

AmericanLifelinesAlliance

A public-private partnership to reduce risk to utility and transportation systems from natural hazards

Development of Guidelines to Define Natural Hazards Performance Objectives for Water Systems Volume II

September 2002

www.americanlifelinesalliance.org

This report was written under contract to the American Lifelines Alliance, a public-private partnership between the Federal Emergency Management Agency (FEMA) and the American Society of Civil Engineers (ASCE). This report was reviewed by a team representing practicing engineers, managers, and academicians.



September 2002

Acknowledgements

The following people (with their affiliations) contributed to this report.

Craig Taylor	Natural Hazards Management Inc.; Torrance, CA
LeVal Lund	Consultant, Los Angeles, CA
John Wiggins	J. H Wiggins Company, Redondo Beach, CA
William Graf	URS Corporation, Los Angeles, CA
Timothy Volz	URS Corporation, Colorado Springs, CO
Danna Judish	URS Corporation, Colorado Springs, CO
Garry Lay	URS Corporation, Los Angeles, CA
Aziz Alfi	Seattle Department of Public Utilities, Seattle, WA
Chuck Call	Salt Lake Dept. of Public Utilities, Salt Lake City, UT
Bill Nabak	Green Bay Water Utility, Green Bay, WI
Dave Putnam	Metropolitan Water District of Southern California, Fontana, CA
Robert Gordon	Hillsborough County Public Works Department, Tampa, FL

Table of Contents

List of Tables	vi
Table 1: Classification of Wind by the Beaufort Scale 20	vi
Table 2: Construct of a Hurricane Damage System 22.....	vi
Table 3: Saffir/Simpson Hurricane Scale Ranges 25.....	vi
Table 4: Exemplary Vulnerability Table for a Selected Filtration Plant (ignoring specific component failure modes) 50	vi
List of Figures	vii
List of Figures	vii
Appendix A Clarification of Project Objectives and Scope	1
Appendix B Defining the Water Utility System at Risk	2
B.1 Introduction	2
B.2 Information and Display Technologies	2
B.3 An Illustrative System	2
B.4 Further Considerations on Hydraulic Modeling	4
Appendix C The Phenomenology of Natural Hazards Covered	13
C.1 Introduction	13
C.2 The Phenomenology of Ground Movement Hazards	13
C.2.1 General Considerations	13
C.2.2 Gravity Landslide	14
C.2.3 Expansive Soil	15
C.2.4 Soil Collapse	15
C.2.5 Frost Heave	17
C.3 The Phenomenology of Flood Hazards	18
C.3.1 General Considerations	18
C.3.2 Riverine Flood and Scour	18
C.3.3 Headwater Flood and Scour	19
C.4 The Phenomenology of Windstorms	19
C.4.1 General Considerations	19
C.4.2 General Severe Wind	20
C.4.3 Tornado	22
C.4.4 Hurricane—General	22
C.4.5 Hurricane-Tornado	24
C.4.6 Hurricane-Cyclone Wind	24
C.4.7 Hurricane-Storm Surge and Scour	25
C.4.8 Hurricane-Headwater Flood and Scour	26
C.4.9 Hurricane-Riverine Flood and Scour	27
C.5 The Phenomenology of Earthquakes	27

C.5.1	General Considerations	27
C.5.2	Local Earthquake—Fault Rupture.....	28
C.5.3	Earthquake—Shaking	29
C.5.4	Earthquake—Landslide	30
C.5.5	Earthquake—Lurching/Lateral Spreads.....	30
C.5.6	Earthquake—Liquefaction.....	31
C.5.7	Earthquake—Tsunami	32
C.5.8	Earthquake—Seiche	33
C.5.9	Earthquake—Fire Following.....	33
Appendix D	Supplementary Notes on Component Vulnerability Modeling..	44
D.1	Introduction	44
D.2	Use of a Power Function.....	44
D.3	Use of a Triangular Distribution	44
D.4	Water Component Subsystems	47
Appendix E	Supplementary Information on Water Systems Evaluations	51
E.1	Introduction	51
E.2	Toward the Formalism of a More Complex Connectivity Evaluation	51
E.3	Prior Assessments of the Operational Importance of Components	52
Appendix G.	Details of Demonstration Water System Evaluation.....	54
G.1	Introduction	54
G.2	Modeling the Hypothetical Water System Before the Hypothetical Natural Hazards Events	54
G.3	A Hypothetical Flood/Scour Event	54
G.3.1	Overview of the Scenario.....	54
G.3.2	Immediate Water System Condition After the Flood	55
G.3.3	Modeling the Restoration of the Water System.....	55
G.3.4	Restarting the System After Repairs.....	55
G.4	A Hypothetical Expansive Soils Event	56
G.4.1	Outline of Natural Hazards Disruption	56
G.4.2	The Immediate Condition of the System After the Disruption	56
G.4.3	Modeling the Water System Restoration	57
G.5	A Hypothetical Earthquake Affecting the Water System	57
G.5.1	The Assumed Immediate Damage	57
G.5.2	Modeling the Immediate Post-Earthquake	58
G.5.3	Modeling the Restoration of the Water System.....	58
G.5.4	Restarting the Water System	59
References		75
Terms and Definitions		87

List of Tables

Table 1:	Classification of Wind by the Beaufort Scale	20
Table 2:	Construct of a Hurricane Damage System	23
Table 3:	Saffir/Simpson Hurricane Scale Ranges.....	25
Table 4:	Exemplary Vulnerability Table for a Selected Filtration Plant (ignoring specific component failure modes)	50

List of Figures

Figure 1:	Hypothetical Demonstration System	5
Figure 2:	Composite Water System Map.....	6
Figure 3:	Map showing distribution of great floods in the coterminous United States since 1889.....	35
Figure 4:	Mountain Downslope Wind.....	36
Figure 5:	Model of wind-speed distribution and streamlines for an extreme (Cat 5) Hurricane, drawn with respect to direction of motion pointing upward.	37
Figure 11:	Three general types of fault movement.....	43
Figure 12:	Triangular Distribution	48
Figure 13:	Flow Diagram for A Water Treatment Plant.....	49
Figure 14:	Hypothetical Water Distribution System Before the Natural Hazard Event (hydraulic pressure contours – psi)	60
Figure 15:	Hypothetical Flood/Scour Event as it Occurs (hydraulic pressure contours – psi)	61
Figure 16:	Water System Restoration for the Hypothetical Flood/Scour Event (hydraulic pressure contours – psi)	62
Figure 17:	Water System Start-Up After the Hypothetical Flood/Scour Event (hydraulic pressure contours – psi)	63
Figure 18:	Hypothetical Expansive Soils Event as it Occurs (hydraulic pressure contours – psi).....	64
Figure 19:	Continued System Failure for the Hypothetical Expansive Soils Event (hydraulic pressure contours – psi)	65
Figure 20:	Water System Start-Up After the Hypothetical Expansive Soils Event (hydraulic pressure contours – psi)	66
Figure 21:	Water System Recovery After the Hypothetical Expansive Soils Event (hydraulic pressure contours – psi)	67
Figure 22:	Water System Restoration After the Hypothetical Expansive Soils Event (hydraulic pressure contours – psi)	68
Figure 23:	Final Water System Restoration After the Hypothetical Expansive Soils Event (hydraulic pressure contours – psi)	69
Figure 24:	Hypothetical Earthquake As It Occurs (hydraulic pressure contours – psi)	70
Figure 25:	Pipe Breaks Isolated After Hypothetical Earthquake (hydraulic pressure contours – psi).....	71
Figure 26:	Partial Pumping Stations & Pipe Break Restoration After Hypothetical Earthquake (hydraulic pressure contours – psi).....	72
Figure 27:	Pumping Stations and Pipe Breaks Repaired After Hypothetical Earthquake (hydraulic pressure contours – psi)	73
Figure 28:	Pipe Leaks Isolated After Hypothetical Earthquake (hydraulic pressure contours – psi).....	74

List of Photographs

1	Water Treatment Plant.....	9
2	Well Pump	9
3	Submersible Pump + Control House.....	9
4	Steel Tank.....	9
5	Prestressed Concrete Tank + Hydropneumatic Tank	9
6	Prestressed Concrete Tank	9
7	Tank Water Level Indicator	10
8	Rigid Piping to Tank.....	10
9	Open Reservoir.....	10
10	Open Reservoir.....	10
11	Aqueduct.....	10
12	Aqueduct near hills	10
13	Open Reservoir.....	11
14	Pump House	11
15	Pump House	11
16	Pump Station Control Room	11
17	Pump Station Interior	11
18	Pumps.....	11
19	Chlorination Bldg + Emergency Generator	12
20	Old Chlorination Unit.....	12
21	Chlorine Tanks.....	12
22	Emergency Generator.....	12
23	Electrical Cabinets	12
24	Emergency Generator Detail	12
25	Large Diameter Underground Pipe	13
26	Lube Oil Tank	13
27	Pipe and Valve.....	13
28	Pipe and Valves.....	13
29	Pipeway	13
30	Propane 'Bullet'	13
31	Vertical Vessel - Surge Tank	14
32	Substation at Pump Station	14