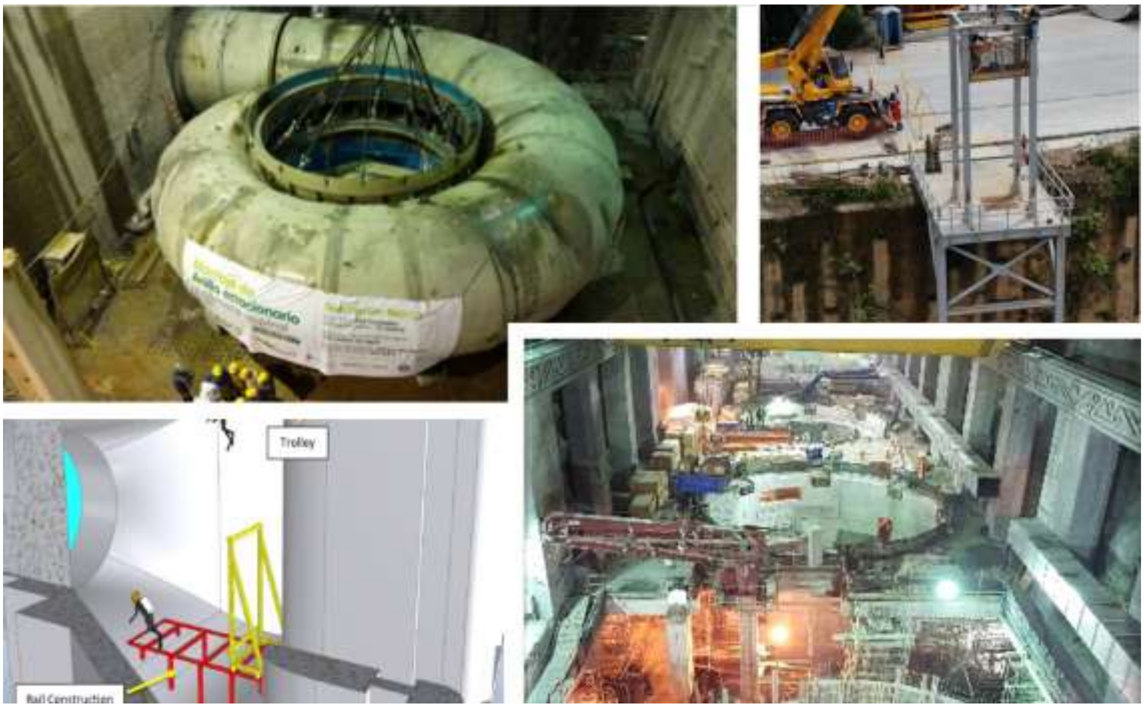
Independent Advisory Panel to IDB Invest

IAP Report N°6, July 2021

Ituango Hydropower Project

Colombia



Alessandro Palmieri
Dam Engineering and Safety (Chair)

Via Massimi 25, 00136 Rome, Italy
Tel. + 39 063 5400737
Arp.palmieri@gmail.com

Federico Ciampitti
Hydraulic, Mechanical & Electric Equipment

Via L Tolstoi 72, 20146 Milan Italy
Tel. +39 335 1007517
Federico.ciampitti@gamail.com

Pavlos Marinos
Engineering Geology and Geotechnical

23A, Penetoliou str. 11741, Athens, Greece
Tel. +30 694 4301993
marinos@central.ntua.gr

Mario Sartori
Budget, chronogram, and construction progress

Via del Blenda 8, 58100 Grosseto, Italy
sartoriavi46@gmail.com

Contents

Acronyms used

ADT	Auxiliary Diversion Tunnel (GAD or SAD in Spanish)
API	Actualización Proyecto-Tema Informativo (July 6th 2021)
BID	Banco Interamericano de Desarrollo
CAP	Capital Investment
CFD	Computational Fluid Dynamics
C&I	Control and Instrumentation (cables)
COD	Commencement of Operation Date (turbine units)
DRM	Disturbed Rock Mass
EBIA	EPMs Board of Independent Advisors
EPM	Empresas Públicas de Medellín
EPP	Emergency Preparedness Plan
FEM	Finite Element Analysis
GIS	Gas Insulated Switchgear
HPP	Hydro Power Plant
HV	High Voltage
IAO	Informe de avance de las obras de estabilización (June 28th 2021)
IAP	Independent Advisory Panel to IDB Invest
IDG	Intermediate Discharge Gallery (DI in Spanish)
IDB	Interamerican Development Bank (BID)
IEC	International Electrotechnical Commission
LOB	Line of Budget method
LV	Low Voltage
MAF	Mean annual flow
MAS	Mean annual sediment yield
m. asl	Meters above sea level
MLO	Middle Level Outlet
MOL	Minimum Operating Level
ANLA	National Authority of Environmental Licenses (ANLA in Spanish)
PERT	Project Evaluation and Review Technique
PF	Probability of Failure
PFMA	Potential Failure Mode Analysis
PH	Powerhouse
RLM	Response Level Matrix
SRF	Strength Reduction Factor (used in slope stability analysis)
TD2	Diversion Tunnel 2 (right)
TLN	Time Line Now

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Overall safety assessment

Despite the unprecedented events that impacted the Project, the undertaken works allow to express a satisfactory assessment on the safety of both surface and underground works.

Sealing the TD2, and secondarily the GAD, presents a moderate risk until the works are completed. A dedicated Emergency Preparedness Plan has been put in place to alert workers and downstream communities during the execution of the sealing works.

The underwater works, required for activating the power intakes, exhibit safety challenges by their own nature.

Technical assessment

Instrumentation and monitoring continue to show satisfactory behaviors of the dam. Some minor slope erosions have been observed in the plunge pool slope; nothing to warry about yet, but they could represent the first signs of “structural fatigue”. Slope stabilization works on the dam’s right abutment are almost completed, and monitoring indicates proper performance.

No new, major eroded zones are anticipated in the North side of the Powerhouse complex (Units 1 to 4).

The assessment relative to the South zone, units 5 to 8, remains challenging due to the extensive and complex treatment works of the disturbed rock mass affecting the pressure shafts. The final design of the permanent works is also being revisited.

Activities continue for the permanent sealing the TD2, and secondarily the GAD. A dedicated emergency preparedness plan (EPP) is in place, which is fit for the purpose.

The possibility to lower the reservoir below 390 m.asl will be contemplated in the Project’s Emergency Preparedness Plan (EPP), the latter should feature two elements:

- a short term (4 units in operation) discharge response system, and
- the extent of the potential damages in case of protracted operation of the units below minimum OL (390).

Based on the surveys executed to date, the IAP believes that a suitable baseline can be defined for monitoring reservoir sedimentation during the life of the Project.

Schedule assessment

During the visit, the IAP learned that, to date, there is still no definition on whether the construction consortium, the supervision consortium and the advisory firm will continue to work after December 31st 2021. The situation is beyond EPM’s control, which makes it the most crucial issue for schedule management, and for the commercial operation of Unit 1 by July 2022.

Two milestones, pertaining to the Loan Agreement between EPM and IDB Invest, have been complied with:

- Overhead 300 ton crane installation for northern generation cavern, and
- Completion of the grid of 62 micropiles for TD2's final plugging.

On July 25th, as this Report was being prepared, the IAP learned that the spiral chamber of Unit 1 had been installed and that the one of Unit 2 was in the process.

In the absence of a PERT, or equivalent analysis, the IAP had to carry out a laborious comparison of the activities included in the EPM Chronogram (*Programa de Ejecucion de Obras_PBE*) of 31st December 2020, with the information contained in the presentations received during the visit.

Application of the Time Line Now method, setting the date on June 30, 2021, permitted to flag the main delays with reference to:

- Waterways to units 1 and 2, including the units themselves - delays assessed between 3 and 6 months, and
- Permanent sealing of TD2 and GAD – delays assessed between 2 and 5 months.

It must be pointed out that this does not necessarily mean that the CODs are subject to the same delays, because:

- EPM's detailed planning may contain elements that the IAP cannot deduct without PERT-like diagrams.
- EPM is implementing acceleration measures to recover the delays.
- The successful installation of U1 spiral case on July 25th is a case in point.

In general, the IAP observes that, compared with February 2021, the free slacks of the Project' schedule have reduced and that the delays due to the additional civil works can only be compensated by accelerating the mechanical and electrical installations.

In the IAP view, the underwater works for the activation of the power intakes are the most challenging activity for the commencement of operation of units 1 and 2.

Given the considerable uncertainties associated with the completion of rehabilitation works in the Southern zone of the PH complex, and of the disturbed rock mass in particular, it is still premature to make any meaningful comment on the achievement of the CODs for units 5 to 8.

During the July 2021 mission, the IAP was informed that EPM's Management was about to decide on a budget increase for the completion of the works. The IAP understands that the budget increase is in line with the estimate contained in the IAP's 5th Report.

1 CURRENT PROJECT SITUATION

1.1 General

The Ituango Hydroelectric Project is under construction at the northwest of Colombia since 2009. The Independent Advisory Panel (IAP) was formed in 2018 to advise IDB Invest on technical matters of primary relevance to safety and sustainability of the Project.

In 2021, the IAP was requested to extend its advisory role to certify that construction progress is in all material respects (a) advancing in order to achieve the Commercial Operations Date by the COD Longstop Date, and (b) complying with internationally acceptable construction standards. The IAP accepted to act accordingly, acknowledging the limitations imposed by the travel restrictions that impose remote visits to the Project.

Due to the concomitant C19 pandemic, the subsequent IAP's missions (fourth in May 2020, and fifth in February 2021) had to be organised virtually. That has also been the case for the sixth mission, in July 2021, which is the object of the present report.

A fourth member, Mr. Mario Sartori, joined the IAP to advise on budget, chronogram, and construction progress. All four IAP members attended the July 2021 mission. Despites the difficulties, thanks to an excellent organisation by EPM, and facilitation by IDB Invest, the virtual mission allowed the IAP to appreciate the progress made and to get an update on the main technical issues of the Project.

The mission consisted of three video conferences, on July 6th, 7th and 8th. The first two days were devoted to presentations and discussions. On the last day, the IAP delivered a brief of their preliminary observations, which are elaborated and presented in this report.

The IAP wishes to acknowledge the highly professional contribution of all stakeholders to the discussions and exchange of views on the complex technical subjects pertaining to Ituango HPP.

1.2 Comparison with February 2021

During its July 2021 virtual mission, the IAP observed the following key aspects.

- Performance of the dam continues to be in line with design expectations, and correspondence between predicted and as-measured performance is excellent.
- The spillway is operating full time, which is beyond the design assumptions, and will continue so until turbine operation will be established. Monitoring of the plunge pool slopes starts to shows localized, very minor signs of incipient distress.
- Power-house cavern complex- North Zone: most of the underground areas have been inspected and repair measures have progressed to a level that allows a reliable assessment of the remaining works.
- Monitoring of the underground openings continues to indicate satisfactory performance.

- Underwater works for the activation of the power intakes have not started yet and should be accelerated.
- Power-house cavern complex- South Zone: the “disturbed rock mass” affecting pressure shafts 5, 6, 7 and 8 has been investigated and delineated; treatment measures are expected to be extensive. Design of the permanent works is being revisited.
- The GAD has been temporarily secured with the installation of gates that can withstand the full reservoir pressure. Activities are concentrated on the TD2 adopting a well-studied methodology. Flow through TD2 is closely monitored during the sealing operations. A dedicated Emergency Preparedness Plan is in place.
- The workshop for penstock assembling is completed, all steel plates are on site and production is ongoing.

1.3 Options for Project’s Completion

The following elements are noteworthy:

- CODs of Units 1 to 4 are substantially unchanged; CODs for units 5 to 8 are revised to February 2025, mainly as a consequence of the important rehabilitation works anticipated in the disturbed rock mass of the South zone.
- Operation of turbine units below reservoir elevation 390 is being included in the Project’s Emergency Preparedness Plan.
- Initial bathymetric surveys allow to define a reliable reservoir geometry as a baseline for future sedimentation assessments.

The following table shows the progression of IAP’s assessment of the “Options for Project Completion” which were put forward since the IAP’s involvement in the Project.

Options	August 2018	March 2019	October 2019	May 2020	February 2021	**July 2021**
Full Rehabilitation	Preferable option; final confirmation after assessment of damages in the powerhouse complex	Confirmed preferable option	Substantially confirmed	Confirmed		
Revise Project’s Outputs	Not envisaged at this stage	Power output unmodified. Schedule of second stage power supply (units 5-8) to be assessed.	Power output unmodified. Sequence for putting in operation the Unit shall be independent from the original two stages power supply.	Power output unmodified. Unit commissioning sequence: U1 (Dec20), U2 (Apr21). Other units still to be defined.	Unit commissioning sequence: Unit 1 (Jul22), U2 (Oct22), U 3 (Jan23), U 4 (Sep23), U 5 (Aug24), U 6 (Oct24), U 7 (Dec 24), U 8 (Feb25)	Unit commissioning sequence: Unit 1 (Jul22), U2 (Oct22), U3 (Mar23), U4 (Sep23), U 5, U6, U7, U8 (Dec25)
Revise Project’s Purposes	Not realistic					

Options	August 2018	March 2019	October 2019	May 2020	February 2021	July 2021
Project re-engineering	Addition of Middle Level Outlet (MLO) essential		Future decision on the MLO to be supported by a Potential Failure Modes Analysis.	PFMA workshop carried out. To be further developed to achieve a risk-informed decision on the additional MLO.	Operating the turbines at elevations below 390 m. asl is essential for dam safety in emergency conditions. Due consideration should be given to adding a MLO during the life of the Project.	Operating the turbines at elevations below 390 m. asl is contemplated, in emergency conditions. Due consideration should be given to adding a MLO during the life of the Project.
Partial/ total retirement	Very unlikely, unless cavern location must be abandoned for excessive damages.	Partial retirement can be excluded.	Partial retirement excluded.			
Long-term vision	Project will have to be decommissioned at the end of its useful life, when coarse sediment management, to sustain run-of-river operation, will no longer be economical.	Bathymetric surveys should be initiated to assess sedimentation trends.	Long-term reservoir management retains its importance.	IAP would like to review results of bathymetric surveys carried out to date.		Baseline for periodic bathymetric surveys can and should be defined.

1.4 Project's Risk Profile

EPM operates a comprehensive risk management system, which covers all elements of risk (safety, cost, time, people, reputation, environment, social). It is appropriate, for the IAP, to concentrate on those elements that are of a technical nature and directly related to safety of the Project and of the downstream population.

With that in mind, the IAP points out the significance, at this stage of the Project, of four areas of technical risk illustrated in figure 1.

Technical Risk	Relevance
Powerhouse South complex 	Currently, the most prominent technical risk for Project's completion. <u>Risk not yet quantified</u> because detailed design of needed interventions is ongoing.

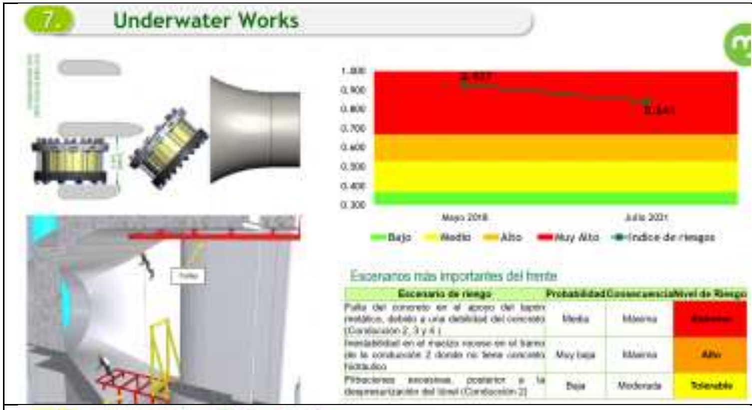
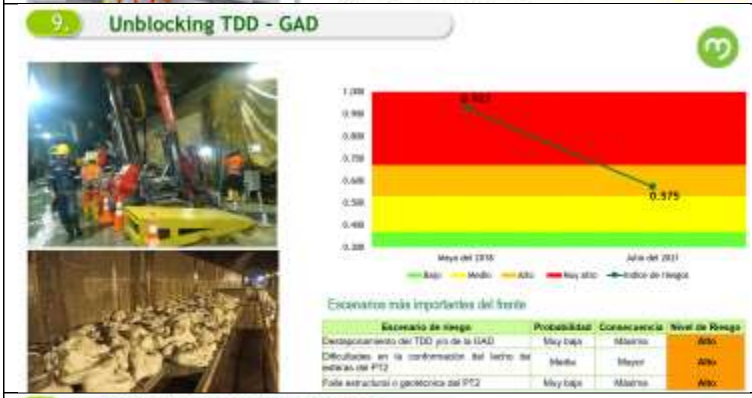
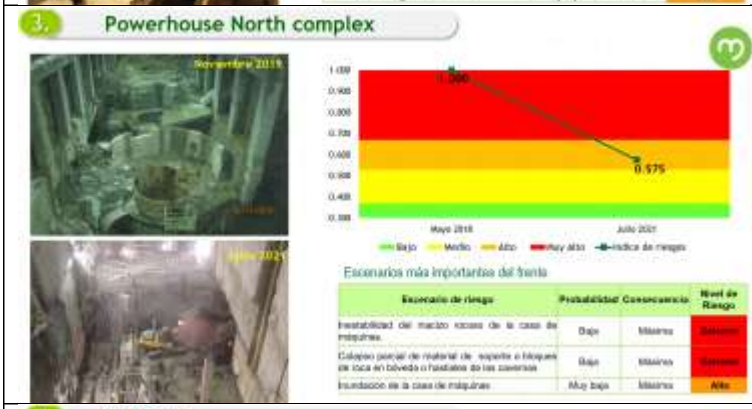
	Complex underwater activities involving specialised subcontractors. Essential for the entrance in operation of units 1 to 4.
	Unconventional remedial works being carried out with innovative solutions for which there is no precedent in the hydro industry. Essential for reducing the level of alert downstream. A dedicated EPP is in place.
	Program of works is under control but highlighted because of its criticality for meeting the CODs.
	Until turbines enter in operation, spillway will operate full time. Operation is about 5 times longer than originally foreseen in the design. Slope monitoring starts to shows localized, very minor signs of incipient distress.

Figure 1: Highlighted Technical Risks

Project's risks during operation are discussed in chapter 2.

1.5 Permanent Sealing of TD2 and GAD

GAD and TD2 have been affected by the April 2018 collapses that caused loss of control on reservoir levels. Currently, the Additional Diversion Tunnel (GAD) is gated, and works are ongoing to plug the Right Diversion Tunnel (TD2). Providing permanent sealing to the TD2 and to the GAD is essential for bringing back downstream safety to pre-contingency time. Technical assessment follows.

<u>GAD</u>

Two wheeled sliding gates have been installed on the GAD as per original design; a concrete plug on the top of the gate structure has been placed to avoid any movement of the gates. With such installation the tunnel is technically plugged, and full hydraulic control has been re-established on the GAD.

Two by-pass systems have been built to control piezometric levels: one around the gates, currently in operation, and the other, almost completed, to be utilised at the time of plugging the GAD, to drain towards the Intermediate Discharge Gallery (located above the GAD).

Gate installation allowed the alert level to be reduced from red to orange, with significant relief for the population downstream.

The next step is to realise a “permanent” concrete plug, 22 m long, downstream of the gates, as foreseen in the original design. Being the GAD currently gated, the plug is not on the critical path and there are sound technical reasons not to rush to install the permanent plug. Both discharge and water pressures are continuously monitored along the GAD; results show stable values for both parameters.

<u>TD2</u>

TD2 is largely obstructed by debris. The resulting gap allows a discharge which has stabilised at about 8 m3/s and is constantly monitored. Water pressures are also monitored. Continuous monitoring is essential because the hydraulic gradient through the obstruction, estimated at 0.55, is high enough to potentially initiate internal erosion. At the same time, the turbidity carried by the river, contributes to a progressive sealing of the debris, a phenomenon that can be associated with the declining trend of water pressures. In sum, while the TD2 cannot yet be considered “technically plugged”, all evidence permits to assign a low probability to the potential collapse of the natural obstruction.

Sealing of the TD2 will have to take place with water flowing and it therefore requires a complex and carefully planned procedure. Due to its unprecedented nature in hydropower projects, TD2 sealing has been thoroughly studied and a feasible solution, involving two pre-plugs and final plugs, is being implemented (Figure 2).

Figure 2: <u>Solution for sealing the TD2</u>

The implementation schedule of the planned solution is analysed in chapter 5.

To date, all the 63 micro piles have been installed, 58 of which fully grouted (figure 3). The 9 additional piles had to be installed to minimise gaps associated with piles' deviations from the vertical.

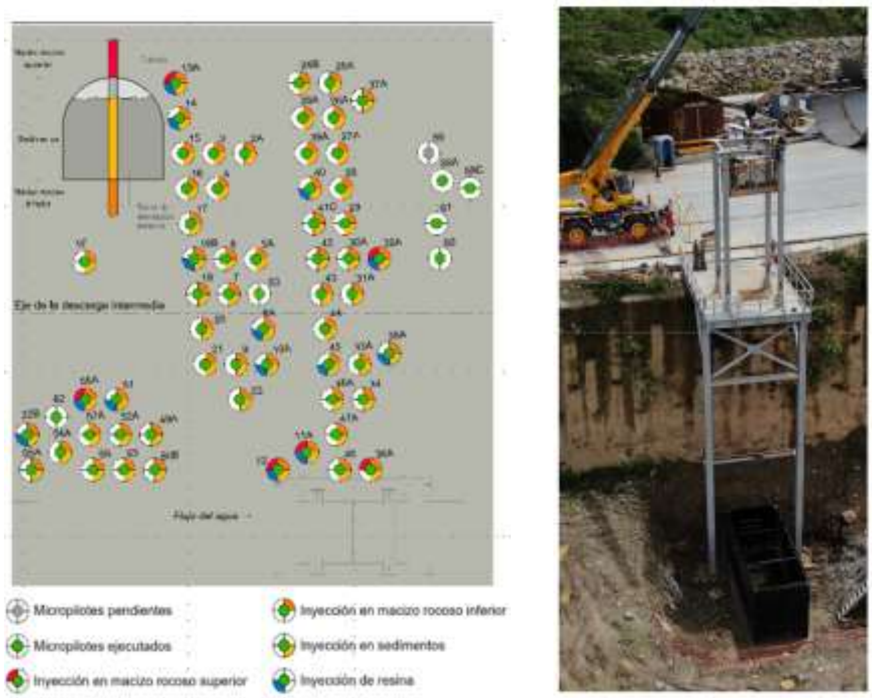


Figure 3: <u>Micro piles and structure for testing the launching of the plastic spheres</u>

A dedicated steel structure (figure 3) has been built to test the launch of the plastic spheres that will be floated to be trapped by the steel piles grid to clog the upper part of the TD2, progressively reducing the spaces among the micro piles' grid. This is expected to force the residual flow through the by-pass system and to facilitate progressive clogging of the waterway by means of gravel and sand first, and of special grouting after. At that point, grouting will be performed with special resin-based mixtures to totally seal the temporary barrier. That is expected to further reduce the flow to nominal values that will permit construction of the permanent plug under safe conditions.

An emergency preparedness plan (EPP) is in place (Figure 4), which is based on the existing monitoring system, to inform three levels of alert for the protection of the downstream areas.

Figure 4: Emergency Preparedness Plan against TD2 unplugging (excerpt)

The EPP is satisfactory because:

- failure modes have been identified,
- a comprehensive monitoring system is in place,
- chain of command and response is defined,
- downstream alert protocol is established, and
- preventive mitigation measures are being implemented.

1.6 Level of Downstream Hazard

Currently, the level of downstream alert of the Project (figure 5) remains at orange (2), because permanent sealing of TD2 is ongoing. It will descend to yellow (1) when that activity is completed.

Nivel de advertencia	Situación	Caudal que genera advertencia (m^3/s)		
		TDD (Medición indirecta a través de velocidad y presión)	GAD (Medición de caudal en descarga)	Qrio – Qvert. (Diferencia de caudales)
0	Condición normal	<10 Caudal nominal actual	<10 Caudal nominal actual	<30 Delta nominal
1	Aumento sensible en el caudal	20 Se duplica la velocidad en el TDD	14 Corresponde a la alerta naranja interna	200 Valor sensible según la medida histórica
2	Generación de alerta interna y notificación a poblaciones aguas abajo	50 Caudal asociado con el gradiente crítico en el TDD	18 Caudal asociado con el gradiente crítico en el TDD	300
3	Activación de desalojo eminente Cuando se triplique el caudal de la alerta interna	150	60	800
4	Activación de desalojo inmediato Cuando se duplique el caudal de desalojo eminente	300	120	1500

Figure 5: Levels of downstream alert

1.7 Safety Assessment

From May 2020 to date safety assessment had to be based on indirect, remotely done, observations. Based on the evolution of health-related travel clearances, the IAP hopes that the next mission can be conducted in presence. That would provide hands-on opportunities to carry out an informed safety assessment.

The main safety-related aspects of the Project can be summarised as follows.

- The level of instrumentation and monitoring of the Project is state of the art: all readings are automatic, centralised to control room, and remotely accessible.
- Performance of the dam is in line with design expectations and correspondence between predicted and measured performance is excellent.
- Activities related to the permanent sealing of TD2 and GAD are defined and their implementation is ongoing.
- The spillway is operating full time, which is beyond the design assumptions, and will continue so until turbine operation will be possible. Monitoring of the plunge pool slopes shows some localised, very minor signs of distress.
- Most of the underground areas, which were affected by uncontrolled river throughflow, have been inspected and needed repairs defined.
- Discovery of major collapsed areas is no longer expected in the North part of the PH cavern where most of the permanent works have been secured.
- The South part of the Cavern and related waterways are affected by an extended zone of disturbed rock mass, which has been investigated and delineated. Treatment measures and final design of the permanent works are under definition.

Overall safety assessment:

- Despite the unprecedented events that impacted the Project, the undertaken works allow to express a satisfactory assessment on the safety of both surface and underground works.
- Sealing the TD2, and secondarily the GAD, presents a moderate risk until the works are completed. A dedicated monitoring system is in place to alert workers and downstream communities in case of emergency situations during the execution of the sealing works.
- The underwater works, required for activating the power intakes exhibit safety challenges by their own nature.

2 RESIDUAL RISK DURING OPERATION

2.1 Reservoir control during Project operation

As a result of a constructive dialogue on the matter, EPM is developing a conscious approach on the possibility of operating the units to control the reservoir level in emergency situations.

In emergency conditions, discharging through the units is the only course of action to lower the reservoir below elevation 405 m a.s.l. (spillway sill). Figure 6 shows reservoir lowering times for different river flows. The calculations assume that all the 8 units are in function.

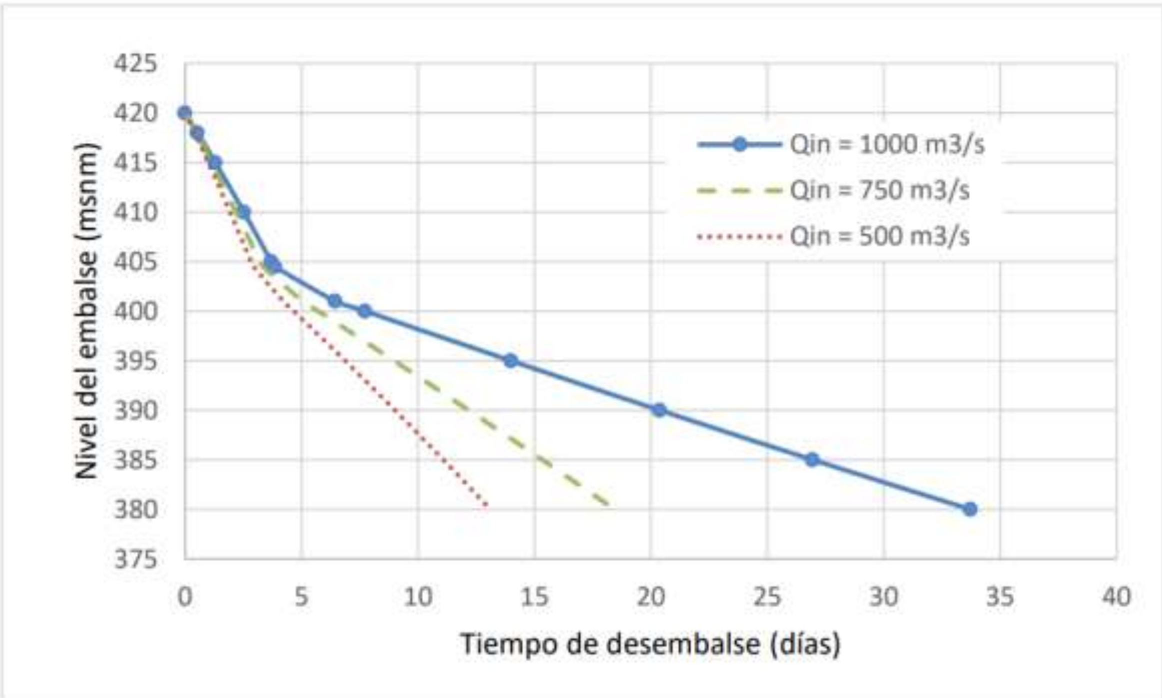


Figure 6: Reservoir lowering times (Integral)

It must be pointed out that the current plan envisages 4 units entering in operation by September 2023, and all the 8 units by February 2025. The data shown in figure 6 will therefore be valid in the long term. Until the year 2025, lowering times will be about twice those shown and effective reservoir control will hardly be possible for river flows exceeding, say, 500 m3/s.

Integral informed that the possibility to lower the reservoir below 390 m.asl will be contemplated in the Emergency Preparedness Plan (EPP) because there are no doubts on the trade-offs between causing temporary damage to the equipment, and failure of the dam. Integral also informed that the plant will store four spare runners that can be mounted from below, making repairs of possible damages easy to perform. This is a very appropriate management measure to mitigate outage risks.

Ituango's EPP should incorporate two elements:

- a short term (4 units in operation) discharge response system, and
- the extent of the potential damages in case of protracted operation of the units below minimum OL (390).

The latter is important because abnormal reservoir lowering may be dictated by the need to verify damage to the works e.g., after a strong earthquake. Should damages not have occurred (which is obviously the preferred outcome), there might be allegations of unnecessary repair costs to the units. It is therefore important that the expected damages are contemplated in the EPP, to demonstrate that the decision to enact abnormal lowering was based on due process.

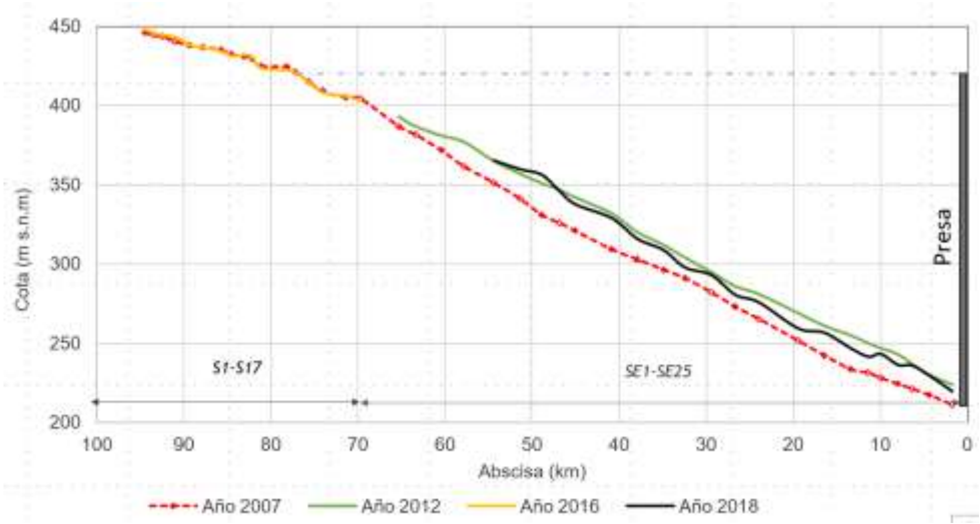
So far, the equipment supplier has either failed to provide such information or have requested an unreasonable fee to perform the necessary studies. Under such conditions, the IAP recommend the following course of action:

- review the existing physical model report to check levels of incipient cavitation phenomena.
- If needed, perform dedicated study by computational fluid dynamics.
- Should uncertainty be still excessive, a new physical model could be commissioned to an independent laboratory.

As discussed in several occasions, based on risk management principles, due consideration should be given to providing additional discharge capacity during the life of the Project.

2.2 Reservoir sedimentation

Figure 7 shows the profile of Rio Cauca upstream of the dam along with the sediment deposits measured to date.



Year	Situation	Methodology
2007	Before reservoir filling	Cartography 2007, LiDAR survey 2012, topographic survey 2016
2012	Reservoir impounded	Bathymetric survey, August 2018

Figure 7: Rio Cauca's longitudinal profile

The IAP observe the following.

- The apparent incongruence between LiDAR (year 2012) and topography (2016), both executed before reservoir filling, is explained by the fact that LiDAR does not fully penetrate wet areas.
- The same explanation applies to the LiDAR survey profile being above the 2018 bathymetric survey.
- Besides, those differences apply only to elevation near to the river bed and, as such, any discrepancy would have a negligible contribution to the reservoir volume (see figure 8).

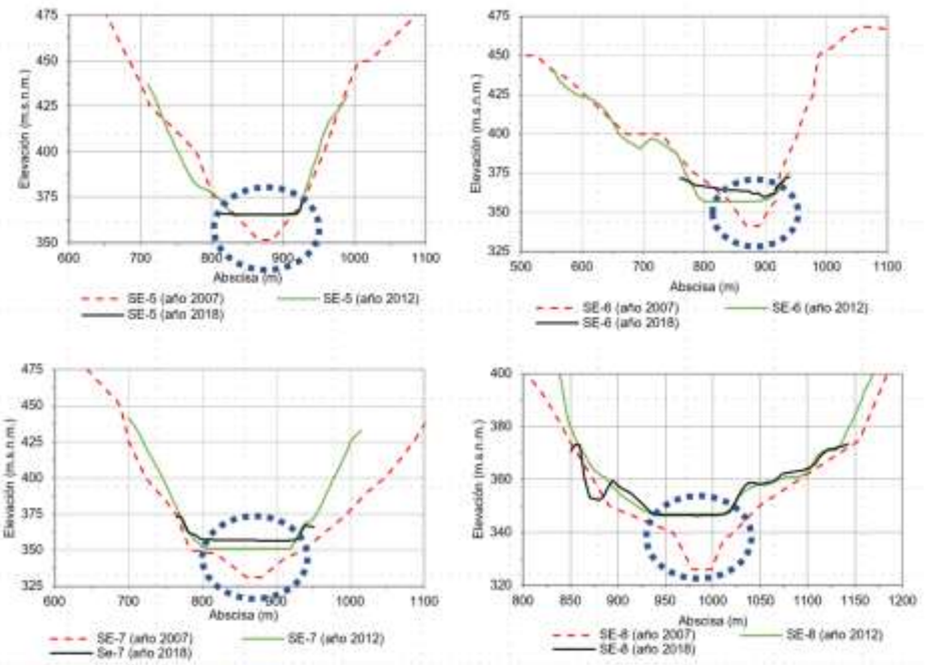


Figure 8: Negligible reservoir's volume in the lower portions of the river valley

In this initial stage of the Project, the key decision to make is about the baseline reservoir's geometry to associate to future bathymetric surveys. Based on the above observation, the IAP believes that the cartography of year 2007, validated by the 2016 topographic surveys, represents a suitable baseline.

3. GEOTECHNICAL ASSESSMENT

In general, the IAP observes no significant modifications, particular behaviour, or unsafe evolutions in the ongoing works. The same cannot yet be stated for the Southern part of the PH complex, in which the final design of the pressure shafts is still under definition. Remarks on the main geotechnical aspects of the different parts of the Project are presented in the following.

3.1 Powerhouse and Surge Shaft Caverns Complex

Rock mass strengthening is proceeding satisfactorily. Massive cavity filling with concrete (fig. 9) is in advanced status of implementation in the surge shafts. Backfilling is the appropriate measure for reinstating continuity of the hydraulic works.

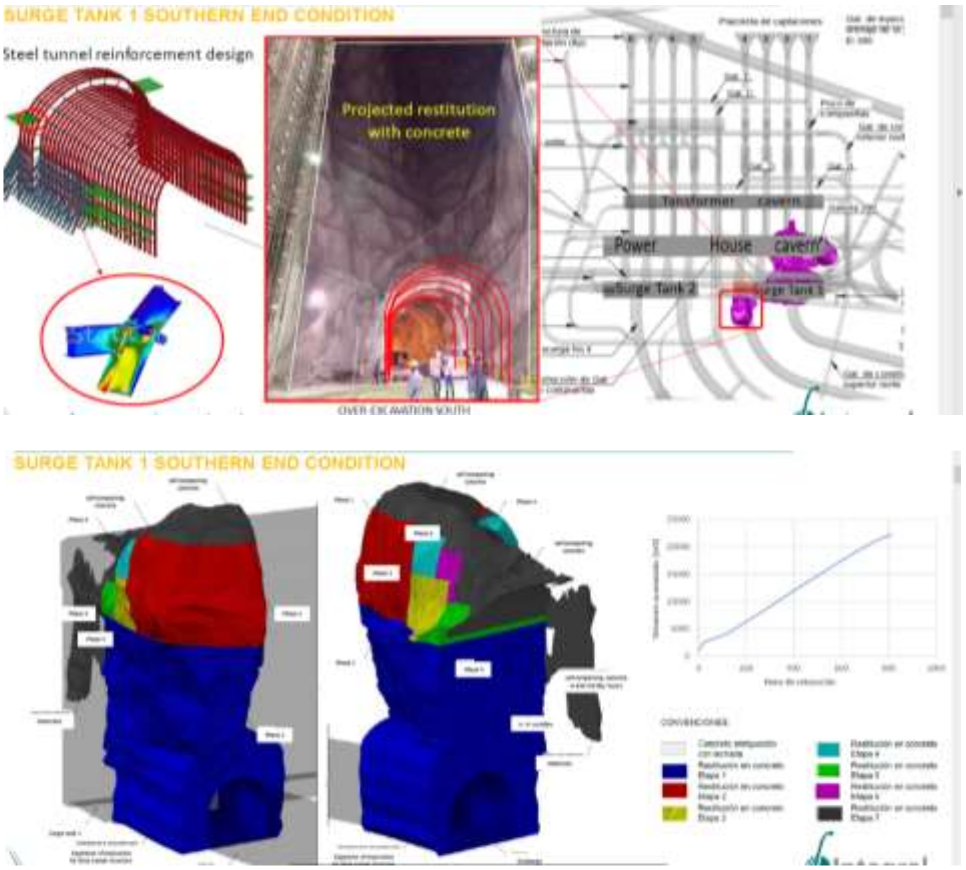


Figure 9: Massive cavity backfilling in surge tank 1

A few extensometers do not show achievement of full equilibrium (see fig. 10). Detailed review of future trends might suggest the need of additional rock mass reinforcement.

Measurement interpretation uses three reference “Thresholds: 0, 1, and 2”; the IAP is not privy to such thresholds and would like to know about them.

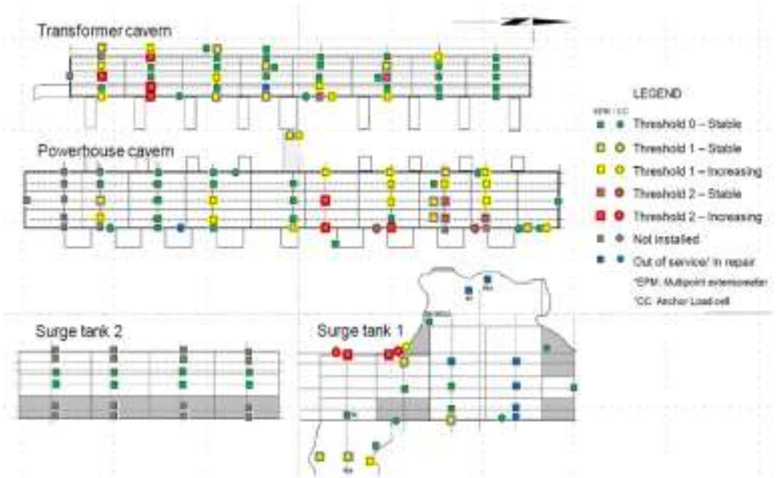


Figure 10: Extensometer readings

Piezometers have never measured ground water pressure, which is a good indication of rock mass integrity. The IAP reiterates the recommendation to provide relief holes to alleviate pressures should they develop during the life of the Project.

Performance of the underground works has been studied by an updated mathematical model. Dimensions, boundaries of the modelled excavations, meshing and staging, appear adequate and reasonable. The fact that the monitoring observations are matching the basic results of the numerical modelling is giving confidence to the credibility of the analyses. It is understood that the analyses have been conducted with elastic - perfectly plastic materials. Given the importance of the structure, and especially under seismic loading, it would be advisable to check the sensitivity of the results to a softening ground behaviour. In case some of the materials exhibit softening behaviour after plasticization, the extent of plastic zones may be broader, although the IAP is of the opinion that this is unlike to happen. Additionally, it would be interesting to comment on the structural response of the linings under the calculated, localized strains.

3.2 Southern zone shafts

Extensive drilling and grouting works have been carried out in the disturbed rock mass affecting the pressure shafts of units 5-8. Final design of the waterways is under definition with all options open, including partial re-construction of the shafts in the South Zone. Associated costs will be assessed after that and included in the budget to completion.

In consideration of the current situation, the IAP offer some reflections and recommendations that the Designer may want to consider in defining the appropriate solution.

Findings of the investigations carried out to date are in line with the geo mechanical model postulated in the IAP’s 5th Report (see fig. 11). Voids seem to be significant although part of them can be explained by a low total core recovery, not necessary associated with voids. Also, a major part of the surrounding is just jointed rock mass. This is clear comparing the recorded grout consumptions with those anticipated. A good number of inclined check holes will be necessary to confirm that strengthening and filling works are acceptable.

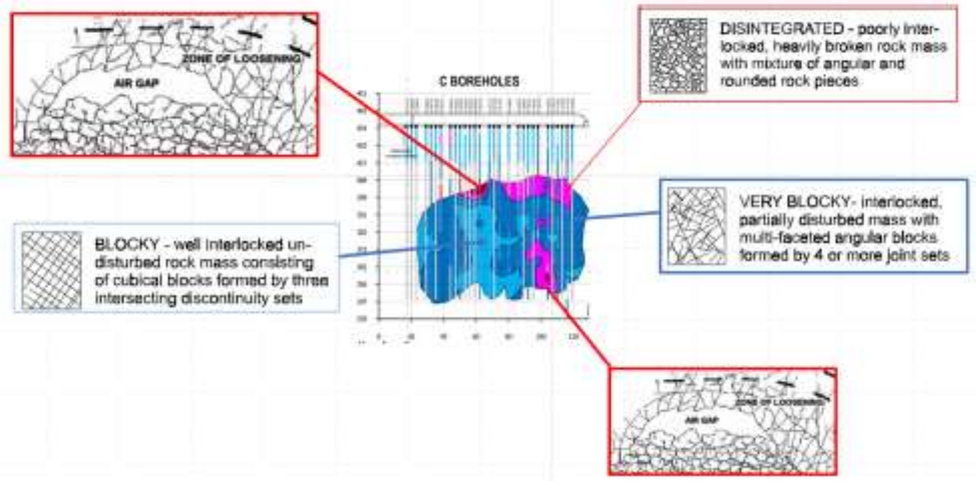


Figure 11: Conceptual model of the Disturbed Rock Mass

It should be expected that, as excavation works reveal the actual rock mass conditions, some areas showing instability or excessive damage will require special reinforcement and/or concrete backfill. The characteristics of such areas will have to be considered in the design of the shafts' permanent lining.

Lining design will depend on the stiffness of the same, relative to that of the rock mass. If the rock mass modulus of deformation is not negligible in comparison to that of the concrete, a fair amount of the internal pressure can be transferred to the rock mass. The IAP believes that the modulus of the less disturbed or even fairly jointed gneissic rock mass is in the order of 10 GPa, allowing part of the internal pressure to be transferred to the rock. This assumes that the zones with large voids are adequately treated/ backfilled.

A careful design, based on a detailed knowledge of the weaker zones, and on adequate treatment of the same, should avoid potential failure modes associated to tensile stresses on the lining leading to local cracking. Regional and local geology seems to indicate the absence of low minimum in situ stresses, unless in situ stress measurements, that the IAP has never seen, have revealed otherwise.

Hydrofracturing is not considered a potential failure mode because internal pressures can be higher than the external, hydrostatic, pressures only during rapid load rejection (water hammer). In such cases, the dynamic moduli of lining and rock mass would be mobilised, which are higher than the static ones. Consequent strains would be smaller and of a short duration.

3.3 Dam

Instrumentation and monitoring continue to indicate a satisfactory performance of the dam. Parameters are il line with design expectations, time-plots do not show abnormal trends, main parameters (notably settlements and seepage rates) are satisfactory for the type and size of Ituango Dam.

The main performance parameters are presented, in the following, as evidenced by the instrumentation and monitoring system.

The measured settlements are very low for a dam of this type and height, also in the top part which was raised in emergency. The curves of measurements tend to be close to each other, indicating a trend towards equilibrium. Only limited measurements, with vibrating-wire cells, exhibit a small increasing trend and are kept under close observation. The IAP believe that this a random local event.

Magnetic extensometers indicate stable vertical settlements of the D-wall (figure 12). These instruments have been showing values below the accuracy range of the devices (2,5 to 10 mm) since the completion of dam's construction.

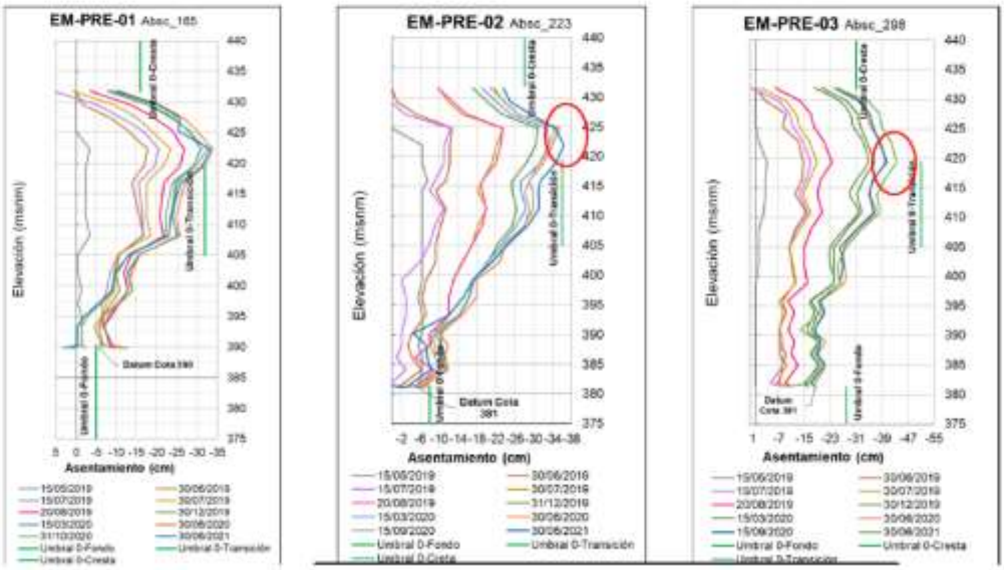


Figure 12: Magnetic extensometers: Vertical settlement in the D-wall

The vibration settlement cells, and the total pressure cells confirm the good performance of the dam.

There is good correspondence between calculated and measures deformations. The displacements of and around the dam are also measured with I Radar SAR-X. Two spots in the left side indicate small displacements which are not confirmed by the surface geodetic measurements at that side. The satellite observation indicates negligible rates of displacements.

Foundation piezometers indicate a good performance of the grout curtain, with low elevations of the piezometric line. Variations in the readings of some piezometers at chainage 400 have been observed due to the grouting performed from gallery 250 MI and towards the deep curtain. In the section at chainage 330 an inverse direction of flow may be observed in association of the double piezometers. A check has to be done, although this is not something of concern. Probably there are different piezometric levels, but always of very low levels.

The piezometers of the dam respond satisfactorily to variations of reservoir levels. No abnormal changes that could mean poor performance of the transition zone downstream of the core, or the integrity of the core, are observed.

In the previous report the IAP had recommended to proceed to the stability analysis of the dam body under different conditions and particularly of the downstream shell. This was presented and compared with the design assumptions. The IAP concur with the stability results.

Total seepage is in the order of 100 l/s, which is considered normal for this size and type of dam and this type of grouted (gneissic) rock mass.

Seepage values from the reservoir are low and acceptable. There is no turbidity. On the right side, part of seepages comes from the adjacent tunnels. The additional grouting at the left abutment did not contribute much to reduce seepage, but the amount of seepage is low anyway.

The performance of the priority fill and of the diaphragm wall is satisfactory. The infiltrations in the downstream side are very low: currently 2.9 l/sec with the reservoir at 406,89.

In conclusion the dam behaves satisfactorily, in terms of settlements, displacements, stability, grout curtain, seepage and ground water flow.

3.4 Spillway and Plunge Pool

Pore pressures, inclinometers, and topographic survey indicate satisfactory performance of the cut slopes. Few survey prisms have to be more closely observed, given a slight trend of increasing values. The IAP would like to know the definition of the threshold values used to interpret instrumentation readings.

Slope stability analyses have been conducted with a finite element code using a strength reduction factor (SRF). The meshing seems adequate; however, the full dimensions of the model are not obvious. If that shown in fig. 13 represents the total FEM model, it is possible that the boundaries may be affecting the results.

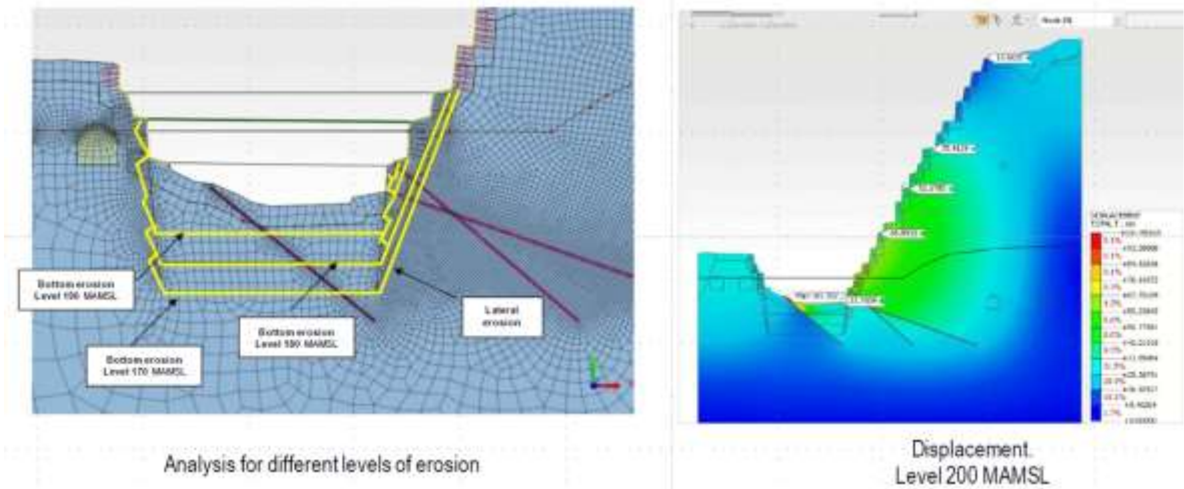


Figure 13: Slope stability analysis – Profile A-A

High pore pressures, that could denote a more unfavourable condition, do not seem to exist. The IAP assumes that seismic conditions were also checked and would like to be briefed about them in the next visit.

Although Profile B-B suggests a more favourable case compared to Profile A-A, with respect to slope height, and this is observed in the resulting displacements, the SRF values for both profiles are identical. The adopted SRF values appear to be quite high, especially for profile A-A. The matter deserves clarification.

It would also be useful to show the maximum shear strain contours, at the critical SRF, that are indicative of the critical failure surface.

For the "Extreme condition - Level 170 m.asl" of Profile B-B, the presented results are identical to those of Profile A-A and not matching with the rest of the results of Profile B-B. It is likely to be a typo.

Some minor signs of incipient erosion are highlighted, in two areas, by the monitoring boreholes from TD1. Their extent is very small, and monitoring will reveal if there is any development in the future.

3.5 Stability of slopes above the gate shaft platform

Stabilization works are almost completed, and stability has been secured.

Monitoring includes topographic monuments, load cells, inclinometers, and piezometers. All values are within the design thresholds.

IAP confirms its agreement with the strengthening measures of the zone over and around the *Romerito* sinkhole. The data show an effective grouting.

3.6 Slope further upstream to the south of Romerito

IAP agree with the proposed measures, designed to prevent the uphill extension of the instability phenomena, and further erosion from surface runoff (figure 14).

IAP reiterate the need to closely monitor the slope with ground monitoring, in addition to remote techniques.

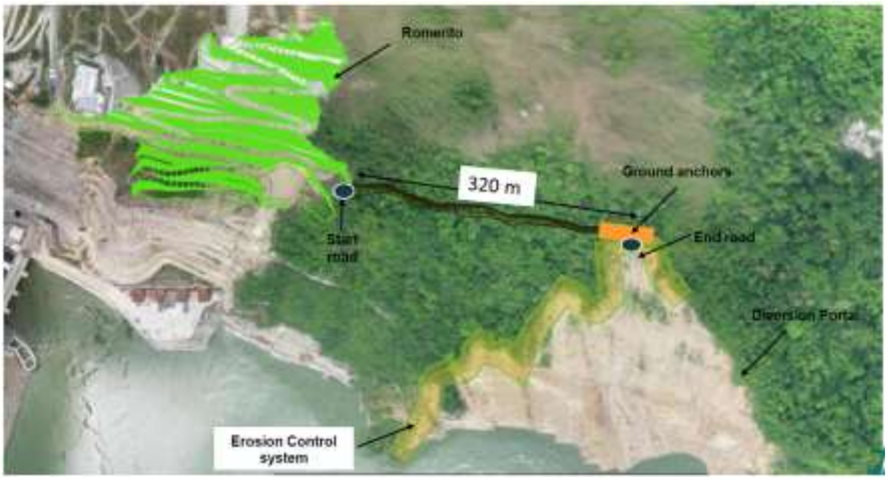


Figure 14: Protection measures to slope above the diversion tunnels

3.7 Instability of the area 0+900 upstream of the dam

The instability area is clearly defined and, although not of a big size, it affects the main route to Ituango and is close enough to the dam to generate impact waves should rapid collapse occur. The area is therefore kept under close monitoring.
Stability analyses are satisfactory. The IAP agree with the geometry of the instable zone and the adopted slope stabilization principles, and recommend the construction of a catch water drain to avoid surface runoff from entering the affected slopes.
The IAP believes that, because of the low permeability local formation, groundwater levels should not be too far from the ground surface. Piezometric monitoring should be further interpreted. Design of a permanent monitoring system is recommended.

4. ELECTRICAL AND MECHANICAL EQUIPMENT

4.1 Equipment in the cavern complex

During the July 2021 virtual mission, the IAP was enabled to observe, by remote cameras, the conditions of and the ongoing activities in the following areas:

- Transformer gallery was last visited in September 2019, together with the cable galleries.
- North powerhouse cavern and the northeast part of the South cavern (the north part was physically inspected in September 2019 while the South part was at that time filled with debris).
- North and South surge shafts were visited in September 2019

A complete assessment of the damages to most of the electromechanical equipment was available since September 2019 and it was confirmed during the May 2020 virtual mission. All the equipment already installed in the powerhouse's North area, including the mechanical parts embedded in concrete, were considered unsuitable for future operation. That assessment also applied to the step-up single-phase transformers and HV cables, the only components for which a possible recovery was not ruled out in principle. However, an EPM-Insurers joint survey decided for a complete replacement, mostly at Insurers cost. It must be added that the transformers' manufacturer (SIEMENS) would have not extended a guarantee for any equipment unless fully replaced.

Currently, 6 transformers are in their final positions; 4 of them were in place in February 2021.

Figure 15: Single-phase transformers 5 and 6

Consolidation of civil works are still ongoing on the southern part of the transformer gallery and in the cable gallery above it.

Figure 16: Single-phase transformer 9 and view from north side

Figure 17: Ongoing civil works at the cable gallery before installation of cable trays

The first 300 tons overhead crane was installed in March 2021; the second one is already on site, and it is not needed in the short term. Installation of the rails is completed on the upstream crane way and is ongoing on the downstream one. Table 18 summarizes the installation progress.

Instalación de rieles del puente grúa de 300 t entre unidades 1 y 6	
Item	**% de avance**
Placas banda Instaladas	100%
Rieles instalados	77%

Table 18: Progress of installation of crane rails

Currently EPM is mainly using mobile cranes and a temporary 25 t overhead.

Figure 19: The first overhead mobile crane with EPM flag just above the loading bay

Figure 20: Works on overhead travelling cranes, rails supports and rails

Figure 21: Overhead crane's travelling rails completed

Rehabilitation of units 1 and 2 started from first phase concrete. Complete removal of units 3 and 4 concrete is ongoing.

Figure 22: Unit 1 construction and installation activities

Figure 23: Unit 2 construction and installation activities

Figure 24: Concrete demolition at units 3 and 4

EPM decided to replace the original reinforced concrete Control Room North with a, faster to build, steel structure; the foundation may be seen in picture 25.

Figure 25: Civil works in the foundation of Control Room North

The civil works necessary for the installation of the guides of the draft tube gates are in progress.

Figure 26: Ongoing works on the draft tube gates in the North Surge Shaft

4.2 Progress of assembling and installation

IAP report N. 4 detailed all the orders placed as of May 2020, for re-establishing the electromechanical supply of Ituango, and report N. 5 listed the remaining signed contracts. All other remaining minor packages are reported to be signed / close to signature. Completion of supply of the electromechanical equipment no longer represents a critical factor for the commercial operation of Unit 1, in July 2022, and that of Unit 2 in October 2022. EPM's attention is therefore concentrated on assembling and installation activities.

Power intakes, steel lining to pressure shafts and turbogenerator of Unit 1 are on the critical path and are analyzed in detail in the subsequent two paragraphs.

Transformers' supply and installation are not on the critical path. The other 19 are already procured and on the way to site.

EPM is currently installing the 6 transformers, out of the of the original supply of 25 single phase transformers, which are sufficient for units 1 and 2.

Seguimiento transformadores	Ejecutado Unidad 1		Ejecutado Unidad 2	
Ensamble mecánico transformadores	100%		41%	
Gas Insulated Busducts	19%		0%	
Neutro	67%		0%	
Instrumentación y control	100%		73%	
Pruebas eléctricas especiales	0%		0%	
Avance – Transformadores	Programado: 83%	Ejecutado: 67%	Programado: 22%	Ejecutado: 33%

Table 27: Progress of installation for the 6 single phase transformers of Unit 1 and 2

Similarly, the damaged 11 HV single-phase cables are procured and on the way to site. Their delivery and installation are not on the critical path.

Draft tube gates have been procured and are expected to be on site in time. Guides are already available and civil works are in progress as shown below.

Draft tube gates- Pórtico de la almenara 1			
Actividad	**Avance acumulado**	**Cantidad total**	**% avance**
Concreto viga de fundación	100.0 m	100.0 m	100%
Concreto vigas aéreas	307.1 m	700.0 m	44%
Concreto columnas	251.9 m	347.4 m	73%
Concreto losas aéreas	66.0 m	200.0 m	33%

Figure 28: Progress of civil works for the draft tube gates in the shaft chamber north

4.3 Critical schedule: Power Intakes

The underwater works for the activation of the power intakes, including cleaning the debris upstream of the trash racks, have not started yet and the main contracts have not yet been signed[1].

The works to be executed are complex and specialised (fig. 29 and 30). Management of unforeseen conditions is a key factor in underwater works. In the IAP's view, this is the most challenging activity for the commencement of operation of units 1 and 2.

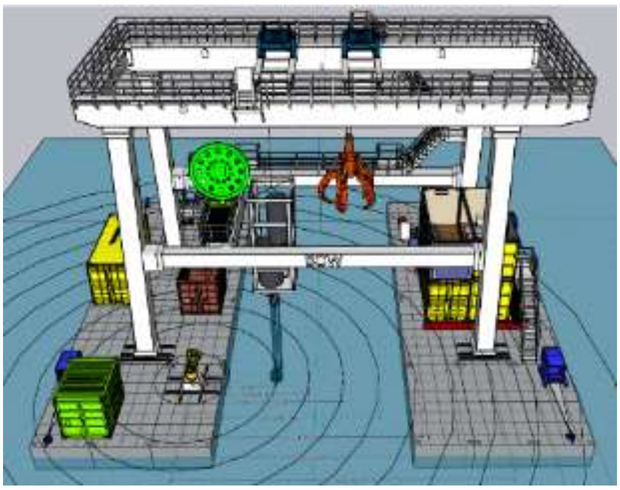


Figure 29: Schematic representation of the ponton for underwater works

[1] The IAP understands that only a 10 million USD contract has been signed up to 30th June 2021.

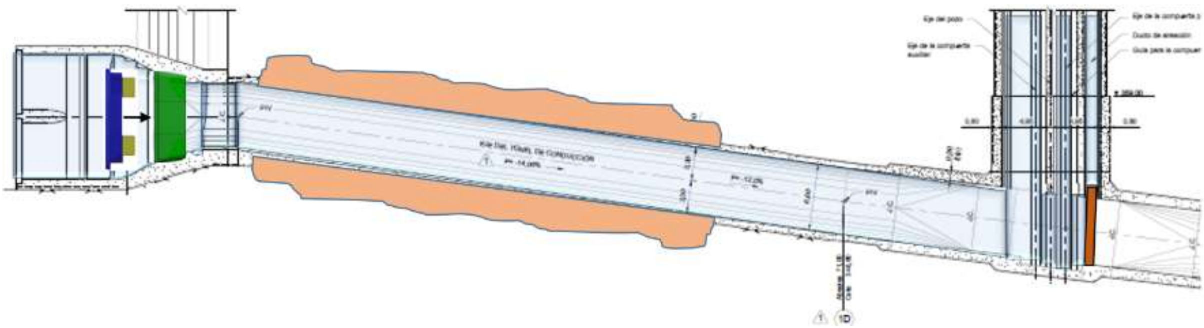


Figure 30: The 20 m unfinished concrete lining of Power intake 2

4.4 Critical schedule: Steel lining to pressure shafts

The original design foresaw steel lining only in the horizontal section between the lower elbow and the spiral cases. The large cavity in the area of pressure shafts 1 and 2, forced to extend the steel lining to the entire shaft lengths.

The installation of steel lining depends on four main drivers.

(i) Access and availability of adequate room, equipped with lifting devices, above the upper elbow.
(ii) Placement of the steel sections in the lower elbow for top-down penstock's installation.
(iii) Availability of enough sections of penstock to maintain adequate installation speed.
(iv) Adequate welding methodology to support the installation pace.

Each driver is separately examined in the following. The associated schedule is analysed and commented in section 5.3, in the general context of completing Units 1 and 2.

(i) Access above the upper elbow

The activities in the D gallery and in the area above the upper elbow are well advanced and will be completed in the next few weeks (table 31 and fig. 32).

Demolición zona de codos superiores para montaje de equipo de blindaje			
Item	**Avance acumulado**	**Cant. Total a ejecutar**	**% avance**
Codo 1 km 0+105,9/118,6	12.7 m	12.7 m	100%
Codo 2 km 0+105,9/118,6	12.7 m	12.7 m	100%
Codo 3 km 0+105,9/118,6	12.7 m	12.7 m	100%
Codo 3 cotas 339,25/329	9.7 m	10.25 m	95%
Codo 4 km 0+105,9/118,6	12.7 m	12.7 m	100%
Codo 4 cotas 339,25/329	10.1 m	10.25 m	99%

Table 31: Progress of civil works for accessing the upper elbow

Figure 32: Foundation of monorail for installation of penstock 1

FIN QUI

(ii) Placement of the steel sections of the lower elbow

Detailed inspection of the steel lining of the lower elbow of units 1 and 2 recommended to replace and selectively rehabilitate these portions of the waterways. The corresponding activities are time consuming and must be carried out sequentially (table, fig. 34 and 35); they represent critical activities. Section 5.3 reviews schedule implications in detail.

Demolición zona de codos conducción inferior para montaje de equipo de blindaje				
Ítem	Avance acumulado	Total a ejecutar	% avance	Avance semanal
Codo 1 desde pozo de presión 1	14,1 m	14,1 m	100,0%	
Codo 1 desde ramal 1	20,5 m	20,5 m	100,0%	
Codo 2 desde pozo de presión 2	14,1 m	14,1 m	100,0%	
Codo 2 desde ramal 2	20,5 m	20,5 m	100,0%	
Demolición zona de túnel de conducción inferior				
Túnel de conducción 1	2,8 m	2,8 m	100,0%	
Túnel de conducción 2 virolas 1 a 4	12,0 m	12,0 m	100,0%	

Table 33: Progress of civil works for removal of existing steel lining and subsequent access to lower elbow for installing new sections

Figure 34: Removing concrete around the existing steel lining of Unit 1 lowest elbow

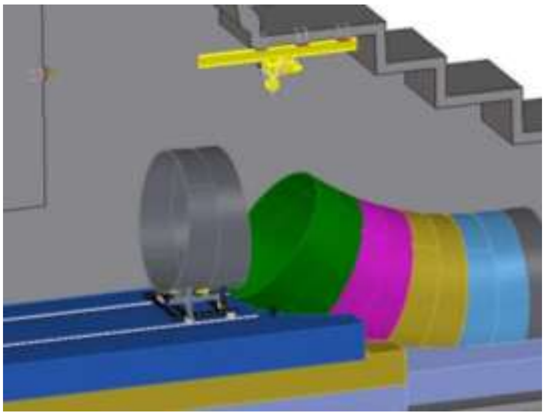


Figure 35: Method for installation of lower elbow

(iii) Availability of enough sections of penstock

Even though a significant part of the workshop capacity and raw steel plate were utilized to replace the steel lining of the lower elbows, the production of vertical sections of the penstock proceed satisfactory and it is not critical.

Figure 36: 28 out of 49 vertical sections for units 1 and 2 available in the storage area

(iv) Welding methodology to support the installation pace

To recover the extra-time needed for the lower elbows, EPM is planning to use an automatic welding machine, owned by ATB, to reduce the timing of each circumferential welding. That will allow to carry out the circumferential welding of three sections of vertical penstock, in the warehouse, which will reduce the number of monoliths during underground installation.

4.5 Critical schedule: Turbo-generator Unit 1

Construction and installation activities for units 1 and 2 are ongoing. Since concrete works had to start approximately 20 m below the lowest part of draft tube, the original sequence for commercial operation has been revisited and unit 1 will be the first one to go in operation.

Concreting works are almost completed at both draft tubes of units 1 and 2; construction and installation activities for Unit 2 are ongoing in parallel to the ones of Unit 1. In parallel with construction and installation of units 1 and 2, EPM is proceeding with the demolition of first and second phase concrete at units 3 and 4.

To shorten the schedule, EPM is using the temporarily backfilled bays of units 5 and 6 as additional loading bays for assembling the spiral cases of units 1 and 2 (fig. 37 and 38). Each spiral case (250 ton) will be translated to the permanent location by the 320 ton Overhead Travelling Crane. Such preassembling will not be replicable in the future because the area of Unit 5 – 8 will soon be affected by civil works.

Figure 37: Spiral cases of Unit 1 and in the background of Unit 2

Figure 38: Progress of spiral cases of Unit 1 [almost finished] and of Unit 2 [well advanced]

Figure 39 shows the 6-phases sequence of electromechanical and civil works for the completion of Unit 1. It includes the civil works to complete the three remaining floors at elevation 204 m asl (Floor 2 - Turbine) 211,90 m asl (Floor 3 – Generator) and 217 m asl (Floor 4 – Plant Hall).

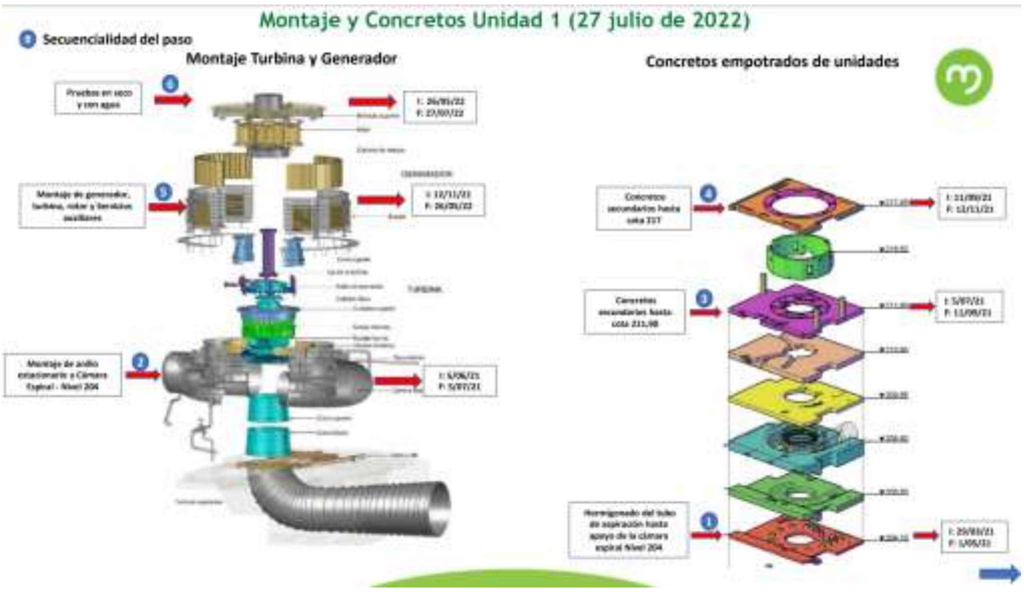


Figure 39: Unit 1 time to completion – electromechanical and civil works

Phase 1 should have been completed on May 1st but, due to assembling of Spiral Case, Phase 2 scheduled to be completed on July 5th 2021 has accumulated some delay.

On July 25th, as this Report was being prepared, the IAP was informed that the spiral chamber of Unit 1 had been installed (fig. 40) and that the one of Unit 2 was in the process.

Figure 40: Unit 1 spiral case in place on July 25th
https://www.elcolombiano.com/antioquia/instalan-equipos-para-llevar-agua-a-las-turbinas-de-hidroituango-OP15292369
This is an important step for the Project and the IAP congratulates EPM and the teams at work that contributed to the success.

4.6 Other electro-mechanical works

500 kV GIS switchyard

The 500 kV switchyard is completed. HV power cables, power and control cables, coming from the power plant, will have to be reinstalled. The cable gallery and its connections with the 500 kV GIS switchyard are in good conditions. Stabilization works have been completed of the slope above the switchyard area.

Intake gates

Activities on the Intake gates and their operating systems are almost completed.

The following table summarizes the IAP's remarks on the Intake gates.

Hydro Mechanical Equipment	Progress of installation and testing	Remarks
Intake Gates Height Sliding Gates, 5.03 x 6.87 m, with stoplogs. Operation: oleo dynamic servomotors.	The area is now safely accessible, and an additional physical protection is installed above pit and control box of Unit 1 to 4. Installation almost completed.	Gates close under balanced pressure conditions and, in emergency, under the maximum hydraulic head and the rated flow of the Unit. However, it was demonstrated their capability to close under flow higher than the rated one.

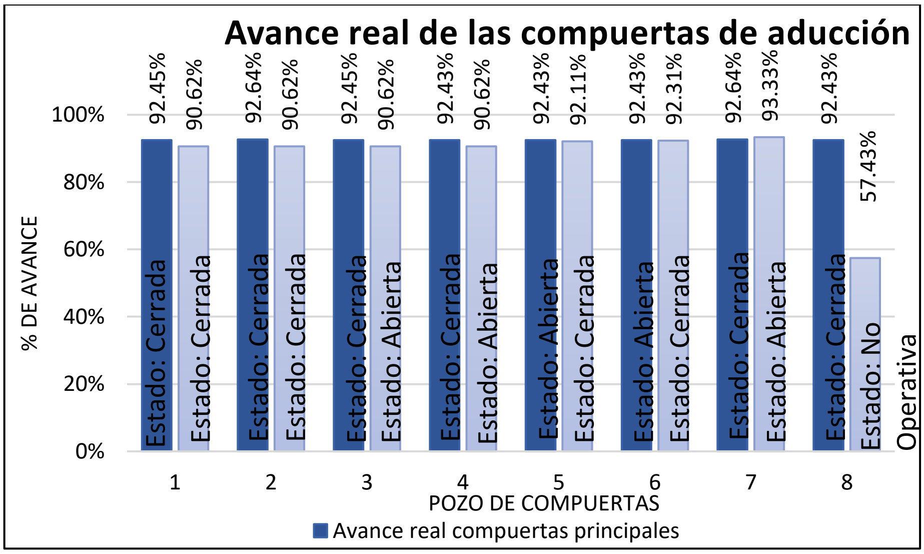


Fig. 41: Intake gates: Progress of installation

GAD gates

The two GAD vertical sliding gates were successfully lowered in February 2020. A concrete plug was placed on the top of the gates to block any movement (with such installation the tunnel is technically plugged) and the lifting systems and cranes were removed and utilized elsewhere. Two temporary by-passes are installed (fig. 42) to alleviate the reservoir pressure on the gates and to further increase safety until the permanent plugging of GAD will be built. One by-pass is direct (currently operated), the other is routed through the IDG (it will be operated at the time of plugging the GAD). After successful plugging of the GAD, the gate control chamber will be abandoned.

Figure 42: GAD gates in their final position with temporary direct by-pass system (left) and through the IDG (right)

Spillway and IDG Gates

The following table summarizes the situation of the Spillway's and IDG's gates. EPM did not report any problems for the operation of the equipment.

Hydro Mechanical Equipment	Progress of installation and testing	Remarks
Spillway Gates Four Radial Gates (two with flap for debris) 15 m x 19,50 m Cumulated discharge capacity: 22.600 m^3/s (PMF) Operation: oleo dynamic servomotors, single control and oleo dynamic stations for each gate + common control	Already in operation, testing and common control completed. Diesel generator testing completed.	In case of earthquake, rockfalls may hit the diesel generators building. Statistics show that reliability of diesel generators in case of exceptional events is lower than expected. Risk assessment is recommended.
Gates to intermediate Discharge Gallery Two Radial Gates + two Emergency Sliding Gates Size: 3 m x 3.90 m (Radial Gates) Setting capacity: 750 m^3/s with both gates in operation for all reservoir elevation higher than 350 m a.s.l. Operation: oleo dynamic servomotors, single control and oleo dynamic stations for each gate.	Already in operation conditions, testing and control completed. Steel lining installation duly completed.	Environmental Authority may consider reducing the operating condition of 450 m3/s.

PROJECT COMPLETION- SCHEDULE AND COST IMPLICATIONS

5.1 Milestones Review

As part of their advisory services, the IAP members are to review and certify the achievement of specific milestones as set forth in Schedule 6 (*Critical Milestones*) and

Schedule 8 (*RDT Critical Milestones*) to the Loan Agreement between EPM and IDB Invest. The following table 43 reviews the achievement of the currently relevant milestones.

Milestone	Observations	Status
Overhead crane installation for northern generation cavern	300-ton crane in place and operational. Rails installed over 77% of the displacement length; adequate for assembling units 1 to 4.	Complied
Completion of the grid of 62 micropiles.	To date, all the 63 micro piles have been installed, 58 of which fully grouted. Piles are 9 more than originally planned to minimise gaps associated with piles' deviations from the vertical.	Complied

Table 43: Milestone achievement

5.2 Progress of underground works' recovery

The scheme shown in fig. 44 provides a snapshot of the progress of the repair and recovery works in the powerhouse cavern complex.

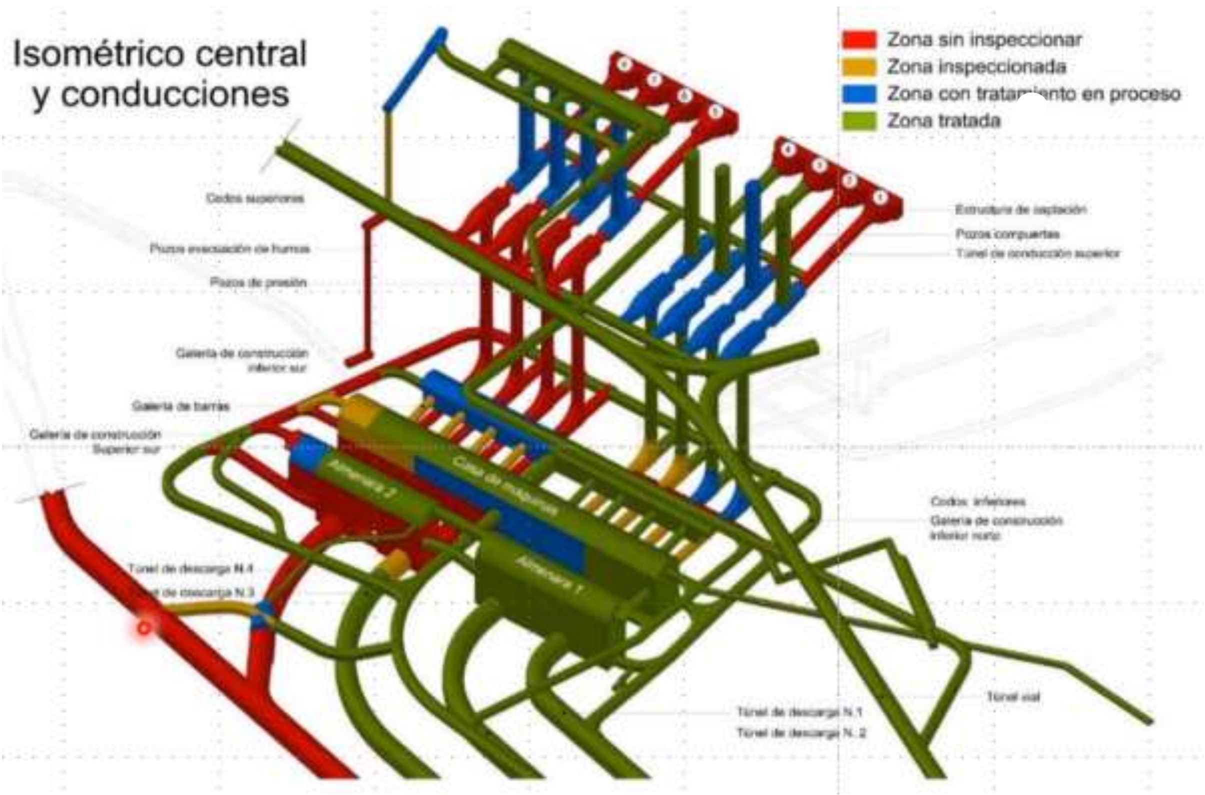


Figure 44: Recovery of underground works, progress overview as of June 2021

The following can be observed:

- Intakes 1 and 2 still require complex completion works, which currently represent the most challenging activity to meet the COD of units 1 to 4. Besides, any adjustment/ modification of such equipment would imply long delivery time.

- The voids that were encountered in the draft tube area of units 1 and 2, have been concrete backfilled and fully stabilised.
- Most of the permanent works have been secured in the North part of the PH cavern, and major collapsed areas are no longer expected at this location.
- The large zone of disturbed rock mass, in the Southern part of the PH has been investigated and delineated. Treatment measures are under definition.
- Treatment of the pressure shafts to units 5 to 8 is ongoing, shafts 7 and 8 will probably need to be re-constructed; detailed design is not yet defined. Since works will have to be done after units 1 and 2 are in operation, a careful design and associated planning are required.
- To ensure safety during operation, EPM plans to stabilise the southern part around the shafts before units 1 to 4 start generation.

5.3 General on Project Schedule

EPM applies the Line of Balance (LOB) method[2]:

- For controlling production, and
- as a project management aid.

In LOB, the Objective Charts are represented as «S curves» (see figure 45), and the Program Charts are the equivalent of the Gantt charts in PERT.

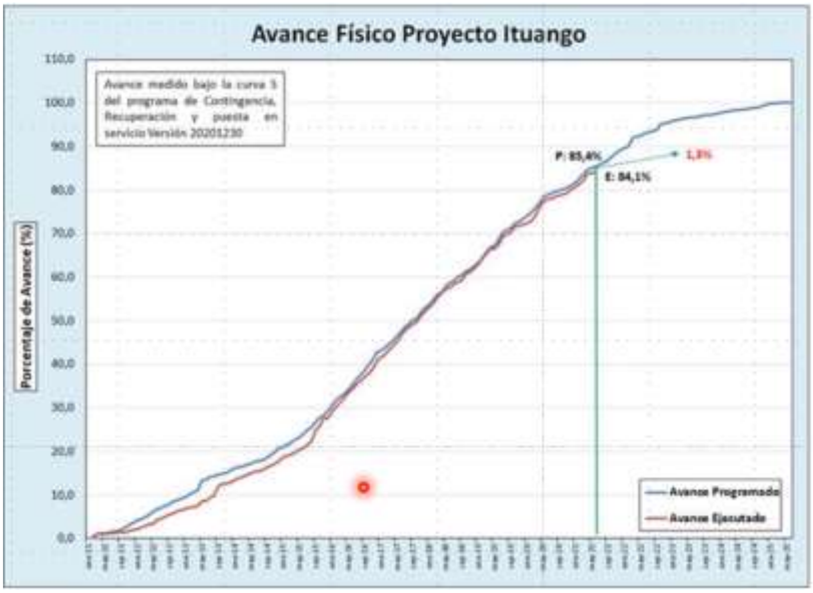


Figure 45: "S" curve showing consolidated Project's progress

LOB is appropriate for high level management of complex projects. It focuses on the planned versus actual progress for individual activities and provides a visual display of the differences between the two. Identification of the differences enables management to

[2] Also referred to as "Metodo por productos finidos"

control progress of the works and to determine priorities for reallocation of resources. Reallocation of resources is effective when several work fronts are opened, which employ common resources (plant, equipment, materials, labour). When few works, of specialised nature, are ongoing, reallocation of resources becomes less effective, if not feasible at all.

When some activities are flagged, in LOB's Program Charts, to be about to becoming critical, PERT planning becomes necessary. As a matter of fact, that is what EPM requests to its contractors when some activities go critical.

At this very advanced stage of implementation, when a few critical activities are identified, PERT method is an essential tool to assess whether construction progress is advancing towards timely achievement of Commercial Operations Dates.

To assess the actual progress, the IAP used the Timeline Now (TLN) tool, which is a method to get a broad vision and a comprehensive evaluation of the consequences of activities included in a critical path. The TLN has been used to analyze two sets of activities, which the IAP regard as critical in this period of Project's implementation:

- Waterways of, and Units 1 and 2.
- Permanent Sealing of TD2 and GAD

TLN has been set on 30th June 2021, which is the date at which most of information on work progress were provided for the July 2021 Visit.

In the temporary absence of PERT, the IAP had to resort to a laborious examination of EPM's presentations to muster an understanding of the physical progress of the critical activities. Cross referencing the information gathered from the presentations to the EPM Chronogram of 31st December 2020 permitted to assess the likely delays.

The two critical schedules are presented and commented on in the following paragraphs.

5.4 Critical schedule: Waterways of, and Units 1 and 2

Figure 46 shows the main activities that need to be completed to materialize the hydraulic route to Units 1 and 2, from upstream (Intakes) to downstream (Units 1 and 2 themselves).

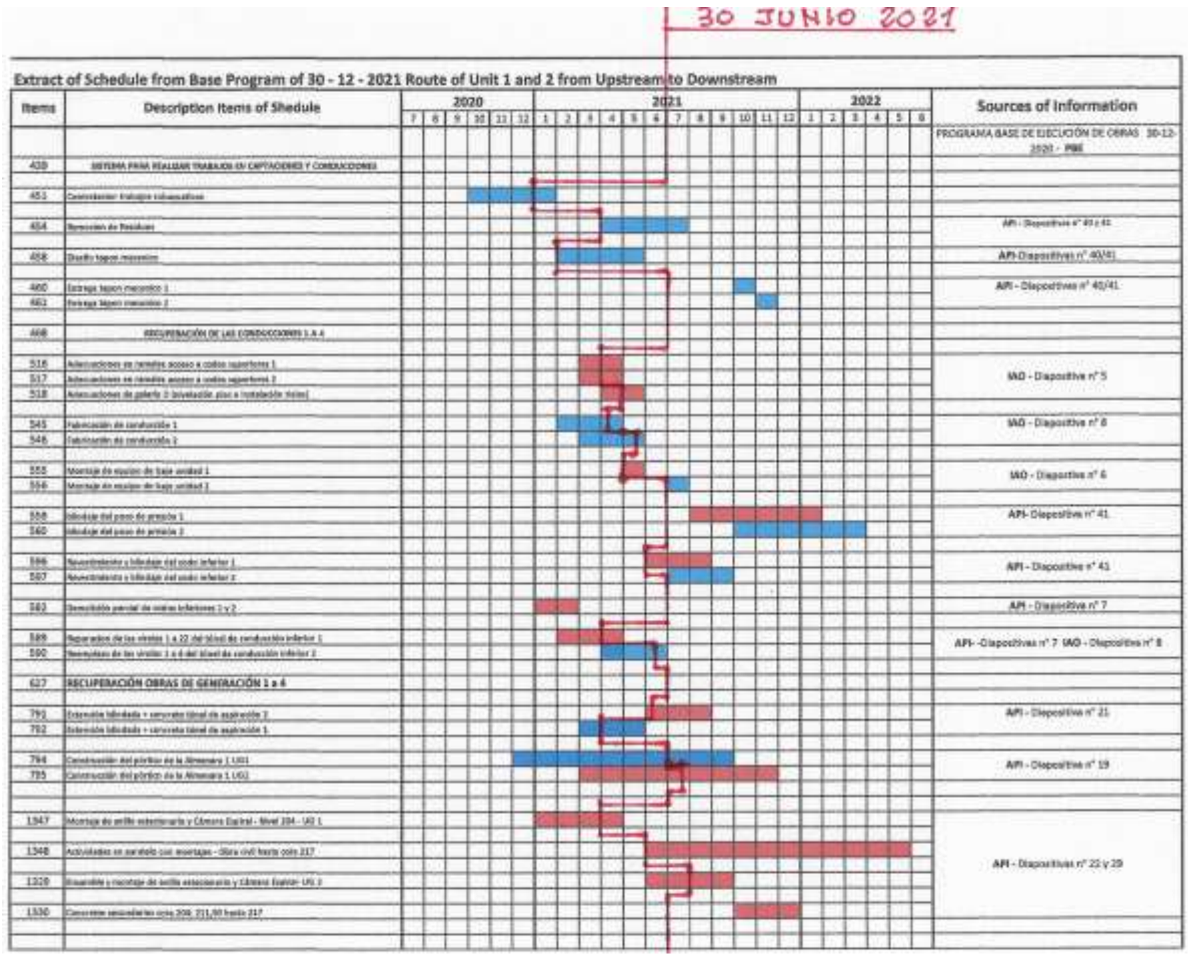


Figure 46: Time Line on 30 June 2021 Waterways of, and Units 1 and 2

The selected work items have been derived from the EPM Chronogram (*Programa de Ejecucion de Obras_PBE*) of 31st December 2020, and the corresponding codes retained (first column). In addition to the PBE, other two sources of information have been used:

API: *"Actualización Proyecto-Tema Informativo" dated 6th July 2021*
IAO: *"Informe de avance de las obras de estabilización" dated* 28th June 2021.

The last column of the figure shows those slides, of either API or IAO, from which information, relevant to specific work items, have been derived.

The TLN allowed to assess the delays shown in table 47, the last column gives the rationale for each assessment.

Section of works	Assessed delay	Rationale
Intake Works	6 months	Item 451: The contracts with the specialised firms for the underwater works were not yet finalised on July 8th, 2021. That constitutes a critical delay because it refers to a resource (specialised sub-contractor) that cannot be e-allocated. The TLN indicates a delay of 6 (six) months for item 451. Item 458: it depends on item 451. Indicated delay 5 months.

		Item 454: not yet started, indicated delay 3 months.
Waterways 1 to 4 (as far as units 1 and 2 are concerned)	3 months	The largest delay is associated with the installation of the steel lining in the lower bends (*codos inferiores*) at the base of the vertical shafts (item 589). In the API presentation, slide 24 shows the lower elbow's demolition as completed, while slide 7 of the same presentation, lists the demolition of the lower elbows of units 1 and 2 *(Demolición de codos inferiores unidades de generación 1 y 2*) among the ongoing work fronts (*Frentes actuales de obra*). This section of the works appears therefore to be in delay, in particular the lower penstocks 1 & 2. The IAP's assessment of such delay is 3 months. Other items, related to the rehabilitation of waterways 1 to 4 have delays (e.g., items 516, 517, 545, and 555), but they are smaller than that of item 589 and considered less critical for the reasons given in section 4.3.
Units 1 and 2	3 months	The estimated delay is associable to items 792 (concreto tunel de aspiracion1). Item 1347 (montaje camara espiral nivel 204 UG1) affects the second phase concrete at el. 217. Item 1348 has a delay of one month. The IAP considers the delay recoverable due to the successful installation of the spiral-case on July 25th.

Table 47: Waterways of, and Units 1 and 2- Assessment of current delays

The IAP considers the situation of the Intake works as the most critical at the moment. The delay can be recovered only with a prompt finalisation of the contracts with the specialised firms, and an accelerated implementation schedule.
Completion of demolition and steel lining installation in the pressure shaft's lower elbows should also be accelerated to recover the current delay.

5.5 Critical schedule: Permanent Sealing of TD2 and GAD

The TLN diagram for the activities related to the permanent sealing of TD2 and GAD is shown in figure 48.

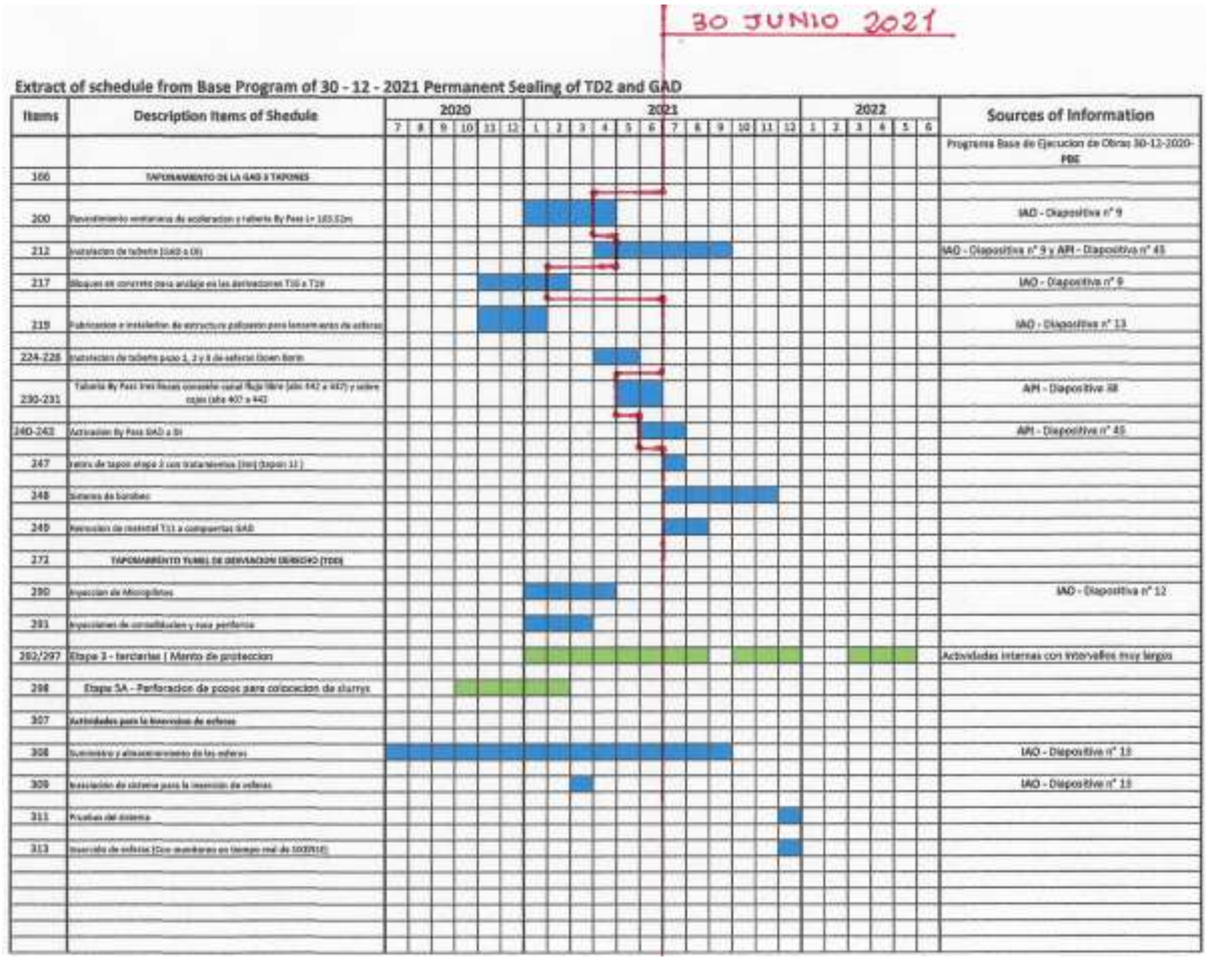


Figure 48: Time Line on 30 June 2021 Permanent Sealing of TD2 and GAD

Also in this case, the work items have been derived from EPM Chronogram (*Programa de Ejecucion de Obras_PBE*) on 31st December 2020, and the corresponding codes retained (first column). In addition to the PBE, other two sources of information have been used:

API: *"Actualización Proyecto-Tema Informativo" dated 6th July 2021.*
IAO: *"Informe de avance de las obras de estabilización" dated 28th June 2021*.

The Time Line Now in fig. 48 reveals an accumulated delay of 5 months for item 217 (*Bloques en concreto para anclaje en las derivaciones T16 a T19*). Besides, there is evidence of a slow implementation pace of activities 292-297 between May and October 2021, the reasons for which are not evident to the IAP.

The IAP believes that, given the independence of the work items involved, from those of Units 1 and 2, there is room for recovery of the assessed delay in the context of the Project's milestones. Certainly, EPM is well aware of this and is kindly requested to review the IAP's assessment and inform on progress achieved in due time.

5.6 Achieving Commercial Operation

During the visit, the IAP learned that, to date, there is still no definition on whether the construction consortium, the supervision consortium and the advisory firm will continue to work after December 31st 2021. The situation is beyond EPM's control, which makes it the most crucial issue for schedule management, and for the commercial operation of Unit 1 by July 2022. The following remarks are made independently of this issue.

The commencement of operation dates of units 1 to 4 are those shown in the following table.

Commencement of Operation dates (COD) as in December 2020 schedule	
Etapa 1	
Unit 1	July 2022
Unit 2	October 2022
Unit 3	January 2023
Unit 4	September 2023

In the previous sections, IAP has assessed delays in the order of 3 to 6 months, for activities which are critical for achieving the scheduled CODs. This does not necessarily mean that the CODs are subject to the same delays, because:

- EPM's detailed planning may contain elements that the IAP cannot deduct without PERT-like diagrams
- EPM is implementing acceleration measures to recover the delays.
- The successful installation of U1 spiral case on July 25th is a case in point.

Anyway, it is the IAP's role to raise the flag and obtain evidence from EPM that the above measures are being implemented. In that context, it should be pointed out that, compared with February 2021, the free slacks of the Project' schedule have reduced and that the delays caused by the additional civil works can only be compensated by accelerating the mechanical and electrical installations.

It should be appreciated that, in the absence of PERT diagrams, the IAP assessment had to be based on cross referencing the December 2020 schedule to the information contained in EPM's presentations. The IAP would not like to repeat this indirect and approximate approach, therefore the IAP will appreciate to receive, at least, TLN diagrams on the EPM schedule of works, which is valid at the date of the IAP's next visit.

Dates pertaining to Etapa 2 i.e., units 5 to 8 have been revised as shown below.

Commencement of Operation dates (COD) as in December 2020 schedule	
Etapa 2	
Unit 5	August 2024
Unit 6	October 2024
Unit 7	December 2024
Unit 8	February 2025

Given the considerable uncertainties associated with the completion of rehabilitation works in the Southern zone of the PH complex, and of the disturbed rock mass in particular, it is still premature to make any meaningful comment on the achievement of those CODs.

5.7 Cost implications of the completion schedule

In its 5th Report, of March 2021, the IAP examined the subject of costs to completion in some more detail, then done before.

The analysis was limited to the values of "*Inversiones*" (investment costs or capital investments- CAP), for the following reasons:

- CAP represents over 80% of the total project cost.
- Estimating the additional cost items (pre-operation, IVA, insurance payments) would require auditing the Project's accounting, which is beyond the IAP' scope.
- CAP estimates can be further refined, should that be necessary, using priced bill of quantities of the works.

Due to the fluctuations of the USD/ COP exchange rate, use was made of COP values only, without converting the figures into USD.

Cumulated costs were derived as shown in fig. 49, using the most updated annual costs, among the three "*Presupuestos*", of the years 2019, 2020, and 2021.

Year	PR2019	PR2020	PR2021	Cumulative	Scaled up
pre 2016	4,276,267			4,276,267	4,276,267
2016	1,330,392			5,606,659	5,606,659
2017	1,738,149			7,344,808	7,344,808
2018	1,392,535	1,455,697		8,800,505	8,800,505
2019	1,048,991	1,067,559		9,868,064	9,868,064
2020	882,622	1,254,602		11,122,666	11,122,666
2021	465,501	869,198	1,554,893	12,677,559	12,677,559
2022	278,995	350,383	768,898	13,446,457	14,261,989
2023	231,247	162,427	283,784	13,730,241	15,649,660
2024		70,593	88,262	13,818,503	15,979,942
2025			30,053	13,848,556	16,014,696

Figure 49: Annual and Cumulated Investment Costs

The orange curve ("scaled up"), with a cumulative investment cost of about 16,000 billion COP, was considered a realistic assessment of the investment costs to Project completion.

During the July 2021 mission, the IAP was informed that EPM’s Management was about to decide on a budget increase for the completion of the works. Timing for the decision is based on the advanced understanding of the underground conditions and of the associated remedial works. The IAP understands that the budget increase is in line with the estimate in fig. 49 above.

ANNEX A: LIST OF DOCUMENTS MADE AVAILABLE TO THE IAP

On July 5, 2021

1. Informe de seguimiento Obras 28-06-2021. EPM

2. 202107_BID_DAM

3. 202107_BID_SPILLWAY PLUNGE POOL

4. 202107_BID_CAVERNS

7.1. 202107_BID_Ob_Sup_Romerito_Des_km0 900

7.2. 02107_BID_Diversion Portal

8. 202107_BID_South Conductions System

9. UNDERTWATER WORKS PRESENTATION (BID 2)

11.1. PHI-AVANCE MONTAJE_ATB_GE_JULIO_2021_V0

11.3. Ituango - Presentación cronograma en barras 20201230 - Junio 2021 BID

11.5. Actualización riesgos técnicos BID_07072021

11.6. Estado medida preventiva Jul2021

11.7. Informacion BatimetricaJulio2021_BID

Updates during the virtual mission

Bathymetric SurveyJuly2021_BID

Estado medida preventiva Jul2021_Inglés

ITUANGO-Avance del costo a mayo de 2021

ITUANGO-Julio 6 de_2021 (002)_ACC_SDU

Premisas y Entradas en operación programa 20201230

Actualización Proyecto Hidroeléctrico Ituango_Tema Informativo

Ituango - Presentación cronograma en barras 20201230 y CS - junio 30 BID 1

Unidad 1 - Desglose de actividades PHI

PR00688-Phase1-ROVInspection Ituango (update)

S curves received on June 25, 2021

ITUANGO-COSTO PRESUPUESTO 2021

ITUANGO-Avance del costo a marzo de 2021

Ituango - Avance curva S, explicación desfases y planes de recuperación

Documentation received on May 5, 2021 partially as a reply to IAP Report N.5

01 Underground_Numerical_Model

02 _ZonaSur_Condicion Previa_2004

02 Additional pics_Southern caverns

02 Afectación Sur

03 Lechadas - Almenaras-2

03 Mezclas aglutinamiento

04 BID MD infiltraciones_ octubre 2020

05 Premisas cronograma versión 20201230

05 Programa Base estabilización 20201230

06 Contingencia Destaponamiento TDD

08 Resolución CREG 061-2007

08 Resolución CREG 158-2020

08 Resolución CREG 194-2020

09 Conexion modificda oct7de2020

09 Garantia 1M davivienda 6 oct 2021

09 Garantia 6M Bancolombia 13 oct 2021

09 Garantia 17M BNP 1 abril 2022

09 Garantía 59M colpatria 21 dic 2021

09 Garantia 110M citi 22 abril 2022

10 Evolución inversiones 2016 – 2021

11 Situación turbinas GE

12 Ituango Blindaje proceso logística montaje_V1