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Leading the way to stormwater control measures asset management: how your research can feed ours!

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Highlights

- Asset management for stormwater control measures is gaining momentum due to preoccupation for utility managers,
- Asset management encompasses different key activities and draws on a wide range of knowledge,
- Many research studies contribute to asset management without even knowing it!

Why is SCMs asset management important?

The first stormwater control measures (SCMs) were installed more than 30 years ago (Fletcher et al., 2014) with the primary (and almost exclusive) focus on stormwater management at the source of the runoff or close to it. They are nowadays widely used and tend to provide more services in relation to the natural environment, the cities and their inhabitants (Belmeziti et al., 2015). Since the emergence of SCMs, operational and research questions have largely focused on optimising hydrologic, hydraulic and water quality performance. After several decades of operation, there is, however, a growing concern regarding their medium and long-term performance and maintenance. This growing concern is confirmed by recent studies (Drake et al., 2013; Al-Rubaei, 2016; Wery et al., 2017; Cherqui et al., 2019). It is also confirmed by the increasing number of guidelines dedicated to their operation and maintenance (O&M) (see <http://tiny.cc/guidelinesSCMs> for an up-to-date list). As with any asset, stormwater control measures (SCMs) need to be managed over their life. Asset management involves managing assets to minimize their ownership and operating cost, while delivering the required level of service (Schulting and Alegre, 2007).

The article aims at presenting five operational or research asset management approaches on SCM – governance, life cycle cost evaluation, performance assessment, evolution, and maintenance and rehabilitation. Essentially, governance oversees and operates every other approach. Life-cycle cost evaluation constrains both performance assessment and maintenance and rehabilitation activities which in their turn, impact each other and SCM evolution. The connections between these five approaches is illustrated in Figure 1.

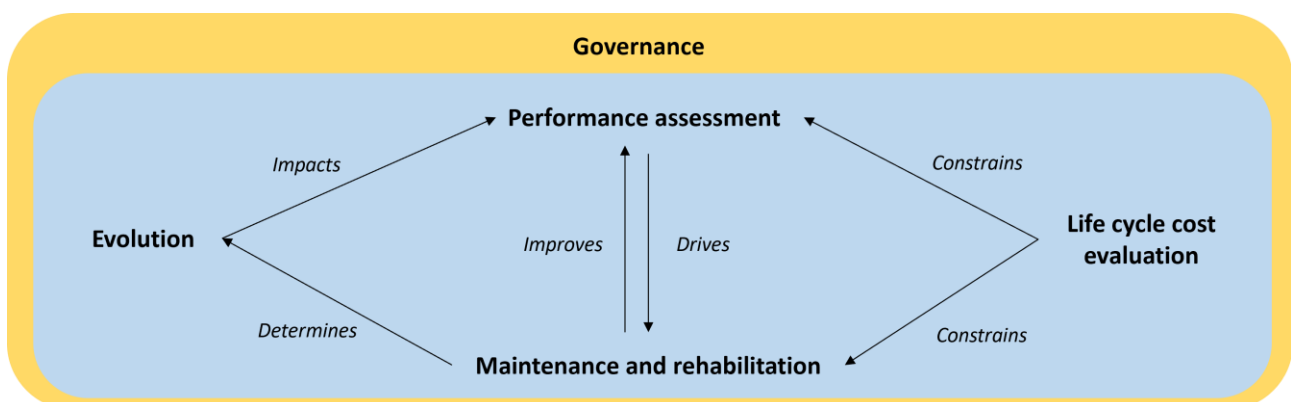


Figure 1. Hierarchy and connections between the five approaches to SCMs asset management.

What approaches in SCMs asset management are already tackled nowadays?

As discussed previously, asset management (AM) draws on many different research fields. While there is a growing interest in the research community, SCMs AM research remains unknown or misunderstood by most researchers. The objective of this section is to create connections between asset management and different fields of research related to SCM, and to show how these researches could contribute to enhance asset management practices and knowledge.

Governance

Governance is essential to realize value through managing risk and opportunity, in order to achieve the desired balance of cost, risk and performance (ISO 55000). Stormwater governance is mainly led by local governments who formulate stormwater policies and programs (Dhakal and Chevalier, 2016; Cossais, 2021). As SCMs are multifunctional assets, the implementation of the asset management system requires coordination and collaboration within and between a large number of organizations (e.g., cleaning department, sanitation department, road department) (Cossais, 2021). Thus, management is fragmented spatially and functionally (ibid). This organizational obstacle appears to be one of the most important to the development of stormwater control measures (Berdier et al., 2007). Governance is thus a key element of asset management as the leading organization defines responsibilities, objectives and strategies which creates the environment for an asset management system (ISO 55000). Research in this field could contribute to better understanding the roles of each party, the decision-making process (equivalent to the work of van Riel et al., 2016, for sewer), and proposing innovative governance system such as the two-tier urban stormwater governance model proposed by Dhakal and Chevalier (2016).

Life cycle cost assessment

The economic assessment of SCMs asset management refers to the costs of maintaining the assets in optimal or good condition throughout their life cycle in order to sustain an efficient level of performance that meets both needs and expectations. These costs encompass capital, inspection, operation, maintenance and rehabilitation operations (Huang et al., 2005). With its asset management cost and capital planning, the US EPA advises utilities to determine the costs associated with near- and long-term maintenance as well as refurbishment to secure and allocate the appropriate funds (US EPA, 2018). Multiple life-cycle costing tools calculate O&M costs on the basis of the cost of capital, using percentages taken from the literature (e.g., E²STORMED, National Stormwater Calculator, Green Values Calculator, Classic DSS) (Solarte Moncayo and Duschene, 2023). For example, a study of seven different types of SCMs estimated annual maintenance costs range from 4% to 19% of the investment cost (Houle et al., 2013). Moreover, SCMs have lower maintenance-related expenses in terms of labor hours and maintenance costs compared to conventional systems (Duffy et al., 2008; Solarte Moncayo and Duschene, 2023). The development of accurate life cycle cost-based models rather than the more common capital cost-based models could help make appropriate investment, address the lack of maintenance funding and reduce asset management costs in the long run. This economic assessment shift requires well-maintained data on O&M cost and thus O&M cost feedback from SCMs operatives.

Performance assessment

Performance assessment helps evaluate whether the asset management objectives set by the utilities are met. It can be indirectly established thanks to condition assessment which is often based on visual inspections (Asleson et al., 2009, Beryani et al., 2021) as it remains the less expensive method. However, assessing the condition of a stormwater control measure means to assess the condition of very different components such as inlets, outlets, filter media, soil and vegetation (ibid, Langeveld et al., 2022). Complementary to condition assessments, direct performance assessment methods encompass site investigations (destructive or non-destructive methods), monitoring (from “short” to “long” term) and modelling.

Regarding stormwater control measure performance, most of the existing literature focuses on hydraulic – reducing stormwater peak flows and discharge volumes, and treatment performance – reduction of pollutant load (Allison and Francey, 2005; Andradóttir et al., 2015; Alsubih et al., 2017). The assessment of hydraulic and treatment performance indicators can be made thanks to monitoring (Bergman et al., 2011; Perales-Momparler et al., 2017; Cotterill and Bracken, 2020). The US EPA provided a recommended set of protocols

in their Best Management Practices (BMP) Monitoring Program for collecting, storing, analyzing, and reporting monitoring data that will lead to better understanding of the efficiency of urban stormwater BMP (US EPA, 2009). In most studies, monitoring periods range from a couple months to a couple years and may also include gaps (Jenkins et al., 2007; Cotterill and Bracken, 2020) making it difficult to evaluate long-term performance. SCMs modelling and simulation is a response to this shortcoming (Jenkins et al., 2007; Bergman et al., 2011; Liu et al., 2018). Predictions of water quality and quantity over the lifespan of a SCM can help define a maintenance planning (Bergman et al., 2011). Moreover, projected precipitation data from climate change scenarios can be incorporated into models to understand the resilience of SCMs in the face of climate change (Wang et al., 2021).

Other types of performances related to biodiversity, social and environmental benefits are also associated with SCMs (Brown et al., 2014; Al-Rubaei, 2016; Dagenais et al., 2016; Dusza, 2017; Belmeziti et al., 2018) but still lack indicators and assessment frameworks.

The main services delivered by stormwater control measures are known (Belmeziti et al., 2015) but research related to stormwater control measures performance assessment is still in its infancy considering that very few indicators are available to assess the whole range of performance (from hydraulic performance to well-being of inhabitants). Many assessment guidelines are developed at the local (city), national or international levels, but so far do not provide a holistic assessment framework, as stated for example by Roghani et al. (2023).

Evolution

SCMs' performances can also vary over time according to their evolution, chosen or undergone. On the one hand, the evolution can be wanted and taken charge of by operators following a change of expectations. New or updated asset objectives such as pollution reduction, increase in catchment size or biodiversity preservation can lead to physical changes on SCMs. For example, the Indre and Loire Department in France chose to extend and retrofit its retention basin into a wetland to create a richer and more biodiverse environment open to the public (Hubert, 2023).

On the other hand, unwanted changes can occur due to new regulations, misuse by visitors (or local residents), or more natural changes such as vegetation growth. For example, sediment deposition and permanent inundation in an infiltration basin in Columbia, Maryland indicated its failure. However, the site also showed the presence and emergence of wetland vegetation, small animals, and some potential for cultural benefit (Natarajan et al., 2015). This condition assessment led to a more precise performance monitoring which proved effective control of storm runoff flows and volumes, and discharge water quality improvement (ibid). In this case, thanks to the basin's measured effective performances, its unexpected evolution into a wetland did not require retrofitting; however in most cases maintenance and rehabilitation actions are highly recommended to prevent unwanted evolutions to occur (Al-Rubaei, 2016). Additional research on undergone evolution could help determine its factors – design, conception, operation or maintenance (Al-Rubei, 2016) – and consequences on performance. Moreover, whether chosen or undergone, SCMs evolutions rely on multiple fields of expertise (law, regulation, urban planning) which should be taken more into consideration in asset management.

Maintenance and rehabilitation actions

To effectively manage an asset, maintenance and rehabilitation activities are implemented during its lifespan (until replacement). Two approaches exist regarding the time and frequency of maintenance: the run-to-failure approach and the pro-active approach (Figure 2). The run-to-failure approach considers that the action will be triggered because of the consequence of a failure which will be observed and reported. This approach is obviously not recommended because the failures decrease the overall performance, and often leads to higher costs (due to the consequences of the failures or to the need for an urgent intervention). The pro-active approach requires to act before the failure of any asset, based on the prediction of its deterioration over time, or based on frequent or continuous monitoring. Frequent scheduled visits are "blind": the operator does not know before the visit if the system will be in good condition (unnecessary visit) or not. Condition-based visit means that the system deterioration is predicted and used to schedule the visits. When considering stormwater control measures, the level of knowledge does not permit today to accurately predict the evolution of hydraulic parameters such as permeability (Gonzalez-Merchan et al., 2012). Continuous visit or monitoring remain thus today the best solution to maximize the system performance and reduce overall

costs, however budget repartition within utilities (CAPEX / OPEX separation) and current monitoring systems don't allow for continuous monitoring of each stormwater control measure.

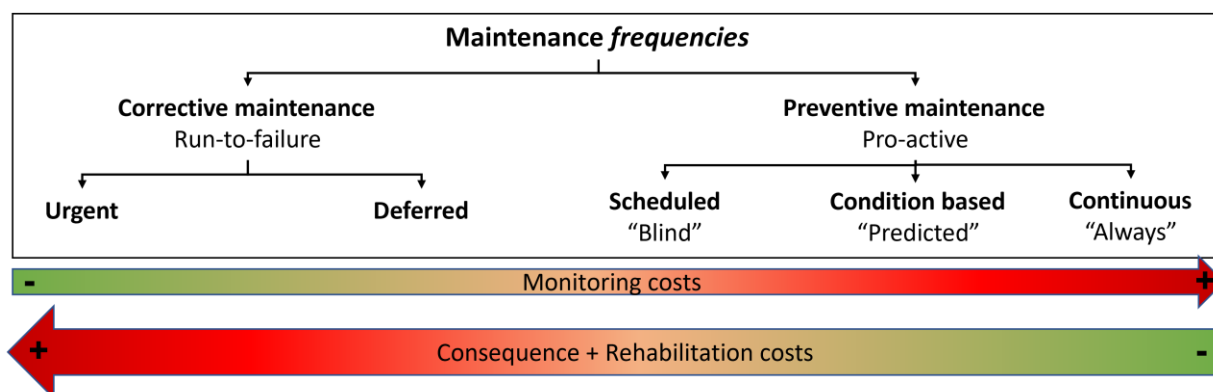


Figure 2. Maintenance strategy (type of site visit or audit) regarding costs, adapted from CEN, 2010

In addition to the frequency of maintenance, three levels of rehabilitation stand out. The first level refers to routine maintenance which includes actions such as grass cutting, regular removal of debris, trash and weeds, and repairing of broken components (UKWIR, 2005; Hunt and Lord, 2006; Duffy et al., 2008). The second level includes renovating techniques. For example, Jenkins et al. (2007) modelled two cases of physical modifications - lowering the outlet orifice or modifying the wetland bathymetry- to improve wetland's vegetation survival and thus, overall hydrological and water quality performance. Lastly, the third level of rehabilitation leads to the renewal and replacement of the asset. All these actions require investment over the asset's lifespan hence the need for a proper life cycle cost assessment acknowledging monitoring and maintenance costs which are often overlooked (Qiao et al., 2019). The need for innovative monitoring systems to provide accurate performance evaluation and feed deterioration models is essential to ensure efficient maintenance and rehabilitation activities and overall asset management in the long run.

Conclusions and future work

This article briefly shows that the five linked approaches to asset management - governance, life cycle cost assessment, performance assessment, evolution, and maintenance and rehabilitation - are already discussed in research and operational fields. However, they are rarely considered as part of a broader asset management vision. Hence, there is a need for better communication and joint research to help feed and consolidate a global asset management approach. This global approach on asset management will help:

- Ensure a common strategy amongst an interdisciplinary pool of organisations to fulfil performance objectives
- Anticipate SCMs' evolution over time
- Guarantee efficient SCMs in terms of stormwater control, environmental preservation and quality of life thanks to the consideration of operation and maintenance actions

The last point is the subject of a thesis which has just begun and aims to model the impact of O&M actions on the performance of SCMs.

References

- Allison, R. & Francey, M. (2005). *WSUD Stormwater Procedures: Stormwater*. 305 p. CSIRO publishing.
- Al-Rubaei, A. (2016) *Long-Term Performance, Operation and Maintenance Needs of Stormwater Control Measures*, Lulea University of Technology, Architecture and Water, Lulea University of Technology, Architecture and Water, 2016.
- Alsubih, M., Arthur, S., Wright, G., & Allen, D. (2017). Experimental study on the hydrological performance of a permeable pavement. *Urban Water Journal*, 14(4), 427-434. <https://doi.org/10.1080/1573062X.2016.1176221>
- Andradóttir, H.Ó. & Vollertsen, G.E.G. (2015). Temporal Variability of Heavy Metals in Suburban Road Runoff in a Rainy Cold Climate. *Journal of Environmental Engineering*, 141(3). [https://doi.org/10.1061/\(ASCE\)EE.1943-7870.0000894](https://doi.org/10.1061/(ASCE)EE.1943-7870.0000894)
- Asleson, B. C., Nestingen, R. S., Gulliver, J. S., Hozalski, R. M., & Nieber, J. L. (2009). Performance Assessment of Rain Gardens. *JAWRA Journal of the American Water Resources Association*, 45(4), 1019-1031. <https://doi.org/10.1111/j.1752-1688.2009.00344.x>
- Belmeziti, A., Cherqui, F., Tourne, A., Granger, D., Wery, C., Le Gauffre, P. and Chocat, B. (2015). Transitioning to sustainable urban water management systems: how to define expected service functions? *Civil Engineering and Environmental Systems*, Taylor & Francis, 32(4), 316-334.
- Berdier, C., & Toussaint, J. Y. (2007). Sept hypothèses sur l'acceptabilité des ouvrages alternatifs d'assainissement des eaux pluviales par infiltration.

- Bergman, M., Hedegaard, M. R., Petersen, M. F., Binning, P., Mark, O., & Mikkelsen, P. S. (2011). Evaluation of two stormwater infiltration trenches in central Copenhagen after 15 years of operation. *Water Science and Technology*, 63(10), 2279-2286. <https://doi.org/10.2166/wst.2011.158>
- Beryani, A., Goldstein, A., Al-Rubaei, A. M., Viklander, M., Hunt, W. F., & Blecken, G.-T. (2021). Survey of the operational status of twenty-six urban stormwater biofilter facilities in Sweden. *Journal of Environmental Management*, 297, 113375. <https://doi.org/10.1016/j.jenvman.2021.113375>
- Brown, H.L., Bos, D.G., Walsh, C.J., Fletcher, T.D. & RossRakesh, S. (2014). More than money: how multiple factors influence householder participation in at-source stormwater management. *Journal of Environmental Planning and Management*, 59(1), 79–97. <https://doi.org/10.1080/09640568.2014.984017>
- CEN (2010) EN 13306 Maintenance - Maintenance terminology.
- Cherqui F., Szota C., James R., Poelsma P., Perigaud T., Burns M.J., Fletcher T., Bertrand-Krajewski J.-L. (2019) Toward proactive management of stormwater control measures using low-cost technology, 10th international conference NOVATECH, 1-5 July, Lyon, France.
- Cossais, N. (2021). Les rôles différenciés de l'organisation des collectivités dans la fabrique de la ville perméable La généralisation du contrôle à la source des eaux pluviales à la métropole de Lyon (Thèse de doctorat). Université de Tours.
- Cotterill, S., & Bracken, L. J. (2020). Assessing the Effectiveness of Sustainable Drainage Systems (SuDS) : Interventions, Impacts and Challenges. *Water*, 12(11), 3160. <https://doi.org/10.3390/w12113160>
- Dagenais, D., Thomas, I. & Paquette, S. (2016). Siting green stormwater infrastructure in a neighbourhood to maximise secondary benefits: lessons learned from a pilot project. *Landscape Research*, Published online: 19 Oct 2016 (0), 1–16. <https://doi.org/10.1080/01426397.2016.1228861>
- Dhakal, K. P., & Chevalier, L. R. (2016). Urban Stormwater Governance: The Need for a Paradigm Shift. *Environmental Management*, 57(5), 1112-1124. <https://doi.org/10.1007/s00267-016-0667-5>
- Drake, J. A. P., Bradford, A., & Marsalek, J. (2013). Review of environmental performance of permeable pavement systems: State of the knowledge. *Water Quality Research Journal*, 48(3), 203-222. <https://doi.org/10.2166/wqrj.2013.055>
- Duffy, A., Jefferies, C., Waddell, G., Shanks, G., Blackwood, D. & Watkins, A. (2008). A cost comparison of traditional drainage and SUDS in Scotland. *Water Science and Technology*, 57(9), 1451. <https://doi.org/10.2166/wst.2008.262>
- Dusza, Y. (2017). Toitures végétalisées et services écosystémiques : favoriser la multifonctionnalité via les interactions sols-plantes et la diversité végétale. (Thèse de doctorat). Université Pierre et Marie Curie - Paris VI. <https://tel.archives-ouvertes.fr/tel-01587757>
- Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P. S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal*, 12(7), 525-542. <https://doi.org/10.1080/1573062X.2014.916314>
- Gonzalez-Merchan, C., Barraud, S., Coustumer, S.L. & Fletcher, T. (2012). Monitoring of clogging evolution in the stormwater infiltration system and determinant factors. *European Journal of Environmental and Civil Engineering*, 16 (sup1), s34–s47. <https://doi.org/10.1080/19648189.2012.682457>
- Houle, J. J., Roseen, R. M., Ballesterio, T. P., Puls, T. A., & Sherrard, J. (2013). Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management. *Journal of Environmental Engineering*, 139(7), 932-938. [https://doi.org/10.1061/\(ASCE\)EE.1943-7870.0000698](https://doi.org/10.1061/(ASCE)EE.1943-7870.0000698)
- Huang, J., James, W., & James, W. R. C. (2005). A Lifecycle Cost Based Design Optimization Model for Stormwater Management Systems. *Journal of Water Management Modeling*. <https://doi.org/10.14796/JWMM.R223-03>
- Hubert, P. (2023). Bassin de Palluau : De la création d'un bassin de stockage d'eaux pluviales à un marais. Végétalisation et biodiversité des bassins de gestion des eaux pluviales.
- Hunt, W. F., and Lord, W. G (2006). Maintenance of stormwater wetlands and wet ponds. Fact Sheet AGW-588-07, North Carolina Cooperative Extension Service, Urban Water Ways Series.
- ISO 55000. (2014). Asset management — Overview, principles and terminology
- Jenkins, G. A., & Greenway, M. (2007). Restoration of a constructed stormwater wetland to improve its ecological and hydrological performance. *Water Science and Technology*, 56(11), 109-116. <https://doi.org/10.2166/wst.2007.754>
- Langeveld, J.G., Cherqui, F., Tscheikner-Gratl, F., Muthanna, T.M., Juarez, M.F.-D., Leitão, J.P., Roghani, B., Kerres, K., do Céu Almeida, M., Wery, C. & Rulleau, B. (2022). Asset management for blue-green infrastructures: a scoping review. *Blue-Green Systems*, 4 (2), 272–290. <https://doi.org/10.2166/bgs.2022.019>
- Liu, Y., Engel, B. A., Flanagan, D. C., Gitau, M. W., McMillan, S. K., Chaubey, I., & Singh, S. (2018). Modeling framework for representing long-term effectiveness of best management practices in addressing hydrology and water quality problems : Framework development and demonstration using a Bayesian method. *Journal of Hydrology*, 560, 530-545. <https://doi.org/10.1016/j.jhydrol.2018.03.053>
- Natarajan, P., & Davis, A. P. (2016). Ecological assessment of a transitioned stormwater infiltration basin. *Ecological Engineering*, 90, 261-267. <https://doi.org/10.1016/j.ecoleng.2016.01.029>
- Perales-Momparler, S., Andrés-Doménech, I., Hernández-Crespo, C., Vallés-Morán, F., Martín, M., Escuder-Bueno, I., & Andreu, J. (2017). The role of monitoring sustainable drainage systems for promoting transition towards regenerative urban built environments: A case study in the Valencian region, Spain. *Journal of Cleaner Production*, 163, S113-S124. <https://doi.org/10.1016/j.jclepro.2016.05.153>
- Qiao, X.-J., Liu, L., Kristofferson, A., & Randrup, T. B. (2019). Governance factors of sustainable stormwater management: A study of case cities in China and Sweden. *Journal of Environmental Management*, 248, 109249. <https://doi.org/10.1016/j.jenvman.2019.07.020>
- Roghani B., Bahrami M., Rokstad M.M., Cherqui F., Muthanna T., Tscheikner-Gratl F. (2023) Performance assessment indicators for green infrastructures: a comparison between international guidelines, Novatech 2023, 11th International Conference on Water in Cities, 3-7th July, Lyon, France.
- Schulting, F.L. & Alegre, H. (2007). Global developments of strategic asset management., Lisbon, Portugal, 2007. Lisbon, Portugal
- Solarte Moncayo, L. M., & Duchesne, S. (2023). Mandat de recherche—Analyse coûts-avantages des infrastructures vertes pour le contrôle à la source des eaux pluviales en milieu urbain.
- UKWIR. (2005). Performance and Whole-life Costs of Best Management Practices and Sustainable Urban Drainage Systems.
- US EPA. (2002). Urban Stormwater BMP Performance Monitoring.
- van Riel, W., van Bueren, E., Langeveld, J., Herder, P. & Clemens, F. (2016). Decision-making for sewer asset management: Theory and practice. *Urban Water Journal*, 13 (1), 57–68. <https://doi.org/10.1080/1573062X.2015.1011667>
- Wang, M., Zhang, D., Wang, Z., Zhou, S., & Tan, S. K. (2021). Long-term performance of bioretention systems in storm runoff management under climate change and life-cycle condition. *Sustainable Cities and Society*, 65, 102598. <https://doi.org/10.1016/j.scs.2020.102598>
- Wery C., Garnier R., Cherqui F., Le Nouveau N, Fletcher T. D., Barraud S., Le Gauffre P. (2017) Research and operational needs to improve the asset management of stormwater control measures, 7th Leading-edge conf. on Strategic Asset management. IWA (Int. Water Assoc.), 20-22 June, Trondheim, Norway.