Article 113

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Runoff and Groundwater Dynamics of Two Swales in Florida

One of the most detailed assessments of the performance of grassed swales was conducted by Harvey Harper (1988) in Central Florida. The monitoring study looked at the changes in the quality of surface water, groundwater and sediments as runoff passed through two 200-foot-long swales draining an interstate highway.

While equal in length, the two swale system were remarkably different in character (Table 1). For example, the "wet swale" was constructed at about the same elevation as the water table, and consequently the surface of the swale system was ponded with at least a few inches of water throughout the year. As a result, wetland plants, such as pickerelweed, water pennywort, and panic grass, grew well across its entire length. The infiltration rate of the wet swale was effectively zero. Therefore, the major pollutant removal processes operating in the wet swale were settling and vegetative filtering. In many respects, it was more comparable to a pocket wetland than a grassed swale.

Table 1: A Tale of Two Swales—Comparative Attributes of Two Swales Monitored by Harper (1988) in Central Florida

Characteristic	Wet Swale	Dry Swale
Swale length	70 meters	70 meters
Underlying soils	sandy soils, < 5% silt clay	sandy soils < 5% silt/clay
Infiltration rate	effectively zero	13.4 inches/hour
Groundwater depth	0 to 2 ft above	2 ft below surface
Vegetation	wetland plants	sparse grass/weeds
Sideslopes	3 to 1 (h:v)	6 to 1 (h:v)
Longitudinal slope	1.8%	0.7%
Age of swale	23 years	16 years
Drainage area	1.17 acres	0.83 acres
Imperviousness	100%	70%
Time of concentration	9 minutes	45 minutes
Storms monitored	11 events	16 events
Groundwater interactions	groundwater moves into swale; creates shallow ponding	80% of runoff infiltrates through swale

The water table was at least two feet below the surface of the "dry swale." This swale had very sandy soils with an extremely high infiltration rate of 13.6 inches/hour. Only a rather sparse cover of annual weeds and grasses became established in the dry swale, even though it had been constructed some 16 years ago. Even so, it was estimated that at least 80% of the incoming runoff to the swale infiltrated into the swale before it reached the outlet. The dry swale also had a gentle slope, and a residence time approximately five times longer than the wet swale. The key pollutant removal process operating within the swale was infiltration of runoff into groundwater, and some sedimentation.

The comparative pollutant mass removal of each swale is depicted in Table 2. Both the wet swale and the dry swale were very effective in removing particulate pollutants contained in highway runoff. However, the nutrient removal capability of the wet swale was rather modest (total nitrogen 40%, total phosphorus 19%). Negative pollutant removal (or export) was noted for dissolved orthophosphate and ammonia. The wet swale also removed most trace metals at rates ranging from 30 to 90%. It should be noted, however, that the dissolved or soluble fractions of the metals were not removed as readily as the particulate fraction (see Table 3). More than 50% of the metals were found in soluble form at the outflow from the swale. It is speculated that the sandy, low organic matter soils did not provide many binding sites to capture soluble metals as they passed through the swale.

The dry swale was the best performer in removing pollutants, with mass reduction rates of 70% or greater for all parameters sampled. Much of the load reduction could be attributed to the infiltration of runoff into the soil of the dry swale. The effect of the swale in reducing pollutant concentrations of runoff that actually reached the outflow sampling point, however, was much less pronounced (Table 3). In fact, the wet swale consistently outperformed the dry swale in reducing the concentration of pollutants that traveled the entire length of the swale. The sparse vegetative cover in the dry swale apparently was not as effective in filtering runoff.

Groundwater and sediment sampling were conducted at both sites to determine the fate of pollutants that had been trapped in the swale. The monitoring indicated that most trace metals were indeed trapped in the upper five centimeters of swale soils, and did not migrate into nearby groundwater. Soluble nutrients, on the other hand, did move into groundwater, particularly at the dry swale site. Overall, however, both swales had only a modest impact on the quality of adjacent groundwater.

The two swales occupy two ends of a continuum of infiltration conditions that can occur within swale systems, ranging from zero to almost unlimited infiltration. Significantly, both swales in this low relief environment were at least moderately effective in removing pollutants in urban stormwater. The swales did have some similarities: neither had dense grass turf nor silty or clay soils that might have provided better exchange sites.

Harpers's study provides further evidence of the value of long swales in treating urban stormwater, and indicates the importance of the water table in designing swales in sandy, low-relief environments.

—***TRS***

Reference

Harper, H. 1988. *Effects of Stormwater Management Systems on Groundwater Quality*. Final Report. Environmental Research and Design, Inc. Prepared for Florida Dept. of Environmental Regulation. 460 pp.

Table 2: Comparative Pollutant Removal Performance of Two Swale Systems (Percent Pollutant Mass Removed)

Pollutant	Wet Swale (%)	Dry Swale (%)
Suspended solids	81	87
BOD (five day)	48	69
Total nitrogen	40	84
Total Phosphorus	17	83
Nitrate-N	52	80
Organic nitrogen	39	86
Ammonia	(-11)	78
Ortho-phosphorus	(-30)	70
Cadmium	42	89
Copper	56	89
Chromium	37	88
Lead	50	90
Nickel	32	88
Zinc	69	90

Table 3: Mean Concentration Reduction Through Two Grassed Swale Systems in Central FL

Water quality parameter	Concentration reduction (%)		Outflow concentration	
	Wet swale	Dry swale	Wet swale	Dry swale
Suspended solids	81	59	6.4 mg/l	28 mg/l
Dissolved solids	3	(-3)	114 mg/l	91 mg/l
Total nitrogen	40	21	0.96 mg/l	1.7 mg/l
Total phosphorus	17	13	0.19 mg/l	0.5 mg/l
Nitrate-N	52	(-2)	0.19 mg/l	0.5 mg/l
Ammonia-N	(-11)	(-8)	0.10 mg/l	0.15 mg/l
Ortho-phosphorus	(-30)	(-48)	0.08 mg/l	0.24 mg/l
Chlorides	(-110)	0	21 mg/l	8 mg/l
Cadmium	41	51	5 µg/l	4 µg/l
Copper	56	54	17 µg/l	36 µg/l
Chromium	37	60	8 µg/l	8 µg/l
Lead	50	49	112 µg/l	705 µg/l
Zinc	69	51	53 µg/l	140 µg/l
Nickel	31	60	32 µg/l	11 µg/l