# Geophysical and Geodetic Characterization of the San Andreas Oasis at The Dos Palmas Preserve

Nathan Pulver (nwpulver@cpp.edu), Stacey Petrashek, Raul Contreras, Jascha Polet

Department of Geologic Sciences, Cal Poly Pomona

## Abstract

The San Andreas Oasis is a dwindling source of water in the Colorado Desert, located just east of the Hidden Springs Fault (HSF) and several kilometers from the northeastern shore of the Salton Sea. Recharge ponds have been placed in the area since the lining of the Coachella Canal in 2006, yet the Oasis has seen a decline in water levels. With no clear image of the subsurface, it is difficult to determine how to best combat these declining water levels. There are two prevalent interpretations of the HSF in this area by Babcock (1969) and Clark (1984). Babcock believes it continues as an uninterrupted fault through our study area, while Clark sees a left step near the Salt Creek area. This presentation will focus on an approximately ½ $km^2$ area of low vegetation just south of the main Oasis, which is thought to have a localized complex fault zone. This study is a portion of a larger research project, which also includes the northern and central parts of the Oasis. We use ground-based magnetic, very low frequency (VLF) and direct current resistivity techniques to better understand the subsurface water flow with respect to local subsurface structures.

A GEM systems proton precession magnetometer with a VLF attachment was used to conduct VLF and magnetic surveys. Significant signals in both the magnetic and VLF data occur along the mapped trace of the HSF and additional anomalies suggest at least one unmapped fault exists to the east. We ran resistivity experiments using an IRIS Syscal Kid and Syscal Pro switch to generate subsurface resistivity models. Profiles were created perpendicular to the HSF and across an area of suspected complex faulting. The resistivity models show a decreased resistivity value near the surface in all profiles except for one, where surface sediments are possibly saturated with brackish or very saline water. In the other resistivity profiles, vertical and sub vertical features indicate the presence of saturated or clay rich fault gouge. We conclude that there is at least one unmapped fault east of and parallel to the HSF, between the Dos Palmas Oasis and the San Andreas Oasis, which likely inhibits groundwater flow between the two oases. A second unmapped fault with a similar strike may be present even further east, but further measurements are needed. Some interferograms were made to gain additional information about subsurface groundwater movement, but the data is currently inconclusive and more interferograms need to be made.

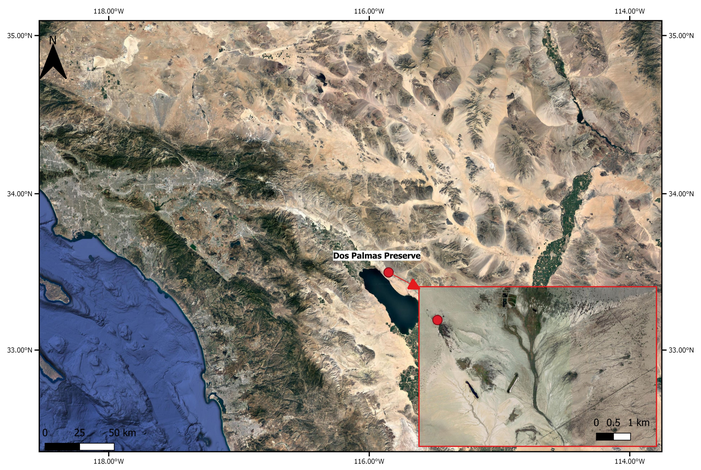


**Figure 1:** Location of the Dos Palmas Preserve, just east of the Salton Sea. The inset map shows the broad area of study.

## Data and Methodology

VLF surveys are effective at identifying conductors. Saturated fault gouge often acts as a conductor in the subsurface, and therefore, VLF surveying was used to identify any saturated fault gouge in the area of interest. A GEM systems magnetometer with a VLF attachment was used to collect both VLF and magnetic data simultaneously. The VLF profiles trend northeast across the study area, covering some of the faults mapped by the USGS as well as the area of the suspected unmapped fault. This unmapped fault was discovered by earlier research for this project, carried out by by S. Petrashek and D. Faherty covering the broader area of the Dos Palmas Preserve. Magnetic data was corrected for diurnal variations and short wavelength spikes using Oasis Montaj before being combined. MAGMAP reduction to pole and upward continuation filters (20m) were employed to remove surface anomalies.

Ground based DC resistivity profiles were collected with an IRIS Syscal Kid and IRIS Syscal Pro switch. Profiles were made with 24 electrodes with spacings of 10m and 5m in order to obtain images of the subsurface at different resolutions. Resistivity surveys are useful in identifying saturated fault zones and variations in depth to ground water height.

In order to obtain information about changes in groundwater movement through temporal and lateral patterns in surface motion, we used Interferometric synthetic aperture radar (InSAR). InSAR is a technique that can be used to create a map of surface deformation. This is done by taking multiple SAR images and finding the differences between the phase of the radar waves that return to an airborne or spaceborne vehicle. We used InSAR to create interferograms using satellite data from ENVISAT for time periods before and during the lining of the Coachella Canal which was finished in 2007.

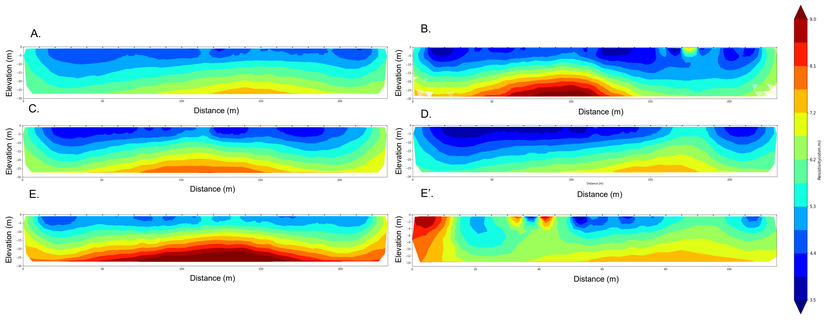


**Figure 2:** DC Resistivity profiles A through E' with corresponding traces shown in figures 3 and 4. All profiles begin on their southwestern most edge and end on their northeastern most edge. Profile E' has the same center point as E but is a shorter length. The electrode spacing for profiles A through E is 10m, while profile E' has a spacing of 5m. The color scale is uniform for all profiles, with color values shown on the right in ohm meters. Inversions were performed using the software ResIPy, a free and open source DC inversion application.

## Results

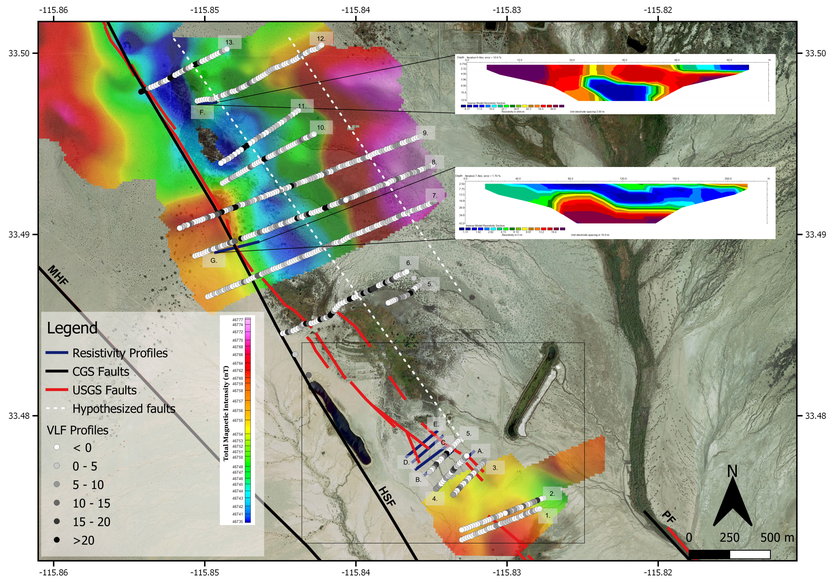


**Figure 3:** Overview of the larger research project. The black box indicates the area of focus for this presentation. Items labeled with numbers indicate VLF profiles, while items labeled with letters indicate resistivity profiles. The western most fault is the Mecca Hills Fault (MHF), and the fault in the south eastern corner is the Powerline Fault (PF). The Hidden Springs Fault (HSF) presents a discrepancy between USGS and CGS location. It is the central fault shown in the image in both black (CGS) and red (USGS). Major VLF anomalies can be seen as dark circles Previous work has shown significant signals outside of the mapped faults, indicating at least one unmapped fault, shown as white dashed lines.

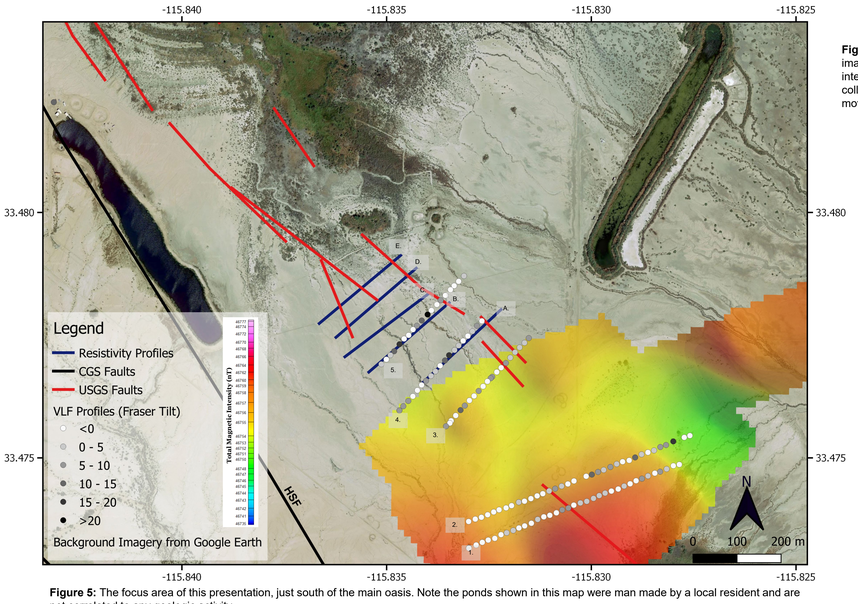


**Figure 5:** The focus area of this presentation, just south of the main oasis. Note the ponds shown in this map were man made by a local resident and are not correlated to any geologic activity.

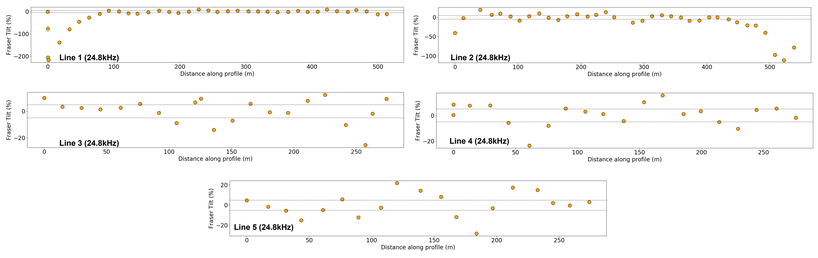


**Figure 6:** VLF lines 1 through 5 showing the distance along the line profiles with Fraser filtered values along the y-axis. A Fraser filter is applied to the VLF data in order constrain the location of structures that cause anomalous values. The dashed lines represent our threshold for considerable Fraser Tilt anomalies. All lines shown correspond to the 24.8 kHz frequency, although data was also collected at 24.0 and 25.2 kHz . The location of the 24.8kHz transmitter is approximately 340 degrees from north.

## Results

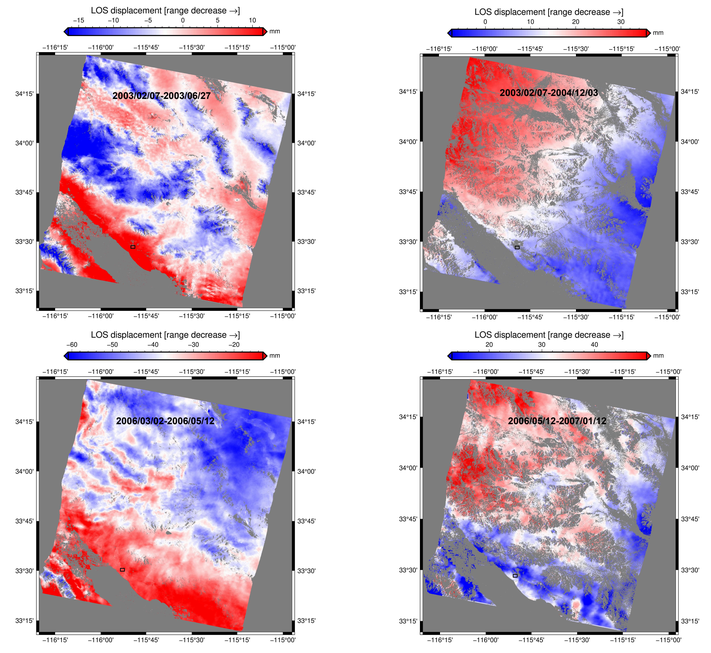


**Figure 6:** Interferograms projected into line of sight (LOS) displacement using Generic Mapping Tools SAR (GMTSAR) software. Raw single look complex (SLC) radar images are from the European Space Agency's (ESA) ENVISAT. The approximate area of the Dos Palmas Preserve can be seen by the black boxes. The top row of interferograms represent data from before the lining of the Coachella canal, which began in 2004 and was completed in 2007. The bottom row of interferograms show data collected during the process of the lining, when water was diverted elsewhere. Positive values of LOS displacement indicate a range decrease, meaning the ground has moved towards the satellite, while negative values indicate the opposite.

## Discussion

- Values for resistivity profiles all range from approximately 3 to 10 ohm meters. In the research area salt deposits are visible on the surface and profiles were collected after a recent rainstorm. With resistivity values so low, it is possible that the profiles are highlighting ranges in groundwater salinity. A small surface anomaly in profiles E and E' may roughly correlate to the eastern USGS fault that intersects profile E.
- VLF lines 1 and 2 show extremely large anomalous values in the same location. These values are not characteristic of geologic materials and are most likely caused by a conductive debris on the ground. Lines 3 through 5 have differing values of Fraser tilt, but the anomalous values (above 5% Fraser Tilt) roughly line up with each other in a NW/SE direction. This could indicate that the faults in the area are more continuous than the USGS faults suggest, or that there are many small sub-faults slicing up the area.
- The interferogram from 2003/02/07 to 2004/12/03, nearly two years, shows LOS velocity, meaning velocity towards or away from the satellite, of approximately 8mm/yr before the lining of the canal while the interferogram 2006/05/12-2007/01/12 during the lining gives a velocity of approximately +37mm/yr. The difference in velocities before and during is then +29mm/yr. These measurements were taken specifically from the Dos Palmas Oasis area in the interferograms. There are many reasons to not take this at face value, for instance because 2006-2007 was an El Nino year. Seasonal signals, atmospheric effects and satellite baselines are all sources of error. More research must be conducted to have conclusive findings.

## Conclusion

Resistivity data was inconclusive due to the wet and saline conditions in the field. More profiles need to be collected during a drier period in order to get a better visual of the subsurface. VLF lines contained some promising findings but further validation should be done in order to constrain the anomalies by conducting additional VLF or resistivity surveys or collecting more comprehensive magnetic data. Additional interferograms should be created with a larger span of date ranges in order to get a better constraint on the effects of the lining of the Coachella Canal. In order to get the best temporal view of changes, an interferometric time series should be created but the large perpendicular baseline of ENVISAT data poses a challenge.

## References

Babcock, E.A., 1974. Geology of the northeast margin of the Salton Trough, Salton Sea, California. *Geological Society of America Bulletin*, *85*(3), pp.321-332.

Blanchy, G., Saneiyan, S., Boyd, J., McLachlan, P. and Binley, A., 2020. ResIPy, an intuitive open source software for complex geoelectrical inversion/modeling. *Computers & Geosciences*, *137*, p.104423.

Clark, M.M., 1984. *Map showing recently active breaks along the San Andreas fault and associated faults between Salton Sea and Whitewater River-Mission Creek, California* (No. 1483).

Faherty, D. and Polet, J., 2018. Geophysical investigation of fault-groundwater interaction: San Andreas Oasis site study. In *SEG Technical Program Expanded Abstracts 2018* (pp. 2496-2500). Society of Exploration Geophysicists.

## Acknowledgements

Research in this publication was supported by the MENTORES (Mentoring, Educating , Networking, and Thematic Opportunities for Research in Engineering and Science) project, which is funded by the Title V grant PPOHA (Promoting Post-baccalaureate Opportunities for Hispanic Americans | U.S. Department of education, Washington D.C. Additional research support was provided by the Learn Through Discovery grant.
We would like to thank the Bureau of Land Management for their logistical support, specifically Joel Minor and Bob Pope. We would also like to thank the individuals who helped collect data in the hot desert with us: Kyle Macy, Peter Flores, Anisha Tyagai, Jose Gomez. Lastly, we would like to thank Eric Lee for allowing us to access his property in order to collect data.