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Ditches or Biological Filters? Classifying Pollutant Removal in Open Channels

Archaeologists tell us that humans started digging ditches several thousand years ago, beginning with the extensive ditch networks dug by early civilizations to irrigate the "fertile crescent" of the Middle East. Ditch digging hasn't changed that much since then, although stormwater engineers now refer to them by fancier terms such as "open channels" or "grass swales." In reality, these terms are rather broad and imprecise, and fail to distinguish the potential differences in pollutant removal potential that various channel designs can have during small storms. In this sense, open channels can be classified into one of four possible categories, based on their hydrologic design. They are the drainage channel, grass channel, dry swale and wet swale (Figure 1).

The open channel design in most common use is termed a *drainage channel*, and is designed to have enough capacity to safely convey runoff during large storm events without erosion. Typically, a drainage channel has a cross-section with hydraulic capacity to handle the peak discharge rate for the ten year storm event, and channel dimensions (i.e., slope and bottom width) that will not exceed a critical erosive velocity during the peak discharge associated with the two-year storm event. Consequently, most drainage channels provide very limited pollutant removal, unless soils are extremely sandy or slopes are very gentle.

To achieve greater pollutant removal, stormwater engineers have recently employed *grass channels* to achieve greater pollutant removal. A grass channel is designed to meet runoff velocity targets for two very different storm conditions: a water quality design storm and the two-year design storm. During the "water quality storm," runoff velocity typically cannot exceed 1.5 fps during the peak discharge associated with the six month rainfall event, and the total length of the channel must provide at least 10 minutes residence time. In some regions of the country, grass channels are termed "biofilters" (Seattle METRO, 1992). To meet the water quality criteria, grass channels must have broader bottoms, lower slopes and denser vegetation than most drainage channels.

A third open channel is termed the *dry swale*. In a dry swale, the entire water quality volume is temporarily retained within the swale during each storm, allowing time for it to filter through 30 inches of prepared soil before it is collected by an underdrain pipe (see Figure 2). A dry swale is often the preferred open channel option in residential settings since it is designed to prevent standing water that makes mowing difficult and generates complaints. The swale is designed to rapidly dewater, thereby allowing front yards to be more easily mowed. Design methods for the dry swale can be found in Claytor and Schueler (1995).

The last open channel design is termed a *wet swale*, and occurs when the water table is located very close to surface. As a result, swale soils often become fully saturated, or have standing water all or part of the year once the channel has been excavated. This "wet swale" essentially acts as a very long and linear shallow wetland treatment system. Like the dry swale, the entire water quality treatment volume is stored and retained within a series of cells in the channel, formed by berms or checkdams. In some cases, the cells may be planted with emergent wetland plant species to improve removal rates.

Few stormwater treatment practices exhibit such a great variability in pollutant removal performance as open channels. In this article, 16 historical performance monitoring studies of "grass swales" were reanalyzed based on the open channel classification presented earlier to try to explain this variability. Ten of the open channels could be classified as "drainage channels" based on two criteria: they were designed only to be non-erosive for the two-year storm, and their particular combination of soil and slope did not allow significant infiltration of runoff into the soil profile. Site data and pollutant removal data are shown in Table 1(a).

The remaining six open channels were either explicitly designed as a grass channel, dry swale or wet swale, or had a combination of soils, slope and water table so that they effectively functioned as one of these three systems (Table1(b)). Given the relatively small number of open channels that met these criteria, they were lumped together as a single group, and are hereafter termed "water quality channels."

As a group, drainage channels provided negligible removal of most pollutants. For example, only four of nine drainage channels had a positive removal rate for suspended sediment, and all but two channels had phosphorus removal rates lower than 15%. Removal rates for all forms of nitrogen were consistently low or nonexistent. The three studies that examined the ability of drainage channels to remove fecal coliform bacteria