The run-of-river Jirau hydroelectric project suffered a historic flood in 2014 that mobilised a large amount of sediment, causing changes to the river’s topographic profile, aggradation near the water intake structures and wear to the hydromechanical equipment. Modification of the operating rule, hydrosuction dredging to remove sediment deposits, and abrasion-resistant coating are among the sediment management measures taken.

The Jirau hydropower plant is located on the Madeira River, in the state of Rondônia in northern Brazil. The power plant’s first electrical unit was commissioned in 2013, with inauguration taking place in 2016 when the final unit entered into operation. Jirau is a run-of-river project, owned and operated by the Energia Sustentável do Brasil (ESBR), of which 40 per cent belongs to Engie, and the remaining 60 per cent is divided equally between Electrobras Electrosul, Electrobras Companhia Hidroelétrica do São Francisco, and Mitsui.

The USD 7 billion hydroelectric project includes a 62 m-high asphalt core dam with a 1,150 m-long crest at an elevation of 94 masl. The eighteen 30.1 m-high sluice gates have an invert elevation at 69 masl and a total discharge capacity of 82,587 m³/s. See the Jirau hydropower plant aerial view in figure 1 and, in more detail, the powerhouse on the left bank, the sluice gates, and the spillway in figures 2, 3 and 4 respectively.

Jirau features two powerhouses, one on the left bank with 22 units and one on the right bank with 28 units. In total, the project has 50 bulb turbines designed to operate under a low head, which are among the most powerful ever manufactured at 75 MW each. The power plants benefit of 15.4 m gross head with a design discharge of 27,500 m³/s. Jirau’s total installed capacity of 3,750 MW at Jirau contributes 19,136 GWh annually to the National Interconnected System (SIN).

At the dam site, the river bed elevation is just 47.4 m, and the river slope is 0.03 mm/m. Due to the plain topography, the dam creates a large reservoir that is 141.8 km long with a total storage capacity of 2,746.73 Mm³ and a live capacity of 1,496.07 Mm³. The reservoir operates between the levels of 82.5
CASE STUDY: JIRAU

Hydrology and sediments

The Madeira River is the main southern tributary to the Amazon River, which drains part of the Peruvian and Bolivian Andes. The catchment tributary to the Jirau hydropower plant comprises 972,710 km², characterised by an annual average temperature of 25.1 °C, an annual average precipitation rate of 2,174 mm and a mean annual inflow of 589,000 Mm³. The coefficient of variation of annual inflows is 0.167.

The monitoring programme measures the river aggradation in the delta of the reservoir at Mutum station. The particle size distribution analysis shows that the sediment deposits in the delta contain 98 per cent sand. On the other hand, the analysis of the sediment deposits in the bottomset shows that the percentage of sand decreases to 29 per cent while the silt percentage increases to 54 per cent. Clay represents the lowest proportion, with 17 per cent. Sand is the main material of the river bed with a D₅₀ grain size of 0.225 mm.

The mean annual bed load is 44.9 Mt which represents less than 10 per cent of the total load; therefore the mean annual suspended sediment load is significantly greater with 582 Mt.

The Madeira River contributes approximately half of the sediment load of the entire Amazon River basin. The daily sediment load varies in the range of 2-4 Mt per day during the peak flow period. The design sedimentation rate is 20 Mm³ per year and the sediment rating curve for suspended load is defined by the formula Qss = 0,0017 * Q²,064.

Sediment problems

The first sedimentation problem occurred one year after commissioning. A historic flood in 2014 mobilised a large amount of sediment, changing the river's topographic profile, causing aggradation near the water intake structures and wear to the hydromechanical equipment.

The aggradation created water damming effects along the river. Sedimentation near the concrete structures and the water intakes resulted in difficulty moving the stop log gates of the power plants. Pump pipes, drainage and sewage wells suffered from sediment accumulation and the filters of the refrigeration systems experienced blockage. The suspended sediment eroded the pumps, the concrete on the spillway intake and the hydromechanical equipment. Other minor issues included damage to the water level sensors.

Future sediment problems identified include the loss of reservoir capacity, decrease in the load for power generation and increase in the frequency repair needed to the turbines and their components, meaning increased operations and maintenance costs for the power plant.
CASE STUDY: JIRAU

Sediment management strategies

The Madeira River carries very high sediment loads which originate primarily in the Beni sub-catchment in Bolivia. Approximately 70 per cent of the tributary basin to the Jirau dam is located outside Brazilian territory, making sediment data monitoring difficult and the application of watershed management strategies beyond the control of the project. However, tree planting has been implemented in the vicinity of the reservoir to minimise the erosion and avoid washout during flooding.

It is of fundamental importance that the natural sediment transport is maintained in the Madeira River without causing negative impacts on the socioeconomic and biophysical environment, or the project infrastructure and its generation potential. The safe transport of sediments, logs, debris, larvae, eggs and juvenile fish through the dam is necessary to secure the maintenance of biophysical environments and therefore comply with environmental regulations. Mathematical and physical models contribute to identifying and minimising sedimentation issues. Prior to construction, the models helped with the design of large dykes on the river banks to minimise the lateral sedimentation and channel the flow to the power houses and spillways.

During the construction phase, following the programme of recovery of degraded areas, the topsoil of excavated areas was stored for reuse in the enhancement and recovery of affected areas following construction. The PACUERA programme is a regulatory requirement that addresses the conservation, recovery and land use of the reservoir’s influence area. ESBR shares satellite imagery with the Brazilian authority responsible for socio-environmental monitoring of the Amazon region to identify any marginal or unstable slopes and maintain a comprehensive database of the area.

Abrasion-resistant coating has been applied to the 50 turbine units in order to minimise the loss of efficiency and maintenance requirements due to the effects of sediment erosion. The operations and strict regulations against sediment flushing effectively avoid the potential of turbid water with an extremely high sediment concentration passing through the turbines.

Operating with variable reservoir water levels, as shown in figure 7, prevents the creation of a delta at the end of the reservoir, with sediment deposition being spread more gradually throughout the reservoir. Modification of the operating rule when needed also avoids any sediment damming effect across the Bolivian border.

Hydrosuction dredging is occasionally carried out to remove sediment deposits along the reservoir to avoid sediment damming effects.

Monitoring

The monitoring programme was in place three years prior to impoundment. It consists of six stations, five upstream and one downstream of the Jirau dam, where the suspended and bedload sediment concentration is measured twice a week upstream and once a week downstream. Over the first five years, bathymetric surveys including 23 control sections measured the changes to the river bed area annually. The field campaigns also included samplings of delta and bottomset sediment.

To identify potential areas of erosion and evaluate the erosion rate, the monitoring programme uses a digital terrain model and high-resolution satellite imagery. A precipitation-runoff model calculates the runoff using data from six telemetric stations in the upper catchment and 13 gauges along the river.

Water quality measurements include the monitoring of abiotic and bacteriological variables, limnologic parameters and aquatic communities (phytoplankton, zooplankton, zoobenthos), water quality index, and groundwater quality at the Velha Mutum station upstream.

The hydro-biogeochemical monitoring programme consists of mercury and methylmercury measurements in the environment and the calculation of trophic state index.
CASE STUDY: JIRAU

Graphs and figures

Figure 1 - aerial view of Jirau hydropower plant (Google Earth)

Figure 2 - downstream view of the Jirau powerhouse on the left bank

...Graphs and figures cont. >
CASE STUDY: JIRAU

Figure 3 - Jirau sluice gates on the right side

Figure 4 - Jirau spillway on the left side

Graphs and figures cont. >
CASE STUDY: JIRAU

Figure 5 - Jirau reservoir level-storage curve

![Graph showing reservoir level-storage curve with green line for Level x Volume and red line for Level x Area.]

Figure 6 - fish ladder at Jirau

![Photo of fish ladder at Jirau.]

Graphs and figures cont. >
CASE STUDY: JIRAU

Figure 7 - Jirau operation gross head 2013-2017