

A Strategy for Modeling Groundwater Contamination Migration Within Fractured Geology

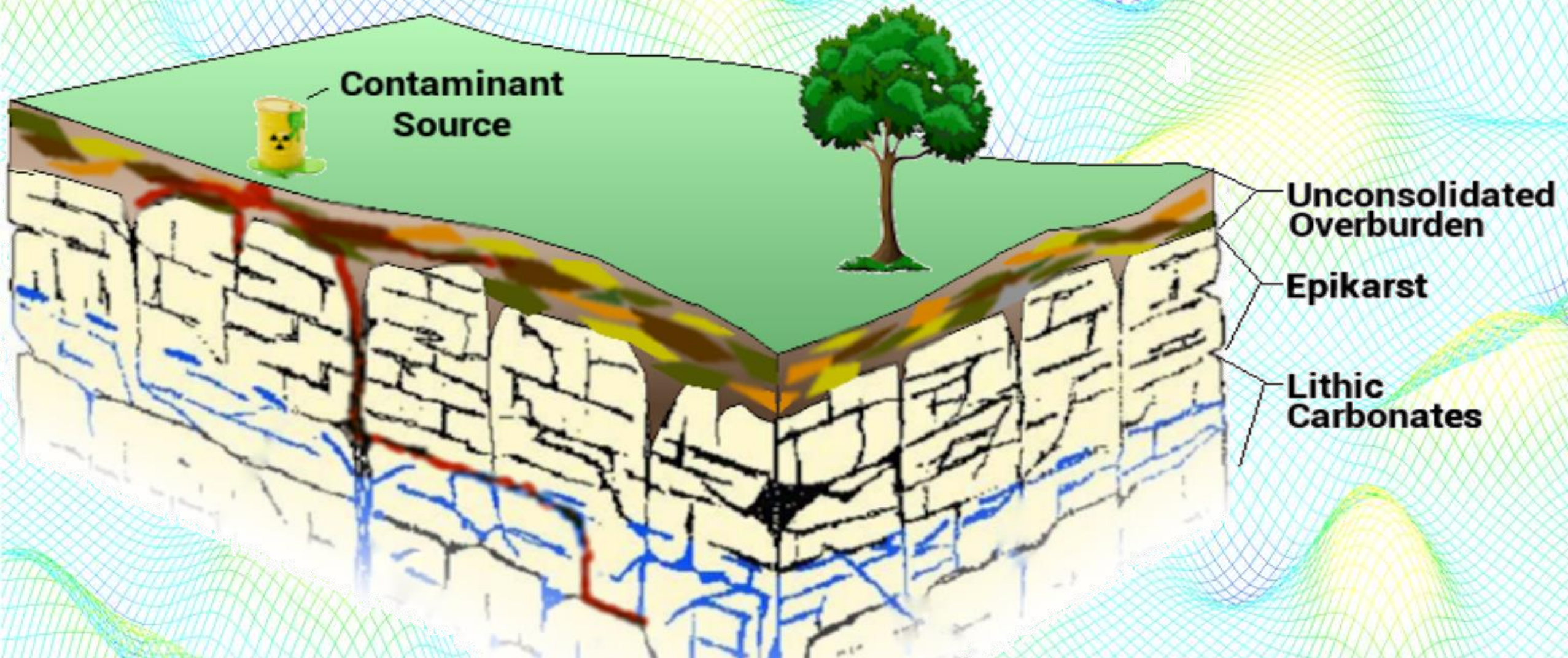
Jim Reed
Geologist / Programmer
RockWare Incorporated
Golden, Colorado USA



Steps

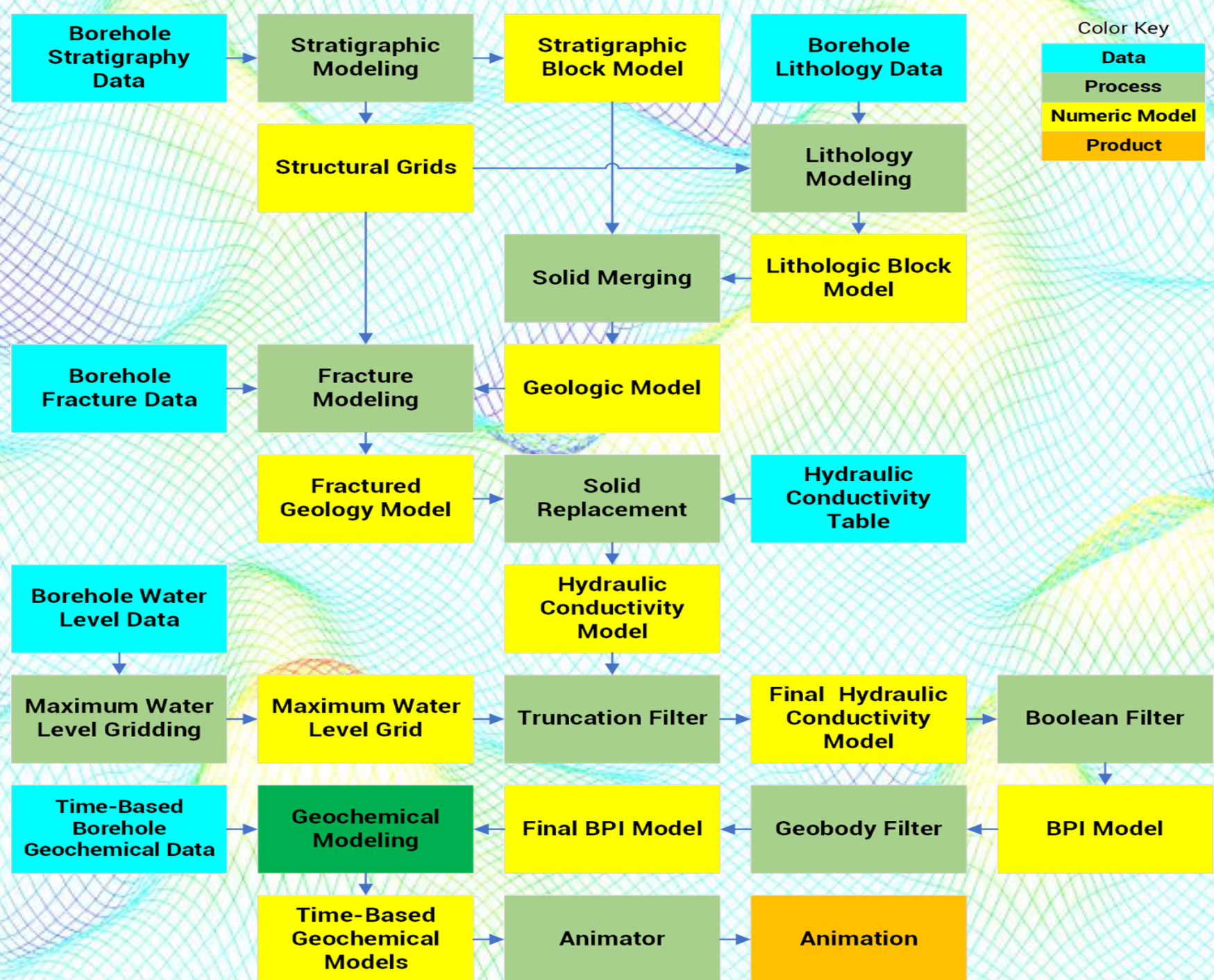
1. Create Database
2. Model Bedrock Stratigraphy
3. Model Unconsolidated Overburden
4. Merge Bedrock Stratigraphy & Overburden
5. Add Fractures to Geology Model
6. Convert Geology Model to Hydraulic Conductivity (K) Model
7. Create Maximum Water Level Model
8. Truncate Hydraulic Conductivity Model Based on Maximum Water Level Model
9. Convert Hydraulic Conductivity Model to Boolean Permeable / Impermeable (BPI) Model
10. Isolate Contiguous Permeable Zones
11. Interpolate Quarterly Geochemical Models
12. Create Animations

Why this topic?



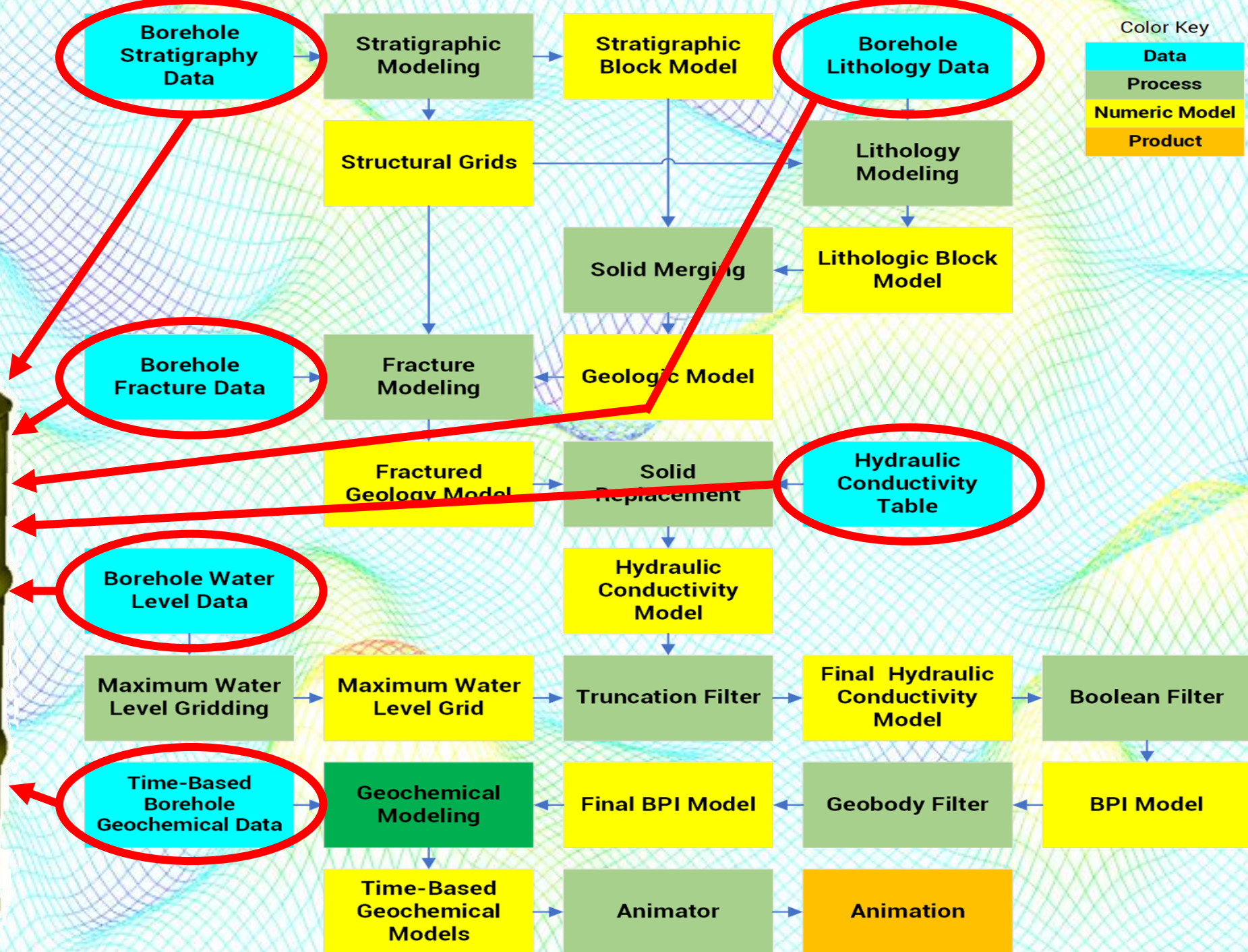
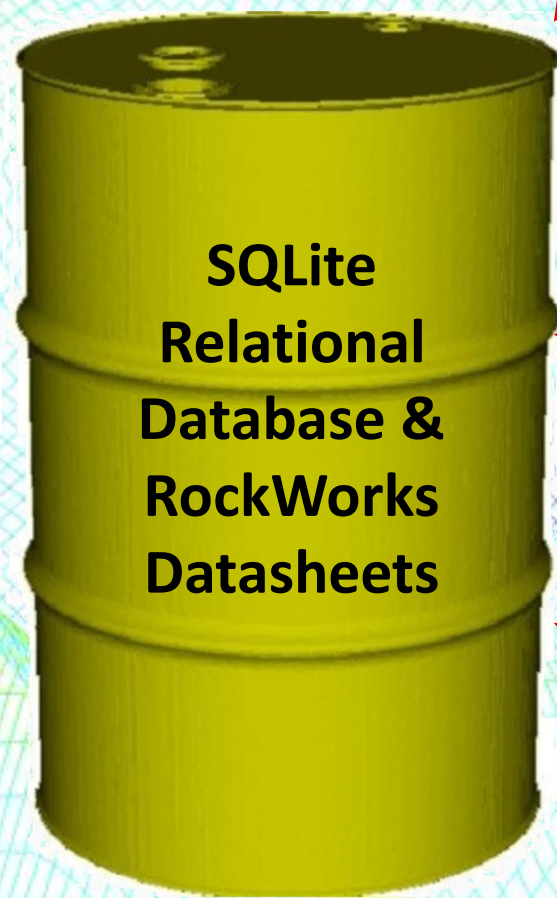
Epikarst covers about 12.5% of the earth's surface!

The Strategy



1

Creating the
Database



Creating a Database (continued)



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Project Folder: C:\Users\Jim\Documents\RockWorks Data\TCE Site\



Datasheet (untitled) Project Manager Borehole Manager Faults Videos Playlist (unnamed) Execution History

File Edit View Video Help

Borehole

- ☒ MW-01
- ☒ MW-02
- ☒ MW-03
- ☒ MW-04
- ☒ MW-05
- ☒ MW-06
- ☒ MW-07
- ☒ MW-08
- ☒ MW-09
- ☒ MW-10
- ☒ MW-11

Borehole Data

QuickMap

Location

Orientation

Lithology

Stratigraphy

I-Data

I-Text

T-Data

P-Data

D-Text

Borehole Name*

MW-01

Symbol

Raster:

Vector:

Collar Coordinates

Comments

Other Coordinate Projections

Horizontal: UTM Meters, Datum: WGS-84 198

Easting* 481,951.70 meters

Northing* 4,399,925.30 meters




Vertical: Meters

Z (Elevation)* 1660.87 meters

Collar Elevation 1660.87 meters

Total Depth* 48.85 meters

Creating a Database (Continued)

Borehole Data	QuickMap		
Location			
Orientation	Datasheet	Litho Types	Tab Manager
Lithology	Depth to Top	Depth to Base	Keywords
Stratigraphy	▶ 0.0	1.0	MH
I-Data	1.0	1.5	GP
I-Text	1.5	2.0	CH
T-Data	2.0	2.5	CL
P-Data	2.5	3.0	OL
P-Text	3.0	4.0	GW
Colors	4.0	4.5	SP
	4.5	5.0	MH

Creating a Database (Continued)

Borehole Data

QuickMap

Location

Orientation

Lithology

Stratigraphy

I-Data

I-Text

T-Data

P-Data



Datasheet



Strata Types



Tab Manager

From

Depth to Top

Depth to Base

Formation

5.06

7.6

Epikarst

7.6

33.94

Dolomite

33.94

33.94

Limestone

33.94





48.85

Shale

48.85

Meta-Diorite

Creating a Database (Continued)

Location				
Orientation	Datasheet	T-Data Types	Tab Manager	From Elevation
Lithology	Top Depth	Base Depth	Sample Date	TCE (PPB)
Stratigraphy	22.0	36.0	2/15/2018	0.01
I-Data	22.0	36.0	5/15/2018	3,952.04
I-Text	22.0	36.0	8/15/2018	1,250.66
T-Data	22.0	36.0	11/15/2018	998.82
P-Data				

Creating a Database (Continued)

Borehole Data

QuickMap

Location

Orientation

Lithology

Stratigraphy

I-Data

I-Text

T-Data


P-Data


P-Text


Colors


Fractures

Water Levels

 Datasheet





 Tab Manager

 From Elevation

 Optimize Columns

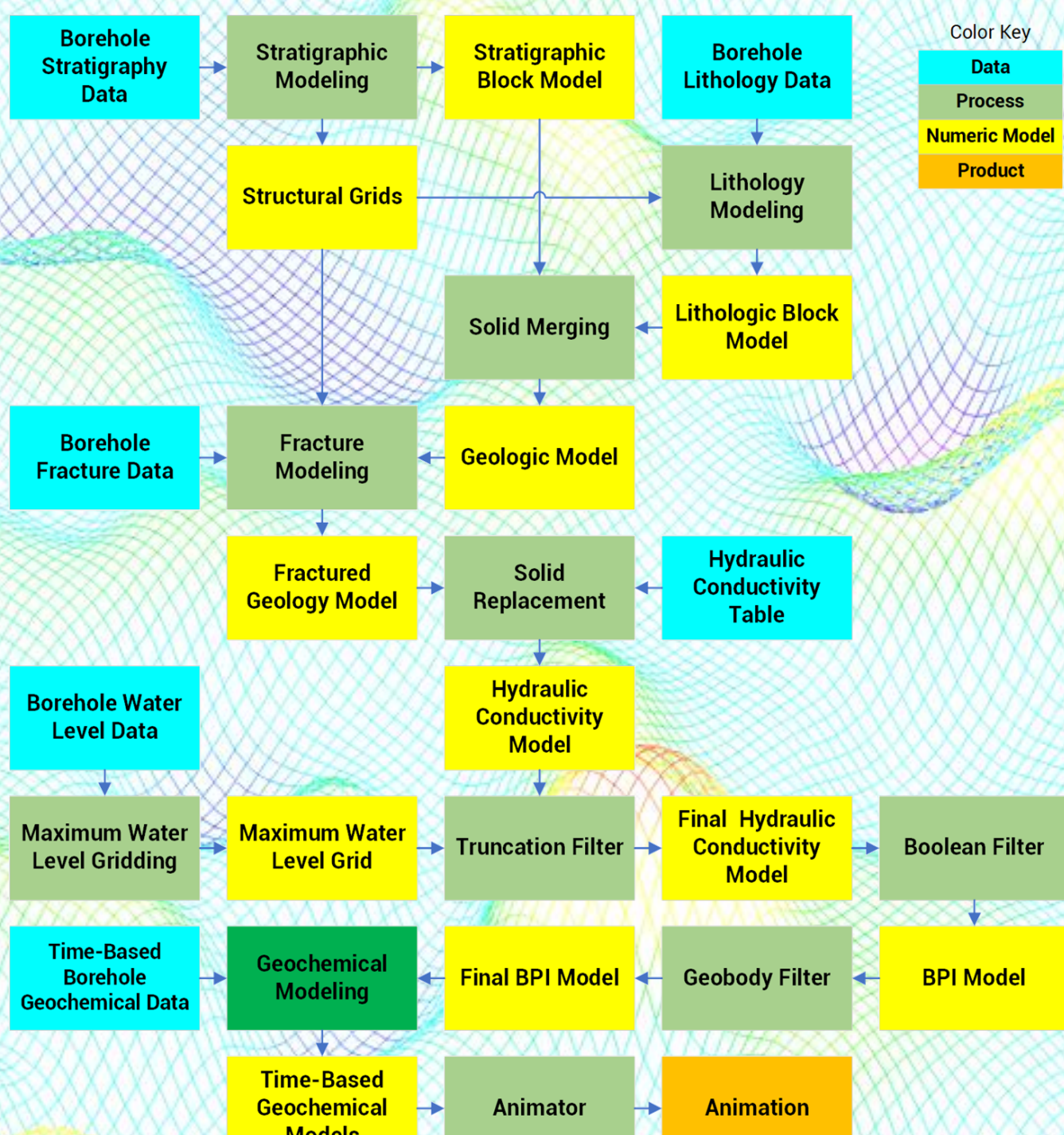
Depth	Dip Direction	Dip Angle	Radius	Aperture	Color	Comment
20.0	1.0	80.0	10.0	1.0		Slickensided

Creating a Database (Continued)

Borehole Data	QuickMap			
Location				
Orientation	Datasheet	Aquifer Names	Tab Manager	From Elevation
Lithology				
Stratigraphy				
I-Data				
I-Text				
T-Data				
P-Data				
P-Text				
Colors				
Fractures				
Water Levels				

Aquifer Name	Date of Sample	Top Depth	Base Depth
▶ Aquifer 1	2/14/2017	9.1	19.0
Aquifer 2	2/14/2017	30.0	49.0
Aquifer 1	5/15/2017	9.1	18.0
Aquifer 1	8/6/2017	9.8	17.0
Aquifer 1	11/18/2017	14.0	16.0
Aquifer 2	11/18/2017	31.0	48.0

Automating the Data Processing Strategy



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Playlist (TCE Modeling & Animation) | Datasheet

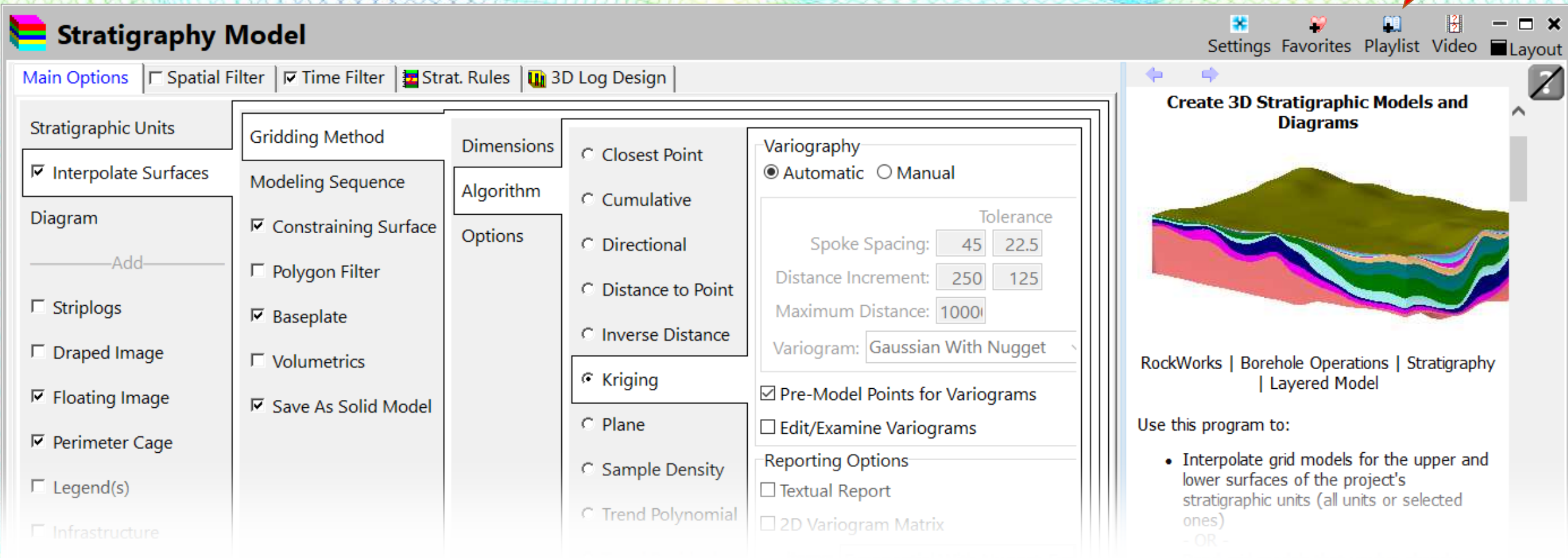
File | Edit | View | Configure | Add

22 Playlist Items (Item # 22)

- ☐ Create 3D Stratigraphy Logs
- ☐ Create Stratigraphy (Bedrock) Model
- ☐ Create 3D Lithology Logs
- ☐ Create Lithology (Overburden) Model
- ☐ Merge Lithology & Stratigraphy Model
- ☐ Create 3D Fracture Logs
- ☐ Add Epikarst & Dolomite Fractures
- ☐ Add Limestone Fractures
- ☐ Add Sandstone Fractures
- ☐ Add Meta-Diorite Fractures
- ☐ Load K Value Conversion Table
- ☐ Convert Geology Model to K-Model
- ☐ Create Aquifer Logs
- ☐ Create Maximum Water Level Model
- ☐ Truncate Hydraulic Conductivity Model
- ☐ Convert K-Model to BPI Model
- ☐ Remove Small Geobodies From BPI Model
- ☐ Create TCE Logs
- ☒ Interpolate Quarterly TCE Models
- ☒ Create Grid Animation
- ☒ Create Solid Animation

PROCESS PLAYLIST

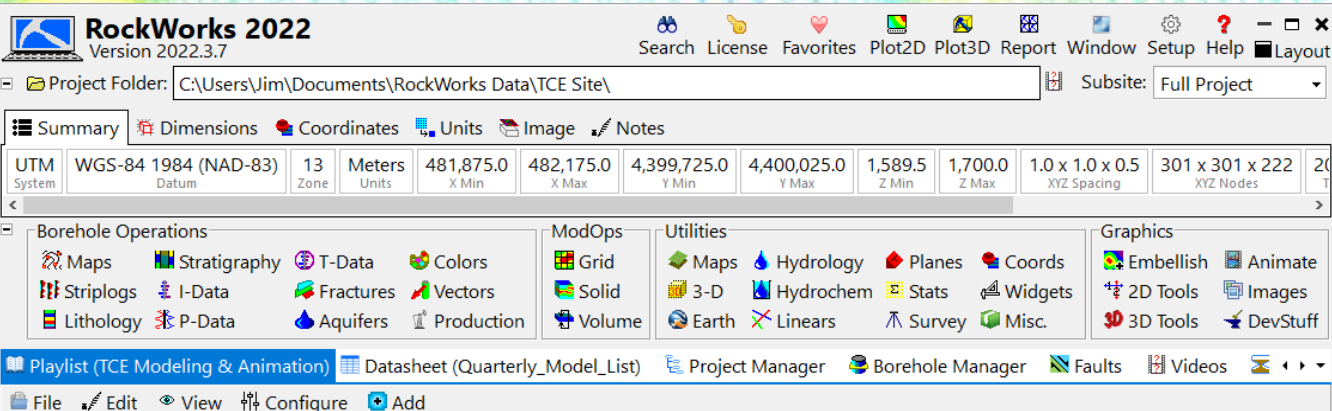
Adding Items to the Playlist



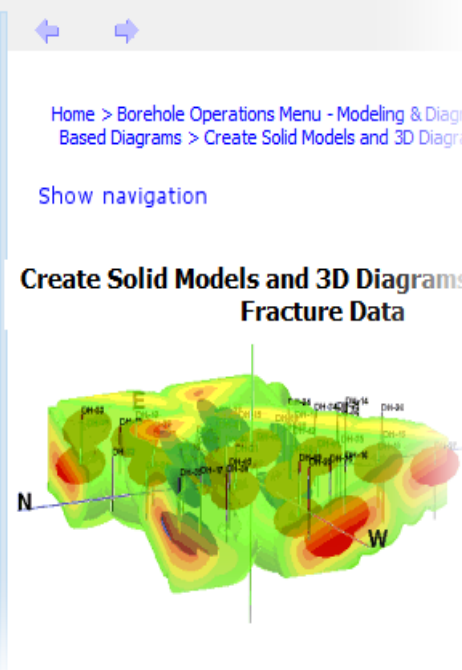
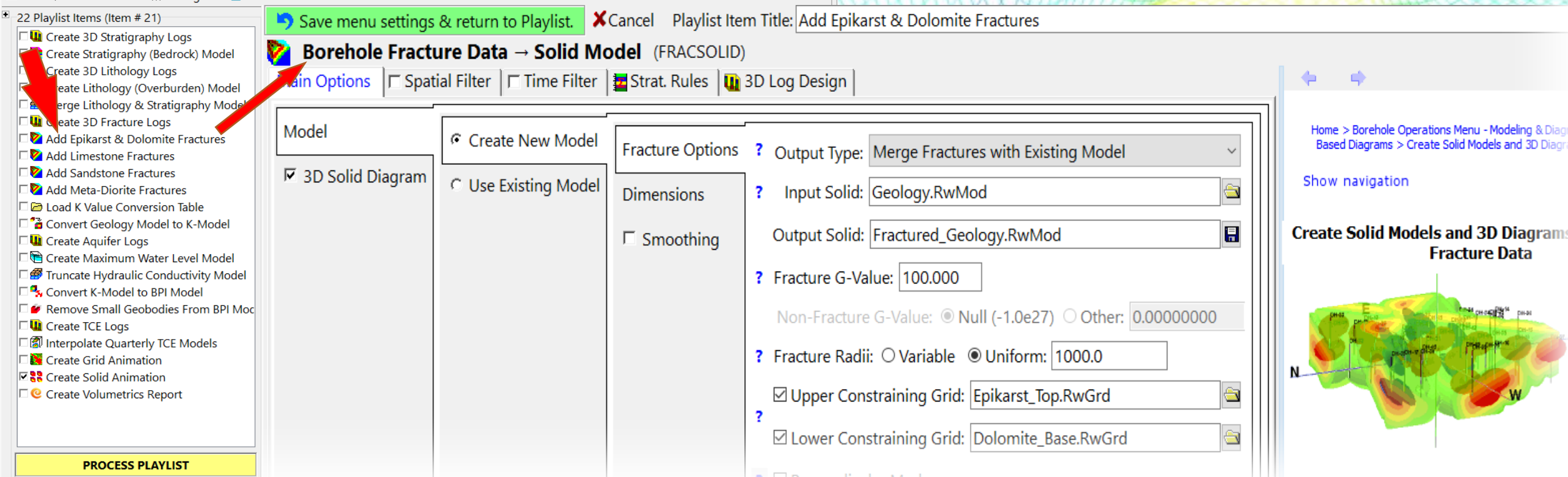
The screenshot shows the 'Stratigraphy Model' application window. The top toolbar contains icons for Settings, Favorites, Playlist, Video, and Layout. A red arrow points to the 'Playlist' icon. The main interface is divided into several panels:

- Main Options:** Includes checkboxes for Spatial Filter, Time Filter, Strat. Rules, and 3D Log Design.
- Stratigraphic Units:** Includes a checked 'Interpolate Surfaces' checkbox and a 'Diagram' section with an 'Add' button and checkboxes for Striplogs, Draped Image, Floating Image, Perimeter Cage, Legend(s), and Infrastructure.
- Gridding Method:** Includes a 'Modeling Sequence' section with checkboxes for Constraining Surface, Polygon Filter, Baseplate, Volumetrics, and Save As Solid Model.
- Dimensions:** Includes an 'Algorithm' section with radio buttons for Closest Point, Cumulative, Directional, Distance to Point, Inverse Distance, Kriging (selected), Plane, Sample Density, and Trend Polynomial.
- Variography:** Includes radio buttons for Automatic (selected) and Manual, input fields for Spoke Spacing (45), Distance Increment (250), and Maximum Distance (1000), a Variogram dropdown (Gaussian With Nugget), and checkboxes for Pre-Model Points for Variograms, Edit/Examine Variograms, Reporting Options, Textual Report, and 2D Variogram Matrix.
- Right Panel:** Titled 'Create 3D Stratigraphic Models and Diagrams', it features a 3D model of a stratigraphic unit and text describing the program's capabilities: 'RockWorks | Borehole Operations | Stratigraphy | Layered Model' and 'Use this program to: Interpolate grid models for the upper and lower surfaces of the project's stratigraphic units (all units or selected ones) - OR -'.

To add items to the Playlist, click on the Playlist option within any of the 800+ RockWorks program menus.



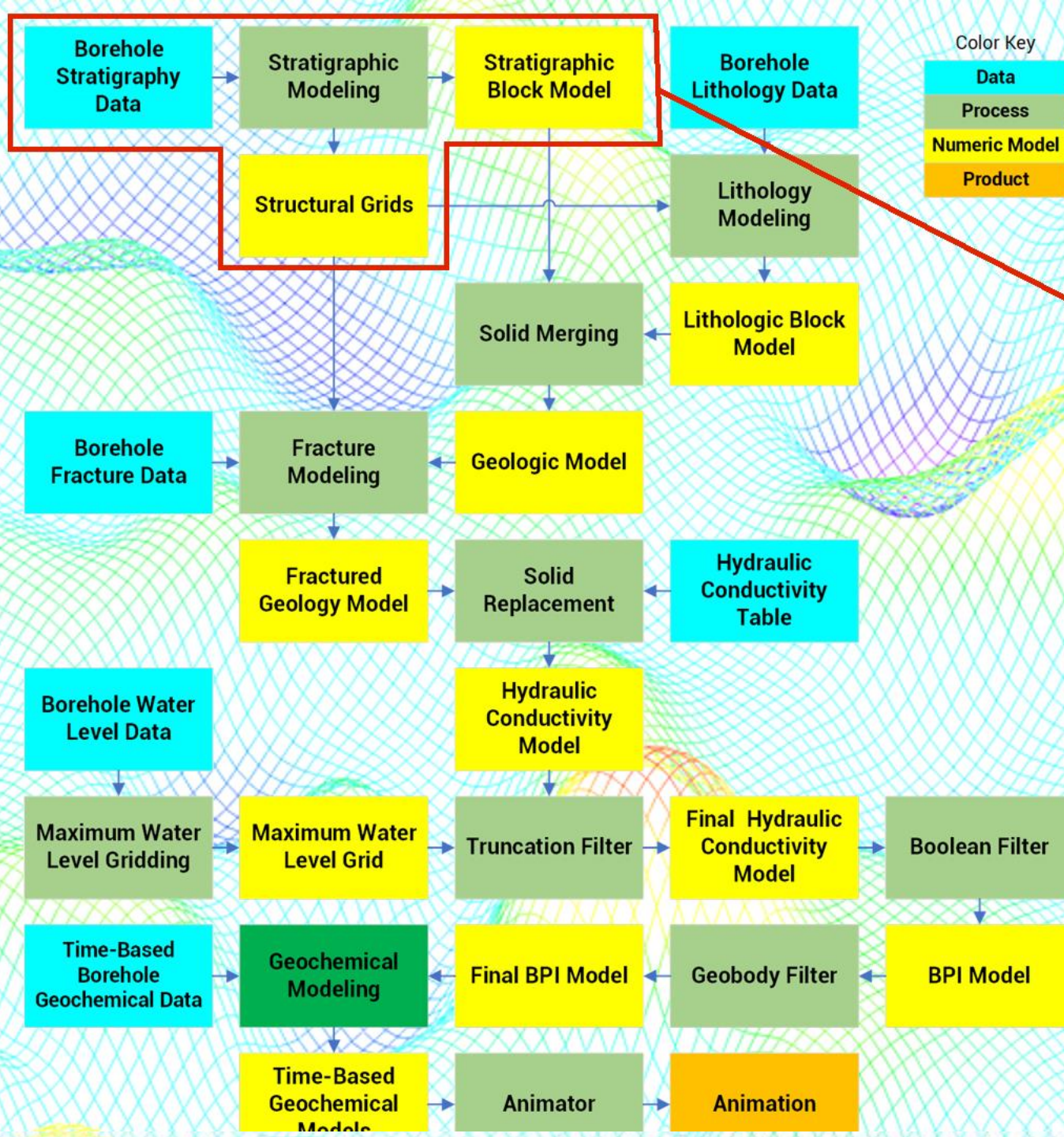
Editing / Examining Items Within the Playlist



To edit or examine items within the Playlist, double-click on the item title.

2

Model Bedrock Stratigraphy



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Playlist (TCE Modeling & Animation) Datasheet

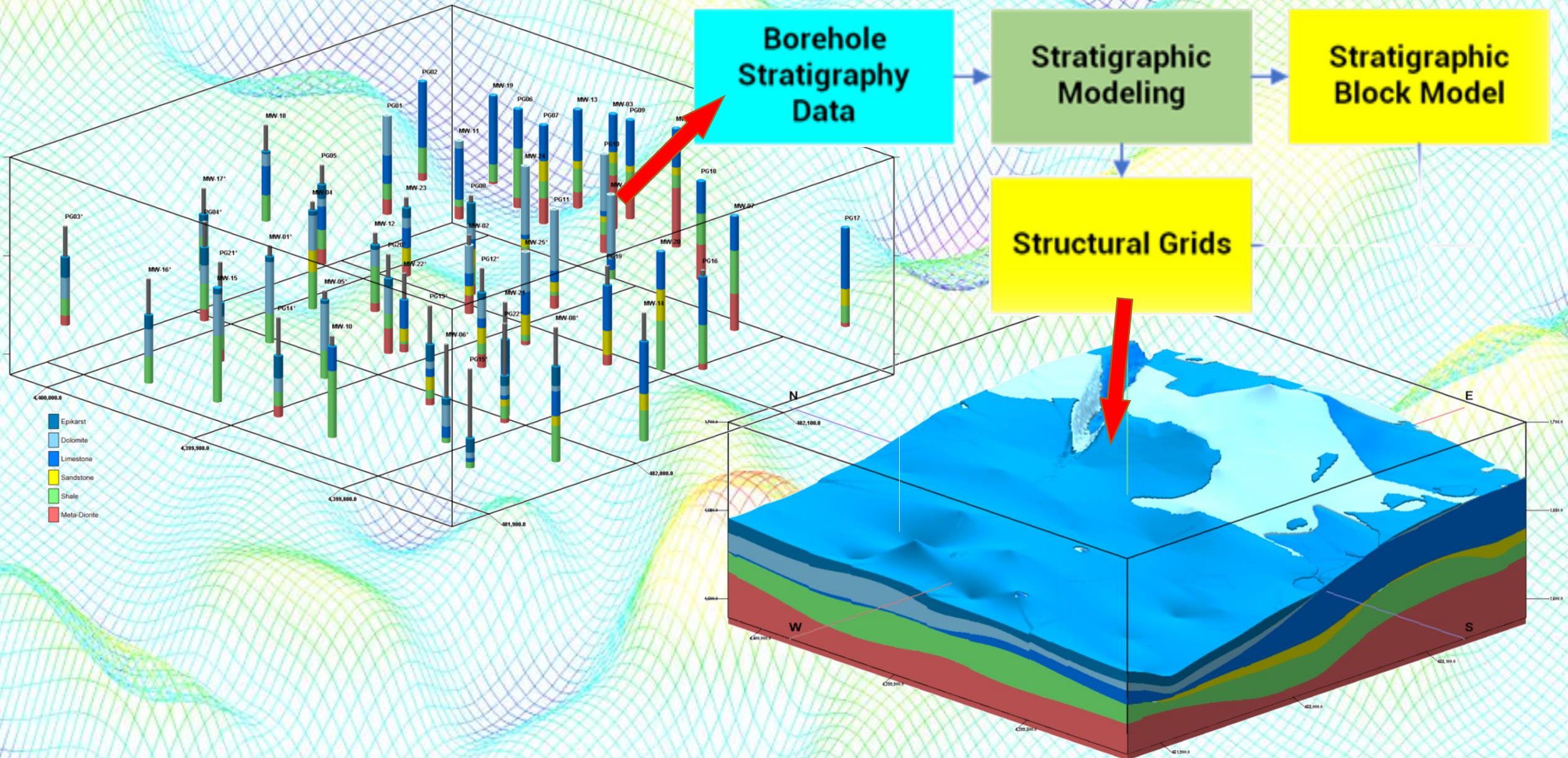
File Edit View Configure Add

22 Playlist Items (Item # 22)

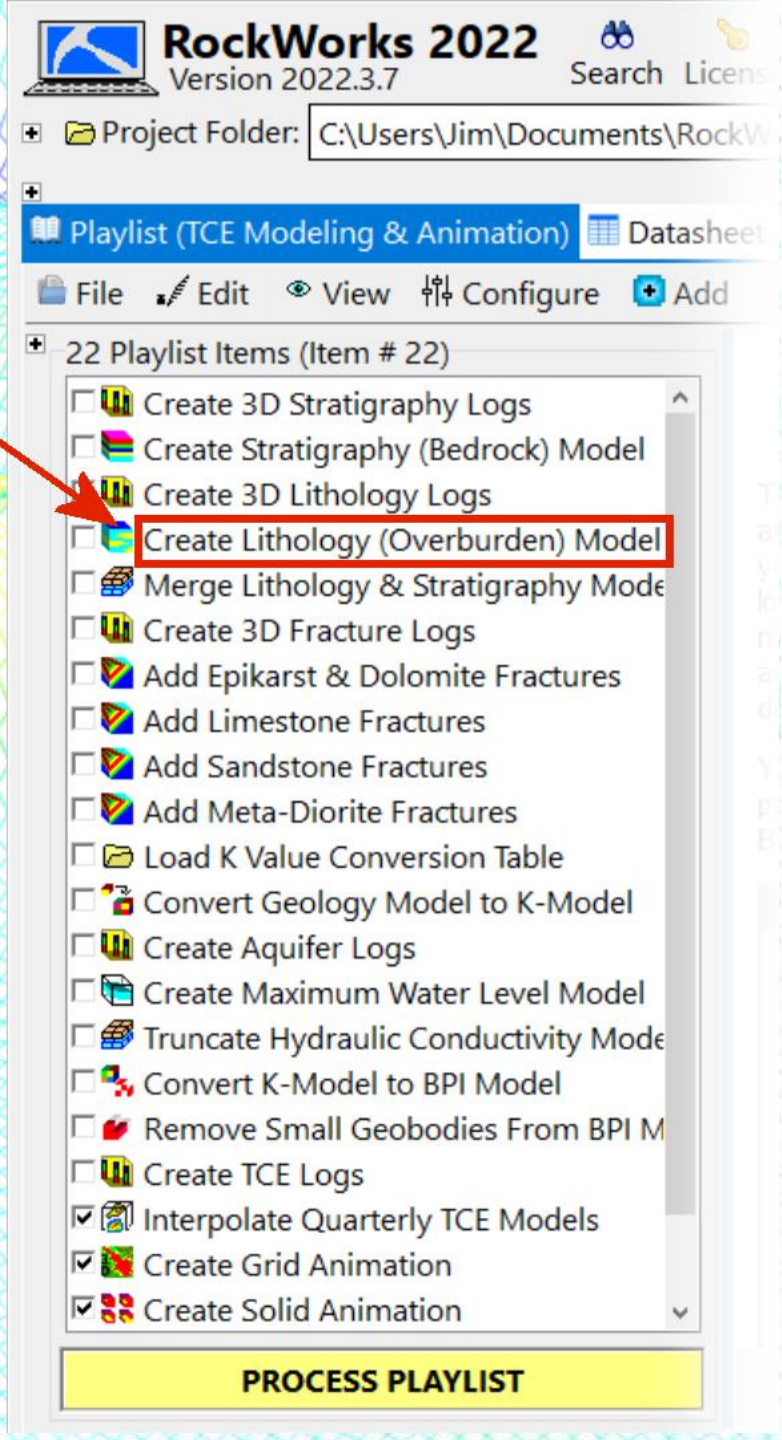
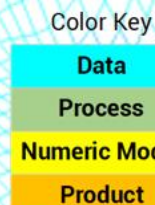
- ☐ Create 3D Stratigraphy Logs
- ☒ **Create Stratigraphy (Bedrock) Model**
- ☐ Create 3D Lithology Logs
- ☐ Create Lithology (Overburden) Model
- ☐ Merge Lithology & Stratigraphy Model
- ☐ Create 3D Fracture Logs
- ☐ Add Epikarst & Dolomite Fractures
- ☐ Add Limestone Fractures
- ☐ Add Sandstone Fractures
- ☐ Add Meta-Diorite Fractures
- ☐ Load K Value Conversion Table
- ☐ Convert Geology Model to K-Model
- ☐ Create Aquifer Logs
- ☐ Create Maximum Water Level Model
- ☐ Truncate Hydraulic Conductivity Model
- ☐ Convert K-Model to BPI Model
- ☐ Remove Small Geobodies From BPI Model
- ☐ Create TCE Logs
- ☒ Interpolate Quarterly TCE Models
- ☒ Create Grid Animation
- ☒ Create Solid Animation

PROCESS PLAYLIST

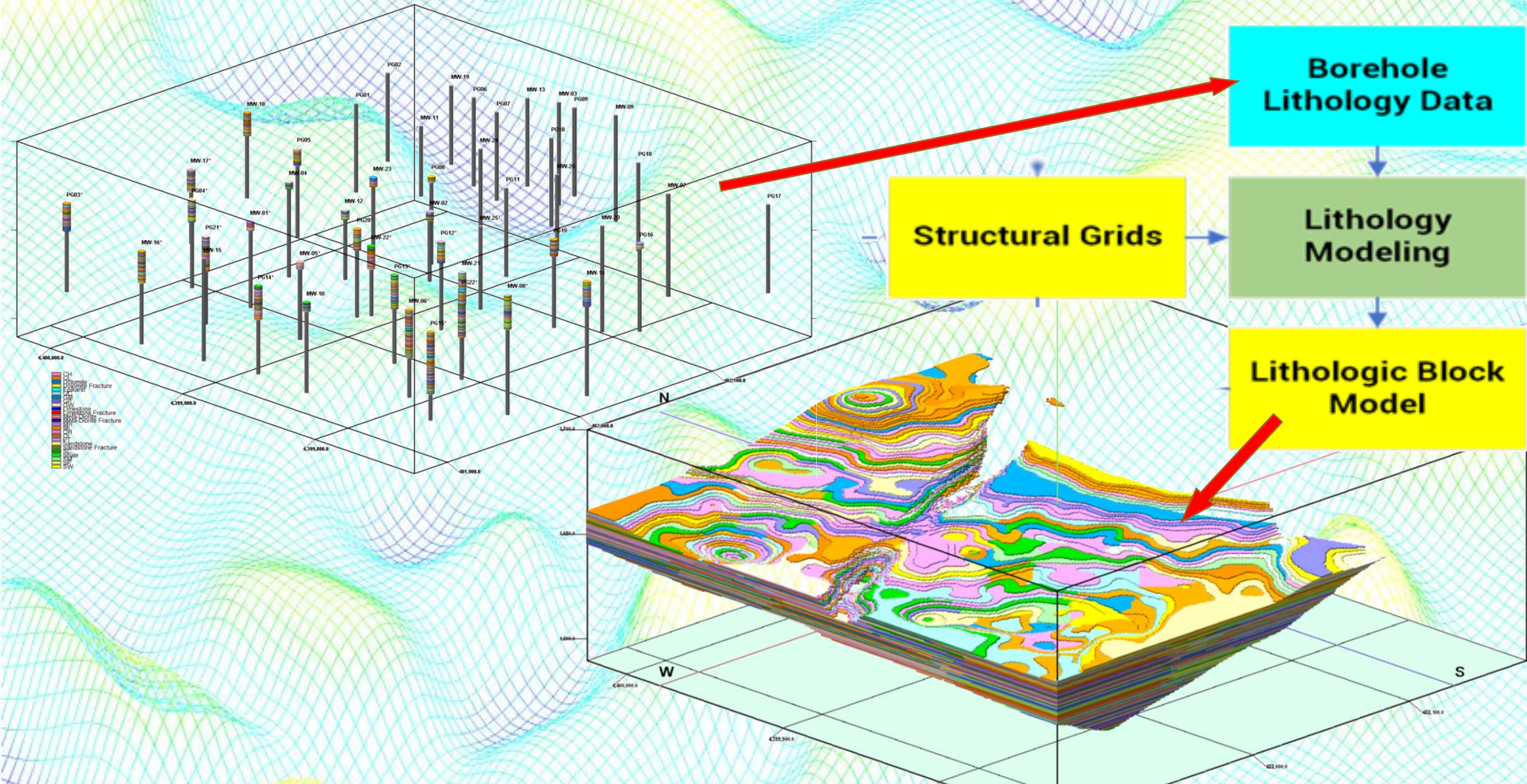
Modeling Bedrock Stratigraphy



Model
Unconsolidated
Overburden

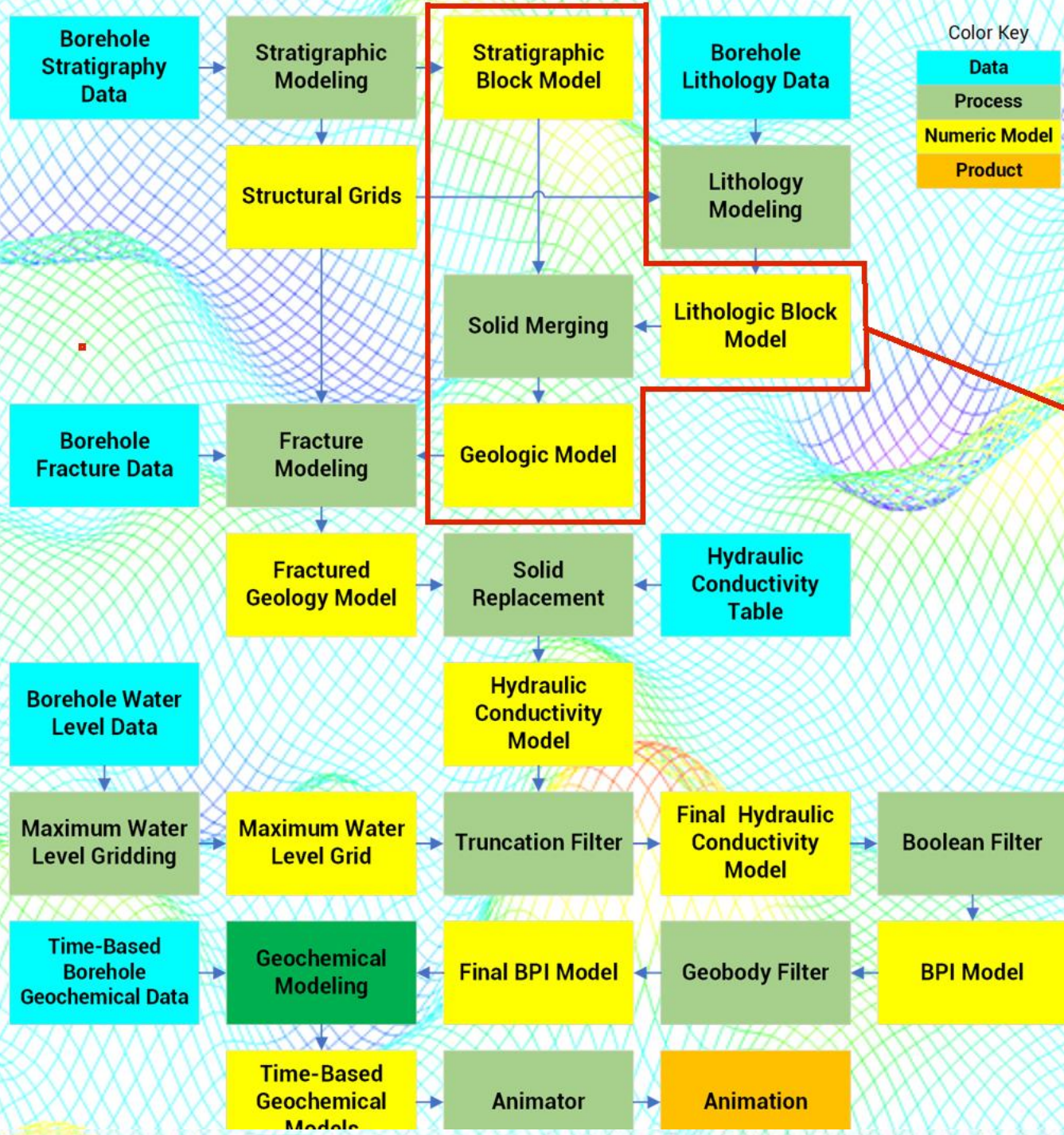


Modeling Unconsolidated Overburden



4

Merge Bedrock Stratigraphy & Overburden



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Playlist (TCE Modeling & Animation)

File

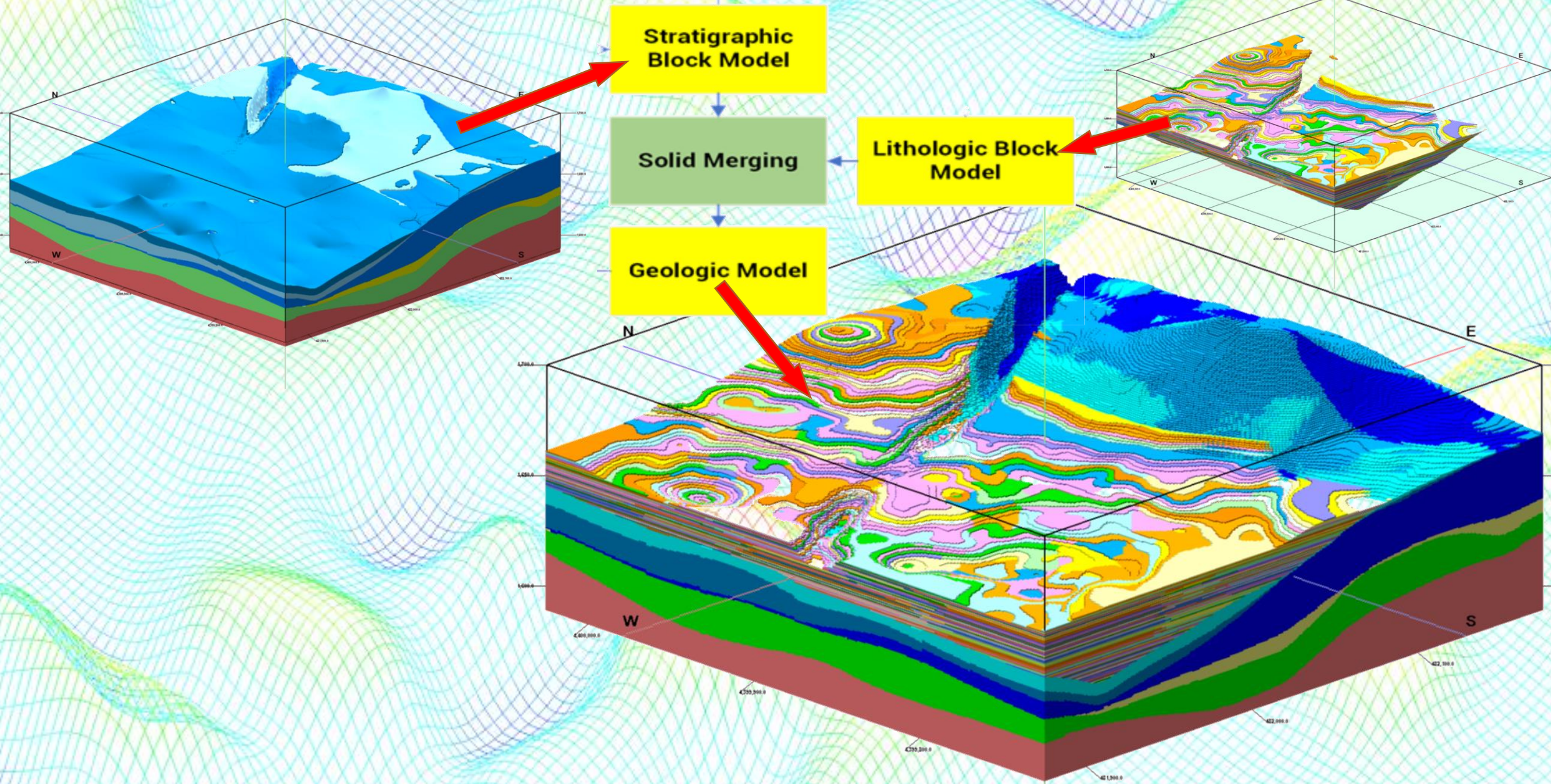
 View

22 Playlist Items (Item # 22)

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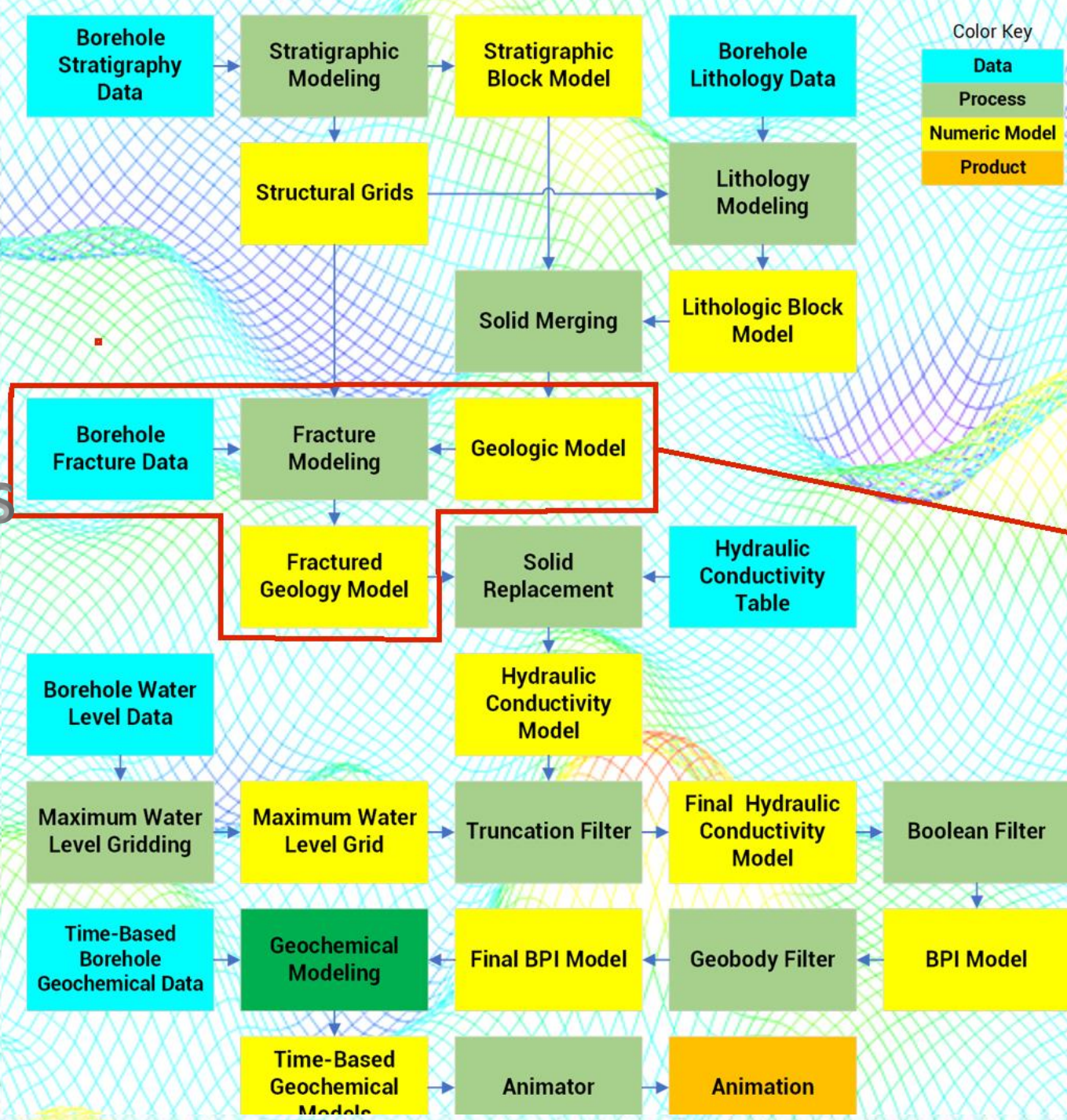
PROCESS PLAYLIST

Merging Models



5

Add Fractures to Geology Model



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Playlist (TCE Modeling & Animation)

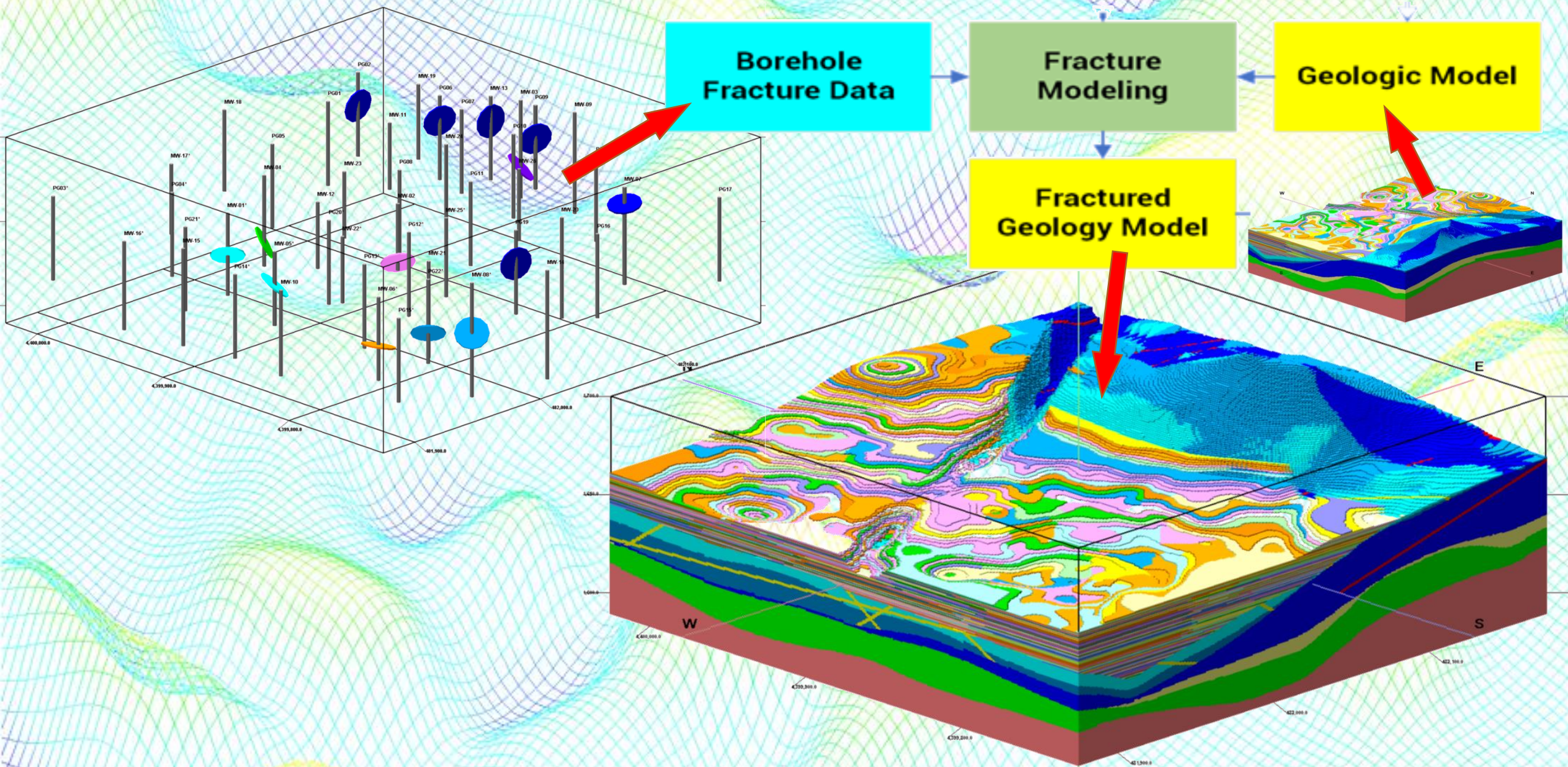
File Edit View Configure Add

22 Playlist Items (Item # 22)

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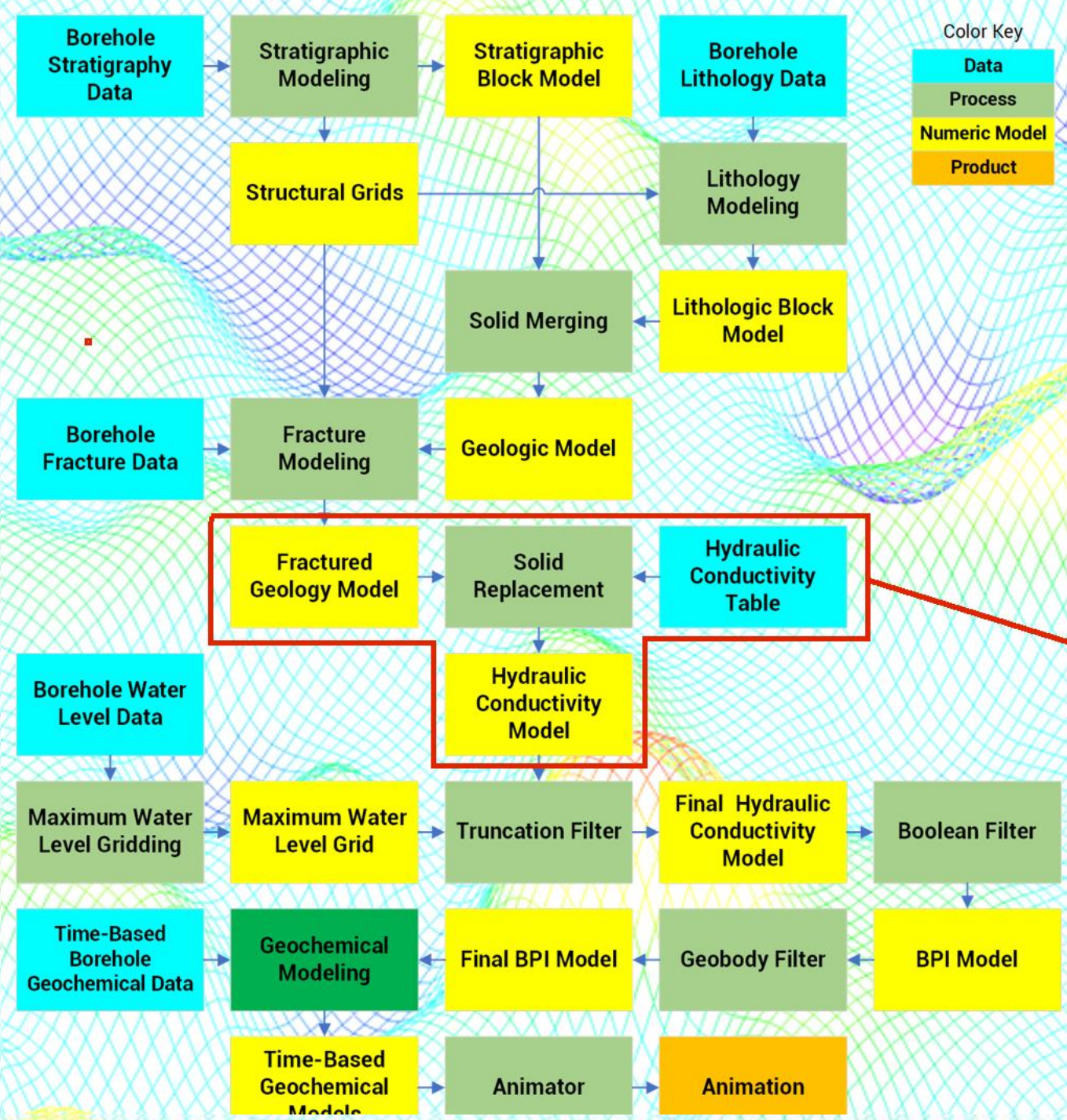
PROCESS PLAYLIST

Adding Fractures to Geology Model



6

Convert Geology Model to Hydraulic Conductivity (K) Model



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Playlist (TCE Modeling & Animation)

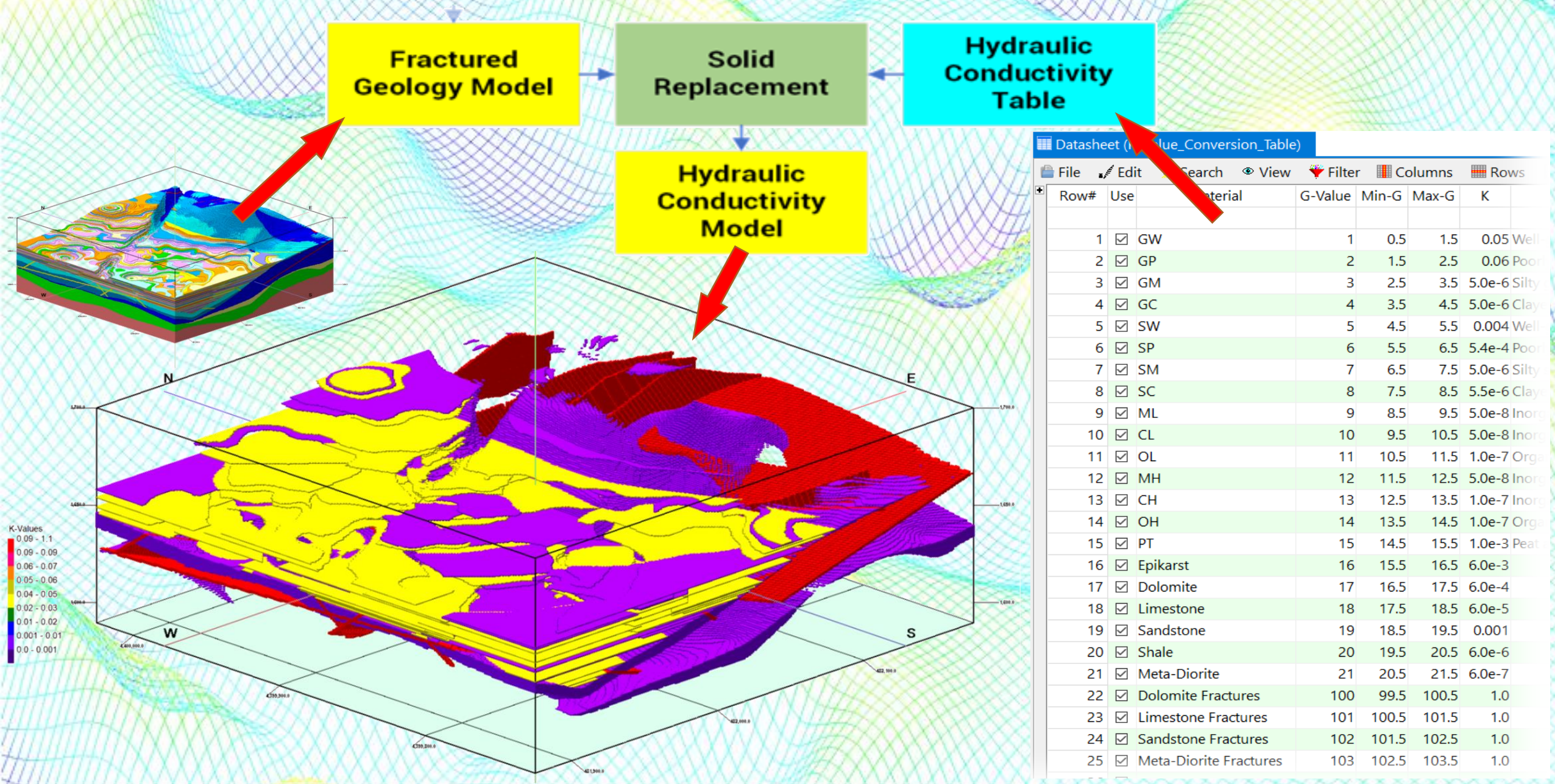
File Edit View Configure Add

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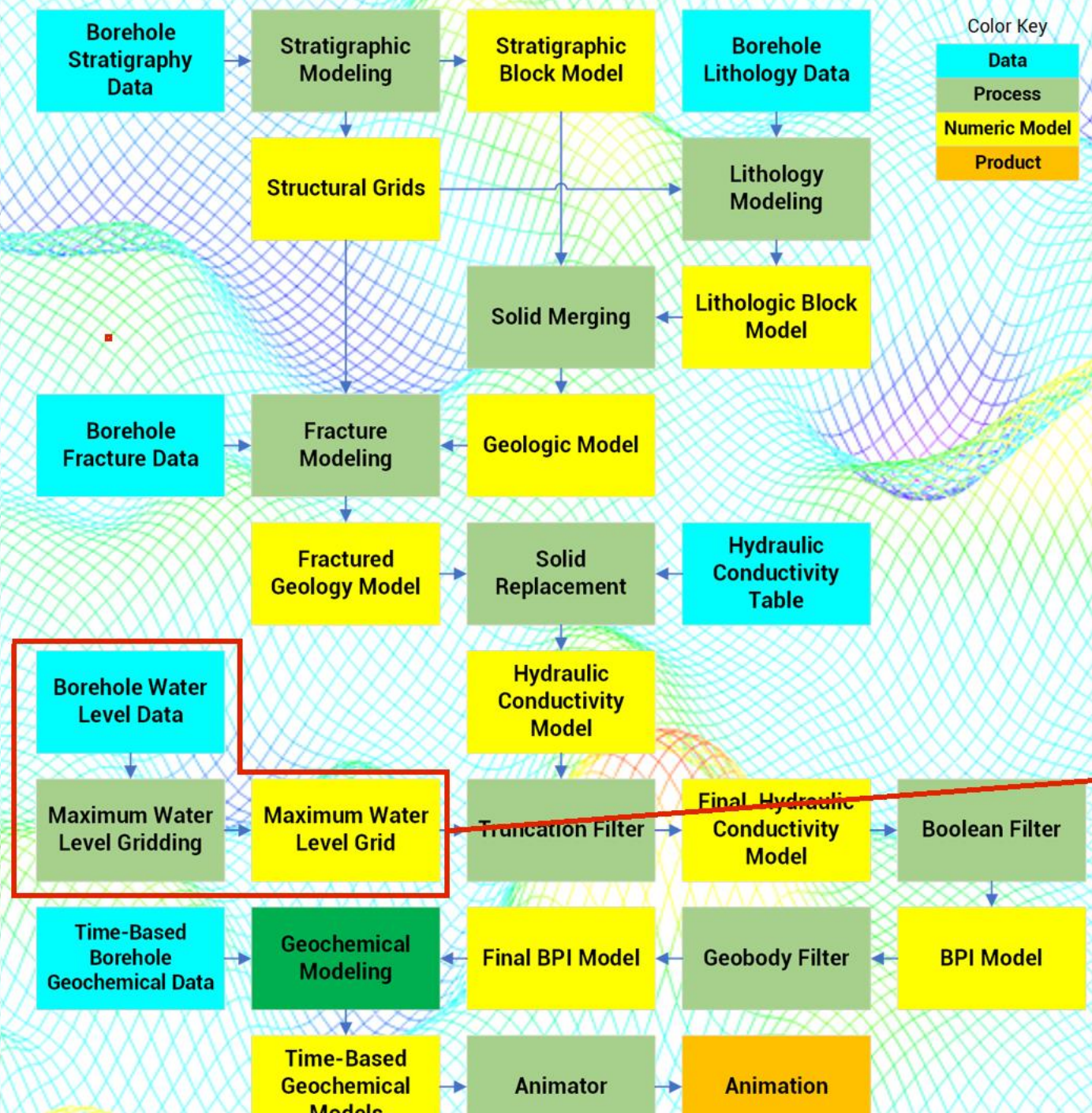
PROCESS PLAYLIST

Converting Geology Model to Hydraulic Conductivity (K) Model



7

Create Maximum Water Level Model



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Playlist (TCE Modeling & Animation)

File

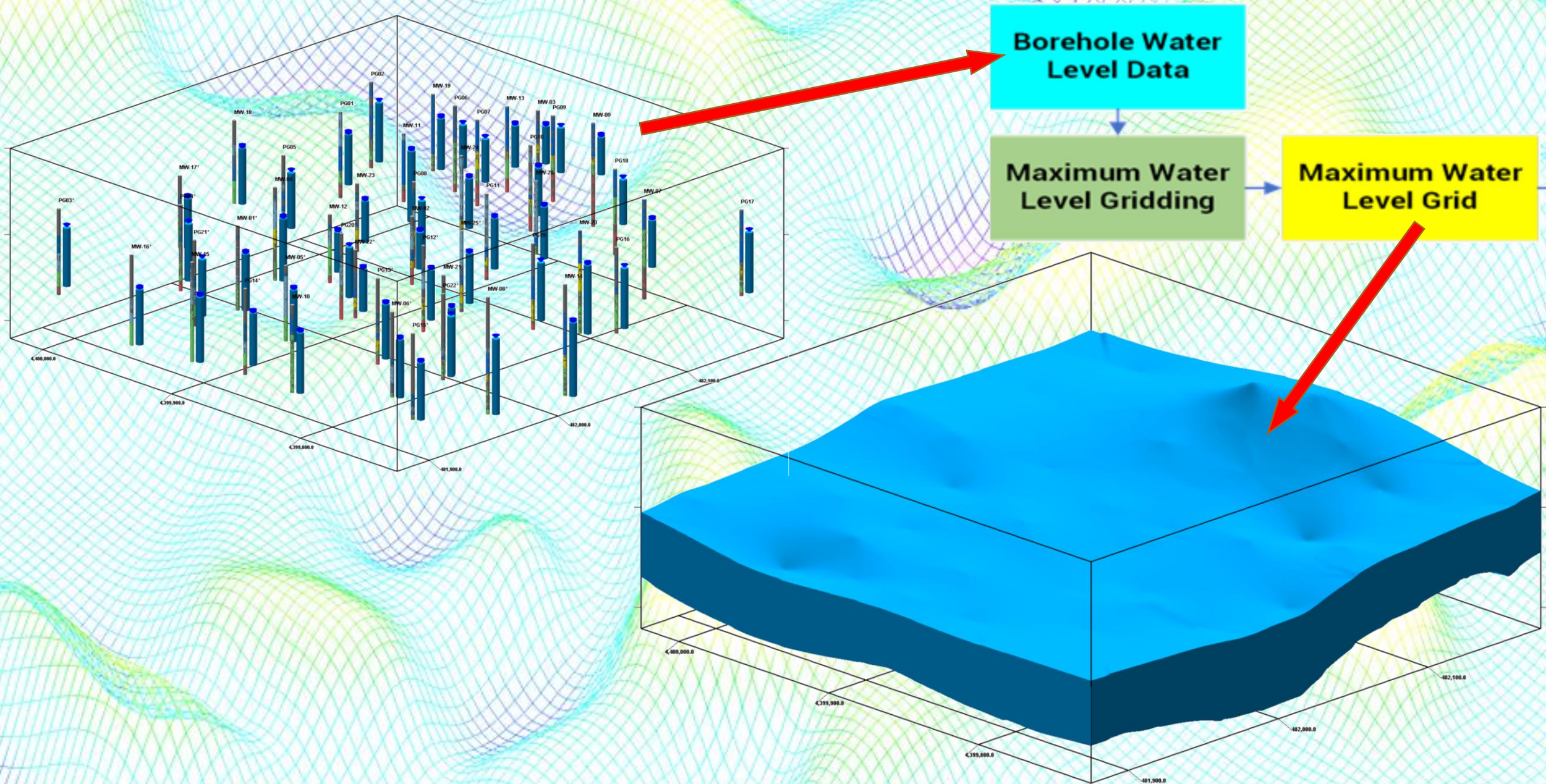
 View

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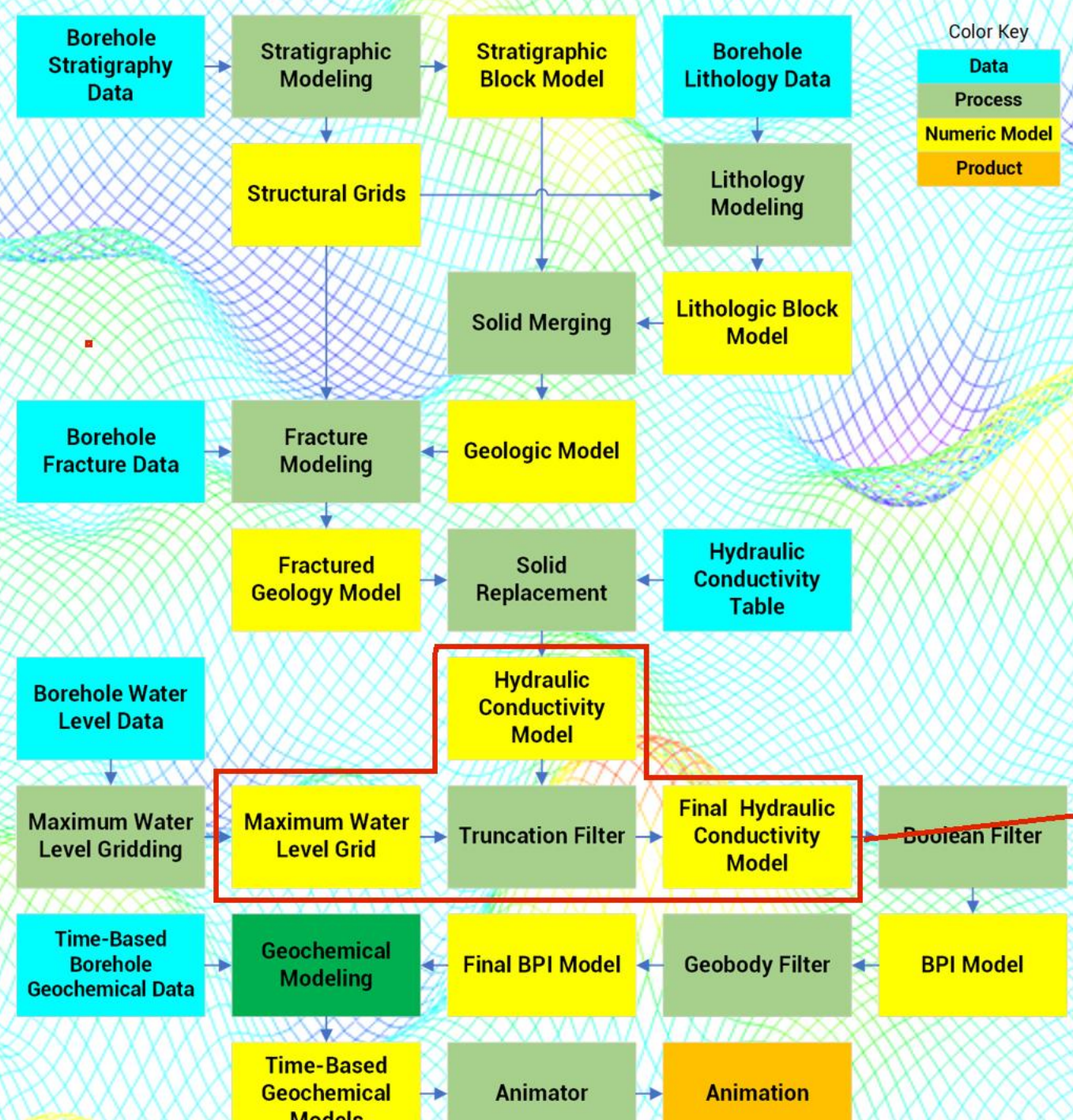
PROCESS PLAYLIST

Creating a Maximum Water Level Model



8

Truncate Hydraulic Conductivity Model Based on Maximum Water Level Model



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Playlist (TCE Modeling & Animation)

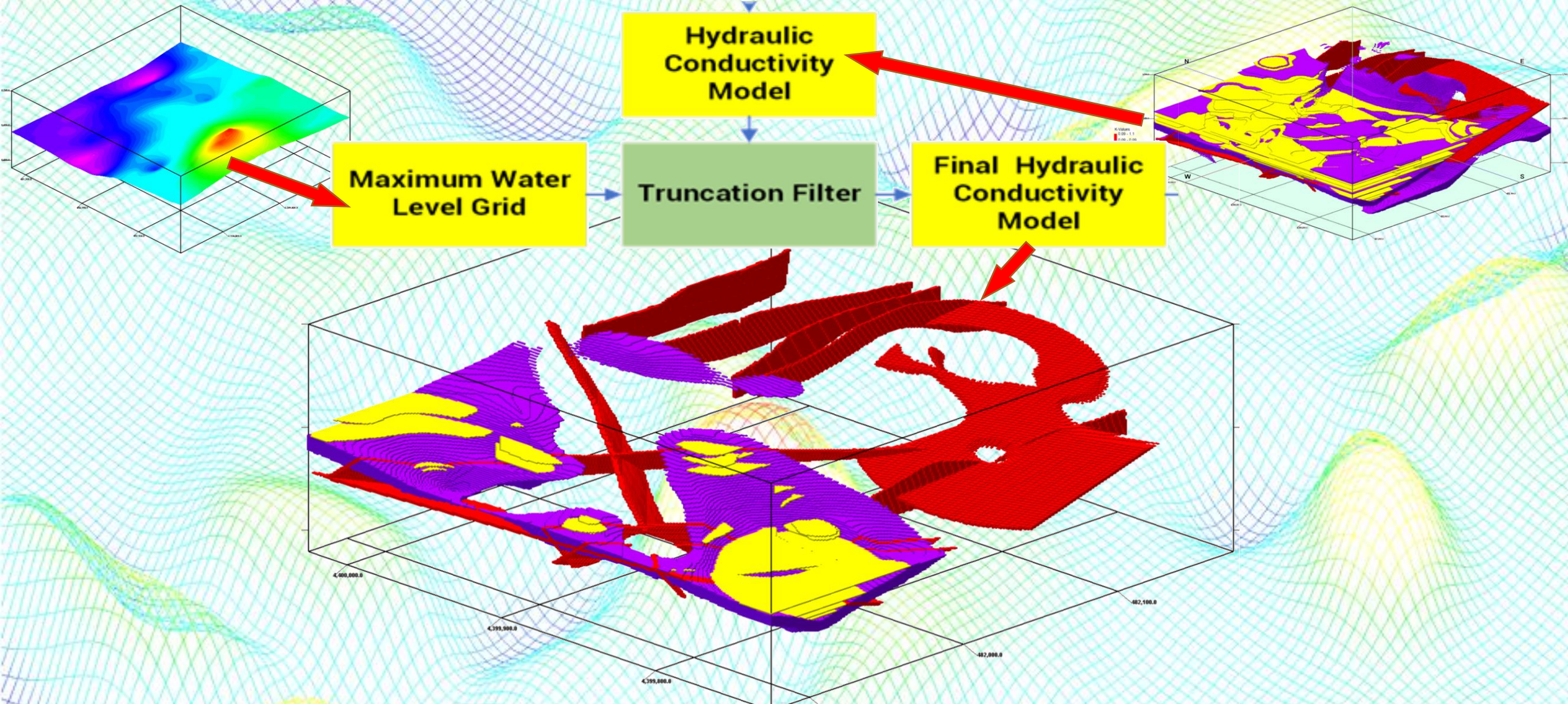
File Edit View Configure Add

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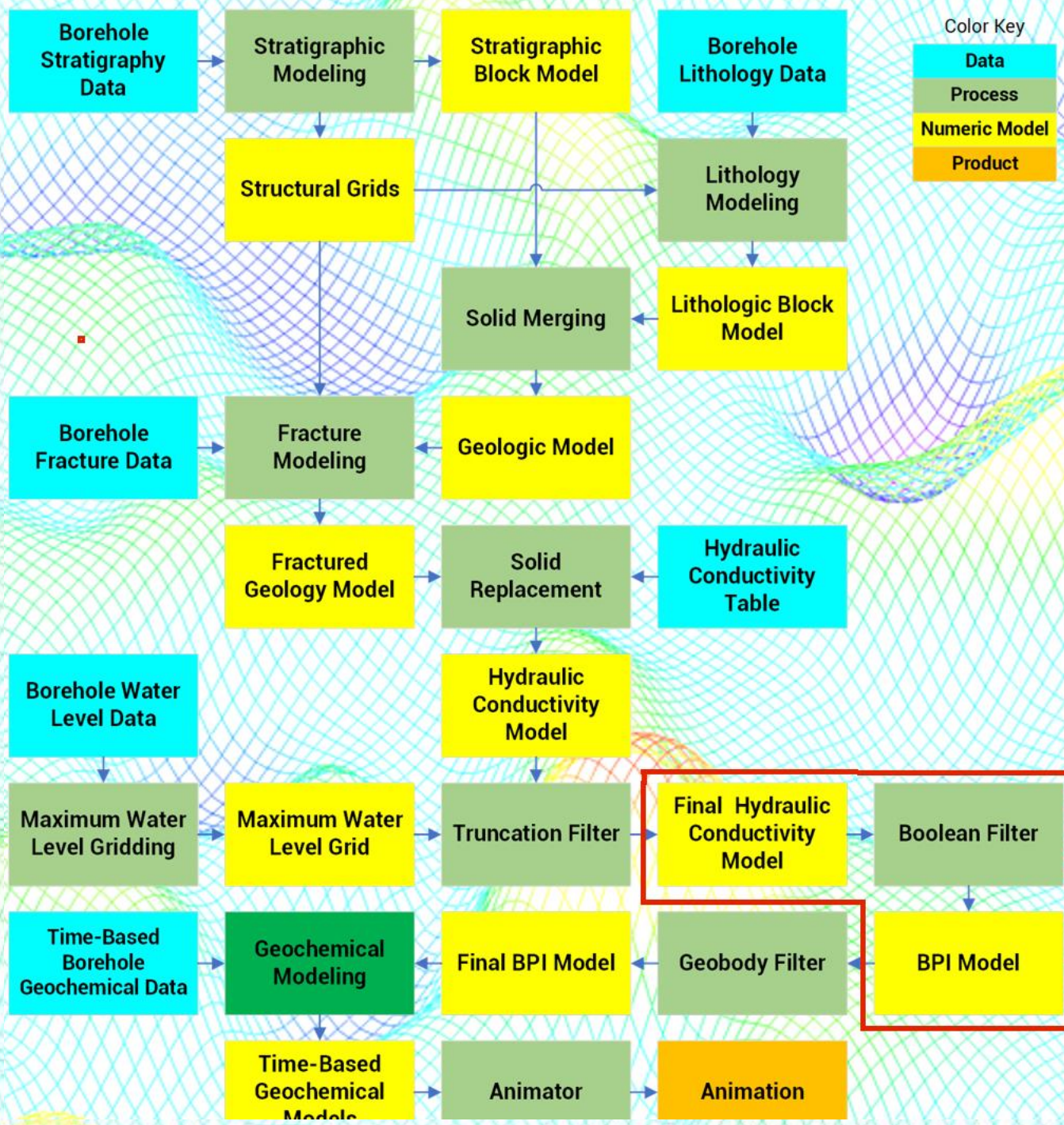
PROCESS PLAYLIST

Truncating Hydraulic Conductivity Model Based on Maximum Water Level Model



9

Convert
Hydraulic
Conductivity
Model to
Boolean
Permeable /
Impermeable
(BPI) Model



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Playlist (TCE Modeling & Animation) Datasheet

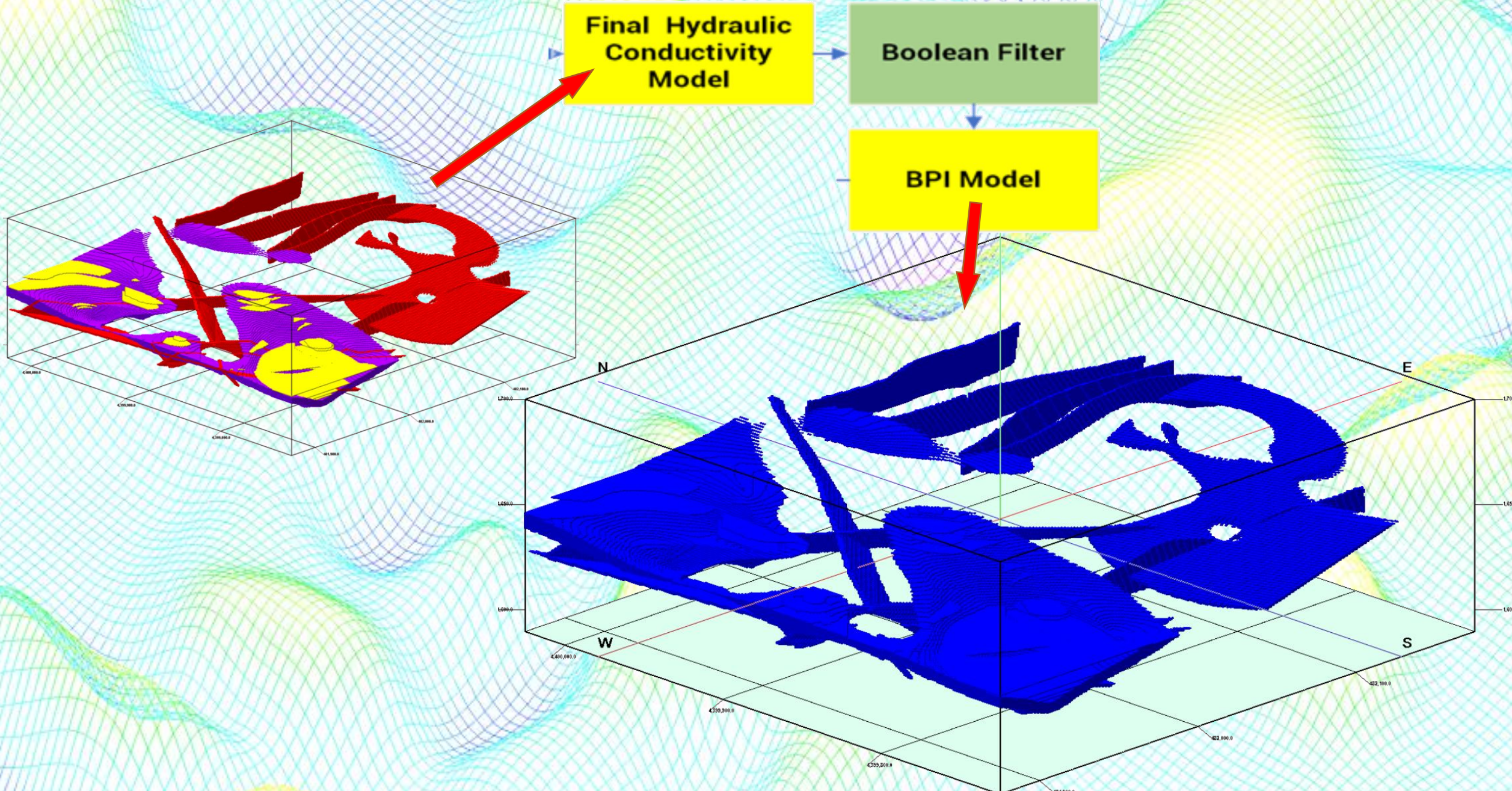
File Edit View Configure Add

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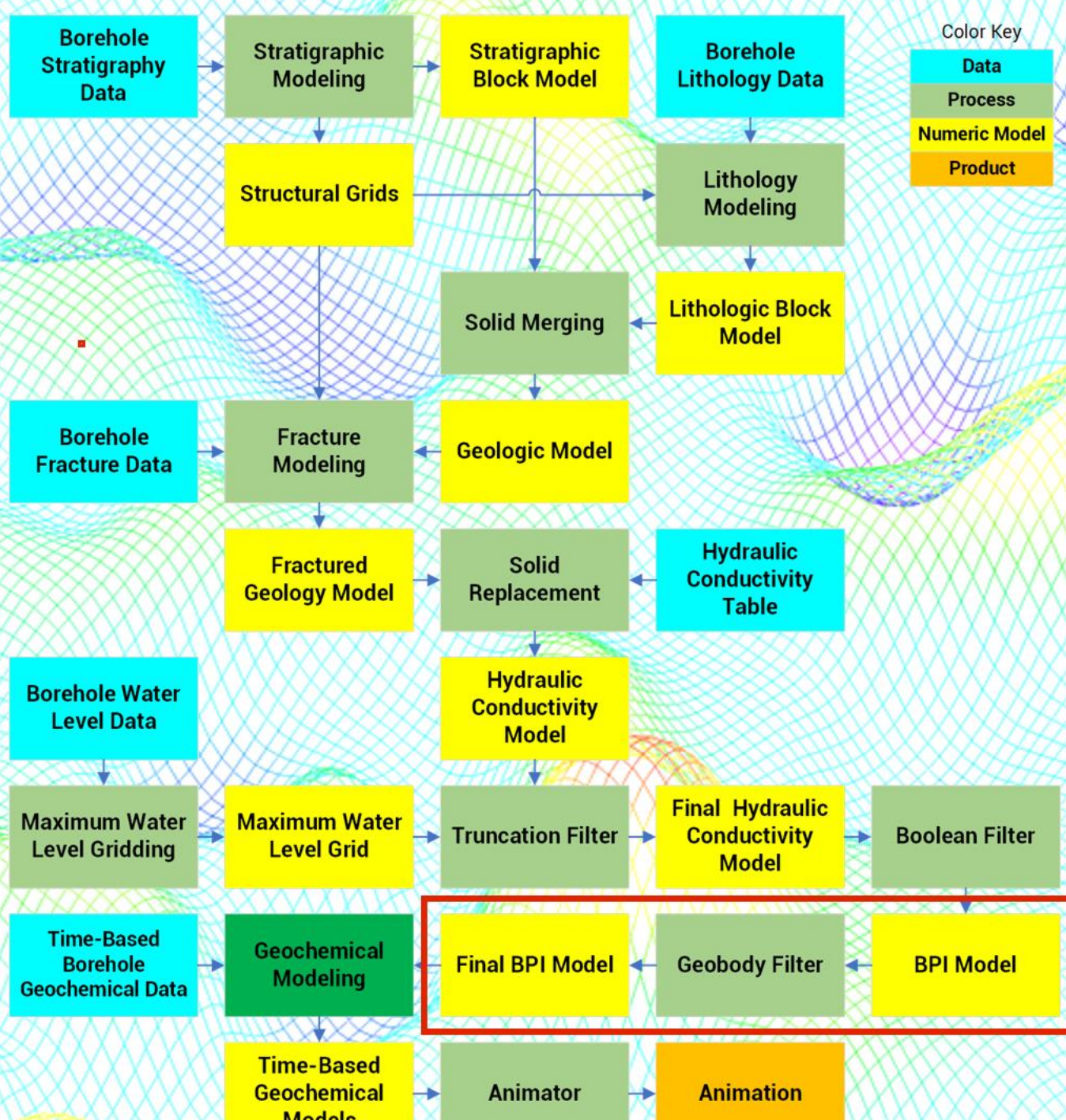
PROCESS PLAYLIST

Converting Hydraulic Conductivity Model to Boolean Permeable / Impermeable (BPI) Model



10

Isolate Contiguous Permeable Zones



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Playlist (TCE Modeling & Animation) Datasheet

File Edit View Configure Add

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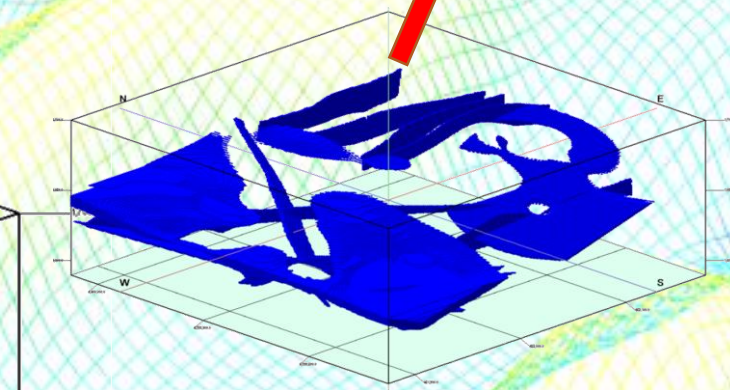
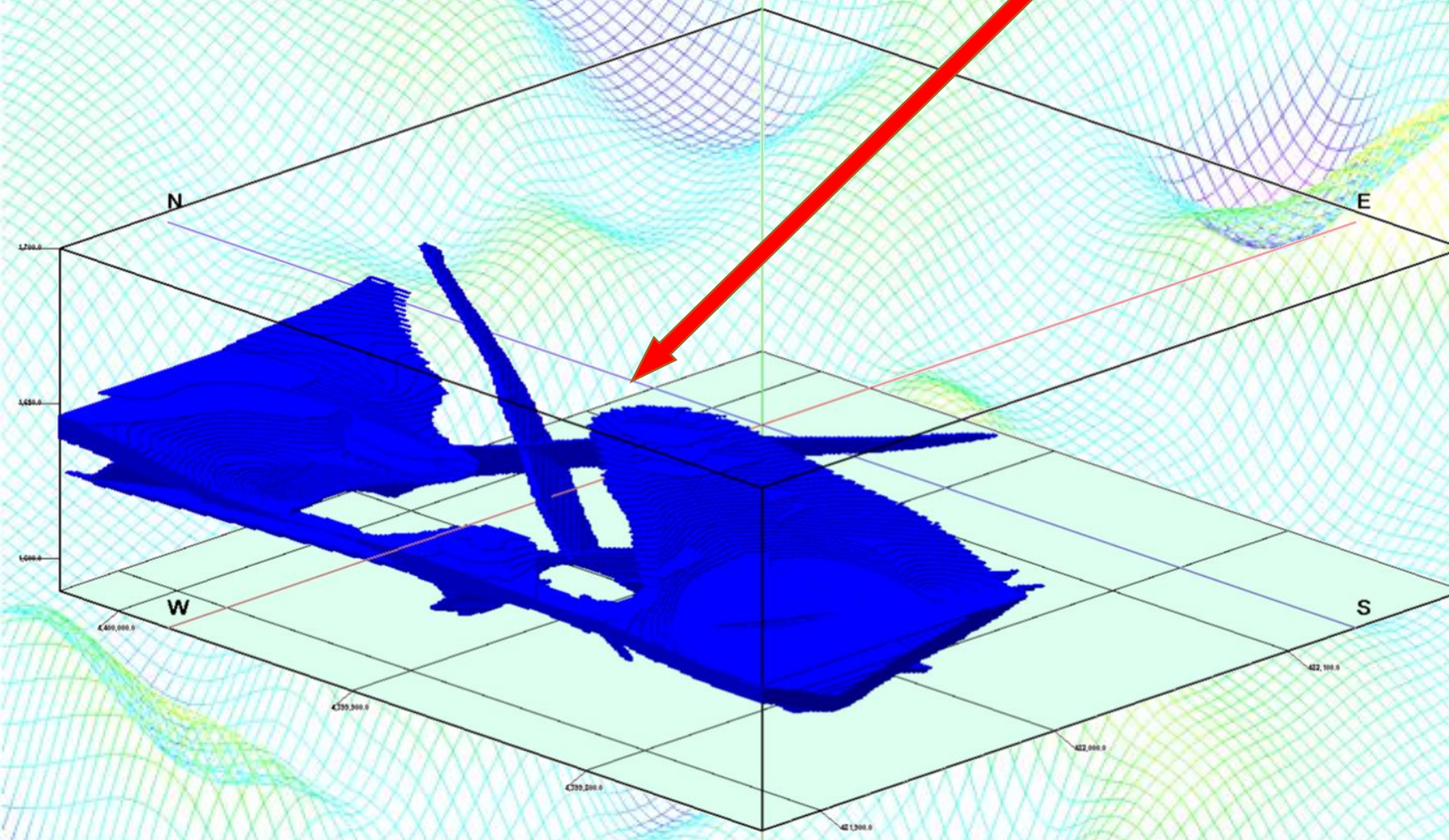
PROCESS PLAYLIST

Isolating Contiguous (Connected) Permeable Zones

Final BPI Model

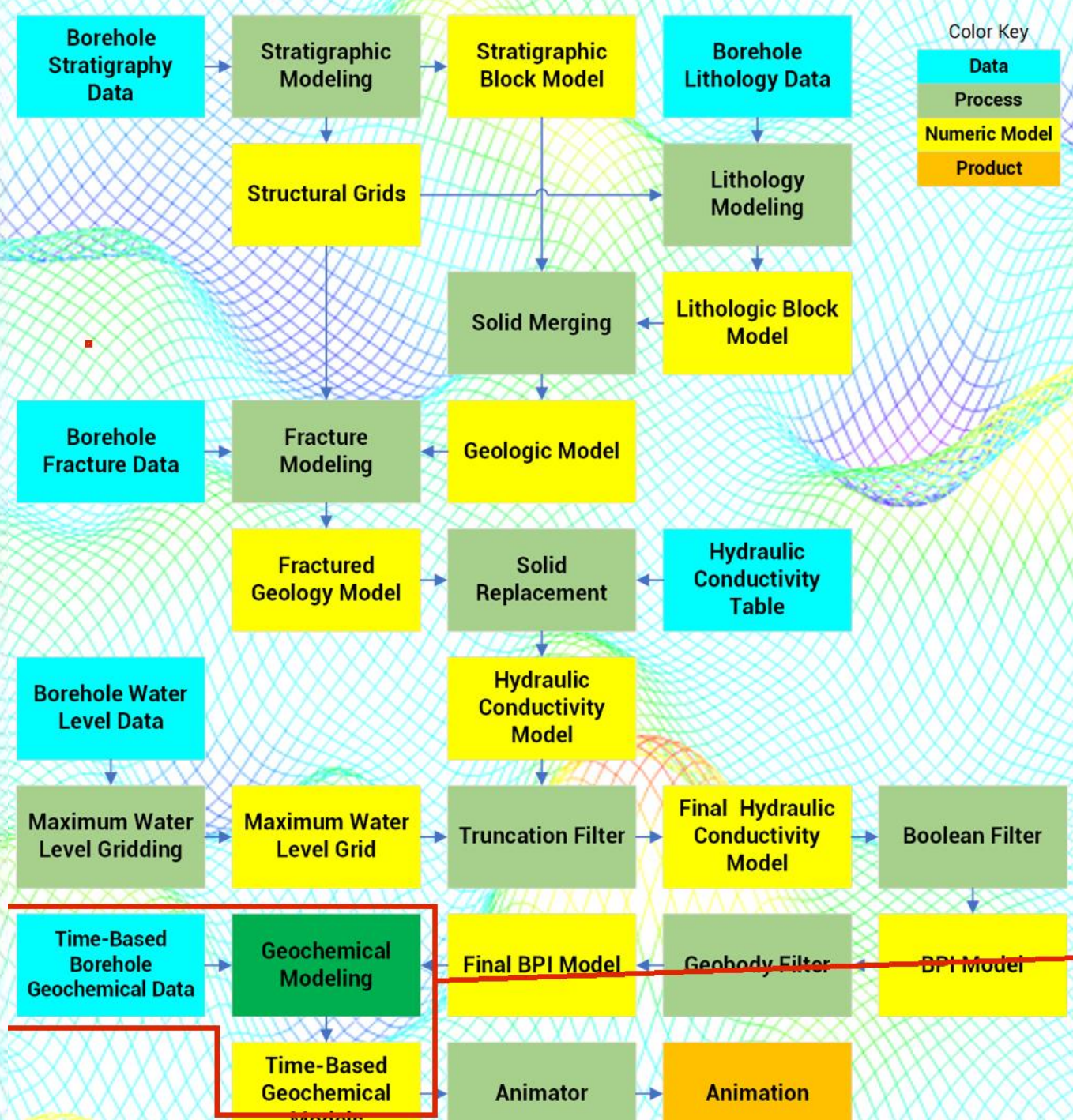
Geobody Filter

BPI Model



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Interpolate Quarterly Geochemical Models



RockWorks 2022
Version 2022.3.7

Search

Project Folder:

Playlist (TCE Modeling & Animation)

File Edit View Configure Add

22 Playlist Items (Item # 22)

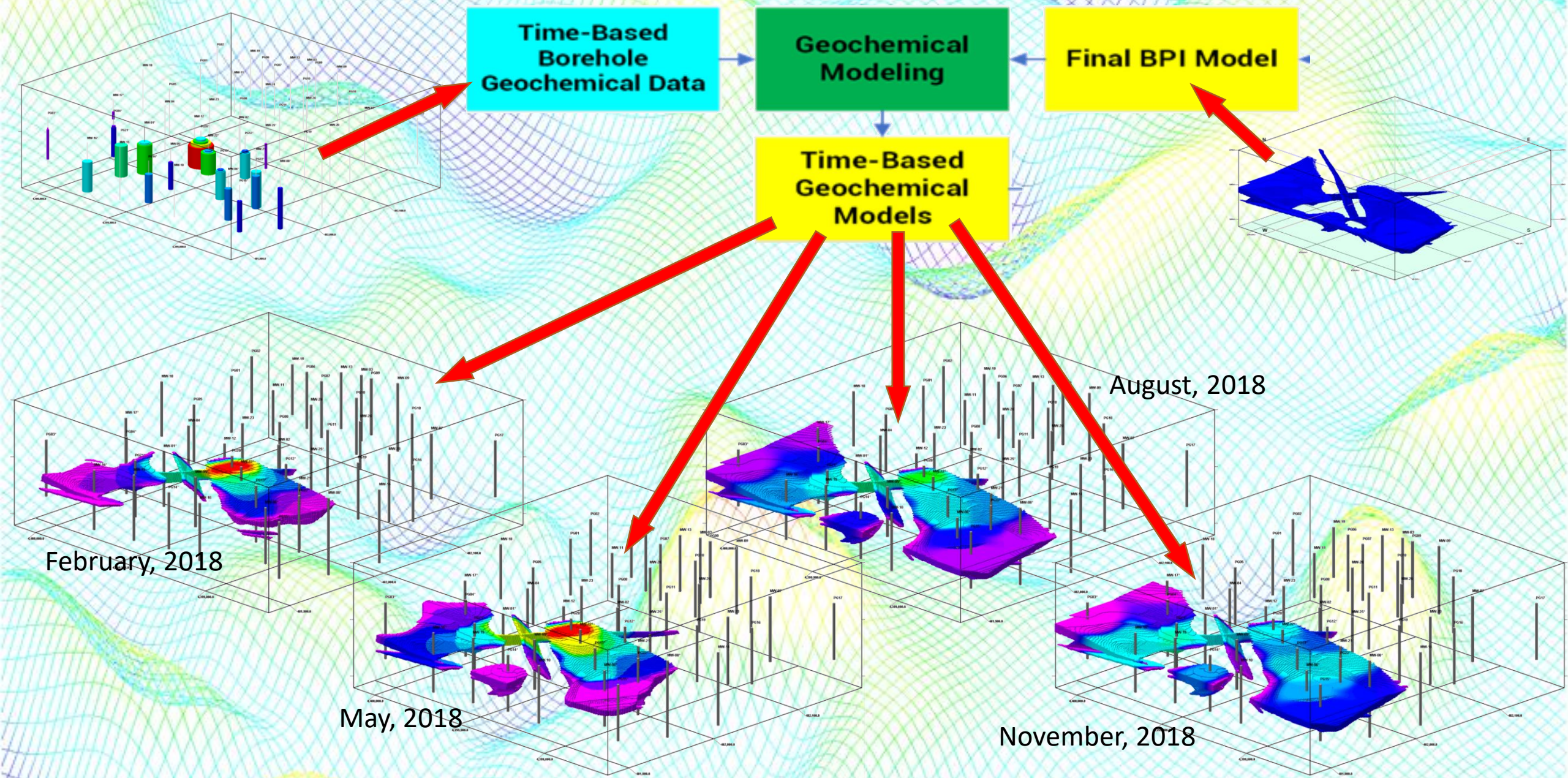
☐

 Create 3D Stratigraphy Logs

☐

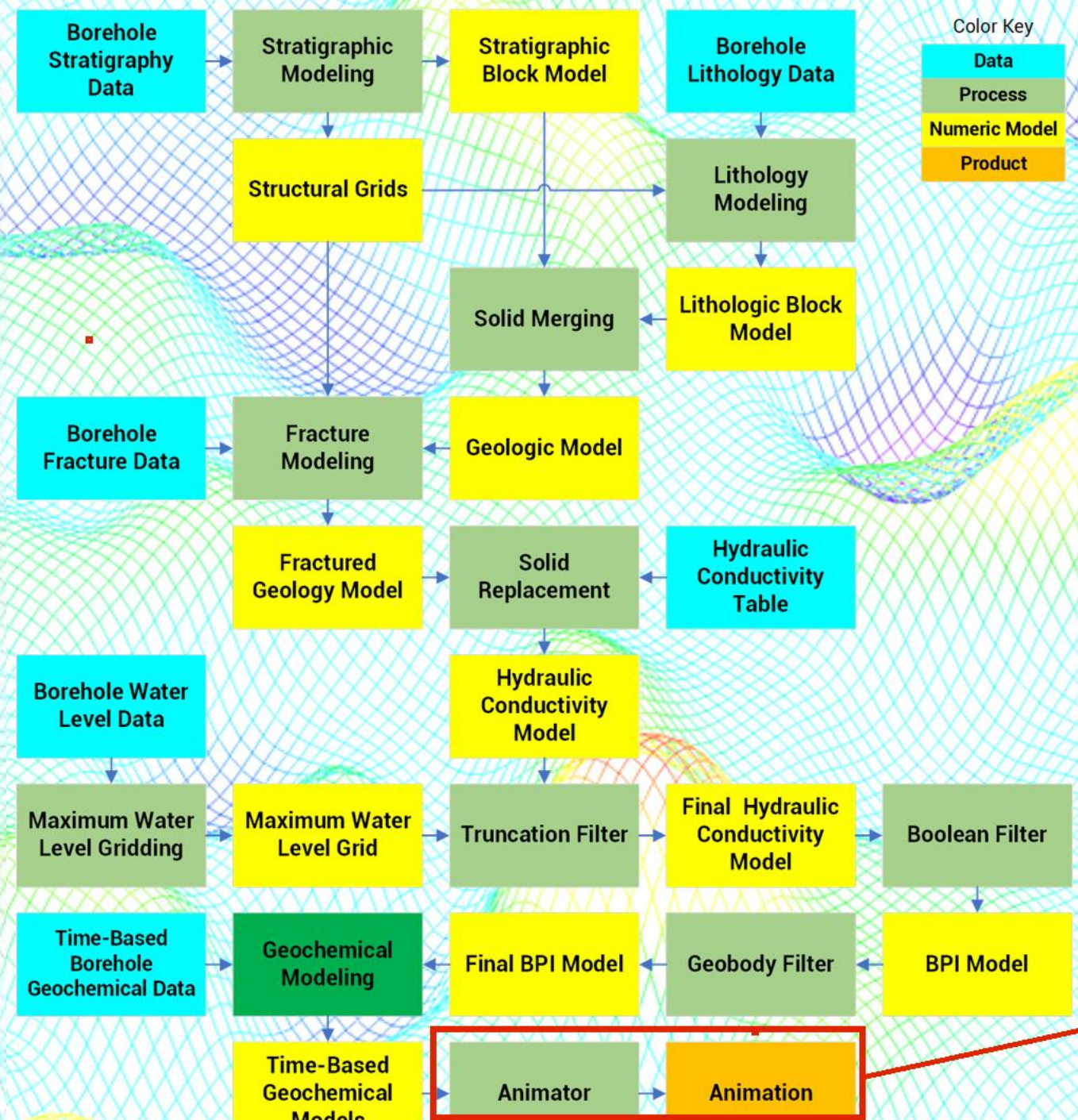
 Create Stratigraphy (Bedrock) Model☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☒☒☒**PROCESS PLAYLIST**

Interpolating Quarterly Geochemical Models



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Create Animations



RockWorks 2022
Version 2022.3.7

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Project Folder:

Playlist (TCE Modeling & Animation)

File Edit View Configure Add

22 Playlist Items (Item # 22)

☐ Create 3D Stratigraphy Logs

☐ Create Stratigraphy (Bedrock) Model

☐ Create 3D Lithology Logs

☐ Create Lithology (Overburden) Model

☐ Merge Lithology & Stratigraphy Model

☐ Create 3D Fracture Logs

☐ Add Epikarst & Dolomite Fractures

☐ Add Limestone Fractures

☐ Add Sandstone Fractures

☐ Add Meta-Diorite Fractures

☐ Load K Value Conversion Table

☐ Convert Geology Model to K-Model

☐ Create Aquifer Logs

☐ Create Maximum Water Level Model

☐ Truncate Hydraulic Conductivity Model

☐ Convert K-Model to BPI Model

☐ Remove Small Geobodies From BPI Model

☐ Create TCE Logs

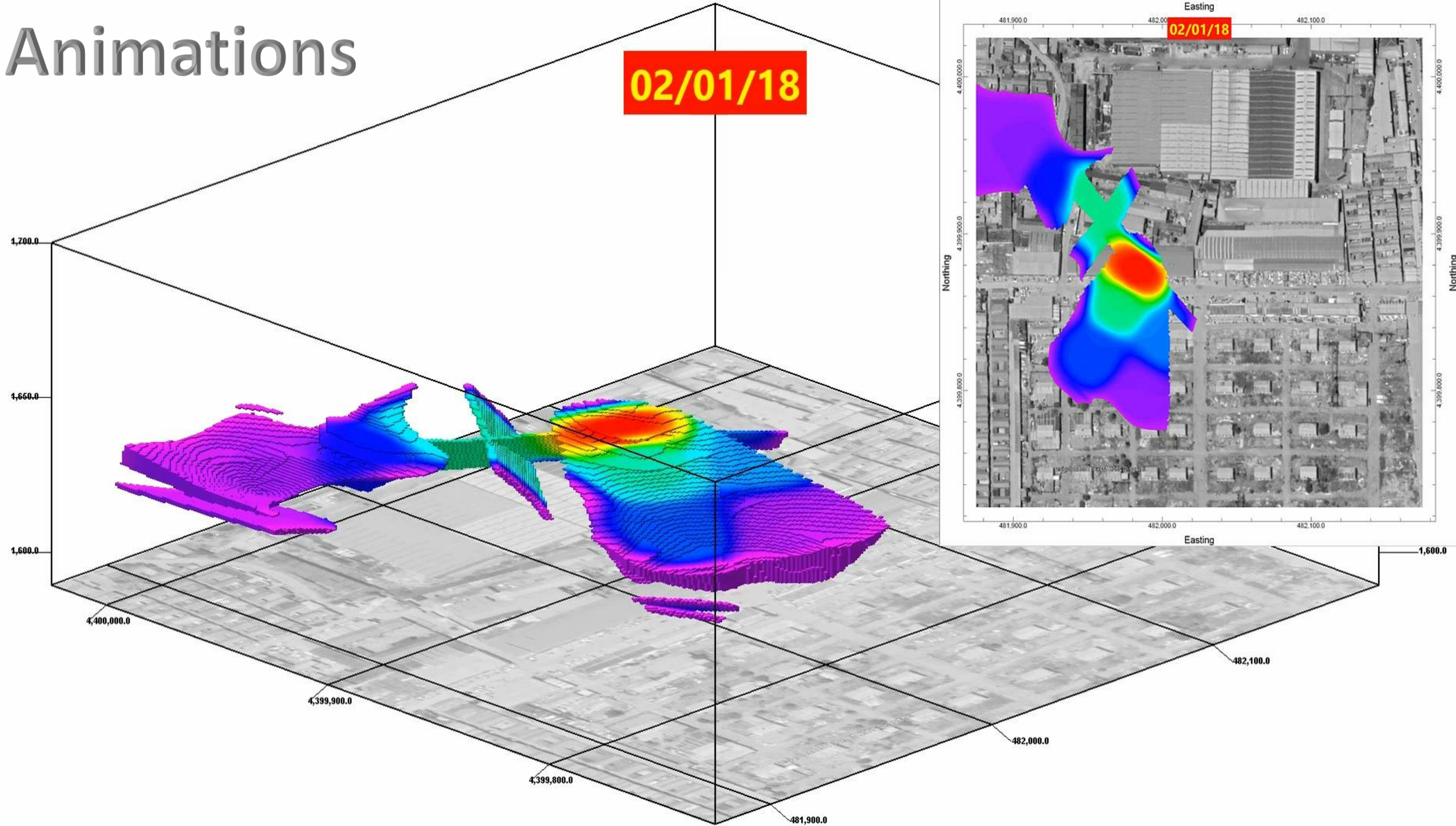
☒ Interpolate Quarterly TCE Models

☒ Create Grid Animation

☒ Create Solid Animation

PROCESS PLAYLIST

Animations



Strategies as Playlists

One year later, the client calls ...

- Three new wells have been drilled.
- All of the models therefore need to be re-generated.
- The client wants to know exactly what was done (e.g., algorithms used) to create last year's report.
- The client needs the results within 24 hours.

Solution: Add new information to database and press *Process Playlist* button.