Indonesia paleotsunami database: Concept and design

I Ibtihaj, M R Septandy and S Supriyanto
Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok, 16424, Indonesia

Corresponding author’s email: supriyanto@sci.ui.ac.id

Abstract. Indonesia’s tectonic conditions are one of the regions in the world with the most active tectonic activity. As a result of these conditions, Indonesia is prone to earthquakes, tsunamis, and volcanic eruptions. Tsunamis are the most violent movements of ocean waves. The mechanism for tsunamis formation is through processes that generate shock waves, such as underwater earthquakes, underwater landslides, volcanic activity, and asteroid impacts. Indonesia has experienced a series of tsunami events that have caused thousands of casualties. Tsunami events are not fully recorded in human historical records. Unrecorded tsunami or paleotsunami events can be studied through the characteristics of paleotsunami deposits or related archaeological information about tsunamis. Knowing the history of tsunami events is essential to understand tsunami frequency and intensity in the present. This study aims to conceptualize and design a historical database of tsunami occurrences in Indonesia. The database will be based on WebGIS. Tsunami event data is sourced from literature related to tsunami events, such as published books, journals, reports, final projects, and others. The results of database processing are 326 data on tsunami events in Indonesia. The WebGIS is an update for tsunami information media in Indonesia to be more comprehensive and informative.

Keywords: Tsunami, paleotsunami, database, Indonesia, WebGIS

1. Introduction
Indonesia has a very complex plate tectonic condition influenced by large and small lithosphere plates [1]. The plate’s complex tectonic conditions make Indonesia one of the world’s most active tectonic activities [2]. Indonesia is a country at the four main plates, namely Eurasia, Indo-Australia, the Philippines, and the Pacific [3]. As a result of these conditions, Indonesia is prone to earthquakes, tsunamis, and volcanic eruptions.

A tsunami is a wave or a sequence of large waves that occur suddenly due to a displacement or vertically in the water column [4]. The removal of the water column that causes tsunamis can occur through processes that produce shock waves, such as underwater earthquakes, underwater landslides, volcanic activity, and asteroid impacts [5]. Meanwhile, a paleotsunami is a tsunami that occurred before the historical record, or there is no written observation [6].

Indonesia has experienced a series of tsunami events that have caused thousands of casualties, both caused by underwater earthquakes and underwater volcanic eruptions. The danger of a tsunami disaster needs to be studied to study the characteristics of its occurrence based on the history of tsunami events. For most of the tsunami events that have hit Indonesia, the tsunami’s mechanism and character are not well known [2]. Tsunami events are not fully recorded in human historical records. Unrecorded tsunami
or paleotsunami events can be studied through the characteristics of paleotsunami deposits or related archaeological information about tsunamis [7]. Knowing the history of tsunami events is essential to understand the frequency and intensity of tsunamis in the present [8].

The collection of information related to tsunami events and paleotsunami deposits is very important for further research and tsunami disaster mitigation [9]. Tsunami incident data covering Indonesia have been published previously in catalog form including Soloviev and Go (1974), Soloviev et al. (1992), and Iida et al. (1967) [10-12]. The catalog is an international tsunami catalog that records tsunami events in the Pacific Ocean. Information in the catalog is less detailed about tsunami events that have occurred in Indonesia. The data in the catalog is also limited and it does not contain paleotsunami information.

Research that contains information on tsunami events in Indonesia has generally been carried out by BMKG (Geophysical Meteorology and Climatology Agency) and Latief et al. (2000) [2]. The research publications are in the form of the Indonesian Tsunami Catalog by Region 416-2018 [13] and Tsunami Catalogs and Zones in Indonesia [2]. This research is limited to recording tsunami events in Indonesia and only in general. Besides, the catalog is limited to the oldest tsunami event in the year 416. The older tsunami events are not recorded in the catalog. Neither the Indonesian Tsunami Catalog nor the Pacific Tsunami Catalog contains detailed paleotsunami and tsunami events. Besides, because it is in the form of a catalog (book) that is not easily accessible by the public.

Paleotsunami research in Indonesia has been specially developed in Sumatra and Java. These studies were conducted by Amijaya et al. (2008), Monecke (2008), Yudhicara et al. (2013), Putra et al. (2015), Sieh et al. (2015), Putra et al. (2016), Rizal et al. (2017), Rubin et al. (2017), Zaim et al. (2018), Zulkarnain et al. (2017), and Stuart (2018) [14-24]. The publication of the research is proof that there are older tsunami incidents in Indonesia that are not recorded in human history. Paleotsunami data have not been recorded in the tsunami catalog. Tsunami data and paleotsunami deposits in Indonesia have not been integrated into one database.

Research related to tsunami databases was developed by Gusiaiov (2001) [9]. The results of this study are a database of earthquake and tsunami events that have occurred in the Pacific Ocean from the year 47 BC - 2000 AD. The Pacific Tsunami Database records earthquake and tsunami characteristics including geographic location, time of occurrence, and intensity scale of the earthquake and tsunami [9].

This research is limited to only recording the characteristics of tsunamis in general and the tsunami information in Indonesia is not very detailed. The characteristics of paleotsunami are also not recorded in the database. The recorded tsunami events are limited to 2000 AD, more recent events have not been recorded. The database developed by Gusiaiov (2001) is accessed in the form of a website [9]. However, this website is not easily accessible to the public, only certain circles can access it because it is not easy to operate. Thus, the research of the WebGIS Indonesia Paleotsunami Database will be an update to the paleotsunami database that is easily accessible to the public.

Research on tsunamis in Indonesia has not developed an information platform that provides information on all tsunami incidents that have hit Indonesia. Therefore, it is necessary to create a database for the history of tsunami events in Indonesia. The concept of a tsunami event database is expected to be an effort to reduce the risk of a tsunami disaster.

This research will be a novelty in tsunami research in Indonesia. The Indonesia Paleotsunami Database will become a tsunami and paleotsunami data integration platform that provides detailed information about the characteristics of tsunamis and paleotsunami deposits in Indonesia. The existence of WebGIS will help facilitate access to information on tsunami events that have hit Indonesia for further research purposes and to increase public insight into the potential for tsunamis.

The database on the history of tsunami events in Indonesia will be made based on WebGIS. WebGIS is a Geospatial Information System (GIS) that uses the internet network as the primary access to distribute spatial data and information as well as GIS analysis [25]. WebGIS is able to display spatial information widely and easily accessible. The use of WebGIS as a means of spatial data related to disasters can increase public insight and increase efforts to minimize disaster risk. The use of WebGIS was chosen because the general public can easily access this method.
2. Methods

2.1. Data collection and processes
This research focuses on creating the concept and design of the tsunami event database in Indonesia in a WebGIS. The database will contain tsunami and paleotsunami events that have hit Indonesia. The data used are scientific journals, papers, research reports, final projects, or other publications related to the history of the tsunami incident in Indonesia. Historical data on Indonesia's tsunami events can come from valid geoscience, archeology, or folklore perspective. Several global tsunami catalogs that have been published previously are used to trace the tsunami trail in Indonesia. These catalogs include Soloviev et al. (1974), Soloviev et al. (1992), Iida et al. (1967), Latief et al. (2000), and BMKG (2019) [2, 10-13]. However, in the catalog, not fully recorded tsunami characteristics, especially paleotsunami traces, were not recorded. So that the collection of paleotsunami information requires more specific literature sources researching paleotsunami. Tsunami event data that has been collected will be processed to be presented in WebGIS. Data processing consists of database processing using Microsoft Excel, ArcGIS Desktop processing with ArcGIS 10.3, and WebGIS processing using ArcGIS Online.

Microsoft Excel is used to process the tsunami data matrix from various literature. All data on tsunami and paleotsunami events in Indonesia are matriculated. This matrix becomes the metadata in the database before it is displayed in WebGIS. This processing is done to facilitate the creation of shapefiles (.shp) in ArcGIS 10.3 and layer processing in WebGIS creation.

ArcGIS 10.3 software is used to process the tsunami event database into shapefiles data. The historical data of the tsunami event will be shapefiles in the form of a point that indicates that a tsunami has occurred at that point. Also, the shapefiles will contain important data about the history of tsunami events at that location.

WebGIS technology is a development of GIS (Geographic Information System) which is integrated with the internet network. WebGIS uses website technologies such as Hypertext Transfer Protocol (HTTP), Hypertext Markup Language (HTML), Uniform Resource Locator (URL), JavaScript, Web Graphics Library (WebGL), WebSocket, and others [26]. Making WebGIS in this study using the ArcGIS Online platform. The data that has been processed on ArcGIS Desktop will be further processed using ArcGIS Online to be presented in the form of WebGIS. WebGIS will present important information content related to tsunamis and paleotsunami in Indonesia. Using the ArcGIS Online data processing platform for website creation, you do not need to process a programming language separately because it is integrated into one platform [27]. So that it will simplify and speed up the creation of WebGIS. Besides, the processing results from ArcGIS Online can be immediately launched and accessed by the public using a browser and the internet.

2.2. Framework and attributes
The tsunami occurrence database in Indonesia uses several attributes to clarify the occurrence of a tsunami. The features used are the most critical and essential attributes to know about the characteristics of a tsunami event. The concept of this database can be useful and informative in understanding the history of tsunami events in Indonesia. The framework and attributes in this database refer to Goff (2008) [28]. A more detailed explanation of the features used is as follows:

1. Province
   - Provincial administrative information where the tsunami occurred
2. Location of the tsunami event
   - More specific information about the tsunami event can be the name of the area, village, sub-district, or district/city
3. The coordinates of the tsunami / paleotsunami point,
   - The latitude and longitude of the tsunami event location, or the location of the paleotsunami deposit
4. Location status
   A statement regarding the presence of physical evidence at the site in the form of deposits.
   Divided into two, namely found deposits and unknown deposits
5. Physical characteristics
   Brief description of the characteristics of the deposit or tsunami event
6. Data Classification
   Data were classified according to time of occurrence. The tsunami event data in this database is
   divided into two-time categories:
   - Historical          tsunami events in 1800 – now
   - Prehistorical      events for tsunamis in < 1800
7. Time of occurrence
   Information on the date, month, and year of the tsunami event
8. Validity
   Validity states the level of accuracy of tsunami event data. The determination of validity is based
   on the number of proxies used to identify tsunami events. Validity is divided into
   - Excellent           proxies used 9 or more
   - Moderate           proxies used 5–8
   - Poor                   proxies used 1–4
9. Nature of evidence
   Evidence in nature falls into two categories: primary and secondary. Primary data is in the form
   of deposits based either on geological evidence or archaeological evidence. Secondary
   information is in the form of historical records or knowledge related to tsunami events.
10. Description of Nature of evidence
    A description of the evidence in nature used. Divided into Sedimentology/Artifacts,
    Geomorphology, anthropology (interviews), or proof in nature as limited as historical records
11. Dating method
    The determining the age of the tsunami event is based on the data used, namely geology,
    archeology, and history.
12. Dating technique
    Age determination based on geological data is divided into stratigraphic and absolute dating
    (radioactive decay). The age determination uses archaeological data based on the age of the
    artifacts found. Meanwhile, historical age determination refers to the time recorded in history
13. Elevation
    Height of tsunami waves
14. Landward limit
    Inundation data for tsunamis reaching land
15. Deposit thickness
    Data thickness of the deposit
16. Source cause
    Information the causes of the tsunami
17. Source location
    Information the location of the source that caused the tsunami
18. Proxies
    The criteria used to identify paleotsunami deposits
19. References
    List of references used as a source of information on tsunami event data

Frameworks and attributes will be parameter data regarding important tsunami characteristics that
need to be recorded in the database. The literature collection that becomes the metadata in this study
will be matriculated based on the frameworks and attributes. The use of these frameworks and attributes
aims to strengthen the argument for evidence of tsunami occurrence and that the characteristics of the
tsunami can be well described [28]. The results of database matriculation using Microsoft Excel are shown in figure 1.

3. Results and discussion

3.1. Indonesia paleotsunami database

Tsunami event data that has been collected amounted to 326 data. The oldest recorded tsunami events are paleotsunami deposits thought to be Late Miocene based on the foraminifera fossils contained [23]. Meanwhile, the most recent incident was the tsunami in 2018 which hit Lombok, West Nusa Tenggara and Palu, Central Sulawesi [29-33].

Based on the database of tsunami events collected, almost all coastal areas in Indonesia have experienced a tsunami. This strengthens from a historical perspective that Indonesia has the potential for a tsunami because, in the past, the tsunami had hit Indonesia. Database view in WebGIS is presented in figure 2.

This database will be a useful information tool to facilitate anyone wishing to access tsunami information in Indonesia. The data in this database will continue to be updated along with research on tsunamis and paleotsunamis in Indonesia to improve data quality, delete erroneous data and add the new data.

3.2. WebGIS design

The WebGIS Indonesia Paleotsunami Database is designed to be exciting and informative. An attractive WebGIS design aims to ensure that those who access WebGIS do not feel bored when reading tsunami-related information. The informative design seeks to make it easier for anyone who accesses this website to understand information about the tsunami that has hit Indonesia easily. The interface display of WebGIS is presented in figure 3.

Figure 1. Database matriculation result
Figure 2. Database design view in WebGIS

Figure 3. WebGIS design interface
This design from WebGIS has several features that can be viewed and can be downloaded. WebGIS displays will present data on tsunami events in Indonesia. The data presented can be selected based on the data category to be displayed. The data categories that can be selected for presentation are the "All Tsunami Events" Layer, by "Classification", or by "Validity". This option can be made by clicking the menu in the upper right corner of WebGIS. The layer display that you want to display is presented in figure 4.

Another feature of WebGIS is that it can find out in detail the characteristics of a tsunami. When tsunami event data appears in WebGIS, viewers can find out detailed information about the tsunami attributes by clicking on the tsunami data located (figure 5). This detailed information is the main framework and features for tsunami characteristics.

Access to WebGIS is designed to be easily accessible. WebGIS can be accessed using computers, laptops, smartphones, and tablets only through a browser and internet connection. Besides, all the data contained in WebGIS can be downloaded easily and for free.

![Figure 4. Data layer on WebGIS](image1)

![Figure 5. WebGIS design of detailed information](image2)
The WebGIS generated from this study has a user-friendly interface. The use of the internet as the main access network makes it easy to access WebGIS by mobile anywhere and anytime [27]. WebGIS has a more modern appearance and digital form, so there is no need to save it as a file. The WebGIS Indonesia Paleotsunami Database is an update for tsunami information media in Indonesia to be more comprehensive and informative, which was previously only a note in the catalog.

The occurrence of a tsunami so far has not been able to predict accurately. However, the tsunami incident in Indonesia is a natural phenomenon that has the potential to occur. Studying past tsunami events that have occurred can help understand tsunamis characteristics in Indonesia [23]. It is hoped that this WebGIS will become a facility for anyone to get information on tsunami characteristics for both research and learning purposes. Also, it is expected that it can increase public awareness of the potential for tsunamis in Indonesia.

4. Conclusion
Data on tsunami events are spread across almost the entire coast of Indonesia, indicating that Indonesia's historical tsunamis have occurred. The Indonesia Paleotsunami database consists of 326 data. The oldest tsunami event is a paleotsunami deposit thought to be Late Miocene. The most recent event is the tsunami in 2018 which struck Lombok, West Nusa Tenggara, and Palu, Central Sulawesi. The data in this database will continue to be updated as the tsunami research progresses. The study of paleotsunami in Indonesia needs to be further developed. Increased research on paleotsunami will improve the quality of the data in this database. The WebGIS Indonesia Paleotsunami Database is an update for tsunami information media in Indonesia to be more comprehensive and informative, which was previously only a note in the catalogue. The concept and design of this WebGIS is an effort to facilitate and educate the public about tsunamis in Indonesia so that there will be increased awareness of the potential for a tsunami disaster.

Acknowledgments
The authors would like to thank Geoscience Study Program (Geology and Geophysics), Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia for supporting this research. This research was funded by Basic Research for Higher Education Grant, Ministry of Research and Technology, Republic of Indonesia.

References
[1] Abdalla R and Esmail M 2019 WebGIS for Disaster Management and Emergency Response (Switzerland: Springer)
[2] Amijaya D H and Sarju W 2008 Media Teknik 2 109-112
[3] BMKG 2019 Katalog Tsunami Indonesia Per-Wilayah Tahun 416-2018 available at https://cdn.bmkg.go.id/Web/Katalog-Tsunami-Indonesia-pertahun-416-2018.pdf
[4] Bryant E 2008 Tsunami the Underrated Hazard (Berlin: Springer-Verlag)
[5] Dunbar P and McCullough H 2012 Natur. Hazard. 63 267-78
[6] Harder C and Brown C 2017 The ArcGIS Book (New York: Esri Press)
[7] Kong N 2018 Catogr. J. 54 188-9
[8] Goff J R 2008 The New Zealand Palaeotsunami Database (Wellington: NIWA)
[9] Goff J, Chagué-Goff C, Nichol S, Jaffe B and Dominey-Howes D 2012 Sediment. Geol. 243-244 70-88
[10] Gusiaiov V K 2001 ITS 2001 Proceedings 1 263-272
[11] Hamilton W B 1979 Tectonics of the Indonesian Region (United States: U.S. Govt. Print. Off.)
[12] Iida K, Cox D C and Pararas-Carayannis G 1967 Preliminary Catalog of Tsunamis Occurring in the Pacific Ocean (Hawaii: Hawaii Institute of Geophysics)
[13] ITIC 2019 Tsunami Glossary available at http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=1064&Itemid=1142&lang=en
[14] Latief H, Nanang T P and Fumihiko I 2000 J. Nat. Disaster Sci. 22 25-43
[15] Monecke K et al. 2008 Nature 455 1232-4
[16] BNPB 2018 Rencana Nasional Penanggulangan Bencana 2015-2019 available at https://www.bnpb.go.id//uploads/renas/1/BUKU RENAS PB.pdf
[17] Omira R et al. 2019 Pure Appl. Geophys. 176 1379-95
[18] Putra P S et al. 2019 Pure Appl. Geophys. 176 2203-13
[19] Putra P S, Aswan A, Maryunani K A, Yulianto E, Nugroho S H and Setiawan V 2020 Pure Appl. Geophys. 177 2479-92
[20] Putra, P. S., Praptisih, Nugroho, S. H and Supriyatna N 2018 Data Ancaman Gempa dan Tsunami Megathrust Selatan Jawa Laporan Penelitian Sub Kegiatan: Penilaian Risiko Bencana
[21] Putra P S, Supartooyo and Praja N K 2016 Prosiding Geotek Expo Puslit Geoteknologi LIPI (Bandung) (Bandung: LIPI), pp 978-9
[22] Putra, P. S., Yulianto, E., Praptisih, Supriyatna, N., Trisukmono, D., Amar, Nurhidayati, A. U., Ridwan, J and Griffin J 2015 Paleotsunami Study in the South Coast of Jawa Prosiding Pentaparan Hasil Penelitian 95–102
[23] Rizal Y et al. 2017 IOP Conf. Ser.: Earth Environ. Sci. 71 012001
[24] Rubin C M, Horton B P, Sieh K, Pilarczyk J E, Daly P, Ismail N and Parnell A C 2017 Nat. Commun. 8 16019
[25] Shiki T, Tsuji Y, Minoura K and Yamazaki T 2008 Tsunamiites - Features and Implications (Amsterdam: Elsevier)
[26] Sieh K et al. 2015 J. Geophys. Res. Solid Earth 120 308-25
[27] Soloviev S L and Go C N 1974 A Catalogue of Tsunamis on the Western Shore of the Pacific Ocean (Moscow: Nauka Publishing House)
[28] Soloviev S L, Go C N and Kim K S 1992 Catalog of Tsunamis in The Pacific 1969-1982 (Moskwa: Soviet Geophysical Committee)
[29] Stuart K L 2018 Discovery of Possible Paleotsunami Deposits in Pangandaran and Adipala, Java, Indonesia Using Grain Size, XRD, and 14C Analyses (Provo: Brigham Young University)
[30] Tsimopoulou V, Micikami T, Hossein T T, Takagi H, Esteban M and Utama N A 2020 Natur. Hazards 103 2047-70
[31] Yudhicara Y, Zaim Y, Rizal Y, Aswan A, Triyono R, Setiyono U and Hartanto D 2013 Indones. J. Geosci. 8 163-75
[32] Zaim Y et al. 2018 Jejak Tsunami Masa Lalu diantara Pangandaran dan Cilacap (Jakarta: Pusat Gempabumi dan Tsunami Kedeputian Bidang Geofisika BMKG
[33] Zulkarnain D A, Amijaya H and Yulianto E 2017 Proceeding, Seminar Nasional Kebumian Ke-10 (Yogyakarta) (Yogyakarta: Universitas Gadjah Mada), pp 1625-36