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Quantifying Uncertainties in Urban Water Hydrology

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Abstract—*Urban hydrology is branch of an applied science that play very important role in the sustainable development and environmental protection of human societies. Cities become the part of the elementary changes in the civilization leading to modernization and socio-economic development. Urban water hydrology (UHW) is highly vulnerable to uncertain current and future changes such as urbanization, population growth, change in socio-economic conditions and deterioration of urban system. These uncertainties have numerous direct and indirect impacts on urban water hydrology. Urban water hydrology typically includes fresh water and waste water collection and storage, water transportation for treatment by aqueducts, water supply and distribution, sanitation and urban water drainage networks. Urban water systems are dynamic and composite. It includes multi decision makers including water consumers, Water Corporation, town municipal board and other bodies. In urban water hydrology uncertainties arises from incomplete knowledge and unknowable knowledge. This paper focuses on the key future change pressure associated with various uncertainties and risk for sustainable system planning. Most of the present decision making approaches developed for risk based not deal with uncertainty properly. These become need for research on risk and uncertainty analysis for sustainable urban water hydrology.*

1. INTRODUCTION

Now –a-days many cities of the world facing severe urban water uncertainties such as droughts and floods due to climate change, increasing population , urbanization, economically globalization , deterioration of infra structure system, governance and privatization, change in public behaviours, emerging technology, risks on critical infrastructure system, consumption of fuel . Urban water hydro logical cycle is similar to hydro logical cycle located within an urban catchment. Urban water cycle is regularly in two parts: water and nutrients cycles (Butter and Maksimoric 2001). Water cycle includes circulation of various water stream throughout an urban environment including surface water, ground water, rain water and waste water and nutrients cycle includes flow of nutrients such as nitrogen and phosphorous. It considered as an integral part of urbanised life, UWH is directly defined as the functions and value of a city and determine people standard of living. Urbanisation has drastically affected the urban hydrology; people have high level of interference with natural processes. The major drastic future change pressure indicates that the sustainable UWH necessitates the consideration of uncertainty. Sustainable Water Management in the City of the Future (SWITCH 2006) focuses on risk and uncertainty analysis to achieve sustainable UWH. Urban water management analysis addresses the urban water hydrology which provides the coalesce concept for climatic, hydrologic, land use and land cover, engineering and ecological concerns in urban areas. Urban water management based on urban water hydrology includes the identification of components of urban water hydrological cycle and effects of urbanisation on water resources, quantification of imprint of human activities, understanding processes at the urban water and soil interface, assessment of the impact of urban water and soil interface, assessment of the impact of urban development land-use and socio-economic changes assessment of the preventive and mitigation measures. It was found that urban water hydrological cycle becomes more multifarious in urban areas because of many anthropogenic activities and influences (Mcpherson 1973, Mcpherson and Schneider 1974). This resulting risks and uncertainties posed by global change pressure in urban water hydrology. The concept of urban water hydrological cycle demonstrates the connectivity and interdependency between humans and urban water resources.

2. OBJECTIVES

There are basically two objectives of this paper include:

1. To quantify the various uncertainties in urban water hydrology
2. To explain and disseminate the impact of uncertainty in urban water hydrology.

3. UNCERTAINTIES IN URBAN WATER HYDROLOGY(UWH)

Uncertainty is described with respect to certainty; according to Knight 1921 “Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated.... The essential fact is that 'risk' means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomena depending on which of the two is really present and operating.... It will appear that a measurable uncertainty, or 'risk' proper, as we shall use the term, is so far different from an un-measurable one that it is not in effect an uncertainty at all”. He describe risk as imperfect knowledge in which possible outcome probabilities are known that is in which the uncertainty is measurable where as uncertainty exists when these probabilities are unknown unable to be measured.

The joint influences of variability and uncertainty contribute to future unpredictability. This combination of variability and uncertainty is often termed total uncertainty. Uncertainty describes the quantity of knowledge concerning risk that needs to be faithfully represented, propagated and presented for decision making. The uncertain information may be stochastic random, vague or subjective. Although numerous risks associated with climate change in UWH are clearly identified it is difficult to predict their magnitude and intensity due to a series of uncertainties cascading from scenarios down to the impact study in an urban scale(Caster et al., 1999; Allein et al.,2000; Gober et al., 2010; Moss et al.,2010; Wilby and Dessai,2010; IPCC 2012). Urbanisation and population growth will have direct impact on UHW through dramatic increase in water demand, wastewater generation or runoff rates. Climatic in socio-economic factors lead to an increase in water consumption and demand for better quality of service and ultimately impacting the performance of UWH.

Some of the main uncertainties include:

1. Uncertainty associated with the scenarios on how the future as a complex no-linear dynamic system will incorporate all the emissions generation, natural processes and variability.
2. Uncertainties added by the different global climate models used for prediction and their capacities.
3. Uncertainties associated with hydrological modelling
4. Uncertainties associated with downscaling and error.
5. Uncertainties associated with impact model.

3.1 Types of uncertainties

From the literature survey defines there are number of classification for types of uncertainty; Der Kiureghian (1989) defined the uncertainties reducible and irreducible, in which uncertainties are related with the unpredictable things are irreducible and uncertainties related with predictable things. Yen and Ang (1971) describe the uncertainties in the two types as objective and subjective: where the objective uncertainty arises from random process and subjective caused by inexactness.

Ayyub and chao (1998), Klir and Folger(1998) and Colyvan (2008) also classified uncertainties according to vagueness, ambiguity and under specificity. An uncertainty derived from unclear statements is a vagueness uncertainty. Ambiguity uncertainty consign to the possibility of multiple outcomes for a system. And last one under specificity uncertainty associated with the generality. Hall (2003); Helton and Burmaster (1996) according to source of information uncertainty classified as randomness or fuzzy types and aleatory and epistemic.

Aleatory uncertainty Anderson and Hattis (1999); Nauta (2000); Parry 1996; Oberkampf et al., (2002); Helton et al.,(2012) refers Aleatory uncertainty shows inherent variability arises from a random process and modelled using probabilities . It includes the spatial and temporal variability in rainfall and become irreducible due to its inherent nature.

Epistemic uncertainty results from need of complete knowledge of the system in question, And describe the system under study. It may due to ignorance where current knowledge is inadequate in describing the uncertainty. However unlike Aleatory uncertainty, epistemic uncertainty can be reduced through greater understanding of the system.

In Urban water hydrology (UHW) there are three different types of uncertainty found, which incorporate in the system that is structural uncertainty, parameter uncertainty and data uncertainty. Structural uncertainty is part of epistemic uncertainty related to the errors in the mathematical representation of reality in the system of conceptualisation, numerical and discretisation. These types of errors are difficult to quantify in the existing system.

Parameter uncertainty may be in the form of both aleatory uncertainty and epistemic uncertainty represents systems components in the urban water hydrology e.g. pipe roughness, physical dimensions of infrastructure system. It can result in large errors in model prediction. And data uncertainty related to measurement either errors in the instrumentation errors or scale or resolution of observation. Measurement uncertainty may be both aleratory and epistemic in nature. In UWH these uncertainties are unknown that leads to uncertain in prediction of model. In uncertainty quantification is to firstly understand the sources of uncertainty in urban water hydrology.

3.2 Source of uncertainties in urban water hydrology

Urban water hydrology (UWH) consists of three principal components: sewer system, waste water treatment plan, and receiving water bodies. Korving et al., (2003) urban water hydrology system (UWHS) have been designed and implemented to meet two major objectives; first to moderate flooding during storm events and second to good sanitation for urban areas by reducing contamination. Two systems are existing to fulfil this requirement these objectives: separate system and combined system. These networks are typically designed as looped structure to rise above the problem of sanitation and user demand flexibility during cut-off and these looped systems are less sensitive to uncertainty with design of system.

Sources of uncertainty are related to uncertainties and their location. From the literature survey found that uncertainty in climate change arises from two quite different sources i.e. incomplete knowledge related to future advances in climate and computing technology and unknowable knowledge arises from inherent indeterminacy of future human societies and climate system.

Mostly uncertainty occurred to the variability of inherent randomness of nature, value diversity, behaviour variability, social variability, randomness and technological surprise. Van Asselt and Rotmans (2002) described the sources of uncertainties up to level of indeterminacy i.e. inexactness, lack of observations/ measurements, practically immeasurable, conflicting evidence, reducible ignorable, indeterminacy and irreducible ignorance. Sources of uncertainty can further range from unreliability to more fundamental, radical, structural or systematic uncertainty.

3.3 Risk and uncertainty criterion

Risks are concluded in terms of the likelihood or probability that an uncontrolled event will occur and the consequences of that event occurring.

$$\text{Risk} = \text{Likelihood of occurrence} \times \text{consequence}$$

Willows & Connell (2003) describe risk assessment (RA) as the process of establishing information concerning hazards, and the exposure and vulnerabilities of defined receptors. Cowel et al. (2002) emphasizes the risk assessment as an estimate of the likelihood and severity of harm associated with a product, process, activity, agent (such as pollutants in different media), or even.

RA techniques may be quantitative, semi quantitative or qualitative used both for describing knowledge to estimate the probabilities Recent new technologies are mainly focusing on the RA techniques and consider the risk parameters such as vulnerability, resilience, uncertainty, reliability and consistency.

The risk is directly the function of undesirable events or probabilities and these undesirable events in Urban water hydrology (UWH) their likelihoods of occurrence and consequences due to the future changes which causes variability and uncertainty.

Hashimoto et al. (1982) recommended that reliability, resilience, uncertainty, consistency and vulnerability are used to indices to assess the performance of an urban water hydrology system in meeting demand. In any Urban water hydrology system (UWHS) reliability is defined as possible probability at the level of satisfactory state; robustness is the adaptability to other than design input conditions; vulnerability is defined in terms of an expected degree or extent of failure when unsatisfactory state occur; Consistency is correlate with reliability or uniformity of successive results or events.

4. CONCLUSION

The future challenges in urban water hydrology during next decades need to plan with several innovative water technologies and management of urban water which fulfil the demand of multi decision maker. The main aim of this paper was to quantify the uncertainties in urban water hydrology for sustainable development in urban areas. Quantification and description of uncertainties is very important steps in uncertainty analysis .the application of uncertainty analysis found in various fields of urban water such as analysis of risk and uncertainty of future water availability ,performance based urban water infrastructure planning, risk of water scarcity analysis and risk management under uncertainty.

Urban water hydrology systems are subjected to various uncertainties, which are exist in demand and these uncertainty are surround by the inputs from domestic and industrial sources. These uncertainties need to be system for simplification either for computational and data constraints. It has been found that much future change pressure will affect the urban water hydrology system due to indeterminacy of future change in terms of variability and in many condition it is not possible to estimate the uncertainty precisely.

Therefore it is need to be developed sustainable, consistent, reliable and vulnerable urban water hydrology system with the quantification of uncertainties in urban system.

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