The Rawa Besar Lake Area (Depok, Indonesia) Study Using Ground Penetrating Radar*

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Search and Discovery Article #80291 (2013)
Posted June 21, 2013

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013,

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Abstract

We performed a GPR study on the Rawa Besar Lake area during summer of 2012. The GPR study was aimed at imaging the lake bottom and shallow sedimentary layers to obtain the water volume of Rawa Besar Lake, which could be estimated by depth and area. The water of the Rawa Besar Lake strongly attenuates radar waves. More than 5 km of radar profiles were obtained in the lake, using GSSI SIR-2000 GPR system with 70 MHz monostatic antennas. Electronics and antennas were placed in a fiberglass boat, and traverses followed ropes. We did the survey in a west-east direction, using continuous profiling techniques. Integrated acoustic and GPR techniques were used in the shallow eastern sector. The GPR profiles processed to date successfully image discontinuities at depths greater than 1000 cm. Comparison with pendulum results show that GPR provides high-resolution images of the depth range of interest (0-800 cm) which complement the information obtained from sub-bottom profilers. A deep (1000 cm) flat sub-horizontal reflector, shallow (0-500 cm) dipping layers, sigmoidal structures and local chaotic lenses are the primary features imaged by GPR in the lake.

Jakarta, the capital city of Indonesia, has many serious problems. Water flooding is one of serious natural hazards that have to be faced every year. The runoff water after heavy rain in Bogor, the higher area located in southern part of Jakarta, could arrive in Jakarta after 7-10 hours. The water runoff flowing through some rivers also passes through some lakes. That is why knowing volume of water of a lake is needed for analyzing the possibility of water flooding in Jakarta. Depok, the small city between Bogor and Jakarta, should be a buffer area of the capital city of Jakarta that has been unable to become an ideal watershed. By such rapid development processes in the region, qualitatively it can be determined that only 35% of the total area in Depok can be water catchment areas. 35% of the catchment area has an important role in inhibiting the flow of water to Jakarta caused by rain that occurred in the area of Depok. Generally, it has a very important function as a supplier of water to the aquifer and is used as a groundwater recharge area, flood absorber, preventing sea water intrution, improving the quality of surface water through a chemical process, arranging the micro climate, being a marine biodiversity advocate, etc.

However, the local government in Depok, the small city between Bogor and Jakarta, still does not have accurate information about water volume that is stored in some lakes in their area. For this reason, we have performed this geophysical survey using georadar methods to monitor the bottom of Rawa Besar Lake, which is located in Depok. A GPR survey was carried out in Rawa Besar Lake Indonesia in April 2012 by a research unit of the geophysics students of the University of Indonesia in the framework of a scientific cooperation program with the Indonesia National College Departments. By drawing attention to these methodological issues, it is anticipated that the quality of future GPR studies can be improved in order to aid both interpretation and comparison between datasets.

The Rawa Besar Lake is the largest lake in Depok City Center, originating from Bogor Rivers and Lakes, and flowing into Jakarta, which has low topography. The study area is close to residential areas, which has coordinates 6°23'39"S and 106°48'58"E. In the connection with the use of landscape changes in Depok, it is questionable whether it can still fulfill its function or not. Therefore, it is necessary to make an assessment in the area of Depok. The assessment includes the number, size, and quality of lakes. It is a necessary part of a solution, such that the water cycle as the main support of human life can be maintained. In most of the polluted water, sedimentation and mineral enrichment (eutrophication) occurs so that weeds flourish. In some areas, the water overflows into the settlement during the rainy season. There are those who doubt the sincerity of government (at all levels) to preserve existing functions in the region of Depok. To address the problem, we conducted this study to measure the area and depth of the lake, using georadar methods. The results of this study will be important information for policy makers, particularly regarding the maintenance of the lakes in Depok.

Field Methodology

Consideration of several factors is essential when designing a survey program. Many types of commercially available GPR systems can be used for data collection. One is GPR GSSI SIR 2000, which is made in the USA. We used it for detecting the bedrock and determining the volume of Rawa Besar Lake. GPR systems consist of an antenna to transmit and receive signals, and a control unit to process signals, store, and display data. In this method, the antenna transmits pulse electromagnetic with frequency of 70 MHz into the ground across the water. Some of which are scattered and absorbed in the earth material, and some of which are reflected back to the receiver antenna. When the radiated energy encounters inhomogenities in electrical properties of the subsurface, some energy is reflected back to the radar antenna (receiver antenna) and some is transmitted downward to deeper material. So, this reflection or scattering of energy is caused by a contrast in the dielectric properties of material. The record shows the total travel time for the signal to pass through the subsurface, reflect from inhomogenities, and return to the surface. This two-way travel time (TWT) is measured in nanoseconds. The method of signal processing depends on object type, which will detect depth of the object and dielectric properties of materials.

A GPR system with a 70 MHz frequency antennae and monostatic configuration was used to profile the depth of bedrock in this study. In the Rawa Besar Lake, the antennae was held by the crew and floated in the water. GPR data were collected by following a rope along linear profiles across the lake while piloting the boat. Data were digitally collected at a continuous rate at as constant a rate of boat speed as possible. The lower the frequency of the antennae the poorer the resolution but the greater the depth of penetration (e.g. Davis and Annan 1989; Jol, 1995). The use of different frequency antennae can often aid data interpretation by allowing a range in the scale of features to be imaged. The field methodology applied when collecting data in the Rawa Besar Lake is given in Table 1.

Processing Methodology

Before interpreting geophysical data, data processing should be done first so that data quality has a physical meaning or significance in accordance with the conditions of the field. Performing data processing means to clarify the quality of the data, by increasing the value of its signal-to-noise ratio. Each data has different characteristics, so the processing is done in different processes and adapted well to the needs of the data. The first thing to be done in the processing of the data is to change from time domain into the depth domain by the following relationship:

$$v = \frac{c}{\varepsilon_r} \qquad (1)$$

v = velocity of waves propagating into the ground (m/s)

c = velocity of light (m/s)

ε_r = dielectric constant

Radar wave velocity is affected by the dielectric constant of the medium, or in this case a layer of sediment. If a layer has a high dielectric constant, the speed of the radio waves will decrease and vice versa. The value of the dielectric constant can be obtained from measurements of CMP (Common Mid Point) field. Dielectric constant values used in this case derived from the results of previous research literature, which is equal to 78.54.

Gain

During acquisition, GPR are set to the default gain setting. We need to remove the default setting to see the real data. After removing the default gain setting, we need to set it manually, depending on the anomaly appearance. Along with increasing time and depth, we set the gain to the higher value so it can be easier to see the data at greater depth.

Subtract DC Shift

Subtracting DC shift has the function of returning the signal to a position that is supposed to be at the center (and not deviated downward or upward), so that the signal will be perfectly sinusoidal. Sometimes the DC offset can be small and insignificant, however it can mask small reflections if one is using narrow palettes in the B-Scan display. A clear sign of the presence of DC offsets is when the general background in otherwise clean data is not the same color as the central color in you palette.

Dewow Filtering

Dewow filtering is the process of removing components of Very Low Frequency (VLF). GPR data often have a low frequency noise component in the trace (< 1 MHz) that obscures real data at higher frequencies (Hatton et al., 1986). The low frequency noise is a result of saturation of the electronics from the large amplitude of the air wave and the direct wave that travels along the ground or interface (Daniels et al., 1988). In the area close to the transmitter, measurement of energy is associated with the low frequency with the inductive and electrostatic area. These VLF component variations often result in a slowing down of the recorded data. This energy causes a rise or fall in the level of base frequencies recorded by the signal (noise). This effect is known as the baseline "wow" in the GPR readings. Wow signal can be suppressed by applying a high-temporal filter on the signal loss detected and the process is known as dewow.

Band Pass Filtering

This process is carried out to refine the signal which is weak or strong. In this process there are four kinds of filters: the low cutoff, lower plateau, upper plateau, and the upper cutoff. The lower cutoff used to eliminate or cut low frequencies. Frequency of the lower value plateau and lower cutoff frequency values are weakened. Frequency of the lower value plateau and upper plateau is the value of the frequency used. The frequency value of the upper plateau and upper cutoff is the value of high frequency attenuated. For the upper cutoff, the high frequency value is cut off and not used. The frequency gates chosen for the Rawa Besar Lake were about 50 MHz. These values were chosen after repetitive trials with different filter parameters.

Background Removal

Background noise is a repetitive signal created by slight ringing in the antennae, which produces a coherent banding effect, parallel to the surface wave, accros the section (Shih and Doolittle, 1984; Goodman, 1994; Stenberg and McGill, 1995; Conyers and Goodman, 1997). To solve this problem, we use background removal. Care must be taken in this process not to remove real linear events in the profile. The time window where the filter operates must, therefore, be specified so that the filter is not applied until after the surface wave.

Static Correction

The static correction process is used to eliminate the effect of direct wave and to make the data on the actual height. In this process, we first determine which area is declared as the starting point in the air and which ones should be eliminated by showing the wiggle window.

Interpretation

To enhance interpretation of the subsurface stratigraphy, ground-truth control is required which can be obtained from trenching following the GPR survey (e.g. Taylor and Macklin, 1997; van Dam et al., see p. 257), coring (e.g. Bridge et al., 1998; Vandenberghe and van Overmeeren, 1999), cut-face experiments (e.g. Liner and Liner, 1995; Asprion and Aigner, 1997; Vandenberghe and van Overmeeren, 1999; van Dam and Schlanger, 2000; Kowalsky et al., 2001), or comparison with output by other independent geophysical techniques (e.g. Camerlynck et al., 1994;

Smith et al., 2002). In this study we only use the result from pendulum to aid GPR data. A 70 MHz frequency GPR profile was collected along an 8 m line. The depth of the lake is known by the first horizontal flat in GPR data.

After calculating with integral approaching method, the area of the Rawa Besar Lake is found, and the value is about 147,336.64 m^2, which is different from the government's data of 130,400 m^2. So by further calculation we obtained the volume of the Rawa Besar Lake, which is about 1,473,366.4 m^3. The data shows that there is a slope at the edge which continues to fall constantly to the center. If the interval is added with the time domain, it shows continuity. However, it will result in poor resolution.

Siltation in the lake is the result of sedimentation into the lake, which is caused by the accumulation of a variety of waste material such as trash, located around the lake. The primary features of the data show local chaotic lenses and sigmoidal structures, and at depths of 1.8 m to 4 m there are dipping layers, caused by sedimentation, and also seen is a flat horizontal reflector at depth 2.3 m.

Conclusions

Jakarta, the capital city of Indonesia, is located relatively lower than other cities in Java. The form is like a basin which has decreased each year, so it is particularly vulnerable to flooding when rainfall is high. In addition, while Depok City should be a buffer area of the flow of water from Bogor to Jakarta, it is not functioning properly as such due to lack of water catchment areas caused by the rampant, poorly controlled development. In addition, a significant shallowing in water catchment areas, such as lakes, caused by the sedimentation process for residual material that cannot be managed well by the people who live around the lake. Therefore, sedimentation must be minimized by changing the culture of the community, especially those living around the lake by less littering of garbage into the lake. From GPR data we can see clearly the anomaly appears at depths of 1.8 m to 4 m.

Acknowledgements

I would like to express my thanks to Dr. Eng. Supriyanto M.Sc. as my lecturer for his support and assistance, and also for his gratefully acknowledged useful comments and stimulating participation in field work.

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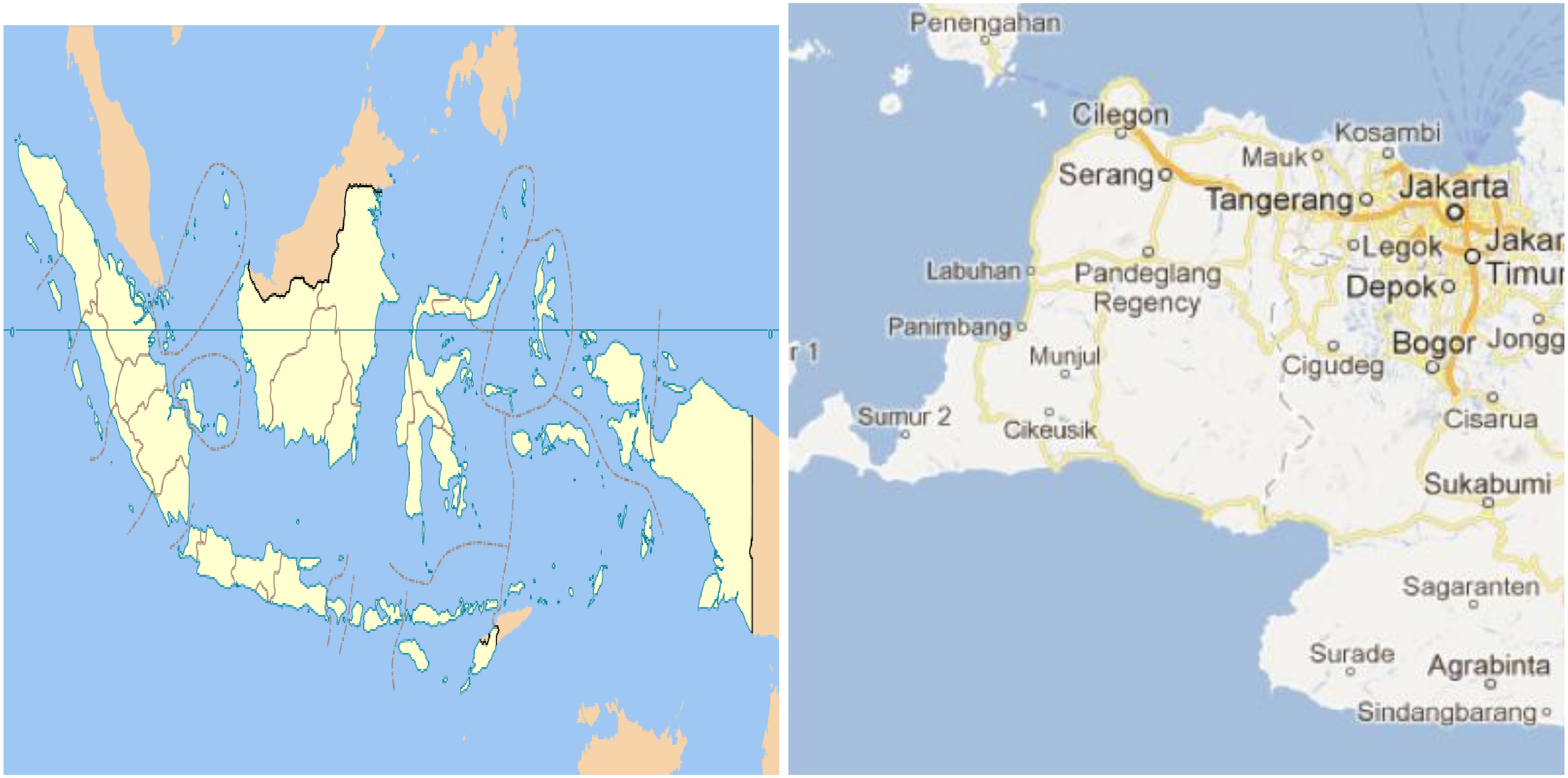

(a) (b)

Figure 1. Location of the Rawa Besar Lake, Indonesia (a) at scale 1:1000, and (b) at scale 1:50.

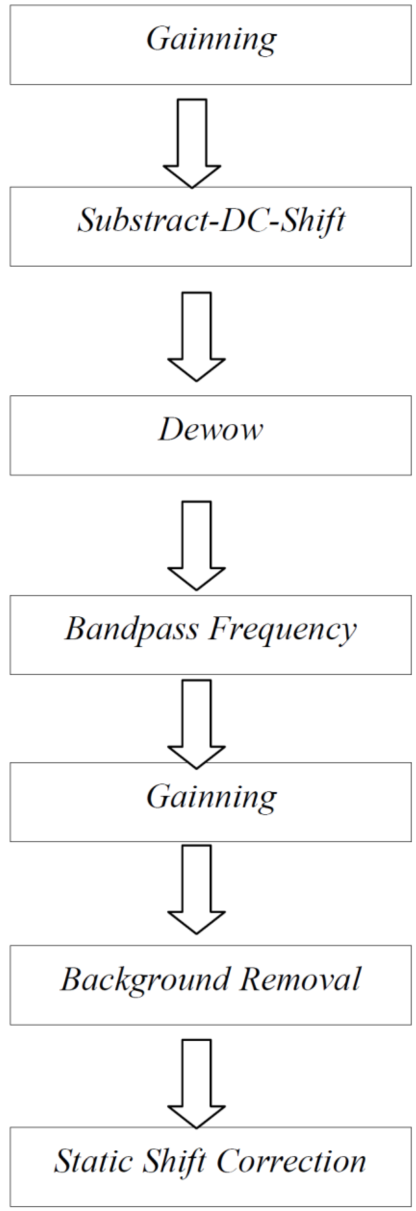

Figure 2. Processing sequence for GPR data.

Figure 3. Acquisition process on the fiber boat by following the rope.

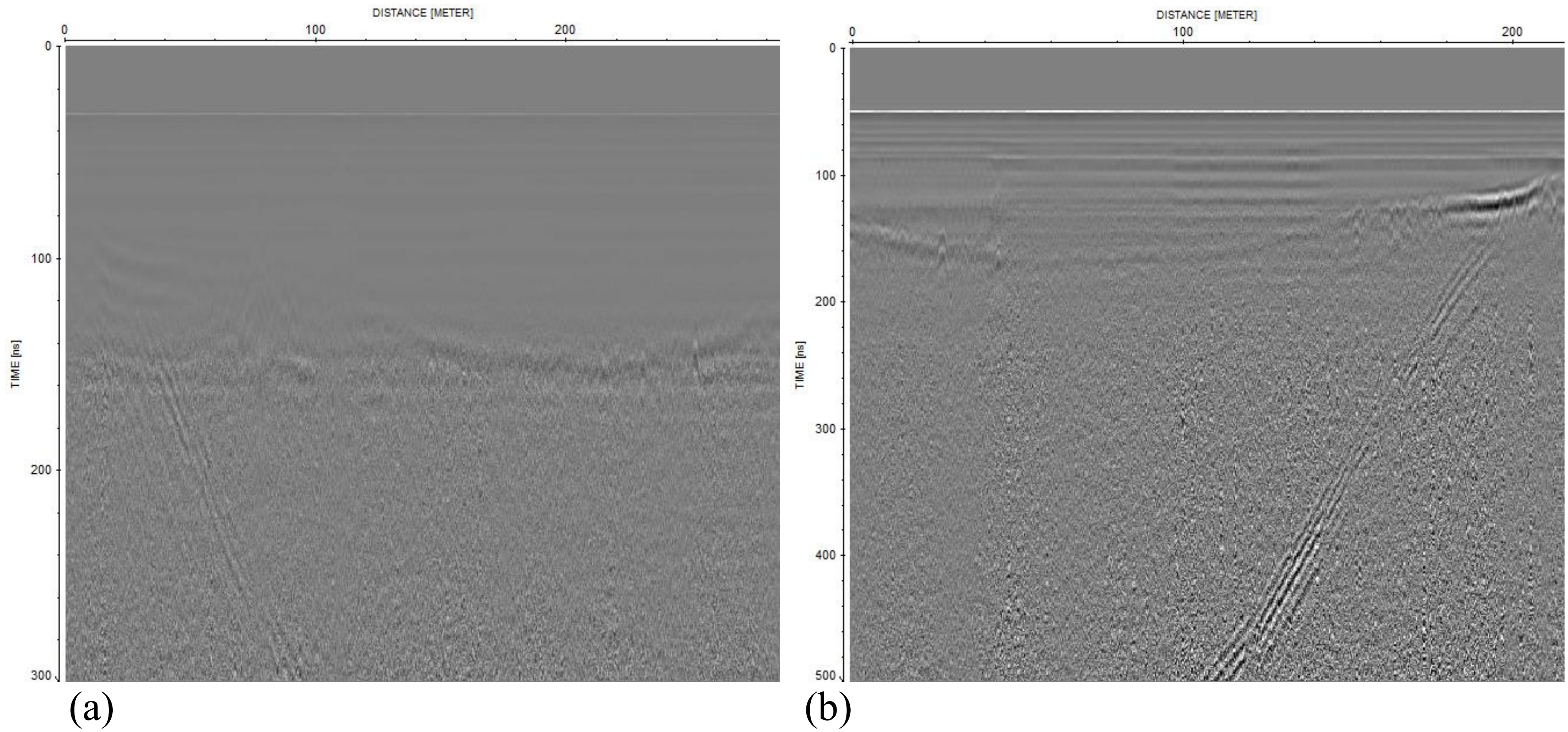

Figure 4. Before data processing (a) File_023, and (b) File_024.

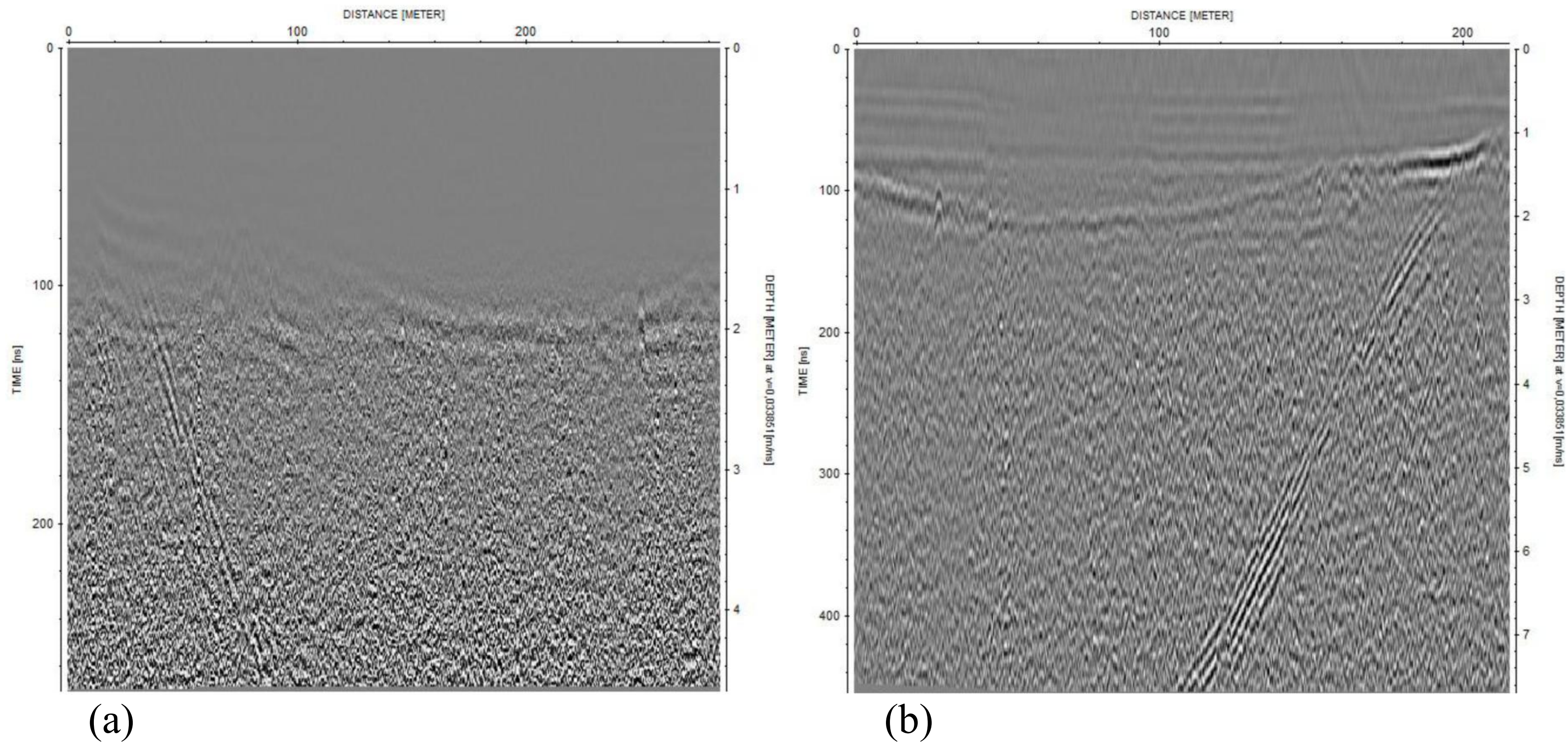

Figure 5. After data processing (a) File_023, and (b) File_024.

Line	File_023	File_024
Direction	West - East	East - West
GPR Unit	GSSI SIR 2000	GSSI SIR 2000
Configuration	Monostatic	Monostatic
Antennae frequency (MHz)	70 MHz	70 MHz
Station spacing (m)	0	0
Mode of data collection	Continue	Continue

Table 1. Details of collection parameters and processing steps for all GPR profiles.