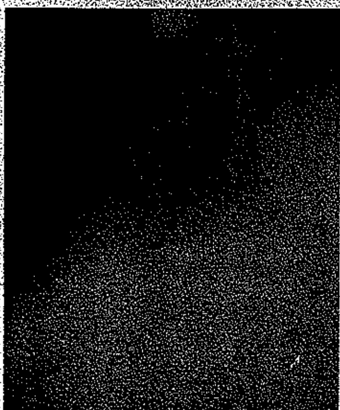
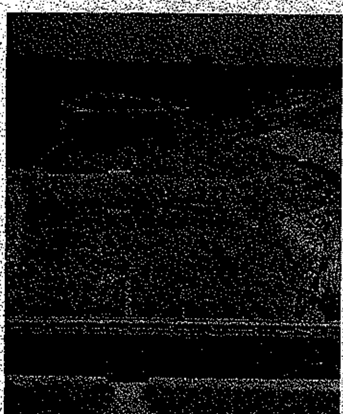
US Army Corps of Engineers

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM





TECHNICAL REPORT REMR-EI-4

SEASONAL REGULATION OF REPAIR EVALUATION, MAINTENANCE, AND REHABILITATION (REMR) ACTIVITIES

by

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This report addresses the subject of environmental alterations associated with repair, evaluation, maintenance, and rehabilitation (REMR) activities of coastal, reservoir, and inland water engineering structures maintained by the US Army Corps of Engineers. Some activities associated with REMR have the potential to affect environmental quality in adjacent aquatic and/or terrestrial habitats. As a consequence, these activities may affect sensitive organisms in the vicinity of the structure. Because the presence and abundance of organisms in these habitats fluctuate seasonally, seasonal regulations of REMR activities at a structure may be justified to protect a given biological resource(s).

The report presents a general evaluation procedure with which Corps personnel (REMR planners) can determine if concerns about sensitive biological resources are justified. In general, potential impacts of REMR activities associated with particular types of

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structures are largely a function of the material makeup of the given structure and preparatory activities at the site. The types of alterations expected around structures in each habitat are discussed in terms of their potential to affect sensitive biological resources.

Preface

The study presented herein was conducted under Contract No. DACW39-86-C-0056 between Headquarters, US Army Corps of Engineers (HQUSACE), and JAYCOR, Vicksburg, MS. Funding was provided by the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. This report was prepared as part of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The REMR Overview Committee consists of Dr. Tony Liu and Mr. James E. Crews, HQUSACE. Mr. Crews also served as the Technical Monitor.

The report was written by Dr. Mark W. LaSalle, JAYCOR, with contributions by Drs. John Nestler, Water Quality Modeling Group (WQMG), and Andrew C. Miller, Aquatic Habitat Group, (AHG), EL, WES. Dr. Douglas G. Clarke, Coastal Ecology Group (CEG), was Contract Monitor for this study under the general supervision of Mr. Edward J. Pullen, Chief, CEG. Technical contributions and critiques were provided by Mr. Craig Smith, Department of Biological Sciences, University of North Carolina at Wilmington, NC; and Messrs. John D. Lunz, CEG; F. Douglas Shields, Water Resources Engineering Group; and Marc J. Zimmerman, WQMG, EL, WES. Program Manager for REMR was Mr. William F. McCleese, Concrete Technology Division, Structures Laboratory, WES.

Dr. Jerome L. Mahloch, Environmental and Water Quality Operational Studies Program, was the REMR Problem Area Leader for the EL. Dr. Conrad J. Kirby was Chief, Environmental Resources Division, EL; and Dr. John Harrison was Chief, EL. This report was edited by Ms. Lee T. Byrne, Information Technology Laboratory, WES.

COL Dwayne G. Lee, CE, is Commander and Director of WES. Technical Director is Dr. Robert W. Whalin.

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Contents

SEASONAL REGULATION OF REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION (REMR) ACTIVITIES

Introduction

1. The purpose of this study, sponsored by the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program, was to identify potential environmental impacts associated with REMR activities on structures maintained by the US Army Corps of Engineers (CE). The specific focus was on a possible need for seasonal regulations of these activities intended to protect seasonally occurring and potentially sensitive biological resources on or in the immediate vicinity of structures scheduled for a REMR activity. Any regulation would be based on consideration of regional location, habitat type, and associated organisms. Procedures generated here would allow CE personnel to evaluate whether problems might exist and, if so, when the potential harmful effects could be minimized or avoided.

2. This report outlines the considerations of potential REMR activities in coastal, reservoir, and riverine habitats. Some REMR activities have the potential to affect environmental quality either directly through the use and handling of construction materials that may affect the surrounding habitat or indirectly through changes in project operation (e.g., reservoir dewatering, drawdown, stream flow alterations) required to complete repairs or inspection. Seasonal considerations are an important aspect of REMR planning since many aquatic organisms have critical life stages, reproductive periods, or migratory patterns that may be disrupted by REMR activities. In addition, terrestrial organisms using habitats adjacent to CE structures may also be disturbed by repair activities.

3. The types of potential REMR activities associated with a structure are largely based on the material makeup of the structure and the type of repair or prerepair procedure being planned. Major activities unique to reservoir and riverine habitats include water drawdown or river flow alterations that may produce sets of alterations independent from the repair activity itself. Many activities may be common to more than one type of structure, and, in addition, more than one type of activity may produce the same general type of physical or chemical environmental alteration. Many of the details of

these activities are only now being outlined as part of the REMR research program (Baumgartner and Carver 1986).

4. The general evaluation procedure outlined herein consists of (a) the development of matrices that incorporate information on structure type (material), potential REMR activities associated with each structure, and potential environmental alterations associated with each activity and (b) a discussion of the potential effect of these alterations on biological communities within the vicinity of a structure. For purposes of this technical report, the use of matrices in the evaluation process is outlined and explained, followed by a discussion of potential environmental alterations associated with REMR activities.

Evaluation Procedure and Matrices

5. The procedure recommended for evaluating whether seasonal environmental regulations of REMR activities are justified requires a minimum of information concerning the structure and the habitat in which it is located. The type of construction material and potential REMR activities associated with this construction material will lead the user through the series of matrices developed for evaluation purposes. In the case of structures constructed of multiple materials, the user will have to consider each material type separately. After any potential environmental alterations have been identified, the user is directed to a discussion of potentially harmful impacts associated with the alteration for a given habitat system. There is no substitute for a common sense approach to potential seasonal environmental problems associated with REMR activities. Funds expended for REMR activities may be partly wasted if insufficient attention is paid to environmental quality concerns resulting in the loss of aquatic natural resources, expensive postauthorization modifications, or lengthy litigation.

Matrix A: Structural material and potential REMR activity

6. Matrix A associates materials used in the structures with the potential REMR activities required to repair or rehabilitate these structures (including preoperational activity) (Figure 1). Activities are associated with materials regardless of the structure type. Also, a given structure may

POTENTIAL REMR ACTIVITY

STRUCTURAL MATERIAL	DREDGING	REMOVAL OF EXISTING STRUCTURE	PLACEMENT OF NEW STRUCTURE	RETRIEVAL OF EXISTING MATERIAL	CORE REPAIR	PILE DRIVING	MASS POUR OF CONCRETE	CHEMICAL REPAIR OF CONCRETE	PHYSICAL REPAIR OF CONCRETE	PAINTING/EPOXY	RESERVOIR DRAWDOWN	RIVER FLOW ALTERATIONS	VEGETATION REMOVAL
RUBBLE	+	+	+	+	+						+	+	+
SHEET PILE (TIMBER/STEEL)		+	+			+				+	+	+	+
CONCRETE		+	+			+	+	+	+		+	+	+
SAND FILLED/ GROUT FILLED BAGS	+		+								+	+	+
EARTH FILL	+	+	+								+	+	+

Figure 1. Matrix A associating materials used in the structures with the potential REMR activities

involve more than one type of material (e.g., steel/timber pile breakwater with rubble stone toe).

Matrix B: Potential REMR activity and environmental alterations

7. Matrix B associates REMR activities with potential environmental alterations (Figure 2). The same alteration may be produced by several different activities, and a single activity may produce more than one type of alteration.

Use of the matrices

8. The following example demonstrates the use of Matrices A and B. A stone-filled pile and timber jetty in a low-salinity habitat was damaged by storms, resulting in damage to pile and timber walls and loss of rubble stone to the surrounding bottom. Review of Matrix A, using material categories of rubble and sheet pile, results in identification of potential REMR activities, including dredging, removal of existing structure, placement of new structure, retrieval of existing structure, core repair, pile driving, and painting/ epoxy. The user identifies each of the activities to be used in the repair of the structure. Applying these activities to Matrix B, the user identifies

POTENTIAL ENVIRONMENTAL ALTERATIONS

POTENTIAL REMR ACTIVITY	SEDIMENT RESUSPENSION	SEDIMENTATION	LEACHING OF FINES	REMOVAL/COVERING OF EXISTING BOTTOM	RELEASE OF SEDIMENT TOXINS	LIME INTRODUCTION	PETROLEUM POLLUTION	CHEMICAL POLLUTION	NOISE	REMOVAL OF COLONIZED HARD SUBSTRATE	ADDITION OF NEW HARD SUBSTRATE	DEWATERING OF AQUATIC HABITAT
REPAIR ACTIVITIES												
DREDGING	+	+		+	+				+			
REMOVAL OF EXISTING STRUCTURE	+	+			+		+		+	+		+
PLACEMENT OF NEW STRUCTURE	+	+	+	+	+		+		+		+	+
RETRIEVAL OF EXISTING MATERIAL	+	+			+		+			+	+	+
CORE REPAIR	+	+	+				+	+	+			+
PILE DRIVING	+	+					+		+		+	+
MASS POUR OF CONCRETE						+		+	+		+	+
CHEMICAL REPAIR OF CONCRETE								+				+
PHYSICAL REPAIR OF CONCRETE									+			+
PAINTING/EPOXY								+				+
PREREPAIR ACTIVITIES												
RESERVOIR DRAWDOWN												+
RIVER FLOW ALTERATIONS	+	+		+	+							+
VEGETATION REMOVAL	+	+		+	+				+	+		

Figure 2. Matrix B associating REMR activities with potential environmental alterations

potential environmental alterations, which include sediment resuspension, leaching of fines, removal/covering of existing bottom, release of sediment toxins, petroleum pollution, noise, removal of colonized hard substrate, and addition of new hard substrate. Using this information, in addition to information about the types of organisms occurring in the habitat, the user can make a more informed decision about the need for seasonal restrictions on the REMR activities.

Coastal Habitats

Habitat/community type

9. Major coastal habitat/community types are defined in the following paragraphs to help categorize the habitat/community in question. These designations reflect information on the physical and biotic nature of each system. The estuarine classification includes categories of low- (oligohaline), medium- (mesohaline), and high- (euryhaline) salinity areas with consideration being given to regional differences in the physical and biotic nature of each. Regional designations include Atlantic Northeast (NE), Atlantic Southeast (SE), Gulf of Mexico (G), Pacific Southwest (SW), and Pacific Northwest (NW). Estuarine classification is complex and requires consideration of parameters such as salinity, temperature, and the degree to which these parameters fluctuate. Regionally distinct subcategories of high-salinity systems include high-energy beaches, rocky shores, coral reefs, and fjords. These systems are discussed separately because of their unique physical and biotic characteristics. Table 1 exemplifies the shifts in dominant biological resources among habitat types. This is an important consideration in the evaluation of impacts induced by REMR operations in different habitats.

10. Habitat types and associated communities are defined as follows:

a. Great Lakes. These freshwater systems receive large amounts of turbid runoff from surrounding drainage basins. The Great Lakes region experiences seasonal temperature and turbidity fluctuations as well as storm events that increase wave energy along shorelines. Icing of shoreline areas is also an important occurrence.

b. Low-salinity estuarine. These estuarine areas have a salinity range of 0.5 to 5.0 ppt and are usually located in the vicinity of a freshwater discharge. They are characterized by seasonal salinity shocks associated with flood conditions and temperature shocks that result from differences in temperature between freshwater runoff and adjacent estuarine waters. These seasonal pulses in salinity and temperature are more distinct in the northeast and northwest temperate areas as opposed to the relatively stable conditions along the southeast and gulf coasts. These areas are also the site of the maximum turbidity zone where freshwater-borne suspended solids mix with higher salinity water, resulting in flocculation and sedimentation. Low-salinity estuarine systems are characterized by supporting relatively few resident species that are tolerant of the fluctuating conditions. Population densities of these species, however, may be quite high. These areas also serve as important nursery areas and migratory routes for many commercially

Table 1

Examples of Regionally Dominant Species* and Associated Life-History Stages in Low-, Medium-, and High-Salinity Estuarine Environments

Region	Salinity Estuarine Environment: Low	Medium	High
NE	Soft clam-all	Surf clam-all	Shrimp (*Penaeus*)-A,S,J
	Blue crab-all	Blue crab-all	Eastern oyster-all
	Spot-J	Eastern oyster-all	Blue mussel-all
		Spot-S,J	
		Shrimp (*Penaeus*)-S,J	
SE/G	Rangia-all	Blue crab-all	Shrimp (*Penaeus*)-S,J
	Blue crab-all	Eastern oyster-all	Eastern oyster-all
	Shrimp (*Penaeus*)-S,J	Shrimp (*Penaeus*)-S,J	Hard clam-all
	Spot-J	Spot-S,J	
SW	Macoma-all	Macoma-all	Shrimp (*Crago*)-A,S,J
	Shrimp (*Crangon*)-S,J	Pacific oyster-all	Pacific oyster-all
	Dungeness crab-S,J	Dungeness crab-S,J	Dungeness crab-A,S,J
		Japanese cockle-all	
NW	Macoma-all	Macoma-all	Macoma-all
	Shrimp (*Crangon*)-S,J	Pacific oyster-all	Pacific oyster-all
	Dungeness crab-S,J	Dungeness crab-S,J	Dungeness crab-A,S,J
		Japanese cockle-all	Shrimp (*Crangon*)-A,S,J
			Blue mussel-all

* A = adult, S = subadult, J = juvenile, all = all stages.

important species (Table 1). Other important biological resources (e.g., salmonid fishes) occur across most habitat types and deserve special consideration in project planning.

c. Medium-salinity estuarine. These estuarine areas have a salinity range of 5 to 20 ppt. They are typically stratified but experience seasonal variation in salinity and suspended solids associated with freshwater runoff, during which time they are generally well mixed. Fluctuations in salinity and temperature are less severe than in low-salinity areas. In addition to serving as nursery and migratory routes, these systems support organisms capable of tolerating moderate fluctuations in salinity (Table 1).

d. High-salinity estuarine. These estuarine areas have a salinity range of 20 to 30 ppt, are typically well mixed by tidal circulation, and do not experience a large seasonal fluctuation in salinity. Suspended solid loads are generally low except in the vicinity of large river systems. These systems support organisms that are generally intolerant of wide or rapid fluctuations in salinity (Table 1).

e. High-energy beaches. These are high-salinity areas along all coastlines exposed to breaking wave action. Tidal ranges vary considerably with the region. These areas support ecologically equivalent biota on all coasts.

f. Rocky shores and fjords. These high-salinity systems are typically exposed to breaking wave action and are common in the Pacific Northwest, Alaska, and Maine, where tidal amplitudes may be quite large. These areas support extensive attached communities of algae and mussels.

g. Coral reefs. These are high-salinity, clear water systems located in tropical areas characterized by moderate current flow and uniform salinity and temperature. The organisms of these areas are very intolerant of fluctuations in salinity and increases in turbidity and sedimentation.

Potential environmental impacts

11. The discussion of the effects of environmental alterations on community types is based on the potential of an alteration to negatively impact organisms in the vicinity of a structure (e.g., interference with migration, reproduction, juvenile forms, etc.). The potential for seasonal impact will depend on the type of REMR-induced environmental alteration(s) occurring at the structure and those normal environmental conditions to which biological resources in the vicinity of the structure are naturally adapted. In cases where REMR-induced alterations are within the range of normal environmental conditions, impacts will be negligible. Critical levels of some of these impacts are generally undetermined and require specific investigation.

12. The resuspension of sediments and the leaching of fines have the potential to affect organisms directly through physical abrasion of external and gill surfaces and clogging of gills and indirectly through additional effects of the sediment plume (e.g., avoidance of high-turbidity plume by migrating organisms). Direct and indirect effects may be particularly problematic in areas in which ambient suspended sediment loads are typically low (i.e., NE and SE low-salinity estuaries; NE, SE, SW, and NW medium-salinity

estuaries; high-salinity estuaries and lagoons; coral reef, rocky shore, and fjord habitats) and the organisms present are not adapted to high levels of suspended sediments.

13. Abrasion is of particular concern when the sediment particles being resuspended or the fines released from new rock or concrete material (riprap) are unweathered or angular (volcanic ash or industrial residues for example). Results of studies on the effects of suspended sediment concentrations on the eggs, larvae, and juveniles of fishes and shellfishes (Table 2) suggest that detrimental effects occur only at relatively high concentrations (>500 mg/ℓ), which are unlikely to occur as a result of most repair activities.

14. Sediment plumes have the potential to block passage of anadromous fishes and migratory shellfishes through behavioral avoidance of the turbid zone by these organisms. This may be a problem in narrow channels, where the sediment plume may extend across the entire water body. Other possible detrimental effects of the sediment plume include reduced available light, affecting embryonic or larval development; interference with the feeding behavior of visually oriented larval or juvenile organisms; and delayed development, resulting in asynchronous occurrence of larvae and their prey.

15. Given these concerns, activities that produce levels of suspended solids considerably above ambient levels (e.g., three to four times) should be regulated and limited during periods of peak spawning and/or migration of organisms in the immediate area. Activities in the vicinity of narrow waterways (<500 m wide) should not be allowed to impact more than half the cross-sectional area of the waterway, allowing for movement around the disturbance.

16. Sedimentation and/or removal of substrate in areas adjacent to structures may affect benthic resources such as mollusc beds, seagrass beds, coral reefs, and the eggs of bottom-dwelling fishes and shellfishes (spawning grounds). Depending upon the amount of material deposited, many mobile organisms are able to migrate vertically up through or horizontally away from settled materials (Chang and Levings 1978, Maurer et al. 1986). However, the added effect of gill clogging must also be considered. Sedimentation impacts on benthic macrofaunal assemblages involve a seasonal aspect in that recolonization rates can be quite different depending on the time of the year and can indirectly affect use of this resource as forage by fishes and shellfishes. In general, however, the amount of sediment resuspension can be controlled through operational modifications or by the choice of equipment.

Table 2

Results of Experimental Determinations of Effects of Suspended Sediments on Eggs, Larvae, Subadult and Adult Fishes and Shellfishes (Modified from Priest 1981)

Reference	Species	Stage	Susp. Sed. Conc., mg/ℓ	Exposure Duration	Types of Sediment	Degree of Effect
Schubel, Williams, and Wise (1977)	Yellow perch	Eggs	50-500	Not stated	Natural	No significant effect on hatching success; some delay in time to hatching noted in samples at >100 mg/ℓ (for all four species)
Schubel, Williams, and Wise (1977)	White perch	Eggs	50-500	Not stated	Natural	
Schubel, Williams, and Wise (1977)	Striped bass	Eggs	50-500	Not stated	Natural	
Schubel, Williams, and Wise (1977)	Alewife	Eggs	50-500	Not stated	Natural	No significant effect on hatching success; some delay in time to hatching noted in samples at >100 mg/ℓ (for all four species)
Morton (1977)	White perch	Eggs	50-5,000	Not stated	Natural	No significant effect on hatching success; definite delay in development at >1,500 mg/ℓ
Morton (1977)	Striped bass	Eggs	20-2,300	Not stated	Natural	No significant effect on hatching success; definite delay in development at >1,300 mg/ℓ
Morton (1977)	White perch	Larvae	1,626-5,380	24-48 hr	Natural	15-48 percent mortality
Morton (1977)	Striped bass	Larvae	1,557-5,210	24-48 hr	Natural	20-57 percent mortality
Auld and Schubel (1978)	Blueback herring	Eggs	50-5,000	Not stated	Natural	No significant effect on hatching success at all test concentrations
Auld and Schubel (1978)	Alewife	Eggs	50-5,000	Not stated	Natural	
Auld and Schubel (1978)	American shad	Eggs	50-5,000	Not stated	Natural	No significant effect on hatching success at all test concentrations
Auld and Schubel (1978)	Yellow perch	Eggs	50-5,000	Not stated	Natural	No significant effect on hatching success at all test concentrations
Auld and Schubel (1978)	White perch	Eggs	50-5,000	Not stated	Natural	Significant effect on hatching success at 1,000 mg/ℓ but not at lower concentrations
Auld and Schubel (1978)	Striped bass	Eggs	50-5,000	Not stated	Natural	
Auld and Schubel (1978)	Yellow perch	Larvae	50-1,000	4 days	Natural	Survival significantly reduced at >500 mg/ℓ
Auld and Schubel (1978)	Striped bass	Larvae	50-1,000	2-3 days	Natural	Survival significantly reduced at >500 mg/ℓ
Auld and Schubel (1978)	Alewife	Larvae	50-1,000	4 days	Natural	Survival significantly reduced at ≥100 mg/ℓ
Stern and Stickle (1978)	Spot	Adult	13,090	24 hr	Processed	LC10*
Stern and Stickle (1978)	Spot	Adult	68,750	24 hr	Natural	LC10
Stern and Stickle (1978)	Striped killifish	Adult	23,770	24 hr	Processed	LC10
Stern and Stickle (1978)	Striped killifish	Adult	97,200	24 hr	Natural	LC10
Stern and Stickle (1978)	Mummichog	Adult	24,470	24 hr	Processed	LC10
Stern and Stickle (1978)	Atlantic silverside	Adult	580	24 hr	Processed	LC10
Stern and Stickle (1978)	Bay anchovy	Adult	2,300	24 hr	Processed	LC10
Stern and Stickle (1978)	White perch	Adult	9,970	24 hr	Natural	LC10
Stern and Stickle (1978)	White perch	Adult	3,050	24 hr	Processed	LC10
Priest (1981)	Striped bass	Subadult	4,000	21 days	Natural	LC10
Saila, Polgar, and Rogers (1968)	Cunner	Adult	133,000	12 hr	Natural	Median tolerance limit
Saila, Polgar, and Rogers (1968)	Cunner	Adult	100,000	24 hr	Natural	Median tolerance limit
Saila, Polgar, and Rogers (1968)	Cunner	Adult	72,000	48 hr	Natural	Median tolerance limit
Saila, Polgar, and Rogers (1968)	Mummichog	Adult	300,000	24 hr	Natural	No mortality
Saila, Polgar, and Rogers (1968)	Sheepshead minnow	Adult	300,000	24 hr	Natural	< 30 percent mortality
Saila, Polgar, and Rogers (1968)	Cunner	Adult	100,000	24 hr	Natural	Median tolerance limit
Saila, Polgar, and Rogers (1968)	Stickleback	Adult	52,000	24 hr	Natural	Median tolerance limit
Davis and Hidu (1969)	American oyster	Eggs	188	Not stated	Natural	22 percent abnormal development
Davis and Hidu (1969)	American oyster	Eggs	250	Not stated	Natural	27 percent abnormal development
Davis and Hidu (1969)	American oyster	Eggs	375	Not stated	Natural	34 percent abnormal development
Davis and Hidu (1969)	American oyster	Eggs	1,000	Not stated	Processed	No significant effect

(Continued)

* Lethal concentration at which 10 percent of the organisms died.

Table 2 (Concluded)

Reference	Species	Stage	Susp. Sed. Conc., mg/ℓ	Exposure Duration	Types of Sediment	Degree of Effect
Davis and Hidu (1969)	American oyster	Eggs	2,000	Not stated	Processed	No significant effect
Davis and Hidu (1969)	American oyster	Larvae	750	12 days	Natural	31 percent mortality
Davis and Hidu (1969)	American oyster	Larvae	2,000	12 days	Processed	20 percent mortality
Davis and Hidu (1969)	American oyster	Larvae	500	Not stated	Processed	78 percent mortality
Davis (1960)	Hard clam	Eggs	750	Not stated	Natural	8 percent abnormal development
Davis (1960)	Hard clam	Eggs	1,000	Not stated	Natural	21 percent abnormal development
Davis (1960)	Hard clam	Eggs	1,500	Not stated	Natural	35 percent abnormal development
Davis (1960)	Hard clam	Eggs	125	Not stated	Processed	18 percent abnormal development
Davis (1960)	Hard clam	Eggs	125	Not stated	Processed	25 percent abnormal development
Davis and Hidu (1969)	Hard clam	Eggs	4,000	Not stated	Processed	31 percent abnormal development
Davis (1960)	Hard clam	Larvae	1,000	Not stated	Natural	No significant effect
Davis (1960)	Hard clam	Larvae	500	12 days	Processed	50 percent mortality
Peddicord and McFarland (1978)	Spot-tailed shrimp	Adult	50,000	200 hr	Processed	LC50*
Priest (1981)	Black-tailed shrimp	Subadult	21,500	21 days	Natural	20 percent mortality (contaminated seds.)
Priest (1981)	Dungeness crab	Adult	3,500	21 days	Natural	LC10
Schreck (1981)	American lobster	Adult	50,000	Not stated	Processed	No mortality
Yagi, Koiwa, and Miyazaki (1977)	American oyster	Adult	4,000-32,000	Extended	Not stated	Detrimental effect
Martin Marietta (1975)**	American oyster	Adult	100-700	Not stated	Mud	No effect
Mackin (1961)	American oyster	Adult	100-4,000	Not stated	Silt	Reduced pumping
Peddicord and McFarland (1978)	Blue mussel	Subadult	100,000	5 days	Processed	10 percent mortality
Peddicord and McFarland (1978)	Blue mussel	Adult	100,000	11 days	Processed	10 percent mortality
Peddicord and McFarland (1978)	Blue mussel	Adult	96,000	200 hr	Processed	LC50

* Lethal concentration at which 50 percent of the organisms died.
** Martin Marietta Laboratories, 1975, "Sonic Monitoring of Fish in the Delaware River," unnumbered progress reports, US Army Engineer District, Philadelphia, Philadelphia, PA.

Activities within 500 m of a significant benthic resource (e.g., productive oyster reef) should be limited to periods of minimal biological activity (e.g., nonreproductive periods) or at least monitored to minimize detrimental effects.

17. Other potential environmental impacts include the release of sediment toxins, lime introduction (concrete), and petroleum and chemical pollution. Activities involving sediments and/or repair materials known to contain chemical toxins should be conducted with special precautions to avoid unnecessary sediment resuspension or chemical release into the water body. Of particular concern is the possibility of introducing chemical repair agents during preparation, application, or cleanup of application equipment. Chemical cleaning agents may also contain toxic compounds.

18. Little is known about the potential effects of these compounds on aquatic organisms, even in trace amounts. However, whether released from resuspended sediments or from repair activities, chemicals may acutely or chronically affect sensitive life-history stages of fishes and shellfishes through sorption onto eggs (causing reduced survival rates and hatching); impaired osmoregulatory ability, causing delayed development or mortality; or impaired sensory ability, affecting feeding, movement, or predator avoidance (Cairns 1968, Sindermann et al. 1982). Olsen (1984) provides a good general review of the literature on the availability and bioaccumulation of heavy metals, petroleum hydrocarbons, synthetic organic compounds, and radionuclides in sediments. Specific information on toxicity, sublethal effects, and bioaccumulation of selected chemical compounds is given by Eisler (1985a, b, and c; 1986a and b) and Eisler and Jacknow (1985).

19. Any release of potentially toxic chemical substances into the water should be particularly avoided during periods when the area is being used by migratory species and/or juvenile forms and during periods of harvest of nearby commercially important shellfishes.

20. Noise pollution from dredging or repair activities may be a major concern when in the proximity of bird nesting sites (Buckley and Buckley 1977; Landin 1986). However, breeding activities are seasonal, and disturbance can be avoided by scheduling REMR operations during nonusage periods.

21. Removal of hard substrate and the addition of new hard substrate will have minimal effect in most areas except in cases where structures represent the only hard substrate available (e.g., rubble mound groins or jetties

on sandy coastlines). In these areas, short-term loss of colonized substrate may reduce species abundances but will represent only short-term losses. Addition of new substrate may act to increase the amount of surface area of a structure available for colonization by attached organisms and use by mobile organisms.

Reservoir Habitats

Environmental alterations

22. Environmental alterations that may result from REMR activities at CE dams include:

- a. Introduction of potentially toxic chemical substances into the water or increases in concentrations of these substances.
- b. Alteration of downstream riverflow. REMR activities often curtail normal release patterns from dams, frequently resulting in the dewatering of downstream river reaches. Flow alterations may also arise from pool drawdown, in which case high flows are released from the project.
- c. Alteration of inpool water level (drawdown). In some cases, REMR activities cannot be completed unless the reservoir is drawn down substantially.
- d. Alteration of water quality in and outside the reservoir. Water quality alterations can result from flow alterations (i.e., increased heating or cooling rates associated with dewatering) and release depth changes (i.e., release of water from Tainter gates instead of through the turbines during conduit repair). Water quality can also be modified by construction associated with REMR activities, resulting in increases in turbidity and suspended solids concentrations and changes in other constituents.
- e. Temporary impedance with fish migration. In some systems, adult fishes may move upstream via fish ladders, or smolts may move downstream through reservoir outlet works.

Potential environmental impacts

23. Toxic effects. The area of toxic effects required further investigation, particularly in the case of potential contaminants or toxicants used in large quantities. Chemicals associated with REMR activities have not been completely catalogued. The potential toxicity of construction materials, preparation materials, breakdown products, and cleanup materials associated with REMR activities is largely unknown. Thus, guidance on the effects or toxicity of materials associated with REMR activities cannot be formulated,

except to suggest that manufacturers' recommendations on the use and disposal of materials be followed. Many early life stages of fishes are highly sensitive to toxicants or contaminants.

24. Downstream flow alterations. Downstream flow alterations are associated with REMR activities involving reservoir outlet works. Activities such as outlet work inspection or repair may require downstream dewatering. At such times, the tailwater ecosystem receives no discharges from the dam except seepage, and portions of the tailwater may be completely dewatered. Dewatering of the tailwater may substantially impact downstream aquatic biota.

25. Effects of dewatering on tailwater ecosystems are determined by the duration of dewatering, project purpose, release depth, river channel shape, and season. Short-term dewatering downstream from a peaking hydropower project discharging no flow other than seepage will have impacts similar to impacts of nongeneration, unless dewatering is of longer duration. Dewatering a flood-control project tailwater may have a more detrimental effect since seepage flow may be substantially less than minimum low flow releases from the project. Consequently, benthos and fishes may become stranded and desiccate, or aquatic biota may be crowded into a few remaining tailwater pools and exposed to poor water quality or increased predation.

26. Effects of dewatering are also determined by the shape of the channel in the tailwater. Channels characterized by deep pools connected by riffle areas will be less susceptible to effects of dewatering since ample habitat will be provided by pools. Some stranding of benthos, however, may occur in riffle areas. Channels characterized by runs, or long sections of river without pools and riffles, are more sensitive to the effects of dewatering since little habitat will remain as discharges are reduced.

27. Seasonal meteorological conditions may have a substantial effect on the impacts of dewatering. Summer insolation during a prolonged dewatering could cause considerable warming of tailwaters that support a coolwater or coldwater fishery with resultant losses of aquatic organisms. The initial release wave from a deep release project could result in thermal or chemical shock to aquatic organisms as water in the tailwater is replaced by reservoir discharges of considerably different quality. Dewatering conducted in wintertime may also stress downstream organisms. Exposed organisms may suffer desiccation and freezing during tailwater dewatering.

28. In general, short-term dewatering will not disrupt the tailwater ecosystem. However, the following recommendations will ensure that effects of dewatering remain minimal:

a. REMR activities at a reservoir project should be completed as quickly as possible to minimize the duration of dewatering.

b. Efforts should be made to supply the tailwater with some flows, particularly if dewatering will last more than several days, by siphoning or pumping water over the dam or by some other means. This consideration is more important for flood-control or hydropower projects that release a regulated minimum low flow than for projects that routinely dewater the tailwater as part of normal operation (peaking hydropower projects). Water quality of replacement flows should meet the requirements of tailwater biota. That is, in the summer, coldwater systems should receive cold water and warmwater systems receive warm discharges.

c. Flow into the tailwater should be increased gradually after the completion of the REMR activity if release water quality differs from water quality conditions in the tailwater.

29. In addition to dewatering, REMR activities may also result in increased downstream flows if the reservoir must be drawn down to complete inspection or repairs. Discharge of high flows during drawdown can result in considerable modification in flow and water quality conditions associated with normal project operation.

30. Drawdown produces changes in both water quality and flow conditions in downstream river reaches. River reaches downstream from projects involved in REMR activities may receive sustained high flows as reservoir storage is evacuated for inspection or repair. Although high discharges may be a considerable departure from normal operations, detrimental effects of these flow alterations should not be severe. However, fishes may spawn during high flows in areas that will be later uncovered as the discharge water from the project decreases. Consultation with the appropriate resource agency prior to drawdown should be considered to eliminate this concern.

31. The timing of drawdown may have a significant effect on the biological dynamics of the tailwater ecosystem. Reservoirs generally destratify from October through December, depending upon latitude and seasonal meteorological conditions. Thus, drawdown may occur either before, during, or after destratification. Downstream water quality effects of drawdown are directly related to stratification patterns in the reservoir and depth of withdrawal relative to the timing of drawdown. If drawdown occurs before

destratification, then the tailwater ecosystem may be subjected to poor water quality, provided that deep floodgates are used to evacuate the reservoir. The reservoir hypolimnion may contain high concentrations of dissolved metals (e.g., iron and manganese), noxious gases (e.g., hydrogen sulfide), and low dissolved oxygen (DO) concentrations. Poor release water quality can have a substantial, negative effect on tailwater aquatic organisms. If fall drawdown occurs after destratification, then transport of contaminants into the tailwater may be reduced, but many reservoir organisms may be transported through the sluiceway and into the tailwater. From a fishery standpoint, this phenomenon has mixed effects. Reservoir fishes may concentrate in the tailwater and thus provide a greater harvest for fishermen. However, this movement of large numbers of fishes into the tailwater may disrupt the normal riverine assemblage of fishes farther downstream from the dam. The significance of the latter phenomenon has not been documented.

32. Two alternatives are available to maintain tailwater water quality during drawdown. Drawdown can be scheduled before or after destratification to avoid subjecting tailwater biota to poor water quality. Alternatively, drawdown for a stratified project can be initiated gradually using a combination of ports to release water of acceptable quality.

33. <u>Inpool drawdown.</u> REMR activities on the upstream face of the dam or on the reservoir outlet works of the dam may require substantial pool drawdown. Drawdown may have a substantial negative impact on the reservoir fishery depending upon the season of drawdown, the rate and extent of drawdown, stratification patterns within the reservoir, depth of withdrawal, and species composition of the reservoir fishery. In the spring, spawning sites and larval fishes in the littoral zone may be stranded as water levels decline. In the summer, drawdown may reduce survival of juvenile fishes by reducing food supply and cover. In the fall, there may not be enough growing season left to allow terrestrial vegetation to establish in exposed areas of the reservoir. Terrestrial vegetation growing in this zone of the pool provides desirable sites for fish spawning in the spring.

34. Drawdown extended over a long period has several advantages. First, it maintains flow in the tailwater closer to historical levels. Second, it lengthens the growing season available for terrestrial vegetation to colonize the fluctuation zone, particularly the upper part of the fluctuation zone that will be exposed the earliest. In the spring, it will

lessen the problem of stranding nests or larval fishes as water levels decline. However, the latter approach may have a negative impact on inpool recreation since water levels may fall during part of the recreation season. In general, reservoir drawdown to facilitate REMR activities should be considered for fall and winter if possible. The appropriate resource agency should be consulted to determine if species sensitive to drawdown in the winter or fall comprise part of the reservoir fishery.

35. Water quality. REMR activities can affect water quality directly through inspection and repair activities or indirectly through modifications in operation. Direct effects include increased levels of turbidity and suspended solids concentrations associated with construction activity and heavy equipment movement. In general, increased turbidity levels and suspended solids concentrations are not serious problems unless extensive precipitation produces high levels of these constituents in runoff from the site. Aquatic biota in the downstream reaches may then be subjected to burial, changes in sediment composition, and other changes resulting from sedimentation, such as depressed DO levels if sediments are high in organic content.

36. To avoid problems associated with runoff from REMR sites, repair work that involves extensive construction activity should be avoided during periods of historically high precipitation. Also, this same time period generally coincides with increased reproductive activity by many riverine fishes. For further avoidance of problems associated with runoff from a REMR site, efforts should be made to reduce or manage runoff.

37. Seasonal water quality changes that can affect biota can also result from alterations in project operation dictated by REMR activities. Water quality changes can result from changes in depth of withdrawal (e.g., discharging water from Tainter gates instead of through a conduit during repair to a conduit) or from extreme reductions in flow resulting in total or partial dewatering of downstream reaches. To avoid problems associated with altered water quality resulting from REMR activities, efforts should be made to ensure that release water quality falls within seasonal requirements of aquatic biota. Such considerations are most important if early life stages are involved, since they are often very sensitive to water quality.

38. Fish migration. Under routine project operation, adult fishes of some species may pass upstream through a project using fish passage facilities

such as fish ladders; smolts may move downstream through project outlet works. REMR activities may impede fish movement either by altering water quality in a manner that prevents fishes from approaching the project or by changing operation of the project so that fishes may not be attracted to the proper part of the dam for passage or diversion. Seasonal regulations should be considered if consultation with the appropriate resource agency indicates that either upstream or downstream passage of fish occurs at the project. This problem is most likely to occur at projects that support anadromous fisheries.

Inland Waterway Habitats

CE structures in navigable waterways

39. The majority of large structures in rivers affected by REMR activities are those associated with navigation facilities (Table 3). Typically, the repair or rehabilitation of a lock and dam, levee, or dike must be completed when there are low water and suitable climatic conditions. When repair or rehabilitation of a riverine structure or facility is conducted, no operational changes usually accompany the action. An exception would be the temporary dewatering of a lock to enable inspection or repair of machinery, gates, lock walls, etc. REMR activities (Table 3) at locks, dams, lock and dam facilities, dikes, levees, and/or revetments could potentially damage sensitive biological resources in flowing water systems.

Potential environmental alterations and impacts

40. Locks. A variety of possible actions can take place at locks for repairs or efficiency and safety. Improving efficiency (e.g., increasing the number of tows per unit time) is advantageous since it is cheaper to increase capacity rather than to construct new facilities. In addition, the environmental effects of barge fleeting, which can include increased turbulence, associated turbidity, bank erosion, and the possibility of spills and collisions, are reduced if tows can be moved quickly through locks rather than be held for long periods of time before moving through the facilities.

41. Fishes typically congregate in and near locks and are easily collected in lock chambers. Although fish eggs and larvae from open-water spawners (such as the freshwater drum) are often collected in lock chambers,

Table 3

Potential REMR Activities Associated with CE Structures in Navigable Waterways

Structure	Activity
Lock	Repair machinery for gates, valves, control systems Concrete repair Dewatering system Add or repair kevels Replace tow haulage system Improve bubbler system Repair jib cranes Add or repair mooring bits Improve lockage waiting areas Reinforce lock guidewalls Add mitergate fenders Institute N-down, N-up locking system
Dam	Replace wiring Rehabilitate machinery Motorize tainter gates Overhaul bulkhead lifting devices Concrete repair Add new roller gates Tainter gate repair
Lock and dam facilities	Upgrade sewer system, parking facilities Modify site (roads, buildings, etc.) Flood proof buildings Improve fire protection
Dike/levee	Add gated culverts Add pumping system Armor old material, add new material Remove debris, deciduous vegetation Notch dikes
Revetments	Remove debris, deciduous vegetation Replace material with riprap, ACM piles, etc.
Diversion structures	Concrete repair Remove debris

these areas should not be considered critical breeding sites. In addition, fishes, freshwater mussels, and other invertebrates are frequently found below locks in large waterways. Fishes feed on invertebrates associated with structures and are also attracted to changes in current velocity; however, these sites are not of critical importance to these organisms.

42. REMR actions at locks may introduce toxic materials associated with chemical repair of concrete, require dewatering for inspection and work, and cause shock, noise, and dust that are part of removal and repair of concrete. Since locks are not important sites for reproduction, recruitment, or feeding by fishes and other freshwater organisms, most REMR actions do not significantly affect aquatic resources in the immediate area. The improvement of efficiency and safety when moving commercial traffic, which is the overall purpose of REMR activities at locks, tends to reduce overall navigation impacts on a large waterway.

43. Dams. Typically, fishes pass dams on navigable waterways by moving through locks when vessels pass. The environmental effects of REMR activities at dams or diversion structures, including chemical and physical repair of concrete or rehabilitation of machinery, do not differ from those associated with locks discussed previously.

44. Lock and dam facilities. Facilities associated with locks and dams requiring REMR actions include natural and protected banks, sewer and power facilities, access roads, and buildings. Most REMR actions associated with these areas have little direct effect on the riverine environment, although terrestrial species in the vicinity may be affected. Small spills, creation of dust, turbidity, noise, etc., cause localized effects and are of little consequence to aquatic resources in large waterways.

45. Dikes and levees. At low flow in large waterways, river training dikes often create isolated or semi-isolated pools with relatively clear, well-oxygenated water. Low-velocity areas around dikes provide favorable habitat for fish larvae, aquatic insects such as *Chaoborus*, fingernail clams, and oligochaete worms. In the upper Mississippi River, submerged dikes reportedly create favorable conditions for freshwater mussels, notably, the uncommon spectacle case, *Cumberlandia monodonta*.

46. Usually, it is necessary to maintain levees following periods of high water. This is done by placing additional fill and removing timber, trash, and other obstructions. Trees and shrubs have to be removed from levees periodically to ensure that root growth does not interfere with structural integrity. Gated culverts are frequently placed in levees to allow

one-way passage of water that facilitates interior drainage. Maintenance takes place any time during low flow, usually in the summer or fall.

47. Vegetation removal from levees causes localized effects and, if conducted early in the year, could disrupt nesting success of spring breeding birds, such as warbler, and ground-nesting birds, such as killdeer. Placement of earthen fill, riprap, and pilings could cause increases in turbidity, although these effects are minimal and not widespread. Local turbidity increases will be most noticeable during summer or fall when ambient levels are reduced. Disruption of larval fishes, aquatic insects, etc., usually associated with dikes and dike fields would be most detrimental in spring or early summer. Disturbances to bivalve mollusc communities could occur at any time since these are long-lived organisms. However, disruptions to aquatic biota as part of maintenance activities on dikes and levees are minor.

48. Revetments. Revetment repair includes placement of additional riprap or articulated concrete mattresses. Revetted banks have been found to support considerable numbers of benthic invertebrates (e.g., caddisflies), and areas beneath riprap are frequently colonized by burrowing mayflies (e.g., *Pentenura* sp., *Tortopus* sp.). Disruption of banks by placing additional riprap can be detrimental to benthic invertebrates, although this effect is temporary. Any impacts would be greatest before and during insect emergence in the spring.

49. Vegetation removal from areas to be riprapped (which would include dikes and levees) can cause localized impacts to spring-nesting birds. In addition, the federally listed endangered Indiana bat (*Myotis sodalis*) has nursery colonies beneath the bark of dead or dying sycamore trees along banks of small- to medium-sized rivers where the numbers of emerging insects for food are adequate. Adults and young bats forage along banks for insects and depend upon vegetative cover. Vegetation removal in the early spring would be most detrimental to this species.

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