

# Multi-purpose management of the Walloon waterways, from local to global control of the structures



7th International Meuse Symposium  
Nathan Bertouille-Philippe Dierickx  
Ludovic Gouverneur  
Tim Franken  
21 September 2021

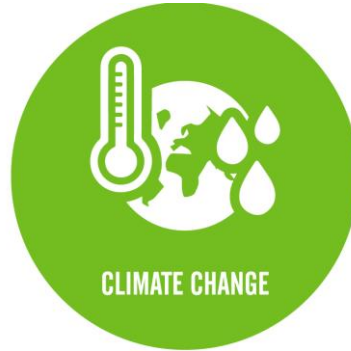
# Agenda

1. Introduction, context and goals (Nathan Bertouille-SPW)
2. Optimisation interface presentation (Ludovic Gouverneur-IMDC)
3. Optimisation module presentation (Tim Franken-Sumaqua)

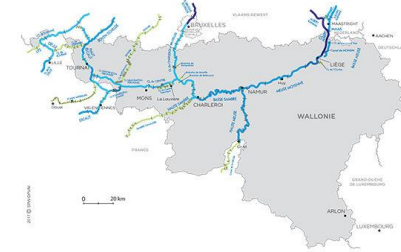
# Why a global control of the structures?



Harmonized waterways management



Climate change



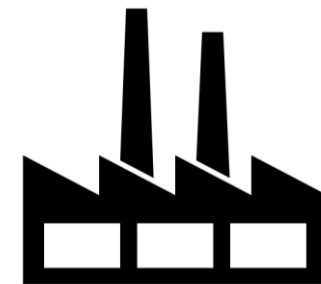
Network complexity



Europe connections

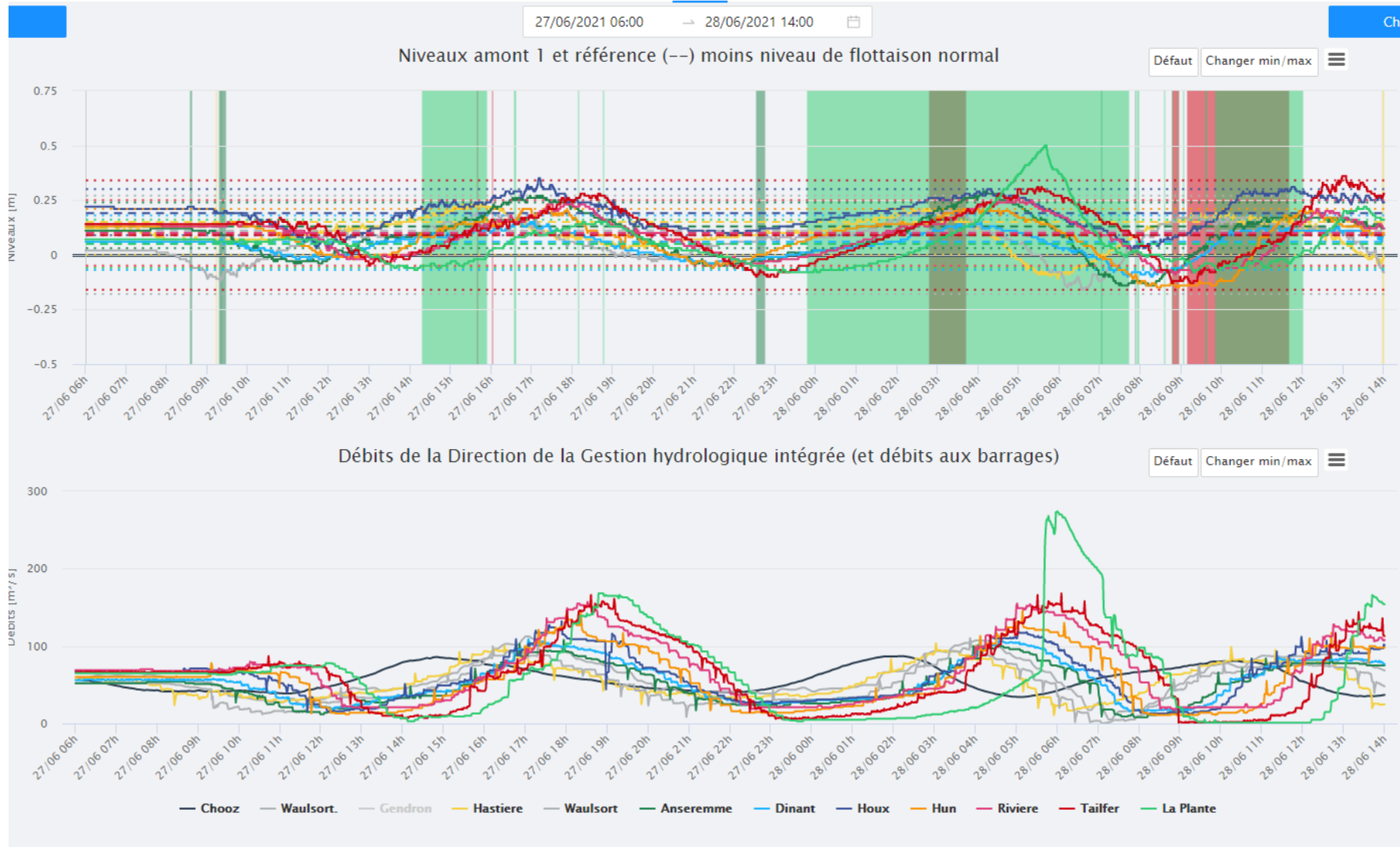


Traffic growth



Industries attractiveness

# Why a global control of the structures?



# Why a global control of the structures?



**Optimisation water management real-time tool**



Goal

to guide the permanent worker in choosing the optimal action to be carried out on waterways hydraulic structures

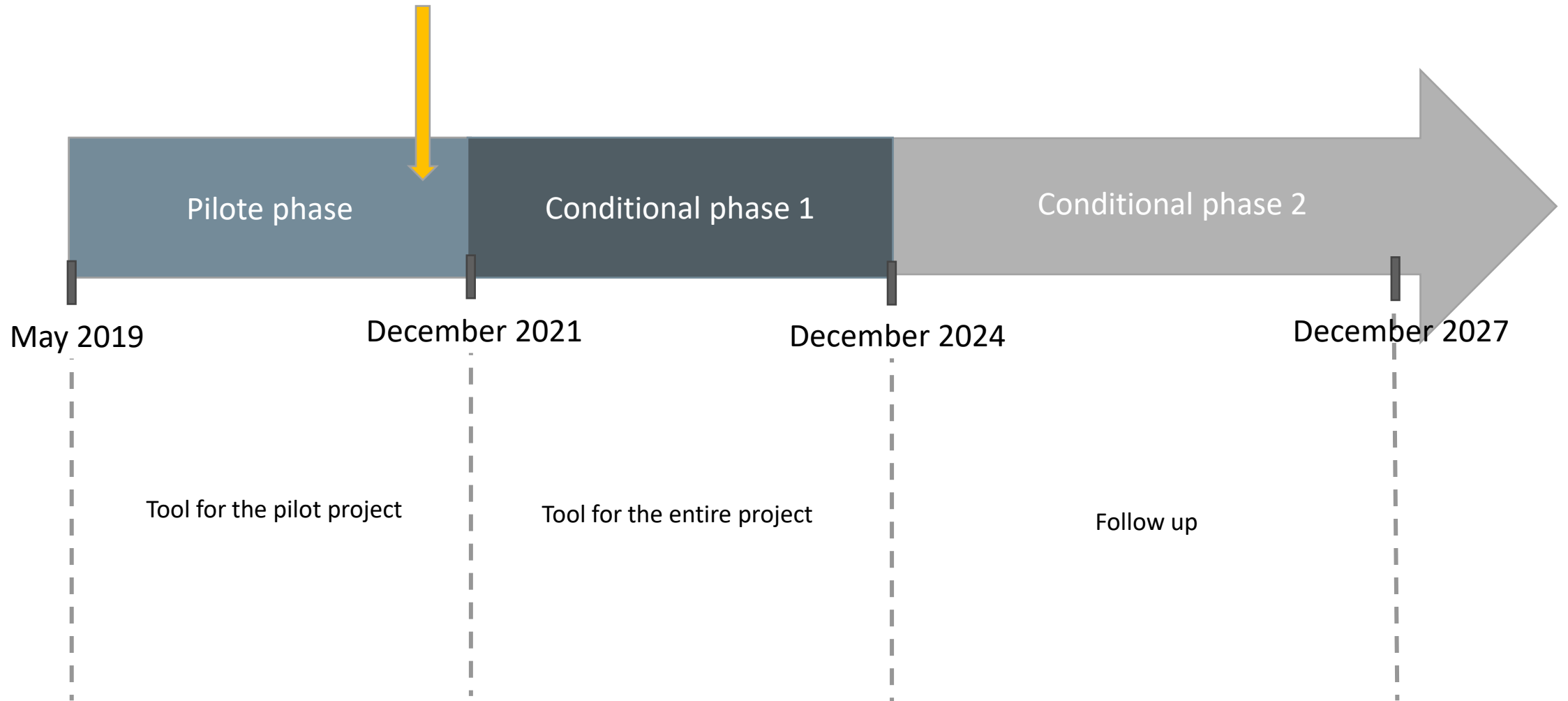
Multi-purpose tool:

- Reach and structure security
- Water level for navigation
- Pumps and turbines optimisation
- Ecological minimum flow
- ...

# PEREX project



# PEREX project

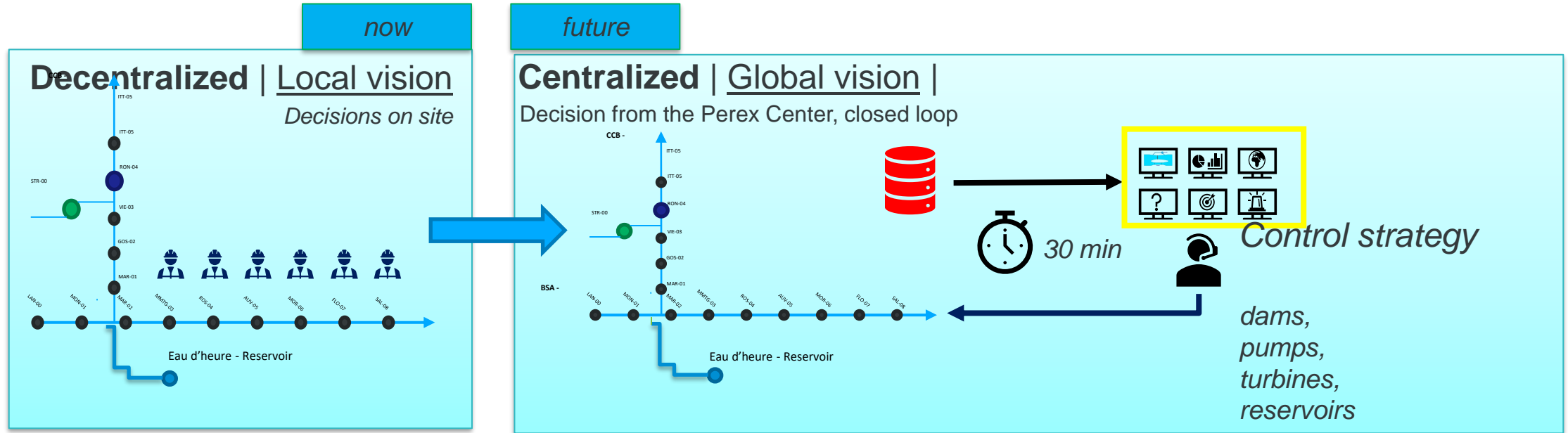


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# Perex project : overview



**Pilot :** 1 river + 1 channel

**Wallonia :** +- 450 km waterways



**Detailed model**

- HEC-RAS
- Calibration
- Validation

**Conceptual model**

**Optimisation**

- Security
- Navigability
- Energy
- ...

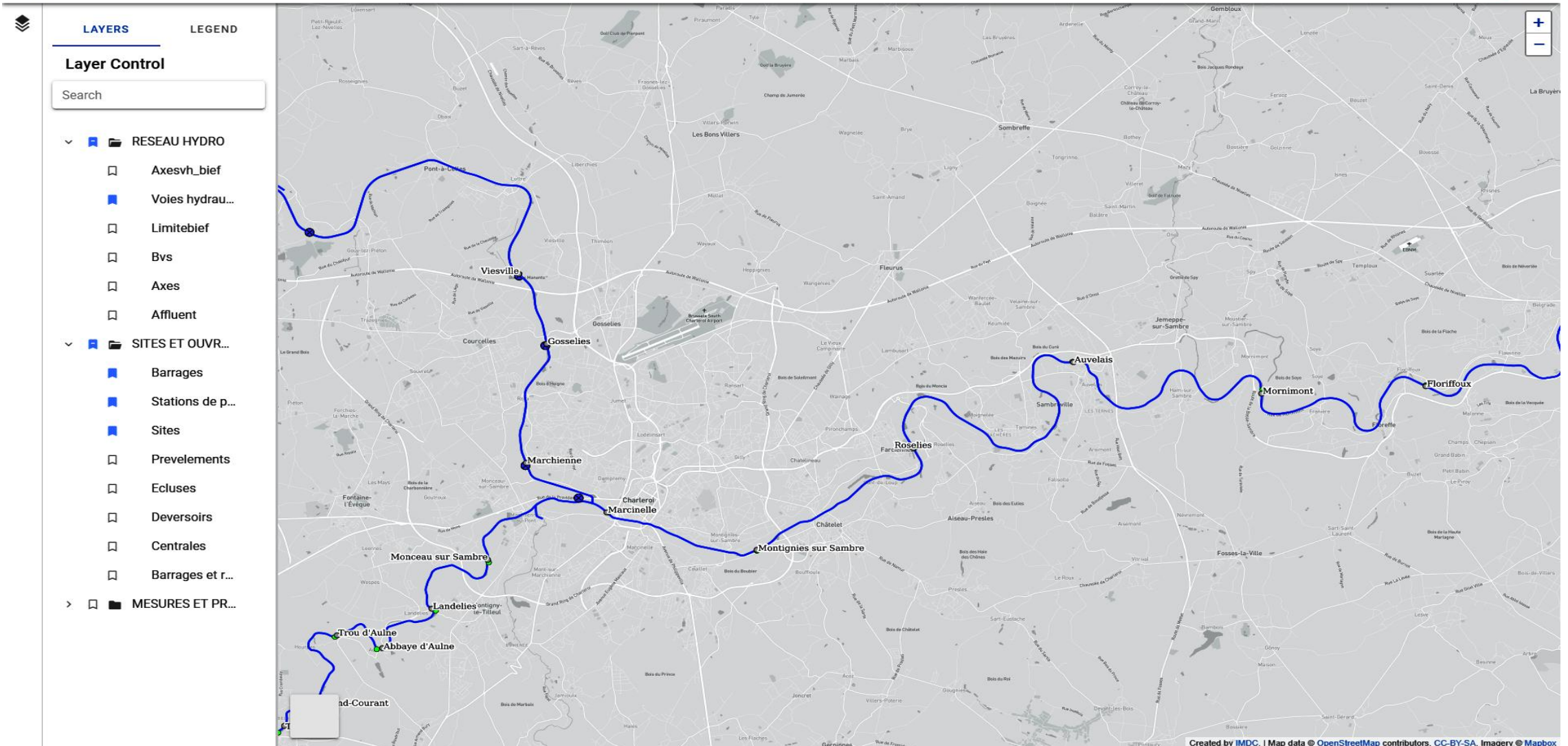
**Interface**

- Metadata search
- Monitoring
- Analysis and control

**Web application**

# Web Application Features : metadata | GIS

Sinapps - perex GIS



Created by IMDC. | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © Mapbox



# Web Application Features : metadata | FICHES per site





V1.0.0 - 12/02/2021  Perex al6075  
Hydro\_Admin 

TABLEAU DE BORD **RÉSEAU** SCÉNARIOS **FICHES** AUTRE 12/02/2021 20:56  

Voie hydraulique: Basse Sambre | Type de Fiche: Site | Nom: Salzennes

[PDF](#)

**Site : Salzennes**

Nom de la VH	Basse Sambre	Nom du site	Salzennes
n° de la VH	41	Direction territoriale	Voies Hydrauliques de Namur (D252)
Identifiant VNAV	731	District	Sambreville (N1)

Version de la fiche : v0.1 | Date de la mise à jour : 12/02/2021

Remarques

**Caractéristiques générales**

Adresse	Quai de l'Abbaye 2, 5000 Namur	Longitude (m)	183954
n-tel	081/73 68 02	Latitude (m)	128883
		Cumulée (km)	85.34

**Niveaux particuliers**

NFN amont (mDNG)	80.1
NFN aval (mDNG)	78.35
Chute (m)	1.75
Z consigne amont (mDNG)	80.4

**Ecluses**

Ecluses	Porte amont	Porte intermédiaire	Porte aval	Largeur utile (m)	Longueur utile (m)	Volume sasement (m³)	Longueur utile 1/2 sas amont (m)	Volume sasement 1/2 sas amont	Contraintes
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Metadata associated with each site :

- Equipements (Turbine power, dimension of the dams) and instrumentation (WL, Q) characteristics

# Web Application Features : monitoring | PROFIL VIEW per



Real-time snapshot of a river/channel : discharges, alarms, indicators

# Web Application Features : Analysis and Control

VI 0.0 - 12/02/2021

service public Perex

86075 HYDR\_Admin

12/02/2021 11:09

TABLEAU DE BORD RÉSEAU SCÉNARIOS FICHES AUTRE

Prochain Calcul: 11:30

Run	Securité - %	Navigabilité - %	Q seuil à Salz - %	Variations Hauteur - m	Variations de Débit - m³/s	Energie - Consommation - kWh	Energie - Consommation - €	Energie - Production - kWh	Energie - Production - €	Actions
Run: 39913 2021-02-12 11:00										
Run: 45227 2021-02-12 10:30	100	86.71	100	0.19	33.15	11898.22	762.86	44471.55	2469.62	
	6.92	1.69	7.99	-0.24	-21.64	-4373.41	-246.55	3740.55	245.94	

Objets par page 10 1 2 of 2

Run

Run	Statut	Securité - %	Navigabilité - %	Q seuil à Salz - %	Variations Hauteur - m	Variations de Débit - m³/s	Energie - Consommation - kWh	Energie - Consommation - €	Energie - Production - kWh	Energie - Production - €	Actions
Run: 45227 2021-02-12 10:30	✓	100.00	86.71	100	0.19	33.15	11898.22	762.86	44471.55	2469.62	
		6.92	1.69	7.99	-0.24	-21.64	-4373.41	-246.55	3740.55	245.94	
Run: 21514 2021-02-12 09:00	✓	99.71	84.99	100	0.48	90.94	18314.28	1161.68	38234.2	2102.55	
		6.92	6.11	6.92	0.09	0.19	-1489.88	-34.67	274.23	26.87	
Run: 71533 2021-02-12 09:30	✓	99.71	82.49	100	0.54	91.56	21480.52	1362.09	39547.09	2141.22	
		6.92	-0.55	4.17	-0.44	-4.77	635.46	48.29	742.02	372.30	
Run: 95134 2021-02-12 09:00	✓	99.78	85.4	100	0.43	83.38	17178.8	1045.29	39267.37	2179.23	
		6.92	-1.47	0.21	-0.22	-0.44	167.72	99.48	-431.36	-0.10	
Run: 91830 2021-02-12 08:30	✓	99.76	85.88	100	0.47	95.25	16696.89	1013.81	38843.34	2134.85	
		1.54	-0.78	2.22	-0.81	-19.32	2391.58	93.45	1940.65	178.50	
Run: 88232 2021-02-12 08:00	✓	99.75	84.83	100	0.46	86.8	16190.54	1054.93	40542.91	2212.82	
		6.92	-0.37	0.00	-0.23	-1.43	2986.10	184.84	-1409.80	-64.17	
Run: 49116 2021-02-12 07:30	✓	99.73	85.25	100	0.43	84.76	15163.95	942.8	42393.11	2329.1	
		6.92	0.20	0.88	-0.82	-3.88	2077.25	289.92	1093.83	26.45	
Run: 96787 2021-02-12 07:00	✓	99.74	84.18	100	0.44	80.53	13934.91	874.95	42774.5	2379.68	
		6.92	0.41	0.00	-0.44	-0.72	663.33	52.98	3844.46	243.27	
Run: 87721 2021-02-12 06:30	✓	99.73	80.89	100	0.45	86.84	14815.09	837.99	40365.24	2206.75	
		2.09	-0.72	0.00	-0.95	-6.76	4979.94	278.43	4300.32	262.86	

Change operational run

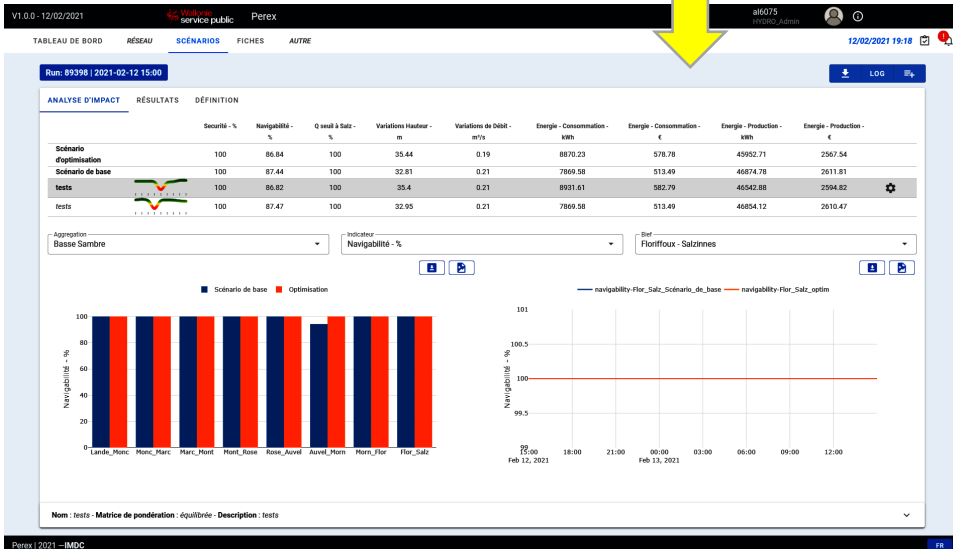


Produce "Variante"



Detailed analysis

Indicators, definition of the run



Time serie visualisation Input/output

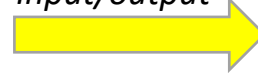


TABLEAU DE BORD RÉSEAU SCÉNARIOS FICHES AUTRE

12/02/2021 10:34

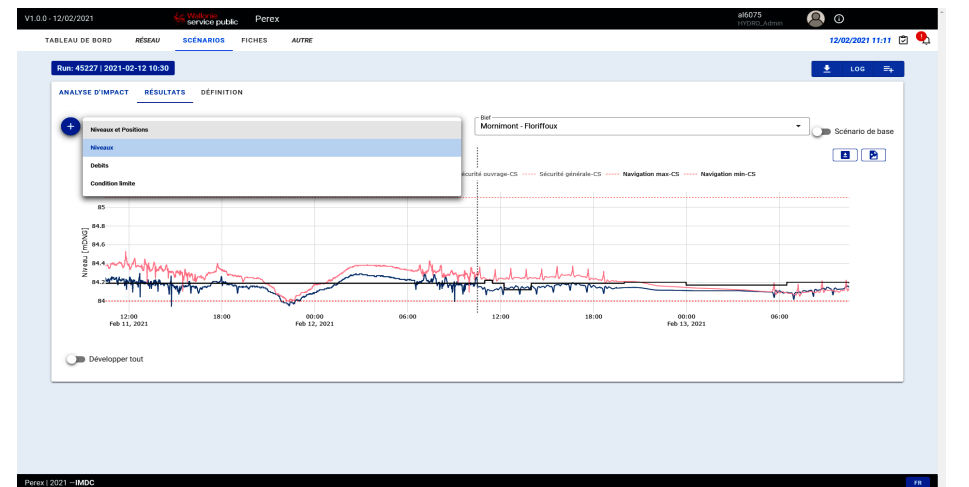
Résolution temporelle & spatiale

Table: Résolution temporelle & spatiale

SÉRIES TEMPORELLES ORGANES A OPTIMISER MATRICE DE FONDÉATION

Site	Statut	Site	Nom
Mariembourg	Statut coverage	Mariembourg	Mariembourg_0615
Navigation max	Statut coverage	Navigation max	Navigation_max_081
Mariembourg	Statut coverage	Mariembourg	Mariembourg_0734
Navigation min	Statut coverage	Navigation min	Navigation_min_054
Mariembourg	Statut coverage	Mariembourg	Mariembourg_0514
Mariembourg	Statut coverage	Mariembourg	Mariembourg_0348
Florifoux	Statut coverage	Florifoux	Florifoux_0205
Salzinnes	Statut coverage	Salzinnes	Salzinnes_008
Verdun	Statut coverage	Verdun	Verdun_Moncaux_0204
Verdun	Statut coverage	Verdun	Verdun_Moncaux_0164
Verdun	Statut coverage	Verdun	Verdun_Lambek_0783

Modifications enregistrées



# Web Application Features : Optimisation dashboard

V1.0.0 - 12/02/2021



Perex

al6075  
HYDRO\_Admin



TABLEAU DE BORD

RÉSEAU

**SCÉNARIOS**

FICHES

AUTRE

12/02/2021 11:09



*Automated operational run (every 30 min) for 24h in the future*

*Editing operational run*

Prochain Calcul: 11:30

	Securité - %	Navigabilité - %	Q seuil à Salz - %	Variations Hauteur - m	Variations de Débit - m³/s	Energie - Consommation - kWh	Energie - Consommation - €	Energie - Production - kWh	Energie - Production - €	Actions
Run: 39913 2021-02-12 11:00 running										
Run: 45227 2021-02-12 10:30	100 0.50	86.71 5.69	100 7.99	0.19 -0.24	33.15 -29.64	11898.22 -4373.41	762.86 -265.55	44471.55 3740.05	2469.62 240.96	

Objets par page 10 1-2 of 2 < >

*Click for in-depth analysis of input/output of a simulation*

*Edit a previous simulation*

Run	Statut	Securité - %	Navigabilité - %	Q seuil à Salz - %	Variations Hauteur - m	Variations de Débit - m³/s	Energie - Consommation - kWh	Energie - Consommation - €	Energie - Production - kWh	Energie - Production - €	Actions
Run: 45227 2021-02-12 10:30		100.00 0.50	86.71 5.69	100 7.99	0.19 -0.24	33.15 -29.64	11898.22 -4373.41	762.86 -265.55	44471.55 3740.05	2469.62 240.96	
Run: 21514 2021-02-12 10:00		99.71 0.00	84.99 0.11	100 0.00	0.48 0.00	90.94 0.19	18314.28 -1469.83	1161.68 -76.67	38234.2 -374.73	2102.55 32.67	
Run: 71232 2021-02-12 09:30		99.71 0.00	84.99 -0.55	100 4.17	0.54 -0.04	91.56 -8.77	21600.52 6363.46	1262.00 438.29	30547.00 7412.02	2141.00 372.20	
Run: 95134 2021-02-12 09:00		99.78 0.00	85.4 -1.47	100 0.21	0.43 -0.02	83.38 -10.44	17178.8 1527.72	1045.28 99.68	39367.37 -431.35	2179.23 -0.10	
Run: 61826 2021-02-12 08:30		99.76 1.56	85.88 -0.78	100 2.22	0.47 -0.01	95.25 11.37	16696.89 2591.98	1013.8 93.45	38843.34 1840.65	2134.85 178.00	
Run: 88232 2021-02-12 08:00		99.75 0.00	84.83 -0.37	100 0.00	0.46 -0.03	86.8 1.43	16190.54 2986.10	1054.93 194.84	40542.91 -1409.60	2212.82 -84.17	
Run: 49116 2021-02-12 07:30		99.73 0.00	85.25 -2.70	100 0.00	0.43 -0.02	84.76 3.08	15163.95 3177.75	942.8 208.90	42393.11 1013.33	2329.1 32.45	
Run: 96397 2021-02-12 07:00		99.74 0.00	84.18 0.61	100 0.00	0.44 -0.04	80.53 -8.72	13934.91 853.03	816.95 52.50	42774.5 3344.66	2379.68 243.27	
Run: 87721 2021-02-12 06:30		99.73 2.09	80.89 -3.72	100 0.00	0.45 -0.05	86.84 -5.70	14815.09 4079.94	837.99 270.43	40365.24 4260.32	2206.75 262.86	

# Web Application Features : Impact analysis (indicators)


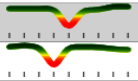
V1.0.0 - 12/02/2021  Perex al6075  
HYDRO\_Admin

TABLEAU DE BORD **RÉSEAU** SCÉNARIOS FICHES AUTRE 12/02/2021 19:18

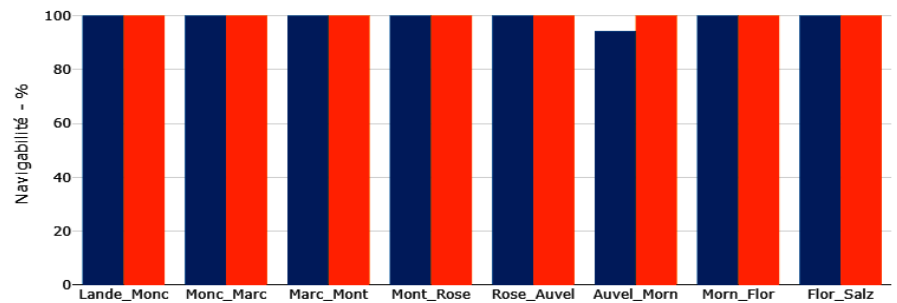
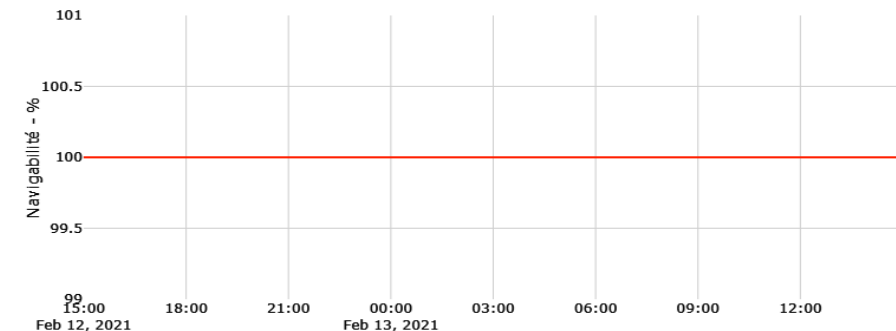
Run: 89398 | 2021-02-12 15:00 LOG

**ANALYSE D'IMPACT** RÉSULTATS DÉFINITION

	Securité - %	Navigabilité - %	Q seuil à Salz - %	Variations Hauteur - m	Variations de Débit - m³/s	Energie - Consommation - kWh	Energie - Consommation - €	Energie - Production - kWh	Energie - Production - €
Scénario d'optimisation	100	86.84	100	35.44	0.19	8870.23	578.78	45952.71	2567.54
Scénario de base	100	87.44	100	32.81	0.21	7869.58	513.49	46874.78	2611.81
tests 	100	86.82	100	35.4	0.21	8931.61	582.79	46542.88	2594.82
tests	100	87.47	100	32.95	0.21	7869.58	513.49	46854.12	2610.47

Aggregation: Basse Sambre | Indicateur: Navigabilité - % | Bief: Floriffoux - Salzinnes

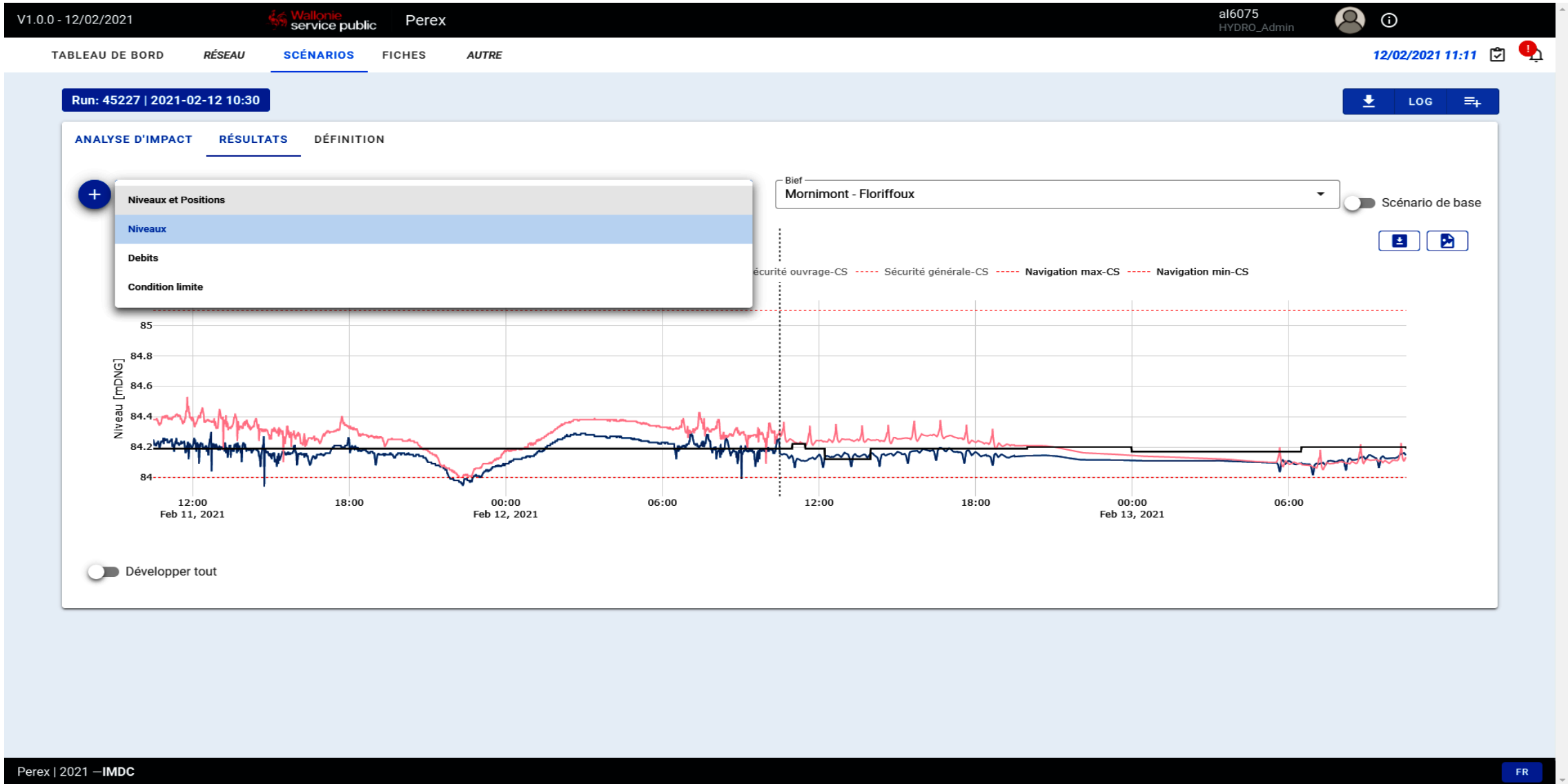
■ Scénario de base ■ Optimisation

Nom : tests - Matrice de pondération : équilibrée - Description : tests

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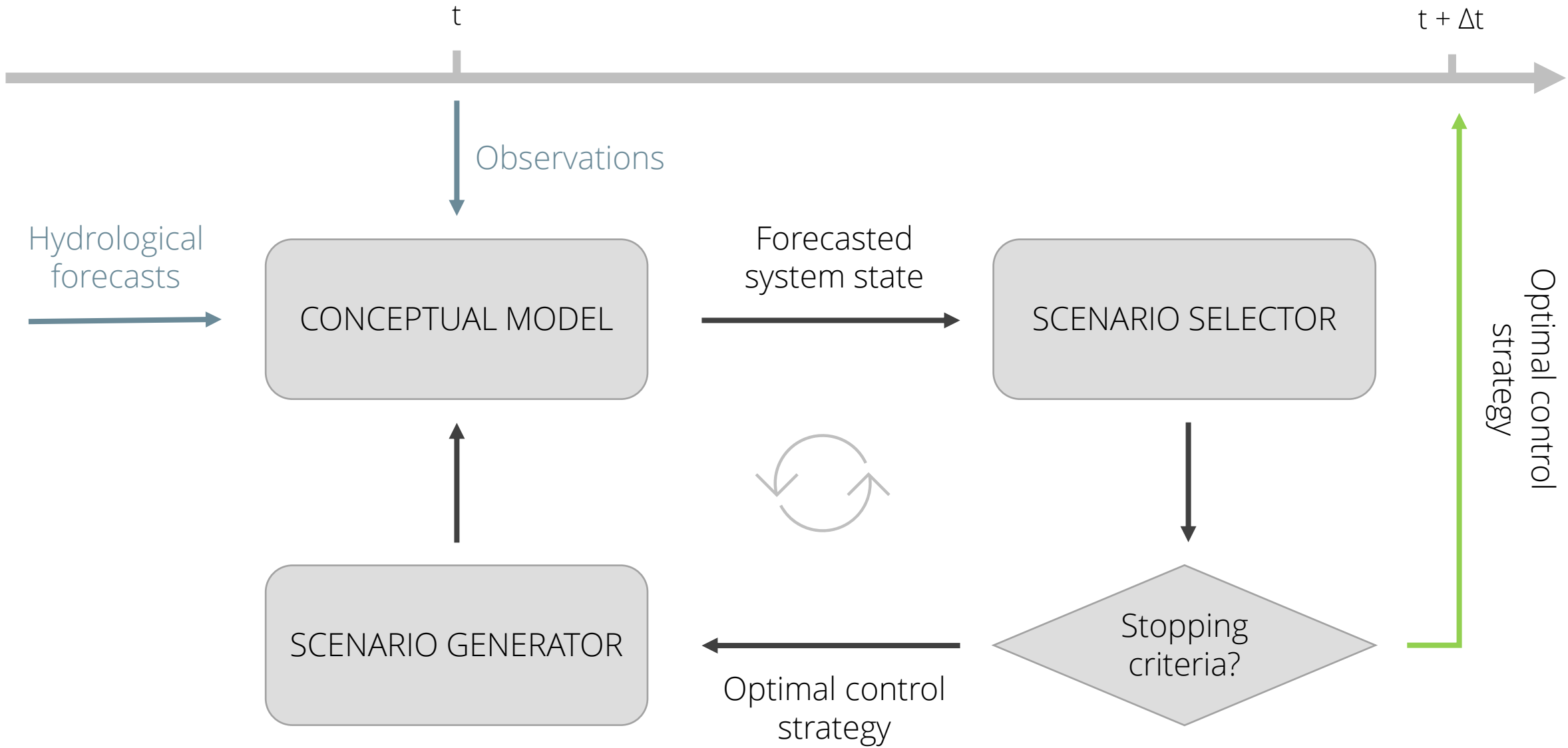
# Web Application Features : Input/Output analysis

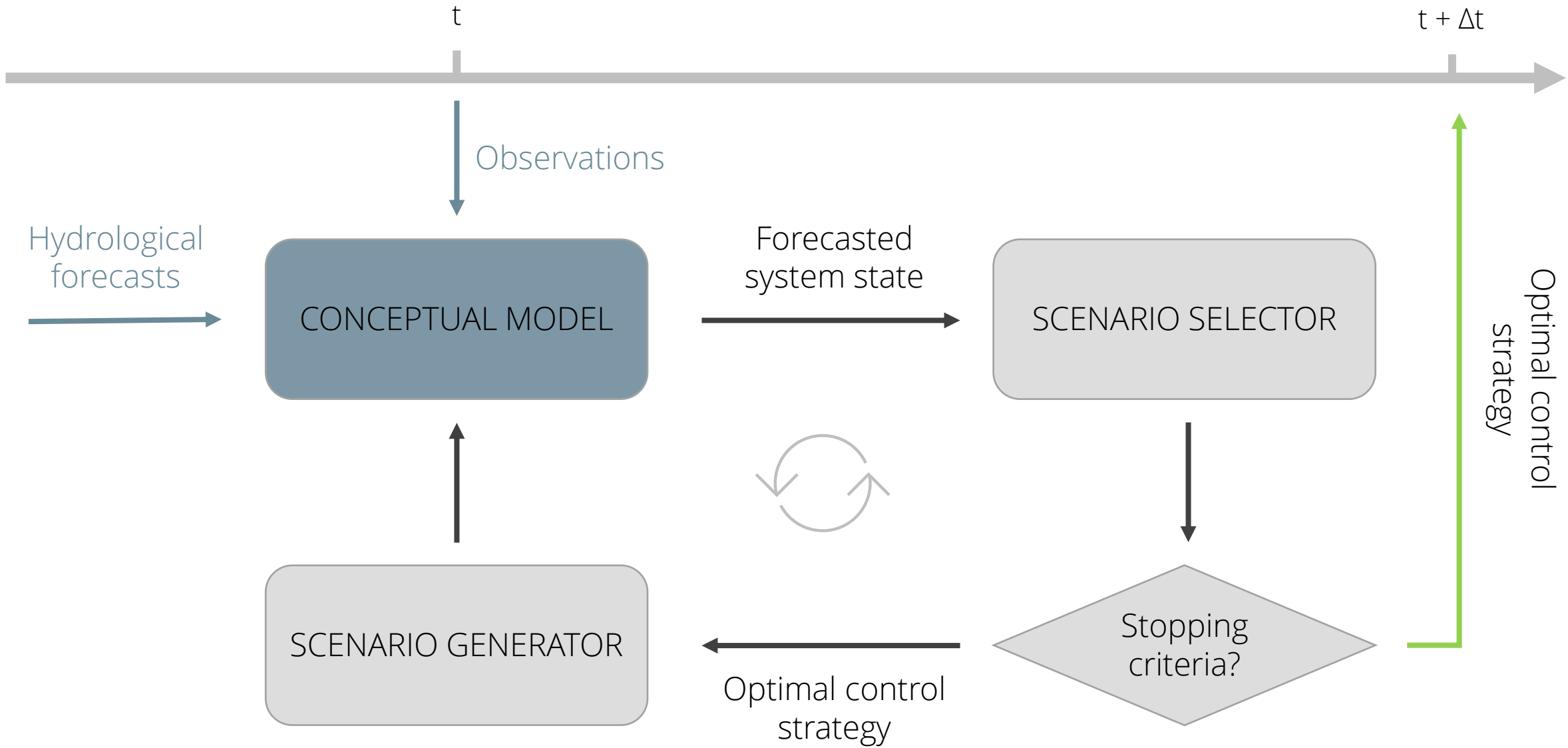




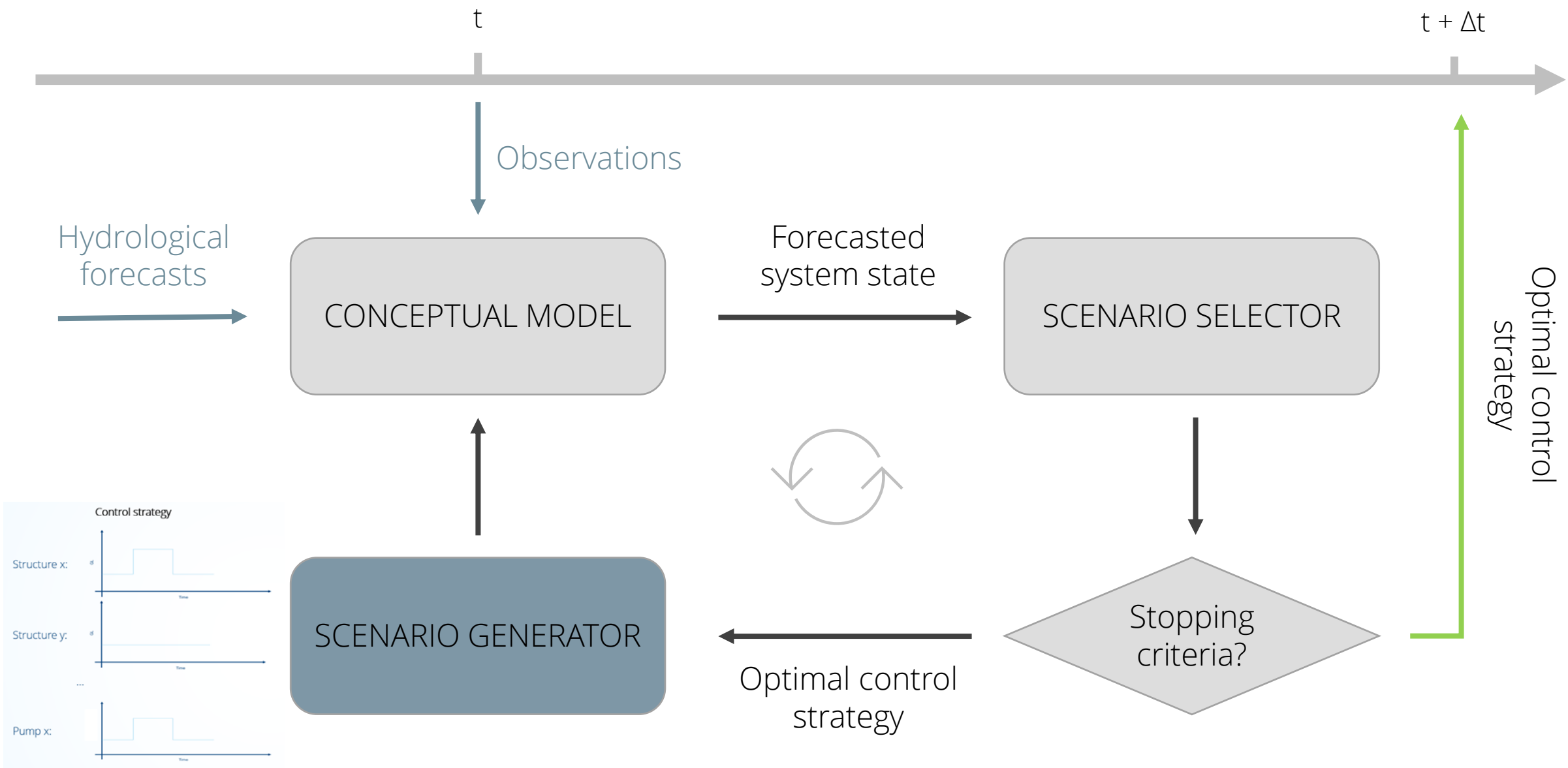
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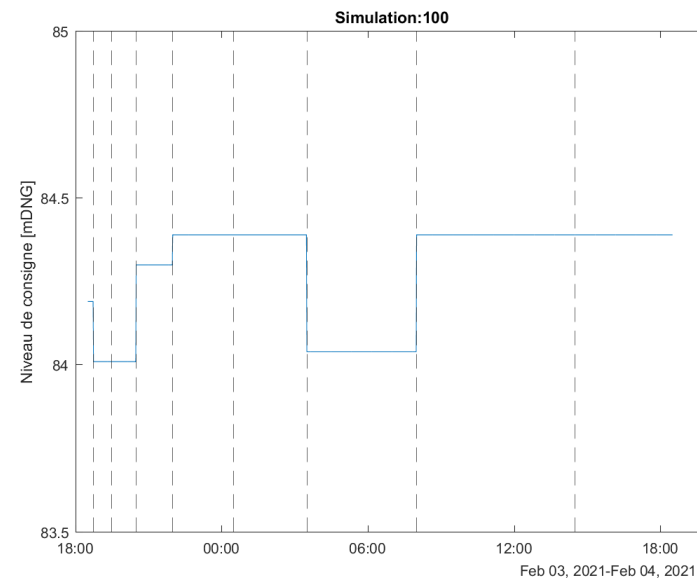
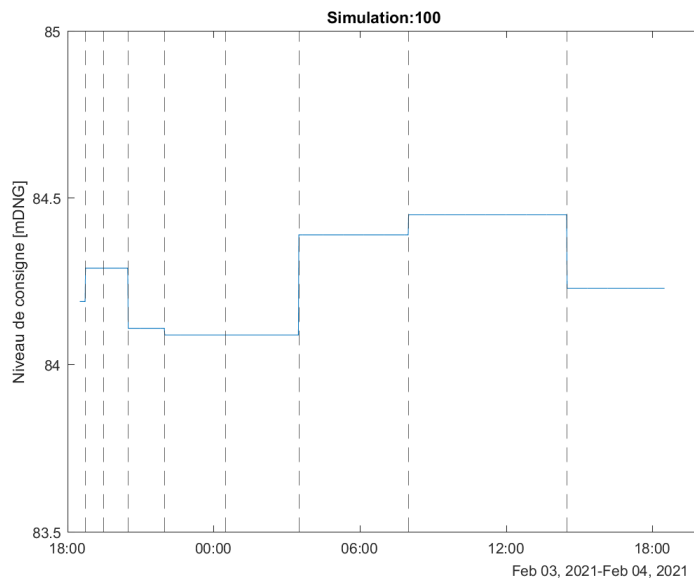
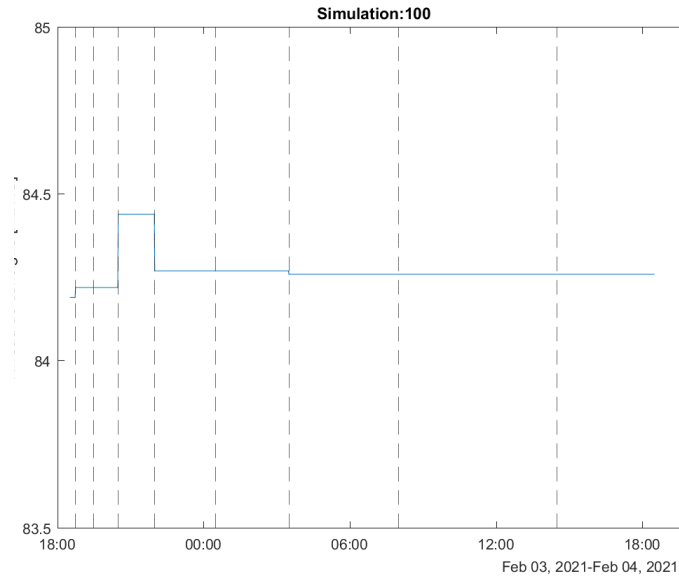
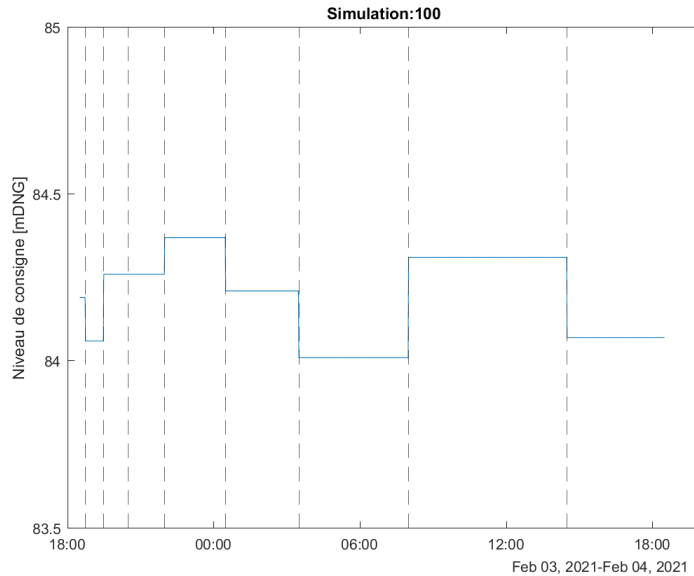




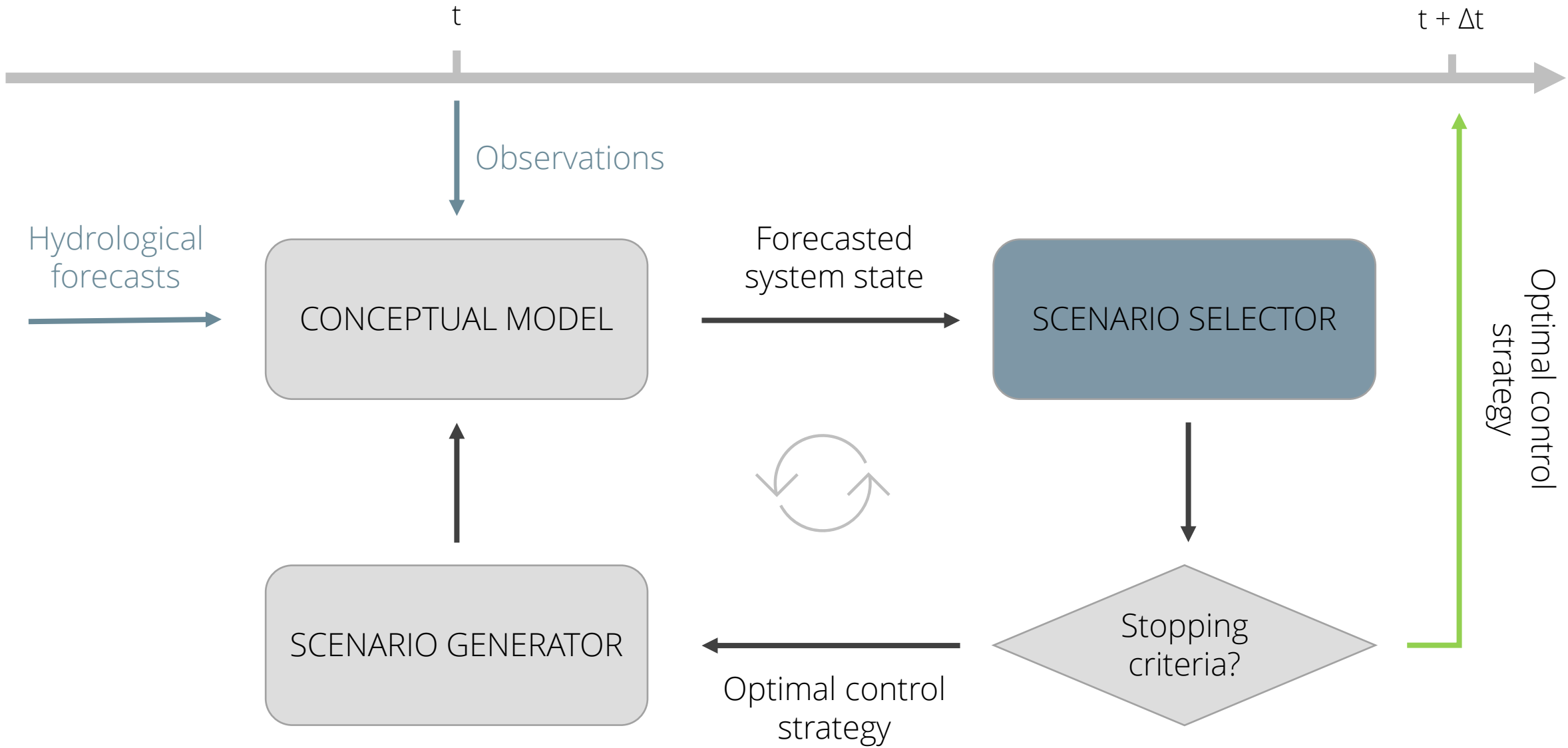




## SCENARIO GENERATOR

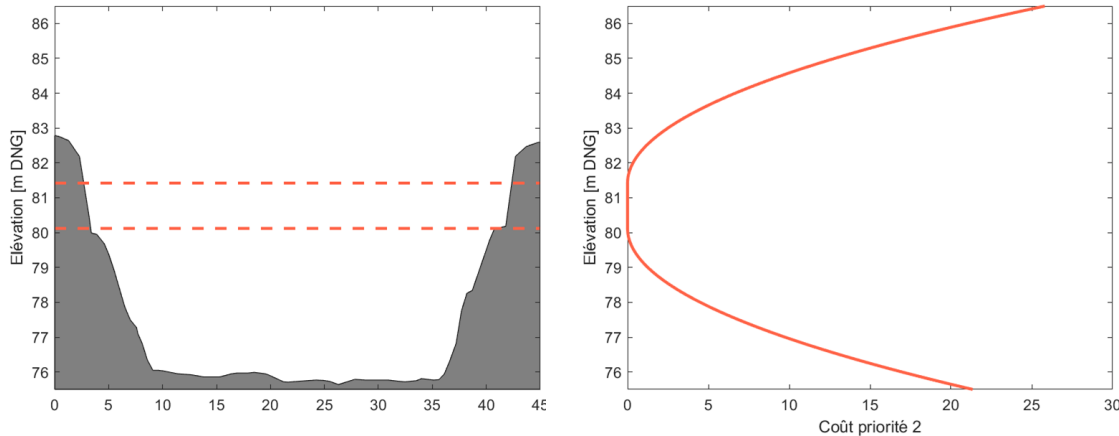


- Parallel Reduced Genetic Algorithm
- Generates **many potential control strategies** within defined limitations:
  - ✓ Can we optimize the structure?
  - ✓ How much / fast can it move?
  - ✓ ...
- New strategies generated as:
  - ✓ **Mutations** of existing strategies
  - ✓ New (pseudo-) **random** strategies
  - ✓ **Cross-overs** between optimized strategies
- **Robust** solution for operational tool
- Pilot project contains 19 manipulated variables



Priority	Objective
1	Safety at the structures
2	General safety
3	Navigation
4	Discharge and water level variations, Ecological discharges, Economic costs and benefits

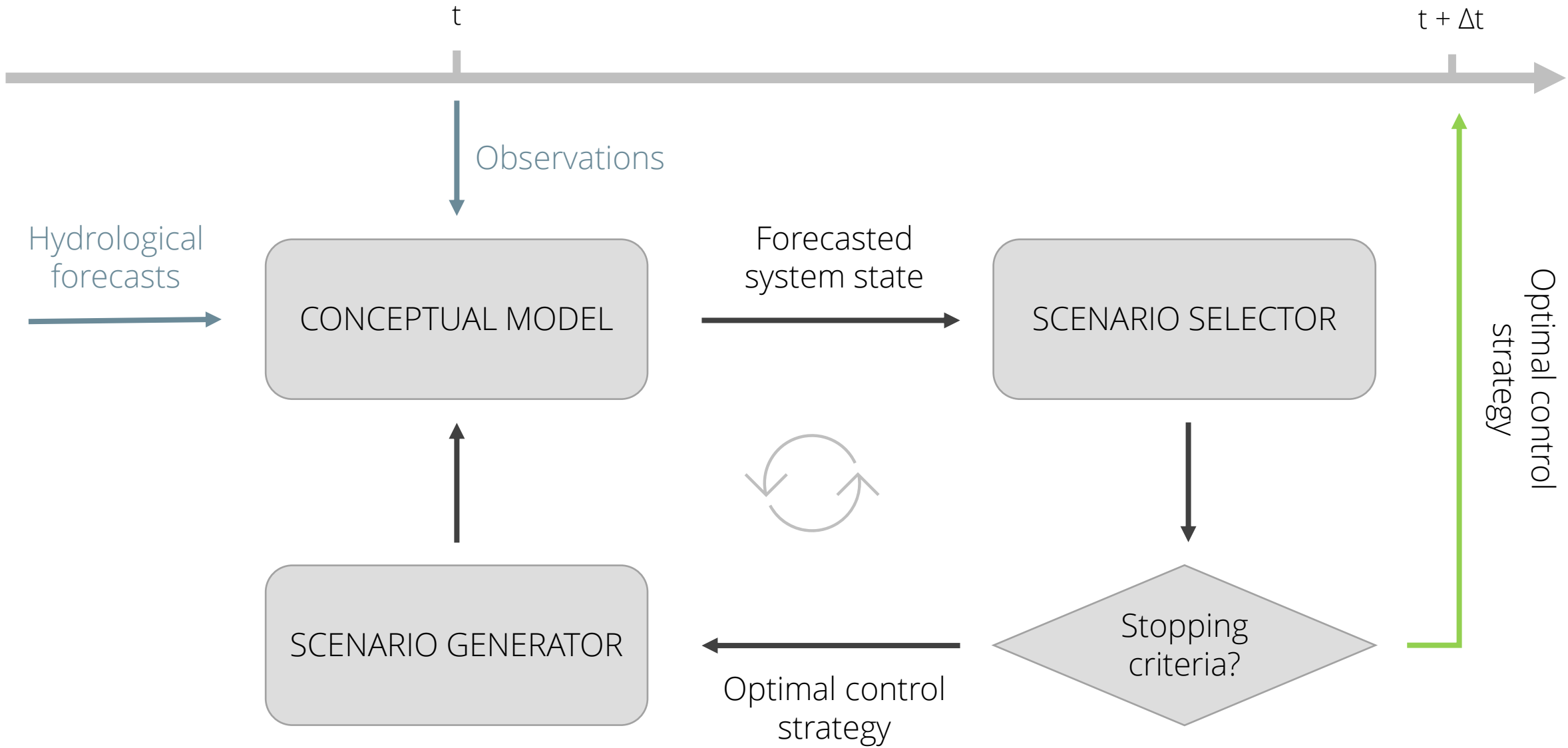
SCENARIO SELECTOR



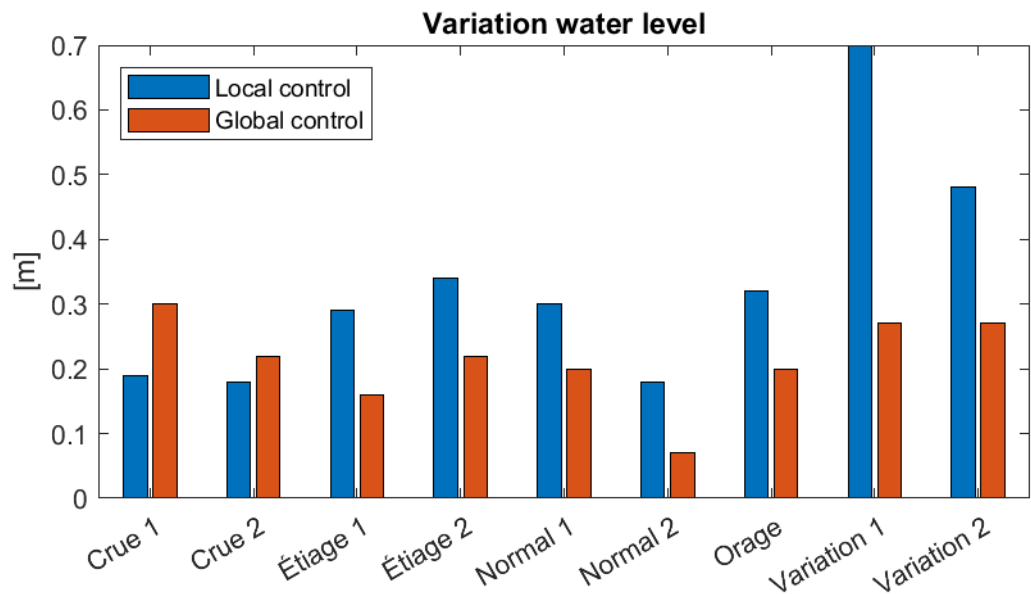
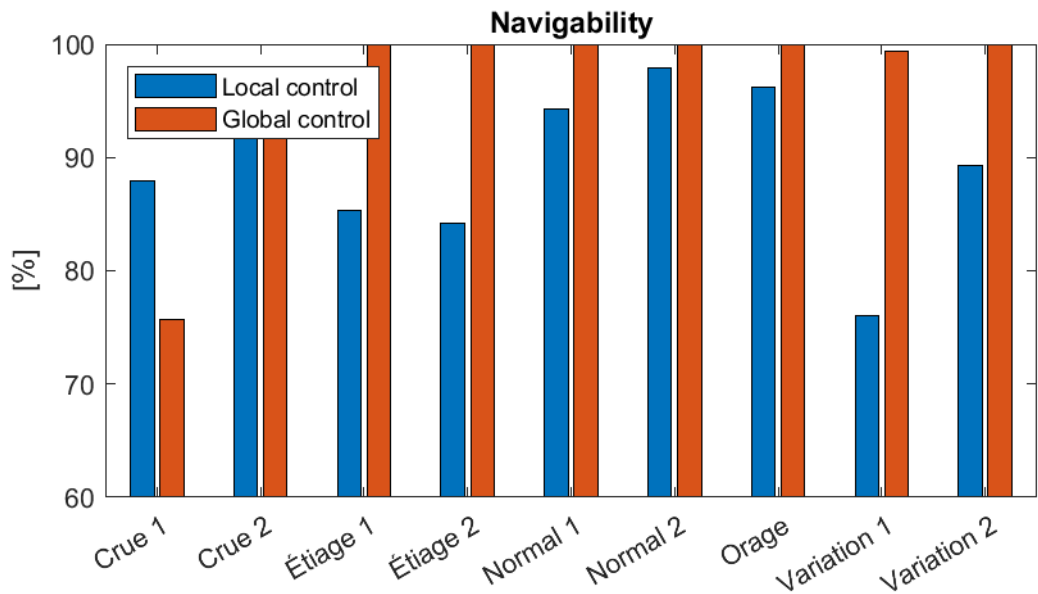
$$\begin{aligned}
 O_{prior4} = & \sum_{i=1}^{n_{MV}} \left( \sum_{j=1}^{N_{ctrl}} c_{i,movepen} (u_{i,j} - u_{i,j-1})^2 \right) \\
 & + \sum_{i=1}^{nbief} \left( \sum_{j=1}^{N_{pred}} c_{i,q,min} * (\min(q_{i,j} - q_{i,min}, 0))^2 + c_{i,\Delta h} * \max(\text{var}(\vec{h}_i)) + c_{i,\Delta q} \right. \\
 & \left. * \max(\text{var}(\vec{q}_i)) \right) + \sum_{i=1}^{npomp} \left( \sum_{j=1}^{N_{pred}} c_{i,p} * (dh_{i,j} * cr_{ip} * q_{i,j}) \right) \\
 & + \sum_{i=1}^{nturb} \left( \sum_{j=1}^{N_{pred}} -c_{i,t} * (dh_{i,j} * cr_{it} * q_{i,j}) \right) + \sum_{i=1}^{nbief} c_{i,v} \left( 60 * \sum_{j=1}^{N_{pred}} q_{i,j} - q_{i,T} \right)^2
 \end{aligned}$$

- Chooses the best potential control strategy
- **Transparent** with different priorities and objective functions
- Soft constraints are used within the objective function to **penalize the exceedance of a threshold**
- **Flexible** system with weight matrix to shift the importance within a priority depending on the situation
- Objective functions incorporate the model results of 87 variables along the pilot project





Results

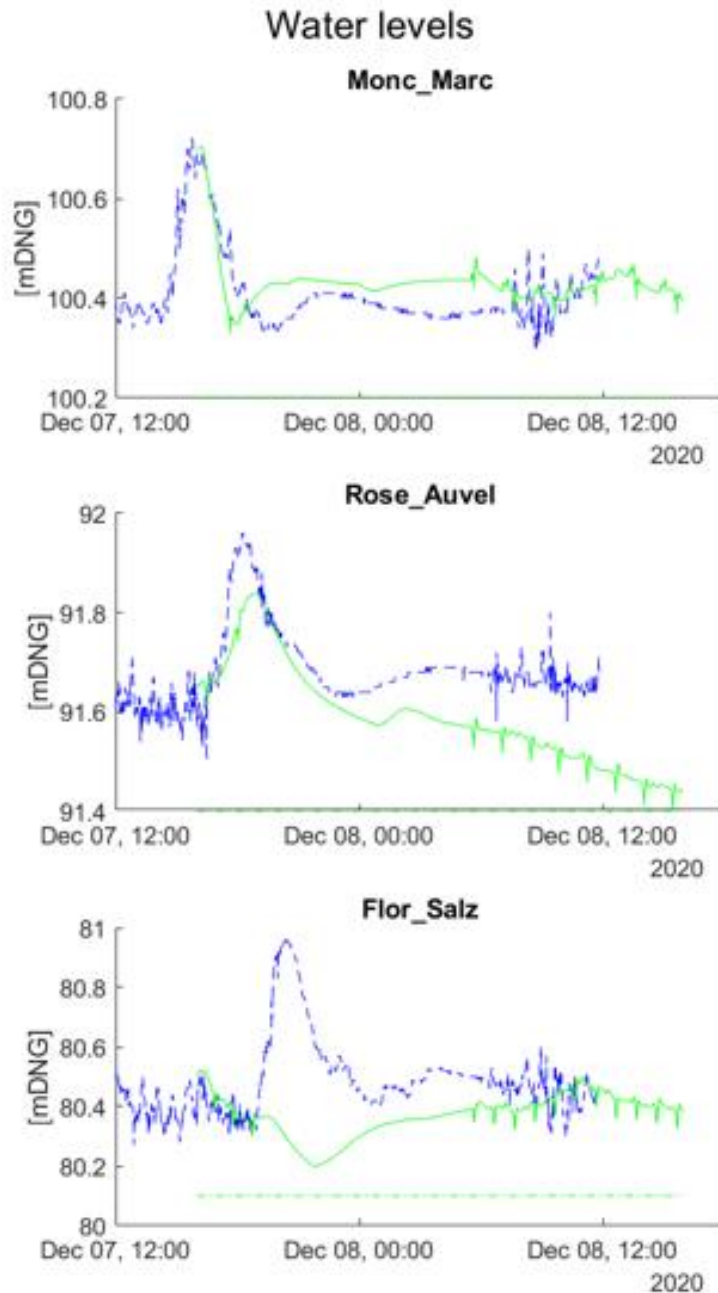


- Optimization reduces the cost of the objective functions resulting in better indicator values for a variety of historical events
- Stable performance across the events
- Improvements in the pro-active and re-active water management

Upstream



Downstream



Measurements  
Optimization results

## Results

- Optimization reduces the cost of the objective functions resulting in better indicator values for a variety of historical events
- Stable performance across the events
- Improvements in the pro-active and re-active water management

# Next steps

- Research to improve the current solution:
  - ✓ Analysis of the operational optimizations over the past months revealed that the data assimilation module could be improved
  - ✓ Further investigate the effect of the (uncertain) hydrological forecasts on the optimization results
- Testing the current solution:
  - ✓ Link between the optimization tool and the terrain will soon be realized
  - ✓ “Real Life” tests to assess the performance of the optimization in operational setting

An aerial photograph of a river system. In the center, a large industrial complex with several large buildings and a crane is situated on a peninsula. A bridge with a prominent arch spans the river to the left. To the right, a multi-lane highway runs parallel to the river. In the foreground, a long, narrow pier extends into the water, topped with a small white structure. The background shows a cityscape and more industrial areas.

Thank you for your attention

Contact:

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[ludovic.gouverneur@imdc.be](mailto:ludovic.gouverneur@imdc.be)

[tim.franken@sumaquabe](mailto:tim.franken@sumaquabe)