possibly much greater and pose the greatest concern for the foundation stability of the dam. Joint surfaces in exposures are commonly wavy, rough to irregular and wide open.

4. An important subsidiary joint pattern trends NNW and controls the direction of the river channel and valley at the dam site and 2 km upstream. A NNW trending right lateral fracture-shear zone emerges from the river channel about 500 meters downstream where the channel abruptly bends to the NNE and N. The fracture-shear zone continues off to the NNW along the Quebrada de la Santa and into a tributary gulley. It is probable that this fracture-shear zone extends SSE downstream below the river channel and the dam site but this has yet to be established.

Recommendations

1. Continued monitoring and definition of the crustal seismic activity in and around the Rio Grande de Loiza, Rio Valenciano and Rio Humacao river valleys. Pursuit and procurement of GPS data to determine estimated movements between the Fajardo, Humacao and Rio Piedras continuous sites.

2. Perforation of 3-4 borings and cores in the river channel along the dam centerline to precisely define the geologic structure below the river bed, in order to determine both the existence and character of the fracture shear zone and the continuity of the sub-horizontal joints below the river.

3. Continued mapping and analysis of bedrock structures in the dam site area, rivers valleys associated with faults or earthquakes and outcrops of previously mapped faults.

Cited References

Black and Veatch Puerto Rico, 2000, East-Central Regional Aqueduct System, Rio Valenciano Dam and Reservoir Data, Infrastructure Financing Authority Report, June 29, 2000; 404 p.

Broedel, C.H., 1961, Preliminary geologic map showing iron and copper prospects in Juncos quadrangle, Puerto Rico: USGS Miscellaneous Geologic Investigations Map I-326.

Cox, D.P. and Briggs, R.P., 1973 Metallogenic map of Puerto Rico; USGS Miscellaneous Geologic Investigations Map I-721.

Cox. D.P., Marvin, R.F., M'Gonigle, J.W., McIntyre, D.H., and Rogers, C.L., 1977, Potassium-argon geochronology of some metamorphic, igneous, and hydrothermal events in Puerto Rico and the Virgin Islands; USGS Journal of Research, v. 5, no. 6, p. 689-703.

Jansma, P.E. and Mattioli, G.S., 2005; GPS results from Puerto Rico and the Virgin Islands: Constraints on tectonic setting and rates of active faulting; in Mann, P., ed., Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands, and Offshore Areas; Geological Society of America Special Paper 385; p.13–30.

Miller J.A., Whitehead, R.L. and Olcott, P.G.. 1997 Ground Water Atlas of the United States Segment 13, Alaska, Hawaii, Puerto Rio and the US Virgin Islands; USGS Hydrologic Investigations Atlas 730-N.

M'Gonigle, J.W., 1978, Geologic map of the Humacao quadrangle, Puerto Rico; USGS Miscellaneous Geologic Investigations Map I-1070.

APPENDIX F

GEOLOGIC EVALUATION STUDIES FOR THE RIO VALENCIANO DAM:
1. FAULT EVALUATION-PHASE ONE – WILLIAMS ASSOCIATES

Preliminary Report

GEOLOGICAL EVALUATION STUDIES FOR THE RIO VALENCIANO DAM

1. Fault Evaluation-Phase One

Prepared for:
CSA Group
San Juan, Puerto Rico

Prepared by:
Williams Associates
West Tisbury, Massachusetts

in collaboration with:
M. Tuttle & Associates
Georgetown, Maine

04 January 2007

Executive Summary

No unequivocal evidence of activity of the Northern Puerto Rico fault zone (NPRFZ), in the region surrounding the proposed Valenciano damsite has been found during Phase 1 of the Valenciano dam fault evaluation study. However three areas containing possible evidence of fault activity have been identified in association with primary bedrock faults. These sites have been inspected in the field and two of the sites exhibit features consistent with activity during the past 35,000 years. To evaluate whether the features identified during phase 1 are, in fact, produced by fault motion, a field program has been developed to test the Phase 1 interpretations with subsurface investigation. At least one trench excavation is recommended at up to four sites. The phase 1 fault study has provided an extensive review of primary materials including aerial photographs and LIDAR data to evaluate activity of the NPRFZ.

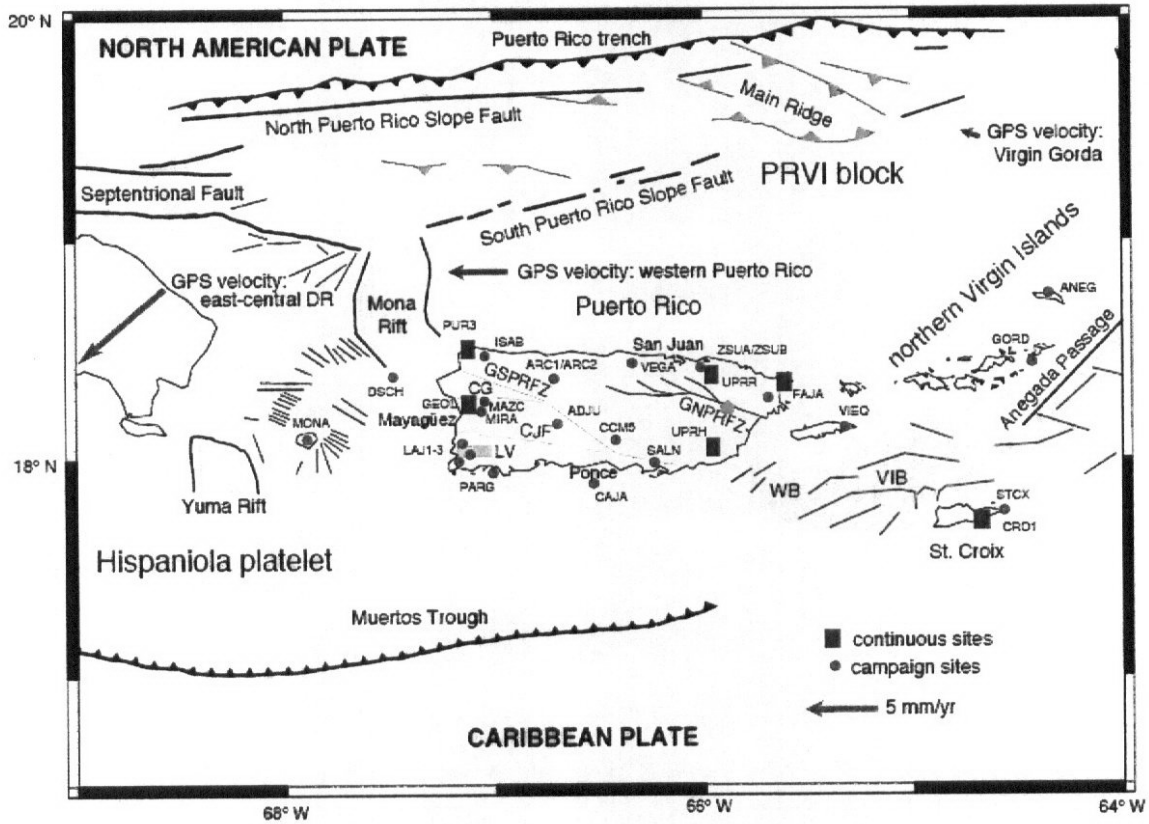

Figure 1 Regional map showing geography and major faults (From Jansma and Mattioli, NEHRP report, 2005). Proposed Valenciano Dam is located at green dot near the top of "F" in GNPRFZ. Blue squares are locations of continuous GPS stations placed to measure differential motion across faults within the Puerto Rico - Virgin Islands block (PRVI). Red dots are benchmark monuments that have been occupied temporarily in "campaign" surveys. Figure 2 shows GPS results to the end of 2005. Grey outlines areas of inferred active extension from fault styles and earthquake geometries. Faults with sawtooth pattern are reverse faults. The flags are located on the hanging wall (overriding) block. Sense of motion on other faults is believed to be lateral or extensional. Mann and others (2005) suggest that the geometry of the GNPRFZ is consistent with right-lateral motion. Jansma et al., indicate that motion between St Croix and eastern Puerto Rico (Andegada Passage fault zone) is less than 2 mm/yr.

Introduction

This Phase-One Fault Evaluation is based on our understanding of the requirements for a Seismic Hazard Analysis (SHA) for completion of the P-EIS for the Rio Valenciano Dam. The purpose of the fault evaluation is to determine whether or not faults in the vicinity of the proposed dam, specifically the Northern Puerto Rico fault zone (NPRFZ), have been active in the past 35,000 years and to estimate maximum magnitude earthquakes and their source locations to be used in the development of seismic design parameters and ground motion records for the Rio Valenciano dam. Primary components of this part of the study are: (1) review of previous studies; (2) interpretation of historical and modern aerial photographs; (3) acquisition, processing and interpretation of regional continuous airborne laser elevation mapping (LIDAR) data; (4) field mapping to evaluate features interpreted in components 2 and 3; (5) report of preliminary findings of these studies with recommendations for critical evaluation of the preliminary findings.

Previous studies

This Valenciano Dam fault evaluation was initiated with compilation and review of primary geological and geotechnical data pertaining to the Rio Valenciano site and the NPRFZ. This study relies on prior studies undertaken by Black & Veatch (2001),

and expands on those studies with primary investigation and with material from publications and consultant's reports. We have endeavored to obtain the most relevant

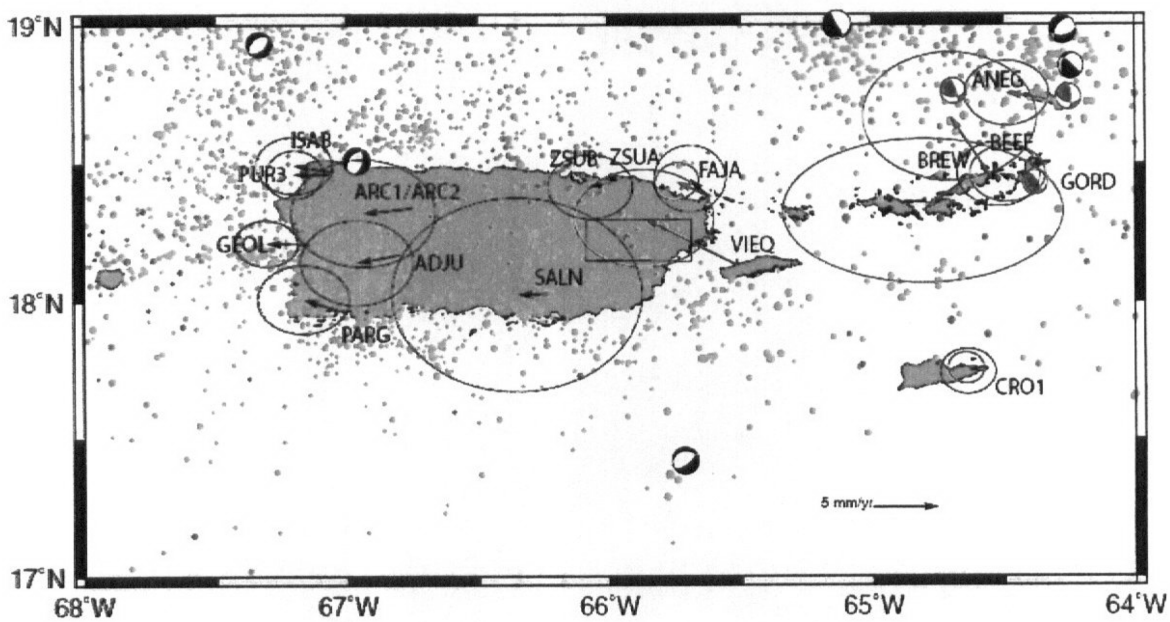

Figure 2. Map of Puerto Rico and Virgin Islands. Study area in rectangle (area of Figure 3) (From Jansma and Mattioli, NEHRP report, 2005).. Epicenters (blue dots) and GPS-derived velocity as of November 2005. Ellipses show uncertainly in GPS vector solution. Velocity scaled to arrow at lower right. Note that motions are relative to St. Croix. Red arrow at FAJA (3mm/yr-NW) is a preliminary solution based on short time series, but appears similar to earlier solution (in black). Comparing FAJA and ZSUB to the best western Puerto Rico vectors, PUR3, GEOL, and PARG indicates 1-2 mm/yr differential motion between these locations

materials for evaluation of fault hazards at the proposed dam site, particularly materials that were generated subsequent to the Black and Veatch investigation. The reviewed materials are listed in the *References* section below.

GPS velocity studies. GPS velocity studies are a primary tool for providing fundamental constraint of potential fault motion. GPS data are collected over a period of several years to detect differential motion across regions of interest. Investigation of deformation across the region of the NPRFZ by means of GPS are by no means conclusive, but as time passes the resolution of those analyses will improve. The reason for current uncertainty in GPS solutions are: (1) slow strain rates, (2) short periods of investigation and (3) problems with instrumentation and site stability (Jansma and Mattioli, 2005). Despite these problems, the GPS studies are permissive of small (i.e. 1 to 3 mm/yr) differential motion across the NPRFZ. The GPS data, and the regional plate tectonic context of Puerto Rico have motivated continuing investigation of seismicity and active faulting on the Island. *Geological history.* The preliminary GPS data discussed above have resulted in the questioning of interpretations developed from extensive prior geological mapping, i.e., that major deformation of Puerto Rico ended in middle to late Tertiary time, at least 10 million years before present. Typical evidence for this is expressed in terminations of extensive Cretaceous-age faults and folds against Eocene (Paleocene?) intrusive rocks (the Rio Blanco stock) in the Luquillo Mountains of northeastern Puerto Rico (Seiders, 1971). Relations such as these are indicative that many onshore faults of Puerto Rico have little or no late Tertiary and post Tertiary activity.

To our knowledge, evidence of Quaternary fault activity has not been found for either the SPRFZ or NPRFZ. Recent work shows, however, that the South Lajas fault in south-westernmost Puerto Rico ruptured twice in the past 7500 years (Prentice and Mann, 2005). In addition, a paleoliquefaction study found evidence of a large earthquake along the north-central coast of Puerto Rico about 2,800 +/- 400 years B.P. and suggested an eastern extension of the Septentrional fault, the Great Northern Puerto Rico fault zone, or some yet unidentified fault as possible sources of the paleoearthquake (Tuttle et al., 2005a).

<u>Quaternary fault assessment.</u>

The principal bedrock faults delineate zones of crustal weakness, and are thereby the most likely locations for reactivation or continuing fault activity. Our approach to detection of late Quaternary and Holocene activity of the NPRFZ has been to focus on the most prominent bedrock fault intersections with valley deposits, and the projection of those fault trends within Quaternary and Recent valley deposits, particularly river terraces and alluvial fans. The presence of faults was also investigated within prominent valley and ridge lineaments and linear valley margins. We searched for evidence of active faulting within sediments of the most prominent linear valleys and along linear valley margins. We also searched for mid valley active fault features in valleys with prominent bedrock faults projecting into the mid valley area. The area of study extends from the east coast of Puerto Rico between Naguabo and Humacao, to the western extent of the Gurabo-Loiza valleys near Caguas (Figure 3).

We note that the geometry of the NPRFZ is distributed and complex, and detection of possible active features requires broad reconnaissance investigation. Some strands of the NPRFZ are more prominent, particularly those associated with extensive linear valleys or separating contrasting and apparently substantially displaced bedrock units. Potential active fault landform features associated with the most prominent faults were closely inspected with the aid of remotely sensed data during the Phase 1 investigations. Those areas with features most suggestive of active faulting were inspected in the field.

Geological maps and digital imagery. We reviewed USGS maps and USGS DEM (digital elevation model) images in the region of study to locate those areas characterized by sedimentary cover, i.e. larger valley areas, because sediment cover is usually required to evaluate the presence and age of Quaternary faulting. The majority of valley areas were then recommended for the project's high-resolution LIDAR survey. As a tool for delineating the Lidar survey area, "Google Earth" (G-Earth) imagery and location tools were employed. We discovered that the G-Earth geo-referencing tools are very adequate for the purposes of this study, and that the G-Earth image quality in the study area is very good (resolution ~2m). Thus G-Earth "Professional" software package was obtained and has been used extensively for compilation, interpretation and presentation. Major fault features from prior mapping were digitized, and new interpretations of larger landform features were compiled in an editable geo-located G-Earth "Place" file. Key areas in the G-Earth compilation, particularly those locating proposed trenches, are presented in Appendix 1.

Aerial photography. An extremely useful acquisition for this project is historical aerial photography. A full island photo set was recorded in 1936-1937. The quality of the photos is threefold. With a few exceptions (from film damage) the images are extremely clear and detailed, the landscape is essentially bare, with most valley areas under cultivation and mountain areas deforested, and cultural landscape modification of valleys and valley margins, particularly in the Caguas- is profoundly less than modern. The historical photos have been examined in a reconnaissance fashion from the area around the Loiza-Gurabo River confluence to the coastal area between Naguabo and Humacao. The Valenciano Valley area was also examined. Selected "reconnaissance" air photo interpretations are presented in Table 1 and Appendix 2.

LIDAR survey. The highlight of the Phase 1 study has been the acquisition, processing, and preliminary review of Lidar imagery. The power of these data to address questions and controversies of fault activity is clear. The Lidar data have been examined through

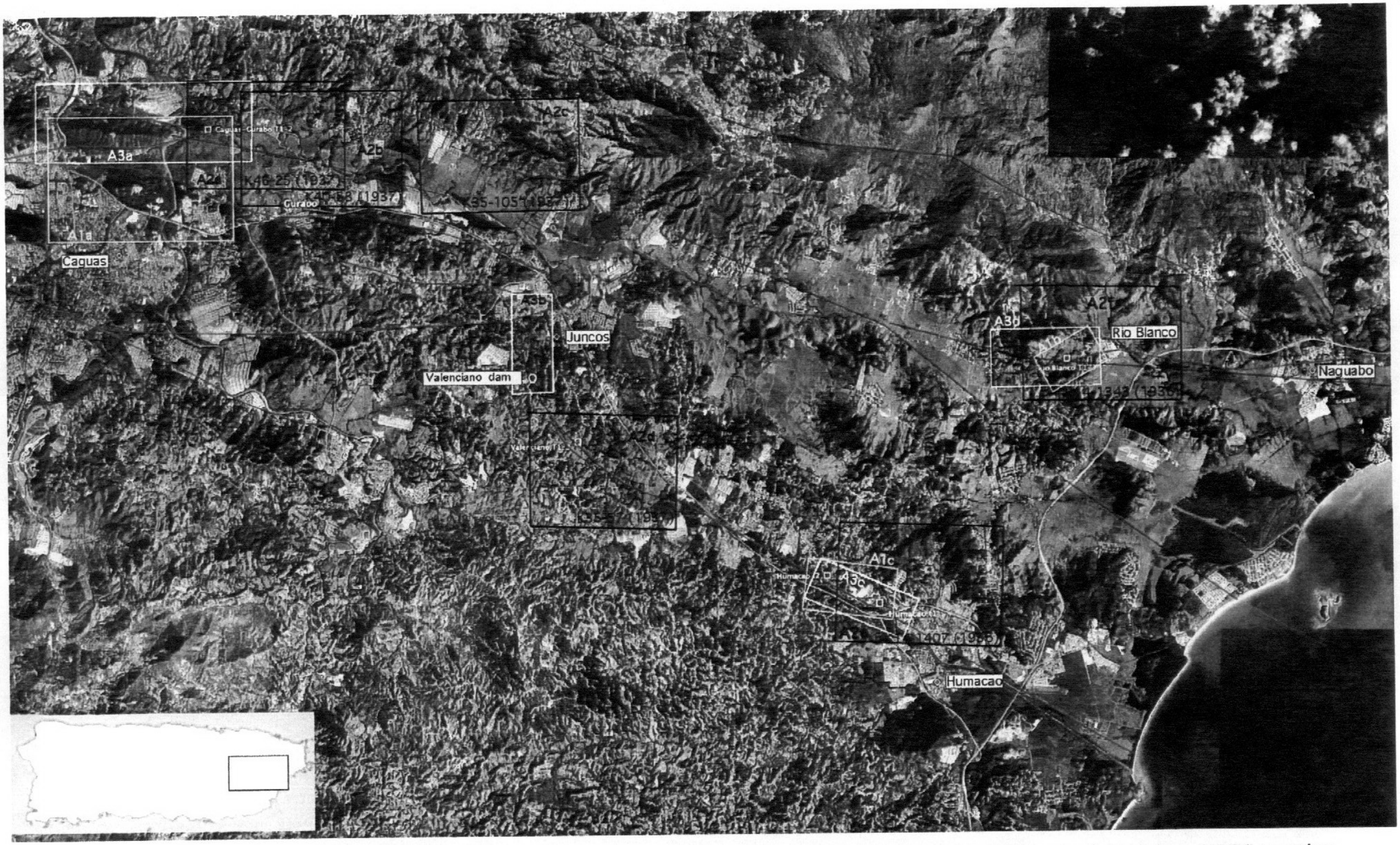

Figure 3. General extent of study area. Map area is 35 by 20 kilometers. Most prominent bedrock faults, colored blue, are derived from USGS mapping. Prominent lineaments (permissive faults) interpreted in this study from landform features viewed in published digital elevation models and Lidar data compiled in this study are denoted by red lines. Possible active fault features selected for continuing investigation in Phase 2 are colored pink. Yellow rectangles are detailed planning maps of candidate trench sites (Williams Appendix 1). Black rectangles are some of the 1936-1937 air photos with suggestive fault or fault-like features (Williams Appendix 2). White rectangles are selected Lidar images in areas proposed for further study (Williams Appendix 3).

fault features, and to further evaluate features seen in photography and in the field. The main drawback of the Lidar data is the extent of modification of areas for development. The pairing of Lidar and good historical photography provides the Valenciano project with powerful tools for fault evaluation in the region. With these high quality tools, the Phase 2 products can be expected to be robust. Sample Lidar data are presented in Appendix 3.

Fieldwork. In order to evaluate our preliminary interpretations of possible active fault feature, we undertook two weeks of field work during Phase 1. Site mapping was conducted in the Rio Blanco, Gurabo, Humacao, Loiza, and Valenciano Valleys. While definitive evidence of active faulting has not been developed, we have evaluated multiple sites with suspect fault features. Firstly near the town of Rio Blanco where a set of right-deflected streams are contained within a body of coarse alluvium, and thus do not appear to be controlled by bedrock joint patterns, secondly near the Loiza-Gurabo River confluence, where a prominent, and apparently youthful lineament extends from Rte 52 to the eastern edge of Caguas, and thirdly near Humacao, where the fault controlled Humacao gorge transitions to a pristine terrace with candidate fault features just SW of the city. More equivocal features have been identified and field checked in the eastern Rio Blanco Valley, and the central and eastern Gurabo Valley.

Because the possibility of active faulting in the immediate area of the dam, however remote, was raised in the original project proposal, two days of field work were focused in the Valenciano Valley area. A reconnaissance study was carried out in the whole valley area, utilizing all the secondary and private roads throughout the valley. Subsequent field mapping is summarized in Table 2, and Appendix 1. Field mapping was focused in the area of a prominent set of fluvial terraces located 2 km upstream of the dam site. A "permissive" alignment for active faulting had been determined in the valley from evidence of continuity of joint sets interpreted in the 1937 air photos. The joints are expressed by multiple parallel stream patterns. The joint patterns are an extremely useful feature for interpretation, in that they exclude youthful faulting across most of the area of the width of the valley, particularly extending into the valley from the south. Mapping shows that shallow bedrock across the terrace "pediment" is not promising for definitive evaluation of active faulting. A soil is developed on a semi-continuous sand deposit and weathered granite "grus". The soil holds limited promise for fault evaluation (i.e. presence of absence of soil offset). Discontinuous bedrock outcrop along the channel can also be further utilized for fault evaluation, by searching for shear zones or weathered-out shear products along the stream margin. Additional Phase 2 work will be undertaken to delineate the gross joint patterns in this area. We hope that the continuity of joint sets will help to address the question of presence or absence of active faulting in the immediate Valenciano Valley area.

Where feasible, the Phase 2 trenching program is designed to move from older to younger deposits at each site such that, if faulting is not found in older materials, younger materials will probably not be investigated unless geometry or confidence of findings is not satisfied in the initial trench investigation. Alternatively, if faulting is found in older materials, younger deposits available at the sub-area can be trenched to evaluate youthfulness relative to the criteria outlined in the original proposal and as defined by FERC guidelines.

Summary

While no unequivocal evidence of active faulting has been developed during Phase 1, three areas of potential active faulting have been identified in association with primary bedrock faults. These features have been inspected in the field and found permissive of an interpretation of fault activity at two of the sites. Strategies have been developed for subsurface investigation by a program of trenching. A sequence of trenches is recommended at up to four subareas. The trench program is designed to move from older to younger deposits, such that if faulting is not found in older materials, younger materials will probably not be investigated, unless geometry or confidence of findings is not satisfied in the intitial trench investigation. Alternatively, if faulting is found in older materials, younger deposits available at the subareas can be trenched to evaluate youthfulness relative to the criteria outlined in the original proposal and as defined by FERC guidelines.

Acknowledgements

Important assistance with this study has been provided by Prof. James Joyce, Mr. Alex Soto, Mr. Jim Swaisgood, and Ms. Mariecarmen Cardova.

Table 1. Review of Aerial Photographs for Identification of Anomalous Features Possibly Related to Faulting or Earthquake-Induced Liquefaction.

Location	**Mapped Surficial Deposits**[†]	**Aerial Photographs* Reviewed**	**Features Possibly Related to Faulting**	**Features Possibly Related to Liquefaction**
Rio Anton Ruiz floodplain in vicinity of Punta Santiago and Anton Ruiz	Quaternary alluvial plain and beach deposits (Qap, Qb)	K12-1278 to 1283 K14-1326 to 1328 K14-1339 to 1341 K14-1382 to 1383	K14-1326: Northwest oriented light-colored lineament coincident with mapped trace of Cerro Mula fault	K12-1280 and K14-1326: Beach ridges with small elliptical light-colored patches; K-14-1383: Small elliptical light-colored patches
Rio Blanco floodplain in vicinity of Naguabo and Rio Blanco	Quaternary alluvial plain and beach deposits (Qap, Qb)	K12-1284 to 1287 K14-1342 to 1345	K14-1342: Coincident with trace of Pena Pobre fault, river channel changes from fairly straight to meandering with large loops and prior channel abandoned for present more southerly course	K12-1284: Peculiar soil pattern near end of abandoned channel may be due to lateral spreading; K14-1342: Large elliptical light-colored patches near Rt 31 bridge.
Rio Humacao floodplain near Humacao	Quaternary alluvial plain and beach deposits	K14-1328 (poor quality) K14-1336, 1337 (poor quality) K14-1385	K14-1385: Linear northwest-oriented depressions near abandoned channel of Rio Humacao between	K14-1385: Anomolous soil pattern between abandoned and recent channels of

	(Qap, Qb)	K30-34 to 35 K14-1405 to 1407	Santa Teresa and Humacao; K14-1406: Linear edge of upper terrace along trend of fault trace mapped along linear northwest oriented section of Rio Humacao	Rio Humacao between Santa Teresa and Humacao
Rio Gurabo floodplain from Pena Pobre to confluence with Rio Loiza	Quaternary alluvium, piedmont fan and alluvial terrace deposits (Qal, Qft, Qt)	K14-1379 to 1381 K49-35 K14-1411 to 1413 K32-19 to 24 K32-61 to 66 K35-51 to 54 K35-101 to 105 K42-48 K40-52 to 55 K32-113 K46- 24 to 26 K41-49 to 51	K14-1380: Aligned linear stream segments and en echelon lineaments near mapped trace of Pena Pobre fault; K32-62 and K35-52: Aligned lineaments crossing and defining edge of alluvial terraces, also along linear river segments; K35-52 and K35-105: Aligned topographic lineaments through saddles, along lateral valleys, and across stream deflections; K40-53: Aligned lineaments crossing and defining edge of alluvial terraces; K46-25: Aligned topographic lineaments across Quaternary terraces, possible sag-ponds, and offset of terrace risers near trace of Cerro Mula fault	K35-52: From Rio to Garabo, river is actively eroding alluvial deposits providing good exposure for reconnaissance; K40-53: Anomalous soil pattern in point bar deposits may be related to sand blows;
Rio Loiza floodplain	Quaternary alluvium, terrace deposits (Qal, Qt)	K42-41 to 45 K32-108 to 110 K46-19 K41-49 to 51	None observed.	None observed; Holocene floodplain is very narrow
Rio Valenciano watershed	None mapped	K32-66 to 69 K35-53 to 58 K35-96 to 102	K32-67: Aligned linear northwest-oriented stream segments along mapped trace of	K35-57: Curvilinear cracks in possible terrace deposit near mapped trace of

			unnamed fault; K35-57: Aligned linear northwest-oriented stream segments and depressions along mapped trace of unnamed fault	unnamed fault; K35-53: Lower river segment actively eroding alluvial deposits providing good exposure for reconnaissance

* Photographs taken in 1936 and 1937.

Table 2.
Field Observations on terrace 2 km upstream of Valenciano dam site PLW 12/17/2006

Loc	Feature	lat	long
1	Unmarked access road	18.1748	65.9031
2	weathered granite outcrop	18.1814	65.9029
3	accessible field, grus cover on bedrock	18.1781	65.9021
6	linear valley	18.1787	65.8942
8	weathered granite outcrop	18.1930	65.9200
9	weathered granite outcrop	18.1924	65.9147
10	granite outcrop	18.1934	65.9171
11	med sand deposit over granite bedrock	18.1946	65.9139
12a	weathered granite: strath terrace	18.1957	65.9145
12b	long rapid through granite boulders	18.1957	65.9145
13	5± m sand on bank	18.1916	65.9120
14	Approx. 4 m sand over boulder in bank of rapids area	18.1957	65.9145
15	trench on projection of valley?	18.1950	65.9161
16	linear ridge	18.1903	65.9158
17	approx. 1m grus over bedrock	18.1918	65.9161

References

Black and Veatch draft EIS 2001.

Calais, E., C. DeMets, T. Dixon, P. Mann, Microplate tectonics in the northeastern Caribbean

Calais, E., Y. Mazabraud, B. Mercier de Lépinay, P. Mann, G. Mattioli, and P. Jansma (2002), Strain partitioning and fault slip rates in the northeastern Caribbean from GPS measurements, *Geophys. Res. Lett.*, *29*(18), 1856, doi:10.1029/2002GL015397

Grindlay, N., Abrams, L.J., del Greco, L., 2005. Toward an integrated understanding of Holocene fault activity in western Puerto Rico: Constraints from high-resolution seismic and sidescan sonar data, in Mann, P., ed, Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands and Offshore Areas, GSA Special Paper 385, p. 139-160.

Hippolyte, J.C., Mann, P., and Grindlay, N.R., 2005, Geologic evidence for the prolongation of active normal faults of the Mona rift into northwestern Puerto Rico in Mann, P., ed, Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands and Offshore Areas, GSA Special Paper 385, p. 16171-160.

Huefano, V., Hillebrandt-Andrade, C., and Baez-Sanchez, G., 2005. Microseismic activity reveals two stress regimes in southwestern Puerto Rico, in Mann, P., ed, Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands and Offshore Areas, GSA Special Paper 385, p. 81-101.

Idriss, I.M., and R.J. Archuletta, 2005. Evaluation of Earthquake Ground Motions, FERC Guidelines Draft Document, http://www.ferc.gov/industries/hydropower/safety/guidelines/eng-guide/chap13-draft.pdf.

Jansma, P.E. Unpublished summary, Microplate tectonics in the northeastern Caribbean. http://comp.uark.edu/~pjansma/research_prvi.html

Jansma, P.E., and G.S. Mattiolli, Constrains on active faulting and diffuse extension in Puerto Rico and the Virgin Islands from GPS geodesy, USGS Annual Report, 2005. http://erp-web.er.usgs.gov/reports/annsum/vol47/ceu/04hqgr0091.pdf

Jansma, P., G. Mattioli, A. Lopez, C. DeMets, T. Dixon, P. Mann and E. Calais, Neotectonics of Puerto Rico and the Virgin Islands, northeastern Caribbean from GPSgeodesy, Tectonics, 19, 1021-1037.

Mann, P., Prentice, C., Hippolyte, J.C., Grindlay, N., Abrams, L., and Lao-Davila, D., 2005. Reconnaissance study of Late Quaternary faulting along Cerro Goden fault zone, western Puerto Rico, in Mann, P., ed, Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands and Offshore Areas, GSA Special Paper 385, p. 115-138.

Mann, Paul; Calais, Eric; Ruegg, Jean-Claude; DeMets, Charles; Jansma, Pamela E.; Mattioli, Glen S., 2002, Oblique collision in the northeastern Caribbean from GPS measurements and geological observations, Tectonics.

Mueller, C.S., Frankel, A.D., Peterson, M.D. and Leyendecker, M.V., 2003. Documentation for 2003 USGS Seismic Hazard Maps for Puerto Rico and the U.S. Virgin Islands, U.S. Geological Survey Open-File Report 03-379, 12 p.

Prentice, C. and Mann, P., 2005. Paleoseismic study of the South Lajas fault: First documentation on an onshore Holocene fault in Puerto Rico, in Mann, P., ed, Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands and Offshore Areas, GSA Special Paper 385, p. 215-222.

Prentice, C., Santos, H., Mann, P., Tuttle, M., Asencio, E., Grindlay, N. and Joyce, J., 2005, Field Trip – Recent Tectonics and Paleoseismology in Western Puerto Rico: Seismological Society of America, Annual Meeting, San Juan, Puerto Rico, May 3-4, 2003, 52 pp.

ten Brink, U.S., Danforth, W., Polloni, C., Andrews, B., Llanes Estrada, P., Smith, S., Parker, E., Uozumi, T., New seafloor map of the Puerto Rico trench helps assess earthquake and tsunami hazards in the northwest Caribbean, EOS, v., 85, no., 37, p. 349, 354, 2004.

ten Brink, U.S. and Lin, J., Stress interaction between subduction earthquakes and forearc strike-slip faults: Modeling and application to the northern Caribbean plate boundary, J. Geophys. Res., 2004JB003031, v. 109, B12310, doi:1029/2004JB003031, 2004.

Tuttle, M. P., Dyer-Williams, K., Schweig, E.S., Moya, J.C., and Sims, J. D., 2005a, Paleoseismology of Puerto Rico from earthquake-induced liquefaction features, U.S. Geological Survey, Final Technical Report, 22 p.

Tuttle, M.P., Dyer-Williams, K., Schweig, E.S., Prentice, C.S., Moya, J.C., and Tucker, K.B., 2005b, Liquefaction induced by historic and prehistoric earthquakes in western

Puerto Rico, in Mann, P., ed, Active Tectonics and Seismic Hazards of Puerto Rico, the Virgin Islands and Offshore Areas, GSA Special Paper 385, p. 263-276.
von Hillebrandt-Andrade, C.G. 2005, USGS NEHRP Report: Holocene Faulting of the Cerro Goden Fault, Western Puerto Rico, Collaborative Research with Judith Zachariasen and University of Puerto Rico at Mayaguez , USGS Annual Report, 2005. http://erp-web.er.usgs.gov/reports/annsum/vol46/ceu/05hqgr0075.pdf

APPENDIX 1 selected planning images

APPENDIX 2 selected 1936-1937 air photos

APPENDIX 3 selected Lidar data