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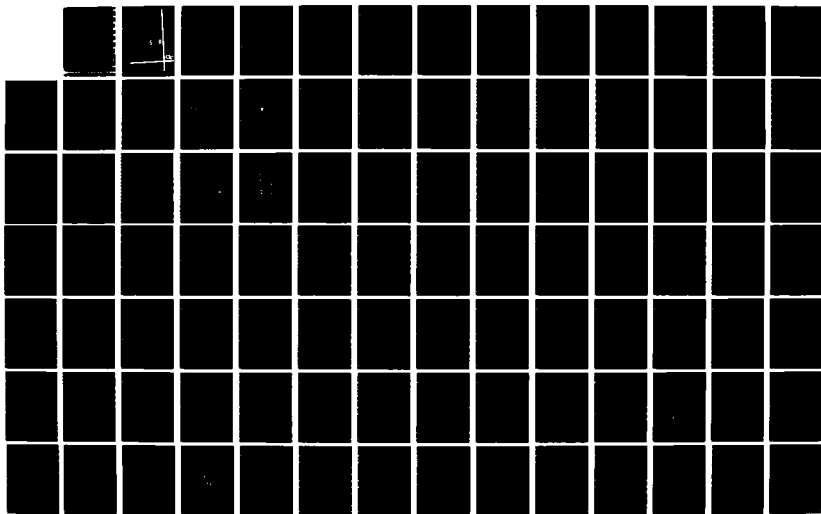
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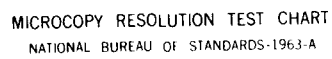
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UNDERDRAIN SYSTEMS FOR LARGE STRUCTURES
PLACED BELOW THE GROUNDWATER TABLE

A Special Research Problem

Presented to

The Faculty of the School of Civil Engineering
Georgia Institute of Technology

CONTRACT # ~~N-00228~~-G-3247

by

Gary N. Pirtle

August, 1986

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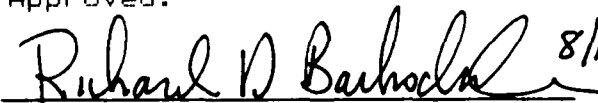
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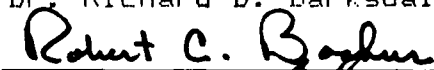
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In Partial Fulfillment
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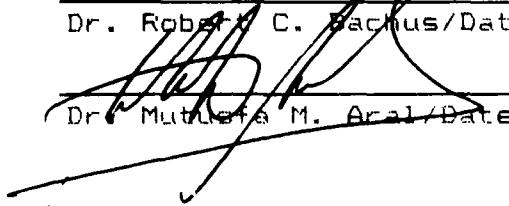
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ABSTRACT

This research is a study in seepage analysis for engineered structures built below the groundwater table; in particular an analysis of underdrain systems for such structures. General seepage theories and design considerations are discussed as part of the literature review. Also design concepts and methods of analysis are covered which gives a brief overview of design considerations and techniques which are currently used for this type of seepage problem.

Key variables to the design of an underdrain system are studied in detail by using a two dimensional, steady state finite element model. Such variables studied are drain spacing, drain width, anisotropic hydraulic conductivity, thickness of the aquifer, head differential and sloping aquifers.

Results are presented in the form of dimensionless plots and nomographs for drain discharge and free surface plots for the different variables studied.

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CHAPTER ONE

INTRODUCTION

For civil engineered structures which interact with soil, a major consideration for design is the presence of groundwater. Dams, buildings, dry dock facilities, underground structures, pavements and earth retaining walls must be designed considering the quantity of seepage, the position of the free surface, seepage forces and seepage control. Good drainage incorporated in the design of these and other structures can often benefit through substantial cost reductions as well as increasing the safety and usefulness of the structure.

Many embarrassing and sometimes disastrous problems often result from man's endeavors to control seepage. Saturated soil backfills have caused many retaining wall failures due to increased hydrostatic pressures following extensive rainfall. Highways and roadways prematurely deteriorate and fail due to trapped water in the pavement section. Basement slabs, pond liners and drydock facilities have been severely damaged by hydrostatic uplift pressures and seepage. Most dam and slope failures can be attributed to excessive seepage or uplift pressures. These examples and untold others indicate that good seepage and drainage control together with an adequate

understanding of groundwater is a key element in the design of most civil engineering structures.

Many civil engineering structures are located in areas where groundwater causes problems of uplift and seepage. The design therefore must consider all problems associated with high groundwater and what measures must be taken to assure the integrity of the overall design. Casagrande(1965), in talking about engineering risks, concludes that, "The margin of safety that we incorporate into our structures should bear a direct relationship to the magnitude of potential losses, and it must also take into account the range of uncertainty involved." This important concept hopefully will be considered throughout the presentation of facts and data obtained in this paper.

Prior to the 20th century, analysis of seepage and the control of drainage for engineering structures was done by experienced engineers who based their designs on trial and error methods which sometimes were successful and sometimes not. Though experience has proven to be very necessary and helpful in the design of drainage systems, very useful tools employed today are numerical methods such as finite element and finite difference techniques which require the use of the digital computer. Their problem solving capabilities have made possible solving very complicated and complex groundwater problems.

The purpose of this research is to study the design of underdrain systems for large structures placed below the groundwater table. In chapter two, basic seepage theories and design requirements, designs concepts and useful methods of analysis are presented as a brief literature review. This chapter covers critical aspects of designs that should be considered and contains a brief review of methods used by geotechnical engineers.

In chapter three, the finite element program developed by Dr. M. Aral, of the School of Civil Engineering at Georgia Institute of Technology, is discussed describing how the design of building underdrain systems can be modeled using this technique. This finite element program made possible studying effects of key variables such as permeability, hydraulic head, drain geometry, depth of groundwater, and anisotropic soils. Program verification is performed using another program, SEEP84, modified by the Civil Engineering Department at Virginia Polytechnic Institute and State University, for the microcomputer. Dupuit's solution is also used to compare selected cases with the finite element programs.

Chapter four presents data generated from the finite element study such as position of the free surface and flow quantity for selected systems of underdrains suitable for use beneath a foundation. The data is presented in the form of charts and nomographs to be used as a guide for underdrain system design.

Chapter five summarizes the results of the study and presents appropriate conclusions.

Appendix A contains program documentation for the finite element program used in this study which details to the user, documentation to the use of the program. Appendix B presents example input and output data generated by this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Seepage Theories and Design Requirements

Groundwater

Soils, sometimes described as a porous media, is a mass made up of solid matter having interconnected voids, passages, fissures or pore spaces. These pore spaces can be filled by a liquid and or a gaseous phase. Figure 2.1 shows several typical soil and rock indices which depicts how pore spaces can act as conduits for water or subcapillary openings in which water may be held by adhesive capillary forces (Meinzer, 1942).

The soil mass forms a complex network of irregular passages through which the fluid may flow. A key parameter of groundwater movement is the porosity of the soil. As gravity acts on the fluid, it moves through the pore spaces at varying rates through each open pore space. From a macro scale, this flow has been mathematically described by several authors (Bear, 1981; Terzaghi, 1943; Cedergrén, 1977; Harr, 1962; Bouwer, 1978; Freeze, 1971).

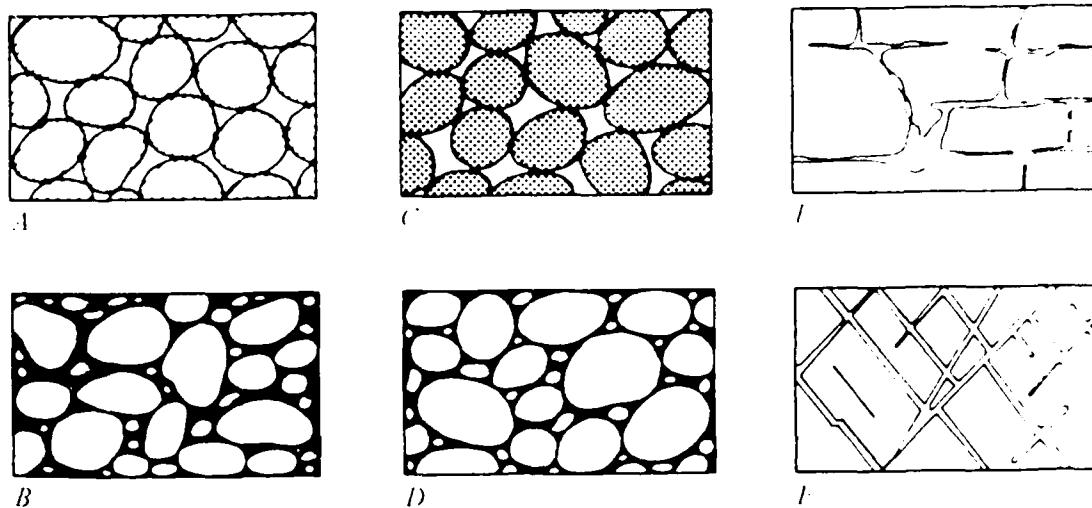


Figure 2.1 Diagram showing soil and rock interstices. A. Well sorted sand deposit having high porosity; B. Poorly sorted deposit having low porosity; C. Particles that may be porous themselves; D. Deposit whose porosity may be diminished by deposition of mineral matter in the interstices; E. Rock that is porous by solution; F. Rock that is porous by fracturing (after Meinzer, 1942)

Moisture content in soils can vary with depth from the surface, as shown by Figure 2.2. Most seepage problems considers the zone of saturation which is the zone where the soil mass is completely saturated. The terms groundwater level, phreatic water level, water table, free surface or groundwater surface are all synonymous to denote the level of water where atmospheric pressure exists.

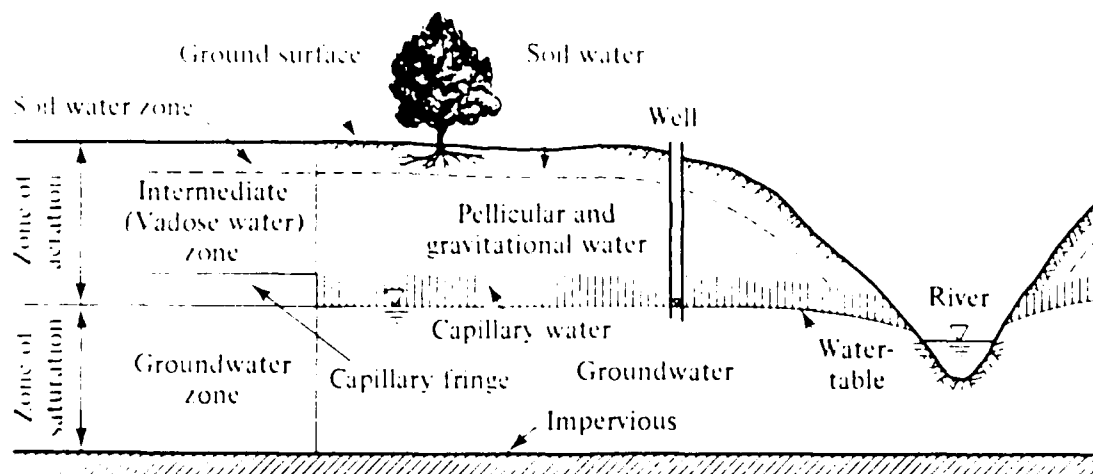


Figure 2.2 Subsurface groundwater distribution.
(after Bear, 1979)

In dealing with capillary fringe in fine grained soils the height of water can very significant. As the pore diameter decreases, the capillary rise increases. Although the soil is considered unsaturated, the soils moisture content will be higher with depth.

The zone of capillary rise and fringe zone may contain large quantities of water for fine grained soils. Water removal by drainage, due to capillary forces, may be difficult for such fine grained soils. Figure 2.3 shows how the actual moisture distribution is approximated by a step distribution. This approximation of the capillary fringe level above the free surface, h_c , is often neglected in some seepage problems. Several empirical methods, based on grain size diameter and porosity of soil, are available to estimate h_c (Mavis and Tsui, 1939; Polubarinova, 1952, 1962; Silin Bekchurin, 1958).

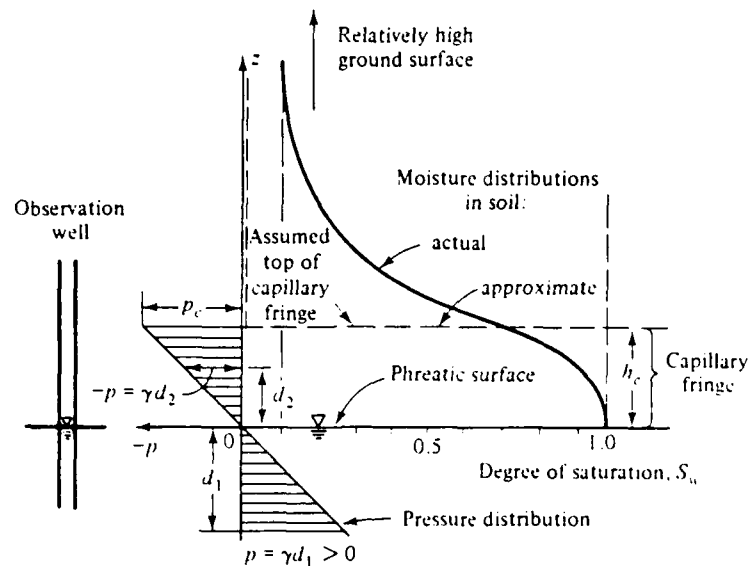


Figure 2.3 Approximation of phreatic surface and capillary fringe zone. (after Bear, 1979)

Many textbooks on seepage and groundwater discuss water bearing and retention capabilities of the capillary fringe and movement of moisture through this zone (Terzaghi, 1943; Kovacs, 1981; Sowers, 1979). However, when this height of water is very small relative to the total thickness of the aquifer, the capillary fringe is sometimes neglected. The geotechnical engineer should be concerned with the unsaturated-saturated flow condition when the stability of the engineered structure is to be analyzed, such as a dam.

Groundwater analysis for seepage problems must consider the quantity of water to be drained, the soils resistance to drainage, and what effects the drainage may have on the soil and the structure. Movement of groundwater can be categorized

either as seepage; capillary rise or flow; percolation; or turbulent flow. For this study, only movement of groundwater by seepage is considered.

Design Requirements

Structures built below the watertable must be designed considering the following:

- (1) structural ability to withstand the applied hydrostatic water pressures,
- (2) drainage control which short-cuts the flow or movement of groundwater from getting to the structure,
- (3) drainage control which is incorporated with the overall design to remove the groundwater,
- (4) assure water velocities be small enough to prevent excess particle migration and erosion.

Savings of dollars, time and natural resources can be recognized when structures can be considered on dry, stable material; in addition to thinner basement slab thicknesses may be used.

Darcy's Law

In 1856, Henry Darcy investigated the flow of water in vertical homogeneous sand. This work has developed the most fundamental relationship which is still used in seepage analysis today.

Darcy's Law states:

$$Q = k i A \quad (2.1)$$

where Q (L^3/T) is a volume discharge or flow of a given cross-sectional area, A (L^2) in a given time. The discharge is also a function of the hydraulic gradient, i (L/L) and a resistance coefficient, k (L/T), the permeability of the soil. Investigators, Muskat (1937), Taylor (1949) and Leonards (1962), have concluded that Darcy's Law is valid where velocities are low or when flow is laminar, i.e. Reynolds number less than 10.

Hydraulic Conductivity

The soils resistance to flow or the coefficient of porportionality, k , for Darcy's Law, is also called the hydraulic conductivity. Hydraulic conductivity is a coefficient which expresses the ease or resistance the water has flowing through the soil. It depends on the soils matrix and fluid properties of the permeant.

Many researchers have performed tests to attempt to develop empirical relationships of the soils properties to hydraulic conductivity. Some of these properties considered are grain or pore size distribution, shape of the grains or pores, tortuosity, specific surface and porosity (Mitchell, 1976; Kozeny, 1927; Carman, 1956; Cedergren, 1977; Kovacs, 1981). All report that careful field investigation and careful conductivity studies are necessary for each design. Figure 2.4 is presented to show some characteristics of various soil types and most important, methods for determination of selected properties (Terzaghi and Peck, 1948).

In the unsaturated zone, the hydraulic conductivity, moisture content and pressure head is extremely complex and not well understood. Again, field measurement is the best method for obtaining the best parameters, such as the use of theistom psychrometer (Kay and Low, 1970) or gamma ray absorption techniques (Ferguson, 1970; Aral, 1983). However, many empirical formulas have been developed to relate the soil parameters to a relative hydraulic conductivity of the un-saturated zone (Kovacs, 1981; Inmay, 1954; Childs and Collis-George, 1950; Gardner, 1958; Brooks and Corey, 1966; Maslia, 1980; Reeves and Duriguid, 1975).

Coefficient of Permeability k in cm per sec (log scale)														
	10^3	10^2	10^1	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	
Drainage	Good						Poor			Practically Impervious				
Soil types	Clean gravel	Clean sands, clean sand and gravel mixtures					Very fine sands, organic and inorganic silts, mixtures of sand silt and clay, glacial till, stratified clay deposits, etc.					"Impervious" soils, e.g., homogeneous clays below zone of weathering		
							"Impervious" soils modified by effects of vegetation and weathering							
Direct determination of k	Direct testing of soil in its original position—pumping tests. Reliable if properly conducted. Considerable experience required													
	Constant-head permeameter. Little experience required													
Indirect determination of k	Falling-head permeameter. Reliable. Little experience required					Falling-head permeameter. Unreliable. Much experience required					Falling-head permeameter. Fairly reliable. Considerable experience necessary			
	Computation from grain-size distribution. Applicable only to clean cohesionless sands and gravels										Computation based on results of consolidation tests. Reliable. Considerable experience required			
											After A. Casagrande and R. E. Fadum			

Figure 2.4 Permeability and Drainage Characteristics for Various Soil Types

2.2 Design Concepts

Seepage Forces

The effects of water on the soil and the structure is controlled by the pressures in the water. In soil mechanics, the water pressure is defined as neutral stress. For water not moving, or steady state, the pressure can be computed from the basic equation of hydrostatics

$$h = \frac{P}{\gamma_w} + z \quad (2.2)$$

where h , energy head, is equal to the position, z , plus the pressure head or piezometric head, P/γ_w . Typically in seepage designs, the velocity head is very small and may be neglected. Then the pressure head plus elevation is equal to head, h (Cedergren, 1977).

For the condition that water pressure is greater than the total load, say of the soil and structure, the pressures are termed uplift pressures and liquifaction can occur. Therefore the control of uplift pressures must be a primary design consideration.

Critical Velocity

According to Darcy's Law, the discharge velocity of seepage through soil is

$$v_d = k \times i \quad (2.3)$$

Seepage is only occurring through the pores and voids.

Therefore the true seepage velocity should be a function of the porosity of the soil mass. Re-writing equation (2.3) the seepage velocity can be expressed as

$$v_{sn} = \frac{k \times i}{n_e} \quad (2.4)$$

where n_e is the effective porosity.

In flow conditions, the saturation of soil is moving into or away from the unsaturated soil. The capillary head, h_c , is working with gravity to increase the hydraulic gradient. For this condition the hydraulic gradient can be expressed

$$i = \frac{h + h_c}{L} \quad (2.5)$$

Figure 2.5 depicts this condition for flow through a sand.

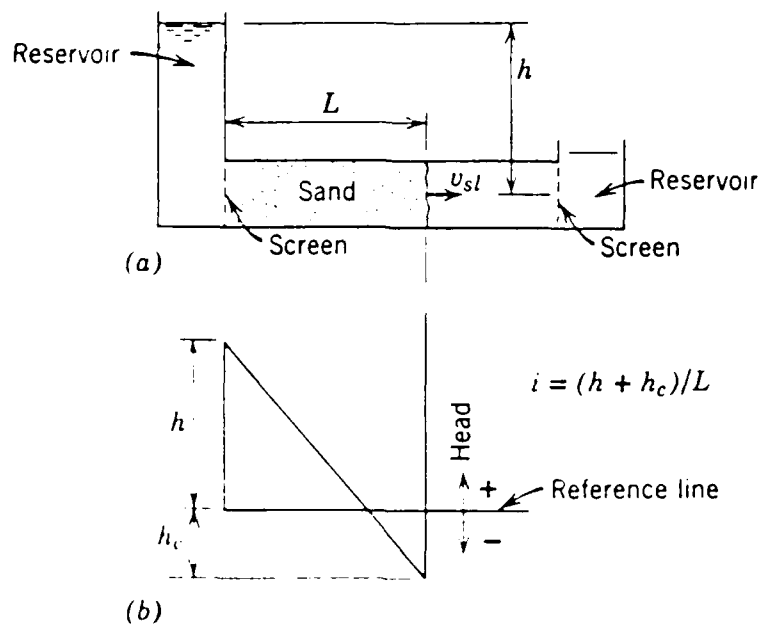


Figure 2.5 Force of saturation.

Boiling occurs when seepage pressures in an upward direction exceeds the downward force of the soil. This must be analysed for all seepage designs. Critical hydraulic gradient, i_c , can be expressed

$$i_c = \frac{\gamma_T - \gamma_w}{\gamma_w} = \frac{\gamma_b}{\gamma_w} \quad (2.6)$$

where γ_T = total unit weight of soil
 γ_w = unit weight of water
 γ_b = buoyant unit weight of soil (NAVFAC, DM-7.1).

Filters

A very important design consideration is the possibility of seepage forces moving erodible soils and rock, termed piping. Betram (1940), under Terzaghi and Casagrande, established the following criteria for filter design, based on grain size.

$$\frac{D_{15} \text{ (of filter)}}{D_{85} \text{ (of soil)}} < 4 \text{ to } 5 < \frac{D_{15} \text{ (of filter)}}{D_{15} \text{ (of soil)}} \quad (2.7)$$

This relationship is represented by Figure 2.6 to illustrate the prevention of piping by filters (Cedergren, 1977).

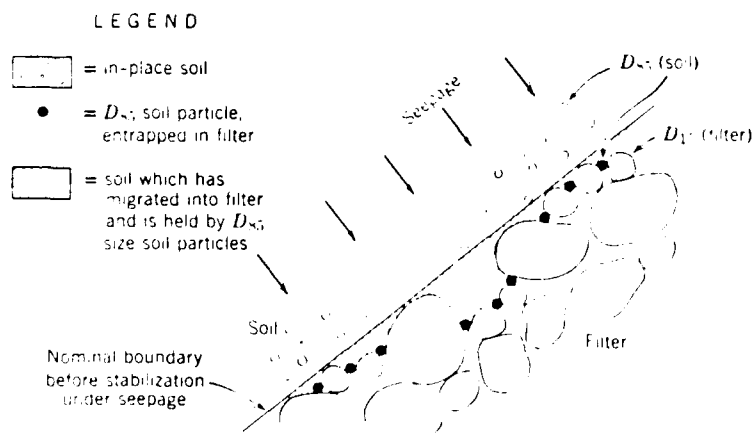


Figure 2.6 Illustration of prevention of piping by filters.
(after Rankilior, 1981)

The ratio of D_{15} of a filter to the D_{85} of a soil is considered the piping ratio. Many authors and organizations have established other criteria for filters, similar to that of equation (2.7) (U.S. Army Corps of Engineers, 1941, 1955; U.S. Bureau of Reclamation, 1955; Sherard, et al, 1963; Cedergren, 1977; Thanikachalam and Sakthivadivel, 1974).

Filters must be designed to meet two major requirements; (1) they must be safe with respect to erosion and piping, and (2) must have sufficient discharge capabilities to remove the seepage quickly and efficiently. This must be done without inducing high seepage forces or hydrostatic pressures. The right side of equation (2.7) states that the D_{15} size of a filter should be at least 4 to 5 times the D_{15} of the soil. This insures that the hydraulic conductivity of the filter and drains is sufficient to prevent the build-up of large seepage forces and hydrostatic pressures.

There is a wide range of engineering properties of materials to be considered for filter drainage systems designs. Properties which may influence hydraulic conductivity are grain size, density, mineralogical composition, the nature of the permeant or the degree of saturation. Much work has gone toward methods for determination and factors which influence hydraulic conductivity (Milligan, 1975; Lambe and Whitman, 1969; Yemington, 1963; Bouwer, 1978). There is still much research necessary to understand better this property of soil.

Trench Drains

For the application of drainage for structures built below the water table, the use of trench drains, which acts as collectors of the seepage or may contain collector pipes, is a very efficient method. Figure 2.7 shows the typical cross-section which may be considered for the application of this type of drainage system. Trench drains will be discussed further in the report and their utilization for this application will be studied in more detail.

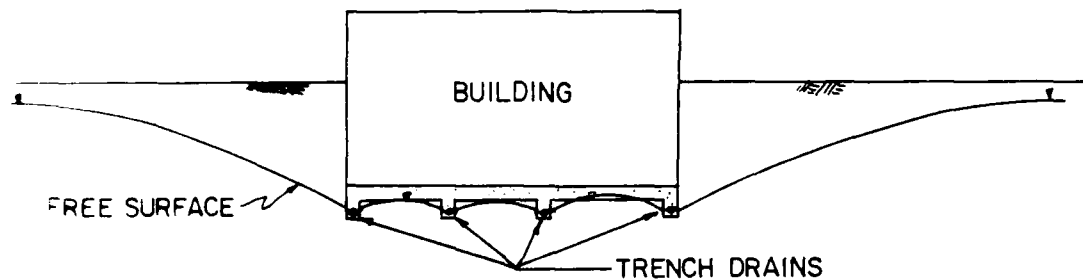


Figure 2.7 Typical application of a trench drain system.

Geosynthetics

Today, new synthetic membranes are used to serve the purpose of either filtration or separation. These two factors are very important parameters for most seepage problems. Figure 2.8 shows comparisons of some of the features of membrane-wrapped drains to conventional granular pipe drains. Also Figure 2.9 shows the bridging effect caused by good separation of the larger materials and smaller particles.

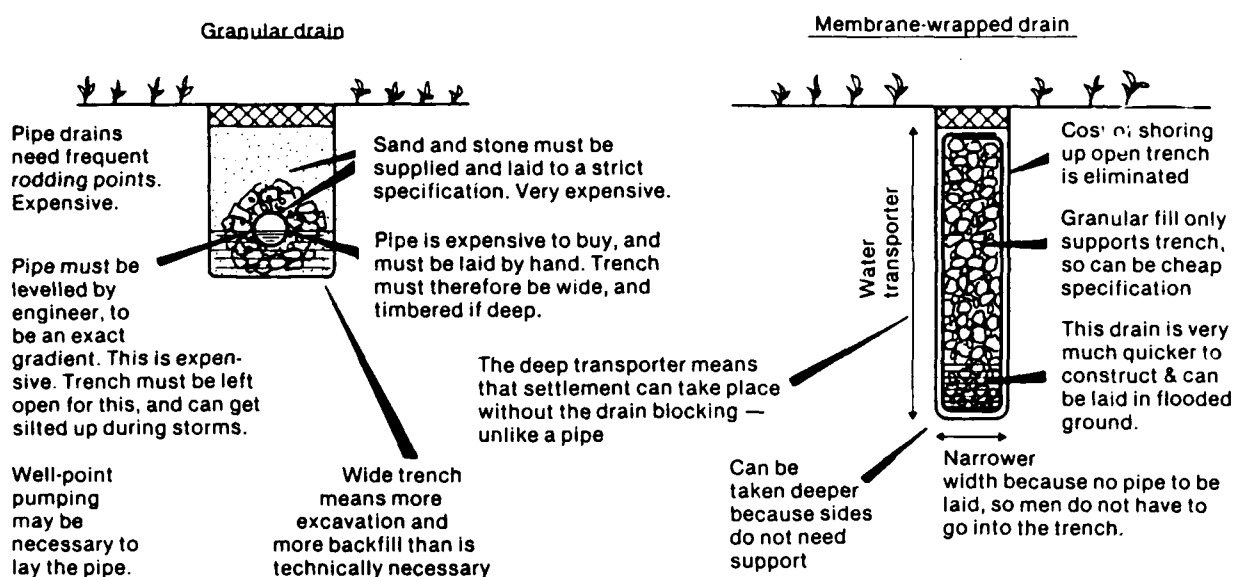


Figure 2.8 Conventional granular pipe trench drain and membrane-wrapped trench drain. (after Rankilior, 1981)

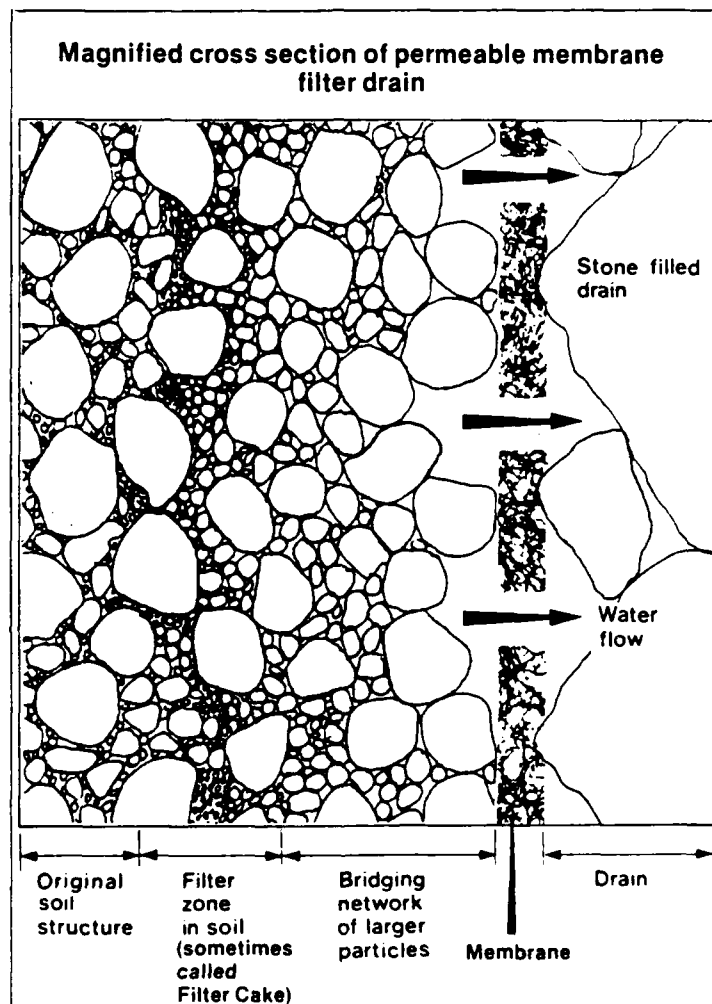


Figure 2.9 Bridging effects caused by use of membrane filter material. (after Rankilior, 1981)

A good representation of how geosynthetics combine action of separation and filtration, is shown by Figure 2.10. As water has more area of flow with the membrane, the seepage can be considered to be at a faster rate or drain quicker (Rankilior, 1981)

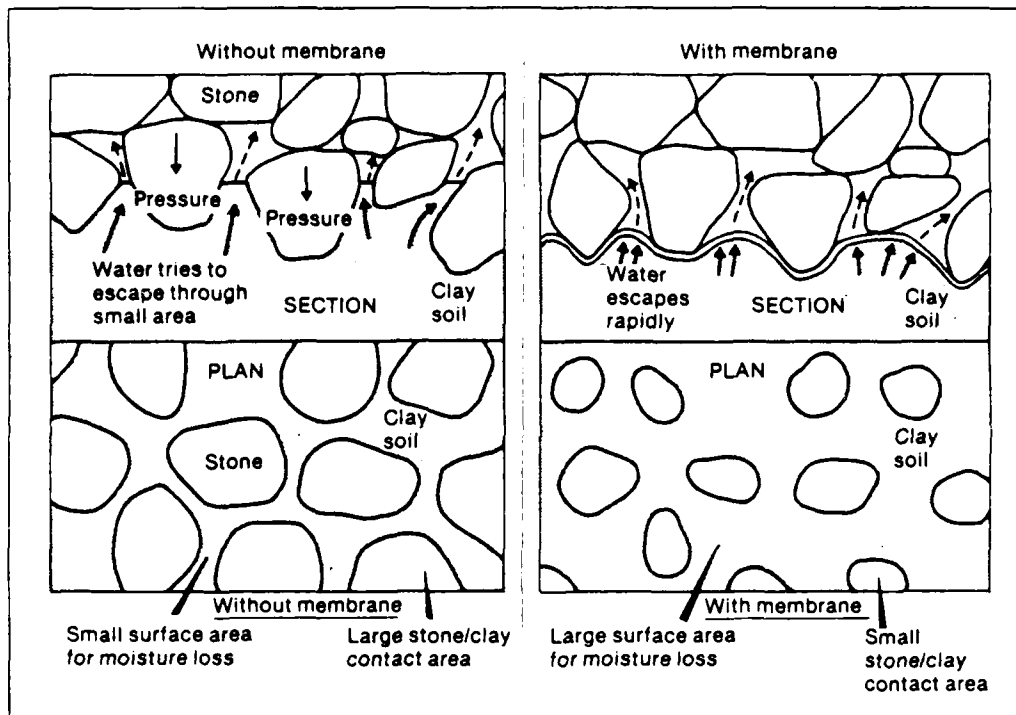


Figure 2.10 Separation effects by using a membrane.
(after Rankilior, 1981)

2.3 Methods of Analysis

In analyzing seepage problems; geometry, boundary conditions, soil parameters, flow quantities and location of the free surface must be quantified by some means. Though this involves many considerations, the engineer must gain reasonable safe results for the design.

Through the history of seepage analysis many techniques and methods have been developed, such as graphical, analytical and numerical solutions. Still used today is the graphical method of flow net construction. However with the complex geometries involved and via the speed of computers, numerical models have been developed as very useful tools for the engineer.

Flow Nets

Many researchers have developed methods for analyzing flow through porous media. The oldest, developed by Casagrande and Terzaghi (1937), is the use of flow nets, a graphical approach to seepage analysis.

The continuity equation in the form

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (2.7)$$

shows for a Cartesian coordinate system, the quantity of water entering an element must equal that leaving. The terms u , v and w are discharge velocity components of directions x , y and z , respectively.

According to Darcy's Law, expressed by equation (2.3), the component of discharge velocity can be expressed

$$u = -k \frac{\partial h}{\partial x}, \quad v = -k \frac{\partial h}{\partial y}, \quad w = -k \frac{\partial h}{\partial z} \quad (2.8)$$

Substituting into equation (2.7)

$$\partial \frac{-k(\partial h/\partial x)}{\partial x} + \partial \frac{-k(\partial h/\partial y)}{\partial y} + \partial \frac{-k(\partial h/\partial z)}{\partial z} = 0 \quad (2.9)$$

If k is constant for the element and then expressed in a typical two-dimensional form, equation (2.9) becomes the common Laplace equation.

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0 \quad (2.10)$$

The general condition of flow analysis using flow nets is represented by Figure 2.11. Rules and good examples are presented in many textbooks (Cedergren, 1977; Harr, 1967).

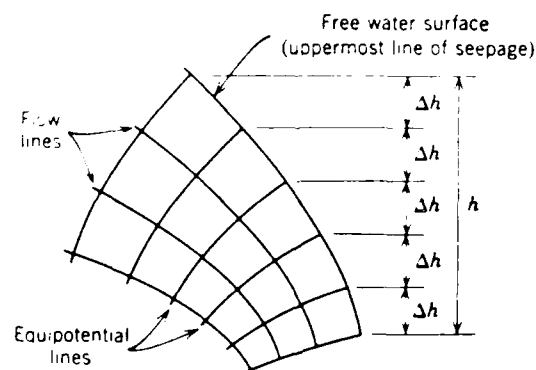


Figure 2.11 General condition for flow lines and equipotential lines in flow net construction.

Dupuit Assumptions

For unconfined seepage problems the engineer must calculate the location of the free surface. Many problems of flow have been approximated based on the Dupuit theory of unconfined flow. Dupuit (1893) assumed; (1) for small inclinations of the line of seepage, the streamlines can be taken as horizontal and equal potential lines vertical, and (2) the hydraulic gradient was equal to the slope of the free surface and invariant with depth (Harr, 1962).

Harr (1962) gives many example problems and has derived the condition of free surface elevations as shown by Figure 2.12.

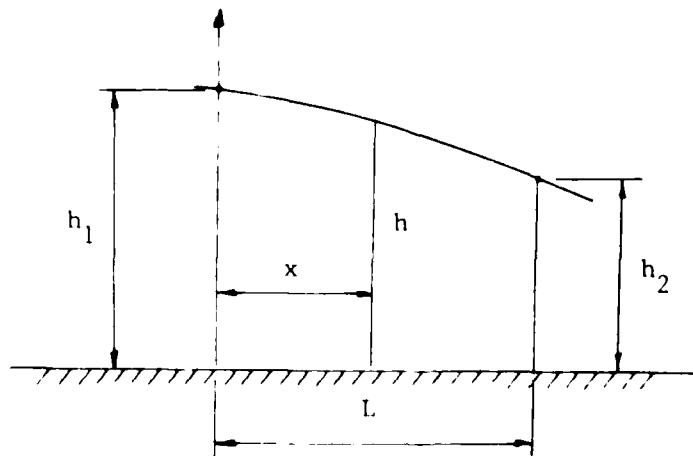


Figure 2.12 Simple free surface notation.

In the case of Figure 2.12 the Dupuit formula is expressed as

$$q = k \frac{h_1^2 - h_2^2}{2L} \quad (2.11)$$

Many other reports and textbooks have presented charts and nomographs based on these assumptions. Later in this study a nomograph for a simple trench drain with blanket drain solution developed by the Federal Highway Administration (1980) will be presented.

Numerical Analysis

Flow through porous media has been approximated by many authors using ordinary non-linear differential equations and partial differential equations. Coupled with the speed of the computer, numerical solutions to many seepage problems have been developed. It should be pointed out that complex mathematical problems solved by numerical methods, are only as accurate as the math model can represent the conceptions and phenomena of seepage flow. In most cases, simplification is the rule, and numerical models can only be treated as approximations to the actual occurrences. Nevertheless, the number crunching capabilities and time savings involved gives the engineer much needed time for the true analysis of the seepage problem.

The analytical and graphical methods mentioned previously are sometimes difficult and limited to flow systems which are

relatively simple. In actual field conditions, the soils may be heterogeneous and anisotropic and boundary conditions very complex. These conditions make closed form methods very difficult and many simplifications would have to be made. However, with the numerical models, these complexities can be easily handled and many more check cases can be made in much less time.

Finite Difference Methods

Many numerical computer models have been developed using finite difference methodology. Since the classic work of Peaceman and Rachford (1955), the oil industry has sponsored many studies on model development. A good historical background of the finite difference methods developed in seepage analysis is giving by Huyakorn (1983). Worth mentioning are the works of Cooley (1971) and Freeze (1971) in the development of other finite difference models. These models solve for the free surface and treat the saturated-unsaturated flow as an immobile air phase.

Finite Element

The finite element method for solving subsurface flow has been widely used and researched by soils engineers and groundwater hydrologists. The program used in this research and discussed in more detail in Chapter 3 is a finite element model.

Most finite element models are built on the Galerkin method. Some earlier finite element models for steady state and saturated flow were developed by Desai and Abel (1972), Conner and Brebbia (1977) and Zienkiewicz (1977). Pinder and Frind (1972) used isoparametric quadrilateral elements with the Galerkin's technique. Neuman (1973, 1974) used a four node quadrilateral element. A good reference for other works in the finite element models that have been developed is reported in Huyakorn and Pinder (1983) and Heijde (1985).

Some significant works were those of Taylor and Brown (1967) where a finite element model was developed for seepage through a dam solving for the free surface. The flow was only considered for the saturated zone in this model. Freeze (1971) demonstrated that the conditions of the unsaturated zone may strongly influence the position of the free surface and results obtained not considering the capillary action for this case could be in error. Fredlund and Morgenstern (1976) developed improved constitutive equations for an unsaturated soil. Lam and Fredlund, et al (1984) presented additional theories and numerical development for further modeling techniques to consider the unsaturated zone in seepage analysis.

CHAPTER 3

FINITE ELEMENT STUDY

3.1 Finite Element Program Theory

Introduction

Finite element analysis of seepage problems can be described as follows (Huyakon and Pinder, 1983):

(1) A discrete number of interconnected nodes to define a series of sub-regions or elements. These can take the form of triangles, quadrilateral or rectangular shapes which are so spaced to define the geometric boundaries and soil types.

(2) A matrix expression is developed to relate flow variables to each node of the elements. The mathematical expression may be of the form of either a variational or weighted function. A weighted residual function is used in the Galerkin method (Conner and Brebbia, 1977).

(3) A set of algebraic equations that describe the entire global system is applied to assemble the element matrices. These equations are derived to consider compatible conditions at each node shared by each adjoining element.

(4) Boundary conditions of flow are incorporated to reflect appropriate limits to the global matrix equations.

(5) The resulting set of simultaneous algebraic equations are solved by some algorithm method. Many algorithms have

been used to efficiently take advantage of the banded and symmetric features of the coefficient matrix (Bathe and Wilson, 1976).

The finite element method has great potential in seepage analysis problems, in that the complex geometries of flow regions can be easily constructed via nodes and elements. This chapter will present the general theories and formulation of equations for the model used in this study.

Program Theory

A finite element program developed by Dr. Mustusfa Aral of the School of Civil Engineering, Georgia Institute of Technology, was used to study the flow and variables involved for subsurface drains as earlier described. This program was used to see effects of different parameters in the analysis performed. The program was operated on the Georgia Institute of Technology main-frame CDC CYBER computer. A complete user's guide for the program is included as Appendix A-1. Also example input and output used in this study is included by Appendix B-1. The formulation for the program presented here was summarized from a previous study (Aral, Sturm and Fulford, 1981).

This model only considers the flow condition of the free surface being the point where the water level is at atmospheric pressure. In other words, this model does not treat the

unsaturated zone of the soil. For this study the flow continuum is modeled to determine the quantity of flow at each drain and to determine the free surface location between each of the drains. This model also computed the velocities at each element for a good check.

Equations of Flow

Darcy's Law is used as the basic relationship governing groundwater flow. Flow is assumed to be laminar and the inertial forces are negligible compared to viscous forces. Rewriting Darcy's Law in the cartesian coordinate system:

$$\vec{v} = -K \vec{\nabla} h \quad (3.1)$$

where $\vec{v}$ is seepage velocity, h is piezometric head and K the hydraulic conductivity. In the two dimensional case, equation (3.1) can be written as

$$v_i = -K_{ij} \frac{\partial h}{\partial x_j}, \quad i = 1, 2 \quad (3.2)$$

where K_{ij} is a conductivity tensor.

The continuity equation for the flow in an element of soil can be expressed

$$\frac{\partial}{\partial x} (\rho v_i) = - \frac{\partial}{\partial t} (\eta \rho) , \quad i = 1, 2 \quad (3.3)$$

where η is porosity of the soil and ρ is the density of the fluid. Assuming the fluid and soil particles are incompressible, equation (3.2) and (3.3) can be used for the following expression in the two-dimensional form:

$$\frac{\partial}{\partial x_i} K_{ii} \frac{\partial h}{\partial x_i} = 0 , \quad i = 1, 2 \quad (3.5)$$

Figure 3.1 can be referred to for notation of the key variables used in this study.

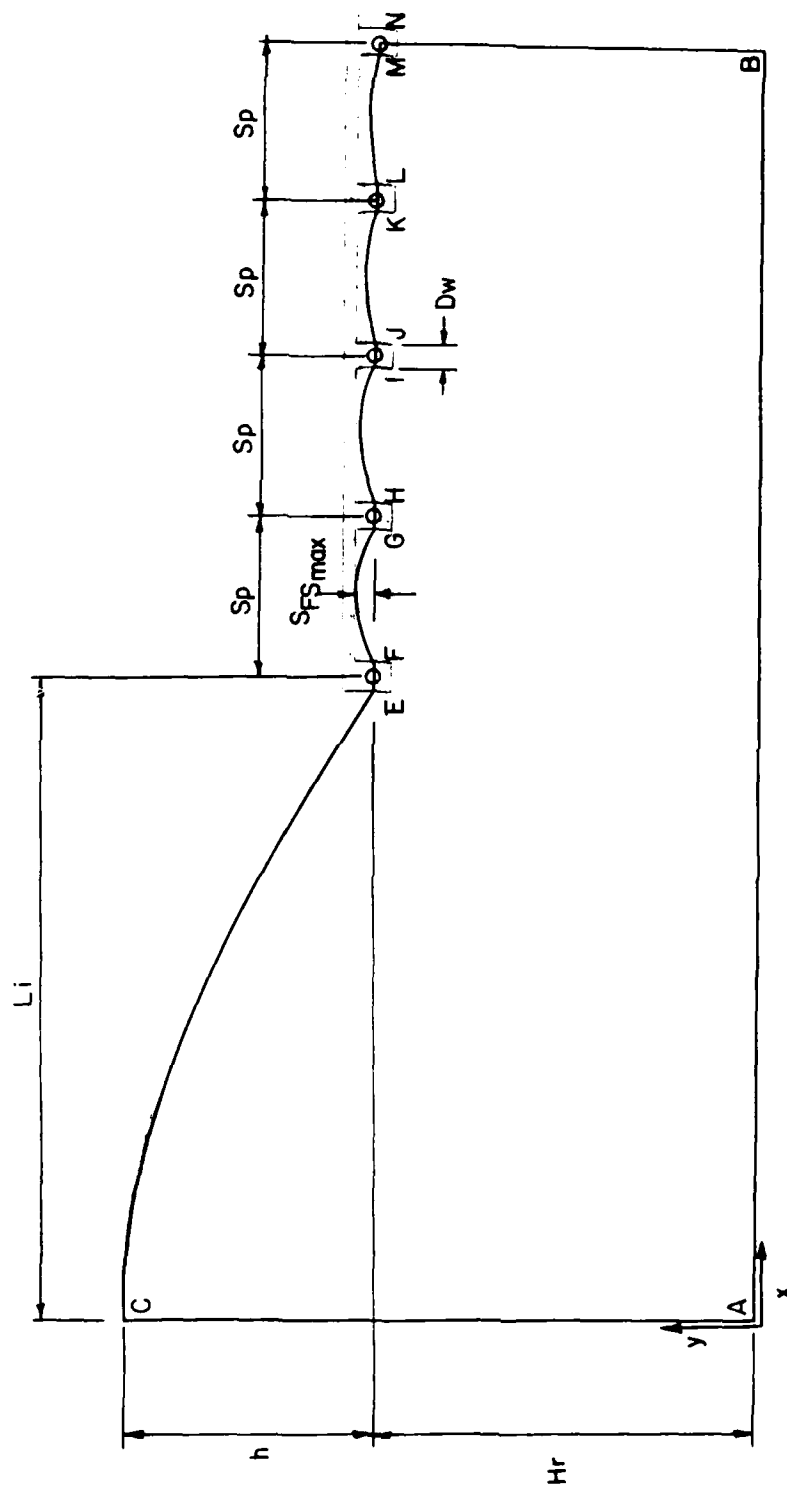


Figure 3.1 Typical Underdrain System with Variable Notation

Boundary Conditions

For free surface problems, which is the case for this study, the exact location of the phreatic surface is not known at the beginning of the solution. Location of the free surface is an iterative process using two independent boundary conditions available at the free surface. The line of seepage at the free surface is the upper streamline of the flow domain. At every point along this streamline the pore pressure is at atmospheric pressure and therefore the piezometric head equals the elevation head. Also the flow across this boundary is zero because of it being a streamline.

Considering the seepage domain as depicted by Figure 3.1, the steady state boundary conditions can be described as follows:

(a) Impervious Boundary (AB): The program considers this boundary as a streamline where velocity to this boundary equals zero.

(b) Constant Head Boundaries (AC) and (EF): Constant hydrostatic pressure is exerted on these boundaries where total piezometric head is constant, i.e. equal to the water level in a piezometric tube.

(c) Phreatic Surface (CE), (FG), (HI), (JK) and (LM): This boundary is a combination of both cases (a) and (b) above. By iteration, described later, both conditions must be satisfied independently.

(d) Seepage Faces (EF), (GH), (IJ), (KL) and (MN): Seepage forces occur at these boundary faces where water exits through the soil continuum, i.e. trench drains. Therefore streamlines of flow must be normal to these boundaries.

3.2 Finite Element Formulation

General Equations

The first step in solving the seepage problem by the finite element method is to discretize the flow region into a finite number of subregions called elements. Using finite elements, equilibrium equations must be made to handle the geometries involved. This results in a set of simultaneous algebraic equations rather than differential equations. Figure 3.2 depicts the quadrilateral elements used for this program and shows how four six nodal triangles are formed internal to the program. A more detailed description is of finite element equations and formulations can be found in Zienkiewicz (1971), Desai (1972) and Aral (1974, 1976).

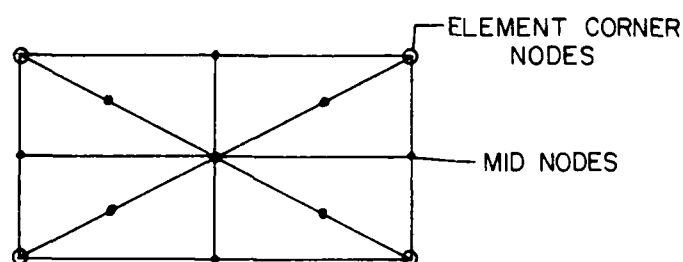


Figure 3.2 Typical element and nodes

A finite element approximation to equation (3.5) can be written through a variational approach. Assuming Dirichlet and Neuman boundary conditions, and considering the two dimensional case of steady flow, the following equations can be expressed:

$$h = \bar{h} \quad \text{on } S_1, \quad (3.7)$$

$$\text{and } v_n = - \left(K_{11} \frac{\partial h}{\partial x_1} \alpha_{n1} + K_{22} \frac{\partial h}{\partial x_2} \alpha_{n2} \right) = \bar{v}_n \quad \text{on } S_2 \quad (3.7)$$

where $\bar{h}$ is the specified Dirichlet boundary condition in terms of piezometric head; $\bar{v}_n$ is the velocity in the direction normal to the boundary; α_{n1} and α_{n2} are the direction cosines of the normal with respect to x_1 and x_2 ; and S_1 and S_2 indicate respective boundaries of the domain. From equations (3.5) and (3.7), the following variational statement can be written:

$$\begin{aligned} \iint_A \left\{ \frac{\partial}{\partial x_1} \left(K_{11} \frac{\partial h}{\partial x_1} \right) + \frac{\partial}{\partial x_2} \left(K_{22} \frac{\partial h}{\partial x_2} \right) \right\} \delta h dx_1 dx_2 \\ = \int_{S_2} \left\{ v_n - \bar{v}_n \right\} \delta h dS \end{aligned} \quad (3.8)$$

Integrating by parts one obtains

$$\iint_A \left\{ K_{11} \frac{\partial h}{\partial x_1} \frac{\partial \delta h}{\partial x_1} + K_{22} \frac{\partial h}{\partial x_2} \frac{\partial \delta h}{\partial x_2} \right\} dx_1 dx_2 - \int_{S_2} \bar{V}_n \delta h dS = 0 \quad (3.9)$$

Since from earlier discussed boundary conditions as for this problem studied, $\bar{V}_n = 0$. Thus, equation (3.9) can be further simplified by eliminating the boundary integrals.

Assuming equation (3.9) is written for a single element, matrix equations can be generated using an interpolation function for approximating h over an element. The interpolation function used in this model is given as

$$h = N_k h_k \quad k = 1, 2, 3, \dots, 6 \quad (3.10)$$

where h_k 's are the unknown nodal values of the dependent variable and N_k is the interpolating polynomial used to approximate h in an element.

For a typical six-nodal triangle element these polynomials are given as

$$N_i = \xi_i (2\xi_i - 1) \quad i = 1, 2, 3 \quad (3.11)$$

$$\text{and } N_{i+3} = 4 \xi_i \xi_j \quad j = 2, 3, 1 \quad (3.12)$$

where ξ_1 , ξ_2 , and ξ_3 are area coordinates defined by the following relations

$$\xi_1 = \frac{A_1}{A} \quad \xi_2 = \frac{A_2}{A} \quad \xi_3 = \frac{A_3}{A} \quad (3.13)$$

where A_1 , A_2 and A_3 are the areas of the three subtriangles subtended by the point (P) and the corners, the index on (A) designating the opposite corner numbers, and A is the area of the triangle (123) shown in Figure 3.3.

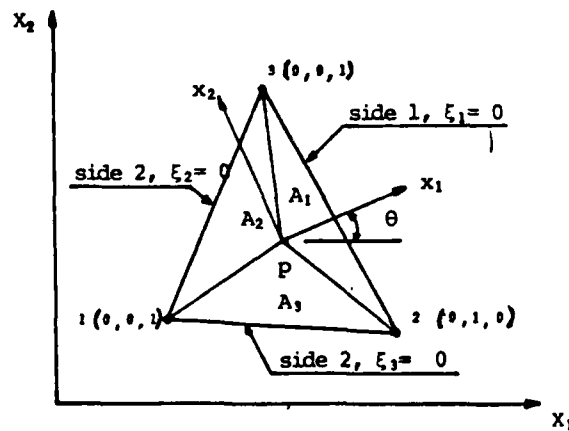


Figure 3.3 Area coordinates.

To simplify the resultant equations, the origin of the local axis which defines the local coordinates of the element, nodes are placed at the centroid of the element and the principle axis are inclined angle θ in the direction of local anisotropy.

Substituting equation (3.10) into equation (3.9) the final form of the approximating equations in an element can be expressed. The stationary condition of equation (3.9) is obtained by equating the first partial derivatives of the function, with respect to the undetermined parameters, h_j , to zero:

$$I^e(h), h_j = \iint_{A^e} \left\{ K_{11} \frac{\partial N_i}{\partial x_1} \frac{\partial N_j}{\partial x_1} + K_{22} \frac{\partial N_i}{\partial x_2} \frac{\partial N_j}{\partial x_2} \right\} h_i dx_1 dx_2, \\ i, j = 1, 2, 3, \dots, 6 \quad (3.14)$$

This results in a six by six element stiffness matrix, S^e , and a six by one element load vector F^e .

The six by six element matrix equations of equation (3.14) is written

$$[S^e] \{h^e\} = \{F^e\} \quad (3.15)$$

where

$$[S^e] = \iint_{A^e} \left\{ K_{11} \frac{\partial N_i}{\partial x_1} \frac{\partial N_j}{\partial x_1} + K_{22} \frac{\partial N_i}{\partial x_2} \frac{\partial N_j}{\partial x_2} \right\} dx_1 dx_2, \\ i, j = 1, 2, 3, \dots, 6 \quad (3.16)$$

The same procedure is taken for all elements. Then the total stiffness matrix is arrived at by combining the element stiffness matrices using structural assembly techniques (Zienkiewicz, 1971)

For a grid of elements, a system of banded simultaneous equations results:

$$[S] \{h\} = \{F\} \quad (3.17)$$

where $[S]$ is the global matrix of coefficients which incorporates the properties of the materials and the geometry of the elements; $\{h\}$ is the vector of the unknown h 's at the nodes; and $\{F\}$ is the load vector. After the introduction of appropriate boundary conditions, this system of equations can now be solved by computations for the unknowns, h , yielding the piezometric head distribution in the solution domain.

Free Surface Computation

The flow domain must initially be established assuming an arbitrary free surface, i.e. the user initially estimates the free surface location. All boundary conditions are solved for the preset conditions of the problem. The nodes which are not fixed are allowed to move, where during the adjustment the interior nodes are also moved in order not to have distortion of the elements. Then additional iterations are made until all boundary conditions and user prescribed error correlations have been met for the configuration.

3.3 Variables and Dimensional Analysis

The variables investigated in this study are shown in Figure 3.1. For the analysis of seepage using the finite element program, variables were changed for each computer run. From each run data was generated to compare the changes occurring for each variable change.

Only the two-dimensional flow condition was considered in this study. For this flow condition, the building drainage system is in one cross-section of the building where each drain collects the seepage and collector pipes or drains take the drainage by gravity to a sump or some exit drain. This is depicted by Figure 3.4.

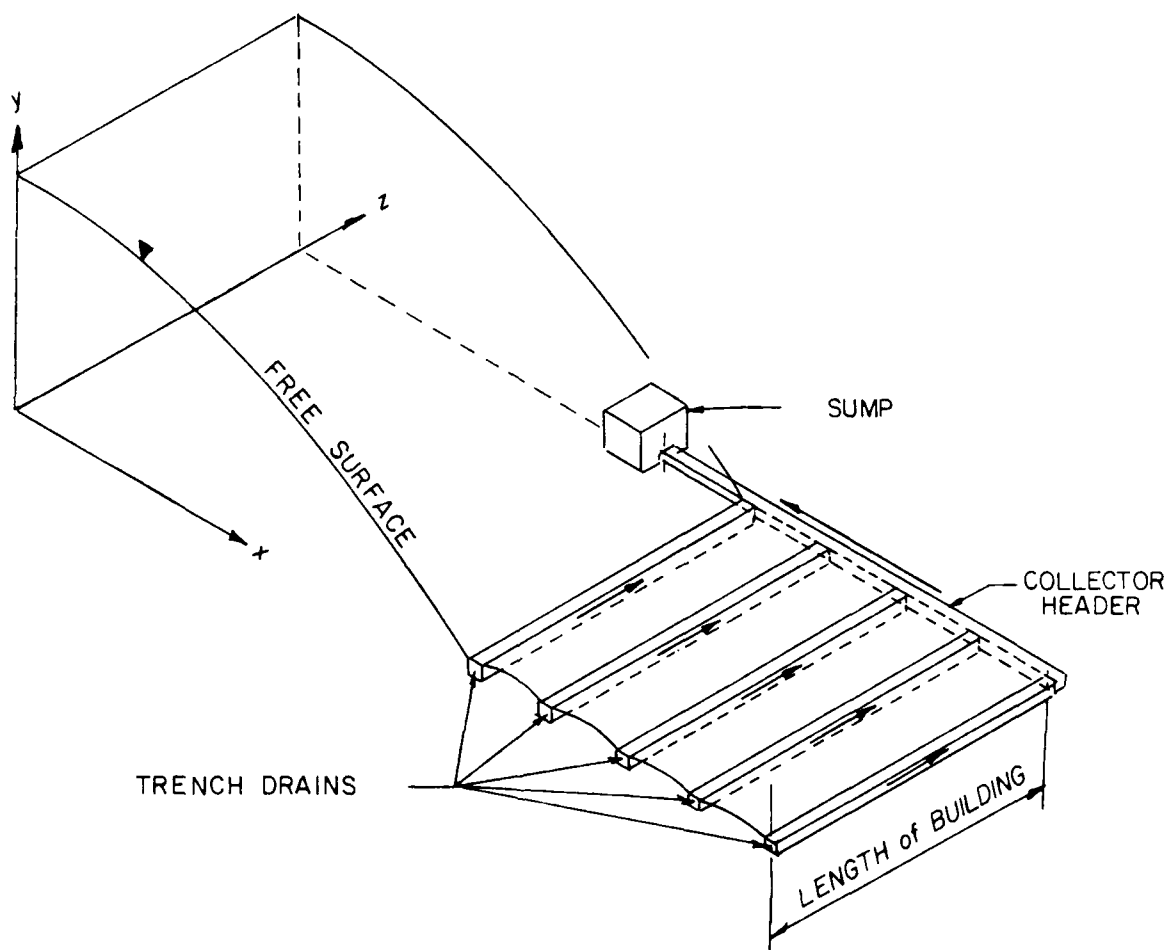


Figure 3.4 Underdrain System For Seepage Removal.

The total discharge of the system, q_T , can be express as the following function:

$$q_T = f(H_r, h, d_w, S_p, K, S_{FS}, \theta) \quad (3.18)$$

where q_T = total discharge of all drains, i.e. the sum of discharges through each seepage face for the model, $\text{ft}^3/\text{day}/\text{ft}$

H_r = depth of saturated soil from the drain discharge elevation to the impervious boundary, ft

h = fixed head of above the drains, ft

d_w = drain width, ft

S_p = drain spacing, ft

K = hydraulic conductivity of the soil, ft/day

S_{FS} = difference in elevation of the free surface to the water level of each drain, ft

θ = slope of the impervious boundary with horizontal, ft/ft

Dimensional analysis of equation (3.18) yields:

$$\frac{q_T}{K h} = f\left(\frac{H_r}{h}, \frac{d_w}{h}, \frac{S_p}{h}, \theta\right) \quad (3.19)$$

Since permeability is moved to the left side of equation (3.19) these variable is made proportional to the discharge. The elevation of the free surface, S_{FS} , is an output variable, so

it is not given in equation (3.19). Also since the slope of the impervious boundary, θ , is already dimensionless it can be given as a single term in FT/FT.

The effects of these functional variables and other results are given in the form of dimensionless plots in Chapter 4. A discussion of the results is given in that chapter. Since considerable interest is in quantities of discharge and the location of the free surface, this analysis can be used to see trends and effects that each variable has on the seepage domain.

3.4 Program Verification

To verify that the computer program used in this study is giving valid results, two other methods of solutions were used for a selected check case. Another micro computer finite element program, SEEP, and an appropriate analytical method based on Dupuit's assumption, was used for the simple configuration of a drainage blanket with a single pipe type drain (Duncan and Wong, 1985). This is shown in Figure 3.5.

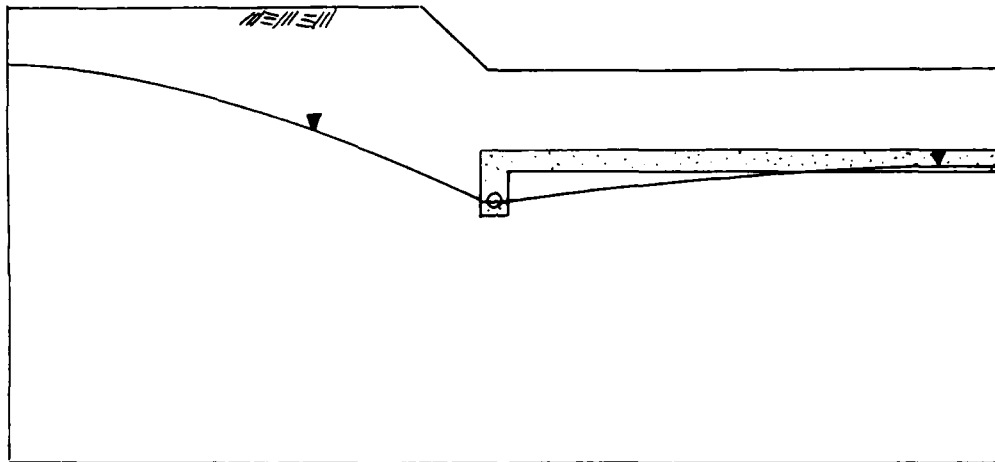


Figure 3.5 Check case example of a blanket drain with single pipe trench drain.

A grid was generated for the SEEP program to match the configuration and boundary conditions as by Figure 3.4. The total flow for this check case is calculated by the SEEP program as based on the Dupuit assumption of a fixed domain and fixed amount of head. Seep also tabulated the flow quantities for all nodal points with fixed heads. For this model, the

free surface converged on the free surface location with an error criteria of 0.16 feet.

The location of the free surface as computed by the Georgia Tech model converged to the free surface having an error factor of only 0.001 feet, a much more accurate and sensitive convergence. However, the two models compared very close as far as the location of the free surface. Table 3.1 lists the elevations of the free surface nodes for the two models.

TABLE 3.1 Elevations of the Free Surface Nodes

	<u>SEEP:VPI</u> <u>Model</u>	<u>Ga Tech</u> <u>Model</u>
<u>x coordinate</u>	<u>y coordinate</u>	
0	78.00	78.00
40	72.55	72.73
70	67.07	67.57
80	64.27	65.17
85	62.03	63.84
87.5	60.39	58.73
90	58.00	58.00
92	58.00	58.00
95	60.08	58.32
97.5	61.16	62.15
100	61.92	62.52
106	63.00	63.28
115	63.76	63.93
130	64.26	64.42
150	64.42	64.62

drain location

To verify that flow quantities were accurate for the Ga Tech model, results were also compared with the results obtained from a Dupuit assumption solution, developed by the Federal Highway Administration's, Highway Subdrainage Design Manual, (1980). Figure 3.6 was used to calculate the quantity of flow to the drain. The following calculations based on Figure 3.6 are presented:

$$\frac{b}{H_o} = \frac{1}{58'} = 0.017, \quad \frac{L_1}{H_o} = \frac{91'}{58'} = 1.57$$

$$\frac{K(H - H_o)}{q_2} = \frac{0.2(78' - 58')}{q_2} = 2.17 \quad (\text{from Figure 3.5})$$

$$\text{therefore } q_2 = \frac{0.2(20)}{2.17} = 1.84 \text{ CFD}$$

$$\frac{q_2}{K} = \frac{1.84}{0.2} = 9.22, \quad \frac{q_1}{K} = \frac{(H - H_o)^2}{2(L - b)} = \frac{(20)^2}{2(91 - 1)} = 2.22$$

$$\frac{q_d}{K} = 9.22 + 2.22 = 11.44$$

$$\text{therefore } q_d = 0.2(11.44) = 2.29 \text{ CFD}$$

The results of this computation is compared with the results of the two finite elements in Table 3.2

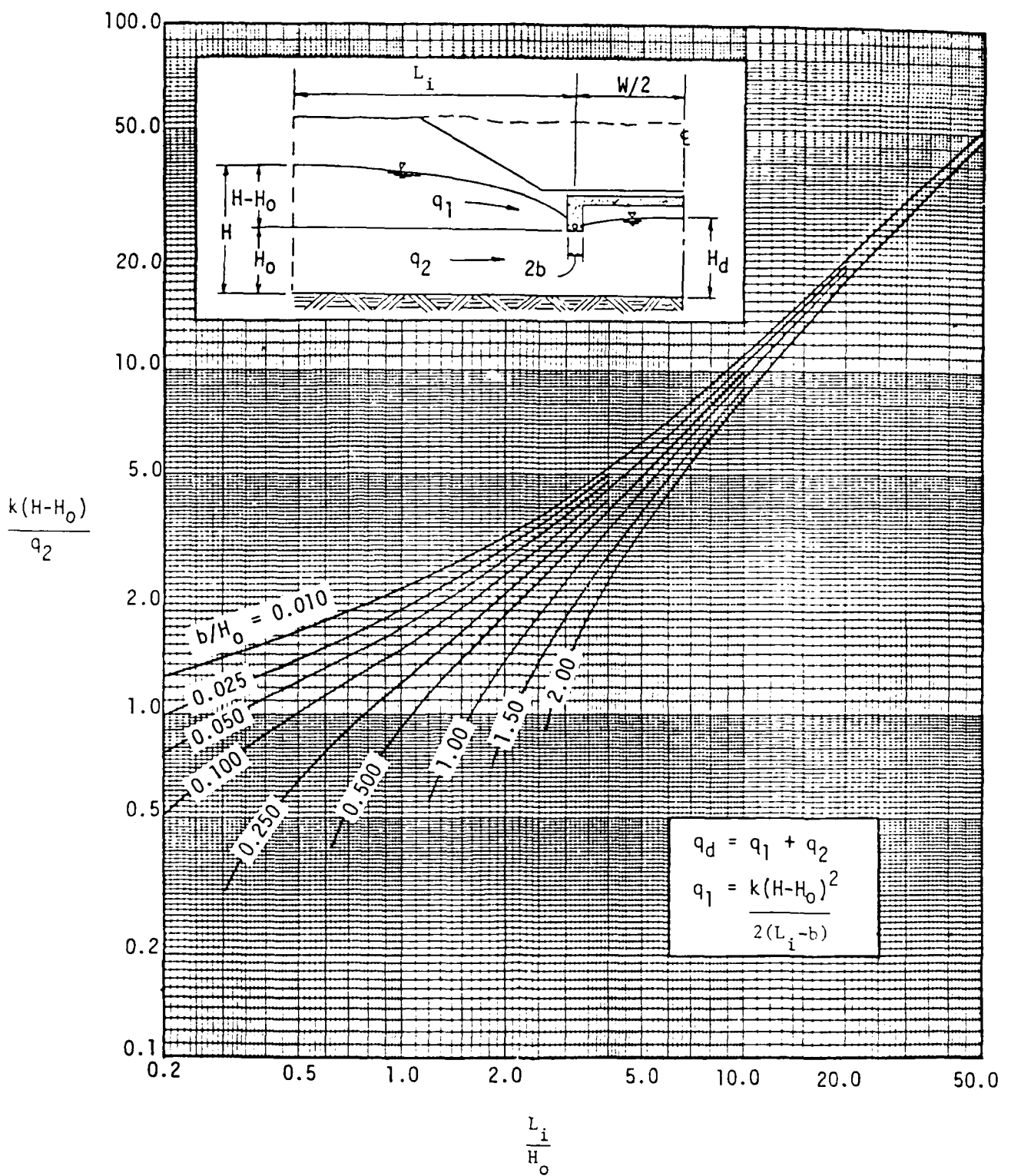


Figure 3.6 Chart for Determining Flow Rate in Symmetrical Underdrains (after FHA, 1980)

Table 3.2 Discharge to the drain check cases, CFD

	Discharge, CFD
SEEP:VPI Model	2.15
Ga Tech Model	2.34
FHA Nomograph	2.29

In summary, the Ga Tech model compares very well with other model and with the FHA nomograph for flow quantities. The Ga Tech model was found to more error criteria sensitive. The free surface location check also proved to compare very well with the SEEP model.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the analysis and results of the two dimensional, steady state, free surface finite element study of seepage to building underdrain systems. Details presented include model set-up such as boundary conditions, grid development and basic first assumptions. Output variables considered are total discharge and discharge at each drain, plus the free surface elevation between the drains.

In studying sensitivity of the model for the input variables, it was found that the distance from the Dirichlet boundary face, or constant head boundary, L_i , to the first drain was critical. L_i was found to be critical in terms of output characteristics, i.e. discharge and location of the free surface between drains. Therefore, two sets of results are presented for two L_i distances of 400 feet and 80 feet.

4.2 Model Set-up

Figure 4.1 shows the basic grid that was developed for this seepage problem. Using 150 elements and 521 nodes, the geometry of the mesh was based on a five drain system. The

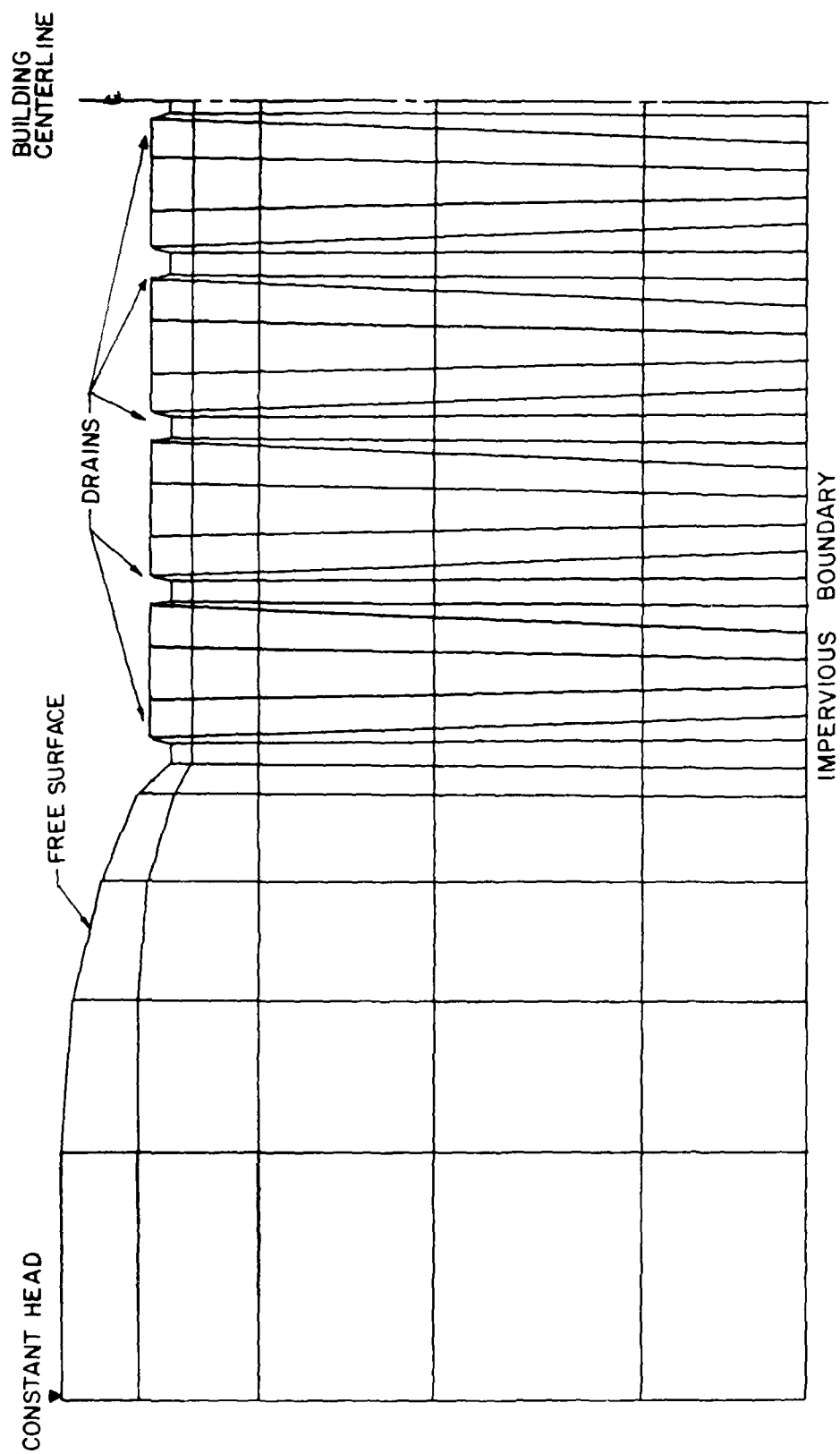


Figure 4.1 Example Mesh Used

sides and bottoms of the drains were modeled as seepage faces. Using the two-dimensional model, the fifth drain is considered to be at the building centerline. Assuming symmetry, only one-half of the building was analysed. The left most boundary, as shown in Figure 4.1, is a Dirichlet boundary condition which has the constant head required to allow for the seepage to enter the drains.

Listed below are some basic assumptions for the study made for this seepage problem:

- (1) Steady state flow conditions
- (2) Two-dimensional analysis where the right most boundary is the building centerline and by symmetry the flows are only one-half of the total for the total width of the building.
- (3) Free surface nodes move to the computed phreatic level, i.e. piezometric head equals atmospheric pressure at the upper most nodes
- (4) Partial saturated flow is not considered
- (5) Evaporation is not considered
- (6) Retardation is not considered
- (7) Infiltration is not considered
- (8) The soil is homogenous being either isotropic or anisotropic.

4.3 Variables Used

For this study, key variables were used in the finite element model to look at their effects on the flow of seepage for the building underdrain system. Two major design parameters necessary to model any seepage problem is the total discharge of the drain system and the location of the free surface. For this study, the following output variables are used:

- q_d = discharge or seepage quantity to each drain
(cubic feet per day per linear foot)
- q_T = total discharge of all drains (same units)
- S_{FS} = height of free surface above drain elevation.

Discharge quantities are in units of flow quantity in time per unit length of the total flow continuum. Therefore, flow for a total system should be multiplied by the length of the structure, i.e. in the third dimension.

Input variables used in this problem to study their effects on seepage are listed below:

- L_1 = distance from the left most constant head boundary to the first drain (feet)
- K = hydraulic conductivity (feet/day)
- K_v = hydraulic conductivity in the vertical

direction (feet/day)

K_h = hydraulic conductivity in the horizontal direction (feet/day)

h = hydraulic head of flow continuum above the drain elevation (feet)

H_r = depth of aquifer between the elevation of the drain and the impervious boundary (feet)

S_p = spacing between drains (feet)

D_w = drain width (feet)

θ = slope of the impervious boundary (%)

For better reference to the notation of the variables refer to Figure 3.1 in Chapter 3.

For this finite element problem the units of feet and days were used to give results for the output variables in cubic feet per day and feet per day for velocity.

Hydraulic conductivity or permeability values used for this study were 0.0002, 0.02, 0.2, and 4 feet per day. A soil's hydraulic conductivity having a value of 0.0002 feet per day is equivalent to a fine grained soil such as a clay. Hydraulic conductivities are tabulated in Table 4.1 to show cross reference to soil types and permeabilities in units of centimeters per second.

Table 4.1 Hydraulic Conductivity Values For Various Soil Types

Fine grained soil	0.0002 feet/day	7×10^{-7} cm/sec
Fine grained soil	0.002 feet/day	7×10^{-7} cm/sec
silt	0.02 feet/day	7×10^{-7} cm/sec
sand, silt	0.2 feet/day	7×10^{-7} cm/sec
clean sand	4 feet/day	1.4×10^{-7} cm/sec

The other input variables used were typically realistic values to meet typical field conditions. Listed below are some of this values, where for each computer run specific variables were changed and the others held constant. The intent was to see what effects that each variable change made on the model.

$L_i = 80', 400' \text{ and } 1000'$

$h = 10', 20' \text{ and } 40'$

$H_r = 20', 58' \text{ and } 100'$

$S_p = 15', 25' \text{ and } 35'$

$D_w = 1', 2' \text{ and } 4'$

$\theta = 0\%, 5\%, 10\% \text{ and } 20\%$

$K_v = .0002, 0.2, 4 \text{ and } 15$

$K_h = 0.2$

$K = 0.0002, 0.02, 4$

4.4 Model Sensitivity

The model was developed assuming a homogeneous isotropic media, except for a few cases where anisotropic conditions were studied. The nodes of the top three rows of elements were allowed to move for iteration of the free surface. In all runs, the maximum number of iterations was six and on an average three to four were found to be adequate. The model was made to iterate to an accuracy of 0.001 feet during the free surface moves.

In calibration of free surface models careful attention must be made to the moving nodes. Problems exist when the elements become less than zero in area or when the elements actual may become so distorted that they may become inverted. This was not the case for the mesh used in this study.

In studying the flow quantities and velocities for the basic geometries and variable changes, all results seemed reasonable and observed trends appeared physically possible. However large variation of output was noticed by the change in distance from the constant head boundary to the first drain, L_1 . The first set of results is presented based on the influence length, L_1 , being 10 times the maximum head difference, i.e. $10 \times 40' = 400'$. Depth of aquifer for this case was held constant at 100 feet. Use of 10 times the head differential is based on Bear's (1979) recommendation.

Figure 4.2 depicts the moved free surface corner nodes for an influence length of 400 feet. For comparison, Figure 4.3 shows the moved free surface corner nodes for L_i equal to 80 feet and a thickness of aquifer, H_r , equal to 58 feet.

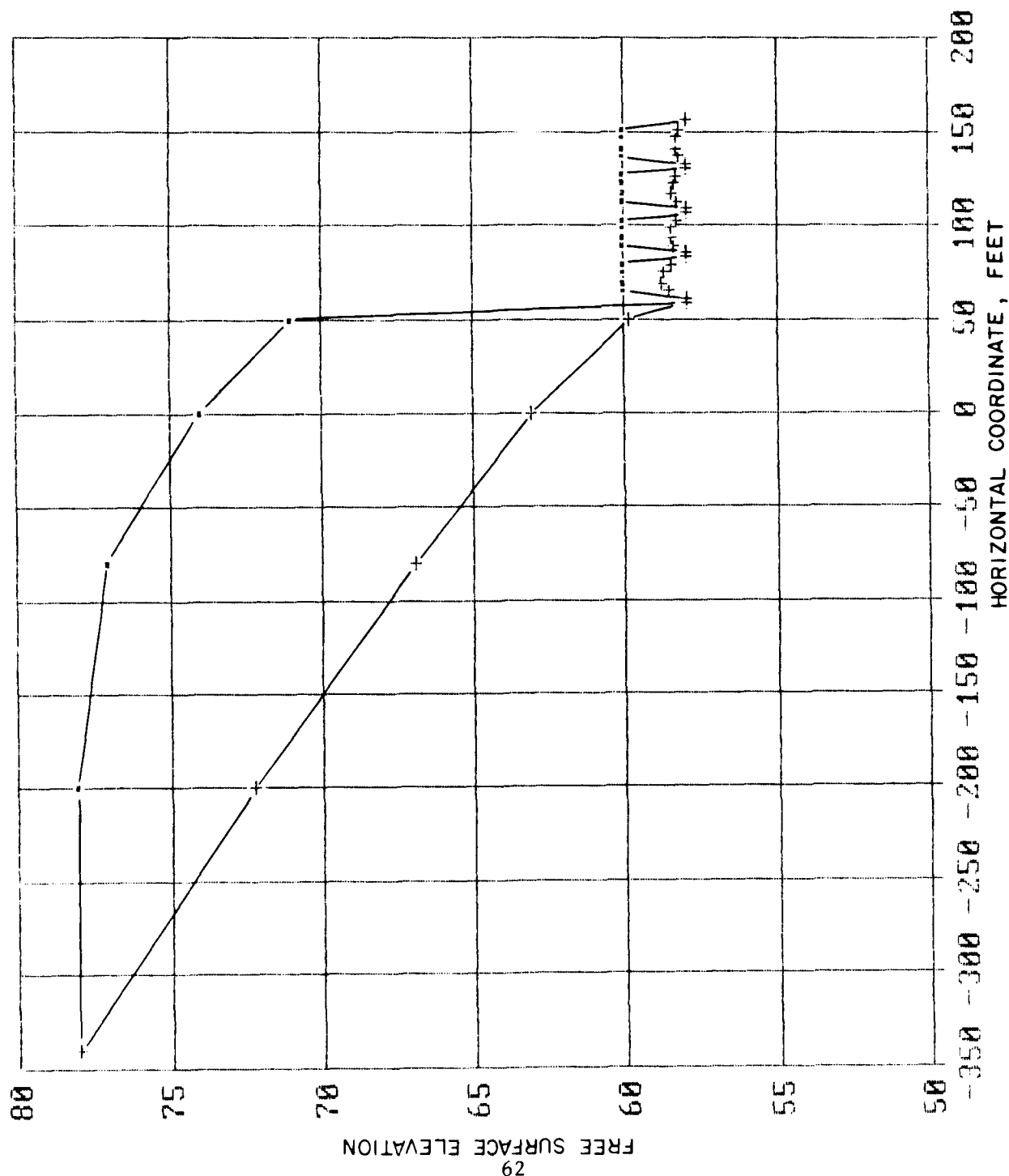


Figure 4.2 Moved Free Surface Corner Nodes vs. Original

$L_i = 400'$, $H_r = 100'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

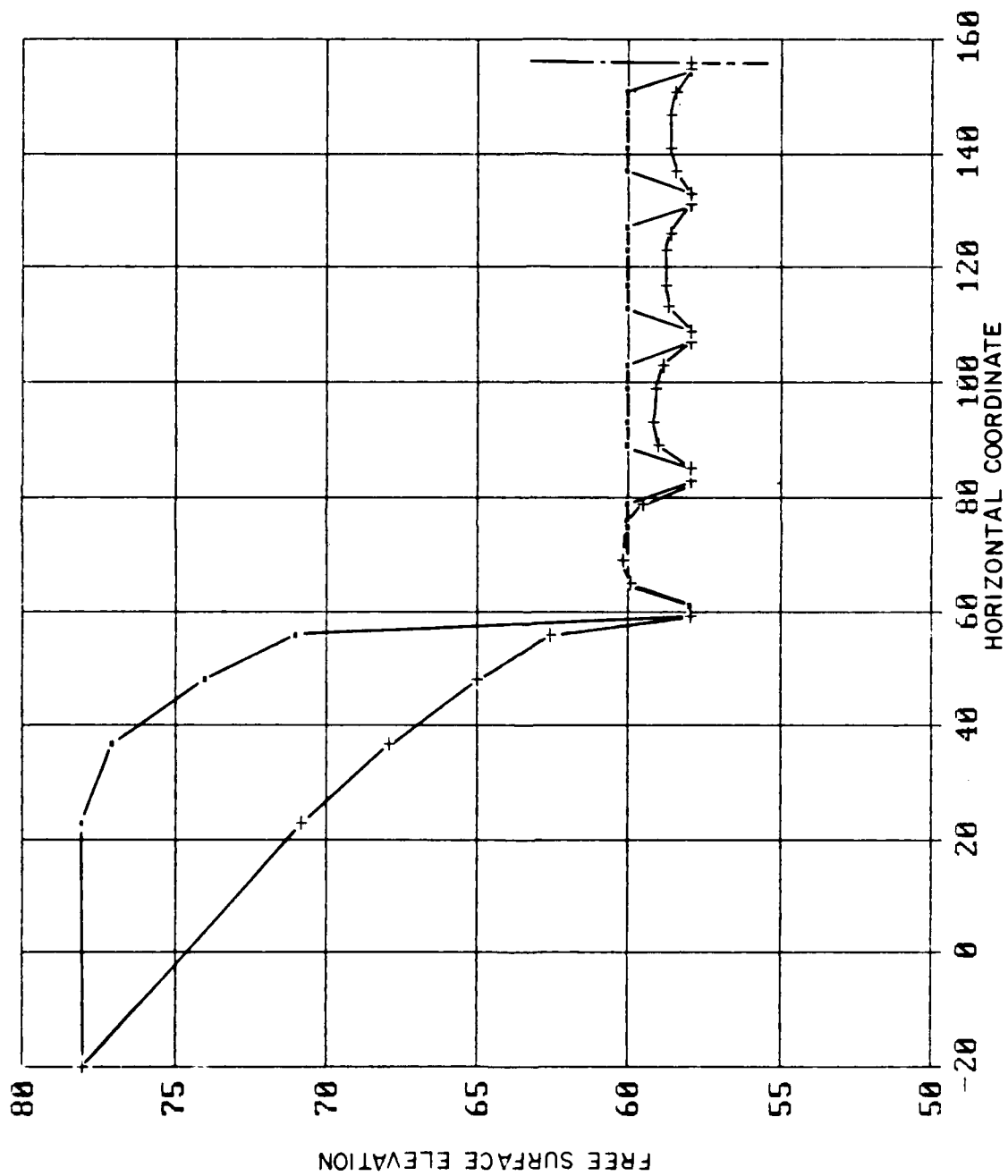


Figure 4.3 Moved Free Surface vs. Original
 $L_i = 80'$, $H_r = 58'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

Figure 4.4 and 4.5 are presented to show the dramatic influence that the distance from the constant head boundary from the first drain, L_1 , has on total discharge and the maximum free surface elevation, respectively. For further reference, the total discharge, q , is the sum of the drain discharges and the maximum free surface is the highest elevation of water above the drain elevation. Lengths between 300' and 400' appear to result in less change in flow quantity and free surface changes. This equates to the distance where the constant head boundary away from the drains begins to cause the least effect on discharge and free surface changes is approximately 15 to 20 times the head differential. This perhaps is good evidence that the actual field conditions for each particular application of groundwater movement should carefully be looked at in terms of this distance.

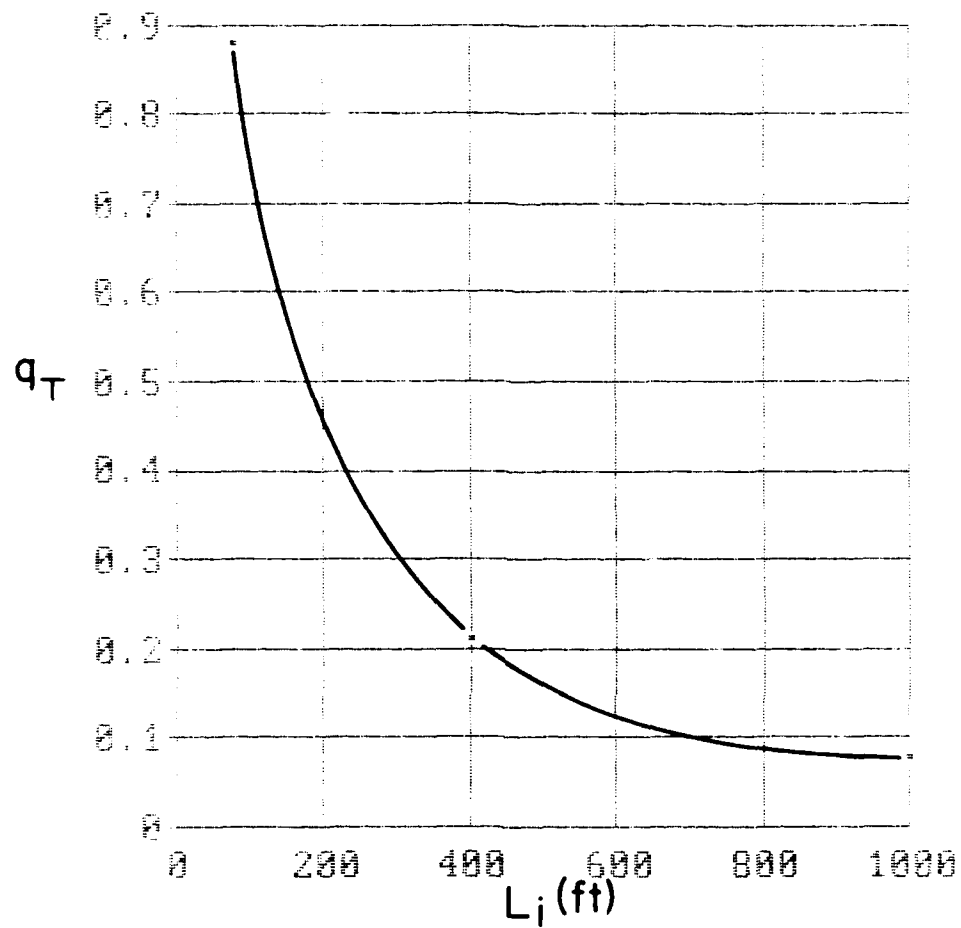


Figure 4.4 Distance from the constant head boundary to the first drain vs. total discharge of drains.
 $h = 20'$, $S_p = 15'$, $K = 0.2$ ft/day

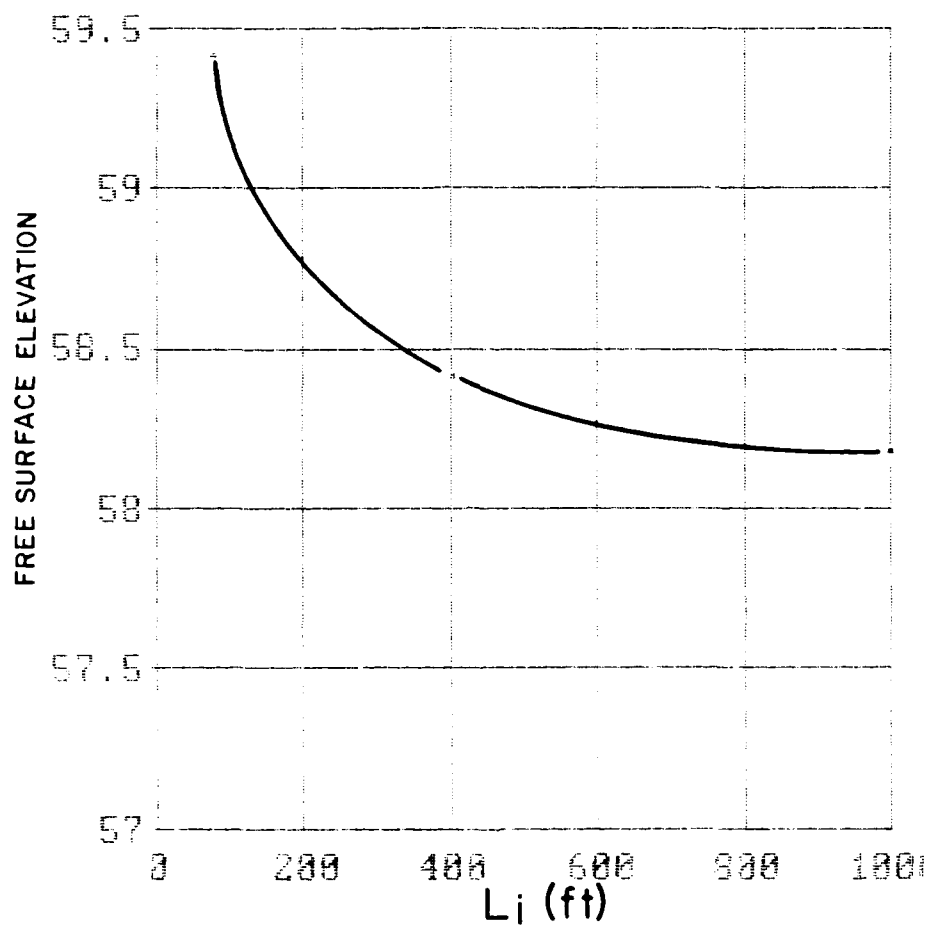


Figure 4.5 Distance from the constant head boundary to the first drain vs. maximum free surface elevation.
 $h = 20'$, $S_p = 15'$, $K = 0.2$ ft/day

4.5 Results

This section will present the computer results in the form of dimensionless plots and other nomographs to show the effects that each variable change has on the seepage problem. Two sets of plots are given where the first set is for the constant head boundary distance, L_i , equals 400 feet and the depth of rock, H_r , equals 100 feet. The second set of plots are essentially the same as the first except L_i equals 80 feet and the H_r equals 58 feet. For variable notation refer to Figure 3.1.

Drain Discharge ($L_i = 400'$ and $H_r = 100'$)

Figure 4.6 shows the influence of drain width, D_w , for head differentials, h , of 10, 20 and 40 feet on total discharge of the drains. This shows that drain width is not particularly critical for low head differences. It is reasonable to assume that total discharge could approach a constant for drain widths greater than four feet and head less than 20 feet. Although total discharge increases with drain width, this plot does not show what drain width is the most effective or most efficient. However, the influence of head can be easily observed

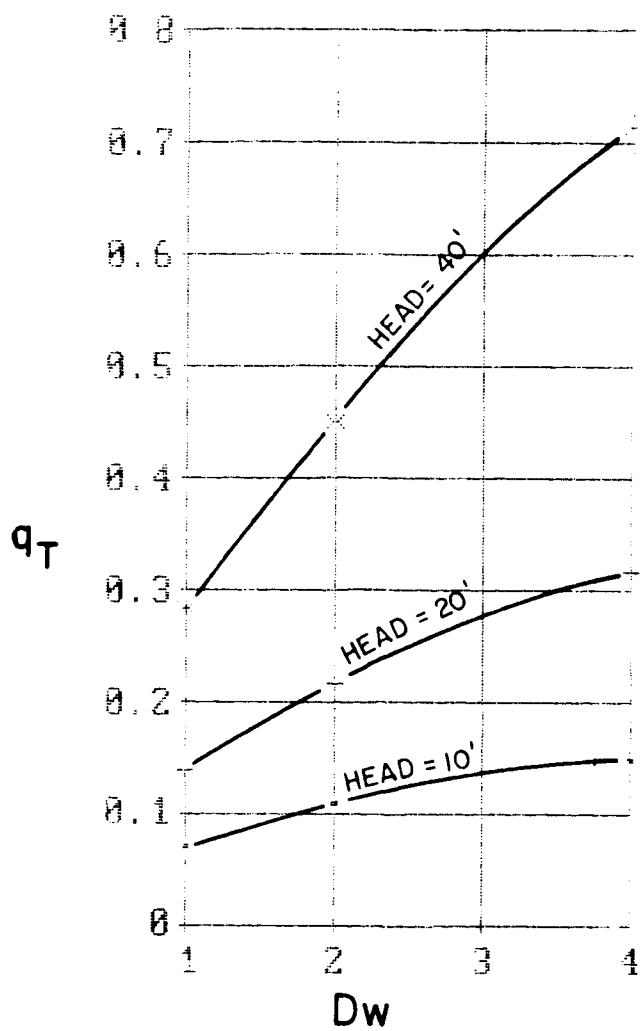


Figure 4.6 Total drain discharge vs. drain width with head differentials.

$L_i = 400'$, $H_r = 100'$, $S_p = 25'$, $K = 0.2$ ft/day

Figure 4.7 depicts the results of varying anisotropic soils with varying heads. In this analysis, vertical hydraulic conductivity varies while horizontal conductivity was held constant. Figure 4.7 shows that with increase in vertical hydraulic conductivity discharge increases. This appears to satisfy theory, that with less resistance flow increases.

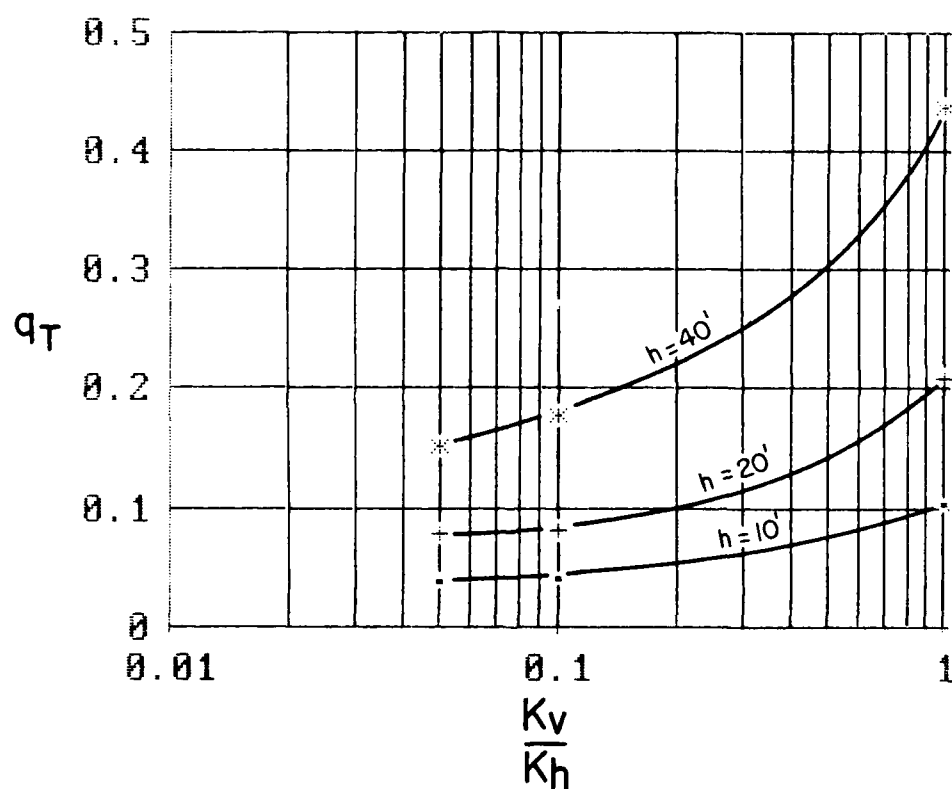


Figure 4.7 Total drain discharge vs. anisotropy with varying head differential.

$L_i = 400'$, $H_r = 100'$, $S_p = 15\%$, $D_w = 2'$, $K_h = 0.2$ ft/day

Figures 4.8 through 4.12 are graphs which show the discharge quantities for each of the five drains. Figure 4.8 depicts the effects of depth of impervious layer, H_r , on the drain discharge for each of the drains. This data shows that with increased depth discharge increases. It is interesting to note that practically no flow is recorded for drain 5 when a shallow depth of impervious layer exists, i.e. $H_r = 20$ feet.

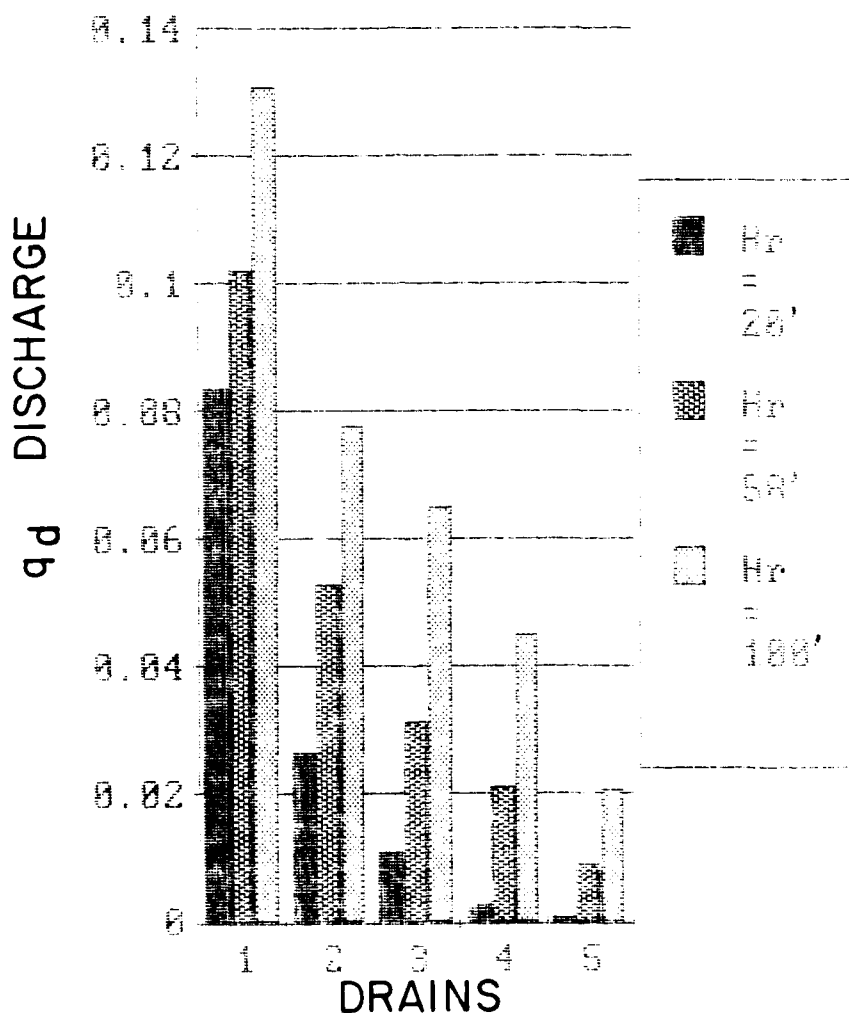


Figure 4.8 Drain discharge vs. thickness of aquifer.
 $L_1 = 400'$, $h = 20'$, $Sp = 25'$, $Dw = 2'$, $K = 0.2$ ft/day

Figure 4.9 shows the effects of head differential on the discharge of each of the drains. It is interesting to see that though the first drain is the most critical drain, i. e. a large amount of the total flow is collected in this drain, the remaining drains collect discharge decreasing linearly from the left. This is possibly due to the influence of the constant head boundary distance, L_1 , being 400 feet away. This shows that for the drains, flow quantity increases linearly with increase in head.

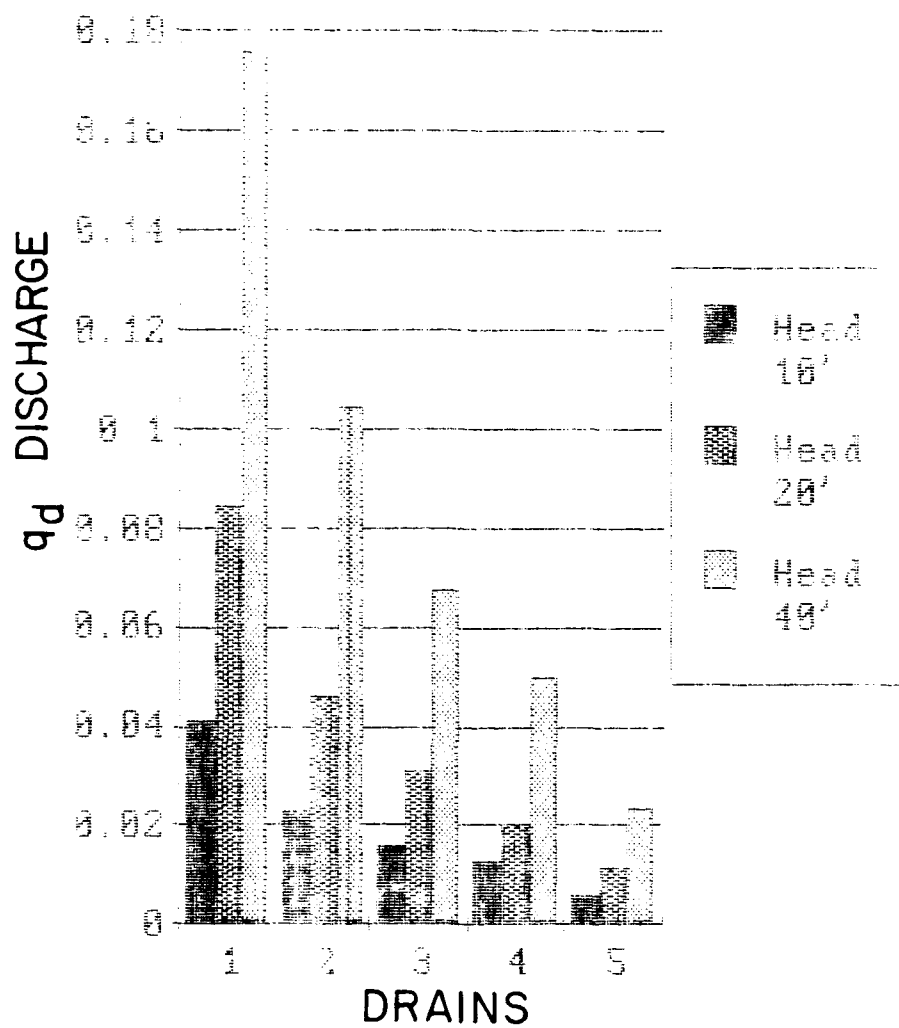


Figure 4.9 Drain discharge vs. head differential.
 $L_i = 400'$, $H_r = 100'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

Figure 4.10 depicts the results of comparing the drain discharge versus the spacing between drains. It is of interest to see that drain number one for spacing equal to 25 feet, collects more seepage than the other discharges for the other spacings. However, at drains 3 through 5 this changes and the discharge for 15 feet spacing is greatest. This will be analyzed later in the dimensional analysis.

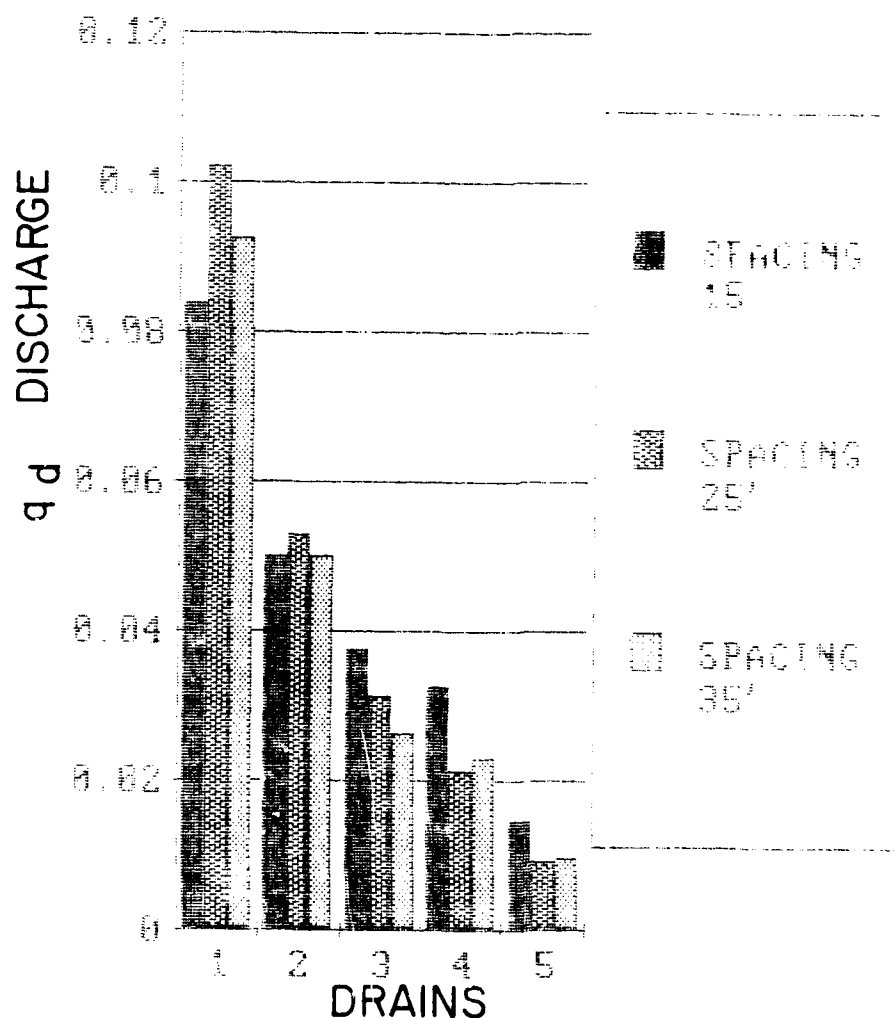


Figure 4.10 Drain discharge vs. drain spacing.
 $L_i = 400'$, $H_r = 100'$, $h = 20'$, $D_w = 2'$, $K = 0.2$ ft/day

Figure 4.11 shows the effects of anisotropy of the soil matrix on drain discharge. It is of interest to see that the discharge for K_v/K_h equal one is much greater than the other drain discharges for K_v/K_h less than one.

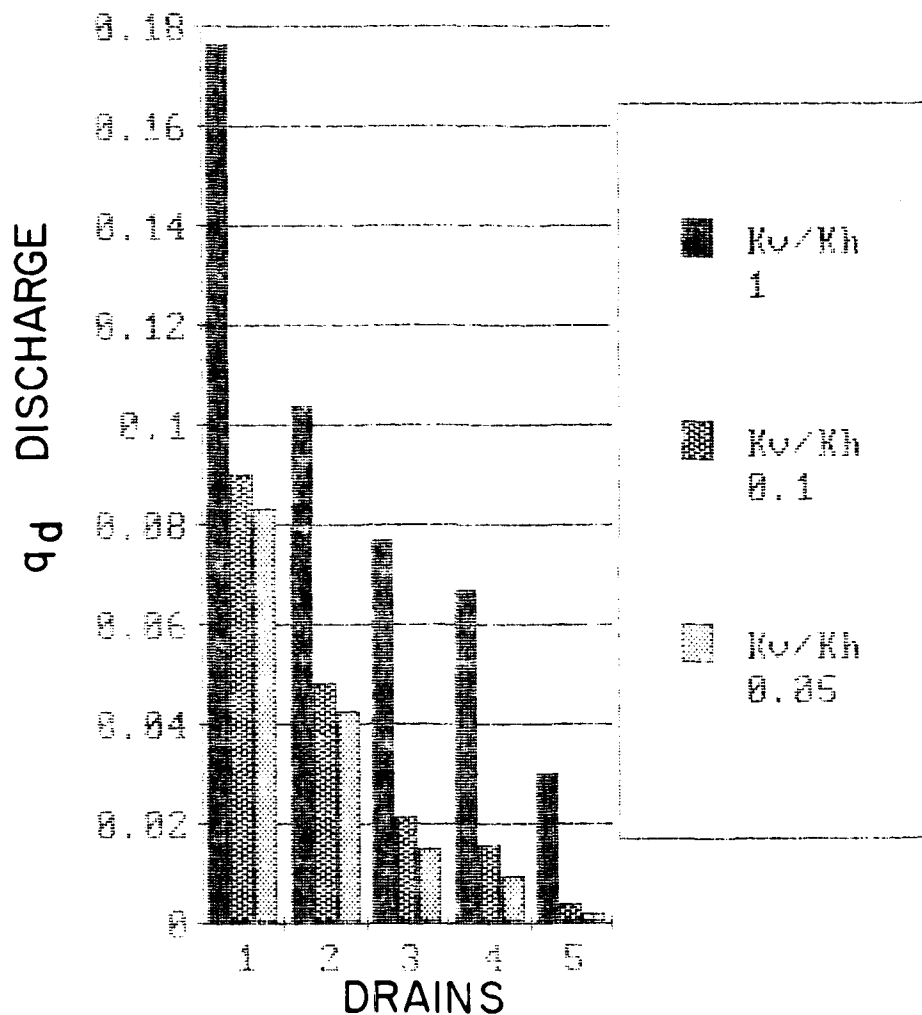


Figure 4.11 Drain discharge vs. anisotropy.
 $L_i = 400'$, $H_r = 100'$, $S_p = 15'$, $D_w = 2$, $h = 20'$

Figure 4.12 depicts data generated for the condition of a sloping impervious layer. The slope of the boundary is given as a percentage of $\Delta x/\Delta y$. The depth of the layer is held constant at drain one and the layer slopes clockwise from the positive x horizontal axis.

Though actual quantities of discharge are only changing in very small amounts, the trend is seen that for slopes greater than 5% the discharge increases in drains 3 through 5. However at some slope between 5% and 10% the discharge decreases. It is also seen that the discharge of drain five is the least effected by any slope change, in terms of discharge quantity.

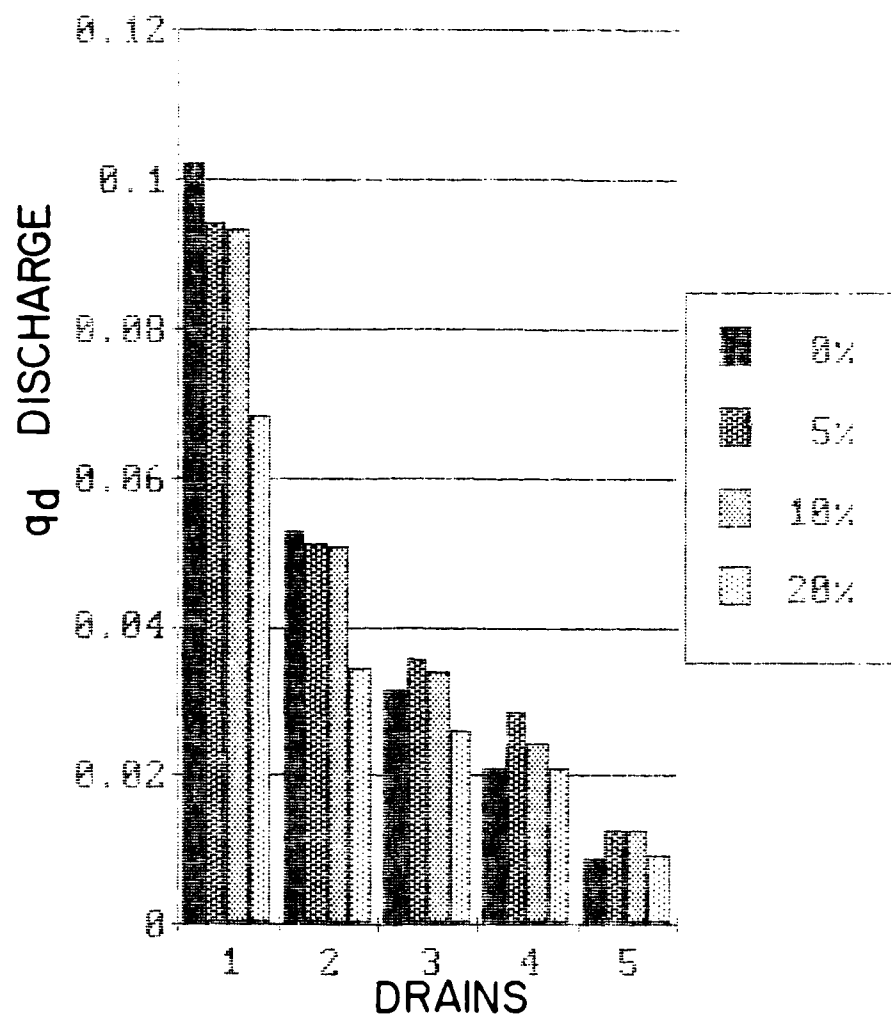


Figure 4.12 Drain discharge vs. slope of the impervious layer.

$L_i = 400'$, $H_r = 100'$ (first drain), $h = 20'$, $S_p = 25'$, $D_w = 2'$,
 $K = 0.2$ ft/day

Free Surface Location ($L_i = 400'$ and $H_r = 100'$)

Figure 4.13 shows the influence of the drain width on the maximum free surface height, $S_{FS_{max}}$. In all cases this occurred between drains one and two. This plot shows how the relationship is linear and that the height of the free surface is not greatly affected by the drain width.

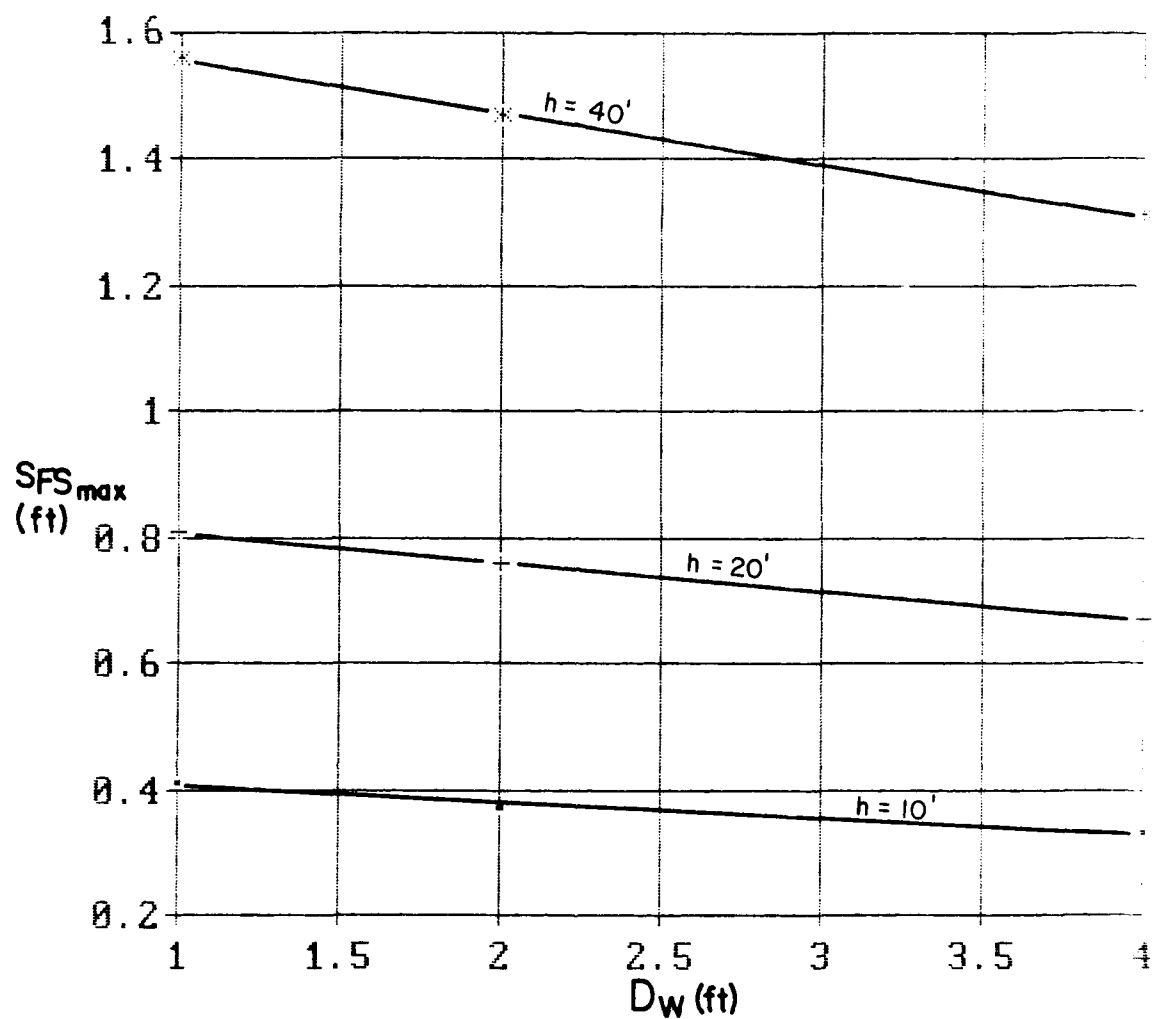


Figure 4.13 Maximum free surface height vs. drain width with varying heads.

$L_i = 400'$, $H_r = 100'$, $S_p = 25'$, $K = 0.2$ ft/day

Figure 4.14 depicts the influence of drain spacing and head on the maximum free surface height. These results show that increased drain spacing causes an increase in the free surface. Therefore one should consider the smaller spacing or possibly deeper drains.

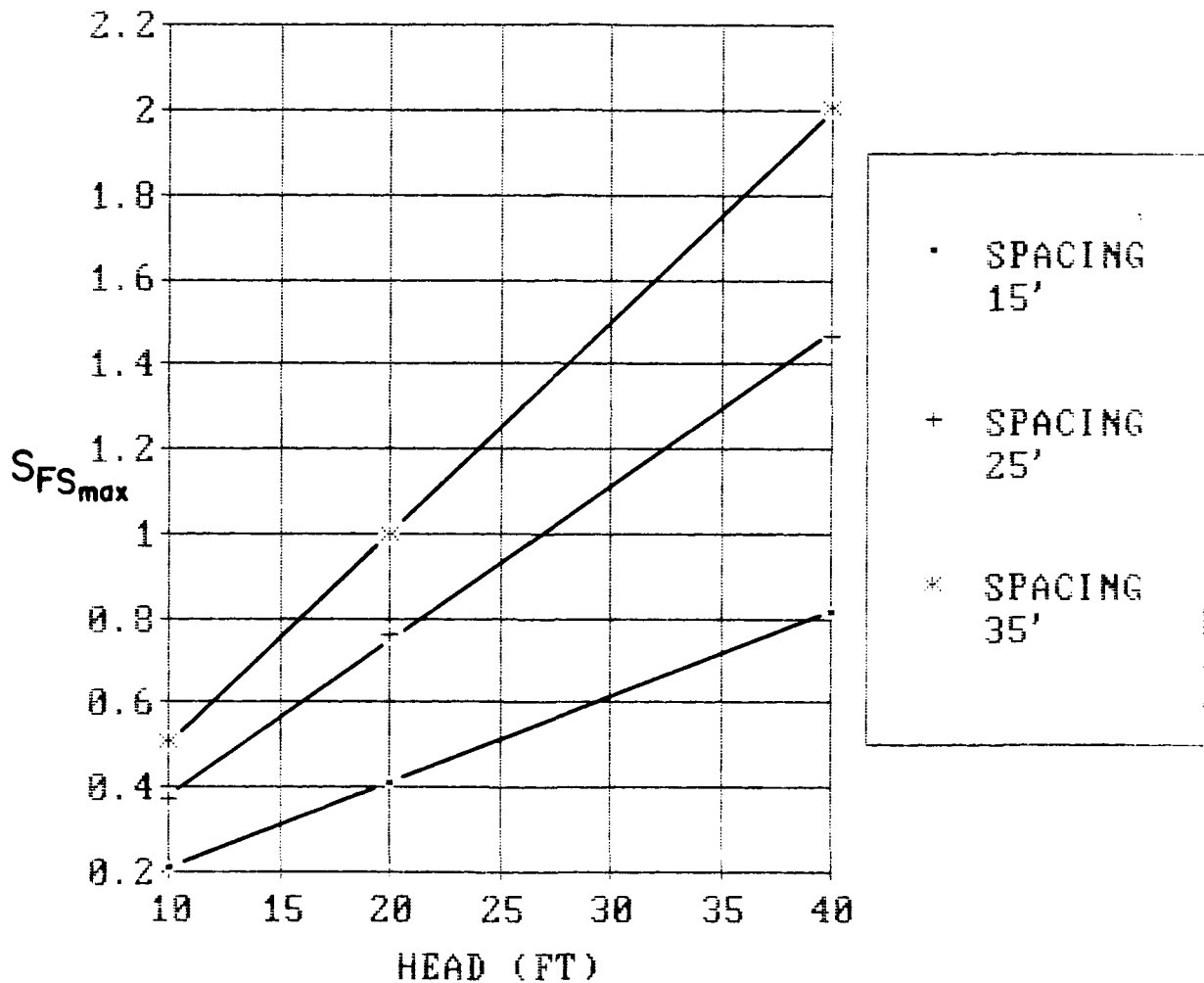


Figure 4.14 Maximum free surface height vs. spacing of drains with varying head.

$L_i = 400'$, $H_r = 100'$, $D_w = 2'$, $K = 0.2$ ft/day

Figure 4.15 shows the relationship of maximum free surface height, $S_{FS_{max}}$, as a function of head, h , and anisotropy, K_v/K_h . The same trend is seen here as noticed with discharge for anisotropy, that with increased vertical hydraulic conductivity the height of the free surface increases.

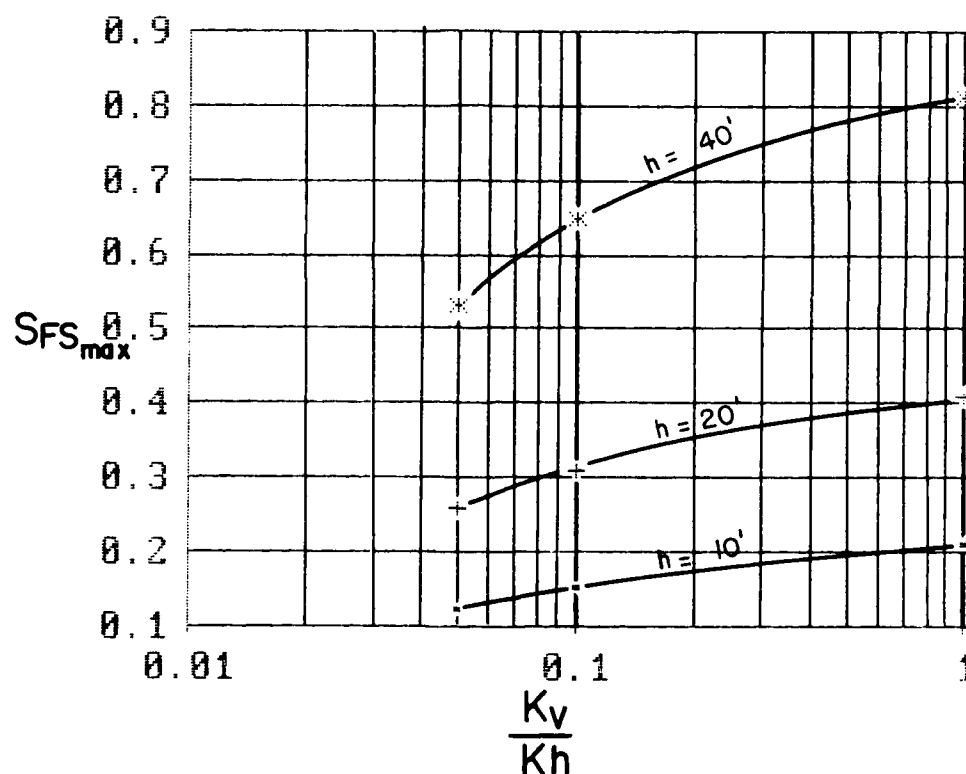


Figure 4.15 Maximum free surface height vs. anisotropy with varying head.
 $L_1 = 400$, $H_r = 100'$, $S_p = 25'$, $D_w = 2'$

In Figures 4.16 through 4.20, the free surface corner nodes are plotted for the different cases of analysis. To see the effects of the free surface changes versus the variable changes only nodes between the drains are plotted. In the sense of design, the maximum height of the free surface would be of the most concern, which is in between the first two drains. However, it is of interest to see the total free surface from a standpoint of total cross section of the building.

In Figure 4.16 the effect of thickness of aquifer on location of the free surface is shown. It is of interest to see, as in the case for discharge shown by Figure 4.8, that for shallow depths of impervious layer, $H_r = 20'$, that very little rise in the free surface occurs in between drains four and five.

Figure 4.17 shows the effects of head differential on the location of the free surface nodes. It is of interest to see for cases of head equal to 20 and 10 feet the free surface nodes are approaching gentle mounds of water in between drains. However for the head equal to 40 feet the free surface peaks rather abruptly between the first two drains but resumes the gentle fall in free surface between the other drains.

Figure 4.18 shows the effects of drain spacing on the location of the free surface nodes. This shows as spacing is increased the free surface increases.

For Figure 4.19, the effects of the sloping aquifer on location of the free surface nodes is shown. The same trend is seen here as in discharge, shown by Figure 4.12, that for slopes greater than 10% the free surface location drops. The change in free surface nodes is very small for the cases of slope equal to 5% and 10%.

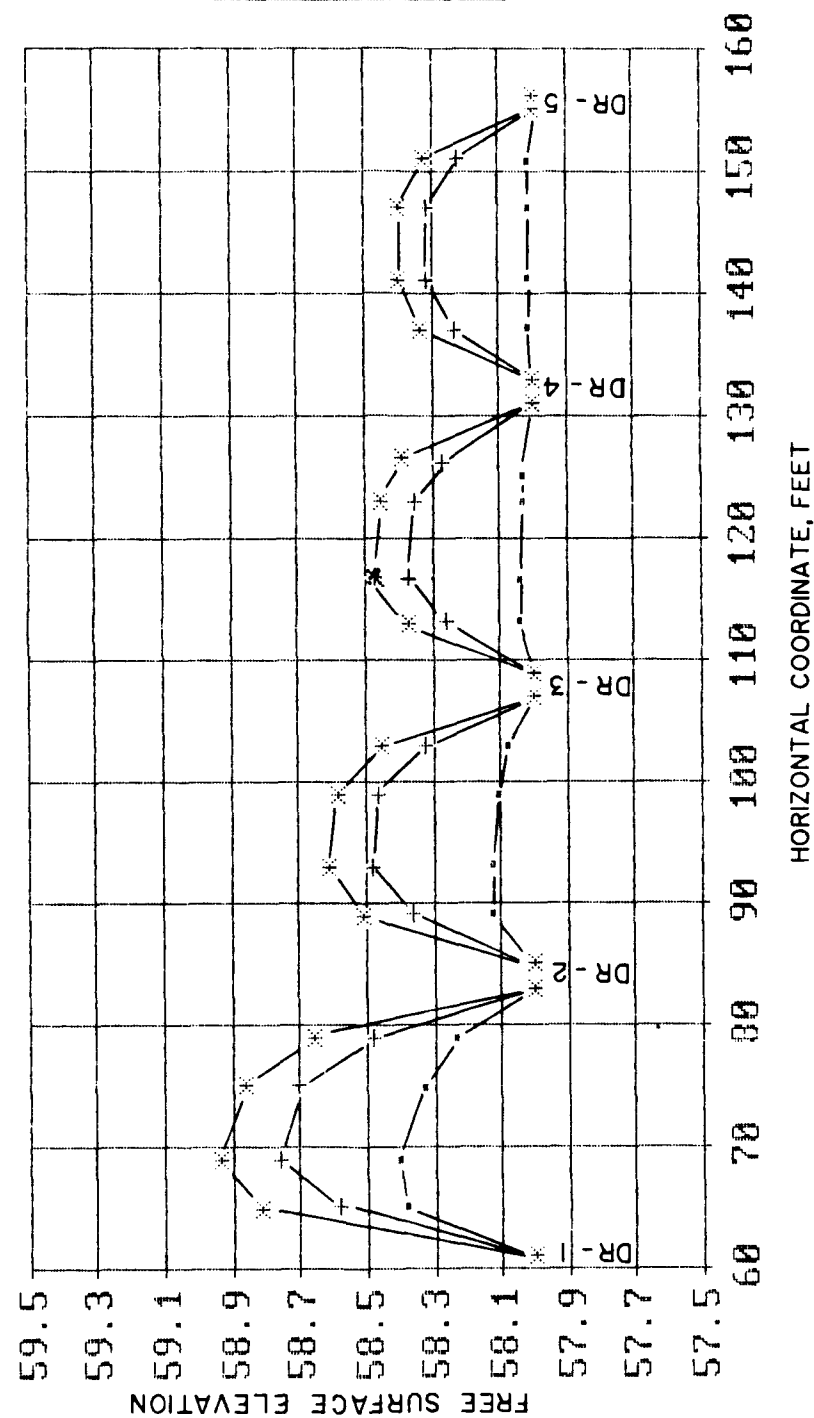


Figure 4.16 Free Surface corner nodes at drains with effects impervious boundary layer.

$L_i = 400'$, $h = 20'$, $D_w = 2'$, $K = 0.2$ ft/day

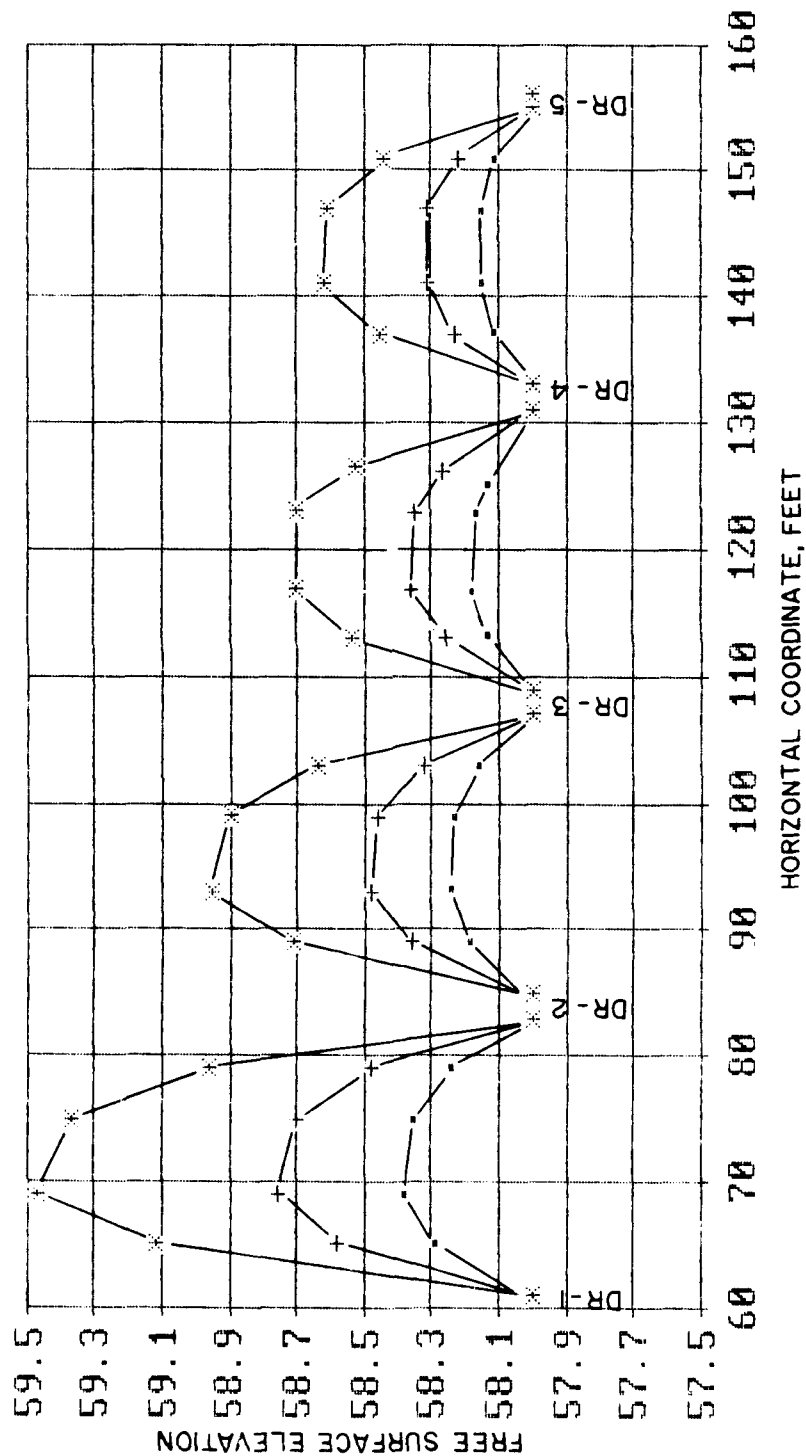


Figure 4.17 Free Surface corner nodes with drains with effects of head differential.

$L_i = 400'$, $H_r = 100'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

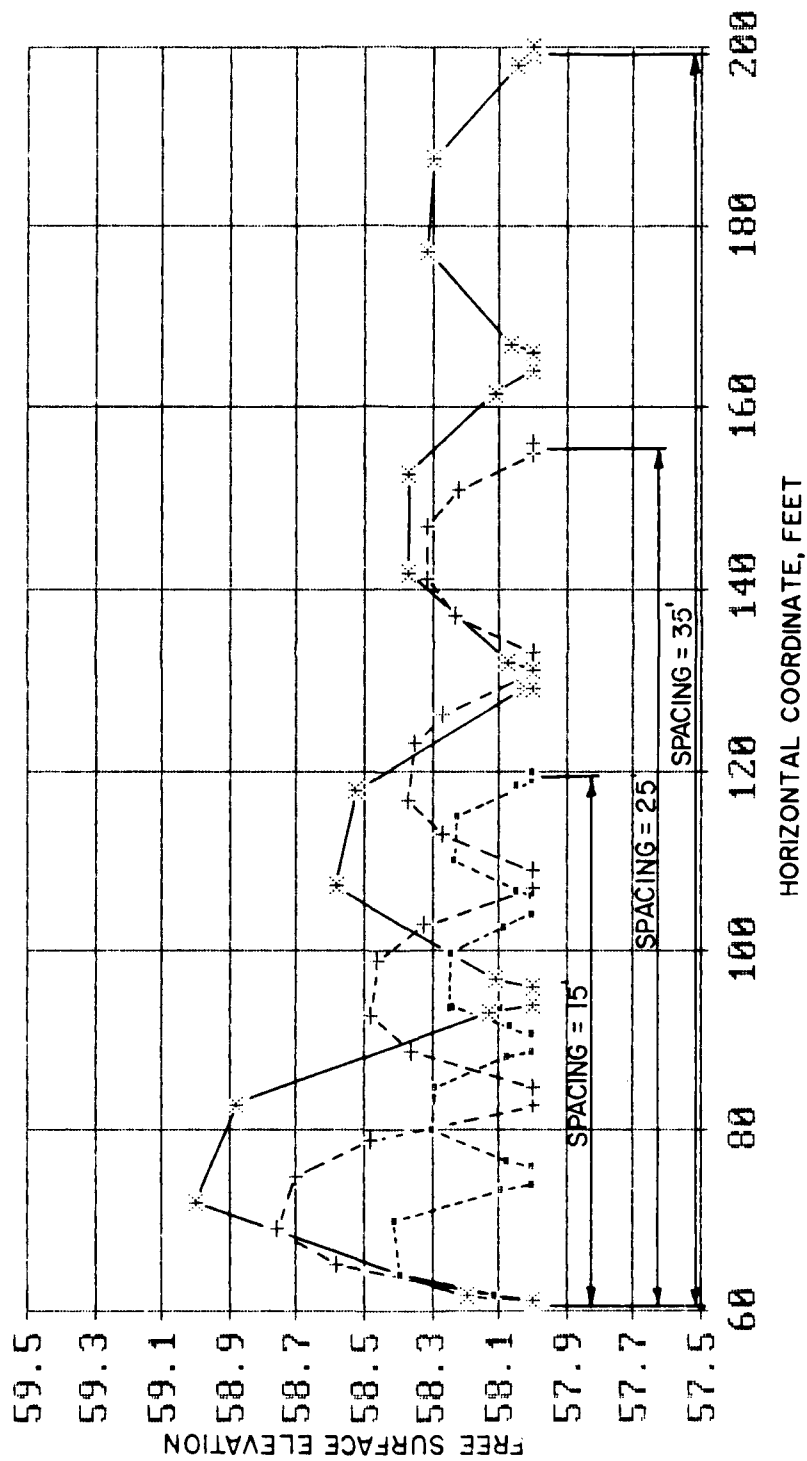


Figure 4.18 Free Surface corner nodes with drains with effects of drain spacing.

$L_i = 400'$, $H_r = 100'$, $h = 20'$, $D_w = 2'$, $K = 0.2$ ft/day

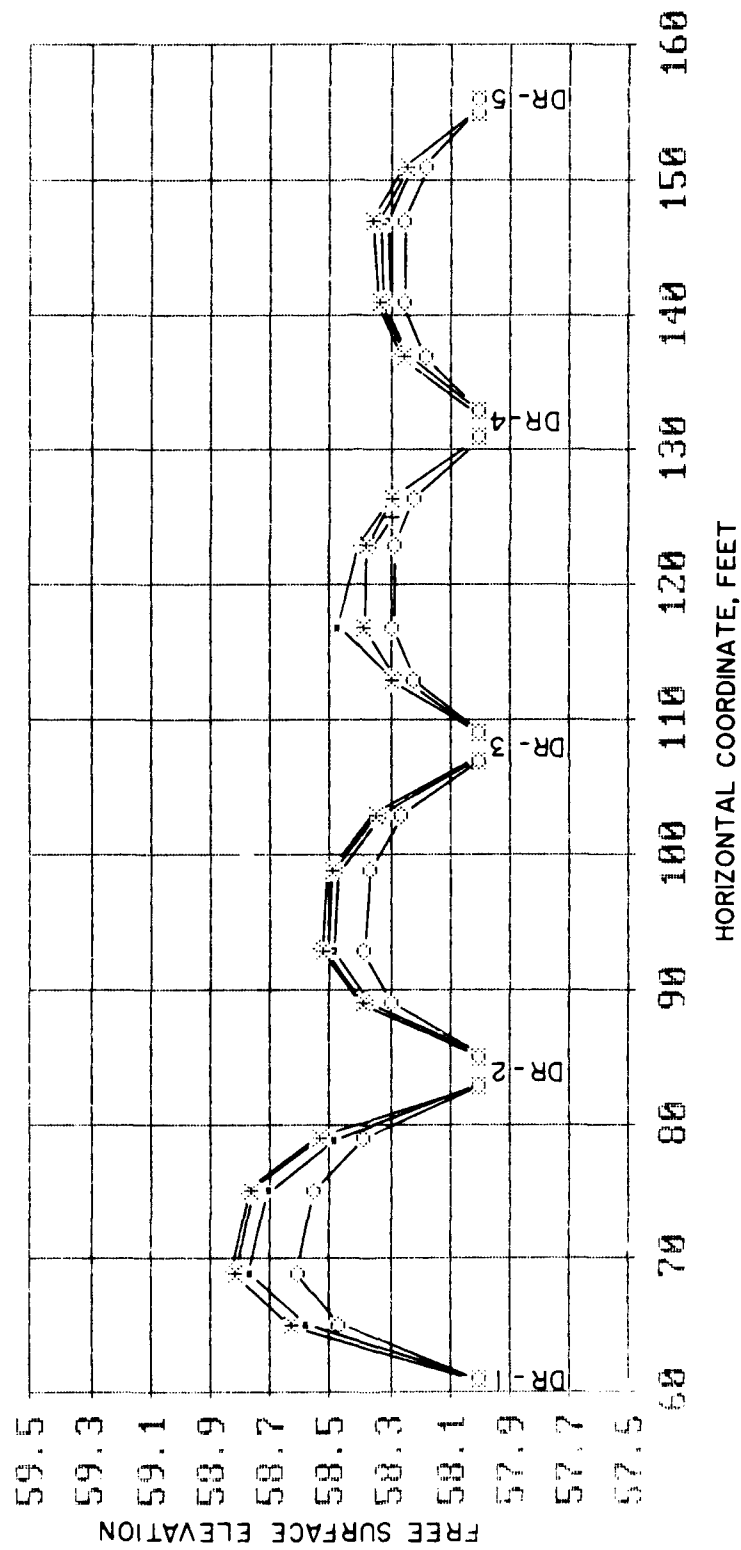


Figure 4.19 Free Surface corner nodes with drains with effects of slope of impervious boundary.

Li = 400', Hr = 100' (first drain), Sp = 25', h = 20', K = 0.2 ft/day

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THE GROUNDWATER TABLE(U) GEORGIA INST OF TECH ATLANTA
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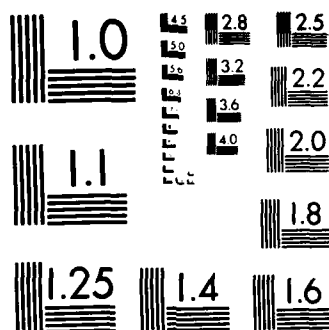
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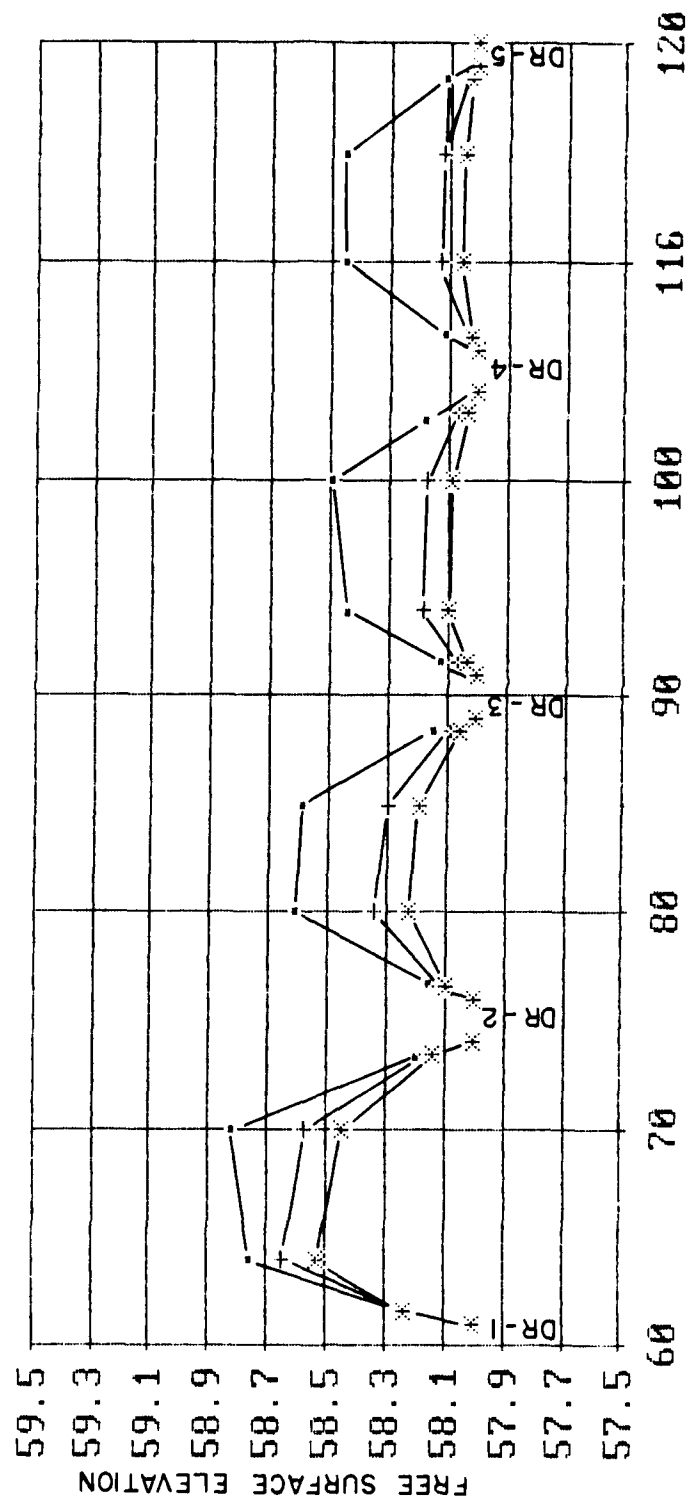


Figure 4.20 Free Surface corner nodes with effects of anisotropy.

$L_i = 400'$, $H_r = 100'$, $Sp = 25'$, $h = 20'$, $D_w = 2'$

Dimensional Analysis ($L_i = 400'$ and $H_r = 100'$)

Figures 4.21 through 4.24 are plots of the data generated by a dimensional analysis as discussed in Chapter 3. The discharge values given are unit discharge quantities and each case is for the particular variables noted in each figure. Unit discharge is defined as the sum of the total drain discharges for each of the drains per unit width in the z axis or the third dimension.

In Figure 4.21 the effect of drain width is analyzed. This plot shows that with increased drain width discharge increases, but with increased head the discharge may increase at a much faster rate. From this analysis it would appear that the greatest increases of flow rate would be for the drain widths between one and two feet wide. The following analysis is performed:

	<u>Drain Widths</u>			
<u>head</u>	1	2	3	4
10	0.034	0.053	0.065	0.073
increase →	0.019	0.012	0.009	
20	0.035	0.055	0.070	0.086
increase →	0.02	0.015	0.016	
40	0.036	0.057	0.075	0.09
increase →	0.021	0.018	0.015	

This analysis shows the increases of the flow function for the different head increases as shown. The maximum increase is seen for the values between drain widths of one and two. Therefore the most effective increase in flow occurs for drain widths between 1 and 2 feet. Another relationship could be stated, that for Dw/h ratios less than 0.2 the flow quantity increases at a rapid rate.

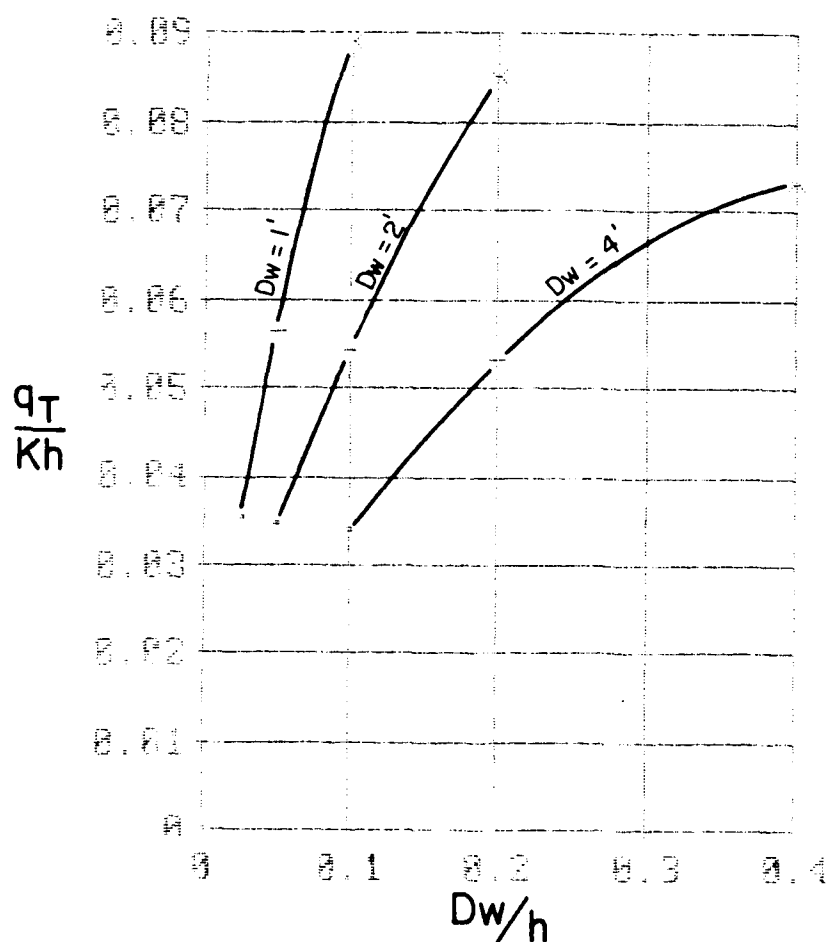


Figure 4.21 Dimensional analysis, Drain width.
 $L_i = 400'$, $H_r = 100'$, $Sp = 25'$, $K = 0.2$ ft/day

In Figure 4.22 the effects of thickness of aquifer is shown for the dimensional analysis. This plot concludes that for Hr/h ratios greater than 2 or 3 the net increase in flow is approaching a linear relationship. This states that with increasing thickness of the aquifer the discharge is expected to increase very near a linear increase and for very shallow thicknesses the flow becomes very small.

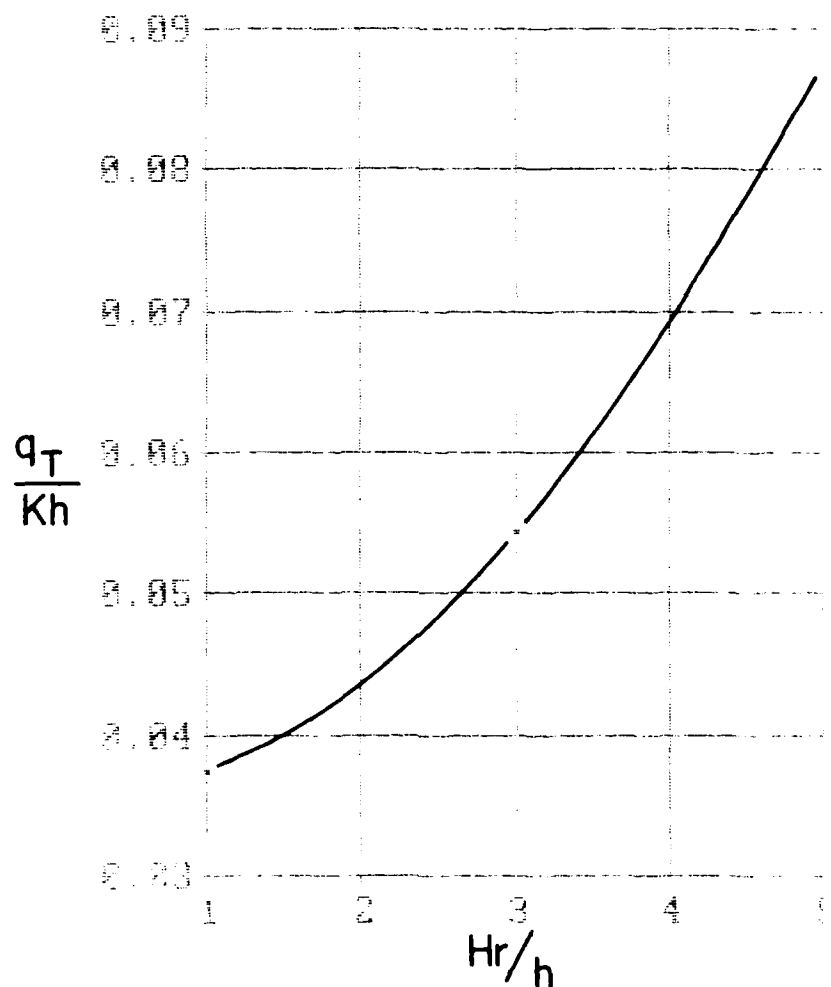


Figure 4.22 Dimensional Analysis, Depths of impervious layer.
 $L_i = 400'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

The effects of drain spacing is presented in Figure 4.23. The flow function for this analysis is treated differently for the spacing changes. As the spacing was increased for each of the computer runs the flow domain increased accordingly to accommodate the five drains at the appropriate spacing. Therefore to gain understanding of the effects of flow relationships with respect to drain spacing, each term was normalized by the corresponding spacing between the drains for each head increase. This analysis shows for decreased spacing discharge increases and as head increases so the discharge.

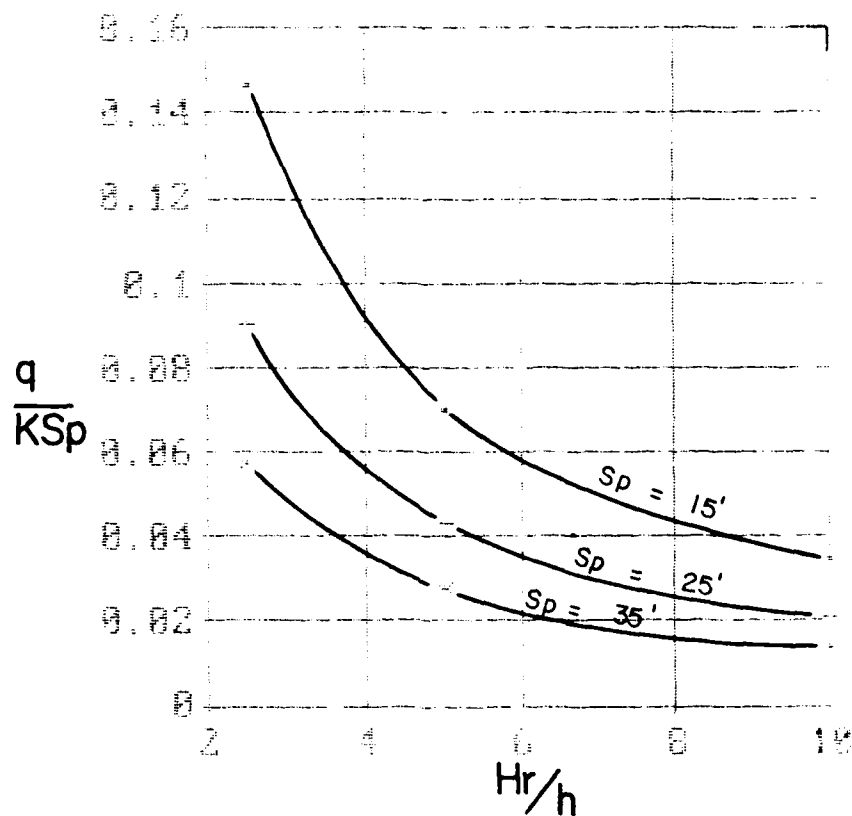


Figure 4.23 Dimensional Analysis, Drain spacing.
 $L_i = 400$, $H_r = 100'$, $D_w = 2'$, $K = 0.2$ ft/day

Figure 4.24 shows the dimensional analysis for effects of the sloping aquifer. For this particular flow matrix as modeled, a definite break in flow increase is noticed. The peak discharge function is at slope, θ equal 0.05.

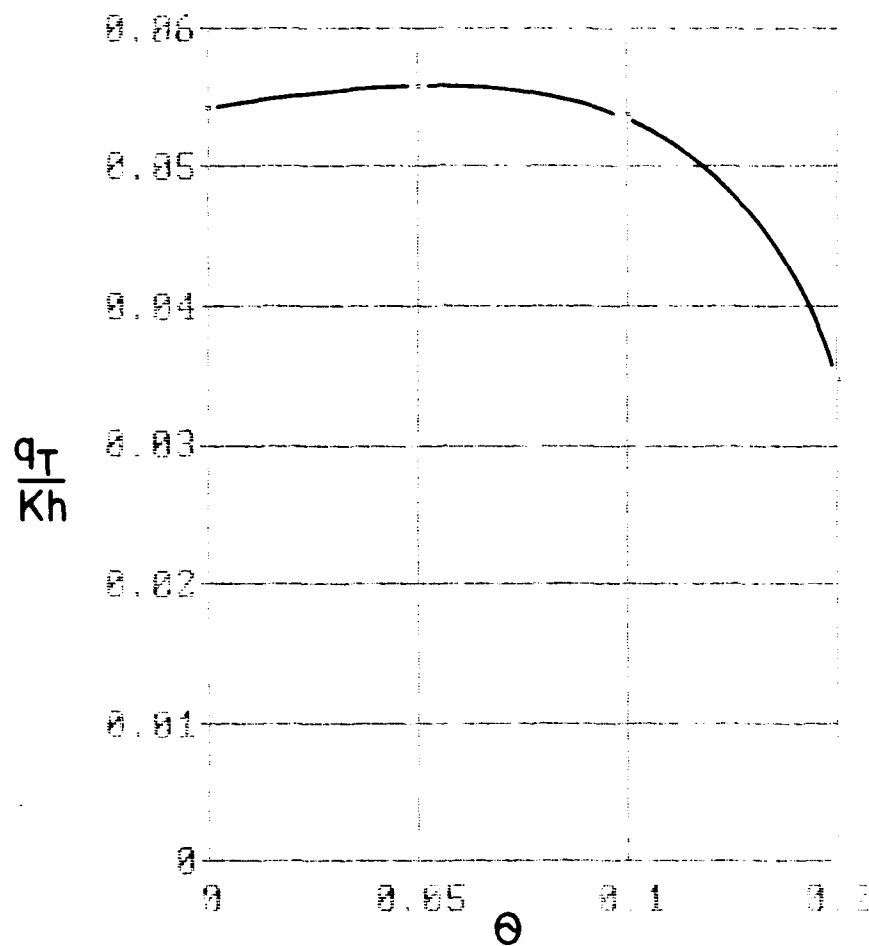


Figure 4.24 Dimensional Analysis, Slope of aquifer.
 $L_i = 400'$, $H_r = 100'$ (first drain), $S_p = 25'$, $D_w = 2'$, $K = 0.2$
 ft/day

Results For $L_i = 80'$ and $H_r = 58'$

The following plots and nomographs are the results for the computer runs where distance from the constant head boundary to the first drain, L_i , equals 80 feet and the thickness of the aquifer equals 58 feet. The plots are essentially the same as for the previous case except these variables are held constant.

Drain Discharge ($L_i = 80'$ and $H_r = 58'$)

Figure 4.25 shows the effects of drain width on total drain discharge. The results are generally the same as shown in Figure 4.6 except discharge quantities range from 3 to 4 times greater.

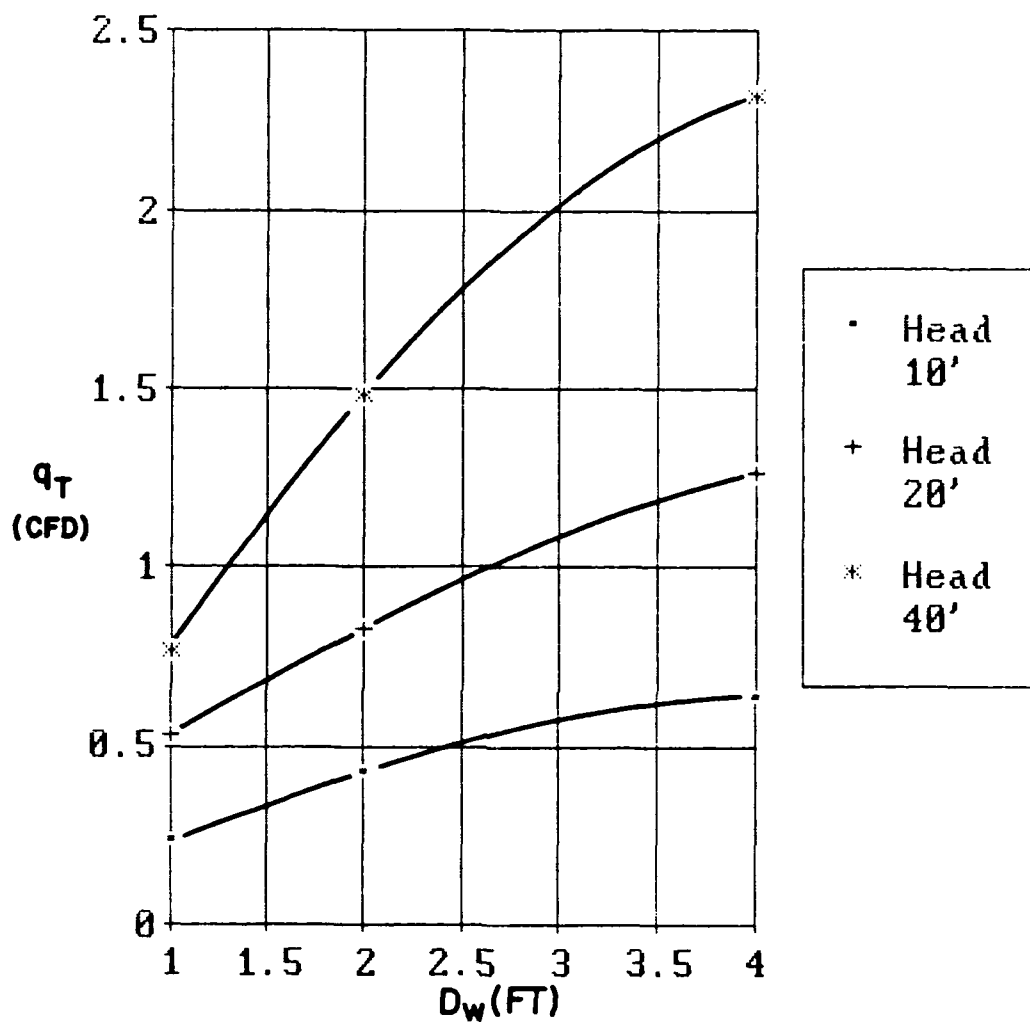


Figure 4.25 Total drain discharge vs. drain width with varying head.
 $L_i = 80'$, $H_r = 58'$, $S_p = 25'$, $K = 0.2$ ft/day

The results of anisotropy of the soil continuum is shown by Figure 4.26 for the short Li distance of 80 feet. The trend is slightly different than for the case for Li equal 400 feet as shown by Figure 4.7. For the largest head value of 40 feet the discharge decreases just slightly with decrease in vertical hydraulic conductivity, but for a K_v/K_h ratio less than 0.1 the discharge decrease is very dramatic. However for the low head value of 10 feet the general decreasing trend is prevalent as the case for Figure 4.7.

For this case the flow quantities have increased approximately 4 to 5 times. This shows the large effects that the distance of the constant head boundary has on the seepage quantities.

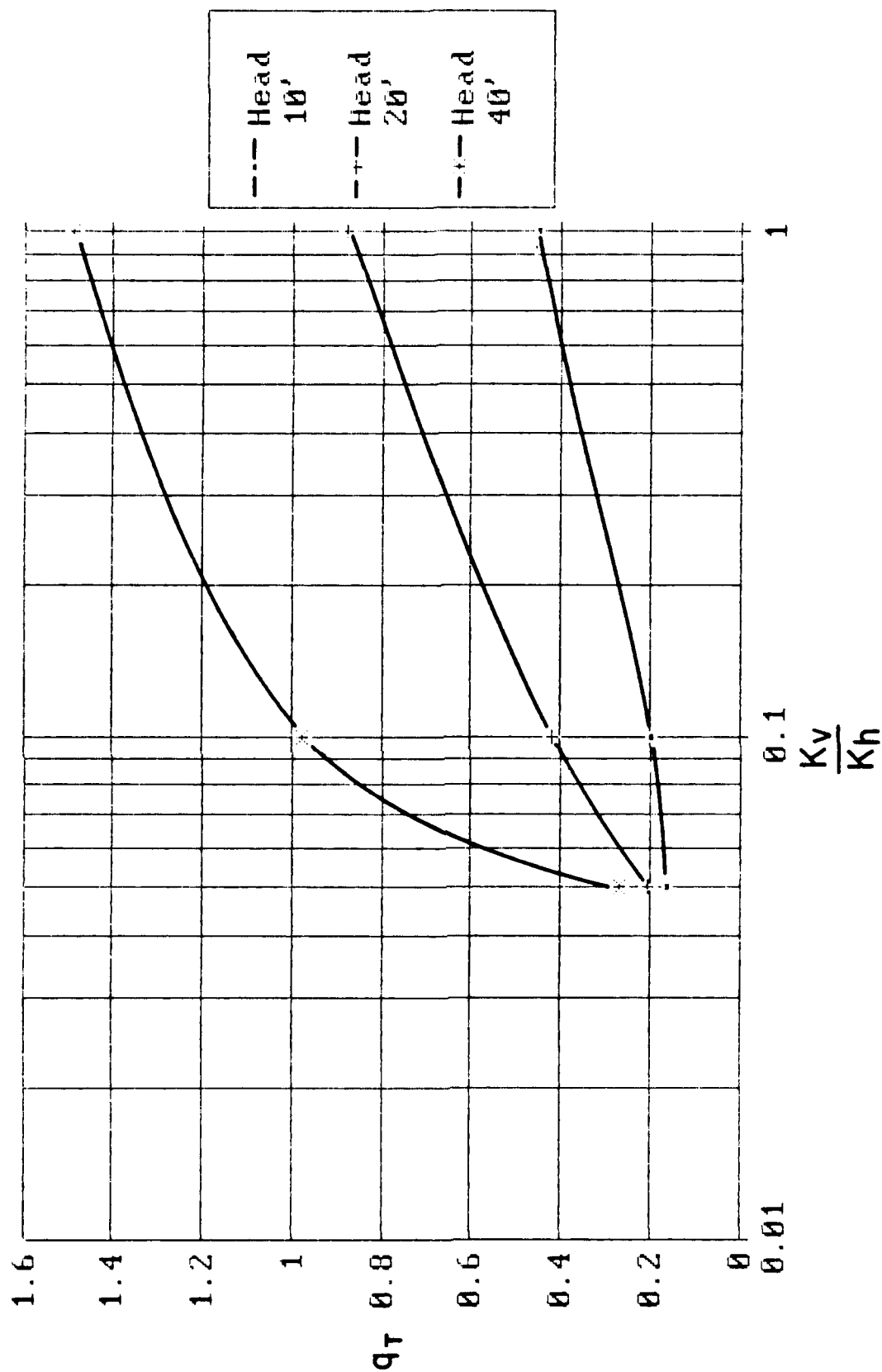


Figure 4.26 Total Drain Discharge vs. Anisotropy with varying heads
 $L_i = 80'$, $H_r = 58'$, $S_p = 15'$, $D_w = 2'$, $K_h = 0.2$ ft/day

Figures 4.27 and 4.28 depict the same general trend of maximum flow at drain one and a general decrease in flow for each consecutive drain is noticed for effects of thickness of aquifier and head respectively. Flow quantities are again 3 to 4 times greater for this case than for the earlier case as shown by Figures 4.8 and 4.9. For this case of shorter distance to the constant head boundary equal 80 feet, the mid-peak discharges at the third drain is not noticed as in Figure 4.9. In Figure 4.28 it is of interest to see that the largest head value equal 40 feet has such a large effect on the first drain collecting a large portion of the total discharge of the system.

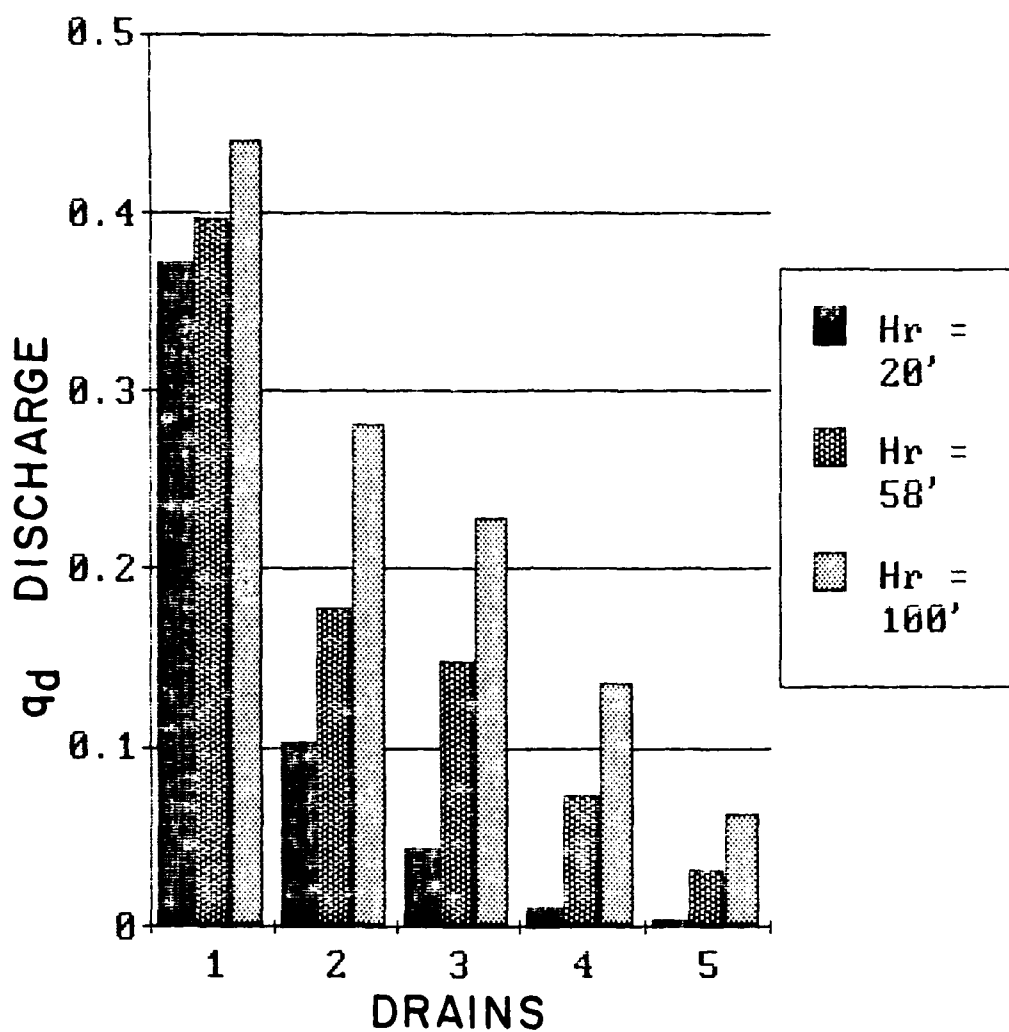


Figure 4.27 Drain discharge vs. depth of aquifer.
 $L_i = 80'$, $h = 20'$, $S_p = 25'$, $K = 0.2$ ft/day, $D_w = 2'$

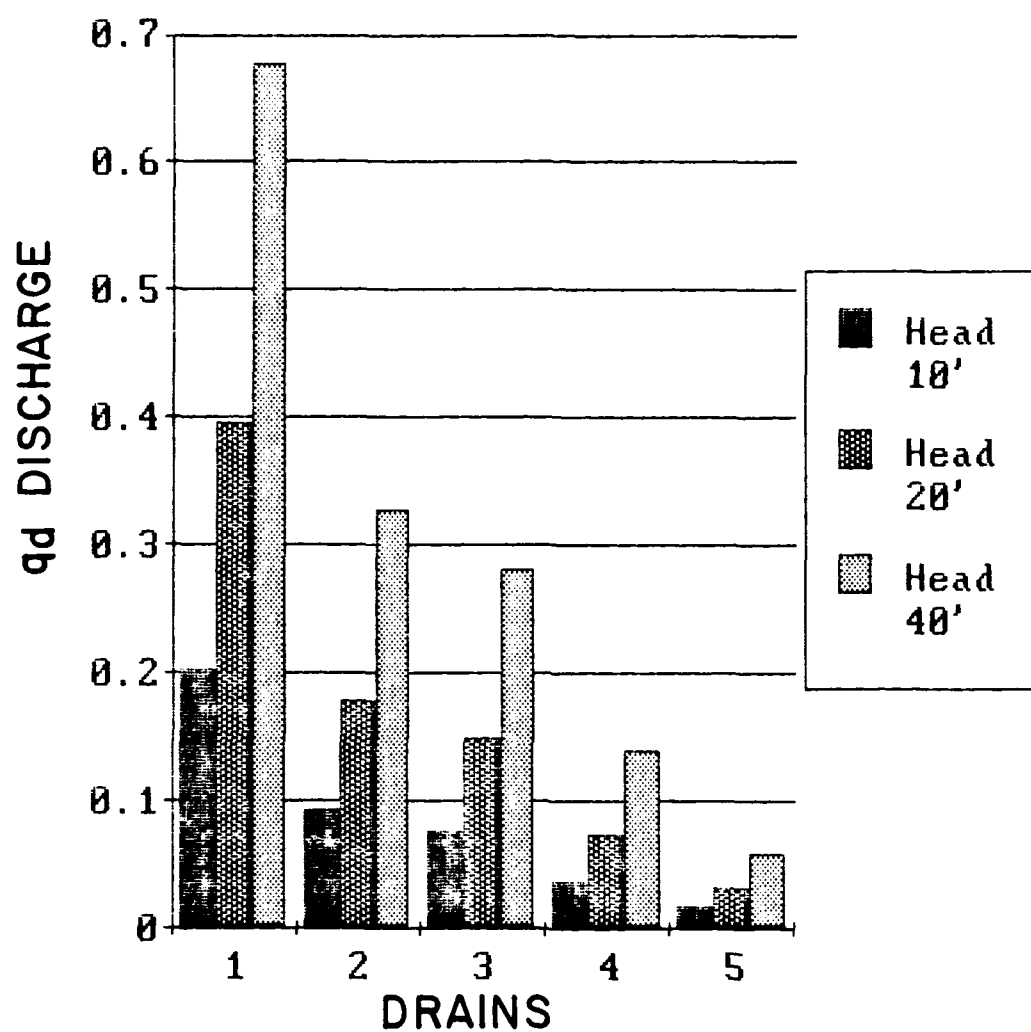


Figure 4.28 Drain discharge vs. head differential.
 $L_i = 80'$, $H_r = 58'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

The effects of drain spacing for distance of the constant head boundary to the first drain, L_i , equal 80 feet, is shown by Figure 4.29. The same trends are seen for this case as that shown by Figure 4.10. Flow increase is somewhat less in this case compared to the earlier case of L_i equal 400 feet. Flow quantities appear to range from 2 to 3 times as great.

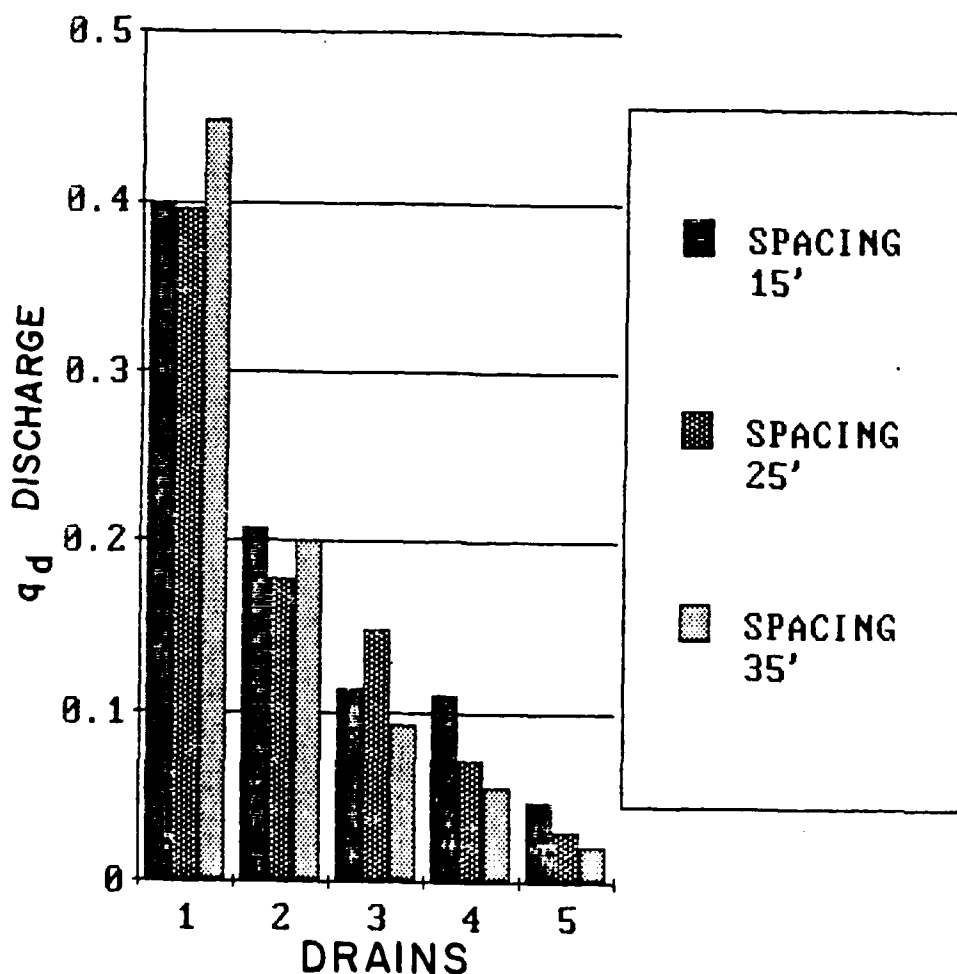


Figure 4.29 Drain discharge vs. drain spacing.
 $L_i = 80'$, $H_r = 58'$, $h = 20'$, $D_w = 2'$, $K = 0.2$ ft/day

In Figure 4.30 the effects of slope of the impervious boundary, θ , is shown for drain discharge. A significant change is noticed for this plot when compared to the earlier plot in Figure 4.12 for sloping aquifer. For L_i equal to 400 feet, the peak discharge occurred for a slope between 5 and 10 percent. In this case, where L_i equals 80 feet, the peak flow is for the case of the steepest slope equal to 20 percent. For drain one, the flow is 8 times greater than the flow for drain one as shown by Figure 4.12, $L_i = 400$ feet. The flow is 5 times greater in drain five in this case than the flow in drain five for the case of $L_i = 400$ feet.

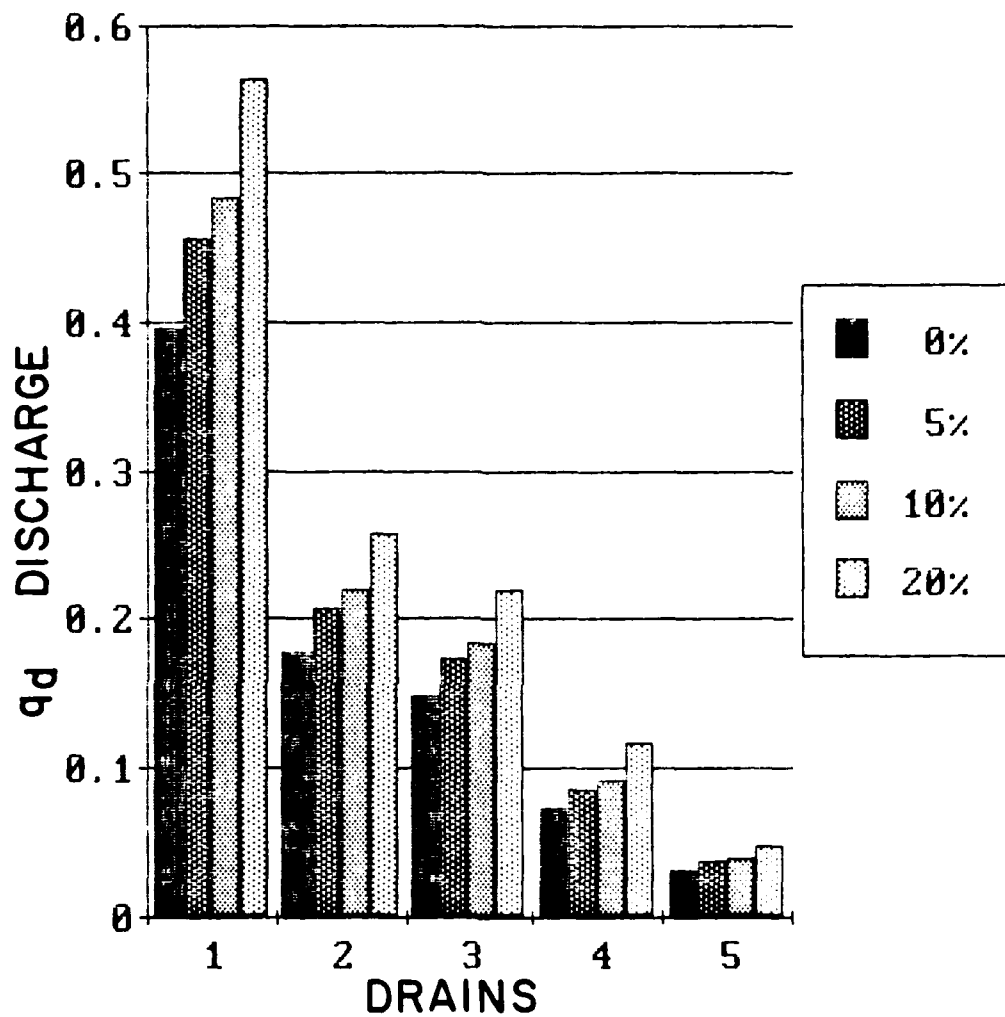


Figure 4.30 Drain discharge vs. slope of the impervious boundary.
 $L_i = 80'$, $H_r = 58'$ (first drain), $h = 20'$, $S_p = 25'$, $D_w = 2'$,
 $K = 0.2$ ft/day

Free Surface Location ($L_i = 80'$ and $H_r = 58'$)

Figures 4.31 through 4.36 show the results of the free surface location plots for the case of L_i equal 80 feet and H_r equal 58 feet. The same general trends are shown for this plots as shown by the earlier case of L_i equal 400 feet and H_r equal 100 feet. In general, the free surface has moved up approximately three times in height. An exception to the earlier case of is shown in Figure 4.36. This figure shows the location of the free surface nodes with the effects of slope of the impervious boundary. It is somewhat different in this case than in the earlier case as shown in Figure 4.19 for L_i equal 400 feet. In this case the free surface continues to increase in height as the slope of the impervious boundary increases.

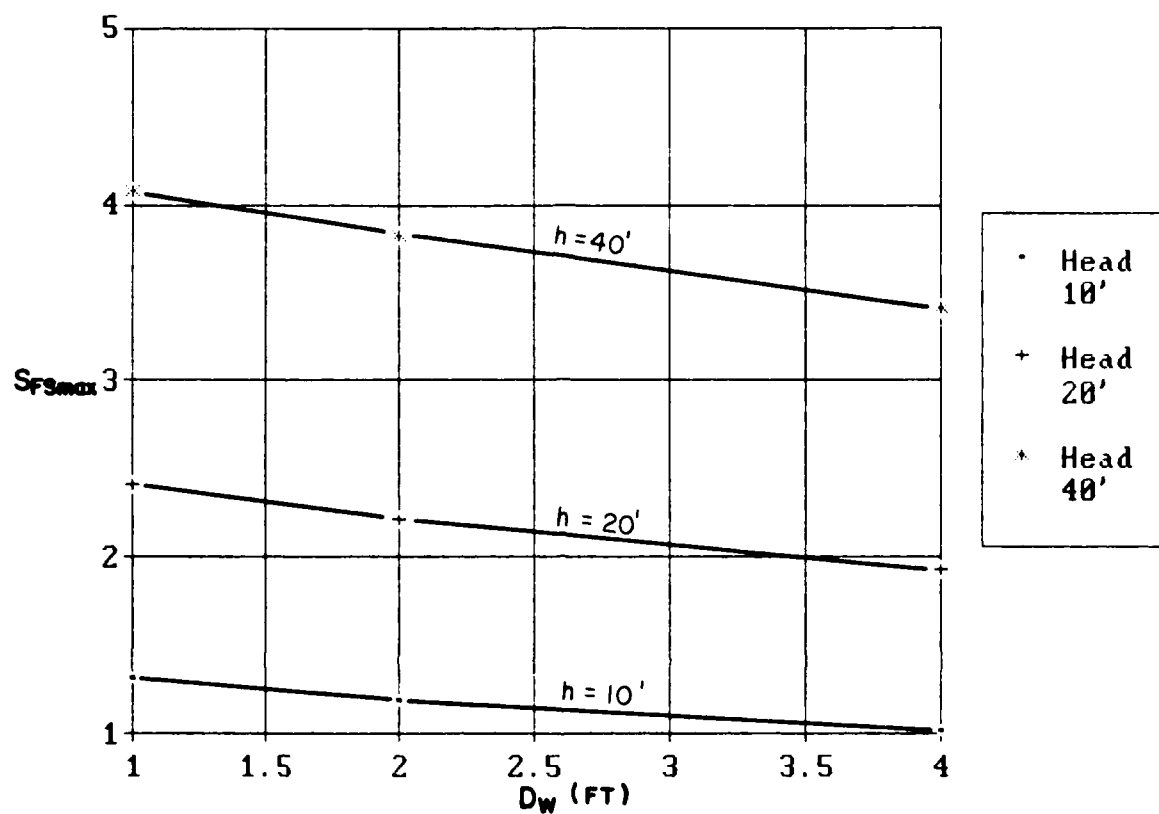


Figure 4.31 Maximum free surface height vs. drain width.
 $L_i = 80'$, $H_r = 58'$, $S_p = 25'$, $K = 0.2$ ft/day

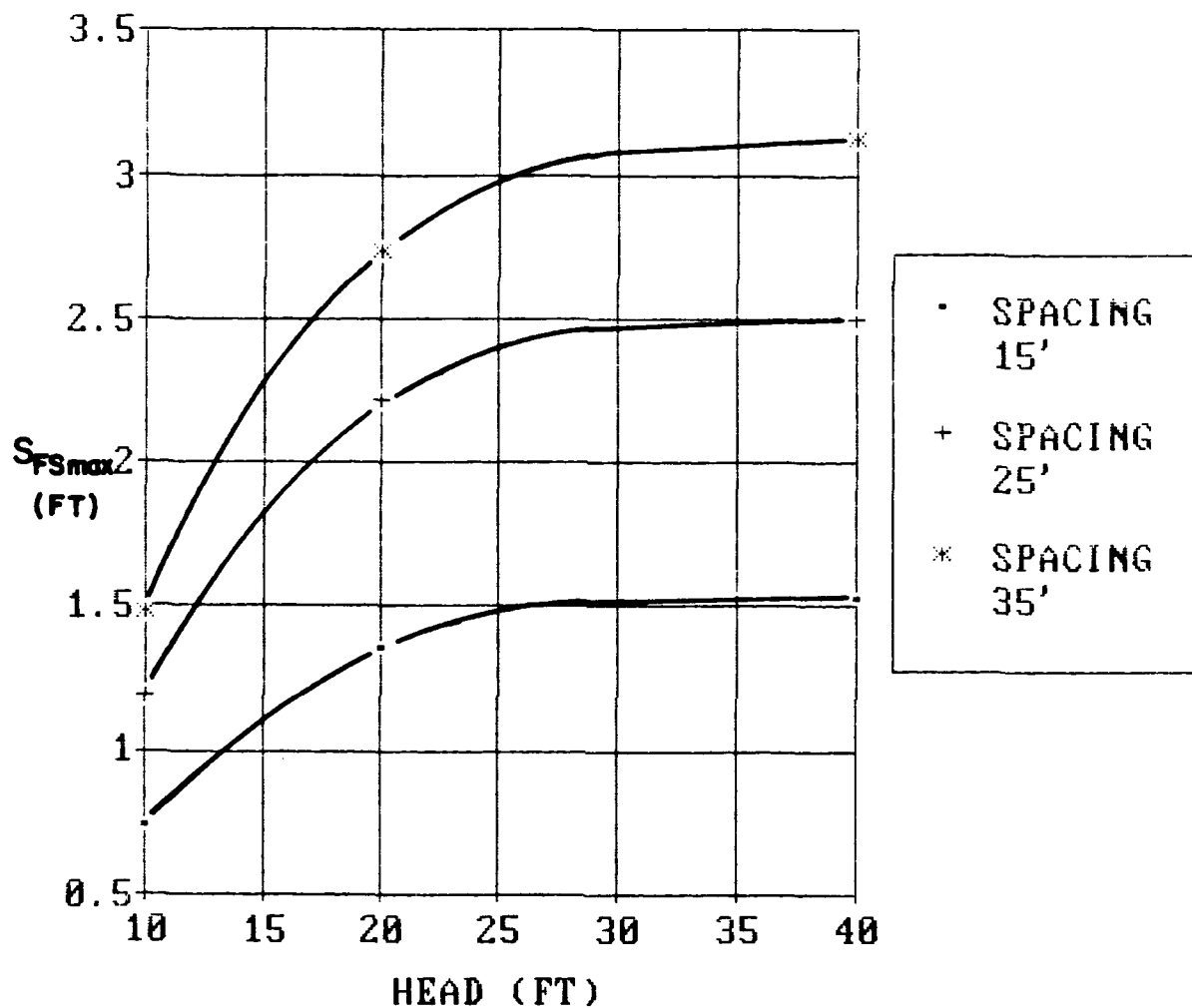


Figure 4.32 Maximum free surface height vs. drain spacing with head varying.
 $L_i = 80'$, $H_r = 58'$, $D_w = 2'$, $K = 0.2$ ft/day

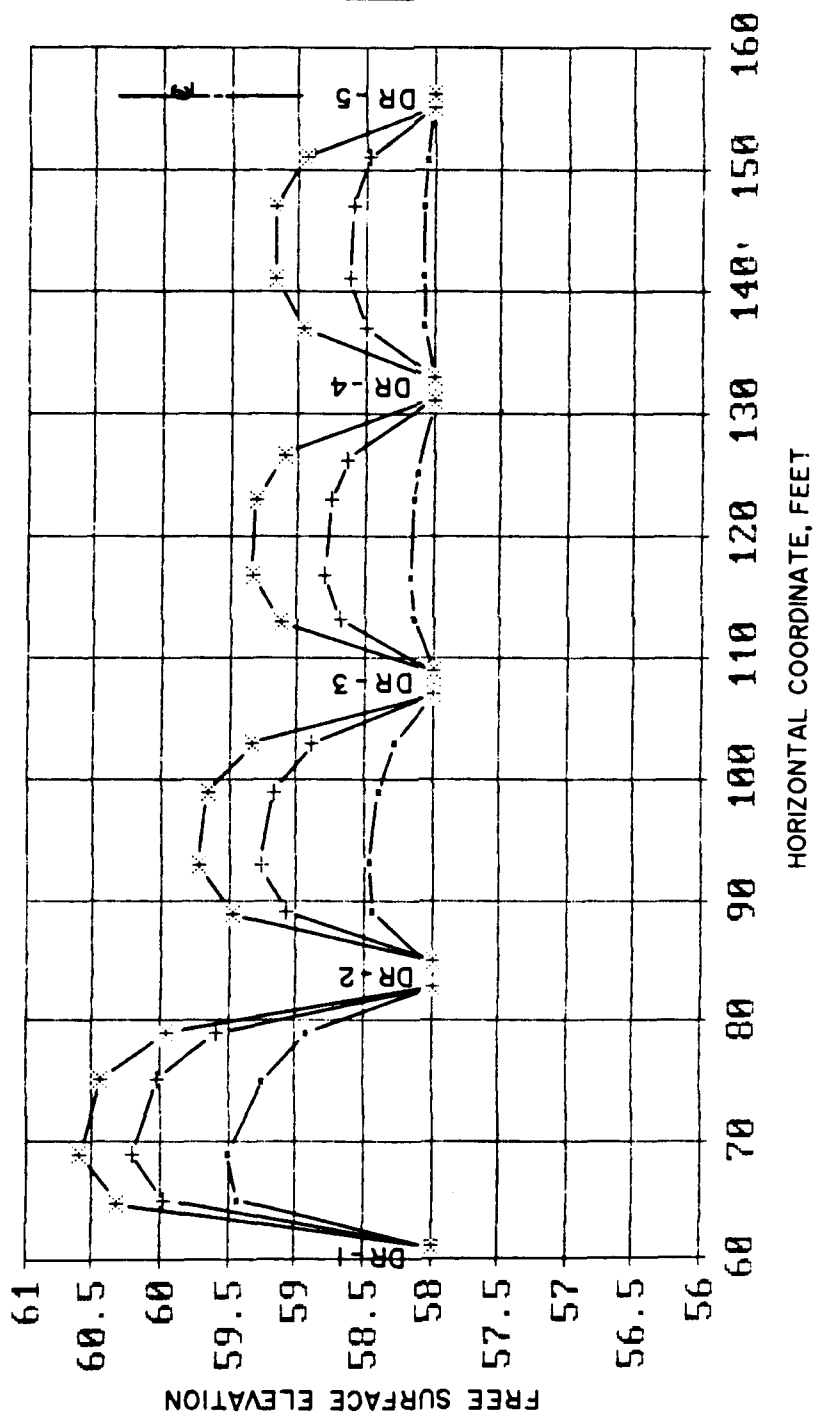


Figure 4.33 Free surface corner nodes with effects of
Depth of impervious boundary.
 $L_i = 80'$, $h = 20'$, $D_w = 2'$, $K = 0.2$ ft/day

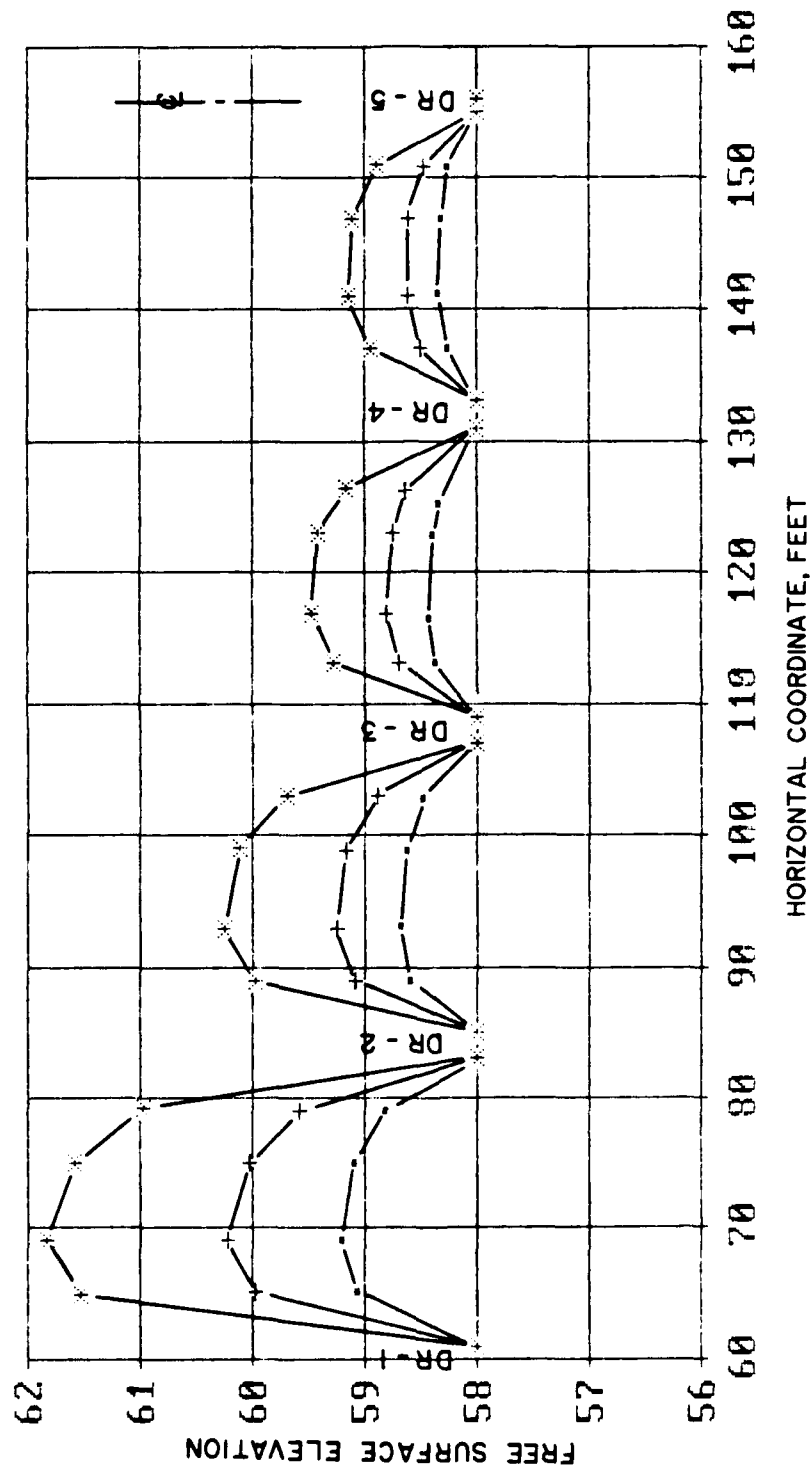


Figure 4.34 Free surface corner nodes with effects of head differential.
 $L_i = 80'$, $H_r = 58'$, $Sp = 25'$, $K = 0.2$ ft/day

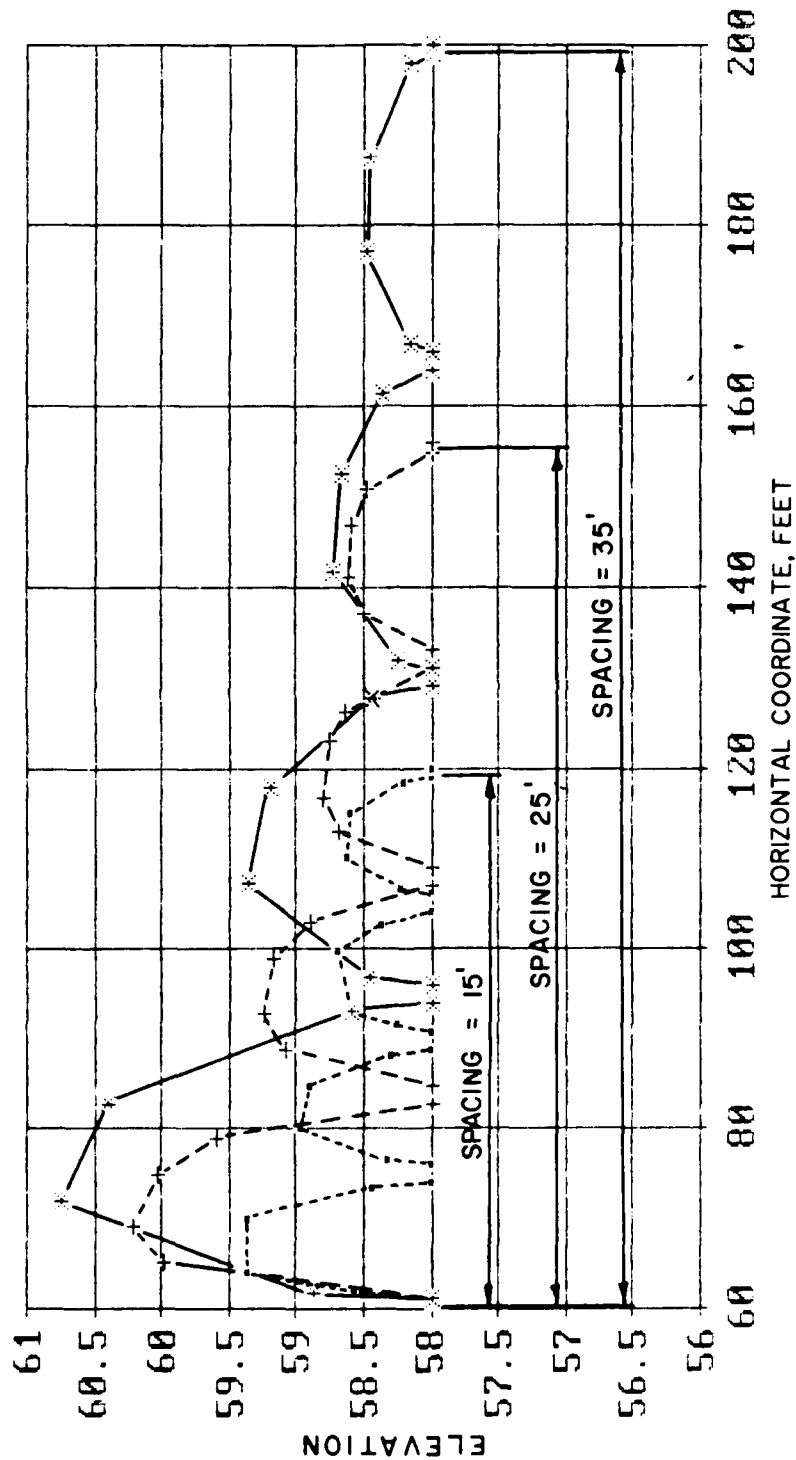


Figure 4.35 Free surface corner nodes with effects of Drain spacing
 $L_i = 80'$, $H_r = 58'$, $h = 20$, $D_w = 2'$, $K = 0.2$ ft/day

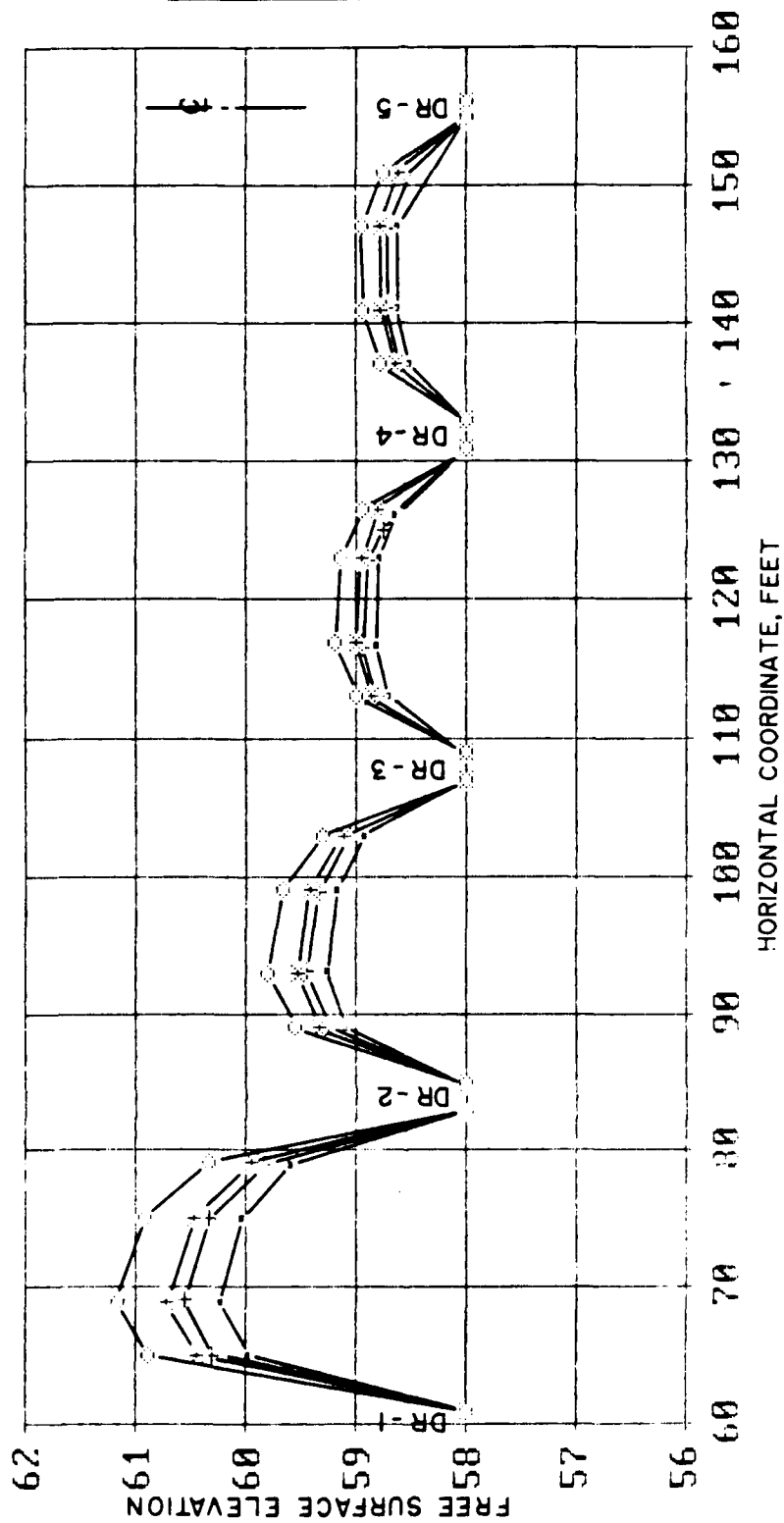


Figure 4.36 Free surface corner nodes with effects of slope of impervious boundary.
 $L_i = 80'$, $H_r = 58'$ (first drain), $D_w = 2'$, $h = 20'$, $K = 0.2$ ft/day

Dimensional Analysis ($L_1 = 80'$ and $H_r = 58'$)

The effects of drain width as shown by the dimensional analysis is shown by Figure 4.37. The general trend of the discharge increasing with drain width is seen in the data. When compared to the earlier case for L_1 equal to 400 feet, it is seen that total discharge is greatly effected, by a factor of three times.

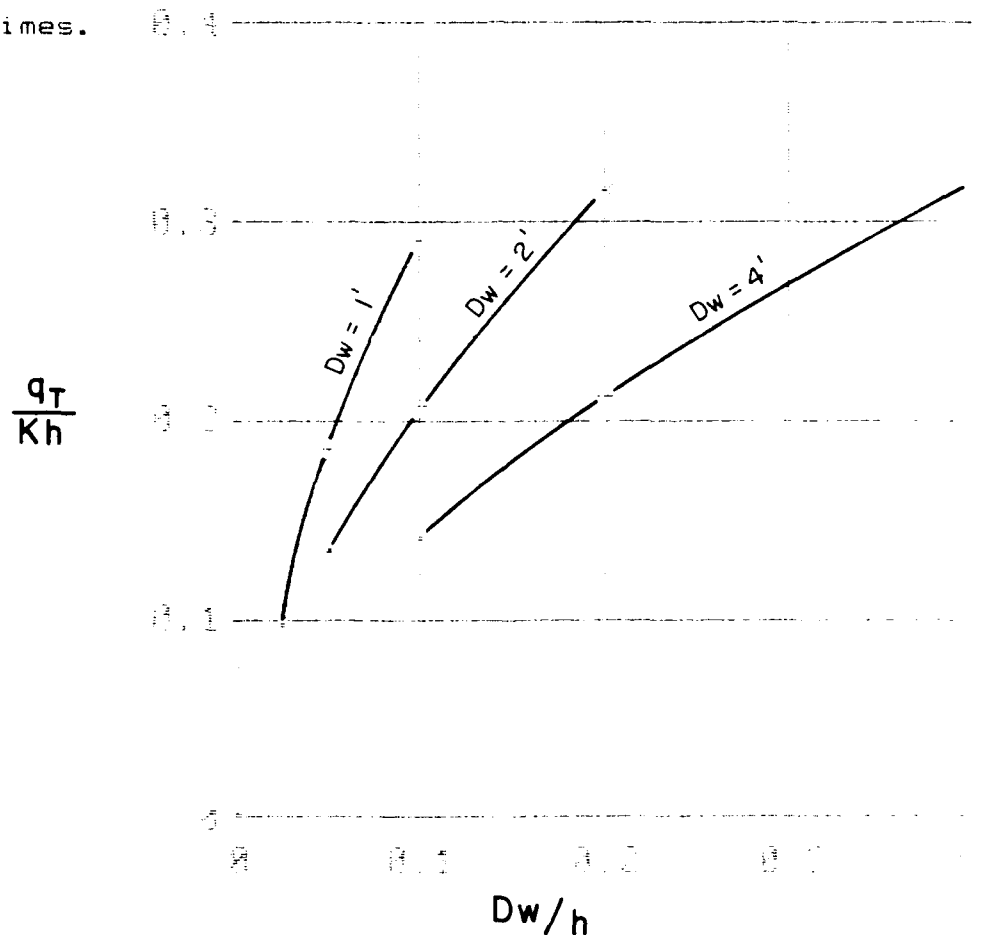


Figure 4.37 Dimensional Analysis, drain width.
 $L_1 = 80'$, $H_r = 58'$, $S_p = 25'$, $K = 0.2$ ft/day

Figure 4.38 shows the dimensional analysis results for thickness of the aquifer. In this case, L_i equal 80 feet, the relationship is more linear than in the case of L_i equal 400 feet as shown in Figure 4.22. This results in the conclusion that the effects of H_r has a pronounce influence on the flow quantities when coupled with the distance L_i . For a shorter distance of L_i , the effects of depths of H_r is more crietical and more of a linear relationship. However when the distance from the constant head boundary is larger, as in the earlier case, the effects of H_r are not as effective when H_r is very small.

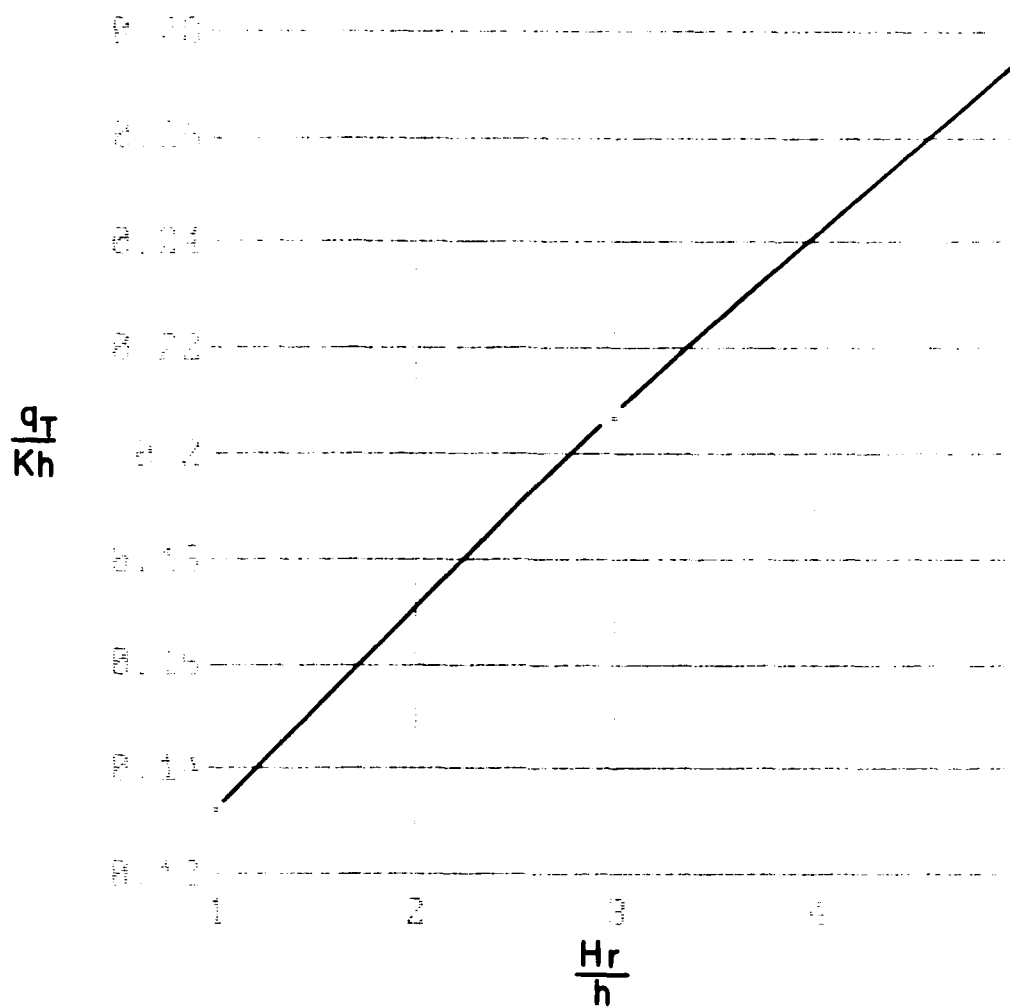


Figure 4.38 Dimensional Analysis, depth of aquifer.
 $L_i = 80'$, $S_p = 25'$, $D_w = 2'$, $K = 0.2$ ft/day

Figure 4.39 shows the results of the dimensional analysis for drain spacing. Again the ordinate is normalized with respect to the area subtended by each flow continuum for each case of spacing. Flow quantity would equate to an increase of approximately 5 to 6 times from this case of L_i equal 80 feet versus L_i equal 400 as shown in Figure 4.23.

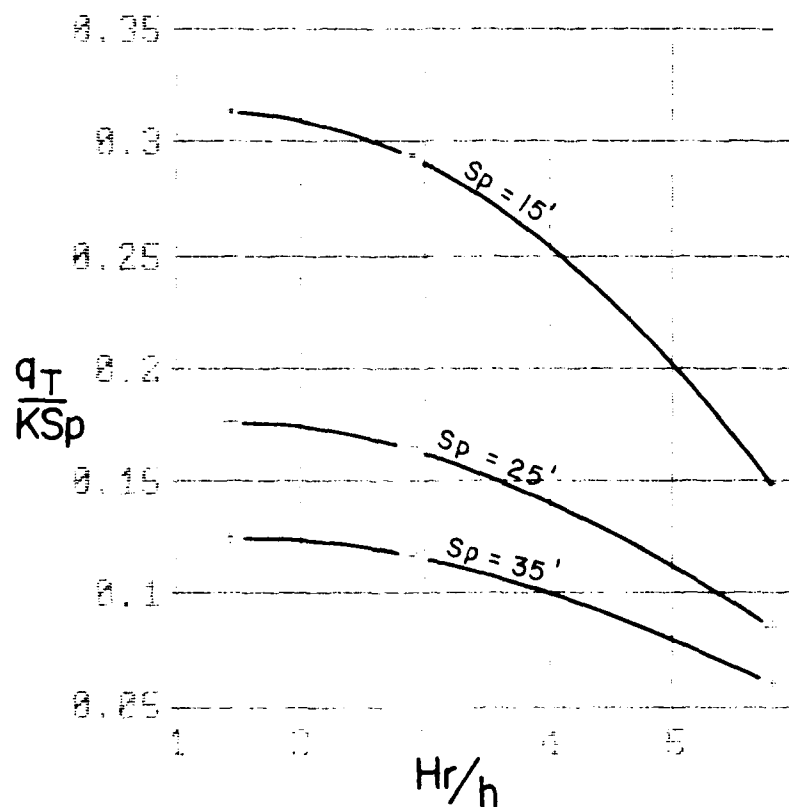


Figure 4.39 Dimensional Analysis, drain spacing.
 $L_i = 80'$, $Hr = 58'$, $Dw = 2'$, $K = 0.2$ ft/day

Figure 4.40 shows the dimensional analysis results for the sloping impervious boundary. For this case, L_i equal 80 feet, as depicted in the earlier plots for sloping aquifer for drain discharge and free surface location, the trend is seen that for and increase in slope the discharge increases.

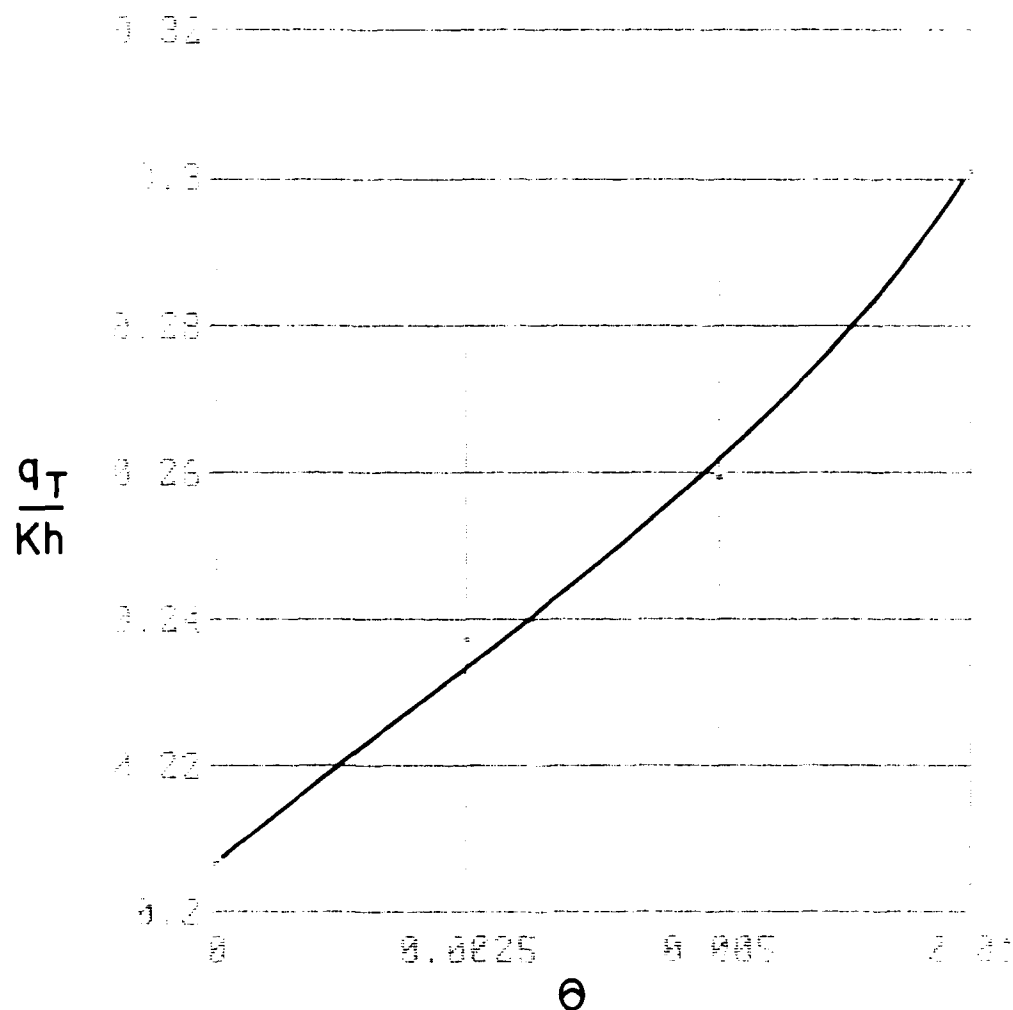


Figure 4.40 Dimensional Analysis, sloping impervious boundary. $L_i = 80'$, $H_r = 58'$, $S_p = 25'$, $D_w = 2$, $K = 0.2$ ft/day

4.6 Summary

This chapter has included the results of many computer runs for the analysis of a building underdrain system. The importance of model sensitivity must be stressed, in that key variables may effect the results very significantly. In this model, it was found that the most critical variables affecting the total discharges of the drains and location of the free surface was the distance from the constant head boundary to the drain system, L_i , and thickness of the aquifer, H_r .

The results obtained appear to be reasonable and within limits of possible field occurrences. However, using these results for quantifying flows and the free surface locations requires a very careful study and background investigation of all geometric configurations and soil conditions. It is intended that this study has presented the results in a manner that one can observe the effects of the variables studied on such a underdrain system.

In summary, the following observations are discussed for the variables used in this analysis.

Constant Head Boundary Distance, L_i

As distance from the constant head boundary to the system

increases the flow quantities increase for the drain system. In terms of a correlation with hydraulic head differential above the drain, as used by other authors, this model study shows that for a distance of approximately 15 times the head, discharge appears to decrease. In terms of gradient, this equates to a 1 over 15 ratio or 0.067 gradient. A slightly higher distance was observed in the analysis of this influence to location of the free surface.

Depth of Aquifer, Hr

The results show that with increased aquifer thickness the drain discharge increases, increasing very near to a linear relationship. It was also observed that for the very shallow thicknesses, the last drains collected very little flow. The height of the free surface is affected in the same fashion. With increased thickness of aquifer the height of the free surface increases between drains.

Drain Spacing, Sp

Drain spacing effects on discharge was greatly affected by the distance of the system from the constant head boundary. A substantial increase of 5 to 6 times the discharge was observed for the two distances used in the results presented. It was observed that as head increases, discharge increases for all drain spacings; and as drain spacing increases, discharge

decreases. It was also observed that from the dimensional analysis, the most efficient drain spacing is for a spacing over head ratio of less than 2. The location of the free surface was observed to increase between drains as drain spacing is increased.

Drain Width, Dw

With increased drain width the discharge increases for all other variables constant. However, there must be a trade off for efficiency of the complete system. It appears that a drain width between 1 to 2 feet is the most effective width. This is also a plus from a standpoint that lateral seepage can be easily drained into thinner trenches or deeper constructed drains.

Slope of Impervious Boundary, θ

For the distance of the constant head boundary to the drain system equal to 80 feet, the drain discharge was observed to increase with increased slope. However, for the distance, L_i equal to 400 feet, the maximum discharge occurs at a slope between 5 to 10 percent. This occurrence is not fully understood and perhaps should be further studied to develop some reasoning. This requires that careful consideration of specific boundary geometries be used in model studies for seepage analysis.

CHAPTER 5

CONCLUSSION

In this day and age, more and more sites are chosen for buildings and engineered structures that are less desirable to work with from a standpoint of site conditions, poor soils and water problems. A less desirable site may easily be where the groundwater table is very near to the surface. Therefore the building's design must incorporate some thought into how the groundwater will be handled and what effects it may have on the structure.

Engineers faced with the analysis of seepage for buildings to be built below the groundwater table must consider such conditions of uplift pressures, critical velocities, seepage control of the water itself or particle migration. Hopefully the design will enhance stability of the structure and prolong the usefulness and life of the structure.

In performing the literature review on this topic, it was found that many authors and researchers are more and more relying on and developing computer models to perform the analysis of complex seepage problems. With the use of general seepage theory and mathematical representation of the seepage theories,

the computer programs can quickly and efficiently aid the engineer in studying the flow conditions. As in this study, the analysis of one particular seepage problem using a finite element program made it possible to study many key variables and develop many relationships.

For this study, underdrain systems for buildings built below the groundwater table were researched. By using a finite element program, and by developing a mesh for this particular flow matrix, many variables of the analysis were studied. It was found that the model could easily be used to efficiently and accurately study these variables. Of major concern, the discharge of the system and location of the free water table was studied in detail versus the various parameters.

This research has attempted to present a clear and concise and useful criteria for use in the design of underdrain seepage problems. It is hoped that the use of the finite element techniques, developed in this study, will aid in the study of variables of the problem. The author must suggest that the assumptions made in this study are somewhat simplistic and that the engineer should consider the parameters and the

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APPENDIX A-1

USER'S MANUAL FOR ARAL SEEPAGE PROGRAM

I. INTRODUCTION:

This seepage program is a finite element model for solving unconfined or confined two dimensional or axisymmetric seepage problems. For unconfined flow analysis the model iterates by moving the free surface nodes to the phreatic level.

In general, the program allows for the porous soil mass to be divided into discrete elements and nodes using either a vertical plane model (two-dimensional, $x-y$) or axisymmetric grid structure. Then applying known boundary conditions, the program simultaneously solves for each element, the continuity equation which satisfies Darcy's Law.

Figure 1 shows a very simple case of a two dimensional unconfined steady state condition which can serve as an example. In this example the free surface location is unknown and the user must begin the process by initiallizing the input by approximating the location. Then the program will iterate to the free surface level until the free surface converges to satisfy the equations of flow.

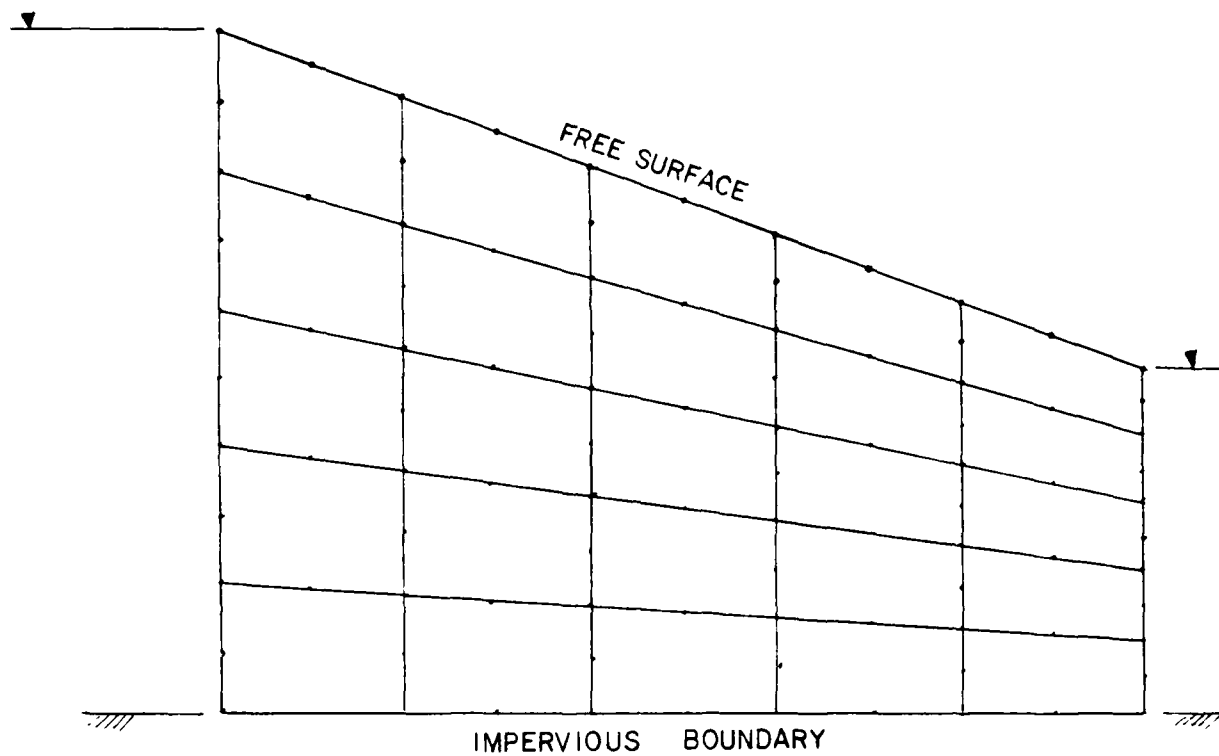


Figure 1 Example Grid for Unconfined Flow Continuum.

II. PROGRAM EXECUTION AND ANALYSIS:

The user has the option of performing a two dimensional problem or an axisymmetric problem. The two dimensional case simply show b figure 1 will serve as an example to explain the parameters. An axisymmetric application might be a well source problem looking at stratified soils having varying permeabilities at different elevations through the porous media.

III. BOUNDARY CONDITIONS OF FLOW:

The potential, ϕ , of flow must be defined as some directional function

$$\phi = f(x, y, z, t)$$

A Dirichlet boundary condition is where the piezometric head, h is constant, or

$$h = f(x, y, z, t)$$

is solved for at a particular point. This boundary condition occurs whenever the flow domain is adjacent to an open body of fluid. Since the piezometric head is constant at the open body of water, the piezometric head of the porous media at the interface

will be constant. This boundary condition denotes a non-zero flux or flow is to be considered possible.

Another boundary condition for flow potential is the Neuman boundaries. This is the case where flow cannot move through the porous media at a specific point defined, i.e. an impervious layer of stratum.

IV. FINITE ELEMENT GRID NOTATION:

The porous soil mass to be analysed must be divided into a grid of elements and nodes. The program uses any shape second-order isoparametric element, shown by figure 2 as a quadralateral element containing four corner nodes and four midpoint nodes.

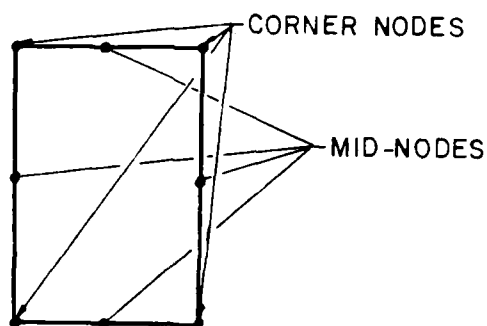


Figure 2 Element and Node Notation.

The nodes must be numbered from some beginning corner, preferably the number one node should be at the bottom left corner of the mesh. Then node numbering increases to the end of each column, beginning at the bottom of each column throughout the mesh. One can see the numbering scheme by the examples presented. Elements are numbered the same as the nodes.

The program automatically generates nodes at equal spacing between corner nodes which are defined by the user. This feature requires that careful attention be made to the node numbering scheme once corner nodes have been established. This feature is good for creating finer mesh grids in particular areas of interest.

Base elements are used to create stationary reference elements typically at the bottom of the mesh or away from the free surface elements. These elements are also used to define changes in hydraulic conductivity in the x and y directions (K_x and K_y).

The free surface or phreatic surface of a media is defined by the user as a first approximation of it's actual location. In the case of a cutoff wall, shown in Figure 3, there is no free surface and the seepage model solves for the flow characteristics of each element and node. However, in the case of a dam as shown in Figure 3, the free surface is unknown and the program will solve for the phreatic surface where the fluid pressure is at

atmospheric pressure. In confined aquifers the water pressures would possible be higher than atmospheric pressure.

Seepage faces are defined by the user to denote a boundary or where seepage is to be allowed. Here flow is quantified and the model solves for the velocity and discharge at this face.

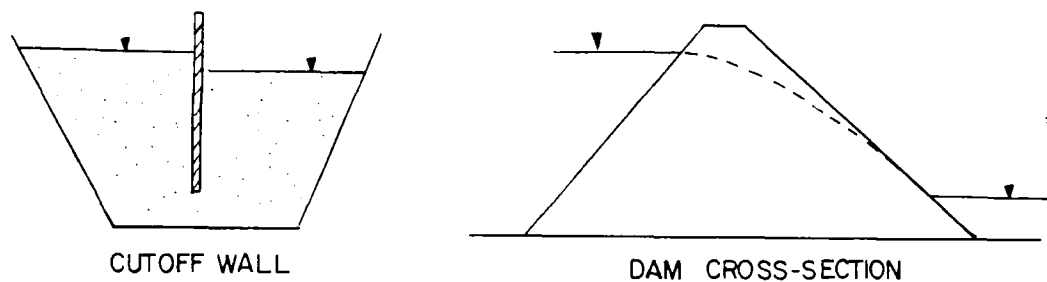


Figure 3 Example of confined flow and unconfined flow.

Permeability of the porous media often depends on the direction of flow. For the condition of soil matrix being anisotropic the velocities and gradients are generally not parallel. For this condition the velocities can be written in the Darcy Law form:

$$V_x = -K_{xx} \frac{\partial h}{\partial x}$$

$$V_y = -K_{yy} \frac{\partial h}{\partial y}$$

$$V_z = -K_{zz} \frac{\partial h}{\partial z}$$

Normally the hydraulic conductivity of the media is similar in the y direction. Therefore treatment of this normal condition requires use of only two directions. For this simplification, the program uses the notation of the two dimensional case. Figure 4 shows the notation that should be used for describing the hydraulic conductivity conditions.

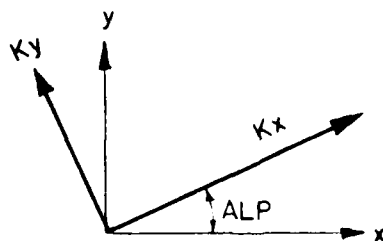


Figure 4 Hydraulic Conductivity Notation.

V. INPUT VARIABLES AND DATA INPUT

Input can be given in unformatted notation where each data input is separated by a comma or space. Careful attention, however, must be made to use the appropriate number input data per line as described by this guide.

Title and Type Problem Card.

TITLE The title can be up to 72 characters.

DIMEN Flow problem e problem is a two dimensional analysis
input 2 and for an axisymetric problem input 1.

Plane Flow Problem 2

Axisymetric Problem 1

FERR Having performed a sensitivity of the model or decided
on an error critiria, input the error required.

Control cards

NNPC Total number of corner nodal points.
These nodes are used to define corners of elements
which are defined by input coordinates. Nodes that
are not listed will be generated between two corner
nodes for each vertical column or row deliniation.

NELEMC Total number of base elements.
Base elements are typically at the bottom of a series
of elements that change the hydraulic conductivity of
the elements above these base elements. These elements
are established as reference elements for the program
to describe permeability of each element.

NFBOC Total number of Neuman Boundary Faces.
A Neuman face is defined as a line of nodes that may
create a barrier or impervious wall for the flow. If
two corner nodes define a line of several nodes that
makes an impervious barrier, this is one Neuman
Boundary face.

NFFS Total number of corner nodes on the free surface.
The user must specify particular corner nodes which
reflect the first approximation of the unknown free
surface. The program uses these nodes and the midpoint
nodes to converge to the free surface.

ITGIV Number of iterations desired.
 This is a safety feature for possible input errors and
 computer time limitation.

NPBDC Total number of Dirichlet Boundary faces.
 Flow is allowed at these faces. Do not count the mid
 point nodes as part of the face.

NSPFAC Total number of seepage faces with Dirichlet
 boundaries. For each face defined by two corner nodes
 for the NPBDC input variable a NSPFAC value should be
 given. As in

NPBDC = 2 NSPFAC = 1

NPBDC = 3 NSPFAC = 2

ITIME Time variable. Input 0 = time independent.
 This is used for transient computation and is not
 used in steady state computations.

Corner Node Location Cards

Corner node number (n)

x(n) x coordinate of node(n)

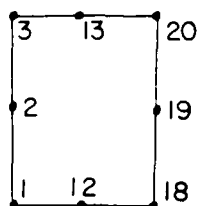
y(n) y coordinate of node(n)

Note: There should be NNFC number of these cards. Use
 appropriate dimensions, i.e. feet, meters which will be carried
 throughout the remaining input variables.

NFMIS Enter a "1" or "0" where
 1 - additional nodes are to be generated after this
 node.
 0 - no nodes will be generated after this node.

Base Reference Elements Identification Cards

NOD For each base element(N), give a counter-clockwise numbering for each node in the element.

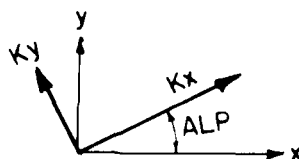


NMIS Total number of elements above the base element before the next base element.

XK(N) Hydraulic conductivity of the elements defined by the base element in the x direction.

YK(N) Hydraulic conductivity in the y direction.

ALP(N) Angle of possible stratification or plane of soil matrix with the horizontal.



Note: There should be NELEMC number of these cards provided.

Neuman Boundary Condition Cards

NSTART The beginning or lowest corner node number of each Neuman Boundary defined.

BVAL The Neuman Boundary value that defines the known potential height or water level measured from the datum reference line of the coordinate system.

NBSAME Total number of boundary faces having same Neuman boundary condition. Each face is a line made by two corner nodes of the same Neuman boundary.

NINC The number of nodal number increases or numerical difference to the next corner node from node NSTART. Do not count mid-nodes only corner nodes.

Note: There should be NPBDC cards provided for this set.

Dirichlet Boundary Condition Cards

NSTAR The beginning or lowest corner node number which defines each Dirichlet boundary.

DEVAL The Dirichlet boundary value that defines the potential or water level height measured from the data reference elevation of the coordinate system.

NDSAME Total number of boundary faces of this Dirichlet boundary condition. Each face is counted between corner nodes defining the boundary or number of elements.

NDINC The number of nodal number increases or numerical difference to the next corner node from node NSTART.

NMID The number of nodal number increases from the NSTART to the next mid-node.

Note: There should be NPBDC cards provided for this set.

Free Surface Nodal Cards (Maximum 16 pairs per card)

NPFSA Free surface corner node number.

NPBOT Node number of the bottom of the movable section of the grid that defines the limits of moving nodes for NPFSA.

Note: There should be NFFS pairs of node numbers given for a maximum of 16 pairs per card. Use as many cards as required. The bottom node (NPBOT) defines the bottom of a seepage face corresponding to the grid geometry and corner node defining the free surface. The program uses this band of nodes and elements to converge on the free surface.

Mid-point Free Surface Nodal Cards.

NPFSM The mid-point nodal numbers between corner nodes
 defining the free surface (NPFS - 1).

Seepage Face Cards

NSPC Beginning node number of the defined seepage face.

NSSAME Number of seepage faces defined by elements for this
 seepage face NSPC.

NSINC Node numbering increase between nodes defined by
 NSSAME.

Note: There should be NSPFAC cards provided for this set.

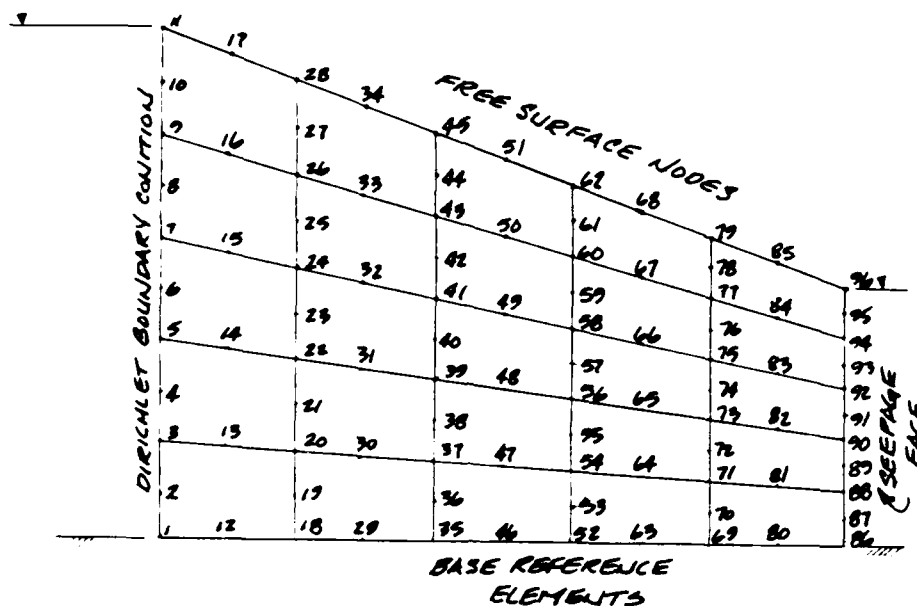
Statement and End Card

End of Problem Statement should be less than 72 characters and
end with a period.

NDIMEN Input a "3" to end the problem.

ERR Specify any error as for FERR.

UNCONFINED FLOW EXAMPLE PROBLEM



Title and Type Problem Card

TITLE - SILTY SAND DAM

DIMEN - 2 (two dimensional)

FERR - 0.01 (error criterion is 0.01)

Control Cards

NMPC - 12 (corner nodes are 18, 52, 35, 45, 52, 62, 69, 79, 86 and 96)

NELEMC - 5 (five base elements - shaded)

NPBOC - 0 (no Neuman Boundaries)

NPFS - 6 (6 nodal points on the free surface - 11, 28, 45, 62, 79 and 96)

ITGIV - 50 (maximum number of iterations)

NPBDC - 2 (There are two faces with Dirichlet boundary conditions, the left side and the right side of the mesh which forms the dam)

NSPFAC - 1 (There is one seepage face - on the right side where flow is to be considered.)

ITIME - 0 (Time independent for steady state conditions)

Corner Node Location Cards

1,0,0,1

Where, the first node is number 1 having an x coordinate of 0 and a y coordinate of 0. Generation of additional nodes will follow.

11,0,110,0

Where, node 11 is at the end of the first column at coordinates 0 and 110 and no generation is required for other nodes in this column.

18,200,0,1
28,200,99,0
35,400,0,1
45,400,88,0
52,600,0,1
62,600,77,0
69,800,0,1
79,800,66,0
86,1000,0,1
96,1000,55,0

Base Reference Elements Identification Cards

1,12,18,19,20,13,3,2,4,0.002,0.002,0

Counter clockwise numbering of nodes for each element and the permeability, 0.002 ft/day for this base element and 4 elements above the base element.

18,29,35,36,37,30,20,19,4,0.002,0.002,0
35,46,52,53,54,47,37,36,4,0.002,0.002,0
52,63,69,70,71,64,54,53,4,0.002,0.002,0
69,80,86,87,88,81,71,70,4,0.002,0.002,0

Neuman Boundary Condition Cards

None specified, so no cards will be provided

Dirichlet Boundary Condition Cards

1,110,5,2,1
86,55,5,2,1

The first node of the first Dirichlet Boundary is node 1 and the DBVAL value is 110 feet. There are 5 elements on this face that makes this Dirichlet boundary condition, NDSAME = 5. NDINC equals 2 for the nodal number increase for the consecutive elements, as in 3 - 1, 5 - 3, 7 - 5, etc. NMID equals 1 for the node numbering increase between successive nodes.

Free Surface Nodal Cards

11,1,28,18,45,35,62,52,79,69,96,86

Here the total mesh is allowed to move, where the user may fix the bottom nodes at any level in the mesh.

Mid-point Free Surface Nodal Cards

17,34,51,68,85

Seepage Face Cards

86,2,2

The seepage is prescribed to start at node 86, NSFC = 86, and there are 2 elements for this seepage face. NSINC is equal to 2 as there is a two nodal increase between element corner nodes, as is 88 - 86 and 90 - 88.

Statement and End Card

END OF SILTY SAND DAM.
3,.001

SILTY SAND DAM .

2,0.01

12,5,0,6,50,2,1,0

1,0,0,1

11,0,110,0

18,200,0,1

28,200,99,0

35,400,0,1

45,400,88,0

52,600,0,1

62,600,77,0

69,800,0,1

79,800,66,0

86,1000,0,1

96,1000,55,0

1,12,18,19,20,13,3,2,4,0.002,0.002,0

18,29,35,36,37,30,20,19,4,0.002,0.002,0

35,46,52,53,54,47,37,36,4,0.002,0.002,0

52,63,69,70,71,64,54,53,4,0.002,0.002,0

69,80,86,87,88,81,71,70,4,0.002,0.002,0

1,110,5,2,1

86,55,5,2,1

11,1,28,18,45,35,62,52,79,69,96,86

17,34,51,68,85

86,2,2

END OF SILTY SAND DAM.

3,0.01

SILTY SAND DAM

DIMEN = 2 PERR = .01000

NNPC = 12 NELEMC = 8 NPBOC = 0 NPFS = 8 ITGIV = 50 NPBOC = 2 NSPPAC = 1 ITIME = 0

GENERATED NODAL POINT DATA AND (X)-(Y) COORDINATES

NODE	X	Y
1	0.0000	0.0000
3	0.0000	22.0000
5	0.0000	44.0000
7	0.0000	66.0000
9	0.0000	88.0000
11	0.0000	110.0000
13	200.0000	0.0000
15	200.0000	18.8000
17	200.0000	37.6000
19	200.0000	56.4000
21	200.0000	75.2000
23	200.0000	94.0000
25	200.0000	112.8000
27	400.0000	0.0000
29	400.0000	17.8000
31	400.0000	35.6000
33	400.0000	53.4000
35	400.0000	71.2000
37	400.0000	89.0000
39	400.0000	106.8000
41	400.0000	124.6000
43	400.0000	142.4000
45	400.0000	160.2000
47	400.0000	178.0000
49	400.0000	195.8000
51	400.0000	213.6000
53	400.0000	231.4000
55	400.0000	249.2000
57	400.0000	267.0000
59	400.0000	284.8000
61	400.0000	302.6000
63	400.0000	320.4000
65	400.0000	338.2000
67	400.0000	356.0000
69	400.0000	373.8000
71	400.0000	391.6000
73	400.0000	409.4000
75	400.0000	427.2000
77	400.0000	445.0000
79	400.0000	462.8000
81	400.0000	480.6000
83	400.0000	498.4000
85	400.0000	516.2000
87	400.0000	534.0000
89	400.0000	551.8000
91	400.0000	569.6000
93	400.0000	587.4000
95	400.0000	605.2000
97	400.0000	623.0000
99	400.0000	640.8000
101	400.0000	658.6000
103	400.0000	676.4000
105	400.0000	694.2000
107	400.0000	712.0000
109	400.0000	729.8000
111	400.0000	747.6000
113	400.0000	765.4000
115	400.0000	783.2000
117	400.0000	801.0000
119	400.0000	818.8000
121	400.0000	836.6000
123	400.0000	854.4000
125	400.0000	872.2000
127	400.0000	890.0000
129	400.0000	907.8000
131	400.0000	925.6000
133	400.0000	943.4000
135	400.0000	961.2000
137	400.0000	979.0000
139	400.0000	996.8000
141	400.0000	1014.6000
143	400.0000	1032.4000
145	400.0000	1050.2000
147	400.0000	1068.0000
149	400.0000	1085.8000
151	400.0000	1103.6000
153	400.0000	1121.4000
155	400.0000	1139.2000
157	400.0000	1157.0000
159	400.0000	1174.8000
161	400.0000	1192.6000
163	400.0000	1210.4000
165	400.0000	1228.2000
167	400.0000	1246.0000
169	400.0000	1263.8000
171	400.0000	1281.6000
173	400.0000	1299.4000
175	400.0000	1317.2000
177	400.0000	1335.0000
179	400.0000	1352.8000
181	400.0000	1370.6000
183	400.0000	1388.4000
185	400.0000	1406.2000
187	400.0000	1424.0000
189	400.0000	1441.8000
191	400.0000	1459.6000
193	400.0000	1477.4000
195	400.0000	1495.2000
197	400.0000	1513.0000
199	400.0000	1530.8000
201	400.0000	1548.6000
203	400.0000	1566.4000
205	400.0000	1584.2000
207	400.0000	1602.0000
209	400.0000	1619.8000
211	400.0000	1637.6000
213	400.0000	1655.4000
215	400.0000	1673.2000
217	400.0000	1691.0000
219	400.0000	1708.8000
221	400.0000	1726.6000
223	400.0000	1744.4000
225	400.0000	1762.2000
227	400.0000	1780.0000
229	400.0000	1797.8000
231	400.0000	1815.6000
233	400.0000	1833.4000
235	400.0000	1851.2000
237	400.0000	1869.0000
239	400.0000	1886.8000
241	400.0000	1904.6000
243	400.0000	1922.4000
245	400.0000	1940.2000
247	400.0000	1958.0000
249	400.0000	1975.8000
251	400.0000	1993.6000
253	400.0000	2011.4000
255	400.0000	2029.2000
257	400.0000	2047.0000
259	400.0000	2064.8000
261	400.0000	2082.6000
263	400.0000	2100.4000
265	400.0000	2118.2000
267	400.0000	2136.0000
269	400.0000	2153.8000
271	400.0000	2171.6000
273	400.0000	2189.4000
275	400.0000	2207.2000
277	400.0000	2225.0000
279	400.0000	2242.8000
281	400.0000	2260.6000
283	400.0000	2278.4000
285	400.0000	2296.2000
287	400.0000	2314.0000
289	400.0000	2331.8000
291	400.0000	2349.6000
293	400.0000	2367.4000
295	400.0000	2385.2000
297	400.0000	2403.0000
299	400.0000	2420.8000
301	400.0000	2438.6000
303	400.0000	2456.4000
305	400.0000	2474.2000
307	400.0000	2492.0000
309	400.0000	2509.8000
311	400.0000	2527.6000
313	400.0000	2545.4000
315	400.0000	2563.2000
317	400.0000	2581.0000
319	400.0000	2598.8000
321	400.0000	2616.6000
323	400.0000	2634.4000
325	400.0000	2652.2000
327	400.0000	2670.0000
329	400.0000	2687.8000
331	400.0000	2705.6000
333	400.0000	2723.4000
335	400.0000	2741.2000
337	400.0000	2759.0000
339	400.0000	2776.8000
341	400.0000	2794.6000
343	400.0000	2812.4000
345	400.0000	2830.2000
347	400.0000	2848.0000
349	400.0000	2865.8000
351	400.0000	2883.6000
353	400.0000	2901.4000
355	400.0000	2919.2000
357	400.0000	2937.0000
359	400.0000	2954.8000
361	400.0000	2972.6000
363	400.0000	2990.4000
365	400.0000	3008.2000
367	400.0000	3026.0000
369	400.0000	3043.8000
371	400.0000	3061.6000
373	400.0000	3079.4000
375	400.0000	3097.2000
377	400.0000	3115.0000
379	400.0000	3132.8000
381	400.0000	3150.6000
383	400.0000	3168.4000
385	400.0000	3186.2000
387	400.0000	3204.0000
389	400.0000	3221.8000
391	400.0000	3239.6000
393	400.0000	3257.4000
395	400.0000	3275.2000
397	400.0000	3293.0000
399	400.0000	3310.8000
401	400.0000	3328.6000
403	400.0000	3346.4000
405	400.0000	3364.2000
407	400.0000	3382.0000
409	400.0000	3400.8000
411	400.0000	3418.6000
413	400.0000	3436.4000
415	400.0000	3454.2000
417	400.0000	3472.0000
419	400.0000	3489.8000
421	400.0000	3507.6000
423	400.0000	3525.4000
425	400.0000	3543.2000
427	400.0000	3561.0000
429	400.0000	3578.8000
431	400.0000	3596.6000
433	400.0000	3614.4000
435	400.0000	3632.2000
437	400.0000	3650.0000
439	400.0000	3667.8000
441	400.0000	3685.6000
443	400.0000	3703.4000
445	400.0000	3721.2000
447	400.0000	3739.0000
449	400.0000	3756.8000
451	400.0000	3774.6000
453	400.0000	3792.4000
455	400.0000	3810.2000
457	400.0000	3828.0000
459	400.0000	3845.8000
461	400.0000	3863.6000
463	400.0000	3881.4000
465	400.0000	3899.2000
467	400.0000	3917.0000
469	400.0000	3934.8000
471	400.0000	3952.6000
473	400.0000	3970.4000
475	400.0000	3988.2000
477	400.0000	4006.0000
479	400.0000	4023.8000
481	400.0000	4041.6000
483	400.0000	4059.4000
485	400.0000	4077.2000
487	400.0000	4095.0000
489	400.0000	4112.8000
491	400.0000	4130.6000
493	400.0000	4148.4000
495	400.0000	4166.2000
497	400.0000	4184.0000
499	400.0000	4201.8000
501	400.0000	4219.6000
503	400.0000	4237.4000
505	400.0000	4255.2000
507	400.0000	4273.0000
509	400.0000	4290.8000
511	400.0000	4308.6000
513	400.0000	4326.4000
515	400.0000	4344.2000
517	400.0000	4362.0000
519	400.0000	4379.8000
521	400.0000	4397.6000
523	400.0000	4415.4000
525	400.0000	4433.2000
527	400.0000	4451.0000
529	400.0000	4468.8000
531	400.0000	4486.6000
533	400.0000	4504.4000
535	400.0000	4522.2000
537	400.0000	4540.0000
539	400.0000	4557.8000
541	400.0000	4575.6000
543	400.0000	4593.4000
545	400.0000	4611.2000
547	400.0000	4629.0000
549	400.0000	4646.8000
551	400.0000	4664.6000
553	400.0000	4682.4000
555	400.0000	4700.2000
557	400.0000	4718.0000
559	400.0000	4735.8000
561	400.0000	4753.6000
563	400.0000	4771.4000
565	400.0000	4789.2000
567	400.0000	4807.0000
569	400.0000	4824.8000
571	400.0000	4842.6000
573	400.0000	4860.4000
575	400.0000	4878.2000
577	400.0000	4896.0000
579	400.0000	4913.8000
581	400.0000	4931.6000
583	400.0000	4949.4000
585	400.0000	4967.2000
587	400.0000	4985.0000
589	400.0000	5002.8000
591	400.0000	5020.6000
593	400.0000	5038.4000
595	400.0000	5056.2000
597	400.0000	5074.0000
599	400.0000	5091.8000
601	400.0000	5109.6000
603	400.0000	5127.4000
605	400.0000	5145.2000
607	400.0000	5163.0000
609	400.0000	5180.8000
611	400.0000	5198.6000
613	400.0000	5216.4000</

NEW COORDINATES OF THE FREE SURFACE LINE

NODE: 79 X : 800.0000 Y : 88.5371
 NODE: 82 X : 800.0000 Y : 81.7788
 NODE: 45 X : 400.0000 Y : 92.3728
 NODE: 28 X : 200.0000 Y : 101.7151
 NODE: 11 X : 0.0000 Y : 110.0000

CONVERGENCE CHECK ERROR : .1710E-02

NODE	X COORDINATE	Y COORDINATE	V-POTENTIAL	X-VELOCITY	Y-VELOCITY	TOTAL VELO.	PRES	COEF
1	0.0000	0.0000	110.0000	-.8318E-04	-.1125E-08	.8318E-04		
2	0.0000	11.0000	110.0000	-.8315E-04	-.1587E-15	.8315E-04		
3	0.0000	22.0000	110.0000	-.8308E-04	-.8251E-07	.8308E-04		
4	0.0000	33.0000	110.0000	-.8296E-04	0.	.8296E-04		
5	0.0000	44.0000	110.0000	-.8278E-04	-.1758E-06	.8278E-04		
6	0.0000	55.0000	110.0000	-.8255E-04	0.	.8255E-04		
7	0.0000	66.0000	110.0000	-.8227E-04	-.2920E-06	.8227E-04		
8	0.0000	77.0000	110.0000	-.8191E-04	0.	.8191E-04		
9	0.0000	88.0000	110.0000	-.8148E-04	-.4499E-08	.8148E-04		
10	0.0000	99.0000	110.0000	-.8098E-04	-.1058E-15	.8098E-04		
11	0.0000	110.0000	110.0000	-.8045E-04	-.7677E-08	.8045E-04		
12	100.0000	0.0000	105.7709	-.8800E-04	-.2138E-07	.8800E-04		
13	100.0000	21.1715	105.7743	-.8595E-04	-.5574E-08	.8595E-04		
14	100.0000	42.3430	105.7848	-.8582E-04	-.1131E-05	.8582E-04		
15	100.0000	63.5145	105.8024	-.8580E-04	-.1739E-05	.8582E-04		
16	100.0000	84.6860	105.8283	-.8530E-04	-.2403E-05	.8533E-04		
17	100.0000	105.8575	105.8638	-.8491E-04	-.3223E-05	.8497E-04		
18	200.0000	0.0000	101.4005	-.8895E-04	-.1188E-07	.8895E-04		
19	200.0000	18.1715	101.4014	-.8895E-04	-.3473E-06	.8895E-04		
20	200.0000	20.3430	101.4044	-.8895E-04	-.8187E-08	.8895E-04		
21	200.0000	30.5145	101.4092	-.8895E-04	-.1157E-05	.8895E-04		
22	200.0000	40.6860	101.4162	-.8895E-04	-.1630E-05	.8895E-04		
23	200.0000	50.8575	101.4248	-.8895E-04	-.1909E-05	.8895E-04		
24	200.0000	61.0291	101.4356	-.8895E-04	-.2431E-05	.8895E-04		
25	200.0000	71.2008	101.4480	-.8895E-04	-.2822E-05	.8902E-04		
26	200.0000	81.3721	101.4622	-.8895E-04	-.3206E-05	.8905E-04		
27	200.0000	91.5436	101.4780	-.8904E-04	-.3255E-05	.8910E-04		
28	200.0000	101.7151	101.4954	-.8904E-04	-.3964E-05	.8913E-04		
29	300.0000	0.0000	95.8349	-.9358E-04	-.6799E-09	.9358E-04		
30	300.0000	18.4088	95.8382	-.9354E-04	-.8735E-08	.9355E-04		
31	300.0000	38.8177	95.8518	-.9350E-04	-.1745E-05	.9352E-04		
32	300.0000	58.2285	95.8730	-.9343E-04	-.2611E-05	.9346E-04		
33	300.0000	77.6384	95.9026	-.9332E-04	-.3488E-05	.9339E-04		
34	300.0000	97.0442	95.9408	-.9318E-04	-.4331E-05	.9328E-04		
35	400.0000	0.0000	92.0447	-.8801E-04	-.4037E-08	.8801E-04		
36	400.0000	8.2373	92.0489	-.8811E-04	-.4821E-08	.8801E-04		
37	400.0000	18.4747	92.0492	-.8800E-04	-.9788E-07	.8800E-04		
38	400.0000	27.7120	92.0549	-.8798E-04	-.1475E-06	.8798E-04		
39	400.0000	38.9494	92.0629	-.8798E-04	-.1957E-05	.8797E-04		
40	400.0000	48.1867	92.0731	-.8792E-04	-.2454E-05	.8795E-04		
41	400.0000	58.4240	92.0855	-.8788E-04	-.2833E-05	.8792E-04		
42	400.0000	68.6614	92.1002	-.8783E-04	-.3423E-05	.8789E-04		
43	400.0000	73.8987	92.1172	-.8778E-04	-.3905E-05	.8785E-04		
44	400.0000	83.1361	92.1382	-.8772E-04	-.4389E-05	.8782E-04		
45	400.0000	92.3734	92.1575	-.8766E-04	-.4874E-05	.8777E-04		
46	500.0000	0.0000	88.9674	-.1043E-03	-.2148E-08	.1043E-03		
47	500.0000	17.4160	88.9922	-.1043E-03	-.1113E-05	.1043E-03		
48	500.0000	34.8300	87.0086	-.1043E-03	-.2223E-05	.1043E-03		
49	500.0000	52.2451	87.0308	-.1042E-03	-.3328E-05	.1042E-03		
50	500.0000	68.8801	87.0642	-.1040E-03	-.4420E-05	.1041E-03		
51	500.0000	87.0761	87.1073	-.1038E-03	-.5508E-05	.1040E-03		
52	500.0000	0.0000	81.8118	-.1108E-03	-.5594E-08	.1108E-03		
53	500.0000	8.1777	81.8129	-.1108E-03	-.8378E-08	.1108E-03		
54	800.0000	18.3554	81.8188	-.1108E-03	-.1270E-05	.1108E-03		
55	800.0000	24.5330	81.8234	-.1108E-03	-.1910E-05	.1108E-03		
56	800.0000	32.7107	81.8325	-.1108E-03	-.2539E-05	.1108E-03		
57	800.0000	40.8884	81.8441	-.1108E-03	-.3171E-05	.1108E-03		
58	800.0000	49.0661	81.8584	-.1104E-03	-.3802E-05	.1105E-03		
59	800.0000	57.2438	81.8751	-.1103E-03	-.4405E-05	.1104E-03		
60	800.0000	65.4214	81.8944	-.1102E-03	-.5053E-05	.1103E-03		
61	800.0000	73.5991	81.9160	-.1101E-03	-.5689E-05	.1103E-03		
62	800.0000	81.7768	81.9401	-.1100E-03	-.6295E-05	.1102E-03		
63	700.0000	0.0000	75.8434	-.1202E-03	-.3217E-08	.1202E-03		
64	700.0000	18.1314	75.8489	-.1202E-03	-.1481E-05	.1202E-03		
65	700.0000	30.2628	75.8555	-.1201E-03	-.2918E-05	.1201E-03		
66	700.0000	45.3942	75.8632	-.1200E-03	-.4358E-05	.1201E-03		
67	700.0000	60.5256	75.8722	-.1198E-03	-.5782E-05	.1200E-03		
68	700.0000	75.6570	75.8827	-.1197E-03	-.7233E-05	.1198E-03		
69	800.0000	0.0000	69.8822	-.1301E-03	-.1815E-07	.1301E-03		
70	800.0000	8.9537	69.8935	-.1301E-03	-.8277E-06	.1301E-03		
71	800.0000	13.8074	69.8980	-.1300E-03	-.1449E-05	.1300E-03		
72	800.0000	20.8611	69.9049	-.1299E-03	-.2481E-05	.1299E-03		
73	800.0000	27.8149	69.9151	-.1298E-03	-.3671E-05	.1298E-03		
74	800.0000	34.7888	69.9275	-.1298E-03	-.4024E-05	.1297E-03		
75	800.0000	41.7223	69.9431	-.1294E-03	-.5431E-05	.1295E-03		
76	800.0000	48.6780	69.9608	-.1292E-03	-.5456E-05	.1293E-03		
77	800.0000	55.6297	69.9810	-.1288E-03	-.7083E-05	.1290E-03		
78	800.0000	62.5834	69.9703	-.1286E-03	-.8670E-05	.1287E-03		
79	800.0000	68.5371	69.9724	-.1282E-03	-.8670E-05	.1285E-03		
80	900.0000	0.0000	62.8858	-.1458E-03	-.1108E-08	.1458E-03		
81	900.0000	12.4537	62.8925	-.1460E-03	-.1723E-05	.1460E-03		
82	900.0000	24.9074	62.9129	-.1460E-03	-.3478E-05	.1461E-03		
83	900.0000	37.3611	62.9475	-.1462E-03	-.5290E-05	.1463E-03		
84	900.0000	49.8149	62.9872	-.1464E-03	-.7196E-05	.1466E-03		
85	900.0000	62.2686	62.9834	-.1466E-03	-.8437E-05	.1468E-03		
86	1000.0000	0.0000	55.0000	-.1615E-03	-.1787E-08	.1615E-03		
87	1000.0000	5.5000	55.0000	-.1616E-03	-.1058E-15	.1616E-03		
88	1000.0000	11.0000	55.0000	-.1617E-03	-.5021E-08	.1617E-03		
89	1000.0000	16.5000	55.0000	-.1620E-03	-.1058E-15	.1620E-03		
90	1000.0000	22.0000	55.0000	-.1623E-03	-.1034E-05	.1623E-03		
91	1000.0000	27.5000	55.0000	-.1629E-03	0.	.1629E-03		
92	1000.0000	33.0000	55.0000	-.1634E-03	-.1827E-05	.1634E-03		
93	1000.0000	38.5000	55.0000	-.1642E-03	0.	.1642E-03		
94	1000.0000	44.0000	55.0000	-.1649E-03	-.2319E-05	.1650E-03		
95	1000.0000	49.5000	55.0000	-.1661E-03	0.	.1661E-03		
96	1000.0000	55.0000	55.0000	-.1688E-03	-.3328E-05	.1688E-03		

SEEPAGE FACE COMPUTATION RESULTS

NB : 88 NE : 88 AVE. VEL : .16180E-03 DS : .11000E+02 DO : .17778E-02
 TOTAL DISCHARGE : .17778E-02
 NB : 88 NE : 90 AVE. VEL : .16202E-03 DS : .11000E+02 DO : .17822E-02
 TOTAL DISCHARGE : .36598E-02

END OF SILTY SAND DAM

DIMEN : 3 FERR : .01000

APPENDIX B-1

SAMPLE INPUT
AND OUTPUT

RUN ADS2 SP = 25 FEET DEPTH = 20 FEET K = .2. DEPTH = 58'.

2,0.0001
93,30,0,30,20,6,5,0
1,-340,0,1
5,-340,34,1
11,-340,78.0,0
18,-200,0,1
22,-200,34,1
28,-200,78.0,0
35,-80,0,1
39,-80,34,1
45,-80,77.0,0
52,0,0,1
56,0,34,1
62,0,74.0,0
69,50,0,1
73,50,34,1
79,50,71.0,0
86,58.75,0,1
90,58.75,34,1
96,59.0,58.0,0
103,62.0,0,1
107,62.0,34,1
113,61.0,58.0,0
120,66.0,0,1
124,66.0,34,1
130,65.0,60.0,0
137,70.0,0,1
141,70.0,34,1
147,69.0,60.0,0
154,74.0,0,1
158,74.0,34,1
164,75.0,60.0,0
171,78.0,0,1
175,78.0,34,1
181,79.0,60.0,0
188,82.0,0,1
192,82.0,34,1
198,83.0,58.0,0
205,86.0,0,1
209,86.0,34,1
215,85.0,58.0,0
222,90.0,0,1
226,90.0,34,1
232,89.0,60.0,0
239,94.0,0,1
243,94.0,34,1
249,93.0,60.0,0
256,98.0,0,1
260,98.0,34,1
266,99.0,60.0,0
273,102.0,0,1
277,102.0,34,1
283,103.0,60.0,0
290,106.0,0,1
294,106.0,34,1
300,107.0,58.0,0
307,110.0,0,1
311,110.0,34,1
317,109.0,58.0,0

324,114.0,0,1
 328,114.0,34,1
 334,113.0,60.0,0
 341,118.0,0,1
 345,118.0,34,1
 351,117.0,60.0,0
 358,122.0,0,1
 362,122.0,34,1
 368,123.0,60.0,0
 375,126.0,0,1
 379,126.0,34,1
 385,127.0,60.0,0
 392,130.0,0,1
 396,130.0,34,1
 402,131.0,58.0,0
 409,134.0,0,1
 413,134.0,34,1
 419,133.0,58.0,0
 426,138.0,0,1
 430,138.0,34,1
 436,137.0,60.0,0
 443,142.0,0,1
 447,142.0,34,1
 453,141.0,60.0,0
 460,146.0,0,1
 464,146.0,34,1
 470,147.0,60.0,0
 477,150.0,0,1
 481,150.0,34,1
 487,151.0,60.0,0
 494,154.0,0,1
 498,154.0,34,1
 504,155.0,58.0,0
 511,156.0,0,1
 515,156.0,34,1
 521,156.0,58.0,0
 1,12,18,19,20,13,3,2,4,0.2,0.2,0.0
 18,29,35,36,37,30,20,19,4,0.2,0.2,0.0
 35,46,52,53,54,47,37,36,4,0.2,0.2,0.0
 52,63,69,70,71,64,54,53,4,0.2,0.2,0.0
 69,80,86,87,88,81,71,70,4,0.2,0.2,0.0
 86,97,103,104,105,98,88,87,4,0.2,0.2,0.0
 103,114,120,121,122,115,105,104,4,0.2,0.2,0.0
 120,131,137,138,139,132,122,121,4,0.2,0.2,0.0
 137,148,154,155,156,149,139,138,4,0.2,0.2,0.0
 154,165,171,172,173,166,156,155,4,0.2,0.2,0.0
 171,182,188,189,190,183,173,172,4,0.2,0.2,0.0
 188,199,205,206,207,200,190,189,4,0.2,0.2,0.0
 205,216,222,223,224,217,207,206,4,0.2,0.2,0.0
 222,233,239,240,241,234,224,223,4,0.2,0.2,0.0
 239,250,256,257,258,251,241,240,4,0.2,0.2,0.0
 256,267,273,274,275,268,258,257,4,0.2,0.2,0.0
 273,284,290,291,292,285,275,274,4,0.2,0.2,0.0
 290,301,307,308,309,302,292,291,4,0.2,0.2,0.0
 307,318,324,325,326,319,309,308,4,0.2,0.2,0.0
 324,335,341,342,343,336,326,325,4,0.2,0.2,0.0
 341,352,358,359,360,353,343,342,4,0.2,0.2,0.0
 358,369,375,376,377,370,360,359,4,0.2,0.2,0.0
 375,386,392,393,394,387,377,376,4,0.2,0.2,0.0
 392,403,409,410,411,404,394,393,4,0.2,0.2,0.0

409,420,426,427,428,421,411,410,4,0.2,0.2,0.0
426,437,443,444,445,438,428,427,4,0.2,0.2,0.0
443,454,460,461,462,455,445,444,4,0.2,0.2,0.0
460,471,477,478,479,472,462,461,4,0.2,0.2,0.0
477,488,494,495,496,489,479,478,4,0.2,0.2,0.0
494,505,511,512,513,506,496,495,4,0.2,0.2,0.0
1,78.0,5,2,1
96,58.0,1,17,6
198,58.0,1,17,6
300,58.0,1,17,6
402,58.0,1,17,6
504,58.0,1,17,6
11,5,28,22,45,39,62,56,79,73,96,90,113,107,130,124
147,141,164,158,181,175,198,192,215,209,232,226,249,243,266,260
283,277,300,294,317,311,334,328,351,345,368,362,385,329,402,396
419,413,436,430,453,447,470,464,487,481,504,498
17,34,51,68,85,102,119,136,153,170,187,204,221,238,255,272
289,306,323,340,357,374,391,408,425,442,459,476,493
96,1,17,198,1,17,300,1,17,402,1,17,504,1,17
SP-25..K = .2..D = 20 FT...END OF PROBLEM.
3,0.0001

1 RUN A052 SP = 25 FEET DEPTH = 20 FEET K = 2. DEPTH = 88'
 NDIMEN = 2 FERR = .00010

NPBC = 93 NLEMC = 30 NPBC = 0 NPFS = 30 ITSIV = 20 NPBC = 8 NPFPAC = 5 ITIME = 0

GENERATED NODAL POINT DATA AND (X)-(Y) COORDINATES

NODE	1	X=	-340.0000	Y=	0.0000
NODE	3	X=	-340.0000	Y=	17.0000
NODE	5	X=	-340.0000	Y=	34.0000
NODE	7	X=	-340.0000	Y=	48.8887
NODE	9	X=	-340.0000	Y=	63.3333
NODE	11	X=	-340.0000	Y=	78.0000
NODE	18	X=	-200.0000	Y=	0.0000
NODE	20	X=	-200.0000	Y=	17.0000
NODE	22	X=	-200.0000	Y=	34.0000
NODE	24	X=	-200.0000	Y=	48.8887
NODE	26	X=	-200.0000	Y=	63.3333
NODE	28	X=	-200.0000	Y=	78.0000
NODE	35	X=	-80.0000	Y=	0.0000
NODE	37	X=	-80.0000	Y=	17.0000
NODE	39	X=	-80.0000	Y=	34.0000
NODE	41	X=	-80.0000	Y=	48.8887
NODE	43	X=	-80.0000	Y=	63.3333
NODE	45	X=	-80.0000	Y=	78.0000
NODE	52	X=	0.0000	Y=	0.0000
NODE	54	X=	0.0000	Y=	17.0000
NODE	56	X=	0.0000	Y=	34.0000
NODE	58	X=	0.0000	Y=	48.8887
NODE	60	X=	0.0000	Y=	63.3333
NODE	62	X=	0.0000	Y=	78.0000
NODE	68	X=	50.0000	Y=	0.0000
NODE	70	X=	50.0000	Y=	17.0000
NODE	72	X=	50.0000	Y=	34.0000
NODE	74	X=	50.0000	Y=	48.8887
NODE	76	X=	50.0000	Y=	63.3333
NODE	78	X=	50.0000	Y=	78.0000
NODE	85	X=	88.7800	Y=	0.0000
NODE	87	X=	88.7800	Y=	17.0000
NODE	89	X=	88.7800	Y=	34.0000
NODE	91	X=	88.8333	Y=	48.8887
NODE	93	X=	88.8887	Y=	63.3333
NODE	95	X=	88.9441	Y=	78.0000
NODE	102	X=	82.0000	Y=	0.0000
NODE	104	X=	82.0000	Y=	17.0000
NODE	106	X=	82.0000	Y=	34.0000
NODE	108	X=	81.8887	Y=	48.8887
NODE	110	X=	81.7778	Y=	63.3333
NODE	112	X=	81.6667	Y=	78.0000
NODE	120	X=	88.0000	Y=	0.0000
NODE	122	X=	88.0000	Y=	17.0000
NODE	124	X=	88.0000	Y=	34.0000
NODE	126	X=	88.8887	Y=	48.8887
NODE	128	X=	89.7778	Y=	63.3333
NODE	130	X=	90.6667	Y=	78.0000
NODE	137	X=	78.0000	Y=	0.0000
NODE	139	X=	78.0000	Y=	17.0000
NODE	141	X=	78.0000	Y=	34.0000
NODE	143	X=	78.8887	Y=	48.8887
NODE	145	X=	79.7778	Y=	63.3333
NODE	147	X=	80.6667	Y=	78.0000
NODE	184	X=	74.0000	Y=	0.0000
NODE	186	X=	74.0000	Y=	17.0000
NODE	188	X=	74.0000	Y=	34.0000
NODE	190	X=	74.3333	Y=	48.8887
NODE	192	X=	74.6667	Y=	63.3333
NODE	194	X=	75.0000	Y=	78.0000
NODE	171	X=	78.0000	Y=	0.0000
NODE	173	X=	78.0000	Y=	17.0000
NODE	175	X=	78.0000	Y=	34.0000
NODE	177	X=	78.3333	Y=	48.8887
NODE	179	X=	78.6667	Y=	63.3333
NODE	181	X=	79.0000	Y=	78.0000
NODE	188	X=	82.0000	Y=	0.0000
NODE	190	X=	82.0000	Y=	17.0000
NODE	192	X=	82.0000	Y=	34.0000
NODE	194	X=	82.3333	Y=	48.8887
NODE	196	X=	82.6667	Y=	63.3333
NODE	198	X=	83.0000	Y=	78.0000
NODE	205	X=	88.0000	Y=	0.0000
NODE	207	X=	88.0000	Y=	17.0000
NODE	209	X=	88.0000	Y=	34.0000
NODE	211	X=	88.8887	Y=	48.8887
NODE	213	X=	89.7778	Y=	63.3333
NODE	215	X=	90.6667	Y=	78.0000
NODE	222	X=	80.0000	Y=	0.0000
NODE	224	X=	80.0000	Y=	17.0000
NODE	226	X=	80.0000	Y=	34.0000
NODE	228	X=	80.8887	Y=	48.8887
NODE	230	X=	81.7778	Y=	63.3333
NODE	232	X=	82.6667	Y=	78.0000
NODE	239	X=	84.0000	Y=	0.0000
NODE	241	X=	84.0000	Y=	17.0000
NODE	243	X=	84.0000	Y=	34.0000
NODE	245	X=	83.8887	Y=	48.8887
NODE	247	X=	83.7778	Y=	63.3333
NODE	249	X=	83.6667	Y=	78.0000
NODE	286	X=	98.0000	Y=	0.0000
NODE	288	X=	98.0000	Y=	17.0000
NODE	290	X=	98.0000	Y=	34.0000
NODE	292	X=	98.3333	Y=	48.8887
NODE	294	X=	98.6667	Y=	63.3333
NODE	296	X=	99.0000	Y=	78.0000
NODE	273	X=	102.0000	Y=	0.0000
NODE	275	X=	102.0000	Y=	17.0000
NODE	277	X=	102.0000	Y=	34.0000
NODE	279	X=	102.3333	Y=	48.8887
NODE	281	X=	102.6667	Y=	63.3333
NODE	283	X=	103.0000	Y=	78.0000
NODE	290	X=	108.0000	Y=	0.0000
NODE	292	X=	108.0000	Y=	17.0000
NODE	294	X=	108.0000	Y=	34.0000
NODE	296	X=	108.3333	Y=	48.8887
NODE	298	X=	108.6667	Y=	63.3333
NODE	300	X=	109.0000	Y=	78.0000
NODE	307	X=	110.0000	Y=	0.0000
NODE	309	X=	110.0000	Y=	17.0000
NODE	311	X=	110.0000	Y=	34.0000
NODE	313	X=	109.8887	Y=	48.8887
NODE	315	X=	109.7778	Y=	63.3333
NODE	317	X=	109.6667	Y=	78.0000
NODE	324	X=	114.0000	Y=	0.0000
NODE	326	X=	114.0000	Y=	17.0000
NODE	328	X=	114.0000	Y=	34.0000
NODE	330	X=	113.8887	Y=	48.8887
NODE	332	X=	113.7778	Y=	63.3333
NODE	334	X=	113.6667	Y=	78.0000
NODE	341	X=	118.0000	Y=	0.0000
NODE	343	X=	118.0000	Y=	17.0000

NODE 345	X	116.0000	Y	34.0000
NODE 347	X	117.8887	Y	42.8887
NODE 348	X	117.3333	Y	81.3333
NODE 351	X	117.0000	Y	80.0000
NODE 355	X	122.0000	Y	0.0000
NODE 360	X	122.0000	Y	17.0000
NODE 362	X	122.0000	Y	34.0000
NODE 364	X	122.3333	Y	42.8887
NODE 368	X	122.8887	Y	81.3333
NODE 368	X	123.0000	Y	80.0000
NODE 375	X	128.0000	Y	0.0000
NODE 377	X	128.0000	Y	17.0000
NODE 379	X	128.0000	Y	34.0000
NODE 381	X	128.3333	Y	42.8887
NODE 383	X	128.8887	Y	81.3333
NODE 385	X	127.0000	Y	80.0000
NODE 388	X	130.0000	Y	0.0000
NODE 394	X	130.0000	Y	17.0000
NODE 398	X	130.0000	Y	34.0000
NODE 398	X	130.3333	Y	42.0000
NODE 400	X	130.8887	Y	80.0000
NODE 402	X	131.0000	Y	88.0000
NODE 409	X	134.0000	Y	0.0000
NODE 411	X	134.0000	Y	17.0000
NODE 413	X	134.0000	Y	34.0000
NODE 415	X	133.8887	Y	42.0000
NODE 417	X	133.3333	Y	80.0000
NODE 418	X	133.0000	Y	88.0000
NODE 428	X	138.0000	Y	0.0000
NODE 428	X	138.0000	Y	17.0000
NODE 430	X	138.0000	Y	34.0000
NODE 432	X	137.8887	Y	42.8887
NODE 434	X	137.3333	Y	81.3333
NODE 438	X	137.0000	Y	80.0000
NODE 442	X	142.0000	Y	0.0000
NODE 445	X	142.0000	Y	17.0000
NODE 447	X	142.0000	Y	34.0000
NODE 449	X	141.8887	Y	42.8887
NODE 451	X	141.3333	Y	81.3333
NODE 453	X	141.0000	Y	80.0000
NODE 460	X	148.0000	Y	0.0000
NODE 462	X	148.0000	Y	17.0000
NODE 464	X	148.0000	Y	34.0000
NODE 468	X	148.3333	Y	42.8887
NODE 468	X	148.8887	Y	81.3333
NODE 470	X	147.0000	Y	80.0000
NODE 477	X	150.0000	Y	0.0000
NODE 479	X	150.0000	Y	17.0000
NODE 481	X	150.0000	Y	34.0000
NODE 483	X	150.3333	Y	42.8887
NODE 485	X	150.8887	Y	81.3333
NODE 487	X	151.0000	Y	80.0000
NODE 484	X	154.0000	Y	0.0000
NODE 486	X	154.0000	Y	17.0000
NODE 488	X	154.0000	Y	34.0000
NODE 500	X	154.3333	Y	42.0000
NODE 502	X	154.8887	Y	80.0000
NODE 504	X	155.0000	Y	88.0000
NODE 511	X	155.0000	Y	0.0000
NODE 513	X	155.0000	Y	17.0000
NODE 515	X	155.0000	Y	34.0000
NODE 517	X	155.0000	Y	42.0000
NODE 519	X	155.0000	Y	80.0000
NODE 521	X	155.0000	Y	88.0000

NUMBER OF NODAL POINTS... 521

NUMBER OF ELEMENTS..... 150

ELE. NO. NODAL POINTS

1	1	12	18	19	20	13	3	2	20000E+00	20000E+00	0
2	3	13	20	21	22	14	5	4	20000E+00	20000E+00	0
3	5	14	22	23	24	15	7	8	20000E+00	20000E+00	0
4	7	15	24	25	26	16	9	8	20000E+00	20000E+00	0
5	9	16	26	27	28	17	11	10	20000E+00	20000E+00	0
6	18	28	35	36	37	30	20	19	20000E+00	20000E+00	0
7	20	30	37	38	39	31	22	21	20000E+00	20000E+00	0
8	22	31	38	40	41	32	24	23	20000E+00	20000E+00	0
9	24	32	41	42	43	33	26	25	20000E+00	20000E+00	0
10	28	33	43	44	45	34	28	27	20000E+00	20000E+00	0
11	35	45	52	53	54	47	37	36	20000E+00	20000E+00	0
12	37	47	54	55	56	48	39	38	20000E+00	20000E+00	0
13	38	48	55	57	58	49	41	40	20000E+00	20000E+00	0
14	41	49	56	59	60	50	43	42	20000E+00	20000E+00	0
15	43	50	60	61	62	51	45	44	20000E+00	20000E+00	0
16	52	62	66	70	71	64	54	53	20000E+00	20000E+00	0
17	54	64	71	72	73	65	56	55	20000E+00	20000E+00	0
18	55	65	73	74	75	66	58	57	20000E+00	20000E+00	0
19	56	66	75	76	77	67	60	59	20000E+00	20000E+00	0
20	60	67	77	78	79	68	62	61	20000E+00	20000E+00	0
21	69	68	88	87	88	81	71	70	20000E+00	20000E+00	0
22	71	81	88	89	90	82	73	72	20000E+00	20000E+00	0
23	73	82	89	91	92	83	75	74	20000E+00	20000E+00	0
24	75	83	92	93	94	84	77	76	20000E+00	20000E+00	0
25	77	84	94	95	96	85	79	78	20000E+00	20000E+00	0
26	66	87	103	104	105	88	88	87	20000E+00	20000E+00	0
27	68	88	105	106	107	89	90	89	20000E+00	20000E+00	0
28	69	89	107	108	109	100	92	91	20000E+00	20000E+00	0
29	82	109	109	110	111	101	94	93	20000E+00	20000E+00	0
30	84	101	111	112	113	102	96	95	20000E+00	20000E+00	0
31	103	114	120	121	122	115	108	104	20000E+00	20000E+00	0
32	105	115	122	123	124	116	107	106	20000E+00	20000E+00	0
33	107	116	124	125	126	117	109	108	20000E+00	20000E+00	0
34	109	117	125	127	128	118	111	110	20000E+00	20000E+00	0
35	111	118	126	128	130	119	112	112	20000E+00	20000E+00	0
36	120	131	137	138	139	122	122	121	20000E+00	20000E+00	0
37	122	132	139	140	141	123	124	123	20000E+00	20000E+00	0
38	124	133	141	142	143	124	126	125	20000E+00	20000E+00	0
39	126	134	143	144	145	125	128	127	20000E+00	20000E+00	0
40	138	135	145	146	147	126	130	129	20000E+00	20000E+00	0
41	137	145	154	155	156	149	139	138	20000E+00	20000E+00	0
42	139	146	155	157	158	150	141	140	20000E+00	20000E+00	0
43	141	156	158	159	160	151	143	142	20000E+00	20000E+00	0
44	143	151	160	161	162	152	145	144	20000E+00	20000E+00	0
45	145	152	162	163	164	153	147	146	20000E+00	20000E+00	0
46	154	155	171	172	173	155	155	155	20000E+00	20000E+00	0
47	155	156	173	174	175	157	156	157	20000E+00	20000E+00	0
48	156	157	175	176	177	158	159	159	20000E+00	20000E+00	0
49	160	158	177	178	179	159	162	161	20000E+00	20000E+00	0
50	162	159	179	180	181	170	164	163	20000E+00	20000E+00	0
51	171	162	188	189	190	163	173	172	20000E+00	20000E+00	0
52	173	163	190	191	192	164	175	174	20000E+00	20000E+00	0
53	175	164	192	193	194	165	177	176	20000E+00	20000E+00	0
54	177	165	194	195	196	166	179	178	20000E+00	20000E+00	0
55	178	166	196	197	198	167	181	180	20000E+00	20000E+00	0
56	188	199	205	206	207	200	190	189	20000E+00	20000E+00	0
57	190	200	207	208	209	201	192	191	20000E+00	20000E+00	0
58	192	201	209	210	211	202	194	193	20000E+00	20000E+00	0
59	194	202	211	212	213	203	196	195	20000E+00	20000E+00	0
60	195	203	213	214	215	204	198	197	20000E+00	20000E+00	0

82	207	217	224	228	228	218	208	208	20000E+00	20000E+00	0
83	208	218	228	227	228	219	211	210	20000E+00	20000E+00	0
84	211	218	228	229	230	220	213	212	20000E+00	20000E+00	0
88	213	220	230	231	232	221	216	214	20000E+00	20000E+00	0
88	222	233	239	240	241	234	224	223	20000E+00	20000E+00	0
87	224	234	241	242	243	236	228	228	20000E+00	20000E+00	0
87	228	238	243	244	245	238	228	227	20000E+00	20000E+00	0
88	235	236	248	248	247	237	230	229	20000E+00	20000E+00	0
70	230	237	247	248	249	238	232	231	20000E+00	20000E+00	0
71	239	250	258	257	258	251	241	240	20000E+00	20000E+00	0
72	241	251	258	259	260	252	243	242	20000E+00	20000E+00	0
73	243	252	260	261	262	253	244	244	20000E+00	20000E+00	0
74	248	253	262	263	264	254	247	248	20000E+00	20000E+00	0
75	247	254	264	265	266	255	248	248	20000E+00	20000E+00	0
76	258	267	273	274	275	268	258	257	20000E+00	20000E+00	0
77	258	268	278	278	277	269	260	259	20000E+00	20000E+00	0
78	260	269	277	278	279	270	262	261	20000E+00	20000E+00	0
79	262	270	279	280	281	271	264	263	20000E+00	20000E+00	0
80	264	271	281	282	283	272	268	265	20000E+00	20000E+00	0
81	273	284	290	291	292	285	278	274	20000E+00	20000E+00	0
82	275	285	292	293	294	288	277	278	20000E+00	20000E+00	0
83	277	286	294	295	296	287	278	276	20000E+00	20000E+00	0
84	278	287	298	297	298	288	281	280	20000E+00	20000E+00	0
85	281	288	298	299	300	289	282	282	20000E+00	20000E+00	0
88	280	301	307	308	309	302	292	291	20000E+00	20000E+00	0
89	282	302	309	310	311	303	294	293	20000E+00	20000E+00	0
88	284	303	311	312	313	304	296	295	20000E+00	20000E+00	0
88	286	304	313	314	315	305	298	297	20000E+00	20000E+00	0
90	288	306	315	316	317	308	300	299	20000E+00	20000E+00	0
91	307	318	324	325	326	319	308	308	20000E+00	20000E+00	0
92	308	318	326	327	328	320	311	310	20000E+00	20000E+00	0
93	311	320	328	329	330	321	313	312	20000E+00	20000E+00	0
94	313	321	330	331	332	322	315	314	20000E+00	20000E+00	0
95	315	322	332	333	334	323	317	316	20000E+00	20000E+00	0
96	324	335	341	342	343	335	326	325	20000E+00	20000E+00	0
97	326	336	343	344	345	337	328	327	20000E+00	20000E+00	0
98	328	337	345	346	347	338	330	329	20000E+00	20000E+00	0
98	330	338	347	348	349	339	332	331	20000E+00	20000E+00	0
100	332	339	348	350	351	340	334	333	20000E+00	20000E+00	0
101	341	352	358	359	360	343	343	342	20000E+00	20000E+00	0
102	343	353	360	361	362	345	344	344	20000E+00	20000E+00	0
103	345	354	362	363	364	347	346	346	20000E+00	20000E+00	0
104	347	356	364	365	366	349	348	348	20000E+00	20000E+00	0
105	348	356	366	367	368	351	350	350	20000E+00	20000E+00	0
106	358	369	375	376	377	370	360	359	20000E+00	20000E+00	0
107	360	370	377	378	379	371	362	361	20000E+00	20000E+00	0
108	362	371	379	380	381	372	364	363	20000E+00	20000E+00	0
109	364	372	381	382	383	373	366	365	20000E+00	20000E+00	0
110	366	373	383	384	385	374	368	367	20000E+00	20000E+00	0
111	378	386	382	383	384	387	377	376	20000E+00	20000E+00	0
112	377	387	384	385	386	388	379	378	20000E+00	20000E+00	0
113	379	388	388	387	388	389	381	380	20000E+00	20000E+00	0
114	381	389	388	389	400	390	383	382	20000E+00	20000E+00	0
115	383	390	400	401	402	391	385	384	20000E+00	20000E+00	0
116	385	402	408	410	411	404	394	393	20000E+00	20000E+00	0
117	384	404	411	412	413	405	396	395	20000E+00	20000E+00	0
118	396	406	413	414	415	408	398	397	20000E+00	20000E+00	0
119	398	406	415	416	417	407	400	399	20000E+00	20000E+00	0
120	400	407	417	418	419	408	402	401	20000E+00	20000E+00	0
121	409	420	426	427	428	421	411	410	20000E+00	20000E+00	0
122	411	421	428	429	430	422	413	412	20000E+00	20000E+00	0
123	413	422	430	431	432	423	415	414	20000E+00	20000E+00	0
124	415	423	432	433	434	424	417	416	20000E+00	20000E+00	0
125	417	424	434	435	436	426	419	418	20000E+00	20000E+00	0
126	428	437	443	444	445	438	428	427	20000E+00	20000E+00	0
127	428	438	445	446	447	439	430	429	20000E+00	20000E+00	0

128	430	438	447	448	449	440	432	431	20000E+00	20000E+00	0
129	432	440	449	450	451	441	434	433	20000E+00	20000E+00	0
130	434	441	451	452	453	442	436	435	20000E+00	20000E+00	0
131	443	454	460	461	462	455	445	444	20000E+00	20000E+00	0
132	445	455	462	463	464	456	447	446	20000E+00	20000E+00	0
133	447	456	464	465	466	457	449	448	20000E+00	20000E+00	0
134	449	457	466	467	468	458	451	450	20000E+00	20000E+00	0
135	451	458	468	469	470	459	453	452	20000E+00	20000E+00	0
136	450	471	477	478	479	472	462	461	20000E+00	20000E+00	0
137	462	472	478	480	481	473	464	463	20000E+00	20000E+00	0
138	464	473	481	482	483	474	466	465	20000E+00	20000E+00	0
139	466	474	483	484	485	476	468	467	20000E+00	20000E+00	0
140	468	475	485	486	487	478	470	469	20000E+00	20000E+00	0
141	477	486	484	485	486	488	479	478	20000E+00	20000E+00	0
142	479	488	488	487	488	490	481	480	20000E+00	20000E+00	0
143	481	490	488	489	490	481	483	482	20000E+00	20000E+00	0
144	483	491	500	501	502	492	485	484	20000E+00	20000E+00	0
145	485	492	502	503	504	493	487	486	20000E+00	20000E+00	0
146	494	505	511	512	513	506	498	495	20000E+00	20000E+00	0
147	496	506	513	514	515	507	498	497	20000E+00	20000E+00	0
148	498	507	515	516	517	508	500	499	20000E+00	20000E+00	0
149	500	508	517	518	519	509	502	501	20000E+00	20000E+00	0
150	502	509	519	520	521	510	504	503	20000E+00	20000E+00	0

DIRICHLET BOUNDARY CONDITION DATA
NODES RESPECTIVE DIRICHLET BOUNDARY CONDITIONS

1- 2	78.0000	78.0000
3- 4	78.0000	78.0000
5- 6	78.0000	78.0000
7- 8	78.0000	78.0000
9- 10	78.0000	78.0000
11- 10	78.0000	78.0000
89-102	88.0000	88.0000
113-102	88.0000	88.0000
189-204	88.0000	88.0000
215-204	88.0000	88.0000
300-308	88.0000	88.0000
317-308	88.0000	88.0000
402-408	88.0000	88.0000
415-408	88.0000	88.0000
504-510	88.0000	88.0000
521-510	88.0000	88.0000

NODAL POINTS ON FREE SURFACE

11	17	28	34	45	51	62	68	79	85	98	102	113	118	130	138	147	153	164	170
181	187	198	204	215	221	232	238	248	255	265	272	283	288	300	308	317	323	334	340
351	357	368	374	385	391	402	408	418	425	435	442	453	459	470	478	487	493	504	0

SEEPAGE FACE NODAL POINT DATA
CONSECUTIVE NODE NUMBERS ON THE SEEPAGE FACE

89-113
189-215
300-317
402-415
504-521

ITER = 1

NEW COORDINATES OF THE FREE SURFACE LINE

NODE=467	X = 150.8272	Y = 58.1088
NODE=470	X = 148.8281	Y = 58.1288
NODE=483	X = 141.0718	Y = 58.1328
NODE=438	X = 137.0728	Y = 58.1120
NODE=418	X = 133.0000	Y = 58.0000
NODE=402	X = 131.0000	Y = 58.0000
NODE=388	X = 128.8874	Y = 58.1382
NODE=388	X = 122.8288	Y = 58.1888
NODE=381	X = 118.7878	Y = 58.3181
NODE=334	X = 113.0710	Y = 58.1888
NODE=317	X = 108.0000	Y = 58.0000
NODE=300	X = 107.0000	Y = 58.0000
NODE=283	X = 102.8313	Y = 58.2148
NODE=288	X = 98.8338	Y = 58.2707
NODE=248	X = 83.0688	Y = 58.2837
NODE=232	X = 88.0871	Y = 58.2880
NODE=218	X = 88.0000	Y = 58.0000
NODE=198	X = 83.0000	Y = 58.0000
NODE=181	X = 78.8382	Y = 58.3828
NODE=184	X = 74.8424	Y = 58.5028
NODE=147	X = 68.0884	Y = 58.5808
NODE=130	X = 68.0878	Y = 58.4878
NODE=113	X = 61.0000	Y = 58.0000
NODE= 88	X = 58.0000	Y = 58.0000
NODE= 78	X = 50.0000	Y = 58.8888
NODE= 82	X = 0.0000	Y = 62.3818
NODE= 48	X = -80.0000	Y = 68.1804
NODE= 28	X = -200.0000	Y = 71.8308
NODE= 11	X = -340.0000	Y = 78.0000

ITER = 2

NEW COORDINATES OF THE FREE SURFACE LINE

NODE=467	X = 150.8288	Y = 58.1412
NODE=470	X = 148.8288	Y = 58.1778
NODE=483	X = 141.0888	Y = 58.1821
NODE=438	X = 137.0712	Y = 58.1488
NODE=418	X = 133.0000	Y = 58.0000
NODE=402	X = 131.0000	Y = 58.0000
NODE=388	X = 128.8923	Y = 58.1848
NODE=388	X = 122.8318	Y = 58.2372
NODE=381	X = 118.7318	Y = 58.3038
NODE=334	X = 113.0883	Y = 58.1881
NODE=317	X = 108.0000	Y = 58.0000
NODE=300	X = 107.0000	Y = 58.0000
NODE=283	X = 102.8334	Y = 58.2872
NODE=288	X = 98.8388	Y = 58.3814
NODE=248	X = 83.0822	Y = 58.3838
NODE=232	X = 88.0843	Y = 58.3281
NODE=218	X = 88.0000	Y = 58.0000
NODE=198	X = 83.0000	Y = 58.0000
NODE=181	X = 78.8410	Y = 58.4882
NODE=184	X = 74.8488	Y = 58.6188
NODE=147	X = 68.0803	Y = 58.6834
NODE=130	X = 68.0838	Y = 58.6088
NODE=113	X = 61.0000	Y = 58.0000
NODE= 88	X = 58.0000	Y = 58.0000
NODE= 78	X = 50.0000	Y = 58.8818
NODE= 82	X = 0.0000	Y = 62.8888
NODE= 48	X = -80.0000	Y = 68.8218
NODE= 28	X = -200.0000	Y = 72.1278
NODE= 11	X = -340.0000	Y = 78.0000

ITER = 3

NEW COORDINATES OF THE FREE SURFACE LINE

NODE=467	X = 150.8288	Y = 58.1410
NODE=470	X = 148.8288	Y = 58.1772
NODE=483	X = 141.0888	Y = 58.1818
NODE=438	X = 137.0712	Y = 58.1488
NODE=418	X = 133.0000	Y = 58.0000
NODE=402	X = 131.0000	Y = 58.0000
NODE=388	X = 128.8918	Y = 58.1834
NODE=388	X = 122.8318	Y = 58.2371
NODE=381	X = 118.7340	Y = 58.3088
NODE=334	X = 113.0880	Y = 58.2048
NODE=317	X = 108.0000	Y = 58.0000
NODE=300	X = 107.0000	Y = 58.0000
NODE=283	X = 102.8333	Y = 58.2871
NODE=288	X = 98.8388	Y = 58.3808
NODE=248	X = 83.0822	Y = 58.3822
NODE=232	X = 88.0843	Y = 58.3280
NODE=218	X = 88.0000	Y = 58.0000
NODE=198	X = 83.0000	Y = 58.0000
NODE=181	X = 78.8410	Y = 58.4888
NODE=184	X = 74.8488	Y = 58.6183
NODE=147	X = 68.0804	Y = 58.6808
NODE=130	X = 68.0838	Y = 58.6082
NODE=113	X = 61.0000	Y = 58.0000
NODE= 88	X = 58.0000	Y = 58.0000
NODE= 78	X = 50.0000	Y = 58.8784
NODE= 82	X = 0.0000	Y = 62.8884
NODE= 48	X = -80.0000	Y = 68.8380
NODE= 28	X = -200.0000	Y = 72.1238
NODE= 11	X = -340.0000	Y = 78.0000

CONVERGENCE CHECK ERROR = .0227E-08

ONODE	X COORDINATE	Y COORDINATE	V-POTENTIAL	X-VELOCITY	Y-VELOCITY	TOTAL VELD.	PRES. COEF.
1	-340.0000	0.0000	78.0000	-.8214E-02	-.1203E-04	.8214E-02	
2	-340.0000	8.8000	78.0000	-.8211E-02	-.9783E-14	.8211E-02	
3	-340.0000	17.0000	78.0000	-.8202E-02	-.9118E-08	.8202E-02	
4	-340.0000	25.8000	78.0000	-.8188E-02	0.	.8188E-02	
5	-340.0000	34.0000	78.0000	-.8188E-02	0.	.8188E-02	
6	-340.0000	41.3333	78.0000	-.8141E-02	-.3002E-04	.8141E-02	
7	-340.0000	48.8887	78.0000	-.8112E-02	-.3081E-04	.8112E-02	
8	-340.0000	56.0000	78.0000	-.8077E-02	0.	.8077E-02	
9	-340.0000	63.3333	78.0000	-.8038E-02	-.4831E-04	.8038E-02	
10	-340.0000	70.8887	78.0000	-.7987E-02	-.1701E-13	.7987E-02	
11	-340.0000	78.0000	78.0000	-.7938E-02	-.7887E-04	.7938E-02	
12	-270.0000	0.0000	78.0770	-.8480E-02	-.2288E-05	.8480E-02	
13	-270.0000	17.0000	78.0801	-.8484E-02	-.8308E-04	.8488E-02	
14	-270.0000	34.0000	78.0894	-.8488E-02	-.1287E-03	.8488E-02	
15	-270.0000	47.8873	78.1018	-.8447E-02	-.1844E-03	.8448E-02	
16	-270.0000	61.3748	78.1194	-.8418E-02	-.2453E-03	.8422E-02	
17	-270.0000	75.0619	78.1427	-.8382E-02	-.3210E-03	.8388E-02	
18	-200.0000	0.0000	72.0870	-.8784E-02	-.1814E-05	.8784E-02	
19	-200.0000	8.8000	72.0878	-.8784E-02	-.4488E-04	.8784E-02	
20	-200.0000	17.0000	72.0809	-.8782E-02	-.6488E-04	.8784E-02	
21	-200.0000	25.8000	72.0888	-.8782E-02	-.1243E-03	.8784E-02	
22	-200.0000	34.0000	72.0723	-.8782E-02	-.1844E-03	.8784E-02	
23	-200.0000	40.3840	72.0763	-.8783E-02	-.2084E-03	.8788E-02	
24	-200.0000	46.7078	72.0888	-.8784E-02	-.2872E-03	.8788E-02	
25	-200.0000	53.0619	72.0838	-.8788E-02	-.2887E-03	.8788E-02	
26	-200.0000	58.4188	72.1028	-.8788E-02	-.3227E-03	.8788E-02	
27	-200.0000	68.7888	72.1121	-.8782E-02	-.3187E-03	.8788E-02	
28	-200.0000	72.1238	72.1238	-.8782E-02	-.3844E-03	.8807E-02	

28	-140 0000	0 0000	88 3838	- 9155E-02	- 1832E-08	9155E-02
30	-140 0000	17 0000	88 3882	- 9154E-02	- 1010E-03	9155E-02
31	-140 0000	34 0000	88 3812	- 9150E-02	- 2023E-03	9152E-02
32	-140 0000	45 7838	88 3883	- 9144E-02	- 2719E-03	9148E-02
33	-140 0000	57 8873	88 4138	- 9138E-02	- 3413E-03	9142E-02
34	-140 0000	68 3808	88 4383	- 9128E-02	- 4127E-03	9134E-02
35	-80 0000	0 0000	88 5838	- 9038E-02	- 5038E-05	9038E-02
36	-80 0000	8 8000	88 5848	- 9032E-02	- 5471E-04	9033E-02
37	-80 0000	17 0000	88 5844	- 9028E-02	- 1188E-03	9030E-02
38	-80 0000	25 8000	88 5742	- 9022E-02	- 1684E-03	9023E-02
39	-80 0000	34 0000	88 5828	- 9014E-02	- 2378E-03	9017E-02
40	-80 0000	43 4387	88 5881	- 9007E-02	- 2801E-03	9010E-02
41	-80 0000	52 8183	88 5887	- 9000E-02	- 3119E-03	9005E-02
42	-80 0000	61 1180	88 5952	- 8982E-02	- 3290E-03	8987E-02
43	-80 0000	70 0000	88 6148	- 8982E-02	- 3520E-03	8980E-02
44	-80 0000	79 1943	88 6251	- 8978E-02	- 4008E-03	8984E-02
45	-80 0000	88 3380	88 6384	- 8988E-02	- 4527E-03	8979E-02
46	-40 0000	0 0000	84 8314	- 8783E-02	- 5881E-05	8783E-02
47	-40 0000	17 0000	84 8387	- 8779E-02	- 6088E-04	8779E-02
48	-40 0000	34 0000	84 8482	- 8818E-02	- 1888E-03	8818E-02
49	-40 0000	44 2208	84 8628	- 8838E-02	- 2704E-03	8842E-02
50	-40 0000	54 4411	84 8808	- 8868E-02	- 3684E-03	8863E-02
51	-40 0000	64 8817	84 9032	- 8888E-02	- 4783E-03	8887E-02
52	0 0000	0 0000	82 8887	- 1004E-01	- 3870E-04	1004E-01
53	0 0000	8 8000	82 8878	- 1008E-01	- 2212E-04	1008E-01
54	0 0000	17 0000	82 8848	- 1011E-01	- 8814E-05	1011E-01
55	0 0000	25 8000	82 8848	- 1018E-01	- 8484E-05	1018E-01
56	0 0000	34 0000	82 8881	- 1023E-01	- 1720E-03	1023E-01
57	0 0000	43 4387	82 8888	- 1018E-01	- 7471E-04	1022E-01
58	0 0000	52 8183	82 8887	- 1018E-01	- 3803E-03	1018E-01
59	0 0000	61 1180	82 8828	- 1011E-01	- 1888E-03	1011E-01
60	0 0000	70 0000	82 8873	- 1000E-01	- 5008E-03	1002E-01
61	0 0000	79 1943	82 8760	- 9834E-02	- 3843E-03	9940E-02
62	0 0000	88 3380	82 8847	- 9848E-02	- 6488E-03	9888E-02
63	25 0000	0 0000	81 4413	- 9317E-02	- 1783E-04	9317E-02
64	25 0000	17 0000	81 4188	- 9880E-02	- 6004E-03	9889E-02
65	25 0000	34 0000	81 3838	- 1032E-01	- 9883E-03	1037E-01
66	25 0000	43 0801	81 3383	- 1088E-01	- 8703E-03	1102E-01
67	25 0000	52 1203	81 3278	- 1171E-01	- 4328E-03	1172E-01
68	25 0000	61 1804	81 3488	- 1200E-01	- 5424E-03	1202E-01
69	50 0000	0 0000	80 3284	- 8248E-02	- 3823E-04	8248E-02
70	50 0000	8 8000	80 3184	- 8388E-02	- 7078E-03	8388E-02
71	50 0000	17 0000	80 2883	- 8882E-02	- 1387E-03	8878E-02
72	50 0000	25 8000	80 1817	- 9088E-02	- 2273E-02	9078E-02
73	50 0000	34 0000	80 0761	- 9887E-02	- 3017E-02	1031E-01
74	50 0000	42 5588	80 0028	- 1080E-01	- 3870E-02	1122E-01
75	50 0000	51 1188	80 1180	- 1143E-01	- 3881E-02	1207E-01
76	50 0000	60 8377	80 2288	- 1284E-01	- 4097E-02	1381E-01
77	50 0000	69 7437	80 3437	- 1480E-01	- 3333E-02	1517E-01
78	50 0000	78 3882	80 8624	- 1578E-01	- 1588E-02	1587E-01
79	50 0000	87 8784	80 8784	- 1288E-01	- 6458E-02	1382E-01
80	54 3780	0 0000	80 1888	- 7708E-02	- 1647E-04	7708E-02
81	54 3780	17 0000	80 0908	- 7841E-02	- 1880E-02	8081E-02
82	54 3780	34 0000	80 8740	- 8892E-02	- 3817E-02	8890E-02
83	54 4187	42 2782	80 8888	- 1017E-01	- 8188E-02	1141E-01
84	54 4883	50 8888	80 4148	- 9188E-02	- 1687E-02	9187E-01
85	54 5000	59 8377	80 1848	- 3732E-01	- 4808E-03	3732E-01
86	58 7800	0 0000	80 8923	- 7303E-02	- 8303E-05	7303E-02
87	58 7800	8 8000	80 8781	- 7378E-02	- 8288E-03	7424E-02
88	58 7800	17 0000	80 8218	- 7478E-02	- 1851E-02	7858E-02
89	58 7800	25 8000	80 8280	- 7778E-02	- 2782E-02	8282E-02
90	58 7800	34 0000	80 8870	- 8153E-02	- 3888E-02	8088E-02
91	58 7817	42 0000	80 8880	- 8488E-02	- 4978E-02	8838E-02
92	58 8333	48 0000	80 4848	- 8623E-02	- 5820E-02	1083E-01
93	58 8780	48 0000	80 3432	- 9878E-02	- 8288E-02	1280E-01
94	58 8187	50 0000	80 1480	- 1014E-01	- 8827E-02	1344E-01
95	58 8883	54 0000	80 8308	- 1780E-01	- 2844E-01	3344E-01
96	58 0000	58 0000	80 0000	- 3148E-01	- 4442E-01	5442E-01
97	60 3780	0 0000	80 9338	- 7180E-02	- 1473E-04	7180E-02
98	60 3780	17 0000	80 8817	- 7314E-02	- 1878E-02	7804E-02
99	60 3780	34 0000	80 8220	- 7848E-02	- 4032E-02	8821E-02
100	60 2800	42 0000	80 4240	- 8323E-02	- 5848E-02	1023E-01
101	60 1280	50 0000	80 0808	- 8830E-02	- 8118E-02	1207E-01
102	60 0000	58 0000	80 0000	- 1882E-12	- 4982E-01	4982E-01
103	62 0000	0 0000	80 8785	- 8882E-02	- 1838E-04	8882E-02
104	62 0000	8 8000	80 8881	- 7048E-02	- 8888E-03	7087E-02
105	62 0000	17 0000	80 8030	- 7122E-02	- 1788E-02	7223E-02
106	62 0000	25 8000	80 7087	- 7311E-02	- 2888E-02	7883E-02
107	62 0000	34 0000	80 8888	- 7827E-02	- 4098E-02	8888E-02
108	61 8333	42 0000	80 4738	- 7882E-02	- 5144E-02	8228E-02
109	61 8887	48 0000	80 3888	- 7841E-02	- 8018E-02	8882E-02
110	61 8000	50 0000	80 2308	- 7881E-02	- 8852E-02	1144E-01
111	61 3333	58 0000	80 0371	- 8888E-02	- 8852E-02	1228E-01
112	61 1887	64 0000	80 7428	- 9281E-02	- 2888E-01	2881E-01
113	61 0000	68 0000	80 0000	- 2283E-01	- 4218E-01	4787E-01
114	64 0000	0 0000	80 8070	- 8802E-02	- 1384E-04	8802E-02
115	64 0000	17 0000	80 7328	- 8802E-02	- 1733E-02	7118E-02
116	64 0000	34 0000	80 4882	- 7142E-02	- 4142E-02	8288E-02
117	62 8788	42 1010	80 2883	- 7084E-02	- 8088E-02	8224E-02
118	62 3812	50 2021	80 8732	- 4482E-02	- 8828E-02	1088E-01
119	62 0288	58 3021	80 4487	- 3118E-01	- 1080E-01	3118E-01
120	65 0000	0 0000	80 7388	- 8888E-02	- 1414E-04	8888E-02
121	68 0000	8 8000	80 7218	- 8828E-02	- 8818E-03	8844E-02
122	68 0000	17 0000	80 6880	- 8873E-02	- 1788E-02	8800E-02
123	68 0000	25 8000	80 6882	- 8738E-02	- 2821E-02	7342E-02
124	68 0000	34 0000	80 4187	- 8778E-02	- 4188E-02	7853E-02
125	68 8423	38 1010	80 3270	- 8871E-02	- 5088E-02	8391E-02
126	68 8648	42 2021	80 2188	- 8848E-02	- 8083E-02	8823E-02
127	68 8288	48 3031	80 0883	- 8438E-02	- 7331E-02	8128E-02
128	68 3881	50 4041	80 8284	- 4142E-02	- 8823E-02	1088E-01
129	68 2113	54 8081	80 7241	- 3738E-02	- 7888E-02	8828E-02
130	68 0838	58 6082	80 6082	- 8784E-02	- 1048E-02	8848E-02
131	68 0000	0 0000	80 8748	- 8387E-02	- 1284E-04	8387E-02
132	68 0000	17 0000	80 8884	- 8438E-02	- 1771E-02	8878E-02
133	68 0000	25 8000	80 3888	- 8408E-02	- 4140E-02	7830E-02
134	67 8840	42 2181	80 1888	- 8887E-02	- 8882E-02	8372E-02
135	67 3880	50 4223	80 8870	- 3882E-02	- 8188E-02	8928E-02
136	67 0820	58 8484	80 8710	- 4280E-02	- 1138E-02	4400E-02
137	70 0000	0 0000	80 8120	- 8182E-02	- 1284E-04	8182E-02
138	70 0000	8 8000	80 8933	- 8188E-02	- 8818E-03	8282E-02
139	70 0000	17 0000	80 8382	- 8218E-02	- 1781E-02	8488E-02
140	70 0000	25 8000	80 4388	- 8178E-02	- 2814E-02	8828E-02
141	70 0000	34 0000	80 2888	- 8088E-02	- 4108E-02	7342E-02
142	68 8417	38 1151	80 2008	- 8878E-02	- 4887E-02	7828E-02
143	68 8838	42 2302	80 0880	- 8620E-02	- 8433E-02	7887E-02
144	68 8282	48 3483	80 8880	- 4724E-02	- 8131E-02	7740E-02
145	68 3888	50 4804	80 8831	- 3380E-02	- 8878E-02	7477E-02
146	68 2088	54 8788	80 7387	- 1103E-02	- 3880E-02	6138E-02
147	68 0804	58 8808	80 8807	- 8178E-02	- 4888E-02	7841E-03
148	72 0000	0 0000	80 8811	- 8888E-02	- 1088E-03	8888E-02
149	72 0000	17 0000	80 4783	- 8878E-02	- 1783E-02	8238E-02
150	72 0000	25 8000	80 2284	- 8783E-02	- 4081E-02	7038E-02
151	71 8888	42 2182	80 0388	- 8243E-02	- 8387E-02	7828E-02
152	71 8881	50 4383	80 8088	- 3833E-02	- 8778E-02	8888E-02
153	71 8888	58 8848	80 8782	- 2480E-02	- 2478E-03	2472E-02
154	74 0000	0 0000	80 4922	- 8784E-02	- 1084E-04	8784E-02
155	74 0000	8 8000	80 4738	- 8771E-02	- 8881E-03	8838E-02
156	74 0000	17 0000	80 4187	- 8788E-02	- 1780E-02	8028E-02
157	74 0000	25 8000	80 3184	- 8643E-02	- 2881E-02	8227E-02
158	74 0000	34 0000	80 1738	- 8488E-02	- 3888E-02	8788E-02
159	74 1878	38 1030	80 0810	- 8221E-02	- 4883E-02	8947E-02

161	74.4734	48.3081	58.8843	-4883E-02	-5333E-02	7084E-02
162	74.8312	50.4122	58.7810	-4818E-02	-5408E-02	7048E-02
163	74.7880	54.5152	58.8873	-4818E-02	-3048E-02	8788E-02
164	74.8488	58.8183	58.8183	-5217E-02	-1124E-02	8218E-02
165	78.0000	0.0000	58.4355	-8575E-02	-8575E-02	8575E-02
166	78.0000	17.0000	58.8923	-8571E-02	-1770E-02	8788E-02
167	78.0000	34.0000	58.1203	-8171E-02	-3812E-02	8484E-02
168	78.0000	42.1808	58.8293	-4722E-02	-5081E-02	8821E-02
169	78.2148	50.3813	58.7054	-4885E-02	-5771E-02	7440E-02
170	78.8438	58.5418	58.5883	-7888E-02	-4188E-03	7878E-02
171	78.0000	0.0000	58.3807	-5378E-02	-8494E-08	5378E-02
172	78.0000	8.5000	58.3823	-5348E-02	-8784E-03	6420E-02
173	78.0000	17.0000	58.3082	-5312E-02	-1788E-02	8848E-02
174	78.0000	25.5000	58.2101	-5141E-02	-2779E-02	8844E-02
175	78.0000	34.0000	58.0700	-4807E-02	-3832E-02	8228E-02
176	78.1888	38.0776	58.8624	-4890E-02	-4381E-02	8418E-02
177	78.3137	42.1862	58.8841	-4481E-02	-4881E-02	8887E-02
178	78.4708	48.2327	58.7751	-4847E-02	-5317E-02	8897E-02
179	78.8273	50.3103	58.8801	-4824E-02	-8238E-02	7743E-02
180	78.7842	54.3878	58.5341	-8287E-02	-4488E-02	8382E-02
181	78.8410	58.4885	58.4884	-1088E-01	-2813E-03	1088E-01
182	80.0000	0.0000	58.3281	-5188E-02	-8888E-08	5188E-02
183	80.0000	17.0000	58.2844	-5080E-02	-1738E-02	5288E-02
184	80.0000	34.0000	58.0224	-4837E-02	-3744E-02	8880E-02
185	80.3238	42.0778	58.8421	-4231E-02	-4788E-02	8388E-02
186	80.8470	50.1882	58.8133	-4818E-02	-5923E-02	7889E-02
187	80.8708	58.2327	58.3188	-2388E-01	-5818E-02	2424E-01
188	82.0000	0.0000	58.2774	-4877E-02	-8271E-08	4877E-02
189	82.0000	8.5000	58.2893	-4838E-02	-8888E-03	5008E-02
190	82.0000	17.0000	58.2046	-4880E-02	-1713E-02	5172E-02
191	82.0000	25.5000	58.1118	-4889E-02	-2878E-02	5381E-02
192	82.0000	34.0000	58.8773	-4383E-02	-3881E-02	5712E-02
193	82.1887	38.0000	58.8853	-4188E-02	-4181E-02	5801E-02
194	82.3333	42.0000	58.8027	-3892E-02	-4821E-02	6048E-02
195	82.5000	48.0000	58.8884	-3800E-02	-5881E-02	8818E-02
196	82.8887	50.0000	58.5700	-3148E-02	-4880E-02	8818E-02
197	82.8333	54.0000	58.4088	-8948E-02	-1388E-01	1888E-01
198	83.0000	58.0000	58.0000	-1837E-01	-2302E-01	2488E-01
199	84.0000	0.0000	58.2287	-4780E-08	-4771E-02	4771E-02
200	84.0000	17.0000	58.1870	-4888E-02	-1887E-02	4882E-02
201	84.0000	34.0000	58.8347	-4140E-02	-3888E-02	4878E-02
202	84.0000	42.0000	58.7718	-3847E-02	-4827E-02	5813E-02
203	84.0000	50.0000	58.8818	-2834E-02	-4789E-02	5828E-02
204	84.0000	58.0000	58.0000	-8088E-13	-2488E-01	2488E-01
205	86.0000	0.0000	58.1818	-4888E-02	-3847E-08	4888E-02
206	88.0000	8.5000	58.1844	-4838E-02	-8288E-03	4810E-02
207	88.0000	17.0000	58.1118	-4488E-02	-1888E-02	4788E-02
208	88.0000	25.5000	58.0221	-4228E-02	-2883E-02	4838E-02
209	88.0000	34.0000	58.8948	-3821E-02	-3488E-02	5228E-02
210	88.8333	38.0000	58.8238	-3888E-02	-3888E-02	5402E-02
211	88.8887	42.0000	58.7420	-3424E-02	-4408E-02	5878E-02
212	88.8000	48.0000	58.8480	-2808E-02	-5388E-02	6132E-02
213	88.3333	50.0000	58.8308	-3012E-02	-4888E-02	5801E-02
214	88.1887	54.0000	58.3780	-1821E-02	-1321E-01	1320E-01
215	88.0000	58.0000	58.0000	-1188E-01	-2138E-01	2488E-01
216	88.0000	0.0000	58.1372	-4383E-02	-2348E-08	4383E-02
217	88.0000	17.0000	58.0880	-4283E-02	-1828E-02	4884E-02
218	88.0000	34.0000	58.8888	-3887E-02	-3383E-02	4884E-02
219	87.8774	42.0847	58.7083	-3101E-02	-4283E-02	5272E-02
220	87.3848	50.1083	58.5124	-1281E-02	-5824E-02	5871E-02
221	87.0322	58.1840	58.2378	-1881E-01	-8848E-02	1781E-01
222	80.0000	0.0000	58.0843	-4208E-02	-1088E-08	4208E-02
223	80.0000	8.5000	58.0773	-4181E-02	-7878E-03	4227E-02
224	80.0000	17.0000	58.0288	-4077E-02	-1888E-02	4378E-02
225	80.0000	25.5000	58.8412	-3822E-02	-2430E-02	4824E-02
226	80.0000	34.0000	58.8208	-3488E-02	-3248E-02	4774E-02
227	88.8441	38.0847	58.7833	-3208E-02	-3882E-02	4888E-02
228	88.8881	42.1083	58.8773	-2807E-02	-4088E-02	5028E-02
229	88.8322	48.1840	58.8818	-2188E-02	-4482E-02	4878E-02
230	88.3782	50.2187	58.4888	-1382E-02	-8381E-02	8888E-02
231	88.2203	54.2734	58.3818	-2801E-02	-4118E-02	4818E-02
232	88.0843	58.3280	58.3280	-8210E-02	-7802E-03	8288E-02
233	82.0000	0.0000	58.0833	-4808E-02	-8238E-08	4008E-02
234	82.0000	17.0000	58.8888	-3878E-02	-1883E-02	4178E-02
235	82.0000	34.0000	58.7888	-3283E-02	-3141E-02	4681E-02
236	81.8878	42.1184	58.8483	-2700E-02	-3880E-02	4738E-02
237	81.3788	50.2388	58.4888	-1238E-02	-4874E-02	4738E-02
238	81.0833	58.3881	58.3878	-2720E-02	-8284E-03	2781E-02
239	84.0000	0.0000	58.0141	-3837E-02	-2307E-08	3837E-02
240	84.0000	8.5000	58.8878	-3783E-02	-7888E-03	3880E-02
241	84.0000	17.0000	58.8480	-3708E-02	-1830E-02	4011E-02
242	84.0000	25.5000	58.8880	-3481E-02	-2284E-02	4138E-02
243	84.0000	34.0000	58.7848	-3132E-02	-3037E-02	4382E-02
244	83.8437	38.0837	58.8922	-2884E-02	-3387E-02	4413E-02
245	83.8874	42.1274	58.8228	-2874E-02	-3882E-02	4802E-02
246	83.8311	48.1811	58.8488	-2024E-02	-3788E-02	4271E-02
247	83.3748	50.2848	58.4724	-1700E-02	-3828E-02	4040E-02
248	83.2188	58.3188	58.4088	-1700E-02	-2248E-02	2288E-02
249	83.0822	58.2822	58.3822	-8828E-03	-2333E-03	7213E-03
250	88.0000	0.0000	58.8788	-3848E-02	-4888E-08	3848E-02
251	88.0000	17.0000	58.8130	-3818E-02	-1488E-02	3821E-02
252	88.0000	34.0000	58.7248	-2888E-02	-2838E-02	4188E-02
253	88.8888	42.1221	58.8841	-2480E-02	-3808E-02	4277E-02
254	88.8888	50.2443	58.4838	-1708E-02	-3380E-02	3788E-02
255	88.8884	58.3884	58.3780	-1078E-02	-1488E-03	1088E-02
256	88.0000	0.0000	58.8412	-3478E-02	-7882E-08	3478E-02
257	88.0000	8.5000	58.8284	-3422E-02	-7388E-03	3810E-02
258	88.0000	17.0000	58.8787	-3382E-02	-1482E-02	3888E-02
259	88.0000	25.5000	58.8018	-3114E-02	-2182E-02	3788E-02
260	88.0000	34.0000	58.8888	-2811E-02	-2838E-02	3888E-02
261	88.1881	38.0884	58.8338	-2881E-02	-3087E-02	4024E-02
262	88.3122	42.1188	58.8888	-2380E-02	-3347E-02	4080E-02
263	88.4848	48.1783	58.4888	-2182E-02	-3308E-02	3881E-02
264	88.8244	50.2338	58.4288	-2113E-02	-3232E-02	3881E-02
265	88.7808	54.2822	58.3738	-2432E-02	-1838E-02	3047E-02
266	88.3888	58.3808	58.3808	-2881E-02	-1121E-03	2884E-02
267	100.0000	0.0000	58.9074	-3280E-02	-1218E-04	3280E-02
268	100.0000	17.0000	58.8480	-3188E-02	-1428E-02	3481E-02
269	100.0000	34.0000	58.8888	-2888E-02	-2747E-02	3821E-02
270	100.3117	42.1028	58.8438	-2270E-02	-3281E-02	3888E-02
271	100.8233	50.2088	58.4088	-2288E-02	-3488E-02	4132E-02
272	100.8380	58.3088	58.3178	-4180E-02	-3808E-03	4204E-02
273	102.0000	0.0000	58.8784	-3128E-02	-1810E-04	3128E-02
274	102.0000	8.5000	58.8888	-3087E-02	-7108E-03	3178E-02
275	102.0000	17.0000	58.8888	-3042E-02	-1388E-02	3347E-02
276	102.0000	25.5000	58.7422	-2808E-02	-2027E-02	3481E-02
277	102.0000	34.0000	58.8427	-2821E-02	-2888E-02	3884E-02
278	102.1888	38.0448	58.8848	-2338E-02	-2908E-02	3730E-02
279	102.3111	42.0880	58.8218	-2183E-02	-3188E-02	3832E-02
280	102.4887	48.1338	58.4840	-2208E-02	-3302E-02	3970E-02
281	102.8222	50.1780	58.3848	-2284E-02	-3731E-02	4388E-02
282	102.7778	54.2228	58.3102	-4408E-02	-2738E-02	5188E-02
283	102.8333	58.2871	58.2870	-5914E-02	-4138E-03	5928E-02
284	104.0000	0.0000	58.8481	-2831E-02	-3140E-04	2831E-02
285	104.0000	17.0000	58.7888	-2880E-02	-1382E-02	3188E-02
286	104.0000	34.0000	58.8182	-2378E-02	-2874E-02	3808E-02
287	104.3222	42.0448	58.8008	-2081E-02	-3073E-02	3700E-02
288	104.8444	50.8880	58.8808	-2482E-02	-3893E-02	4387E-02
289	104.8887	58.1338	58.1814	-1338E-01	-3723E-02	1388E-01
290	108.0000	0.0000	58.8188	-2783E-02	-8084E-04	2783E-02
291	108.0000	8.5000	58.8008	-2778E-02	-8888E-03	2884E-02

283	108 0000	28 8000	88 8888	- 2518E-02	- 1808E-02	3180E-02
284	108 0000	34 0000	88 8881	- 2280E-02	- 2482E-02	3387E-02
285	108 1887	38 0000	88 8408	- 2076E-02	- 2482E-02	3448E-02
286	108 3333	42 0000	88 4814	- 1891E-02	- 2887E-02	3618E-02
287	108 8000	48 0000	88 4182	- 1839E-02	- 3511E-02	3883E-02
288	108 8887	80 0000	88 3380	- 1488E-02	- 3008E-02	3347E-02
289	108 8333	84 0000	88 2617	- 3788E-02	- 8282E-02	8103E-02
300	107 0000	88 0000	88 0000	- 8243E-02	- 1388E-01	1881E-01
301	108 0000	0 0000	88 7803	- 2528E-02	- 8047E-04	2528E-02
302	108 0000	17 0000	88 7308	- 2588E-02	- 1282E-02	2801E-02
303	108 0000	34 0000	88 6734	- 2114E-02	- 2414E-02	3209E-02
304	108 0000	42 0000	88 4883	- 1771E-02	- 2800E-02	3388E-02
305	108 0000	80 0000	88 3286	- 1371E-02	- 2840E-02	3244E-02
306	108 0000	88 0000	88 0000	- 1137E-12	- 1488E-01	1488E-01
307	110 0000	0 0000	88 7882	- 2337E-02	- 1830E-03	2342E-02
308	110 0000	8 8000	88 7478	- 2488E-02	- 7180E-03	2671E-02
309	110 0000	17 0000	88 7084	- 2481E-02	- 1282E-02	2788E-02
310	110 0000	28 8000	88 8408	- 2280E-02	- 1788E-02	2878E-02
311	110 0000	34 0000	88 8528	- 1888E-02	- 2338E-02	3072E-02
312	108 8333	38 0000	88 8082	- 1822E-02	- 2888E-02	3174E-02
313	108 8887	42 0000	88 4818	- 1888E-02	- 2423E-02	3274E-02
314	108 8000	48 0000	88 3822	- 1382E-02	- 3528E-02	3824E-02
315	108 3333	80 0000	88 3187	- 1407E-02	- 3022E-02	3333E-02
316	108 1887	84 0000	88 2282	- 1288E-02	- 7838E-02	8042E-02
317	108 0000	88 0000	88 0000	- 7281E-02	- 1288E-01	1478E-01
318	112 0000	0 0000	88 7448	- 1837E-02	- 2677E-03	1860E-02
319	112 0000	17 0000	88 8817	- 2308E-02	- 1182E-02	2588E-02
320	112 0000	34 0000	88 8338	- 1883E-02	- 2280E-02	2829E-02
321	111 8782	42 0341	88 4388	- 1480E-02	- 2738E-02	3118E-02
322	111 8883	50 0883	88 3131	- 4188E-03	- 3373E-02	3388E-02
323	111 0348	88 1024	88 1483	- 1024E-01	- 3878E-02	1088E-01
324	114 0000	0 0000	88 7278	- 1831E-02	- 8688E-03	1823E-02
325	114 0000	8 8000	88 8888	- 2271E-02	- 8018E-03	2408E-02
326	114 0000	17 0000	88 8883	- 2238E-02	- 1132E-02	2808E-02
327	114 0000	28 8000	88 8880	- 2008E-02	- 1881E-02	2824E-02
328	114 0000	34 0000	88 8188	- 1780E-02	- 2188E-02	2878E-02
329	113 8448	38 0381	88 4708	- 1888E-02	- 2408E-02	2878E-02
330	113 8887	42 0883	88 4210	- 1387E-02	- 2837E-02	2884E-02
331	113 3388	48 1024	88 3887	- 8884E-03	- 2617E-02	2877E-02
332	113 3784	80 1388	88 3088	- 8308E-03	- 3284E-02	3338E-02
333	113 2242	84 1707	88 2440	- 1784E-02	- 2818E-02	3078E-02
334	113 0880	88 2048	88 2048	- 3442E-02	- 8313E-03	3482E-02
335	118 8282	1 8884	88 7040	- 2837E-02	- 7837E-03	2848E-02
336	118 8282	17 8803	88 8342	- 2123E-02	- 1187E-02	2422E-02
337	118 8282	34 1812	88 4881	- 1848E-02	- 2132E-02	2888E-02
338	118 8180	42 1848	88 4072	- 1288E-02	- 2830E-02	2840E-02
339	118 2087	80 2088	88 3034	- 4418E-03	- 2887E-02	2801E-02
340	114 8018	88 2222	88 2288	- 1887E-02	- 4218E-03	2041E-02
341	117 8824	3 1888	88 8881	- 3038E-02	- 3118E-03	3081E-02
342	117 8824	10 8887	88 8481	- 1888E-02	- 7881E-03	2288E-02
343	117 8824	18 7888	88 8102	- 1880E-02	- 1202E-02	2288E-02
344	117 8824	28 8718	88 8844	- 1772E-02	- 1880E-02	2422E-02
345	117 8824	34 3824	88 4818	- 1884E-02	- 2080E-02	2888E-02
346	117 4883	38 3418	88 4387	- 1387E-02	- 2248E-02	2848E-02
347	117 3482	42 3218	88 3842	- 1227E-02	- 2428E-02	2721E-02
348	117 1832	48 3010	88 3483	- 8123E-03	- 2438E-02	2800E-02
349	117 0401	80 2808	88 2887	- 4770E-03	- 2447E-02	2483E-02
350	118 8871	84 2801	88 2888	- 2232E-03	- 1441E-02	1488E-02
351	118 7340	88 2388	88 2410	- 7818E-03	- 1838E-03	7788E-03
352	118 8282	1 8884	88 8388	- 2028E-02	- 2284E-02	2041E-02
353	118 8282	17 8803	88 8848	- 1888E-02	- 1118E-02	2188E-02
354	118 8282	34 1812	88 4872	- 1482E-02	- 2004E-02	2474E-02
355	118 8284	42 1888	88 3808	- 1188E-02	- 2314E-02	2883E-02
356	118 8307	80 2188	88 2808	- 2188E-02	- 2188E-02	2318E-02
357	118 8328	88 2323	88 2431	- 4828E-03	- 8800E-04	4833E-03
358	122 0000	0 0000	88 8214	- 1118E-02	- 8611E-04	1121E-02

359	122 0000	8 8000	88 8117	- 1782E-02	- 4888E-03	1848E-02
360	122 0000	17 0000	88 8787	- 1782E-02	- 1021E-02	2037E-02
361	122 0000	28 8000	88 8284	- 1880E-02	- 1483E-02	2183E-02
362	122 0000	34 0000	88 4837	- 1388E-02	- 1833E-02	2382E-02
363	122 1883	38 0378	88 4123	- 1888E-02	- 2072E-02	2413E-02
364	122 3108	42 0787	88 3881	- 1117E-02	- 2228E-02	2480E-02
365	122 4888	48 1138	88 3224	- 1088E-02	- 2182E-02	2428E-02
366	122 8212	80 1814	88 2783	- 1070E-02	- 2130E-02	2384E-02
367	122 7788	84 1824	88 2424	- 1348E-02	- 1218E-02	1818E-02
368	122 8318	88 2271	88 2270	- 8748E-02	- 1188E-03	1878E-02
369	123 4828	1 8884	88 8114	- 1884E-02	- 2887E-03	1713E-02
370	123 4828	17 8803	88 8828	- 1833E-02	- 1040E-02	1838E-02
371	123 4828	34 1812	88 4421	- 1282E-02	- 1801E-02	2283E-02
372	123 8008	42 1808	88 3888	- 1088E-02	- 2187E-02	2480E-02
373	124 1088	80 2008	88 2883	- 1181E-02	- 2284E-02	2638E-02
374	124 4187	88 2102	88 2122	- 2288E-02	- 2287E-02	2280E-02
375	124 8880	3 1888	88 8820	- 2278E-02	- 8888E-04	2277E-02
376	124 8880	10 8887	88 8782	- 1888E-02	- 8880E-03	1788E-02
377	124 8880	18 7888	88 8481	- 1888E-02	- 1088E-02	1888E-02
378	124 8880	28 8718	88 4884	- 1383E-02	- 1478E-02	2028E-02
379	124 8880	34 3824	88 4311	- 1214E-02	- 1870E-02	2230E-02
380	128 1377	38 2342	88 3817	- 1122E-02	- 2014E-02	2308E-02
381	128 2808	42 3080	88 3484	- 1031E-02	- 2188E-02	2402E-02
382	128 4433	48 2778	88 3048	- 1102E-02	- 2208E-02	2488E-02
383	128 8880	80 2487	88 2800	- 1208E-02	- 2372E-02	2882E-02
384	128 7488	84 2218	88 2183	- 2322E-02	- 1887E-02	2813E-02
385	128 8018	88 1834	88 1834	- 2888E-02	- 2834E-04	2870E-02
386	127 4828	1 8884	88 8627	- 1823E-02	- 3882E-03	1884E-02
387	127 4828	17 8803	88 8321	- 1418E-02	- 9811E-03	1731E-02
388	127 4828	34 1812	88 4182	- 1108E-02	- 1808E-02	2118E-02
389	127 8118	42 1820	88 3383	- 8888E-03	- 2118E-02	2324E-02
390	128 1312	80 1248	88 2488	- 1153E-02	- 2488E-02	2780E-02
391	128 4888	88 0887	88 1372	- 7888E-02	- 2033E-02	7828E-02
392	130 0000	0 0000	88 8484	- 8811E-03	- 3880E-03	1028E-02
393	130 0000	8 8000	88 8480	- 1278E-02	- 3088E-03	1311E-02
394	130 0000	17 0000	88 8184	- 1288E-02	- 8180E-03	1880E-02
395	130 0000	28 8000	88 4721	- 1148E-02	- 1327E-02	1783E-02
396	130 0000	34 0000	88 4088	- 1001E-02	- 1748E-02	2012E-02
397	130 1887	38 0000	88 3883	- 8178E-03	- 1813E-02	2122E-02
398	130 3333	42 0000	88 3288	- 8307E-03	- 2080E-02	2221E-02
399	130 8000	48 0000	88 2637	- 8388E-03	- 2411E-02	2882E-02
400	130 8887	80 0000	88 2307	- 8888E-03	- 2148E-02	2244E-02
401	130 8333	84 0000	88 1838	- 2238E-02	- 8874E-02	8088E-02
402	131 0000	88 0000	88 0000	- 8708E-02	- 8140E-02	1078E-01
403	132 0000	0 0000	88 8388	- 8788E-02	- 1787E-02	8878E-02
404	132 0000	17 0000	88 8074	- 1153E-02	- 8828E-03	1448E-02
405	132 0000	34 0000	88 3971	- 8081E-03	- 1708E-02	1834E-02
406	132 0000	42 0000	88 3280	- 7838E-02	- 2027E-02	2182E-02
407	132 0000	80 0000	88 2271	- 8014E-03	- 2088E-02	2144E-02
408	132 0000	88 0000	88 0000	- 1137E-12	- 1008E-01	1008E-01
409	134 0000	0 0000	88 8278	- 8288E-03	- 8138E-04	8243E-03
410	134 0000	8 8000	88 8221	- 1027E-02	- 3888E-03	1091E-02
411	134 0000	17 0000	88 4888	- 1084E-02	- 8821E-03	1383E-02
412	134 0000	28 8000	88 4811	- 8478E-03	- 1272E-02	1888E-02
413	134 0000	34 0000	88 3884	- 8277E-03	- 1888E-02	1883E-02
414	133 8333	38 0000	88 3840	- 7488E-03	- 1842E-02	1888E-02
415	133 8887	42 0000	88 3180	- 8783E-03	- 1888E-02	2100E-02
416	133 8000	48 0000	88 2737	- 8108E-03	- 2384E-02	2408E-02
417	133 3333	80 0000	88 2228	- 8821E-03	- 2102E-02	2181E-02
418	133 1887	84 0000	88 1878	- 1228E-02	- 8818E-02	8880E-02
419	133 0000	88 0000	88 0000	- 8240E-02	- 8812E-02	8878E-02
420	138 0000	0 0000	88 8180	- 8888E-03	- 8378E-04	8878E-03
421	138 0000	17 0000	88 4888	- 8433E-03	- 8383E-03	1280E-02
422	138 0000	34 0000	88 3808	- 7388E-03	- 1838E-02	1788E-02
423	138 8788	42 0248	88 3088	- 8838E-03	- 1862E-02	2031E-02
424	138 8788	88 0248	88 3088	- 8838E-03	- 1862E-02	2031E-02

426	136 0288	88 0747	88 1084	7439E-02	2802E-02	7881E-02
428	138 0000	0 0000	88 1107	8082E-03	2888E-04	8087E-03
427	132 0000	8 5000	88 8031	8350E-03	3888E-03	9208E-03
428	138 0000	17 0000	88 4778	8467E-03	8228E-03	1180E-02
428	138 0000	25 8000	88 4338	7818E-03	1224E-02	1442E-02
430	138 0000	34 0000	88 3738	8830E-03	1804E-02	1738E-02
431	137 8482	38 0248	88 3404	8838E-03	1748E-02	1843E-02
432	137 8804	42 0488	88 3041	8030E-03	1907E-02	1872E-02
433	137 8388	48 0747	88 2847	2838E-03	2018E-02	2034E-02
434	137 3808	80 0897	88 2233	1838E-08	2328E-02	2328E-02
435	137 2280	84 1248	88 1778	1832E-02	1774E-02	2368E-02
436	137 0712	88 1488	88 1488	2701E-02	3848E-03	2728E-02
437	140 0000	0 0000	88 8031	7181E-03	1884E-04	7183E-03
438	140 0000	17 0000	88 4887	7382E-03	8138E-03	1089E-02
439	140 0000	34 0000	88 3874	8810E-03	1878E-02	1878E-02
440	138 8802	42 0882	88 2888	4322E-03	1880E-02	1888E-02
441	138 3804	80 1104	88 2238	3370E-04	2034E-02	2034E-02
442	138 0708	88 1888	88 1711	1810E-02	2781E-03	1833E-02
443	142 0000	0 0000	88 4883	8388E-03	8172E-08	8388E-03
444	142 0000	8 5000	88 4881	8488E-03	3932E-03	7888E-03
445	142 0000	17 0000	88 4828	8488E-03	8081E-03	1032E-02
446	142 0000	28 8000	88 4303	8838E-03	1187E-02	1232E-02
447	142 0000	34 0000	88 3820	8088E-03	1881E-02	1832E-02
448	141 8480	38 0303	88 3388	4834E-03	1870E-02	1730E-02
449	141 8800	42 0808	88 2884	3820E-03	1788E-02	1842E-02
450	141 8380	48 0808	88 2892	2480E-03	1787E-02	1803E-02
451	141 3800	80 1211	88 2238	2820E-04	1770E-02	1770E-02
452	141 2248	84 1814	88 1843	3788E-03	1031E-02	1088E-02
453	141 0888	88 1818	88 1818	8888E-03	8847E-04	8888E-03
454	144 0000	0 0000	88 4804	8478E-03	8188E-08	8477E-03
455	144 0000	17 0000	88 4888	8488E-03	7888E-03	8862E-03
456	144 0000	34 0000	88 3873	4348E-03	1830E-02	1881E-02
457	144 0000	42 0888	88 2811	3488E-03	1784E-02	1788E-02
458	143 8888	80 1188	88 2220	2378E-03	1881E-02	1878E-02
459	143 8888	88 1888	88 1888	1814E-03	7887E-04	1888E-03
460	148 0000	0 0000	88 4883	4888E-03	2413E-08	4888E-03
461	148 0000	8 5000	88 4770	4888E-03	3928E-03	6040E-03
462	148 0000	17 0000	88 4819	4840E-03	7948E-03	8182E-03
463	148 0000	28 8000	88 4102	4137E-03	1181E-02	1232E-02
464	148 0000	34 0000	88 3833	3847E-03	1813E-02	1887E-02
465	148 1880	38 0288	88 3214	3348E-03	1824E-02	1888E-02
466	148 3100	42 0881	88 2873	3088E-03	1744E-02	1771E-02
467	148 4848	48 0888	88 2818	3470E-03	1718E-02	1783E-02
468	148 8188	80 1181	88 2178	4484E-03	1888E-02	1743E-02
469	148 7748	84 1477	88 1887	7288E-02	8732E-03	1222E-02
470	148 8288	88 1772	88 1772	8718E-03	8381E-04	8782E-03
471	148 0000	0 0000	88 4812	3888E-03	1008E-08	3888E-03
472	148 0000	17 0000	88 4478	3800E-03	7802E-03	8882E-03
473	148 0000	34 0000	88 3800	2832E-03	1801E-02	1828E-02
474	148 3087	42 0830	88 2844	2732E-03	1748E-02	1788E-02
475	148 8118	80 1081	88 2128	8172E-03	1874E-02	1844E-02
476	148 8282	88 1881	88 1841	1813E-02	2428E-03	1828E-02
477	180 0000	0 0000	88 4740	2788E-03	7738E-07	2788E-03
478	180 0000	8 5000	88 4887	2744E-03	3911E-03	4778E-03
479	180 0000	17 0000	88 4447	2700E-03	7888E-03	8318E-03
480	180 0000	28 8000	88 4038	2478E-03	1148E-02	1171E-02
481	180 0000	34 0000	88 3474	2210E-03	1482E-02	1808E-02
482	180 1848	38 0238	88 3160	2181E-03	1818E-02	1832E-02
483	180 3088	42 0470	88 2820	2122E-03	1788E-02	1788E-02
484	180 4843	48 0708	88 2484	3848E-03	1838E-02	1873E-02
485	180 8180	80 0840	88 2074	4878E-03	2048E-02	2148E-02
486	180 7738	84 1178	88 1881	1817E-02	1888E-02	2488E-02
487	180 8288	88 1418	88 1418	2782E-02	3342E-03	2812E-02
488	182 0000	0 0000	88 4787	1837E-03	4838E-08	1837E-03
489	182 0000	17 0000	88 4428	1780E-03	7840E-03	8041E-03
490	182 0000	34 0000	88 3488	1482E-03	1488E-02	1483E-02

491	182 3214	42 0238	88 2802	1830E-03	1787E-02	1784E-02
492	182 8428	80 0470	88 2013	8024E-03	2881E-02	2188E-02
493	182 8842	88 0708	88 0877	7808E-02	2807E-02	7378E-02
494	184 0000	0 0000	88 4742	8228E-04	8248E-08	8228E-04
495	184 0000	8 5000	88 4880	8128E-04	3900E-03	4008E-03
496	184 0000	17 0000	88 4412	8880E-04	7824E-03	7878E-03
497	184 0000	28 8000	88 4003	8240E-04	1138E-02	1141E-02
498	184 0000	34 0000	88 3444	7412E-04	1481E-02	1483E-02
499	184 1887	38 0000	88 3134	7120E-04	1830E-02	1832E-02
500	184 3333	42 0000	88 2781	8422E-04	1748E-02	1780E-02
501	184 8000	48 0000	88 2418	1332E-03	2087E-02	2071E-02
502	184 8887	80 0000	88 1882	3088E-04	1782E-02	1782E-02
503	184 8333	84 0000	88 1387	1448E-02	4848E-02	8087E-02
504	188 0000	88 0000	88 0000	4880E-02	7888E-02	8372E-02
505	188 0000	0 0000	88 4740	4882E-04	1044E-08	4884E-04
506	188 0000	17 0000	88 4408	4483E-04	7822E-02	7838E-03
507	188 0000	34 0000	88 3442	3232E-04	1482E-02	1482E-02
508	188 1887	42 0000	88 2780	1888E-04	1788E-02	1788E-02
509	188 3333	80 0000	88 1887	8821E-04	1728E-02	1730E-02
510	188 8000	88 0000	88 0000	2728E-12	8788E-02	8788E-02
511	188 0000	0 0000	88 4738	1308E-08	1111E-08	1114E-08
512	188 0000	8 5000	88 4888	1048E-08	3888E-03	3888E-03
513	188 0000	17 0000	88 4407	4220E-08	7821E-03	7821E-03
514	188 0000	28 8000	88 3888	1888E-08	1137E-02	1137E-02
515	188 0000	34 0000	88 3441	3088E-07	1483E-02	1483E-02
516	188 0000	38 0000	88 3130	1788E-08	1828E-02	1828E-02
517	188 0000	42 0000	88 2780	2888E-08	1788E-02	1788E-02
518	188 0000	48 0000	88 2408	2018E-04	3082E-02	2083E-02
519	188 0000	80 0000	88 1888	8438E-04	1778E-02	1780E-02
520	188 0000	84 0000	88 1388	1197E-03	4822E-02	4822E-02
521	188 0000	88 0000	88 0000	3188E-04	8888E-02	8888E-02

SEEPAGE FACE COMPUTATION RESULTS

NB = 88	NE = 112	AVE. VEL = .81200E-01	DS = .20000E+01	DQ = .10240E+00
TOTAL DISCHARGE = .10240E+00				
NB = 112	NE = 188	AVE. VEL = .28107E-01	DS = .22000E+02	DQ = .83838E+00
TOTAL DISCHARGE = .84078E+00				
NB = 188	NE = 218	AVE. VEL = .28382E-01	DS = .20000E+01	DQ = .82704E-01
TOTAL DISCHARGE = .88348E+00				
NB = 218	NE = 300	AVE. VEL = .20481E-01	DS = .22000E+02	DQ = .48088E+00
TOTAL DISCHARGE = .14440E+01				
NB = 300	NE = 317	AVE. VEL = .18848E-01	DS = .20000E+01	DQ = .31288E-01
TOTAL DISCHARGE = .14783E+01				
NB = 317	NE = 402	AVE. VEL = .12784E-01	DS = .22000E+02	DQ = .28128E+00
TOTAL DISCHARGE = .17888E+01				
NB = 402	NE = 418	AVE. VEL = .10883E-01	DS = .20000E+01	DQ = .21188E-01
TOTAL DISCHARGE = .17778E+01				
NB = 418	NE = 504	AVE. VEL = .88810E-02	DS = .22000E+01	DQ = .21738E+00
TOTAL DISCHARGE = .18881E+01				
NB = 504	NE = 521	AVE. VEL = .80187E-02	DS = .10000E+01	DQ = .80187E-02
TOTAL DISCHARGE = .20042E+01				

SP=28 K = 2.0 D = 20 FT. END OF PROBLEM.

END

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DTIC