22 states and two territories. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/recoveryact.html

3.2.5.5 U.S. Department of the Interior - U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service received $65 million in recovery funding and $102 million in resilience funding from the Department of the Interior through the Disaster Relief Appropriations Act of 2013 for a total of more than 60 approved projects. Some of the projects the USFWS plans on implementing over the course of the next few years include investing more than $77 million in coastal marsh, beach, dune and barrier island restoration to preserve and enhance critical habitat and help protect coastal communities from erosion, storm surge, and predicted sea level rise. In addition to investing more than $10 million in aquatic connectivity/flood mitigation projects to remove obsolete dams and road culverts and restore more than 170 miles of river and tributary habitat to migrating fish species, they are working to restore natural sediment transport regimes that help rebuild eroding coastlines and protect adjacent communities from storm flooding and dam failure.

3.2.5.6 U.S. Army Corps of Engineers

Under its civil works program, the USACE plans, builds, operates, and maintains a wide range of water resource facilities. Its civil works responsibilities are principally to support navigation, reduce flood and storm damage, and protect and restore aquatic ecosystems. Most environmental infrastructure projects are financed 75 percent Federally and 25 percent locally (Carter et al. 2015). USACE also works on interagency programs that aim to provide multiple benefits. The Federal portion of the funding is typically provided or authorized by Congress to the USACE while specifics of the management of the non-federal portion varies by project. A project will be approved only if there is Congressional authorization for work in the specified area and the activity undertaken is covered by that authorization. Recent efforts by the USACE for regional sediment management for beneficial reuse of dredged materials may be repurposed for future flood storage and diversion programs that are in need of fill material. A successful application of regional sediment management for ecosystem restoration and flood mitigation is the Jamaica Bay Marsh Islands in New York.

3.2.5.7 Department of Housing and Urban Development

The USHUD's Sustainable Communities Regional Planning Grant Program supports metropolitan and multijurisdictional planning efforts that integrate housing, land use, economic and workforce development, transportation, and infrastructure investments in a manner that empowers jurisdictions to consider the interdependent challenges of economic competitiveness and revitalization; social equity, inclusion, and access to opportunity; energy use and climate change; and public health and environmental impact. Additional information can be found at http://portal.hud.gov/hudportal/HUD?src=/program_offices/economic_resilience/sustainable_communities_regional_planning_grants

Community Development Block Grant Program

USHUD CDBGs are programs that may provide grants for long-term needs to rehabilitate, construct, or buy public facilities/infrastructures such as water and sewer systems. In the past, these grants have been used to develop new water sources, improve water treatment, and replace distribution systems. Recipient communities must spend at least 70 percent of their funds for activities that benefit low- and moderate-income persons. Grantees may fund activities that meet community development needs of particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community and other financial resources are not available to meet such needs. CDBGs may be used to match FEMA grants.

In addition, in response to specific disasters, Congress may appropriate additional funding under CDBG Disaster Recovery grants to rebuild in Presidentially Declared Disaster areas and provide crucial seed money to start the recovery process. Among eligible activities used for recovery efforts under CDBG Disaster Recovery funds are several relating to infrastructure.

CDBG Section 108 loan guarantees provide communities with a source of financing for public facilities, economic development, housing rehabilitation, and large-scale physical development projects. It allows local governments to transform a small portion of their CDBG funds into Federally guaranteed loans large enough to pursue physical and economic revitalization projects.

Additional information on the CDBG programs can be found at http://water.epa.gov/infrastructure/watersecurity/funding/fedfunds/hudcgrants.cfm and http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs

3.2.6 Summary of Programmatic Considerations

The primary benefit of a floodwater diversion and storage project is the reduction in flood damages. Therefore, the project is likely to be an effective, stand-alone mitigation activity to reduce losses to infrastructure. The project may also provide drought resiliency. While establishing a traditional recurrence interval for drought may be difficult, the subapplicant should use the best available data and methodology deemed appropriate by the design engineer.

The project must not duplicate flood prevention activities of other Federal agencies and may not constitute a section of a larger flood control system. While the project can be sized based on the risk in the project area, HMA requirements of a 3-year period of performance for implementation should be considered. While a CatEx may be applied in some cases to reduce the EHP requirements for review of the project (as explained in Section 3.2.4), early screening of the site is recommended to determine if an EA or an EIS would be likely based on project complexity and site conditions.

While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing implementation and drought resiliency throughout the U.S.

drought resiliency throughout the U.S.

3.2.7 Example Implementation Success Stories

3.2.7.1 Fisher Slough Restoration Project, Skagit River Delta, Washington

Fisher Slough, in the greater Skagit River Delta, is located in northwestern Washington, south of Mt. Vernon. The Skagit Delta is a nationally important agricultural area. This restoration project increased flood storage capacity on site and reduced flood risk in the lowland reaches of the 23-square mile (14, 720 acres) Fisher Watershed by restoring a tidally influenced marsh complex (Photo 3-3).

Completed in October 2011, this project included replacement of existing side-hinge floodgates at the mouth of Fisher Slough with regulated floodgates, relocation of a large drainage and irrigation ditch known as “Big Ditch” and the associated culvert system, setback of a network of levees, and restoration of the marsh to provide natural stream and tidal processes. These actions restored 60 acres of freshwater tidal marsh habitat and allowed for fish passage through the slough while improving flood protection for the local community and reducing maintenance costs for the local dike and drainage districts. This project was a collaborative effort between The Nature Conservancy (TNC), Dike District No. 3, Drainage District No. 17, Skagit County, and a number of other government agencies, technical reviewers, and local landowners.

Source: Marlin Greene/One Earth Images 2013.

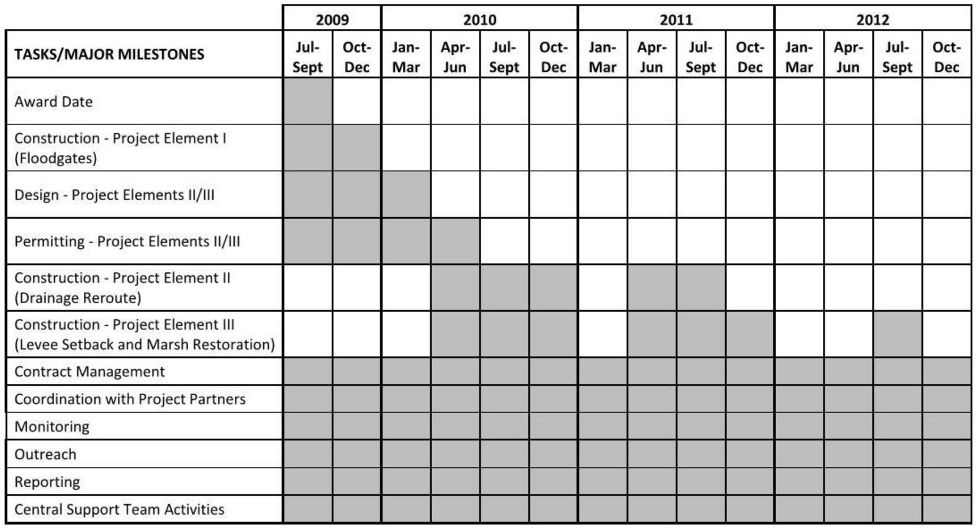
Photo 3-3. Fisher Slough, WA Project Aerial Post-Construction Showing Restored Marsh

The primary objectives of the project include the following (The Nature Conservancy 2009):

- Improve flood storage to protect agricultural uses of adjacent properties
- Create a diverse array of native vegetative communities
- Create freshwater tidal marsh habitat and provide fish passage

The project was initiated and TNC was invited by local stakeholders to manage the project in 2004. Initial efforts included land acquisition, feasibility, and design, which were funded by a number of local, state, and Federal grants and private donations. The total cost of the project was $8.3 million, which included land acquisition, feasibility and modeling, design and permitting, project management, engineering, construction, and pre- and post-project monitoring into 2015. While the total project cost ($8.3 million) exceeds the upper range of costs targeted for this evaluation ($1-$5 million), there are several sub-projects included within the overall cost that independently would provide significant benefits and be within the range of $1-$5 million.

There were three major construction elements: (1) replacement of a floodgate, (2) realignment of the "Big Ditch" and installation of a large siphon, and (3) levee removal and setback and tidal marsh restoration (Nature Conservancy (Tetra Tech), 2009). These major project elements are summarized in a condensed project timeline on Figure 3-10 and shown in the construction photographs below (Photo 3-4).



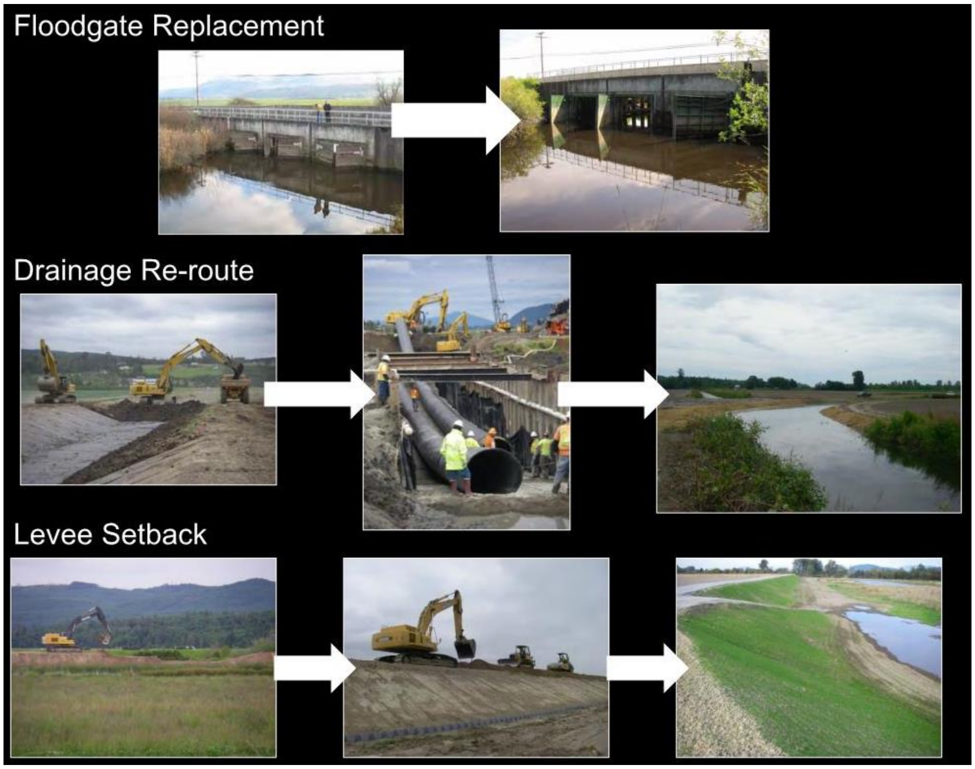
Source: The Nature Conservancy 2013.

Figure 3-10. Fisher Slough, WA Project Condensed Timeline Elements

The project cost of $8.3 million (The Nature Conservancy 2015c) was funded from multiple private, local, state and Federal funding sources, the largest of which was from NOAA in 2009. The costs associated with similar floodwater diversion and storage are subject to differences in scope, scale, and project location. For Fisher Slough, the cost breakdown by project element was:

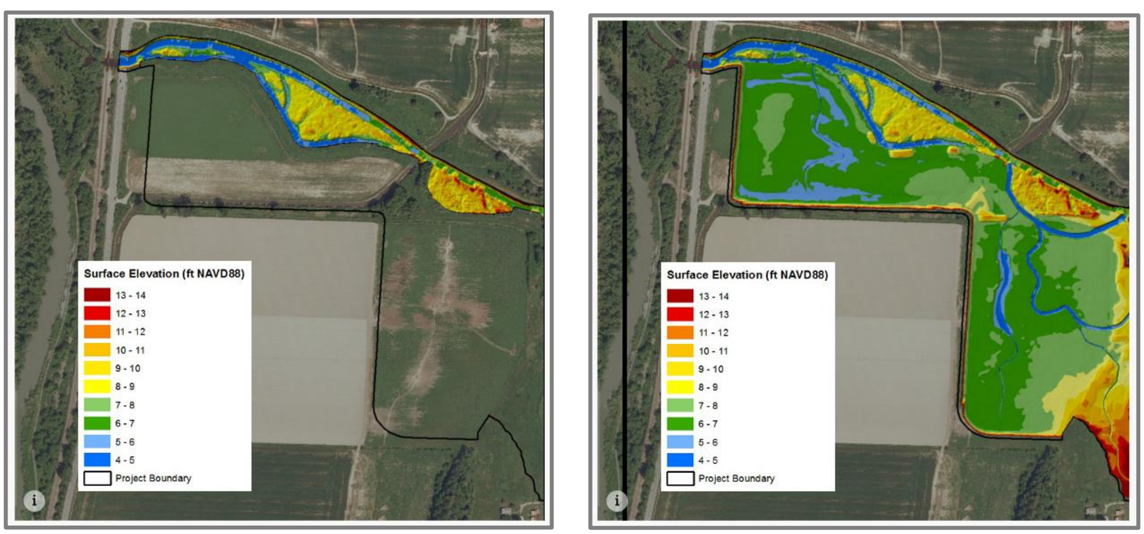
- Floodgate Replacement: approximately $400,000
- Big Ditch Realignment and Installation of Siphon: approximately $1.8 million
- Levee Setback and Tidal Marsh Restoration: approximately $4 million
- Detailed cost breakdown was not available for the overall construction costs, but is approximately 25% of capital cost. It includes land acquisition, feasibility, design and permitting, project management, pre-and post-project monitoring and was approximately $2.1 million.

Based on 2 years of post-restoration data, the project, as a whole, effectively increased flood storage capacity by a total of 245 acre-feet and restored a total of 56 acres of freshwater marsh. The project also resulted in improved adult fish passage to 15 stream miles of stream habitat, aiding in the production of up to an additional 22,000 new juvenile salmon annually, and also improved passage through the new floodgates for juvenile Chinook and adult Coho and Chum salmon. Figure 3-11 shows the project boundary and the change in flood storage area before and after project completion.



Source: Tetra Tech and The Nature Conservancy 2012a.

Photo 3-4. Fisher Slough, WA Project Construction and Progress Photos
(Top) Replacement of traditional tide gates with self-regulating tide gates (before and after)
(Middle) Rerouting of drainage infrastructure (during, construction of the "Big Ditch" and after)
(Bottom) Modifications and setting back of the tidal levee (during and after)



Source: NOAA 2012.

Figure 3-11. The Fisher Slough, WA Project boundary and the change in flood storage area before (left) and after (right) project completion.

Another critical piece of the project was the multi-stakeholder efforts in both outreach and technical review, along with cooperation from funding agencies, demonstrating that leveraging both resources and funds can yield a successful multi-goal, multi-benefit effort that reduces flood risk and provides estuarine habitat.

3.2.7.2 The Pontilly Neighborhood, New Orleans, Louisiana

The New Orleans Redevelopment Authority (NORA), in collaboration with the City of New Orleans and FEMA, conducted a program to remove repetitive loss of structures and retrofit remaining areas for better flood storage and reduced risk in the neighborhoods of Pontchartrain Park and Gentilly Woods, collectively known as the Pontilly study area. Pontilly is 855 acres, contains approximately 2,400 lots, the Southern University of New Orleans, the New Orleans Baptist Theological Seminary, and Pontchartrain Golf Course (Figure 3-12). Like many of New Orleans' neighborhoods, Pontilly sits on what was once swamp land that has been reclaimed largely as residential space and currently faces subsidence and flooding issues. Land elevations within Pontilly range from 1 foot above mean sea level to -10 feet, and the area is shaped like a "bowl".

After Hurricane Katrina, a neighborhood revitalization plan for the Pontilly area was developed (CDM Smith 2012). Part of the plan utilizes floodwater storage and diversion concepts through site-specific stormwater management strategies. The Pontilly project includes the design and proposed installation of over 50 different stormwater interventions (also referred to as BMPs) at various sites in the neighborhood. This network of stormwater BMPs, as a means to provide floodwater diversion and storage, collectively reduce the potential flood risk and flood damages that may impact these communities. In addition to physical changes, the Pontilly project aims to create a socially, environmentally, and economically beneficial place to live.

The intent of the Pontilly Stormwater project is to evaluate and design stormwater BMP solutions that provide flood mitigation throughout the study area over the course of 50 years. The design solution includes the following measures implemented across the entire project area in specific neighborhoods and locations:

Source: CDM Smith 2014.

Figure 3-12. Pontilly Study Area Major Landmarks

- Re-purposing post-Hurricane Katrina unrestored residential lots and other existing green spaces into urban pocket parks with stormwater detention and wetlands

- Incorporation of porous pavement for new and re-development
- Developing bioswales along roadways, in medians, and where sufficient space exists
- Street-side bioretention cells that redirect stormwater runoff into detention facilities
- Widening of the existing drainage canal
- Incorporating overland flow from areas with topographic impediments to standard drainage design into the newly created floodwater storage areas

The approach of this project is to "Retain, Detain, Drain," with the overarching concept to manage each drop of water wherever it falls. The principal goal of this project is to reduce peak runoff volumes and lower peak floodwater elevations by diverting stormwater to these interventions, storing them, and allowing them to infiltrate or drain from the area.

The separate elements will vary in cost; opinions of probable cost are summarized in **Table 3-5**. While the total project cost ($8.2 million) exceeds the upper range of costs targeted for this evaluation ($1-$5 million), there are several sub-projects included within the overall cost that independently would provide significant benefits and be within the range of $1-$5 million. The opinions of probable cost include demolition, pavement upgrades, and plantings for the stormwater BMPs. Individual stormwater BMP elements can be implemented at the scale and location of interest, keeping a similar function, to divert and store floodwater at a site-by-site scale to lessen future flood damages for the parcel, or as part of the system can lessen flood damages for the entire neighborhood.

While exact design and permitting costs for this particular project is unknown, it is estimated that these tasks would be approximately 15% to 20% of the total project costs and that annual maintenance, while not fundable by FEMA, is an estimated 1% of capital costs.

Table 3-5. Opinion of Probable Cost, Pontilly Stormwater Project, New Orleans, LA

Item	*Quantity*	*Unit*	*Unit Cost*	*Item Budget**
General BMPs				
Stormwater Lot (Basic)	29	EA	$ 16,240	$ 471,000
Stormwater Lot (Enhanced)	20	EA	$ 18,840	$ 377,000
Pervious Parking, On Street (Sq.Yd.)	1,165	SY	$ 175	$ 204,000
Corner Street Basin (Basic)	52	EA	$ 6,980	$ 363,000
Corner Street Basin (Enhanced)	15	EA	$ 12,005	$ 181,000
Mid-Block Street Basin (Basic)	6	EA	$ 6,900	$ 42,000
Mid-Block Street Basin (Enhanced)	6	EA	$ 10,965	$ 66,000
Mid-Block Street Basin (Pedestrian)	7	EA	$ 2,880	$ 21,000
Green Alley	16	EA	$ 7,325	$ 118,000
Urban Bioswale (10 LF unit)	565	EA	$ 1,900	$ 1,074,000
Specific BMPs				
Bioswale Golf Course (1,000 sq.ft. unit)	88	EA	$ 6,435	$ 567,000
Stormwater Park 1				$ 209,000
Stormwater Park 2				$ 63,000
Stormwater Park 3				$ 406,000
Pipe (incl. street over pipe)				$ 1,639,000
Railroad Swale				$ 213,000
Dwyer Canal				$ 2,207,000

SUBTOTAL (Itemized Costs)			**$ 8,221,000**
Mobilization	5%	$ 412,000	
SUBTOTAL (Direct Costs)		**$ 412,000**	$ 8,633,000
GC Field General Conditions	7%	$ 605,000	
Insurance	1%	$ 130,000	
GC Bonds	1.5%	$ 194,000	
SUBTOTAL (Indirect Costs)		**$ 929,000**	$ 9,562,000
GC Margin	10%	$ 1,291,000	
SUBTOTAL		**$ 1,291,000**	$ 10,853,000
Construction Contingency	25%	$ 2,056,000	
SUBTOTAL		**$ 2,056,000**	$ 12,909,000
Total Contingency and Fees		**$ 4,688,000**	
TOTAL			**$ 12,909,000**

Source: CDM Smith 2014.

3.2.7.3 North Platte River, Nebraska

NORTH PLATTE RIVER, NE

Smaller and mid-sized communities, such as those along the Platte River in Nebraska, have implemented floodwater diversion projects and have jointly lessened the impact of flooding and preserved groundwater supply. The North Platte River, fed by many mountain streams in the Rocky Mountains of Colorado and Wyoming, is an important river system in southeastern Wyoming and western Nebraska. The waters are stored and used for irrigation and power development; however, flooding along the Platte River historically has plagued the area while groundwater shortages have occurred in past years.

The main project objective is to store excess surface water flows for later use in the surface water system and aquifer adjacent to the Upper Platte River, thereby mitigating the negative impacts of flooding events to the region, a form of conjunctive management that doubled as flood mitigation (Photo 3-5). The project also provided an opportunity for the project sponsors to demonstrate their capability for coordination and implementation of timely action when a mutually beneficial opportunity presents itself.

Source: Nebraska Department of Natural Resources.

Photo 3-5. (L) Dry Canal Prior to Groundwater Recharge Demonstration Project; (R) Filled Canal During Groundwater Recharge Demonstration Project

In conjunction with the State of Nebraska Natural Resources Department and several natural resources and irrigation districts, a flow diversion study began in 2010. Ultimately, a 2011 demonstration project diverted approximately 140,000 acre-feet of excess streamflow into existing canals and purposefully recharged approximately 65,000 acre-feet. That year, the Bureau of Reclamation had predicted flooding in the area, and the Natural Resources Department worked with local irrigation districts and canal companies to arrange permitting.

During April and May of 2011, 21 irrigation districts in the Upper Platte River watershed participated in a Recharge and Flood Mitigation demonstration project. Similar efforts occurred during the fall between September and December of 2011. A total of 23 canals diverted water from the North Platte River, South Platte River, and Platte River (**Figure 3-13**).

Source: Nebraska Department of Natural Resources.

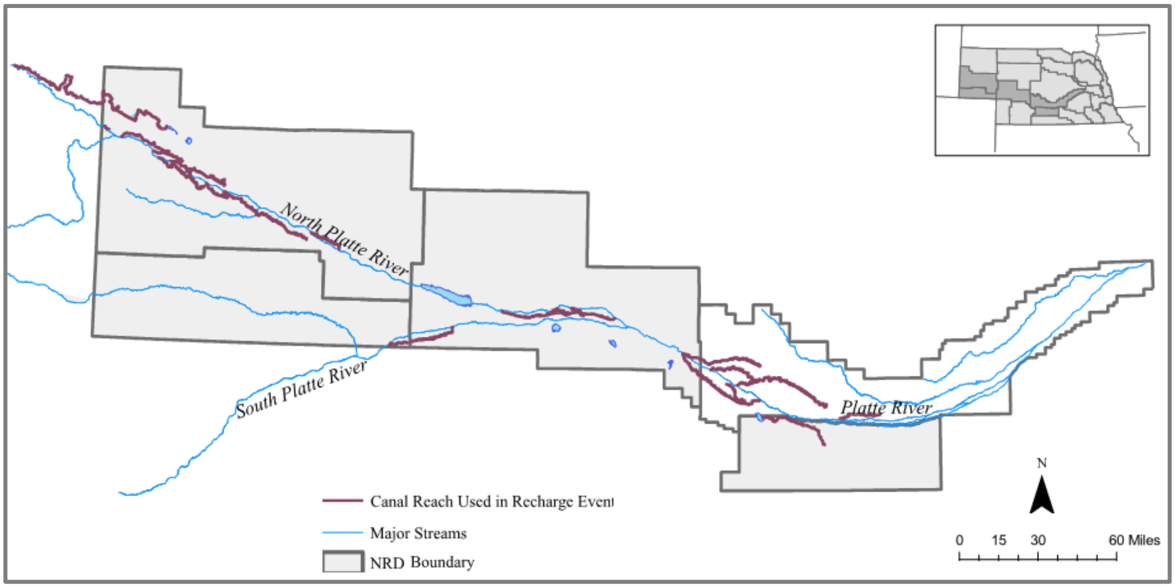


Figure 3-13. Platte River, NE Study Area

The Natural Resource Department Field Office along with the natural resource and irrigation districts monitored the diversions of the stream to the canal. The project sponsors were able to work through administrative requirements, implement the project in a timeframe that allowed for taking advantage of seasonal flood flows present at the time, and recharge a significant amount of water to the aquifer.

Ultimately, the project was a success, and a similar effort was undertaken in the fall of 2013 due to the extreme flooding in Eastern Colorado. Preliminary estimated peak flows at various points in the South Platte River Basin indicated that potential new record high water marks could be achieved. Diversions under the same coordinated efforts from the 2011 demonstration project were undertaken (**Photo 3-6**). A smaller number of canals were used during the 2013 diversion (a total of 9), and the efforts diverted 44,000 acre-feet of excess flood flow and recharged a total of 27,000 acre-feet. The total cost of the 2013 diversion was estimated to be approximately $700,000. Similar efforts were also implemented in 2015 as above average snowmelt and precipitation were observed in Colorado. Excess flows are being diverted into canals for storage and groundwater recharge until irrigation season.

Source: Nebraska Department of Natural Resources

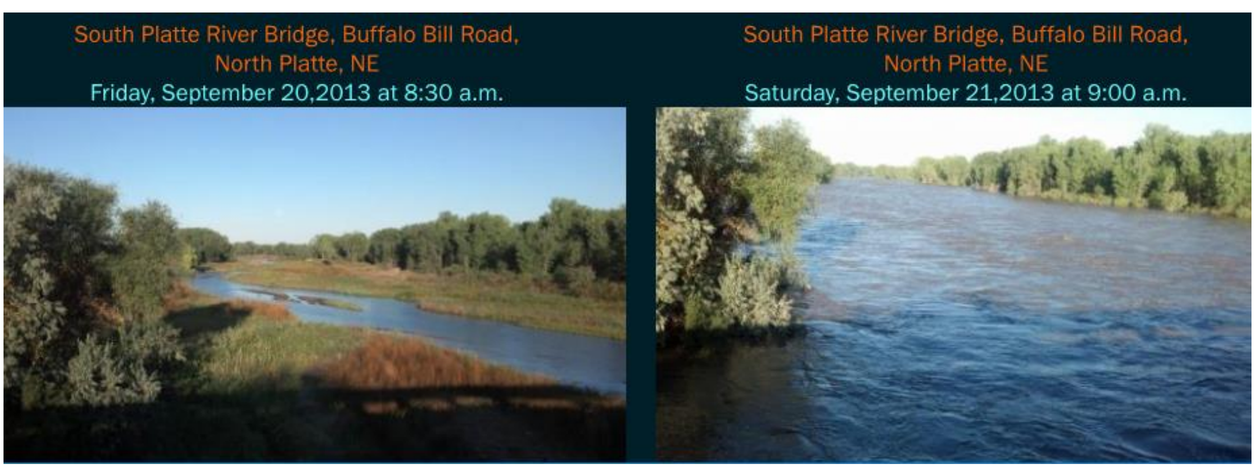


Photo 3-6. North Platte River, NE during the 2013 Diversion

3.3 FLOODPLAIN AND STREAM RESTORATION

3.3.1 Description

Any natural events and human activities can contribute significantly to changes in the dynamic equilibrium of stream systems across the country. Natural events include floods, landslides, and earthquakes; while human activities include urbanization, logging, agriculture, dams, and channelization. The changes in river dynamics from these anthropogenic activities can lead to stream degradation. Examples of the most significant types of degradation include bank erosion, sedimentation, and water pollution (Figure 3-14). Stream degradation ultimately results in water quality issues, loss of water storage and conveyance capacity, loss of habitat for fish and wildlife, and decreased recreational and aesthetic values (NRC 1992) while risks to flooding and erosion increase. A Climate Resiliency Snapshot for floodplain and stream restoration is provided on Figure 3-15.The U.S. has more than 3.5 million miles of rivers and streams that, along with closely associated floodplain and upland areas, comprise corridors of great economic, social, cultural, and environmental value (Federal Interagency Stream Restoration Working Group [FISRWG] 1998). When healthy, these systems can provide stream flood mitigation, mitigate bank erosion concerns, and provide ecological benefits. Additional benefits include the creation of habitat for fish and wildlife and increased stream baseflow, improvement of water quality, improved

Source: Center for Wetland Protection 2005.

Figure 3-14. Potential Sources of Stream Degradation

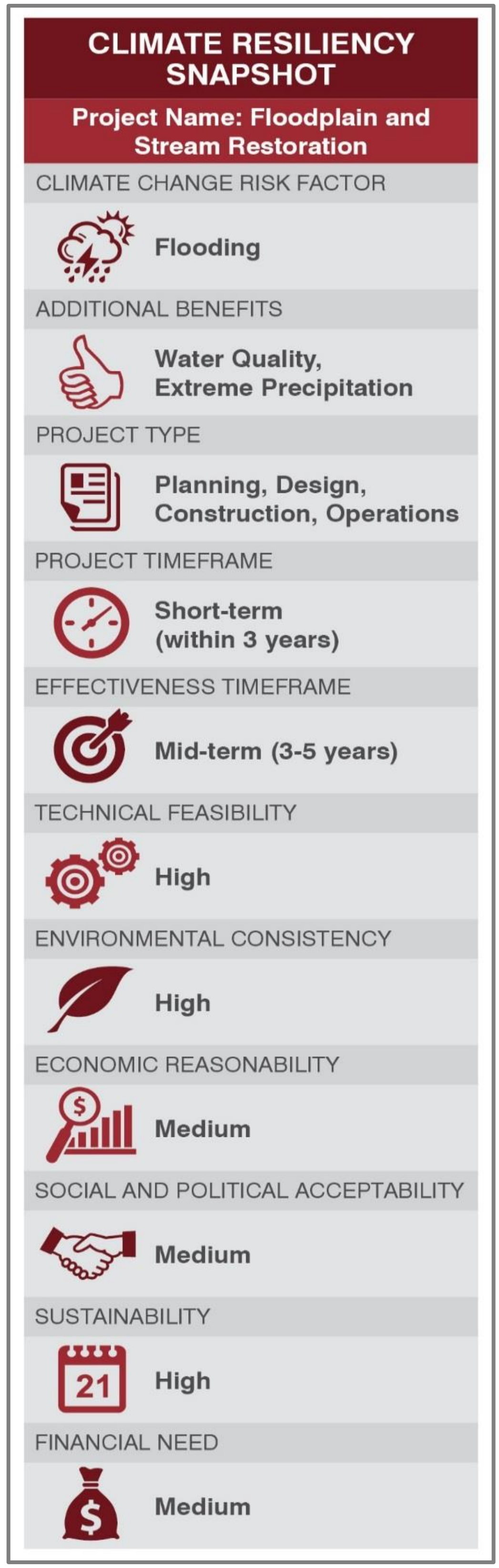


Figure 3-15. Floodplain and Stream Restoration Snapshot

air quality and reduced heat island effect from enhanced vegetation, water supply benefits, drought mitigation, and recreation opportunities.

Restoration is the reestablishment of the structure and function of ecosystems and floodplains. Ecological restoration is the process of returning an ecosystem as closely as possible to pre-disturbance conditions and functions. Implicit in this definition is that ecosystems are naturally dynamic. It is, therefore, not possible to re-create a system exactly, the restoration process reestablishes the general structure, function, and dynamic, but self-sustaining, behavior of the ecosystem (USDA-NRCS 2007).

Restoration of disturbed river systems is accomplished by adjusting the physical stability and biological function of an impaired river to that of a natural stable river. Channel improvements generally involve alterations to degraded channel floodplain storage, side slopes, sinuosity (degree of meandering), vegetation, bed slope, and roughness. The floodplain of a riverine or stream system provides capacity for storing stormwater runoff, reducing the number and severity of floods, and minimizing non-point source pollution. Restoring floodplains and wetlands and their native vegetation are integral components of stream restoration efforts. Comprehensive considerations of the streams at a watershed scale are also a component of stream restoration efforts.

3.3.2 Feasibility and Effectiveness

A wide variety of techniques can be applied to stream restoration planning and channel design. It is important to note that there are no one-size-fits-all approaches, and stream restoration requires a site-specific approach based on sound stream restoration analysis and design. A successful stream restoration project must incorporate multi-disciplinary techniques from hydrology and hydraulics, fluvial geomorphology, engineering, and stream ecology.

3.3.2.1 Manuals and Guidance Documents

Currently, there are several stream restoration manuals and guidance documents that have been published by various Federal agencies. These agencies include FISRWG (1998), USDA-NRCS (2007), USACE (Copeland et al. 2001), and NOAA-National Marine Fisheries Service (Skidmore et al. 2011). The guidance documents published by these Federal agencies should be included as part of a working body of knowledge. These documents provide several design techniques and case studies, specifically USDA-NRCS 2007. The Center for Watershed Protection, a non-federal organization, published the Unified Stream Assessment Manual (Center for Watershed Protection 2005) that was produced under a cooperative agreement with the USEPA's Office of Water.

3.3.2.2 Initial Assessment, Objectives, and Constraints

Clearly defining the objectives of the stream restoration project reduces ambiguity for all parties involved. Objectives should not only be specific, but also realistic, achievable, and measureable (USACE 2007). The ultimate goal is a stabilized system with increased connectivity between the waterway and the floodplain that reduces flooding, minimizes erosive velocities, and promotes ecosystem diversity while achieving a self-sustaining stream.

Assessment

In establishing objectives for a stream restoration project, it is advisable to assess the following factors:

- The existing condition of the stream and watershed and desired future conditions
- The scale and severity of the resource loss or degradation due to stream instability
- Factors and controls that have resulted in unstable stream condition
- The condition the channel is likely to evolve to without a restoration project
- Physical constraints on possible restoration measures, such as water quality, available right-of-way or construction area, as well as budget constraints

The range of alternative solutions that are both feasible and acceptable to stakeholders

Objectives

Typical goals and objectives include the following:

- Reduce peak velocities and streambank erosion
- Reduce peak flood stages
- Protect bridge abutments, bridges, road crossings, and other infrastructure
- Protect valuable residential and agricultural land
- Increase or improve municipal water supply (main source works and water quality)
- Restore fish and other ecological habitats
- Restore or improve water quality

Risks and Constraints

Potential constraints and risks to a restoration project include the following:

- Permitting requirements (surveying, clearing, earth-moving, dredging, and cultural resources)
- Ownership/land rights (purchase of easements, properties and/or structures)
- Site access (season, timing, and physical limitations)
- Material availability (earth materials and plant materials)
- Construction scheduling (season, environmental windows, and flow conditions)
- Local ordinances
- Tolerance for risk and uncertainty
- Utilities (underground, overhead)
- Pollution control (instream, parking areas, sediment control, and chemical control)
- Safety concerns (working on slopes, in water, around heavy equipment, and using hand tools)

- Threatened or endangered species

3.3.2.3 Project Scale

Project scale is a major consideration for stakeholders and the design team in setting objectives. Project scope and scale control the breadth of restoration options (Smith and Klingeman 1998). Early stream restoration projects were usually small-scale efforts to manipulate physical habitat and typically focused on local scour and deposition but often did not consider sediment transport beyond the immediate site. Initial successes and failures showed the need to develop approaches that would operate at watershed and ecosystem scales using concepts from physical and biological sciences. A larger-scale project may address major system processes such as channel meandering, ecosystem diversity, and ecosystem complexity.

Watershed-scale actions are generally preferred from an engineering and ecological perspective because they have the greatest potential to influence fundamental causes of degradation. Fluvial processes operating at landscape or watershed scale can govern system response at smaller scales. However, economic and political factors usually dictate smaller-scale strategies for restoration projects. Local measures often used for restoration include erosion control structures (e.g., bank protection measures or grade control structures), floodplain and streambank revegetation, and habitat structures. At a slightly larger scale, reach-scale measures include local measures applied over long reaches and include channel reconstruction, floodplain reconnection, dam removal, and revision of reservoir release strategies. On a large scale, watershed-level efforts include widespread application of these local and reach strategies in addition to programs that address exotic species and watershed hydrology factors such as land use management, best management practices for forestry and agriculture, and stormwater management, including green infrastructure. Additionally, public awareness and education is a vital component of every restoration effort.

3.3.2.4 Design Considerations and Flood Damage Reduction Techniques

Channel Design

Channel design is a critical portion of the overall stream restoration process. There are a wide variety of techniques and considerations based on criterion previously listed. Simply put, channels can be divided into two general categories based on sediment load and stability of the channel boundary during normal flow conditions. These two categories are threshold and alluvial channels. Threshold channels have a rigid channel boundary and erosion resistant streambed while alluvial channels have a flexible boundary and more mobile streambed material. Threshold and alluvial channels are further defined in the glossary while guidance and design techniques are discussed in more detail in the USDA-NRCS 2007 *Stream Restoration Handbook.*

General Design Considerations

Constructability and environmental impacts are two critical items to consider during the design phase. Other things to consider when designing a stream restoration project are the following:

- It is necessary to recognize that each watershed is unique, and site-specific information is needed to allow the designer to effectively analyze the system and develop an effective restoration design.

- When removing obstructions, it is important to do so in an environmentally sound manner and keep disruptions to habitat at a minimum (helicopters can be used for sensitive areas).
- Obstruction removal should always be considered before any severe stream modifications are taken.
- Stream geometry modification should result in peak stream velocities and shear stresses that are below critical threshold levels for streambank erosion and/or streambed scour.
- Designer should strive to reestablish connectivity between stream and floodplain and restore floodplain storage.
- Designer should compute and check stream stability criteria to provide that the proposed project does not result in adverse impacts to the waterway or surrounding areas. One such guide can be found in the *Stability Thresholds for Stream Restoration Materials* (USACE 2001).
- Designer should utilize native plant materials in the restoration effort.

Flood Damage Reduction Techniques

Flood damage reduction techniques should simultaneously provide flood protection benefits while restoring natural environmental functions. Careful planning, analysis, and design are required for the successful implementation of these changes. The functions of structural restoration practices are to deflect, redirect, or retard flows. Some of the most common channel modification techniques are listed, with a brief description, as follows:

- **Flood setbacks:** Removing structures from the floodplain and restoring the channel to its historic configuration. The stream is left to freely meander and flood its overbanks.
- **Levee setbacks:** Similar to flood setbacks, except overbank floodplain is limited by levees. The levees should not encroach upon the meander belt so that the channel may still migrate within this morphologically active corridor.
- **Two stage channels:** Involves an upper channel section to provide flood conveyance with a natural low-flow channel within it to provide habitat enhancement and improved sediment transport capacity.
- **Relief channels:** This technique typically involves restoring the channel to its original configuration and constructing a high-flow channel or relief culvert to provide for additional flood conveyance. The restored channel provides habitat benefits while the high-flow channel can be designed to divert excess flows, providing wetland or lowland habitat or for recreational benefits.
- **Addition of in-stream structures:** Flow changing devices are a broad category of structures that can be used to divert flows away from eroding banks. They are often used to shield banks from eroding flows, build up the toe of the bank, and direct flows to create a stable alignment. This technique includes the addition of boulders, wing deflectors, stone weirs, rock vanes, rootwads, bendway weirs, rock barbs, and Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids (LUNKERS), which are three sided wooden fish cribs that protect against erosion while providing in-stream habitat.

- **Addition of bank vegetation and seeding:** Trees and shrubs can provide lowland habitat, channel shading, stabilization, and aesthetic benefits. Vegetation may increase channel roughness, and hydraulic analysis is required to evaluate the impacts.

- **Armoring Countermeasures:** Stream restoration and stabilization may require the use of armoring countermeasures to provide lateral or vertical stability to a stream. Armoring countermeasures include concrete lining and other rigid revetments, rock riprap, gabion baskets, gabion mattresses, or articulating concrete block (ACB) revetment systems.

Technical supplements of the USDA-NRCS 2007 *Stream Restoration Design Handbook* may be referenced for implementation guidance for these design techniques.

It is important to consider that stream and floodplain restoration on a watershed scale may involve restoration strategies beyond the stream and floodplain. For example, if changes to hydrologic conditions due to anthropogenic influences have impacted the stream and floodplain, watershed-wide green infrastructure practices may be viable components of the restoration effort.

3.3.2.5 Sediment Impact Assessments

Sedimentation analysis is a key aspect of design since many projects fail due to excessive erosion or sediment deposition. A sediment impact assessment is conducted to assess the effect that a full range of natural flows will have on possible significant aggradation or degradation within a project area.

The first step in understanding and implementing a sediment impact assessment is to define the anticipated channel bed response. This is an assessment of bed stability to determine if the channel bed is aggrading, degrading, or is relatively stable. A variety of techniques may be used to assess the impact of sediment on a project area. A final sediment impact assessment should be viewed as a closure loop at the end of the design process to:

- Validate the efficacy of the design channel geometry

- Identify flows that may cause aggradation or degradation over the short term (these changes are inevitable and acceptable in a dynamic channel)

- Recommend minor adjustments to the channel design to provide for dynamic stability over the medium to long term

A common technique for assessing sediment impact is referred to as Lane's balance. This approach is described in more detail in **Attachment 3**.

3.3.2.6 Implementation Guidance

Implementing a successful stream restoration solution requires detailed planning, analysis, and design phases. Once the restoration plan is designed, it is important to carefully execute the construction, maintenance, and monitoring phases. A summary of typical pre-construction activities for stream restoration projects are provided in Table 3-6, and discussed in further in this section.

Pre-construction Activities

Evaluation and Feasibility (Planning) Phase

Implementing a stream restoration solution must begin with a detailed, site-specific plan. Identification of the true nature and causes of the stream issues is a critical step in the overall planning process and one that has been abbreviated or overlooked on many failed or poorly performing restorations. Appropriate and effective stream solutions can only be designed when the goals and objectives of the planned solutions are clear, realistic, and adequately formulated.

Engineering Analysis (Assessment) Phase

The alternatives analysis process may be iterative in that the initial alternative may require cycling back through some of the planning steps, making decisions, possibly modifying goals and objectives, and re-evaluating alternatives. The design process includes the development of the target flow rates for the stream. Flow rates can be obtained from previous studies or developed from regional regression equations, analysis of historical stream flow data, and hydrologic modeling.

Table 3-6. Typical Pre-Construction Activities for Floodplain and Stream Restoration Projects

Phase	Components	Definition	Remarks
Planning	***Scope of Work***	Identify climate change risk factor (consequence of climate change) and effects related to degradation	Flooding, water quality impacts, erosion, sedimentation, drought, ecosystem impacts
		Conduct Initial Assessment	Identify need for the mitigation project (scale and severity), describing work to be done and where (project and study area boundaries)
			Identify existing condition of the stream and watershed and desired future stream and habitat conditions
			Identify range of alternative solutions that are both feasible and acceptable to stakeholders
		Set goals and define objectives /benefits	Flood mitigation, water supply/water quality improvements, bank stability, habitat restoration, increased conveyance/storage, drought mitigation, and recreational and aesthetic
		Identify risks and constraints	Permitting requirements, land ownership and site access, tolerance for risk/uncertainty, underground and overhead utilities, threatened and endangered species, public acceptance, cost and/or funding, sediment & pollution control, construction feasibility and safety, and schedule
	Data Collection	Major data types that are needed to conduct initial assessment and engineering evaluation of alternative solutions	Existing and Future Watershed Land Use and setbacks
			Soil Type (National Resource Conservation Service) http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/
			Topographic and Surveying data (Specific to the project extents, identifying utilities and other avoidance areas)
			Geotechnical and/or Hydrogeological data (historical and current)
			Historical Rainfall Data (NOAA) https://www.ncdc.noaa.gov/cdo-web/

Phase	Components	Definition	Remarks
			Historical Streamflow and Stage (USGS) http://waterdata.usgs.gov/nwis/sw, or best estimates based on engineering analyses National Wetland Inventory (NWI) http://www.fws.gov/wetlands/; site assessment
Assessment	***Data Evaluation***	Determine modeling tool for use in engineering evaluation (pre- and post-project conditions)	Hydrologic and Hydraulic modeling tools may include: HEC-HMS, HEC-RAS, SWMM, HSPF, ICPR, or others
			Geotechnical and fluvial geomorphological evaluation
		Manuals and Guidance Documents	FISRWG (1998); USDA-NRCS (2007); Copeland (2001); NOAA-NMFS (2011); CWP (2005)
		Identify alternatives	Project scale and flood reduction and restoration techniques
		Establish design criteria	Define design storm, discharge rate, bankfull stage, sediment stability
		Analyze bed and banks, channel stability	Analyze existing problems upstream and downstream from project area
			Identify project effects (physical and biological)
		Develop recommendations	Develop alternatives based on analysis
			Develop sampling and data collection plan and analysis to support design
	Stream Restoration Feasibility Report	Conduct Desktop Feasibility of Stream Restoration Implementation	Evaluate and compare alternatives and make recommendation for selected alternative. Considerations consist of sedimentation, flood storage, habitat and ecology, land acquisition, and other goals and objectives set.
Design	***Basis of Design Report***	Document modeling methodology, results, and design recommendations	Methodology should be based on a sound scientific approach, results should present values for key restoration parameters and provide trends suggesting restoration benefits, and recommendations should be supported by the results provided.
	Construction Drawings and Specifications	Describe work to be performed, providing specific implementation strategies, construction details, and construction materials and equipment	Includes a 30%, 60%, 90%, and Final design process for selected alternative
	Create Bid Schedule (Cost Estimate)	List of pay items, units of measurement, and estimated quantities for proposed scope of work	Consider maintenance as part of cost estimations.

Phase	Components	Definition	Remarks
	Estimate Construction Schedule	List project's milestones, activities, and deliverables, with intended start and finish dates	-
Environmental Planning and Historic Preservation (EHP)	***EHP Coordination and Compliance***	Coordinate efforts throughout each stage of design with FEMA and demonstrate compliance with EHP requirements	Conduct initial screening of current environmental and historic conditions to identify design constraints
			NEPA Determination (Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement)
			Meet with FEMA at 30%, 60%, and/or 90% design stages to discuss EHP considerations
			Provide copies of all documentation to FEMA of any environmental, historic, and archaeological consultation and permitting
Cost Effectiveness	***Project Cost Effectiveness***	Demonstrate project cost effectiveness using BCA methodology	Prepare BCA using data developed in the design process. Provide supporting documentation (figures and narrative) related to this analysis. Cost effectiveness is demonstrated when the benefits of a project exceed the costs (i.e., Benefit Cost Ratio > 1.0).
Permitting and Site Access	***Permitting (EHP) Requirements***	List of permits to be acquired prior to initiation of construction and operation of project	Section 404 Dredge and Fill Permit (USACE); General environmental/stormwater permit applicable to local and State requirements; See Section 3.3.4 for a complete list of permits for stream restoration projects.
	Ownership/ Land Rights/ Site Access	Obtain site access and easements (acquire land as necessary) prior to initiation of construction	-
Potential Challenges to Implementation	***Project Challenges and Resolutions***	Describe challenges and potential resolutions	Restoring to historic conditions, long term channel stability, erosion & sediment control, maintaining conveyance during construction, re-establishing riparian habitat, representative modeling of system.

Note: HEC-RAS = USACE Hydrologic Engineering Center-River Analysis System; SWMM = EPA Storm Water Management Model

Design Phase

The Design process is integrated with the overall planning process. To design a solution means to fit it into the landscape, into the stream system, so that the result meets the goals and objectives of the plan. Stream designs may include a variety of solutions ranging from public education and upland watershed and riparian area management practices, such as green infrastructure, that may be needed, large-scale reconstructions of entire stream reaches, localized applications that can involve earth materials live and inert plant materials, and manufactured materials.

Implementation and Construction

The uniqueness of stream restoration construction requires that contractors be qualified for this specialized work and have sufficient experience installing successful restoration projects. The Implementation and Construction phase components are outlined in Table 3-7.

Table 3-7. Implementation and Construction Phase Components (Adapted from Garcia 2008 and NRCS 2007)

Components	Remarks/ Responsibilities
Construction Phases	
Obtain Permits, Access, and Easements	Must be acquired prior to construction
Identify Utilities and Other Avoidance Areas	Must be identified prior to construction (e.g., EHP)
Initiate Site Preparation/Clearing	Proper erosion and sediment control (E&SC), minimal stream disturbances, clear marking of site access, and staging areas
Installation/Construction	Installation of improvements must closely follow plans and details; critical for project success
Ongoing Inspections	Ongoing review and approval of improvements from site expert
Final Cleanup	Removal of temporary E&SC, spoil piles, construction waste, and equipment
Construction Team members	
Owner/Contracting Officer	Ensure performance of all necessary actions for effective contracting, ensuring compliance with contract, and safeguarding interest of the U.S. and its contractual relationship
Engineer	Responsible for technical requirements of project installation and represents owner; technical and contract administration duties
Specialist	Support specific elements of design, to monitor site conditions for plants and animals and assure that the goals of project are realized through construction and implementation
Government representative	Protect government/owners interest
Construction Inspector	Quality assurance testing, engineering surveys, daily documentation of construction activities, and maintaining as-built plans
Contractor	Firm that installs the stream restoration measures

Monitoring, Maintenance, and Adaptive Management

Once the restoration has been implemented, success of the project must be confirmed with monitoring and appropriate maintenance. Monitoring plans ensure that a project is performing as designed and achieving the intended goals. A monitoring plan is a necessary part of any restoration effort. The restored stream should be monitored at least semi-annually under varying flow regimes for a period of 3 to 5 years, with any deficiencies noted being addressed immediately. Monitoring phase components are specified in Table 3-8.

Table 3-8. Monitoring Phase Components (Adapted from Garcia 2008 and NRCS 2007)

Components	Remarks
Physical Parameters	Channel cross-section, hydrologic/hydraulic conditions, watershed trends, sedimentation, and erosion
Chemical Parameters	Turbidity, TSS, biochemical oxygen demand, dissolved oxygen, nutrients, BOD, DO, pH, temperature
Biological Parameters	Zooplankton, fish, riparian wildlife, vegetation, and habitat structure
Reference Sites	Restoration reach compared to representative reach
Stakeholder Response	Public meetings, surveys, recreational activity

Maintenance is the set of actions taken to ensure that a project's goals or objectives continue to be met. Maintenance may involve the repair of specific project features in response to some damage or the implementation of periodic and/or scheduled actions. While projects should be designed to minimize maintenance requirements, the designer should consider what may be required and how it can be linked to the monitoring plan. An ideal maintenance and monitoring plan should provide specific parameters to be assessed to determine whether the project is performing as intended as well as what maintenance actions should be undertaken. Restoration projects should be inspected and maintained after any large rainfall event (e.g., >2 to 5 year return period events) to assess functionality and stability.

Adaptive management is a dynamic approach to natural resource management that incorporates monitoring of project outcomes and uses the monitoring results to make informed revisions and refinements to ongoing management and operations actions. It is considered a process of establishing checkpoints to determine whether proper actions have been taken and are effective in providing desired results. Adaptive management is a continually evolving process that provides the opportunity for course correction through evaluation and action and is recommended when monitoring and managing stream and floodplain restoration projects.

3.3.3 Evaluation and Summary of Benefits and Costs

The primary benefit of floodplain and stream restoration is to reduce flood damages to structures and infrastructure while restoring natural and beneficial function of the floodplain. The project also provides a wide range of ecosystem service benefits, including:

- Improved water quality. Studies supported by the USEPA and USGS have shown that ecological restoration can be used to enhance the ability of a stream to remove sediment, floating debris, and nutrients, such as phosphorus, though vegetative uptake and nitrogen through denitrification, the process performed naturally by microorganisms in the water and substrate.
- Increased habitat connectivity through the connection of streams and wetlands within the riparian area.

3.3.3.1 Benefits

The primary benefit of floodplain and stream restoration is to reduce flood damages to structures and infrastructure while restoring natural and beneficial function of the floodplain. The benefits due to a reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project.

As described in Section 2.3.1, CDM Smith (2015c) in collaboration with Earth Economics provided standard values for ecosystem service benefits per acre for various land types as shown in Table 2-2. If a Floodplain and Stream Restoration project results in new or restored Wetlands, Estuaries, Riparian or Green Open Space, the total annual benefits for these categories can be included in the BCA. The subapplicant would need to quantify the area (in acres) of restored ecosystem and the land use type.

If applicable, benefits related to increased water supply capacity can be captured based on the two values presented in Section 2.3.2. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

Finally, stream restoration can stabilize stream banks as a way to control erosion. These benefits can be quantified based on documented erosion rates pre-project (e.g. using aerial photos) and information about the structures at risk. The project useful life for floodplain and stream restoration projects is 35-50 years. The goal of stream restoration is to provide a self-sufficient long-term solution and improvements typically exclude mechanical or electrical systems.

3.3.3.2 Costs

The costs of stream and floodplain restoration measures are very site-specific and depend on numerous factors such as tributary area, size and condition of floodplain, depth, width, sinuosity, and flow of the stream. These factors, along with bank slopes, access, existing and proposed vegetation, extent of erosion, type of soil/rock comprising the streambed and stream bank, and the amount of land required for easement or acquisition, all result in a complex array of costs.

Construction costs typically range from about $13/linear foot for low intensity efforts to a range of $500 to $1,500/linear foot of restored stream. Costs may vary depending on the scope, scale, and location of the project. Common line items include:

- Survey
- Geotechnical investigations
- Data collection and analysis
- Hydrologic and hydraulic analyses
- Engineering report with alternatives
- Consulting services for the design, permitting, project management, and supervision of the construction
- Construction and mobilization costs (e.g., erosion and sediment control, channel clearing and shaping, riprap, restoration structures, seeding and mulching, earthfill and drainfill, etc.)
- Pre- and post-project monitoring.

Lack of maintenance and monitoring of restoration projects can lead to potential failure. However, maintenance costs should decrease once floodplain and stream restoration features become established as the intent of the project is to restore natural functions. Although the O&M costs will not be funded by FEMA, they are required to be included in the BCA and therefore should be considered. O&M costs are extremely variable, and can sometimes be very costly early in the restoration process, before vegetation has been stabilized. The typical range to anticipate for O&M is 5-20% of the original construction cost. This considers vegetative/riparian maintenance and adjustment of in-stream structures. Costs for monitoring are typically dependent on the requirements of local regulatory agencies. The benefits versus costs of a particular restoration effort can vary widely based on the extent of services provided by the project and the magnitude of cost.

3.3.4 EHP Requirements

A simple floodplain restoration project that only involves land acquisition, removal of structures, and planting of indigenous vegetation might be covered under CatExs (d)(2)(vii), property acquisition and demolition and (d)(2)(xi), planting of vegetation. A more complex project that involves construction activities such as setback and reconstruction of levees, regrading stream beds and banks, or armoring countermeasures would likely not be eligible for a CatEx and would need to be analyzed in an EA. Most restoration projects would likely be covered by an EA, but larger projects or watershed scale projects may require an EIS to be prepared. Even though a floodplain or stream restoration project is likely to result in more beneficial effects on balance, if there are adverse impacts that would remain following all reasonable mitigation measures, then those would need to be disclosed through an EIS. Costs for each type of EHP document would be similar to those described under Section 3.1.4.

3.3.5 Potential Coordination with Other Federal Agencies

Several Federal agencies are already engaged in stream and floodplain restoration activities, and many agencies help support and provide funding for restoration activities. A list of Federal agencies that currently support stream restoration projects is listed below. This presents an opportunity to coordinate and align HMA funding, but may also require consideration of duplication of program concerns.

3.3.5.1 U.S. Department of Agriculture - Natural Resources Conservation Service

For 80 years, NRCS and its predecessor agencies have worked in close partnerships with farmers and ranchers, local and state governments, and other Federal agencies to maintain healthy and productive working landscapes. The NRCS provides many services to farmers, ranchers, and landowners, including technical and financial assistance, to make improvements to their land. Most of these programs are under the 2014 Farm Bill. More information on the programs can be found at www.nrcs.usda.gov/getstarted.

Emergency Watershed Protection

The NRCS administers the EWP Program, which responds to emergencies created by natural disasters. It is not necessary for a national emergency to be declared for an area to be eligible for assistance. This is a viable local match funding source where the NRCS may pay up to 75 percent of the construction costs of emergency measures. Up to 90 percent may be paid for projects within limited-resource areas as identified by U.S. Census data. The remaining costs must come from local sources and can be made in cash or in-kind services.

EWP is an emergency recovery program that provides assistance to project sponsors (state, local, general improvement districts, and conservation districts) and individuals in implementing emergency recovery measures. The program is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, windstorms, and other natural occurrences that cause a sudden impairment of a watershed. In recent disasters, flood retarding structures were built by the USDA-NRCS to store rainfall runoff caused by heavy storms. In February 2015, NRCS invested $84 million in EWP to fund more than 150 recovery projects in 13 states. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

Environmental Quality Incentives Program

EQIP provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation, or improved or created wildlife habitat. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Agricultural Management Assistance (AMA)

AMA provides financial and technical assistance to agricultural producers to voluntarily address issues such as water management, water quality, and erosion control by incorporating conservation into their farming operations. This is a viable local match funding source where the NRCS may pay up to 75 percent of the cost of installing conservation practices.

Producers may construct or improve water management structures or irrigation structures; plant trees for windbreaks or to improve water quality; and mitigate risk through production diversification or resource conservation practices, including soil erosion control, integrated pest management, or transition to organic farming. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ama/

Agricultural Conservation Easement Program (ACEP)

ACEP provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. Under the Agricultural Land Easements component, NRCS helps Indian tribes, state and local governments and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. Under the Wetlands Reserve Easements component, NRCS helps to restore, protect and enhance enrolled wetlands. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep/

Soil and Water Conservation Assistance (RCA)

The Soil and Water Resources Conservation Act of 1977, as amended (RCA) provides the USDA broad strategic assessment and planning authority for the conservation, protection, and enhancement of soil, water, and related natural resources.

Emergency Conservation Program (ECP)

The Emergency Conservation Program (ECP) provides emergency funding and technical assistance to farmers and ranchers to rehabilitate farmland damaged by natural disasters and for implementing emergency water conservation measures in periods of severe drought. Funding for ECP is appropriated by Congress.

Watershed and Flood Prevention Operations

The WFPO Program provides technical and financial assistance to states, local governments, and Tribes (project sponsors) to plan and implement authorized watershed project plans for the following purposes:

- Watershed protection
- Flood mitigation
- Water quality improvements
- Erosion reduction & sediment control

- Rural, municipal and industrial water supply
- Irrigation
- Fish and wildlife enhancement
- Hydropower

The program provides cost-share funds for engineering and construction costs. Under the Watershed Program, NRCS cooperates with states and local agencies to carry out works of improvement for soil conservation and for other purposes, including flood prevention; conservation, development, utilization, and disposal of water; and conservation and proper utilization of land. Additional information can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/

3.3.5.2 U.S. Department of the Interior (USDOI) – U.S. Fish and Wildlife Service

Natural Resource Damage Assessment Restoration Program (NRDA Restoration Program)

The mission of the USDOI NRDA Restoration Program is to restore natural resources that have been degraded as a result of oil spills or hazardous substance releases into the environment. Additional information can be found at http://www.doi.gov/restoration/about/index.cfm

3.3.5.3 U.S. Army Corps of Engineers

Under its civil works program, the USACE plans, builds, operates, and maintains a wide range of water resource facilities. Its civil works responsibilities are principally to support navigation, reduce flood and storm damage, and protect and restore aquatic ecosystems. Most environmental infrastructure projects are financed 75 percent Federally and 25 percent locally (Carter et al. 2015). USACE also works on interagency programs that aim to provide multiple benefits. The Federal portion of the funding is typically provided or authorized by Congress to the USACE while specifics of the management of the non-federal portion varies by project. A project will be approved only if there is Congressional authorization for work in the specified area and the activity undertaken is covered by that authorization. Recent efforts by the USACE for regional sediment management for beneficial reuse of dredged materials may be repurposed for future flood storage and diversion programs that are in need of fill material. A successful application of regional sediment management for ecosystem restoration and flood mitigation is the Jamaica Bay Marsh Islands in New York.

3.3.5.4 National Oceanic and Atmospheric Administration - National Marine Fisheries Service (NMFS)

Coastal Wetland Planning, Protection and Restoration Act

NOAA works through the Coastal Wetland Planning, Protection and Restoration Act to restore Louisiana's coastal habitat, which is the state's first line of defense during storms, reducing the devastating effects of wind, waves, and flooding. It works to fund and implement large-scale restoration projects to ensure healthy and sustainable coastal habitat for Louisiana's fisheries. These projects are significant at the local and national scale for their role in improving marine fisheries and their ability to protect communities and vital oil and gas infrastructure from storm damage. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/cwppra.html

Community-based Restoration Program

The NOAA Restoration Center's Community-based Restoration Program invests funding and technical expertise in high-priority habitat restoration projects that instill strong conservation values and engage citizens in hands-on activities. The program invests millions of dollars annually in restoration, leveraging double and triple the outcome by working with partner organizations. The program also provides restoration science and technical guidance, including assistance with environmental compliance and monitoring. Federal funds awarded under this program must be matched with non-Federal funds (cash or in-kind services) at a 2:1 ratio of Federal to non-federal contributions. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/crp.html

Damage Assessment, Remediation, and Restoration Program

NOAA's Damage Assessment, Remediation, and Restoration Program (DARRP) restores natural resources at hazardous waste sites and after oil spills and other physical impacts. NOAA cooperates with the public to identify restoration projects that benefit a wide variety of habitats and biological resources. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/darrp.html

Coastal Restoration through the Recovery Act

NOAA received $167 million from the American Recovery and Reinvestment Act of 2009 to restore coastal habitat and help jump-start the nation's economy by supporting thousands of jobs. NOAA's Recovery Act restoration efforts are spread over 22 states and two territories. Additional information can be found at http://www.habitat.noaa.gov/restoration/programs/recoveryact.html

3.3.6 Summary of Programmatic Considerations

The benefits of a floodplain and stream restoration project vary greatly based on the design and site conditions. While there are many environmental and ecological benefits, the project must act as an effective, stand-alone mitigation activity to reduce losses to infrastructure or people. The project may reduce losses to infrastructure, but may also provide benefits related to drought mitigation. From an HMA program standpoint, it will be important to establish the benefits during the project design phase to be able to justify it as a mitigation project. While establishing a traditional recurrence interval for drought may be difficult, the subapplicant should use the best available data and methodology deemed appropriate by the design engineer.

The project must not duplicate flood prevention activities of other Federal agencies and may not constitute a section of a larger flood control system. While the project can be sized based on the risk in the project area, HMA requirements of a 3-year period of performance for implementation should be considered. While a CatEx may be applied in some cases to reduce the EHP requirements (as explained in Section 3.3.4) for review of the project, early screening of the site is recommended to determine if an EA or an EIS would be likely based on project complexity and site conditions.

While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing resiliency throughout the U.S.

3.3.7 Example Implementation Success Stories

3.3.7.1 Longview Branch and Longview Branch Tributary Stream Restoration, Raleigh, North Carolina

Longview Branch and Longview Branch Tributary are two urban streams in Raleigh, North Carolina that were restored in 2008 as detailed in the City of Raleigh Upper Longview Lake System Improvements Project report (CDM 2008). Longview Branch Tributary is 1,040 linear feet, and Longview Branch is 2,325 linear feet. The project provided approximately 3,000 linear feet of stream restoration. Primary objectives of the restoration were to improve hydrologic function and create a more stable and ecologically integrated system. Other goals and objectives included an increase of stream capacity, removal of pollutants, increase the capacity of the system to support life, and improve aesthetics and safety of the stream and wetland, including providing educational opportunities.

Several culverts throughout the system were experiencing undermining to the extent that flow was bypassing some of the culvert sections. Also, some of the pipe segments were dislodged, which restricted fish passage. Significant bank erosion also occurred along several sections of the stream, coupled with a lack of connectivity between the stream and the floodplain, which contributed to overall habitat degradation. Due to anthropogenic disturbances, the stream system was at a state of instability. Scouring caused the channel to erode in some areas while excessive deposition occurred in others.

During the assessment phase, field surveys and soil sampling were conducted to understand stream channel conditions, riparian corridor, existing infrastructure, and subsurface conditions. Stream sinuosity (or tendency to move back and forth across the floodplain), stream width and depth, width of floodprone areas, slope, effects of localized constraints, degrees of erosion/sedimentation, vegetation, and substrate characteristics were measured and evaluated from field investigation data. The stream was divided into eight reaches based on common characteristics and hydraulic constraints. The Rosgen channel classification method was applied to the eight reaches of the Longview Branch and Longview Branch Tributary. Hydraulic and hydrologic modeling was performed to analyze the pre-restoration conditions to guide design discharge determinations and design dimensions. Varying levels of natural stream channel design were applied, ranging from restoration of the historical channel elevation to in-place stabilization, within the confined corridor, to improve both habitat conditions and channel stability. The natural channel design was intended to emulate natural conditions, which foster productive ecosystems.

Infrastructure along the stream was protected with stream bed and bank stabilization design and protection measures. Enhancement of natural conditions was designed by connecting the channel to a floodplain bench; controlling velocities and erosion with in-stream vane structures; providing habitat with riffle pool sequences, deep pools, long vanes, and stream bank vegetation; and planting of a dense native riparian buffer.

Permits were obtained for this project to fulfill the Clean Water Action Section 404 requirements with corresponding North Carolina 401 General Certifications to fulfill Section 401 requirements. Correspondence with the USACE Raleigh Regulatory Field Office also allowed for the use of Nationwide Permits (NWP) with a Pre-Construction Notification submittal. NWP 3(maintenance of existing structures), 13 (bank stabilization), 18 (minor discharges), and 27 (aquatic habitat restoration) for

Section 404 jurisdictional permitting were obtained. Restoration had to comply with fill limits and limits to the loss of perennial stream bed associated with NWP 18 and the Regional General Condition 3.1, respectively. The 401 Division of Water Quality (DWQ) General Water Quality Certifications Nos. 3402, 3494, and 3495 correspond with the NWPs mentioned above. Qualitative and quantitative monitoring, along with general maintenance, were recommended to ensure the success of the project. Annual monitoring reports were recommended to be produced for 5 years to evaluate the success of the project.

The total project construction cost was approximately $1.4 million (approximately $470/linear foot of restoration), which was funded via a no interest loan through the State Revolving Fund (SRF) Loan Program. Design of the project cost approximately $350,000 and included some scope beyond the stream restoration exclusively. Of that design cost, approximately $28,000 was budgeted for permitting. This cost did not include monitoring and maintenance costs, which were the responsibility of the City of Raleigh. The success of the restoration project is illustrated in the photographs below (Photo 3-7).

Photo 3-7. Illustration of Longview Stream System Improvements in Raleigh, NC

3.3.7.2 Wiley Creek Streambank Protection, Linn County, Oregon

Wiley Creek is a tributary to the Santiam River, which flows into the Willamette River in Oregon State. Fifty-seven square miles with approximately 3,700 feet of relief drain to Wiley Creek. The watershed of Wiley Creek has changed drastically due to anthropogenic influences. Many streams in this region have been splash-dammed to transport logged timber, which has impacted the geomorphology of streams, as well as instream habitat and biodiversity, and has influenced the hydrology of the region.

Two structures were located 5 feet from the edge of a 23-foot-high vertical bank along Wiley Creek and faced imminent loss of property. This bank had eroded more than 40 feet since a major rain-on-snow event in 1996 and was no longer at a stable angle, placing the structures at risk. The dominant bank failure mechanism was streamflow undercutting the bank, resulting in mass wasting. This project was designed in 2003-2004, with a goal to protect the two structures, as detailed in the National Engineering Handbook (USDA-NRCS 2007). Secondary goals included bank stabilization and fisheries habitat improvements without causing a significant increase to the pre-project flood elevations.

The USDA-NRCS Oregon State Office designed, permitted, and performed construction management on the project. The project included a 180-foot-long reinforced earth embankment with three engineered log jams and two stream barbs. The project area is also Federally listed as being spawning and rearing habitat for steelhead and Chinook salmon, which necessitated environmentally sensitive engineering design at the site, more stringent permitting requirements, and additional implementation considerations.

Site surveys and hydrologic, hydraulic, and geotechnical modeling were used to help guide the design of the revised bank condition. Reinforced earth and soil bioengineering techniques were selected to protect the structures on the site and improve habitat conditions at the site. These techniques were selected based on their success in prior applications, ease of permitting, and ability to incorporate habitat enhancement features. NRCS Plant Materials Centers were consulted to select appropriate vegetation for the site. Willows were selected and planted in clumps along the bottom of the embankment.

Construction of the project had to occur during a specified window of time to accommodate threatened and endangered salmon species. Flow was diverted from the project site with the use of a cofferdam during construction. The total project cost was $107,000 (approximately $595/linear foot of restoration), which included construction labor and materials. While exact design and permitting costs for this particular project is unknown, it is estimated that these tasks would be approximately 15% to 20% of the total project costs. Photographs of the construction process are provided below (Photo 3-8).

Source: USDA-NRCS 2007.

Photo 3-8. Embankment Construction Process Wiley Creek Streambank Protection Project, Linn County, OR

The project was completed In August 2004. Several months following completion, the design was tested with a significant snowfall event in the Cascade Mountains, which melted quickly during a subsequent rainfall event. The combined snowmelt runoff and rainfall runoff created a considerable streamflow, but the project site performed well and did not experience any erosion during the storm. The vegetation and plantings had not been fully established at that time and offered little benefit to the project; however, the reinforced earth and bioengineering techniques performed well. Since that event, the plants and vegetation have taken hold and offer additional erosion protection. This project was successful at providing the bank stabilization protection for the structures and reducing the risk to loss of property. Photographs of the completed project (left) and the same view approximately 16 months later with established vegetation (right) are provided below (Photo 3-9).

Source: USDA-NRCS 2007.

Photo 3-9. Established Vegetation along Embankment Wiley Creek Streambank Protection Project, Linn County, OR

3.3.7.3 Holmes Run Stream Stabilization, Fairfax County, Virginia

Holmes Run, located in the Potomac River watershed, is a highly urbanized stream subject to extreme flows during storm events. Storm events have resulted in high erosion rates, channel incision, mass wasting (movement of sediment downslope), and bank failure in areas along the stream. In this particular project site along Holmes Run, erosion jeopardized an active sanitary sewer junction box. Stream bank stabilization features were designed (CDM 2010) to provide long-term bed and bank stability with minimal maintenance. Several additional factors influenced the design, including permitting, agency acceptance, negotiation with adjacent landowners, and coordination with an adjacent bike trail and planned downstream stream rehabilitation.

To design the project, site specific stormwater modeling of the area was conducted to predict the extent of scour along the banks (CDM 2010). The resulting design included a 140-foot-long imbricated riprap wall and riprap within the stream around the sanitary sewer junction box to protect it from future erosion. Backfill behind the riprap wall was planted with native shrubs and seeds of native herbaceous plants. Two in-stream structures were also added to stabilize the stream and protect the banks while providing aquatic habitat via a variable streambed. A J-hook was designed upstream of the wall to direct flows away from the upstream end of the riprap wall and prevent erosion. A grade control rock cross-vane was added downstream of the crossing sewer to direct water away from the banks below the junction box.

The project was designed and constructed from 2009 to 2012. The construction phase of the project cost approximately $2 million, with design, analysis, and consulting costs totaling approximately $140,000. Permits were acquired for construction of the project from the USACE and Virginia Marine Resources Commission, and the project adhered to the Chesapeake Bay Preservation Act requirements. Collaboration and coordination occurred during the execution of the project with stakeholders, including Fairfax County Wastewater Collection Division, Fairfax County Park Authority, the City of Alexandria, and adjacent property owners. Post construction photographs are provided below (Photo 3-10).

Source: CDM 2010.

Photo 3-10. Holmes Run Stream Stabilization Project, Fairfax County, VA

3.3.7.4 Rose River, Madison County, Virginia

The Rose River is located in Madison County, Virginia in a mountainous area with a watershed of approximately 14 square miles. The river was damaged by several large floods in the mid-1900s as noted in the *National Engineering Handbook* (USDA-NRCS 2007). The river, in its degraded condition prior to restoration, posed several risks. If the restoration was not performed, an adjacent state road would have been undercut, fish habitat would further deteriorate due to sedimentation from bed instability, and flooding would be more significant because of large cobble and debris that was restricting the channel after damage from the floods.

In 1998, under the EWP Program, 4,200 feet of the Rose River was restored to a more stable condition through the collaboration between the USDA and the NRCS. Cooperators of the project included the Virginia Department of Game and Inland Fisheries, Virginia Department of Forestry, Virginia Department of Conservation and Recreation, and Graves Mountain Lodge Corporation. The goal of the restoration effort was to restore the hydraulic function of the river and, more specifically, the vertical dimensions of the reach. Secondary goals included public safety at the site, habitat for stocked trout, and protection of infrastructure on adjacent properties. Total cost of the construction was approximately $120,000, or $29 per linear foot (USDA-NRCS 2007). While exact design and permitting costs for this particular project is unknown, it is estimated that these tasks would be approximately 15% to 20% of the total project costs.

The Rosgen method of stream classification was used to inform the restoration effort. The river could not be improved from the pre-storm condition due to limitations with the funding provided for the project. Under the EWP Program rules, the cost of the protection of agricultural land cannot exceed the value of the agricultural land, which added additional constraints to restoration. To restore the river, large sediment deposits were removed along the channel, and nine vortex rock weirs, two sets of rootwad revetments, and 400 linear feet of riprap were installed (**Photo 3-11**). Rootwads are commonly available in the floodplain after a flood event and therefore can be used to provide protection for only the cost of installation. For this project, rootwads were acquired from an adjacent project site that had several available rootwads. These rootwads helped the cost requirement of protecting agricultural lands for no more than the value of the land they protect. Trees were planted in the riparian zone, which added additional site stability. The upper end of the river was also rerouted to its pre-flood location.

Performance of the restoration effort was monitored. Photographs taken annually showed little change in the river from 1998 to 2003. A survey of the channel was performed in 2004 and showed some areas of the river had filled in while others had a change in slope.

Source: USDA-NRCS 2007.

Photo 3-11. (L) Weir Constructed on the Channel; (R) Rootwads in the Channel Rose River, Madison County, VA

3.4 LOW IMPACT DEVELOPMENT/ GREEN INFRASTRUCTURE

3.4.1 Description

LID is a sustainable approach to natural landscape preservation and stormwater management (USEPA 2013). This approach emphasizes conservation and the use of onsite natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions (PSAT 2005). GI can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID (USEPA 2014c). Both LID and GI are BMP approaches that can be combined in a BMP Treatment Train to enhance benefits and reduce costs. A Climate Resiliency Snapshot for LID/GI is provided on Figure 3-16.

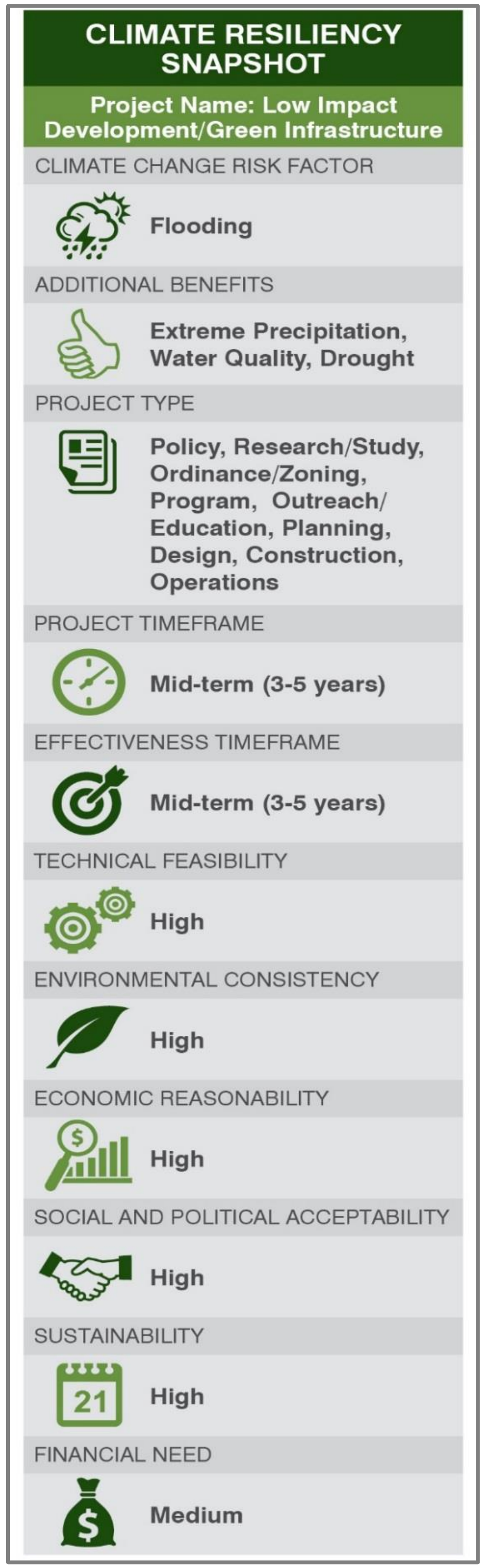


Figure 3-16. LID/GI Snapshot

Originally, the term GI was used to describe a network of green spaces that were connected, offering multiple ecosystem benefits (Economides 2014). In the last decade, LID and GI have often been used interchangeably; however, LID focuses specifically on water management issues while GI's scope can be broader and used to mitigate issues such as air pollution, urban heat island effects, wildlife conservation, and recreational needs (Chau 2009). In this report, when possible, more focus will be given to the stormwater management and flood control/management mitigation aspects offered by using LID/GI practices. Some examples of these LID/GI practices are included in Attachment 4.

LID/GI takes a very different approach to water management as compared to conventional "gray" stormwater strategies. Conventional methods aim to move water off site and into the storm drains as quickly as possible while LID/GI seeks to do just the opposite and keep as much water on site as possible for storage, absorption, and infiltration (Economides 2014). The goal of GI is to design a built environment that remains a functioning part of an ecosystem rather than existing apart from it. This is an innovative approach to urban stormwater management that strategically integrates stormwater controls throughout the urban landscape and does not rely solely on conventional end-of-pipe structural techniques (Maimone et al. 2007). Instead of large, centralized treatment plants and water storage facilities, LID/GI emphasizes local, decentralized solutions that capitalize on the beneficial services that natural ecosystem functions can provide. LID/GI is most effective when it is applied on a wide scale and encompasses much more than just water infiltration, as it can be used to mitigate floods downstream, filter pollutants, and capture and store water for use at a later time. Storing potential floodwaters on site in LID/GI practices allows for a controlled baseflow release and attenuates peak flows, stages, and velocities to mitigate flooding. The diversion, storage, and infiltration of these waters can also replenish water supply aquifers and enhance usable water supply to mitigate the effects of drought.

One of the primary motivations for LID/GI for a number of communities in the U.S. is to reduce stormwater runoff, which may contribute to combined sewer overflow (CSO) events. Overflow occurs in cities with combined sewer systems (CSS) where wastewater (i.e., sanitary sewage), stormwater, and urban runoff water are collected in the same pipe network and routed to a treatment plant (Economides 2014). If the capacity of the downstream treatment plants cannot handle the amount of water collected, excess flows, inclusive of sanitary sewage, are often routed directly to the nearest body of water.

LID/GI is an ecosystem-based approach used to replicate a site's predevelopment hydrologic function. The primary goal of LID/GI is to design each development site to protect, or restore, the natural hydrology of the site so the overall integrity of the watershed is protected (Maimone et al. 2007). This is done by creating a "hydrologically" functional landscape. As such, the following are key principles that characterize the goals of LID/GI (Maimone et al. 2007; Chau 2009):

- Decentralize and micromanage urban runoff to integrate water management throughout the watershed. Emphasize a distributed (not concentrated) control of stormwater
- Preserve or restore the ecosystem's natural hydrological functions and cycles, including the conservation of significant natural resources and habitat
- Account for a site's topographic features in its design. Minimization of the environmental impact resulting from the change in land use (minimum disturbance, minimum maintenance)
- Reduce impervious ground cover, roads, building footprints, and other infrastructure necessary to support development
- Maximize infiltration on site. If infiltration is not possible, then capture water for filtration and/or reuse

3.4.2 Feasibility and Effectiveness

In the face of a changing climate, LID/GI can potentially play an increasingly important role to reduce local impacts for community resources and waters. By reducing the volume of runoff entering sewer systems and increasing natural features that can reduce the effects of flooding, LID/GI can add resiliency to climate change adaptation planning (American Rivers et al. 2012).

Modeling can be conducted to predict potential impacts that LID/GI practices would have in an area. For example, GI has been found to provide substantial benefits related to flood protection (Medina et al. 2011). GI practices such as bioretention filters, pervious pavement, green roofs, and cisterns were designed to store a given volume of water that corresponds to a threshold rainfall depth, such that a large fraction of the annual rainfall volume would be controlled (Medina et al. 2011). The effects of the GI practices were investigated using the Hydrologic Modeling System (HMS) software and the River Analysis System (RAS) hydraulic modeling software developed by the Hydrologic Engineering Center

(HEC) of the USACE. The results of this particular analysis were evaluated through the application of FEMA's Hazus software. It was concluded that GI would not appear to have a significant impact in reducing the extent of the 100-year floodplain; however, the reduction in the extent of flooding associated with GI implementation for less severe, but nonetheless flood-inducing events has significant impacts on overall flood risk exposure. It was concluded that to be effective, implementation of GI needs to take place on a watershed-wide basis and that these practices must be deployed as part of a holistic approach to watershed management that affords benefits in water quality, channel stability, reduced flood risk, ecosystem integrity, natural resource protection, and recreation and aesthetic benefits to the public (Medina et al. 2011).

Acceptance of LID/GI practices over traditional gray infrastructure strategies is often a concern for local municipalities. The USEPA reported on the benefits of LID/GI programs for 13 case studies in 2013. Regarding social and political acceptability, some communities have encouraged comprehensive programs with open space set-aside requirements, incentives for LID/GI, and intergovernmental collaboration. In some cases, governance structure was modified to increase interdepartmental collaboration to promote the adoption of LID/GI program elements. Education was noted as an important issue, particularly for acceptance of the LID/GI components of a community's development standards (USEPA 2013).

The following sections present items that must be considered when implementing LID/GI practices.

3.4.2.1 Scales of Implementation

LID/GI practices can be applied to design at multiple scales including those from individual buildings, lots, and neighborhoods to entire cities and metro regions, and the benefits can range in scale accordingly. Projects can be implemented via large centralized public "macro" projects or smaller decentralized "micro" applications on private property (CCAP 2011). LID can have a significant impact when implemented on a large scale. It can be integrated into overall regional, municipal, and area planning to identify areas suitable for development and to concentrate appropriate development in those areas (Perrin et. al 2009). At the largest scale, the preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) are critical components of GI. On a smaller scale, GI practices may include rain gardens, porous pavements, and green roofs (St. Johns, 2011). Multiple benefits can be offered through a combination of different LID/GI practices, and how a combination of practices may lead to the highest net climate adaptation benefits depending on local needs, capacities, and resources should be considered (CCAP 2011).

3.4.2.2 Site Design Considerations

Since every site is unique, there is no single LID/GI solution that is appropriate for all sites, terrains, soils, or climates. LID/GI design should involve an individualized approach to site inventory and analysis that requires assessing all relevant site issues and creating a detailed understanding of how these factors work together and influence one another. Topography, hydrology, natural features, and other resources all need to be carefully identified and mapped (Perrin et. al 2009). Regional and local variables, such as climate, also play a large role. Two GI installations with the exact same specifications can result in drastically different levels of benefits when implemented in different locations (CNT 2010). Therefore, LID/GI solutions need to be custom fit to address site-specific challenges to provide for maximum effectiveness.

Typical pre-construction activities related to implementation of LID/GI projects are summarized in Table 3-9.

Table 3-9. Typical Pre-Construction Activities for LID/GI Projects

Phase	Components	Definition	Remarks
Planning	***Scope of Work***	Identify climate change risk factor (consequence of climate change) and effects related to degradation	Flooding, water quality improvement, drought
		Conduct Initial Assessment	Identify need for the mitigation project (scale and severity), describing work to be done and where LID/GI practices will be located.
			Identify existing conditions and desired future conditions
			Identify range of LID/GI practices that are both feasible and acceptable to stakeholders
		Set goals and define objectives/benefits	May include: flood control, water supply/water quality improvements, increased storage, and recreational/aesthetic.
		Identify risks and constraints	Permitting requirements, land ownership and site access, tolerance for risk/uncertainty, utilities, public acceptance. LID/GI solutions need to be custom fit to address site-specific challenges
	Data Collection	Major data types that are needed to conduct initial assessment and engineering evaluation of alternative solutions	Existing and future watershed land use
			Topographic and surveying data (specific to the project extents, identifying utilities and other avoidance areas)
			Geotechnical and/or hydrological data
			Soil Type (National Resource Conservation Service) http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/
			Historical rainfall data (NOAA) https://www.ncdc.noaa.gov/cdo-web/ Land use cover data (USGS) http://landcover.usgs.gov/
Assessment	***Data Evaluation***	Determine modeling tool(s) for use in engineering evaluation (pre- and post-project conditions)	Tools such as GIS can be used to document and analyze existing conditions. The existing conditions inventory can include maps of land use, impervious surfaces, and open space opportunities which support locational strategies to implement LID/GI practices
			Geotechnical investigation including soil borings to determine soil characteristics (field and laboratory) as well as the depths to groundwater table and bedrock
			Site investigations and soil testing requirements vary depending on the LID/GI practice. They can help identify historic cut and/or fill, soil compaction, building debris, infiltration rates, contamination, pH, lack of plant nutrients and other issues

Phase	Components	Definition	Remarks
			Modeling tools such as EPA's BMPs Siting Tool can be used to identify potentially suitable LID/GI areas
		Manuals and guidance documents	See Attachment 5
		Identify alternatives	For example, traditional gray infrastructure practices
		Establish design criteria	Define items such as impervious area, design storm, storage volume, infiltration rate
		Develop recommendations	Project alternatives
			Future data collection and analysis to support design
Design	***Basis of Design Report***	Document model methodology, results, and design recommendations	
	Construction Drawings and Specifications	Describe work to be performed, providing specific implementation strategies, construction details, and construction materials and equipment	Includes a 30%, 60%, 90%, and Final design process for selected alternative
	Create Bid Schedule (Cost Estimate)	List of pay items, their units of measurement, and estimated quantities for proposed scope of work	
	Estimate Construction Schedule	Listing of a project's milesto nes, activities, and deliverables, with intended start and finish dates	
Environmental Planning and Historic Preservation (EHP)	***EHP Coordination and Compliance***	Coordinate efforts throughout each stage of design with FEMA and demonstrate compliance with EHP requirements	Conduct initial screening of current environmental and historic conditions to identify design constraints
			NEPA Determination (Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement)
			Meet with FEMA at 30%, 60%, and/or 90% design stages to discuss EHP considerations
			Provide copies of all documentation to FEMA of any environmental, historic, and archaeological consultation and permitting

Phase	Components	Definition	Remarks
Cost Effectiveness	***Project Cost Effectiveness***	Demonstrate project cost effectiveness using BCA methodology	Prepare BCA using data developed in the design process. Provide supporting documentation (figures and narrative) related to this analysis. Cost effectiveness is demonstrated when the benefits of a project exceed the costs (i.e., Benefit Cost Ratio > 1.0).
Permitting and Site Access	***Permitting Requirements***	List of permits to be acquired prior to initiation of construction and operation of project	Variability depending on location, but typical permits include those associated with stormwater BMPs.
	Ownership/Land Rights/Site Access	Obtain site access and easements (acquire land as necessary) prior to initiation of construction	
Potential Challenges to Implementation	***Project Challenges and Resolutions***	Describe challenges and potential resolutions	Regional and local geographic and hydrologic variability, physical size limitations

There are several factors to consider when deciding which LID/GI practice should be implemented, including (Perrin et al. 2009):

- Watershed size
- Existing soils
- Site stability
- Seasonal high water table
- Seasonal low water table
- Topography (slope) of the potential site
- Costs (including land requirements, design and construction, and long-term maintenance)
- Other project goals and needs, such as parking, aesthetics, and water harvesting

As such, not all sites are suitable for LID/GI and the use of these practices may not completely replace the need for conventional stormwater controls (USEPA 2000). For example, LID techniques that primarily focus on infiltration may not be feasible in portions of some areas prone to flooding due to factors such as high groundwater levels, soil quality, slope, drainage, and vegetative cover type (FEMA 2013). In other areas, LID techniques that are focused on water quality are more likely to be successful in meeting habitat goals than techniques that attempt to increase infiltration rates (FEMA 2013).

Even with site-specific limitations, LID/GI practices should generally accomplish the following (USEPA 2014):

- Reduce impervious surfaces
- Disconnect impervious areas
- Conserve natural resources
- Use cluster/consolidated development
- Use xeriscaping and water conservation practices

For example, for undeveloped sites, rather than completely clear-cutting and leveling, designers should preserve as much wooded area as possible and try to avoid disturbing natural topographic depressions. Home sites should be designed with narrow driveways and minimal sidewalks. Streets should be kept as narrow as local zoning and building codes will allow (Davis 2005). To minimize soil compaction, the use of heavy equipment should be discouraged. Vegetated swales are encouraged, instead of curb-and-gutter systems that rapidly convey runoff. Rooftop downspouts can be directed into vegetated areas, and rain barrels can be used to capture water for later use. Permeable paving materials can be used rather than traditional asphalt and concrete. Collectively, these actions assist in keeping precipitation and runoff away from traditional gray infrastructure. Fewer impervious surfaces create less runoff. Swales and natural depressions allow for some on-lot storage, thus promoting compaction of soils encourages natural infiltration. Overland water flow is slowed by vegetation, depressions, and meandering; this gives water time to seep into the ground, mobilizes fewer pollutants, and allows particulate matter to settle or be filtered (Davis 2005).

3.4.2.3 Design Guidance and Technical Manuals

Based on decades of research and the actual construction of LID/GI practices, there is a large body of knowledge available. The selected manuals and technical guides in Attachment 5 provide valuable information on how some communities throughout the U.S. approach LID/GI. Most of these documents also include introductory information about LID/GI and many also contain technical information on specific practices. This information is organized by regions in the U.S. due to the potential spatial variability and effectiveness of the same LID/GI practices.

3.4.2.4 LID/GI Practice Selection Guidance

Local and site-specific variability from factors such as rainfall, runoff, background water quality characteristics, and development options can greatly influence the selection of LID/GI practices. Design is often an iterative process, beginning at the planning stage of a project, adjusted during detailed design when more information about a site is available and reevaluated during construction given field conditions (City of Philadelphia 2014). With this in mind, a number of communities around the U.S. have conducted the necessary research and developed guidance recommending the selection of various LID/GI practices in their area.

In order to achieve a “best fit” LID/GI practice for a site, qualitative guidance decision tools like the following examples have been developed to allow potential users to quickly understand the benefits or challenges of different LID/GI practices in a particular area of the country. With such a tool, users can simplify the planning approach and focus on only those LID practices which are practical for their desired application. For example, Figure 3-17 presents an LID guidance matrix that was developed for

Sarasota County, Florida. From this matrix, users can make decisions on what type of practices could be effective considering general site conditions, specific environmental conditions, and special watershed site conditions.

Another example of selection guidance can be seen in Table 3-10, which was developed for the Yakima Region in Washington. This table describes suitable LID practices based on different landscapes and soils found throughout the area. The authors of the Yakima Region LID guidance document note that this guidance selection table is intended to be used as a starting point for geographically evaluating various LID opportunities and challenges; however, site-specific identification and analysis of on-site conditions would need to be performed prior to design (Carlson et al. 2011).

LOW IMPACT DEVELOPMENT PLANNING CONSIDERATIONS	PROJECT APPLICABILITY (Y or N)	LOW IMPACT DEVELOPMENT ALTERNATIVES AVAILABLE TO MEET STORMWATER MANAGEMENT SITE NEEDS IN SARASOTA COUNTY							
		DETENTION WITH BIOFILTRATION (SEE SECTION 3.1)	PERVIOUS PAVEMENTS (SEE SECTION 3.2)	STORMWATER HARVESTING (SEE SECTION 3.3)	GREENROOF TREATMENT (SEE CHAPTER 3.4)	RAINWATER HARVESTING (CHAPTER 3.5)	SHALLOW BIORETENTION (CHAPTER 3.6)	VEGETATIVE FILTER STRIPS (CHAPTER 3.7)	CONFINED URBAN VEGETATIVE SYSTEMS (CHAPTER 3.8)
A. GENERAL SITE CONSIDERATIONS									
A.1-THE PROJECT IS PLANNED TO BE CONSTRUCTED ON UNDEVELOPED LAND WITH FLEXIBLE LOCATIONS FOR STORMWATER MANAGEMENT.		●	●	●	●	●	●	●	●
A.2-THE PROJECT IS A REDEVELOPMENT AREA OR RETROFIT PROJECT WHERE NO STORMWATER PONDS EXIST.		◐	●	○	●	●	◐	◐	●
A.3-THE PROJECT IS A PROPOSED LINEAR PROJECT (I.E. NEW ROADWAY).		●	●	○	○	○	●	●	◐
A.4-THE PROJECT IS COMPRISED OF A LARGE MIXED USE OR PLANNED DEVELOPMENT (RESIDENTIAL/COMMERCIAL DEVELOPMENT)		●	●	●	●	●	●	●	●
A.5-THE SITE IS PLANNED FOR A COMMERCIAL LARGE "BIG BOX". BUILDINGS AND LARGE PARKING AREAS.		●	●	●	●	◐	●	◐	●
A.6-THE PROJECT IS PLANNED AS A CLUSTERED, HIGH INTENSITY MULTI-FAMILY RESIDENTIAL OR "NEW URBANISM" PROJECT.		●	●	●	●	◐	●	◐	●
B. ENVIRONMENTAL SITE CONSIDERATIONS									
B.1-THE SEASONAL HIGH GROUNDWATER TABLE IS LESS THAN 1.5 FEET BELOW LAND SURFACE.		●	○	●	●	●	○	○	●
B.2-THE SOILS ON THE SITE ARE POORLY DRAINED WITH LESS THAN 2 INCHES/HR INFILTRATION (I.E. SCS TYPE B/D OR D).		●	◐	●	●	●	◐	◐	●
B.3-THE SITE LIES WITHIN THE 100 YEAR FLOODPLAIN.		●	◐	●	●	●	●	◐	●
B.4-THE PROJECT AREA INCLUDES SPECIAL HABITATS OF CONCERN OR REQUIRES SPECIAL PROTECTION MEASURES.		●	◐	●	●	●	●	●	●
B.5-THE PROJECT IMPACTS WETLANDS OR THERE ARE EXISTING IMPACTED WETLANDS THAT MAY BENEFIT FROM STORMWATER.		●	◐	●	◐	●	●	◐	◐
B.6-THE SITE REQUIRES FILL MATERIALS FOR DEVELOPMENT		●	●	●	◐	●	●	●	●
B.7-THERE ARE OPPORTUNITIES TO PRESERVE FORESTED AREAS FOR NON-PRESUMPTIVE STORMWATER TREATMENT BENEFITS.		●	●	●	●	●	●	●	●
B.8-THE PROJECT SITE HAS NO POSITIVE OUTFALL		◐	◐	●	●	●	◐	◐	◐
C. SPECIAL WATERSHED SITE CONSIDERATIONS									
C.1 THE PROJECT LIES WITHIN A WATERSHED OF SPECIAL CONCERN (I.E. WITHIN A PEAK SENSITIVE OR VOLUME SENSITIVE AREA).		◐	◐	◐	◐	◐	◐	◐	◐
C.2 THE WATERSHED RECEIVING STREAM IS AN OUTSTANDING FLORIDA WATER (OFW).		◐	◐	◐	◐	◐	◐	◐	◐
C.3 THE WATERSHED LIES WITHIN AN IMPAIRED WATER BODY AND MAY HAVE SPECIFIC TMDL'S INDENTIFIED FOR NUTRIENTS.		◐	◐	◐	◐	◐	◐	◐	◐

LID SITE EVALUATION AND GUIDANCE LEGEND		
THE LID PRACTICE IS BOTH FEASIBLE AND PRACTICAL AND IS RECOMMENDED FOR CONSIDERATION		●
THE LID PRACTICE MAY BE FEASIBLE BUT MAY REQUIRE SPECIAL MEASURES FOR PRACTICAL IMPLEMENTATION		◐
THE LID PRACTICE POSES PRACTICAL CHALLENGES FOR IMPLEMENTATION THAT MAY LIMIT THE APPLICATION		○

Source: Sarasota County 2011.

Figure 3-17. Example LID Selection Guide for Sarasota County, Florida

Table 3-10. Example LID Guidance for the Yakima Region in Washington

Landscape Group	General Map Unit	Description	Suitable LID BMPs
Floodplains and Terraces	Umapine-Wenas	Seasonal high water table Subject to flooding Affected by salts and alkali Wet soils Wetlands	Minimal excavation foundations Vegetated roofs Rainwater collection
	Weirman-Ashue	Low available water capacity Require frequent irrigation Subject to flooding Wetlands	All LID BMPs
	Quincy-Hezel	Sandy Subject to wind erosion Main Limitations: slope, depth to bedrock, permeability, stones	All LID BMPs
	Warden-Equatzel	Largest soil unit Well suited for development Erosion hazards Main Limitations: slope, depth to bedrock, permeability, stones	All LID BMPs
High Dissected Terraces	Harwood-Gorst-Selah	Erosion hazards Moderately deep or shallow Hardpan a limitation Depth to bedrock a limitation	All LID BMPs Depth to hardpan may hinder bioretention and permeable paving
Ridgetops and Plateaus	Lickskillet-Starbuck	Shallow Depth to bedrock a limitation	All LID BMPs Depth to hardpan may hinder bioretention and permeable paving
	Willis-Moxee	Erosion hazards Moderately deep or shallow Hardpan a limitation Depth to bedrock a limitation	All LID BMPs Depth to hardpan may hinder bioretention and permeable paving
	Ritzville-Starbuck	Erosion hazards Well suited for development Main Limitations: slope, depth to bedrock, permeability, stones	All LID BMPs Depth to hardpan may hinder bioretention and permeable paving
	Taneum-Tieton	Main Limitations: shrink-swell potential	All LID BMPs Shrink-swell potential may hinder permeable paving
	Rock Creek-McDaniel	Main Limitations: slope, depth to bedrock, permeability, stones	Minimal excavation foundations Vegetated roofs Rainwater collection
	Cowiche-Roza	High shrink-swell potential	All LID BMPs Shrink-swell potential may hinder permeable paving
Mountains and Canyons	Jumpe-Sutkin-Sapkin	Forested Main Limitations: slope, depth to bedrock, permeability, stones	Depth to rock may hinder bioretention and permeable paving
	Naxing-Darland	Forested Main Limitations: slope, depth to bedrock, permeability, stones Extreme Climate	Minimal excavation foundations Vegetated roofs Rainwater collection

There are also different approaches to using a developed LID/GI selection guide. For example, the USEPA has published data and modeling tools, which can be used to determine what types of potential LID/GI practices may be suitable for any given area in the U.S. (USEPA 2015). One example includes the USEPA's *BMPs Siting Tool*, which can be used to identify potential suitable areas (lot- to watershed-scales) for implementing different types of LID techniques. Criteria such as drainage area, slope, soils, and groundwater table depth are used by the program to make recommendations on various types of LID/GI practices (USEPA 2014).

3.4.3 Evaluation and Summary of Benefits and Costs

Since the primary benefit of LID/GI is reducing peak flows, and therefore a reduction of flood damages, this project type is consistent with HMA requirements for a reduction in risk to infrastructure or people. The project may also provide benefits related to increased water supply and ecosystem services. As some of the water supply benefits may be for day-to-day use rather than specifically for drought conditions, it is be important to identify the hazard mitigation benefits of the project to ensure eligibility for FEMA funding. While the project may also provide ecosystem service benefits per acre for various land types, this should be evaluated on a case-by case basis as the benefits provided by each project may vary greatly. In addition to the benefits listed above, there are several additional benefits to LID/GI projects that are either not readily quantifiable or not currently considered appropriate for inclusion in a BCA, and are discussed below.

3.4.3.1 Benefits

The primary benefit for many LID/GI projects is the reduction of flood damages to structures and infrastructure through stormwater detention and infiltration. The reduction of flood impacts from peak stormwater flows can be quantified using traditional FEMA BCA methodologies in the current FEMA BCA Tool. The subapplicant should provide hydrologic and hydraulic information to estimate the reduction in flood elevation pre- and post-project.

As described in Section 2.3.1, CDM Smith (2015c) in collaboration with Earth Economics provided standard values for ecosystem service benefits per acre for various land types as shown in **Table 2-2**. If a LID/GI project results in new or restored Wetlands, Estuaries, Riparian or Green Open Space, the total annual benefits for these categories can be included in the BCA. The subapplicant would need to quantify the area (in acres) of restored ecosystem and the land use type.

If applicable, benefits related to increased water supply capacity can be captured based on the two values presented in Section 2.3.2. The subapplicant would have to identify the quantity of additional water supply provided by the project (in millions of gallons). Ideally, the subapplicant would also demonstrate the amount of water required for day-to-day use versus the amount required for drought mitigation.

Since LID/GI practices are typically at the surface, and not below the ground like gray infrastructure, an area can be provided with multiple benefits which are defined and listed in **Table 3-11.** The bolded items in the table are captured in either ecosystem services or traditional mitigation benefits. The remaining benefits are not currently considered for BCA analysis, but potential evaluation methodologies are provided below.

Table 3-11. Typical Benefits of LID/GI

Economic Benefits	Environmental Benefits	Social Benefits
Gray infrastructure deferment/reduction	Greenhouse gas emission reduction	***Public amenities/green oasis creation***
Chemical and energy cost reduction for water and wastewater treatment	***Ecosystem habitat expansion***	Heat island impact reduction and improved public health
Resiliency to extreme weather events	***Watershed improvements from reduced water supply exports***	
	Flood management	

Source: CDM Smith 2013a.

Non-Traditional Benefits

Benefits of implementing LID/GI practices can be significant, and include reduced stormwater runoff and pollutants, reduced localized flooding and erosion, reduced CSOs, reduced costs for stormwater conveyance systems, improved water quality, improved groundwater recharge, reduced urban heat stress, reduced greenhouse gas emissions, improved building energy savings, and improved air quality (CDM Smith 2013a; USEPA 2013). Other social benefits include enhanced property values, improved habitat, aesthetic amenities, and improved quality of life. LID/GI can also provide many opportunities to retrofit existing highly urbanized areas with stormwater controls, as well as address environmental issues in areas that are going to be developed (USEPA 2000). In addition, LID/GI approaches can help to achieve sustainability and resilience goals over a range of outcomes in addition to climate adaptation. The climate adaptation benefits of GI are related to the ability of these practices to moderate the impacts of extreme precipitation or temperature (CCAP 2011). Environmental benefits include reductions in pollutants, protection of downstream water resources, groundwater recharge, reductions in pollutant treatment costs, reductions in the frequency and severity of CSOs, habitat improvements, and flood prevention/mitigation (USEPA 2007; CCAP 2011). Land value benefits include reductions in downstream flooding and property damage, increases in real estate value, increased parcel lot yield, increased aesthetic value, and improvement of quality of life by providing open space for recreation (USEPA 2007). Studies have found that infiltration-based approaches reduce runoff volume by 73 to 99 percent (NRDC 2011). Moreover, large reductions in runoff volume achieved through infiltration can dramatically reduce the pollutants carried to water bodies. These practices can provide surface water quality protection since they infiltrate runoff directly into the ground and help to restore hydrological conditions (NRDC 2011). Additionally, while not providing a comprehensive list of LID/GI practices, Figure 3-18 from the Center of Neighborhood Technology (CNT) examines the range of benefits that five practices can offer (CNT 2010). This benefits matrix is an illustrative summary of how these practices can produce different combinations of benefits; however, CNT noted that that these benefits accrue at varying scales according to local factors such as climate and population.

Methods to Quantify Non-Traditional Benefits

Beyond the quantification of ecosystem services and traditional benefits, studies have quantified other services of GI/LID, and while they are not currently considered benefits for FEMA BCAs, they are included for completeness. The City of Portland, Oregon has quantified benefits for the hydrology, habitat, and water quality improvements generated from implementing various LID/GI practices. Similarly, other benefits that are more social or economic in nature have also been investigated including community livability, air quality, energy savings, carbon sequestration, and cost effectiveness (ENTRIX, 2012). For example, it has been estimated that green streets in Portland (i.e., vegetated curb extensions, streetside planters, or rain gardens that collect stormwater runoff from streets) are able to improve air quality by removing particulate matter less than 10 micrometers in diameter (PM_{10}) at a rate of 0.04 lbs/facility/year, saving energy by reducing carbon dioxide (CO_2) emissions at a rate of 0.3 metric tons/facility/year, and improving community livability by increasing surrounding property values by 3 to 5 percent. Another example is that green roofs improve air quality by removing PM_{10} at a rate of 7.7 lbs/acre/year and conserve energy by reducing CO_2 emissions at a rate of 7.1 metric tons/acre/year. Additional information on this study is provided at: Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits.

Benefit	Reduces Stormwater Runoff											Improves Community Livability						
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

Source: CNT 2010.

Figure 3-18. Range of Benefits Offered by Various LID/GI Practices

Additional studies to quantity economic benefits conducted by the USEPA and the CNT include the following:

- USEPA 2014. The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA, 2014: http://www.cnt.org/sites/default/files/publications/CNT_EPA_LancasterGICaseStudy.pdf
- USEPA 2014. Cost-Benefit Analyses Resources: http://water.epa.gov/infrastructure/greeninfrastructure/gi_costbenefits.cfm
- CNT 2010. The Value of Green Infrastructure: A guide to Recognizing Its Economic, Environmental and Social Benefits: http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf

- CNT 2010. Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits: http://www.cnt.org/sites/default/files/publications/CNT_CNTLIDpaper.pdf

Timeframe for Project Implementation and Realization of Benefits

Depending on the type, scale, and number of LID/GI practices that are to be constructed, the timeframe for implementation and realization of benefits from a project can be very short (months) to quite long (decades). It is important to understand the amount of maintenance involved in achieving the full benefit from a given practice when undertaking large-scale green infrastructure (CNT 2010). Many benefits of LID/GI practices depend on regular maintenance. For example, vegetation will only filter carbon as long as it is routinely maintained.

Immediate benefits might always not be recognized when an LID/GI practice is first installed when compared to a traditional gray infrastructure strategy that was implemented. However, the benefits of LID/GI extend beyond those offered by traditional gray infrastructure strategies (such as CSO control). Due to the fact that a project provides multiple benefits, LID/GI is expected to produce greater benefits over time (Figure 3-19).

Source: Economides 2014.

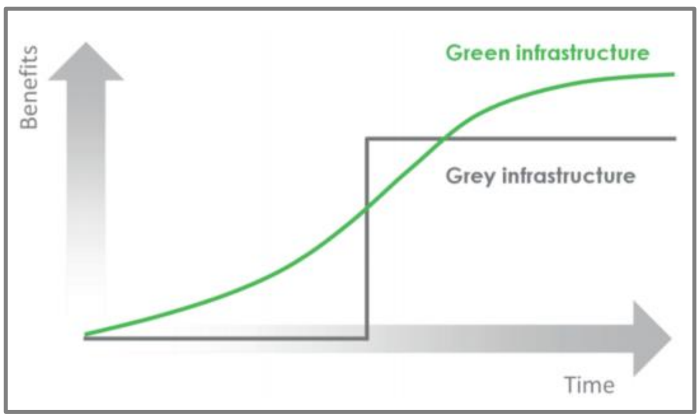


Figure 3-19. Benefits of Green versus Gray Infrastructure over Time

3.4.3.2 Costs

An USEPA report from 2007 summarizes 17 case studies of developments that include LID practices and concludes that applying LID techniques can reduce project costs and improve environmental performance. In general, LID practices were shown to provide financial and environmental benefits to communities. There were some cases where LID project costs were higher than those for conventional stormwater management projects, but in the majority of cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping (USEPA 2007). On average, total capital cost savings ranged from 15 to 80 percent when LID methods were used (USEPA 2007).

Clearly written management practices, protection mechanisms, and ongoing maintenance are necessary for long-term LID benefits. Although the O&M costs will not be funded by FEMA, they are required to be included in the BCA and therefore should be considered. Ongoing maintenance includes weeding, watering, erosion and sediment control, and replacement of dead plant material (PSAT 2005). O&M

costs for LID/GI practices vary depending on site-specific conditions, however, ongoing maintenance need diminishes as plant materials establish and the site stabilizes.

Cost of LID/GI practices vary widely depending on site-specific site conditions and the type of GI techniques being used. For example, Table 3-12 reports cost per acre constructed for various LID/GI practices estimated by the City of Philadelphia. Table 3-13 provides a range of project useful life estimates and annual O&M costs for a variety of LID/GI projects. Many of the guidance documents in Attachment 5 provide cost estimates for various LID/GI practices in different regions of the U.S.

Table 3-12. Impervious Acreage Construction Costs for Various Stormwater BMPs in Philadelphia

Stormwater BMP	Type	($/impervious acre)			
		Minimum Cost	Median Cost	Mean Cost	Maximum Cost
Porous Pavement	Retrofit	$65,000	$120,000	$160,000	$410,000
	Redevelopment	$44,000	$90,000	$110,000	$200,000
Subsurface Infiltration	Retrofit	$65,000	$120,000	$160,000	$410,000
	Redevelopment	$44,000	$90,000	$110,000	$200,000
Green Roof	Retrofit	$430,000	$500,000*	$500,000	$570,000
	Redevelopment	$200,000	$250,000*	$250,000	$290,000
Bioretention	Retrofit	$65,000	$120,000	$160,000	$410,000
	Redevelopment	$44,000	$90,000	$110,000	$200,000
Street Tree	Retrofit	$18,000	$18,000	$18,000	$18,000
	Redevelopment	$15,000	$15,000	$15,000	$15,000

**Other cities have been experiencing costs in the range of $7-16 per square foot ($305,000-$700,000 per impervious acre), with a typical*

Source: City of Philadelphia 2009.

Table 3-13. Project Useful Life and Annual O&M Costs for Various LID/GI Project Types

LID/GI Practice	Useful Life	Annual O&M Cost
Permeable Pavement- Porous Asphalt	20-40	$0.090 - $0.230 per SF
Green Roof	25-50	$0.020 - $0.412 per SF
Bioswales (Parking Lot and Roadside)	20-50	$0.060 - $0.210 per SF
Native Plants	100	$0.030 - $0.080 per SF
Rain Garden	25-50	$0.310 - $0.610 per SF
Cisterns	20-50	$0.000 - $0.070 per gallon
Vegetated Filter Strips	20-50	$0.070 per SF
Amended Soil	25-50	$0.023 per CY

Center for Neighborhood Technology, 2009

3.4.4 EHP Requirements

Section 3.1.4 details common requirements for EHP compliance for HMA grants. The following permits and supporting documentation may be required as part of any LID/GI project and may be required to show compliance with EHP requirements. The requirements may include:

- Water Quality Certification
- Hydraulic Project Approval
- No-rise certification or CLOMR
- General construction permits

Other permits or approvals may be necessary if special circumstances such as wetlands, streams, or endangered species are present. Because many LID/GI projects are located within the built environment, there is the potential for historic resources to be affected and the project would need to be evaluated for compliance with Section 106.

Many types of LID/GI projects may be covered under existing CatExs when they are replacing existing structures resulting in the same developed footprint and similar form and function. Projects such as porous pavement, green roofs, and planting street trees could be covered by CatExs (d)(2)(xv) for reconstruction or retrofitting existing facilities and (d)(2)(xvi) for the construction of small scale hazard mitigation measures. Whenever a CatEx is applied care must be taken to review the project site for the presence of extraordinary circumstances such as a greater scope or size than normally expected for a category of action or the presence of endangered or threatened species or their critical habitat, or archaeological, cultural, historical or other protected resources.

It may also be important to note that while most LID/GI projects would be expected to meet the general criteria for a CatEx found in 40 CFR 1508.4, unless the activity would be covered under a specific CatEx in 44 CFR 10.8, it would require an EA. As explained in the FEMA NEPA Desk Reference, the general criteria are for use of FEMA's Environmental Officer in determining future CATEX categories. The general criteria cannot be used as the basis for deciding upon a CATEX as the appropriate level of EHP documentation for a specific action.

Projects involving subsurface infiltration and bioretention are less likely to conform to the constraints of the existing CatExs and an EA would need to be prepared for those projects. As with floodplain restoration projects, most LID/GI projects provide considerable beneficial effects that may mitigate some of the adverse construction-related effects. However, if adverse impacts would still remain following all reasonable mitigation measures, then those would need to be disclosed through an EIS. Costs for each type of EHP document would be similar to those described under Section 3.1.4.

3.4.5 Potential Coordination with Other Federal Agencies

The following documents report on possible funding mechanisms for LID/GI projects:

- *Getting to Green: Paying for Green Infrastructure, Financing Options and Resources for Local Decision-Makers* (USEPA 2014): This report summarizes various funding sources for supporting stormwater management programs or financing individual projects. Sources covered include taxes and general funds, fees, stormwater utilities, grants, bonds, loans, and public-private partnerships. Municipal program examples are included with the discussion of each funding source along with lists of additional resources. A comparative matrix is provided to compare advantages and disadvantages of funding options.

- *A Business Model Framework for Market-Based Private Financing of Green Infrastructure* (ECT 2014): This report identifies the barriers to private investment in GI and recommends how best to eliminate those barriers. The Project Team assessed financial options available to public and private entities, explored potential demonstration pilot projects, identified likely business models that would facilitate private investment, and received input from the community of practitioners and experts that may facilitate public-private partnerships (P-3) for GI funding.
- *Community Based Public-Private Partnerships and Alternative Market-Based Tools for Integrated Green Stormwater Infrastructure* (USEPA 2015): This guide is the result of a multi-year effort by USEPA Region 3 and partners to identify tools to help Mid-Atlantic communities address water quality challenges through faster, cheaper, and greener methods. Specifically, this report introduces the Community-Based Public-Private Partnership (CBP3) approach as a flexible, performance-based platform for implementing affordable, integrated green stormwater infrastructure to meet a variety of regulatory and community needs.

LID/GI efforts are often one part in an otherwise larger conservation effort. Identifying and planning for LID/GI, including the identification of funding sources, is integral to project success. The National Association of Regional Councils (NARC) in partnership with Virginia Tech University has developed a "road map" tool (**Figure 3-20**) to assist local government, regional councils, and their communities to better understand how each Federal agency defines, implements, and funds GI (NARC 2013).

Given the potential of GI to support a wide range of purposes, a number of agencies including USEPA, USDOT, USHUD, USDA, USDOI, and the USDOE are offering expertise and resources that can be used to help communities, plan, design, and then implement GI practices (USEPA 2014). This presents an opportunity to coordinate and align HMA funding, but may also require consideration of duplication of program concerns.

USEPA states in their *Green Infrastructure Strategic Agenda 2013* that one of their five major focus areas is Federal coordination. This includes objectives such as leveraging existing Federal partnerships, continuing Federal dialogue on critical GI barriers and knowledge gaps, demonstrating commitment to GI through Federal projects, developing information on large-scale GI systems as a component of community resiliency and disaster relief, and continuing to integrate source water protection into stormwater management practices (USEPA 2013). The USEPA recognizes that lack of funding is often cited as a barrier to the implementation of GI, and has summarized various funding sources and tools as follows: http://water.epa.gov/infrastructure/greeninfrastructure/gi_funding.cfm

A ROADMAP TO GREEN INFRASTRUCTURE IN THE FEDERAL AGENCIES

KEY: ● Addresses Issue; ○ Does Not Address Issue

ISSUE AREAS	DOC Department of Commerce	DOD Department of Defense	DOE Department of Energy	DHS Department of Homeland Security	DOI Department of the Interior	DOT Department of Transportation	EPA Environmental Protection Agency	HHS Health and Human Services	HUD Housing and Urban Development	USACE Army Corps of Engineers	USDA Department of Agriculture
Air Quality	○	○	○	○	○	●	●	○	○	○	○
Biodiversity and Land Conservation	○	●	○	○	○	○	●	○	○	●	●
Climate Adaptation and Disaster Mitigation	●	○	○	●	○	○	○	○	○	●	●
Economic and Community Development	○	●	●	○	●	●	●	○	●	○	○
Urban Forestry	○	○	●	○	●	○	○	○	○	○	●
Public Health	○	○	○	○	○	●	●	●	○	○	○
Stormwater Management and Water Quality	●	●	●	●	●	○	●	○	○	●	●

FEDERAL AGENCIES

Source: NARC, 2013.

Figure 3-20. Green Infrastructure Roadmap Tool for Various Federal Agencies

3.4.6 Summary of Programmatic Considerations

The benefits of a LID/GI project vary greatly based on the design and site conditions. While there are many environmental and ecological benefits, the project must act as an effective, stand-alone mitigation activity to reduce losses to infrastructure or people. The project may reduce losses to infrastructure, but may also provide benefits related to drought mitigation. From an HMA program standpoint, it will be important to establish the benefits during the project design phase to be able to justify it as a mitigation project. While establishing a traditional recurrence interval for drought may be difficult, the subapplicant should use the best available data and methodology deemed appropriate by the design engineer.

The project must not duplicate flood prevention activities of other Federal agencies and may not constitute a section of a larger flood control system. While the project can be sized based on the risk in the project area, HMA requirements of a 3-year period of performance for implementation should be considered. While a CatEx would likely apply in many cases to reduce the EHP requirements (as explained in Section 3.4.4) for review of the project, early screening of the site is recommended to determine if an EA or an EIS would be likely based on project complexity and site conditions.

While duplication of programs issues should be explored by FEMA, there may be a way to collaboratively fund these types of projects with other Federal agencies, increasing resiliency throughout the U.S.

3.4.7 Example Implementation Success Stories

LID/GI practices have been implemented in numerous communities throughout the U.S. The following examples demonstrate the successful performance of some of these practices. These various projects were selected based on their LID/GI scale (individual lot to city-wide) and geographic areas (northeast, midwest, and western) within the U.S.

3.4.7.1 New York City, New York

A major challenge for New York City (NYC) has been its combined sewer systems, where an estimated 27 billion gallons of water passes through 6,600 miles of sanitary, storm, and combined sewer pipes, much of which is released into adjacent rivers without treatment. Fourteen water pollution control plants distributed among the five NYC boroughs process 1.5 billion gallons of wastewater each day. On average, a combined sewer overflow event occurs once every week, and up to 70 times per year at some treatment facilities. With the impact to surrounding waterways, NYC recognizes these events as being threats to human health and the environment (Economides 2014).

Thus, in 2011 the New York City Department of Environmental Protection (NYC DEP) began implementing a city-wide GI Program to manage stormwater runoff that would otherwise discharge into the combined sewer systems and contribute to combined sewer overflows. The area-wide design includes right-of-way bioswales, stormwater green streets, and public on-site property retrofits. To date, NYC DEP and partner agencies have constructed more than 200 right-of-way GI projects city-wide (NYC DEP 2013). Examples of NYC GI projects include right-of way bioswales (Photo 3-12) and blue/green roofs (Photo 3-13). Long-term goals are to reduce CSO volumes by 3.8 billion gallons per year and capture rainfall from 10 percent of impervious surfaces in CSO areas by 2030. Annual reports released by the NYC DEP discuss the previous year's activity and future goals (NYC DEP 2010; 2013).

Source: NYC DEP

Photo 3-12. Example of a Right-of-Way Bioswale, Denton Place, Brooklyn

Photo 3-13. Example of a Blue/Green Roof, Osborne Association

It has been estimated that the cost to implement the overall GI plan is $1.5 billion less than the gray alternative, with GI stormwater capture alone saving $1 billion at a cost per gallon of about $0.15 less. Sustainability benefits over the 20-year life of the project range from $139 to $418 million depending on measures implemented. It has also been estimated that every fully vegetated acre of GI would provide total annual benefits of $8,522 in reduced energy demand, $166 in reduced CO2 emissions, $1,044 in improved air quality, and $4,725 in increased property value (CCAP 2011).

An LID example from the NYC GI program is Edenwald Houses. This development includes 41 buildings with 5,450 residents and the total drainage area is approximately 53 acres (54 percent impervious area). GI practices implemented include vegetated bioretention areas, rain gardens, porous pavements, and rooftop runoff redirected to GI. Ultimately, 35 percent of the impervious area is managed by GI as shown on Figure 3-21. Example estimated and bid costs per impervious acre managed for north Edenwald Houses is shown on Figure 3-22.

Source: CDM Smith 2015b.

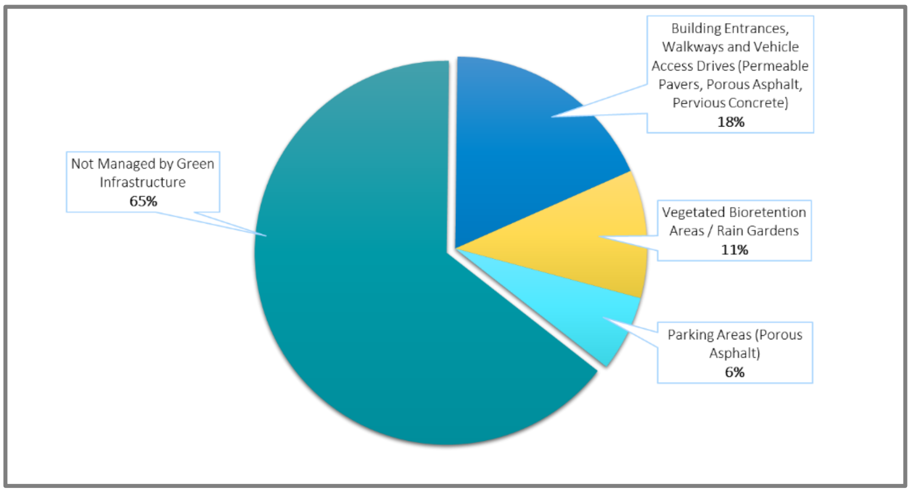


Figure 3-21. Edenwald Houses, NY – Percentage of Impervious Areas Managed by GI

Source: CDM Smith 2015b.

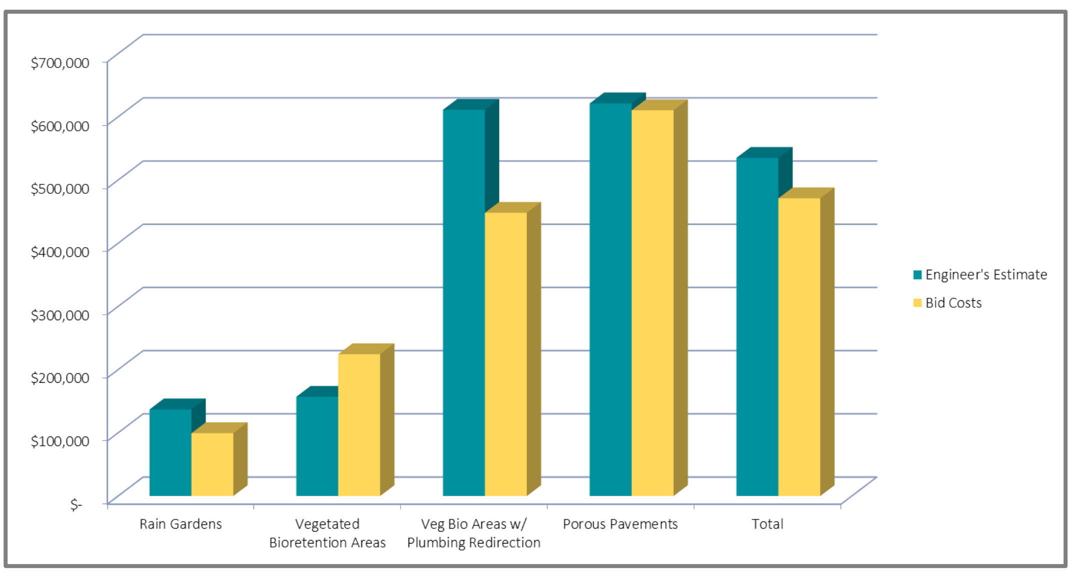
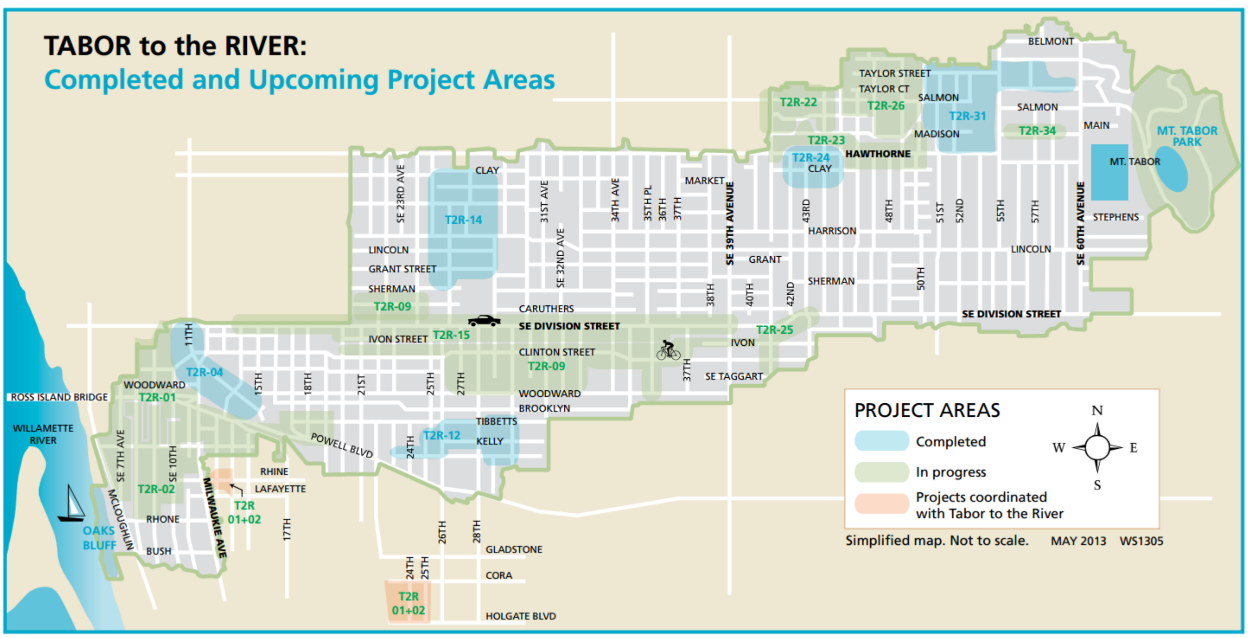


Figure 3-22. Edenwald Houses, NY – Example GI Practice Costs per Impervious Acre Managed

3.4.7.2 Portland, Oregon

As in a growing number of urban areas, increasing development in the City of Portland, Oregon has led to greater volumes and velocities of stormwater runoff, which has threatened critical waterways. Combined sewer overflows caused by flows greater than what systems were designed to manage 100 years ago have also decreased water quality in the area. In search of methods to alleviate these environmental strains, the City of Portland Bureau of Environmental Services analyzed the key ecosystem benefits of replacing traditional gray infrastructure with GI and encouraging innovative stormwater management (CNT 2010).

One example of this effort is the "Tabor to the River Program", which began in 2009 and covers approximately 2.3 square miles (Figure 3-23) from Mt. Tabor to the Willamette River, and includes the Richmond, Hosford-Abernethy, Brooklyn, and Mt. Tabor neighborhoods. Due to the increases in pavement and other impervious surfaces and decreases in tree canopy, heavy rains have caused sewers to back up into basements, flood streets, and overflow to the Willamette River. This multiple-neighborhood scale project will take more than 15 years to complete.



Source: City of Portland, Bureau of Environmental Services 2013.

Figure 3-23. Tabor to the River Program Area in Portland, Oregon

Through the on-going Tabor to the River Program, the City has worked together with community members, neighborhood groups, businesses, and other organizations to ultimately improve watershed health in the following ways (City of Portland 2015):

- Planting 3,500 trees
- Adding 500 green streets
- Building 100 private stormwater projects

- Repairing or replacing 81,000 feet of sewer pipe
- Removing invasive plants from parks and natural areas
- Improving wildlife habitat, cleaning the air, and making neighborhoods healthier

It has been estimated that resolving the combined sewer system issues in the Tabor to the River Program area with only gray infrastructure pipe solutions would have cost an estimated $144 million. By adding GI projects to the overall stormwater plan, the multiple benefits associated with GI are being recognized, in addition to reducing the estimated cost to $81 million (City of Portland 2013). The average unit cost from two capital projects from this program (70 green street facilities in 2010 and 67 green street facilities in 2011) is approximately $50 per square foot of facility or about $110,000 per acre of managed impervious area (Stevens 2013). These costs include construction, water service improvements, transportation improvements, and planting/plant establishment.

3.4.7.3 Paso Robles, California

As the City of Paso Robles, California built out its infrastructure in the late 1800s, conveyance of water from Mountain Springs Creek was modified from a natural open channel that once served as a tributary branch of the nearby Salinas River to a buried storm drain pipe under 21st Street. Historic runoff from this creek, along with subsequent development of the urban areas over several decades (flow from a 1,230-acre watershed), resulted in frequent flooding, degraded pavement, and inadequate facilities for bicycles and pedestrian traffic (Cannon Corporation 2012). For example, even small storms like a two-year storm that generates peak flows of 24 cubic feet per second, was enough to flood the street and impede traffic, overtop the curb line and crossing walkways, and erode landscape areas (Rowe and Kraemer 2015).

To improve flooding, the City of Paso Robles decided to retrofit a large section of 21st Street into a green street. LID/GI practices included in the design were bioretention, pervious pavers, landscaped open-channel drainage, and an infiltration trench to cleanse and capture runoff while minimizing flooding during storms and preserving the pavement (Rowe and Kraemer, 2015).

Project goals included the following (Cannon Corporation 2012):

- Reduce the frequency and severity of street flooding
- Increase stormwater infiltration
- Improve water basin recharge while enhancing stormwater runoff reaching the Salinas River and increasing sediment removal
- Improve pedestrian safety
- Reduce traffic speeds by incorporating traffic calming devices
- Addition of bike lanes
- Increase shade and aesthetic appeal by planting trees and drought tolerant plants

- Promote infill and redevelopment

Flow from Mountain Springs Creek is treated separately from polluted runoff from impervious surfaces immediately adjacent to, and including 21st Street. Flows from Mountain Springs Creek are directed to a central vegetated channel (Photo 3-14), while runoff from streets and other impervious surfaces are managed in a series of bioretention planters (ranging in size from less than 100 square feet to more than 1,000 square feet) where runoff volumes and pollutants are captured, treated, and infiltrated (Cannon Corporation 2012; Rowe and Kraemer 2015). Additional benefits of the project include new bike lanes, improved pedestrian safety, and new landscape including native plants and drought tolerant species.

These LID/GI practices have the capacity to treat at least 6,000 cubic feet of stormwater per storm event (Photo 3-15). A five-year storm event with peak flows of 76 cubic feet per second is now contained within the median channel. Stormwater performance results for the project include a reduction of 26,000 square feet of impervious surface; for every rain event greater than 0.50 inch, over 50,000 gallons of runoff are treated in bioretention areas and infiltrated into the ground (Rowe and Kraemer 2015).

The City applied for and obtained an Urban Greening Grant from the California Natural Resources Agency in the amount of $993,000 to assist with the funding of this project and the total project cost of approximately $2.5 million (Cannon Corporation 2012). Construction of the 21st Street design, which provides flood control, runoff treatment, and groundwater recharge began in the spring of 2013 and was completed in 2014.

Source: Cannon Corporation Civil Engineeringand Landscape Architecture 2012.

Photo 3-14. Green Street in Paso Robles, CA

Source: Central Coast LID Initiative 2015.

Photo 3-15. Example of Stormwater Storage during a Rainfall

3.4.7.4 Cuyahoga Falls, Ohio

CUYAHOGA FALLS, OH

The City of Cuyahoga Falls is a Northeast Ohio community that was severely impacted by flooding in the last decade, and was declared a Federal disaster zone by FEMA twice in a two-year period (Ohio EPA). City officials worked with FEMA and the Ohio Emergency Management Agency to develop a plan to reduce stormwater runoff in a specific neighborhood that experienced severe and repetitive flooding. With the use of FEMA funds and cooperation of the residents involved, the city purchased and demolished four flood-prone homes located midblock in a low-lying area to provide localized flood relief. In their place, the site was developed into a community park, which implemented LID/GI practices such as rain gardens, pervious concrete pavement, and pervious recycled tire pavement.

The 24,000 square foot Rain Garden Reserve Park opened in 2008 and serves a tributary area of 3.2 acres. Three rain gardens were installed on the site demonstrating a commercial size rain garden of 6,000 square feet (Photo 3-16) and two residential size rain gardens of approximately 100 square feet (Cuyahoga County Planning Commission). The larger rain garden serves a tributary area of approximately 3.1 acres and can hold and filter 30,000 gallons of water. Benefits from this project include localized flood relief, reduced imperviousness of drainage area, increased storage capacity, provided an alternative to standard flood mitigation solutions, and has been used to educate the public on GI.

Funding for the project was obtained through FEMA (acquisition of four flood damaged residential properties). The total construction cost for the project was approximately $160,000 including fencing and other site needs. Costs included the following major elements (Ohio EPA):

- Design costs-$43,330 (Includes soil sampling/testing)
- Excavation costs-$13,240
- Permeable asphalt and concrete-$4,820
- Pipes/drainage/sump pump-$4,650
- Native plants and trees-$22,570
- Rain garden amended soil-$10,490

Source: Cuyahoga County Planning Commission

Photo 3-16. Commercial Rain Garden (Rain Garden Preserve Park) in Cuyahoga Falls, OH

SECTION FOUR SUMMARY AND RECOMMENDATIONS

4.1 SUMMARY

To assist FEMA with meeting the goals of the 2014 OGSI, Executive Order 13653 (Preparing the United States for the Impacts of Climate Change), The President's Climate Action Plan (2013), and FEMA's Climate Change Adaptation Policy (2011-OPPA-01), this report was prepared to inform future FEMA guidance and funding decisions on mitigation planning and implementation of climate resilient infrastructure under the HMA grant programs

This report evaluated four climate resilient project options (Aquifer Storage and Recovery, Floodwater Diversion and Storage, Floodplain and Stream Restoration and Low Impact Development/Green Infrastructure) that reduce the risk of impacts attributed to climate change weather extremes to people and infrastructure.

To support FEMA's evaluation of project eligibility for the implementation of climate resilient infrastructure under the HMA grant programs, the following areas specific to each project type were further explored:

- Link measure/activity to loss/risk reduction and identify benefits
- Identify other potential benefits (e.g., social, environmental, and economic) and methods for quantifying
- Identify timeframe, costs, and technical feasibility for implementation and consistency with HMA program
- Consider EHP requirements for each activity
- List agencies for potential OFA coordination to leverage resources and funds
- Identify and discuss programmatic considerations
- Include examples of implementation success stories with project sizes in the $1 to $5 million range that provide geographic diversity and ranges of scale and cost.

4.2 RECOMMENDATIONS

To date, FEMA funding efforts for mitigation has been in response to natural and manmade disasters. FEMA's focus on risk management is expanding to include proactively anticipating climate changes and planning for additional new funding programs in support of climate resilient infrastructure. In particular, the HMA programs may be expanded to meet the goals of long-term climate resilience through the OGSI, as a portion of the proposed funding would support competitive grants to local, Tribal, and State governments through the PDM program. The OSGI funding would be applied to cost-effective project grants to reduce flood losses and other eligible hazard mitigation activities that reduce disaster losses and protect life and property from future disaster damages. Projects that best address climate change weather extremes could receive additional funding consideration by FEMA.

All four climate change adaptation project options presented in this report are consistent with FEMA's HMA programmatic requirements and guidelines and will help mitigate the impacts of climate change related disaster. They are also proven methods for feasible and effective mitigation activities when planning, siting, sizing and design, construction, and O&M recommendations are followed.

Additional areas that will require further exploration to facilitate the funding of these climate resilient projects include:

- **Cost Effectiveness** –While benefits such as ecosystem services and water supply have been identified for the project types, tying these projects to quantifiable hazard mitigation is critical to ensure the availability of FEMA funds. If other Federal agencies have a funding mechanism, FEMA should consider ways to leverage available funding sources to implement mitigation actions that have other benefits.

- **Duplication of Programs** – Projects considered for funding under OGSI will need to be further evaluated by FEMA to determine if duplication of programs exists. While other Federal Agencies have authorities related to these project types, when possible, FEMA may consider these opportunities to leverage funding, technical resources and best practices, rather than view them as duplication of programs.

- **Guidance and Tools** – As subapplicants and Applicants begin to apply for funding for new project types, there will be a need for additional guidance and tools to facilitate the development of complete and technically sound subapplications. FEMA will also benefit from these products by having a clear set of evaluation metrics to ensure consistency across Regions. Because PDM does not fund 5 percent initiative projects, well documented BCAs, quantifying both traditional and environmental benefits of these projects, will be needed. Although the intent is for OGSI funding to be provided under PDM, a phased approach to these projects due to their complexity may be considered

- **Environmental Benefits** – Continued evaluation and quantification of environmental benefits such as regional variation of per capita water consumption, water demand reduction projects, ecological health, and proximity to urban areas, will allow for a more holistic evaluation of drought mitigation and disaster risk reduction benefits for inclusion in a future update of the FEMA BCA Tool.

The funding of climate resilient projects and enhanced land/floodplain development regulations are critical to building stronger, more resilient communities. Climate resilient planning and infrastructure projects allow communities to be better prepared for climate change related disasters in order to minimize, or avoid, damage. Climate change mitigation planning results in less post-disaster damage and, therefore, reduced costs to rebuild communities post-disaster. Strategic funding by FEMA of climate resilient projects will help communities proactively plan and be better prepared for impacts related to climate change weather extremes.

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ATTACHMENT 1 GLOSSARY OF TERMS

- **Acre-feet**: A volumetric unit of measurement equal to one foot of water over an area of one acre.
- **Aggradation**: Raising of the streambed elevation, an increase in width/depth ratio, and a corresponding decrease in channel capacity due to the deposition of sediment.
- **Alluvial Channel Design**: Alluvial channel design techniques are generally used for movable boundary systems and streams with beds and banks made of unconsolidated sediment particles. The channel geometry and flow conditions in an alluvial stream are interrelated. The river's shape and size are determined by the river itself through the processes of erosion, sediment transport, sedimentation, and resuspension. Alluvial rivers are free to adjust section, pattern, and profile in response to hydraulic changes. Alluvial streams flow through channels with bed and banks made of sediments transported by the stream under current conditions. Alluvial channel design approaches fall into five general categories: regime, analogy, hydraulic geometry, extremal, and analytical methods. Each method has its advantages and disadvantages, depending on the stream reach being restored.
- **Aquifer**: A water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring.
- **Arsenic leaching**: A process in which naturally occurring arsenic which is bound in an aquifer matrix is released to a water soluble form due to differences in the chemical nature of natural groundwater and injected water.
- **Articulating concrete block**: A matrix of interconnected concrete block units installed to provide an erosion resistant revetment with specific hydraulic characteristics (NRCS 2007).
- **Attenuate**: To lessen or reduce the force or effect of flooding or peak flood flows.
- **AwwaRF**: American Water Works Association Research Foundation now known as Water Research Foundation
- **Bankfull flow**: Flow that transports the greatest amount of sediment over a long period of time and controls the channel geometry (approximately a 1.5-year flow event). Does not necessarily mean flow to the top of channel bank.
- **Baseflow**: The portion of streamflow that is not runoff and results from seepage of water from the ground into a channel slowly over time. The primary source of running water in a stream during dry weather.
- **Bendway weirs**: Similar to stream barbs, a rock structure that extends off of the bank and encourages perpendicular flow over the weir. One benefit is reduced velocity near the bank.
- **Best Management Practice (BMP)**: Strategies or engineered devices implemented to capture, control, treat, or prevent stormwater runoff.
- **Bioretention cells**: These elements are swales and/or landscaped depressions or shallow basins used to slow and treat on-site stormwater runoff. Stormwater is directed to the basin

and then percolates through the system where it is treated by a number of physical, chemical, and biological processes.

- **Bioswale**: These channels are vegetated or mulched and provide treatment and retention-detention as they move stormwater from one place to another. Vegetated swales slow, infiltrate, and filter stormwater flows.
- **Brackish water**: Water that is more saline than fresh water, but less saline than sea water. Typically, total dissolved solids concentrations in brackish water range from 1,000 to 10,000 milligrams per liter.
- **Carbon sequestration**: Where carbon dioxide is captured and removed from the atmosphere via photosynthesis and other natural processes.
- **Channelization**: Alterations made to the channels of rivers, streams, or drainageways, usually to improve drainage, relocate the channel, or increase its flood carrying capacity. Channels respond with horizontal movement (lateral migration, avulsion, channel widening, channel narrowing) and vertical movement (incision and aggradation), depending on site-specific circumstances and watershed conditions. Human landscape disturbance can exaggerate or constrain channel migration by affecting local and watershed processes of flooding, erosion, and deposition.
- **Channel boundary**: The deepest and most defined portion of a stream or river that provides conveyance during normal flow conditions. Outside the channel boundary is anything above bankfull stage, and is typically referred to as the floodplain.
- **Channel-forming flow (see Bankfull flow)**
- **Class V well**: Injection well that inject non-hazardous fluids into or above an aquifer. When properly designed, sited, operated, and maintained, Class V wells do not endanger drinking water sources.
- **Cofferdam**: A temporary enclosure built within, or in pairs across, a body of water and constructed to allow the enclosed area to be pumped out, creating a dry work environment for the major work to proceed.
- **Combined sewer overflow**: Overflow that occasionally discharges excess wastewater directly to a local waterbody during periods of heavy rainfall or snowmelt when the capacity of the sewer system is exceeded.
- **Combined sewer systems**: Sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe.
- **Confined aquifer**: A water bearing subsurface unit in which groundwater exists under pressure that is significantly greater than atmospheric pressure.
- **Consumptive Use Permit**: A permit that provides a water allocation to a user for consumption purposes

- **Cryptosporidium**: A water borne microscopic parasitic organism that comes from fecal contamination of drinking water and causes diarrhea when ingested. They live in the intestines of people and animals and they become encased within hard shells called cysts, which allows them to survive outside the intestines for months.

- **Cycle test**: The process of injecting, storing, and recovering a source water through and Aquifer Storage and Recovery system to test the system's effectiveness and efficiency, and to condition the storage zone of the aquifer for future use.

- **Deflector structures**: Form a physical barrier that protect the banks and force the flow to change direction by direct impact or deflection. Examples include riprap, concrete lining, jetties, gabions, and dikes.

- **Degradation**: Erosion of a stream or river bank and/or bed which can lower the streambed from floodplains, lowers the water table, and increases bank height, which adds to bank erosion and long-term instability.

- **Detention**: The storage and slow release of stormwater following a precipitation event by means of an excavated pond, enclosed depression or tank. Detention is used for pollutant removal, stormwater storage, and peak flow reduction. Both wet and dry detention methods can be applied.

- **Extraction well (see Recovery well)**

- **Fecal coliforms**: Bacteria that live in the intestines of warm-blooded animals.

- **Floodplain**: A nearly flat plain along the course of a stream or river that is naturally subject to flooding. It is adjacent to a river that is susceptible to inundation and often bears geophysical evidence of previous flood events.

- **Floodway**: The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

- **Fluvial**: Processes associated with rivers and streams and the deposits and landforms created by them.

- **Fresh water**: Water that generally contains less than 1,000 milligrams per liter of total dissolved solids

- **Gabion baskets**: A cage, cylinder, or box filled with rocks, concrete, or sometimes sand and soil used to stabilize shorelines, stream banks or slopes against erosion. Other uses include retaining walls, temporary flood walls, or to direct the force of a flow of flood water around a vulnerable structure.

- **Giardia**: A water borne microscopic parasitic organism that comes from fecal contamination of drinking water and causes diarrhea when ingested. They live in the intestines of people and animals and they become encased within hard shells called cysts, which allows them to survive outside the intestines for months.

- **Gray infrastructure**: Traditional engineered systems designed to capture and convey runoff, such as gutters, storm sewers, tunnels, and culverts.
- **Green infrastructure**: Practices that use or mimic natural processes to infiltrate or reuse stormwater/runoff on the site where it is generated.
- **Green roof**: A roof with vegetation planted on it.
- **Green street**: A streetscape designed to integrate a system of stormwater management within its right-of-way and to reduce the amount of runoff into storm sewers.
- **Groundwater**: The water present underground in the cracks and pores in soil, sand, and rock.
- **Heat island**: Heat islands form as an area's natural land cover is replaced with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat.
- **Impervious area**: Any hard-surfaced, manmade area that does not readily absorb or retain water.
- **Impoundment**: A body of water within an enclosure, such as a reservoir. Typically, they can be created by levees or dams.
- **Infiltration**: Percolation of water into the ground.
- **Injection well**: Class V Underground Injection control wells that are used to inject fluids to recharge an aquifer.
- **Levee**: An elongated, earthen embankment built to prevent the overflow of a river into the floodplain or other low-lying areas.
- **Little Underwater Neighborhood Keepers Encompassing Rhetotactic Salmonids**: Constructed structures to provide fish habitat in the form of edge cover. Typically made of wood or rock, they are tied into the streambank and also provide stabilization.
- **Low impact development**: An approach to land development (or redevelopment) that works with nature to manage stormwater/runoff close to its source. Practices are employed to preserve and recreate natural landscape features while minimizing impervious surfaces.
- **Meander belt**: An average meander width measured from outer bank to outer bank instead of from centerline to centerline.
- **Mixing zone**: A transitional water quality zone that occurs due to mixing along the interface of the naturally occurring groundwater and the injected source water.
- **Native groundwater**: Underground water that is naturally occurring.
- **Oxidized water**: Water that has a high oxygen content.
- **Permeable pavement**: A type of pavement that allows water to infiltrate the surface layer and enter into a high-void, aggregate, sub-base layer. The captured water is stored in the sub-base layer until it infiltrates the underlying soil.

- **Porous pavement and pavers**: Alternatives to conventional asphalt that utilize a variety of porous media, often supported by a structural matrix, concrete grid, or modular pavement, which allows water to percolate through to a sub-base for gradual infiltration.
- **Potable water**: Raw or treated water that is considered safe to drink.
- **Rain garden**: See Bioretention Cells.
- **Raw water**: Untreated water from a source (surface water or groundwater).
- **Reclaimed water**: Municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for a range of purposes. The term recycled water is synonymous with reclaimed water.
- **Recovery well**: A well, typically located downgradient of an injection well or spreading basin, used in an Aquifer Recharge and Recovery System to pump groundwater for potable or industrial use.
- **Redirective structures**: Design to be placed in the stream to minimize direct impact and rely more on the characteristics of fluid mechanics to modify streamflow direction. Examples include bendway weirs, stream barbs, spurs, and rock vanes.
- **Reduced water**: Water that has a very low oxygen content
- **Reno mattresses**: Similar to gabion baskets, Reno mattresses are woven wire mesh baskets. These are more specifically used for river bank and scour protection, channel linings for erosion control, and embankment stability.
- **Retard structures**: Increases flow resistance by increasing drag, there by slowing the velocity in the vicinity of the structure. Examples include fence jetties, Killner jacks, timber piling, live poles, and bioengineered structures.
- **Revetments**: Sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water.
- **Riparian corridor**: A unique plant community consisting of the vegetation growing near a river, stream, lake, lagoon or other natural body of water. It serves a variety of functions important to people and the environment. It contains a combination of physical and biological characteristics driven by the presence a stream or river.
- **Riprap**: Rock or other material used to armor shorelines, streambeds, bridge abutments, pilings and other structures against scour and water or ice erosion.
- **Rootwads**: Root wads include the root mass or root ball of a tree plus a portion of the trunk. Root wads are used to armor a streambank by deflecting stream flows away from the bank. They also provide structural support to the streambank, habitat for fish and other aquatic animals, as well as a food source for aquatic insects.
- **Runoff**: Water from rainfall, snowmelt, or otherwise discharged that flows across the ground surface instead of infiltration into the ground.

- **Salmonids**: A fish of the Salmon family.
- **Saltwater intrusion**: Displacement of fresh or groundwater by the advance of salt water due to its greater density, usually in coastal and estuarine areas.
- **Sinuosity**: A rivers tendency to move back and forth across its floodplain, in an S-shaped pattern, over time. As the stream meanders across the flood plain, it may leave behind scars of where the river channel once was.
- **Siphon**: A tube or conduit in the form of an inverted U-shape that carries water between two bodies of water with a pressure greater than atmospheric pressure.
- **Spreading basin**: A constructed system on the ground surface designed to allow water to infiltrate below ground, through the unsaturated zone and to the water table.
- **Stormwater intervention**: Synonymous with a stormwater BMP (see associated definition).
- **Spur dikes**: Extend out from the bank to divert flow. Typical top elevation above the flood stage or equal to bank elevation.
- **Storage zone**: The targeted portion of the aquifer in which source water has been injected. The source water will stay within the storage zone until it is recovered or pumped out.
- **Stream barbs**: Stream barbs are a low-sill rock structures that extend into the stream flow to modify flow patterns and bed topography.
- **Surface water**: The water on the surface of the earth such as rivers, streams, creeks, lakes, reservoirs, and wetlands
- **Surface Water Treatment Rule**: Adopted by the USEPA in 1989, is a federal regulation that requires all drinking water systems in the nation drawing from surface water sources to meet specific, measurable water treatment standards. The Rule seeks to prevent waterborne diseases caused by viruses, Legionella, Crypotosporidium, and Giardia lamblia. These disease-causing microbes are present at varying concentrations in most surface waters.
- **Swale**: A vegetated channel, ditch, or low-lying or depressional tract of land that is periodically inundated by conveying stormwater from one point to another.
- **Threshold channel design**: A threshold channel is a channel in which movement of the channel boundary material is negligible during the design flow. The term threshold is used because the applied forces from the flow are below the threshold for movement of the boundary material. The streambed is composed of very coarse material or erosion-resistant bedrock, clay soil, or grass lining. The objective of the threshold channel design procedure is to ensure that the design hydraulic parameters are less than the allowable values for the channel boundary.
- **Tributary**: Contributing drainage area or stream channel from upstream land areas.
- **Unconfined aquifer**: A subsurface water bearing unit containing groundwater that exists under atmospheric pressure.

- **Underground Source of Drinking Water**: An aquifer or portion of an aquifer that supplies any public water system or that contains a sufficient quantity of ground water to supply a public water system, and currently supplies drinking water for human consumption, or groundwater that contains less than 10,000 milligram per liter total dissolved solids and is not an exempted aquifer.
- **Vanes**: Rock structures constructed in the stream designed to redirect flow by changing the rotational eddies normally associated with streamflow. Vanes act to guide the flow away from bank, to reduce bank erosion, promote local sedimentation and encourage vegetation growth. Examples are Rosgen style cross vane and J-hook structures.
- **Watershed**: The land area, or catchment that contributes water to a specific water body. All of the rain or snow that falls within this area flows to the water bodies as surface runoff, in tributary streams, or as groundwater.
- **Water table**: The boundary between the saturated and unsaturated zones. Generally, the level to which water will rise in a well in an unconfined or surficial aquifer.
- **Water quality**: The chemical, physical, and biological characteristics of water.
- **Xeriscape**: Landscape in a style which requires little or no irrigation.

ATTACHMENT 2 GUIDANCE ON ASR FEASIBILITY METRICS

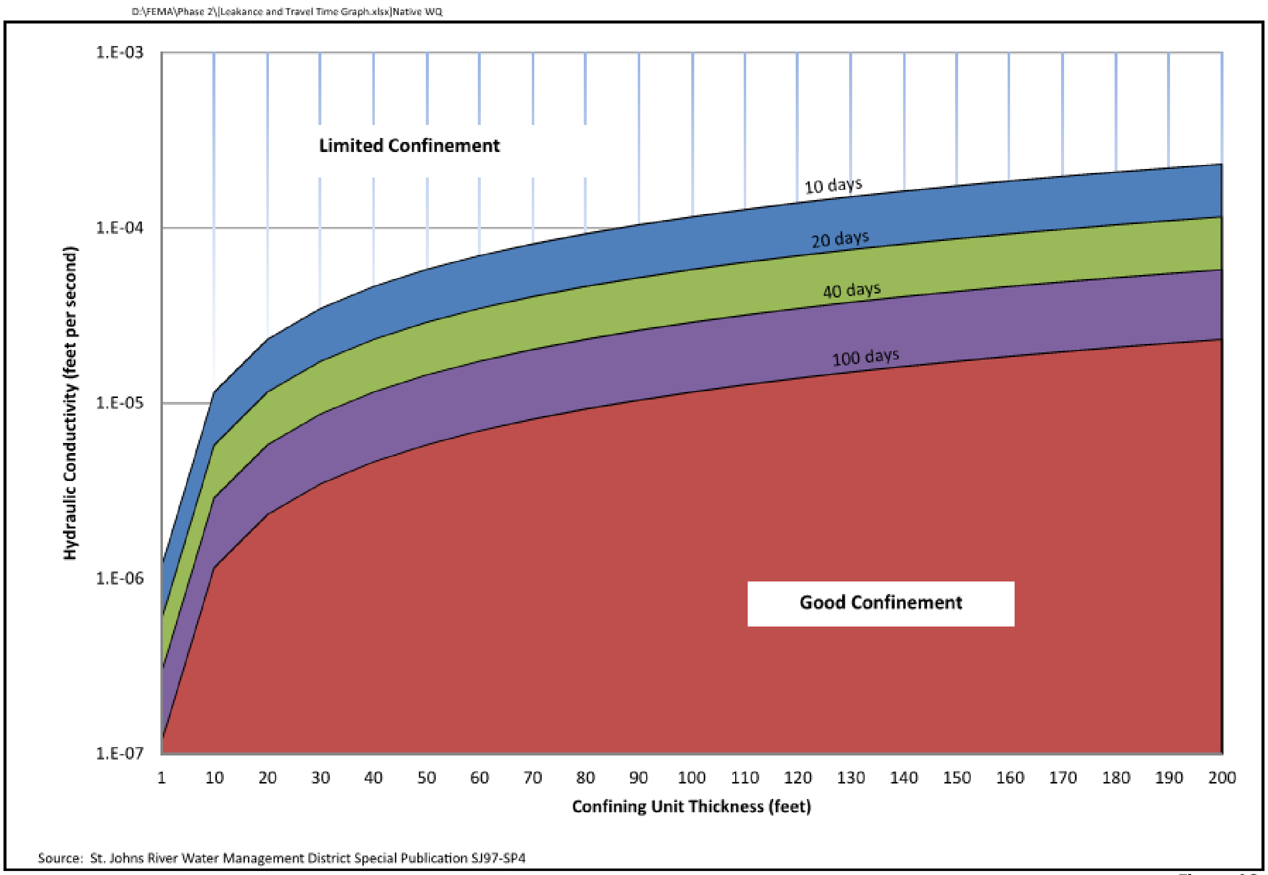

Figure A2-1
Storage Zone Confinement and Travel Time through the Confinement Related to Preventing Vertical Migration of Injected Fluids

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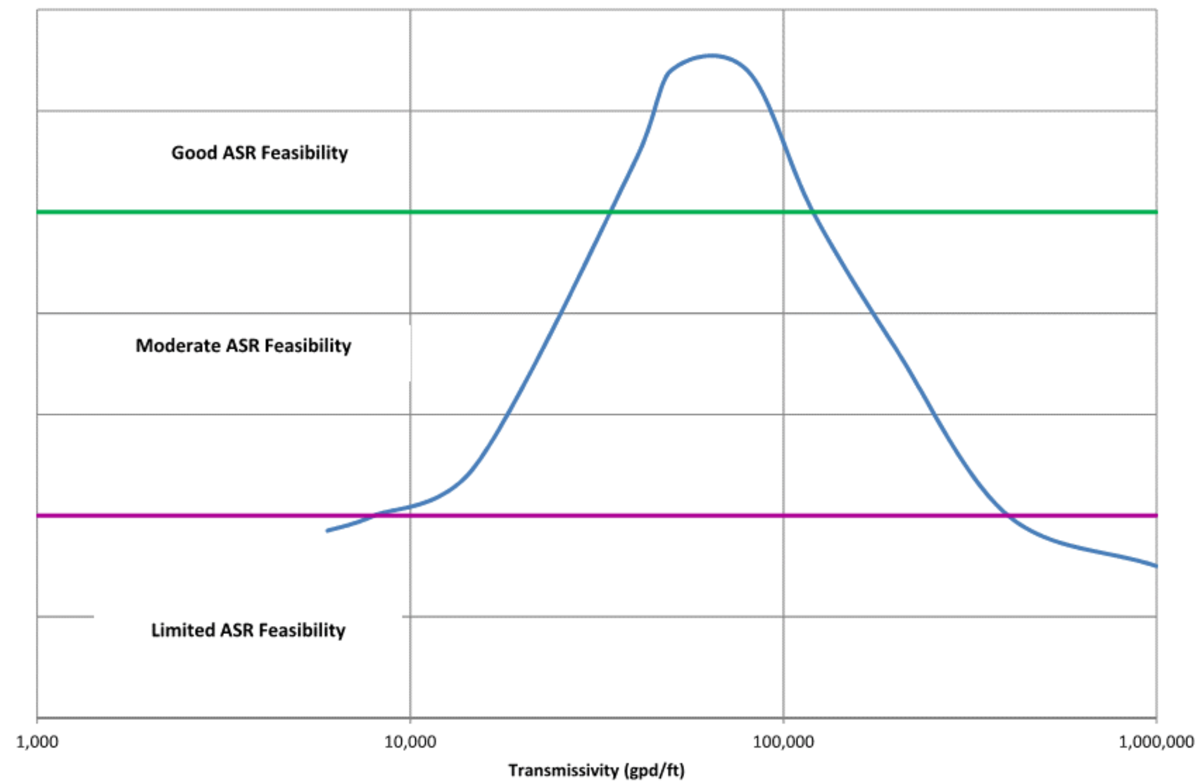

Source: St. Johns River Water Management District Special Publication SJ97-SP4

Figure A2-2
ASR Feasibility Related to Transmissivity of the ASR Storage Zone Using Finshed Water as the Source of Supply

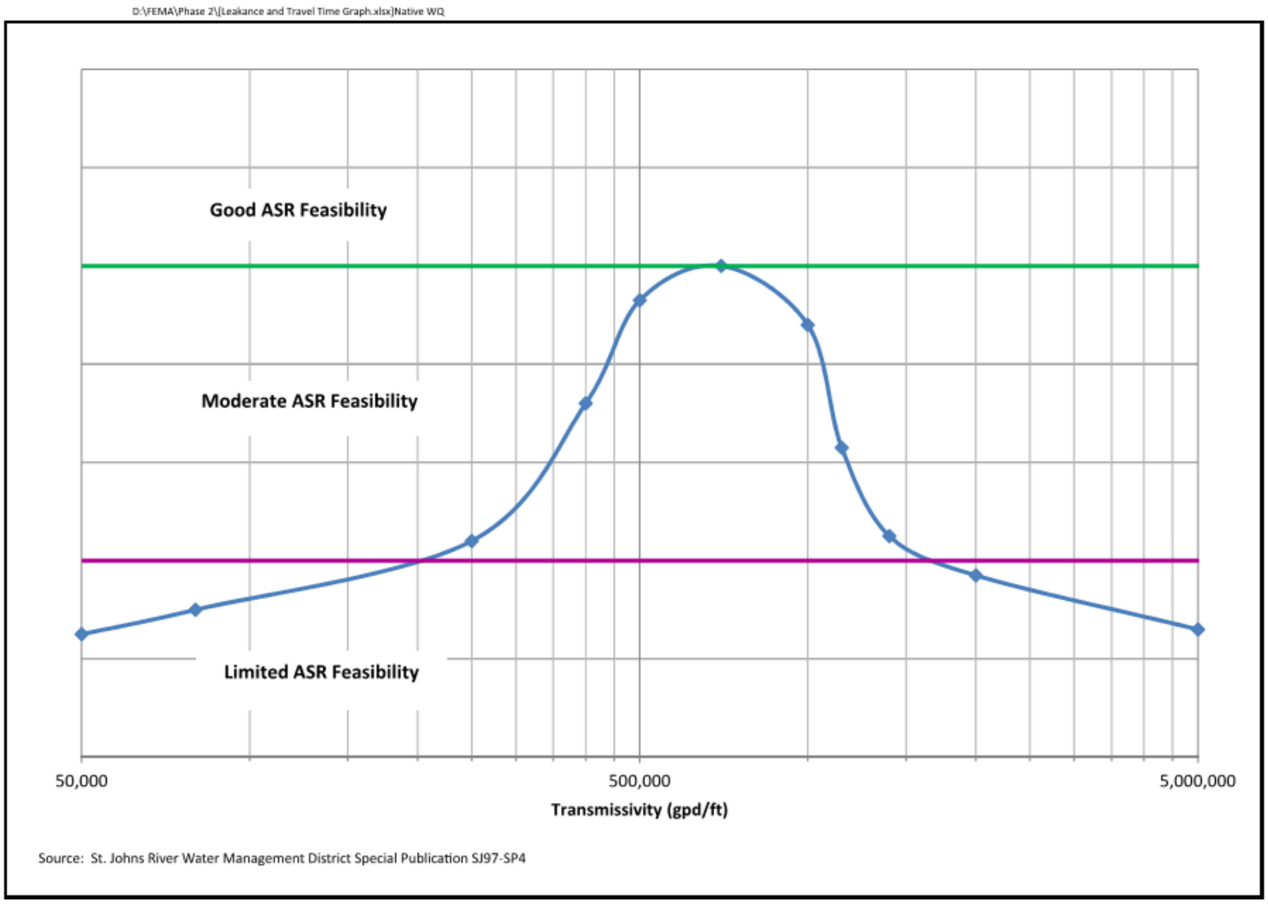

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Figure A2-3
ASR Feasibility Related to Transmissivity of the ASR Storage Zone Using Untreated Surface Water as the Source of Supply

Table A2-1. ASR Storage Zone Transmissivity Related to ASR Feasibility

Transmissivity (gpd/ft)		Applicability
Potable Water	Untreated Surface Water	
Less than 8,000	Less than 80,000	Limited
8,000 to 15,000	80,000 to 250,000	
15,001 to 40,000	250,001 to 400,000	
40,001 to 50,000	400,001 to 500,000	
50,001 to 80,000	500,001 to 1,000,000	Optimal
80,001 to 120,000	1,000,001 to 1,150,000	
120,001 to 200,000	1,150,001 to 1,400,000	
200,001 to 400,000	1,400,001 to 2,000,000	
Greater than 400,000	Greater than 2,000,000	Limited

Source: St. Johns River Water Management District Special Publication SJ97-SP4

Table A2-2. Aquifer Gradient and Groundwater Flow Direction Related to ASR Feasibility

Aquifer Gradient	Direction Criterion
Many strong influences exist	Extreme artificial gradient, reevaluate location of ASR system
Several strong influences	Exaggerated gradient, investigation needed
Multiple minor influences exist	Affected gradient worth investigating
Single minor influence or abnormal natural gradient	Minor investigation or existing data search
No influence	No influence

Source: St. Johns River Water Management District Special Publication SJ97-SP4

Table A2-3. Recharge Water Quality Relative to the Secondary Drinking Water Standards for Salinity Parameters

Chloride Concentration (mg/L)	Total Dissolved Solids Concentration (mg/L)	Compliance with Secondary Drinking Water (SDW) Standards*
Less than 50	Less than 100	Well within SDW standards
50 to 100	100 to 200	
101 to 170	201 to 350	Moderately meets SDW standards
171 to 200	351 to 450	
200 to 250	450 to 500	Just within SDW standards

Source: St. Johns River Water Management District Special Publication SJ97-SP4

Table A2-4. Native Water Quality Related to ASR Recovery Efficiency

Chloride Concentration (mg/L)	Total Dissolved Solids Concentration (mg/L)	Water Quality	Influence on Recovery Efficiency
Less than 400	Less than 700	Near Freshwater	Higher Recovery
400 to 800	700 to 1,300		
801 to 3,000	1,301 to 5,000	Slightly Brackish	
3,001 to 6,000	5,001 to 10,000		
Greater than 6,000	Greater than 10,000	Very Brackish	Lower Recovery

Source: St. Johns River Water Management District Special Publication SJ97-SP4

ATTACHMENT 3 LANE'S ALLUVIAL CHANNEL BALA

Lane's balance or Lane's relationship is a qualitative conceptual model that can be used as an aid to visually assess stream responses to changes in flow, slope, and sediment. The model is based on the general theory that if force applied by the flowing water on an alluvial channel boundary is balanced with strength of the channel boundary and the delivered sediment load, the channel will be stable and neither aggrade nor degrade. This equilibrium condition in the channel can be expressed as a balance of four basic factors (Lane 1955):

- Sediment discharge, Qs;
- Median grain size of bed material, D50;
- Dominant discharge or streamflow, Qw; and
- Thalweg slope or energy slope, S.

This balance can be expressed in the proportional relationship: (Qs) (D50) α (Qw) (S)

Lane's relationship suggests that a stream will remain in equilibrium as along as these four variables are kept in balance (Figure A3-1). If one variable changes significantly, the stream will respond by aggrading or degrading, and another variable must adjust to restore balance. A limitation of this conceptual model is that it does not indicate which variable will adjust, the magnitude of the adjustment, or the timeframe that will be involved.

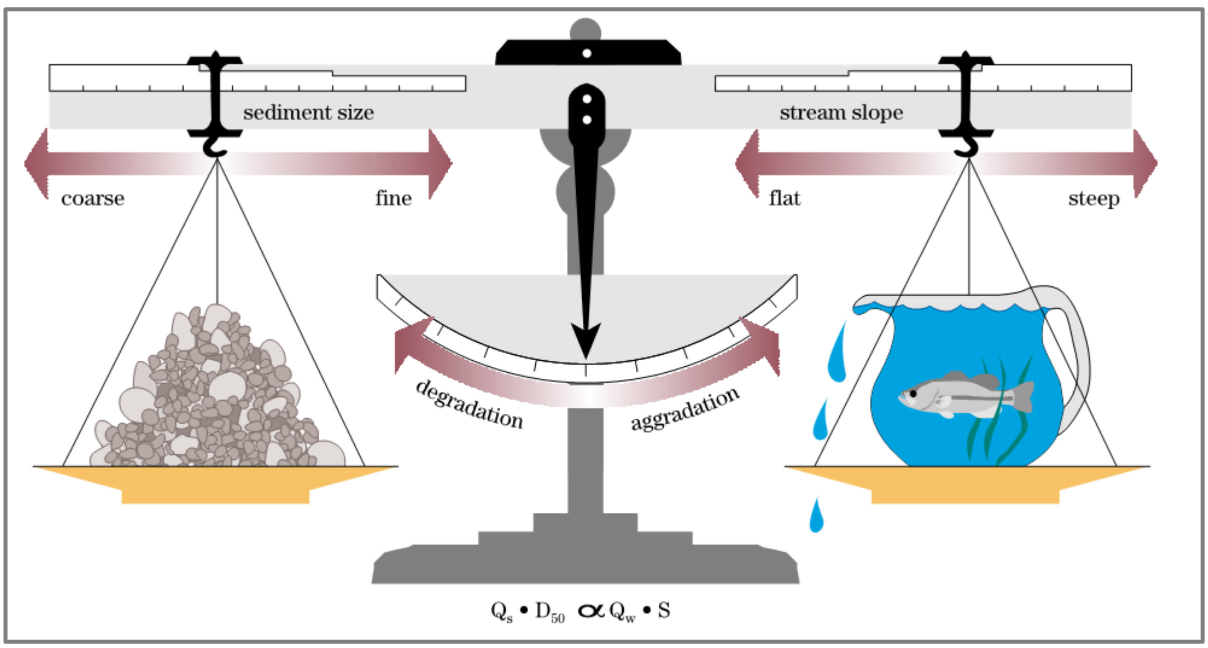

Figure A3-1. Lane's Balance (Rosgen, 1996)

ATTACHMENT 4 EXAMPLE LOW IMPACT DEVELOPMENT/GREEN INFRASTRUCTURE PRACTICES

Preserving and recreating natural landscape features and minimizing effective imperviousness are principles employed by LID to create functional, as well as appealing, site drainage that treats stormwater as a resource, rather than a waste product. There are numerous LID developments across the U.S., Canada, and Europe, and ample amounts of literature on the many practices that have been used to adhere to LID/GI principles, including the following (PSAT 2005; PSP 2012; USEPA 2014d; NYC DEP 2014):

- Distributed Solutions
    - Lot-level:
        - Bioretention/Rain Gardens (**Photo A4-1**) – designed to collect and absorb rainwater, capture pollutants, and drain or detain standing water efficiently. Generally planted with native species that are wet- and dry-tolerant and often add to the biodiversity of an urban area.
        - Cisterns/Rain Barrels – retains stormwater that washes off rooftops. This water can be reused for irrigation or other water needs.
        - Disconnecting impervious areas – involves managing runoff by intercepting, infiltrating, or filtering water as it moves across impervious surfaces to the stormwater conveyance system.
        - Soil modifications/enhancements – rehabilitation or reconditioning of soils to support GI. This includes the adjustment of drainage characteristics, improvement of soil structure, addition of organic matter, and the mitigation of soil compaction.

Source: FEMA, Kevin Vinneau 2015.

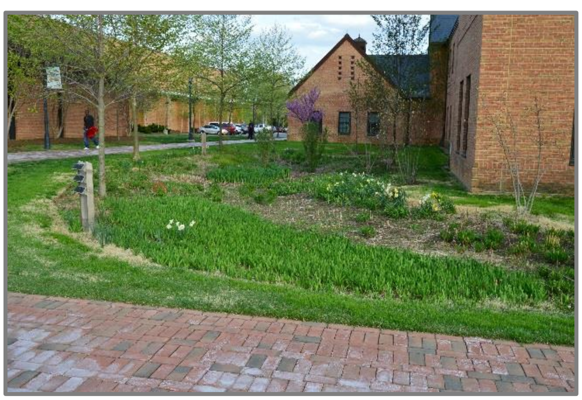

Photo A4-1. Example of Rain Garden Pavement

Photo A4-2. Example of Permeable Pavement

- Right-of-Way: Integration with transportation plans is a common element of many GI programs. Green streets and green parking areas take advantage of the need for periodic resurfacing, adding stormwater management elements when paved areas are repaired or replaced (Wise 2008).

  - Permeable pavements (Photo A4-2) – use of permeable pavement for all or a portion of the road surface. Rainfall that infiltrates directly below the road surface reduces the amount of stormwater collection needed, improves safety, and reduces road noise.
  - Bioswales (Photo A4-3) – stormwater runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters.
  - Grass swales (Photo A4-4) – vegetated stormwater management technology that can remove surface runoff contamination through sedimentation, filtration by the grass blades, infiltration to the soil, and likely some biological processes.
  - Bump-outs – vegetated curb extensions that protrude into the street and are composed of stone, soil, and plants. An inlet or curb-cut directs runoff into the bump-out structure where it can be stored, infiltrated, and taken up by vegetation. Also provides traffic calming benefits.
  - Infiltration trenches – excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.
  - Stormwater inlet retrofits – stormwater inlets that redirect a portion of inflow to a vegetated area for infiltration and plant use, or through a hydrodynamic treatment system to improve water quality.

Source: NYC DEP.

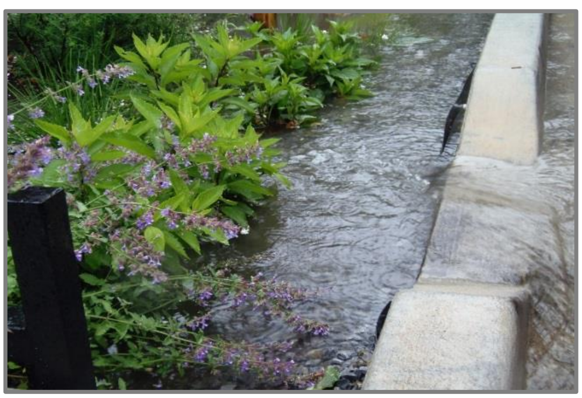

Photo A4-3. Bioswale During a Storm Event

Source: FEMA, Kevin Vienneau 2015.

Photo A4-4. Example of Grass Swale

- Centralized Solutions
  - Stormwater detention/retention pond systems (Photo A4-5) – used to settle suspended sediments and other solids present in stormwater runoff. Retention ponds have a permanent pool of water that fluctuates in response to runoff from the surrounding areas. Maintaining a water pool keeps deposited sediments at the bottom and discourages resuspension. Detention ponds are used to slow down the water flow and settle stormwater particles. Detention ponds hold water for a short time period.

- Constructed wetlands – artificially designed wetlands that remove sediments and pollutants from wastewater and stormwater runoff. Also used to create or restore habitat for native wildlife.

- Buildings
  - Green roofs – roof system that is partially or completely covered with vegetation. Used to filter out pollutants and metals by absorbing rainwater, reduce energy costs by providing better building insulation, and reduce the urban heat island effect.
  - Blue roofs – roof structures such as an open water surface or a closed water surface. Porous media or a deck can cover a closed water surface structure. Used for stormwater storage to mitigate the impacts of runoff from a building and to allow for water reuse in or near the building.

- Other Strategies
  - Aquatic buffers – There are four primary aquatic buffer types including non-tidal stream (or riparian), wetland, pond/lake, and tidal shoreline. For each, a buffer defines and establishes a vegetated transition zone between upland areas and an aquatic resource such as surface water or wetland. This position in the landscape enables aquatic buffers to influence and mitigate the impacts of one land use on another (St. Mary’s College 2014).

Source: FEMA, Kevin Vienneau 2015.

Photo A4-5. Example of Detention Pond

ATTACHMENT 5 LOW IMPACT DEVELOPMENT/GREEN INFRASTRUCTURE TECHNICAL GUIDES AND MANUALS

The following guides and manuals are excellent sources of information about low impact development and green infrastructure.

Northeast Region

- New York City, New York
  - NYC DEP Standards for Green Infrastructure, 2014: Standard engineering details for GI practices such as bioswales and rain gardens constructed in New York City. http://www.nyc.gov/html/dep/pdf/green_infrastructure/bioswales-standard-designs.pdf
  - NYC DEP Procedure Governing Limited Survey for Right-of-Way Bioswales, Rain Gardens, and Stormwater Greenstreets, 2015: Information regarding the standard survey that must be conducted to gather site information on topography, surface/subsurface features, trees, utilities, and vaults within the defined survey area before a GI practice is constructed. http://www.nyc.gov/html/dep/pdf/green_infrastructure/ogi-survey-procedure.pdf
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