Army Non-Market Valuation

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- Dr. Marc Kodack, Net Zero Water Lead, Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability, ODASA(E&S)
- Ms. Kristen Thomas, Program Manager, ODASA(E&S)
- Mr. Chris Otto, Water Manager, Fort Riley, KS
- Mr. Norm Zukert, Energy Manager, Fort Riley, KS

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EXECUTIVE SUMMARY

This report is a joint deliverable under Subcontract Number: 1353, Task Order Number: CE331.03, from the Project Team (LMI, Concurrent Technologies Corporation (CTC) and Enviance) for Subtask 7, *Final Report on Use of Non-market Valuation (NMV) Methods for Army Water Infrastructure Projects*. Subtask 7 requires the Team to provide a summary of the objectives, approach, results, conclusions, and recommendations based on the other products delivered as part of this Task Order. The Team was contracted by the Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability (ODASA(E&S)) to develop and demonstrate a framework that incorporates NMV principles in the Army's investment process. The project objectives were to:

1. Identify and assess established NMV methods that could be used by Army personnel to enhance the Army's valuation of water-related infrastructure projects;
2. Develop an analytical framework that Army analysts can use to identify and estimate project-related benefits and costs that are not traditionally captured in Army cost-benefit analyses (CBAs);
3. Demonstrate the validity of the NMV framework in a realistic pilot application for a specified water-related infrastructure project;
4. Secure stakeholder feedback with respect to the use of NMV methods in analyzing Army water-related projects; and
5. Provide findings and recommendations on the feasibility, importance, and barriers to incorporating these methods into existing Army project evaluation methods.

This final report summarizes the Task Order Number CE331.03 effort and includes a review of: (1) the NMV methods; (2) a proposed NMV framework for Army infrastructure projects; (3) an explanation of the pilot site project and site selection process; (4) the results from the demonstration at Fort Riley; (5) an analysis of stakeholder feedback; and, (6) recommendations for next steps.

This report shows that NMV methods have the potential to add significant internal (Army) and external (non-Army) information on impacts and related economic values for proposed infrastructure projects. During the Fort Riley NMV demonstration, the Team concluded that the evaluation of non-market values increased the savings-to-investment ratio (SIR) of the project from 0.34 to 0.52 (increase of 53%). These non-market values represented 35% of the total benefit realized by the evaluated project. However, the use of NMV methods is hampered by a lack of awareness by Army personnel, incomplete access to required data, and analytical complexity.

Given the Team's findings, we recommend additional Army efforts to refine and simplify NMV method applications, and finding means to improve access to data. We also recommend that the Army continue to investigate NMV applications through demonstrations at sites with the potential for substantial enhancement to project performance metrics. Finally, we recommend

continued Army support for education and training in NMV methods. This training is necessary to prepare installation, Command, and HQDA staff for using the analysis in project proposals.

1.0 INTRODUCTION

The Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability (ODASA(E&S)) provides strategic leadership, policy guidance, program oversight and outreach for energy and sustainability throughout the Army enterprise to enhance current installation and operational capabilities, safeguard resources, and preserve future options. To improve the funding decisions for water-related infrastructure projects, the Army seeks to identify, evaluate, and test acceptable methods that incorporate the full range of benefits into Army cost-benefit analyses (CBAs). ODASA(E&S) is interested in understanding the value of proposed infrastructure projects that reduce mission risk associated with energy and water supply disruptions and decrease costs associated with environmental-related impacts and liabilities.

ODASA(E&S) is evaluating methods for assessing the benefits not traditionally captured by Army budget analysis. Non-market valuation (NMV) methods can be used to help estimate the total economic value[1] of a proposed water-related infrastructure project. These methods have not been consistently used by the Army, but the potential importance of doing so makes research into their application an important step forward towards more informed project selection.

The Project Team (LMI, Concurrent Technologies Corporation (CTC), and Enviance), was contracted by the ODASA(E&S) to develop a framework that incorporates NMV principles into the Army's project selection process. The project objectives were to:

1. Identify and assess established NMV methods that could be used by Army personnel to enhance the Army's valuation of water-related infrastructure projects;
2. Develop an analytical framework that Army analysts can use to identify and estimate project-related benefits and costs that are not traditionally captured in Army CBAs;
3. Demonstrate the validity of the NMV framework in a realistic pilot application for a specified water-related infrastructure project;
4. Secure stakeholder feedback with respect to the use of NMV methods in analyzing Army water-related projects; and

[1] The total economic value of a water-related infrastructure project is the net change in stakeholder utility (positive or negative) resulting from the implementation of the project. It represents the net present value of all benefits and costs (market and non-market).

5. Provide findings and recommendations on the feasibility, importance, and barriers to incorporating these methods into existing Army project evaluation methods.

This final report summarizes the entirety of the effort and includes: (1) a review of the NMV methods; (2) a proposed NMV framework for the Army; (3) an explanation of the site selection and pilot project process; (4) the results from the demonstration at Fort Riley; (5) an analysis of stakeholder feedback; and, (6) recommendations for next steps.

2.0 BACKGROUND

Historically, the Army's evaluation of water project investments is based on CBAs, which should capture the total costs and benefits to the Army and then compare these with other projects during the proposal evaluation process. CBAs are critical to the funding process as they result in simple metrics that allow for easy comparison of competing projects and communicate tradeoffs to decision makers. Projects are considered for funding if their benefits exceed costs as measured by various metrics, depending on Army funding source guidance. Example metrics include present value, payback period, or savings-to-investment ratio (SIR[2]). SIR was used in the present effort since it is a key metric used by the Army to evaluate water projects supported by infrastructure funding sources.

Army CBA calculations are typically limited to market-based benefits and costs, such as capital expenditures and energy or water cost savings. In general, prices charged to Army water users are based only on the costs of collecting, treating, and distributing water and not on values associated with mission security or costs imposed on external stakeholders due to water use, e.g., reduced availability of water, degradation of ecosystem function. This means that the valuation of an Army water-related infrastructure project based only on market prices is likely to under-estimate the project's actual value. Due to the typically low cost of water, these methods often result in unfavorable results causing water infrastructure projects to not be funded.

Use of NMV methods can therefore be useful for evaluating Army projects that have significant internal or external non-market benefits and costs. Many of these water-related infrastructure projects provide additional benefits to the Army, e.g., water security, improved quality of life, reduced liability, that are not captured by market transactions and thus cannot be estimated using the Army's current analytical methods. However, recent progress in the development and use of NMV methods raises the prospect that these methods could be included in CBAs, potentially improving the comprehensiveness and accuracy of the Army's assessment of a project's value.

[2] SIR = The ratio of the present value of the cash flow savings stream over the economic life time of a project to the present value of the costs of making and maintaining the investment.an energy or water conservation measure (10 CFR 436.21).

3.0 METHODS AND APPROACH

To achieve the objectives of this project, the Team performed the following activities:

1. Conducted a literature review of NMV methods
2. Developed a framework for incorporating NMV into analyses
3. Identified and selected a pilot project
4. Demonstrated the use of the framework for a membrane bioreactor (MBR) project at Fort Riley, Kansas
5. Obtained and analyzed stakeholder feedback
6. Developed recommendations

This section provides an overview of each phase of the framework for development and demonstration of NMV methods. Results from the demonstration, analysis of stakeholder feedback, and recommendations are described in the latter sections of this report.

3.1 Literature Review of Non-Market Valuation Methods

At the onset of this task, the Team conducted a literature review of NMV methods. Three NMV approaches, qualitative, quantitative, and monetary, comprising 17 different NMV methods were identified. Appendix A summarizes the advantages and disadvantages of each.

The advantages and disadvantages of NMV methods predispose each to certain types of water projects. The Team concluded that the ideal NMV method for valuing a water project will depend on the type of project and associated costs and benefits. Consequently, as part of the literature review process, the Team created Army water project classifications to help align groups of projects with the ideal set of NMV methods[3]. Appendix B provides an overview of the Army water project classifications with their associated costs and benefits.

Upon completing the project classifications, the Team used a scoring method to objectively identify the best NMV methods for Army water projects. The scoring process showed that NMV monetary methods consistently result in better scores than other NMV qualitative and quantitative methods. Although some funding mechanisms offer opportunities to incorporate qualitative and quantitative valuation, e.g., Army priorities, monetary valuation is likely the only NMV approach that can be used universally to support project-funding decisions. Due to this broad applicability, the Team recommends that Army analysts use monetary valuation methods whenever possible.

[3] The Team concluded that multiple techniques often should be used to capture all non-market benefits and costs associated with a particular project type.

The monetary valuation approach composes multiple NMV methods (see Appendix A), not all of which are applicable to Army water projects. For example, revealed and stated preference methods are not ideal for use by the Army because they are typically time and resource intensive, require skill sets that budget analysts often lack, are not always scalable at the enterprise level, and can be difficult to integrate with existing Army processes. Cost-based methods are most applicable to the Army's budgetary process because they estimate value using a credit-and-debit system that closely mirrors the Army's traditional cost accounting framework. Cost-based methods also tend to be less time and resource intensive, use installation-specific data that are readily available, and require skill sets that are accessible to analysts completing the analysis.

The four cost-based NMV methods that are most universally applicable to the Army's valuation of water-related infrastructure projects are: damage cost avoided, substitute cost, budget constraint, and replacement cost.[4]

3.2 Framework for Incorporating Non-Market Valuation into Army Project Evaluation

The Team developed a framework for incorporating NMV methods into infrastructure project CBAs. Building upon the NMV method literature review, the steps below provide a structured framework for guiding Army analysts in the selection of appropriate NMV methods.

- **STEP 1. Identify project classification:** There are many types of water-related infrastructure projects that have differing attributes, with different values (benefits or costs) to Army and external stakeholders. The first step towards integrating NMVs into a project CBA is to identify the project type (see Appendix B).
- **STEP 2. Identify relevant benefits and costs:** A project's benefits and costs are directly associated with its project type. Appendix C includes a table of project profiles that can be used to quickly identify market and non-market benefits and costs that are typically associated with each project type. If a project is classified under more than one type, all benefits and costs associated with each relevant project profile should be considered.
- **STEP 3. Choose appropriate NMV method(s):** After identifying all relevant benefits and costs for a particular project, analysts should identify the appropriate NMV method, or collection of methods, to use for estimating the value of those benefits and costs. Appendix C offers

[4] For more information on NMV methods, Army water project classifications, and the NMV method scoring method, see *Final Non-Market Evaluation Assessment Report* from May 2014.

recommended NMV methods for assigning value to these common benefits and costs.

- **STEP 4. Complete NMV and integrate into CBA:** Once the appropriate NMV methods have been identified, analysts should complete the valuation of all relevant benefits and costs. After doing so, all relevant non-market values can be incorporated into the project CBA and combined with more traditional market-based costs to calculate appropriate financial metrics, e.g., savings-to-investment ratio, payback time, net present value.

3.2.1 Incorporating Probabilities into Water-Related Non-Market Valuation

Many of the non-market water-related values identified and quantified using cost-based methods are contingent on whether or not the driver of the cost actually occurs. For example, the substitute cost for an installation's supply of water is only realized when the supply from the original water source has actually been disrupted and use of the substitute source implemented. The probability of the cost occurring may influence the assessment of the non-market value that is derived from the cost.

Risk assessment is a common approach used to incorporate probabilities of future events that affect water availability. Risk assessment provides an integrated decision framework for analyzing the: (1) probability of disruptive (threat or hazard) events occurring; (2) vulnerability of potentially affected water systems; and, (3) consequences if the disruptive event occurs, the net costs and benefits of a loss. A wide range of probabilistic analysis approaches are available for these assessments and the ease and robustness of such methods range from qualitative assessments by subject matter experts to sophisticated econometric models and simulation.

3.2.2 Implementing Risk Assessment for Water-Related Non-Market Valuation

Risk assessment can be a time consuming and challenging process for NMV applications, especially for new situations. At this time, the Team only suggests that analysts consider the availability of resources, e.g. time, funding, and expertise, and data needed to complete a risk analysis to derive value from the results. For qualitative methods, subject matter experts must be available to assess the probability of identified threats, the vulnerability of water systems, and the economic consequences of threat occurrence. For quantitative methods, robust data on historical water shortages, their effects, and expertise in econometrics is needed to assess probabilities and loss consequences for proposed projects. In many cases, limitations in resources or data availability will restrict use of this type of analysis.

3.3 Pilot Project

The Team selected a water project and an Army installation to demonstrate the proposed NMV framework. The selection process was designed to identify a project/installation combination that satisfied the following selection criteria:

1. **Site Collaboration:** Site project personnel must be willing to participate in the pilot study by providing project data and reviewing the demonstration results.

2. **Type of Candidate Projects:** Projects that enhance water supply through the provision of alternative water sources, such as recycled/reclaimed water, rainwater capture, and water storage, are more attractive because a common benefit from these projects is increased water security, which is not captured by traditional market-based cost benefit analysis.

3. **Project Data Availability:** The availability of certain data items will affect the NMV method selected for demonstration. Readily available data that both supports the demonstration and does not increase the burden on the installation personnel is another consideration.

4. **Personnel Availability:** Installation personnel must be available to work together with the Team within the required task schedule.

To begin information gathering on potential demonstration sites, the Team sent a survey to the Army's net zero water pilot sites. Four sites responded to the survey and indicated a willingness to participate further in the project: Fort Riley, Camp Rilea, Joint Base Lewis-McChord, and Tobyhanna Army Depot. Fort Carson was also considered since their net zero water roadmap indicated potentially attractive projects, but this installation did not express an interest in participating in the project. The sites were contacted to discuss the objectives of the task and obtain basic site information. A review of key literature, such as water balances and net zero roadmap studies, was conducted to gather basic installation data.

In addition to site characteristics, available water project information at the responding sites was also reviewed using the above criteria. The Team considered several types of water projects, including water efficiency, rainwater harvest, water and wastewater treatment, and water storage. To align the review effort with interests of higher priority to the Army, the Team recommended a focus on alternative water supply projects.

After evaluating and discussing the four candidate sites, the membrane bioreactor (MBR) project at Fort Riley, KS, was selected. This was based on both the collaborative outlook of site personnel and the high level of Army interest in potential future applications of membrane technology across fixed installations. The MBR is a decentralized biological waste treatment technology that extracts and treats wastewater from sewer lines ("sewer mining") and permits water reuse to fill non-potable needs, such as irrigation or cleaning. The MBR technology has the potential for more efficient wastewater processing than large centralized treatment plants, especially for smaller scale systems that are low maintenance and energy efficient. Decentralized treatment facilities like MBR technology can also increase water security if such a plant is appropriately connected to a critical facility that must always have water treatment as an uninterruptible service. Selection of the MBR at Fort Riley as a demonstration project was approved by ODASA(E&S).

3.3.1. Fort Riley Water Source and Infrastructure Background

Fort Riley is an Army installation in northeastern Kansas on about 100,000 acres near Junction City and Manhattan, Kansas (see Figure 1). Fort Riley's mission is to (1) provide trained and ready forces to meet Joint Force requirements across the full spectrum of current and future operations; (2) transform and manage unit readiness; (3) execute unit re-stationing, as directed by Forces Command; and, (4) conduct homeland defense operations and support civil authorities.

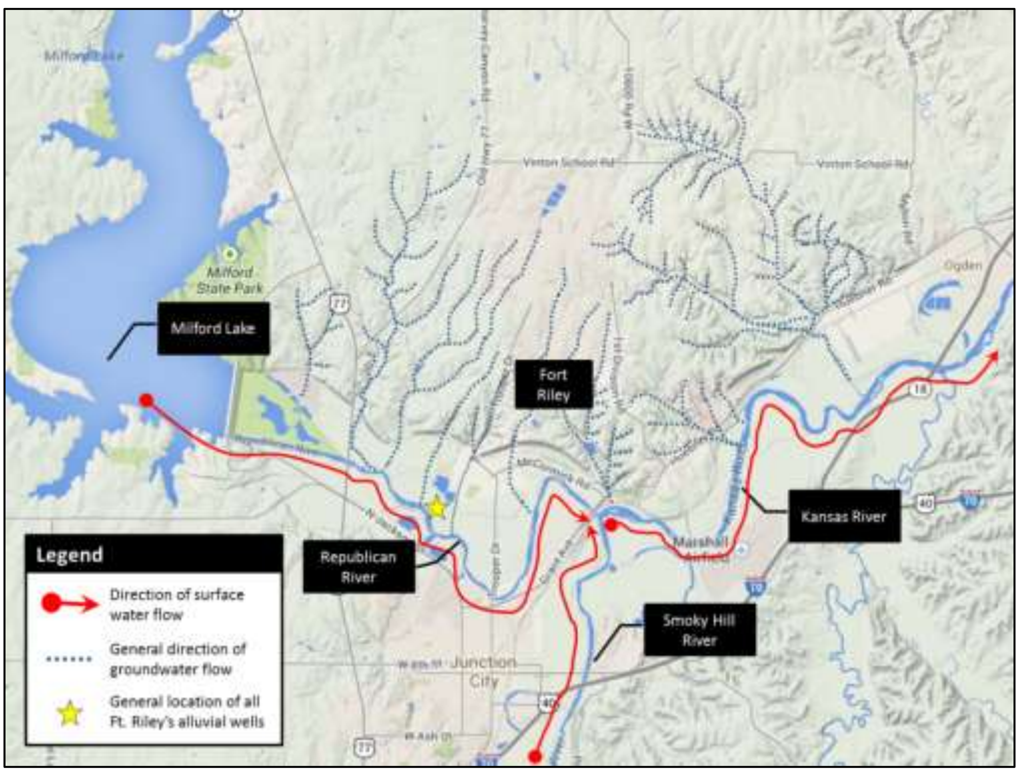

Figure 1. Overview Map Outlining Fort Riley's Sources of Freshwater

Fort Riley withdraws its freshwater from shallow alluvial aquifers that border the Republican River downstream of Milford Lake, but upstream from where the Republican River joins the Smoky Hill River (see Figure

1). Eight groundwater wells in the Camp Forsythe area withdraw freshwater which supplies Fort Riley's central water treatment facility. Withdrawal of water from the Lower Republican River is based on water allocations in the Republican River Compact signed between Colorado, Nebraska, and Kansas. The water allocations are highly disputed between the states.

Fort Riley also handles on-post water treatment with one water treatment plant (WTP) and two wastewater treatment plants (WWTP), one of which is expected to close in the near future. The WTP produces an average of 2 to 3 million gallons (Mgal) per day. The WWTP's discharge eventually goes to the Kansas River.

3.3.2. Description of Fort Riley Membrane Bioreactor Pilot Project

The aerobic MBR at Fort Riley treats wastewater after going through Fort Riley's distribution system and before entering the waste water treatment plant (WWTP) (see Figure 2). The MBR technology is an example of direct sewer mining. The MBR will reduce the amount of water pumped to the WWTP, treated, and returned to the local watershed, which reduces the amount of energy consumed by the WWTP and pumps (see brown line in Figure 2). Instead of going to the WWTP, water leaving Fort Riley's distribution system will go to the MBR for treatment and then be pumped to the settling basins (see purple dotted line in Figure 2). From the settling basins, water goes to the transfer station and eventually arrives at the installation vehicle wash facility (IVWF) for use. Water from the IVWF is returned to the settling basins before repeating the same closed-loop cycle. Water loss occurs at the settling basins through evaporation and infiltration. To make up for this, Fort Riley diverts potable water from its distribution system to the settling basins (see blue line in Figure 2). Water provided by the MBR (see purple dotted line) will replace water loss from the settling basins due to evaporation and infiltration, thereby eliminating the need to use potable water (see blue line). As a result, the MBR reduces the amount of water withdrawn from groundwater sources and treated in the water treatment plant (WTP).

Fort Riley faces a number of long term water challenges which include growing water demand, increased risk of drought, disputed surface water rights in the Lower Republican basin, aging distribution infrastructure, forecasted climate change effects, water shortages in the face of increasing regional population, and a water recharge shortage that is projected to continue into the future. The MBR offers Fort Riley mission-oriented value by providing the capability to reuse wastewater in mission-critical applications. As such, the MBR technology has the potential to mitigate risk associated with potable water depletion and infrastructure failure.

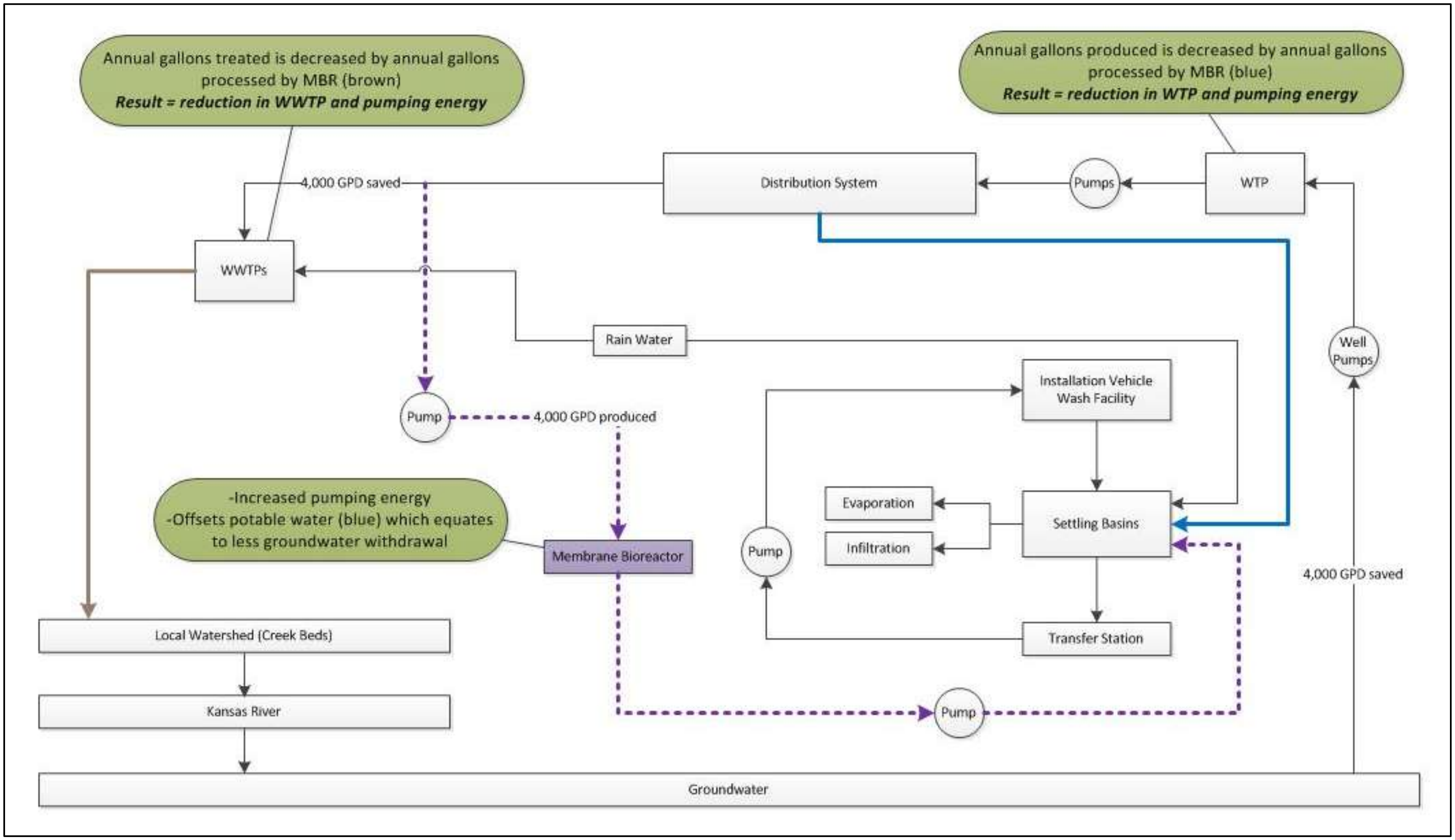

Figure 2. Flow Diagram of Fort Riley's Water Infrastructure and the MBR

3.4 Use of the NMV Framework for the Pilot Project

After selecting the MBR project at Fort Riley, the Team applied the proposed framework for incorporating NMV methods into the Army's CBA process. This section summarizes the actions taken by the Team to demonstrate the use of the NMV framework for the Fort Riley case study. It follows the steps outlined previously (Section 3.2).

STEP 1. Identify Project Classification: Per the guidance in the *Final Non-Market Evaluation Assessment Report* (May 2014), MBR technologies fall under both quality- and quantity-related project groupings. The quality-related grouping includes water treatment technologies that purify water for human use, e.g., desalination, bioreactors, and returning the water to the environment. The quantity-related grouping includes projects that improve water supply by extracting water from alternative sources, in this case wastewater. As such, the MBR operates under multiple project classifications, which includes (1) on-site water recycling; (2) on-site water treatment/purification; and, (3) on-site wastewater treatment.

STEP 2. Identify Relevant Benefits and Costs: The current pilot MBR at the IVWF has demonstrated the potential for water-supply risk mitigation as well as reduced external impacts. Using the value identification matrix in Appendix C, the Team identified all relevant benefits and costs, market and non-market, associated with the project classifications identified in Step 1. The costs and benefits are summarized in Table 1.

Market-based costs associated with the procurement and maintenance of the MBR were considered. Procurement costs were provided by the installation. The Team also estimated the cost savings associated with the operation of the MBR. In general, MBR technology results in lower variable costs ($/gal) associated with the operation and maintenance of the system. These lower variable costs are mostly due to the MBR's significantly lower energy requirements. However, Fort Riley was unable to provide data for other variable costs associated with the MBR and also for operation of the baseline WTP and WWTP facilities. As a result, the Team conducted a literature review to capture a range of variable costs associated with existing water and wastewater treatment technologies and the new MBR technology.

Table 1. Relevant Value Indicators (Benefits and Costs) for the MBR

Value Classification	Value Indicator	Value Description	Considered in this analysis
Value captured in a typical CBA	1. Capital Cost (Internal)	The cost to acquire and install the MBR system.	YES
	2. Reduced WTP and WWTP Operating Costs (Internal)	The MBR reduces processing volumes for water and wastewater based on reductions in water withdrawn from primary sources and treated in both water and wastewater treatment facilities. Also includes reduced water and wastewater pumping.	YES
Internal value from water security aspects	3. Reduced Risk of Supply Disruption (Internal)	**Diminishing Groundwater Replenishment:** Any water consumed by the Army, not returned back to source, depletes groundwater reserves. The rate of extraction in the local watershed is currently outpacing the rate of replenishment. As such, any reduction in the current rate of extraction reduces the risk of water disruption in the future.	YES
		Legal Agreements: The Lower Republican River and associated alluvial aquifer certainly may be affected by the withdraw rates of any users of groundwater and surface water systems in the Republican River watershed and variations to aquifer recharge rates.	NO
		Infrastructure Capacity Limits and Failure: With the MBR in place, the IVWF is no longer at risk of water supply shortages due to WTP processing capacity constraints or failure. Furthermore the MBR reduces processing burden on both the WTP and WWTP.	NO
		Pollution: As a decentralized waste/wastewater treatment unit, the MBR makes the IVWF less vulnerable to polluted groundwater wells not directly tied to the facility. However, out of the roughly 50 species of water pollutants, e.g., chemical discharges and farmland runoff, present in the local watershed, only 3 could be treated by the MBR unit. Therefore, the Team concluded that the MBR unit would not reduce risk of pollution.	YES
Value captured through externalities	4. Reduced Human Health Effects (External)	The reduction of water consumption and the energy required for water processing (WTP and WWTP) reduces the risk of impacts to human health associated with (1) reduced water supply in the region and (2) emissions from energy consumption (on-site and off-site).	YES
	5. Reduced Biodiversity Impacts (External)	The reduction of water consumption and the energy required for water processing (WTP and WWTP) reduces the risk of impacts to ecosystem health associated with (1) reduced water supply in the region and (2) emissions from energy consumption (onsite and offsite).	YES
	6. Reduced Effects to Resource Productivity (External)	As conventional non-renewable sources of energy (fossil fuels) are depleted, increased extraction from unconventional sources will be required to meet the world's steeply increasing demand for such energy. The increased energy intensity reduces the economic productivity of each additional energy unit extracted, which results in a cost to society. The reduction of water consumption also reduces embedded energy consumption.	YES
	7. Reduced Climate Change Effects (External)	The energy embedded in all of Fort Riley's water use generates greenhouse gas (GHG) emissions. These GHG emissions contribute to global warming, which ultimately leads to incremental climate change that result in economic damage.	YES

Table 1. (cont') Relevant Value Indicators (Benefits and Costs) for the MBR

Value Classification	Value Indicator	Value Description	Considered in this analysis
Internal value from water security aspects	8. Reduced Risk of Supply Disruption (Internal)	**Diminishing Groundwater Replenishment:** Any water consumed by the Army that is not returned back to source depletes groundwater reserves. The rate of extraction in the local watershed is currently outpacing the rate of replenishment. As such, any reduction in the current rate of extraction reduces the risk of water disruption in the future.	YES
		Legal Agreements: The Lower Republican River and associated alluvial aquifer may be affected by the withdraw rates of any users of groundwater and surface water systems in the Republican River watershed as well as by variations in aquifer recharge rates.	NO
		Infrastructure Capacity Limits and Failure: With the MBR in place, the IVWF is no longer at risk of water supply shortages due to WTP processing capacity constraints or failure. Furthermore, the MBR reduces processing burden on both the WTP and WWTP.	NO
		Pollution: As a decentralized waste/wastewater treatment unit, the MBR makes the IVWF less vulnerable to polluted groundwater wells not directly tied to the facility. However, only 3 of the roughly 50 species of water pollutants (e.g., chemical discharges and farmland runoff) present in the local watershed could be treated by the MBR unit. Therefore, the Team concluded that the MBR unit would not reduce risk of pollution.	YES
Value captured through externalities	9. Reduced Human Health Effects (External)	The reduction of water consumption and the energy required for water processing (WTP and WWTP) reduces the risk of impacts to human health associated with (1) reduced water supply in the region and (2) emissions from energy consumption (on-site and off-site).	YES
	10. Reduced Biodiversity Effects (External)	The reduction of water consumption and the energy required for water processing (WTP and WWTP) reduces the risk of impacts to ecosystem health associated with (1) reduced water supply in the region and (2) emissions from energy consumption (onsite and offsite).	YES
	11. Reduced Impacts to Resource Productivity (External)	As conventional non-renewable sources of energy (fossil fuels) are depleted, increased extraction from unconventional sources will be required to meet the world's steeply increasing demand for such energy. The increased energy intensity involved in the extraction of unconventional sources reduces the economic productivity of each additional energy unit extracted, which results in a cost to society. The reduction of water consumption also reduces embedded energy consumption.	YES
	12. Reduced Climate Change Effects (External)	The energy embedded in all of Fort Riley's water use generates greenhouse gas (GHG) emissions. These GHG emissions contribute to global warming, which ultimately leads to incremental climate change, resulting in economic damage.	YES

Table 1. (con't) Relevant Value Indicators (Benefits and Costs) for the MBR

Internal value from water security aspects	13. Reduced Risk of Supply Disruption (Internal)	**Diminishing Groundwater Replenishment:** Any water consumed by the Army that is not returned back to source depletes groundwater reserves. The rate of extraction in the local watershed is currently outpacing the rate of replenishment. As such, any reduction in the current rate of extraction reduces the risk of water disruption in the future.	YES
		Legal Agreements: The Lower Republican River and associated alluvial aquifer may be affected by the withdraw rates of any users of groundwater and surface water systems in the Republican River watershed as well as by variations in aquifer recharge rates.	NO
		Infrastructure Capacity Limits and Failure: With the MBR in place, the IVWF is no longer at risk of water supply shortages due to WTP processing capacity constraints or failure. Furthermore, the MBR reduces processing burden on both the WTP and WWTP.	NO
		Pollution: As a decentralized waste/wastewater treatment unit, the MBR makes the IVWF less vulnerable to polluted groundwater wells not directly tied to the facility. However, only 3 of the roughly 50 species of water pollutants (e.g., chemical discharges and farmland runoff) present in the local watershed could be treated by the MBR unit. Therefore, the Team concluded that the MBR unit would not reduce risk of pollution.	YES
Value captured through externalities	14. Reduced Human Health Effects (External)	The reduction of water consumption and the energy required for water processing (WTP and WWTP) reduces the risk of impacts to human health associated with (1) reduced water supply in the region and (2) emissions from energy consumption (on-site and off-site).	YES
	15. Reduced Biodiversity Effects (External)	The reduction of water consumption and the energy required for water processing (WTP and WWTP) reduces the risk of impacts to ecosystem health associated with (1) reduced water supply in the region and (2) emissions from energy consumption (onsite and offsite).	YES
	16. Reduced Effects to Resource Productivity (External)	As conventional non-renewable sources of energy (fossil fuels) are depleted, increased extraction from unconventional sources will be required to meet the world's steeply increasing demand for such energy. The increased energy intensity involved in the extraction of unconventional sources reduces the economic productivity of each additional energy unit extracted, which results in a cost to society. The reduction of water consumption also reduces embedded energy consumption.	YES
	17. Reduced Climate Change Effects (External)	The energy embedded in all of Fort Riley's water use generates greenhouse gas (GHG) emissions. These GHG emissions contribute to global warming, which ultimately leads to incremental climate change, resulting in economic damage.	YES

In terms of enhancing water supply, the IVWF MBR offsets roughly 4,000 gallons per day (GPD) of potable water that otherwise would be extracted from groundwater and treated by the WTP. Additionally, this unit offsets roughly 4,000 GPD of wastewater treated by the WWTP and returned to the local watershed. As such, the MBR reduces or eliminates freshwater demand for vehicle maintenance at the IVWF, allowing this water use application to continue during freshwater supply disruptions as long as the waste-water supply stream required by the MBR is available. The mission-oriented value arises from providing a water source that alleviates the need to withdraw groundwater, thereby extending water resources that can be diverted to mission-critical uses in times of need.

In addition to preserving mission assurance, the MBR provides other non-market internal and external benefits. Reducing the installation's rate of water consumption directly increases the rate of aquifer replenishment which has internal and external benefits, e.g., increased availability of water and reduced effects to biodiversity. In addition to saving water, the energy savings resulting from MBR implementation have benefits that are both direct, e.g., reduced energy costs, and indirect, e.g., reduced impacts on energy resources, human health, biodiversity and climate change. Anaerobic MBR's save more energy than aerobic MBRs and can even be energy neutral if the methane produced is captured and used. In this project, the produced gas is not being captured, so this potential benefit was not included in the analysis.

STEP 3. Choose Appropriate NMV Method(s): Using the value identification matrix in Appendix C, the Team identified appropriate NMV methods for estimating the values identified in Step 2. The analysis demonstrated three widely used NMV methods that are attractive for Army use because they estimate value using a credit-and-debit system that mirrors the Army's current cost accounting framework. The three methods—Substitute Cost, Indicator, and Benefit Transfer methods—are summarized below:

- **Substitute Cost Method:** This method estimates the value of a water-related ecosystem service as the cost of the "next-best source of water," e.g., lowest cost, for the specified water-use application. This substitute cost serves as a proxy value for the benefit that the water as a resource provides to the installation. In the Army's context, this method is applicable to mission-critical uses of water where the water demand is inelastic and the probability is high that a substitute source of water would be used when the primary water source is unavailable. The value of this water is taken to be the cost of the next best source of water, which is assumed to be bulk water delivered by truck. Depleting less water today reduces the risk of water disruption in the future, and the value of this benefit is quantified as the cost of the substitute water that no longer will be needed.

- **Indicator Method:** The indicator method uses scientifically proven natural phenomena to communicate water-related values. Drawing upon peer-reviewed scientific and statistical models, analysts can develop cause-effect relationships that quantify the effect, positive or negative, that is expected from a specific action, e.g., implementing a water-related infrastructure project. Indicators are used to communicate effects that would occur to human health and the environment and are often represented as an effect per activity ratio or metric, e.g., biodiversity lost per gallon of water consumed, human health degraded per gallon of effluent.

  The indicator method is a quantitative NMV method that must be used with a complementary NMV method that converts physical quantities into economic values, e.g., benefit transfer.

- **Benefit Transfer Method:** The benefit transfer method estimates values for ecosystem services by using the results of completed studies in different locations and/or contexts. For example, the value of a watershed may be approximated by using the results of a study conducted on a wetland using other valuation methods. To properly analyze the transfer results, any information used from other studies must be analytically adjusted when there are significant differences in location- or context-specific conditions. In this analysis, the Team used the budget constraint model proposed in Weidema (2009) to convert impact indicators for human health, biodiversity, and energy resource productivity into economic value. The Team also used the Environmental Protection Agency's estimate of the social cost of carbon to determine the economic value of external climate change impacts (EPA, 2013).

STEP 4: Complete NMV Analysis and Integrate into CBA: After identifying the appropriate NMV methods to capture non-market values, the Team derived estimates for these values and incorporated those estimates into the overall CBA to better represent the MBR's total economic value. After doing so, the Team calculated appropriate financial metrics, e.g., savings-to-investment ratio (SIR)[5] and net present value, for communicating the project's value.

3.5 Stakeholder Feedback

Once the demonstration task was completed, the Team obtained feedback from Army installation community personnel regarding the potential for use of NMV methods in the Army budget review process. An initial group of 12 people was identified, although adjustments had to be made due to schedule conflicts or lack of interest in participating. Seven Army members with knowledge and experience

[5] SIR = The ratio of the present value of the cash flow savings stream over the economic life time of a project to the present value of the costs of making and maintaining the investment.an energy or water conservation measure (10 CFR 436.21).

in proposing or reviewing installation water projects did provide feedback. These personnel represented Headquarters, Department of the Army (HQDA), Army National Guard or Office of the Secretary of Defense (OSD) organizations: ODASA(E&S), Office of the Deputy Assistant Secretary of the Army for Strategic Integration (ODASA(SI)), Office of the Assistant Chief of Staff for Installation Management (OACSIM) and OSD Energy Conservation Investment Program (ECIP).

Interview topics and potential discussion questions were developed to understand both the feasibility and usefulness of NMV methods for water infrastructure project evaluations. The interview process was flexible to enable an open discussion from which the respondent's views could be obtained and documented. Example questions are shown in Table 2 by major topic.

Table 2. Example Questions for Stakeholder Interviews

Usefulness of NMV Methods for Water Proposals
1. Would NMV methods provide a useful contribution to strengthening a project's justification for funding? Why or why not?
2. Would NMV analysis estimates be acceptable to Army budget organizations (e.g., G-8 (Resourcing) or the Assistant Secretary of the Army, Financial Management & Comptroller (ASA(FM&C)) in financial evaluations? Why or why not?
3. Should anything be done to make the NMV analysis easier or more successful in helping to fund water projects?
Feasibility of NMV Methods for Water Proposals
1. Is the NMV framework too complex for the installation Department of Public Works (DPW) water personnel? What steps are difficult?
2. Do you believe that field personnel at Army installations would actually use the NMV methods in preparation of project proposals using, for example, Form 1391s (Military Construction)? Why?
3. Do Army proposal evaluators place enough importance on External Project Impacts (e.g., human health, biodiversity, future resource productivity, climate change) to make NMV analysis worth the effort? Why or why not?

A fact sheet that provided an overview of results from the NMV demonstration at Fort Riley was provided to interviewees and used as background information to discuss the NMV demonstration methods and results. Discussion notes were recorded during each interview and compiled for review and analysis.

3.6 Recommendation Development

This study is likely the first comprehensive investigation and evaluation of NMV methods for installations, including a demonstration of their use for valuing Army installation water projects. The final phase of the task focused on developing conclusions and recommendations for (1) additional study of NMV methods; (2) integrating NMV methods into the Army's budget review process; and, (3) follow-on work to improve the prospects for application of these tools for Army water and other infrastructure projects.

4.0 RESULTS

The results and findings from this study are presented in this section.

4.1 Demonstration Results for Non-Market Valuation at Fort Riley

The results of the NMV analysis described in Step 4 of the NMV Framework (see Section 3.4) are shown in Table 3. Seven MBR value indicators are shown in column A of Table 3 to indicate the internal (indicators 1-3) and external (indicators 4-7) MBR impact factors included in the analysis (see Table 1 for definitions). The results are shown in columns F-J. The difference between the project's SIR without NMV results is shown in column F, but the more comprehensive total SIR result, which includes NMV, is shown in column J.

Table 3. Summary of Impact Valuation Results for the Fort Riley MBR

A-Value Factor Description	B-Value Type	C-Valuation Method	D-Discount Rate	E-Value Location	F-Mean Value	G- % Total Savings	H-CBA Analysis	I-Army SIR	J-Total SIR
1. MBR Installation	Capital Investment	Market	Financial	INTERNAL TO FORT RILEY	($358,659)	--	Current Army CBA Results	**0.34**	**0.52**
2. Potable Water, Wastewater Treatment	Operations & Maintenance	Market	Financial		$122,674	65.4			
3. Supply Disruption Risk Effects	Non-Market	Substitute Cost	Financial		$30,446	16.2	NMV CBA Results		
4. Human Health Effects	Non-Market	Indicator and Benefit Transfer	Environmental	EXTERNAL TO FORT RILEY	$2,444	1.3			
5. Biodiversity Effects	Non-Market	Indicator and Benefit Transfer	Environmental		$31,712	16.9			
6. Energy Resource Effects	Non-Market	Indicator and Benefit Transfer	Environmental		$4	0.0			
7. Climate Change Effects	Non-Market	Indicator and Benefit Transfer	Environmental		$390	0.2			
				Total Mean PV Savings[1]	$187,670	100.0			
				Total Mean NPV[2]	**($170,989)**	--			

NOTES:
1-MBR Savings = Present Value (PV) of savings = sum of Rows 2-7
2-NPV = Net Present Value = sum of Row 1-7 (includes capital investment)
3-Columns F – J are based on a Monte Carlo simulation of the Factors in column A to analyze the sensitivity of assumptions and derive an expected value.

4.1.1. Non-Market Valuation Analysis Results

The SIR for this project increases from **0.34** ($122,674 / $358,659) to **0.52** ($187,670 / $358,659), an increase of 53%, when the NMV factors are included in the calculation. This also represents an increase of 38% in mean NPV (from -$235,985 to -$170,989). These gains are not enough to qualify the MBR for funding, e.g., for SIR>1.0, as an ECIP projects.

The Fort Riley NMV analysis shows that traditionally unaccounted for NMV factors (lines 3-7 in Table 3) compose 35% of the total savings generated by the MBR ($64,996/$187,670) . This result represents a significant percentage of the total benefit that would have been neglected if traditional Army project evaluation methods were used (see Table 3). Despite this result, including non-market valuation does not produce a positive NPV for the pilot MBR project [6].

4.1.2. The Potential Contribution from Non-Market Valuation Results in Water Project Evaluation

Table 3 shows that NMV results can significantly increase the SIR calculation and improve the prospects for a project being funded. In this pilot demonstration, the results could have been more favorable for the MBR. Lack of data availability prevented the Team from capturing all non-market value associated with the MBR unit. A sensitivity analysis conducted by the Team showed that 90% of the variance in the NMV results was driven by the Team's valuation of the reduced risk of supply disruption which is an estimate of the value of incremental water supply to Fort Riley. Since this value was estimated using the substitute cost NMV method, the Team was also required to estimate (1) the probability of a water supply disruption event; (2) the effect that event would have on the installation; and, (3) the incremental benefit the MBR would provide should it occur. When assessing the risk of water supply disruption, the Team was only able to account for risk associated with extreme droughts[7] and was unable to account for supply risks associated with the failure of the onsite water supply infrastructure, e.g., groundwater wells, distribution pipes, water treatment.

Given Fort Riley's aging infrastructure and recent issues with groundwater well production, the risk of water supply disruption probably was

[6] Due to uncertainties in some of the data elements provided for the analysis, the Team completed a Monte Carlo simulation to identify an expected NPV (mean) and a distribution range at a 95% level. The Team also completed a sensitivity analysis to determine the main drivers of this variance.

[7] Extreme droughts were considered to be on the order of severity of the Kansas droughts of the 1930's (the Dust Bowl) and 1950's. It was assumed that such a drought would require on-base water rationing and the need to import water for mission-critical operations.

underestimated by the Team, and thus, the actual value of MBR's ability to mitigate supply risks probably was also underestimated.

In general, non-market values can represent a large proportion of the value that composes a project's benefit, e.g., cost savings. Although not the case in this particular example, the results suggest that non-market valuation of projects could change a funding decision by more accurately estimating the returns to a project that would be considered to be a poor investment (negative NPV) under traditional Army budgeting methods. For a more thorough analysis and discussion of the NMV demonstration results at Fort Riley, see *Application of NMV Methods to an Army Water Project* (July 2014).

4.2 Integrating Non-Market Valuation into Army CBA Processes

Specific steps for incorporating NMV results into Army CBA procedures must be developed and widely disseminated if NMV methods are to be successfully used by Army personnel. Analysis conducted during this project has shown that NMV methods and results can be readily incorporated into the standard CBA process carried out by Army infrastructure proposals (refer to the *Use of Non-Market Valuation (NMV) Methods in Army Processes to Evaluate Energy and Water Security Projects*). Army policy requires the CBA as the basic economic method to evaluate all proposed project investments. The CBA must include estimated project total costs and benefits to the Army over the life cycle of the investment (ODASA(CE), 42013).

Water infrastructure projects can be funded by a variety of sources, including appropriations, such as the Operations and Maintenance (O&M) or Military Construction (MILCON) accounts. In both of these cases, NMV results would be included in the economic analysis calculations along with traditional market-based components that are part of the CBA. For MILCON projects, the proposal process and the steps for economic analysis are included in guidance for completing and submitting the Department of Defense (DD) Form 1391.

Water-related projects are considered viable candidates for funding if their benefits exceed costs as measured by various metrics. Common CBA metrics, calculated over the economic lifetime of the investment, include present value of project cash flows, payback period or SIR which is a standard metric for energy and water projects. Army CBA calculations are typically limited to market-based benefits and costs, such as capital expenditures, energy or water savings, and operations and maintenance expenses. Other benefits, such as enhancements to biodiversity and human health or mitigation of climate change have not traditionally been included in CBAs since methods to measure these positive aspects are not readily available.

To incorporate non-market benefits, the SIR can be calculated using the sum of market and non-market benefits in the numerator to be divided by the sum of market-based and non-market costs in the denominator.

SIR = the ratio of the present value of savings to the present value of costs of an energy or water conservation measure (10 CFR 436.21)

Including NMV effects in the SIR calculation will often increase the SIR result over the outcome for market-based components alone. With a requirement for SIR > 1.0, MILCON and ECIP water projects provide a significant economic threshold for projects to qualify for Army or OSD funding. This means that including NMV can be an important benefit contribution for water infrastructure projects.

The major steps to incorporate NMV methods are shown below:

1. The project proposer at an installation develops a project description and rationale for funding support, including both market-based and non-market effects, include Army requirement.
2. The project proposer conducts an economic analysis for both market-based and non-market effects, e.g., per DD Form 1391 instructions[8]. Non-market valuation results would be included in the economic SIR analysis for DD Form 1391.
3. The installation Garrison Commander approves the completed DD 1391 and retains the overall lead responsibility with support services requested from USACE to provide some or all of the needed functions.
4. Additional Chain of Command approvals include the Command, regional and HQDA budget reviews. These steps involve close scrutiny of the entire proposal package and its economic savings performance, including the NMV contribution.

No changes to existing Army CBA steps, other than expansion of the SIR calculation and the related details of NMV analysis, are required to incorporate NMV results.

4.3 Stakeholder Feedback Results

The stakeholder feedback results provided a variety of useful insights into how NMV methods could be used by the Army and what would be necessary for their successful application. The feedback provided during this study was mixed in that many stakeholders were positive about the potential role NMV methods

[8] See for example: AR 415-15, "Army Military Construction Program Development and Execution"; DA PAM 415-3, "Economic Analysis: Description and Methods"; Energy Conservation Investment Program (ECIP) Guidance.

could play, but were concerned about whether the methods would actually be used, especially without further awareness and training in the tools and their proper application. A summary of their key responses is shown below by main interview topic:

4.3.1. General Comments

Analysis methods like NMV that are new to the Army face an important hurdle to acceptance. Most stakeholders noted that the Army is basically a conservative organization – an organization that is slow to change and embrace new approaches – even when the change is designed to improve an Army process. Later, after the value of these methods has been convincingly demonstrated, it still will take time for the Army to accept their routine use. For example, one stakeholder mentioned that the concepts and tools to determine the Fully Burdened Cost of Energy (FBCE) took several years to be adopted by Army organizations even after their beneficial contribution to energy analysis was established.

4.3.2. Feedback on NMV Usefulness

Virtually all stakeholder comments noted that NMV methods are an interesting, useful, and potentially important approach to valuing "intangible" effects of infrastructure projects, but they also recognized that military analysts and leaders will continue to focus most on effects that either: (1) preserve/enhance the military mission, or (2) save money. Other effects, such as external environmental and economic effects such as those analyzed in this study, are generally "nice to have," but not essential. Furthermore, all stakeholders recognized that while it is desirable for the Army to "do the right thing" as a "good citizen" regarding generation of external environmental and economic benefits, military personnel are not likely to count those actions or investments as a high priority relative to mission contribution and cost savings.

NMV methods were also recognized as very useful to provide a more comprehensive picture of the benefits of infrastructure investments and their value. Stakeholders understood that NMV methods can add value to some projects, possibly enough to push them over the minimum funding qualifying threshold. But, some participants noted that benefits such as biodiversity are not important concerns for most Army personnel unless analysis can show that current investments with a biodiversity benefit can reduce future Army costs, such as those that might arise from environmental litigation, e.g., concerning endangered species, or to mitigate adverse biodiversity effects.

Some stakeholders noted that the intangible benefits addressed by NMV methods are of interest to some key stakeholder groups, such as selected

Army and Department of Defense leaders and members of Congress, and that analysis of these benefits using NMV methods would be viewed favorably by those groups.

4.3.3. Feedback on NMV Feasibility

Most comments on the feasibility of applying NMV methods focused on the difficulties of implementation. A key point was that installation and HQDA personnel involved in infrastructure resource proposals are for the most part not familiar with NMV methods and would require additional education, training, and subject matter expert assistance to use them. Most respondents said that the methods are complex to understand and explain to others, e.g., to the Army chain of command. Also, a few interviewees noted that some NMV methods require data that may not be readily available. Implementation barriers also include what some saw as the significant work load to complete an NMV analysis and incorporate it into the CBA framework along with market based proposal analysis.

Virtually all interviewees stated a strong need for a clear, straightforward, and readily understandable process to carry out the NMV analysis. Something like a step-by-step method to identify the relevant NMV factors, the related benefits and how to value them would be an essential ingredient for use of NMV methods.

4.3.4. Comments on Communicating NMV Methods and Results

Most feedback concerned the topic of communicating NMV methods and results. Interview subjects discussed how improved communication and transparency are essential to further use of NMV. A key issue is how to communicate the effect valuation problem for the proposal under consideration as well as the NMV process and results serving as a solution. Several stakeholders focused on visualization, noting that clear graphics to show methods, assumptions, calculations and results – in terms that are familiar to the audience – are essential to effective communication. It is also very important to use easy-to-understand examples to convince stakeholders that what is being addressed is important and that NMV methods are worth the effort. Explaining the NMV factors and why they are relevant is an obvious need, but also showing the difference between a business as usual (BAU) base case without a proposed project and the NMV case with the project and its related benefits would be a very important approach for most stakeholders. Several stakeholders pointed out that support for NMV methods by selected senior Army leaders is a key foundation for successful efforts to begin and continue use of these tools in infrastructure proposals.

Overall, these stakeholder results indicate that NMV methods have the potential to add important value to Army water infrastructure proposals, but the complexity of the methods and data gathering process provide disincentives to their use. Future use of these methods will depend on increasing awareness of NMV methods and applications among Army personnel. Essential steps to improve the prospects for NMV methods include training on: (1) how the methods can be used for particular types of projects; (2) which methods to apply; and, (3) how to carry out the data gathering and calculations. The NMV analysis process must be made simple to use and more transparent, perhaps through the use of more examples.

4.4 Challenges and Lessons Learned

The Team encountered four important challenges during this NMV analysis and identified lessons learned that can benefit future Army NMV analysis.

4.4.1 Challenge 1. Data Challenges

This project provided important information on the potential feasibility and usefulness of NMV methods to aid in justification of Army water infrastructure investments. The demonstration provided insight into data challenges that face personnel who plan to use NMV methods. Most NMV methods for water projects require a variety of data types that must come from both installation-specific and general external sources. Water project data needs can include qualitative, quantitative, or monetary information for both current and historical conditions and for both internal (on-site) and external topics. Example data requirements for water NMV studies are:

- **Internal on-site**: the on-site water system (water balance, flows, consumption, quality and end-uses), water and energy prices and bill payers by category, water system component and operation characteristics, e.g., water and waste-water treatment and distribution infrastructure, on-site population by government and private sector category, proposed water technology and installation water challenges. A key requirement is the supply of and demand for water to support mission-critical on-site functions and assets.
- **External community or region:** local and regional water sources, stocks and flows, quality, costs and long term challenges. External data to assess potential project effects, such as human health, biodiversity, economic energy productivity and climate change, are also required. For Fort Riley, this data was obtained from external public sources.

- **Personal or expert opinions or preferences (stated or observed):** some NMV methods require judgments by either local or technical experts or stakeholders, including third parties to the analysis. This type of data was not required in the Fort Riley analysis.

In general, data issues for NMV analysis can include availability, accuracy and data-related assumptions. Limitations on data availability can pose significant barriers to a successful NMV analysis and can require significant amounts of time and collaboration to obtain needed information. In this project, the most significant data issue the Team faced was availability, especially of internal installation information. The Team obtained some useful information from the Fort Riley energy and water personnel, without which the NMV analysis could not have been conducted. However, owing to limitations in site water system current and historical records, a number of data items were not available. These included sufficient historical water billing data for water rates and consumption to support demand curve analysis, energy consumption and cost data for the WT and WWT plants for the substitution cost analysis, and data on the MBR energy and operations activity and costs.

The external data gaps were less significant. We made assumptions regarding mechanisms and costs for installation water supply options to address long term water emergencies. To complete the NMV demonstration, the Team assumed that trucked in water would be used from commercial trucking sources from the Fort Riley region. It was not possible to identify a local water source for water trucking, so cost data ($/kgal) was obtained from a water supply company in Pennsylvania.

Data quality is also a relevant concern for NMV analysis since the quality of input data will ultimately affect the accuracy of the analysis. An even more difficult challenge is data of uncertain accuracy which can also diminish confidence in analysis results, sometimes in unclear ways. It is always desirable to test the validity of key data for consistency, confidence, and reasonableness. In this project, data quality was not a concern. Based on experience with other Army installation water project analysis and comments from water experts, collected data for the Fort Riley analysis was within reasonable ranges.

In some cases, assumptions based on third party sources are required to overcome data gaps or accuracy issues. For instance, in this study, characterization of MBR technology required assumptions and use of publicly available data sources when site-specific characteristics could not be obtained. Also, assumptions for general economic parameters, such as discount rates, are necessary for life cycle analysis and to conduct forecasts of key variables. It may be necessary to qualitatively estimate water-related values for water-use applications; this can sometimes help improve the accuracy of analysis results and/or reduce data collection time spent. For example, impact-based changes in ecosystem services and/or economic productivity can be difficult to gather for assessment or forecasts and may need to be assumed.

Because the purpose of the Fort Riley analysis was only to demonstrate details of how a NMV analysis process would work using easily obtained data, the data issues encountered in this project need not reflect barriers to successful project proposals elsewhere. But, the efforts conducted in this project to obtain data for a typical NMV analysis do illustrate the importance of readily available, high quality data for submission of an actual project proposal to be considered for funding.

4.4.2 Challenge 2. Estimating the Value of Water as a Resource

The Team's demonstration of non-market valuation returned mixed results. Using a combination of indicator and benefit transfer NMV methods, the Team was able to demonstrate a repeatable process for estimating common externalities[9] associated with the Army's water consumption. However, estimating the non-market value of the water as an Army resource presented a significant challenge. After completing the demonstration, the Team was unable to propose a repeatable method for estimating the Army's non-market value of water as a resource. We offer the following reasons for this challenge:

The criticality of the Army's water-use applications is poorly defined or unknown. The challenge in estimating the value of water as an Army resource is rooted in the fact that the criticality of water-use applications drives this value. At the most basic level, water-use applications on Army installations can be categorized as mission- and non-mission-critical. Whereas non-critical water use, e.g., irrigation, recreation, some domestic uses, can be reduced or eliminated during drought or supply disruptions, critical applications, e.g., drinking water, medical services, equipment cooling, fire protection, are essential and must typically continue their necessary levels of water use regardless of supply conditions.

The criticality of the water-use application significantly influences the overall demand for water, and thus, the value of water, what the Army is willing to pay to use or preserve access to the resource. Generally speaking, the Army's demand for non-critical water-use applications is

[9] Includes impacts such as climate change, human health degradation, loss of biodiversity, and resource depletion.

relatively elastic, meaning that as the supply of water decreases or the cost of consumption increases, the Army's demand for water will decrease, e.g., through the application of conservation measures during a drought or infrastructure failure. Conversely, the demand for critical water-use applications is inelastic, meaning that the Army will continue to provide water to those applications at higher costs, and oftentimes regardless of the cost. Simply put, the value of water for critical water-use applications is significantly higher than the value of water for non-critical water-use applications.

Defining the mission criticality of a particular water-use application is typically site-specific and classified. Thus, the criticality of mission requirements needs to be assessed case-by-case. Still, generalizations for common applications that occur across Army installations and operations can be made. At this point though, more research is required to properly identify and categorize common critical water-use applications.

No single NMV method can be used to universally assess resource value across all water-use applications. Generally speaking, the Army's willingness to pay for water to support a specified water-use application, critical or non-critical, can be captured using cost-based, revealed preference, or stated preference approaches. As discussed in greater detail in the *Final Non-Market Evaluation Assessment Report* (2014), stated preference methods are not applicable for the Army and are not considered in detail in this report. Instead, the Team focused on the other two approaches. Each of these approaches, cost-based and revealed preference, present challenges that make generalizing a method for the valuation of water as a resource difficult. The significant tradeoffs between the two approaches are summarized below and may cause complications for standardizing the value of water to the Army.

- **Cost-based Methods:** These approaches can be easy to justify and implement when cost-related data exist and expected costs are clearly identified. However, as the Team learned with the Fort Riley demonstration, cost-based methods can become complicated and oftentimes have to rely on oversimplified or heroic assumptions. The source of this complication stems from the fact that most cost-based methods are consequential in nature, substitute cost, damage cost, which requires the analyst to identify and quantify the risk, probability and cost of occurrence, associated with consequences that can be directly tied to the water project under evaluation.

The above complications arose in two ways during the Fort Riley demonstration. First, the Team was unable to obtain some site- and technology-specific data associated with Fort Riley's on-site water production, most notably the energy requirements for water pumping, treatment (supply water and wastewater) and the MBR, as well as the substitute cost of bulk water delivery. As a result, the Team was required to make assumptions based on outside studies and to use Monte Carlo simulations to account for uncertainty in these assumptions. Furthermore, the Team was required to incorporate event-based modeling and additional simulation to account for the value associated with Fort Riley's risk of water shortage from extreme drought.

Secondly, the Fort Riley demonstration highlighted a significant limitation of some cost-based methods. These methods, especially the substitute cost method, are more applicable for critical water-use applications that directly support a mission that has an inelastic demand for water. In fact, the appropriateness of the application of such methods improves when the demand for water is more inelastic. This is because the likelihood that the installation will use a substitute source of water during a supply disruption is higher when the mission cannot continue without it. Although it is important to mention a key tradeoff that occurs, this method's ability to approximate the value of the water resource decreases as demand becomes more inelastic; meaning that users would be willing to pay even more than the cost of the substitute cost to ensure the mission.

- **Revealed Preference Methods:** As explained in the *Final Non-Market Evaluation Assessment Report* (2014), revealed preference methods are not attractive at the project level because they typically require an unmanageable amount of effort and resources, including skill sets that most budget analysts do not have. However, at the installation or enterprise level, the development of an inverse demand function, price is measured as a function of quantity demanded, could be a very useful tool because it provides insight into what the Army historically is willing to pay for water in the most critical applications, the first marginal units, and least critical applications, the last marginal units. This method is immune to the criticality issues associated with cost-based methods and does not require analysts to predict the occurrence and effects of future events. This method is arguably more justifiable than cost-based methods in that the value is determined from actual observations and fewer assumptions are needed to derive such value.

  The inverse demand method would have been particularly ideal for assessing the resource value of the surface water displaced by the MBR at Fort Riley. During the demonstration, the Team built a regression model to derive the installations inverse demand function, but was unable to run the model due to lack of water and wastewater billing data. In particular, the Team was only able to collect a total of 12 months of complete data across the five rate groups on the installation. Based on a total of 60 observations, this sample size was not large enough to produce statistically significant results. This lack of data highlighted the problems associated with this method when applied in the Army project evaluation process.

4.4.3 Challenge 3. NMV Implementation Challenges

Two important challenges facing Army users of NMV methods are the level of complexity and the specialized analytical skills that are needed to understand and apply some NMV methods. As shown in the Team's *Non-Market Valuation Assessment Report*, several NMV methods have the potential for use in proposed Army water projects. However, many of the methods require analysis and data management skills that may not be present at Army installations. This is apparent when the types of benefits that can be addressed by NMV methods are examined. Even though benefits are based on physical water-based ecosystem processes that usually have measurable attributes, assessing the specific magnitude of benefits that can occur in a particular situation like Fort Riley and then assigning an economic value to them can be complex and difficult.

The demonstration work completed in this task also illustrated important barriers that can be faced when implementing NMV methods. In addition to the data gathering difficulties discussed above, the three NMV methods used, substitution cost, indicator method, and benefit transfer, required sophisticated skills to execute. To illustrate, the analytic methods used required the knowledge/skills shown below:

- Life cycle cost analysis (LCCA), to calculate benefits and costs over the MBR's economic lifetime
- Statistical analysis, e.g., regression analysis to construct a water demand curve, and evaluate Monte Carlo simulation to support analysis of all water effects over the MBR lifetime
- Operations research, event-based modeling of water scarcity/drought for the Fort Riley region
- Economics/sustainability assessment, to identify appropriate indicators and related studies for benefit transfer to value the external effects of the MBR, such as biodiversity, energy productivity and climate change.

Advanced level education and training is needed to perform the analyses listed above. Each of these skills by themselves may be available to Army installation water management personnel at some sites. However, the combination of all skills needed for the Fort Riley demonstration analysis are not likely to be present at most Army installations or chain of command organizations.

Lesson Learned – Acceptance of NMV Results in the Army Budget Review Process.

Feedback from the stakeholders interviewed for this study provided both favorable and skeptical impressions of NMV with regards to acceptance by the Army financial and budget communities. What is clear is that full acceptance of NMV analytic inputs to, say, the Form 1391 or other proposal templates, is likely to take a long time – on the order of several years. Similar to the timeframe associated with introducing the concept of Fully Burdened Cost of Fuel (FBCF), now called the Fully Burdened Cost of Energy (FBCE), into the Army project proposal and planning processes, several years is a realistic time horizon for developing and explicating NMV methods.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Four conclusions were developed during this analysis of NMV methods. Each conclusion contains at least one recommendation.

CONCLUSION 1. NMV Methods have the potential to provide important insight into the full range of benefits from Army infrastructure projects by providing a more comprehensive picture of the value of internal and external project effects.

This study has shown that NMV methods can make an important contribution to understanding and quantifying the benefits of water infrastructure projects. The key finding is that potentially significant increases in project NPV and SIR metrics are possible when using NMV techniques, thereby improving the chances that water infrastructure projects can meet minimum metric thresholds to be considered for funding. In addition, NMV methods provide a framework for project proposals to include quantification of additional benefits in evaluation metrics that have not previously been captured – both benefits internal to Army installations and benefits external to the site that cover the surrounding community and region.

RECOMMENDATION: The Army should consider further development of NMV methods to better understand how they can best be applied, to identify applications where they can be most successfully used, to increase awareness of their usefulness, to improve the process of identifying and valuing relevant effects, and to reduce the complexity of their application so as to enable analysts realistically to use them.

CONCLUSION 2. Additional refinement and simplification of NMV methods is needed for practical Army applications.

This effort was a first step toward capturing the true economic value of Army infrastructure projects by: (1) better defining the issues that should be considered; (2) identifying available methods for capturing non-market value; and, (3) providing a framework for quickly sorting through these methods. Although a good intermediate step, the proposed framework does not provide a uniform approach, is difficult to apply, and can lead to inconsistencies in results across infrastructure CBAs.

The approach used in the Fort Riley demonstration was not ideal for multiple reasons. First, this approach required a collection of NMV methods to derive the project's total economic value. The approach used may not be scalable and would require analysts to diversify their NMV skill sets, as different infrastructure projects would require different NMV methods under this approach. Although no one-size-fits-all method for assessing non-market value exists, it may be possible to further reduce the list of NMV methods to be used by the Army. For example, the project Team identified a repeatable method for estimating the non-market value of external effects associated with climate change, human health degradation, loss of biodiversity, and resource depletion.

Second, cost-based NMV methods may be more difficult to implement than originally believed. The cost elements required in these analyses rely on assumptions that can drive the project's total economic value. In the case of the Fort Riley demonstration, the use of simulation to capture the sensitivity of parameter assumptions and event-based modeling to incorporate the probability of severe drought was required and further complicated the analysis. Although necessary to ensure quality results, this complication directly contradicted the project Team's objective to identify relatively simple methods for the Army's use of non-market valuation.

RECOMMENDATION: The Team recommends further refinement of the proposed framework, especially means to simplify it. The Team also recommends that the Army complete additional demonstrations to improve its understanding of data availability and its ability to implement the various NMV methods.

RECOMMENDATION: The Team recommends that the Army consider a future project to establish an Army-wide water demand curve. Although poorly scored in the *Final Non-Market Evaluation Assessment Report* (2014), innovative use of an inverse water demand curve may offer greater benefits than cost-based methods. When accurately derived, an inverse demand curve can be used to quickly and easily estimate the Army's willingness to pay for water at a specified quantity. Assuming that the most critical water-use applications would be the first marginal units consumed, analysts can capture the total resource value (consumer surplus) of the water as the shaded area in Figure 3. This value captures both the price paid by the Army user as well as the incremental amount that user would have paid for the specified quantity of water.

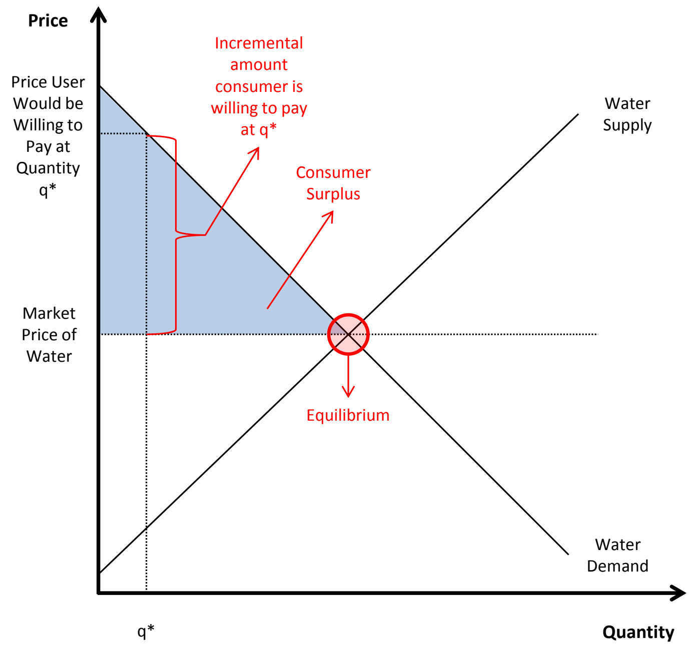

Figure 3. Example Demand Curve

As explained in the *Final Non-Market Evaluation Assessment Report* (2014) and further revealed in the Fort Riley demonstration, it is unrealistic to expect Army budget analysts to construct installation-specific water demand curves. Most budget analysts do not have the required skills or resources to complete this type of analysis, and, as the Team concluded in the Fort Riley demonstration, installations may not have enough data to support such an effort. However, building a more general demand curve that covers water use across Army installations and applications could offer a convenient and scalable alternative for capturing the NMV of water as an Army resource. This would require one effort instead of multiple installation-specific efforts and would not suffer from data limitations. Data samples collected across installations with varying conditions can provide a robust data set for econometric modeling.

This method may be more justifiable than the use of cost-based methods because it requires significantly less analytical effort and does not require parameter and risk-based assumptions based on observed behavior.

It would be possibly to use the net zero water installations for data. They represent great diversity in climate, operations, size, and function. An Army-wide demand curve could be assembled to better capture the Army's perceived value of water per unit consumed, according to a pre-determined grouping of water-use applications. This method would be based on observation, not forecasting and simulation. Similar to inflation and discounting factors used by Army budget analysts, these data could potentially be translated into resource valuation indices for greater ease of use. This indexing approach could standardize and simplify the valuation of water and other resources, e.g., energy.

CONCLUSION 3. Further use of NMV methods is hampered by a lack of awareness about their usefulness, prompting some stakeholders to remain unconvinced that the methods should be used.

The stakeholder feedback obtained during this study strongly indicated that use of NMV methods faces important hurdles before acceptance by the Army installation community and budget reviewers becomes a reality. Most persons interviewed stated that the newness of the methods, their complexity, and the work required for data gathering and analysis pose barriers to NMV use in other than the a few high importance situations by installations having personnel with strong technical expertise. Presentations on NMV methods, especially briefings that contain example applications, for Army installation community leaders would be beneficial.

RECOMMENDATION: The Team recommends that the Army develop detailed guidance and procedures to implement use of NMV methods, including suggestions on the most potentially promising infrastructure project applications for water and energy. The guidance should include procedures to include NMV in Army CBAs and other investment justification efforts. The guidance should follow after one or more additional demonstration projects to develop additional experience and lessons learned for use of NMV methods.

RECOMMENDATION: The Team recommends that, as NMV techniques are further developed, illustrated and simplified for practical use, the Army undertake education and training efforts for appropriate installation and budget personnel to increase awareness and practical understanding of the usefulness of NMV methods and how they can be applied effectively. The education and training should include practical demonstrations of how NMV can be applied for key types of infrastructure projects and how to incorporate the results in CBAs. The example applications should include direction and helpful hints on data gathering, analysis assumptions, calculation tools, and communication aids.

CONCLUSION 4. Routine use of NMV methods for water project justification faces the important barrier of a lack of easy access to data needed to perform NMV analysis.

This study demonstrated that the difficulty of access to key internal and external data to apply NMV tools can restrict the insights and potential usefulness of a NMV analysis and can increase the workload to complete the product. In this study, for example, considerable effort was applied to estimate an installation-wide water demand curve for Fort Riley. However, lack of sufficient historical data on water price and consumption levels limited the quality of the demand curve regression results. This meant that the demand curve NMV method was not used.

RECOMMENDATION: The Team recommends that the Army investigate a variety of approaches to develop more readily accessible and possibly standardized data sources such as look-up tables for commonly used parameter values, e.g. water distribution system characteristics and cost data. Standard sets of reference sources or perhaps default values in some cases, organized by the types of data provided, appropriately vetted and validated, would be helpful for commonly used NMV variables. In addition, developing organized, step-by-step and transparent approaches to apply common NMV methods would ease the burden of easy access to gathering and using NMV data. This information should be included in Army guidance on use of NMV methods.

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APPENDIX A

Summary of Advantages and Disadvantages of NMV Methods

	Method	Advantages	Disadvantages
Qualitative Valuation Approach	Interview Method	- Semi-structured interviews are open ended, which allows the analyst to capture information on any parameters desired.	- Consistency in information across interviewed stakeholders can be difficult when using this method, which can make it less likely to reach definitive conclusions on value. - Quantification of the results is not possible. - This method can be very subjective and is vulnerable to interviewer bias. - One-on-one interviews can be very time consuming, depending on the number of stakeholders interviewed.
	Panel Method	- Panels are open-ended, which allows the analyst to capture information on any parameters desired. - This method can take less time than one-on-one interviews and can be used to understand perceptions about the future (forecasted effects). - An individual's opinions can be influenced by another's opinions (this can sometimes be a disadvantage).	- The panel proceedings are vulnerable to personal opinion, cultural perspectives, and attitudes about the importance of proven versus unproven impacts. - The questionnaires and group facilitation methods used can take a lot of effort to construct. - This method requires careful selection of participating individuals/groups.
	Relative Valuation Method	- Relative valuation is open-ended, which allows the analyst to capture information on any parameters desired.	- Relative valuation is vulnerable to personal opinion, cultural perspectives, and attitudes about the importance of proven versus unproven impacts. - This method requires careful selection of thresholds for criteria used to evaluate parameters.
Quantitative Valuation Approach	Survey Method	- Compared to the qualitative interview method, quantitative surveys are more uniform in format, allowing for greater opportunity for quantification. - The structured format of the questionnaire allows for easy scaling when using survey technologies. - Any parameters desired can be included in this method.	- The rigid structure of the questionnaire offers less opportunity to capture broader information. - Similar to the qualitative interview method, this method can also be very subjective and is vulnerable to interview or survey bias.

	Method	Advantages	Disadvantages
	Indicator Method	- The indicator method can include any parameters desired. - This method can be informed by water inventories and repeatable scientific methods such as risk assessment and life cycle assessment. - Indicators can inform other NMV methods.	- The link between actions and impact in cause-effect models sometimes require heroic assumptions that may not hold, and thus, invalidating the conclusions reached.
	Multi-Criteria Analysis Method	- MCA can include any parameters desired. - The MCA analysis can be as simple or complex as needed.	- MCA can become overly complicated when many criteria must be assessed. - MCA methods usually require stakeholder consensus building for criteria weighting and scoring. (Note: The DEA method can be used to bypass the need to build consensus for criteria weights)
Monetary Valuation Approach	Stated Preference – Contingent Valuation	- This method is inherently very flexible because the underlying methods can be used to value any environmental, social or economic water-related benefit. - Contingent valuation gives the analysts control over the information embedded in the data collected, which avoids many economic modeling problems common to most observational data sets. This method provides analysts with the ability to examine the differences in water-related values at different time periods (past, present and future). - By asking individuals about their preferences, this method offers the greatest insight into the actual value of the water, as stated preference methods are the only monetization methods that uses primary data. Conceptually, an individual's WTP response should include all water-related values.	- Developing stated preference questionnaires are very time and resource intensive. - Derived values are not based on actual behavior but instead on perceived preferences that are vulnerable to survey bias. This can result in poor or meaningless results. Individuals often have trouble quantifying their WTP. It is common for a participant's implied preferences through actual actions (observed behavior) to differ from his or her stated preferences. For example, a skydiver may value his or her life very highly in a WTP questionnaire, but the high-risk activity of skydiving might cause an analyst to infer otherwise.

	Method	Advantages	Disadvantages
	Stated Preference – Choice Experiment	- This method is inherently very flexible because the underlying methods can be used to value any environmental, social or economic water-related benefit. - Contingent valuation gives the analysts control over the information embedded in the data collected, which avoids many economic modeling problems common to most observational data sets. This method provides analysts with the ability to examine the differences in water-related values at different time periods (past, present and future). - By asking individuals about their preferences, this method offers the greatest insight into the actual value of the water, as stated preference methods are the only monetization methods that uses primary data. Conceptually, an individual's WTP response should include all values (market and non-market) associated with the use of water.	- The development of stated preference questionnaires is very time and resource intensive. - Derived values are not based on actual behavior, but instead on perceived preferences that are vulnerable to survey bias. This can result in poor or meaningless results. An individual's choices can change and can be influenced by many conditions including the individual's emotional state at the time of the survey.
	Revealed Preference – Market Prices	- Unlike with the stated preference method, the results for all revealed preference methods are based on actual observations and are not theoretical. - Data on market prices, when available, are typically easy to collect and process and can represent an individual's WTP. - Market prices are transparent and typically easier to justify, despite the fact that the oftentimes significantly undervalue water as a resource.	- This method is only applicable when a market exists. - Even when a market exists, there can be market distortions (see discussion in Appendix B for further explanation) such that prices significantly underestimate water-related values.
	Revealed Preference – Change in Productivity	- Unlike with the stated preference method, the results for all revealed preference methods are based on actual observations and are not theoretical. - If data are available, this method is relatively straightforward to apply.	- The cause-effect relationship between the ecosystem service and production is often difficult to determine and complex models may be required to produce accurate results. - Obtaining data on both the change in the ecosystem service and change in productivity is often difficult.

	Method	Advantages	Disadvantages
	Revealed Preference – Travel Cost	- Unlike with the stated preference method, the results for all revealed preference methods are based on actual observations and are not theoretical. - The results are relatively easy to interpret and explain.	- This method is limited to direct use recreational benefits. - This method assumes that recreational values gained from visiting a particular site are strongly correlated with the frequency of visits and the expenses incurred during those visits. This is can be a poor assumption. - Difficulties in apportioning costs when trips are to multiple places or are for more than one purpose (very common). Issues affecting the generally accessibility of a site must also be considered and typically require difficult and time consuming econometric modeling. - Considering travel costs alone ignores the opportunity cost of time while travelling and thus underestimates the true value of the resource. This opportunity cost should also be considered when using this method.
	Revealed Preference – Hedonic Pricing	- Unlike with the stated preference method, the results for all revealed preference methods are based on actual observations and are not theoretical. - Based on market data and WTP, hedonic pricing is transparent and easy to justify. - Property markets are generally very responsive, and thus, are good indicators of values.	- This method is typically limited to values related to property. - Property markets are affected by a number of factors in addition to environmental attributes, so these factors need to be identified and controlled for in the analysis. Lacking data availability for these factors complicate the analysis.
	Cost Based – Replacement Cost	- The replacement cost method provides surrogate measures of value for regulatory services, which are difficult to value by other means. - This method is readily transparent and defensible method when based on market data.	- Replacement costs do not reflect social preferences for services or behavior in the absence of the ecosystem service. - The underlying assumption in this method is that the costs of replacement equal the benefits that society derives from the naturally provided service. In most cases, the replacement service probably only represents a proportion of the full range of services provided by the natural resource. For example, the wetland described above also provides services such as enhancing biodiversity by acting as a breeding ground and recreation; both of which are not considered in the replacement cost associated with the construction of a wastewater treatment plant.

	Method	Advantages	Disadvantages
	Cost Based – Substitute Cost	- The substitute cost method offers a good approach for estimating the value of water as a resource across multiple types of water-use applications and ecosystem services. This method offers a unique ability to account for the aggregated preferences for all relevant water-related ecosystem services without identifying and quantifying all resulting consequences relating to the loss of those services. - Substitute costs can be informed by water inventories and market prices. Such data are typically readily available.	- Substitute costs can only be used to value provisioning services, typically off-stream in nature (see Appendix A for additional information on provisioning services). - A contingency plan should be in place to properly use this method. Without a plan, the value of an alternative source may be improperly inferred. - This method does not account for external social or ecosystem values. - When used to value water for mission-critical applications, an installation's water-use inventory must discern the difference between mission- and non-mission-critical applications.
	Cost Based – Damage Cost Avoided	- Damage cost avoided models can be informed by water inventories and risk assessment methods that are repeatable. - This method can provides surrogate measures of value for regulatory services that are difficult to value by other means (e.g., storm, flood and erosion control) (see Appendix A for additional information on regulatory services).	- This method can be difficult and complex if reasonably accurate values are required. - Damage cost avoided models are largely limited to services related to properties, assets and economic activities. - This method can overestimate values.
	Cost Based – Budget Constrained	- Budget constraint values for a specified indicator can be developed by the analyst or can be referenced from published studies. - This method can be informed by water inventories and repeatable scientific methods, such as a life cycle assessment. - This method is one of only a few valuation methods that adequately accounts for external social or ecosystem values.	- Heroic assumptions for constructing the budget constraint for non-human values may be required when market-oriented information (e.g., salary information, gross domestic product data) is unavailable. - This method can overestimate values as the budget constraints may be higher than actual WTP.
	Benefit Transfer Method	- The benefit transfer method is a low cost and typically rapid method, depending on the extent of any data adjustments needed, for estimating recreational and non-use values (see Appendix A for more information of recreational services and non-use values).	- The results of a benefits transfer can be questionable unless carefully applied. - This method relies on the availability of other valuation studies which may be more robust and numerous for some services than for others.

APPENDIX B

Army Water Project Classifications, Benefits, and Costs

	Project Type	Description	Benefits	Costs
Water Conservation	Efficiency	Decreases water use per activity without actually reducing the level of activity	- Reduced water use - Reduced energy consumption - Reduced impact to surrounding communities and ecosystems - Supply resilience	- Initial investment and implementation
	Conservation	Decreases water use by reducing the level of activity	- Reduced water use - Reduced energy consumption - Reduced impact to surrounding communities and ecosystems	- Costs associated with a reduced level of activity using water
	Onsite Water Recycling	Decreases water purchased or withdrawn by recycling water used onsite	- Reduced water use from utility - Reduced impact to surrounding communities and ecosystems - Increased production/services - Supply resilience	- Initial investment and implementation - Operation and maintenance
	Distribution Infrastructure Repair/ Replacement	Decreases water loss from leaking distribution infrastructure	- Reduced water use from utility - Reduced impact to surrounding communities and ecosystems	- Initial investment and implementation
Distribution Infrastructure	Distribution Infrastructure for Supply of Potable Water	New infrastructure that provides accessibility of potable water to new water-use applications	- Increased access to potable supply	- Initial investment and implementation - Potential increase in impact to surrounding communities and ecosystems
	Distribution Infrastructure for Wastewater	New sewer infrastructure that transports wastewater to treatment plant or final place of discharge	- Reduced liability tied to pollution/ecosystem contamination - Improved sanitation	- Initial investment and implementation

	Project Type	Description	Benefits	Costs
Water Treatment	Onsite Water Treatment/ Purification	New infrastructure that transforms water collected from an onsite source into potable supply	- Increased assurance of potable water supply - Improved quality of water - Lower cost of water ($/gal) - Improved sanitation	- Initial investment and implementation - O&M (including energy consumption) - Increased impact to surrounding communities and ecosystems (if Army water use precludes external use) -
	Onsite Wastewater Treatment	New infrastructure that transforms used onsite into a water quality that is appropriate for non-potable uses or for discharge to the environment.	- Reduced environmental liability - Lower sewer costs - Reduced impact to surrounding communities and ecosystems - Improved sanitation	- Initial investment and implementation - O&M (including energy consumption)
Alternative Source/Supply Security	Onsite Groundwater Extraction	New infrastructure that extracts water from onsite groundwater sources.	- Assured supply of water (not necessarily potable) - Revenue if sold to local community	- Initial investment and implementation - O&M (including energy consumption) - Increased impact to surrounding communities and ecosystems (if Army water use precludes external use)
	Onsite Rainwater Harvest	New infrastructure that collects rainwater for onsite use.	- Reduced water use from utility - Reduced impact to surrounding communities and ecosystems - Increased production/services	- Initial investment and implementation - Increased water treatment (if necessary)
	Onsite Water Storage	New infrastructure that stores water for future use.	- Reduced water use from utility - Reduced impact to surrounding communities and ecosystems - Increased production/services - Supply resilience	- Initial investment and implementation - Increased water treatment (if necessary)

Note: Some projects can be classified in more than one project type. For example, a reservoir can be considered as both onsite water storage and rainwater harvest, depending on how the infrastructure is used. In such instances, the water-related values for both project types apply and should be considered in the project's CBA.

APPENDIX C

Water-Related Values and Available NMV Techniques by Water Project Type

Appendix C includes a table of project profiles that can be used to quickly identify market and non-market benefits and costs that are typically associated with each project type classification.

NMV Assessment Framework.xlsx