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Procedia Engineering 209 (2017) 34–41

Procedia Engineering

www.elsevier.com/locate/procedia

Urban Subsurface Planning and Management Week, SUB-URBAN 2017, 13-16 March 2017, Bucharest, Romania

Good practices in cultural heritage management and the use of subsurface knowledge in urban areas

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Abstract

City growth threatens sustainable development of cities. Over the past decades increased urbanization has created more pressure - not only on the suburban outskirts - but also in the inner core of the cities, putting important environmental issues such as water management and cultural heritage under stress. Cultural heritage, either standing monuments or archaeological remains, is internationally recognized as an important legacy of our history. The European Convention on the Protection of the Archaeological Heritage incorporates concepts and ideas that have become accepted practice in Europe. Conservation and enhancement of archaeological heritage is one of the goals of urban planning policies. One of the key objectives of the European policy is to protect, preferably in-situ, archaeological remains buried in the soil or seabed and to incorporate archaeological heritage into spatial planning policies. Conflicts with prior uses and unappreciated impacts on other subsurface resources, amongst them archaeological heritage, make use of underground space in cities suboptimal. In terms of ecosystem services, the subsurface environment acts either as a carrier of archaeological heritage in situ (stewardship) or supports above-ground cultural heritage. Often, it's not enough to protect the heritage site or monument itself: new developments outside a specific protected area can lead to changes in groundwater level, and cause serious damage to heritage buildings and archaeological deposits. This paper presents good practices in cultural heritage management and the use of subsurface knowledge in urban areas.

Peer-review under responsibility of the scientific committee of the Urban Subsurface Planning and Management Week.

Keywords: cultural heritage, groundwater, subsurface, water balance, management

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Peer-review under responsibility of the scientific committee of the Urban Subsurface Planning and Management Week.
10.1016/j.proeng.2017.11.127

1. Introduction

City growth threatens sustainable development - a pattern of growth in which resource use aims to meet human needs while preserving the environment for present and future generations [6] - of cities. Over the past decades increased urbanization has created more pressure - not only on the suburban outskirts - but also in the inner core of the cities, putting important environmental issues, such as water management and cultural heritage, under stress.

Historic cities face the challenge of new developments. This (re)development is typically part of a planned renewal, but at the same time directs attention to how historic buildings and archaeological deposits in the inner city should be managed [9]. In contrast to the attention given to the visible (above-surface) expressions of cities, there is a marked lack of appreciation of the subsurface among those who plan, develop and manage cities [13]. The subsurface contains a legacy of former developments (Fig. 1), that should be acknowledged in modern urban development. This lack of appreciation of the subsurface is manifested in a lack of coordinated policy on the subsurface. Consequently, the area beneath the cities is used inefficiently at best and unsustainably at worst; safeguarding of subsurface ecosystem services, such as “stewardship” for archaeological heritage, lacks robustness and conflicting uses of the subsurface are largely unaddressed. Conflicts with prior uses and unappreciated impacts on other subsurface resources, amongst them archaeological heritage, make use of underground space in cities suboptimal. In terms of ecosystem services, the subsurface environment acts either as a carrier of archaeological heritage in situ (stewardship) or supports above-ground cultural heritage. Often, it’s not enough to protect the heritage site or monument itself: new developments outside a specific protected area can lead to changes in groundwater level, and cause serious damage to heritage buildings and archaeological deposits [2].

This paper provides examples of good practice related to the protection and preservation of 1) standing monuments and sites, and 2) archaeological heritage and artefacts *in-situ*, in a dynamic city environment. The main objective of this paper is to enhance awareness of cultural heritage as a driver for urban subsurface knowledge development and related sustainable urban water management.

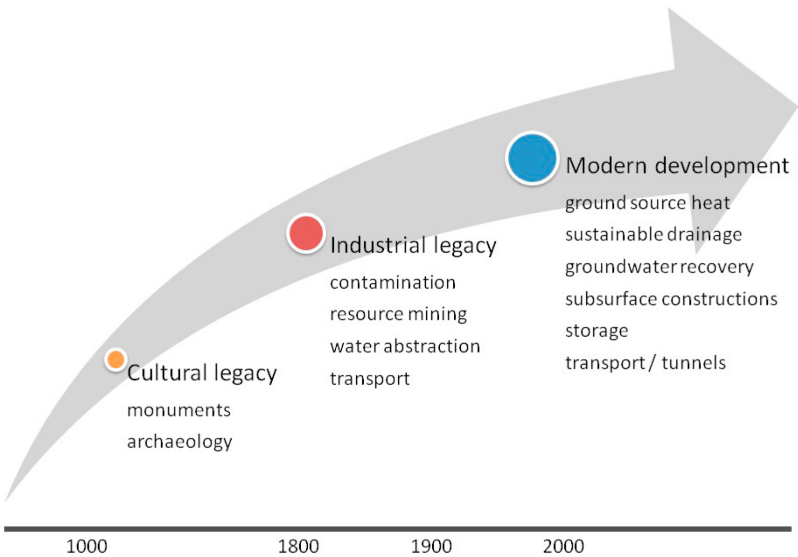

Fig. 1 Urban development legacies

1.1. Context

Cultural heritage can be regarded as one of the fields of application of subsurface knowledge acquisition, interpretation, management and modelling. Although protection and preservation of tangible cultural heritage often is dependent on the subsurface, or on dynamic processes within the subsurface, cultural heritage management is still not seen as a driver for urban subsurface knowledge development. In recent years, the field of cultural heritage preservation, and particularly archaeological (subsurface) heritage preservation, has seen a significant progress towards a more holistic approach, involving a range of different disciplines. This progress has also been triggered by some international examples of alarming developments where environmental changes, caused by urban development, resulted in accelerated decay of archaeological deposits as well as in damage to above-ground heritage buildings.

The European Convention for Archaeological Heritage [8] states that archaeological heritage preferably should be preserved in situ, within the subsurface environment. A proper understanding of the natural and man-made subsurface environments that affect heritage is essential for in situ preservation, mitigation design as well as management of heritage sites. Management of cultural heritage is often related to surface -and groundwater management. Dewatering is one of the greatest concerns for those managing waterlogged archaeological sites, as well as a great danger for wooden foundations of above-ground monuments. To ensure their long-term survival, waterlogged organic material needs to remain waterlogged year-round as this significantly reduces the diffusion of oxygen required for most bacterial decay and aerobic corrosion reactions [10].

1.2. Structure

This short paper is structured according to two main cultural heritage topics, each briefly illustrated by a good practice example case, collected during COST Action TU1206 (2013-2017):

1. Standing cultural heritage; monuments and historic buildings and sites;
2. Subsurface cultural heritage; archaeological deposits and artefacts *in-situ*.

Based on these topics, the overarching interconnection between urban water management and cultural heritage management is elaborated and discussed. Water management is not only central in both topics, it also represents a significant cultural heritage value by itself in many historic cities across Europe and beyond. For a more extended review of good practices in cultural heritage management and the use of subsurface knowledge in urban areas, the reader is referred to COST Action Work package report 2.7 [3].

2. Standing cultural heritage; monuments and historic buildings and sites

Many historic cities in Europe and beyond contain important monuments, historic buildings and other standing remains of human activity. Depending on the historic city development, it is a collective good ranging from the infancy of the city, to evidence of trade, industrial and pre-modern development. The protective management of standing monuments and historic sites depends on knowledge of geological and man-made subsurface conditions and processes affecting the stability and degradation of this cultural legacy. The Vondelpark case illustrates this dependency and how subsurface knowledge contributes to improved protection of standing monuments and sites.

The Vondelpark is one of the largest city parks in Amsterdam, and certainly the most famous park in the Netherlands, which welcomes more than 10 million visitors every year. The name Vondelpark was adopted in 1867 when a statue of Dutch poet Joost van den Vondel was situated into the park. The statue was constructed on wooden piles, to avoid subsidence in the muddy subsurface. By 1877 the park was enlarged and it reached its current space of 45 hectares. At that time, its site was on the edge of Amsterdam, since then it has become central in the city, close to Leidseplein and Museumplein. Since 1996 the whole park is designated as a National Monument (www.amsterdam.info/parks/vondelpark). Constructed on a muddy dump area, the Vondelpark must go through a total renovation each 30 year. This is because the actual ground level of the park constantly lowers itself. If these works would not be done, the whole park would be covered by water. It is visible after heavy rains at the end of the period before the next renovation, when whole parts of the park become vast ponds. The water cannot be simply pumped out as this would lower the groundwater around the park and endanger the wooden foundations of the buildings nearby. Subsidence of the Vondelpark with an average rate of 1 cm per year during the last 150 years has resulted in 1.5 meter lower terrain levels. This is clearly visible at the Vondel statue, which is now positioned high in the terrain due to the stable foundation of wooden piles (Fig. 2).

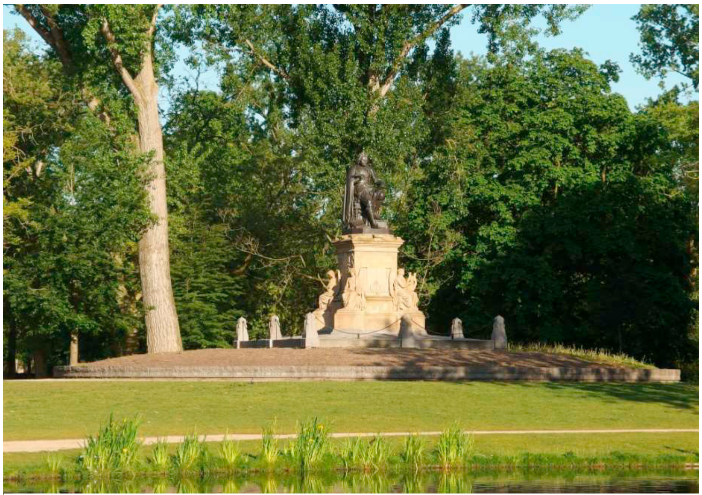

Fig. 2 Statue of Vondel (photo: Guilhem Vellut, creative commons)

Subsidence invokes serious problems not only for the maintenance and water management within the park itself, but particularly along the borders of the park, where monumental houses founded on wooden piles are located. The wooden foundations are threatened by the lowering groundwater levels necessary to keep the park dry. A series of geotechnical and hydrogeological investigations have been carried out to find good solutions [21]. Some seem to be less effective, such as implementing an infiltration drain, because of the complex groundwater system [17]. Some are implemented with more success: one of the solutions was developed in the area called "Slurf", a narrow entrance section of the park. A historic small creek was revived using a water circulation plan to improve water quality with a waterfall, cascades and natural seepage. Different disciplines have reached agreement on an almost perfect solution [20]. A combined system with a dry swale with soil passage, constructed wetland, drainage, infiltration and a hydrological barrier now secures improved groundwater conditions and supply of clean surface water that is circulated over a constructed wetland to improve the water quality. It resulted in more durable paths and lawns, trees are growing older and wooden pile foundations are no longer threatened by low groundwater levels. Involvement and cooperation with stakeholders has been a key success factor in this case study and is also recognized by other studies on heritage and water management [16]. Close cooperation by the consulting agency TAUW BV with the municipality of Amsterdam and the water authority, including active consultation of residents, resulted in a solution where the historical park design and modern requirements are considered. All stakeholders have co-operated in a fruitful way, and their dedication shows that the Vondelpark really is a valuable cultural heritage asset, and not only a "green" area in the urban environment.

3. Subsurface cultural heritage; archaeological deposits and artefacts in-situ

There are quite a few good examples of how archaeological heritage depends on subsurface conditions and processes, particularly related to hydrological conditions [11, 22]. In this section, an example is given on how archaeological heritage and earth sciences disciplines can interact and benefit from each others' techniques and competence. The case of the World Heritage Site Bryggen in Bergen, Norway, is probably one of the best documented case studies in the world on how urban development can threaten both standing monuments and archaeological remains, and how mitigation measures using subsurface knowledge have contributed to its preservation. The Bryggen

Project is described in city case study report TU1206-WG1-003 [19] and in a separate book by Riksantikvaren [18].

A large part of the Bergen centre, the Vågsbunnen area, is situated on top of several metres of archaeological deposits that are vulnerable for degradation and consequential subsidence. Bryggen in Bergen is part of this area, and designated as a World Heritage Site since 1979, and this includes the invalueable archaeological deposits below the historic buildings – reaching thicknesses in excess of 10 metres in places (Fig 3.).

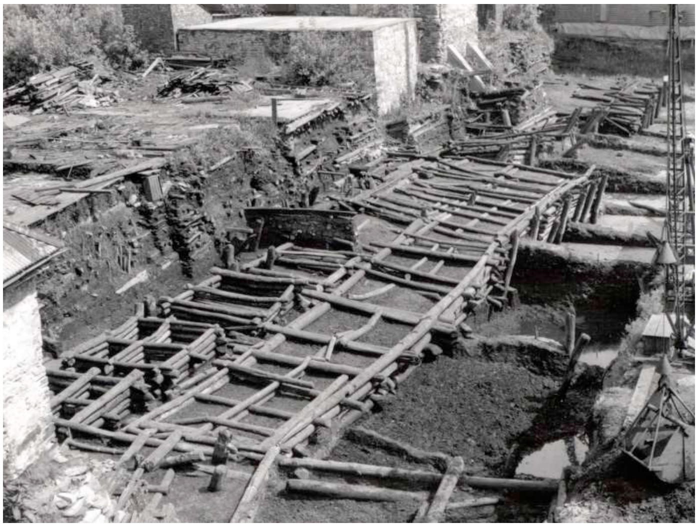

Fig. 3 Archaeological deposits at Bryggen in Bergen; Quay structure, 800 AD (photo: Bymuseet Bergen).

These deposits encapsulate the entire history of the settlement and the people who lived and worked in it. By the end of the 20th century, it had become apparent that the buildings were suffering from severe subsidence, and terrain and building level surveying showed that the rate of subsidence in some parts of the site was alarming. It did not take long to identify a likely causal train; simply stated, loss of groundwater, leading to decay of organic matter in the archaeological deposits, resulting in accelerated subsidence. A monitoring programme was developed under the patronage of the Directorate for Cultural Heritage in Norway to map, analyse and interprete the subsurface conditions of the site: the state of preservation of the archaeological deposits, the preservation conditions in the deposits, and the complex hydrogeological system that controls the preservation conditions. The program established a link between the loss of groundwater and the documented damages to the buildings and archaeological deposits, and identified drainage of groundwater towards the neighbouring hotel site constructed in 1979, as the principle cause of the problem [7, 1, 5]. The Norwegian Parliament approved an extraordinary allocation of NOK 45 million to combat the problem, with the overall aim of raising the groundwater levels and reducing the rates of organic decay and, ultimately, subsidence. The work should entail negligible removal of intact archaeological deposits, thus making it necessary to mainly find non-disturbing, hydrological methods for reaching this aim. A variety of specialists from geoscientific disciplines and heritage science and management were recruited to form an advisory team [18].

A range of mitigation measures were implemented to improve preservation conditions. These measures were mostly focused on re-establishing higher and less dynamic groundwater flow conditions, which should lead to more reduced conditions at the site. Reduction of groundwater temperature was not considered an imminent mitigation goal in comparison to obtaining more saturated conditions, although it was agreed that temperatures should be monitored and preferably not increased as a consequence of mitigation. During redevelopment and construction of the neighbouring hotel in 1979, large amounts of the existing low permeable archaeological remains and natural grounds were replaced by modern fill materials and a piled building construction with underground parking. The piezometric head below the archaeological deposits is largely controlled by this ‘made ground’ and its drainage capacity [1]. Local shallow groundwater levels were affected also, dependent on the thickness, permeability, and distribution of the archaeological deposits, and on the proximity to the hotel. Shallow groundwater level changes are an immediate threat to the preservation of archaeological deposits, as organic material is exposed to air and rapid oxidation processes [4, 12, 14]. The main mitigation target has therefore been to create a hydrological barrier between the area where urban redevelopment has disturbed the local water balance and the affected areas at Bryggen that are characterized by poor preservation conditions. Focus has been put on increasing the shallow groundwater levels and reducing dynamic flow conditions [3]. The hydrological barrier consists of a connected series, or “treatment train”, of sustainable urban drainage systems (SuDS), with rainwater gardens, green swales and a subsurface infiltration-transport system with adjustable infiltration levels (Fig. 4).

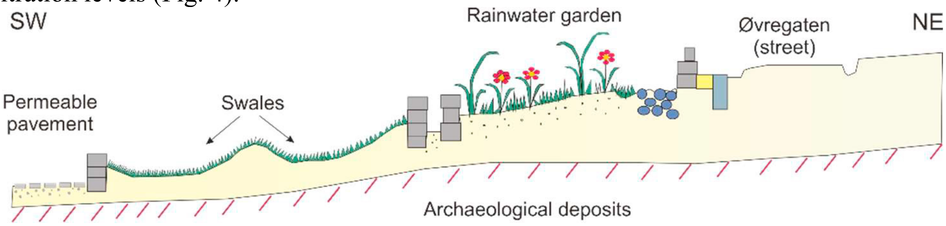

Fig. 4 Upper section of SuDS treatment train, Bryggen in Bergen, leading to the subsurface infiltration-transport system downstream of swales (drawing, A. Seither, NGU).

Through this system, rainwater from roofs and surfaces is infiltrated to the subsurface and archaeological deposits. The system not only actively contributes to increasing groundwater levels, but also to a strong reduction of groundwater variations. Before establishing this infiltration system, leakages through the existing sheet piling around the hotel areas were repaired as best as possible. Remaining leakages through and below the sheet piling still result in lowering groundwater levels at Bryggen, and are therefore a permanent threat to the site. In order to reduce the risk of low groundwater levels during dry periods, groundwater pumps were installed to extract excess leakage water from below the hotel area, and re-infiltrate this water into the infiltration system.

Early monitoring results shown that the preservation conditions in substantial volumes of archaeological deposits have been either stabilized or improved [14]. Subsidence of the buildings and ground has been reduced to more or less natural rates. However, the damage suffered by the archaeological deposits since the redevelopment of the area in 1979, cannot be reversed. Permanent alteration of the ground conditions made it impossible to re-establish the original hydrogeological conditions. Infiltration will continue to be necessary for the foreseeable future in order to maintain the area’s water balance. The choice for SuDS ensures the most sustainable water supply for infiltration and will be resilient in the face of climate change. Continued monitoring will be necessary to follow trends and changes in the future.

4. Conclusions

This work carried out through COST Action TU1206 has enabled us to collect and assess best or good practice in relation to the role of subsurface knowledge in cultural heritage management, and particularly in relation to *in-situ* archaeological heritage preservation. The European Convention for Archaeological Heritage [8] states that archaeological heritage preferably should be preserved *in-situ*, within the subsurface environment.

In recent years, the field of cultural heritage preservation, and particularly archaeological heritage preservation, has seen a significant progress towards a more holistic approach, involving a range of different disciplines. This progress has also been triggered by some international examples of alarming developments where environmental changes caused by urban development resulted in accelerated decay of archaeological deposits as well as damage to above ground heritage buildings. A proper understanding of the natural and man-made subsurface environment that affect heritage is essential for *in-situ* preservation, mitigation design as well as management of heritage sites. Only then in-situ preservation is feasible and mitigation and management of heritage sites can be successful.

The good practice examples that are highlighted in this paper show that early and active involvement and cooperation of stakeholders in different disciplines are key success factors. Both the Vondelpark case study and the Bryggen case show that sustainable water management systems not only improved resilience with respect to a changing climate with prolonged periods of droughts and more intense precipitation events, but at the same time contribute to preserve both standing and buried cultural heritage. A key lesson learned from the case studies is the recognition by decision makers that sustainable water management solutions not only deliver multiple benefits in terms of climate adaption and social benefits by “greening”, but also can be beneficial for heritage preservation.

There is a large risk of heritage deterioration by unforeseen circumstances. The reasons for these are plenty; natural, political or management decisions, characteristics of the soil, historical activities, water circulation, human action or just the wrong location. This work carried out in COST Action TU1206 has enabled us to identify some key knowledge gaps; both within planning processes, technological design and not in the least related to awareness.

The multiple benefits that sustainable water management systems can provide, including heritage support, are not yet fully recognized. A knowledge gap exists in terms of awareness of the option to retrofit climate adaptation measures in historic cities. Technological knowledge gaps exist in terms of modifications to water management systems when they are to be applied in areas with vulnerable cultural heritage, either standing monuments or buried archaeological deposits. Any new subsurface structure can potentially damage archaeology, directly or indirectly through water balance changes. This trade-off requires special attention and experience, which does not yet exist.

Acknowledgements

This paper is based upon work from COST Action TU1206 Sub-Urban and particularly working group 2.7. The authors are very grateful to the COST Association for Science and Technology for the financial support that made it possible to bring together expertise in both geoscience and heritage fields. The authors wish to acknowledge the contributions of all participants at the workshop “Cultural Heritage and the Subsurface”, held on March 16, 2015: prof. H. Kars (VU Univ., NL), prof. G. Gianighian (IUAV, IT), dr. H. Matthiesen (National Museum of Denmark, DK), dr. Musa (Univ. of Mostar, BA), R. Stuurman (Deltares, NL), R. Stenbro (NIKU, NO), D. Kreminska (NIVA, NO), A. Seither (NGU, NO), dr. T. M. Muthanna (NTNU, NO), dr. G. Ganerød (NGU, NO) and M. Vorenhout (MvH Consult, NL). The authors also wish to thank the Directorate for Cultural Heritage in Norway for its support and encouragement to share data and knowledge related to the Bryggen Project.

References

[1] J. de Beer, Statusrapport grunnvannsovervåking og hydrogeologisk modellering ved Bryggen i Bergen. NGU-report 2008.069 (2008) 72 p.
[2] J. de Beer, A. Seither, Groundwater and cultural heritage, Guest Editorial in: Quat. Intl. 368 (2015) pp. 1-4.
[3] J. de Beer, Cultural Heritage, a review of good practices in cultural heritage management and the use of subsurface knowledge in urban areas. TU1206 COST Sub-urban WG2 report, TU1206-WG2.7-007 (2016).
[4] J. de Beer, H. Matthiesen, Groundwater monitoring and modelling from an archaeological perspective: possibilities and challenges. NGU Special Publication 11 (2008), pp. 67-81.
[5] J. de Beer, H. Matthiesen, A. Christensson, Quantification and Visualization of In Situ Degradation at the World Heritage Site Bryggen in Bergen, Norway. Conservation and Management of Archaeological Sites Volume 14(Nos 1-4):215-27, 2013.
[6] The Brundtland Commission, Report of the World Commission on Environment and Development: Our Common Future, Published as Annex to General Assembly Document A/42/427, Development and International Co-operation: Environment (1987).
[7] A. Christensson, Z. Paszkowski, J.A. Spriggs, L. Verhoef, Safeguarding historic waterfront sites. Bryggen in Bergen as a case study. 1st Edition. Stiftelsen Bryggen and Polytechnika Szczecinska, Bergen, Norway, 2004.
[8] Council of Europe, European Convention on the protection of the archaeological heritage (revised). European Treaty Series No. 143, Valetta, 16.1.1992.
[9] K. Harvold, K. Larsen, J. de Beer, F.C. Boogaard, V.V. Martens, H. Matthiesen, T.M. Muthanna, A.M. Seither, R. Skogheim, M. Vorenhout, Protecting the Past and Planning for the Future: Results from the project "Cultural Heritage and Water Management in Urban Planning" (Urban WATCH). CIENS report 1:2015 (2015), 53 p.
[10] Historic England 2016 Preserving archaeological remains: Decision-taking for sites under development. Swindon. Historic England.
[11] Huisman, H. (ed.), Degradation of Archaeological Remains. Den Haag, 2009, SDU Uitgevers, 236 p.
[12] J. Hollesen, H. Matthiesen, The Influence of Soil Moisture, Temperature and Oxygen on the Oxic Decay of Organic Archaeological Deposits, Archaeometry 57(2), April 2014, pp. 362-377.
[13] T. Malim, I. Panter, M. Swain, The hidden heritage at Nantwich and York: Groundwater and the urban cultural sequence. Quaternary International 368 (2016) pp. 5-18.
[14] H. Matthiesen, J. Hollesen, R. Dunlop, A.M. Seither, J. de Beer, Monitoring and Mitigation Works in Unsaturated Archaeological Deposits, Conservation and Management of Archaeological Sites 18(1-3):86-98, September 2016
[15] H. Matthiesen, J. Hollesen, R. Dunlop, A.M. Seither, J. de Beer, In situ measurements of oxygen dynamics in unsaturated archaeological deposits, Archaeometry 57(6), 2015 pp. 1078-1094.

[16] Mitchell, Katherine D., "Cultural Heritage and Rising Seas: Water Management, Governance, and Heritage in Venice and Amsterdam" (2017). UVM Honors College Senior Theses. 161. http://scholarworks.uvm.edu/hcoltheses/161
[17] RIZA, Grondwaterzorg(en) in de praktijk. Eindrapport, 2002.
[18] J. Rytter, J., I Schonhowd (ed.), Monitoring, Mitigation, Management. The Groundwater Project – Safeguarding the World Heritage Site of Bryggen in Bergen. Riksantikvaren. Oslo, 2015, 213 p.
[19] A. Seither, G.V. Ganerød, J. de Beer, T. Melle, I. Eriksson, Bergen. TU1206 COST Sub-Urban WG1 Report, TU1206-WG1-003, 2016.
[20] Q.A. Verhoog. Vondelpark behoudt romantisch karakter. Land+Water, May 2007.
[21] A.J. Varkevisser, I.A. de Groot, Beschrijving geohydrologische situatie Vondelpark en Willemsparkbuurt te Amsterdam, Tauw BV, 2013.
[22] Willem J. H. Willems & Henk P.J. van Schaik (ed.), Water and Heritage, Material, Conceptual and Spiritual Connection, 2015 Leiden, Sidestone Press.