the metals company

NORI

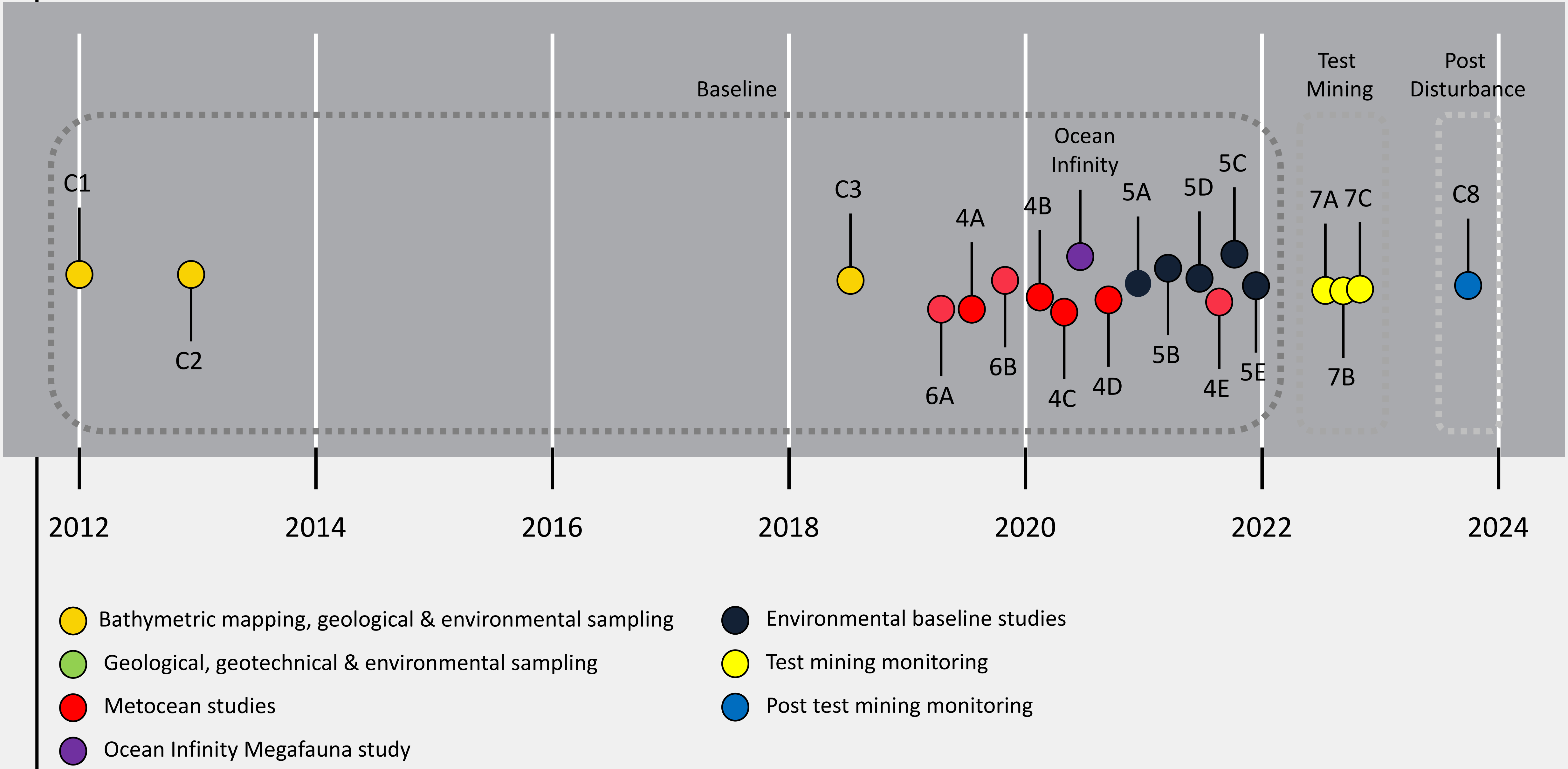
NAURU OCEAN RESOURCES INC.

NORI-D Environment Program Update

November 2023

Offshore campaigns

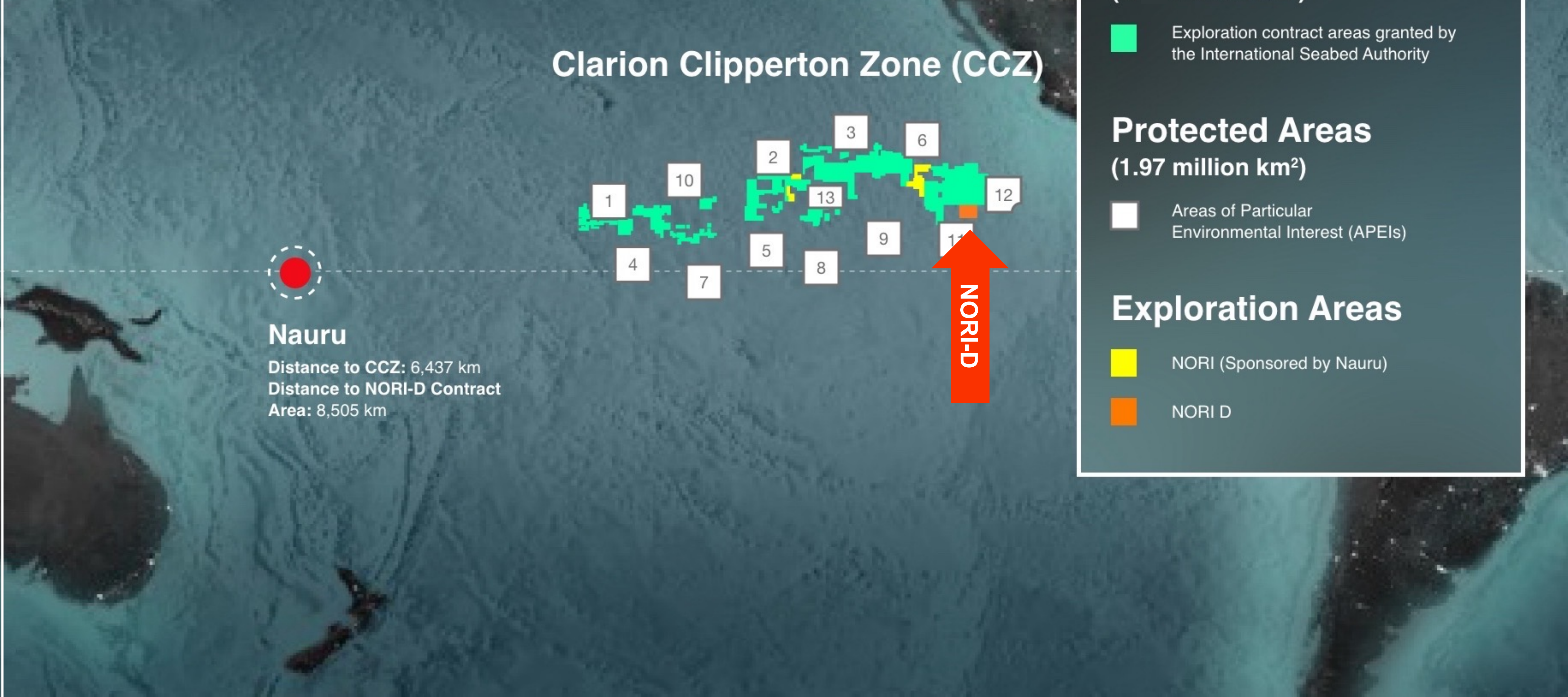
Data to inform EIA will be collected over 20 offshore campaigns spanning 11 years.

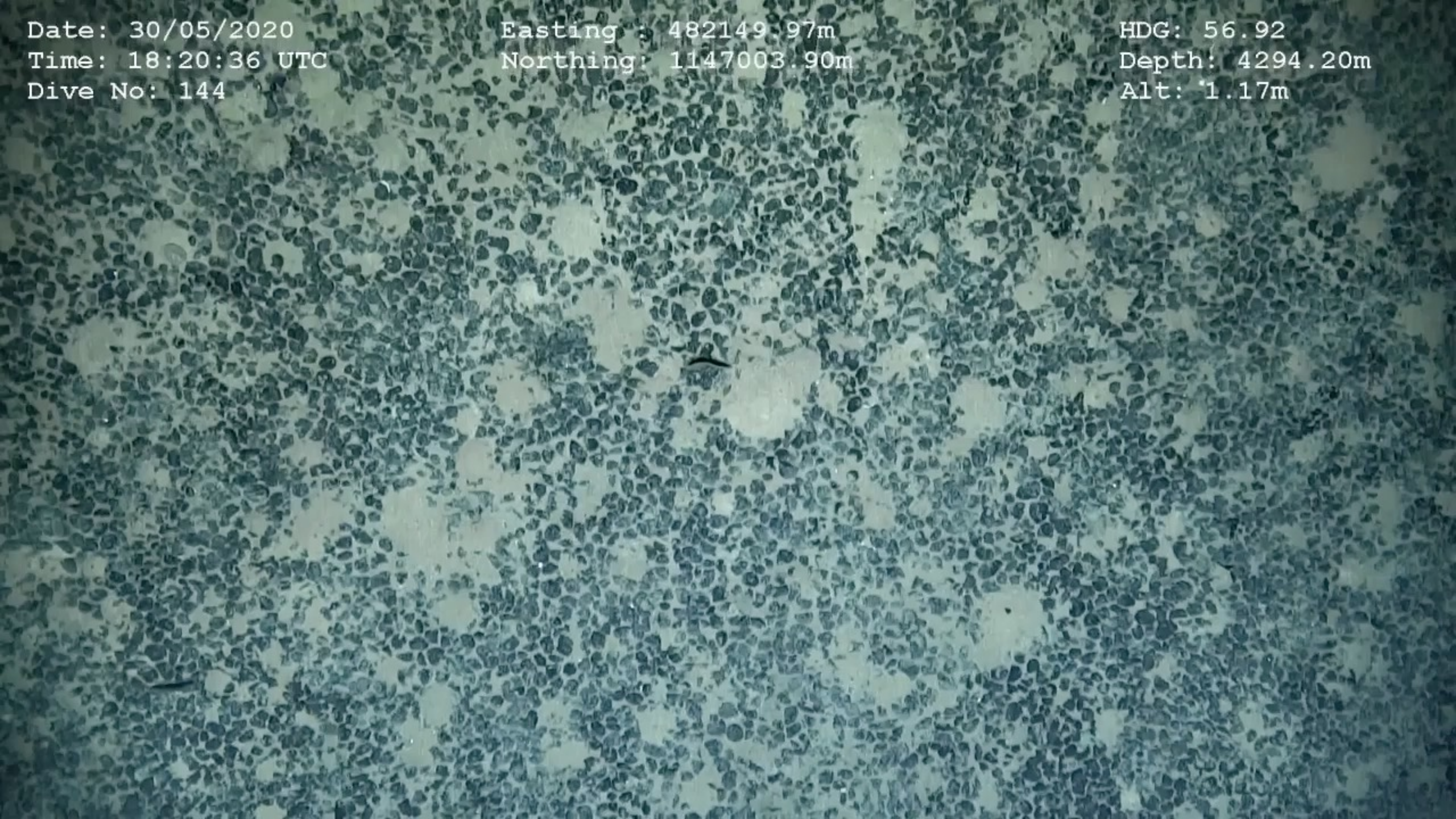


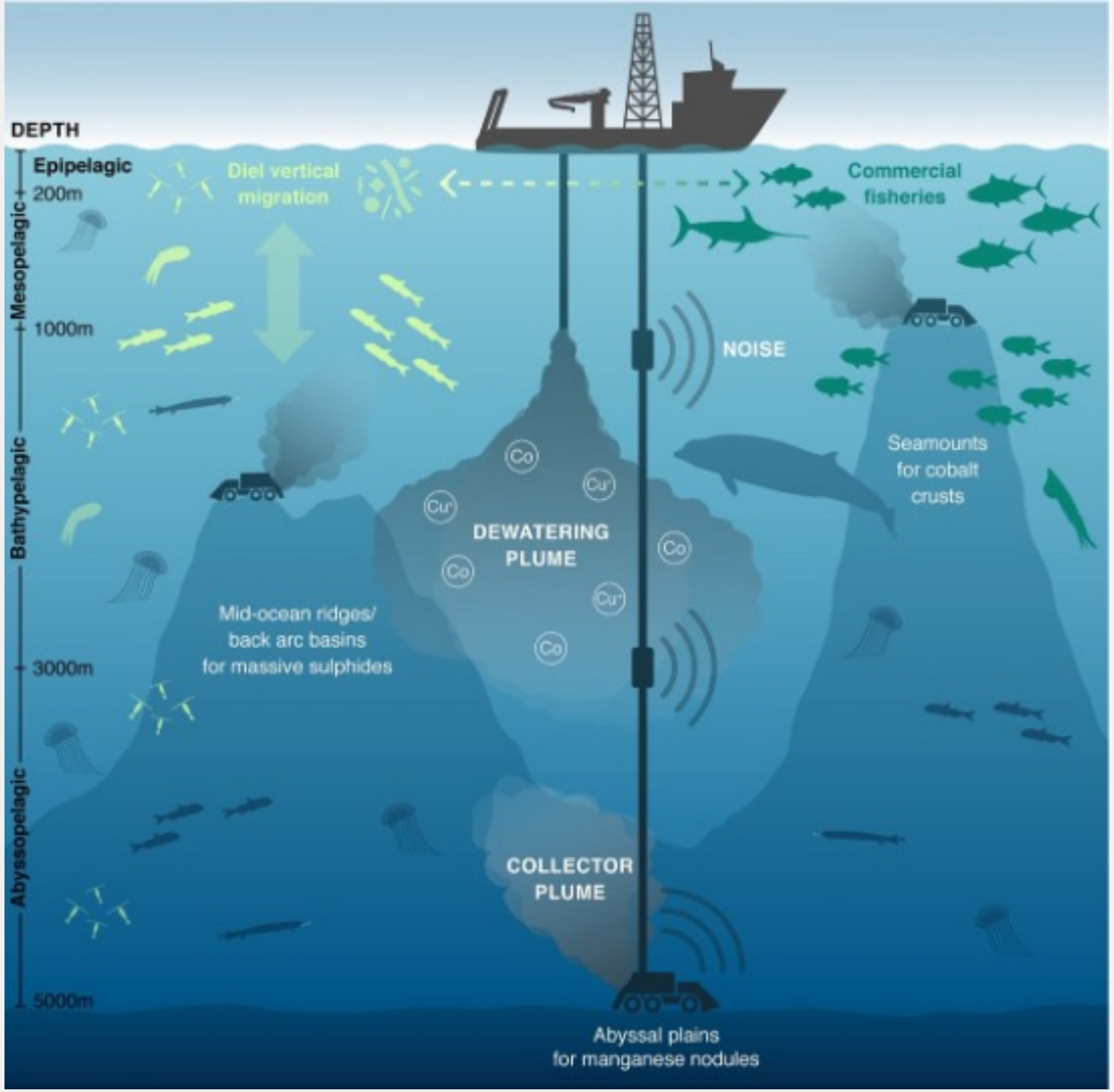
EIA progress

Benthic Plume

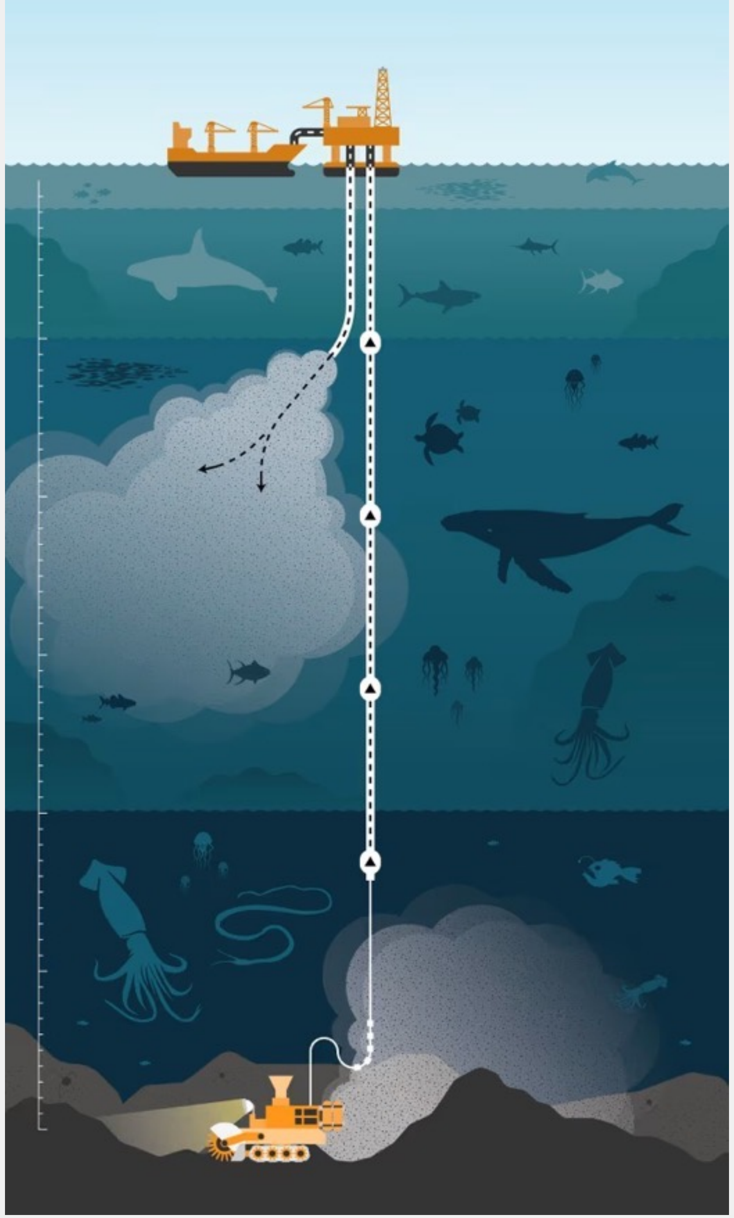
Distance to NORI Contract Areas from Nauru




Date: 30/05/2020
Time: 18:20:36 UTC
Dive No: 144
Easting : 482149.97m
Northing: 1147003.90m
HDG: 56.92
Depth: 4294.20m
Alt: 1.17m



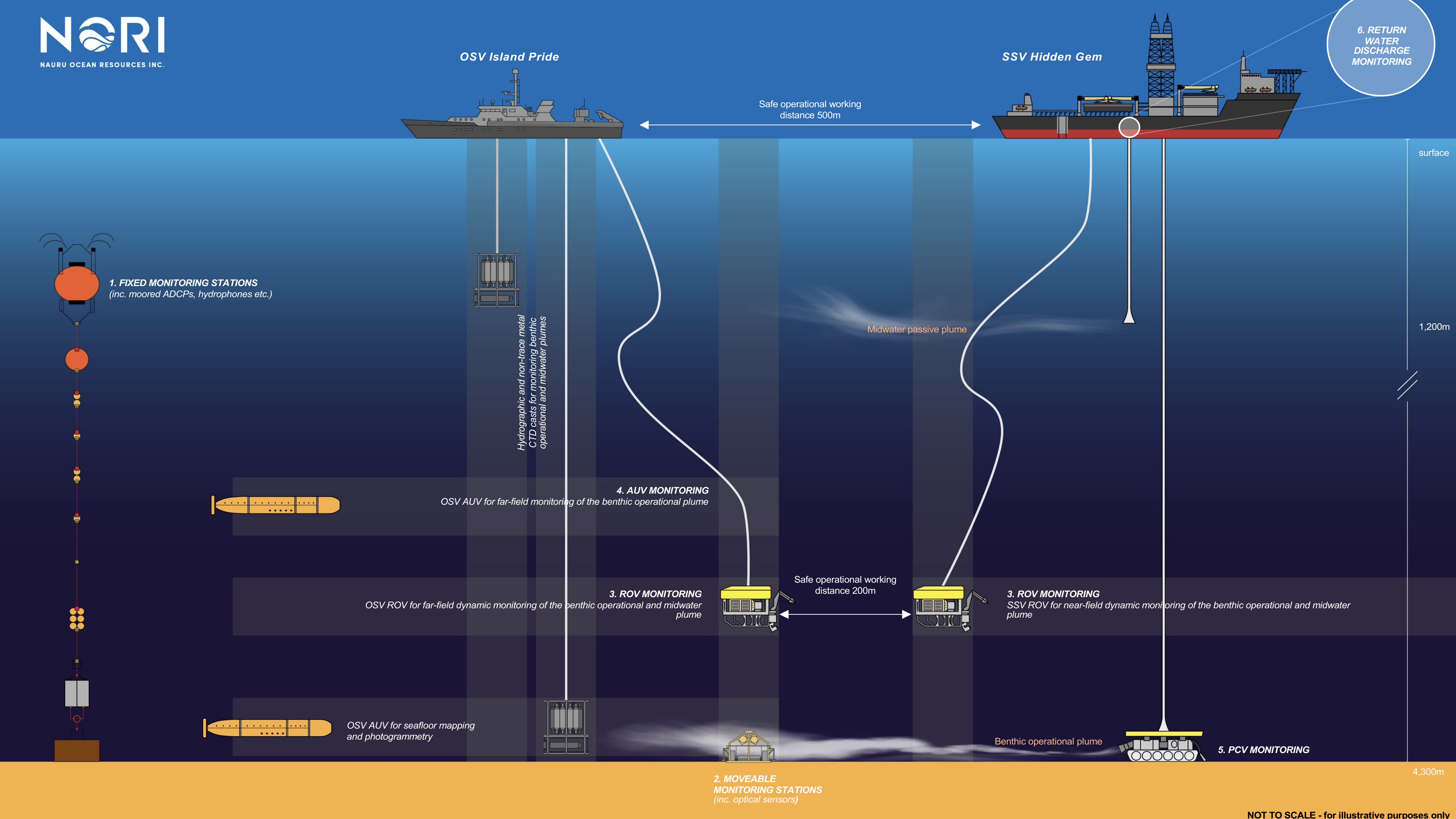
Drazen, Jeffrey C., et al. "*Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining*." Proceedings of the National Academy of Sciences 117.30 (2020): 17455-17460.



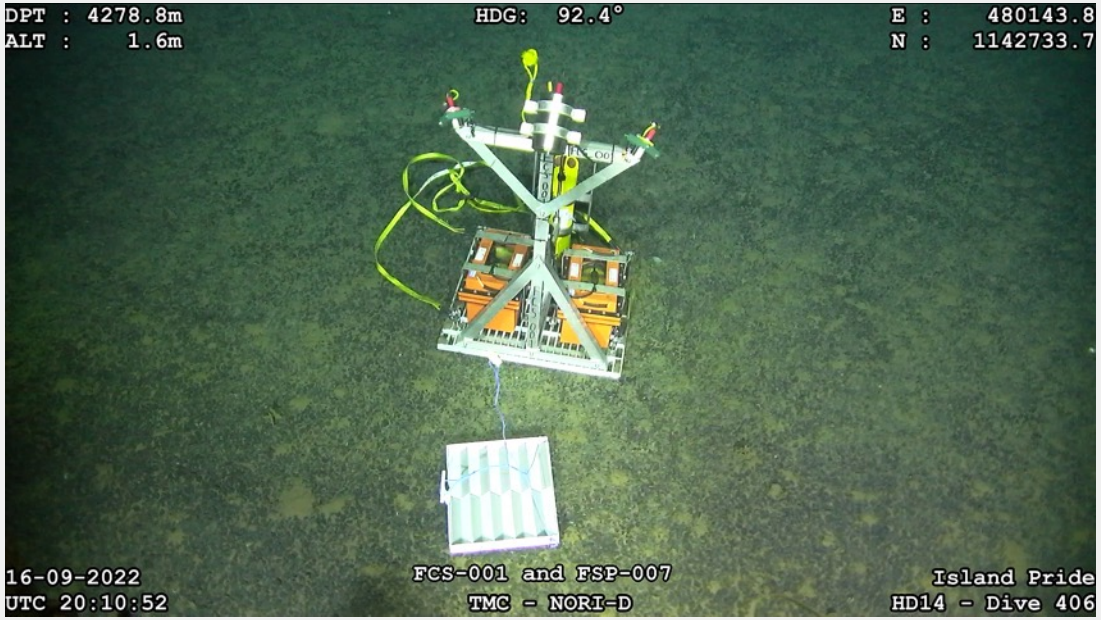
The Guardian. 2023 “*Is it too late to halt deep-sea mining? Meet the activists trying to save the seabed*” deepsea conservationcoalition

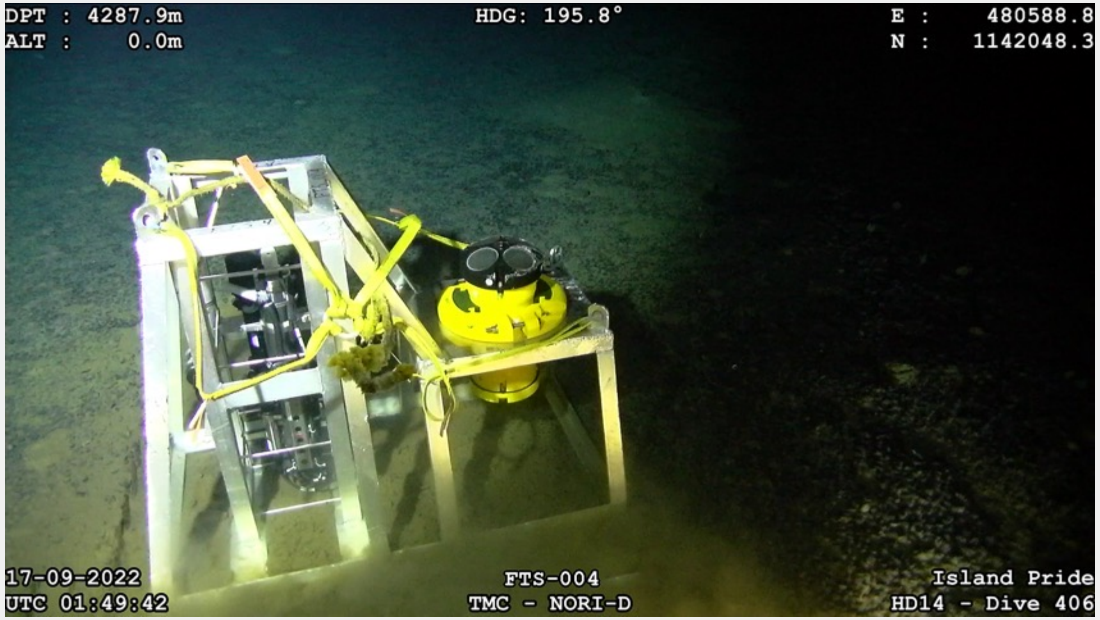
Source: https://savethehighseas.org/deep-sea-mining/impacts-of-deep-sea-mining/ (Accessed 24/10/2023)

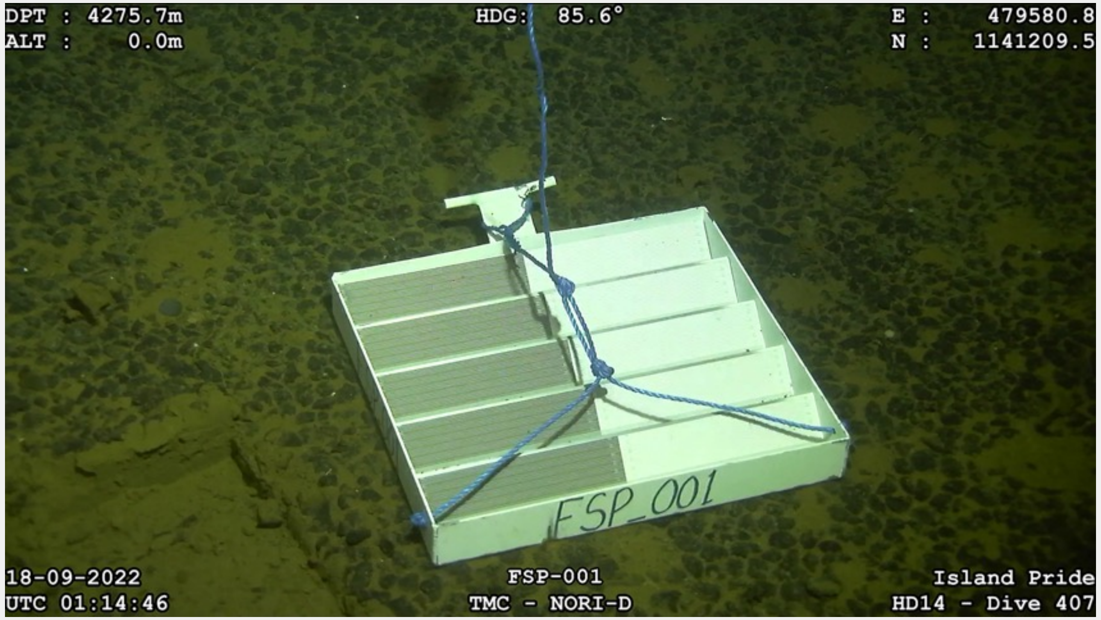
"Plumes of sediment will be created as mining stirs up the seafloor, possibly spreading ***tens of thousands of square kilometres beyond the mining sites****. The effect this will have on filter feeders such as corals and sponges is unknown."*

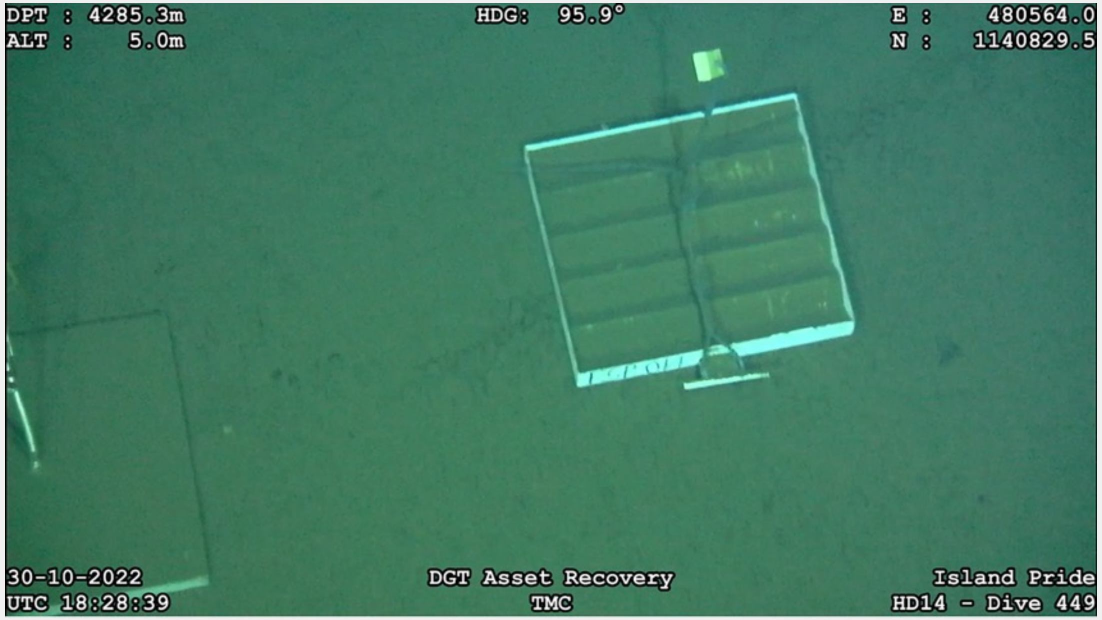


NORI
NAURU OCEAN RESOURCES INC.
OSV Island Pride
SSV Hidden Gem
6. RETURN WATER DISCHARGE MONITORING
Safe operational working distance 500m
surface
1. FIXED MONITORING STATIONS
(inc. moored ADCPs, hydrophones etc.)
Hydrographic and non-trace metal CTD casts for monitoring benthic operational and midwater plumes
Midwater passive plume
1,200m
4. AUV MONITORING
OSV AUV for far-field monitoring of the benthic operational plume
3. ROV MONITORING
OSV ROV for far-field dynamic monitoring of the benthic operational and midwater plume
Safe operational working distance 200m
3. ROV MONITORING
SSV ROV for near-field dynamic monitoring of the benthic operational and midwater plume
OSV AUV for seafloor mapping and photogrammetry
Benthic operational plume
5. PCV MONITORING
4,300m
2. MOVEABLE MONITORING STATIONS
(inc. optical sensors)
NOT TO SCALE - for illustrative purposes only


DPT : 4278.8m
ALT : 1.6m
HDG: 92.4°
E : 480143.8
N : 1142733.7
16-09-2022
UTC 20:10:52
FCS-001 and FSP-007
TMC - NORI-D
Island Pride
HD14 - Dive 406


DPT : 4287.9m
ALT : 0.0m
HDG: 195.8°
E : 480588.8
N : 1142048.3
17-09-2022
UTC 01:49:42
FTS-004
TMC - NORI-D
Island Pride
HD14 - Dive 406

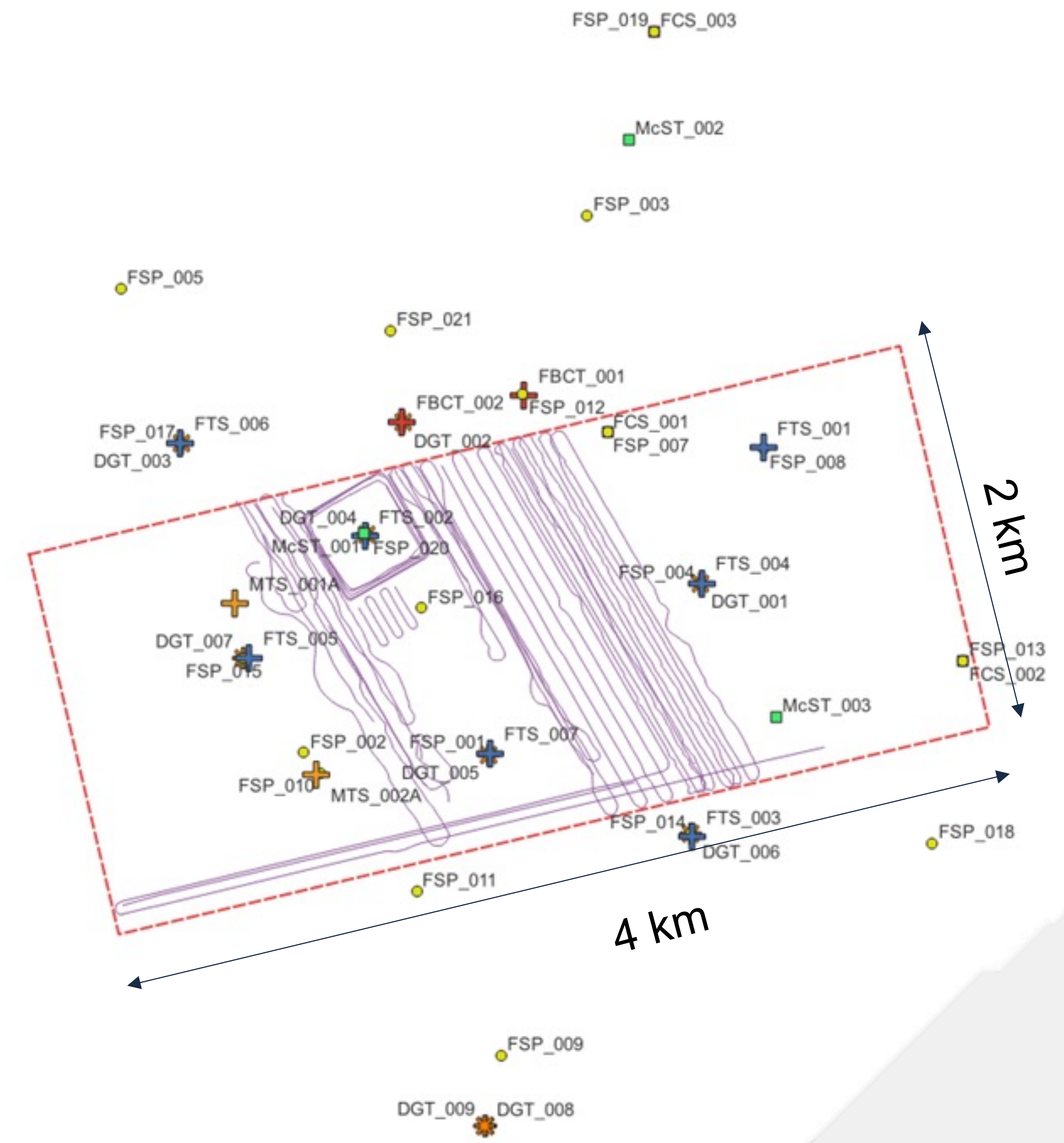

DPT : 4275.7m
ALT : 0.0m
HDG: 85.6°
E : 479580.8
N : 1141209.5
FSP_001
18-09-2022
UTC 01:14:46
FSP-001
TMC - NORI-D
Island Pride
HD14 - Dive 407

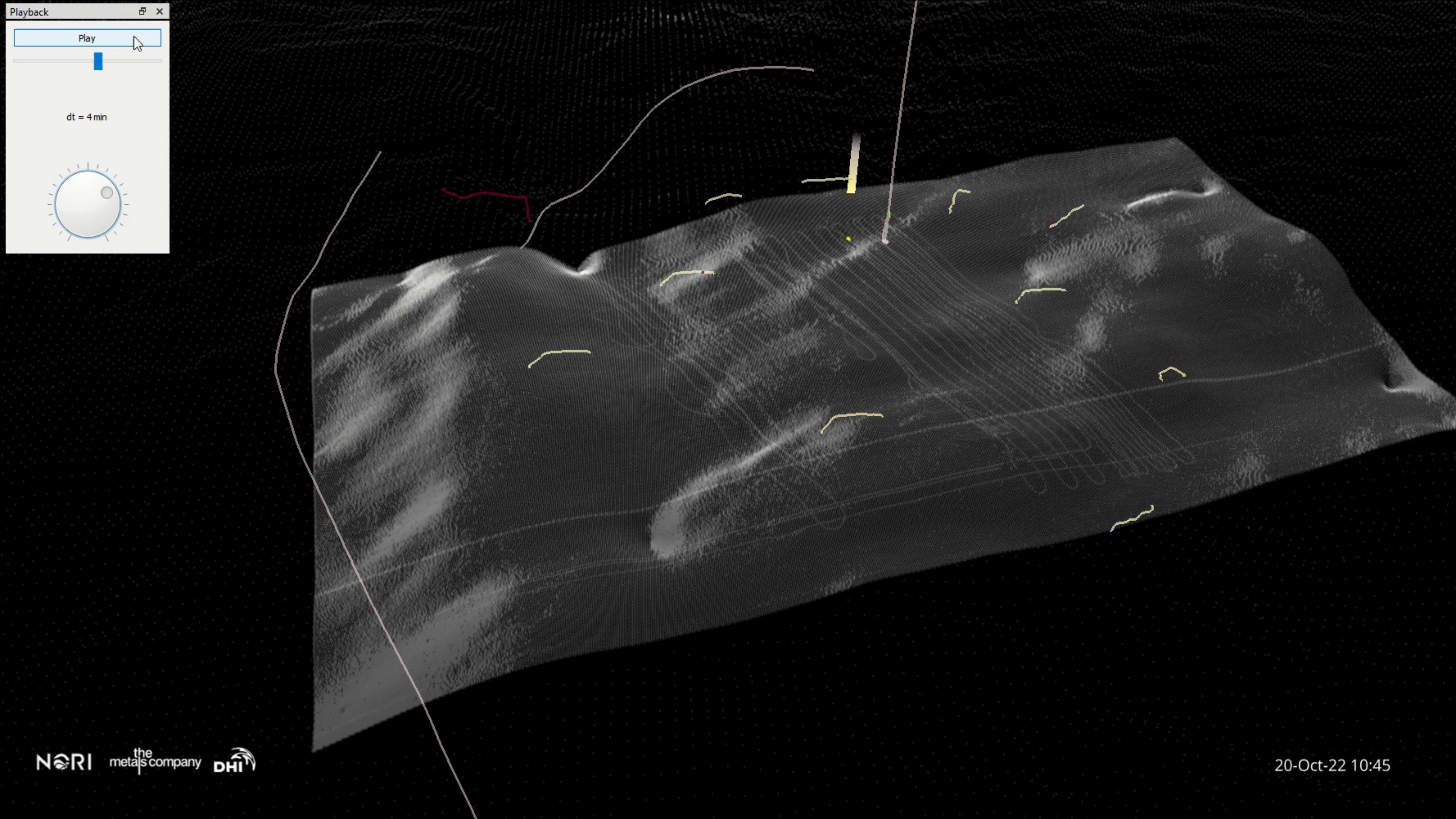

DPT : 4285.3m
ALT : 5.0m
HDG: 95.9°
E : 480564.0
N : 1140829.5
30-10-2022
UTC 18:28:39
DGT Asset Recovery
TMC
Island Pride
HD14 - Dive 449

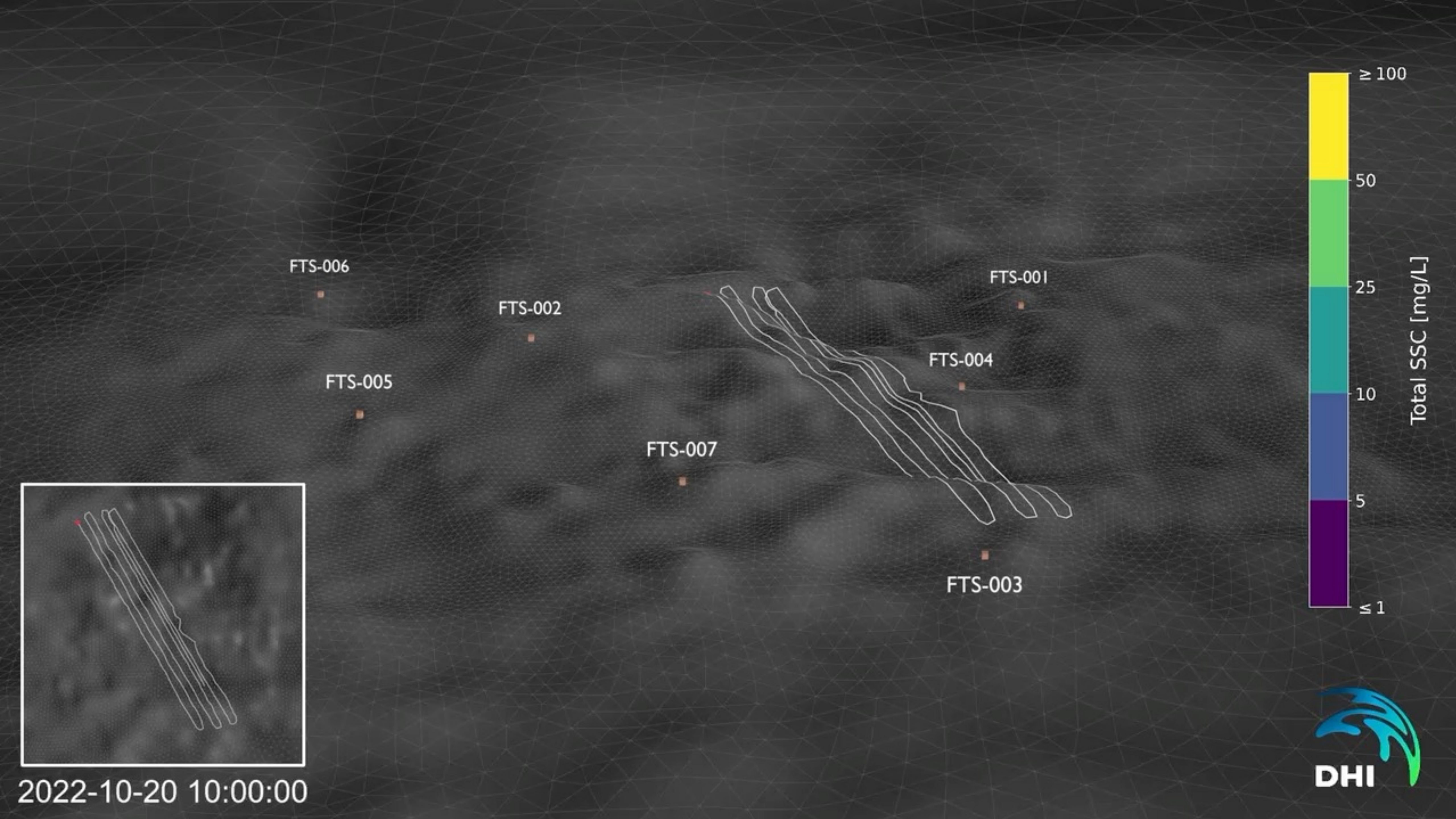
50 monitoring stations distributed in and around the test field to monitor and map the near and far field plume *in situ*.

BENTHIC PLUME ARRAY

- 7 x Fixed Landers with ADCPs, CTDs, OBS – optical backscatter
- 2 x Fixed bottom current and turbidity landers with acoustic modems that we interrogate in real time
- 3 x McLane sediment traps
- 20 x sediment plates measuring sedimentation
- 4 x Camera landers recording sedimentation
- 1 x acoustic mooring
- 1 X acoustic lander
- 1 x midwater mooring that we interrogate for midwater currents
- 7 x DGTs diffuse gel samplers
- 2 x AUVs mapping near and far field

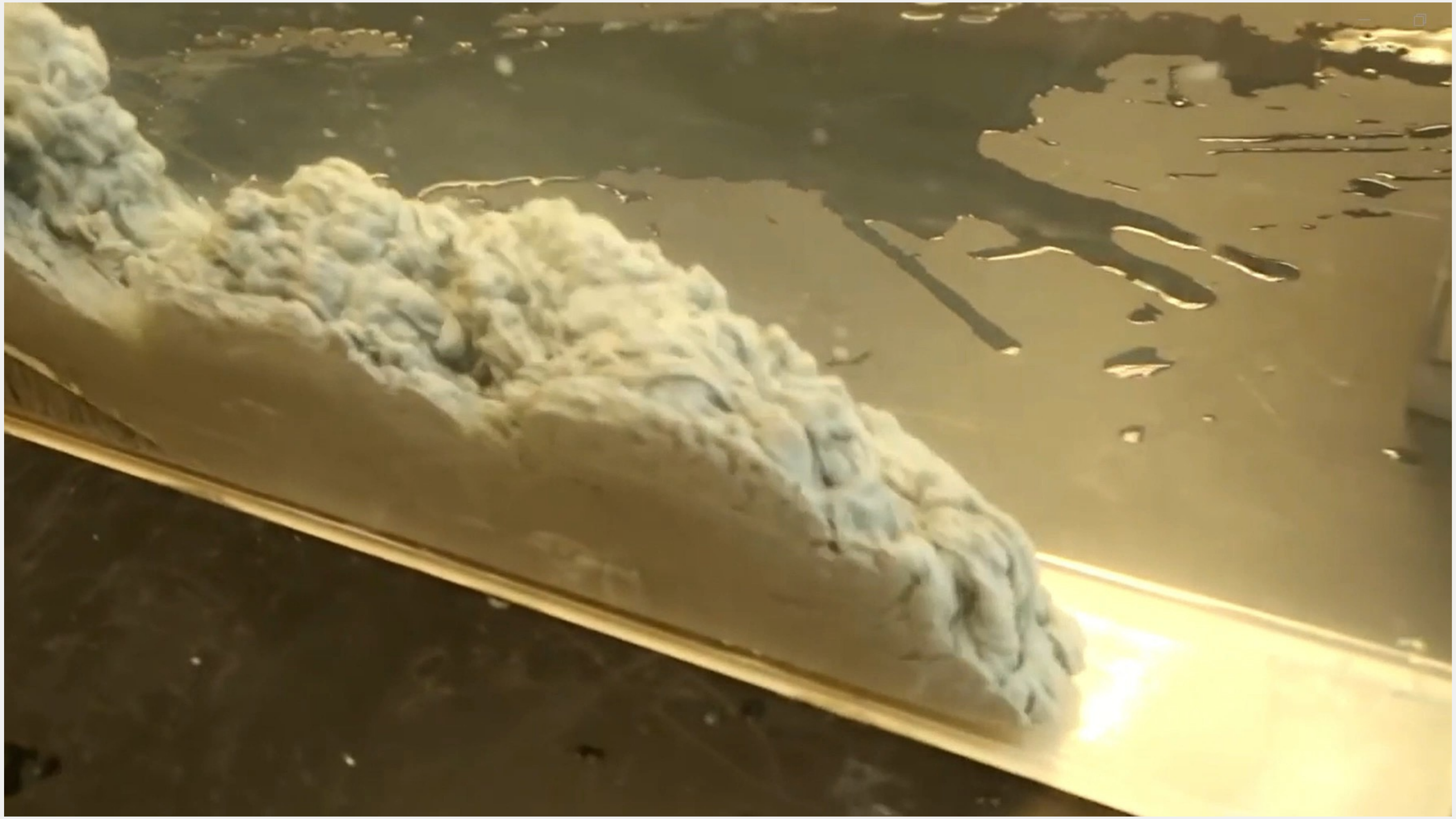



Playback
Play
dt = 4 min
NORI
the metals company
DHI
20-Oct-22 10:45



FTS-006
FTS-002
FTS-005
FTS-007
FTS-001
FTS-004
FTS-003
≥ 100
50
25
10
5
≤ 1
Total SSC [mg/L]
2022-10-20 10:00:00
DHI

Increasing evidence to suggest that the benthic plume forms a turbidity current at the seabed.



"*A turbidity current is a lateral, gravity-driven spreading of sediment-laden water under its own weight away from the collector tracks and not a case of the sediment being passively carried away by the background ocean currents*" – Thomas Peacock

Peacock. T. The GSR Patania II Expedition: Technical Achievements & Scientific Learnings. Global Sea Mineral Resources. Internal Report. March 2023.

Early lab–based evidence

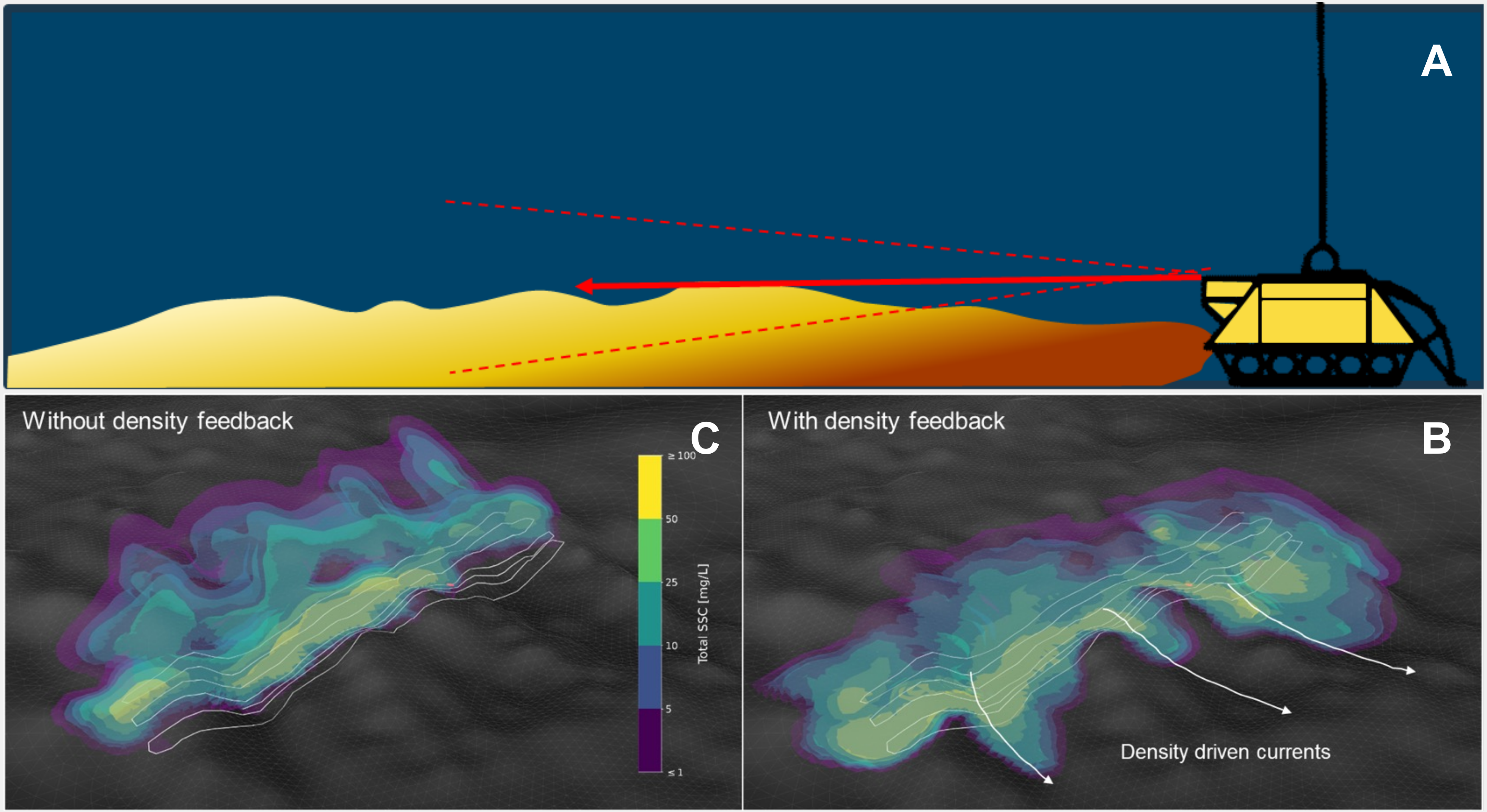
- Same holds true for the exhaust pipe behind the collector. The plume will descend down to the seafloor and aggregation will take place." – *Gillard et al. (2020)*
- "The experiments reveal the formation of a wedge-shaped gravity current front which narrows as the ratio of collector-to-buoyancy velocity increases." – *Ouillon et al. (2021)*

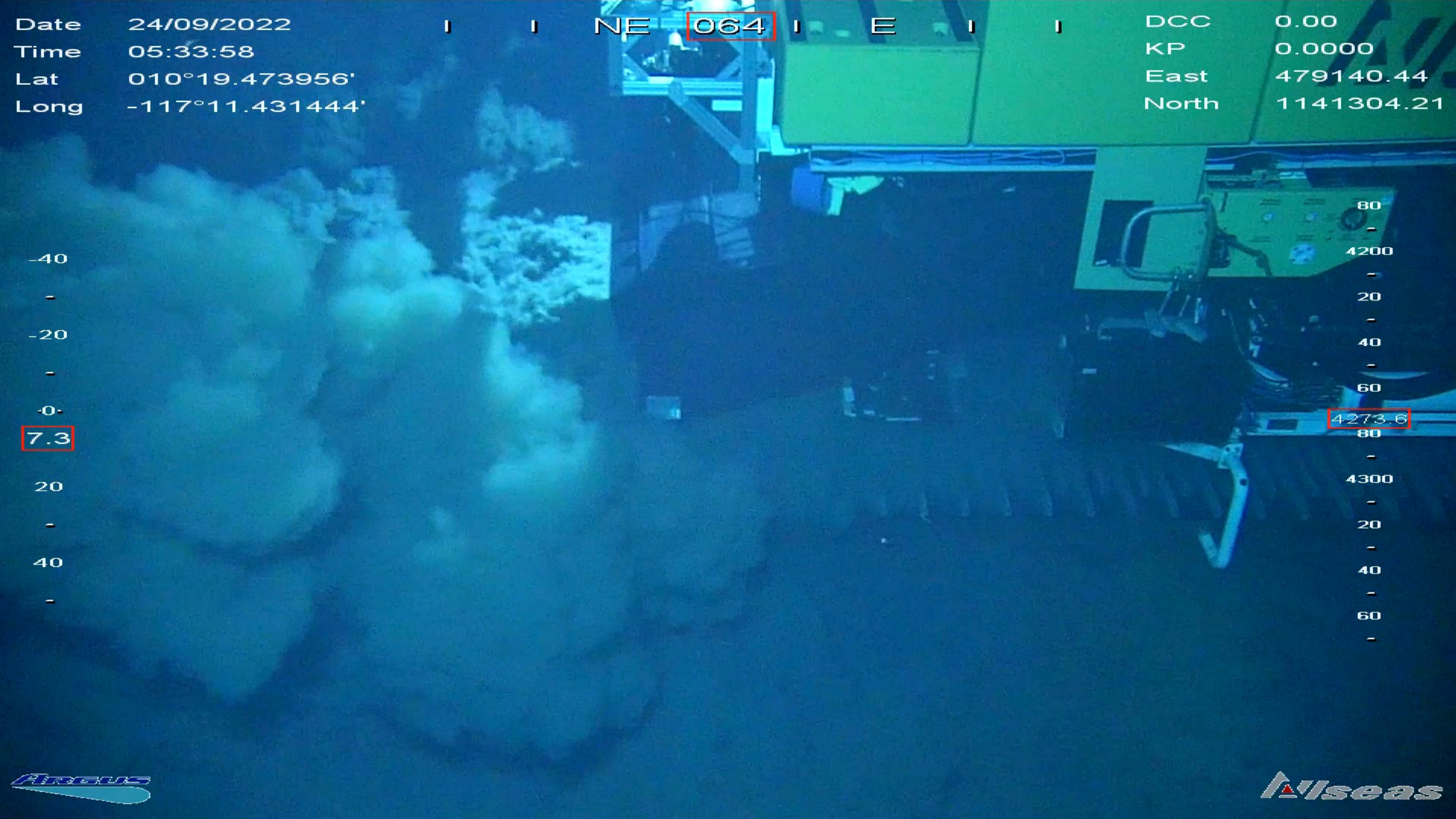
Verified by field evidence

- "Volume of resuspended sediments significantly lower than assumed. Sediment aggregations is fast leading to fast settling." – *DHI (2023)*
- "As such, it can be concluded that the sediment plume created behind Patania II initially took the form of a turbidity current." – *Peacock (2023)*
- "It was found that the generated sediment plume extended no >2m above the seabed close to the source (<100m) but increased in height at greater distance. Furthermore, turbidity values decreased rapidly with increasing distance to the source." – *Haalboom et al. (2023)*

Haalboom, Sabine, et al. "Monitoring of a sediment plume produced by a deep-sea mining test in shallow water, Málaga Bight, Alboran Sea (southwestern Mediterranean Sea)." Marine Geology 456 (2023): 106971.
DHI presentation Sediment Plume Monitoring and Modelling For Impact Analysis of Deep-Sea Mining. Presented at the side event at the ISA Council 28th session on 20th March 2023 in Kingston, Jamaica.
Peacock. T. The GSR Patania II Expedition: Technical Achievements & Scientific Learnings. Global Sea Mineral Resources. Internal Report. March 2023.
Ouillon, R., Kakoutas, C., Meiburg, E., & Peacock, T. (2021). Gravity currents from moving sources. Journal of Fluid Mechanics, 924, A43.
Gillard, B., and Thomsen, L. (2020) Characterization of sediment plumes behind mining vehicles in the NORI area (laboratory analyses). iSeaMC. Report commissioned by DeepFreen Inc. 2020.

Plume modeling.



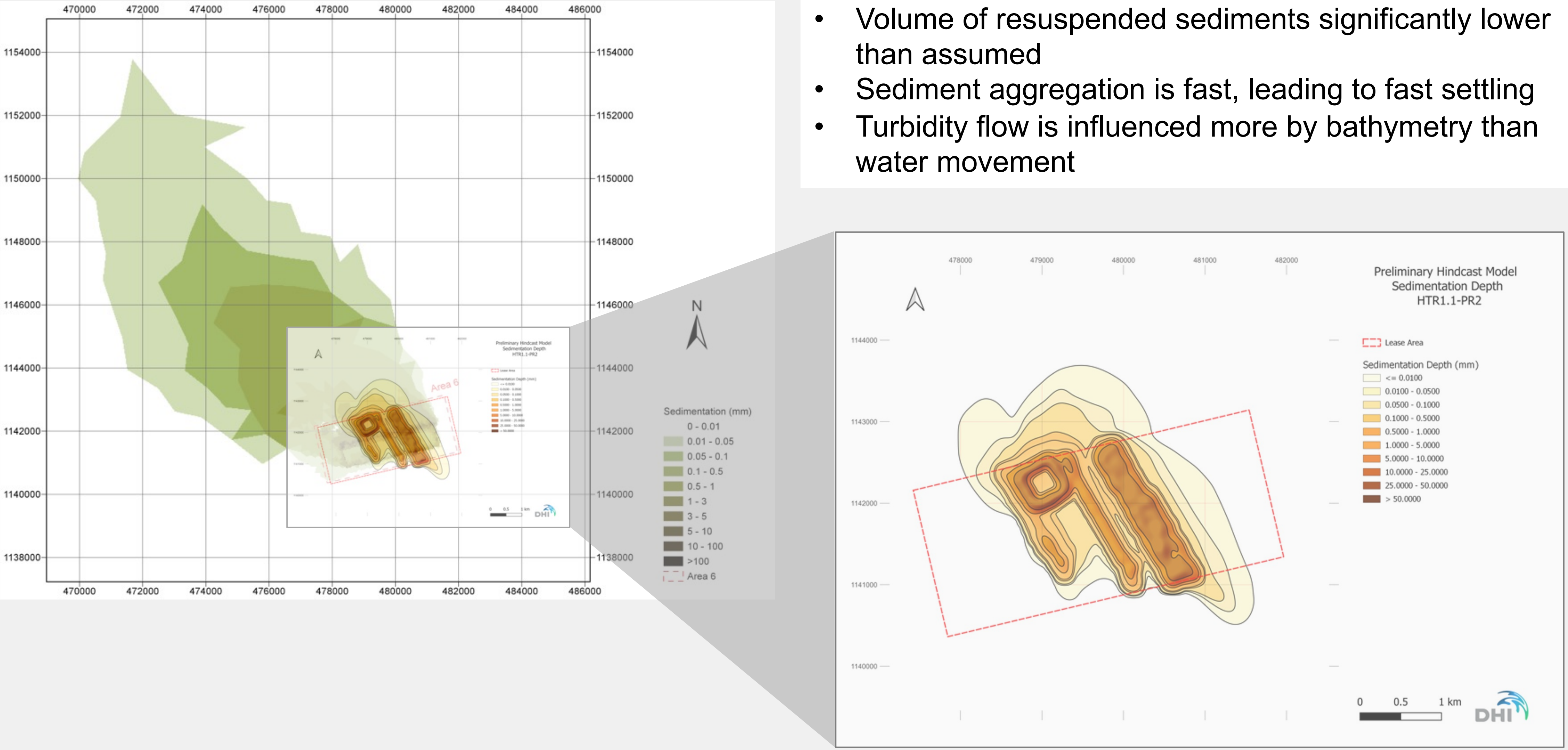

Date 24/09/2022
Time 05:33:58
Lat 010°19.473956'
Long -117°11.431444'
NE 064 E
DCC 0.00
KP 0.0000
East 479140.44
North 1141304.21
-40
-20
0
7.3
20
40
80
4200
20
40
60
4273.6
80
4300
20
40
60

Date 22/09/2022
Time 14:46:30
Lat 010°19.765835'
Long -117°11.636904'
W NW 326 N
DCC -4.17
KP 0.5547
East 478765.85
North 1141842.30
0
20
43.0
60
80
80
4200
20
40
60
4277.9
4300
20
40
60

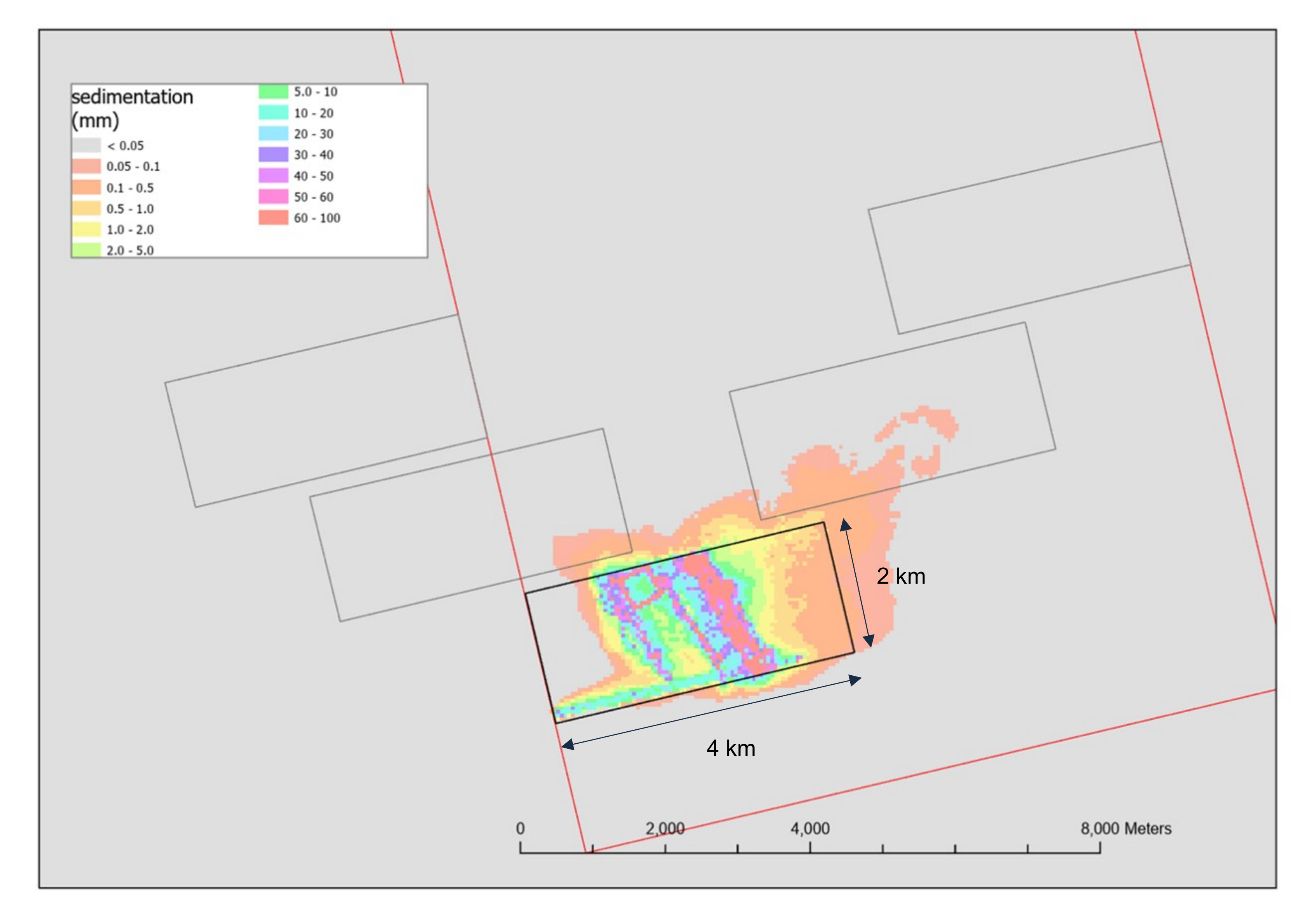
Plumes – Benthic – Sedimentation.

Why is the sedimentation footprint so small?

- Cut depth lower than assumed
- Volume of resuspended sediments significantly lower than assumed
- Sediment aggregation is fast, leading to fast settling
- Turbidity flow is influenced more by bathymetry than water movement

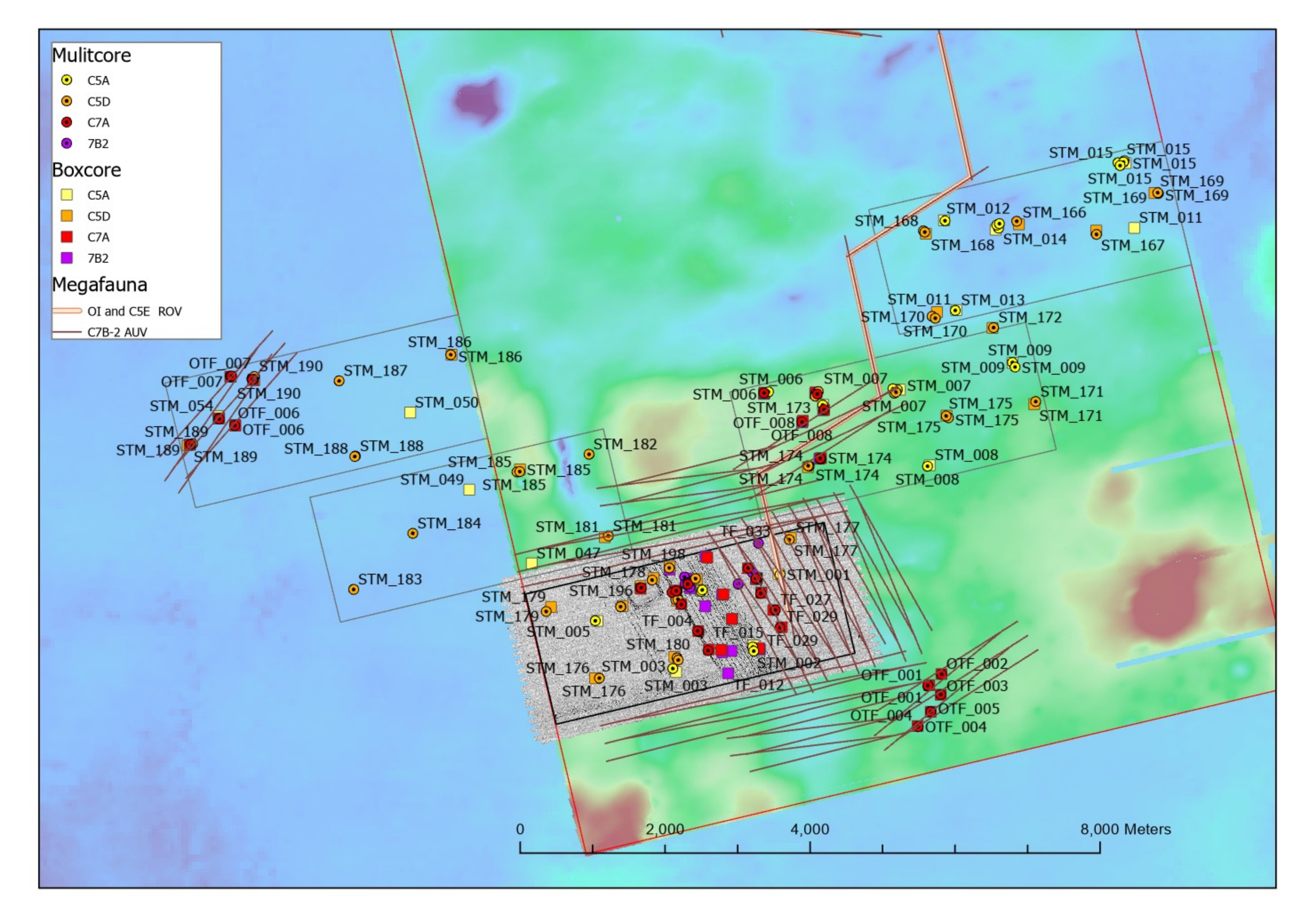


Benthic Sedimentation Model

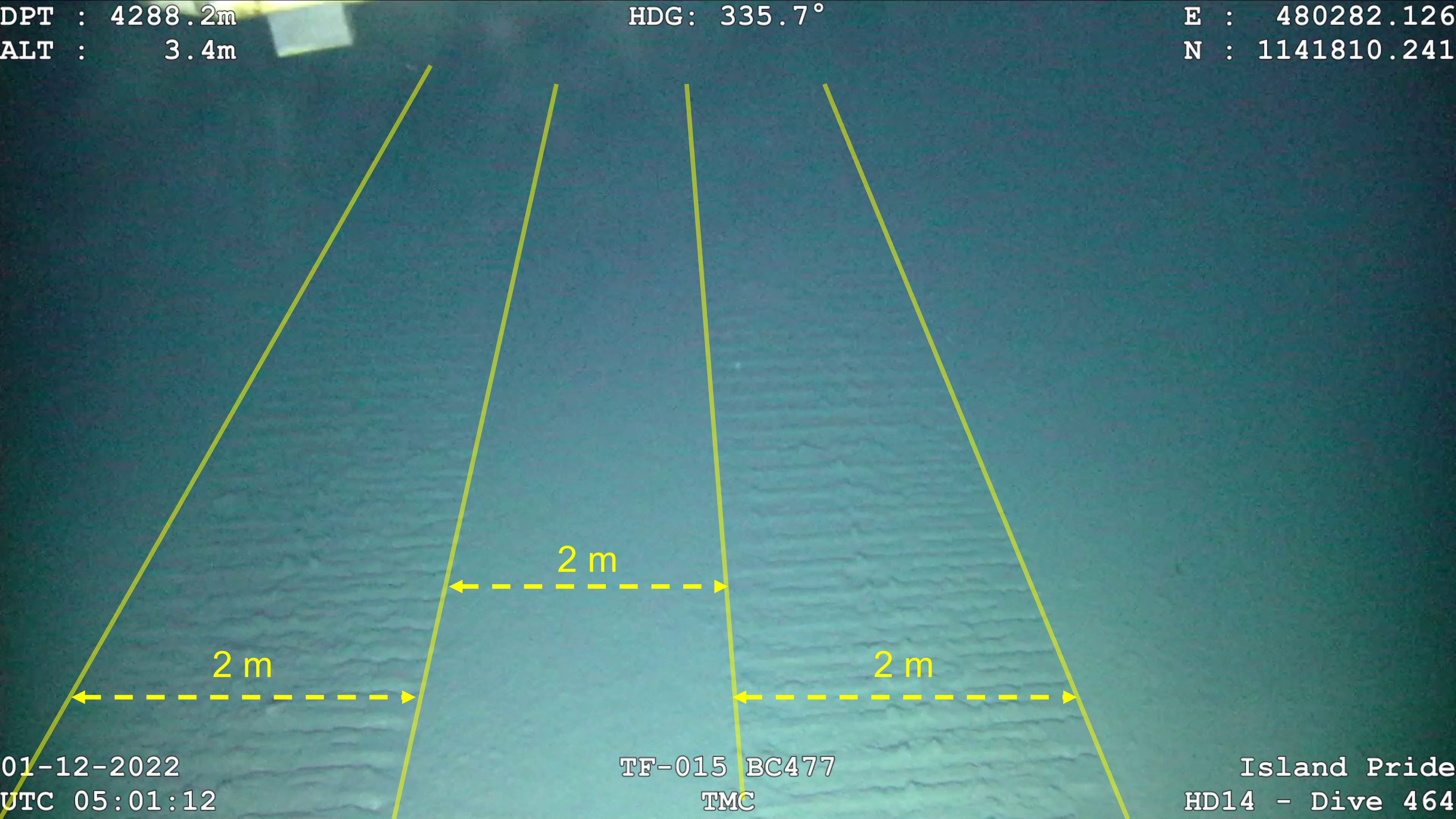


Biological Sampling.

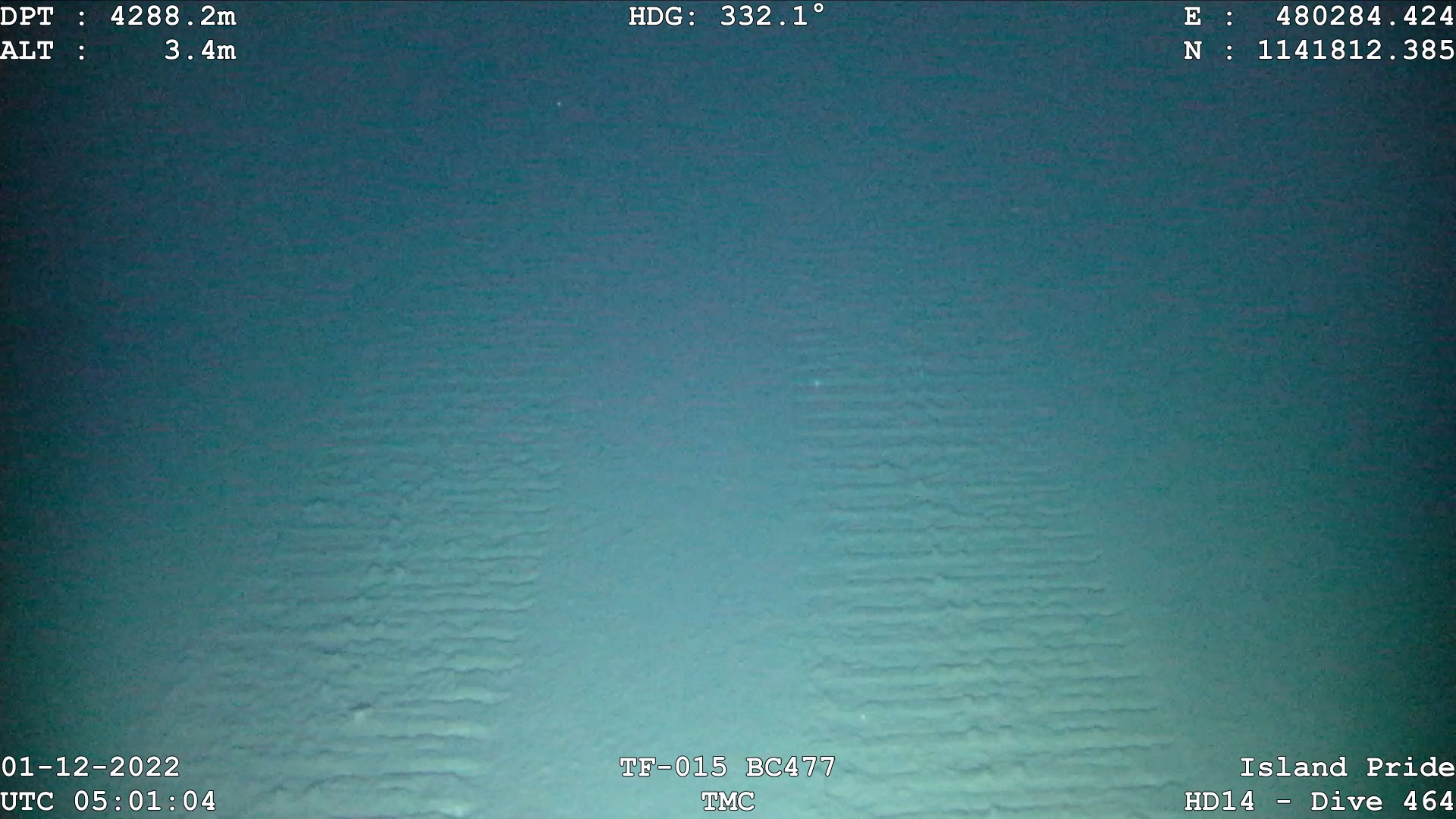
Total of 346 multicore and boxcore deployments plus >240 km of ROV/AUV transects targeted for megafauna analysis



>20 organizations engaged & >200 terabytes of data collected.

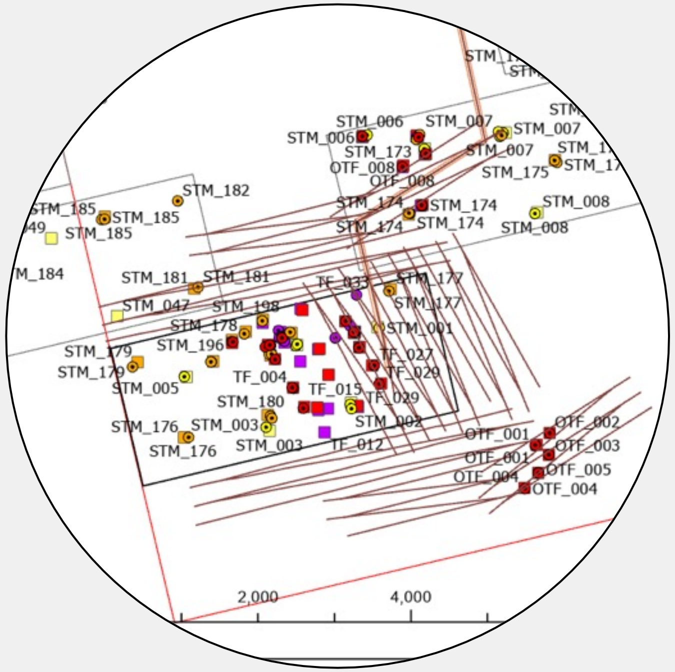

DPT : 4288.2m
ALT : 3.4m
HDG: 335.7°
E : 480282.126
N : 1141810.241
2 m
2 m
2 m
01-12-2022
UTC 05:01:12
TF-015 BC477
TMC
Island Pride
HD14 - Dive 464


DPT : 4275.3m
ALT : 4.7m
E : 479667.352
N : 1142302.254
02-12-2022
UTC 13:41:08
TF-007-MCR2 MC205
TMC
Island Pride
HD14 - Dive 465

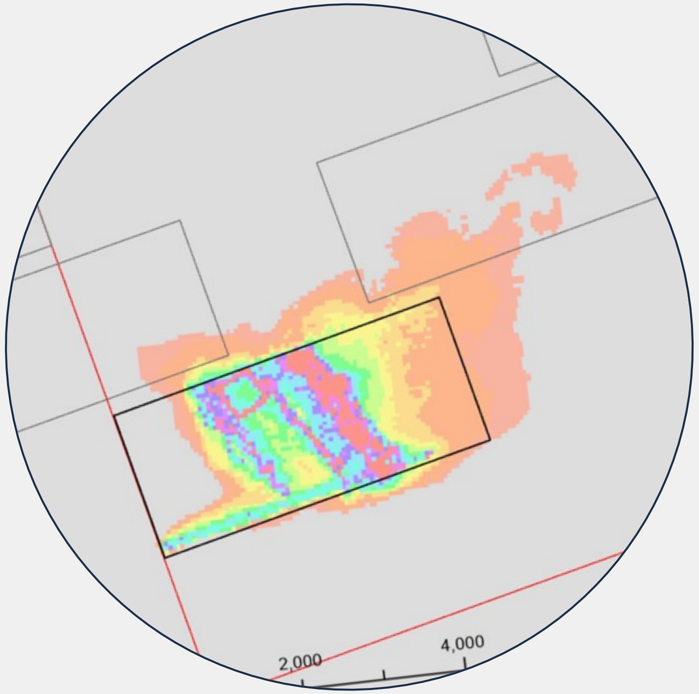

DPT : 4288.2m
ALT : 3.4m
HDG: 332.1°
E : 480284.424
N : 1141812.385
01-12-2022
UTC 05:01:04
TF-015 BC477
TMC
Island Pride
HD14 - Dive 464

Impact Assessment.

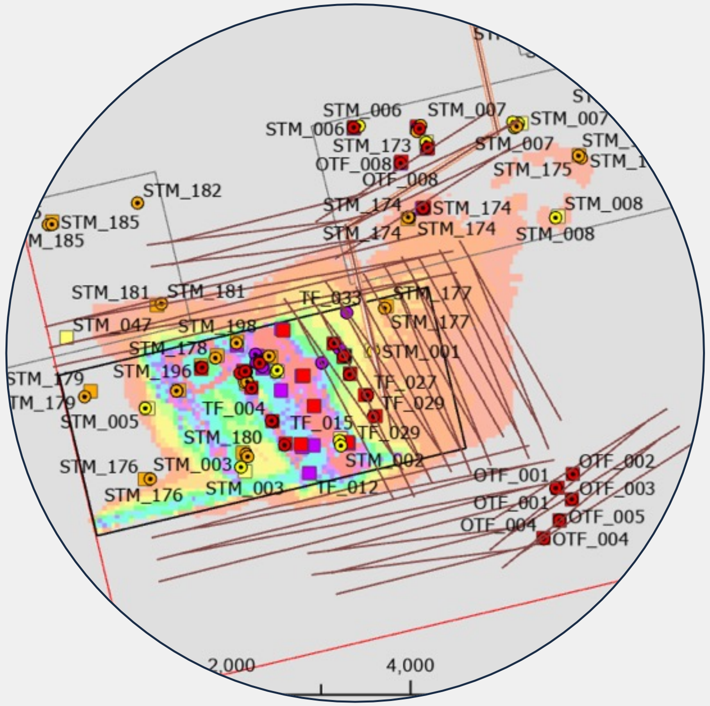
Biological Data



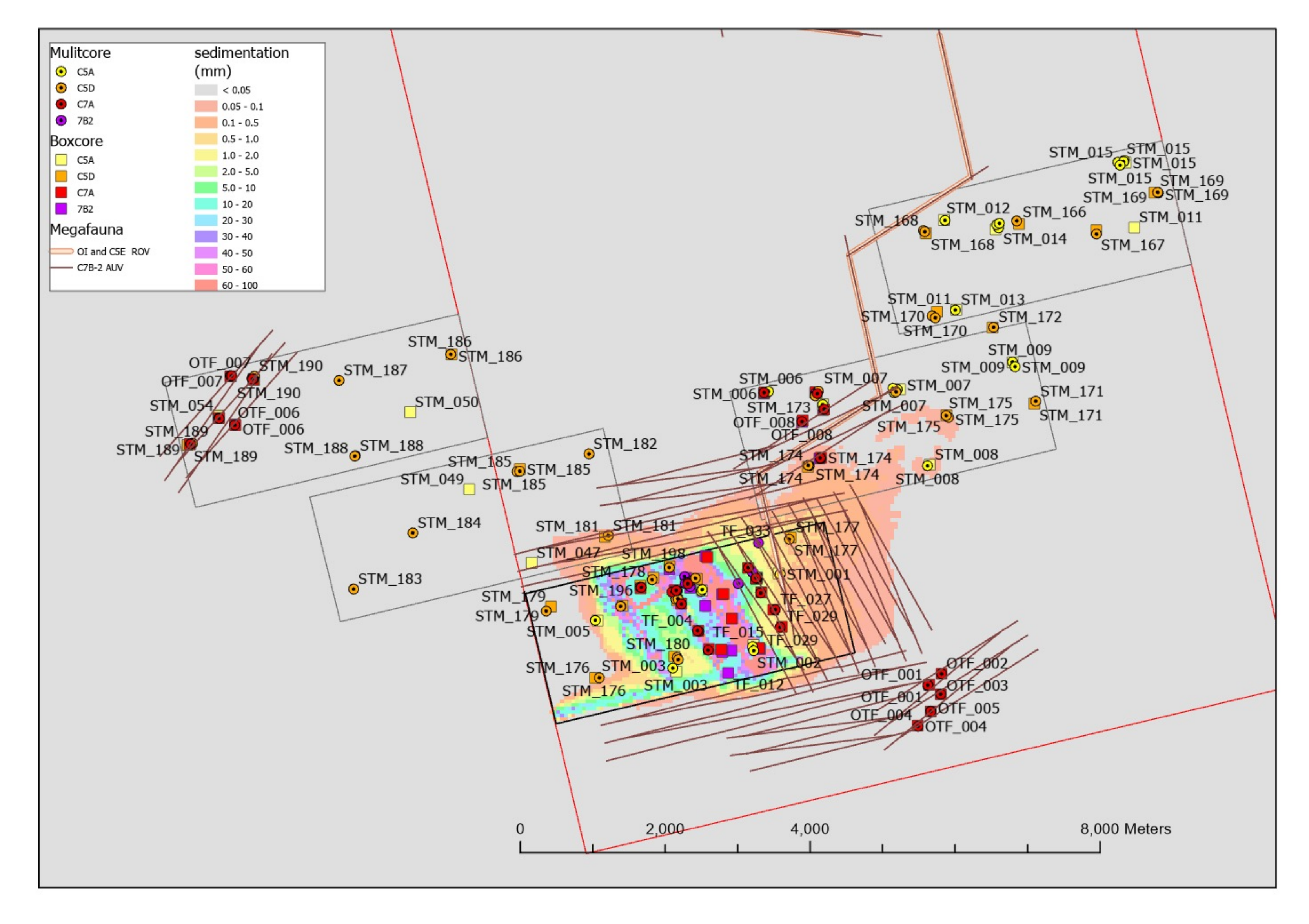
Sediment Footprint Model



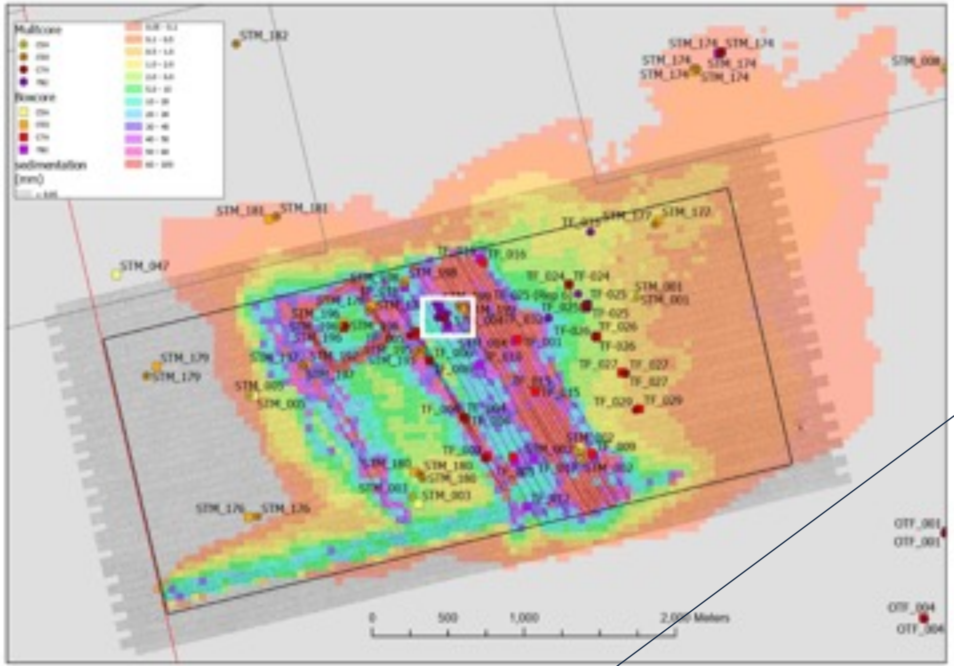
Impact Assessment

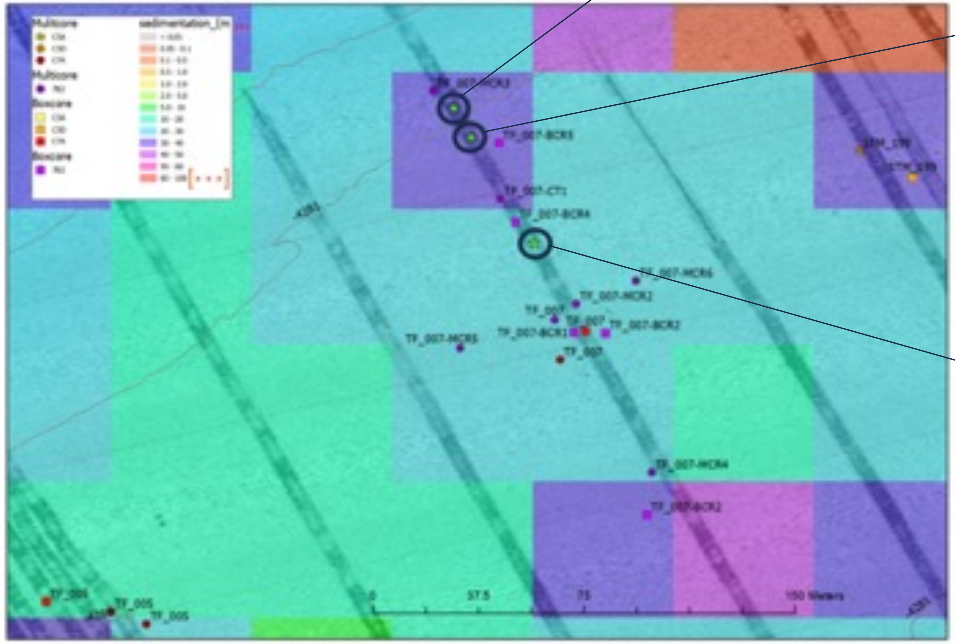


Plumes – Benthic – Sedimentation.

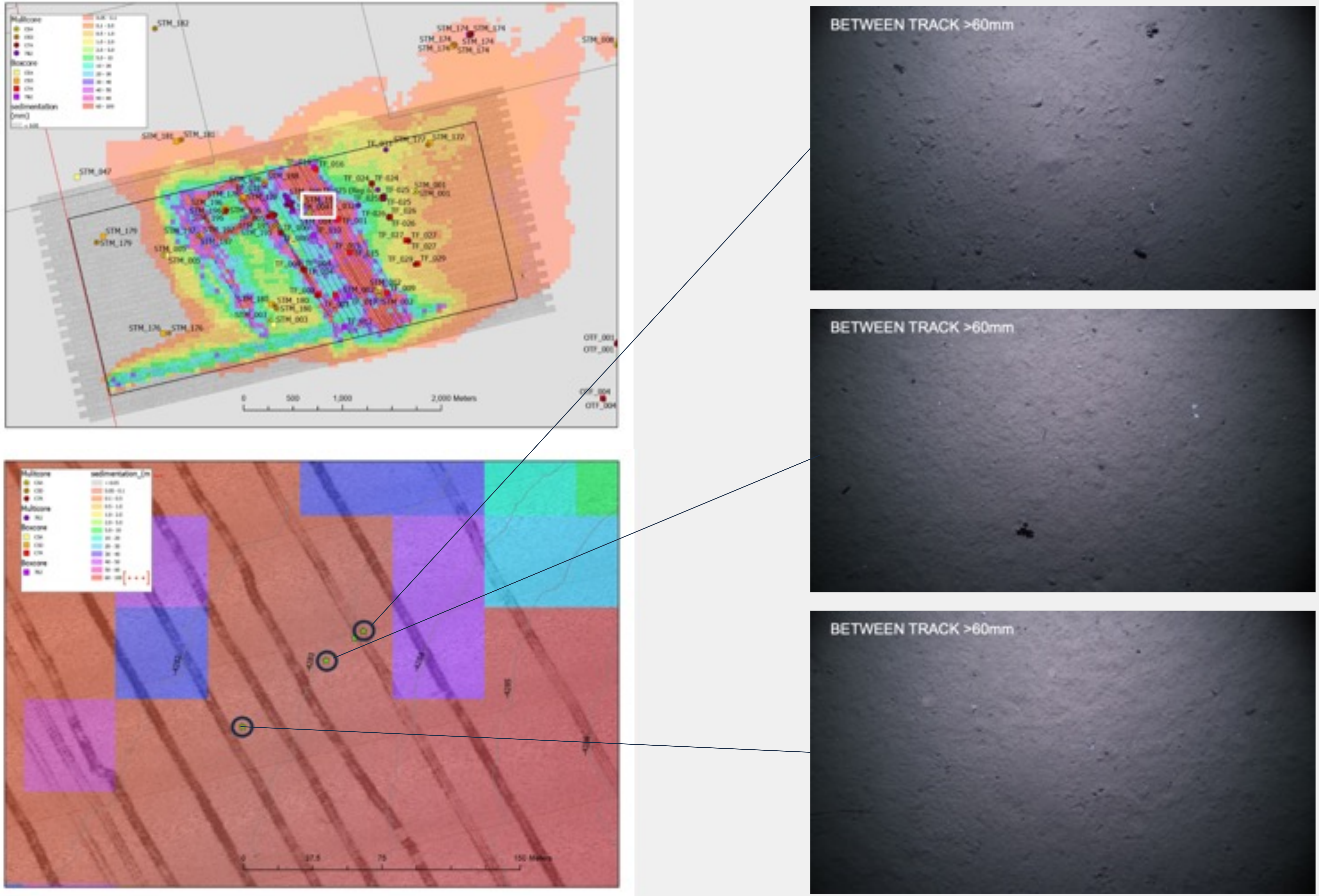


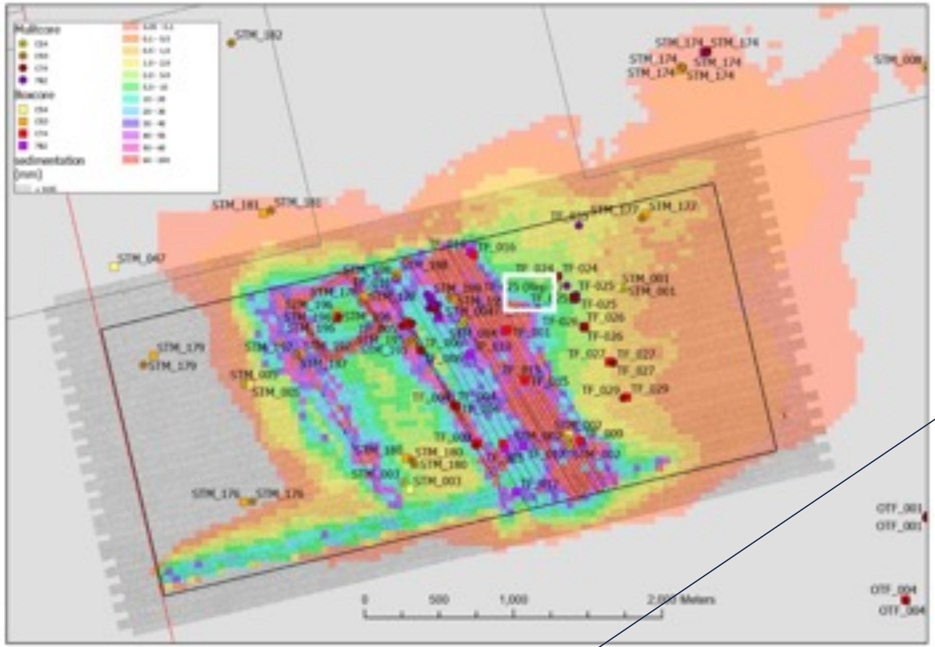
TF-007 – IN TRACK – DIRECT IMPACT

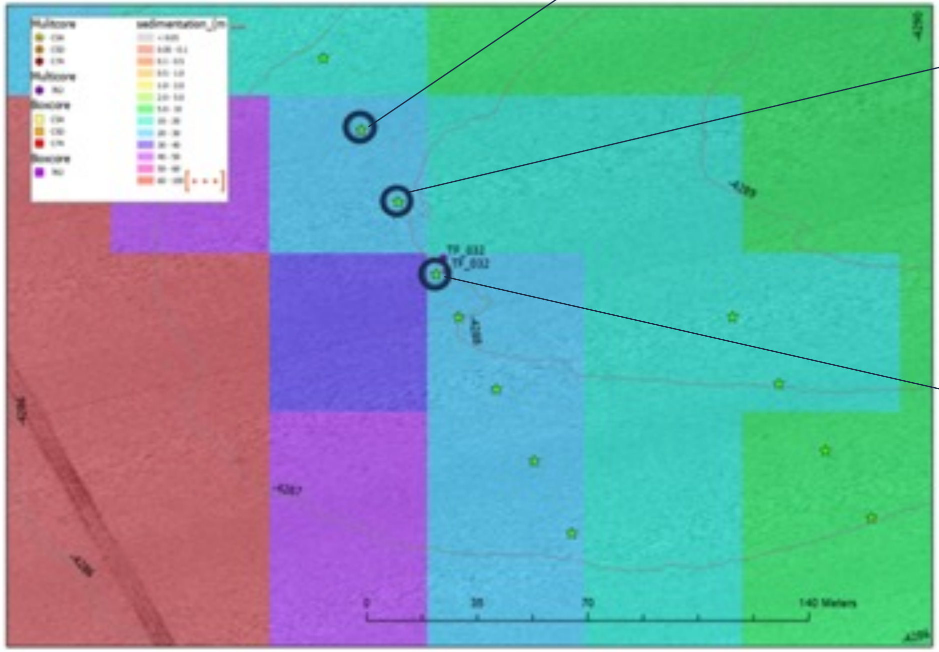


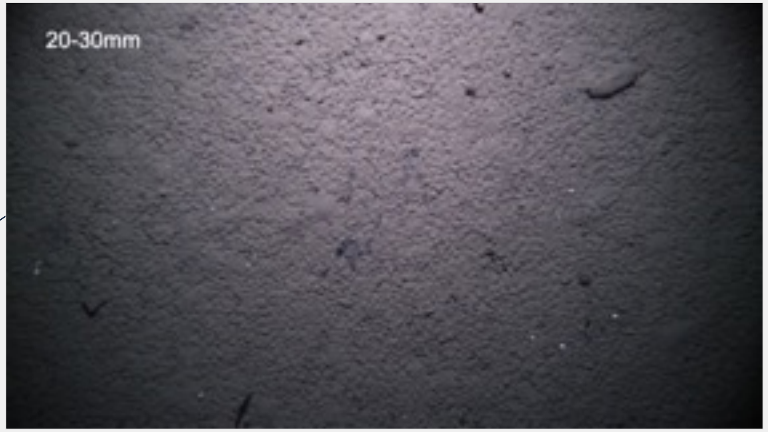


TF-NEW – Between Track - > 60 mm modelled



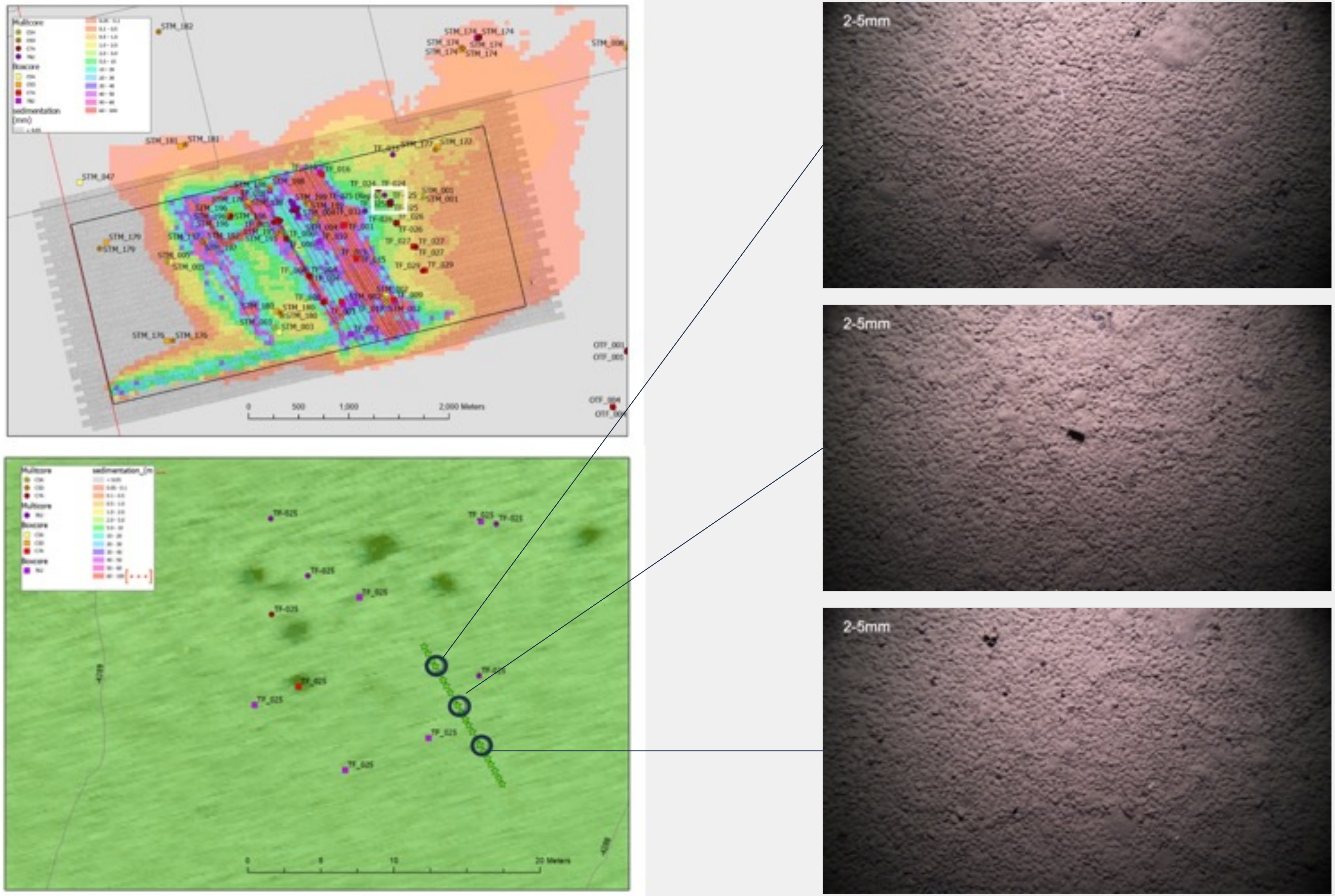


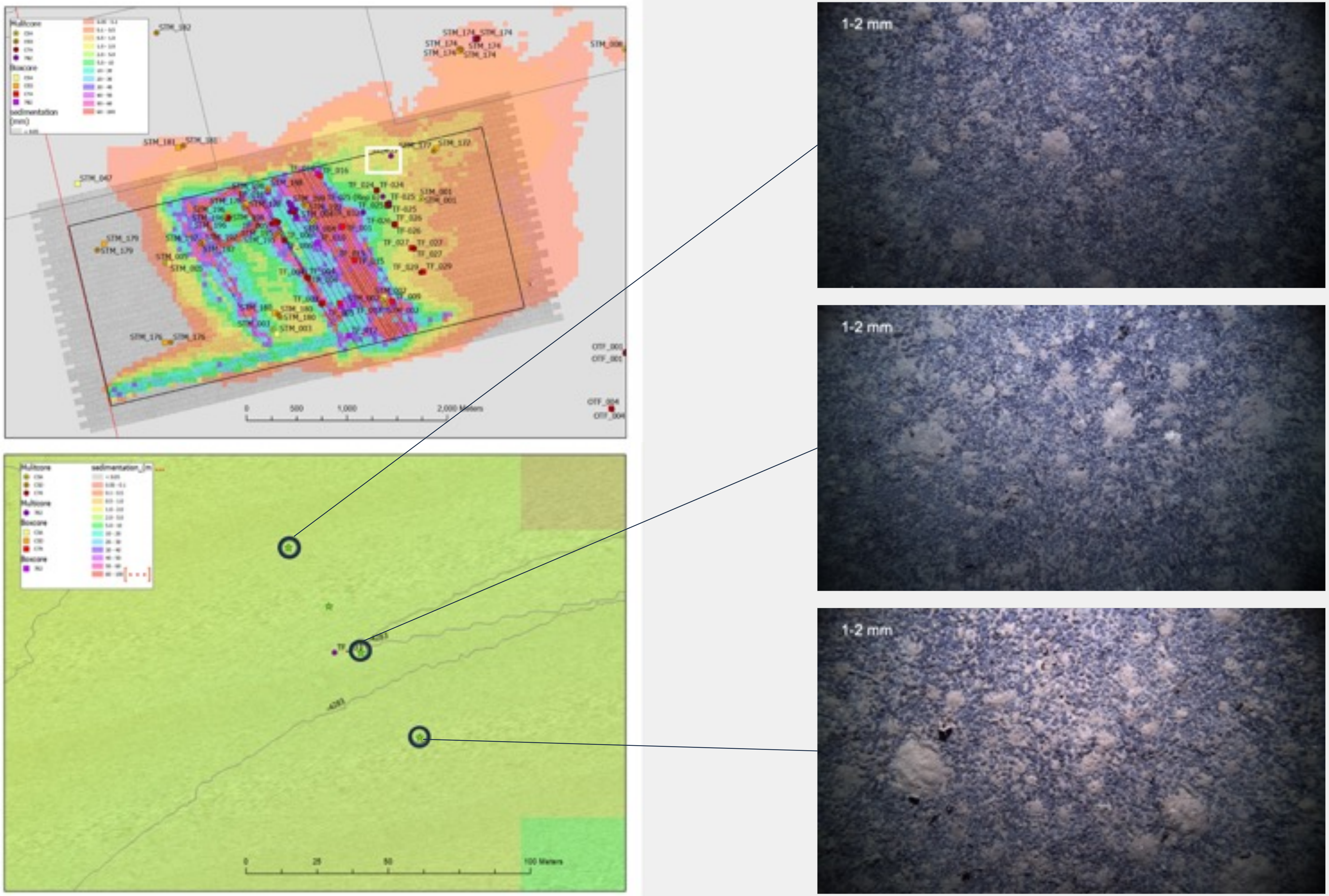




TF-032 – 20 – 30 mm modelled

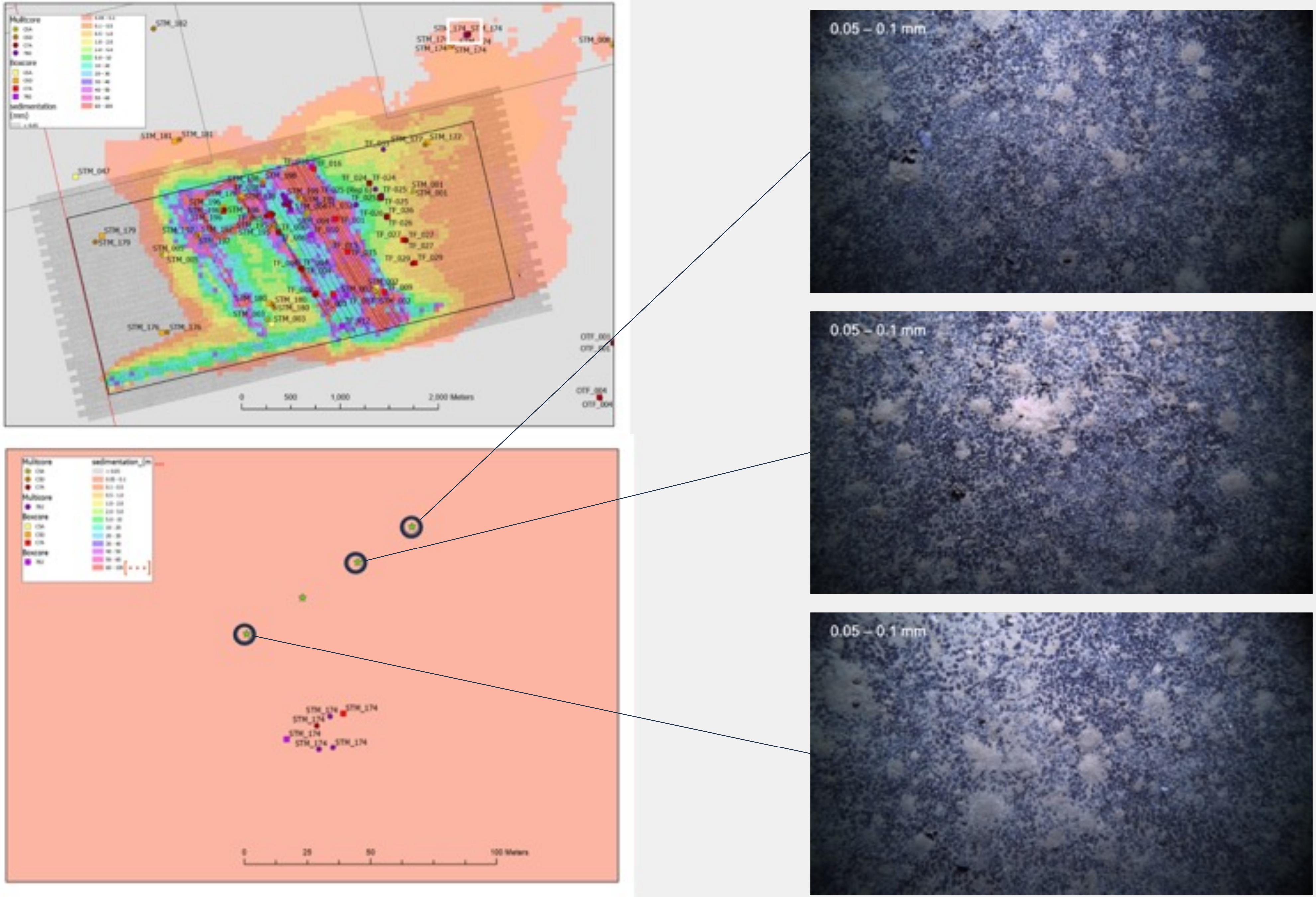
TF-025 – 2 – 5 mm modelled



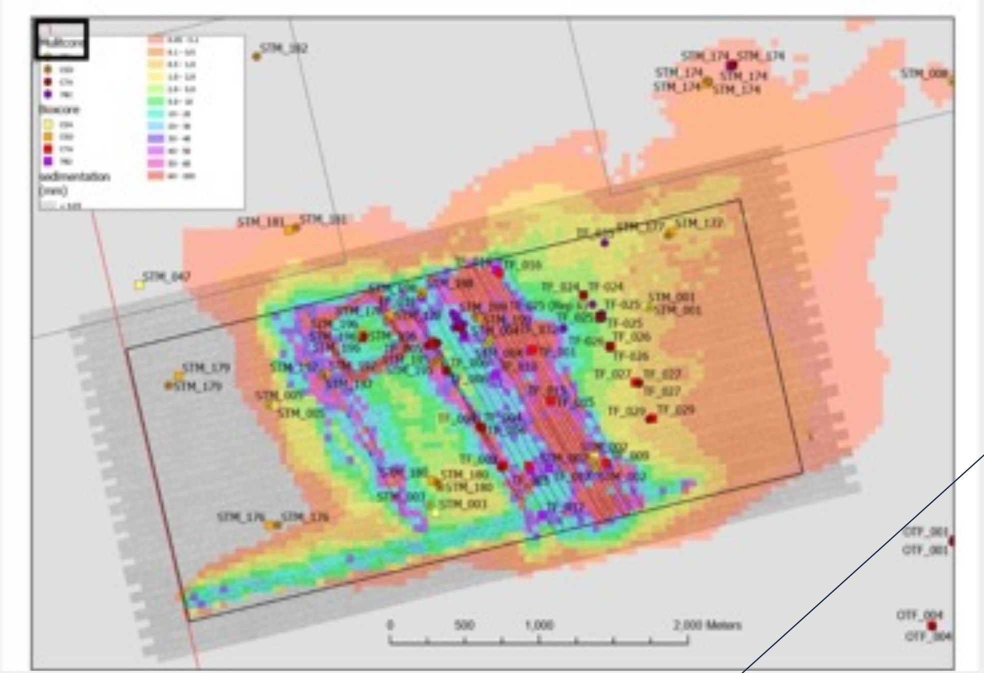


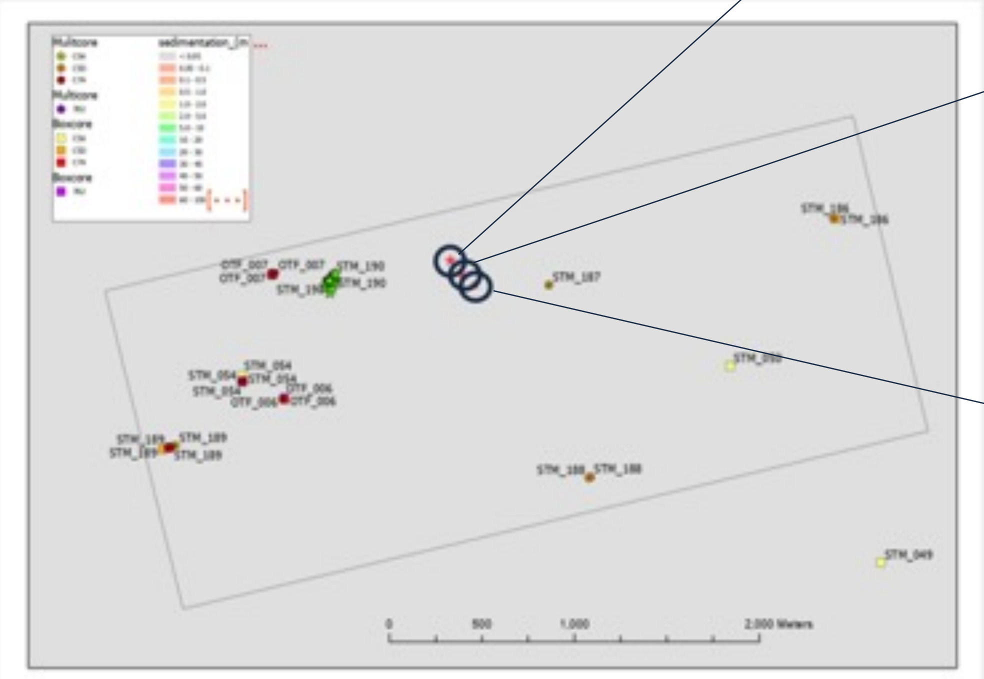
TF-033 – 1 – 2 mm modelled

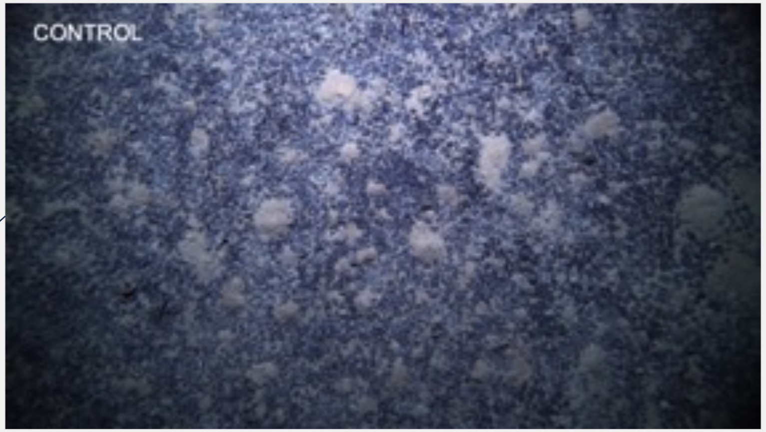
STM-174 – 0.05 – 0.1 mm modelled

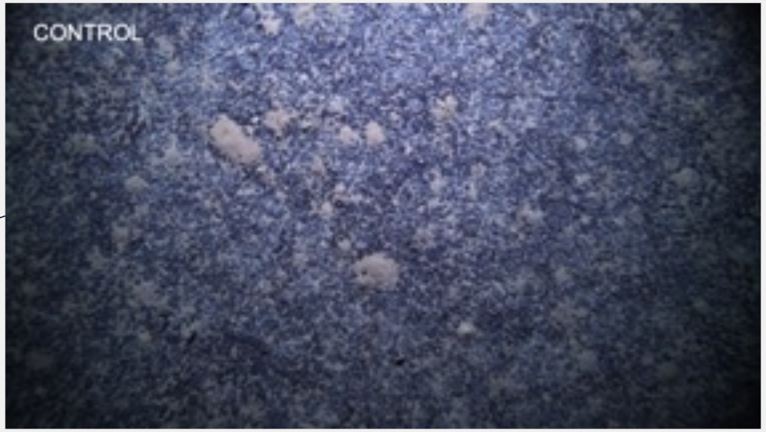


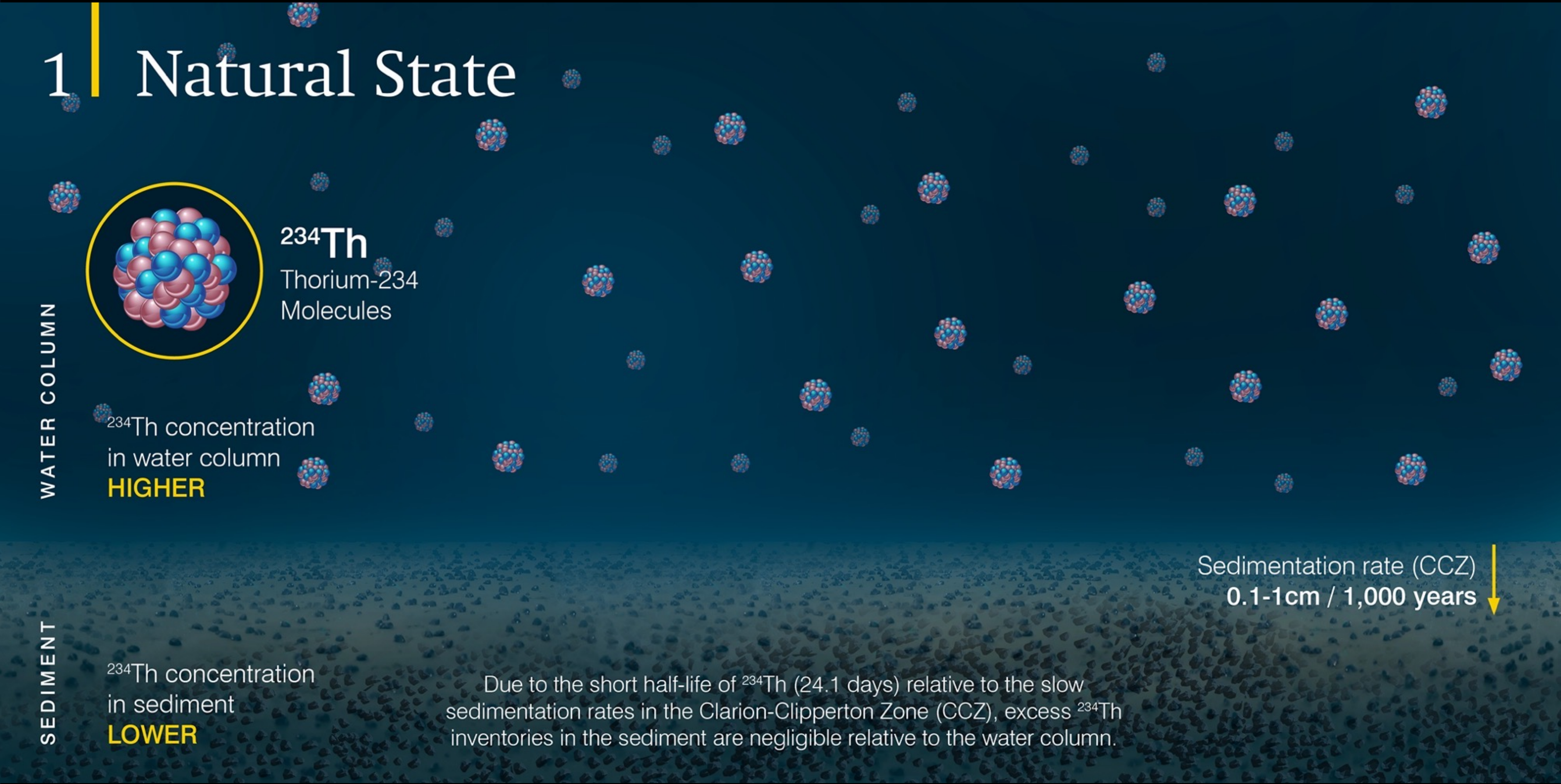
CONTROL-NW-FF – 0.00 mm modelled

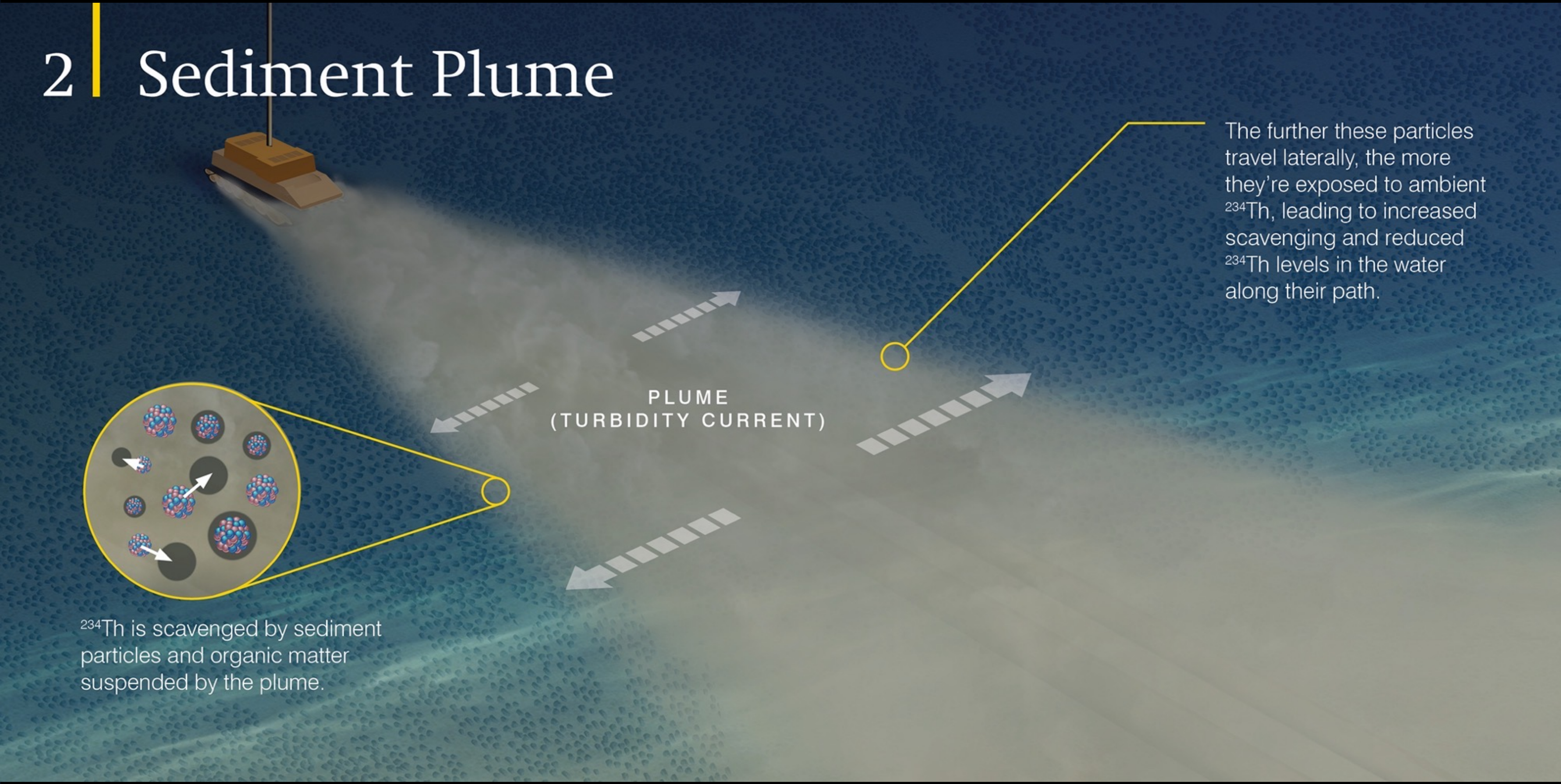






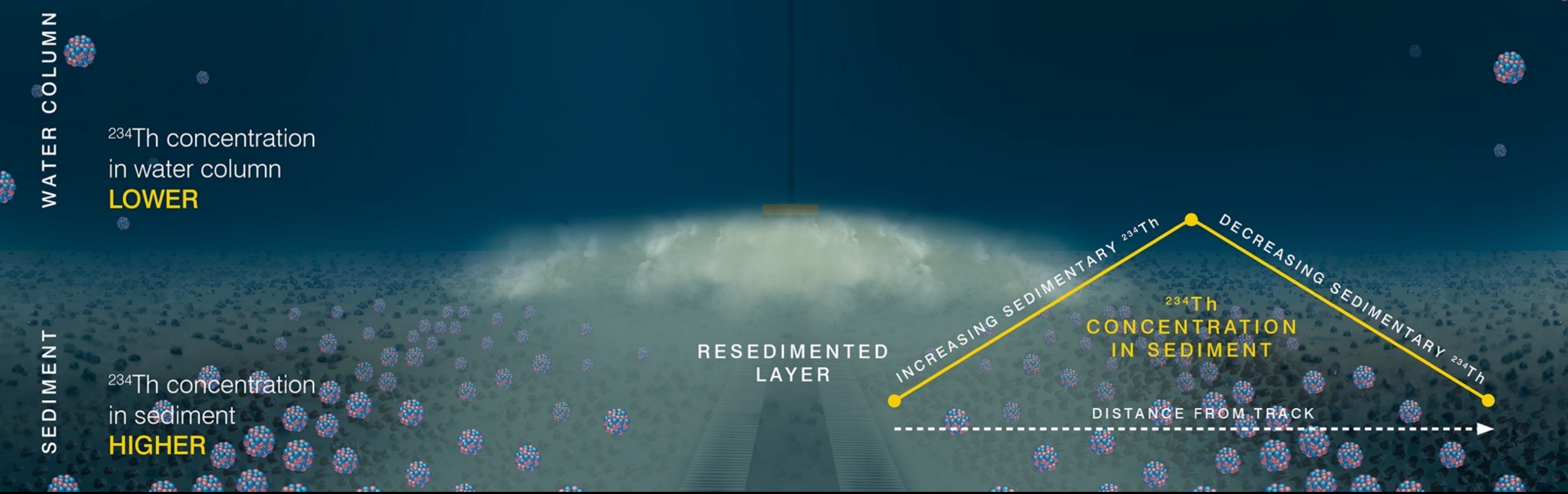



1 Natural State
234Th
Thorium-234
Molecules
WATER COLUMN
234Th concentration
in water column
HIGHER
SEDIMENT
234Th concentration
in sediment
LOWER
Sedimentation rate (CCZ)
0.1-1cm / 1,000 years
Due to the short half-life of 234Th (24.1 days) relative to the slow sedimentation rates in the Clarion-Clipperton Zone (CCZ), excess 234Th inventories in the sediment are negligible relative to the water column.

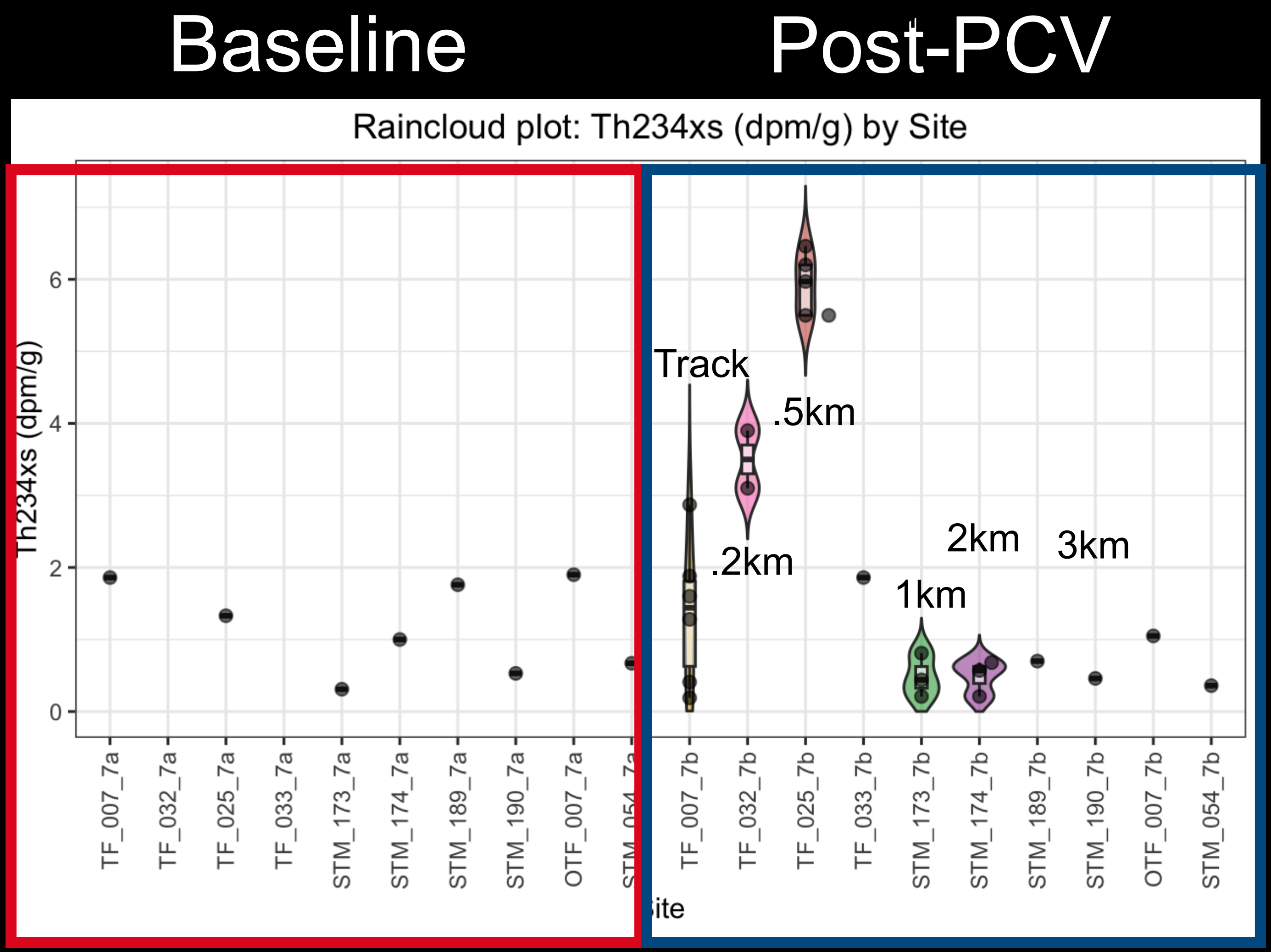

2 Sediment Plume
The further these particles travel laterally, the more they're exposed to ambient ^{234}Th, leading to increased scavenging and reduced ^{234}Th levels in the water along their path.
PLUME (TURBIDITY CURRENT)
^{234}Th is scavenged by sediment particles and organic matter suspended by the plume.

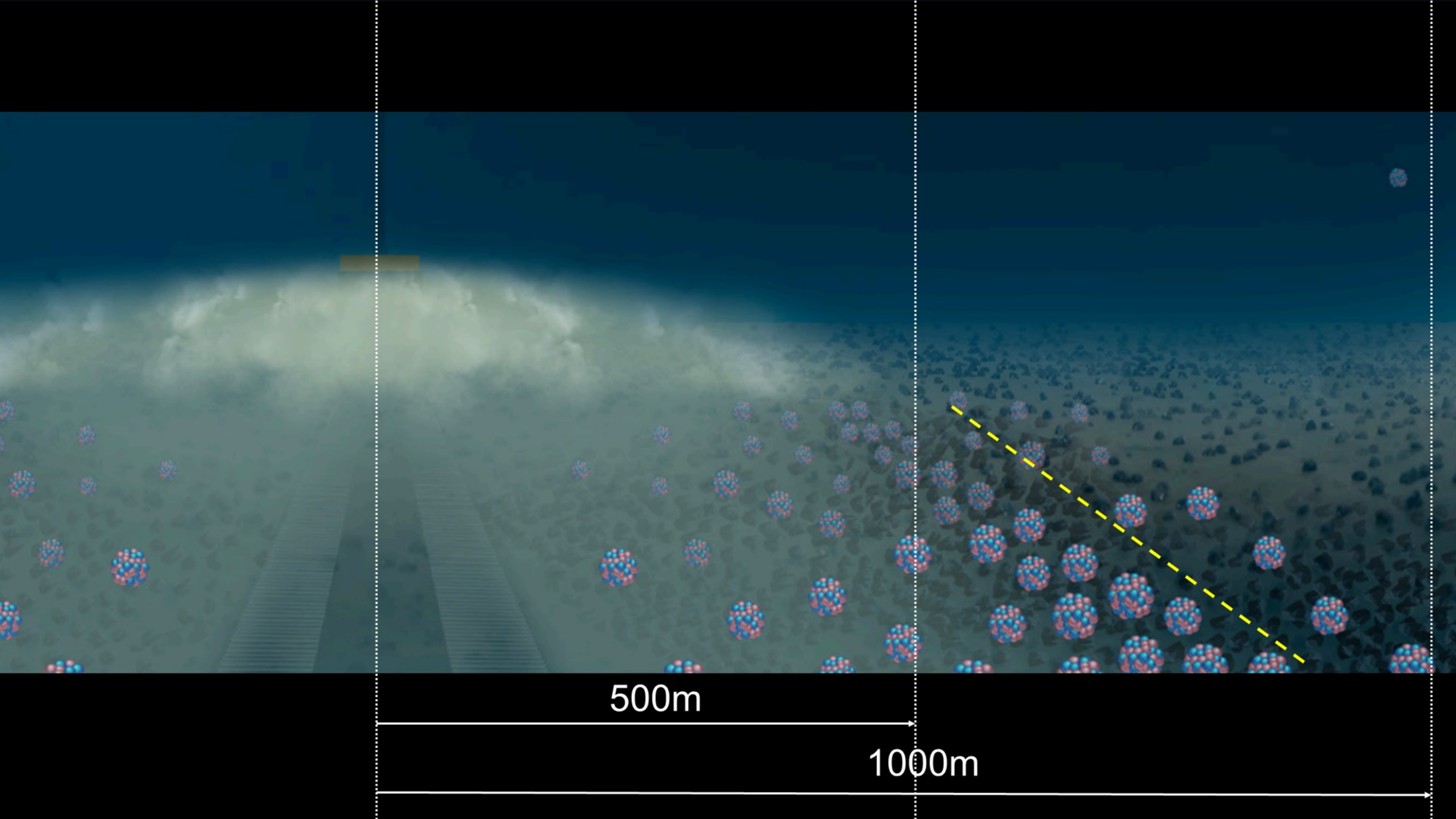
3 Sediment Post Impact

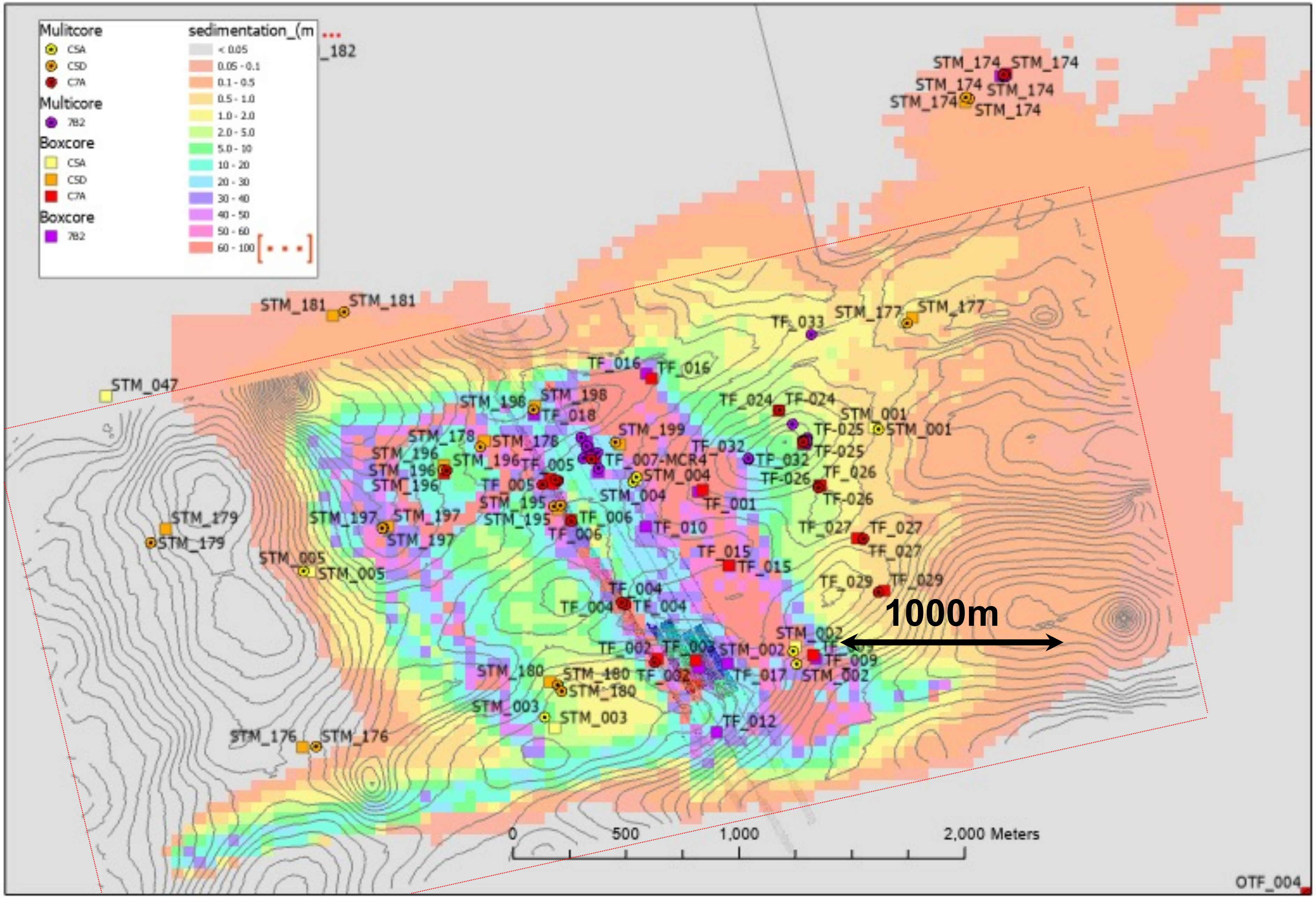
The novel use of Thorium-234 allows us to accurately measure how far sediment plumes spread at the seafloor.



7A and 7B Th-234 concentrations

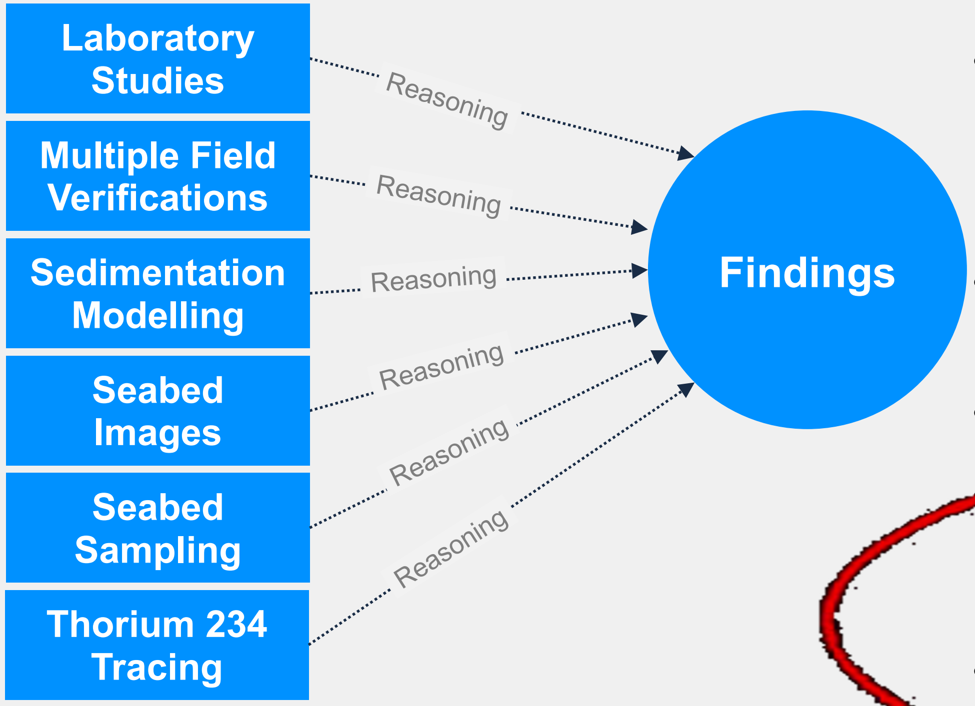



500m
1000m


Mulitcore
CSA
CSD
C7A
Multicore
7B2
Boxcore
CSA
CSD
C7A
Boxcore
7B2
sedimentation_(m
< 0.05
0.05 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 5.0
5.0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 100
1000m
0
500
1,000
2,000 Meters
OTF_004

Benthic plume dispersal.

Multiple lines of evidence

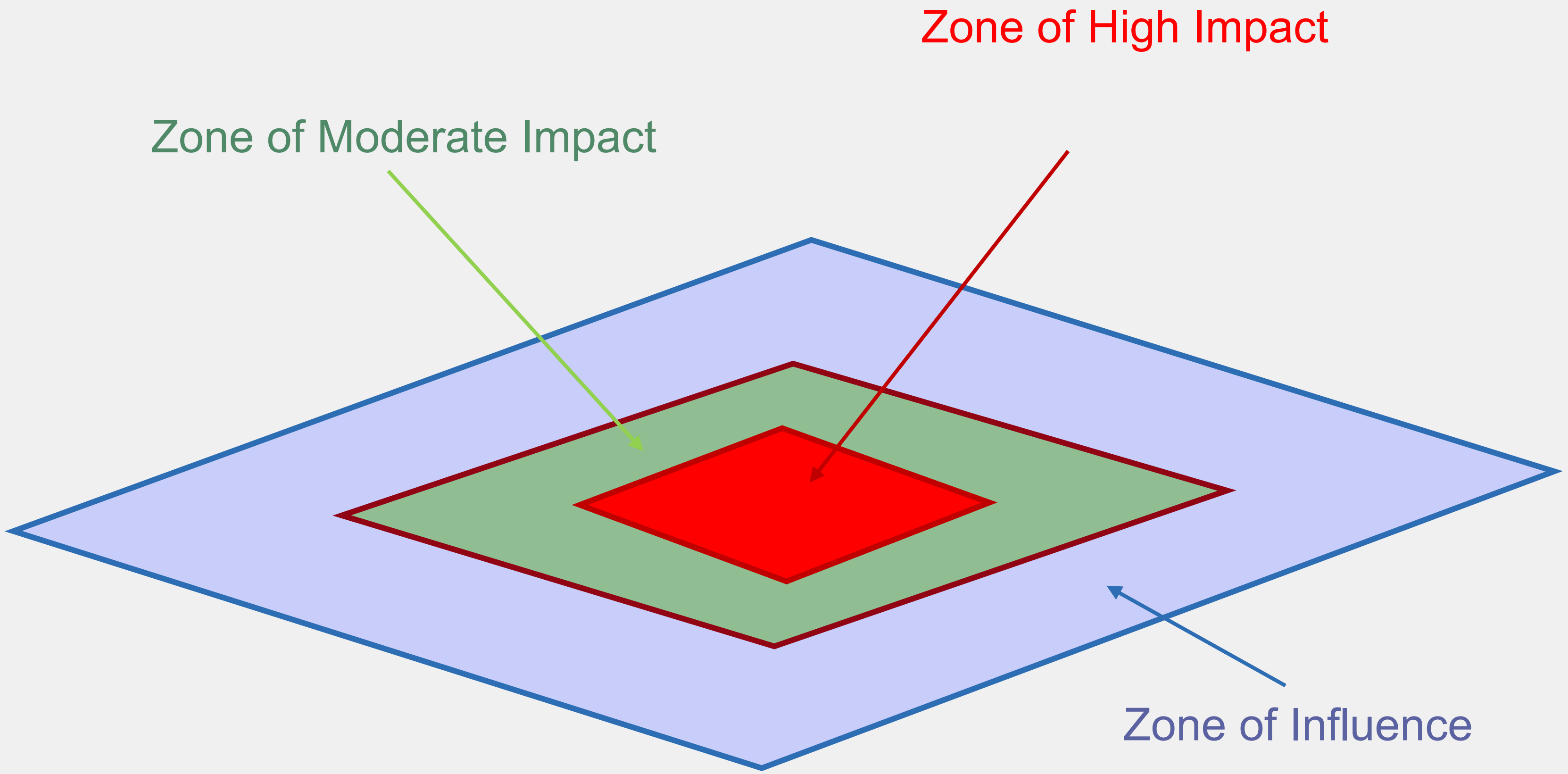


Indicating that:

- The sediment plume is low lying*
- The sediment plume initially forms a turbidity current*
- A turbidity current is a lateral, gravity-driven spreading of sediment-laden water under its own weight away from the collector tracks and not a case of the sediment being passively carried away by the background ocean currents*
- 92-98% of the sediment initially stays below two meters above the seabed*
- There is heavy local deposition in the vicinity of the collector tracks
- **Evidence suggests that the dispersal of the gravity-driven turbidity flow is more influenced by bathymetry than ocean currents**
- **Global current models are a poor indicator of benthic current dynamics**

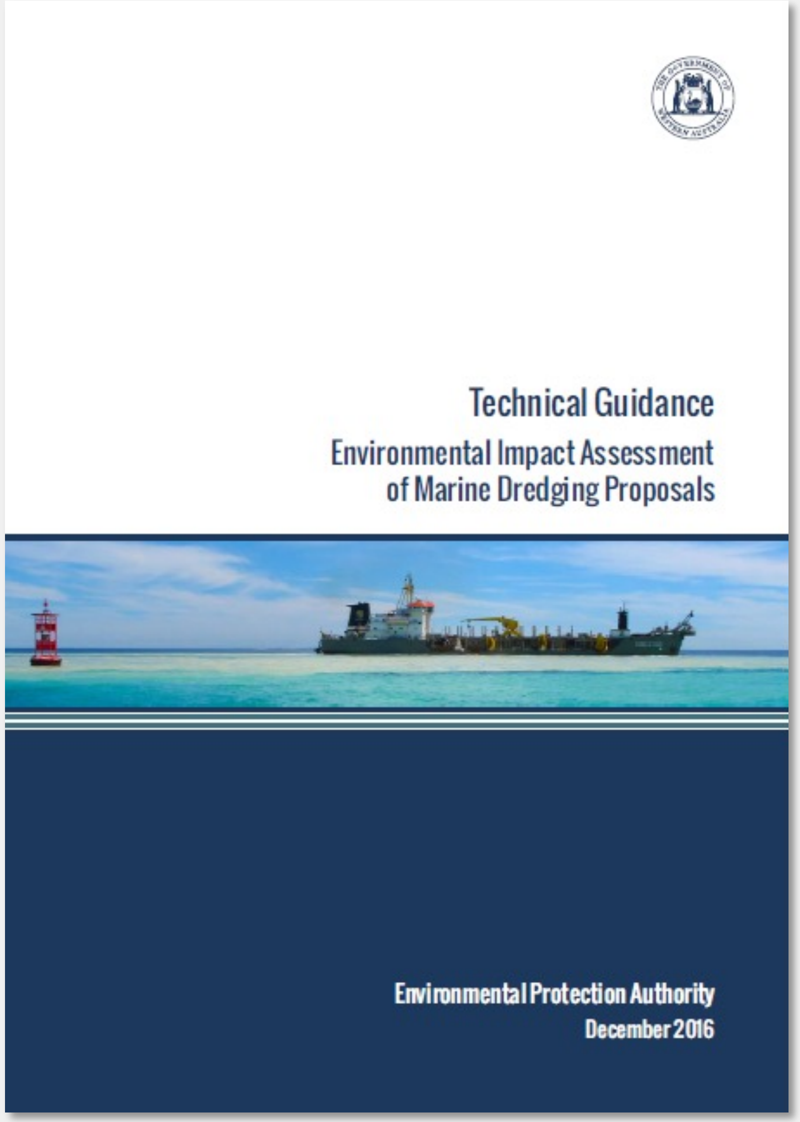
*Muñoz-Royo, C., Ouillon, R., El Mousadik, S., Alford, M. H., & Peacock, T. (2022). An in situ study of abyssal turbidity-current sediment plumes generated by a deep seabed polymetallic nodule mining preprototype collector vehicle. *Science Advances*, *8*(38), eabn1219.

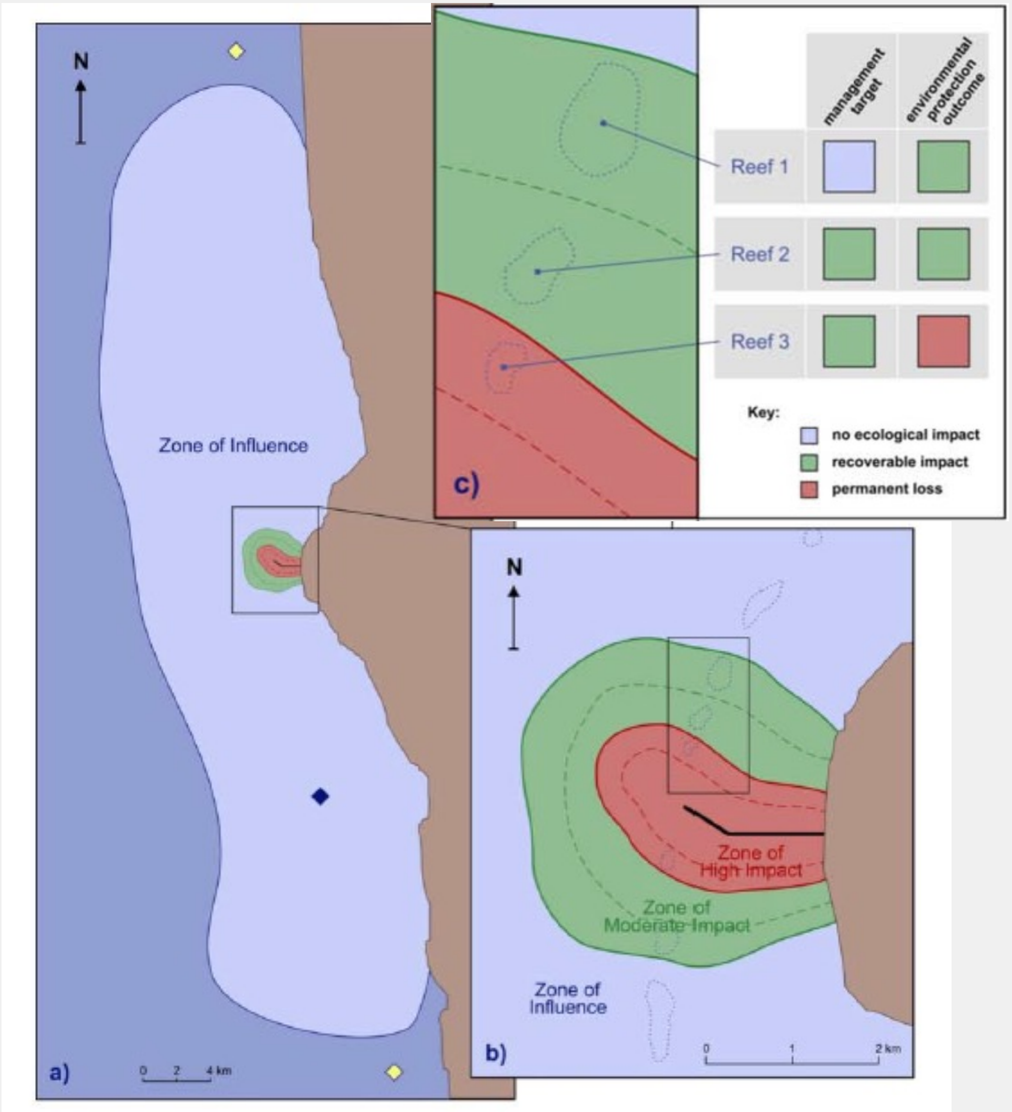
Zones of Impact & Influence.



Source: International Institute for Sustainable Development - www.iisd.org/learning/eia/eia-7-steps/step-2-scoping/ (Adapted)

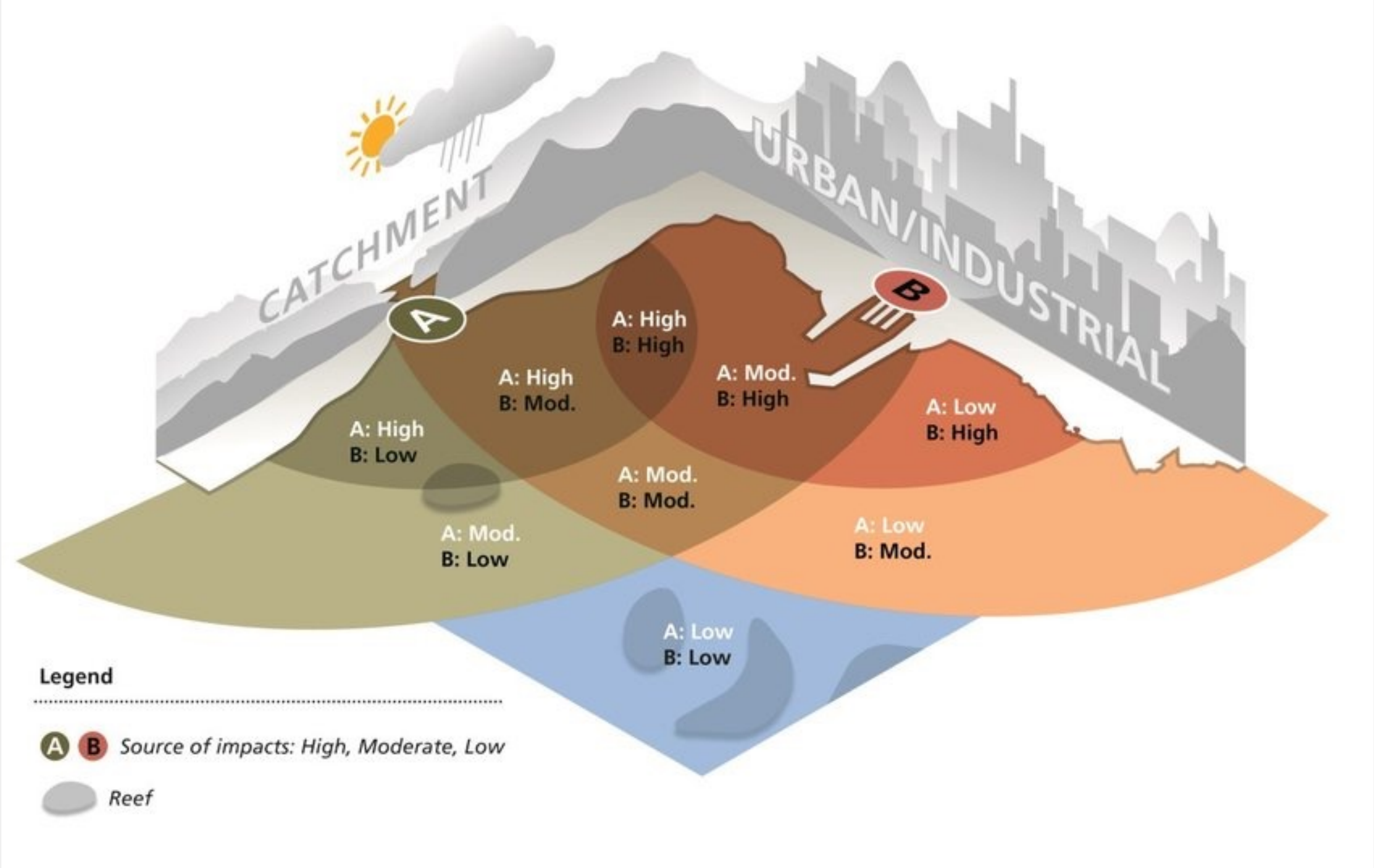
Zones of Impact & Influence.





Environmental Protection Authority. "Technical Guidance: Environmental Impact Assessment of Marine Dredging Proposals." Environmental Protection Authority, Perth, Western Australia (2016).

Zones of Impact & Influence.

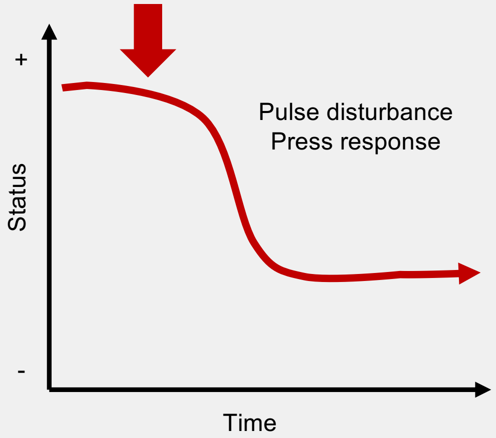


Great Barrier Reef Marine Park Authority. Cumulative impact management policy. Great Barrier Reef Marine Park Authority, 2018.

Zones of Impact & Influence.

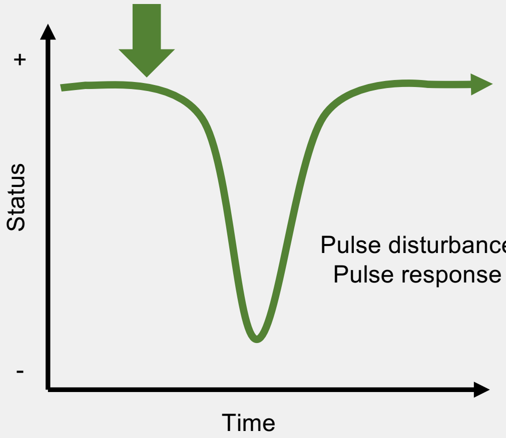
Zone of High Impact (ZoHI)

is the area/volume of the receiving environment where impacts to biota and/or habitats are predicted to be significant.



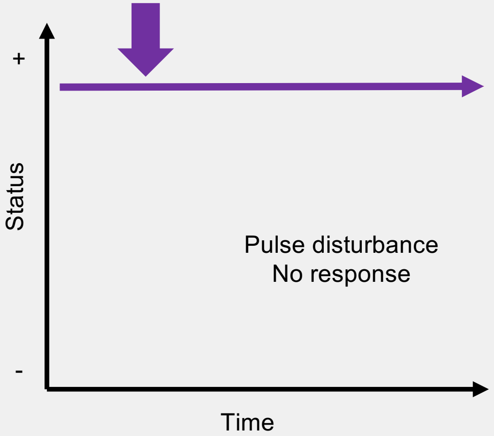
Zone of Moderate Impact (ZoMI)

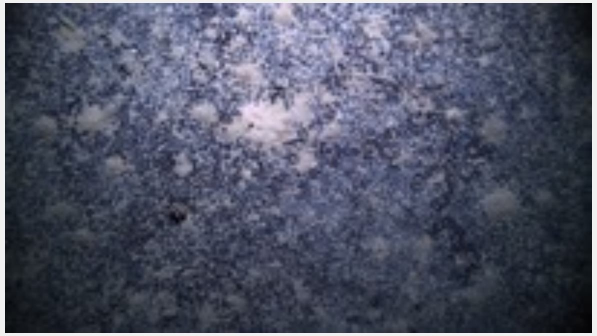
is the area/volume of the receiving environment where impacts to biota and/or habitats are predicted to be recoverable following removal of the pressure.



Zone of Influence (ZoI)

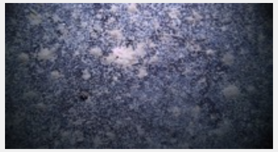
is the area/volume of the receiving environment in which changes to the environmental quality associated with mining activities are predicted but the changes do not result in a detectible impact to biota and/or habitats.



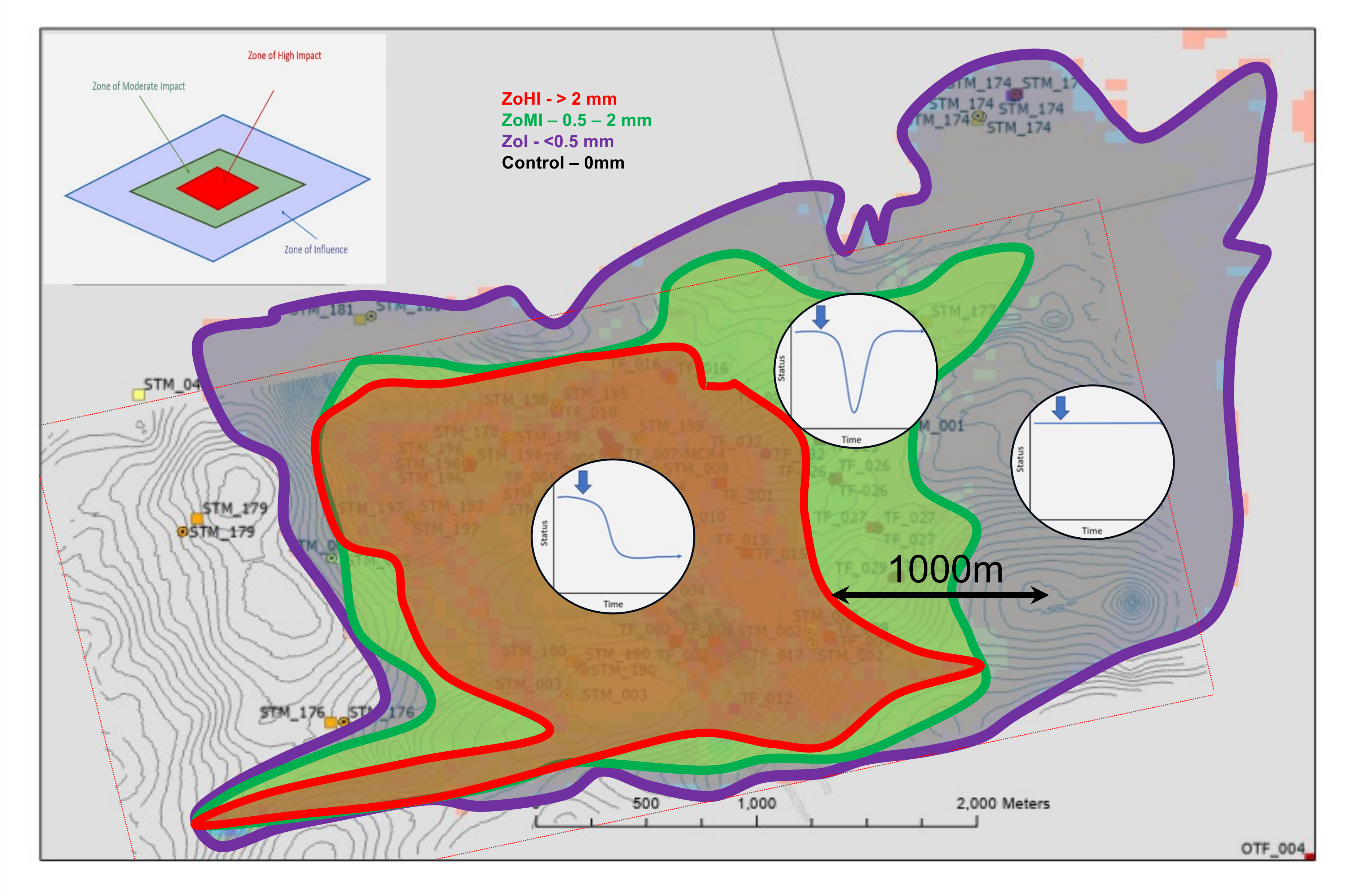


Source: Environmental Protection Authority 2016, *Technical Guidance – Environmental Impact Assessment of Marine Dredging Proposals*, EPA, Western Australia. (Adapted)
Source: Lake, P. S. (2000). Disturbance, patchiness, and diversity in streams. *Journal of the north American Benthological society*, *19*(4), 573-592. (Adapted)

Ecological Metrics.

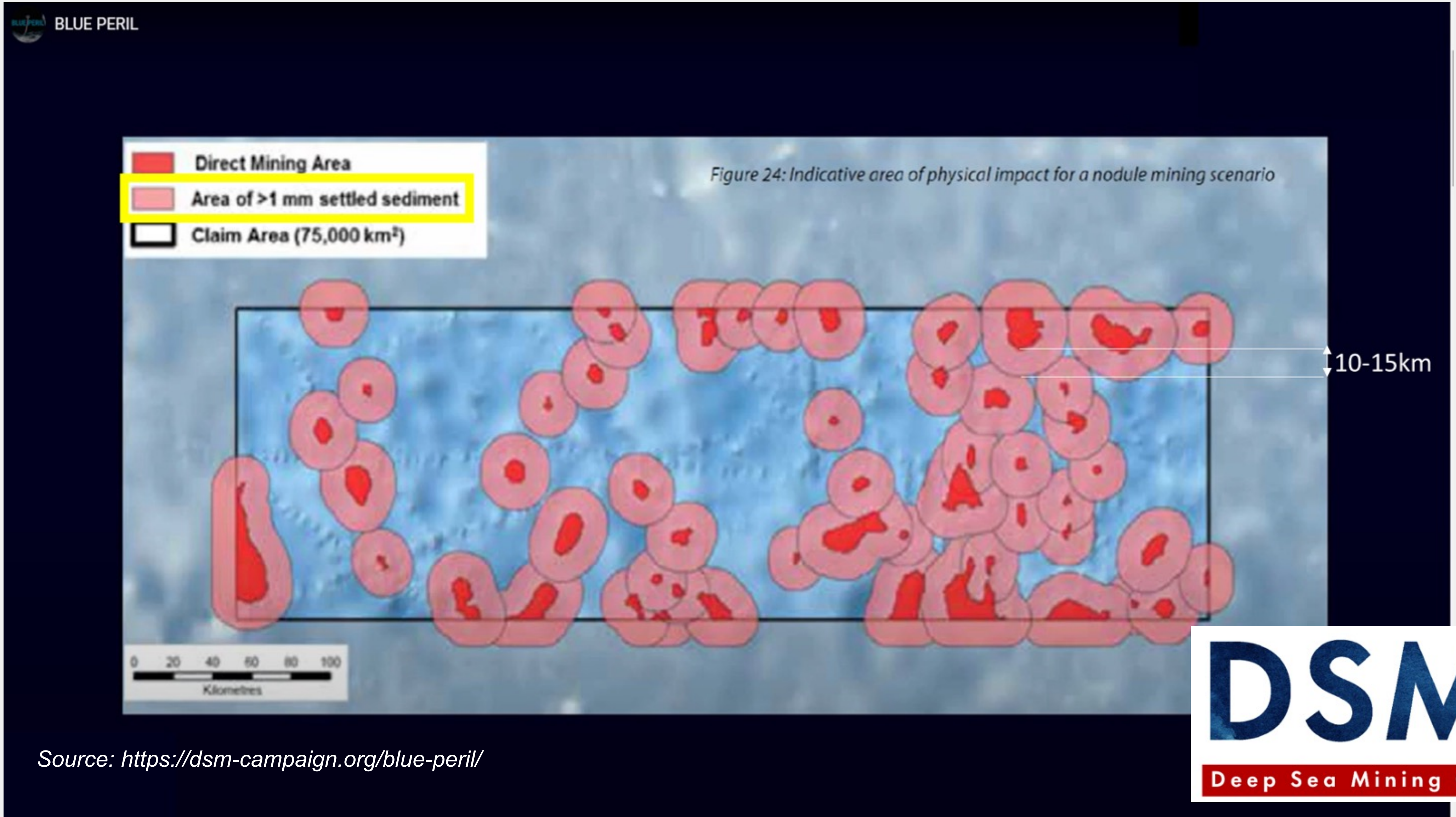
<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>CONTROL:
NO IMPACT
(NWFF)</td><td>ZONE 5:
0.05 – 0.1mm
(STM_174)</td><td>ZONE 4:
1 – 2mm
(TF_033)</td><td>ZONE 3:
2 – 5mm
(TF-025)</td><td>ZONE 2:
20 – 30mm
(TF_032)</td><td>ZONE 1:
60 – 1000mm
(TF_BL)</td><td>DIRECT IMPACT
IN TRACK</td></tr>
<tr><td>Megafauna (sessile)</td><td colspan="7" rowspan="8">Key ecological metrics measured for baseline, T0, T1, T2……..
e.g.
• Total abundance
• Relative abundance
• Species composition
• Diversity</td></tr>
<tr><td>Megafauna (motile)</td></tr>
<tr><td>Macrofauna (nodules)</td></tr>
<tr><td>Macrofauna (sediment)</td></tr>
<tr><td>Meiofauna (nodules)</td></tr>
<tr><td>Meiofauna (sediment)</td></tr>
<tr><td>Foraminifera (xenos)</td></tr>
<tr><td>Foraminifera (meiofauna)</td></tr>
<tr><td>ECV (ecosystem function)</td><td colspan="7" rowspan="2">• O2 production
• C assimilation</td></tr>
<tr><td>13C (ecosystem function)</td></tr>
</table>

Zones of Impact.



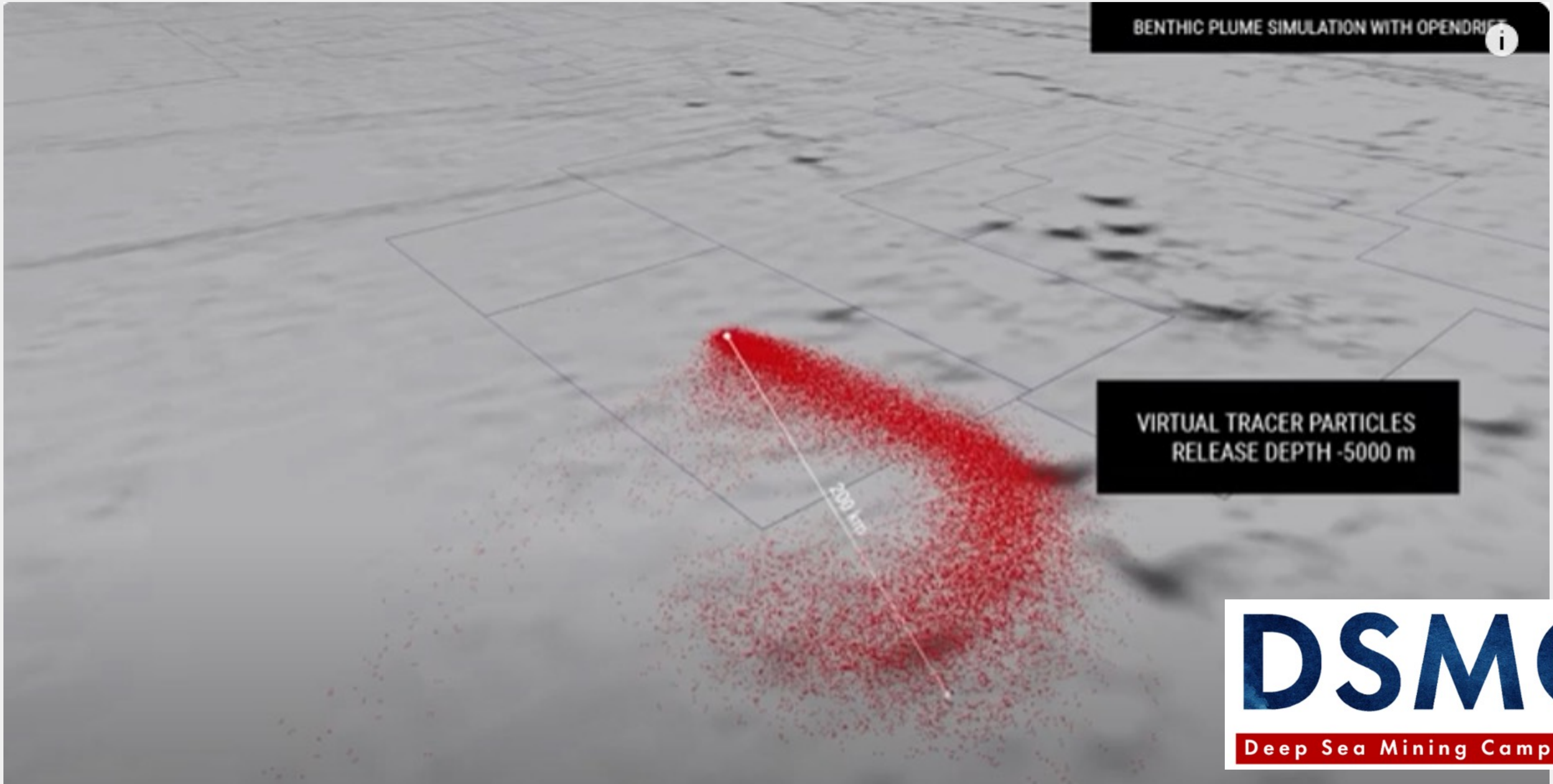
Zones of Impact.

“sediment will settle over 1mm deep 10-15 kilometres away from the direct mining area”

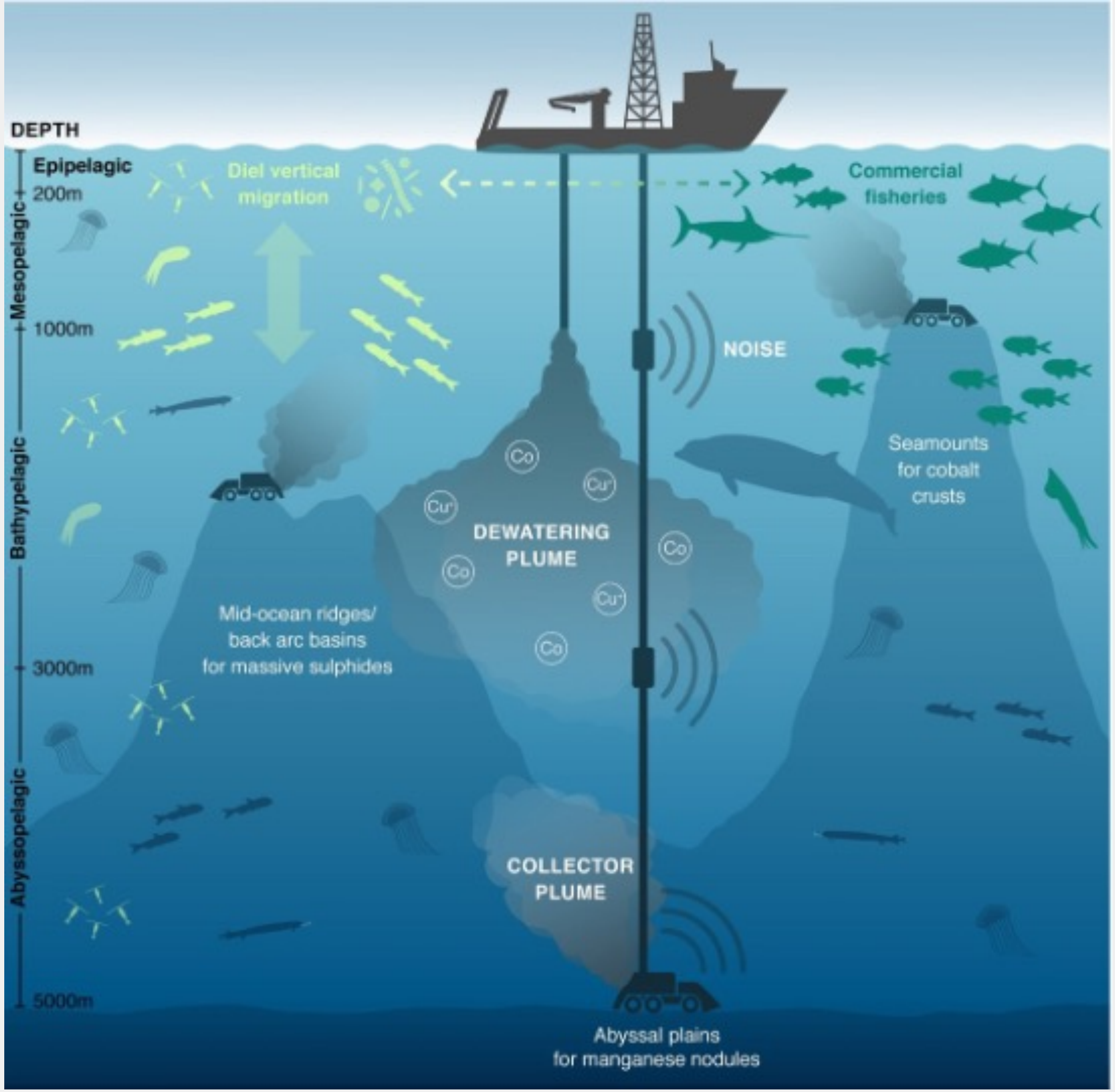


Zones of Impact

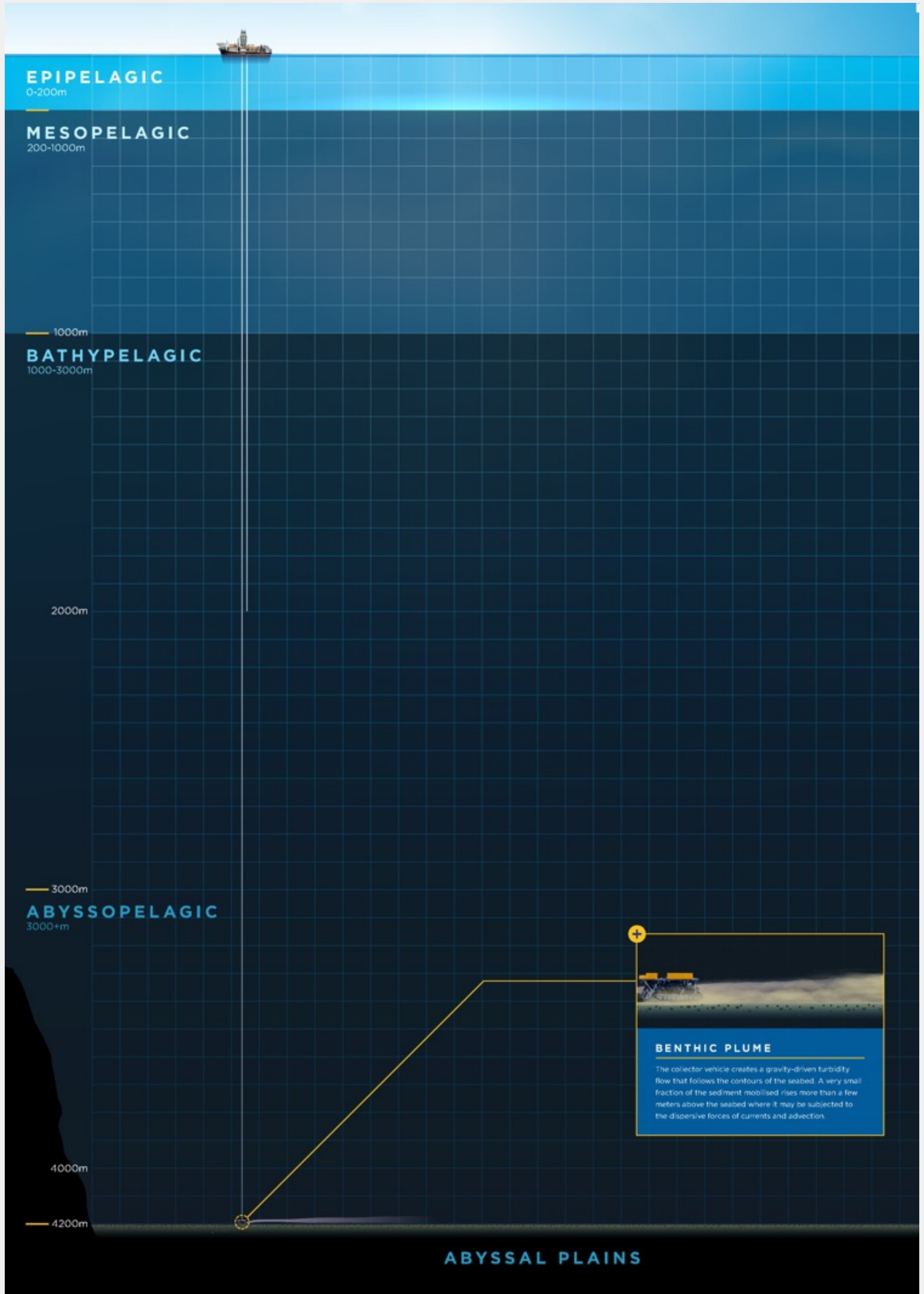
“Here we model the seabed plume in the NORI-D contract area using ‘OpenDrift’”. In just over 30 days virtual sediment particles released 8 m from the sea floor travel over 200 kms’



DSMC
Deep Sea Mining Campaign



Drazen, Jeffrey C., et al. "*Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining*." Proceedings of the National Academy of Sciences 117.30 (2020): 17455-17460.



deepsea conservationcoalition

Source: https://savethehighseas.org/deep-sea-mining/impacts-of-deep-sea-mining/

*"Plumes of sediment will be created as mining stirs up the seafloor, possibly spreading **tens of thousands of square kilometres beyond the mining sites**. The effect this will have on filter feeders such as corals and sponges is unknown."*

(accessed 24/10/23)

*"As collector vehicles mine the seafloor, seafloor sediments would be resuspended, creating plumes which **could disperse over tens to hundreds of kilometres beyond mining sites.** These sediment plumes would smother suspension feeders such as cold-water corals and sponges on the seafloor adjacent to mining areas – however, the full extent of potential impacts is unknown as there is limited scientific data on the effect of plumes on individual species and habitats"*

(accessed 8/11/23)

MIT News
ON CAMPUS AND AROUND THE WORLD

SUBSCRIBE BROWSE SEARCH NEWS

Ocean scientists measure sediment plume stirred up by deep-sea-mining vehicle

A new field study reveals a previously unobserved fluid dynamic process that is key to assessing impact of deep-sea mining operations.

Their measurements showed that the vehicle created a dense plume of sediment in its wake, which spread under its own weight, in a phenomenon known in fluid dynamics as a “turbidity current.” As it gradually dispersed, the plume remained relatively low, staying within 2 meters of the seafloor, as opposed to immediately lofting higher into the water column as had been postulated.

“It’s quite a different picture of what these plumes look like, compared to some of the conjecture”

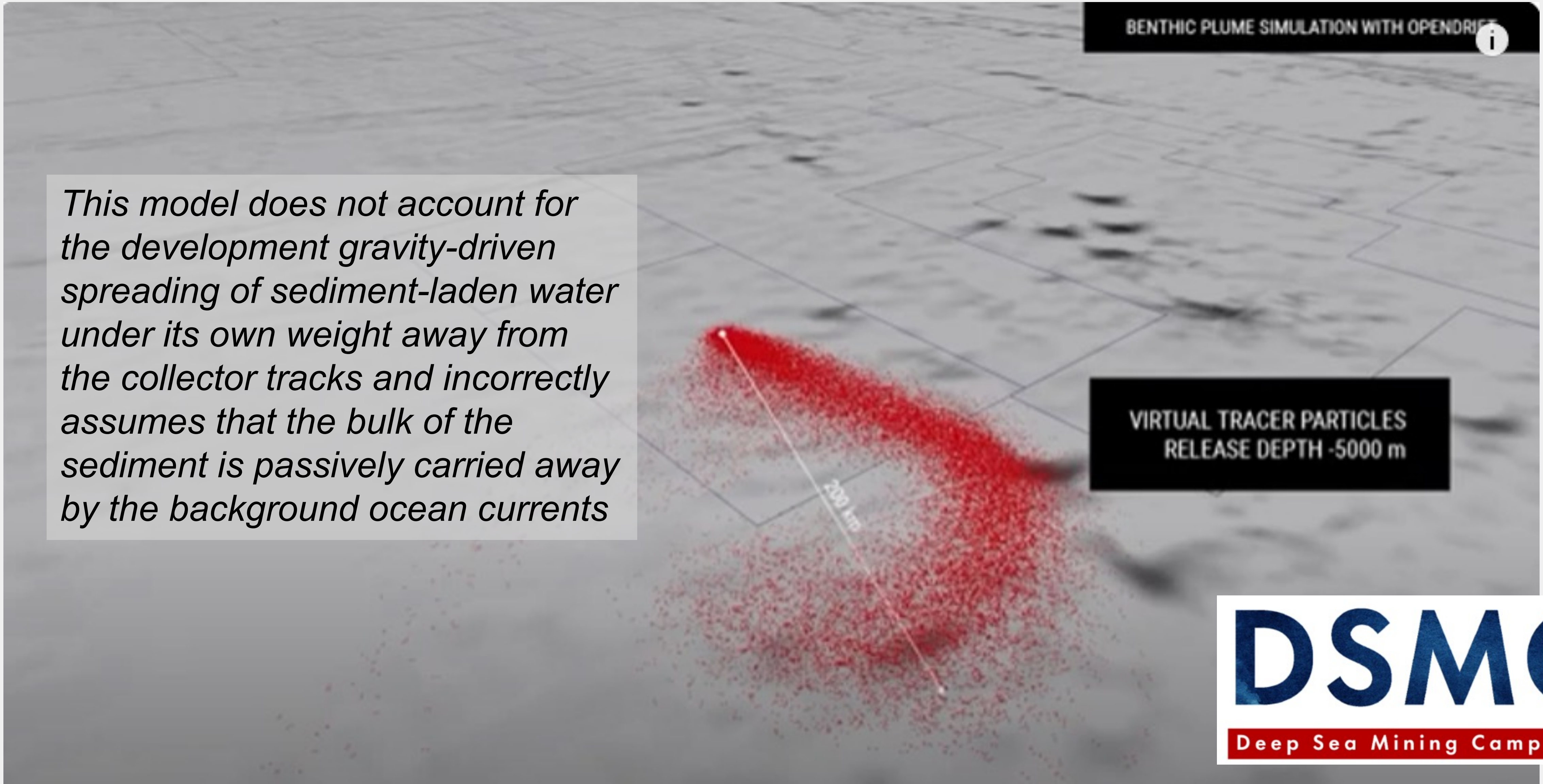
“Modelling efforts of deep-sea mining plumes will have to account for these processes that we identified, in order to assess their extent.”

Thomas Peacock, professor of mechanical engineering at MIT

Source: https://news.mit.edu/2022/sediment-deep-sea-mining-0921

Zones of Impact

"Here we model the seabed plume in the NORI-D contract area using 'OpenDrift'". In just over 30 days virtual sediment particles released 8 m from the sea floor travel over 200 kms'



This model does not account for the development gravity-driven spreading of sediment-laden water under its own weight away from the collector tracks and incorrectly assumes that the bulk of the sediment is passively carried away by the background ocean currents

DSMC
Deep Sea Mining Campaign

Upcoming focus for the Environmental Program

- Coordinate science studies for Campaign 8
- Use emerging data and modelling to address remaining key issues, including:
  - Concentrations, dispersal and impact of mid-water plumes
  - Chemistry of mid-water plume and potential for impacts on fisheries
  - Noise generation and attenuation
  - Potential for impacts to biodiversity


the metals company
NORI
NAURU OCEAN RESOURCES INC.
Thank you
PELAGIC