Hydrogeological Modeling Framework for Dhaka Region Groundwater Flow System (DGFS), Bangladesh

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BACKGROUND

- The hydrogeology of DGFS is stratigraphically and structurally complex and difficult to understand with the current state of knowledge and limited lithological data.
- Groundwater is the only major sources of DGFS for water supply for nearly 20 million of population
- For groundwater modeling, a detail characterization of sedimentological information is crucial
- Hydrogeological Framework Model (HFM) is therefore an important approach, which account the sedimentological stratigraphy and geological component in a complex system and systematically account the heterogeneity of the sedimentation process.
- To construct the HFM, geostatistical simulation techniques have been applied to characterized the spatial distribution of lithofacies of the DGFS.

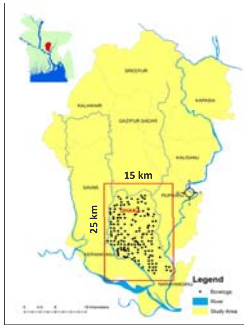
Objectives

1. To Explore the 3-D spatial structural characteristics of sediment facies in DGFS and assess different methods (SIS and Transition Probability Markov Chain Model)

2. Develop a 3D Lithological model for hydrological framework model in the DGFS.

STUDY AREA AND DATA

1. Research area is located at the Dhaka City, ~ 375 Km^2 (15 x 25 km dimension).
2. Topography is mainly flat, elevation ranges from 18 to 6 m from north to south direction.
3. Total 170 Borelogs lithological information was collected to model the sedimentological facies.
4. Average depth of borelog ~ 200 m
5. The sedimentological facies was subdivided into five major categories: Clay, Silt, Fine Sand, Medium Sand and Coarse Sand
6. The study area was gridded with a grid size of 300X300X-2 in the X,Y and Z direction. And the number of grid is 50X85x200 in the X,Y and Z direction



Map-1 Study Area and borelog locations

HYDROGEOLOGY

- Hydrogeology consisting of sediment accumulation from Ganges, Bhrahmaputra and Meghna (GBM) river basin
- Quaternary alluvial sequences of Madhupur Tract
- Primary aquifer is Dupi Tila formation and overlain by the Madhupur Clay

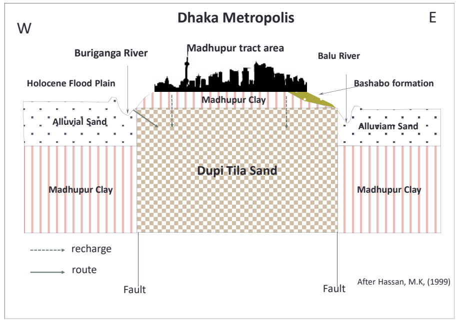


Fig-1 Generalized geological cross section provides overview of the Dupi Tila aquifer system of Dhaka area

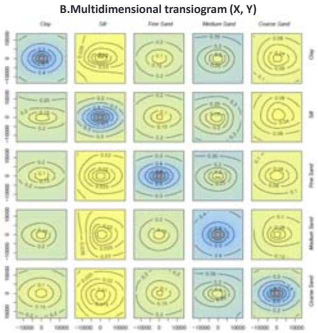
FACIES RECONSTRUCTION MODELING

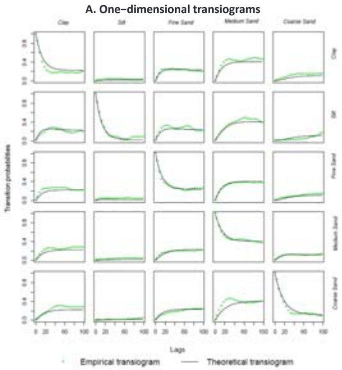
Indicator Variogram and ***Continuous-Lag Spatial Markov Chains*** were used to describe the spatial structural characteristics of sedimentation facies. **Sequential Indicator Simulation** and **Transition Probability Markov Chain Model** were then used to simulate and estimate the 3D spatial distribution of the sediment facies at the regional scale

A. Transition Probability Markov Chain Model

This method predict facies location in continuous multidimensional spaces. It analyzes any categorical random variable Z(**s**) at the d-dimensional position which satisfies $S \in R^d$ the Markov Property. A three steps approach:

1. Estimations of one-dimensional continuous lag models
2. Estimations of multidimensional continuous lag models
3. Categorical spatial random filed simulation and prediction





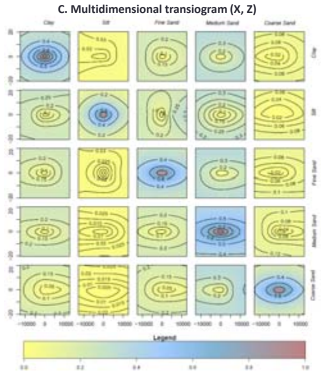


Figure 2- Transiogram Models, A- One Dimensional; B&C- Multidimensional in XY and XZ direction respectively

B. Sequential Indicator Simulation (SIS)

For a categorical variable, the algorithm for SIS relies on Indicator Kriging (IK) to infer the probability density function (pdf) of categorical variable Z(u). For simulating the SIS, it requires indicator variogram model which measures the spatial relationship of the variables. The formula used in indicator variograms is:

$$r_I(h;z_k) = \frac{1}{2N(h)}\sum_{i=1}^{N(h)}[I(\mathbf{u};z_k) - I(\mathbf{u}+h;z_k)]^2 \qquad (1)$$

where $I(\mathbf{u}; zk)$ is the indicator variable of category k at location of $\mathbf{u}$, h is the lag, and $N(h)$ is the number of data pairs separated b h

Table- 1: Parameters of indicator variogram models in the vertical direction with nested structures and in the horizontal direction
C_0 is nugget, C is sill, a is range, and SH is nugget-to-sill ratio value ($C_0/(C_0 + C_1)$); all fitted models used were exponential

Facies	C_0	C_1	$\alpha_{(m)}$	SH
		Vertical Direction		
Clay	0.00	0.19	2	0.00
Silt	0.00	0.043	2	0.00
Fine Sand	0.00	0.2	2	0.00
Medium Sand	0.00	0.23	2	0.00
Coarse Sand	0.00	0.08	2	0.00
		Horizontal Direction		
Clay	0.15	0.03	2000	0.83
Silt	0.015	0.02	2250	0.48
Fine Sand	0.01	0.19	1500	0.05
Medium Sand	0.15	0.085	2750	0.63
Coarse Sand	0.06	0.0165	1500	0.78

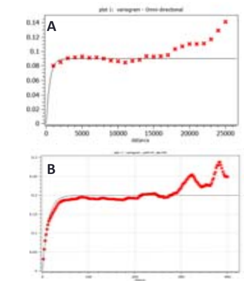


Figure-3. Variogram Model of Horizontal (A) & Vertical direction (B) for Fine Sand facies

RESULTS

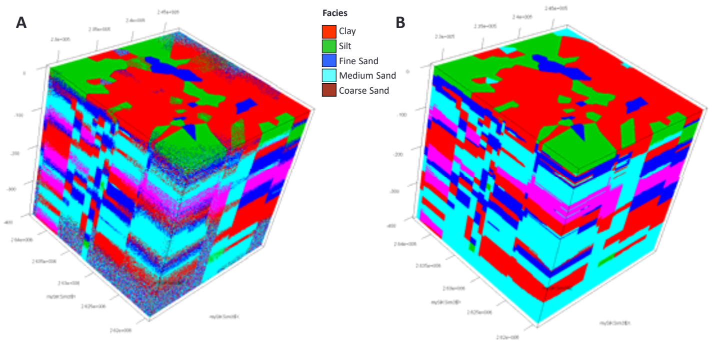


Figure-4. 3D realization of Categorcial Spatial random filed (A) Simulation and (B) Prediction

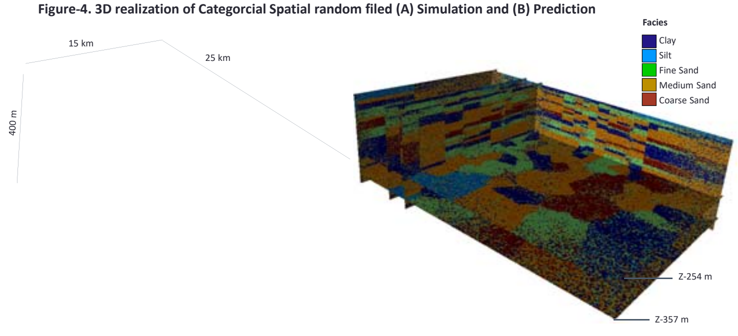


Figure-5. 3D SIS realization (Facies reconstruction Model)

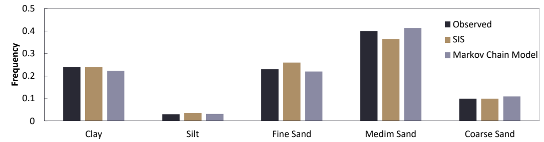


Figure-6 Histogram reproduction of the frequency distribution of the 5 facies by SIS and Markov Chain Model

CONCLUSIONS AND OUTLOOK

1. Both of the methods describe here are able to produce quite good results.
2. Caution is required for variogram modeling and also dense data would increase the model performance.
3. This model will expand to the entire Dhaka region and incorporation of more lithologi data would substantially increase the model performance in terms of accuracy.
4. Further investigation on porosity and hydraulic conductivity distribution will be evaluated for HFM.