Hydrogeophysics for community monitoring of groundwater in degraded dry forest quebradas of Peru

Geoscientists without Borders Application
Final Report Follow-up Form

(See GWB Final Report Full Form for complete instructions by logging into your account in Foundant: https://www.grantinterface.com/Home/Logon?urlkey=SEG)

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Basic Project Information	
Lead Organization (Include website links, if applicable.)	EcoSwell www.ecoswell.org
Project Primary Contact: Name, email, phone	Diego Almendrades diego.almendrades@ecoswell.org +51 954779509
Project Location, Country	Lobitos, Peru
Project Start Date	05/17/2021
Project End Date	11/20/2023
Report Authors	Diego Almendrades (Director, EcoSwell) Ximena Morante Sutta (Conservation Projects Supervisor, EcoSwell) Molly Baxter (Intern, EcoSwell) Andrew Binley (Prof. Hydrogeophysics, Lancaster University) Lai Bun Lok (Research Fellow and Lecturer, UCL)

Executive Summary

The Executive Summary section of the report should succinctly yet comprehensively summarize the project and its outcomes. Greater detail on the project will be provided as outlined in the additional sections of the report.

Introduction Provide a brief, focused introduction to the project and its need (Character Limit: 1500**)**

Located in Lobitos, Peru, for addressing water scarcity and ecosystem degradation using low-cost geophysical equipment. It built local capacity and support for replicating hydrogeological surveys.

Project Goals and Objectives

Describe the project goal(s) and objectives as outlined in the Phase II application or subsequent project revisions approved by the GWB Committee.

Project aims for longer term humanitarian benefit in arid coastal NW Peru by empowering marginalized communities in need of better water sources through the training and application of hydrogeophysical techniques at a degraded watershed "quebrada" demonstration site:
1) Develop a methodology for modeling quebradas hydrogeophysics
2) Develop a community hydrogeophysics training program
3) Build local capacity for replication in similar quebradas nearby the province of Talara, region of Piura

Project Participants

List the names of all project participants

Diego Almendrades, Director of Sustainable Development & Finances, EcoSwell
Andrew Binley, Professor of Hydrogeophysics, Lancaster Environment Centre, LU
Lai Bun Lok, Royal Society University Research Fellow and Lecturer, University College London (UCL)
Ximena Morante Sutta, Conservation Projects Supervisor, EcoSwell
Florian Kleinhoven, Water Engineer, EcoSwell
Quenni Carreño, Project Coordinator at EcoSwell
Barbara Grados Vargas, student from Universidad Nacional Agraria La Molina, Peru, volunteer-intern at EcoSwell
Jimmy Boyd, Lancaster University PhD student
Syed Osama Kamal, PhD student, University College London
Paul McLachlan, Post-doctoral Researcher, Aarhus University, Denmark
International student volunteer-interns at EcoSwell: Aminah Beg, Lauren Keohan, Cleopatra Pierides, Taylor Bastianelli, Hannah Udall, Laurel Skorina, Fiona Vail, Karlee Bane, Kristin Sibeth, Leeza Saed, Lily Wisniewski, Sofia Curto, Emilie Mackeown and Molly Baxter
Gladys Purizaca, Accounting & Financial Administration, EcoSwell
Michael Alderson, Director of Outreach & International operations, EcoSwell
Alejandro Pizarro, Director of Research, Monitoring & Communications, EcoSwell
Jesús Espinoza, Volunteer Program Coordinator, EcoSwell
Andrés Bustamante, Director of Marketing & Public Relations, EcoSwell

Methods Used

List all methods used, including application and specific instrumentation.

Resistivity: (Clark and Page 2011) low-cost DC resistivity meter for VES of shallow lithology and saline groundwater differentiation, 2 layer modeling
Seismic: Piezoelectric sensor on sledgehammer (Clark and Page 2011) to geophone receiver with 500 MHz USB oscilloscope for refraction surveys and enhanced interpretation of VES.
GPR: Custom-built at LU for constant-offset transects with 100 MHz antenna, common-midpoint surveys for near-surface stratigraphy and water table level determination.

Summary of Results and Key Findings Provide a summary of the project's results and key findings

In 5-8 Sept 2023, 5 VES were conducted along a 4.5km of Quebrada Monte (from the coast, in-land). These were to evaluate the performance of the instrument built and for university experts to train the EcoSwell staff ("train the trainers"). An existing well allowed comparison between geophysical interpretation and actual groundwater level and salinity. In 25-29 Sept. 2023, 3 more sites were selected for more VES as training for 17 community members. The seismic system was demonstrated and evaluated on 2 of the VES sites during the 5-8 Sept field campaign, as well as the GPR on one of the locations.
Low subsurface resistivities limited depth of investigation. Weak receiver voltages were experienced at electrode spacing of 20m and above (Wenner configuration). However we obtained a two layer electrical model at each site (moderate resistivity over very low resistivity). The results suggest saline groundwater at a depth of 4 to 5m in most sites, although further up (>~3.5km from the coast) higher resistivities were noted. Seismic surveys with geophone spacings of 1m, 2m…30m revealed a unit of significantly higher seismic velocity at a depth of ~5m, consistent with the VES results. GPR was not successful due to low subsurface resistivities attenuating signal.
Results reveal there is likely a groundwater body at a depth of 4 to 5m, however the very low resistivities in the lower section of the quebrada (within ~3.5km from the coast) suggest this groundwater is saline or brackish (estimated ~25-40 mS/cm). Translating our modeled resistivities to fluid salinity is subject to uncertainty but we know that if lower layer resistivity is very low (<5 ohm.m) it is likely that either the fluid electrical conductivity is too high (saline) for drinking water and/or subsurface is clay rich and permeability may be too low. Both of these possibilities are undesirable for a productive well. Further up from ~3.5km we find higher resistivities and lower estimated salinities ~3-8 mS/cm.

Conclusion and Implications

List the conclusions that the project team derived and the implications those conclusions have

The field campaign demonstrated the resistivity and seismic system's potential for shallow groundwater exploration by marginalized communities in degraded environments of northern coastal Peru. Results reveal the likely presence of relatively shallow (i.e. accessible) groundwater along Quebradra Monte, however it is likely it is too saline for human drinking up to a certain distance (~3.5km) from the coast.
Beyond this point, an inferred "salinity threshold" suggests less saline water more suitable for productive wells (less treatment will likely be needed for drinking but could be good enough for irrigation, livestock drinking). This valuable information, along with depth estimation, can inform future wells' locations and sets an example method for communities to follow in similar quebradas, something that has never happened here before. A PDF document summarizes all findings and discussions.
More significantly, we provided simple geophysical instruments and processing tools for local community use, empowering them to conduct cost-effective groundwater surveys. With this know-how and low-cost equipment, they can now save money which would otherwise be needed

to pay consultants for costly surveys and be better informed through their own actions before drilling investments.
In new project stages, the aim is for pastoral communities to enhance their quality of life with this new water source (after relevant treatment depending on intended use) and use it responsibly to avoid depletion. The final ideal scenario is for communities to drill in strategic locations to follow a regenerative grazing plan around their degraded landscape (as water for livestock), restoring soil health and reversing desertification. This will improve the small water cycle within their quebradas watersheds and maximize groundwater recharge in a positive feedback loop of water, ecosystem restoration and agricultural productivity, with high replicability for the region and other arid environments.

Deliverables

List all deliverables that will be discussed in the final report, including those given to in-country partners and participants**.** (Character Limit: 1500)

3-way agreement with partner UK universities: LU and UCL
Sourcing and direct participation of national and international students (undergraduate, graduate, PhD, post-doc) remote and in-person: 18 in total
Series of community workshops
Health & Safety
Custom-built 3 low-cost geophysical units and importing them from UK through national customs to Lobitos, Peru. Procurement and shipping of more international and local materials/equipment through Lima, Peru
Romotely-guided field tests in Lobitos
UK Experts flown to Lobitos to train EcoSwell in-person
Training Materials: lectures, manuals, presentations, translations, tutorials
Community Training Program for 17 people (4 communities, public officials)
Data collected, processed, results and modeled graphics
Authorities engaged and committed
Abundant audiovisuals - social media publications (facebook, instagram), filming for editing educational videos, articles
Future Participation in SEG IMAGE event August 2024 by PM Diego Almendrades

Links to shared files (pictures, reports, etc.):

Health & Safety guidelines, briefings and PPE implemented for all project participants (English and Spanish):
https://drive.google.com/drive/folders/1PA_gEAuWuB86hgEyj4DW2OfHx4rFpOPk?usp=sharing

Preliminary Field Tests in Lobitos, Peru of imported equipment (with remote guidance from university expert partners):
https://drive.google.com/drive/folders/1uBWWNK_0iYxi8LK38Y9DXCwTIQSI2Tmg?usp=sharing

Experts Fieldtrip to Lobitos (in-person field training to EcoSwell staff) - pictures and videos Day by Day:
https://drive.google.com/drive/folders/13FF8JacdZgRWxouXuQVZhEUK1AEWT4V5?usp=sharing

Training Materials - lectures, operating manuals, presentations, translations and interpretations to Spanish:

https://drive.google.com/drive/folders/1-5H3zpA53WvyKH6dOi_E_G3hvlbMkOs0?usp=sharing

Resistivity Solver software tutorial -
https://drive.google.com/drive/folders/10rGW8hsHpyZq3LfcEyPyhM8BjpBx5SUf?usp=sharing

GPR Radar software tutorial session - https://drive.google.com/drive/folders/1eDIRCrVIZh-5I9RdHUU_jjJQCsmf1NVM?usp=sharing

Community Training Program - Presentations Day 1, Day 2-3 and Report
https://drive.google.com/drive/folders/1ovEqu1FwxEIg8OxuTN5_p5J8SFsyaRsl?usp=sharing

Pictures and Videos - Community Training Program - Day by Day:
https://drive.google.com/drive/folders/1jk8Tl7xo6oa5dzqyWCW-h6cNWg_c6j5e?usp=sharing

Field Data obtained and processed with computer software:
https://drive.google.com/drive/folders/1gyiOMbU4S2PhS147HJT_8GrGDx3pD-aN?usp=sharing

Results and modeled graphics - Resistivity Summary
https://drive.google.com/drive/folders/1vC2oZgD0X8nMsujKzyCvxNI1zE7APr5A?usp=sharing

Closure Workshop Report
https://docs.google.com/document/d/1UPLOAgPMFQkcKizlhy9QMhKWw25gRIyNYsYu_KfYero/edit?usp=sharing

Students (Involvement of students in the project. Character Limit: 1500)

Students and interns actively participated in (both remotely and in-person.): training sessions, fieldwork, data collection and interpretation, fabrication and application of geophysical equipment, creation of audiovisual and social media content, report-writing, etc.

A total of 18 students (national and international volunteer-interns, undergraduate, graduate, PhD candidates, post-doc) were sourced participated directly in the project (remote and in-person).

Students, involved with the UK university partners:
Jimmy Boyd, Lancaster University PhD student - developed the seismic data plotting program
Syed Osama Kamal, UCL PhD student, PGR Electrical & Electronic Engineering
Paul McLachlan, Post-doctoral Researcher, Aarhus University, Denmark

Students involved with EcoSwell, international:
Aminah Beg (Master of Development Practice candidate, University of Waterloo, Canada), Cleopatra Pierides (Civil Engineering undergrad, University of Glasgow, UK), Taylor Bastianelli (Master in Public Health candidate, Liberty University, USA), Lauren Keohan (USA), Hannah Udall (UK), Laurel Skorina (USA), Fiona Vail (US)A, Karlee Bane (USA), Kristin Sibeth (UK), Leeza Saed (USA), Lily Wisniewski (USA), Sofia Curto (USA), Emilie Mackeown (Ireland) and Molly Baxter (UK).

Students involved with EcoSwell, local:
Barbara Grados Vargas, undergraduate thesis student from Universidad Nacional Agraria La Molina (UNALM), Peru

Final Report

Project Location and Geologic Setting (Character Limit: 500 or attach a file > 5 MB.)

Lobitos north Peru is hyper-arid dry forest biome. Water scarcity worsened by deforestation/desertification. Quebradas/dry valleys are crucial with fragmented vegetation, infrequent intense rains (El Niño) flash-flood runoff to Pacific
Q Monte enters aquifer permeable conglomerates shales to quartz sandstones. Then impermeable shale intercalations sandstones, clayed silt matrix. Then permeable unconsolidated porous aquifers and poorly consolidated conglomerates lumachelic fine-coarse sands

(attachment)

Project Location continued (KMZ file Limit: 1 MB)

(attachment)

Humanitarian Need and Benefit (Character Limit: 750)

The project addresses urgent humanitarian needs in remote coastal quebradas of north Peru, focusing on marginalized communities like Lobitos, Síchez, Piedritas and Fernández. Water scarcity, exacerbated by desertification, contributes to poverty conditions. Local people are now empowered with skills for sustainable groundwater monitoring through hydrogeophysics training, allowing informed decisions on drilling and usage. "Trained-trainers" can now train more people, ensuring long-term benefits. Ultimately, the aim is for pastoral communities to use geophysics in regenerative agriculture, siting of strategic wells for grazing livestock drinking water, restoring their degraded ecosystem while enhancing their water sources and quality of life.

Project Goals and Objectives (Character Limit: 1000)

Project aims for longer term humanitarian benefit in arid coastal NW Peru by empowering marginalized communities in need of better water sources through the training and application of hydrogeophysical techniques at a degraded watershed "quebrada" demonstration site:

1) Develop a methodology for modeling quebradas hydrogeophysics
2) Develop a community hydrogeophysics training program
3) Build local capacity for replication in similar quebradas nearby the province of Talara, region of Piura

List of completed project tasks:
Task 1: Planning and Preparations
Task 2: Training, Education Workshops and Events

Task 3: Custom-built Equipment
Task 4: Fieldwork
Task 5: Data Processing & Reporting
Task 6: Closure workshop with authorities & community members

Previous Studies in the Project Area (Character Limit: 2000)

In Jan. 2021 Geofisica Aplicada SRL (GASRL consultancy company) carried out three VES in Quebrada Síchez, Lobitos, to assess the potential for water well development there for the Síchez community. Their report mentions the Regional Government of Piura requested their services for that specific part of the Lobitos District Municipality terrain. We interpreted their report in relation to the EcoSwell surveys conducted as part of the GWB project in Sept. 2023 in another area of Lobitos Q. Monte some 5km apart, and also did some further modeling with their data and our data to see how the EcoSwell resistivity unit would compare in performance.

Full comments and interpretations detailed in this report: https://drive.google.com/file/d/1Hswj-aYwbiJDIpbGykC3tm1n53c-zHnN/view?usp=sharing

The comparison showed that the match for the upper two layers is very good. We conclude that, hypothetically, had the EcoSwell resistivity instrument been used, then a similar interpretation for the upper two layers would have resulted. The Q. Síchez and Q. Monte surveys show similar behaviour interpretations, i.e. a shallow resistive unit (assumed to represent relatively dry sands/silts) over a much less resistive (i.e. electrically conductive) lower layer (representing saturated sediments). One would interpret low resistivity to imply that the location is not suitable for groundwater extraction. However, EcoSwell surveyed 8 points, 5 more than GASRL did, and with that were able to find an inferred "salinity threshold" from a certain distance upstream, where estimated salinity in the second layer drops and suggests a location for a productive well. We should try to find a similar threshold upstream in Q. Síchez with our unit. It appears the EcoSwell resistivity instrument is likely to be capable of performing useful groundwater evaluation surveys in the area, just as costly third-party hired services would but at a fraction of the cost and performed by empowered local inhabitants.

Field Studies (Character Limit: 4000, file size limit 2 MB)

Field studies were conducted in two stages. Stage 1 “Train-the-Trainers” (5-8 September 2023) focused on: (1) evaluating the instruments that were manufactured in the UK for the project in the local environment; (2) training members of the EcoSwell team and participating students on the use of the instruments, including health and safety aspects. This stage was led by UK academics (Binley and Lok) and was followed by training the EcoSwell team on the use of tools for analysis of data. The EcoSwell team then carried out field investigations independently to develop confidence in the use of the tools provided. Stage 2 “Community Training Program” (25-29 September 2023) then involved training local community members and certain professional public officials on theory, field application and data processing, creating training content (presentations, translated manuals, etc.). The final stage of this training session was joined (online) by the UK academics. EcoSwell supervised all Health & Safety considerations at all times.

It is important to note that our primary goal was to empower members of local marginalized communities in the use of geophysical tools for groundwater exploration. Given the non-scientific background, sometimes only completed primary school or less, and limited IT skills, we needed to adopt approaches for measurement and data analysis that were simple to follow. We avoided the use of sophisticated software and developed bespoke tools simple to use. Furthermore, the EcoSwell trainers had no prior geophysics experience and thus the development of very clear step-by-step guides on all aspects was essential. The UK team developed guides and manuals in English, that were subsequently translated and interpreted into relatable Spanish by the EcoSwell team for the community training.

Stage 1 involved carrying out 5 VES, 2 seismic refraction and 2 GPR surveys along a 4km length of Quebrada Monte. Stage 2 focussed entirely on doing 3 more VES surveys within the same quebrada length, with specific survey sites informed by Stage 1 findings.

Figure 1 shows the location of the VES surveys conducted in Stages 1 and 2.

The photographs in Figure 2 illustrate the surface conditions encountered at all sites.

We adopted a Wenner configuration for the VES surveys. This configuration was chosen rather than the conventional Schlumberger array due to (1) the need to maximize signal strength and (2) the simplicity of the array (keeping in mind that non-specialists were the intended end-users). We encountered difficulty in measurements at electrode spacings greater than 20m (i.e. an AB spacing of 60m) due to the very low resistivity of the subsurface. Greater spacing would lead to very low measured voltages, often highly variable repeat measurements and/or negative apparent resistivity. In some cases we were only able to achieve reliable measurements at an electrode spacing of 10m. All soundings resulted in similar data patterns characteristic of a moderately resistive overburden and very low resistivity lower unit. Consequently, we developed a spreadsheet-based tool for data analysis based on a two layer resistivity model (more layers would lead to non-unique solutions). Figure 3 shows an example VES dataset and modeled response.

Seismic refraction surveys were carried out at sites 23090501 and 23090801 (see Figure 1 for locations). Given that the instrument is based on a single geophone, the survey consisted of burying the geophone (to minimize noise) at one end of a transect and then recording traces due to hammer shots at distances 1m, 2m, 3m, … 30m from the geophone. For each shot position we performed three hammer blows and stacked the recorded traces. Figure 4 shows the survey layout. Figure 5 shows the recorded traces for the survey at site 23090801 (the survey results for site 23090501 are similar). The directed and refracted arrivals are clearly visible in the dataset.

(attachment)

Interpretation of Data (Character Limit: 4000, file size limit 2 MB)

The previous Field Studies section shows an example VES dataset and interpreted model for survey 23091701. Figure 6 shows the same for survey 23090502 near the well (the furthest downstream site in the quebrada that we surveyed). Poor data for electrode spacing greater than 10m for the 23090502 survey clearly limits confidence in the depth and resistivity of the lower unit in the two-layer model, however, a clear low resistivity exists at shallow depth (interpreted depth is 2.7m). Figure 7 shows a photograph of the well near to VES site 23090502. On 7 September 2023 the water level in the well was measured at 4.75m (although note that the elevation of the ground at the well is higher than the bed of the quebrada where the VES survey was carried out). The electrical conductivity of the well water was measured at 18.5 mS/cm (equivalent to 0.54 ohm.m). This is consistent with the VES lower unit resistivity of 1.5 ohm.m (i.e. assuming a formation factor of 3).

Figure 8 summarizes the results of the VES surveys. Throughout the western (downstream) section of the quebrada we see evidence of a relatively shallow low resistivity unit. Given independent observations of shallow saline water in the well near VES site 23090502 (noted above) we may conclude that such salinity exists further upstream of the quebrada and thus would not be suitable for water well development. In the eastern (upstream) section of the survey area we see evidence of the lower unit increasing slightly in resistivity. This may be a result of reduced salinity of the groundwater with distance from the coast, although as shown in Figure 9, existing regional geological maps indicate a transition to less permeable strata in this upstream section. The increase in resistivity may then be a result of increased formation factor. Nevertheless, the resistivities are still sufficiently low to suggest that freshwater is not present.

Figure 10 shows the estimated conductivity, with all the uncertainty involved in that estimate mentioned in a previous section “Summary of Results and Key Findings” and in the document Resisitivity Results Summary here:
https://drive.google.com/file/d/1LwUxw5QX1UpmyNB228ZOKeA6IYdWXZWk/view?usp=sharing

For the downstream section conductivity ranges between 27-40 mS/cm, while for the upstream section it ranges between 3-8 mS/cm. It would still brackish water, but considerably less saline than downstream and therefore more attractive for water well development and/or treatment, depending on intended use.

Figure 11 shows the result of analysis of the seismic refraction survey at site 23090801. The resulting depth to the high velocity unit is 5.6m. This is comparable to the VES-interpreted depth of 4m at the same location (see Figure 9). We conclude that the seismic refraction offers additional support for the interpretation of the VES data. We recognize that the lower unit in both VES and seismic data analysis could be interpreted as a result of a lower clay rich unit rather than a saturated zone in a well-drained sand. However, the independent observations in the water well at VES site 23090502 suggests the latter.

(attachment)

Human Element (Character Limit: 750)

Lai Bun Lok, UCL Lecturer in Electronics
Andrew Binley, LU Professor of Hydrogeophysics

18 Students participated, national and international - equipment assembly and testing, project logistics planning and execution, fieldwork, training content creation, training program execution, audiovisual material and social media content. Jimmy Boyd, Lancaster University PhD student - developed the seismic data plotting program

Quenni Carreño, Lobitos woman leader and Project Coordinator at EcoSwell, H&S Supervisor
Jesús Espinoza, Lobitos youth and inclusion leader and VP Coordinator at EcoSwell, social media community manager
17 people from 4 communities and public entities (Regional Government of Piura, Water Authority-Tumbes) successfully trained

Project Sustainability (Character Limit: 1000)

We consider this is our main strength. Ours is not a project where experts simply go in with their own instruments, collect data and leave. We set out as with all EcoSwell projects, with a clear focus on sustainability and transferring capabilities. Staff received training directly from experts and we now have local permanent custody over the instruments. Trained staff have then trained 17 leaders from 4 communities and public officials from important stakeholders, the first cohort of trained-trainers who will train more people in the future. They also signed a letter of intent to continue the project and address key issues such as creating jobs for trained leaders as groundwater monitors. The plan is to do regenerative agriculture for ecosystem restoration, to effectively raise the water table. Our permanent presence ensures proper equipment usage and replicable methods for more campaigns in similar quebradas. As more data is collected, models and strategies will keep improving.

Education (Character Limit: 1000)

Academics from LU and UCL (UK) led the assembly of the equipment, the first stage of the Peru educational campaign in-person for EcoSwell staff and created the original training content and manuals, all the while integrating participation from their post-graduate students.

3 EcoSwell staff were trained (1 being a local resident) plus 1 Peruvian student from UNALM, those 4 then created and led the successful Community Training Program of knowledge-transfer and capacity-building to a further 17 local people (13 residents and 4 professional government officials). A closure workshop "graduation ceremony" for all trained people helped to recognize the effort given, making them feel invested in the project.

18 students participated throughout the project, including partner university students but also undergraduate volunteer-interns sourced from all over the world by EcoSwell's Volunteer-

Internship Program. Extensive video documentation will ensure long-lasting educational material.

Lessons Learned (Character Limit: 1000)

Main complication was our timeline, effectively extending a 12-month project into 30 months. This was due to two main factors: 1) administrative times taken with partner universities to discuss and sign a 3-way agreement and waiver and 2) external factors such as covid, socio-political unrest and climate events in Peru.
For the future, current agreements can now be simply extended without lengthy administrative times but these still should not be underestimated. Also, alternative plans are needed to avoid delays from external factors.

Fluent and frequent communications between all partners are crucial for the project. Real-time calls are better than text or email to overcome difficult barriers.

The most valuable and engaging time was during the academic experts trip to Peru, many objectives were achieved and the team learned and connected a lot in a very short time: these trips should be as long and frequent as possible and carefully planned to avoid clashes with academic semesters.

Financials (Character Limit: 1000, file size limit 2 MB)

The attached file shows two sheets: the original approved project budget and the actual expenses.

At the end of the project, there are two outstanding future expenditures (confirmed and committed), please see attached. These include the expenses for attending the SEG annual IMAGE event in August 2024 and the reimbursement of expenses by partner UCL (awaiting their invoice confirmation in January-February 2024).

(attachment)

Deliverables

Access to Data (Character Limit: 500)

Data associated with this project are available and can be accessed via the following URL: https://drive.google.com/drive/folders/1gyiOMbU4S2PhS147HJT_8GrGDx3pD-aN?usp=sharing . Note: A digital object identifier (DOI) linking to the data in a general or discipline-specific repository is strongly preferred.

Photos and Videos (Character Limit: 250)

Pictures and Videos folder 1: https://drive.google.com/drive/folders/13FF8JacdZgRWxouXuQVZhEUK1AEWT4V5?usp=sharing .
Pictures and Videos folder 2: https://drive.google.com/drive/folders/1jk8Tl7xo6oa5dzqyWCW-h6cNWg_c6j5e?usp=sharing

References

References (Character Limit: 2000)

Clark & Page, 2011, Inexpensive Geophysical Instruments Supporting Groundwater Exploration in Developing Nations, Journal of Water Resource and Protection, 2011, 3, 768-780, doi:10.4236/jwarp.2011.310087, URL: https://file.scirp.org/pdf/JWARP20111000002_23639434.pdf .

Kwizera, Clark, Hangen, Jones, McKee & Page, Inexpensive Resistivity Instruments for Groundwater Exploration: Experiences of African National Geophysical Teams, 7th RWSN Forum “Water for Everyone”, 29 Nov - 02 Dec 2016, Abidjan, Côte d’Ivoire, URL: https://rwsnforum7.files.wordpress.com/2016/11/full_paper_0139_submitter_0222_clark_james.pdf

O. Palacios, C. Alban, Mapa Geológico del Cuadrángulo de Lobitos, REPÚBLICA DEL PERU, SECTOR ENERGÍA Y MINAS, INSTITUTO GEOLÓGICO MINERO Y METALÚRGICO - INGEMMET - Geological map of site.

Current and Planned Abstracts, Articles, and Presentations (Character Limit: 2000)

Planned abstract and project presentation: for the SEG IMAGE '24 event and other events with Peruvian stakeholders and authorities.

Planned journal article: for publishing survey results and community training program in a scientific magazine

Figures for Interpretation of Data

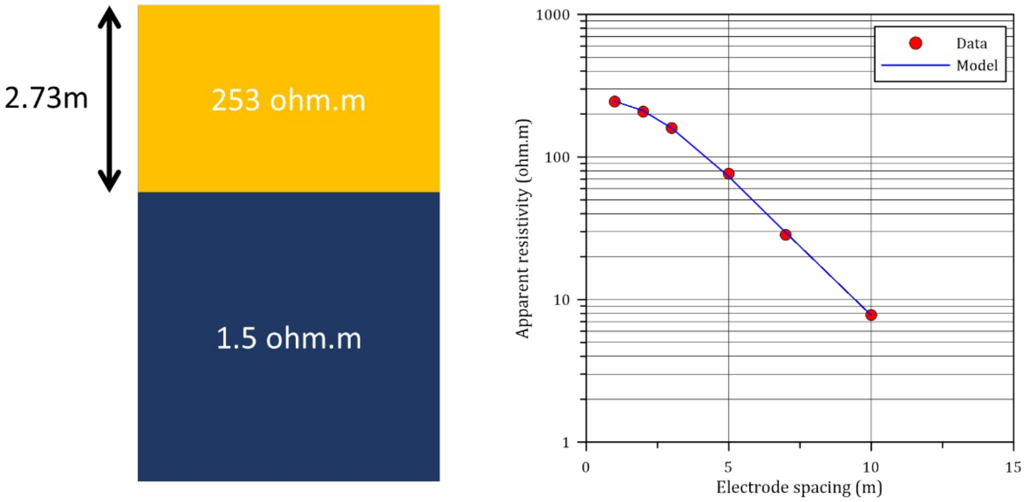

Fig 6. VES data and interpreted model for survey 23090502 (near well).

Fig 7. Photograph of well (in foreground) and quebrada in the background where the VES survey 23090502 was carried out.

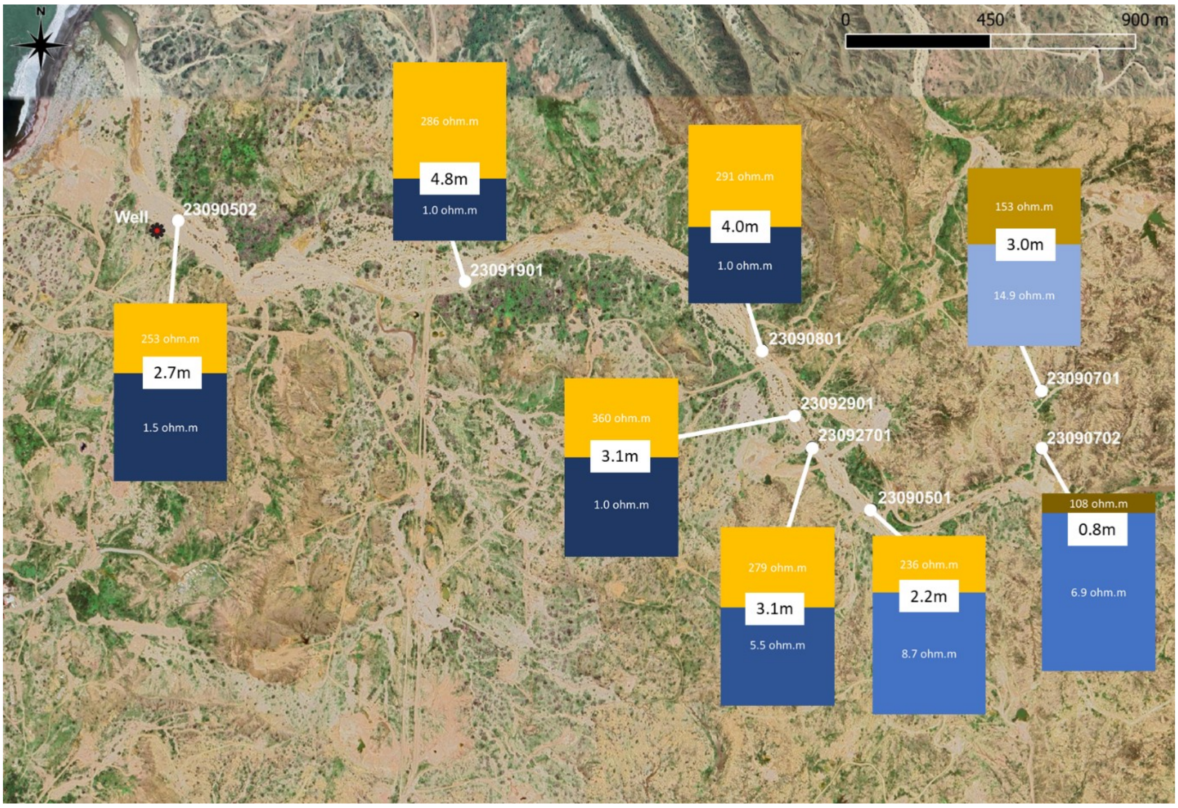

Fig 8. Summary of interpreted VES data within Quebrada Monte.

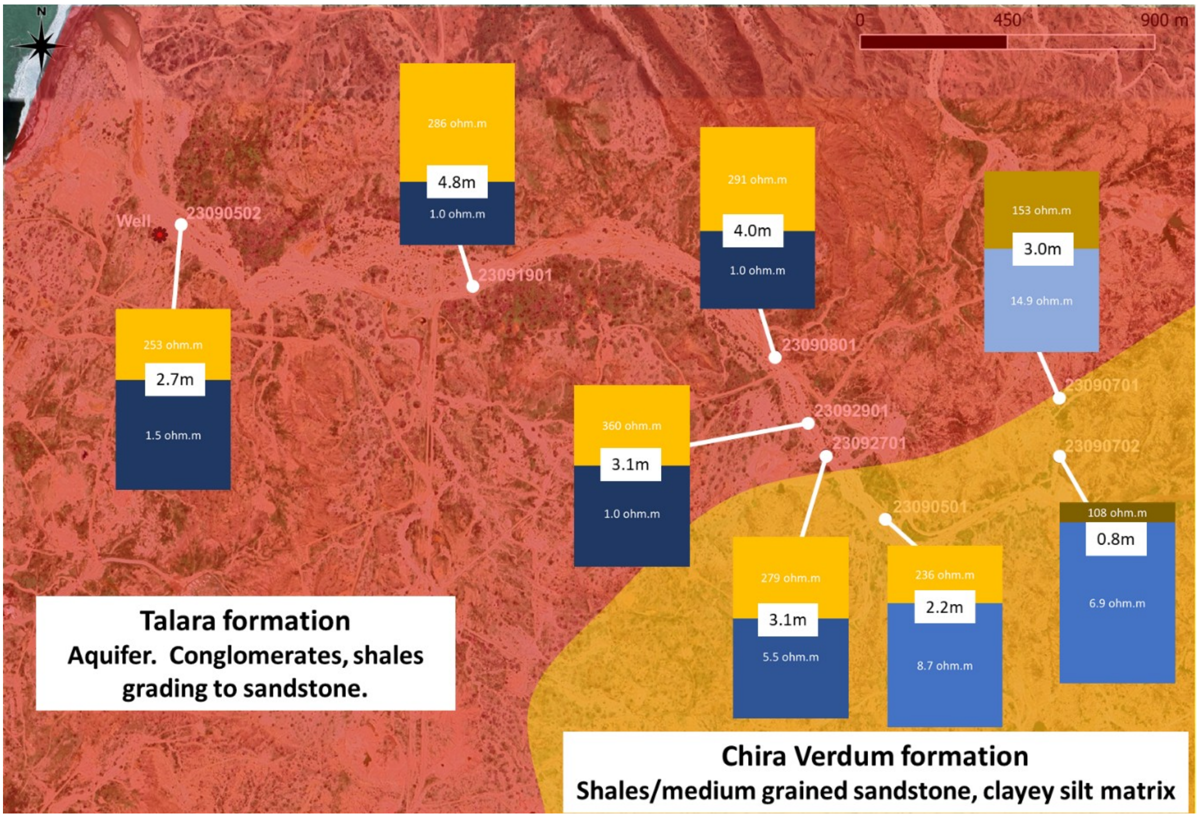

Fig 9. Summary of interpreted VES data within Quebrada Monte with geological transition obtained from existing regional geological maps (O. Palacios, C. Alban, REPÚBLICA DEL PERU, SECTOR ENERGÍA Y MINAS, INSTITUTO GEOLÓGICO MINERO Y METALÚRGICO - INGEMMET).

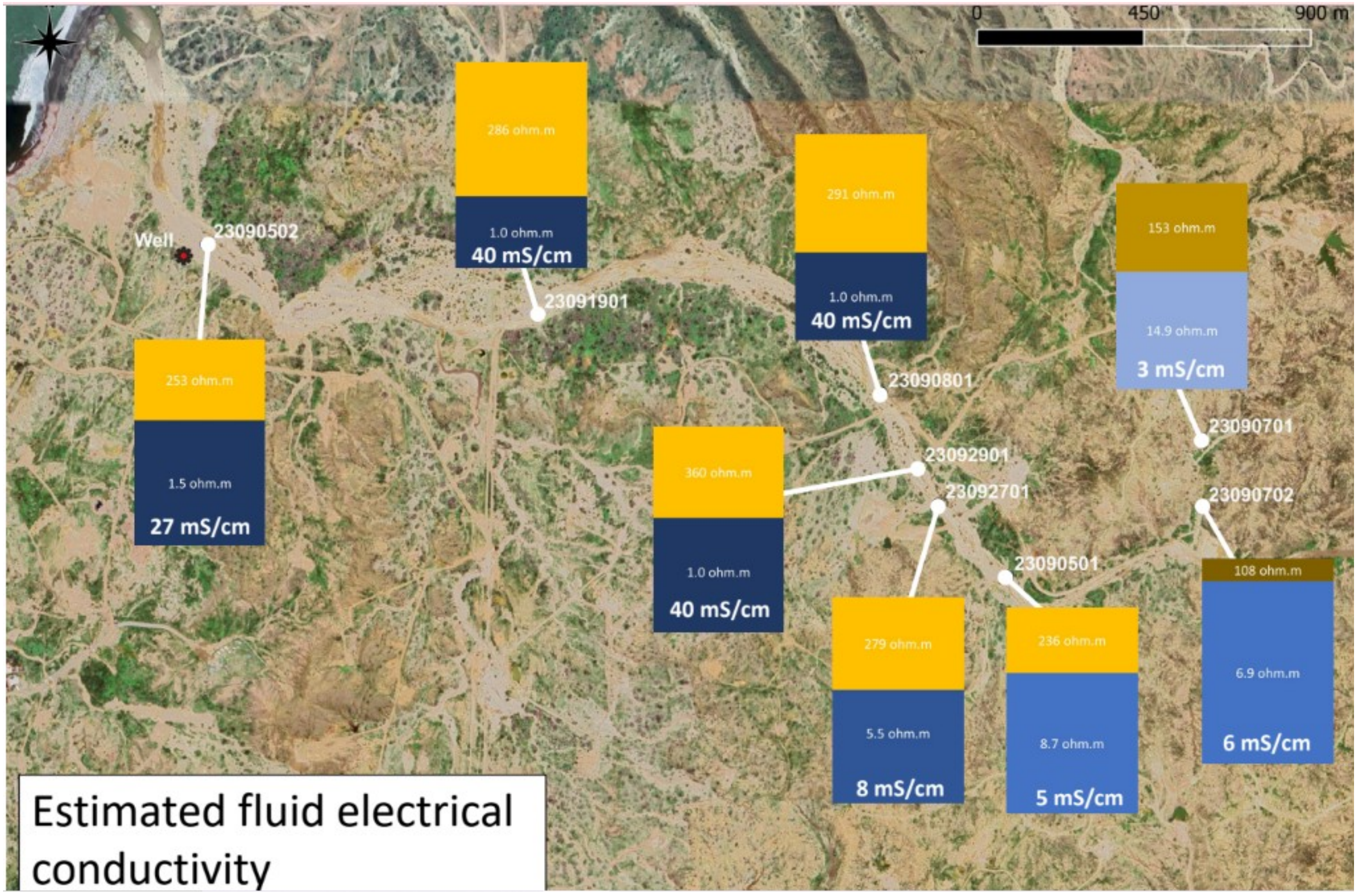

Fig 10. - Estimated fluid electrical conductivity from VES results (subject to uncertainties and assumptions)

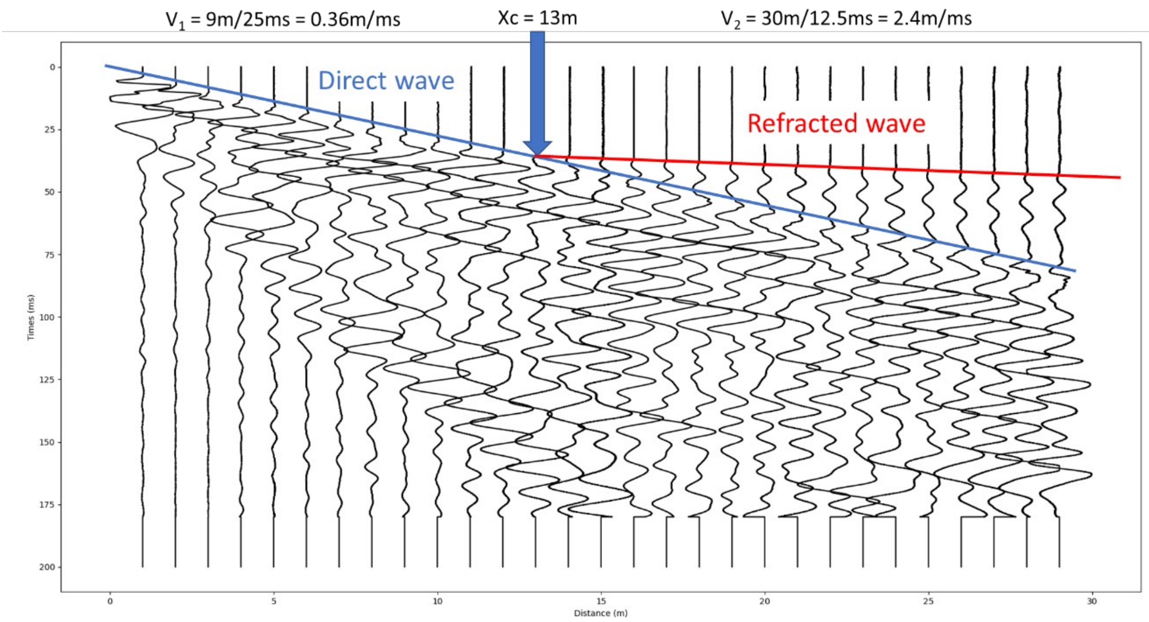

Fig 11. Measured and modelled seismic refraction dataset for site 23090801.

Figures for Field Studies

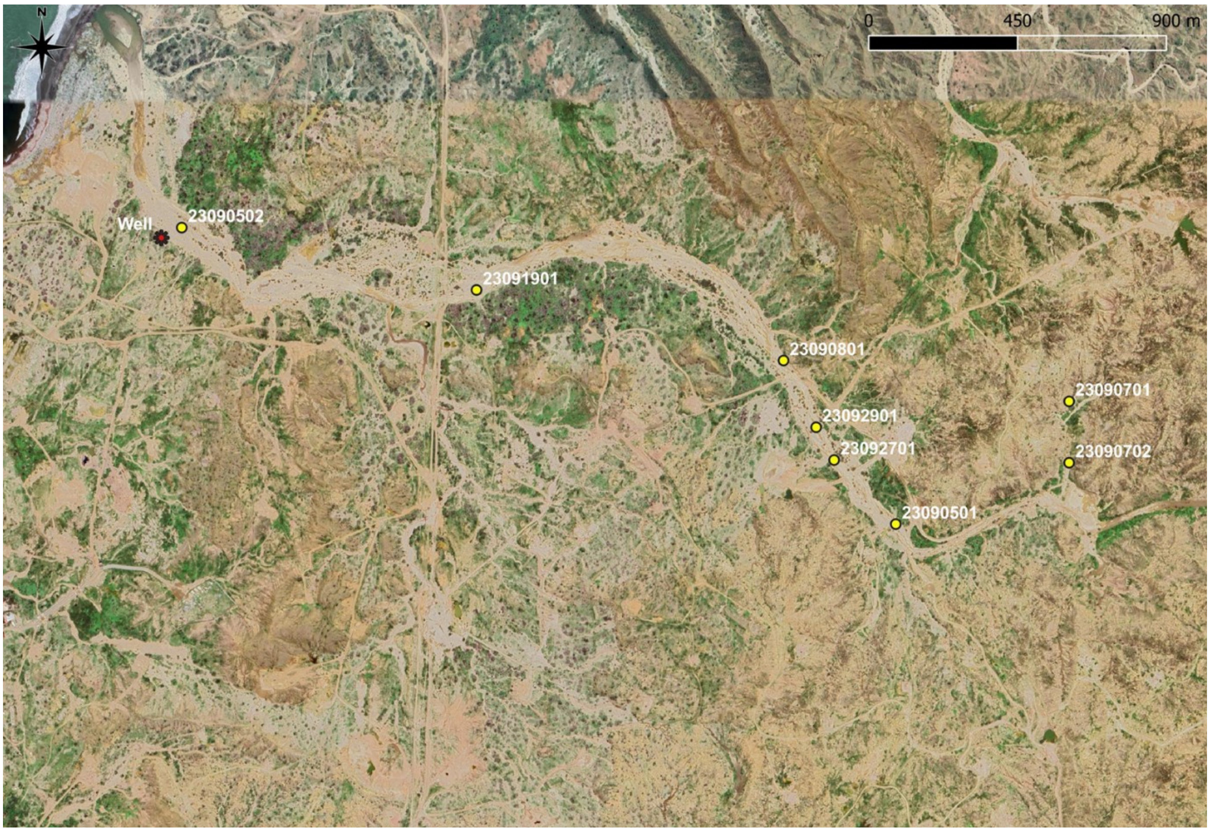

Fig 1. VES survey locations on the Quebrada Monte (5 – 29 September 2023). An existing well is also marked on the map. Each survey is labeled uniquely by YYMMDDNN, where YY is the year, MM is the month, DD is the day and NN is the survey number of the day.

Fig 2. Photographs of the operation and layout of Stage 1 VES surveys in Quebrada Monte. Note the very dry surface conditions. High contact resistance due to the very dry surface soil was overcome by the addition of small quantities of nearby seawater to each electrode.

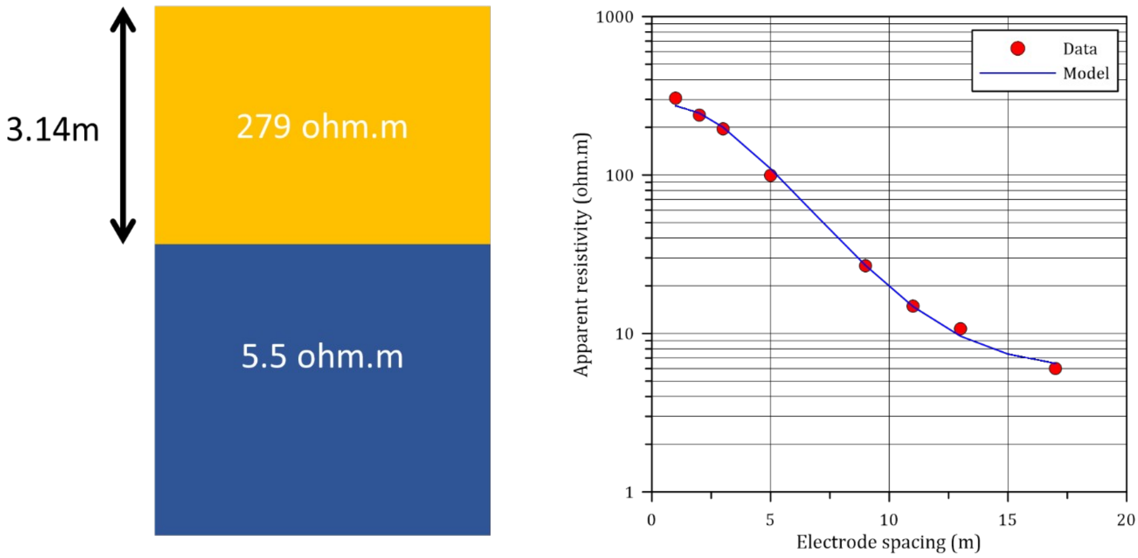

Fig 3. Measured and modeled VES data for site 23091701.

Fig 4. Seismic refraction survey layout and operation, Stage 1 (site 23090801).

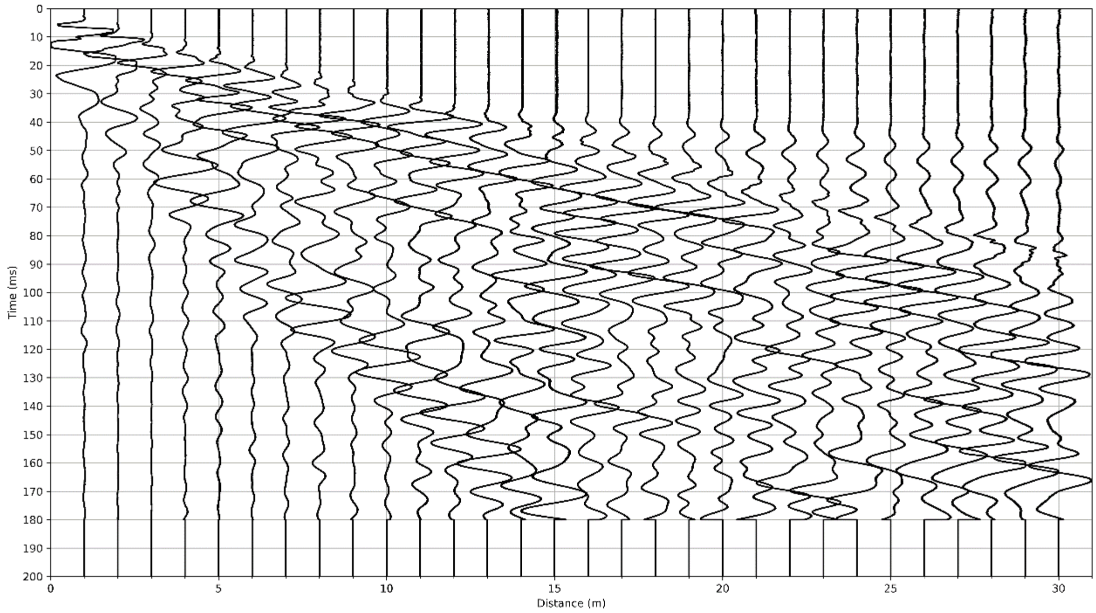

Fig 5. Measured seismic refraction dataset for site 23090801.


Quebrada Monte
Lobitos district
Lobitos District
Talara
Aeropuerto Internacional Capitán FAP Victor...
Google
ECUADOR
QUITO
Guayaquil
BRAZIL
PERU
PACIFIC OCE
Trujillo
Callao
LIMA
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