Rules of the Road for Water Movement in Soils

Understanding how water responds to soil characteristics in the landscape—S.D. Day

Soil Texture and Structure Affect Drainage

Soil texture is related to a soil's ability to drain. A sandy loam, for instance, usually drains faster than a silt loam. It is not precisely the presence of the sand itself, however, that makes a sandy loam drain well. It drains quickly simply because it has a high proportion of large soil pores (*macropores*). Soil pores are the spaces in between the soil solids that hold air or water. Small pores (*micropores*) retain water, while large pores allow drainage. Pore size distribution is the determining factor in questions of drainage.

Soil structure also has a profound effect on pore size—and, consequently, on drainage. Soil structure refers to the way in which soil particles are cemented together into aggregates by organic matter and clays through biological activity and physical changes such as freezing and thawing cycles. Aggregates are huge when compared with individual soil particles and can maintain large pore spaces and thus good drainage. The damage to soil structure caused by compaction is the primary reason that water movement is so restricted in many landscape soils. Even a moderate weight on a very moist clay soil, for example, will crush soil aggregates. The macropores created by these aggregates are then lost and poor drainage results.

The effects of soil texture and structure on drainage are a result of their effects on ***soil pore size distribution***. Disturbed urban soils, however, often present a more complicated picture. It is not uncommon to have a compacted clay subsoil, perhaps sculpted with berms, overlain with a topsoil of a very different texture and structure. The picture could be further complicated by old submerged pavement, runoff from an adjacent paved area, soil amendments, or an impermeable surface layer. How will water move in such complicated scenarios?

Rules of the Road

Water moves through soil in two ways: *unsaturated (capillary) flow* and *saturated flow*. These two types of water movement more or less govern how water will move in soil. By understanding the physics of these two types of water movement, you will be able to understand how water is likely to move through any landscape situation. Many practices thought to “improve drainage” or “improve aeration” actually do nothing of the kind. By understanding these concepts you can make sound assessments of situations you might encounter.

Unsaturated flow

When water is not under pressure (such as by standing water) and soil is not saturated, capillary forces govern water movement. Essentially this means that smaller diameter pores exert a greater attractive force and water will move into these pores rather than enter the larger pores, which will remain filled with air. This is why if you have clay soil (more small pores) laid over a layer of sand (more large pores), water will move through the clay soil (both downwards and sideways) and stop at the sand layer. It will not penetrate the sand layer at all until conditions of saturated flow take over (i.e. so much water has soaked into the clay that all pores are filled and water will flow through the large pores where it is not tightly held).

Saturated flow

Saturated flow occurs when soil pores are entirely filled with water. Under these conditions, the force of gravity (plus pressure if there is standing water on the surface) primarily governs water movement. Because water flows exponentially faster through larger pores, most of the saturated flow will be through the largest pores. This is why sandy soils (more large pores) drain faster than clayey soils (more small pores).

Examples in the Landscape

- ✓ Gravel in the bottom of a planting hole or pot does not improve drainage. Rather, it reduces the usable rooting space. Water flow will stop at the gravel (a "perched" water table) until soil above is saturated. It may serve as a temporary sump—but it will not store a large volume of water and will not improve drainage.
- ✓ Shallow soil layers set over old gravel parking lots can mean a larger scale perched water table. A clay hardpan can check water infiltration for long periods and even result in ponding. Overly wet soils and shallow rooting can lead to windthrow.
- ✓ Internal drainage must be connected to an outlet if the water table is to be lowered. Sump "drains" under a planting hole will not improve site drainage, but may, when the planting hole is completely saturated, serve as a temporary reservoir away from roots for water that would otherwise collect in the bottom of the hole.
- ✓ Water movement will be strongly influenced by soil texture and structure, regardless of the subsurface drainage system used. An analogy can be made to holding a wet sponge over a sink. The sink will drain away the water that drips from the sponge, but it will not suck the water out of the sponge, which holds the water tightly in its pores. Eventually the sponge will stop dripping, just as the soil will stop draining, although it may still be very wet. A drainage system can, however, prevent roots from being flooded by high water tables.
- ✓ Above-ground containers for tree planting must be very carefully designed. Not only must they be large enough to provide adequate rooting volume and protection from temperature extremes, but they must also be proportioned well and filled with an appropriate soil mix. Too wide and shallow a container will stay too wet even in a very porous soil. Mineral soils may stay too wet, unless the container is open at the bottom and sitting on existing soil. Alternatively, a deep container will allow room for a saturated soil zone on the bottom.
- ✓ Surface drains must be open to the air in order to collect water. Otherwise water may actually avoid the drain much as it avoids entering the gravel in the bottom of the planting hole (i.e. until surrounding soil is saturated).
- ✓ Soil interfaces usually restrict water flow. An interface refers to any place where soil texture or structure abruptly changes, such as between the soil mix of a container plant and a typical site soil. Heavily amended backfill in a planting hole can create a situation where the rootball alternates between very wet and very dry. What happens depends on the individual soils and moisture conditions.

Improving Drainage

Very poor drainage creates unlivable conditions for many species. At times, drainage may be impeded by a soil hardpan, an old foundation, or other impermeable layer. In this case, breaking up the obstructing layer may be sufficient to improve the situation. Sometimes, however, water will need to be diverted and removed by means of a drainage system—or this system may just be a backup system to provide peace of mind. Surface drainage can be used to remove surface water and runoff, to prevent water from collecting in undesirable spots. Subsurface drainage can remove excess water that has already moved into the soil profile. This type of drainage essentially lowers the level of the water table in the vicinity of the drain, preventing roots from being flooded.

SITE GRADING

Surface drainage can be achieved through site grading. Swales (wide, shallow trenches) can be formed in the soil to direct surface runoff. Runoff can be diverted to an outlet for removal from the site, or simply collected on site. Low areas that might collect water in undesirable locations can be eliminated.

SUMPS

When connected to the surface, these provide limited surface drainage. As there is no outlet, water will simply collect in the drain and then seep into the ground. Sumps will not draw down the water table, but may reduce runoff in areas of poor surface infiltration. Because the collect water, they may reduce, rather than increase, the oxygen available in the soil surrounding them.

SUBSURFACE DRAINAGE

This type of drain will lower the water table to the level of the drain, or somewhat above that in the areas between drains. It is installed much as traditional agricultural clay tile drains. Usually perforated plastic pipe is laid horizontally well below the rooting zone and covered with geotextile or gravel "envelope" to reduce clogging of the drain with silt. The drain must be connected to an outlet and must be laid at the proper grade to conduct water to the outlet. Insufficient slope or an unprotected outlet may result in the drain clogging with silt because of slow water movement. These drains may have connecting drains leading to the surface, adding surface drainage.

USEFUL TERMS

Macropores: Large pores, having a diameter greater than 0.08 mm. Gravitational forces predominate in macropores.

Micropores: Small pores, generally within structural aggregates and having a diameter less than 0.06 mm.

Adhesion: When a molecule sticks or adheres to another surface—such as a water molecule sticking to a soil particle.

Cohesion: When two like molecules are held together, usually used to describe water molecules. Water has a + charge on the hydrogen end, and a - charge on the oxygen end, so they stick together.

Capillary Forces: Capillary forces (cohesion and adhesion) hold water against the force of gravity.

Capillary Water: Capillary water is that held in micropores, usually with a tension >60 cm of water.

Saturated Flow: Flow dominated by gravitational forces, usually through macropores. It is a downward flow.

Unsaturated Flow: Flow dominated by capillary forces, may be in any direction.

Soil Colloids: Clays and humus with a very small particle size and a correspondingly large surface area per unit of mass. Generally have charged surfaces and are highly reactive