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Blending between desalinated water and other sources

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ABSTRACT

Desalinization may be a crucial component in solving the water resource development of coastal areas. The possibility to detect useful systems to correct and balance water quality needs, as necessary for the intended users, has been a fundamental target of recent desalination projects. Other sources may be locally available and can be retained as a complement to decrease the production cost and to correct the water quality parameters as per the WHO requirements. In coastal areas were groundwater of lower quality may be available, blending two or more sources are the winning solution. However, blending needs constant monitoring and continuous adjustments of proportions in the final mix. In order to meet this target, the operators need a decisional tool that enables the correct blending between different water sources. A simple but comprehensive blending tool, integrated by a hydrogeological dynamic verification tool for a better management of the overall system, was developed by Lotti Ingegneria, Italy. The blending tool, with methodological approach is reported herein, is an operational instrument aimed at calculating the chemical parameters concentration at blending reservoir level, on the basis of input and control data, by warming as well as in case of possible critical situations. The tool is based on a groundwater database spreadsheet described in terms of actual and target quality parameters and blending points (blending reservoirs) where the blending will be between desalinated water and other water sources. It was developed to be interfaced with supervisory control and data acquisition and allows easy monitoring and prompt evaluation of corrective actions as needed. Water obtained by a desalination process is extremely low in terms of salt concentration, for this reason it is necessary to pay attention to the aggressiveness and the taste of tap water. The solution to improve the flavor of tap water is blending desalinated water with available local water sources.

Keywords: Blending; Management; Hydrogeological verification; Sustainability; Flavor

1. Blending between desalinated water and other resources

In the arid areas where the freshwater sources are non-plenty to satisfy the human needs the blending with desalted water become one of the main tool to supply safe waters to their inhabitants [1,2]. In the Gaza strip the lack of freshwater and the increase of population caused an overexploitation of groundwater allowing the pollution by seawater intrusion in many areas of the country [3,4].

Furthermore water obtained by a desalination process is extremely low in terms of salt concentration, for this reason

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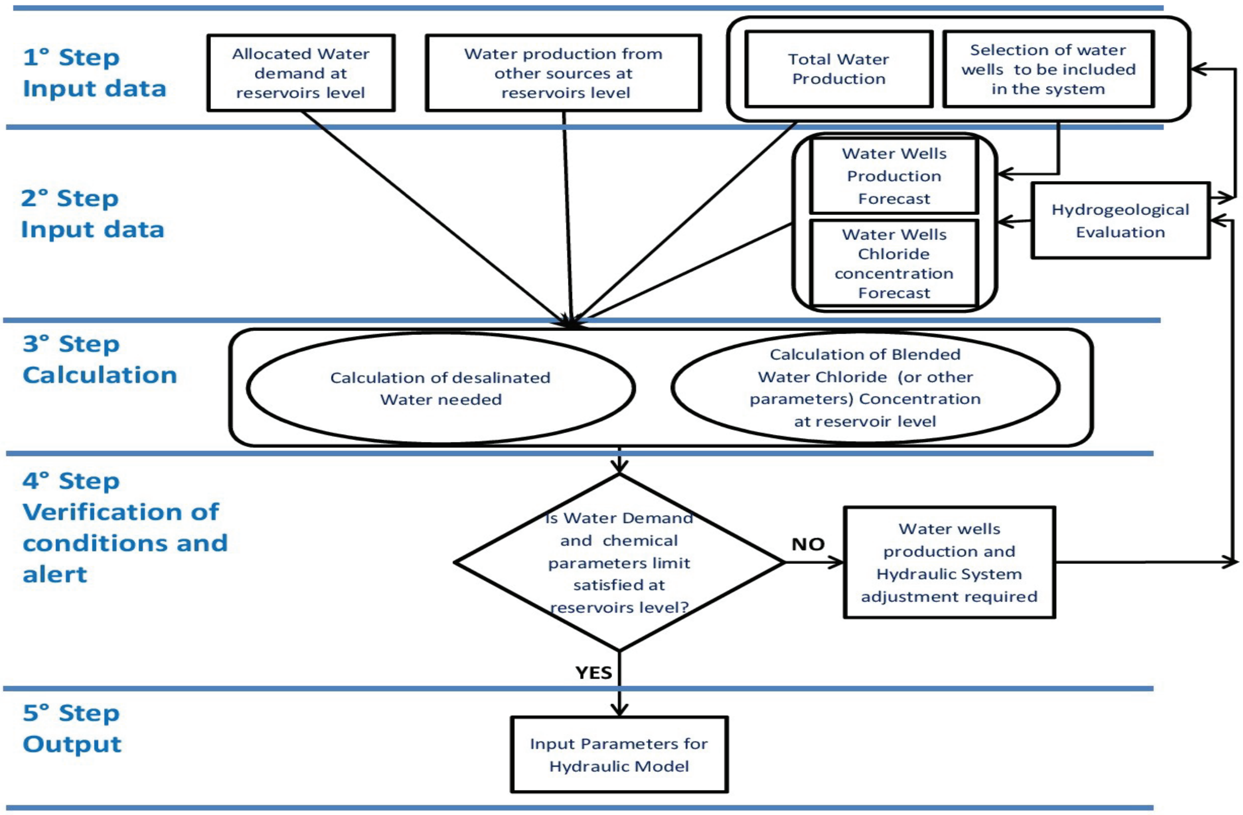

Fig. 1. Blending tool – flowchart.

it is necessary to pay attention to the aggressiveness and the taste of tap water [5].

One of the solution to improve the flavor of tap water is blending desalinated water with available local freshwater sources [6,7].

In order to meet the targets, the contribution of the different and blending forecast must be calculated at reservoir level, providing the requested detailed data needed for the hydraulic analysis performances for conveying to the blending reservoirs the water designing dedicated transmission pipes. In particular, for each reservoir the final concentration of chloride (or other chemical parameters) in output must be evaluated in order to comply the standard limits of chloride, nitrate and other critical parameters concentration indicated by the World Health Organization (WHO) [8]. To achieve this goal the "blending tool" was designed.

The blending tool is an operational instrument aimed at calculating the chemical parameters concentration at reservoir level, on the base of input and control data, by warming as well as in the case of possible critical situations.

Summarizing by steps the operating principles of the tool, in Fig. 1 is shown in the flowchart related to the blending tool.

The following input and output data can be pointed out:

(a) Input data:
- ➢ Total water production
- ➢ Allocated water demand at reservoir level
- ➢ Selection of the wells which are included in the system on the basis of the hydrogeological study
- ➢ Projections of chloride (or other chemical parameters) concentration for all the wells included in the system
- ➢ Water well production forecast
- ➢ Water production from all the sources at reservoir level

(b) Processing:
- ➢ Calculation of desalinated water needed
- ➢ Calculation of chloride (or other parameters) concentration related to the blended water at reservoir level
  - Verification 1:
    - – Are the reservoir water demands satisfied?
      - ○ Yes: end of the verification
      - ○ **No: adjustment of water well production required at reservoir level**
  - Verification 2:
    - – Are blending reservoir chloride (or other chemical parameters) concentration limits satisfied?
      - ○ Yes: end of verification
      - ○ **No: adjustment of water well production required at reservoir level**

(c) Output data:
- ➢ Parameters for hydraulic model related to water needed from the different sources at reservoir level
- ➢ Quality of blended water at reservoirs level

2. Method of calculation

Once completed the input process, the blending tool performs automatically the calculation of water needed from desalination plants in order to comply with the total water production and blending chloride (or other parameters) concentration at reservoirs level. The desalinated water came out from the following equation calculated at reservoirs level:

$$\text{Desalinated water} = \text{Total water production} - \text{Other sources} - \text{Water wells production}$$

The quantity of waters from each source has to be taken into account to evaluate the final quality of waters in terms of chloride and nitrate following the WHO indications [4]. The blending will be done into the reservoirs, where water from different sources will be mixed.

For the different scenarios, it has to be considered different amount of waters, to lead the aims to rationalize and optimize the water wells abstractions. Thus, depending on the source used, also the concentration of chloride in output would be changing. On the basis of the water provided by each available source at reservoirs level, the quality of blended water has to be analyzed taking into account the water quality of the groundwater resources as well as by other available sources.

The final chloride concentration of the blended water at reservoirs level is calculated considering the molar ratios of several sources involved in the blending [9].

The formula applied to calculate the blending chloride concentration [9] is shown in the following equation. Moreover, the standard deviation by final concentration is calculated for each reservoir or group of reservoirs.

$$\text{Cl}\left(\text{mg/L}\right)\text{ output concentration} = \Sigma\frac{\left(V\text{source}_n \times C\text{source}_n\right)}{\text{Total } V} \pm \text{SD}$$

where Cl: chloride; V: volume in MC/d; C: concentration in mg/L; SD: standard deviation of molar ratios.

It can be noted that several water sources are conveyed in each reservoir and this can be used as a dynamic system. In other words, the output chloride concentration is dependent by the initial concentration of every source used, thus can be calibrated by changing the amount of each source in input the final concentration. Moreover, it is important to stress that the strength of this tool is the ability to do continuous and constant monitoring activity. Should one or more sources in arrival to the reservoir show sign of worsening parameters, a quick correcting action can be done at once.

3. Verification of conditions and alert

As shown in the Fig. 2, the blending tool is devised for making verification automatically at two main levels:

- Satisfaction of required water demand at reservoir level;
- Satisfaction of chloride (or other parameters) requirements at reservoir level.

If both requirements were satisfied, the outputs of the blending tool could be input in the hydraulic model.

If one of or both requirements were not satisfied, there is a need for some adjustment of water well production required at reservoir level through sound hydrogeological approach [9,10].

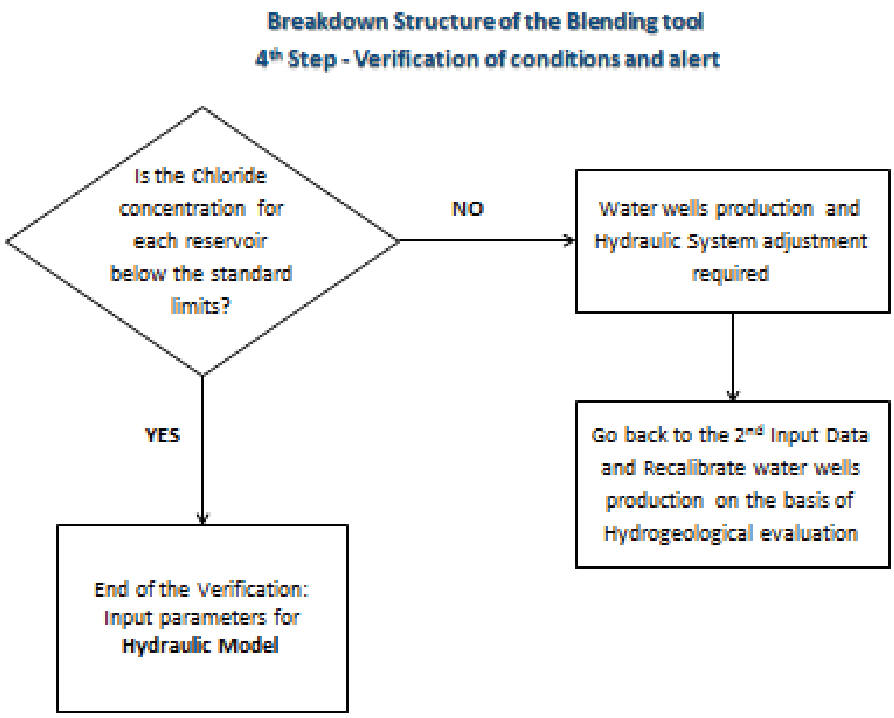

Fig. 2. Blending tool – verification of condition of alert.

Chloride (or other parameters) concentration projections are updated automatically by the blending tool, once integrated new WQ data.

Water well production forecast will be updated manually through sound approach depending on the warning raised by the blending tool.

Once verified the results at reservoirs level, the blending tool will be able to provide with the needed input for hydraulic modeling:

- Desalinated water needed at reservoir level;
- Quality of blended water at reservoirs level.

4. Management of the system – hydrogeological dynamic verification tool

The "Hydrogeological Dynamic Verification Tool" was devised as a comprehensive instrument of support to the groundwater production planning [11] and subsequent groundwater balance control [12] through a continuous updating and verification of results on the basis of the monitoring program [13,14].

The main purposes of this tool are:

- Automatically providing warning for measure values mismatching with the predictions;
- Automatically providing warning in case of the updated predictions mismatches with the current projections;
- Automatically providing warning for unexpected and unforeseen trend of the behavior of the aquifer;
- Supporting the decision-makers in planning future scenarios.

Fig. 3 shows the flowchart related to the hydrogeological dynamic verification tool.

5. GIS integration with the Tools

The blending tool is designed to be embedded in GIS and to run interactively with the spatial data and their attributes. However, the experience of integrating the blending tool with GIS reveal some issues that has to be accounted for. Using such a tool requires a comprehensive spatial database that involves the water resources in addition to the associated assets. The tool must involve a precheck of the data completeness prior to running the analysis. All null data or unlinked tables/entities shall be identified for intervention. Furthermore, the structure of the spatial database has to be designed to accommodate any futuristic development of the water system and any changes in the status or characteristics of different assets; and to maintain the service of data entry by different firms. In addition, the structure of the geodatabase was redesigned according to the blending tool requirements to consider the emerging data and relations when applying the blending tool.

The use of GIS adds the privilege of utilizing the "location" characteristics of the entities. Additionally, it provides a direct utilization of the data as they are updated by different stakeholders. Topological analysis is used in order

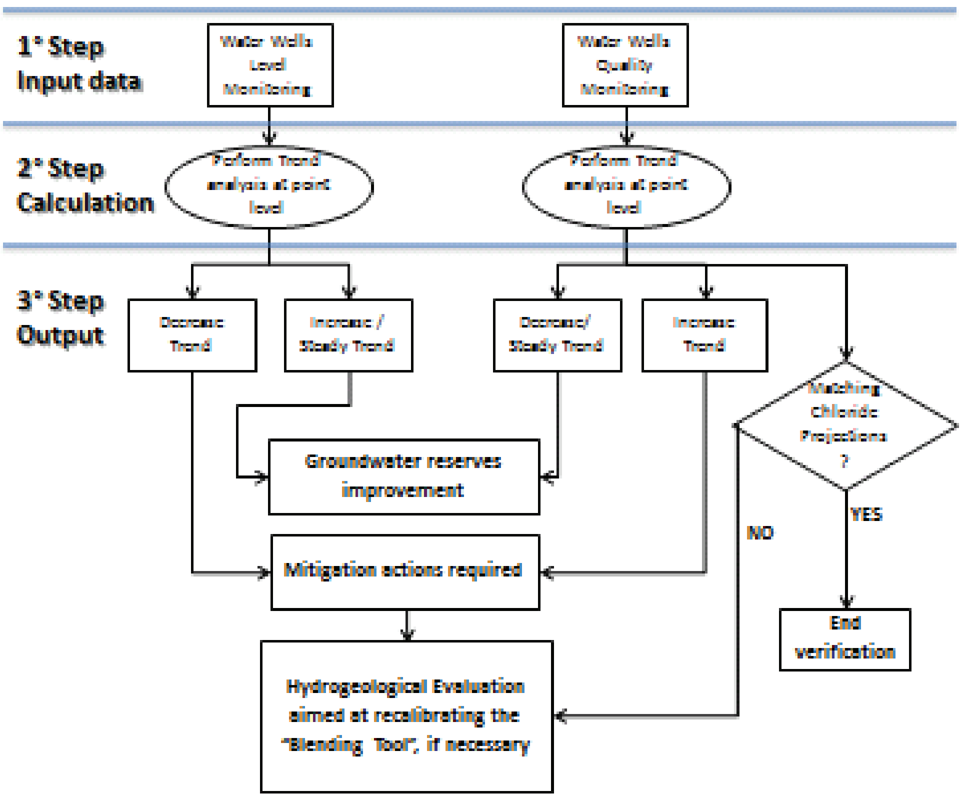

Fig. 3. Hydrogeological dynamic verification tool – flowchart.

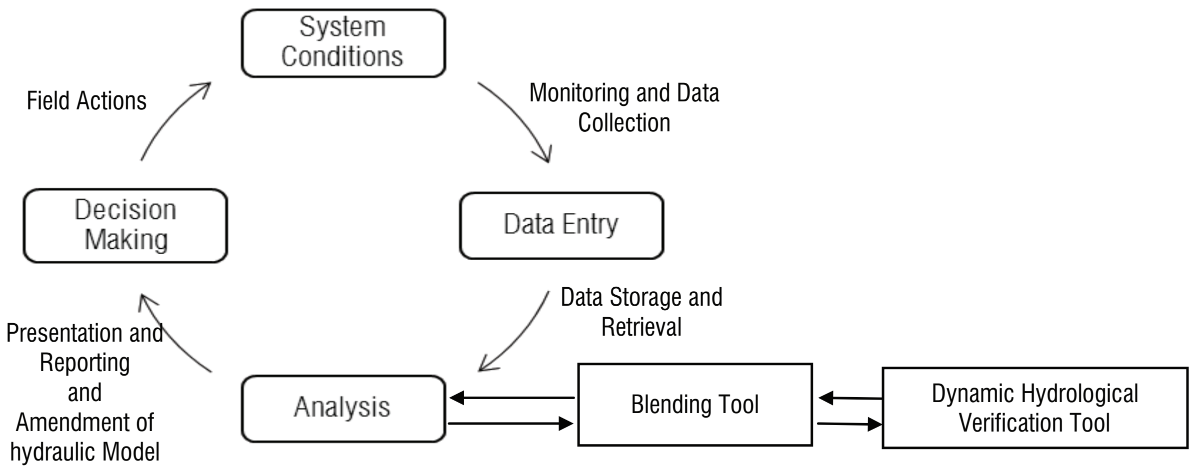

Fig. 4. GIS-based blending tool.

to update the demand at the reservoirs level. The demand is updated according to the attributes of the administrative maps, which include the population of each distribution zone. The record of the groundwater quality at the pumping and monitoring wells is updated regularly in the geodatabase. The tool is flexible with regards to the changes in the operational schemes since they are governed by the built-in relations that governed the geodatabase structure. Furthermore, any changes in the status of the system components are detected at the beginning of the analysis process.

The blending tool would be part of the analysis process of the GIS-based decision-making cycle, as shown in Fig. 4. The analysis processes are conducted through GIS models. These GIS models involve the blending tool (including the blending verification tool), and the hydrogeological dynamic verification tool. These two tools are strictly interconnected with each other and interact with the hydraulic model. The tools are programmed according to the flowcharts that were elaborated in previous sections. Warnings will be raised once, any unbalanced water budget is detected, or any quality standards are violated [15]. The entities that require intervention will be highlighted on the map in order to facilitate amendments of the operational schemes.

Despite that the graphical user interface was simplified as possible, the blending tool that described by the current paper was designed to be used by water resources experts who have basic knowledge with GIS. The tool will be used to examine different management scenarios in order to achieve the best operational schemes, which is mainly governed by the experience in the field. The results of the analysis and calculations performed through the hydrogeological dynamic verification tool are then reported to the decision-makers for implanting the potential mitigation actions as required [16–18]. The final results will be used to amend the parameters used for the hydraulic model.

Albeit the team achieved a very important result, there is still a great opportunity for developing the blending tool in the future. Using GIS allows for integration with data from other sectors, and to examine other governing parameters, such as energy, spatial expansion of urbanization, etc. Furthermore, the use of GIS helps adopting other techniques for decision-making with regards to the required intervention. For example, the blending tool can be integrated with a hydrogeological model [12,19] or adopt mathematical modeling for decision-making [20]. Such integrations are recommended for future research.

6. Conclusions

In those difficult environments, characterized by shortage of water resources, energy, affordability, the leader variables of the system are those related to the water quality and provision of an equity service. In order to make the management of the system sustainable, blending two or more sources are the winning solution in order to satisfy demand with affordable tariffs.

The constant monitoring of the blended water along the bulk water supply system and in all water distribution networks is a necessary requirement to ensure a correct management of water quality. The blending tool is an easy and flexible interface to ensure the correct management.

The targets of the monitoring are not only to record a specific number or concentration but can be read as a suggestion to operate with a good practice to prevent the worsening of the water quality related to existing available groundwater source.

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