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Palo Viejo

HYDROELECTRIC PROJECT

developing green power for Guatemala

HATCH™

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Project Description

Cotzal intake - before impoundment

Enel Green Power (EGP) develops and manages energy generation from renewable sources around the world. EGP has developed more than 720 plants in 16 countries within the wind, solar, hydro, geothermal and biomass sectors for a total installed capacity of 8,207 MW.

As Owner's Engineer, Hatch designed EGP's Palo Viejo hydroelectric project in Guatemala to meet strict economic, social and environmental criteria, despite the project's complex natural setting. This was achieved through innovative designs, including cost-effective intakes, landslide-resistant conveyances, inverted siphons, and unique oil separation systems. Improvements to clean energy supply, employment, local infrastructure, and a significant contribution to the country's energy independence have resulted.

The Palo Viejo hydroelectric project, located in the Municipality of San Juan Cotzal in the Departmento de Quiche in Guatemala, utilizes water from the Cotzal River and three Cotzal River tributaries, Chipal, Regadio and Escondido. Hatch designed a 19.9-kilometre canal system to connect the headworks to the powerhouse by routing around the river. Although the canal route was elaborate, the canals were able to utilize water from more sources than a previously proposed layout, and required no flooding of the river. Initial project layouts connecting the headworks to the powerhouse with only a tunnel system proved to be uneconomical.

Power flow is diverted from the river and creeks at elevations between 1200 m and 1190 m, and conveyed to a 305,000 m^3 daily storage regulating reservoir equipped with dewatering and overflow structures. The main river and creek intakes integrate desanders. The primary conveyance system comprises 19.9 km of canal, 0.3 km of tunnel, 0.5 km of inverted siphons, and 0.8 km of steel penstock.

An 87.2 MW surface powerhouse with two vertical Francis turbines generating units converts 25.5 m^3/s of flow and 388 m of head into 370,000,000 kWh each year. The powerhouse is connected to a 230 kV substation through two step-up transformers, and is ultimately connected to the

Guatemalan grid through 35 km of transmission line. Crucial to the project's construction were 17 kms of new access roads and 15 kms of improved access roads.

The Cotzal intake is the main project intake and accounts for 16.0 m^3/s of flow. Its diversion dam is of concrete gravity type and is 13 m in height. The dam includes a two-bay spillway equipped with radial gates, and a low level sluiceway equipped with a single radial gate. Water enters along the right bank through trashracks and is controlled by two slide gates before entering a 52-m long bi-chamber desander of suitable length to remove sediment coarser than 0.25 mm.

The Chipal and Regadio intakes account for 2.8 m^3/s and 6.1 m^3/s, respectively. Design is similar to the Cotzal intake except the spillways are not equipped with gates. Further, the Regadio intake comprises two separate intakes and uses a short canal to connect to a shared desander. The three Escondido intakes account for 0.6 m^3/s and have a more simple design; lacking separate intakes, spillways and desanders.

Two large inverted siphons span the Chipal and Regadio creek valleys. The Chipal siphon drops 71 m, spans 350 m and is 2.6 m in diameter. The Regadio siphon drops 100 m, spans 273 m and is 3.0 m in diameter. Both have separate dewatering valves and one sediment flushing chamber with associated energy-dissipation structures.

Joining the various intakes to the reservoir are five separate canal systems. Two basic cross sections were used for the design of the canals, namely a rectangular section and a trapezoidal section. Slotted piers and overflow spillways are associated with each canal, enabling protection of the surrounding area from landslide blockage. Steel pipes directly connect Escondido 1 and 2 intakes to the reservoir.

The reservoir was constructed off-river on a semi-flat area at an approximate elevation of 1180 m and is comprised of membrane lined embankments and excavations. It has a usable capacity which is sufficient to assure full plant capacity during market peak hours; up to a four-hour period. A geomembrane liner/drainage system assures impermeability and drainage of undesirable pressures beneath the liner. Concrete structures associated with the reservoir include a reservoir intake, an emergency overflow spillway, and the penstock intake.

Cotzal desander - under construction

Downstream of the reservoir, a 310 m long, 2.9 m diameter low pressure penstock feeds a 540 m long, 4.5 m D-shaped tunnel and a 750 m long, 2.5 m diameter high-pressure penstock, which in turn feed the powerhouse. Flow in the penstock bifurcates before entering the powerhouse and is controlled by two large spherical valves before entering the units. The powerhouse is a reinforced concrete substructure protected by a structural steel superstructure which also supports a 100-tonne crane. The design accommodates three storeys of offices and control rooms, as well as a service bay, and separate floors for a machine room, generators, turbines, turbine valves, and dewatering galleries.

Powerhouse - interior

Project Highlights

Trapezoidal canal

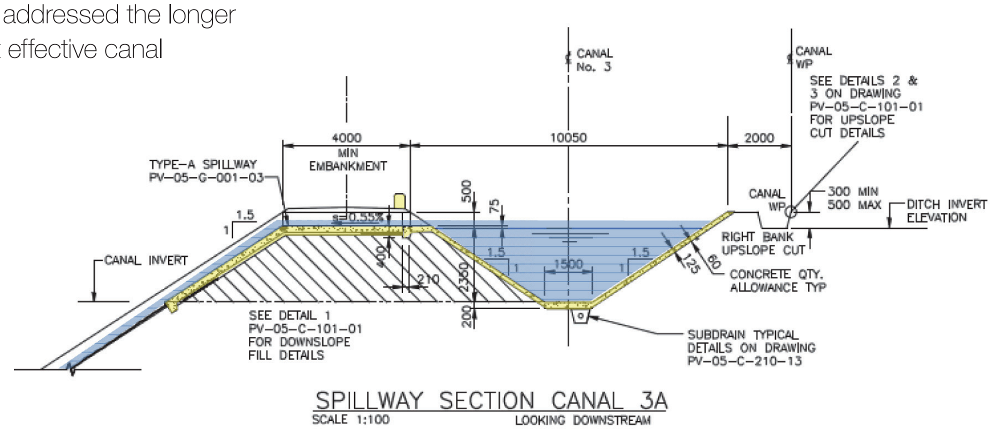
Innovations

A cost effective layout in a complex natural setting

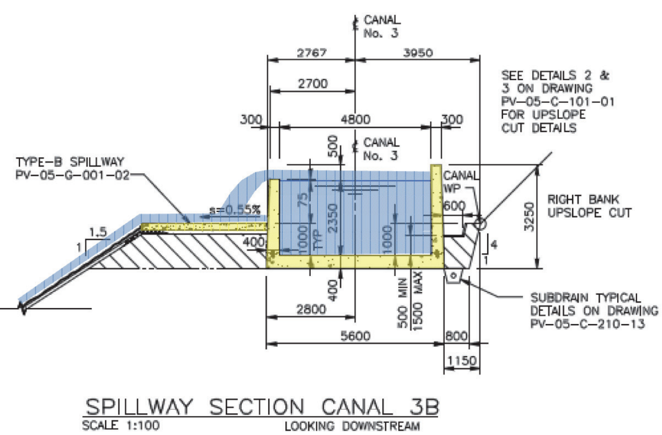
The Palo Viejo hydroelectric project required innovative applications of engineering techniques to successfully solve the several challenges posed by the site's complex natural setting. Multiple intakes had to be routed to the powerhouse, as the geometric layout of the river, with a slight curve to the left, did not allow for a conventional left-side tunnel conveyance without EPG going well over-budget.

A longer route on the opposite side of the river was assessed involving two large river valleys. The longer route would not help the project's economics; the large river valleys would suggest multiple powerhouses. Hatch addressed the longer route by using a series of custom-cost effective canal sections; rectangular in shape when the side slopes were steep, and trapezoidal when less steep. The trapezoidal sections reduced reinforcing steel requirements and proved to be the most cost-effective resource. The rectangular sections reduced real estate requirements and proved to be the most space-effective resource.

The Hatch team saw an opportunity to further improve project economics by capturing additional sources of water, including the two large tributaries, by building canals on the opposite side of the river. Seven separate sources were identified, requiring special economic designs for each intake. Shared desanders were used where possible. Simple overflow intakes, without separate desanders or gates were also used. An off-river flat site was identified to construct a storage reservoir, allowing for maximum energy production during peak demand hours. These measures alone dramatically improved the project's economics.



Construction of a rectangular canal



Typical sections of canals

Landslide resitant slope excavation

Overflow spillway protection

Landslides are exceedingly common in this area of Guatemala. The system of canals had to be protected due to the exceedingly common landslides in the area. Hatch developed custom material-dependent excavated slopes, complete with custom surface and groundwater drainage systems. Where risk of landslides were especially high, Hatch designed special structures to divert the slide, and/or devised methods of allowing the slide to flow over the canal. As final protection, Hatch developed an innovative system of isolation gates and overflow spillways along the canal which will divert flow from any landslide blockage into existing dried up watercourses.

Landslide canal protection

Regadio siphon - under construction

Specialized inverted siphons

The Hatch team was driven to find an innovative way to bring the water across the two steep valleys that ran between the folds of the mountains, in a cost effective manner. Instead of building bridges and aqueducts, which would have been costly for EGP, Hatch designed and constructed specialized inverted siphons to carry water over the deep creek crossings. The need for several powerhouses was avoided through the use of these siphons.

The siphons are engineering marvels. They are up to 100 m in height, spanning valleys as wide as 350 m, have slopes as steep as 60 degrees, and efficiently convey water across the valleys with a minimum of energy loss. Dewatering for maintenance is facilitated by a unique system of pressure relief valves, designed by Hatch. River sediments are removed at the bottom of the siphons by custom-flushing and energy-dissipating chambers.

Oil separation technology

Lubricating oils often contaminate drainage water from the turbines and machinery, and the water must be treated to remove the oil before discharge. A technology to separate the contaminated particles from the water in the facility was needed.

The application of an oil separation technology commonly used in the petrochemical industry was innovatively applied. Hatch designed a custom-system based on this technology, complete with separation baffles and valves. This system allows for the efficient removal of contaminants, all within a small powerhouse footprint. To our knowledge, this is the first time this particular technology has been applied to a hydroelectric facility.

Project Complexity

The Palo Viejo project is a testament to complexity. The project is comprised of seven separate water intakes, five different canals, spillways, sluiceways, desanders, inverted siphons, reservoirs, a tunnel, penstocks, a powerhouse, a substation, a transmission line, and many kilometres of access road. All of these systems are set in a remote, mountainous, highly seismic region, subject to tropical storms, landslides, and social challenges. Hydroelectric projects of this size are not typically this complex.

Site remoteness

The site, situated in the middle of the country, is located in an isolated area. Most of the equipment and material used for the project was sourced either from overseas or distant locations in Guatemala. Existing infrastructure to transport the equipment and material was inadequate in some areas. Beyond the expected upgrade of existing roads, the project required construction of new off-site roads and a complete highway bridge, which had been destroyed by a tropical storm.

Regadio intakes and desander

230 kV Transmission line transversing the Guatemalan Highlands

Social challenges

The project location is home to the Ixil First Nations, a traditional community of the Mayan people. Historically, the Ixil have a general mistrust of people perceived to be in a position of authority.

Despite EGP's best efforts to engage with the locals, two years into construction of the facility, a local community, the San Felipe Chenlà, staged a roadblock. Protest leaders did not object to the construction of the plant, but instead the community felt the local resources were inherent to them and demanded compensation. The community wanted 20% of the revenues generated from the hydroelectric plant. EGP remained pro-active throughout the roadblock and worked closely with local authorities to resolve the issue.

San Felipe Chenlà and EGP agreed in May 2011 to evolve an original cooperation plan. The agreement was to initiate a shared 20-year program based on an in-depth study of the local needs for the community. The roadblock was eventually removed. Following the roadblock, monthly public meetings were held to ensure there was continuous dialogue between the locals and EGP representatives.

Hatch accommodated some of the lost-time of the roadblock with changes to the design, by using materials that were already available on-site. The roadblock was in place for four-months.

Social & Economic Impact

Palo Viejo has helped Guatemala reduce its dependency on fossil fuel and has contributed to its overall energy independence. This impact has been felt country-wide. Before Palo Viejo, surrounding local communities suffered from daily energy blackouts, despite being connected to the national energy grid. Palo Viejo's energy contribution has reduced the number of blackouts and contributed green power to the local communities.

Economic impact

Palo Viejo has had a direct social economic impact on the local town of San Juan Cotzal. In 2008, the Government of Guatemala, the Municipality of San Juan Cotzal and its communities agreed to a cooperation plan that was. developed by a non-governmental organization. The plan outlined that EGP would contribute to the economic and social growth of the surrounding communities.

The agreement promotes the appropriate use of funds as well as municipal and community participation in prioritization of socially-useful projects. Twenty-four projects have been completed or identified in the local area, including new schools, a church, a water treatment plant, infrastructure improvements and a road network. The plan also included the acquisition of an ambulance, and trucks and equipment for 14 police officers.

The Palo Viejo project created 2,300 jobs for workers either directly at site, in the surrounding communities, across Guatemala or in supporting countries, including Canada. Approximately 1000 Guatemalans and 300 Ixil people were hired directly for construction. Money earned was spent in the surrounding communities.

Since discovering a Mayan soccer field and meeting place while excavating along the riverside for the canals, EGP has made an effort to support the local archaeological group. In addition to the donation for improving the local communities, EGP made a contribution of $380,000 to the local university in support of its archaeological program.

Typical construction activity along canal route

Environmental Impact

Promoting green power

Palo Viejo is EGP's fifth hydroelectric development in Guatemala, a country with a rapidly growing electricity demand. With the new hydroelectric plant, EGP's current "zero-emissions" capacity in Guatemala is 161 MW. The project is capable of producing 370,000,000 kWh annually, which will help Guatemala eliminate 280,000 tonnes of CO_2 emissions each year. The power generated by the project displaces electricity that would have alternatively been produced by other fossil-fuel power plants that previously supplied the national electricity grid.

One of the objectives for EGP was to design the project to be as sustainable as possible. EGP has committed more than $1.4 million to conserving the ecosystem of the site area, establishing programs for reforestation and protection of local flora and fauna.

No river dams or flooding required

Hatch designed the project to have all the environmental advantages of a run-of-river plant, while enabling storage of energy for maximum revenue. The project has no large storage dams with associated flooding of lands and did not require relocation of people. The project also does not consume water, instead, returns it to the watercourse to be used for agricultural and domestic needs. In fact, water quality is improved after it has passed through the various desanders installed at the intakes.

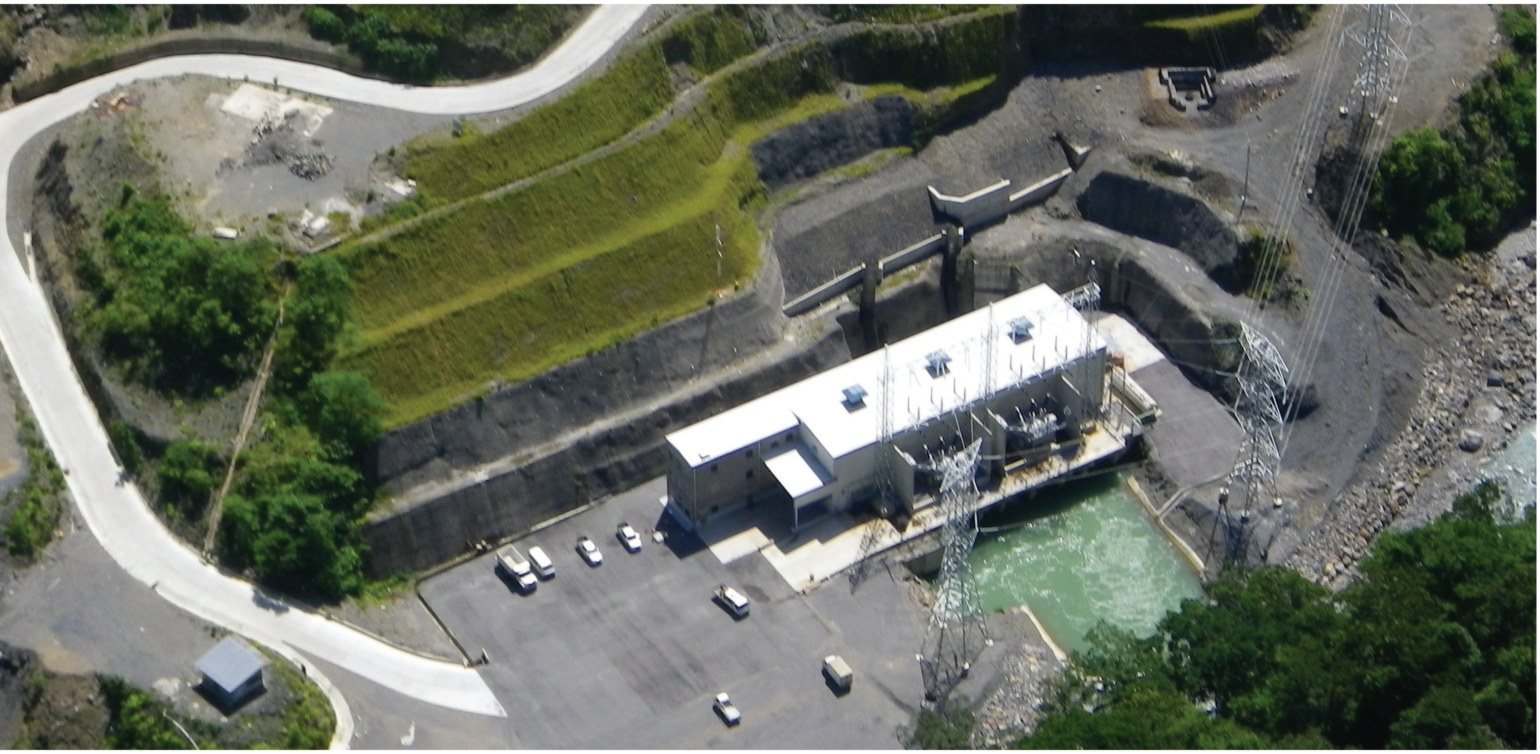
Re-routed canal and protection structure

Protecting ancient Mayan ruins

During the construction phase, as workers excavated the project's fifth canal, ruins of a Mayan meeting/sports complex were uncovered. EGP alerted the appropriate authorities and facilitated the processing of the site by several archaeologists. Hatch redesigned the canal route and added a protection structure adjacent to the ruins.

Off-river reservoir - 305,000 m^3 capacity

Preserved ancient Mayan ruins



Commissioned 87.2 MW powerhouse

Meeting Client Needs

EGP is committed to contributing to sustainable development that ensures energy supply security, and enhances the country's energy independence. These goals were met through the Palo Viejo project, largely through innovations developed by Hatch.

Strict economic, social and environmental criteria

As Owner's Engineer, Hatch designed the project to meet strict economic, social and environmental criteria, despite the project's complex natural setting. Hatch worked hand-in-hand with EGP from concept through to commissioning to meet their goals. The unique layout of the site, the use of cost effective structures, the flexibility in design, and the innovative systems all contributed to the project's success.

On-time, on-budget

The 87.2 MW Palo Viejo project was completed on-budget and was connected to the National Electricity Grid in March, 2012. The construction schedule was followed closely; but, due to the four-month roadblock the project was completed slightly behind schedule. Some of this delay, however, was reduced due to proactive measures taken by Hatch.

Working together safely

Given the dangerous natural environment, the pressures of schedule, the presence of various languages (Spanish, Ixil, Italian, English, and Hebrew), and the multiple work fronts, safety can suffer. As such, EGP tasked Hatch with auditing existing safety programs, recommending changes, and monitoring subsequent success. Hatch initiated additional training, created a system of rewards, and addressed issues surrounding language. As a result, the project achieved over six and a half-million work-hours without a lost-time injury.

Safety rewards recognition