

Construction Management Impacts of the Francis Scott Key Bridge Collapse

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Abstract

This study examines the construction-related environmental impacts and management responses following the collapse of the Francis Scott Key Bridge in Baltimore, Maryland, on March 26, 2024. While immediate environmental risks were largely contained, the reconstruction and salvage phases introduced significant challenges associated with dredging, sediment disturbance, emissions from construction activities, and large-scale debris removal. Drawing upon federal and state agency reports, this paper evaluates the effectiveness of construction-phase mitigation strategies, including containment measures, monitoring systems, and coordinated interagency response frameworks. Particular attention is given to the role of dredging and heavy equipment operations in mobilizing legacy contaminants and altering benthic habitats. The study also assesses the balance between rapid infrastructure recovery and long-term environmental protection. Findings indicate that while emergency construction operations successfully restored navigation and minimized acute contamination, long-term environmental risks are primarily associated with sediment resuspension and cumulative impacts from reconstruction activities. The paper highlights key lessons for construction management, environmental monitoring, and policy development in large-scale infrastructure recovery projects.

Keywords

Bridge Collapse, Construction Management, Dredging, Environmental Monitoring, Sediment Disturbance

1. Introduction

The collapse of the Francis Scott Key Bridge on March 26, 2024, following a collision with the containership Dali, resulted in a large-scale infrastructure failure requiring immediate and sustained construction intervention [1]. The incident

introduced tens of thousands of tons of structural debris into the Patapsco River, obstructing navigation and halting operations at the Port of Baltimore [2].

From a construction and engineering perspective, the response required rapid mobilization of salvage operations, implementation of debris removal strategies, and planning for full bridge reconstruction. These activities were conducted in an environmentally sensitive and industrially contaminated waterway, introducing risks associated with sediment disturbance, hazardous material exposure, and emissions from heavy equipment.

The Patapsco River contains legacy contaminants such as heavy metals, petroleum hydrocarbons, and polychlorinated biphenyls (PCBs), which can be reactivated through construction activities such as dredging and debris removal [3]. As a result, construction operations became a primary driver of environmental risk following the initial incident.

This paper focuses specifically on construction-related impacts, including salvage operations, dredging requirements, emissions, and long-term reconstruction effects. The objective is to assess how construction practices influenced environmental outcomes and to evaluate the effectiveness of mitigation and monitoring strategies implemented during recovery. This paper distinguishes among three phases of recovery. The emergency salvage phase includes vessel stabilization, hazardous-material management, and debris removal activities immediately following the collapse. The channel restoration phase includes dredging and navigation-channel reopening activities necessary to restore access to the Port of Baltimore. The reconstruction phase includes bridge replacement planning, foundation installation, pile driving, and long-term construction activities [4]-[6]. Although these phases overlap operationally, they involve distinct environmental risks and management challenges that are evaluated separately throughout this paper.

Methods

This study was conducted through a review of publicly available agency reports, technical memoranda, environmental monitoring updates, and scientific assessments related to the Francis Scott Key Bridge collapse and subsequent recovery activities. Primary sources included reports from the U.S. Environmental Protection Agency (EPA), Maryland Department of the Environment (MDE), U.S. Army Corps of Engineers (USACE), National Transportation Safety Board (NTSB), and University of Maryland Center for Environmental Science (UMCES) [1]-[3] [7]-[9]. Document selection focused on materials published between March 2024 and early 2026 that addressed salvage operations, channel restoration, dredging, environmental monitoring, reconstruction planning, and ecological impacts. The effectiveness of mitigation and monitoring measures was evaluated based on whether actions prevented documented contaminant releases, maintained compliance with applicable environmental standards, and provided sufficient environmental oversight during salvage, restoration, and reconstruction activities.

2. Cleanup and Removal Operations

2.1. Salvage and Debris Removal Procedures

The collapse deposited approximately 50,000 tons of bridge steel and concrete into the navigation channel [2]. The U.S. Army Corps of Engineers led structural clearance efforts, while the Environmental Protection Agency (EPA) and Maryland Department of the Environment (MDE) provided environmental oversight [7] [8].

Construction operations included segmentation and lifting of bridge sections, stabilization of the vessel, and controlled removal of hazardous cargo. These tasks required the use of cranes, cutting torches, and heavy lifting equipment, introducing mechanical disturbance to the riverbed. To reduce environmental risks during construction, several containment measures were implemented. These included sealing deck scuppers, constructing berms to prevent runoff, pumping accumulated rainwater into storage systems, and applying patches to damaged sections of the vessel. These measures were critical in preventing secondary contamination during debris removal.

The scale and complexity of the operation required phased execution, with debris removed in segments to minimize structural instability and environmental disturbance.

2.2. Monitoring during Recovery

Construction-phase monitoring included water quality testing, waste sample analysis, and air monitoring throughout salvage operations. Water-quality measurements included pH, dissolved oxygen, hydrocarbons, and metals. EPA and MDE monitoring reported no widespread exceedances of applicable Maryland surface-water quality standards during the response period, although localized variations were observed near debris-removal areas [8]. Waste sample analyses identified variable pH conditions and the presence of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) within confined compartments of the Dali, while bridge-paint testing detected lead concentrations of approximately 235 ppm [9]. These findings indicate that environmental concerns were largely localized rather than representative of system-wide contamination.

Water quality parameters such as pH, dissolved oxygen, hydrocarbons, and metals were monitored throughout the salvage process. Results indicated no widespread exceedances of environmental standards, although localized variations were observed near debris fields.

Air monitoring was implemented to protect workers from exposure to hazardous materials, including volatile organic compounds and emissions from damaged cargo. Worker Air Protection Levels (WAPLs) were established to guide personal protective equipment requirements during salvage operations [9].

Material testing identified the presence of lead in bridge paint and variable chemical conditions in confined waste compartments. Although asbestos was not detected in preliminary samples, continued monitoring was required.

2.3. Contaminant Containment and Sediment Resuspension Risks

Construction operations caused the resuspension of contaminated sediment. The Patapsco River contains legacy pollutants, including heavy metals, petroleum hydrocarbons, and PCBs, that may be mobilized through dredging and debris removal activities [3].

Activities such as dredging, cutting, and lifting of debris increase turbidity and reintroduce contaminants into the water column. These contaminants can be absorbed by aquatic organisms and transferred through the food web.

Although containment measures such as booms and controlled water pumping reduced visible contamination, the cumulative effects of repeated disturbance during prolonged construction remain a significant concern. Long-term monitoring of sediment, water, and biological systems is required to assess these impacts.

The scale of debris removal required careful coordination and phased execution to maintain structural stability and minimize disruption to ongoing operations. This approach allowed for controlled progress while addressing both safety and environmental considerations.

3. Bridge Reconstruction Impacts

3.1. Dredging Requirements in Construction

Reconstruction of the bridge required extensive dredging to remove debris and prepare the riverbed for new structural elements [2] [10]. Dredging operations disturbed sediments containing heavy metals, petroleum hydrocarbons, PCBs, and other contaminants [3] [10].

The resuspension of these materials increased turbidity and reduced light penetration, affecting submerged aquatic vegetation and aquatic ecosystems. Dredging in shallow and previously undisturbed areas introduced additional risks due to higher contaminant concentrations.

The timing of dredging operations near spawning seasons further increased ecological sensitivity, particularly for species such as striped bass and blue crabs.

Mitigation strategies included the use of silt curtains, controlled dredging techniques, and timing restrictions to reduce ecological impacts. However, these measures were difficult to implement fully in an active port environment.

3.2. Air Emissions from Construction and Freight Rerouting

Construction activities required continuous use of diesel-powered equipment [8] [9], including cranes, dredges, pile drivers, and transport vehicles. These operations generated emissions such as nitrogen oxides, particulate matter, sulfur dioxide, and carbon dioxide.

The closure of the bridge also resulted in the rerouting of freight traffic, increasing emissions from trucks traveling longer distances. This contributed to regional air quality degradation and increased exposure in nearby communities.

While mitigation measures such as air monitoring and containment were im-

plemented for worker safety, broader community-level air quality impacts were less extensively addressed. This created additional environmental and public health concerns during the reconstruction phase.

3.3. Long-Term Water and Habitat Impacts from Construction

Construction activities altered both the chemical and physical characteristics of the river system. Sediment disturbance and contaminant mobilization introduced long-term risks to aquatic ecosystems.

Persistent contaminants such as PCBs and heavy metals can accumulate in sediments and organisms [3]. Long-term impacts associated with repeated sediment disturbance during construction, therefore, require continued monitoring.

In addition, physical disturbances such as dredging and pile driving altered benthic habitats and disrupted ecological processes.

Although immediate impacts were limited, long-term ecological consequences are expected to emerge over time because of cumulative construction activities.

4. Agency Roles in Construction and Environmental Oversight

Construction and environmental management were coordinated among multiple agencies. The Environmental Protection Agency provided technical support, including monitoring plan development, laboratory analysis, and worker safety guidance.

The Maryland Department of the Environment led water quality monitoring and regulatory oversight, including sediment and debris analysis. The U.S. Army Corps of Engineers managed dredging and debris removal operations, prioritizing rapid restoration of navigation.

Scientific institutions contributed expertise on ecological risks, particularly related to sediment disturbance and fisheries impacts. Non-governmental organizations emphasized community concerns and environmental accountability.

This multi-agency coordination enabled effective implementation of construction operations while maintaining environmental oversight, although challenges remained in addressing long-term impacts.

The U.S. Army Corps of Engineers (USACE) played a central role in operational execution, including dredging, debris removal, and channel restoration. These activities were coordinated with environmental monitoring efforts led by the EPA and regulatory oversight provided by MDE.

This division of responsibilities enabled simultaneous progress in construction operations and environmental protection, although coordination challenges remained in balancing efficiency with oversight.

5. Discussion

A distinction should be made between observed environmental impacts and anticipated long-term risks. Observed impacts documented during the response pe-

riod primarily included localized sediment disturbance, debris-related contamination, temporary navigation disruption, and increased emissions associated with salvage and construction activities. By contrast, many ecological concerns discussed in this paper include contaminant bioaccumulation, fisheries impacts, habitat degradation, and cumulative community health effects and represent anticipated risks based on established environmental processes rather than impacts that have been directly measured. Consequently, projections regarding long-term ecological outcomes should be interpreted with recognition of the uncertainties associated with environmental forecasting.

5.1. Observed versus Anticipated Environmental Impacts

Environmental impacts associated with the Key Bridge collapse can be divided into those that have been observed and those that remain potential long-term concerns. During the response and recovery period, agencies documented sediment disturbance, debris-management challenges, and disruptions to navigation resulting from salvage operations [2] [8] [9]. Monitoring data generally indicated that environmental effects were localized and that major contamination events were avoided.

Long-term concerns are less certain. Previous studies and agency assessments suggest that continued dredging and reconstruction activities could affect aquatic habitats and influence the movement of contaminants already present in river sediments [3] [11]. Because reconstruction is still underway, the extent of these effects cannot yet be fully evaluated. Continued environmental monitoring will therefore be important for determining whether projected impacts develop over time.

5.2. Effectiveness of Construction Management Strategies

Construction management strategies successfully prevented catastrophic environmental contamination and enabled the rapid restoration of navigation channels. Containment measures and monitoring systems were effective in reducing immediate risks.

However, the focus on rapid response limited the extent of long-term environmental assessment. Construction activities introduced cumulative impacts that were not fully addressed during the emergency phase.

5.3. Trade-Offs between Construction Efficiency and Environmental Protection

The urgency of reopening the Port of Baltimore created pressure to accelerate construction operations. This resulted in trade-offs between economic recovery and environmental protection.

While infrastructure functionality was restored efficiently, environmental risks associated with sediment disturbance and emissions persist. These trade-offs highlight the need for integrated planning in future projects.

5.4. Lessons for Future Construction Projects

The incident demonstrates the importance of integrating environmental considerations into construction planning, particularly in marine and industrial environments. Construction sequencing, sediment management, and continuous monitoring should be incorporated into project design to reduce long-term risks. In addition, emergency response frameworks should account for both operational efficiency and environmental protection to ensure balanced outcomes during large-scale infrastructure recovery.

The Key Bridge collapse demonstrates the importance of:

- Integrating environmental considerations into construction planning
- Prioritizing sediment management in marine construction
- Maintaining continuous monitoring throughout construction phases
- Balancing emergency response with long-term environmental assessment

5.5. Freight Rerouting and Construction-Related System Impacts

The closure of the bridge required rerouting of freight traffic, resulting in increased travel distances and associated emissions. This shift affected regional transportation systems and introduced additional logistical challenges during reconstruction.

Coordination with transportation and environmental assessments highlighted the broader system-level impacts of infrastructure disruption, extending beyond the immediate construction site.

5.6. Potential Limitations

The paper is based on information made available through government agencies, technical reports, environmental monitoring programs, and published research related to the Francis Scott Key Bridge collapse. As a result, the findings are dependent on the availability and scope of those sources. In addition, detailed construction information for reconstruction activities was not publicly available in all cases [4]. Some aspects of ongoing construction and environmental monitoring may therefore change as the project progresses and additional information becomes available.

Because bridge reconstruction remains ongoing, many of the long-term environmental effects discussed in this paper represent potential outcomes identified in previous research and agency assessments rather than impacts that have already been observed [3] [4]. Continued monitoring will be important in evaluating these potential effects over time.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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