USACE SOUTHWESTERN DIVISION CIVIL WORKS STRATEGIC PLAN

REPORT SUMMARY

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ACRONYMS AND ABBREVIATIONS

A/E	Architect/Engineer
ACS	American Community Survey
AOR	Area of Responsibility
AR	Arkansas
ASCE	American Society of Civil Engineers
BCR	Benefit-Cost Ratio
BEA	Bureau of Economic Analysis
BL	Business Line
BLS	Bureau of Labor Statistics
CAP	Continuing Authorities Program
CIP	Capital Improvement Plan
CO2	Carbon Dioxide
CW	Civil Works
CWMS	Corps Water Management System
CWSP	Civil Works Strategic Plan
DFW	Dallas/Fort Worth
EDA	U.S. Economic Development Administration
EM	Engineer Manual
ER	Ecosystem Restoration
FEMA	Federal Emergency Management Agency
FPMS	Floodplain Management Services
FR	Flood Risk
FRM	Flood Risk Management
GHG	Greenhouse Gas
GI	General Investigation
GIWW	Gulf Intracoastal Waterway
GW	Gigawatt
H&H	Hydrologic and Hydraulic
HP	Hydropower
HQ	Headquarters
HUD	U.S. Department of Housing and Urban Development
HVRI	Hazards & Vulnerability Research Institute
IT	Information Technology
IWRM	Integrated Water Resources Management
KS	Kansas
LA	Louisiana
LULC	Land Use and Land Cover
MKARNS	McClellan-Kerr Arkansas River Navigation System
MO	Missouri
NAV	Navigation
NED	National Economic Development
NEPA	National Environmental Policy Act
NNBF	Natural and Nature-Based Features

NOAA	National Oceanic and Atmospheric Administration
NW	Northwest
O&M	Operations and Maintenance
OK	Oklahoma
P3	Public-Private Partnership
PAS	Planning Assistance to States
PM/PL	Project Manager/Project Leader
PPP	Public-Private Partnership
PR&G	Principles, Requirements, and Guidelines
RPEC	Regional Planning and Environmental Center
SLR	Sea Level Rise
SoVI	Social Vulnerability Index
SWD	Southwestern Division
SWF	Fort Worth District
SWG	Galveston District
SWL	Little Rock District
SWOT	Strengths, Weaknesses, Opportunities, and Threats
SWT	Tulsa District
TES	Threatened and Endangered Species
TIS	Technical Innovation Strategy
TX	Texas
TxDOT	Texas Department of Transportation
UHI	Urban Heat Island
USACE	United States Army Corps of Engineers
USC	University of South Carolina
UVA	University of Virginia
VLCC	Very Large Crude Carriers
WS	Water Supply

1.0 Civil Works Strategic Plan (CWSP) Development Process

To ensure that the development of the CWSP would be informative and relevant to all levels of the SWD organization districts, stakeholders, and the division all provided input. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) and Risk Analysis was used, along with a trend analysis, to develop a series of future scenarios used in the planning exercises. The scenarios were used to identify key gaps that, if addressed, enable SWD and its districts to prepare for multiple possible futures. All these efforts resulted in a synthesis of a framework for action that includes a comprehensive vision across the SWD goals and objectives.

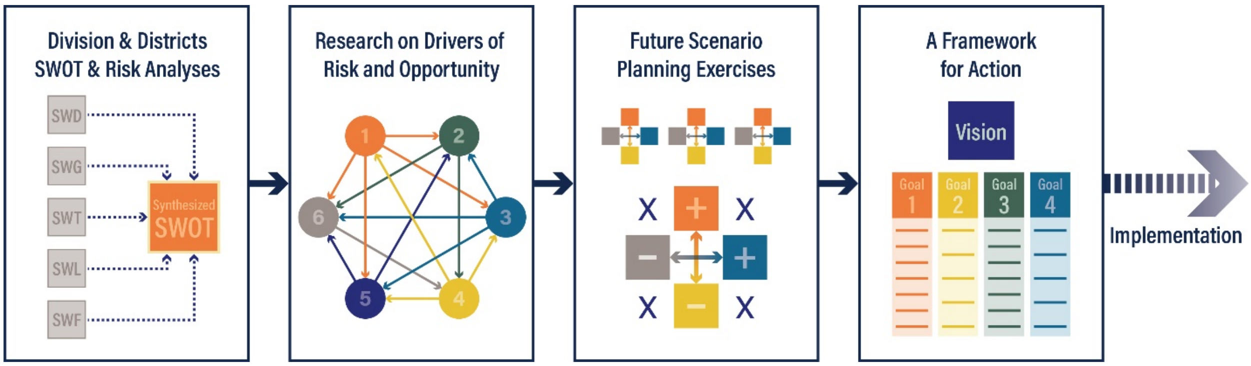

Figure 1: Conceptual diagram of the SWD Civil Works Strategic Plan Development Process

Beyond SWD expertise spanning CW Mission Areas, one of its key strengths is excellent relationships with stakeholders and sponsors who are eager to work with SWD in addressing the region's needs. The Division has complemented this strength with advancement in key internal areas, such as the development of a Regional Planning and Environmental Center (RPEC) to provide centralized, robust support to CW projects across the AOR. In addition, each of the Districts possesses existing capacity that can be leveraged and expanded to meet new challenges, along with vital experience and expertise across varying core CW Mission Areas. With these existing strengths serving as a firm foundation, SWD can be bold in shifting toward more innovative and integrated approaches to project planning and execution. Such a paradigm shift will be essential in addressing the unique challenges that affect the Division's CW Mission Areas in the face of an uncertain future.

2.0 Evolving Risks and Opportunities: Key Drivers

A series of socio-economic and bio-physical trends with global analogues are manifesting in complex ways at varying scales throughout the region. These trends, and their uncertainty, represent evolving risks and opportunities for the SWD Civil Works program, especially when analyzed in the context of a rapidly growing and urbanizing population, a changing regional landscape, changing extreme weather patterns, a water-food-energy nexus pressured by an uncertain energy future and competing uses, and aging infrastructure. These trends have been identified as key drivers for the Civil Works Program in the region, as their uncertainty and considerable implications for USACE Mission Areas present challenges that can only be met with a movement toward a more integrated and adaptive paradigm of water resources management.

2.1 Driver 1: Rapid Population Growth and Urbanization

According to the American Community Survey (ACS) 5-year estimates, the total population of all counties contained within SWD's boundaries grew 12.4% from 2010-2018, from about 31.7 million to 35.7 million. Between 2010-2019, the DFW Metropolitan area exhibited the largest growth in population in the nation and was closely followed by the Houston Metropolitan area, which exhibited the second highest increases during this period[1]. Population growth and urbanization are also central drivers of economic activity and recent trends in key industries in the region. Many of these industries have significant implications for regional Integrated Water Resources Management (IWRM) and Civil Works, with their viability closely linked with future energy uncertainty and increasing demand on limited water resources.

Over the past decade, the oil, gas, and petrochemicals industries in Texas and Oklahoma have seen a boom as demand for energy continues to increase with population growth. However, since 2014, employment and drilling operations in energy production industries have seen a relative decline, possibly correlated with increasing global demand for, and availability of, renewable and diversified energy sources. Notably, increasing demand for wind and solar energy is also likely to drive increased demand for existing hydropower plants to play a stabilizing role in power generation throughout the region; studies have shown that hydropower can facilitate the integration of wind and solar energy into power grids by compensating for their high variability.[2]

2.2 Driver 2: A Changing Regional Landscape

Accompanying the regional trend of rural-urban migration patterns is the transformation of many rural landscapes, including farmland, forests, and pastures, to more urbanized areas (for example, in Northwest Arkansas).[3] Studies around the world have consistently found that urbanization and increased impervious surface coverage transform fluvial landscapes, habitats, and natural hydrology with broad implications.[4] LULC impacts due to urbanization include impacts to flood discharge, water quality, channel morphology, local water balance, and

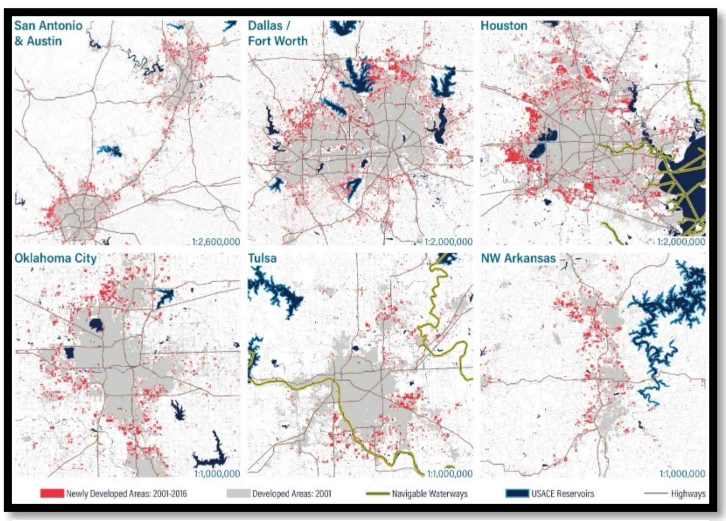

Figure 2: Maps of New Development in Metropolitan Areas, 2001-2016

[1] U.S. Census Bureau. 2020. Metropolitan and Micropolitan Statistical Areas Population Totals and Components of Change: 2010-2019. Available online at: https://www.census.gov/data/datasets/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html. Accessed on September 10, 2020.

[2] Jurasz, J., J. Mikulik, M. Krzywda, B. Ciapała, and M. Janowski. 2018. Integrating a wind- and solar-powered hybrid to the power system by coupling it with a hydroelectric power station with pumping installation. Energy. 144:549-563.

[3] Yan and Edwards (2013).

[4] Kang, R., D. E. Storm, and R. Marston. 2010. Downstream Effects of Urbanization on Stillwater Creek, Oklahoma. Physical Geography. 31(2):186-201.

biodiversity.[5] In particular, multiple studies have demonstrated that expansion of impervious surface coverage reduces an area's infiltration capacity, thereby leading to higher rates of downstream runoff, often carrying pollutants and debris along the way.[6] In some cases, this may result in USACE flood control projects receiving more runoff than they were designed for, accelerating the need to update outdated flood protection infrastructure downstream of areas experiencing LULC change in order to ensure they continue to meet their intended level of protection. This presents an additional challenge of uncertainty for various USACE Civil Works Mission Areas including Flood Risk Management, Navigation, Water Supply, and Environmental Stewardship, although these effects have not been as thoroughly studied.[7] The Texas Gulf Coast is experiencing unique and substantial land cover changes in the form of coastal erosion driving the retreat of the coastline. Rates of beach erosion of up to nearly 10 feet per year are largely driven by storm surge and high tides combined with sea level rise (SLR). The consequent impacts to water quality and water depth are accelerating the disappearance of wetlands, marshes, barrier islands, and other coastal habitats, all of which can play a crucial role in protecting coastal areas against storm surge.[8]

Many habitats in the region are sensitive to and directly impacted by increased variability in extreme weather; shifting food, energy, and water dynamics; and changing landscapes driven largely by urbanization. Leveraging opportunities to conserve and restore habitat can positively impact multiple USACE Mission Areas. Additionally, changing habitat patterns have allowed and continue to allow the introduction and establishment of invasive species that may increase risk to agricultural production, biodiversity, ecosystem stability, water quality, and various types of water infrastructure including dams, levees, hydropower systems, navigation channels, and lock chambers.[9] While increasing water temperatures, rising sea levels, and increases in extreme weather can facilitate the success of many aquatic invasive species,[10] recent studies have also suggested that urbanization may increase the invasive potential of alien species.[11] Some invasive species of particular concern to USACE Mission Areas include zebra mussels, which can grow on many water infrastructure systems, impeding function;[12] blue-green algae, which pose

[5] Yan and Edwards (2013).
[6] Li, Y. and C. Wang. 2009. Impacts of urbanization on surface runoff in Dardenne Creek watershed, St. Charles County, Missouri. Physical Geography. 30(6):556-573.
Olivera, F. and B. B. Defee. 2007. Urbanization and Its Effect On Runoff in the Whiteoak Bayou Watershed, Texas. Journal of the American Water Resources Assocation.43(1):170-182.
[7] Kang, R. and R. A. Marston. 2006. Geomorphic effects of rural-to-urban land use conversion on three streams in the Central Redbed Plains of Oklahoma. Geomorphology. 79(3-4):488-506.
[8] U.S. Global Change Research Program (2017b).
[9] Ibid.
Vissichelli, M. 2018. *Invasive Species Impacts on Federal Infrastructure*. National Invasive Species Council Secretariat. Available online at: https://www.doi.gov/sites/doi.gov/files/uploads/invasive_species_impacts_on_federal_infrastructure.pdf. Accessed on September 10, 2020.
[10] U.S. Environmental Protection Agency. 2008. *Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research*. National Center for Environmental Assessment.
[11] Marques, P. S., L. R. Manna, T. C. Frauendorf, E. Zandonà, R. Mazzoni, and R. El-Sabaawi. 2020. Urbanization can increase the invasive potential of alien species. Journal of Animal Ecology. Early View.
[12] U.S. Department of the Interior Invasive Species Advisory Committee. 2016. *Invasive Species Impacts on Infrastructure.* Available online at: https://www.doi.gov/sites/doi.gov/files/uploads/isac_infrastructure_white_paper.pdf. Accessed on September 10, 2020.

hazards to water quality and health;[13] and water hyacinth, which negatively impact water quality and impede navigation and fishing.[14]

2.3 Driver 3: Increases in Extreme Weather: Droughts and Floods

2.3.1 Severe Drought

Increasing weather variability—driven by annual global temperature increases associated with elevated greenhouse gas (GHG) emissions—is linked to unpredictable swings, or dipole events, in precipitation patterns experienced in recent decades. Projections under the high GHG emissions scenario suggest an overall decrease in spring and summer precipitation in the region of 10-30% by the end of the century,[15] despite increases in the intensity of such events. Increasing intensity of precipitation events elevates flood risk, even during periods of drought.[16] Increases in the severity, frequency, and duration of drought in the region will continue to strain the region's available sources of water supply. As the strain on water resources is further exacerbated by increasing tradeoffs for different uses, risk to food and energy production will grow as rapid population growth and rural-urban shifts increase demand.

Reservoir storage capacity is being lost due to increased sedimentation in the region, often as a result of flooding events. In conjunction with that loss, it is likely that drought-stressed surface water availability (see Figure 7) will increase the pressure to reallocate water storage at multi-purpose reservoirs to water supply purposes,[17] especially as overall demand for water is projected to increase significantly in the region over the next 50 years. These challenges to multi-purpose reservoir operations are consistent with USACE policy and guidance for drought contingency plans.[18] In general, drought and increased heat, especially warmer winter night temperatures, have made winter crop productivity less dependable, increased soil moisture stress, and a exacerbated proliferation of invasive species, insects, and pests in some areas.[19] This not only has negative impacts to agricultural food production, but on stable regional biodiversity at large.

2.3.2 Extreme Rainfall and Tropical Storms

Although overall average annual precipitation is largely projected to decrease across most of the region, especially in the summer, both the frequency and intensity of extreme rainfall events and

[13] United State Geological Survey. n.d. Cyanobacterial (Blue-Green Algal) Blooms: Tastes, Odors, and Toxins. Available online at: https://www.usgs.gov/centers/kswsc/science/cyanobacterial-blue-green-algal-blooms-tastes-odors-and-toxins-0?qt-science_center_objects=0#qt-science_center_objects. Accessed on September 10, 2020.

[14] Wainger, L. A., N. E. Harms, C. Magen, D. Liang, G. M. Nesslage, A. M. McMurray, and A. F. Cofrancesco. 2018. Evidence-based economic analysis demonstrates that ecosystem service benefits of water hyacinth management greatly exceed research and control costs. PeerJ. 6:e4824.

[15] U.S. Global Change Research Program. 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, Washington, DC, USA. http://nca2014.globalchange.gov/report. Accessed on September 10, 2020.

[16] USACE Engineering and Design. 2018. *Drought Contingency Plans.* Available online at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1941.pdf. Accessed on September 10, 2020.

[17] USACE Institute for Water Resources. 2016. *Status and Challenges for USACE Reservoirs.* Available online at: https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2016-RES-01.pdf. Accessed on September 10, 2020.

[18] USACE Engineering and Design (2018).

[19] Steiner, J. L., J. M. Schneider, C. Pope, P. Ford, and R. F. Steele. 2015. *Southern Plains Assessment of Vulnerability and Preliminary Adaptation and Mitigation Strategies for Farmers, Ranchers, and Forest Land Owners.* T. Anderson, Ed., U.S. Department of Agriculture Southern Plains Climate Hub.

major tropical cyclones are projected to increase.[20] Flooding due to extreme rainfall events and tropical cyclones has been severely disruptive in the region, and this flood risk is expected to continue increasing. Tropical cyclones are associated with extraordinarily heavy rainfall rates, with the heaviest rainfall amounts from such events up 5%-7% over the past century.[21] Moreover, most rivers in the region are not fed from mountain snowpack and are therefore highly sensitive to flooding caused by seasonal rainfall.[22] Extreme rainfall events directly threaten lives, livelihoods, agriculture and energy production, and critical services and infrastructure, while also placing a heavy strain on aging infrastructure such as older dams and levees. Rapid population growth and urbanization also increase exposure to the hazards posed by heavy flood events while exacerbating flood hazard itself via increased stormwater runoff. Further, extreme flood events can exceed a reservoir's storage capacity, especially for those that have exceeded the analysis period for which they were designed and were constructed before extreme weather events began occurring more frequently.[23] This challenge is further complicated by a trend of increasing sedimentation buildup in reservoirs, affecting their ability to meet intended storage capacity. Many of these reservoirs may require recapitalization, updates to their operating plans, and improved sedimentation management to minimize the risk of catastrophic downstream releases of stored water.[24] Hurricanes and rainfall events similarly impact coastal navigation, requiring significant post-storm dredging.[25]

2.3.3 Storm Surge and Sea Level Rise

Extreme storm surge events combined with relative sea level rise (RSLR) increase flood and life safety risks along the Texas Gulf Coast. Over the past century, relative sea levels in the region have risen 5-17 inches.[26] The rates of relative SLR along the Texas Coast have shown substantial variability, from 0.08 inches per year from 1957-2011 at Port Mansfield to 0.26 inches per year at Galveston Pleasure Pier.[27] These variations are driven in large part by varying levels of vertical land movement, or subsidence, combined with global, or eustatic, sea level changes.[28] Upwards of 1,000 square miles of land along the Texas Coast are now within five feet of the high tide line.[29] RSLR increases both the risk of severe storm surge from extreme weather events and the ongoing risk of chronic tidal flooding which, while having less catastrophic acute

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[20] U.S. Department of Energy Office of Energy Policy and Systems Analysis. 2015a. *Climate Change and the U.S. Energy Sector: Regional Vulnerabilities and Resilience Solutions*. Available online at: https://toolkit.climate.gov/sites/default/files/Regional_Climate_Vulnerabilities_and_Resilience_Solutions_0.pdf. Accessed on September 10, 2020.
Runkle and Kunkel (2019).
[21] U.S. Global Change Research Program (2017b).
[22] Ibid.
[23] USACE Institute for Water Resources (2016).
Medina et al (2019).
[24] Ibid.
[25] Bloodgood, P. 2017. District works to overcome Harvey's impacts to Texas' shipping industry. USACE Galveston District Public Affairs Office. Available online at: https://www.swg.usace.army.mil/Media/News-Stories/Article/1310292/district-works-to-overcome-harveys-impacts-to-texas-shipping-industry/. Accessed on September 10, 2020.
[26] U.S. Global Change Research Program (2017b).
[27] USACE SWG. 2018. *Coastal Texas Protection and Restoration Feasibility Study: Draft Integrated Feasibility Report and Environmental Impact Statement*. Available online at: https://www.swg.usace.army.mil/Portals/26/docs/Planning/Public%20Notices-Civil%20Works/Coastal-TX%20DIFR-EIS/Coastal%20Texas%20DIFR-EIS_Oct2018.pdf?ver=2018-10-24-162409-300. Accessed on September 10, 2020.
[28] Ibid.
[29] U.S. Global Change Research Program (2017b).

impacts, can drive major socio-economic shifts and impacts to existing facilities and infrastructure in the long-term. Rapid rates of beach erosion along the Texas Coast, meanwhile, are largely driven by storm surge and high tides combined with RSLR. The consequent impacts to water quality and water depth are causing a reduction in the extent of wetlands, marshes, barrier islands, and other coastal habitats, all of which play a role in protecting coastal areas against storm surge.[30] Populations, critical infrastructure, port terminals, and petroleum and natural gas refining facilities along the Texas Coast are therefore highly vulnerable to both acute and chronic flooding events, and these risks will continue to grow. Oil and gas production and transportation facilities along the Texas Coast are directly exposed to extreme coastal events wind and flooding events and the effects of sea level rise and subsidence.[31]

2.4 Driver 4: Uncertain Future of Energy

In recent years, the oil and gas industry in Texas has seen a boom, driving fossil fuel exports. Nevertheless, downturns in global demand and falling oil and natural gas prices at an annualized rate of 6.9% from 2014-2019 have slowed this rate of growth.[32] This slowdown is corroborated by employment data produced by the Bureau of Economic Analysis (BEA), which shows a 12.9% drop in employment in the mining, quarrying, and oil and gas extraction industries between 2013-2018 compared with the 40.3% rise in the five years prior (2008-2013).[33] Long-term energy production and local supply capacity is under pressure due to the combination of increased weather variability, limited supply of fossil fuels and water, and increasing demand due to population growth and urbanization. For example, increases in annual average temperatures and heatwaves drive demand for energy and water while increasing strain on energy infrastructure cooling systems and available surface water.[34] During the 2011 Texas drought, electricity demand and generation increased by 6% and water consumption for electricity increased by 9%.[35] Therefore, it is likely that oil and gas-driven energy production will increasingly enter into a positive (exacerbating) feedback loop with increasing energy demand and limited supply capacity due to extreme weather exposure and strained water resources.

Demand for energy, food, and various primary and intermediate products is expected to continue growing as populations and urbanization expand, even as risks increase and new and emerging threats materialize. As such, demand for USACE channel deepening will likely continue to grow, especially for very large crude carriers (VLCC) and fully loaded deep-draft container vessels. The Gulf Intercoastal Waterway (GIWW), Texas' myriad of ports, and the McClellan-Kerr Arkansas River Navigation System (MKARNS) are paramount to the transportation of energy products, agriculture supplies, and food in and out of the region.

2.5 Driver 5: Increasing Demand on Limited Water Resources

Water supply is crucial both for agricultural uses and irrigation as well as for energy generation activities such as oil and gas operations, power plant cooling, and thermoelectric and

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[30] Ibid.
[31] U.S. Department of Energy Office of Energy Policy and Systems Analysis (2015a).
[32] IBIS World. 2019. *Oil Drilling & Gas Extraction in Texas – Market Research Report.*
[33] Bureau of Economic Analysis. 2020. BEA Data. Available online at: https://www.bea.gov/data. Accessed on September 10, 2020.
[34] U.S. Global Change Research Program (2017b).
[35] Scanlon, Duncan, and Reedy (2013).

hydropower generation; in addition, the agriculture industry relies on adequate sources of energy.[36] Population growth and urbanization are therefore driving a redistribution of demand at the nexus of food, energy, and water, with urbanization-driven changes in consumption patterns linked to growing global demand for all three.[37] For instance, the current consensus is that, at its current pace, global population growth will likely require 70-100% more food production in the next several decades,[38] which will directly affect the extensive agricultural industries and exports in the region. Water demand for municipal, agricultural, and energy uses is therefore projected to increase substantially in the region over the next 50 years.[39] Further, rural-urban population shifts increase pressure to allocate limited water supply resources from traditional centers of agriculture and toward growing metropolitan centers.[40]

Water supply is a relatively important Mission Area for SWD, comprising 75% of all USACE water supply storage.[41] SWD operates and maintains 50 major lakes providing one-third of all surface water supplies for Texas and Oklahoma and 20% of all supplies for Kansas, in addition to 10 lakes which provide significant water supplies in Arkansas.[42] As water demand for municipal, agricultural, and energy uses continues to climb in the context of increasingly strained water resources driving competition for water, SWD decisions regarding water availability will become increasingly consequential. This is especially true in multi-purpose reservoirs in which water allocation and releases must be carefully balanced with other Mission Area needs and as changing needs in regional water supply turn increasingly away from surface water and toward groundwater. Conflicts may especially arise with increases in dipole events of drought and flooding, wherein the threat of extreme rainfall events introduces challenges in managing reservoirs to decrease flood risk even as the increasing threat of drought stresses the region's water supply. It is challenging to optimize the reservoir operations under these conditions, entailing decisions such as when and how much water to release.

Outdoor and water recreation across the region support a thriving ecotourism economy along the Texas Coast and the MKARNS system, both of which depend on water availability and freshwater flows.[43] Many popular water-related outdoor recreation activities in the region are made accessible by USACE projects and depend on biodiverse ecosystems supported by USACE. In addition, the USACE Environmental Restoration Mission Area plays a critical role in managing water releases to help maintain the stability of these ecosystems. For example, minimum flow and downstream thermal requirements for fish habitat as well as to prevent algal issues are included in management practice.[44] There is a growing challenge in managing these

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[36] Ibid.
U.S. Department of Energy Office of Energy Policy and Systems Analysis (2015a).
[37] National Intelligence Council. 2012. *Global Trends 2030: Alternative Worlds.* Available online at: https://www.dni.gov/files/documents/GlobalTrends_2030.pdf. Accessed on September 10, 2020.
[38] Tscharntke, T., Y. Clough, T. C. Wanger, L. E. Jackson, I. K. Motzke, I. Perfecto, J. J. Vandermeer, and A. M. Whitbread. 2012. Global Food Security, Biodiversity Conservation and the Future of Agricultural Intensification. Biological Conservation. 151(1):53–59.
[39] U.S. Global Change Research Program (2017b).
[40] Oklahoma Water Resources Board (2011).
[41] USACE SWD. n.d. Water Supply. Available online at: https://www.swd.usace.army.mil/Missions/Civil-Works/Water-Supply/. Accessed on September 10, 2020.
[42] Ibid.
[43] U.S. Global Change Research Program (2017b).
Medina et al (2019).
[44] USACE Institute for Water Resources (2016).

ecosystems due to uncertainties posed by increased demand for water resources in conjunction with increases in drought and other extreme weather events, changes in natural hydrology, ecological changes, and demand for non-federal hydropower facilities at USACE dams.[45]

2.6 Driver 6: Aging Infrastructure

Every USACE Civil Works Mission Area is faced with challenges related to aging infrastructure and a backlog of operations and maintenance. The majority of USACE dams throughout the country were constructed over 50 years ago and are beyond the planning life initially used in their design.[46] These dams play a central role in providing multiple benefits at USACE reservoirs related to Water Supply, Hydropower, Navigation, Flood Risk Management, Recreation, and Environmental Stewardship. Most federal reservoir storage projects are in need of substantial recapitalization and updates to their operating plans.[47] Further, changing trends such as population growth, drought, inland and coastal flooding, and habitat loss intensify competing water demands and the careful tradeoffs needed to balance multiple uses under future conditions.

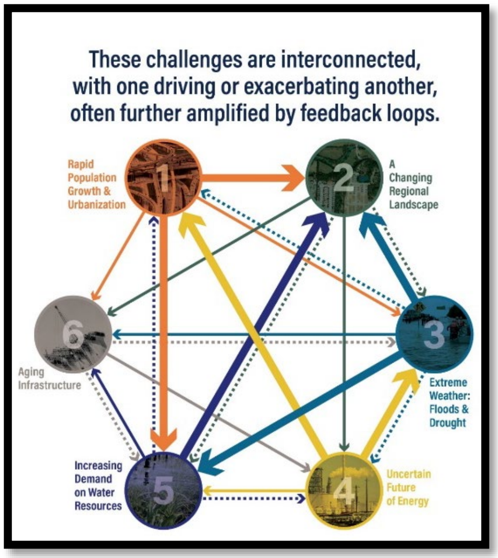
The American Society of Civil Engineers' (ASCE) 2017 infrastructure report card highlights issues endemic to the region, such as the prevalence of high hazard dams lacking regular maintenance and inspections, uncontrolled spillways, decreasing USACE funding for major flood reduction projects, inordinate timelines, and other challenges to planning, designing, and constructing new capital projects.[48] Inadequate maintenance heightens the threat of catastrophic downstream releases of stored flood water from critical infrastructure failure, an issue exacerbated by limited and decreasing flood storage capacity at reservoirs due to sediment accumulation as well as worsening degradation from heavy rainfall stress and downstream sedimentation.[49]

Lack of regular maintenance for sedimentation also limits the water available in reservoirs for Water Supply and Hydropower, and significantly impacts channel depth and width at inland waterways and ports. Aging navigation infrastructure, coupled with maintenance backlogs, also present a major challenge for the future viability of navigable waterways. Inconsistent maintenance at many ports and locks often lead to unscheduled outages, significant delays, and difficulties in adequately meeting traffic demand.[50]

Finally, recreational facilities such as boat launches, marinas, campground facilities, roads, parking lots, and other structures under the management of the Recreation Mission Area are degrading, threatening the continued vitality of the recreation and ecotourism industries.[51]

Medina et al (2019).
[45] USACE Institute for Water Resources (2016).
[46] USACE Institute for Water Resources (2016).
[47] USACE Institute for Water Resources (2016).
[48] American Society of Civil Engineers. 2017b. *Report Card for Texas' Infrastructure*. Available online at: https://www.texasce.org/wp-content/uploads/2018/11/FullReport-TX_2017.pdf. Accessed on September 10, 2020.
[49] U.S. Global Change Research Program (2017b).
USACE Institute for Water Resources (2016).
Medina et al (2019).
[50] American Society of Civil Engineers. 2017a. *2017 Infrastructure Report Card: Inland Waterways*. Available online at: https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Inland-Waterways-Final.pdf. Accessed on September 10, 2020.
[51] USACE and the Bureau of Reclamation. 2019. *State of the Infrastructure.* Available online at: https://www.usbr.gov/infrastructure/docs/jointinfrastructurereport.pdf. Accessed on September 10, 2020.

2.7 Complex Reginal Challenges



Significantly, the six drivers outlined in the previous sections are interconnected, with one driving or exacerbating another, often further amplified by positive feedback loops. For example, increasingly extreme weather plays a large role in driving changes to the regional landscape, especially in its impacts to habitats and biological communities that are sensitive to drought and flooding. As these habitats change and in some cases disappear, various processes ensue that further exacerbate the hazards posed by extreme weather, such as disappearance of natural storm barriers and impacts of erosion and invasive species on water infrastructure—especially when combined with other changes to the natural landscape driven by urbanization. As such, these six drivers should not be considered independent of one another, but as part of one and the same unfolding process, integral with USACE Water Supply, Navigation, Flood Risk Management, Hydropower, Environmental Stewardship, and Recreation activities.

Table 1: Drivers Impacts to Civil Works Business Lines

Driver	Water Supply	Navigation	Flood Risk Management	Coastal Storm Risk Management	Hydropower	Environmental Restoration	Recreation
1. Rapid Population Growth and Urbanization	Increased demand for water, in addition to food and energy production which rely on water availability.	Increased demand for natural resources driving increased demand for navigable waterways, channel deepening, and larger, more efficient vessels in international shipping to coastal ports.	Increased exposure to extreme rainfall and flooding, particularly socially vulnerable populations.	Increased exposure to coastal storm surge and tidal flooding, particularly socially vulnerable populations.	Increased demand for energy production with growing demand for renewables, including increased reliance on hydropower for stability.	Landscape-level impacts of urbanization-driven LULC.	Increased demand for outdoor and water-related recreational opportunities.
2. A Changing Regional Landscape	Impacts to water quality, local water balance, and groundwater.	Impacts to channel morphology and infrastructure operations.	Increased flood discharge peak and volume rates as well as debris hazard.	Beach erosion and sea level rise cause coastal habitats to disappear. This also eliminates natural coastal protection to storm surge.	Impacts to natural hydrology and channel morphology.	Pressures on natural resource boundaries, habitats, biodiversity, and ecosystem health.	Declining biodiversity and ecosystem health in waterways potentially leading to decrease in recreational use.
3. Extreme Weather: Floods & Droughts	Drought impacts to water levels and quality. Flooding straining reservoir storage capacity.	Drought impacts to water levels. Increased exposure of navigation infrastructure and port terminals to flood risk, especially storm surge. Extreme storm impacts to channel conditions and vessel restrictions.	Increased demand for more structural and nonstructural flood mitigation measures, and increased strain on existing flood control infrastructure.	Increased risk of coastal storm surge and tidal flooding.	Drought impacts to water levels, straining competing resource demands. Dependence on hydropower for power and first responder radio communications during major storm events.	Impacts to water quality, salinity levels, water temperatures, sedimentation, and invasive species—threating ecosystem health and habitats.	Increased exposure of recreation infrastructure to flood risk.
4. Uncertain Future of Energy	Increasing global demand for energy increases water demand for energy production purposes.	Larger channels may be needed to meet demand for energy exports. Ports serving as hubs of energy production at risk of extreme storm surge.	n/a	Extreme storm surge threatens 40% of national petroleum and natural gas refining capacity and port infrastructure for exports in Texas.	Increases in global demand for renewable energy sources could lead to increased demand for hydropower.	Pollution and other environmental impacts from continued reliance on hydraulic fracturing and fossil fuel extraction to meet growing demand.	n/a
5. Increasing Demand on Water Resources	Pressure to reallocate water storage at multi-purpose reservoirs to meet water supply demand.	Low water levels can interrupt shipping and waterborne commerce.	Pressure to reallocate water storage at multi-purpose reservoirs to water supply, while flood storage threatened by reduced reservoir capacity.		Low water levels can interrupt hydropower generation. Pressure to reallocate water storage at multi-purpose reservoirs to water supply.	Trade-offs in freshwater flows which moderate salinities and temperature and provide crucial nutrients.	Trade-offs in freshwater flows which support a variety of habitats.
6. Aging Infrastructure	Most dams more than 50 years old. Dam safety is an issue.	Aging navigation infrastructure and O&M, including channel depths, lack capacity or redundancy to meet growing demand.	Aging dams, levees, and flood control structures with outdated policies, levels of protection, and planning life. Dam/levee safety is an issue.	Aging levees and flood control structures with outdated policies, levels of protection, and planning life. Levee safety is an issue.	Most dams more than 50 years. Dam safety is an issue.	Aging levees and associated facilities require maintenance or upgrades to minimize impacts to the environment.	Degrading facilities. Many recreation-related facilities constructed 50-70 years ago. Need for routine O&M.

3.0 Future Scenarios Summary

The interconnected regional risks and opportunities identified in the previous chapter provide a baseline understanding of trends that may drive future demand for water resources in the region over the coming decades. However, the future is inherently uncertain, and the high degree of interdependence and volatility within each of regional drivers of Civil Works demand only adds to this uncertainty. Addressing the uncertainties of the future requires a planning process that lays the groundwork for identifying and implementing flexible and adaptable response strategies that lead to positive outcomes across a range of potential futures. In doing so, SWD can identify gaps that must be filled to enable positive outcomes regardless of what the future specifically holds. Doing so requires understanding the key uncertainties associated with important drivers of Civil Works (CW) demand and linking them to actions SWD and its Districts can take now to build capacity, update policies and procedures, and improve ope0072ations to meet the challenges the region will face in the future. A scenario planning process was utilized in CWSP development to address these uncertainties and inform the building blocks and strategic actions that will help lead to positive outcomes in 2035 and beyond. While not intended to predict the future, scenario planning provides USACE with a structure to support clear communication and decision making on the possible choices and outcomes for CW in the face of future of uncertainty.

Three focused scenario themes were selected based on identifying drivers that have substantial potential impact on the SWD Civil Works Program and are also associated with significant uncertainty in future trends. Each theme includes a set of four scenarios capturing the range of future outcomes considering both the uncertainty in the underlying drivers and the potential strategies USACE could take to influence those outcomes. In addition, a set of overarching scenarios was developed to broadly connect trends in drivers with regional impacts and the potential strategies SWD can take to right-size capacity for the future. This final set of scenarios builds on the focused themes and captures the complex interconnectivity among drivers, uncertainties, direct USACE action, and partner involvement across the landscape of water resource management issues. These scenarios explore the feedbacks between, for example, population growth, increase in impervious surface land cover, changing weather patterns, flood risk, and water supply. In doing so, they illustrate the overarching potential and benefits of Integrated Water Resource Management (IWRM) and the most likely paths to SWD providing maximum value to the Nation through both direct USACE action and partnering opportunities.

3.1 Scenario 1: Future Population Growth & Water Supply

The region has been experiencing rapid population growth and diversification throughout its jurisdiction. The Dallas-Fort Worth metropolitan area exhibited the largest growth in population in the nation between 2010-2019 and was closely followed by the Houston metropolitan area, which exhibited the second highest increases during this period. This population growth is expected to continue, with Texas projected to have the highest growth rate in the nation through 2040. Other urban areas in the region, such as northwest Arkansas, are also experiencing rapid rates of growth, and the region at large is experiencing an increasing pattern of rural to urban migration. As these growth trends continue and accelerate, there is an increasing demand for water supply and strain on the region's water resources to meet these needs. In Texas alone, municipal water use as a percentage of overall water use is projected to increase to 41% by 2060, from 9% in 2010. SWD faces significant and growing challenges in balancing water supply demand and allocations to meet the growing demand for other uses. This challenge is further exacerbated as the Division's aging infrastructure is increasingly unable to cope with current climate variability impacts and development-driven increases in flood risk.

The drivers of water supply demand include a complex equation of industry and population growth, coupled with the impacts of local policy and planning actions aimed at managing development and conserving water resources. Focusing purely on the first part of the equation risks exacerbating further unchecked development and water use by industrial, commercial, and residential users in the region. While USACE authority in addressing water supply challenges is limited, partner response opportunities may be able to more broadly address issues related to water supply demand. Opportunities for a more comprehensive approach to managing regional capacity may be enabled through partnering, such as coordinating water use across all USACE and non-USACE reservoirs in the state and expanding the distribution of safe potable water to vulnerable areas that will be most impacted by scarcity. This scenario also exposes the importance of planning holistically for water supply together with flood risk management. With more extreme flooding and drought anticipated in the future, demands on both functions will increase and trade-offs between the two will need to be more closely and dynamically managed. Additionally, efforts like sediment management can maximize reservoir storage capacity during periods of droughts. While this scenario is focused on the Water Supply Mission Area, a similar set of strategic implications exists for a set of scenarios focused on Flood Risk Management in combination with growth and development. Reducing future flood risk in the region requires a combination of smarter land use practices as well as investments in existing and new Civil Works. As is the case with this set of scenarios related to water supply, there is a need for coordinated management of local, state, and federal tools to address regional flood risk comprehensively.

3.2 Scenario 2: Future of Energy

The future of global energy and demand for oil and gas resources from America's Energy Coast is highly uncertain and potentially volatile over time. Simultaneously, population growth, combined with increases in average temperatures, drive increasing need for energy production. Questions of long-term sustainability of fossil fuel-driven energy production may lead to shifts in global demand for oil and gas resources. Strained natural resources and vulnerability of infrastructure may also limit local supply. The energy sector is key to the strategic importance of the region. The value to the Nation provided by SWD's Navigation projects, especially those along the Texas coast, is closely tied to the oil and gas economy. Volatility or long-term decline in oil exports from the Texas coast—whether due to an economic recession, damage to local infrastructure, or a transition of global demand towards renewable energy sources—not only will have significant impacts on the regional economy, but will also have national impacts. Volatility and uncertainty are inherent within the energy economy that drives much of the navigation demand in coastal Texas. Adaptability is key to increasing USACE responsiveness to industry demand to ensure that resources are directed in a timely manner where they are needed most. Additionally, this area has a potential competitive advantage as a hub for renewable energy production. Parts of the region's geography may be well suited for solar and wind energy, and hydropower supply at SWD reservoirs may see a corresponding increase in importance. This may include exports of materials/machinery for renewable energy production; for example, wind energy materials production has been rising in Texas in recent years.

3.3 Scenario 3: Future Extreme Weather Variability

Recent and projected increases in frequency and intensity of droughts, extreme precipitation and coastal flooding events severely stress aging infrastructure and present Mission Area tradeoffs for Integrated Water Resource Management. Population growth and development trends compound this challenge by driving increasing multi-purpose demand for water and contribute to increasing flood and drought risk within the region.

The region has experienced major extreme weather events, both droughts and floods, in the past decade. While the science on climate trends points towards more frequent and intense floods and droughts in the future, the next decade may not be as extreme as the last for the region. There will always be periods of surge and of wane. A proactive response mode is key. However, the USACE role has historically been to respond to disasters as they occur. This role is reflected throughout the organization, including in the emphasis on economic benefit in project prioritization (vs. risk mitigation) and a funding model where resources often do not flow until after a disaster occurs. While this approach may be relatively successful in supporting communities in responding to isolated storms or droughts, it will leave SWD unprepared to support the region under scenarios where the frequency and severity of major extreme weather events increases. In those cases, the cumulative value of pre-disaster investment to mitigate the economic impact of future events increases considerably. In addition, failure to adequately account for risk to human life and other social impacts can result in significant loss in the region under increasing frequency or severity of extreme weather.

The unpredictability and potential for high variability in extreme weather and the impacts of droughts and floods across CW Mission Areas requires an integrated approach to water resources management. Further operationalizing IWRM as a central approach will position SWD to manage impacts and tradeoffs across Mission Areas, projects, and regions. As highlighted in the water supply and development scenarios, a comprehensive approach to hazard mitigation and adaptation in coordination with local, state, and federal partners is also key. There is a complex interplay of extreme weather trends and population and land use trends, such as the feedback loop between impervious surfaces and their impacts on flood risk and extreme heat. The tools and actions of partners must be coordinated closely with those of USACE.

3.4 Overarching Future Scenarios

A rapidly changing world means several possible futures for SWD in 2035. Analysis of the key trends, drivers, and external uncertainties allow for identification of more likely eventualities, inform the choices SWD can make to influence these futures, and facilitate the development of response opportunities to ensure the Division and Districts can meet future conditions and pivot quickly as needed. SWD's ability to continually analyze and, when possible, right-size capacity is critical to meeting future conditions and changing demand. Moreover, its ability to monitor and analyze changing data is vital to ensuring the Division can proactively realign the CW Program with the most probable emerging future(s) and acute risks that may cause rapid change.

3.4.1 **Tumbleweeds**

In this future, external drivers have combined to reduce demand for Civil Works and existing capacity is appropriately scaled for this period of reduced need. However, this capacity is maintained with limited flexibility and adaptability to significant changes in trends and conditions that may affect Civil Works. This leaves SWD unable to adequately and effectively meet surges in demand or shifts in need and with limited options for responding to change in the absence of significant investment to increase capacity. Potential factors driving reduced demand could include declining populations and economic contraction over time, major shifts in energy sectors that may alter the regional economic landscape and associated funding for civil works for SWD and regional partners, or prolonged periods of reduced extremes in weather variability and catastrophic natural disasters. Moreover, the limited investment in Civil Works capacity is perpetuated by reductions in available funding, and capacity may start to further decline as a result. In this future scenario, SWD is in a reactive mode and is less prepared to adapt to shifts in demand or need, leaving the region is increasingly vulnerable to catastrophic events and the emerging threats of an uncertain and likely volatile future.

3.4.2 Southwestern Crossroads

In this future, the region continues to experience economic and population growth, and high demand for Civil Works. However, while demand has grown, SWD has seen limited growth in Civil Works investments, with few new starts and limited resources for ongoing operations and maintenance. As a result, the Division faces ever-increasing challenges to maintain level of service while managing tradeoffs in water resources uses and allocations to meet the demands of a growing region. Furthermore, aging SWD infrastructure is increasingly vulnerable to elevated risks from natural hazards and extreme weather variability, and the region as a whole is extremely vulnerable to widespread economic disruption from catastrophic events (e.g. hurricanes) as capacity to meet changing conditions is stagnant or in decline. In addition, limited investment in water resources infrastructure means SWD is not adequately positioned to proactively and efficiently adapt operations to changing trends or respond to rapid change—resulting in a Division that is ill-prepared to execute the USACE Mission and risks losing credibility in the region. However, the growing demand for Civil Works in the region due to continued growth and/or catastrophic hazards combined with the clear gap in capacity to meet that demand may attract a surge of resources to SWD (for example, in the form of post-disaster grants). In this scenario, short-term solutions may allow the Division to temporarily cope with conditions in the future, potentially masking a long-term trend of a gap between Civil Works demand and capacity. A threshold may also exist where lack of effective capitalization on these short-term investments may compromise the SWD's ability to execute the USACE Mission in the region. Insufficient USACE capacity can negatively impact the region's resilience in a future of elevated risks and uncertainties, thereby threatening the economic prosperity that is a major driver of demand for Civil Works in the region and reducing the pool of potential local sponsors for projects.

3.4.3 Controlled Release

In this future, SWD has invested in increasing Civil Works capacity to meet and adapt to changes in risk, trends, and drivers and to prepare for an uncertain future. The region and its stakeholders have invested in capacity to mitigate and adapt to risk from natural hazards and extreme weather variability through advancements in planning, land use, infrastructure, and partnerships. Regional drivers and trends have combined to lower demand for Civil Works with possible factors including population and economic contraction, major shifts in energy sectors affecting the regional economic landscape, prolonged periods of reduced extremes in weather variability/catastrophic natural disasters, or restoration of natural systems and advancements in land use and water management practices. Adaptability is a key component to a successful future under this scenario, wherein a nimble and proactive SWD is: prepared to effectively manage tradeoffs for water resources uses and allocations; well positioned to analyze trends and drivers and use that information to prepare for changes in demand; and enabled with a broader range of future responses to potential surges in demand. Prolonged periods of reduced Civil Works demand may result in the potential for SWD to be over-built and over-resourced. However, as the Division is highly adaptable to changing conditions and shifts in need, it allows SWD to proactively right-size resources and, in a controlled manner during times of surge, redirect them appropriately within the region and potentially beyond as conditions change. This future presents a potential feedback loop where SWD is positioned as a center of expertise and innovation that supports Integrated Water Resources Management at the national level.

3.4.4 **A Resilient Southwestern Region**

A prosperous region and growing population drives increased regional demand for water resource infrastructure, which is efficiently met by a robust SWD providing maximum value to the Nation (see Figure 22). While development and growth continue across the region in urban and suburban centers especially, the region and its stakeholders—benefitting from streamlined processes that strengthen collaboration with USACE—have invested in their capacity to mitigate and adapt to growing risk from natural hazards through advancements in planning, land use, infrastructure, and partnerships. SWD has increased Civil Works capacity to meet growing demand; nimbly and proactively adjust to changes in regional drivers and trends; better manage tradeoffs for water resources uses and allocations; and better withstand and respond to elevated risk from natural hazards and extreme whether variability. As a result, the region's collective resilience to heightened risk and volatility provides a potential feedback loop that contributes to investor and public confidence and desirability, that in-turn continues driving regional economic growth and ultimately increasing demand for IWRM. SWD's capacity and adaptability to future volatility require proactive planning and continuous evaluation to ensure appropriate capacity exists to maintain level of service as conditions and demand change. As risks grow in this future, the region and SWD are better prepared and more resilient yet remain vulnerable to impacts from catastrophic hazard events, economic volatility and changing macroeconomic conditions, and other possible threats associated with a volatile future. For example, while risks from extreme weather variability are projected to grow, the region may experience prolonged periods of drought and periods of increased precipitation and flooding, or it may experience accelerated or volatile shifts between these extreme weather events. To address this uncertainty, SWD balances the development of core internal capacity with flexible use of external resources so that it is right-sized for both surges and lulls. The Division must also be prepared under this scenario to be more proactive in times of reduced volatility while shifting to response mode as needed during intense increases in demand.

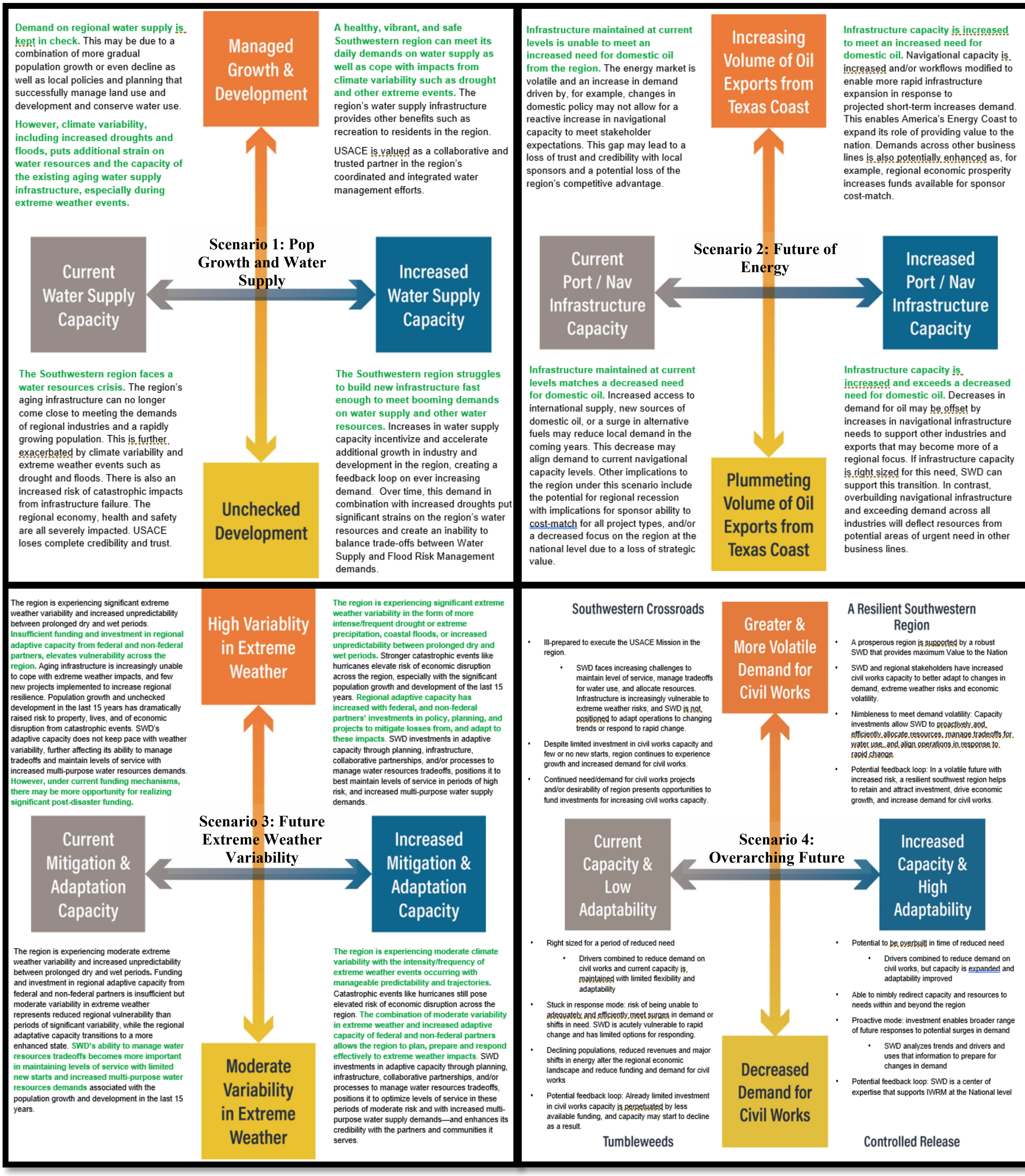


Figure 3: Scenario Summaries

4.0 Framework for Action

This strategy map builds on the action opportunities identified in the scenario planning exercises to address the key drivers of future risk and demand for Civil Works in the region, as well as the inherent uncertainties within them. The Goals and Objectives were developed by pairing the analysis on future trends with strengths, weaknesses, opportunities, and threats identified through a series of interviews with USACE staff and leadership at SWD, SWG, SWF, SWT, and SWL as well as meetings with local partners and stakeholders at each District. Central to this vision and framework for action is a focus on Integrated Water Resources Management (IWRM). Operationalizing IWRM requires an integrated approach to project development, organizational processes and procedures, and partnership building.

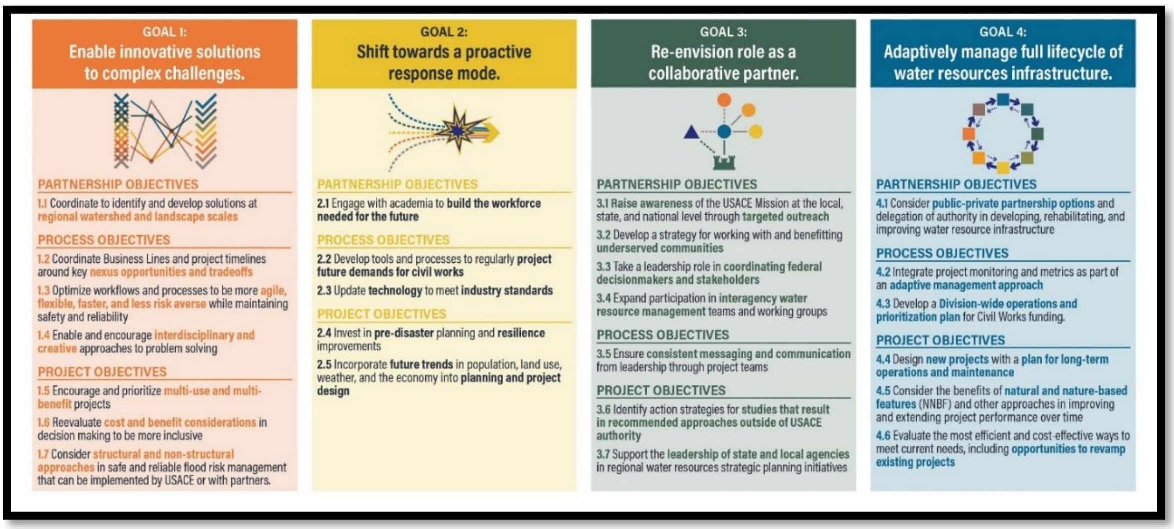


Figure 4:Strategic Goals and Objectives

5.0 Implementation Strategy

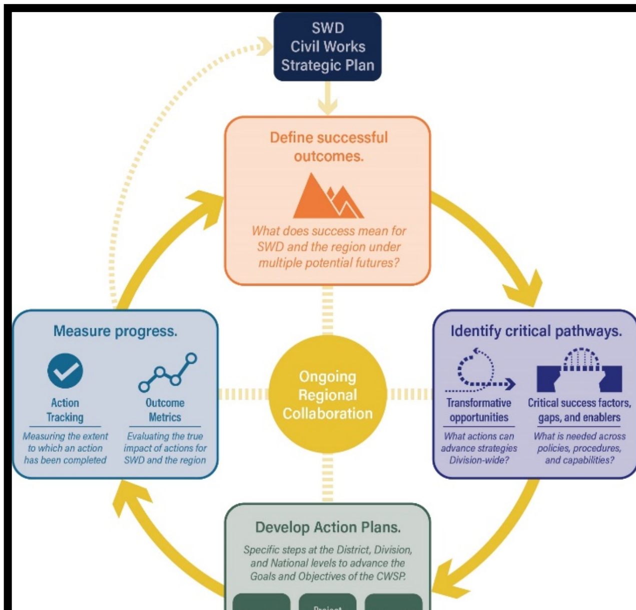


Figure 5: SWD CWSP Non-Linear Approach to Implementation Planning

This CWSP was intentionally developed with a strong focus on being quickly and easily transitioned into implementation, with the CWSP sections designed to facilitate action plan development and the advancement of IWRM principles throughout the Division and beyond. SWD set forth on a deliberate approach to enable implementation planning steps that will result in a CWSP that achieves implementation through action, is adaptable to future uncertainties, promotes accountability, and is focused on maximizing the probability of positive outcomes for the Division, its Districts, and those it serves.

To help in achieving these results, a new approach to implementation planning is needed—one that is outcome-driven, focuses on truly holistic and coordinated approaches to IWRM across Division Missions and Business Lines, and addresses the complex and sometimes competing interests and priorities involved with managing these resources and helping to meet the needs of partners and stakeholders throughout SWD. This approach to implementation requires thinking and acting outside of a traditional linear format—revisiting Goals and Objectives as conditions change or additional gaps and enablers are identified. This non-linear approach is more complex to manage and assess but is more responsive to changing conditions (see Figure 4).

Defining Successful Outcomes. The process of implementation planning in SWD will begin with a broad focus—envisioning and defining what success looks like for USACE and the region under multiple future scenarios, and what positive outcomes may indicate that implementation of the CWSP has been successful and continues to be successful.

Developing Tactical Action Plans. These components will be synthesized and used to develop a prioritized set of tactical actions that outline specific steps to advance the Goals and Objectives of the CWSP. Action Plans will be developed at the Division and District levels and may include recommended actions at the USACE HQ level.

Ongoing Regional Coordination. Successful implementation of the CWSP will require an integrated approach across every aspect of the CW Program—at the project, Mission Area, District, and Division-wide scales. The Division will foster and facilitate regular forums for engagement and collaboration across Districts, Mission Areas, and Business Lines to support the holistic development and implementation of Action Plans across policies, processes, projects, and partnerships.

Measuring Progress. Tracking progress in implementing the CWSP is critical to maintaining SWD credibility and maximizing support for the CW program from the public, external partners, and across USACE. In addition, tracking progress enables SWD to adaptively manage the implementation of the CWSP itself, refining and advancing response plans as needed based on their effectiveness in advancing Goals and Objectives. The focus must remain on evaluating the true impact of actions on catalyzing positive outcomes for SWD and the region it serves through advancement of the strategic Goals and Objectives of the CWSP.