

PAPER • OPEN ACCESS

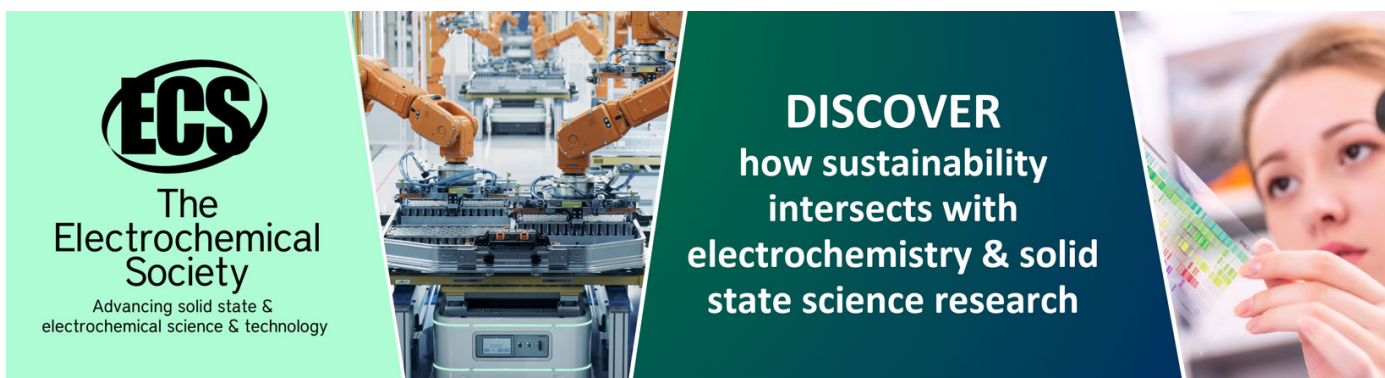
Gravity survey of groundwater characterization at Labuan Basin

To cite this article: L Handayani *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **118** 012015

View the [article online](#) for updates and enhancements.

You may also like

- [Effect of Climate Change on Groundwater Age of Thailand's Lower Chao Phraya Basin](#)
Pinit Tanachaichoksirikun and Uma Seeboonruang
- [Identification of freshwater - saltwater interface in coastal areas using combination of geophysical and geochemical methods: A case study in Mekong Delta, Vietnam](#)
Quang-Khai Ha, Phu Le Vo, Chu-Nam Phan et al.
- [A model comparison assessing the importance of lateral groundwater flows at the global scale](#)
Inge E M de Graaf and Kerstin Stahl



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Gravity survey of groundwater characterization at Labuan Basin

L Handayani¹, D D Wardhana¹, P Hartanto¹, R Delinom¹, Sudaryanto¹, H Bakti¹ and RF Lubis¹

¹ Research Center for Geotechnology, Indonesia Institute of Sciences (LIPI), Bandung 40135

E-mail: lina@geotek.lipi.go.id

Abstract. Labuan groundwater basin currently has an abundance of water. As a deltaic area of Lada Bay, groundwater supply comes from local precipitation and also from recharge region in mountain ranges surrounding. However, Labuan has been experiencing a fast economic development with high population and tourism industry growth. Such progress would lead to the increase of water consumption. A comprehensive groundwater management should be prepared for possible future problems. Therefore, a groundwater investigation is a necessary step towards that purpose. Gravity method was applied to identify the regional condition of the basement. The assessment of deep buried basin and basement relationship using gravity data is a challenge in groundwater investigation, but previous studies had indicated the efficiency of the method to obtain basic information and can be used as a foundation for more advanced studies.

1. Introduction

Labuan Basin is located in Pandeglang Regency in the vicinity of the Special Economic Zone of Tanjung Lesung. This Special Economic Zone (SEZ) was designated for such purposes as increasing trades, investments and new jobs creation. Consequently, a rapid infrastructures development is expected. New hotels, roads, and settlements will be built. Such progress will also lead to rapid population increase. Consequently, groundwater as a basic need will be abstracted more than current practice. Increased uncontrolled groundwater extractions obviously would be the threat. Currently, there is neither decrease in water table depth nor water quality has been reported [1]. But uncharacteristically, decreasing water supply in dry seasons and flooding in rainy seasons occurred in a few areas sporadically [2]. Therefore, a proper management of groundwater-use is necessary to avoid future regrets. For that purpose, more groundwater data is required. The preliminary study required is characterizing the regional groundwater basin. Data of basin properties is essential for more advanced investigations.

There are four groundwater basins within the boundaries of Pandeglang Regency; Rawadanau, Labuan, Serang, and Malingping. We focused in Labuan groundwater basin in Cilemer River watershed. The area is the deltaic region of Lada Bay, from Tarogong – Panimbang – Citeureup (north to south), and from coastline to Saketi-Picung (west to east). The primary purpose of the research is to identify the regional condition of the basement, such as the boundary between the deltaic sedimentary and the volcanic-deposition region. Gravity survey, with its capability in mapping regional distribution of densities, is the right method to investigate such regional basement characterization, which correlates to the groundwater basins in this area.



2. Delta Basin

Some groundwater basins have apparent boundaries, identified by geological deposits of rock strata and geological structures. The condition might also be observable whether aquifers are continuous or not. However, some basins do not have distinctive boundaries. Groundwater basins also might be composed of aquifers at various depths that might be designated as sub-basins if the different supply of groundwater were identified. Two significant concerns with a groundwater basin are the risk of overutilization and contamination. Groundwater does recharge but occasionally, especially in highly populated area, people use water more than the ability of the aquifers to recharge. While climate change might also affect the aquifers (related to recharge), the increased of groundwater abstraction might be the main problem in the near future [3]. For this general case, a comprehensive groundwater basin study is required to observe the possible balance between available water and amount of water utilization.

Groundwater basins in deltas have complicated problems. Deltas are where rivers end their course and meet the sea. As rivers' primary mean is to transfer materials from continent to ocean, deltas are the major reservoirs of sediments, nutrients, and carbons [4]. These surface depositions would affect groundwater, mostly at shallow aquifers. Surface water and groundwater interactions in a delta vary widely depending on the properties of the delta itself [5], but the common problems are pollutant contaminations, saltwater intrusions and fresh groundwater discharges [3–6]. Groundwater contamination occurred when some contaminants spilled in the basin and spread to the aquifers. Information on groundwater basin geometry will be critical due to its relation to the source of the groundwater and the direction of groundwater flow. Since deltas are located at the coast, there are also direct influences from subsidence of lands and uplifts of the sea level. Therefore, a substantial regional analysis of the whole delta is required. Consequently, the very first thing to have is a description of the groundwater basins of the area.

3. Gravity method for groundwater

The term of hydrogeophysics field has been used recently to describe the application of geophysical methods in providing quantitative information about subsurface hydrogeological conditions [7]. Optimal geophysics approaches for mining and oil industries have been achieved through very long operation. There is a relatively good correlation of the geophysical result or model with the subsurface environment. Hydrogeophysics researches have challenges to deal with shallow and less consolidated subsurface environment where the properties contrasts are usually not as apparent as those of deeper subsurface. Furthermore, the relationships that link geophysical attributes to subsurface parameters also vary between different types of subsurface environments [8].

Among all geophysical methods, electrical/resistivity approach is commonly used in characterized local groundwater. However, the gravity method is still the best option for regional basins studies. The gravity method was applied in groundwater exploration in granite rock environments [9]. In that research, residual gravity anomaly data was used to distinguish igneous from weathered rocks, find faulty structures, and identify potential layers as aquifers. The Minnesota Geological Survey had a gravity investigation to map the thickness and potential of groundwater in a sedimentary rock environment [10]. One of the oldest previous gravity survey applications was the groundwater exploration project in the glacier region [11]. They mapped the locations of valleys buried beneath the surface and the depth of bedrock for groundwater sources inventory. There are also several other studies that used a combination of gravity methods and different geophysical methods [12–15]. Overall studies have shown that gravity methods are efficient methods for the scale of regional reviews in groundwater exploration.

Gravity is sensitive to subsurface mass variations, and better improvements in gravity meters allow current investigation in small changes caused by decreasing water within unconfined aquifers [16, 17]. A gravity research in Colorado has indicated that groundwater changes can be detected by gravity

anomaly differences, measured in a same place at two different times. Definite differences correlate with groundwater influx and negative contrasts with the water removal [18]. Continuous monitoring of gravity is also possible and might be a common practice in the near future [16].

Some small variations of hydrological conditions, such as seasonal changes, also influence local gravity field in the order of 10 microgals. Such small gravity fluctuation can be detected by microgravity meters [19–21]. On the other hand, for broader regional groundwater research, gravity data from a satellite called GRACE (Gravity Recovery and Climate Experiment) have been more commonly used. GRACE data can even show dynamic variations in groundwater conditions that changes over time. However, due to its low resolution, this method can only be used for regional scale such as in a continent [22–24].

Based on those previous studies, we applied the conventional gravity method to study the regional groundwater basin in Pandeglang Regency. Bouguer gravity anomaly mapping and its derivatives can illustrate regional subsurface condition, especially the basement configuration and main structures that might directly influence the aquifers distribution.

4. Gravity survey in Labuan Basin

The main feature in this area is the delta of Ciliman-Cibungur Watershed. Geomorphology of the region consists mainly of alluvial plains and slightly undulating hills, surrounded by mountains and inter-mountainous plain. Quaternary sedimentary deposit covered most of the delta area (Figure 1) and a few small parts of the region are covered by some older deposition. A previous geological study had indicated at least three phases of tectonic activities in this area since Late Miocene [25]. Two steps of tectonic uplifts occurred in Miocene – Pliocene, and Plio – Pleistocene. The second phase was also accompanied by volcanic activities of volcanoes around the area (Mt. Gede and Mt. Old Danau). Those events generated a caldera lake, which part of had been covered by Upper Banten Tuff at later Mt. Old Danau's eruption. At the End of Pleistocene, a sea level rise occurred which is indicated by coral limestone overlying volcanic rocks. Those ancient buried calderas might be potential groundwater basins.

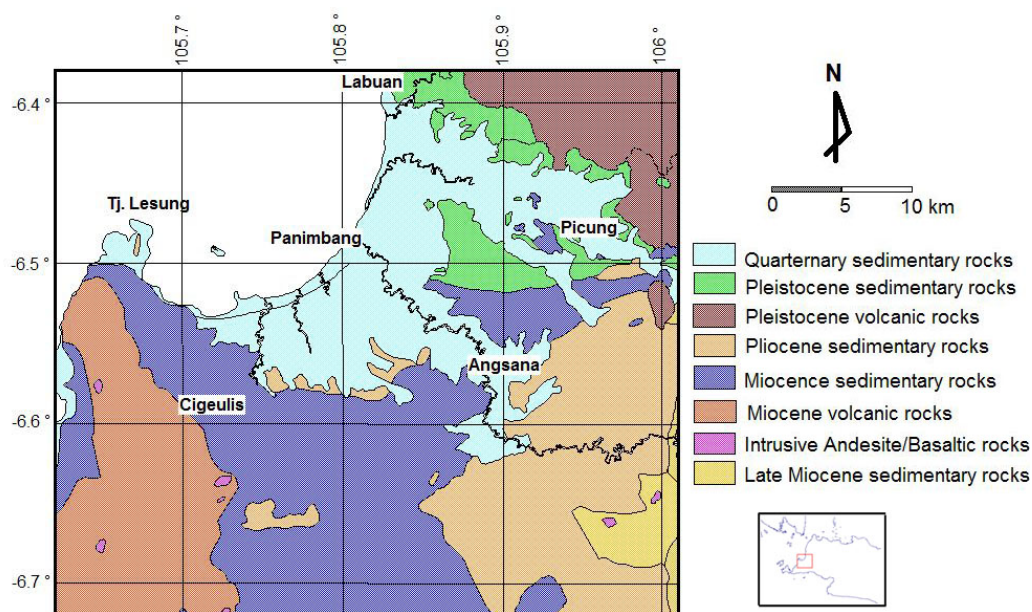


Figure 1. Geological map of Pandeglang, Banten. Modified from [26].

The combination of some stages of uplifts, a sea level rise and current condition in the deltaic plain signify the importance of comprehensive studies of Labuan Basin. For instance, the previous sea level rise might increase the salinity of local groundwater. But there was no indication of such high salinity of local groundwater in this area [1]. One mechanism that might keep salt water away from the sediments is a lateral flush and not vertical rainfall dilution [3, 6]. Therefore, we might expect that the lateral flow of groundwater in this area is rapid enough, without many obstacles, from the mountainous zone to the open sea. To understand the subsurface lateral flow is one of the objectives in mapping the subsurface condition. Regional investigation in basement mapping is the preliminary study before working on smaller areas. For this purpose, gravity method is the right tool to have due to its capability in differentiating subsurface properties in the regional area.

Acknowledgments

We thanked the reviewer and the editor of GCGE2017 for their constructive comments and suggestions.

References

- [1] Sukmawijaya J 2016 *Pengawasan dan evaluasi air tanah di Kabupaten Pandeglang* (Dinas Energi dan Sumber Daya Mineral Provinsi Banten)
- [2] Komarawidjaja W, Tjahjono H, Wibowo K and Samsuhadi 2012 Peran injeksi air secara artifisial dalam upaya pemulihan air tanah di Kabupaten Pandeglang *J. Tek. Lingkung.* **13** 231–237
- [3] Mabrouk M B, Jonoski A, Solomatine D, and Uhlenbrook S 2013 A review of seawater intrusion in Solid the Nile Delta groundwater system – the basis for assessing impacts due to climate changes and water resources development *Hydrol. Earth Syst. Sci. Discuss.* **10** 10873–10911
- [4] Kolker A S, Cable J E, Johannesson K H, Allison M A and Inniss L V 2013 Pathways and processes associated with the transport of groundwater in deltaic systems *J. Hydrol.* **498** 319–334
- [5] Sawyer A H, Edmonds D A, Knights D, Kolker A S, Cable J E, Johannesson K H, Allison M A, Inniss L V, Bethke C M, Johnson T M, Winter T C, Harvey J W, Franke O L, Alley W M, Fan Y, Article R, Fan Y, Gleeson T, Befus K M, Jasechko S, Luijendijk E, Cardenas M B, Vandersteen J, Sophocleous M A, Taniguchi M, Alley W M, Allen D M, and Zhou Y 2015 Pathways and processes associated with the transport of groundwater in deltaic systems *Nat. Publ. Gr.* **3** 319–334
- [6] Gning A A, Orban P, Gesels J, Diop F, Dassargues A, Malou R and Brouyère S 2017 Journal of Hydrology : Regional Studies Factors controlling the evolution of groundwater dynamics and chemistry in the Senegal River Delta *J. Hydrol. Reg. Study* **10** 133–144
- [7] Kirsch R 2009 *Groundwater Geophysics* 2nd ed (Berlin Heidelberg: Springer)
- [8] Rubin Y and Hubbard S S 2005 *Hydrogeophysics* (Netherlands: Springer)
- [9] Murty B V S and Raghavan V K 2002 The gravity method in groundwater exploration in crystalline rocks : a study in the peninsular granitic region of Hyderabad, India *Hydrogeol. J.* **10** 307–321
- [10] Chandler V W 1994 *Gravity investigation for potential groundwater resources in Rock County, Minnesota* (St. Paul)
- [11] Carmichael R S and Henry G J 1977 Gravity exploration for groundwater and bedrock topography in glaciated areas *Geophysics* **42** 850–859
- [12] Selim E S, Abdel-raouf O and Mesalam M 2016 Implementation of magnetic, gravity and resistivity data in identifying groundwater occurrences in El Qaa Plain area, Southern Sinai, Egypt *J. Asian Earth Sci.* **128** 1–26

- [13] Sultan S A, Mohameden I M and Santos F M 2009 Hydrogeophysical study of the El Qaa Plain, Sinai, Egypt *Bull. Eng. Geol. Environ.***68** 525–537
- [14] Santos F A M, Sultan S A and El Sorady A L 2006 Joint inversion of gravity and geoelectrical data for groundwater and structural investigation : application to the northwestern part of Sinai, Egypt *Geophys. J. Int.***165** 705–718
- [15] Van Overmeeren R A 1981 A combination of electrical resistivity, seismic refraction, and gravity measurements for groundwater exploration in Sudan *Geophysics***46** 1304–1313
- [16] Kennedy J, Ferre T P A, Guntner A, Abe M and Creutsfeldt B 2014 Direct measurement of subsurface mass change using the variable baseline gravity gradient method *Geophys. Res. Lett.*, **41** 2827–2834
- [17] Gonzales-Quiros A and Fernandez-Alvarez J P 2014 Simultaneous solving of three-dimensional gravity anomalies caused by pumping tests in unconfined *Math Geosci***46** 649–664
- [18] Gehman C L, Harry D L, Sanford W E, Stednick J D and Beckman N A 2009 Estimating specific yield and storage change in an unconfined aquifer using temporal gravity surveys *Water Resour. Res.***45** 1–16
- [19] Supriyadi, Santoso D, Gunawan W, Sarkowi and Gunawan D 2016 Separation method of anomaly source : The time-lapse microgravity data separation method of anomaly source : The Time-Lapse Microgravity Data *AIP Conf. Proc* **1862** 030162–1 – 030162–5 Soetantri B, Samuel L, Nayoan G A S 1973 *The Geology of Oilfields in North East Java Proc. Int. Conf. on Indonesian Petroleum Association Ann. Conv.* (Jakarta)
- [20] Tanaka T, Miyajima R, Asai H, Horiuchi Y, Kumada K, Asai Y and Ishii H 2013 Hydrological gravity response detection using a gPhone below- and aboveground *Earth Planets Sp.***65** 59–66
- [21] Kang K, Li H, Peng P, Hao H and Wei J Seasonal variations in hydrological influences on gravity measurements using gPhones *Terrestrial Atmos. Ocean. Sci.***22** 157–168
- [22] Chen J, Famiglietti J S, Scanlon B R and Rodell M 2016 Groundwater storage changes: Present status from GRACE Observations *Surv. Geophys.***37** 397–417
- [23] Mohamed A, Sultan M, Ahmed M, Yan E and Ahmed E 2016 Aquifer recharge, depletion, and connectivity : Inferences from GRACE, land surface models, and geochemical and geophysical data,” *Geol. Soc. Am. Bull.***129** 1–13 Soetantri B, Samuel L, Nayoan G A S 1973 *The Geology of Oilfields in North East Java Proc. Int. Conf. on Indonesian Petroleum Association Ann. Conv.* (Jakarta)
- [24] Rodell M, Chen J, Kato H, Famiglietti J S, Nigro J and Wilson C R 2007 Estimating groundwater storage changes in the Mississippi River basin (USA) using GRACE *Hydrogeol. J.***15** 159–166
- [25] Lumban Batu U M and Poedjoprajitno S 2012 Quaternary geological phenomena in Labuhan Area, Pandeglang Regency, Banten Province Fenomena Geologi Kuarter Daerah Labuhan *Indones. J. Geol.***7** 211–226
- [26] Sudana D and Santosa S 1992 *Geological Map of Cikarang, Jawa* (Bandung: Geological Research and Development Center)