Mitigating The Environmental Impact of Best Management Practice Stormwater Management Systems

Rodney L. Horton
1037 Shearwater Dr., Audubon, PA 19403-2011, horton_rl@verizon.net

Mitigating the environmental impact of best management practice stormwater management systems is the necessary way of future development. This is the 5th in a series of rudimentary articles that are intended to produce environmentally sound development and mitigate the environmental damage of past and current best management practice stormwater management systems. (They are available on the internet at www.valleyforgetu.org, with an appropriate disclaimer.)

The basic change proposed is to quantify “best” in terms that are clear to all involved. Current best management practice specifies constraints on runoff flow velocity. DEP's proposed best management practice specifies constraints on runoff flow volume. Both are applied to major events and mishandle minor events, Emerson, ref. 1. The adverse environmental impact is significant for all events. Both have been promoted as “best”, without defining good or better.

The basis of the my proposed solution, the capitalist management plan (CMP), places dollar values on the elements of the hydrologic cycle, Figure 1. The function of stormwater management systems is to manage the hydrologic cycle of events. The capitalist approach is to get the best return on investment. A current example of this type of implementation is the Pennsylvania Department of Environmental Protection's Montgomery County office building at 2 Main Street, Norristown. (There a 5000 gallon cistern acquires roof rainwater and stores the water, having potential value of $643.00, for subsequent use on roof gardens, etc. It would seem that DEP does know the value of water.)

Hydrologic Cycle Values

The conventional depiction of the hydrologic cycle is pleasant, reassuring, and misleading. It shows what we've always known. The item values in the hydrologic cycle, Figure 1., highlight their relative importance. The values are based on a 5 cents per kilowatt hour cost of electricity and the local $4.15 per thousand gallons for public water.

Evapotranspiration, valued at $3,500 per acre inch, dominates the item values, Horton, ref. 2. Evapotranspiration is a heat transfer process. Moving heat, via water vapor, from a surface, into the atmosphere where it is released. Public water is valued at $110. per acre inch. Infiltration might be acquired for public use. Depending on the probability of infiltrated water being ultimately used, its value may range from $0.11 to $110. per acre inch.

Rain, the most delightful of the precipitation events, begins its descent to earth from cloud level where it is significantly colder than the earth surface. To set the cooling value of rain at $35. per acre inch assumes a temperature differential of 10.54 degrees Fahrenheit between the rain and the surface. (The 10.54 value was selected to produce the easy to remember 100 to 1 ratio relative to evapotranspiration.

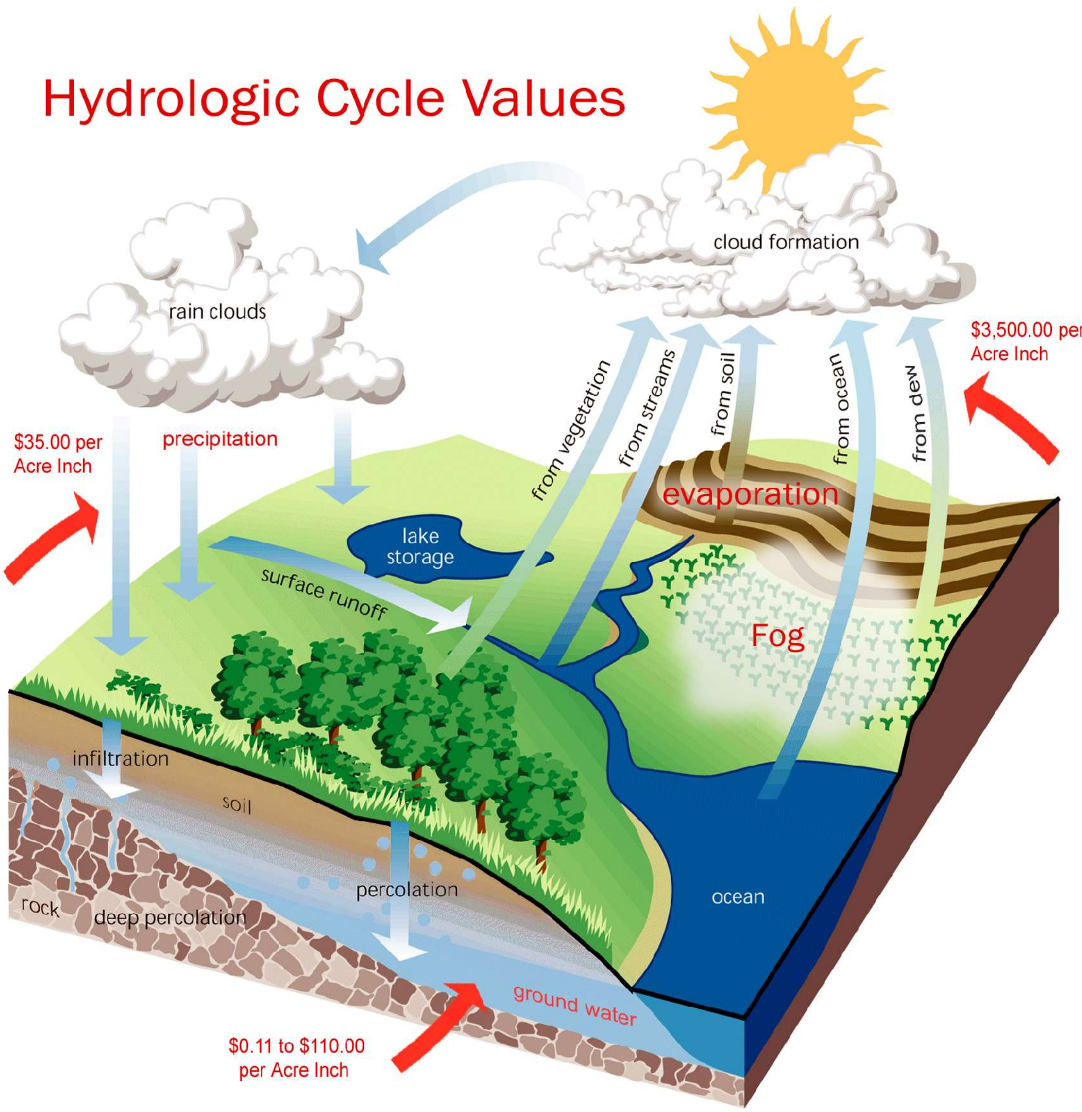

Figure 1. Hydrologic Cycle Values

The value is in the appropriate range to produce observed rain event temperature changes at the Hale Eddy and Trenton gages on the Delaware River.) Hail, sleet, and snow can be assigned the same value for these casual evaluations.

Runoff is the unwanted discard. When discarded it is valueless or at best a lost opportunity. When it is collected (in DEP's Cistern) it can become $3500 per acre inch evapotranspiration from roof gardens or less valuable graywater. (It can be captured for subsequent use in mitigation applications where it becomes more valuable than public water.)

It is important to note that the values of evaporation and precipitation are values received from natural processes (although we can implement areas (acres) for evaporation) while groundwater values must be purchased (and paid for) prior to use.

Weather Systems and Hydrologic Cycle Values

Weather systems move about the earth in response to thermal conditions that develop as the systems move. As they move from here to there they are influenced by where they have been, where they are and where they are going. A system arrives with a “nominal” load of moisture plus an increment that evaporated during the rain where it was. The event occurring here is a function of how much arrived. The preceding comments apply to where the system is going.

The events are processed by the stormwater management systems where it has been. The results become the follow-up weather that will arrive ”here”. Runoff and infiltration cannot be transported to another site. Post-event evapotranspiration can be transported to another site. There it will precipitate and have value. It will be handled by the stormwater management system, and acquire the value attainable in that specific system, Horton, ref. 4. (This is a “self full-filling do unto others” opportunity in that you maximize the value you receive from the rain event as you maximize the value you send to your neighbors.) Flushing runoff from the site and infiltrating gathered water produce little value and sends nothing to others.

In the past the dew process has been ignored. Inches of rain have greater value than tenths of inches of dew merely because of its greater volume. The dew process requires humidity and the temperature to drop below the dew point, similar to becoming a cloud. These conditions are not met at hot dry sites. Thus dew events are indicators of environmental quality. Adverse stormwater management systems produce few dew events because the water is disposed of before it can be evaporated. A measure of successful environmental mitigation would be an increase in the frequency of dew events.

Environmental Impact Assessment of Stormwater Management Systems

The environmental value of rain events occurring on sites having stormwater managed by each of four stormwater management concepts was addressed in Horton, ref. 5. Their performance was compared with the value from a pristine forest of colonial times, see Figure 2. The colonial forest has CN = 55, the Rate of Flow Constraint BMP has CN = 78, a “low impact development” version has CN = 68, the Volume Constraint BMP has CN = 78, and a Capitalistic Management Plan (with Kalb = 1.1, Ket = 1.1) site has CN = 58.

In Horton, ref. 4, an expansive approach is taken to account for the impact on adjacent watersheds and the ocean. The environmental value of a rain on a site is computed as the sum of the values of the site water budget in response to the rain. The site water budget, rain value equals the sum of runoff value, of recharge/infiltration value, and of evapotranspiration value. Evapotranspiration value is $3500. per acre inch, based on $.05 per kWh and 1054 btu/lb. Infiltration value is $110. per acre inch corresponding to local water rates($4.15 per thousand gallons). Runoff value is negative$1805. per acre inch assuming it could have been either infiltration or evapotranspiration. It is negative since it is a lost business opportunity.

The runoff vs rainfall was obtained from the TR-55 manual for curve numbers of interest for hydrologic soil group B. The expressions defining the curves were entered in a spreadsheet. Curve numbers of

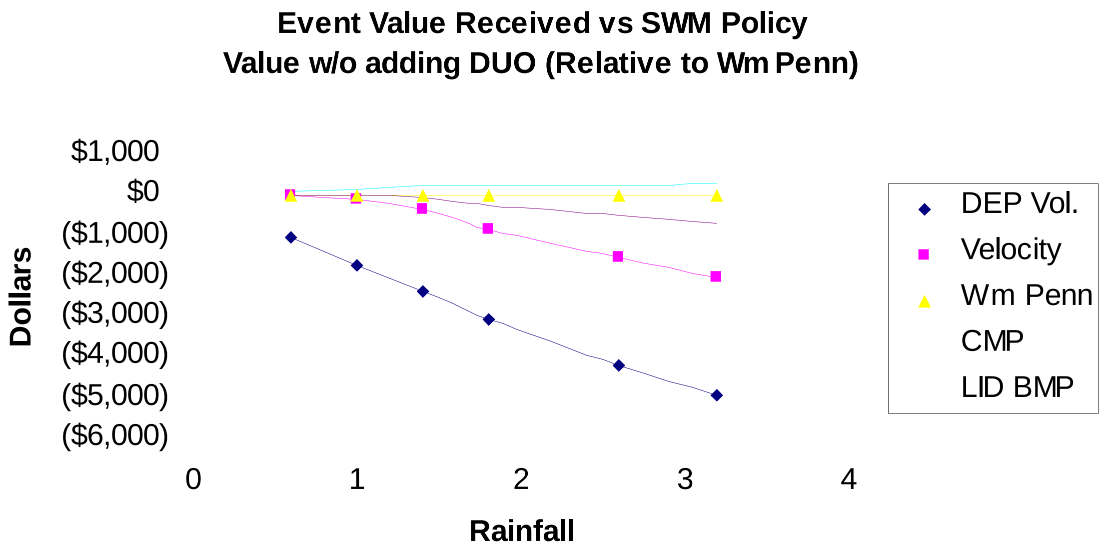

Figure 2. Event Value (dollars/acre) versus Rainfall (inches)

interest were solved for to obtain exact values, eliminating the need to interpolate.

The site water budgets were calculated for rains of 0.6, 1.0, 1.4, 1.8, 2.6 and 3.2 inches. The last two values are the 1 year and 2 year rain events.

Figure 2. Shows the value of rain events for all systems. The Volume concept has the lowest value of all as the concept states “Infiltrate so that runoff for up to the two year storm is not increased.” The Rate of Flow Constraint BMP has higher value than the Volume concept. The Low Impact Development Rate of Flow Constraint is better yet, as it includes natural areas for achieving evapotranspiration. All receive less value per rain than the pristine Wm. Penn woods. The top valued plan is the Capitalistic Management Plan with its requirement that post-development evapotranspiration be 10% greater than pre-development. It requires storing water for subsequent use. It beat Wm. Penn's Pristine woods

WERA Concept

Mitigation of the environmental losses of “best management practice” can be achieved through Watershed Environment Recovery Areas (WERA) that are dedicated, and financed, to achieve specific goals. With environmental cooling, i.e. evapotranspiration, over 30 times as valuable as infiltration it is appropriate to have evapotranspiration the principal goal of WERA sites, Horton, ref. 3. The basic idea is to dedicate an area to be watered for the express purpose of having the water evapotranspire. Buying commercial water from Aqua America for $110. per acre inch and disbursing it to evaporate for $3,500. worth of cooling produces a profit of $3,390.

Dedicated pumping systems, Table 1, can provide untreated water for as little as $0.69 per acre inch at a 100 foot dynamic head to $3.44 at a 500 foot dynamic head. Costs vary with the height the water must

	Pumping Costs and Values				0.06 CostpKWh:		
TDH	100	300	500		HOURS	1000	
GPM	PowerCost			Gallons	Acre In.	ET Value	Half Recharge Half ET
10	$15.19	$45.58	$75.96	600,000	22.10	$77,335.86	$38,667.93
20	$30.38	$91.15	$151.92	1,200,000	44.19	$154,671.72	$77,335.86
30	$45.58	$136.73	$227.88	1,800,000	66.29	$232,007.58	$116,003.79
40	$60.77	$182.31	$303.84	2,400,000	88.38	$309,343.43	$154,671.72
50	$75.96	$227.88	$379.81	3,000,000	110.48	$386,679.29	$193,339.65
100	$151.92	$455.77	$759.61	6,000,000	220.96	**$773,358.59**	$386,679.29
200	$303.84	$911.53	$1,519.22	12,000,000	441.92	$1,546,717.17	$773,358.59
300	$455.77	$1,367.30	$2,278.84	18,000,000	662.88	$2,320,075.76	$1,160,037.88
400	$607.69	$1,823.07	$3,038.45	24,000,000	883.84	$3,093,434.34	$1,546,717.17
500	$759.61	$2,278.84	$3,798.06	30,000,000	1104.80	$3,866,792.93	$1,933,396.46
600	$911.53	$2,734.60	$4,557.67	36,000,000	1325.76	$4,640,151.52	$2,320,075.76
800	$1,215.38	$3,646.14	$6,076.90	48,000,000	1767.68	$6,186,868.69	$3,093,434.34
1000	$1,519.22	$4,557.67	$7,596.12	60,000,000	2209.60	$7,733,585.86	$3,866,792.93

Table 1. Pumping Costs and Evapotranspiration Value vs Head and Pumping Rates
(courtesy of R. Botz, Peerless Pumps, rbotz@peerlesspumps.com)

be pumped to move it from the source to the WERA. Scavenge water from high flow events, short-term store it for programmed use. Capital costs are site specific and dependent on the particular features of the site water storage and disbursing system. (Pumping sites near power plants could receive reduced rates, pumping could be scheduled for “off peak hours”.)

Mitigation of In-stream Environmental Damage

In-stream environmental damage consists of undercut banks caused by high velocity water. Damage occurs as the water velocity and volume are increasing. The flow scours away obstructions, gravel, and silt which are subsequently deposited downstream, destroying the food supply and habitat. Environment warming has increased the intensity of rain events. The old-time gentile soaking rain lasting a few hours had the impact of a sequential series of nominal events that the headwater areas could handle. Todays intense rain events are effectively several nominal events occurring simultaneously. They deliver raging flow for a short time.

Mitigation requires reducing the flow rate and volume during the event. This requires catching stream flow, piping it to cisterns, and delaying its redistribution to the watershed.

Crabby Creek, a first (or second) order stream in the Valley Creek, Chester County, PA watershed where wild trout spawning habitat is being destroyed and warmed. It would benefit from the installation of three sets of “cisterns” in its headwaters. The design of the release area should accommodate some infiltration. Cistern catch locations of N40 2.904 W75 28.186, N40 2.820 W75 27.936, and N40 2.997 W75 27.830 would intercept runoff before the junction of the three valleys. (The runoff is coming from 1950's era development.) The cisterns are 400 yards south of the railroad tracks.

North of the tracks Crabby passes through a swamp where it is joined by runoff from steep-slope development and recreation fields. The combined waters have ravaged the creek bed, uncovering the sewer line necessitating repairs. (A project to address the problem is underway.)

Little Valley Creek flows east along route 202 at the foot of the south slope of the valley. It is at the edge of development that produced a watershed that is 25% impervious surface. It is in need of cisterns to catch and delay the release of the runoff to the stream. Over three miles of railroad grade with adjacent riparian buffer brush lots are available to receive and evaporate the runoff. Each of the valleys offer the opportunity to collect runoff.

Blue Marsh Lake, above Reading, PA, feeds the Tulpehocken Creek, and the Schuylkill River. It is surrounded farms and state game land 280. Cisterns at N40 25.090 W76 7.780 could feed a WERA a 0.55 mile long, 100 yards wide on both sides of Bright School Rd, 40 total acres. The nominal head for pumping this site is less than 300 feet. A thousand hours of pumping costing $455.7 could produce three quarters of a million dollars worth of environment cooling. After receiving that cooling the game land would happily wave goodbye to the six million gallons of water vapor that would become dew or 221 acre inches of rain. The recipient of the rain would receive $7,000 cooling on impact and the opportunity to acquire $700,000 of evaporative cooling, or $350,000 of cooling plus some infiltration.

The Tulpehocken (Tully to fishermen) below the Blue Marsh Dam is a tailwater fishery. Stream flow is managed to accommodate lake recreation activities, the water company, weather systems, and perhaps, fishermen. Often the flow decisions produce abysmal fishing as water is flushed to accommodate expected events. The WERA could be tool useful in moderating the flow variations in the tailwater fishery.

Graterford Prison has significant farm acreage. The Perkiomen Creek is adjacent and there are opportunities for catching runoff from an on site stream. Pumping costs could be less than for Blue Marsh.

The Susquehanna River below Harrisburg, has plenty water and (off-peak) power to support hundreds of acres of WERA. The opportunities there make far outweigh those at Blue Marsh Lake.

Mitigating Valley Creek's Imperviousness

The Valley Creek watershed's 25% impervious surface presents a serious environmental problem. The impervious area absorbs more heat and generally does not retain water for evaporative cooling. The workload that would be placed on the pervious area to maintain a nice average environment would be high. The modifications imposed on many fine residences would not be acceptable to residents.

The problem needs to viewed, examined, made public. The basics: during each event the watershed loses a quarter of the value of the event, from five square miles of impervious surface. How can the remaining fifteen square miles pick up the slack. Each must do 1/3 more! That is of course not possible, but it indicates the nature of the solution. Cisterns, groups of cisterns, that store water have the opportunity to do the job during the time between events.

It is a challenge to consider storing rain from five square miles. It may be prudent to wait a couple years until we reach 30% impervious. Then we could handle rain from six square miles, on even less space.

References

1. Emerson, Clay H., Evaluation of the Additive Effects of Stormwater Detention Basins at the Watershed Scale, MSEE Thesis, August 2003, Drexel University, Philadelphia, PA

2. Horton, R. L., Environment Recovery using Enhanced Best Management Practices, http://www.valleyforgetu.org/protect/whitepapers.html, ,Project, Research and Papers; also a poster at Villanova Stormwater Management Conference, Villanova, PA, October 2003

3. Horton, R. L.,Managing Watershed Environment Recovery – an economic model, http://www.valleyforgetu.org/protect/whitepapers.html, ,Project, Research and Papers; also a poster at Schuylkill River Watershed Conference, Feb. 2004

4. Horton, R. L., Cooling of watersheds via “Catch and Release” Runoff Management, http://www.valleyforgetu.org/protect/whitepapers.html, ,Project, Research and Papers; also a poster at Wild Trout VIII, Yellowstone National Park, September 20-22, 2004

5. Horton, R. L., Environmental Impact Assessment of a Volume Stormwater Management Policy, http://www.valleyforgetu.org/protect/whitepapers.html, ,Project, Research and Papers; slides presented at Watershed Summit on the Delaware, Wilmington, Delaware,Sept. 13-15 Sept. 2004