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The authors thank the discusser for the comments about the original paper. Responses to each point raised in the discussion paper follow.

The discussion questions Eq. (25) of the original paper, arguing that the supply may exceed demand ($S_{i,h} > De_{i,h}$); however, this argument is erroneous. Eq. (25) and other efficiency criteria presented in the original paper were used to evaluate the performance of the developed optimization model. The optimization model presented in the original paper prescribes that the amount of supply is always less than or equal to the demand. Therefore, the condition in which the supply exceeds the demand does not occur in any nodes of the network at any time. $S_{i,h}$ is a state variable of the optimization model. In other words, $S_{i,h}$ derives from the demand supply index ($\alpha_{i,h}$) so that $S_{i,h} = \alpha_{i,h} \times De_{i,h}$. The value of $\alpha_{i,h}$ is related to the decision variables of the optimization model and is equal to zero or one. When $\alpha_{i,h} = 1$, the demand of node i at hydraulic time step h is fully supplied ($S_{i,h} = 1 \times De_{i,h} = De_{i,h}$); when $\alpha_{i,h} = 0$, the demand of node i at hydraulic time step h is not supplied ($S_{i,h} = 0 \times De_{i,h} = 0$). Consequently, the only possible values for $S_{i,h}$ are $De_{i,h}$ or zero, and $S_{i,h}$ does not exceed $De_{i,h}$ [see Eqs. (5)–(10) of the original paper].

The discussion proposed a demand-based weighted mean for evaluating resiliency instead of Eq. (26) of the original paper, which evaluates resiliency with the geometric mean; however, a demand-based weighted mean is not appropriate for evaluating resiliency of a water distribution network (WDN) under water shortage. The demand-based weighted mean presented in the discussion considers nodes with high demand to be more important than nodes with low demand. This consideration is not fair under the water shortage situation because the individuals who are connected to a low-demand node have the same right as those individuals who are connected to a high-demand node. Rather, using a geometric mean that emphasizes equality among nodes is a fairer proposition. Solgi et al. (2015) discussed equanimity and justice principles in water distribution networks under water shortage and presented efficiency criteria including resiliency and reliability based on the geometric mean. Other studies applied the geometric mean for evaluating the resiliency of WDNs under intermittent water supply (Soltanjalili et al. 2013; Bozorg-Haddad et al. 2016b). A geometric mean reflects a better value for a condition in which all nodes have the same resiliency, in comparison to a condition in which some nodes have a good resiliency but others do not. Implementation of a demand-based weighted mean is reasonable in some cases. For example, in the initial design of WDNs, using a demand-based weighted mean is prevalent (e.g., Wang et al. 2014; Bozorg-Haddad et al. 2016a, 2017). The purpose of an initial design is satisfying demands with a desirable pressure. Whenever a demand is satisfied with an undesirable pressure, it is considered as a failure. Application of a demand-based weighted mean is justified because during a failure, the demand of customers is fully satisfied, but with a small violation of the desired pressure; however, the operation of WDNs under water shortage as it is proposed in the original paper is such that during a failure period, customers do not have any access to water even with a low, undesirable pressure. This means that operators and customers face a serious water supply interruption. In this case, it is not fair that individuals connected to low-demand nodes endure long periods without water, whereas individuals connected to high-demand nodes are well supplied. For these reasons, the demand-based weighted mean proposed by the discusser has serious shortcomings. A demand-based weighted mean would be a viable choice for a condition in which high-demand nodes have good resiliency and low-demand nodes have poor resiliency in comparison to a condition in which all nodes have the same resiliency. For example, consider a network with two nodes, whose resiliency in two different cases, A and B, are listed in Table 1. Nodes 1 and 2 have low and high demand, respectively. Case A imposes a much longer period of failure on Node 1 in comparison to Node 2; however, Case B is a condition in which both Nodes 1 and 2 have the same resiliency. Case A represents an unfair condition, whereas Case B represents a fair condition for all customers, regardless of the type of node to which they are connected. Thus, Case B is preferable over Case A. However, applying the demand-based weighted mean, the average resiliencies of Cases A and B, respectively, are $(2 \times 0.056 + 12 \times 0.333)/14 = 0.293$ and $(2 \times 0.167 + 12 \times 0.167)/14 = 0.167$, which shows that Case A is superior to Case B. In contrast, the geometric mean applied by the original paper correctly shows that Case B is superior to Case A. The average resiliencies of Cases A and B are $\sqrt{(0.056 \times 0.333)} = 0.137$ and $\sqrt{(0.167 \times 0.167)} = 0.167$, which shows that the average resiliency of Case B is better (larger) than that of Case A. Using a demand-based weighted mean may be misleading for evaluating the performance of a WDN under water scarcity. A geometric mean that emphasizes equality among nodes, on the other hand, is preferable over a demand-based weighted mean. By implementing a

Table 1. Data for a Water Distribution Network with Two Nodes under Two Different Conditions

Node	Demand (unit)	Number of failures (time steps)		Number of failure events (spells)		A_i	
		Case A	Case B	Case A	Case B	Case A	Case B
1	2	18	6	1	1	0.056	0.167
2	12	3	6	1	1	0.333	0.167

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demand-based operation, some operators of WDNs may provide a good service to many customers at the expense of a small number of customers. From the perspective of a single customer, the WDN fails if the network cannot satisfy its demand, regardless of whether the customer is connected to a high-demand or a low-demand node. Consequently, in the original paper, the same importance is assigned to all nodes of the network by applying a geometric mean.

The discussion proposed applying a demand-based weighted mean for Eq. (27) of the original paper, which evaluates water-quality resiliency with a geometric mean; however, using the applied geometric mean is more appropriate than the proposed demand-based weighted mean for evaluating water-quality resiliency. This is so because the applied geometric mean is more conservative. By using the geometric mean, the occurrence of low water-quality resiliency at only one node of the network considerably affects the mean resiliency of the network. The proposed demand-based weighted mean, on the other hand, is such that good resiliency at high-demand nodes may hide poor resiliency at low-demand nodes. Given the importance attached to water quality and its effects on human health in the original paper, the geometric mean is more conservative and therefore preferable over the demand-based approach insinuated by the discussers.

Several studies have considered water quality in the normal operation of WDNs (e.g., Sakarya and Mays 2000; Biscos et al. 2003; Kang and Lansey 2010; Kurek and Ostfeld 2014). The original paper recently considered water quality in optimal operation of WDNs under water shortage, which is a topic that had previously received minimal attention. Yet, there are possibilities for improvement that shall be covered in future studies by the authors of the discussed paper.

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