Tile Drain

Subsurface drainage is used for agricultural, residential and industrial purposes to remove excess water from poorly drained land. An important feature statewide, drainage enhances Wisconsin agricultural systems, especially in years with high precipitation. Drainage systems improve timeliness of field operations, enhance growing conditions for crop production, increase crop yields on poorly drained soils and reduce yield variability. In addition to agronomic benefits, subsurface drainage can improve soil quality by decreasing soil erosion and compaction.

To maintain agricultural productivity and protect water quality, producers, consultants and agency personnel must understand tile drainage, locate drainage systems and properly maintain them.

> "Once the tiles are located, producers or consultants should develop accurate maps and keep copies (both electronic and paper) in a secure file system. Modifications to existing systems or the installation of new tiles should also be identified. Your local Land Conservation Departments should be able to provide copies of aerial photos or base maps."

Subsurface drainage is not a new management practice. Evidence of these systems dates as far back as ancient Rome. In Wisconsin, drainage systems were originally constructed using short (1-foot) segments of clay or cylindrical concrete "tiles." Tiles were initially installed manually, requiring hand excavation. Modern drain tiles are corrugated, perforated plastic pipes typically installed mechanically using a trencher. These plastic pipes are available in a variety of diameters to accommodate different flow rates. They are typically installed at a depth

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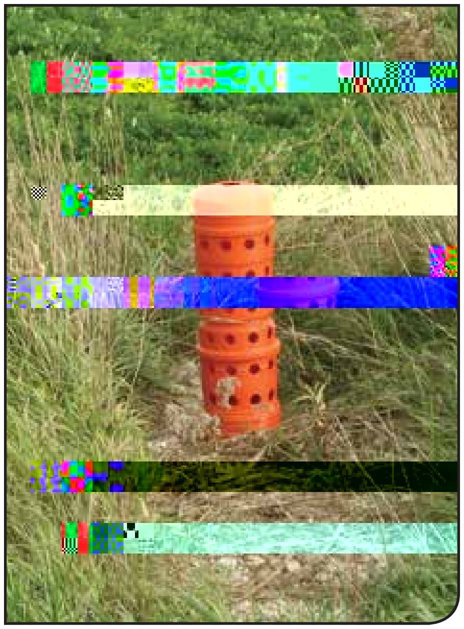

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be able to locate tile lines and outlets. Although it is often hard to identify old

under flooding and high water tables. Since subsurface drain outlets are typically open to the atmosphere, soils around drains are aerobic (contain oxygen) at low levels. As groundwater enters the aerobic zone in and around the drain, solid iron precipitation occurs, creating optimal conditions for ochre growth. Ongoing maintenance is the only economical option for controlling iron ochre formation. If iron ochre has formed on plastic drain tiles, high and low pressure water jet cleaning is the most cost-effective management option. Higher pressure (> 400 psi) can be used with larger drain tile perforations or when drains are enveloped in gravel. Lower pressure (< 400 psi) should be used in sandy soils, when drain tile perforations are small, or when a synthetic sock is used to envelop the tile (Ford and Harmon, 1993).

NRCS standard practices (NRCS Code 606) should be followed when designing, modifying or installing tile drainage systems (NRCS, 2002). A detailed installation plan should be developed addressing specific drainage needs. Preparation of this plan requires assistance from knowledgeable individuals, such as an engineer or experienced tile installer, and should consider crop and soil types as well as site topography. A sub-surface drain system is composed of lateral, sub-main and main line piping. Laterals are the initial collectors of excess water from the soil. Several laterals convey flow to a main or sub-main. A sub-main carries flow to a main line that typically drains to the outlet (**4)**. When enlarging lines or adding new laterals to existing drainage systems, be certain main lines are adequately sized to accommodate the additional flow, thus avoiding back pressure and blowouts. Air vent installation is recommended to maintain atmospheric pressure through out the system. This allows for maximum flow capacity and relief from back pressure conditions.

Tile system vents are open at the ground surface in order to expose the system to the atmosphere (**5)**. Vents should protrude above the ground approximately one foot to minimize clogging. They are commonly placed in low traffic areas (e.g. along fence rows), making them difficult to locate. If your system has vents they should be located, mapped, inspected and cleared of obstructions. Some (typically older) tile systems may not have vents. Tile flow rates and water level inspection can be conducted through a vent opening with a flashlight. Also note that because tiles lines located within 80 feet of trees may have flow obstructed by tree roots entering the line, tiled waterways and buffers should be kept clear of trees.

Good record keeping is an essential part of any drainage maintenance program. The location of tile lines, vents, surface inlets and outfalls is critical for troubleshooting and design modifications. Modern GPS technology has become an indispensable tool for mapping tile lines. Tile system mapping should be conducted when new

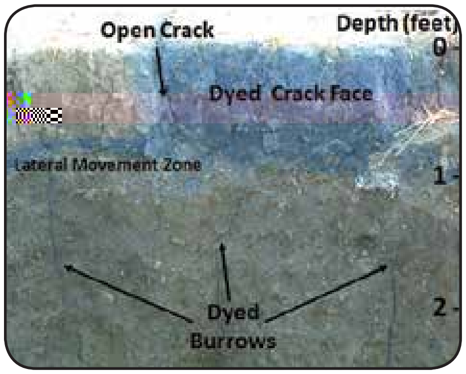
Managing Tile-Drained Landscapes to Prevent Nutrient Loss

Tile drainage of agricultural land has the ability to improve yields and reduce surface runoff and erosion losses. However, with a reduction in surface runoff, more water infiltrates the soil and percolates through the soil profile. This is of particular importance to farmers, as this water can also transport essential plant nutrients, specifically nitrogen and phosphorus, out of the root zone. Once nutrients reach the tile drain, they are directly transported to surface waters.

Tile-drained agricultural land must be well-managed to reduce the loss of nutrients to surface waters. Nutrient management practices must be carefully followed to minimize the risk of nutrient loss and to maximize fertilizer use efficiency. Additional considerations need to be taken with manure applications on tile-drained land to both minimize nutrient loss and prevent manure entry into tile drains.

One of the key factors in nutrient loss to tile drains is preferential flow through the soil profile, which is also referred to as macropore flow. Preferential flow paths are direct conduits from the soil surface to deeper depths in the soil profile. Preferential flow paths are formed by earthworm burrows, decayed root channels, shrinkage cracks, and the structural porosity of the soil. As water percolates through the soil, it travels through preferential flow paths and rapidly transports soluble nutrients below the root zone. As observed with methylene blue dye applied to the surface of the soil in 1, the dye moved through the soil using a combination of preferential flow paths. Most of the dye entered the soil through shrinkage cracks in the soil surface, then moved laterally along the plow layer and finally moved deeper in the soil profile through earthworm burrows. Water and nutrient transport through the soil matrix is much slower than through macropores. 1 clearly illustrates that unknown subsurface soil conditions are a main cause of nutrient leaching losses.

The development of preferential flow paths in soil varies significantly with soil type and management. Long-term no-till typically results in increased macropore development as a result of lack of tillage to disrupt preferential flow paths. Soils with higher clay content often develop large shrinkage cracks that occur as soil dries and that can go deep into the soil profile. Nutrients and organic material can be transported rapidly through these shrinkage cracks. For example, plant debris has been observed in well-developed shrinkage cracks down to 17 feet in Fond du Lac County (Fred Madison, personal communication).



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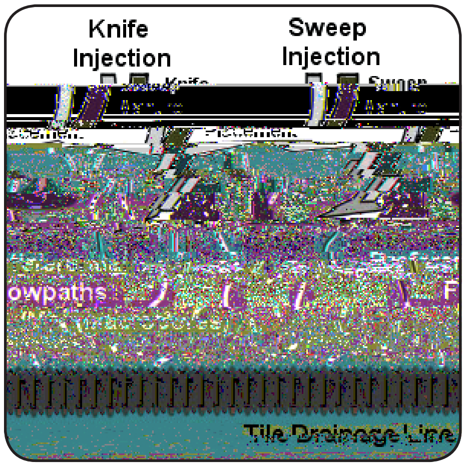
Earthworm activity results in considerable macropore development in soil, and earthworm activity tends to be greater in no-till fields than in fields that are annually tilled. Several studies have shown that earthworm populations in no-till fields were approximately twice that of tilled fields (Kladivko et al., 1997; Kemper et al., 2011). The area over tile drains also creates a prime habitat for earthworms because this area is less frequently saturated. Earthworm populations over tile lines can be double of those between tile lines (Shipitalo et al., 2004). This is important because earthworm burrows that exist within two feet of a tile drain cause direct drainage from the burrow to the tile outlet (Smetler, 2005).

When applying manure on tile-drained landscapes, additional precautions are needed because of the presence of preferential flow paths which can lead to direct transport of manure to tile drains. The application method, specifically for liquid manure, can have a large effect on the potential to transmit manure to tile drains. The key to preventing applied manure from leaching is to disrupt the macropores around and below the application area.



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Although manure transmission can occur with all application methods (e.g., irrigation, surface spreading, and subsurface injections), the two application methods that have the highest potential to lead to leaching of nutrients via preferential flow are knife injection and application using horizontal sweeps. For each of these application methods, there are specific conditions that lead to the high risk of manure leaching. Knife injection can be problematic if sufficient tillage is not performed before application. As shown in 2, as the knife passes through the soil, it leaves a column of manure behind the knife. If sufficient tillage has not been performed prior to injection, the fluid pressure forces the manure down earthworm burrows, shrinkage cracks, or other preferential flow paths. Tillage and the resulting breakup of macropores decrease the likelihood that the applied manure will leach.

Similarly, horizontal sweep injection can be problematic if sweeps are placed too close together or if the implement is pulled through the soil too rapidly. This results in lifting the soil above the sweep, filling the void with manure. As the weight of the soil comes down on the manure, it may be forced into preferential flow paths and eventually into the tile drains (figure 2). Increasing the spacing distance between knife and sweep injectors increases the loading of manure in a localized area near the injection zone. For example, an 8,000 gallon/acre application made using a horizontal sweep injection toolbar with 10-inch sweeps and 30-inch spacing would result in an effective rate of 24,000 gallon/acre in the area above the sweep (2). The soil loading in the localized application area would be three times larger than a uniformly distributed load. Localized soil loading for knife injection is typically higher than the example used. Emerging technologies for manure injection may disrupt preferential flow pathways and reduce the potential for nutrient leaching.

The consistency and rate of liquid manure applications also factor into the potential for manure transport into tile drains. Manure consisting of greater than 5% solids has enough particulate matter to decrease the probability of preferential flow. Application of manure containing less than 2% solids has a high probability of moving via preferential flow and has been observed in fields (Frank Gibbs, personal communication). The higher the application rate, the greater the volume of water that is added to the soil, thus increasing the potential risk to transmit manure to tile drains. An application of 13,000 gallons of liquid manure per acre has the same amount of water applied to the soil as a half-inch rainfall event.

Soil moisture is an important factor in the potential to transmit manure to tile drains. Both high and low soil moisture can greatly increase this potential. When soils are near saturation, additional water added by liquid manure applications can initiate tile flow, thus facilitating manure entry into tile drains. In general, liquid manure should not be applied

✔ [illegible] This also includes any other management practice that increases nitrogen conservation in the soil and reduces erosion. These practices that reduce soil loss also reduce sediment-attached nutrient movement on the soil surface and will also help to reduce the potential of loss to tile drains.

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If manure enters tile drains, take immediate steps to stop the flow and prevent discharge to fresh water systems. This can be performed by blocking or diverting the tile outlet, intersecting the tile system, and digging a pit directly downstream of the spill site to collect manure. Contact the Wisconsin DNR Spills Hotline at 1-800-943-0003 to report the spill and get assistance with subsequent remedial actions.

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There are technologies available that can be used to retain water and nutrients in the soil profile. Drainage water management is the practice of controlling water table elevation to desired levels throughout the year. Water level control structures are used to maintain the water level higher in the soil profile after crops are removed to minimize nitrogen loss, predominantly in nitrate form, to surface water (**4)**. The control elevation is then lowered in the spring to remove excess water from the soil profile and to allow the soil to dry out for field access and planting. Once crops are planted, the control elevation is often raised to hold the water level closer to the root zone, especially for crops that are prone to drought stress. Once crops are removed, the control elevation is raised farther to store more water and to prevent nutrient loss until spring. Additional information on drainage water management can be found in Drainage water management for the Midwest: Questions and answers about drainage water management for the Midwest.

Water table management in many of Wisconsin's tile-drained landscapes is limited by the slope of the land. Slopes of less than ½% are suitable for drainage control structures to be practical. Slopes greater than ½% will only allow for drainage control on a small portion of the land surface and may result in high fluid head pressures in tile systems and tile blowouts. Many of Wisconsin's tile-drained landscapes have 2–6% slopes. New technologies allow for infield drainage control for lands with higher slopes (**5)**. This type of system has two benefits: It is installed underground so as not to interfere with field operations (including deep tillage), and it can be "stair-stepped" to control drainage on higher sloped land up to 2% (**5)**. The level in each of the structures is controlled by the downstream water control structure located either at a field boundary or tile outlet.

Constructed wetland treatment of tile drainage flow has been shown to be more effective for nitrogen (N) than phosphorus (P) removal, but there are many limitations with this practice (Miller et al., 2002). Constructed wetlands can take large amounts of land out of production for effective treatment sizing. Reported P removal and N concentration reductions vary due to a number of factors, including system design, retention time, and local climatic and physical conditions. Temperature effects on microbial activity may have large influence on N removal capacity, especially in the cold temperature extremes of the northern regions,