COCA RIVER REGRESSIVE EROSION PHENOMENON, CAUSES AND IMPACTS. OVERVIEW OF THE PROBLEM.

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Pablo Espinoza-Girón, Studies, Design and Monitoring Division Leader, Comisión Ejecutora Río Coca, Corporación Eléctrica del Ecuador, Quito, Ecuador.
pablo.espinoza@celec.gob.ec

Paul Boyd, USACE, Omaha, NE
paul.m.boyd@usace.army.mil

EXTENDED ABSTRACT

San Rafael Waterfall Ecuador's tallest, at approximately 150 m in height, was located in the Ecuadorian Amazon Region, approximately 100 Km northeast of Quito (capital of Ecuador), 20 Km downstream of the confluence of Quijos and Salado (Coca River main tributaries). On February 2nd, 2020, the San Rafael Waterfall, collapsed naturally. The waterfall was created by one of the multiple eruptions by Reventador Volcano that produced a lava flow that cloaked the Coca River, such that the riverbed became a giant natural reservoir that, eventually were to be filled with more volcanic material (avalanches), alluvial and lacustrian solids brought by the river. Over the last twenty thousand years, the Coca reached an equilibrium state.

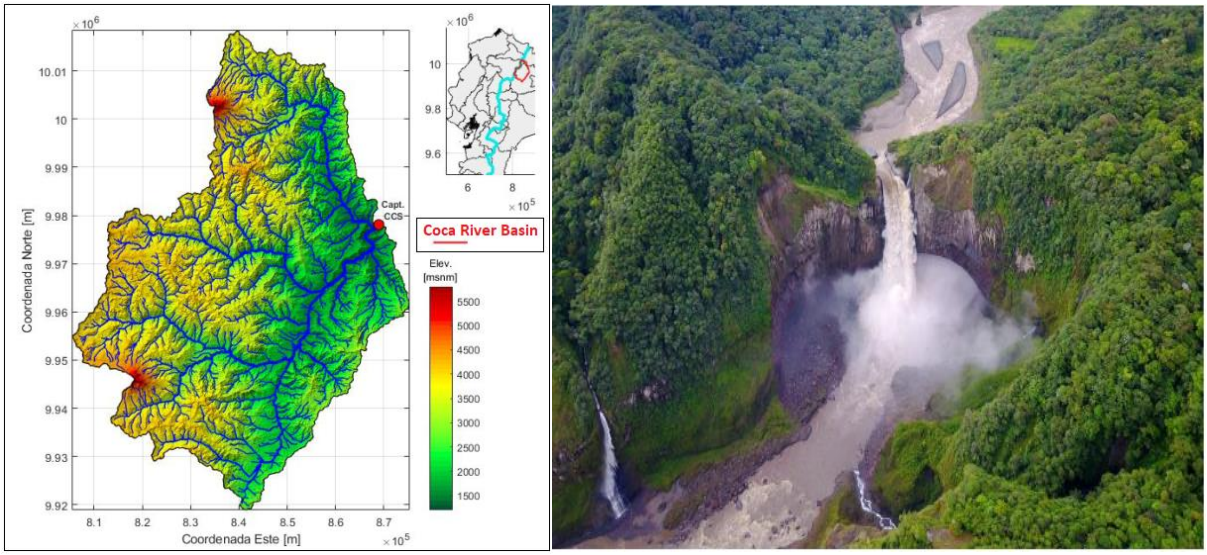

Figure 1: Coca River basin general location. San Rafael Waterfall, 2015

With the collapse, a regressive erosion process of the Coca River and its tributaries began, which has generated an undermining of the main channel, erosion of both bank slopesand subsequent landslides, and damage to infrastructure located along the course of the river (oil pipelines, roads, power lines). Approximately 300 million tons of not-consolidated-nor-competent volcanic, alluvial and lacustrian material have been eroded and subsequently deposited downstream up to 100 Km beyond the waterfall site.

Figure 2: Reventador Volcano's directly influence over the Coca River valley.

The intake structures of Coca-Codo-Sinclair (CCS), Ecuador's largest hydroelectric complex, are located about 19 Km upstream of where the waterfall once stood. CCS has 1500 MW of installed capacity, and pulls water from the Coca River through a 25 Km tunnel by its right bank. CELEC EP (Ecuador Electric Corporation) is the government company that is responsible for the operation and maintenance of this complex. CELEC's 7,000 employees serve in 14 districts, one of which is the Río Coca Executive Commission, in charge of monitoring the erosion and sedimentation processes, carrying out studies, and building the necessary structures in order to prevent erosion that could affect the normal operation of CCS and its ability to produce electricity.

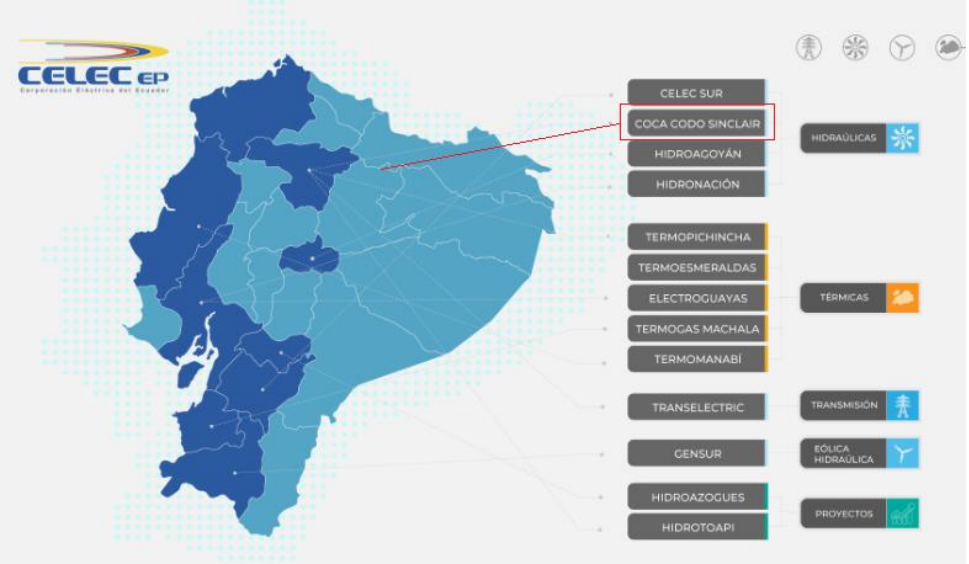

Figure 3: CELEC EP organizational chart.

The erosion front (headcut) as of April 8th, 2023 has advanced to 7+560 Km distance from the intake structure. The rate of advancement has varied since the waterfall collapse, for it depends on several factors, among them, the hardness of the riverbed materials, the width of the channel, and especially the flows. The greatest longitudinal migrations of the erosion front and deepening of the river correspond to events with more than 1,500 cms.

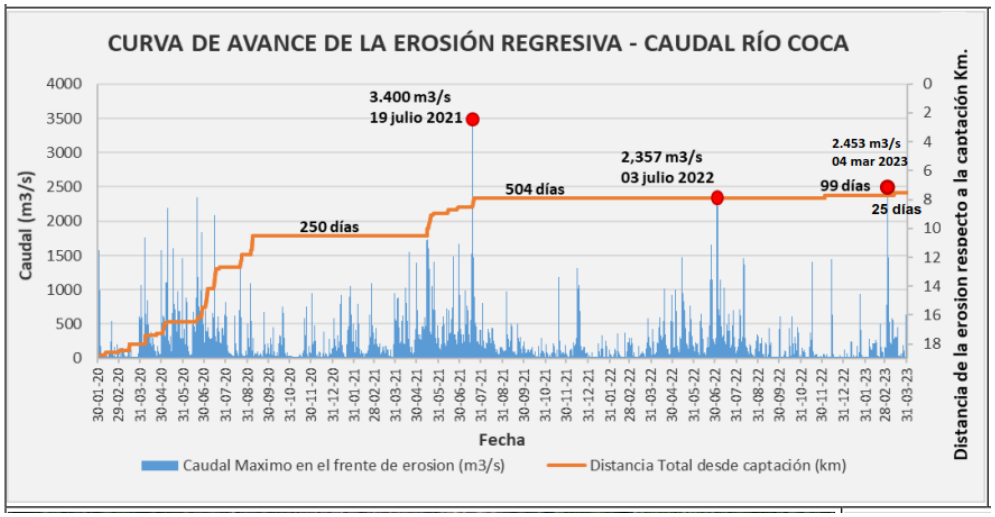

Figure 4: Erosion front evolution and daily maximum flows since February 2020.

Along with the periodic monitoring (meteorological, topographic photogrammetry and Lidar surveys, field inspections), CELEC has contracted or performed field geotechnical measurements to help understand the problem, update the river morphologic and geologic models, and make decisions on pivotal infrastructure protection projects, such as the Lombardi subsurface screens and the Permeable Dam. Both designs were tested in physical models at ERDC in Vicksburg, Mississippi as part of the ongoing collaboration with USACE. Stage 0 of the Lombardi screens is currently 95% completed, and alternatives to continue with Stage 1 are being analyzed. Ultimately, CELEC has developed a feasibility study to build a new intake in the Quijos River, upstream of the confluence with Salado River to ensure water supply to CCS Power Plant.

Figure 5: Photogrammetry of the Coca River. 2020 vs. 2023. San Luis Area, station 12+500. Shows 40+ meters of river channel degradation.

This paper summarizes the importance and benefits of the Coca Codo Sinclair power plant for Ecuador, the genesis of the problem, and all actions taken by CELEC since the waterfall collapse: studies, construction plans (emergent and long-term), and pursuit of international collaboration and assessment to prevent the erosion and sedimentation affecting CCS structures.