Fact Sheet 2.0: Water Control Facilities

The mitigation objective of this Fact Sheet series is to protect lives and property by effectively controlling the flow of water retained in impoundments and flowing through channels

Hurricane and Flood Mitigation

Public water control facilities help to control the flow of water by retaining or directing it to protect lives and property. Under Presidential Policy Directive 21 (PPD 21), the National Infrastructure Protection Plan (NIPP), water control facilities are one of sixteen critical infrastructure sectors. They can be used to provide hydroelectric power generation, habitats for wildlife, inland passage for barges and ships, irrigation, and recreation opportunities such as boating, swimming, and fishing. They also support other critical infrastructure sectors. The water control facilities discussed in this section of the handbook include channels, aqueducts and canals, basins and dams. Levees are another type of water control facility, but because they generally are the responsibility of USACE, they are not discussed in this fact sheet series. Additional information about levee maintenance and mitigation is available on the USACE website.

Hurricanes and floods can adversely impact water control facilities when inundation, overtopping, erosion, scour, or debris impact structures. Inundation from storm surge and heavy rains may exceed the capacity of the structures, resulting in overtopping and breaches. Flowing water can cause erosion and scour, which can lead to overtopping or undermining of the structures, or seepage through the structures. Floodwaters can carry large quantities of sediment and debris which can clog drainage structures and canals, resulting in overtopping.

Mitigation Fact Sheets

This section of the handbook groups water control facilities into three Fact Sheets. Some features presented, such as armoring, are relevant to other public facilities and may be referenced in other Fact Sheets in the handbook. The three Water Control Facilities Fact Sheets are as follows:

- **2.1 Channels, Aqueducts, and Canals** can be earthen or lined with materials such as concrete or stone (Figure 2.0.1). These inland conveyance structures collect, carry, and distribute water for purposes such as irrigation, transportation, and water supply.

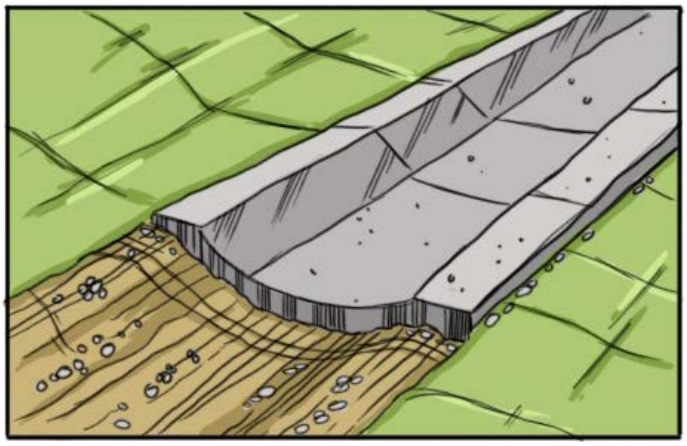


Figure 2.0.1. Channels, aqueducts and canals collect, carry, and distribute water.

- **2.2 Basins** are in-ground structures that hold water (Figure 2.0.2). Basins collect stormwater that can be used immediately or released as needed, help sediment settle out of water before it is used for drinking purposes, or direct and control water flow.
- **2.3 Dams and Reservoirs** – Dams can be earthen or "hard" materials such as concrete. Dams retain water in basins behind them, such as reservoirs, and control the release of water downstream (Figure 2.0.3).

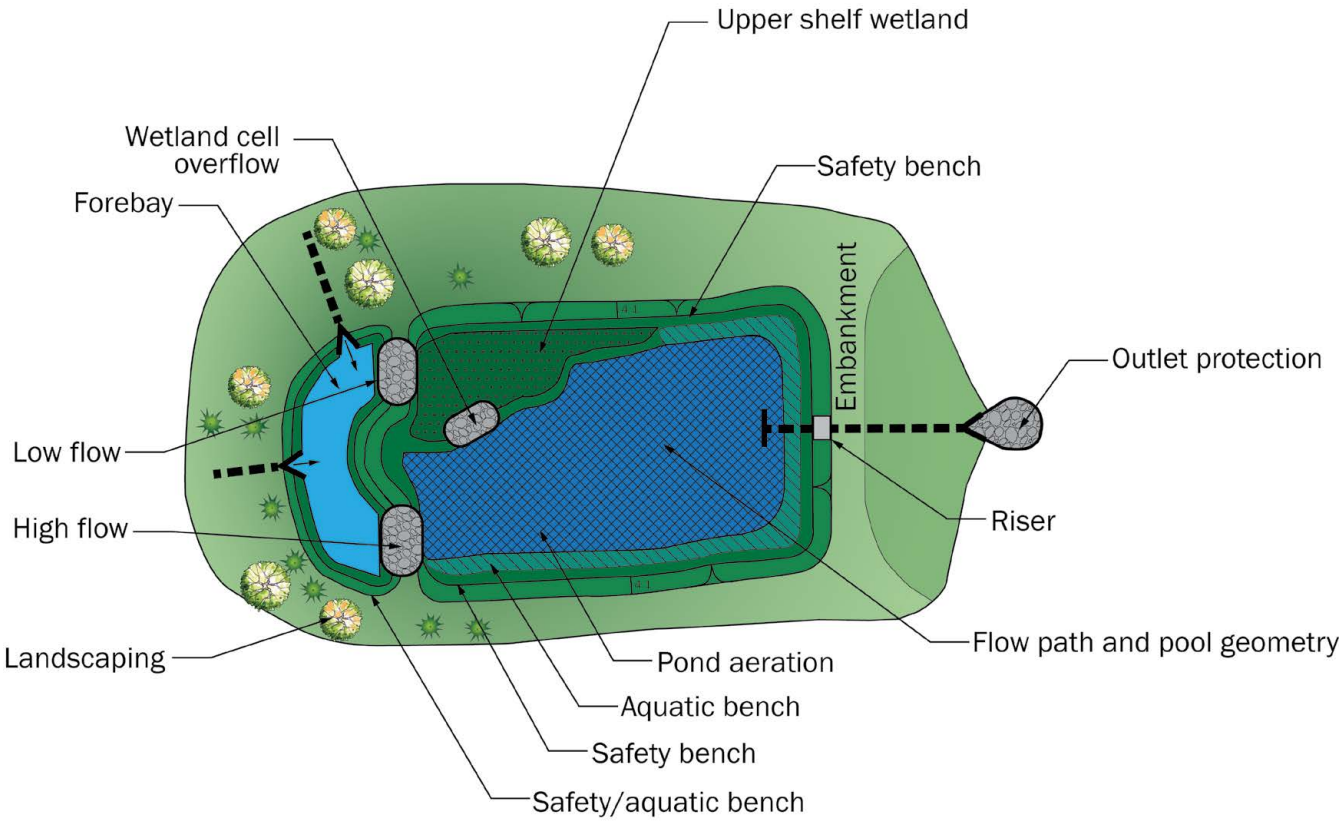


Figure 2.0.2. Basins are in-ground structures used to hold water.

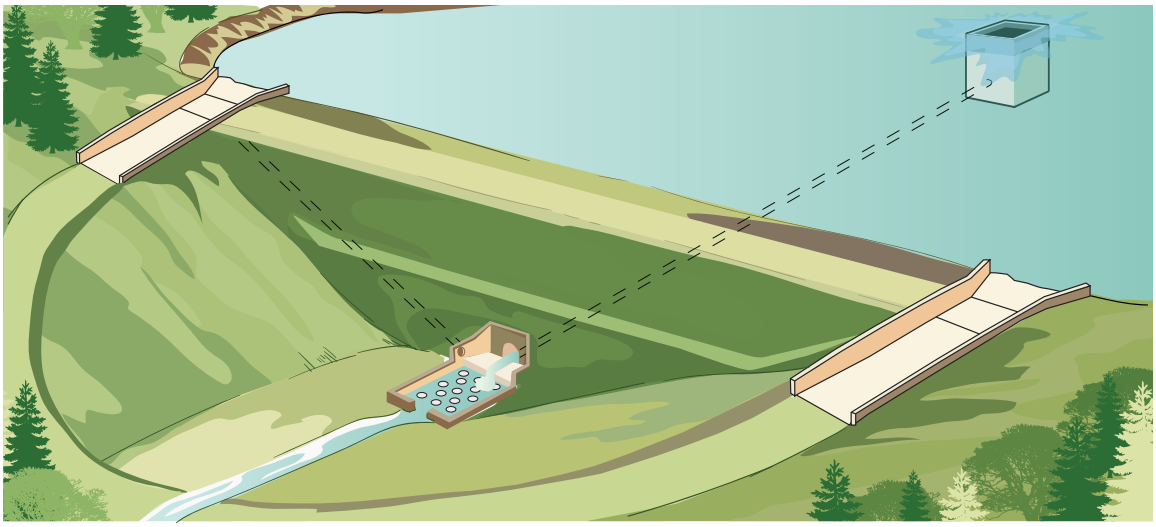


Figure 2.0.3. Dams are used to retain and control the flow of water.

Mitigation Strategies

Water control facilities must remain in operation during severe flooding events, such as those caused by hurricanes and severe rainstorms. Structurally retrofitting these structures can improve their resilience by increasing their stability and capacity, controlling seepage and erosion, and lessening debris impacts. The applicable mitigation measures may depend on project constraints such as the availability of land, materials, and environmental requirements. There are many potential mitigation strategies that can be employed, including:

- Armoring or lining
- Improving slope or bank stability
- Increasing height or freeboard
- Increasing capacity of spillways and other structures
- Installing or improving drainage systems
- Installing gates and valves
- Installing screens
- Realigning channels and structures
- Using bioengineering strategies (e.g., seeding, erosion control mats)
- Deepening or dredging
- Using clay cores
- Installing sheet piles
- Pressure grouting

In addition to structural mitigation measures, implementing non-structural measures is also often essential to safe and efficient operation of water control facilities. Non-structural measures are generally cost-effective compared with structural measures because the latter often require large capital investments. Non-structural measures are generally included in a safety program for such facilities, and may include:

- Implementing a surveillance and monitoring program
- Preparing and regularly updating an emergency action plan

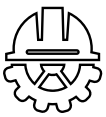
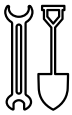
Non-Structural Mitigation for Safety of Dams and Reservoirs

A good resource for guidance on non-structural mitigation and resilience measures for dams and reservoirs may be found at the Association of State Dam Safety Officials (ASDSO) website (www.damsafety.org). Specific guidance on Emergency Action Plans is given at https://damsafety.org/dam-owners/emergency-action-planning#Rerces .

Icons

The fact sheets include ideas/points to consider about developing and starting each option. Symbols/icons that represent these common considerations are summarized in Table 2.0.1.

Table 2.0.1. Icons Used to Represent Considerations about Hazard Mitigation Strategies

Icon	*Considerations about Hazard Mitigation Strategies*
	**Cost** — The cost to carry out the mitigation option may be high, which could make using the option cost prohibitive.
	**Engineering** — A qualified engineer would likely need to design the mitigation option.
	**Environmental and Historic Preservation** — The mitigation option likely will need to comply with local, state and/or federal environmental and historic preservation requirements.
	**Floodplain Management** — Carrying out the mitigation option might impact the floodplain, triggering compliance with floodplain management requirements.
	**Operations and Maintenance** — The mitigation option might require additional operations and maintenance activities beyond those currently being performed.
	**Permitting** — Evaluate the local, state or federal permits required to carry out the mitigation option.

REFERENCES:

Recommended practice and guidance concerning listed topics can be found in the following publications and trade publications:

Bryant, S.D., and C.D. Jewell. 1996. *Analysis of Siphon Lake Drain Performance for a Small Earthen Dam, Association of State Dam Safety Officials 1996 Annual Conference Proceedings.*

Clemson Cooperative Extension. 2020. Stormwater Pond Design, Construction and Sedimentation. Available at: https://www.clemson.edu/extension/water/stormwater-ponds/problem-solving/construct-repair-dredge/index.html

Federal Emergency Management Agency (FEMA). Prepared by Interagency Committee on Dam Safety 1979. Reprinted 2004. FEMA 93, *Federal Guidelines for Dam Safety.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_P-93.pdf.

Federal Emergency Management Agency (FEMA). 2001. *Flood Hazard Mitigation Handbook for Public Facilities*. Available at: https://www.hsdl.org/?abstract&did=34754

Federal Emergency Management Agency (FEMA). 2005. *FEMA 511, Reducing Damage from Localized Flooding.* Available at: https://www.fema.gov/pdf/fima/FEMA511-complete.pdf.

Federal Emergency Management Agency (FEMA). 2011. FEMA 10, *Filters for Embankment Dams, Best Practices for Design and Construction.* Available at: https://www.hsdl.org/?abstract&did=696738

Federal Emergency Management Agency (FEMA). 2012. FEMA P-919, *Summary of Existing Guidelines for Hydrologic Safety of Dams.* Available at: https://www.fema.gov/media-library/assets/documents/28555.

Federal Emergency Management Agency (FEMA). 2013. FEMA P-94, *Selecting and Accommodating Inflow Design Floods for Dams.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_inflow-designs_P-94.pdf.

Federal Emergency Management Agency (FEMA). 2014. FEMA P-1015, *Technical Manual: Overtopping Protection for Dams, Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair.* Available at: https://www.fema.gov/emergency-managers/risk-management/dam-safety/publications.

Federal Highway Administration. 2006. *Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular Number 14 (HEC 14), Third Edition.* Available at: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf.

International Code Council. 2018. *International Plumbing Code.* Available at: https://codes.iccsafe.org/content/IPC2018P3.

Li, Yuchen, Zhou, Zhiyong, Li, Zhengnong. 2006. "Equivalent Along-Wind Loads of Aqueduct Bridges." *The Fourth International Symposium on Computational Wind Engineering.* Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1041.2984&rep=rep1&type=pdf

Miller, C.F. and J.A. Dickerson. 1999. *The Use of Native Warm Season Grasses for Critical Area Stabilization.* Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.631.944&rep=rep1&type=pdf.

U.S. Army Corps of Engineers. 1989. *Retaining and Flood Walls, EM 1110-2-2502.* Available at: https://www.publications.usace.army.mil/portals/76/publications/engineermanuals/em_1110-2-2502.pdf.

U.S. Army Corps of Engineers. 1992. *Design, Construction, and Maintenance of Relief Wells, EM 1110-2-1914.* Available at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1914.pdf.

U.S. Army Corps of Engineers. 1994. *Standard Practice for Concrete for Civil Works Structures, EM 1110-2-2000.* Available at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-2000.pdf.

U.S. Army Corps of Engineers. 1995(a). *Engineering and Design Structural Design of Concrete Lines Flood Control Channels (EM 1110-2-2007).* Available at: https://www.cedengineering.com/userfiles/Structural%20Design%20of%20Concrete%20Lined%20Flood%20Control%20Channels.pdf.

U.S. Army Corps of Engineers. 1995(b). *Construction Control for Earth and Rock-fill Dams, EM 1110-2-1911.* Available at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1911.pdf.

U.S. Army Corps of Engineers. 2004. *Engineering and Design - General Design and Construction Considerations for Earth and Rock-Fill Dams*, EM 1110-2-2300. Available at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-2300.pdf.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). August 1997. Revised March 2001. *National Engineering Handbook (NEH), Part 628 – Dams, Chapter 52 Field Procedures Guide for the Headcut Erodibility Index.* Available at: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=36147.wba.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 2000. *Conservation Practice Standard, Pond, Code 378.* Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046898.pdf.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 2014. *National Engineering Handbook (NEH), Part 628 – Dams, Chapter 50 Earth Spillway Design.* Available at: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=35546.wba.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). 2014. *Watershed Rehabilitation Program.* Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ga/programs/planning/wr/?cid=nrcs144p2_021811.

U.S. Department of Agriculture, U. S. Forest Service. 2012. *Assessing Dams and Impoundments: A Beginner's Guide.* Available at: https://www.fs.fed.us/eng/dams/olt/index.html#!27-problems

U.S. Department of the Interior, Bureau of Reclamation (USBR). 1987. *Design of Small Dams, A Water Resources Technical Publication, Third Edition.* Available at: http://www1.frm.utn.edu.ar/laboratorio_hidraulica/Biblioteca_Virtual/Desing%20of%20small%20dams/SmallDams.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2012(a). *Best Practices for Preparing Concrete Surfaces Prior to Repairs and Overlays, Report No. MERL 12-17.* Available at: https://www.usbr.gov/research/projects/download_product.cfm?id=446.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2012(b). *Embankment Dams, Chapter 10: Embankment Construction (Design Standards No. 13 (DS-13(10)-16: Phase 4 - Final)).* Available at: https://www.usbr.gov/tsc/techreferences/designstandards-datacollectionguides/finalds-pdfs/DS13-10.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2012(c). *Embankment Dams, Chapter 6: Freeboard* (Design Standards No. 13 (DS-13(6)-2: Phase 4 - Final)). Available at: https://www.usbr.gov/tsc/techreferences/designstandards-datacollectionguides/finalds-pdfs/DS13-6wMIR.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2012(d). *Overtopping protection for dams - a technical manual overview, Report Number PAP-1093.* Available at: https://www.usbr.gov/tsc/techreferences/hydraulics_lab/pubs/PAP/PAP-1093.pdf. (Note: Paper giving overview of FEMA P-1015.)

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2014(a). *Embankment Dams, Chapter 7: Riprap Slope Protection (Design Standards No. 13 (DS-13(7)-2.1: Phase 4 - Final))*. Available at: https://www.usbr.gov/tsc/techreferences/designstandards-datacollectionguides/finalds-pdfs/DS13-7.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2014(b). *Embankment Dams, Chapter 16: Cutoff Walls* (Design Standards No. 13 (DS-13(16)-14: Phase 4 - Final)). Available at: https://www.usbr.gov/tsc/techreferences/designstandards-datacollectionguides/finalds-pdfs/DS13-16.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2014(c). *Appurtenant Structures for Dams (Spillways and Outlet Works) Design Standard, Chapter 3: General Spillway Design Considerations.* Available at: https://www.usbr.gov/tsc/techreferences/designstandards-datacollectionguides/finalds-pdfs/DS14-3.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2015. *Guide to Concrete Repair, Second Edition.* Available at: https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/Guide2ConcreteRepair2015_Final.pdf.

U.S. Department of the Interior, Bureau of Reclamation (USBR). 2017. *Design and Construction Considerations for Hydraulic Structures, Roller-Compacted Concrete.* Available at: https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/RCCManualFinal09-2017-508.pdf.

U.S. Department of the Interior, Fish and Wildlife Service. 2008. *Low Hazard Dams, Standing Operating Procedures.* Available at: https://damsafety.org/sites/default/files/files/US%20Fish%20And%20Wildlife%20Service%20SOP.pdf.

Virginia Department of Conservation and Recreation. 1999. *Virginia Stormwater Management Handbook, Volume 1, First Edition.* Available at: https://sswm.info/node/4737

Virginia Department of Conservation and Recreation. 2013(a). *Bioretention, Stormwater Design Specification No. 9.* Available at: https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/2017/11/BMP-Spec-No-9_BIORETENTION_v1-9_03012011.pdf.

Virginia Department of Conservation and Recreation. 2013(b). *Constructed Wetlands, Stormwater Design Specification No. 13.* Available at: https://swbmpvwrrc.wp.prod.es.cloud.vt.edu/wp-content/uploads/2018/07/BMP_Spec_No_13_CONSTRUCTED_WETLAND.pdf.

Virginia Department of Conservation and Recreation. 2013(c). *Dry Swales, Stormwater Design Specification No. 10 Dry Swales.* Available at: http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/02/DCR-BMP-Spec-No-10_DRY-SWALE_Final-Draft_v1-9_03012011.pdf.

Virginia Department of Conservation and Recreation. 2013(d). *Extended Definition (ED) Pond, Stormwater Design Specification No. 15.* Available at: https://swbmpvwrrc.wp.prod.es.cloud.vt.edu/wp-content/uploads/2017/11/BMP-Spec-No-15_EXT-DETENTION-POND_v1-9_03012011.pdf.

Virginia Department of Environmental Quality (VA DEQ). 2011. *Introduction to the New Virginia Stormwater Design Specifications, Appendix B: Principal Spillway, Version 1.0.* Available at: https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/2017/11/Introduction_App-B_Principal-Spillways_03012011.pdf.

Zhang, H, L. Liu, X. He, and A. Ji. 2018. *Investigation of Wind-Induced Response of Fluid-Solid Coupling System for High Bent-Type Aqueduct*. Available at: http://scientiairanica.sharif.edu/article_4531_7483da16edab09fa478789cfb4411c0b.pdf.