Variability of interactions between ground water, rivers and gravel pit lakes in the Seine alluvial plain of La Bassée, France.

Anne Jost[1] (*Anne.Jost@sorbonne-universite.fr*), Adem-Ilyes Chader[1], Fulvia Baratelli[1], Romane Nespoulet[1] & Nicolas Flipo[2]
[1]Metis, Sorbonne Université [2]Mines ParisTech, PSL Research University

www.sorbonne-universite.fr

1. Introduction

Hydrological time series analysis is a key asset for understanding hydrosystems' behaviour. It relies on in situ and high frequency data acquisition. Such a water level monitoring network has been deployed for several years along the alluvial corridor of the upper Seine River. In this lowland wet area, rivers, oxbows and gravel pit lakes interact with the chalk and alluvial aquifers.

We introduce the hydrological observatory deployed in the floodplain and present some preliminary results from the available water level time series in the different surface and underground water compartments.

2. Natural resources & territorial challenges

The alluvial plain of La Bassée in the middle reach of the Seine River (France) is both of environmental importance as a major wetland and at the centre of strategic issues regarding inland waterways transport, flood prevention, water and granular resources. The area has a rural and peripheral character, mainly in its upstream part, an agricultural land still regularly submerged in the case of large floods. Downstream of the plain, the extensive exploitation of aggregates and the river channelisation have shaped the landscape for decades (Lestel et al. 2020).

3. Diversity of ground water & surface water

The alluvial deposits and the underlying fractured chalk host aquifers containing significant ground water resources. About a thousand water bodies, the majority of which are gravel pit lakes, covers more than 8 % of the areal extent of the plain, mainly downstream. Typically small in size, a few metres deep, most of them are filled with waters from the aquifers. The river network is dense and anthropised. In particular, the Seine River channel rectification has led to additional oxbows along the river course. Flood protection and low-water discharge regulation for Paris led to the creation of four reservoirs, two of which are located upstream of the alluvial plain on the Seine and Aube rivers.

4. La Bassée hydrological observatory

A network of over 100 monitoring points:

73 piezometers monitoring alluvial shallow ground water
43 △ & chalk aquifer 26 ▲ or both 4 ▲
33 surface water gauging stations: 20 rivers ◆ including 9 on the Seine ◆, 1 canal, 7 gravel pit lakes ○ & 5 oxbows ○
2 weather stations ✚

Data are from national databases of Météo France (2) ADES (6), Banque Hydro (6), in connection with Seine Grands Lacs (SGL) flood protection project (44), monitored by the National Nature Reserve of La Bassée (24) & installed by us (26).

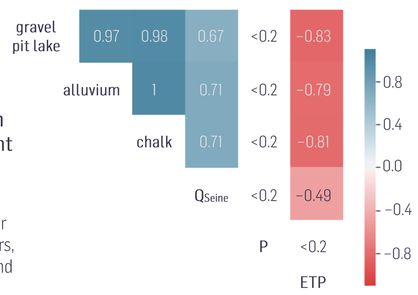
Loggers measured the water level at 15-min to daily intervals. The study period selected here is 2015-2021.

Data is managed through the Observation Analysis Tool OAT for the FREEWAT GIS environment (Rossetto et al. 2018).

Additional water-level measurements are available in the area but not used herein, in particular those installed as part of the Seine wide-gauge waterway VNF-led project (data transfer agreement in progress).

5. An overview of the hydrological functioning of the Bassée plain

The memory effect (here defined as the length of the auto-correlation function where its value is smaller than e^{-1}) is on average one and a half months in groundwater compared to almost one month for the Seine River. The inertia of the ground water system is of varying magnitude : it lengthens with distance from the Seine and during exceptional winter floods.



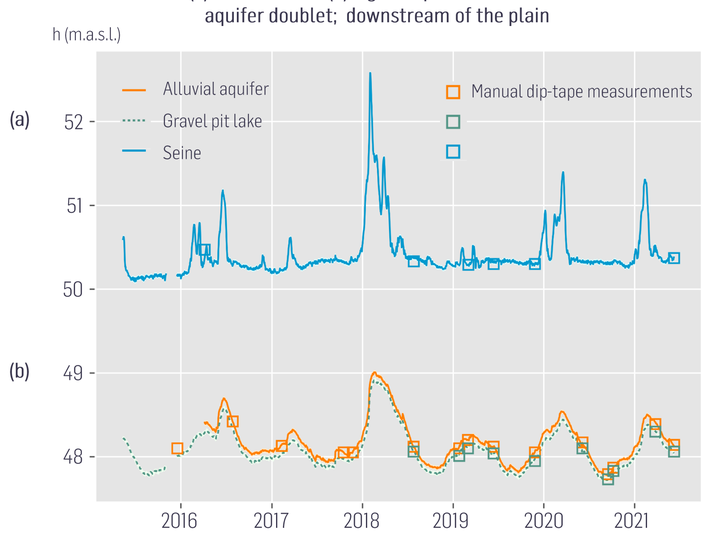
Representative correlation matrix between the different hydrosystem components downstream of the plain

(gravel pit lake water level, water levels in alluvial and chalk aquifers, Seine River flow, precipitations and 3 months shifted ETP)

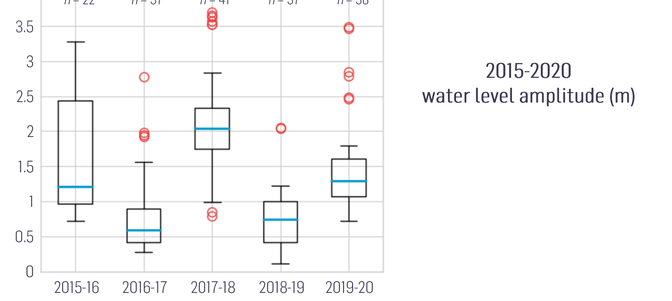
Time series are highgly correlated in the alluvial plain. The water level fluctuations of the monitored gravel pits reflect above all those of the aquifers, thus revealing their potential as a proxy for water resources. The alluvial and chalk aquifers are also closely connected and near equilibrium. In triplets, stream – aquifers interactions are often challenging to characterize based on recorded water levels as differences fall within the range of the measurement error interval.

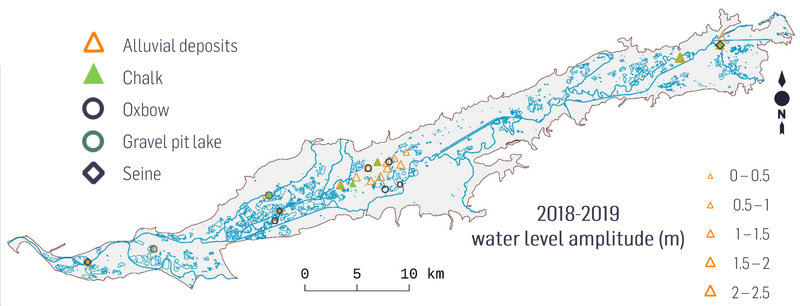
The Bassée plain is a highly human-modified hydrosystem in which river stage water levels are regulated both in high and low flow periods.

Illustrative plot showing water level time series: (a) Seine River & (b) a gravel pit lake – alluvial aquifer doublet; downstream of the plain



Gravel pit lake hydrographs show variations coincident with ground water level and of similar amplitude, indicating limited clogging, even for gravel pits that are a few decades old.





Annual water level variations in the Bassée hydrosystem have amplitudes of a few dozen centimetres to a few metres. Seasonal fluctuations are more pronounced in the upstream rural area and in years of major flooding (June 2016 & August 2018). They are also more prominent along the hillsides than near the river, except in the case of major floods.

6. Work in progress & Perspectives

Further analysis is required regarding the identification of the preponderant factors leading water level fluctuations in each surface and underground water compartments. We are still collecting data to refine our description of the plain hydrodynamics. Water temperature data will provide additional elements for the interpretation of surface water – ground water interactions.

The dynamics of the numerous gravel pit lakes that are present in the alluvial plain will soon be accessible for SWOT satellite observation : remote sensing will offer an integrated vision of water resources in the alluvial plain (Ottlé et al. 2020).

Data will also serve as a basis for ground water model calibration. We have already started building the model using the CaWaQS platform including a gravel pit module (Jost et al. 2016, 2020).

Future research may investigate how ground water - surface water interactions influence the water quality in the area. Several geochemical sampling campaigns have already been conducted during high and low flow periods.

References

Jost, A., S. Wang, B. Labarthe & N. Flipo (2016) – Impact of sand and gravel mining on groundwater resources in La Bassée alluvial plain, France. AGU, 12-16 December, San Francisco, California (U.S.A.).

Jost, A., T. Verbeke, C. Ottlé, N. Flipo, S. Wang, F. Colleoni, A. Bernus & A. Rivière (2020) – Modelling lake-groundwater interactions in preparation of future SWOT mission: the case of the gravel pit lakes in the Seine River alluvial plain, France. EGU, 3-8 May, Vienna (Austria).

Lestel L, Eschbach D, Meybeck M, Gob F (2020) The Evolution of the Seine Basin Water Bodies Through Historical Maps. In: Flipo N, Labadie P, Lestel L (eds) The Seine River Basin. The Handbook of Environmental Chemistry, vol 90. Springer, Cham.

Ottlé, C., A. Bernus, T. Verbeke, K. Pétrus, Z. Yin, S. Biancamaria, A. Jost, D. Desroches, C. Pottier, C. Perrin, A. de Lavenne, N. Flipo & A. Rivière (2020) – Characterization of SWOT water level errors on Seine reservoirs and La Bassée gravel pits: impacts on water surface energy budget modeling. Remote Sensing, 12, 2911.

Rossetto R, De Filippis G, Borsi I, Foglia L, Cannata M, Criollo R, Vázquez-Suñé E (2018) Integrating free and open source tools and distributed modelling codes in GIS environment for data-based groundwater management. Environmental Modelling & Software, 107: 210–230.

Acknowledgements

This work is funded by the PIREN Seine research programme & CNES through the TOSCA-SPAWET programme. Data are partly from Météo France, Banque HYDRO, ADES, Seine Grands Lacs & National Nature Reserve of La Bassée databases. Thanks to all those who accompanied us during the field campaigns.

48th IAH Congress BRUSSELS BELGIUM 2021 Inspiring Groundwater