INNOVATIVE USES OF ENGINEERED SOILS AND FUNCTIONAL LANDSCAPES IN STORMWATER MANAGEMENT AND LAND PLANNING

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Abstract. Soils are the essential link to both water quality and quantity. "Water loss, contamination, and purification are all directly affected by the soil. When soil no longer stores nutrients, regulates water flow, or filters chemical and biological contaminants, water quality is directly compromised (USCC, 1997). A soils management strategy, like the Clean Air and Water Act, is needed to address the fundamental problem of the loss of soil functions as we turn natural forested or grasslands into urban landscapes. A soil and landscape system should be viewed as a tool for stormwater infiltration, water conservation, and pollution control. Properly functioning soils have the potential to simultaneously improve the control of stormwater runoff, conserve water during the low-flow summer period, and reduce pollution associated with runoff. Currently, the permitting process does not recognize the value of a deep and permeable soil system as a stormwater management tool. A new approach to "Engineered Soils" (soils that perform to a measure of permeability, stability, and fertility) should be adopted to begin reversing this trend in land development (CH2MHILL, 2000). As this information is presented it will become evident that a relatively modest investment in more robust soil and landscape systems can have a leveraged beneficial effect on soil and water quality.

INTRODUCTION

Soil degradation and water pollution are widely recognized as environmental problems. Experts disagree on the rate of topsoil loss or the decline in water quality, but few deny that these processes are a threat to a sustainable future. According to the U.S. Department of Agriculture, the United States loses more than 2 billion tons of topsoil through erosion each year. Monsanto CEO Robert Shapiro argues that we've lost something on the order of 15% of our topsoil over the last 20 years, that our irrigation practices are increasing salinity of the soil, and that current fertilizer and pesticide practices are not sustainable (USCC, 1997). Over the last 200 years we have lost 1/3 of our nation's topsoil and continue to lose it ten times faster than it is being formed (Rod Tyler, 2001). The decline in water quality and quantity is often viewed in isolation from the decline in soil. The decline and degradation of soil starts a chain reaction with profound consequences for water quality.

BACKGROUND

Interest and concern have been growing about the poor quality of soils that follow disturbance from development and the resulting loss of environmental functions that native soils and their related vegetation systems typically provide. This points to a need for an effective, affordable, nonpolluting alternative to the energy-intensive engineering processes that we are currently using to manage stormwater. One significant function of the soil is water storage. Storage of water in the soil reduces surface runoff and erosion and retains water on-site for infiltration and use by soil microorganisms and plant life. Another important function of the soil is the cleansing of water and the binding of chemicals that could become water pollutants. Compost-amended soils filter out urban pollutants such as hydrocarbons and heavy metals. Functionally, the soil acts as a giant biofilter (CH2MHILL, 2000). Water loss, contamination, and purification are all directly affected by the soil.

Examination of the Stormwater Management Process

Let's examine what happens as we turn forest and grassland into urban development. Dr. Bruce Ferguson, (University of Georgia) who has been described in Stormwater Magazine as an expert on stormwater infiltration, explains it this way: In healthy, predevelopment landscapes, precipitation represents the inflow that infiltrates into vegetated soil, providing evapotranspiration to sustain the ecosystem; percolating through the filtering soil to maintain a continual, moderate base flow; providing regular recharge to ground water supplies; and discharging moderately into surface waterways. Urban development, in contrast, has created the “disease” of runoff. By creating impervious surfaces and denying access of precipitation to the soil, we have created more than the problems of point and non-point source pollution. Conventional stormwater management, by rushing water downstream, also aggravates flooding; reduces groundwater, base flow, and drinking water supplies; and encourages erosion, flooding, and habitat destruction (Kathleen Webb Tunney, 2002).

In native forests, approximately 40% of the rainfall returns to the atmosphere through evapotranspiration. At least 35% of the rain is infiltrated into groundwater and the rest is detained in interflow through the upper soil layers (National Engineering Handbook, 1998). Almost none runs off the surface. This function of soils and forest reduces damaging storm peaks, while recharging groundwater to provide “base flows” of cool water to streams in the summer.

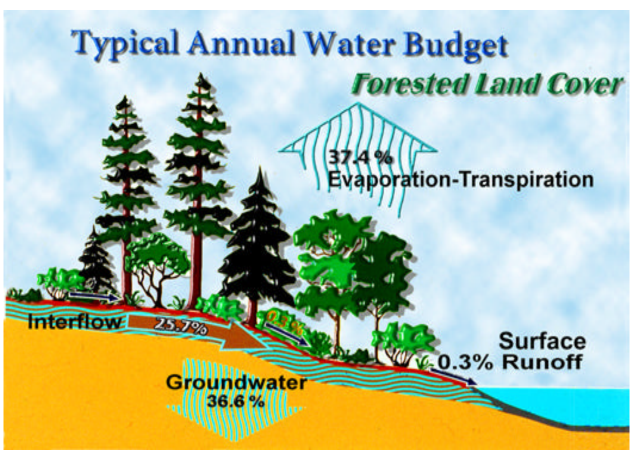

Figure 1. Natural Conditions.

By comparison, in developed urban areas, where soils have been stripped and compacted, less than 30% of rainfall is returned to the atmosphere through evaportranspiration, and less than 16% is detained and infiltrated into groundwater (National Engineering Handbook, 1998). Impervious surfaces like roads and roofs detain none at all. The result is extremely fast runoff during storms, which erodes surface soil and stream banks, carries urban pollutants into streams, destroys aquatic life, and leaves beds used for spawning choked with sediment. Groundwater is not recharged;

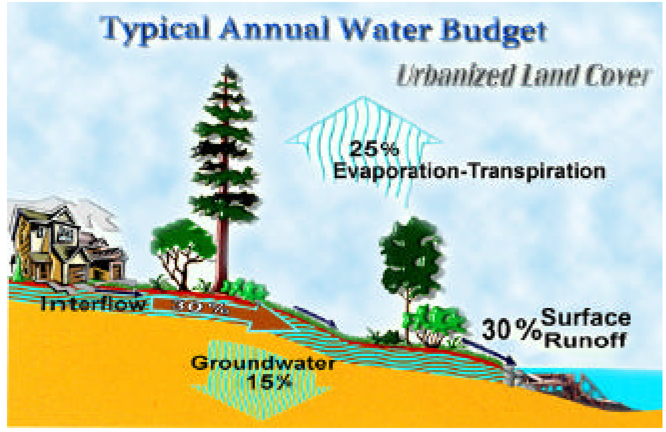

Figure 2. Developed Conditions.

therefore, summer base flows are reduced, leaving streams shallower and warmer.

Conventional stormwater management practices using end-of-pipe technology have significantly altered the natural hydrology cycle and continue to contribute to our water quality and quantity problems. Communities in highly developed urban areas like Atlanta are struggling with the economic reality of funding aging and ever-expanding stormwater infrastructure. Impervious surfaces created during construction combined with our conventional stormwater management practices have contributed to issues, including combined sewer overflows (CSOs), National Pollutant Discharge Elimination Systems (NPDES) Stormwater Phase II permits, Total Maximum Daily Load (TMDL) permits, Non-point Source Program Goals, and other water quality standards.

Stormwater practices, such as retention/detention ponds, only provide a degree of mitigation to land development. The use of ponds is a recognition and acceptance that site hydrology has been drastically modified, and an increase in the volume of stormwater runoff is inevitable. These ponds, like silt fences, are becoming a regular part of the Georgia landscape and bring with them a whole new set of environmental problems. Safety and environmental concerns have been raised with stormwater ponds and more recently the issue has been the potential of these ponds to become mosquito breeding grounds.

Low Impact Development (LID) Techniques

A more environmentally sound technology, Low Impact Development is gaining ground in many parts of the United States that can and should be used as a bellwether for urban growth in Georgia. One of the primary goals of LID design is to reduce runoff volume by infiltrating rainfall water into soils and groundwater, evaporating rainwater back to the atmosphere after a storm, and finding beneficial uses for water rather than exporting it as a waste product down storm sewers. At the heart of LID is the fundamental principle of using functional soils and landscapes to infiltrate, filter, store, evaporate, and detain runoff as close to the source as possible. The idea is to mimic a site's predevelopment hydrology and offset impervious surfaces using cost effective landscape features located at the site. Not only do these techniques provide stormwater benefits, such as groundwater recharge and cleaner streams, but they also increase the urban forest, reduce the urban heat island, improve air quality, reduce stream pollution, and provide a more aesthetically pleasing and sustainable environment. Case studies and pilot programs show at least a 25% reduction in cost associated with site development, stormwater fees, and maintenance for residential developments that use LID techniques. This savings is achieved by reductions in clearing, grading, pipes, ponds, inlets, curbs and paving (LID Development Center, 2002).

Impervious Surfaces

Generally, scientists say that a stream can remain healthy if the amount of paved over surface in its watershed, or drainage area, is less than 10%. A stream that has 10-25% of its drainage area paved over clearly shows signs of degradation, and when 25% or more is imperviousness its generally very difficult for the stream to recover (Jim Harrison, 2002). After this level of impervious surface stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases. As impervious surfaces in a water shed increase, infiltration and evapotranspiration both drop substantially. To put these numbers into perspective, typical total imperviousness in medium density, single-family home residential areas ranges from 25% to nearly 60% (NRDC, 2001).

Imperviousness is an essential factor to consider in stormwater management, both quantitatively and qualitatively. Reducing imperviousness in any and all ways possible translates into a direct reduction in volume of stormwater runoff generated and in reduction of pollutants generated. Infiltration of stormwater runoff is the only process that reduces the overall volume of stormwater exiting a developed site. A major contributor to impervious surfaces in urban development is the current practice of soil stabilization and landscaping. Soils that remain after development has occurred have been stripped of vegetation and organic matter and are largely dysfunctional. During land disturbance activities measures must be taken to stabilize the soil. This is usually accomplished by vegetative means with little regard for the underlining soil. The prevailing practice in most development today is to provide a permanent vegetative cover by placing sod or seed over highly compacted clay or subsoil just before sale or occupancy of a new property.

Figure 3. Construction Impacts on Soils.

The combination of soil compaction and loss of organic matter has several undesirable consequences:

- Infiltration capacity of the site is significantly reduced.
- Rainwater more quickly runs off into local streams increasing erosion.
- The rate of groundwater recharge decreases.
- The availability of subsurface water to plants is reduced.
- Increased runoff volume and frequency carries pollutants such as pesticides, fertilizers, and animal waste into local streams.
- Homeowners have to apply pesticides, fertilizers and irrigation water in increasing amounts in order to maintain the landscapes that are essentially on life support.

Engineered Soils

A new approach using "engineered soils" (soils that perform to a measure of permeability, stability, and fertility) should be considered to begin reversing this trend in land development. When soils begin to be viewed as a hydrologic tool, the possibilities for improved urban hydrology become achievable. While it may not always be possible to preserve green space, it is possible to mimic pre-development conditions. A soil and landscape system that addresses depth, compaction, percent organic matter content and permeability is the best mitigation for disturbance and removal of native soils and offers the best chance to mimic pre-development hydrology site conditions (CMH2Hill, 2000). Hydrology models and runoff curve numbers for different soil types exist today that would allow designers and architects to use functional landscapes as a flow control system. The problem is that there are no incentives to encourage their use and civil engineers are not working with the landscape architects in the design of these types of infiltration practices.

Soil Hydrology and Functional Landscapes

The NRCS Technical Release 55 (TR-55) model presents simplified procedures to calculate storm runoff volume, peak rate of discharge, and storage volumes. This model begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff curve number (CN). CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Infiltration rates of soils vary widely and are affected by subsurface permeability, as well as surface intake rates. Soils are classified into four hydrologic soil groups (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Group A soils have low runoff potential and high infiltration rates where Group D soils have high runoff potential and very low infiltration rates (Prince George's County, Maryland, 1999). While not every soil can be perfectly defined by the values for permeability and percent organic matter, each of the four basic hydrologic soil groups have recognizable or typical runoff performance characteristics that are functional for soil type classification.

Table 1. Representative Lid Curve Numbers

LAND USE/COVER	CURVE NUMBER (CN) FOR HYDROLIC SOILS GROUPS (%)			
HYDROLIC SOIL GROUPS (HSG)	A	B	C	D
IMPERVIOUS AREA	98	98	98	98
GRASS	39	61	74	80
WOODS (FAIR CONDITION)	36	60	73	79
WOODS (GOOD CONDITION)	30	55	70	77

A- Sand, loamy sand, or sandy loam
B-Silt loam or loam
C-Sandy clay loam
D-Clay loam, silty clay loam, sandy clay, Silty clay or clay
HSG = Indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting.

Using the TR-55 model and taking a look at representative runoff CN for different types of Hydrological Soil Groups (HSG) helps to explain the differences that a functional soil and landscape system can make. For example, an impervious surface area would have a representative CN of 98. Grass in a HSG "A" would have a CN-39 which is typical of a forested condition with a high infiltration rate. The same grass in a HSG "D" (similar to placing sod on top of a compacted clay surface) would have a CN of 80 or be near impervious. Soil amendments like compost could be used to improve the hydrology and move from one soil group to another. The TR-55 model makes it possible to use functional soil and landscapes to offset the impervious surfaces created during construction and reduce the footprint of retention/detention ponds. In some cases it may be possible to use functional landscapes to eliminate these ponds altogether. This will become even more important when NPDES Phase II becomes effective and a land disturbance permit for one acre or more is required.

CASE STUDIES

Preliminary data using engineered soil and landscape systems as a stormwater management tool looks promising. Several case studies document the effectiveness of these systems in controlling stormwater runoff volume and reducing pollutant loadings to receiving waters. Studies have also demonstrated that these systems are usually more cost effective and lower in maintenance than conventional stormwater controls. Significant work involving hydrologic predictive modeling using engineered soil and landscape systems was prepared by CH3MHILL in a three-volume report at the request of Snohomish County Public Works in Washington State (CH2MHILL, 2000). The most significant source for Low Impact Development is Prince George's County, Maryland where many of the LID practices were developed and implemented. The United States Environmental Protection Agency, working with the Low-Impact Development Center, has also prepared a Literature Review to determine the availability and reliability of data to assess the effectiveness of LID practices in stormwater management (US EPA, 2000).

CONCLUSIONS

It is important to understand the soil and water connection and realize what we do with our soils will ultimately determine the fate of our land and water.

Healthy soils are the essential link to water quality and quantity. We need to take a hard look at the way we are managing our natural resources. Stormwater management should not be stormwater disposal. Stormwater should not be destined for storm sewers any more than organic residuals should be destined for landfills. The environmental benefits of diverting organics previously destined for landfills speaks to the potential benefits of improved stormwater management. In particular are the benefits that can be derived from using these organics to engineer our soil and to design and develop functional landscapes that protect our natural resources, most important, of which, is water.

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