

## ***Interactive comment on “A risk assessment methodology to evaluate the risk failure of Managed Aquifer Recharge in Mediterranean basin” by Paula Rodríguez-Escales et al.***

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Received and published: 14 February 2018

We thank Dr. Dell’Oca for his comments and suggestions. In the spirit of HESS discussions, we discuss below the issues that are potentially controversial or that require further explanations. Editorial corrections will be included in the revised manuscript, when a full response to all reviewer comments will be produced, but are not addressed at this point.

COMMENT 1: Would it be possible to evaluate the MAR’ failure probability on the base of the results in Fig. 1? I intend that frequency of events (based on the literature review and not the managers’ opinions) as the probabilities of each event ‘unconditional’

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from the specific managers' opinions. Maybe these frequencies/probabilities are more general and less conditioned by the manager point of view. Interestingly enough from Fig. 1 it seems that technical aspects are more frequent than the non-technical ones, while the analysis based on the managers opinions suggest an opposite behavior! (Do bureaucracy and legislation bother the technician/managers more than technical problems?) I suggest the Authors to perform the analysis on the base of Fig.1- frequencies if they think it would be of interest.

RESPONSE: This is a good point, but the answer is: in general, no. We used data from Fig 1 to produce some initial guesses that could be used for a new facility if no additional input was involved. Now, MAR facilities are all quite distinct from each other, and the national and local realities are really very significant. An evaluation based on data from Fig 1 would be of little relevance. We understand the scientific point of view of the reviewer, but here conditioning on expert opinions and local geological and hydrological conditions make unconditional guess quite irrelevant. We believe that one of the challenging aspects of our work is to evaluate and to compare the risk of six Mediterranean MAR sites considering the 65 quasi-independent events. We believe that developing the analysis from the events defined in the literature (supporting information and Figure 1) could be a little tendentious, since we only know what the report/paper described. Furthermore, the different events are defined in a different way in the different sites. Thus, we can only define categories and not basic events. Then, we relied on additional support material, plus the authors' experience and the results from the EU project to elucidate the basic events that were finally included in the tree. There is an additional point that emerges from the referee's comment. As he correctly noticed, the most significant events that we found in the literature were the technical ones, rather than the non-technical. Then our analysis on the six Mediterranean sites concluded the opposite. We do not have enough information to know if this is real, but we really think so, and we attribute this discrepancy in a clear bias in the scientific literature to technical issues. We could not find information on MAR facilities failure in journals devoted to social or economic sciences. Independently of this, we believe

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is quite interesting to add this difference in the discussion of the paper. So, we will improve section 6.2 of the manuscript adding a discussion based on the comparison of the Figure 1 and the current results of the MAR RISKAPP.

COMMENT 2: In the introduction the Authors state that in Probabilistic Risk Assessment (PRA) the risk is defined 'as the probability of an undesired outcome to happen (evaluated in percentage of occurrence, return period, etc.) and an evaluation of the potential damage that a particular outcome might cause (amount of damage, adverse health effects, etc.)'. I agree with this definition, but in the rest of the work it seem to me that the Authors deal only with first part, i.e. definition of probabilities of failure, and not with the evaluation of the potential damage, that would lead to the risk. I suggest to add a statement about this point or to review the terminology trough out the paper since, to me, it seems that probability of failure is the right wording instead of risk of failure. Note that in Section 3.3 the Authors only deal with the probabilistic representation of the fault tree and no mention is done to the evaluation/representation of the potential damage.

RESPONSE: We agree with the reviewer and we will improve the definition according to the use we have done. As commented by the reviewer, our work has been focused on the probability of an undesired outcome to happen (the MAR facility ceasing operation) instead of the evaluation of the potential damage caused. We will improve the definition in the final revised manuscript. The modifications will be done in the definition in the section 1 and a complete revision of the text will be done to ensure the complete text will be consistent.

COMMENT 3: At line 9-10 at pp. 7 the Authors state 'it is very relevant to state that these preliminary numbers (i.e. probability of events assigned by managers or local people opinions) should always be on the conservative side, meaning that the less technical the evaluation is, the more caution should be included in the actual figures'. I agree with this statement, but immediately started to wonder 'which is the conservative side? Is it the high probability of failure of the MAR facility (e.g. as wished by some

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local people) or is it the low probability of failure (e.g. as wished by investors)?'. What do the Authors think about this point?

RESPONSE: It is quite clear that most of the basic events can be considered uncertain. Therefore, in most of them there is a lack of specific knowledge of the actual risk values associated to the basic events, and this uncertainty increases whenever the evaluation is less technical and more based on opinions or data from the literature. In such a case, we want to use always an engineering approach, providing values that are on the conservative side. Now, the reviewer questions whether a conservative assessment would mean associating larger or smaller probabilities. This is correct, and it really depends on the target of the risk assessment. Nonetheless, we think that the way we posed the problem it should be clear that we are looking from either the administration of the managerial side, looking to potential problems and trying to improve the methodologies to reduce potential failure. So, in short to answer the reviewer, we consider "safe" to use values that are equal or above the actual probability of failure for the individual events. We introduced this idea in the revised text (Section 3.4). Thanks for pointing it out.

COMMENT 4: I really appreciate the description in Section 3.4 of the dynamicity of the proposed approach!

RESPONSE: Thanks for the nice comment.

COMMENT 5: Section 5.1 risk probability assignment. From the provided text is not clear to me how 'the qualitative answers were then translated to absolute values of probabilities, in coherence with the importance of the event in a potential failure of the facility'. Could the Authors elaborate more on the way they assigned probabilities in the fault tree starting from the experts' opinions? This point could be useful and relevant to interested readers.

RESPONSE: We try to clarify it. The persons who answered the questionnaire had to choose between four different categorical variables (high, medium, low and no risk).

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The questionnaire includes the same basic events as the fault tree does, but sorted as a list at different levels (Event 1, Event 1.1., ...). At this point, we obtained some qualitative perception of risk for the different events. A default table associates these qualitative opinions into quantitative probability values (obviously sorted from high to low); such values are given by default, but can be edited manually and updated whenever a better evaluation of probability is available (this is why we say that the values can be updated at any time, whenever new information becomes available). From then on, these values are included in the tool, and probability of events located at higher levels are computed based on the rules from Boolean Algebra, until the top box is reached. We will also clarify this point in the manuscript in order to facilitate the global understanding of the methodology (Section 5.1).

COMMENT 6: Please increase the quality of the writing part in Fig.2, Fig. 4 and Fig. 6. It is really hard to read them.

RESPONSE: Thanks for the comment. We will improve the legibility (and the quality) of the figures in the final revised manuscript.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2018-8>, 2018.

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