APPENDIX

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1.1 Problem Formulation

The problem considered in this thesis is the drainage gallery constructed inside the dam body, which is constructed across a river. The various assumptions made in the formulation of the problem are:

- The permeability of the rockmass is isotropic.
- The rock foundation is isotropic and homogeneous.
- The rock foundation is not grouted before the construction of the dam.
- The drain holes from drainage gallery are just extended to touch the rock foundation, without penetrating the rock.
- The is no effect of the filling of the drain holes i.e. the pressure inside the drain holes is atmospheric at any time.
- No tensile crack is developed in the concrete dam heel and the drainage gallery is functioning properly without choking of the drain holes
- The concrete dam is completely impervious and no water flows though the dam.
- The rock foundation is assumed as the horizontal river bed.
- The dam axis is assumed perpendicular to the flow direction of the river.
- The quantity of water drained by the circular drain holes is same as that drained by the rectangular hole of same cross-secional area (assumed for calculating the spacing of drain holes).
- The water inside the drainage trench (in the plane strain formulation) is drained by the circular drain holes (assumed for calculating the spacing of drain holes).
- The discharge velocity in the cross-section of drain holes is constant, which is equal to the discharge velocity at the center of the drain holes (assumed for calculating the discharge of drain holes).
- The entry of water into the drainage gallery is only assumed through the drain holes.
- Drainage gallery is functioning properly without chocking of the drain holes.

The plan and sections of the formulated problem are shown in the figures below:

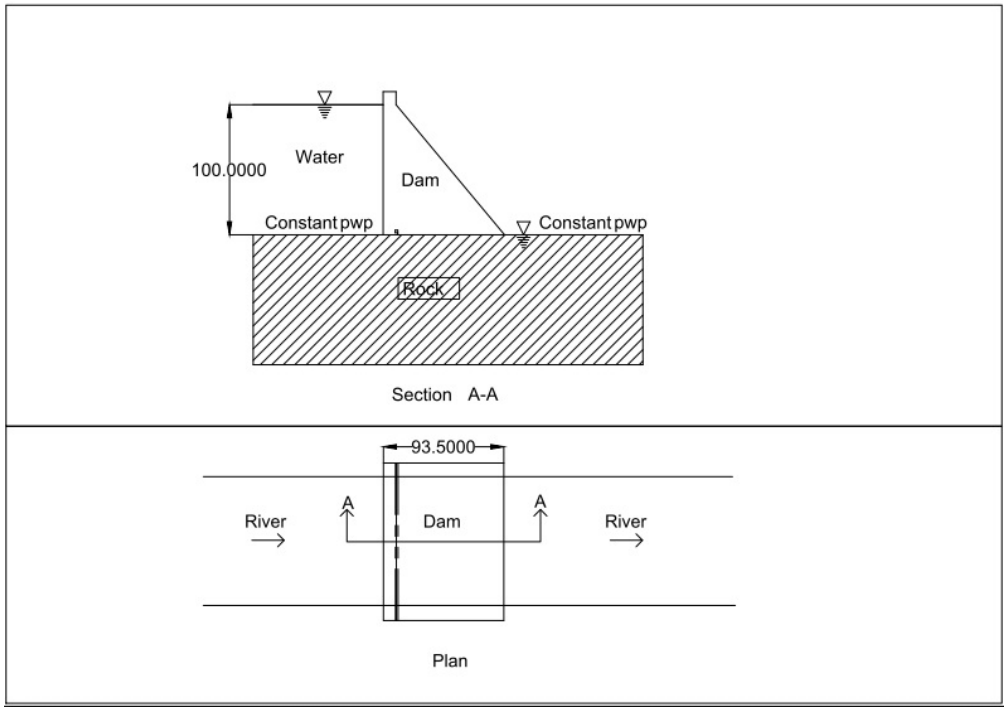

Figure 1-1: Plan and section of the formulated problem(dimensions in metre)

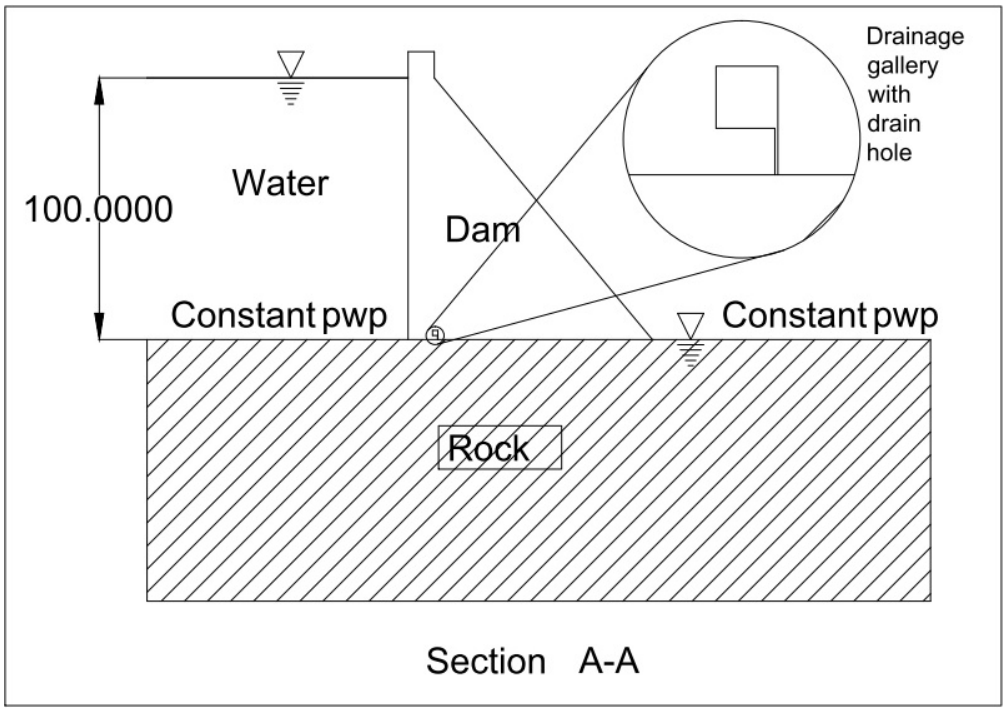

Figure 1-2: Section A-A of the formulated problem showing drainage gallery with drain hole (dimensions in metre)

1.2 Model Description

The model is prepared and analyzed in Rocscience Phase^2 8.0.

The depth of the water stored at the dam upstream is assumed as 100m whereas the dam downstream portion is assumed as the seepage surface with zero water depth. A freeboard of 10m is assumed. The height to width ratio of the dam is considered as 1:0.85 (Salmasi et al, 2011). The model extends 100m upstream and 200m downstream, from the heel of the dam. Since the portion of the river bed at upstream of heel and downstream of toe is acted upon by a constant pore water pressure, the extension of the model in these direction does not affect the results of the simulation. The depth of the model is kept equal to the upstream water depth i.e. 100m. So, the size of the model for numerical analysis is 300m X 100m. From dam geometry, the width of the dam base is 93.5m.

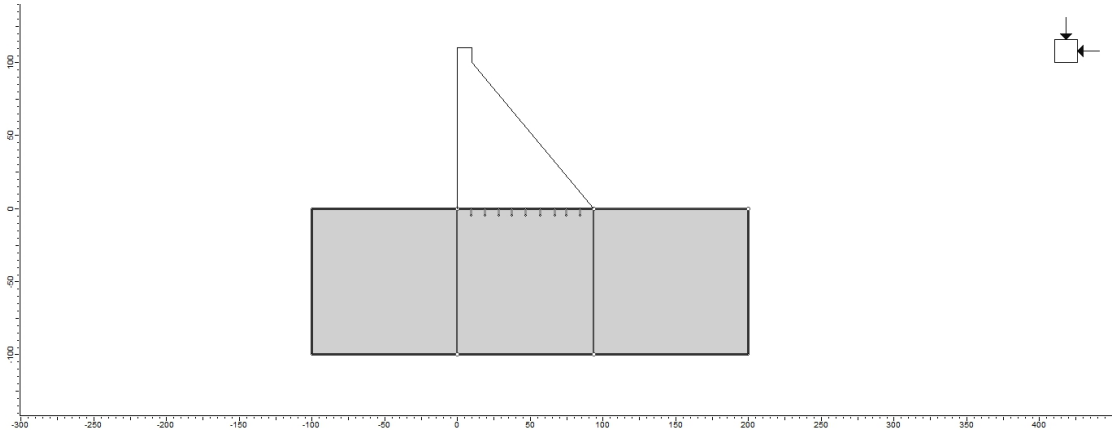

Figure 1-3: FEM Model showing dam foundation

The model is prepared for the rock foundation only, since the flow of water is restricted into the concrete dam. Since the entry of water into the drainage gallery is only through the drain holes, the hydraulic boundary condition can be applied to the dam-rock interface which is equal to the peizometer reading of the drain hole at the base of the dam.

A 50-stage model is prepared with varying upstream water level from 100m to 10m and varying position of drainage gallery from 10% to 40% of base width from upstream face of the dam.

The problem is formulated as plain strain problem. The loading problem is solved by using Gaussian elimination with maximum iteration of 500 steps. The tolerance for calculation is 0.001. For groundwater analysis, finite element analysis(FEA) is used with pore fluid unit weight of 9.81kN/m^3 . The groundwater problem is solved with maximum iteration of 500 steps and tolerance of 1e-6.

For meshing of the problem domain, uniform mesh is generated with three-noded triangle elements.

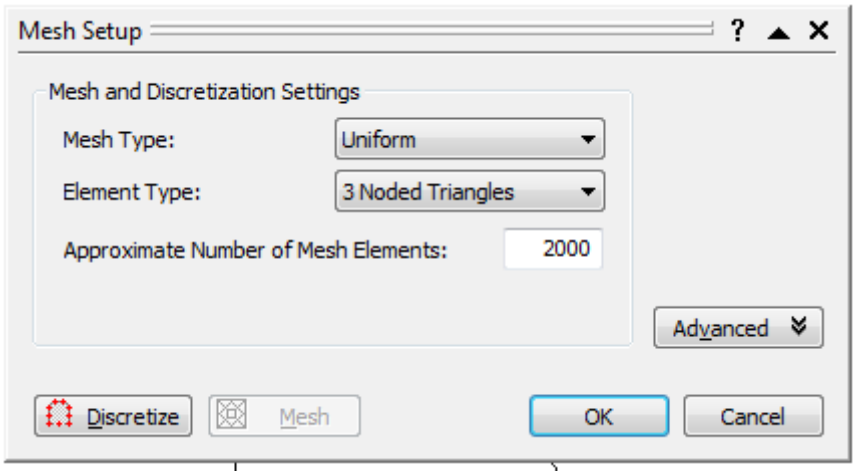

Figure 1-4: Mesh Setup with Element type and number

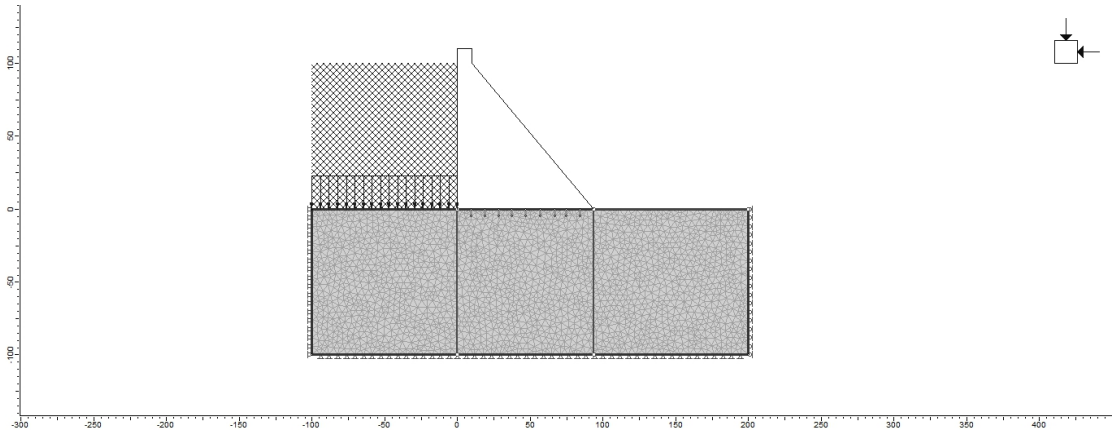

Figure 1-5: Model Discretization

The hydraulic boundary condition varies with upstream water level of 100m to 10m. Whereas zero pressure hydraulic boundary condition is applied at the drain hole position in the dam-rock interface and at downstream portion of the dam.

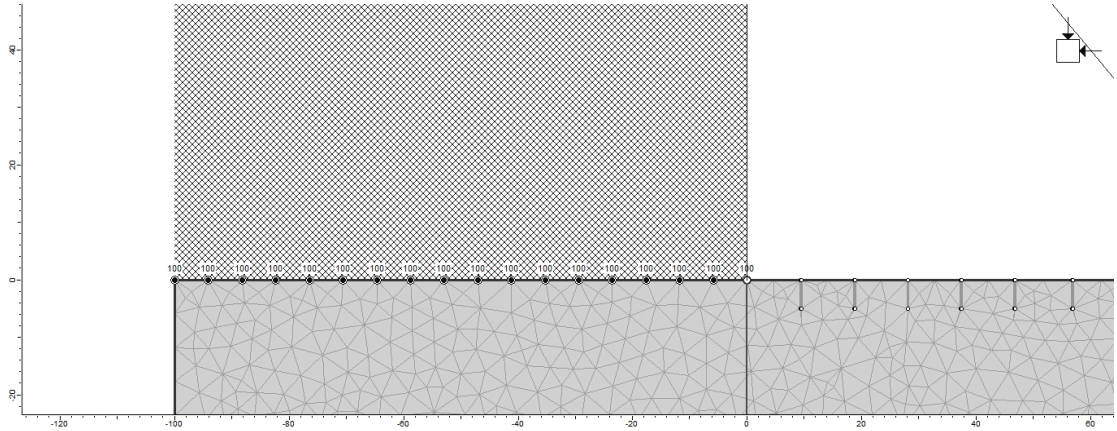

Figure 1-6: Model Discretization with upstream hydraulic boundary condition

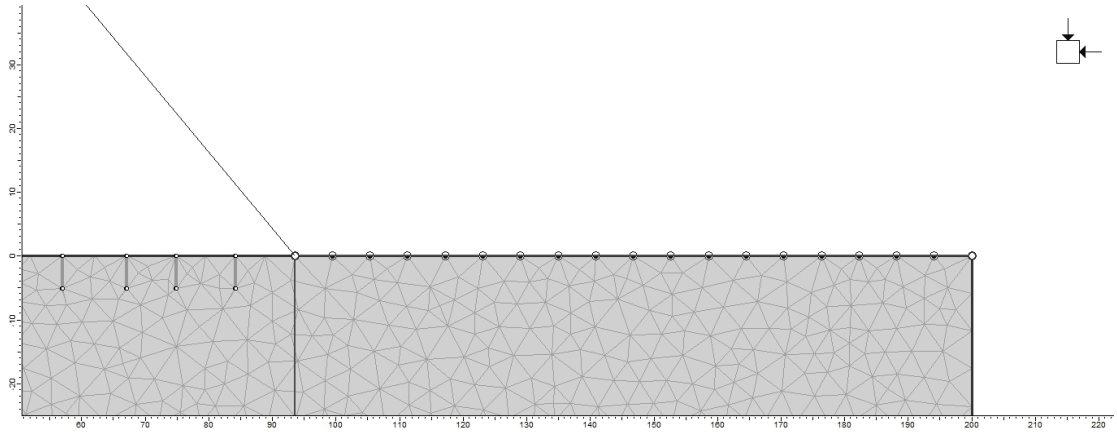

Figure 1-7: Model Discretization with downstream hydraulic boundary condition

The material model used for the rock foundation is assumed as homogeneous and isotropic. The properties of the material model used for the dam foundation is summarized in Figure 1-6.

Color	
Initial element loading	field stress & body force
Unit weight	0.027 MN/m3
Elastic type	isotropic
Young's modulus	20000 MPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Peak tensile strength	0 MPa
Residual tensile strength	0 MPa
Peak friction angle	35 degrees
Peak cohesion	10.5 MPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees

Air Entry Value	0 MPa
Hydraulic model	Simple
Soil Type	General
Ks	1e-007 m/s
K2/K1	1
K Angle	0 degrees

Figure 1-8: Material model used for the dam foundation

The model prepared is analyzed and results for contour of pore pressure is obtained. The results for pore pressure for different cases are compared to obtain the suitable position of drainage gallery which gives the minimum uplift pressure. The results and comparision graphs are shown in “Chapter 4 Analysis, Result and Discussion” of the main report. The results for upstream water level 100m and various positions of the drainage gallery are shown in Figure 1-7 to Figure 1-11.

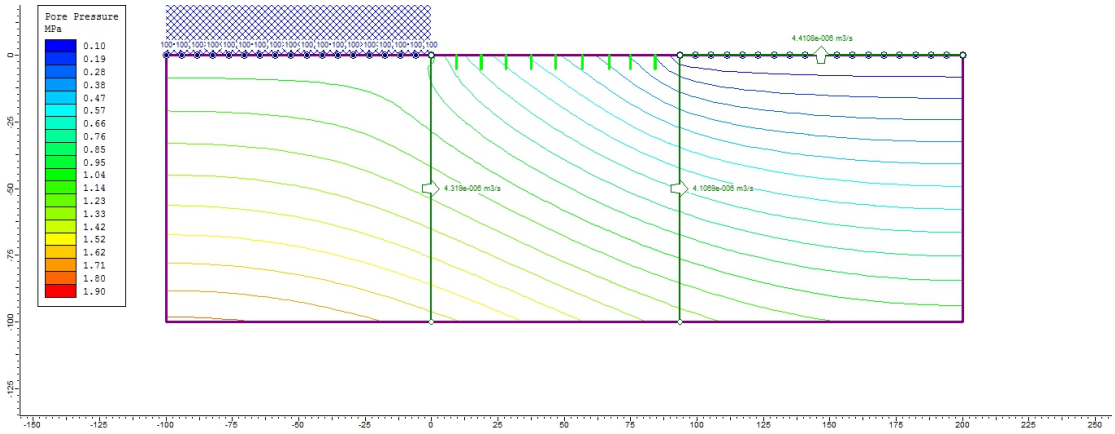

Figure 1-9: Contour obtained for pore pressure without drainage gallery

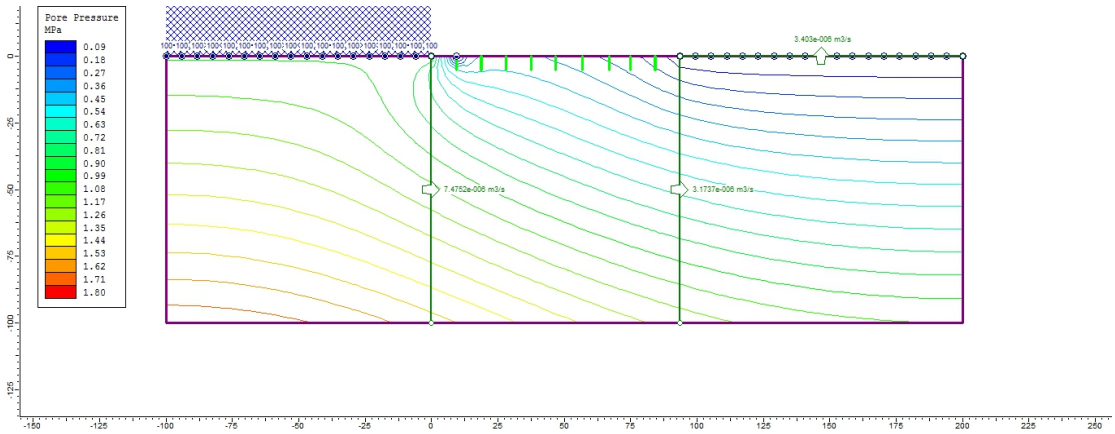

Figure 1-10: Contour obtained for pore pressure when drainage gallery is placed at 10% of base width from upstream face

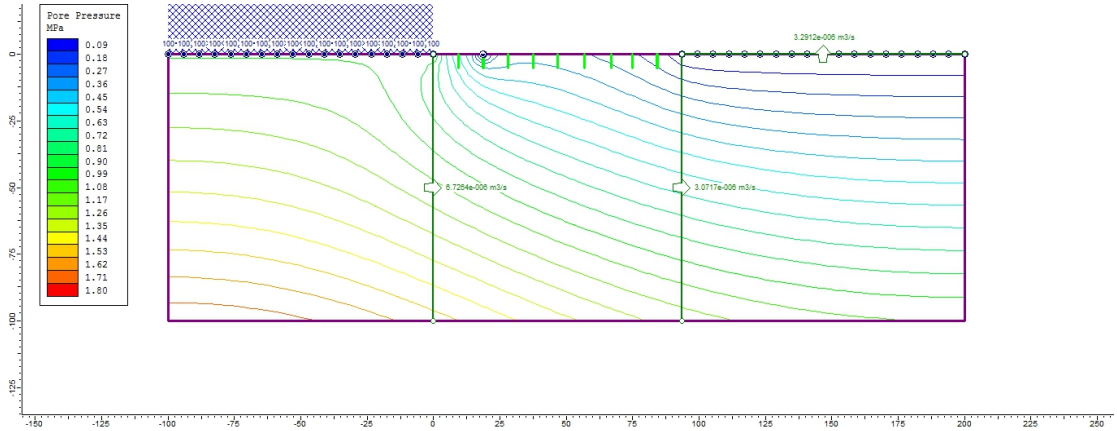

Figure 1-11: Contour obtained for pore pressure when drainage gallery is placed at 20% of base width from upstream face

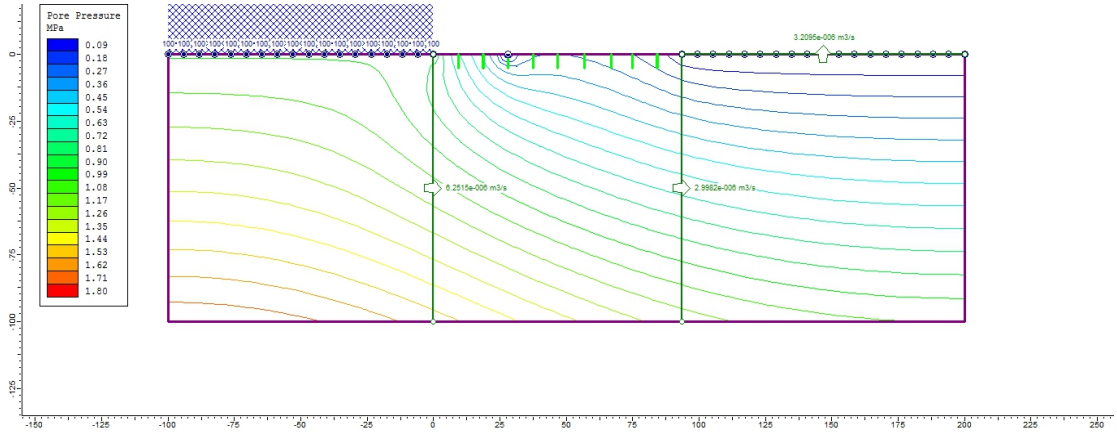

Figure 1-12:- Contour obtained for pore pressure when drainage gallery is placed at 30% of base width from upstream face

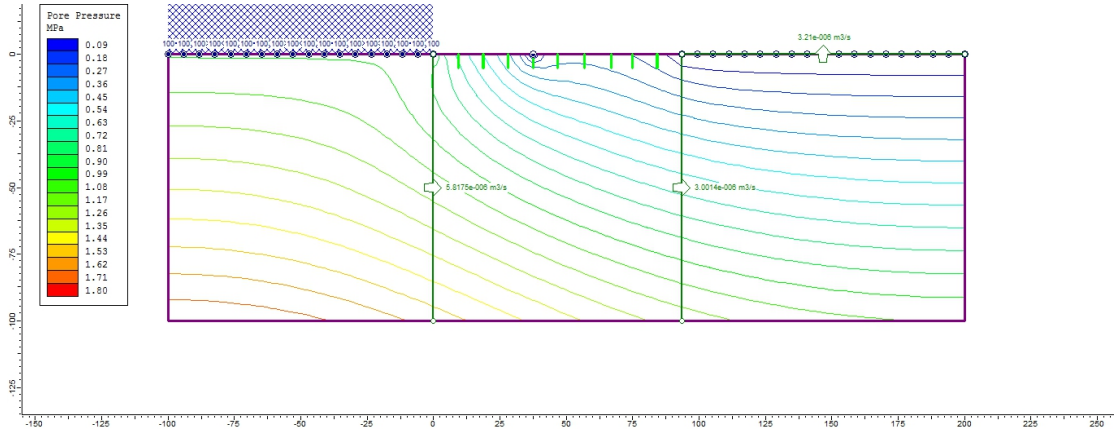

Figure 1-13:- Contour obtained for pore pressure when drainage gallery is placed at 40% of base width from upstream face

Similarly, flownets are constructed and the effect of drainage gallery is clearly shown in the plot of flownet. The flownets for upstream water level 100m and various positions of the drainage gallery are shown in Figure 1-12 to Figure 1-16.

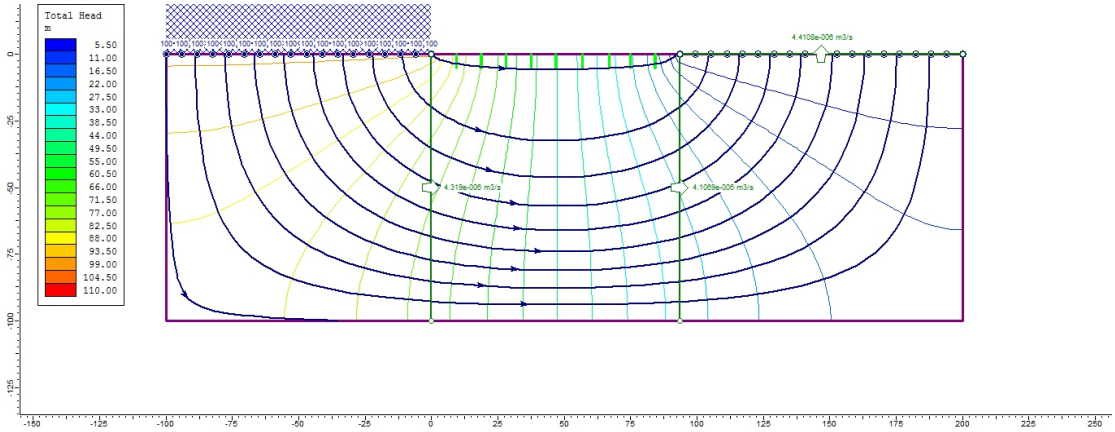

Figure 1-14: Flownet obtained with no drainage gallery

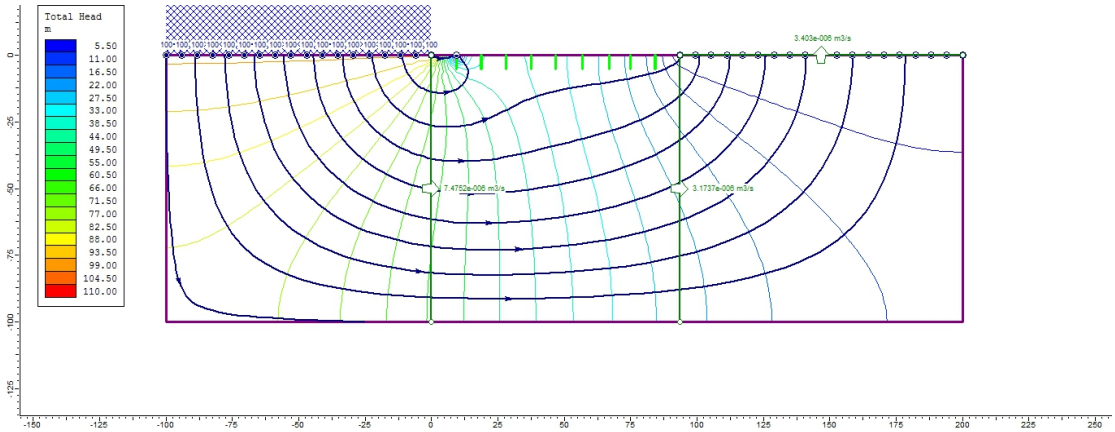

Figure 1-15:- Flownet obtained when drainage gallery is placed at 10% of base width from upstream face

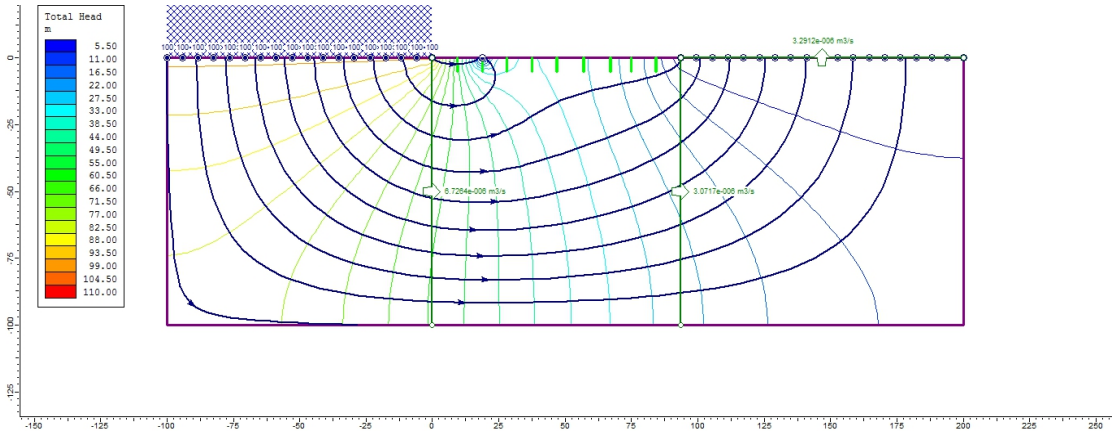

Figure 1-16: Flownet obtained when drainage gallery is placed at 20% of base width from upstream face

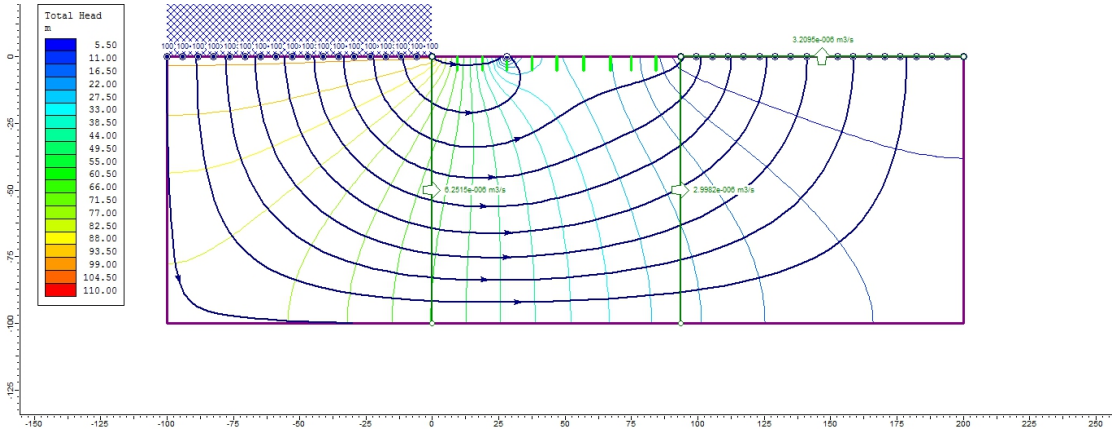

Figure 1-17: Flownet obtained when drainage gallery is placed at 30% of base width from upstream face

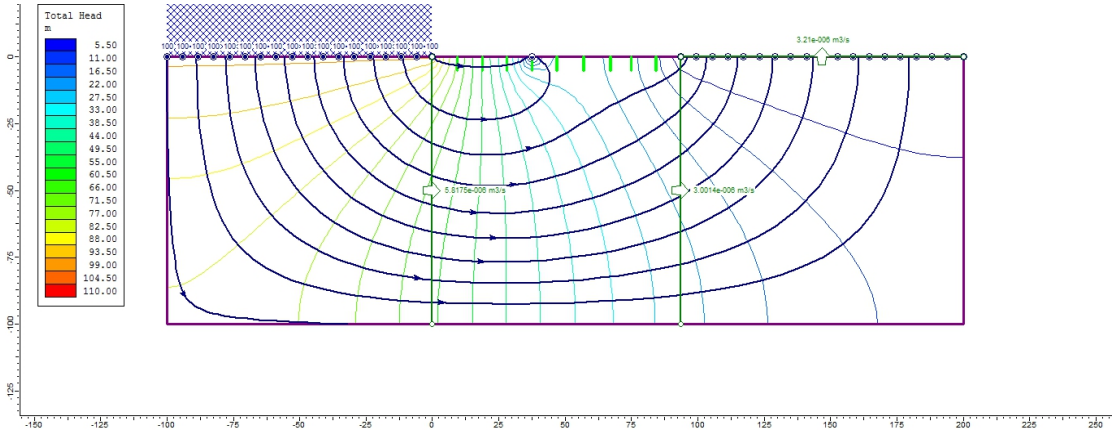

Figure 1-18: Flownet obtained when drainage gallery is placed at 40% of base width from upstream face

2 APPENDIX II

2.1 Calculation and Results

The calculations are carried out in Microsoft Office Excel from the results obtained in Phase^2 v8.0. A sample calculation for 100m upstream head and placement of drainage gallery at 20% of base width from upstream face of the dam is shown here.