HYDROGEOLOGICAL ASSESSMENT OF THE THAR LIGNITE PROSPECT

1. R.N. Singh and L. R. Stace , *The University of Nottingham , UK*
2. A.S. Atkins *Staffordshire University, UK*
3. A. G. Pathan, *Mehran University of Engineering and Technology, Sindh, Pakistan*
4. F Doulati Ardejani, *Shahrood University of Technology, SHAHROOD, IRAN*

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Paper is concerned with

- Geological and hydro-geological studies of Thar coal field
- Bara formation-depth 130-250m
- In a mining prospect of 40 Km^2
  Total reserves 9 billion Tonnes.
  Recoverable 3 billion Tonnes
- Thickness of lignite – 50-60m
- Lignite contains- 42-49% moisture

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Paper Presents

- Results of pumping out tests
- Ground water model to simulate de-pressuring of aquifers
- Results show that 22 pumping out wells are required
  - Period of 10 years
  - Overall pumping rate of 53 L/sec

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Problems of lignite mining

1. Lignite deposits are under-laid and overlaid by aquifers presenting problems:
   - Inflow of water causing safety, operational and environmental problems.
2. Confined aquifers below the deposit cause:
   - In-pit flooding,
   - Erosion of toe of high-wall,
   - High-wall instability.

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Background

The paper presents;

- Hydrogeological appraisal of proposed mining operations in Thar Lignite prospect, Sindh , Pakistan
- Thar coalfield -9000 km2,
- Estimated reserves- 192 Bt lignite;
  - Depth of seams- 130 to 250m,
  - Seam thickness- between 7.5m to 36m,
  - Maximum thickness of individual seam 23m,
  - Eight blocks have been explored which have;
    - 9 Bt proven reserves.
    - Coal seams surrounded by three aquifers.

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Main Approach

In brief, the paper addresses two questions;

1. Dewatering Schemes for top, intermediate and bottom aquifers,
2. Estimation of inflow quantities from each aquifer using;
   (a) Equivalent well approach
   (b) SEEP/W Finite Element Software Package

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Thar Lignite Field, Sindh, Pakistan

- 7th largest in the world discovered in 1994.
- 400 Km. East of Karachi.
- Total area of 9000 km^2
- Estimated resources of 193 Bt.
- Mining Area 40 km^2
- 9 Bt reserves

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Average Composition of Lignite

Moisture	46.77 %
Fixed carbon	16.66%
Volatile matter	23.46%
Ash	6.24%
Sulphur	1.16%
Heating value	10,898 Btu/lbs

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Thar prospects

- Eight areas being prospected.
- Proven coal reserves in 2005 were over 9 Bt in eight Prospects
- Total lignite resources in whole coalfield - 193 Bt

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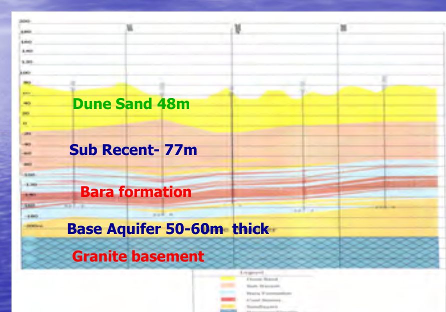
Geology of the Thar prospect



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Hydrogeology

1. Top aquifer
   - At the base of dune sand
   - Permeability 3 x 10^{-7}m/s
   - Water column up to 5m thick
   - Water table 10-12m, above mean sea level
2. Intermediate aquifer
   - Scattered lenses of sand
   - Permeability 10^{-5} to 10^{-7} m/s
3. Bottom aquifer
   - Beneath the coal formation down to the granite base
   - Fine to coarse sand grains, non-homogeneous permeability
   - 50-60m thick aquifer
   - Piezometric surface 25m above mean sea level
   - Aquifer covers an area of 15000 Km^2

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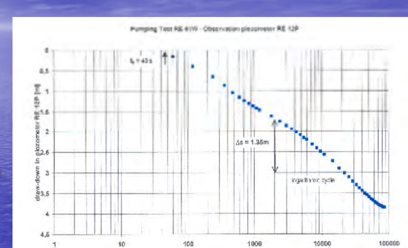
Evaluation of Pumping Test

Q=14 L/s

Δs=1.35m (draw down in one log cycle)



Pumping out well RE51; Observation well RE12P

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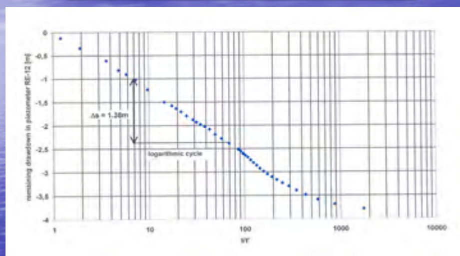
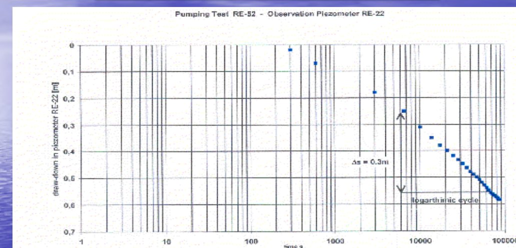
Recovery test on RE 51 and Observation well RE-12



Q=13L/s Δs= 1.38m in 1 log cycle

Pumping out test on RE-52 & Observation well RE 22



Piezometer distance = 30m;

Δ_s= Draw down in one log cycle = 0.3 m

T = 2.3x0.013/4x3.14x0.3 = 7.9x10^{-3} m^2/s

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Pumping Out Test in Well Results

PUMPING OUT TESTS	Results
1. RE51-RE12P Δs= 1.35m; Q=0.013 m3/s to=43s; r=25m	k=6.3 x 10^{-5} m/s S=2.0x10^{-4}
2. RE51-RE12P Δs= 1.38; Q=0.014 m3/s	k=8.0x 10^{-5} m/s S=8x 10^{-4}
3. RE52-RE22 Δs=0.3m; Q=0.013m3/s	k= 2.63 x 10^{-4} m/s S= 2.7 x 10^{-3}

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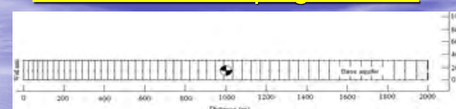
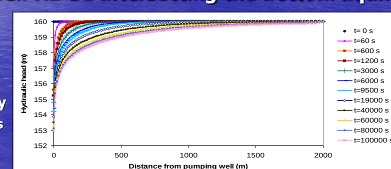
FE Model of Pumping out test



258 nodes, 50 elements in single 30m layer, model length-2000m, 8-noded elements

F E model of well RE-51 intersecting the Bottom aquifer

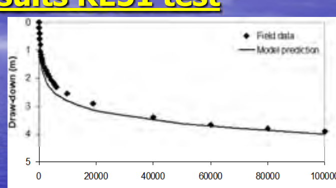
1.No flow U & L Boundaries.
2. Head Boundary on RHS
3LHS FLUX Boundary
4. k= 7.3 x 10-5 m/s
S= 2.9x 10-4
Initial Head= 160m



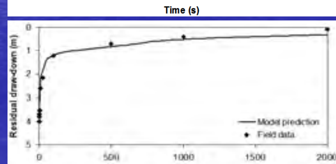
Hydraulic head vs. draw down of RE-51 well at different radial distances for 24 time steps Transient flow condition 16

Comparison of field and predicted results RE51 test

Comparison of model and field results



Residual draw down RE12P vs. time



Close agreement

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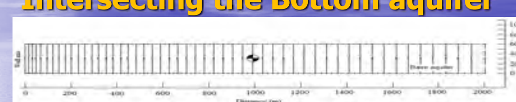
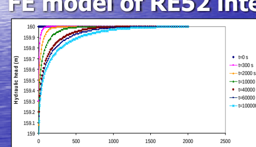
Finite element model of well RE-52 Intersecting the Bottom aquifer

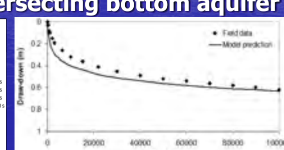


258 nodes, 51 elements 60m thick layer -2000m length; 8nodded elements

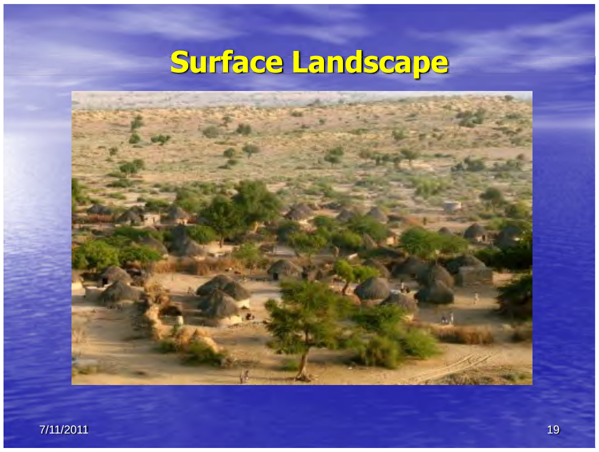
FE model of RE52 intersecting bottom aquifer



Hydraulic head vs distance from well



Draw down vs time
Showing Reasonable agreement 18


Surface Landscape
7/11/2011
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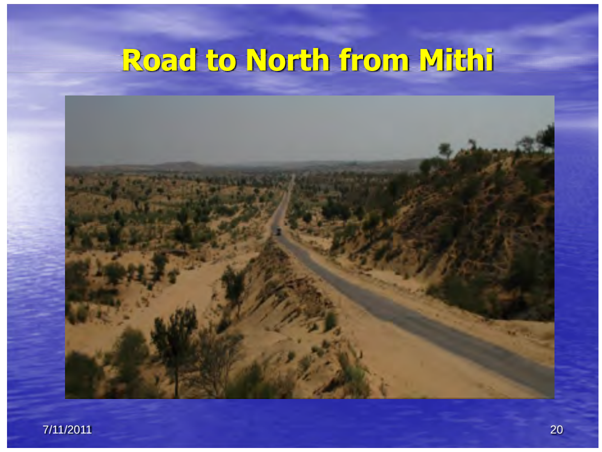
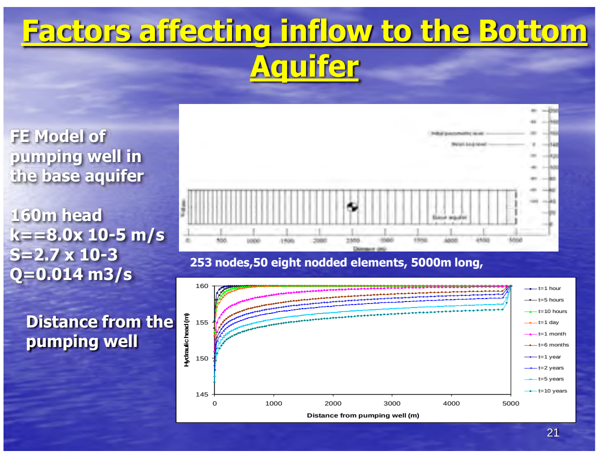
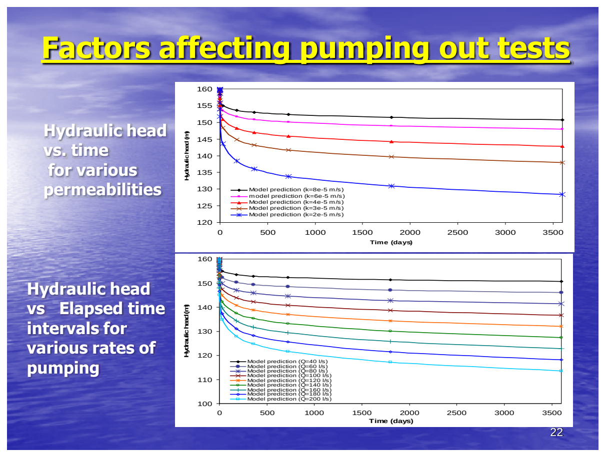
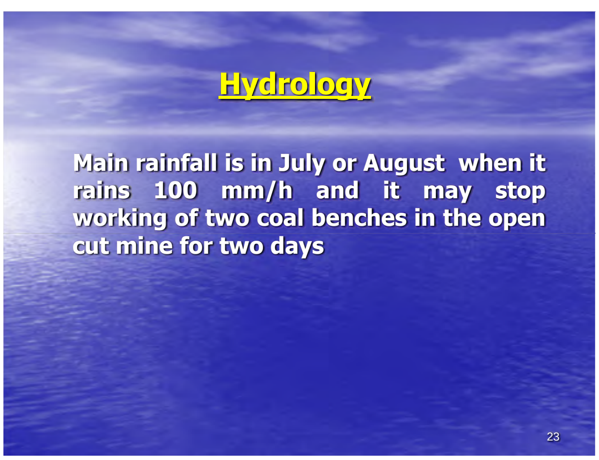

Road to North from Mithi
7/11/2011
20


Factors affecting inflow to the Bottom Aquifer
FE Model of pumping well in the base aquifer
160m head
k==8.0x 10-5 m/s
S=2.7 x 10-3
Q=0.014 m3/s
253 nodes,50 eight nodded elements, 5000m long,
Distance from the pumping well
Distance from pumping well (m)
21


Factors affecting pumping out tests
Hydraulic head vs. time for various permeabilities
Hydraulic head vs Elapsed time intervals for various rates of pumping
Time (days)
22


Hydrology
Main rainfall is in July or August when it rains 100 mm/h and it may stop working of two coal benches in the open cut mine for two days
23


Mithi district after rain
7/11/2011
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After Rain – Mithi District

After Rain , Thar Desert, Sindh

Total water inflow due to rainfall

Q = 2.78 K A I

= 2.78 x 463.77 x 0.58 x 100

= 7.5 x 10 ^{4} litres/s

Where,

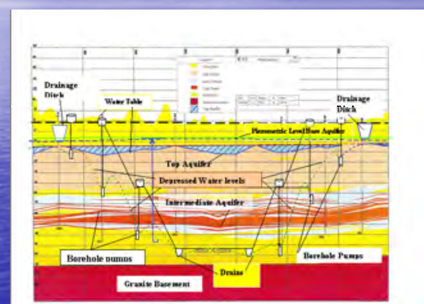
Q = Peak flow in litres/s

A = Catchment area in hectares = 463.77 hectares

K = run-off co-efficient in decimal = 0.58

I = rainfall intensity = 100 mm/h

Aquifers Dewatering in The Thar Prospect

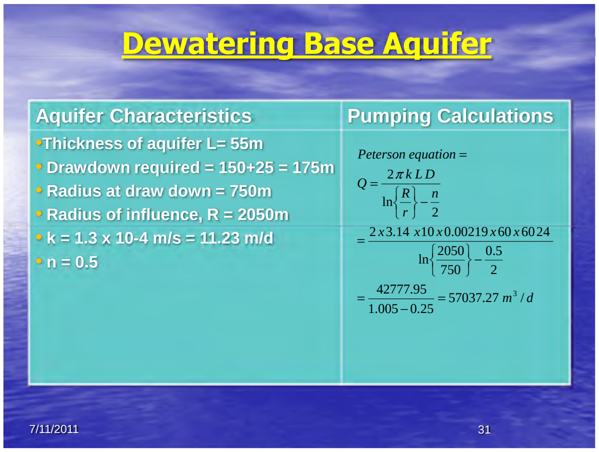


Dewatering First Aquifer

Aquifer Characteristics	Pumping Calculations
• Thickness of aquifer L= 5m • Drawdown require D = 20m • Radius at which draw down required = 2100m	Unconfined steady state linear aquifer Modified Dupuit (1865) Equation:
• Radius of influence, R = 3000m • k = 3 x 10-7 m/s = 0.0259 m/d • T = transmissivity = 0.0259 x 5 = 0.13 m²/d • h = 12m • H = 20	$Q = \frac{\pi\ k\left(H^{2} - h^{2}\right)}{\ln\left\{\frac{R}{r}\right\}}$ $= \frac{3.14\ x\ 0.0259\ \left(20^{2} - 12^{2}\right)}{\ln\left\{\frac{3000}{2100}\right\}}$ $= 58\ m^{3} / d$

Dewatering Second Aquifer

Aquifer Characteristics	Pumping Calculations
Scattered lenses • Thickness of aquifer L= 10m • Drawdown required = 89+20=100m • Radius at draw down = 1050m	$Q = \frac{2\pi k\ L D}{\ln\left\{\frac{R}{r}\right\} - \frac{n}{2}}$ (Peterson Equation)
• Radius of influence, R = 2500m • k = 10-6 m/s = 0.086 m/d • n = 0.5	$= \frac{2\pi\ x\ 0.86\ x\ 10\ x\ 100}{\ln\frac{2500}{1050} - \frac{0.5}{2}}$ $= \frac{5.4\ x\ 100}{0.367} = 14.69\ m^{3} / d$


Dewatering Base Aquifer
Aquifer Characteristics
Pumping Calculations
Thickness of aquifer L= 55m
Drawdown required = 150+25 = 175m
Radius at draw down = 750m
Radius of influence, R = 2050m
k = 1.3 x 10-4 m/s = 11.23 m/d
n = 0.5
Peterson equation =
$Q = \frac{2\pi k L D}{\ln\left\{\frac{R}{r}\right\} - \frac{n}{2}}$
$= \frac{2 x 3.14\, x 10 x 0.00219 x 60 x 6024}{\ln\left\{\frac{2050}{750}\right\} - \frac{0.5}{2}}$
$= \frac{42777.95}{1.005 - 0.25} = 57037.27\ m^3/d$
7/11/2011
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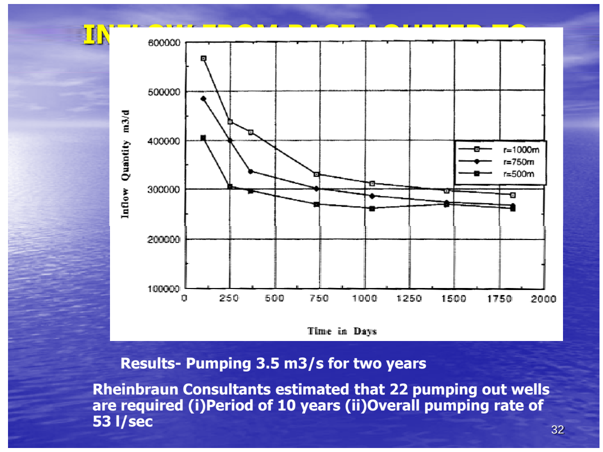
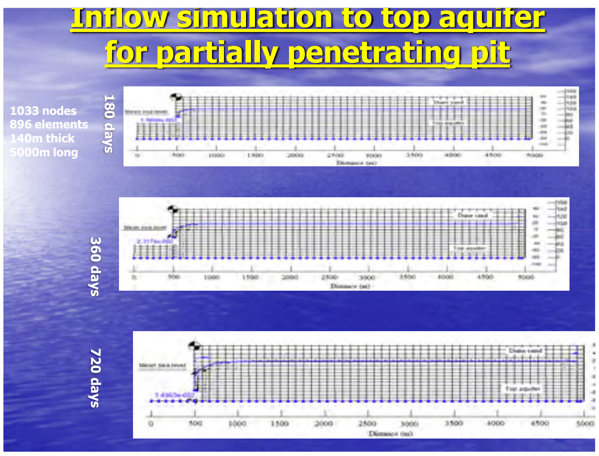
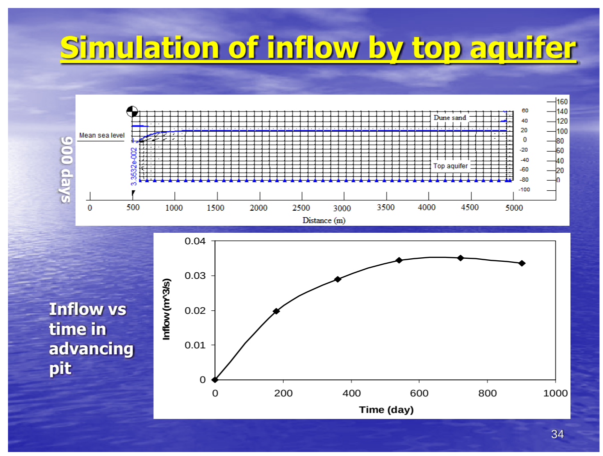
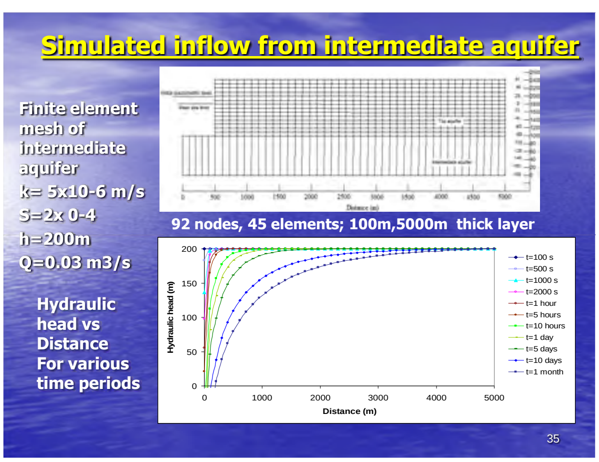
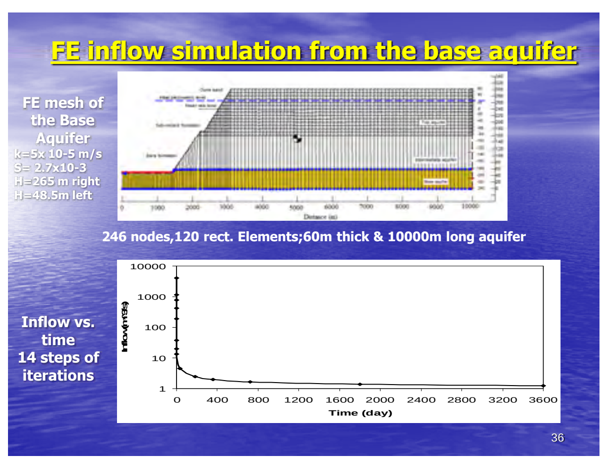

Inflow Quantity m3/d
Time in Days
r=1000m
r=750m
r=500m
Results- Pumping 3.5 m3/s for two years
Rheinbraun Consultants estimated that 22 pumping out wells are required (i)Period of 10 years (ii)Overall pumping rate of 53 l/sec
32


Inflow simulation to top aquifer for partially penetrating pit
1033 nodes
896 elements
140m thick
5000m long
180 days
360 days
720 days

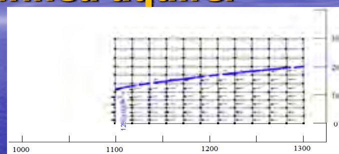

Simulation of inflow by top aquifer
900 days
Mean sea level
Dune sand
Top aquifer
Distance (m)
Inflow vs time in advancing pit
Inflow (m^3/s)
Time (day)
34


Simulated inflow from intermediate aquifer
Finite element mesh of intermediate aquifer
k= 5x10-6 m/s
S=2x 0-4
h=200m
Q=0.03 m3/s
92 nodes, 45 elements; 100m,5000m thick layer
Hydraulic head vs Distance For various time periods
Hydraulic head (m)
Distance (m)
t=100 s
t=500 s
t=1000 s
t=2000 s
t=1 hour
t=5 hours
t=10 hours
t=1 day
t=5 days
t=10 days
t=1 month
35


FE inflow simulation from the base aquifer
FE mesh of the Base Aquifer
k=5x 10-5 m/s
S= 2.7x10-3
H=265 m right
H=48.5m left
246 nodes,120 rect. Elements;60m thick & 10000m long aquifer
Inflow vs. time
14 steps of iterations
Time (day)
36

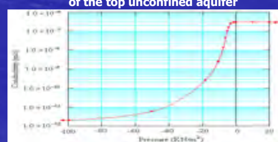
Steady state flow in top unconfined aquifer

Constant Head=20m
RADIAL DISTANCE= 1300m
r=1100m
Constant head at pit=12m
K=3.0x 10-7 m/s
Nodes =132nodes,
110 Elements
10 Layers of 3m thick



Finite Element grid, velocity vectors and water table of the top unconfined aquifer

Inflow k to fully penetrating top aquifer is 112 m3/d



Modified k of unconfined aquifer

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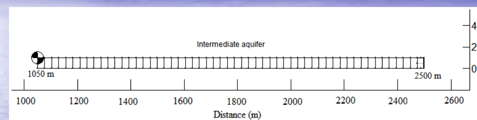
Intermediate Confined aquifer



55 Elements, 116 nodes,in single layer 10m thick and 1450m long
Aquifer thickness= 10m
K= 1.0 x 10-6 m/s
D=100m
Inflow quantity= 141 m3/d

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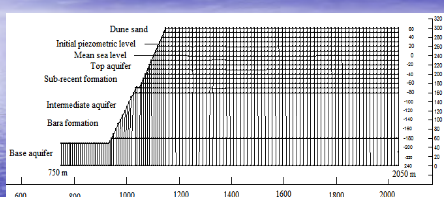
FE Grid of bottom confined aquifer



Axis symmetrical grid 246 nodes, 120 rectangular elements 55m thick single layer
k= 2.19x 10-3 m/s
D=260m ; r= 750m ; radius of influence=2050m

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Comparison of analytical and numerical Inflow Results

Inflow Rate m^3/d	Analytical solution m^3/d	Numerical solution m^3/d	% Error
Top Unconfined Aquifer	Modified Dupuit Eq. Q=116 m^3/d	112 m^3/d	3.4%
Intermediate Con. Aquifer	Peterson EQ. 147 m^3/d	141 m^3/d	4.1%
Base Aquifer Confined k=2.19 x 10^{-5}m/s k= 1.3 x 10^{-4}m/s	Peterson Eq. Q= 2.25 x 10^5 m^3/d Q=1.34 x10^5 m^3/d	2.34x10^5 m^3/d 1.4x 10^5 m^3/d	6.4% 4.43%

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CONCLUSIONS

- The paper uses the SEEP/W software to analyse pumping out data in RE-51 and RE-52 wells in an infinite confined aquifer in the Thar Lignite prospect.
- The pumping test simulation results were close to the analytical results and field data.

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Conclusions (Continued)

- A model simulation of a hypothetical pumping out well carried out a sensitivity analysis of various factors affecting ground water inflow.
- It was indicated that the model is sensitive to permeability of the aquifer as an input data.

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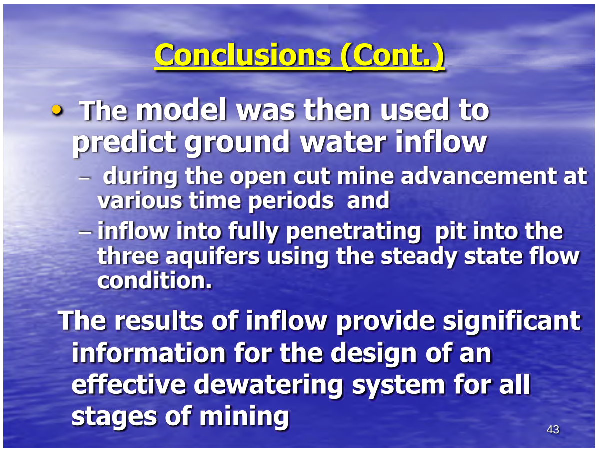
Conclusions (Cont.)
The model was then used to predict ground water inflow
– during the open cut mine advancement at various time periods and
– inflow into fully penetrating pit into the three aquifers using the steady state flow condition.
The results of inflow provide significant information for the design of an effective dewatering system for all stages of mining
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Thank You Very Much for Your Attention
Raghu N. Singh
University of Nottingham
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