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Detention Basins for Water Quality Enhancement

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Detention Basins for Water Quality Enhancement

***Introduction*:**
Urbanization brings flooding problems and an increase in pollutant loads in surface runoff. The replacement or compaction of pervious surfaces, removal of natural vegetation and loss of natural depressions cause increases in peak flow rates and volumes of runoff. Storm water management can mitigate the negative impacts of urbanization through a combination of drainage structures such as detention/retention basins, channels, pipes, levees, streets, etc. The purpose of on-site detention/retention basins is to lower the risk of downstream flooding and reduce the size and expense of the overall public storm drainage system by having individual developments take responsibility for their own drainage.

Definition:
A "detention basin" is a man made or natural depression designed to store storm runoff temporarily, releasing it at a controlled rate until the basin is empty. For economic reasons, detention basins can not be designed for the most extreme runoff events; instead, they are commonly designed for a specified storm frequency.

A "retention basin" functions in the same general way as a conventional settling basin and is often used as a sedimentation basin for removal of pollutants from the storm water. During storm events, the basin receives runoff that is stored until it dissipates by infiltration and evaporation. In contrast to detention basins, a retention basin has no outlet but can have a weir for overflow.

Detention/retention basins can provide benefits by temporarily storing flood volumes and reducing pollutant loads in storm water runoff. The principal mechanisms with which detention can prevent pollutants from entering surface waters include infiltration into the vadose zone and separation of suspended solids by sedimentation prior to discharge of runoff. Studies have shown the principal pollutants in urban runoff are compounds that adhere to the surface of suspended solids. These commonly include phosphorus, heavy metals, and petroleum-based organic compounds. Adherence of these compounds to suspended particles indicates that sedimentation can be a very effective method in reducing pollutants and improving water quality.

Common Pollutants in Urban Runoff:
The following standard pollutants are commonly used to characterize urban runoff and have been adopted by the EPA (1983) for their National Urban Runoff Program:

1. TSS (Total suspended solids) - includes particulate matter and floating material such as oils and scum. Suspended solid concentrations found in urban runoff may be 2 to 3 times that found in domestic wastewater.

2. BOD (Biochemical oxygen demand) - Oxygen demanding material, includes degradable organic matter and certain nitrogen compounds that consume available dissolved oxygen as they are degraded. The biochemical demand of storm runoff is usually in the 20 to 30 mg/L range, almost the same as secondary treatment plant effluent.

3. COD (Chemical oxygen demand) - excessive plant nutrients in water, occurring as nitrates and phosphates.

4. TP - Total Phosphorous (as P).

5. SP - Soluble Phosphorous (as P).

6. TKN - Total Kjeldahl nitrogen (as N).

7. $NO_{2\&3}$ - Nitrite and nitrate (as N).

8. Cu - Total copper.

9. Pb - Total lead.

10. Zn - Total zinc.

Planning Considerations:
Permits: Certain governmental regulations should be met before work is started. These should be taken into consideration and made part of the planning process.

Storm Water Drainage: Individuals planning to construct a detention basin or other drainage system should approach the proper regulating agencies for construction requirements. Drainage design plans will need the approval of the jurisdictional agency through a permitting process in accordance with the existing drainage regulations. Most cities handle permitting for developments within their boundaries. Developments within the unincorporated area of Maricopa County must obtain permits from the Stormwater Drainage section of the Flood Control District of Maricopa County. A meeting should be arranged with the jurisdictional agency while planning is in the preliminary stage.

Floodplain: If any portion of the development lies within a delineated floodplain, a floodplain use permit will be required prior to start of construction. Floodplains generally consist of ponding areas (A and AH zones), areas of shallow flooding (AO zones with 1 to 3 feet anticipated flood depth), and riverine type flood zones (AE zones with known floodways and floodway fringes). Each jurisdiction has floodplain regulations that must be incorporated into basin designs. The Floodplain Regulations for Maricopa County provide detailed information on obtaining floodplain use permits.

NPDES Permits: The U.S. Environmental Protection Agency (EPA) requires a National Pollutant Discharge Elimination System (NPDES) General Permit in Arizona for storm water discharges associated with industrial activities including construction which disturbs 5 acres or more. The permit process involves filing a Notice of Intent (NOI), Storm Water Pollution Prevention Plan (SWPPP), Notice of Termination (NOT), and includes site inspection requirements. The Arizona Department of Environmental Quality (ADEQ) evaluates the application under EPA's supervision and issues a water quality certification to projects which meet the rules and statutes.

404 Permits: In accordance with the Clean Water Act, Section 404, any land clearing, excavation or fill affecting waters of the U.S. may require a permit from the U.S. Army Corp of Engineers. The permit is administered jointly by the Corp, EPA and ADEQ. ADEQ reviews the federal permit for state water quality compliance and issues a 401 Permit if the project is consistent with state statutes and rules. A 401 Permit must be issued before a 404 Permit. Information and a brochure are available from ADEQ Water Quality Division, Engineering Review Information Desk.

Factors to Consider:

Site Selection: Detention basins located near the source (known as source control) provide more flexibility on the downstream conveyance system. The basins can be constructed at onsite locations where pollutant loads are heaviest. Basins located at the downstream end of the watershed is known as downstream control. Appropriate basin sizing and the hydrologic impact of source vs. downstream control can be determined using suitable computer modeling.

Types of Detention Basins: The type of detention basin should be appropriate for the climate and should be determined during the planning stage.

1. Dry Basin: A dry basin is designed to completely evacuate all waters.[1] This is particularly appropriate in places where dry weather base flow can not be used to maintain minimum water levels such as Arizona and Southern California. Dry basins can be designed to hold runoff for short or extended periods. Those that hold runoff for any extended period are commonly called extended detention basins. Figure 1 shows a typical extended detention basin. In designing a dry basin, the following may be used as a guide:[2]

   a. Extend the flow length as much as possible between the inlet and outlet.
   b. Minimize short circuiting during the filling phase.
   c. For sedimentation to be effective, provide sufficient volume to capture as much runoff as possible.
   d. Extend its use and aesthetics during periods between storms.
   e. Provide features to enhance ease of routine maintenance.

2. Wet Pond:[3] A wet pond is a basin with a permanent pool of water, usually with rooted wetland vegetation along the perimeter. The permanent pool of water provides a quiescent volume for continued settling of particulate contaminants and uptake of dissolved contaminants by aquatic plants between storms. The wetland vegetation is necessary to improve removal of dissolve contaminants and to reduce the formation of algae mats. However, emergent vegetation is not allowed if retaining walls are used due to economy of space. The average depth of the wet pool is 3 to 9 feet. An improved wet pond includes a forebay for removing floatables and initial settling of sediments. Figure 2 shows a typical wet pond.

   Dissolved contaminants are removed by a combination of processes: physical adsorption to bottom sediments and suspended fine sediments, natural chemical flocculation, and uptake by aquatic plants. Reduction in dissolved fractions of phosphorous and some metals have been observed but does not necessarily mean they are removed in the pond. Some metals may be incorporated into the algae or absorbed into fine particulate matter which exits the facility in the effluent. In designing a wet pond, the following may be used as a guide:[2]

   a. Extend the flow length as much as possible between the inlet and outlet.
   b. Minimize the hydraulic surface loading during regularly occurring rainstorms.
   c. Prevent short circuiting of flow.
   d. Provide sufficient volume in the permanent pool to capture as much runoff as possible for quiescent removal between storms.
   e. Enhance conditions for biological treatment between storms.

SOURCE: Urban Storm Drainage Criteria Manual, Volume 3
Urban Drainage and Flood Control District
Denver, Colorado

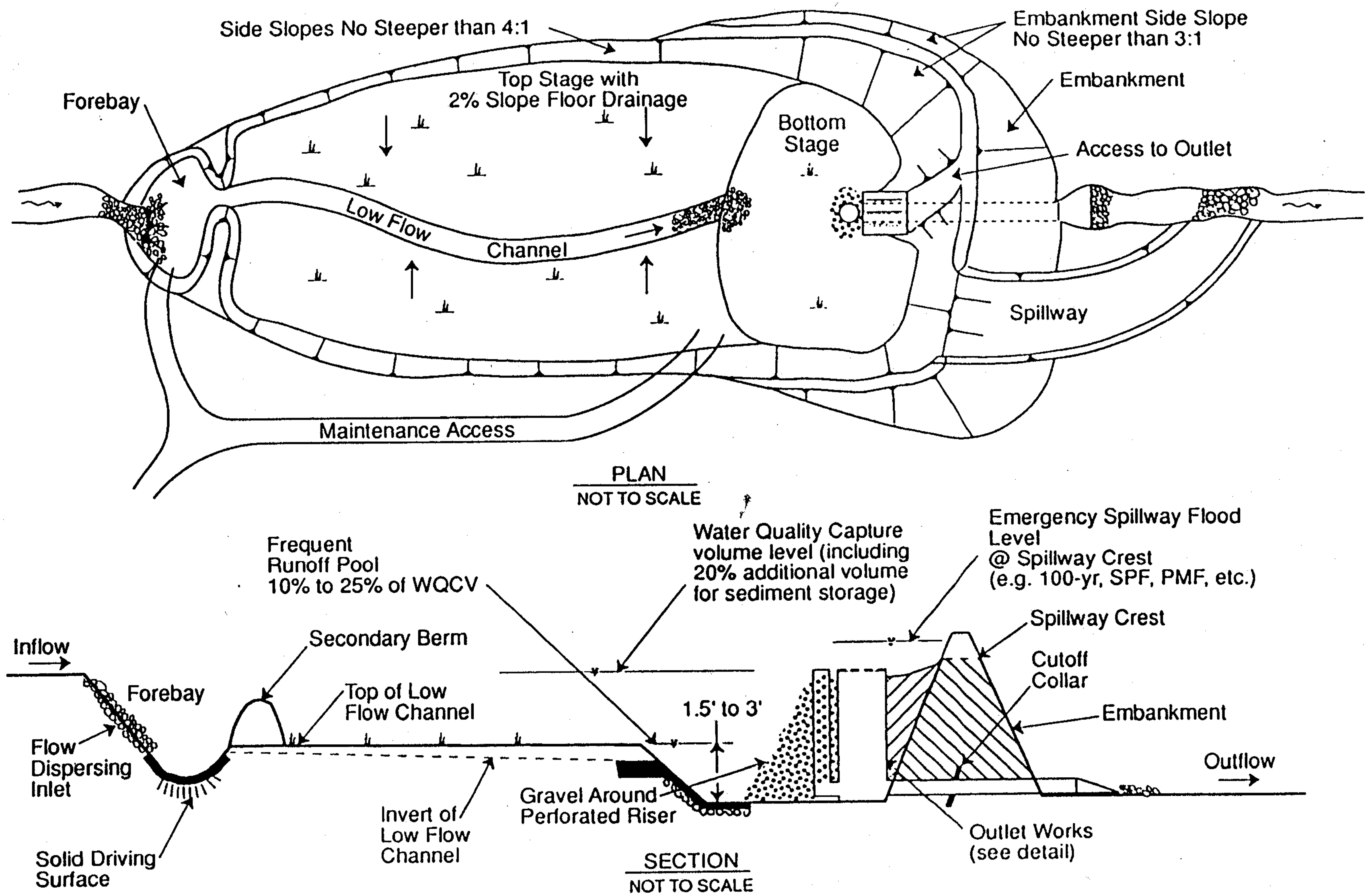

FIGURE 1: PLAN AND SECTION OF A DRY EXTENDED DETENTION BASIN

SOURCE: Urban Storm Drainage Criteria Manual, Volume 3
Urban Drainage and Flood Control District
Denver, Colorado

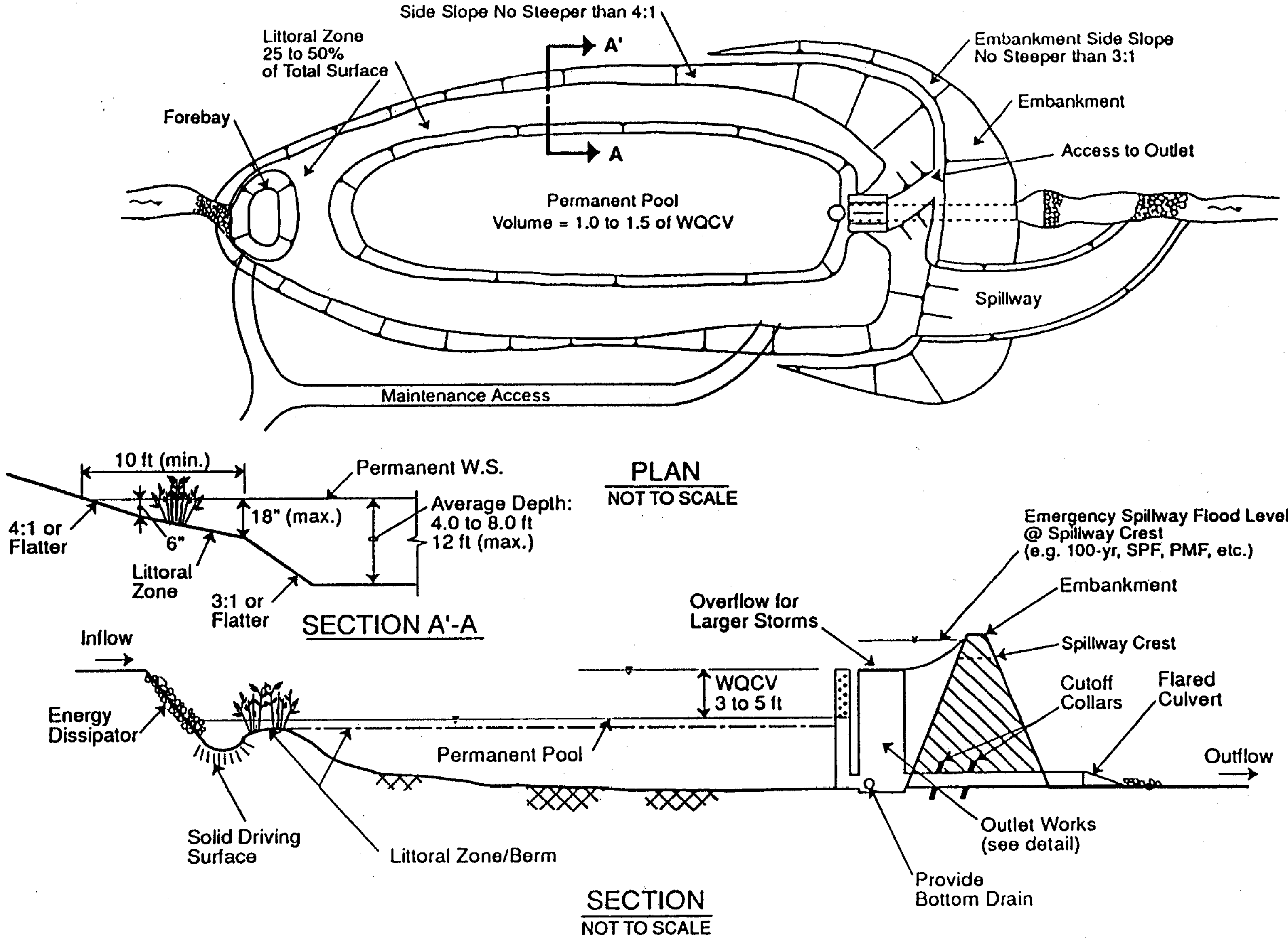

Figure 2: Plan and Section of a Wet Pond

Inflow: The nature, volume and inflow energy of water entering the basin ultimately determines the effectiveness of the basin at controlling flooding and removing constituent loads. The shape and size of the basin, combined with the density and energy of the inflowing water can result in short circuiting of flows between the inlet and outlet features. To avoid short circuiting problems, inflow energy can be reduced by installation of energy dissipating structures. A settling zone should be provided near the inlet by designing a deeper bottomed inflow structure and stabilizing it with soil cement, prefabricated slabs or concrete paving. The inflow structure should accomplish the following:[1]

1. Dissipate flow energy at the inflow.
2. Drop the inflowing water elevation when it enters the pond above the pond's water surface.
3. Accelerate diffusion of the inflow plume.
4. Provide protection against erosion.
5. Provide maintenance access for repairs to the inlet and removal of sediments.
6. Incorporate safety features to protect the public (i.e., gentle slopes, fencing or railing at vertical faces).
7. Be unobtrusive to the public by blending the inlet into the surrounding terrain.

Outflow: Detention basins are commonly designed to detain runoff for a development so that flows do not exceed pre-development levels. Many detention ponds are designed to control runoff from a single frequency storm, making them ineffective if greater storms occur. Detention basins designed to control a range of storm frequencies are characterized by staged outlets. A restricted outlet is placed at the lowest elevation of the outlet structure to provide longer retention. A restricted or staged outlet design is effective for treating the "first flush" of a storm. The first flush is generally considered the first one-half inch of storm runoff or runoff from the first 15 minutes of a storm. First flush runoff usually contains the majority of the sediment and pollutant load and commonly includes petroleum products, asbestos fibers from brake pads, tire rubber and fine metal dust from wearing parts. In designing outlets, the following factors should be considered:[1]

1. Design the outlet control orifice in a way that makes unauthorized enlargements impractical. Use of a pipe section that limits the flow rate is one method of achieving this.
2. Design the outlet for maximum safety to the public.
3. Whenever possible, design for the control of two or three levels of flow (e.g., 2- and 100-year; 10 and 100-year; etc.).
4. Provide maintenance access to the outlet.
5. If possible, use no moving parts or pumps as an outlet.
6. Use massive components to reduce damage from vandalism.
7. Provide erosion protection at the inlet and outlet ends of the outlet pipe.
8. Provide coarse gravel packing to screen out debris whenever a perforated riser is used in a dry detention basin.
9. Provide a skimmer type shield around a perforated riser in a wet pond to skim off floating debris.
10. Always design with maintenance and aesthetics in mind.

Effect on Groundwater: In a dry basin, water available for incidental groundwater recharge is limited to that available immediately following storm events. The storm water temporarily detained in the basin dissipates via infiltration and/or outflow. Due to the temporary nature of the water supply, recharge volumes are minor and likely have a minimal effect on groundwater, particularly in regions with deep aquifers. Communication between the infiltrating storm water and the water table are possible, however, and contamination of the aquifer with storm water pollutants can be a concern. Water quality enhancement features generally designed to protect surface waters can also be effective in reducing potential groundwater contamination.

Wet basins are commonly designed with relatively impermeable substrate to continously maintain shallow water levels in the basin. Consequently, infiltration volumes are low and groundwater effects are minimal.

Secondary Uses: Dry detention basins can be used as playgrounds, ball parks and picnic areas between storm events and can enhance the aesthetics of the area. Wet basins improve aesthetics by providing habitat for riparian wildlife, fish and aquatic organisms. Some wet basins can be used for recreation as well. Wildlife, however, can create unaesthetic conditons and local contamination due to animal wastes.

Design:
Detention Pond Design Steps for Water Quality Control:[4] Detention basins are typically designed for peak flow reduction of the design storm. To design a detention pond to incorporate pollutant removal, the following steps are recommended:

1. Determine the critical pollutant(s).
2. Determine design settling velocity based on design storm water inflow and particle sizes to be removed.
3. Calculate required retention time, flow length and resulting surface area from design settling velocity.
4. Determine infiltration rate of soil.
5. Select pond type: wet or dry.
6. Select outlet system: riser, underdrains and/or infiltration.
7. Calculate needed riser, height and pond depth by design storm considerations.
8. Select pond configuration: long and narrow, two stage or in series.
9. Determine pond locations and pollutant removal efficiencies needed through use of a storm water management computer model. Remember that the necessary pollutant removal efficiencies will vary with: (1) the pond location in the watershed, (2) the type of receiving water, and (3) the nature of the critical pollutant(s).

Maintenance Requirements:
Proper maintenance is an important consideration for effective performance of the detention basin. A well designed basin will not be able to reduce flood volumes and improve storm water quality if deposited sediments and debris are not removed promptly after every storm. Poorly maintained basins may even contribute to local and downstream flooding. Plants growing in the basin may need to be harvested and dying and decaying plants should be taken away. The basin floor may need periodic maintenance to ensure desired infiltration rates.

If the basin is used as a playground or picnic area, vegetation must be maintained and grass clippings and trash removed regularly. After storm events, the banks, slopes, inlet and outlet structures and rock riprap or soil cement protection should be inspected for erosion or damage and repaired promptly.

Adequate funding for maintenance is necessary in order to maintain the efficiency and life of the structure. For more information on maintenance of detention basins, please refer to Hydraulics, Volume II, Drainage Design Manual of Maricopa County.

References:

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3. Camp Dresser & McKee, et. al., *Treatment Control BMPs*, California Storm water Best Management Practice Handbooks, March 1993.

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