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Reduction of streamflow monitoring networks by a reference point approach

Cem P. Cetinkaya *, Nilgun B. Harmancioglu

Water Resources Management Research and Application Center (SUMER), Dokuz Eylul Univ., Tinaztepe Campus, Buca 35160, Izmir, Turkey

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SUMMARY

Adoption of an integrated approach to water management strongly forces policy and decision-makers to focus on hydrometric monitoring systems as well. Existing hydrometric networks need to be assessed and revised against the requirements on water quantity data to support integrated management. One of the questions that a network assessment study should resolve is whether a current monitoring system can be consolidated in view of the increased expenditures in time, money and effort imposed on the monitoring activity. Within the last decade, governmental monitoring agencies in Turkey have foreseen an audit on all their basin networks in view of prevailing economic pressures. In particular, they question how they can decide whether monitoring should be continued or terminated at a particular site in a network. The presented study is initiated to address this question by examining the applicability of a method called "reference point approach" (RPA) for network assessment and reduction purposes. The main objective of the study is to develop an easily applicable and flexible network reduction methodology, focusing mainly on the assessment of the "performance" of existing streamflow monitoring networks in view of variable operational purposes. The methodology is applied to 13 hydrometric stations in the Gediz Basin, along the Aegean coast of Turkey. The results have shown that the simplicity of the method, in contrast to more complicated computational techniques, is an asset that facilitates the involvement of decision makers in application of the methodology for a more interactive assessment procedure between the monitoring agency and the network designer. The method permits ranking of hydrometric stations with regard to multiple objectives of monitoring and the desired attributes of the basin network. Another distinctive feature of the approach is that it also assists decision making in cases with limited data and metadata. These features of the RPA approach highlight its advantages over the existing network assessment and reduction methods.

1. Introduction

Since the early 90s, adverse effects of environmental problems, increases in domestic, industrial and irrigation water demand, the needs for prevention of droughts and floods, and/or economic considerations have necessitated a basin-wide "integrated" management of water resources, while regarding the sustainability of its use. This need for an integrated and sustainable approach to river basin management is strongly emphasized at international levels in Agenda 21 of Rio 1992 (UN, 1992), Rio+10 Johannesburg 2002 (http://www.worldsummit2002.org) and Rio+20 2012 declarations (UN, 2012) and accepted by the participating governments and institutions. Adoption of an integrated approach to water management strongly forces policy and decision-makers to focus on hydrometric monitoring systems as well. Current streamflow gauging networks need to be evaluated and revised against the data requirements on water quantity to support integrated management. To this end, improvement of the efficiency of existing networks for production of reliable and informative data is an essential task for informed decision making on sustainable water resources management (UN, 1992 ch. 40; Fedra, 1997).

A monitoring activity for data collection is expected to reflect the spatial and temporal variations in environmental processes and is subject to the financial and operational constraints of monitoring agencies. In essence, hydrometric monitoring is a dynamic and iterative procedure which should be assessed regularly to meet the changing information demands on variability of natural and/or man-made processes related to water resources (Moss, 1979; Langbein, 1979).

* Corresponding author. Tel.: +90 232 3017016.
E-mail addresses: cem.cetinkaya@deu.edu.tr (C.P. Cetinkaya), nilgun.harmancioglu@deu.edu.tr (N.B. Harmancioglu).

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The first data collection procedures for water quantity foresaw the gauging of major streams for water resources assessments, generally at potential sites for water resources developments. Until the 70s, hydrometric data collection in particularly the developing countries focused primarily on the planning, design and operation of particular structures and water systems such as dams, weirs, and irrigation schemes, so that most of the monitoring activities had been problem or project-oriented (Harmancioglu et al., 1998, 1999). Many countries established their networks on the basis of these needs and developed today's basin-wide networks (Davar and Brimley, 1990). Recently, however, the accelerated growth of environmental problems has put broader needs on information availability regarding both their extent and scale. Therefore, the collection of reliable hydrometric data in time and space and the management of monitoring networks on rivers have gained increasing importance (WMO, 2008). Regarding these developments, most countries have started to assess and redesign their existing networks (Davar and Brimley, 1990; Burn, 1997; Harmancioglu et al., 1998, 1999, Laize, 2004, Mishra and Coulibaly, 2009, 2010, Hannah et al., 2011).

Turkey, as a typical developing country, has established its water quantity monitoring networks since late 30s, where governmental agencies design, operate and make the necessary investments in these networks. The growing economic pressures in the last decade have led these agencies to question the performance of their networks for their efficiency and cost-effectiveness. More specifically, the government has foreseen an audit and a reorganization of all nation-wide activities, including hydrometric monitoring, as dictated by prevailing financial constraints. Similar to other parts of the world, the major issue raised has been whether basin networks can be consolidated to cut down excessive costs while preserving or even increasing their information productivity. In particular, monitoring agencies have started to question how they can decide whether monitoring should be continued or terminated at a particular site in a network. In respect of this question, network assessment and redesign procedures have been initiated (Harmancioglu, 1997; Harmancioglu et al., 1999; Cetinkaya, 2007; Cetinkaya and Harmancioglu, 2012). These developments basically comply with the recommendations expressed at international levels towards improved availability of information on the water environment for better water management. Examples include the Dublin Statement of the International Conference on Water and Environment (Sections 4.6 and 4.8); Agenda 21 of UNCED (Chapters 18 and 40); various workshops and meetings held by WMO, WHO, UNESCO, UNEP, the World Bank, IAHS, and IAWQ; recent Directives foreseen by the EU Community; and a number of international programmes such as the EEA (European Environmental Agency) work programme, WHYCOS of WMO and the World Bank, GRID and GEMS of UNEP, to name but a few.

A review of past studies shows that, basically, designers and researchers recognize hydrometric monitoring as a statistical procedure and address the design problem by means of statistical methods (Cetinkaya and Harmancioglu, 2012). This implies that the selection of monitoring strategies (sampling sites, frequencies, and duration) can be realized by starting off with such a statistical approach (Langbein, 1979; Ward and Loftis, 1986; Sanders et al., 1983; Loftis et al., 1991). Statistical analyses based on regression theory as well as time series analysis, decision theory and optimization techniques are used to select the spatial and temporal design features of a network. Within this context, Harmancioglu and Alpaslan (1992); Ozkul et al. (2000) have proposed the use of the entropy theory to decide upon the required numbers and locations of stations. According to this theory, decisions may be made to reduce the number of stations where information is redundant or to increase sampling sites at regions where additional information is required. On the other hand, some researchers have proposed that several techniques should be employed in combination with each other for a better assessment of the design problem (Moss, 1989; WMO, 2008). This is a plausible approach as none of the methods have yet been widely accepted due to particular deficiencies associated with each technique. Moss (1989) has emphasized that network design should be realized with such a combined approach based on hydrology, optimization techniques, decision theory and data analysis methods.

On the other hand, researchers emphasize the proper delineation of monitoring objectives as an essential step before attempting the technical design of the network. This step is to provide answers to the questions of why we monitor and what information we expect from monitoring. In practice, the definition of objectives is not an easy task since it requires the consideration of several factors, including social, legal, economic, political, administrative and operational aspects of monitoring goals and practices. Therefore, the delineation of monitoring objectives inevitably includes assumptions and subjective views of the designers and decision-makers no matter how objectively the problem is approached (Harmancioglu et al., 1998, 1999).

The problem of network consolidation or more specifically the problem of station discontinuance is a controversial issue for hydrometric data networks. There are no definite criteria yet established to decide whether monitoring should be continued or terminated at a particular site, although there are some studies carried out for streamflow gauging stations (Wood, 1979; Lane et al., 1979). A plausible approach to solve this issue basically requires the identification of monitoring objectives and the priorities of stations in the network with respect to these objectives.

The presented study is initiated to examine the applicability of a method called "reference point approach" (RPA) for network consolidation purposes. The main objective of the study is to develop an easily applicable and flexible network reduction methodology, regarding the fact that monitoring performance should be reassessed from time to time due to the dynamic nature of hydrologic processes. The RPA provides a methodology that ranks hydrometric stations against some desired attributes, and the ranking procedure reflects the priority of stations with respect to monitoring objectives. The priority ranking of stations is realized by delineating their importance within the network with regard to overall or station specific monitoring objectives. Furthermore, in large river basins, water management problems and monitoring objectives may vary widely in different parts of the basin so that each monitoring station should fulfill an objective specific for its location, rather than meet a global monitoring objective for the entire basin. A station ranking method such as RPA should also serve to evaluate such cases.

The study is focused only on assessment of the operational "performance" of existing streamflow monitoring networks. The *Electrical Works Authority* (EIE), one of the main governmental monitoring agencies in Turkey, requested an assessment of a reduction in their network. EIE was established in 1935 and had been the main authority to assess and develop the hydroelectric potential of Turkish surface waters until it was merged with the State Hydraulic Works (DSI) a few years ago. The RPA method is applied to reduce the thirteen stations in the Gediz River Basin, as requested by EIE. The question posed by EIE was which three stations should be closed in respect of economic constraints while still preserving the objectives of the network. The results are evaluated with respect to ten operational and the three stations already discontinued by EIE, where the question still remained as to which three stations should actually be closed in respect of cost-effectiveness and preservation of monitoring objectives. In conclusion, the advantages and disadvantages of the presented method are discussed in view of the results obtained from the case study.