IMPROVING SUBSURFACE DRAINAGE DESIGN USING GEOSTATISTICAL ANALYSIS OF THE HYDRAULIC CONDUCTIVITY IN THE NILE DELTA

By

Mohamed Fawzy Mohamed Mahmoud

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Irrigation and Hydraulics Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

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Key Words:
Hydraulic conductivity; subsurface drainage; Kriging; geostatistical analysis

Summary:

The agricultural subsurface drainage system is used all over the Nile Delta of Egypt to drain excess water from the soil to enhance crop production and to ensure irrigated agriculture sustainability. The design spacing between lateral drains is playing an important role in determining the efficiency of the subsurface drainage. The main input for the design is the value of the saturated hydraulic conductivity of the soil. Currently, the design practice involves using a grid of 500mX500m in field investigations to measure the hydraulic conductivity at each point of the grid using the auger-hole method. The main objective of this study is to determine the optimal sampling density to be used in the design. Using geostatistical analysis (Kriging) and a data base of over 6000 hydraulic conductivity tests from different projects in the Nile Delta of Egypt, the optimal sampling density was obtained and correlated with the soil clay content using empirical equations. Also, a new design procedure based on Kriging was developed to enhance the future design of the subsurface drainage system. Using the available data base, a contour map of the hydraulic conductivity in the Nile Delta was developed to help the decision makers in taking critical decisions such as preliminary cost estimate for the subsurface drainage project even before conducting a detailed field investigation.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Nomenclature

ANOVA	Analysis of Variance
ArcGIS	Geographic information system for working with maps and geographic information.
cm	Centimeter
DRI	Drainage Research Institute
EPADP	Egyptian Public Authority for Drainage Projects
Feddan	Feddan = 4200 m2
Geomean	Geometric Mean
ha	Hectare = 10000 m2
ISAWIP	Integrated Soil and Water Improvement Project
K	Hydraulic conductivity
m	Meter
m/d	Meter per day
NWRC	National Water Research Center
RMSE	Root Mean Square Error

Abstract

The agricultural subsurface drainage system is a system which almost all the Nile Delta of Egypt uses to drain excess water from the soil to enhance crop production and to ensure irrigated agriculture sustainability. The design spacing between lateral drains is playing an important role in determining the efficiency of the subsurface drainage system and its cost. The main input for design is the value of the saturated hydraulic conductivity of the soil. The current practice in Egypt for economical and practical considerations requires dividing the drainage area into blocks and using a single spacing in this block. The selection of the value of the hydraulic conductivity that can be used in the design for this block is challenging due to the high spatial variability of the hydraulic conductivity. Currently, the design practice involves dividing the drainage block into a grid of 500 m X 500 m and the hydraulic conductivity is measured at each point of the grid using the auger-hole method. After conducting the field measurements, an average value of the measured hydraulic conductivities is obtained and used in the design. These practices have been applied for years and are applied for every new subsurface drainage project.

However, several questions may arise here and spark the needs for further investigations. A previous research stated that grid spacing 500 m X 500 m is sufficient to capture the spatial variability. However, it was site specific and it doesn't state if it is the optimum from the economic point of view, its relation to soil type, and if Kriging can provide a better way for estimating the hydraulic conductivity to be used in the design. Also, if we can get benefit of the available database in the Egyptian Public Authority for Drainage Projects (EPADP) to enhance the future designs and reduce the cost of new projects.

The main objective of this study is to determine the most suitable and feasible grid spacing to be used in the design. To fulfill this objective a geostatistical analysis (Kriging) and a data base of over 6000 hydraulic conductivity tests from different projects in the Nile Delta of Egypt has been used. The main software used for Kriging, generating data, and spatial analysis is the Geostatistical Analyst extension of ArcGIS, a geographic information system software for working with maps and geographic information. The data was digitized and analyzed from different aspects such as if Kriging conditions are applicable on the data. After that the ordinary Kriging was applied to create a fine grid spacing of 125mX125m using the available data of each project. New reduced grids were generated by excluding some points of the fine grid. Kriging estimates from the reduced grids were compared to the fine grid estimated from the actual data. The generated grids have been tested using ANOVA test to select the optimal sampling density of the hydraulic conductivity. After obtaining the optimal sampling density for every project it was correlated with the soil type. Two empirical equations function of soil type and two design charts were developed to obtain the optimal sampling density.

Based on the results, a new design procedure was developed to enhance the future design of the subsurface drainage system. Using the available data base, a contour map of the hydraulic conductivity in the Nile Delta was developed to help the decision makers in taking critical decisions such as preliminary cost estimate for the subsurface drainage project even before conducting a detailed field investigation.