THREE DIMENSIONAL FEM ANALYSIS OF SUB-SURFACE FLOW UNDER DRAINAGE BARREL

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT
(CIVIL)

By

BHARTI CHAWRE

WATER RESOURCES DEVELOPMENT TRAINING CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

JUNE, 2004

CANDIDATES'S DECLRATION

I hereby declare that the work presented in this dissertation entitled, **"THREE DIMENSIONAL FEM ANALYSIS OF SUB-SURFACE FLOW UNDER DRAINAGE BARREL"** in partial fulfillment of the requirement for the award of Degree of Master of Technology in Water Resources Development (Civil) submitted in the Department of WRDTC, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out since July 2003 to June, 2004 under the supervision of **Dr. Ram Pal Singh**, Professor and **Dr. B. N. Asthana** , Visiting Professor at WRDTC, IIT, Roorkee.

The matter embodied in this dissertation has not been submitted by me for award of any other degree.

Dated: June 27, 2004

(BHARTI CHAWRE)

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(Dr. RAM PAL SINGH)
Professor,
Water Resources Development
Training Centre
Indian Institute of Technology
Roorkee – India, 247667

(Dr. B. N. ASTHANA)
Visiting Professor,
Water Resources Development
Training Centre
Indian Institute of Technology
Roorkee – India, 247667

ACKNOWLEDGEMENT

It is my proud privilege to express the deep sense of gratitude to **Dr. Ram Pal Singh**, Professor and **Dr. B.N. Asthana**, Visiting Professor, WRDTC for their expert guidance, continuous encouragement and valuable suggestions in the preparation of this dissertation.

I also acknowledge with the thanks, the advice and inspiration I received from other Faculty Members of Water Recourses Development Training Center during this study.

I would like to thank all the staffs of WRDTC for their help and co-operation during the studies.

I m very much grateful to Central Soil & Materials Research Station, New Delhi, Govt. of India for nominating me to avail this opportunity of higher study in Water Resources Development.

At last I would like to thank my parents and friends which gave me moral support and encouragement during this study.

(BHARTI CHAWRE)

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOL

SYMBOLS	DETIALS
V	Velocity
H	Head
L	Length of Flow Path
K	Coefficient of permeability
Q	Discharge
Φ	Potential at any Point
i	Hydraulic Gradient
u/s	up stream
d/s	down stream
G_e	Exit Gradient
d	Depth of cut-off
FEM	Finite Element Method
EHDA	Elector-hydro Dynamic Analogues
EAM	Electrical Analogy Method
FEA	Finite Element Analysis

SYNOPSIS

Practically every hydraulic structure has to face the problem of seepage beneath it. The major works constructed in India on alluvial rivers in the 19^{th} century were mainly designed on experience as no rational theory of seepage had been worked out by then. In the case of hydraulic structures constructed like weir and barrage across wide streams where the width of the floor is considerably greater than its length, flow pattern is two dimensional. In the case where the width/length ratio of the structure is small, the seepage flow will be markedly thee dimensional. The correct approach in the estimation of the uplift below the hydraulic structures built on the porous media appears to be the one that treat the seepage flow to be three dimensional. Seepage in a three dimensional flow net will occur in accordance with the Laplace Equation in three dimensions ($\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} = 0$) with the imposed boundary conditions. There is no analytical solution for the 3-dimensional seepage for complex conditions of the boundary. A solution may be obtained by the method of relaxation but it is very laborious and intricate for the three dimensional case. For a reliable estimation of the seepage pressure under the floor, model studies of geometrically similar models or electrically analogy models are the only expeditious methods.

The present study is concerned with seepage analysis to know the pattern of uplift pressure under a hydraulic structure built in the river with high water table on the banks. The finite Element Method using ANSYS package is used for

1. Uplift pressure, exit gradient and elevation of HG Line for the Drainage Crossing at km 7.125 of BAN SAGAR FEEDER CHANNEL, MIRJAPUR, U. P. (case study), and comparison of these results with the EHDA (Electro Hydro Dynamic Analogues Technique) results of IRI, Roorkee.
2. Uplift pressure and exit gradient under the drainage barrel for varying length of lining of canals and depth of cut off for three test cases:

   1. Higher Canal lined and lower unlined,

   2. Both canals lined, and

   3. Both canals unlined.

When the both canals are unlined the flow pattern is conform to two dimensional and the results of analysis of third case have been compared with the case no 1 and 2.

In this study an assumption is made that the water table is at the level of the drainage bed. The method of analysis duly account for the three dimensional seepage based on Darcy's law. Uplift pressure distribution along the base of the floor and the Exit gradient the u/s & d/s cut off have been evaluated and plotted.

Based on the analysis uplift pressure distribution curves for different length of lining have been developed for each test cases for different depth of cut off. Similarly Exit gradient variation curve also plotted for the same cases. This study shows that the uplift pressure and exit gradient significantly effected by the lining, depth of cut off. Lining length is effective for reduce the uplift pressure and cut off depth play a significant role for reducing Exit gradient to safeguard the hydraulic structure against undermining.

The computer software ANSYS has now made possible this complex analysis. The finite element method is one such powerful numerical tool which enables us to incorporate intrinsic conditions with idealized assumptions.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND FOR THE STUDY

Throughout recorded history there is evidence that mankind has feared and respected the destructive power of water. Out in the open, in the form of tides and floods, it is one of the most powerful forces of the nature. Hidden in rock crevices and soil pores, it exerts unbelievable forces that tear down mountainsides and destroy engineering works. Railroad engineers, highway people, dam designers and builders and many others have long known of the great importance of controlling water in pores and cracks in earth and rock formations. When ground water and seepage are uncontrolled, they can cause serious economic losses and take many human lives. Controlled, they need not be feared.

Most of the problems of ground water hydraulics relate to the seepage of ground water through porous media. Study of seepage is important not only from the point of ground water development but also from the point of view of design of hydraulic structures, where water seeping below the floors causes not only loss of water but uplift pressure on the impervious floors of structures.

Practically every hydraulic structure that is not founded on solid rock has to face the problem of seepage beneath it. The flow of water through the sub soil with its attendant hydraulic gradients and uplift pressure plays a major and important role in the design of hydraulic structures resting on the porous media. Seepage endangers the stability of the work in two ways namely piping or under mining and by uplift pressures. For the hydraulic structures to be safe against these two factors the uplift pressure on the floor and the exit gradient at the toe of the structure should be within safe limits. Taking into account, the conception of failure by undermining and uplift due to the flow of water below the structure through the sub soil a rational theory of design of weirs on permeable foundations was developed by Khosla (10).

The present day practice of the designers is to treat all the sub soil flow problems under hydraulic structures as only two-dimensional. There is an inherent lacuna in this approach as in a large number of cases the seepage flow is generally 3-dimensional rather than 2-dimensional except in the case of wide structures.

For the cross drainage work flow will take place as a three dimensional flow net in accordance with Laplacian equation and the imposed conditions. For these types of hydraulic structures, no approximation to a two dimensional case is possible as there is no typical plane across which there is no flow (compared with weirs, barrage etc). A solution may be obtained by the "method of relaxation" but this is very laborious and intricate for three dimensional cases. For reliable estimate of seepage pressure, model studies on the geometrically similar models or electrical analogy models are the only expeditious methods.

1.2 SCOPE OF THE STUDY

The object of the study is to assess the influence of length of lining of the canal on the hydrostatic uplift pressure below a drainage barrel floor, in addition to finding out the exit gradient near the u/s & d/s cut off, using FEM. The definition sketch of the seepage model in this study is shown in fig 1.1; it is a drainage barrel under the Ban Sagar Main Canal.

In this study, FEM (ANSYS Package) is used to analyze flow conditions under different conditions and the results have been complied and presented in the form of charts and tables. The results have also been compared with available results from the electrical analogy technique used by IIR Roorkee.

1.3 ORGANISATION OF THE STUDY

The study is presented in five chapters. The content of each chapters in brief are given below:

Chapter 1 : Gives an introduction to the subject, objectives and scope of study and organization of dissertation report.

Chapter 2 : Gives the brief literature review.

Chapter 3 : Gives basic of FEM and its application in seepage flow.

Chapter 4 : Gives details of three dimensional seepage model and basic process of ANSYS package.

Chapter 5 : Results and analysis part is discussed in this chapter. This chapter is divided into two parts in which first part shows the results of seepage analysis by FEM of Drainage Crossing at km7.125 of Ban Sagar Canal Feeder Channel, Mirzapur U.P, and comparison of these results with the

Electrical Analogy Results of IRI Roorkee, part two deals with the determination of uplift pressure and exit gradient for different lengths of canal lining for different cases and the comparison of 2- d & 3 – results.

Chapter 6 : Contains conclusions, recommendations and suggestion for further studies.

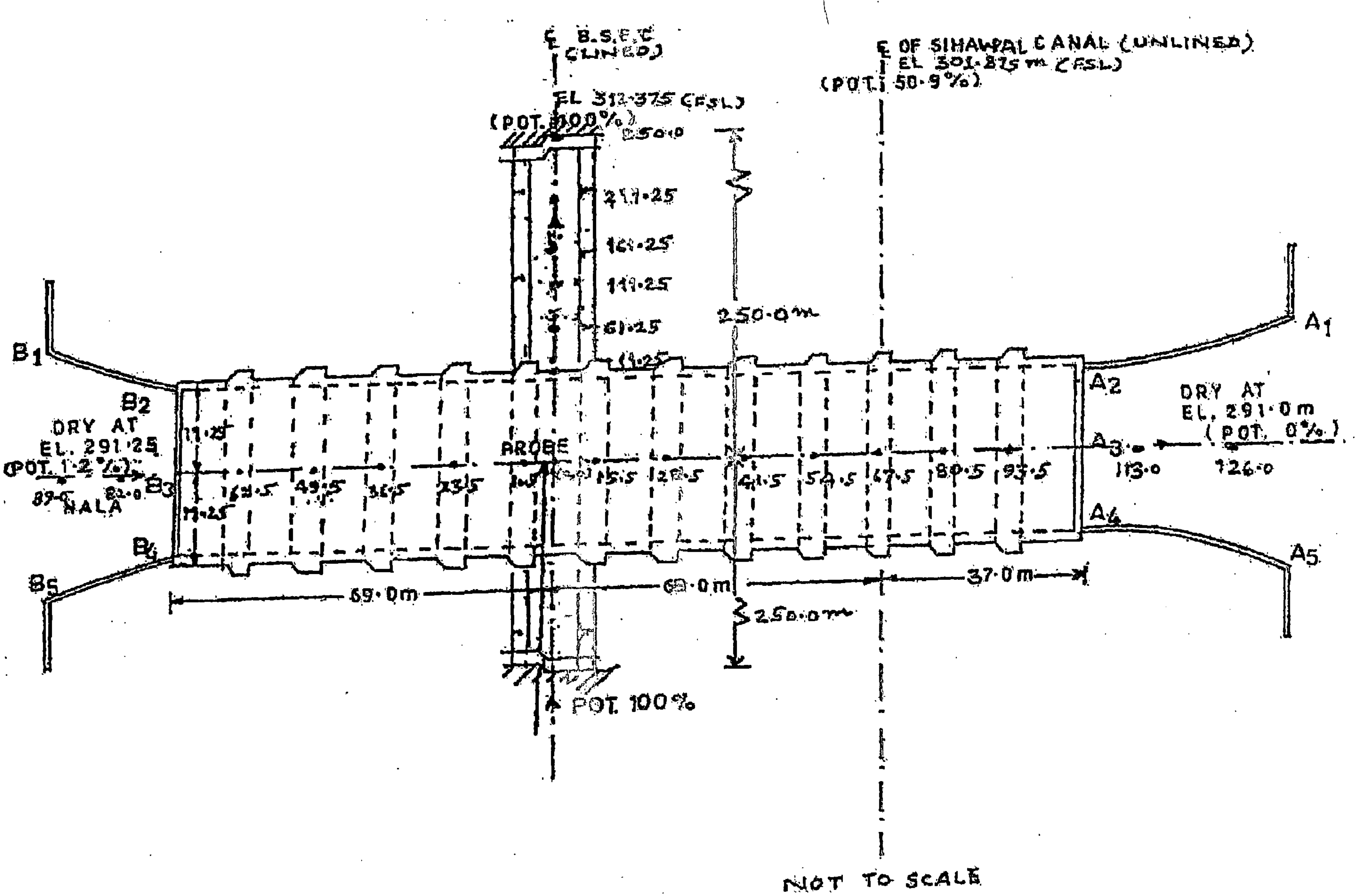


FIG. 1.1 SCHEMATIC LINE DIAGRAM OF DRAINAGE CROSSING AT km 7.125 OF BAN SAGAR FEEDER CHANNEL MIRZAPUR (U.P)

CHAPTER 2

.LITERATURE REVIEW

2.1 GENERAL

The design of hydraulic structures founded on permeable soils presents problems of complex nature in respect of determination of uplift pressures and exist gradient. The floors are subjected to uplift pressures due to seepage from the bed of the canal to the bed of the drainage. This condition will be most severe when the canal is at F. S. L. and drainage is dry with water at its bed level. In the other case with canal water passing through the barrels under the drainage bed the floor is subjected to uplift pressures due to seepage from the drainage bed to the bed of the canal. The worst condition on this case would occur when the river is in the high flood and the canal is empty.

In addition to the uplift pressures below these structures the value of the exit gradient at the end of the structure has to be taken into account to ensure safety against piping. Thus the failure of hydraulic structure from seepage flow can occur because of:-

a. Uplift pressure under the floor being in excess of the weight on the floor, and
b. Undermining of the subsoil by sub surface erosion

2.2 UPLIFT PRESSURE

a. Water seeps through the sub soil beneath the structure and loses head gradually along the passage till it emerges at the exit. The head is reduced to zero. Thus at each point under the floor of the structure the water has a certain residual pressure depending on pressure gradient, (the rate of which the pressure head is being dissipated). The pressure gradient at any point also represents the force which the sub soil water exerts on soil in direction of flow. Uplift in this case will be maximum when canal is at F.S.L. and no water in the drain. Seepage flow will be three dimensional and hence will follow the Laplacian equation in three dimensions

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0$$

where x, y, z are three space axes and Φ is the pressure function at that point, which satisfies the differential equation. The value of Φ is to be determined by a solution of the differential equation such that it satisfies the boundary conditions for a particular problem. There is no analytical solution for the 3 – d seepage for complex conditions of the boundary, and Khosla's (10) method is applicable for 2-D flow. For reliable estimation of seepage pressures under the floors, model studies on geometric similar models or electrical analogy models are the only expeditious methods.

2.3 EXIT GRADIENT

At each point of the seepage path, there is residual pressure carried by the seepage water. This pressure reduces towards the d/s direction. Hence, there acts a pressure gradient on the flow line. This pressure gradient exerts uplift on the soil particles at the exit end and tries to lift them. The pressure gradient at the exit end is known as the Exit Gradient.

When this exit gradient is more than a certain limiting value, the subsurface erosion starts at the tail end and moves upstream below the structure progressively. This phenomenon is known as critical exit gradient.

The concept of undermining was first put forward by the Terzaghi (7) in 1925 and independently arrived by FF Haigh in 1930. Darcy's Law of flow of water through subsoil states

$$V = K \frac{H}{L}$$

Where V = velocity of flow,

L = length of the path of flow

K = A constant called the 'transmission constant' or 'Hydraulic conductivity".

Consider the element of the soil, the various forces acting on it are:-

I. Submerge weight of the particle acting downwards; and

II. The force acting on the particles due to pressure gradient in the direction of flow.

The submerge unit weight of the particles would be given by the relation

$$\gamma_b = (G - 1)(1 - \eta)\gamma_w \qquad (2.1)$$

Where, G = specific gravity of soil grain,

η = porosity, and

γ_w= unit weight of water.

Downward force $= (G-1)(1-\eta)\gamma_w$ (per unit volume)

Seepage force in the direction of flow

$$= p.a - (p + dp)a$$
$$= -dp.a$$

Force per unit vol. $= \frac{dp.a}{a.dl}$

$$= -\frac{dp}{dl}$$

The force is +ve whereas dp/dl is negative as 'p' decreases in the direction of l. This force acts upward at the exit and as the stream line at the tail and emerges vertically.

For critical condition to be reached, the upward seepage force $-dp/dl$ on unit volume of soil will just balance γ_b, therefore

$$-\frac{dp}{dl} = \gamma_w (G-1)(1-\eta) \qquad (2.2)$$

or $$-\frac{dh}{dl} = (G-1)(1-\eta) \qquad (2.3)$$

Here dh/dl represents the rate of loss of head, or the gradient at the Exit end (Ge). Taking value of G= 2.65, n = 0.4 for normal sands, the

Critical Ge = (1- 0.4) (2.65 - 1)

= 0.6* 1.65

= 1.0

2.4 FACTOR OF SAFETY

It is most important to keep exit gradient less than unity to make the structure safe against the effect of undermining. Factor of safety over the critical exit gradient depends upon the following uncertainties;

a. The foundation soil may not be homogeneous,

b. The packing and pore space may differ in places,

c. There may be local intrusion of clay beds which deflect the flow lines, or there may be zones of very porous materials which may introduce concentration of flow from around.

All these deviations and uncertainties in the nature must be allowed for; if safe structures are to be designed a factor of safety is thus, to be applied to the critical exit gradient to obtain the safe working value. This factor of safety will also cover cases where, due to retrogression of bed level or floor scour, the upper part of piles at downstream and is exposed.

Dr. Khosla (10) has recommended the following values of factor of safety to be applied to the critical exit gradient for safe design in case of various types of soils.

Shingle	4 to 5
Coarse sand	5 to 6
Fine sand	6 to 7

These are not applicable for clays which are more or less impervious.

2.5 HISTORICAL DEVELOPMENT OF THE STUDY OF SEEPAGE PROBLEMS

Ground water moves from levels of higher energy to levels of lower energy. The potential energy is essentially dependent on the elevation and pressure. Kinetic energy which is proportional to the square of the velocity may be neglected because ground water velocities are usually so small that the flow remains purely laminar. While flowing, ground water experiences a loss in energy due to frication against the surface of the particles of the granular medium along its seepage path. This loss per unit length traveled, or the hydraulic gradient is proportional to the velocity of flow (7). The proportionality is expressed mathematically by a linear equation in Darcy's law as $v = k - \frac{H}{L}$

Where V = velocity of flow;

L = length of the path of flow;

K = a constant called the "transmission constant" or "Hydraulic conductivity".

The validity of the above law enunciated by the French Hydraulican Henry Darcy (1856) was verified in relation to the weir design by Col. Clibborn in 1896 in connection with the proposals for the repairs to the damages on the Khanki weir on the river Chenab (10). As a result of the experiments by Col. Clibborn the 'Hydraulic Gradient Theory' originated between Sir Jhon Ottley and Thomas Higham. The 'hydraulic Gradient theory' became generally accepted by 1898 in India. In 1910, Bligh (12) put forth his theory based on Col. Clibbron,s work. Bligh stated that the length of the path of flow had the same effect length for length in reducing the uplift pressures whether the path is along the horizontal or vertical. Forchheimer developed a geometrical method of plotting stream lines and equipotential lines in1911. This method is known as the flow net method for determining the potentials at various points in the flow field with a free surface. In 1915, Colman carried out tests with models of weir resting on sand, to find the distribution of pressure on the base of the floor and the effects of upstream and downstream cutoffs(10). In 1929, Karl Terzaghi made a notable contribution to the design criteria. He stated and proved by laboratory experiments that failures of structures occur by undermining when the exit gradient is in excess of the floatation gradient.

The first full size experiments were conducted by Knosla (10) around 1930, on the upper Chenab siphons and the main conclusions derived from these researches gave the idea that failure of structures would occur if the exit gradient exceeds the critical gradient. It was also found that outer faces of the vertical cut off had greater efficacy than the inner faces. About the same time Prof. Warren Weaver developed his mathematical treatment of the 2-dimensional flow of water through subsoil.

In 1934(12), Lane proposed his 'weighted creep theory' as a modification of the Bligh theory and suggested a weight of 3 for vertical and 1 for horizontal creep (12). In this theory the flow was assumed to follow the line of contact between the structure of the dam and its foundation. He further stated that the contact surfaces which are inclined at slope less than 45° to the horizontal offer only 1/3 the resistance offered by 45° or more. While this theory was an improvement on the original Bligh theory it was empirical and lacked the background of a rational or analytical basis.

In 1934, Haigh and Harza carried out investigations on the lines suggested by Weaver and the results were verified with electrical models. Based on his investigations Harza suggested that a cut off at the toe is necessary to have a safe exit gradient.

The problem of determination of uplift pressures on structures with sheet piles was studied by Pavlovsky and Muskat independently and the results were found to agree with those obtained by experiments based on electrical analogy. The effect of sheet pile on the seepage below floors in two dimensional flows was analyzed mathematically by Kochina and Pavlovsky and Harr and Dean.

The study of 2-dimensional flow problem by electrical analogy method was conducted by Moore, Wyckoff, Reed and Botset, Relf, childs, Lane, Campbell and Price Cheers, Raymer and Fowler, Vaidyanathan and Uppal, Salem and others(17). A rational method for the design of structures on Porous media was given by Khosla in 1936, based on mathematical analysis and model studies using electrolytic tank. Khosla's method gives the basis for the determination of uplift pressures and exit gradients on floors with intermediate and end sheet piles taking into account the effect of floor thickness and sloping bottom surface.

Using the electric analogy method Luthra (1954) investigated the uplift pressures for stratified foundations (13). He used an electrolytic tank for the study, simulating the different layers of the foundation by increasing or decreasing the depth of the electrolyte corresponding to each layer in the ratio of the perm abilities of different layers. Later Sanga, Bansal and others used the electrolytic tank for deciding the location of intermediate filters and effect of stratification on the pressure distribution below depressed floors. An electrical resistance network was used by Bouewer and Little and Luthin to obtain the solution for 2-dimensional flow problems. The effects of leaky sheet piles have also been studied for 2-dimensional flow(7). The method of analysis employing the electrical resistance network is simple and permits easy representation of even complex boundary conditions and layered strata of different permeability.

In all the above mentioned cases the studies were mainly confined to laboratory investigations only as analytical solution of Laplacian equation for 3 – dimensional seepage flow with appropriate boundary conditions has not been developed so far. In 1933, Reltove(17) for the first time attempted to predict uplift pressure on the structures built on heterogeneous foundations using an electric model. To represent the heterogeneous character of the soil he used graphite, powdered marble or fine quartz of sand adding enough quantity of water to make it cohesive. Using simple wax models, similar studies were conducted at the Hydraulic Research Station Poona in 1952 and 1958. The study of 3- dimensional seepage below pervious abetments was carried out by Twelker around 1957 using flow nets based upon the Dupit- Forchhermer theory for flow with free surface. At the U.P. Irrigation Research Institute, studies were conducted on electric models of Jangpura Syphon across Sarda Main Canal. During the three dimensional studies on the electrical analogy model, it was found that in normal conditions a major portion of the subsoil flow took place from the canal into the river on the two sides of the structure and there was no portion of the structure experiencing the 2-dimensional ones. While the structure was found to be entirely unsafe when checked by normal procedure of design, the fact that the structure withstood the test of time indicated the marked existence of 3- dimensional flow conditions. The total uplift pressure found by 3- dimensional approach was 32% less than that for 2- dimensional flow conditions. Studies on Jangpura siphon model were conducted considering the seepage to and from the water table. While working on the problem it was found that the boundary conditions of the sub soil water mound have a great influence on the uplift pressure distribution. The boundary effects due to limited size of electrolytic tank was studied and it was suggested that if the dimensions of the electrolytic tank are more than 3.75 times the size of the model the effect of confinement of the actual infinite medium by a finite medium in the tank would be negligible. Study of seepage pressure on floors using electrolytic tank without representing the water table (i.e., without accounting for the free surface) were conducted at the experimental research station of U. S. army Corps of Engineers. Vidaya Sagar conducted similar studied for the distribution of seepage pressures below a simple depressed floor. Satish Chandra (1968) studied 3-dimensional seepage below narrow hydraulic structures both analytically and experimentally (13). The analytical part involves the solution of 3-dimensional Laplace's equation with the actual boundary conditions considering the geometry of the free surface behind the abutment from the canal to the water-table. A suitable analytical method for dealing with such problems is not available. In his investigation Satish Chandra has evolved a now method of solution treating it as a half space problem neglecting the seepage region above the level of the floor and the existence of the water table. Under these assumptions the seepage from the upstream portion of the canal to the downstream was considered to determine the distribution of pressure below the floor. Using Dupuit Forehhiemer theory neglecting the vertical component of velocity of seepage from and to the canal he computed the build up of the free surface behind the abutment for a canal floor of negligible width. Free surface contours have been determined for different distances of the water table, from the canal, for different elevations of water-table. The effect of the free surface on the distribution of potential below the floor was taken into account by fixing cupper wires at the bottom of the tray along the contours of water-table. The different water table elevations were represented by assigning different electric potential to a cupper plate fixed on a wall of the electrolyte tank. The numerical method comprised of the superposition of known solutions for the potential due to circular discs on the surface of the half plane of seepage for confined boundary.

The above mentioned investigations were carried out to develop electric models representing the pattern of 3-dimensional seepage below hydraulic structures under confined flow for homogeneous or stratified formations. Further a method has been found to represent the unconfined boundaries with free surface. These studies are limited to flat, depressed floor for different water-table condition. Anand Prakash (1969) investigated the effect of sheet pile on the pressure below floors and the resulting exit gradient in 3-dimensional seepage with water-table at the same elevations as the tail water-table(2). A. Jagadheesan (1971) investigated the effect of boxing on three dimensional seepage pressures below floors of hydraulic structures (1). Design aspects of siphon aqueduct with special reference to U L siphon aqueduct on Sarda Sahayak project was studied by Bhikhan Lal (1972).

2.6 3-DIMENSIONAL FEM APPROCH

In the case of hydraulic structures constructed across wide stream where width of the floor is considerably greater than its length, the flow can be treated as 2-D. for a reliable estimation of 3-D seepage pressure under the floors, models studies on geometrically similar model or electrical analogy models are the expeditious methods.

This study is based on the FEM analysis using ANSYS for the estimation of seepage pressures under the drainage barrel floor and exit gradient all-round the structure, for different canal lining lengths and depth of cut off. The study will indicate the effect lining of canals over the pressure on the floor and the exit gradients in the 3-dimensional case as compared to the 2-dimensional values. As the combination of lining of the canal and side sheet pile for the barrel will work as a cut off to the seepage path in the transverse direction, its effect in the 3-dimensional case would be considered. To what extent seepage pressures below the floor and exit gradients be modified by such lining and sheet piles depth, has been analytically studied in this study.

CHAPTER 3

FINITE- ELEMENT ANALYSIS OF SEEPAGE

3.1 GENERAL

Finite element method or finite element analysis some times abbreviated as FEM or FEA, data back to a mathematician R. Courant in a 1943 paper (11). He proposed breaking a continuum problem into triangular regions and replacing the fields with piecewise approximations within the triangles, and it was probably established by several pioneers almost independently. However, nothing was done with Courant's ideas for a decade because computers large and fast enough were not available until the 1950s and then only in large aircraft companies. In 1966 substantial finite element software development had started in structural mechanics field, and now it is being widely used in different fields like heat transfer, electromagnetic and fluid flow.

Seepage problems in soil mechanics are often solved by sketching flow nets (14). This method of solution is practical when the boundary of the region of seepage is clearly defined and the soil medium is homogeneous and isotropic with respect to permeability. If the soil is uniformly anisotropic, that is, the ratio of the principal permeability is constant and the directions of the principle axes of permeability preserve a constant direction, the flow net may be sketched on a transformed section(7) and afterwards transferred to the real region of seepage. However, if, as is often the case, the region is homogeneous and uniformly anisotropic, a solution by flow nets is scarcely practical. For such problems Zeinkiewicz and Cheung have presented a general method of analysis for use with an electronic digital computer.

The method is based on the concept of representing the continuous distribution of pressure head in the region of flow by the values of the head at a finite number of points. The region is divided into a network of triangle called finite element and the head or potential in each element is specified in terms of the values of the potentials at the nodes. Thus, the seepage problem is considered solved when the potentials at the nodes are known. Because the continuum is divided into finite elements, the method has been termed the finite element method of analysis.

Application of the finite element method to problem of steady state seepage in which the boundary of the seepage is fully known a priori have been given by Zeinkeiwicz, Mayer, and Cheung(14)

The method was soon applied to problems governed by Laplacian's or poisson's equations as these equations were related to the minimization of a functional. The first applications were to conduction heat transfer.

3.1.1 BOUNDARY VALUE PROBLEMS

The basic differential equation governing a wide spectrum of physical problems such as seepage, flow, heat conduction, electrostatic or electromagnetic fields etc in steady state is given in two dimensions by

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial \phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial \phi}{\partial y}\right) = f(x,y) \qquad (3.1.1)$$

Where K_x, K_y and f are given functions independent of ϕ, the field variable. For homogeneous medium K_x, K_y are constant, while for isotropic media $K_x = K_y = K$.

The description of the field problem is not complete until boundary conditions are specified. Usually on some part of the boundary value of ϕ is specified function such as

$$\phi = \Phi\,(x,y) \text{ on } S_1 \qquad (3.1.2)$$

while on the other part of the boundary we have

$$K_x \frac{\partial \phi}{\partial x} n_x + K_y \frac{\partial \phi}{\partial y} n_y + g(x,y) = 0 \text{ on } S_2 \qquad (3.1.3)$$

Where g is known a priori and n_x, n_y are the directions cosines of the outward normal of the surface.

The above equation reduces to poisson's equation if $k_x = k_y = k$

i.e. $\nabla^2 \phi = \frac{f}{k}(x,y)$

And to the Laplace equation if $f = 0$

i.e. $\nabla^2 \phi = 0$

The latter equation governs the potential flow problems.

3.1.2 VARIATIONAL PRINCIPLE

We have already seen that for stress problems the equilibrium conditions are automatically satisfied if we minimize a functional such as the total potential energy π of the system.

A functional is a scalar integral function of the field variable and its derivatives.

It can be shown that the function $\phi(x,y)$ that satisfies the governing equation (3.1.1) and the boundary conditions (3.1.2) and (3.1.3) also minimizes the functional

$$\pi(\phi) = \frac{1}{2}\int\left[k_x\left(\frac{\partial\phi}{\partial x}\right)^2 + k_y\left(\frac{\partial\phi}{\partial y}\right)^2\right]dv - \int_{s_2} g\phi \, ds_2$$

Assuming $f = 0$

$$\pi(\phi) = \frac{1}{2}\int\left[k_x\left(\frac{\partial\phi}{\partial x}\right)\left(\frac{\partial\phi}{\partial x}\right) + k_y\left(\frac{\partial\phi}{\partial y}\right)\left(\frac{\partial\phi}{\partial y}\right)\right]dv - \sum Q\phi$$

This is analogous to the total potential energy of the system in the case of structural problems.

3.1.3 THE SEEPAGE PROBLEM

In the two dimensional stress problem the field variable ϕ is the displacement vector $\begin{Bmatrix} u \\ v \end{Bmatrix}$

In the case of seepage problem it is the total fluid head or potential

$$\phi = \frac{p}{\gamma} + z$$

Where p is the fluid pressure, γ = density of water and z the elevation head.

In the case of flow problem it is the velocity potential defined by

$$v_x = \frac{\partial\phi}{\partial x}, \qquad v_y = \frac{\partial\phi}{\partial y}, \qquad \text{i.e. } \phi = \phi$$

In the case of thermal problem it is the temperature i.e. $\phi = T$

We shall illustrate the details of the FEM applied to the seepage problem in some detail.

Step 1 : Discretize the field

We shall use the simplest triangular elements as used for the stress problems.

Step 2 : The field variable selected is the fluid potential ϕ and a linear model,

$$\phi = \alpha_1 + \alpha_2 x + \alpha_3 y$$

is adopted. Using the transformations as in structural case we obtain

$$\phi = [N]\{q\}$$
$$= \lfloor N_i \;\; N_j \;\; N_m \rfloor \{q\}$$

Where

$$N_i = \frac{1}{2\Delta}(a_i + b_i x + c_i y)$$

$$N_j = \frac{1}{2\Delta}(a_j + b_j x + c_j y)$$

$$N_m = \frac{1}{2\Delta}(a_m + b_m x + c_m y)$$

The constants a_j, b_j, c_j etc. have the same meaning as before

i.e. $a_i = x_j y_m - y_j x_m$

$b_i = y_j - y_m$

$c_i = x_m - x_j$

And so on

We now determine the gradient of ϕ

$$\{g\} = \begin{bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \end{bmatrix} \phi = [L]\phi$$

$$= \begin{bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \end{bmatrix} [N_i \;\; N_j \;\; N_m] \{q\}$$

$$= \begin{bmatrix} \frac{\partial N_i}{\partial x} & \frac{\partial N_j}{\partial x} & \frac{\partial N_m}{\partial x} \\ \frac{\partial N_i}{\partial y} & \frac{\partial N_j}{\partial y} & \frac{\partial N_m}{\partial y} \end{bmatrix} \{q\}$$

$$= \frac{1}{2\Delta} \begin{bmatrix} b_i & b_j & b_m \\ b_i & b_j & b_m \end{bmatrix} \{q\}$$

$$\{g\} = [B] \; \{q\}$$

where $$[B] = \begin{bmatrix} b_i & b_j & b_m \\ b_i & b_j & b_m \end{bmatrix}$$

Step 3 : Define the Constitutive law-

In case of structural problem we used the Hooke's law. For the case of seepage problems we similarly used the Darcy's law which state that

$v = k\,i$ And $Q = v\,A$

Where k is the permeability, i is the hydraulic gradient, v is the velocity and Q is the discharge. The constitutive law then becomes

$$\{v\} = \begin{Bmatrix} v_x \\ v_y \end{Bmatrix} = -\begin{bmatrix} k_x & 0 \\ 0 & k_y \end{bmatrix} \begin{Bmatrix} \frac{\phi}{x} \\ \frac{\phi}{y} \end{Bmatrix}$$

$$= [D] \; \{g\}$$

This is generally written as

$$\{v\} = -[R][B]\{q\}$$

This is similar to the stress equation and $\{v\}$ is equal to the discharge intensity per unit area and $[R]$ equivalent to $[D]$ be the permeability matrix.

$$[R] = \begin{bmatrix} k_x & 0 \\ 0 & k_y \end{bmatrix}$$

Step 4 : Determine the element ' stiffness' or element equations

We have seen that the minimization of the functional given earlier gives the necessary conditions. This functional is of the same form as in the case of structural problem and could in face be interpreted as an energy equation. In case of seepage problem $k_x\left(\frac{\partial\phi}{\partial x}\right)$ is equivalent to the discharge and $\frac{\partial\phi}{\partial x}$ is the head loss. Hence the product is an energy term.

Obviously $Q\phi$ is also an energy term.

We can write

$$\pi(\phi) = \frac{1}{2}\int \begin{Bmatrix} \frac{\partial\phi}{\partial x} \\ \frac{\partial\phi}{\partial y} \end{Bmatrix}^T \begin{bmatrix} k_m & 0 \\ 0 & k_y \end{bmatrix} \begin{Bmatrix} \frac{\partial\phi}{\partial x} \\ \frac{\partial\phi}{\partial y} \end{Bmatrix} dv - Q^T\phi$$

$$\pi(\phi) = \frac{1}{2}\int [B]^T [D][B]\phi^2\, dv - Q^T\phi$$

Since

$$\frac{\partial\pi(\phi)}{\partial(\phi)} = 0$$

As in the structural problems.

$$[k] = \{Q\}$$

Hence

$$[k] = \int [B]^T [D][B] dv = [B]^T [D][B]\Delta t$$

$$= \frac{t}{4\Delta}\begin{bmatrix} b_i & c_i \\ b_j & c_j \\ b_m & c_m \end{bmatrix} \begin{bmatrix} k_x & 0 \\ 0 & k_y \end{bmatrix} \begin{bmatrix} b_i & b_j & b_m \\ c_i & c_j & c_m \end{bmatrix}$$

$$= \frac{t}{4\Delta}\begin{bmatrix} b_i & c_i \\ b_j & c_j \\ b_m & c_m \end{bmatrix} \begin{bmatrix} k_x b_i & k_x b_j & k_x b_m \\ k_y c_i & k_y c_j & k_y c_m \end{bmatrix}$$

$$= \frac{t}{4\Delta}\begin{bmatrix} k_x b_i^2 + k_y c_i^2 & k_x b_i b_j + k_y b_i b_m & k_x b_i b_m + k_y b_i b_m \\ & k_x b_j^2 + k_y c_j^2 & k_x b_j b_m + k_y b_j b_m \\ & & k_x b_m^2 + k_y c_m^2 \end{bmatrix}$$

Step 5,6,7 & 8 :

These steps are exactly identical. The secondary unknowns are the velocities, discharge intensity and total discharge.

3.2 SEEPAGE EQUATIONS FOR THREE DIMENSIONAL PROBLEMS

The steady state seepage through a porous medium is governed by the following differential equation.

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial \phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial \phi}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial \phi}{\partial z}\right) + Q = 0$$

With the boundary condition $\phi = \phi_B$ on the S_1 where

Φ: is the unknown (potential)

K_x, K_y, K_z: are the permeability coefficients in x, y, and z directions respectively

Q = internal recharge in the continuum (pumping is negative Q)

S_1 = that part of the boundary on which the potential Φ is prescribed

S_2 = is the other part of the boundary which the external flux is prescribed

The energy term corresponding to the above equation will be

$$\Pi = \frac{1}{2}\int \left[k_x\left(\frac{\partial \phi}{\partial x}\right)^2 + k_y\left(\frac{\partial \phi}{\partial y}\right)^2 + k_z\left(\frac{\partial \phi}{\partial z}\right)^2 \right] dv - \int Q\phi \; dv$$

Now

$$k_x\left(\frac{\partial \phi}{\partial x}\right)^2 + k_y\left(\frac{\partial \phi}{\partial y}\right)^2 + k_z\left(\frac{\partial \phi}{\partial z}\right)^2 = \left\{\frac{\partial \phi}{\partial x}\;\frac{\partial \phi}{\partial y}\;\frac{\partial \phi}{\partial z}\right\} \begin{bmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & k_z \end{bmatrix} \begin{Bmatrix} \frac{\partial \phi}{\partial x} \\ \frac{\partial \phi}{\partial y} \\ \frac{\partial \phi}{\partial z} \end{Bmatrix}$$

Let

$$\begin{Bmatrix} \frac{\partial \phi}{\partial x} \\ \frac{\partial \phi}{\partial y} \\ \frac{\partial \phi}{\partial z} \end{Bmatrix} = \{g\} \text{ and } \begin{bmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & k_z \end{bmatrix} = [D]$$

$$\therefore \prod = \frac{1}{2}\int \{g\}^T [D]\{g\}dv - \int Q\phi dv$$

$$\phi^e = \sum_{i=1}^{n} N_i\phi_i = N_1\phi_1 + N_2\phi_2 + \dots\dots\dots\dots + N_n\phi_n$$

Where n = no. of nodes/element

ϕ_i = Potential at node i

N_i = shape function for node i

$$\frac{\partial \phi}{\partial x} = \sum \frac{\partial N_i}{\partial x}\phi_i \; ; \; \frac{\partial \phi}{\partial y} = \sum \frac{\partial N_i}{\partial y}\phi_i \quad \text{and} \quad \frac{\partial \phi}{\partial z} = \sum \frac{\partial N_i}{\partial z}\phi_i$$

$$\therefore \{g\} = \begin{Bmatrix} \frac{\partial \phi}{\partial x} \\ \frac{\partial \phi}{\partial y} \\ \frac{\partial \phi}{\partial z} \end{Bmatrix} = \begin{bmatrix} \frac{\partial N_1}{\partial x} & \frac{\partial N_2}{\partial x} & \frac{\partial N_3}{\partial x} \\ \frac{\partial N_1}{\partial y} & \frac{\partial N_2}{\partial y} & \frac{\partial N_3}{\partial y} \\ \frac{\partial N_1}{\partial z} & \frac{\partial N_2}{\partial z} & \frac{\partial N_3}{\partial z} \end{bmatrix} \begin{Bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \\ \phi_n \end{Bmatrix}$$

or $\{g\} = [B] \; \{\phi^e\}$

$$\text{Where} \quad [B] = \begin{bmatrix} \frac{\partial N_1}{\partial x} & \frac{\partial N_2}{\partial x} & \dots\dots & \frac{\partial N_n}{\partial x} \\ \frac{\partial N_1}{\partial y} & \frac{\partial N_3}{\partial y} & \dots\dots & \frac{\partial N_n}{\partial y} \\ \frac{\partial N_1}{\partial z} & \frac{\partial N_2}{\partial z} & \dots\dots\dots & \frac{\partial N_n}{\partial z} \end{bmatrix}$$

And $\{\phi^e\}$: vector of nodal potentials $\begin{Bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \\ \\ \phi_n \\ . \end{Bmatrix}$

Therefore the energy term is

$$\prod = \frac{1}{2}\int\{\phi^e\}^T[B]^T[D][B]\{\phi^e\}dv - \int Q\phi dv$$

Now $\phi = [N]\{\phi^e\}$

Where $[N] = \lfloor N_1 \ \ N_2 \ \ ....N_n \rfloor$

Therefore, the energy form becomes

$$\prod = \frac{1}{2}\int\{g^e\}^T[B]^T\{\phi^e\}dv - \int Q[N]^T dv = 0$$

Since for equilibrium $\dfrac{\partial\prod}{\partial\phi} = 0$

Therefore $\int[B]^T[D][B]\{\phi^e\}dv - \int Q[N]^T dv = 0$

If there is no recharge or pumping Q = 0

Then $\lfloor K^e \rfloor\{\phi^e\} = 0$

Where $\lfloor K^e \rfloor = \int[B]^T[D][B]dv$

CHAPTER 4

SEEEPAGE MODEL

4.1 GENERAL

A 3-D FEM model has been prepared as per the dimensions given in the drawing of BAN SAGAR FEEDER CHANEL, PROJECT, which is used by IIR Roorkee for model testing by EHDA (Electrical Hydro Dynamic Analogue Technique).

4.2 ASSUMPTIONS IN THE MODEL

1. The strata are homogeneous and isotropic up to infinite depth.
2. The water table is at the bed level of the drainage.
3. The sub surface flow follows Darcy's law.

4.3 DIMENSIONS OF THE MODEL

A 3-D FEM model has been prepared as per the dimensions given in the drawing of BAN SAGAR FEEDER CHANEL, PROJECT, which is used by IRI, Roorkee for model testing by EHDA (Electrical Hydro Dynamic Analogue) technique. The salient features of the drain and canals are given below:

Drain	
Bed level: U/S of the crossing	291.25m (global origin: 0, 0, 0,)
D/S of the crossing	291.00m
Mean general ground level	295.00m (5m above the global)
HFL	294.83m
Bed width of the drain	22.5m
Length of the barrel	169.00m
Depth of the U/S cutoff	6.5m
Depth of the D/S cutoff	6.5m
Depth of the pervious strata	30.0m
Main canal, Ban Sager Feeder Canal	
Bed width	5.0m
Bed level at crossing	308.825m

FSL	312...375m (21.375m above the global)
Side slope	1.5: 1
Impervious lining of the canal	500.00m

(250.0m in the both side of the U/S & D/S of the crossing)

Lower Canal, Sihawal Canal

Bed width	3.50m
Bed level at crossing	300.135m
FSL	301.875m (10.875m above the global)
Side slope	1.5: 1
Depth of the pervious strata (Below the drainage barrel)	30.0m

4.3.1 BOUNDARY CONDITIONS

The study is carried out for the condition when main canal (Ban sagar feeder canal) is at FSL 312.375m and the drainage nala is dry, water at bed level (u/s of the drain is at EL. 291.250m and d/s of the drain at EL. 291.00m). This model has been tested for the same boundary conditions which are used by IIR Rookee, so that results may be validated. There are given in the following table:

Sl.No	Location		Elevation in m	Potential in % of Maximum differential. Head
1	Lined Ban Sagar Feeder Channel	Bed and side slopes up to FSL	312.375	100
2	Unlined Sihawal Canal	Do	301.875	50.91
3	Bed level of Drain	U/S of crossing D/S of crossing	291.25 290.00	1.2 0.0
4	Mean Ground Level		295.00	18.71

5	Maximum differential head	(321.375-291.00)	21.375m	
6	Depth of U/S & D/S cutoff		6.50m	
7	Depth of pervious strata		30.0m	

In the above table maximum differential head 21.375m (elevation difference between FSL of Ban sagar canal and the d/s bed level of drainage) is assumed as 100% head. On the basis of this head, the potential on the Sihawal canal (difference of FSL of lower Sihawal canal and d/s bed level of drainage) is 50.91%. Similarly the potential at the u/s & d/s of crossing and at the mean ground level is 1.2%, 0%and 18.71% respectively.

4.3.2 MODELING AND MESHING

Seepage model has been created by 30 nos. of volumes. Volume no. 1 & 2 shows the volume of u/s & d/s cutoff, volume no. 3 for the drainage bed, volume no 4.& 5 for the filling from the bottom of the cut off to the level of mean ground level (295.00m), volume no 6 for the pervious strata (below the cut off), volume no. 7 shows the barrel volume. Rest 23 nos. of volumes for the canals (500. m canal has been divided into 24 nos. of sections). The seepage model and meshing of model is given in fig 4.1a and 4.1b respectively.

4.4 PROCESS IN ANSYS

ANSYS programmer has many finite element analysis capabilities, ranging from a simple linear, static analysis to a complex, non linear, transient dynamic analysis.
The distinct steps in ansys are as follows:

1. Preference : Define discipline(s)
2. Preprocessor : 1 Define element type
   2 Define real constant

3 Define material properties

4 Building the model

5 Meshing the model in elements and nodes

3. Solution:

1 Apply boundary conditions and loads

2 Solve for unknown

4. General postprocessor:

1. Plot results: Nodal solution

Element solution

4.5 ANSYS Inputs

1 Preference : Thermal

2 Preprocessor : Element Type : Tetrahedral 10node 87

(For three dimensional analyses)

Material property: Isotropic,

$K_{xx} = 1 * 10^{-5}$ cm/sec (0.000864 m/day)

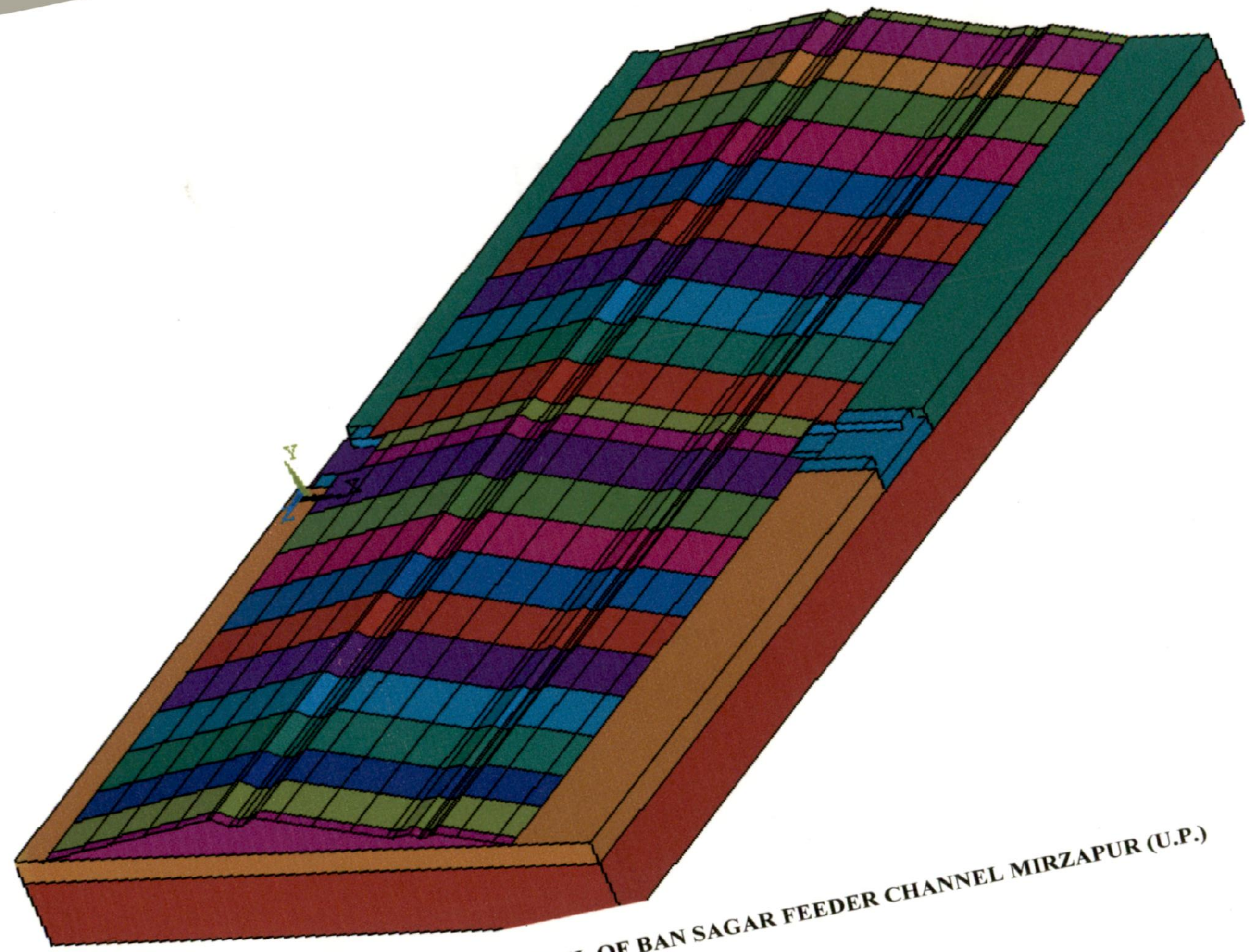


FIG. 4.1a SEEPAGE MODEL OF BAN SAGAR FEEDER CHANNEL MIRZAPUR (U.P.)

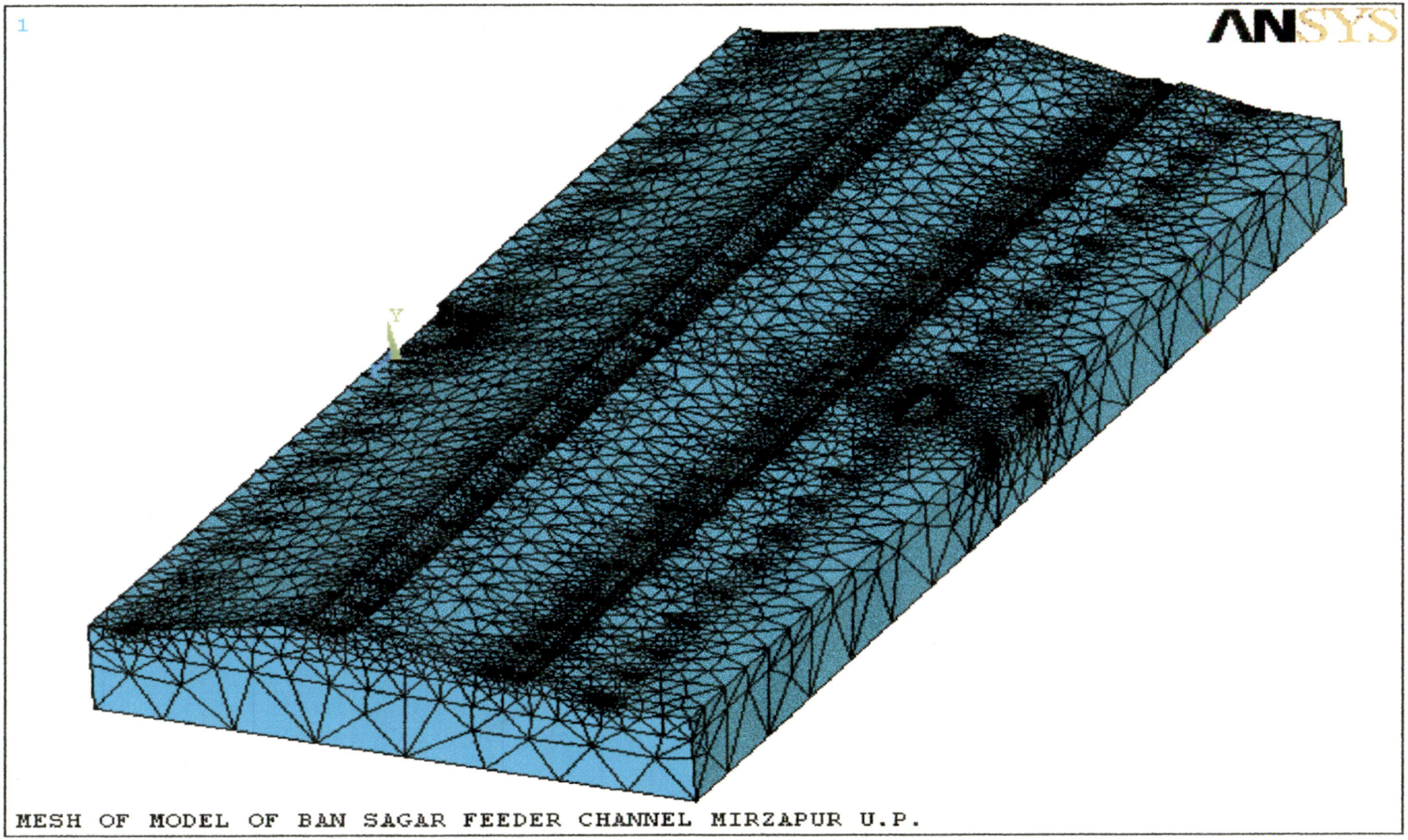


FIG. 4.1b MESHING OF SEEPAGE MODEL OF BAN SAGAR FEEDER CHANNEL MIRZAPUR (U.P.)

CHAPTER 5

ANALYSIS AND RESULTS

5.1 INTRODUCTION

The drainage crossing barrel of Ban Sagar Feeder Canal has been analyzed through 3-D FEM model using ANSYS. This barrel has been analyzed by EHDA (Electro Hydro Dynamic analog) technique by IIR, Roorkee. These results of experiments study have been used for the validation of the model.

The study has been carried out in two parts. Part-I shows the results of 3-D FEM analysis by ANSYS of Drainage Crossing at km7.125 of Ban Sagar Canal Feeder Channel, Mirzapur U.P, and comparison of these results with the EHDA results of IRI Roorkee, part-II deals with the determination of uplift pressure and exit gradient for different lengths of canal lining and depth of cut off for different cases and the comparison of 2- D & 3 –D results.

5.2 PART-I OF STUDY
(THE PROJECT)

A common water carrier is proposed to off take from the Ban Sagar Dam for carrying water for irrigation for M.P. and U.P. and water required for power generation by M.P. along with for drinking. The main Ban Sagar Canal runs parallel to the existing Sihawal Canal. The canal crosses drainage at km 7.125. The drainage crossing provided is a barrel under the canals. The salient features of the drainage are given in para4.3.

A 3-D FEM model has been prepared as per the dimensions given in the drawing of BAN SAGAR FEEDER CHANNEL, PROJECT, which is used by IRI; Roorkee for model testing by EHDA (Electrical Hydro Dynamic Analogue) technique. The assumptions, dimensions and boundary conditions are given in chapter 4.

5.3 RESULTS OF ANALYSIS

❖ UPLIFT PRESSURE

The uplift pressure distribution below the barrel floor has been analyzed for three different sections (fig 5-1), started from the c/l towards u/s side i.e. Z = 0 (c/l of barrel floor), 5.625m (mid section between c/l and u/s edge) and 11.25m (u/s edge) are shown in figure-5.2. Each series shows the uplift pressure distribution along the length of barrel.

It is clear from the figure- 5.3 the maximum uplift pressure is 37.845% has been observed at the distance of X = 152.54m for the u/s edge of the barrel (section of barrel i.e. Z = 11.25), at Z = 5.625m maximum uplift pressure is 34.738% occurred at the distance of X = 146.16m, similarly at z = 0.0m (c/l of barrel) maximum uplift pressure is 34.326% which is occurred at the distance of 143.58m.

The observations shows that the maximum uplift pressure for all sections is nearly same and occurring towards the unlined canal side, it is concluded that width of the barrel is very small as compare to the length of canal, so the pressure distribution is nearly same for these three sections, except at the centre of the unlined canal where the difference is of the order of 3%. Minimum value of uplift pressure is 17.77%at the u/s end of the barrel and is going on increasing gradually towards the c/l line of the lower canal where it attains its maximum value, after this it drops rapidly up to d/s end. Fig-5.79 shows the contour plot for the barrel floor. Table- 5.1 shows the details of the uplift values at different sections.

❖ EXIT GRADIENT

Figure-5.3and 5.4 shows the variation of Hydraulic Gradient along the depth of u/s and d/s cut-off respectively for the following locations given in table 5-I (fig-5.1).

It is clear from the graph gradient is constant up to 4.5.0m of depth, it increased at the depth of 5.5m abruptly then up to toe of cut off(d=6.5m) it decreased again. The trend of variation of gradient at the left & right end and at left & right corner of cut off for the u/s and the d/s cut off are nearly same. Table 5.2 shows the values of hydraulic gradient. Exit Gradient at A_1 = 1/3.56, A_2 = 1/2.65, A_3 = 1/2.67, A_4 = 1/3.56 and 1/2.13, 1/3.40, 1/3.14 and 1/ 2.12 for B_1, B_2, B_3 and B_4 respectively

Table-5-I

	U/S FACE OF U/S CUT-OFF			
LOCATIONS	RIGHT CORNER	RIGHT END	LEFT END	LEFT CORNER
	A1: X= 5.0, Z=11.25m	**A2**: X=20.0, Z=11.25m	**A3**: X=20.0, Z= -11.25m	**A4**: X=5.0, Z=-11.25m
	D/S FACE OF D/S CUT-OFF			
	B1: X= 189.0, Z=11.25m	**B2**: X=214.0, Z=11.25m	**B3**: X=214.0, Z= -11.25m	**B4**: X=189.0, Z=-11.25m

At the toe (d=6.5m) of the sheet pile the value of gradient is 1/ 2.22, 1/ 154, 1/1.64and 1/ 2.52 for u/s cut off, 1/1.19, 1/ 2.08, 1/ 2.22 and 1/ 1.17 for d/s cut off. Table 5.3 Show the Exit gradient for u/s & d/s cut off.

❖ ELEVATION OF HG LINE

At any point, the hydraulic grade line measures the extent to which there is residual head to cause uplift pressures. If a piezometric pipe is bored through the impervious floor up to its bottom, water will rise up in the pipe to the level of hydraulic gradient line.

The HG line for Ban Sagar Feeder Channel and Sihawal canal is shown in model as per drawing supplied by field authority. The observations have been taken at 11.25m, 61.25m, 111.25m, 161.25m 211.25m, and 250.00m from centre line of drain on u/s side of crossing for homogeneous & isotropic condition and presented in Table5-4 and 5-5 respectively. Plot of HG line at X- section line of 61.25m, 161.25m and 250.0m from centre line of drain are shown in Drg No 5-5 and 5-6.

5.4 COMPARISON OF RESULTS

The results of FEM analysis described in para 5.3 have been compared with the results of EHDA (Electro Hydro Dynamic Analogue technique) given in IIR, Roorkee test report. Comparison is shown in Table5-3 for Exit Gradient, Table 5-4 and 5-5 for HG Line. Comparative plot of HG line is shown in fig 5-5 and 5-6. The comparison reveals that:

1 The FEM results of Exit gradient show higher values (i.e. lesser factor of safety) in comparison to the EHDA values and the difference is of the order

of 19%. The observations may be differing because EHDA values show the average of the exit gradient values along the cut off but in ANSYS we can get the exit gradient at each and every node. The values given in table-5.3 are at exit end.

2 The elevation of HG lines in FEM analysis as well as EHDA results are quite close to each other at a distance of 61.25m from the central line of the barrel. But for the distance of 250.0m and 161.25m the values are lower in FEM analysis than EDHA values. The HG line at 250m (the end of the lining) is very high being the junctions of lined & unlined section.

5.5 SUMMARY OF RESULTS

1 The value of maximum uplift pressure below the barrel floor is observed as 37.845% of the head (21.375m) at the location of lower unlined canal.

2 The values of Exit Gradient in the d/s side of d/s drain cut off (d = 6.5m) are observed for the homogeneous and isotropic strata as 1/2.13, 1/3.40, 1/3.14, 1/2.12 at the points B_1, B_2, B_3 and B_4 respectively. Similarly at u/s drain cut off values are observed as 1/ 3.56, 1/ 2.65, 1/ 2.67 and 1/ 3.56 at the points of A_1, A_2, A_3 and A_4 respectively.

3 The elevation of HG line at various X – sections on left side of Ban Sagar Feeder Channel goes on rising as we move away from the centre line of drainage crossing towards unlined reach and indicated in **Dg no 5-5**. The observed of HG line must be given proper earth cover as per requirement of the site conditions.

4 The elevation of HG line at various X –section on right side of Ban Sagar Feeder Channel also goes on rising as we move away from centre line of drainage crossing towards unlined reach and indicated in **Dg no 5-6**.The observed HG line must be given proper earth cover as per requirement of site conditions.

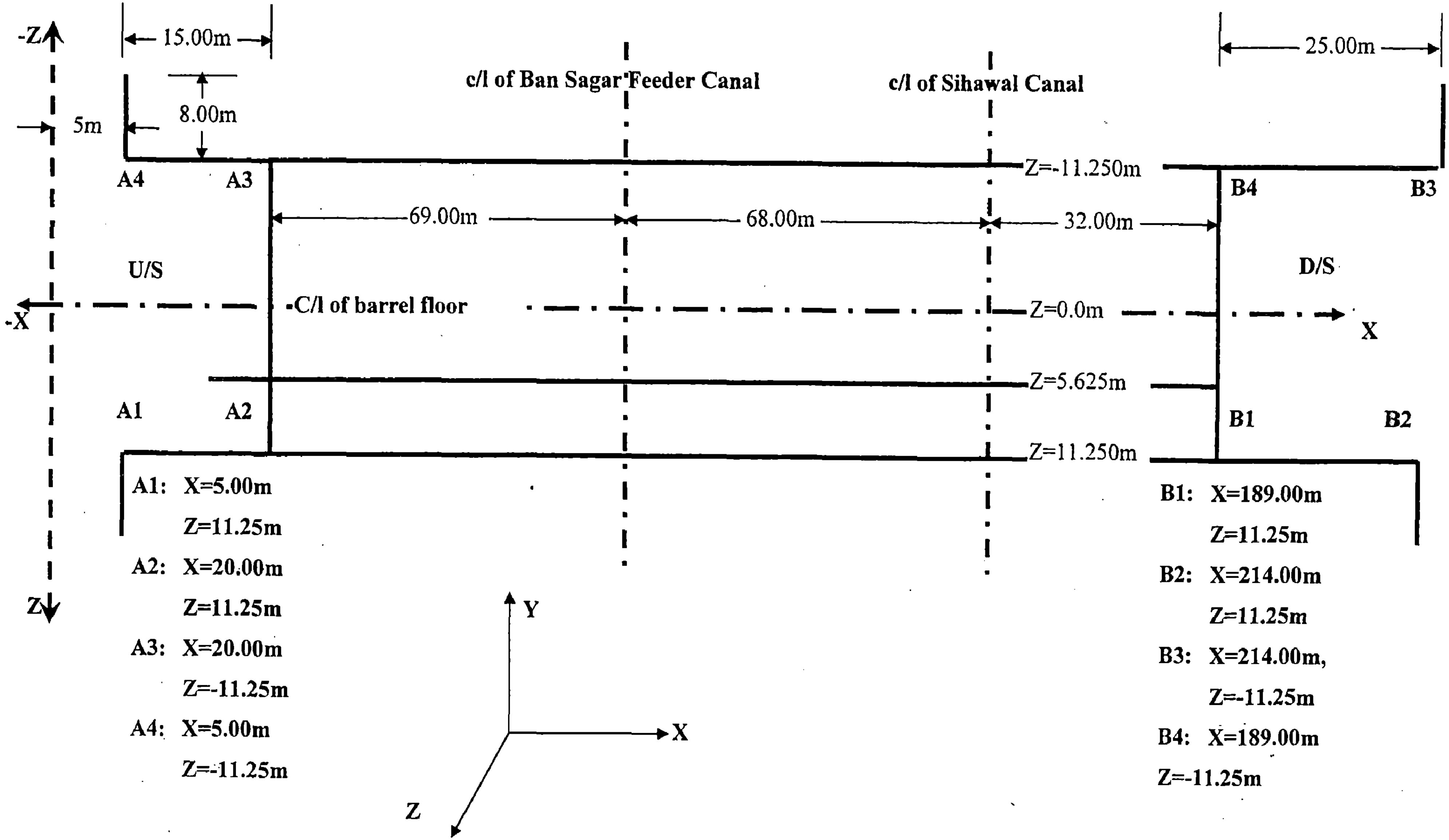


FIG. 5.1 PLAN OF BARREL FLOOR AND CUT-OFF

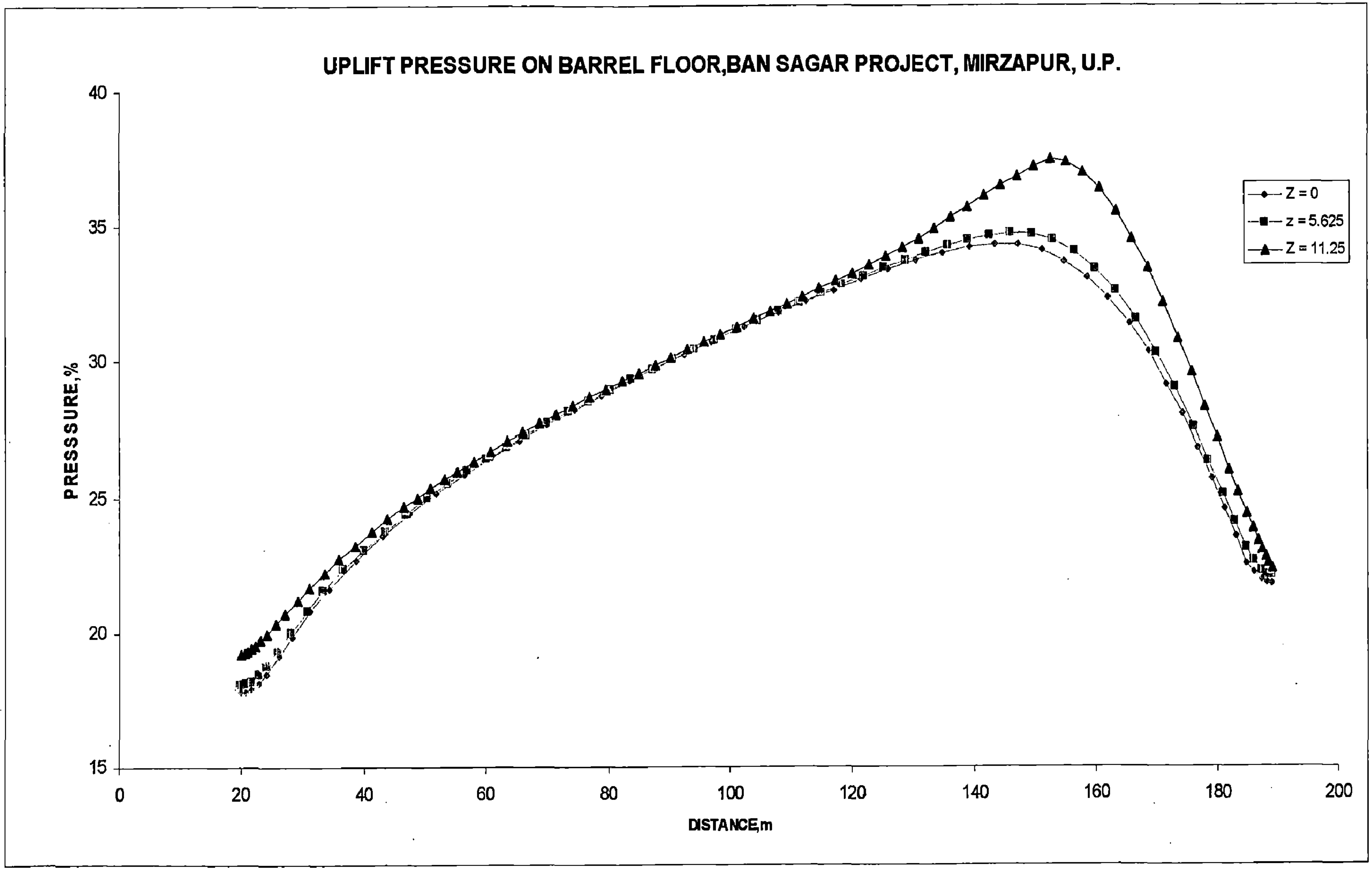


FIG. 5.2 UPLIFT PRESSURE ALONG BARREL FLOOR FOR BAN SAGAR FEEDER CHANNEL MIRZAPUR U.P.

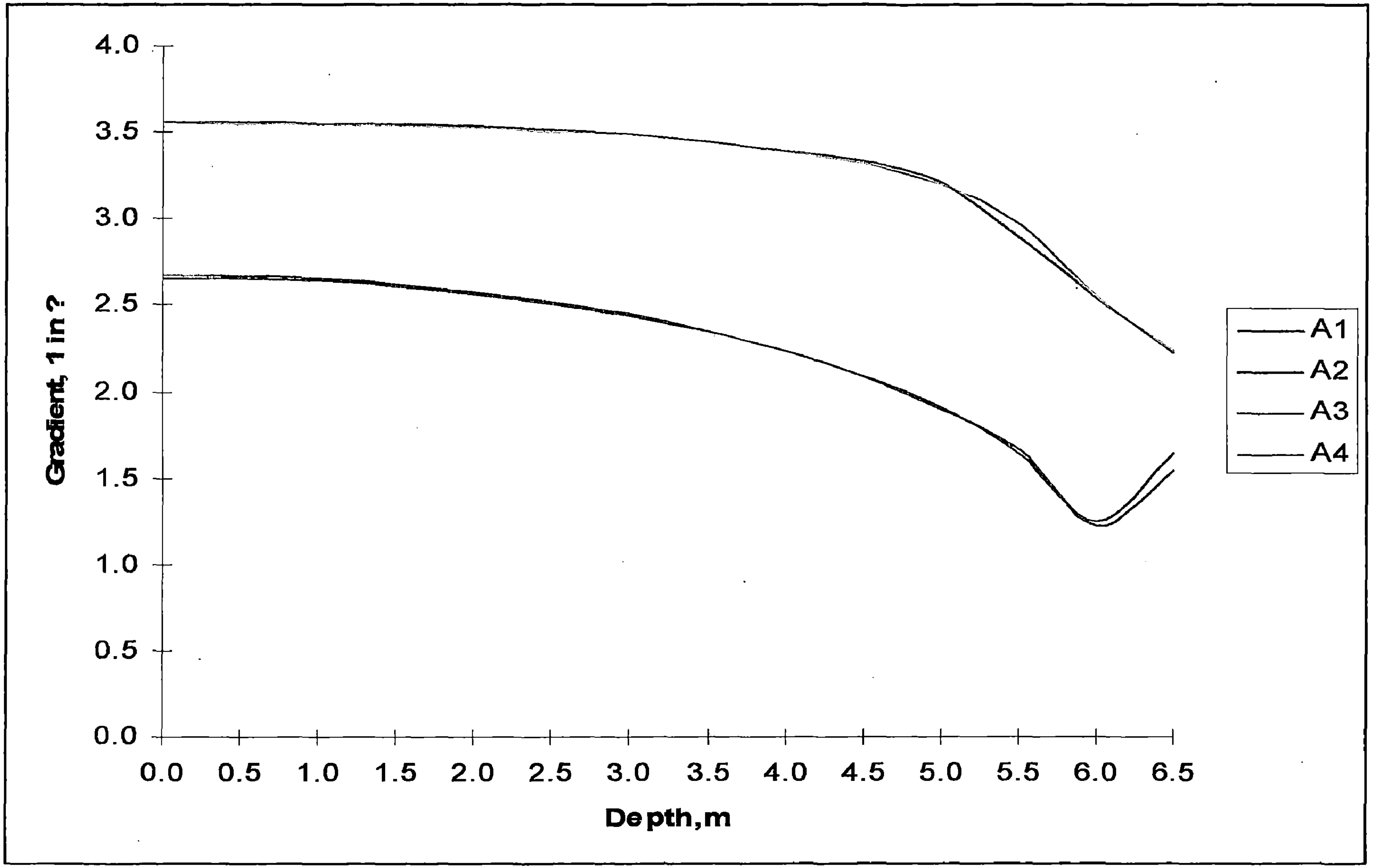


FIG. 5.3 HYDRAULIC GRADIENT ALONG UP STREAM CUT-OFF DEPTH

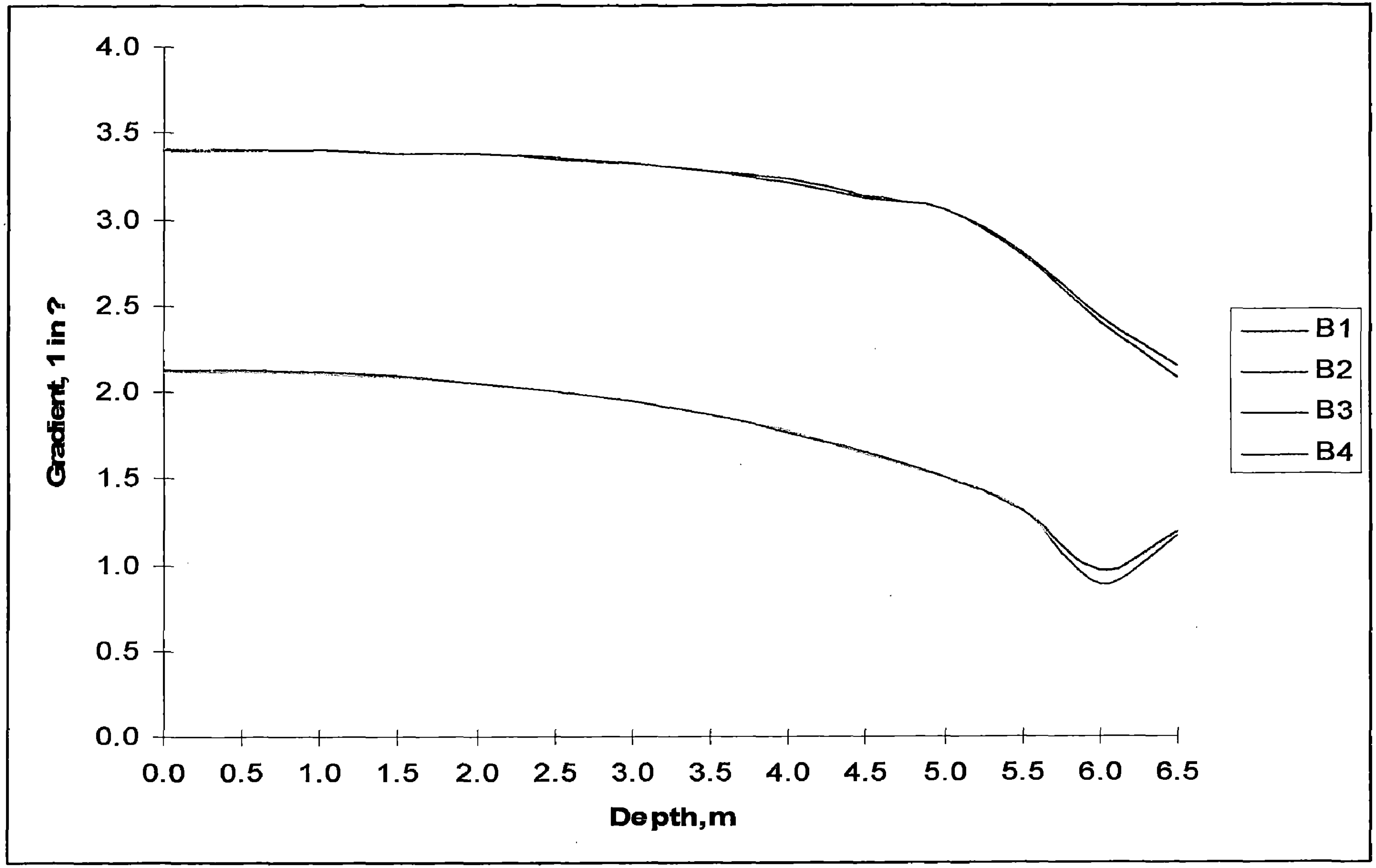


FIG. 5.4 HYDRAULIC GRADIENT ALONG DOWN STREAM CUT-OFF DEPTH

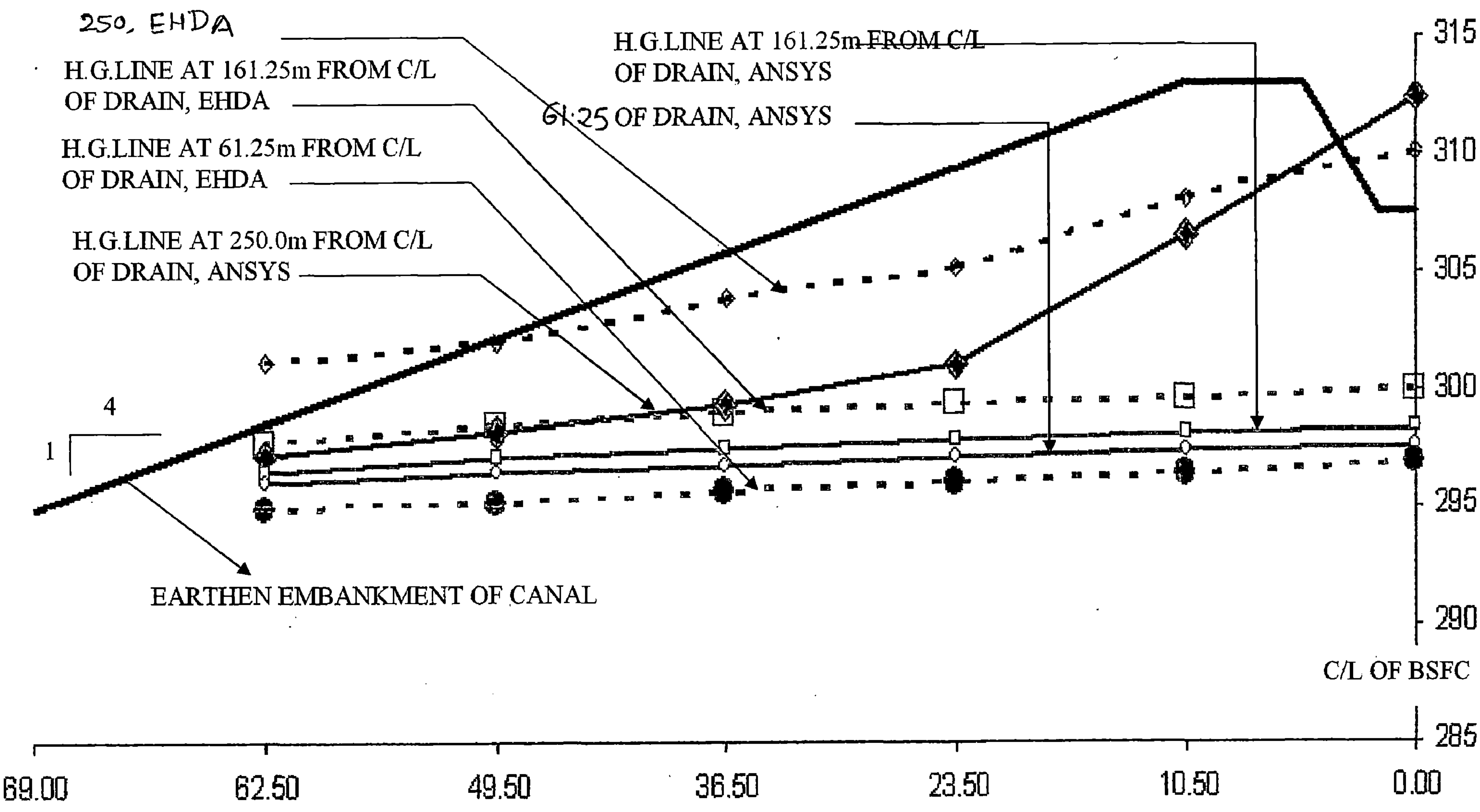


FIG. 5.5 H. G. LINE AT LEFT SIDE OF B.S.F.C.

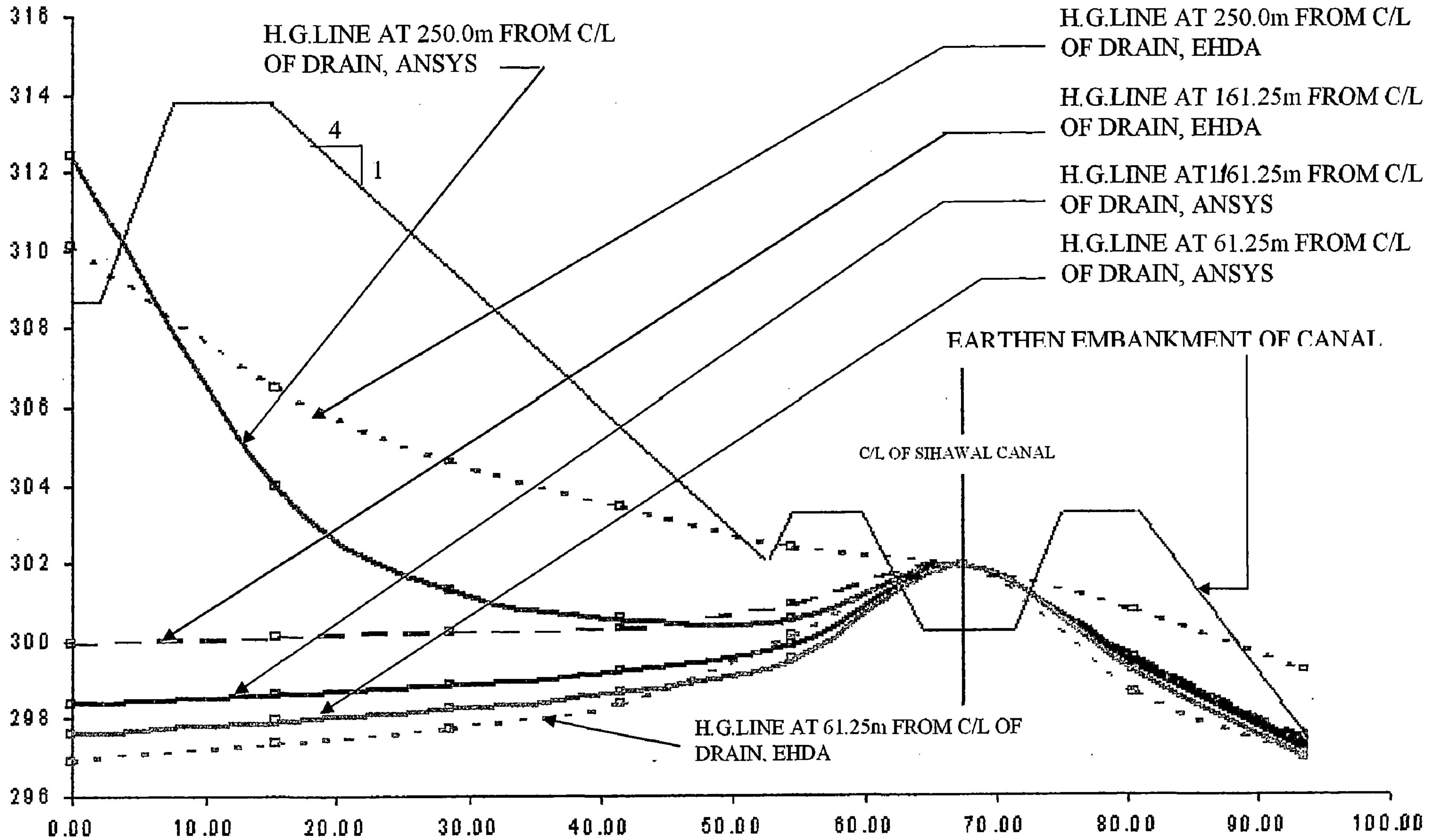


FIG. 5.6 H. G. LINE AT RIGHT SIDE OF B.S.F.C.

Table-5.1

UPLIFT PRESSURE ON BARREL FLOOR

[DRAINAGE CROSSING AT km 7.125 OF BAN SAGAR FEEDER CHANNEL, MIRZAPUR (U.P.)]

S. No.	At Z=11.25m		At Z=5.625m		At Z=0.00m	
	X,m	HEAD,%	X,m	HEAD,%	X,m	HEAD,%
1	20.00	19.19	20.00	18.07	20.00	17.77
2	20.48	19.22	20.80	18.10	20.80	17.80
3	20.96	19.28	21.60	18.19	21.60	17.89
4	21.57	19.40	22.86	18.43	22.88	18.11
5	22.19	19.53	24.11	18.75	24.16	18.44
6	23.13	19.73	26.08	19.37	26.21	19.14
7	24.08	19.94	28.05	20.00	28.26	19.82
8	25.56	20.30	30.73	20.80	31.31	20.77
9	27.03	20.68	33.42	21.53	34.37	21.62
10	29.05	21.18	36.73	22.34	38.75	22.67
11	31.06	21.66	40.05	23.06	43.13	23.58
12	33.48	22.20	43.51	23.75	47.60	24.41
13	35.91	22.70	46.97	24.38	52.08	25.16
14	38.55	23.23	50.42	24.96	56.58	25.85
15	41.20	23.72	53.88	25.50	61.08	26.49
16	43.89	24.20	57.07	25.97	65.58	27.10
17	46.59	24.66	60.26	26.42	70.08	27.67
18	48.78	25.00	63.45	26.86	74.58	28.22
19	50.96	25.33	66.63	27.28	79.08	28.75
20	53.15	25.65	70.09	27.71	83.58	29.26
21	55.34	25.96	73.55	28.13	88.08	29.75
22	58.04	26.34	77.01	28.54	92.58	30.23
23	60.74	26.71	80.47	28.94	97.08	30.70
24	63.44	27.05	83.92	29.33	102.59	31.25
25	66.14	27.39	87.38	29.71	108.10	31.79
26	68.84	27.72	90.84	30.08	112.60	32.21
27	71.54	28.04	94.30	30.44	117.10	32.62
28	74.24	28.36	97.75	30.80	121.60	33.02
29	76.94	28.66	101.21	31.15	126.10	33.39
30	79.64	28.97	104.67	31.49	130.56	33.72
31	82.34	29.27	108.13	31.83	135.03	34.02
32	85.04	29.56	111.59	32.16	139.31	34.23
33	87.74	29.85	115.04	32.49	143.58	**34.33**
34	90.44	30.14	118.50	32.81	147.45	34.30
35	93.14	30.43	121.96	33.13	151.32	34.09
36	95.84	30.71	125.42	33.44	154.99	33.69
37	98.54	30.99	128.87	33.73	158.65	33.09
38	101.24	31.27	132.33	34.01	162.12	32.32
39	103.94	31.55	135.79	34.28	165.58	31.35
40	106.64	31.83	139.25	34.48	168.68	30.32

Table-5.1 (contd....)

UPLIFT PRESSURE ON BARREL FLOOR

[DRAINAGE CROSSING AT km 7.125 OF BAN SAGAR FEEDER CHANNEL, MIRZAPUR (U.P.)]

S. No.	At Z=11.25m		At Z=5.625m		At Z=0.00m	
	X,m	HEAD,%	X,m	HEAD,%	X,m	HEAD,%
41	109.34	32.11	142.71	34.64	171.79	29.13
42	112.04	32.39	146.16	34.74	174.40	28.02
43	114.74	32.68	149.62	34.70	177.02	26.79
44	117.44	32.97	153.08	34.48	179.22	25.69
45	120.14	33.26	156.53	34.07	181.42	24.53
46	122.84	33.57	159.95	33.42	183.21	23.54
47	125.54	33.89	163.38	32.57	185.01	22.52
48	128.24	34.21	166.72	31.52	186.20	22.21
49	130.94	34.55	170.06	30.29	187.40	21.94
50	133.64	34.92	173.15	28.99	188.20	21.80
51	136.34	35.31	176.24	27.55	189.00	21.74
52	139.04	35.71	178.66	26.34		
53	141.74	36.16	181.08	25.07		
54	144.44	36.52	183.00	24.08		
55	147.14	36.85	184.92	23.12		
56	149.84	37.23	186.16	22.60		
57	152.54	37.49	187.40	22.23		
58	155.24	37.37	188.20	22.10		
59	157.93	36.99	189.00	22.06		
60	160.60	36.39				
61	163.28	35.55				
62	165.89	34.55				
63	168.50	33.45				
64	171.00	32.17				
65	173.50	30.85				
66	175.79	29.58				
67	178.08	28.30				
68	180.03	27.17				
69	181.99	26.02				
70	183.45	25.19				
71	184.92	24.38				
72	185.87	23.86				
73	186.81	23.38				
74	187.43	23.06				
75	188.05	22.78				
76	188.52	22.58				
77	189.00	22.37				

Table-5.2

HYDRAULIC GRADIENT ALONG CUT-OFFE DEPTH

(BAN SAGAR FEEDER CHANNEL MIRZAPUR, U.P.)

Cut-off Location	S.No.	Depth,m	Gradient 1 in ?
B1 X=189.00m Z=11.25m	1	0.00	2.13
	2	0.50	2.12
	3	1.00	2.11
	4	1.50	2.08
	5	2.00	2.05
	6	2.50	2.00
	7	3.00	1.94
	8	3.50	1.86
	9	4.00	1.77
	10	4.50	1.65
	11	5.00	1.50
	12	5.50	1.31
	13	6.00	0.95
	14	6.50	1.19
B2 X=214.00m Z=11.25m	1	0.00	3.40
	2	0.50	3.40
	3	1.00	3.40
	4	1.50	3.38
	5	2.00	3.38
	6	2.50	3.34
	7	3.00	3.32
	8	3.50	3.28
	9	4.00	3.23
	10	4.50	3.13
	11	5.00	3.05
	12	5.50	2.79
	13	6.00	2.40
	14	6.50	2.08

Cut-off Location	S.No.	Depth, m	Gradient 1 in ?
A1 X=5.00m Z=11.25m	1	0.00	3.56
	2	0.50	3.56
	3	1.00	3.55
	4	1.50	3.54
	5	2.00	3.54
	6	2.50	3.51
	7	3.00	3.49
	8	3.50	3.45
	9	4.00	3.39
	10	4.50	3.33
	11	5.00	3.21
	12	5.50	2.88
	13	6.00	2.53
	14	6.50	2.22
A2 X=20.00m Z=11.25m	1	0.00	2.65
	2	0.50	2.65
	3	1.00	2.64
	4	1.50	2.61
	5	2.00	2.56
	6	2.50	2.51
	7	3.00	2.44
	8	3.50	2.34
	9	4.00	2.23
	10	4.50	2.08
	11	5.00	1.90
	12	5.50	1.66
	13	6.00	1.23
	14	6.50	1.54

Table-5.2 (contd...)

HYDRAULIC GRADIENT ALONG CUT-OFFE DEPTH

(BAN SAGAR FEEDER CHANNEL MIRZAPUR, U.P.)

Cut-off Location	S.No.	Depth,m	Gradient 1 in ?
B3 X=214.00m Z=-11.25m	1	0.00	3.41
	2	0.50	3.40
	3	1.00	3.40
	4	1.50	3.38
	5	2.00	3.37
	6	2.50	3.35
	7	3.00	3.32
	8	3.50	3.28
	9	4.00	3.21
	10	4.50	3.12
	11	5.00	3.06
	12	5.50	2.80
	13	6.00	2.43
	14	6.50	2.15
B4 X=189.00m Z=-11.25m	1	0.00	2.12
	2	0.50	2.11
	3	1.00	2.10
	4	1.50	2.08
	5	2.00	2.05
	6	2.50	2.00
	7	3.00	1.94
	8	3.50	1.86
	9	4.00	1.77
	10	4.50	1.64
	11	5.00	1.51
	12	5.50	1.31
	13	6.00	0.88
	14	6.50	1.17

Cut-off Location	S.No.	Depth, m	Gradient 1 in ?
A3 X=20.00m Z=-11.25m	1	0.00	2.67
	2	0.50	2.66
	3	1.00	2.65
	4	1.50	2.61
	5	2.00	2.57
	6	2.50	2.52
	7	3.00	2.44
	8	3.50	2.35
	9	4.00	2.24
	10	4.50	2.09
	11	5.00	1.90
	12	5.50	1.64
	13	6.00	1.25
	14	6.50	1.64
A4 X=5.00m Z=-11.25m	1	0.00	3.56
	2	0.50	3.55
	3	1.00	3.55
	4	1.50	3.54
	5	2.00	3.53
	6	2.50	3.50
	7	3.00	3.49
	8	3.50	3.44
	9	4.00	3.38
	10	4.50	3.32
	11	5.00	3.20
	12	5.50	2.97
	13	6.00	2.55
	14	6.50	2.23

Table_5.3

COMPARISON OF EXIT GRADIENT
(BAN SAGAR FEEDER CHANNEL MIRZAPUR, U.P.)

Strata condition	Values of exit gradient at d/s face of d/s cut-off							
	A1		A2		A3		A4	
	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA
Homogeneous and Isotropic strata upto Infinite depth	1/3.56	1/4.26	1/2.65	1/4.67	1/2.67	1/3.91	1/3.56	1/4.67
	Values of exit gradient at u/s face of u/s cut-off							
	B1		B2		B3		B4	
	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA
	1/2.13	1/3.17	1/3.4	1/3.6	1/3.41	1/4.24	1/2.12	1/4.17

Table-5.4

ELEVATION OF HG LINE ON LEFT SIDE OF BSFC

Dist. From c/l of drain	Distance from c/l of BSFC on left side (m)											
	0		10.5		23.5		36.5		49.5		62.5	
	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA
0.00	297.45	296.02	297.23	295.55	296.97	295.02	296.65	294.80	296.29	294.57	295.97	294.03
11.25	297.45	296.11	297.23	295.60	296.97	295.10	296.63	294.85	296.23	294.63	295.74	294.23
61.25	297.60	296.88	297.38	296.37	297.12	296.07	296.81	295.60	296.45	295.21	296.03	294.91
111.25	297.88	298.05	297.67	297.41	297.42	297.11	297.11	297.24	296.74	296.77	296.27	296.28
161.25	298.35	299.91	298.14	299.55	297.88	299.38	297.53	298.99	297.10	298.48	296.55	297.71
211.25	299.53	302.71	299.31	302.63	298.91	302.44	298.36	302.07	297.73	301.47	296.98	299 .91
250.00	312.38	310.09	306.55	308.10	301.07	305.19	299.32	303.85	298.24	302.03	297.27	301.20

Table-5.5

ELEVATION OF HG LINE ON RIGHT SIDE OF BSFC

Dist. From c/l of drain	Distance from c/l of BSFC on right side (m)															
	0		15.5		28.5		41.5		54.5		67.5		80.5		93.5	
	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA	ANSYS	EHDA
0.00	297.45	296.02	297.78	296.43	298.12	296.79	298.67	297.03	299.90	297.05	301.88	296.51	300.50	295.13	299.62	294.40
11.25	297.45	296.11	297.78	295.54	298.11	296.99	298.60	297.41	299.59	297.82	301.88	297.41	299.62	295.83	297.18	294.61
61.25	297.60	296.88	297.91	297.31	298.22	297.71	298.66	298.37	299.49	300.08	301.88	301.88	299.17	298.63	296.95	297.03
111.25	297.88	298.05	298.18	298.35	298.47	298.65	298.88	299.17	299.65	300.34	301.88	301.88	299.25	299.02	297.01	297.28
161.25	298.35	299.91	298.63	300.08	298.87	300.19	299.20	300.30	299.85	300.88	301.88	301.88	299.33	299.51	297.10	297.41
211.25	299.53	302.71	299.73	302.67	299.77	302.46	299.86	302.22	300.23	301.94	301.88	301.88	299.43	299.96	297.19	297.84
250.00	312.38	310.09	303.92	306.48	301.29	304.57	300.55	303.44	300.52	302.37	301.88	301.88	299.48	300.73	297.26	299.17

5.6 PART –II OF STUDY

(DETERMINATION OF UPLIFT PRESSURE AND EXIT GRADIENT FOR VARYING LENGTH OF LINING)

In this study model has been analyzed for the same boundary conditions as shown in table 5-II for the different length of lining (36.25m, 61.25m, 86.25m, 111.25m, 136.25m, 161.25m, 186.25m, 211.25m, 230.625m, 250.00m). First case for which the model has been tested is higher canal lined and the lower canal unlined.

In the other case the model has been analyzed keeping both canals lined for the same boundary conditions and the length of the lining is also varied as the first case.

In the third case both canals are unlined and the boundary conditions are same as in other cases.

Three seepage models of different **cut off depth: 10.0m, 6.5m, and 3.0m**, are analyzed for the above three cases. Exit gradients at the u/s & d/s cut off and uplift pressure below the barrel floor (for three sections: Z = 0m, 5.625m, 11.25m) have been evaluated and presented.

5.6.1 LOADING CONDITIONS

Table - 5-II

S.No.	Depth of Cut off	Case	Boundary Conditions
1	10.00m	(i) Higher canal lined, lower unlined	Same as given in para:4.3.1
		(ii) Both canals lined	Do
		(iii) Both canals unlined	Do
2	6.50m	Do	Do
3	3.00m	Do	Do

Note: Three models which are specified above have been tested for 10 different lining length started from 250.0m to 36.25m.

5.7 RESULTS OF ANALYSIS:

5.7.1 UPLIFT PRESSURE

1 Case No. 1: Higher Canal Lined & Lower Canal Unlined

3-D FEM analysis has been conducted for the three depths of cut off (d = 10.0m, 6.5m and 3.0m).

Figures 5.7 to 5.9 show the uplift pressure distribution along the base of barrel floor for cut off depth (d) equal to 10.0m. Each figure shows the uplift pressure distribution for different length of lining (from 250.0m, 230.625m, 211.25m, 186.25m, 161.25m, 136.25m, 111.25m, 86.25m, 61.25m and 36.25m), for the different sections(Z = 11.25,5.625 and0.0m) of barrel floor.

It is clear from the graph, when Z = 11.25m, length of lining = 250.0m maximum uplift pressure is 43.82% , which is at the location of unlined canal and this trend is almost same up to lining 136.25m but for the smallest lining length 36.25m the maximum uplift pressure is 62.99% at the lined canal side. For the lining length 111.25m the maximum value of uplift pressure is 45.61% so pressure variation is not affected up to this length but abrupt rise in pressure value is occurred for the smaller lining length. At the end (d/s edge) of the barrel pressure rise is very small (24% to 27.1%) as compared to the u/s edge of barrel floor (21.33% to 35.86%) from the higher lining length to the lower lining length. For the section (Z = 11.25m), the variation of the pressure values for the minimum and maximum length of lining is ranging from 5.76% to 19.17%. Figure5.8 shows the pressure distribution for d = 10.0m at Z = 5.625m for different lengths of lining. For the lining length 250.0m maximum uplift pressure is 34.80% and for smallest lining length is 59.42%, similarly minimum pressure is 20.64% and 30.10% respectively. At the u/s end of the barrel floor pressure ranging from 20.64% to 36.91% for consecutive increasing length of lining, at the d/s end pressure is ranging from 24.98% to 30.10% respectively. The pressure distribution for Z = 0, maximum pressure ranging from 30.48% to 59.08%, minimum pressure ranging from 24.94% to 30.28% for the lining from 250.0m to 36.25m respectively.

Combined graph for maximum uplift pressure for these three sections of floor v/s length of lining is shown in fig 5.16 to 5.18. It is clear from the graph that uplift pressure is going on deceasing with the increasing length of lining and the potential drop is taking place from the last section i.e. Z = 11.25m towards the c/l of barrel Z= 0.0m.

Second and third 3-D FEM analysis has been conducted for seepage model for the cut off depth d = 6.5m and 3.0m respectively. Table-5.6 to 5.8 gives the uplift pressure values for these models at the three sections Z = 11.25m, 5.625m and 0.0m of the barrel floor. The trend of results has been found to be almost the same as discussed in previous para for d= 10.0m.

Figure 6.1 to 6.3 show the comparisons of this case for all three cut off depths. The results reveal that there is no significant change in uplift pressure with the change in depth of cut off from 6.5m to 3.0m but an increased in uplift pressure occurred for cut off depth equal to 10.0m. It is also clear that length of lining is also we can reduced up to 136.25m instead of 250.0m because up to this length rise in uplift is very small, nearly 5% . Contour plot of uplift pressure on the barrel floor, for this case is given in figure 5.69, 5.70 and 5.71 for the depth of cut off 10.0m, 6.5m and 3.0m respectively.

2 <u>Case No. 2: Both Canals Lined</u>

For this case also three seepage models has been tested for cut off depth is equal to 10.0m, 6.5m, 3.0m,

Figure 5.10 shows the pressure distribution along the barrel floor for the d= 10.0m at the Z = 11.25m, the pressure variation is uniform for the lining from 250.0m to 161.25m, maximum value is 18.603% and the minimum value is 16.875%, variation is only 1%, but with the decreasing length of lining this variation goes on increasing, it showed maximum values for lining length 86.25m to 36.25m.Uplift pressure attains its maximum value at the higher canal side i.e. X= 89.0m.

Figure 5.11 and 5.12 shows the pressure distribution for the Z = 5.625m and Z = 0m respectively. The trend of the graph is almost same as the Z = 11.25m.

Fig-5.16 to 5.17 shows the variation of maximum uplift pressure v/s length of lining for all three longitudinal sections, it is clear that the uplift pressure is inversely proportional to the lining length. For 36.25m lining length the pressure values under the barrel are nearly same i. e. 65% but for 250.0m of lining the pressures are quite low nearly 25%.

Results of seepage models for d= 6.5m and 3.0m given in table 5.12 to 5.17, shows the trend of pressure distribution similar to that for 10.0m depth of cut off. Lining v/s maximum uplift pressure plot is given in figure 5.10 to 5.12 trend of distribution is almost same. Contour plot of uplift pressure on the barrel floor, for this case is given in figure 5.72, 5.73 and 5.74 for the depth of cut off 10.0m, 6.5m and 3.0m respectively.

3 <u>Case No. 3: Both Canals Unlined</u>

For unlined canals model has been tested for three cut off depth 10.0m, 6.5m and 3.0m respectively. The variation of uplift pressure for each section of barrel is shown in figure-5.13 to 5.15 for cut-off depth 10.0m.

For the depth of cut off 10.0m: at the first section when Z =11.25m fig-5.13 show the uplift graph along the barrel, from the graph it is clear that maximum value of uplift is 81.061% at the higher canal side, at the section z = 5.625m this value reduced up to 69.205% almost at the same location, similarly for the c/l of barrel maximum value of uplift pressure is 68.383% at the exactly same point as above. Uplift pressure at the u/s edge is 40.283%, 40.77% and 41.834% for Z = 11.25m, 5.625m and Z = 0 m respectively, at the d/s edge this value is 27.681%, 31.033% and 31.263% respectively.

Second model has been tested for the depth of cut off 6.5m.The uplift pressure distribution for different section of barrel Z = 11.25m, 5.625m and Z = 0m has been observed the maximum value of uplift is ranging from 68.807% to 73.557% and minimum value of uplift pressure is ranging from 26% to 27% .Pressure difference in u/s edge & d/s edge 9%, which is nearly same for all three sections. Details values are given in table-5.18 to 5.20.

Third FEM analysis has been conducted for the smallest depth of cut off d = 3.0m.

For this case maximum uplift pressure is 74.176%, 70.097% and 69.299% for Z = 11.25m, 5.625m and 0m respectively at the center line of higher canal. Minimum value of pressure is ranging from 18.465% to 22.345%. At the u/s edge value is varying only 6% but at d/s edge this variation is nearly 4%. Details values are given in table-5.21 to 5.23. Contour plot of uplift pressure on the barrel floor, for this case is given in figure 5.75, 5.76 and 5.77 for the depth of cut off 10.0m, 6.5m and 3.0m respectively.

SUMMARY OF RESULTS

The comparison of results reveals that:

1 The uplift pressure is inversely proportional to the length of lining.

2 For both lined canals case the uplift pressure attains less magnitude as compared to other two cases.

3 The pressure values are decreasing from the section on u/s side of barrel towards the c/l of barrel.

4 Uplift attains its maximum value when both canals are unlined. Uplift pressure values are higher for depth of cut off equal to 10.0m and its going on decreasing when depth of cut off is reduced but for the 6.5m and 3.0m depth of the cut off this increment not so significant. Comparison for all three cases with respect to length of the barrel is given in fig-6.1 to 6.3.

5 It is clear from the above chart that length of lining and the depth of the cut off will play an important role regarding uplift pressure on the barrel floor.

5.7.2 EXIT GRADIENT

1 Case No. 1: Higher Canal Lined & Lower Canal Unlined

As discussed earlier for uplift pressure, exit gradient is also found at u/s & d/s cut off for the three types of seepage models for varying lining length.

All FEM analysis has been conducted for the depth of cut off equal to 10.0m, 6.5m and 3.0m. Variation of gradient has been observed at the eight locations of u/s & d/s cut off given in table-5.25 to 5.28 and figure-5.19 to 5.26.

First FEM analysis for depth equal to 10.0m has been conducted, figures 5.19 to 5.26 shows the hydraulic gradient variation along the depth of the u/s & d/s cut off. Each figure shows variation at each location from A_1, A_2, A_3, A_4, B_1, B_2, B_3 and B_4 respectively, for different length of lining. It is clear from the graph that the hydraulic gradient is increasing with decreasing lining length that is inversely proportional to the length of lining. It is observed from the graph gradient is initially increasing then start decreasing up to 80% of the depth of the cut off after that it increased abruptly then again it decreased up to toe of the cut off. At A_1 the Exit gradient is ranging from1: 4.21 to 2.46

for the lining length of 250.00m to 36.25m respectively. At toe this value is varied from 1: 3.988 to 2.52.Graph is symmetrical for A_1 & A_4, A_2 & A_3, B_1 & B_4 and B_2 & B_3. Lesser values of exit gradient have been observed at A_1 & A_4 and B_2& B_3 as compared to the rest locations. Figure-5.27 and 5.28, show the variation of exit gradient v/s lining length, this graph shows that exit gradient is uniformly increasing with the reduction in lining length. For u/s end & d/s end different graph is plotted. The trend of results has been found to be almost same for the u/s & d/s end. Results reveal that exit gradient nearly constant for lining length 250.00m to 211.25m, 186.25 to 86.25m and 61.25m to 36.25m for A_1 to A_4 but for the d/s end for the d/s end values are nearly same.

When depth of cut off is equal to 6.5m the hydraulic gradient variation along the depth of cut off is changed significantly. Values are goes on decreasing from the toe of cut off towards exit end. For the lining length 250.0m exit gradient is 1/3.56 to 1/2.65 at u/s end for d/s end 1/3.41 to 11/2.12. Up to lining length 161.25m values are slightly varying but after this lining length exit gradient increasing abruptly. For d/s end B_2 & B_3 exit gradient increasing slightly with decreasing in the lining length, at B_1 & B_4 up to 111.25m exit gradient is nearly constant but after this it is going on increasing. Table-5.35 shows the exit gradient variation with respect to lining length.

Third analysis conducted for the smallest depth of cut off 3.0m. The trend of variation of hydraulic gradient same as above cases only values is increased. Exit gradient variation with the lining length is given in table-5.35.

From above analysis it is clear that exit gradient is going on decreasing with depth of cut off is increased from 3.0m to 6.5m and 10.0m, up to lining length 250.0m to 136.25m there is no significant variation in the exit gradient values when lining length is reduced more exit gradient increased effectively.

2 <u>Case No. 2: Both Canals Lined</u>

3-D FEM analysis for this case has been conducted for the same conditions and same depth of cut off. Eight nos. of graph has been plotted for different locations which are described above, for each depth of cut off for different length of lining.

It is clear for the cut off depth 10.0m hydraulic gradient is reduced considerably as compared to previous case for the same depth of cut off the difference is the order of 30%. For the lining of 250.0 to 211.25m the exit gradient is nearly same (1: 4.2).Along the depth of cut off gradient is almost constant. At the locations A_1 & A_4 and B_2 & B_3 the exit gradient is lesser than other location's values. Graphs are plotted and shown in figure-5.29 to 5.38.

For the cut off depth 6.50m, the trend of the graph has been found to be almost same as the above; values are lesser the 10.0m cut off results. For both lined canals exit gradient is decreasing uniformly with the increasing lining length at the both u/s & d/s cases. Variation is 52% from the longest lining to the shortest lining for the u/s cot off and 42% for the d/s cut off respectively, which same for the 10.0m is cut off depth. So it is clear that exit gradient is reduced when cut off depth increased but some times it is not economical to increased cut off depth. Investigations required ensuring absolute safety with utmost economy.

For 3.0m cut off depth results reveal that Exit gradient is increased tremendously which is very unsafe for structure, results are given in table-5.31 to 5.34 and 5.36 shows the variation of gradient at each location for different lining length.

3 Case No. 3: Both Canals Unlined

For unlined case at d= 10.0m the exit gradient 1/2.26 to 1/1.85 at the u/s end and 1/3.42 to 1/2.47 at the d/s end has been observed, figure-5.39 to 5.46 shows the variation.

Second depth of cut off equal to 6.50m, values are 1/1.97 to 1/1.37 at u/s cut off and 1/2.97 to 1/1.76 at the d/s cut off. Table-5.33 gives the details of these results.

Results of 3.0m cut off depth reveal that the exit gradient value at u/s & d/s cut off ranging from 1/1.58 to 1/.77 and 1/2.326 to 1/.975 respectively. Results are given in table-5.34.

SUMMARY OF RESULTS

The comparison reveals that:

1. Exit gradient are decreasing with increasing length of lining.
2. For particular lining length exit gradient is heaving higher factor of safety for both lined canals as compared to other cases (higher lined canal and unlined canals).
3. Exit gradient is decreasing with increasing depth of cut off.

5.8 COMPARISION OF 2 –D and 3 – D RESULTS

When the both canals are unlined (third case) the flow pattern is confirm to two dimensional, so in this study the results of seepage models which has been analyzed for unlined case (length of unlined canals is 250.0m) for different cut off depth (3.0m, 6.50m, and 10.0m) are compared with the results of first & second cases for the lining length 250.00m for the respective depth of cut off. Comparisons of results with three dimensional results are shown in the tables 5.37 and 5.38.

From the observation it has been found that for two dimensional flow the uplift pressure is higher than the three dimensional flow. Highest value of uplift pressure is 81.061% for the section Z= 11.25m (u/s edge from the c/l of the barrel) for the cut off depth equal to 10.0m. Fig-5.47 to 5.49 shows the pressure distribution along the drainage barrel at the three sections, when depth of the cut off is equal to 10.0m, for three dimensional flows this value is 43.82 %(higher canal lined) and 18.603% for both lined canals, table-5.37 gives the comparison of 2-d & 3-d results. For 2-d flow maximum value of uplift pressure is occurred at the location of higher canal side but for 3-d flow this variation is uniform. The trend of the results has been found to be almost same for all cases and for respective depths of cut off (6.5m and 3.0m). Maximum uplift pressure v/s depth of the cut off plot shows that uplift pressure is going on increasing with cut off depth for 2-dimensional flow but for 3- dimensional flow this affect is nominal (fig-5.50 to 5.52). Actually pressure variation is occurred at the u/s edge of the barrel floor (Z = 11.25m) but for other sections pressure values are nearly same.

The exit gradient variation is nearly 83% from 2-d to 3-d. Highest values of exit gradient (1:1.76) has been observed for 2-d but this value reduced up 1:3.21 for 3-d. For 2-d flow by increasing the depth of cut off exit gradient will decreased same trend has been observed for 3-d flow. Fig-5.53 to 5.60 and 5.61 to 5.68 show the variation of hydraulic gradient along the depth of cut off and variation of exit gradient for different depth of cut off respectively. The detail of exit gradient results is given in table-5.38. Hydraulic gradient along the cut off depth is nearly same for 2-d flow but for 3-d flow. Gradient is constant for the distance of 70% of cut off depth then it increased abruptly (difference is of the order of about 11 to 15%) after that it is going on increasing up to toe of cut off. Exit gradient is decreasing gradually with the increasing depth of the cut off.

5.9 SUMMARY OF RESULTS

From the results of FEM analysis described in previous para, the following conclusions are made.

- From the comparison of the results of uplift pressure for three depths of cut off, for different length of lining, for the all cases (shown in figure-6.1 to 6.3), at the c/l of barrel floor i.e. Z= 0 and Z=5.625m it is observed that the variation of uplift pressure is negligible as compared to the sections at Z = 11.25m for all the depth of cut off.
- Uplift pressure is higher for unlined canals case.
- When both canals are lined uplift pressure is higher for the d= 10.0m but for 6.5m & 3.0m cut off depth up lift pressure is nearly same.
- Length of lining for higher lined canal we can reduced up to 161.25m instead of 250.0m for 6.50m cut off & 3.0m cut off but for d= 10.0m it can be reduced up to 111.25m.
- Variation of maximum uplift pressure with respect to lining length for three cases shows that for the longest lining length 250.0m pressure drops significantly from unlined & higher lined cases towards the both lined case but for the smallest lining length 36.25m there no significant drop in pressure except unlined case where pressure is same for all ~~lining~~ canals lengths.
- Variations of uplift pressure is nearly same for all sections of barrel except the u/s & d/s edge (given in contour plots from fig-5.69 to 5.77) so it is concluded that the width of the barrel is very small as compared to the length of canals so pressure is not changing significantly.
- For the constant depth of cut off for all three cases lesser value of exit gradient is have been observed for the both canals lined case, highest value for unlined case.
- Exit gradient is inversely proportional to the depth of the cut off i.e. if depth of the cut off will increase exit gradient will decrease.
- With the increasing length of lining the exit gradient is also going on decreasing.

- Exit gradient variation is symmetrical for the right end & left end and right corner & left corner for the both u/s & d/s cut off.
- Exit gradient values at the left & right corner are lesser than end values.
- It is seen from the all figures, that the three dimensional FEM values are lower than the two dimensional.

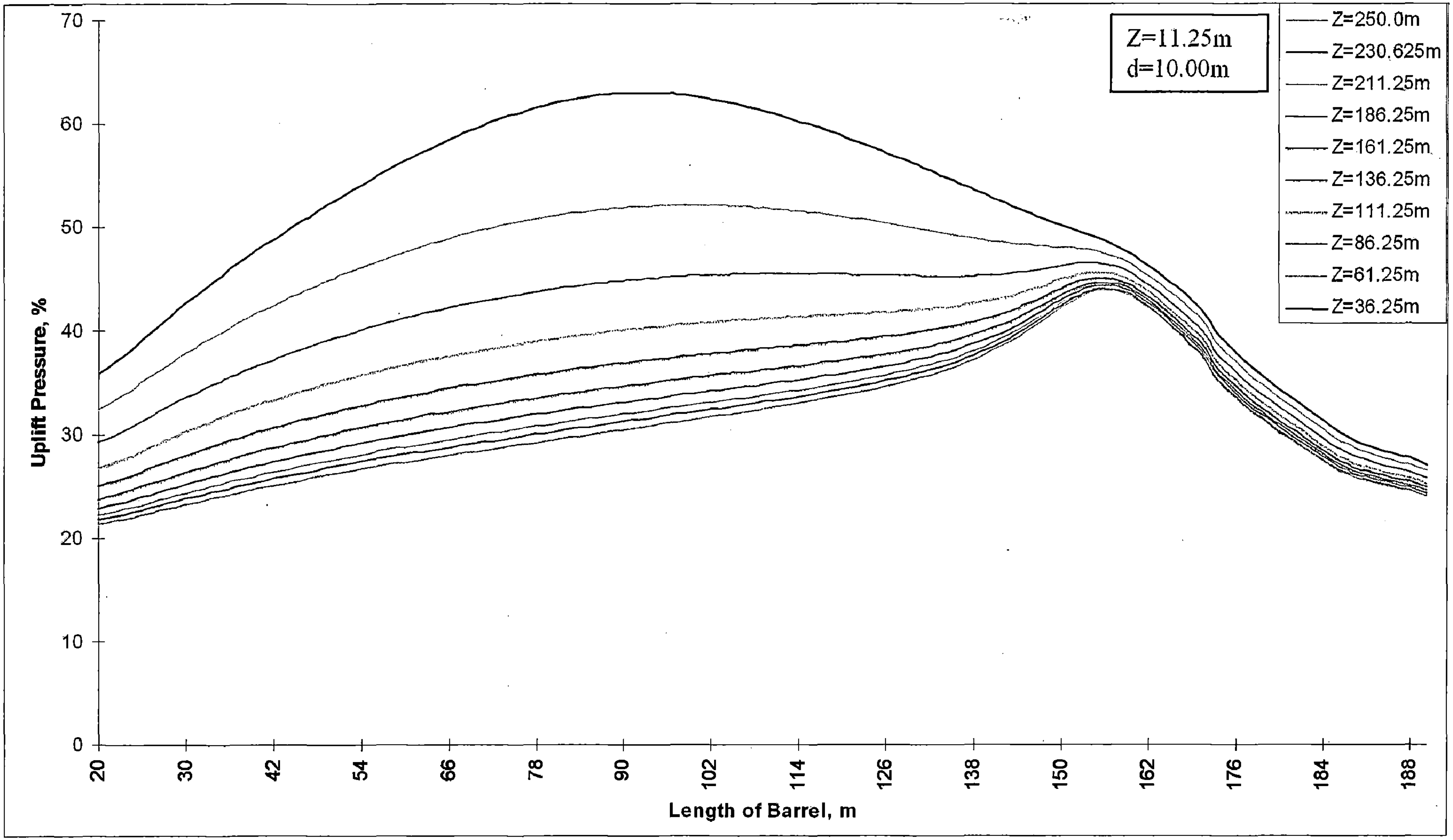


FIG. 5.7 UPLIFT PRESSURE ALONG THE BARREL FOR HIGHER LINED CANAL

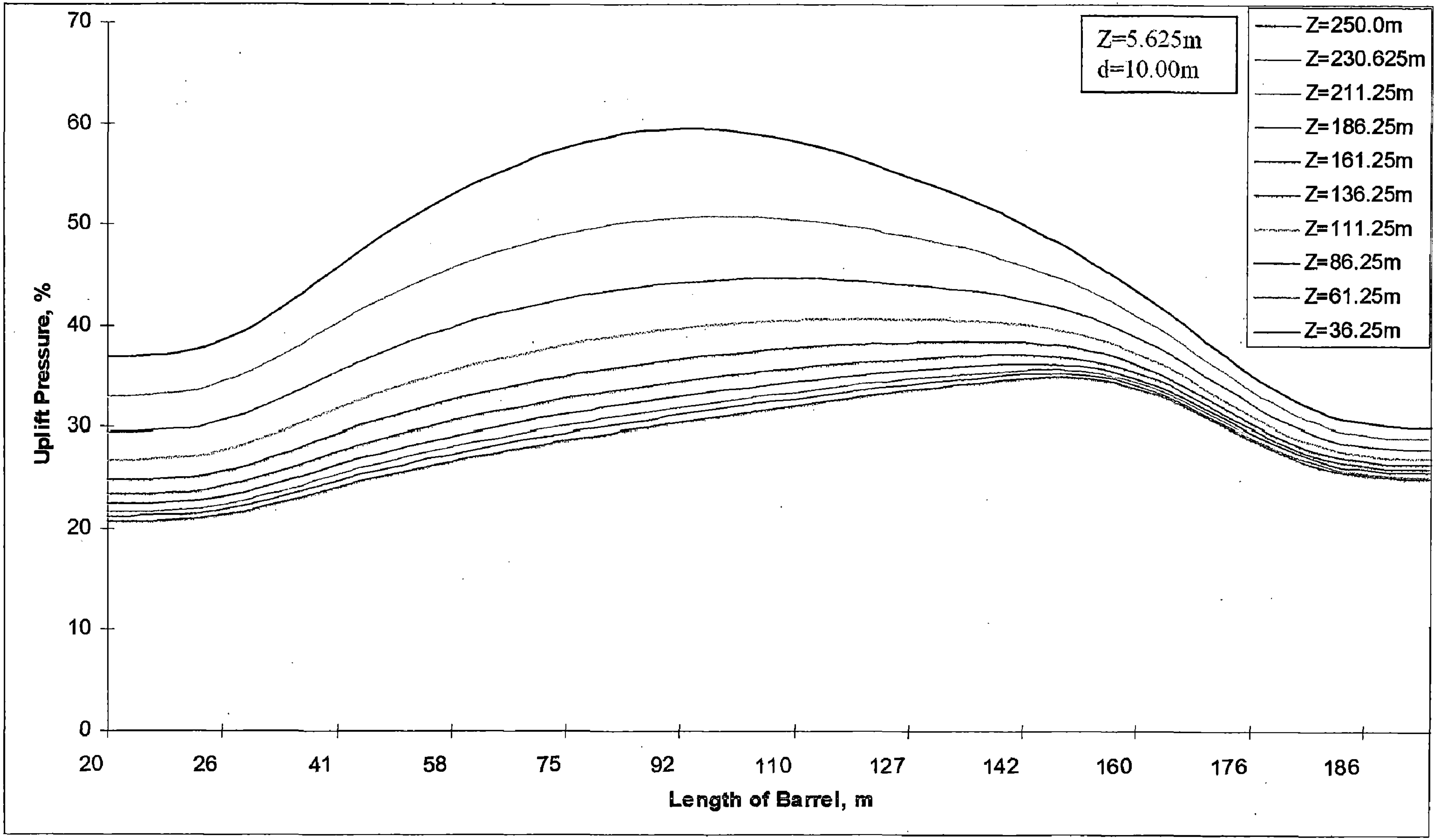


FIG. 5.8 UPLIFT PRESSURE ALONG THE BARREL FOR HIGHER LINED CANAL

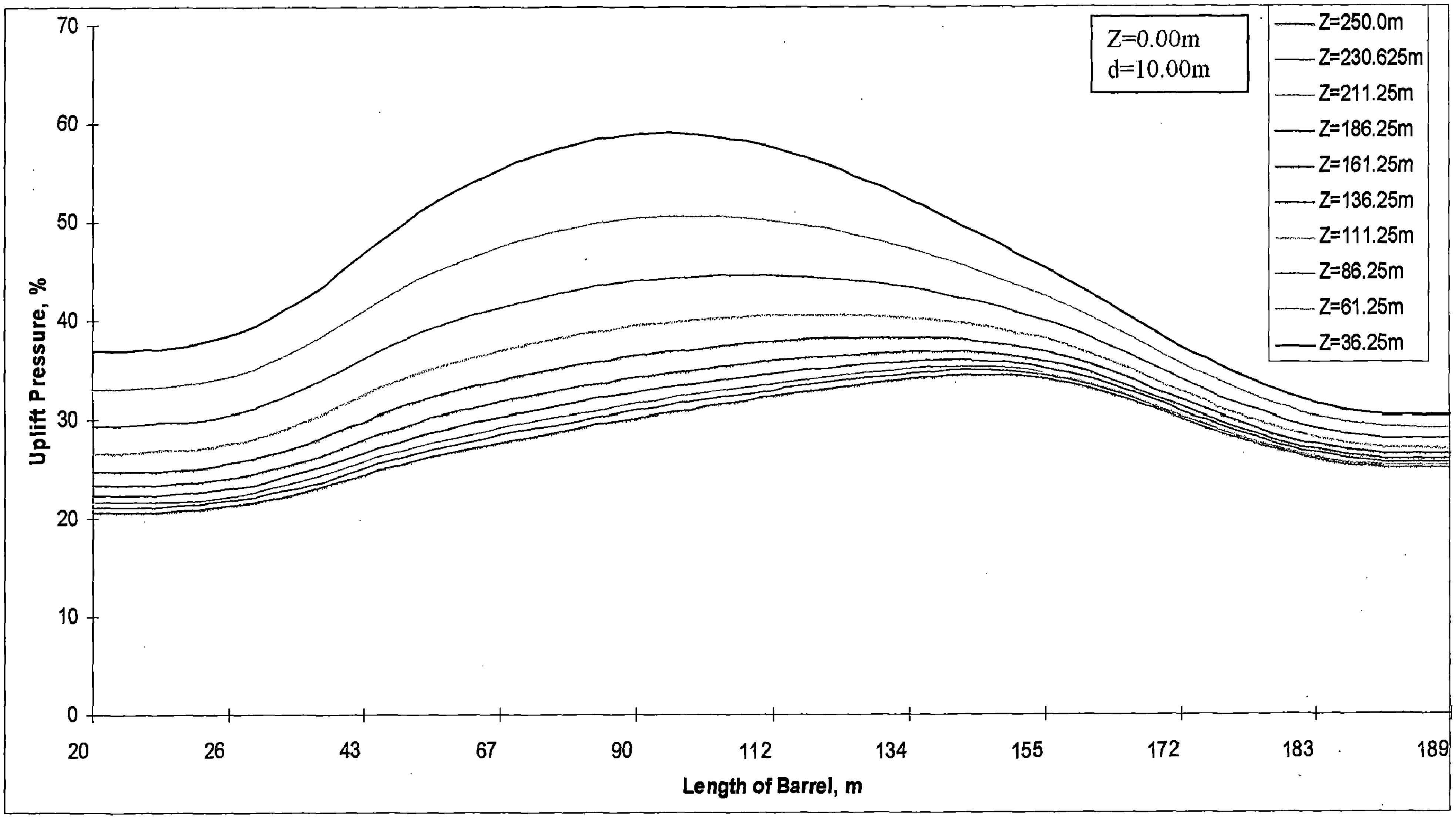


FIG. 5.9 UPLIFT PRESSURE ALONG THE BARREL FOR HIGHER LINED CANAL

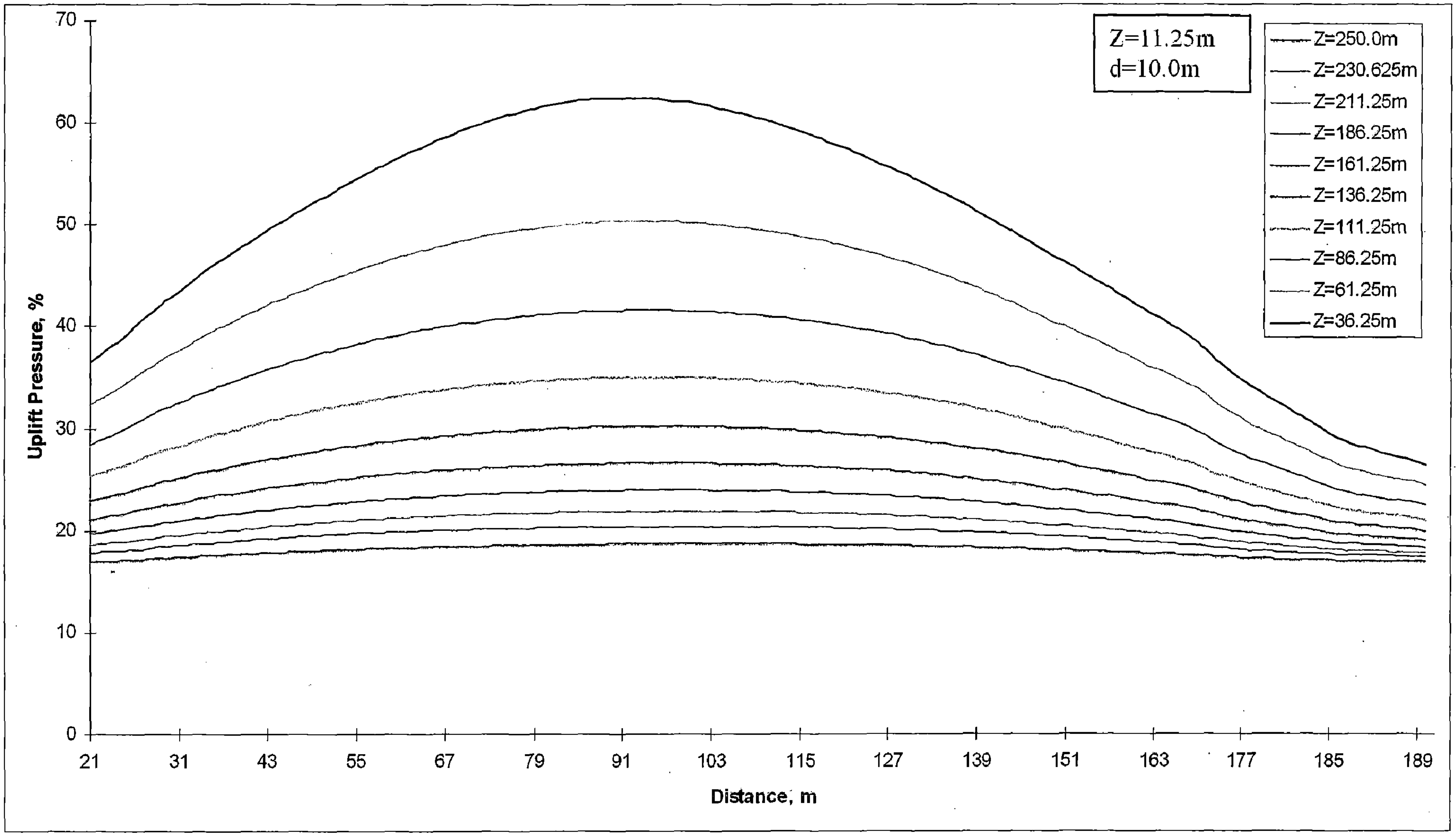


FIG. 5.10 UPLIFT PRESSURE ALONG THE BARREL FOR BOTH LINED CANALS

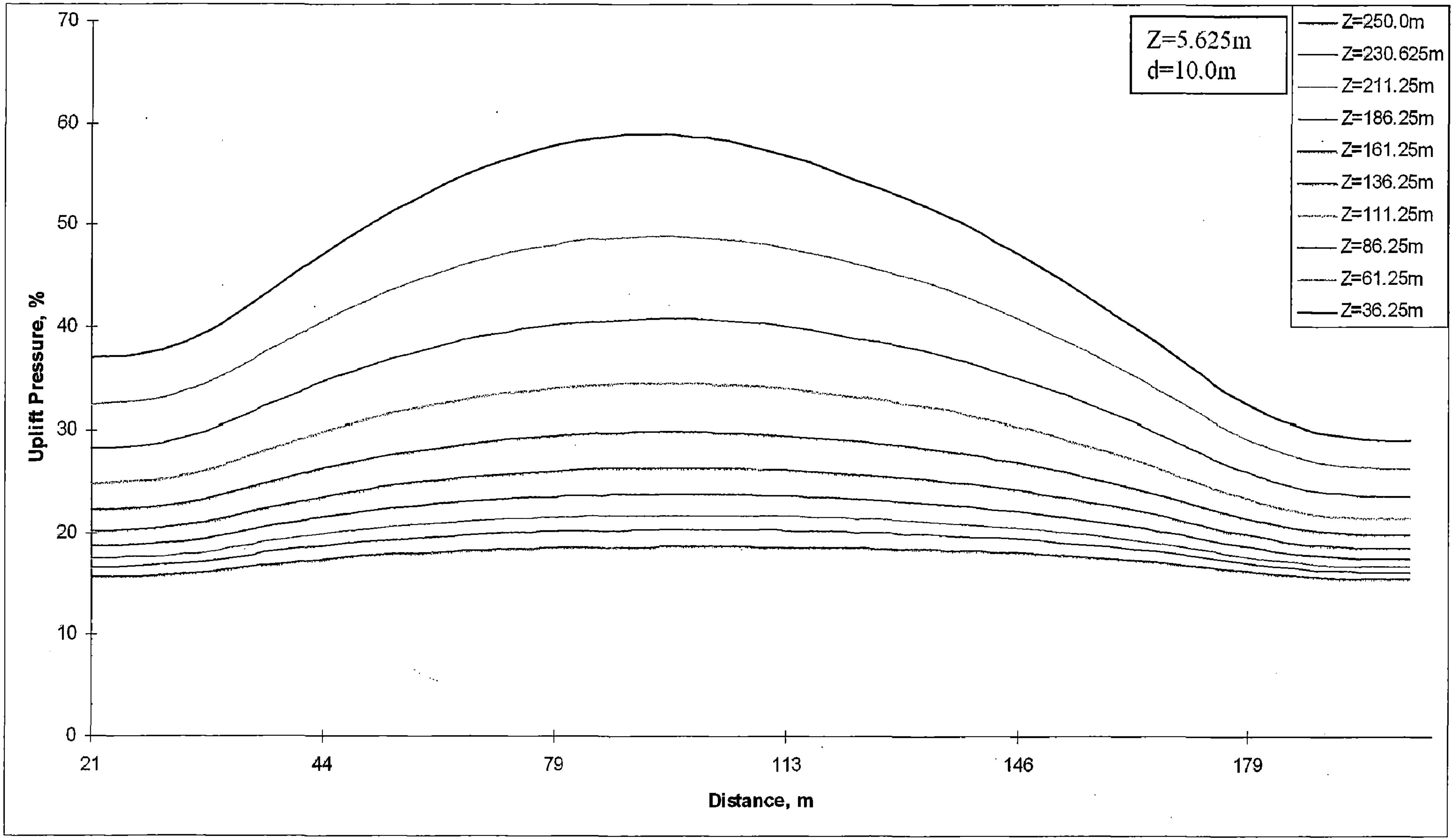


FIG. 5.11 UPLIFT PRESSURE ALONG THE BARREL FOR BOTH LINED CANALS

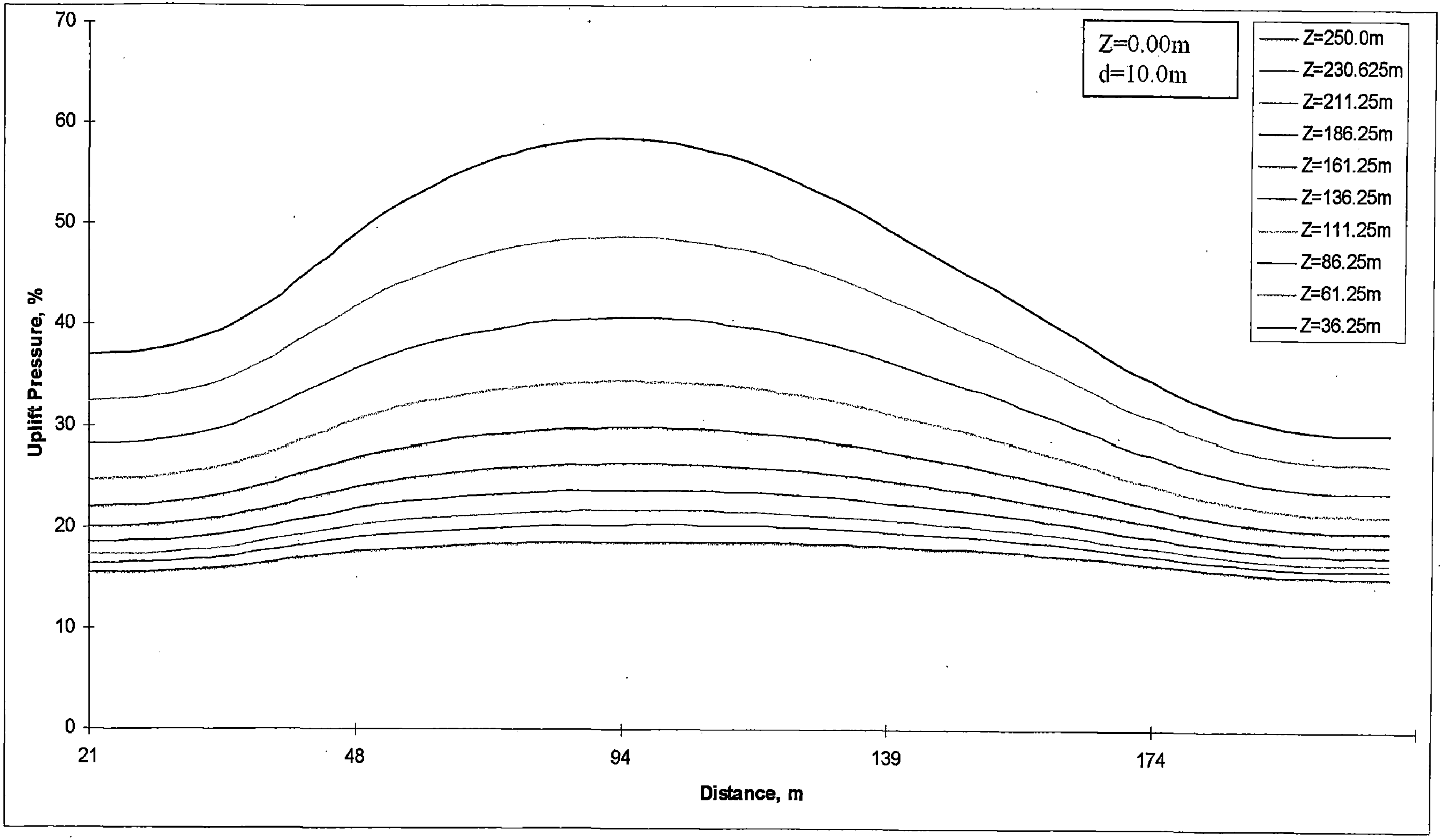


FIG. 5.12 UPLIFT PRESSURE ALONG THE BARREL FOR BOTH LINED CANALS

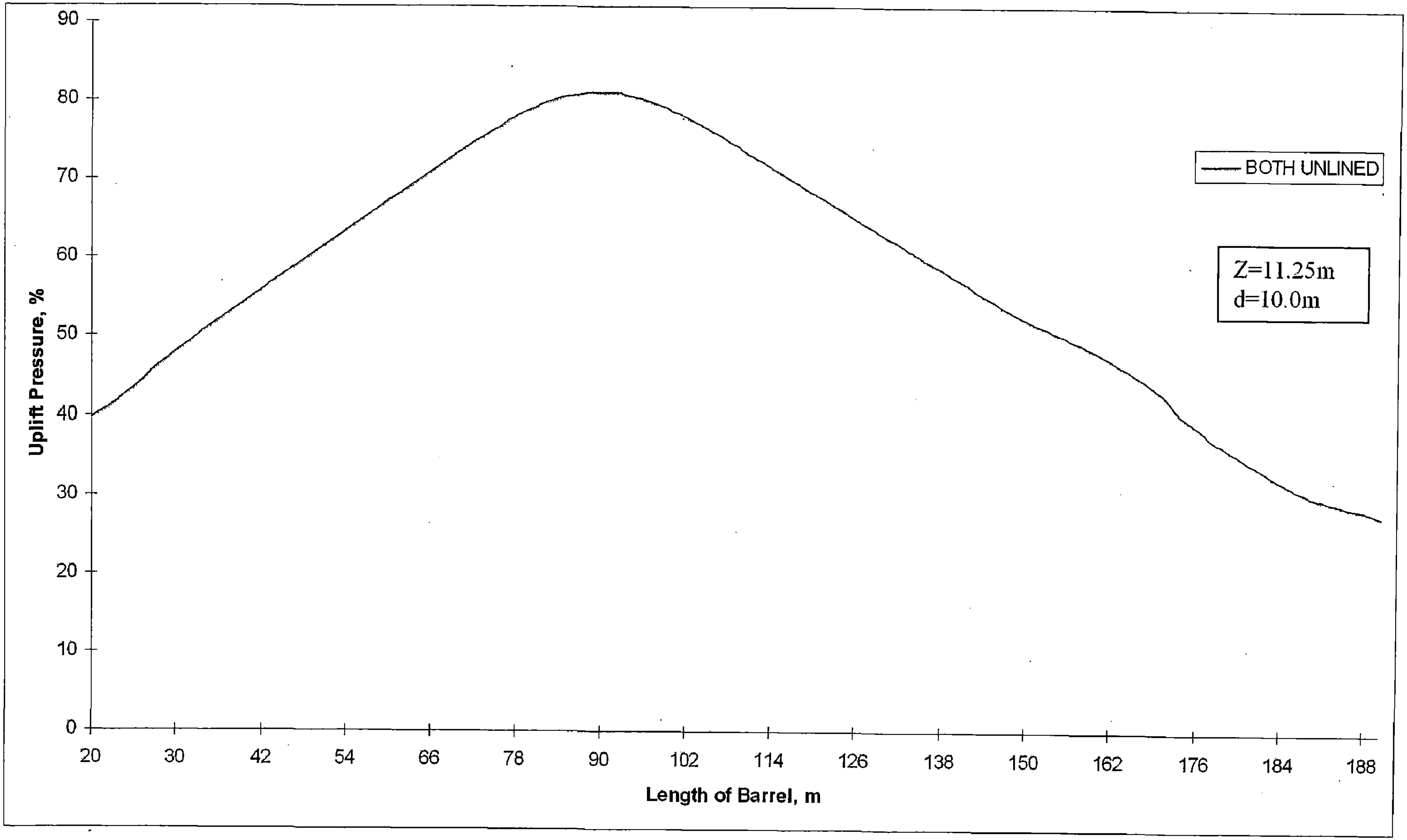


FIG. 5.13 UPLIFT PRESSURE ALONG THE BARREL FOR BOTH UNLINED CANALS

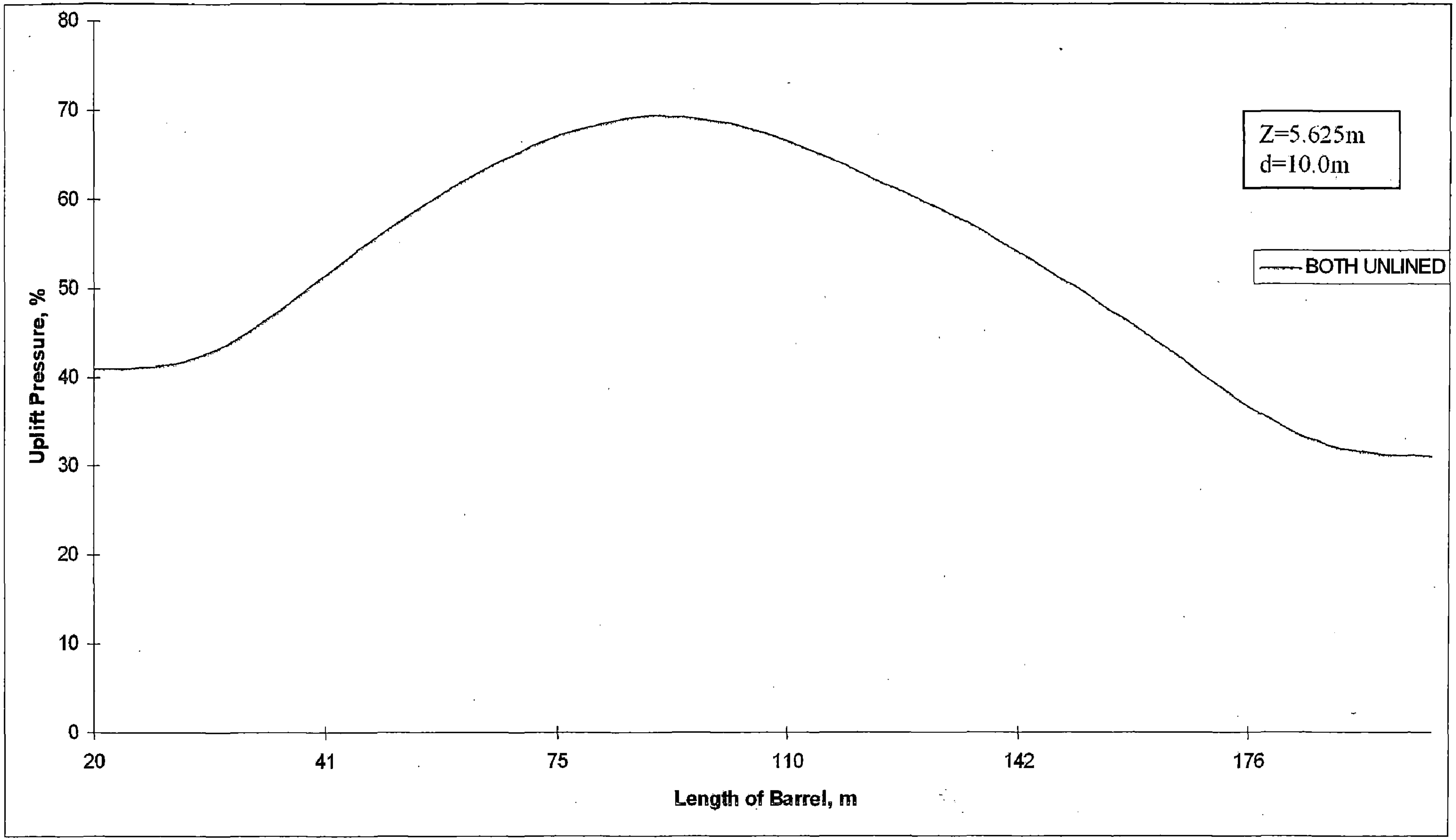


FIG. 5.14 UPLIFT PRESSURE ALONG THE BARREL FOR BOTH UNLINED CANALS

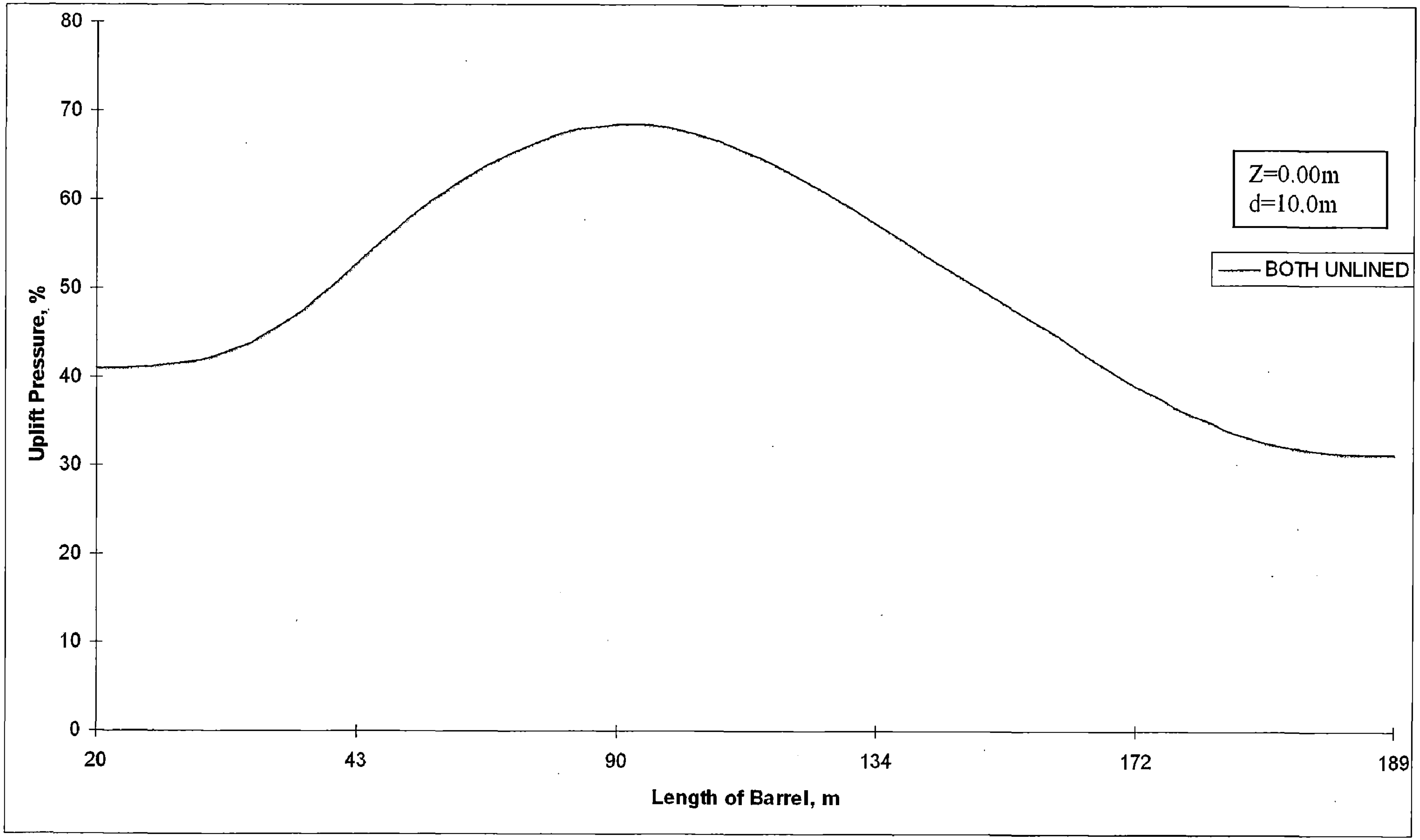


FIG. 5.15 UPLIFT PRESSURE ALONG THE BARREL FOR BOTH UNLINED CANALS

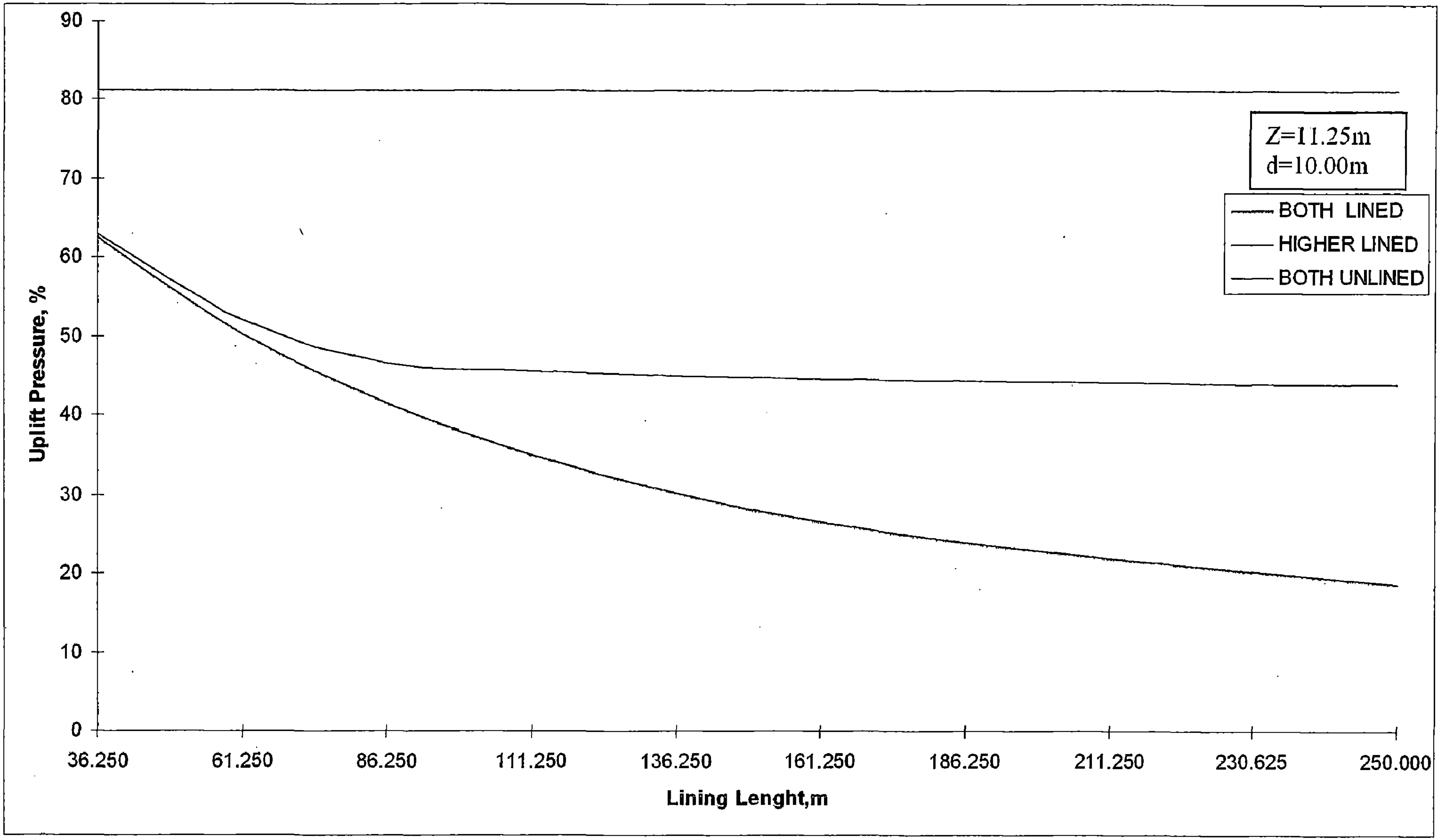


FIG. 5.16 MAXIMUM UPLIFT PRESSURE V/S LINING

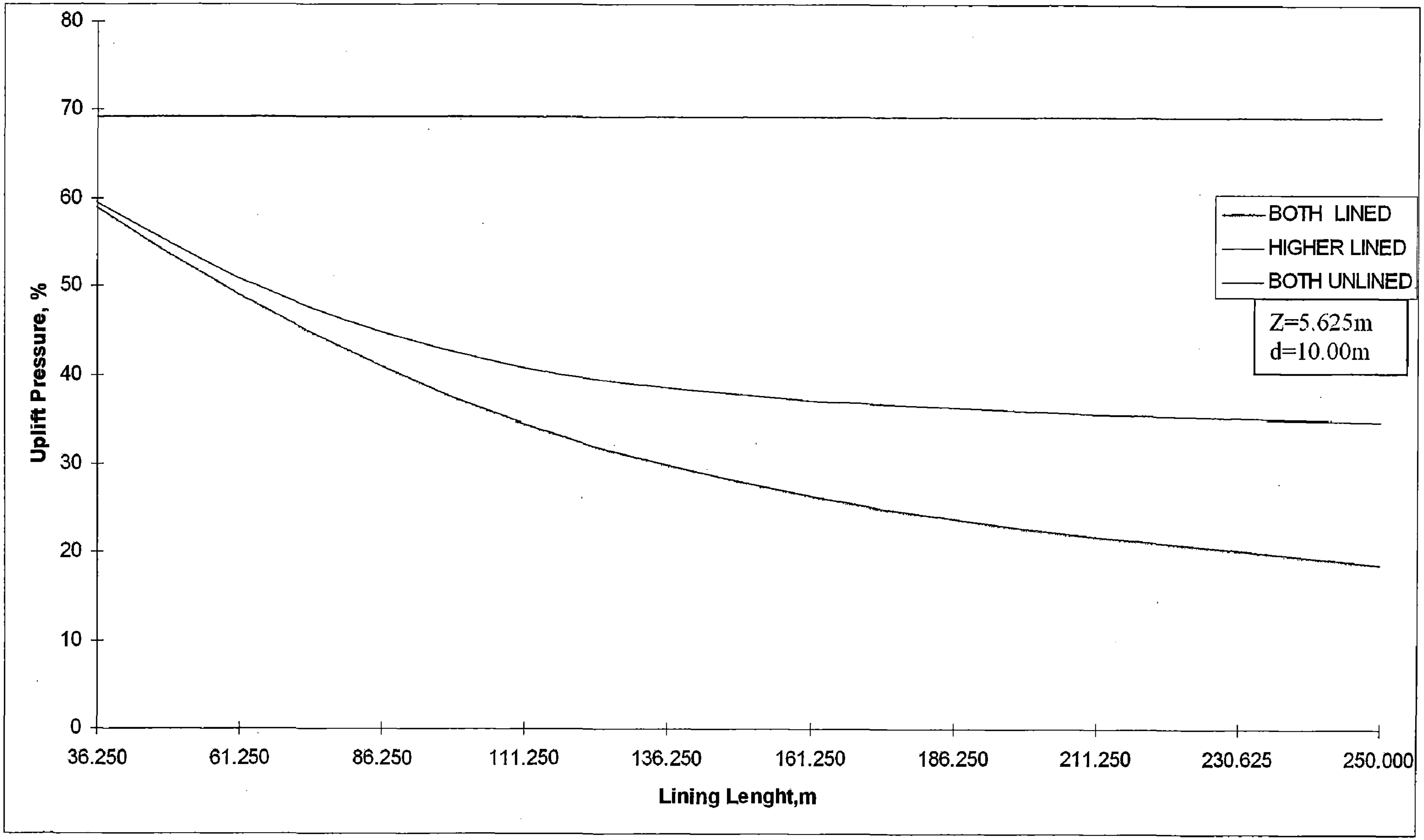


FIG. 5.17 MAXIMUM UPLIFT PRESSURE V/S LINING

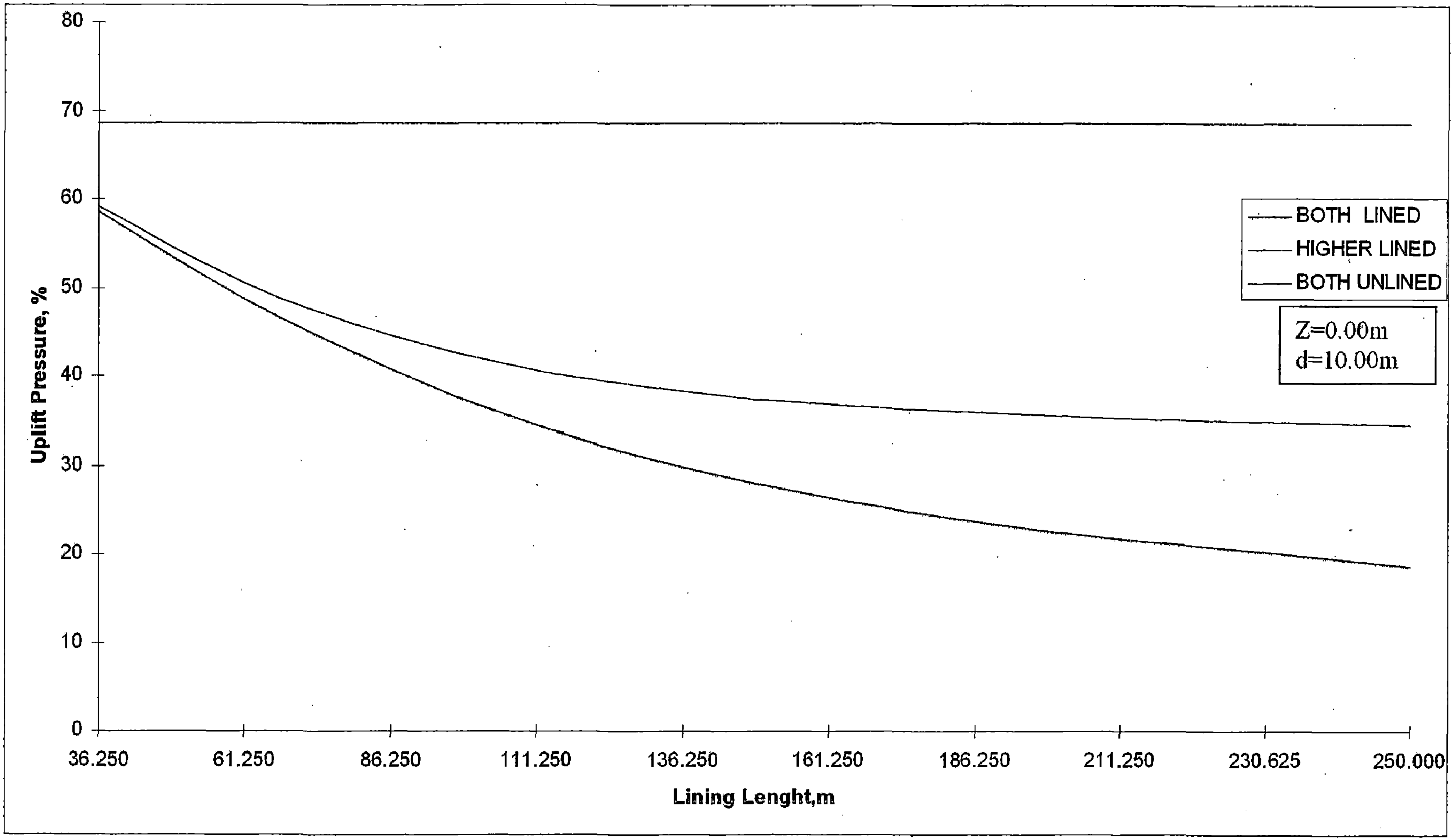


FIG. 5.18 MAXIMUM UPLIFT PRESSURE V/S LINING

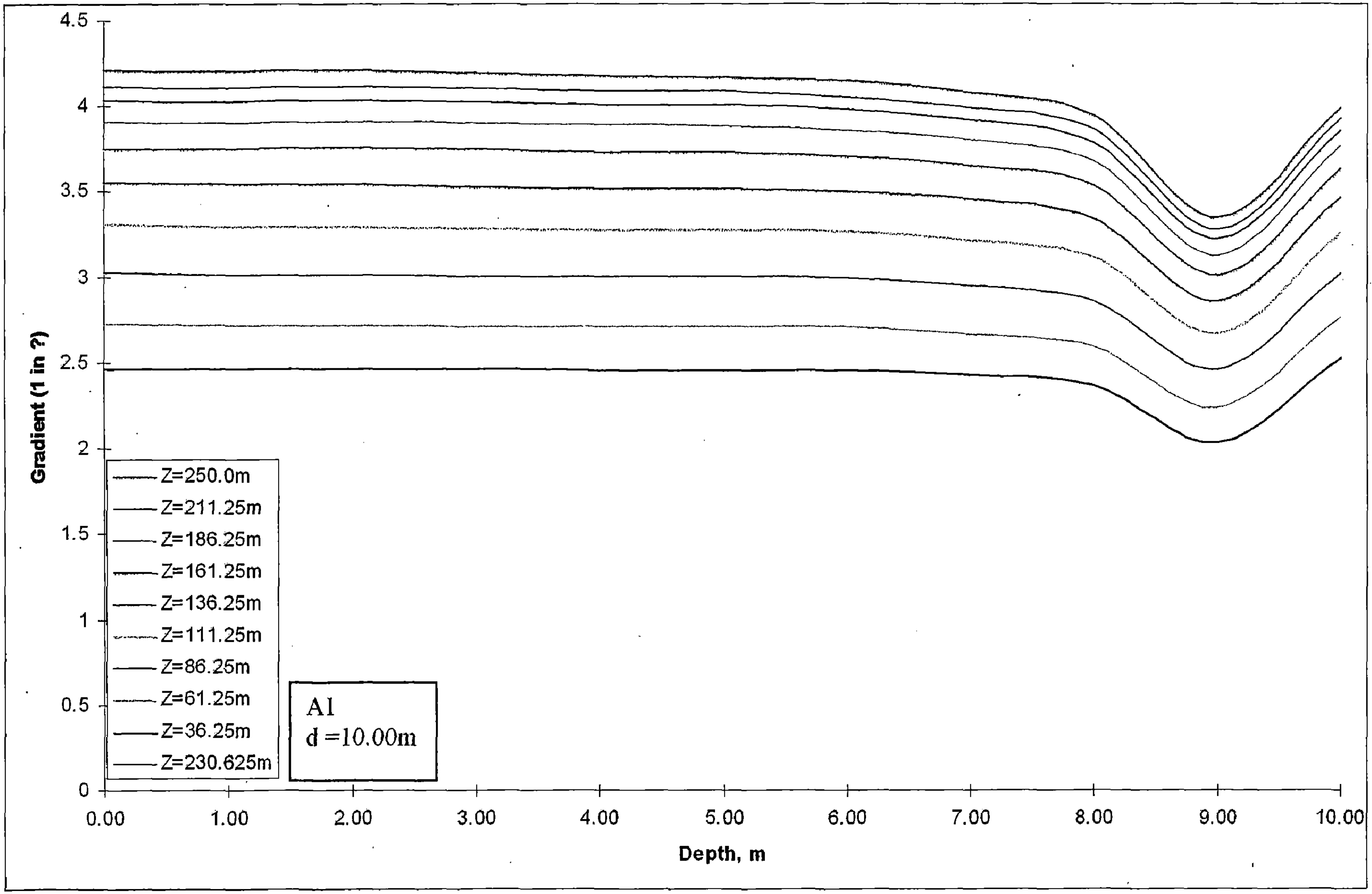


FIG. 5.19 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

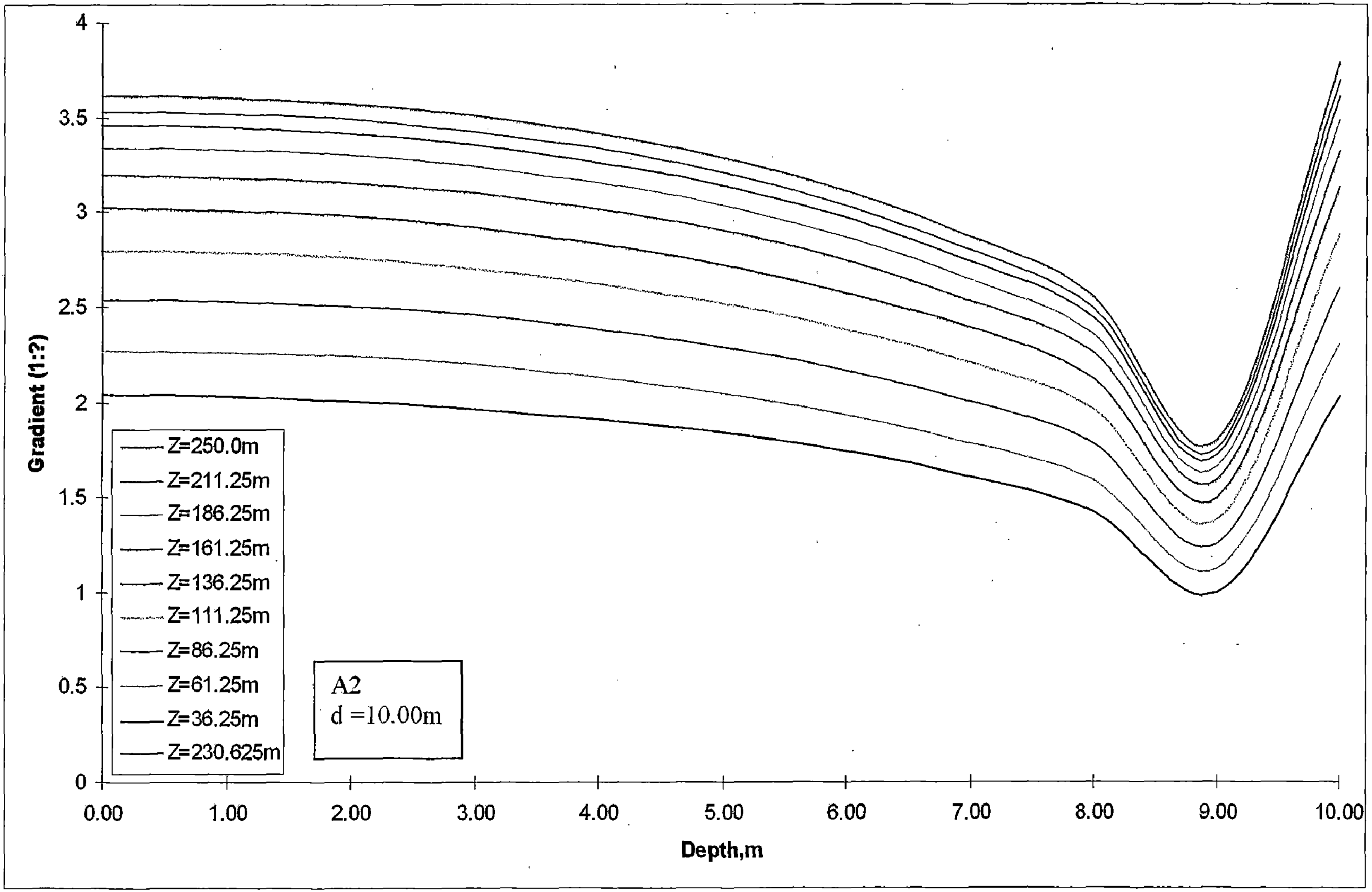


FIG. 5.20 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

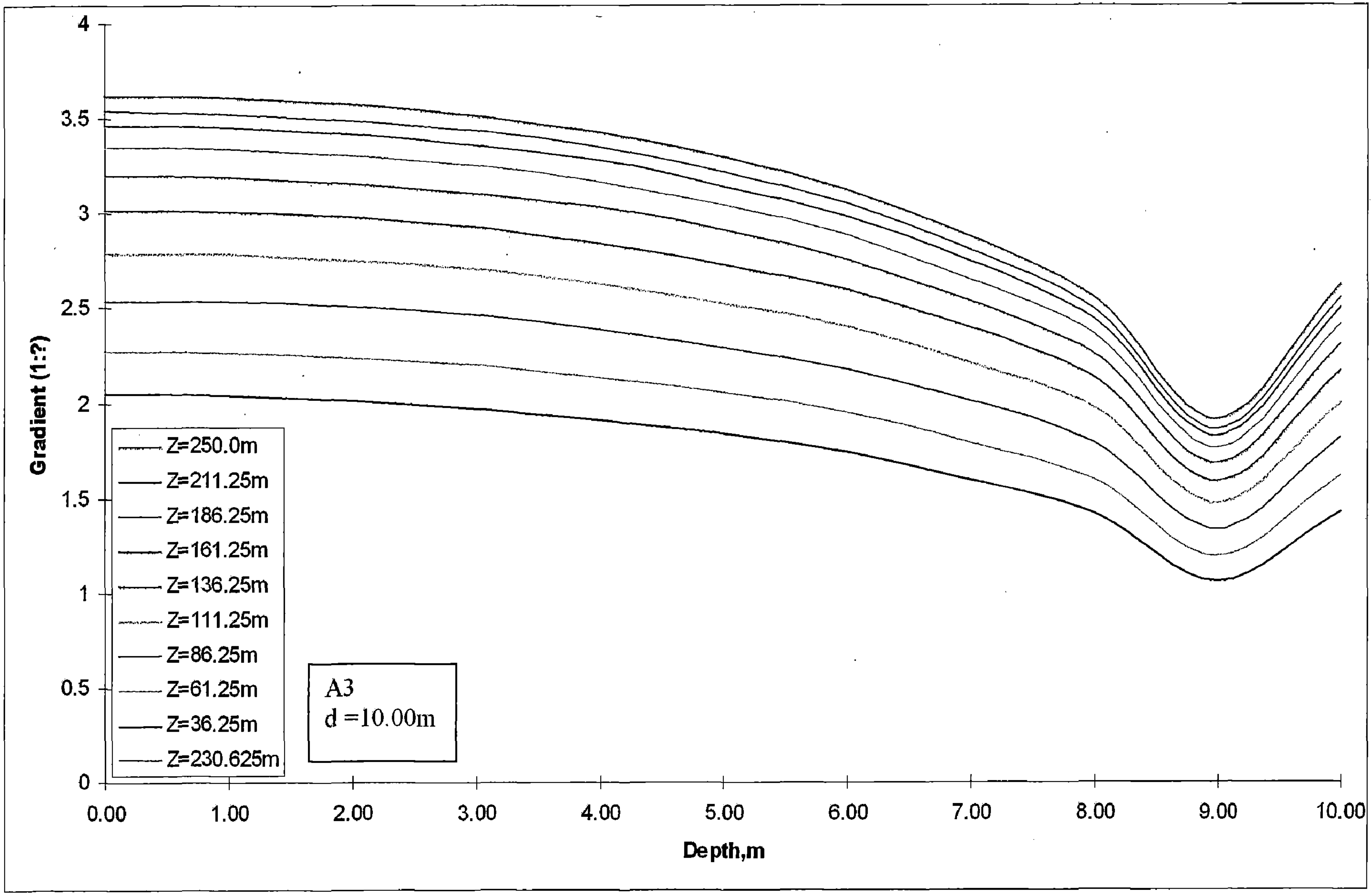


FIG. 5.21 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

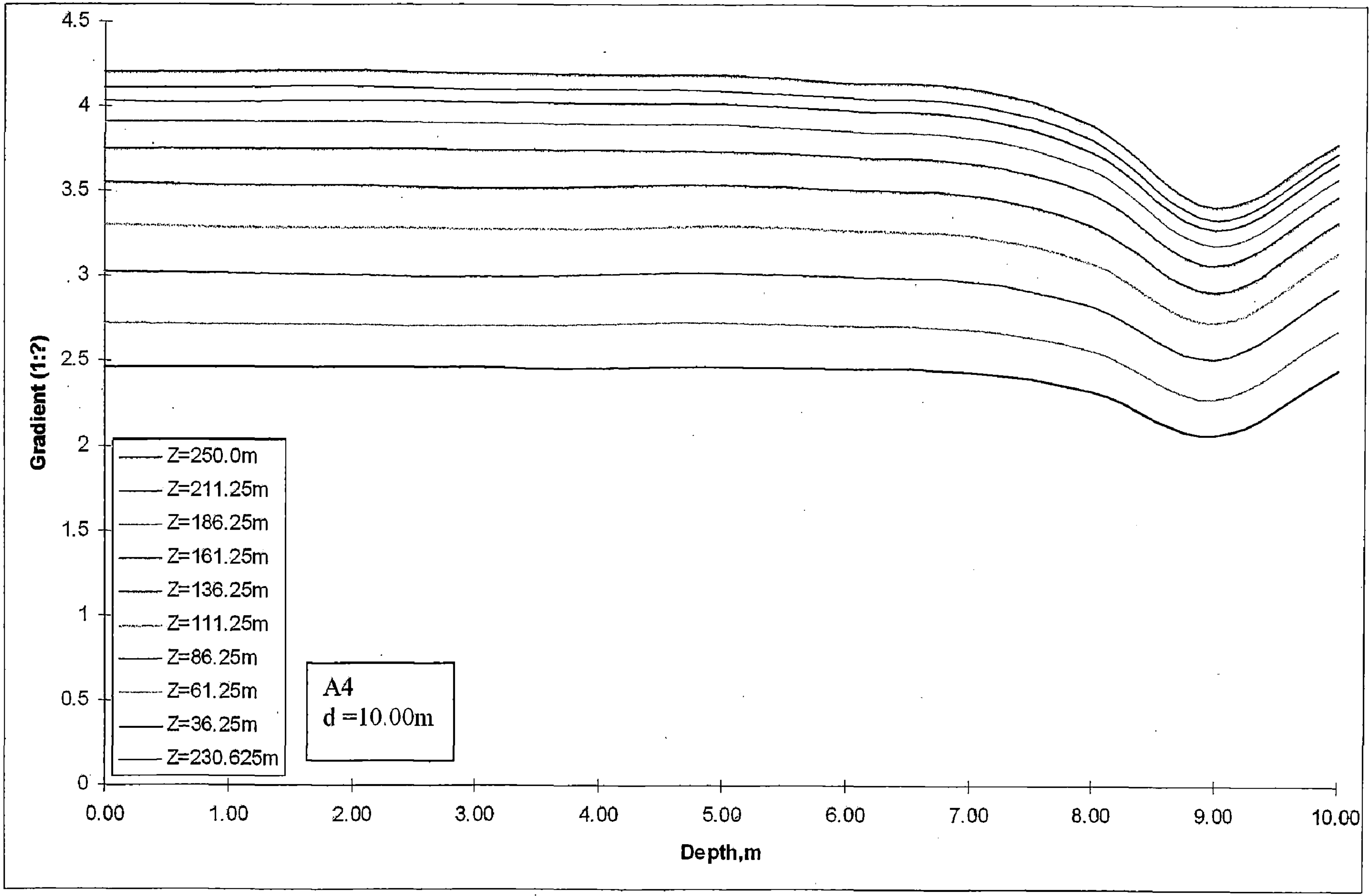


FIG. 5.22 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

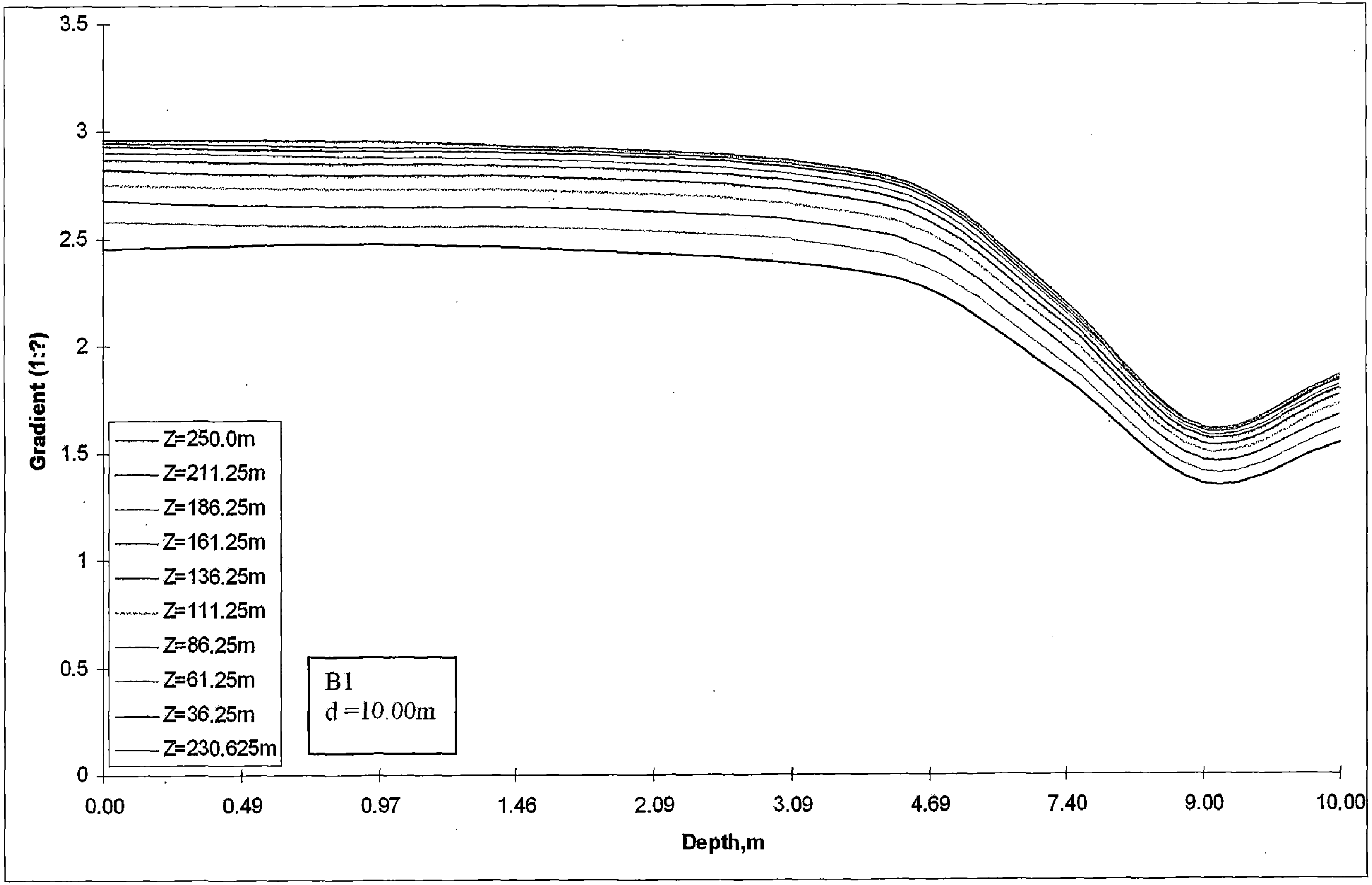


FIG. 5.23 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

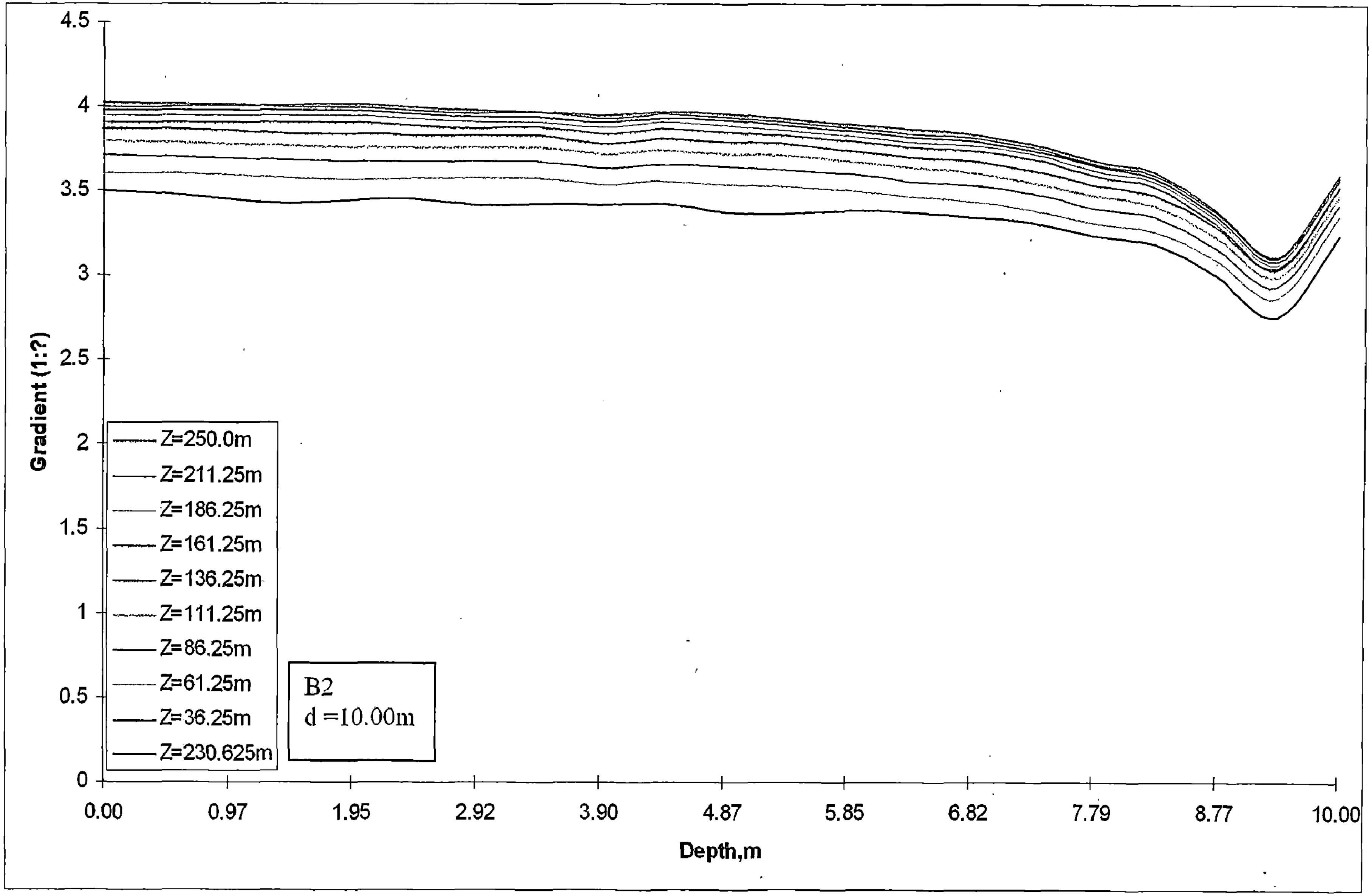


FIG. 5.24 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

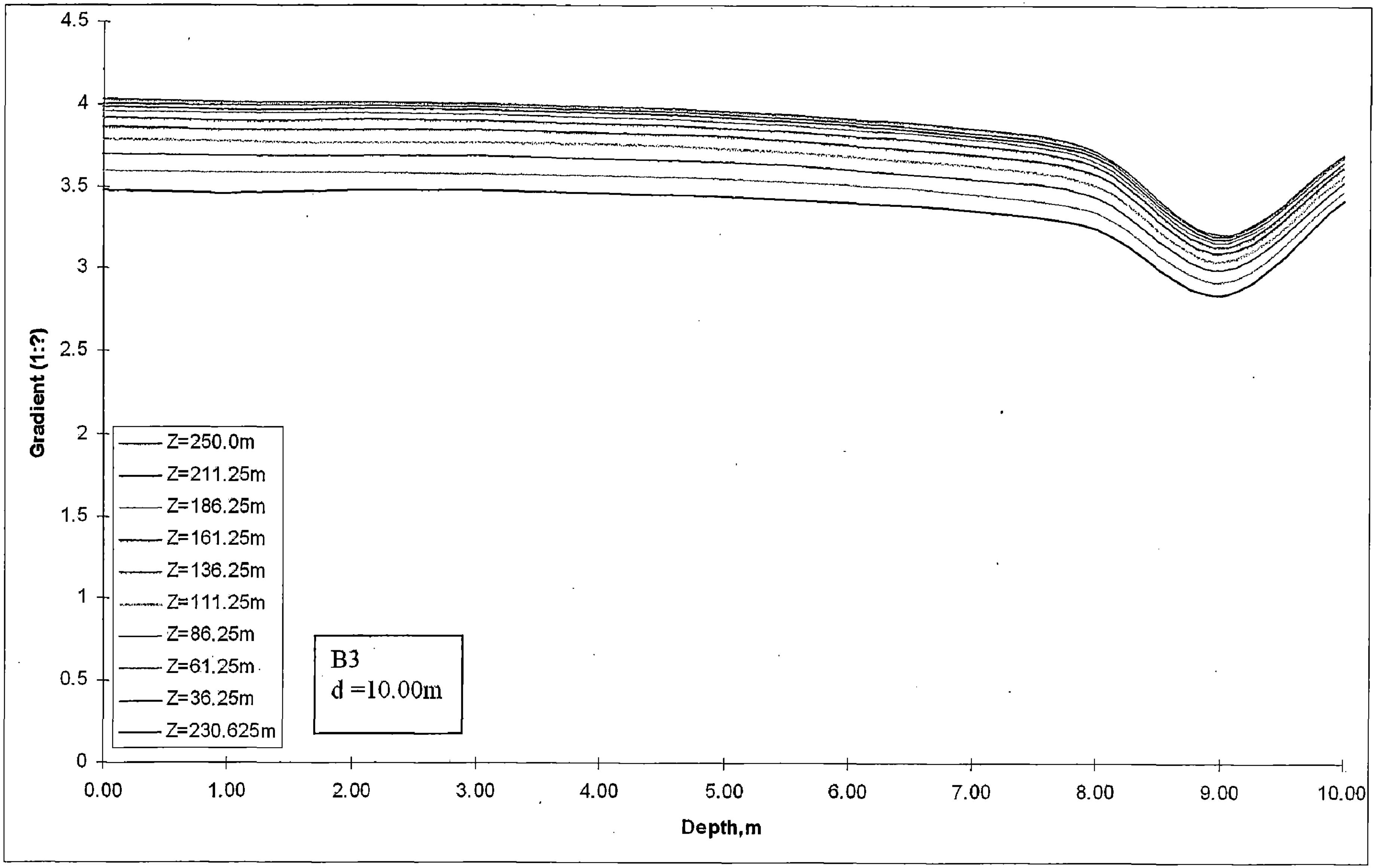


FIG. 5.25 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

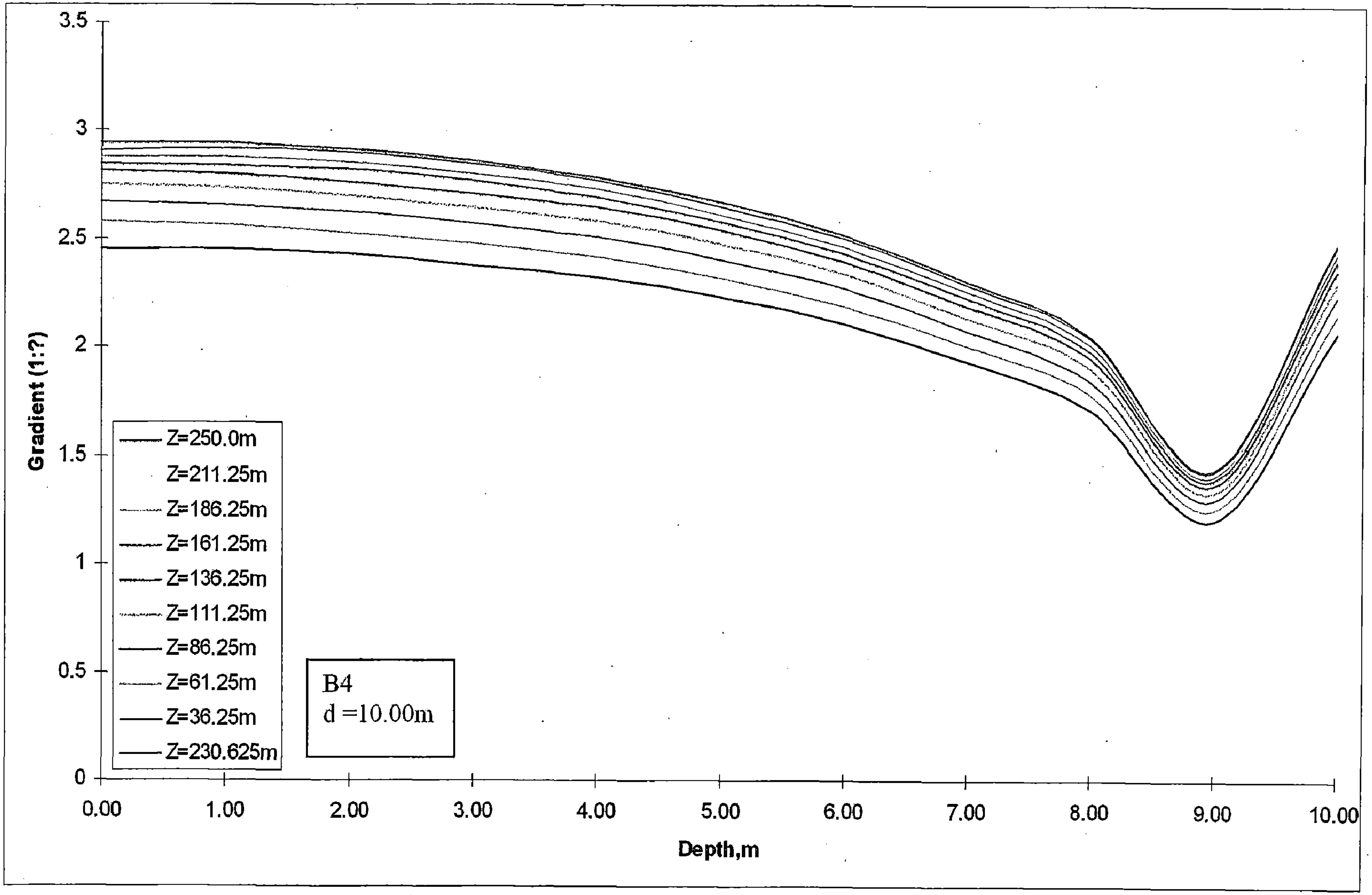


FIG. 5.26 HYDRAULIC GRADIENT ALONG THE CUT-OFF FOR HIGHER LINED CANAL

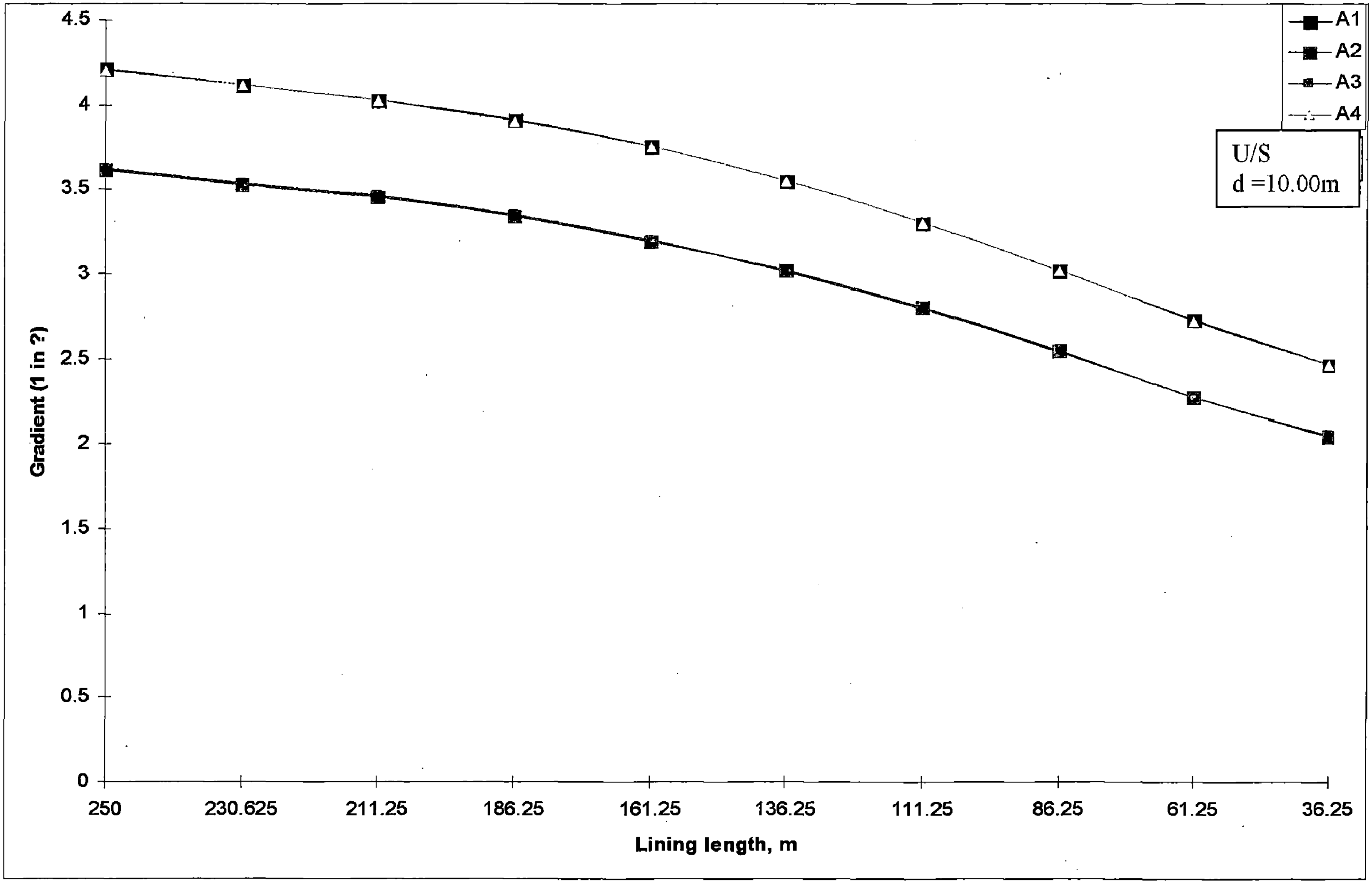


FIG. 5.27 EXIT GRADIENT V/S LINING FOR HIGHER LINED CANAL

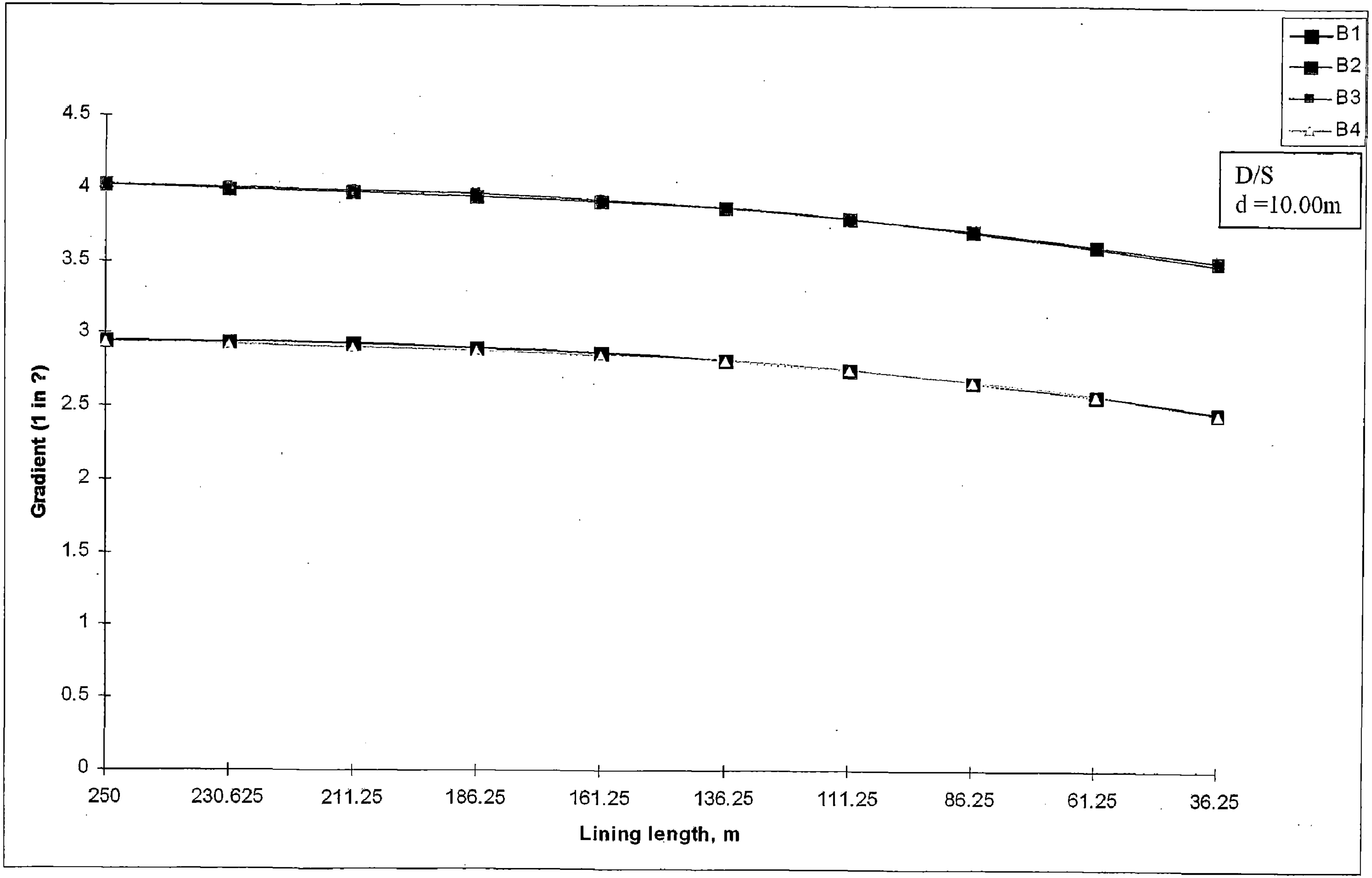


FIG. 5.28 EXIT GRADIENT V/S LINING FOR HIGHER LINED CANAL

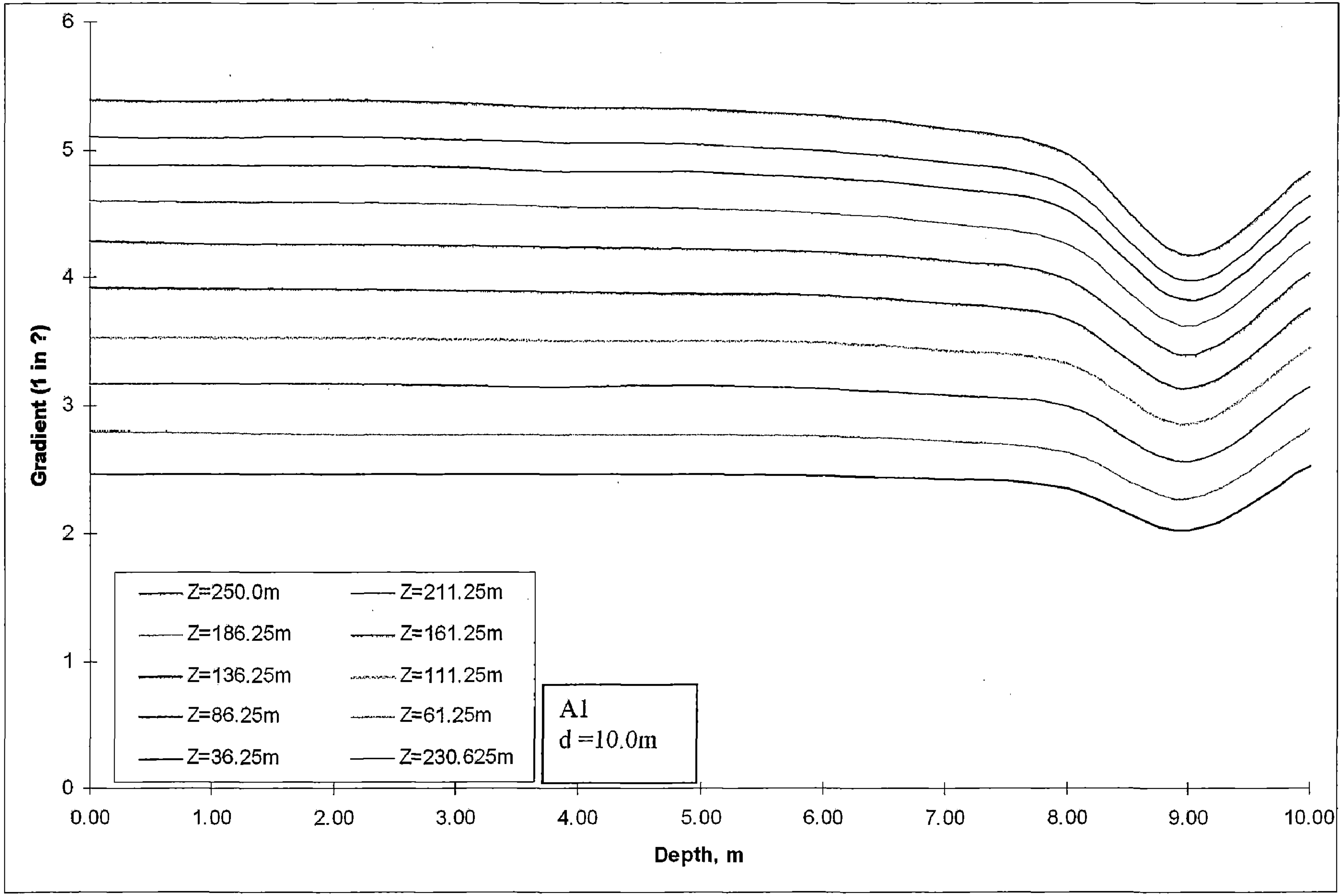


FIG. 5.29 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

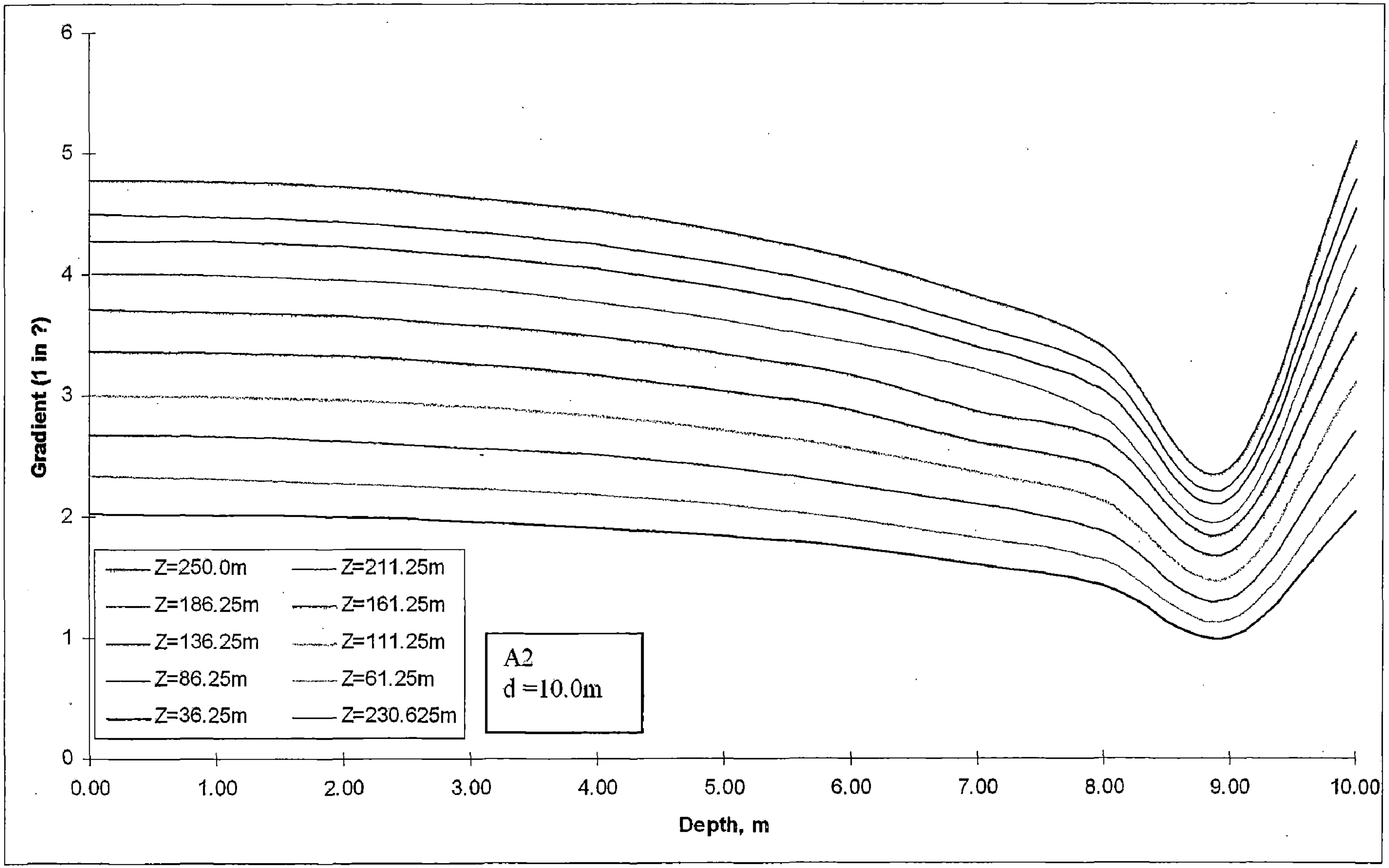


FIG. 5.30 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

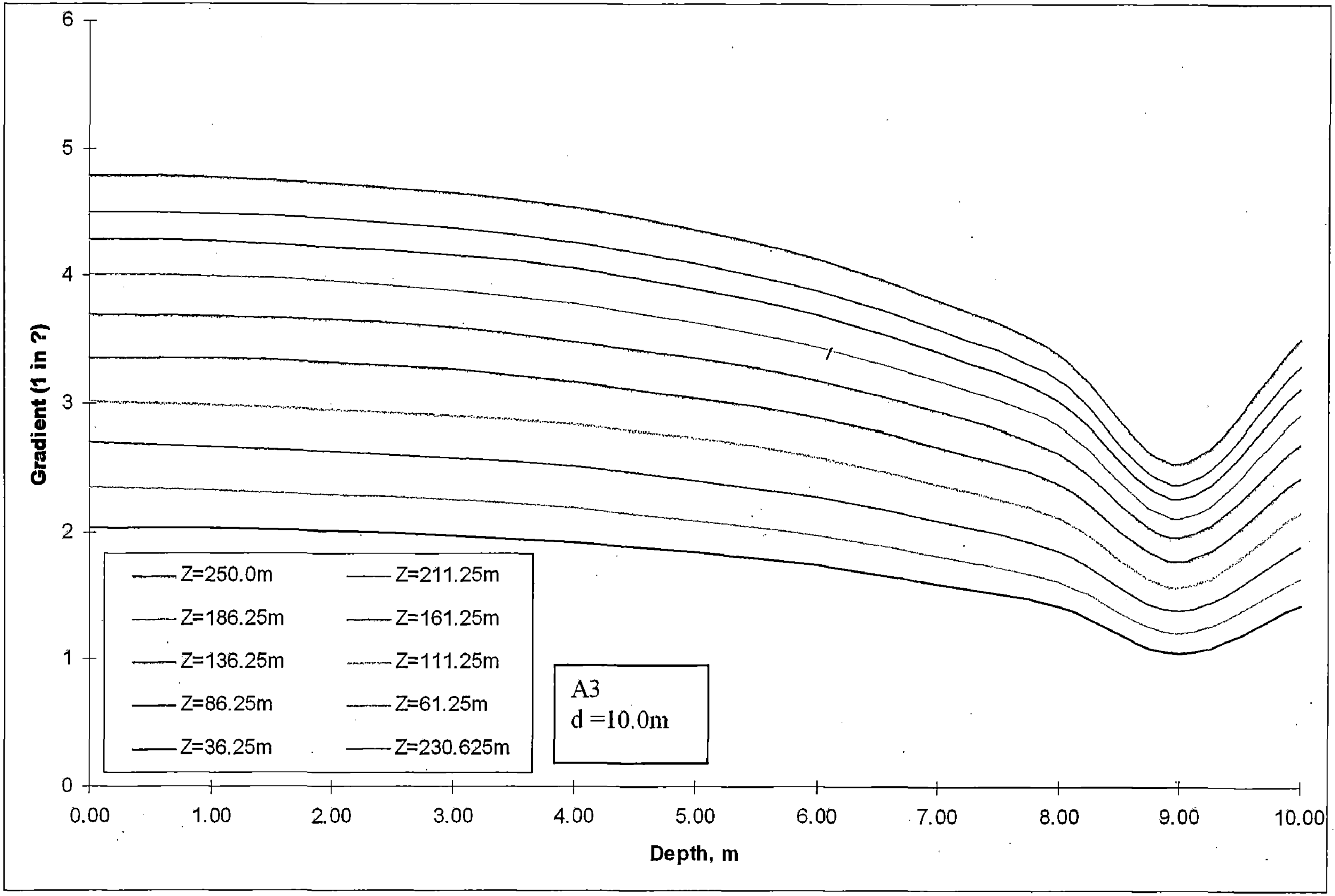


FIG. 5.31 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

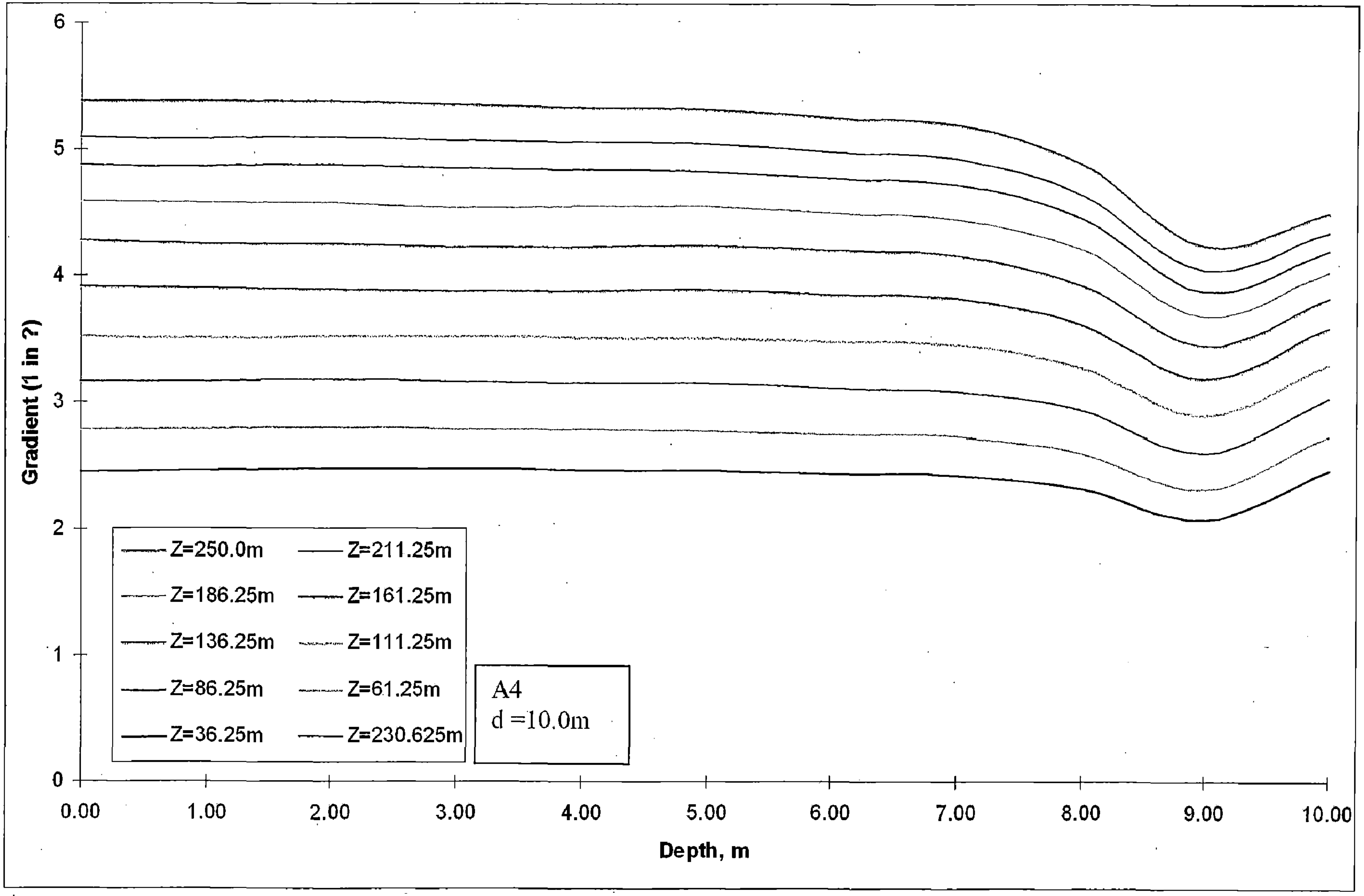


FIG. 5.32 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

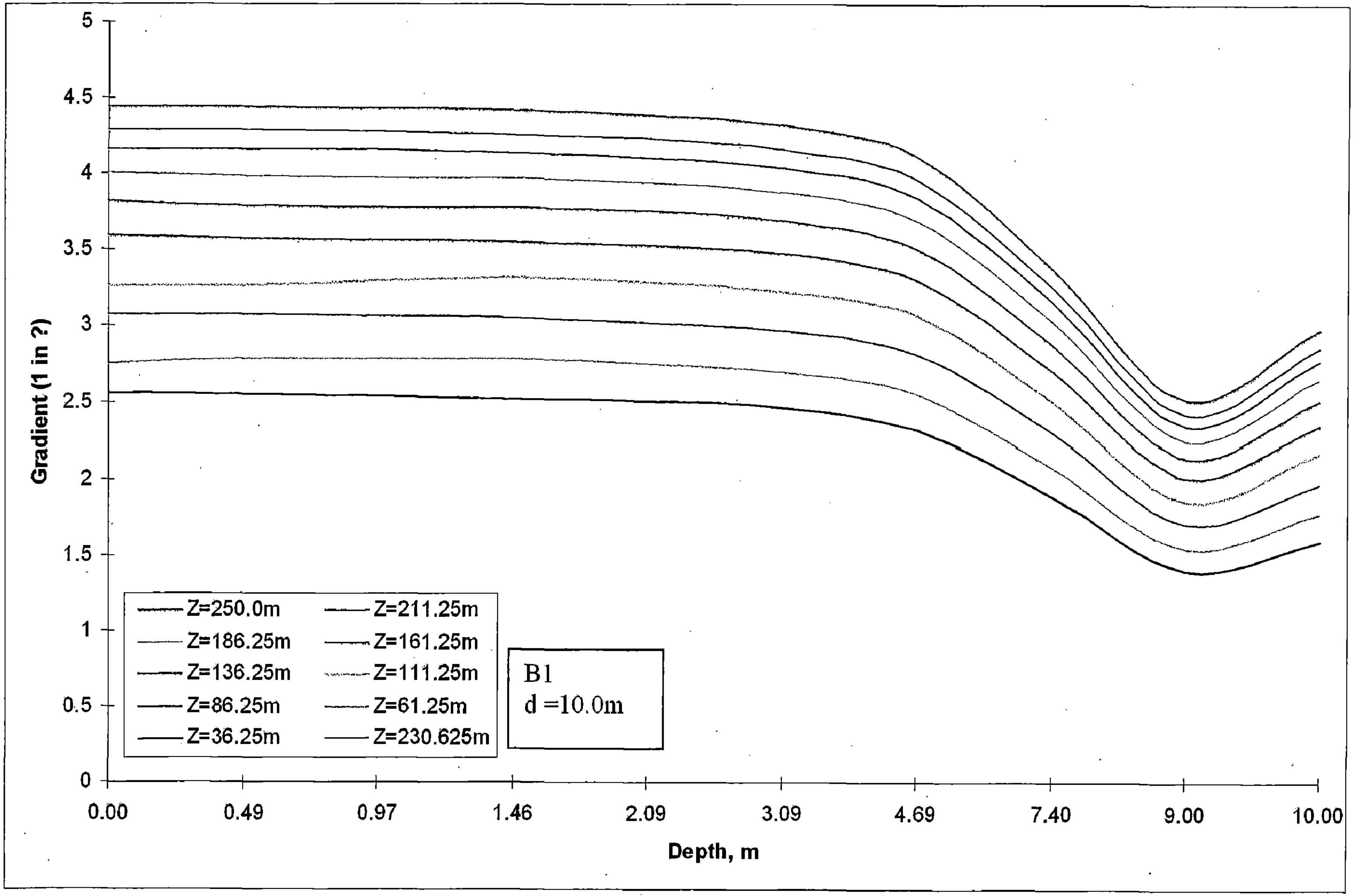


FIG. 5.33 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

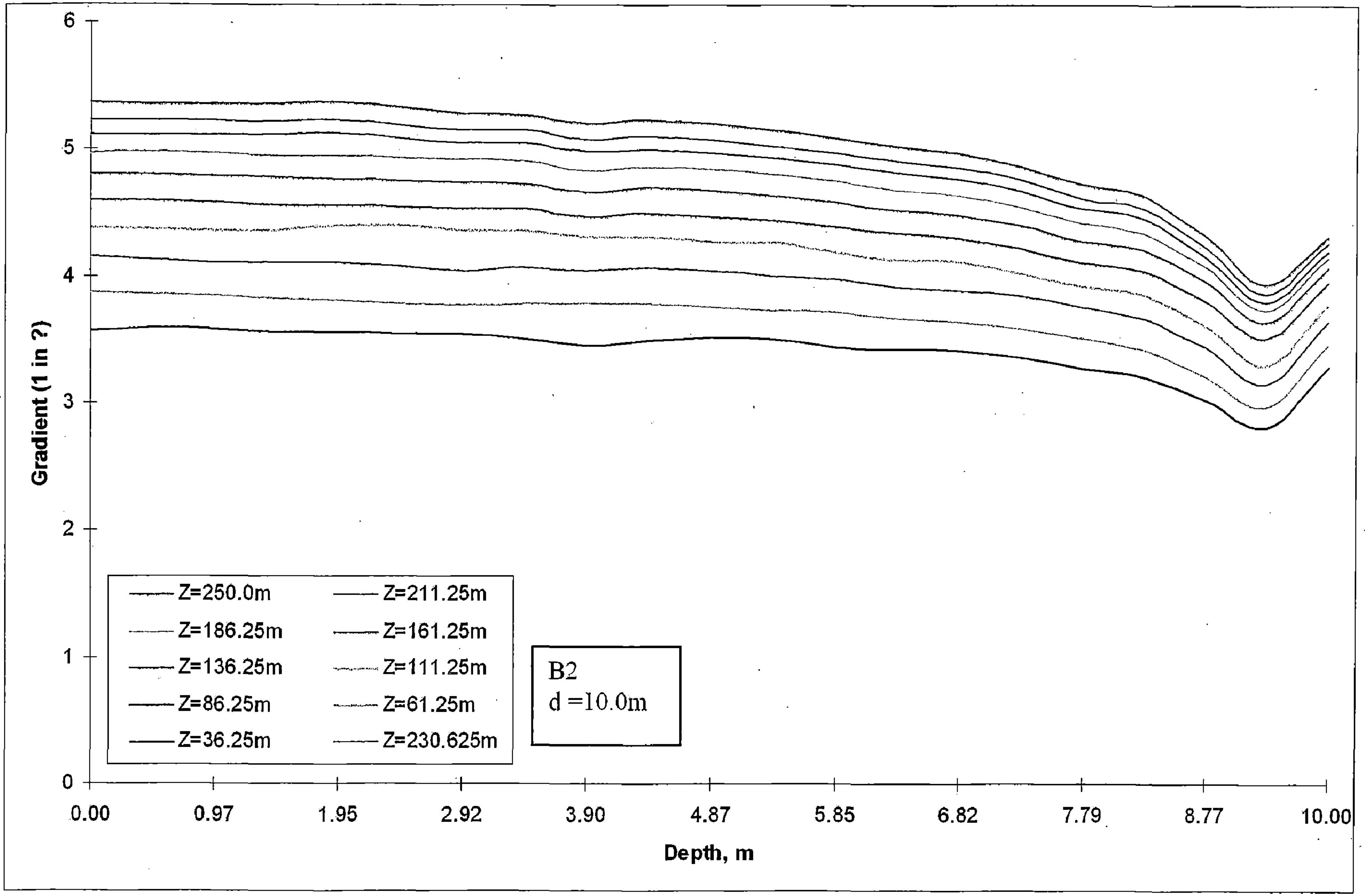


FIG. 5.34 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

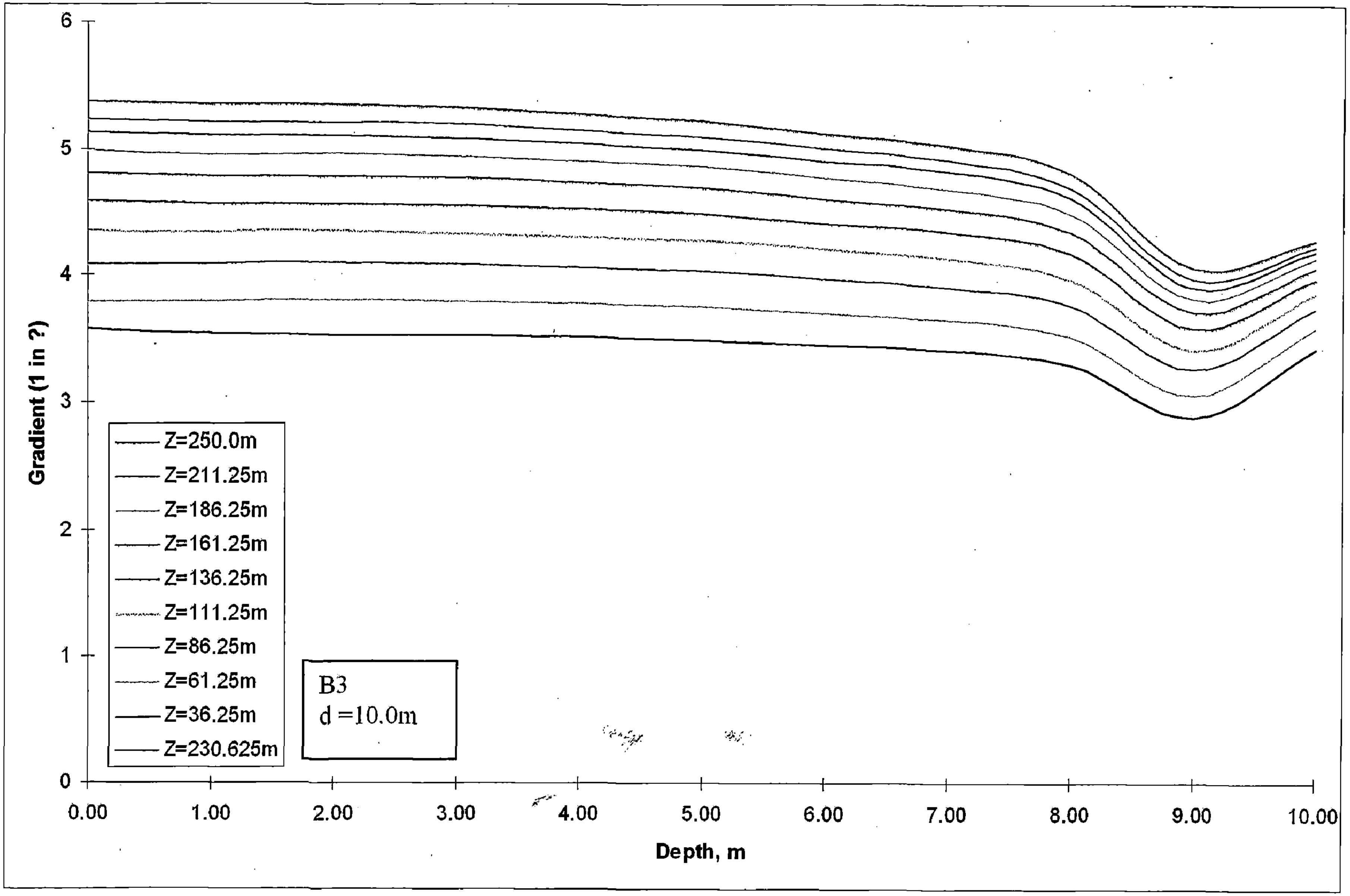


FIG. 5.35 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

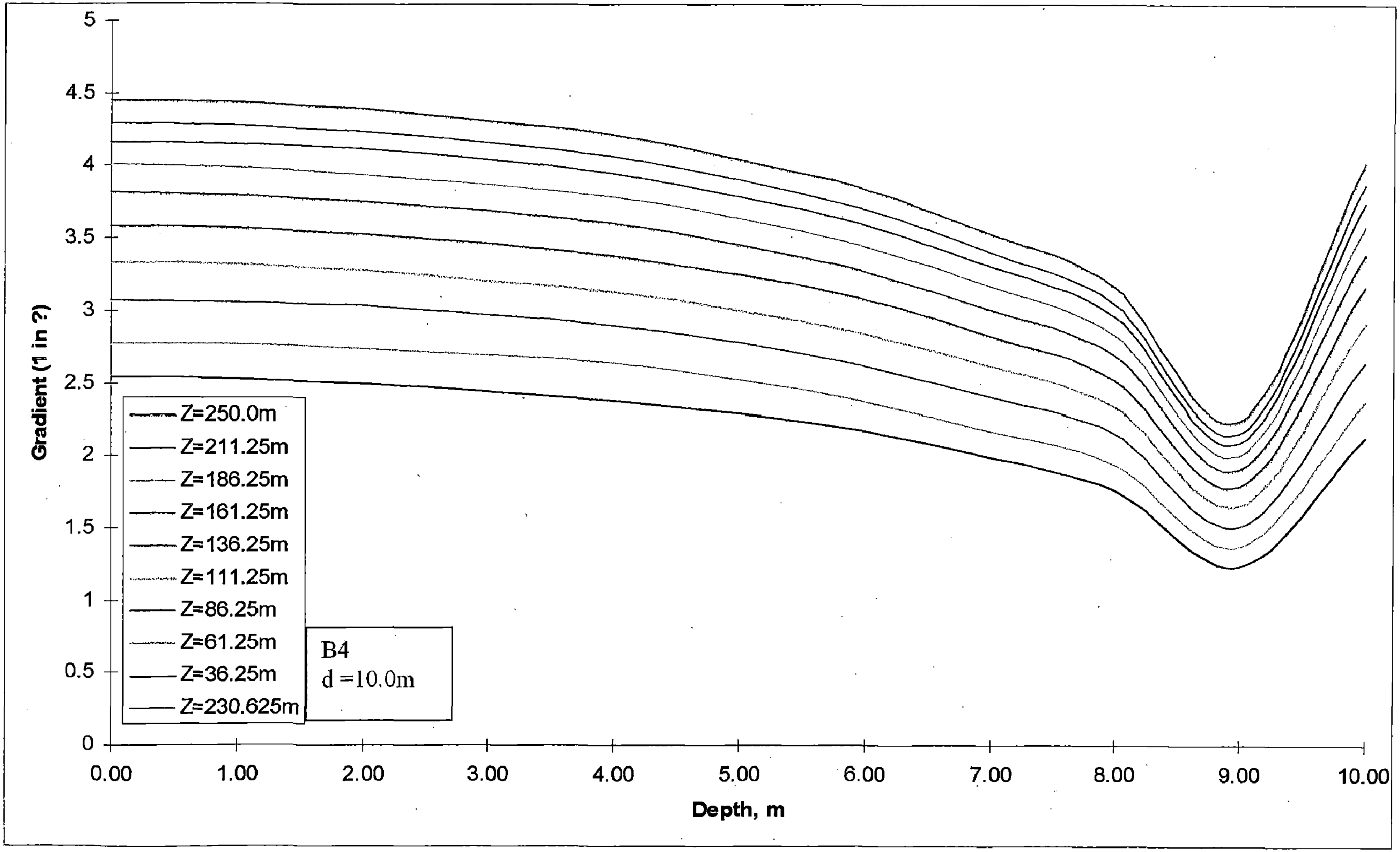


FIG. 5.36 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH LINED CANALS

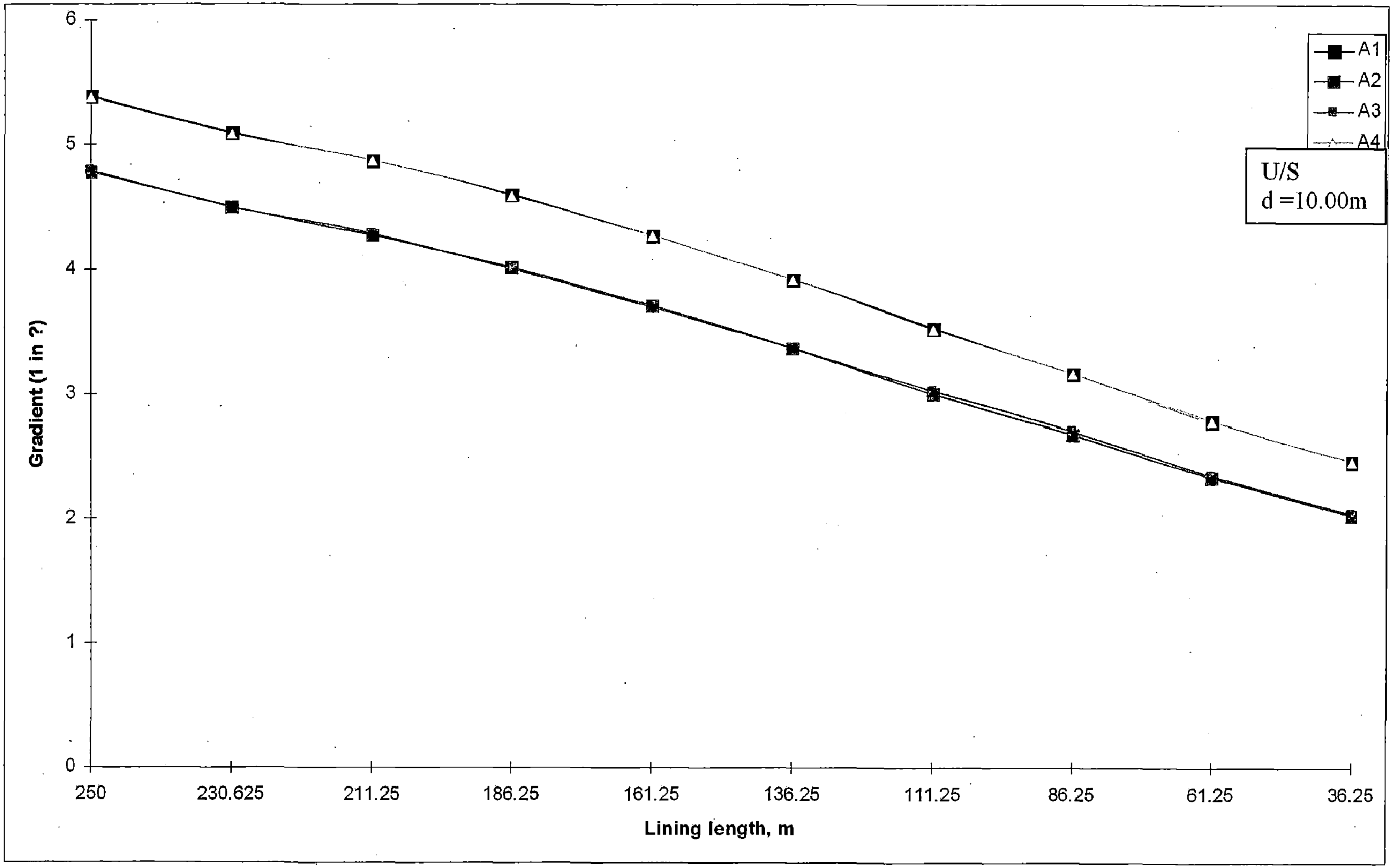


FIG. 5.37 EXIT GRADIENT V/S LINING FOR BOTH LINED CANALS

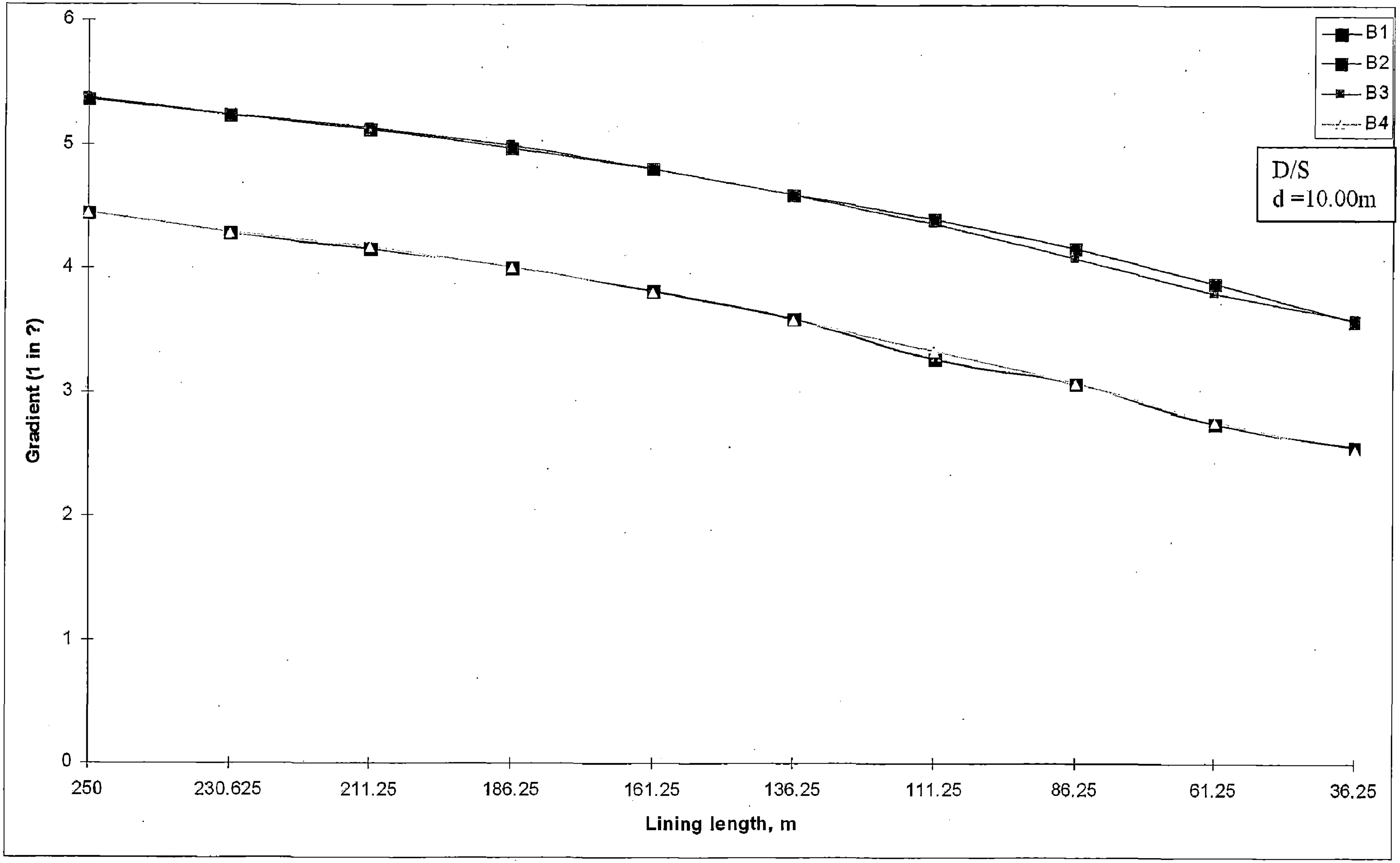


FIG. 5.38 EXIT GRADIENT V/S LINING FOR BOTH LINED CANALS

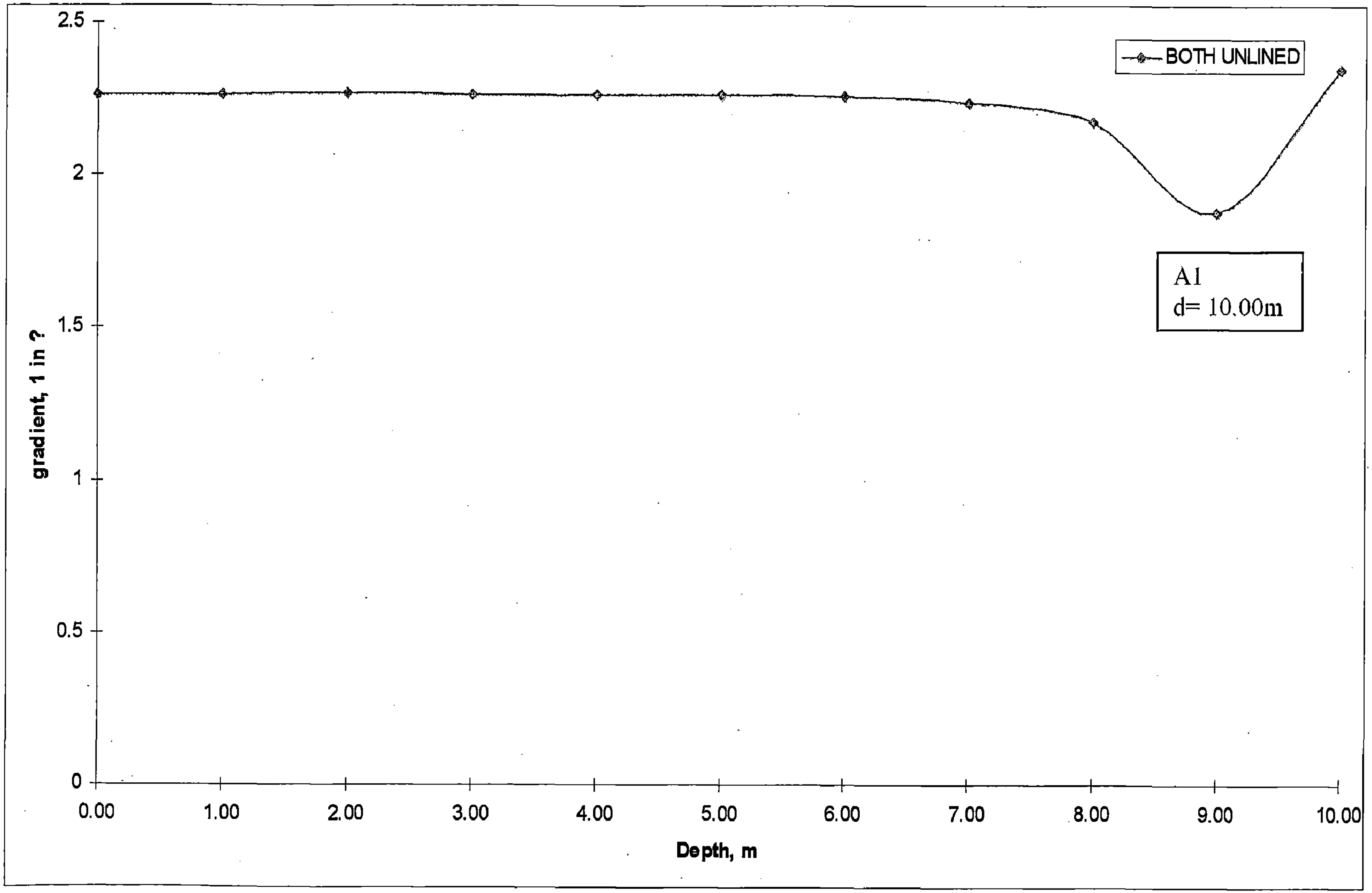


FIG. 5.39 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

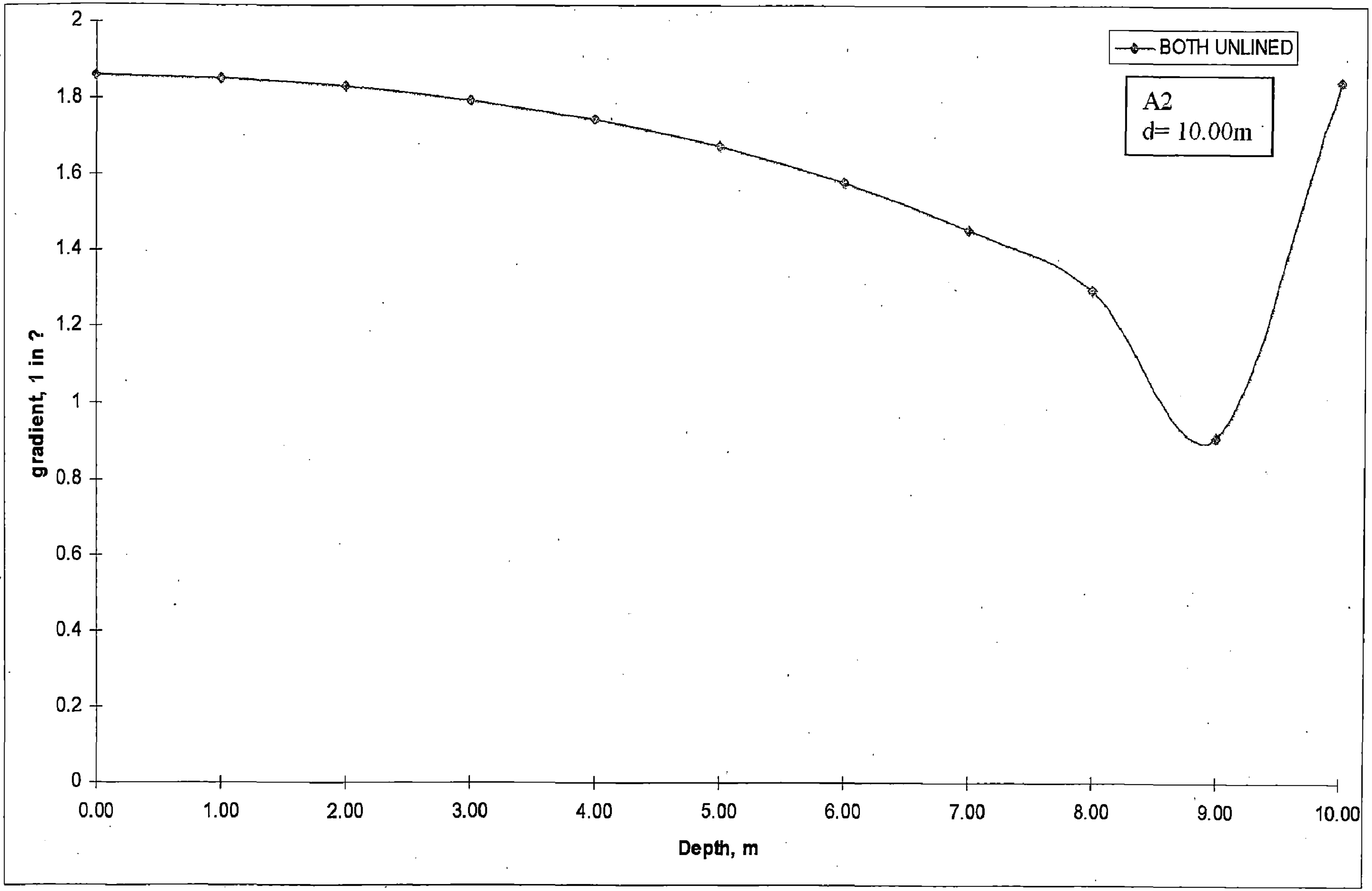


FIG. 5.40 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

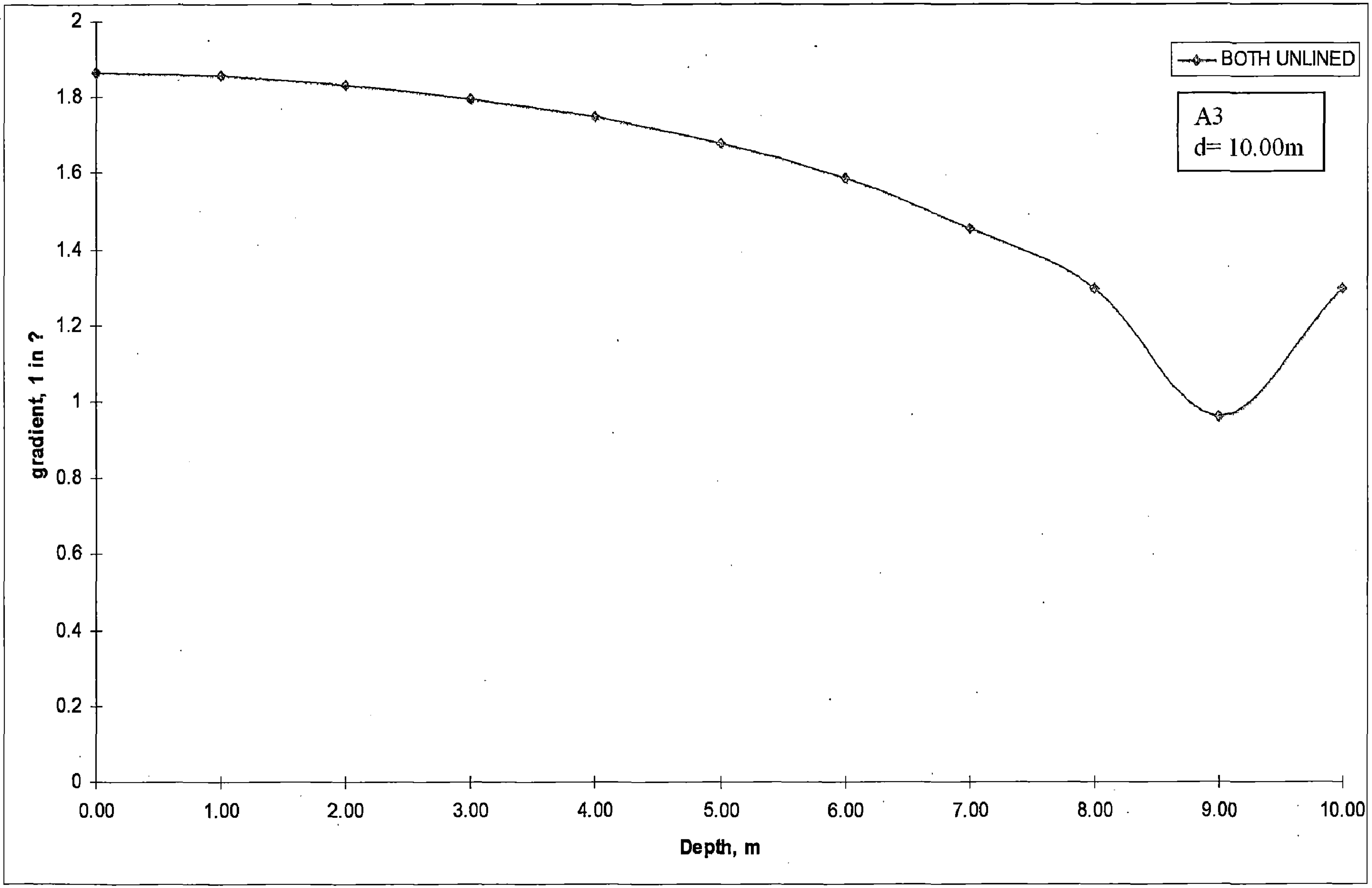


FIG. 5.41 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

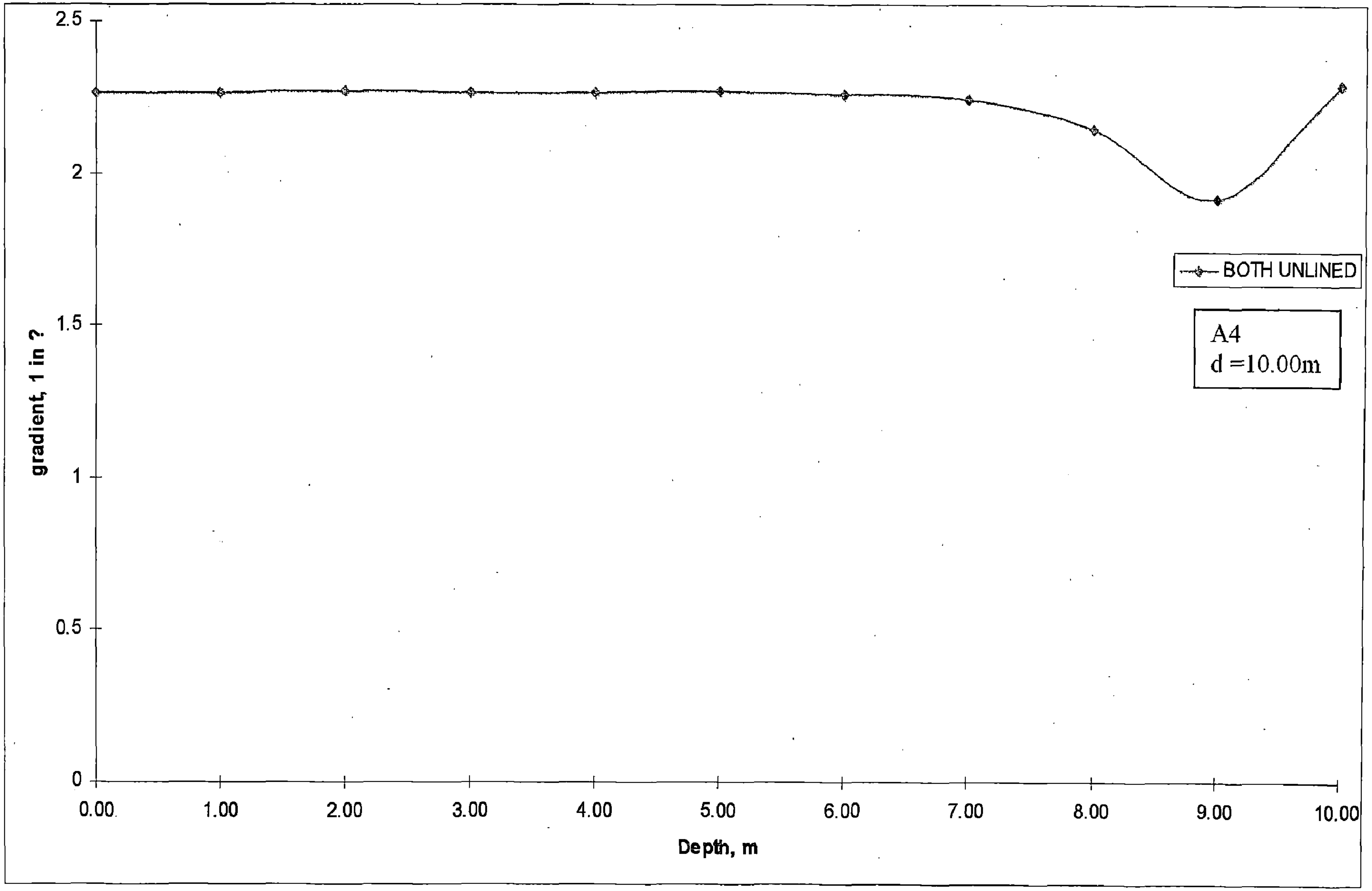


FIG. 5.42 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

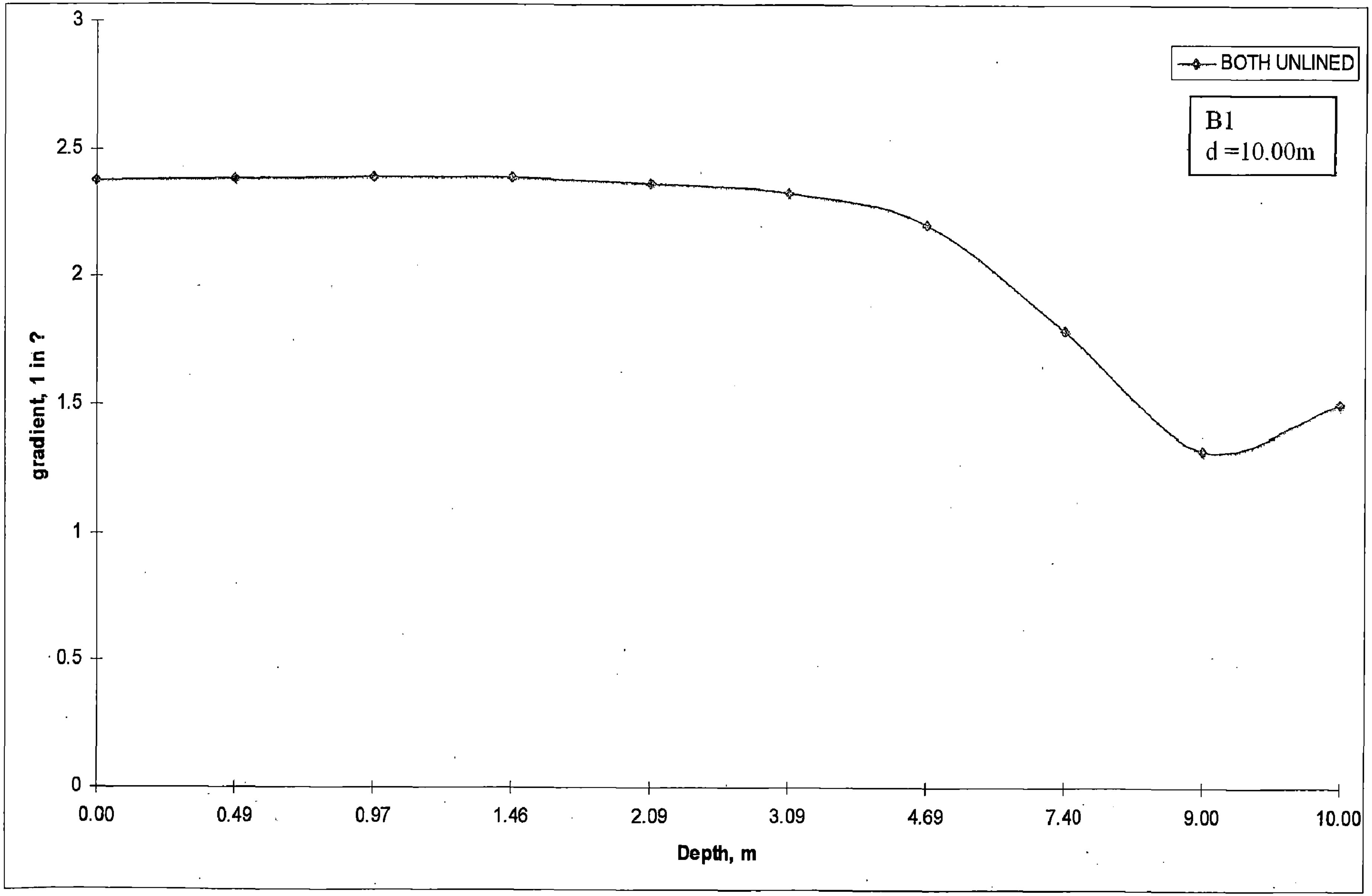


FIG. 5.43 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

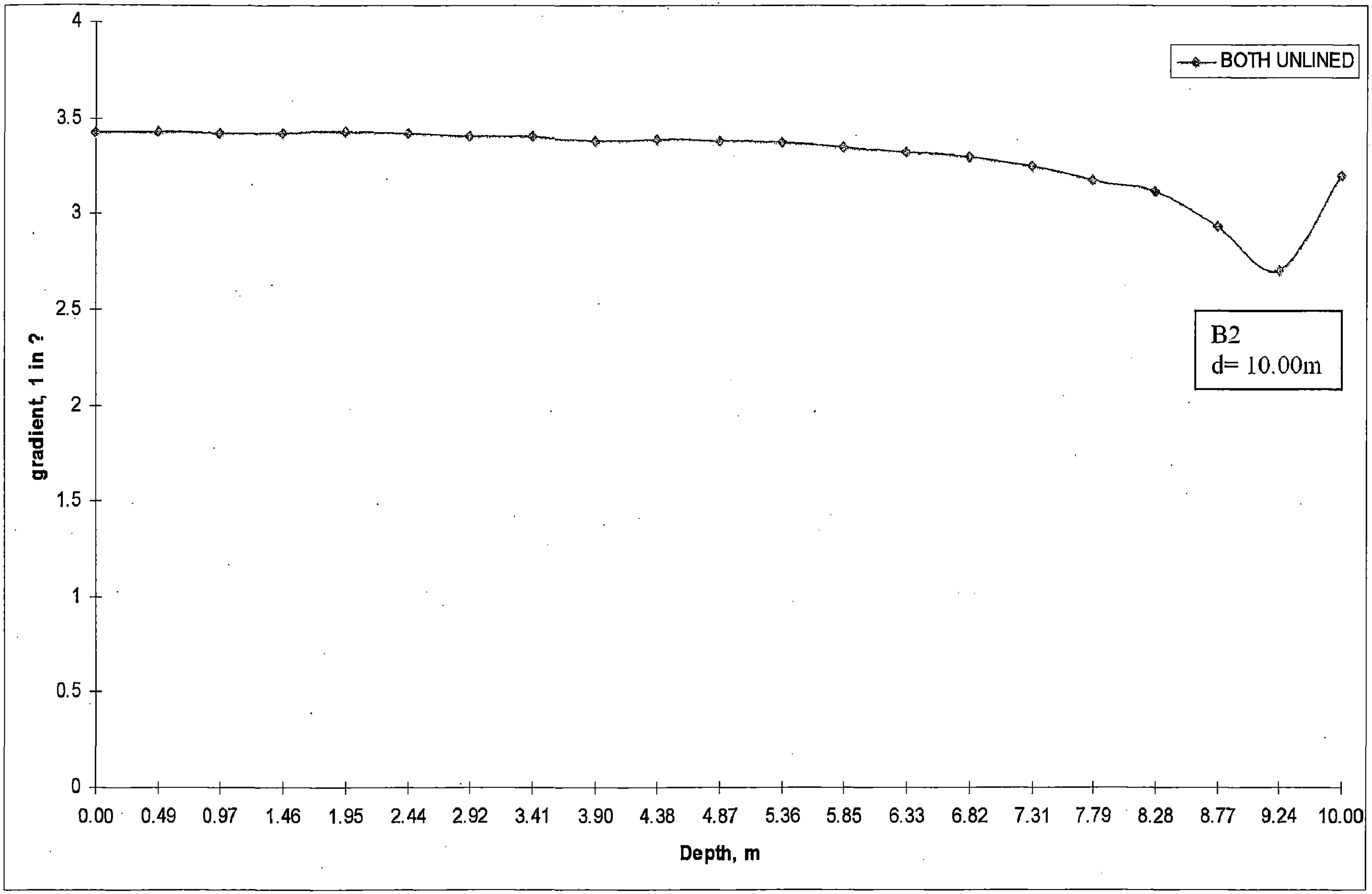


FIG. 5.44 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

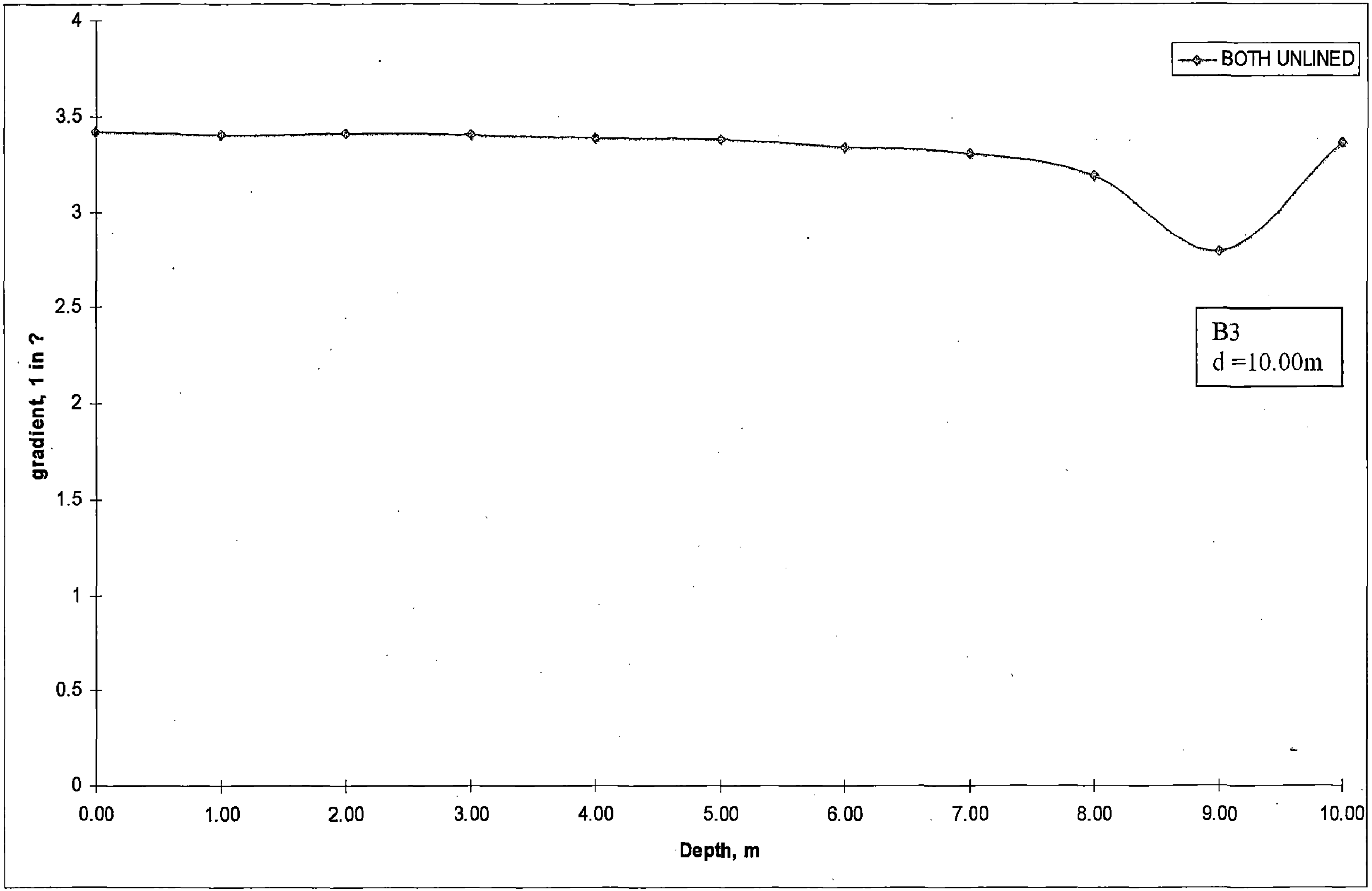


FIG. 5.45 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

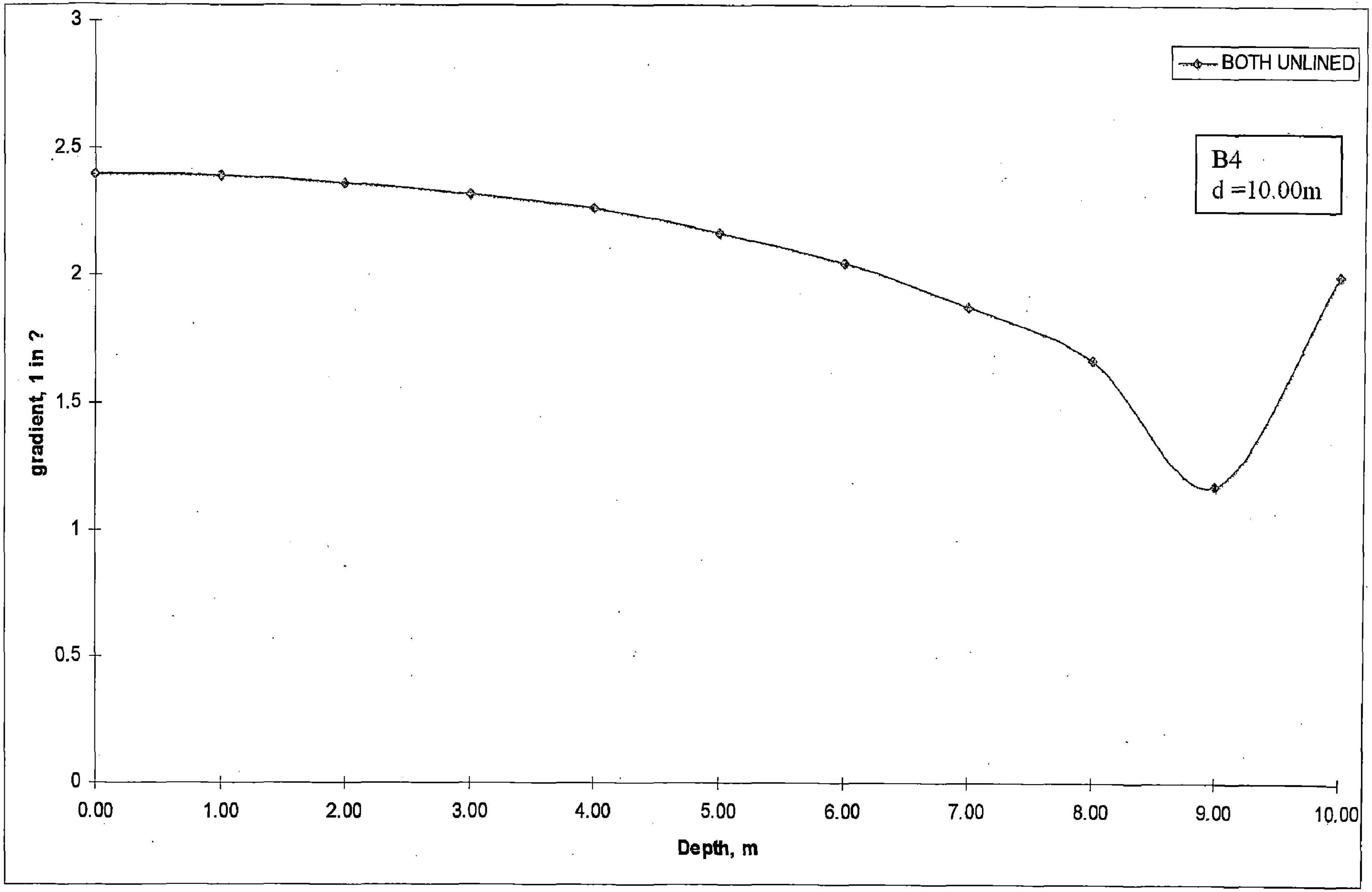


FIG. 5.46 HYDRAULIC GRADIENT ALONG THE CUT-OFF DEPTH FOR BOTH UNLINED CANALS

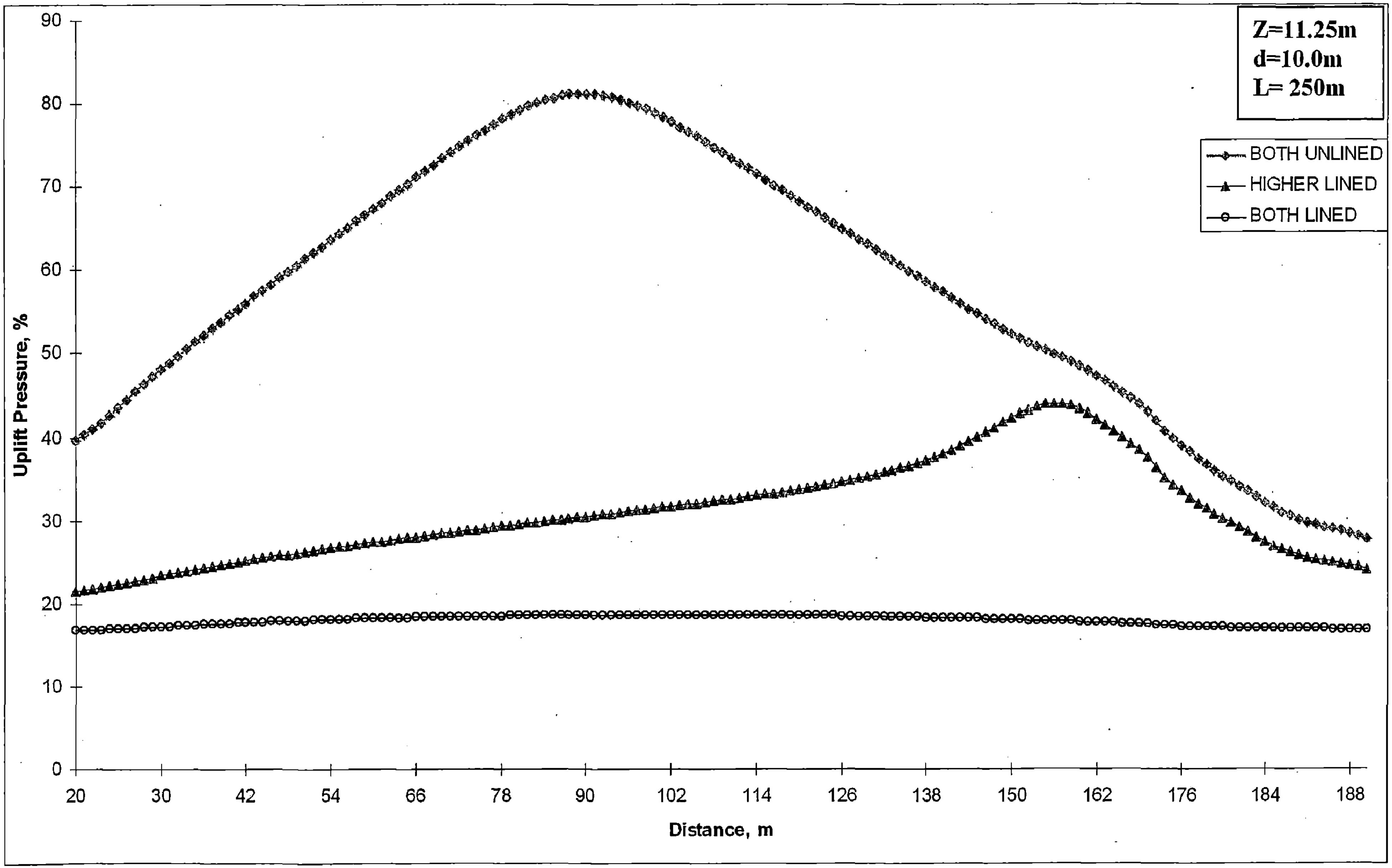


FIG. 5.47 UPLIFT PRESSURE ALONG THE BARREL FOR DIFFERENT CASES

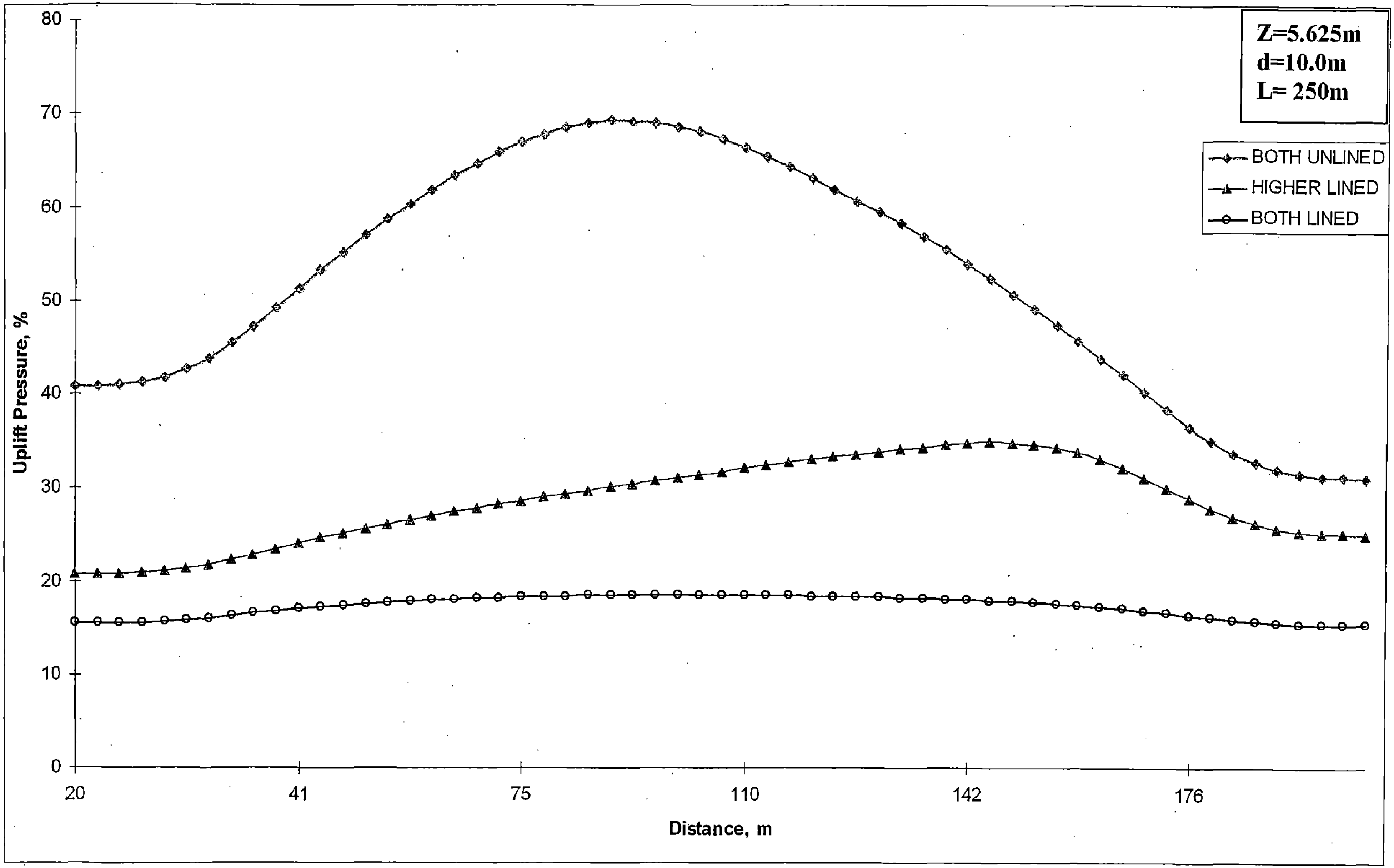


FIG. 5.48 UPLIFT PRESSURE ALONG THE BARREL FOR DIFFERENT CASES

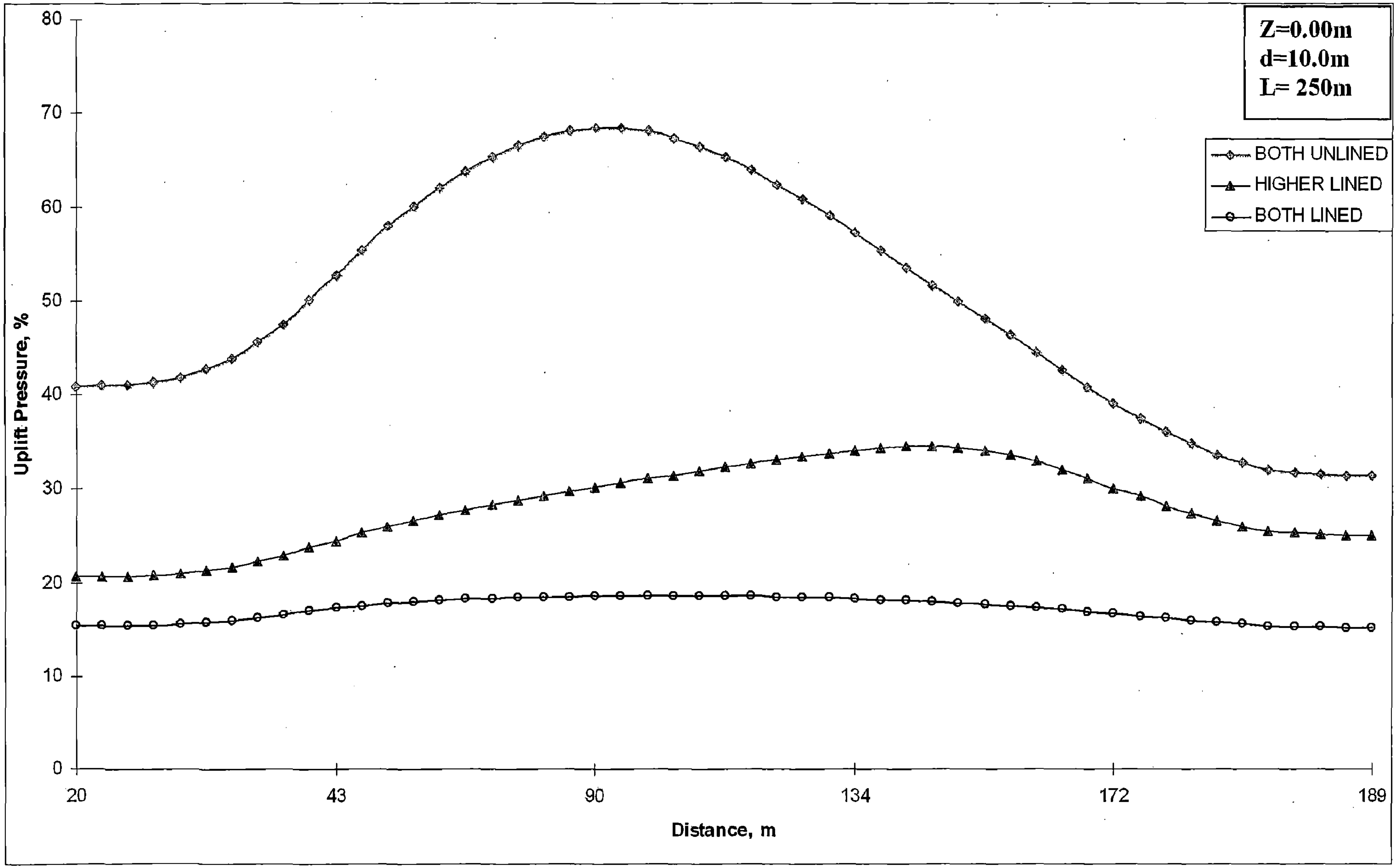


FIG. 5.49 UPLIFT PRESSURE ALONG THE BARREL FOR DIFFERENT CASES

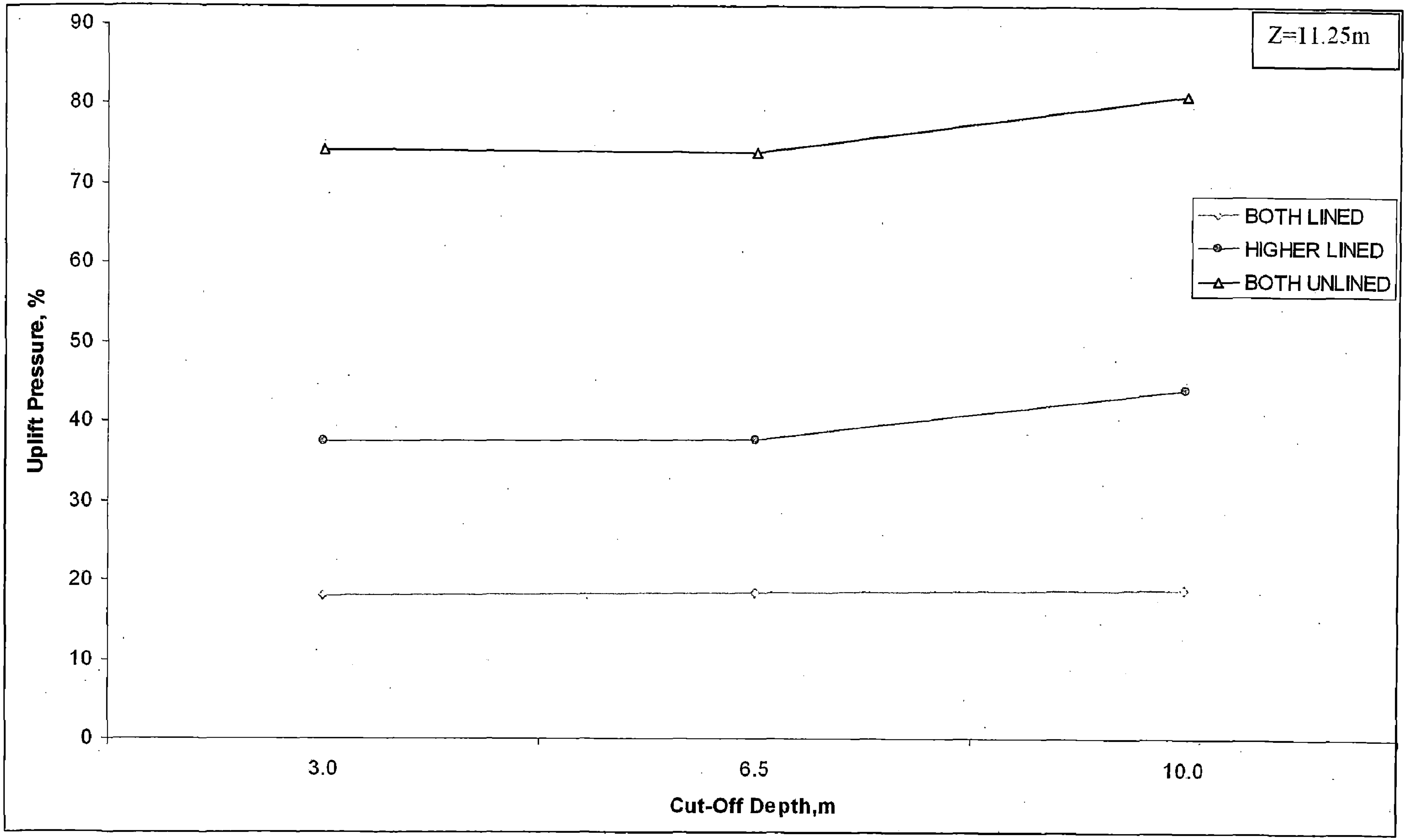


FIG. 5.50 MAXIMUM UPLIFT PRESSURE ON BARREL V/S CUT-OFF DEPTH

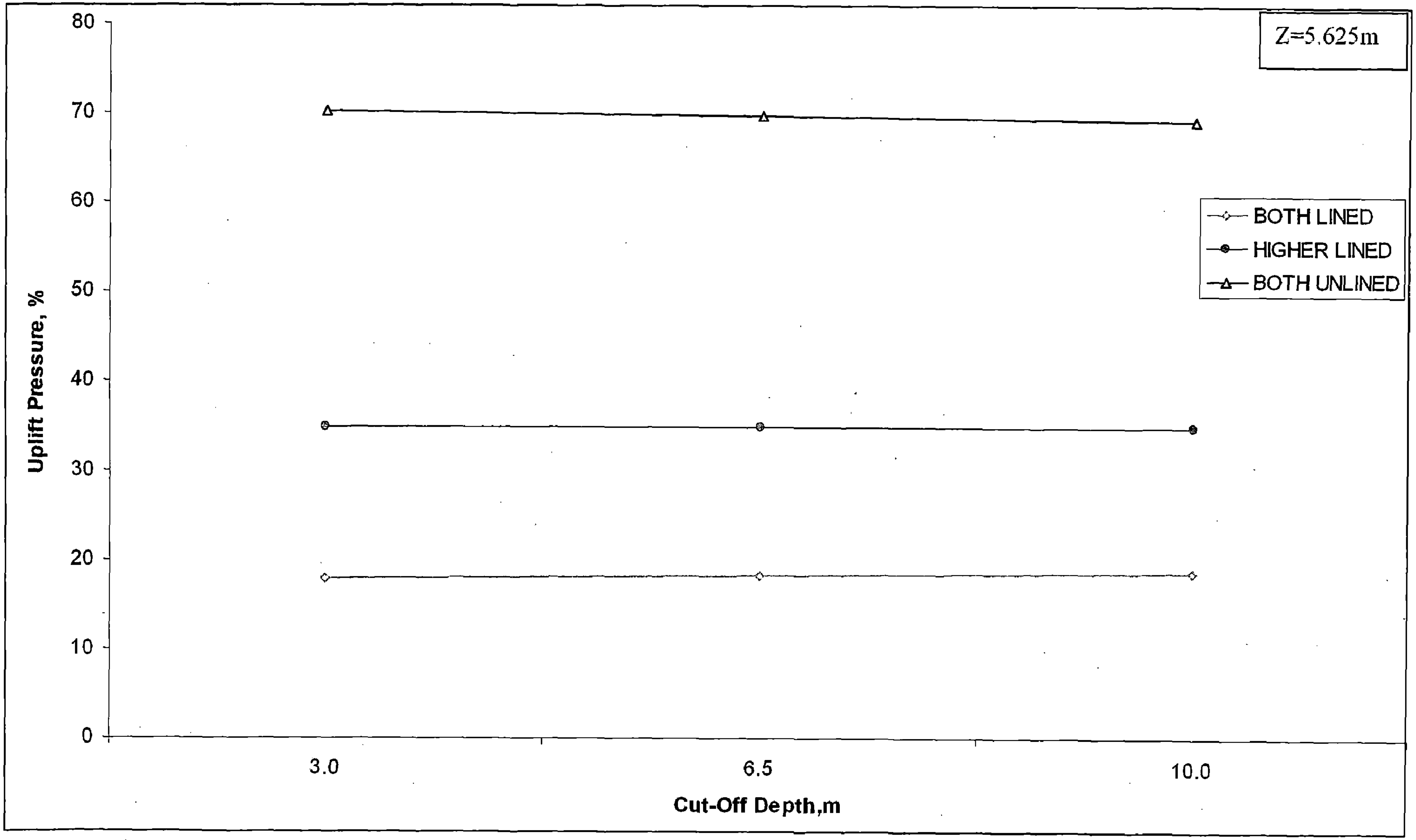


FIG. 5.51 MAXIMUM UPLIFT PRESSURE ON BARREL V/S CUT-OFF DEPTH

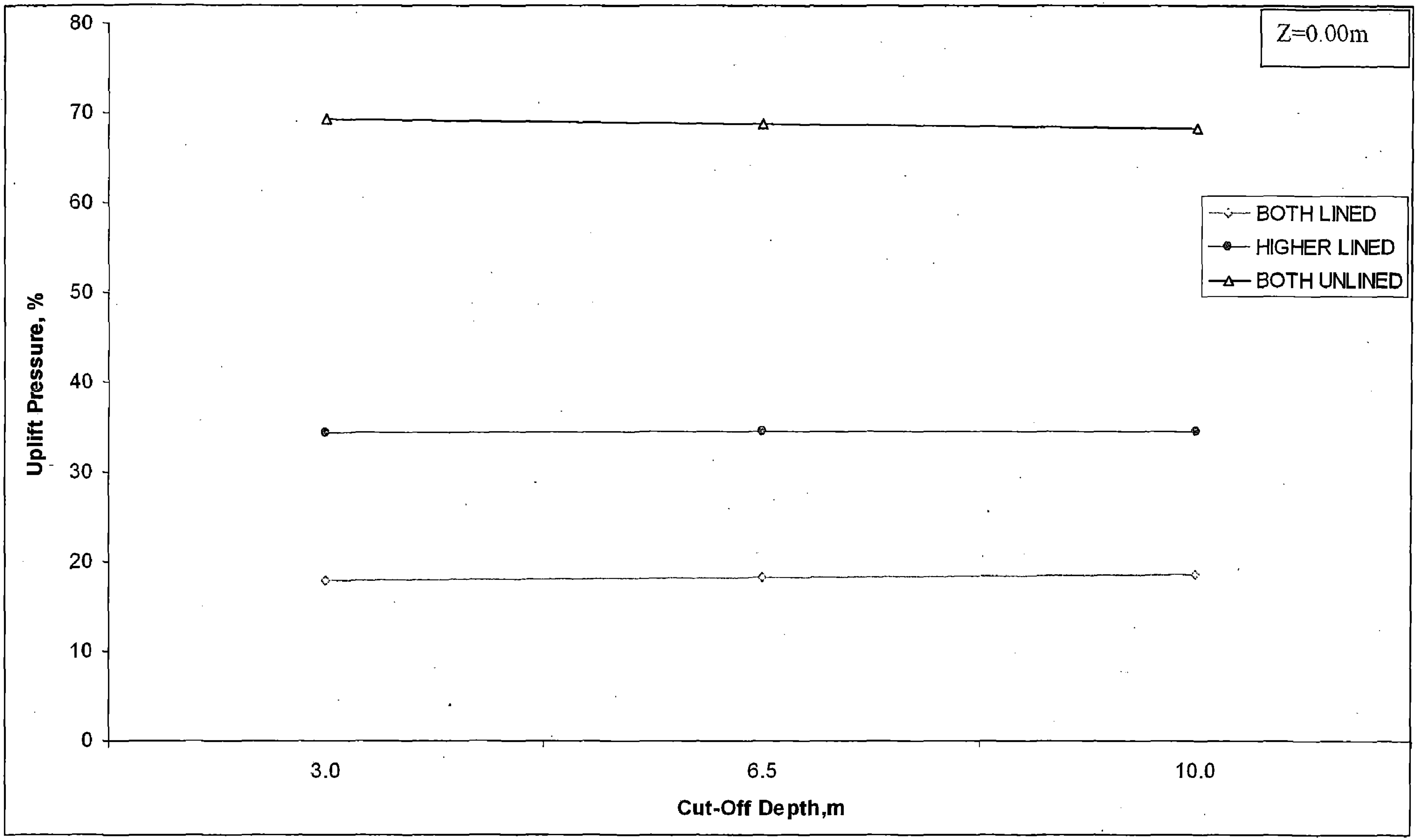


FIG. 5.52 MAXIMUM UPLIFT PRESSURE ON BARREL V/S CUT-OFF DEPTH

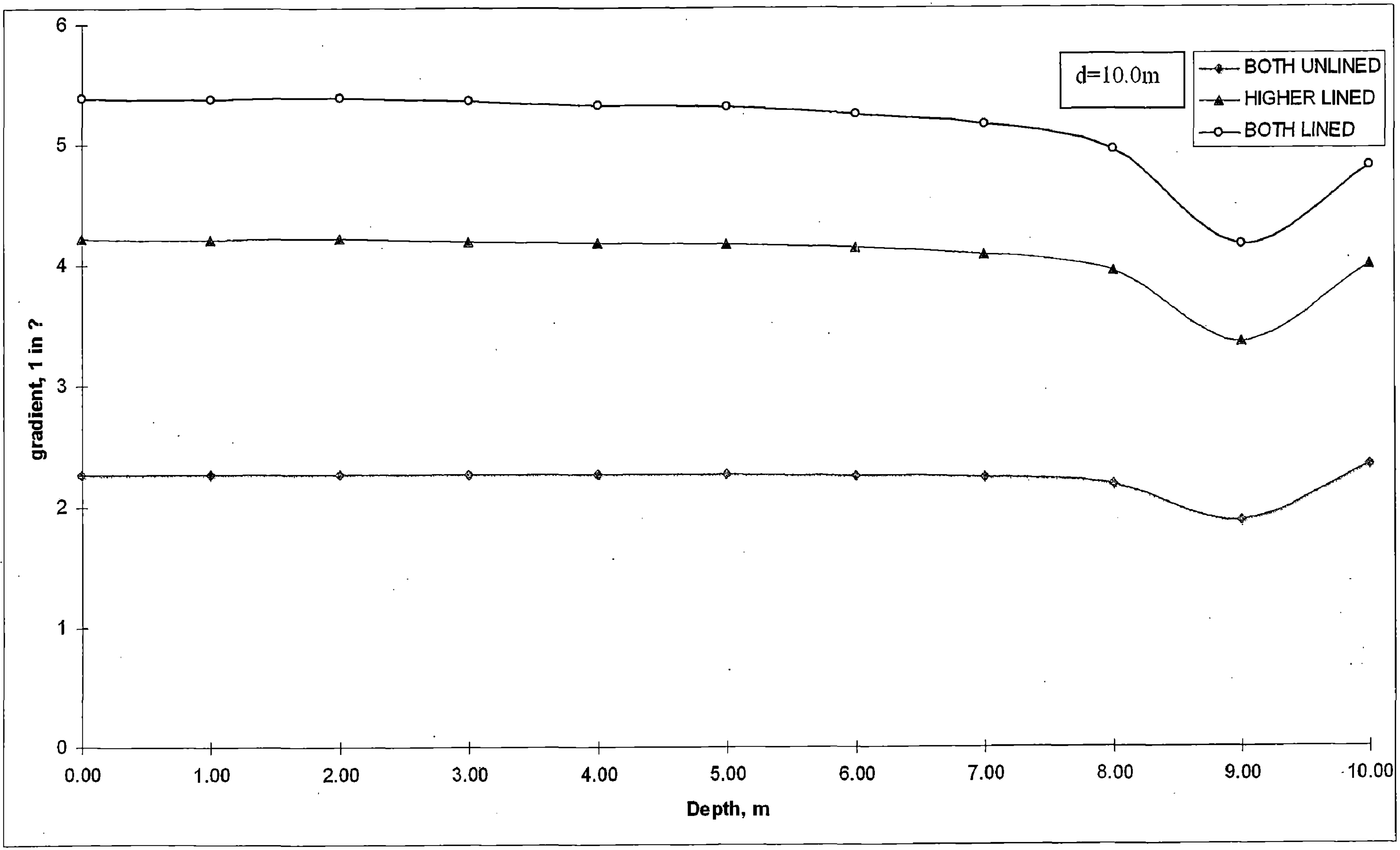


FIG. 5.53 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT A1

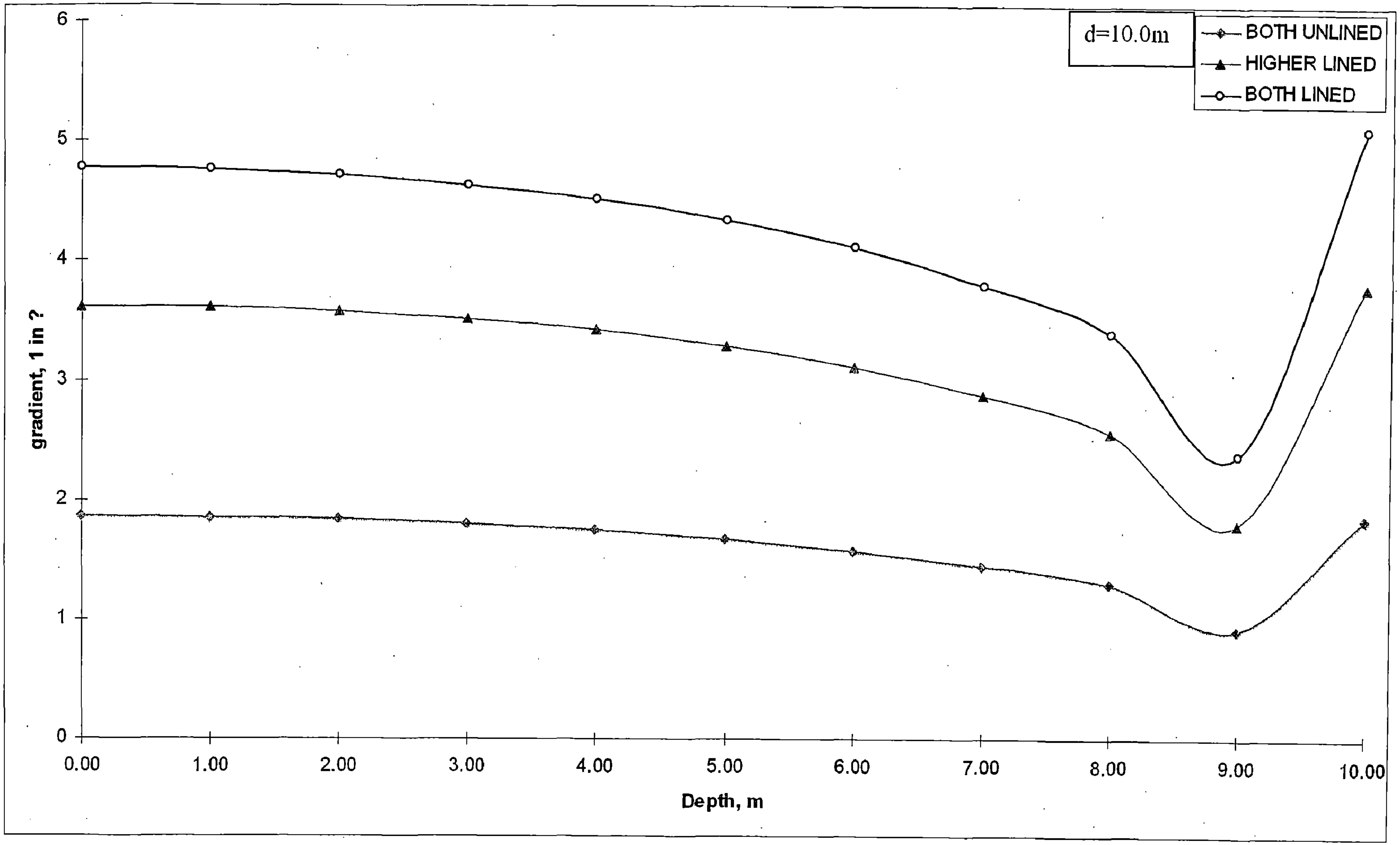


FIG. 5.54 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT A2

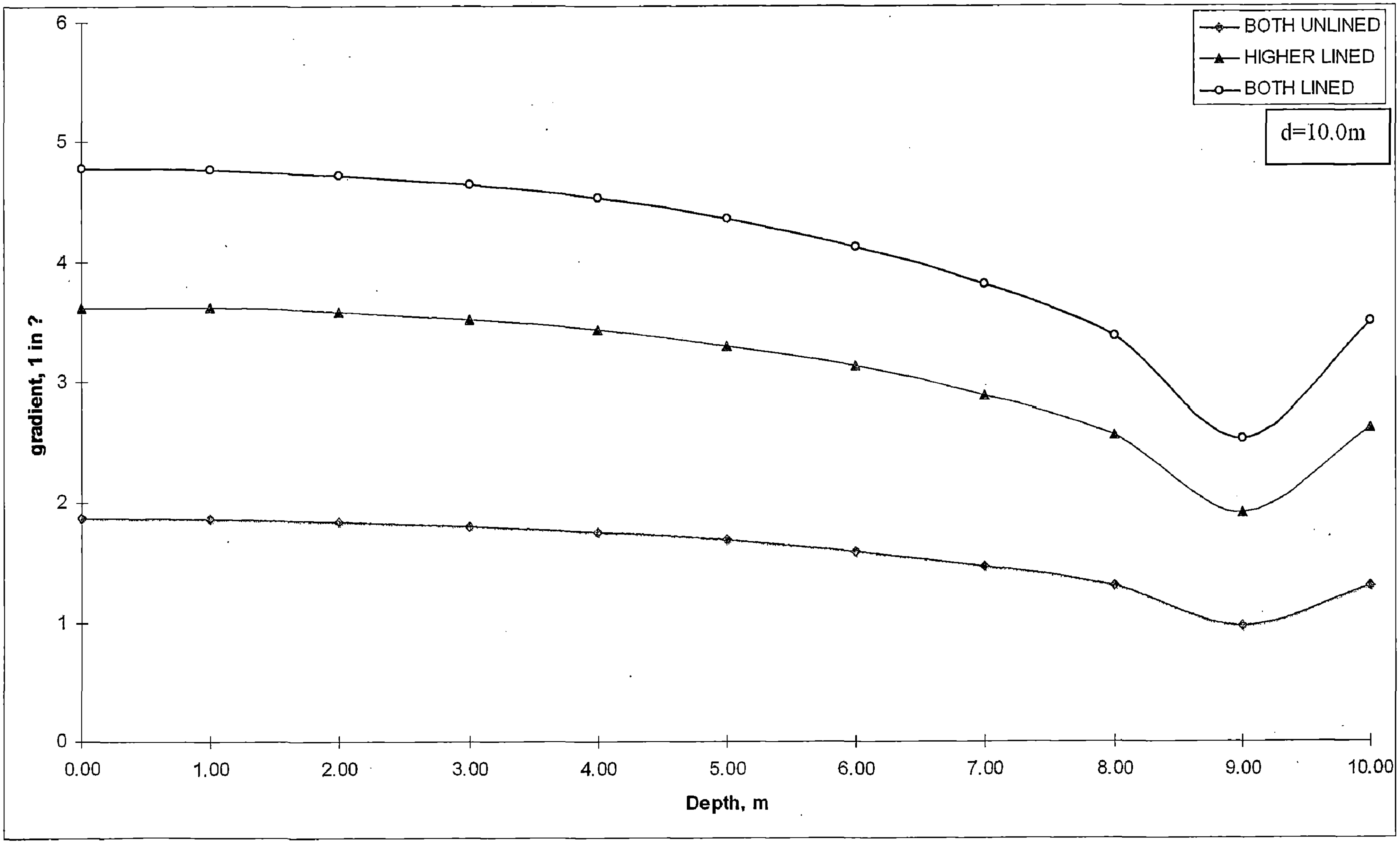


FIG. 5.55 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT A3

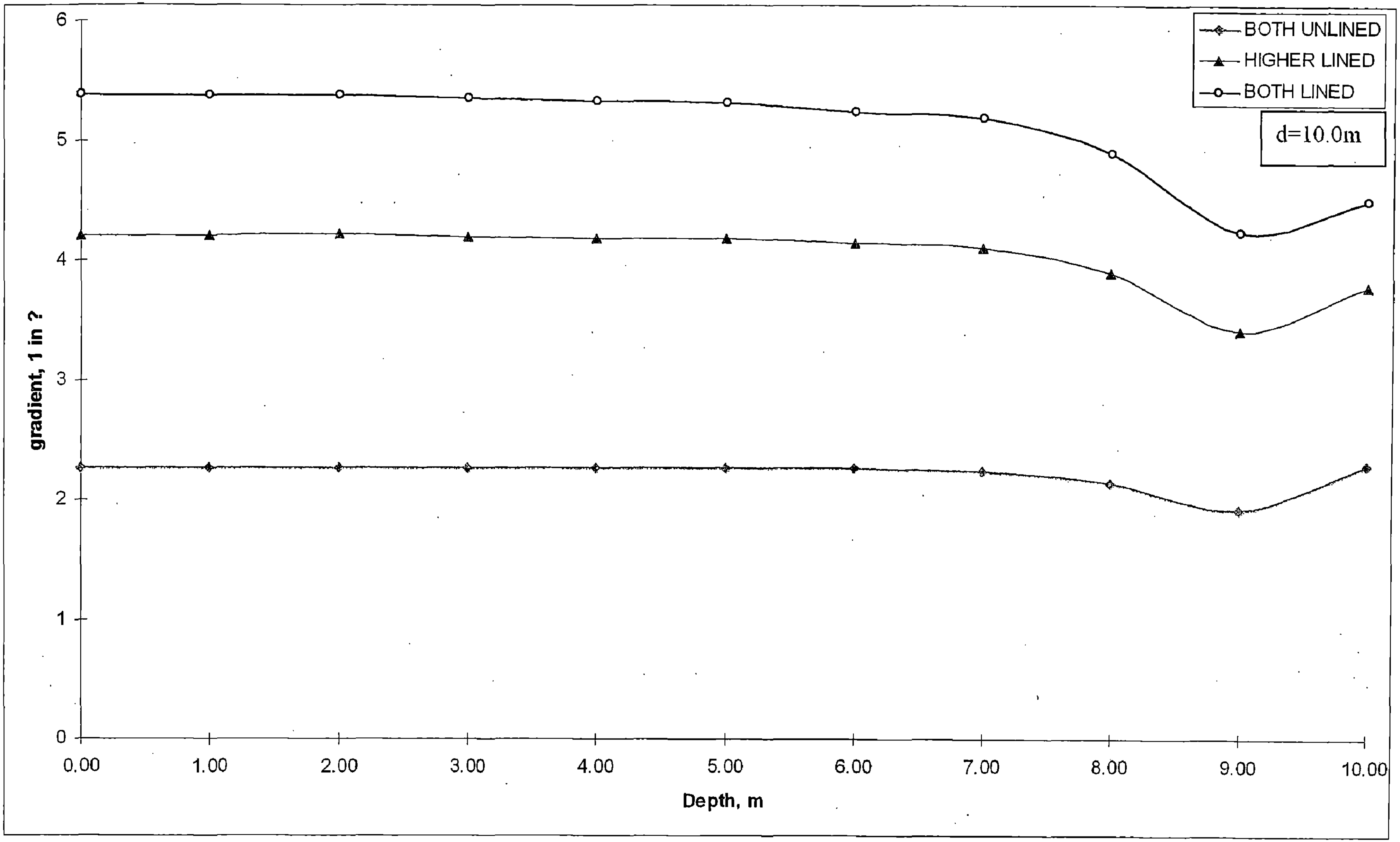


FIG. 5.56 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT A4

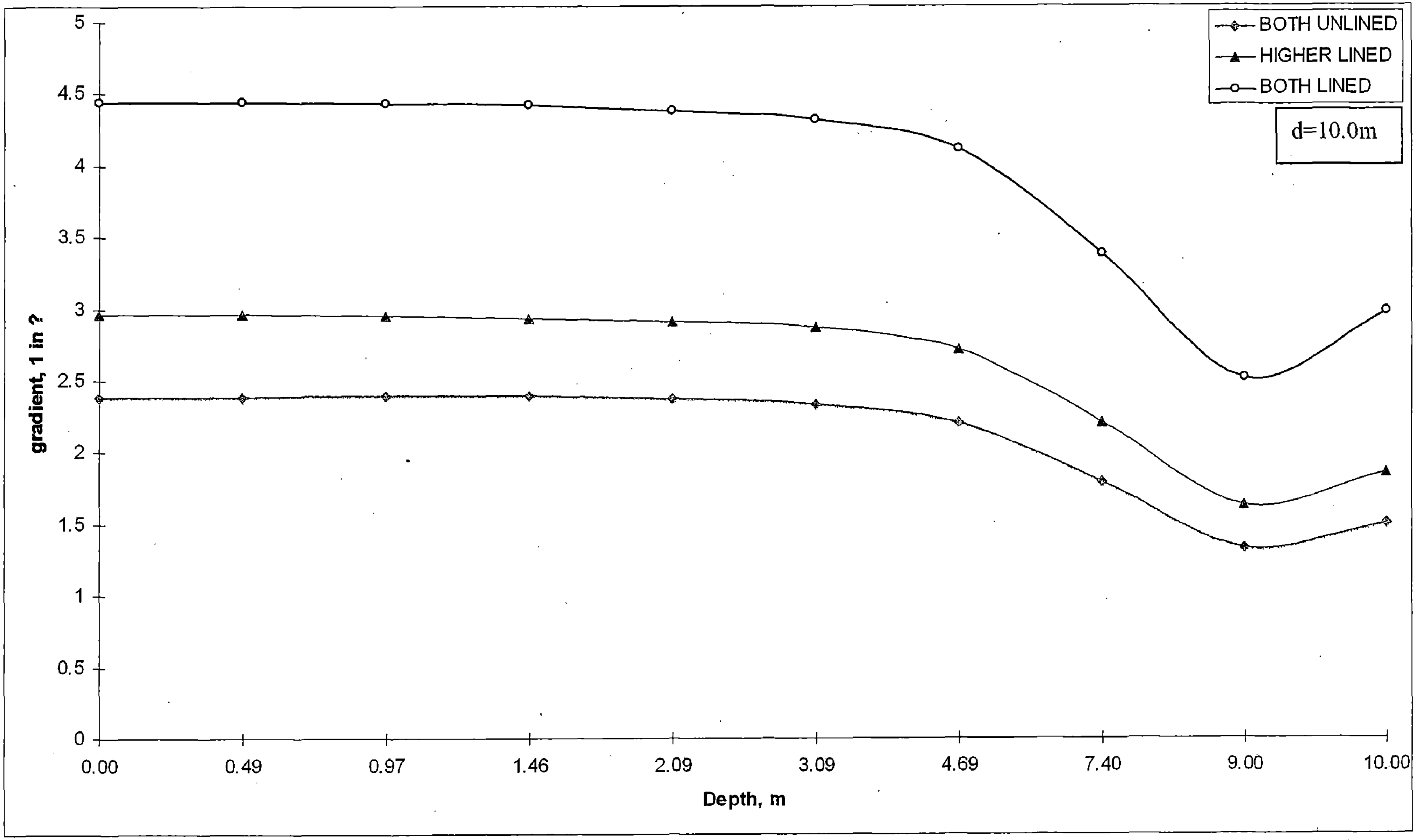


FIG. 5.57 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT B1

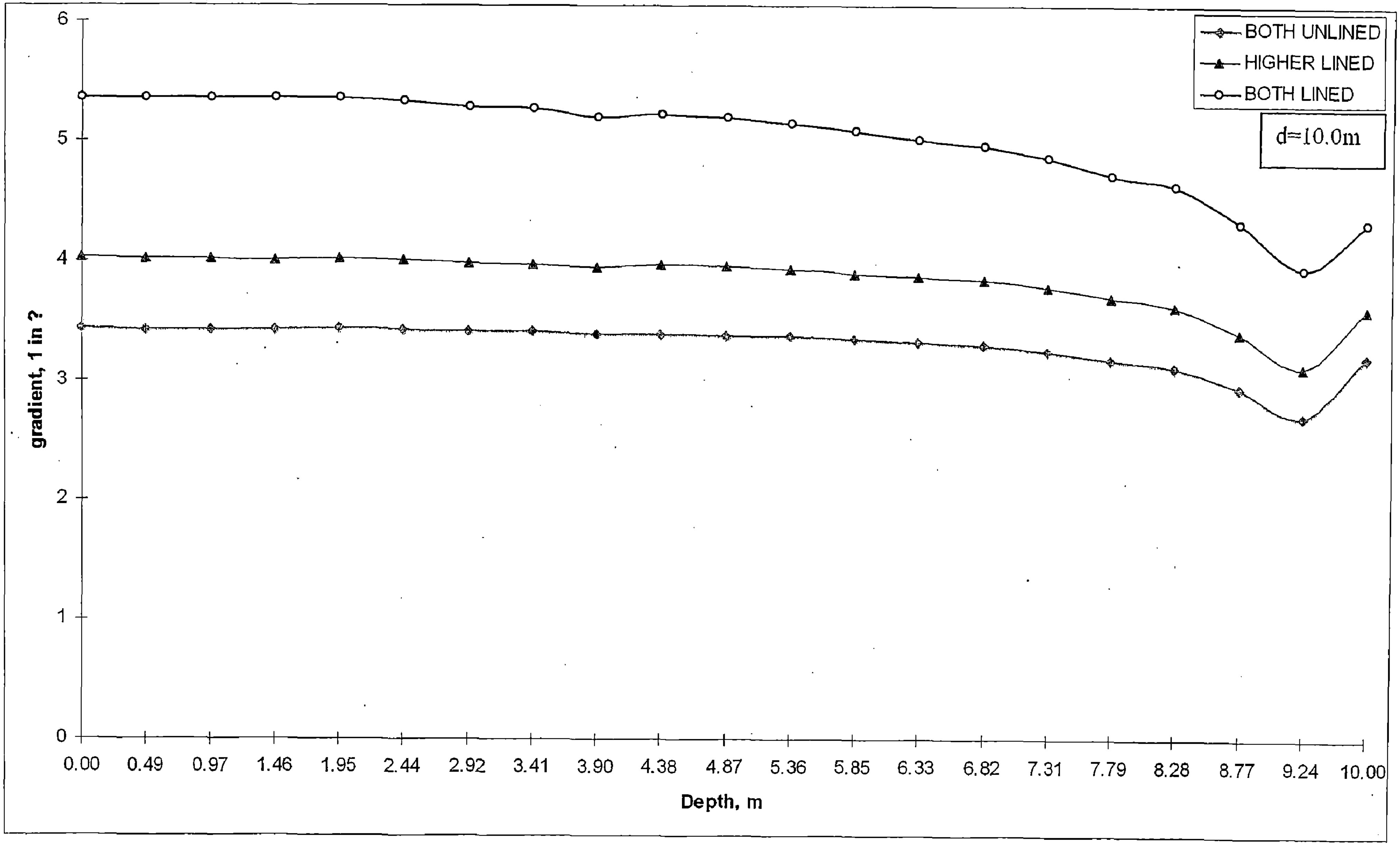


FIG. 5.58 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT B2

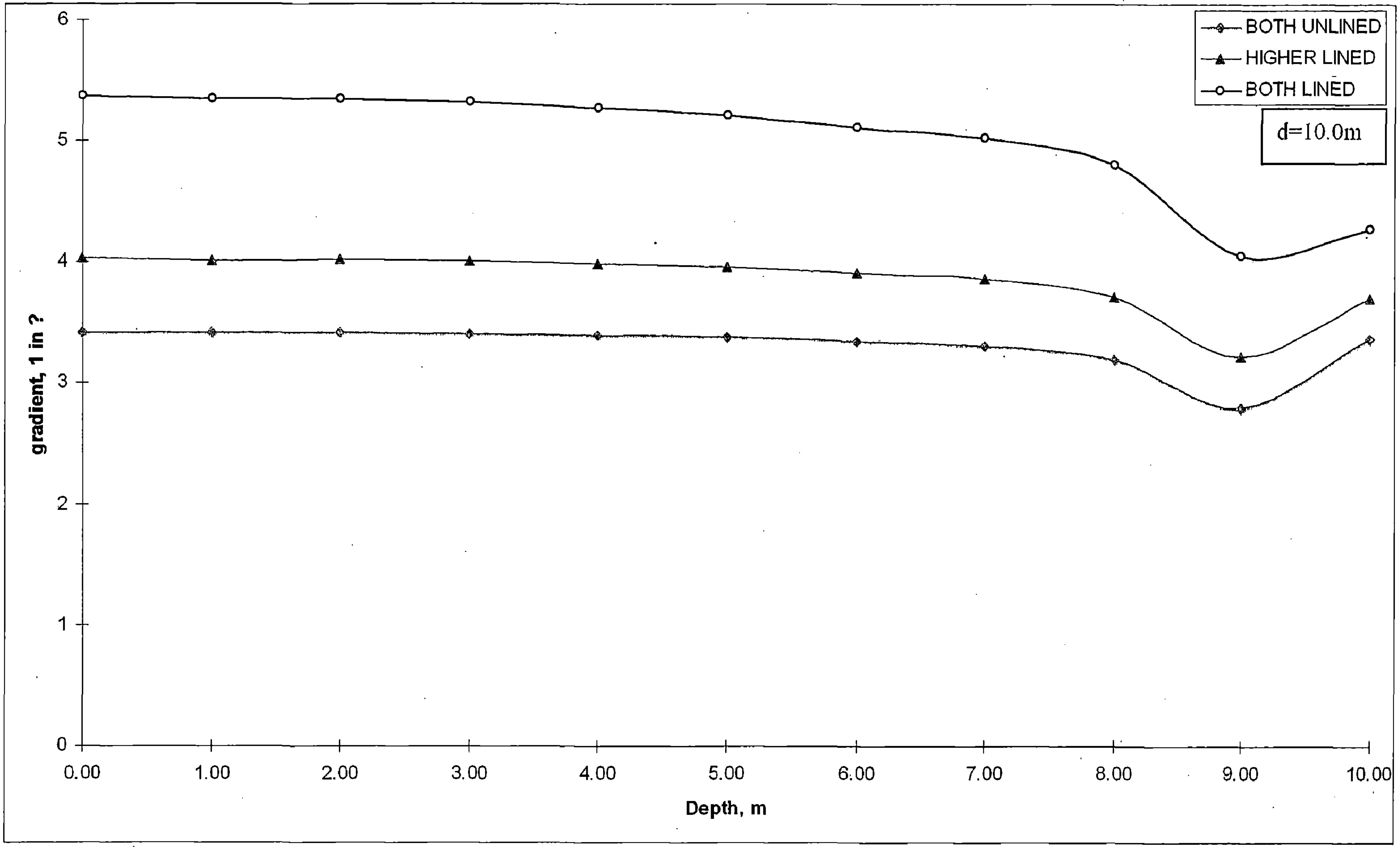


FIG. 5.59 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT B3

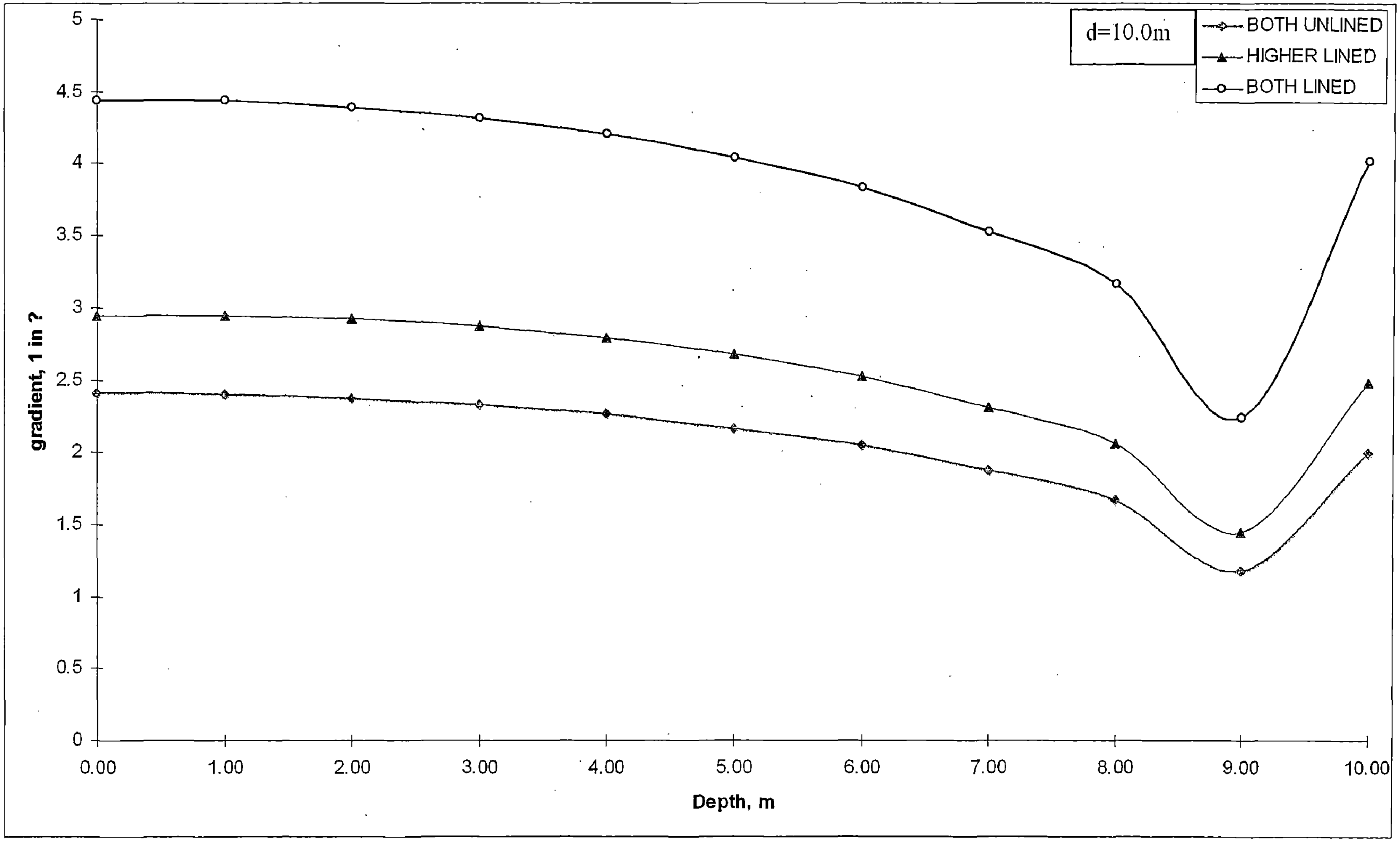


FIG. 5.60 HYDRAULIC GRADIENT ALONGT THE CUT-OFF DEPTH AT B4

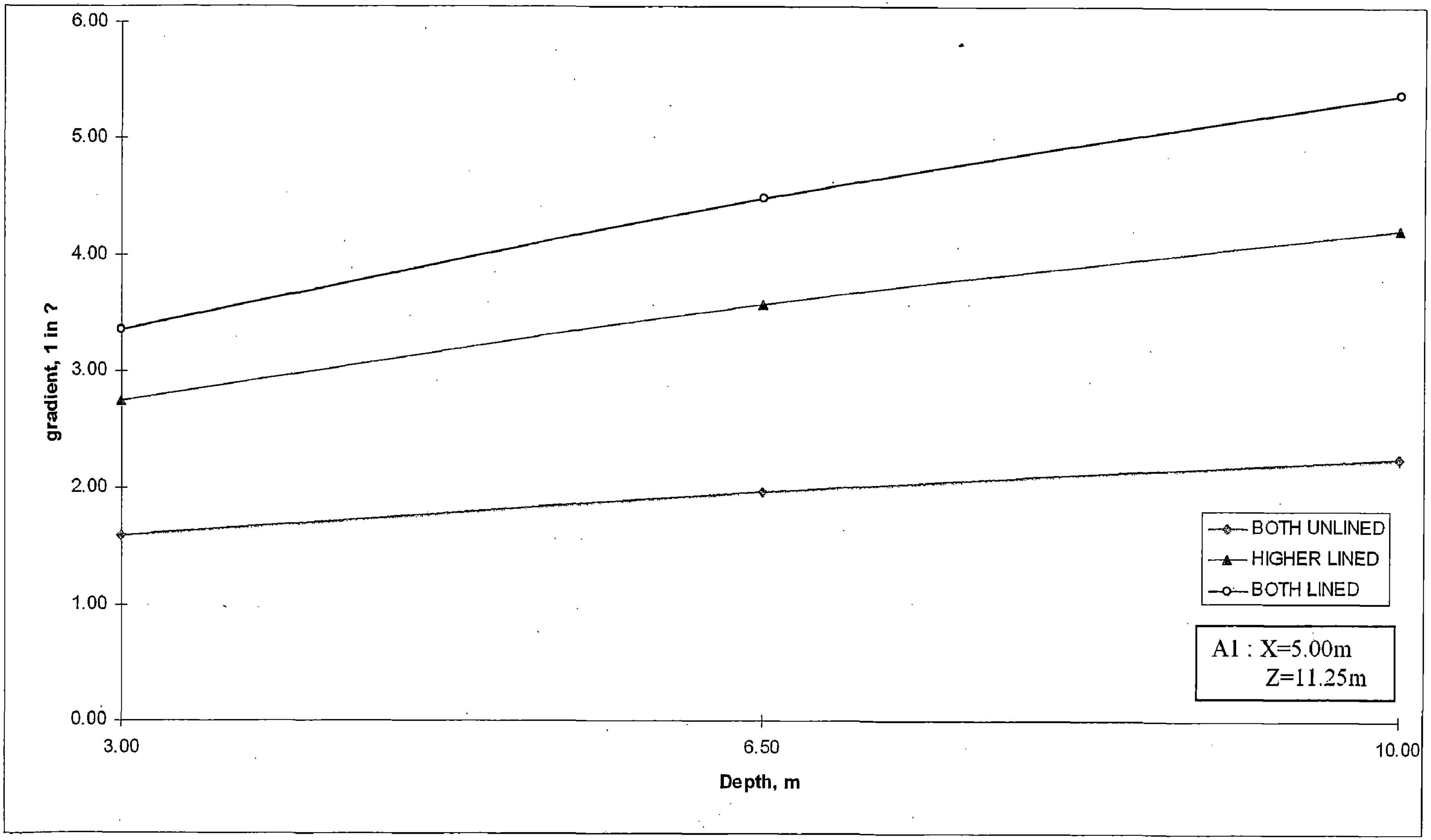


FIG. 5.61 EXIT GRADIENT V/S CUT-OFF DEPTH

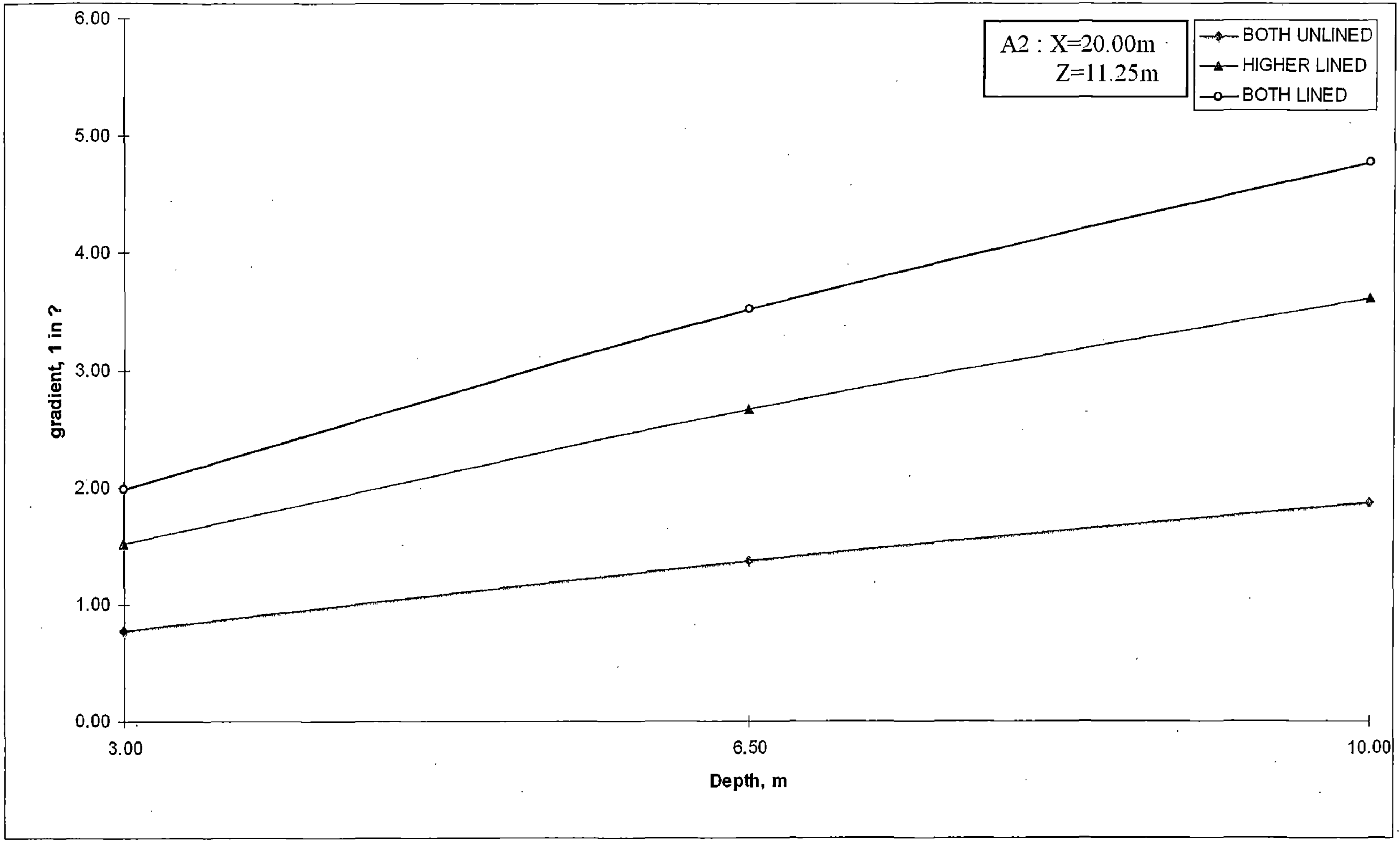


FIG. 5.62 EXIT GRADIENT V/S CUT-OFF DEPTH

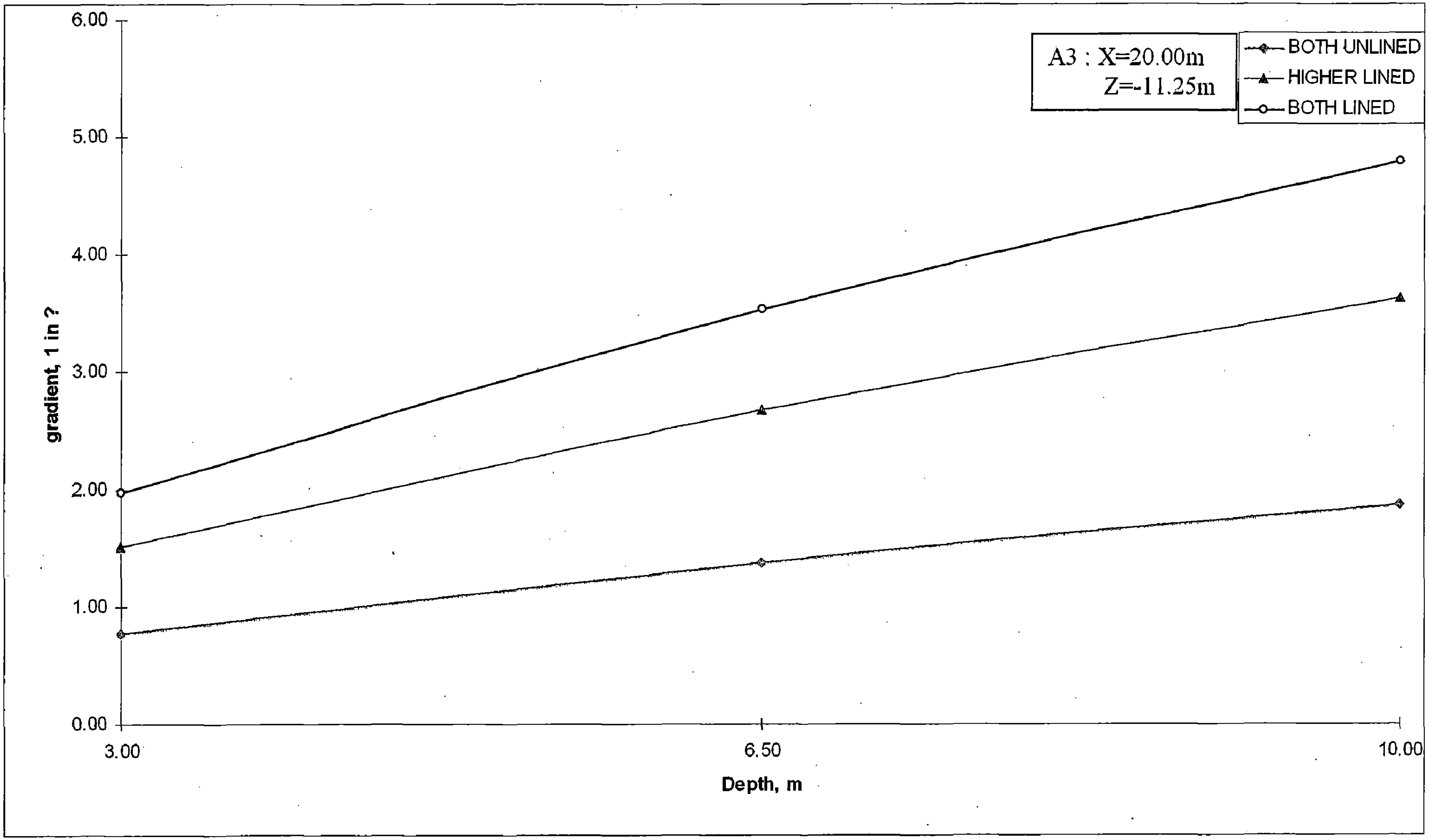


FIG. 5.63 EXIT GRADIENT V/S CUT-OFF DEPTH

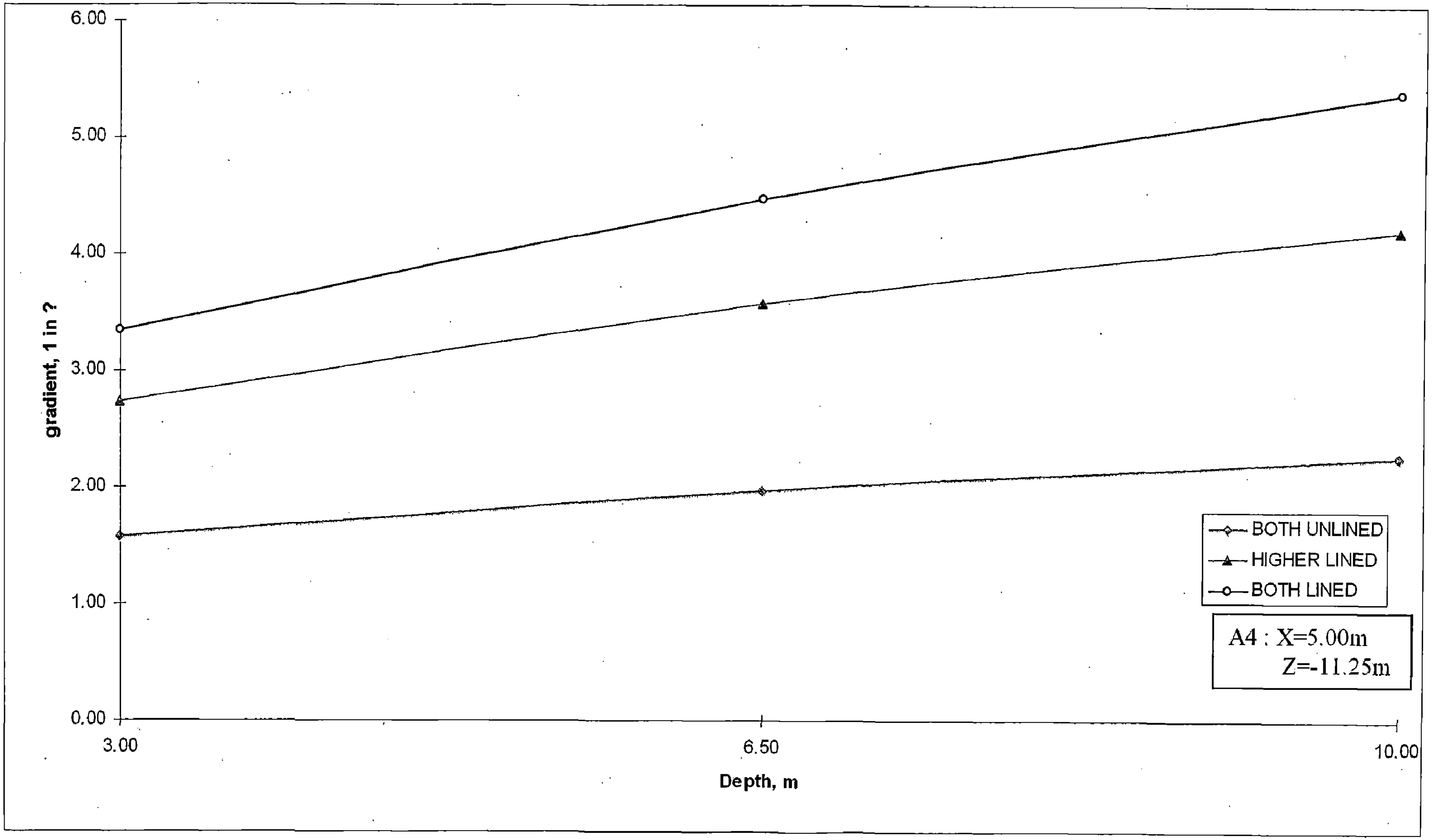


FIG. 5.64 EXIT GRADIENT V/S CUT-OFF DEPTH

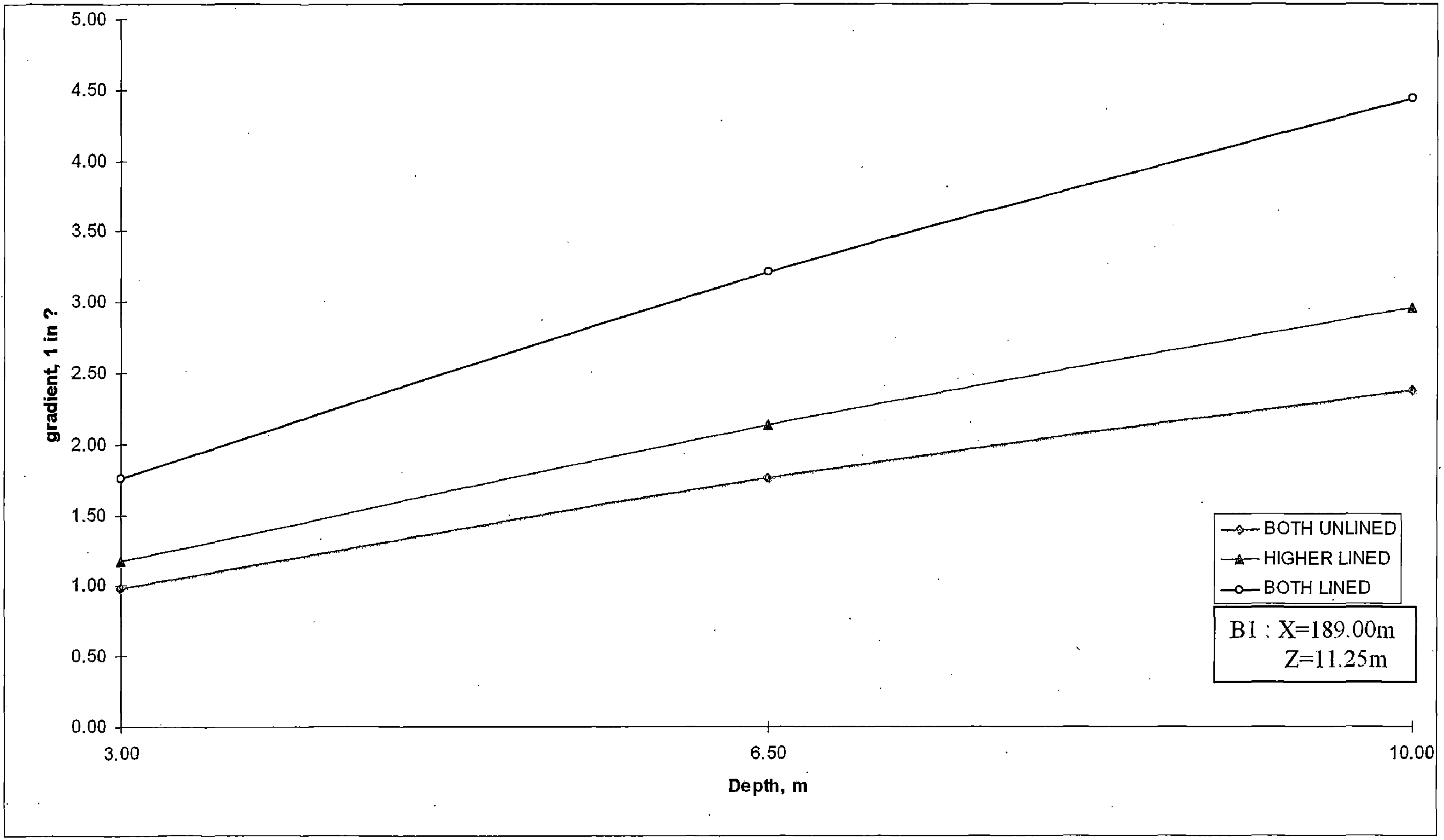


FIG. 5.65 EXIT GRADIENT V/S CUT-OFF DEPTH

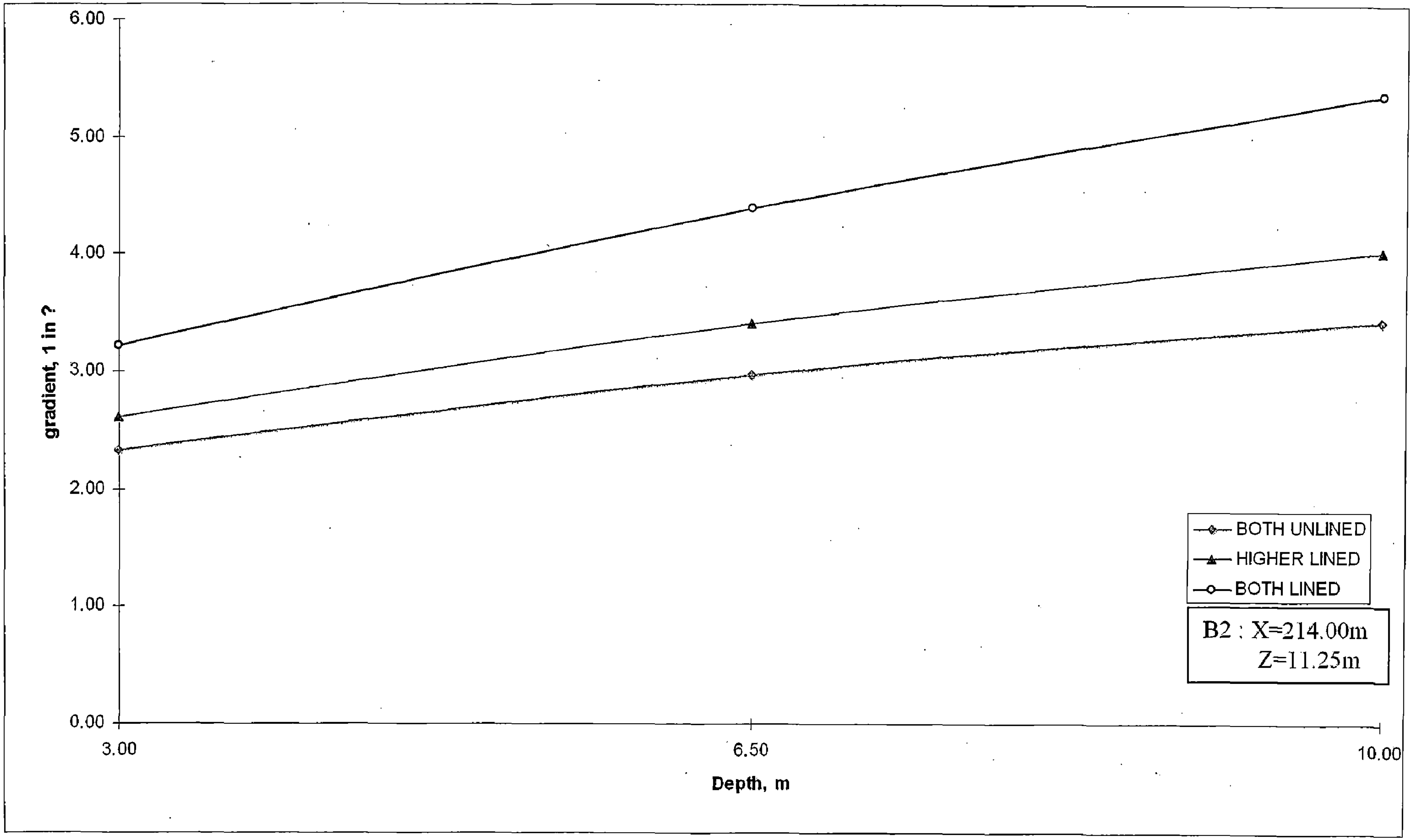


FIG. 5.66 EXIT GRADIENT V/S CUT-OFF DEPTH

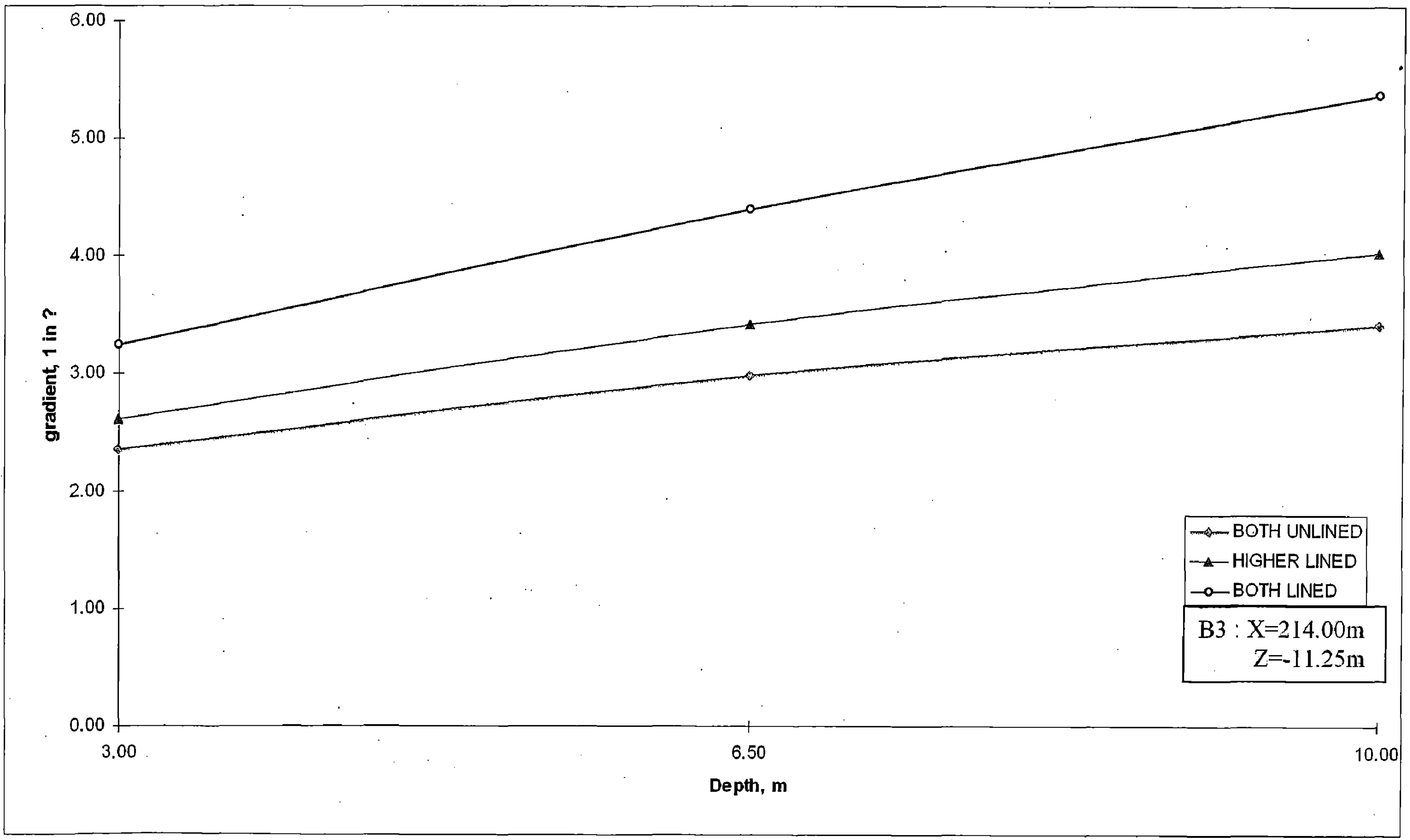


FIG. 5.67 EXIT GRADIENT V/S CUT-OFF DEPTH

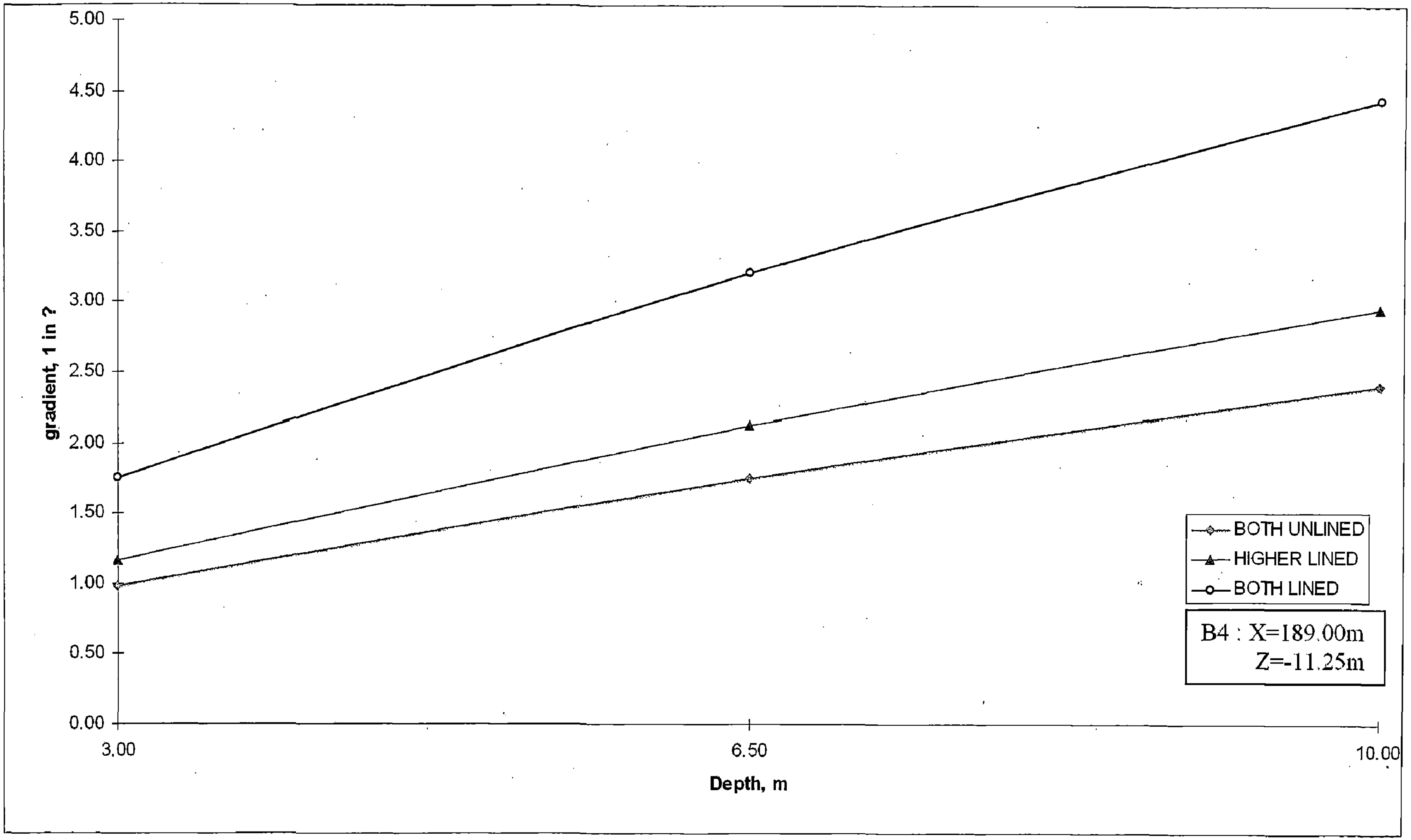


FIG. 5.68 EXIT GRADIENT V/S CUT-OFF DEPTH

CHAPTER – 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the results of FEM analysis described in chapter 5 for the drainage barrel resting over a homogeneous and isotropic stratum under the canal embankment, the following conclusions are made.

- From the comparison of FEM and EHDA, it is found that the elevation of HG lines in FEM analysis as well as EHDA results are quite close to each other at a distance of 61.25m and 161.25m from the central line of the barrel. But for the distance of 250.0m the values are lower in FEM analysis than EDHA values. The HG line at 250m (the end of the lining) is very high being the junctions of lined & unlined section.
- Exit gradient obtained by FEM are lesser than these obtained by EHDA and the difference is about 19%.
- By increasing the length of lining of the canal, uplift pressure decreased. So it is concluded from the study that length of lining in u/s & d/s of barrel should be decided on economic considerations with safe barrel floor. In this case lining length may be reduced to 150m (seven times of the head) without significantly affecting the uplift pressure.
- By increasing the depth of cut off, an increase generally occurs in uplift pressure but exit gradient decreases significantly. So it is concluded that depth of the cut off more than the requirements of scour and safe exit gradient should not be provided (figure-6.4 to 6.9).
- There is no significant difference in uplift pressure at different sections under the barrel floor in this case, because of the lesser width of barrel than the length of canals.
- Figures from 6.1 to 6.3 shows that the lining length reduced up to 90.0m by keeping both canals lined instead of providing lining in higher canal up to 250.0m without significant change in uplift pressure.

6.2 RECOMMENDATIONS

- FEM analysis is the only method for quick assessment of uplift pressures and exit gradients for three dimensional flows.

6.3 FURTHER STUDIES

- FEM analysis for varying water heads, for homogeneous and stratified foundations shall be conducted to generalize the lining length requirement in terms of differential head.
- The study is made on simplified boundary of structure with one set of boundary conditions. Finer mesh to represent the structure should be adopted in further study and model may be run for changed boundary conditions.

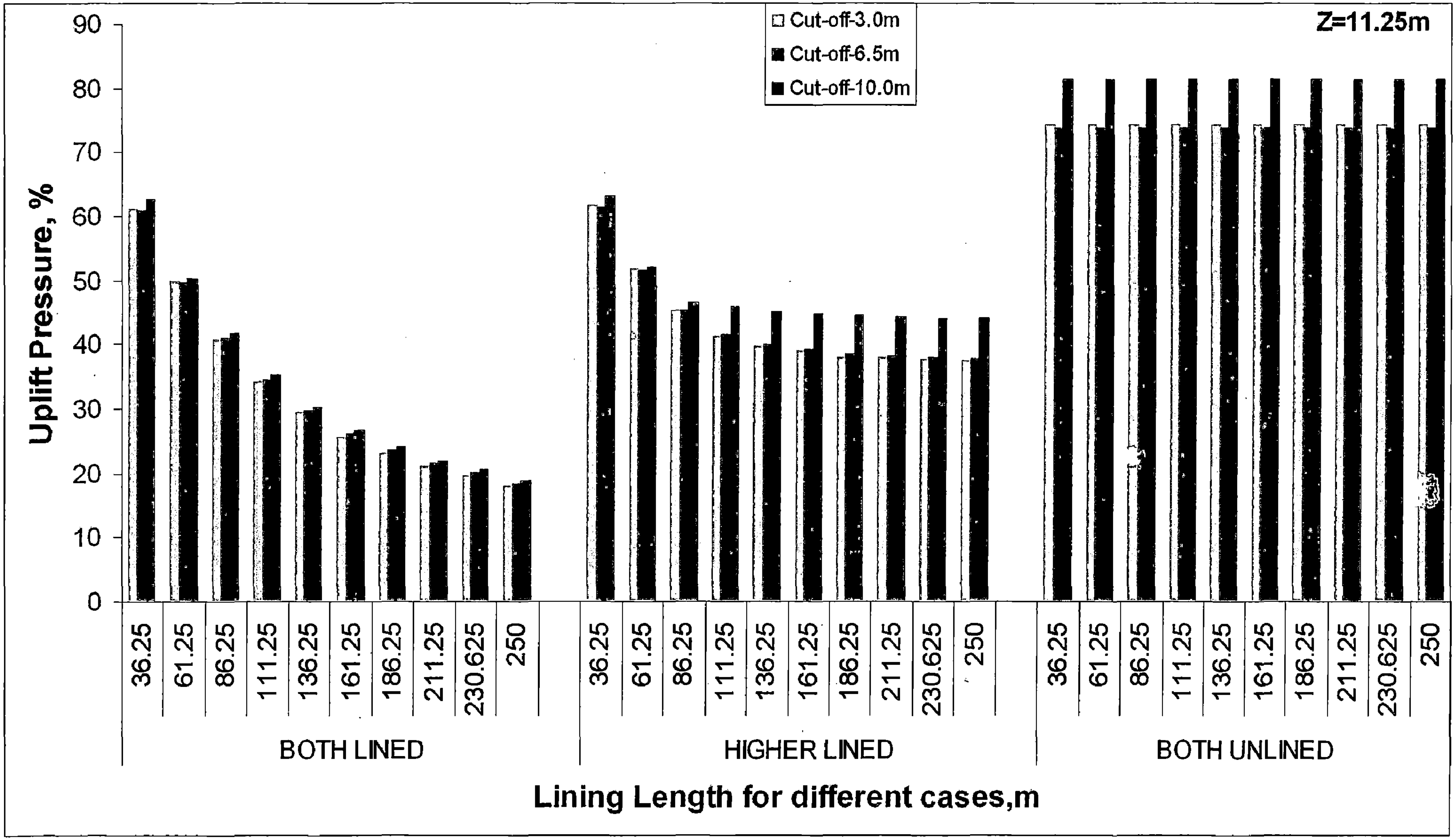


FIG. 6.1 UPLIFT PRESSURE V/S LINING FOR DIFFERENT CASES OF CANALS FOR DIFFERENT CUT-OFF DEPTHS

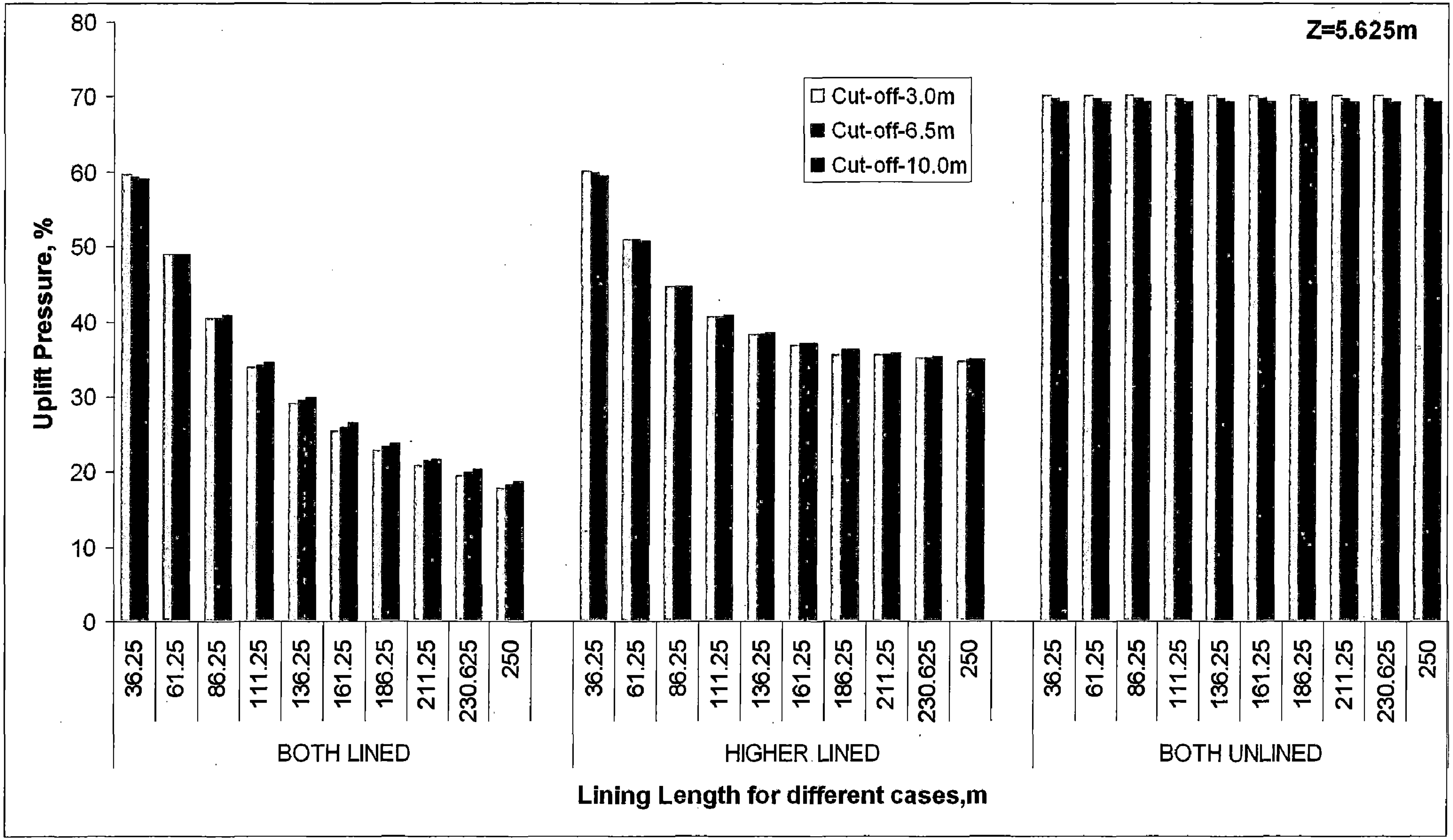


FIG. 6.2 UPLIFT PRESSURE V/S LINING FOR DIFFERENT CASES OF CANALS FOR DIFFERENT CUT-OFF DEPTHS

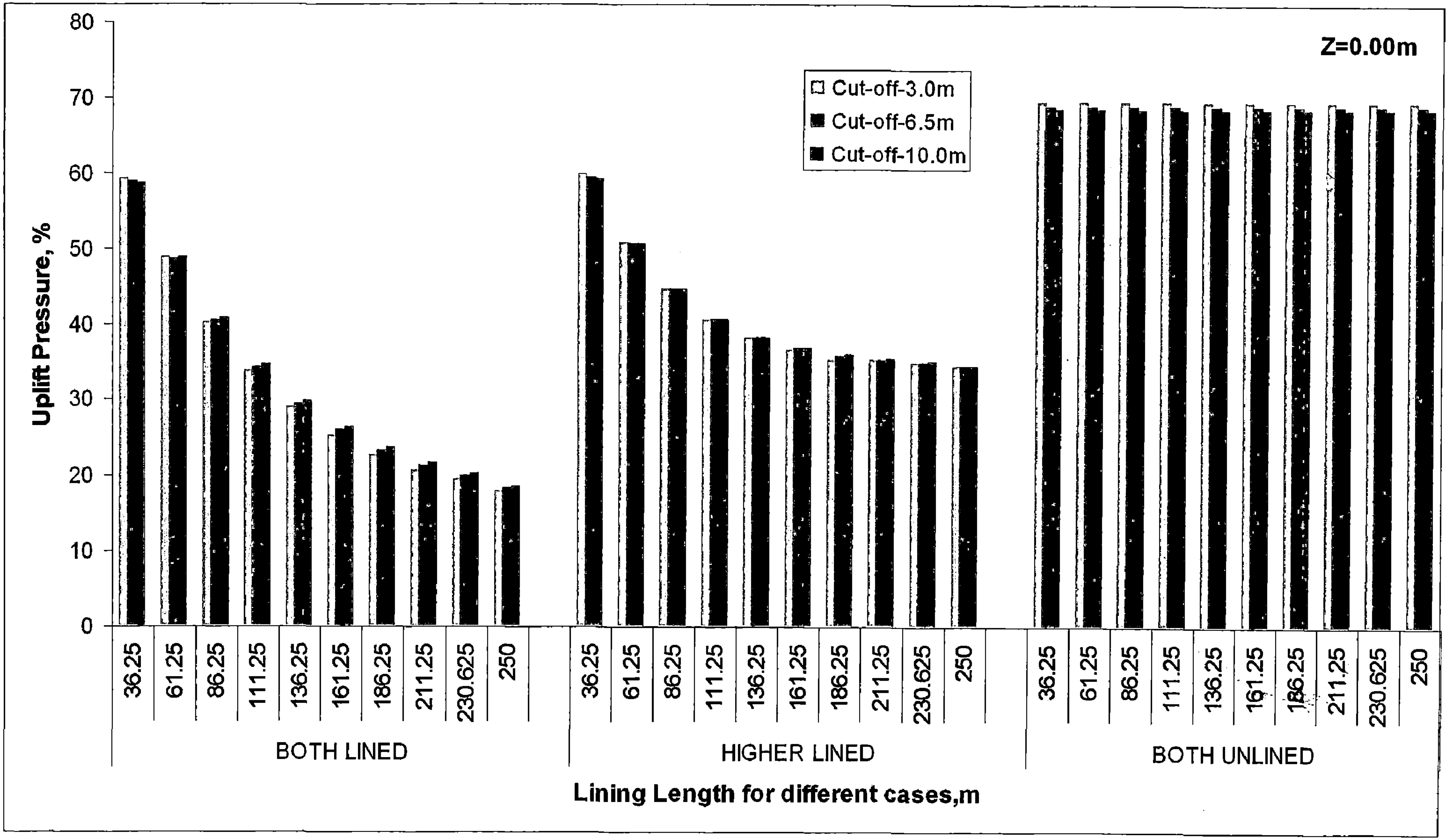
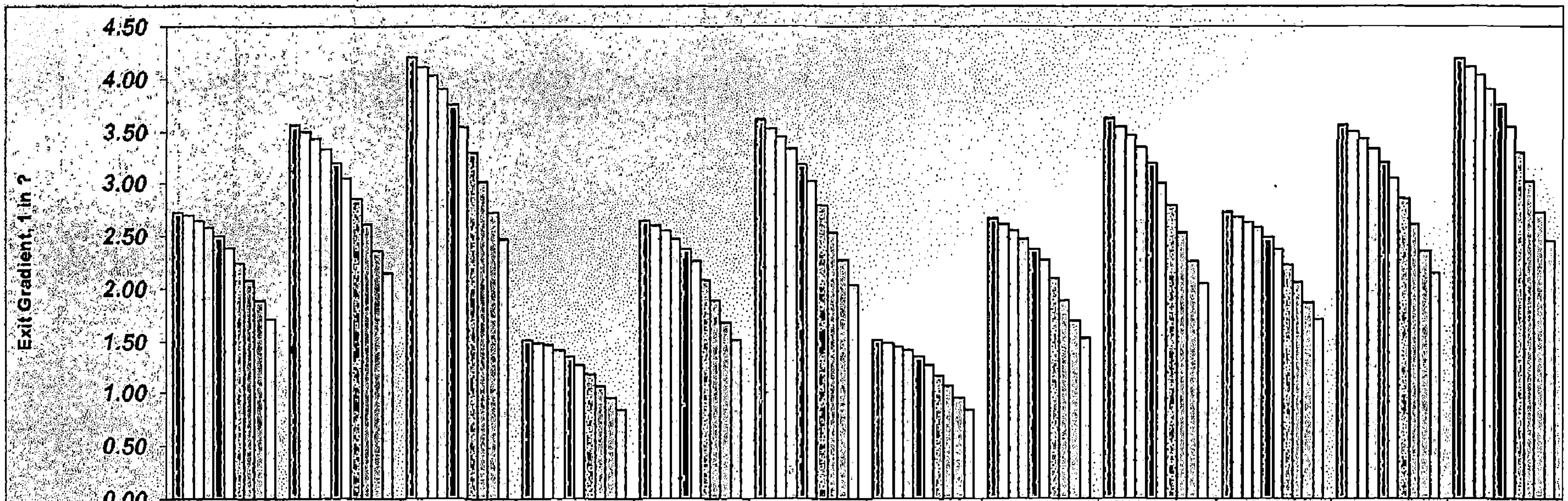


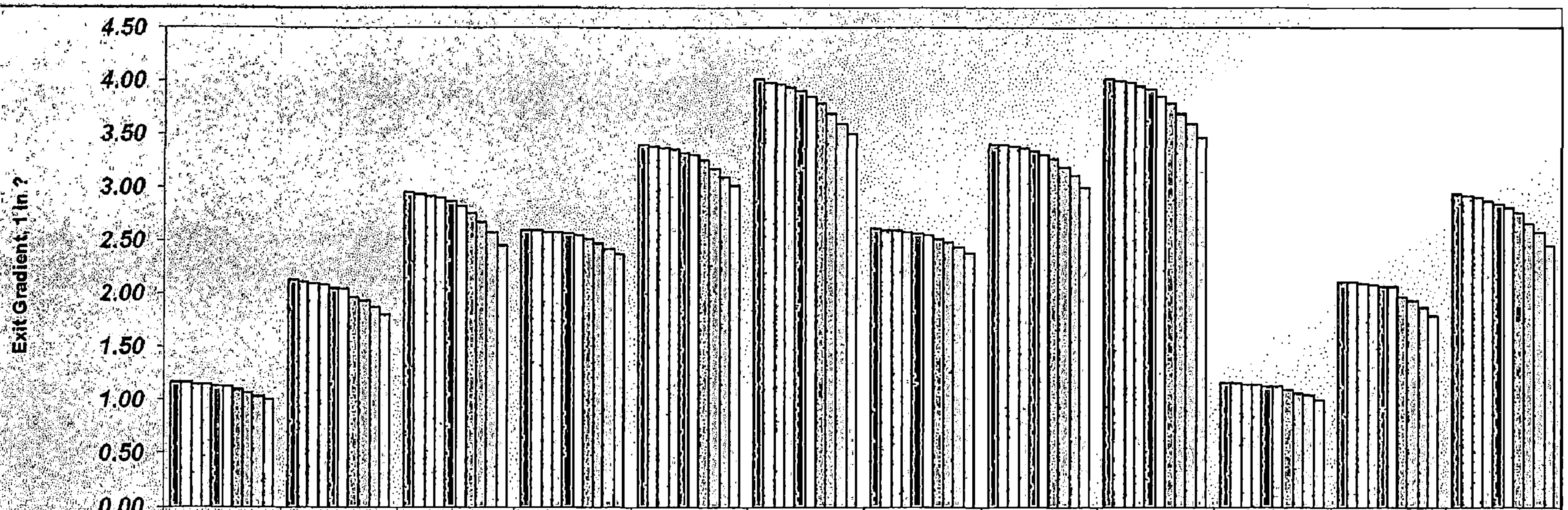
FIG. 6.3 UPLIFT PRESSURE V/S LINING FOR DIFFERENT CASES OF CANALS FOR DIFFERENT CUT-OFF DEPTHS



	A1			A2			A3			A4		
	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00
250	2.74	3.56	4.21	1.51	2.65	3.61	1.51	2.67	3.62	2.72	3.56	4.20
230.625	2.69	3.49	4.11	1.48	2.61	3.52	1.48	2.61	3.53	2.68	3.49	4.11
211.25	2.65	3.42	4.03	1.45	2.55	3.45	1.45	2.56	3.46	2.64	3.43	4.03
186.25	2.59	3.32	3.91	1.41	2.47	3.33	1.41	2.48	3.34	2.58	3.33	3.90
161.25	2.50	3.20	3.75	1.35	2.37	3.19	1.35	2.37	3.19	2.49	3.21	3.75
136.25	2.38	3.06	3.55	1.27	2.26	3.02	1.27	2.27	3.01	2.37	3.05	3.55
111.25	2.24	2.86	3.30	1.18	2.08	2.79	1.17	2.10	2.79	2.23	2.86	3.30
86.25	2.07	2.61	3.02	1.07	1.88	2.54	1.07	1.88	2.53	2.07	2.61	3.02
61.25	1.88	2.36	2.72	0.95	1.68	2.27	0.95	1.68	2.26	1.87	2.36	2.72
36.25	1.71	2.15	2.46	0.85	1.50	2.04	0.84	1.52	2.05	1.70	2.14	2.46

Cut-off depth at different locations

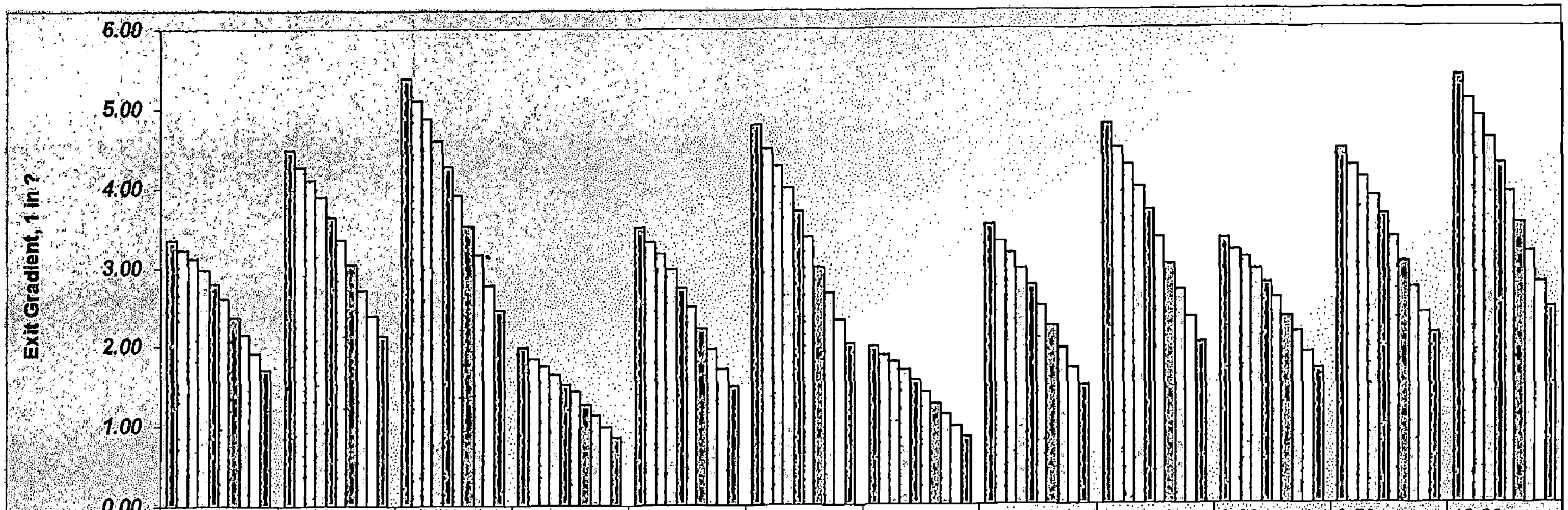
FIG. 6.4 EXIT GRADIENT V/S CUT OFF DEPTH (HIGHER LINED CANAL CASE), U/S



	B1			B2			B3			B4		
	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00
250	1.16	2.13	2.95	2.60	3.40	4.02	2.61	3.41	4.02	1.16	2.12	2.94
230.625	1.16	2.11	2.94	2.59	3.39	3.99	2.60	3.40	4.00	1.16	2.11	2.92
211.25	1.15	2.10	2.93	2.59	3.38	3.97	2.60	3.39	3.98	1.15	2.10	2.90
186.25	1.15	2.08	2.90	2.58	3.36	3.94	2.58	3.37	3.95	1.14	2.08	2.88
161.25	1.14	2.06	2.86	2.56	3.33	3.90	2.57	3.34	3.91	1.14	2.06	2.84
136.25	1.12	2.05	2.82	2.54	3.30	3.86	2.55	3.30	3.86	1.12	2.07	2.81
111.25	1.10	1.97	2.75	2.51	3.26	3.79	2.52	3.27	3.79	1.10	1.96	2.75
86.25	1.07	1.93	2.67	2.47	3.18	3.70	2.48	3.19	3.70	1.07	1.93	2.67
61.25	1.04	1.86	2.58	2.42	3.10	3.60	2.43	3.11	3.59	1.04	1.87	2.57
36.25	1.00	1.81	2.45	2.37	3.01	3.50	2.38	3.00	3.47	1.00	1.79	2.45

Cut-off depth at different locations

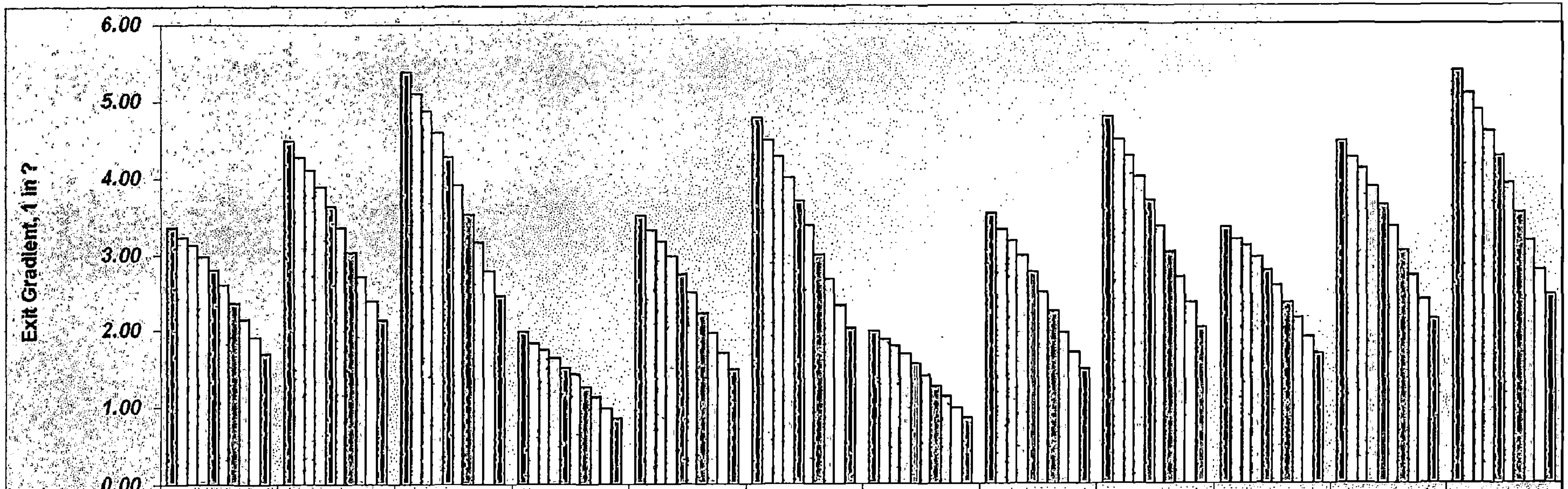
FIG. 6.5 EXIT GRADIENT V/S CUT OFF DEPTH (HIGHER LINED CANAL CASE), D/S



	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00
	A1			A2			A3			A4		
250.0	3.35	4.48	5.38	1.99	3.51	4.78	1.98	3.53	4.78	3.33	4.47	5.38
230.625	3.22	4.26	5.09	1.84	3.31	4.49	1.88	3.32	4.49	3.19	4.25	5.09
211.25	3.11	4.10	4.87	1.76	3.16	4.27	1.80	3.17	4.28	3.09	4.09	4.87
186.25	2.97	3.88	4.60	1.65	2.96	4.00	1.69	2.97	4.00	2.95	3.87	4.59
161.25	2.80	3.63	4.27	1.52	2.74	3.70	1.57	2.75	3.69	2.78	3.63	4.27
136.25	2.60	3.35	3.91	1.42	2.49	3.36	1.42	2.50	3.35	2.58	3.34	3.91
111.25	2.38	3.03	3.52	1.27	2.23	3.00	1.27	2.24	3.02	2.35	3.03	3.51
86.25	2.15	2.71	3.16	1.13	1.96	2.67	1.12	1.96	2.69	2.16	2.70	3.16
61.25	1.91	2.40	2.79	0.97	1.70	2.33	0.97	1.71	2.35	1.91	2.39	2.78
36.25	1.70	2.14	2.46	0.85	1.50	2.02	0.85	1.50	2.03	1.69	2.14	2.46

Cut-off depth at different locations

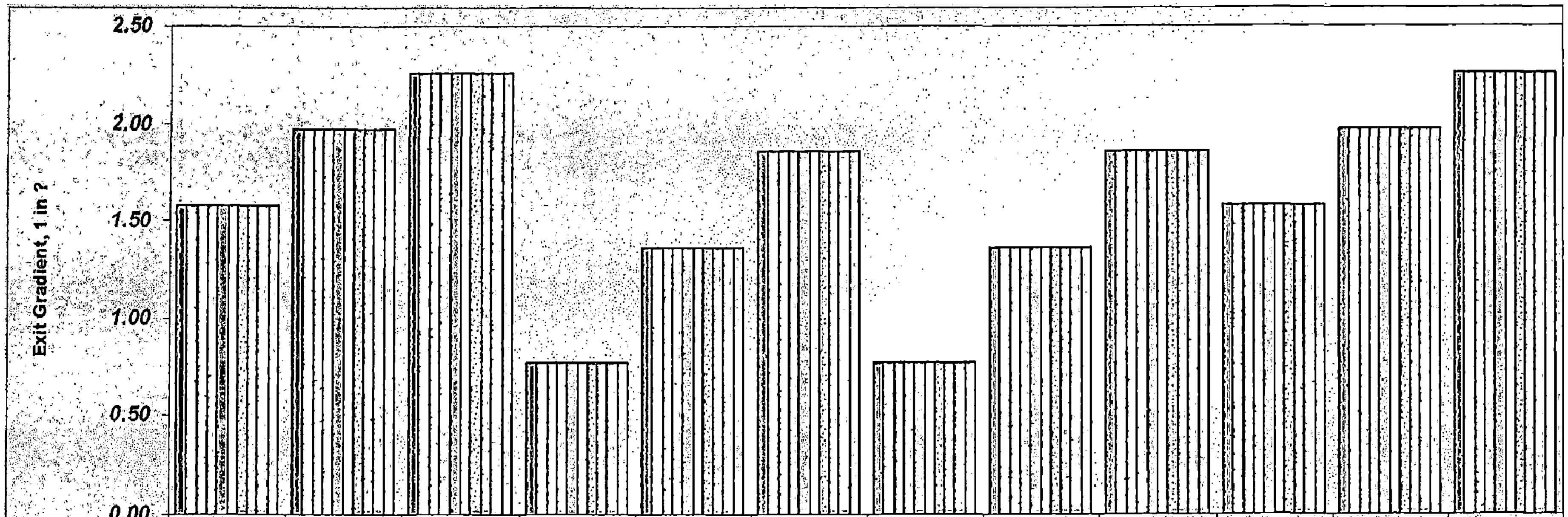
FIG. 6.6 EXIT GRADIENT V/S CUT OFF DEPTH (BOTH LINED CANAL CASE), U/S



	A1			A2			A3			A4		
	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00
250.0	3.35	4.48	5.38	1.99	3.51	4.78	1.98	3.53	4.78	3.33	4.47	5.38
230.625	3.22	4.26	5.09	1.84	3.31	4.49	1.88	3.32	4.49	3.19	4.25	5.09
211.25	3.11	4.10	4.87	1.76	3.16	4.27	1.80	3.17	4.28	3.09	4.09	4.87
186.25	2.97	3.88	4.60	1.65	2.96	4.00	1.69	2.97	4.00	2.95	3.87	4.59
161.25	2.80	3.63	4.27	1.52	2.74	3.70	1.57	2.75	3.69	2.78	3.63	4.27
136.25	2.60	3.35	3.91	1.42	2.49	3.36	1.42	2.50	3.35	2.58	3.34	3.91
111.25	2.38	3.03	3.52	1.27	2.23	3.00	1.27	2.24	3.02	2.35	3.03	3.51
86.25	2.15	2.71	3.16	1.13	1.96	2.67	1.12	1.96	2.69	2.16	2.70	3.16
61.25	1.91	2.40	2.79	0.97	1.70	2.33	0.97	1.71	2.35	1.91	2.39	2.78
36.25	1.70	2.14	2.46	0.85	1.50	2.02	0.85	1.50	2.03	1.69	2.14	2.46

Cut-off depth at different locations

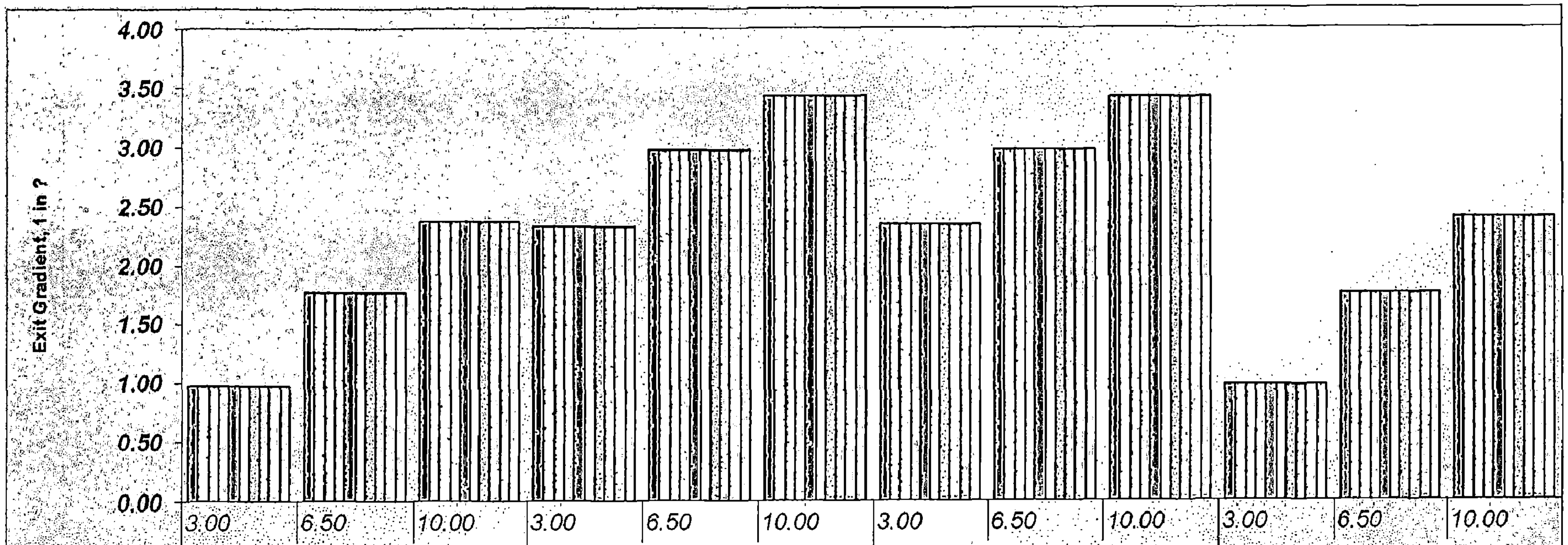
FIG. 6.7 EXIT GRADIENT V/S CUT OFF DEPTH (BOTH LINED CANAL CASE), D/S



	A1			A2			A3			A4		
	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00
250	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
230.625	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
211.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
186.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
161.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
136.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
111.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
86.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
61.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26
36.25	1.58	1.97	2.26	0.77	1.36	1.86	0.77	1.36	1.86	1.58	1.97	2.26

Cut-off depth at different locations

FIG. 6.8 EXIT GRADIENT V/S CUT OFF DEPTH (BOTH UNLINED CANAL CASE), U/S



	B1			B2			B3			B4		
	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00	3.00	6.50	10.00
250	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
230.625	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
211.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
186.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
161.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
136.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
111.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
86.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
61.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40
36.25	0.98	1.76	2.37	2.33	2.97	3.42	2.34	2.97	3.41	0.98	1.75	2.40

Cut-off depth at different locations

FIG. 6.9 EXIT GRADIENT V/S CUT OFF DEPTH (BOTH UNLINED CANAL CASE), D/S

REFERENCES

1 A. JAGADHEESAN (1971), "Study of the effect of Boxing on three dimensional seepage pressure below floors of hydraulic structures", M. Tech. Dissertation, WRDTC, IIT, Roorkee.

2 ANAND PRAKASH (1969), "Study of three dimensional seepage pressure below hydraulic structure with cut-off", M.E. Thesis, UOR, Roorkee.

3 B. PANT (1982), "An Introduction to Finite Element Method for Practicing Engineers", WRDTC, Roorkee.

4 BHARAT SINGH (1988), "Fundamentals of Irrigations Engineering", Nem Chand & Brothers, Roorkee

5 BHIKHAN LAL (1972), "A Study of Design Aspects of Syphon Aqueduct with Special Reference to U/L Syphon Aqueduct on Sarda Sahayak Pariyojana.

6 CHANDRAKANT S. DESAI (1979), "Element Finite Element Method", Prentice-Hall, Inc., New Jersey.

7 GOSH, B. K. & GOSH, S. N. (1968),"Some Basic Studies regarding Seepage flow in Irrigation structures", The Journal of Indian National Society of Soil Mechanics and Foundations Engineering.

8 HARR M. E. (1962), "Ground Water and Seepage", McGraw-Hill Book Company, New York.

9 HARRY R. CEDERGEN (1966) "Seepage, Drainage, and flow Nets", John Wiley & Sons, Inc. New York.

10 IRRIGATION RESEARCH INSTITUTE Report of "3-D EHDA Model Study for Drainage Crossing at km 7.125 of Ban Sagar Feeder Channel, Mirzapur (U.P.).

11 J.B.T.Colman (1956),"The Action of Water under Dams", Assc. M. Am. Soc.C.E. Paper 1956

12 KHOSLA: BOSE AND TAYLOR: "Design of Weirs on Permeable foundations", C. B. I.P. Publication No. 12, 1936.

13 LANE, E.W. (1935),"Security for under seepage masonry dams on Earth Foundations", trans. A.S.C.E. Vol.100.

14 LUTHRA,(1954),"Study of Ground Water Flow Through Layers of different Permeability below a structure by Electrical methods", Journal C.B.I. & P. Vol.2, No 4.

15 MOHD. MOHY MOHAMMED (2002), "Seepage Analysis through Permeable Foundation Of Finite Depth Under a Weir Using FEM", M. Tech. Dissertation, WRDTC, IIT, Roorkee.

16 R. S. VARSHNEY (1982), "Theory & Design of Irrigation Structures", Nem Chand & Brothers; Roorkee.

17 RELTOV, B.F. (1936),"Electrical Analogy Applied to 3-D study of Percolation under Dams Built on Pervious Heterogeneous Foundations", Proc. Second Congress on Large dams, Vol. V.

18 SATISH CHANDRA (1968), "Three dimensional seepage below hydraulic structure laid on pervious foundation", Ph.D. Thesis, UOR, Roorkee.

19 VIDYA NATHAN, V. I. & GURUDAS RAM, "The Electric method of Investigating the uplift Pressure under Dams and Weirs", Research Publications Vol. No. 4.

20 W.D. LIAM FINN, A.M. ASCE (1967),"Finite Element analysis of seepage through dams", J, ASCE; SM6, Proc. Paper 41, Nov.1967.

Table-5.6

UPLIFT PRESSURE ON BARREL FLOOR AT Z=11.25m, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	19.19	19.58	19.95	20.54	21.35	22.41	24.01	26.41	29.39	32.63
2	20.48	19.22	19.62	20.00	20.60	21.42	22.51	24.14	26.58	29.62	32.93
3	20.95	19.28	19.68	20.07	20.67	21.51	22.61	24.27	26.75	29.84	33.21
4	21.57	19.40	19.81	20.20	20.81	21.67	22.79	24.48	27.00	30.14	33.61
5	22.19	19.53	19.95	20.35	20.97	21.84	22.98	24.71	27.27	30.47	34.02
6	23.13	19.73	20.16	20.57	21.21	22.10	23.28	25.05	27.68	30.98	34.64
7	24.08	19.94	20.38	20.80	21.46	22.37	23.57	25.40	28.09	31.49	35.27
8	25.56	20.30	20.76	21.19	21.88	22.83	24.08	25.98	28.78	32.33	36.31
9	27.03	20.68	21.16	21.61	22.32	23.31	24.60	26.58	29.49	33.19	37.36
10	29.05	21.18	21.68	22.16	22.90	23.93	25.29	27.37	30.42	34.32	38.76
11	31.06	21.66	22.18	22.67	23.45	24.52	25.95	28.12	31.30	35.39	40.09
12	33.48	22.20	22.74	23.26	24.07	25.20	26.70	28.97	32.31	36.61	41.63
13	35.91	22.70	23.27	23.81	24.65	25.82	27.39	29.76	33.24	37.76	43.07
14	38.55	23.23	23.82	24.38	25.26	26.47	28.12	30.59	34.21	38.95	44.60
15	41.20	23.72	24.33	24.91	25.82	27.08	28.79	31.35	35.11	40.06	46.04
16	43.89	24.20	24.83	25.43	26.37	27.66	29.44	32.10	35.98	41.15	47.47
17	46.59	24.66	25.31	25.92	26.89	28.22	30.06	32.80	36.81	42.18	48.84
18	48.78	25.00	25.66	26.29	27.27	28.63	30.52	33.32	37.41	42.94	49.84
19	50.96	25.33	26.01	26.64	27.64	29.03	30.96	33.82	37.99	43.66	50.82
20	53.15	25.65	26.34	26.98	28.00	29.41	31.38	34.29	38.55	44.36	51.78
21	55.34	25.96	26.66	27.31	28.35	29.78	31.78	34.74	39.07	45.01	52.68
22	58.04	26.34	27.05	27.71	28.77	30.22	32.27	35.29	39.70	45.81	53.80
23	60.74	26.71	27.43	28.10	29.17	30.65	32.73	35.80	40.29	46.55	54.86
24	63.44	27.05	27.78	28.46	29.54	31.04	33.15	36.27	40.82	47.21	55.79
25	66.14	27.39	28.12	28.81	29.90	31.41	33.55	36.71	41.31	47.82	56.67
26	68.84	27.72	28.46	29.15	30.25	31.78	33.94	37.13	41.79	48.40	57.51
27	71.54	28.04	28.79	29.49	30.59	32.13	34.31	37.53	42.22	48.94	58.30
28	74.24	28.36	29.11	29.81	30.92	32.46	34.66	37.89	42.62	49.41	58.97
29	76.94	28.66	29.42	30.12	31.23	32.77	34.99	38.24	42.98	49.83	59.57
30	79.64	28.97	29.72	30.43	31.54	33.08	35.30	38.56	43.32	50.22	60.11
31	82.34	29.27	30.02	30.73	31.84	33.38	35.61	38.87	43.63	50.56	60.58
32	85.04	29.56	30.31	31.02	32.12	33.67	35.89	39.14	43.90	50.83	60.89
33	87.74	29.85	30.60	31.30	32.40	33.94	36.15	39.39	44.14	51.06	61.13
34	90.44	30.14	30.89	31.58	32.68	34.20	36.41	39.63	44.35	51.24	61.30
35	93.14	30.43	31.17	31.86	32.94	34.46	36.65	39.85	44.53	51.38	61.38
36	95.84	30.71	31.44	32.12	33.20	34.70	36.88	40.05	44.68	51.46	61.32
37	98.54	30.99	31.71	32.38	33.45	34.93	37.09	40.22	44.80	51.49	61.16
38	101.24	31.27	31.98	32.65	33.70	35.16	37.29	40.39	44.90	51.50	61.00
39	103.94	31.55	32.25	32.91	33.94	35.38	37.48	40.53	44.97	51.47	60.74

Table-5.6

UPLIFT PRESSURE ON BARREL FLOOR AT Z=11.25m, d = 6.50m (contd...)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
40	106.64	31.83	32.52	33.16	34.18	35.59	37.65	40.65	45.01	51.37	60.36
41	109.34	32.11	32.78	33.41	34.41	35.80	37.82	40.76	45.02	51.23	59.92
42	112.04	32.39	33.05	33.67	34.64	36.00	37.98	40.85	45.02	51.06	59.44
43	114.74	32.68	33.33	33.93	34.88	36.20	38.13	40.94	44.99	50.86	58.92
44	117.44	32.97	33.60	34.18	35.11	36.39	38.27	40.99	44.92	50.60	58.29
45	120.14	33.26	33.87	34.44	35.34	36.58	38.40	41.04	44.84	50.31	57.63
46	122.84	33.57	34.16	34.70	35.57	36.78	38.53	41.08	44.74	49.99	56.95
47	125.54	33.89	34.45	34.98	35.81	36.97	38.66	41.12	44.63	49.64	56.23
48	128.24	34.21	34.75	35.26	36.06	37.17	38.79	41.13	44.49	49.26	55.45
49	130.94	34.55	35.06	35.54	36.31	37.37	38.91	41.15	44.34	48.84	54.64
50	133.64	34.92	35.40	35.86	36.58	37.59	39.06	41.17	44.18	48.43	53.83
51	136.34	35.31	35.77	36.20	36.88	37.83	39.21	41.20	44.03	47.99	52.99
52	139.04	35.71	36.14	36.54	37.18	38.06	39.35	41.21	43.85	47.52	52.11
53	141.74	36.16	36.56	36.93	37.52	38.34	39.54	41.25	43.68	47.06	51.24
54	144.44	36.52	36.89	37.23	37.78	38.53	39.64	41.22	43.44	46.52	50.30
55	147.14	36.85	37.18	37.50	37.99	38.69	39.70	41.14	43.16	45.95	49.34
56	149.84	37.23	37.53	37.82	38.27	38.89	39.81	41.11	42.93	45.42	48.41
57	152.54	37.49	37.76	38.01	38.42	38.98	39.81	40.98	42.60	44.82	47.46
58	155.24	37.37	37.62	37.85	38.22	38.74	39.50	40.56	42.03	44.03	46.39
59	157.93	36.99	37.22	37.43	37.77	38.25	38.96	39.94	41.28	43.10	45.22
60	160.60	36.39	36.60	36.80	37.12	37.56	38.23	39.14	40.38	42.06	43.98
61	163.28	35.55	35.75	35.94	36.25	36.66	37.30	38.15	39.30	40.87	42.64
62	165.89	34.55	34.74	34.92	35.21	35.60	36.21	37.02	38.10	39.57	41.21
63	168.50	33.45	33.63	33.80	34.07	34.45	35.03	35.80	36.81	38.19	39.72
64	171.00	32.17	32.33	32.50	32.76	33.13	33.69	34.43	35.39	36.70	38.14
65	173.50	30.85	31.00	31.16	31.41	31.76	32.30	33.01	33.91	35.16	36.51
66	175.79	29.58	29.74	29.89	30.13	30.45	30.97	31.65	32.50	33.68	34.95
67	178.08	28.30	28.45	28.59	28.81	29.12	29.61	30.26	31.05	32.16	33.34
68	180.03	27.17	27.31	27.44	27.66	27.95	28.41	29.02	29.77	30.81	31.93
69	181.99	26.02	26.15	26.27	26.48	26.75	27.19	27.76	28.46	29.44	30.48
70	183.45	25.19	25.31	25.43	25.62	25.89	26.30	26.84	27.51	28.43	29.41
71	184.92	24.38	24.49	24.61	24.79	25.04	25.42	25.93	26.56	27.43	28.36
72	185.87	23.86	23.97	24.08	24.25	24.49	24.86	25.34	25.96	26.79	27.69
73	186.81	23.38	23.48	23.59	23.76	23.99	24.34	24.81	25.40	26.20	27.06
74	187.43	23.06	23.16	23.27	23.43	23.65	23.99	24.45	25.03	25.81	26.65
75	188.05	22.78	22.88	22.98	23.13	23.35	23.68	24.13	24.69	25.44	26.27
76	188.52	22.58	22.68	22.77	22.93	23.14	23.45	23.90	24.44	25.17	25.96
77	189.00	22.37	22.46	22.56	22.71	22.91	23.21	23.64	24.16	24.87	25.63

Table-5.7

UPLIFT PRESSURE ON BARREL FLOOR AT Z=5.625, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	18.07	18.48	18.87	19.49	20.34	21.47	23.19	25.66	28.81	32.36
2	20.80	18.10	18.51	18.90	19.52	20.37	21.51	23.23	25.70	28.86	32.42
3	21.60	18.19	18.60	18.99	19.61	20.47	21.62	23.35	25.84	29.02	32.60
4	22.86	18.43	18.85	19.25	19.88	20.75	21.92	23.69	26.23	29.47	33.13
5	24.11	18.75	19.18	19.59	20.24	21.14	22.33	24.14	26.75	30.08	33.85
6	26.08	19.37	19.82	20.25	20.93	21.87	23.12	25.02	27.75	31.25	35.24
7	28.05	20.00	20.47	20.92	21.63	22.61	23.93	25.92	28.78	32.46	36.68
8	30.73	20.80	21.30	21.78	22.53	23.57	24.97	27.07	30.11	34.04	38.59
9	33.42	21.53	22.06	22.56	23.35	24.44	25.92	28.14	31.35	35.52	40.38
10	36.73	22.34	22.90	23.43	24.26	25.42	26.99	29.34	32.74	37.19	42.44
11	40.05	23.06	23.65	24.20	25.08	26.29	27.94	30.41	33.99	38.70	44.33
12	43.51	23.75	24.36	24.94	25.85	27.12	28.85	31.44	35.18	40.16	46.17
13	46.97	24.38	25.02	25.62	26.56	27.87	29.68	32.37	36.27	41.49	47.88
14	50.42	24.96	25.62	26.24	27.21	28.56	30.44	33.23	37.26	42.71	49.47
15	53.88	25.50	26.18	26.81	27.82	29.20	31.14	34.01	38.17	43.83	50.94
16	57.07	25.97	26.66	27.31	28.34	29.76	31.74	34.68	38.94	44.78	52.20
17	60.26	26.42	27.13	27.79	28.83	30.27	32.31	35.31	39.65	45.65	53.38
18	63.45	26.86	27.57	28.24	29.30	30.76	32.84	35.89	40.31	46.46	54.46
19	66.63	27.28	28.00	28.67	29.74	31.23	33.34	36.43	40.92	47.20	55.46
20	70.09	27.71	28.44	29.13	30.21	31.71	33.84	36.98	41.52	47.92	56.44
21	73.55	28.13	28.87	29.56	30.64	32.16	34.31	37.48	42.07	48.56	57.30
22	77.01	28.54	29.28	29.97	31.06	32.58	34.75	37.94	42.55	49.12	58.03
23	80.47	28.94	29.68	30.37	31.46	32.98	35.16	38.36	42.99	49.60	58.64
24	83.92	29.33	30.07	30.75	31.85	33.36	35.54	38.73	43.36	49.99	59.11
25	87.38	29.71	30.44	31.13	32.21	33.72	35.90	39.08	43.69	50.31	59.45
26	90.84	30.08	30.81	31.49	32.56	34.06	36.23	39.38	43.96	50.55	59.66
27	94.30	30.44	31.16	31.83	32.90	34.38	36.53	39.65	44.19	50.71	59.73
28	97.75	30.80	31.51	32.17	33.22	34.68	36.80	39.89	44.36	50.80	59.67
29	101.21	31.15	31.85	32.50	33.53	34.97	37.06	40.09	44.48	50.81	59.47
30	104.67	31.49	32.17	32.81	33.83	35.24	37.29	40.26	44.56	50.74	59.17

Table-5.7

UPLIFT PRESSURE ON BARREL FLOOR AT Z=5.625, d = 6.50m (contd...)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
31	108.13	31.83	32.50	33.12	34.11	35.49	37.49	40.40	44.59	50.61	58.76
32	111.59	32.16	32.81	33.42	34.38	35.72	37.67	40.50	44.57	50.40	58.23
33	115.04	32.49	33.12	33.71	34.64	35.94	37.83	40.58	44.51	50.14	57.62
34	118.50	32.81	33.42	33.99	34.89	36.14	37.96	40.61	44.40	49.79	56.89
35	121.96	33.13	33.72	34.26	35.13	36.33	38.08	40.62	44.25	49.39	56.10
36	125.42	33.44	34.00	34.52	35.34	36.49	38.17	40.60	44.05	48.93	55.23
37	128.87	33.73	34.27	34.76	35.55	36.64	38.23	40.54	43.81	48.41	54.30
38	132.33	34.01	34.51	34.98	35.73	36.76	38.26	40.44	43.52	47.83	53.29
39	135.79	34.28	34.75	35.19	35.88	36.85	38.27	40.31	43.18	47.19	52.22
40	139.25	34.48	34.92	35.33	35.98	36.89	38.21	40.11	42.78	46.49	51.09
41	142.71	34.64	35.05	35.43	36.03	36.87	38.10	39.86	42.32	45.73	49.91
42	146.16	34.74	35.11	35.46	36.02	36.79	37.93	39.54	41.79	44.90	48.66
43	149.62	34.70	35.04	35.36	35.88	36.59	37.63	39.10	41.16	43.97	47.35
44	153.08	34.48	34.79	35.09	35.56	36.21	37.16	38.51	40.38	42.92	45.95
45	156.53	34.07	34.35	34.62	35.05	35.65	36.53	37.76	39.45	41.75	44.46
46	159.95	33.42	33.69	33.94	34.33	34.88	35.69	36.82	38.36	40.45	42.87
47	163.38	32.57	32.82	33.04	33.41	33.91	34.66	35.69	37.10	38.99	41.17
48	166.72	31.52	31.74	31.95	32.29	32.76	33.45	34.40	35.69	37.42	39.38
49	170.06	30.29	30.50	30.70	31.01	31.43	32.07	32.95	34.12	35.70	37.48
50	173.15	28.99	29.18	29.36	29.65	30.04	30.64	31.45	32.53	33.97	35.59
51	176.24	27.55	27.73	27.89	28.16	28.52	29.07	29.81	30.80	32.12	33.59
52	178.66	26.34	26.50	26.66	26.91	27.25	27.76	28.45	29.38	30.60	31.96
53	181.08	25.07	25.22	25.36	25.59	25.91	26.39	27.03	27.89	29.02	30.27
54	183.00	24.08	24.21	24.35	24.57	24.87	25.31	25.92	26.72	27.78	28.95
55	184.92	23.12	23.25	23.38	23.59	23.87	24.28	24.86	25.62	26.62	27.72
56	186.16	22.60	22.73	22.86	23.06	23.33	23.72	24.29	25.03	25.99	27.05
57	187.40	22.23	22.36	22.48	22.68	22.94	23.32	23.88	24.60	25.54	26.57
58	188.20	22.10	22.23	22.35	22.54	22.81	23.18	23.73	24.45	25.38	26.40
59	189.00	22.06	22.18	22.30	22.50	22.76	23.14	23.68	24.40	25.33	26.34

Table-5.8

UPLIFT PRESSURE ON BARREL FLOOR AT Z=0.00, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	17.77	18.17	18.56	19.18	20.02	21.16	22.89	25.33	28.48	32.05
2	20.80	17.80	18.21	18.60	19.21	20.06	21.20	22.93	25.38	28.54	32.11
3	21.60	17.89	18.29	18.69	19.31	20.16	21.31	23.05	25.51	28.69	32.28
4	22.88	18.11	18.53	18.92	19.55	20.42	21.59	23.35	25.87	29.10	32.75
5	24.16	18.44	18.87	19.28	19.92	20.81	22.01	23.81	26.39	29.71	33.47
6	26.21	19.14	19.58	20.01	20.69	21.62	22.87	24.77	27.48	30.97	34.96
7	28.26	19.82	20.29	20.73	21.44	22.42	23.74	25.73	28.57	32.25	36.48
8	31.31	20.77	21.27	21.75	22.50	23.55	24.96	27.08	30.13	34.08	38.68
9	34.37	21.62	22.15	22.66	23.46	24.56	26.06	28.30	31.54	35.76	40.71
10	38.75	22.67	23.24	23.79	24.64	25.82	27.44	29.85	33.33	37.91	43.36
11	43.13	23.58	24.19	24.76	25.67	26.92	28.64	31.20	34.89	39.81	45.73
12	47.60	24.41	25.05	25.65	26.59	27.90	29.72	32.41	36.30	41.53	47.93
13	52.08	25.16	25.82	26.44	27.43	28.79	30.69	33.50	37.56	43.07	49.92
14	56.58	25.85	26.53	27.17	28.19	29.59	31.57	34.48	38.69	44.45	51.74
15	61.08	26.49	27.19	27.85	28.89	30.33	32.36	35.37	39.69	45.67	53.36
16	65.58	27.10	27.81	28.48	29.54	31.01	33.10	36.17	40.60	46.78	54.83
17	70.08	27.67	28.40	29.08	30.15	31.65	33.77	36.89	41.40	47.73	56.11
18	74.58	28.22	28.95	29.64	30.72	32.23	34.38	37.54	42.10	48.55	57.16
19	79.08	28.75	29.49	30.17	31.26	32.77	34.94	38.12	42.70	49.23	58.04
20	83.58	29.26	29.99	30.68	31.77	33.28	35.45	38.62	43.22	49.77	58.69
21	88.08	29.75	30.48	31.17	32.25	33.75	35.91	39.07	43.64	50.18	59.13
22	92.58	30.23	30.95	31.63	32.70	34.18	36.32	39.45	43.98	50.46	59.34
23	97.08	30.70	31.41	32.07	33.12	34.58	36.70	39.78	44.22	50.61	59.33
24	102.59	31.25	31.94	32.59	33.61	35.03	37.09	40.09	44.41	50.62	59.04
25	108.10	31.79	32.45	33.07	34.06	35.43	37.42	40.32	44.48	50.44	58.45
26	112.60	32.21	32.85	33.45	34.40	35.72	37.65	40.44	44.44	50.16	57.77

Table-5.8

UPLIFT PRESSURE ON BARREL FLOOR AT Z=0.00, d = 6.50m (contd...)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
27	117.10	32.62	33.24	33.81	34.72	35.99	37.83	40.51	44.33	49.77	56.93
28	121.60	33.02	33.60	34.15	35.01	36.22	37.97	40.51	44.13	49.27	55.94
29	126.10	33.39	33.95	34.46	35.28	36.41	38.07	40.47	43.87	48.67	54.83
30	130.56	33.72	34.24	34.72	35.49	36.55	38.10	40.34	43.50	47.95	53.59
31	135.03	34.02	34.49	34.94	35.65	36.64	38.07	40.15	43.07	47.14	52.25
32	139.31	34.23	34.67	35.08	35.74	36.65	37.97	39.88	42.55	46.27	50.87
33	143.58	34.33	34.73	35.11	35.71	36.54	37.75	39.49	41.92	45.28	49.38
34	147.45	34.30	34.67	35.01	35.56	36.32	37.44	39.03	41.24	44.28	47.95
35	151.32	34.09	34.42	34.74	35.24	35.94	36.96	38.40	40.41	43.15	46.42
36	154.99	33.69	33.99	34.28	34.74	35.38	36.32	37.64	39.46	41.93	44.87
37	158.65	33.09	33.37	33.63	34.05	34.64	35.50	36.70	38.35	40.59	43.21
38	162.12	32.32	32.58	32.82	33.21	33.75	34.54	35.64	37.14	39.18	41.53
39	165.58	31.35	31.59	31.82	32.17	32.67	33.39	34.40	35.78	37.62	39.73
40	168.68	30.32	30.54	30.75	31.08	31.54	32.21	33.14	34.41	36.10	38.01
41	171.79	29.13	29.34	29.53	29.83	30.26	30.88	31.74	32.90	34.44	36.18
42	174.40	28.02	28.20	28.38	28.67	29.06	29.65	30.44	31.52	32.95	34.55
43	177.02	26.79	26.97	27.13	27.40	27.76	28.31	29.04	30.04	31.37	32.84
44	179.22	25.69	25.85	26.01	26.26	26.60	27.12	27.80	28.73	29.97	31.34
45	181.42	24.53	24.68	24.83	25.06	25.38	25.87	26.50	27.37	28.52	29.80
46	183.21	23.54	23.68	23.82	24.04	24.34	24.79	25.40	26.22	27.30	28.50
47	185.01	22.52	22.65	22.78	22.99	23.27	23.69	24.27	25.05	26.06	27.18
48	186.20	22.21	22.34	22.46	22.67	22.95	23.35	23.92	24.68	25.68	26.76
49	187.40	21.94	22.07	22.19	22.39	22.67	23.05	23.62	24.38	25.35	26.41
50	188.20	21.80	21.93	22.05	22.25	22.52	22.90	23.47	24.22	25.18	26.23
51	189.00	21.74	21.87	22.00	22.20	22.47	22.84	23.41	24.16	25.12	26.16

Table-5.9

UPLIFT PRESSURE ON BARREL FLOOR AT Z=11.25m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	16.19	16.50	16.80	16.80	17.94	18.93	20.31	22.20	24.76	27.79
2	20.48	16.22	16.54	16.84	16.84	18.01	19.01	20.41	22.34	24.94	28.03
3	20.95	16.32	16.65	16.96	16.96	18.15	19.16	20.59	22.56	25.22	28.37
4	21.57	16.58	16.92	17.23	17.23	18.46	19.50	20.97	23.01	25.74	28.99
5	22.19	16.86	17.21	17.53	17.53	18.80	19.87	21.39	23.49	26.30	29.66
6	23.13	17.30	17.66	18.00	18.00	19.32	20.44	22.03	24.23	27.18	30.69
7	24.08	17.74	18.12	18.47	18.47	19.85	21.01	22.67	24.96	28.05	31.73
8	25.57	18.39	18.79	19.17	19.17	20.63	21.86	23.62	26.07	29.36	33.28
9	27.06	19.00	19.42	19.82	19.82	21.36	22.66	24.51	27.10	30.59	34.75
10	29.27	19.76	20.21	20.64	20.64	22.28	23.67	25.65	28.43	32.18	36.68
11	31.47	20.43	20.91	21.36	21.36	23.10	24.56	26.66	29.62	33.61	38.42
12	34.09	21.17	21.67	22.15	22.15	23.99	25.54	27.77	30.92	35.19	40.35
13	36.71	21.84	22.37	22.88	22.88	24.81	26.44	28.79	32.12	36.65	42.17
14	39.41	22.45	23.00	23.53	23.53	25.56	27.26	29.72	33.21	37.99	43.85
15	42.10	23.02	23.60	24.14	24.14	26.25	28.02	30.58	34.23	39.24	45.44
16	44.91	23.58	24.17	24.74	24.74	26.92	28.76	31.42	35.22	40.47	47.01
17	47.72	24.11	24.72	25.31	25.31	27.56	29.46	32.21	36.16	41.63	48.53
18	50.42	24.58	25.21	25.81	25.81	28.13	30.07	32.90	36.97	42.64	49.86
19	53.12	25.03	25.68	26.29	26.29	28.66	30.65	33.56	37.74	43.60	51.13
20	55.82	25.47	26.13	26.76	26.76	29.18	31.22	34.19	38.48	44.53	52.38
21	58.52	25.89	26.57	27.21	27.21	29.67	31.75	34.78	39.17	45.39	53.57
22	61.22	26.29	26.97	27.62	27.62	30.12	32.23	35.32	39.80	46.17	54.63
23	63.92	26.67	27.37	28.03	28.03	30.56	32.70	35.83	40.39	46.91	55.67
24	66.62	27.05	27.75	28.42	28.42	30.98	33.14	36.32	40.95	47.59	56.63
25	69.32	27.41	28.12	28.79	28.79	31.38	33.56	36.77	41.46	48.22	57.51
26	72.02	27.76	28.48	29.16	29.16	31.76	33.97	37.21	41.94	48.81	58.34
27	74.72	28.11	28.83	29.51	29.51	32.13	34.35	37.61	42.39	49.34	59.09
28	77.42	28.45	29.17	29.85	29.85	32.48	34.71	37.98	42.79	49.80	59.73
29	80.12	28.78	29.50	30.19	30.19	32.82	35.05	38.33	43.16	50.22	60.29
30	82.82	29.10	29.82	30.51	30.51	33.13	35.36	38.65	43.48	50.56	60.71
31	85.52	29.42	30.14	30.82	30.82	33.44	35.67	38.95	43.78	50.87	61.05
32	88.22	29.73	30.45	31.13	31.13	33.74	35.96	39.23	44.04	51.12	61.31
33	90.92	30.05	30.76	31.44	31.44	34.03	36.24	39.50	44.29	51.35	61.56
34	93.62	30.35	31.06	31.73	31.73	34.30	36.49	39.73	44.49	51.49	61.59
35	96.32	30.66	31.36	32.02	32.02	34.56	36.73	39.94	44.66	51.59	61.55
36	99.02	30.96	31.65	32.30	32.30	34.82	36.96	40.14	44.80	51.65	61.46
37	101.72	31.26	31.94	32.58	32.58	35.06	37.18	40.31	44.92	51.66	61.28
38	104.42	31.55	32.22	32.85	32.85	35.29	37.38	40.46	44.99	51.61	60.97

Table-5.9

UPLIFT PRESSURE ON BARREL FLOOR AT Z=11.25m, d = 3.0m **(Contd...)**

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
39	107.12	31.84	32.50	33.12	33.12	35.51	37.56	40.59	45.03	51.50	60.58
40	109.82	32.14	32.78	33.39	33.39	35.73	37.74	40.70	45.06	51.38	60.16
41	112.52	32.43	33.06	33.65	33.65	35.94	37.90	40.80	45.05	51.19	59.66
42	115.22	32.72	33.33	33.91	33.91	36.15	38.05	40.87	45.01	50.96	59.08
43	117.92	33.02	33.61	34.17	34.17	36.34	38.20	40.93	44.95	50.69	58.45
44	120.62	33.32	33.90	34.44	34.44	36.54	38.34	40.98	44.87	50.40	57.79
45	123.32	33.65	34.20	34.72	34.72	36.75	38.48	41.04	44.78	50.09	57.12
46	126.02	33.96	34.49	34.99	34.99	36.94	38.60	41.05	44.64	49.70	56.34
47	128.72	34.29	34.80	35.28	35.28	37.14	38.73	41.07	44.50	49.30	55.55
48	131.42	34.62	35.11	35.56	35.56	37.34	38.85	41.08	44.33	48.87	54.72
49	134.12	34.98	35.44	35.87	35.87	37.55	38.98	41.08	44.15	48.42	53.87
50	136.82	35.36	35.79	36.19	36.19	37.77	39.11	41.09	43.97	47.94	52.98
51	139.52	35.76	36.16	36.54	36.54	38.01	39.26	41.10	43.77	47.45	52.06
52	142.22	36.18	36.55	36.90	36.90	38.26	39.41	41.11	43.57	46.94	51.13
53	144.92	36.62	36.96	37.28	37.28	38.52	39.58	41.12	43.37	46.42	50.19
54	147.62	36.95	37.26	37.55	37.55	38.68	39.64	41.04	43.07	45.82	49.19
55	150.32	37.22	37.50	37.75	37.75	38.77	39.64	40.90	42.73	45.18	48.17
56	153.02	37.31	37.56	37.80	37.80	38.72	39.50	40.63	42.28	44.46	47.11
57	155.72	37.17	37.40	37.61	37.61	38.44	39.15	40.18	41.66	43.62	45.98
58	158.42	36.74	36.95	37.15	37.15	37.91	38.56	39.50	40.85	42.62	44.74
59	161.12	36.05	36.25	36.43	36.43	37.13	37.73	38.60	39.85	41.46	43.39
60	163.81	34.97	35.16	35.33	35.33	35.99	36.56	37.38	38.55	40.06	41.85
61	166.50	33.80	33.98	34.14	34.14	34.76	35.30	36.07	37.17	38.58	40.23
62	169.15	32.49	32.66	32.82	32.82	33.40	33.91	34.64	35.68	37.00	38.54
63	171.79	31.03	31.19	31.34	31.34	31.89	32.37	33.06	34.04	35.27	36.71
64	174.32	29.56	29.71	29.84	29.84	30.36	30.81	31.47	32.38	33.53	34.87
65	176.85	27.98	28.12	28.25	28.25	28.73	29.15	29.76	30.61	31.67	32.90
66	179.03	26.54	26.67	26.79	26.79	27.23	27.63	28.20	28.98	29.97	31.11
67	181.21	25.00	25.13	25.24	25.24	25.64	26.01	26.53	27.25	28.15	29.19
68	182.82	23.75	23.86	23.96	23.96	24.34	24.68	25.18	25.84	26.68	27.65
69	184.44	22.45	22.56	22.65	22.65	23.00	23.32	23.77	24.39	25.16	26.05
70	185.44	21.64	21.74	21.83	21.83	22.16	22.45	22.88	23.46	24.19	25.03
71	186.45	20.79	20.88	20.96	20.96	21.27	21.55	21.96	22.50	23.18	23.97
72	187.08	20.30	20.39	20.47	20.47	20.76	21.04	21.42	21.94	22.59	23.35
73	187.71	19.84	19.93	20.00	20.00	20.29	20.55	20.92	21.42	22.04	22.77
74	188.11	19.57	19.65	19.72	19.72	20.00	20.26	20.62	21.10	21.71	22.42
75	188.50	19.33	19.41	19.47	19.47	19.75	19.99	20.35	20.81	21.41	22.10
76	188.75	19.22	19.30	19.37	19.37	19.63	19.88	20.22	20.68	21.26	21.94
77	189.00	19.14	19.22	19.28	19.28	19.55	19.79	20.13	20.57	21.14	21.81

Table-5.10

UPLIFT PRESSURE ON BARREL FLOOR AT Z=5.625m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	13.00	13.28	13.54	13.54	14.54	15.39	16.60	18.28	20.52	23.19
2	20.80	13.13	13.41	13.67	13.67	14.69	15.54	16.77	18.46	20.73	23.43
3	21.60	13.58	13.87	14.14	14.14	15.20	16.09	17.36	19.13	21.49	24.31
4	22.87	14.58	14.89	15.19	15.19	16.34	17.32	18.70	20.63	23.21	26.29
5	24.13	15.55	15.89	16.21	16.21	17.45	18.50	20.00	22.09	24.89	28.23
6	26.15	16.86	17.24	17.60	17.60	18.98	20.14	21.80	24.12	27.24	30.96
7	28.17	17.94	18.35	18.74	18.74	20.23	21.49	23.29	25.82	29.22	33.28
8	31.01	19.19	19.64	20.07	20.07	21.70	23.08	25.05	27.83	31.57	36.07
9	33.84	20.23	20.71	21.17	21.17	22.93	24.40	26.53	29.53	33.59	38.49
10	37.30	21.28	21.80	22.29	22.29	24.18	25.76	28.05	31.29	35.70	41.05
11	40.75	22.19	22.74	23.26	23.26	25.26	26.94	29.37	32.83	37.54	43.32
12	44.21	22.99	23.56	24.11	24.11	26.21	27.98	30.54	34.19	39.20	45.39
13	47.67	23.71	24.31	24.88	24.88	27.07	28.92	31.59	35.42	40.70	47.29
14	51.12	24.37	24.99	25.58	25.58	27.85	29.76	32.53	36.52	42.05	49.01
15	54.58	24.98	25.62	26.23	26.23	28.57	30.54	33.41	37.54	43.30	50.63
16	57.60	25.48	26.14	26.76	26.76	29.15	31.17	34.10	38.35	44.29	51.92
17	60.62	25.96	26.63	27.26	27.26	29.70	31.75	34.75	39.10	45.21	53.12
18	63.65	26.42	27.10	27.74	27.74	30.22	32.31	35.37	39.80	46.06	54.26
19	66.67	26.86	27.55	28.20	28.20	30.71	32.83	35.93	40.44	46.83	55.28
20	70.13	27.34	28.04	28.70	28.70	31.23	33.38	36.53	41.11	47.63	56.33
21	73.58	27.81	28.51	29.18	29.18	31.74	33.90	37.09	41.72	48.36	57.28
22	77.04	28.26	28.96	29.63	29.63	32.20	34.38	37.59	42.27	48.97	58.07
23	80.50	28.69	29.40	30.07	30.07	32.65	34.83	38.06	42.76	49.52	58.77
24	83.96	29.12	29.82	30.49	30.49	33.07	35.25	38.48	43.18	49.97	59.29
25	87.41	29.53	30.23	30.90	30.90	33.46	35.64	38.86	43.55	50.34	59.68
26	90.87	29.93	30.63	31.29	31.29	33.83	36.00	39.19	43.86	50.61	59.91
27	94.33	30.32	31.01	31.67	31.67	34.18	36.32	39.49	44.12	50.80	59.99
28	97.79	30.70	31.39	32.03	32.03	34.51	36.63	39.76	44.33	50.92	59.98
29	101.25	31.08	31.75	32.38	32.38	34.82	36.90	39.98	44.48	50.95	59.82
30	104.70	31.44	32.10	32.72	32.72	35.11	37.14	40.16	44.57	50.89	59.50

Table-5.10

UPLIFT PRESSURE ON BARREL FLOOR AT Z=5.625m, d = 3.0m (Contd....)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
31	108.16	31.80	32.44	33.05	33.05	35.38	37.37	40.31	44.62	50.77	59.10
32	111.62	32.16	32.78	33.36	33.36	35.63	37.57	40.43	44.61	50.57	58.57
33	115.08	32.50	33.10	33.66	33.66	35.86	37.74	40.50	44.56	50.29	57.94
34	118.54	32.83	33.40	33.95	33.95	36.07	37.88	40.54	44.44	49.94	57.20
35	121.99	33.14	33.70	34.22	34.22	36.25	37.98	40.54	44.28	49.52	56.37
36	125.45	33.46	33.99	34.48	34.48	36.43	38.08	40.52	44.08	49.05	55.49
37	128.91	33.75	34.25	34.73	34.73	36.57	38.14	40.45	43.82	48.50	54.52
38	132.37	34.03	34.51	34.95	34.95	36.69	38.17	40.35	43.51	47.90	53.48
39	135.82	34.29	34.73	35.15	35.15	36.78	38.16	40.20	43.16	47.24	52.37
40	139.28	34.47	34.89	35.27	35.27	36.79	38.08	39.97	42.72	46.48	51.17
41	142.74	34.64	35.02	35.38	35.38	36.78	37.97	39.71	42.24	45.68	49.93
42	146.20	34.68	35.03	35.36	35.36	36.64	37.73	39.33	41.64	44.77	48.61
43	149.66	34.57	34.89	35.19	35.19	36.37	37.36	38.82	40.93	43.75	47.20
44	153.11	34.31	34.60	34.88	34.88	35.95	36.85	38.18	40.09	42.63	45.71
45	156.57	33.82	34.09	34.34	34.34	35.31	36.13	37.33	39.07	41.35	44.10
46	160.02	33.08	33.32	33.55	33.55	34.43	35.18	36.27	37.84	39.90	42.36
47	163.48	32.04	32.27	32.47	32.47	33.28	33.97	34.96	36.39	38.25	40.45
48	166.88	30.85	31.06	31.25	31.25	31.98	32.60	33.51	34.81	36.48	38.46
49	170.27	29.41	29.60	29.77	29.77	30.43	31.00	31.83	33.00	34.50	36.27
50	173.36	27.86	28.03	28.19	28.19	28.79	29.31	30.07	31.13	32.49	34.09
51	176.44	26.10	26.25	26.39	26.39	26.93	27.41	28.09	29.05	30.27	31.69
52	178.84	24.51	24.65	24.78	24.78	25.27	25.71	26.33	27.20	28.32	29.60
53	181.25	22.71	22.84	22.95	22.95	23.40	23.79	24.35	25.14	26.14	27.29
54	183.11	21.11	21.23	21.33	21.33	21.74	22.10	22.61	23.33	24.23	25.28
55	184.96	19.28	19.38	19.48	19.48	19.84	20.16	20.63	21.26	22.07	23.00
56	186.18	17.93	18.03	18.12	18.12	18.45	18.74	19.17	19.76	20.49	21.35
57	187.40	16.54	16.63	16.71	16.71	17.01	17.28	17.67	18.21	18.87	19.66
58	188.20	15.93	16.02	16.09	16.09	16.38	16.64	17.02	17.53	18.16	18.92
59	189.00	15.79	15.88	15.95	15.95	16.24	16.49	16.87	17.37	18.00	18.75

Table-5.11

UPLIFT PRESSURE ON BARREL FLOOR AT Z=0.0m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	12.41	12.67	12.92	12.92	13.89	14.71	15.87	17.50	19.66	22.24
2	20.80	12.55	12.82	13.07	13.07	14.05	14.88	16.06	17.70	19.90	22.51
3	21.60	13.01	13.29	13.55	13.55	14.58	15.44	16.67	18.39	20.68	23.41
4	22.88	14.04	14.35	14.64	14.64	15.76	16.70	18.05	19.93	22.45	25.44
5	24.16	15.04	15.37	15.69	15.69	16.90	17.92	19.39	21.43	24.17	27.43
6	26.21	16.44	16.81	17.16	17.16	18.51	19.65	21.28	23.56	26.62	30.28
7	28.26	17.60	18.01	18.39	18.39	19.86	21.10	22.87	25.37	28.72	32.74
8	31.31	19.02	19.47	19.89	19.89	21.52	22.89	24.85	27.62	31.35	35.84
9	34.37	20.18	20.66	21.12	21.12	22.88	24.36	26.48	29.49	33.56	38.48
10	38.75	21.52	22.04	22.54	22.54	24.46	26.07	28.40	31.71	36.20	41.69
11	43.13	22.63	23.19	23.72	23.72	25.78	27.51	30.00	33.57	38.45	44.46
12	47.60	23.60	24.20	24.76	24.76	26.94	28.77	31.42	35.22	40.45	46.97
13	52.08	24.46	25.09	25.68	25.68	27.95	29.87	32.65	36.66	42.20	49.19
14	57.59	25.42	26.07	26.69	26.69	29.07	31.07	33.99	38.20	44.09	51.63
15	63.10	26.29	26.96	27.61	27.61	30.06	32.13	35.16	39.56	45.74	53.78
16	67.60	26.95	27.63	28.29	28.29	30.79	32.90	36.00	40.51	46.88	55.27
17	72.10	27.57	28.27	28.93	28.93	31.46	33.61	36.76	41.35	47.88	56.57
18	76.60	28.17	28.87	29.54	29.54	32.09	34.26	37.44	42.09	48.72	57.64
19	81.10	28.74	29.44	30.11	30.11	32.67	34.84	38.05	42.72	49.42	58.50
20	85.60	29.28	29.99	30.65	30.65	33.21	35.38	38.58	43.26	49.98	59.12
21	90.10	29.81	30.51	31.17	31.17	33.70	35.86	39.04	43.69	50.38	59.51
22	94.60	30.32	31.01	31.66	31.66	34.16	36.29	39.44	44.03	50.64	59.66
23	99.10	30.82	31.49	32.13	32.13	34.58	36.67	39.77	44.28	50.77	59.59
24	103.60	31.30	31.95	32.58	32.58	34.97	37.01	40.03	44.44	50.76	59.30
25	108.10	31.76	32.40	33.00	33.00	35.32	37.30	40.23	44.51	50.61	58.81
26	112.60	32.21	32.82	33.40	33.40	35.64	37.54	40.36	44.49	50.34	58.13
27	117.10	32.63	33.22	33.77	33.77	35.92	37.74	40.44	44.38	49.94	57.27

Table-5.11

UPLIFT PRESSURE ON BARREL FLOOR AT Z=0.0m, d = 3.0m (Contd...)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF HIGHER CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
28	121.60	33.04	33.59	34.12	34.12	36.15	37.89	40.45	44.18	49.42	56.26
29	126.10	33.41	33.94	34.43	34.43	36.35	37.98	40.38	43.90	48.79	55.10
30	130.56	33.75	34.24	34.70	34.70	36.49	38.01	40.25	43.52	48.05	53.82
31	135.03	34.02	34.47	34.90	34.90	36.55	37.96	40.03	43.04	47.19	52.41
32	139.31	34.21	34.63	35.02	35.02	36.54	37.83	39.73	42.49	46.25	50.96
33	143.58	34.29	34.67	35.02	35.02	36.40	37.58	39.31	41.81	45.20	49.39
34	147.45	34.18	34.53	34.85	34.85	36.12	37.19	38.76	41.04	44.10	47.85
35	151.32	33.91	34.22	34.52	34.52	35.67	36.64	38.06	40.12	42.87	46.22
36	154.99	33.46	33.74	34.01	34.01	35.05	35.94	37.23	39.09	41.56	44.55
37	158.65	32.78	33.04	33.28	33.28	34.23	35.03	36.20	37.89	40.10	42.76
38	162.12	31.91	32.15	32.37	32.37	33.23	33.96	35.02	36.55	38.54	40.92
39	165.58	30.77	30.98	31.18	31.18	31.97	32.63	33.60	34.99	36.78	38.92
40	168.68	29.55	29.75	29.94	29.94	30.65	31.27	32.16	33.42	35.05	36.98
41	171.79	28.14	28.32	28.49	28.49	29.14	29.70	30.51	31.67	33.14	34.88
42	174.40	26.77	26.94	27.09	27.09	27.69	28.21	28.96	30.01	31.36	32.94
43	177.02	25.20	25.36	25.50	25.50	26.04	26.51	27.20	28.16	29.38	30.81
44	179.22	23.70	23.85	23.97	23.97	24.47	24.91	25.54	26.41	27.53	28.82
45	181.42	21.98	22.11	22.22	22.22	22.67	23.07	23.64	24.43	25.43	26.60
46	183.21	20.37	20.49	20.60	20.60	21.00	21.36	21.88	22.60	23.51	24.57
47	185.01	18.53	18.63	18.73	18.73	19.09	19.41	19.88	20.52	21.33	22.27
48	186.20	17.19	17.29	17.37	17.37	17.71	18.00	18.43	19.02	19.76	20.62
49	187.40	15.85	15.94	16.02	16.02	16.32	16.60	16.99	17.52	18.20	18.99
50	188.20	15.13	15.21	15.29	15.29	15.58	15.83	16.21	16.72	17.36	18.11
51	189.00	14.92	15.01	15.08	15.08	15.36	15.62	15.98	16.49	17.12	17.86

Table-5.12

UPLIFT PRESSURE ON BARREL FLOOR AT Z=11.25m, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	15.04	15.82	16.48	17.44	18.68	20.33	22.53	25.40	28.91	32.72
2	20.48	14.99	15.79	16.46	17.44	18.70	20.38	22.62	25.54	29.13	33.02
3	20.95	14.98	15.79	16.47	17.47	18.75	20.45	22.73	25.69	29.34	33.29
4	21.57	15.01	15.84	16.53	17.55	18.85	20.59	22.90	25.92	29.64	33.68
5	22.19	15.07	15.91	16.61	17.64	18.97	20.74	23.10	26.17	29.96	34.08
6	23.13	15.14	16.00	16.73	17.79	19.15	20.96	23.39	26.55	30.45	34.70
7	24.08	15.22	16.10	16.85	17.93	19.33	21.19	23.68	26.93	30.94	35.32
8	25.56	15.37	16.29	17.07	18.20	19.65	21.59	24.19	27.57	31.75	36.34
9	27.03	15.55	16.50	17.31	18.48	19.99	22.01	24.70	28.23	32.59	37.38
10	29.05	15.77	16.77	17.62	18.85	20.43	22.55	25.38	29.09	33.68	38.76
11	31.06	15.98	17.02	17.91	19.19	20.85	23.06	26.02	29.90	34.72	40.07
12	33.48	16.21	17.30	18.23	19.58	21.31	23.63	26.74	30.82	35.91	41.59
13	35.91	16.41	17.55	18.52	19.93	21.74	24.16	27.40	31.67	37.02	43.01
14	38.55	16.62	17.81	18.82	20.28	22.17	24.70	28.09	32.55	38.17	44.52
15	41.20	16.80	18.04	19.08	20.60	22.56	25.19	28.71	33.37	39.24	45.93
16	43.89	16.97	18.25	19.33	20.91	22.94	25.66	29.32	34.15	40.29	47.33
17	46.59	17.13	18.45	19.56	21.19	23.29	26.10	29.88	34.89	41.28	48.68
18	48.78	17.23	18.58	19.72	21.39	23.53	26.41	30.28	35.42	41.99	49.67
19	50.96	17.33	18.71	19.87	21.58	23.77	26.70	30.66	35.93	42.68	50.63
20	53.15	17.42	18.83	20.02	21.75	23.99	26.98	31.03	36.41	43.34	51.57
21	55.34	17.51	18.94	20.15	21.91	24.19	27.24	31.36	36.86	43.96	52.45
22	58.04	17.61	19.07	20.30	22.11	24.43	27.55	31.77	37.40	44.71	53.54
23	60.74	17.70	19.19	20.45	22.29	24.65	27.84	32.14	37.90	45.40	54.59
24	63.44	17.77	19.29	20.57	22.44	24.85	28.08	32.46	38.33	46.01	55.50
25	66.14	17.84	19.38	20.68	22.58	25.02	28.31	32.76	38.73	46.57	56.35
26	68.84	17.91	19.47	20.78	22.71	25.19	28.52	33.04	39.11	47.10	57.17
27	71.54	17.97	19.55	20.88	22.83	25.34	28.71	33.29	39.44	47.58	57.93
28	74.24	18.02	19.61	20.96	22.93	25.47	28.88	33.51	39.74	47.99	58.58
29	76.94	18.07	19.67	21.03	23.02	25.58	29.03	33.70	40.00	48.36	59.15
30	79.64	18.11	19.73	21.10	23.10	25.68	29.16	33.87	40.23	48.68	59.67
31	82.34	18.14	19.78	21.16	23.17	25.77	29.27	34.02	40.42	48.96	60.12
32	85.04	18.17	19.82	21.20	23.23	25.84	29.36	34.13	40.57	49.16	60.40
33	87.74	18.20	19.85	21.24	23.28	25.90	29.43	34.22	40.69	49.32	60.61
34	90.44	18.22	19.88	21.28	23.31	25.94	29.48	34.29	40.78	49.43	60.74
35	93.14	18.24	19.90	21.30	23.34	25.98	29.52	34.34	40.83	49.49	60.79
36	95.84	18.25	19.91	21.31	23.36	25.99	29.54	34.35	40.85	49.49	60.70
37	98.54	18.26	19.92	21.32	23.36	25.99	29.54	34.34	40.82	49.43	60.51
38	101.24	18.27	**19.92**	21.32	23.36	25.99	29.52	34.32	40.78	49.35	60.30
39	103.94	**18.27**	19.92	21.31	23.34	25.96	29.49	34.27	40.70	49.21	60.01

Table-5.12

UPLIFT PRESSURE ON BARREL AT Z=11.25m, d = 6.50m (contd....)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
40	106.64	18.27	19.91	21.30	23.32	25.92	29.43	34.18	40.58	49.01	59.59
41	109.34	18.26	19.89	21.27	23.28	25.87	29.36	34.08	40.42	48.76	59.11
42	112.04	18.25	19.87	21.24	23.24	25.81	29.27	33.95	40.24	48.47	58.60
43	114.74	18.23	19.84	21.20	23.18	25.73	29.16	33.80	40.02	48.15	58.03
44	117.44	18.21	19.81	21.15	23.11	25.64	29.03	33.62	39.76	47.75	57.35
45	120.14	18.19	19.76	21.09	23.03	25.53	28.88	33.41	39.47	47.31	56.63
46	122.84	18.16	19.72	21.03	22.94	25.40	28.71	33.18	39.14	46.83	55.88
47	125.54	18.12	19.66	20.95	22.84	25.27	28.53	32.93	38.79	46.32	55.09
48	128.24	18.08	19.60	20.87	22.73	25.12	28.32	32.65	38.39	45.75	54.23
49	130.94	18.04	19.53	20.78	22.60	24.95	28.09	32.33	37.96	45.13	53.33
50	133.64	17.99	19.45	20.68	22.46	24.77	27.85	32.00	37.51	44.49	52.41
51	136.34	17.94	19.36	20.57	22.32	24.57	27.59	31.65	37.02	43.81	51.46
52	139.04	17.87	19.27	20.44	22.15	24.35	27.30	31.26	36.48	43.07	50.45
53	141.74	17.81	19.17	20.31	21.98	24.12	27.00	30.85	35.92	42.30	49.41
54	144.44	17.73	19.06	20.17	21.79	23.88	26.66	30.41	35.32	41.48	48.32
55	147.14	17.65	18.94	20.02	21.59	23.61	26.32	29.94	34.70	40.63	47.20
56	149.84	17.57	18.81	19.86	21.38	23.34	25.96	29.46	34.06	39.77	46.08
57	152.54	17.47	18.68	19.69	21.16	23.06	25.58	28.96	33.39	38.88	44.93
58	155.24	17.37	18.53	19.51	20.93	22.75	25.19	28.44	32.69	37.95	43.73
59	157.93	17.26	18.38	19.31	20.68	22.43	24.77	27.89	31.96	36.99	42.51
60	160.60	17.14	18.21	19.11	20.42	22.10	24.34	27.32	31.22	36.01	41.26
61	163.28	17.01	18.03	18.89	20.14	21.75	23.88	26.74	30.44	35.00	39.99
62	165.89	16.87	17.85	18.66	19.86	21.39	23.42	26.14	29.66	33.99	38.70
63	168.50	16.72	17.65	18.43	19.56	21.01	22.94	25.52	28.85	32.94	37.38
64	171.00	16.55	17.43	18.17	19.24	20.61	22.43	24.86	28.01	31.86	36.02
65	173.50	16.37	17.19	17.88	18.89	20.17	21.89	24.17	27.12	30.72	34.60
66	175.79	16.18	16.95	17.60	18.54	19.75	21.36	23.50	26.26	29.62	33.23
67	178.08	15.98	16.70	17.30	18.18	19.31	20.80	22.79	25.35	28.47	31.81
68	180.03	15.79	16.46	17.03	17.85	18.90	20.30	22.15	24.54	27.45	30.54
69	181.99	15.58	16.21	16.73	17.50	18.47	19.77	21.49	23.70	26.39	29.24
70	183.45	15.46	16.05	16.54	17.26	18.17	19.39	21.01	23.09	25.61	28.27
71	184.92	15.34	15.89	16.35	17.02	17.88	19.02	20.53	22.48	24.83	27.31
72	185.87	15.25	15.78	16.22	16.86	17.68	18.78	20.22	22.08	24.33	26.69
73	186.81	15.19	15.70	16.12	16.73	17.52	18.56	19.94	21.72	23.87	26.12
74	187.43	15.15	15.64	16.05	16.64	17.41	18.42	19.76	21.48	23.57	25.74
75	188.05	15.13	15.60	16.00	16.58	17.32	18.30	19.60	21.27	23.29	25.39
76	188.52	15.16	15.62	16.00	16.57	17.28	18.24	19.50	21.12	23.08	25.12
77	189.00	15.22	15.67	16.04	16.58	17.27	18.19	19.41	20.97	22.85	24.81

Table-5.13

UPLIFT PRESSURE ON BARREL AT Z=5.625m, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	13.64	14.47	15.16	16.18	17.48	19.22	21.55	24.57	28.30	32.36
2	20.80	13.66	14.49	15.19	16.20	17.51	19.25	21.58	24.62	28.35	32.42
3	21.60	13.71	14.55	15.25	16.27	17.59	19.34	21.69	24.74	28.51	32.61
4	22.86	13.87	14.72	15.43	16.47	17.81	19.60	21.99	25.11	28.95	33.13
5	24.11	14.07	14.94	15.67	16.74	18.11	19.95	22.40	25.60	29.54	33.85
6	26.08	14.45	15.36	16.13	17.25	18.69	20.61	23.18	26.54	30.68	35.22
7	28.05	14.82	15.77	16.58	17.75	19.26	21.28	23.97	27.50	31.86	36.65
8	30.73	15.27	16.28	17.14	18.38	19.99	22.13	24.99	28.74	33.40	38.53
9	33.42	15.66	16.73	17.63	18.94	20.63	22.89	25.92	29.88	34.82	40.31
10	36.73	16.06	17.19	18.14	19.54	21.33	23.72	26.94	31.16	36.44	42.34
11	40.05	16.38	17.57	18.58	20.05	21.93	24.46	27.84	32.30	37.90	44.21
12	43.51	16.67	17.92	18.97	20.51	22.48	25.13	28.69	33.38	39.30	46.02
13	46.97	16.91	18.21	19.31	20.91	22.97	25.73	29.44	34.35	40.57	47.71
14	50.42	17.12	18.46	19.60	21.26	23.40	26.26	30.12	35.23	41.74	49.27
15	53.88	17.29	18.68	19.85	21.57	23.77	26.73	30.72	36.02	42.80	50.72
16	57.07	17.43	18.86	20.06	21.82	24.09	27.13	31.23	36.68	43.69	51.95
17	60.26	17.55	19.01	20.25	22.05	24.37	27.48	31.68	37.28	44.51	53.10
18	63.45	17.66	19.15	20.41	22.25	24.62	27.80	32.09	37.83	45.25	54.16
19	66.63	17.76	19.27	20.56	22.43	24.84	28.08	32.47	38.32	45.93	55.14
20	70.09	17.85	19.39	20.70	22.60	25.06	28.36	32.82	38.80	46.58	56.08
21	73.55	17.93	19.49	20.82	22.75	25.25	28.60	33.13	39.21	47.15	56.91
22	77.01	17.99	19.58	20.92	22.88	25.40	28.80	33.39	39.56	47.63	57.61
23	80.47	18.05	19.65	21.01	22.99	25.54	28.97	33.61	39.85	48.03	58.18
24	83.92	18.10	19.72	21.08	23.08	25.65	29.10	33.79	40.08	48.34	58.62
25	87.38	18.14	19.77	21.14	23.14	25.73	29.21	33.92	40.25	48.57	58.92
26	90.84	18.17	19.80	21.18	23.20	25.79	29.28	34.01	40.37	48.71	59.09
27	94.30	18.19	19.83	21.21	23.23	25.83	29.32	34.06	40.42	48.77	59.13
28	97.75	18.21	19.85	21.23	23.24	25.84	29.33	34.07	40.42	48.74	59.02
29	101.21	18.22	19.85	21.23	23.24	25.83	29.31	34.03	40.36	48.64	58.78
30	104.67	18.22	19.84	21.21	23.22	25.79	29.26	33.96	40.25	48.45	58.43

Table-5.13

UPLIFT PRESSURE ON BARREL AT Z=5.625m, d = 6.50m (contd....)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
31	108.13	18.21	19.83	21.19	23.18	25.74	29.18	33.84	40.07	48.18	57.96
32	111.59	18.20	19.80	21.15	23.12	25.66	29.07	33.68	39.85	47.84	57.38
33	115.04	18.17	19.76	21.10	23.04	25.55	28.93	33.48	39.56	47.42	56.71
34	118.50	18.14	19.71	21.03	22.95	25.42	28.75	33.24	39.22	46.92	55.92
35	121.96	18.11	19.65	20.94	22.84	25.27	28.54	32.96	38.83	46.35	55.06
36	125.42	18.06	19.57	20.85	22.71	25.10	28.31	32.63	38.38	45.71	54.11
37	128.87	18.01	19.49	20.74	22.56	24.90	28.04	32.27	37.87	45.00	53.09
38	132.33	17.94	19.39	20.61	22.39	24.67	27.74	31.86	37.32	44.22	51.99
39	135.79	17.87	19.28	20.47	22.20	24.42	27.40	31.41	36.70	43.37	50.82
40	139.25	17.78	19.15	20.31	21.99	24.15	27.04	30.92	36.04	42.46	49.59
41	142.71	17.69	19.01	20.13	21.75	23.85	26.64	30.39	35.33	41.50	48.31
42	146.16	17.58	18.86	19.93	21.50	23.52	26.21	29.82	34.56	40.47	46.95
43	149.62	17.45	18.68	19.72	21.23	23.16	25.75	29.21	33.75	39.38	45.54
44	153.08	17.31	18.49	19.48	20.92	22.78	25.25	28.56	32.88	38.24	44.07
45	156.53	17.15	18.28	19.22	20.59	22.36	24.72	27.86	31.97	37.04	42.54
46	159.95	16.97	18.03	18.93	20.24	21.91	24.15	27.13	31.01	35.79	40.96
47	163.38	16.75	17.76	18.61	19.84	21.42	23.53	26.34	29.99	34.47	39.30
48	166.72	16.51	17.46	18.25	19.41	20.89	22.87	25.51	28.92	33.11	37.61
49	170.06	16.22	17.10	17.84	18.92	20.31	22.15	24.60	27.78	31.66	35.82
50	173.15	15.89	16.71	17.40	18.41	19.70	21.41	23.69	26.64	30.23	34.06
51	176.24	15.49	16.25	16.89	17.82	19.01	20.59	22.69	25.40	28.70	32.21
52	178.66	15.13	15.84	16.43	17.30	18.41	19.88	21.84	24.37	27.44	30.69
53	181.08	14.70	15.36	15.91	16.72	17.75	19.12	20.93	23.28	26.12	29.11
54	183.00	14.34	14.96	15.48	16.24	17.21	18.50	20.21	22.41	25.07	27.88
55	184.92	13.97	14.55	15.04	15.76	16.67	17.89	19.50	21.58	24.09	26.71
56	186.16	13.75	14.32	14.80	15.49	16.38	17.55	19.11	21.12	23.55	26.09
57	187.40	13.60	14.16	14.62	15.30	16.16	17.31	18.83	20.79	23.16	25.64
58	188.20	13.54	14.10	14.56	15.23	16.08	17.22	18.73	20.68	23.02	25.48
59	189.00	13.53	14.08	14.54	15.20	16.06	17.20	18.70	20.64	22.98	25.43

Table-5.14

UPLIFT PRESSURE ON BARREL AT Z=0.00m, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
1	20.00	13.34	14.16	14.86	15.87	17.17	18.90	21.22	24.25	27.97	32.03
2	20.80	13.36	14.18	14.88	15.89	17.20	18.94	21.26	24.29	28.03	32.10
3	21.60	13.41	14.24	14.94	15.97	17.28	19.03	21.37	24.42	28.17	32.27
4	22.88	13.56	14.40	15.11	16.15	17.49	19.27	21.65	24.75	28.57	32.75
5	24.16	13.77	14.64	15.37	16.43	17.80	19.62	22.06	25.24	29.17	33.46
6	26.21	14.21	15.12	15.89	17.00	18.44	20.36	22.92	26.27	30.40	34.93
7	28.26	14.63	15.58	16.39	17.56	19.07	21.08	23.77	27.29	31.64	36.43
8	31.31	15.18	16.20	17.06	18.32	19.93	22.08	24.96	28.74	33.43	38.61
9	34.37	15.65	16.73	17.64	18.97	20.68	22.96	26.03	30.05	35.06	40.62
10	38.75	16.17	17.33	18.31	19.74	21.58	24.04	27.34	31.69	37.13	43.24
11	43.13	16.57	17.80	18.85	20.37	22.32	24.94	28.46	33.11	38.95	45.58
12	47.60	16.89	18.19	19.29	20.90	22.96	25.73	29.45	34.37	40.60	47.75
13	52.08	17.16	18.52	19.67	21.35	23.51	26.40	30.30	35.48	42.07	49.71
14	56.58	17.37	18.79	19.98	21.73	23.97	26.99	31.05	36.45	43.37	51.49
15	61.08	17.55	19.01	20.25	22.05	24.37	27.49	31.69	37.30	44.52	53.08
16	65.58	17.70	19.20	20.47	22.33	24.72	27.92	32.26	38.04	45.53	54.51
17	70.08	17.82	19.36	20.66	22.56	25.01	28.29	32.74	38.68	46.40	55.75
18	74.58	17.93	19.49	20.82	22.75	25.25	28.60	33.13	39.20	47.11	56.77
19	79.08	18.01	19.60	20.95	22.91	25.44	28.84	33.45	39.62	47.69	57.60
20	83.58	18.08	19.69	21.05	23.03	25.59	29.03	33.69	39.95	48.13	58.21
21	88.08	18.13	19.75	21.12	23.12	25.70	29.17	33.87	40.17	48.42	58.59
22	92.58	18.17	19.80	21.17	23.18	25.77	29.25	33.97	40.29	48.57	58.75
23	97.08	18.19	19.82	21.20	23.21	25.80	29.28	33.99	40.32	48.58	58.69
24	102.59	18.20	19.83	21.20	23.20	25.78	29.24	33.93	40.21	48.40	58.32
25	108.10	18.20	19.81	21.16	23.14	25.70	29.13	33.76	39.97	48.01	57.65
26	112.60	18.18	19.77	21.11	23.07	25.59	28.97	33.55	39.66	47.55	56.90

Table-5.14

UPLIFT PRESSURE ON BARREL AT Z=0.00m, d = 6.50m (contd....)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		250.000	230.625	211.250	186.250	161.250	136.250	111.250	86.250	61.250	36.250
27	117.10	18.14	19.71	21.03	22.96	25.44	28.77	33.27	39.26	46.97	55.98
28	121.60	18.10	19.63	20.93	22.81	25.25	28.51	32.91	38.76	46.25	54.91
29	126.10	18.03	19.54	20.80	22.64	25.02	28.20	32.49	38.18	45.43	53.70
30	130.56	17.96	19.42	20.65	22.44	24.75	27.84	32.00	37.50	44.48	52.36
31	135.03	17.86	19.28	20.47	22.20	24.43	27.42	31.44	36.74	43.43	50.90
32	139.31	17.76	19.12	20.27	21.94	24.10	26.98	30.84	35.93	42.32	49.41
33	143.58	17.63	18.95	20.05	21.65	23.72	26.48	30.18	35.04	41.12	47.81
34	147.45	17.50	18.76	19.82	21.36	23.34	25.98	29.53	34.17	39.95	46.28
35	151.32	17.35	18.55	19.56	21.03	22.92	25.45	28.82	33.24	38.71	44.68
36	154.99	17.19	18.33	19.29	20.69	22.49	24.89	28.10	32.29	37.47	43.09
37	158.65	16.99	18.08	18.99	20.32	22.02	24.29	27.33	31.29	36.16	41.42
38	162.12	16.77	17.80	18.66	19.92	21.53	23.68	26.54	30.27	34.84	39.77
39	165.58	16.52	17.48	18.30	19.47	20.99	23.00	25.69	29.18	33.45	38.04
40	168.68	16.25	17.15	17.92	19.02	20.45	22.34	24.86	28.13	32.13	36.40
41	171.79	15.92	16.77	17.48	18.52	19.84	21.61	23.97	27.01	30.72	34.68
42	174.40	15.59	16.38	17.05	18.02	19.27	20.93	23.14	25.99	29.46	33.15
43	177.02	15.19	15.94	16.56	17.47	18.63	20.18	22.24	24.90	28.12	31.54
44	179.22	14.80	15.50	16.09	16.95	18.04	19.49	21.42	23.92	26.94	30.13
45	181.42	14.36	15.02	15.57	16.36	17.39	18.75	20.56	22.88	25.71	28.67
46	183.21	13.94	14.56	15.08	15.84	16.81	18.09	19.80	22.00	24.66	27.45
47	185.01	13.48	14.06	14.55	15.27	16.18	17.39	19.00	21.07	23.58	26.20
48	186.20	13.36	13.93	14.41	15.11	16.00	17.19	18.77	20.80	23.25	25.81
49	187.40	13.24	13.81	14.28	14.97	15.85	17.01	18.56	20.56	22.97	25.48
50	188.20	13.18	13.74	14.21	14.89	15.76	16.92	18.45	20.43	22.82	25.31
51	189.00	13.15	13.71	14.18	14.86	15.73	16.88	18.41	20.38	22.76	25.25

Table-5.15

UPLIFT PRESSURE ON BARREL AT Z=11.25m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		36.25	61.25	86.25	111.25	136.25	161.25	186.25	211.25	230.625	250.00
1	20.00	27.73	24.37	21.30	18.97	17.07	15.68	14.65	13.85	13.32	12.67
2	20.48	27.97	24.55	21.42	19.05	17.12	15.69	14.65	13.84	13.29	12.64
3	20.95	28.30	24.83	21.63	19.20	17.23	15.79	14.72	13.90	13.34	12.67
4	21.57	28.92	25.34	22.04	19.54	17.51	16.02	14.92	14.07	13.50	12.81
5	22.19	29.59	25.89	22.49	19.91	17.82	16.28	15.15	14.28	13.69	12.98
6	23.13	30.62	26.74	23.19	20.47	18.30	16.68	15.50	14.59	13.97	13.23
7	24.08	31.64	27.59	23.88	21.03	18.77	17.09	15.85	14.90	14.26	13.49
8	25.57	33.18	28.85	24.92	21.87	19.47	17.68	16.37	15.36	14.68	13.86
9	27.06	34.64	30.05	25.89	22.66	20.13	18.24	16.85	15.79	15.07	14.21
10	29.27	36.55	31.60	27.13	23.65	20.94	18.92	17.44	16.30	15.52	14.61
11	31.47	38.27	32.99	28.23	24.52	21.65	19.50	17.93	16.73	15.91	14.94
12	34.09	40.20	34.52	29.44	25.47	22.42	20.14	18.47	17.19	16.32	15.29
13	36.71	42.00	35.93	30.55	26.34	23.12	20.71	18.95	17.60	16.68	15.60
14	39.41	43.66	37.22	31.55	27.11	23.73	21.21	19.37	17.95	16.99	15.86
15	42.10	45.24	38.43	32.47	27.82	24.30	21.66	19.74	18.27	17.27	16.08
16	44.91	46.79	39.61	33.37	28.51	24.84	22.10	20.10	18.57	17.53	16.30
17	47.72	48.29	40.73	34.21	29.15	25.34	22.50	20.43	18.84	17.76	16.49
18	50.42	49.61	41.69	34.94	29.70	25.77	22.84	20.71	19.07	17.96	16.65
19	53.12	50.87	42.61	35.62	30.21	26.17	23.15	20.96	19.28	18.14	16.79
20	55.82	52.12	43.48	36.27	30.70	26.54	23.45	21.20	19.48	18.31	16.93
21	58.52	53.30	44.30	36.86	31.14	26.89	23.72	21.42	19.66	18.46	17.05
22	61.22	54.35	45.03	37.39	31.54	27.19	23.96	21.61	19.81	18.59	17.15
23	63.92	55.37	45.72	37.90	31.91	27.48	24.19	21.80	19.96	18.72	17.25
24	66.62	56.32	46.35	38.35	32.24	27.73	24.39	21.96	20.09	18.83	17.34
25	69.32	57.19	46.92	38.76	32.55	27.97	24.57	22.10	20.21	18.93	17.42
26	72.02	58.01	47.45	39.14	32.83	28.18	24.74	22.24	20.32	19.02	17.49
27	74.72	58.74	47.92	39.47	33.08	28.37	24.89	22.36	20.42	19.10	17.55
28	77.42	59.37	48.33	39.76	33.29	28.54	25.02	22.47	20.51	19.18	17.61
29	80.12	59.91	48.69	40.02	33.48	28.69	25.14	22.56	20.58	19.24	17.66
30	82.82	60.31	48.96	40.22	33.64	28.80	25.23	22.64	20.64	19.30	17.70
31	85.52	60.63	49.19	40.39	33.77	28.91	25.31	22.70	20.70	19.34	17.74
32	88.22	60.87	49.37	40.52	33.87	28.99	25.38	22.76	20.75	19.38	17.78
33	90.92	61.08	49.52	40.63	33.96	29.06	25.44	22.81	20.79	19.42	17.81
34	93.62	61.09	49.58	40.68	34.01	29.10	25.48	22.84	20.82	19.45	17.83
35	96.32	61.01	49.59	40.70	34.03	29.12	25.50	22.86	20.84	19.46	17.84
36	99.02	60.89	49.55	40.69	34.03	29.12	25.51	22.87	20.85	19.48	17.86
37	101.72	60.68	49.47	40.64	34.01	29.11	25.50	22.87	20.85	19.48	17.87
38	104.42	60.32	49.30	40.54	33.94	29.07	25.47	22.85	20.84	19.48	17.87

Table-5.15

UPLIFT PRESSURE ON BARREL AT Z=11.25m, d = 3.0m (Contd...)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		36.25	61.25	86.25	111.25	136.25	161.25	186.25	211.25	230.625	250.00
39	107.12	59.88	49.08	40.40	33.86	29.01	25.43	22.83	20.82	19.47	17.87
40	109.82	59.42	48.83	40.24	33.75	28.94	25.38	22.79	20.80	19.45	17.86
41	112.52	58.86	48.52	40.04	33.61	28.84	25.31	22.74	20.77	19.43	17.85
42	115.22	58.22	48.15	39.79	33.44	28.72	25.23	22.68	20.72	19.40	17.83
43	117.92	57.53	47.73	39.51	33.25	28.59	25.13	22.61	20.67	19.36	17.80
44	120.62	56.80	47.27	39.19	33.03	28.43	25.02	22.52	20.61	19.31	17.78
45	123.32	56.06	46.78	38.86	32.80	28.26	24.89	22.43	20.54	19.26	17.75
46	126.02	55.20	46.21	38.46	32.51	28.06	24.74	22.32	20.46	19.20	17.71
47	128.72	54.31	45.61	38.03	32.21	27.84	24.58	22.20	20.37	19.13	17.66
48	131.42	53.38	44.95	37.57	31.88	27.60	24.40	22.07	20.27	19.05	17.61
49	134.12	52.42	44.26	37.07	31.52	27.34	24.21	21.92	20.16	18.97	17.55
50	136.82	51.39	43.52	36.53	31.13	27.05	24.00	21.76	20.04	18.87	17.49
51	139.52	50.32	42.72	35.96	30.71	26.74	23.77	21.59	19.91	18.77	17.42
52	142.22	49.22	41.89	35.35	30.27	26.41	23.53	21.40	19.77	18.66	17.34
53	144.92	48.08	41.02	34.71	29.80	26.06	23.26	21.20	19.61	18.53	17.25
54	147.62	46.88	40.10	34.03	29.29	25.68	22.98	20.98	19.44	18.40	17.16
55	150.32	45.66	39.16	33.33	28.76	25.28	22.68	20.75	19.26	18.25	17.05
56	153.02	44.41	38.18	32.59	28.21	24.86	22.36	20.50	19.07	18.10	16.94
57	155.72	43.12	37.17	31.83	27.63	24.42	22.03	20.24	18.86	17.93	16.82
58	158.42	41.80	36.13	31.04	27.03	23.95	21.68	19.96	18.64	17.75	16.68
59	161.12	40.45	35.06	30.22	26.40	23.47	21.30	19.67	18.41	17.55	16.53
60	163.81	39.04	33.94	29.36	25.74	22.95	20.90	19.34	18.15	17.33	16.36
61	166.50	37.58	32.79	28.46	25.05	22.41	20.47	19.00	17.87	17.09	16.17
62	169.15	36.09	31.60	27.53	24.33	21.84	20.03	18.64	17.57	16.84	15.97
63	171.79	34.50	30.32	26.53	23.54	21.21	19.52	18.22	17.22	16.54	15.73
64	174.32	32.88	29.02	25.50	22.73	20.56	19.00	17.79	16.86	16.22	15.47
65	176.85	31.16	27.63	24.38	21.85	19.85	18.41	17.30	16.44	15.86	15.16
66	179.03	29.56	26.33	23.33	21.02	19.17	17.85	16.83	16.04	15.50	14.86
67	181.21	27.85	24.93	22.20	20.11	18.42	17.23	16.30	15.58	15.09	14.51
68	182.82	26.47	23.78	21.26	19.34	17.77	16.68	15.82	15.15	14.70	14.17
69	184.44	25.01	22.57	20.26	18.52	17.08	16.08	15.29	14.69	14.28	13.79
70	185.44	24.08	21.80	19.61	17.99	16.63	15.69	14.95	14.39	14.00	13.54
71	186.45	23.11	20.98	18.93	17.41	16.13	15.26	14.58	14.04	13.68	13.25
72	187.08	22.55	20.51	18.54	17.09	15.86	15.03	14.37	13.86	13.52	13.11
73	187.71	22.02	20.07	18.17	16.79	15.61	14.82	14.19	13.70	13.37	12.98
74	188.11	21.70	19.81	17.95	16.61	15.46	14.69	14.08	13.60	13.28	12.90
75	188.50	21.41	19.57	17.76	16.46	15.33	14.59	13.99	13.53	13.22	12.85
76	188.75	21.27	19.46	17.68	16.41	15.31	14.57	13.99	13.53	13.23	12.86
77	189.00	21.15	19.38	17.63	16.39	15.31	14.59	14.01	13.57	13.27	12.91

Table-5.16

UPLIFT PRESSURE ON BARREL AT Z=5.625m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		36.25	61.25	86.25	111.25	136.25	161.25	186.25	211.25	230.625	250.00
1	20.00	23.15	20.19	17.47	15.40	13.75	12.52	11.62	10.92	10.45	9.89
2	20.80	23.39	20.40	17.65	15.56	13.88	12.64	11.72	11.02	10.54	9.97
3	21.60	24.26	21.15	18.28	16.10	14.36	13.06	12.11	11.38	10.88	10.29
4	22.87	26.23	22.83	19.70	17.32	15.42	14.01	12.97	12.18	11.63	10.99
5	24.13	28.17	24.47	21.09	18.50	16.45	14.92	13.80	12.94	12.35	11.65
6	26.15	30.88	26.76	23.01	20.12	17.85	16.15	14.91	13.95	13.30	12.53
7	28.17	33.19	28.69	24.61	21.46	18.99	17.15	15.80	14.76	14.06	13.22
8	31.01	35.96	30.99	26.50	23.01	20.30	18.29	16.81	15.67	14.90	13.98
9	33.84	38.35	32.95	28.09	24.31	21.38	19.21	17.62	16.39	15.56	14.58
10	37.30	40.88	35.00	29.73	25.61	22.47	20.12	18.41	17.09	16.19	15.13
11	40.75	43.13	36.78	31.14	26.72	23.38	20.88	19.05	17.65	16.69	15.57
12	44.21	45.17	38.37	32.38	27.70	24.16	21.52	19.60	18.12	17.11	15.93
13	47.67	47.05	39.82	33.49	28.57	24.85	22.08	20.07	18.52	17.47	16.23
14	51.12	48.76	41.10	34.47	29.32	25.45	22.57	20.47	18.85	17.76	16.47
15	54.58	50.37	42.29	35.38	30.01	25.99	23.00	20.83	19.15	18.02	16.69
16	57.60	51.64	43.22	36.08	30.54	26.41	23.34	21.10	19.38	18.22	16.84
17	60.62	52.83	44.09	36.72	31.03	26.79	23.64	21.35	19.59	18.39	16.99
18	63.65	53.95	44.88	37.31	31.47	27.13	23.91	21.57	19.77	18.55	17.11
19	66.67	54.96	45.60	37.84	31.87	27.44	24.15	21.76	19.93	18.69	17.22
20	70.13	56.00	46.32	38.37	32.27	27.75	24.40	21.96	20.09	18.83	17.33
21	73.58	56.93	46.97	38.84	32.62	28.03	24.62	22.14	20.24	18.95	17.43
22	77.04	57.70	47.51	39.23	32.92	28.25	24.80	22.29	20.36	19.06	17.52
23	80.50	58.37	47.97	39.57	33.18	28.45	24.96	22.42	20.47	19.15	17.59
24	83.96	58.86	48.34	39.83	33.38	28.61	25.09	22.52	20.56	19.22	17.65
25	87.41	59.22	48.60	40.03	33.54	28.74	25.19	22.61	20.63	19.28	17.70
26	90.87	59.42	48.77	40.17	33.65	28.82	25.26	22.67	20.68	19.33	17.74
27	94.33	59.47	48.85	40.24	33.71	28.88	25.31	22.71	20.72	19.37	17.77
28	97.79	59.40	48.85	40.25	33.73	28.90	25.33	22.73	20.74	19.39	17.79
29	101.25	59.20	48.76	40.20	33.71	28.89	25.33	22.73	20.75	19.40	17.81
30	104.70	58.82	48.57	40.08	33.63	28.84	25.29	22.71	20.73	19.39	17.81

Table-5.16

UPLIFT PRESSURE ON BARREL AT Z=5.625m, d = 3.0m (Contd....)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		36.25	61.25	86.25	111.25	136.25	161.25	186.25	211.25	230.625	250.00
31	108.16	58.37	48.31	39.91	33.51	28.76	25.24	22.68	20.71	19.38	17.80
32	111.62	57.78	47.95	39.67	33.35	28.65	25.16	22.62	20.67	19.35	17.79
33	115.08	57.08	47.51	39.37	33.15	28.50	25.05	22.54	20.61	19.31	17.77
34	118.54	56.27	46.98	39.00	32.89	28.32	24.92	22.44	20.54	19.26	17.73
35	121.99	55.37	46.37	38.57	32.59	28.10	24.76	22.32	20.46	19.19	17.69
36	125.45	54.40	45.70	38.09	32.25	27.86	24.58	22.19	20.36	19.11	17.64
37	128.91	53.33	44.95	37.55	31.86	27.58	24.37	22.03	20.24	19.02	17.58
38	132.37	52.18	44.12	36.96	31.43	27.26	24.14	21.86	20.10	18.92	17.51
39	135.82	50.96	43.22	36.30	30.95	26.90	23.88	21.66	19.95	18.79	17.42
40	139.28	49.64	42.23	35.59	30.42	26.51	23.58	21.43	19.78	18.65	17.32
41	142.74	48.27	41.19	34.82	29.85	26.08	23.26	21.18	19.58	18.50	17.21
42	146.20	46.82	40.08	33.99	29.23	25.62	22.91	20.91	19.37	18.32	17.08
43	149.66	45.30	38.91	33.10	28.57	25.11	22.52	20.60	19.13	18.12	16.93
44	153.11	43.71	37.67	32.17	27.86	24.56	22.10	20.27	18.86	17.90	16.77
45	156.57	42.06	36.36	31.17	27.09	23.96	21.63	19.90	18.56	17.65	16.57
46	160.02	40.31	34.98	30.10	26.26	23.32	21.12	19.48	18.22	17.36	16.34
47	163.48	38.48	33.51	28.95	25.37	22.61	20.56	19.02	17.83	17.03	16.07
48	166.88	36.57	31.98	27.74	24.41	21.84	19.94	18.50	17.40	16.65	15.75
49	170.27	34.52	30.31	26.41	23.35	20.98	19.23	17.90	16.88	16.18	15.36
50	173.36	32.50	28.64	25.07	22.26	20.08	18.47	17.25	16.31	15.67	14.91
51	176.44	30.28	26.79	23.55	21.02	19.03	17.57	16.47	15.61	15.03	14.34
52	178.84	28.34	25.16	22.19	19.89	18.06	16.73	15.72	14.93	14.40	13.77
53	181.25	26.18	23.32	20.64	18.57	16.92	15.72	14.81	14.10	13.62	13.05
54	183.11	24.28	21.69	19.25	17.38	15.88	14.78	13.95	13.31	12.87	12.35
55	184.96	22.13	19.82	17.64	15.97	14.62	13.65	12.90	12.33	11.94	11.47
56	186.18	20.56	18.44	16.44	14.92	13.68	12.78	12.10	11.57	11.21	10.78
57	187.40	18.95	17.02	15.19	13.81	12.68	11.86	11.23	10.75	10.42	10.04
58	188.20	18.24	16.39	14.64	13.32	12.23	11.45	10.85	10.39	10.07	9.70
59	189.00	18.08	16.25	14.52	13.21	12.14	11.36	10.77	10.31	10.00	9.63

Table-5.17

UPLIFT PRESSURE ON BARREL AT Z=0.0m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		36.25	61.25	86.25	111.25	136.25	161.25	186.25	211.25	230.625	250.00
1	20.00	22.21	19.34	16.71	14.72	13.12	11.93	11.06	10.39	9.93	9.39
2	20.80	22.48	19.57	16.90	14.89	13.27	12.06	11.18	10.50	10.04	9.49
3	21.60	23.37	20.33	17.55	15.44	13.76	12.50	11.58	10.87	10.38	9.81
4	22.88	25.39	22.06	19.02	16.70	14.85	13.48	12.47	11.69	11.16	10.54
5	24.16	27.37	23.75	20.44	17.91	15.91	14.42	13.32	12.48	11.91	11.23
6	26.21	30.20	26.15	22.46	19.62	17.39	15.73	14.51	13.57	12.93	12.17
7	28.26	32.64	28.20	24.17	21.06	18.62	16.81	15.48	14.45	13.76	12.93
8	31.31	35.72	30.77	26.29	22.81	20.11	18.11	16.63	15.50	14.73	13.82
9	34.37	38.34	32.93	28.04	24.24	21.32	19.14	17.54	16.31	15.48	14.49
10	38.75	41.51	35.48	30.09	25.89	22.68	20.29	18.54	17.19	16.28	15.20
11	43.13	44.24	37.65	31.80	27.24	23.78	21.20	19.32	17.87	16.89	15.73
12	47.60	46.73	39.57	33.30	28.40	24.71	21.97	19.96	18.42	17.38	16.15
13	52.08	48.94	41.23	34.58	29.39	25.50	22.60	20.49	18.87	17.77	16.48
14	57.59	51.35	43.02	35.93	30.43	26.32	23.26	21.03	19.33	18.17	16.80
15	63.10	53.48	44.57	37.08	31.30	27.00	23.80	21.48	19.69	18.48	17.06
16	67.60	54.95	45.62	37.86	31.89	27.45	24.16	21.77	19.94	18.69	17.23
17	72.10	56.22	46.52	38.52	32.39	27.85	24.47	22.02	20.14	18.87	17.37
18	76.60	57.27	47.26	39.06	32.80	28.16	24.72	22.23	20.31	19.01	17.48
19	81.10	58.09	47.85	39.49	33.13	28.42	24.93	22.39	20.45	19.13	17.58
20	85.60	58.68	48.28	39.81	33.38	28.61	25.09	22.52	20.56	19.23	17.66
21	90.10	59.02	48.56	40.02	33.55	28.75	25.20	22.62	20.64	19.30	17.71
22	94.60	59.12	48.68	40.13	33.64	28.82	25.26	22.67	20.69	19.34	17.76
23	99.10	59.00	48.65	40.12	33.65	28.84	25.28	22.70	20.71	19.37	17.78
24	103.60	58.64	48.47	40.01	33.58	28.80	25.26	22.69	20.71	19.37	17.79
25	108.10	58.08	48.14	39.80	33.44	28.71	25.19	22.64	20.68	19.35	17.79
26	112.60	57.32	47.66	39.48	33.22	28.55	25.08	22.56	20.63	19.32	17.77
27	117.10	56.38	47.05	39.05	32.92	28.34	24.93	22.45	20.55	19.26	17.73

Table-5.17

UPLIFT PRESSURE ON BARREL AT Z=0.0m, d = 3.0m (Contd...)

S.No.	X,m	UPLIFT PRESSURE FOR LINING LENGTH(m) OF BOTH CANAL IN %									
		36.25	61.25	86.25	111.25	136.25	161.25	186.25	211.25	230.625	250.00
28	121.60	55.26	46.30	38.52	32.55	28.07	24.74	22.31	20.44	19.18	17.68
29	126.10	54.00	45.42	37.89	32.10	27.75	24.50	22.13	20.31	19.07	17.61
30	130.56	52.59	44.42	37.17	31.58	27.37	24.22	21.91	20.15	18.95	17.52
31	135.03	51.05	43.29	36.35	30.98	26.93	23.89	21.66	19.95	18.79	17.42
32	139.31	49.46	42.10	35.48	30.34	26.44	23.53	21.38	19.74	18.62	17.30
33	143.58	47.75	40.80	34.52	29.63	25.91	23.12	21.07	19.49	18.42	17.15
34	147.45	46.11	39.54	33.57	28.92	25.37	22.71	20.75	19.24	18.21	17.00
35	151.32	44.38	38.20	32.56	28.15	24.78	22.25	20.39	18.95	17.97	16.81
36	154.99	42.66	36.85	31.53	27.36	24.17	21.78	20.00	18.64	17.71	16.61
37	158.65	40.85	35.41	30.42	26.50	23.50	21.25	19.58	18.29	17.41	16.37
38	162.12	39.05	33.97	29.30	25.62	22.80	20.70	19.12	17.91	17.09	16.11
39	165.58	37.13	32.42	28.08	24.66	22.03	20.07	18.60	17.47	16.70	15.78
40	168.68	35.29	30.93	26.88	23.71	21.25	19.43	18.06	17.00	16.28	15.43
41	171.79	33.30	29.30	25.57	22.64	20.37	18.69	17.42	16.44	15.78	14.99
42	174.40	31.49	27.79	24.34	21.63	19.52	17.96	16.79	15.88	15.26	14.53
43	177.02	29.49	26.11	22.94	20.47	18.54	17.11	16.03	15.20	14.63	13.95
44	179.22	27.63	24.53	21.62	19.35	17.57	16.26	15.26	14.50	13.97	13.35
45	181.42	25.54	22.72	20.09	18.04	16.42	15.23	14.33	13.63	13.16	12.60
46	183.21	23.62	21.06	18.66	16.80	15.32	14.24	13.42	12.79	12.35	11.84
47	185.01	21.43	19.14	17.00	15.35	14.02	13.06	12.32	11.76	11.37	10.91
48	186.20	19.87	17.76	15.80	14.29	13.07	12.18	11.50	10.98	10.63	10.21
49	187.40	18.31	16.38	14.58	13.21	12.09	11.28	10.67	10.19	9.87	9.48
50	188.20	17.46	15.63	13.92	12.62	11.56	10.79	10.20	9.75	9.44	9.07
51	189.00	17.22	15.42	13.73	12.45	11.41	10.65	10.07	9.63	9.32	8.96

Table-5.18

UPLIFT PRESSURE ON BARREL AT Z=11.25, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
1	20.00	35.875
2	20.48	36.245
3	20.95	36.583
4	21.57	37.041
5	22.19	37.524
6	23.13	38.258
7	24.08	38.995
8	25.56	40.212
9	27.03	41.458
10	29.05	43.108
11	31.06	44.694
12	33.48	46.536
13	35.91	48.287
14	38.55	50.161
15	41.20	51.947
16	43.89	53.749
17	46.59	55.517
18	48.78	56.833
19	50.96	58.127
20	53.15	59.403
21	55.34	60.633
22	58.04	62.22
23	60.74	63.787
24	63.44	65.129
25	66.14	66.431
26	68.84	67.779
27	71.54	69.074
28	74.24	70.14
29	76.94	71.085
30	79.64	72.045
31	82.34	72.885
32	85.04	73.287
33	87.74	73.557
34	90.44	73.721
35	93.14	73.71
36	95.84	73.307
37	98.54	72.721
38	101.24	72.216
39	103.94	71.564

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
40	106.64	70.639
41	109.34	69.64
42	112.04	68.695
43	114.74	67.697
44	117.44	66.506
45	120.14	65.312
46	122.84	64.14
47	125.54	62.954
48	128.24	61.676
49	130.94	60.379
50	133.64	59.123
51	136.34	57.843
52	139.04	56.516
53	141.74	55.197
54	144.44	53.834
55	147.14	52.475
56	149.84	51.164
57	152.54	49.861
58	155.24	48.511
59	157.93	47.129
60	160.60	45.71
61	163.28	44.225
62	165.89	42.687
63	168.50	41.096
64	171.00	39.444
65	173.50	37.733
66	175.79	36.096
67	178.08	34.41
68	180.03	32.924
69	181.99	31.403
70	183.45	30.271
71	184.92	29.154
72	185.87	28.447
73	186.81	27.781
74	187.43	27.346
75	188.05	26.938
76	188.52	26.618
77	189.00	26.255

Table-5.19

UPLIFT PRESSURE ON BARREL AT Z=5.625, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
1	20.00	35.752
2	20.80	35.82
3	21.60	36.032
4	22.86	36.639
5	24.11	37.458
6	26.08	39.044
7	28.05	40.704
8	30.73	42.916
9	33.42	45.018
10	36.73	47.461
11	40.05	49.741
12	43.51	51.987
13	46.97	54.114
14	50.42	56.122
15	53.88	58.016
16	57.07	59.656
17	60.26	61.212
18	63.45	62.669
19	66.63	64.063
20	70.09	65.4
21	73.55	66.595
22	77.01	67.613
23	80.47	68.453
24	83.92	69.06
25	87.38	69.442
26	**90.84**	69.615
27	94.30	69.558
28	97.75	69.253
29	101.21	68.75
30	104.67	68.096

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
31	108.13	67.277
32	111.59	66.294
33	115.04	65.236
34	118.50	64.02
35	121.96	62.752
36	125.42	61.397
37	128.87	59.982
38	132.33	58.498
39	135.79	56.96
40	139.25	55.386
41	142.71	53.774
42	146.16	52.115
43	149.62	50.422
44	153.08	48.678
45	156.53	46.884
46	159.95	45.033
47	163.38	43.101
48	166.72	41.12
49	170.06	39.039
50	173.15	37.004
51	176.24	34.866
52	178.66	33.129
53	181.08	31.34
54	183.00	29.953
55	184.92	28.654
56	186.16	27.954
57	187.40	27.452
58	188.20	27.275
59	189.00	27.218

Table-5.20

UPLIFT PRESSURE ON BARREL AT Z=0.00, d = 6.50m

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
1	20.00	35.428
2	20.80	35.504
3	21.60	35.704
4	22.88	36.247
5	24.16	37.059
6	26.21	38.752
7	28.26	40.489
8	31.31	43.029
9	34.37	45.416
10	38.75	48.561
11	43.13	51.437
12	47.60	54.146
13	52.08	56.659
14	56.58	58.987
15	61.08	61.097
16	65.58	63.067
17	70.08	64.79
18	74.58	66.204
19	79.08	67.375
20	83.58	68.215
21	88.08	68.692
22	**92.58**	68.807
23	97.08	68.571
24	102.59	67.846
25	108.10	66.688
26	112.60	65.478

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
27	117.10	64.076
28	121.60	62.504
29	126.10	60.813
30	130.56	58.981
31	135.03	57.069
32	139.31	55.158
33	143.58	53.165
34	147.45	51.307
35	151.32	49.386
36	154.99	47.497
37	158.65	45.541
38	162.12	43.611
39	165.58	41.591
40	168.68	39.696
41	171.79	37.705
42	174.40	35.947
43	177.02	34.11
44	179.22	32.514
45	181.42	30.88
46	183.21	29.515
47	185.01	28.137
48	186.20	27.704
49	187.40	27.339
50	188.20	27.152
51	189.00	27.081

Table-5.21

UPLIFT PRESSURE ON BARREL AT Z=11.25m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
1	20.00	30.433
2	20.48	30.734
3	20.95	31.132
4	21.57	31.849
5	22.19	32.618
6	23.13	33.806
7	24.08	34.995
8	25.57	36.795
9	27.06	38.505
10	29.27	40.759
11	31.47	42.822
12	34.09	45.137
13	36.71	47.345
14	39.41	49.387
15	42.10	51.369
16	44.91	53.351
17	47.72	55.303
18	50.42	57.037
19	53.12	58.725
20	55.82	60.438
21	58.52	62.13
22	61.22	63.619
23	63.92	65.12
24	66.62	66.564
25	69.32	67.929
26	72.02	69.265
27	74.72	70.508
28	77.42	71.554
29	80.12	72.481
30	82.82	73.079
31	85.52	73.539
32	88.22	73.858
33	90.92	74.176
34	93.62	73.985
35	96.32	73.631
36	99.02	73.258
37	101.72	72.704
38	104.42	71.86

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
39	107.12	70.915
40	109.82	70.002
41	112.52	68.957
42	115.22	67.824
43	117.92	66.662
44	120.62	65.488
45	123.32	64.343
46	126.02	63.055
47	128.72	61.774
48	131.42	60.471
49	134.12	59.159
50	136.82	57.811
51	139.52	56.442
52	142.22	55.07
53	144.92	53.683
54	147.62	52.271
55	150.32	50.876
56	153.02	49.47
57	155.72	48.053
58	158.42	46.585
59	161.12	45.049
60	163.81	43.379
61	166.50	41.642
62	169.15	39.842
63	171.79	37.921
64	174.32	35.989
65	176.85	33.939
66	179.03	32.058
67	181.21	30.059
68	182.82	28.457
69	184.44	26.79
70	185.44	25.726
71	186.45	24.624
72	187.08	23.974
73	187.71	23.362
74	188.11	22.995
75	188.50	22.659
76	188.75	22.492
77	189.00	22.345

Table-5.22

UPLIFT PRESSURE ON BARREL AT Z=5.625m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED	S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
1	20.00	25.53	31	108.16	67.835
2	20.80	25.805	32	111.62	66.839
3	21.60	26.786	33	115.08	65.729
4	22.87	28.999	34	118.54	64.494
5	24.13	31.183	35	121.99	63.15
6	26.15	34.269	36	125.45	61.791
7	28.17	36.918	37	128.91	60.326
8	31.01	40.136	38	132.37	58.799
9	33.84	42.954	39	135.82	57.219
10	37.30	45.983	40	139.28	55.548
11	40.75	48.714	41	142.74	53.855
12	44.21	51.233	42	146.20	52.107
13	47.67	53.592	43	149.66	50.3
14	51.12	55.754	44	153.11	48.448
15	54.58	57.842	45	156.57	46.523
16	57.60	59.505	46	160.02	44.498
17	60.62	61.09	47	163.48	42.357
18	63.65	62.613	48	166.88	40.146
19	66.67	63.984	49	170.27	37.769
20	70.13	65.425	50	173.36	35.43
21	73.58	66.748	51	176.44	32.883
22	77.04	67.822	52	178.84	30.683
23	80.50	68.813	53	181.25	28.25
24	83.96	69.478	54	183.11	26.146
25	87.41	69.929	55	184.96	23.773
26	90.87	70.097	56	186.18	22.056
27	94.33	70.015	57	187.40	20.298
28	97.79	69.803	58	188.20	19.529
29	101.25	69.367	59	189.00	19.356
30	104.70	68.628			

Table-5.23

UPLIFT PRESSURE ON BARREL AT Z=0.00m, d = 3.0m

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
1	20.00	24.512
2	20.80	24.813
3	21.60	25.814
4	22.88	28.084
5	24.16	30.317
6	26.21	33.537
7	28.26	36.33
8	31.31	39.896
9	34.37	42.966
10	38.75	46.753
11	43.13	50.092
12	47.60	53.182
13	52.08	55.964
14	57.59	59.074
15	63.10	61.903
16	67.60	63.862
17	72.10	65.602
18	76.60	67.039
19	81.10	68.152
20	85.60	68.927
21	90.10	69.299
22	94.60	69.296
23	99.10	68.95
24	103.60	68.275
25	108.10	67.297
26	112.60	66.064
27	117.10	64.621

S.No.	X,m	UPLIFT PRESSURE FOR UNLINED
28	121.60	63.004
29	126.10	61.233
30	130.56	59.346
31	135.03	57.338
32	139.31	55.327
33	143.58	53.233
34	147.45	51.252
35	151.32	49.202
36	154.99	47.189
37	158.65	45.08
38	162.12	42.985
39	165.58	40.747
40	168.68	38.621
41	171.79	36.342
42	174.40	34.27
43	177.02	32.005
44	179.22	29.911
45	181.42	27.573
46	183.21	25.448
47	185.01	23.05
48	186.20	21.338
49	187.40	19.642
50	188.20	18.726
51	189.00	18.465

TABLE-5.24

MAXIMUM UPLIFT PRESSURE ON BARREL FLOOR FOR DIFFERENT CASES

Location	Lining Condition	Cut-off depth	Uplift Pressure for Lining Length (m)									
			36.250	61.250	86.250	111.250	136.250	161.250	186.250	211.250	230.625	250.000
Barrel Floor at Z=11.25m	BOTH LINED	3.00	61.091	49.586	40.7	34.032	29.123	25.505	22.868	20.85	19.482	17.868
		6.50	60.787	49.493	40.846	34.351	29.538	25.992	23.36	21.319	19.924	18.27
		10.00	62.436	50.21	41.482	34.966	30.095	26.533	23.863	21.77	20.32	18.603
	HIGHER LINED	3.00	61.591	51.663	45.061	41.122	39.639	38.774	37.798	37.798	37.563	37.311
		6.50	61.379	51.501	45.02	41.252	39.814	38.98	38.417	38.011	37.755	37.485
		10.00	62.99	52.038	46.472	45.605	44.996	44.585	44.302	44.095	43.963	43.823
	BOTH UNLINED	3.00	74.176	74.176	74.176	74.176	74.176	74.176	74.176	74.176	74.176	74.176
		6.50	73.721	73.721	73.721	73.721	73.721	73.721	73.721	73.721	73.721	73.721
		10.00	81.061	81.061	81.061	81.061	81.061	81.061	81.061	81.061	81.061	81.061
Barrel Floor at Z=5.625m	BOTH LINED	3.00	59.468	48.854	40.25	33.731	28.899	25.33	22.733	20.745	19.396	17.808
		6.50	59.126	48.77	40.422	34.066	29.332	25.839	23.241	21.227	19.85	18.217
		10.00	58.907	48.837	40.738	34.47	29.774	26.292	23.677	21.627	20.206	18.525
	HIGHER LINED	3.00	59.993	50.953	44.619	40.54	38.167	36.788	35.38	35.38	35.027	34.675
		6.50	59.734	50.806	44.586	40.621	38.268	36.885	36.033	35.462	35.111	34.738
		10.00	59.415	50.698	44.604	40.658	38.353	37.041	36.173	35.571	35.195	34.796
	BOTH UNLINED	3.00	70.097	70.097	70.097	70.097	70.097	70.097	70.097	70.097	70.097	70.097
		6.50	69.615	69.615	69.615	69.615	69.615	69.615	69.615	69.615	69.615	69.615
		10.00	69.205	69.205	69.205	69.205	69.205	69.205	69.205	69.205	69.205	69.205
Barrel Floor at Z=0.00m	BOTH LINED	3.00	59.122	48.676	40.125	33.648	28.841	25.283	22.696	20.713	19.372	17.792
		6.50	58.748	48.577	40.316	33.993	29.278	25.797	23.207	21.199	19.829	18.204
		10.00	58.557	48.678	40.637	34.397	29.718	26.252	23.649	21.605	20.189	18.512
	HIGHER LINED	3.00	59.659	50.768	44.509	40.445	38.009	36.553	35.019	35.019	34.665	34.287
		6.50	59.338	50.619	44.477	40.513	38.098	36.646	35.737	35.106	34.729	34.326
		10.00	59.079	50.54	44.507	40.558	38.18	36.757	35.83	35.196	34.792	34.361
	BOTH UNLINED	3.00	69.299	69.299	69.299	69.299	69.299	69.299	69.299	69.299	69.299	69.299
		6.50	68.807	68.807	68.807	68.807	68.807	68.807	68.807	68.807	68.807	68.807
		10.00	68.383	68.383	68.383	68.383	68.383	68.383	68.383	68.383	68.383	68.383

Table-5.25

HYDRAULIC GRADIENT ALONG UPSTREAM CUT-OFF DEPTH (6.5m)

Cut-off	S.No.	Depth m	GRADIENT FOR VARIOUS LINING LENTH(m) OF HIGHER CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
A1 X=5.00m Z=11.25m	1	0.00	3.56	3.49	3.42	3.32	3.20	3.06	2.86	2.61	2.36	2.15
	2	0.50	3.56	3.48	3.42	3.32	3.20	3.06	2.86	2.61	2.36	2.14
	3	1.00	3.55	3.48	3.41	3.32	3.20	3.05	2.86	2.60	2.35	2.13
	4	1.50	3.54	3.47	3.41	3.32	3.19	3.04	2.85	2.60	2.35	2.13
	5	2.00	3.54	3.47	3.40	3.31	3.19	3.03	2.85	2.59	2.35	2.14
	6	2.50	3.51	3.45	3.39	3.30	3.17	3.02	2.83	2.59	2.34	2.13
	7	3.00	3.49	3.43	3.37	3.28	3.16	3.00	2.80	2.57	2.33	2.12
	8	3.50	3.45	3.39	3.33	3.23	3.12	2.97	2.76	2.54	2.30	2.10
	9	4.00	3.39	3.32	3.26	3.17	3.06	2.92	2.72	2.50	2.26	2.07
	10	4.50	3.33	3.27	3.21	3.12	3.01	2.86	2.68	2.46	2.23	2.03
	11	5.00	3.21	3.16	3.10	3.02	2.91	2.76	2.59	2.39	2.16	1.96
	12	5.50	2.88	2.84	2.79	2.72	2.62	2.49	2.34	2.16	1.96	1.78
	13	6.00	2.53	2.49	2.45	2.39	2.31	2.21	2.07	1.91	1.74	1.59
	14	6.50	2.22	2.19	2.16	2.12	2.06	1.99	1.89	1.77	1.64	1.52
A2 X=20.00m Z=11.25m	1	0.00	2.65	2.61	2.55	2.47	2.37	2.26	2.08	1.88	1.68	1.50
	2	0.50	2.65	2.60	2.55	2.47	2.37	2.25	2.09	1.88	1.67	1.50
	3	1.00	2.64	2.58	2.53	2.45	2.35	2.23	2.08	1.86	1.66	1.49
	4	1.50	2.61	2.56	2.51	2.43	2.33	2.20	2.05	1.84	1.65	1.47
	5	2.00	2.56	2.51	2.46	2.38	2.28	2.16	2.00	1.81	1.61	1.45
	6	2.50	2.51	2.46	2.41	2.33	2.23	2.11	1.96	1.77	1.58	1.41
	7	3.00	2.44	2.38	2.33	2.26	2.16	2.05	1.90	1.72	1.53	1.37
	8	3.50	2.34	2.29	2.24	2.17	2.08	1.97	1.83	1.65	1.47	1.32
	9	4.00	2.23	2.18	2.13	2.06	1.98	1.87	1.74	1.57	1.40	1.26
	10	4.50	2.08	2.03	1.99	1.93	1.85	1.74	1.62	1.46	1.30	1.17
	11	5.00	1.90	1.85	1.81	1.75	1.68	1.59	1.47	1.33	1.18	1.06
	12	5.50	1.66	1.62	1.58	1.53	1.47	1.39	1.28	1.16	1.04	0.93
	13	6.00	1.23	1.19	1.17	1.13	1.08	1.02	0.95	0.86	0.76	0.68
	14	6.50	1.54	1.50	1.47	1.42	1.36	1.29	1.19	1.08	0.96	0.85
A3 X=20.00m Z=-11.25m	1	0.00	2.67	2.61	2.56	2.48	2.37	2.27	2.10	1.88	1.68	1.52
	2	0.50	2.66	2.61	2.56	2.47	2.37	2.26	2.10	1.88	1.68	1.51
	3	1.00	2.65	2.59	2.54	2.46	2.36	2.25	2.08	1.87	1.67	1.50
	4	1.50	2.61	2.56	2.51	2.43	2.33	2.21	2.05	1.84	1.65	1.47
	5	2.00	2.57	2.52	2.47	2.39	2.29	2.17	2.02	1.82	1.62	1.45
	6	2.50	2.52	2.46	2.41	2.34	2.24	2.12	1.97	1.77	1.58	1.42
	7	3.00	2.44	2.39	2.34	2.27	2.17	2.06	1.91	1.72	1.54	1.38
	8	3.50	2.35	2.29	2.25	2.17	2.08	1.98	1.82	1.65	1.47	1.32
	9	4.00	2.24	2.18	2.14	2.07	1.98	1.87	1.74	1.57	1.40	1.26
	10	4.50	2.09	2.04	1.99	1.93	1.85	1.74	1.62	1.47	1.31	1.17
	11	5.00	1.90	1.86	1.82	1.76	1.69	1.59	1.47	1.34	1.19	1.06
	12	5.50	1.64	1.60	1.57	1.52	1.45	1.37	1.26	1.15	1.02	0.91
	13	6.00	1.25	1.22	1.20	1.16	1.11	1.04	0.96	0.88	0.78	0.69
	14	6.50	1.64	1.60	1.57	1.51	1.45	1.37	1.26	1.14	1.02	0.90
A4 X=5.00m Z=-11.25m	1	0.00	3.56	3.49	3.43	3.33	3.21	3.05	2.86	2.61	2.36	2.14
	2	0.50	3.55	3.48	3.42	3.32	3.20	3.05	2.85	2.60	2.36	2.13
	3	1.00	3.55	3.48	3.42	3.32	3.20	3.05	2.85	2.60	2.35	2.14
	4	1.50	3.54	3.46	3.40	3.30	3.18	3.03	2.84	2.59	2.35	2.14
	5	2.00	3.53	3.46	3.39	3.30	3.17	3.02	2.83	2.59	2.34	2.13
	6	2.50	3.50	3.44	3.38	3.28	3.16	3.00	2.81	2.57	2.33	2.12
	7	3.00	3.49	3.43	3.37	3.28	3.15	2.99	2.80	2.57	2.33	2.11
	8	3.50	3.44	3.39	3.33	3.23	3.11	2.96	2.76	2.54	2.30	2.09
	9	4.00	3.38	3.32	3.26	3.17	3.05	2.91	2.72	2.50	2.26	2.06
	10	4.50	3.32	3.25	3.19	3.10	2.99	2.86	2.67	2.45	2.22	2.03
	11	5.00	3.20	3.14	3.08	3.00	2.89	2.76	2.58	2.37	2.15	1.96
	12	5.50	2.97	2.91	2.86	2.79	2.69	2.56	2.41	2.21	2.01	1.83
	13	6.00	2.55	2.51	2.47	2.40	2.32	2.21	2.08	1.92	1.75	1.60
	14	6.50	2.52	2.49	2.46	2.41	2.35	2.27	2.16	2.03	1.88	1.74

Table-5.26

HYDRAULIC GRADIENT ALONG DOWNSTREAM CUT-OFF DEPTH (6.5m)

Cut-off	S.No.	Depth, m	GRADIENT FOR VARIOUS LINING LENTH(m) OF HIGHER CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
B1 X=189.00m Z=11.25m	1	0.00	2.13	2.11	2.10	2.08	2.06	2.05	1.97	1.93	1.86	1.81
	2	0.50	2.12	2.11	2.10	2.08	2.06	2.03	1.98	1.93	1.87	1.80
	3	1.00	2.11	2.10	2.10	2.08	2.06	2.01	1.98	1.93	1.86	1.78
	4	1.50	2.08	2.08	2.07	2.06	2.03	1.99	1.95	1.91	1.84	1.76
	5	2.00	2.05	2.04	2.03	2.01	1.99	1.95	1.92	1.87	1.80	1.74
	6	2.50	2.00	1.99	1.98	1.97	1.95	1.92	1.87	1.83	1.76	1.70
	7	3.00	1.94	1.93	1.92	1.91	1.89	1.86	1.80	1.77	1.71	1.65
	8	3.50	1.86	1.86	1.85	1.83	1.81	1.78	1.74	1.70	1.65	1.59
	9	4.00	1.77	1.76	1.76	1.74	1.72	1.70	1.65	1.62	1.56	1.51
	10	4.50	1.65	1.64	1.64	1.62	1.61	1.58	1.55	1.51	1.46	1.41
	11	5.00	1.50	1.49	1.49	1.47	1.46	1.44	1.41	1.37	1.33	1.28
	12	5.50	1.31	1.30	1.29	1.28	1.27	1.26	1.24	1.19	1.15	1.12
	13	6.00	0.95	0.95	0.94	0.93	0.92	0.92	0.90	0.87	0.84	0.82
	14	6.50	1.19	1.18	1.18	1.17	1.16	1.14	1.12	1.09	1.05	1.02
B2 X=214.00m Z=11.25m	1	0.00	3.40	3.39	3.38	3.36	3.33	3.30	3.26	3.18	3.10	3.01
	2	0.50	3.40	3.39	3.37	3.35	3.33	3.29	3.25	3.17	3.10	3.02
	3	1.00	3.40	3.40	3.38	3.36	3.33	3.29	3.26	3.18	3.11	3.03
	4	1.50	3.38	3.36	3.35	3.33	3.30	3.28	3.22	3.15	3.08	3.02
	5	2.00	3.38	3.37	3.36	3.33	3.31	3.27	3.22	3.16	3.08	3.01
	6	2.50	3.34	3.33	3.32	3.30	3.27	3.22	3.20	3.13	3.05	2.98
	7	3.00	3.32	3.33	3.31	3.29	3.27	3.20	3.18	3.12	3.05	2.96
	8	3.50	3.28	3.27	3.26	3.24	3.22	3.17	3.12	3.07	3.00	2.92
	9	4.00	3.23	3.22	3.21	3.19	3.16	3.13	3.08	3.03	2.96	2.88
	10	4.50	3.13	3.11	3.10	3.09	3.06	3.03	2.98	2.93	2.86	2.80
	11	5.00	3.05	3.03	3.02	3.00	2.98	2.96	2.92	2.85	2.79	2.74
	12	5.50	2.79	2.78	2.77	2.75	2.73	2.71	2.67	2.62	2.56	2.52
	13	6.00	2.40	2.39	2.39	2.37	2.36	2.34	2.30	2.27	2.22	2.18
	14	6.50	2.08	2.08	2.08	2.07	2.07	2.05	2.03	2.02	2.00	1.98
B3 X=214.00m Z=-11.25m	1	0.00	3.41	3.40	3.39	3.37	3.34	3.30	3.27	3.19	3.11	3.00
	2	0.50	3.40	3.39	3.38	3.36	3.33	3.29	3.25	3.18	3.10	3.00
	3	1.00	3.40	3.38	3.37	3.35	3.32	3.30	3.25	3.17	3.09	3.03
	4	1.50	3.38	3.36	3.35	3.33	3.30	3.29	3.22	3.15	3.08	3.02
	5	2.00	3.37	3.36	3.35	3.33	3.30	3.28	3.21	3.15	3.08	3.00
	6	2.50	3.35	3.33	3.32	3.30	3.28	3.24	3.18	3.13	3.05	2.97
	7	3.00	3.32	3.30	3.29	3.27	3.25	3.20	3.17	3.10	3.03	2.95
	8	3.50	3.28	3.28	3.26	3.25	3.22	3.16	3.13	3.08	3.00	2.94
	9	4.00	3.21	3.21	3.20	3.18	3.15	3.09	3.07	3.01	2.94	2.90
	10	4.50	3.12	3.11	3.10	3.09	3.06	3.02	2.98	2.93	2.86	2.81
	11	5.00	3.06	3.04	3.03	3.02	2.99	2.96	2.91	2.87	2.80	2.75
	12	5.50	2.80	2.79	2.78	2.76	2.75	2.71	2.68	2.64	2.58	2.53
	13	6.00	2.43	2.42	2.41	2.40	2.38	2.36	2.33	2.29	2.24	2.21
	14	6.50	2.22	2.22	2.22	2.21	2.20	2.18	2.17	2.16	2.13	2.13
B4 X=189.00m Z=-11.25m	1	0.00	2.12	2.11	2.10	2.08	2.07	2.04	1.96	1.93	1.87	1.79
	2	0.50	2.11	2.10	2.09	2.08	2.05	2.02	1.97	1.93	1.86	1.79
	3	1.00	2.10	2.09	2.08	2.06	2.04	2.00	1.97	1.91	1.85	1.78
	4	1.50	2.08	2.07	2.06	2.04	2.02	1.98	1.95	1.89	1.83	1.75
	5	2.00	2.05	2.04	2.03	2.01	1.99	1.95	1.92	1.87	1.81	1.73
	6	2.50	2.00	1.99	1.98	1.96	1.94	1.90	1.86	1.82	1.76	1.70
	7	3.00	1.94	1.93	1.92	1.90	1.88	1.85	1.81	1.77	1.71	1.66
	8	3.50	1.86	1.85	1.84	1.83	1.81	1.78	1.74	1.70	1.64	1.60
	9	4.00	1.77	1.76	1.76	1.74	1.72	1.69	1.66	1.62	1.56	1.52
	10	4.50	1.64	1.63	1.63	1.61	1.60	1.57	1.53	1.50	1.45	1.41
	11	5.00	1.51	1.50	1.49	1.48	1.47	1.45	1.42	1.38	1.33	1.29
	12	5.50	1.31	1.30	1.29	1.28	1.27	1.26	1.23	1.19	1.16	1.12
	13	6.00	0.84	0.84	0.84	0.83	0.82	0.81	0.80	0.77	0.75	0.72
	14	6.50	1.17	1.16	1.16	1.15	1.14	1.12	1.10	1.07	1.04	1.00

Table-5.27

HYDRAULIC GRADIENT ALONG UPSTREAM CUT-OFF DEPTH (3.0m)

Cut-off	S.No.	Depth m	GRADIENT FOR VARIOUS LINING LENTH(m) OF HIGHER CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
A1 X=5.00m Z=11.25m	1	0.00	2.74	2.69	2.65	2.59	2.50	2.38	2.24	2.07	1.88	1.71
	2	0.50	2.69	2.65	2.61	2.55	2.46	2.35	2.21	2.04	1.85	1.69
	3	1.00	2.67	2.63	2.59	2.52	2.44	2.33	2.19	2.03	1.84	1.67
	4	1.50	2.60	2.55	2.51	2.45	2.37	2.27	2.13	1.97	1.79	1.63
	5	2.00	2.37	2.33	2.30	2.25	2.17	2.07	1.95	1.81	1.65	1.50
	6	2.50	2.12	2.09	2.06	2.01	1.95	1.86	1.75	1.63	1.49	1.35
	7	3.00	2.58	2.54	2.50	2.43	2.38	2.25	2.11	1.85	1.75	1.58
A2 X=20.00m Z=11.25m	1	0.00	1.51	1.48	1.45	1.41	1.35	1.27	1.18	1.07	0.95	0.85
	2	0.50	1.49	1.46	1.43	1.39	1.33	1.26	1.16	1.06	0.94	0.83
	3	1.00	1.45	1.41	1.39	1.35	1.29	1.22	1.13	1.02	0.91	0.81
	4	1.50	1.33	1.30	1.28	1.24	1.19	1.12	1.04	0.94	0.84	0.74
	5	2.00	1.22	1.20	1.17	1.14	1.09	1.03	0.95	0.87	0.77	0.68
	6	2.50	0.82	0.80	0.79	0.77	0.73	0.69	0.64	0.58	0.52	0.46
	7	3.00	1.41	1.38	1.35	1.31	1.26	1.18	1.10	0.99	0.88	0.78
A3 X=20.00m Z=-11.25m	1	0.00	1.51	1.48	1.45	1.41	1.35	1.27	1.17	1.07	0.95	0.84
	2	0.49	1.50	1.47	1.44	1.40	1.34	1.26	1.17	1.06	0.95	0.84
	3	0.97	1.44	1.41	1.39	1.35	1.29	1.22	1.13	1.03	0.91	0.81
	4	1.46	1.34	1.31	1.29	1.25	1.20	1.13	1.05	0.95	0.85	0.75
	5	1.94	1.19	1.17	1.14	1.11	1.07	1.01	0.93	0.85	0.75	0.67
	6	2.50	0.92	0.90	0.88	0.85	0.82	0.77	0.72	0.65	0.58	0.51
	7	3.00	1.49	1.46	1.43	1.38	1.32	1.25	1.16	1.04	0.93	0.82
A4 X=5.00m Z=-11.25m	1	0.00	2.72	2.68	2.64	2.58	2.49	2.37	2.23	2.07	1.87	1.70
	2	0.50	2.70	2.66	2.62	2.56	2.47	2.36	2.21	2.05	1.86	1.69
	3	1.00	2.66	2.62	2.58	2.52	2.43	2.32	2.18	2.02	1.83	1.67
	4	1.50	2.58	2.54	2.50	2.44	2.36	2.25	2.12	1.96	1.78	1.62
	5	2.00	2.40	2.36	2.33	2.27	2.20	2.10	1.98	1.83	1.67	1.52
	6	2.50	2.08	2.05	2.02	1.97	1.91	1.83	1.72	1.60	1.46	1.33
	7	3.00	2.55	2.52	2.49	2.44	2.38	2.29	2.17	2.03	1.87	1.72

Table-5.28

HYDRUALIC GRADIENT ALONG DOWNSTREAM CUT-OFF DEPTH (3.0m)

Cut-off	S.No.	Depth m	GRADIENT FOR VARIOUS LINING LENTH(m) OF HIGHER CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
B1 X=189.00m Z=11.25m	1	0.00	1.162	1.157	1.152	1.145	1.137	1.121	1.100	1.072	1.040	1.004
	2	0.49	1.151	1.146	1.142	1.135	1.125	1.110	1.090	1.061	1.030	0.994
	3	0.97	1.109	1.104	1.101	1.093	1.084	1.069	1.051	1.022	0.993	0.958
	4	1.46	1.038	1.034	1.030	1.024	1.014	1.000	0.983	0.958	0.930	0.898
	5	1.94	0.928	0.924	0.921	0.915	0.906	0.895	0.877	0.857	0.832	0.804
	6	2.50	0.730	0.726	0.723	0.719	0.713	0.704	0.691	0.674	0.654	0.633
	7	3.00	1.004	0.999	0.995	0.989	0.981	0.968	0.950	0.928	0.901	0.872
B2 X=214.00m Z=11.25m	1	0.00	2.602	2.595	2.588	2.579	2.563	2.543	2.513	2.471	2.415	2.372
	2	0.50	2.579	2.571	2.563	2.554	2.541	2.518	2.487	2.448	2.394	2.350
	3	1.00	2.530	2.522	2.514	2.507	2.491	2.471	2.439	2.402	2.353	2.307
	4	1.50	2.447	2.440	2.434	2.423	2.410	2.391	2.363	2.325	2.282	2.236
	5	2.00	2.338	2.333	2.330	2.316	2.305	2.285	2.261	2.226	2.187	2.143
	6	2.50	1.983	1.978	1.974	1.966	1.955	1.941	1.920	1.892	1.861	1.825
	7	3.00	2.209	2.206	2.203	2.196	2.189	2.178	2.165	2.140	2.116	2.089
B3 X=214.00m Z=-11.25m	1	0.00	2.608	2.602	2.596	2.583	2.571	2.547	2.521	2.483	2.432	2.382
	2	0.50	2.573	2.568	2.561	2.550	2.536	2.514	2.486	2.446	2.398	2.349
	3	1.00	2.530	2.523	2.517	2.506	2.492	2.473	2.440	2.399	2.353	2.307
	4	1.50	2.425	2.420	2.414	2.404	2.388	2.370	2.339	2.302	2.259	2.213
	5	2.00	2.335	2.329	2.324	2.314	2.299	2.281	2.254	2.220	2.178	2.135
	6	2.50	1.880	1.873	1.868	1.862	1.854	1.840	1.823	1.794	1.764	1.731
	7	3.00	2.031	2.027	2.024	2.019	2.014	2.005	1.994	1.972	1.950	1.928
B4 X=189.00m Z=-11.25m	1	0.00	1.162	1.155	1.151	1.145	1.136	1.121	1.099	1.069	1.040	1.002
	2	0.49	1.151	1.146	1.142	1.135	1.125	1.110	1.090	1.061	1.032	0.994
	3	0.97	1.108	1.103	1.099	1.092	1.082	1.067	1.050	1.022	0.993	0.957
	4	1.46	1.039	1.035	1.032	1.025	1.015	1.002	0.987	0.961	0.933	0.900
	5	1.94	0.929	0.925	0.922	0.916	0.908	0.896	0.880	0.858	0.833	0.806
	6	2.50	0.716	0.713	0.710	0.706	0.700	0.691	0.677	0.662	0.642	0.622
	7	3.00	1.018	1.013	1.009	1.003	0.995	0.982	0.962	0.941	0.912	0.883

Table-5.29

HYDRAULIC GRADIENT ALONG UPSTREAM CUT-OFF DEPTH (6.5m)

Cut-off	S.No.	Depth, m	GRADIENT FOR VARIOUS LINING LENTH(m) OF BOTH CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
A1 X=5.00m Z=11.25m	1	0.00	4.48	4.26	4.10	3.88	3.63	3.35	3.03	2.71	2.40	2.14
	2	0.50	4.48	4.26	4.09	3.88	3.63	3.34	3.03	2.70	2.39	2.14
	3	1.00	4.46	4.25	4.09	3.87	3.62	3.34	3.03	2.70	2.39	2.14
	4	1.50	4.45	4.23	4.07	3.86	3.61	3.33	3.02	2.69	2.39	2.14
	5	2.00	4.44	4.23	4.06	3.85	3.60	3.33	3.01	2.69	2.38	2.13
	6	2.50	4.40	4.19	4.03	3.82	3.58	3.30	3.00	2.68	2.37	2.12
	7	3.00	4.38	4.16	4.01	3.80	3.56	3.29	2.98	2.66	2.36	2.11
	8	3.50	4.30	4.10	3.94	3.74	3.51	3.24	2.95	2.63	2.34	2.09
	9	4.00	4.22	4.02	3.87	3.68	3.45	3.19	2.90	2.59	2.30	2.06
	10	4.50	4.14	3.95	3.81	3.61	3.39	3.13	2.85	2.55	2.26	2.02
	11	5.00	3.98	3.80	3.66	3.48	3.27	3.02	2.75	2.46	2.19	1.96
	12	5.50	3.55	3.40	3.28	3.12	2.93	2.72	2.48	2.23	1.99	1.79
	13	6.00	3.09	2.97	2.86	2.73	2.58	2.40	2.19	1.97	1.76	1.59
	14	6.50	2.58	2.50	2.44	2.35	2.25	2.13	1.98	1.82	1.66	1.52
A2 X=20.00m Z=11.25m	1	0.00	3.51	3.31	3.16	2.96	2.74	2.49	2.23	1.96	1.70	1.50
	2	0.50	3.50	3.30	3.15	2.95	2.73	2.49	2.22	1.95	1.70	1.49
	3	1.00	3.48	3.28	3.13	2.93	2.72	2.47	2.21	1.94	1.69	1.48
	4	1.50	3.44	3.24	3.09	2.90	2.69	2.44	2.18	1.92	1.67	1.47
	5	2.00	3.38	3.19	3.04	2.85	2.64	2.40	2.15	1.89	1.64	1.44
	6	2.50	3.30	3.12	2.98	2.79	2.58	2.35	2.10	1.84	1.60	1.41
	7	3.00	3.21	3.03	2.89	2.71	2.51	2.28	2.04	1.79	1.56	1.37
	8	3.50	3.09	2.91	2.78	2.61	2.41	2.20	1.96	1.72	1.50	1.31
	9	4.00	2.94	2.77	2.64	2.48	2.29	2.09	1.86	1.64	1.42	1.25
	10	4.50	2.75	2.59	2.47	2.32	2.15	1.95	1.74	1.53	1.33	1.17
	11	5.00	2.50	2.36	2.25	2.11	1.95	1.78	1.59	1.39	1.21	1.06
	12	5.50	2.20	2.07	1.97	1.85	1.71	1.55	1.39	1.22	1.06	0.93
	13	6.00	1.62	1.53	1.46	1.36	1.26	1.15	1.02	0.90	0.78	0.68
	14	6.50	2.04	1.92	1.83	1.72	1.59	1.44	1.28	1.12	0.97	0.85
A3 X=20.00m Z=-11.25m	1	0.00	3.53	3.32	3.17	2.97	2.75	2.50	2.24	1.96	1.71	1.50
	2	0.50	3.51	3.31	3.16	2.96	2.74	2.50	2.23	1.96	1.71	1.50
	3	1.00	3.49	3.29	3.14	2.94	2.73	2.48	2.22	1.95	1.70	1.49
	4	1.50	3.44	3.25	3.10	2.91	2.69	2.45	2.19	1.92	1.68	1.47
	5	2.00	3.39	3.20	3.05	2.86	2.65	2.41	2.15	1.89	1.65	1.45
	6	2.50	3.31	3.13	2.99	2.80	2.59	2.36	2.11	1.85	1.61	1.41
	7	3.00	3.22	3.04	2.90	2.72	2.52	2.29	2.04	1.80	1.56	1.37
	8	3.50	3.10	2.92	2.79	2.61	2.42	2.20	1.96	1.72	1.50	1.32
	9	4.00	2.95	2.78	2.65	2.49	2.30	2.09	1.87	1.64	1.43	1.25
	10	4.50	2.75	2.59	2.47	2.32	2.15	1.95	1.74	1.53	1.33	1.17
	11	5.00	2.51	2.37	2.26	2.12	1.96	1.78	1.59	1.39	1.21	1.06
	12	5.50	2.16	2.04	1.94	1.82	1.69	1.53	1.37	1.20	1.04	0.91
	13	6.00	1.65	1.55	1.48	1.39	1.28	1.17	1.04	0.91	0.79	0.69
	14	6.50	2.18	2.05	1.95	1.83	1.69	1.53	1.37	1.19	1.03	0.90
A4 X=5.00m Z=-11.25m	1	0.00	4.47	4.25	4.09	3.87	3.63	3.34	3.03	2.70	2.39	2.14
	2	0.50	4.46	4.24	4.08	3.86	3.62	3.33	3.02	2.70	2.39	2.13
	3	1.00	4.46	4.25	4.09	3.87	3.62	3.34	3.03	2.70	2.39	2.14
	4	1.50	4.43	4.22	4.06	3.85	3.60	3.32	3.01	2.69	2.38	2.13
	5	2.00	4.42	4.21	4.05	3.83	3.59	3.32	3.01	2.68	2.38	2.13
	6	2.50	4.39	4.18	4.02	3.81	3.57	3.29	2.99	2.67	2.37	2.12
	7	3.00	4.36	4.15	4.00	3.79	3.55	3.28	2.98	2.66	2.36	2.11
	8	3.50	4.30	4.09	3.94	3.74	3.50	3.24	2.94	2.63	2.33	2.09
	9	4.00	4.21	4.02	3.87	3.67	3.45	3.18	2.89	2.59	2.30	2.06
	10	4.50	4.12	3.93	3.79	3.60	3.38	3.13	2.84	2.55	2.26	2.03
	11	5.00	3.96	3.78	3.64	3.46	3.25	3.01	2.74	2.46	2.19	1.96
	12	5.50	3.66	3.50	3.38	3.21	3.02	2.80	2.55	2.29	2.04	1.83
	13	6.00	3.11	2.98	2.88	2.75	2.59	2.41	2.20	1.98	1.77	1.60
	14	6.50	2.91	2.83	2.76	2.66	2.55	2.42	2.26	2.08	1.90	1.74

Table-5.30

HYDRAULIC GRADIENT ALONG DOWNSTREAM CUT-OFF DEPTH (6.5m)

Cut-off	S.No.	Depth, m	GRADIENT FOR VARIOUS LINING LENTH(m) OF BOTH CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
B1 X=189.00m Z=11.25m	1	0.00	3.21	3.11	3.02	2.91	2.78	2.62	2.43	2.23	2.03	1.87
	2	0.50	3.21	3.10	3.02	2.90	2.77	2.61	2.43	2.23	2.03	1.86
	3	1.00	3.18	3.08	3.00	2.88	2.75	2.60	2.41	2.21	2.01	1.85
	4	1.50	3.15	3.05	2.96	2.85	2.72	2.57	2.39	2.19	1.99	1.82
	5	2.00	3.10	3.00	2.92	2.81	2.68	2.52	2.35	2.15	1.96	1.79
	6	2.50	3.04	2.93	2.85	2.75	2.62	2.47	2.30	2.11	1.92	1.75
	7	3.00	2.95	2.85	2.77	2.67	2.54	2.40	2.23	2.04	1.86	1.70
	8	3.50	2.83	2.74	2.67	2.56	2.45	2.31	2.14	1.96	1.79	1.64
	9	4.00	2.69	2.61	2.54	2.44	2.33	2.19	2.04	1.87	1.70	1.56
	10	4.50	2.52	2.44	2.37	2.28	2.18	2.05	1.91	1.75	1.59	1.45
	11	5.00	2.30	2.22	2.16	2.08	1.98	1.87	1.74	1.59	1.45	1.32
	12	5.50	2.02	1.95	1.90	1.83	1.74	1.64	1.52	1.39	1.27	1.15
	13	6.00	1.47	1.42	1.38	1.33	1.27	1.20	1.11	1.02	0.92	0.84
	14	6.50	1.86	1.80	1.75	1.68	1.60	1.51	1.40	1.28	1.16	1.05
B2 X=214.00m Z=11.25m	1	0.00	4.39	4.31	4.23	4.13	4.01	3.86	3.68	3.48	3.26	3.08
	2	0.50	4.38	4.30	4.22	4.12	4.00	3.85	3.67	3.47	3.26	3.07
	3	1.00	4.39	4.30	4.23	4.13	4.01	3.86	3.68	3.47	3.26	3.08
	4	1.50	4.35	4.26	4.19	4.09	3.97	3.83	3.65	3.45	3.24	3.06
	5	2.00	4.34	4.26	4.19	4.09	3.97	3.83	3.65	3.45	3.24	3.05
	6	2.50	4.28	4.19	4.13	4.03	3.91	3.77	3.60	3.41	3.20	3.02
	7	3.00	4.25	4.17	4.10	4.01	3.89	3.75	3.58	3.39	3.19	3.01
	8	3.50	4.17	4.09	4.03	3.94	3.83	3.69	3.53	3.34	3.14	2.97
	9	4.00	4.10	4.02	3.96	3.87	3.77	3.64	3.48	3.29	3.10	2.93
	10	4.50	3.95	3.88	3.82	3.74	3.64	3.51	3.36	3.18	3.00	2.84
	11	5.00	3.84	3.78	3.72	3.64	3.54	3.42	3.27	3.11	2.93	2.78
	12	5.50	3.48	3.42	3.37	3.30	3.22	3.11	2.99	2.84	2.69	2.55
	13	6.00	2.94	2.90	2.86	2.80	2.74	2.66	2.56	2.44	2.32	2.21
	14	6.50	2.32	2.30	2.29	2.27	2.24	2.20	2.16	2.11	2.04	1.98
B3 X=214.00m Z=-11.25m	1	0.00	4.40	4.31	4.24	4.14	4.01	3.86	3.68	3.48	3.26	3.08
	2	0.50	4.39	4.30	4.23	4.13	4.00	3.85	3.67	3.47	3.26	3.07
	3	1.00	4.39	4.29	4.22	4.12	4.00	3.85	3.67	3.47	3.26	3.07
	4	1.50	4.34	4.25	4.18	4.09	3.97	3.82	3.64	3.44	3.24	3.05
	5	2.00	4.34	4.25	4.18	4.08	3.96	3.82	3.64	3.44	3.23	3.05
	6	2.50	4.29	4.20	4.14	4.04	3.92	3.78	3.61	3.41	3.21	3.03
	7	3.00	4.23	4.15	4.09	3.99	3.88	3.74	3.57	3.38	3.18	3.00
	8	3.50	4.17	4.10	4.03	3.94	3.83	3.70	3.53	3.34	3.15	2.98
	9	4.00	4.06	3.99	3.93	3.84	3.74	3.61	3.45	3.27	3.08	2.92
	10	4.50	3.93	3.87	3.81	3.73	3.63	3.51	3.36	3.18	3.00	2.85
	11	5.00	3.84	3.78	3.72	3.64	3.55	3.43	3.28	3.11	2.94	2.78
	12	5.50	3.48	3.42	3.38	3.31	3.22	3.12	3.00	2.85	2.70	2.56
	13	6.00	2.97	2.93	2.89	2.84	2.77	2.69	2.58	2.47	2.34	2.23
	14	6.50	2.46	2.45	2.43	2.41	2.38	2.35	2.30	2.25	2.18	2.12
B4 X=189.00m Z=-11.25m	1	0.00	3.20	3.10	3.02	2.90	2.77	2.61	2.43	2.23	2.03	1.85
	2	0.50	3.20	3.09	3.01	2.90	2.76	2.61	2.42	2.22	2.02	1.85
	3	1.00	3.17	3.07	2.99	2.88	2.75	2.59	2.41	2.21	2.01	1.83
	4	1.50	3.13	3.04	2.96	2.84	2.71	2.56	2.38	2.18	1.99	1.81
	5	2.00	3.10	2.99	2.91	2.80	2.67	2.52	2.34	2.15	1.96	1.79
	6	2.50	3.03	2.92	2.85	2.74	2.61	2.46	2.29	2.10	1.91	1.75
	7	3.00	2.94	2.85	2.77	2.66	2.54	2.40	2.23	2.04	1.86	1.70
	8	3.50	2.83	2.74	2.66	2.56	2.45	2.30	2.14	1.96	1.79	1.63
	9	4.00	2.70	2.61	2.54	2.44	2.33	2.20	2.04	1.87	1.70	1.56
	10	4.50	2.50	2.42	2.36	2.27	2.16	2.04	1.89	1.74	1.58	1.45
	11	5.00	2.31	2.23	2.17	2.09	1.99	1.88	1.74	1.60	1.45	1.33
	12	5.50	2.01	1.94	1.89	1.82	1.74	1.63	1.52	1.39	1.26	1.16
	13	6.00	1.30	1.26	1.22	1.18	1.12	1.06	0.98	0.90	0.82	0.75
	14	6.50	1.82	1.76	1.71	1.65	1.57	1.48	1.37	1.25	1.14	1.03

Table-5.31

HYDRAULIC GRADIENT ALONG UPSTREAM CUT-OFF DEPTH (3.0m)

Cut-off	S.No.	Depth m	GRADIENT FOR VARIOUS LINING LENTH(m) OF BOTH CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
A1 X=5.00m Z=11.25m	1	0.00	3.35	3.22	3.11	2.97	2.80	2.60	2.38	2.15	1.91	1.70
	2	0.50	3.29	3.16	3.06	2.92	2.76	2.56	2.34	2.12	1.89	1.68
	3	1.00	3.26	3.13	3.03	2.89	2.73	2.54	2.31	2.11	1.87	1.66
	4	1.50	3.17	3.04	2.94	2.81	2.65	2.47	2.25	2.05	1.82	1.63
	5	2.00	2.88	2.77	2.68	2.56	2.42	2.26	2.07	1.88	1.67	1.49
	6	2.50	2.56	2.46	2.39	2.28	2.16	2.02	1.86	1.70	1.51	1.35
	7	3.00	2.89	2.80	2.75	2.60	2.45	2.31	2.12	1.91	1.71	1.52
A2 X=20.00m Z=11.25m	1	0.00	1.99	1.84	1.76	1.65	1.52	1.42	1.27	1.13	0.97	0.85
	2	0.50	1.96	1.87	1.79	1.68	1.56	1.40	1.25	1.11	0.96	0.83
	3	1.00	1.90	1.84	1.77	1.66	1.56	1.37	1.21	1.07	0.93	0.81
	4	1.50	1.75	1.65	1.58	1.49	1.38	1.25	1.11	0.99	0.85	0.74
	5	2.00	1.61	1.51	1.44	1.36	1.26	1.15	1.03	0.91	0.78	0.68
	6	2.50	1.08	1.02	0.98	0.92	0.85	0.78	0.69	0.61	0.53	0.46
	7	3.00	1.86	1.75	1.67	1.57	1.45	1.33	1.18	1.04	0.90	0.78
A3 X=20.00m Z=-11.25m	1	0.00	1.98	1.88	1.80	1.69	1.57	1.42	1.27	1.12	0.97	0.85
	2	0.49	1.97	1.86	1.78	1.67	1.55	1.41	1.26	1.11	0.97	0.84
	3	0.97	1.90	1.79	1.72	1.61	1.50	1.36	1.21	1.08	0.93	0.81
	4	1.46	1.77	1.67	1.60	1.50	1.39	1.27	1.12	1.00	0.86	0.75
	5	1.94	1.57	1.49	1.42	1.33	1.24	1.13	1.00	0.89	0.77	0.67
	6	2.50	1.21	1.14	1.09	1.03	0.95	0.87	0.77	0.68	0.59	0.51
	7	3.00	1.97	1.86	1.78	1.67	1.54	1.40	1.25	1.09	0.94	0.83
A4 X=5.00m Z=-11.25m	1	0.00	3.33	3.19	3.09	2.95	2.78	2.58	2.35	2.16	1.91	1.69
	2	0.50	3.30	3.17	3.07	2.93	2.77	2.57	2.34	2.14	1.89	1.68
	3	1.00	3.25	3.12	3.02	2.88	2.72	2.53	2.31	2.10	1.86	1.65
	4	1.50	3.14	3.02	2.92	2.79	2.64	2.46	2.24	2.04	1.81	1.61
	5	2.00	2.92	2.81	2.72	2.60	2.46	2.29	2.10	1.91	1.70	1.51
	6	2.50	2.51	2.42	2.34	2.24	2.12	1.98	1.82	1.66	1.48	1.33
	7	3.00	2.98	2.90	2.82	2.72	2.60	2.45	2.27	2.11	1.90	1.72

Table-5.32

HYDRAULIC GRADIENT ALONG DOWNSTREAM CUT-OFF DEPTH (3.0m)

Cut-off	S.No.	Depth m	GRADIENT FOR VARIOUS LINING LENTH(m) OF BOTH CANAL									
			250.00	230.63	211.25	186.25	161.25	136.25	111.25	86.25	61.25	36.25
B1 X=189.00m Z=11.25m	1	0.00	1.758	1.708	1.667	1.609	1.540	1.467	1.363	1.256	1.143	1.041
	2	0.49	1.742	1.693	1.652	1.595	1.526	1.451	1.350	1.242	1.129	1.029
	3	0.97	1.680	1.632	1.592	1.537	1.471	1.394	1.297	1.193	1.087	0.991
	4	1.46	1.575	1.527	1.490	1.438	1.376	1.302	1.211	1.121	1.014	0.926
	5	1.94	1.407	1.364	1.331	1.285	1.230	1.166	1.084	1.002	0.907	0.827
	6	2.50	1.110	1.077	1.051	1.014	0.971	0.919	0.855	0.792	0.715	0.654
	7	3.00	1.544	1.497	1.460	1.410	1.349	1.279	1.190	1.097	0.993	0.903
B2 X=214.00m Z=11.25m	1	0.00	3.220	3.165	3.125	3.070	2.999	2.904	2.810	2.698	2.548	2.404
	2	0.50	3.185	3.134	3.094	3.038	2.970	2.883	2.778	2.658	2.522	2.378
	3	1.00	3.121	3.064	3.026	2.972	2.906	2.835	2.722	2.606	2.465	2.339
	4	1.50	3.007	2.957	2.922	2.870	2.806	2.736	2.630	2.515	2.374	2.267
	5	2.00	2.858	2.822	2.786	2.739	2.679	2.605	2.519	2.393	2.261	2.165
	6	2.50	2.389	2.358	2.332	2.294	2.248	2.193	2.126	2.024	1.926	1.845
	7	3.00	2.488	2.470	2.453	2.430	2.399	2.371	2.318	2.248	2.174	2.105
B3 X=214.00m Z=-11.25m	1	0.00	3.238	3.172	3.134	3.076	3.005	2.919	2.805	2.690	2.517	2.423
	2	0.50	3.180	3.131	3.090	3.036	2.967	2.870	2.760	2.649	2.495	2.378
	3	1.00	3.113	3.070	3.032	2.978	2.909	2.818	2.712	2.595	2.473	2.332
	4	1.50	2.972	2.926	2.891	2.841	2.776	2.698	2.605	2.496	2.364	2.242
	5	2.00	2.854	2.810	2.776	2.729	2.670	2.595	2.513	2.398	2.272	2.174
	6	2.50	2.257	2.224	2.200	2.165	2.123	2.078	2.006	1.924	1.828	1.757
	7	3.00	2.268	2.254	2.240	2.219	2.193	2.162	2.116	2.061	1.996	1.937
B4 X=189.00m Z=-11.25m	1	0.00	1.758	1.702	1.660	1.603	1.534	1.465	1.363	1.253	1.134	1.034
	2	0.49	1.743	1.691	1.650	1.592	1.524	1.450	1.349	1.240	1.123	1.028
	3	0.97	1.680	1.632	1.592	1.537	1.471	1.393	1.296	1.194	1.081	0.992
	4	1.46	1.577	1.532	1.495	1.443	1.381	1.306	1.214	1.120	1.020	0.931
	5	1.94	1.411	1.368	1.335	1.289	1.234	1.169	1.086	1.005	0.913	0.831
	6	2.50	1.088	1.054	1.029	0.994	0.951	0.903	0.841	0.779	0.705	0.641
	7	3.00	1.568	1.520	1.483	1.432	1.370	1.297	1.205	1.112	1.008	0.915

Table-5.33

HYDRAULIC GRADIENT ALONG CUT-OFF DEPTH (6.5m)
BOTH UNLINED CANALS

UPSTREAM

Cut-off	S.No.	Depth m	Exit Gradient (1: ?)
A1 X=5.00m Z=11.25m	1	0.00	1.97
	2	0.50	1.97
	3	1.00	1.97
	4	1.50	1.97
	5	2.00	1.96
	6	2.50	1.96
	7	3.00	1.95
	8	3.50	1.93
	9	4.00	1.90
	10	4.50	1.87
	11	5.00	1.81
	12	5.50	1.65
	13	6.00	1.47
	14	6.50	1.42
A2 X=20.00m Z=11.25m	1	0.00	1.36
	2	0.50	1.36
	3	1.00	1.35
	4	1.50	1.34
	5	2.00	1.31
	6	2.50	1.28
	7	3.00	1.25
	8	3.50	1.20
	9	4.00	1.13
	10	4.50	1.06
	11	5.00	0.96
	12	5.50	0.84
	13	6.00	0.62
	14	6.50	0.77
A3 X=20.00m Z=-11.25m	1	0.00	1.36
	2	0.50	1.36
	3	1.00	1.36
	4	1.50	1.34
	5	2.00	1.32
	6	2.50	1.29
	7	3.00	1.25
	8	3.50	1.20
	9	4.00	1.14
	10	4.50	1.06
	11	5.00	0.96
	12	5.50	0.83
	13	6.00	0.63
	14	6.50	0.82
A4 X=5.00m Z=-11.25m	1	0.00	1.97
	2	0.50	1.97
	3	1.00	1.97
	4	1.50	1.96
	5	2.00	1.96
	6	2.50	1.95
	7	3.00	1.95
	8	3.50	1.93
	9	4.00	1.90
	10	4.50	1.87
	11	5.00	1.81
	12	5.50	1.69
	13	6.00	1.48
	14	6.50	1.63

DOWNSTREAM

Cut-off	S.No.	Depth m	Exit Gradient (1: ?)
B1 X=189.00m Z=11.25m	1	0.00	1.76
	2	0.50	1.75
	3	1.00	1.74
	4	1.50	1.72
	5	2.00	1.69
	6	2.50	1.65
	7	3.00	1.60
	8	3.50	1.54
	9	4.00	1.46
	10	4.50	1.36
	11	5.00	1.25
	12	5.50	1.09
	13	6.00	0.80
	14	6.50	0.99
B2 X=214.00m Z=11.25m	1	0.00	2.97
	2	0.50	2.96
	3	1.00	2.97
	4	1.50	2.96
	5	2.00	2.95
	6	2.50	2.92
	7	3.00	2.91
	8	3.50	2.88
	9	4.00	2.84
	10	4.50	2.75
	11	5.00	2.68
	12	5.50	2.47
	13	6.00	2.14
	14	6.50	1.96
B3 X=214.00m Z=-11.25m	1	0.00	2.97
	2	0.50	2.96
	3	1.00	2.96
	4	1.50	2.94
	5	2.00	2.95
	6	2.50	2.93
	7	3.00	2.90
	8	3.50	2.87
	9	4.00	2.82
	10	4.50	2.75
	11	5.00	2.70
	12	5.50	2.49
	13	6.00	2.16
	14	6.50	2.09
B4 X=189.00m Z=-11.25m	1	0.00	1.75
	2	0.50	1.75
	3	1.00	1.74
	4	1.50	1.72
	5	2.00	1.69
	6	2.50	1.65
	7	3.00	1.60
	8	3.50	1.53
	9	4.00	1.46
	10	4.50	1.35
	11	5.00	1.25
	12	5.50	1.09
	13	6.00	0.70
	14	6.50	0.97

Table-5.34

HYDRAULIC GRADIENT ALONG CUT-OFF DEPTH (3.0m) FOR BOTH UNLINED CANALS

UPSTREAM				DOWNSTREAM			
Cut-off	S.No.	Depth m	Exit Gradient (1: ?)	Cut-off	S.No.	Depth m	Exit Gradient (1: ?)
A1 X=5.00m Z=11.25m	1	0.00	1.58	B1 X=189.00m Z=11.25m	1	0.00	0.975
	2	0.50	1.56		2	0.49	0.967
	3	1.00	1.55		3	0.97	0.933
	4	1.50	1.51		4	1.46	0.874
	5	2.00	1.39		5	1.94	0.783
	6	2.50	1.26		6	2.50	0.617
	7	3.00	1.34		7	3.00	0.849
A2 X=20.00m Z=11.25m	1	0.00	0.77	B2 X=214.00m Z=11.25m	1	0.00	2.326
	2	0.50	0.76		2	0.50	2.308
	3	1.00	0.73		3	1.00	2.269
	4	1.50	0.68		4	1.50	2.201
	5	2.00	0.62		5	2.00	2.112
	6	2.50	0.42		6	2.50	1.800
	7	3.00	0.71		7	3.00	2.069
A3 X=20.00m Z=-11.25m	1	0.00	0.77	B3 X=214.00m Z=-11.25m	1	0.00	2.344
	2	0.49	0.76		2	0.50	2.310
	3	0.97	0.74		3	1.00	2.267
	4	1.46	0.68		4	1.50	2.177
	5	1.94	0.61		5	2.00	2.101
	6	2.50	0.46		6	2.50	1.707
	7	3.00	0.74		7	3.00	1.910
A4 X=5.00m Z=-11.25m	1	0.00	1.58	B4 X=189.00m Z=-11.25m	1	0.00	0.975
	2	0.50	1.57		2	0.49	0.967
	3	1.00	1.54		3	0.97	0.932
	4	1.50	1.50		4	1.46	0.877
	5	2.00	1.41		5	1.94	0.784
	6	2.50	1.24		6	2.50	0.605
	7	3.00	1.61		7	3.00	0.860

Table-35

EXIT GRADIENT AT THE CUT OFF END FOR HIGHER LINED CANAL

	A1	A2	A3	A4	B1	B2	B3	B4
250	2.74	1.51	1.51	2.72	1.16	2.60	2.61	1.16
230.625	2.69	1.48	1.48	2.68	1.16	2.59	2.60	1.16
211.25	2.65	1.45	1.45	2.64	1.15	2.59	2.60	1.15
186.25	2.59	1.41	1.41	2.58	1.15	2.58	2.58	1.14
161.25	2.50	1.35	1.35	2.49	1.14	2.56	2.57	1.14
136.25	2.38	1.27	1.27	2.37	1.12	2.54	2.55	1.12
111.25	2.24	1.18	1.17	2.23	1.10	2.51	2.52	1.10
86.25	2.07	1.07	1.07	2.07	1.07	2.47	2.48	1.07
61.25	1.88	0.95	0.95	1.87	1.04	2.42	2.43	1.04
36.25	1.71	0.85	0.84	1.70	1.00	2.37	2.38	1.00

Table-36

EXIT GRADIENT AT THE CUT OFF END FOR BOTH LINED CANAL

Lining	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**
250	3.35	1.99	1.98	3.33	1.76	3.22	3.24	1.76
230.62	3.22	1.84	1.88	3.19	1.71	3.17	3.17	1.70
211.25	3.11	1.76	1.80	3.09	1.67	3.13	3.13	1.66
186.25	2.97	1.65	1.69	2.95	1.61	3.07	3.08	1.60
161.25	2.80	1.52	1.57	2.78	1.54	3.00	3.00	1.53
136.25	2.60	1.42	1.42	2.58	1.47	2.90	2.92	1.46
111.25	2.38	1.27	1.27	2.35	1.36	2.81	2.80	1.36
86.25	2.15	1.13	1.12	2.16	1.26	2.70	2.69	1.25
61.25	1.91	0.97	0.97	1.91	1.14	2.55	2.52	1.13
36.25	1.70	0.85	0.85	1.69	1.04	2.40	2.42	1.03

Table-5.37

UPLIFT PRESSURE ON BARREL FLOOR FOR DIFFERENT CUT-OFF DEPTH

(Length of lining = 250.00m)

Location	Lining Condition	Cut-off depth, m	Uplift Pressure, %
Barrel Floor at Z=11.25m	BOTH LINED	3.00	17.868
		6.50	18.27
		10.00	18.603
	HIGHER LINED	3.00	37.311
		6.50	37.485
		10.00	43.823
	BOTH UNLINED	3.00	74.176
		6.50	73.721
		10.00	81.061
Barrel Floor at Z=5.625m	BOTH LINED	3.00	17.808
		6.50	18.217
		10.00	18.525
	HIGHER LINED	3.00	34.675
		6.50	34.738
		10.00	34.796
	BOTH UNLINED	3.00	70.097
		6.50	69.615
		10.00	69.205
Barrel Floor at Z=0.00m	BOTH LINED	3.00	17.792
		6.50	18.204
		10.00	18.512
	HIGHER LINED	3.00	34.287
		6.50	34.326
		10.00	34.361
	BOTH UNLINED	3.00	69.299
		6.50	68.807
		10.00	68.383

Table-5.38

EXIT GRADIENT FOR DIFFERENT CUT-OFF DEPTH

Location	Cut-off Depth, m	Exit Gradient for different cases, (1 in ?)		
		Both Lined	Higher Lined	Unlined
A1	3.00	3.35	2.74	1.58
	6.50	4.48	3.56	1.97
	10.00	5.38	4.21	2.26
A2	3.00	1.99	1.51	0.77
	6.50	3.51	2.65	1.36
	10.00	4.78	3.61	1.86
A3	3.00	1.98	1.51	0.77
	6.50	3.53	2.67	1.36
	10.00	4.78	3.62	1.86
A4	3.00	3.33	2.72	1.58
	6.50	4.47	3.56	1.97
	10.00	5.38	4.20	2.26
B1	3.00	1.76	1.16	0.98
	6.50	3.21	2.13	1.76
	10.00	4.44	2.95	2.37
B2	3.00	3.22	2.60	2.33
	6.50	4.39	3.40	2.97
	10.00	5.36	4.02	3.42
B3	3.00	3.24	2.61	2.34
	6.50	4.40	3.41	2.97
	10.00	5.37	4.02	3.41
B4	3.00	1.76	1.16	0.98
	6.50	3.20	2.12	1.75
	10.00	4.44	2.94	2.40

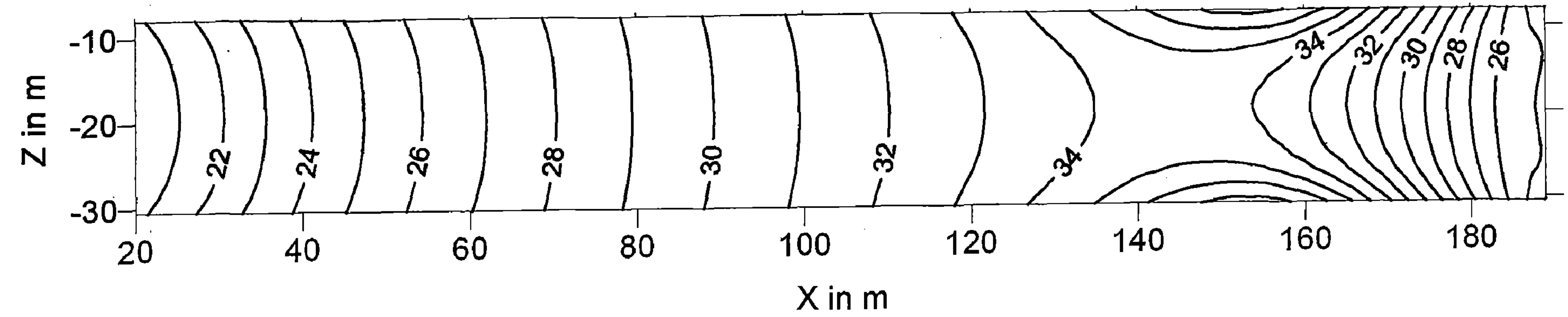


FIG. 5.78 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR HIGHER LINED CANAL, d= 10.0m

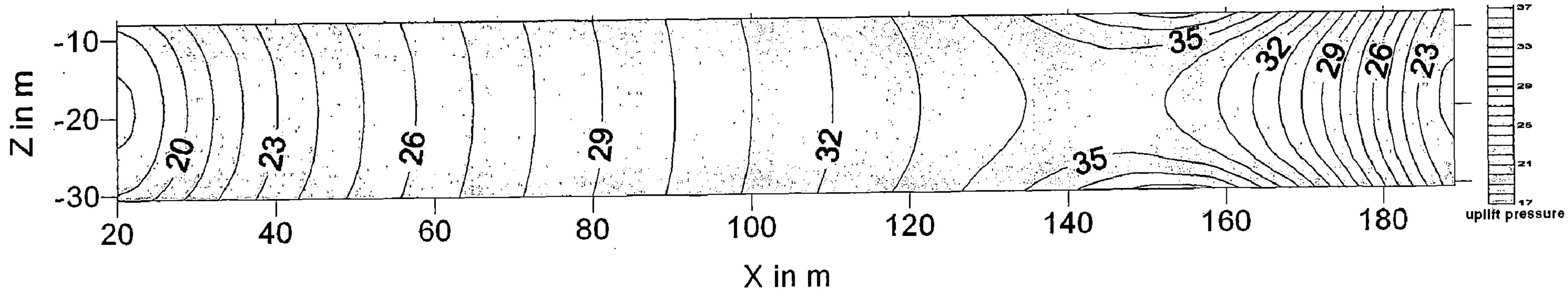


FIG. 5.79 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR HIGHER LINED CANAL, d= 6.5m

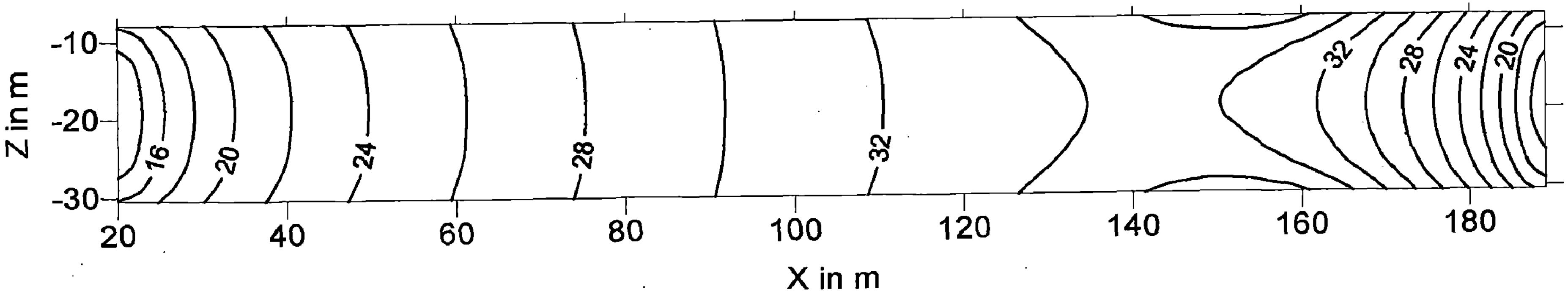


FIG. 5.80 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR HIGHER LINED CANAL, d= 3.0m

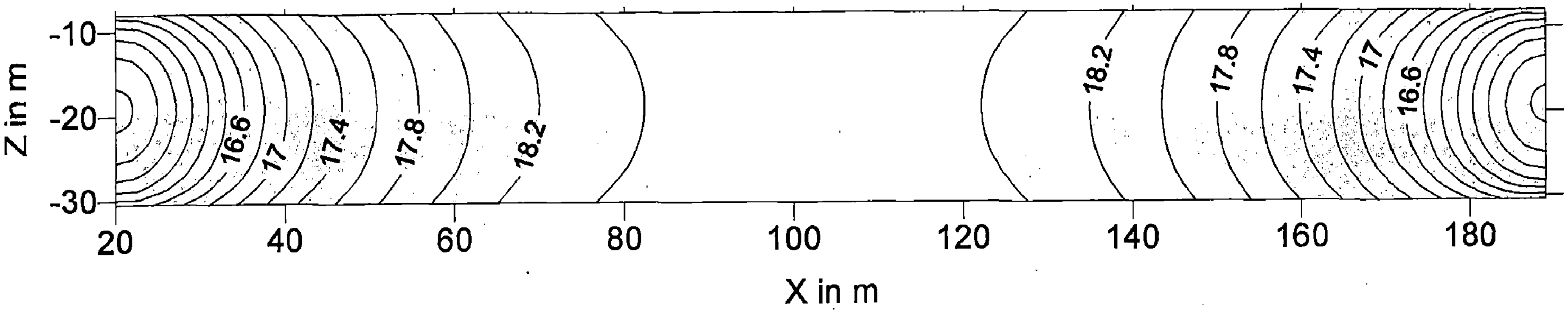


FIG. 5.81 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR BOTH LINED CANALS, d= 10.0m

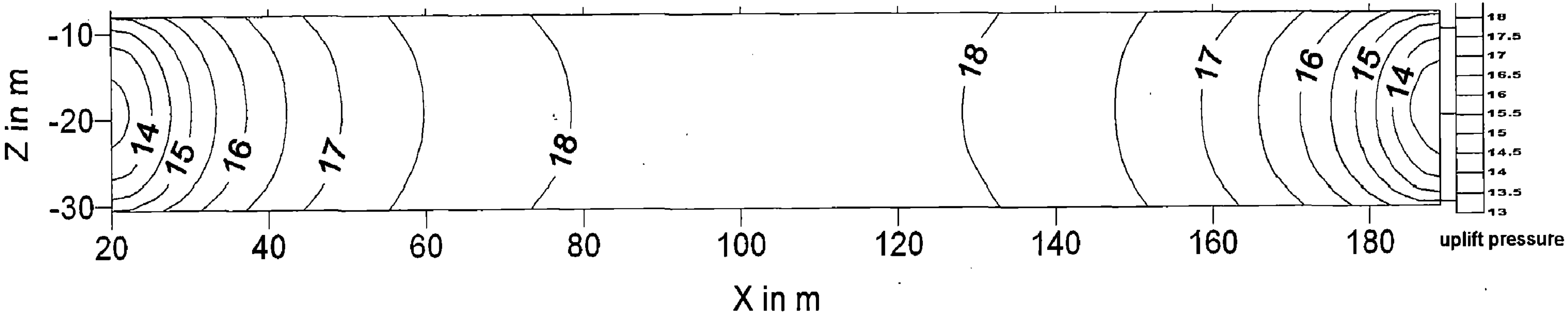


FIG. 5.82 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR BOTH LINED CANALS, d= 6.5m

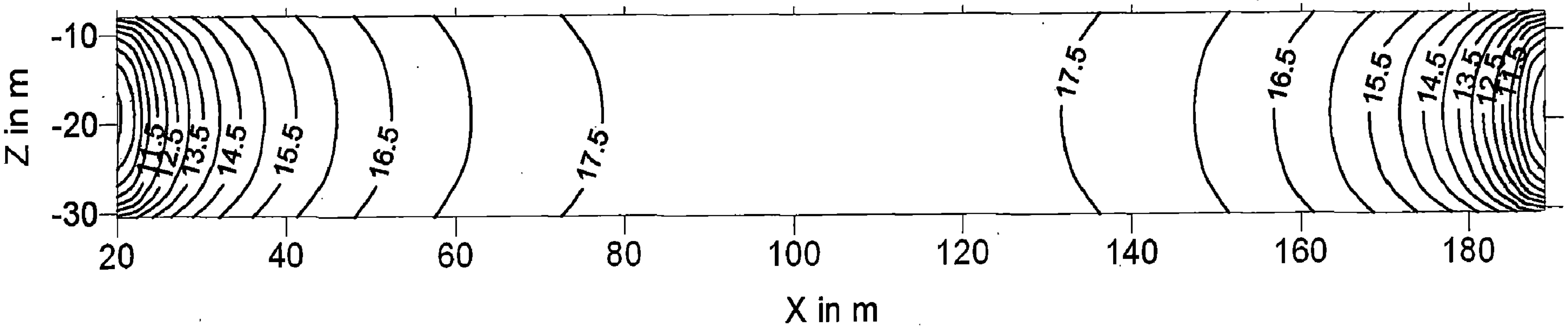


FIG. 5.83 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR BOTH LINED CANALS, d= 3.0m

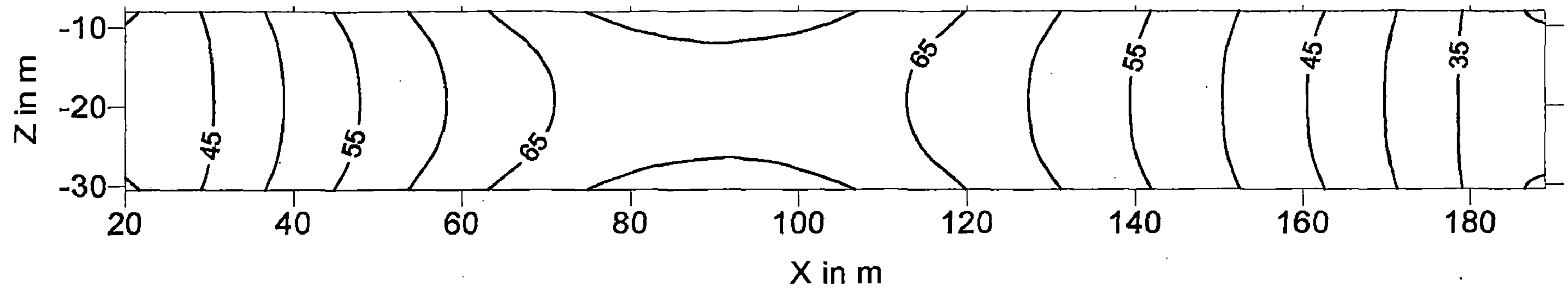


FIG. 5.84 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR UNLINED CANALS, d= 10.0m

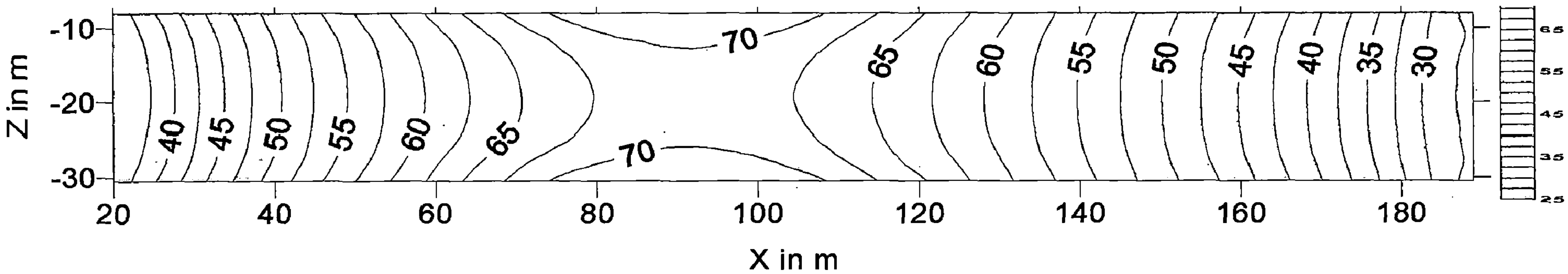


FIG. 5.85 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR BOTH UNLINED CANALS, d= 6.5m

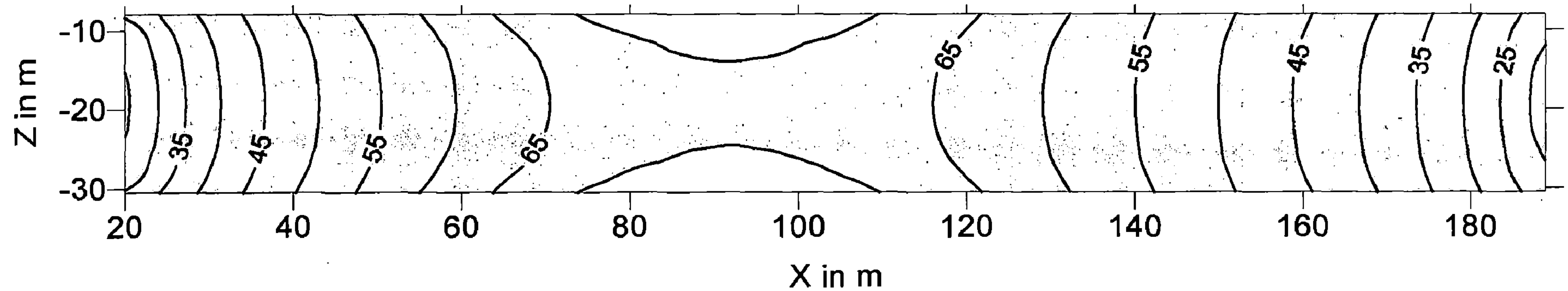


FIG. 5.86 UPLIFT PRESSURE CONTOUR ON THE BARREL FLOOR FOR BOTH UNLINED CANALS, d= 3.0m