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## APPLICATION OF AGRICULTURAL DRAINAGE SYSTEMS FOR WATERLOGGED AND SALT-AFFECTED SOILS

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**S**ustainable agricultural production requires maintaining a favourable balance between soil moisture and aeration within the crop root zone. While irrigation ensures adequate water supply, excess water accumulation results in waterlogging, oxygen deficiency, nutrient imbalance, and secondary salinization. In canal command areas, deltaic plains, coastal regions, and heavy clay soils, poor drainage has become a major constraint to productivity. Agricultural drainage refers to the planned removal of excess surface or subsurface water from agricultural lands to maintain an optimal root zone environment. Scientifically designed drainage systems regulate groundwater levels, enhance soil aeration, improve nutrient dynamics, and prevent long-term soil degradation.

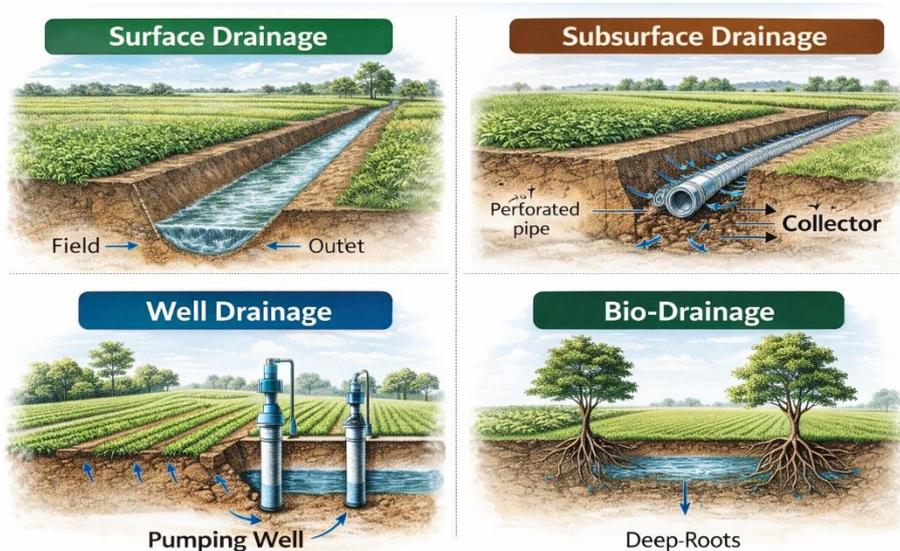
### Causes and Nature of Waterlogging

Waterlogging occurs when the groundwater table rises into or near the effective crop root zone for prolonged periods, typically above a critical depth of 0.6–1.2 m depending on crop type. Saturation of soil macropores restricts oxygen diffusion, creating hypoxic or anaerobic conditions in the rhizosphere. Under such conditions, root respiration declines, nitrification is inhibited, denitrification increases, and reduced compounds such as Fe<sup>2+</sup>, Mn<sup>2+</sup>, and hydrogen sulphide accumulate, adversely affecting plant growth.

The principal causes include seepage from unlined canals, excessive irrigation beyond crop evapotranspiration requirements, flat topography with inadequate natural drainage, presence of low-permeability subsurface layers, and high-intensity rainfall exceeding infiltration capacity. Poor maintenance of drainage networks further aggravates stagnation. In irrigated semi-arid regions, shallow saline groundwater intensifies the problem through capillary rise and salt accumulation in the root zone. Effective drainage planning therefore

requires hydrological assessment, groundwater monitoring, measurement of soil hydraulic conductivity, and estimation of an appropriate drainage coefficient to maintain a favourable root environment.

### Types of Drainage System



**Fig 1.** Types of Drain System

### Surface Drainage Systems

Surface drainage removes excess water from the soil surface before infiltration contributes to groundwater rise. It is particularly effective in high rainfall areas and heavy soils with low infiltration capacity.

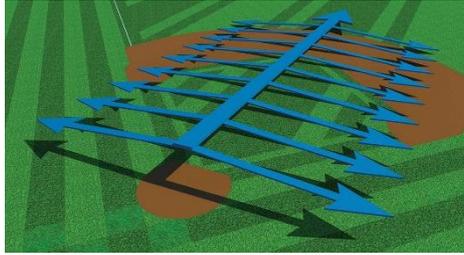
Surface Drainage by Open Channels: Open channel drainage consists of shallow field ditches constructed along natural slopes to intercept and convey runoff. These channels collect excess rainfall or irrigation overflow and discharge it safely to an outlet. Hydraulic design is based on runoff estimation and permissible flow velocity, commonly determined using



**Fig 2.** Surface Drainage by open Channel

Manning's equation. Proper longitudinal slope prevents sediment deposition while avoiding erosion. Although economical and easy to maintain, open channels may reduce cultivable area.

**Graded Land Drainage:** Graded drainage involves reshaping land to provide a uniform mild slope, generally between 0.1% and 0.3%, enabling controlled runoff toward an outlet. This system ensures uniform drainage without excessive erosion and is widely adopted in large, mechanized fields. Precision land levelling technologies such as laser levelling have improved its efficiency.



**Fig 3.** Graded Land Drainage

**Bedding System (Raised Bed and Furrow System):** In the bedding system, crops are planted on raised beds separated by furrows that act as drainage channels. The raised micro-relief enhances aeration and prevents root zone saturation. This method is particularly effective for row crops and vegetables grown in heavy soils.



**Fig 4.** Bedding System (Raised Bed and Furrow System)

**Parallel Surface Drains:** Parallel surface drains are constructed at regular intervals across fields with uniform slopes. They intercept surface runoff and convey it to a main drain. The spacing depends on rainfall intensity, soil infiltration capacity, and allowable duration of ponding.

### Subsurface Drainage Systems

Subsurface drainage regulates groundwater levels by removing excess water from beneath the soil surface. It is essential for chronically waterlogged and salt-affected areas.

1. **Tile Drainage (Pipe Drainage System):** Tile drainage consists of perforated pipes installed at depths typically between 1.0 and 1.5 m. Groundwater enters the pipe through perforations and flows by gravity to an outlet. Filter materials prevent soil intrusion and clogging. The system lowers the water table by creating a hydraulic gradient toward the drain line. It is highly effective in controlling salinity and improving soil structure. Though installation costs are higher, the long-term benefits in reclaimed lands are substantial.



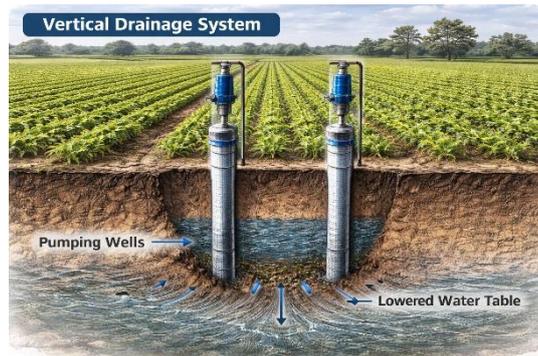
**Fig 5.** Tile Drainage (Pipe Drainage System)

2. **Mole Drainage:** Mole drainage involves forming unlined cylindrical channels in clay soils at depths of 0.4–0.7 m using a mole plough. These temporary channels facilitate lateral movement of water toward collectors. This method is economical and suitable for heavy clay soils but has a limited lifespan, generally three to five years.



**Fig 6.** Mole Drainage

3. **Vertical Drainage System (Drainage by Wells):** Vertical drainage lowers the groundwater table through pumping from wells or tube wells. It is effective in areas with high aquifer transmissivity. Pumped water can be reused for irrigation under conjunctive use strategies. Design considerations include aquifer characteristics, pumping rate, radius of influence, and groundwater quality. Improper management may cause saline upconing or land subsidence.



**Fig 7.** Vertical Drainage

### Bio-Drainage System

Bio-drainage utilizes deep-rooted tree species with high evapotranspiration rates to lower the water table. Species such as Eucalyptus and Casuarina extract groundwater and reduce soil saturation through transpiration. Although environmentally sustainable and low-cost, bio-drainage effectiveness depends on climatic conditions and groundwater salinity. It is best used as a supplementary measure rather than a primary engineered solution.



**Fig 8.** Bio-Drainage

### Layout Systems of Subsurface Drainage

The layout of subsurface drainage systems determines hydraulic performance and economic efficiency. The selection depends on topography, field geometry, and outlet position.

1. **Parallel Layout:** In this arrangement, lateral drains are installed parallel to each other at uniform spacing. It is suitable for fields with uniform slope and soil conditions. This layout ensures systematic water table control across the entire field.

2. Herringbone Layout: The herringbone layout consists of a central main drain with laterals entering at an angle from both sides. It is appropriate for fields with a central depression or natural valley.
3. Gridiron Layout: The gridiron system connects laterals perpendicularly to collectors, forming a grid pattern. It is suitable for flat lands requiring uniform drainage in multiple directions.

### Drain Depth and Spacing

Drain depth and spacing are critical design parameters governed by soil hydraulic conductivity, drainage coefficient, and crop rooting depth. Drain depth usually ranges from 1.0 to 1.5 m. Greater depth permits wider spacing but increases installation cost.

Drain spacing may vary from 20 m in heavy clay soils to 100 m in permeable sandy soils. The spacing is determined using hydraulic equations such as Hooghoudt's equation:

$$L^2 = (8KD(H - h)) / q$$

Where L represents spacing, K is hydraulic conductivity, D is equivalent depth, H is initial water table height, h is desired water table height, and q is drainage coefficient.

### Conclusion

Agricultural drainage systems comprise surface, subsurface, vertical, and bio-drainage approaches that collectively regulate excess water and maintain a favorable root zone environment. The selection of an appropriate system must be guided by a comprehensive evaluation of hydrological regime, soil hydraulic properties, groundwater dynamics, crop tolerance to waterlogging, and economic viability. Scientifically designed drainage not only restores soil aeration and root respiration but also mitigates secondary salinization, stabilizes soil structure, and improves nutrient use efficiency

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