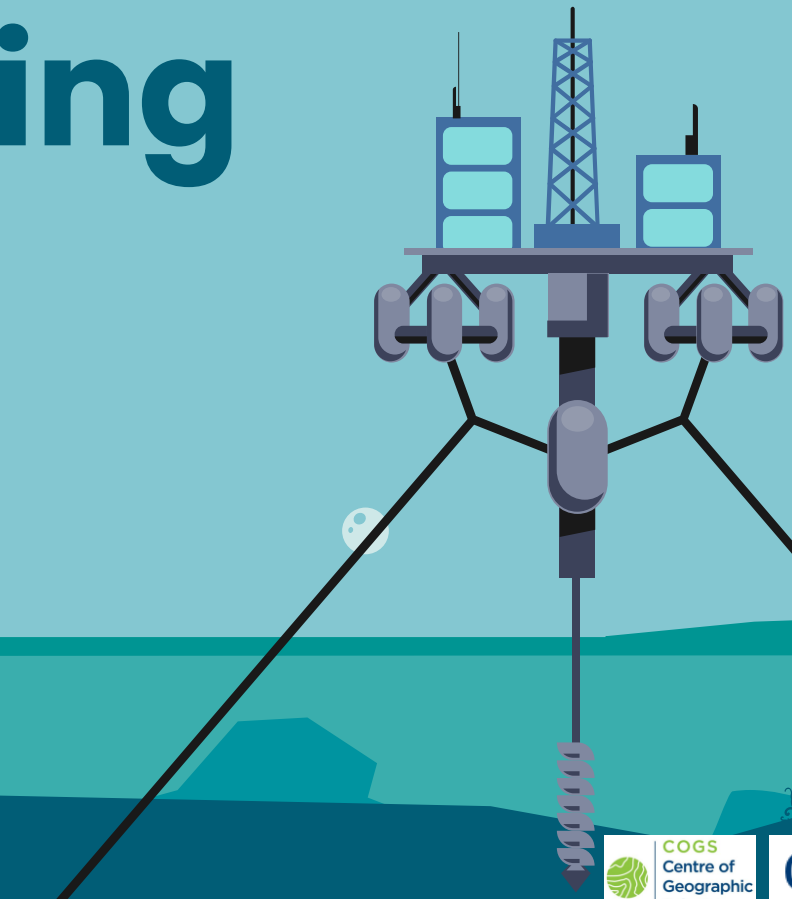
Automating Offshore Pipeline Routing



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Alex Moss
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COGS Centre of Geographic Sciences nscc

Geosyntec consultants

OVERVIEW

01 BACKGROUND

02 THE DATA

03 OBJECTIVES

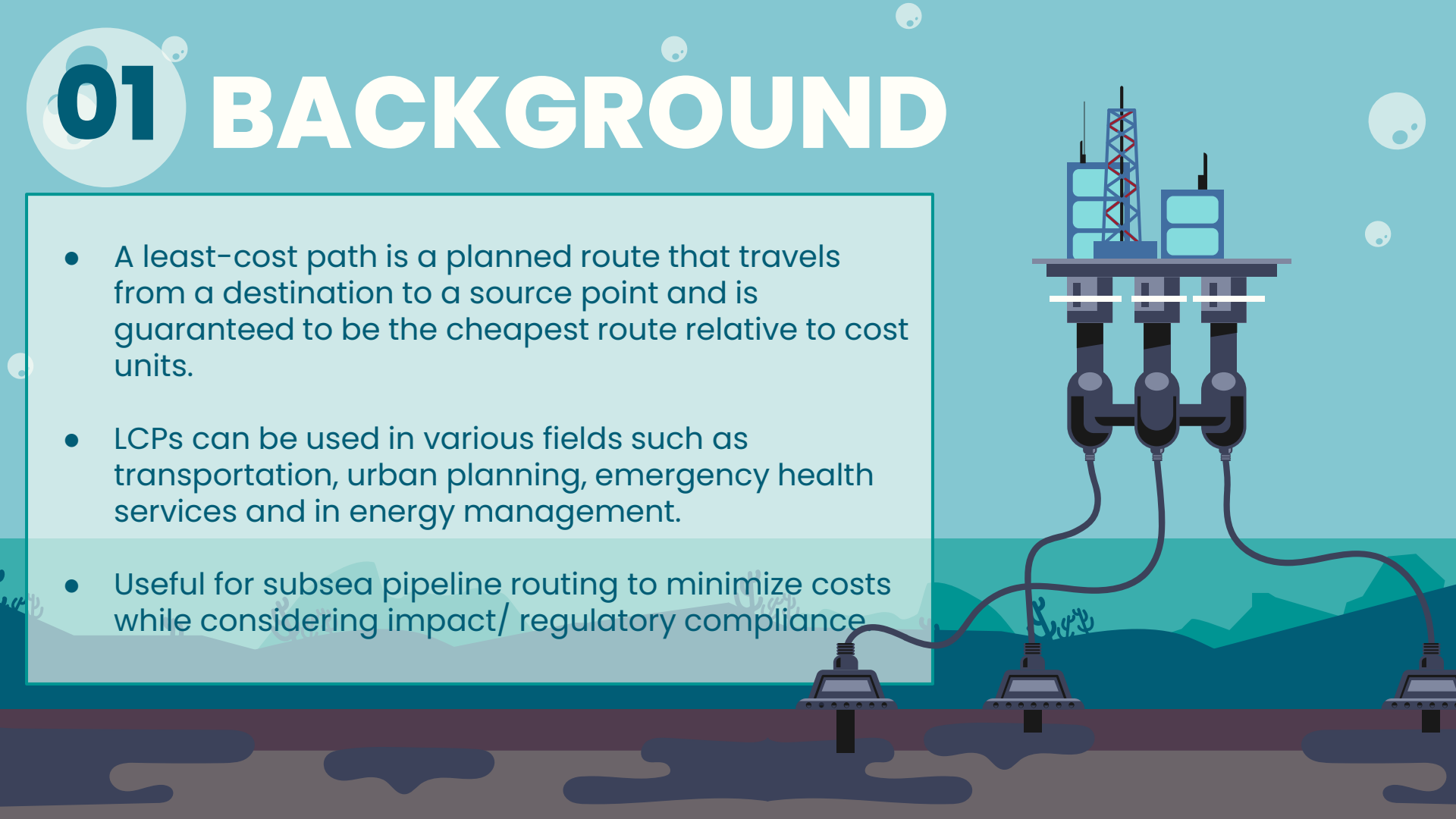
04 METHODOLOGY

05 RESULTS

06 DISCUSSION

01 BACKGROUND

- A least-cost path is a planned route that travels from a destination to a source point and is guaranteed to be the cheapest route relative to cost units.
- LCPs can be used in various fields such as transportation, urban planning, emergency health services and in energy management.
- Useful for subsea pipeline routing to minimize costs while considering impact/ regulatory compliance



01 BACKGROUND

- Study are for this project is in the Gulf of Mexico (GoM).
- Covers over 600 000 km^2 of seafloor.
- This regions oil and gas industry is one of the most developed in the world.
- All data required for the project was provided to us by Geosyntec.

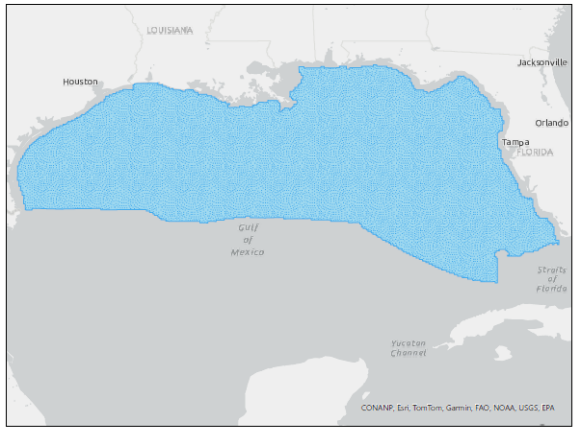
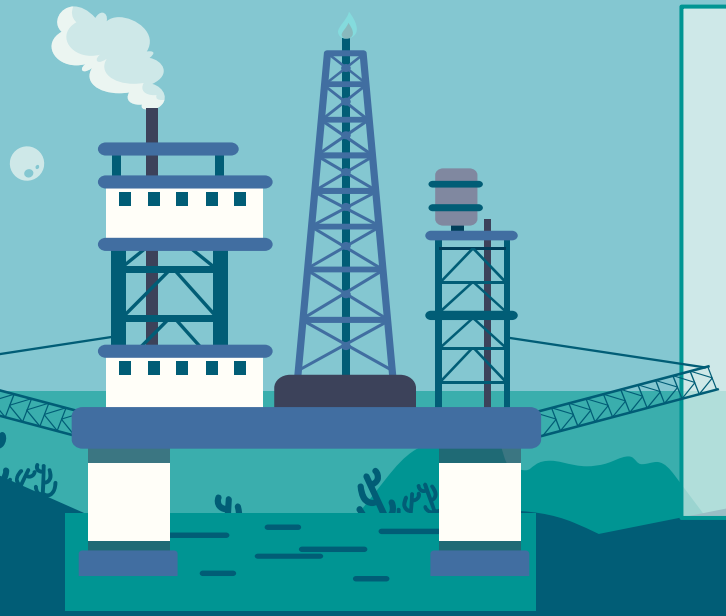


Figure X. Total BOEM Protraction Area

02 THE DATA

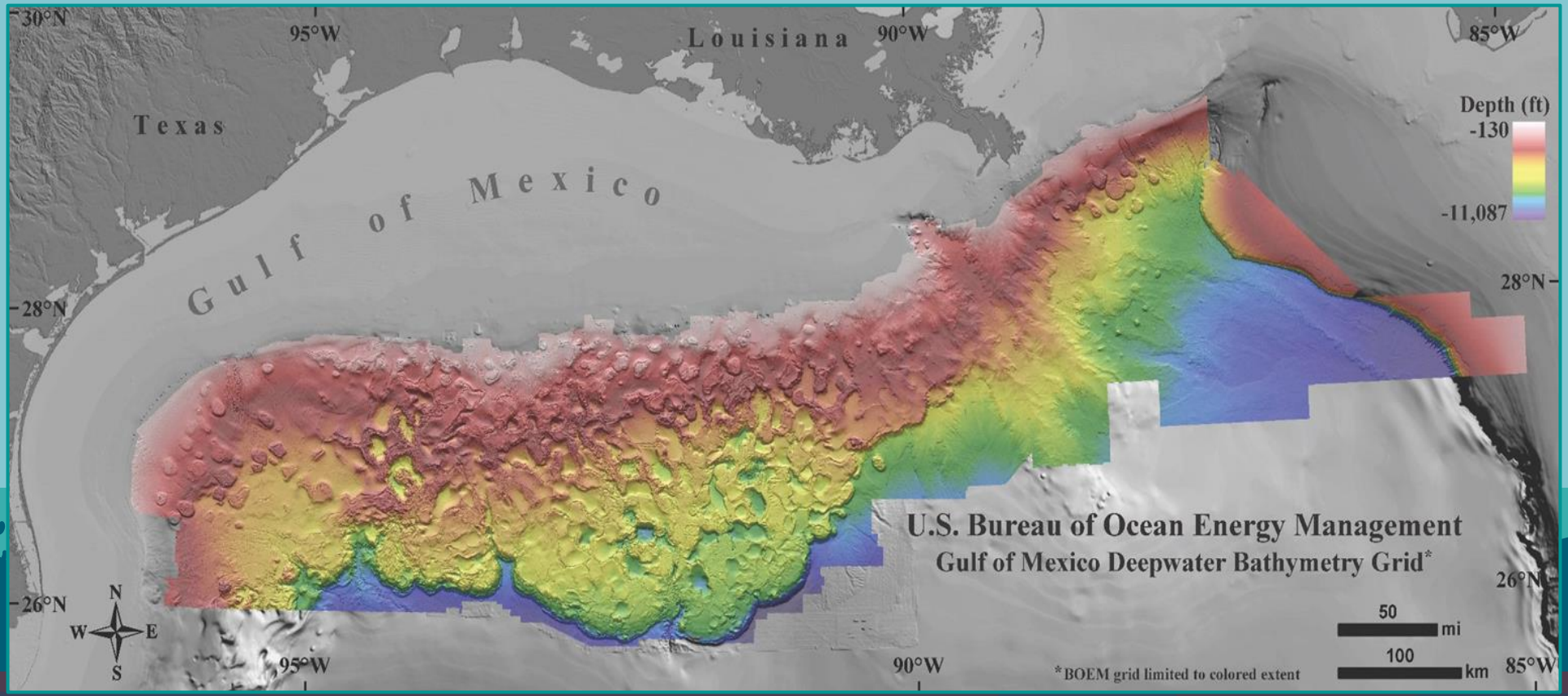


- Geosyntec provided us with crucial data to undertake this project with. The data can be broken down into three main categories:

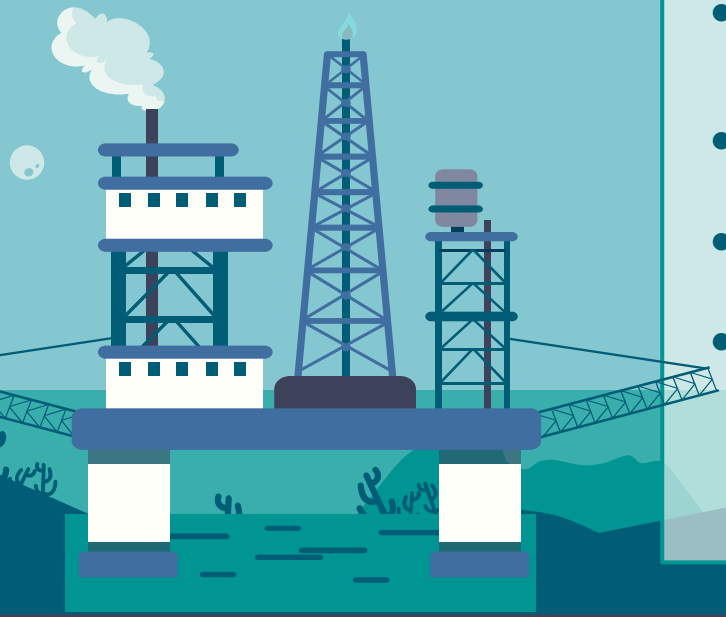
  1. Bathymetry of the Gulf of Mexico
  2. Seafloor anomalies
  3. Existing subsea pipelines and their associated infrastructure

02 THE DATA

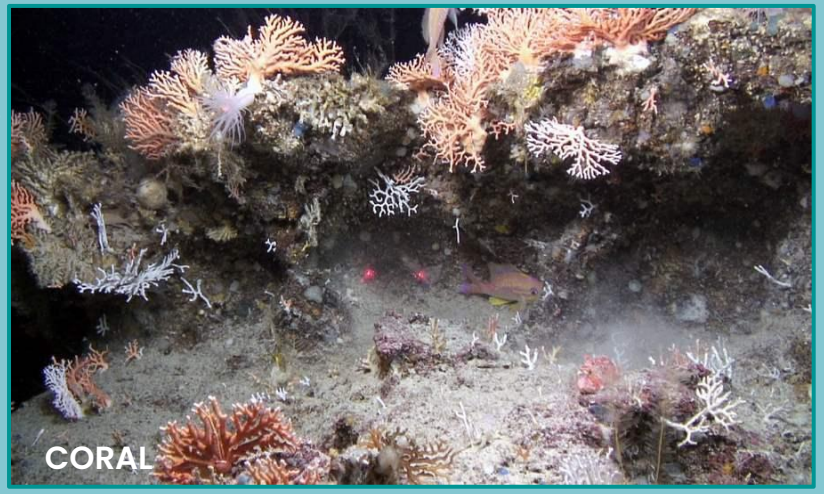
- The bathymetry grid was created by stitching together survey data that covers more than 90,000 square miles.
- The grid is comprised of 1.4 billion 40 by 40 feet cells that range from -130 feet to -11,087 feet (-40 to -3,379m).
- Seafloor slope plays a huge role when setting up infrastructure and planning pipeline routes.


30°N
95°W
Louisiana
90°W
85°W
Texas
Gulf of Mexico
Depth (ft)
-130
-11,087
28°N
28°N
U.S. Bureau of Ocean Energy Management
Gulf of Mexico Deepwater Bathymetry Grid*
26°N
26°N
N
W
E
S
50
mi
100
km
95°W
90°W
*BOEM grid limited to colored extent
85°W

02 THE DATA



- The seafloor anomalies data consist of natural hydrocarbon seeps and related benthic fauna.
- Avoiding seafloor anomalies is crucial in the offshore oil and gas industry.
- Anomalies can compromise the stability and safety of subsea infrastructure.
- Environmental protection is essential, as seafloor anomalies often host unique and sensitive ecosystems.

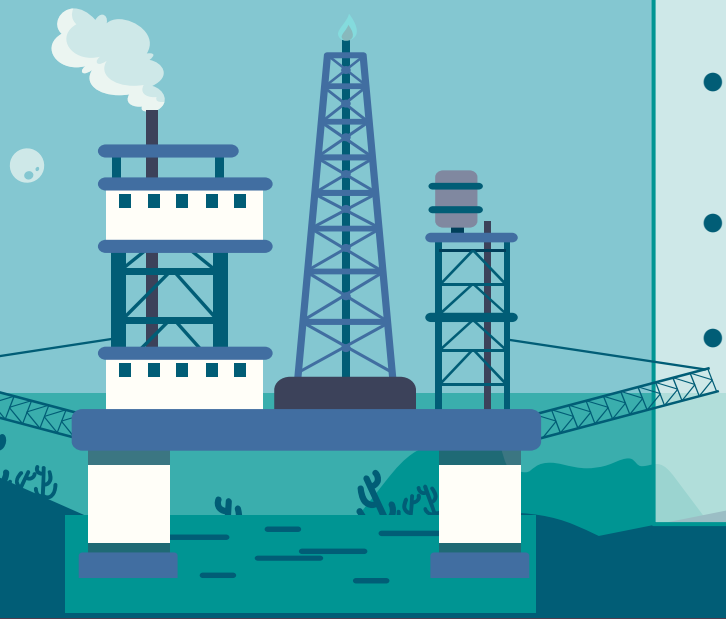

CORAL


SALT VOLCANOES


TAR LILY


OIL SEEP

02 THE DATA



- Gulf of Mexico’s offshore drilling accounts for 14.5% of U.S crude oil production (2022).
- The region is densely populated with existing subsea pipelines and associated infrastructure.
- This extensive infrastructure can make it challenging to route new pipelines.

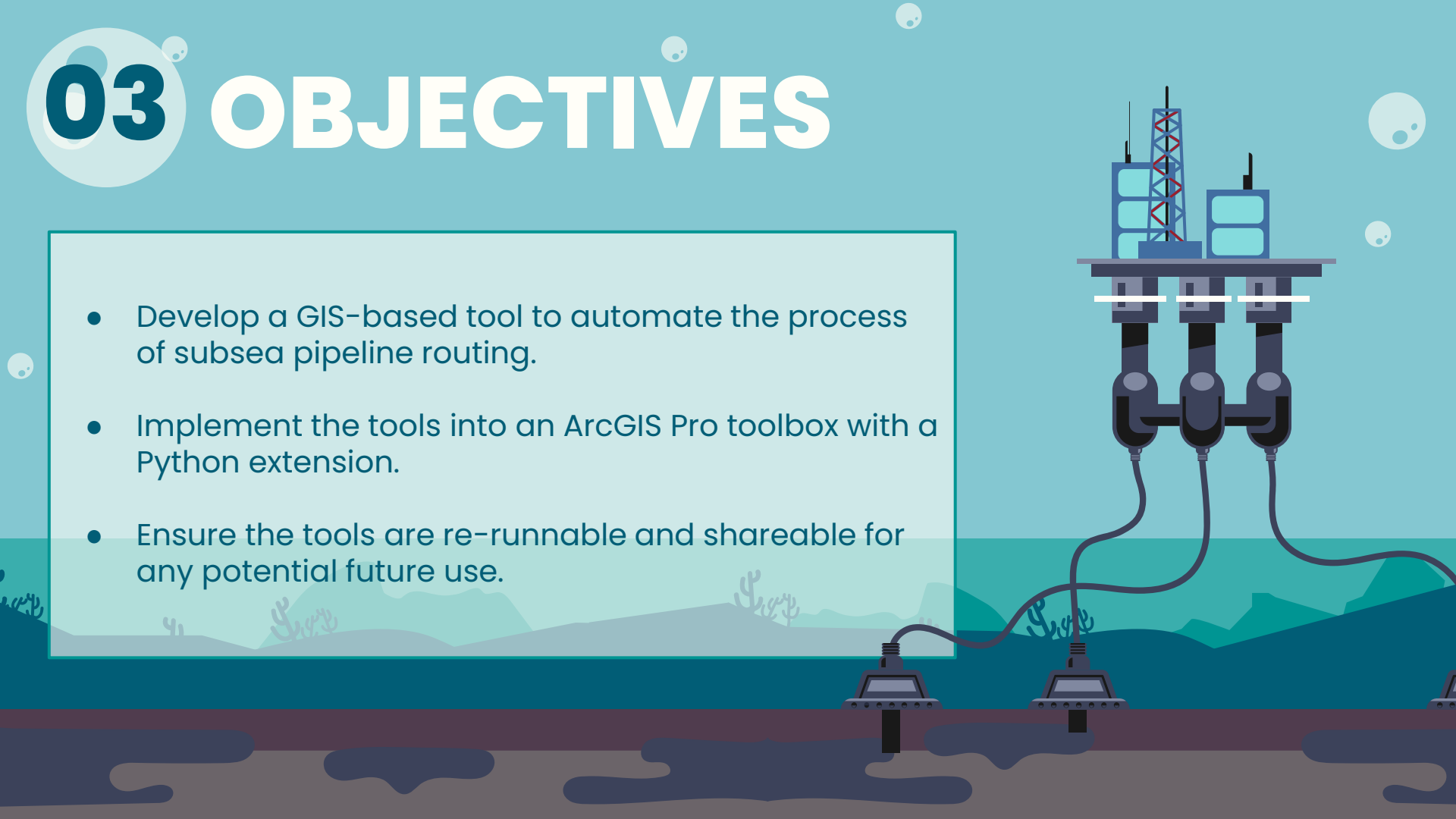

SUBSEA PIPELINES


PLATFORMS


PLATFORMS

03 OBJECTIVES

- Develop a GIS-based tool to automate the process of subsea pipeline routing.
- Implement the tools into an ArcGIS Pro toolbox with a Python extension.
- Ensure the tools are re-runnable and shareable for any potential future use.



04 METHODOLOGY

MODEL BUILDER

Create least-cost path model using various geoprocessing tools within ArcGIS Pro

PYTHON TOOLBOX

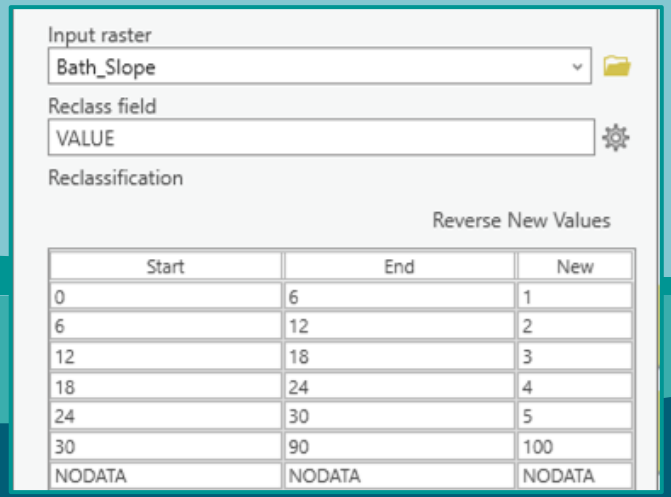
Automate pipeline routing process allowing users to input own parameters

PARAMETERS

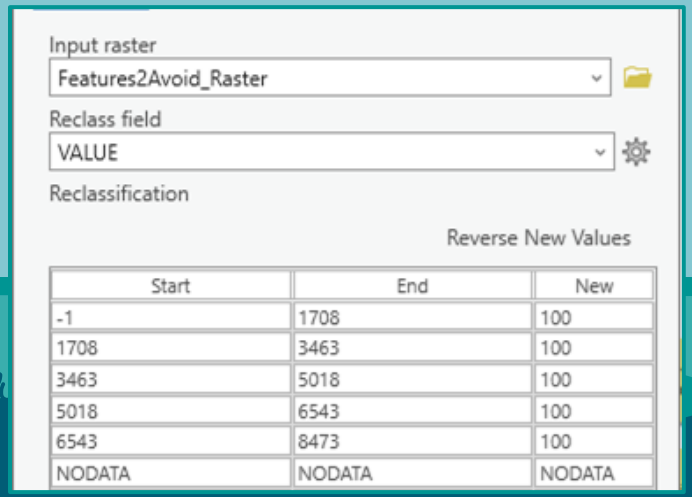
- Gradient avoidance degree: 30°
- Anomaly avoidance distance: 500 ft
- Well infrastructure avoidance distance: 500 ft
- Platform infrastructure avoidance distance: 500 m
- Pipeline avoidance distance: 200 ft, if a pipeline must be crossed, it should do so perpendicularly
- Start Point (X / Y): 1,948,443.499 ft / 9,496,072.400 ft
- End Point (X / Y): 2,535,851.500 ft / 10,250,934.201 ft

MODEL BUILDER

- Create slope raster from bathymetry data - reclassify
- Combine all rasters layers to avoid and include buffers
- Raster Calculator



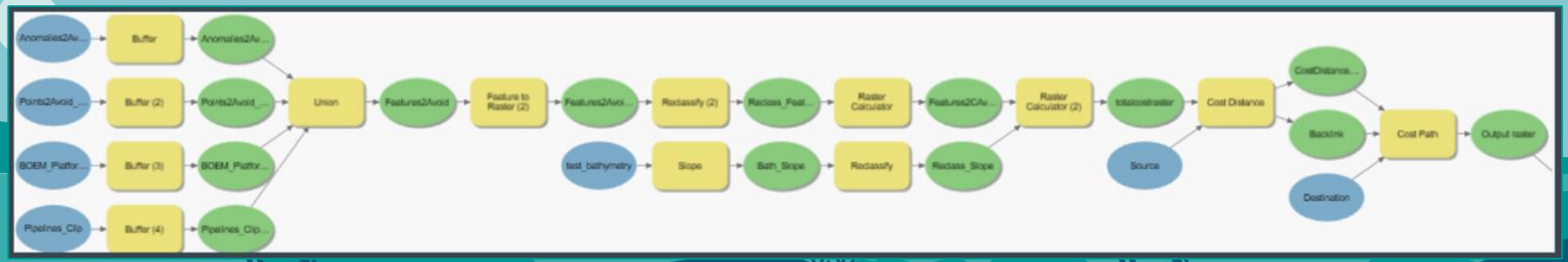
Start	End	New
0	6	1
6	12	2
12	18	3
18	24	4
24	30	5
30	90	100
NODATA	NODATA	NODATA



Start	End	New
-1	1708	100
1708	3463	100
3463	5018	100
5018	6543	100
6543	8473	100
NODATA	NODATA	NODATA

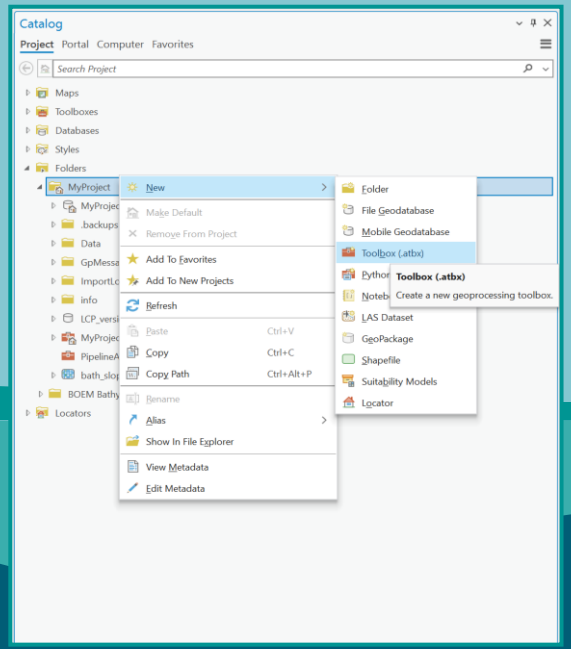
MODEL BUILDER

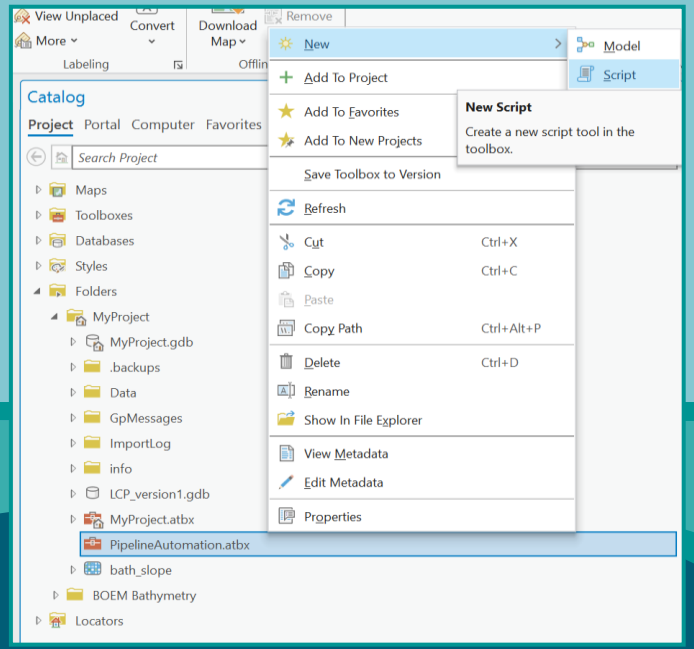
- Cost Distance
- Cost Path
- Convert to Polyline



PYTHON TOOLBOX

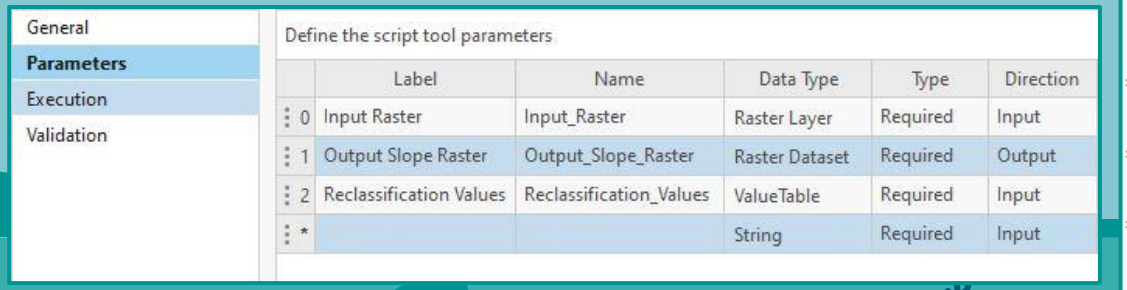
Within Catalog Pane in ArcGIS Pro, add a new toolbox with associated Python script

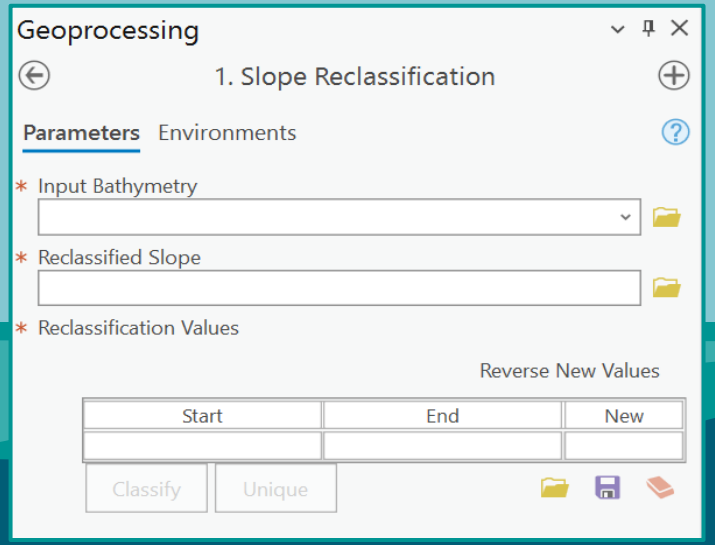




PYTHON TOOLBOX

1. **Slope Raster Reclassification**
- Input Raster
- Output Raster
- Reclassification Values

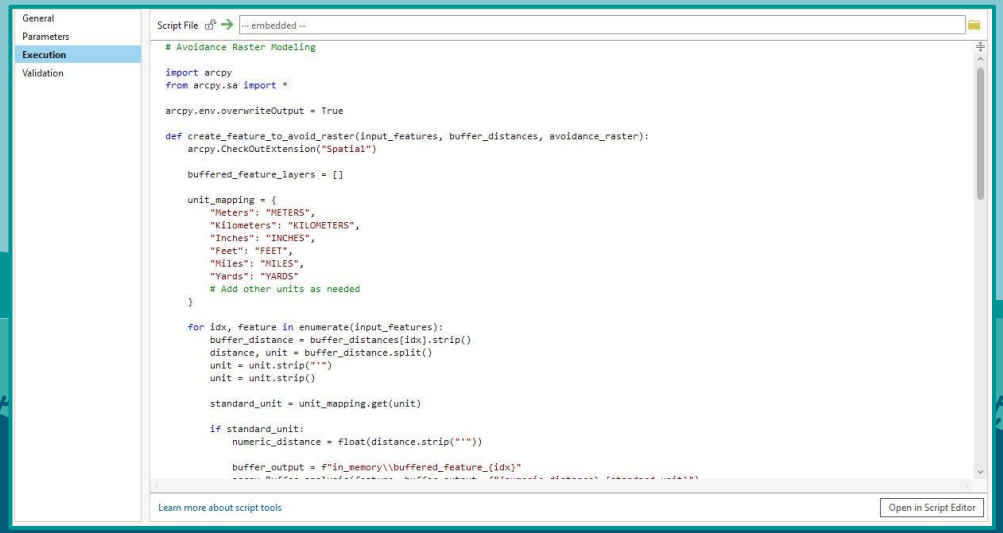


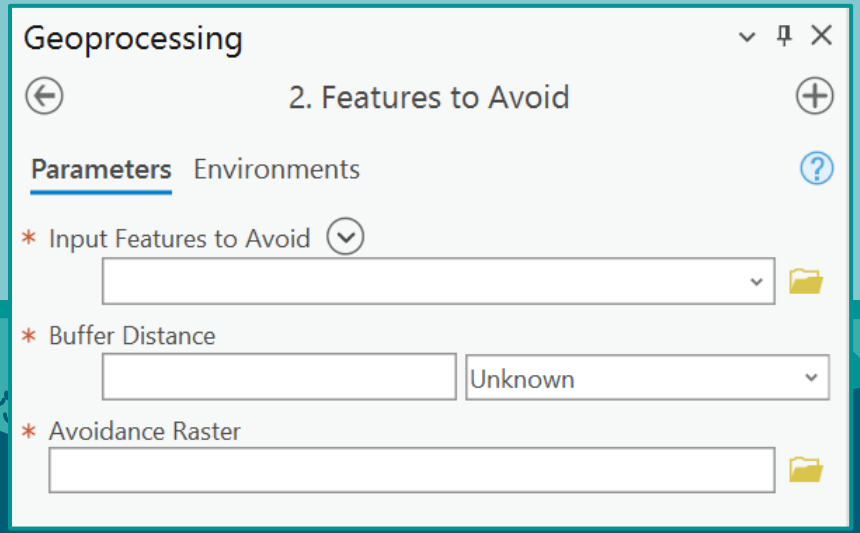


PYTHON TOOLBOX

2. Avoidance Raster Reclassification

- Input Raster(s)
- Buffer Distances
- Output Raster





PYTHON TOOLBOX

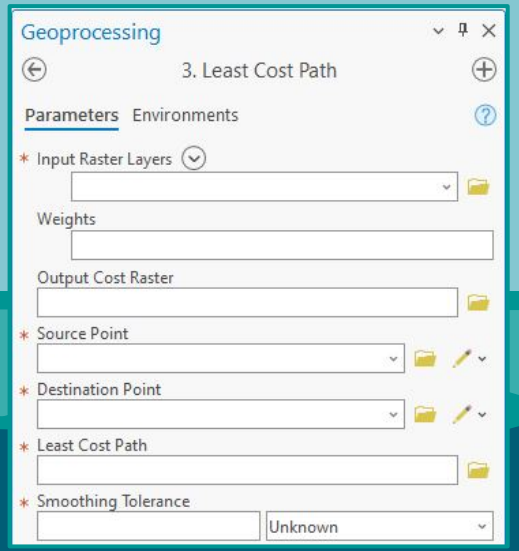
3. Least Cost Path

- Input Raster(s)
- Weights
- Output Cost Raster
- Source Point
- Destination Point
- Least Cost Path
- Smoothing Tolerance

General
Parameters
Execution
Validation

Define the script tool parameters

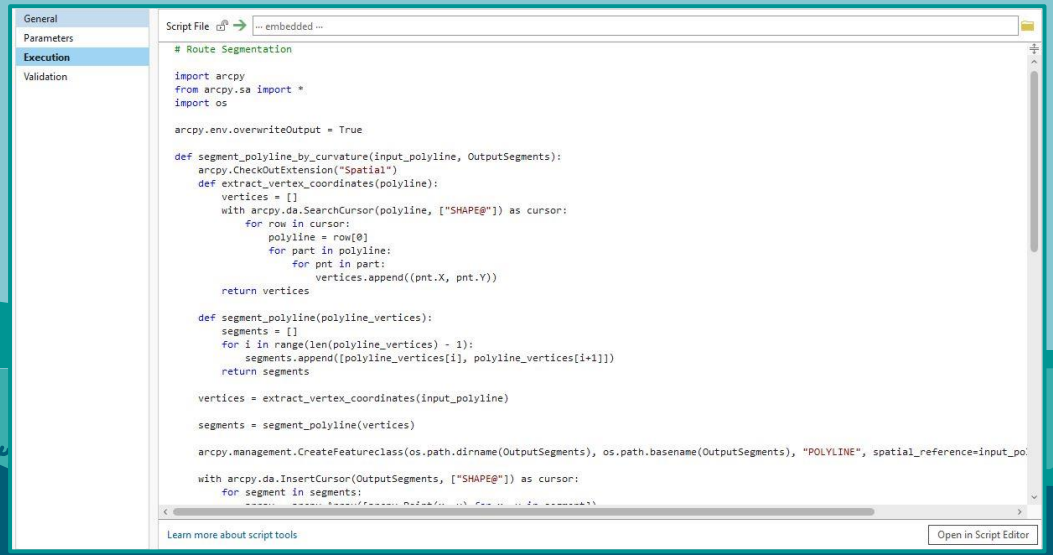
	Label	Name	Data Type	Type	Direction
0	Input Raster Layers	Input_Raster_Layers	[Raster Layer]	Required	Input
1	Weights	Weights	[String]	Optional	Input
2	Output Cost Raster	Output_Cost_Raster	Raster Dataset	Optional	Output
3	Source Point	Source_Point	Feature Set	Required	Input
4	Destination Point	Destination_Point	Feature Set	Required	Input
5	Least Cost Path	Least_Cost_Path	Feature Class	Required	Output
6	Smoothing Tolerance	Smoothing_Tolerance	Linear Unit	Required	Input
*			String	Required	Input

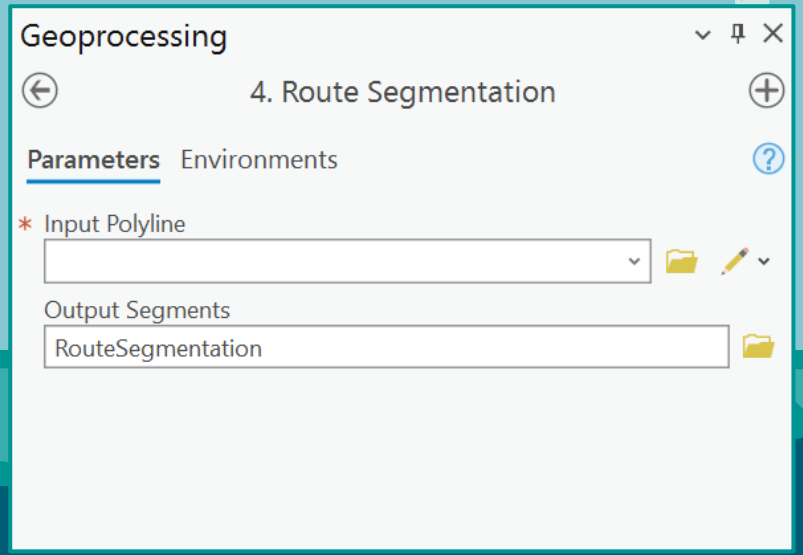


PYTHON TOOLBOX

4. Route Segmentation

- Input Route
- Output Route Segments

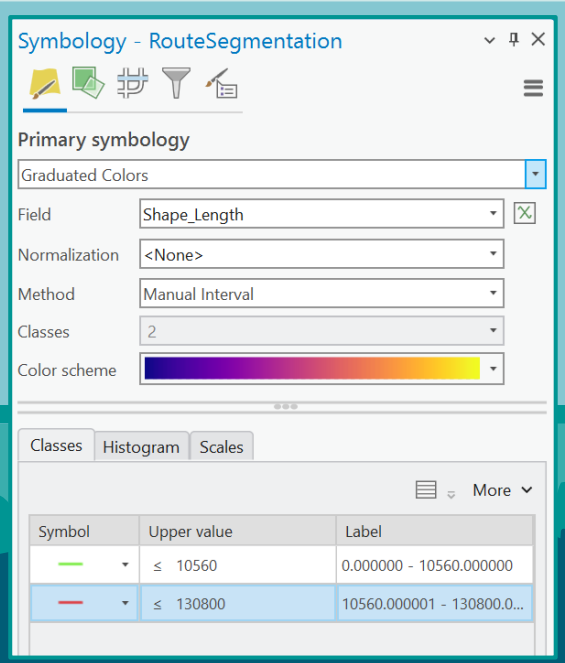




PYTHON TOOLBOX

4. Route Segmentation - Symbology

- Input Route
- Output Route Segments



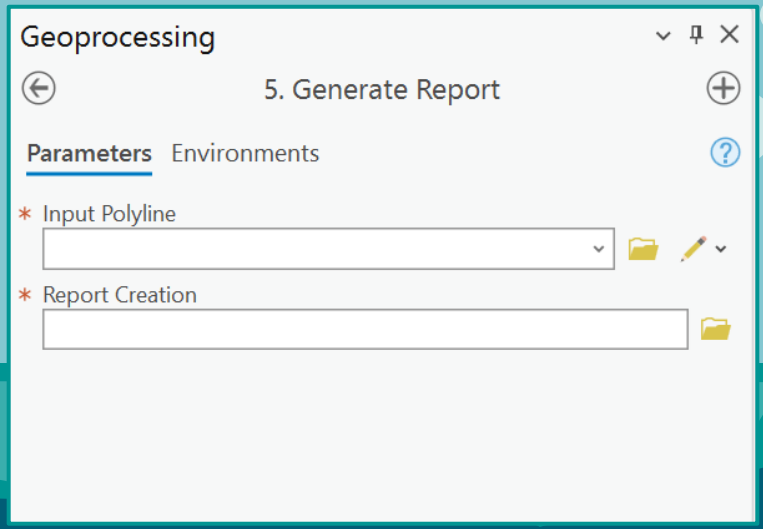
PYTHON TOOLBOX

5. Report Creation

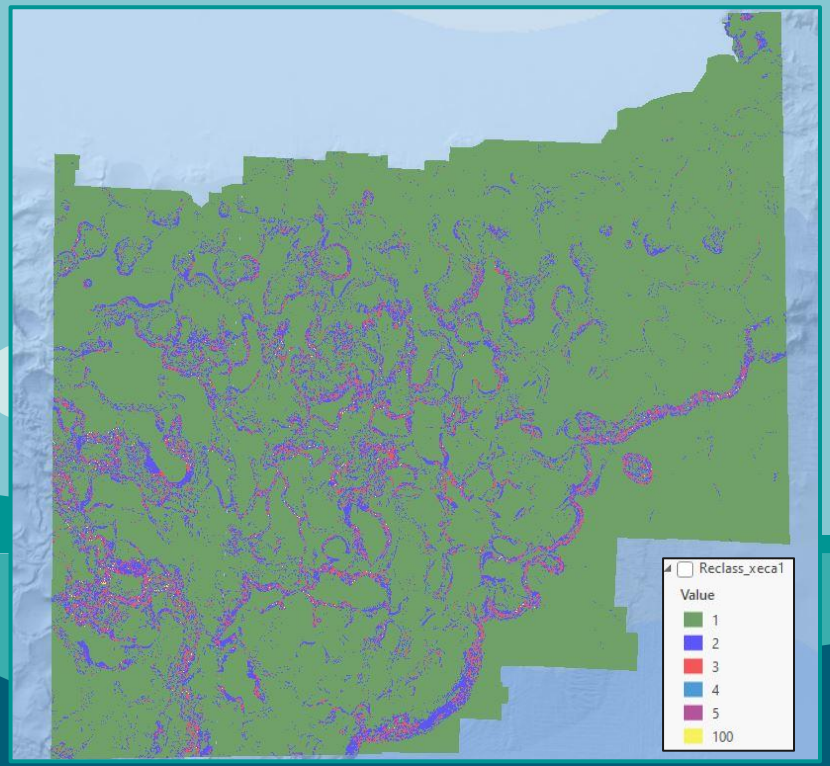
- Input Route
- Output Report

General
Parameters
Execution
Validation

	Label	Name	Data Type	Type	Direction
0	Input Polyline	Input_Polyline	Feature Set	Required	Input
1	Report Creation	Report_Creation	File	Required	Output
*			String	Required	Input



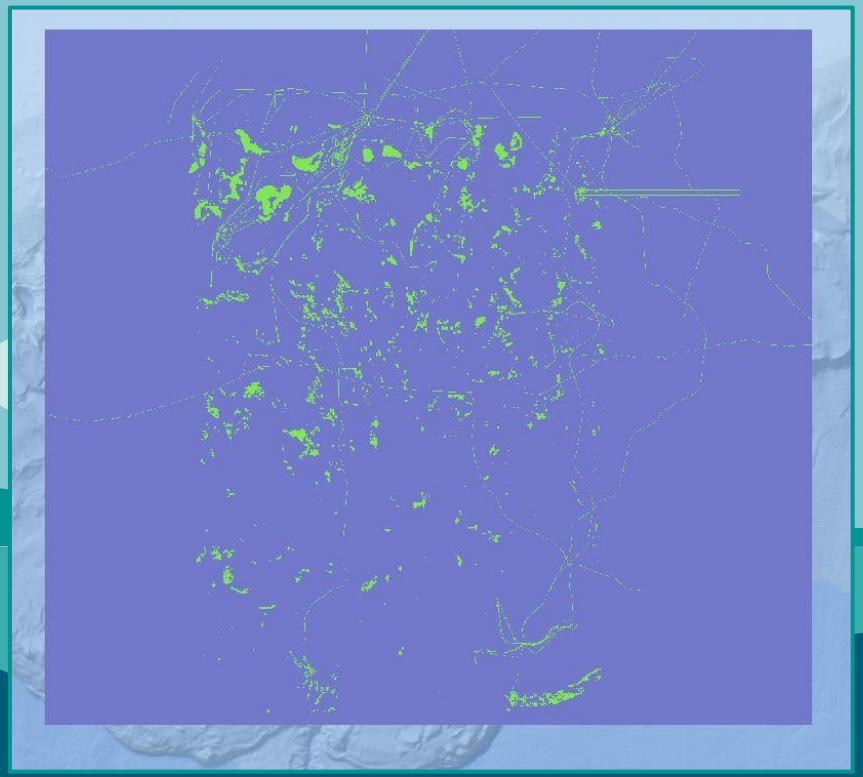
05 RESULTS



Slope Raster Reclassification

- This raster shows the classifications assigned to the bathymetric raster, with lower values indicating gentler slopes.
- Ensures slopes greater than thirty degrees are classified as impassable (given a value of 100).

05 RESULTS



Avoidance Raster Reclassification

- The reclassified raster showing the features we want to avoid plus their buffers.
- The bright green indicates the features which have a weight of 100 and are impassable (with the exception of crossing pipelines perpendicularly).
- Purple represents surrounding areas and has a weight of 0.

05 RESULTS

Cost Surface

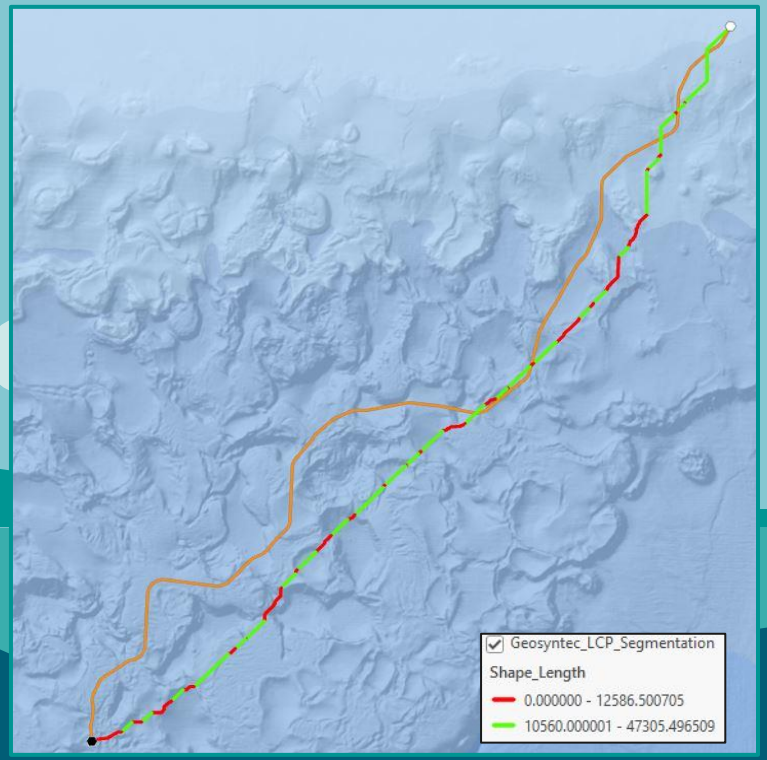
- The Cost Surface shows the slope and Avoidance rasters combined with appropriate weights assigned to each.
- Black areas indicate a cost of zero to traverse, and white areas indicate that areas are impassable (minus pipeline exception).

05 RESULTS

Least Cost Path

- Image displays the output from the Least Cost Path tool.
- Yellow path is our calculated route.
- Orange path is the existing pipeline.
- Shows how our toolbox would route the coordinates of a pre-existing pipeline, for comparison purposes.
- Various reasons why routes are different including costing implementation, data quality, and others.

05 RESULTS



Route Segmentation

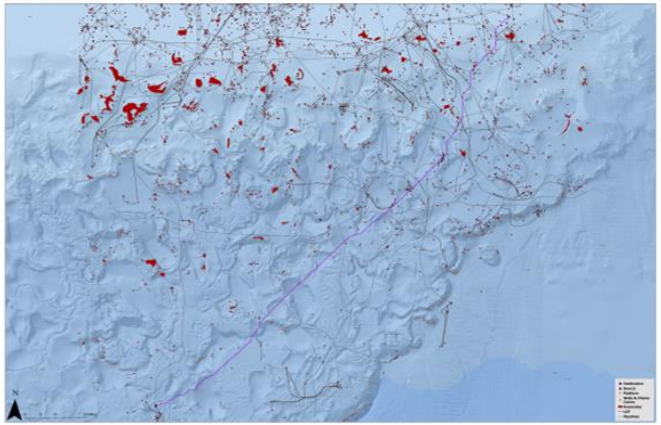
- Red + Green line is the LCP after running Segmentation tool.
- Segments that have a straight distance of < 2 miles are red.
- Segments that have a straight distance of > 2 miles are green.

05 RESULTS

Least Cost Path Report

Attribute	Value
Length of Polyline	195.09 miles
Start Coordinates	(603530.0, 10254468.748356499)
End Coordinates	(-20169.999999996275, 9527318.748356499)
Coordinate Reference System	NAD_1927_Transverse_Mercator

Map Layout

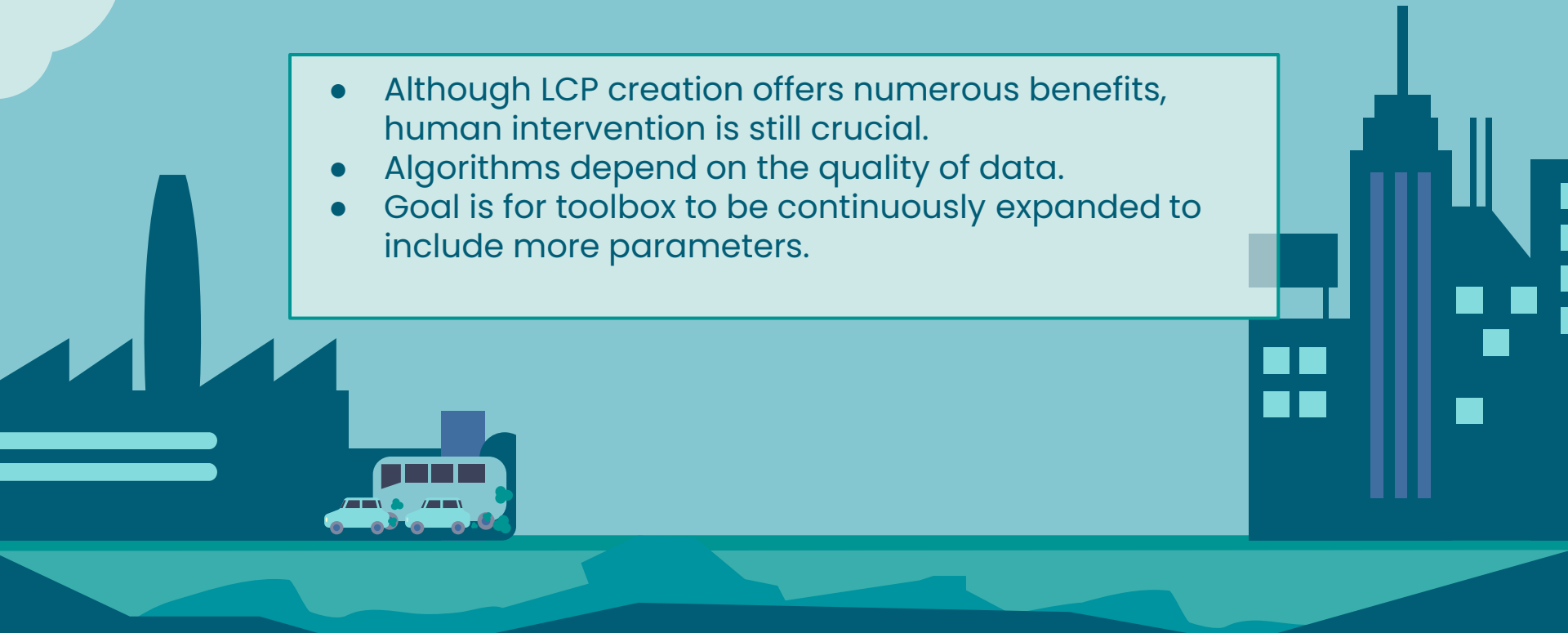


Report Creation

- The pdf output of the reporting tool includes key details about the LCP.
- This tool is optional, and we have created a map frame template to use if desired.

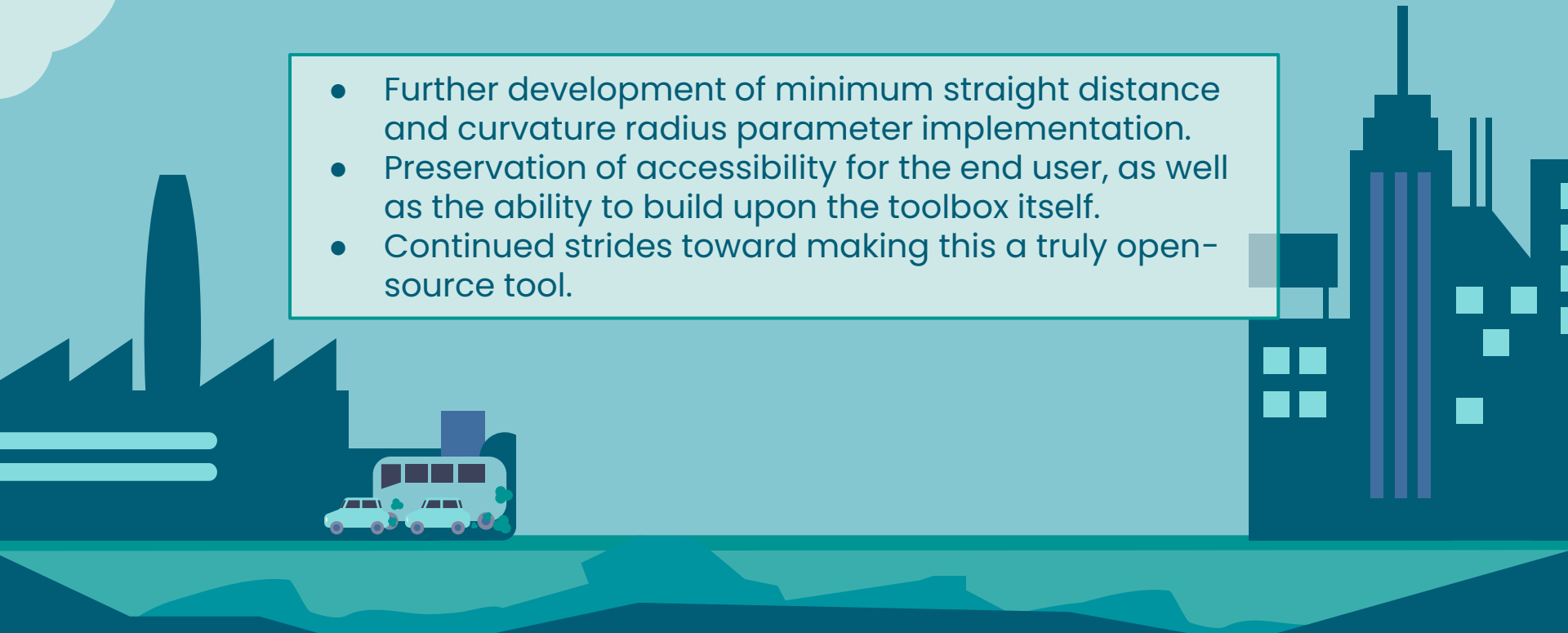
DISCUSSION

- Although LCP creation offers numerous benefits, human intervention is still crucial.
- Algorithms depend on the quality of data.
- Goal is for toolbox to be continuously expanded to include more parameters.



ADVANCEMENTS

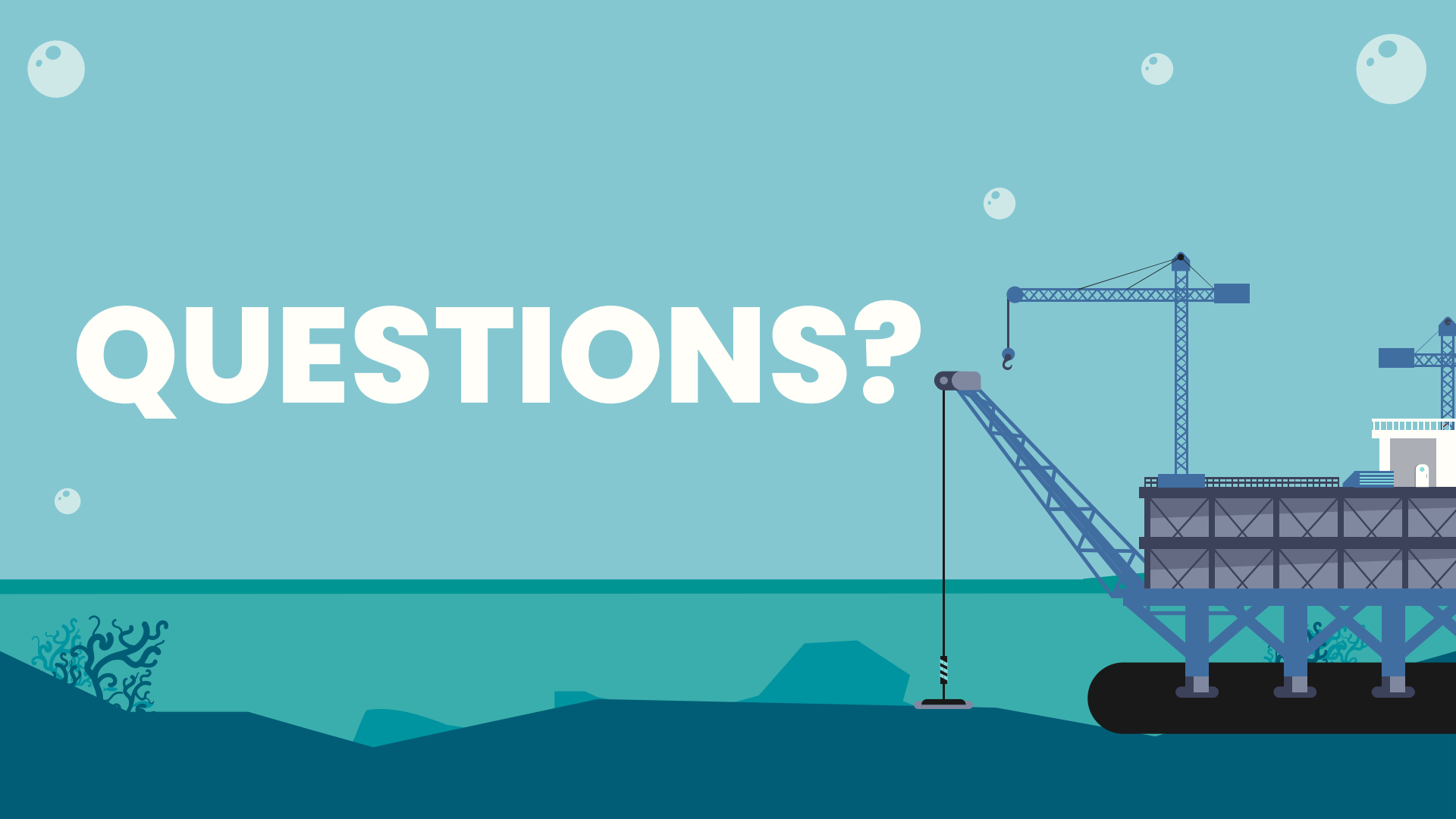
- Further development of minimum straight distance and curvature radius parameter implementation.
- Preservation of accessibility for the end user, as well as the ability to build upon the toolbox itself.
- Continued strides toward making this a truly open-source tool.



CONCLUSION

- By combining the data obtained from Geosyntec with our own research, we were successful in automating the pipeline routing process.
- Model Builder provided a solid foundation to further our understanding in creating a Python Toolbox.
- The Toolbox can be shared with other users and is very user-friendly.

QUESTIONS?



THANK YOU