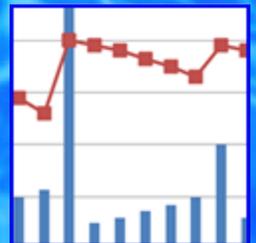


Best Practices in Asset Management

2013-R-08



ABSTRACT

The U.S. Army Corps of Engineers (USACE or Corps) serves the Armed Forces and the nation by providing vital engineering services and capabilities in support of national interests. With environmental sustainability as a guiding principle, the Corps is working diligently to strengthen our nation's security by building and maintaining America's infrastructure and providing military facilities where our service members train, work and live.

The USACE is the steward of the fourth largest asset portfolio, by monetary value, of all federal agencies. USACE is responsible for almost a quarter trillion dollars (i.e., plant replacement value) worth of the nation's water resources assets. Water resource development activities, including flood risk management, navigation, recreation, environmental stewardship and emergency response, are a core part of USACE Civil Works programs. These programs are responsible for the Civil Works activities of eight engineering divisions and 38 districts nationwide, employing 294 officers and 23,033 civilian employees who operate and maintain civil infrastructure with a replacement value of \$250 billion. The infrastructure portfolio includes more than 693 dams, 4,254 recreation areas, over 12,000 miles of commercial inland waterways, and approximately 926 harbors.

The wide range of Corps assets consisting mainly of water resources infrastructure, and the varied levels of ownership and responsibility add complexity to the task of managing water infrastructure assets. The Corps' infrastructure portfolio includes massive structures such as bridges; locks and dams; reservoirs; levees and buildings; hydropower production facilities--penstocks and turbines; and other equipment such as boats and dredges. In addition, the Corps owns or controls landscape features including recreational sites channels, ports and harbors. This large, complex mix of infrastructure creates a high degree of diversity, leading to scenarios where recreation sites, which provide highly visible benefits to few campers, compete for asset management attention with large dams, which provide almost unseen benefits to many.

Another complicating factor is that the Corps does not own or control all water resources infrastructure. The Corps coordinates with other federal and non-federal asset owners. In addition, under public law 84-99, the Corps has defined responsibilities for infrastructure that was built by the Corps and turned over to others, as well as for qualifying infrastructure constructed by others. Mainly, the Corps is responsible for restoring this infrastructure following an extreme event. This restoration activity competes with other assets for management attention and budgetary resources. Typically, restoration is funded by borrowing budgetary resources planned for other infrastructure. This "loan" is later repaid from supplemental appropriations. This complexity makes management of the Corps infrastructure much more difficult than most organizations' infrastructure management and challenges.

The intent of this effort is to evaluate all available sources of information regarding asset management practices, including those from other agencies in the United States and international agencies, and locate candidates of best practices in asset management that could be adapted for use by the USACE.

This report was prepared by Woolpert on behalf of the Institute for Water Resources (IWR).

ACKNOWLEDGEMENTS

The study was conducted by Principal Investigator John Przybyla, Woolpert, Inc. senior vice president. The document has been through eight drafts and was reviewed by nearly 20 individuals, whose help was invaluable in improving the final product. The review team includes the following individuals in no particular order:

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INTRODUCTION

BACKGROUND

The U.S. Army Corps of Engineers (USACE or Corps) serves the Armed Forces and the nation by providing vital engineering services and capabilities in support of national interests. With environmental sustainability as a guiding principle, the Corps is working diligently to strengthen our nation's security by building and maintaining America's infrastructure and providing military facilities where our service members train, work and live.

The USACE is the steward of the fourth largest asset portfolio, by monetary value, of all federal agencies. USACE is responsible for almost a quarter trillion dollars (i.e., plant replacement value) worth of the nation's water resources assets. Water resource development activities, including flood risk management, navigation, recreation, environmental stewardship and emergency response, are a core part of USACE Civil Works programs. These programs are responsible for the Civil Works activities of eight engineering divisions and 38 districts nationwide, employing 294 officers and 23,033 civilian employees who operate and maintain civil infrastructure with a replacement value of \$250 billion. The infrastructure portfolio includes more than 693 dams, 4,254 recreation areas, over 12,000 miles of commercial inland waterways, and approximately 926 harbors.

The wide range of USACE assets consisting mainly of water resources infrastructure, and the varied levels of ownership and responsibility add complexity to the task of managing water infrastructure assets. The USACE's infrastructure portfolio includes massive structures such as bridges; locks and dams; reservoirs; levees and buildings; hydropower production facilities--penstocks and turbines; and other equipment such as boats and dredges. In addition, the USACE owns or controls landscape features including recreational sites channels, ports and harbors. This large, complex mix of infrastructure creates a high degree of diversity, leading to scenarios where recreation sites, which provide highly visible benefits to few campers, compete for asset management attention with large dams, which provide almost unseen benefits to many.

Another complicating factor is that the USACE does not own or control all water resources infrastructure. The USACE coordinates with other federal and non-federal asset owners. In addition, under public law 84-99, the USACE has defined responsibilities for infrastructure that was built by the USACE and turned over to others, as well as for qualifying infrastructure constructed by others. Mainly, the USACE is responsible for restoring this infrastructure following an extreme event. This restoration activity competes with other assets for management attention and budgetary resources. Typically, restoration is funded by borrowing budgetary resources planned for other infrastructure. This "loan" is later repaid from supplemental appropriations. This complexity makes management of the USACE infrastructure much more difficult than most organizations' infrastructure management and challenges.

DRIVING FORCES

The current USACE Civil Works infrastructure represents a substantial investment of the nation's resources and delivers daily benefits to almost every U.S. household, ranging from water-borne transportation to hydroelectric power, and recreational opportunities to flood protection. As the infrastructure USACE operates ages, it often becomes more difficult and more expensive to maintain to meet performance goals, and to efficiently provide the economic and environmental benefits for which they were designed and constructed. Conversely, the annual federal budget for the USACE Civil Works funding has been flat or falling for a number of years, and the operations and maintenance portion of that budget is not adequate to maintain the current infrastructure over time. Given the current economic climate, significant additional funding is not expected from the U.S. government. This situation, left unchecked, will result in a loss of the integrity and operational capability of this infrastructure over time.

Because of the limited availability and inconsistency of funding for operations and maintenance, the USACE often defers maintenance from its planned (and optimal) time until funding is available. Over time, this results in an invisible, but insidious reduction of the ability of the infrastructure to support its mission. The result is a decrease of performance, increased incidence of operational outages, loss of revenue, and increased risk of catastrophic failure.

The USACE is now employing a multi-pronged approach to continue to enable the citizens of the U.S. to receive benefits from these investments. This approach includes:

- Defining the concept of value to the nation (VTN) from each project in the USACE Civil Works infrastructure.
- Determining if local government, state, or private organizations might be better stewards of some assets.
- Utilizing a comprehensive, best-practices asset management approach to provide the most cost effective operations and maintenance of those assets that remain with the USACE.
- Determining which items must continue to be supported, and which, based on their value, may no longer be supported by the USACE.

The USACE Civil Works Strategic Plan for 2011-2015 addresses these needs through the USACE Initiative for Sustainable Water Resources Infrastructure. Specifically, Theme 1, Lifecycle Infrastructure Management, incorporates multiple sub-themes which are relevant to this report, including one that is specific to asset management.

The USACE understands that when fully implemented, asset management must provide the means to maintain performance and meet the needs of the users of its asset portfolio at an optimized and sustainable overall cost. This document is focused on maximizing the potential for asset management practices to fulfill needs and designed purposes.

PURPOSE

The intent of this effort is to evaluate all available sources of information regarding asset management practices, including those from other agencies in the United States and international agencies, and locating candidates of best practices in asset management that could be adapted for use by the USACE.

The goals of this effort include the following:

- Review asset management practices.
- Identify best practices in asset management.
- Inventory computer-based tools for asset management.
- Compare USACE asset management approach to best practices.
- Determine if suitable alternate strategies exist.
- Develop recommendations for next steps.

ASSET MANAGEMENT DEFINITION AND VISION

Asset management has many potential definitions. USACE defines asset management in the Program Management Plan for Asset Management as the following:

Fundamentally, asset management is a disciplined corporate approach for the management of the USACE asset portfolio. It requires integration and collaboration with all corporate organizations and programs, and their respective activities and contributions¹.

The USACE defines its vision for asset management as the following:

A persistent catalyst for holistically integrating and enhancing the sustainment, restoration, modernization and disposition of USACE water resources [assets] to continually serve the nation.²

This document concurs with both the definition and vision of asset management as defined by the USACE.

ASSET MANAGEMENT SOURCE REVIEW

SOURCES INVESTIGATED

A literature search was conducted to locate sources of information on best practices in asset management worldwide. The investigation was conducted primarily through the Internet, although much of the research involved following up on references to items initially located on the web. Research was limited to organizations that managed at least one of the types of assets USACE manages. During the investigation, it became obvious that some of the best practices in asset management have come from professional organizations, so the research was expanded to include the relevant organizations. The organizations selected for research included ten U.S. federal agencies, seven U.S. professional organizations, 13 international professional organizations, eight international government agencies and six software products. For each source, the following information was captured:

- Relevant asset types included.
- Documented asset management process.
- Elements included in the asset management approach.
- Maturity/sophistication of asset management.
- Applicability to USACE infrastructure types.

The organizations selected for evaluation are as follows:

U.S. FEDERAL AGENCIES

- U.S. Coast Guard (Department of Homeland Security [DHS])
- U.S. Navy (Defense Department [DoD])
- Bureau of Land Management (Department of the Interior [DOI])
- Bureau of Reclamation (DOI)
- National Park Service (DOI)
- Federal Highway Administration (Department of Transportation [DOT])
- Department of Energy (DoE)
- Environmental Protection Agency (EPA)
- General Services Agency (GSA)
- National Aeronautics and Space Administration (NASA)
- Tennessee Valley Authority

INTERNATIONAL GOVERNMENT AGENCIES

- St. Lawrence Seaway Management Corporation
- British Waterways
- Federal Ministry of Transport (Germany)
- Ministry of Infrastructure and Environment (Netherlands)
- Waterways and Sea (Belgium)
- Infrastructure Australia
- Institute of Water Resources and Hydro Power Research (China)
- Public Works Research Institute (Japan)
- Korea Water Resources Corporation
- Infrastructure Canada

U.S. PROFESSIONAL ORGANIZATIONS

- Federal Facilities Council (FFC)
- American Public Works Association (APWA)
- National Association of Clean Water Agencies (NACWA)
- International Facility Managers Association (IFMA)
- Association of Physical Plant Administrators (APPA)
- New Mexico Environmental Finance Center
- Maryland Center for Environmental Training

INTERNATIONAL PROFESSIONAL ORGANIZATIONS

- World Association for Waterborne Transportation Infrastructure (PIANC)
- Institute of Asset Management (IAM)
- Institute for Sustainable Infrastructure (ISI)
- European Federation of National Maintenance Societies (EFNMS)
- Asset Management Council (Australia)
- Institute for Infrastructure Asset Management (IIAM)
- National Asset management Working Group (Canada)
- Asset Management Quarterly International (AMQI)
- International Organization for Standardization (ISO)
- Global Forum on Maintenance and Asset Management (Switzerland)
- Next Generation Infrastructures (Netherlands)
- Centre for Infrastructure Management (Canada)
- World Congress on Engineering and Asset Management (Australia)

SOFTWARE PRODUCTS

- BUILDER/ROOFER/MicroPAVER (USACE)
- Harfan
- RIVA
- SIMPLE (WERF)
- Envision (ISI)
- Infrastructure Optimization (Woolpert)

The results of the research are tabulated in a spreadsheet titled "Asset Management Source Review," which is provided in Appendix A.

KEY FINDINGS OF SOURCE REVIEW

UNITED STATES

Information regarding asset management programs of U.S. federal agencies showed that there was generally a high degree of similarity among U.S. federal agencies' asset management practices. This is due to many reasons, including the following:

- Many federal agencies began their asset management implementations in response to Executive Order 13327 (4 February 2004), and have remained focused on its requirements.
- Other than the USACE, few federal agencies manage facilities for primary use by others. Therefore, their requirements and expectations are more similar to each other than to the USACE.
- The Defense Department military branches all use a similar approach, which is somewhat less sophisticated than the current USACE Civil Works approach.
- Multiple agencies fall under the umbrella organization of the Department of the Interior (DOI), and DOI agencies generally have a consistent approach.

The focus of many federal agencies on the requirements of [EO 13327](#)³, which is centered on the desire to minimize acquisition and reduce holdings of real property, means that their programs have only limited applicability to the needs of the USACE. Implementation of EO 13327, which is performed by the Federal Real Property Council (FRPC) under the oversight of the General Services Agency (GSA), is by its very nature focused on land and facilities. While this EO is relevant to the USACE activities, it does not include specific methodology for addressing civil-type assets such as locks and dams that can fail if not properly maintained. Its requirements are only applicable as a baseline to the much more sophisticated requirements of the USACE.

The [Government Performance and Results Act](#)⁴ (GPRA), which was enacted in 1993, is designed to improve government project management. The GPRA requires agencies to engage in project management tasks such as setting goals, measuring results, and reporting their progress. In order to comply with the GPRA, agencies produce strategic plans, performance plans, and conduct gap analysis of projects. Although the GPRA was not focused on asset or real property management, it defined a series of implementation approaches that mimic those of asset management. The USACE has adopted both EO 13327 and GPRA, and has implemented a number of organizational changes as a result. Both the EO and GPRA guidance together provide elements that should be included in a comprehensive asset management program, but neither provides a complete template.

Based on the information available from the agencies investigated, two potential sources of asset management knowledge outside the Department of Defense (DoD) are the Bureau of Reclamation (Reclamation) and the National Park Service (NPS). While both have strong maintenance and asset management programs, neither appears to have implemented asset management in a more sophisticated manner than the USACE. In this case, neither is likely to provide much added guidance for improving USACE practices.

However, it is widely known that relatively sophisticated levels of asset management implementations abound in U.S. states (transportation assets) and larger municipal governments (transportation, water and sewer assets). While few of these agencies provide detailed implementation documentation, some, such as the Cities of Seattle, Washington and Columbus, Ohio reference sources from professional organizations as inspiration for their asset management programs. This will be discussed in greater detail below.

INTERNATIONAL

Although information was gathered from organizations that manage similar infrastructure from across northern Europe and the largest countries in Asia, there was very little detail on asset management

programs that was gleaned directly from the government sources. Instead, it was discovered that like many non-federal locations in the U.S., the agencies that implemented asset management used information developed by outside professional organizations as the foundation for their programs.

ASSET MANAGEMENT IN RESPONSE TO PUBLIC-PRIVATE PARTNERSHIPS

The strongest international asset management programs are in the countries in which the central government has made long-term funding for infrastructure asset management a top priority, and has promulgated requirements to both their federal and local public agencies. This was in response to the privatizing of formerly public utility systems and the need for government oversight to maintain long-term viability of these systems' infrastructure. Canada, Australia, New Zealand, and the United Kingdom have been leaders in this process. In all cases, this effort spurred the development of peer-developed best practices in asset management by professional organizations, which originated in these countries.

While many of the countries of Western Europe have implemented comprehensive asset management programs, for the most part, their programs are less sophisticated than those of USACE. This may, in part, be due to the fact that much of their infrastructure was built after World War II and has not required the level of attention of much of the infrastructure of the U.S.

PROFESSIONAL/PRIVATE ORGANIZATIONS

The best information regarding state-of-the-art practices in asset management comes from professional, or private sector, organizations. Based on evaluation of hundreds of documents from all of the agencies listed above, the following general sources of asset management thought leadership have been selected for in depth investigation:

- International Infrastructure Management Manual (Australia, New Zealand)
- Institute of Asset Management (British PAS-55)
- Delft University of Technology (Netherlands)

In addition, other sources of information on best practices in asset management have been evaluated based on specific asset types by the following organizations:

- National Association of Clean Water Agencies
- International Facility Management Association

SOFTWARE VENDORS

Many of the software vendors of products used for asset management developed publications with good insight into innovative practices in asset management. The GIS software vendor Esri is in the process of developing a book titled, *Best Practices for Building a Sustainable GIS and Asset Management Integration*, which is due to be published in late 2013.

SUMMARY

Through this exhaustive review of worldwide Asset Management practices, standards for best practices have emerged. The best practices are described in greater detail in the following section.

BEST PRACTICES IN ASSET MANAGEMENT

INTRODUCTION

At one time, the best practices in asset management were limited to designing/ constructing for the long-term, and performing effective preventative and corrective maintenance operations once assets were placed into service. Over time, the understanding of asset management has grown to be very sophisticated and developed into its own discipline.

As described above, the best practices in asset management are being employed today in Great Britain, Australia, New Zealand, and Canada. These best practices came about in reaction to the privatization of formerly public utilities that began 20 to 30 years ago. In order to protect the public's interest in the long-term maintenance of the infrastructure, the concept of optimizing lifecycle infrastructure asset costs was developed, and over time refined to the highest level of sophistication. The USACE is now entering a situation somewhat similar to the one that spawned some of these best practices.

After analyzing the worldwide sources for best practices in asset management, the following were selected as resources for knowledge:

- Overview of best practices: Institute of Asset Management PAS-55
- Best implementation details: International Infrastructure Management Manual (IIMM)
- Innovative Research: Delft University of Technology

Each of these will be discussed in detail below.

BEST PRACTICE STRATEGIES

INSTITUTE OF ASSET MANAGEMENT - PAS 55

The Institute for Asset Management (IAM) is the driving body behind the development of the British Standards Institute's [Publicly Available Standard 55](#) (PAS 55) for optimized management of physical assets.

PAS 55, which is asset-type independent, provides a 28 point specification for establishing and verifying an integrated whole-life management system for physical assets. It is mostly focused on developing the philosophy and framework to enable asset management, rather than the specifics of any individual asset management implementation.

PAS 55 defines asset management as the following:

*Systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks, and expenditures over their life cycles for the purposes of achieving its organizational strategic plan.*⁵

This definition is consistent with the USACE's definition of asset management. PAS 55 incorporates a complete set of principles as shown below in Figure 1.⁶

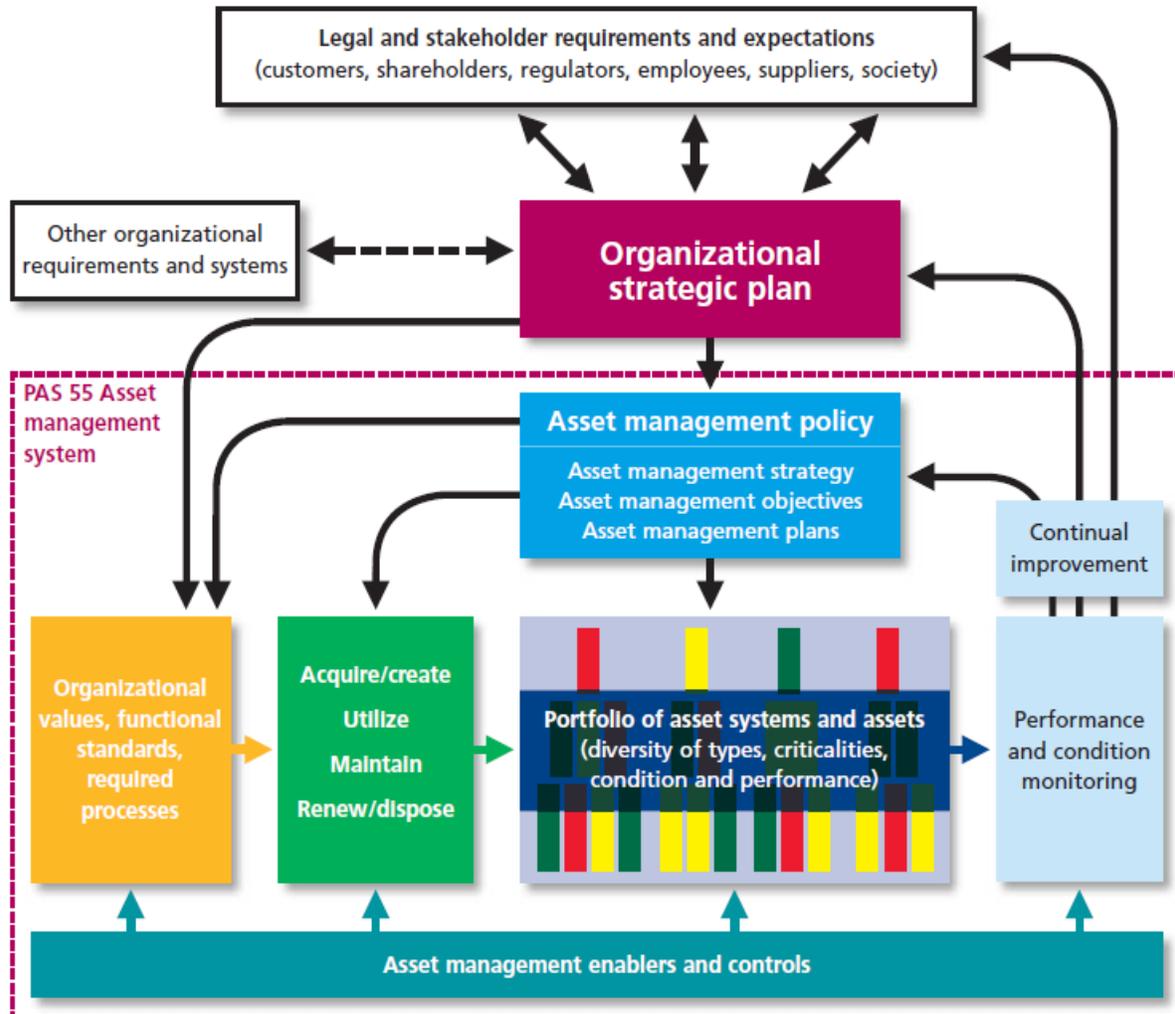


Figure 1: PAS 55 asset management system. Source: *The Institute of Asset Management*.⁷

PAS 55 is largely limited to describing principles of implementing asset management, rather than how to implement it for a specific asset type. As shown in the diagram, PASS-55 requires development of an asset management policy, which serves as the basis to develop organizational values, functional standards, and requires asset management processes for acquisition, utilization, maintenance and disposal of assets. PAS-55 also requires performance and condition monitoring so that continual improvements can be made to policies and procedures. As such, it provides a viable asset management implementation framework, but virtually no detailed implementation support.

The elements of PAS 55 are defined such that they correlate with the requirements of other commonly employed international organizational frameworks including International Organization for Standardization (ISO) 14000 (Environmental) and ISO 9000 (Quality Management). There is an active effort underway through the International Organization for Standardization (ISO) to develop three international standards for asset management; ISO 55000 (overview), ISO 55001 (Management systems) and ISO 55002 (Guidelines). These products, which will use the PAS 55, International Infrastructure Management Manual (IIMM), and other international methodologies, are expected to be published in 2014.

PAS 55 includes a methodology for assessment of asset management maturity. This methodology is often used by organizations to evaluate their progress toward implementation of the PAS-55 elements.

INTERNATIONAL INFRASTRUCTURE MANAGEMENT MANUAL

The [International Infrastructure Management Manual](#) (IIMM) was developed originally in 2000, and updated in 2002, 2006, and 2011. The original development was led by the New Zealand National Asset Management Steering (NAMS) Group and the Institute of Public Works Engineering of Australia (IPWEA). These organizations were spurred into action due to government regulations in both nations that required use of asset management principles to manage infrastructure. Over the years, this document gained worldwide use, and the more recent editions have included contributors from around the world, including Canada, South Africa, and the U.S. Today, it is commonly seen as one of the most authoritative sources of asset management knowledge. Its methodology is in use by hundreds of organizations worldwide, including those listed in Table 1 below:⁸

Organizations Using IIMM Asset Management Methodology	
Severn Trent Water (UK)	British Columbia Ministry of Transport (Canada)
United Utilities (UK)	Water Supplies Department, Hong Kong
Aberdeen Harbour Board (UK)	National Grid Transco (NZ)
British Columbia Hydro (Canada)	Province of Nova Scotia (Canada)
Network Rail (UK)	South African Department of Provincial and Local Government
London Underground (UK)	Infrastructure Canada
UK Highway Agency	Public Works and Government Services Canada
New Zealand Transport Agency	City of Portland, Oregon
Transpower NZ	Federal Highway Administration (US)
Gas Association of NZ	Seattle Public Utilities
NZ City and District Councils (all)	Seattle Department of Transportation
Various Australia City and District Councils (250+)	Orange County (CA) Sanitation District
Ports Australia	Tucson Water
Anglican Water (UK)	East Bay Municipal Utility District, CA
Ontario Provincial Government (Canada)	Milwaukee Metropolitan Sewerage District
Various Canadian City and District Councils (10+)	City of San Diego
Scottish Power	BC Transmission Corporation (Canada)
Scottish Water	CE Electric UK
National Grid (UK)	CLP Power (UK)
E.ON UK	City of Cape Town, South Africa

Table 1: Organizations using IIMM asset management methodology. Source: New Zealand Asset Management Support, "International Infrastructure Management Manual," (2001).⁹

IIMM FRAMEWORK

The IIMM provides a much greater level of detail than PAS-55 in defining best practices for asset management. As such, it provides a complete "cookbook" for the development and implementation of

a comprehensive asset management program. Any organization that implements the IIMM will by definition also satisfy the requirements of PAS 55 and, very likely, the upcoming ISO 55000 standard. The overall framework of asset management as defined in the IIMM includes the following components seen in Figure 2 below:¹⁰

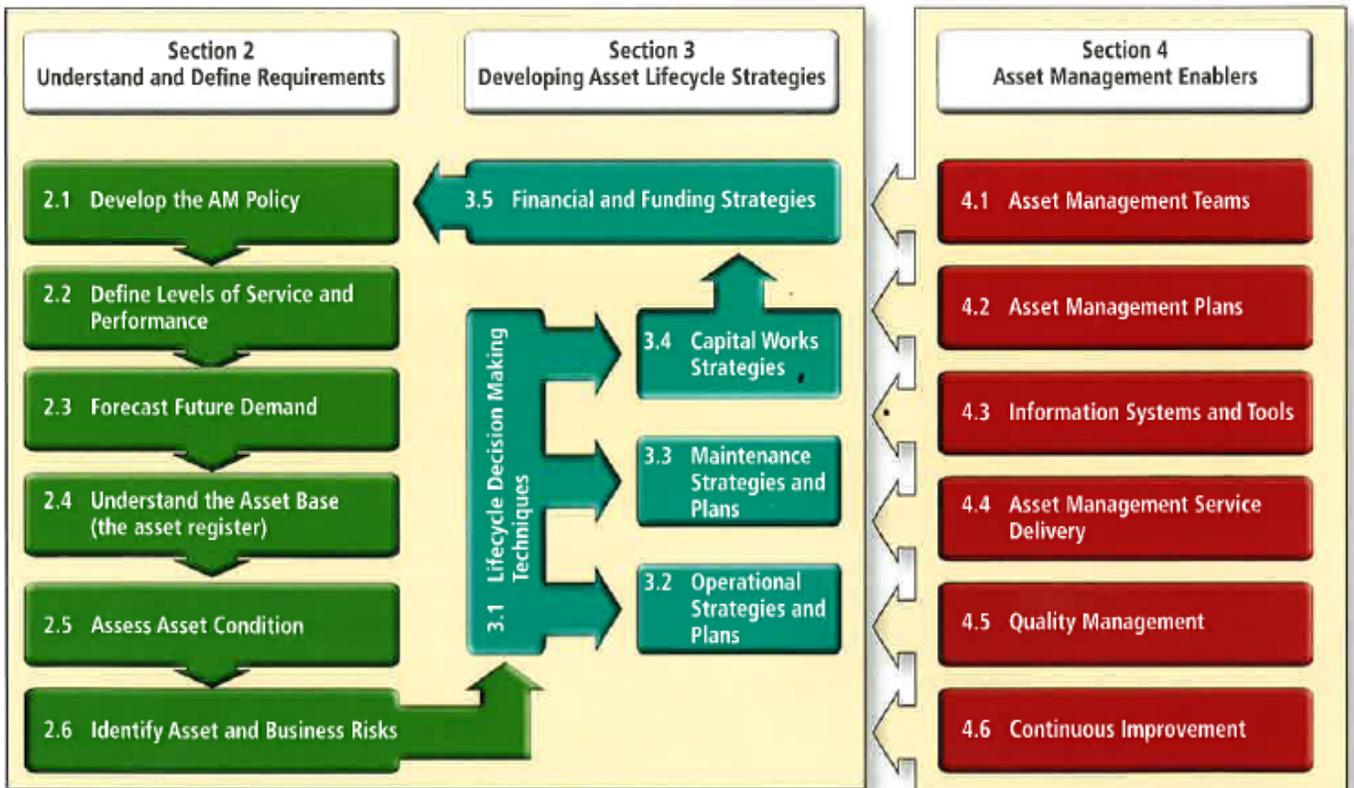


Figure 2: IIMM asset management framework. Source: New Zealand Asset Management Support.¹¹

The diagram shows three major sections of the IIMM method (Section 1 was the Introduction). The elements listed in Section 2 are the foundational elements of asset management that are needed as inputs to the decision making techniques and strategies shown in Section 3. Section 4 shows the operational plans, processes, and tools that must be in place to enable asset management to be successful according to the IIMM. While the full scope of the IIMM methodology is much too detailed to present here in full, some topics are presented in detail below.

DEFINING LEVELS OF SERVICE

A critical concept is that of defining levels of service. Defining an explicit level of service to be provided by an asset (or system of assets) allows an organization to understand that the goal of perfection is not expected or possible, and that acceptable, measurable goals need to be developed.

Levels of service are always defined based on the users of the service. For instance, they might be defined on the basis of percent of time that the service is available, number and duration of unplanned disruptions in service, compliance with environmental regulations, number of complaints, etc. There is a close parallel between this effort and the effort used to develop the value to the nation (VTN)

calculations. For instance, the amount of power produced by a hydroelectric facility might be both a level of service measure and an input to the VTN calculation.

DEVELOPING PERFORMANCE MEASURES

Developing performance measures, to measure levels of service from the perspective of users, requires a significant investment in consultation with users of the infrastructure and development of techniques to quantify the tradeoffs between service priorities and costs. The IIMM includes a number of detailed approaches to developing and measuring service level information. Some examples of performance measures for various types of physical assets are shown in Table 2 below.¹²

Service	Performance Measure	Service	Performance Measure
General	Return on Investment. Cost per connection or km network. Customer satisfaction with service provided. Response timeliness. Availability of service or supply.	Wastewater	Notification of planned shutdown. Availability of service. Compliance with discharge standards. Infiltration rate. Sewage over flow due to public sewer fault: <ul style="list-style-type: none"> • Number on any property. • Time taken to clean up over flow. • Number sewer blockages/100km sewer. • Pump station overflows per year. • Number of complaints- odour from treatment facility.
Roads	Skid Resistance. Total accidents /year per 1M population. Travel time / intersection delays. Frequency of condition inspections. Minimum illumination level (x) lux. Grass verges mown when the grass height exceeds (x)mm. Average travel speeds on selected urban routes -peak and off-peak. % signs found missing or ineffective during routine safety inspections.	Gas	Unaccounted for gas volumes. Number unplanned interruptions/ 1000 km/year. Number of leaks per 1000km surveyed. Minutes supply lost /month/ 1000 customers.
Electricity	Forced (unplanned outages). Average number of disruptions per connection per year.	Stormwater	Number of blockages per year Number of times roads closed due to flooding per year. Compliance with discharge standards. Number of complaints – blocked drains, surface flooding.
Water Supply	Notification of planned shutdown. Duration of disruption. Unaccounted for water. Pressure at connection. Storage capacity in each supply zone. Domestic water consumption per head population. Number of complaints- dirty water, taste.	Parks and recreation facilities	Availability of sports grounds. Distance between residence and closest park. Operating cost per hectare of park maintained. Opening hours per week. Cost per swim. Number of reported playground accidents per year. Number of complaints- aesthetics of parks, condition of facilities, entry prices etc.
Property	Proportion of unplanned versus planned maintenance per annum. Proportion of the population living within (y) km of a (type) community facility. Number of public buildings that are accessible to people with disabilities. % of the community identifies cost as a barrier to using the facilities. Rentals/ fees are comparable to market. Time taken to remove graffiti. Time taken to make safe property damaged by vandalism. Frequency of cleaning. Operating and maintenance costs recovered from user charges. Level of customer satisfaction with air temperature, building cleanliness, lift wait times etc.	Flood/Land Drainage	% Properties protected from x% return frequency events. % Properties affected by x% return frequency events per annum. Number of complaints - cost of scheme, blocked culverts and drains.
Rivers	Timeliness of flood warning. Time taken to remove blockages, obstructions or impediments to the channel flow. Compliance with environmental consents. % drains maintained at grade and free of vegetation.	Refuse	% Properties provided with regular refuse collection service. % Properties provided with regular recyclables collection service. Cost of service per annum. Opening hours of refuse/ recycling sites. Average volume of waste per household per annum. Number of complaints- missed collections, odour from refuse site, untidy streets following collection etc.

Table 2: Performance measures. Source: New Zealand Asset Management Support.¹³

DEVELOPING AN ASSET REGISTER STRUCTURE AND HIERARCHY

One of the biggest and most costly challenges facing many organizations when beginning an asset management program is the development of an asset registry data structure at the appropriate level of detail and with a suitable hierarchy. This issue is discussed in detail in the IIMM, as are examples of specific levels of asset detail that are appropriate for each asset type. Best practices for level of detail can vary by asset type, but the general rule is that any asset or component that requires inspection, preventative maintenance, has a value of over \$1,000, or is critical to the operation of the overall system would be included in the registry. Table 3 below shows the typical information that might be included for each asset (additional information would be provided based on asset type) within an asset register.¹⁴

Asset ID	Replacement cost
Type of asset	Installation/construction/renewal date
Location	Installation contractor
Manufacturer	Service life (initial and remaining)
Material	Condition grade
Size/capacity	Performance grade
Original cost	Inspection date

Table 3: Standard asset registry information. Source: National Association for Clean Water Agencies.¹⁵

Developing the hierarchy is also important. The hierarchy defines the relationship of individual components so that small items (bearings) are related to larger items (gates), which then are related to larger items (locks), which then relate to systems (navigation segment). The hierarchy defines the criticality of each of the items to the overall system so that decisions can be optimized as part of the risk management process.

This topic is clearly one that each organization has to work out for each infrastructure type that it manages. This is also an area where industry-specific guidelines will be of value in defining best practices.

DEFINING CONDITION MONITORING APPROACHES

Given the many different types of assets that need to be managed, there are many tools and techniques that can be used to assess and monitor their condition. No one tool or technique will apply to all assets. The challenge becomes normalizing the information gathered by different techniques on differing types of assets into a single uniform evaluation. The IIMM provides an example table, Table 4 below, showing some potential monitoring techniques that might be applied depending on the type of asset.¹⁶

Asset Groups	Condition Monitoring Systems																							
	Vibration	Temperature	Oil Usage/Level/Contaminants	Efficiency Change (Head Loss)	Infra Red Thermography, Ground Penetrating Radar	Hours Run	Power Usage Monitoring	Concrete Composition Testing and Core Sampling	X-ray	Remote Control Television Inspection	Pressure Testing	Smoke Testing	Capacity Modelling (for failure)	Leak Testing	Intelligent Pigs	Protection (Paint) Thickness	Manual Inspection (Operators)	Alarms/Auto Shutdown/Shutdown Telemetry Protection	Life Expectancy Review	Visual Assessments	Laser Profiling/Roughness Meters	Pavement Strength Testers	Skid Resistance Testers	
Dynamic Assets																								
Mechanical Plant	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓	✗	✗	✓	✓	✓	✓	✗	✗	✗	
Electrical Plant	✗	✓	✓	✗	✓	✓	✓	✗	✗	✗	✗	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗	
Instruments	✗	✓	✗	✗	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	✗	
Control Systems (electronic)	✗	✓	✗	✗	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	✗	
Passive Assets																								
Roads	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✓	✗	✓	✓	✓	✓	✓	✓	
Reservoirs/Dams	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗	✗	✓	✓	✗	✗	✓	✗	✓	✓	✓	✗	✗	✗	
Structures																								
Concrete	✓	✗	✗	✗	✓	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✗	✓	✓	✗	✗	✗		
Earthen	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	
Buildings	✗	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✓	✗	✗	✓	✓	✗	✓	✓	✓	✗	✗	✗	
Pipelines																								
Gravity Conduits	✗	✗	✗	✓	✓	✗	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗	✗	✗	✗	
Pressure Conduits	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	
Electrical																								
Poles	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✓	✓	✗	✗	✗	✗	
Wires	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗	
✗ Denotes Not Applicable ✓ Denotes Applicable																								

Table 4: Asset monitoring techniques. Source: New Zealand Asset Management Support.¹⁷

DEFINING BUSINESS RISK EXPOSURE AND MULTI-CRITERIA ANALYSIS

Business Risk Exposure (BRE) is defined as the probability of failure (PoF) multiplied by the consequence of failure (CoF). With good condition monitoring data and asset deterioration curves, the PoF can be modeled to some degree of confidence. However, assessing the CoF given all of the potential factors can often be difficult if not impossible. The IIMM provides an example of a risk consequence rating system that combines economic, environmental, and social factors into a single, (although somewhat simple) numeric rating system as shown in Table 5 below.¹⁸

Consequence			Impact (Risk)				
TBL Aspect	Description	Weight	1 Insignificant (<\$2,000)	2 Minor (\$2,000-\$20,000)	3 Severe (\$20,000-\$100,000)	4 Major (\$0.2M- \$2M)	5 Catastrophic (>\$2M)
Social	Safety & Health	5	Negligible injury	Minor injury Medical attention required.	Serious Injury Hospitalisation required.	Loss of life (\$0.2M- \$2M)	Multiple loss of life or city-wide epidemic (>\$2M)
	3rd Party Losses	3	Minimal liability for consequential loss	Liability for consequential loss	Liability for consequential loss -(\$20,000-\$100,000)	Liability for consequential loss	Liability for consequential loss - (>\$2M)
	Loss of Service-Extent/ Duration	4	Small number of customers experiencing minor service disruption	Significant service disruption affecting small number of customers	Significant localised disruption over extended period (\$20,000-\$100,000)	Major localised disruption over extended period (\$0.2M- \$2M)	Major long term city wide service disruption
	Corporate Image	3	Event only of interest to individuals Nil effect or community concern	Minor community interest Local media report	Public community discussion Broad adverse media coverage	Loss of confidence in Council National publicity. Public agitation for action	Public investigation International coverage. Management changes demanded
Environmental	Environment	5	Negligible impact Reversible within 1 week	Material damage of local importance. Prosecution possible. Impact fully reversible within 3 months	Serious damage of local importance Prosecution probable. Impact fully reversible within 1 yr	Serious damage of national importance Prosecution expected. Impact reversible within 5 yrs	Serious damage of national importance Prosecution. Long term study. Impact not fully reversible
Economic	Business Costs (Total Recovery)	3	Total direct revenue loss & cost to restore service	Total direct revenue loss & cost to restore service	Total direct revenue loss & cost to restore service	Total direct revenue loss & cost to restore service	Total direct revenue loss & cost to restore service

Table 5: Risk consequence rating system. Source: New Zealand Asset Management Support. ¹⁹

The table above categorizes potential risks into three categories (social, environmental, and economic). For each potential risk, it provides a user definable weight, which might vary by project, and also documents the criteria used to define impact of the severity of the risk (consequence of failure).

For the USACE, it may be possible to use the work already developed for VTN as a way of calculating the financial impact of risk-based decisions, eliminating the need to recreate such calculations across the entire portfolio.

The table shows how Multi-Criteria Analysis (MCA) is used when comparing the tradeoffs between alternatives that are not always reducible to economic factors. With MCA, a number of different criteria or indicators are chosen to represent the different cost and benefit impacts of the project. The project is then “scored” against each of the indicators. Scoring can either be quantitative (e.g. number of beach closures per year), or qualitative (e.g. community acceptability) based on user feedback. All scoring has to be normalized to an agreed upon set of measures. The MCA technique is critically important when some of the elements of a decision (social, environmental) cannot be easily converted into economic measures. An example of an MCA scoring system is shown in Table 6 below. Each criterion is considered separately, and each is assigned a weighting factor based on its relative importance. This example shows how the potential risk impacts are quantified for each scenario, multiplied by the weighting factor, and totaled to provide an overall score (the score for Scenario 1 is $5 \times 3 + 3 \times 2 + 4 \times 3$, and so on). In this example, high numbers indicate high risk, so the scenario with the lowest overall score would be the most desirable.

Multi-Criteria Analysis Scoring					
Description	Weight	Scenario 1	Scenario 2	Scenario 3	
Safety and Health	5	3	2	2	
3rd Part Losses	3	2	2	1	
Loss of Service	4	3	2	1	
Corporate Image	3	3	3	2	
Environment	5	3	2	2	
Economic	3	3	2	3	
Totals		66	49	42	

Table 6: Multi-Criteria Analysis scoring system. Source: New Zealand Asset Management Support.²⁰

One challenge with an approach such as this that uses subjective factors is that the results may be difficult to defend unless the process by which the weightings and factors were computed has itself been validated through a rigorous process. This is where involving stakeholders becomes critical.

DELFT UNIVERSITY OF TECHNOLOGY/NEXT GENERATION INFRASTRUCTURES

Although there are many other international organizations that are involved in the asset management field, most are focused on one specific asset type, or are largely repeating many of the concepts already discussed in the IIMM or PAS 55. However, innovative research is being performed at the Delft University of Technology in the Netherlands, some of which has been commercialized through an organization known as [Next Generation Infrastructures](#) (NGI).

The research conducted by these organizations includes the following:

- Defining asset management drivers and barriers within organizations.
- Embracing complexity and systems theory in managing assets.

Staff of the Delft University of Technology has described a number of innovative ideas with respect to implementation of asset management. These include the development of the Mass Spring metaphor of asset management as shown in Figure 3 below.²¹

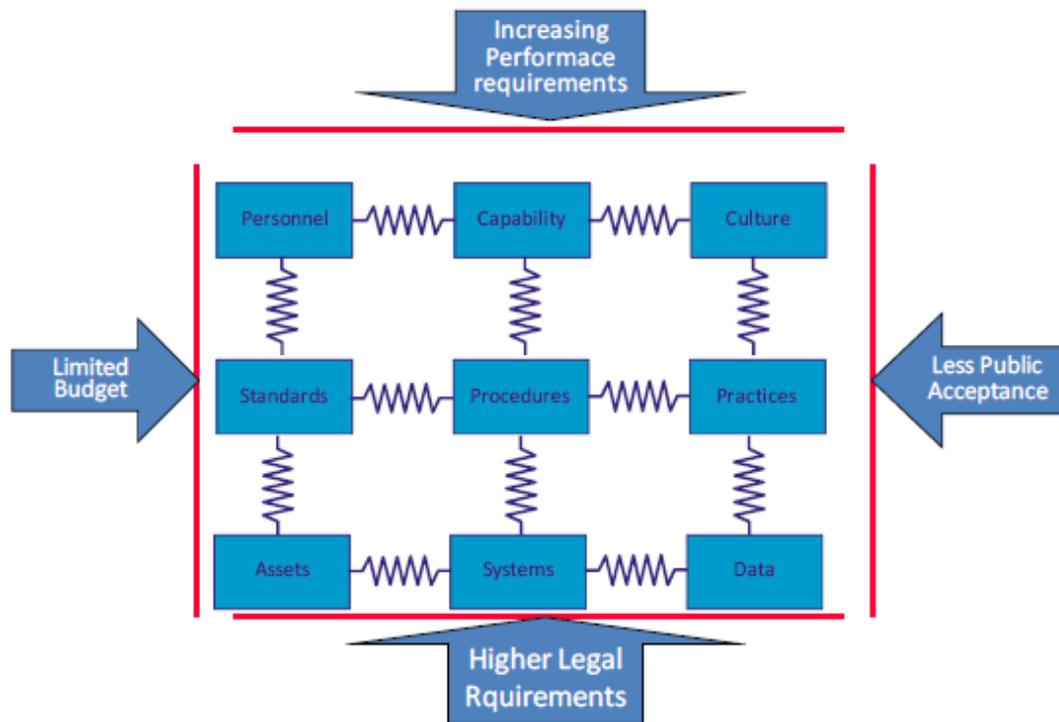


Figure 3: Mass Spring metaphor of asset management. Source. Y.C. Wijniaa and P.M. Herdera, "The State of Asset Management in the Netherlands." ²²

This metaphor provides a framework for understanding why asset management is so challenging to implement. It shows that force applied to one object causes a reaction to other objects in a chain reaction manner. This movement will exert forces that cause the whole system to adjust until it comes back to a tension-free point. Short-term gains can be achieved in any given area, but sustaining them requires making changes to the entire organization. If multiple forces are exerted simultaneously but not aligned, the system can't move and will be put under significant stress, leading to failures at multiple levels. Putting less attention into a given area (postponing maintenance) will have an impact over time in other areas (loss of capability). When the concepts of time (aging infrastructure) and space (watersheds as systems) are included, the level of complexity is even higher.

One important conclusion that can be drawn from this concept is that achieving lasting results in asset management requires an integrated approach that addresses multiple areas. This requires an all-encompassing approach that impacts all areas of an organization. The USACE asset management vision fully embraces this concept.

The appropriate location for the asset management function within an organization is another related element derived from the concept above. The Delft University of Technology research article indicated that asset management is best implemented as a business line function rather than a staff function, but that ultimately it must become embedded within the operations of all line functions within the organization.

EMBRACING COMPLEXITY AND SYSTEMS THEORY IN MANAGING ASSETS

Infrastructures, such as ports and utilities, can be characterized as complex, multi-actor systems. The behavior of complex infrastructures, such as ports and utilities, can be modeled and simulated in various ways for decision-making or research. Serious gaming involves the use of concepts and technologies derived from computer entertainment games for non-entertainment purposes such as for research, policy and decision-making, training and learning. The Next Generation Infrastructures

Serious Gaming initiative includes a set of software tools to support the incorporation of these concepts into asset management strategies including the following:

- Game prototyping and development of proof of concepts.
- Serious game and simulation-game design for and with partners.
- Serious gaming sessions for in-company training and learning.
- Seminars, demonstrations and workshops.
- Game design courses, e.g. for PhDs and practitioners.
- Lectures and keynotes on serious gaming.
- Applied research and advice.

These concepts could be adapted for use in managing the complex systems of systems that make up the USACE's infrastructure portfolio.

CASE STUDIES

The detailed case studies below document just a few of the many organizations that have implemented best practices in asset management as described in the section above.

CITY OF CAPE TOWN ELECTRICITY SERVICES²³

The City Of Cape Town (CoCT) provides electricity services to a population of 3.4 million people. The Electrical Support Services organization manages all electrical infrastructure including over 25,000 km of underground cabling, 3,000 km of overhead lines, and 9,000 sub stations. They implemented best practices in asset management in accordance with the International Infrastructure Management Manual (IIMM) beginning in 2006. Their asset management improvement plan incorporated improvements on each of 17 key performance areas, with the goal of upgrading their performance from a level one to level four out of five on the asset management maturity level in each category. By the time the system was fully implemented in 2011, the following accomplishments had been achieved:

- The asset management strategy was integrated into all operations through cross functional frontline teams.
- Asset condition was being managed in near real-time, and proactively used for capital planning.
- The number of completed work orders increased by a factor of more than 10, while the workforce was reduced by 25 percent, and the average cost per job was reduced by 38 percent.
- Average customer satisfaction ratings improved from "Fair" to "Very Good."
- Asset management decisions were all made based on whole-life costing.
- Average asset management maturity level improved to four out of five.

HUNTER WATER CORPORATION, AUSTRALIA²⁴

Hunter Water Corporation, which serves about 500,000 people on the East Coast of Australia, implemented a comprehensive asset management program in the 1990s based on the concepts that became the International Infrastructure Management Manual (IIMM). They implemented a quantitative risk-based decision making model that incorporated assessing the combination of the probability of failure and the consequence of failure for each significant asset in their inventory. As a result, they were able to do the following:

- Cut operating costs per property by nearly 40 percent.
- Reduce capital expenditures by AU \$185 million.
- Improve their level of service.

Change in Operating Costs over Time

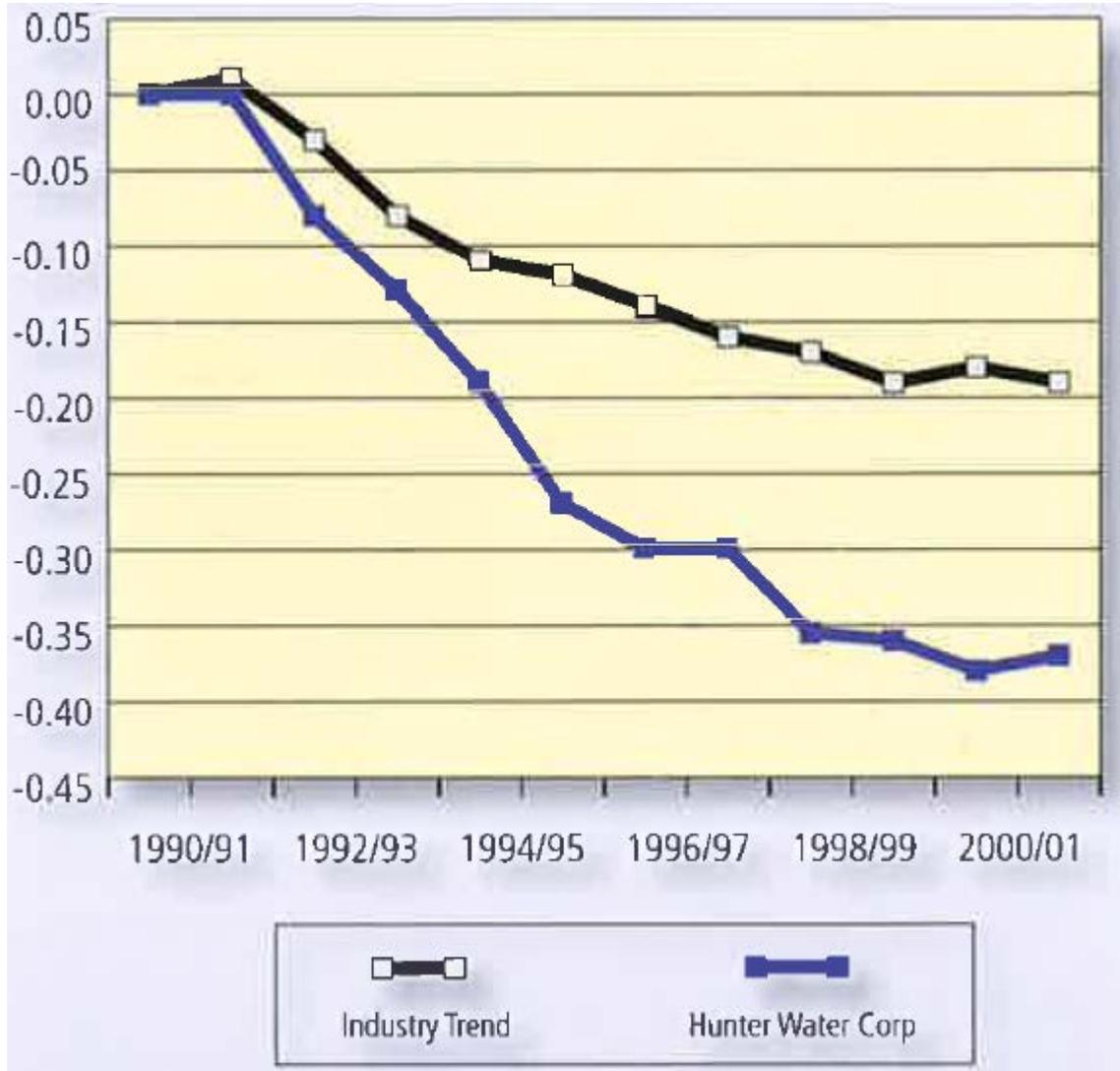


Figure 4: Change in operating costs over time. Source: New Zealand Asset Management Support.²⁵

Figure 4 above shows the cumulative percent change in operating costs on a year-by-year basis for Hunter Water. Over the period shown, the industry trend generally showed slight decreases from year to year leading to a cumulative reduction in costs of about 19 percent, while Hunter Water showed much greater decreases leading to a cumulative decrease of about 37 percent.

WATERCARE SERVICES, NEW ZEALAND²⁶

Watercare Services is the bulk water supply and wastewater utility authority serving the Auckland Region of New Zealand, a population of 1.4 million. Since its establishment in 1992 (privatized from a formerly public agency) Watercare has had a statutory requirement to prepare a comprehensive asset management plan every year and to consult with its consumers over planning and pricing implications

of its decisions. Watercare has established a comprehensive asset management organizational framework as shown in Figure 5 below.

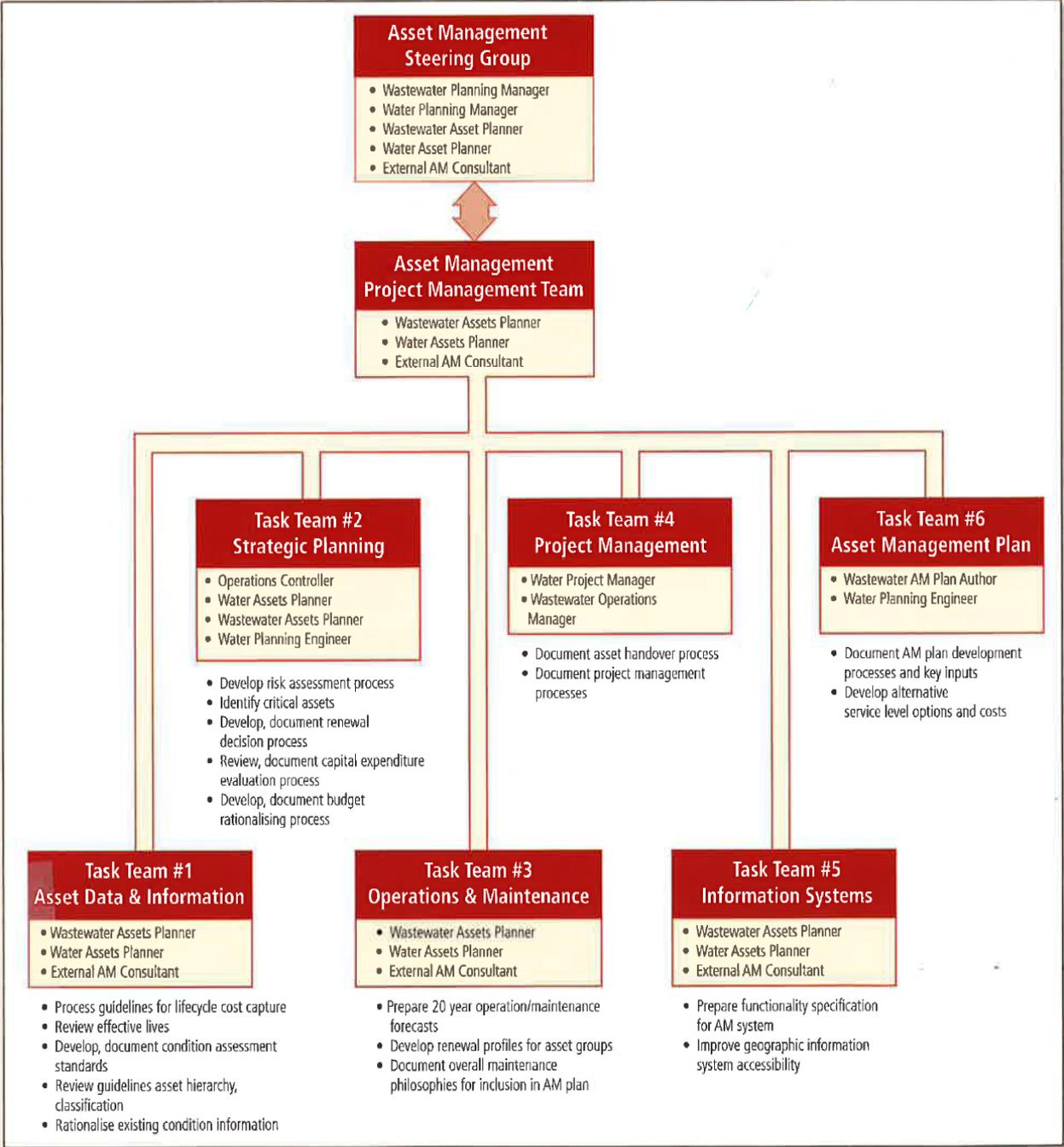


Figure 5: Watercare's asset management organizational framework. Source: New Zealand Asset Management Support. ²⁷

SEATTLE PUBLIC UTILITIES²⁸

Seattle Public Utilities provides drinking water, sewer, drainage, and solid waste services to more than 1.3 million customers in the Seattle area. It began an asset management program in 2002 based on the concepts of the International Infrastructure Management Manual (IIMM) to deal with challenges

associated with aging infrastructure, more stringent regulatory obligations, and the need to use resources more efficiently. It adopted a fast-track plan to implement asset management using the following four steps:

Step 1 - Educate, Train, and Communicate

- Implemented staff training curriculum.
- Restructured organization to focus on asset management.
- Developed their Strategic Asset Management Plan.
- Added focus on integration and multi-skilling in operations.

Step 2 - Determine Service Levels

- Developed service levels through consultation with users.
- Assessed asset criticality and risk.

Step 3 - Implement Capital Review Process

- Reviewed future projects for level of service and asset management implications.
- Project authorized in phases to improve cost tracking and decision making.
- Renewed emphasis on projects that extended life of infrastructure (relining pipes, improved replacement models, replacement of equipment that was costly to operate).

Step 4 - Review Operations and Maintenance Activities and Costs

- Developed a framework for long-term operational savings.
- Performed benchmarking and adjusted operations accordingly.

Seattle Public utilities achieved impressive gains through this process, with savings of about \$10 million per year in operations and maintenance and \$40 million in capital costs.

ALBURY CITY WATER, AUSTRALIA²⁹

Albury City provides a water supply network to the community of Albury. Their assets include pumping stations, filtration plants, water mains and associated infrastructure. They developed a detailed Asset Management Plan based on the IIMM, which is available for download at the following website: http://www.alburycity.nsw.gov.au/resources/documents/Water_Asset_Management_Plan2.pdf. Their Asset Management Plan incorporates virtually all of the best practice items described in the section above.

Table 7 describing their current service levels and performance measures is shown below:

Key Performance Area	KPI	Performance Measure Process	Indicator	How Measured	Target
Water supply management	Process operations	Water quality	Complies/meets Australian Drinking Water Guidelines (ADWG)	Laboratory tests	99%
	Operational costs	Water treatment operational costs	Comparison with budget	\$ per kilolitre of produced treated water	12 ^c
	Demand management	Water consumption	Meets water conservation objectives	Annual consumption is less than annual entitlement ¹ (megalitres - ML)	10,928
	Service levels	Level of service in infrastructure management	Customer enquiries, complaints and maintenance results	Water service complaints per 1000 properties	9 ²
				Number of water main breaks per 100 km of water main	9 ²
				Customer survey: response to question "are you satisfied with overall quality of tap water supplied to your property?"	75%
Works program	Completion of annual works program	Completed within time	Monthly review against programmed timeframe	95%	
Environment	Treatment standards	Effectiveness of water treatment	Compliance with environmental monitoring standards	Laboratory analyses in accordance with EPA Licence requirements	100%
Financial management	Revenue	In accordance with Best-practice criteria	Modelled revenue over 30-year plan	Actual revenue against modelled prediction	90% of predicted
	Expenditure	Budget comparison	At or below budget levels	Actual expenditure (by functional area) against budget	Between 95% and 100% of budget
	Capital works program	Completion of annual works	Completed within budget	Monthly review against budget	95%

Table 7: Albury City Water service levels and performance measures. Source: Institute of Public Works Engineering Australia.³⁰

The plan includes a projection of needed capital renewal expenditures over time as shown in Figure 6 below. Note that the differing colors in the graph below represent different categories of expenditures. These projections have been used to determine the potential funding gaps and the amount of revenue required to meet the funding requirements. Based on these requirements, a funding strategy was developed that included a variety of funding sources to meet the needs. This provides a means to ensure the long-term financial viability of the utility.

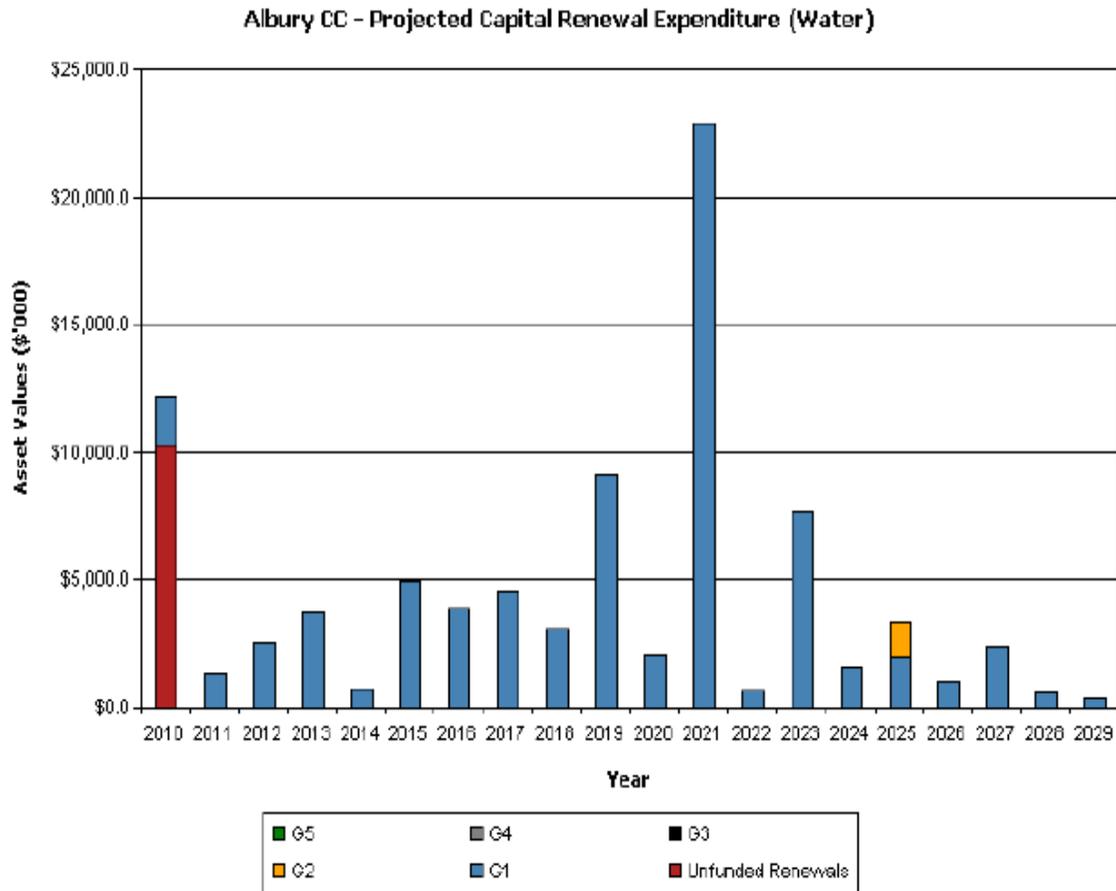


Figure 6: Albury CC - projected capital renewal expenditure. Source: Institute of Public Works Engineering Australia.³¹

SUMMARY

These case studies show results that are common across a large number of organizations, including the following:

- Asset management takes time to implement, and its benefits accrue over many years.
- Asset management does deliver measurable financial benefits to an organization.
- Asset management leads to improved customer satisfaction.
- Asset management can provide a long-term understanding of the financial impacts of aging infrastructure.

USACE APPROACH TO ASSET MANAGEMENT

INTRODUCTION

SOURCES CONSULTED

The following sources of information, along with discussions with multiple USACE staff members, were used to document the current approach to asset management.

REPORTS

- Draft Program Management Plan for Asset Management 2013-2015
- Toward Sustainable Water Resources Infrastructure Systems (Draft, July 2012)
- USACE Strategic Maintenance Management (June 2012)
- Maintenance Management Improvement Plan (Draft, June 2012)
- Minimum Fleet Capital Investment Report, 2012-2061 (2011)
- Fiscal Year 2012 Civil Works Budget Details (aka Budget Justification)
- Asset Management Plan (2006)

BRIEFINGS

- A Risk-Informed Approach to Asset Management (2012)
- Mapping of Asset Locations Project Review (2012)
- Infrastructure Strategy (2011)
- Asset Management Update (2011)
- Public Sector Asset and Portfolio Management (2010)
- Asset Management Program (2008)
- Can Traditional Highway Asset Management Strategies be Adapted to Waterway Infrastructure Analysis? (2006)

USACE APPROACH

ANNUAL BUDGET JUSTIFICATION

The USACE develops a detailed (1000+ pages) Civil Works budget justification document every year that includes all of the planned expenditures for the next fiscal year. That document is developed by business line managers and senior leadership. The budget priorities are based on operations and maintenance and rehabilitation requirements as submitted by USACE districts, and validated through USACE divisions. There is limited visibility of data at the district and division level, so decisions are made with limited and inconsistent information.

While there is a relationship between these expenditures and operational metrics, the operational metrics that are most important are those that relate to the expenditure of money and the completion of projects, rather than those that relate directly to the health and condition of assets, or the perception of value as defined by users. With respect to operations and maintenance costs, there is no comprehensive means to directly relate perceived public benefit to the actual funding in a way that

money can be allocated to assets in a value-optimized fashion across the entire USACE, although this does exist in some USACE business lines.

PROGRAM MANAGEMENT PLAN³²

[Note: Text below in *italics* is taken verbatim from the draft Program Management Plan (PgMP), dated 22 Aug 2012. While it is a fraction of the overall report, it contains the essential elements.]

This Program Management Plan (PgMP) establishes the approach to asset management (AM) to be implemented by the U.S. Army Corps of Engineers (USACE).

While significant progress has occurred in the basic development of asset management within USACE Civil Works, many foundational aspects are still in need of development.

USACE has been a proficient steward in managing new and existing assets, but most of the processes currently in use have the following attributes:

- *Developed to support a specific authorized and appropriated mission or purpose.*
- *Independently developed local or regional solutions.*
- *Subjective processes that rely heavily on local subject matter experts.*
- *Focused on primary business line assets and missions as independent entities.*
- *Lacking standardization, documentation, and often without a means of insuring repeatable results.*
- *Incorporating limited assessment of the consequences and impacts of functional failure.*
- *Designed to support the originally planned delivery level of service of each asset.*

The historical USACE Civil Works approach to asset management was derived in large measure through the Congressional authorization process. Congress authorizes USACE to perform certain water resource missions and to plan, construct, operate, maintain, modernize, and manage assets that address these missions and deliver value to the nation (VTN).

The asset, mission and VTN relationship, in combination with the condition and risk relationship provide the basis of a risk-informed approach to support lifecycle investment decisions.

The keys to understanding the USACE Asset Management approach are identifying:

- 1) *What assets are being managed (i.e., an accurate inventory of existing or proposed).*
- 2) *Existing conditions of the assets (i.e., consistent condition assessments).*
- 3) *How the assets are being cared for (i.e., a well defined maintenance management program).*
- 4) *Which assets are critical to mission success (i.e., relationships between assets and value to nation).*
- 5) *Investment priorities for limited funds given conditions and risks (or consequences) of mission failure (i.e., understanding risks associated with assets degradation or failure and value to nation).*
- 6) *Which lifecycle investment alternatives to consider (i.e., sustain, restore, modernize, or divest).*

The objective of USACE asset management is to develop and implement a risk-informed investment strategy for managing the USACE Civil Works infrastructure portfolio that will optimize the value to the nation. Within this objective lie two major thrusts of asset management including the following:

- a) *The development of appropriate tools to quantify and analyze asset data and relationships.*
- b) *The development of disciplined business behavior to build robust processes within which to apply the use of those tools.*

The historical perspective between USACE assets and value to nation must mature from a simple one-to-one relationship to a more complex one-to-many relationship. Existing USACE assets provide a host of benefits to the Nation. This change in paradigm requires a rigorous approach to asset management.

USACE assets produce a wide range of value to the nation across multiple business lines. The multi-assets, multi-mission perspective of the Civil Works asset portfolio and the corresponding dynamic relationships of the assets to multiple missions and value to the nation are shown in Figure 7 below.

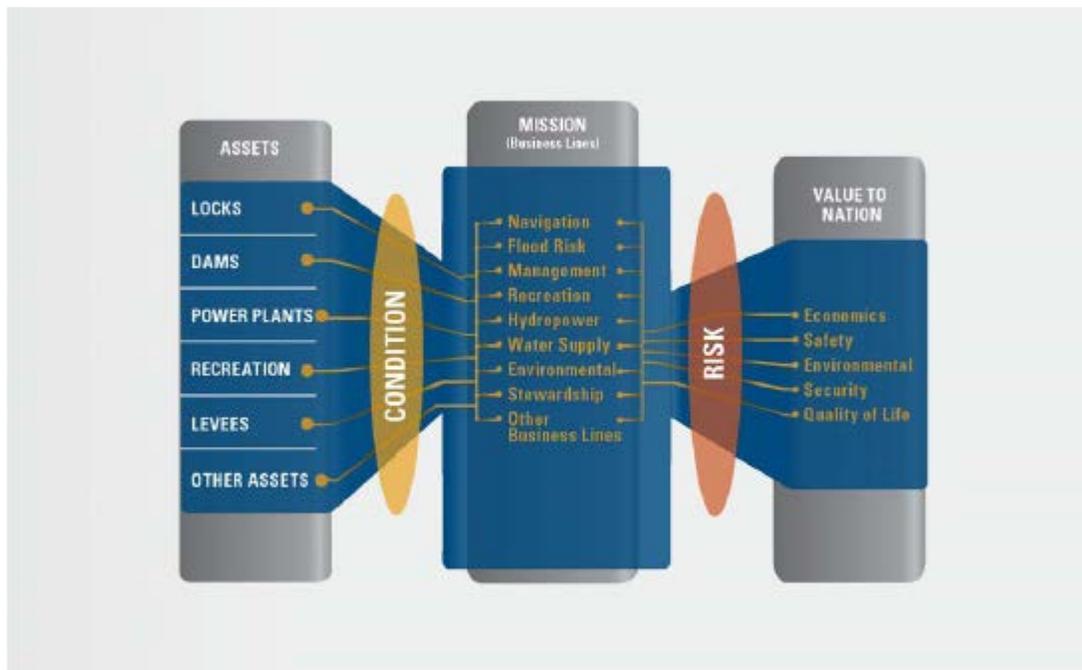


Figure 7: USACE Civil Works asset management framework. Source: U.S. Army Corps of Engineers.³³

When viewed holistically, USACE asset management is moving from an approach that assesses individual asset[s] aligned with specific business lines and value to the nation, to a multi-purpose portfolio approach wherein individual asset[s] support multiple business lines and associated value(s) to the nation. This transition necessitates a strategic and integrated approach to asset management, but will enable USACE to tell a more compelling and complete story about the value of its assets.

Asset management currently focuses on accomplishing the authorized mission and then assesses the corresponding changes in the assets and value produced. While the basic relationships have proven quite successful, consideration of benefits provided at USACE sites beyond the authorized purpose are ignored, minimized, or often minimally considered if at all in decision-making.

CIVIL WORKS STRATEGIC INVESTMENT FRAMEWORK

The Civil Works - Strategic Investment Framework (CW-SIF) is the framework upon which the Asset Management approach is built. It is essentially the structure by which asset management addresses the complexities of the USACE Civil Works asset portfolio. [The] Civil Works Strategic Investment Framework (CW-SIF) illustrates the essential relationships and decision processes that collectively provide an effective means of meeting the challenges associated with the USACE unique, multi-purpose asset portfolio and the desire for an integrated risk-informed methodology.

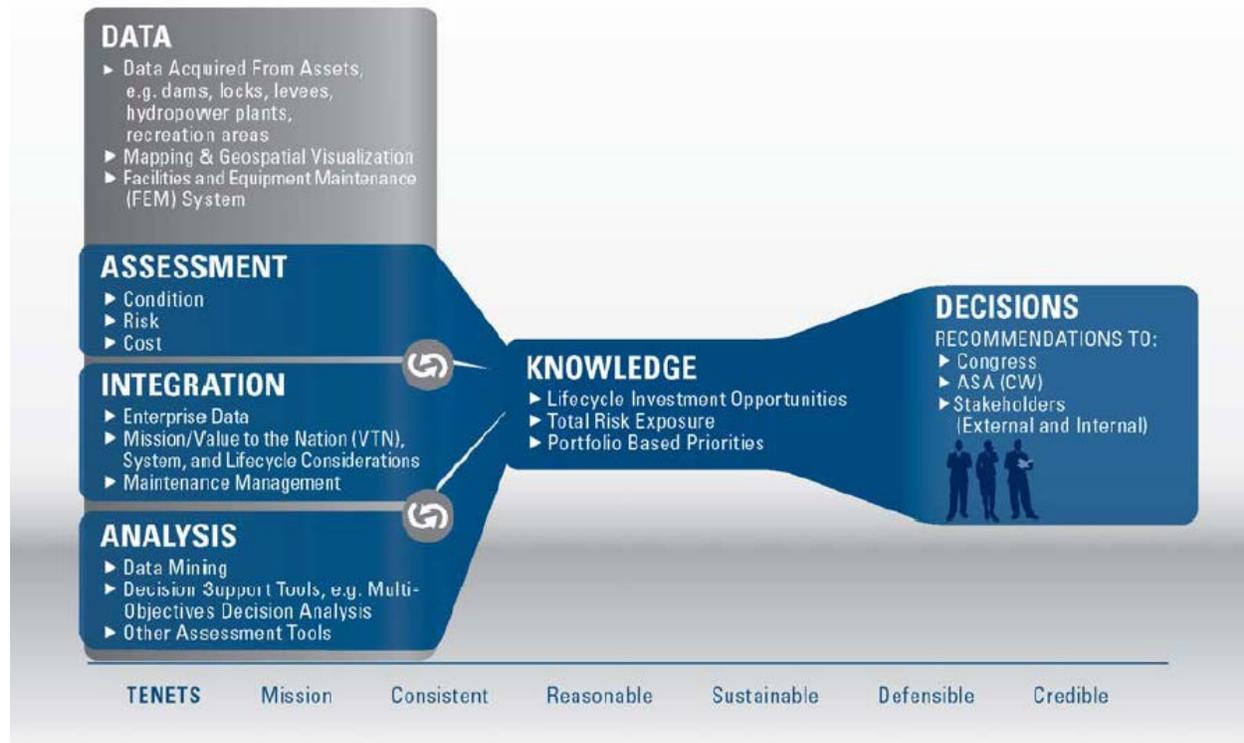


Figure 8: Civil Works Strategic Investment Framework. Source: U.S. Army Corps of Engineers.³⁴

The formalized USACE Asset Management approach is in the early phases of development. As mentioned in Section 1.5, the two major thrusts of asset management are the following:

- The development of appropriate tools to quantify and analyze asset data and relationships (Focus Areas One and Two); and*
- The development of disciplined business behavior to build robust processes within which to apply the use of those tools (Focus Area Three).*

Focus Areas One and Two provide the appropriate emphasis and direction for the development of appropriate tools and analytical capabilities, while Focus Area Three drives the required disciplined business behavior to leverage those tools for effective asset management.

Focus Area One: Focus Area One includes the basic building blocks of a risk-informed asset management strategy. In order to move from subjective to more objective inventory and assessment processes, consistent, repeatable, transparent and standardized methods for inventory, condition assessment, risk assessment, cost assessments, and maintenance management must be in place.

Focus Area One incorporates a strong emphasis on the development of a complete understanding of the existing USACE asset inventory, condition, and risk as a baseline for establishing appropriate maintenance management objectives for USACE’s aged infrastructure. This focus area is not only business line focused, but also specific project site and operations and maintenance budget account focused. Data associated with these efforts will directly tie to and support advancement of the foundation in Focus Areas Two.

Focus Area Two: The asset management process must consider the interdependencies of the entire asset portfolio and impacts not only at a limited static point in time, but also throughout the dynamic range of the assets’ entire lifecycle. This focus area represents the full transition from a business line centric approach to a true portfolio approach, which better represents and recognizes each asset’s

contribution to the value to the nation within a system. This enables knowledge and decisions to be based on an overall understanding of tradeoffs associated with portfolio risks and benefits. One key initiative in this focus area is identification of new sources of funding to support strategic recapitalization of USACE's aging infrastructure. The asset management principles and processes developed and implemented will primarily determine the "what, where and when" for the lifecycle investment strategy; the recapitalization effort will identify legislative and alternative financial initiatives necessary to determine "how" to accomplish infrastructure revitalization.

Focus Area Three: Focus Areas One and Two deal with the development and implementation of the CW-SIF model to assist risk-informed decision analysis. Focus Area Three involves establishing activities and processes that will emplace the asset management process throughout USACE. It includes: a) emphasis on integration and collaboration of organizational efforts to achieve efficiency and elimination of duplicative activities; b) communication and education of asset management principles and tenets; c) defining metrics and standards to measure performance; and d) assessment and adjustments to ensure sustainability and credibility of the asset management efforts.

In general, Headquarters Asset Management will request, in the annual budget submission for USACE, funds for strategic development of the asset management goals, policies, procedures and guidance and for development of business processes and related tools pertaining to Focus Areas One through Three. Funding for field application of the processes at the Major Support Command (MSC) and district levels will be from appropriated sources including project specific sources.

As USACE asset management matures, the tools and processes created will influence corporate budget development. Consistent condition and risk assessment procedures are in progress and will be integrated into the budget development process as they are completed and synchronized.

Operational Condition Assessment/Operational Risk Assessment Framework

(Based on the Inland Navigation Operational Condition Assessment/ Operational Risk Assessment (OCA/ORR) effort and serves as an example of the OCA/ORR approach)

The basic ingredients for the condition assessment and risk assessment framework are graphically displayed in Figure 9 as follows:

OCA: A snapshot of the operational condition of a subsystem component relative to: 1) the magnitude of the deficiency; 2) the level or degree to which the deficiency degrades the component performance; and 3) the degree of overall affect to the service level of the project.

P(f): The probability of operational failure over the lifetime for a subsystem component. Focus should be on critical to mission and/or safety, but the Project Delivery Team (PDT) may also consider the entire inventory determined previously. Examples of the former would be navigation lock gate operating machinery, and of the latter would be project roads.

Mission and Safety Importance Factors (MIF / SIF): A factor that represents the relative importance of that component or sub-components contribution to executing the mission as defined by the BLM and PDT.

CONSEQ: The monetary and /or nonmonetary primary BL consequences that could be attributable to an operational failure of a subsystem component.

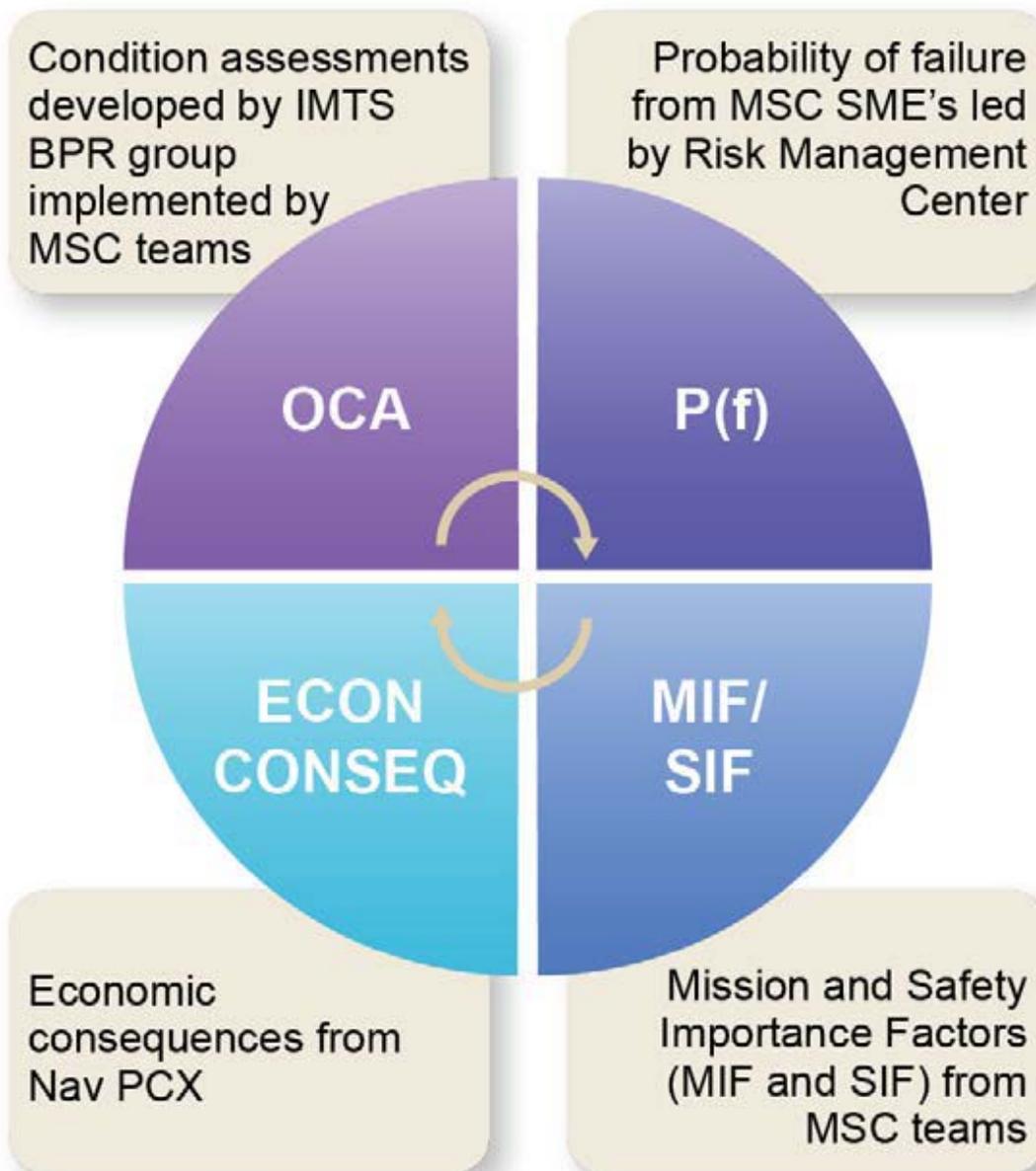


Figure 9: Operational Condition Assessment/Operational Risk Assessment. Source: U.S. Army Corps of Engineers.³⁵

CIVIL WORKS WATER RESOURCES TRANSFORMATION³⁶

As described in the draft document, USACE Civil Works is in the process of transformation through a series of integrated initiatives. The USACE Infrastructure Strategy (UIS) is directly connected to the Civil Works Transformation effort and the Civil Works Strategic Plan. The UIS aims to establish the foundation for the future of the USACE water resources portfolio by integrating water resources management.

UIS is one of the four transformation pillars, and encompasses four major initiatives, including the following:

- **Comprehensive Watershed Approach:** the evaluation of projects at the watershed/system level, and includes efforts to collaborate with other federal and non-federal partners on projects within watershed systems.
- **Alternative Financing Opportunities:** working within existing authorities to expand our available financing options, and working with stakeholders to truly understand investment interests to ensure reliable infrastructure to meet their needs.
- **Strategic Communications:** reconfiguring existing strategies to better communicate to internal and external audiences.
- **Lifecycle Portfolio Management:** development of national portfolio map, and development of Operational Condition Assessments (OCAs) for all projects.

The Lifecycle Portfolio Management is the component of the UIS most related to the content in this document. This component of the UIS considers what infrastructure will be required now and into the future by developing long- and short-term infrastructure sustainability requirements that focus on the performance across the entire asset lifecycle. This document will fit into the Lifecycle Portfolio Management effort.

REGIONAL INFRASTRUCTURE STRATEGY (RIS)

The Mississippi Valley Division (MVD) Regional Infrastructure Strategy (RIS) is another ongoing effort that this report will inform. RIS is structured similarly to the USACE Infrastructure Strategy (UIS) strategy, but focuses on regional efforts specific to MVD. The RIS is composed of the following components:

- **Lifecycle Portfolio Management:** optimizing investments to maximize performance of assets over their lifetime, including initiation, sustainment, restoration, modernization, and disposition.
- **Asset Management:** developing methods to estimate all maintenance needs based on condition and likelihood of failure, and repeatable risk-informed analysis to prioritize operations and maintenance and optimize the USACE budget.
- **Reimagining Operations and Maintenance:** examining and eliminating redundancies to accomplish greater levels of service. Includes defining levels of service and reducing operational costs.
- **Alternative Financing Pilots:** proposed opportunities for alternative financing under UIS, and further exploration of potential options with Headquarters.

While UIS focuses on national values and performance of infrastructure, RIS focuses more regionally. The Lifecycle Portfolio Management and Asset Management components of RIS relate most to this document and its recommendations.

USACE RISK-INFORMED APPROACH TO ASSET MANAGEMENT³⁷

A briefing was given to the Federal Facilities Council Meeting on June 19, 2012 regarding the implementation of asset management by the USACE, which added greater detail from that described in the PgMP. The narration described the slides as showing the current state of asset management development for USACE's Inland Navigation business line.

This slide shows the development of a consistent and repeatable process to assign condition ratings as shown in Figure 10 below.

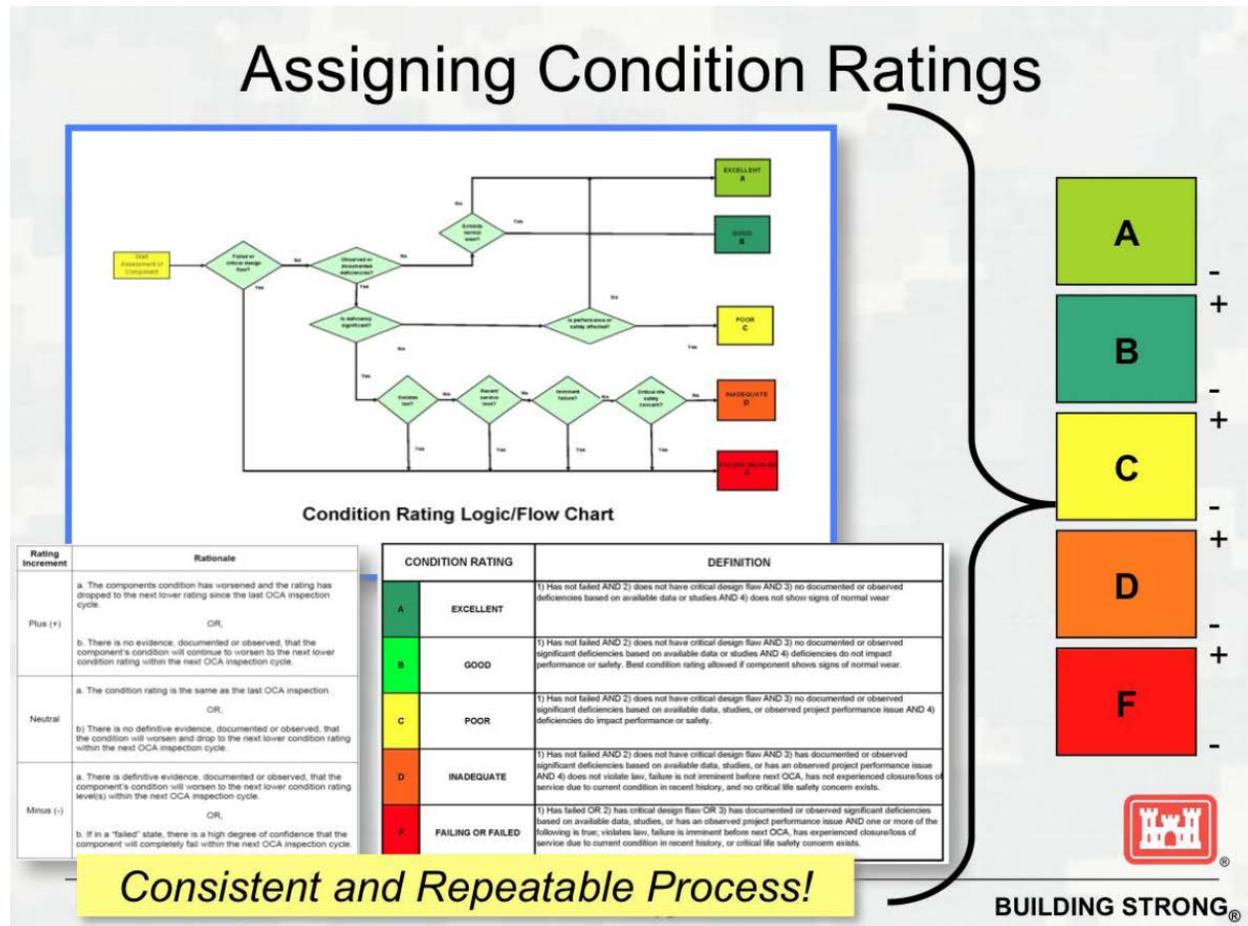


Figure 10: Assigning condition ratings. Source: U.S. Army Corps of Engineers.³⁸

The condition data is then used to predict probability of failure as shown in Figure 11 below. As shown, a non-linear curve (technically a “Weibull curve”) is commonly used to project failure probabilities based on condition. To begin the process, a universal curve can be used as shown here.

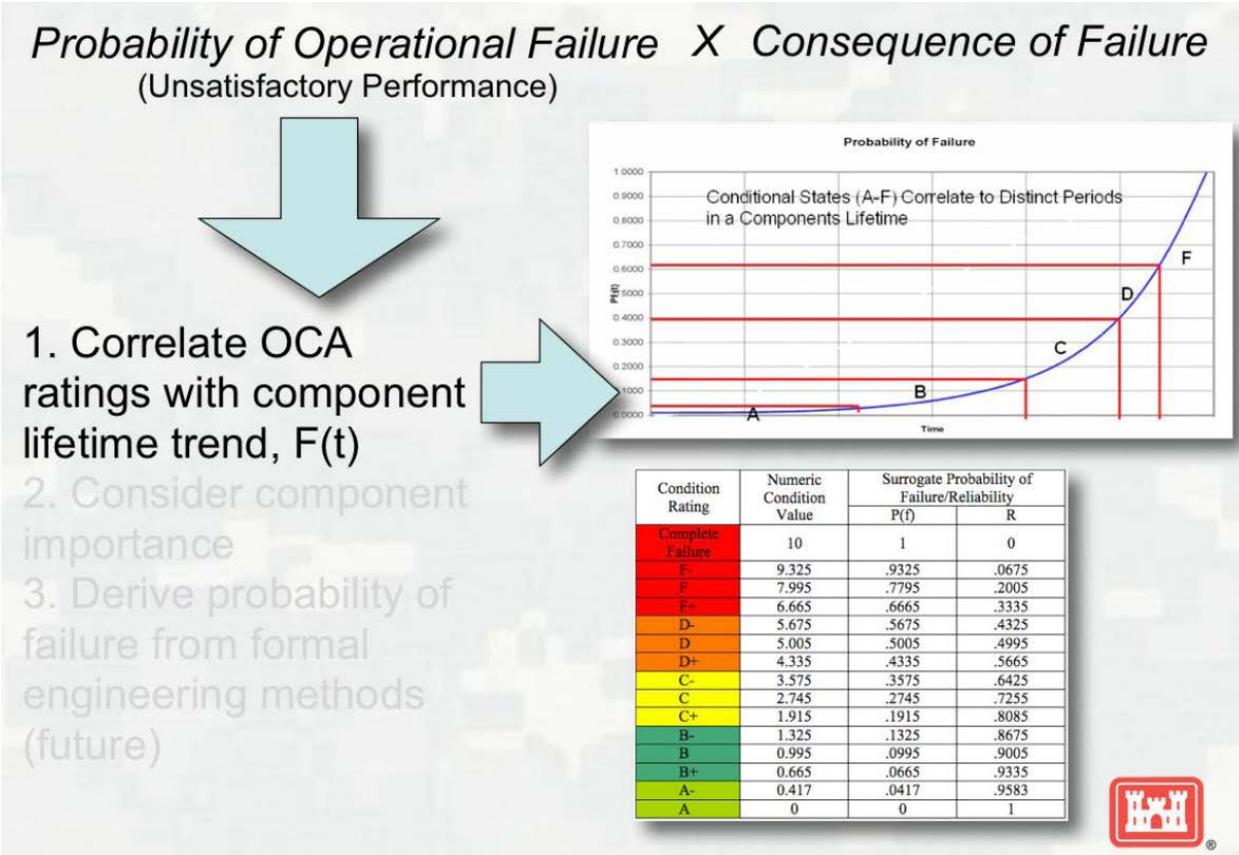


Figure 11: Probability of failure. Source: U.S. Army Corps of Engineers.³⁹

The process incorporates a number of factors related to the importance of the component used to define the consequence of failure as shown in Figure 12 below.

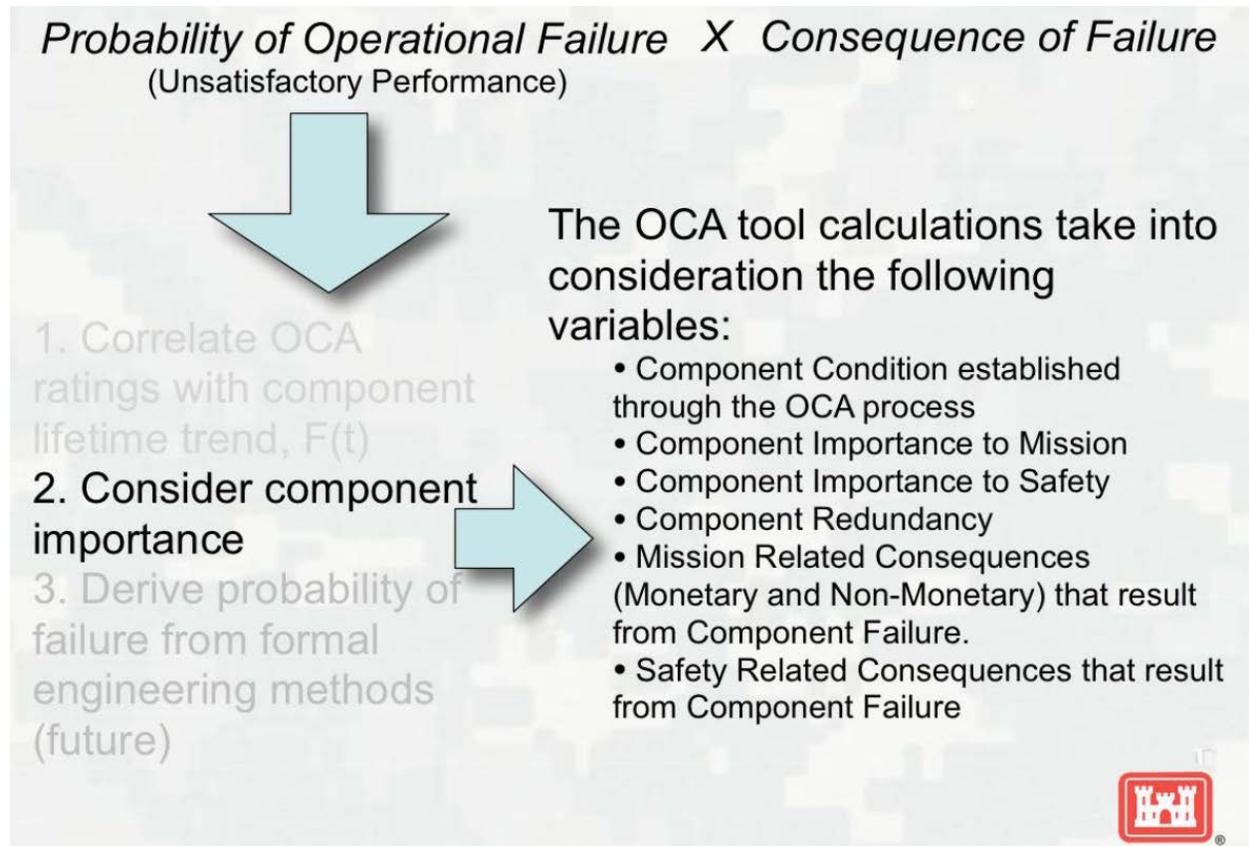


Figure 12: Consequence of failure. Source: U.S. Army Corps of Engineers.⁴⁰

This information is compiled on a component-by-component basis to define the expected impact recovery duration to recover from an unscheduled outage per component and the potential monetary impacts based on economic calculations of the impact of loss of service to shippers, as shown in Figure 13 below.

Probability of Operational Failure X Consequence of Failure
(Unsatisfactory Performance)

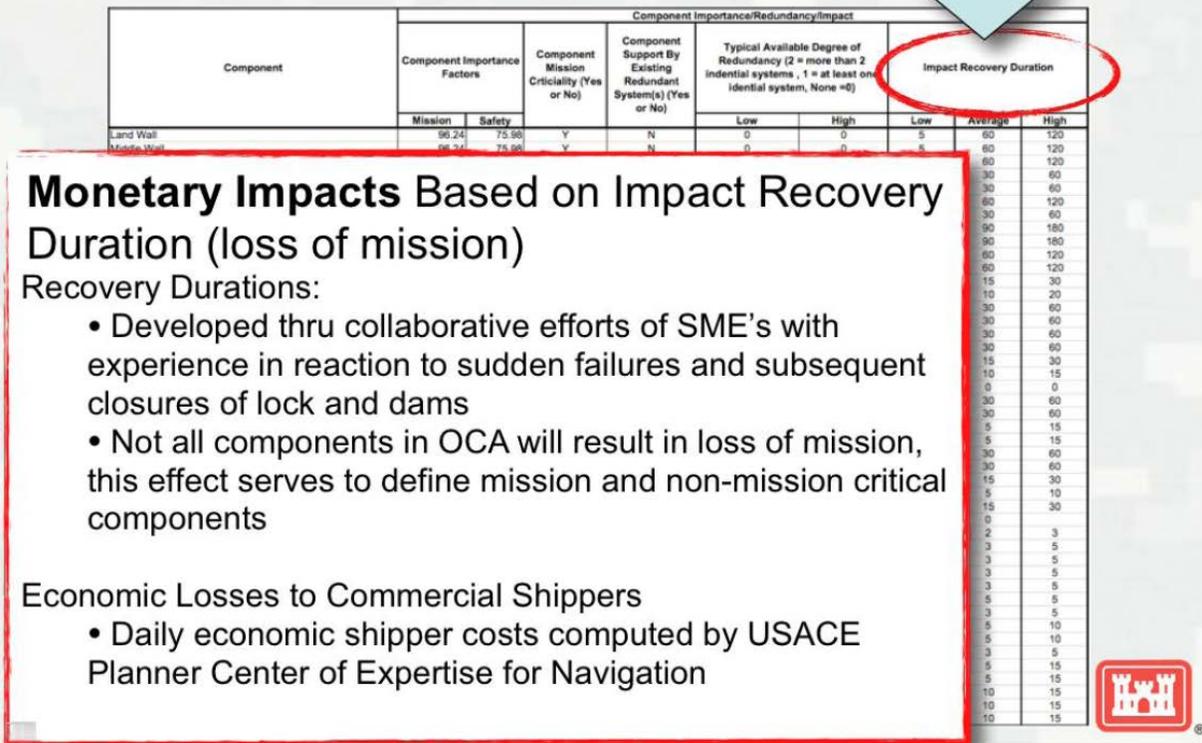


Figure 13: Impact recovery duration and monetary impacts. Source: U.S. Army Corps of Engineers. 41

This process clearly delivers a formal asset management-based decision making set of outputs that fulfill many of the requirements of best practices in asset management. However, the process is at this time limited to the Inland Navigation business line, and its application to the remaining business lines will require multiple years of development to be viable across all business lines. More importantly, this process will require a level of effort to update that is probably unsustainable without other operational changes. The best practices section which follows describes those changes.

USACE STRATEGIC MAINTENANCE MANAGEMENT⁴²

The USACE Strategic Maintenance Management report, prepared by Jacobs, resulted in findings that were summarized in three general observations, including the following:

1. USACE lacks a corporate maintenance management strategy.
2. Inconsistent maintenance policies, processes, practices, and terms.
3. No alignment between desired performance levels and maintenance investments.

The report developed three specific recommendations to enhance the stewardship of the Civil Works asset portfolio with effective maintenance management including the following (text in Italics is from the report):

1. Implement a USACE Maintenance Management Strategy

Organization-wide consistency driven by a maintenance management strategy offers an opportunity to move the focus and priorities of maintenance management toward “best-in class” performance. This is achieved through a consistently-articulated vision and policy for maintenance management, and supported by common processes for planning, execution, and monitoring, as well as standardized terms and definitions regardless of business line or function. These processes also offer industry-validated performance benefits through improved efficiency and effectiveness. Consistent maintenance management practices are essential to effective stewardship of the assets.

2. Focus the Maintenance Management Strategy on Critical Components

Critical components are those portions of USACE assets whose degradation or failure has a direct and significant correlation to the asset or project’s ability to meet mission/ business line objectives. Critical components form the foundation of the maintenance management strategy, are present in all business lines and projects, and represent the portion of the overall Civil Works portfolio that, at a minimum, should be proactively managed. Focusing on critical components and reducing administrative and oversight requirements for non-critical components enhances maintenance effectiveness while substantially reducing the administrative workload.

3. Link Level of Service Objectives to Maintenance Investments

Defining level of service (LOS) objectives allow USACE Civil Works leadership to identify desired performance levels for assets, determine which assets should move to a lower LOS under less-than-full funding, and establish a relationship between various levels of funding and associated performance (VTN). It also provides a clear directive between the desired service level and daily maintenance choices, allowing leadership at all levels to align with investment choices. The ability to clearly articulate the relationship between maintenance resource investments and associated LOS focuses the organization on a common objective.

These recommendations have yet to be implemented by USACE.

DRAFT MAINTENANCE MANAGEMENT IMPROVEMENT PLAN⁴³

The text below in italics is from the Draft Maintenance Management Improvement Plan report.

The purpose of this document is to guide the implementation of a [national] approach to planning, executing and documenting maintenance for USACE real and personal property assets. As a part of the Headquarters USACE Asset Management initiative, this effort will align with life-cycle asset management principles.

Accordingly, Maintenance Management goals are expressed through five organizational expectations initially aimed at the Operating Project Manager or activity level but applicable at each level of the organization.

1. INVENTORY: *Maintenance Managers must know and understand their project asset inventory of both real and personal property. They must be able to articulate how each asset contributes to the mission of the project down to the critical component level (inventory, mission, and priority/criticality).*

2. *CONDITION: Managers must know and understand the condition of each asset down to the critical component level and be able to articulate how that condition affects the ability of the asset and the project to perform its mission (condition, risk).*

3. *RESOURCES AVAILABLE: Managers must know and understand all of the resources available to the project for routine and non-routine operations and maintenance (funding, people, and assets), and be able to articulate the maintenance activities and their associated costs supported by those resources to the asset and critical component level. This includes maintenance activities supported by operations and other sources (resources, activities and associated costs).*

4. *RESOURCES NEEDED: Managers must know and understand what resources are required to adequately maintain the project assets throughout the entire life span of the project. This includes recapitalization required to continue to meet the project's mission.*

5. *MANAGING THE GAP: Managers must be able to articulate the management decisions regarding the project maintenance activities that result from the resources available to the project not being sufficient to adequately maintain the project. Managers should be able to articulate the consequences of those decisions.*

According to the report, these five operational expectations are in the process of being implemented.

MINIMUM FLEET CAPITAL INVESTMENT PLAN, 2012-2061⁴⁴

The Minimum Fleet Capital Investment Plan report documents the development of a capital investment plan for the USACE's fleet of dredging vessels. The report documents that the current minimum fleet operation is not sustainable. This report, while focused on a very specific asset category, uses a lifecycle approach that is consistent with the asset management principles described above in the International Infrastructure Management Manual.

COMPARISON OF USACE APPROACH TO BEST PRACTICES

INTRODUCTION

The USACE approach to asset management is the strongest of any U.S. federal agency, and does incorporate most of the best practices today. It is generally consistent with the requirements of PAS-55, and is expected to comply with the upcoming ISO 55000 Asset Management standards. Developing such a program has been a huge effort and the USACE is to be commended for the effort so far. However, there are significant opportunities for the addition of other best practice elements that could be incorporated into the USACE asset management effort that would elevate it to the highest level.

Information from PAS-55, the IIMM, NGI, and other sources has been consolidated into a series of best practice strategies below. Each strategy component has been evaluated with respect to its adoption by the USACE.

As described in the section above, the OCA/ORA process is the foundation upon which the USACE asset management program is based. It incorporates many of the elements of the best practices in asset management, including the following:

- Development of Operational Condition at a component level (OCA).
- Definition of the probability of failure (PoF) of the component.
- Definition of the relative important of the component to the overall mission.
- Definition of the economic consequence of failure (CoF) of the component.

The effort to fully deploy this process is ongoing, and according to the PgMP, expected to be completed by fourth quarter of fiscal year 2013. Assuming that it can be performed in a consistent fashion across the USACE portfolio, the OCA/ORA process does appear to provide a valid set of inputs into the asset management process, but does not incorporate all of the best practices identified in this document. The following section documents the elements of best practices and how they could be included in the USACE's asset management strategy.

CONSOLIDATED BEST PRACTICES

PART 1 - DEFINE REQUIREMENTS

The requirements for asset management define the processes, procedures and operational components of the core of the implementation. If any of these components are not included in an asset management implementation, that implementation will be logically inconsistent and will fail to meet its goals. Each of the best practice asset management requirement components are described below, and compared to the current USACE practice.

DEFINE USER-BASED LEVELS OF SERVICE

While the PgMP does include an element of defining which assets are critical to mission success, this is only one element of developing a quantified assessment of customer expectations. While in some cases, the USACE has incorporated the strategy of comprehensively managing the desired levels of service (hours of availability, condition of facilities, percent of down time, etc.) of its infrastructure

components in its existing asset management program, this approach is not universal. While in some cases USACE measures service levels such as megawatts of power produced or hours of service, level of service data is not gathered consistently for this purpose. Without working with users of the assets to define desired levels of service, the USACE is unable to document the priorities of the various users of its infrastructure, and so is unaware of many of the situations in which tradeoffs in availability and performance might be acceptable.

Although the USACE has spent considerable effort defining the concept of value to the nation (VTN) that is derived from its assets, VTN does not document the critically important levels of service information, which can only be defined based on the needs of the users. The lack of a process to track and measure levels of service is an important gap in the existing strategy, and will require a process of ongoing communications with the users of its infrastructure and services. Note that this recommendation is consistent with the recommendations of the USACE Strategic Maintenance Management report and the draft Maintenance Management Improvement Plan.

DEVELOP USER-BASED PERFORMANCE MEASURES

Performance measures are defined goals for user-based levels of service (e.g. the hydro facility will generate X MW of power 98 percent of the time over a given fiscal year). It does not appear that the USACE has developed a set of comprehensive performance measurements to define the levels of service as perceived by the users of their assets. This strategy component, which is the next step after service levels are developed, is an essential means to document the performance of the USACE's infrastructure versus the expectations of users. Performance measures define targets to be achieved that are consistent with level of service expectations as defined by users. They differ from Government Performance and Results Act (GPRA) performance measures, which are focused on internal measures of efficiency and effectiveness. Defining these measures provides the foundation for the decision making elements used in the development of strategy alternatives. Note that this recommendation is consistent with the recommendations of the USACE Strategic Maintenance Management report and the draft Maintenance Management Improvement Plan.

PERFORM ONGOING DEMAND MODELING

Demand modeling requires the performance of engineering analyses regarding the expected future demands on the infrastructure. While the USACE does perform extensive demand modeling at the time of new project planning, the uses and demands on infrastructure often change over time in unanticipated ways. In cases where the use of the infrastructure has evolved significantly from the original mission, or the demand has changed significantly, it would be prudent to include an element of revised demand modeling in the asset management program so as to take into account these changes over time and more accurately reflect the benefits derived. The effort to perform this demand modeling could also integrate with a process to calculate updated VTN based on the changes in demand or mission that occur over time.

REFINE AND INTEGRATE EXISTING ASSET INVENTORY

The USACE has developed multiple asset databases within many software products, many of which are not consistent with each other (even within individual business lines), and which are not interconnected into a single data repository. The asset management team has recently developed the first comprehensive geospatial inventory of USACE assets and projects that links to these existing databases and projects. Detailed inventories of some assets, their components, repair histories, and other details are contained in the USACE's Facilities and Equipment Maintenance (FEM) system, although it is not consistent. This data, which is used operationally to manage the facilities and equipment, is not generally used for downstream decision making regarding repair/rehabilitate/replace decisions. The PgMP describes how the Civil Works Strategic Investment Framework (CW-SIF) is intended to provide the mechanism to integrate this information into a more comprehensive information framework, but elements of that framework itself (databases, table structures, integrations, etc.) are not yet well defined. Long-term improvements in the FEM database (more

complete, accurate, and current) as well as annual updates and improvements to the geospatial data (including updating linkages to USACE databases and adding additional databases) is needed and should be part of the implementation plan. Note that this recommendation is consistent with the recommendations of the draft Maintenance Management Improvement Plan, but adds to them.

STANDARDIZE THE ASSESSMENT OF ASSET CONDITION

The planned OCA implementation as defined in the PgMP is attempting to define these processes with the goal that they be deployed in fourth quarter fiscal year 2013. It is important that the planned OCA implementation is comprehensive and consistent enough to allow data to be combined, consolidated, and normalized across asset types, business lines, and other operational purposes (e.g. dam safety).

STANDARDIZE THE IDENTIFICATION OF BUSINESS RISK EXPOSURE

The USACE currently uses a risk-informed perspective to manage its assets. The PgMP describes the use of a sophisticated risk analysis, based on the concept of multi-purpose assets. It further describes the guidelines for the national asset management product team, which includes the full OCA/ORA framework. While this framework appears to incorporate all of the concepts of Business Risk Exposure, it will be important that this effort produce consistent results across asset types and business lines. Ultimately, quantification of business risk exposure must incorporate a synergistic combination of complete loss of service, partial loss of service, and safety considerations.

PART 2 - DEVELOP LIFECYCLE MANAGEMENT STRATEGIES

While the requirements described above are the inputs into an asset management process, the strategies below are where the operational decision making occurs and the resulting benefits are achieved. Each of the best practice asset management strategies are described below, and compared to the current USACE practice.

DEVELOP OPERATIONAL STRATEGIES

Asset management is a complex undertaking that involves virtually every part of an organization, and requires tradeoffs between multiple potential alternative solutions. The operational strategies that underlie the decision making processes are critical to the development of the foundational strategies for asset management. While the Civil Works Strategic Investment Framework (CW-SIF) documents the need for data mining techniques and the development of decision support tools, it does not explicitly define the criteria for decision making that incorporates Benefit Cost Analysis, Multi-Criteria Analysis, risk sensitivity, and systems theory. Information such as incremental user benefits, current replacement costs, rehabilitation costs, and consequence of failure costs must all be captured and maintained. While a method to incorporate many of these factors has been demonstrated for Inland Navigation, similar efforts have not been undertaken for other business lines. Developing and refining these strategies may be the most important and most difficult part of implementing asset management for the USACE.

UPDATE MAINTENANCE STRATEGIES

Maintenance activities are performed and managed today as a primarily stand-alone function within USACE, and is not fully integrated into asset management decision making. As the asset management program is more fully developed, it is critical that maintenance be optimized to support lifecycle operations, that advanced information such as performance history, failure modes, and lifecycle cost be captured on every asset, and that maintenance techniques such as Root Cause Failure Analysis be incorporated into the asset management program to optimize costs. This is an important element in improving the ability to reliably predict component failures and optimize the application of resources. Note that this recommendation is consistent with the recommendations of the draft Maintenance Management Improvement Plan.

SUPPORT DEVELOPMENT OF NORMALIZED CAPITAL INVESTMENT STRATEGIES

The development of normalized, consistent data will lead to the development of a much more effective, consistent, and defensible set of capital investment strategies that will ultimately turn into budget justification recommendations. A fully integrated asset management process will be able to link the functional needs as defined by the public with the USACE's ability to support those needs based on allocated funding, and the consequences associated with various funding and operating scenarios. This process will provide a direct correlation between dollars expended and value received, therefore providing the means to optimize the dollars expended to achieve the greatest value.

SUPPORT DEVELOPMENT OF UPDATED FUNDING STRATEGIES

While the development of funding strategies (alternative financing, etc.) is beyond the scope of the asset management effort, the incorporation of a comprehensive best-practices asset management solution will have a dramatic impact on the operations of the USACE and will be the means to accomplish much of the planned Civil Works Transformation. The comprehensive asset management process will provide critical information to support the value to the nation effort, greatly improve the annual budgeting process, and define candidates for systems that may be divested or privatized (assuming that such authority will exist).

PART 3 - IMPLEMENT ASSET MANAGEMENT

Given the broad and deep focus of asset management within an organization's operations, one of the greatest implementation challenges is the human element. The components of the asset management strategy described below define the implementation processes.

EMPOWER TEAMS

The PgMP describes, in some detail, the teams that have been empowered to implement asset management for the USACE and their responsibilities. Based on the information described above in this report, it is not expected that substantial changes would be needed, other than to incorporate the new ideas presented here.

DEVELOP DETAILED PLAN

The PgMP is a detailed plan based on the approach that is in place at the USACE. If the USACE adopts the recommendations contained in this report, the plan will be impacted, but the core elements will remain as documented.

FULLY EMPLOY ASSET MANAGEMENT TECHNOLOGY

Employing asset management includes developing and deploying the technology needed to manage the massive amounts of information required to make such a system operate smoothly. While the PgMP does define some aspects of technology that are required, the details are unclear. As part of the asset management planning that has yet to occur, a much more detailed technology plan will also be developed. Implementing the asset management technology elements (databases, software applications, integration with existing systems) will be a significant effort by itself, but it must follow the development of the strategies described in Part 2, above.

DEVELOP QUALITY MANAGEMENT SYSTEM FOR ASSET MANAGEMENT

The PgMP does not provide much documentation regarding the development of a quality management system that will ensure that the asset management program is based on documented, repeatable, and effective processes across the organization. Such a program should be included in the overall asset management program. This element is not documented in the PgMP, and should be added to the overall program.

ENABLE CONTINUOUS IMPROVEMENT

Once an asset management program is established, the work does not end. Processes, results, and outcomes must be monitored and regularly re-assessed to be sure they are effective, and adjusted if necessary. This continuous improvement component must be defined and included in the asset management program from the beginning.

RECOMMENDATIONS

INTRODUCTION

Asset management is currently housed within Civil Works Headquarters operation, and is practiced in a somewhat inconsistent pattern across the multiple business lines, divisions, and districts within USACE. As part of the Transformation Initiative within USACE, asset management can ultimately become completely embedded within the operations of the USACE such that it will become the operational framework of a sustainable Civil Works organization. However, this will not occur all at once. Given the amount of change that is anticipated, and the degree to which any organization resists change, implementation must take place in multiple stages and over a multi-year timeframe.

The text below describes the recommendations for changes to the existing asset management PgMP, and a potential staged implementation plan.

RECOMMENDED BEST PRACTICES CHANGES TO EXISTING ASSET MANAGEMENT PLAN

The PgMP for asset management is a well thought out plan that incorporates most of the critical elements of asset management. However, it is missing a number of key components which should be incorporated into an amended version of the plan. The following best practices changes are recommended to be included in the amended plan:

1. Include a plan to define qualitative levels of service and performance measures for all projects/business lines, where maintenance is defined in terms of levels of operation. This will require development of means of defining levels of service by business line, and extensive communication with stakeholders and users of the USACE infrastructure to gather the data.
2. Incorporate demand modeling into the asset management benefit analysis where appropriate, using information from the VTN process. The result of this will be an accurate and consistent (assuming that the VTN process was both) calculation of the benefits of each project.
3. Incorporate a plan for completion and maintenance of a comprehensive, integrated asset inventory. Organizational policies and procedures, and advanced technology must be utilized to enable the inventory to be comprehensive, accurate, and current. This inventory must be both geographically (through GIS technology) and hierarchically based so that data can be rolled up from a component to an asset to a project to a system.
4. Using the information from the steps one through three above, develop an interim OCA process that can be fully deployed within one year. Concentrate on developing some measure of condition for every major component for every asset as soon as possible. Begin with simple qualitative condition measures (rating A-F) until the more quantitative OCA process is complete for all assets. Over time this can be expanded to incorporate more advanced condition assessment methodologies, but it is more important to have generalized data on all assets than specific data on some assets.
5. Develop the operational decision making criteria defined in the Civil Works Strategic Investment Framework (CW-SIF) for basic lifecycle investment decisions based on levels of service, VTN (benefits), asset inventory, risk, cost, and asset condition. Base strategies on existing data that can

be obtained from existing sources and databases described above so that no additional data calls are needed.

6. Begin to include integration of maintenance strategies into the asset management framework as defined in this document. This includes incorporating the day-to-day Facilities and Equipment Maintenance (FEM) results to adjust asset lifecycle projection Weibull curves by asset type, and using the results of planned lifecycle replacement timing to optimize day-to-day maintenance. Note that this recommendation is consistent with the recommendations of the draft Maintenance Management Improvement Plan, but adds to them.
7. Begin incorporating continuous improvement methods into the asset management process. This includes continuously refining the business risk exposure, which incorporates loss of service, reduction in service, and safety considerations. Revisit and redefine the asset management and budgeting strategies based on the overarching Civil Works Transformation effort and including other related endeavors such as innovative financing and value to the nation initiatives.
8. Throughout the process, include the amended and more detailed elements of the plan and define clear roles and responsibilities for the implementation teams. Reduce, modify, and/ or expand roles as needed, ensuring district and MSC representation as much as possible.
9. Once the initial asset management implementation has been established, develop an updated comprehensive implementation plan that provides a roadmap to further improve the process over the next five year timeframe.
10. Research existing asset management technology that is being developed by both the USACE and the private sector. Define anticipated needs for new asset management technology and develop preliminary plan with Engineer Research and Development Center (ERDC) to obtain and deploy these new advances.
11. Develop a quality management system for asset management. Formalize the incorporation of quality management concepts into the entire asset management process.
12. Define the Key Performance Indicator (KPI) target values that will allow monitoring the effectiveness of asset management and enable continuous improvement. Develop a process to raise the target values to match or exceed industry standards as performance improves.
13. Investigate the potential to incorporate serious gaming (simulation) techniques into risk-based decision making regarding lifecycle asset management. The USACE has developed a number of tools that use a watershed based approach to define and document assets. The combination of watershed-based management and serious gaming based simulation techniques could be the foundation for better decision-making tools that could be much more effective in managing risk-based decisions. This may best be accomplished by modification and integration of existing information systems, including those currently owned by USACE, rather than the development of completely new software products.

The effort needed to modify the Program Management Plan to incorporate these concepts is significant, but with support from senior leadership, this task could be accomplished in approximately six months. Assuming a start time of second quarter fiscal year 2013, the effort could be complete in fourth quarter fiscal year 2013.

POTENTIAL STAGED IMPLEMENTATION PLAN

There are many possible approaches that could be used to implement asset management over time. While the development of a specific implementation plan is beyond the scope of this effort, one

example of a potential staged implementation plan is described below. It is expected that each of these stages could be implemented within a 24 month timeframe, or possibly less. Assuming the steps are run sequentially, full implementation is expected to take up to six years. Note that there is overlap between the stages described below and the existing asset management PgMP and the Maintenance Management Improvement Plan (MMIP), both of which are in flux, although the recommendations contained in this document generally are additive to those efforts.

As the process occurs over time, the USACE could utilize an independent organization to perform periodic audits using the Capability Maturity Matrix (CMM) as developed by the Institute for Asset Management to gauge progress. This would also prepare for eventual ISO certification that could be pursued once the work of the ISO 55000 committee concludes and the standard is published (not until 2014).

STAGE 1: DEVELOP AN INTERIM ASSET MANAGEMENT SYSTEM USING EXISTING DATA

Implement best practices one through five defined above. One immediate result will be a ranking of the value of various USACE projects across the portfolio on a simple qualitative scale (Green/Amber/Red). Information gathered in the VTN process will be used to define benefits, eliminating the need for additional data development at this stage.

As part of this stage, develop linkages between the budget data within the existing USACE databases (OCA) and proposed levels of performance/VTN. Concentrate on using simple condition assessments (combination of quantitative and qualitative measures) from existing business line data and existing procedures. Also develop linkages of these data (OCA, level of service, and VTN) and map them to the geospatial asset inventory.

Use the results of the rankings to define levels of service, benefits, and associated performance measures on a qualitative basis, and evaluate Operations and Maintenance Budget Engineering Circulars (EC) expenditures using this information.

STAGE 2: DEVELOP A COMPREHENSIVE BEST PRACTICES IMPLEMENTATION

Implement best practices six through 10 defined above. Utilize more comprehensive customer involvement measures to generate a more refined understanding of desired levels of service, VTN, and condition assessments. The results will be a more refined documentation of customer-focused performance measures, and the ability to use the information in multi-criteria analysis regarding asset management decisions. This effort will be an extension of the OCA/ORR work already undertaken for the Inland Navigation business line, but will be done in a comprehensive and consistent manner.

The results of this stage will be a fully realized asset management implementation based on the principles of PAS-55 and the IIMM.

STAGE 3: IMPLEMENT ALL ASPECTS OF BEST PRACTICES IN ASSET MANAGEMENT

Implement all remaining aspects of best practices in asset management as defined in this report. This includes all steps one through 13 above, along with additional elements contained in the IIMM (quality management through monitoring of key performance indicators, continuous improvement, fully integrated IT systems, etc.). This stage might involve re-organizing the Civil Works structure to more

closely match the way work will be performed within an asset management framework. Complete implementation of this third level might be many years away, but the process should continuously work toward it.

CORRELATION TO SUSTAINABLE WATER RESOURCES INFRASTRUCTURE INITIATIVE

The recommendations above are fully consistent with the elements of the USACE Strategic Plan, and are specifically appropriate within the sub-themes of Theme 1: Lifecycle Infrastructure Management, as show below:

- Revitalization Plan: this theme is addressed by recommendations one and two above.
- Integrated Systems: this theme is incorporated in the entire set of recommendations described above.
- Adaptable Infrastructure and Green Solutions: this theme is inherently incorporated into the set of recommendations described above.
- USACE Asset Management: this theme is the core of the recommendations of this report.

POTENTIAL OUTCOMES

The USACE already uses sophisticated analyses techniques that assist it in making day-to-day and year-to-year decisions, although, as discussed above, numerous opportunities exist to improve that process. However, the ability to project the long-term sustainable cost of ownership of individual assets, projects, and the portfolio as a whole is not a current capability. If the USACE is to succeed in providing the services needed by the nation, some means of quantifying these costs must be found so that the tough decisions can be made.

There are multiple outcomes that will result from the sustainable comprehensive asset management program as described in this section. Perhaps the most important will be the ability to predict operations and maintenance lifecycle costs over a very long timeframe (20 years+) for every project in the USACE's portfolio, and then to be able to roll up those costs by division, MSC, business line, and for the Civil Works.

This would start with the development of a specific, condition-driven, time-based graph which projects both the costs and risk-adjusted likelihood of providing the intended value to the nation over time **for each asset or combination of assets** similar to that shown in Figure 14 below:

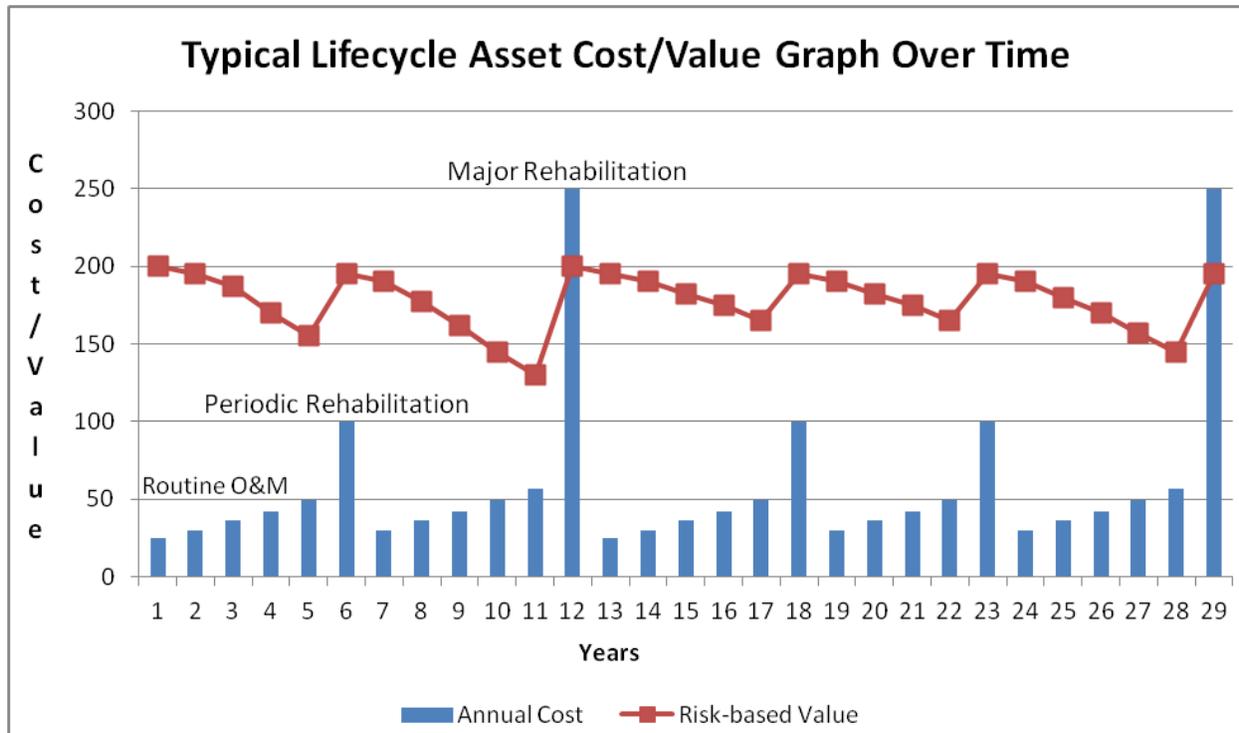


Figure 14: Typical lifecycle asset cost/value graph over time. Source: John Przybyla, Woolpert, Inc.

The asset management process described above would consolidate the information for each asset into a similar projection of lifecycle costs for each project in the USACE portfolio, incorporating routine operations and maintenance costs, periodic rehabilitation costs, major renewal costs, and, when needed, complete replacement costs. This information will also be essential in comparing the long-term cost of ownership to the long-term VTN on a project basis, thereby leading to the development of a list of candidates ranked by their net VTN over time.

Adding up these individual lifecycle calculations leads to an overall chart that can be generated for any organizational level. A typical example is shown below.

The graph in Figure 15 below shows gradually increasing combined portfolio lifecycle cost over time (represented as a range of costs from low to high) along with gradually increasing value over time.

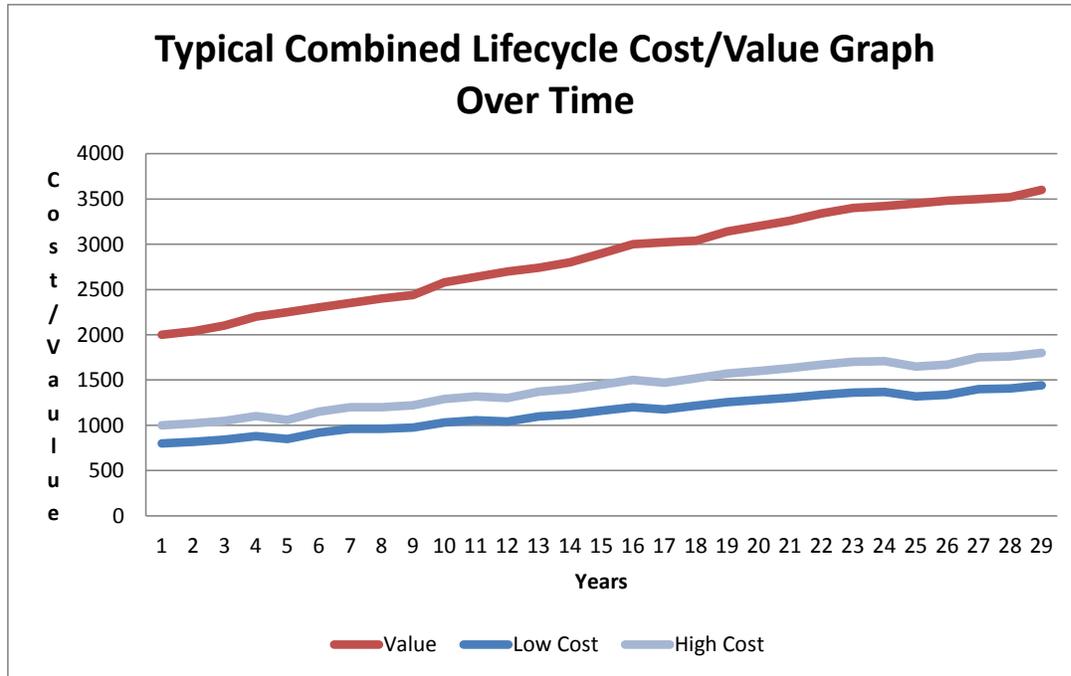


Figure 15: Typical combined lifecycle cost/value graph over time. Source: John Przybyla, Woolpert, Inc.

This information can then be used as information to assist in making the tough decisions regarding the potential for “mothballing”, deauthorizing, or privatizing selected projects and be confident that the USACE will be able to reduce its operations and maintenance costs to a long-term sustainable level. This is essential to the long-term fulfillment of the mission of the USACE.

SUMMARY

The USACE is implementing a comprehensive asset management program that is more advanced and mature than any U.S. federal government agency. However, the program could be enhanced by implementing other organizations’ best practice ideas. This report recommends that the USACE modify its asset management implementation in a staged manner over a number of years to adopt the best practices. This would result in effective and sustainable service to the users of the USACE’s services at the lowest possible lifecycle cost to the citizens of the United States.

APPENDIX A - ASSET MANAGEMENT SOURCE REVIEW DOCUMENTATION

NAME OF ORGANIZATION	Department of Homeland Security - US Coast Guard	Department of Defense - US Navy	Department of the Interior - Bureau of Land Management	Department of the Interior - Bureau of Reclamation	Department of the Interior - National Park Service	Department of Transportation - Federal Highway Administration
Asset Management Program	Real Property Asset Management Manual	Real Property Inventory Procedures Manual	Asset Management	Asset Management	Real Property Asset Management	Office of Asset Management
Type/Date	Document/2001	Document/2008	Document/2009	Document/2008	Document/2006	
URLs/ Addresses	http://www.uscg.mil/	https://portal.navfac.navy.mil/portal/page/portal/NAVFAC/NAVFAC_WW_PP/NAVFAC_HQ_PP/NAVFAC_BDD_PP	http://www.blm.gov/wo/st/en/prog/more/asset_management_print.html	http://www.usbr.gov/assetmanagement/	http://www.nps.gov/policy/DOrders/DOrder80.htm	http://www.fhwa.dot.gov/infrastructure/asmtgmt/
Generalized asset types covered	Land and Facilities	Land and Facilities	Dams, facilities, bridges, roads, facilities, recreation	Dams, hydropower, canals, drains, laterals	Park facilities, roads, bridges, utilities, etc.	Bridges, pavements, tunnels
Asset management strategy maturity	Low	Medium			Medium	High
Success metrics included	No	No	No	No	No	No
Decision support tools included	No	No	No	No	No	No

NAME OF ORGANIZATION	Department of Energy	Environmental Protection Agency	General Services Agency	National Aeronautics and Space Administration	Tennessee Valley Authority	Federal Facilities Council (FFC)
Asset Management Program	Real Property Asset Management Plan	Asset Management: A handbook for Small Water Systems	Asset Management Program	Real Property Asset Management Plan	Enterprise Asset Management	Asset Management Strategies for the 21st Century
Type/Date	Document/2005	Document/2003		Document/2008		Document/2004
URLs/ Addresses	http://energy.gov/management/downloads/doctype-0060-real-property-asset-management-plan	http://water.epa.gov/infastructure/sustain/asset_management.cfm	http://www.gsa.gov/pportal/category/21273	http://www.hq.nasa.gov/office/codej/codejx/	https://supplier.tva.gov/FAQs_SC.html	http://sites.nationalacademies.org/DEPS/FFC/
Generalized asset types covered	Land and Facilities	Water, sewer infrastructure	Land and facilities	Land and Facilities	All	Facilities
Asset management strategy maturity	Medium	Medium	Low	Medium	Unknown	Low
Success metrics included	Includes Asset Utilization Metric	Yes	No	Key Performance Measures	No	No
Decision support tools included	No	Yes - worksheets	No	No	No	No

NAME OF ORGANIZATION	American Public Works Association (APWA)	Association of Metropolitan Sewerage Agencies (AMSA)	National Association of Clean Water Agencies (NACWA)	International Facility Managers Association (IFMA)	Association of Physical Plant Administrators (APPA) (Higher Ed)	New Mexico Environmental Finance Center
Asset Management Program	Facility Asset Management (Part of Public Works Administration)	Managing Public Infrastructure Assets (Asset Management Handbook)	Implementing Asset Management: A Practical Guide	Asset Lifecycle Model for Total Cost of Ownership Management	Facilities Management: A Manual for Plant Administration	Asset Management: A Guide for Water and Wastewater Systems
Type/Date	Document/2007	Document/2002	Document/2007 - Also AMWA and WEF	Document	Document	Document/2006
URLs/ Addresses	www.apwa.net	www.nacwa.org	www.nacwa.org	www.ifma.org	www.appa.org	
Generalized asset types covered	Facilities	Water Utilities, sewer systems	Water Utilities, sewer systems	Facilities	Facilities	
Asset management strategy maturity	Medium	High	High	High	High	Medium
Success metrics included	Yes - FCI	Yes - generic	Yes	Yes, FCI, FOI, other	Yes, FCI, other	Yes - good rules of thumb
Decision support tools included	No	No	Referenced	No	Unknown	Yes - worksheets

NAME OF ORGANIZATION	Maryland Center for Environmental Training	World Association for Waterborne Transportation Infrastructure (PIANC)	Institute of Asset Management (IAM)	European Federation of National Maintenance Societies (EFNMS)	Asset Management Council (Australia)	Institute for Infrastructure Asset Management
Asset Management Program	Asset Management for Wastewater Utilities Train-the-Trainer program	Waterway Infrastructure Asset Maintenance Management (InCom Working Group 129)	PAS 55:2008 - Asset Management	European Asset Management Committee	International Infrastructure Management Manual	No products
Type/Date	Documents	Committee (no products)	Document/2008	Committee (no products)	Document/2011	No products
URLs/ Addresses	http://www.mcet.org/am/am%20toolkit.html	http://www.pianc.org/	http://www.theiam.org/	http://www.efnms.org/	http://www.amcouncil.com.au/ http://www.nams.org.nz/	http://www.infrastructurereinstitute.org/ http://www.giam.org/
Generalized asset types covered	Wastewater infrastructure	Navigation, Ports, Waterways	All	Mechanical Equipment	All	Roadways
Asset management strategy maturity	Medium	N/A	High	N/A	Very High	N/A
Success metrics included	Yes	No	Process to develop	No	Performance indicators, asset life tables	No
Decision support tools included	Yes - software	No	No	No	AM Planning tool online - subscription (NAMS PLUS)	No

NAME OF ORGANIZATION	National Round Table for Sustainable Infrastructure (Canada)	Asset Management Quarterly International (AMQI)	International Organization for Standardization (ISO)	Global Forum on Maintenance and Asset Management (Switzerland)	Next Generation Infrastructures (Netherlands)	Centre for Infrastructure Management (Canada)
Asset Management Program	NRTSI Final Report	Journal of practice	ISO 55000, 55001, 55002 Asset Management	Asset Management Landscape		Asset Management Seminar
Type/Date	Document/2009		2014 (target)	Document/2011	Numerous publications	2009
URLs/ Addresses	http://nrtsi.ca/e/abo_home_.cfm	https://www.amqi.com/	http://www.iso.org/iso/iso_technical_committee.html?commid=604321	http://gfmam.org/	http://www.nextgenerationinfrastructures.eu/	http://commons.bcit.ca/infrastructure/
Generalized asset types covered	All	All	All	All	All	All
Asset management strategy maturity	N/A	High	Unknown	High	High	Medium/High
Success metrics included	No	Maybe	Unknown	Yes	Yes	Yes
Decision support tools included	No	Maybe	Unknown	No	Yes	Yes

NAME OF ORGANIZATION	World Congress on Engineering and Asset Management (Australia)	St. Lawrence Seaway Management Corporation	British Waterways	Federal Ministry of Transport (Germany)	Ministry of Infrastructure and Environment (Netherlands)	Waterways and Sea (Belgium)	Infrastructure Australia
Asset Management Program	Conferences	Asset Renewal Plan	Asset Management Programme	None found	AM mentioned in Annual Report	AM Mentioned in Presentation	Infrastructure Decision Making Guidelines
Type/Date	2011	Document/2011			Document/2010	Document	Document
URLs/ Addresses	http://www.wceam.com/	http://www.greatlakes-seaway.com/en/management/index.html	http://www.britishwaterways.co.uk/our-work/maintenance-and-improvement/asset-management-programme	http://www.bmvbs.de/EN/TransportAndMobility/TransportModes/WaterborneTransport/waterborne-transport_node.html	http://www.rws.nl/en/waterways/main_water_systems/	http://operations.usace.army.mil/nav/10feblocks/VanBesien-20100209LockMaintenanceWorkshop.pdf	http://www.infrastructureaustralia.gov.au/
Generalized asset types covered	All	Locks	Waterways, locks	Waterways, locks, ports	Waterways, dams, locks, levees	Waterways, dams, locks, levees	Water, Energy, transportation, Ports, Broadband
Asset management strategy maturity	Medium/High	Unknown	Unknown	Unknown	Unknown	Unknown	High
Success metrics included	Yes	No	No	No	No	No	No
Decision support tools included	Yes	No	No	No	No	No	Yes

NAME OF ORGANIZATION	Infrastructure Canada	Institute of Water Resources and Hydro Power Research (China)	Public Works Research Institute (Japan)	Korea Water Resources Corporation	Department of Defense - USACE - CERL
Asset Management Program	Building for Prosperity	None	Asset management research on Highway structures	None	BUILDER/ROOFER/MicroPaver
Type/Date	Document		Report/ 2008	Annual Report /2010	Software/Current
URLs/ Addresses	http://www.infrastructure.gc.ca/index-eng.html	http://www.iwhr.com/iwhr99/introduction/e-basic.html	http://www.pwri.go.jp/eindex.html	http://english.kwater.or.kr/	http://www.erdcpub.usace.army.mil/pls/erdcpub/www_welcome.navigation_page?tmp_next_page=52524&tmp_main_topic=
Generalized asset types covered	All	Dams, levees, hydropower	All	Dams, levees, hydropower, water supply, wastewater	Facilities/Roads
Asset management strategy maturity	Medium	Low	Low	Low	High
Success metrics included	No	No	No	No	Yes
Decision support tools included	No	No	No	No	Yes - software

NAME OF ORGANIZATION	Harfan	RIVA	Water Environment Research Foundation (WERF)	Institute for Sustainable Infrastructure (ISI)	Infrastructure Optimization (Woolpert)
Asset Management Program	Integrated Decisions Support System (IDSS)	RIVA Modeling	SIMPLE	<i>envision</i>	Infrastructure Optimization
Type/Date	Software/Current	Software/Current	Rating Tool/2006	Rating System/ 2011	Software/Current
URLs/ Addresses	http://www.harfan.com/eng/home/index2.asp	http://www.rivamodeling.com/solutions/index.aspx	www.werf.org	www.sustainableinfrastructure.org	http://www.woolpert.com/southgate-water-and-sanitation-district-asset-management-implementation
Generalized asset types covered	All	All	Water/ Wastewater	All	All
Asset management strategy maturity	High	High	Medium	Mature, but focused on new projects only	High
Success metrics included	Yes	Yes	Yes	Yes	Yes
Decision support tools included	Yes	Yes	Yes	Yes	Yes

Note: Yes/No information shows that this approach could be applicable to the Specific USACE asset types listed.

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2. Ibid., 7.
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6. Ibid., viii.
7. Ibid., viii.
8. New Zealand Asset Management Support, "International Infrastructure Management Manual," (2001).
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12. Ibid., 2-23.
13. Ibid., 2-23.
14. National Association for Clean Water Agencies, "Implementing Asset Management: A Practical Guide," (2007), 14.
15. Ibid.
16. New Zealand Asset Management Support, 2-78.
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21. Y.C. Wijniaa and P.M. Herdera, "The State of Asset Management in the Netherlands," (2009), 2.
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23. New Zealand Asset Management Support, 4-75.
24. Ibid., 1-6.
25. Ibid., 1-6.
26. Ibid., 4-6.
27. Ibid., 4-6.
28. Ibid., 4-13.
29. Institute of Public Works Engineering Australia, "Water Asset Management Plan," (2010).
30. Ibid.
31. Ibid.
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33. Ibid.
34. Ibid.
35. Ibid.
36. USACE, "Toward Sustainable Water Resources Infrastructure Systems - Draft," (July 2012).
37. USACE, "A Risk-Informed Approach to Asset Management," (2012).
38. Ibid.
39. Ibid.
40. Ibid.
41. Ibid.

42. USACE, "USACE Strategic Maintenance Management," (June 2012)
43. USACE, "Draft Maintenance Management Improvement Plan," (June 2012)
44. USACE, "Minimum Fleet Capital Investment Plan, 2012-2061," (2011)

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- New Zealand Asset Management Support. 2001. "International Infrastructure Management Manual.", 1-99.
- Office of Management and Budget. *Government Performance Results Act of 1993*. (January 5, 1993) *The White House*, <http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m> (accessed October 25, 2012).
- The Institute of Asset Management, "PAS-55." , v, viii.
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- . 2012. "USACE Strategic Maintenance Management."
- . 2012. "Draft Maintenance Management Improvement Plan."
- . 2011. "Minimum Fleet Capital Investment Plan, 2012-2061."
- Wijniaa, Y.C., and P.M. Herdera. 2009. "The State Of Asset Management in the Netherlands." Delft University of Technology, 2.

Institute for Water Resources

The Institute for Water Resources (IWR) is a U.S. Army Corps of Engineers (USACE) Field Operating Activity located within the Washington DC National Capital Region (NCR), in Alexandria, Virginia and with satellite centers in New Orleans, LA; Davis, CA; Denver, CO; and Pittsburg, PA. IWR was created in 1969 to analyze and anticipate changing water resources management conditions, and to develop planning methods and analytical tools to address economic, social, institutional, and environmental needs in water resources planning and policy. Since its inception, IWR has been a leader in the development of strategies and tools for planning and executing the USACE water resources planning and water management programs.

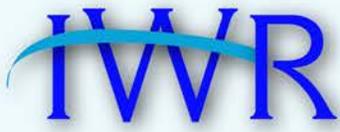
IWR strives to improve the performance of the USACE water resources program by examining water resources problems and offering practical solutions through a wide variety of technology transfer mechanisms. In addition to hosting and leading USACE participation in national forums, these include the production of white papers, reports, workshops, training courses, guidance and manuals of practice; the development of new planning, socio-economic, and risk-based decision-support methodologies, improved hydrologic engineering methods and software tools; and the management of national waterborne commerce statistics and other Civil Works information systems. IWR serves as the USACE expertise center for integrated water resources planning and management; hydrologic engineering; collaborative planning and environmental conflict resolution; and waterborne commerce data and marine transportation systems.

The Institute's Hydrologic Engineering Center (HEC), located in Davis, CA specializes in the development, documentation, training, and application of hydrologic engineering and hydrologic models. IWR's Navigation and Civil Works Decision Support Center (NDC) and its Waterborne Commerce Statistical Center (WCSC) in New Orleans, LA, is the Corps data collection organization for waterborne commerce, vessel characteristics, port facilities, dredging information, and information on navigation locks. IWR's Risk Management enter is a center of expertise whose mission is to manage and assess risks for dams and levee systems across USACE, to support dam and levee safety activities throughout USACE, and to develop policies, methods, tools, and systems to enhance those activities.

Other enterprise centers at the Institute's NCR office include the International Center for Integrated Water Resources Management (ICIWaRM), under the auspices of UNESCO, which is a distributed, intergovernmental center established in partnership with various Universities and non-Government organizations; and the Conflict Resolution and Public Participation Center of Expertise, which includes a focus on both the processes associated with conflict resolution and the integration of public participation techniques with decision support and technical modeling. The Institute plays a prominent role within a number of the USACE technical Communities of Practice (CoP), including the Economics CoP. The Corps Chief Economist is resident at the Institute, along with a critical mass of economists, sociologists and geographers specializing in water and natural resources investment decision support analysis and multi-criteria tradeoff techniques.

The Director of IWR is Mr. Robert A. Pietrowsky, who can be contacted at 703-428-8015, or via e-mail at: robert.a.pietrowsky@usace.army.mil. Additional information on IWR can be found at: <http://www.iwr.usace.army.mil>. IWR's NCR mailing address is:

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