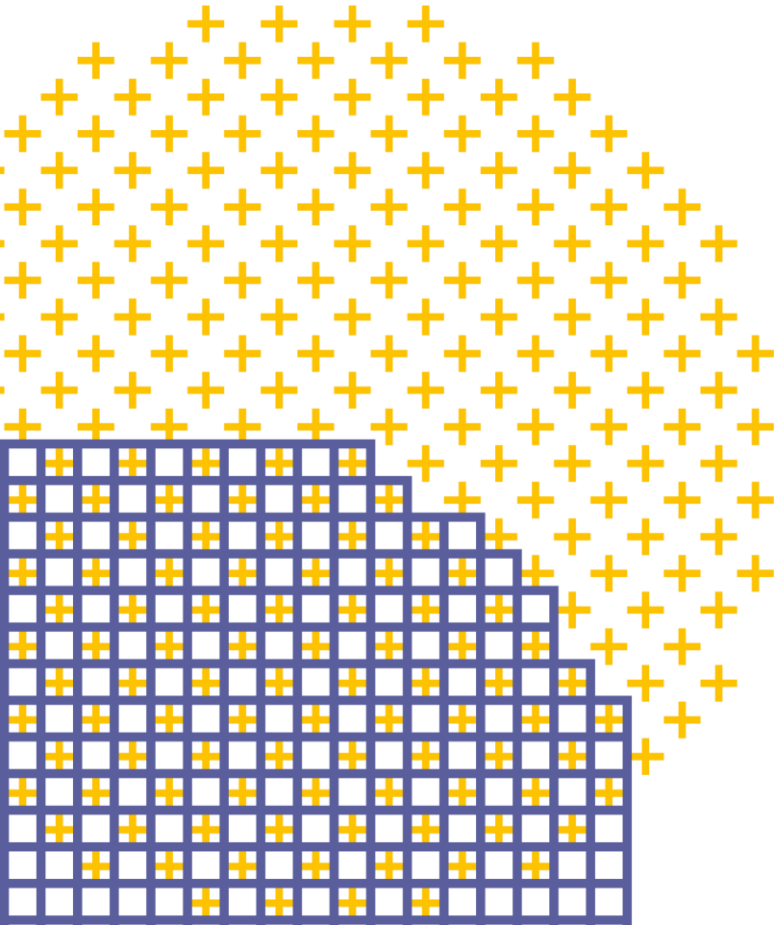
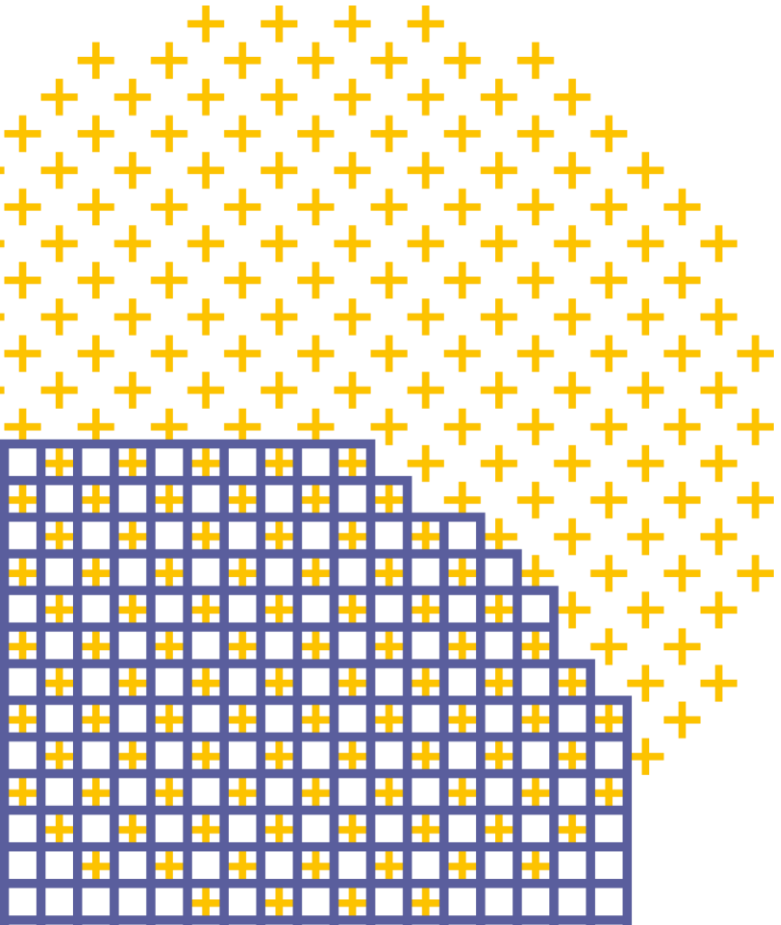


NATIONAL DIGITAL TWIN PROGRAMME

Climate Resilience Demonstrator (CReDo)

Jethro Akroyd
Jens Jensen
Benjamin Mawdsley



NATIONAL DIGITAL TWIN PROGRAMME

CReDo – an introduction

Benjamin Mawdsley
Hartree Centre - STFC

Climate and our national infrastructure

- National infrastructure can be vulnerable to **extreme weather events**
- The impact of these events can be surprising and severe
- Climate Change Committee report[1]:

"***Whilst understanding of sectoral risks has improved over the last few years, the impacts of climate change could be amplified by interdependencies between infrastructure sectors, and these interactions are not well understood***."

BBC Sign in Home News Sport Weather iPlayer Sounds

NEWS

Home | War in Ukraine | Coronavirus | Climate | UK | World | Business | Politics | Tech | Science | Health

UK | England | N. Ireland | Scotland | Alba | Wales | Cymru | Isle of Man | Guernsey | Jersey | Local News

Storm Eunice: Power cuts continue amid new yellow warnings

By Victoria Lindrea & Mary O'Connor
BBC News

19 February

Storm Dennis: Treherbert flooding due to overwhelmed pipes finds

A report into the cause of flooding in Treherbert finds five drainage tunnels became overwhelmed.

17 November 2021 | News | Wales

BBC Sign in Home News Sport Weather iPlayer Sounds

NEWS

Home | War in Ukraine | Coronavirus | Climate | UK | World | Business | Politics | Tech | Science | Health

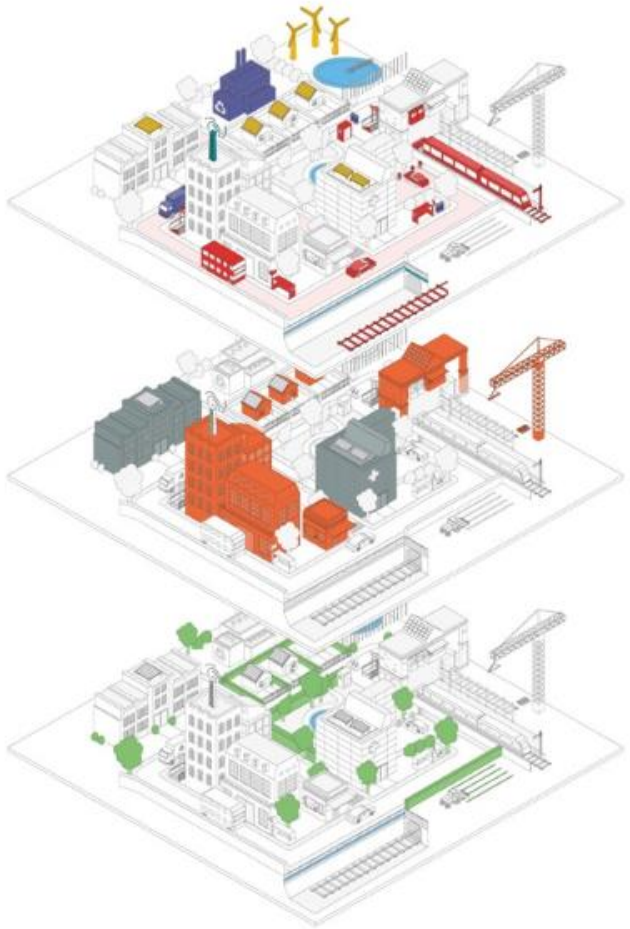
England | Local News | Regions | Cumbria

Storm Arwen: Why power cuts left people unable to phone for help

By Francesca Williams
BBC News

12 December 2021

1) https://www.theccc.org.uk/uk-climate-change-risk-assessment-2017/ccra-chapters/infrastructure/



Economic Infrastructure

Social Infrastructure

Natural Infrastructure

Built Environment

CReDo is a climate change adaptation digital twin

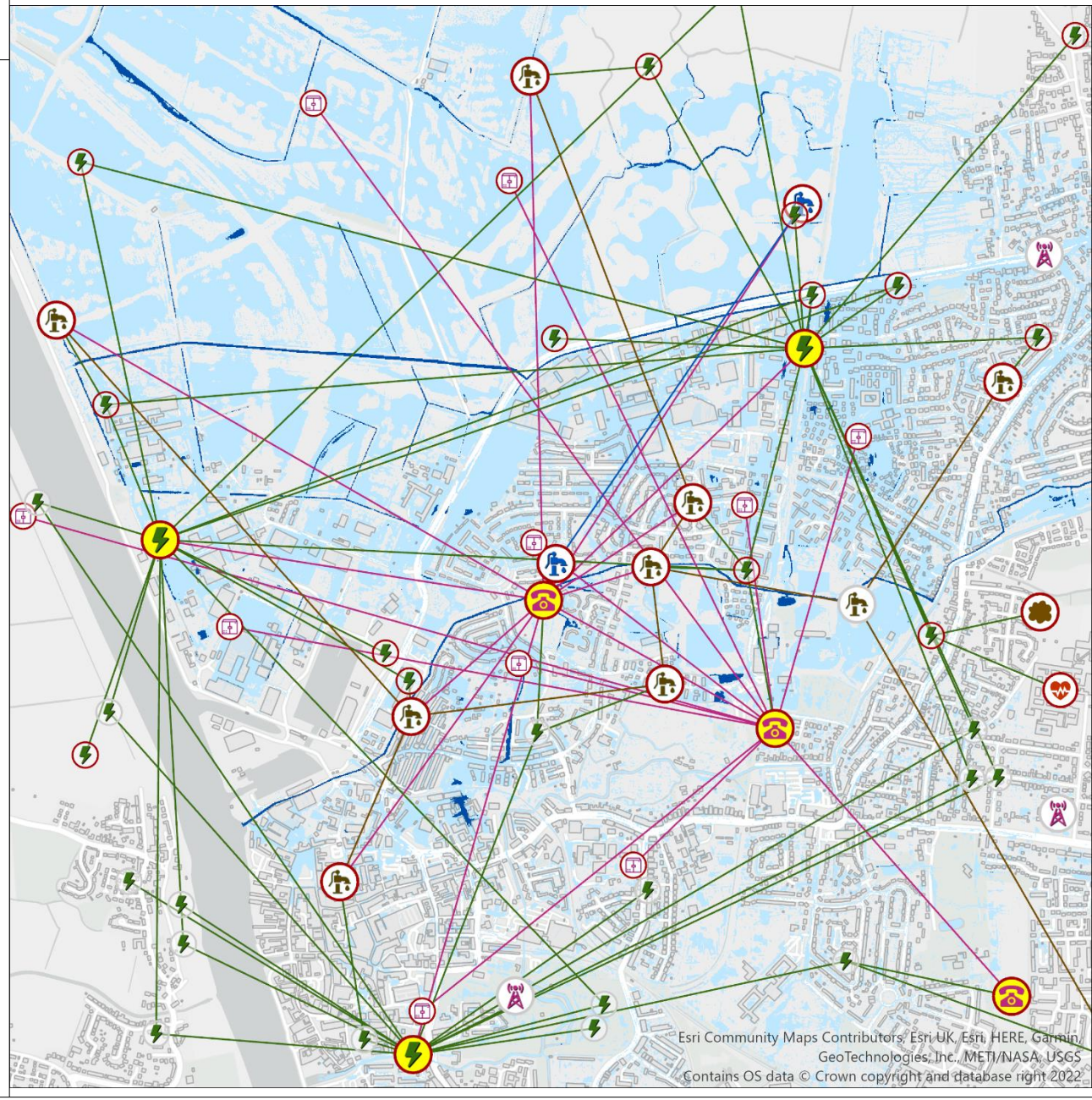
CReDo brings together data across energy, water and telecoms networks

- Anglian Water's water and sewerage assets,
- BT's communication assets and
- UKPN's power network assets.

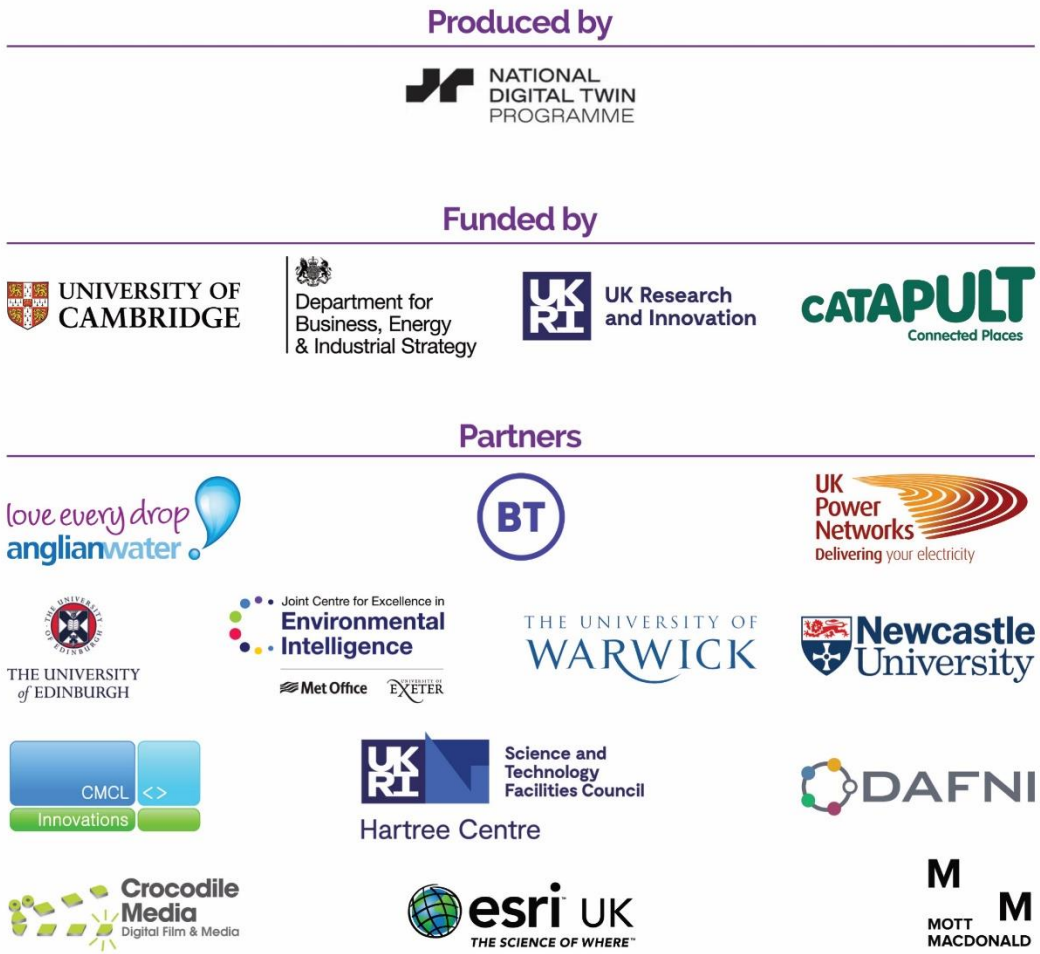
with flood data to understand

- Infrastructure interdependencies
- Asset failure and system impact
- What can we do to prepare or respond?

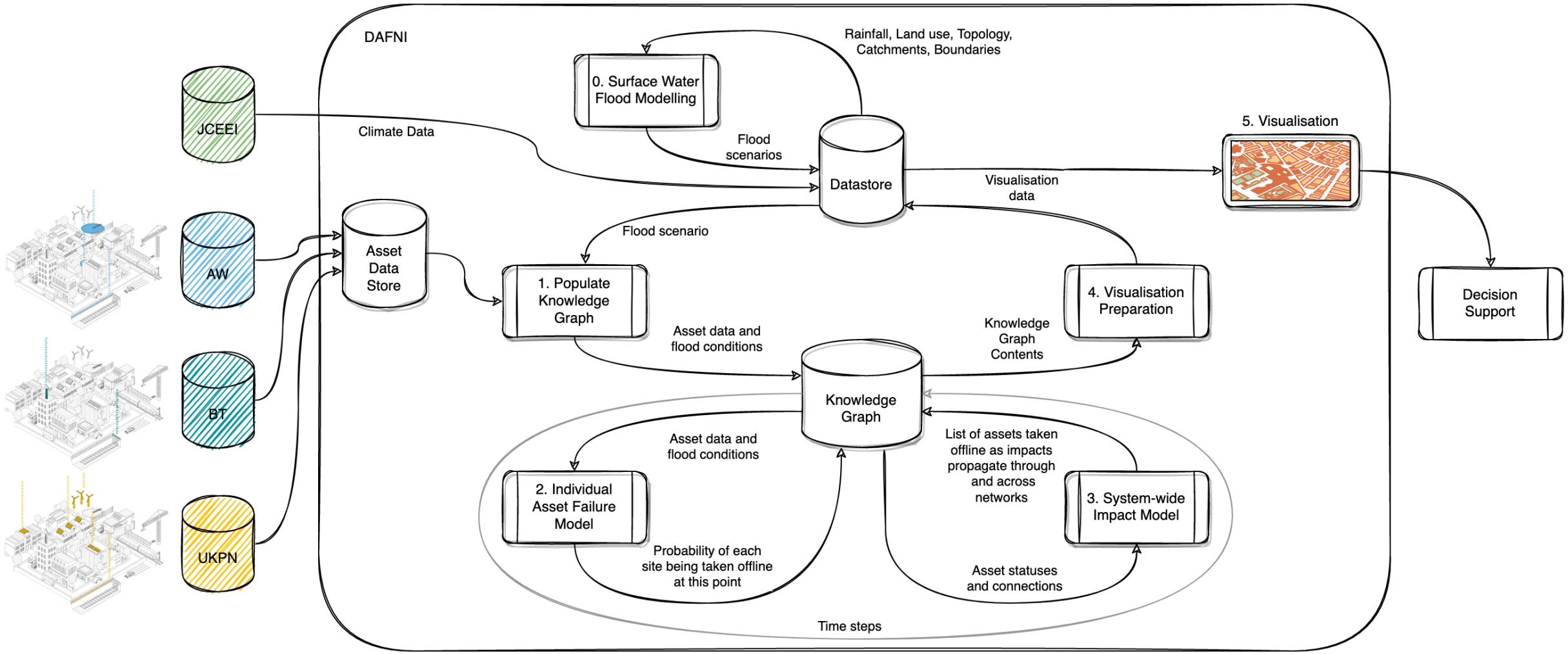
How do we increase system resilience and adapt?



The CReDo collaboration



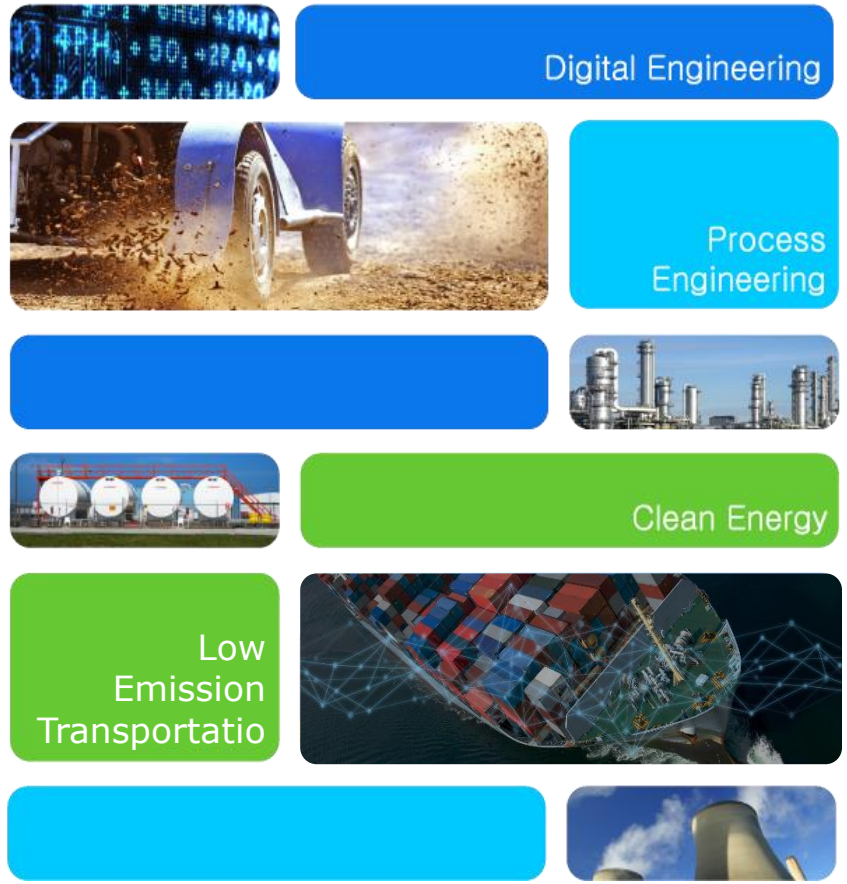
Building a Connected Digital Twin



CReDo
Climate Resilience Demonstrator

Demonstration

Jethro Akroyd
CMCL Innovations
14 June 2022



https://digitaltwinhub.co.uk/credo/
https://kg.cmclinnovations.com/credo/visualisation/

Camera: DoF

Bird's Eye
Pitched

Terrain: 3D

- Light
- Dark
- Outdoors
- Blueprint
- Satellite (Raw)
- Satellite (Labelled)

Layers:

- Area of interest
- Flood depth
- Communications Network
  - Exchange
  - Mobile mast
  - Cabinet
- Water Network
  - Sludge Site
  - Water Site
  - Sewage Site
- Power Network
  - Secondary sub-station
  - Primary sub-station
- Connections
  - Supplies phone to
  - Supplies power to
  - Supplies sewage to
  - Supplies water to
- Environment Agency
- Buildings
  - Education
  - Medical care
  - Emergency services

Scenario: 1:100 yr, 8 hr, 45% uplift

Timestep: 0

Longitude: 1.48380
Latitude: 55.36169

CReDo: The National Digital Twin Climate Resilience Demonstrator Project

Increasing our climate resilience through connected digital twins.

CReDo is a climate change adaptation digital twin looking at the impact of flooding on infrastructure interdependencies across energy, water and telecoms networks:

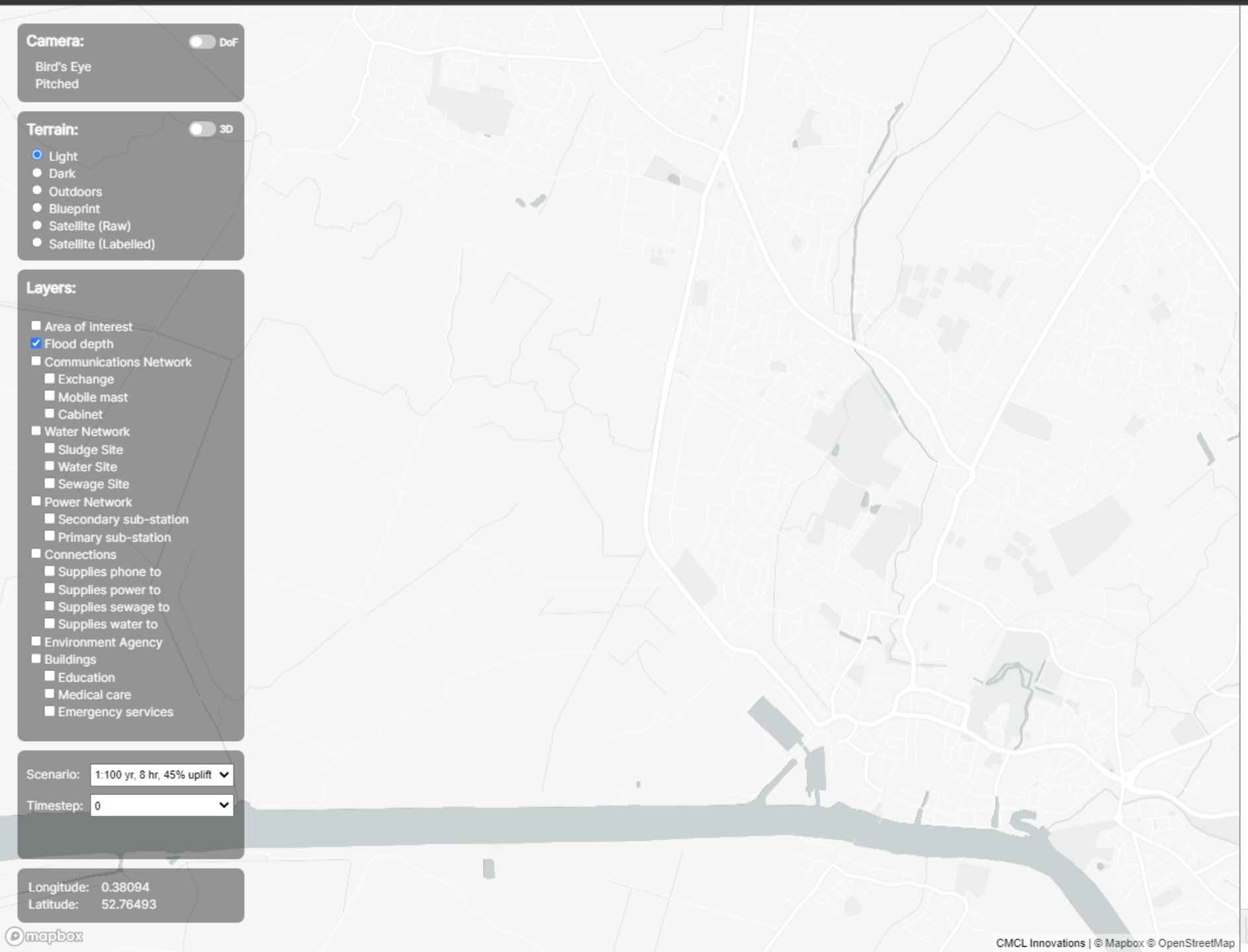
- Anglian Water's water and sewerage assets
- BT's communication assets and
- UKPN's power network assets

In the future, CReDo could inform decisions in operations and capital planning, and real-time response to extreme weather events caused by climate change.

Read more about the CReDo Digital Twin and how it was created here.

Details on the Digital Twin's data coverage can be seen here.

General | Legend | Additional Files



CReDo: The National Digital Twin Climate Resilience Demonstrator Project

Water Network:

- Clean Water Sites
- Sewage Sites
- Sludge Sites
- Masts
- Other Sites

Communications Network:

- Cabinets
- Exchanges
- Masts
- Other Sites

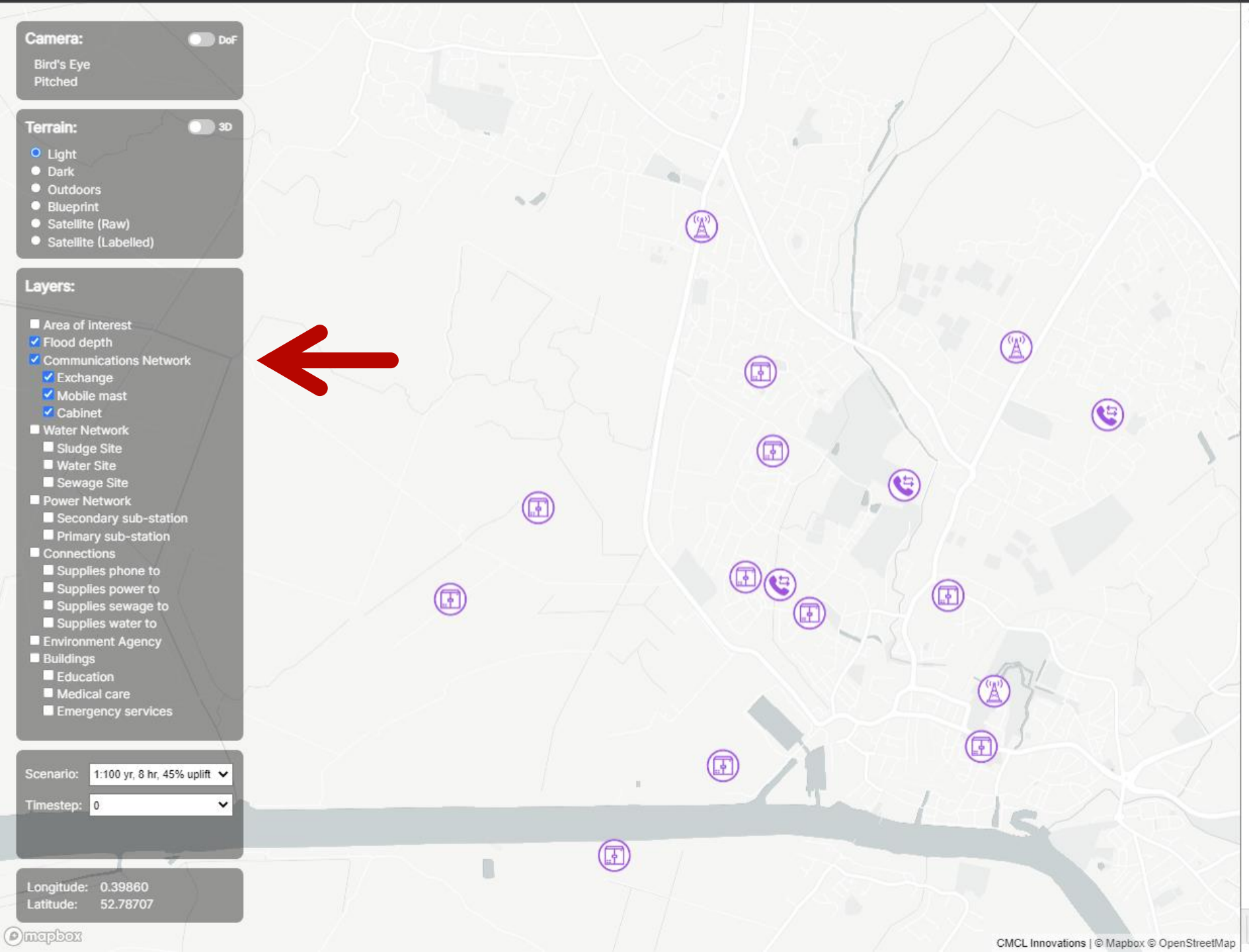
Power Network:

- Primary Substations
- Secondary Substations
- Other Sites

Environment Agency:

- Flow
- Water Level
- Rainfall
- Temperature
- Wind

General | Legend | Additional Files



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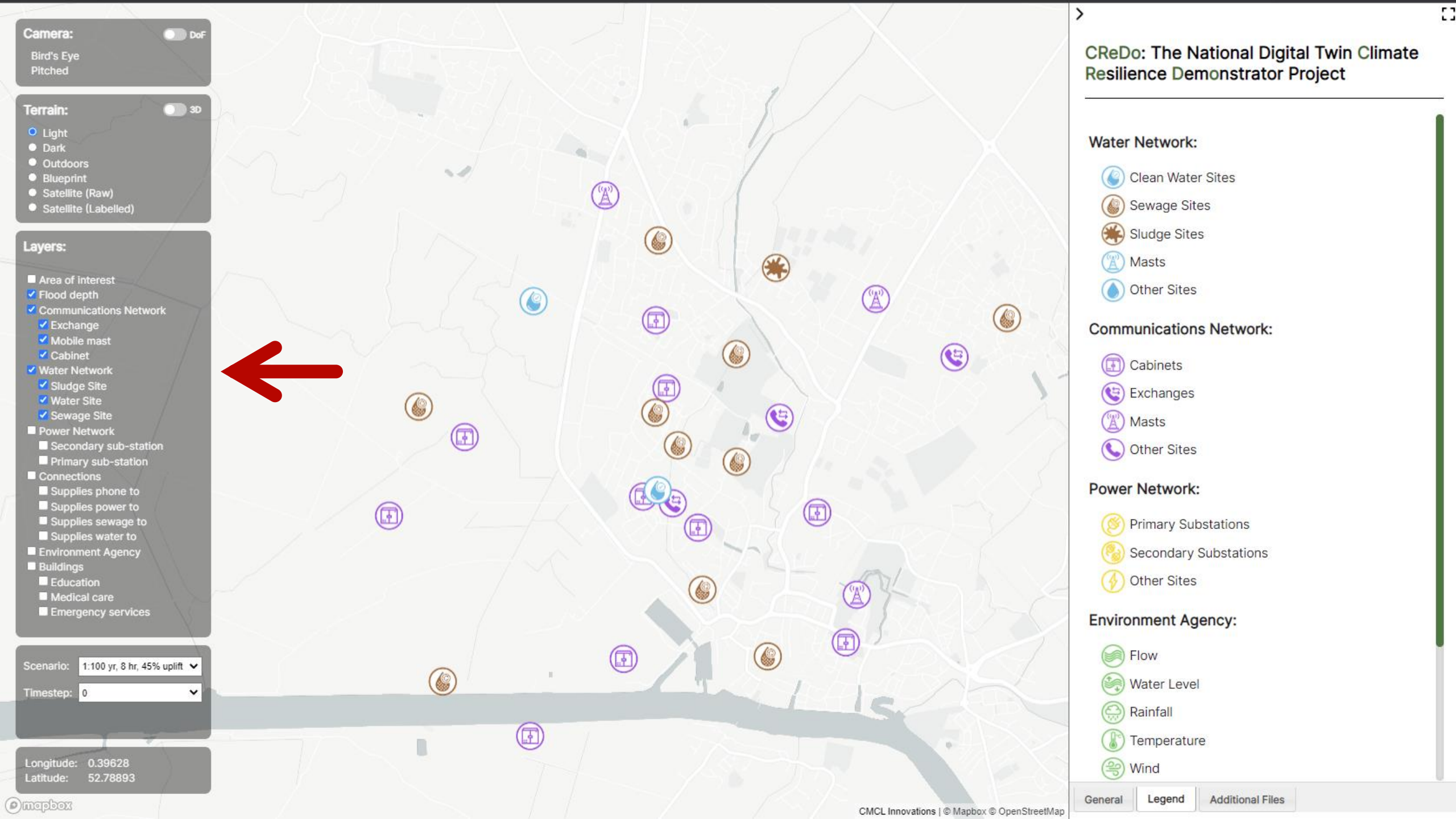
General | Legend | Additional Files



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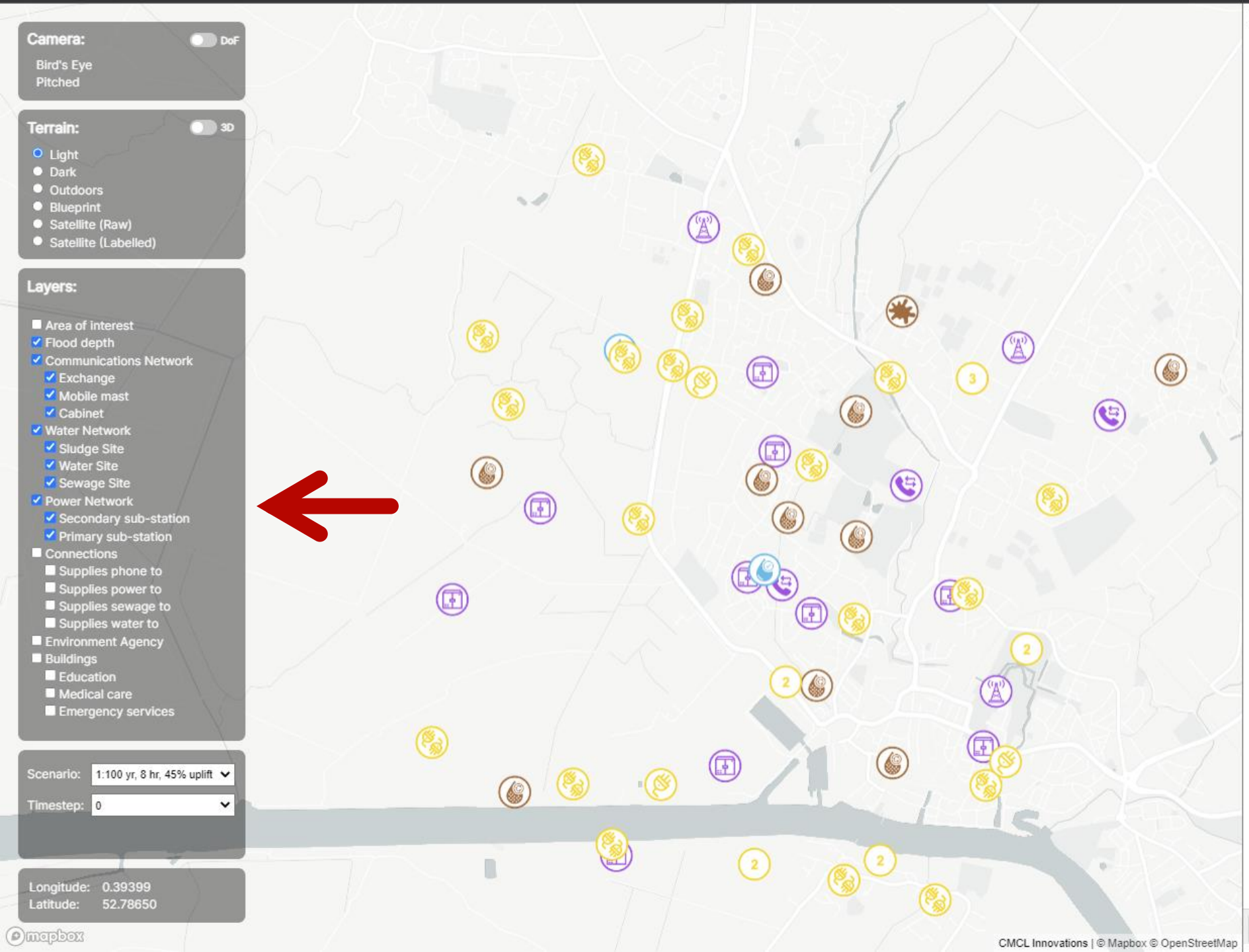
General | Legend | Additional Files



CReDo: The National Digital Twin Climate Resilience Demonstrator Project

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- Water Level
- Rainfall
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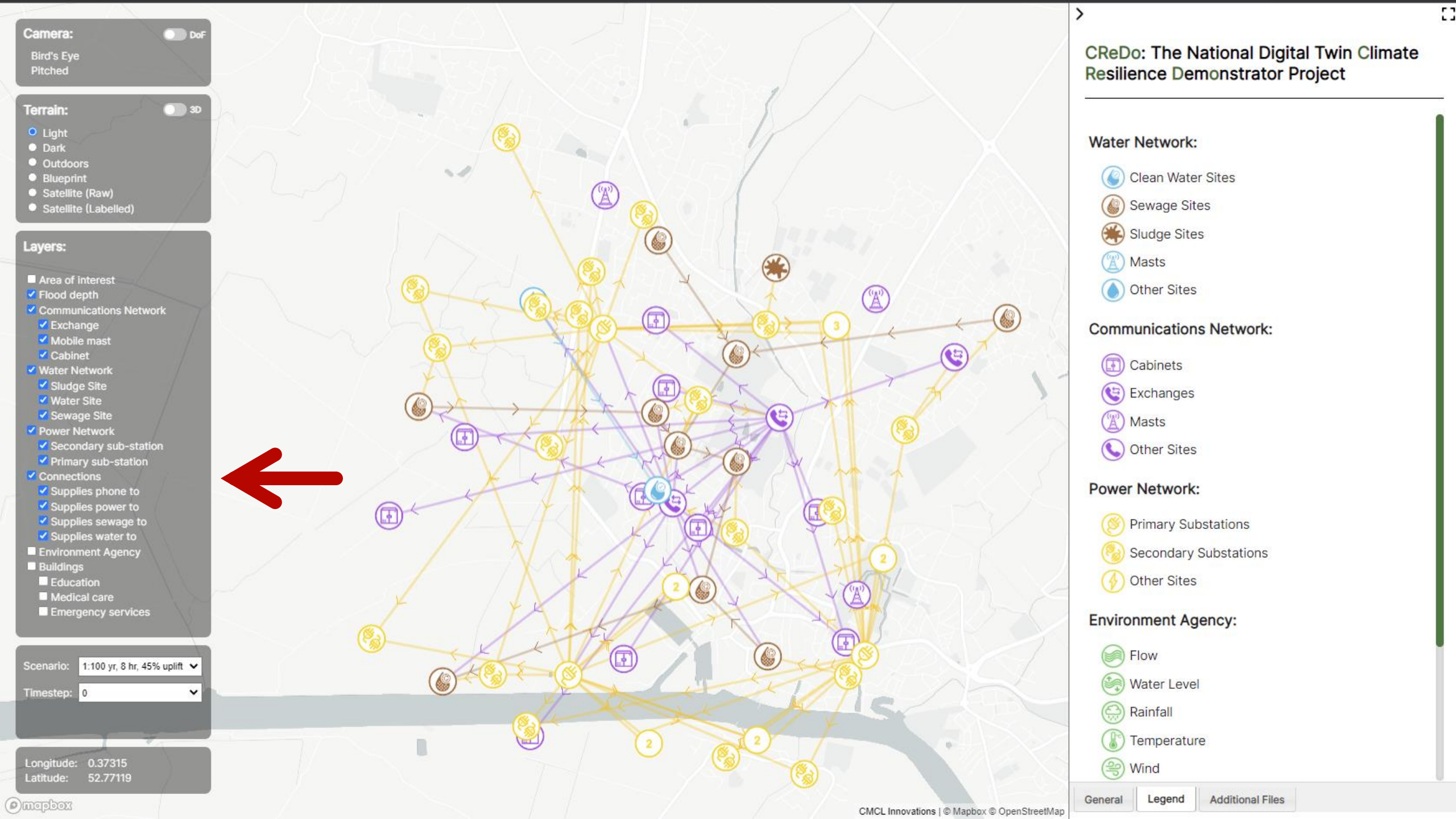
- Wind

General | Legend | Additional Files


Camera:
DoF
Bird's Eye
Pitched
Terrain:
3D
Light
Dark
Outdoors
Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
Flood depth
Communications Network
Exchange
Mobile mast
Cabinet
Water Network
Sludge Site
Water Site
Sewage Site
Power Network
Secondary sub-station
Primary sub-station
Connections
Supplies phone to
Supplies power to
Supplies sewage to
Supplies water to
Environment Agency
Buildings
Education
Medical care
Emergency services
Scenario:
1:100 yr, 8 hr, 45% uplift
Timestep:
0
Longitude: 0.37315
Latitude: 52.77119
CReDo: The National Digital Twin Climate Resilience Demonstrator Project
Water Network:
Clean Water Sites
Sewage Sites
Sludge Sites
Masts
Other Sites
Communications Network:
Cabinets
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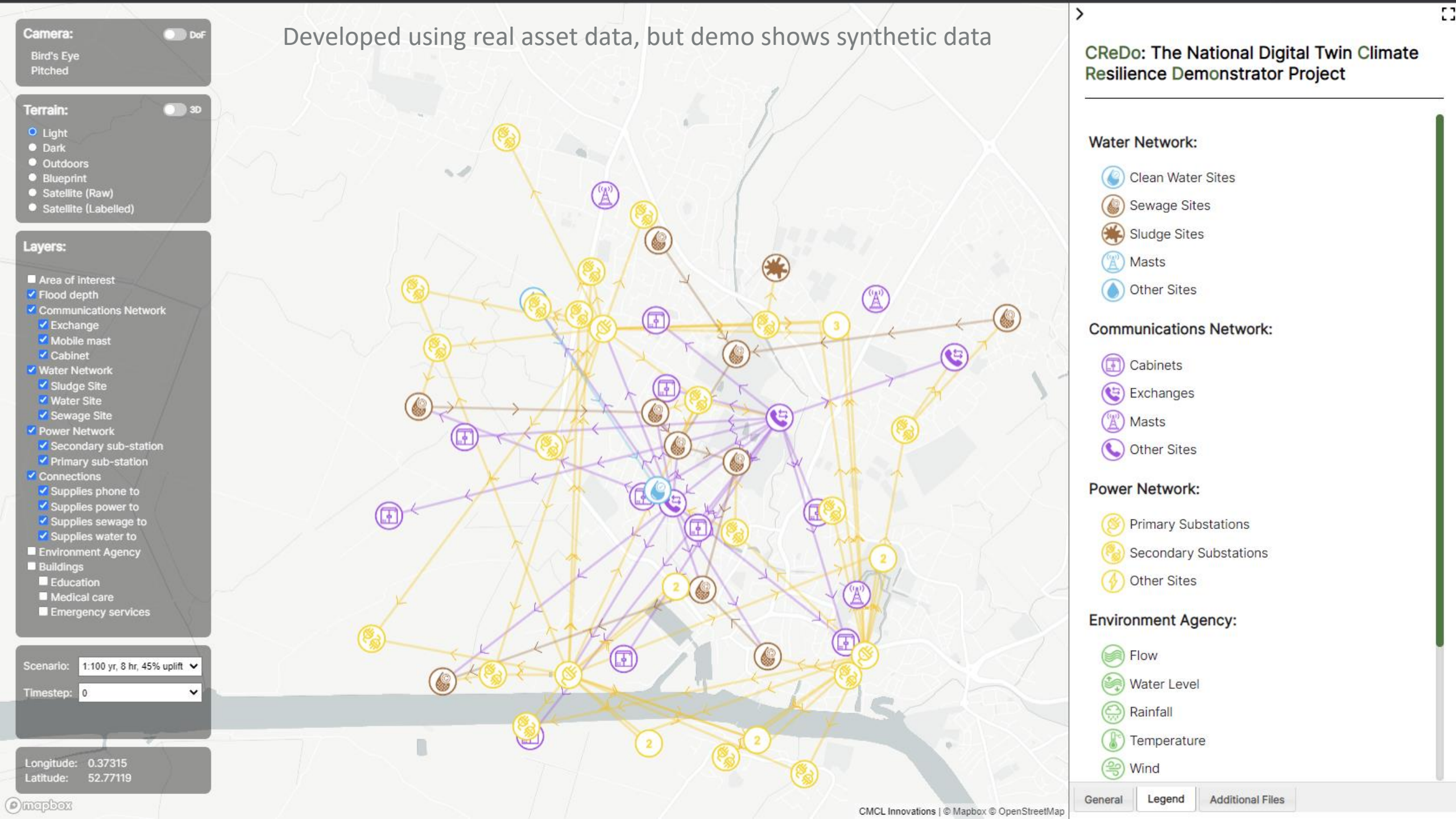
Masts
Other Sites
Power Network:
Primary Substations
Secondary Substations
Other Sites
Environment Agency:
Flow
Water Level
Rainfall
Temperature
Wind
General
Legend
Additional Files
mapbox
CMCL Innovations | © Mapbox © OpenStreetMap


Developed using real asset data, but demo shows synthetic data
Camera:
DoF
Bird's Eye
Pitched
Terrain:
3D
Light
Dark
Outdoors
Blueprint
Satellite (Raw)
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mapbox
CMCL Innovations | © Mapbox © OpenStreetMap
CReDo: The National Digital Twin Climate Resilience Demonstrator Project
Water Network:
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Cabinets
Exchanges
Masts
Other Sites
Power Network:
Primary Substations
Secondary Substations
Other Sites
Environment Agency:
Flow
Water Level
Rainfall
Temperature
Wind
General
Legend
Additional Files

Developed using real asset data, but demo shows synthetic data

Resembles data structure of underlying knowledge graph

Camera: DoF

Bird's Eye
Pitched

Terrain: 3D

- Light
- Dark
- Outdoors
- Blueprint
- Satellite (Raw)
- Satellite (Labelled)

Layers:

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  - Emergency services

Scenario: 1:100 yr, 8 hr, 45% uplift

Timestep: 0

Longitude: 0.37315
Latitude: 52.77119

mapbox

CMCL Innovations | © Mapbox © OpenStreetMap

CReDo: The National Digital Twin Climate Resilience Demonstrator Project

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Communications Network:

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- Other Sites

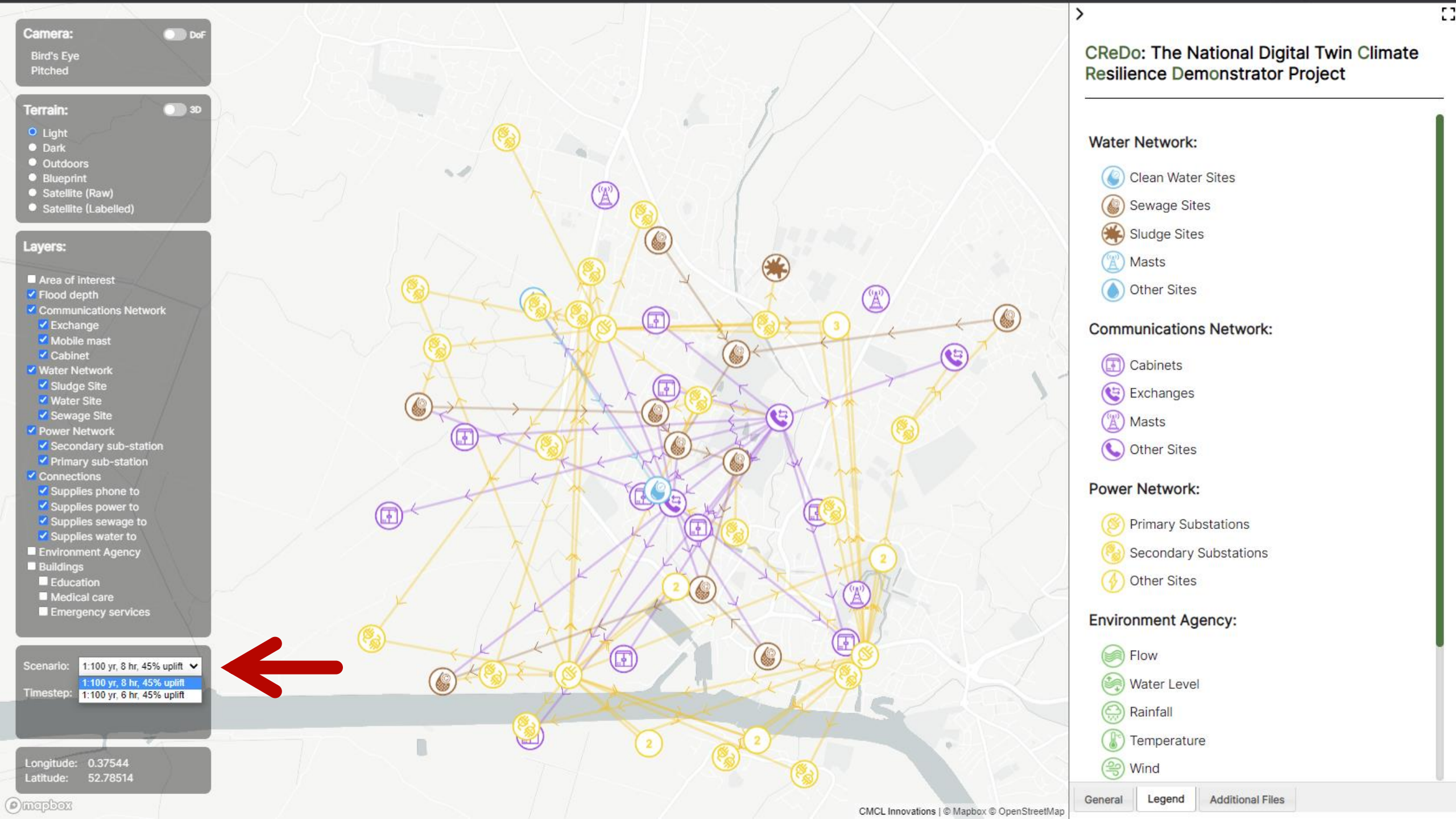
Power Network:

- Primary Substations
- Secondary Substations
- Other Sites

Environment Agency:

- Flow
- Water Level
- Rainfall
- Temperature
- Wind

General | Legend | Additional Files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Terrain:
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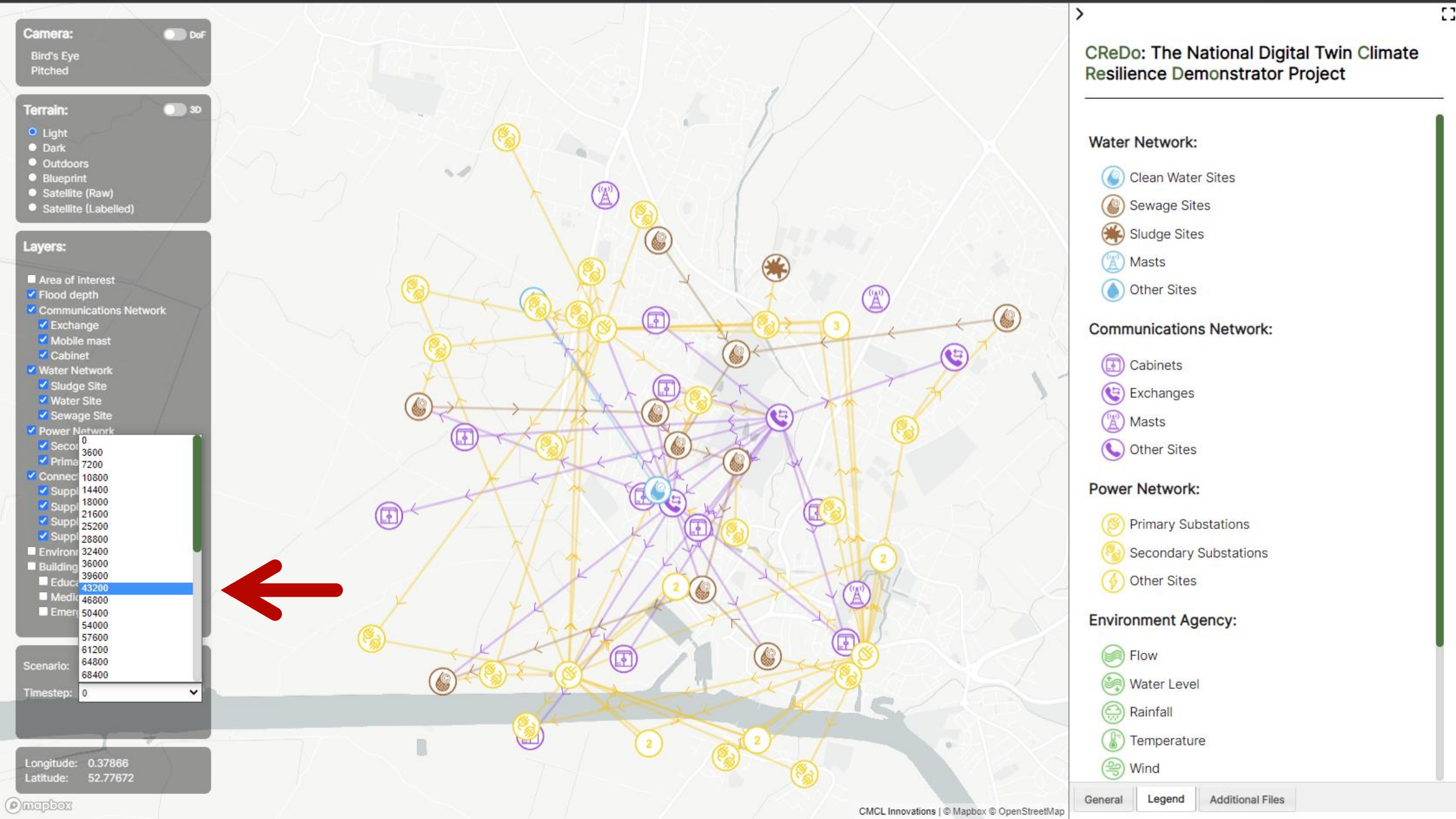
Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
Flood depth
Communications Network
Exchange
Mobile mast
Cabinet
Water Network
Sludge Site
Water Site
Sewage Site
Power Network
Secondary sub-station
Primary sub-station
Connections
Supplies phone to
Supplies power to
Supplies sewage to
Supplies water to
Environment Agency
Buildings
Education
Medical care
Emergency services
Scenario:
1:100 yr, 8 hr, 45% uplift
Timestep:
1:100 yr, 8 hr, 45% uplift
1:100 yr, 6 hr, 45% uplift
Longitude: 0.37544
Latitude: 52.78514
mapbox
CMCL Innovations | © Mapbox © OpenStreetMap
CReDo: The National Digital Twin Climate Resilience Demonstrator Project
Water Network:
Clean Water Sites
Sewage Sites
Sludge Sites
Masts
Other Sites
Communications Network:
Cabinets
Exchanges
Masts
Other Sites
Power Network:
Primary Substations
Secondary Substations
Other Sites
Environment Agency:
Flow
Water Level
Rainfall
Temperature
Wind
General
Legend
Additional Files


Camera:
DoF
Bird's Eye
Pitched
Terrain:
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Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
Flood depth
Communications Network
Exchange
Mobile mast
Cabinet
Water Network
Sludge Site
Water Site
Sewage Site
Power Network
0
3600
7200
10800
14400
18000
21600
25200
28800
32400
36000
39600
43200
46800
50400
54000
57600
61200
64800
68400
Scenario:
Timestep:
0
Longitude: 0.37866
Latitude: 52.77672
CReDo: The National Digital Twin Climate Resilience Demonstrator Project
Water Network:
Clean Water Sites
Sewage Sites
Sludge Sites
Masts
Other Sites
Communications Network:
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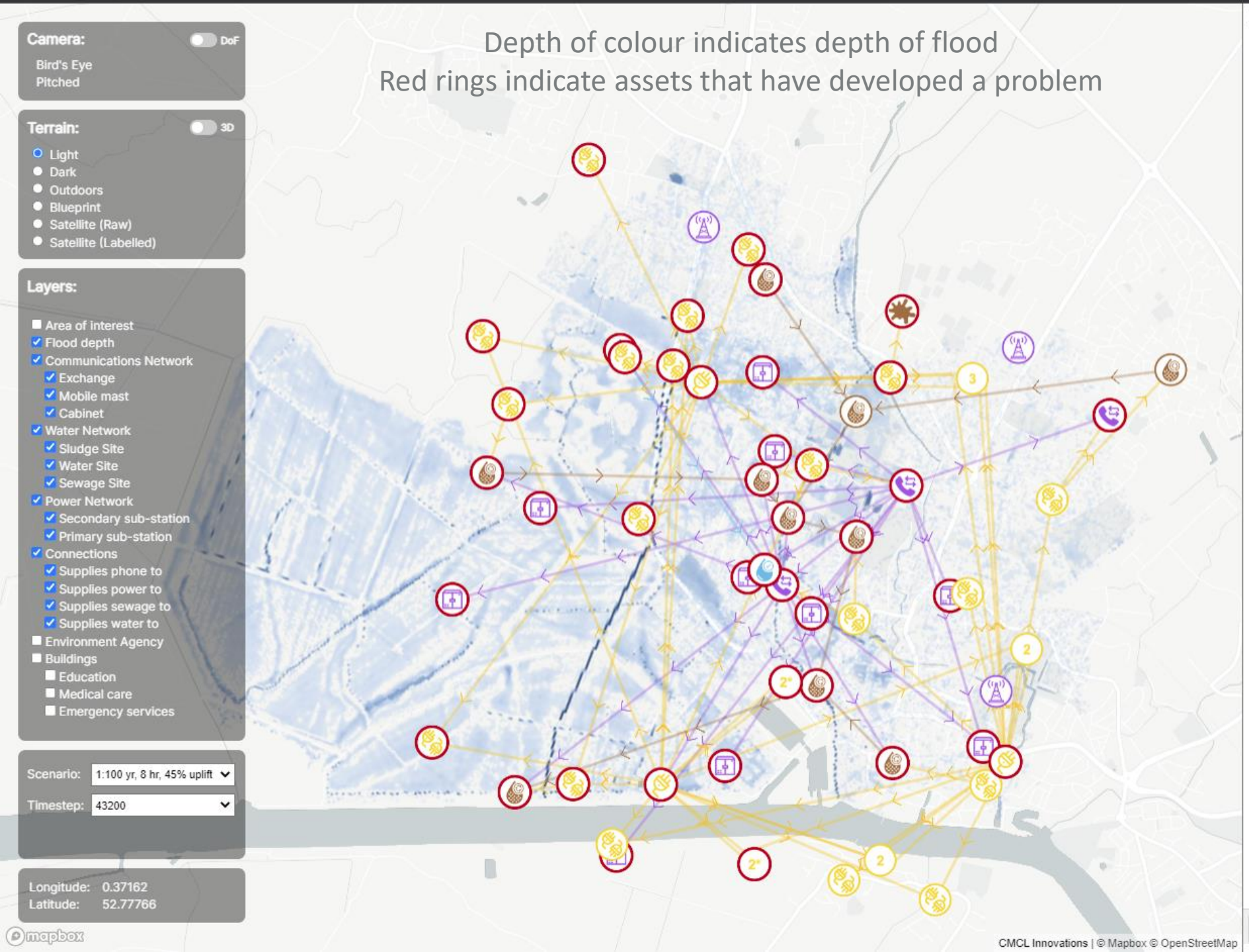
mapbox
CMCL Innovations | © Mapbox © OpenStreetMap



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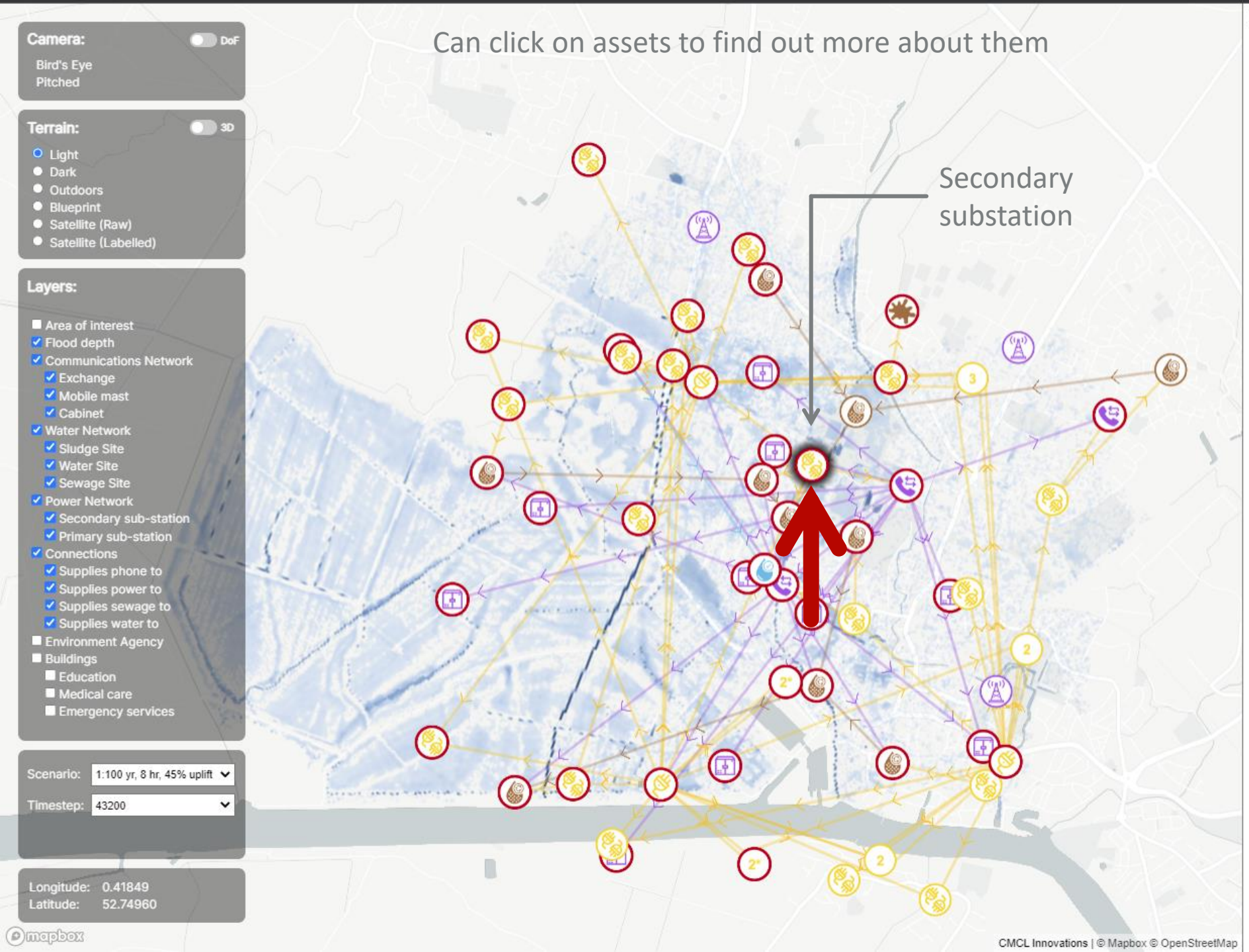
Environment Agency:

- Flow
- Water Level
- Rainfall
- Temperature
- Wind

General | Legend | Additional Files



Power Network: Secondary sub-station (Secondary Substation 18)

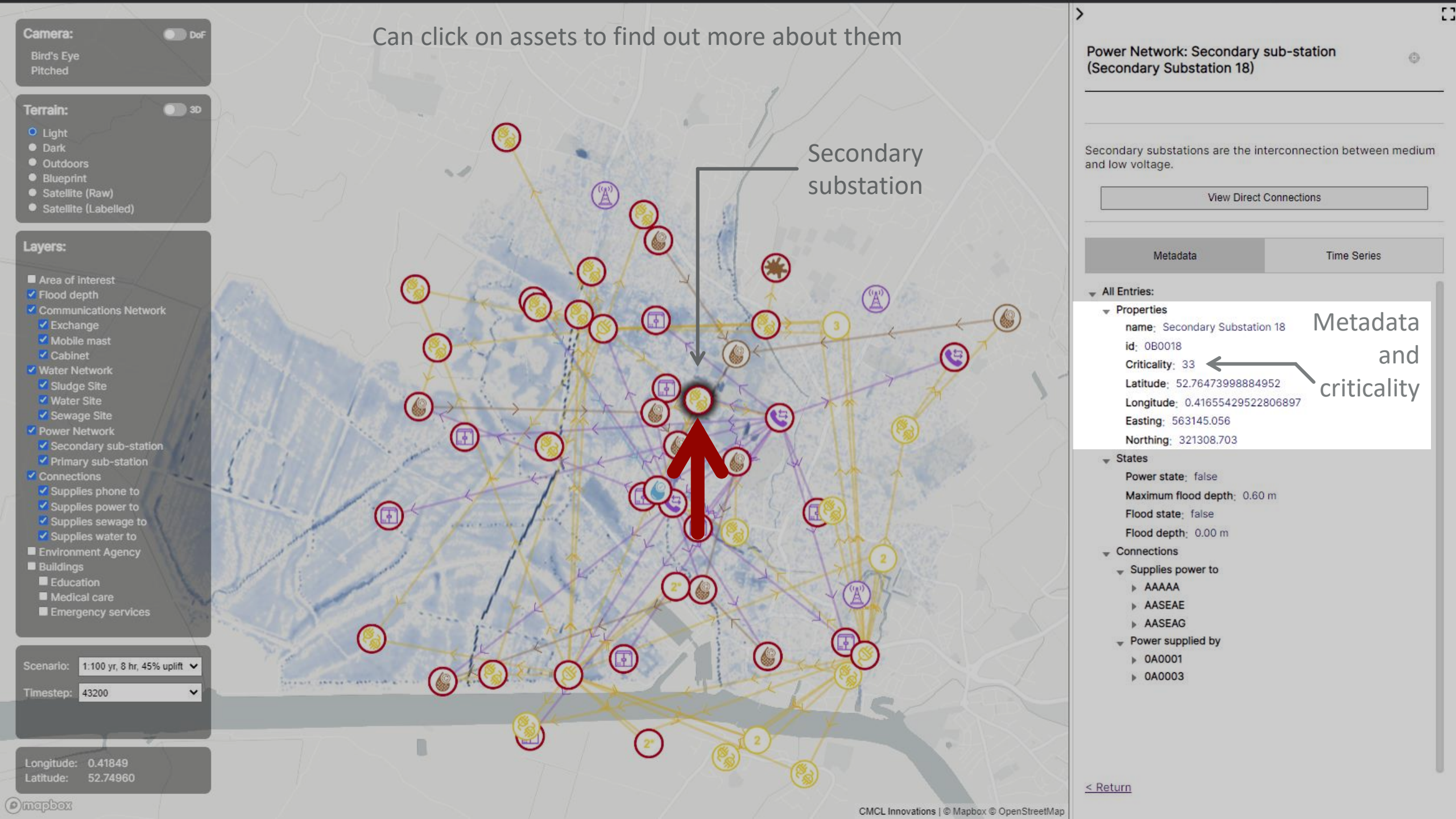
Secondary substations are the interconnection between medium and low voltage.

View Direct Connections

Metadata | Time Series

- All Entries:
  - Properties
    - name: Secondary Substation 18
    - id: 0B0018
    - Criticality: 33
    - Latitude: 52.76473998884952
    - Longitude: 0.41655429522806897
    - Easting: 563145.056
    - Northing: 321308.703
  - States
    - Power state: false
    - Maximum flood depth: 0.60 m
    - Flood state: false
    - Flood depth: 0.00 m
  - Connections
    - Supplies power to
      - AAAAA
      - AASEAE
      - AASEAG
    - Power supplied by
      - 0A0001
      - 0A0003

< Return


Can click on assets to find out more about them
Secondary substation
Metadata and criticality
Camera:
DoF
Bird's Eye
Pitched
Terrain:
3D
Light
Dark
Outdoors
Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
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Water Network
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Water Site
Sewage Site
Power Network
Secondary sub-station
Primary sub-station
Connections
Supplies phone to
Supplies power to
Supplies sewage to
Supplies water to
Environment Agency
Buildings
Education
Medical care
Emergency services
Scenario: 1:100 yr, 8 hr, 45% uplift
Timestep: 43200
Longitude: 0.41849
Latitude: 52.74960
Power Network: Secondary sub-station (Secondary Substation 18)
Secondary substations are the interconnection between medium and low voltage.
View Direct Connections
Metadata
Time Series
All Entries:
Properties
name: Secondary Substation 18
id: 0B0018
Criticality: 33
Latitude: 52.76473998884952
Longitude: 0.41655429522806897
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Northing: 321308.703
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AASEAE
AASEAG
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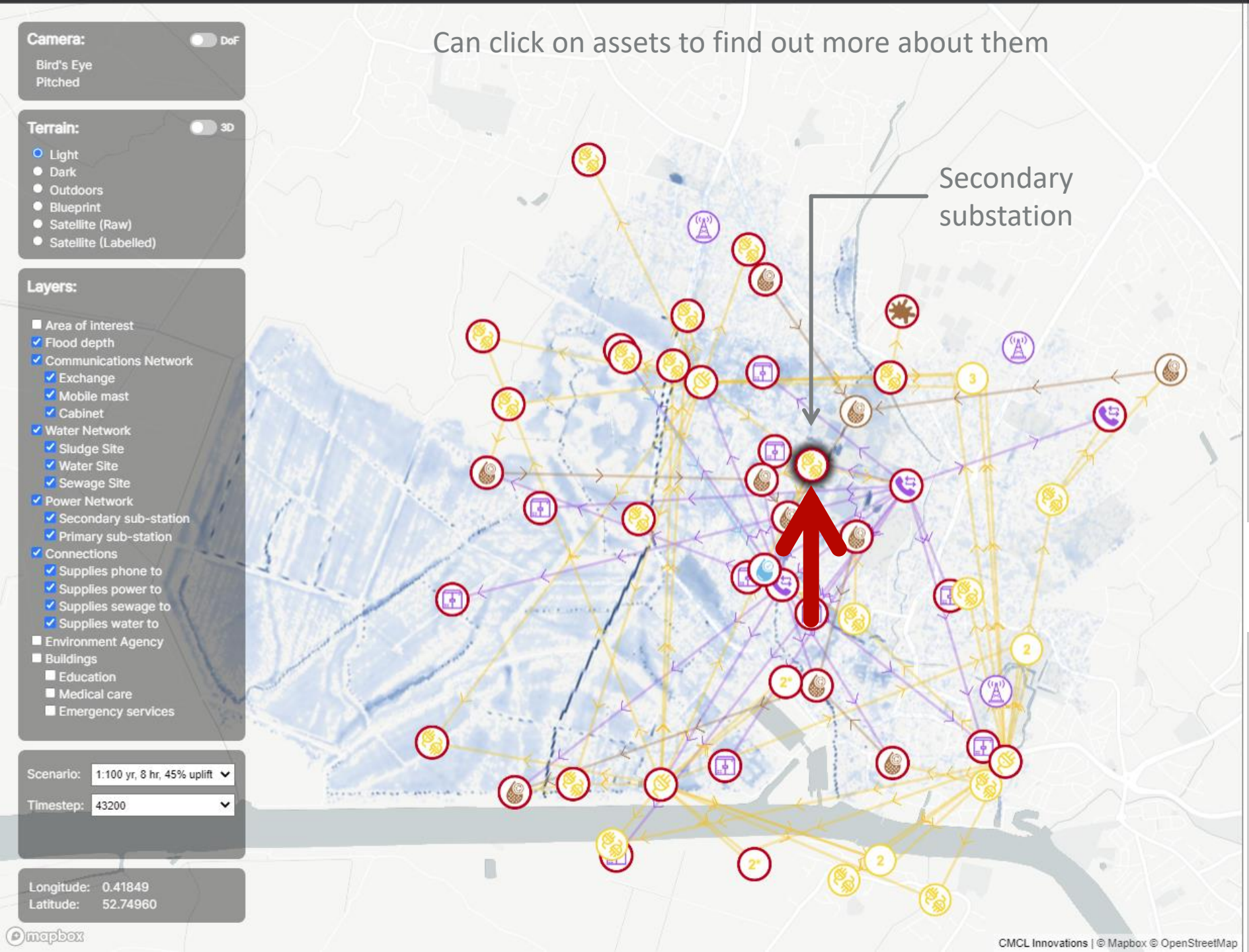
0A0001
0A0003
< Return
mapbox
CMCL Innovations | © Mapbox © OpenStreetMap



Power Network: Secondary sub-station (Secondary Substation 18)

Secondary substations are the interconnection between medium and low voltage.

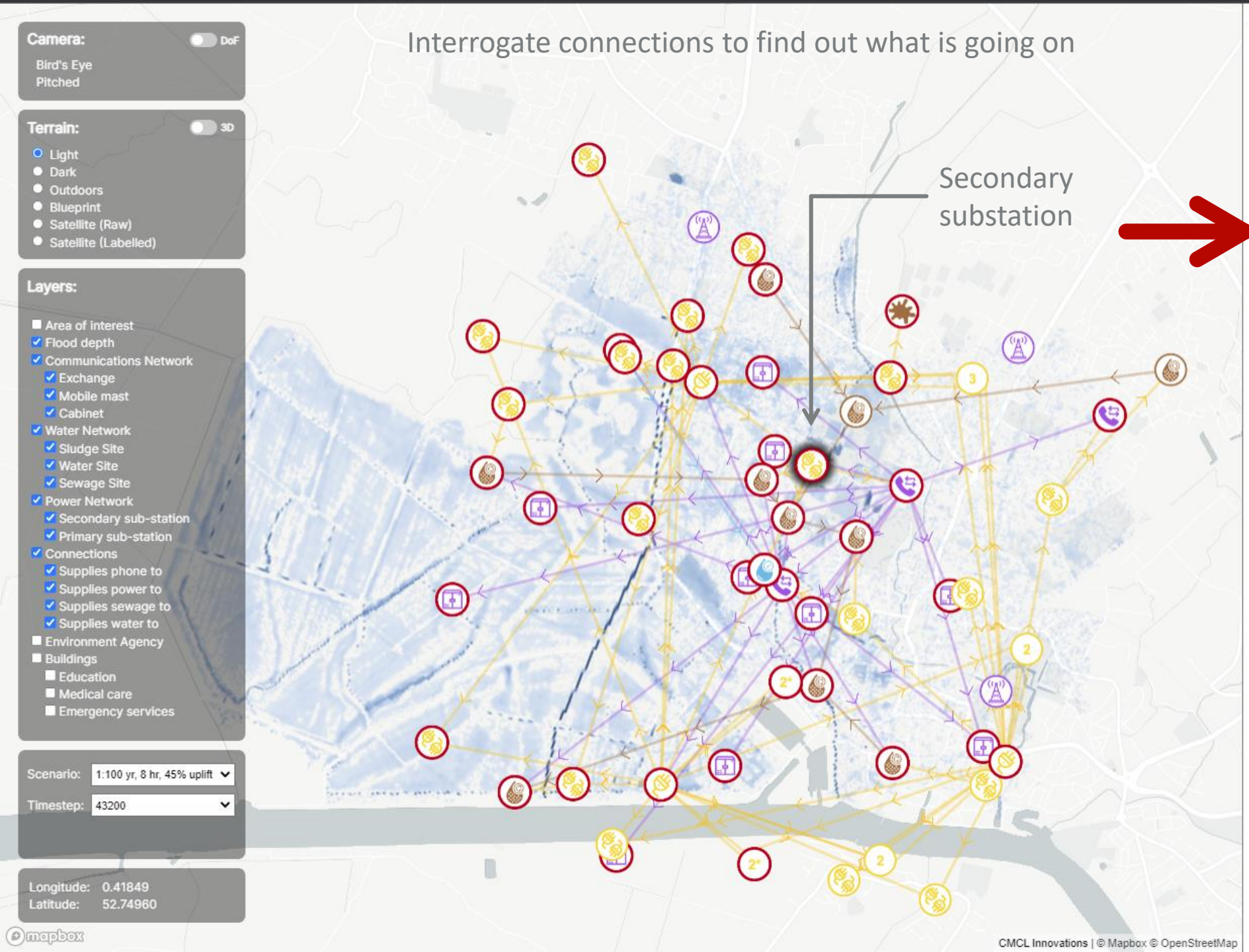
View Direct Connections

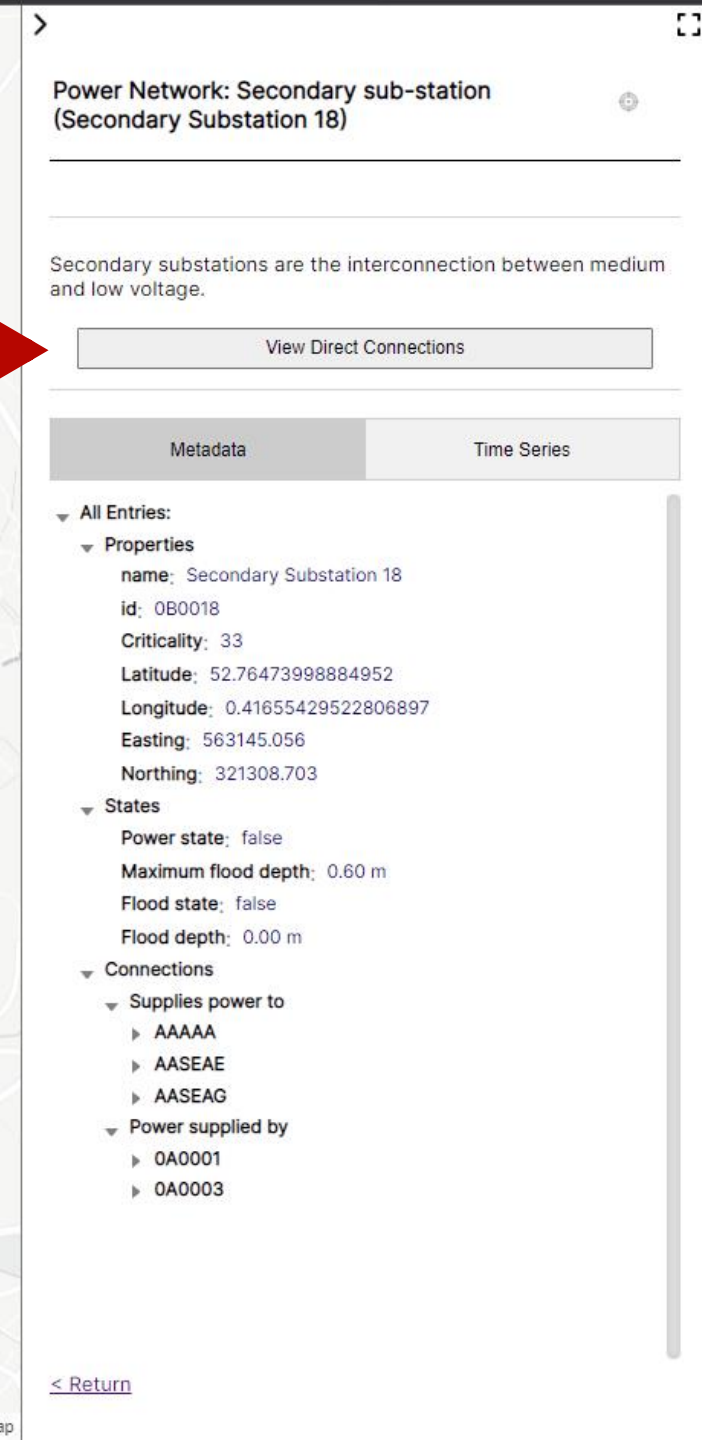
Metadata | Time Series

- All Entries:
  - Properties
    - name: Secondary Substation 18
    - id: 0B0018
    - Criticality: 33
    - Latitude: 52.76473998884952
    - Longitude: 0.41655429522806897
    - Easting: 563145.056
    - Northing: 321308.703
  - States
    - Power state: false ← Lost power, but not flooded
    - Maximum flood depth: 0.60 m
    - Flood state: false
    - Flood depth: 0.00 m ← Lost power, but not flooded
  - Connections
    - Supplies power to
      - AAAAA
      - AASEAE
      - AASEAG
    - Power supplied by
      - 0A0001
      - 0A0003

< Return

Interrogate connections to find out what is going on

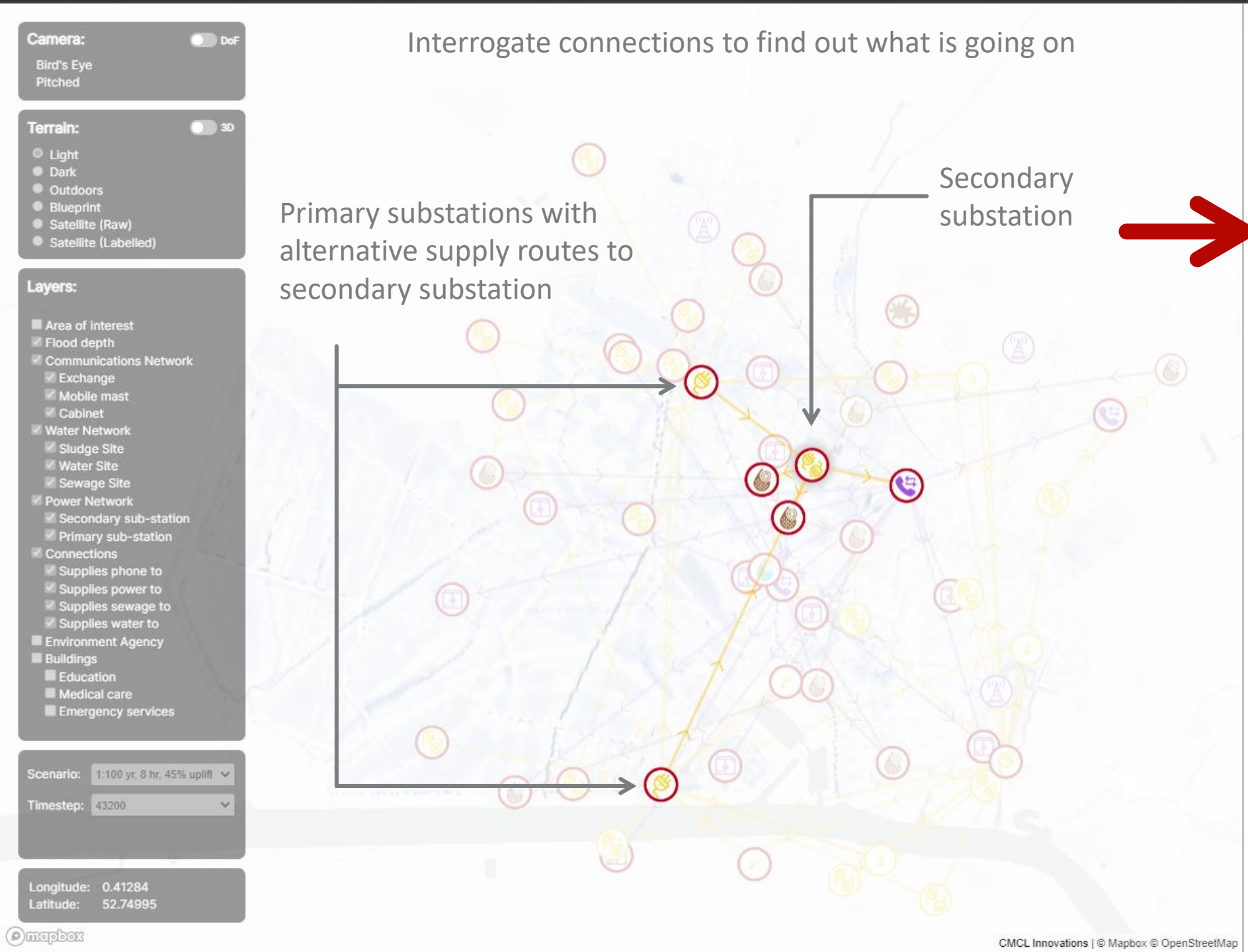




Interrogate connections to find out what is going on

Primary substations with alternative supply routes to secondary substation

Secondary substation



Power Network: Secondary sub-station (Secondary Substation 18)

Secondary substations are the interconnection between medium and low voltage.

Exit Connection View

Maximum Connection Depth: 1

Metadata | Time Series

- All Entries:
  - Properties
    - name: Secondary Substation 18
    - id: 0B0018
    - Criticality: 33
    - Latitude: 52.76473998884952
    - Longitude: 0.41655429522806897
    - Easting: 563145.056
    - Northing: 321308.703
  - States
    - Power state: false
    - Maximum flood depth: 0.60 m
    - Flood state: false
    - Flood depth: 0.00 m
  - Connections
    - Supplies power to
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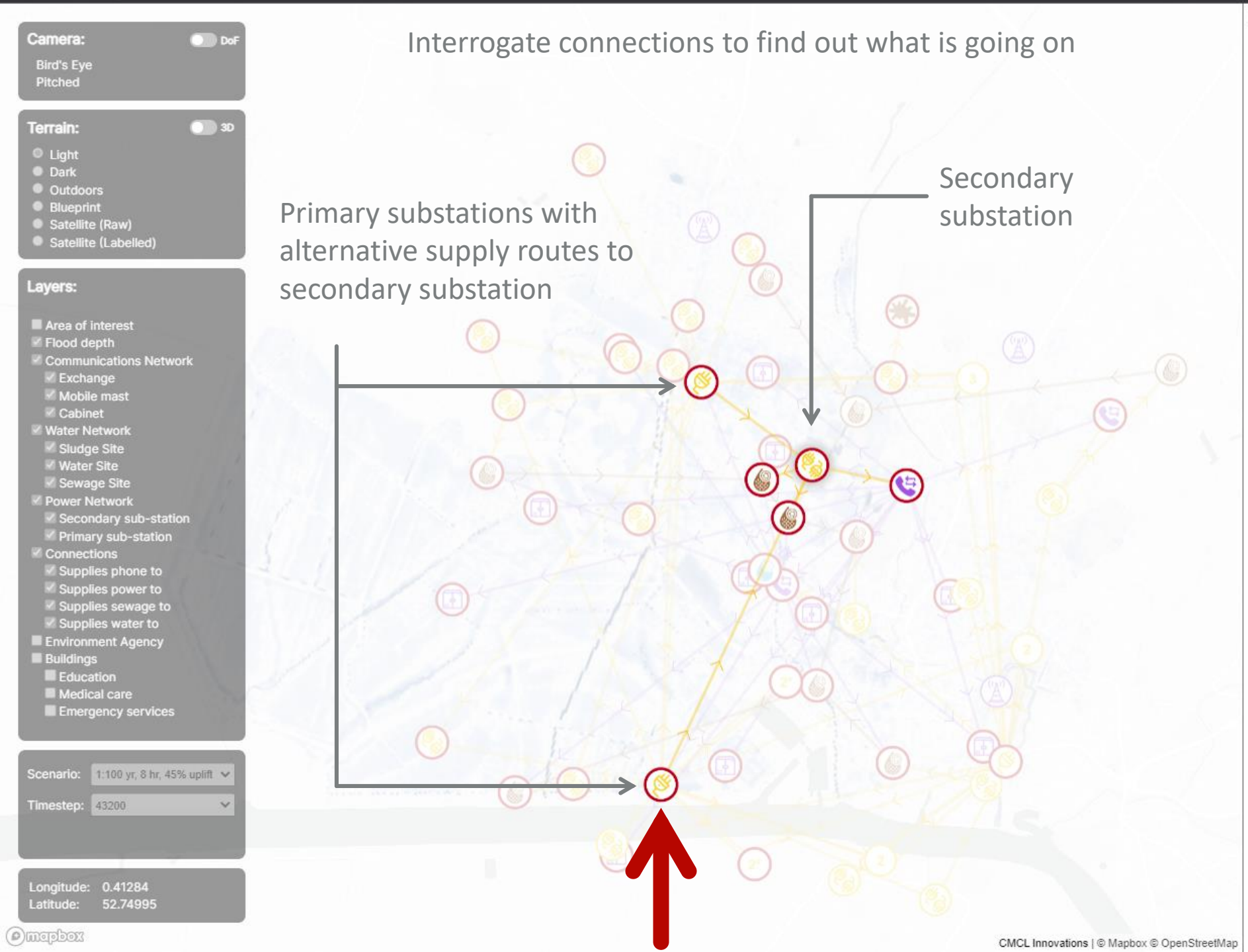
      - AASEAE
      - AASEAG
    - Power supplied by
      - 0A0001
      - 0A0003

< Return

Interrogate connections to find out what is going on



Power Network: Secondary sub-station (Secondary Substation 18)

Secondary substations are the interconnection between medium and low voltage.

Exit Connection View

Maximum Connection Depth:

Metadata | Time Series

- All Entries:
  - Properties
    - name: Secondary Substation 18
    - id: 0B0018
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    - Latitude: 52.76473998884952
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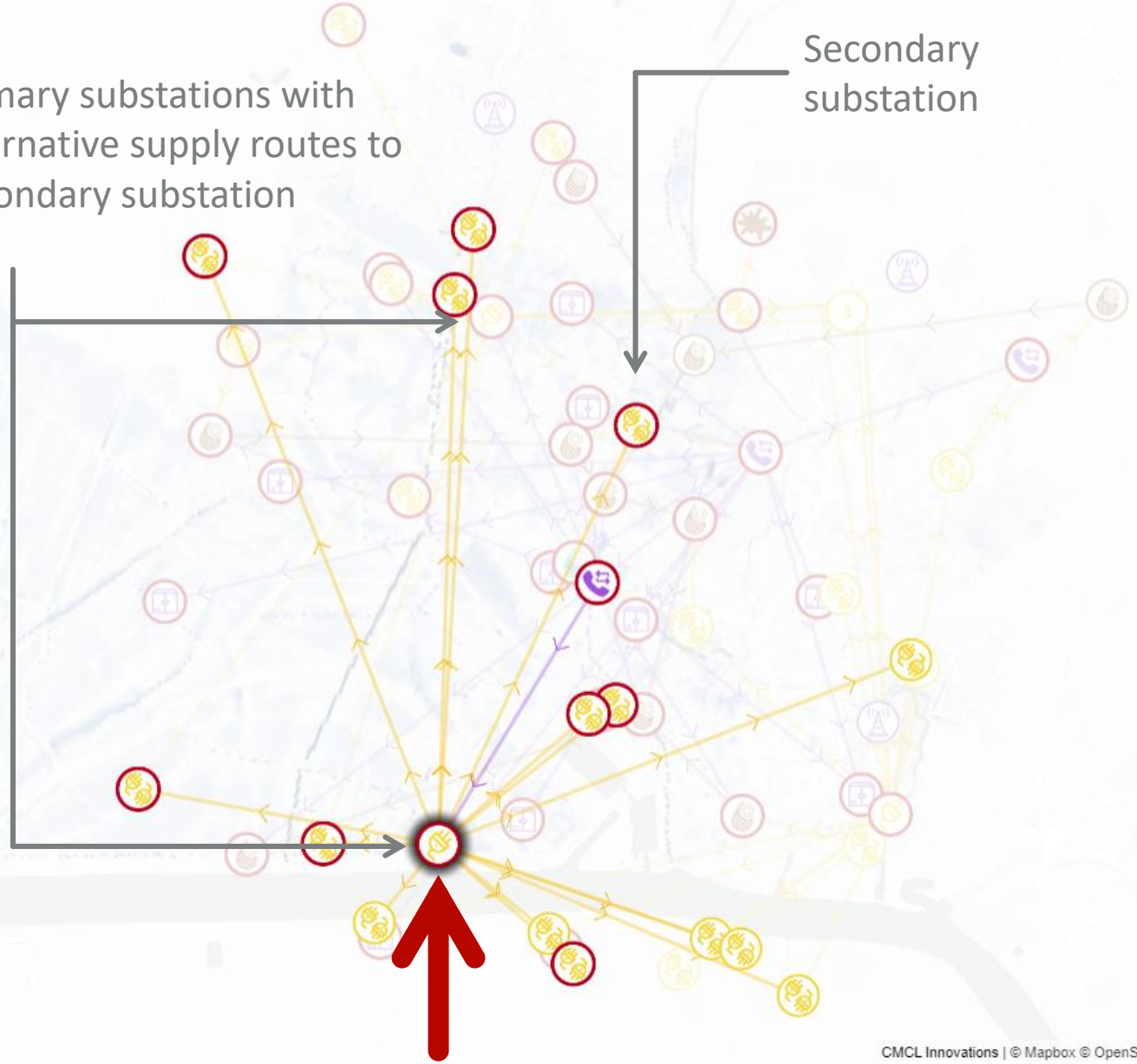
< Return

Interrogate connections to find out what is going on

Primary substations with alternative supply routes to secondary substation

Secondary substation



Camera: DoF
Bird's Eye
Pitched

Terrain: 3D
- Light
- Dark
- Outdoors
- Blueprint
- Satellite (Raw)
- Satellite (Labelled)

Layers:
- Area of interest
- Flood depth
- Communications Network
  - Exchange
  - Mobile mast
  - Cabinet
- Water Network
  - Sludge Site
  - Water Site
  - Sewage Site
- Power Network
  - Secondary sub-station
  - Primary sub-station
- Connections
  - Supplies phone to
  - Supplies power to
  - Supplies sewage to
  - Supplies water to
- Environment Agency
- Buildings
  - Education
  - Medical care
  - Emergency services

Scenario: 1:100 yr, 8 hr, 45% uplift
Timestep: 43200

Longitude: 0.37329
Latitude: 52.77122

mapbox

CMCL Innovations | © Mapbox © OpenStreetMap

Power Network: Primary sub-station (Primary Substation 01)

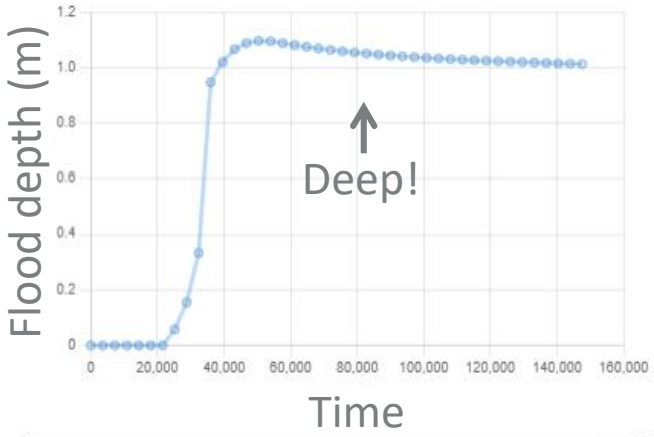
Primary substations are the interconnection between high voltage and medium voltage.

Exit Connection View

Maximum Connection Depth:

Metadata | Time Series

Select a data set: Flood depth [m]



Time	Flood depth [m]
0	0
3600	0
7200	0
10800	0
14400	0
18000	0

< Return

Interrogate connections to find out what is going on

Primary substations with alternative supply routes to secondary substation

Secondary substation

Also deep!

Time

Camera: DoF
Bird's Eye
Pitched

Terrain: 3D
- Light
- Dark
- Outdoors
- Blueprint
- Satellite (Raw)
- Satellite (Labelled)

Layers:
- Area of interest
- Flood depth
- Communications Network
  - Exchange
  - Mobile mast
  - Cabinet
- Water Network
  - Sludge Site
  - Water Site
  - Sewage Site
- Power Network
  - Secondary sub-station
  - Primary sub-station
- Connections
  - Supplies phone to
  - Supplies power to
  - Supplies sewage to
  - Supplies water to
- Environment Agency
- Buildings
  - Education
  - Medical care
  - Emergency services

Scenario: 1:100 yr, 8 hr, 45% uplift
Timestep: 43200

Longitude: 0.36807
Latitude: 52.77972

Power Network: Primary sub-station (Primary Substation 03)

Primary substations are the interconnection between high voltage and medium voltage.

Exit Connection View

Maximum Connection Depth:

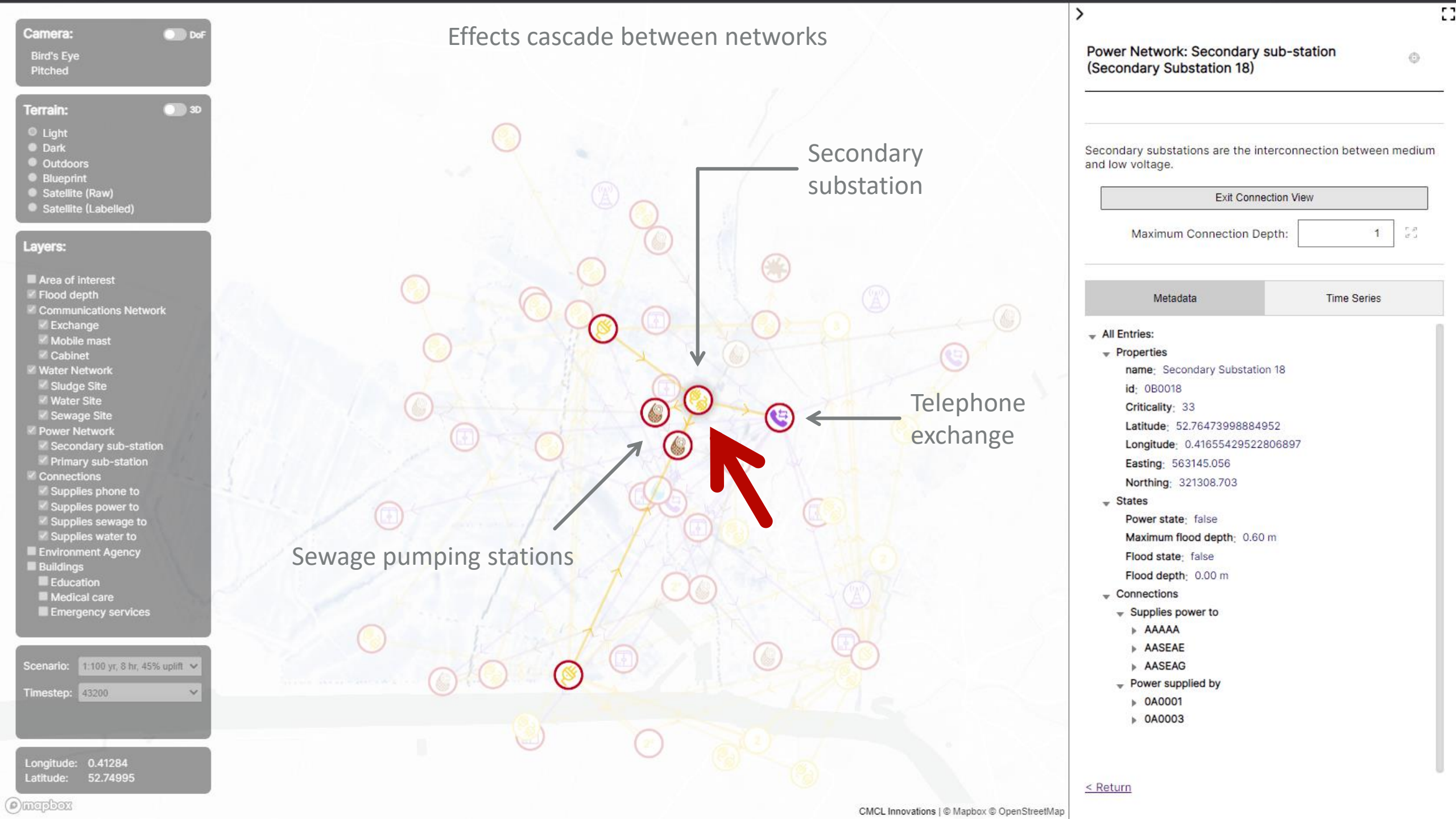
Metadata | Time Series

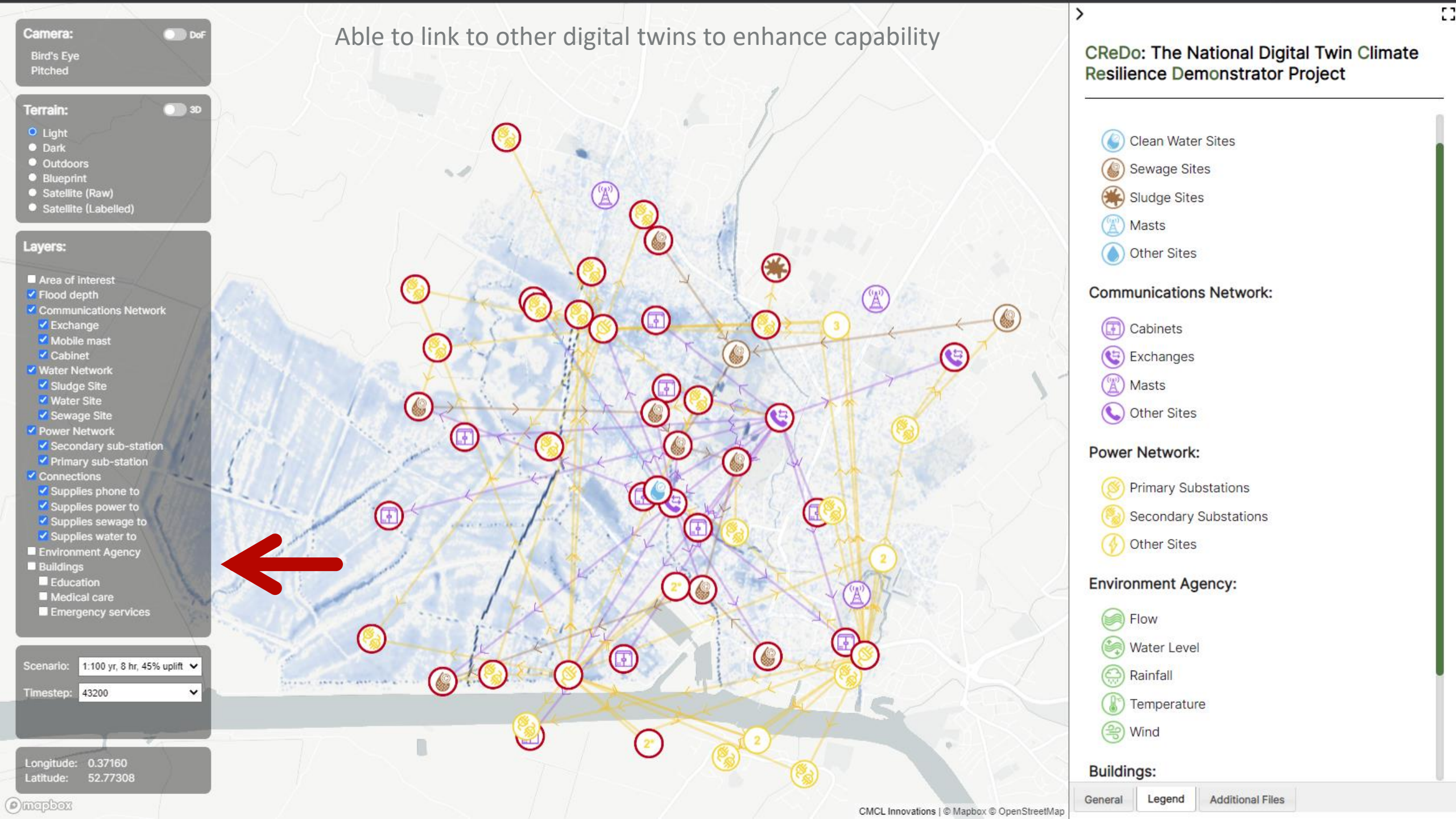
Select a data set: Flood depth [m]

Flood depth (m)

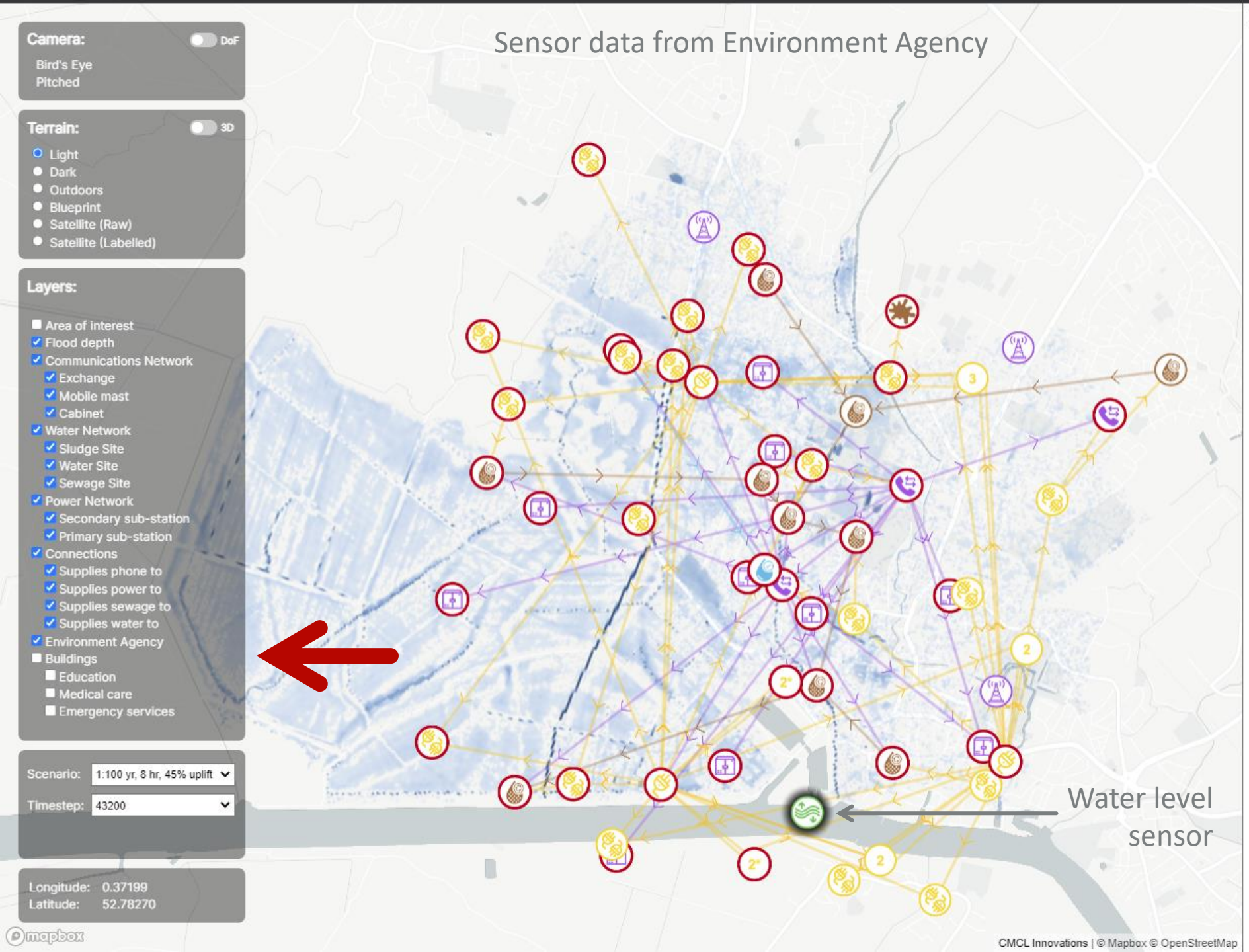
Time	Flood depth [m]
0	0
3600	0
7200	0
10800	0
14400	0
18000	0

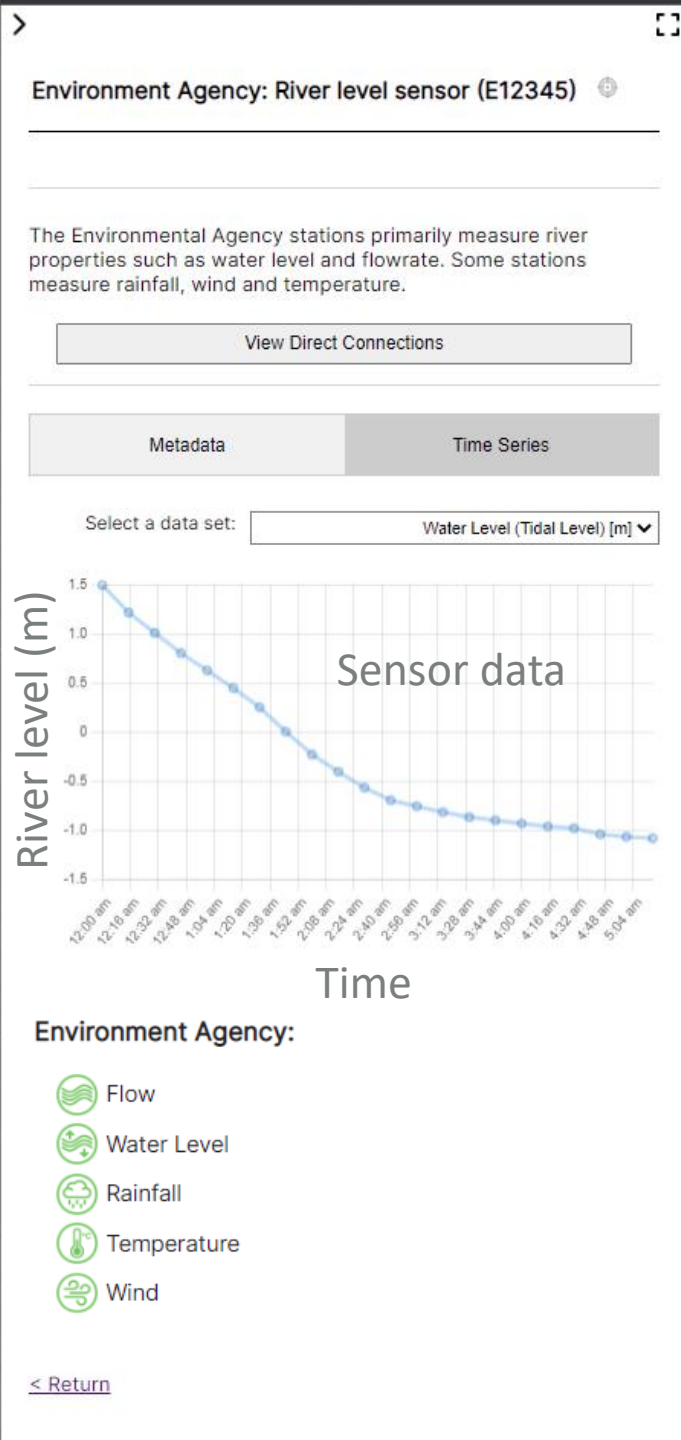
< Return

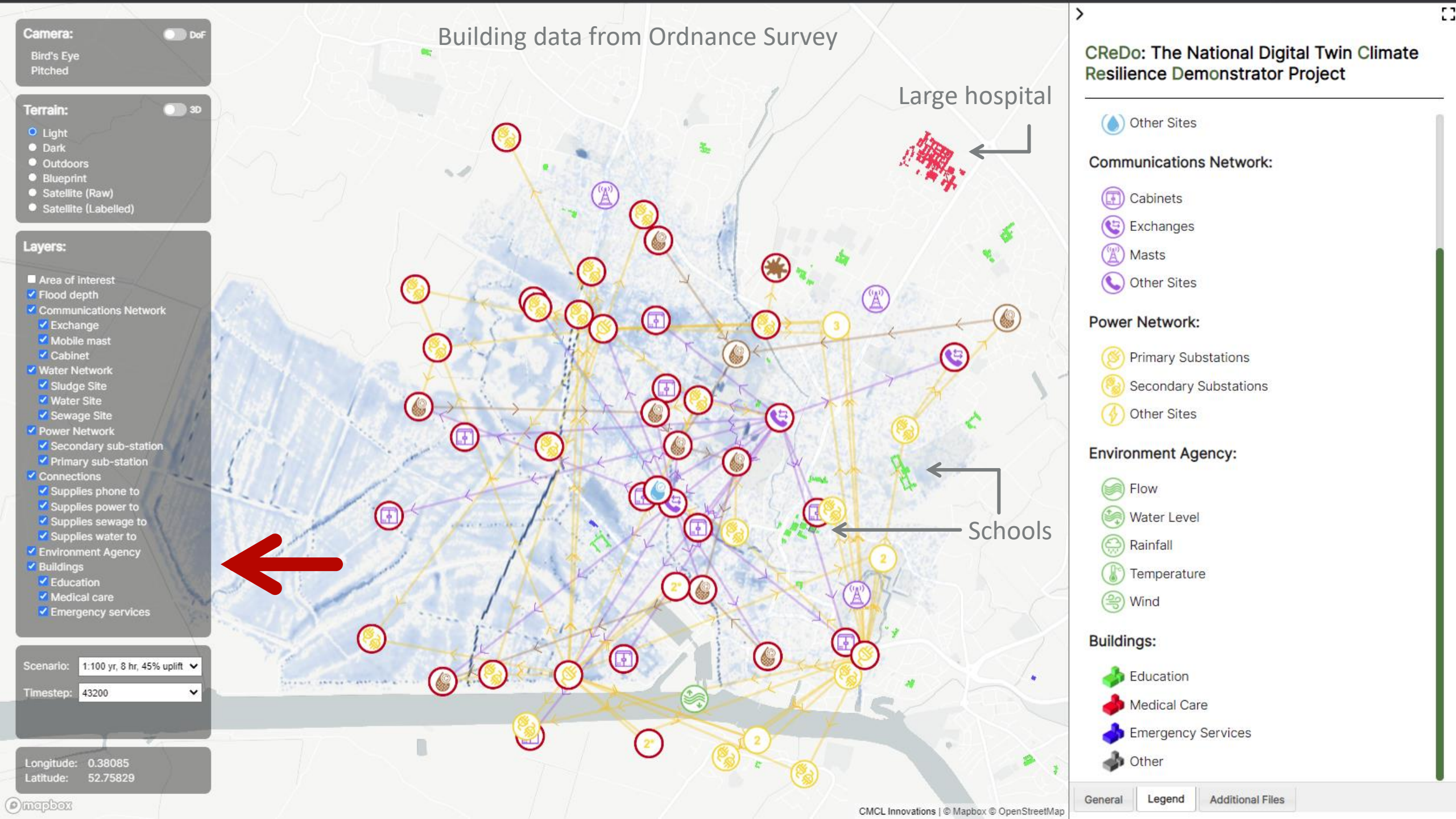

Effects cascade between networks
Secondary substation
Telephone exchange
Sewage pumping stations
Camera:
DoF
Bird's Eye
Pitched
Terrain:
3D
Light
Dark
Outdoors
Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
Flood depth
Communications Network
Exchange
Mobile mast
Cabinet
Water Network
Sludge Site
Water Site
Sewage Site
Power Network
Secondary sub-station
Primary sub-station
Connections
Supplies phone to
Supplies power to
Supplies sewage to
Supplies water to
Environment Agency
Buildings
Education
Medical care
Emergency services
Scenario:
1:100 yr, 8 hr, 45% uplift
Timestep:
43200
Longitude: 0.41284
Latitude: 52.74995
Power Network: Secondary sub-station (Secondary Substation 18)
Secondary substations are the interconnection between medium and low voltage.
Exit Connection View
Maximum Connection Depth:
1
Metadata
Time Series
All Entries:
Properties
name: Secondary Substation 18
id: 0B0018
Criticality: 33
Latitude: 52.76473998884952
Longitude: 0.41655429522806897
Easting: 563145.056
Northing: 321308.703
States
Power state: false
Maximum flood depth: 0.60 m
Flood state: false
Flood depth: 0.00 m
Connections
Supplies power to
AAAAA
AASEAE
AASEAG
Power supplied by
0A0001
0A0003
< Return
CMCL Innovations | © Mapbox © OpenStreetMap
mapbox


Able to link to other digital twins to enhance capability
Camera:
DoF
Bird's Eye
Pitched
Terrain:
3D
Light
Dark
Outdoors
Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
Flood depth
Communications Network
Exchange
Mobile mast
Cabinet
Water Network
Sludge Site
Water Site
Sewage Site
Power Network
Secondary sub-station
Primary sub-station
Connections
Supplies phone to
Supplies power to
Supplies sewage to
Supplies water to
Environment Agency
Buildings
Education
Medical care
Emergency services
Scenario:
1:100 yr, 8 hr, 45% uplift
Timestep:
43200
Longitude: 0.37160
Latitude: 52.77308
mapbox
CMCL Innovations | © Mapbox © OpenStreetMap
CReDo: The National Digital Twin Climate Resilience Demonstrator Project
Clean Water Sites
Sewage Sites
Sludge Sites
Masts
Other Sites
Communications Network:
Cabinets
Exchanges
Masts
Other Sites
Power Network:
Primary Substations
Secondary Substations
Other Sites
Environment Agency:
Flow
Water Level
Rainfall
Temperature
Wind
Buildings:
General
Legend
Additional Files

Sensor data from Environment Agency



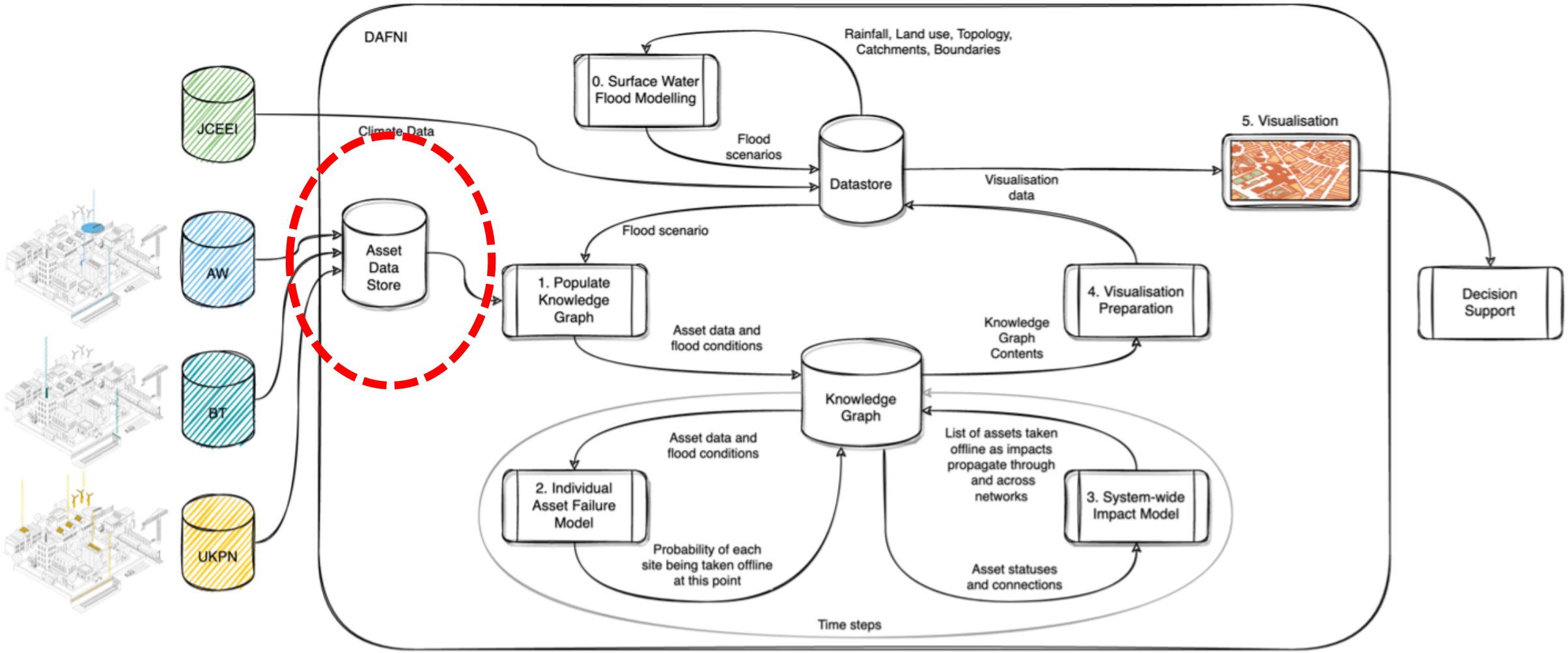



Building data from Ordnance Survey
Large hospital
Schools
Camera:
DoF
Bird's Eye
Pitched
Terrain:
3D
Light
Dark
Outdoors
Blueprint
Satellite (Raw)
Satellite (Labelled)
Layers:
Area of interest
Flood depth
Communications Network
Exchange
Mobile mast
Cabinet
Water Network
Sludge Site
Water Site
Sewage Site
Power Network
Secondary sub-station
Primary sub-station
Connections
Supplies phone to
Supplies power to
Supplies sewage to
Supplies water to
Environment Agency
Buildings
Education
Medical care
Emergency services
Scenario:
1:100 yr, 8 hr, 45% uplift
Timestep:
43200
Longitude: 0.38085
Latitude: 52.75829
mapbox
CMCL Innovations | © Mapbox © OpenStreetMap
CReDo: The National Digital Twin Climate Resilience Demonstrator Project
Other Sites
Communications Network:
Cabinets
Exchanges
Masts
Other Sites
Power Network:
Primary Substations
Secondary Substations
Other Sites
Environment Agency:
Flow
Water Level
Rainfall
Temperature
Wind
Buildings:
Education
Medical Care
Emergency Services
Other
General
Legend
Additional Files

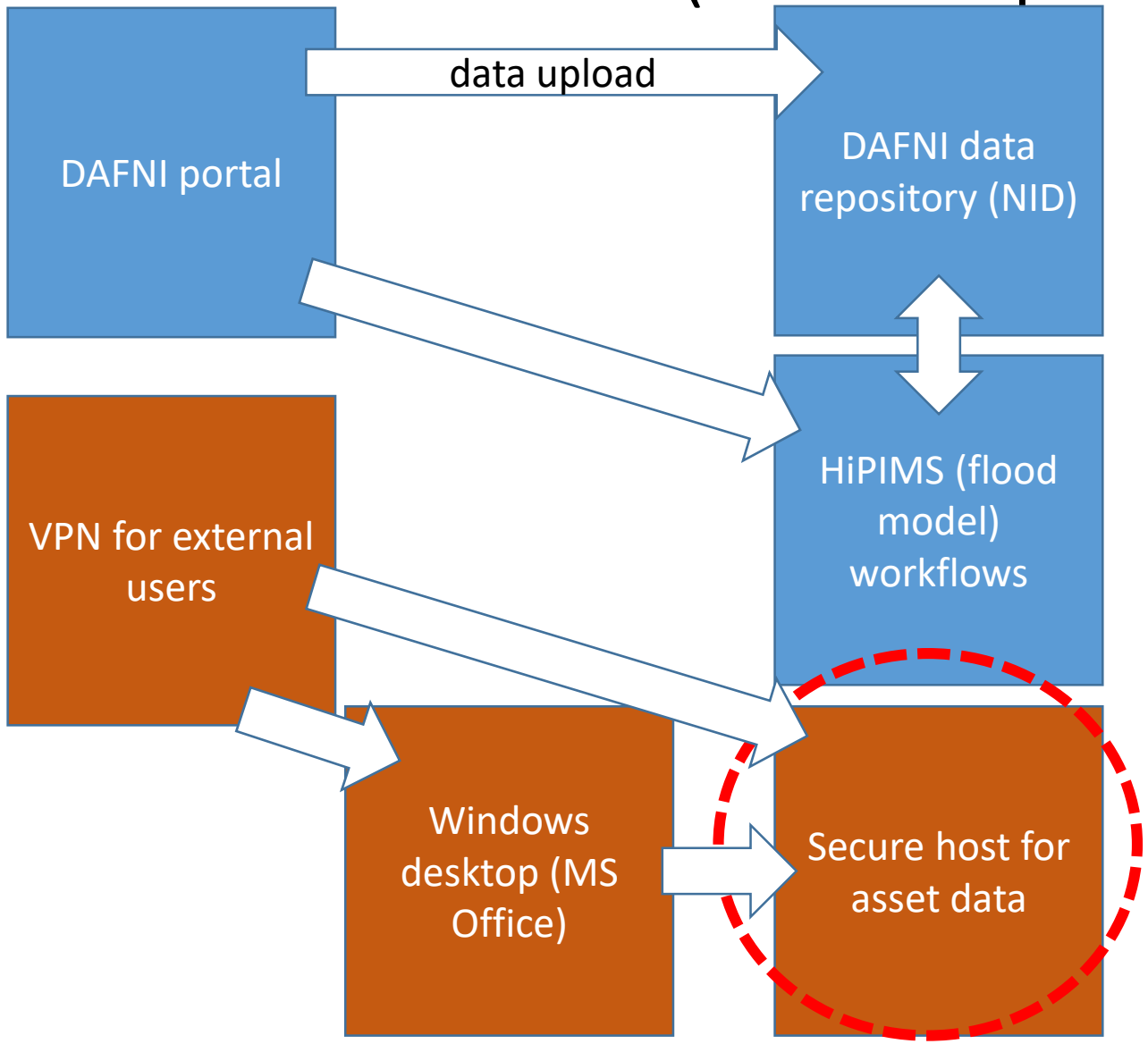
Implementing CReDo on DAFNI

Jens Jensen, STFC, 05.07.2022

Building a Connected Digital Twin



DAFNI architecture (CReDo perspective)



The orangeish colour is CReDo-specific infrastructure; the blueish boxes are standard DAFNI bits also used by CReDo.

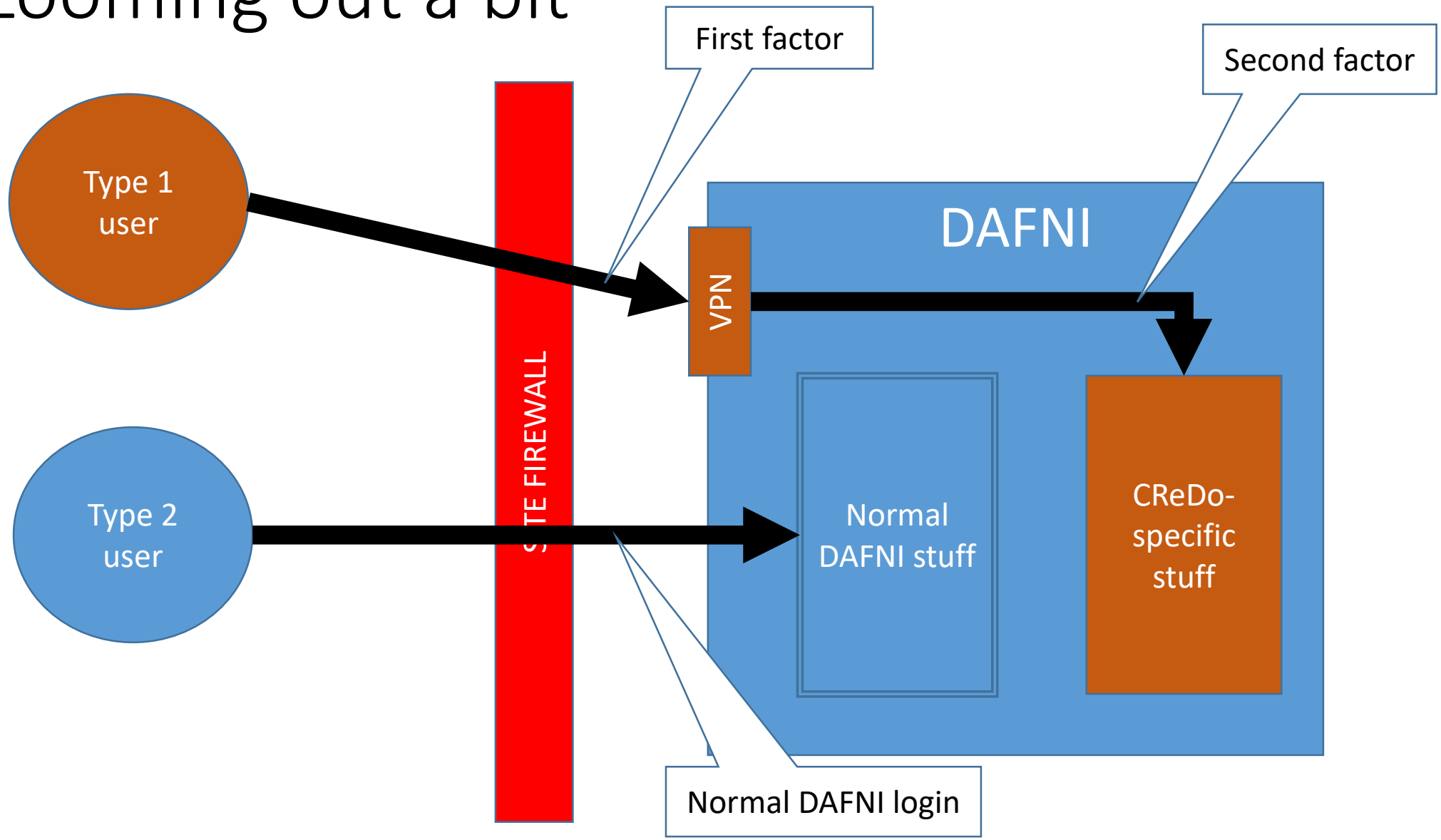
The secure host has the original data as read-only and a shared collaboration area (as well as individual working areas).

Project participants build models (based on HiPIMS) and upload the models to DAFNI

Two kinds of DAFNI users

1. Developers
   - Who access the secure host and collaborate building models
2. Users who run the models
3. And the third kind
   - Users who should the run the models but can’t

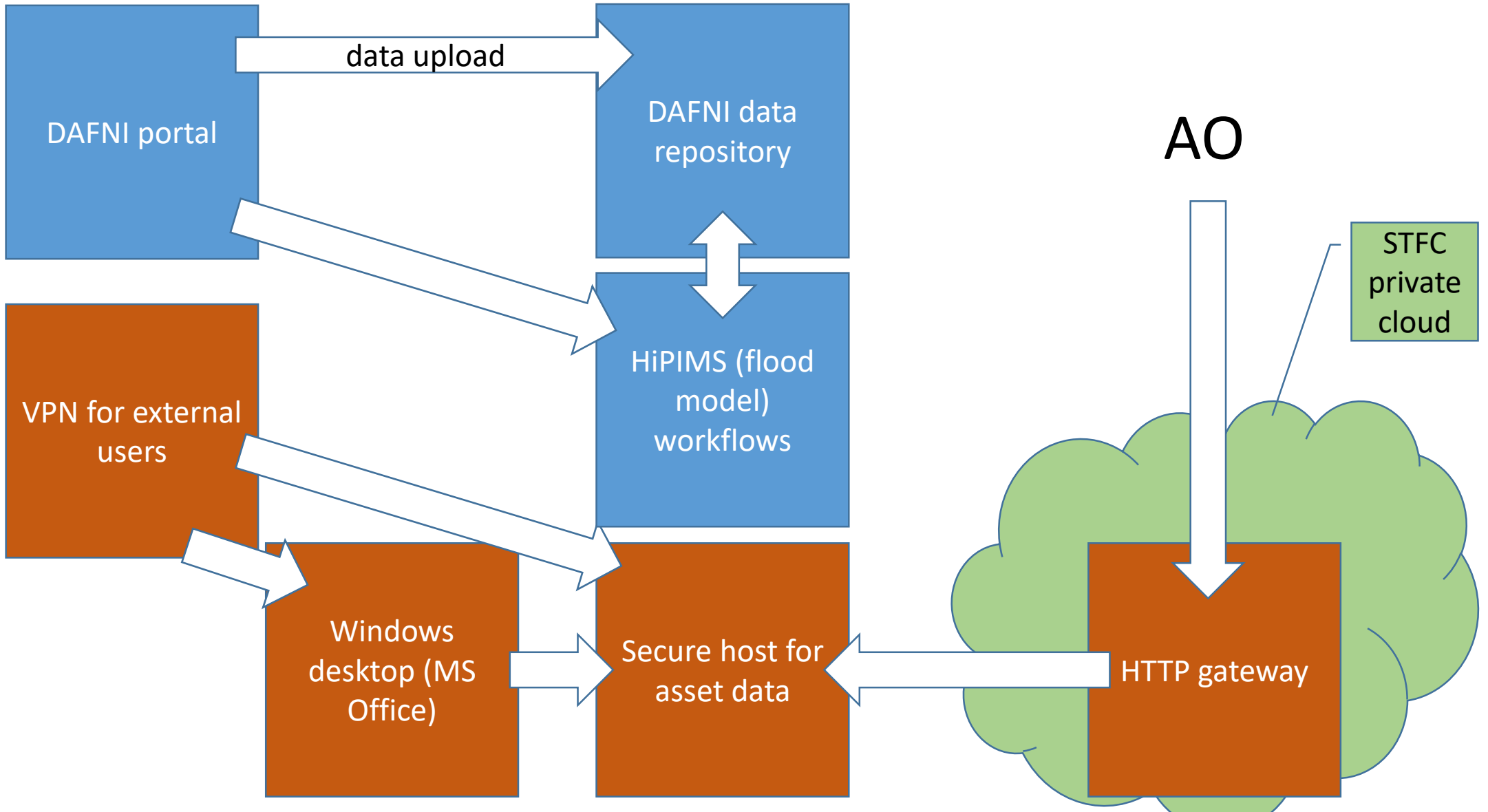
Zooming out a bit



Problem statement

- The data sharing agreement stipulates that asset owners' data must not leave the secure host
- However, this prevents AOs from exploring their data
  - Data cannot be copied off the secure host
  - Some AOs cannot install the VPN client which would give them (the first factor) of access to the secure host
  - No asset owner user is Type 1
- We also can't do the "decision/support" (RHS of DT diag.) without a human

How to get 3rd kind access to the secure host?



Other options

- BT’s proposal: AOs keep AO data between themselves
  - An API manages cascade effects
- Homomorphic encryption
  - And similar too-clever ideas
- Confidential computing
  - As offered by commercial cloud providers

… sed hanc marginis exiguitas non caperet