UCL
Université catholique de Louvain

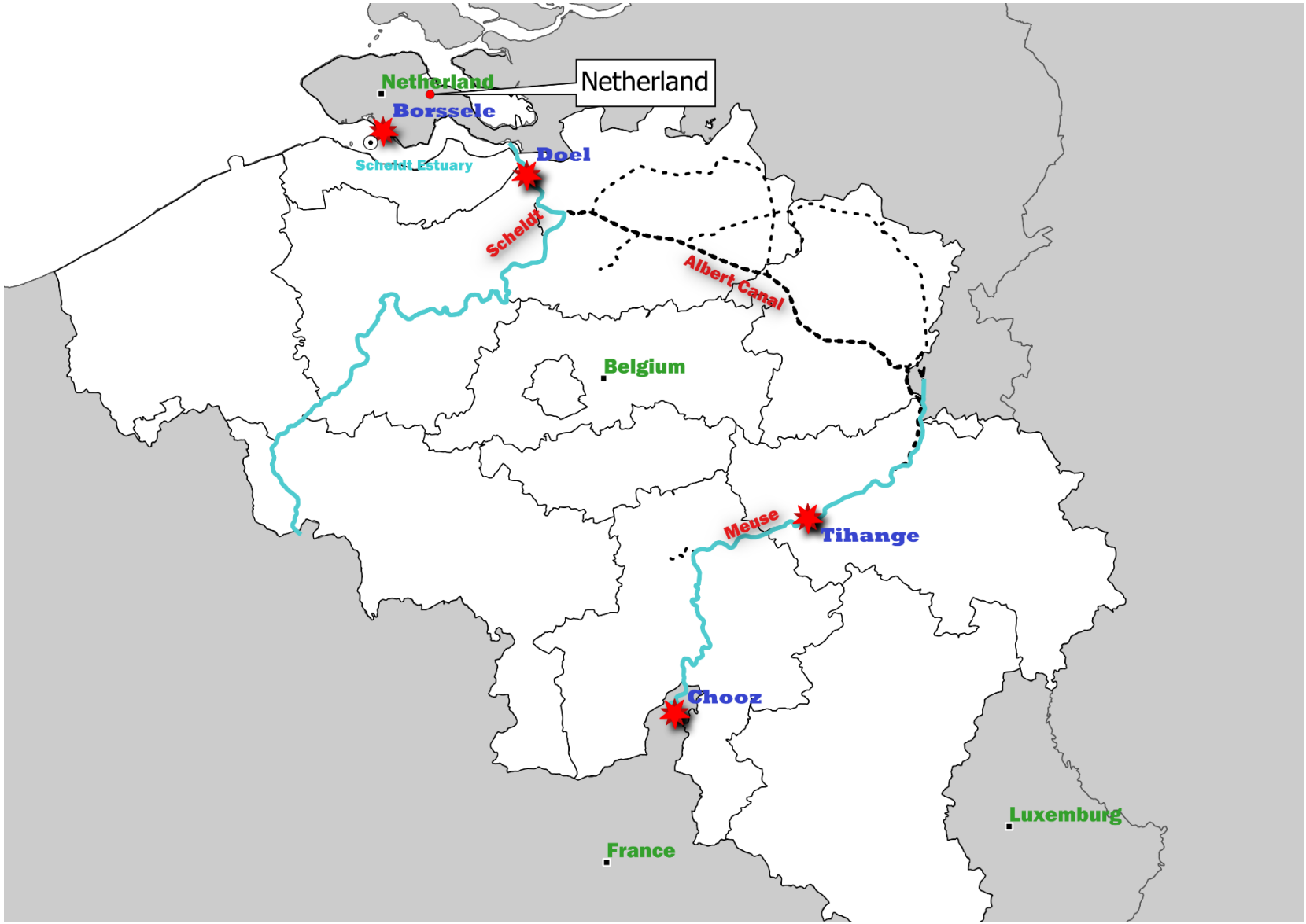
ENGIE

Numerical Simulation of the Impact of Accidental Radioactive Releases into the Meuse and Scheldt Aquatic Systems.

—Amit Ravindra Patil - 04/07/2024

sck cen
Belgian Nuclear Research Centre

Meuse -Scheldt Aquatic Systems in Belgium



Develop model to Simulate radionuclide transport

- Assessment of possible risks associated with accidental release
- Decision support tool (DST) for emergency responder

Hydrodynamic Model

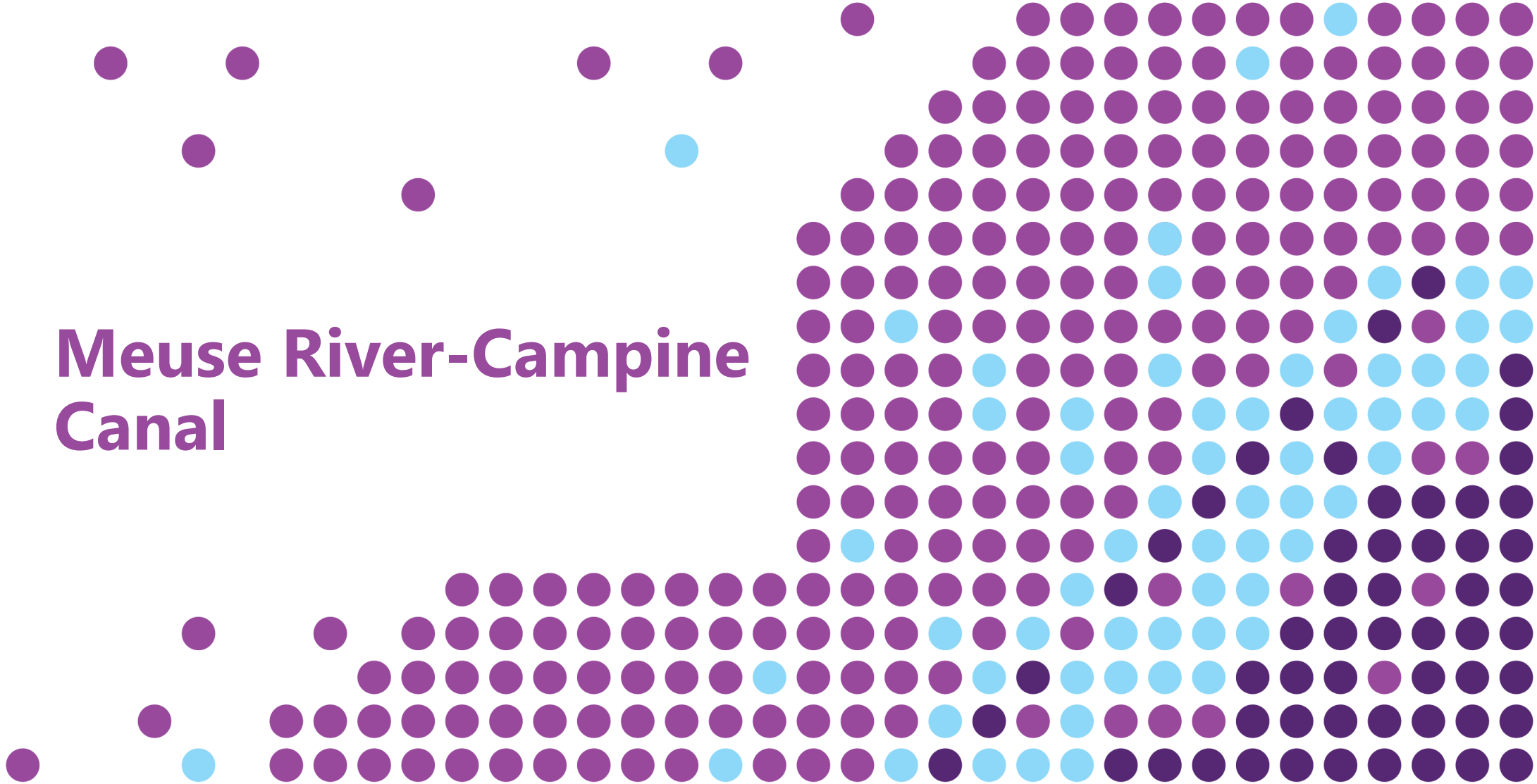
To simulate and predict the water flow dynamics

Transport Model

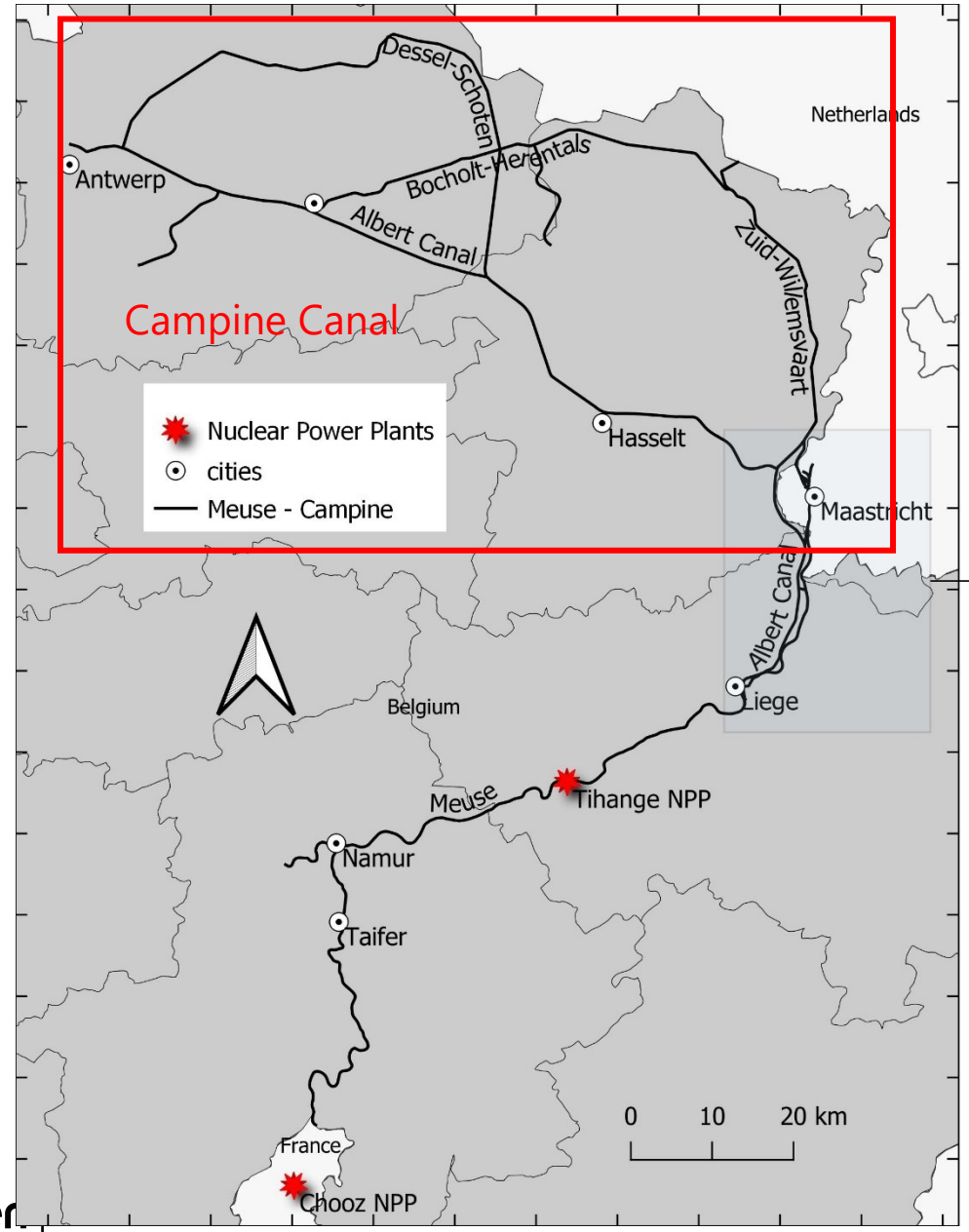
Able to predict the fate and transport of radioactive elements

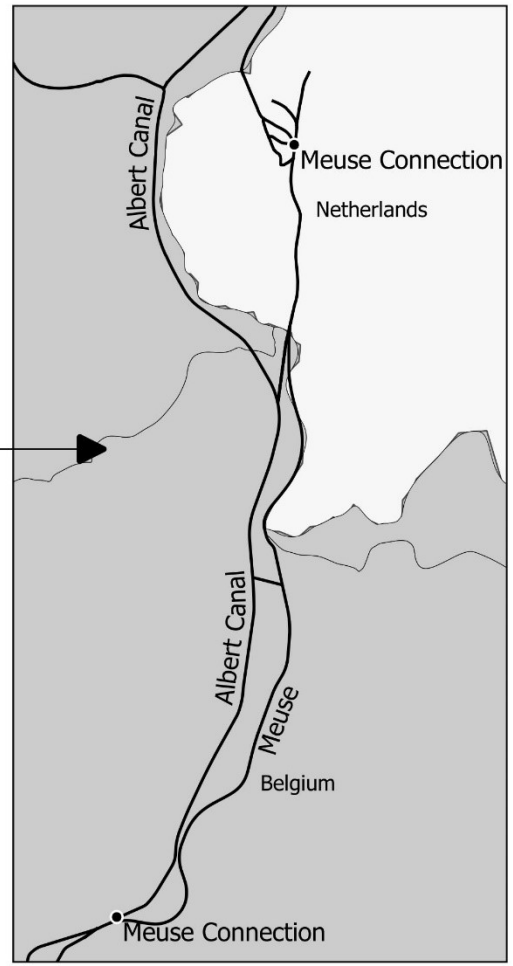
Model Study

Meuse River-Campine Canal



Meuse Aquatic Systems in Belgium





MEUSE RIVER

Meuse river in flows across Belgium with the Influence of Hydraulic structures

CAMPINE CANAL

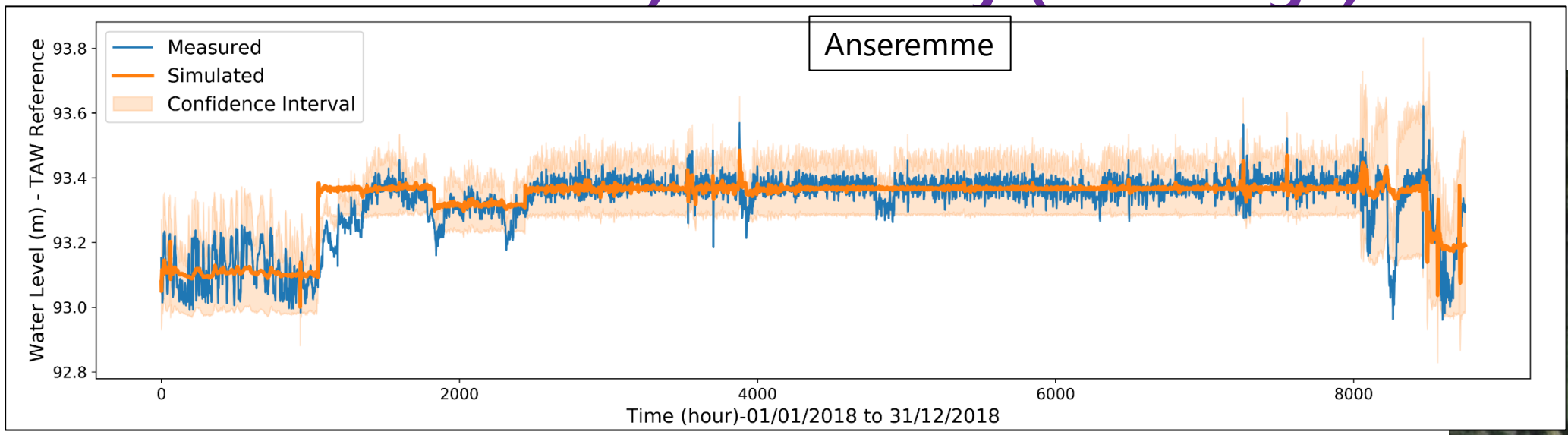
Campine Canal Constitutes of several canals Connecting and including the Albert Canal and Zuid-Willemsvart Canal

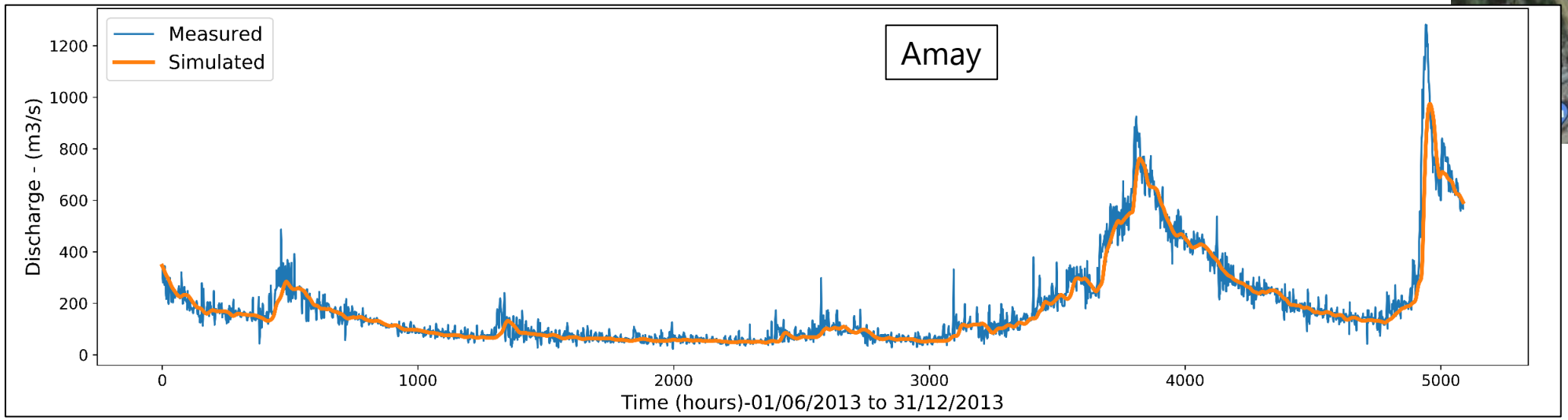
Hydrodynamic Model

Meuse river basins considering the influence of hydraulic works and navigational structure.

(SLIM – Second Generation Ice-Ocean Model) – DG Finite element Method

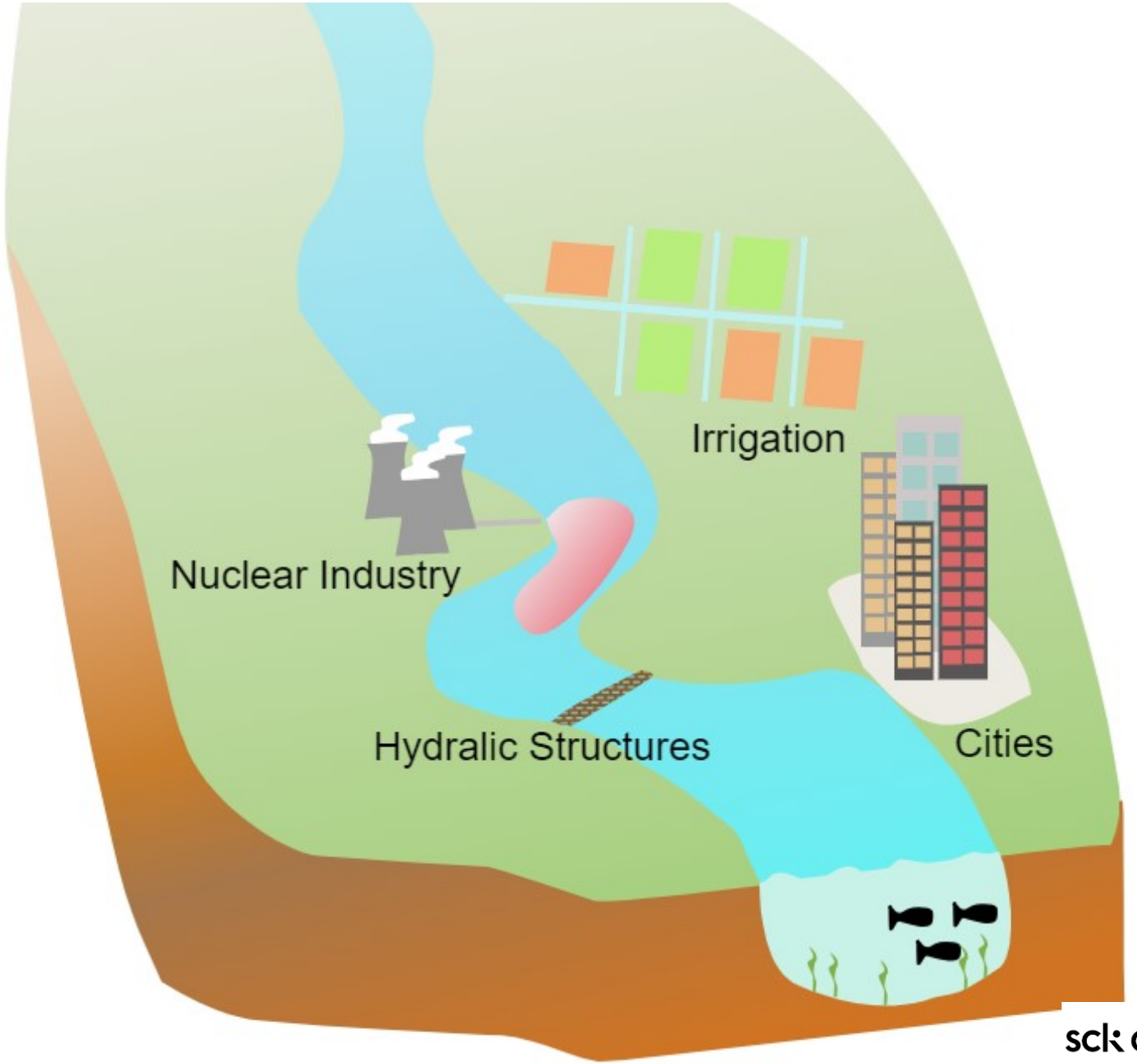
Measurement Comparison at Anseremme (water Level) And Amay (discharge)





Transport Model

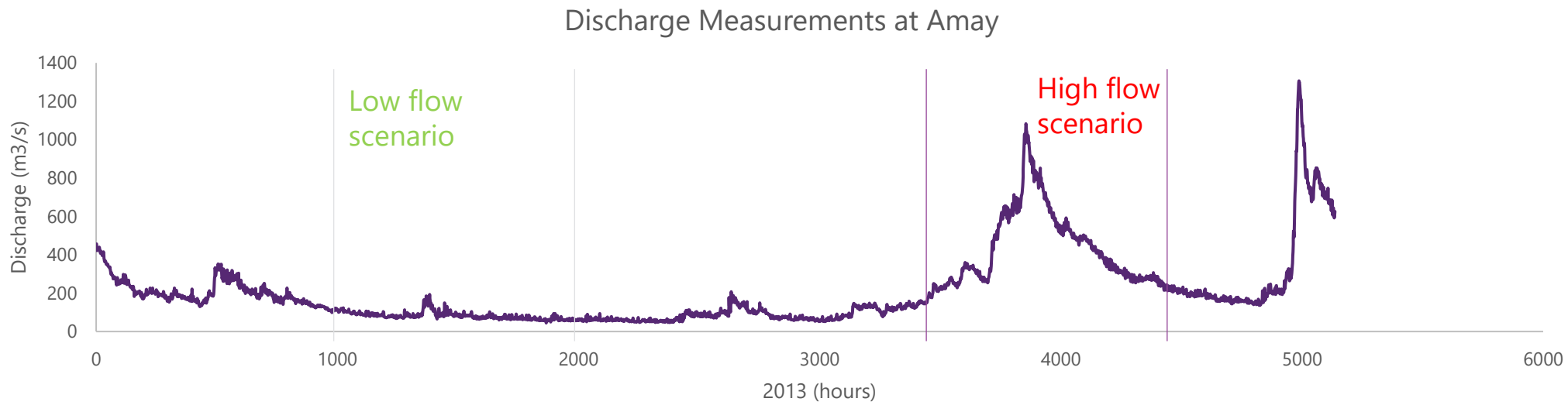
Fate and transport of radioactive elements along the Meuse river and Campine canal.



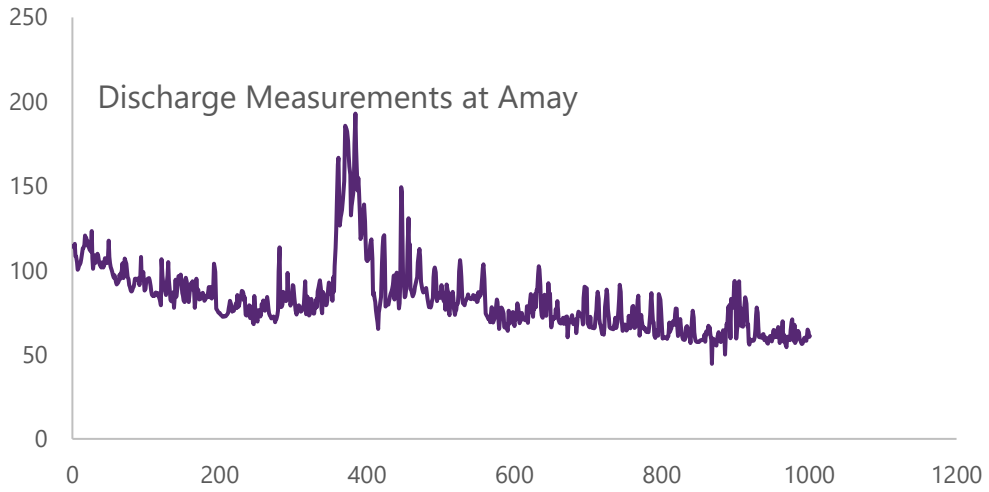
Scenarios for radionuclide Transport

Tihange and Chooz Nuclear Power Plant

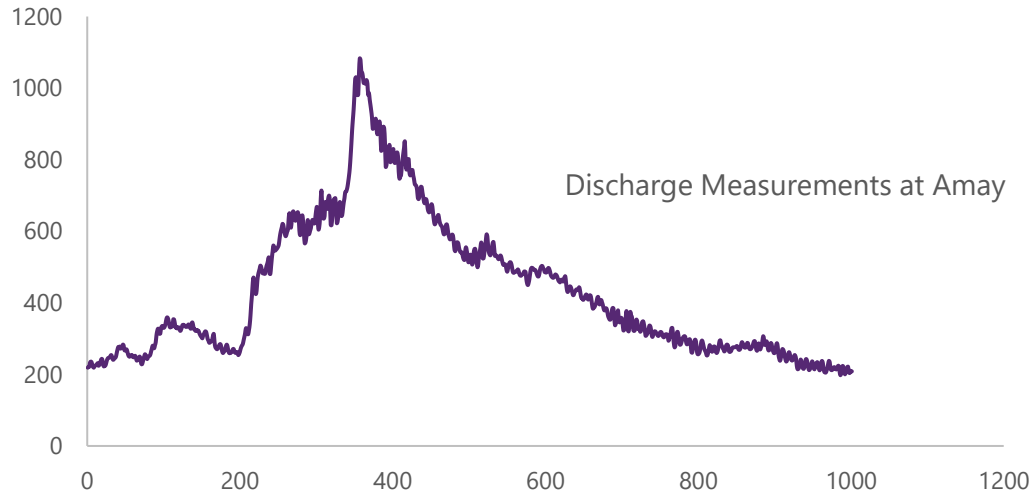
River discharge: Scenarios



Low flow scenario



High flow scenario



Scenarios – ^{137}Cs and ^{131}I

United Nations Scientific Committee on the Effects of Atomic Radiation

Fukushima Disaster

SOURCES, EFFECTS AND RISKS OF IONIZING RADIATION

UNSCEAR 2013 Report

Volume I

REPORT TO THE GENERAL ASSEMBLY

SCIENTIFIC ANNEX A:

Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami

Pathways: Atmospheric Releases
Major radionuclides: ^{131}I and ^{137}Cs

Table 1. Comparison of range of estimates given in the UNSCEAR 2013 Report [U10] with estimates made since of the total amounts of ^{131}I and ^{137}Cs released to the atmosphere as a result of the Fukushima Daiichi Nuclear Power Station accident

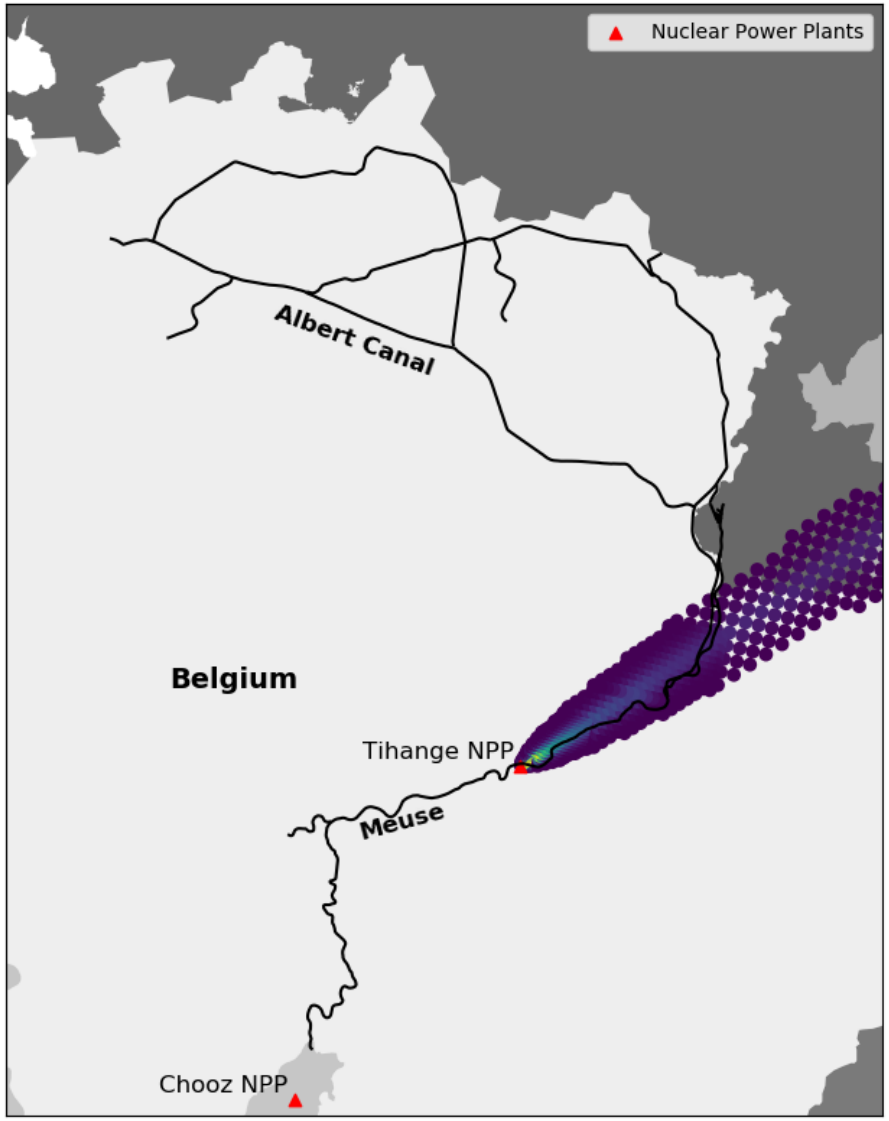
Reference	*Date of publication*	*Total release (PBq)*	
		^{131}I	*^{137}Cs*
UNSCEAR 2013 Report [U10]	2014	100–500	6–20

Scenarios in this study

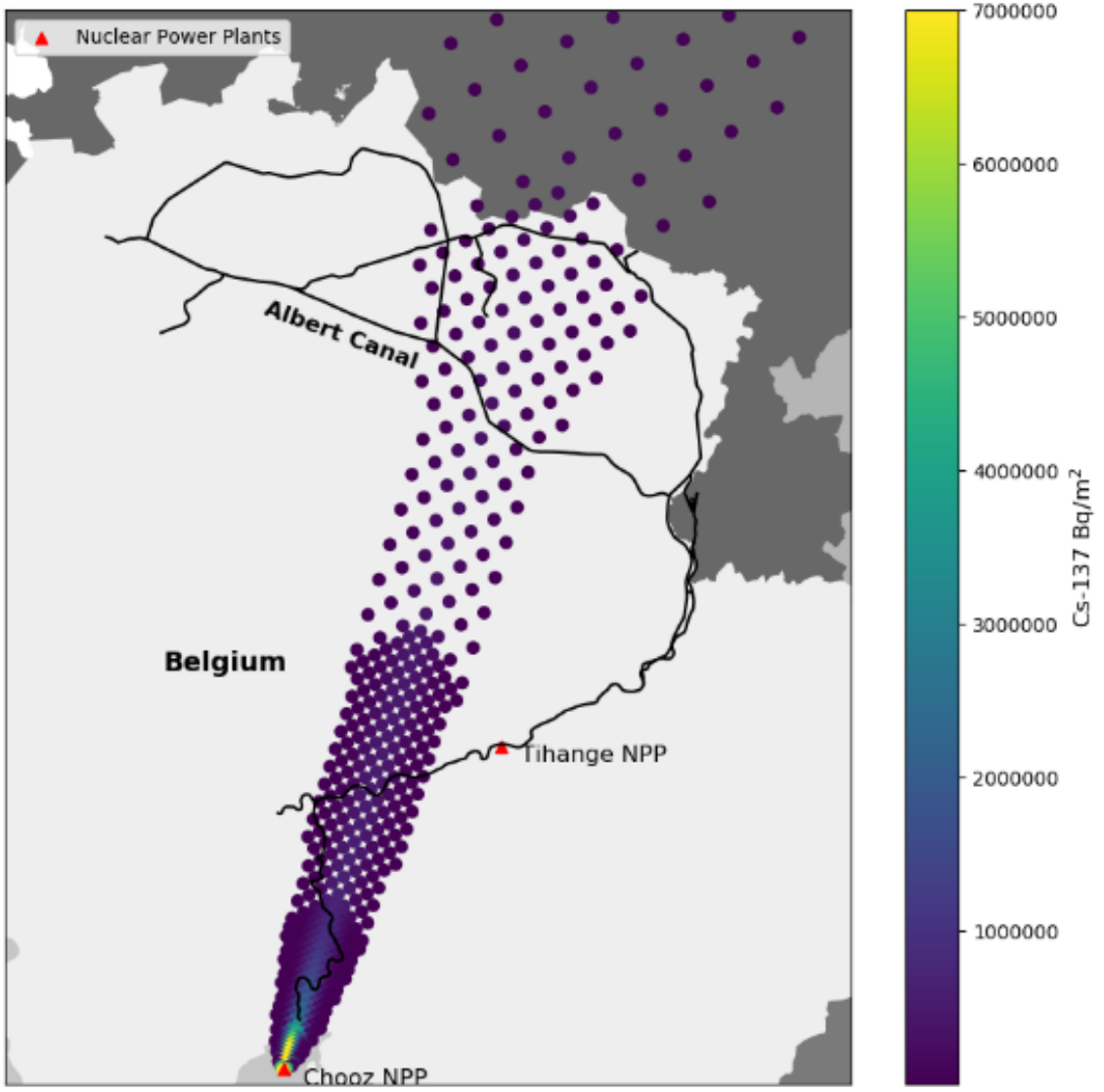
^{131}I	^{137}Cs
100 PBq	6 Bq

Atmospheric deposition scenarios – ^{137}Cs (JRODOS)

Tihange – 213^0 wind direction



Chooz – 253^0 wind direction

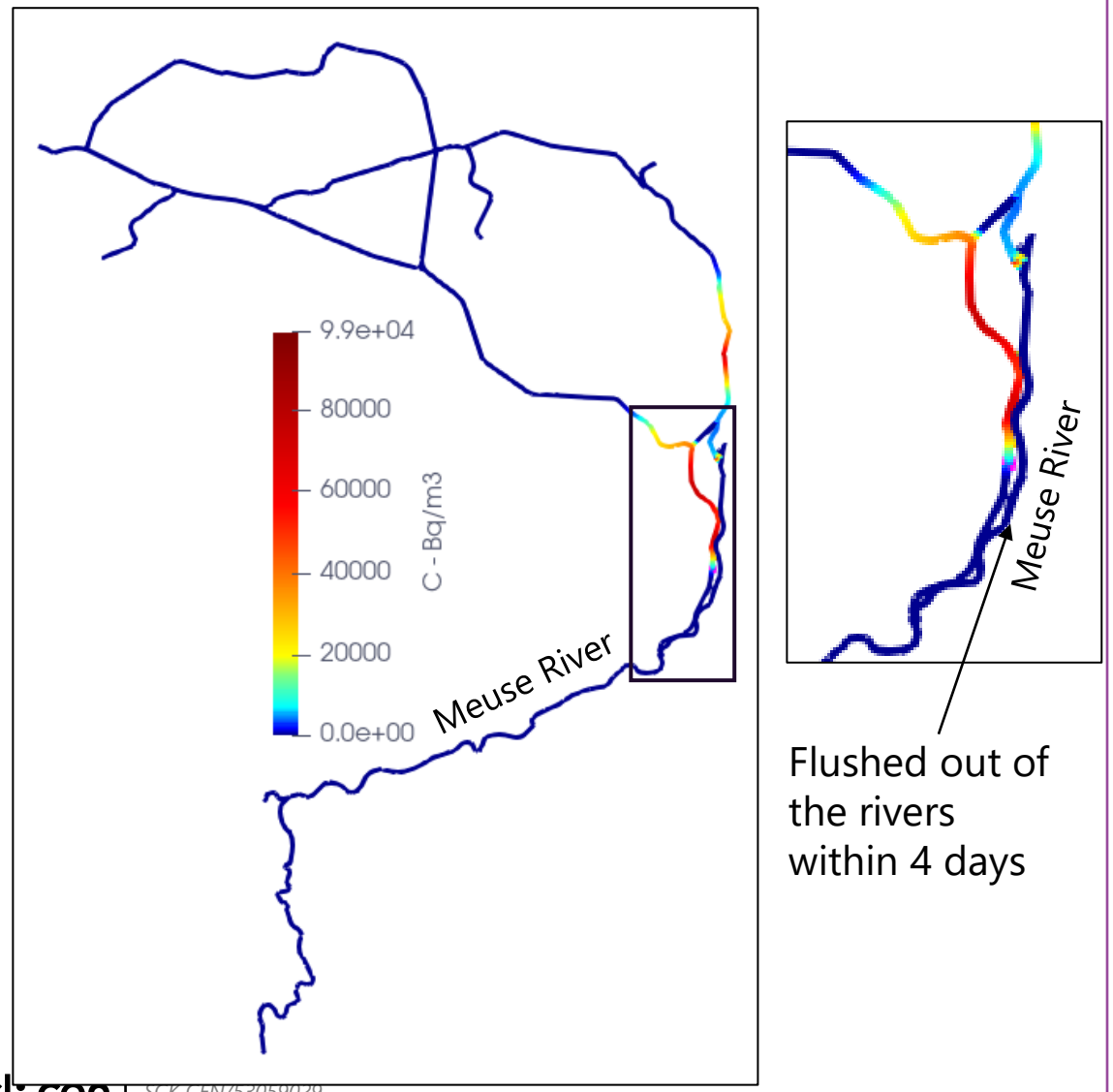


Meuse River – Albert Canal Scenarios results

Tihange Nuclear Power Plant

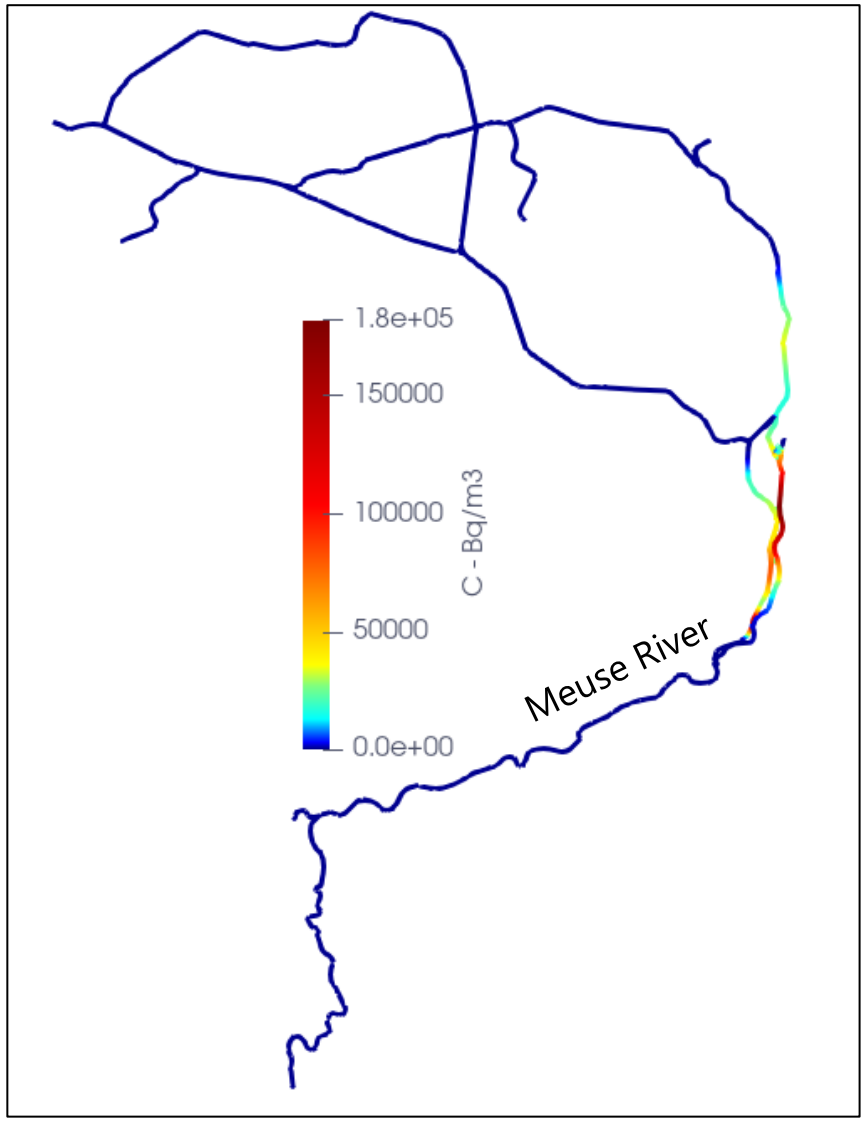
Scenarios – ^{137}Cs – Flow scenarios

Scenario → High flow – 100th hour



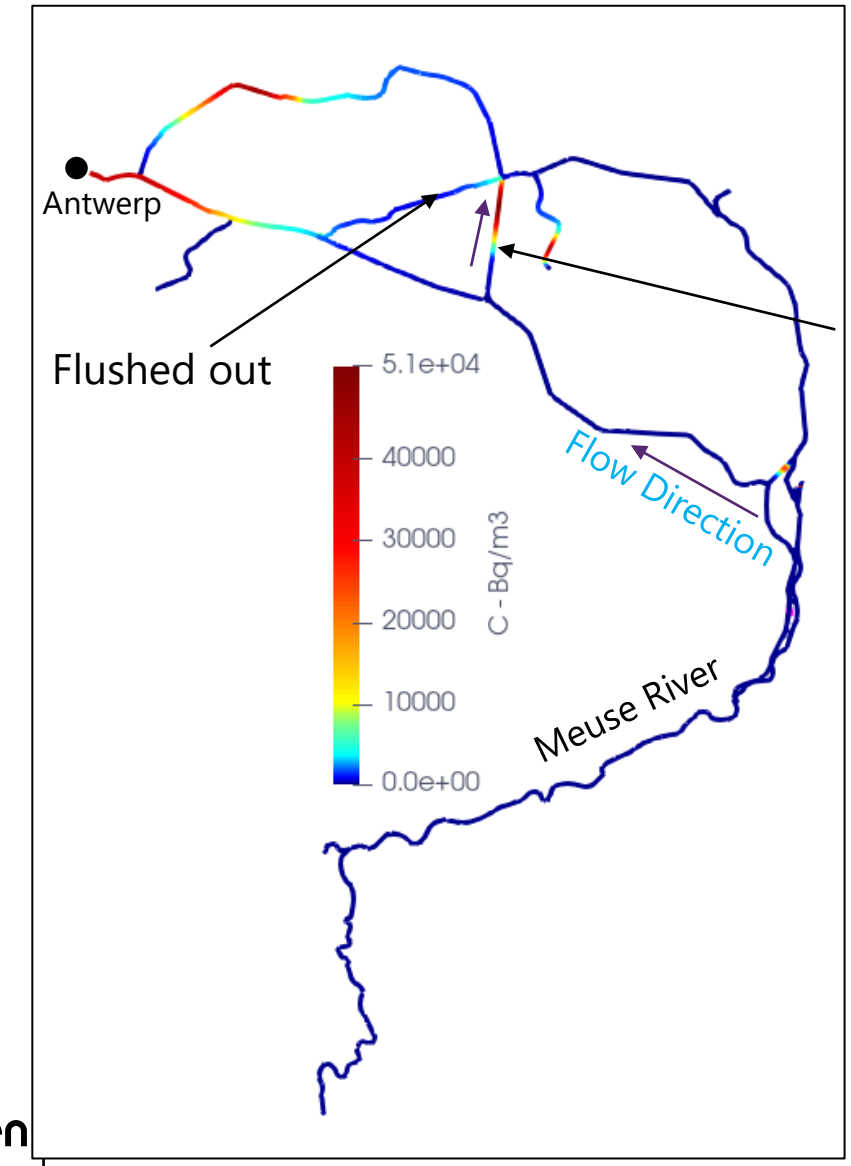
Flushed out of the rivers within 4 days

Scenario → Low flow – 100th hour

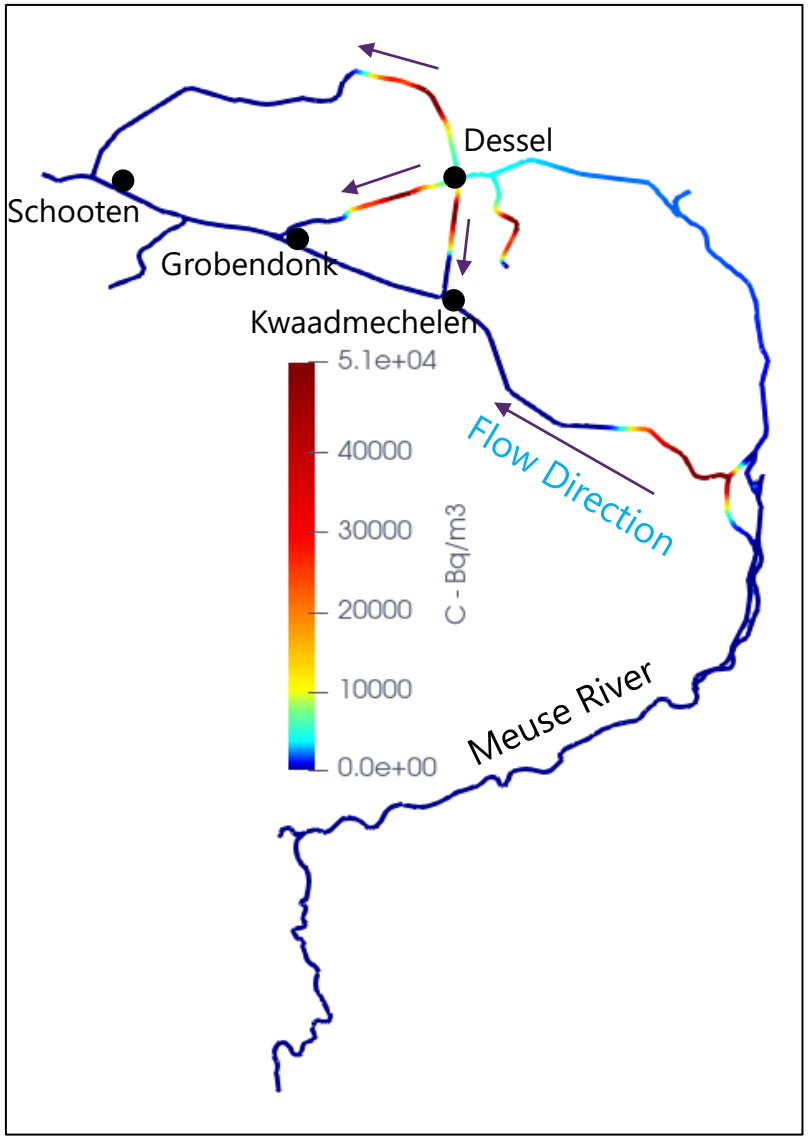


Scenarios– ^{137}Cs – Flow scenarios

Scenario → High flow – 700th hour

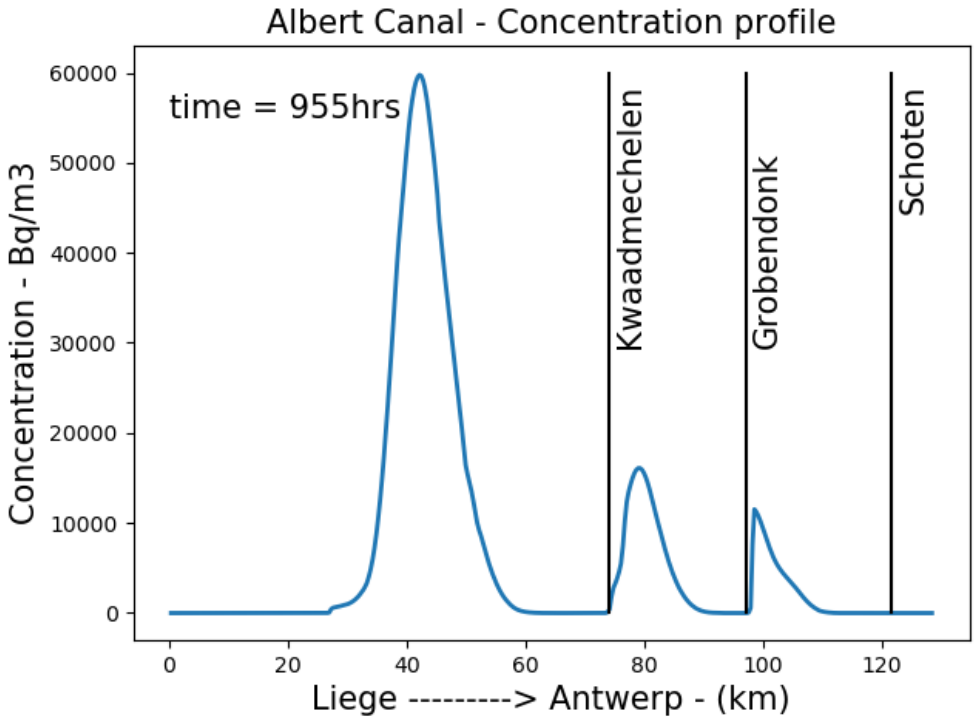


Scenario → Low flow – 700th hour



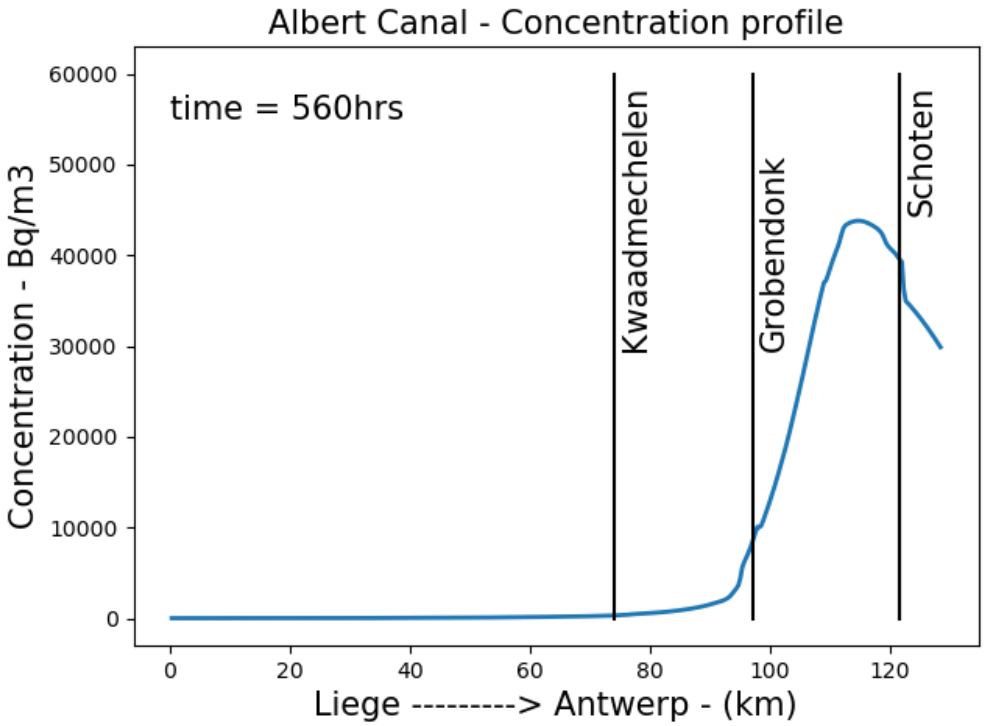
Scenarios– ^{137}Cs – evaluation of conc. Profile

Scenario – 1 – Low flow – Albert Canal



- Plume in Albert canal Travels Slower
- The plume from Grobendonk and Schoten has reached before

Scenario – 1 – High flow – Albert Canal



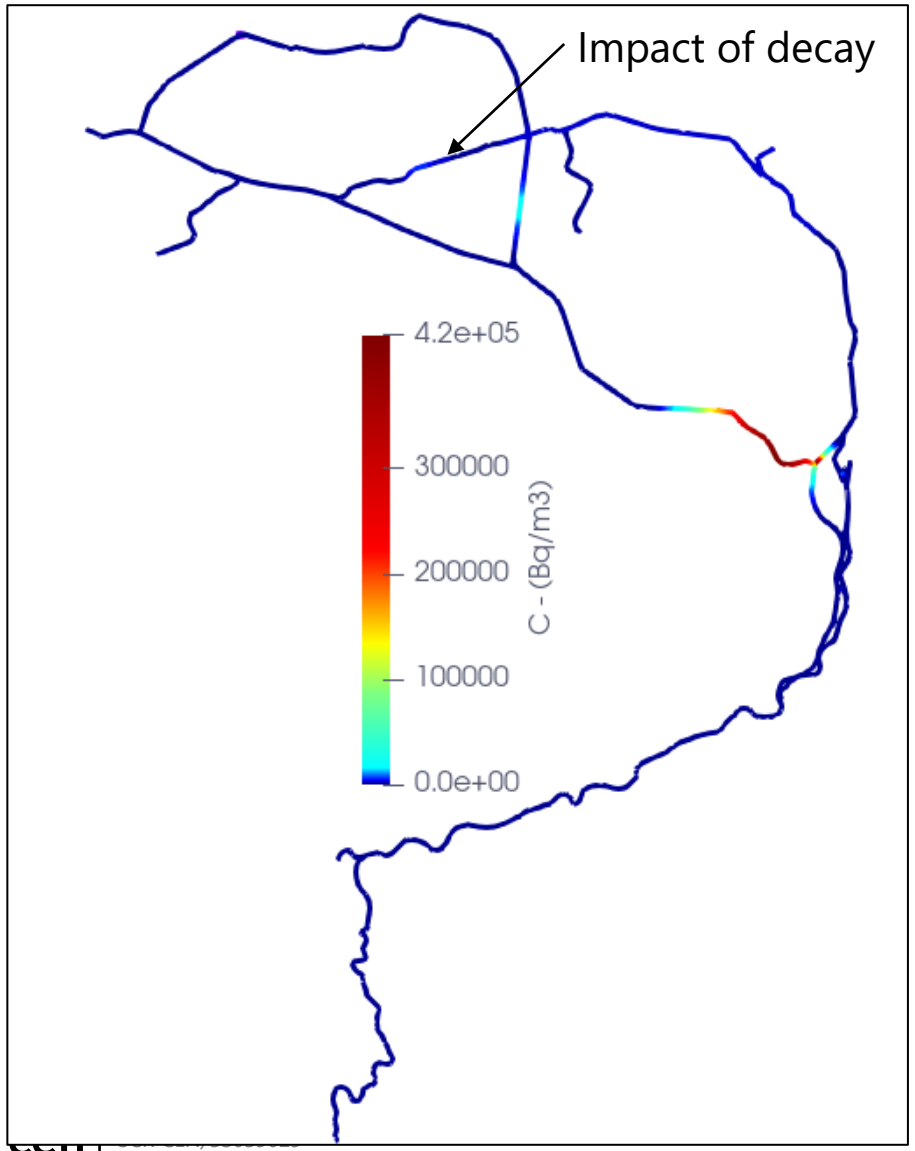
- Plume in Albert canal Travels faster
- The plume from Grobendonk and Schoten almost reaches at the same time

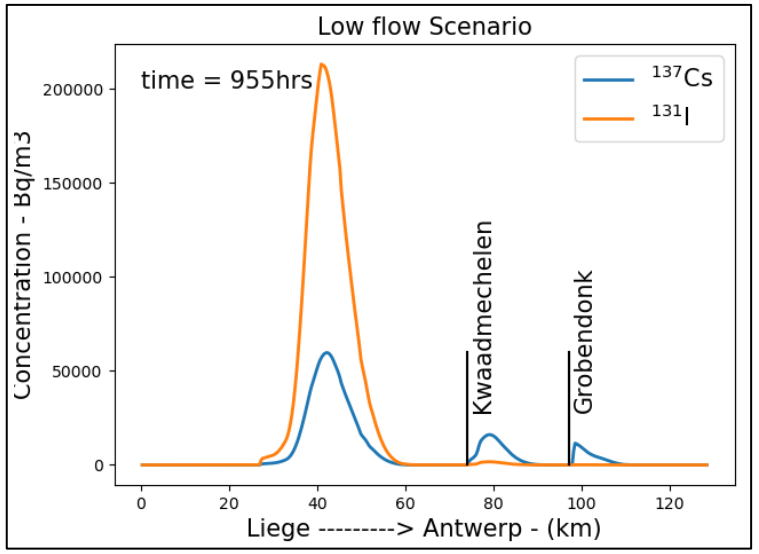
Scenarios–^{131}I

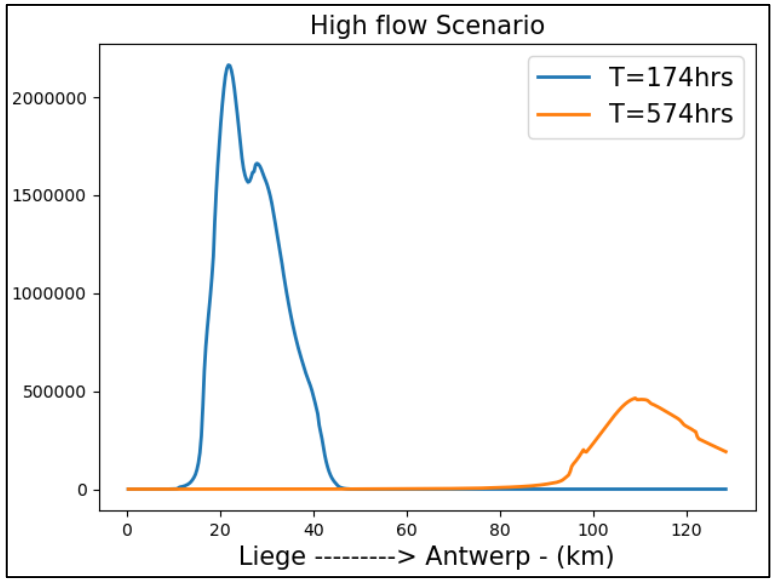
Tihange Nuclear Power Plant

Scenarios – ^{131}I

^{131}I -->scenario 1: Low flow – 700th hour







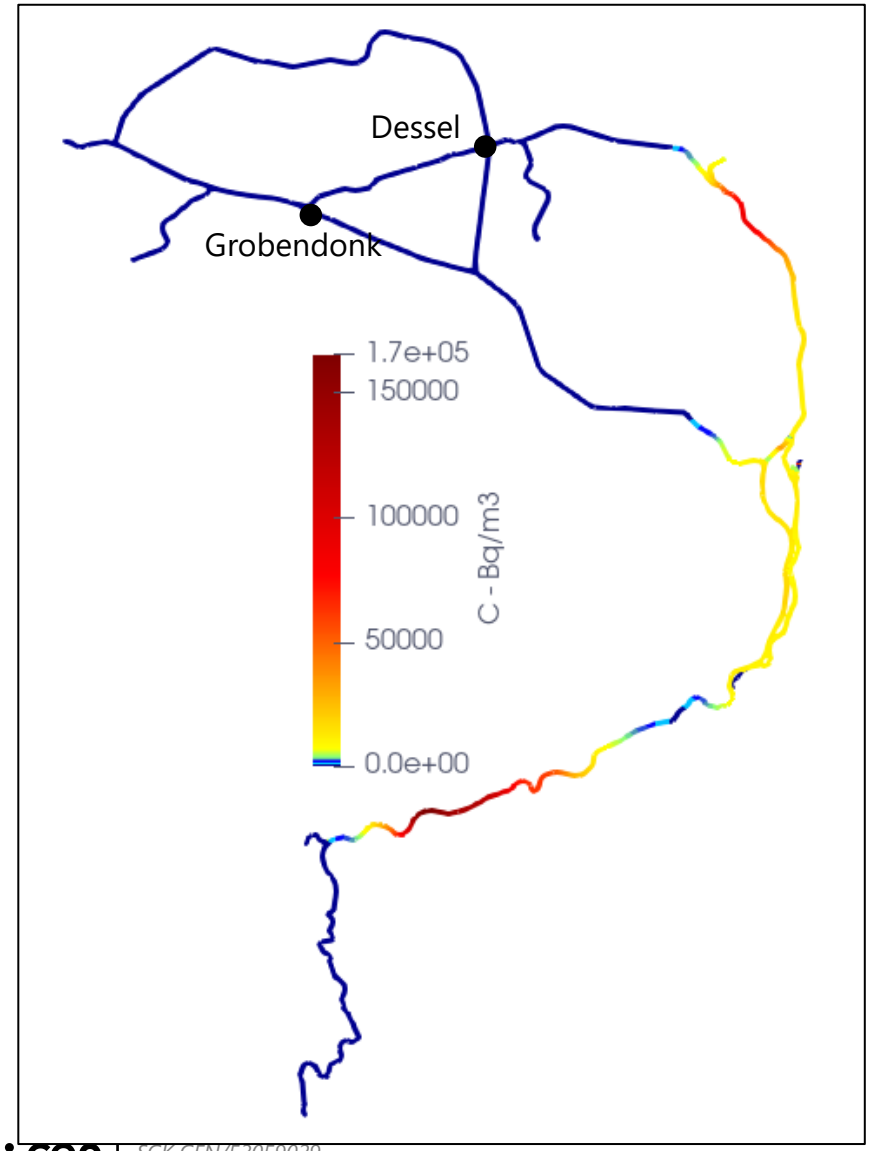
- In low flow scenario the ^{131}I decays significantly.
- Doesnot reach Grobendonk and Kwaadmechelen
- After 550 hrs decays almost the level of ^{137}Cs

Scenarios–Chooz Nuclear Power Plants

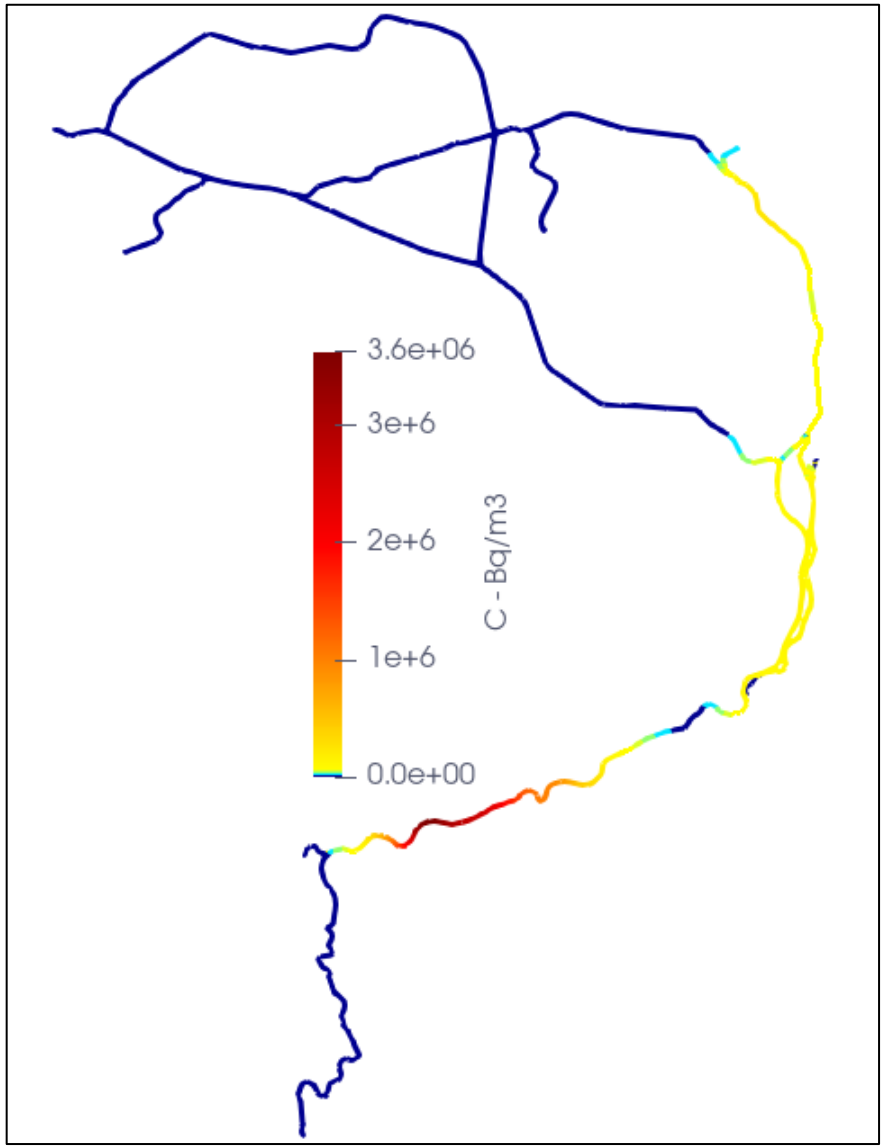
^{131}I and ^{137}Cs

Scenarios – Chooz Nuclear Power Plants

^{137}Cs --> 100th hour



^{131}I --> 100th hour

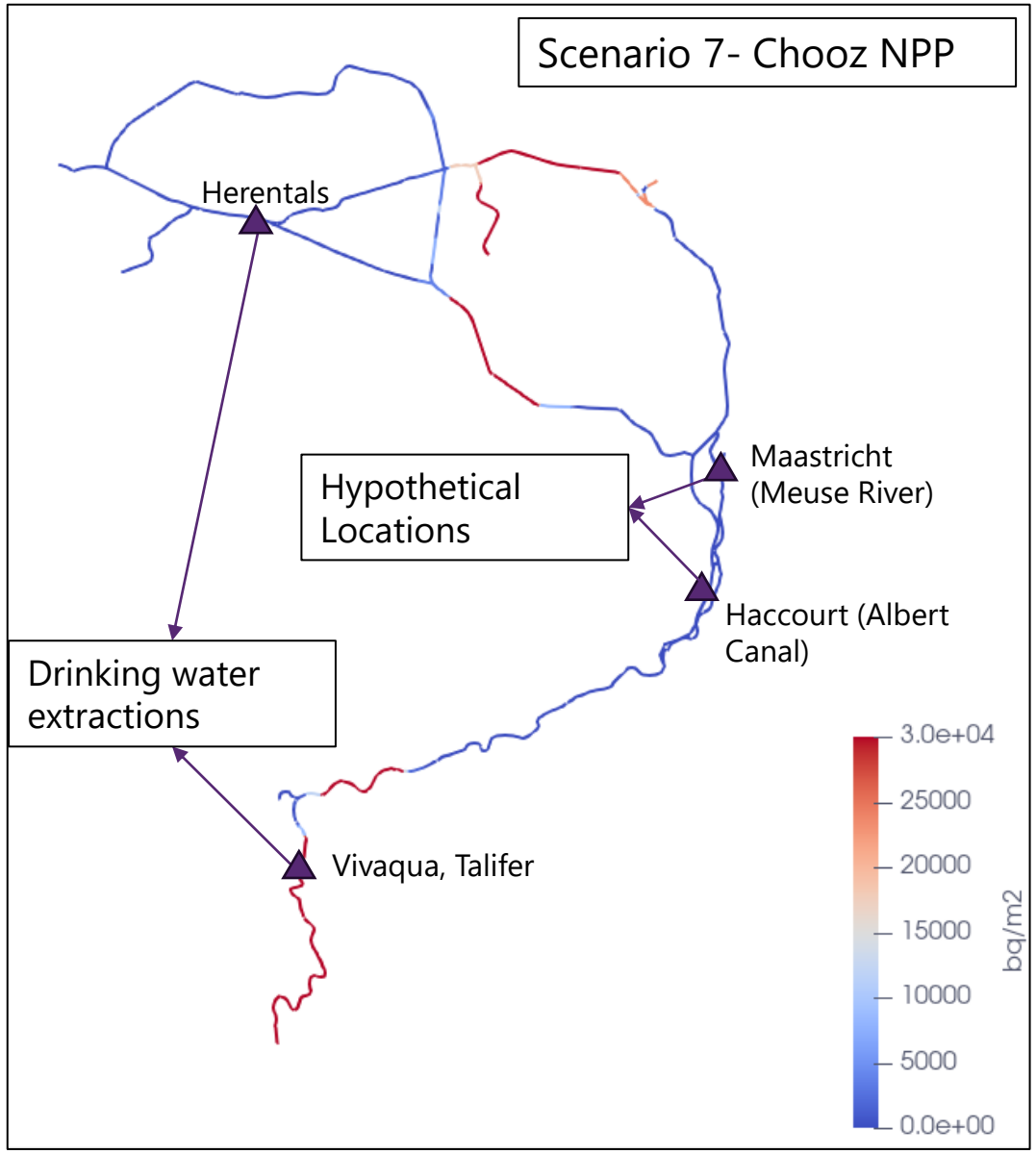


- In Campine canal the ^{131}I decays significantly.
- In the Dessel-Herentals canal, the peak is about 9 kBq/m^3 that occurs after a month
- Albert Canal with high concentration of approximately 0.19 MBq/m^3, even after a month

Dose-Impact assessment in Meuse-Campine canal

Chooz Nuclear Power Plants

Drinking Water Locations



Dose Impact Parameters

For individual dose Calculation:

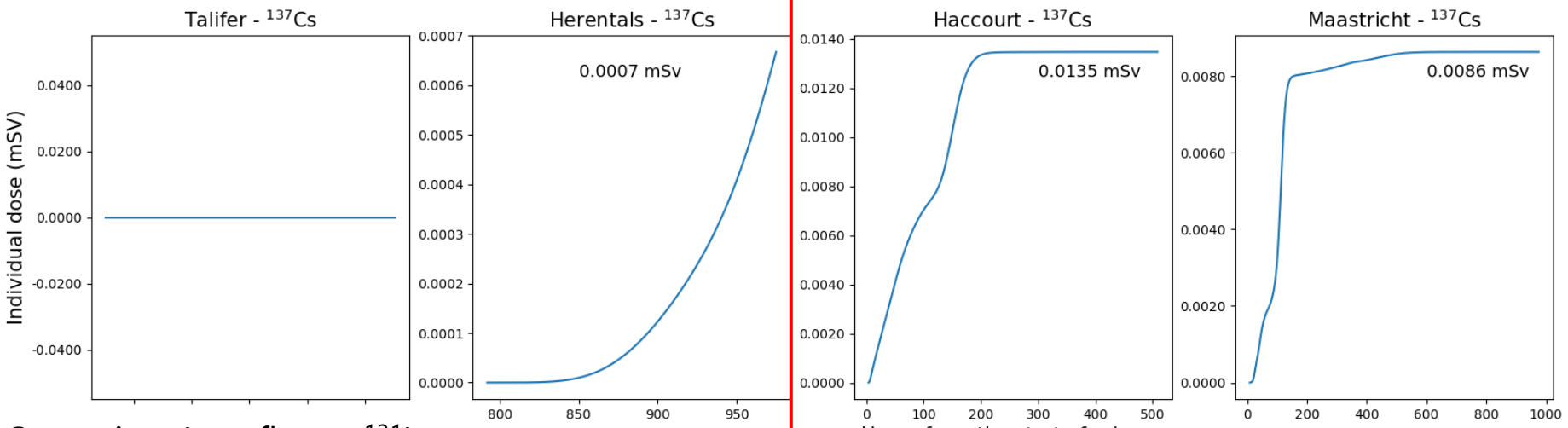
- Average Daily consumption of drinking water: 2 liters per individual

A study conducted by Dutch think-tank Deltares, states that some 7 million Flemish and Dutch people rely on the Meuse for their drinking water. In Flanders, 40% of drinking water is drawn from the Albert Canal.

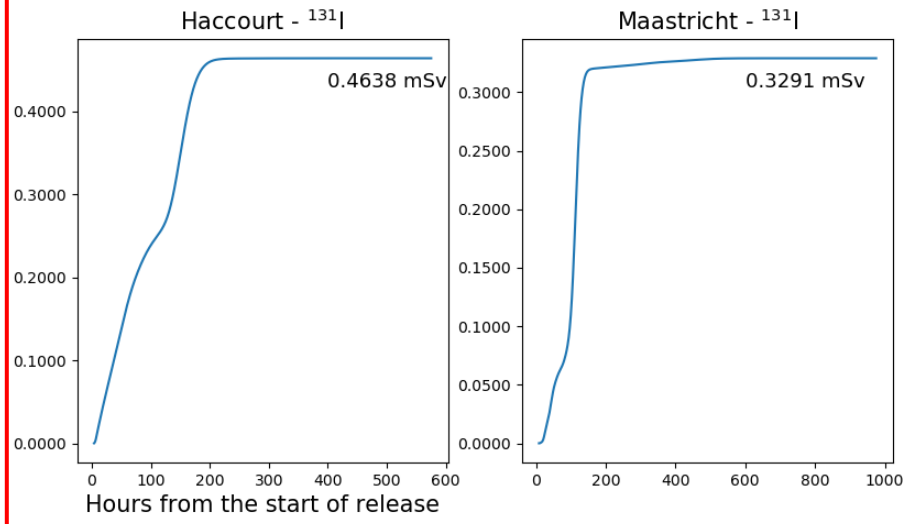
Individual dose Calculation - results

Releases from Tihange Nuclear Power Plant

Scenario – Low flow – ^{137}Cs



Scenario – Low flow – ^{131}I



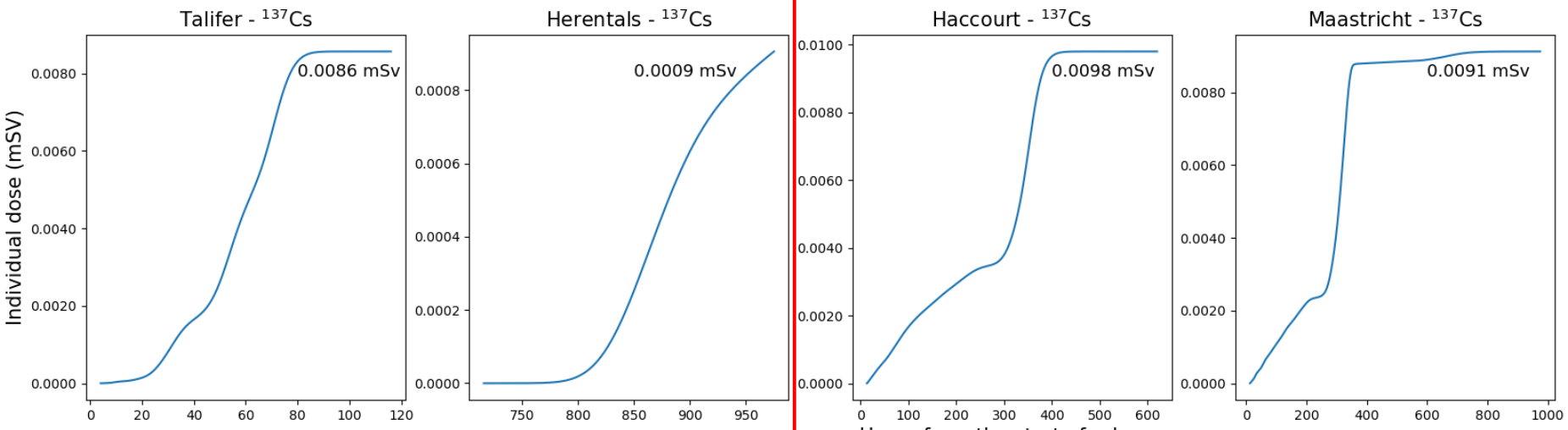
Hypothetical Locations

Current legislation for safe limits in drinking water : 0.1 mSV/yr

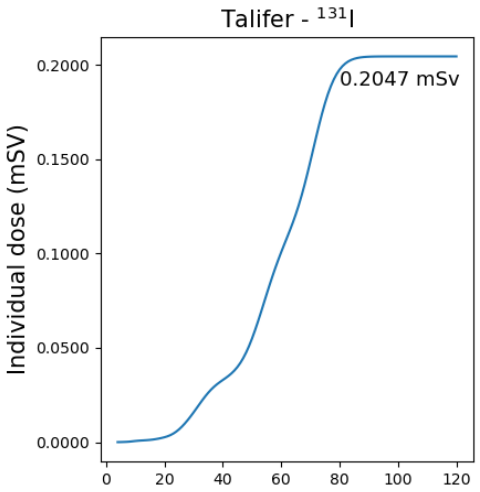
Individual dose Calculation - results

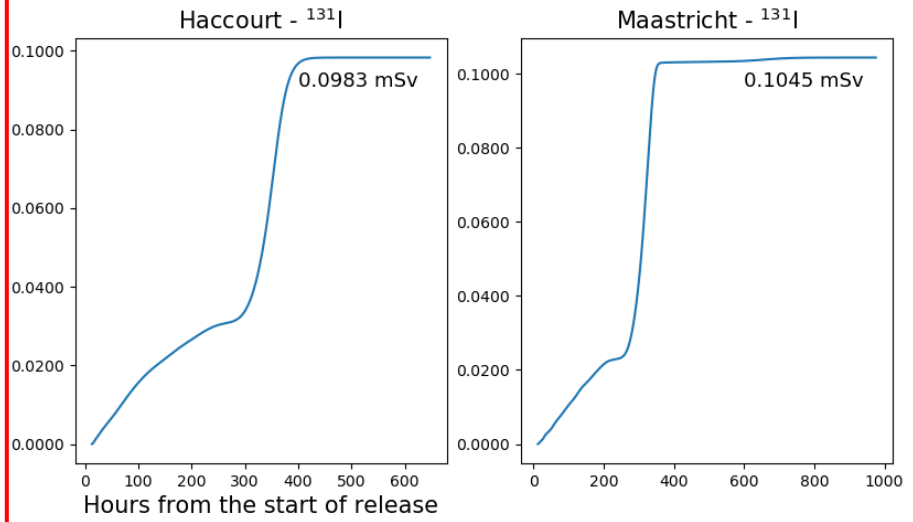
Releases from Chooz Nuclear Power Plant

Scenario – Low flow – ^{137}Cs



Scenario – Low flow – ^{131}I





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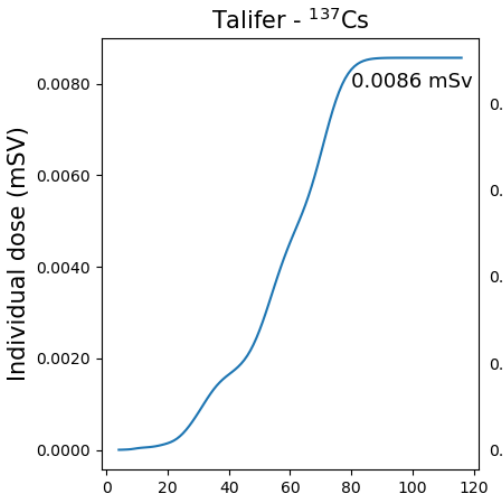
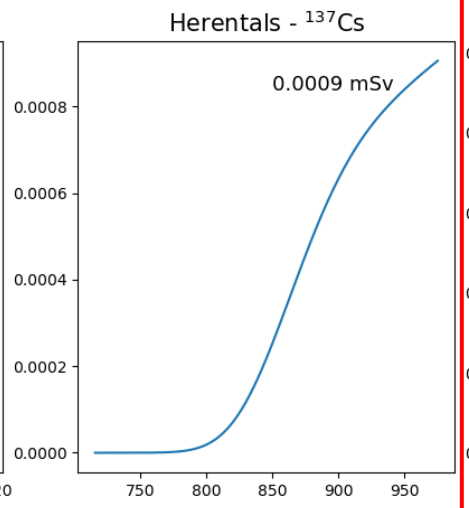
Current legislation for safe limits in drinking water : 0.1 mSV/yr

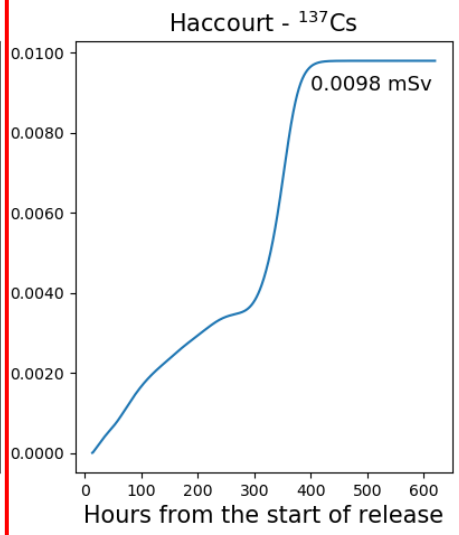
Individual dose Calculation - results

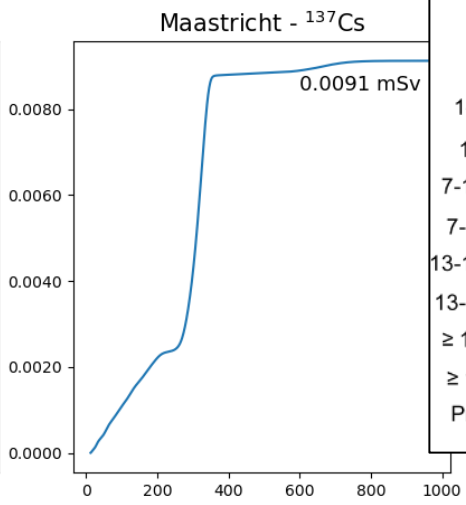
Releases from Chooz Nuclear Power Plant

Scenario – Low flow – ^{137}Cs

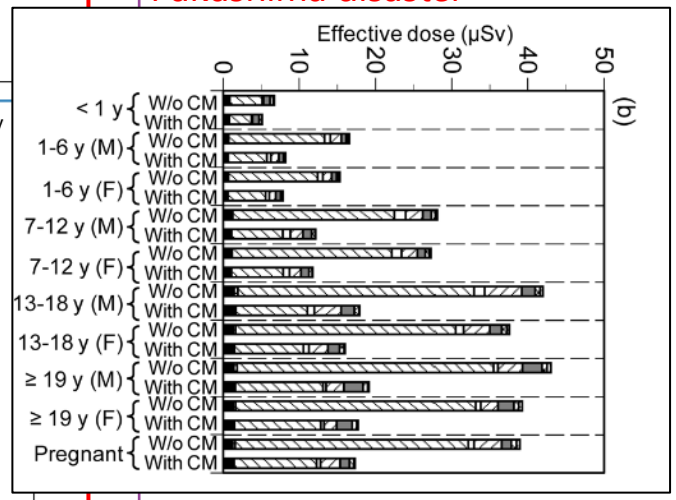




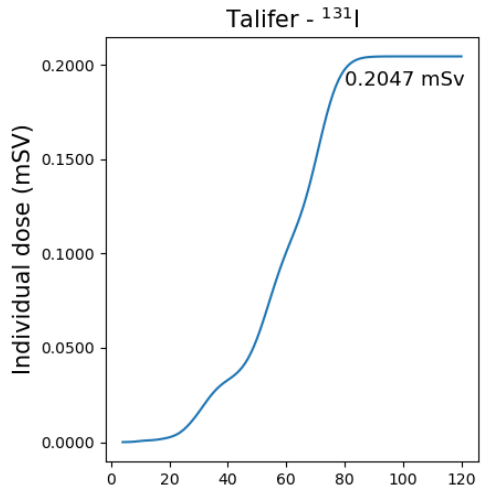


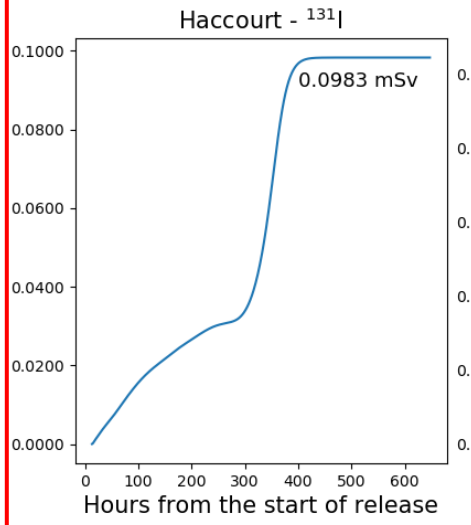


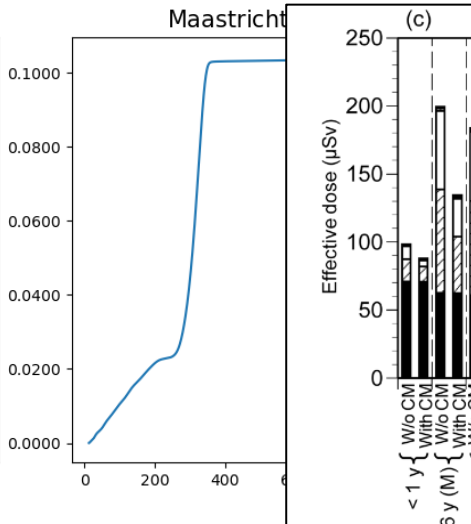
^{137}Cs dose estimated after Fukushima disaster



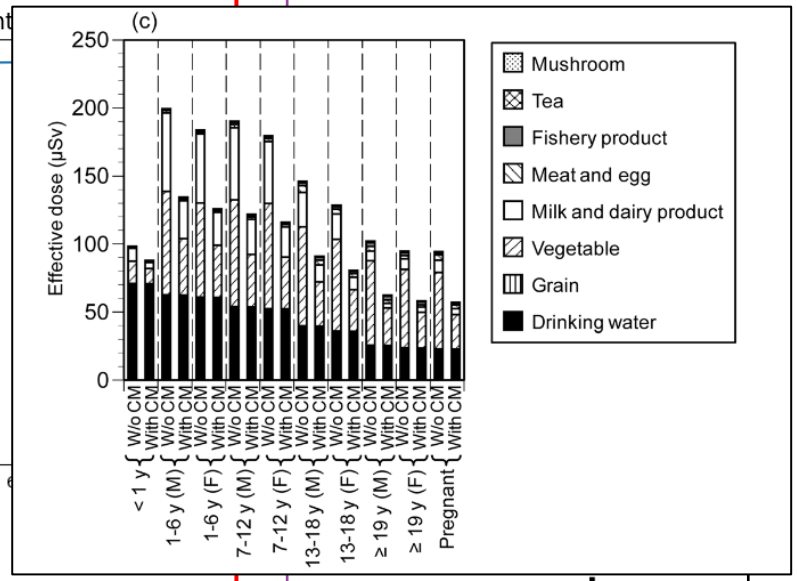
Scenario – Low flow – ^{131}I





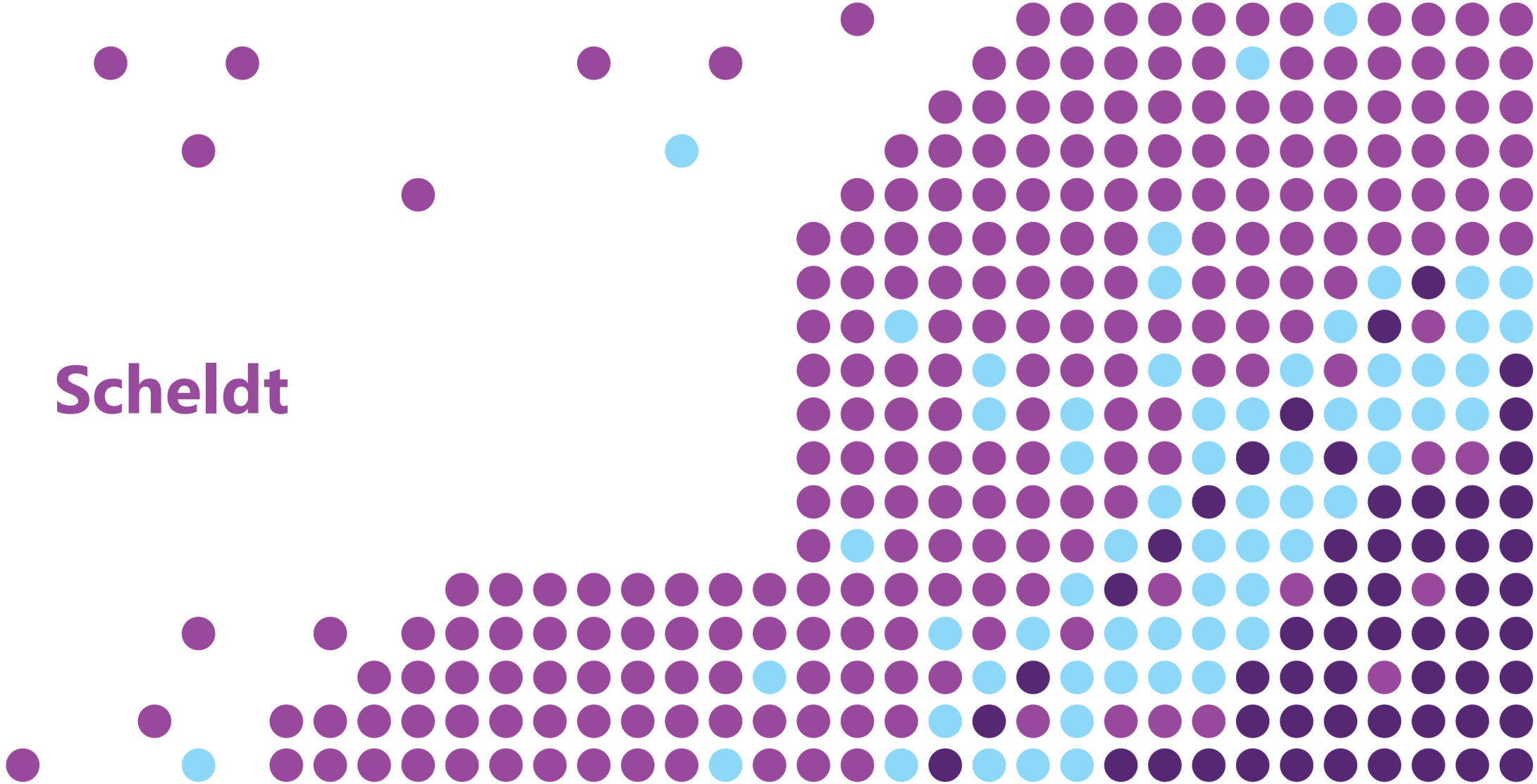


Total dose estimated after Fukushima disaster

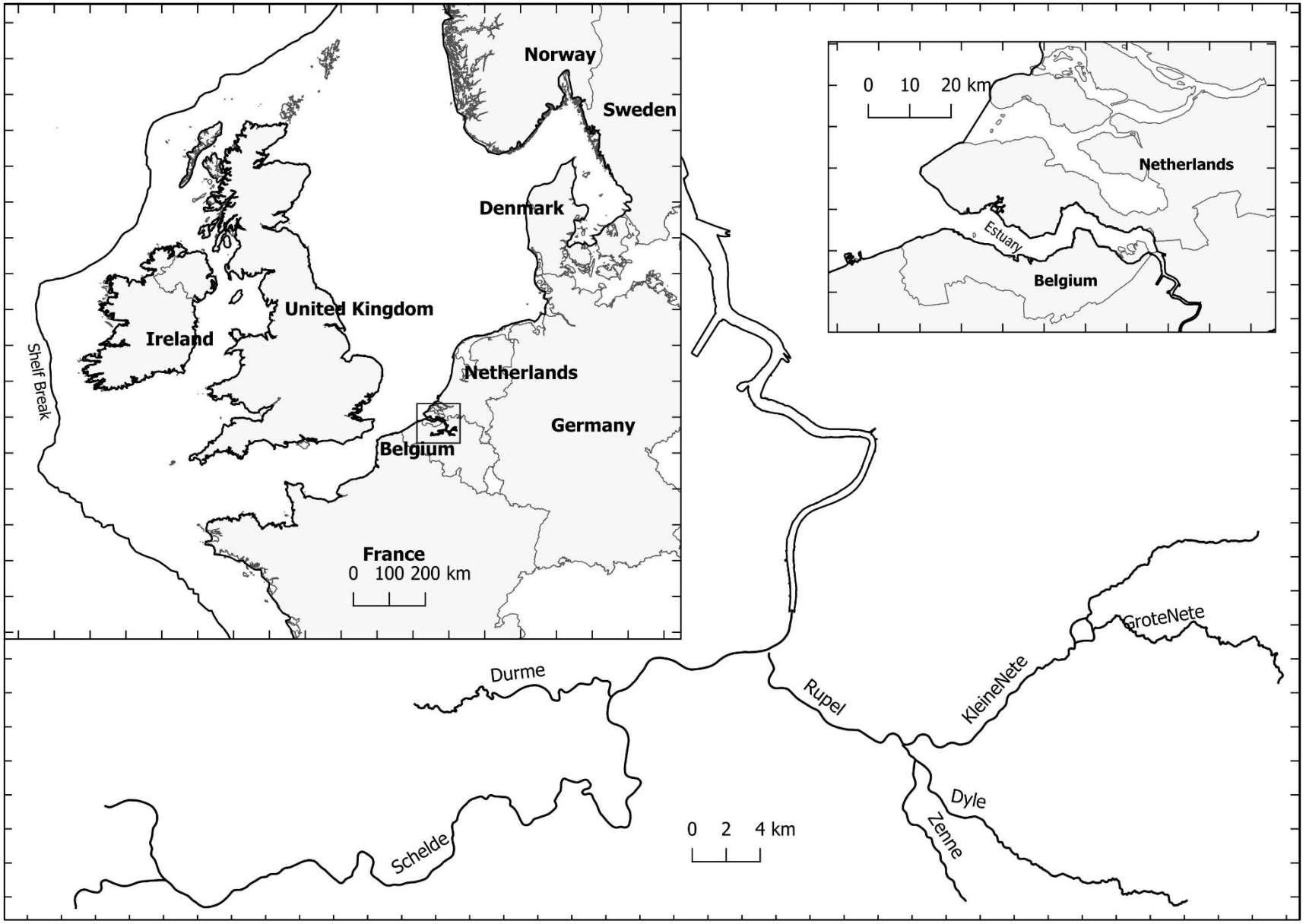


Hypothetical Locations

Scheldt

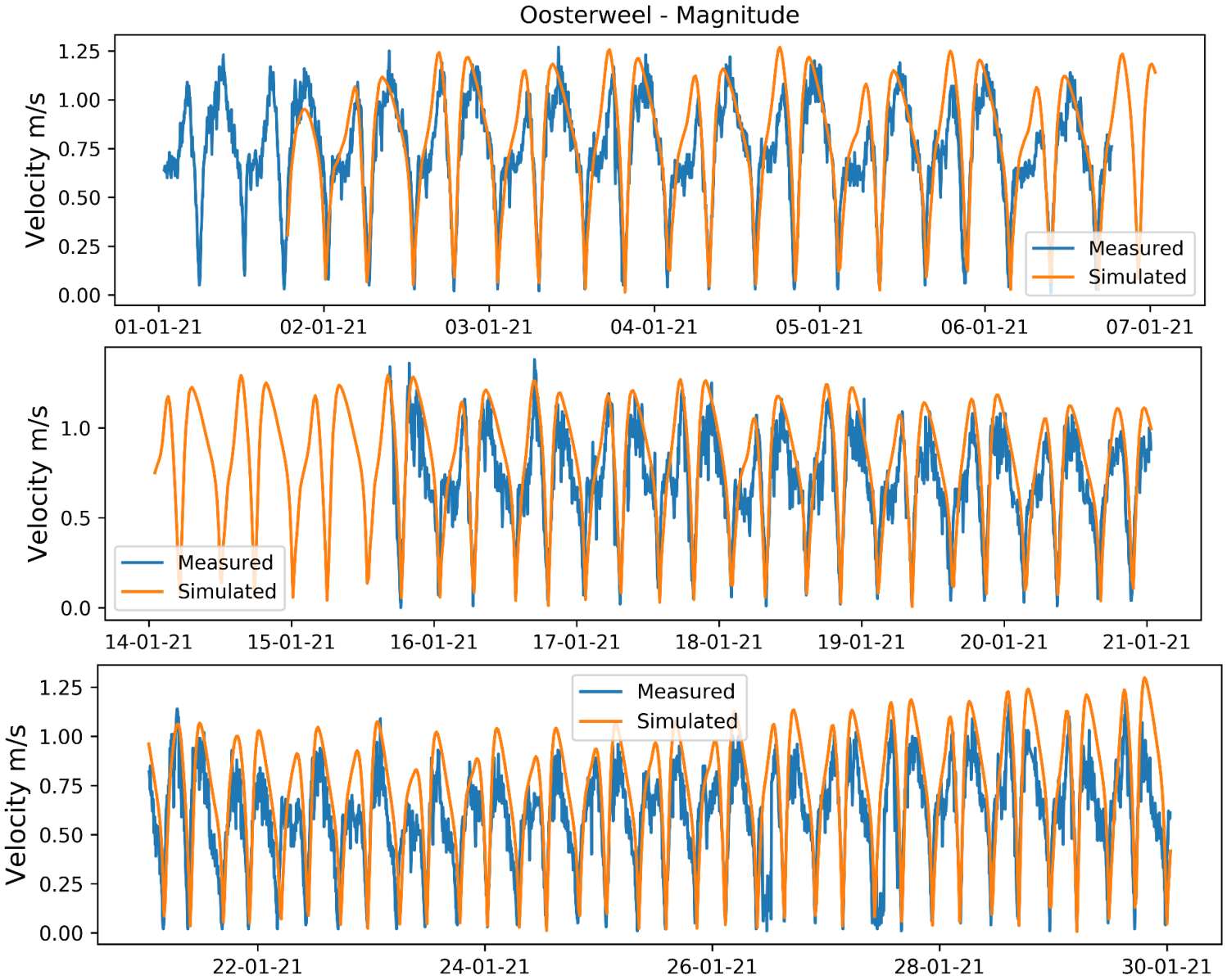


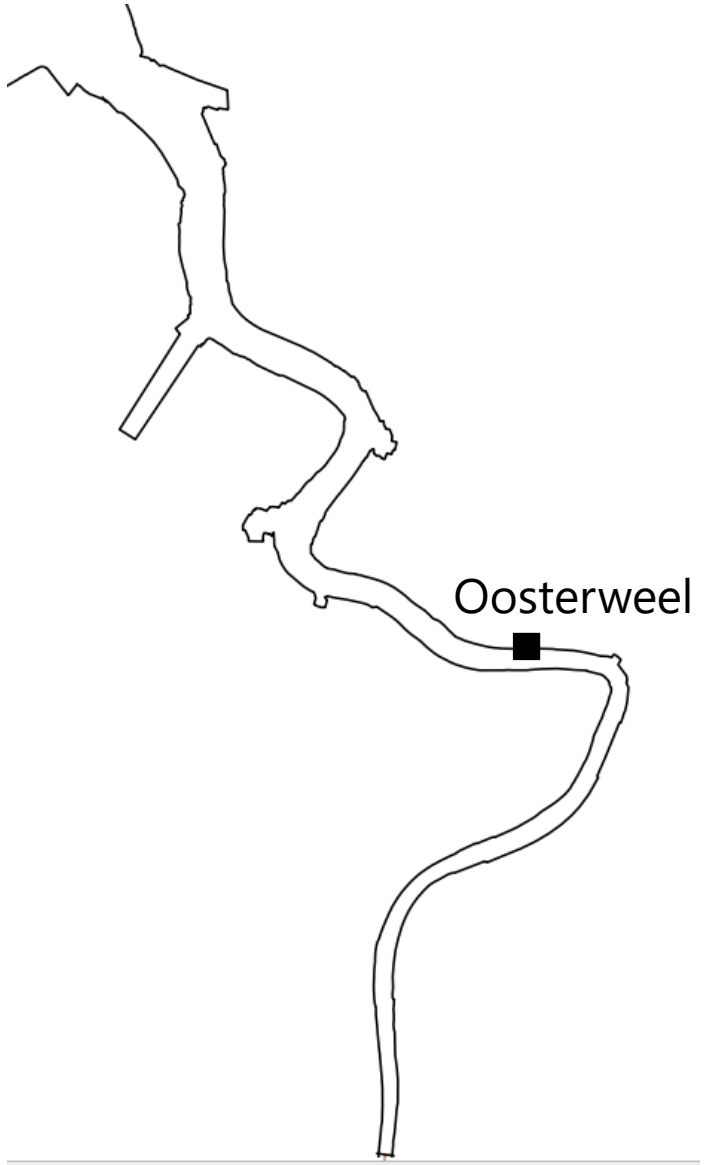
Domain for Study



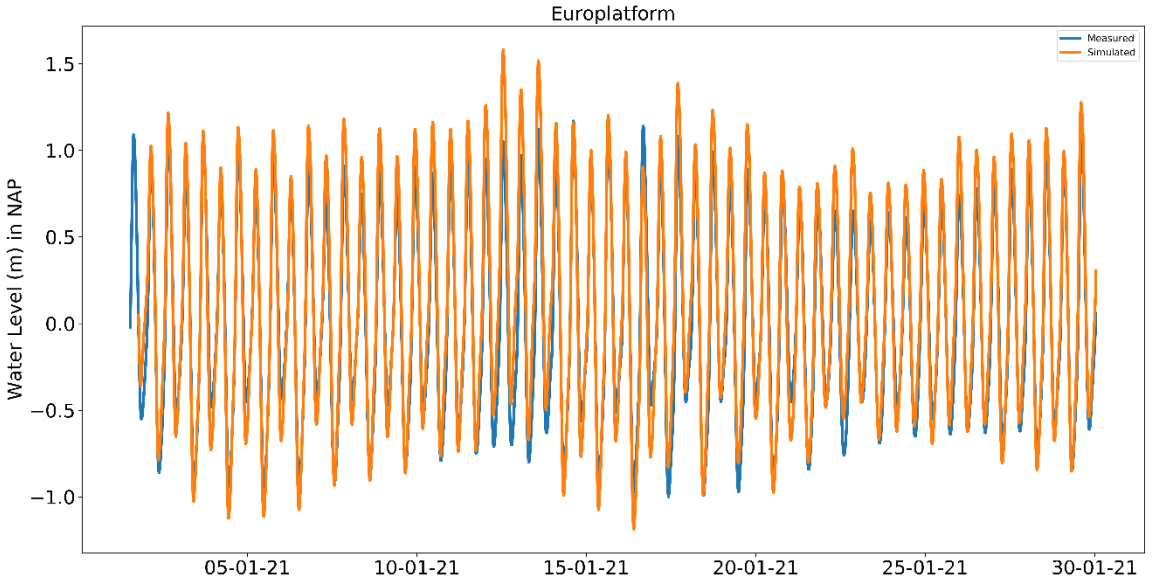
Scheldt - Hydrodynamics

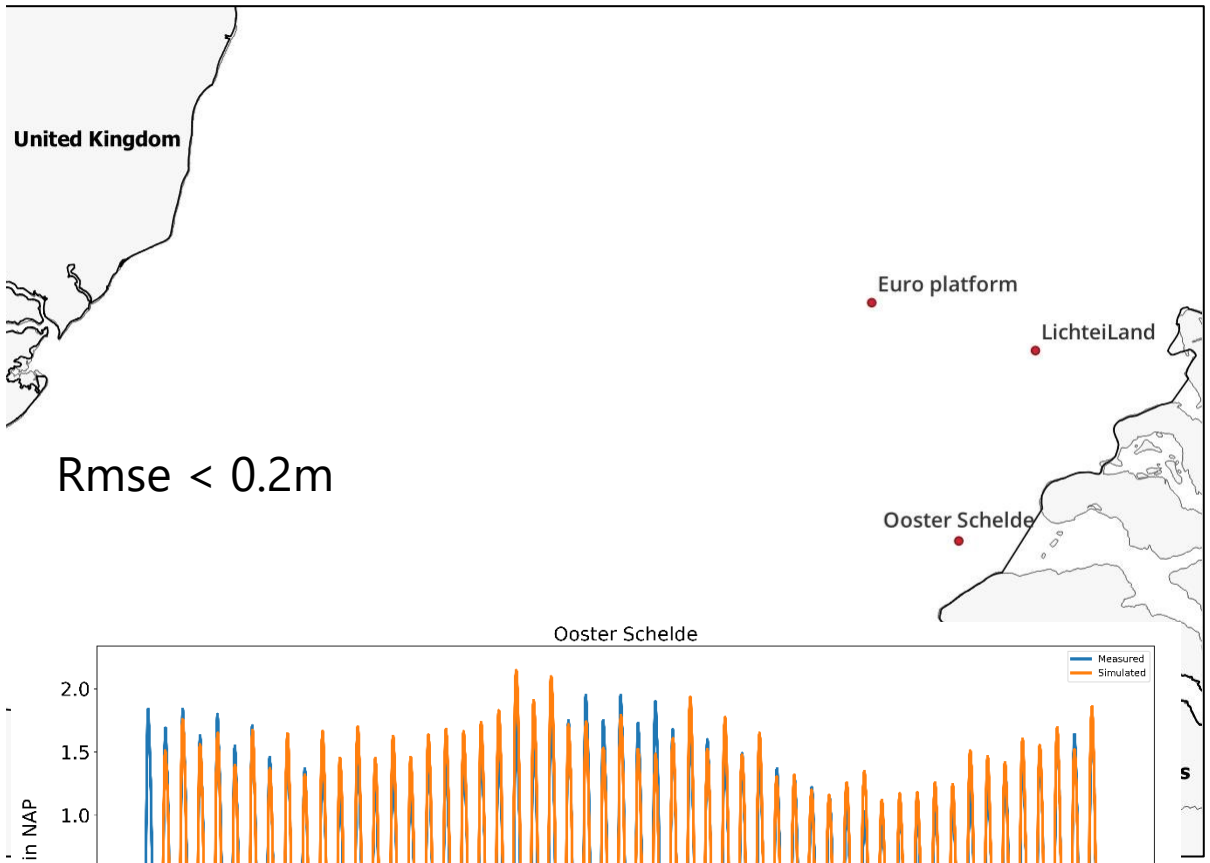
Scheldt Coupler: Velocity



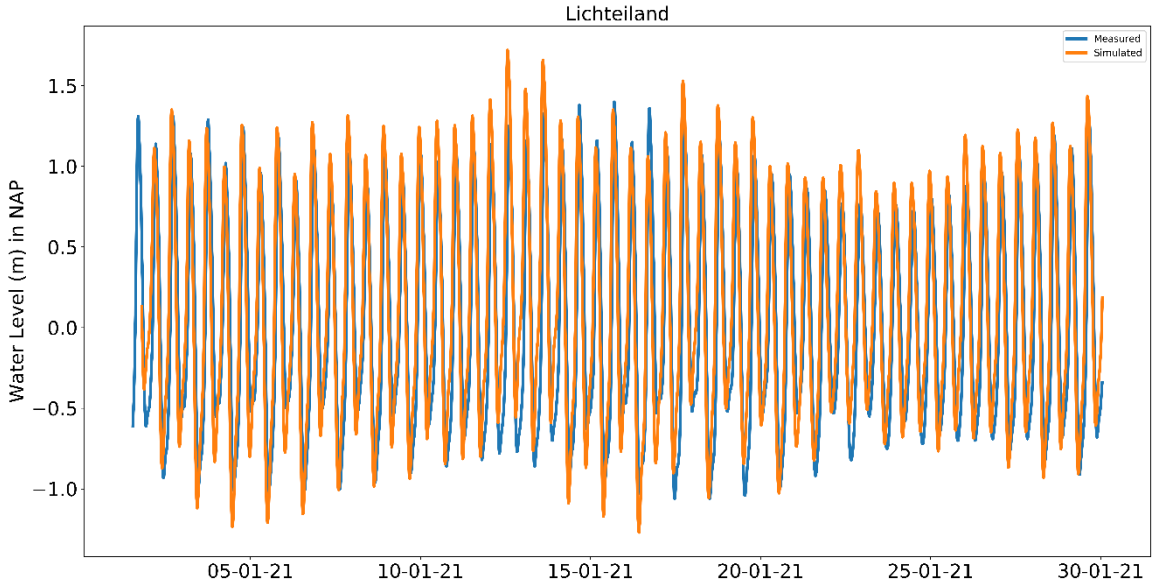


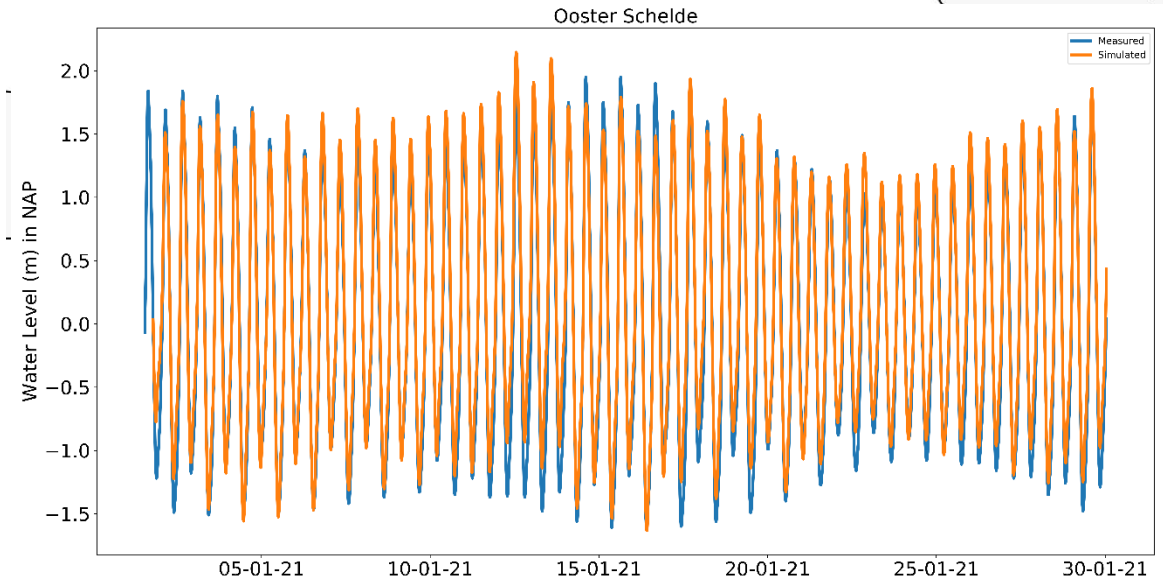
Coastal region





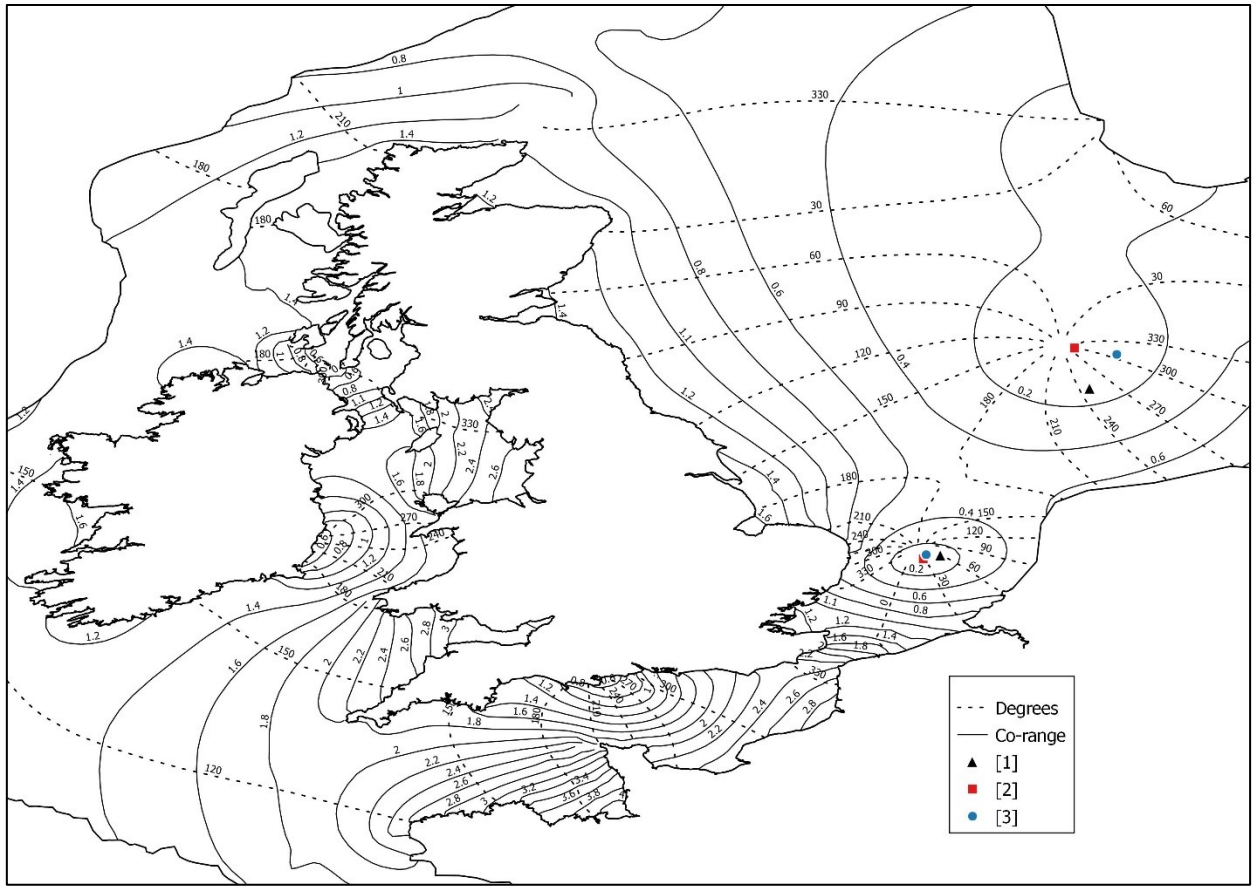
Rmse < 0.2m



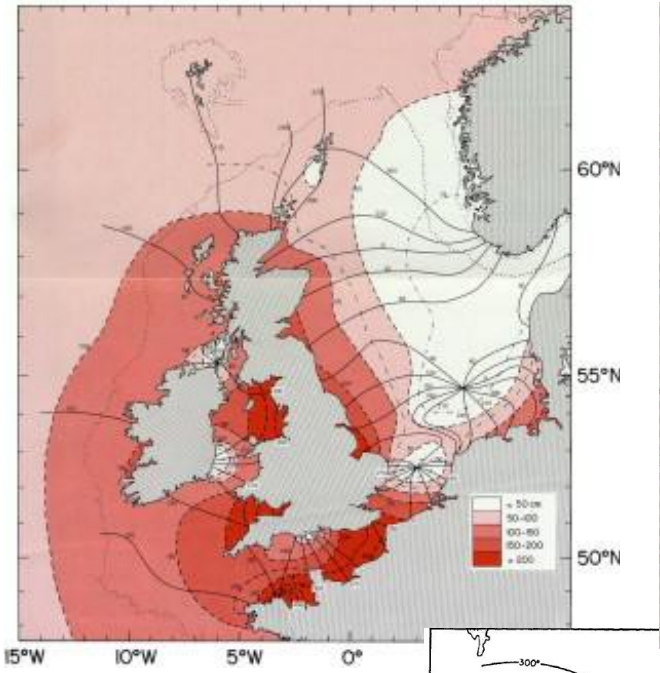


M2 Tide: Co-range and Degrees

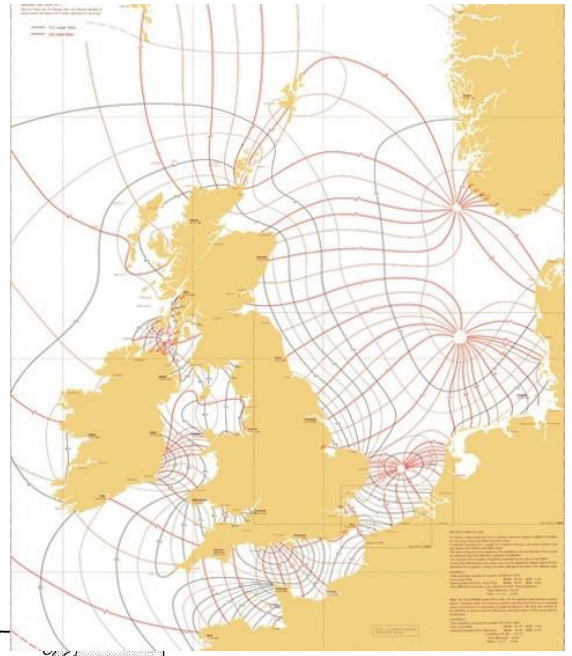
Simulated Results



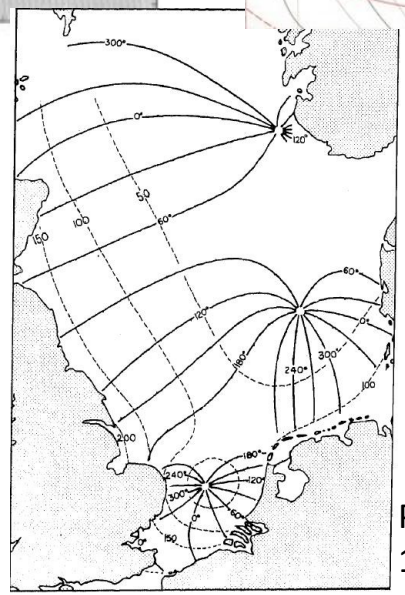
Based on Measured Data



Howarth, 1990 [1]



UK Hydrographic Office [2]



Proudman & Doodson, 1924 [3]

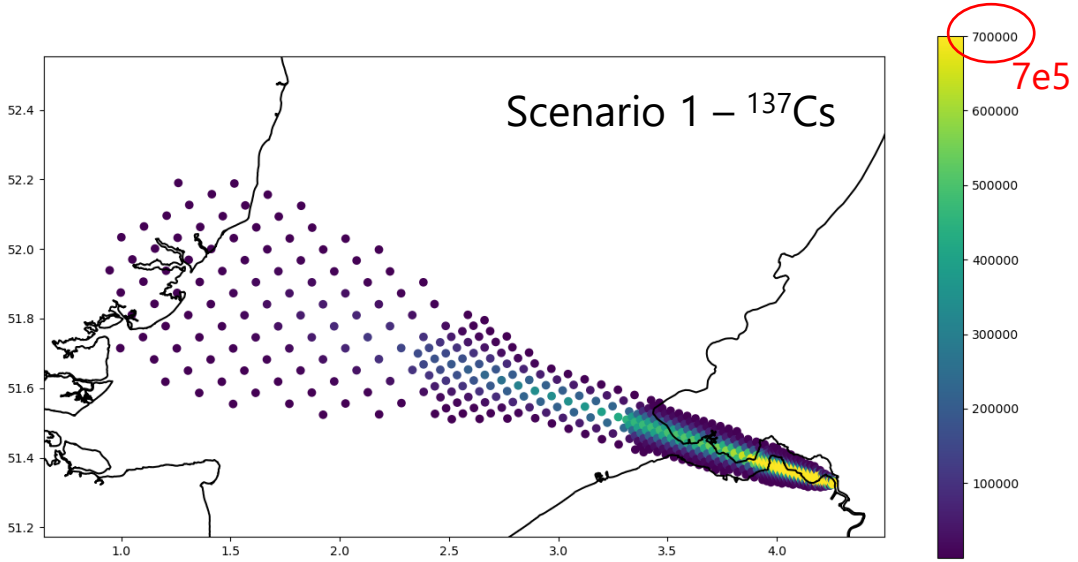
1. Coughlan, Clare., & Stips, Adolf. (2015). *Modelling the tides on the North West European Shelf, European Commission, Joint Research Centre, Institute for Environment and Sustainability*
2. Luxford, F., Stansby, P. K., & Rogers, B. D. (2014). The Importance of long wave reflections in tidal modelling on a continental shelf. *Coastal Engineering*.
3. Otto, L., Zimmerman, J. T. F., Furnes, G. K., Mork, M., Saetre, R., & Becker, G. (1990). Review of the physical oceanography of the north sea. *Nethterlands Journal of Sea Research*, 161–238.

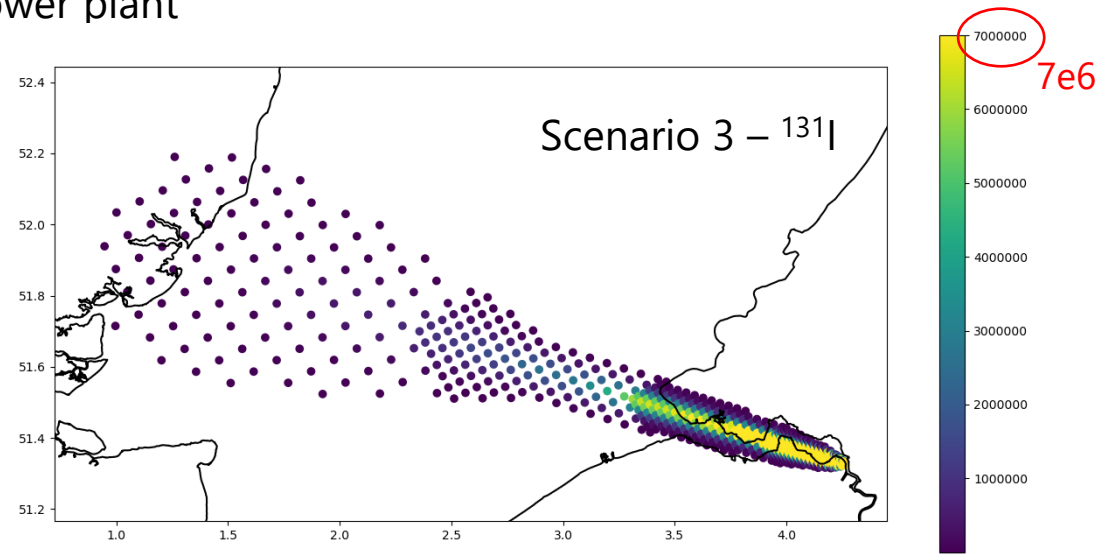
Scenarios for radionuclide Transport

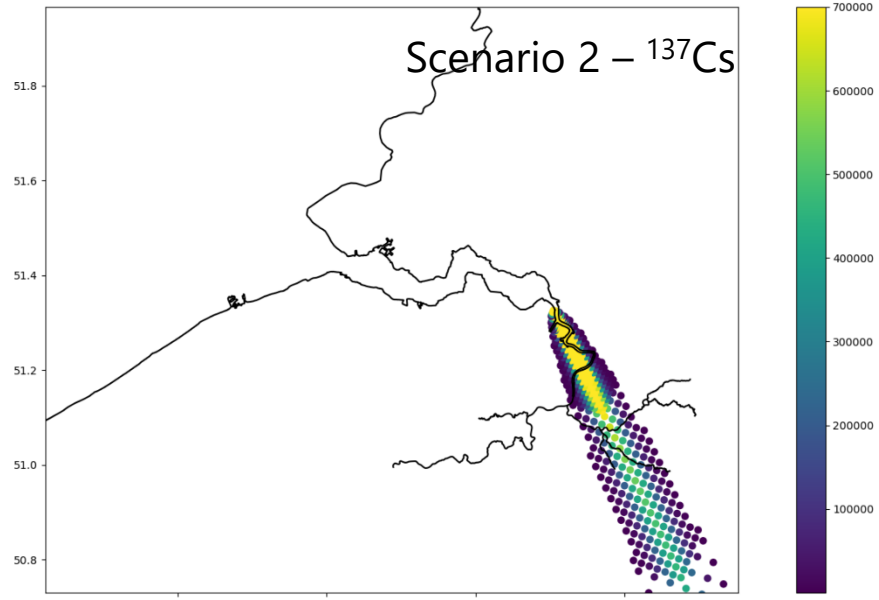
Doel Nuclear Power Plant

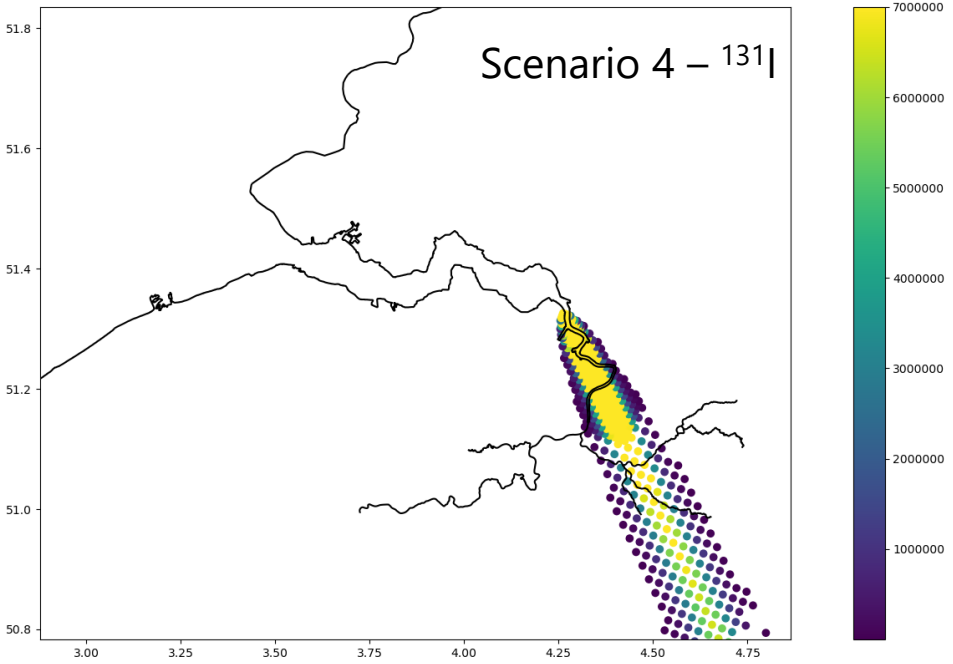
Atmospheric deposition scenarios

Doel Nuclear power plant







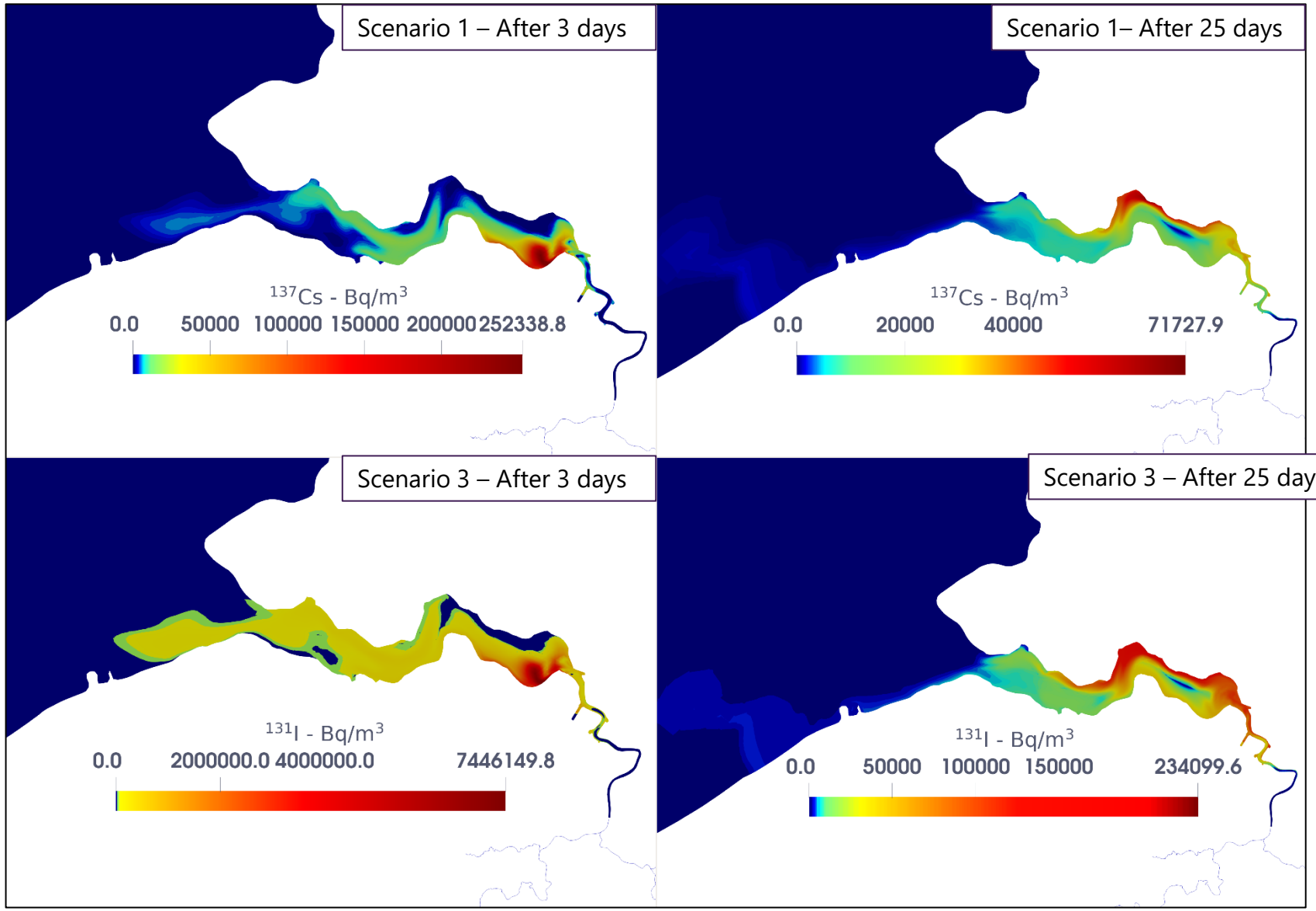


Longitude

Latitude

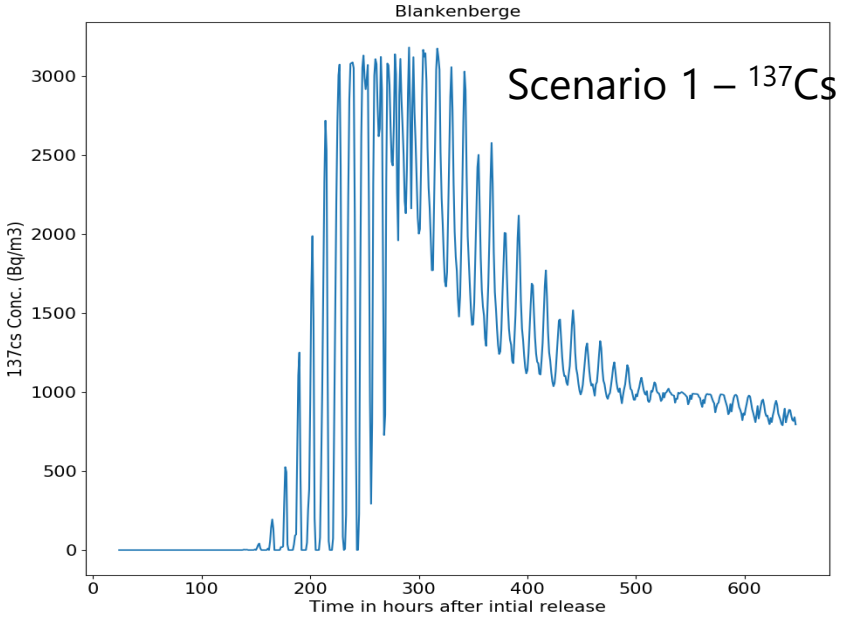
Scenario 1 and 3

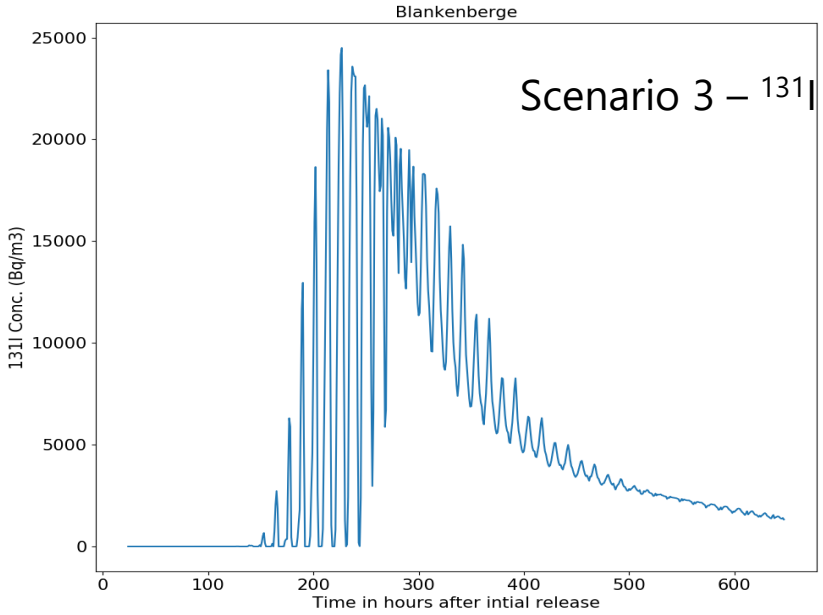
Releases from Doel Nuclear Power Plant

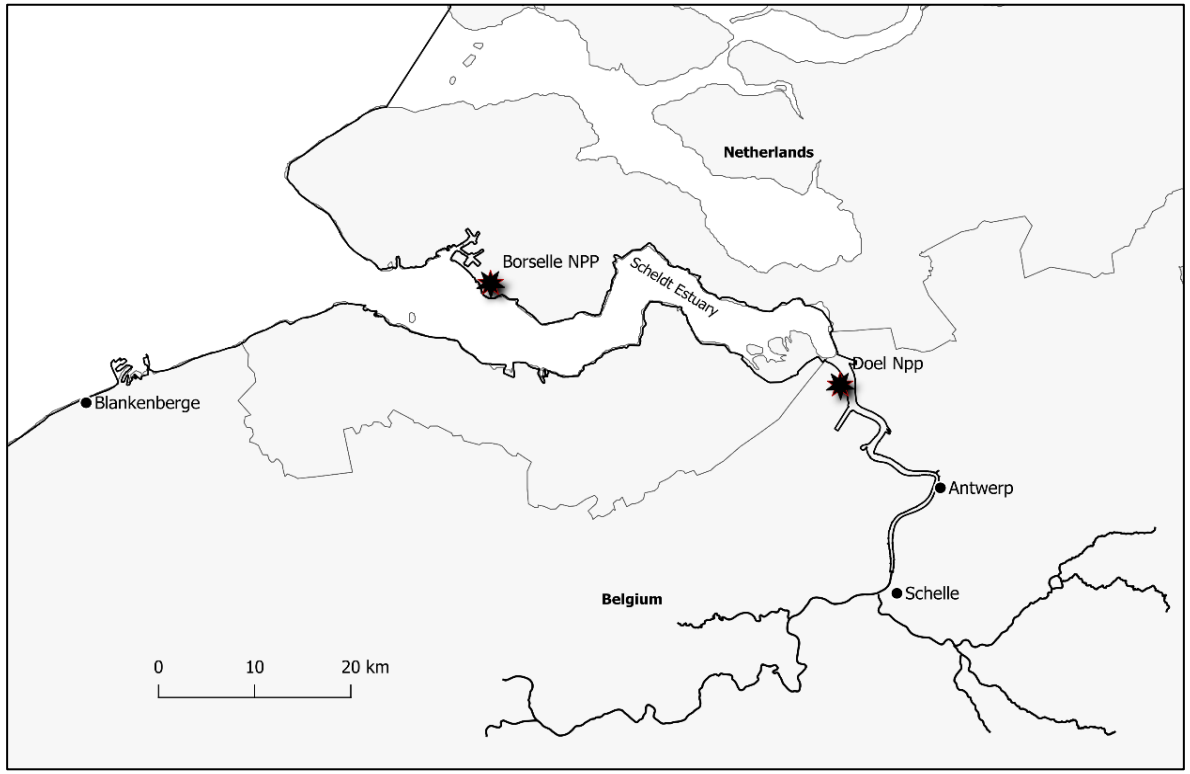


Scenario 1 and 4

Releases from Doel Nuclear Power Plant



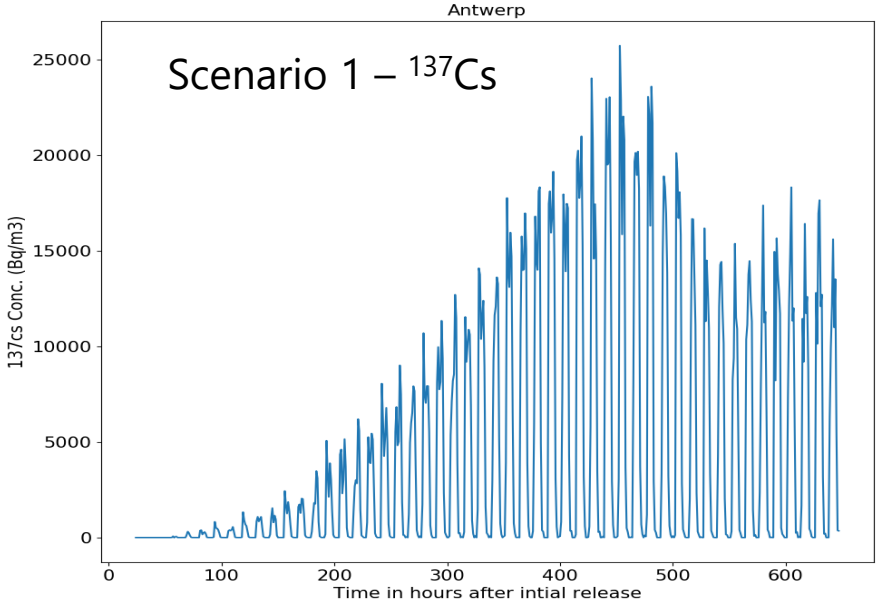


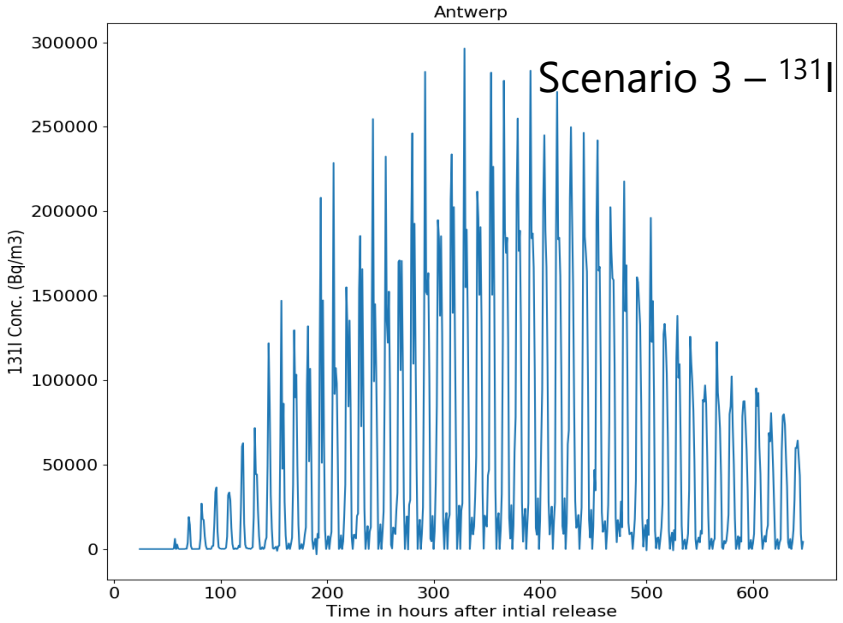


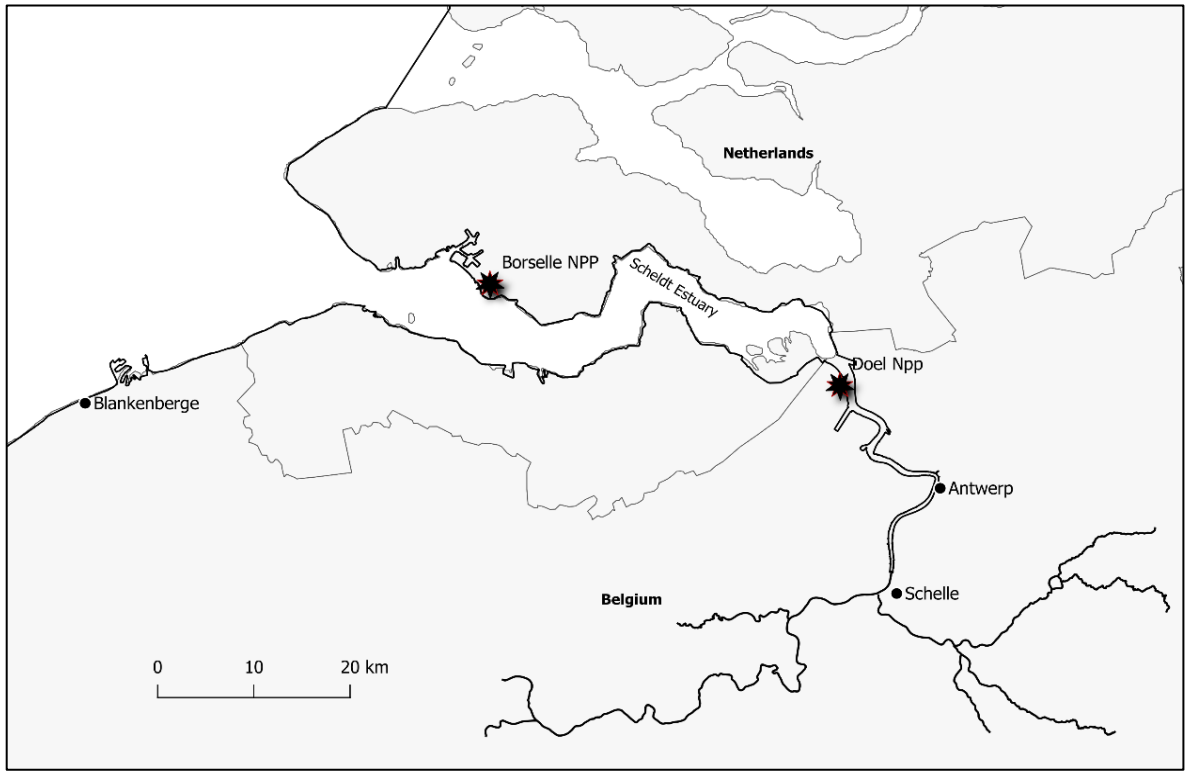
- Higher concentration (>10000 Bq/m3) for ^{131}I reach until 7 days following the first release.
- Drops below the restricted levels at about 2 weeks of the initial release

Scenario 1 and 4

Releases from Doel Nuclear Power Plant



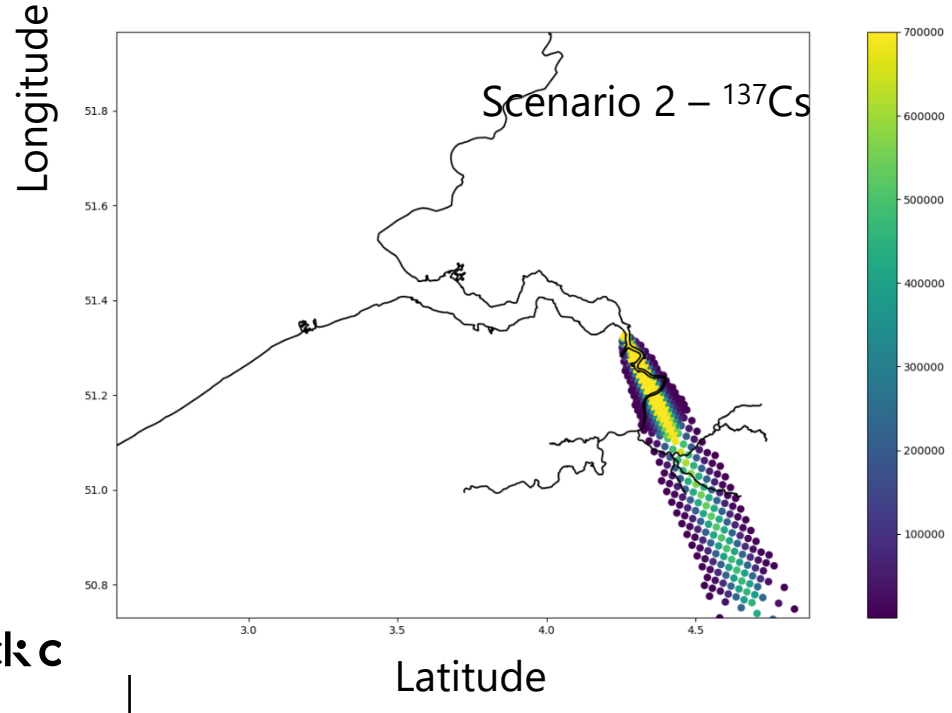


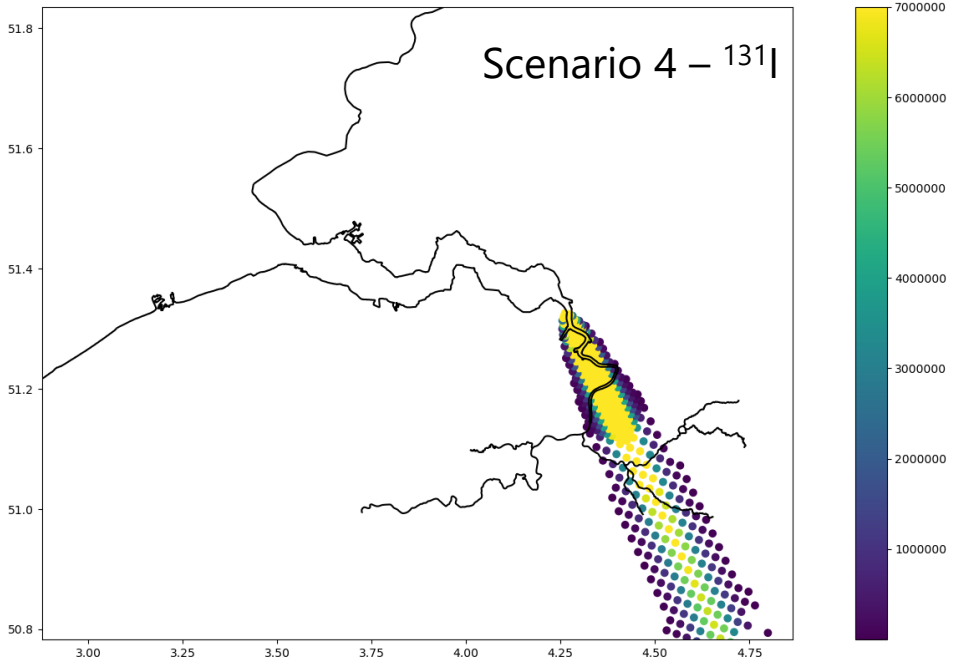


- ^{131}I exceed the safe limit only after the 3 days and ^{137}Cs after 9 days of release from the NPP
- It reaches the maximum at around 12th day and 18th day for ^{131}I and ^{137}Cs respectively

Atmospheric deposition scenarios

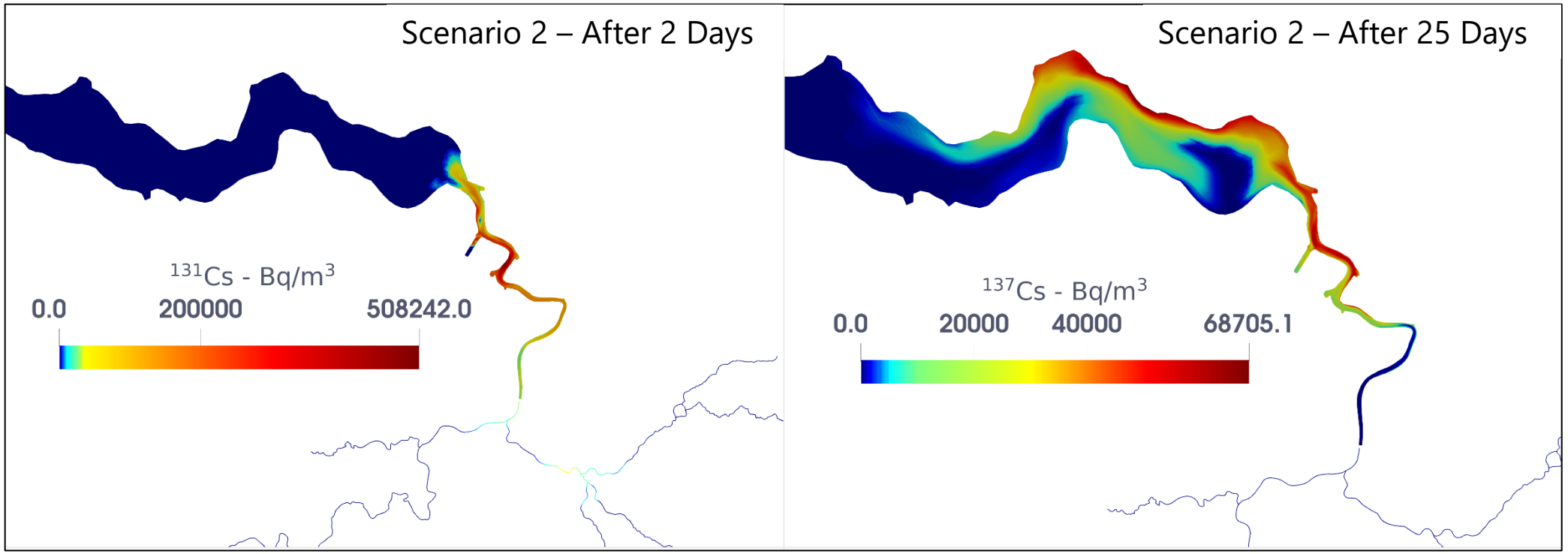
Doel Nuclear power plant





Scenario 2 and 4

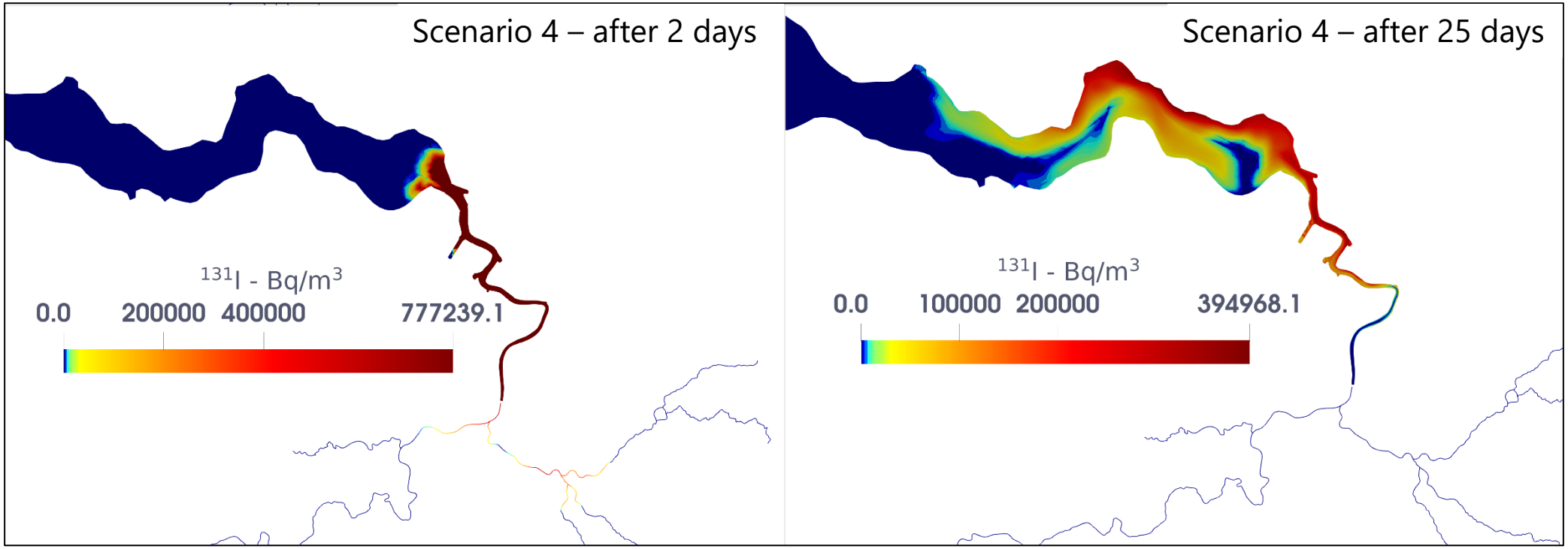
Releases from Doel Nuclear Power Plant



- In these scenarios contamination is limited to the spread in estuary and the distribution of radionuclides in Belgian coast is not observed.

Scenario 2 and 4

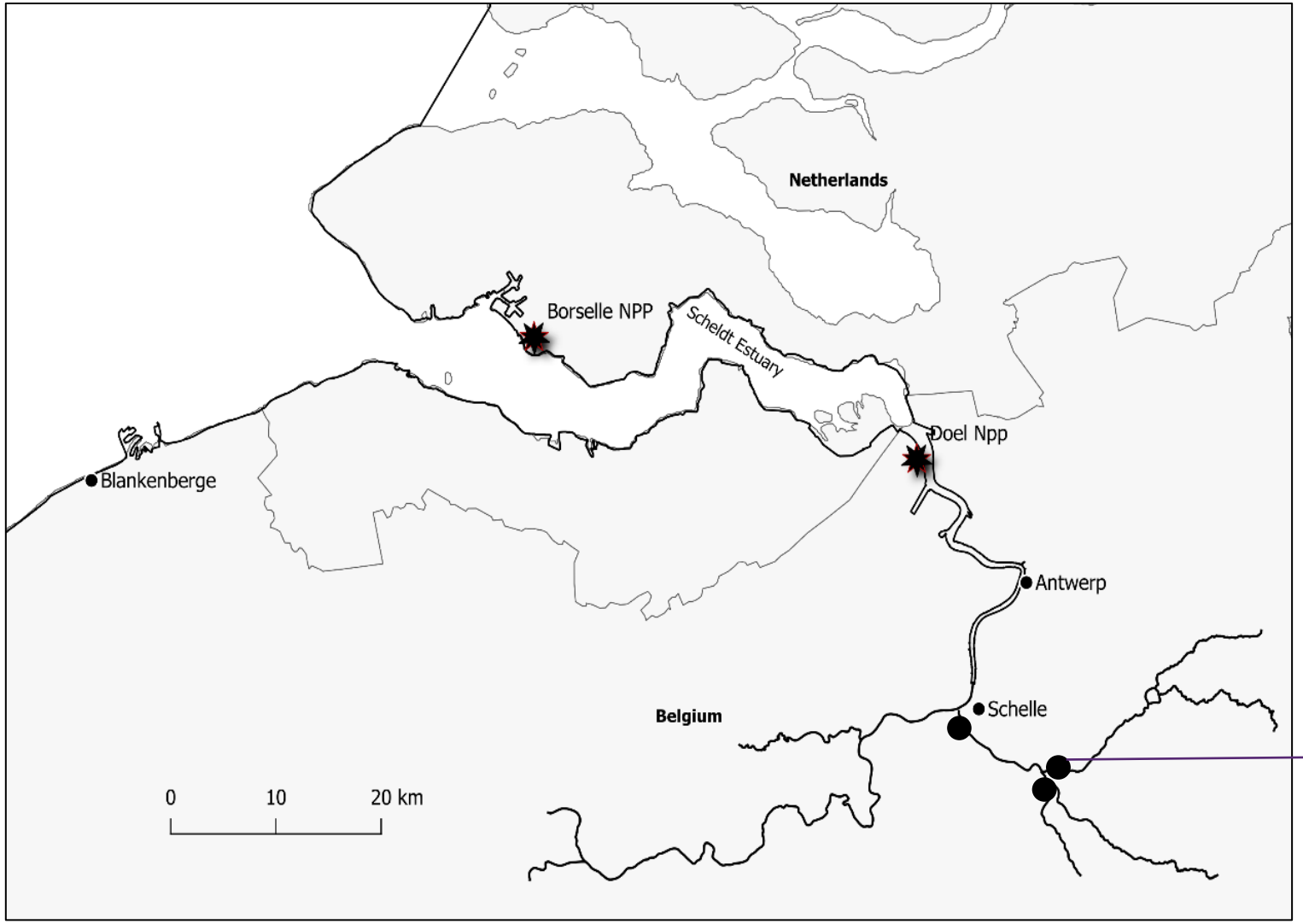
Releases from Doel Nuclear Power Plant



- The deposited plume on the far reach of tributaries arrive faster at the confluence of Rupel.
- But in addition to the influence from its tributaries, the Rupel River has an spike in concentration due to tidal motion from the Scheldt River

Scenario 2 and 4: Concentration at different rivers

Releases from Doel Nuclear Power Plant

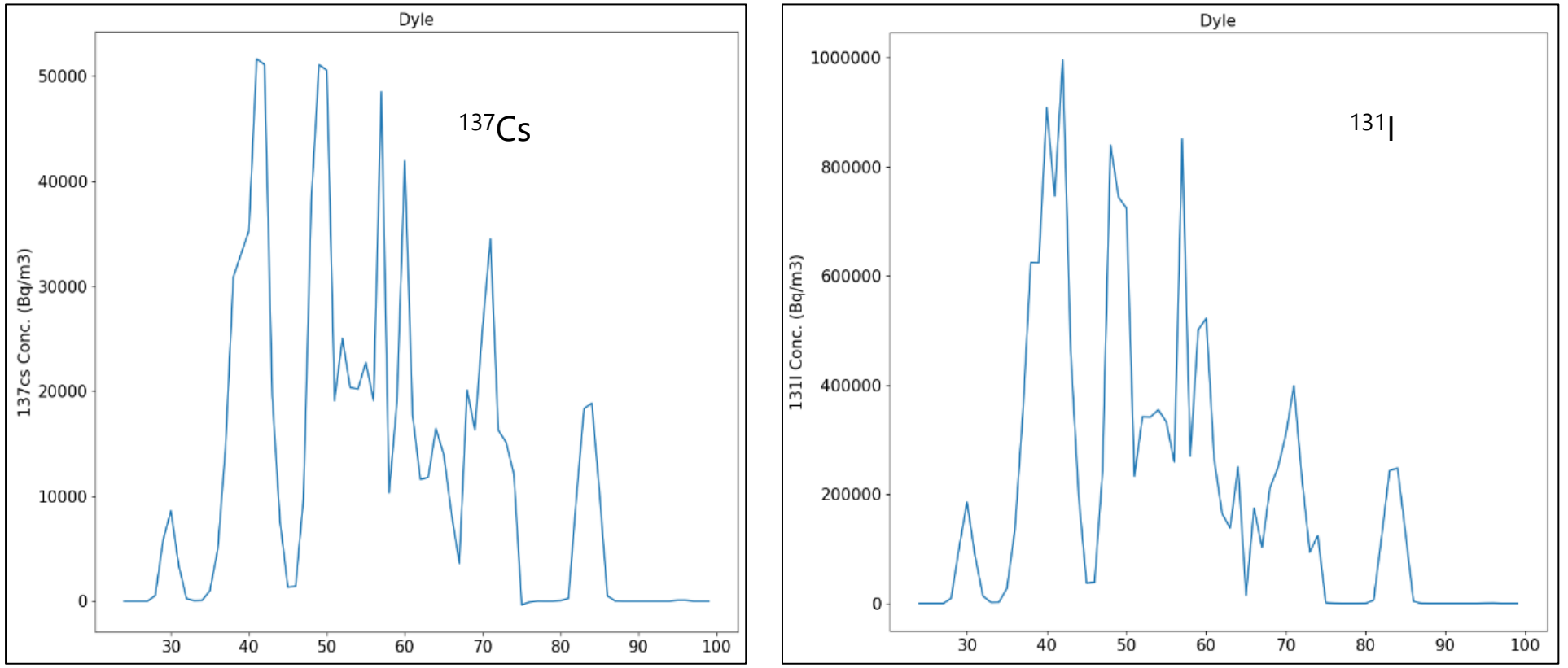


Concentration points at Confluence

Scenario 2 and 4: Concentration at different rivers

Releases from Doel Nuclear Power Plant

Dyle River



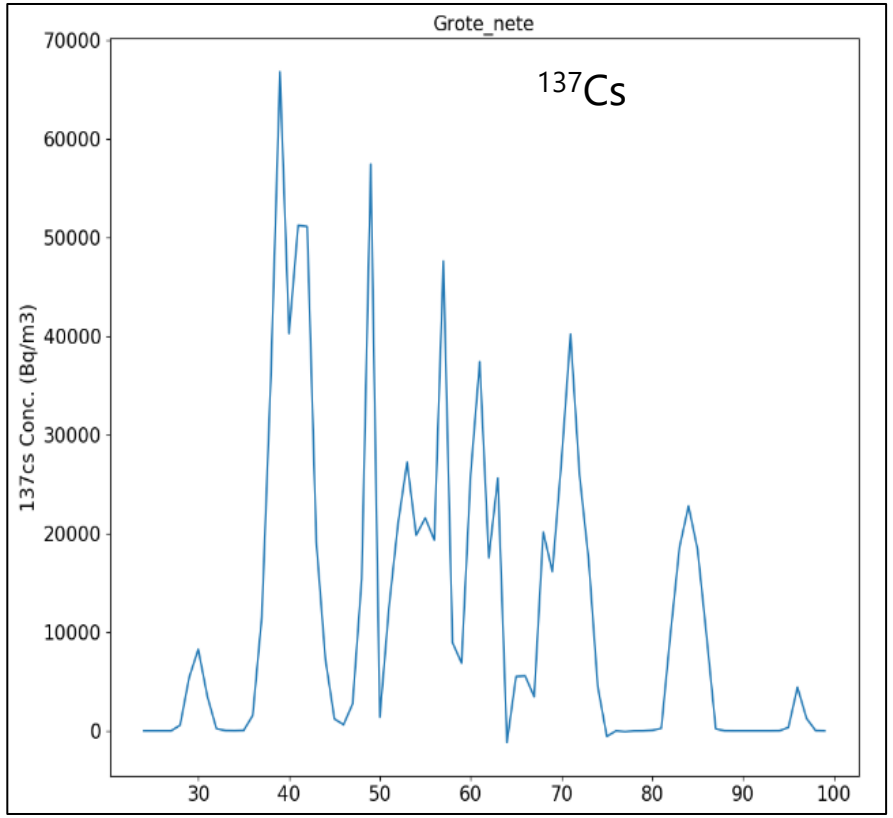
Time since after initial releases

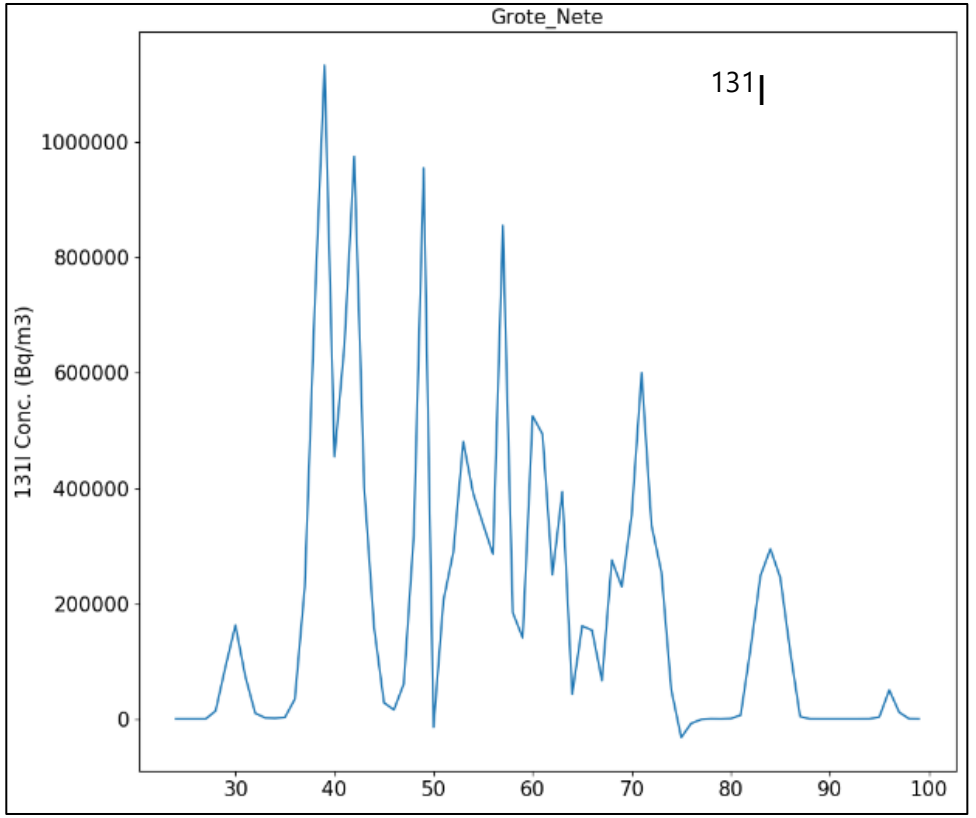
- The radioactive plume only lasts for approximately 4 days in the Grote Nete, Dyle, and even other tributaries like the Kleine Nete and Zenne
- Significant quantities of up to 70 KBq/m^3 in the case of ^{137}Cs and 1 GBq/m^3 for ^{131}I

Scenario 2 and 4: Concentration at different rivers

Releases from Doel Nuclear Power Plant

Grote Nete River





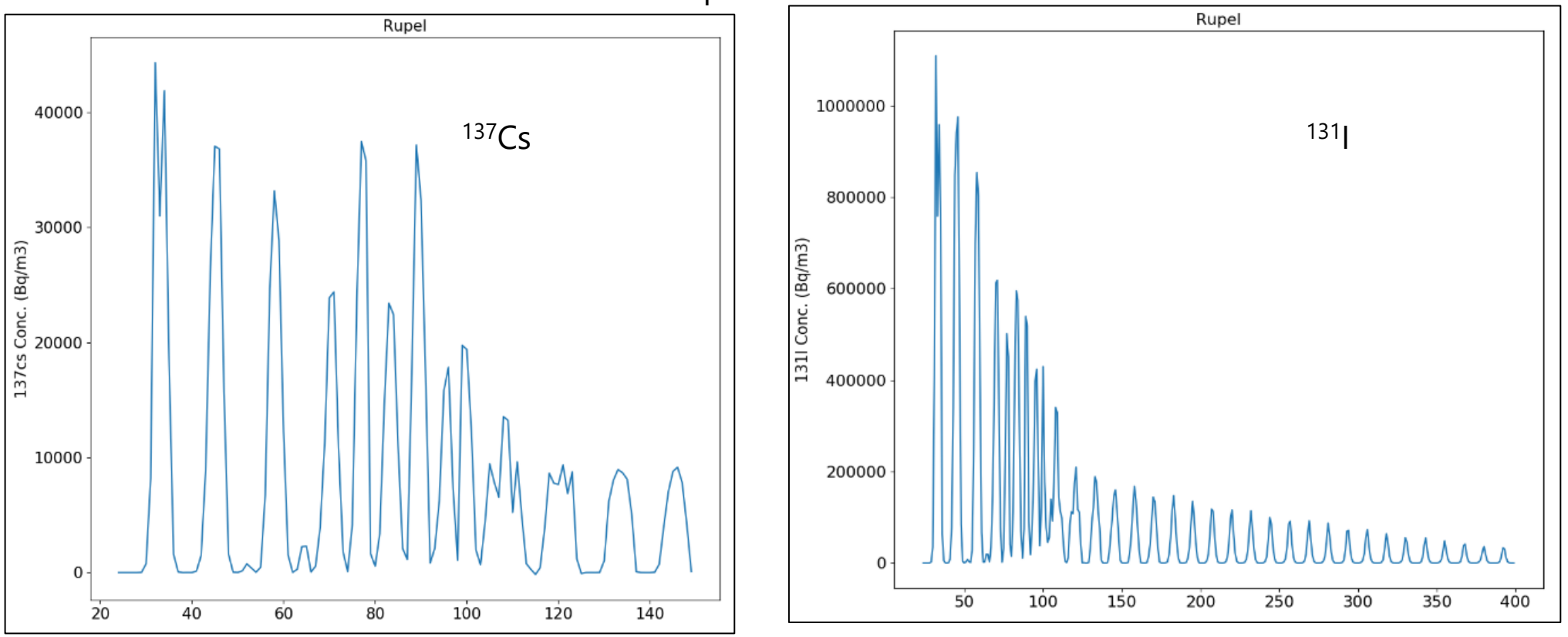
Time since after initial releases

- Slightly Larger impact than the Dyle river due to higher deposition.
- Order of magnitude remains the same

Scenario 2 and 4: Concentration at different rivers

Releases from Doel Nuclear Power Plant

Rupel River



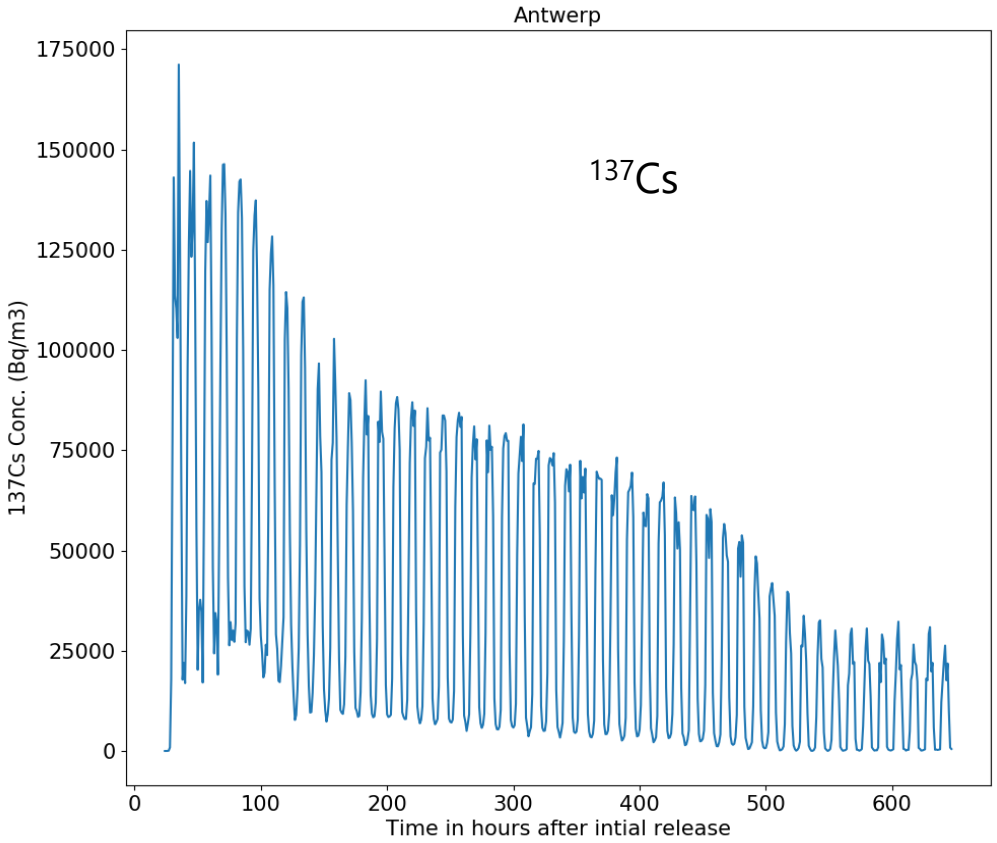
Time since after initial releases

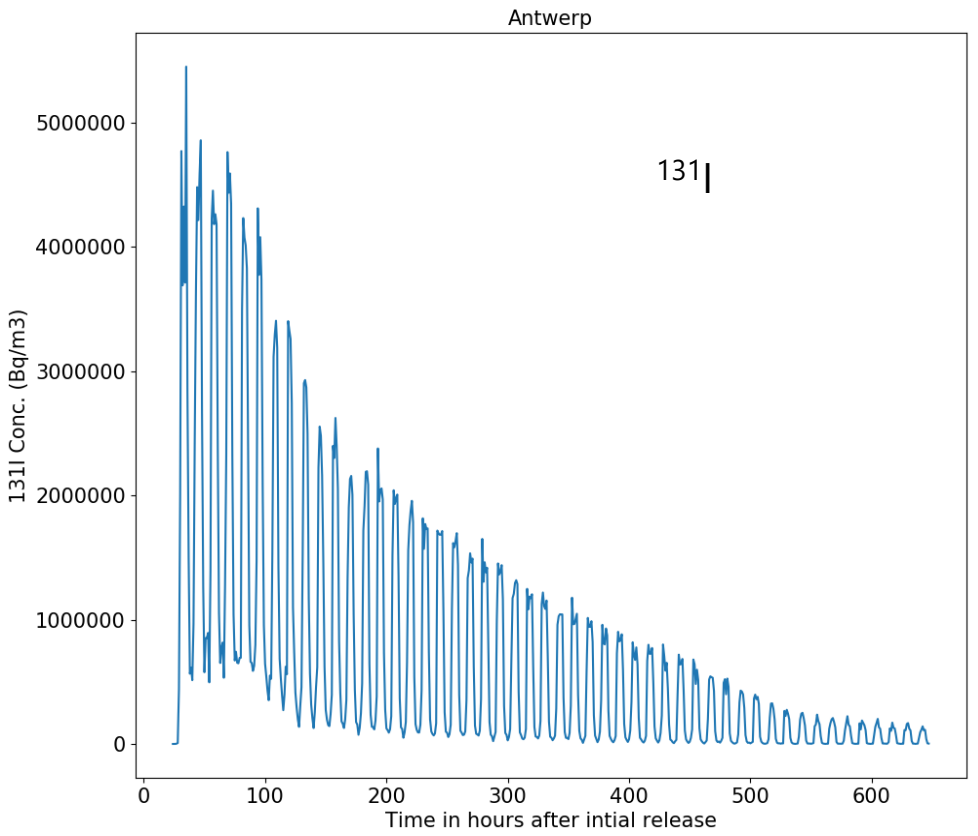
- It takes roughly 6 days to reach below the safe concentration threshold in Rupel for ^{137}Cs and around 19 days in the case of ^{131}I
- The spikes between days 2 and 3, both the plumes join in the Rupel River and travel towards the estuary

Scenario 2 and 4: Concentration at different rivers

Releases from Doel Nuclear Power Plant

Antwerp





Time since after initial releases

- Maximum value is almost immediate which is also highest compared to the other scenarios
- After approximately 3 weeks, the ^{137}Cs appears to stabilize for up to 4 days with variations up to 30 KBq/m^3

Direct release scenarios

Doel Nuclear power plant

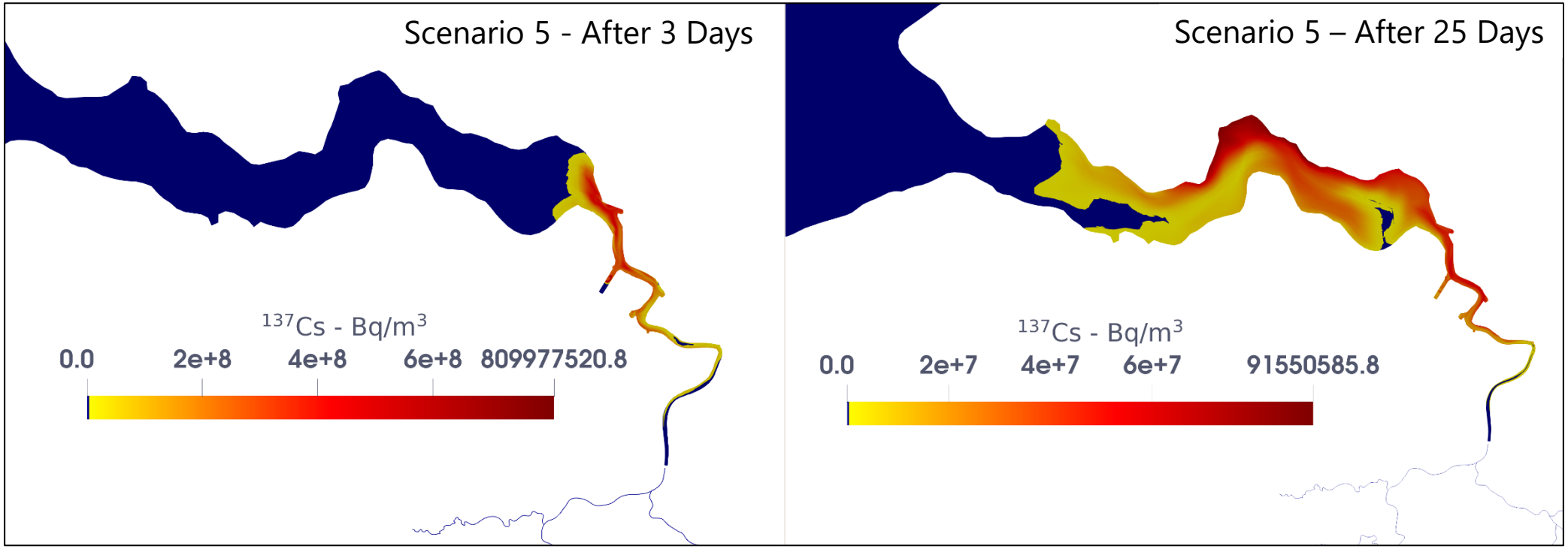
Table 2. Summary of estimates of total releases to the marine environment in the initial phase (March–April 2011)

Radionuclide	*Estimated release in the initial phase*	*References*
DIRECT RELEASES FROM THE FDNPS SITE		
^{137}Cs (and ^{134}Cs)	3.5–5.6 PBq	[E6, K11, K30, M35, T48, T49]
^{131}I	9–13 PBq	[K11, K30, T48]

Scenarios	**NPP**	**Pathway**	**Source term**	**Release time**
5	Doel NPP	Direst release	127 GBq/min (I-131)	6-hour release
6			52 GBq/min (Cs – 137)	

Scenario- Direct releases

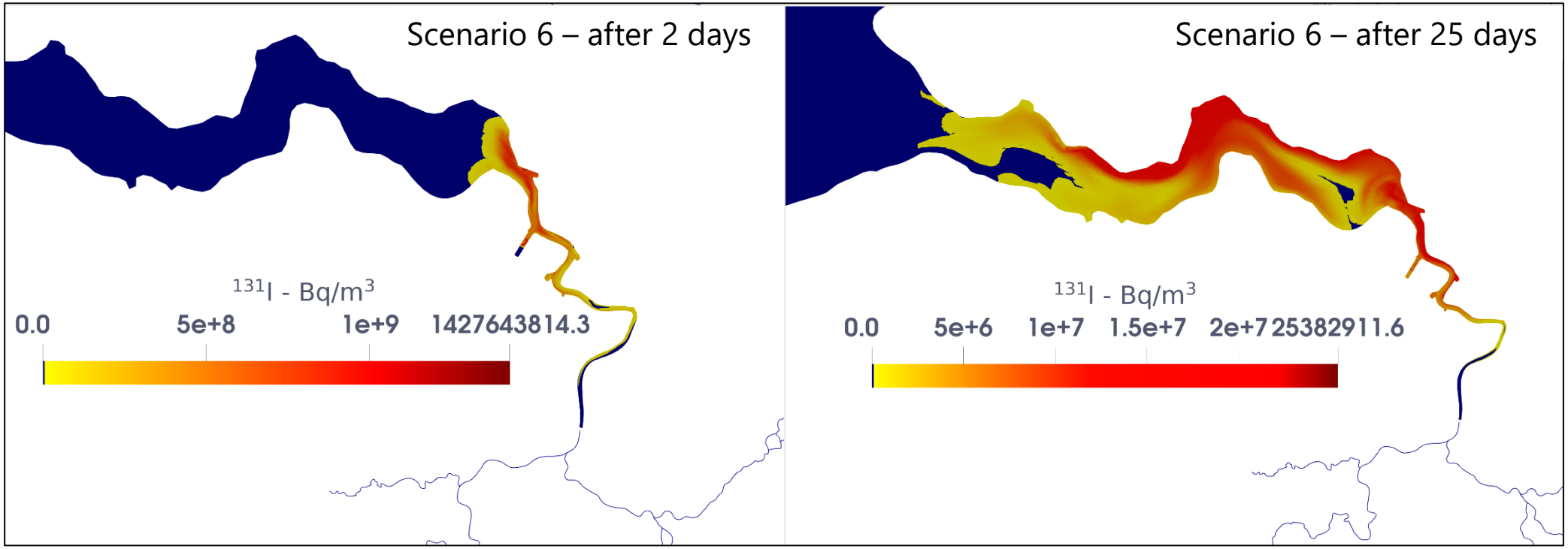
Releases from Doel Nuclear Power Plant



- The entire lower estuary becomes contaminated within a few days and begins to penetrate the upper estuary

Scenario- Direct releases

Releases from Doel Nuclear Power Plant

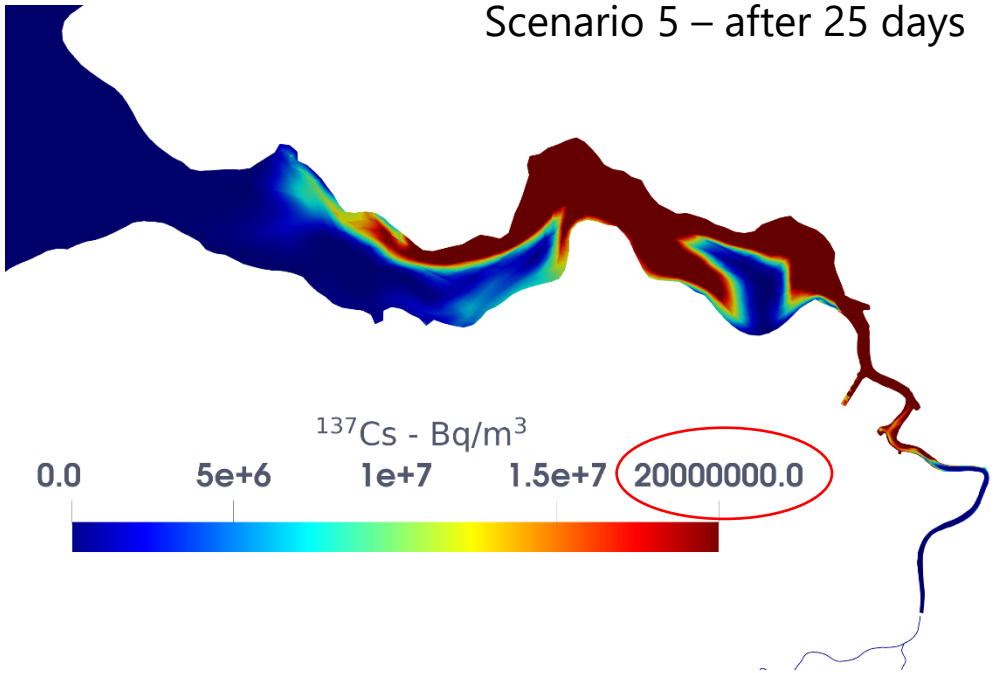


- the affected areas (>10000 Bq/m3) after two days of release for both radionuclides are comparable
- the total inventory released in these scenarios is 45.72 TBq of ^{131}I and 1.8 TBq of ^{137}Cs

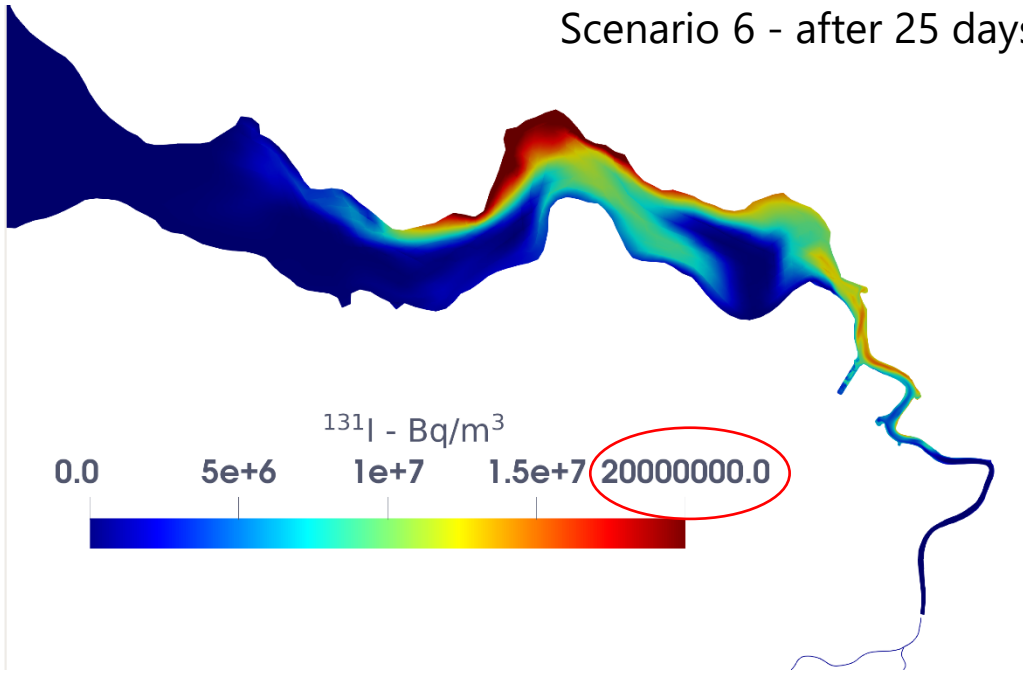
Scenario- Direct releases

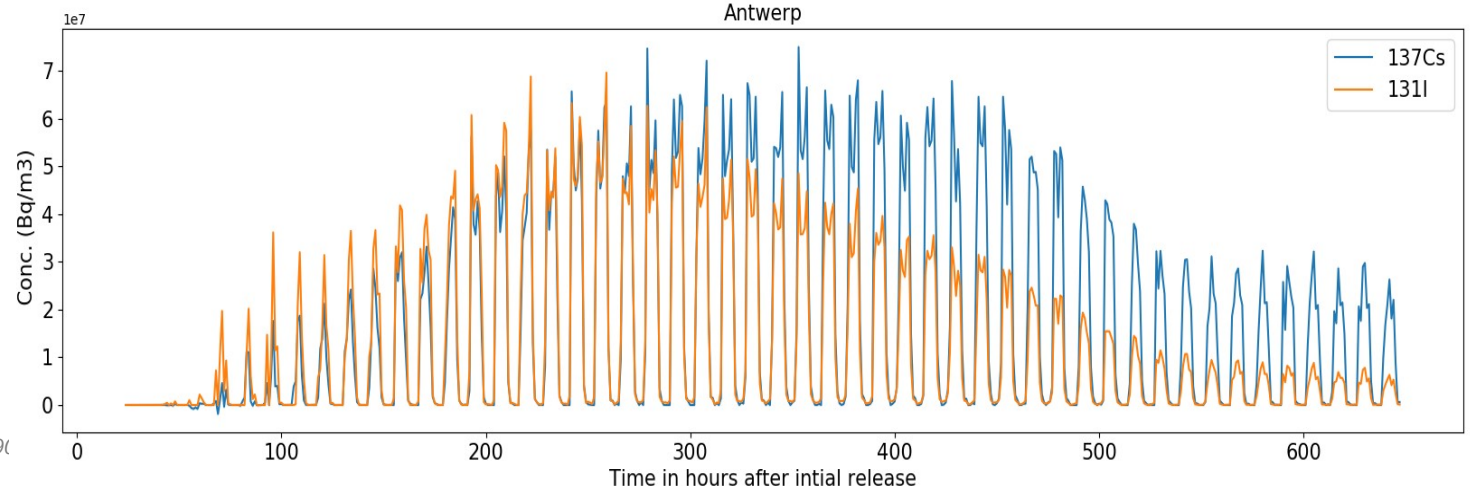
Releases from Doel Nuclear Power Plant

Scenario 5 – after 25 days



Scenario 6 - after 25 days

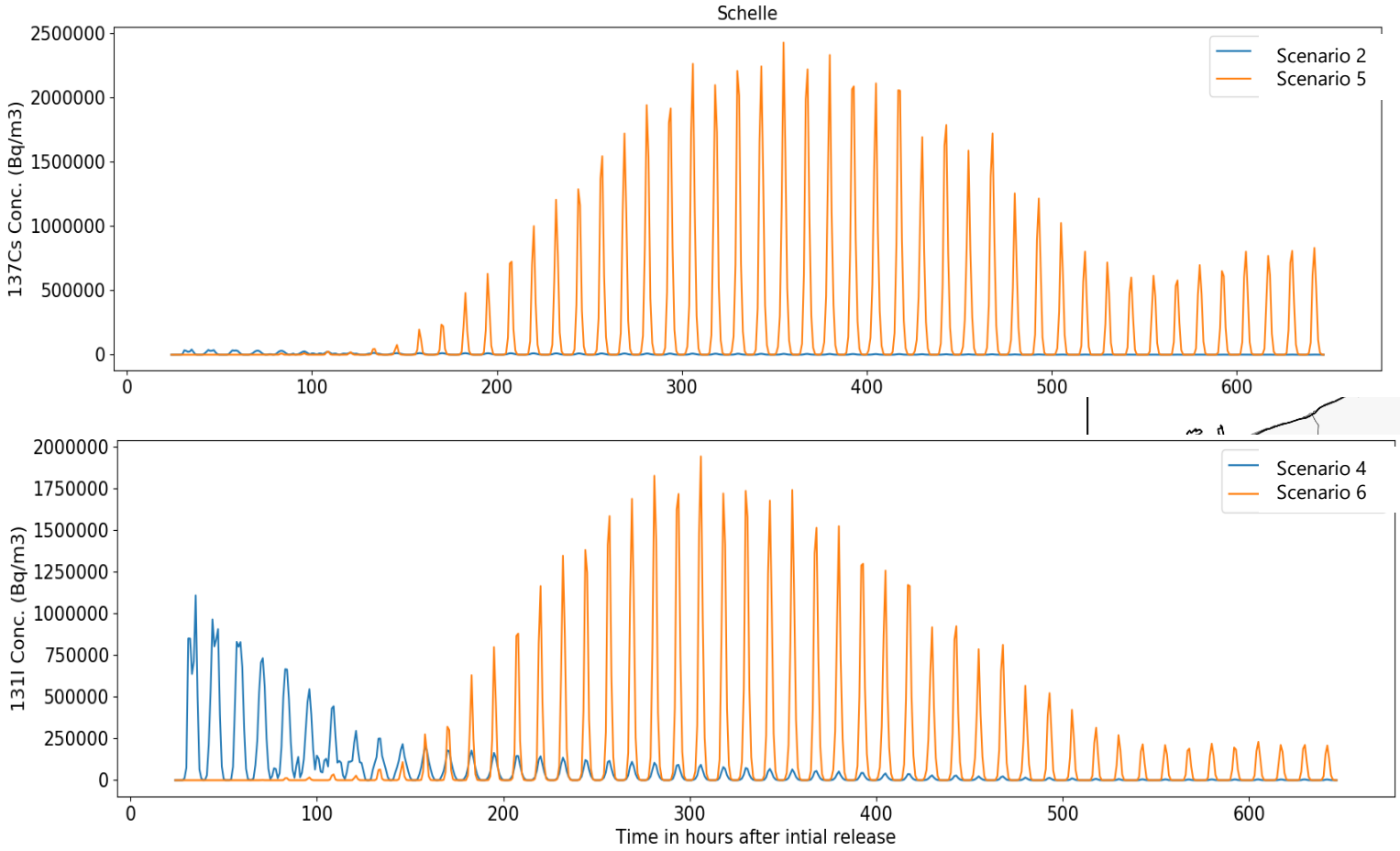


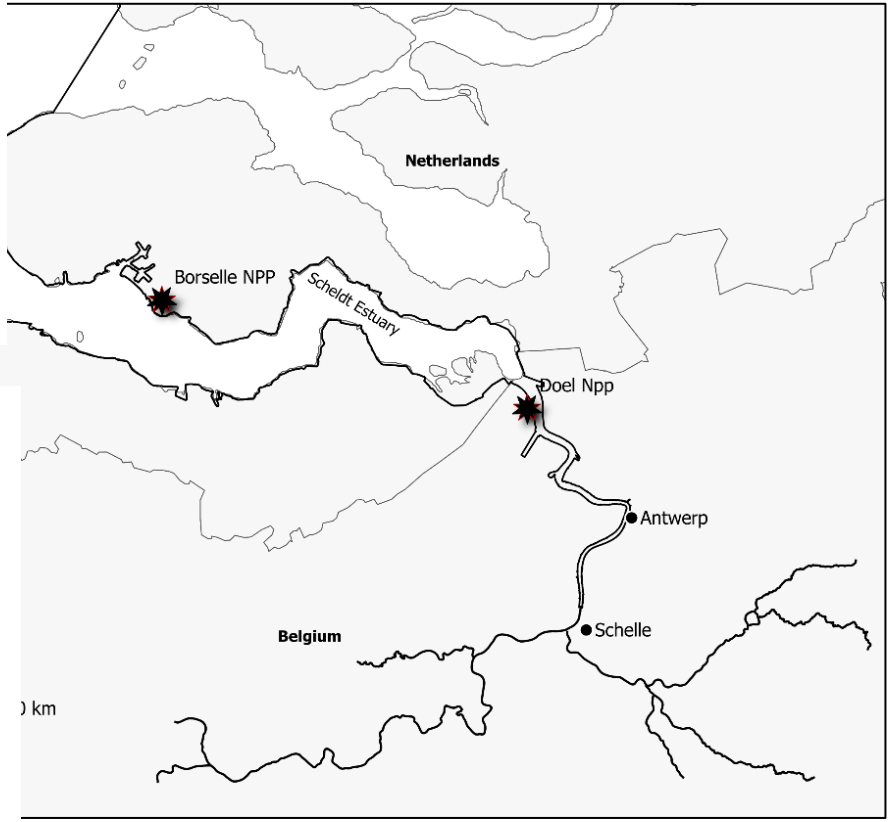


^{131}I decay Impact

Scenario- Direct releases

Releases from Doel Nuclear Power Plant





- Extent of affected areas toward inland rivers appears to be greater in these scenarios than in the others
- The concentration in direct release scenario stays below the safe level for up to 3-4 days
- Due to the late arrival of the radionuclide plume at this location, the peak concentration of ^{131}I (1.9 GBq/m^3) is actually lower than that of ^{137}Cs (2.56 GBq/m^3).

Thank You