‘Geophysics to enhance agricultural productivity and livelihoods of smallholder farmers through improved groundwater management of the Vientiane Plain, Lao PDR’

Final Report

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Project partners
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1 Abstract

Lao PDR is a poorly developed country with a large rural population, which relies heavily on agricultural production systems. Part of Lao PDR experiences prolonged dry seasons with pronounced and common water scarcity, which is increasingly met with supplies from groundwater. As groundwater management is still at a very basic level and perhaps the single most important constraint to progress, this project’s goal was to build human and institutional capacity in-country and resilience in agricultural productivity through sustainable use of groundwater for local farmers on the Vientiane Plain, Lao PDR. Hydrogeophysical techniques have been used to identify and characterize the hydrogeology and determine the quantity and quality of groundwater over a cross-section of the Vientiane Plain that best represents the variable terrain, main geology types and previously identified areas for irrigated agricultural development. The project collaboration has built and strengthened capacity within stakeholders from government, university and the community. It has developed and progressed the hydrogeological field mapping and provided local undergraduate and postgraduate training opportunities using several different geophysical techniques. This project has contributed to the development of hydrogeological maps and delineation of good and poor-quality water to lower the risk of well failure and groundwater contamination on the Vientiane Plain. It has assisted local community members, farmers and government in their efforts to expand groundwater development for agricultural production and strengthened therefore the resilience of agriculture to climatic uncertainties. The hydrogeological knowledge gained, training and engagements greatly benefit rural livelihood enhancement through the sustainable use of groundwater and addressed some of the perceptions about groundwater as a reliable, safe and secure resource. This project has been a great steppingstone for further intensified engagement and collaboration of the project partners in enhancing the utility of groundwater for agricultural development.

2 Background Information

2.1 Project goals

The general aim of the project was to provide much needed new knowledge and skills that will serve to improve groundwater management in the Vientiane Plain. As such, the project enables the wellbeing and livelihoods of smallholder farmers and the wider community to be improved through sustainable access to groundwater resources. The development of appropriate tools and management plans will assist:

- in evaluating the potential impacts of groundwater development on surface water systems;
- in examining risks of over-pumping and pollution of the resource;
- in developing improved capacity amongst the local communities and authorities that plan, develop and manage the resource.

Socio-economic constraints such as the costs of groundwater infrastructure, labor availability and how groundwater irrigation is perceived by farmers as compared to other livelihood earning strategies are some of the main limitations for developing groundwater for agricultural irrigation (ACIAR, 2016).
Foremost, this project collaboration aimed to strengthen capacity within the in-country Laos project partners, team members and other stakeholders from the community, government, university and private sector. Human and institutional capacity in Laos in hydrogeology and groundwater management is at an extremely low level and perhaps the single most important constraint to progress (Pavelic et al., 2014). The project design facilitated several opportunities to develop and progress hydrogeological field mapping and provide in-country undergraduate and postgraduate training opportunities. Education and training were undertaken using different geophysical techniques, including frequency and time domain electromagnetic induction (FDEM and TDEM), electrical resistivity, ground penetrating radar (GPR), downhole nuclear magnetic resonance (NMR), and hydrogeological field and sampling skills.

Another major component of the project was the transfer of knowledge with local community members and district water officers where the field surveys were conducted. The goal was to encourage ownership of the project, whereby a number of hydrogeological field test kits were distributed to the district water office to conduct water level monitoring of a network of shallow groundwater monitoring network during the project to capture the seasonal variation between the dry and wet monsoon months.

Specifically, in this project we aimed to:

- Train students and staff of the National University of Laos (NUOL) and in-country government agencies in the use of near-surface geophysics, as well as the collection and use complementary hydrogeological data sets;
- Educate and train local community members in the use of field test kits for long-term monitoring of water levels in the shallow aquifers used for domestic and agricultural water supply;
- Improve understanding of the hydrogeological system underlying the Vientiane Plain so that socioeconomic benefits from investment in drilling and groundwater infrastructure is maximized (e.g. identifying areas of low permeability associated with high salinity and low yields and appropriate siting of wells, construction depths and screen intervals);
- Demonstrate the benefits of using near-surface geophysics for identifying groundwater resource conditions in pilot areas in the Vientiane Plain and provide scoping opportunities for future, large-scale investigations (e.g. airborne electromagnetic induction-AEM surveys).
- Validate and ‘ground-truth’ these new geophysical data sets with the collection of hydrogeological and hydrochemistry data and water balance modelling; all information needed to improve the chances of making informed water management decisions.

### 2.2 Location

The Vientiane Plain (VP) is a large area (~4,500 km²), situated in the central region of Lao PDR, which hosts a population of around 0.8 million (Figure 1). Annual rainfall is on average 2,500 mm per year and most falls during the 5-month rainy season (May to October) compared to the dry season when there is little to no rainfall (November to April). The fertile, flat lowland with elevations ranging from 160 to 190 meters above sea level are flanked to the east and west by forested mountains up to 1600 meters high and by the Mekong River to the south. The Vientiane Plain is one of the major food production areas of Lao PDR. Levels of poverty in Vientiane province are around 20 percent, with associated problems of
malnutrition and stunted growth of children (Pimhidzai et al., 2014). Rice is grown throughout the Vientiane Plain in the rainy season, whilst during the dry season irrigation is used for higher valued crops close to the Nam Ngum River (which flows through the central region of the VP). Irrigation water is supplied via pumping from the river onto the floodplain, as well as by gravity flow in areas downstream of major reservoirs. For most villages on the VP, however, dry season irrigation for cash crop production is desirable but not possible due to the high cost in pumping water long distances from the major river systems.

Groundwater is more accessible than surface water, it has potentially a lower cost and allows accessing year-round water for domestic use and cash-crop production (ACIAR, 2016). It is common for each household or small community to have a shallow hand dug well (typically constructed with a backhoe or manually hand dug with shovels; 1 to 2 meters in diameter, lined with bricks or stones) for domestic use and home garden vegetable production. Given the shallow depth, these wells often go dry during the dry season, and historical trends have indicated an increasing number of wells going dry and deteriorating water quality is also increasing in some areas. High concentrations of faecal coliforms have been found in Phouhong and Thoulakhom; two districts on the VP, where the water table is relatively shallow and septic tank construction inadequate (ACIAR, 2016). Despite some households with higher income having the capacity to construct deeper wells, difficulties are experienced in accessing reliable groundwater supplies with significant storage and water quality due to the lack of geological and hydrogeological data and the complex hydrogeological setting.
2.3 Geological setting

The Vientiane Plain has been in-filled with alluvium (sand, gravels and clays) deposited by major watercourses, which overlies more competent sandstone units up to the more mountainous areas (Figure 2). The sandstone units in the mountainous areas generally do not hold large quantities of groundwater, and communities regularly face problems of insufficient yields from shallow wells in these areas. Nothing is known about the potential to access the deeper aquifer systems. Moreover, in some areas, rock salt, rich potash and gypsum deposits are found close to the ground surface or at depth (25 to 50 meters) and are associated with a confining layer comprised of anhydrite inter-bedded with claystone (Long et al., 1986). The interfaces between the main hydro-stratigraphic units, the location of the geological features (e.g. faults), which may influence groundwater flow and the spatial extent of the alluvial sediments are poorly understood and based on limited information.
Figure 2. Geological map of study area with the locations of the 3 study sites (S1 to S3) and the inferred 2D geological cross-sections.
3 Geophysical Need

Human and institutional capacity in Laos in hydrogeology and groundwater management is at an extremely low level and the application and use of near surface geophysics provided an important tool to build capacity in Laos. The project design facilitated several opportunities to develop and progress hydrogeological field mapping and provide in-country undergraduate and postgraduate training opportunities. Several different geophysical techniques were used as part of the project investigation, including frequency and time domain electromagnetic induction (FDEM and TDEM), electrical resistivity, ground penetrating radar (GPR), downhole NMR, and hydrogeological field and sampling skills. These techniques are described in further detail in the section Field Studies.

4 Field Studies

In the first months of the project the team has detailed the scope and spent significant time and effort on selecting the field sites and planning the two main field surveys that were conducted as part of the project.

Three study sites have been selected based on available existing hydrogeological information and other socio-hydrological information, provided by villages and communities as part of previous investigations (ACIAR, 2016) (Figure 2). Further details of each of the selected sites is addressed below.

4.1 Phousan (S1)

Phousan is located at the edge of the alluvial valley of the VP and the use of groundwater for domestic, livestock (mainly poultry) and household gardening is limited due to most wells being hand dug into the shallow weathered bedrock to less than 8 meters depth and often fail during the dry season. Despite the need for a reliable water supply, there are very few wells dug beyond this depth due to the high cost of drilling construction and high failure rate of wells as a result of poor siting and well design construction techniques used. The few wells drilled to 30 meters depth into the sandstone units have modest yields but appear to be strongly related to local geological features.

Hydrogeophysical techniques used in this study will provide a methodology to bring together information from the sparse dataset available and ensure greater success in the construction of deeper wells and improve understanding of the complex hydrogeological setting at this site.

4.2 Ekxang (S2)

Groundwater is being recognized as an important source for domestic use and agriculture in Ekxang district. Most villagers are rice and cash crop farmers, producing rice during the wet season and small-scale cash crops during the dry season, which are irrigated by shallow production wells (also referred to as tube wells) and hand dug wells. The higher value cash crops are more desirable, however, there is a much higher risk of crop failure due to poor water supply from the shallow well infrastructure which experiences large seasonal fluctuations and often go dry. The International Water Management Institute (IWMI) launched a groundwater irrigation trial in Ekxang and if the trial is successful there is likely to be a greater uptake of groundwater irrigation in the VP (ACIAR, 2016). The capacity of the deeper groundwater aquifers and water quality are poorly understood in this area, and hence, combining near
surface geophysical techniques and water quality surveys as part of this project will provide a clearer map for the development of groundwater irrigation.

### 4.3 Viengkham district (S3)

Viengkham district, like Ekxang, is an agricultural area where dry season cash crops are heavily reliant on groundwater from shallow wells constructed in the alluvial aquifer. Water shortages are common due to the seasonal water level fluctuation, shallow well completions and increased demand on the resource. Application and use of non-invasive hydrogeophysical techniques at this site will provide local communities, government agencies and not for profit organizations valuable baseline information to ensure that groundwater is not over-exploited and managed sustainably. This would include determining the extent and thickness of the alluvial aquifer and identify any saline groundwater hotspots that are associated with the Ngone Formation. The site is also located where the extent of the alluvial aquifer is supposedly at its greatest depth, however, there are very few drillholes in the area to confirm this.

### 4.4 Field survey

The major field survey was undertaken in March 2018 (Figure 3) with a follow up survey in February 2019 to disseminate and share the findings with the local partners. Planning of the fieldwork and local engagement was critical to the successful project and getting optimal results from training with the shipped geophysical equipment that was used to investigate and understand the groundwater resources of the Vientiane Plains.

*Figure 3a. Participants of the hydrogeophysics field training Vientiane Plain, Laos, 16-23 March 2018. Other pictures and movies from the field campaign conducted in March 2018 are available on request.*
Figure 3b. Hydrogeophysical surveys with the ‘CMD’ frequency domain electromagnetic conductivity meter.

Figure 3c. Setting up the electrical resistivity tomography survey transect (480 m long, 96 electrodes).
Figure 3d. RTK-GPS positioning of field measurements and for georeferencing the drone survey

Figure 3e. Drilling and installing shallow observation wells at the field sites.
Figure 3f. Groundwater level measurements in installed observation wells.
5  Interpretation of the Data

5.1  Data Summary
Over the course of this project five geophysical techniques were trialed over 18 sites across a rough transect starting west of Village “Km 52” (Ban Lak 52) to the Nam Ngum River, east of Ekxang Village. Figure 4 and 5 show the location of all the main field sites where measurements and data was collected. Electrical resistivity tomography data (Iris Syscal Pro Switch96), shallow transient electromagnetic induction (Zonge NanoTEM), shallow frequency domain electromagnetic induction (FDEM – GF Instruments CMD) and ground penetrating radar (GPR –Mala) data sets were all collected at field sites 1 to 5. The GPR data are not presented here as they did not show useful information. At site 6, all the same data were collected, except for the CMD data. Individual NanoTEM soundings were also collected at sites 7 to 18 to ‘infill’ between the main field sites. Five shallow monitoring wells were also drilled and completed up to 8 m deep). Water level dataloggers were installed in these monitoring wells and sampled for later analysis. A downhole NMR survey was conducted on the drillholes which stayed open (4 out of 5 that were drilled). Additional elevation / survey information and imagery was collected at sites 1 to 6 using a drone, and an RTK GPS.

Figure 4. Map of survey area showing location of all data collected over this survey. Yellow lines show locations of ERT and CMD data sets. Red dots show locations of NanoTEM soundings. Smaller purple dots show the locations of the drillholes that were completed during this project.
Figure 5. Detailed location maps showing survey locations at each of the main field sites 1 to 6.
5.2 Electrical Resistivity Tomography - ERT

ERT data were collected at sites 1 to 6. These data were collected using an Iris Syscal Pro Switch 96 system (http://www.iris-instruments.com/syscal-pro.html). Locations of the ERT survey lines are shown in Figure 1. These data were inverted using Loke’s Res2dinv code (Loke and Barker 1996). Inversion results for sites 1 to 3 are shown in Figures 6 to 8.

Figure 6. Inversion results of ERT data collected at site 1. Insert: Location map of site 1.
Figure 7. Inversion results of ERT data collected at site 2. Insert: Location map of site 2.
Figure 8. Inversion results of ERT data collected at site 3. Inserts: Location map of site 3 and also interpretation of subsurface structure at site 3.
5.3 Frequency domain electromagnetic induction

Extensive data sets were collected at sites 1 to 6 using the GF CMD Explorer (http://www.gfinstruments.cz/index.php?menu=gi&cont=cmd_ov). Only the results from the survey lines that coincided with the ERT surveys are shown here. The CMD system collects data at a single frequency (10,000 hertz). Internally the transmitter and receiving dipoles are set up at three different separations, i.e. the system is sensitive to variations in conductivity at three depths (up to approximately 7 m depth in the high moment configuration). Data may be collected with the transmitting and receiving dipoles oriented vertically, these data are collected using the “high moment” configuration and penetrate more deeply than when data are collected with the transmitting and receiving dipoles are oriented horizontally (“low moment”).

The datasets were inverted using the University of Aarhus Aarhusinv 1D inversion code (http://hgg.au.dk/software/aarhusinv/) (Auken et al. 2015). Results are presented as resistivity-depth sections. Only high moment data were inverted and are shown in this report. Resistivity-depth sections for sites 1 to 5 are shown in Figures 9, 10, 11, 12 and 13. All data were collected along a survey line that traversed from west to east.

Figure 9. CMD data collected at site 1.
Figure 10. CMD data collected at site 2.
Figure 11. CMD data collected at site 3. Note that section location for line 3a is highlighted in green and 3b is highlighted in yellow.
Figure 12. CMD data collected at site 4.
Figure 13. CMD data collected at site 5. Note that section location for line 5a is highlighted in green and 5b is highlighted in yellow.
5.4 Transient electromagnetic induction- TEM
Extensive shallow TEM data sets were collected at eighteen sites during this project. Data were collected using Zonge Engineering’s NanoTEM system (http://zonge.com/geophysical-methods/electrical-em/nanotem/). Transmitter loops were 20 m x 20 m, with a 5 m x 5 m receiver loop set up in the center of the transmitter loop. NanoTEM data were processed using Zonge Engineering software.

Nearly all of the TEM data collected during this survey appear to have been affected by induced polarisation (IP) effects (Flis et al. 1989), rendering these data difficult to process and invert. Figure 14 shows an example of raw decay data showing clear signs of “contamination” by IP. During the processing of the CMD data (see previous section) it was noted that much of the data (especially in-phase data, with some out-of-phase/conductivity data affected as well) were negative. This will be an area of research for the scientists involved in this project, as it seems likely that this may reflect IP noise affecting the CMD data as well; to our knowledge this has not been noted before. Examination of the limited deeper drill hole data collected in this area do not suggest any obvious sources for the IP in these data. We would expect that there would be a zone of shale or chargeable clay apparent in the logs. So far, we are unaware that any of the materials collected in the drillholes is chargeable, with no obvious shale units.

![Figure 14. Typical NanoTEM decay data collected during this project. Note that most TEM data collected during this project appear to be affected by IP "noise" and were not suitable for inversion. Positive magnitudes are shown with the blue line, negative values are shown with red dots.](image)

5.5 Downhole NMR
Downhole NMR data were collected in four of the five monitoring wells drilled for this project. The drillhole at site 5 collapsed shortly after drilling, only 0.75m of data were collected at this site. Downhole NMR data were collected using a Vista Clara Dart system (http://www.vista-clara.com/instruments/discus/). The data shown here were processed using Vista Clara’s borehole NMR processing suite. These data are presented in Figures 15 to 18.
Figure 15. Borehole NMR data collected at Site 1.

Figure 16. Borehole NMR data collected at Site 3.

Figure 17. Borehole NMR data collected at Site 4.
5.6 Integration of Geophysical techniques

This project provided an opportunity to apply, demonstrate and train staff and students from Laos government institutes and the National University of Laos in several of the most widely used geophysical techniques for hydrogeological investigations. These techniques include time domain electromagnetic induction (NanoTEM), frequency domain electromagnetic induction (FDEM), electrical resistivity tomography (ERT) and ground penetrating radar (GPR), as well as newer technology for groundwater applications like downhole nuclear magnetic resonance (NMR).

Each of the geophysical techniques that were used have their strengths and weaknesses in terms of their depth of investigation, responsiveness to subsurface geological structures and ability to measure physical characteristics of the subsurface (including parameters like porosity and water quality), sensitivity to cultural noise, and difficulty in transporting equipment to remote sites. In environments where there is little to no information on the geology and quality of the groundwater, the use and integration of multiple geophysical techniques is extremely valuable in determining which method works best in that setting, but also to cross-validate the measured results from other techniques run in the area (as well as any drilling).

In the surveys that were conducted at 18 sites west of the Nam Ngung River in the Vientiane Plain as part of this project, the ERT surveys had a good depth of investigation (up to 75 m) and ERT was able to identify a significant contact between two contrasting rock types. However, the time required to set up the survey was significant. For example, Figure 8 shows a more resistive, possibly hardrock feature towards the western end of the survey line at Site 3, which was overlaid by shallow conductive material. Towards the eastern end of the line and at depth there was a much more conductive zone, interpreted to be a localised salt deposit. Interestingly, salt deposits have been encountered in other drilling investigations for groundwater quality across the Vientiane Plain, so this feature is not unique in the area. Discussions with local members of the community about this feature suggests that the water in this area is known to be more saline than in surrounding areas. An opportunity to follow up with some investigative drilling at each end of this survey line at Site 3 would provide valuable information in ground truthing the geophysics results and assist in guiding further geophysical surveys to map better quality aquifer systems.

The FDEM is an excellent technique for covering a large area in a relatively short amount of time, however, its depth of investigation is focused on the near surface (< 7 m). The results from these surveys conducted at each of the sites was useful in identifying subtle subsurface features beneath the rice paddy cultivation, which was the primary land use at each of the field sites. Borehole NMR and shallow groundwater monitoring wells that were installed at some of the sites during this project provided potentially useful information about the shallow subsurface in the study area. Zones were
identified that were characterised to be zones of heavy (impermeable) clays and particularly high-water content in both surveys (and not interpreted from other work in the area).

Unfortunately, due to the more conductive clay material in the near surface, the GPR surveys did not provide any meaningful results in the sites that were surveyed and was not pursued further during the field program; the trainees, however, did get an opportunity to familiarize themselves with the equipment and its use. Poor results were also the case for the NanoTEM surveys, where the late time windows of the decay curve show unusual responses, which was interpreted to be related to strong induced polarization (IP) effects that seem to occur relatively frequently in tropical to sub-tropical settings. A review of the limited deeper drill hole data in the study area did not suggest any obvious IP sources like zones of shale or chargeable clay. Despite our best efforts it was not possible to invert the NanoTEM data.

6 MyWell Application

Apart from the geophysical measurements, with the help of the village head from Ban Ekxang, one of the villages in which we worked, we have initiated the use of the MyWell smart-phone app to monitor weekly groundwater depths in shallow wells in several village communities. The app has been developed for the Managing Aquifer Recharge and Sustaining Groundwater Use through Village-level Intervention (MARVI) Australian Centre for International Agricultural Research (ACIAR) project in India (Maheshwari et al., 2017). Details on the app are given at https://vesselstech.com/mywell.html. The start page of the app (Figure 19 left) shows how it can be used to store groundwater level, rainfall, water quality and check dam data. The data can be entered directly by farmers themselves via a cellphone. Figure 19 (middle) shows another page of the app where you can browse a map for registered wells, in this case it shows monitored wells in the Vientiane Plains and in the village of Exkang (Figure 19 right).

![Figure 19. Left: Start page of the MyWell app; Middle: Registered wells north of Vientiane, in the Vientiane Plains; Right: Registered wells with groundwater level observations made by farmers in the village of Ekxang.](image)
An example of the date that is stored in the app for one of the monitored groundwater wells- 100-077 in the village of Ekxang is shown in Figure 20 (left). Within the app, when you click on the well icon, the app shows that the well is owned by Mr Amkha (Figure 20 middle). This window also allows the user to add new groundwater depth observations. Selecting the time series option on the top of this window, shows the groundwater depth time series for the past years (Figure 20 right). The app allows farmers to get a better understanding of the groundwater conditions in their wells and is a means to organize crowd sourcing of data for water managers. This tool will be further trialed in Lao PDR in follow-up projects.

Figure 20. A popup window when clicked on the green dot

7 The Human Element

This project collaboration built and strengthened the capacity of the in-country Laos project partners, team members and other stakeholders from the community, government and university sectors. From the two main field trips and video conferencing throughout the project it was possible to establish and foster positive working relationships towards the project aims. As part of the project there were several outcomes contributing to the human element of the project and these are described in further detail below.

- Workshop discussions with our local partners: Division of Groundwater Management, part of the Department of Water Resources, Ministry of Natural Resources and Environment; Faculty of Natural Sciences and Faculty of Water Resources both of which are under the National University of Laos and the Ministry of Education and Sports; and the International Water Management Institute – Southeast Asia Office. The partners showed great interest in the project and ways of collaborating during this project and in the future. Several of the hydrogeophysical techniques that this project introduced have never been used in Lao PDR, hence the field training opportunity was highly beneficial for the institutes and local partners.
• A half-day workshop at the Faculty of Natural Sciences was organized and attended by 25 participants, including academic staff of the university, technical staff of the Department of Water Resources, and several geophysics students. The aim of the workshop was to introduce the aims of the project, background to the advanced geophysical tools and examples of how hydrogeophysical techniques can be used for groundwater exploration and management.

• Field training in a suite of geophysical techniques in the Vientiane Plains. This training benefited over 20 representatives from government institutes and the National University of Laos, while more than half of them were students of the University. All participants received up to eight days training in the use of hydrogeophysics and had ample opportunity to practice with the various methods, including, Nano TEM (transient electromagnetic), electrical resistivity tomography, ground penetrating radar, frequency domain electromagnetic induction and downhole nuclear magnetic resonance (NMR). In addition, RTK-GPS and a drone were used for mapping the area to generate high resolution imagery and digital elevation model of the study area. Moreover, some shallow groundwater observation boreholes were drilled, constructed and installed with water level loggers. Department of Water Resources staff, university staff and especially students benefitted greatly from this additional activity (Table 1). All participants received a Statement of Attendance (Figure 21).

• Results of the field activities were summarized, presented and discussed at a workshop in February 2019 (Figure 22-23). Also, in February 2019 follow-up discussions were organized with district water offices and community members on the results and outcomes of the field studies. Posters were made in both English and Laos and given to the District Water Office in Ekxang (Figure 24).

Table 1. List of participants as part of the field survey in March 2018.

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<tr>
<th>Names</th>
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<tr>
<td>Miss Iodchana Vongsamad</td>
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<td>Mr Souvieng Pharsai</td>
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<td>Mr Soun Intavong</td>
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<td>Mr Lengha Chongcher</td>
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<td>Miss Noysai Jidkeolar</td>
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<td>Mr Detnavanh Phosalath</td>
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<td>Dr Sounthone Singsoupho</td>
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<td>Mr Dalor Vardu</td>
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<td>Mr Aekphazai</td>
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<td>Miss Khonesavanh Thannavong</td>
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<td>Miss Douangdy Soudthixay</td>
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<td>Miss Chanphengyang Touhoua</td>
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<td>Mr Amphone Duangkhamdy</td>
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<td>Mr Bounsavanh Xaysombath</td>
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<td>Mr Vilaphong Santaince</td>
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<td>Mr Lounthong Keomanykham</td>
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<td>Miss Sounipha Xaiyakeo</td>
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<td>Mr Somphasith Douangsavanh</td>
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<td>Mr Phingsaliao Sithengtham</td>
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</tbody>
</table>
Statement of Attendance

This is to certify that

Mr Amphone Duangkhamdy

has successfully completed

Lao-Australian Groundwater Geophysics Short Course (full eight days)

Professor Okke Batelaan

Held in Vientiane, Lao PDR
16-23 March 2018
Figure 22. Presentation of the summary of the fieldwork to staff and students at National University of Laos, February 2019.

Figure 23. Discussion of the field survey findings with staff and students at the National University of Laos, February 2019.
8 Project Outputs

8.1 Project achievements

- The project had extensive engagement with the Lao government, university staff and students in teaching and field activities demonstrating the beneficial use of multiple hydrogeophysical techniques for improving the understanding of the hydrogeology and sustainable development and management of groundwater resources in Lao PDR.
- A large group of Lao PDR students were informed and trained via workshops and field participation in the measurements of hydrogeophysical techniques. Several students from Laos benefited from this project in supporting their research and achievements in receiving a MSc/PhD degree at Flinders University.
- The project has contributed to the on-ground capacity for better valuing the opportunities of groundwater as a reliable, safe and secure resource to support increased agricultural productivity and livelihood of small-holder farmers, therefore increasing the resilience of agriculture to climatic uncertainties. Multiple follow-on activities indicate the strong interest from the Lao PDR government and foreign donors to further support these activities.
- The project interacted with farmers on measuring groundwater levels and informing them and district representatives of the role and opportunities of groundwater resources in local development.
- The project has contributed to the development of hydrogeological maps and delineation of good and poor-quality water to lower the risk of well failure and groundwater contamination on the Vientiane Plain.
- An abstract was submitted, and a presentation was made to the SEG18, Anaheim, 14-19 Oct 2018 conference. Progress and outcomes of the project were highlighted.
• Multiple abstracts, presentations, papers and theses are produced based on or with support of this project. In almost all cases Laos staff are the first author, hence greatly contributing to the technical reporting capacity of the Laos staff and students.

• Project progress, engagement with the partners, and the fieldwork was promoted via tweets, the university website and the Groundwater Solutions Initiative for Policy and Practice (GRIPP) newsletter.

8.2 Presentations/Abstracts


• Hatch, M., Batelaan, O., Banks, E. and Douangsavanh, S., 2019, Geophysics used to help find good quality groundwater in the Vientiane Plain, Lao PDR. Extended abstract for Australasian Exploration Geoscience Conference (AEGC), 2-5 September, Perth.


• Phingsaliao Sithiengtham, 2019, Projecting water demand and availability under climate change through the application of WEAP in the Nam Ngum downstream area, Laos. Thesis Master of Science (Water Resources Management), Flinders University.


8.3 Follow-on activities

This SEG-GWB project has been a catalyst for further follow-on engagement activities in enhancing groundwater management in Lao PDR.

• A one year ‘Small research and development activity’ ACIAR project was approved and is currently under execution. The project title is ‘Exploring opportunities to expand groundwater use for livelihood enhancement and climate change adaptation in Laos’ and is led by IWMI with project partner Flinders University and collaboration input from the National University of Laos. In this project we continue to explore the use of hydrogeophysical techniques for groundwater characterization and sustainable groundwater management. The study sites are in the South of Laos in the Outhoumpon and Champassak provinces. A major goal of the project is also to further strengthening the capacity of staff of Government of Lao, Division of Groundwater Management of the Department of Water Resources and of the National University of Laos.

• The Flinders University PhD student Somphasith Douangsavanh is continuing his research on the anthropogenic changes in the (ground)water resources in the Vientiane Plain. He has benefited from this project by obtaining additional hydrogeophysical information of the Plains. He also has continued water level monitoring and engagement with the local farmers (MyWell app). Multiple publications are in progress from his work.

• Phingsaliao Sithiengtham is a staff member of the Department of Water Resources, Government of Lao and was during 2017-2019 a Flinders University MSc ‘Water Resources Management’ student. He was involved in and benefitted from this SEG-GWB project. He wrote a MSc thesis on ‘Projecting water demand and availability under climate change through the application of WEAP in the Nam Ngum downstream area, Laos’.
• Phousavanh Fongkhamdeng is a staff member of the Department of Water Resources, Government of Lao and was during 2017-2019 a Flinders University MSc ‘Water Resources Management’ student. He was benefitted from this SEG-GWB project. He wrote an MSc thesis on ‘Surface water balance and future water demands under environmental flow requirements, Nam Xong Watershed, Laos’.

• IWMI-Flinders University have proposed to ACIAR a 4 year follow-up study on ‘Sustainable expansion of (diversified farm production through) groundwater use for livelihood enhancement and climate resilience in Lao PDR’. This proposal is due to funding reductions on hold but might be resubmitted next year.

• We advised the Department of Water Resources, Government of Lao to write a proposal and submit it to the Australian Water Partnership (AWP) for supporting further activities in building groundwater management capacity (field investigations, capacity building). Based on this initiative AWP has agreed to fund an Australian expert to ‘Support to the development of a Groundwater Profile for Lao PDR and a Sustainable Groundwater Management Plan for the Sekong Basin’. Flinders University together with IWMI have proposed to AWP to supply the expertise.

9 Problems Encountered
The command of English of some of the project partners was low (although overall it was quite reasonable). We were very fortunate to have had two Flinders students from Lao PDR working with us in the field, planning the logistics prior to arriving in country, negotiating with landholders and local water authority offices. They were fantastic and helped tremendously in communicating, transferring of knowledge and expertise.

One of the original aims of the project was to help support and train local community members in the use of field test kits for long-term monitoring of water levels in the shallow aquifers used for domestic and agricultural water supply. Despite our best intentions with strong support from our Lao students and project partners it was not possible to fully deliver on this objective. However, we were able to engage one of the district water officers in collecting water level data from a network of shallow groundwater wells over the project, which was an adaptation of engaging a group of community members in monitoring a much larger network of wells.

Managing transportation of equipment to and from Lao PDR was challenging, time consuming and costly. Thanks to the excellent collaboration with the in-country International Water Management Institute (IWMI) and NUOL collaborators, we were able to overcome the issues and make this project successful.

10 Conclusion
This SEG-GWB project strengthened the capacity of in-country Laos project partners, team members and other stakeholders from the community, government, university and private sector. Capacity building is essential as human and institutional capacity in Laos in hydrogeology and groundwater management is the single most important constraint to progress (Pavelic et al., 2014). The project successfully facilitated several opportunities to develop and progress hydrogeological field mapping and provided in-country opportunities for training of undergraduate and postgraduate students, university and government staff. Training was provided in different geophysical techniques, including frequency and time domain electromagnetic induction, electrical resistivity, ground penetrating radar, downhole nuclear magnetic resonance), and hydrogeological field and groundwater sampling skills.

The project transferred new hydrogeological knowledge to the local community members and district water officers in the area of study sites. This SEG-GWB project has been a great steppingstone for further intensified engagement and collaboration of the project partners in enhancing the utility of groundwater for agricultural development.
12 References

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