Appendix B
Representative Quotations Regarding Safety from General Engineering and Landscape Architecture Literature

Quotations in this appendix are organized by the following topics:

1. General
2. Outlet Structures, Culverts and Trash/Safety Racks
3. Ponds, Dams, Embankments and Side Slopes

1. GENERAL

Operation, Maintenance, and Management of Stormwater Management Systems
Watershed Management Institute, Inc.
Office of Water, U.S. Environmental Protection Agency
August 1997

5. BMP Design Considerations: A Checklist
5.1 Safety

For many reasons, the safety of the stormwater management system must be the primary concern of the designer. Due to its structural nature and, in many instances, the fact that it will impound water either permanently or temporarily, a stormwater facility will inherently pose some degree of safety threat.

Those at risk will include people living, working, or traveling downstream of the system and whose safety and/or property will be jeopardized if the facility were to fail and release stored runoff. Since this is a risk that has been created solely by the system, the designer must assure that the probability of such a failure is acceptably small.

However, also at risk at the facility are maintenance personnel, inspectors, mosquito control personnel, and equipment operators, who must work in and around it. Typical hazards include deep water, excessively steep slopes, slippery or unstable footing, limited or unsafe access, and threats posed by insects and animals. As noted above**, the responsible stormwater designer understands the importance of minimizing and facilitating facility maintenance. Providing a safe working environment for the system maintainer is one important way to do it.**

Finally, those living, working, traveling, attending school, or playing in the vicinity of a facility may also be at risk, particularly if the system serves both as a stormwater management and recreational facility. Once again, such things as standing water, steep slopes, unstable footings, and insect and animal bites must be addressed by the designer in order to avoid creating a system that is a detriment to the community it is intended to serve. Failure to do so will only alienate those

members of the community that are being asked to play a vital role in the community's stormwater management efforts.
(Pages 3-13 – 3-14)

Handbook of Hydrology
David R. Maidment, Editor-in-Chief
McGraw–Hill, Inc.
1993

Safety. Safety is only partially a hydrologic design issue, and it also includes the structural integrity of the water-impounding embankment and its ability to withstand floods greater than the nominal design. Safety to the public when the facility is in operation and when the facility is dormant, namely, between runoff events, is very important. The designer needs to consider flow velocities, water depth, and how to prevent and to discourage the public from being exposed to high-hazard areas during periods of storm runoff. In addition, the designer needs to size an emergency spillway and/or design the embankment so it will not fail catastrophically during a very large event.

When the facility is not operational, which is most of the time, its layout should minimize the use of high vertical drops, deep water near the shore, and steep side slopes above and below the permanent water level. Also, outlet and inflow structures require special attention. Use of flat side slopes, flat benches above and below permanent pool water level, planting thorny shrubs around the inflow and outflow structures, and the use of trash/safety racks at all outlet orifices and pipes all help to enhance the safety of detention facilities.
(Page 28.33)

Detention Ordinances—Solving or Causing Problems?
Proceedings of the Conference on Stormwater Detention Facilities Planning, Design, Operation and Maintenance
Thomas N. Debo
American Society of Engineers and Engineering Foundation
1982

Health and Safety Problems. Closely associated with maintenance problems are several health and safety related problems. Stagnant pools and moist ground associated with many detention facilities become ideal places for mosquito breeding and attract rodents and other pests. Also many facilities located in or adjacent to residential areas can create safety problems. Since these facilities collect sediment and other litter, have steep banks, and often contain several feet of water, they are not ideal places for neighborhood children to play. The usual means to protect local residents is to install a fence around the facility. These fences are often unsightly and prone to vandalism and many times are a hazard to local children.

Drainage Manual
State of Florida Department of Transportation
January 2006

> Stormwater management facilities shall be designed with due consideration of the need for protective treatment to prevent hazards to persons. . . . Flat slopes shall be used when practical. Retention areas shall be fenced. . . to prevent entry into areas of unexpected deep standing water or high velocity flow. Grates shall be considered to prevent persons from being swept into long or submerged drainage systems. Guards shall be considered to prevent entry into long sewer systems under no-storm conditions, to prevent persons from being trapped. (Page 45)

Stormwater Manual
Lexington–Fayette Urban County Government
Lexington, Kentucky
January 1, 2009

> This manual includes requirements for the stormwater infrastructure that is routinely designed and constructed, including rational engineering principles and practices. However, more comprehensive methods of analysis and design may be required for unusual conditions not specifically covered in this manual or where otherwise appropriate from an engineering standpoint to assure public safety and quality in infrastructure design and construction. (Page 1–2)

Urban Surface Water Management
Stuart G. Walesh
John Wiley & Sons, Inc.
1989

[This book contains a section on calculating the force exerted on a person by moving floodwaters. The section contains a hydraulic analysis procedure using a drag equation and information on drag shapes and Reynolds numbers. The results are presented in the following table.]

TABLE 5.1 Forces Exerted on a Person by Moving Floodwater

Velocity (ft/sec)	Depth (ft)	Drag Force (lb)
1	1	1.7
	3	5.2
2	1	7.0
	3	21.0
4	1	27.9
	3	83.8
6	1	62.9
	3	188.6
8	1	111.7
	3	335.2
10	1	174.6
	3	523.8

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2. OUTLET STRUCTURES, CULVERTS AND TRASH / SAFETY RACKS

Georgia Stormwater Management Manual
Volume 2: Technical Handbook
August 2001. First Edition

2.3.6 Trash Racks and Safety Grates
In most instances trash racks will be needed. Trash racks and safety grates are a critical element of outlet structure design and serve several important functions:

- Ensuring that people and large animals are kept out of confined conveyance and outlet areas
- Providing a safety system that prevents anyone from being drawn into the outlet and allows them to climb to safety (Page 2.3–17)

The location and size of the trash rack depends on a number of factors, including head losses through the rack, structural convenience, safety and size of outlet. (Page 2.3–17)

There are no universal guidelines for the design of trash racks to protect detention basin outlets, although a commonly used "rule-of-thumb" is to have the trash rack area at least ten times larger than the control outlet orifice. (Page 2.3–18)

Trash racks at entrances to pipes and conduits should be sloped at about 3H:1V to 5H:1V to allow trash to slide up the rack with flow pressure and rising water level—the slower the approach flow, the flatter the angle. (Page 2.3–19)

Collapsible racks have been used in some places if clogging becomes excessive or a person becomes pinned to the rack. (Page 2.3–19)

The channel protection orifice . . . should be adequately protected from clogging by an acceptable external trash rack. (Page 3.4–4)

Stormwater Management Manual
City of Tulsa, Oklahoma
Public Works Department
September 2004

The outlet works create a potential hazard when in operation due to the possibility of a person being carried in the opening. Grating or trash racks are often used, however, a person can be forced against the grate or trash rack with substantial pressure, preventing escape. Low entrance velocities at the trash rack are recommended. Fencing or other effective measures should be provided to exclude people from potentially hazardous areas. Alternative measures include education, site grating, signing, planting of thorny shrubs, and grading for safety ledges along the pond perimeter. Outlet works can be designed to reduce the hazard to the

public where heavy recreational use is anticipated. A vertical riser of concrete, timber or steel can have a series of openings of 12 inches or less from top to bottom with sufficient total area to cause low velocity at the entrances. The top of such risers can be grated or even closed. In some instances, the outlet works can be fenced.

Drainage and Flood Control Manual
Nebraska Department of Roads
August 2006

Grates or modified debris barriers should be provided at culvert openings where access by children or animals could create hazardous situations (primarily in urban areas).

Urban Surface Water Management
Stuart G. Walesh
John Wiley & Sons, Inc.
1989

Safety provisions potentially applicable to culverts and bridges include:
1. Cages or grates installed on entrances to long culverts
2. Fences or guardrails placed near the top edge of headwalls and wingwalls

(Page 169)

Drainage Criteria Manual
City of Lincoln, Nebraska
Public Works and Utility Department
February 2000

Trash racks and safety grates serve several functions. . . they provide a safety system whereby persons caught in them will be stopped prior to the very high velocity flows immediately at the entrance to outlet works and persons will be carried up and onto the outlet works allowing for a possibility to climb to safety. (Page 6-26)

Catalog of Stormwater Best Management Practices for Idaho Cities and Counties
Idaho Department of Environmental Quality
August 2001

Dangerous outlet facilities should be protected by enclosure. (Page 65)

Model Drainage Manual 1991
American Association of State Highway and Transportation Offices
1991

> Culverts shall be designed to accommodate debris or proper provisions shall be made for debris maintenance.
>
> Culverts shall be located and designed to present a minimum hazard to traffic and people. (Page 9–6)

Hydraulic Design of Highway Culverts
Hydraulic Design Series Number 5
Publication No. FHWA-NHI-01-020
U.S. Department of Transportation, Federal Highway Administration
September 2001 (Revised May 2005)

> Culverts have always attracted the attention and curiosity of children. In high population areas where hazards could exist, access to culverts should be prevented. Safety grates can serve this function. If clogging by debris is a problem, fencing around the culvert ends is an acceptable alternative to grates. (Page 171)

3. PONDS, DAMS, EMBANKMENTS, AND SIDE SLOPES

Model Stormwater Drainage and Detention Ordinance: A Guide for Local Officials
Northeastern Illinois Planning Commission (NIPC)
1990

> One of the principal objectives of detention basin design should be to eliminate the need to fence the final facility. Fencing increases maintenance difficulty and limits any multiple use and aesthetic value the detention basin may have had. In effect it is frequently an admission that comprehensive design objectives could not be achieved. The key to not fencing detention facilities is the design of specific safety measures to make basins reasonably safe under the full range of stormwater conditions it is likely to encounter.
>
> Specific recommendations have been suggested by a number of organizations. The [Metropolitan Water Reclamation District {Chicago}] has suggested that wet basins have a safety ledge of 4 to 6 feet in width and 30 to 36 inches below the permanent pool level to provide footing in the event someone falls into the pond. The MWRD also recommends a ledge 12 to 18 inches above the permanent pool elevation to prevent accidental falls into the basin. NIPC has also recommended safety ledges and flat shoreline (5 horizontal to 1 vertical) and underwater bank slopes (3 to 1). . . The APWA and ASCE have stressed the need to design safe outlet structures. . . They recommend a variety of sloping outlet trash racks which will not trap a person on them during high flows. Finally, they suggest that hand holds be provided to allow people to pull themselves out of steep areas of the

basin or areas where velocities may be high. MWRD has also recommended the installation of 20 foot wide safety ramps at slopes of 6 to 1 in detention basins to allow emergency exit from basins. (Page 1–39)

Evaluation and Management of Highway Runoff Water Quality
Federal Highway Administration
June 1996

The water depth at the perimeter of a storage pool should be limited to that which is safe for children. This is especially necessary if bank slopes are steep or if ponds are full and recirculating in a dry period. Restriction of access (fence, walls, etc.) may be a consideration if land availability dictates… The side slopes for grassed area should be gentle enough to facilitate maintenance and to reduce safety hazards.

Stormwater Best Management Practice Handbook: New Development and Redevelopment
California Stormwater Quality Association
January 2003

Safety Considerations—Safety is provided either by fencing of the facility or by managing the contours of the pond to eliminate drop-offs and other hazards. Earthen side slopes should not exceed 3:1 (H:V) and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter should be fenced. (Page 6 of TC-22)

Conservation Practice Standard: Pond Sealing or Lining—Flexible Membrane Code 525A
Natural Resources Conservation Service
2006

Safety. Design shall include appropriate safety features to minimize the hazards of the structure. Warning signs, fences, ladders, ropes, bars, rails and other devices shall be provided as appropriate to ensure the safety of humans and livestock.

Time-Saver Standards for Landscape Architecture
Harris and Dines
1997

Figure 330-49 shows a typical cross section for a wet detention pond. Safety is a concern in pond design. Slopes along the shoreline should be gradual (1:4 or less) and/or protected by dense upland plantings. A 6000 mm (20 ft) flat shelf (1:10 slope or less) should be provided at the water's edge if possible. Safety fencing should be avoided, unless no other alternative is available.

Figure 330-49 is a sketch of "Recommended cross section for wet detention pond." It specifies a "dense barrier of upland woody plants" on a maximum 3:1 slope, with a 6:1 slope recommended for wildlife access. A "flat shelf (10:1 slope)" for "20 ft. typ." is specified, and the sketch shows thick vegetation on this shelf. From the shelf to the permanent pool depth, the slope is specified to be 3:1.

Site Engineering for Landscape Architects
Strom, Nathan and Woland
2004

Pool depth should be between 4 and 8 ft (1.2–2.4 m). Depths less than 4 ft can result in elevated water temperatures and resuspension of sediment due to surface disturbance. A level safety bench at least 10 ft (3 m) wide by 1 ft (0.3 m) deep should be provided around the perimeter of the pond to reduce potential safety problems.

Measures should be taken to reduce safety hazards that may be created by retention and detention ponds located in populated areas. Safety issues are related to access, large volumes of flowing water, constrictions created by pipes and culverts, and the intermittent nature of storm water storage. Safety measures may include installing fencing, avoiding steep side slopes or sudden drops, minimizing constriction points, and covering outlets with properly designed grates. As a minimum, the construction of detention and retention basins must meet all applicable federal, state, and local regulations, including state dam safety regulations where appropriate.

Urban Surface Water Management
Stuart G. Walesh
John Wiley & Sons, Inc.
1989

On-site safety provisions and devices that may be applicable to detention/retention facilities include the following:

1. Removable safety cages or grates mounted on the entrance to otherwise open storm sewers which flow either into or out of the detention/retention facility. Installation of safety cages or grates is critical where inlet and outlet pipes are connected directly to a long or extensive underground pipe system, that is, where such pipes are not simply short culverts beneath roadways or through berms. Cages or grates installed on the entrance to outlet pipes should be sloped so that water moving through the grate will tend to exert an upward force component on a person or object trapped against the grate. The total grate area should be large enough to reduce to safe levels drag forces at the face of the grate.
2. Guardrails or fences installed near the top edge of vertical or steep walls or slopes, especially along the top of headwalls and wingwalls at inlet and outlet structures.

3. Steps, including hand rails, strategically located on the periphery of a detention/retention facility if there are no or few mildly sloped areas to provide access to and exit from the lower areas of a detention/retention facility.
4. Signs placed around the perimeter of a detention/retention facility to indicate its occasional use for storage of water.
5. Use of mild side slopes (e.g., 7 horizontal to 1 vertical or flatter) under water around the periphery of a retention pond.
6. Maximum lateral and longitudinal slopes on concrete cunnettes or trickle channels of 4 percent (about 0.5 in./ft) to minimize the possibility of falling on wet, slippery surfaces.
7. Positioning of active recreation areas such as ballfields and playgrounds away from busy streets, and locating these facilities so that they are easily visible from areas outside, but close to, the detention/retention facility.
8. Provision of rescue equipment, such as lifesaving rings and small boats, near retention facilities.
9. Freeboard above design stages.

[A summary of off-site safety provisions is provided, including such items as an emergency spillway, emergency downstream flow path, seepage collars on outlet pipes, cut-off trench, riprap, and controls on downstream development or land use.]

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The Journal of Dam Safety
"Hidden Dangers and Public Safety at Low-head Dams"
Bruce A. Tschantz
Kenneth R. Wright
Association of State Dam Safety Officials
Vol. 9, Issue 1, 2011

> Low-head dams, a.k.a. "killer dams" or "drowning machines," often present a safety hazard to the public because of their ability to trap victims in a submerged hydraulic jump formed just downstream from the dam. Most of these dams, normally producing vertical water surface drops ranging from one to a dozen feet, have been constructed across rivers and streams to raise the water level for the purpose of improving municipal and industrial water supplies, producing hydropower, and diverting irrigation water. Hundreds were built in the 1800s to power gristmills and small industries. Many have fallen into disrepair or been abandoned, posing dangerous conditions to the public. Kayakers, canoers, rafters, swimmers, and other water users are often unaware of the existence of hazards at low-head dams, and sometimes end up getting trapped and drowning in the strong recirculating currents. Although hundreds have been killed over the last four decades, few states regulate these dangerous structures because of their small heights. Moreover, state dam safety regulations focus primarily on structural integrity and prevention of failure, but they do not generally consider public safety issues at or around dams. (Page 8)