# THE HYDROGEOLOGICAL FRAMEWORK OF DEEP AQUIFERS IN BANGLADESH

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## Motivation

Throughout much of Bangladesh, beneath the Holocene floodplains to a depth of *ca* 150 m, elevated concentrations of arsenic render groundwater unpotable. Deeper groundwater has become the principal target for 'arsenic-safe' water supplies, yet despite there being *ca* 2000 'deep tubewells' in the recent DPHE 'deep aquifer' database (*DPHE, 2006*), there remains much uncertainty about the very existence of a discrete 'deep aquifer', and appropriate ways of characterising it and representing it in models. This poster describes progress towards an improved understanding of the 'deeper' hydrogeological environments in the floodplain regions of Bangladesh.

## Is there a discrete deeper aquifer?

Hydrogeological depth profiles illustrate the presence of a silty-clay aquitard, possibly discontiunous, at a depth of > 160 m at Meherpur and Magura (western Bangladesh). Elsewhere, *eg* at Manikganj and Faridpur (central Bangladesh) there appears to be no well-defined, continuous, deep aquitard. Only at Khulna (southern Bangladesh) there is operational evidence for the presence of an aquitard which protects a deep aquifer from vertical leakage of arsenic, and chloride, which are ubiquitous at shallower levels; pumping at > 15,000 m$^3$/day from 250-350 m has continued for > 25 years, with no adverse effects (*LGED/BRGM, 2005*), and an extensive aquitard is evident in lithological logs. Data from eastern Bangladesh are being assembled (see adjacent).

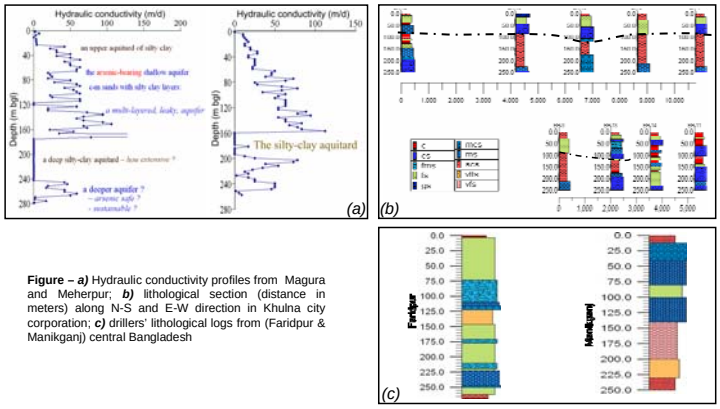



**Figure –** ***a)*** Hydraulic conductivity profiles from Magura and Meherpur; ***b)*** lithological section (distance in meters) along N-S and E-W direction in Khulna city corporation; ***c)*** drillers' lithological logs from (Faridpur & Manikganj) central Bangladesh

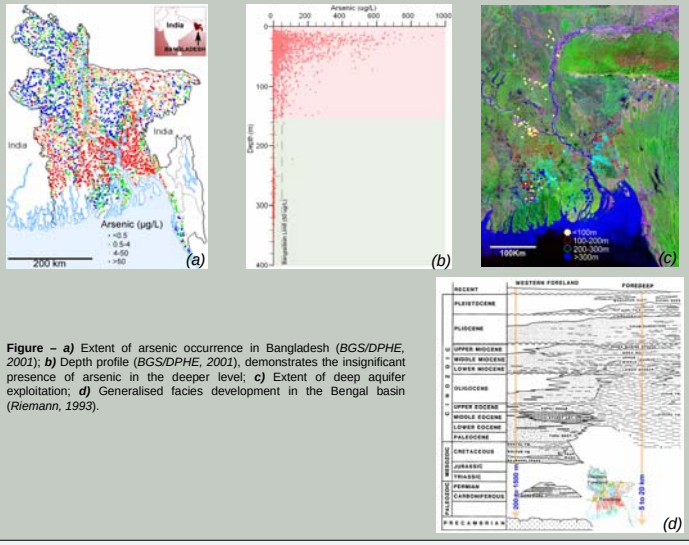
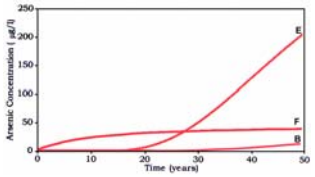



**Figure –** ***a)*** Extent of arsenic occurrence in Bangladesh (*BGS/DPHE, 2001*); ***b)*** Depth profile (*BGS/DPHE, 2001*), demonstrates the insignificant presence of arsenic in the deeper level; ***c)*** Extent of deep aquifer exploitation; ***d)*** Generalised facies development in the Bengal basin (*Riemann, 1993*).

## Preliminary Modelling

Preliminary numerical models of a deep tubewell catchment (pumping at 1600 m$^3$/day, from 230–250m) have indicated that tubewells pumping from these depths may be vulnerable under some conditions and should not be assumed 'arsenic-safe' everywhere, nor for ever (*Burgess et al, 2007*).




Summary of exploratory modelling
As arrival times & concentration at 50 years

| Model | 1 µg/l | 50 µg/l | As at 50 yrs |
|---|---|---|---|
| *B. base case* | 35 yrs | n/a | 9 µg/l |
| *D. sorption* | n/a | n/a | 0 |
| *E. discontinuous aquitard* | 15 yrs | 30 yrs | 213 µg/l |
| *F. deep source* | < 1 year | n/a | 34 µg/l |

## Observations of the 'deep aquifer' in eastern Bangladesh

The available types of data are : * drillers' lithological logs (DPHE) * sieve analyses from drill cuttings (GSB) * geophysical logs (BWDB) * hydrochemistry (USGS) * piezometry (BWDB). Additional data are being collected, including * environmental isotopes * hydraulic conductivity

These data are being combined in order to develop a local hydrostratigraphy for Katchua, and a regional hydrostratigraphy for the eastern region, as a basis for 'deep aquifer' characterisation.

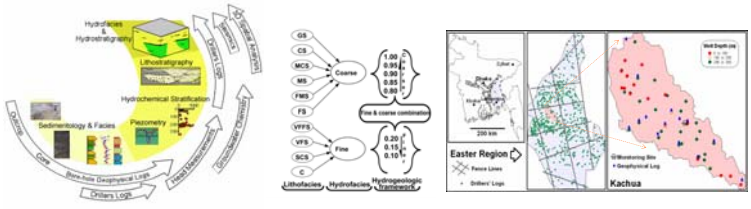



**Figure** ***(left to right)*** **-** Aproach and data types used in the hydrogeological analysis**;** Drillers' log description were grouped into 10 litho-facies and coded in a way to get three hydrofacies (coarser - channel fill deposits and finer - produced by floodplain processes, and combination of these two – indicating zone of higher spatial variability in grain-size)**;** Study area in Bangladesh context, eastern region with drillers' logs and fence lines, and Kachua area with well-location for water-sample, geophysical log and location of monitoring site.

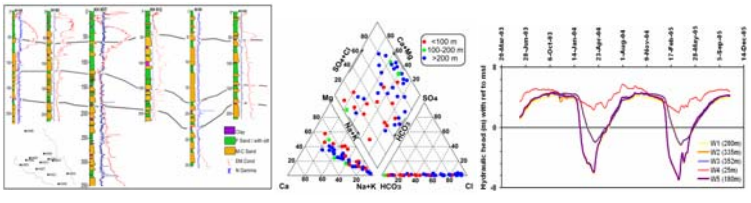
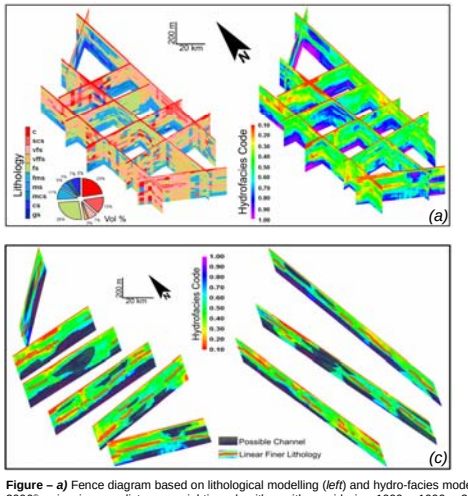



**Figure** ***(left to right)*** **-** Bore-hole geophysical logs with interpreted sedimentary facies, and log response (N Gamma) based layering indicating alternating apparently more heterogeneous and less heterogeneous deposits**;** Piper plot of Kachua hydrochemistry data**;** Hydrographs of piezometers at Kachua for March 2003 to December 2005.



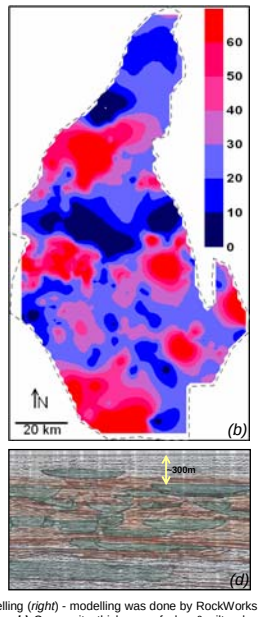




**Figure –** ***a)*** Fence diagram based on lithological modelling (*left*) and hydro-facies modelling (*right*) - modelling was done by RockWorks 2006® using inverse-distance weighting algorithm with a grid size 1000mx1000mx2m; ***b)*** Composite thickness of clay & silty clay between 100 to 200 meter bgl; ***c)*** Exfoliated view of the hydrofacies fence with annotated channel sand body and orientation of the finer-association in the vertical column; ***d)*** similar type of channel sand-body can be traced on seismic section (from western Bangladesh) (annotated after *Lindsay et al, 1991*).

## Conclusions

***Representation of the deep aquifer***

1) The coarser sandy embodiment in the aquifers may result from aligned paleo-channels. Channel stacking may provide vertical connectivity, complex horizontal as well as vertical anisotropy, and may result in preferential flow-paths.

2) In general, no single extensive confining unit exists. The 'deep' hydrogeological environment is variably separated from the shallow levels of the aquifer system.

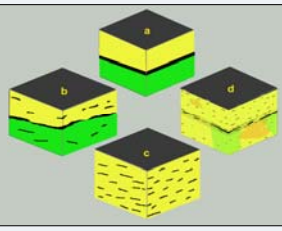



**Figure –** Alternative conceptualisations of the Bengal basin aquifer system: ***(a)*** Simple discrete two aquifers system, ***(b)*** discontinuous clay aquitard (eg, *Mukherjee et al., 2007*), ***(c)*** Single anisotropic aquifer (eg, *Michael & Voss, submitted*), ***(d)*** complex horizontal, and stratified vertical anisotropy with localised discrete deep aquifer; Representation might be numerical (deterministic, stochastic) or analytical.

**Acknowledgement**

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