Coastal Structures

FEMA Coastal Flood Hazard Analysis and Mapping Guidelines Focused Study Report

February 2005

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Acronyms

BFEs	Base Flood Elevations
CEM	Coastal Engineering Manual
CFR	Code of Federal Regulations
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
NGDC	National Geophysical Data Center
PWA	Philip Williams & Associates
SFHA	Special Flood Hazard Area
SPM	Shore Protection Manual
USACE	U.S. Army Corps of Engineers

1 INTRODUCTION

Existing FEMA guidance for treatment of coastal structures refers to seawalls, bulkheads, revetments and coastal levee-type structures, i.e., those that are intended to retain fill and offer protection against flooding and waves, and that are constructed along or parallel to the shoreline. Groins, jetties and detached breakwaters are not mentioned specifically, but should also be considered for flood hazard mapping purposes.

A coastal structure can modify flood levels, wave effects and topography, both landward of, seaward of and adjacent to the structure, and must be considered during the mapping of coastal flood hazards. Two scenarios are commonly encountered:

1. *Existing* coastal structures are analyzed during a Flood Insurance Study, and their effects (if any) must be reflected by the resulting FIRM. This process is described in Appendix D to the *G&S* (FEMA, 2003).
2. *Existing, new or proposed* coastal structures often serve as the basis for revisions to FIRMs, and their stability and effects must be evaluated. The map revision instructions and form MT-2 (FEMA 2002) address this scenario.

1.1 CATEGORY AND TOPICS

Seven coastal structures topics were identified at Workshop 1 and are identified below. There were no "Critical" topics identified. Five topics were designated "Available" and two were identified as "Helpful." Each of these will be considered in this paper.

1.2 COASTAL STRUCTURES FOCUSED STUDY GROUP

The Coastal Structures Study Group is made up of Bob Batallio, Ida Brøker, Kevin Coulton, Jeff Gangai, Darryl Hatheway, Jeremy Lowe, Ron Noble, and Chris Jones, who served at Team Leader.

1.3 CURRENT FEMA GUIDANCE FOR COASTAL STRUCTURES

FEMA's existing guidance for coastal structures is limited to the Atlantic, Gulf of Mexico and Great Lakes Coasts, as summarized in the *G&S for Flood Hazard Mapping Partners* (FEMA, 2003). Sections D.2.2.8 and D.2.3 address the Atlantic and Gulf of Mexico; nearly identical sections D.3.2.7 and D.3.3 address the Great Lakes. No coastal structure guidance specific to sheltered shorelines or the Pacific Coast exists in Appendix D, although it is reasonable to expect that existing guidance for other coasts will apply.

Coastal Structures Topics and Priorities					
Topic Number	Topic	Topic Description	Priority		
			Atlantic / Gulf Coast	Pacific Coast	Non-Open Coast
25	Flood Protection Structures	Review *G&S* language – (SC not required to evaluate all structures using 89-15); add new procedure for flood hazard modeling in the presence of coastal structures	A	A	A
21	Failed Structures	Clarify guidance that when a structure is determined to fail under base flood conditions, the structure is removed, fill/topo remains and is subject to erosion, wave analyses	A	A	A
23	Buried Structures	Add *G&S* language that buried structures are to be evaluated	A	A	A
27	Coastal Levees v. Structures	Review *G&S* and regs regarding treatment of coastal levees and structures; identify conflicts; clarify *G&S* that evaluations of all "structures" to be per 89-15	A	A	A
24	Structures - Tsunamis	Review 89-15 and other literature for tsunami failure information/guidance	--	A	I
22	Failed Structure Configuration	Investigate configuration of failed structures	H	H	H
26	Adjacent Properties	Review data on (and add to *G&S*) effects of structures on flood hazards on adjacent properties, flooding/waves behind structures via adjacent properties	H	H	H
Key: C = critical; A = available; I = important; H = helpful					

Excerpts and major elements of the existing coastal structure guidance are summarized below:

- "The crucial first consideration in evaluating a coastal structure is whether it was properly designed and has been maintained to provide protection during the 1-percent-annual-chance flood. If it can be expected to survive the 1-percent-annual-chance flood, the structure should figure in all ensuing analyses of wave effects (erosion, runup, and wave height). Otherwise, it should be considered destroyed before the 1-percent-annual-chance flood and removed from subsequent transect representations." (Section D.3.3, paragraph 1).

- Specific criteria for evaluating coastal structures are contained in a memorandum (FEMA 1990), reproduced in Appendix CS-1. The criteria are based in large part on a study performed by the USACE for FEMA (Walton, et al., 1989; also referred to as "TR-89-15"), and cover such topics as:

  - Design parameters (water levels and wave heights; breaking wave forces),
  - Freeboard (above 1% stillwater level, and relative to the runup elevation),

- Toe protection,
- Backfill protection,
- Structural and geotechnical stability (sliding, overturning, settlement, soil slip, ice and impact forces, etc.),
- Materials (strength and durability, including stone size, filter characteristics, expected lifetime, etc.),
- Adverse impacts,
- Maintenance plan, and
- Engineering certification.

Similar criteria are contained in the *Coastal Structures Form* (MT-2, Form 5, reproduced in Appendix CS-2) used to evaluate coastal structures as the basis for FIRM revisions.

In performing analyses for a Flood Insurance Study (FIS) FEMA (2003) directs the mapping contractor (partner) to obtain documentation for each coastal structure possibly providing protection from 1-percent-annual-chance flood. That documentation is to include the following:

- Type and basic layout of structure;
- Dominant site particulars, (e.g., local water depth, structure crest elevation, ice climate);
- Construction materials and present integrity;
- Historical record for structure, including construction date, maintenance plan, responsible party, repairs after storm episodes; and
- Clear indications of effectiveness or ineffectiveness.

Unfortunately, few FIS projects have sufficient funds to support a detailed evaluation of coastal structures, and the *G&S* call for development of "much of this information through office activity, including a careful review of aerial photographs. In some cases of major coastal structures, site inspection would be advisable to confirm preliminary judgments." (Section D.2.2.8, last paragraph).

Cost considerations aside, the *G&S* also recognize that information about existing coastal structures may not be available or sufficient to complete a detailed evaluation. In such cases, the mapping contractor (partner) "shall make an engineering judgment about its likely stability based on a visual inspection of physical conditions and any historical evidence of storm damage and maintenance." (Section D.2.3, second paragraph).

2 CRITICAL TOPICS

There were no "Critical" topics identified in Workshop 1.

3 AVAILABLE TOPICS

3.1 TOPIC 25: ADD GUIDELINES AND SPECIFICATIONS TEXT THAT STATES STUDY CONTRACTORS ARE NOT REQUIRED TO EVALUATE ALL COASTAL STRUCTURES USING THE CRITERIA IN FEMA (1990) AND WALTON, ET AL. (1989); ADD A RECOMMENDED PROCEDURE FOR MAPPING FLOOD HAZARDS AT TRANSECTS WITH COASTAL STRUCTURES

3.1.1 Description of Topic and Suggested Improvement

Sections D.2.3 and D. 3.3 of the existing guidance make reference to the FEMA criteria for the evaluation of coastal structures (FEMA, 1990; Walton, et al., 1989), and imply these criteria should be applied by study contractors, unless available information is not sufficient to perform detailed evaluations. The *G&S* should be revised to state clearly that detailed evaluations of all structures are not required of study contractors.

Instead, the following structure evaluation procedure is recommended for inclusion in the *G&S*:

1. The Study Contractor should determine whether available information clearly indicates a coastal structure will fail or survive a base flood event, then perform the subsequent erosion and wave analyses on the indicated (intact or failed structure) profile. In the case of revetment type structures that tend to fail progressively, study contractors should be allowed the discretion to allow for partial – rather than complete – failure (see Topics 21a and 22). It should be clearly communicated to communities and property owners that Study Contractor structure performance determinations are for mapping purposes only, are not intended to substitute for detailed structural evaluations, and should not serve as a basis for Study Contractor liability in the event of structure failure.

2. If available information does not clearly point to survival or failure of a coastal structure, the Study Contractor may either: a) conduct a detailed evaluation using TR-89-15 procedures, or b) perform the erosion and wave analyses for both the intact and failed structure cases, and map the flood hazards associated with the more hazardous case. If option 2.b) is selected, the Study Contractor should clearly document the results of both cases (structure intact, structure failed) and specify which case is used for mapping purposes. Also, see section 5.1.1, Topic 22.

Implications of not Performing Detailed Coastal Structure Evaluations During the FIS

Flood study contracts typically do not have sufficient budget to carry out detailed evaluations of coastal structures, and study contractors commonly assume the structures will fail as a default condition (since they have not performed detailed evaluations). There are two important implications of this assumption:

- Failed coastal structures may or may not yield the highest BFEs and greatest flood hazards. See Topic 22 for additional discussion.

- Property owners frequently request (and receive) revisions to FIRMs after retaining engineers who perform detailed evaluations and certify that coastal structures will withstand the 1% flood event. As a result, the revised FIRMs may display highly irregular flood hazard zone boundaries and BFE lines, and may be constantly changing as additional detailed evaluations are performed. See Topic 27 for additional discussion.

3.1.2 Availability

Information to address Topic 25 is available and easily incorporated into existing guidance.

3.2 TOPIC 21: CLARIFY GUIDANCE REGARDING TREATMENT OF BACKFILL/TOPOGRAPHY WHEN A STRUCTURE IS DETERMINED TO FAIL UNDER BASE FLOOD CONDITIONS, AND IS REMOVED FROM THE TRANSECT

3.2.1 Description of Topic and Suggested Improvement

Existing guidance calls for the removal of a coastal structure (from analysis transects) when it has been determined that the structure will not withstand the 1% event (see Section D.2.3, first paragraph; Section D.3.3, first paragraph).

However, no details are provided as to how such a removal should be accomplished for those types of structures contemplated by the *G&S* (seawalls, bulkheads, revetments, levees), and no details are provided regarding other types of coastal structures whose failure during a base flood event could affect coastal flood hazards (e.g., groins, jetties, detached breakwaters).

Dealing with the former issue will be straightforward, but dealing with the latter will not. Guidance on how to predict the failure of groins and jetties – which usually fail by loss of profile (through settlement or displacement) and/or by becoming detached at their landward ends – is not readily available. Likewise, guidance on how to predict the failure of detached breakwaters (usually through loss of profile) is not readily available.

The recommended approach can be divided into two components:

- Topic 21a. For *seawalls, bulkheads, revetments and coastal levees*: remove the failed structure (or estimate a partial collapse of revetment structures, where appropriate) and

alter the remaining soil to achieve its likely slope immediately after structure failure (note that this is not necessarily the same as the long-term stable slope in the case of bluffs and cliffs). This slope will then be subjected to an event-based erosion analysis and wave height and runup analyses.

- Topic 21b. For *groins, jetties and detached breakwaters*: evaluate the overall condition and performance of the structures over time; determine whether the structures (or similar structures nearby) have been damaged or detached during prior major storms; document the structural damage and any resulting shoreline recession attributable to the structural damage; use this information to predict the likely shoreline configuration (in plan view) if the structures fail during the base flood. The altered shoreline will then be subjected to an event-based erosion analysis and wave height and runup analyses. Note that in the case of groins and jetties, it is unlikely that their failure will require "removal" from analysis transects (removal of a detached breakwater from a transect is more likely to occur). The effects of the structures on the shoreline configuration, however, will be removed.

3.2.2 Availability

Information to address Topics 21a is available and easily incorporated into existing guidance.

Existing guidance can be modified to mention Topic 21b, but detailed guidance is not readily available. Developing detailed guidance could require site-specific studies using analytical or numerical methods.

Therefore, it is recommended that guidance be expanded to discuss removal of seawalls, bulkheads, revetments, coastal levees and that guidance allow for partial failure of revetments, where appropriate. Mention in guidance removal of the effects of groins, jetties, detached breakwaters on the shoreline. Develop specific guidance on how to remove the effects of groins, jetties, and detached breakwaters on the shoreline.

3.3 TOPIC 23: ADD GUIDELINES AND SPECIFICATIONS TEXT THAT BURIED STRUCTURES ARE TO BE EVALUATED

3.3.1 Description of Topic and Suggested Improvement

Existing guidance is vague regarding those coastal structures that should be evaluated for their durability during the 1% flood event. The guidance is clear that exposed structures must be evaluated, but does not mention coastal structures that are known to exist, but are buried. The recommended approach is simple:

Modify the *G&S* text to state that study contractors should:

1. Inquire as to whether buried coastal structures exist within their study area,

2. Mention the apparent presence or absence of buried coastal structures in the study documentation,

3. Apply evaluation techniques to buried coastal structures that are similar to those applied to exposed coastal structures.

4. Add examples to the *G&S*.

3.3.2 Availability

Information to address Topic 23 is available and easily incorporated into existing guidance.

3.4 TOPIC 27: REVIEW GUIDELINES AND SPECIFICATIONS AND NFIP REGULATIONS REGARDING TREATMENT OF COASTAL LEVEES AND STRUCTURES; IDENTIFY CONFLICTS; REVIEW AND UPDATE TR-89-15 STRUCTURE EVALUATION CRITERIA; CONSIDER REQUIRING ALL COASTAL STRUCTURES (EXISTING AND NEW) TO MEET THE SAME EVALUATION CRITERIA

3.4.1 Description of Topic and Suggested Improvement

There are potential inconsistencies in the treatment of coastal levees and other coastal flood protection structures, and in the evaluation of coastal structures. The issues are as follows:

- Topic 27a – incomplete explanation of the differences between coastal levees and other coastal structures, and how the designation affects their treatment in flood hazard mapping;

- Topic 27b – the evaluation criteria in Walton et al. (1989) should be reviewed in light of the methods contained in the *Coastal Engineering Manual* (USACE, 2002); and

- Topic 27c – existing coastal flood protection (non-levee) structures can be incorporated into a coastal flood study based on engineering judgment, without meeting the same engineering and certification requirements for new or proposed structures; consider requiring all structures to meet the same criteria; maintenance plan criteria for private structures are problematic.

Topic 27a: Coastal Levees vs. Other Coastal Structures

There are two general classes of coastal structures that can provide some degree of protection against coastal flooding: coastal levees and other coastal structures.

Coastal levees are structures that are designed to provide low-lying coastal areas with total protection during the 1% flood. In other words, the coastal levee must be substantial enough to prevent any flooding or wave overtopping landward of the levee crest. NFIP regulations (44CFR part 65.10; reproduced in Appendix CS-3) spell out the requirements

a coastal levee must meet to be credited as providing complete protection from flooding, including a freeboard requirement specific to coastal levees – the crest elevation of the levee must be elevated at least two feet above the 1% stillwater elevation, and above the elevation of the 1% wave height or the maximum wave runup elevation (whichever is greater).

Other coastal structures (seawalls, bulkheads, revetments) can be recognized on flood hazard maps as long as they remain intact during the 1% flood, even if they are overtopped. They can provide limited protection against flooding and waves, yet still be considered for flood hazard mapping purposes. These types of structures are often used by property owners to reduce flood hazards and to revise flood hazard zones on the FIRM (i.e., to change V zones to A zones or X zones).

The *G&S* do not explain the differences between coastal levees and other coastal structures, do not discuss the different design and certification requirements, and do not discuss how the designation affects their treatment for flood hazard mapping purposes.

On a related matter, one source of much discussion has been the maintenance plan criteria in FEMA (1990) and 44CFR65.10. The maintenance plan requirements in the regulations only apply to coastal levees, but in FEMA (1990), the same criteria apply to all coastal structures. This has been problematic since the criteria only allow certification of levees/structures where a maintenance plan has been adopted by and maintenance activities are the responsibility of a federal, state or community agency. Private structures will not be able to meet this requirement. As a practical matter, however, government agencies can require private owners to maintain their coastal structures. This effectively satisfies the intent of the maintenance plan requirement.

Topic 27b: Update to Coastal Structure Evaluation Criteria

FEMA coastal structure evaluation criteria (adopted in 1990) are based on a USACE report (Walton, et al., 1989). The report also forms the basis for the evaluation criteria contained in the *G&S,* in 44CFR 65.10, and in the flood map revision form for coastal structures (*MT-2, Form 5*).

The criteria should be reviewed in light of more recent guidance and methods contained in the USACE's *Coastal Engineering Manual* (CEM).

Topic 27c: Consistency of Coastal Structure Design/Certification in Flood Studies and Map Revisions, Including Maintenance Plan Criteria

Existing non-levee coastal flood protection structures can be incorporated into a coastal flood insurance study or restudy, without meeting all the specific requirements that new structures are expected to meet to justify a map revision.

The study contractor documentation specified in Section D.2.2.8 can serve as the basis for the evaluation of existing coastal structures. The documentation includes:

- Type and basic layout of structure;
- Dominant site particulars, (e.g., local water depth, structure crest elevation, ice climate);
- Construction materials and present integrity;
- Historical record for structure, including construction date, maintenance plan, responsible party, repairs after storm episodes; and
- Clear indications of effectiveness/ineffectiveness.

Given the fact that the *G&S* allow the Study Contractor to develop much of this documentation through an office review of available data, *engineering judgment* using the above factors can determine whether an existing coastal flood protection structure is incorporated into the coastal hazard assessment, and whether it influences BFEs and flood hazard zones.

In contrast, a new coastal flood protection structure is required to be certified with all supporting calculations and technical documentation specified in FEMA (1990) and Walton et al. (1989), including the maintenance plan requirement.

It would appear – for consistency purposes – that a similar level of engineering and certification should be required of both existing and new/proposed structures. It is recommended that consistent engineering and certification requirements be used for existing and new/proposed structures, with an exception for the maintenance plan criteria for private structures (which are not adopted by government agencies; such agencies will not be responsible for maintenance). Maintenance for private structures should be the responsibility of private owners and enforced through deed restrictions instituted at the time of the FIS or map revision.

Note that these recommendations will not only require a revision to the existing guidance in the *G&S*, they will require a significant increase in the level of effort (and cost) required for flood insurance studies, and will require a revision to FEMA's (1990) adopted criteria for privately owned coastal structures. Making such changes is more than a technical issue, and will require FEMA policy change.

3.4.2 Availability

Information to address Topic 27a is available and incorporated into existing guidance; however, inconsistencies will have to be resolved by FEMA.

Information on Topic 27b is available in the CEM and changes to evaluation criteria can be proposed based on this information.

Information related to Topic 27c is available; however, changes to require consistent engineering and certification requirements will necessitate FEMA policy changes and could have significant time and cost consequences.

3.5 TOPIC 24: REVIEW WALTON, ET AL. (1989) AND OTHER LITERATURE FOR DAMAGE TO COASTAL STRUCTURES DURING TSUNAMIS

3.5.1 Description of Topic and Suggested Improvement

Sections D.2.3 and D. 3.3 of the existing guidance do not reference evaluation criteria that may be appropriate for coastal structures in tsunami-prone areas. While the existing guidance may be pertinent for non-bore type tsunamis, it will probably not be adequate for bore-type tsunamis.

A review of the literature should be undertaken to document tsunami damage to coastal structures. Camfield (1980) summarizes the state-of-the-art as of two decades ago, and should be included in the review.

More recent reports and information sources should also be reviewed. For example:

- National Tsunami Hazard Mitigation Program: http://www.pmel.noaa.gov/tsunami-hazard/index.htm;
- Tsunami data at the National Geophysical Data Center (NGDC): http://www.ngdc.noaa.gov/seg/hazard/tsu.html;
- NOAA Tsunami Research Program: http://www.pmel.noaa.gov/tsunami/;
- International Journal of the Tsunami Society, *Science of Tsunami Hazards* (available at http://epubs.lanl.gov/tsunami/ (see the article by J.F. Landers, L.S. Whiteside and P.A. Lockridge, *Two decades of Global Tsunamis – 1982-2002*, in Vol. 21, No. 1, 2003);
- The Tsunami Research Group at the University of Southern California is dedicated to the investigation of tsunamis and some information may be found from their works: http://www.usc.edu/dept/tsunamis/;
- Mitigation of local tsunami effects project: http://engr.smu.edu/waves/index.html;
- Professor Philip L-F Liu at Cornell University is devoted to studies of the causes and effects of tsunami, and some information may be found in his publications: http://www.cee.cornell.edu/index.cfm; and
- The O.H. Hinsdale Wave Research Laboratory at Oregon State University is designated by the National Science Foundation as a site for tsunami research. This tsunami model basin is presently the largest one in the world for analyzing the impacts of tsunami waves: http://wave.oregonstate.edu/.

The *G&S* should be revised to incorporate revised coastal structure evaluation criteria for areas subject to bore-type tsunamis.

3.5.2 Availability

Information to address Topic 24 is available. This effort should be coordinated with the Tsunami Study Group.

4 IMPORTANT TOPICS

There were no "Important" topics identified in Workshop 1.

5 ADDITIONAL OBSERVATIONS - HELPFUL TOPICS

5.1 TOPIC 22: INVESTIGATE CONFIGURATIONS OF FAILED COASTAL STRUCTURES

5.1.1 Description of Topic and Suggested Improvement

The discussion in Section 3.1 summarizes the current *G&S* treatment of failed coastal structures, namely, they are to be removed from the analysis transects. However, in the case of seawalls, revetments and similar structures, outright removal may not result in the highest BFEs and flood conditions. Moreover, in the case of revetments, partial failure rather than complete failure (and removal) may be a more appropriate scenario for analysis due to the creation of higher runup condition or greater depths of ponding.

A proposed procedure for handling this situation was developed during the Whatcom County, WA, FIS (PWA, 2002). A modified PWA procedure is recommended for incorporation into the *G&S* as follows:

- In the absence of structure certification, conduct coastal flood analysis for intact and failed conditions, and use the worst case for flood mapping; note that maintaining the results of both analyses may be useful in the event that map revisions are requested in the future based on intact structures;
- Apply simple geometric approaches to estimate the failed condition for vertical or near-vertical rigid structures:
  - Estimate toe scour based on the Shore Protection Manual (SPM) or similar approximations (scour to the water depth at the structure toe, based on the largest unbroken wave anticipated at the toe);
  - Extend the toe erosion offshore a distance related to the incident wave length;
  - Presume the rigid structure breaks apart, into a rough, porous failed slope at 1.5:1. The slope is selected with the understanding that runup typically reaches a

maximum at about this slope, which is also consistent with the potential angle of repose of rough angular material; and

- Note that assuming a failed slope of 1.5:1 may lead to undermining of buildings situated very close to the coastal structure. This scenario should be investigated during Phase 2 to determine the appropriate mapping course of action.

- In the case of revetments, consider whether complete or partial failure is more likely during the base flood, and model the selected failed condition. If the failure condition is uncertain, modeling of total and partial revetment failure can be carried out.

In the case of the Sandy Point FIS, application of the above procedure indicated the failed structure condition *typically* did not yield the highest runup elevation, but could result in greater overtopping rates than the intact structure condition.

Parts V-3 (Basco, 2003) and VI-5 (Burcharth and Hughes, 2003) of the CEM (and other documents – see Section 5.2.1) should be reviewed for possible guidance regarding the configurations of failed structures. However, it is proposed that the PWA method be considered an interim method (for seawalls, bulkheads and revetment type structures) and evaluated for future refinement.

Methods for handling failed groins, jetties and breakwaters have not been proposed here, but may be considered for future enhancements of the *G&S* – see Topic 21b.

5.1.2 Availability

Information to address Topic 22 is available. This effort should be coordinated with the Runup/Overtopping Study Group.

5.2 TOPIC 26: REVIEW DATA ON THE EFFECTS OF COASTAL STRUCTURES ON FLOOD HAZARDS ON ADJACENT PROPERTIES; REVIEW FLOODING/WAVE EFFECTS BEHIND STRUCTURES

5.2.1 Description of Topic and Suggested Improvement

One of the coastal structure evaluation considerations included in FEMA (1990), FEMA (2002) and FEMA (2003) is *adverse impacts*. Unfortunately, the level of guidance contained in those documents is *inadequate*:

- FEMA's (1990) memorandum regarding the evaluation of coastal structures states: "All requests for flood map revisions based upon new or enlarged coastal flood control structures shall include an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent, to the protected area.";

- FEMA's (2002) flood map revision coastal structures form asks flood map revision requestors, "... will the structure impact flooding and erosion for areas adjacent to the structure? If yes, attach an explanation."; and

- FEMA's (2003) *G&S*, section D.2.3, states, "... a structure might decrease flood hazards in one area while increasing flood and erosion effects at adjacent sites."

Impact of Coastal Structures (Seawalls, Revetments) on Adjacent Property

Impacts can be divided into erosion impacts and hydraulic impacts. Erosion impacts will include the short- or long-term effects of a coastal structure on the topography of adjacent property. Hydraulic impacts will include such things as wave reflection, concentration of flow, etc.

Fortunately, the literature contains numerous papers and studies related to erosion impacts:

- Dean (1987) assessed commonly expressed concerns about seawall impacts. The assessment is summarized in Figure 1.

- Fulton-Bennett and Griggs (1986) document case histories of 32 shore protection structures at sites between San Francisco and Carmel, CA. The report concluded that few of the structures survived the long-term test of time without some damage to the structure or the upland areas. Maintenance costs of the structures were much higher than originally anticipated.

- Griggs, et al. (1994) summarized the results of field monitoring at sites in Monterey Bay, CA. They concluded after seven years of detailed monitoring that there was "an absence of measurable or significant differences" between the seawall backed beach and the natural beach.

- Kraus and Pilkey (1988), and Kraus and McDougal (1996) present detailed literature reviews concerning the effects of seawalls on beaches. Both papers were published in the *Journal of Coastal Research*, the first being in a special issue devoted to the topic (Kraus and Pilkey, 1988).

- McDougal et al. (1987) conducted laboratory and field investigations in Oregon to assess the impacts of shore protection structures on adjacent unprotected properties. The studies found the "excess erosion" on adjacent properties was consistent with the findings of Chiu (1977): the depth of excess erosion was found to be equal to approximately 10% of the seawall length (see Figure 2).

Taken as a whole, these studies indicate the erosion effects of shore protection structures on nearby properties will vary, depending on the local coastal processes and morphology, sediment budget, and structure location/characteristics. However, the effects can be divided into three general categories:

The effects of impoundment (sediment landward of the structure being prevented from eroding and nourishing the beach) and passive erosion (continuation of ongoing shoreline recession, resulting in a narrower beach in front of a structure) are relatively uncontroversial and can be quantified for a site.

Table V-3-3
Assessment of Commonly Expressed Concerns Related to Coastal Armoring (Dean 1987)

No.	Concern		Assessment
1	Coastal armoring placed in an area of existing erosional stress causes increased erosional stress on the beaches adjacent to the armoring.	True	By preventing the upland from eroding, the beaches adjacent to the armoring share a greater portion of the same total erosional stress.
2	Coastal armoring placed in an area of existing erosional stress will cause the beaches fronting the armoring to diminish.	True	Coastal armoring is designed to protect the upland, but does not prevent erosion of the beach profile waterward of the armoring. Thus, an eroding beach will continue to erode. If the armoring had not been placed, the width of the beach would have remained approximately the same, but with increasing time, would have been located progressively landward (see 2b).
2a	Beaches on eroding coastlines will diminish in front of fixed dune positions.	True	An eroding beach continues to erode relative to a fixed dune position. The width of the beach must diminish if the shoreline is eroding (Figure 1).
2b	Natural beaches on retreating barriers maintain the same beach width.	True	Relative to a retreating duneline, a shoreline eroding at the same rate results in a stable beach width.
3	Coastal armoring causes an acceleration of beach erosion seaward of the armoring.	Probably False	No known data or physical arguments support this concern.
4	An isolated coastal armoring can accelerate downdrift erosion.	True	If an isolated structure is armored on an eroding beach, the structure will eventually protude into the active beach zone and will act to some degree as a groin, interrupting longshore sediment transport and thereby causing downdrift erosion.
5	Coastal armoring results in a greatly delayed poststorm recovery.	Probably False	No known data or physical arguments support this concern.
6	Coastal armoring causes the beach profile to steepen dramatically.	Probably False	No known data or physical arguments support this concern.
6a	Coastal armoring destroys foreshore bar and trough features.	Probably False	No known data or physical arguments support this concern.
7	Coastal armoring placed well-back from a stable beach is detrimental to the beach and serves no useful purpose.	False	In order to have any substantial effects to the beaches, the armoring must be acted upon by the waves and beaches. Moreover, armoring set well-back from the normally active shore zone can provide "insurance" for upland structures against severe storms.
8	Seawalls increase the longshore sediment transport.	Unknown	No known data exists, physical arguments can support or discredit this concern. Needs research.
9	Seawalls cause sand transport a far distance offshore.	Probably False	No known data or physical arguments support this concern.
10	Other		

Figure 1. Review of concerns related to coastal armoring (Dean, 1987, as compiled by USACE, 2003).

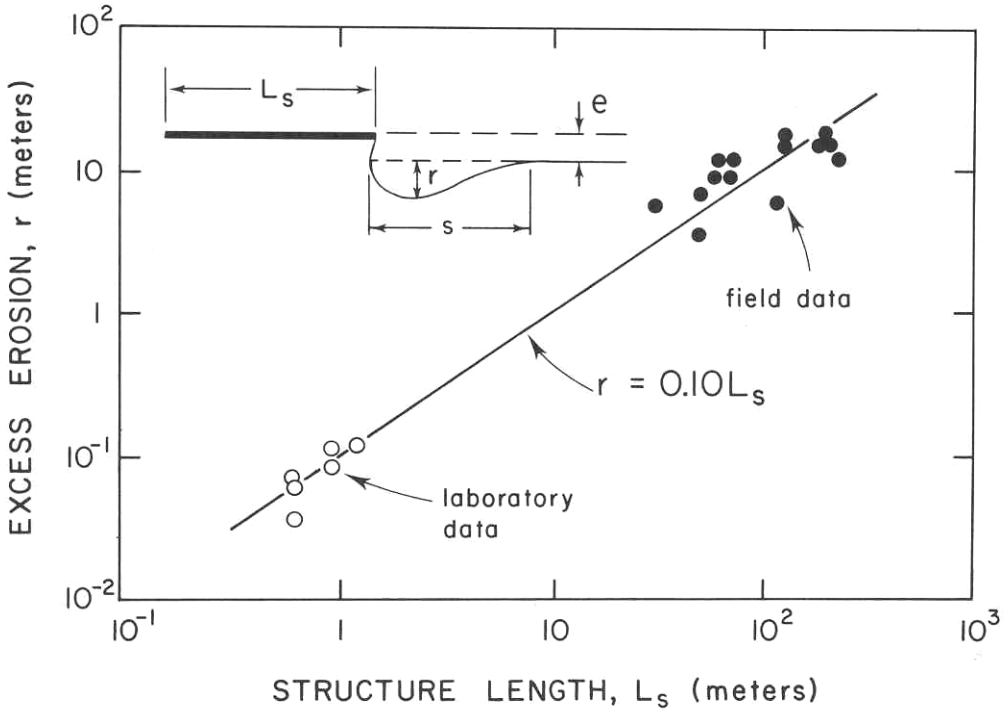

Figure 2. Excess erosion caused by seawalls (McDougal, et al., 1987).

The effects of active erosion (postulated erosion and scour due to the presence of the structure) remain the subject of dispute and are more difficult to quantify. The previously mentioned work of Dean (1987), McDougal et al. (1987) and Kraus (1988, 1996) should serve as guidance for evaluating active erosion effects.

Thus, this Focused Study concludes that the approximate or expected erosion effects of coastal structures can be determined for flood hazard mapping purposes. Guidance can be developed for study contractors to use in their evaluations.

Looking forward, the more difficult issue will be how to incorporate this knowledge into FEMA policy regarding treatment of coastal structures:

- If adverse effects of existing coastal structures are documented or of new/proposed structures are predicted, should mitigation be required? If so, in what form?
- Should unmitigated effects be considered in flood hazard mapping (and is this getting into the future conditions area)? Should mitigation efforts be credited in flood hazard mapping (this is similar to the issue surrounding credit for beach nourishment)?
- Should map revisions be permitted based on structures that are predicted or known to cause adverse effects on adjacent properties?

This topic will undoubtedly be the subject of additional debate, and the work described in Table 1 is intended to provide limited technical guidance until the policy issues are resolved.

The wealth of literature devoted to erosion effects of coastal structures does not exist for hydraulic effects. However, the hydraulic effects of many coastal structures can be approximated using the methods of hydraulics, fluid mechanics and wave mechanics, coupled with documents such as the *Coastal Engineering Manual*. There may be some instances where the hydraulic effects of large structures can be better addressed via numerical modeling, but this is expected to be the exception rather than the rule (at least for the near future). For the present, it is recommended that a general discussion of hydraulic effects be included in the *G&S*.

Flooding and Erosion Behind Coastal Structures (Seawalls, Revetments, etc.)

A second issue of importance to FEMA is whether the dimensions of a coastal structure are sufficient to prevent flooding and erosion from occurring landward of the structure during the 1% flood event. This issue will be important for both, flood insurance studies and the evaluation of flood map revisions based on coastal structures.

Flooding behind a structure can be caused by overtopping of the shore-parallel section of the structure, or due to overtopping of the shore-perpendicular (return wall) section of the structure.

Erosion behind a structure can be caused by undermining at the structure toe, overtopping, or other structural failures. The erosion can be initiated at or across the shore-parallel or shore-perpendicular sections.

The *G&S* can be expanded to address these hazards, by stating that the TR-89-15-type analyses shall consider both the shore parallel and shore-perpendicular sections of coastal structures.

For the mapping of flood hazard zones landward of structures determined to withstand the 1% flood event, the following procedure is recommended.

Case 1, isolated structure with return walls:

- Evaluate the shore-parallel and shore-perpendicular portions of the structure;
  - if the returns are too short or will not withstand the 1% event, remove the entire structure from the transect prior to further flood analyses (unless the structure is very long compared to the parcel frontage being evaluated), and
  - if the return walls are adequate, determine the mean overtopping rate across the shore-parallel section of the structure.
- Map the resulting BFEs and flood hazard zone boundaries behind and parallel to both the shore-parallel section and any shore-perpendicular sections. This procedure assumes overtopping can occur over any section of the structure. See Figure 3; and

- Calculate the maximum overtopping and determine if any ponding or drainage problems will exist behind the structure; adjust the mapped flood hazard zones and heights/elevations to reflect the ponding or drainage problems.

Case 2, series of structures:

This case will be encountered by Study Contractors, and will likely occur when a one property owner requests a map revision based on a portion of a single structure or one of a series of structures;

- Consider each distinct structure separately – determine whether the land behind the structure is separated from adjacent lands by return walls;
  - if yes, evaluate as in case 1 above, unless the adjacent shore-parallel sections are long and will withstand the 1% flood event (in which case the return wall analysis and mapping are not required); and
  - if no, evaluate the adjacent shore-parallel sections for their stability during the 1% event.
    - if adjacent sections will not withstand the 1% event, the subject coastal structure may be damaged or destroyed as the adjacent structures fail (and may need to be removed prior to any flood analyses); and
    - if adjacent shore-parallel sections will withstand the 1% event, and if they are sufficiently long to preclude flanking behind the subject structure, continue as described below.
- If the analysis goes forward, determine the mean overtopping rate across the shore-parallel section of the structure; and
- Map the resulting BFEs and flood hazard zone boundaries behind and parallel to both the shore-parallel section and any shore-perpendicular sections. This procedure assumes overtopping can occur over any section of the structure. Check for ponding and drainage problems.

Adjust the zones and BFEs along the boundaries with adjacent parcels, as dictated by the stability of adjacent coastal structures.

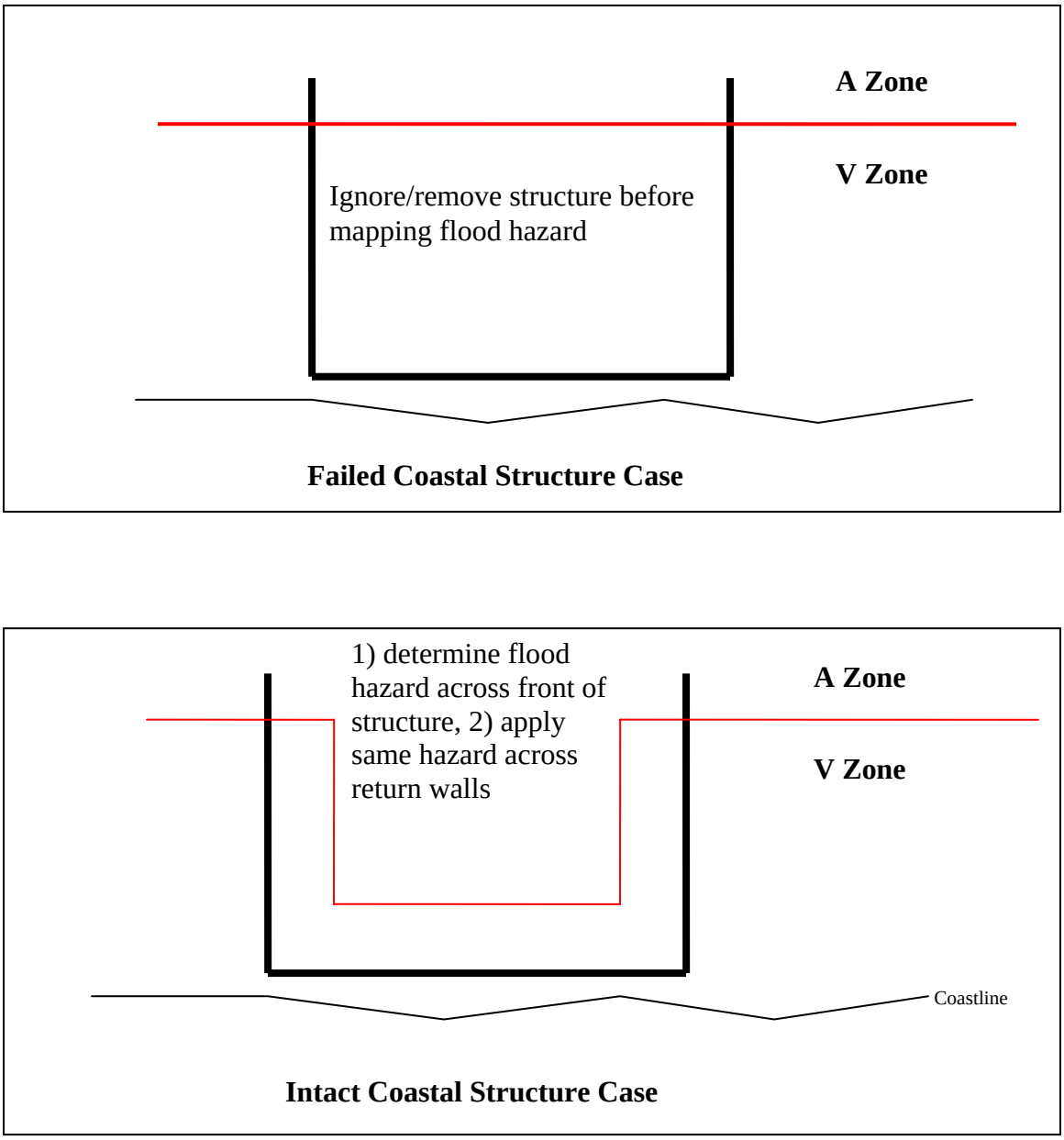

Figure 3. Sample mapping of flood hazards at failed coastal structure – through physical failure or insufficient return walls – and at intact coastal structure (actual flood hazard zones and BFEs will vary with site/structure conditions).

Note that the above procedures do not establish a minimum coastal structure length required to gain flood hazard mapping credit (either during an FIS or a map revision). However, as a first approximation, a structure length less than twice the mapped overtopping zone width behind the structure (see *G&S* Table D-7) would probably not provide significant flood hazard reduction for the area landward of the structure. For a more rigorous analysis, the minimum length required will depend upon:

- whether the structure is intended to remove an area from the SFHA or merely to reduce the flood severity/BFE/zone,
- the height of the structure and its associated base flood overtopping rate,
- whether the structure is isolated or part of a longer structure, and
- whether the subject parcel is isolated by return walls that can withstand the base flood event.

Minimum structure lengths might be developed through analyses of selected structures and flood conditions, but this should be considered for future enhancements to the *G&S*.

Recommendations and availability are summarized in Table 1.

5.2.2 Availability

Information to address Topics 26a, 26b, and 26d is readily available. Information to address Topic 26e can be gathered and used, but may require greater effort. Addressing Topic 26c requires as much policy development as technical work. Therefore, Workshop 2 deleted Topics 26c and 26e from further consideration during the present project.

6 SUMMARY

Table 1. Summary of Findings and Recommendations for Coastal Structures

Topic Number	Topic	Coastal Area	Priority Class	Availability/ Adequacy	Recommended Approach	Related Topics
25	Flood Protection Structures	AC	A	Y	Mention in guidance: detailed TR-89-15 evaluation/certification of coastal structures are not required during FIS, but discuss implications (see Topic 22)	22, 26, 27
		GC	A	Y		
		PC	A	Y		
		SW	A	Y		
21	Failed Structures	AC	A	Y	Expand guidance to discuss removal of seawalls, bulkheads, revetments, coastal levees; allow	13, 22
		GC	A	Y		
		PC	A	Y		

Table 1. Summary of Findings and Recommendations for Coastal Structures

Topic Number	Topic	Coastal Area	Priority Class	Availability/ Adequacy	Recommended Approach	Related Topics
		SW	A	Y	for partial failure of revetments, where appropriate. Mention in guidance, removal of the effects of groins, jetties, detached breakwaters on the shoreline. Develop specific guidance on how to remove the effects of groins, jetties, detached breakwaters on the shoreline.	
23	Buried Structures	AC	A	Y	Mention in guidance: buried structures may exist, should be located and should be considered in analyses.	22
		GC	A	Y		
		PC	A	Y		
		SW	A	Y		
27	Coastal Levees v. Structures	AC	A	Y	Revise Appendix D to differentiate coastal levee requirement from those for other costal flood protection structures; identify conflicts. Review CEM for new or additional guidance on evaluation of coastal structures; Consider requiring all structures (existing and new) to meet the same evaluation criteria.	11, 25
		GC	A	Y		
		PC	A	Y		
		SW	A	Y		
24	Structures - Tsunamis	AC	--	--	Review literature and revise guidance for coastal structure evaluation criteria in tsunami-prone areas.	22
		GC	--	--		
		PC	I	PRODAT		
		SW	I	PRODAT		
22	Failed Structures	AC	H	Y	Review literature for treatment of failed structures; Revise coastal structure evaluation guidance to reflect PWA Interim method and literature review.	21, 24
		GC	H	Y		
		PC	H	Y		
		SW	H	Y		
26	Adjacent Properties	AC	H	Y	Review literature and develop guidance for evaluating the erosion effects of coastal structures on adjacent properties. Review literature and develop guidance for evaluating the hydraulic effects of coastal structures on adjacent properties. Develop guidance for evaluating flooding and erosion from adjacent properties.	11, 22
		GC	H	Y		
		PC	H	Y		
		SW	H	Y		

Table 1. Summary of Findings and Recommendations for Coastal Structures

Topic Number	Topic	Coastal Area	Priority Class	Availability/ Adequacy	Recommended Approach	Related Topics

Key:
Coastal Area
AC = Atlantic Coast; GC = Gulf Coast; PC = Pacific Coast; SW = Sheltered Waters
Priority Class
C = critical; A = available; I = important; H = helpful
(Recommend priority italicized if focused study recommended a change in priority class)
Availability/Adequacy
"Critical" Items: MIN = needed revisions are relatively minor; MAJ = needed revisions are major
"Available" Items: Y = availability confirmed; N = data or methods are not readily available
"Important" Items: PRO = procedures or methods must be developed; DAT = new data are required; PRODAT = both new procedures and data are required

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COASTAL STRUCTURES FOCUSED STUDY

APPENDIX A-1

FEMA 1990 MEMORANDUM:

CRITERIA FOR EVALUATING COASTAL FLOOD PROTECTION STRUCTURES

Federal Emergency Management Agency

Washington, D.C. 20472

APR 23 1990

MEMORANDUM FOR: FEMA REGIONAL DIRECTORS

FROM: Harold T. Duryee, Administrator
Federal Insurance Administration

SUBJECT: Criteria for Evaluating Coastal Flood Protection Structures for National Flood Insurance Program (NFIP) Purposes

In order to better guide our staff, study contractors, and technical evaluation contractors, in the performance of flood insurance studies and in the review of flood map revision requests based on coastal structures, the Federal Insurance Administration has developed the attached proposed criteria statement. The proposed criteria would establish the conditions, procedures, and standards under which coastal flood protection structures would be credited on NFIP Flood Insurance Rate Maps as providing protection from the base flood.

It is our intention to issue these criteria as rulemaking during FY 1991. Any coments you have should be forwarded to the Office of Risk Assessment by May 25, 1990.

Also, attached is a copy of the Corps' Technical Report CERC-89-15, "Criteria for Evaluating Coastal Flood-Protection Structures" for your reference. CERC-89-15 was used as the basis for this proposed interim procedure.

Attachments

Criteria for Evaluating Coastal Flood Protection Structures

Background

Many property owners and communities along the U.S. coast are resorting to the construction of coastal flood control structures to protect existing or new development from potential damage associated with hurricanes and other major coastal storm events. Flooding and erosion caused by natural processes, sea level rise, and/or man-made influences are factors contributing to the decision to construct structures such as seawalls, revetments, bulkheads, and coastal levees/dikes. Although there is continued debate on the overall impact of these coastal structures, their construction and use requires that FEMA evaluate their effectiveness for reducing flood risk and their viability as an alternative to the non-structural flood loss reduction approaches required for community participation in the National Flood Insurance Program (NFIP).

The areas protected by coastal flood protection structures are frequently designated as Coastal High Hazard Areas (V zones) on the Flood Insurance Rate Maps (FIRMs) published by FEMA. FEMA is often requested to revise FIRMs to reflect the protection provided by a coastal structure against the base (100-year) flood. Because of the different types of coastal structures, materials, and construction methods, FEMA must perform a detailed review of these requests to assure that the structure is adequately designed and constructed to provide the stated level of protection, and to withstand the 100-year flooding event.

Part 65 of the NFIP regulations requires that any requester of a FIRM revision based on flood protection structures provide an analysis of the revised flood hazards, demonstrate and certify that the structure is designed and constructed for 100-year flooding conditions, and provide assurance that the structure will be maintained. Revision requests based on coastal structures are currently reviewed on a case-by-case basis using these regulations. A wide variation has been found in the quality of data submitted. Some possible reasons for this variation include the requester's inexperience or unfamiliarity with the different types of structures, the available design guidance, and/or the base (100-year) flood considered by the NFIP. In order to improve the quality of information submitted, and the ability of FEMA to review revision requests based on coastal structures, FEMA has decided to establish minimum design criteria that must be addressed in the request.

FEMA commissioned the U.S. Army Corps of Engineers, Waterways Experiment Station (WES), Coastal Engineering Research Center to identify or develope criteria for evaluating the effectiveness of

all types of coastal flood protection structures in preventing or reducing damages and flooding from the 100-year event. This study identified and defined the different coastal structures that provide protection against flooding to property landward of the structure, and documented successful and unsuccessful cases for each structure type. The minimum criteria, considerations, and/or conditions applicable to the 100-year flooding event that are necessary for an evaluation of a coastal structure were also identified. The WES study recommended a procedure using these criteria to evaluate the adequacy, of a coastal flood protection structure to survive the 100-year flooding event, and to provide protection against flooding, wave runup and overtopping, wave forces, and erosion.

The WES Technical Report CERC-89-15 "Criteria for Evaluating Coastal Flood Protection Structures" was used as the basis for these critera. These criteria will also be used to resolve appeal challenges and in the conduct of flood insurance studies, when sufficient design and construction data are available.

Mapping of areas protected by coastal flood protection structures.

(a) General. For purposes of the NFIP, FEMA will only recognize in its flood hazard and risk mapping effort those coastal flood protection structures that meet, and continue to meet, minimum design and maintenance standards that are consistent with the level of protection sought through the comprehensive floodplain management criteria established by 44 CFR Part 60.3. Accordingly, this procedure describes the types of information FEMA needs to recognize, on NFIP maps, that a coastal flood protection structure provides protection from the base flood. This information must be supplied to FEMA by the community or other party seeking recognition of such a coastal flood protection structure at the time a flood risk study or restudy is conducted, when a map revision under the provision of Part 65 of this subchapter is sought based on a coastal flood protection structure, and upon request by the Administrator during the review of previously recognized structures. The FEMA review will be for the sole purpose of establishing appropriate risk zone determinations for NFIP maps and shall not constitute a determination by FEMA as to how a structure will perform in a flood event.

(b) Design Criteria. For coastal flood protection structures to be recognized by FEMA, sufficient evidence must be provided that adequate design, construction, and maintenance have been undertaken to provide reasonable assurance of durable protection from the base flood. The following requirements must be met:

(1) Design Parameters. A coastal flood protection structure must be designed using physical parameters that fully represent the base (100-year) flooding event, including the following:

(i) Design water levels evaluated should range from

the mean low water level at the site to the 100-year stillwater surge elevation. The full range of elevations must be examined to determine the critical water level since the most severe conditions may not occur at either extreme.

(ii) Wave heights and periods must be calculated for each water level analyzed. At a minimum, significant wave height and periods should be used for "flexible" structures such as revetments, with larger wave height, up to the one-percent wave height (1.67 times the significant wave height), used for more rigid structures such as seawalls and bulkheads. The U.S. Army Corps of Engineers (COE) Shore Protection Manual (1984 or later edition), provides guidance and procedures for determining appropriate wave heights and periods.

(iii) Breaking wave forces under structure-perpendicular loading must be considered in the design unless it can be demonstrated that the structure will not be subject to breaking waves. The very high, short duration "shock" pressures must be used for low mass structures such as bulkheads, while only the secondary "non-shock" pressures need to be used for massive structures such as gravity seawalls. Analyses of the breaking wave forces using methods such as those identified in the COE report "Criteria for Evaluating Coastal Flood Protection Structures," (WES TR CERC-89-15) must be submitted.

(2) Minimum Freeboard. The minimum freeboard for coastal flood protection structures to be recognized on FEMA flood maps for protection against the storm surge component of the base flood shall be two feet above the 100-year stillwater surge elevation.

(3) Toe Protection. The loss of material and profile lowering seaward of the structure must be included in the design either through the incorporation of adequate toe protection or an evaluation of structural stability with potential scour equal to the maximum wave height on the structure. Engineering analyses such as those recommended in the COE's "Geotechnical Engineering in the Coastal Zone" (WES IR CERC-87-1) or "Design of Coastal Revetments, Seawalls, and Bulkheads" (COE EM 1110-2-1614) must be submitted for the toe protection, or an analysis of scour potential such as found in "Criteria for Evaluating Coastal Flood Protection Structures" (WES TR CERC-89-15) must be submitted.

(4) Backfill Protection. Engineering analyses of wave runup, overtopping, and transmission must be performed using methods provided in the COE report "Criteria for Evaluating Coastal Protection Structures" (WES TR CERC-89-15). Where the structure height is not sufficient to prevent overtopping and/or wave transmission, protection of the backfill must be included in the design. This should address prevention of loss of backfill material by rundown over the structure, by drainage landward, under, and laterally around the ends of the structure; as well as through joints, seams, or drainage openings in the structure.

(5) Structural Stability, Minimum Water Level. Analyses of the ability of the structures to resist the maximum loads associated with the minimum seaward water level, no wave action, saturated soil conditions behind the structure, and maximum toe scour must be submitted.

(i) For coastal dikes and revetments, a geotechnical analyses of potential failure in a landward direction by rotational gravity slip must be submitted.

(ii) For gravity and pile-support seawalls, engineering analyses of seaward sliding, of seaward overturning, and of foundation adequacy using the maximum pressures developed in the sliding and overturning calculations must be submitted.

(iii) For anchored bulkheads, engineering analyses of shear failure, moment failure, and the adequacy of the tiebacks and deadmen to resist the loadings must be submitted.

(6) Structural Stability - Critical Water Level. Analyses of the ability of the structure to resist the maximum loads associated with the critical water level, which may be any water level from the mean low water level to the 100-year stillwater elevation, including hydrostatic and hydrodynamic (wave) loads, saturated soil conditions behind the structure and maximum toe scour, must be submitted.

(i) For coastal dikes and revetments, geotechnical analyses of potential failure in a seaward direction by rotational gravity slip and of foundation failure due to inadequate bearing strength must be submitted.

(ii) For revetments, engineering analyses of the rock, riprap, or armor blocks' stability under wave action; uplift forces on the rock, riprap, or armor blocks; toe stability, and adequacy of the graded rock and geotechnical filters must be submitted.

(iii) For gravity and pile-supported seawalls, engineering analyses of landward sliding, of landward overturning, and of foundation adequacy using the maximum pressures developed in the sliding and overturning calculations must be submitted.

(iv) For anchored bulkheads, engineering analyses of shear and moment failure using "shock" pressures must be submitted.

(7) Material Adequacy. Documentation and/or analyses must be submitted that demonstrate that the materials used for the construction of the structure are adequate and suitable including life expectancy considerations, for the conditions that exist at the site.

(8) Ice and Impact Alignment. Where appropriate, analyses of ice and impact forces must be submitted.

(9) Structure Plan Alignment. A shore protection project should present a continuous structure with redundant return walls at frequent intervals to isolate locations of failure. Isolated structures or structures with a staggered alignment must submit analyses of the additional forces from concentrated, diffracted, and/or reflected wave energy on the different sections and ends.

(10) Other Design Criteria. FEMA will require that flood protection structures, regardless of type described above, be evaluated on the basis of how they may react structurally to applied forces. Therefore, analyses normally required of one structure type may also be required by another type which would react in a similar manner to applied forces. In unique situations, FEMA may require that other design criteria and analyses be submitted to show that the structure provides adequate protection. In such situations, sound engineering practice will be the standard on which FEMA will base its determinations. FEMA will provide the rationale for requiring any additional information.

(c) Adverse Impact Evaluation. All requests for flood map revisions based upon new or enlarged coastal flood control structures shall include an analysis of potential adverse impacts of the structure on flooding and erosion within, and adjacent, to the protected area.

(d) Community and/or State Review. For coastal flood protection structures to be recognized, evidence must be submitted to show that the design, maintenance, and impacts of the structures have been reviewed and approved by the affected communities and by any Federal, state or local agencies that have jurisdiction over flood control and coastal construction activities.

(e) Maintenance Plans and Criteria. For a coastal flood protection structures to be recognized as providing protection from the base flood, the structure must be maintained in accordance with an official adopted maintenance plan, and a copy of this plan must be provided to FEMA by the owner of the structure when recognition is being sought or when the plan for a previously recognized structure is revised in any manner. All maintenance activities must be under the jurisdiction of a Federal or state agency, an agency created by Federal or state law, or an agency of a community participating in the NFIP that must assume ultimate responsibility for maintenance. This plan must document the formal procedure that ensures that the stability and overall integrity of the structure and its associated structures and systems are maintained. At a minimum, maintenance plans shall specify the maintenance activities to be performed, the frequency of their performance, and the person by name or title responsible for their performance.

(f) Certification Requirements. Data and analyses submitted to support that a given coastal flood protection structure complies with the structural design requirements set forth in paragraphs (b)(1) through (10) above must be certified by a registered professional engineer. Also, certified as-built plans of the structure must be submitted. Certifications are subject to the definition given at § 65.2 of 44 CFR Part 65. In lieu of these certification requirements, a Federal agency with responsibility for design of coastal flood protection structures may certify that the structure has been adequately designed and constructed to provide protection against the base flood.

COASTAL STRUCTURES FOCUS STUDY

APPENDIX A-2

FEMA MT-2, FORM 5

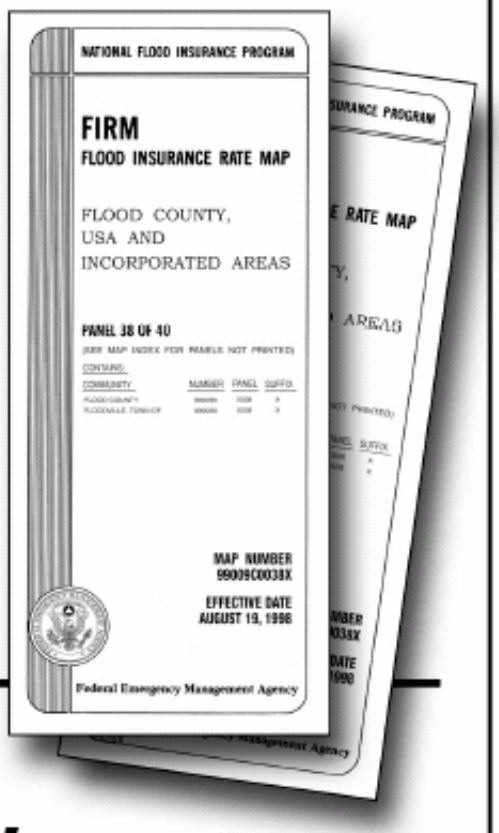
COASTAL STRUCTURES ANALYSIS FORM

MT-2

FEDERAL INSURANCE AND MITIGATION ADMINISTRATION
HAZARD MAPPING DIVISION

REVISIONS TO NATIONAL FLOOD INSURANCE PROGRAM MAPS

APPLICATION FORMS AND INSTRUCTIONS FOR CONDITIONAL LETTERS OF MAP REVISION, AND LETTERS OF MAP REVISION



MT-2
FEMA FORM 81-89 SERIES
SEPT 02

FEMA

Federal Emergency Management Agency

INSTRUCTIONS FOR COMPLETING THE COASTAL STRUCTURES FORM (FORM 5)

The Coastal Structures Form is to be completed when a revision to coastal flood hazard elevations and/or areas is requested based on coastal structures being credited as providing protection from the base flood. The purpose of the Coastal Structures Form is to ensure that the structure is designed and constructed to provide protection from the base flood without failing or causing an increase in flood hazards to adjacent areas. Refer to the *Consolidated Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping* which can be obtained from the Federal Emergency Management Agency's (FEMA's) Internet site at http://www.fema.gov/mit/tsd/dl_cgs.htm, for the criteria for evaluating flood protection structures.

If the coastal structure is a levee/floodwall, complete the Levee/Floodwall System section of the Riverine Structure Form (Form 3), in addition to this form. When the Coastal Structures Form is submitted, the Coastal Analysis Form (Form 4) should also be submitted.

Section A: Background

Information about the type of structure, the location, the material being used, and the age of the structure must be provided. Certified "as built" plans must also be provided. If these plans are not available, an explanation must be given with sketches of the general structure dimensions as described. If the structure design has been certified by a Federal agency to provide flood protection and withstand forces from the 1% annual chance (base) flood, the dates of the project completion and certification of the structure should be provided, and the remainder of the form does not need to be completed.

Section B: Design Criteria

Documentation must be provided that ensures a coastal structure is designed and constructed to withstand the wind and wave forces associated with the base flood. The minimum freeboard of the structure must be in compliance with National Flood Insurance Program (NFIP) Regulation 44 CFR Ch. 1, Section 65.10. Additional concerns include the impact to areas directly landward of the structure that may be subjected to overtopping and erosion along with possible failure of the structure due to undermining from the backside and the possible increase in erosion to unprotected properties at the ends of the structure. The evaluation of protection provided by sand dunes must follow the criteria outlined in NFIP Regulation 44 CFR Ch. 1, Section 65.11.

Section C: Adverse Impact Evaluation

If the structure is new, proposed, or modified, and will impact flooding and erosion for the areas adjacent to the structure, provide an explanation and documentation to support your conclusions.

Section D: Community and/or State Review

Provide documentation of Community and/or State review of the revision.

Section E: Certification

The licensed professional engineer and/or land surveyor should have a current license in the State where the affected communities are located. While the individual signing this form is not required to have obtained the supporting data or performed the analyses, he or she must have supervised and reviewed the work.

If the requester is a Federal agency who is responsible for the design and construction of flood control facilities, a letter stating that "the analyses submitted have been performed correctly and in accordance with sound engineering practices" may be submitted in lieu of certification by a registered professional engineer. Regarding the certification of completion of flood control facilities, a letter from the Federal agency certifying its completion and the flood frequency event to which the project protects may be submitted in lieu of this form.

FEDERAL EMERGENCY MANAGEMENT AGENCY

COASTAL STRUCTURES FORM

O.M.B. No. 3067-0148
Expires September 30, 2005

PAPERWORK REDUCTION ACT

Public reporting burden for this form is estimated to average 1 hour per response. The burden estimate includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the needed data, and completing, reviewing, and submitting the form. You are not required to respond to this collection of information unless a valid OMB control number appears in the upper right corner of this form. Send comments regarding the accuracy of the burden estimate and any suggestions for reducing this burden to: Information Collections Management, Federal Emergency Management Agency, 500 C Street, SW, Washington DC 20472, Paperwork Reduction Project (3067-0148). Submission of the form is required to obtain or retain benefits under the National Flood Insurance Program. **Please do not send your completed survey to the above address.**

Flooding Source:
Note: Fill out one form for each flooding source studied

A. BACKGROUND

1. Name of structure (if applicable):

2. Structure location:

3. Type of structure (check one):

☐ Levee/Floodwall* ☐ Anchored Bulkhead ☐ Revetment ☐ Gravity Seawall

☐ Breakwater ☐ Pile supported seawall ☐ Other:

***Note:** If the coastal structure is a levee/floodwall, complete Section E of Form 3 (Riverine Structures Form). The remainder of this form does not need to be completed.

4. Material structure is composed of (check all that apply):

☐ Stone ☐ Earthen fill ☐ Concrete ☐ Steel

☐ Sand ☐ Other

5. The structure is (check one):

☐ New or proposed ☐ Existing ☐ Modification of existing structure

☐ Replacement structure of the same size and design as what was previously at the site

Describe in detail the existing structure and/or modifications being made to the structure and the purpose of the modifications:

If existing, please include date of construction:

6. Copies of certified "as-built" plans ☐ are ☐ are not attached. Attach all design analyses that apply.

If "as-built" plans are not available for submittal, please explain why and attach a sketch with general structure dimensions including: face slope, height, length, depth, and toe elevation referenced to the appropriate datum (e.g. NGVD 1929, NAVD 1988, etc.).

7. Has a Federal agency with responsibility for the design of coastal flood protection structures designed or certified that the structures have been adequately designed and constructed to provide protection against the 1%-annual-chance event?

☐ Yes ☐ No

If Yes, specify the name of the agency and dates of project completion and certification.

If Yes, then no other sections of this form need to be completed.

B. DESIGN CRITERIA

1. Design Parameters

   a. Were physical parameters representing the 1%-annual-chance event or greater used to design the coastal flood protection structure?

      ☐ Yes ☐ No

   b. The number of design water levels that were evaluated (number) range from the mean low water elevation of feet to the 1%-annual-chance stillwater surge elevation of feet. The critical water level is feet. The datum that these elevations are referenced to is (e.g.: NGVD 1929, NAVD 1988, etc.).

      Attach an explanation specifying which water levels and associated wave heights and periods were analyzed.

   c. Were breaking wave forces used to design the structure?

      ☐ Yes ☐ No If No, attach an explanation why they were not used for design.

2. Settlement

   a. What is the expected settlement rate at the site of the structure?

      Please attach a settlement analysis.

3. Freeboard

   a. Does the structure have 1 foot of freeboard above the height of the 1%-annual-chance wave-height elevation or maximum wave runup (whichever is greater)?

      ☐ Yes ☐ No

   b. Does the structure have freeboard of at least 2 feet above the 1% annual chance stillwater surge elevation?

      ☐ Yes ☐ No

4. Toe Protection

   Specify the type of toe protection:

   If no toe protection is provided, provide analysis of scour potential and attach an evaluation of structural stability performed with potential scour at the toe.

5. Backfill Protection

   Will the structure be overtopped during the 1%-annual-chance event? ☐ Yes ☐ No

   If the structure will be overtopped, attach an explanation of what measures are used to prevent the loss of backfill from rundown over the structure, drainage landward, under or laterally around the ends of the structure, or through seams and drainage openings in the structure.

6. Structural Stability - Minimum Water Level

   a. For coastal revetments, was a geotechnical analysis of potential failure in the landward direction by rotational gravity slip performed for maximum loads associated with minimum seaward water level, no wave action, saturated soil conditions behind the structure, and maximum toe scour?

      ☐ Yes ☐ No

   b. For gravity and pile-supported seawalls, were engineering analyses of landward sliding, landward overturning, and of foundation adequacy using maximum pressures developed in the sliding and overturning calculations performed?

      ☐ Yes ☐ No

   c. For anchored bulkheads, were engineering analyses performed for shear failure, moment failure, and adequacy of tiebacks and deadmen to resist loading under low-water conditions?

      ☐ Yes ☐ No

B. DESIGN CRITERIA (CONTINUED)

C. ADVERSE IMPACT EVALUATION

If the structure is new, proposed, or modified, will the structure impact flooding and erosion for areas adjacent to the structure?

☐ Yes ☐ No

If Yes, attach an explanation.

D. COMMUNITY AND/OR STATE REVIEW

Has the design, maintenance, and impact of the structure been reviewed and approved by the community, and any Federal, State, or local agencies having jurisdiction over flood control and coastal construction activities in the area the structure impacts?

☐ Yes ☐ No

If Yes, attach a list of agencies who have reviewed and approved the project.

If No, attach an explanation why review and approval by the appropriate community or agency has not been obtained.

E. CERTIFICATION

As a Professional Engineer, I certify that the above structures will withstand all hydraulic and wave forces associated with the 1% annual chance flood without significant structural degradation. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name:

License No.: Exp. Date:

Company Name:

Telephone No.: Fax. No.:

Signature: _____ Date:

Seal (optional)

COASTAL STRUCTURES FOCUS STUDY

APPENDIX A-3

FEMA REGULATIONS FOR COASTAL LEVEES:

CFR PART 44 SECTION 65.10

a reissuance or revision of the flood insurance study or maps and will be deferred until such time as a significant change occurs;

(f) An additional 90 days is required to evaluate the scientific or technical data submitted; or

(g) Additional data are required to support the revision request.

(h) The required payment has not been submitted in accordance with 44 CFR part 72, no review will be conducted and no determination will be issued until payment is received.

[51 FR 30315, Aug. 25, 1986; 61 FR 46331, Aug. 30, 1996, as amended at 62 FR 5736, Feb. 6, 1997]

§ 65.10 Mapping of areas protected by levee systems.

(a) *General.* For purposes of the NFIP, FEMA will only recognize in its flood hazard and risk mapping effort those levee systems that meet, and continue to meet, minimum design, operation, and maintenance standards that are consistent with the level of protection sought through the comprehensive flood plain management criteria established by §60.3 of this subchapter. Accordingly, this section describes the types of information FEMA needs to recognize, on NFIP maps, that a levee system provides protection from the base flood. This information must be supplied to FEMA by the community or other party seeking recognition of such a levee system at the time a flood risk study or restudy is conducted, when a map revision under the provisions of part 65 of this subchapter is sought based on a levee system, and upon request by the Administrator during the review of previously recognized structures. The FEMA review will be for the sole purpose of establishing appropriate risk zone determinations for NFIP maps and shall not constitute a determination by FEMA as to how a structure or system will perform in a flood event.

(b) *Design criteria.* For levees to be recognized by FEMA, evidence that adequate design and operation and maintenance systems are in place to provide reasonable assurance that protection from the base flood exists must be provided. The following requirements must be met:

(1) *Freeboard.* (i) Riverine levees must provide a minimum freeboard of three feet above the water-surface level of the base flood. An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted. An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.

(ii) Occasionally, exceptions to the minimum riverine freeboard requirement described in paragraph (b)(1)(i) of this section, may be approved. Appropriate engineering analyses demonstrating adequate protection with a lesser freeboard must be submitted to support a request for such an exception. The material presented must evaluate the uncertainty in the estimated base flood elevation profile and include, but not necessarily be limited to an assessment of statistical confidence limits of the 100-year discharge; changes in stage-discharge relationships; and the sources, potential, and magnitude of debris, sediment, and ice accumulation. It must be also shown that the levee will remain structurally stable during the base flood when such additional loading considerations are imposed. Under no circumstances will freeboard of less than two feet be accepted.

(iii) For coastal levees, the freeboard must be established at one foot above the height of the one percent wave or the maximum wave runup (whichever is greater) associated with the 100-year stillwater surge elevation at the site.

(iv) Occasionally, exceptions to the minimum coastal levee freeboard requirement described in paragraph (b)(1)(iii) of this section, may be approved. Appropriate engineering analyses demonstrating adequate protection with a lesser freeboard must be submitted to support a request for such an exception. The material presented must evaluate the uncertainty in the estimated base flood loading conditions. Particular emphasis must be placed on the effects of wave attack and overtopping on the stability of the levee. Under no circumstances, however, will a freeboard of less than two

feet above the 100-year stillwater surge elevation be accepted.

(2) *Closures.* All openings must be provided with closure devices that are structural parts of the system during operation and design according to sound engineering practice.

(3) *Embankment protection.* Engineering analyses must be submitted that demonstrate that no appreciable erosion of the levee embankment can be expected during the base flood, as a result of either currents or waves, and that anticipated erosion will not result in failure of the levee embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability. The factors to be addressed in such analyses include, but are not limited to: Expected flow velocities (especially in constricted areas); expected wind and wave action; ice loading; impact of debris; slope protection techniques; duration of flooding at various stages and velocities; embankment and foundation materials; levee alignment, bends, and transitions; and levee side slopes.

(4) *Embankment and foundation stability.* Engineering analyses that evaluate levee embankment stability must be submitted. The analyses provided shall evaluate expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the levee foundation and embankment will not jeopardize embankment or foundation stability. An alternative analysis demonstrating that the levee is designed and constructed for stability against loading conditions for Case IV as defined in the U.S. Army Corps of Engineers (COE) manual, "Design and Construction of Levees" (EM 1110–2–1913, Chapter 6, Section II), may be used. The factors that shall be addressed in the analyses include: Depth of flooding, duration of flooding, embankment geometry and length of seepage path at critical locations, embankment and foundation materials, embankment compaction, penetrations, other design factors affecting seepage (such as drainage layers), and other design factors affecting embankment and foundation stability (such as berms).

(5) *Settlement.* Engineering analyses must be submitted that assess the potential and magnitude of future losses of freeboard as a result of levee settlement and demonstrate that freeboard will be maintained within the minimum standards set forth in paragraph (b)(1) of this section. This analysis must address embankment loads, compressibility of embankment soils, compressibility of foundation soils, age of the levee system, and construction compaction methods. In addition, detailed settlement analysis using procedures such as those described in the COE manual, "Soil Mechanics Design—Settlement Analysis" (EM 1100–2–1904) must be submitted.

(6) *Interior drainage.* An analysis must be submitted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than one foot, the water-surface elevation(s) of the base flood. This analysis must be based on the joint probability of interior and exterior flooding and the capacity of facilities (such as drainage lines and pumps) for evacuating interior floodwaters.

(7) *Other design criteria.* In unique situations, such as those where the levee system has relatively high vulnerability, FEMA may require that other design criteria and analyses be submitted to show that the levees provide adequate protection. In such situations, sound engineering practice will be the standard on which FEMA will base its determinations. FEMA will also provide the rationale for requiring this additional information.

(c) *Operation plans and criteria.* For a levee system to be recognized, the operational criteria must be as described below. All closure devices or mechanical systems for internal drainage, whether manual or automatic, must be operated in accordance with an officially adopted operation manual, a copy of which must be provided to FEMA by the operator when levee or drainage system recognition is being sought or when the manual for a previously recognized system is revised in any manner. All operations must be under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of a community participating in the NFIP.

(l) *Closures.* Operation plans for closures must include the following:

(i) Documentation of the flood warning system, under the jurisdiction of Federal, State, or community officials, that will be used to trigger emergency operation activities and demonstration that sufficient flood warning time exists for the completed operation of all closure structures, including necessary sealing, before floodwaters reach the base of the closure.

(ii) A formal plan of operation including specific actions and assignments of responsibility by individual name or title.

(iii) Provisions for periodic operation, at not less than one-year intervals, of the closure structure for testing and training purposes.

(2) *Interior drainage systems.* Interior drainage systems associated with levee systems usually include storage areas, gravity outlets, pumping stations, or a combination thereof. These drainage systems will be recognized by FEMA on NFIP maps for flood protection purposes only if the following minimum criteria are included in the operation plan:

(i) Documentation of the flood warning system, under the jurisdiction of Federal, State, or community officials, that will be used to trigger emergency operation activities and demonstration that sufficient flood warning time exists to permit activation of mechanized portions of the drainage system.

(ii) A formal plan of operation including specific actions and assignments of responsibility by individual name or title.

(iii) Provision for manual backup for the activation of automatic systems.

(iv) Provisions for periodic inspection of interior drainage systems and periodic operation of any mechanized portions for testing and training purposes. No more than one year shall elapse between either the inspections or the operations.

(3) *Other operation plans and criteria.* Other operating plans and criteria may be required by FEMA to ensure that adequate protection is provided in specific situations. In such cases, sound emergency management practice will be the standard upon which FEMA determinations will be based.

(d) *Maintenance plans and criteria.* For levee systems to be recognized as providing protection from the base flood, the maintenance criteria must be as described herein. Levee systems must be maintained in accordance with an officially adopted maintenance plan, and a copy of this plan must be provided to FEMA by the owner of the levee system when recognition is being sought or when the plan for a previously recognized system is revised in any manner. All maintenance activities must be under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of a community participating in the NFIP that must assume ultimate responsibility for maintenance. This plan must document the formal procedure that ensures that the stability, height, and overall integrity of the levee and its associated structures and systems are maintained. At a minimum, maintenance plans shall specify the maintenance activities to be performed, the frequency of their performance, and the person by name or title responsible for their performance.

(e) *Certification requirements.* Data submitted to support that a given levee system complies with the structural requirements set forth in paragraphs (b)(1) through (7) of this section must be certified by a registered professional engineer. Also, certified as-built plans of the levee must be submitted. Certifications are subject to the definition given at §65.2 of this subchapter. In lieu of these structural requirements, a Federal agency with responsibility for levee design may certify that the levee has been adequately designed and constructed to provide protection against the base flood.

[51 FR 30316, Aug. 25, 1986]

§65.11 Evaluation of sand dunes in mapping coastal flood hazard areas.

(a) *General conditions.* For purposes of the NFIP, FEMA will consider storm-induced dune erosion potential in its determination of coastal flood hazards and risk mapping efforts. The criterion to be used in the evaluation of dune erosion will apply to primary frontal dunes as defined in §59.1, but does not