Response to reviewer's comments on "Estimation of groundwater potential and aquifer hydraulic characteristics using resistivity and pumping test techniques in Makassar Indonesia, Reference No: HRL22-00026", Paper, by Badaruddin et al.

Dear Editor,

We are pleased to resubmit an improved manuscript on our investigation of groundwater potential and aquifer hydraulic characteristics in Makassar City, Indonesia, using resistivity and pumping test techniques.

We have addressed the comment (given in italics) from the reviewer and our responses are detailed below. We acknowledge that the reviewer input allowed for significant improvements to be made to this article. Please note that any changes mentioned in this revision notes are referring to the clean revised manuscript.

Best wishes,

Sugiarto Badaruddin

Reviewer 1:

First of all, I had a difficulty in finding novelty of this research. The results seem to be less interesting for potential readers of this journal. It is like an engineering report rather than an original research paper. Moreover, visibility of figure 3 is quite low and is difficult to understand.

Response:

Thank you for your comments. In this research, groundwater potential and aquifer characteristic in all area of Makassar City were investigated for the first time in integrated manner using resistivity method and pumping test. Makassar city is a very important and one of the most

populated metropolitan cities in Indonesia and located in coastal area which is very susceptible to seawater intrusion. Little information is available on the groundwater's availability while the use of groundwater is progressively being carried out by the community and industry. There is no research available explaining in detail about groundwater potential and also the depth of groundwater aquifer in entire area of the city. Therefore, the present study aims to provide for the first time, comprehensive information of groundwater conditions and also aquifer characteristics in the form of map which covers all area of the city. The results are expected can be used as a basis for future groundwater model of the respected region and also as preliminary data to give the new insight for the local community in exploiting groundwater in sustainable manner. To highlight the novelty and the significance of the current research, we have added some sentences in Lines 17 to 19 in the abstract section, in Lines 66 to 79 and Lines 83 to 88 in the introduction section. We have also changed the Figure 3 to increase the clarity. Since there is a limitation on the article length (journal's article format) and there are 16 points available on the interpretation results, therefore to increase the clarity of the figure, only five of interpretation results were selected and presented in Figure 3. The complete interpretation results are shown in Figure S2 to S4 and Table S3 in the Supplement section.

Reviewer 2:

Dr. Sugiarto Badaruddin, and colleagues attempted to estimate groundwater potential and aquifer hydraulic characteristics using resistivity and pumping test at the densely populated city, Makassar Indonesia. Though the result shows somehow interesting spatial distribution of groundwater potential, the logical derivation of this result seems to have low reliability largely due to the lack of important explanation of method they used. Thus, to be a scientifically reliable article, considerable amendment is required. My general suggestions are the following.

Response:

Thank you for your suggestion and we have revised the manuscript accordingly.

1. Though it very important to interpret the result of electric resistivity survey, no detail explanation of interpretation processes are given. Only the reference is shown. Since the maximum words for the main text is limited (5000 words), I recommend to give this explanation as a supplemental material. Related to this, Figure 3 is too small to identify the values of x, y

axis and color charts. Moreover, different geological layers might be shown by using the column in the central part of each figure, but these are almost unidentifiable.

Response:

Thank you for your suggestion and we have revised the manuscript by adding some tables and a figure in the Supplement section to address this comment. For example, Tables S1 and S2 for identifying the relationship between resistivity values and type of water and rock minerals, Figure S1 to S4 and Table S3 for showing the inversion results of geo-electric data and its interpretation, and Figure S5 to show the drawdown data outlined in a semi-logarithmic graph to determine the aquifer parameter values. Related to Figure 3, we have changed the figure to increase the clarity. For clarity of the figure, only five interpretation results from five of observation points are selected and presented in Figure 3. The complete interpretation results (i.e., 16 observation points) are provided in the Supplements section (see Figure S1 to S4 and Table S3). This has been explained in Lines 175 to 178.

2. How the authors calculate 'optimum pumping discharge' is not explained. But, the result obtained by authors does heavily depend on the spatial distribution of estimated optimum pumping discharge. So, the explanation of calculation processes should be given clearly.

Response:

Thank you for your comments and we have explained how to determine the optimum pumping discharge in Lines 140 to 144 in the Methods section: "The essence of this pumping test is the comparison between the decreasing rates of water level during pumping to the increasing rate of water level during recovery (Ha et al., 2020). Using the interpolation technique between pumping discharge and the rate of change of groundwater level in the well during pumping and recovery, the optimum discharge value from the aquifer can be determined."

English proof reading and reconsideration of expression is required. For example, too many expression `it can be seen` is used to give explanation of figures.

Response:

Thank you for your suggestion and we have revised and checked the entire manuscript to improve the English of this article.

Specific comments

Line 83 'Astronomically' -> inappropriate expression.

Response:

Thank you for your comments. We have deleted the expression in Line 93 in the revised manuscript.

Line 94 and 96 -> Redundant expression. The same description appeared two times.

Response:

Thank you for your comments. We have deleted the repetitive expression to avoid redundancy.

Line 118 In the '2 x 250m', mathematical operator should not be 'x'.

Response:

Thank you for your suggestion. We have revised this in Line 129.

Line 139 - 143: In three equations, some variables without definition is used. ΔS, t0, and r. All of three variables have no definition.

Response:

Thank you for comments. We have added definition to these variables in the revised manuscript in Lines 162 to 165.

Line 168 'values ranging from 5.6 to 164.0Ωm' -> why this range can correspond to tuff/sandstone layer? You need some references.

Response:

Thank you for your suggestions. We have put some references to address this comment such as (1) Palacky GJ. 1987. Resistivity characteristics of geologic targets. *Electromagnetic methods in applied geophysics* **1**: 52-129, (2) Riwayat AI, Nazri MAA, Abidin MHZ. 2018. Application of electrical resistivity method (ERM) in groundwater exploration. *Journal of Physics: Conference Series* **995(1)**. IOP Publishing, and (3) Vingoe P. 1972. Electrical resistivity surveying. *Atlas Copco ABEM*.

Line 169-170 'it is also known...'-> who knows this? Some references or fact to show this statement is required.

Response:

Thank you for your comments. We have revised the sentence in this line and replace it with "In addition, it is also discovered in this research that there is brackish to salty water in the subsurface soil layers, namely in GLP 04, GLP 06, GLP 07, GLP 10, GLP 12, GLP 14, GLP 15, and GLP 16" in Lines 191 to 193.

Line 182-183: The expression 'three ratio conditions' is difficult to understand for readers. Reconsider the expression.

Response:

Thank you for your suggestion. We have revised the sentence with "Figure 4 indicates that in general, there are three conditions of the rate of change of the groundwater level during pumping and recovery." in Lines 213 to 214.

Line 216, 218, 224, 225 The values have ± sign, why these values have positive and negative values? For example, depth to the groundwater aquifer is given as ±120m. But, the depth itself should only have positive value... Why?

Response:

Thank you for your correction. It should be positive value only. We have revised this in the manuscript.

Response to reviewer's comments on "Estimation of groundwater potential and aquifer hydraulic characteristics using resistivity and pumping test techniques in Makassar Indonesia, Reference No: HRL22-00026R1", Paper, by Badaruddin et al.

Dear Editor,

We are pleased to resubmit an improved manuscript on our investigation of groundwater potential and aquifer hydraulic characteristics in Makassar City, Indonesia, using resistivity and pumping test techniques.

This is the second revision and we have addressed the comment (given in italics) from the reviewer and our responses are detailed below. We acknowledge that the reviewer input allowed for significant improvements to be made to this article. Please note that any changes mentioned in this revision notes are referring to the clean revised manuscript.

Best wishes,

Sugiarto Badaruddin

Editorial Office:

Your study may be influenced by the previous study of Anomohanran et al. (2021):
Ochuko Anomohanran, Jude Isioma Oseme, Ruth E. Iserhien-Emekeme & Merrious Oviri Ofomola. Determination of groundwater potential and aquifer hydraulic characteristics in Agbor, Nigeria using geo-electric, geophysical well logging and pumping test techniques. Modeling Earth Systems and Environment 7, pp.1639–1649. It is necessary for your paper to cite the previous study properly.

Response:

Thank you for your comment and suggestion. Now we have cited the reference in the manuscript in Line 155.

Reviewer 2:

In this manuscript, Dr. Badaruddin and colleagues investigate the basic structure of aquifer which might be widely underlain in Makassar City, Indonesia. Combined use of resistivity method and pumping tests, they identified the most promising area for groundwater usage presumably for the future human activity of this region. While there finds almost no scientifically novel point in this manuscript, some contribution to knowledge accumulation on groundwater aquifer survey techniques might be the valuable aspect of this manuscript. From this viewpoint, even after the considerable manuscript revision, some inadequate points seem to be remained. Thus, I have a several additional requests to authors.

General comments

1. The area where the largest transmissivity value was found is corresponding to the groundwater discharge zone identified by the previous study. This might be the most important finding of this manuscript. However, only correspondence remains in confirmation. How techniques used in this study will strengthen or improve the knowledge on this aquifer in addition to the previous knowledge obtained by the past studies? We need this kind of description in this manuscript.

Response:

Thank you for your comments. Following this suggestion, we have explained the method used in the previous study in the manuscript in Lines 277 to 283.

As I already pointed out in the first review, results obtained by the resistivity method is very important in this study. After authors reorganized the constellation of figure 3, it improves somewhat. However, why these 5 cross-section (GLP01, GLP04, GLP08, GLP12, and GLP16) were selected is not well explained. Furthermore, which depth zone is the most important aquifer might only be understood by experts of resistivity method. It's better to put the primer aquifer zone in each figure of the Figure 3. Also, GLP number shown in the Figure 2 is too small to be read.

Response:

Thank you for your suggestion and we have revised the manuscript accordingly. Why these 5 cross sections were selected has been explained in Lines 176 to 180 which is for clarity and

brevity of the manuscript and also to meet the required number of page allowed by the journal. In addition, positions of these five observation points are relatively distributed evenly throughout the Makassar City area and may represent the geological conditions of Makassar City in general. As your information, the complete interpretation results are still provided in the Supplements section (see Figure S1 to S4 and Table S3 in the manuscript) which describes the depth and the thickness of the aquifer in each location.

I could not understand the meaning or the implication of three different types of pumping test. Especially, difference between type 3 and others seems very slight. Even if there are some differences between each pumping test, what this difference indicate or imply for the aquifer characteristics? This kind of interpretation of three different types should be addressed.

Response:

Thank you for your comments. For your information, the results of the pumping test in this study were analyzed using the Cooper-Jacob method as explained in Lines 150 to 166 and there will be some aquifer parameters obtained from this analysis (i.e., transmissivity (T), specific capacity (Sy) and storativity (S)). The interpretation of parameter values obtained from the analysis was conducted using the result of some previous studies. For example, the type of aquifer can be determined from storativity values as described in Pongmanda and Suprapti (2020) and the capability of the aquifer to supply water can be determined from transmissivity values as explained in Krásný (1993). Meanwhile, as explained in Lines 138 to 144, the optimum groundwater discharge of the aquifer can be determined using the graph of pumping and recovery.

Pongmanda S, Suprapti A. 2020. Performing application of cooper-jacob method for identification of storativity. *IOP Conference Series: Earth and Environmental Science* **419(1)**: 012128: IOP Publishing. DOI: 10.1088/1755-1315/419/1/012128.

Krásný J. 1993. Classification of transmissivity magnitude and variation. Groundwater 31(2): 230-236. DOI: 10.1111/j.1745-6584.1993.tb01815.x.

Reviewer 3:

The authors have demonstrated the aquifer characteristics and possible development volumes in the study area through multisite resistivity surveys and pumping tests, which I believe have been substantially revised from the first manuscript. However, I would like to see additional consideration of some of the following aspects of the authors' work, as they lack credibility and objectivity.

(1) The geologic distribution known from previous studies is described (L105-112). However, the lack of a description of the extent to which the geologic differences inferred from the resistivity survey are consistent with the geologic survey (L180-195) prevents an assessment of the reliability of the results of the resistivity survey.

Response:

Thank you for your comments. It is important to know that the geologic distribution derived from previous studies in Lines 105-112 describes the geologic condition in general for the whole area of south Sulawesi province while the resistivity survey reveals the geologic condition in the specific area (i.e., Makassar city). Nonetheless, the results from resistivity survey provided in this research (see Lines 187 to 190 and Table S3) are still consistent with the geologic condition explained in the previous study where the soil in Makassar city consists of alluvium deposits in the form gravel, sand, mud, clay, and also volcanic rock formation in the form of tuff rock and volcanic breccia.

(2) You seem to estimate the thickness of the aquifer in this area based on the results of a resistivity survey (L191), but please show the validity of applying the relationship between resistivity and fresh water in other areas (or obtained experimentally) as it is to this area.

Response:

Thank you for your suggestion. Some previous studies have shown the relationship between resistivity values and freshwater such as Islami (2011), Jansen (2011), and Singh et al. (2004) and this has been used in many other previous geophysical research. There is also a reference (Vingoe, 1972) in Line 135 and a table provided (i.e., Table S2) in the supplement section to show this relationship.

Islami N. 2011. Geoelectrical resistivity method for salt/brackish water mapping. *Journal of Coastal Development* **14(2)**: 104-114.

Jansen JR. (2011). Geophysical methods to map brackish and saline water in aquifers. *Georgia Institute of Technology*.

Singh UK, Das RK, Hodlur GK. (2004). Significance of Dar-Zarrouk parameters in the exploration of quality affected coastal aquifer systems. *Environmental Geology* **45**: 696-702.

Vingoe P. 1972. Electrical resistivity surveying. Atlas Copco ABEM.

(3) You mention that brackish to salty water was observed in the soil layer at several stations (L192), but I do not understand how you determined this. For example, there are two high resistivity zones in the shallow layer of GLP04, but I would like an explanation of how this is interpreted.

Response:

Thank you for your comments. Interpretation of brackish water is based on the value of resistivity in Table S2 (in the supplement section) which is obtained from a reference written in Line 135 (Vingoe, 1972) and also some other references listed in Line 195 in the manuscript. The range of resistivity value for brackish water is lower than 7 **Ω**m as used in Islami (2011), Jansen (2011), Singh et al. (2004), and etc. and these values are used to estimate the position of brackish water in the aquifer layer in this study.

Islami N. 2011. Geoelectrical resistivity method for salt/brackish water mapping. *Journal of Coastal Development* **14(2)**: 104-114.

Jansen JR. (2011). Geophysical methods to map brackish and saline water in aquifers. *Georgia Institute of Technology*.

Singh UK, Das RK, Hodlur GK. (2004). Significance of Dar-Zarrouk parameters in the exploration of quality affected coastal aquifer systems. *Environmental Geology* **45**: 696-702.

(4) You present three conditions based on the rate of change in the groundwater table between pumping and recovery as shown in Fig. 4. Please explain whether the determination of these conditions was statistically determined or based on appearance (L213).

Response:

Thank you for comments. This condition can be determined directly from the graph of pumping and recovery (see Figure 4) which shows the trend of groundwater table in each condition (i.e.

pumping and recovery). This trend basically shows the velocity of groundwater table changes in response to pumping and recovery condition. The trend of change in groundwater table during pumping and recovery is determined using linier regression.

(5) You have determined the optimum pumping rate (L224), but how does this value compare (is it larger or smaller) to locations in a similar regional setting to the study area? It would be helpful to present some examples of comparative studies to help us get a better picture of the validity of this value.

Response:

Thank you for your comments and suggestion. Unfortunately, there is no published data available providing the information of optimum groundwater pumping rate for areas around Makassar city, however if we compare the optimum pumping rates obtained in this study and the results of the research from Amah et al. (2012), we may conclude that the results of this study are reasonable and valid. Moreover, the results obtained in this study were derived from in-situ pumping test in several locations in Makassar. We have added the result from previous study as a comparison in Lines 271 to 274: "These values are considered reasonable compared to the results of Amah et al. (2012) which obtained the values range from 0.036 to 1.833 m^3/min for the optimum groundwater discharge in Calabar coastal aquifers, Nigeria."

Amah EA, Ugbaja AN, Esu, EO. 2012. Evaluation of groundwater potentials of the Calabar coastal aquifers. Journal of geography and geology 4(3):130.

(6) Are there any data that can verify the consistency with actual groundwater parameters measured, such as lower DO values in areas where the groundwater Transmissivity value (L241) was estimated to be small? The study would be positioned with more validity if there were actual measured data to support the groundwater environment estimated in this study, such as the actual occurrence of groundwater salinization in areas with small optimal pumping (L265).

Response:

Thank you for your comments. We have added a result from a previous study in the manuscript in Lines 196 to 199: "This is in a good agreement with the results of Meyke et al. (2020) that identified higher groundwater salinity in Untia village in Biringkanaya district (near GLP 10)

where the optimum groundwater discharge in this area is relatively small." to address this comment.

Meyke , Soemarno , Riniwati H, Tamsil A. 2020. Spatial Distribution and Vulnerability of Sea Water Intrusion in Makassar City. Journal of Engineering and Applied Sciences 15: 2272-2278. DOI: 10.36478/jeasci.2020.2272.2278.

Some other specific comments:

Figure 1: The entire Indonesia region is also color-coded, but it should not match the legend in the lower right corner. I felt that the figure for all of Indonesia should be kept to one color.

Response:

Thank you for your suggestion. We have revised Figure 1 accordingly.

Figure 3: The resolution of this figure remains low. For example, the aspect ratio of the numbers on both axes is unnatural, and small letters and numbers are illegible. Also, the meaning of the dashed line in Fig. 3d is unclear.

Response:

Thank you for comments. We have revised Figure 3 accordingly.

Response to reviewer's comments on "Estimation of groundwater potential and aquifer hydraulic characteristics using resistivity and pumping test techniques in Makassar Indonesia, Reference No: HRL22-00026R2", Paper, by Badaruddin et al.

Dear Editor,

We are pleased to resubmit an improved manuscript on our investigation of groundwater potential and aquifer hydraulic characteristics in Makassar City, Indonesia, using resistivity and pumping test techniques.

This is the third revision and we have addressed the comment (given in italics) from the reviewer and our responses are explained below. We acknowledge that the reviewer's comments allowed for significant improvements to be made to this article. Please note that any changes mentioned in this revision notes are referring to the clean revised manuscript.

Best wishes,

Sugiarto Badaruddin

Reviewer 3:

I feel this is a big improvement from the last version. This version addresses useful comments from other reviewers and will be an outcome that could contribute to the sustainable development of groundwater in this study area. However, there are still a few unclear points below, please consider addressing these.

Response:

Thank you for your comments.

L133: Kalilu et al (2022) is missing from the reference list.

Response:

Thank you for your comments. We have added the reference in the list in the revised manuscript.

L203(Figure 3): The small letters and numbers in the center of the figure are likely illegible in the version at the time of publication. The meaning of the dashed lines in Figure 3d is also unclear and does not improve on our previous point. ※Figure S1-S4 as well.

Response:

Thank you for your comments. We have revised Figure 3 and also Figure S1 to S4 accordingly. The dashed line in Figure 3d has been removed since there is no specific meaning represented by the line.

L218-224: The following is a section that I pointed out in my previous peer review comments: the authors have separated the conditions for the rate of change in groundwater level during pumping and recovery in Fig. 4, judging by the author's appearance. However, GLP02 and GLP03, for example, show fairly similar rates of change, but the conditions are determined to be different. I would think that readers would be as curious as I am as to how this was determined, and it seems unkind not to explain it in the text.

Response:

Thank you for your comments. Despite the similar appearance in rates of change between GLP02 and GLP03 in Figure 4, there is a different in velocity noticed in the rates of change between these two observations, where the rate of change of groundwater level during pumping is smaller than during recovery occurred in GLP 02 while the same rates of change of groundwater level during pumping and recovery is occurred in GLP 03. This has been explained in Lines 219-224 in the manuscript.