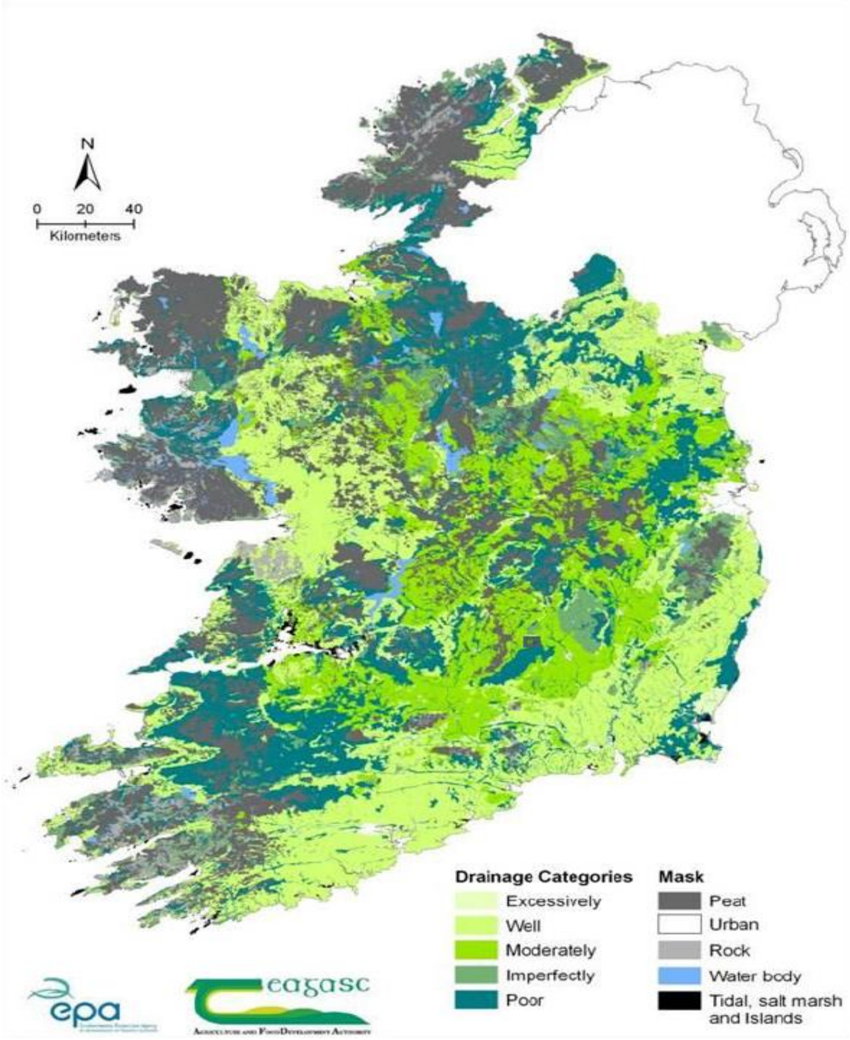
Land Drainage Systems

Teagasc Animal and Grassland Research and Innovation

Presentation to ASSAP programme_02052019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Kilometers
Drainage Categories
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epa
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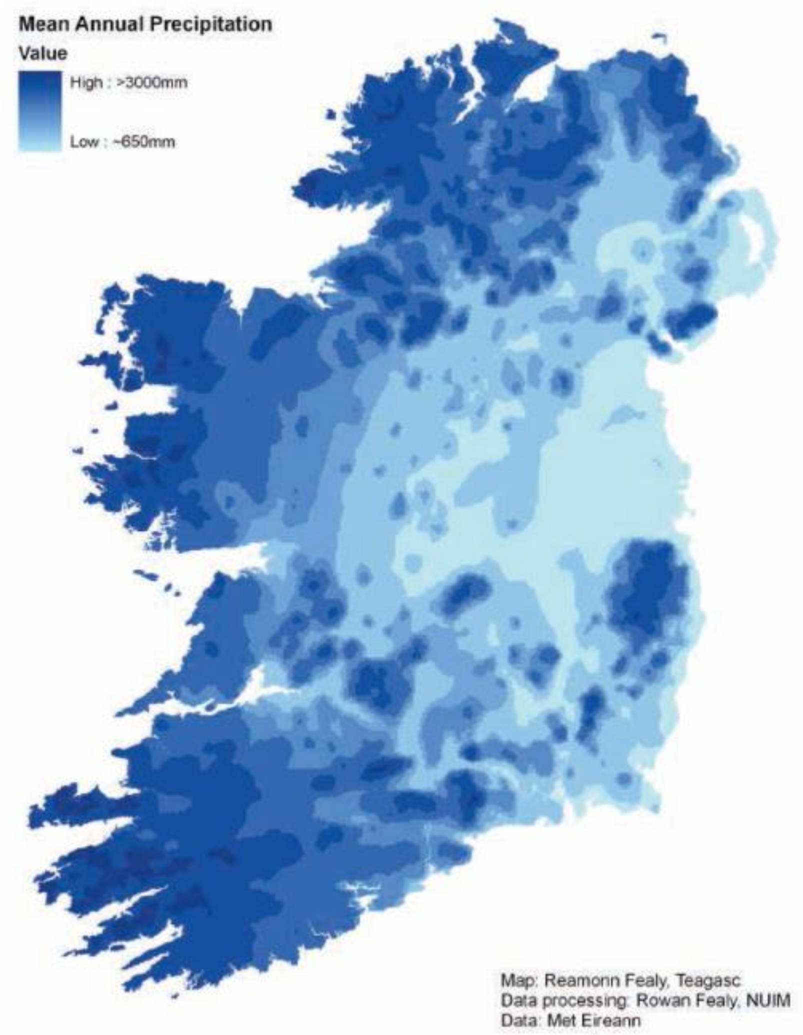
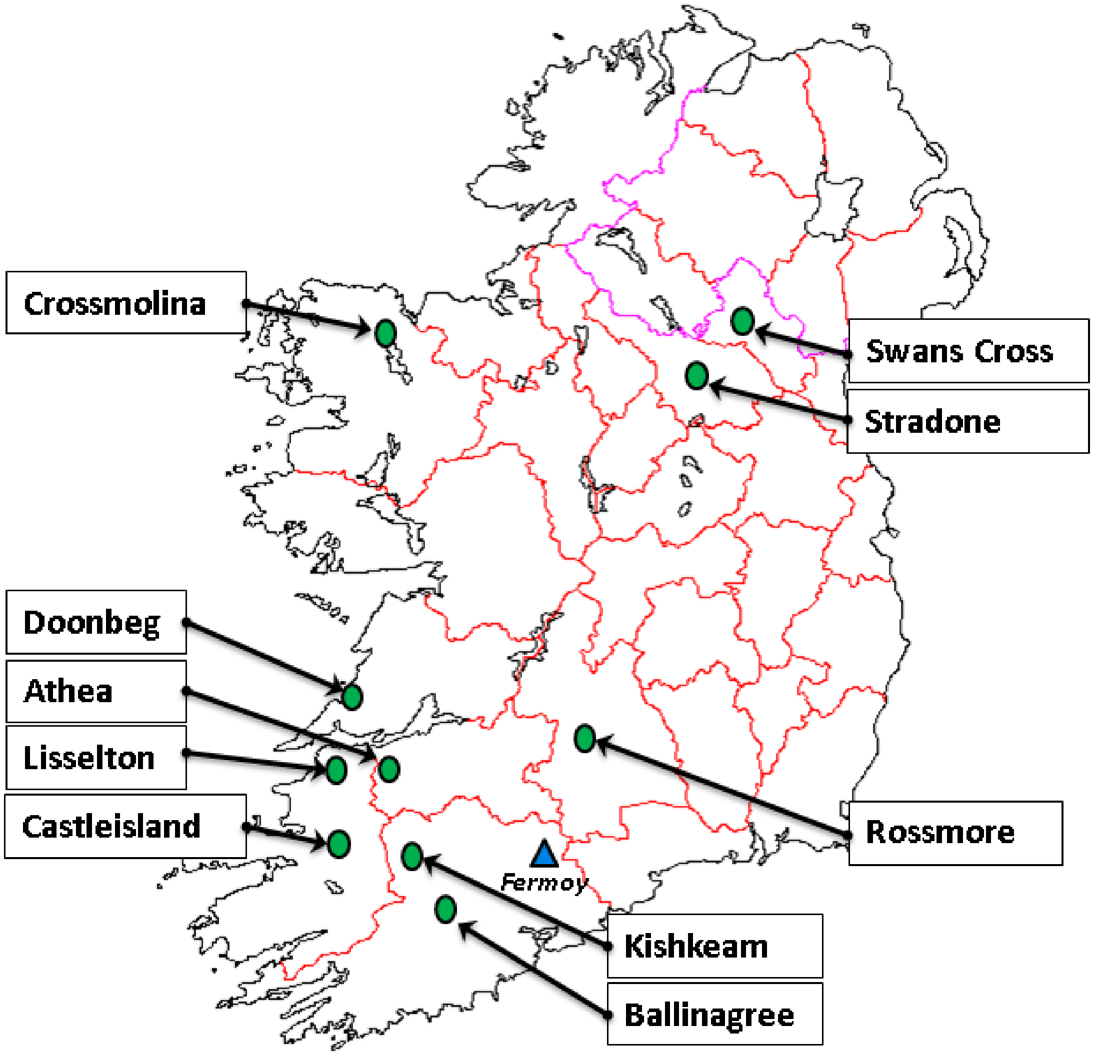

Mean Annual Precipitation
Value
High : >3000mm
Low : ~650mm
Map: Reamonn Fealy, Teagasc
Data processing: Rowan Fealy, NUIM
Data: Met Eireann

Heavy Soils Programme Farms

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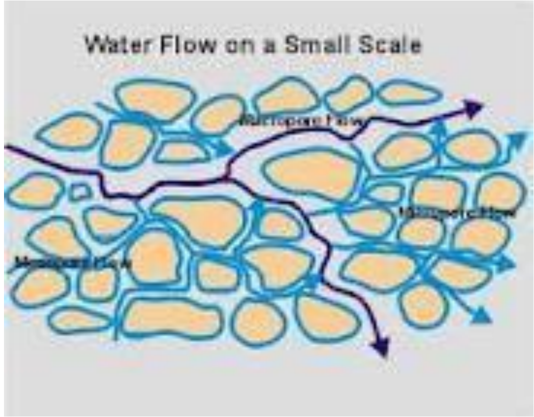
Water movement through Soil

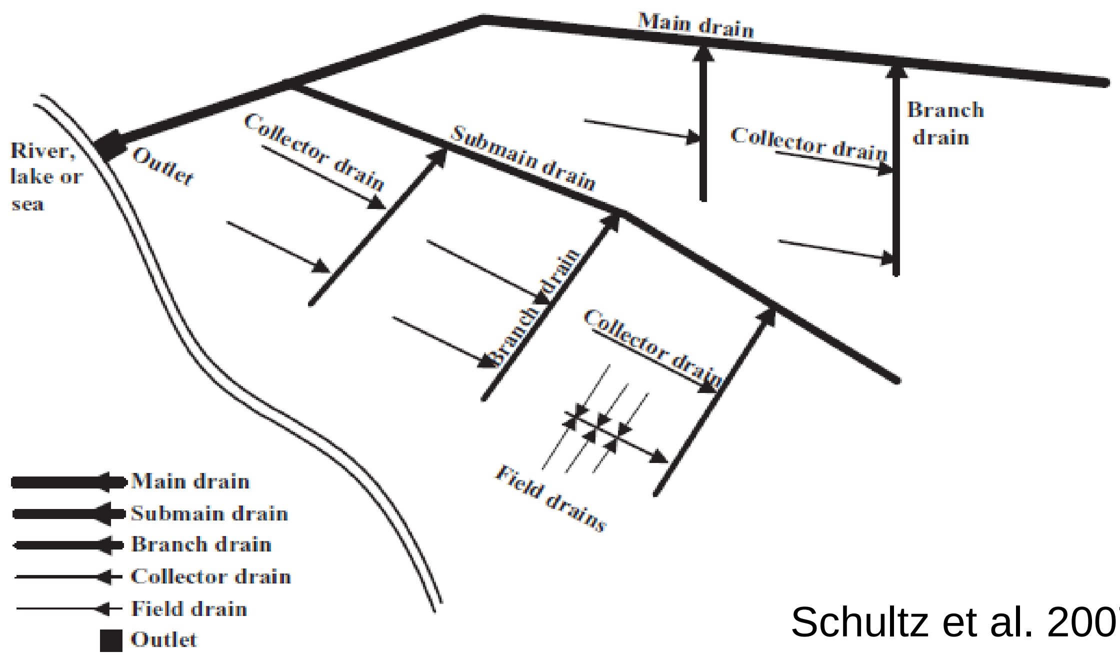
- In free draining soils the rate of water flow through the soil will be higher than all bar very extreme rainfall rates.

- In poorly drained soil the rate of water flow can be regularly exceeded by rainfall rate due to:
  - Low hydraulic conductivity
  - High Water table due to low lying position and poor out-fall
  - Upward movement of water from seepage and springs



Main Drainage System

- The function of a main drainage system is to **collect, transport and dispose of water** collected from the field drainage system through an outlet
- Main drains may, also **collect excess water directly** from the fields themselves (surface and groundwater).
- Main drains also **store a certain amount of water** during wet periods
- Main drains are generally open trenches (some are piped)



Schultz et al. 2007

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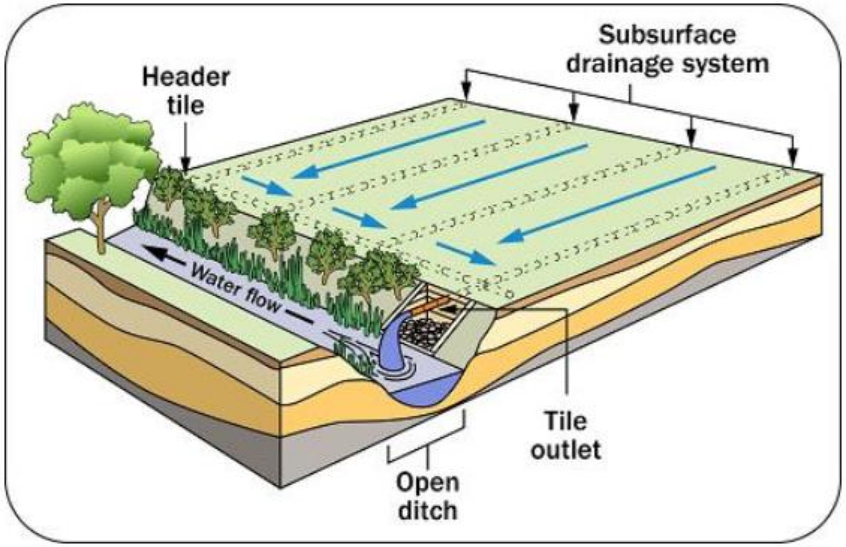
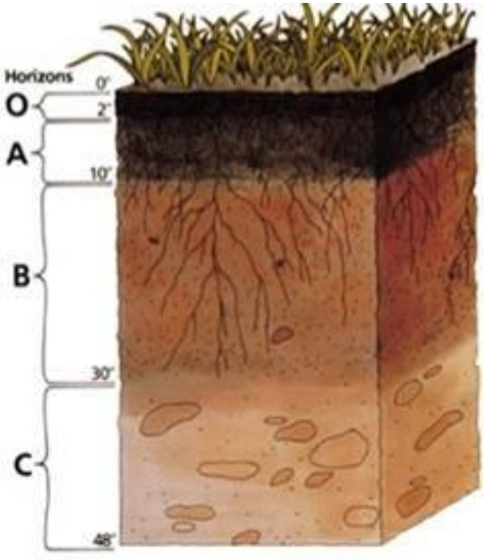
Main Drainage System

- The construction of field drains is **normally preceded** by excavating new open main drains or deepening and widening existing ones
- As the main drainage system dictates the drainage base level in the field, it must be suitably deep to allow for efficient collection of excess water in the field.
- Suitable depths generally range from 0.3 – 2.0 m below the soil surface



Drainage Investigations

- **When planning a drainage system an investigation into the causes of poor drainage must first be undertaken**
- No “one size fits all” solution
- A number of test pits (at least 2.5m deep) should be dug within the area to be drained
- As the test pits are dug the faces of the pits are observed, soil type (texture and structure) should be established (varying with depth) and rate of water seepage (if any) recorded.
- **Are there layers impeding or permitting water movement ?**



Types of field drainage system

- The depth and type of drain to be installed depends entirely on the interpretation of the test pits.

- Two principle types are distinguished:

  - **Groundwater drainage system:** A network of deeply installed piped drains exploiting permeable layers

  - **Shallow Drainage system:** Where soil is heavy and infiltration of water is impeded at all depths and permeability needs to be improved

Groundwater Drainage System

- **A Groundwater drainage system is a network of field drains collecting groundwater which can move through soil layers of high permeability**
- They work by exploiting the natural capacity for movement of water at a certain depth in certain soils
- Often heavy textured soils overlie soils of much higher permeability (**poorer sub-soils closer to the surface and more permeable layers underneath**)

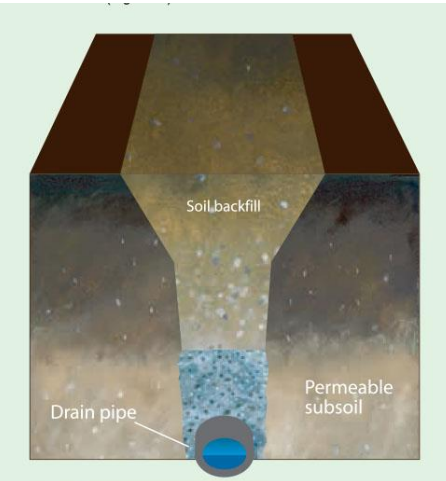
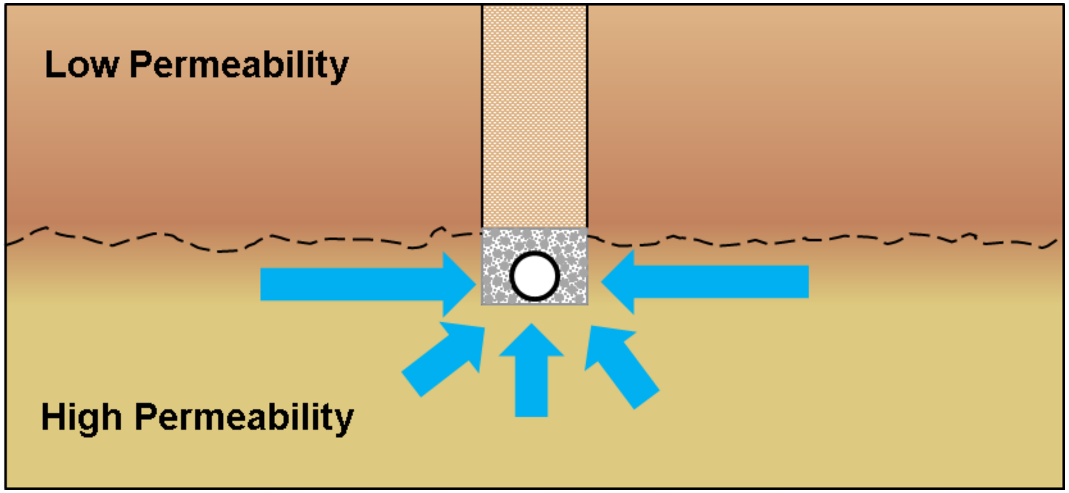
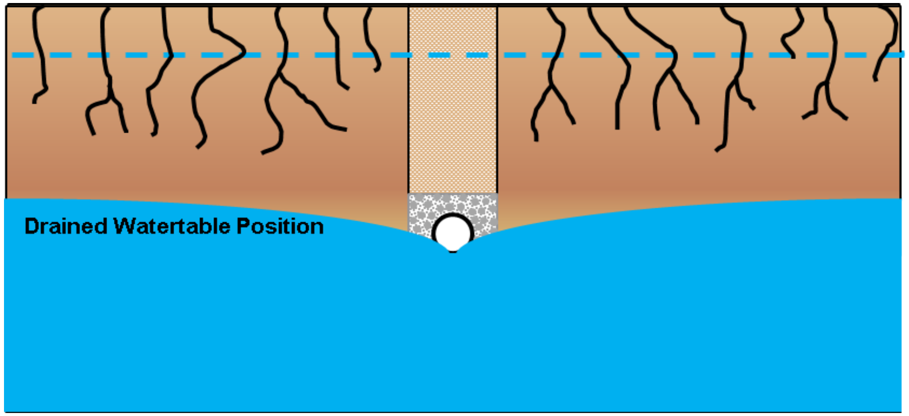


Figure 1. Connection with permeable layer.



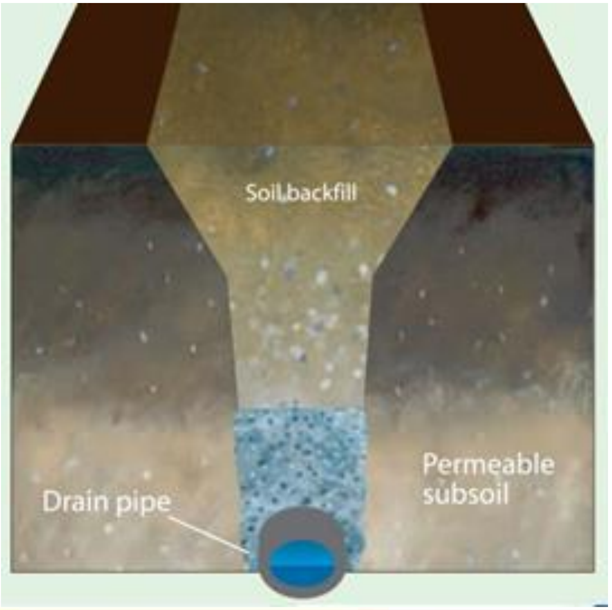
Groundwater Drainage System

- By "tapping" into this natural capacity for water movement the system works by lowering the watertable and reducing the amount of water stored in the soil
- When it rains water can now infiltrate through the soil. Water storage is reduced so capacity is increased
- By controlling the water table,natural (cracking, root penetration) or artificial (sub-soiling/ripping*)* improvements in permeability in the shallower layers can occur



Backfilling groundwater drains

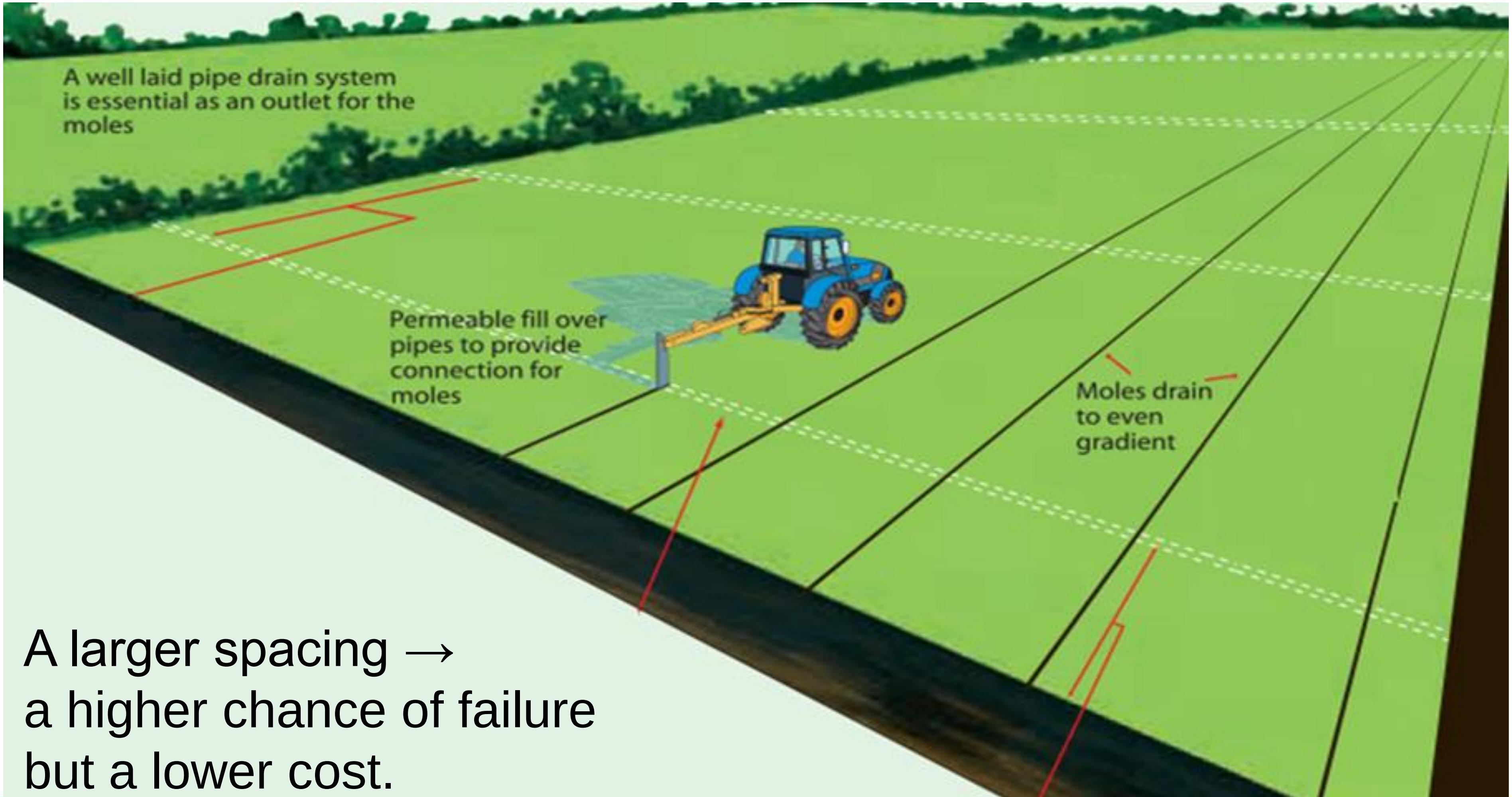
- Drainage stone should:
  - be filled to a **minimum depth of 30 cm** from the drain bottom
  - provide connectivity with layer of high permeability
  - be **clean** aggregate (10-40 mm / 0.4 -1.5 inch)



Shallow Drainage System

- **Where no inflow of water to test pit**
- NO permeable layer to be exploited
- Drainage must incorporate a soil disruption technique in tandem with collector drains.
- The aim of such a system is to improve soil structure and permeability

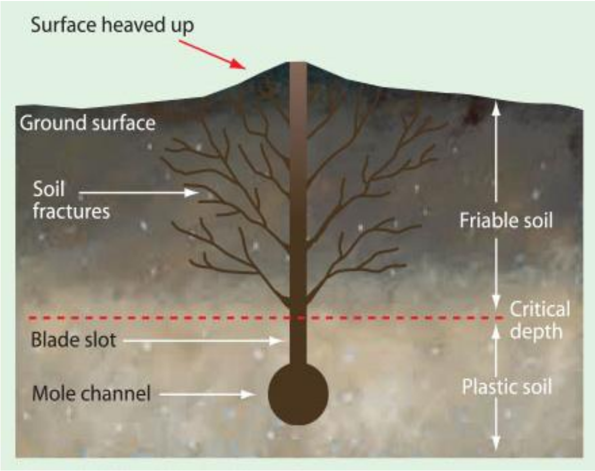
Shallow drainage-collector drains



A larger spacing →
a higher chance of failure
but a lower cost.

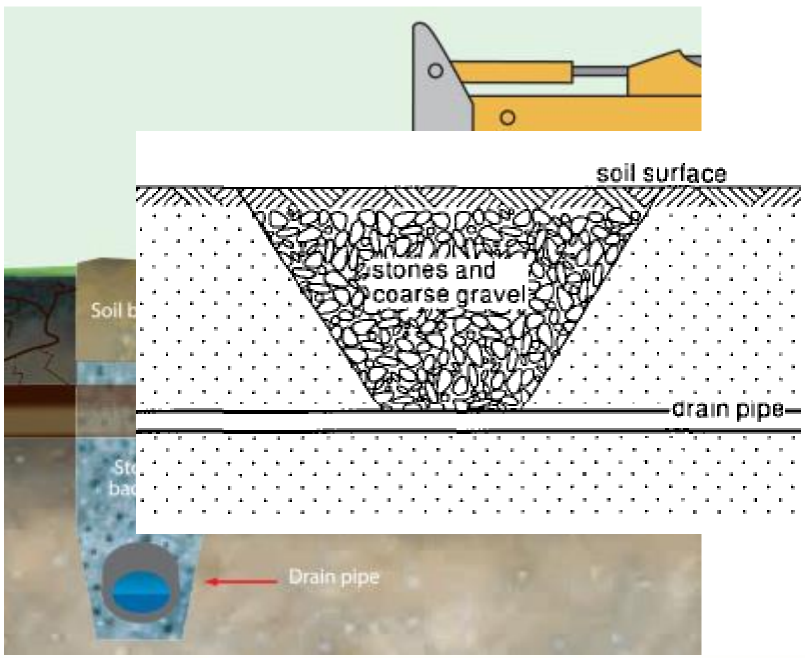
Shallow Drainage

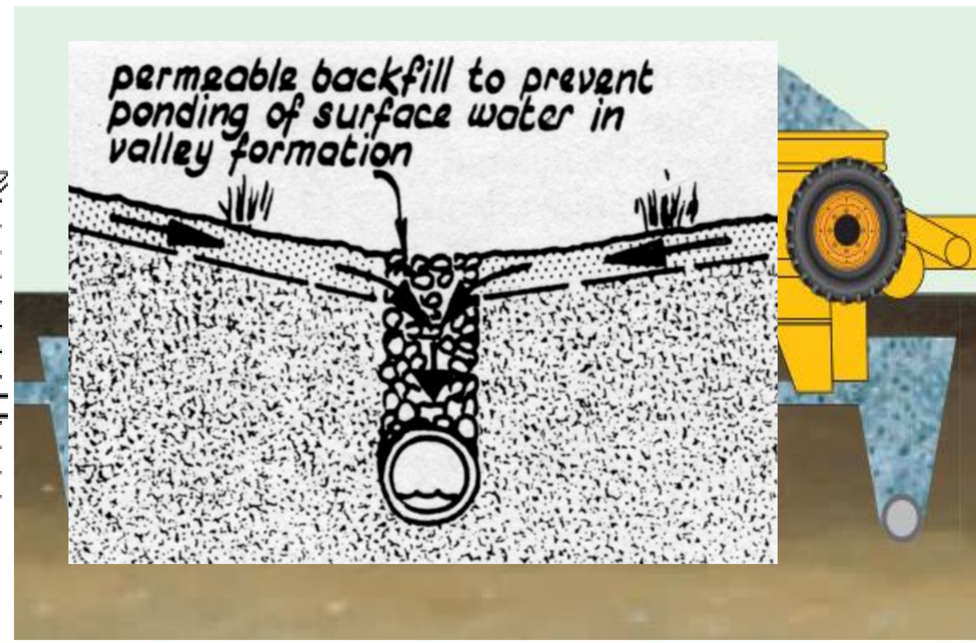
- **Mole drainage**
  - Increased permeability at shallower depths and creates drainage channel
- **Gravel mole drainage**
  - Gravel moles increase lifespan (extra cost)
- **Subsoiling/Ripping**
  - To break a pan at shallow depth or to supplement both shallow and groundwater drainage systems
- **Carried out when upper soil layers are dry**
- Installed at spacings of 1.0 to 2.5m at 0.4 – 0.6m depth.



Backfilling collector drains

- Drainage stone should:
  - fill the trench to within 25 cm of ground surface
  - provide connectivity with mole channels and topsoil
  - be **clean** aggregate (10-40 mm / 0.4 -1.5 inch)

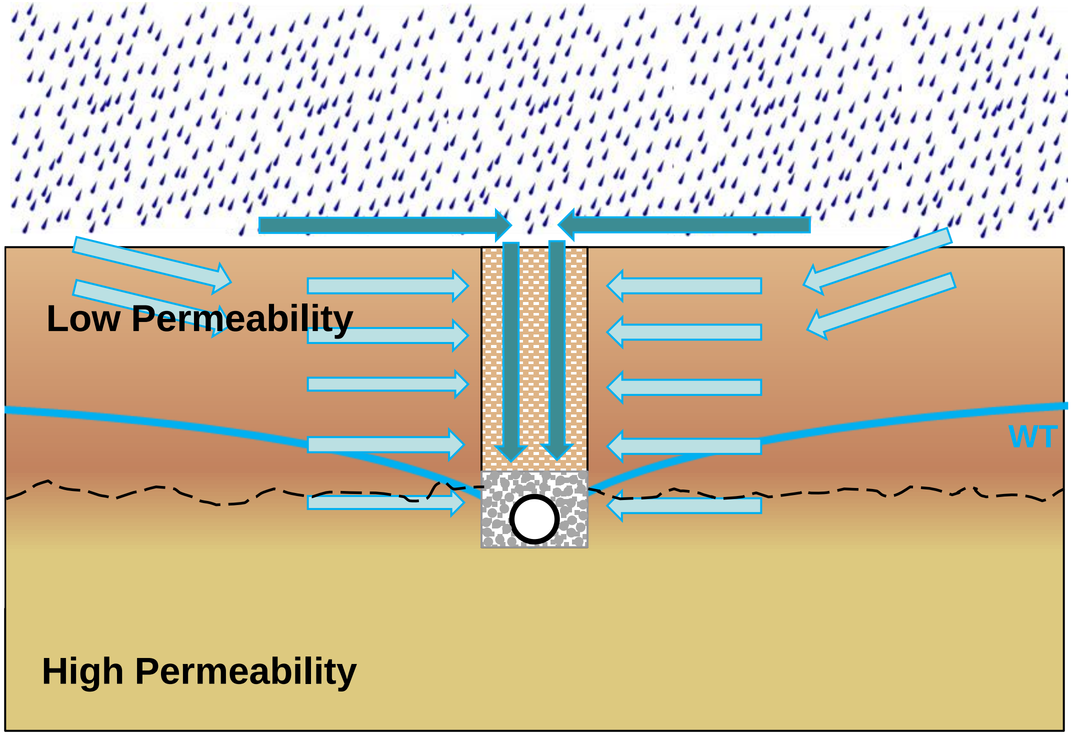




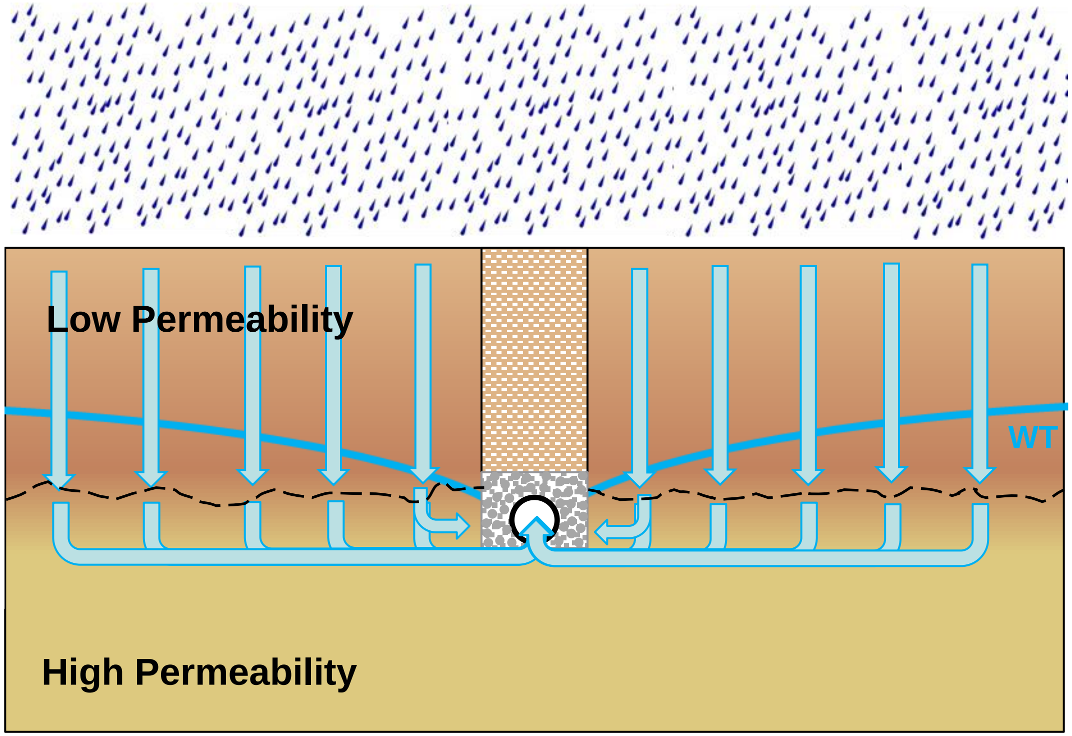
Drainage pipe and stone

- The drainage pipe facilitates a unobstructed flow path from the field drain.
- Only short drain lengths (less than 30 m) are capable of operating at full efficiency without a pipe. (also allows maintenance)
- Perforated corrugated pipe is the cheapest and most convenient
- Drainage stone has three functions
  - Hydraulic: to facilitate water flow to the pipe
  - Filter: to prevent the entry of fine particles to the pipe
  - Bedding: to provide support for the pipe and prevent collapse
- Stone backfill should be **clean** aggregate (5-40 mm)

Perception?? Water movement to GW drain



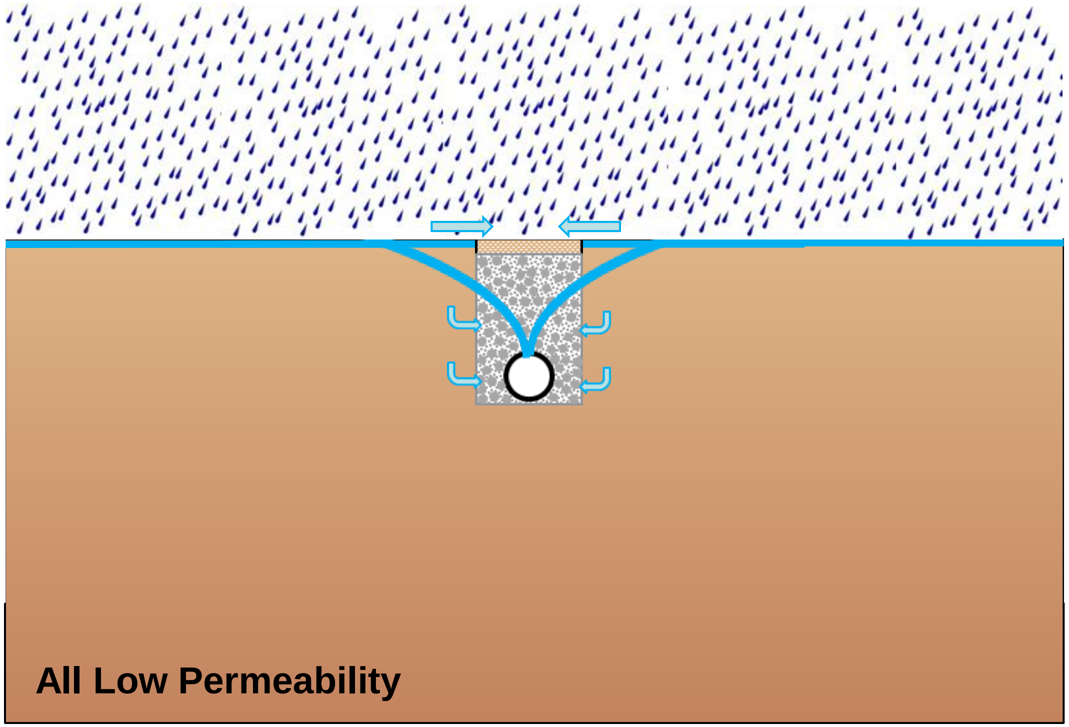
Reality: Water movement to GW drain



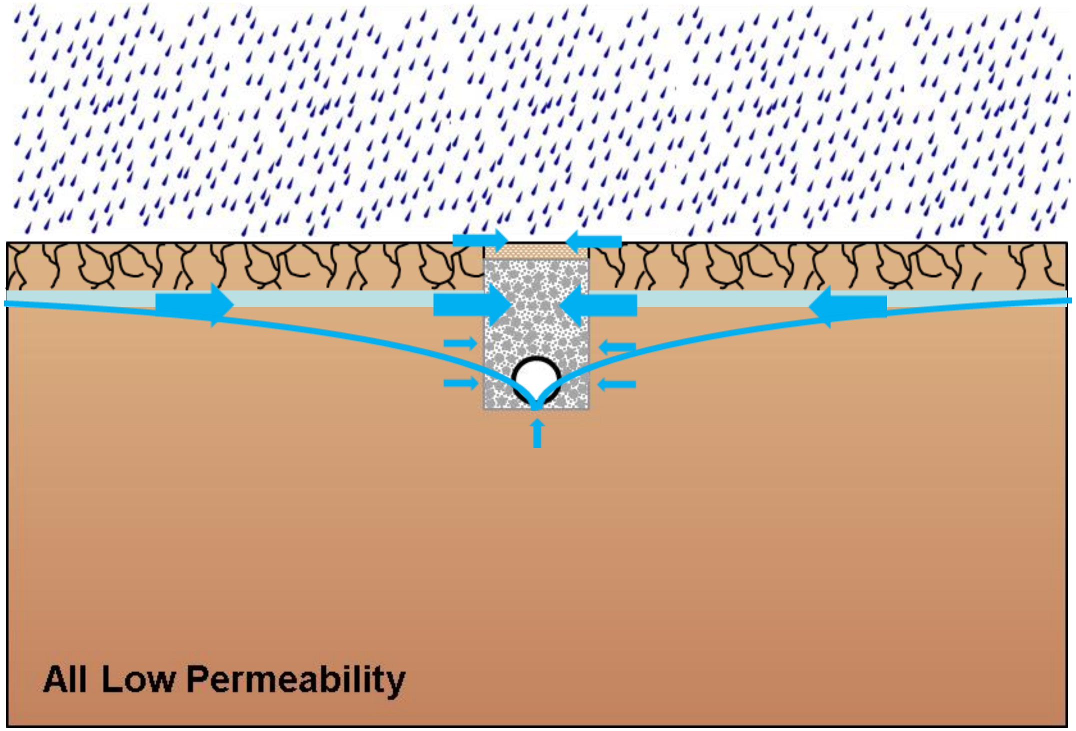
"Drains should always be installed in the most permeable zone that is within an economical excavation depth, usually within about 3 meters (10 feet) of the ground surface. Often fine-textured soils overlie soils of much higher permeability. However, this type of two-layer drainage can work efficiently. ***Sand tank models have shown that the water moves vertically down to the more permeable layer, horizontally through the permeable layer, then back up almost vertically to the drain****"*

USBR, 1993

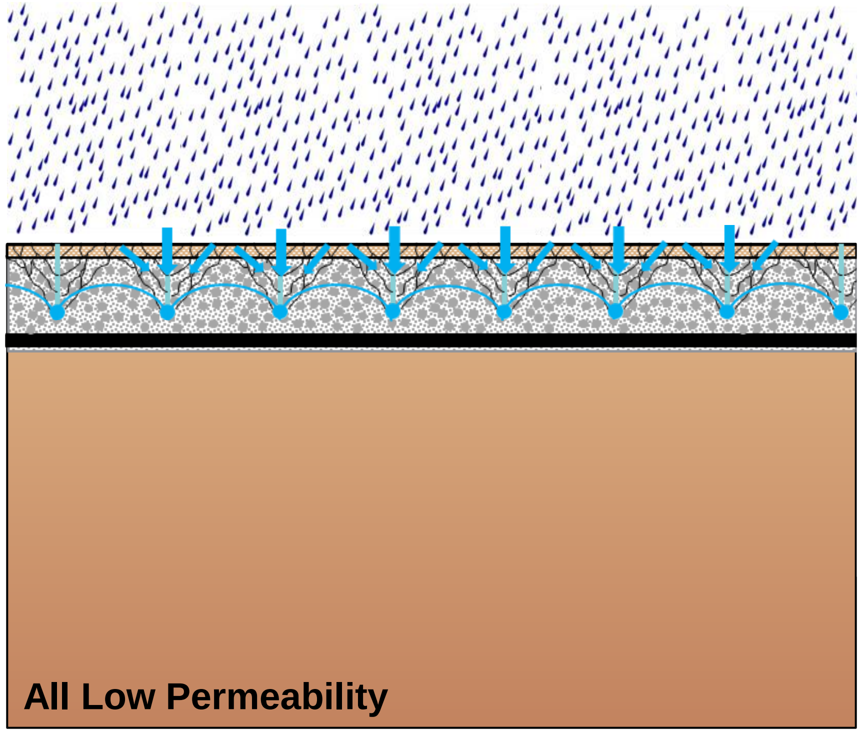
Water movement to Shallow Drains



Water movement to Shallow Drains



Water movement to Shallow Drains



Appropriate Drainage systems

- ***<u>Guiding principles:</u> Where water can move freely within the soil profile (at a particular depth), a groundwater system must be installed to collect and discharge this water. Where all the profile is poorly permeable and water movement is severely restricted then efforts must be made to improve the movement of water close to the surface***

- ***Water moves to a field drain naturally (through a suitable soil layer) or through avenues that are created artificially (mole channels, etc). If neither of these pathways is available then the watertable will not be controlled.***

- ***If the drainage system does not control the watertable, then (at best) it will only remove ponded surface water and will not reduce the moisture content of the soil below saturation***

Groundwater

Shallow

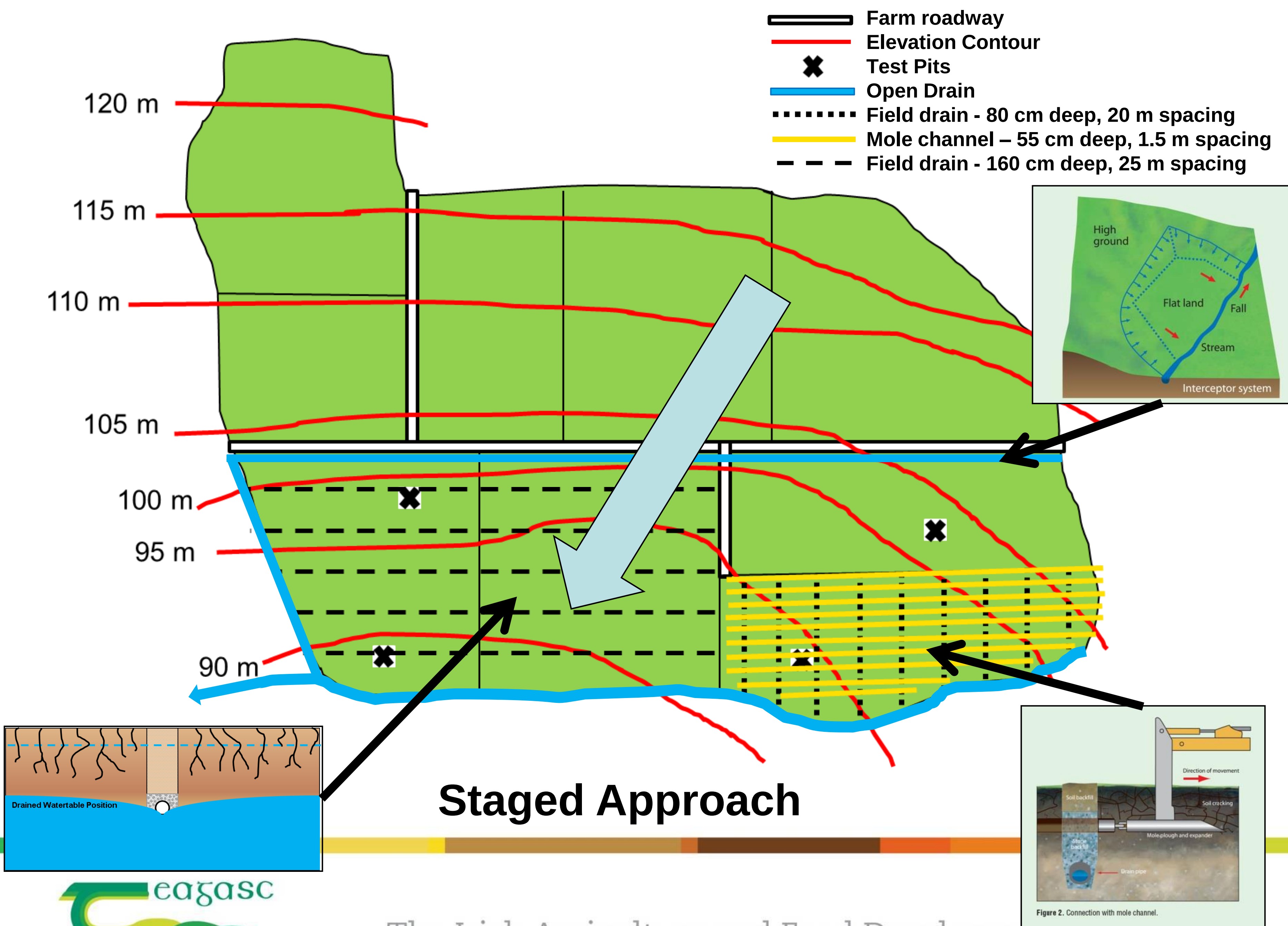
Peat

<u>Solutions</u>

1. **Main drainage System**
2. **Groundwater drainage system**
3. **Groundwater Interceptor drains**
4. **Shallow drainage system**
5. **Mole drainage**
6. **Gravel mole drainage**
7. **Sub-soiling (Pan-busting)**
8. **Land Forming**
9. **Peat Drainage**

8. **Land Forming**

9. **Peat Drainage**



Staged Approach

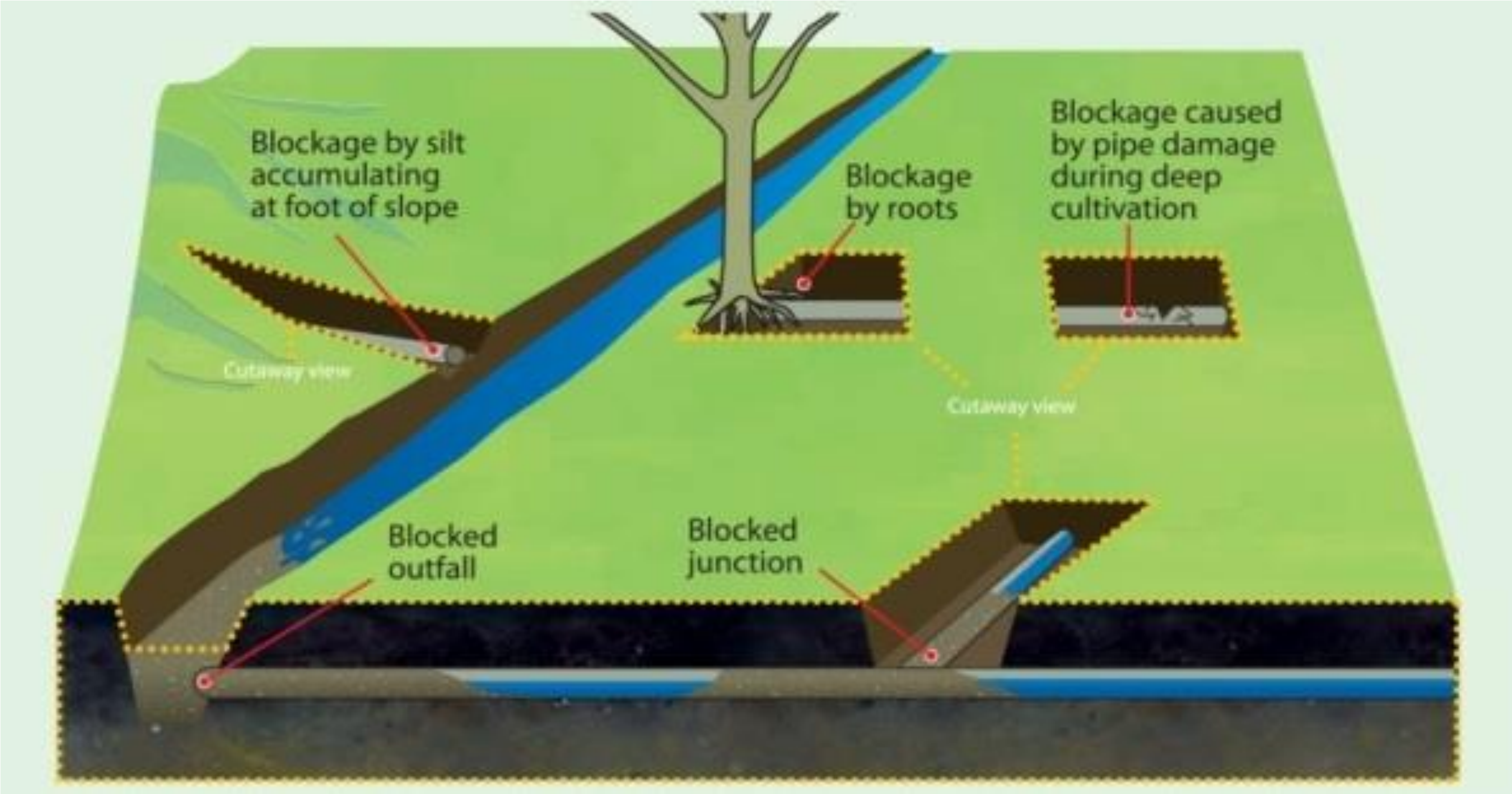
Factors affecting drain performance

What causes drains to block?

- ***Fine soil particles:*** silt and clay particles are many times smaller than aggregate or pipe slits and settle in low flow conditions. They can wash out into open drains.
- ***Iron ochre deposits***: these are predominantly 'rust' and occur naturally in certain soil types.
- ***Plants and their roots:*** can thrive in open channels, at the pipe outlet and deep within the system.
- ***Collapse/sedimentation:*** of open drains, due to flow conditions, undercutting of banks or livestock damage.

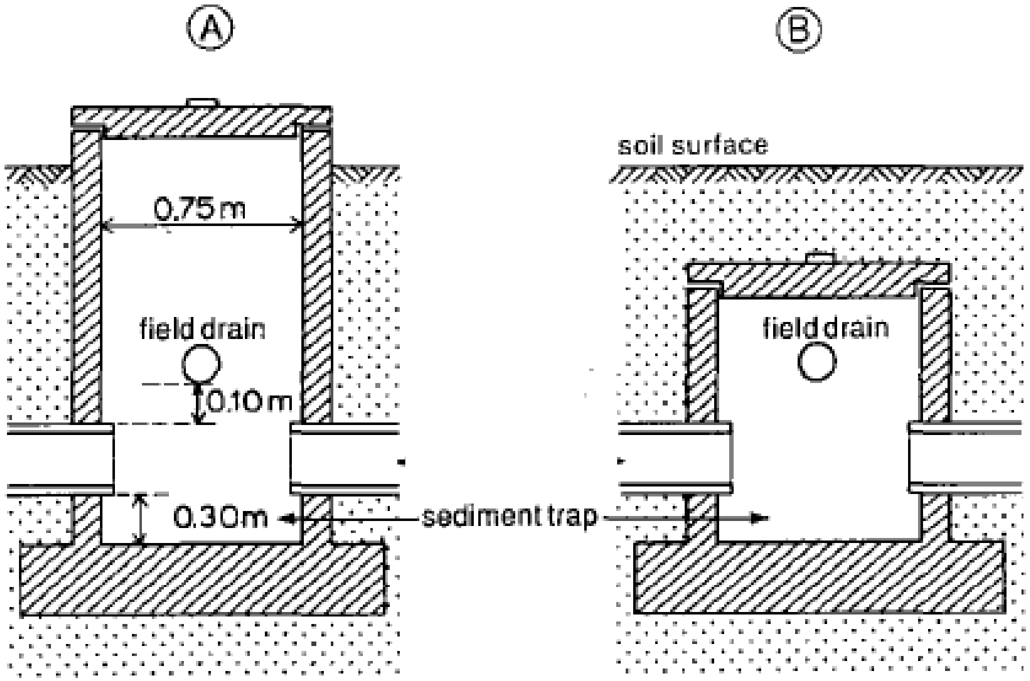
Factors affecting drain performance

- Blockages are more likely at pipe outlets and junctions but can occur anywhere.
- Sharp turns and dips in pipe alignment can also encourage blockages.



Plan for maintenance during design

- Always consider future ease of maintenance during design/installation
  - Avoid piping existing open drains
  - Avoid overly elaborate networks
  - Avoid junctions where possible
  - Install access points where required (at junctions etc.)



Sediment trap will need cleaning

System maintenance

- Open drains must be cleaned regularly to remove any obstructions, they should be established to as great a depth as possible to aid flows

- Ensure good outfalls and consistent flows.

- Spoil from such works, where suitable, can be spread on adjacent land filling depressions, but must not impede overland flow or runoff

- Unsuitable material can be buried and cover with topsoil or removed to waste ground

- Take care to **ensure field drain outlets are protected** during cleaning of open drains

- Exclude livestock access to open drains and outlets.

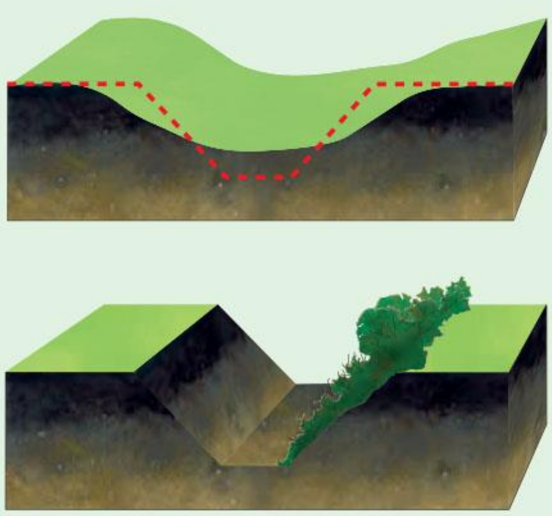
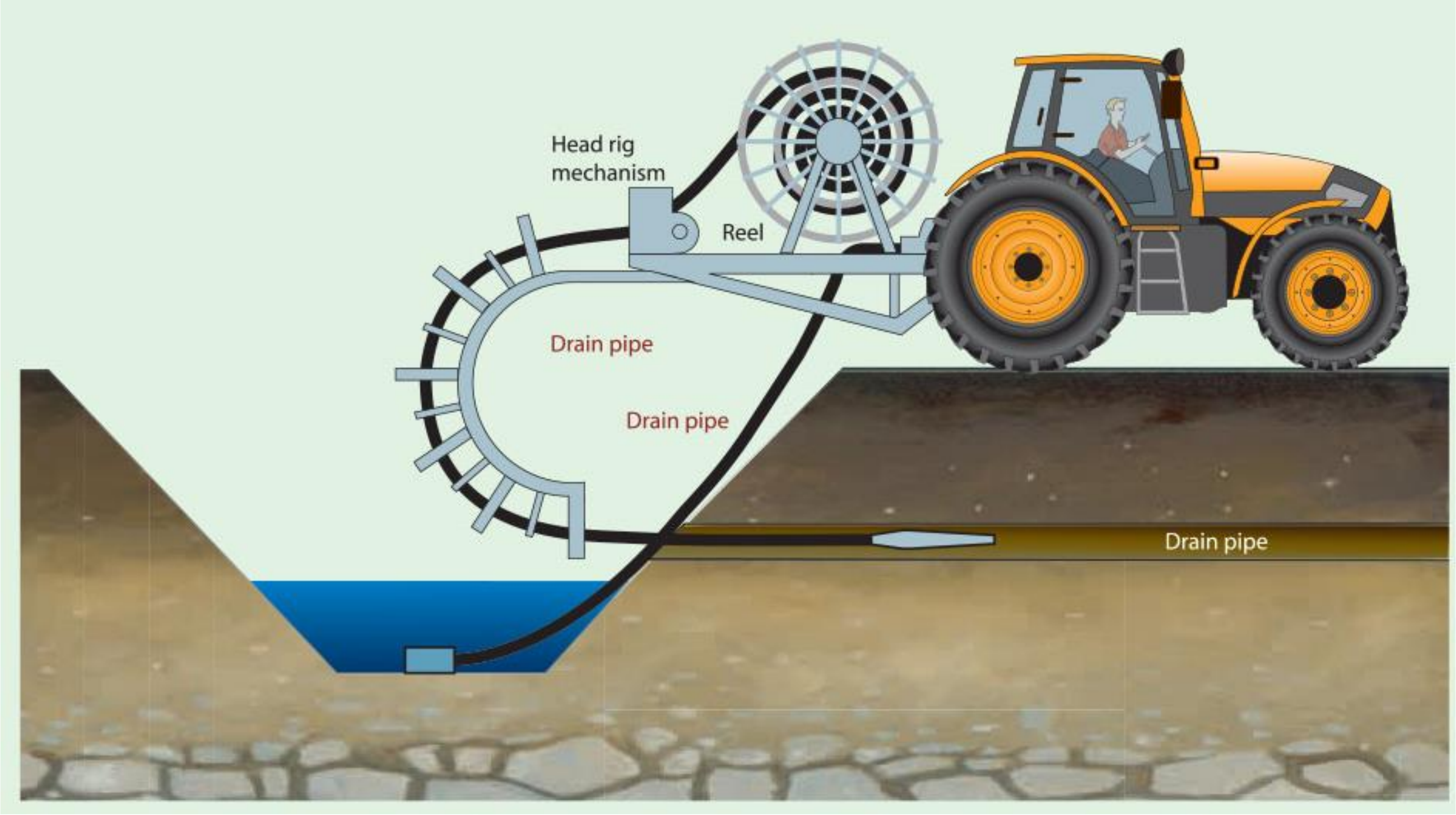
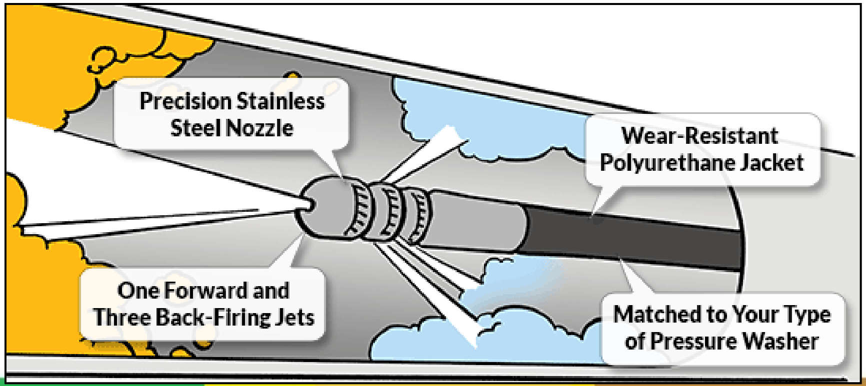


Figure 3. Maintenance of open drains changes the shape of the drain and makes them more efficient for water transport. Wider and deeper drains will help with sediment trapping.

Maintenance



System maintenance



https://www.youtube.com/watch?v=PCIlphDXPnU

Maintenance: environmental concerns

- When cleaning drains be aware of potential damage to fish and their habitats, including impacts downstream
- Fish and their spawning grounds are protected under Fisheries Acts
- In - stream work from July to September is least disruptive to fish
- If in doubt, consult Inland Fisheries Ireland www.fisheriesireland.ie

- https://www.teagasc.ie/media/website/publications/2016/Drainage_Maintenance-Q&A_Update.pdf

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Some Background

- Of the 3.18 million Ha of managed grassland nationally, it is estimated that 0.96 million Ha (30%) are imperfectly or poorly drained, and a further 0.24 million Ha (7.5%) is peat **(O' Sullivan et al. 2015).**

- The installation of artificial drains alters soil permeability such that migrating water interacts with soil and sediment biogeochemistry to mobilise or attenuate phosphorus………Drainage design, maintenance, and measures for P mitigation require an assessment of surface and subsurface P dynamics to ensure a 'right measure right place' approach **(Daly et al. 2017).**

- Deep groundwater drainage systems maintain their soil N attenuation potential but installation of shallow drainage systems can cause a negative shift, resulting in loss of this function, pollution swapping and increased water quality impacts from nutrient loadings in drainage **(Clagnan et al. 2018).**

- Drainage of mineral soils can aid in the reduction of nitrous oxide which is highest in poorly drained soils. However the drainage of humic (gleysols and podsols) and histic (peat) soils would result in substantial CO2 emissions to the atmosphere **(Teagasc GHG Working Group-MACC curve).**

Drain Outflow as % of total field water output

Table 2. Selected values reported for annual tile outflow as a percentage of total field water output.

Location	Land Use	Tile outflow as % of total field water output	Reference
NY	Grass	95%	Klaiber 2015
NY	Corn	40%	Hergert et al. 1981
OH	Corn-soybeans	47%	King et al. 2014
Quebec	Corn	81%	Enright and Madramootoo (2004)
Quebec	Corn-grains	98%	Goulet et al. 2006
Ontario	Corn-soybeans	97%	Tan and Zhang 2011
Ontario	Corn-soybeans-wheat	78-87%	Van Esbroeck 2015.
England	Pasture	50-66%	Bilotta et al. 2008
Finland	Barley-grass	Old system: 10-40%	Turtola and Paajanen 1995
Finland	Barley-grass	New system: 50-90%	Turtola and Paajanen 1995
Albania	Corn	47-69%	Grazhdani et al. 1996

http://www.lcbp.org/wp-content/uploads/2017/01/83_TileDrainage_LitReview.pdf

% of total P export from field drains

Table 6. Selected reports of the fraction of total site P export occurring in tile drainage.

Location	Total P (%)	Dissolved P (%)	Reference
Quebec	95%	91%	Goulet et al. 2006
Ontario	95 – 97%	--	Tan and Zhang 2011
Ontario	24%	31%	Ball Coelho et al. 2012
Ontario	--	55 – 68%	Gaynor and Findlay 1995
Ontario	40 – 77%	19 – 67%	Van Esbroeck et al. 2016
Wisconsin	17 – 53%	--	Ruark et al. 2012
Wisconsin	21 – 52%	21 – 68%	Madison et al. 2014
Indiana	25 – 80%	49%	Smith et al. 2015a
Louisiana	7%	--	Bengston et al. 1995.
England	29 – 41%	--	Bilotta et al. 2008

http://www.lcbp.org/wp-content/uploads/2017/01/83_TileDrainage_LitReview.pdf

In an extensive review, King et al. (2015) identified the major factors that influence P transport in tile drain systems:

- Soil characteristics
  - Preferential flow: preferential flow paths (cracks/fissures, macropores) provide a direct connection between the soil surface and tile drains.
  - P sorption capacity: research results are mixed, may be less important when macropores are extensive.
  - Redox conditions: reducing conditions under high water tables influences P mobility.
- Drainage depth and spacing: the depth and spacing of drain lines influence P concentration, drainage volume, and P mass losses.
- Surface inlets: P losses tend to be equivalent to those representative of surface runoff, higher than typical of tile drainage.
- Management practices
  - Tillage: Subsurface P transport is greater under ridge tillage and no-till compared with conventional tillage due to preferential flow coupled with stratification of P in soils due to greater surface application of fertilizers.
  - Cropping system: overall results of research mixed; most consistent influence is the level of P input associated with the cropping system
  - Soil test P: elevated levels of soil test P lead to greater concentrations of dissolved P in subsurface drainage.
  - P source – organic vs. inorganic: Research suggests that that losses from organic sources are greater than those from inorganic sources.
  - P placement – broadcast vs. incorporated: losses tend to be greater with broadcast applications as incorporation promotes soil adsorption; but differences diminish after several rainfall events
  - P application rate: potential for P loss increases with an increase in P application rate, especially if rates are greater than the crop removal rate.
  - P application timing: when applied relative to planting and how soon after application before a precipitation event are most important.
- Hydrology and Climate
  - Hydrology: baseflow and event flow: Majority of P loss through tile drainage generally observed during periods of elevated flow. Some studies report positive association between tile flow rate and P concentrations, but others report no relationship.
  - Season: non-growing season tends to represent a significant portion of annual discharge and P loss.

Structural, treatment, and management approaches to mitigate subsurface P transport — such as practices that disconnect flow pathways between surface soils and tile drains, drainage water management, in-stream or end-of-tile treatments, and ditch design and management

EIA Legislation

Land drainage works on lands used for agriculture is covered by the EIA (Agriculture) Regulations and is controlled by DAFM. Such drainage works include the following:

- Installing open drains
- Installing field drains (not open) such as field drains using plastic pipe with drainage stone or field drains with drainage stone only or mole drains (no pipe or drainage stone) or gravel filled mole drains (no pipe but filled with gravel)
- Opening of a short distance of watercourse

Subsoiling is not covered by the Regulations. Cleaning of open drains and adjacent levelling of spoil from such cleaning operations is also exempt.

EIA Legislation

- Screening by DAFM is required where drainage work exceeds 15ha

- **For the purposes of the Regulations the area will be considered to be the area of works (drains plus immediate vicinity) rather than the area of the field.**

- The thresholds will be the areas of works undertaken in any one year or the sum of such areas over a five year period, beginning on the 8th September 2011.

- http://www.agriculture.gov.ie

References

- Teagasc Land Drainage guidebook
- Teagasc Manual on Drainage and soil management