

DESIGN OF SUBSURFACE DRAINAGE SYSTEM

by

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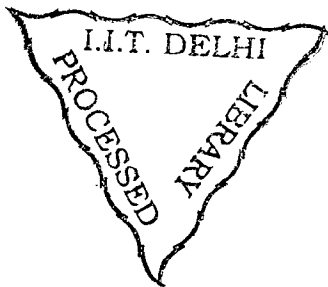
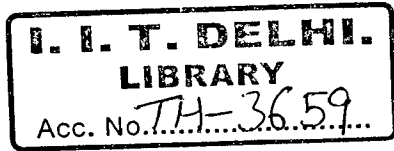
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Subsurface drainage system - functional analysis

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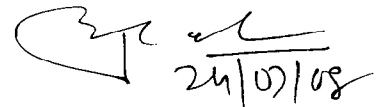
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CERTIFICATE

This is to certify that the thesis entitled “**DESIGN OF SUBSURFACE DRAINAGE SYSTEM**” being submitted by Mr. **Ghanshyam P. Vadodaria** to the *Indian Institute of Technology, Delhi* for the award of the degree of *Doctor of Philosophy* is a bonafide record of research work carried out by him under my guidance and supervision. The thesis work in my opinion, has reached the requisite standard, fulfilling the requirements for the degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.



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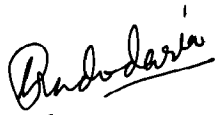
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ABSTRACT

Irrigation is widely practised in many parts of arid and semi-arid regions of the world to supply food, fibre, bio-energy and bio-industrial needs of the growing population mainly due to uncertainty in rain-fed agriculture. However, introduction of irrigation to such regions has resulted in serious water logging and secondary salinization problems because of the poor drainage characteristics of heavy textured soil. Apart from irrigation, high rainfall leading to flooding may also cause water logging. Water logging is also a problem experienced on cricket grounds, golf courses, race courses, parks and others amenities. The problems due to water logging and soil salinity can be alleviated by application of a proper subsurface drainage, which is a key element to sustainable high yield irrigated production system, a safeguard for sustainable investment in irrigation, and a tool for conservation of land resources. The goal of sub surface drainage system design is to provide adequate and uniform drainage of a field or area and removes only excess water and not water that plants can use.

Tiles/pipe drains, mole drain or ditches are commonly used as subsurface drainage system. One of the main drawbacks in the installation of tile type subsurface drainage system is its high initial investment and complex installation process. Generally ditches are used as an expedient drainage method or feasible dewatering tools in flooded areas or shallow unconfined aquifers as compared with tile drains or mole drain. The important advantages of open ditches are easy to construct, low initial cost, easy to inspect, low gradient and ability to carry large quantities of water; while the disadvantages are interference with farming operations, removal of land, regular maintenance, and side slope stability.

Planning an effective drainage system takes time and requires consideration of a number of factors including soil type, wetland impact, adequacy of system outlet, field slope and topography, economic feasibility, present and future cropping strategies, environmental impacts, easements and right-of-ways etc. The drain spacing and depth depend on soil type, soil permeability and stratification, the crops to be grown, the desired drainage coefficient, and the degree of surface drainage. The subsurface flux into ditches depends on the hydraulic conductivity of the soil, soil depth and drain spacing and depth.

As such a great variety of drainage situation occurs in the field, the actual field problem is simplified to make it possible to get a mathematical solution. Problems of two dimensional steady groundwater flow through homogeneously permeable porous media involving a free boundary may be solved by means of approximate manner by application of 'Domain' methods such as finite difference method or finite element method, series solution to Laplace's equation or the hodograph method in combination with boundary integral techniques. Exact solutions may be obtained by using the conformal mapping involving velocity hodograph and Schwarz-Christoffel transformation. The solutions to subsurface drainage problems with different boundary conditions are available in the literature using various techniques. The available solutions for drainage of ponded surface do not consider the effect of depth of impervious layer, ponded water depth, width and depth of ditch.

In the present study, a general solution to the problem of drainage of a ponded field in a homogeneous and isotropic soil medium overlaying an impervious substratum by an array of partially penetrating ditches have been developed using hodograph and Schwarz-Christoffel transformation. The solution includes expressions for the drain discharge, the quantity of seepage from seepage face, the velocity

potential at key points, and the velocity distribution of seeping water. Further, particular solutions (e.g. single ditch, empty ditch, ditch of negligible width, impervious layer at infinite depth or at the bottom of ditch) have been obtained.

It has been found from the study that as the spacing between the ditches decreases the drainage rate into individual ditch also decreases. The drainage quantity is maximum for an empty ditch and infinite spacing. For small spacing the quantity of drainage is very sensitive. With the increase in depth of water in a ditch, the quantity of seepage decreases first at a slower rate and then at a faster rate to become zero for full ditch. The effect of ditch width on the drainage quantity is not substantial. This effect further reduces with decrease in the depth of the impervious layer. The velocity variation gives some insight about salt removal rates along the ponded surface as the rate of leaching is proportional to the drainage velocity. Thus closer spacing between the ditches and smaller water depths in ditches are beneficial from this aspect. With increase in the ponded water depth the drainage quantity also increases. Moreover, the variation in the drainage quantity is linear upto the water depth in a ditch equal to or less than the ponded depth and it is nonlinear otherwise.

Minimization of cost, by proper choice of depth and spacing of drains, constitutes an important aspect of subsurface drainage of ponded surface of homogeneous and isotropic porous medium of finite depth for different combinations of depth of impervious layer. The cost of installation of drainage system by an array of ditches depends on the costs per unit length and the number of ditches per unit area. The cost function includes the depth-dependent earthwork cost and the capitalized cost of pumping of drain discharge. Essentially it is a problem of minimization of a non-linear objective function of single variable. A methodology has been developed for fixing optimal spacing between ditches. The input variables

consist of rainfall intensity, hydraulic conductivity of the porous medium, width and depth of ditches and earthwork and pumping cost parameters.

The thesis embodies general solution for the design of subsurface drainage system for ponded area by an array of partially penetrating ditches using hodograph and Schwarz-Christoffel transformation, which may be useful to practising engineers in controlling waterlogging and secondary salinization in irrigated lands, play grounds, parks and other urban utilities.

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