



# Jakarta groundwater modeling: a review

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## Abstract

Jakarta is the center of Indonesia's economy and development. However, the city of Jakarta suffers from many problems related to groundwater, and good groundwater governance is needed to realize groundwater sustainability. Groundwater management can be initiated by undertaking conceptual and numerical groundwater modeling. This paper reviews several previous studies related to groundwater modeling of the Jakarta groundwater basin that have provided information about the groundwater system and groundwater quantity. However, improvements are required for any further studies. The critical challenges to providing a complete picture of the groundwater conditions in the Jakarta groundwater basin are the availability of reliable data and improved groundwater flow models.

**Keywords** Groundwater · Numerical model · Conceptual model · Groundwater basin, Jakarta, Indonesia

## Introduction

Jakarta, the capital of the Republic of Indonesia (Cybriwsky and Ford 2001) is a megalopolis, having a population of more than 10 million people (Delinom 2008; Lubis et al. 2009), and is the center of Indonesia's economy and urban development. However, Jakarta faces various groundwater management challenges (Kagabu et al. 2011; Seizarwati et al. 2018), such as land subsidence and flooding (Chausard et al. 2013; Delinom 2008; Kagabu et al. 2010; Lubis et al. 2009). The central government of Indonesia and the provincial government of Jakarta struggle to realize groundwater sustainability aimed at saving the city from disasters derived from the excess use of groundwater (Lubis 2011). Past efforts have included issuing a Governor's Decree prohibiting the use of groundwater by Jakarta residents, including terminating new groundwater drilling permits and the sealing of drilled wells in the city of Jakarta. Therefore, it is necessary to manage existing water resources in Jakarta, particularly groundwater, which as a source of clean water

for most of humanity, is a serious concern, particularly for the citizens of Jakarta (Lubis 2018).

Groundwater management efforts can be effectively initiated by building conceptual models that can be translated into numerical groundwater models (Bayanzul et al. 2019; Fitts 2013; Francés et al. 2014; Nash and Sutcliffe 1970; Viguier et al. 2018). Several researchers have applied conceptual models and numerical models to groundwater resource management in urban areas worldwide (Bayanzul et al. 2019; Liu et al. 2004; Wang et al. 2013). By modeling actual groundwater conditions, the modeling approach can be used to quantitatively determine groundwater conditions in Jakarta and simulate future groundwater conditions, which is useful knowledge for determining groundwater management plans (Braadbaart and Braadbaart 1997; Chausard et al. 2013; Kagabu et al. 2011; Khan et al. 2016; Liu et al. 2004; Lu et al. 2016; Tirtomihardjo 2016). Although groundwater management decision-making for Jakarta is not only based on the results of groundwater modeling, by using the modeling approach, basic assumptions can be made about how the groundwater management should be undertaken.

Acknowledging the importance of a Jakarta groundwater model, this paper aims to review the extent to which groundwater modeling has been carried out in Jakarta and its surroundings. The goal of this paper is to understand with certainty existing conceptual models and the development of numerical modeling concepts for the Jakarta groundwater

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basin. To achieve this, this paper reviewed the approaches taken, the data used, and the numerical modeling results and their contribution, and it uncovered the challenges faced by previous researchers. It is hoped that this paper will improve both conceptual and numerical modeling in Jakarta by guiding researchers as they build future groundwater models.

## Hydrogeology of the Jakarta groundwater basin

According to Lubis et al. (2008), The Jakarta groundwater basin is one of the most developed basins in Indonesia where Jakarta city is located, with an elevation ranging between 0 and 200 m above sea level (m asl) (Fig. 1). Jakarta city, which is the capital of the Republic of Indonesia, lies on the coastal plain of the Java Sea (to the north) and is bordered by Jakarta Bay in the north, West Java province in the south and east, and Banten province in the west. The city is located between  $106^{\circ}33'$  and  $107^{\circ}$  E longitude and  $6^{\circ}10'30''$  and  $6^{\circ}18'30''$  S latitude with an area around  $652 \text{ km}^2$  (Fig. 1). Greater Jakarta has a humid tropical climate; the annual rainfall is high between 1500 and 2500 mm due to the influence

of monsoon. Land use in Greater Jakarta mostly comprises housing, industry and commerce while some agriculture is practiced in the urban fringe areas (Djaeni et al. 1986).

According to Engelen and Kloosterman (1996), structurally, the Jakarta Basin is part of the so called a Northern Zone comprising the low hilly areas of folded Tertiary strata, and coastal lowlands bordering the Java Sea. Regionally, Jakarta Area is occupied by lowland area that has five main landforms (Rimbaman and Suparan, 1999) that consists of:

- (1) Volcanic and alluvial landforms, that are found in southern part of the basin,
- (2) Marine origin landforms, which are occupied the northern area adjacent to the coastline,
- (3) Beach ridge landforms, which are discovered along the coast with east–west direction,
- (4) Swamp and mangrove area landforms, which are encountered in the coastal fringe,
- (5) Paleo-channels, which run perpendicular to the coastline.

Geologically, the study area is dominated by quaternary sediment and, unconformably, the base of the basin is

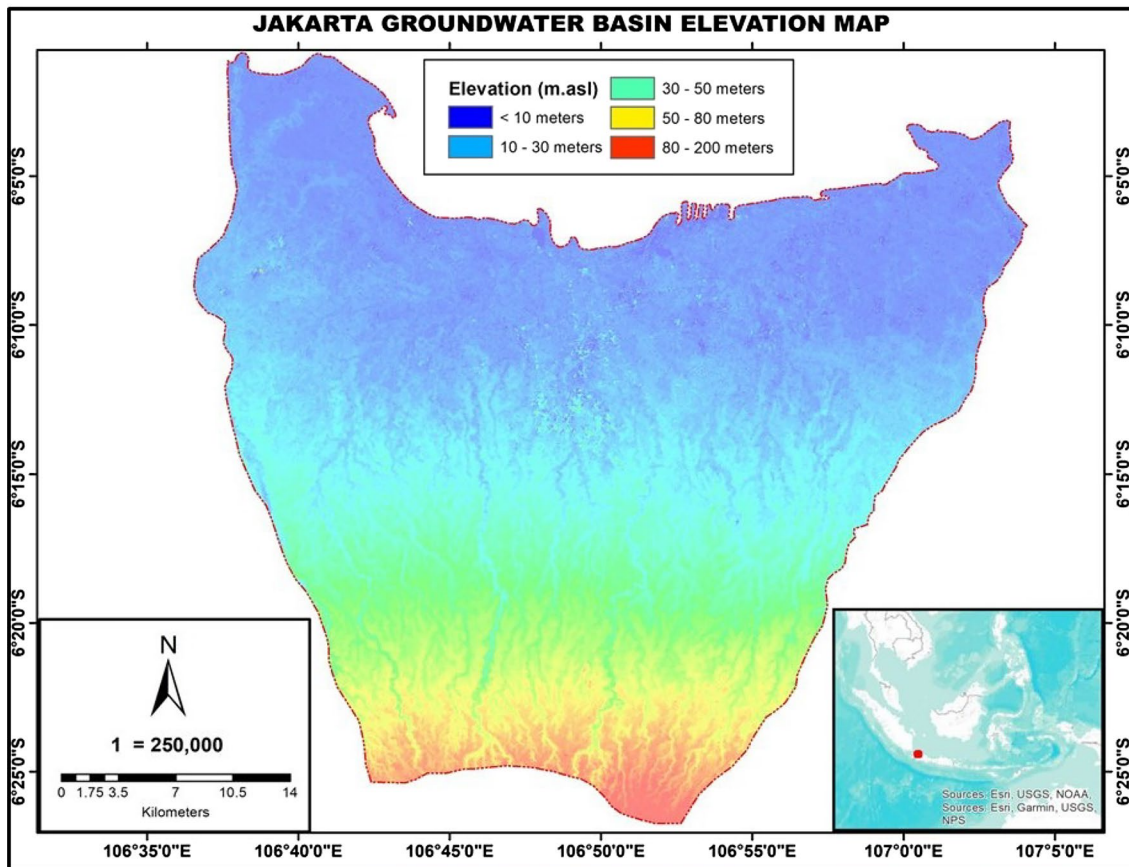


Fig. 1 Jakarta groundwater basin

formed by impermeable Miocene limestone sediments cropping out at the southern area, which were known as Bojongmanik and Klapanunggal Formation (Delinom 2011). The basin fill, which consist of marine Pliocene and quaternary sand and delta sediments, is up to 300 m thick. Individual sand horizons are typically 1–5 m thick and comprise only 20% of the total fill deposits. Silts and clays separate these horizons. Fine sand and silt are very frequent components of these aquifers (Martodjojo 1984; Assegaf 1998), and the sand layers were connected to each other (Fachri et al. 2002). This conclusion was based on stratigraphic cross correlation of South–North direction from core and cutting evaluation of 20 boreholes around Jakarta Basin.

In Delinom et al. (2009), there are 50 wells for monitoring the shallow ground water level which were located on the area of 50 elementary schools and 51 wells for monitoring deep groundwater level which were randomly distributed within the Jakarta Basin area. Among the 51 monitoring wells for deep groundwater level, only 30 wells were equipped with automatic water level recorders (AWLR). There is no AWLR available for shallow groundwater monitoring wells. Generally, the shallow groundwater monitoring wells were constructed using 4 inch diameter pipes reaching 12–20 m depth. No data of screen positions were available and the wells are open-ended. The water level measurements were carried out once a month during the 2002–2005 period. Those wells were located on the Bogor Alluvial Fan with an unconfined aquifer. The deep monitoring wells were constructed using 5 in. diameter pipes reaching 200 m deep and the screens were located on the target aquifers depth. The wells were drilled exclusively to monitor groundwater level and land subsidence caused by groundwater withdrawal.

Based on the water level measurement data of the 2002–2005 periods, it was shown that in general the shallow groundwater level has a negative trend, it was decreasing. The deep groundwater monitoring wells have been constructed within the period of 1994–2000. Total of the monitoring well is 51 wells and only 30 wells were equipped with automatic water level recording (AWLR) of which 1 (one) was defect and could not be used even manually. At the end of 2005, only 48 wells still existed and only 22 AWLR were still working. Based on the range of screen depths, which was assumed to be identical with the aquifer position, those 50 wells could be grouped into 5 clusters i.e., 0–40 m, 40–95 m, 95–140 m, 140–190 m, and 190–250 m.

- Cluster 0–40 m Aquifers. This cluster consists of 5 monitoring wells with water level fluctuated between –2.18 and –32.68 m below sea level (b.s.l.). Most of those wells are located on the Bogor Alluvial Fan. Based on water level data of those wells, 1 well showed a positive trend (Bapedalda, Central of Jakarta), 1 well with a negative trend (Senayan, Central of Jakarta), and 3 wells

just fluctuated as the season changed i.e., Pasar Rebo and Cilandak (South of Jakarta), Tongkol (North of Jakarta)

- Cluster 40–95 m Aquifers. This cluster comprises 7 monitoring wells with water level ranging between –4.12 and –25.80 m b.s.l. The seasonal fluctuating water level could only be observed at the Duren Sawit monitoring well in the eastern part of Jakarta. The wells located on the southern part of Jakarta (Jagakarsa, PT SCTI, and National Gobel) showed a positive trend, while all wells located in the central and northern part of Jakarta (Tongkol, Senayan, and Yamaha Motor), showed a negative trend. Generally, this cluster is relatively balanced between negative and positive trends.
- Cluster 95–40 m Aquifers. This cluster consists of 10 monitoring wells with water levels ranging between –1.34 and –51.05 m b.s.l. The water levels in the north-western part of Jakarta (Sunter, Kapuk and Jelambar) mostly show seasonal fluctuation. In the eastern part of Jakarta (Sinar Sostro), the water level is relatively stable. A positive trend was observed in the northern part of Jakarta (Walangbaru and Tongkol) while a negative trend was observed in south and central Jakarta (Dharmawangsa, Joglo, Tegal Alur and Jakarta Land).
- Cluster 140–190 m Aquifers. Five monitoring wells belong to this cluster. The water level ranged between –10.56 and –31.82 m b.s.l. In the eastern part (Tambun Rengas), the water level tended to be positive, while the other four wells which are located in the central part (DPR/MPR and Gedung Jaya) and in the northern part (Kamal Muara and Sunter) of Jakarta show a negative trend. Therefore, for this cluster, generally, the water levels are decreasing.
- Cluster 190–250 m Aquifers. Within this deepest aquifer, 6 monitoring wells were drilled. Only one well (Walang Baru in northern part of Jakarta), showed a positive water level trend. The other 5 wells, Cakung (north–east), DPRD DKI (central), Pasar Minggu (south), Sunter (north–west), and Tongkol (north), showed a negative trend. Generally, the water level of this aquifer is decreasing.

The geological and hydrogeological conditions of Jakarta, as comprehensively discussed by Delinom et al. (2009), are presented in the following description (Fig. 2). Quaternary deposits (Pliocene to Pleistocene; 1–2 ma to recent) dominate the geology of the study area, with a Tertiary basement bounded by the Tangerang horst to the west and the Rengasdengklok horst to the east.

The Quaternary deposits comprise volcanic alluvium fans (resulting from volcanic eruptions to the south of Jakarta), coastal alluvium, and river channel deposits. These units are interfingering due to Quaternary erosion, the formation of river channels, coast line development, and longshore

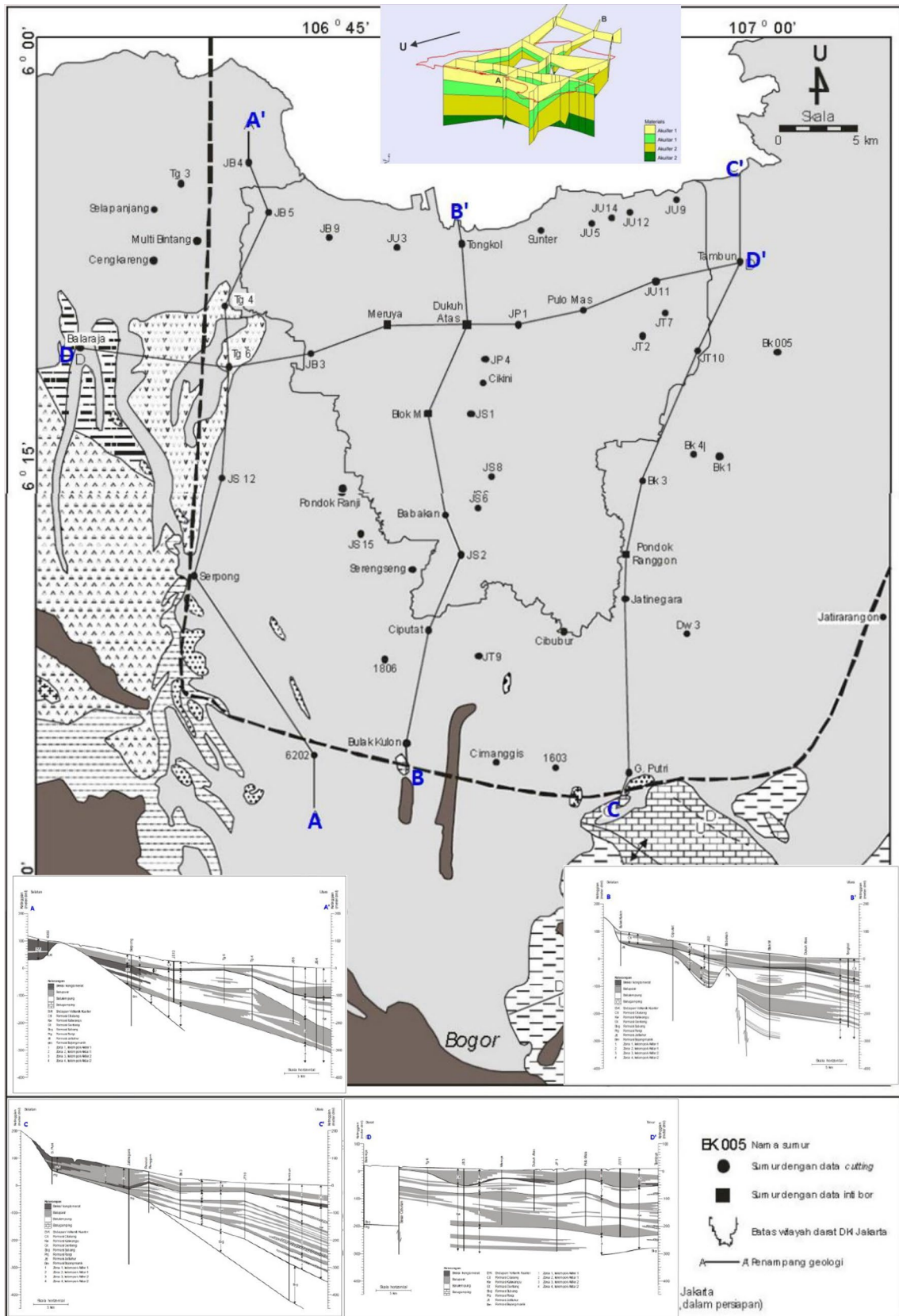


Fig. 2 Hydrogeological cross section of Jakarta groundwater basin Seizarwati et al. (2018)

sediment transport. The Quaternary sediment thickness is estimated to range from 65 m (in the Ciputat area) to 300 m (in the Jakarta Kota area). The Quaternary deposits in the study area lie unconformably on a Tertiary sedimentary basement, thought to be claystone and marl with Pliocene limestone inserts.

The volcanic-fan alluvium units, comprising alluvium deposits originating from Mount Gede and Mount Salak, extend from the Bogor area, where they originate, to Jakarta. Their main constituents are partially well-consolidated tuff clays and tuff sands with intercalated conglomerate.

Geological structures can act as both channels (Watts 1987) and barriers to groundwater flow (Davies and DeWeist 1966; Delinom 2009; Denison 1994; Haneberg 1995; Knipe 1992; Titus 1963; Yielding et al. 1997). In the Jakarta groundwater basin, fault structures are observed to act more as groundwater channels than barriers because the fault direction is generally the same as the direction of groundwater movement.

A hydrostratigraphic column for the Jakarta groundwater basin has been compiled by Fachri et al. (2002) comparing rock units and their physical properties related to the transmission of water (Fig. 3).

## Results and discussion

### Conceptual modeling

Fachri et al. (2002) used lithocorrelation to vertically zone the aquifer system in the Jakarta groundwater basin based on the distribution of rock-forming units as follows (Fig. 3):

- (a) Zone I (aquifer group), comprising the Citalang Formation and Quaternary volcanic deposits, is identified as an aquifer because it is dominated by permeable lithologies. The constituent lithologies include sandstone, conglomerate, breccia, and claystone lenses. This zone

(20–110 m thick) thickens to the north and thins to the west.

- (b) Zone II (aquitard group), comprising the upper Kaliwangu Formation, is identified as an aquitard because it is dominated by impermeable lithologies, such as claystone with intercalated sandstone. This zone (5–110 m thick) thickens to the north.
- (c) Zone III (aquifer group), composed of the Genteng, middle Kaliwangu, and Serpong Formations, is identified as an aquifer because it is dominated by permeable lithologies. The constituent lithologies are sandstone, breccia, conglomerate, and intercalated claystone. This zone thickens toward the north and in the middle of the basin in a west–east direction.
- (d) Zone IV (aquitard group), composed of the lower Kaliwangu Formation, is identified as an aquitard because it is dominated by impermeable lithologies: claystone and intercalated sandstone. This zone thickens to the north but is relatively uniform in the west–east direction.

It is generally accepted that The Jakarta groundwater basin model’s boundary conditions are limited in the north by a constant head boundary, in the west and east by groundwater divides, and in the south by no flow boundary. The boundary conditions comprise faults to the west and east, the sea to the north, and lithological boundaries to the south.

de Roover (2015) use 4 layer conceptual model in the study area. represent two aquifer (aquifer 1(layer 1) & aquifer 2(layer3)) and to aquitard (aquitard 1 (layer 2) and aquitard 2 (layer 4)) (Fig. 4). Boundaries of the study area were set on the boundaries of the Jakarta basin. These boundaries were no flow boundaries, which were the Cisdane river to the west, the Bekasi and Cikeas rivers to the east, Jakarta bay to the north and a upward ‘bump’ in aquifers to the south, which caused a presumed negligible inward flow.

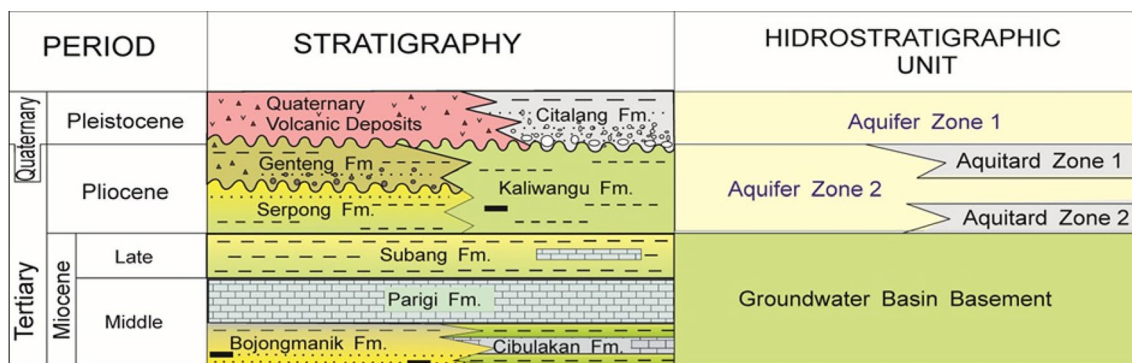
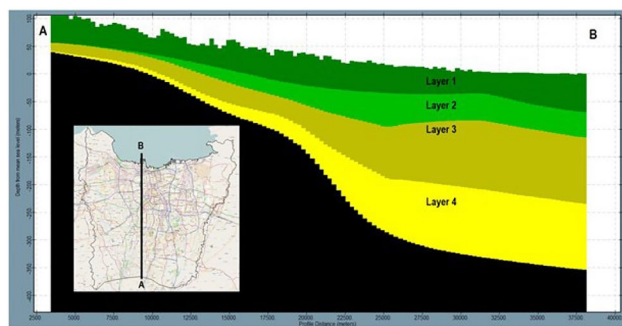


Fig. 3 Hydrostratigraphy of the Jakarta groundwater basin (from Fachri et al. 2002)



**Fig. 4** Conceptual model from de Roover (2015)

## Numerical modeling

Lubis et al. (2014) defined the hydraulic conductivity of the Jakarta groundwater basin as follows: layer 1 = 50 m/day, layer 2 = 0.01 m/day, layer 3 = 8.6 m/day, and layer 4 = 0.0001 m/day. Seizarwati et al. (2018) defined the hydraulic conductivity specific to layer 2 as follows: 1 m/day in the northern part of the basin, 1.5 m/day in the middle of the basin, and 2 m/day in the southern part of the basin. According to Herlambang and Indriatmoko (2005), hydraulic conductivity in the x-direction ( $K_x$ ) for the north Jakarta area is between  $6.5 \times 10^{-4}$  and 2.9 m/day, while in central Jakarta it ranges from  $1.32 \times 10^{-4}$  to 2.3 m/day, and in southern Jakarta, it ranges from  $1.4 \times 10^{-4}$  to 1.1 m/s. Hydraulic conductivity in the y-direction ( $K_y$ ) was set at 1/100 the value of  $K_x$ .

These published hydraulic conductivity values differ because of the authors' differing assumptions and the limited availability of groundwater data. Researchers generally agree that the subsurface conditions in the Jakarta groundwater basin can be divided into four zones, as described by Fachri et al. (2002): aquifer 1, aquifer 1, aquifer 2, and aquitard 2. These hydrogeological units have varying hydraulic conductivities, including vertical ( $K_v$ ) and horizontal hydraulic conductivities ( $K_h$ ). For  $K_v$ , de Roover (2015) defined the values of 833 m/day (layer 1), 1250 m/day (layers 2 and 3), and 1000 m/day (layer 4). These  $K_v$  values were also used for Seizarwati's (2018) Jakarta groundwater model.

According to Herlambang and Indriatmoko (2005), the transmissivity of the entire Quaternary layer (250 m thick) is approximately 250 m/day near the coast, increasing to 500 m/day in the southern area.

The storativity of the deep aquifer system in Jakarta is between  $10^{-4}$  and  $10^{-6}$ , typical for a confined aquifer (Soefner et al. 1986). According to Herlambang and Indriatmoko (2005), the coefficient of freshwater storage in deep, confined aquifers is between  $10^{-2}$  and  $10^{-6}$ . The water retention coefficient,  $10^{-6}$ , for the Jakarta confined aquifer was assumed to be homogeneous, while it ranged from  $1 \times 10^{-4}$

to  $3.6 \times 10^{-3}$  for confined aquifer II and  $1 \times 10^{-4}$  to  $3.6 \times 10^{-3}$  for confined aquifer II and was 0.2 for the shallow aquifers (Herlambang and Indriatmoko 2005). According to Seizarwati et al. (2018), storativity in the Jakarta groundwater basin ranges from  $10^{-8}$  to  $10^{-1}$ .

Herlambang and Indriatmoko (2005) assumed the porosity was homogeneous, particularly confined aquifers I and II (0.15% and 0.05%, respectively), while the porosity of the shallow aquifers ranged from 5 to 15%. Assuming that the soil porosity was on a continuum, the porosity ranged from 0.3 and 0.7 (Herlambang and Indriatmoko 2005).

Similarly, because each study used different assumptions and approaches when determining groundwater recharge, this value was quite diverse. Seizarwati et al. (2017) stated that although groundwater recharge in Jakarta is quite varied, generally, recharge in the Jakarta groundwater basin is < 250 mm/year, although there are a small number of areas that potentially have higher recharge rates. According to Seizarwati et al. (2018) recharge ranges from 4 to 20%, and the average recharge rate in the Jakarta groundwater basin is 15% of rainfall. Seizarwati et al. (2018) used a water balance approach to obtain groundwater recharge values, while Lubis (2014) defined the groundwater recharge as around 182.5 mm/year. According to Roover (2015), groundwater recharge ranged from 1642.5 mm/year in the south to 255.5 mm/year in the north. Seizarwati et al. (2018) assumed that evapotranspiration (1150 mm/year) was the same in all areas; however, evapotranspiration varies according to rainfall, and, as is well known, the rainfall intensity in southern Jakarta is higher than in northern Jakarta.

Only some researchers referred to conductance. For example, Seizarwati et al. (2018) and de Roover (2015) stated that river conductance in the Jakarta groundwater basin is about 100–700  $\text{m}^2/\text{day}$ , and the depth of the river relative to the surface was  $-5$  to  $-10$  m. However, according to Lubis et al. (2014), river conductance in the Jakarta groundwater basin is around 200  $\text{m}^2/\text{day}$ . Lubis et al. (2014) used this value from calibrated model. de Roover (2015) used this conductance value from the previous study (JWRMS). So, no one author clearly describe the value of river conductance.

Reported rates of extraction via groundwater pumping from the Jakarta groundwater basin vary, and these rates are believed to be far below the actual values due to a large number of illegal, unrecorded groundwater wells. Approximate total abstraction from the Jakarta groundwater basin varies: 50.3 million  $\text{m}^3/\text{year}$  in 1985 (Djaeni 1985; Soefner et al. 1986) and 12.3 million  $\text{m}^3/\text{year}$  in 1992 (Maathuis et al. 1996). Groundwater extraction peaked in 1995 when it reached 35 million  $\text{m}^3/\text{year}$  (Seizarwati et al. 2018). Soetrisno et al. (1997) however said that the deep groundwater abstractions at unregistered wells JWRMS found was too small, and stated that unregistered abstractions in 1995 were at least 1.5 times the registered abstracted

volumes. According to Soetrisno et al. (1997), the real deep groundwater abstraction thus had a multiplier of 2.5, without already taking shallow groundwater abstractions into account. For the abstractions, Roover (2015) used well data from Maathuis et al. (1996) and the BPLHD. For the actual abstracted volumes no multiplier was used. Locations and the abstraction from wells are shown in Fig. 5.

According to Soetrisno et al. (1997), the piezometric level in north Jakarta has fallen from 12.5 m above sea level in 1910 to about 37.4 below sea level in 1970, and it further significantly deepened to 30–50 m below sea level in 1990.

To determine the most influential factors for the restoration of groundwater levels in Jakarta, Seizarwati et al. (2018) presented several numerically simulated groundwater flow scenarios using IMOD software for actual and projected conditions until 2080. The simulations included additional groundwater extraction, a reduction in groundwater extraction, an increase in groundwater recharge capacity, additional groundwater well injection, and a combination of additional injection wells with additional extraction and an increase in recharge capacity. Seizarwati’s (2018) groundwater flow analysis included hydraulic conductivity,

groundwater extraction, and groundwater recharge; boundary conditions; and groundwater level data from throughout the Jakarta groundwater basin. Digital elevation model data, drainage maps, and river properties were categorized as static data. The amount of land uptake; groundwater-surface contours; and the data used to calculate groundwater recharge, including rainfall, land use maps, and population density, were categorized as dynamic data.

Seizarwati (2018) considered the Kh to be the same for all aquifers over three modeled segments: north (1 m/day), middle (1.5 m/day), and south (2 m/day). However, Seizarwati (2018) only included the simulated conditions for aquifer II and tended to ignore other aquifer conditions. Also, the conceptual model was not well developed. Seizarwati (2018) did not describe either the conceptual model in three dimensions or the relationship between the aquifer and the aquitard, including the parameters for each aquifer.

The resolution of Seizarwati’s (2018) groundwater level data was too low, being annual data, because daily groundwater level data is optimum for analyzing groundwater level conditions. Also, Seizarwati’s (2018) groundwater basin boundary conditions were very different from the

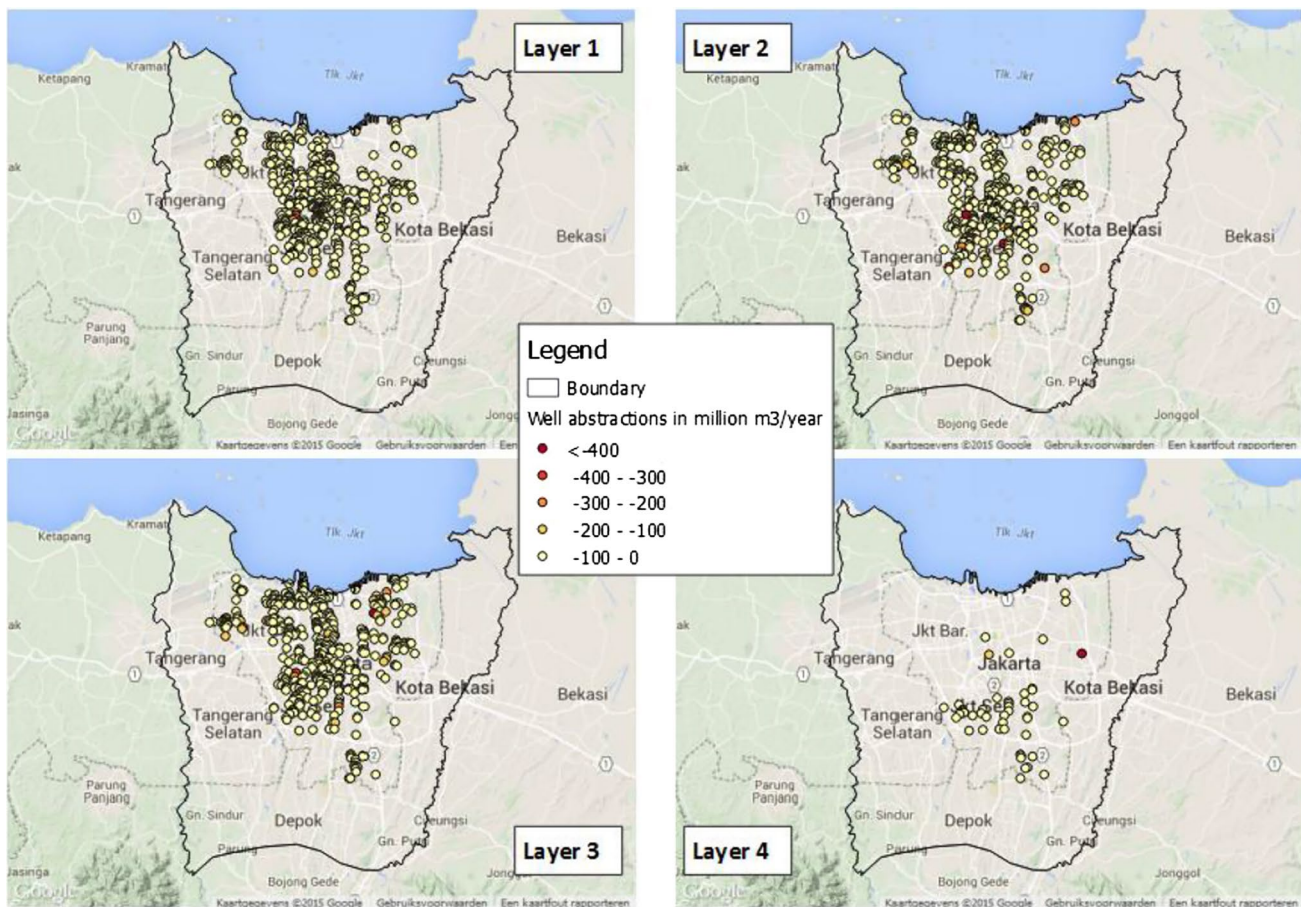


Fig. 5 Abstraction well

actual conditions, and this is important considering that the groundwater basin definition used by the author was very different from the Jakarta groundwater basin boundary in general.

Lubis's (2014) groundwater modeling, using Groundwater Vistas 5.0 software to analyze groundwater level fluctuations in Jakarta, encountered the same problem as Seizarwati (2018); that is, the resolution of the annual groundwater level data was too low. Also, the only aquifer parameter Lubis (2014) described was hydraulic conductivity; the other parameters were not well explained. Because Lubis's (2014) groundwater modeling boundary conditions were not explained in detail, it is difficult to envisage how the modeled groundwater system works.

Setiawan et al. (2016) used spatial processing software to analyze groundwater level information; however, aquifer parameters; boundary conditions; hydrological factors; and quantities, including evaporation, rainfall, and rivers, were not included. Thus, the results are simplified and do not describe the actual groundwater flow conditions. Similarly, Samsuhadi's (2009) model did not reflect the overall groundwater conditions in Jakarta. The model only analyzed two aquifers for the optimization of groundwater utilization, and the parameters and boundary conditions were not well defined. Like previous authors, only annual groundwater level data were used. Herlambang and Indriatmoko's (2005) model, developed with an emphasis on seawater intrusion and groundwater management, only made available aquifer conductivity values for one aquifer:  $K_x$  values for the south, middle, and north. Also, as the groundwater level was not well defined in this study, the resolution of the data could not be properly determined.

Only Roover's (2015) model included a sensitivity analysis, and their comprehensive conceptual model included a description of the inputs and data processing performed. However, this model also encountered the problem of a too-large groundwater level data resolution, and the aquifer parameters used were too general. In addition, there was no formal stratigraphic framework and no precise geotechnical/hydrogeological data 40 m below the surface, uncertainty about well distribution, drawn volumes, and how the subsidence was measured, and the drillers' sediment descriptions were of poor quality. Seizarwati et al (2018) use groundwater level data in 1900 as calibration target in steady state model and used the calibrated steady state model as a based model for transient model (data from 1991–2013). the model only calibrated for aquifer 2 while the conceptual model also include the aquifer 1. the parameter for calibration did not state clearly. Most recently, Wijaya et al. (2019) study modeled saltwater intrusion into coastal aquifers. However, the conceptual model is very simple, which impacted the accuracy of the selection of aquifer values, and almost all the input parameters for the groundwater modeling were derived

from previous research. In this case, the use of inadequate data meant that the model is less than optimum.

## Conclusion

Accurately predicting the future of the Jakarta groundwater basin by obtaining a complete concept requires the building of two- and three-dimensional models. However, to date, researchers modeling the Jakarta groundwater basin have not used well-described conceptual models; they have tended to carry out numerical modeling before obtaining a conceptual model based on actual conditions. Therefore, we suggest that a comprehensive conceptual model of the Jakarta groundwater basin be developed before further numerical analysis is undertaken.

To undertake accurate groundwater quantification of the Jakarta groundwater basin, we suggest the following. We suggest the collection and use of daily groundwater level data to obtain more optimal results. Obtaining pumping data is less of a challenge, although this data is estimated. The availability of aquifer parameter data is also challenging, and many studies have assumed the same  $K_h$  for the whole aquifer, which decreases the accuracy of numerical modeling. Boundary head conditions have not been included in many models, even though they are crucial. Both conceptual and numerical modeling should be improved by accounting for hydrogeological conditions.

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**Author contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Gumilar Utamas Nugraha, Hendra Bakti and Rachmat Fajar Lubis. The first draft of the manuscript was written by Gumilar Utamas Nugraha and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Data availability** Available under request.

## Declarations

**Conflict of interest** The authors declare no conflict of interests.

**Ethical approval** Not applicable.

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.



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