



Investigation of the Performance of the New Orleans Flood Protection Systems in Hurricane Katrina on August 29, 2005

Volume II: Appendices

by

R. B. Seed, R. G. Bea, R. I. Abdelmalak, A. G. Athanasopoulos, G. P. Boutwell, J. D. Bray,
J.-L. Briaud, C. Cheung, D. Cobos-Roa, J. Cohen-Waeber, B. D. Collins, L. Ehrensing, D. Farber,
M. Hanemann, L. F. Harder, K. S. Inkabi, A. M. Kammerer, D. Karadeniz, R.E. Kayen, R. E. S. Moss, J. Nicks,
S. Nimmala, J. M. Pestana, J. Porter, K. Rhee, M. F. Riemer, K. Roberts, J. D. Rogers, R. Storesund,
A. V. Govindasamy, X. Vera-Grunauer, J. E. Wartman, C. M. Watkins, E. Wenk Jr., and S. C. Yim

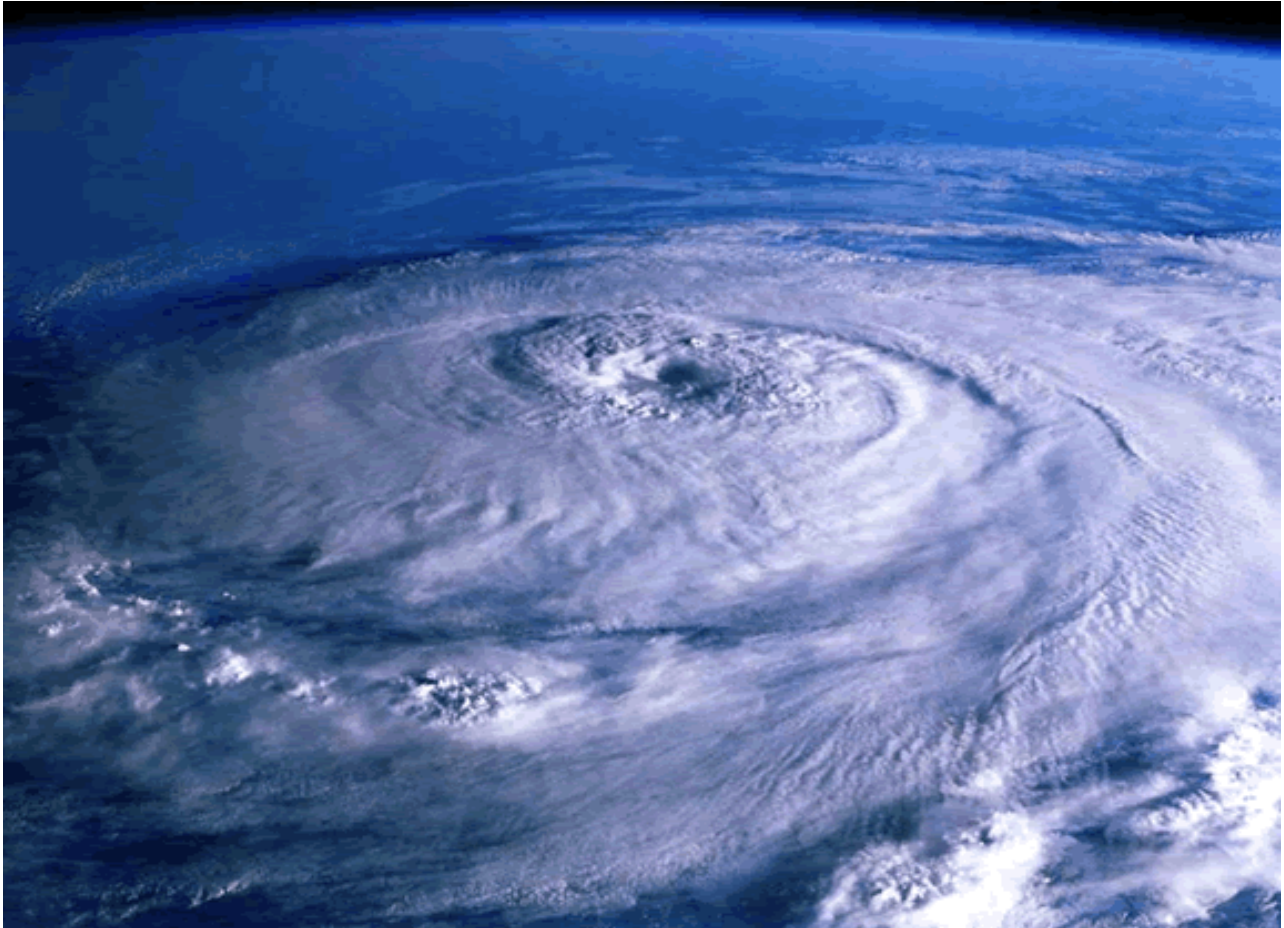
**Final Report
July 31, 2006**



This project was supported, in part, by the National Science Foundation under Grants No. CMS-0413327 and CMS-0611632. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the Foundation.

This report contains the observations and findings of an investigation by an independent team of professional engineers and researchers with a wide array of expertise. The materials contained herein are the observations and professional opinions of these individuals, and do not necessarily reflect the opinions or endorsement of any other group or agency.

Note: Cover Image from <http://www.photolibrary.fema.gov/photodata/original/15022.jpg>



Source: www.noaa.gov

This report is dedicated to the people of the greater New Orleans region;
to those that perished, to those that lost friends and loved ones,
and to those that lost their homes, their businesses, their place of work,
and their community.

New Orleans has now been flooded by hurricanes six times
over the past century; in 1915, 1940, 1947, 1965, 1969 and 2005.

It must be our goal that it not be allowed to happen again.

Table of Contents

EXECUTIVE SUMMARY	xix
The Investigation Team	xxvi
Acknowledgements	xxix

VOLUME I: MAIN TEXT AND EXECUTIVE SUMMARY

PART I – INTRODUCTION:

Chapter 1: Introduction and Overview

1.1 Introduction	1-1
1.2 Initial Post-Event Field Investigations.....	1-1
1.3 Current Studies and Investigations	1-2
1.4 Organization of This Report	1-3
1.5 Elevation Datum	1-5
1.6 References	1-5

PART II – TECHNICAL STUDIES:

Chapter 2: Overview of Hurricane Katrina and its Aftermath

2.1 Hurricane Katrina	2-1
2.2 Overview of the New Orleans Flood Protection Systems	2-1
2.3 Overview of Flood Protection System Performance During Hurricane Katrina	2-3
2.3.1 Storm Surge During Hurricane Katrina	2-3
2.3.2 Overview of the Performance of the Regional Flood Protection System	2-5
2.3.3 Brief Comments on the Consequences of the Flooding of New Orleans	2-11
2.4 References	2-13

Chapter 3: Geology of the New Orleans Region

3.1 General Overview of the Geology of New Orleans	3-1
--	-----

3.1.1	Introduction	3-1
3.1.2	Evolution of the Mississippi Delta beneath New Orleans	3-1
3.1.3	Pine Island Beach Trend	3-3
3.1.4	Interdistributary Zones	3-4
3.1.5	Paludal Environments	3-5
3.1.5.1	Marshes	3-5
3.1.5.2	Swamps	3-6
3.1.5.3	Lacustrine Deposits	3-8
3.1.6	Recognition Keys for Depositional Environments	3-9
3.1.7	Holocene Geology of New Orleans	3-9
3.1.8	Faulting and Seismic Conditions	3-11
3.2	Geologic Conditions at 17 th Street Canal Breach	3-11
3.2.1	Introduction	3-11
3.2.2	Interpretation of Geology from Auger borings	3-11
3.2.3	Interpretation of Data from CPT Soundings	3-14
3.3	Geologic Conditions at London Avenue Canal (North) Breach	3-15
3.3.1	Introduction	3-15
3.3.2	Geology Beneath the Levees	3-15
3.4	Geologic Conditions at London Avenue (South) Canal Breach	3-16
3.4.1	Introduction	3-16
3.4.2	Geology Beneath the Levees	3-16
3.5	Geologic Conditions along the Inner Harbor Navigation Canal	3-17
3.5.1	Introduction	3-17
3.5.2	Geology	3-17
3.6	Paleontology and Age Dating	3-18
3.6.1	Introduction	3-18
3.6.2	Palynology	3-18
3.6.3	Foraminifera	3-18
3.6.4	Carbon 14 Dating	3-19
3.7	Mechanisms of Ground Settlement and Land Loss in Greater New Orleans	3-19
3.7.1	Settlement Measurements	3-19
3.7.2	Tectonic Subsidence	3-19
3.7.3	Lystric Growth Faults	3-19
3.7.4	Compaction of Surficial Organic Swamp and	

Marsh Deposit	3-20
3.7.5 Structural Surcharging	3-21
3.7.6 Extraction of Oil, Gas, and Water	3-21
3.7.7 Coastal Land Loss	3-22
3.7.8 Negative Impact of Ground Settlement on Storm Surge	3-22
3.7.9 Conclusions about Ground Settlement	3-23
3.8 References	3-23
Chapter 4: History of the New Orleans Flood Protection System	4-1
4.1 Origins of Lower New Orleans	4-1
4.2 Mississippi River Floods	4-2
4.2.1 Mississippi River is the High Ground	4-2
4.2.2 Flooding from the Mississippi River	4-2
4.3 The Mississippi River and Tributaries Project 1931-1972	4-6
4.3.1 Dimensions of Navigation Channels Maintained by the Corps of Engineers on the Lower Mississippi River	4-8
4.4 Flooding of the New Orleans Area by Hurricanes	4-9
4.5 Flooding of New Orleans Caused by Intense Rain Storms	4-12
4.6 New Orleans Drainage Canals	4-13
4.7 City Adopts Aggressive Drainage System	4-16
4.7.1 Pre-Katrina Conditions and Maintenance by the S&WB	4-19
4.7.2 Damage to S&WB Facilities and Capabilities Caused by Hurricane Katrina and Rita	4-19
4.7.2 Reclamation of the Mid-City Lowlands (early 1900s)	4-20
4.7.3 1915 Flood Triggers Heightening of Drainage Canal Levees	4-20
4.7.4 The Lakefront Improvement Project (1926-34)	4-21
4.7.5 Second Generation of Heightening Drainage Canal Levee Embankments (1947)	4-22
4.7.6 Federal Involvement with the City Drainage Canals (1955 – present)	4-22
4.7.7 Hurricane Katrina Strikes New Orleans – August 2005	4-23
4.8 Commercial Navigation Corridors	4-24
4.8.1 Inner Harbor Navigation Canal/Industrial Canal	4-24
4.8.2 Flooding Problems Around the IHNC	4-26
4.8.3 Intracoastal Waterway	4-26
4.8.4 Mississippi River Gulf Outlet	4-27

4.9 Influence of Elevation Datums on New Orleans Flood Protection System	4-28
4.9.1 Introduction	4-28
4.9.2 17 th Street Outfall Canal	4-29
4.9.3 London Avenue Outfall Canal	4-29
4.9.4 Orleans Outfall Canal	4-29
4.9.5 Inner Harbor Navigation Canal – East Levee	4-29
4.9.6 Inability to Apply Universal Corrections for Elevation Datums ..	4-30
4.10 Names of New Orleans Neighborhoods	4-30
4.11 References	4-30

Chapter 5: The Lower Mississippi Region and Plaquemines Parish

5.1 Overview	5-1
5.2 Point a la Hache	5-2
5.3 Erosion Studies	5-3
5.4 Summary	5-3
5.5 References	5-4

Chapter 6: The St. Bernard Parish and Lower Ninth Ward Protected Area

6.1 Introduction	6-1
6.2 The Northeast Frontage Levee	6-1
6.3 The Two large Breaches on the East Bank of the IHNC at the Lower Ninth Ward	6-5
6.3.1 The IHNC East Bank (South) Breach at the Lower Ninth Ward	6-6
6.3.2 The IHNC East Bank (North) Breach at the Lower Ninth Ward	6-13
6.3.3 Summary	6-14
6.4 Summary and Findings	6-15
6.5 References	6-16

Chapter 7: The New Orleans East Protected Area

7.1 Introduction.....	7-1
7.2 New Orleans East Hurricane Protection System	7-1
7.3 Performance of the New Orleans Hurricane Protection System In Hurricane Katrina	7-2
7.3.1 Overview	7-2
7.3.2 Chronology of Events in the New Orleans East Protected Area	7-2

7.3.3	Damage to Levee System Frontages	7-3
7.3.3.1	GIWW Frontage (Citrus Back and New Orleans East Back Levees	7-3
7.3.3.2	IHNC Frontage (IHNC East Levee)	7-5
7.3.3.2	Lake Pontchartrain (New Orleans Lakefront, Citrus Lakefront and New Orleans East Lakefront Levees) and East Side Frontages (New Orleans East Levee)	7-5
7.4	Summary of Findings for New Orleans Protected Area	7-5
7.5	References	7-6

Chapter 8: The Orleans East Bank (Downtown) and Canal District Protected Area

8.1	Overview	8-1
8.2	Performance of the Flood Protection System Along the West Bank of the Inner Harbor Navigation Channel (IHNC)	8-3
8.2.1	An Early Breach at About 4:45 am	8-3
8.2.2	The CSX Railroad Breach	8-4
8.2.3	Breaches and Distressed Sections at the Port of New Orleans	8-5
8.2.3.1	Breach at Rail Yard Behind the Port of New Orleans	8-6
8.2.3.2	Erosional Distress at Floodgate Structure Behind the Port of New Orleans	8-7
8.2.3.3	Two Adjacent Erosional Embankment Breaches at the North End of the Port of New Orleans	8-8
8.2.4	Summary and Findings	8-8
8.3	The Canal District Failures	8-10
8.3.1	Introduction	8-10
8.3.2	The Lining of the Drainage Canals	8-11
8.3.3	The E-99 Sheetpile Wall Test Section	8-12
8.3.4	Field Tests for Assessment of Underseepage Risk at the Canals ..	8-13
8.3.5	Water Levels Within the Canals During Hurricane Katrina	8-14
8.3.6	The Orleans Canal	8-15
8.3.7	The 17 th Street Canal	8-17
8.3.7.1	The Breach on the East Bank	8-17
8.3.7.2	Distressed Section on the West Bank	8-31
8.3.8	The Breach Near the South End of London Avenue Canal	8-32
8.3.9	The Breach and Distressed Sections Near the North End of the London Avenue Canal	8-35
8.3.10	Summary and Findings	8-39

8.4	References	8-42
-----	------------------	------

Chapter 9: Overtopping-Induced Erosion Studies

9.1	Erodibility: A Definition	9-1
9.2	Erosion Process	9-1
9.3	Velocity vs. Shear Stress	9-1
9.4	Erosion Threshold and Erosion Categories	9-2
9.5	Erodibility of Coarse-Grained Soils	9-2
9.6	Erodibility of Fine-Grained Soils	9-4
9.7	Erodibility and Correlation to Soil Properties	9-6
9.8	The EFA: Erosion Function Apparatus	9-7
9.9	Some Existing Knowledge on Levee Erosion	9-9
9.9.1	Current Considerations in Design	9-9
9.9.2	Failure Mechanism	9-9
9.9.3	Numerical Modeling	9-10
9.9.4	Laboratory Tests	9-10
9.9.5	Field Tests	9-11
9.9.6	Factors Influencing Resistance to Overtopping	9-12
9.9.7	Influence of Grass Cover on Surface Erosion	9-13
9.10	Soil and Water Samples Used for Erosion Tests	9-14
9.11	Erosion Function Apparatus (EFA) Test Results	9-16
9.11.1	Sample Preparation	9-16
9.11.2	Sample EFA Test Results	9-16
9.11.3	Summary Erosion Chart	9-17
9.11.4	Influence of Compaction on Erodibility	9-17
9.11.5	Influences of Water Salinity on Erodibility	9-18
9.12	Index Properties of the Samples Tested in the EFA	9-18
9.13	Levee Overtopping and Erosion Failure Guideline Chart	9-18
9.14	Summary	9-19
9.15	References	9-19

Chapter 10: Earthen Levee Evaluation

10.1	Overview	10-1
10.2	Levee Failure Mechanisms	10-1
10.1.1	Structural Causes	10-2
10.1.2	Causes due to Hydraulic Forces	10-2

10.1.3	Causes Involving Surface Degradation	10-3
10.3	Design Standards	10-4
10.3.1	United States Army Corps of Engineers Design Standards	10-4
10.3.1.1	Primary Design Procedure	10-5
10.3.1.2	Material Selection	10-6
10.3.1.3	Required Levee Soil Compaction	10-6
10.3.1.4	Embankment Geometry	10-7
10.3.1.5	Identified Failure Modes	10-7
10.3.1.5	Erosion Susceptibility	10-7
10.3.2	United States Federal Emergency Management Agency Design Standards	10-9
10.3.2.1	Freeboard	10-9
10.3.2.2	Closures	10-9
10.3.2.3	Embankment Protection	10-9
10.3.2.4	Embankment and Foundation Stability	10-9
10.3.2.5	Settlement	10-10
10.3.2.6	Interior Drainage	10-10
10.3.2.7	Other Design Criteria	10-10
10.3.2.8	Other FEMA Requirements	10-11
10.6	Storm Surge and Wave Action During Hurricane Katrina	10-11
10.7	Field Reconnaissance and Levee Condition Mapping	10-11
10.7.1	Location 1 – Lakefront Airport	10-12
10.7.2	Location 2 – Jahncke Pump Station Outfall	10-13
10.7.3	Location 3 – Eastern Perimeter of New Orleans East	10-14
10.7.4	Location 4 – Southeast Corner of New Orleans East	10-14
10.7.5	Location 5 – Entergy Michoud Generating Plant	10-15
10.7.6	Location 6 – ICWW/MRGO Southern Levee	10-15
10.7.7	Location 7 – Bayou Bienvenue Control Structure	10-16
10.7.8	Location 8 – Mississippi River Gulf Outlet	10-17
10.7.9	Location 9 – Bayou Dupre Control Structure	10-18
10.7.10	Location 10 – St. Bernard Parish Interior Levee	10-19
10.7.11	Summary of Observed Performance Factors	10-20
10.8	Erosion Evaluation	10-22
10.9	Establishment of Design Criteria and Acceptability Performance	10-26
10.9.1	USACE Risk Management Approach	10-26

10.9.2 Other Risk-Based Approaches	10-28
10.10 Conclusions	10-29
10.11 References	10-30

Chapter 11: Summary of Engineering Lessons

11.1 Introduction	11-1
11.2 Overarching Strategic Issues	11-1
11.2.1 Targeted Levels of Safety and Reliability	11-1
11.2.2 Funding and Resources	11-2
11.3 Principal Engineering Findings and Lessons	11-4
11.3.1 Introduction and Overview	11-4
11.3.2 Plaquemines Parish	11-5
11.3.3 The East Flank; New Orleans East and the St. Bernard/Lower Ninth Ward Protected Areas	11-5
11.3.4 The Central Region; the IHNC and the GIWW/MRGO Channel Frontages	11-9
11.3.5 The Lake Pontchartrain Frontage, and the Drainage Canals	11-14
11.4 References	11-22

PART III – ORGANIZATIONAL AND INSTITUTIONAL ISSUES:

Chapter 12: Organized for Failure

12.1 Introduction	12-2
12.2 Purposes	12-2
12.3 Failure of the NOFDS	12-2
12.4 Extrinsic Factors	12-4
12.5 Intrinsic Factors	12-10
12.5.1 Standard Project Hurricane	12-11
12.5.2 Failure Modes and Safety Factors	12-13
12.6 Life-Cycle Development of Flaws	12-16
12.7 Findings – Looking Back	12-17
12.8 References	12-19

Chapter 13: Organized for Success

13.1 How Safe is Safe Enough	13-3
13.1.1 The Engineering Response to “How Safe is Safe?”	13-5

13.1.2	Insights from Addressing These Issues	13-6
13.2	Maximizing How Safe is Safe Enough in the U.S. Army Corps of Engineers (Context)	13-7
13.2.1	The Office of the President, the Congress, and the Corps	13-7
13.2.2	Additional External Interstices for the Corps	13-9
13.2.3	The Corps' Internal Interstices	13-11
13.4	Preventing the Next Katrina	13-11
13.5.	Re-engineering the USACE	13-12
13.5.1	Rebuilding the USACE Capacity	13-13
13.5.2	Restructuring the Federal/State Relationship in Flood Defense	13-13
13.5.3	Developing a National Flood Defense Authority	13-14
13.5.4	Creating Effective Disaster Planning	13-14
13.5.4.1	Creating a National Disaster Advisory Office in the White House	13-15
13.5.4.2	Creating a Catastrophic Risk Office in Congress.....	13-15
13.5.4.3	Making FEMA an HRO	13-16
13.6	Recommendations – Organizing for Success	13-16
13.7	References	13-17

Chapter 14: Engineering for Success

14.1	Introduction	14-1
14.2	Engineering Considerations	14-3
14.2.1	Physical Facilities	14-3
14.3	Engineering Criteria and Guidelines	14-10
14.4	References	14-11

PART IV – SUMMARY AND FINDINGS

Chapter 15: Findings and Recommendations

15.1	Overview	15-1
15.2	Performance of the Regional Flood Defense System During Hurricane Katrina	15-1
15.3	Engineering Issues	15-5
15.4	Looking Back – Organized for Failure	15-8

15.5 Looking Forward – Organizing for Success	15-10
15.5.1 Strategic and Engineering System Issues	15-10
15.5.2 Technology Delivery System Developments – Organizing for Success	15-12
15.6 Conclusion	15-13

VOLUME II: APPENDICES

APPENDIX A: TERRESTRIAL LIDAR IMAGERY OF NEW ORLEANS LEVEES AFFECTED BY HURRICANE KATRINA

A.1 Introduction	A-1
A.2 Methodology	A-1
A.3 Georeferencing of LIDAR survey data	A-3
A.4 Processing of LIDAR Imagery	A-4
A.5 Data Coverage: LIDAR scan sites at Levee Breaks within the New Orleans Area	A-4
A.6 Analysis Examples of Levee Deformation Using LIDAR Data	A-4
A.7 Summary	A-6
A.8 References	A-6

APPENDIX B: BORING LOGS B-1

APPENDIX C: CPT LOGS C-1

APPENDIX D: STE LABORATORY TESTING D-1

APPENDIX E: U.C. BERKELEY LABORATORY TESTING AND ILIT IN-SITU FIELD VANE SHEAR TESTING E-1

APPENDIX F: LOOKING BACK

F.1 Synopsis of History of the New Orleans Flood Defense System 1965 – 2005	F-1
F.2 Learning from Failures	F-7
F.2.1 Engineered Systems	F-7
F.2.2 Causes of Failures	F-8
F.2.3 Magnitude of Failures	F-9
F.2.4 Breaching Defenses	F-9
F.2.5 Knowledge Challenges	F-10
F.2.6 Organizational Malfunctions	F-11
F.2.7 Engineering Challenges	F-12
F.2.8 Initiating, Contributing, Compounding Events	F-13
F.2.9 High and Low Reliability Organizations: The NASA Columbia Accident Investigation	F-14

F.2.10	High Reliability Organizations	F-14
F.2.11	Low Reliability Organizations	F-17
F.2.12	Columbia Accident Investigation Board Findings	F-17
F.2.13	Summary	F-21
F.3	Quotations from Key Reports and Papers	F-22
F.3.1	Townsend, F.F (2006). <i>The Federal Response to Hurricane Katrina, Lessons Learned</i> , Report to the President of the United States, The White House, Washington, D.C., February	F-22
F.3.2	Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina, 2006. <i>A Failure of Initiative</i> , U.S. Government Printing Office, Washington, D.C.	F-23
F.3.3	Report of the Committee on Homeland Security and Governmental Affairs. <i>Hurricane Katrina, A Nation Still Unprepared</i> , United States Senate, Washington, D.C., May 2006.	F-28
F.3.4	American Society of Civil Engineers External Review Panel (ERP). Letter to LTG Carl Strock, Chief of U.S. Army Corps of Engineers, February 20, 2006.	F-39
F.3.5	Committee on New Orleans Regional Hurricane Protection Projects, National Academy of Engineering and the National Research Council, 2006. Report to The Honorable John Paul Woodley, Assistant Secretary of the Army, Civil Works, Washington, D.C. February..	F-41
F.3.6	U.S. Government Accountability Office, Army Corps of Engineers History of the Lake Pontchartrain and Vicinity Hurricane Protection Project, Statement of Anu Mittal, Direction Natural Resources and Environment, Testimony Before the Committee on Environment and Public Works, U.S. Senate, November 9, 2005; also Testimony before the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives, September 28, 2005	F-42
F.3.7	U.S. General Accounting Office, Improved Planning Needed by the Corps of Engineers to Resolve Environmental, Technical, and Financial Issues on the Lake Pontchartrain Hurricane Protection Project, Report to the Secretary of the Army, August 17, 1982.	F-43
F.3.8	Houck, O. (2006). "Can We Save New Orleans?" Tulane Environmental Law Journal, Vol 19, Issue 1, 1-68, New Orleans, Louisiana.	F-44
F.3.9	Member Scholars of the Center for Progressive Reform (2005). <i>An Unnatural Disaster: The Aftermath of Hurricane Katrina</i> , Center for Progressive Reform Publication, CPR Publication #512, September.	F-51

F.3.10	Braun, S. and Vartabedian, R. (2005). “The Politics of Flood Control,” Los Angeles Times, December 25.	F-55
F.3.11	Vartabedian, R. and Braun, S. (2006). “Fatal Flaws: Why the Walls Tumbled in New Orleans,” Los Angeles Times, January 17.	F-61
F.3.12	Irons, L. (2005). “Hurricane Katrina as a Predictable Surprise,” Homeland Security Affairs, Vol. I, Issue 2, Article 7, http://hsaj.org/hsa	F-66
F.3.13	Congressional Research Service Report for Congress (2005). <i>Protecting New Orleans: From Hurricane Barriers to Floodwalls</i> , N.T. Carter, Washington, D.C., December.	F-69
F.3.14	Congressional Research Service Report for Congress (2005). <i>Flood Risk Management: Federal Role in Infrastructure</i> , N. T. Carter, October, Washington, D.C.	F-72
F.3.15	Office of Management and Budget (2006). <i>Agency Scorecards</i> , Washington, D.C.,	F-76
F.3.16	Senator Susan Collins and Senator Joseph Lieberman, Senate Homeland Security Committee Holds Hurricane Katrina Hearing to Examine Levees in New Orleans, Press Release, November 2, 2005.	F-76
F.3.17	Senator Susan Collins (2005). “Hurricane Katrina: Who’s in Charge of the New Orleans Levees?” Hearing Statement Before Homeland Security and Governmental Affairs Committee, December 15, Washington, D.C.	F-77
F.3.18	Herman Leonard and Arnold Howitt (2006). “Katrina as Prelude: Preparing for and Responding to Future Katrina-Class Disturbances in the United States,” Testimony U.S. Senate Homeland Security and Governmental Affairs Committee, Washington, D.C., March 8.	F-77
F.3.19	Congressional Research Service (2003). <i>Army Corps of Engineers Civil Works Program: Issues for Congress</i> , Issue Brief for Congress, N. Carter and P. Sheikh, Washington, D.C., May 21..	F-78
F.3.20	U.S. General Accounting Office (2003). <i>Corps of Engineers Improved Analysis of Costs and Benefits Needed for Sacramento Flood Protection Project</i> , Report to Congressional Requesters, GAO-04-30, Washington, D.C., October	F-80
F.3.21	Heinzerling, L. and Ackerman, F. (2002). “Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection,” Georgetown Environmental Law and Policy Institute, University Law Center	F-82
F.4	References	F-83

APPENDIX G: LOOKING FORWARD

G.1 High Reliability Organization: The USN Nuclear Propulsion Program	G-2
G.1.1 The USN Nuclear Propulsion Program	G-2
G.1.2 Personnel and Recruitment Retention	G-4
G.1.3 Engineering Assumptions	G-6
G.1.4 Conclusion	G-6
G.2 Findings from Other Studies: Organizing for Success	
G.2.1 Report of the Committee on Homeland Security and Governmental Affairs (2006). Hurricane Katrina, A Nation Still Unprepared, United States Senate, Washington, D.C., May	G-7
G.2.2 Senator Susan Collins (2006). "Opening Statement," Committee on Homeland Security and Governmental Affairs, Hurricane Katrina: Recommendations for Reform," Washington, D.C., March 8	G-10
G.2.3 Newt Gingrich (2006). "Why New Orleans Needs Saving." Time Magazine, March 6.	G-10
G.2.4 Houck, O. (2006). "Can We Save New Orleans?" Tulane Environmental Law Journal, Vol. 19, Issue 1, 1-68, New Orleans Louisiana	G-11
G.2.5 Netherlands Water Partnership (2005). <i>Dutch Expertise, Water Management & Flood Control</i> , Delft, The Netherlands, November.	G-17
G.2.6 Interagency Floodplain Management Review Committee (1994). <i>Sharing the Challenge: Floodplain Management into the 21st Century</i> , Report to Administration Floodplain Management Task Force, Washington, D.C. June.	G-18
G.2.7 Input from Citizens of the Greater New Orleans Area: Levees.Org.	G-19
G.2.8 Congressional Research Service (2005). <i>Aging Infrastructure: Dam Safety Report</i> , Report for Congress, K. Powers, Washington, D.C., September 29.	G-20
G.2.9 Sparks, R.E., (2006). "Rethinking, Then Rebuilding New Orleans," Issues in Science and Technology, National Academy Press, Winter 2006, p 33-39, Washington, D.C.	G-20
G.2.10 Curole, W. (2005). <i>Comprehensive Hurricane Protection Plan Guidelines</i> , General Manager, South Lafourche Levee District Presentation to French Quarter Citizens Group, November 2005.	G-23
G.2.11 Lopez, J. (2005). <i>The Multiple Lines of Defense Strategy to Sustain Louisiana's Coast</i> . Report to Lake Pontchartrain	

Basin Foundation, New Orleans.	G-23
G.2.12 Committee on the Restoration and Protection of Coastal Louisiana (2006). <i>Drawing Louisiana's New Map</i> , Ocean Studies Board, National Research Council, The National Academies Press, Washington, D.C.	G-27
G.2.13 Working Group for Post-Hurricane Planning for the Louisiana Coast, A New Framework for Planning the Future of Coastal Louisiana after the Hurricanes of 2005, University of Maryland Center for Environmental Science, Cambridge, January 26, 2006.	G-33
G.3 References	G-41

APPENDIX H: HOW SAFE IS SAFE? Coping with Mother Nature, Human Nature and Technology's Unintended Consequences

H.1 Preface	H-1
H.2 Introduction	H-2
H.2.1 How Safe is Safe?	H-2
H.2.2 Risk Analysis as a Survival Skill	H-7
H.2.3 Tradeoffs Between Risks, Cost of Mitigation, and Performance	H-11
H.2.4 Voluntary versus Involuntary Risk	H-13
H.2.5 Coping with Threats to Life, Liberty, Property, and the Environment	H-14
H.3 Government's Responsibility for Security	H-17
H.3.1 Risk Management: Our Constitution, Public Policy and our Culture	H-17
H.3.2 Resolution by Political Power and Political Will	H-19
H.3.3 The President and Congress: Needs for Advice and Counsel	H-21
H.4 Technology and Its Side Effects	H-21
H.4.1 Beyond Technique, Technology as a Social Process	H-21
H.4.2 Technology's Unintended Consequences	H-24
H.4.3 What You Can't Model You Can't Manage	H-27
H.4.4 Over-Design as a Safety Margin	H-28
H.5 Bed Rock Values in Public Policy	H-31
H.5.1 The Rainbow of Stakeholders	H-31
H.5.2 Conflict Management to Balance Benefits and Costs	H-33
H.5.3 Tensions Between Industry and Government	H-35
H.6 The Ethics of Informed Consent	H-37

H.6.1	The Role of Media in Exposing Risks	H-37
H.6.2	The Power of Informed Consent	H-40
H.7	Lessons from the Past	H-42
H.7.1	The <i>Exxon Valdez</i> as a Metaphor for System Failure	H-42
H.7.2	Deficits of Foresight, Vigilance, Contingency Resources, Political Will and Trust	H-45
H.8	Thinking About The Future	H-48
H.8.1	Evaluating Social Choice by Outcomes for the Children	H-48
H.8.2	Foresight as an Imperative in Risk Management	H-49
H.8.3	Pathologies for the Short Run	H-51
H.8.4	Early Warning of Close Encounters	H-53
H.9	The Anatomy of Risk – A Summary	H-54
H.9.1	Applying These Concepts to Katrina	H-56

**APPENDIX I: EROSION TEST RESULTS ON
NEW ORLEANS LEVEE SAMPLES**

I.1	The EFA: Erosion Function Apparatus	I-1
I.1.1	EFA test procedures	I-1
I.1.2	EFA test data reduction.....	I-1
I.2	Soil and Water Samples Used for Erosion Tests	I-3
I.3	Erosion Function Apparatus (EFA) Test Results	I-5
I.3.1	Sample preparation	I-5
	EFA Test Results	I-7