Supporting Information for the following manuscript submitted to *Groundwater*:

An open, object-based framework for generating anisotropy in sedimentary subsurface models

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Table S1. Selected architectural element parameters

Parameter	Clay sheet	Sand sheet	Clay lens	Cross-bedded scour	Sandy gravel	Silt sheet	Meander channel
Geometry	Sheet	Sheet	Truncated ellipsoid	Truncated ellipsoid	Sheet	Sheet	Extruded parabola
Aggradation height or lens thickness [m]	0.2	0.3	0.2	0.2	-	0.1	0.5
Hydrofacies	5	4	6	1, 2, 3	0	6	5, 0 (lag)
Internal structure	None	None	None	Random (dip-set, bulb set)	None	None	Lag surface
$\mathrm{w} \times d$ $[\times \ell]$ [m]	-	-	8 × 0.3 ×10	10.4 × 1.2 × 22 [a]	-	-	10 × 1.5
Frequency per layer [1/m^2]	-	-	1×10^{-3}	3×10^{-3}	-	-	-
Paleoflow [°]	-	-	[-90, 90]	[-45, 45][a]	-	-	-
Dip [°]	-	-	-	[10, 25]	-	-	-
Azimuth [°]	-	-	-	[-45, 45]	-	-	-
Set thickness [m]	-	-	-	0.1 (bulb set) 0.7 (dip set)	-	-	-
Background hydrofacies	-	-	4	0	-	-	6

[a](Jussel, Stauffer, & Dracos, 1994)

For generating internal heterogeneity of hydrofacies, horizontal and vertical correlation lengths of λ_h =13 m and λ_h =1.6 m reported by Rehfeldt et al. (1992) were used for both hydraulic conductivity and porosity. Variance of log-normal distributions of hydraulic conductivity and normal distributions of porosity were set to 1 and 5×10^{-4} respectively for all hydrofacies.

Table S2: Hydraulic properties of natural clays. Adapted from Mitchell (1956).

Location	Depositional environment	Notes	K_h [m/s]	K_v [m/s]	$\frac{K_h}{K_v}$	ϕ
Boston blue	Marine		2.70×10^{-9}	1.57×10^{-9}	1.7	0.47
Boston blue	Marine		3.80×10^{-9}	1.05×10^{-9}	3.6	0.48
Fore river	Marine	Silty	1.65×10^{-9}	7.51×10^{-10}	2.2	0.51
Goose Bay	Marine	Silty	9.10×10^{-10}	2.68×10^{-10}	3.4	-
Chicago	Lacustrine		6.71×10^{-10}	4.80×10^{-10}	1.4	0.51
Beauharnois	Marine		2.71×10^{-9}	1.17×10^{-9}	2.3	0.63
St Lawrence	Marine		1.60×10^{-9}	1.07×10^{-9}	1.5	0.62
Dow Field	Marine (?)	Silty	5.79×10^{-9}	4.75×10^{-9}	1.2	-
Mexico City	Lacustrine		1.51×10^{-9}	2.51×10^{-9}	0.6	-
Cincinatti	Freshwater	Silty	2.28×10^{-9}	1.03×10^{-9}	2.2	0.39
Texas	Freshwater		1.21×10^{-9}	3.10×10^{-10}	3.9	-
Louisiana	Freshwater		4.35×10^{-10}	4.81×10^{-10}	0.9	0.51
Pump site	Freshwater		2.08×10^{-9}	6.91×10^{-9}	0.3	0.44
	Mean values	Silty	2.66×10^{-9}	1.70×10^{-9}	2.26	0.45
		Non-silty	2.00×10^{-9}	1.82×10^{-9}	1.68	0.52

A number of hydraulic parameters for fine-grained/cohesive hydrofacies was derived from Mitchell (1956) who performed laboratory tests on natural clays. Mean hydraulic parameter values were derived from this data by calculating the anisotropic ratio K_h/K_v for each sample and then averaging all samples that were silty or non-silty. Note that we only considered undisturbed sample results.

S3: Example model input parameter file for MADE site simulation.

```
## Example HyVR model parameter input file
# HyVR 0.2 simulation package
# https://github.com/driftingtides/hyvr/
# Jeremy P. Bennett, University of Tuebingen, 2017-2018

[run]
# ------------------
# Run parameters
# ------------------

# Name of model simulation run
runname = small

# Number of realisations
numsim = 1

## Outputs
# Required outputs
# vtk: *.vtk
# py: python pickle
# mat *.mat
dataoutputs = [vtk,mat,py]
modeloutputs = [mf6]

# Full Filepath/directory for outputs
# Default is the directory of the parameter initialization file
# if modeldir == 'select'
#modeldir = select

# Overwrite parameter files
flag_ow = true

# Will anisotropy be assigned?
anisotropy = true
het = true


[model]
# ------------------
# Model parameters
# ------------------
# Grid cell dimensions [m]
dx = 0.5
dy = 0.5
dz = 0.1

# Model dimensions [m]
lx = 100
#lx = 40
ly = 50
#ly = 20
lz = 11

# Is domain periodic?
periodic = false

# Lowest hierarchical level of heterogeneity to assign
#       -ae
#       -facies
#       -internal
hetlev = internal

[strata]
# ------------------
# Strata parameters
# ------------------
## List of sequences
ssm = [clay, transition, glaflu, meander]

## List of sequence top contact depths
```

```
ssm_top = [1.5, 3, 8, 11]

#  [variance, correlation length x, corr. length. y]
ssm_contact_model = [[0.05,6,6],[0.05,6,6],[0.05,6,6],[0.05,6,6]]

## Architectural element lookup table
#ae_table = ae_lu_19-09-2017_10.39.18.txt

## Contact surfaces
# flat:         horizontal contacts <default>
# random: random surfaces
#                               - requires geostatistical model "l_contact_model"
# user: Use-defined contact surfaces
#                               - requires input path "contact_file"
ssm_contact = random

# List of architectural elements in model
ae = [clay_sheet, sand_sheet, clay_lens, crossbedded_scour, sandy_gravel, mc_sheet, meander_channel]

# Which architectural elements are included in each sequence
# - Must have same length as l_seq,
# - Architectural elements must be identical to section names (except [model],[hydraulics])
ssm_ae = [[clay_sheet],[sand_sheet,clay_lens],[crossbedded_scour, sandy_gravel],[mc_sheet,
meander_channel]]

# The probability of an architecutral element occuring
ae_prob = [[1.0],[0.4,0.6],[0.8,0.2],[0.3, 0.7]]

# Mean thickness of architectural element
ae_z_mean = [[3.0],[0.3,0.3],[1.7, 0.2],[1.0, 2.0]]

## Erosion / deposition rules
# Avulsion probability
avul_prob = [[0],[0],[0.7],[0]]

# Avulsion depth range [m]
avul = [[0.0,0.0],[0.0,0.0],[0.2, 0.4],[0.0,0.0]]

# Background parameters for unassigned cells
# [fac, azim, dip]
bg = [0, 0, 0]


[crossbedded_scour]
# ------------------
# Scour pool element
# ------------------
geometry = trunc_ellip

# Internal structure
structure = random
agg = 0.2

# Contact type
contact = random
#  [variance, correlation length x, corr. length. y]
contact_model = [0.01,6,6]

# Number of elements per simulation elevation
el_z = 3e-3

# Migration of troughs [mean & var migration in x, y]
migrate = [10, 0.5, 10, 0.5]

# Do not generate troughs close to bottom contact
# Value is proportion of trough depth
buffer = 0.8

# Mean trough geometry [m]
length = 22
width = 10.4
depth = 1.2

# Mean angles [deg]
```

```
paleoflow = [-45, 45]
dip = [10, 25]
azimuth = [-45, 45]

# Hydrofacies (refer to [hydraulics]l_hydro; 0-indexed)
facies = [1,2,3]

# Alternating facies
# List of what hydrofacies can follow those listed in l_facies
# To generate cyclical facies each list entry should have only one facies value
altfacies = [[1,2],[1,2],[3]]

# Thickness of lenses (or) spatial period (lambda) of inclined set [m]
bulbset_d = 0.1
dipset_d = 0.7

# Background parameters for unassigned cells
# [fac, azim, dip]
bg = [0, 0, 0]

# Geometry trend with elevation
# Trends are linear, moving from bottom to top of domain
# Percentage change of mean value with dx = 1m
geo_ztrend = [2, 0.5]

[meander_channel]
# ------------------
# Meander channel element
# ------------------
geometry = ext_par
agg = 1
width = 10
depth = 1.5

# Internal structure
structure = massive

# Contact type
contact = random
#  [variance, correlation length x, corr. length. y]
contact_model = [0.001,12,6]

# Migration of channels [mean & var migration in x, y]
#migrate = [10, 0.5, 10, 0.5]

# Channel shape parameters
h = 0.4
# Wavenumber
k = 0.5
# Channel distance for calculations
ds = 1
eps_factor = 0.1

# Channels per iteration
channel_no = 1

# Dip range ([0,0] = massive bedding without any dip)
dip = [0, 0]

# Do not generate troughs close to bottom contact
# Value is proportion of trough depth
buffer = 0.4

# Hydrofacies (refer to [hydraulics]l_hydro; 0-indexed)
facies = [5]

# Lag surface at bottom of feature
# [lag depth, hydrofacies]
lag = [0.3, 0]

# Background parameters for unassigned cells
# [fac, azim, dip]
bg = [6, 0, 0]
```

```
[sandy_gravel]
# ------------------
# Sandy gravel sheet element
# ------------------
# Geometry
geometry = sheet
lens_thickness = -1
structure = massive

# Contact type
contact = random
#  [variance, correlation length x, corr. length. y]
contact_model = [0.05,6,6]

# Hydrofacies (refer to [hydraulics]l_hydro)
facies = [0]

[sand_sheet]
# ------------------
# Sand sheet element
# ------------------
# Geometry
geometry = sheet
lens_thickness = 0.3
structure = massive

# Contact type
contact = flat

#  [variance, correlation length x, corr. length. y]
contact_model = [0.01,6,6]

# Dip range ([0,0] = massive bedding without any dip)
dip = [0, 0]

# Spatial period (lambda) of inclined set [m]
setlamb = 0.3

# Hydrofacies (refer to [hydraulics]l_hydro)
facies = [4]

# Global hydraulics trend with elevation
# Trends are linear, moving from bottom to top of domain
k_ztrend = [0.5, 5]

[clay_sheet]
# ------------------
# Clay sheet element
# ------------------
# Geometry
geometry = sheet
lens_thickness = 0.2
structure = massive

# Contact type
contact = flat
#  [variance, correlation length x, corr. length. y]
contact_model = [0.01,6,6]

# Dip range ([0,0] = massive bedding without any dip)
dip = [0, 0]

# Spatial period (lambda) of inclined set [m]
setlamb = 3

# Hydrofacies (refer to [hydraulics]l_hydro)
facies = [5]

# Global hydraulics trend with elevation
# Trends are linear, moving from bottom to top of domain
k_ztrend = [0.5, 2]
```

```
[mc_sheet]
# ------------------
# silt/clay sheet element
# ------------------
# Geometry
geometry = sheet
lens_thickness = 0.1
structure = massive

# Contact type
contact = flat
contact_model = [0.01,6,6]

# Spatial period (lambda) of inclined set [m]
setlamb = 3

# Dip range ([0,0] = massive bedding without any dip)
dip = [0, 0]

# Hydrofacies (refer to [hydraulics]l_hydro)
facies = [6]

[clay_lens]
# ------------------
# Clay/silt lens
# ------------------
geometry = trunc_ellip

# Internal structure
structure = flat
agg = 0.2

# Contact type
contact = flat
#  [variance, correlation length x, corr. length. y]
contact_model = [0.01,6,6]

# Number of elements per simulation elevation
el_z = 1e-3

# Migration of troughs [mean & var migration in x, y]
#migrate = [20, 1, 10, 1]

# Do not generate troughs close to bottom contact
# Value is proportion of trough depth
# buffer = 0.2

# Mean trough geometry [m]
length = 10
width = 8
depth = 0.3

# Mean angles [degrees]
paleoflow = [-90, 90]
dip = [0, 0]
azimuth = [0, 0]

# Hydrofacies (refer to [hydraulics]l_hydro; 0-indexed)
facies = [6]

# Alternating facies
# List of what hydrofacies can follow those listed in l_facies
# To generate cyclical facies each list entry should have only one facies value
altfacies = [[6]]

# Thickness of lenses (or) spatial period (lambda) of inclined set [m]
setlamb = 0.2

# Background parameters for unassigned cells
# [mat, fac, azim, dip]
bg = [4, 0, 0]

# Geometry trend with elevation
# Trends are linear, moving from bottom to top of domain
```

```
# Percentage change of mean value with dx = 1m
geo_ztrend = [1, 1]

[hydraulics]
# ------------------
# Hydraulic parameters
# ------------------
# Simulation of hydraulic parameters?
gen = true

# List of hydrofacies codes
hydro = [sG, scG, oG, S, fS, C, mS]

# mean horizontal hydraulic conductivity [m/s]
k_h = [1e-5, 1e-7, 1e-1, 1e-4, 1e-5, 2e-9, 3e-9]

# variance of log hydraulic conductivity [-]
#sig_y = [1, 1, 1, 1, 1, 1, 1]
sig_y = [0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5]

# default correlation lengths for log(K) in each hydrofacies in x,y,z-directions
ycorlengths = [[13,13,1.6],[13,13,1.6],[13,13,1.6],[13,13,1.6],[13,13,1.6],[13,13,1.6],[13,13,1.6]]

# List of perpendicular anisotropy ratios (i.e K_h/K_v) [-]
k_ratio =  [1, 0.25, 0.025, 1, 2.3, 2.3, 1.7]

# list of mean porosity values [-]
n = [0.2, 0.17, 0.35, 0.43, 0.43, 0.52, 0.45]

# variance of porosity values [-]
sig_n = [0.0005, 0.0005, 0.0005, 0.0005, 0.0005, 0.0005, 0.0005]

# default correlation lengths for n in each hydrofacies in x,y,z-directions
ncorlengths = [[3,3,0.3],[3,3,0.3],[3,3,0.3],[3,3,0.3],[3,3,0.3],[3,3,0.3],[3,3,0.3]]

# Global hydraulics trend with elevation
# Trends are linear, moving from bottom to top of domain
#k_ztrend = [1.5, 0.9]
#k_xtrend = [1.5, 0.9]


[flowtrans]
# ------------------
# Flow and transport modelling parameters
# ------------------
# Boundary conditions (head in/out [m])
hin = [1, 0, 0]
hout = [0, 0, 0]
```

References

Jussel, P., Stauffer, F., & Dracos, T. (1994). Transport modeling in heterogeneous aquifers: 1. Statistical description and numerical generation of gravel deposits. *Water Resources Research*, *30*(6), 1803–1817. https://doi.org/10.1029/94WR00162

Mitchell, J. K. (1956). The fabric of natural clays and its relation to engineering properties. In F. Burggraf (Ed.), *Proceedings of the 35th Highway Research Board Annual Meeting*. Washington, D.C.: Highway Research Board.

Rehfeldt, K. R., Boggs, J. M., & Gelhar, L. W. (1992). Field study of dispersion in a heterogeneous aquifer: 3. Geostatistical analysis of hydraulic conductivity. *Water Resources Research*, *28*(12), 3309–3324. https://doi.org/10.1029/92WR01758