



*Supplement of*

## **Hierarchical sedimentary architecture governs basin-scale solute dispersion: from pre-asymptotic dynamics to uncertainty propagation**

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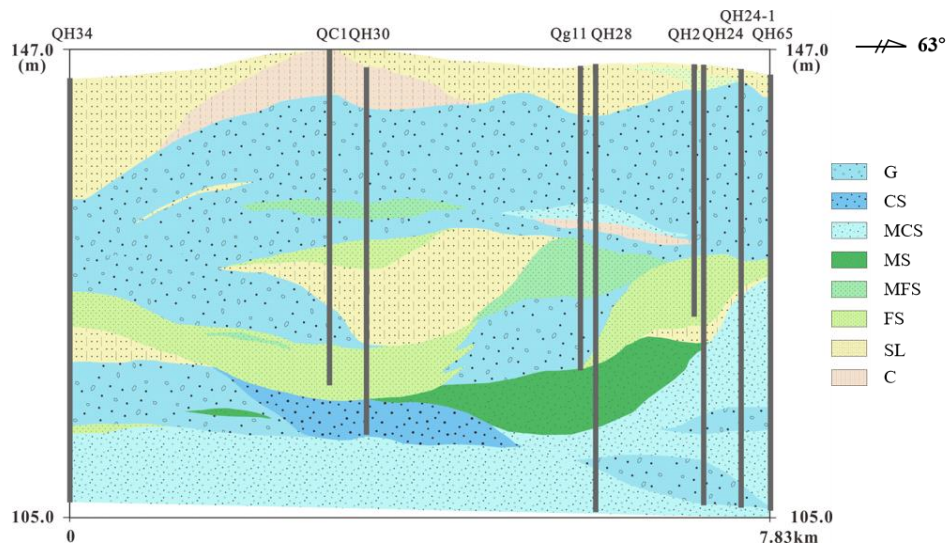


Figure S1. Small-scale lithofacies distribution map on cross-section 1.

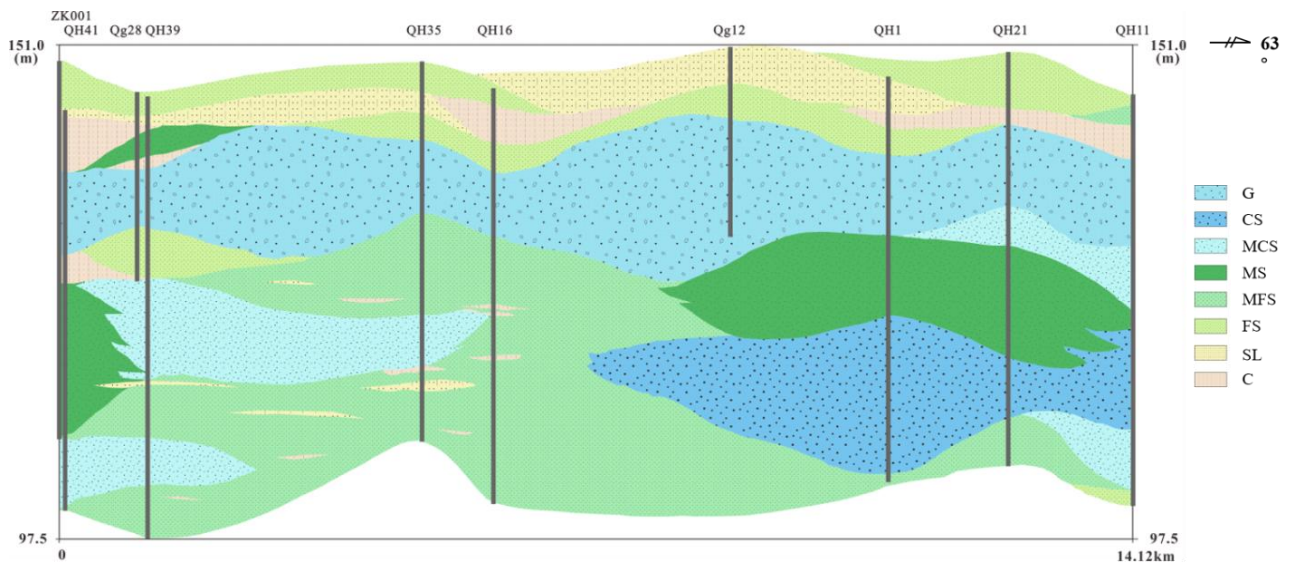


Figure S2. Small-scale lithofacies distribution map on cross-section 2.

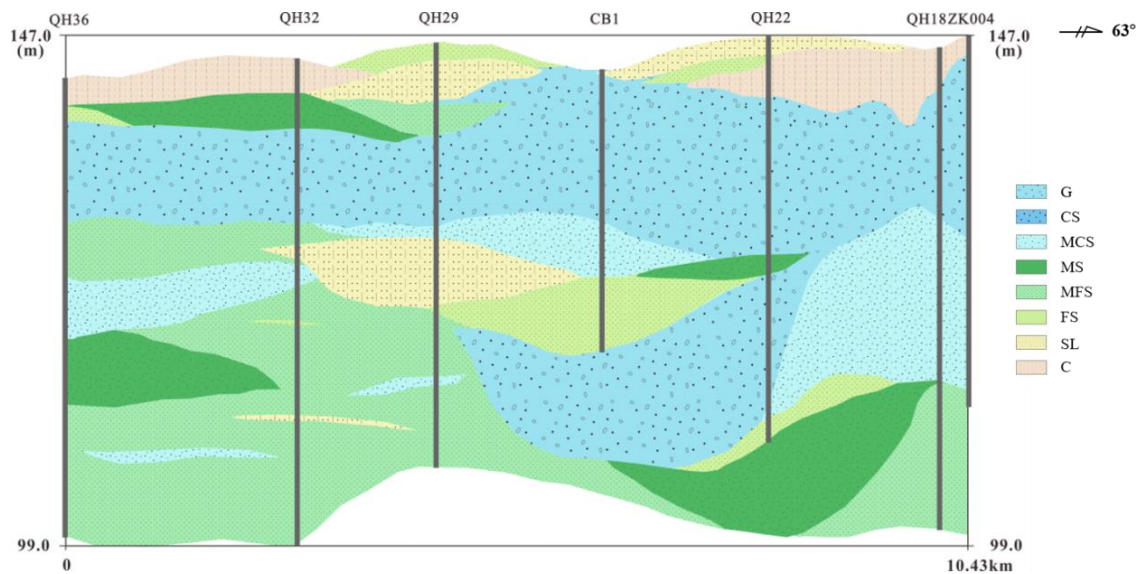


Figure S3. Small-scale lithofacies distribution map on cross-section 3.

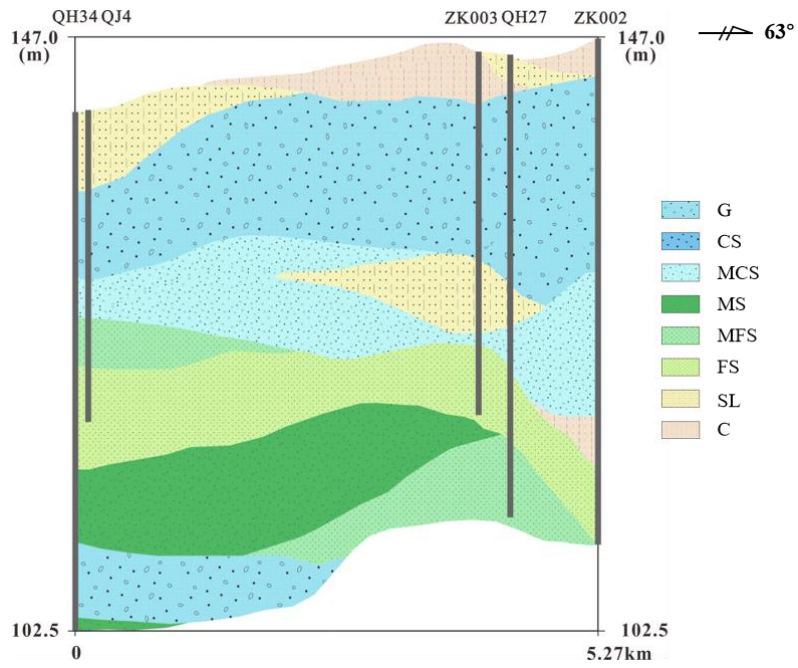


Figure S4. Small-scale lithofacies distribution map on cross-section 4.

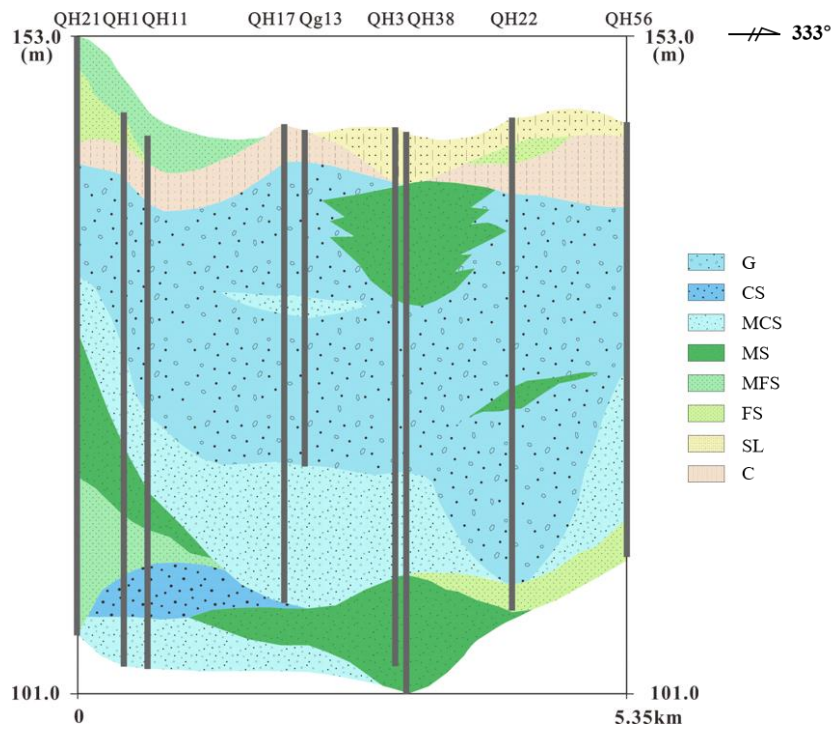
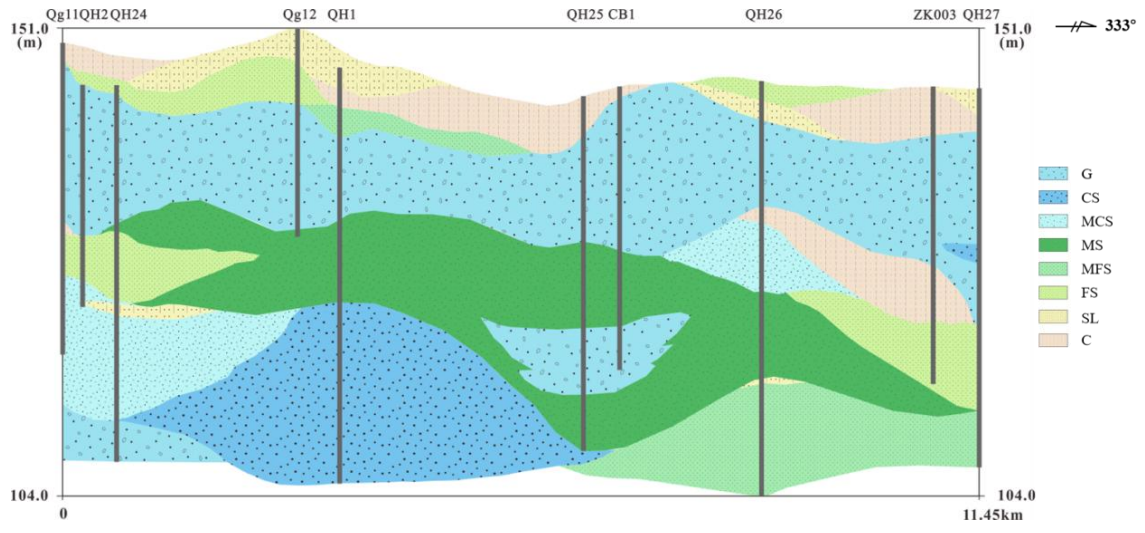
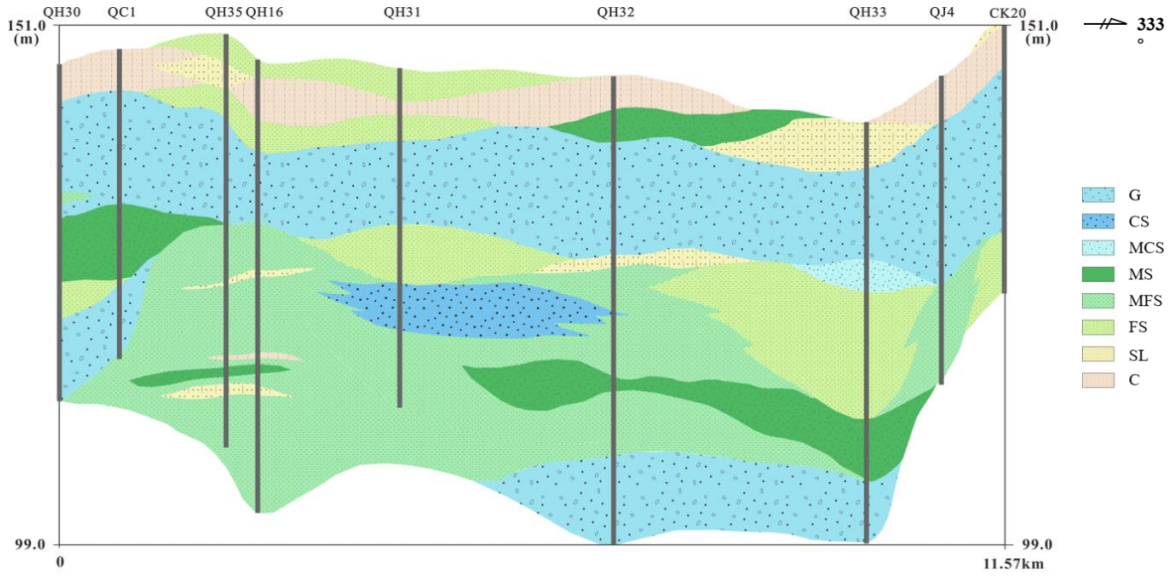


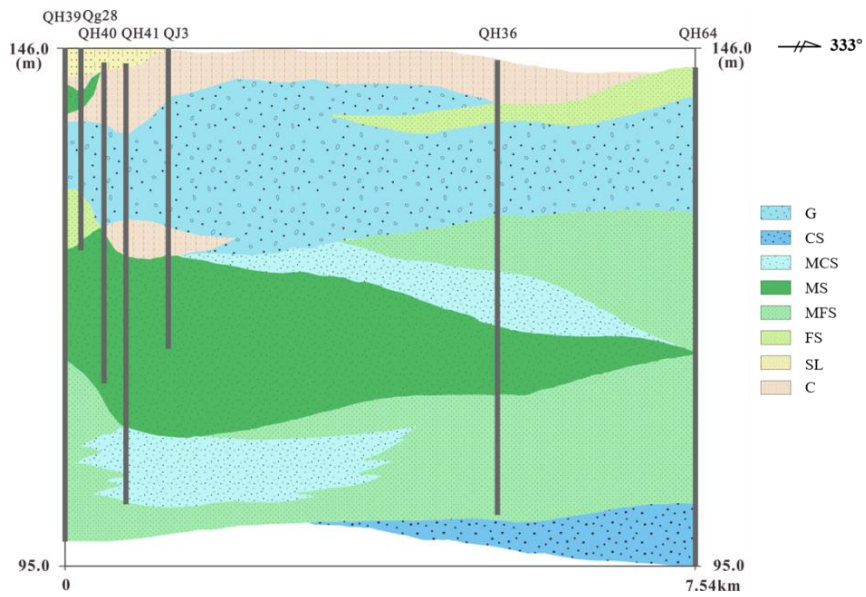
Figure S5. Small-scale lithofacies distribution map on cross-section 5.



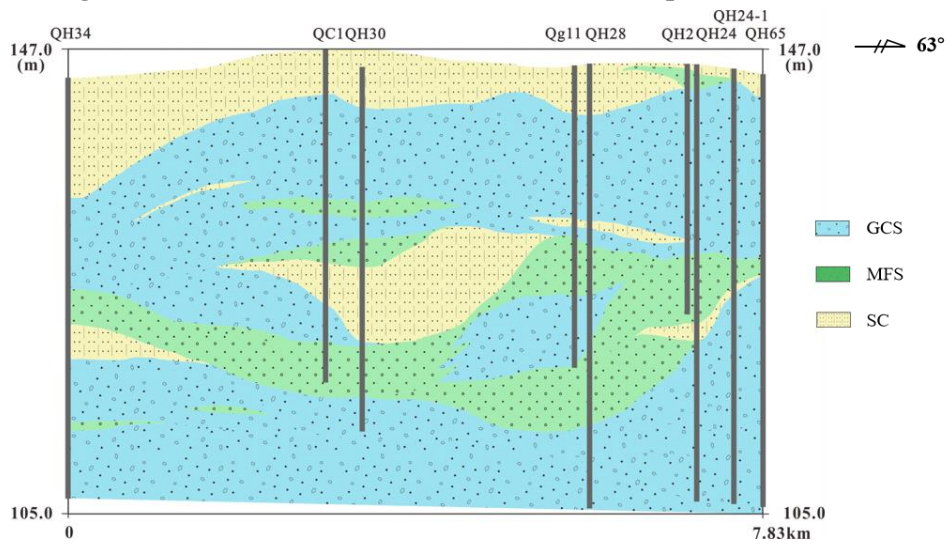
**Figure S6. Small-scale lithofacies distribution map on cross-section 6.**



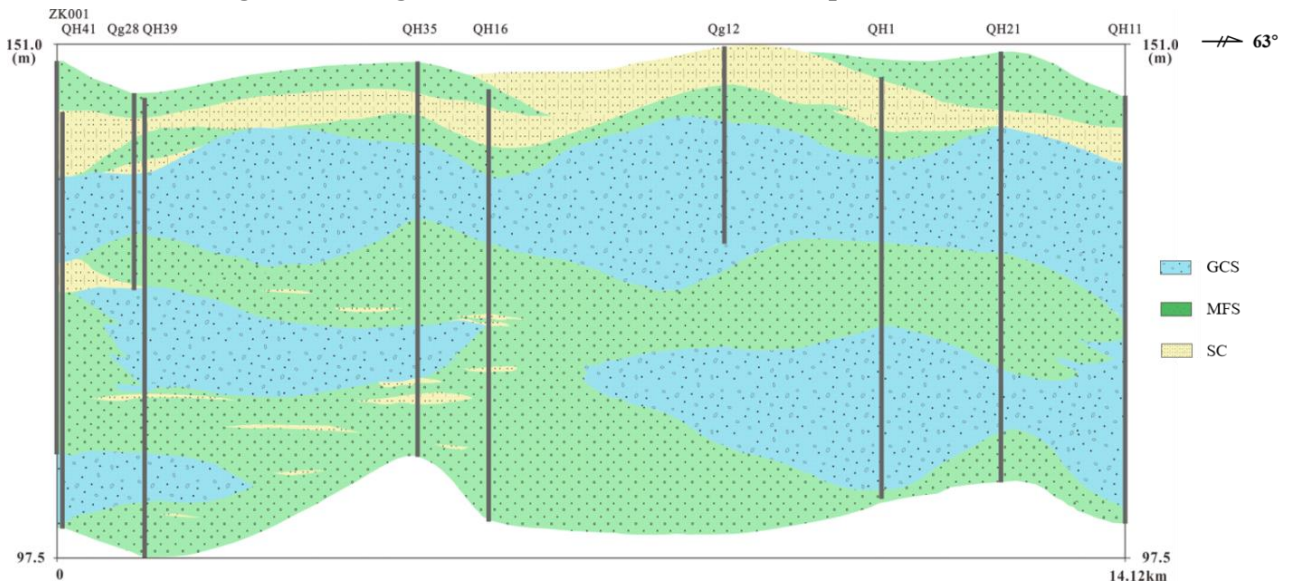
**Figure S7. Small-scale lithofacies distribution map on cross-section 7.**



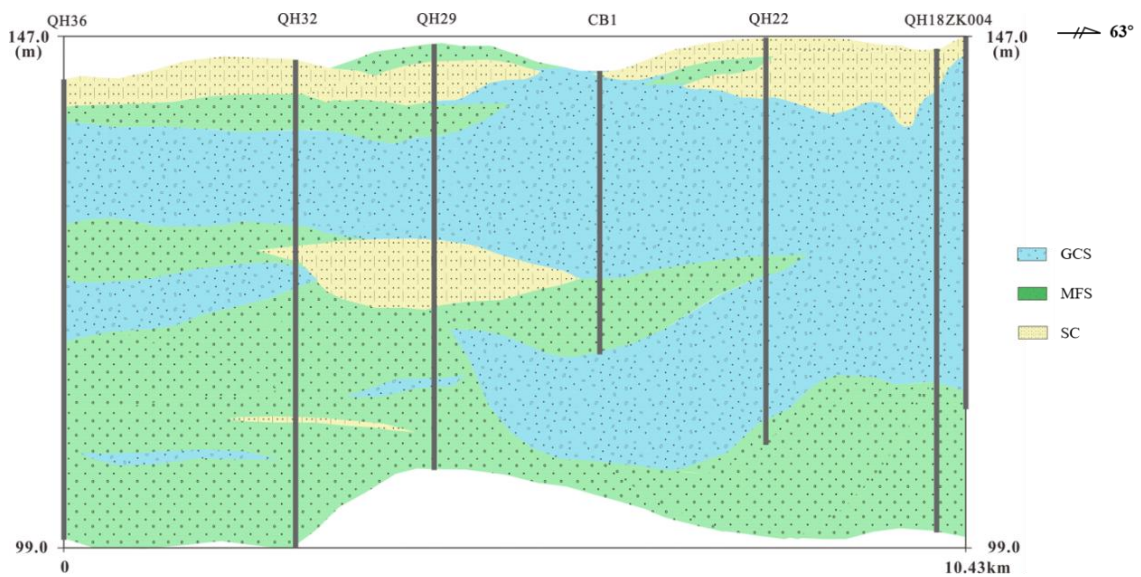
**Figure S8. Small-scale lithofacies distribution map on cross-section 8.**



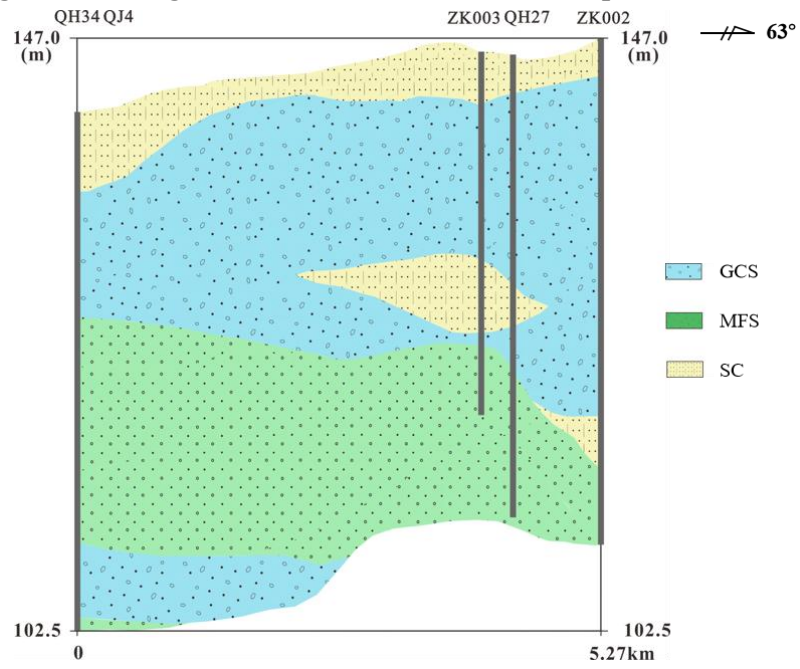
**Figure S9. Large-scale lithofacies distribution map on cross-section 1.**



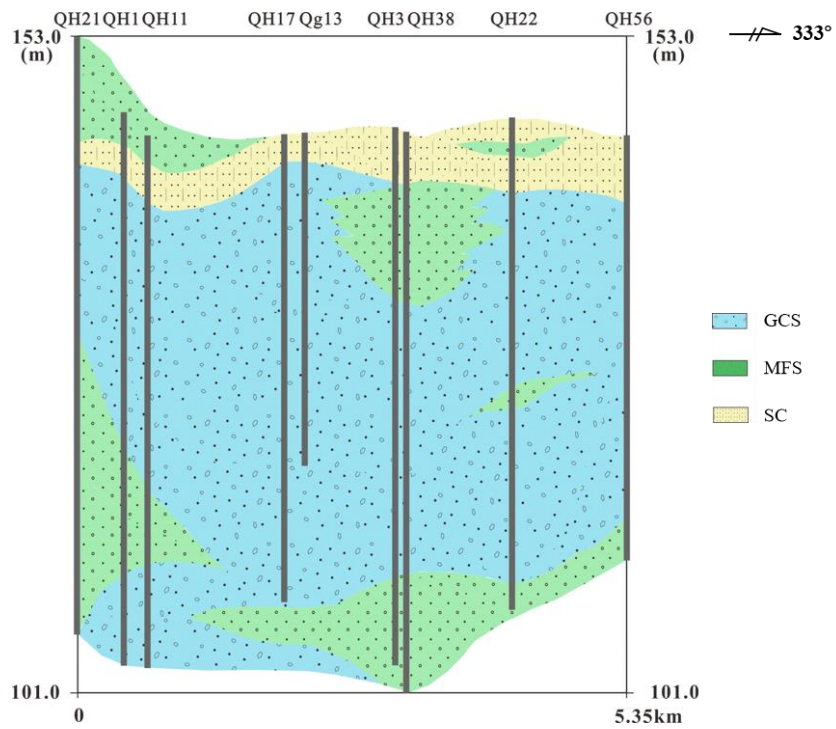
**Figure S10. Large-scale lithofacies distribution map on cross-section 2.**



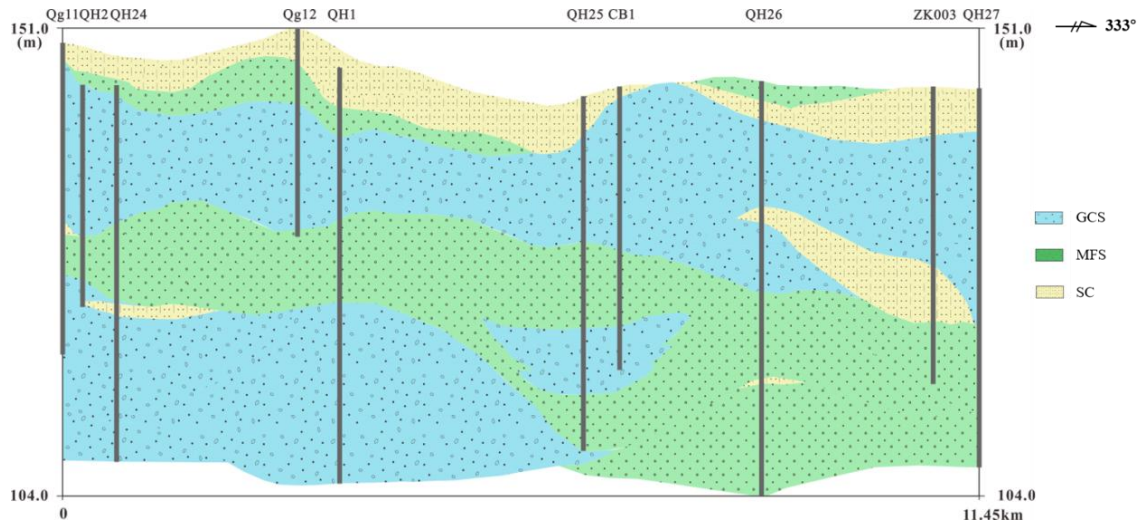
**Figure S11. Large-scale lithofacies distribution map on cross-section 3.**



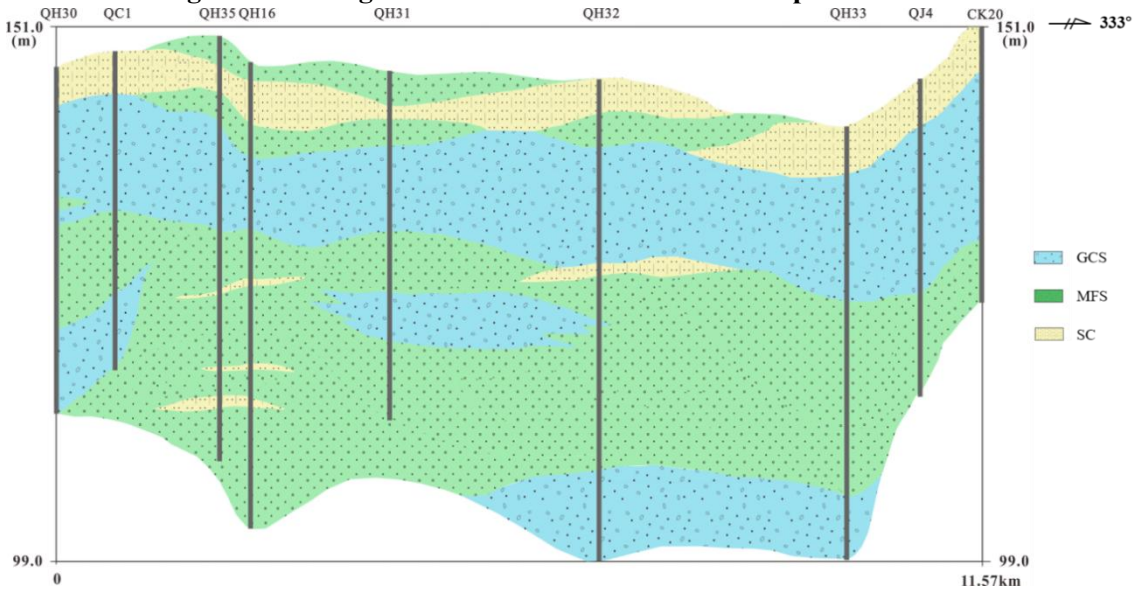
**Figure S12. Large-scale lithofacies distribution map on cross-section 4.**



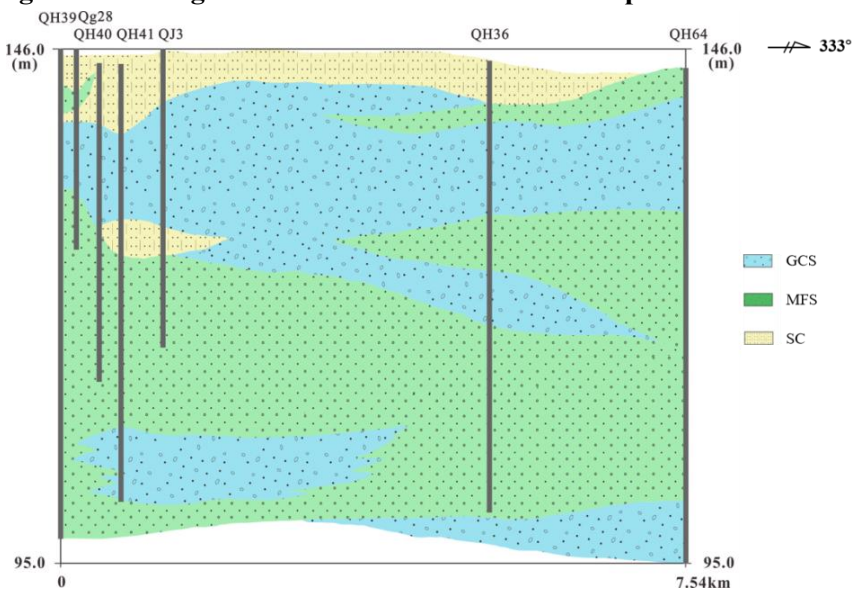
**Figure S13. Large-scale lithofacies distribution map on cross-section 5.**



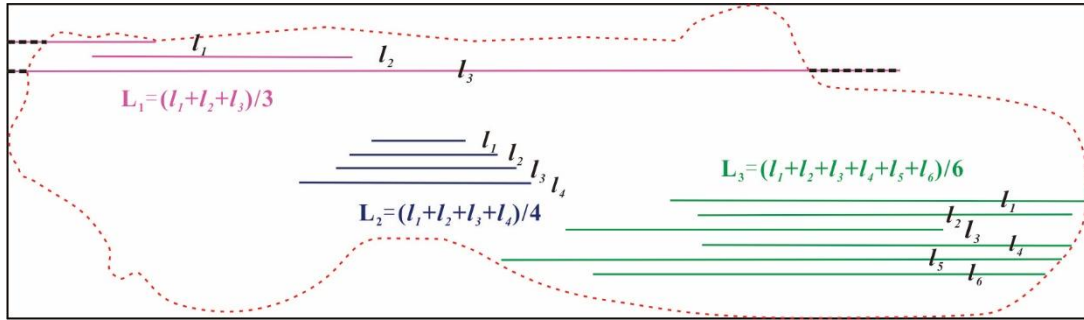
**Figure S14. Large-scale lithofacies distribution map on cross-section 6.**



**Figure S15. Large-scale lithofacies distribution map on cross-section 7.**



**Figure S16. Large-scale lithofacies distribution map on cross-section 8.**



**Figure S17. Schematic diagram for calculating the mean length of lithofacies at the cross-section**

**Table S1. Proportionate values and errors of lithofacies volume counted in the boreholes and on the profiles of Scale I and Scale II**

Scale	Facies type	$P_D$		$P_S$		$P_D - P_S$	
		$X$	$Y$	$X$	$Y$	$X$	$Y$
Scale I	G	0.349	0.332	0.358	0.328	-0.009	0.004
	CS	0.058	0.046	0.064	0.048	-0.006	-0.002
	MCS	0.082	0.137	0.081	0.138	0.001	-0.001
	MS	0.139	0.111	0.155	0.098	-0.016	0.013
	MFS	0.181	0.172	0.165	0.174	0.016	-0.002
	FS	0.088	0.076	0.079	0.093	0.009	-0.017
	SL	0.031	0.067	0.024	0.078	0.007	-0.011
C	0.072	0.059	0.074	0.043	-0.002	0.016	
Scale II	GCS	0.489	0.515	0.503	0.514	-0.014	0.001
	MFS	0.409	0.359	0.399	0.365	0.010	-0.006
	SC	0.103	0.126	0.098	0.121	0.005	0.005

Note:  $P_D$  is the volume proportion of lithofacies based on borehole statistics;  $P_S$  is the volume proportion of lithofacies based on profile statistics;  $P_D - P_S$  is the error value of the volume proportion of lithofacies based on borehole and profile statistics. When calculating using borehole data, the cumulative length of a phase is divided by the total statistical length of all lithofacies to obtain the volume proportion of that phase.

**Table S2. Empirical methods for estimating the hydraulic conductivity from grain size**

Formula	$\phi(n)$	$d_e$	$C$	Applicability
Hazen	$1+10(n-0.26)$	$d_{10}$	$6 \times 10^{-4}$	$0.10\text{mm} < d_e < 3.00\text{mm}$
Slichter	$n^{3.287}$	$d_{10}$	0.01	$0.01\text{mm} < d_e < 5.00\text{mm}$
Pavichich	$\frac{n^3}{1-n^2}$	$d_{17}$	1	$0.06\text{mm} < d_e < 1.50\text{mm}$
Beyer	1	$d_{10}$	$6 \times 10^{-4} \log\left(\frac{500}{\eta}\right)$	$0.06\text{mm} < d_e < 0.60\text{mm};$ $1 < \eta < 20$
Sauerbrei	$\frac{n^3}{1-n^2}$	$d_{17}$	$3.75 \times 10^{-3}$	Sands and sandy clay, $d_e < 0.50\text{mm}$
Kozeny	$\frac{n^3}{1-n^2}$	$d_{10}$	$8.3 \times 10^{-4}$	Large-grain sand
USBR	1	$d_{20}$	$4.8 \times 10^{-4} (d_{20})^{2.3}$	Medium-grain sands

## [S1]. Source and sink calculation

Based on the recharge conditions of phreatic water, the lithology and thickness of the air-packed zone, building cover and cultivated land, a total of four water resources calculation zones have been delineated (shown in Figure 1b).

### S1.1 Groundwater recharge term

#### S1.1.1 Lateral groundwater recharge ( $Q_{lg}$ )

Lateral groundwater recharge from the east boundary is calculated by applying Darcy's formula:

$$Q_{lg}=KIML \quad (S1)$$

Where:  $Q_{lg}$  is the amount of lateral groundwater recharge ( $10^4 \text{ m}^3/\text{a}$ );  $K$  is the equivalent conductivity of the aquifer (m/d);  $I$  is the hydraulic gradient of the groundwater;  $M$  is the average thickness of the aquifer (m); and  $L$  is the width of the lateral recharge section (m).

The conductivity is 61.46 m/d and the width of the inflow section is 20.57 km, the thickness of the aquifer on the boundary was taken as the average value of 32 m, and the hydraulic gradient is about 0.0009. The lateral recharge is then calculated to be  $1328.96 \times 10^4 \text{ m}^3/\text{a}$ .

#### S1.1.2 Precipitation infiltration recharge ( $Q_p$ )

Calculations were made according to the 4 plots that were divided:

$$Q_p = \sum_{i=1}^4 \alpha_i F_i P \quad (S2)$$

Where:  $Q_p$  is the amount of precipitation infiltration recharge ( $10^4 \text{ m}^3/\text{a}$ );  $\alpha_i$  is the precipitation infiltration coefficient of subarea  $i$  (dimensionless),  $F_i$  is the area of subarea  $i$  ( $\text{m}^2$ ); and  $P$  is the multi-year average rainfall (m). The values of above parameters for each subarea are shown in Table S3. According to the rainfall monitoring data of Qiqihar City from 1990 to 2013, it is known that the multi-year average rainfall in the area is 437.7 mm.

**Table S3 Calculation of recharge from precipitation**

Area	$F$ ( $\text{km}^2$ )	$\alpha$	$C_i$ (mm)	$Q_p$ ( $10^4 \text{ m}^3/\text{a}$ )
1	66.7	0.28	437.7	817.3
2	57.66	0.05	437.7	126.2
3	117.17	0.2	437.7	1025.7
4	189.09	0.15	437.7	1241.4
Total	430.62	/	/	3210.6

#### S1.1.3 Mining return recharge ( $Q_M$ )

According to statistics, the total annual mining volume of phreatic water in the area is  $2163.41 \times 10^4 \text{ m}^3/\text{a}$ , of which the agricultural water consumption is  $915 \times 110^4 \text{ m}^3/\text{a}$ . The mining return coefficient is taken to be 0.3, so that the calculated mining return recharge volume is  $274.50 \times 10^4 \text{ m}^3/\text{a}$ .

## S1.2 Groundwater discharge term

### S1.2.1 Evaporative emissions ( $Q_{ep}$ )

Phreatic water evaporation is calculated using the evaporation coefficient method:

$$Q_{ep} = F\varepsilon, \varepsilon = \varepsilon_0(1-h/l)^n \quad (\text{S3})$$

Where:  $Q_{ep}$  is the amount of phreatic water evaporation discharge ( $10^4 \text{ m}^3/\text{a}$ );  $F$  is the area of evaporation zone ( $\text{m}^2$ );  $\varepsilon$  is the phreatic water evaporation intensity ( $\text{m}/\text{a}$ );  $\varepsilon_0$  is the water surface evaporation intensity ( $\text{m}/\text{a}$ );  $h$  is the phreatic water average depth of burial ( $\text{m}$ );  $l$  is the evaporation limit depth ( $\text{m}$ );  $n$  is the evaporation index related to the soil texture and climate of the air-bearing zone, and the value taken here is 1.

Only the evaporation during the thawing period is calculated. The limit depth of phreatic water evaporation in the area is 3 m. Since the average depth of groundwater in subarea II is greater than 3 m, so only subareas I, II, and IV are involved for calculation. The multi-year average evaporation  $\varepsilon_0$  from April to September is 951 mm, and the multi-year average evaporation intensity  $\varepsilon_i = \varepsilon_0 \cdot F_i/F$  assigned to each sub-area. The results are shown in Table S4.

**Table S4 Calculated results of evaporation discharge**

Area	$F$ ( $\text{km}^2$ )	$\varepsilon_i$ ( $\text{m}$ )	$h$ ( $\text{m}$ )	$l$ ( $\text{m}$ )	$Q_{ep}$ ( $10^4 \text{ m}^3/\text{a}$ )
1	66.7	0.15	1.79	3	397.8
3	117.17	0.26	2.8	3	202.1
4	189.09	0.42	2.79	3	552.7
Add up the total	372.96	/	/	/	1152.7

Note.  $F$  is the area of the evaporation zone;  $\varepsilon_i$  is the water surface evaporation intensity;  $h$  is the average depth of groundwater;  $l$  is the maximum depth for groundwater evaporation.

### S1.2.2 Vertical discharge ( $Q_V$ )

As the water level of confined groundwater in this study area is always lower than the water level of phreatic water, and accompanied by a large number of concentrated mining of confined groundwater, it increases the water level difference between phreatic water and confined groundwater so that the phreatic water under the action of the head pressure of the cross-flow recharge to the confined groundwater. The amount of discharge of the phreatic water is equal to the amount of recharge of the confined groundwater:

$$Q_V = FT\Delta HK'/M' \quad (S4)$$

Where:  $Q_V$  for phreatic water discharge ( $10^4 \text{ m}^3/\text{d}$ );  $F$  for the discharge area ( $\text{m}^2$ );  $T$  is the time for leakage (d/a);  $\Delta H$  for phreatic water and confined groundwater between the water level difference (m);  $K'/M'$  for the leakage coefficient (1/d).

The average leakage coefficient is set as 0.0019(1/d) and the average water level difference  $\Delta H$  between phreatic water and confined water is 0.7 m. The area of the main interact zone is  $68.6 \text{ km}^2$ . The vertical discharge of phreatic water is calculated to be  $3330.19 \times 10^4 \text{ m}^3/\text{a}$ .

### **S1.2.3 Groundwater extraction ( $Q_{ex}$ )**

The phreatic water is mainly used for irrigation, followed by production and domestic use. According to the report on groundwater dynamics in Qiqihar City (1990-2013), the average extraction amount of phreatic water is  $2163.41 \times 10^4 \text{ m}^3/\text{a}$ .