

Interim Independent External Peer Review of the Missouri River Bed Degradation Feasibility Study

Final Report

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Prepared by: Analysis Planning and Management Institute, Inc.

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Executive Summary

Project Background

The U.S. Army Corps of Engineers (USACE) is conducting The Missouri River Bed Degradation Feasibility Study in order to identify and evaluate alternatives to address the impacts of river bed degradation on the lower Missouri River from Rulo, NE to the mouth of the river at St. Louis, MO. The Feasibility Study will identify and evaluate alternatives to minimize or eliminate future impacts of the bed degradation to the Federal infrastructure and local public infrastructure in the river reach under study. The Study will identify and evaluate various combinations of measures to form alternatives with applicable environmental assessment. The project will produce a Feasibility Report with an Environmental Impact Statement.

Two separate Independent External Peer Reviews (IEPR) will be conducted as part of preparing the Feasibility Study. The first IEPR is an Interim IEPR of selected technical appendices (the Study Appendices) that support the analysis presented in the Feasibility Study. The second IEPR will be conducted on the full Draft Decision Document and its technical appendices. This report includes the results of the Interim IEPR.

Independent External Peer Review Process

The LMI Team, comprising Logistics Management Institute (LMI) and Analysis Planning and Management Institute (APMI), has conducted the Interim IEPR of the Study Appendices. These appendices address project hydraulics and hydrology and economic models. The interim IEPR has been conducted in accordance with the procedures described in the Department of the Army, USACE Engineer Circular (EC) No. 1165-2-214, *Civil Works Review*, dated 15 December 2012. The IEPR was conducted to analyze the adequacy and acceptability of methods, modeling, data, and analyses used. The IEPR focused on an engineering and economic technical review and did not involve policy review.

The IEPR review was conducted by a panel of subject matter experts with the following expertise and experience:

- Hydraulic and Sedimentation Engineering
- Civil Works Planning
- Economics

The IEPR panel (the Panel) was “charged” with providing a broad technical evaluation of the material contained in the selected technical appendices of the Feasibility Study and supporting documentation. This report provides the final comments of the IEPR panel.

Results of the Interim IEPR

The Panel generally agreed on the adequacy, philosophy of approach, and acceptability of the economic, engineering methodology, and analysis used in the appendices reviewed that support the Study Appendices. The Panel found that the supporting documentation adequately communicated the systematic development and evaluation of alternatives to address relevant potential failure modes. The panel members determined that, in general, the planning and design efforts are of high quality and conform to

current criteria and guidance. The panel offered a number of comments to improve the Study and clarify specific content issues.

There were a total of 22 comments. Of these, 2 were identified as having High significance, none as Medium High significance, 8 as Medium significance, 1 as Medium Low significance, and 11 as Low significance. The following paragraphs provide a summary of the Panel's comments in specific subject matter areas.

Hydraulic and Sedimentation Engineer

The level of effort and the results of the Study Appendices are of a high quality. It is clear that a great deal of thought and consideration went into the modeling for the project. For this, the project team should be commended, particularly in light of the challenges of this type of sediment transport modeling effort. The comments below improve the documentation.

There are two areas in which the documentation requires updates to address important issues: 1) addressing the development of the inflowing sediment boundary conditions, and 2) the development of the methodology calculating the loss of transported sediment to the floodplain. Both of these areas are important to ensuring confidence in the final model product since they both strongly influence the model bed response.

There are several areas in which the model documentation requires improvement. These updates include areas of clear reservoir discharges, model section spacing, tributary sediment limits, movable bed limits, dike orientation to the bank, and model output comparison with observed data. These areas are important to model bed response and require additional documentation of information in order to ensure confidence in the final model product. In addition, these areas typically need additional interpretation and description.

Civil Works Planning & Economics

The selection of models and application of data within the models is appropriate for use in the evaluations. The Economic model is adequately developed and reflects the uncertainty regarding the costs and inputs supporting the economic benefits. Future Without Project flow and dredging conditions are reasonable and appropriate. The model provides a means of assessing how changes to commercial dredging rates affect the rate of degradation, and the conclusions regarding the effect of commercial dredging on bed degradation are reasonable and supported.

The Panel had two comments that concern the overall understanding of the project. First, the Natural Valley Width was reported to have been computed using the 1% Annual Exceedance Probability (AEP) flows and removing levees from the FEMA floodway instead of Future Without Project conditions widths. The Study Appendices do not make it clear that the Natural Valley Width was also modelled. At the Mid-Point meeting the USACE verbally acknowledged the need to revise the narrative and figures to address this.

Secondly, a comparison of the model output using the "no dredging" scenario to model output using dredging levels for the period of 1994 to 2014 indicated that 1 ton of dredging resulted in 0.94 tons of bed loss, and the model output using the permitted dredging level for December 2015 indicated that 1

ton of dredging resulted in 0.81 tons of persistent bed loss. No information is provided on the dredging quantities for the two periods. As a result, the Panel cannot reconcile the difference in the model output for the model runs that included historic dredging levels from 1994 to 2014 and the permitted dredging level as of December 2015.

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Introduction

1.1 Introduction and Report Overview

This Interim Independent External Peer Review (IEPR) Final Report provides the results of the review of selected technical appendices (the Study Appendices) associated with the Missouri River Bed Degradation Feasibility Study. The Feasibility Study is being conducted by the Kansas City District of the US Army Corps of Engineers (USACE). The USACE is conducting the Feasibility Study in order to identify and evaluate alternatives that address the impacts of river bed degradation on the lower Missouri River from Rulo, NE to the mouth of the river at St. Louis, MO. The US Congress has authorized the USACE to improve and maintain a navigation channel that is 9-foot deep and 300-foot wide in this river reach. The Feasibility Study will identify and evaluate alternatives to minimize or eliminate future impacts of the bed degradation to the Federal infrastructure and local public infrastructure in the river reach under study.

Two separate IEPRs are being conducted as part of preparing the Feasibility Study. The first IEPR is an Interim IEPR of selected technical appendices that support the analysis presented in the Feasibility Study. The second IEPR will be conducted on the full Draft Decision Document and its technical appendices. This Interim IEPR Final Report contains the final comments of the IEPR panel (the Panel) on the Feasibility Study appendices (heretofore referred to as the Study Appendices).

The purpose of the Interim IEPR was to assess the adequacy and acceptability of specific economic and engineering methods, models, and analyses presented in the Study Appendices. The Interim IEPR focused on engineering and economic technical review and did not involve policy review.

The Interim IEPR was conducted by an independent panel comprising subject matter experts with experience in engineering and economic, areas relevant to the technical issues of this project. The panel members were nominated, screened for technical qualifications and presence of Conflict of Interest (COI), and “charged” with providing a broad technical (engineering and economic) evaluation of the overall project as well as responding to specific technical questions. The Panel review was guided by the general charge questions listed in Appendix A.

The Panel reviewed the assumptions that underlie the analyses and evaluated the soundness of models, surveys, investigations, and methods. The Panel assessed whether the assumptions of the planning analysis are sound and whether or not the conclusions based on the planning analysis are appropriate and logically follow from the stated problems, opportunities, objectives, constraints, screening, and alternatives evaluation.

Section 1 of the Interim IEPR Final Report provides a description of the objectives of this effort and general background information on the IEPR. Section 2 provides an overview of the Missouri RBDFS. Section 3 summarizes the process followed to perform the IEPR. Section 4 describes the IEPR panel composition and the panel members’ expertise. Section 5 presents the IEPR panel comments. Appendix A provides the charge to the Panel. Appendix B summarizes the qualifications of the IEPR panel members.

1.2 Independent External Peer Review Process

The USACE lifecycle review strategy for Civil Works projects provides for a review of project documents from initial planning through the project phases of design; construction; and operation, maintenance, repair, replacement and rehabilitation. The strategy provides procedures for ensuring the quality and credibility of USACE decision, implementation, and operations and maintenance documents and work products.

Peer reviews, such as this IEPR, are one of the important procedures used to ensure that the quality of USACE published information meets the standards of the scientific and technical community. Peer review typically evaluates the clarity of hypotheses, validity of the research design, quality of data collection procedures, robustness of the methods employed, appropriateness of the methods for the hypotheses being tested, extent to which the conclusions follow from the analysis, and strengths and limitations of the overall product.

The objective of this Interim IEPR was to review Study Appendices that address hydrology and hydraulic and economics models that support the analyses in the Feasibility Study. To ensure the adequacy of the Study Appendices, the Panel analyzed the adequacy and acceptability of methods, modeling, data, and analyses in accordance with the procedures described in the Department of the Army, USACE Engineer Circular (EC) No. 1165-2-214, *Civil Works Review*, dated 15 December 2012.

1.3 IEPR Management Team

This IEPR was conducted by a group of independent experts under the auspices of Analysis Planning and Management Institute (APMI) as a subcontractor to the Logistics Management Institute (LMI). Both organizations are not-for-profit science and technology organizations that provide impartial, independent assistance, free of conflict of interest, for federal government organizations. Neither organization has performed or advocated for or against any federal water resources projects or have real or perceived conflict of interest for conducting IEPRs. APMI, LMI and the panel members for this IEPR have not been involved in any capacity with the projects documented in the Missouri RBDFS. For this IEPR, both organizations are free from conflict of interest with the USACE.

2 Project Description

The USACE is conducting The Missouri River Bed Degradation Feasibility Study in order to identify and evaluate alternatives to address the impacts of river bed degradation on the lower Missouri River from Rulo, NE to the mouth of the river at St. Louis, MO. This Study will identify and evaluate alternatives to minimize or eliminate future impacts of the bed degradation to the Federal infrastructure and local public infrastructure. The Feasibility Study will identify and evaluate various combinations of measures to form alternatives with applicable environmental assessment. The alternatives may include measures for implementation by others, for cost-shared implementation, and possibly for implementation by the USACE. The USACE project will produce a Feasibility Report with an Environmental Impact Statement. The report will require major subordinate command, Head Quarters USACE, and Chief of Engineers approval and Congressional authorization to move forward to a cost-shared design and construction project.

The USACE is conducting the Feasibility Study under its General Investigations Program. Authorization for the Study is via Section 216 of Public Law 91-611, Flood Control Act of 1970. The Missouri River Bank Stabilization and Navigation Project (BSNP) originally authorized by the Rivers and Harbors Act of 1912, and modified by subsequent authorizations in 1925, 1927, and 1945 is the project of interest, both as a causal factor and as part of the impacted federal infrastructure. The Study will examine the effects of degradation on the long-term stability and sustainability of the BSNP. There are significant flood risk management features, located primarily within the Kansas City Reach and near St. Joseph, MO, that are dependent on the stability of the BSNP and are potentially also impacted by continued bed degradation. Measures recommending structural or operating changes that have potential for minimizing degradation impacts will be considered. In addition, the Study will consider approaches to help, maintain, or enhance the viability of federally-constructed ecosystem projects such as constructed wetlands and shallow water habitat. The Study will also inventory and assess measures that protect local and public infrastructures. If the decision document is approved by the Chief of Engineers, implementation of a recommended plan will require Congressional authorization and appropriation. Based on preliminary study analysis (from September 2014) the costs for implementation could range from approximately \$2.5M to \$165M.

The most recent BSNP authorization (1945) describes improving and maintaining a navigation channel that is 9-foot deep and 300-foot wide. Features of the BSNP consist mainly of rock revetments and dikes that restrict lateral movement of the river channel and maintain at a minimum 9-foot deep by 300-foot wide self-scouring navigation channel. Adjustments are made occasionally to these features to maintain the navigation channel at the authorized depth. The BSNP is a self-scouring system with no associated locks and dams. Water to support required flows during the navigation season are made from releases from the system of dams on the main stem of the Missouri River and also with limited amounts of flow from dams on the tributaries to the Missouri River. The management of releases is through the Missouri River Basin Water Management Office and as described in the Mainstem System Master Water Control Manual, revised March 2006 (Master Manual).

There are a number of channel improvements, levees, and floodwalls within the Kansas City reach that comprise the Kansas City's Metropolitan Levee System. This flood risk management (FRM) system covers a two-state and multi-community area with multiple levee districts and supporting agencies. Other FRM systems exist along the lower Missouri River to provide protection for other communities. The federal FRM systems are operated and maintained by public entities. In some cases, there are shared boundaries between the FRM systems' structures and the features of the BSNP.

A fish and wildlife mitigation program was authorized for the BSNP in the Water Resources Development Act of 1986, based on a 1981 feasibility study and environmental impact statement. In 2000, the USACE completed formal consultation with the U.S. Fish and Wildlife Service (USFWS) for protection of the pallid sturgeon, a federally listed endangered fish species native to the Missouri River. In addition, the USFWS issued a biological opinion in 2000 (amended in 2003) requiring the Corps of Engineers to restore 7,530 acres of shallow water habitat. The restoration activities are undertaken via the Missouri River Recovery Program.

From the standpoint of alternative formulation, the Study is complex. Implementable measures will improve the long-term stability of the river bed to different degrees. Individually, each measure may provide benefit to certain infrastructures of concern but on their own merits; however, there is not likely a single implementable measure that would provide comprehensive benefits. Some measures may have environmental benefits and others may need more in-depth consideration of environmental impacts. Some measures may require implementation of a surveillance plan to evaluate their effectiveness and require some mechanisms for future adjustments. It is envisioned that the Study will require development of several combinations of measures to form alternatives for comparisons.

3 Independent External Peer Review Process

This section summarizes the process for conducting this Interim IEPR. APMI performed the Interim IEPR in accordance with the procedures described in EC 1165-2-214.

3.1 Project Management

APMI developed and executed a Work Plan to define and manage the process for conducting the IEPR. The Work Plan described the process for screening and selecting independent reviewers, communicating and meeting with the USACE project team, maintaining the project schedule and quality control, compiling and disseminating the independent reviewers' comments, and project management and administration.

3.2 Selecting the Independent External Peer Review Panel

Reaching out to its various pools of experts, APMI identified experts who met and exceeded the technical expertise and requirements of this IEPR. APMI identified any potential conflict-of-interest (COI) issues that potential panel members could have with the project following the standards of the National Academy of Science and Office of Management and Budget (OMB) M-05-03, *Final Information Quality Bulletin for Peer Review*. APMI considered the following criteria in the screening of the candidates:

- **Expertise:** Ensuring the selected reviewer has the knowledge, experience, and skills necessary to perform the review.
- **Independence:** Ensuring that the reviewer was not involved in this project or in producing the documents to be reviewed.
- **Conflict of interest:** Identifying any financial or other interest that conflicts with the service of an individual on the Panel because it could impair the individual's objectivity or could create an unfair competitive advantage for a person or organization.
- **Availability:** Assessing the candidates' availability to meet the project schedule.

After an initial screening of candidates to exclude those with inadequate expertise or potential conflict of interest (COI) issues, APMI selected several candidates for further in-depth screening and evaluation to ensure they met or exceeded the requirements of this task. The list was then narrowed down to identify the most qualified candidates that would be available to serve on the IEPR panel while ensuring a balanced panel representing perspectives from academia, industry and government. APMI provided the list of selected panelists along with their summary qualifications relevant to this IEPR and detailed résumés to the USACE. The USACE used this information to determine if any proposed panel members had a potential COI based on USACE's general knowledge of the candidate's past employment or current involvement with the project. USACE acknowledged the relevancy of panel members' experience relative to the requirements of the IEPR and that there were no real or perceived COI issues. Information about the Panel members is provided in Appendix B.

3.3 Preparing and Charging the Panel

The USACE provided to APMI the documents to be reviewed by the IEPR panel. Table 1 includes the list of the documents used in this review as well as the corresponding file names provided on a hard drive, which also contained the Mobile Bed Model HEC-RAS (Version 5.0 Beta) and the Economic Model

provided as a reference. APMI provided these documents to the panel members along with the final Charge to Reviewers. These charge questions established the general boundaries for the IEPR. The charge questions are in Appendix A.

Table 1: IEPR Documentation

Documents	File Name
Missouri River Bed Degradation Economic Model Documentation	MO_River_Model_Documentation_15May2013
Missouri River Bed Degradation Study Technical Appendix Future Without Project Model Projections with Risk and Uncertainty	MR Degradation FWOP and RU
Missouri River Bed Degradation Study Mobile Bed Model Calibration Report	MR_Bed_Deg_MBM_Calibration_Report_ATR_Draft_Jan_26_2016
Reduction in Dike Lengths to Account for Expansion and Contraction	Reduction_in_Dike_Lengths_April_30_2015
Other Documents	<ul style="list-style-type: none"> • IEPR - Degradation Questions JS • MOBed 50 Alt1 PD SYC 12Aug14 for Review

APMI and the Panel had an introductory meeting. At the meeting, APMI outlined the steps of the IEPR process, identified the overall schedule and deadlines, and instructed the IEPR panel members on how to obtain the documentation and to undertake the review.

APMI provided the panel with templates and instructions for preparing their comments to ensure proper coverage of all important issues and consistency in preparing the IEPR comments. APMI instructed the Panel that APMI would be the conduit for information exchange between the panel and USACE throughout the project in order to ensure a truly independent review.

3.4 Performing the Independent External Peer Review

This review involved conducting an interim independent technical peer review of the Study Appendices to analyze the adequacy and acceptability of engineering methods, models, data, and analyses presented in the documents. The review focused on conducting a technical review and did not involve policy issues. The Panel used the charge questions as guidance for identifying relevant information and developing their comments and recommendations.

APMI held a model review meeting with the Panel and USACE prior to the midpoint review meeting. At this meeting, the Panel provided additional model scenarios, which the USACE agreed to analyze. APMI then held a web meeting with the Panel and the USACE at the approximate midpoint of the review process so that the Panel could ask clarifying questions from of the USACE, request any additional information related to panel concerns, and discuss technical issues associated with the project. The USACE presented the results of the additional model scenario analyses that the panel had requested.

Throughout the review process APMI communicated to the panel all relevant project information, instructions, and required actions and deadlines. APMI acted as the conduit for information exchange

between the panel and USACE throughout the project in order to maintain the integrity of the IEPR process.

3.5 Finalizing the Panel Comments

After completing the review, the Panel submitted a draft of their comments to APMI. We collated the panel comments and ensured they were complete and responsive to the charge. Overall themes were identified that were presented by multiple peer reviewers or repeated by one reviewer, comments that indicated conflicting peer review opinions, and other noteworthy comments. APMI ensured that the Panel comments focused on performing a technical review of the documents and did not comment on policy-related issues.

APMI coordinated with the Panel to reach consensus on the comments, identify any overlapping comments, and resolve any contradictions. Further refinement and consolidation of the comments occurred via email exchange and telephone discussions.

Each IEPR final panel comment consisted of four parts:

- **Comment:** A clear statement of the concern.
- **Basis for Comment:** A narrative describing the basis for the concern.
- **Significance:** A significance rating (see Section 5) of the concern (the importance of the concern with regard to project implementability) as well as a statement supporting this significance rating. Comments are rated as “high”, “medium high”, “medium”, “medium low”, or “low” to indicate the general significance the comment has to project implementability.
- **Recommendation[s] for Resolution:** Recommended actions necessary to resolve the concern to include a description of any additional research that would appreciably influence the conclusions.

3.6 USACE Responses to Panel Comments

After submitting the IEPR report, APMI entered the final Panel comments into the Design Review and Checking System (DrChecks) for USACE internal tracking of the final Panel comments and recommendations as well as the formal responses by the USACE and backcheck by the IEPR panel to complete the IEPR process. DrChecks is an Internet-based review and checking application that the USACE uses¹.

The final panel comments will be reviewed and responded to by the USACE. The USACE will either “Concur” or “Non-Concur” with each panel comment and will “Adopt” or “Not Adopt” each recommendation provided with that comment. The USACE will prepare a draft written evaluator response to each comment.

¹ Hosted on the USACE’s PROJect extraNET (ProjNet), a web service that allows secure exchange of information.

The IEPR panel will then review the USACE draft evaluator responses. APMI will hold a meeting with the Panel and the USACE evaluators so that the panel and USACE can discuss the draft evaluator responses and ensure there is a clear understanding of the intent of original panel comments. After this meeting, the USACE will finalize their evaluator responses and enter them into DrChecks. The USACE's responses usually indicate whether documentation will or will not be expanded, revised, or changed.

3.7 Panel Backcheck Responses

After the USACE final evaluator responses are submitted and entered into DrChecks, APMI will meet with the panel, as needed, to discuss the responses and the approach for preparing the panel's responses (called the Backcheck). As part of the Backcheck process, the panel will select either "Concur" or "Non-Concur" with each USACE final evaluator response and provided comments (as needed) to indicate whether each response adequately addresses the panel's identified concerns. APMI will enter the panel Backcheck responses to each USACE evaluator response into DrChecks.

4 Panel Organization

APMI assembled a panel of experts that met the qualifications set forth by the USACE in the Performance Work Statement for the task. APMI supported and assisted the panel in carrying out its review and served as the intermediary for communications between the panel and USACE during the IEPR process. Figure 1 shows the organization of this IEPR. The purpose of this organization is to assure the independence of the review.

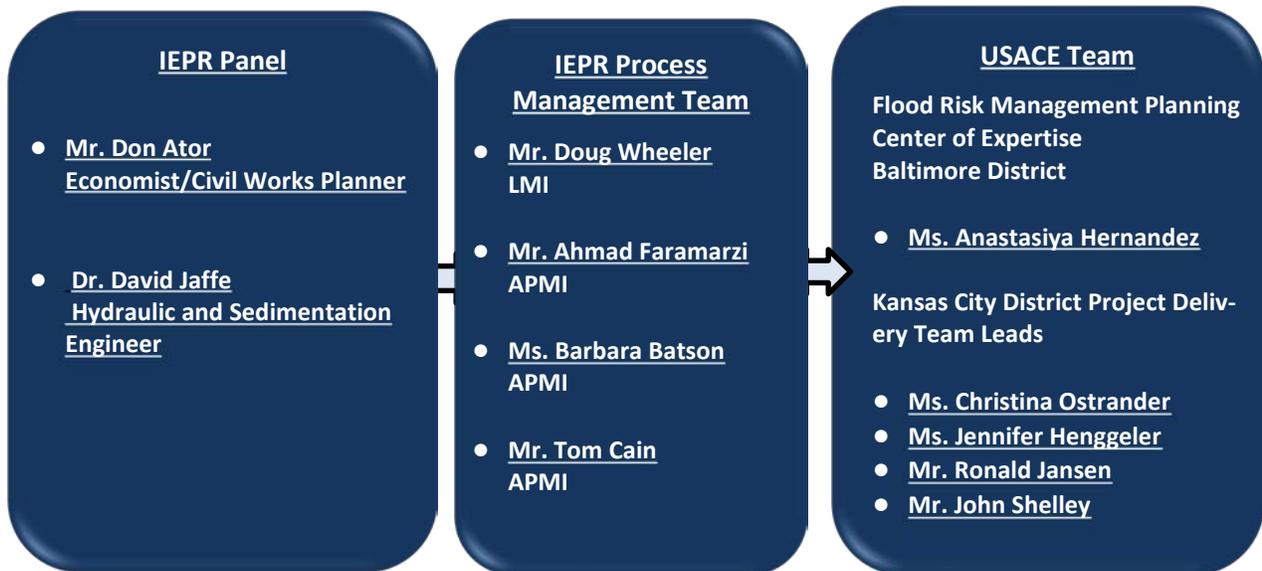


Figure 1: IEPR Organization

4.1 IEPR Panel Description

The Panel members satisfied the qualification requirements for each of the areas of expertise. The Panel members have experience working in academia, industry, and government. Table 2 depicts the Panel members' qualifications and experience.

Table 2: Summary of IEPR Panel Member Qualifications by Discipline

Requirements		Prof. Don Ator	Dr. David Jaffe
Subject Matter Expertise	Highest Degree	MBA	PhD
	Years of Experience	35	15
	Past Experience with USACE (Direct [D], Indirect [I], and none [N])*	D	I
Civil Works Planner	Have a minimum of 10-years demonstrated experience in public works planning.	✓	
	Familiar with USACE plan formulation process, procedures and standards as it relates to flood risk management.	✓	
	Familiar with evaluation of alternative plans for flood risk management.	✓	
	Have a minimum of 5-year experience directly dealing with the USACE six-step planning process, policies, methodologies and procedures as governed by ER 1105-2-100, Planning Guidance Notebook.	✓	
	Active participation in related professional societies is encouraged.	✓	
Economist	Have a Master’s degree or higher in economics and a minimum of 15 years demonstrated experience in economics.	✓	
	Direct experience working for or with USACE is highly preferred, but no required	✓	
	Expertise in flood risk management, evaluating and conducting complex multi-objective public works projects with high public and interagency interest.	✓	
	Familiar with the USACE flood risk management analysis, economic benefit calculations, and expertise in economic analysis for flood risk management; specifically, with acceptable methodologies for estimating damages, and use of Hydrologic Engineering Center’s Flood Damage Reduction Analysis (HEC-FDA).	✓	
	Familiar with Palisade @RISK Software and experience in determining the cost effectiveness of alternatives evaluations.	✓	
Hydraulic and Sedimentation Engineer	Registered professional engineer with a minimum of 15 years’ experience in hydrologic and hydraulic engineering.		✓
	Experience with all aspects of hydraulic and sedimentation engineering including: analysis of large complex river systems, urban hydraulics, open channel systems, effects of management practices and low impact development on hydrology, design of earthen dams and detention ponds.		✓
	Experience with reviewing FRM and similar water resources projects for assessment and presentation of risk and public safety considerations.		✓
	Familiar with Hydraulic Engineering Center River Analysis System (HEC-RAS).		✓
	Familiar with degradation projects and gravel mining operations.		✓

*Direct experience: A past USACE employee
 Indirect experience: Work experience with USACE projects
 None: No working experience with USACE projects

4.2 IEPR Panel Members

Professor Don Ator

Role: Economist/Civil Works Planner

Donald Ator was chosen primarily for his civil works economics experience and expertise. He earned an MS in Economics and Agriculture Economics from Louisiana State University in 1978 and an MBA in Finance and Accounting from Louisiana State University in 1984. He has over 35 years of experience working for 26 USACE districts. During this time he worked first as a full-time employee with USACE, and then in the private sector with a not for profit research institute, and with three architect-engineer firms. He has conducted more than 500 economics flood risk management studies evaluating and conducting complex multi-objective public works projects with high public and interagency interest nationwide. He has worked extensively with USACE conducting economics studies in accordance with ER 1105-2-100 and other pertinent guidance, laws, and regulations applicable to the USACE Six-Step Planning Process and EC 1165-2-209 review requirements.

Mr. Ator is nationally recognized for experience with USACE flood risk management analysis, economic benefit calculations, and expertise in economic analysis for flood risk management; specifically, with appropriate methodologies for estimating damages, and use of Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA). He is intimately familiar with Palisade @RISK Software and has demonstrated experience in determining the cost effectiveness of alternatives evaluations. Mr. Ator is actively involved in professional engineering and scientific societies including The American Society of Civil Engineers (ASCE) The Society of American Military Engineers (SAME).

Dr. David Jaffe

Role: Hydraulic and Sedimentation Engineer

Dr. Jaffe was chosen primarily for his extensive experience in using numerical models for coastal and riverine analysis, both commercial and proprietary. Dr. Jaffe's modeling experience includes significant use of modeling packages from federal agencies, HEC in particular. This work has included analysis, design and related regulatory elements. Dr. Jaffe has focused his technical expertise on the translation of engineering science into actionable environmental benefit including protection, restoration and remediation. His areas of technical focus reside in hydrology, hydraulics and sediment transport. Dr. Jaffe utilizes a broad scope of numerical and analytical methods, including a wide range of numerical models, and is an expert in applying existing, off-the-shelf tools to provide in-depth and forward-looking analysis and insight to complex hydraulic problems.

Dr. Jaffe has maintained his academic and research ties and currently serves as a lecturer in civil and environmental engineering analysis and design. Additionally, his current area of research focuses on using sediment transport, through modeling and measurement, as a proxy for several facets of environmental analysis and design. David's background in physical marine science, riverine hydraulics and numerical modeling provides a broad foundation for developing solutions in a diverse pallet of aquatic habitats, including those at the intersections of littoral and riverine systems. Dr. Jaffe also manages projects and programs that deal with environmental policy and systematic risk. These project and programs include large or regional government projects and small, locally driven initiatives covering a broad spectrum of agencies and interests. Dr. Jaffe has served as a project manager for federal and state projects, in particular those of FEMA, NMFS, USACE, USEPA and USBR.

4.3 IEPR Process Management Team

The IEPR process management team consisted of the following members.

Doug Wheeler, PMP, CCP, RMP, Program Manager (LMI)

Mr. Wheeler is an industrial and mechanical engineer with more than 20 years of experience in strategic process engineering and financial analysis including work for USACE, DOE, and GSA. For USACE, he led a consultant and client team in a business process reengineering effort for the Navigation Locks and Dams High-Performing Organization. He also led project teams in a variety of tasks to provide reengineering services to the USACE IT function. Because of his work leading the review of the USACE MKARNS maintenance activity and his support for the USACE IMTS, Mr. Wheeler understands the USACE's water navigation business area and supporting projects. He has also focused on real property and lease-related projects for GSA as well as economic assessments of infrastructure projects for DOE. Mr. Wheeler will apply LMI's COI process by reviewing each TO PWS with LMI's management team. LMI's process ensures that each LMI business unit manager is aware of TO scope and can raise organizational COI issues before LMI responds. He currently is focused on LMI's project cost engineering practice, privatization, and competitive sourcing services. Mr. Wheeler holds an MBA and a Bachelor of Science in mechanical engineering from Columbia University and an MSE in industrial engineering from Arizona State University.

Ahmad Faramarzi, PE, PMP, Project Manager (APMI)

Mr. Faramarzi supervised project personnel and communicated policies, procedures, and goals to the IEPR Team. In coordination with Mr. Wheeler, Mr. Faramarzi maintained regular contact with USACE and was responsible for the overall project plan, project performance, and client satisfaction on this as well as future tasks for USACE. He will also have multiple technical and administrative staff as direct reports. Mr. Faramarzi is a registered professional engineer and a certified project management professional with 35 years of experience providing managerial and technical expertise to government clients, including the USACE, Office of the Secretary of Defense, the U.S. Army, the U.S. Air Force, and Defense Nuclear Facilities Safety Board. He has organized and managed several important and highly visible expert panels in response to recommendations by the NAS. Mr. Faramarzi has a Post-Masters applied scientist/engineer degree from The George Washington University in Aerospace and Mechanical engineering (fluid mechanics), an MS in Thermofluid Engineering, and a Bachelor of Science in Nuclear Engineering. He is on the Board of Directors of the Washington, DC Section of the American Society of Mechanical Engineers and an active member of the Fluid Dynamics branch.

Barbara Batson, Task Leader (APMI)

Ms. Batson has over 20 years of experience with project management and facilitation with both Government and Corporate clients where she was responsible for ensuring project quality was maintained and schedules were completed on time. She has worked on projects for the Dept. of Defense, Dept. of Education, US Treasury, Social Security Administration, and the Dept. of Energy. Her project responsibilities included managing global projects with aggressive schedules and facilitating team members on multiple continents. Her experience with project management will ensure the project stays on schedule and all milestones are met.

Tom Cain, Analyst (APMI)

Mr. Cain is a Principal Chemical/Process Engineer with over 30 years of experience providing managerial and technical expertise to government clients, including the USACE, Office of the Secretary of Defense, the US Army, the US Air Force, the Department of Justice, and other government agencies. He has organized and managed and/or participated in several important and highly visible expert panels and conducted numerous studies in response to recommendations by the National Academy of Sciences. Mr. Cain has experience with environmental regulations, including the National Environmental Policy Act process, and with analyzing the environmental impacts of a wide variety of types of federal projects, particularly the technical aspects. Mr. Cain has routinely applied his engineering, scientific, and analytical skills to unclassified, sensitive, and classified government programs. Areas of expertise are primarily related to the Chemical, Biological, Radiological, Nuclear, and high-yield Explosive (CBRNE) field with particular subject matter expertise in chemical and explosives areas. Roles range from team contributor to technical lead to task/project/program manager while working across multiple disciplines and organizations to solve challenges, collaborate in research, and share expert knowledge.

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5 Independent External Peer Review Findings

The panel members generally agreed on the adequacy, philosophy of approach, and acceptability of the economic, engineering methodology, and analysis used to support the Missouri RBDFS. The panel members found that the supporting documentation adequately communicated the systematic development and evaluation of alternatives to address relevant potential failure modes. The panel members determined that, in general, the planning and design efforts are of high quality and conform to current criteria and guidance. The panel offered a number of comments to clarify specific content issues and improve the project.

There were a total of 22 comments. Of these, 2 were identified as having high significance, none as Medium High significance, 8 as Medium significance, 1 as Medium Low significance, and 11 as Low significance. The following paragraphs provide a summary of the Panel's comments in specific subject matter areas.

Hydraulic and Sedimentation Engineer

The level of effort and the results of the Study Appendices are of a high quality. It is clear that a great deal of thought and consideration went into the modeling for the project. For this, the project team should be commended, particularly in light of the challenges of this type of sediment transport modeling effort. The comments below improve the documentation.

There are two areas in which the documentation requires updates to address important issues: 1) addressing the development of the inflowing sediment boundary conditions, and 2) the development of the methodology calculating the loss of transported sediment to the floodplain. Both of these areas are important to ensuring confidence in the final model product since they both strongly influence the model bed response.

There are several areas in which the model documentation requires improvement. These updates include areas of clear reservoir discharges, model section spacing, tributary sediment limits, movable bed limits, dike orientation to the bank, and model output comparison with observed data. These areas are important to model bed response and require additional documentation of information in order to ensure confidence in the final model product. In addition, these areas typically need additional interpretation and description.

Civil Works Planning & Economics

The selection of models and application of data within the models is appropriate for use in the evaluations. The Economic model is adequately developed and reflects the uncertainty regarding the costs and inputs supporting the economic benefits. Future Without Project flow and dredging conditions are reasonable and appropriate. The model provides a means of assessing how changes to commercial dredging rates affect the rate of degradation, and the conclusions regarding the effect of commercial dredging on bed degradation are reasonable and supported.

The Panel had two comments that concern the overall understanding of the project. First, the Natural Valley Width was reported to have been computed using the 1% Annual Exceedance Probability (AEP) flows and removing levees from the FEMA floodway instead of Future Without Project conditions widths.

It is not clear that the Natural Valley Width was also modelled. At the Mid-Point meeting the USACE verbally acknowledged the need to revise the narrative and figures to address this.

Secondly, the assessment of the impact of commercial dredging on bed elevations in the Missouri River was made by running the calibration model with “no dredging” and comparing the results to model runs that included historic dredging levels from 1994 to 2014 and the permitted dredging level as of December 2015. A comparison of the model output using the “no dredging” scenario to model output using dredging levels for the period of 1994 to 2014 indicated 1 ton of dredging resulted in 0.94 tons of bed loss and the model output using the permitted dredging level for December 2015 indicated 1 ton of dredging resulted in 0.81 tons of persistent bed loss. No information is provided on the dredging quantities for the two periods in the Missouri River Degradation Study, Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty, ATR Draft – 24 May 2016. As a result, the reviewer cannot reconcile the difference in the model output for the model runs that included historic dredging levels from 1994 to 2014 and the permitted dredging level as of December 2015.

5.1 Independent External Peer Review Panel Comments

This section contains the complete set of comments of the IEPR panel. Each comment consists of four parts:

- Comment
- Basis for comment
- Significance of the concern, and
- Recommendation for resolution of the comment

Comments were rated to indicate the general significance the comment has to the project implementability. The final comments below are grouped by the significance level from high to low using the following definitions:

- **High** – Comment describes a fundamental problem with the project that could affect the recommendation or justification of the project.
- **Medium High** – Comment affects the completeness or overall understanding of the recommendation or justification of the project. Resolution of the issue determines if it is fundamental problem with the project or not.
- **Medium** – Comment affects the completeness or overall understanding of the recommendation or justification of the project.
- **Medium Low** – Comment affects the technical quality and understanding of the project based on the presentation of information related to the recommendation or justification of the project. However, the panel does not have sufficient information to determine the effect on project implementability.
- **Low** – Comment affects the technical quality and understanding of the project based on the presentation of information related to the recommendation or justification of the project, but there is limited concern regarding project implementability.

Significance: High

Comment #1
Two different methods are used to develop the inflowing sediment boundary condition (inflowing sediment load), but it is unclear if the approach of combining the two methods is reasonable. The text needs to be revised to clarify for the reader the procedures utilized and the benefits and consequences of the approach.
Basis for Comment
Inflowing boundary sediment load was developed using both daily and annual estimates of suspended load. The text describes that an inflowing load condition is based on the inflowing discharge. The inflowing (boundary) load is then modified to fit within an annual average load at the boundary. It is unclear in the text how two data sets are combined over the course of model simulations since it appears that the sediment load boundary condition would revert to the annual estimates. That is, the annual average adjustment of inflowing load would supersede the inflowing discharge based load. Moreover, only sand and gravel classes are included, while smaller classes may dominate some portions of the inflowing sediment load. No clear explanation is given for excluding the smaller size classes from the inflowing sediment load.
Significance – High
Inflowing sediment boundary condition is one of the most important modeling parameters for riverine sediment transport models. Its impact on the modeling outcome cannot be overstated. For example, an inflowing load may lead the model to predict too much deposition relative to the actual deposition in the system being modeled.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none">1. Only sand and gravel is included in the inflowing sediment load, but this approach will underestimate total sediment load. The rationale for this decision should be included in the text.2. Add additional text to clarify the method of combining the inflowing sediment load.

Comment #2
Other parameters may be better representative of floodplain sediment deposition than flood event duration.
Basis for Comment
In the present modeling effort event-transported sediment loss to the floodplain is estimated using event duration as a proxy for modeling sediment deposition. While it is understood that there is limited data on the deposition of sediment in the floodplain during the 2011 event, event duration is only one proxy for estimating sediment deposition in the floodplain. Other proxies may be better representative of floodplain sediment deposition, such as event average or event peak discharge. This is because the exact mechanism, beyond overbank flooding) for sediment deposition in the floodplain is unclear, and may vary from event to event. The analysis should consider the fact that sediment transport is a function of several factors, including grain size class, event peak discharge and event average discharge. A sensitivity analysis is typically employed to determine how a model responds to variation in its parameters. In this instance a sensitivity analysis can be employed to determine the model sensitivity to estimates of floodplain sediment deposition.

Significance – High
It is possible that event duration is not the best proxy for sediment lost to the floodplain. Other parameters, or combination of parameters, may be provide more representative model results. It is important to have some level of confidence in the estimating methodology, even where there is a paucity of measurements. In this case sediment lost to the floodplain cannot move through the stream and may result in increased erosion, in sediment transport discontinuities, or otherwise influence model bed changes. As with other model parameters an understanding of the impact on this parameter will increase confidence that the model is behaving predictably and representing natural phenomena within the limits of available data.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none"> 1. Perform a sensitivity analysis for sediment deposition in the floodplain using other proxies for deposition.

Significance: Medium

Comment #3
The Natural Valley Width was reported to have been computed using the 1% Annual Exceedance Probability (AEP) flows and removing levees from the FEMA floodway instead of Future Without Project and/or existing conditions widths.
Basis for Comment
In the ATR Draft Jan 2016, the narrative and Figure 2, <i>Valley Width and River Top Width at Different Flood Levels</i> , should make it clear that the Natural Valley Width was also modelled.
Significance – Medium
This affects the completeness or overall understanding of the recommendation or justification of the project. It also describes an issue with the project, which does not align with the currently assessed level of risk assigned at this stage in the USACE’s SMART Planning process. Based on the information provided, this issue raises the risk level if not appropriately addressed.
Recommendation for Resolution
The Panel has devised the following recommendation(s) related to this comment: <ol style="list-style-type: none"> 1. Provide an explanation in the report narrative of why the Natural Valley Width was computed using the 1% Annual Exceedance Probability (AEP) flows and removing levees from the FEMA floodway. At the Mid-Point Conference the USACE verbally acknowledged the need to revise the narrative and Figure 2 to make it clear that the Natural Valley Width was included in the model.

Comment #4
Clearer reservoir discharges are expected to have lower sediment loading than other types of flows.

Basis for Comment
Section 2.4 of the text discusses the 2011 event and notes that the event was important for several reasons including “a majority of the flow volume passed through the upstream reservoirs, as opposed to local tributary inputs.” The implication in this section of the text is that flows passing the reservoirs carry lower sediment loads. Specifically, if high reservoir discharges occurred then the River flows resulting from these discharges would likely be lower in sediment load than discharges that did not pass through the reservoirs. It is important to understand the influence on these type of discharges on the model output since more clear flows will have a different bed response than less clear flows.
Significance – Medium
This fact and/or assumption appears to be important in other elements in the study. Because of that importance, it should be clearly stated in this section so the reader can follow the logic while moving through the description of the analysis.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none"> 1. If the point that flows passing through reservoirs have lower sediment loads, it should be explicitly stated in the documentation. Provide clarification in the text.

Comment #5
Although the resolution of model sections (section spacing) is generally good, no discussion is provided or references cited, which provides uncertainty for continuity and understanding bed change.
Basis for Comment
In Section 3.1 of the Calibration report it is stated that model sections are spaced at 1.85/mile, on average, which is approximately 2,852 feet between sections. This resolution is good, generally, but there is no discussion of resolution, nor does it appear to be referenced. The maximum and minimum and variation of the resolution do not appear to be stated.
Significance – Medium
Model section resolution is important for continuity and for understanding bed change. Maximum, minimum and variation of spacing is important to understanding any flaws of, and certain results in, the numerical modeling.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none"> 1. Add a description in the documentation regarding the maximum, minimum and variation in section spacing. 2. Describe the impact of model section spacing may have on the modeling results.

Comment #6
Tributary sediment load discussion should be expanded
Basis for Comment
Tributary percent of total load is described in the text, but not how it was determined. The inflowing sediment load contributes between 9 and 17% of the total (Section 2.5). There is no discussion of how these values were determined or how they are addressed directly.

Significance – Medium
Inflowing sediment load is a strong driver of bed response. Low sediment inflowing load may result in bed degradation, while high inflowing load may result in bed aggradation. How the inflowing tributary load was determined has implications for model bed response, thus the method for determining these values is significant to understanding model output.
Recommendation for Resolution
The Panel has the following recommendation(s): <ul style="list-style-type: none"> 1. Expand the description of the tributary sediment loads, the determination of their values, and how they are implemented in modeling.

Comment #7
Describe the sensitivity analysis for movable bed limits.
Basis for Comment
The description of the sensitivity analysis of movable bed limits is insufficient for the level of effort that developing the extents must have taken. The effort is only described in one sentence. Moreover, it is unclear how the analysis was completed, the assumptions of the analysis, or the results of the analysis. The text states “During calibration, the moveable bed limits were adjusted inward 40 to 120 ft to decrease the active channel width over the final 13.3 miles.” The intervals of these adjustments are not described, nor are the resulting changes in bed elevation described. Finally, it is unclear why only 13.3 miles of stream bed were considered and not the entire model reach, as is typical.
Significance – Medium
Moveable bed limits are an important modeling parameter in sediment transport modeling. They have a very strong influence on the calculation of bed change. The Corps of Engineers has long recognized the importance of bed limits on model output, going back in time at least as far as Training Document 13 (TD-13). A full discussion of the development of this modeling parameter is warranted so the reader can understand the development of the bed limits and their influence on model output.
Recommendation for Resolution
The Panel has the following recommendation(s): <ul style="list-style-type: none"> 1. Expand the discussion of the movable bed limits to include the sensitivity analysis of this parameter and explain/describe the results of the analysis. The analysis and description of it can follow the procedures of TD-13 or more recent guidance, as applicable.

Comment #8
In Figure 39, “Comparison between National Weather Service and Model Annual Peak Elevations”, of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report”, the overall bias seems low, but individual station bias appears to exist.
Basis for Comment
While most of the data in the figure seems centered on 0.0 some stations appear to have averages that are not centered on 0.0. This is particularly true of the Atchison station. Differences between model and gage Water Surface Elevation (WSE) suggest systemic model error should be addressed in calibration. It is unclear what the variation in bias is between stations and what is the cause. It is also

unclear what the influence is on (or more likely what is the influence that resulted in) the model output.

Significance – Medium

The Figure appears to show that compared to measured data the average bias in model output is around 0.0. A review of the data indicates that some stations in the model do not well represent the observed water surface elevation peak data. This implication is important since bed change at these locations may be similarly not well represented by the model, particularly since the local hydraulics impacts the local bed change. Moreover, this data implies that while the model peak bed change may be representative of the study reach, on average, there are sections in the model that are not expected to be representative. This finding and its implications should be discussed.

Recommendation for Resolution

The Panel has the following recommendation(s):

1. Revise the analysis to address the bias and its significance to the modeling effort. Address the causes of the bias, the concerns about the observed results, and how the observed bias impact the modeling conclusions.

Comment #9

There is insufficient discussion of deviation of the model output from observed hydraulic parameters.

Basis for Comment

There is relatively little discussion of model output deviation from of observed data; either in the model calibration or final runs. It is unclear if and where any systematic model errors occur and what the causes may be. This is true for all parameters, such as volume, velocity, depth, water surface elevation, etc.

The documentation should identify and describe the model deviation from observed data for a wide range of model output parameters. The documentation should also list the possible causes of the observed deviations and their impact on the model results and any potential consequences of these results.

Significance – Medium

It is important for readers to understand where the model exhibits systemic deviation from observed behavior, where it occurred in the model and what the causes of the deviation are. This should be a major element of the documentation so that the reader can trust that the model has been set up and vetted properly.

Recommendation for Resolution

The Panel has the following recommendation(s):

1. Identify and describe the model deviation from observed data for a wide range of model output parameters.
2. List the possible causes of the observed deviations and their impact on the model results and any potential consequences of these results.

Comment #10

Other types of dike orientation may need to be considered for length reduction.

Basis for Comment
<p>There may be instances where effective dike length is a function of velocity or depth (or the averages thereof). This may be considered as analogous to the change in Manning’s roughness as a function of depth. Also, the absolute dike length should be considered in light of the angle of the dike to the bank. That is, an angled dike is likely to have a shorter effective length than a dike placed at 90 degrees to the bank. It is unclear from the text if shore parallel dikes exist. If so, it is unclear if they would require shortening under the current methodology. It is also unclear how the range-of or average velocity or depth be considered in the shortening equation just as it is unclear about how to consider the angle to the bank.</p> <p>The documentation should show how effective dike length is independent of velocity and depth, dike angle to the bank. Also, it should indicate direction of flow and location of banks in dike figures.</p>
Significance – Medium
<p>Dikes can impact the sediment transport in several ways. For example, the dikes can directly trap sediment or they can alter local channel hydraulics in ways that subsequently alter sediment transport. There are many characteristics of the dikes that will produce the impacts, including, dike length, dike spacing, dike orientation to the bank (angle), dike height above the bed, dike depth below the water surface, etc. Dike orientation to the bank may effectively alter the length of dike observed by the stream flow. For example, a dike that is severely skewed toward the downstream may only impact the flow (and subsequent sediment transport) in a manner that is less intense than the dike length would suggest since the total distance into the flow is short relative to the overall dike length. Conversely, a dike that is slightly skewed toward the upstream bank may have more impact on the stream flows since skew may effectively direct water toward the bank. Orientation as well as spacing should be considered as part of dike length adjustment.</p>
Recommendation for Resolution
<p>The Panel has the following recommendation(s):</p> <ol style="list-style-type: none"> 1. Show how effective dike length is independent of velocity and depth and of dike angle to the bank. 2. Indicate direction of flow and location of banks in dike figures.

Significance: Medium/Low

Comment #11
<p>No information is provided on the dredging quantities for the two periods in the “Missouri River Degradation Study, Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty”. As a result, the difference in the model output for the two periods cannot be reconciled.</p>
Basis for Comment
<p>The assessment of the impact of commercial dredging on bed elevations in the Missouri River was made by running the calibration model with “no dredging” and comparing the results to model runs that included historic dredging levels from 1994 to 2014 and the permitted dredging level as of December 2015. A comparison of the model output using the “no dredging” scenario to model output using dredging levels for the period of 1994 to 2014 indicated 1 ton of dredging resulted in 0.94 tons</p>

of bed loss and the model output using the permitted dredging level for December 2015 indicated 1 ton of dredging resulted in 0.81 tons of persistent bed loss.
Significance – Medium/Low
This affects the technical quality and understanding of the project based on the presentation of information related to the recommendation or justification of the project. However, the panel does not have sufficient information to determine the effect on project implementability.
Recommendation for Resolution
The Panel has devised the following recommendation(s) related to this comment: <ol style="list-style-type: none"> 1. Include information on the dredging quantity inputs for the model runs for the two periods documented and an explanation of why they are different in the Missouri River Degradation Study, Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty, ATR Draft – 24 May 2016.

Significance: Low

Comment #12
Figure 2, “Valley Width and River Top Width at Different Flood Levels”, of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” needs a slight adjustment.
Basis for Comment
The 2% AEP top width is greater than the valley width at River Mile (RM) 500.
Significance – Low
This appears to be a plotting error and occurs at the very end of the graph, posing little impact to the results, but confusing the interpretation of the figure.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none"> 1. Revise Figure 2 to eliminate the 2% AEP top width being greater than the valley width at River Mile (RM) 500.

Comment #13
The first paragraph in Section 2.4 of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” is confusing by not describing the return interval event for 1997.
Basis for Comment
The first paragraph of Section 2.4, “Cumulative Mass of Bed Change”, states, “From 1994 to 2009 the river experienced a range of flows with the largest peak flow event occurring in 2007 at 286,000 cfs at the Kansas City gage, which is slightly smaller than a 20-year return interval event, and the longest duration flow being 1997 when the river was near bankfull a majority of the year due to very high runoff upstream of the mainstem dams.” The text refers to the 2007 event as corresponding to slightly smaller than a 20-year event. The text next discusses the 1997 event as being bankfull, but does not describe the return interval. This makes this discussion confusing. The return interval should be discussed.

Significance – Low
Confusing use of mixed terms makes it difficult for the reader to clearly understand these important factors.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none"> 1. Add a discussion for the return interval to the first paragraph of Section 2.4 of the Calibration Report.

Comment #14
Figure axes directions are inconsistent when identifying River Miles, making it difficult to interpret data in similar areas.
Basis for Comment
In some figures in the reports the x-axis is labeled in such a way that a downstream-to-upstream convention is used (left to right), while others are labeled using an upstream-to-downstream convention. This is confusing to read and makes it difficult to interpret data in similar areas. A few have x-axes where the River Mile increases, whereas all others decrease (the opposite direction). This makes it confusing and difficult to interpret and compare the data from those figures to the others. A standard x-axis direction for the River Miles needs to be established. The graphs where the River Miles increase are: <ul style="list-style-type: none"> • Figures 2 and 26 of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” (provided they have not been renumbered, which they need to be) • Figure 23 of the “Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty” • Figure 3 of the “Reduction in Dike Lengths to Account for Expansion and Contraction”
Significance – Low
Confusing inconsistency of x-axis labeling for the River Miles on the graphs make data interpretation difficult for the reader.
Recommendation for Resolution
The Panel has the following recommendation(s): <ol style="list-style-type: none"> 1. Determine the most representative axis labeling convention and apply it universally to all graphs in all reports.

Comment #15
Paragraph 4, section 2.5, “Principal Causes of Degradation”, of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” provides summary values without any corresponding information to show how they were generated.
Basis for Comment
Paragraph 4, section 2.5, “Principal Causes of Degradation”, of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report”, states “... the total tons dredged from Kansas City (RM

350 to 400) represent 219% of the active channel bed degradation seen in that time period.” And, “From 2009 to 2013, the period that includes the 2011 flood, the dredging represents 121% of degradation in the Kansas City reach.”

An explanation of how this value was determined or calculated should be included in the text.

Significance – Low

It is helpful to the reader to understand assumptions, calculations and results that statements about calculation methodology be clear.

Recommendation for Resolution

The Panel has the following recommendation(s):

1. Provide discussion in section 2.5 Principal Causes of Degradation, of the Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” explaining how this value was determined or calculated.

Comment #16

Some model sections appear to be skewed (not perpendicular) to the channel center line.

Basis for Comment

It is unclear if section skew was addressed in cutting sections from the 1994 survey. The method that section skew is addressed in the model needs to be described. Typically, skew is addressed by adjusting model reach lengths. This methodology is particularly effective when channel planform requires sections be cut perpendicular to the channel center line, but not parallel to one another, such as at bends. Skew becomes most critical in one-dimensional models in locations where the physical system does not conform to the model assumption of one-dimensional flow.

Significance – Low

Section skew is an important modeling parameter. It is unclear in the text, however, if and how the survey information was incorporated in the numerical modeling with respect to skew adjustments, and what form these adjustments took.

Recommendation for Resolution

The Panel has the following recommendation(s):

1. Describe how section skew is addressed in the modeling with respect to the development of the sections.

Comment #17

Include drainage area maps

Basis for Comment

In the Flows subsection of section 2.4 of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report”, it is noted in paragraph 3 states, “Tributaries that enter the Missouri River between Kansas City and Waverly are insignificant, causing an increase in drainage area of only 0.4%.” However, tributary areas of approximately 3% and larger can strongly influence sediment transport trends in fluvial systems.

Significance – Low
Although likely to have a low impact in this instance (as 0.4% of the drainage area is likely below the threshold), the information should still be provided to the reader when possible and especially when modeling assumptions are made about their interaction with the main channel model.
Recommendation for Resolution
The Panel has the following recommendation(s): Illustrate locations of tributary inflow, and provide a table of inflow water and sediment discharges in the Flows subsection of section 2.4 of the “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” when discussing the model assumptions for reader clarity.

Comment #18
The second paragraph under Sediment Load, section 3.4 of “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report”, is unclear what is being discussed and how it relates to this subsection.
Basis for Comment
This paragraph, “USGS (2010) estimates annual suspended sand loads at Missouri River gages through Water Year (WY) 2005. The total estimated sand load for WY 1995 – WY 2005 is 105,120,000 tons. Seven of the years include an estimate for the upper 95% confidence limit of 1.11 to 1.23 times the estimated load. Assuming a similar ratio for the four years remaining without a computed upper confidence limit, the total 95% confidence limit can be approximated as 121,162,461 tons.”, appears to be cut and pasted into its current location and does not make clear what is being discussed and how it relates to the other information in the subsection.
Significance – Low
Confusing text like this affects the clarity of this report, but there is little concern that this information will affect the model.
Recommendation for Resolution
The Panel has the following recommendation(s): 1. Revise the second paragraph under Sediment Load, section 3.4 of “Missouri River Bed Degradation Study Mobile Bed Model Calibration Report” for readability and improved comprehension.

Comment #19
Cumulative dredging by year in Figure 26, “Cumulative Dredging by River Mile as Percent of the Total Dredging 1997 – 2009”, in the “Missouri River Bed Degradation Study, Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty” are indistinguishable.
Basis for Comment
All lines for yearly values are the same color, making them indistinguishable. It is clear from the figure that the average is developed from the annual data. It is not possible to distinguish trends annually, if any, because the different water years are not discernable from one another.

Significance – Low
Confusing graphs like this affect the understanding and clarity of this report. There is value in visualizing the yearly progression of the data that develops the trend line. For example, certain events or series of events in the past may be so pronounced that they have a strong influence on the determination of the trend.
Recommendation for Resolution
The Panel has the following recommendation(s): <ul style="list-style-type: none"> 1. Revise the figure to make the different water years clear. This can be accomplished any number of ways as long as there is some distinguishing features that allow the reader to distinguish between the different water years.

Comment #20
Figure 41, “Longitudinal Cumulative Mass Calibration: 1994 to 2009”, in the “Missouri River Bed Degradation Study, Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty”, requires clarification.
Basis for Comment
Because of the resolution of the plot, it is unclear how well the model compared to observations. The average, standard deviation, maximum and minimum of difference should be discussed. The scale of the plot is such that important behaviors within the model can be masked in the data.
Significance – Low
Graphs like this without supporting data affect the understanding and clarity of this report. There are other graphs with similar issues (for example, Figure 42). For this figure, and the ones like it, it is unclear where there are significant variations or deviations from the observed data. Identifying significant variations or deviations may assist in detecting locations in the model that need adjustments to parameters or where further review is warranted.
Recommendation for Resolution
The Panel has the following recommendation(s): <ul style="list-style-type: none"> 1. Discuss the average, standard deviation, maximum and minimum of difference of Figure 41, “Longitudinal Cumulative Mass Calibration: 1994 to 2009”, in the “Missouri River Bed Degradation Study, Technical Appendix, Future Without Project Model Projections with Risk and Uncertainty”. Note any important characteristics in the data.

Comment #21
Standardization of symbology should be considered between figures to increase comprehension of the report data.
Basis for Comment
Within the different plots in the documents there are many different colors, shapes, and formats used in the symbology for the same data or representation. The authors should standardize the graphical information among all figures. For example, a single symbology for existing, proposed, modeled, observed, 2005, 2011, etc. may benefit readers.

Significance – Low
Graphs and figures without a standardized symbology affect the understanding and clarity of this report. It is presently challenging to the reader to sort out the symbology for so many different graphs and figures. A common symbology among all graphs and figures would benefit the reader
Recommendation for Resolution
The Panel has the following recommendation(s): <ul style="list-style-type: none"> 1. Consider standardizing the symbology of all the figures and graphs in the various reports.

Comment #22
The terminology bed load vs. bed flux and related terms needs to be clarified in the reports.
Basis for Comment
Typically, terms like bed load, bed flux, and others are used interchangeably despite having very different meanings. Terminology must be used uniformly and for specific technical attributes.
Significance – Low
Nonstandard terminology affects the technical understanding and clarity of this report. While there is little concern that this terminology will affect the model it remains unclear to the reader how which phenomena is being described.
Recommendation for Resolution
The Panel has the following recommendation(s): <ul style="list-style-type: none"> 1. Review the use of terminology like bed load and bed flux to ensure that they are used uniformly and according to their technical definitions to ensure clarity in the text.

Appendix A **Charging the Independent Peer Review Panel**

Products for Review

Following is a list of products to that were reviewed in this Interim IEPR.

- a. **Mobile Bed Model:** The quasi-steady, one-dimensional flow, HEC-RAS v 5.0.
The purpose of this model is to evaluate river bed and water surface profiles for future without and with project conditions.
- b. **Economic Model:** The economic model consists of a Microsoft Excel spreadsheet with Palisade @RISK Software. The Economic model spreadsheet accepts output from the mobile bed model, contains facility operational conditions input, and facility repair, reconstruction or replacement cost data. The model evaluates future facility repair, reconstruction, or replacement costs under without-project and alternative with-project conditions.
 - Technical Appendix: Mobile Bed Model Calibration Report
 - The purpose of this appendix is to document the model calibration including model geometry, boundary conditions, flow conditions, sediment loadings, and dredging condition.
- c. **Technical Appendix: Future Without Project (FWOP) Model Projections**
The purpose of this appendix is to document the degradation projections conducted in conjunction with the Missouri River Bed Degradation Feasibility Study for the Future Without Project condition. This appendix describes updates to model geometry, explains the development of the hydrologic boundary condition for the projection period and provides Future Without Project bed elevation and water surface elevation projections.
- d. **Technical Appendix: Future With Project (FWP) Model Projections**
The purpose of this appendix is to document the degradation projections conducted in conjunction with the Missouri River Bed Degradation Feasibility Study for the Future With Project condition. Bed bathymetry, structure heights, hydrologic input, dredging condition, output time step, and temporal smoothing are all the same as for the Future Without Project analysis, as described in the previous appendix. Analyses for 15 alternatives are presented in this appendix. Each alternative includes one of five structural actions (indicated by a letter designation) and one of three dredging conditions (indicated by a number designation).
- e. **Technical Appendix: Modeling Sensitivity Analysis**
The purpose of this appendix is to define the sensitivity of degradation projections under hydrologic scenarios, dredging conditions, and sediment loadings that differ from those used in the FWOP and FWP model runs.
- f. **Technical Appendix: Economic Write-up with Model Documentation**
The purpose of this appendix is to document the benefits and costs associated with each alternative. The one time use Excel spreadsheet with the @Risk add-on is to incorporate output from the mobile bed model, facility operational conditions input, and facility repair, reconstruction or

replacement cost data to evaluate future facility repair, reconstruction, or replacement costs under without-project and alternative with-project conditions.

Key General Review Considerations

- a. Was the selection of models appropriate for use in evaluations?
- b. Was the application of data within those models appropriate?
- c. Was the interpretation of and conclusions drawn from model results reasonable?
- d. Are the sources, amounts, and levels of detail of the data used in the analysis appropriate for the complexity of the project?
- e. Do the appendices represent an integrated and technically consistent product?

Specific Risk and Uncertainty Review Considerations

- a. Does the economic spreadsheet model adequately reflect uncertainty regarding costs and inputs supporting economic benefits? Note that the spreadsheet includes the @Risk add-on feature.
- b. Does the overall analytical approach (including the economic model, mobile bed model, sensitivity analyses and scenario analyses) adequately address risk and uncertainty?

Specific Product Review Considerations

These questions have been developed to seek confirmation that the developments of these models, documentations, analyses, and conclusions have been developed with sound engineering practices, reasonable engineering judgement, good methodology, reasonable assumptions and that these models are adequate for their intended purpose.

a. Model Creation/Calibration

- i. Is use of quasi-steady, one-dimensional flow, HEC-RAS v 5.0 beta, with the bed mixing algorithm (Exner 5), including the cover layer gradations which coarsen and dynamically armor underlying finer sands, an appropriate software / approach for the study?
- ii. Are the grain size fractions of degradation reasonable?
- iii. Is dredging assumptions and analysis appropriately included in the model?
- iv. Does the model correctly compute sediment transport?
- v. Is the approach of not “dynamically adjusting” dikes and sills over time reasonable and adequate for model calibration?

- vi. Is calibration to mass or volume appropriate, rather than calibrating to channel invert or average bed elevation of individual cross-sections?
- vii. Is cross-section spacing appropriate to assess the effects of study alternatives, including dike/sill modifications and dredging restrictions?
- viii. Are Manning 'n' values reasonable and appropriate?
- ix. Is the mobile bed model adequately calibrated considering sediment volumes, velocities, and water surfaces?

b. Future Without Project

- i. Is the update of the model to 2013 bed geometry and dike/sill elevations appropriate?
- ii. Are the FWOP flow condition assumptions reasonable and appropriate?
- iii. Are the FWOP dredging condition assumptions reasonable and appropriate?
- iv. Is the approach of not "dynamically adjusting" dikes and sills over time reasonable and adequate for the FWOP conditions?

c. Alternatives

- i. Are the alternatives adequately reflected in the RAS geometry?
- ii. Does the model provide an adequate means for assessing changes to BSNP geometry for screening, ranking, and evaluating the effectiveness of measures for impacting the rate of degradation?
- iii. Does the model provide an adequate means for assessing how changes to commercial dredging extraction rates impact the rate of degradation?

d. Sensitivity Analysis

- i. Is the variability in future flows adequately assessed and are reasonable bounds provided, understanding that robust statistical tools are not available for mobile-bed modeling?
- ii. Are the conclusions in the report/appendix regarding the affect of commercial dredging on bed degradation reasonable and adequately supported by the analyses?
- iii. Are the effects of potential future increases or decreases to sediment load adequately assessed?
- iv. Is the sensitivity analysis provided sufficient to conclude the model's adequacy for estimating the effects of BSNP changes and dredging changes and for screening, ranking, and assessing impacts to the rate of degradation, and that uncertainty with major parameters is unlikely to alter the conclusions and relative ranking of alternatives?

e. Model Interface

- i. Are the outputs of the HEC-RAS model adequate for inputs to the economic model?
- ii. Does the overall approach with regards to outputs from the HEC-RAS model to inputs of the economic model reasonable and produce adequate results for evaluating alternatives?

All products are considered draft and pre-decisional and shall not be released outside the Corps of Engineers except when an organization or Architect/Engineering firm is under direct contract to perform specific activities for the project.

Appendix B **Qualifications of the Independent External Peer Review Panel Members**

The qualifications of the IEPR panel members (in alphabetical order) are provided below in summary form to show their expertise for this project.

B.1 Prof. Don Ator

Role: Economist/Civil Works Planner

Prof. Donald Ator was chosen primarily for his civil works economics experience and expertise. He earned an MS in Economics and Agriculture Economics from Louisiana State University in 1978 and an MBA in Finance and Accounting from Louisiana State University in 1984. He has over 35 years of experience working for 26 USACE districts. During this time he worked first as a full-time employee with USACE, and then in the private sector with a not for profit research institute, and with three architect-engineer firms. He has conducted more than 500 economics flood risk management studies evaluating and conducting complex multi-objective public works projects with high public and interagency interest nationwide. He has worked extensively with USACE conducting economics studies in accordance with ER 1105-2-100 and other pertinent guidance, laws, and regulations applicable to the USACE Six-Step Planning Process and EC 1165-2-209 review requirements. Mr. Ator is nationally recognized for experience with USACE flood risk management analysis, economic benefit calculations, and expertise in economic analysis for flood risk management; specifically, with appropriate methodologies for estimating damages, and use of Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA). He is intimately familiar with Palisade @RISK Software and has demonstrated experience in determining the cost effectiveness of alternatives evaluations. Mr. Ator is actively involved in professional engineering and scientific societies including The American Society of Civil Engineers (ASCE) The Society of American Military Engineers (SAME).

Prof. Ator is a Research Associate, Professor, and Undergraduate Advisor in the Department of Agriculture Economics and Agribusiness at Louisiana State University. Prof. Ator's responsibilities include research, grant writing and proposal development, extension and outreach, undergraduate advising and teaching Agricultural Commodity Marketing and Risk Management. His current research is in financial resiliency planning for local governments in Louisiana, Texas, Alabama, Mississippi, Florida, Georgia, Kentucky, and Nebraska.

Prof. Ator has over 35 years of demonstrated experience in public works planning, working with project teams to identify and evaluate measures and alternatives using appropriate planning methodologies to reduce life safety risk. He earned his MS in economics and agricultural economics and has an MBA in finance and accounting from Louisiana State University. He has worked with 22 different USACE districts nationwide, as well as with the Bureau of Land Management, Bureau of Reclamation, and the Department of Commerce. He was the associate director and senior economist for the Gulf South Research Institute and project/program manager and senior economist at three private engineering firms. He has conducted more than 500 Civil Works projects nationwide that required the development of relevant and credible socioeconomic information and analysis, and performed the quality assurance review for all economic aspects of these projects. He is experienced in determining the scope and appropriate methodologies for impact assessment and analyses for a variety of projects and programs with high public and interagency

interests. His scope includes: Economic Evaluation of Benefits from Beneficial Use Disposal Alternatives of Dredged Material for Consistency with State of Texas Coastal Management Plan, Texas (USACE, Galveston District); Missouri River Authorized Purposes Study (MRAPS) Project Management Plan (USACE, Omaha and Kansas City Districts); and the Municipal and Industrial Water Use Forecast, Southwest Florida Feasibility Study, Florida (USACE, Jacksonville District).

Prof. Ator's experience has made him intimately familiar with the USACE plan formulation process, procedures, and standards as they relate to flood risk management. He has demonstrated proficiency in the USACE six-step planning process as evidenced by development of a template for preparing Project Management Plans for feasibility studies for USACE Regional Planning and Environment Division South, Mississippi Valley Division in 2011 and field testing the template in 2012. Most recently, he worked with the USACE New Orleans District Project Delivery Team to develop the Project Management Plan for the West Shore Lake Pontchartrain Flood and Storm Damage Risk Reduction Project. In 2010, Prof. Ator served as a team leader while embedded in the Plan Formulation Branch USACE New Orleans District directing plan formulation activities of three plan formulators and providing project oversight and review to ensure compliance with USACE guidelines.

Prof. Ator is familiar with the USACE structural flood-risk management analysis and economic benefit calculations and standard USACE computer programs, including HEC-FDA. He has conducted structure inventory surveys for flood damage reduction studies, developed content-to-structure value relationships for urban flood control economic analyses, and has prepared Section 905(b) flood damage reduction and ecosystem restoration reconnaissance reports. A majority of the projects he has conducted have required use of the HEC-FDA computer program. He attended a USACE-sponsored workshop on the model certified version of HEC-FDA in March of 2010 hosted by the Mississippi Valley Division. His related project experience includes the Structure and Content Depth Damage Relationship Surveys, Ouachita Parish, Louisiana (USACE, Vicksburg District); the Development of Content to Structure Value Relationships for Urban Flood Control Economic Analysis, Cypress Creek, Texas (USACE, Galveston District.); and the Orleans Parish, Louisiana, Urban Flood Control Feasibility Study, Structure Inventory (USACE, New Orleans District).

Prof. Ator's experience with National Economic Development analysis procedures, particularly as they relate to flood risk management, includes serving as a team leader in 2010 while embedded in the Plan Formulation Branch (USACE, New Orleans District). His responsibilities included directing plan formulation activities, and providing project oversight and review to ensure compliance with USACE guidelines. In this capacity, he worked closely with Project Delivery Teams to identify and evaluate measures and alternatives using appropriate planning methodologies on 13 projects to reduce life safety risk, all of which included a combination of flood risk management, life-loss probability analysis, population at risk, residual risk, and vulnerability analysis. For example, Prof. Ator's work on the Greens Bayou Residual Flood Plain Properties Buyout Analysis, Texas (USACE, Galveston District) included flood risk management, population at risk, residual risk, and vulnerability analysis. In addition, the Donaldsonville to the Gulf - Flood Damage Risk Reduction Feasibility Study, Louisiana (USACE, New Orleans District) included flood risk management, life loss probability analysis, population at risk, residual risk, and vulnerability analysis.

In Prof. Ator's 35+ years of experience, he has worked on social effects evaluation of large Civil Works projects for hundreds of NEPA compliance documents, including experience with community cohesion/identity, cultural and historical value, low-income population, economic vitality of the community, and vulnerability of the population. For example, he contributed to a social impact assessment for the Little Colorado River in Holbrook, Arizona (USACE, Los Angeles District) and an environmental impact

statement for U.S. Navy Home Porting Projects (USACE, Galveston District), both of which dealt with community cohesion and identity. His work on the Historic American Building Survey Documentation for the Perry Creek Flood Control Project in Sioux City, Iowa (USACE, Omaha District) and on screening the cultural and historic features at the Di-Lane Plantation, Georgia (USACE, Savannah District) illustrates his experience with evaluating cultural and historical value. He gained experience working with low-income populations through assessing the socioeconomic impacts from flooding and flood control measures in the Yazoo Delta, Mississippi (USACE, Vicksburg District) and through the development of an initial job training program for the Community Impact Mitigation Plan for the Inner Harbor Navigation Canal Lock in New Orleans, Louisiana (USACE, New Orleans District). Prof. Ator has experience with the economic vitality of the community through working on the Memphis Riverfront Development Project (USACE, Memphis District) and on an analysis of economic development benefits from the construction of a floodwall and levee system along the Greenbrier River and Knapp Creek in Marlinton, West Virginia (USACE, Huntington District). Finally, he is familiar with the vulnerability of the population through his work on a social impact assessment for the Kissimmee River Upper Basin Restoration Project (USACE, Jacksonville District) and from the Environmental Impact Statement for the proposed widening of the Pascagoula Lower Sound/Bayou Casotte Channel (USACE, Mobile District).

B.2 Dr. David Jaffe

Role: Hydraulic and Sedimentation Engineer

Dr. Jaffe has worked for more than 15 years at the intersection of water resource development, water infrastructure design, and water policy in coastal and riverine environments. This work has included analysis, design and related regulatory elements. Dr. Jaffe has focused his technical expertise on the translation of engineering science into actionable environmental benefit including protection, restoration and remediation. His areas of technical focus reside in hydrology, hydraulics and sediment transport. David utilizes a broad scope of numerical and analytical methods, including a wide range of numerical models, and is an expert in applying existing, off-the-shelf tools to provide in-depth and forward-looking analysis and insight to complex hydraulic problems.

Dr. Jaffe has maintained his academic and research ties and currently serves as a lecturer in civil engineering design. He earned his PhD in Civil & Environmental Engineering. He is a registered Civil Engineer and a member of the American Society of Civil Engineers. Dr. Jaffe is also a diplomat for the American Academy of Water Resource Engineers.

Dr. Jaffe's current area of research focuses on using sediment transport, through modeling and measurement, as a proxy for several facets of environmental analysis and design. His background in physical marine science, riverine hydraulics and numerical modeling provides a broad foundation for developing solutions in a diverse pallet of aquatic habitats, including those at the intersections of littoral and riverine systems. Dr. Jaffe also manages projects and programs that deal with environmental policy and systematic risk. These project and programs include large or regional government projects and small, locally driven initiatives covering a broad spectrum of agencies and interests. Dr. Jaffe has served as a project manager for federal and state projects, in particular those of FEMA, NMFS, USACE, USEPA and USBR.

Dr. Jaffe has extensive experience in using numerical models for coastal and riverine analysis, both commercial and proprietary. Dr. Jaffe modeling experience includes significant use of modeling packages from federal agencies, HEC in particular.

In a recent project, Dr. Jaffe participated to include the analysis to evaluate the impacts from changes to local scour resulting from proposed bridge improvements. A HEC-RAS model was employed for analysis of stream hydraulics. Sediment and hydrologic data was taken from previous efforts, and additional analysis was required to determine down-stream boundary conditions for tidally controlled water surface elevation. The study followed HEC-18 criteria in that general, long-term and local bed adjustment was considered. Bridge hydraulics and related scour were modeled in HEC-RAS. The study found the pier and abutment scour dominated bed impacts. Long-term bed adjustment was found not to be significant factor in impacts since the stream is in an aggrading condition, with regular dredging to control stream bed shape and elevation. Dr. Jaffe led the bridge hydraulics and bridge scour effort as part of the bridge replacement effort.

Dr. Jaffe led the technical review of the numerical modeling and alluvial fan analysis of the project. Douglas County, Nevada retained an outside consultant to perform a restudy of the Airport Wash, Johnson Lane Wash, Buckbrush Wash and Sunrise Pass Wash watersheds and Phase II of the Buckeye/Martin Slough watershed located in western Douglas County, Nevada. The purpose of the restudy was to submit a FEMA Physical Map Revision (PMR) and substantially revise portions of the effective 2010 Flood Insurance Study (FIS) and corresponding Digital Flood Insurance Rate Maps (DFIRMs). The restudy sought establish updated FIS peak flow rates and hydrographs at specific locations and provide corresponding floodplain mapping revisions to portions of the 2010 Effective Flood Insurance Rate Maps (FIRMs) for Douglas County. The modeling review consisted of multiple FLO-2D models and the methods used by the outside consultants for hydraulically connecting the different models through differing boundary conditions. Other areas of specialty review included the use or absence of culverts, model stability (CFL condition), and boundary condition applications. The supporting LOMR documentation was also reviewed.

Dr. Jaffe developed protocols for and led the pilot study that examined the hydraulic climate change impacts to infrastructure along the south bank of Guadalupe River in San Jose based on a 50-year (2012-2062) time horizon. The study compared the existing and future conditions levee deficiency and resulting existing and future conditions flood plain using one- and two-dimensional hydraulic modeling, as well as GIS-based tool sets. Sea level rise was a primary consideration. The impacts to existing bridge soffits in the existing and future conditions were also examined. A preliminary economic impacts analysis was conducted using parcel assessment maps and GIS tools based on 2012 dollars. The conclusion of the study outlined future analytic pathways for analysis of climate change impacts to infrastructure and habitat in riverine systems, including sediment transport and bulking, and watershed burn and sediment yield.

He also participated on a project evaluating the HEC-6T numerical modeling, based on recently update FEMA HEC-RAS numerical models, was employed to determine the magnitude and extent of impacts that large bed load particles would have on improvements to the Freeman Diversion in Santa Clara River. Specifically, improvements to the diversion are intended to improve sensitive and endangered fish species migration within the River. Several design, operation, and long-term maintenance elements of these improvements are dependent on the size range and relative frequency of the largest particles transported as bed load during 100-year and other large flow events. The study, led by Dr. Jaffe, estimated the largest size of particulate impacting the structure during the FEMA 100-year discharge and the relative frequency of these large particles in the bed load. Approximate contract value \$60,000.

He led the modeling and design support team to develop improvements to the existing ACOE levee with the City of San Jacinto. Led sediment data collection efforts and hydrology determination, including design storm and long-term hydrographs, numerical modeling, gas pipeline protection measures, levee top- and toe-elevation determination, bridge design criteria and downstream habitat impacts analysis.

Project included historical and gravel mining operations analysis. Coordinated with local Indian tribe to address local tribal concerns. The primary design concern was to restore River habitat and functions while minimizing impacts to downstream special habitat areas. Approximate contract value: \$300,000.

Dr. Jaffe lead two-dimensional numerical modeling of the Oxnard Floodplain, including drainage channels, was conducted to determine the extent of flooding below Highway 101 and upstream of the Pacific Ocean for the 100-year floodplain. The study examined the three sub-watersheds developed by the Ventura County Watershed Protection District including Hueneme Drain, "J" Street Drain, and Rice/Industrial Drain, separately. The goals of the study were 1) to estimate the locations and extents of flooding on the Oxnard floodplain, including acreage of inundation and 2) determine the discharges at the floodplain outflow. A FLO-2D numerical model was developed for each of the three sub-watersheds, the boundaries of which closely follow those used in Ventura County's VCRat model. The model grid was assembled using FLO-2D's GDS software and established by importing DTM data provided by Ventura County into the GDS. Model parameters were then imported into the GDS. Following collection and importation, data was area averaged on a grid cell by grid cell basis. Hydrology for all simulations is the County's design 100-year, 24-hour rainfall, Zone B, and was provided by the County's hydrology branch. Modeling suggested that existing topographic conditions determined where flooding occurred adjacent to existing channels. Improvements were recommended based on the location of the topographic controls.

Acronyms

AEP	Annual Exceedance Probability
APMI	Analysis Planning and Management Institute
BiOp	Biological Opinion
BSNP	Bank Stabilization and Navigation Project
COI	Conflict of Interest
DrChecks	Design Review and Checking
EC	Engineer Circular
FRM	Flood Risk Management
FWOP	Future Without Project
FWP	Future With Project
GI	General Investigations
HEC-FDA	Hydraulic Engineering Center's Flood Damage Reduction Analysis
HEC-RAS	Hydraulic Engineering Center's River Analysis System
IEPR	Independent External Peer Review
LMI	Logistics Management Institute
MBA	Masters of Business Administration
MMRP	Missouri River Recovery Program
MO	Missouri
MRBWM	Missouri River Basin Water Management Office
MS	Master of Science
OMB	Office of Management and Budget
RAS	River Analysis System
RBDFS	River Bed Degradation Feasibility Study
USFWS	U.S. Fish and Wildlife Service