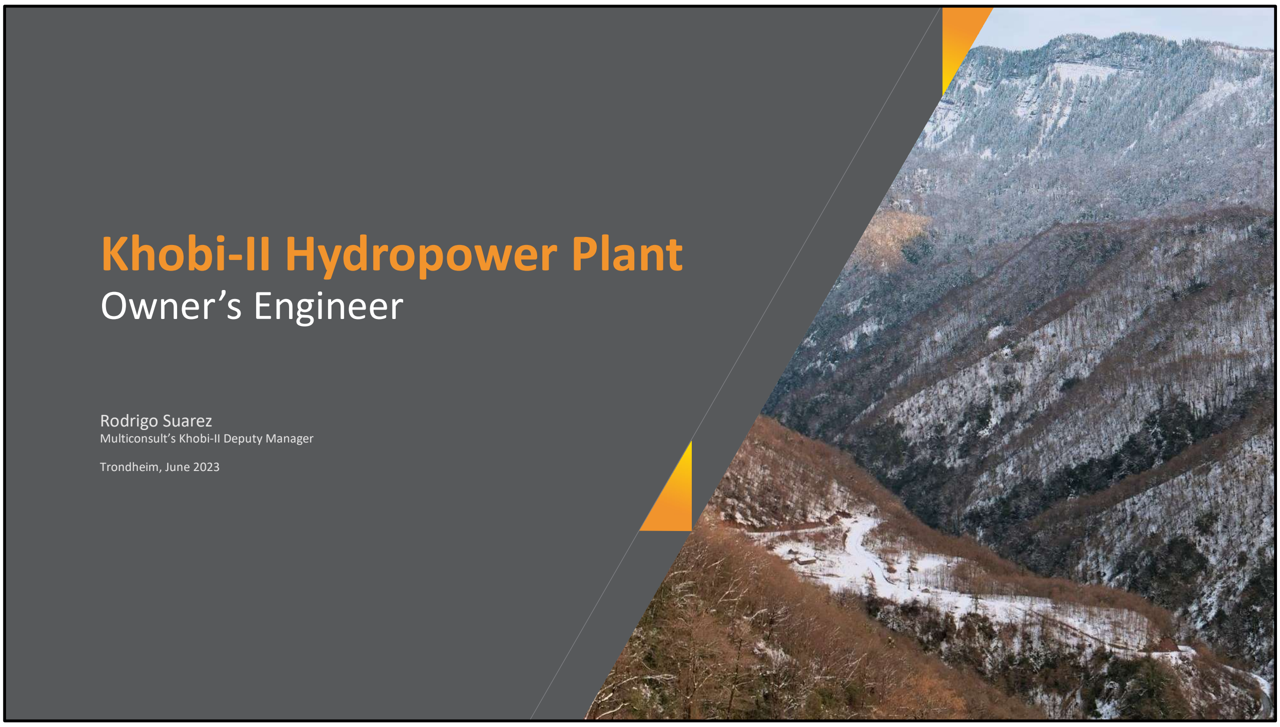
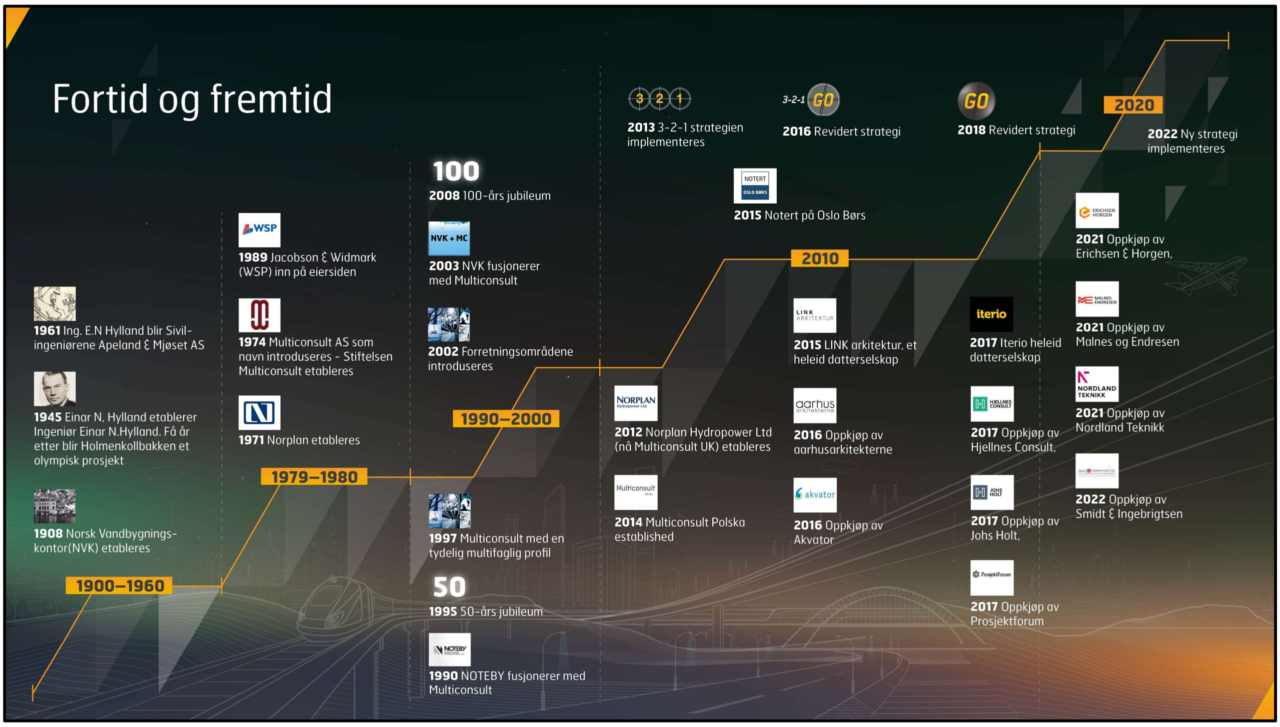


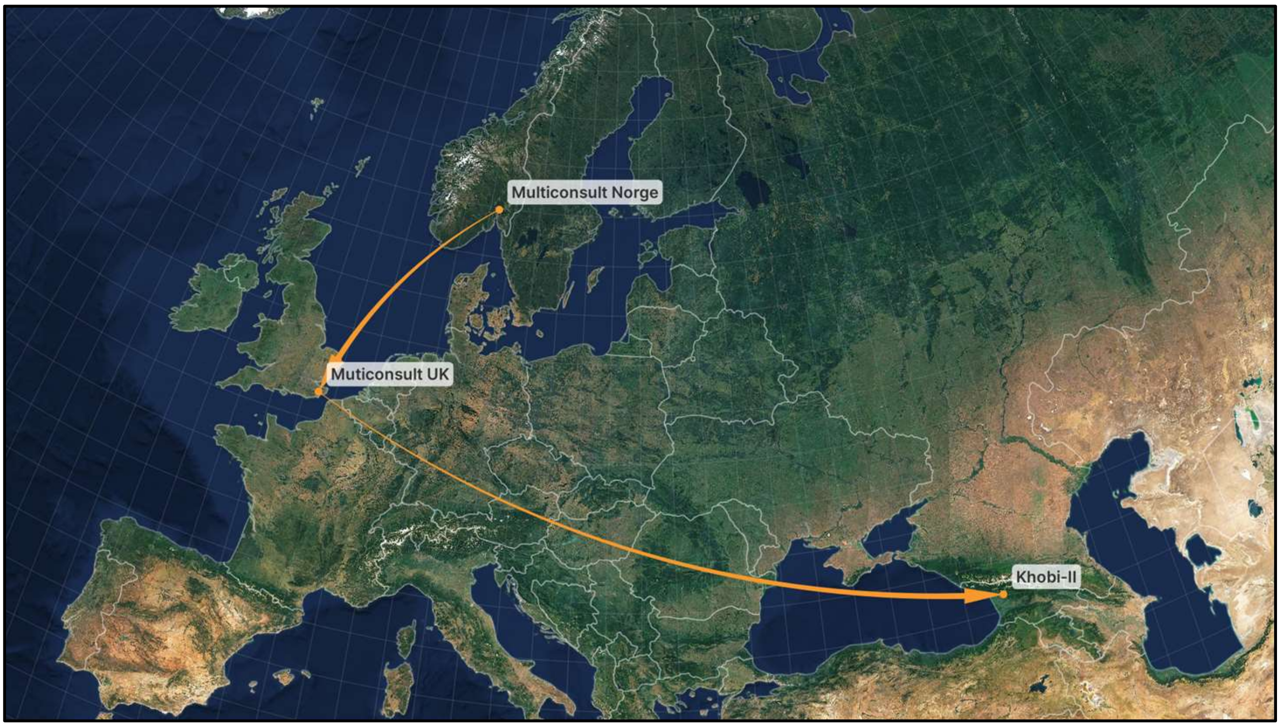
Hello everyone, today I'm going to give you a tour on Khobi-II, which in reality pronounced Jobi, and as you know is a hydropower plant located in Georgia.

I'm the deputy project manager for this project that started back in February 2021.

So to start, let's have a brief introduction about who we are in Multiconsult and the project I'm going to present today.


Fortid og fremtid
1900–1960
1908 Norsk Vandbygnings-kontor(NVK) etableres
1945 Einar N. Hylland etablerer Ingeniør Einar N.Hylland. Få år etter blir Holmenkollbakken et olympisk prosjekt
1961 Ing. E.N Hylland blir Sivil-ingeniørene Apeland & Mjøset AS
1979–1980
1971 Norplan etableres
1974 Multiconsult AS som navn introduseres - Stiftelsen Multiconsult etableres
1989 Jacobson & Widmark (WSP) inn på eiersiden
1990–2000
1990 NOTEBY fusjonerer med Multiconsult
50
1995 50-års jubileum
1997 Multiconsult med en tydelig multifaglig profil
2002 Forretningsområdene introduseres
2003 NVK fusjonerer med Multiconsult
100
2008 100-års jubileum
2010
2012 Norplan Hydropower Ltd (nå Multiconsult UK) etableres
2014 Multiconsult Polska established
2013 3-2-1 strategien implementeres
2015 Notert på Oslo Børs
2015 LINK arkitektur, et heleid datterselskap
2016 Oppkjøp av aarhusarkitekterne
2016 Oppkjøp av Akvator
2016 Revidert strategi
2017 Iterio heleid datterselskap
2017 Oppkjøp av Hjellnes Consult,
2017 Oppkjøp av Johs Holt,
2017 Oppkjøp av Prosjektforum
2018 Revidert strategi
2020
2021 Oppkjøp av Erichsen & Horgen,
2021 Oppkjøp av Malnes og Endresen
2021 Oppkjøp av Nordland Teknikk
2022 Oppkjøp av Smidt & Ingebrigtsen
2022 Ny strategi implementeres

Map of Multiconsult Offices and Projects



Even though Multiconsult has plenty of international experience, you might be wondering:

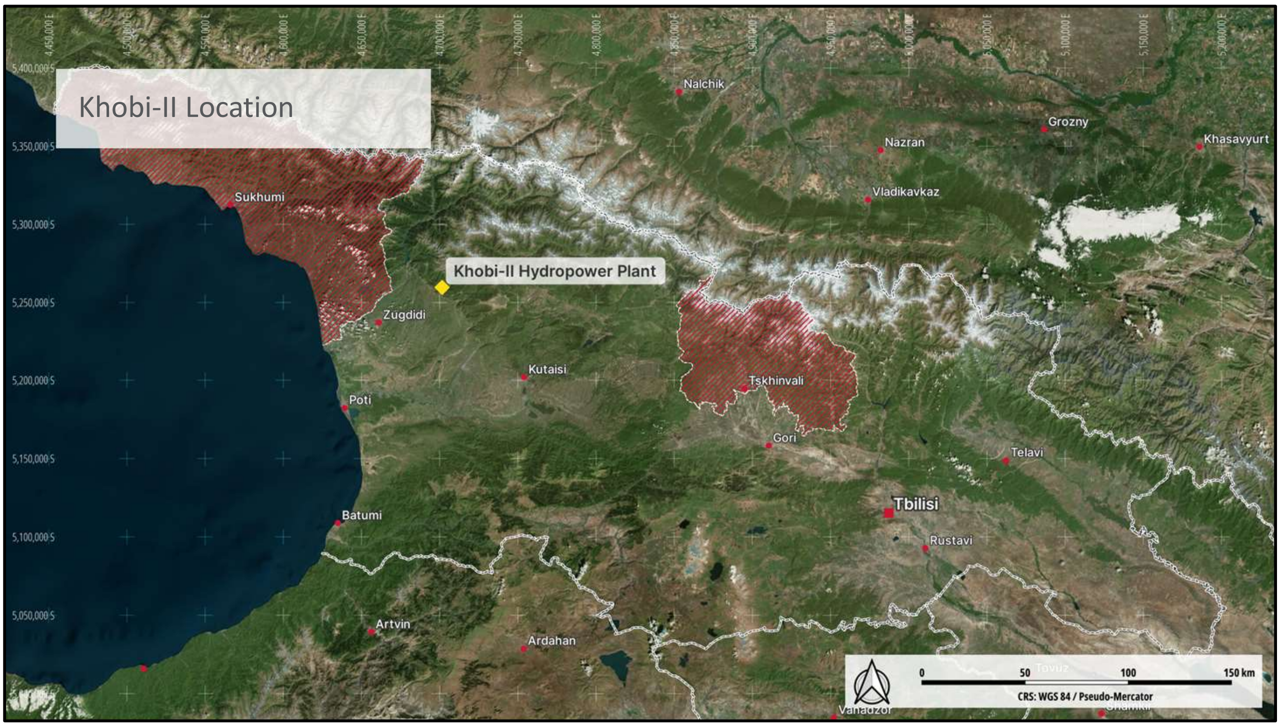
How is it that a Norwegian company, through its office in the UK ended up in the exotic lands of Georgia?

Why Georgia?

- One of the only remaining countries in Europe with relevant untapped hydropower potential.
- In 2017, only 20% of the hydro potential was utilised.
- "The country is pinning its hopes for faster growth on a **continued effort to build up infrastructure**, enhance support for entrepreneurship, simplify regulations, and improve professional education, in order to attract foreign investment and boost employment, with a focus on transportation projects, tourism, **hydropower**, and agriculture."

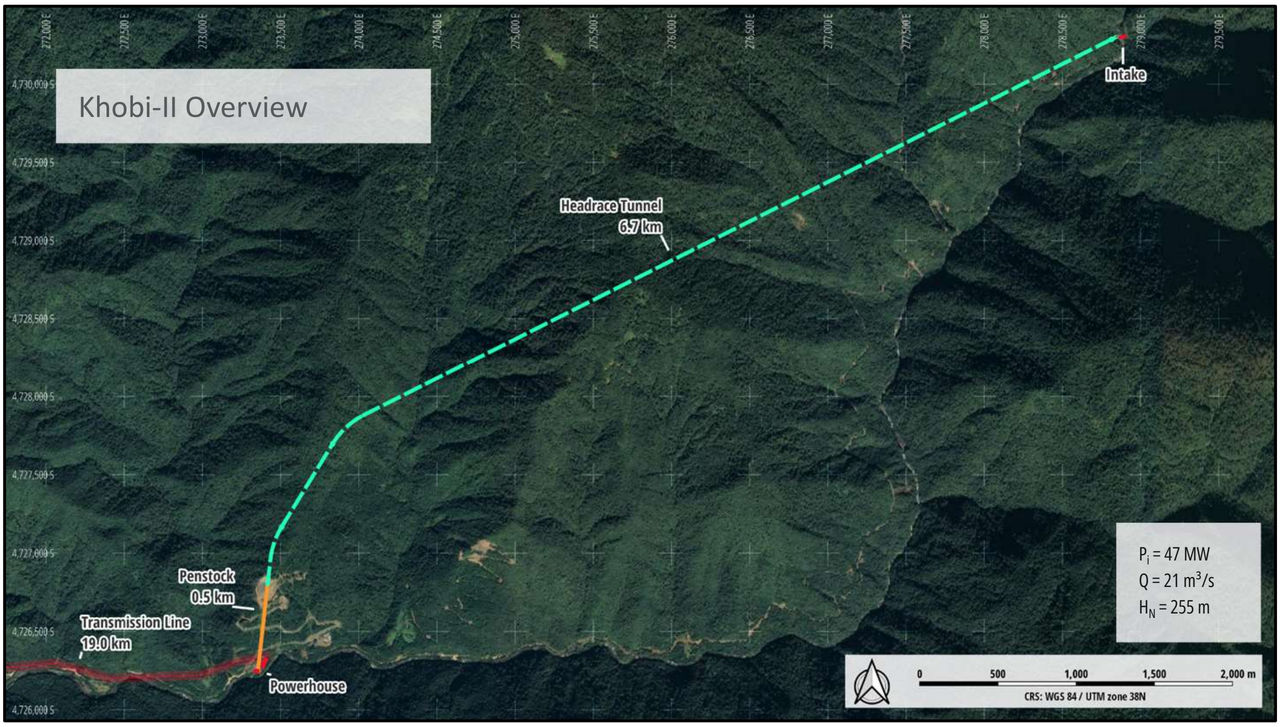
Well, the country is one of the few remaining in Europe to still have a relevant untapped hydropower potential. For reference, in 2017 only 20% was being used.

Moreover, the country has the goal is to be part of the European Union (and eventually NATO), so they are working hard to reach the development level required by focusing on several fronts, among them infrastructure and hydropower.*



Now, back to Khobi, the project is located in the northwest part of Georgia, just at the base of the Caucasus mountain.

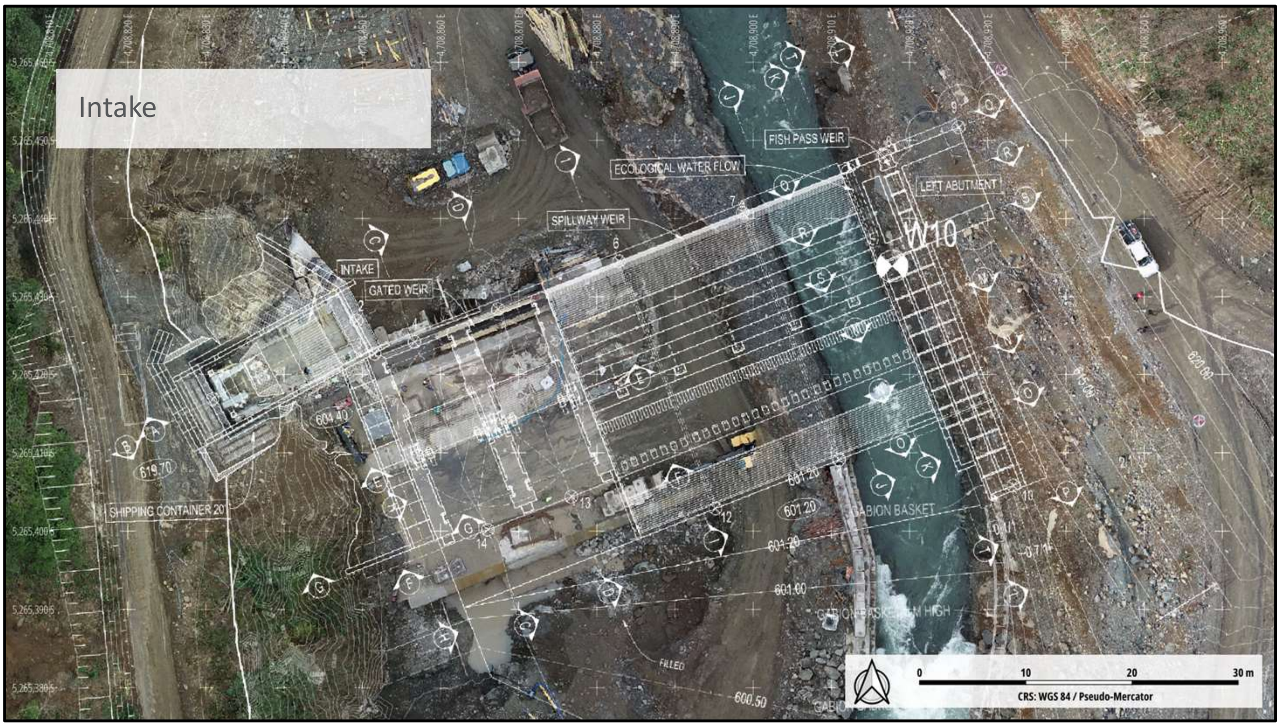
As you can see is quite close to Abkhazia, and to get to the project from the Capital Tbilisi, you have to drive very close to South Ossetia. Both of these territories are occupied by Russia in the same style they did with Crimea in Ukraine*



Khobi-II is a run-off-the-river hydropower project, that starts with an intake on the river Khobi.

From there the water goes into a tunnel of about 6.7 km which ends in a pressured pipe or penstock that finally reaches a superficial powerhouse.

Some technicalities: The powerplant has an installed capacity of 47 MW, a design discharge of 21 m³/s and a net head of 255 m*



The headworks has 2 radial gates, each one of 6.2 m wide by 11.5 m high.

Next to the gates there is an uncontrolled stepped spillway with a length of 30 m and a height of approximately 8 m.

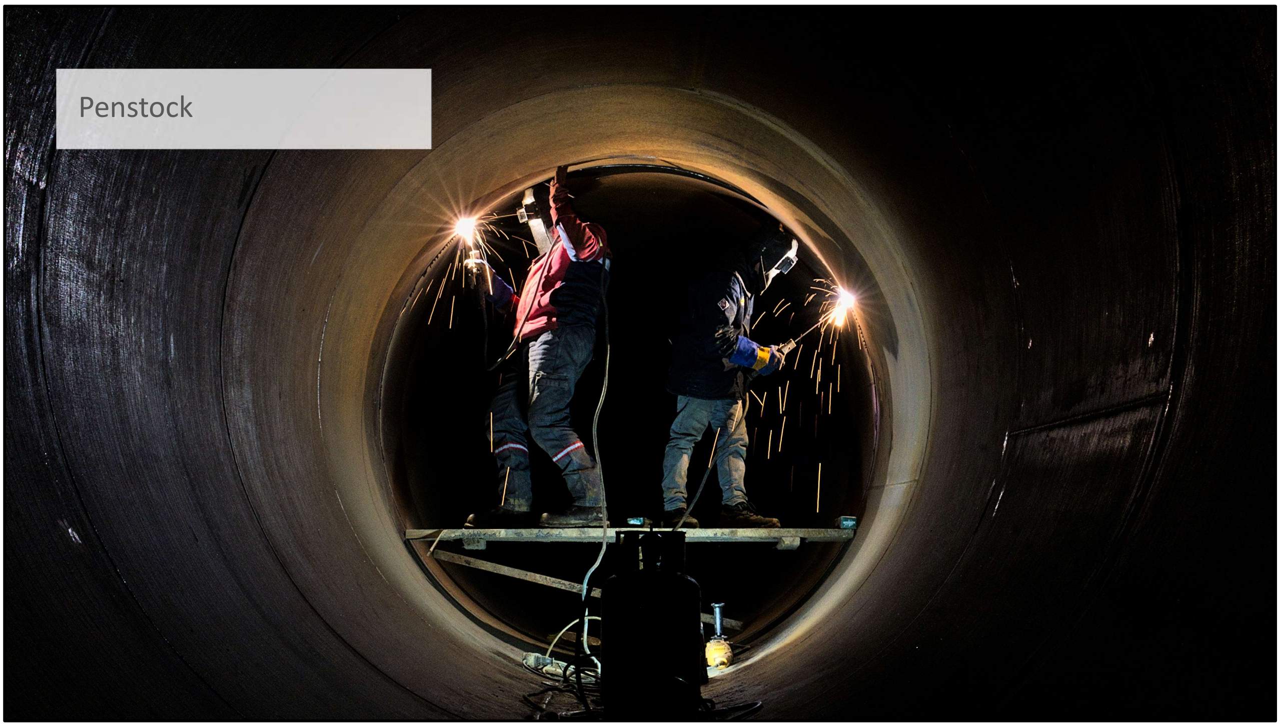
In the far left of the intake we find a fish ladder and the minimum flow release.

Finally, on the right we have the intake structure itself that takes the water to the headrace tunnel.*

This is a downstream view of the headworks as a reference.*

The headrace tunnel, excavated with a TBM and with 3.5 m in diameter.

From the tunnel we have a superficial steel penstock of approximately 500 m in length and…*



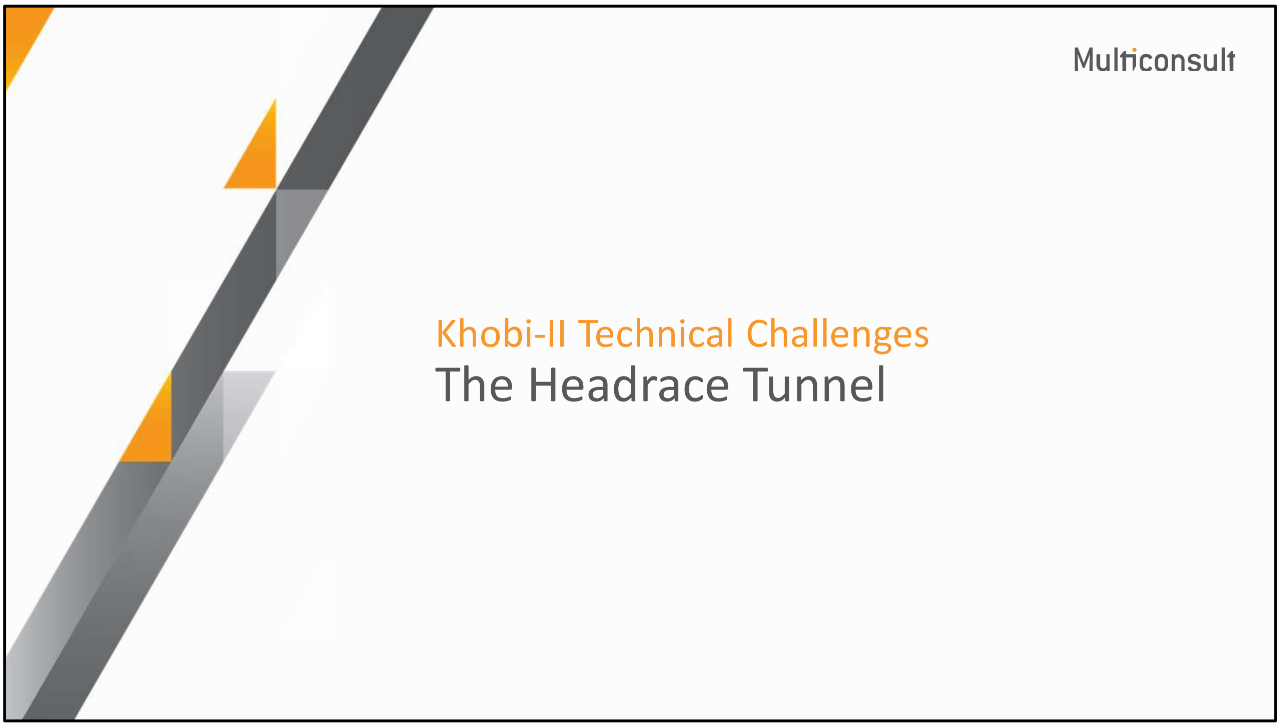
2.3 m of internal diameter.

The powerhouse includes two identical Pelton units, vertical axis, with a total installed capacity of 47 MW.*

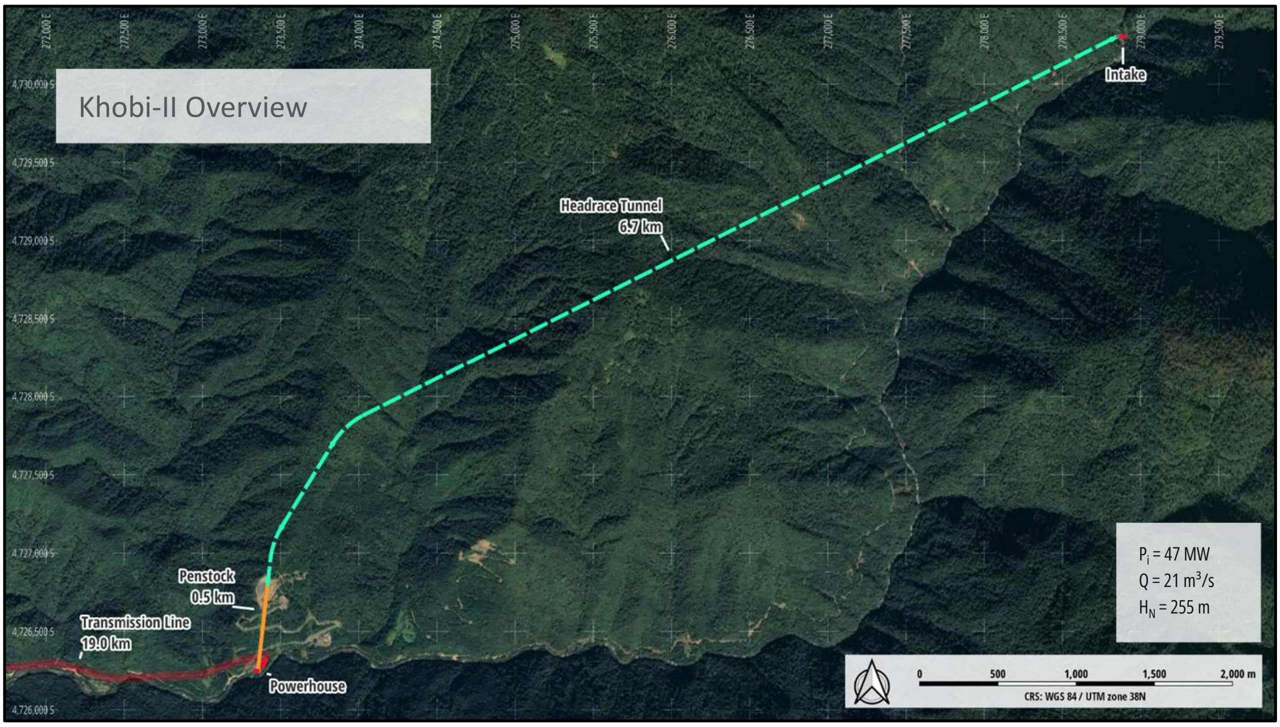
This is how the powerhouse looks on the inside.

Now that we know the scheme…*

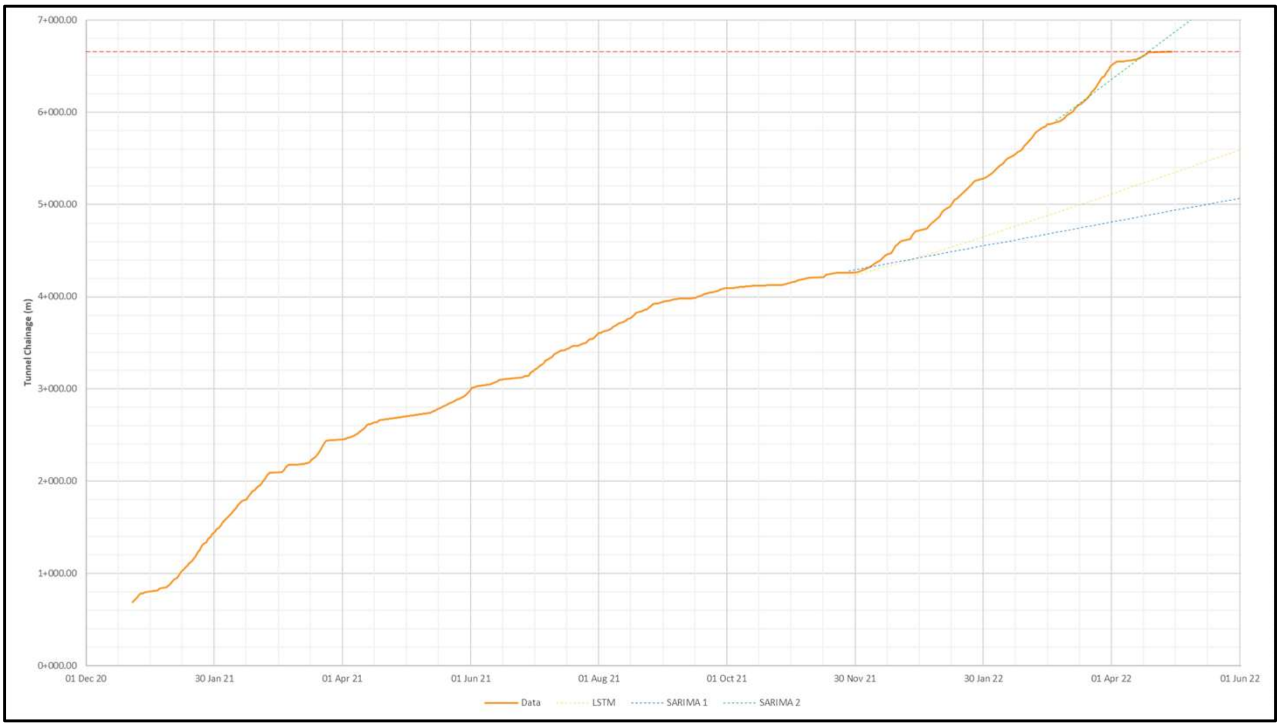
Let’s get into business, and let’s talk about the Technical Challenges we have been facing as Owners Engineers*



Let’s start with the headrace tunnel for now. *



As mentioned, it is approximately 6.7 km long and was completely excavated by a TBM in about 1 year and 4 months. *



The graph shows how the rate of excavation progressed.

On average, the TBM made about 14 m/day of excavation which is considered quite good and above what is expected.

However we must clarify a couple of things about this good rate. *

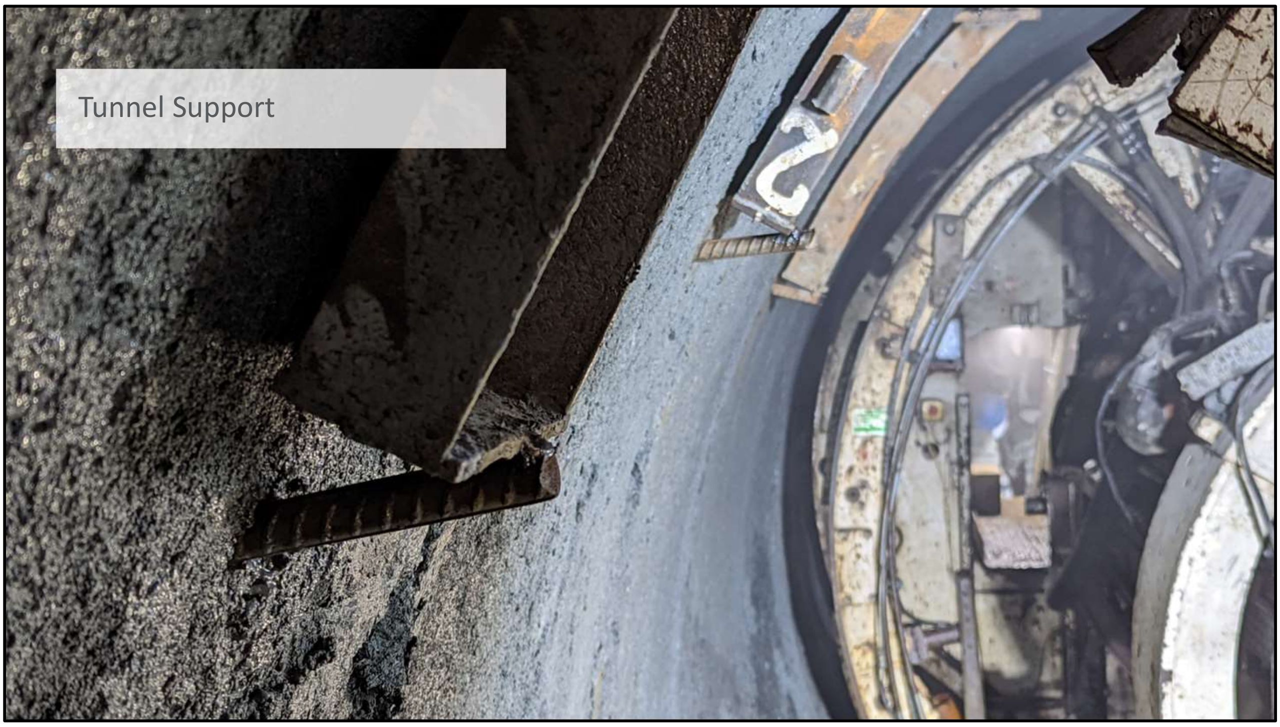
The first one is that they didn’t install a primary support to the tunnel, which as you can imagine is far from ideal.

This was due the incentives from the Contractor to its staff, they promised a bonus for finishing the excavation only, not the whole package including the support, that again, is far from ideal.

In the picture Here you can see the crown of the tunnel, with a mesh that is meant to hold any loose material that may fall off.

The mesh, the weight of the material and the contraction of the tunnel itself is supported by the steel ribs seen here.

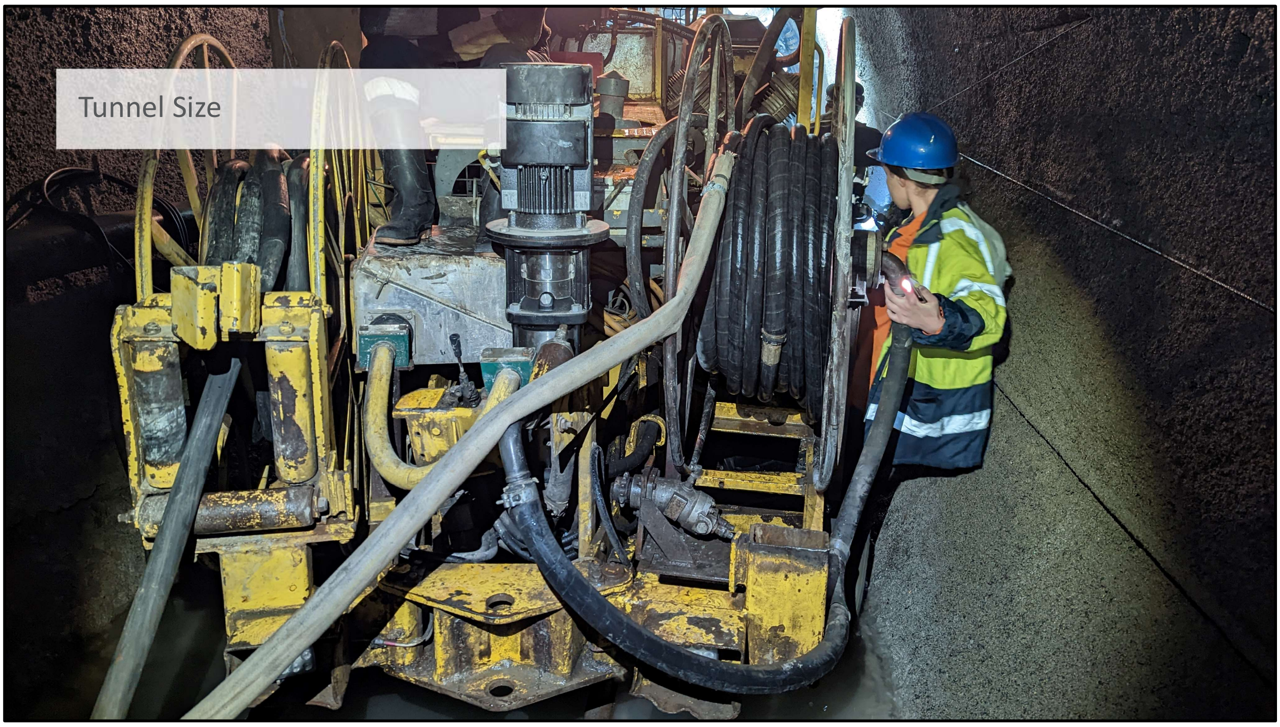
As you can imagine, the steel ribs are under a lot of stress and need a proper foundation*



Well, here they are, the foundations of the ribs. Nothing else than rebar in the wall.

As you are imagining, again, far from ideal.

Another big challenge has to do with the size of the tunnel itself. The TBM is 3.5 m in diameter which sounds not too bad, except when you're actually inside*



Considering the machinery and all what’s happening, it is tiny and doesn’t leave space for much.

Here we can see the H&S staff trying to get to the other side of the machine and… *

This is, for example, a shotcrete torpedo arriving to the shotcrete robot.

As is possible to see, the space is pretty tight.

But ok, is small, so what’s the big deal? Well, everything becomes more difficult to properly execute, from the installation of rockbolts to shotcreting. *

Talking about shotcrete, since it is so difficult to manoeuvre inside the shotcrete finish has been substandard as we can see in the picture *

Or completely inadequate as you see here.*

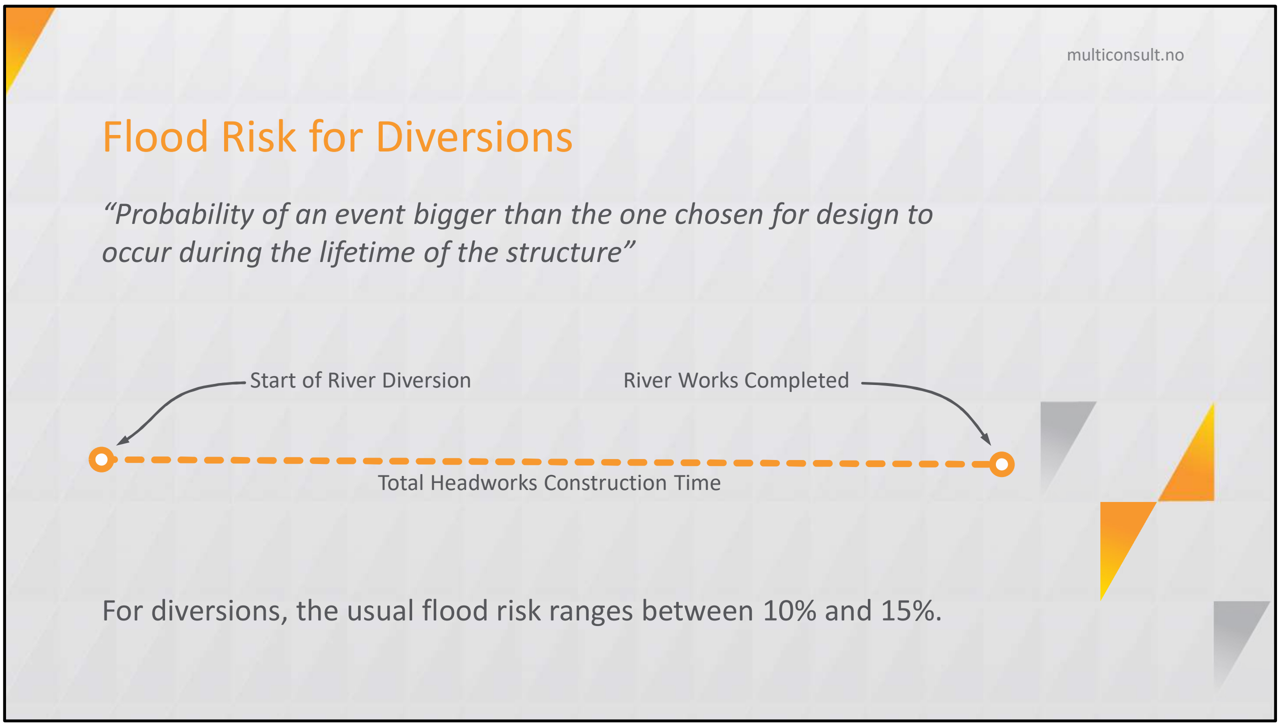
These are some of the most contingent issues we have been facing with the tunnel, there are still some more, but if I start talking about them I could last the whole day here, so it is better is we move on to the*

River diversion*

The river diversion is thought in two stages:

1) The first one is the one you see in the picture. A cofferdam with a excavated channel on the side.
2) The second one will be the side channel to be blocked and the cofferdam removed using the original riverbed as the diversion.

Just to give you some context, when sizing a diversion system, this is the channel and the cofferdam, one must consider the flood risk*



Which is defined as the probability of an event bigger than the one chosen for design to occur during the lifetime of the structure.

For diversions, and depending on the importance and the consequences of failure, usually, the accepted flood risk ranges between 10% and 15%.

In other words, it is considered during the diversion period there is an 85% to 90% of probability the diversion structure will not fail.*

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Design Flood Selection

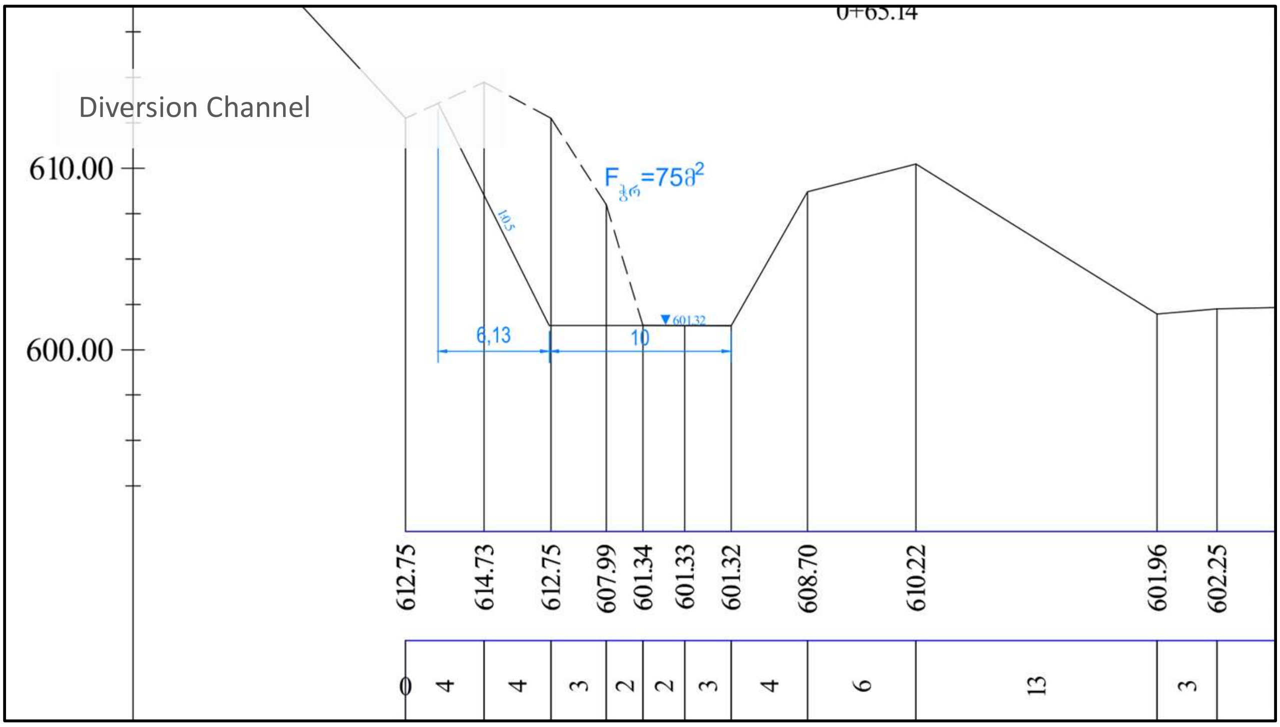
Consultant	Diversion Design Discharge (m^3/s)	Envisioned Return Period (yr.)	Real Return Period (yr.)	Diversion Flood Risk (%)
Designer	185	5	2.5	49%
Contractor	123	20	Less than 2	~100%
Multiconsult	316	8.5	8.5	15%

When we received the design of the diversion, we discovered there was a misinterpretation of the hydrological report, and even though the designer believed it was designed for a flood event with a return period of 5 years, in reality, and due to their misinterpretation, the design was for 2.5 years, resulting in flood risk of about 49%.

This is completely unacceptable.

Funny enough, the Contractor believed the designer was being too cautious and they did their analysis, using highly questionable assumptions and calculation methods, resulting in a design flood event so small that was almost guaranteed to be surpassed during the construction period.

For reference, this is our recommended design flood magnitude for the diversion*



After the flood design magnitude discussion was settled, the Contractor send their plans for the diversion channel.

Here you can see a typical cross-section of it, with a trapezoidal channel, very common, considering 10 m in base width.

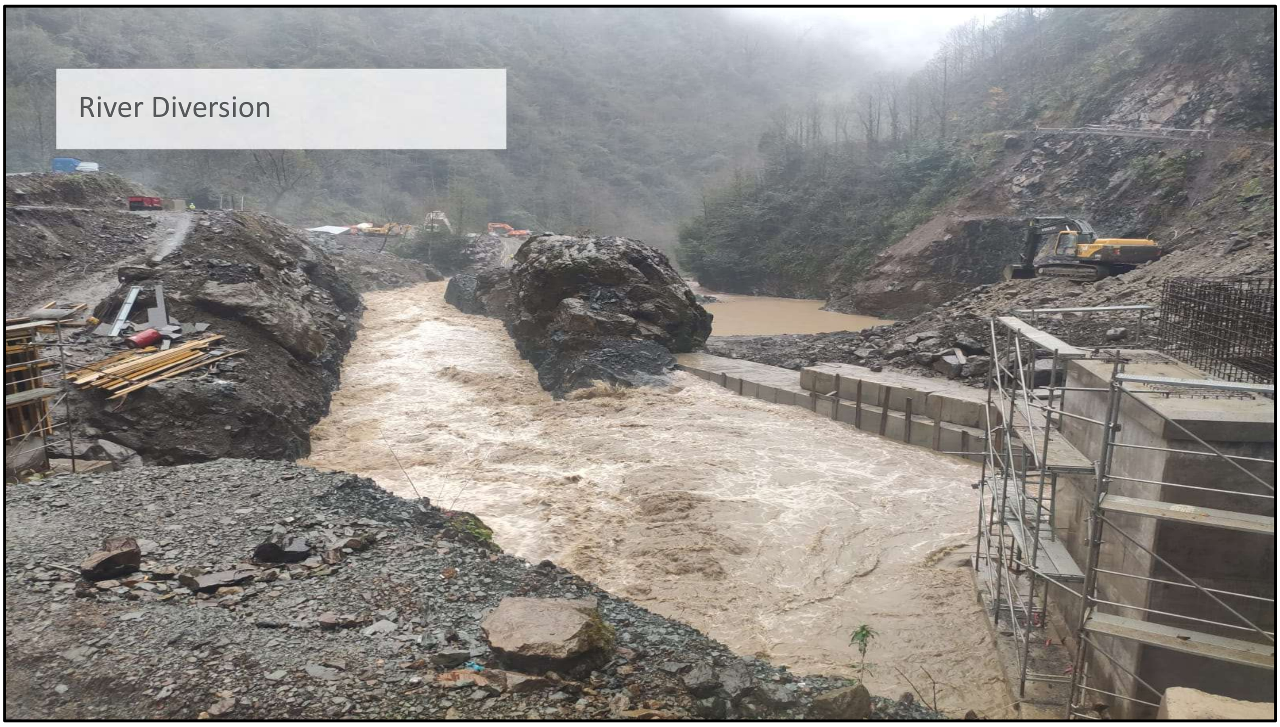
We believe this section was not enough and issued some recommendations to either increase the capacity of the channel or raise the cofferdam height.

But surprise surprise, once we visited the construction site*

We realised the channel was not built according to their drawings...

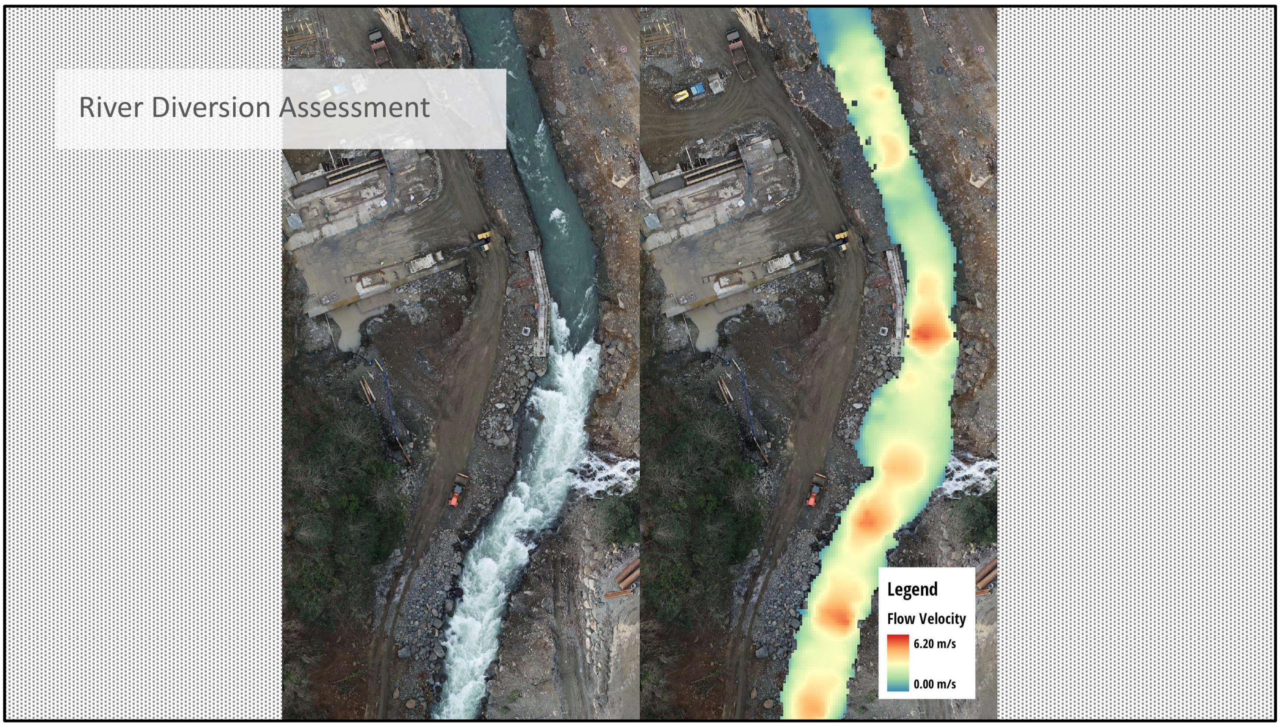
And what about raising the cofferdam?*

We realised the channel was not built according to their drawings... *



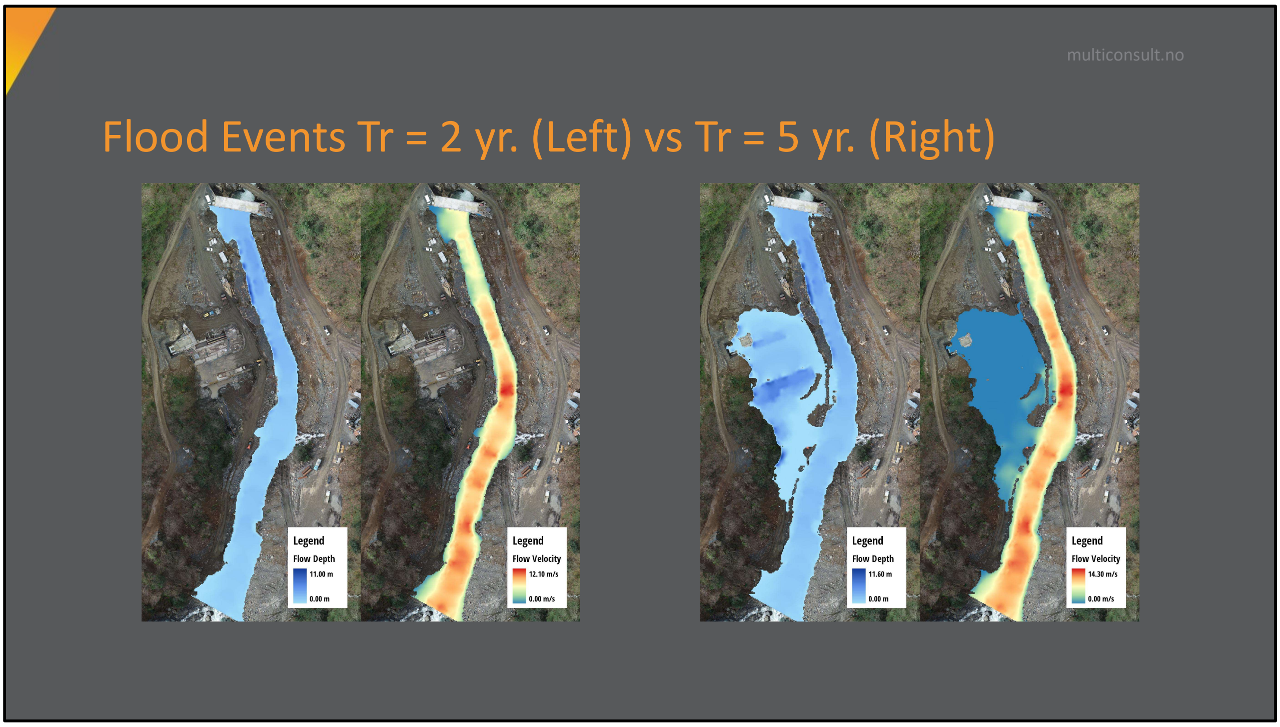
In the meantime, they had a couple of flood events that as you can see couldn’t be handled by the diversion system.

After a lot of pushing and hunting, the Contractor managed to send us a topographical survey of the headworks area that allowed us to make a proper hydraulic analysis of the diversion system and back engineer the this flood event you see in the picture*



When the model was built and run, we visually compared the results with the orthophotos available, and luckily for us, they made a lot of sense as you can see here.

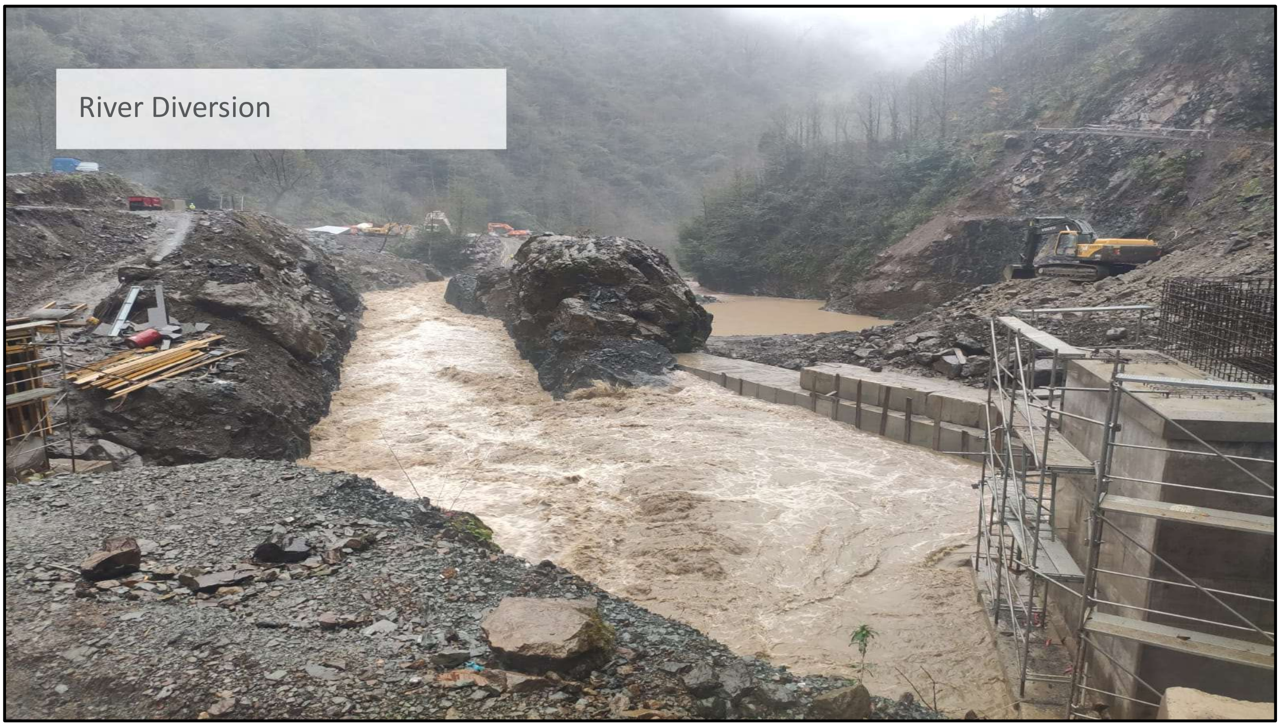
With this, we run some flood scenarios*



On the left you could see what would happen for a return period of 2 years, while on the right for 5 years.

This result was interesting because it gave us a couple of insights:

- The cofferdam, which we believe was too low ended up being ok.
- The flooding of the construction area was going to happen from the downstream end*



And what about this flood event?

It ended up being a 3.6 years return event.

Well under our recommendation of 8.5 years*

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Khobi-II Technical Challenges

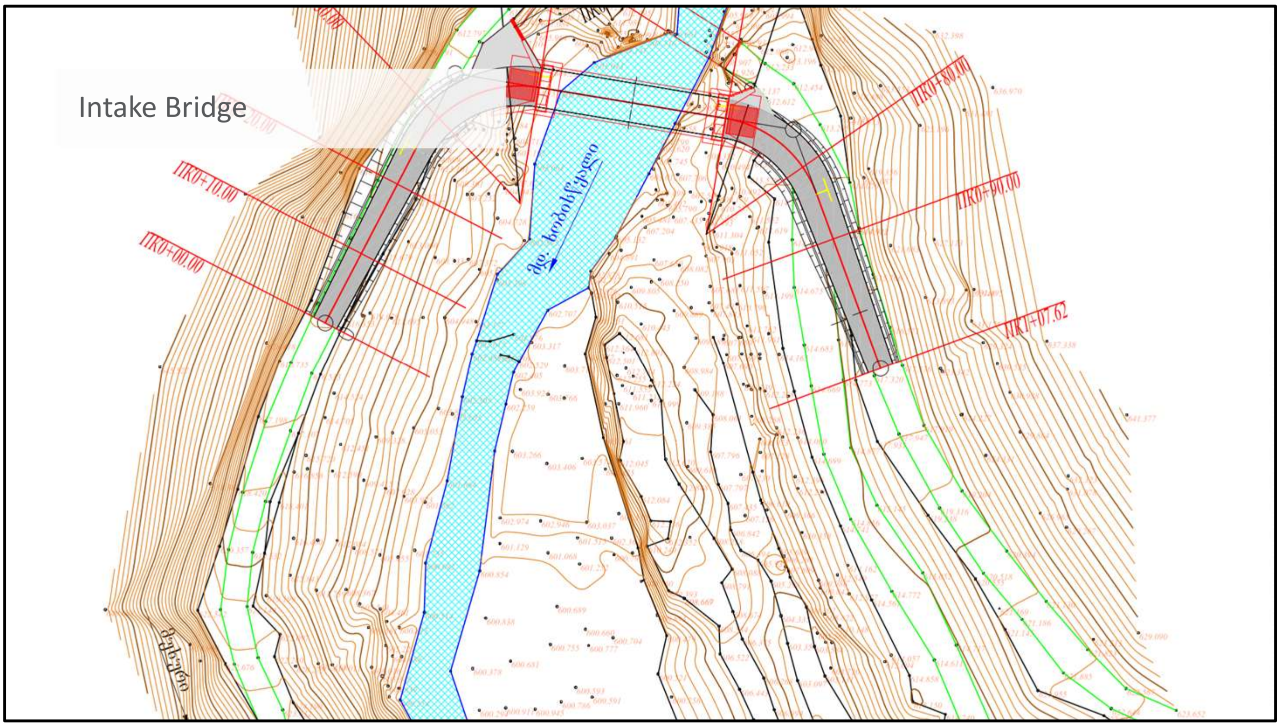
Intake Bridge

The final (interesting?) challenge I will talk about refers to the intake bridge.

As you can see in this picture, the bridge is located just upstream of the headworks and the intake.

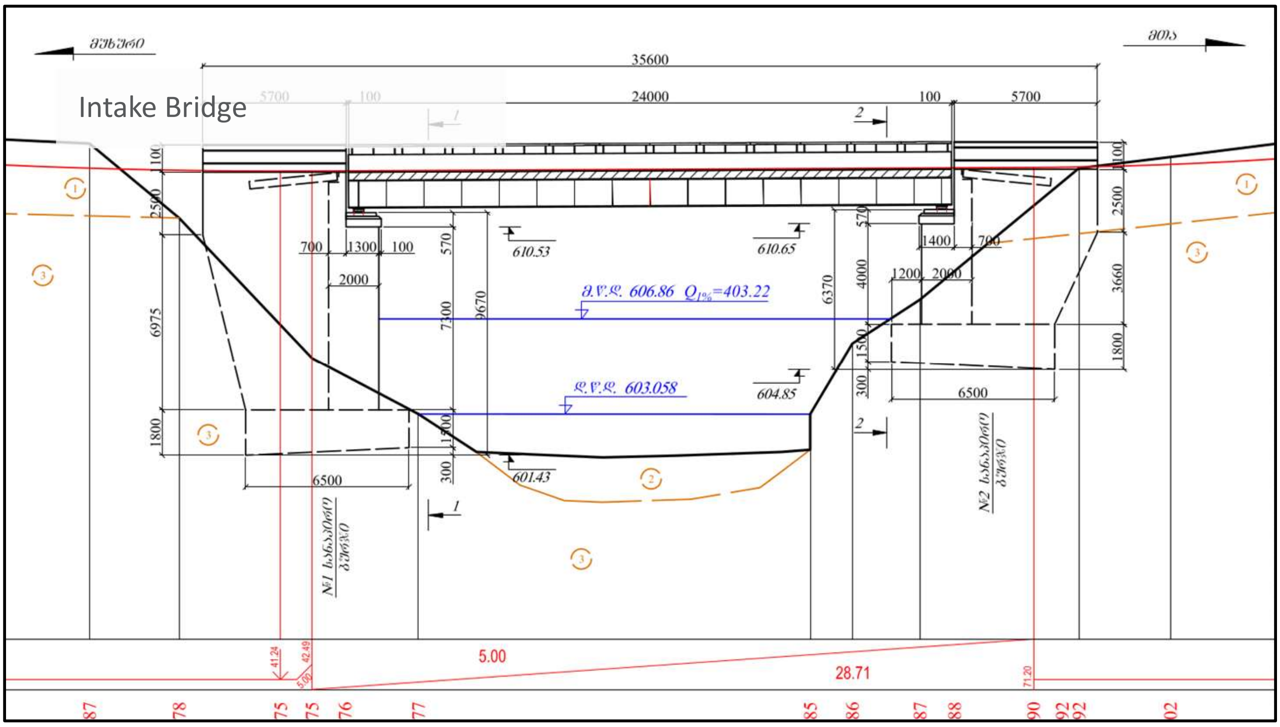
This is the back of the cofferdam and the diversion channel goes around the back.

And, even though this has nothing to do with the challenge I'm going to talk about* here are some friendly piggies that made me company while I was taking the picture.*

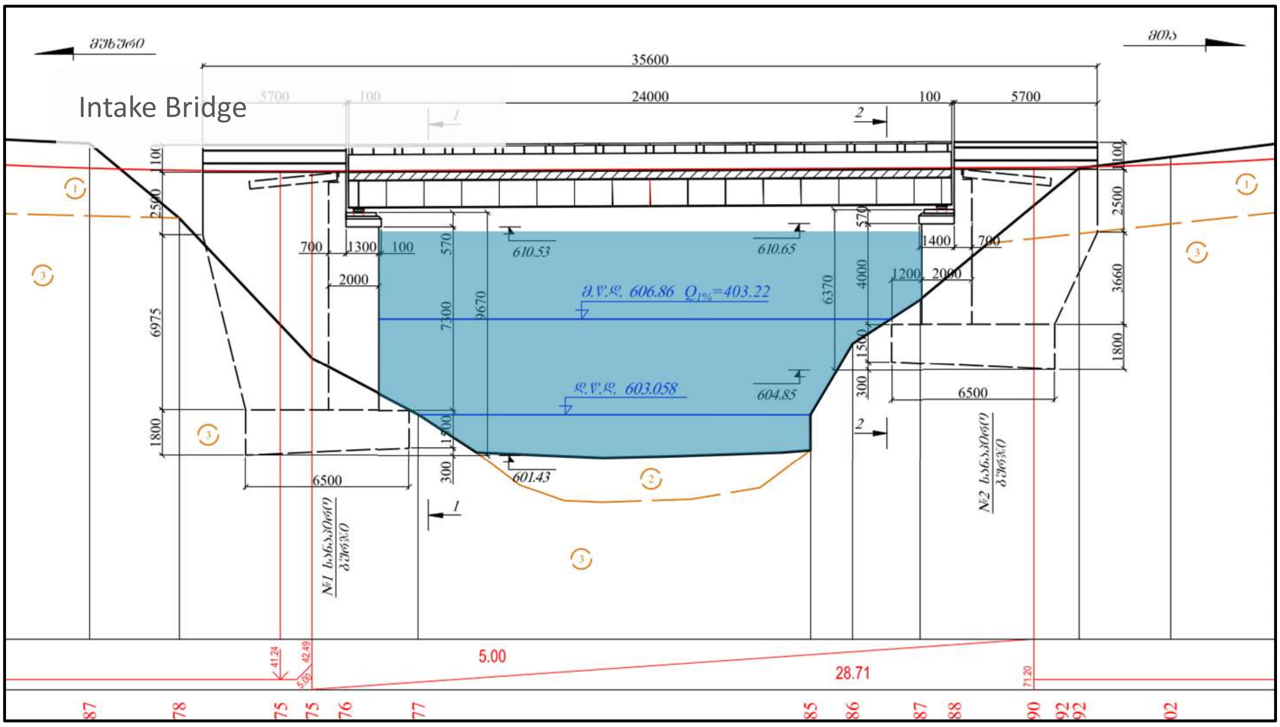


When we received the drawings of the bridge, we almost immediately noticed something in them, can you see it?

There is no headwork in the drawings. The river is flowing as it does in its natural state*

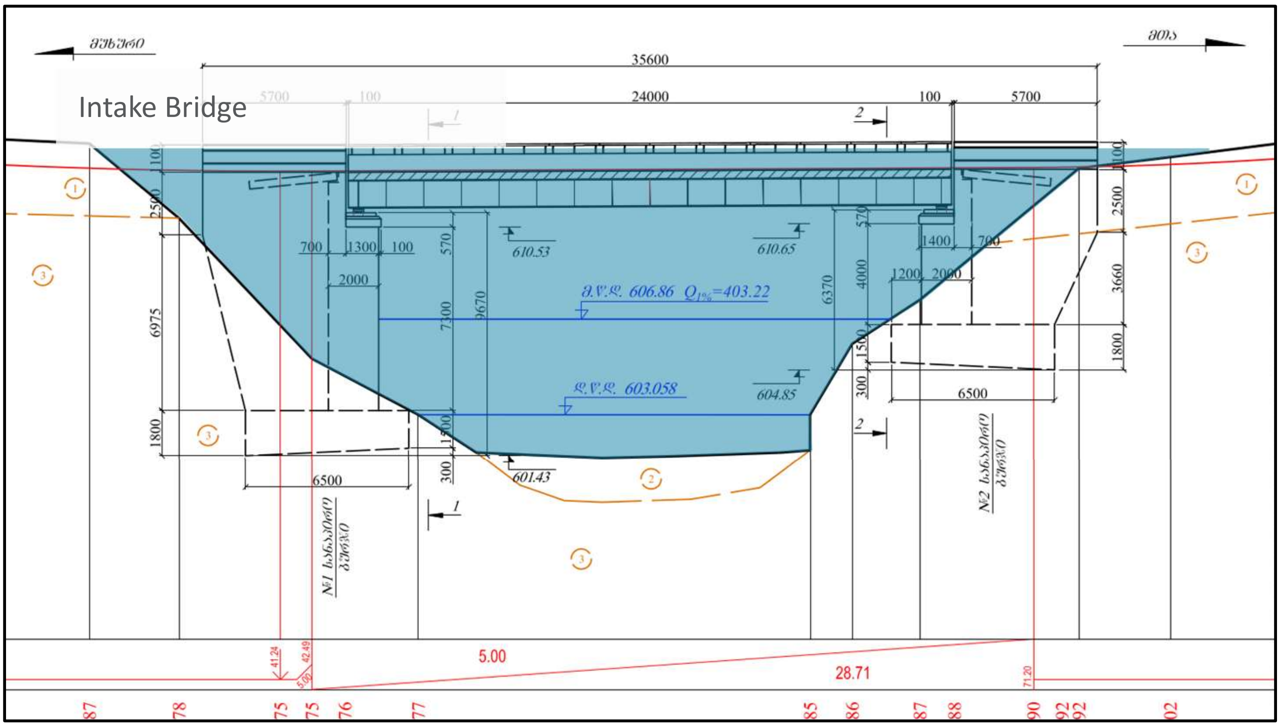


These are the average water level in the river and the 100 years flood event water elevation according to the bridge designer*



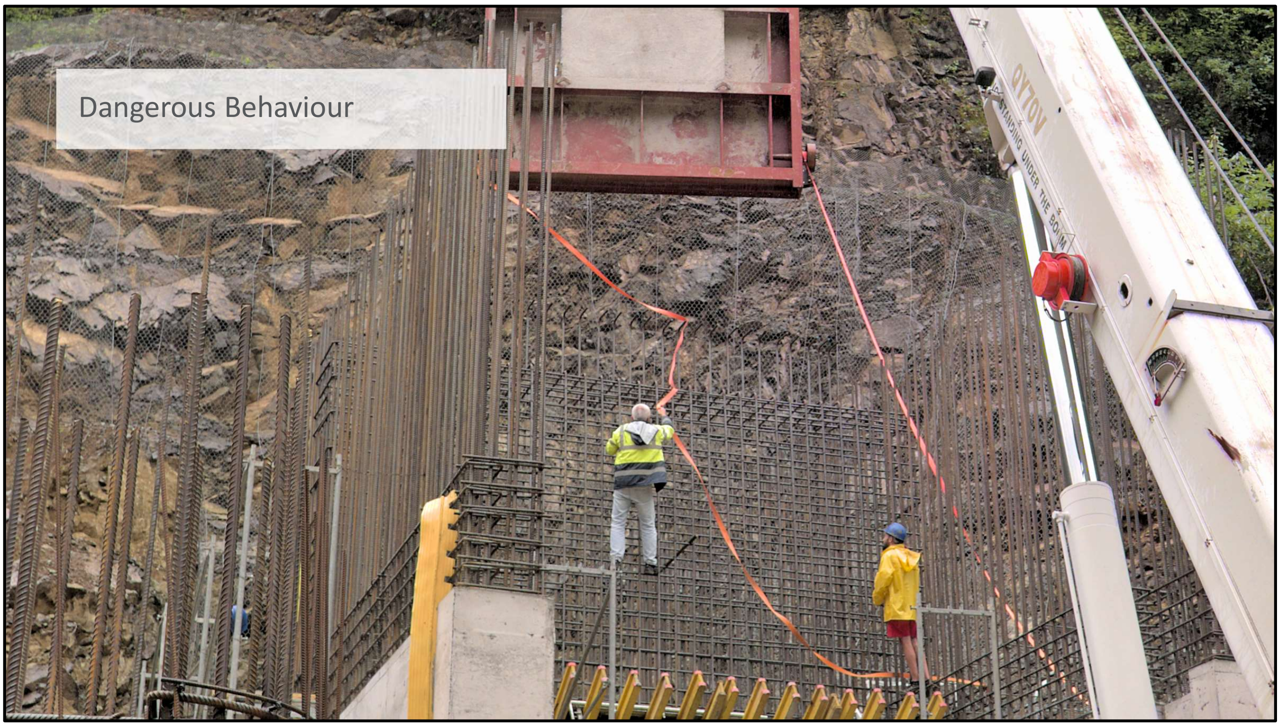
Nevertheless, when the headwork is finished and working, this will be the normal water level in the small reservoir upstream of the intake.

Less than a meter between the water surface and the bridge bearings



And if we consider the design flood event of the headworks, the bridge will be submerged*

Even though this is a non-technical challenge, it is truly important we as consultants don’t only pay attention of the concrete and steel, but also to the flesh and bone.



Georgians (at least the ones we have worked with) are not used to comply with international H&S standards that may look obvious and usual to us.

For example, here you can see workers without any harness or PPE whatsoever working on heights, hanging from one hand and using the other to move a very heavy gate.*

Similar to the one before, they were installing rockbolts on a slope without any PPE or harness whilst inside an excavator bucket!

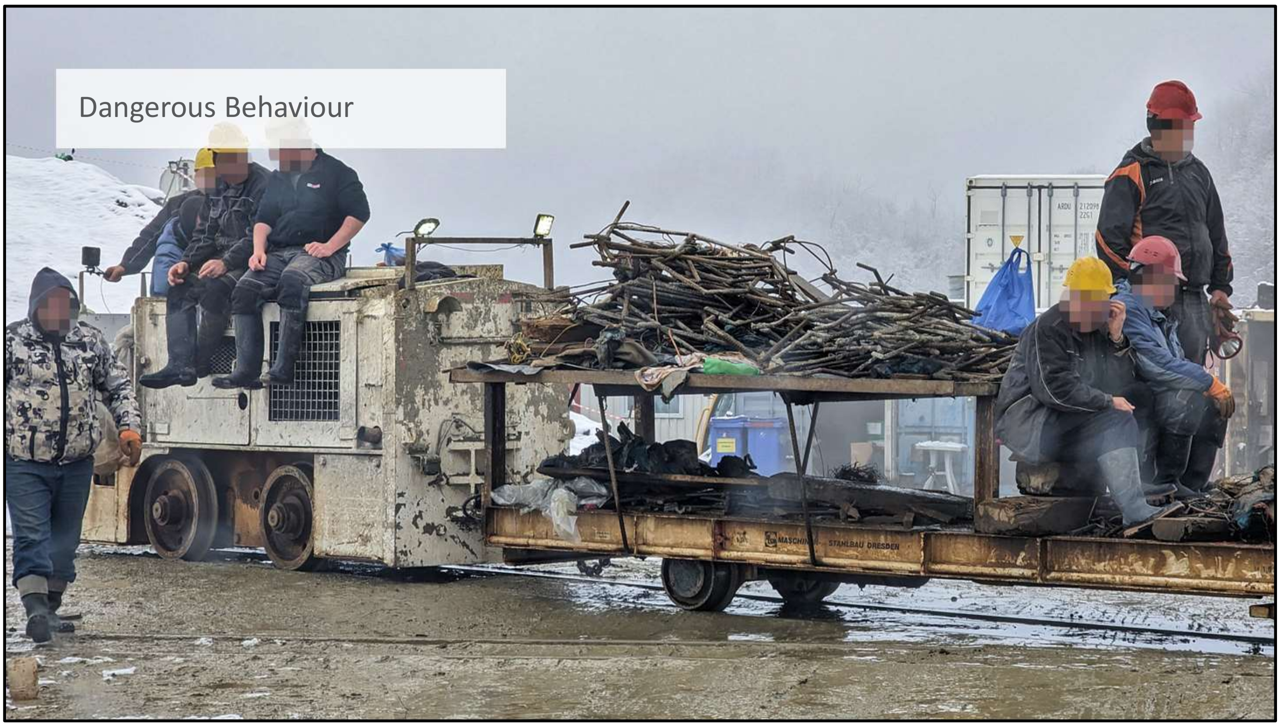
Not only that…*

They were doing this in from of the Contractor H&S manager who seem pretty ok with what was going on.*

Tunnel Portal

In the tunnel portal, we can find this sign which has been there since the project started:

“The movement of people in freight cars is PROHIBITED”*



Well…*

The powerhouse was no exception.

As you can see the floor of the powerhouse was a minefield of vertical rebars with rubbish in between, creating a truly dangerous place to work or even walk.

The risk was heightened when you consider*

That the Contractor staff likes to do some dangerous activities, the result could be catastrophic.

To finish, Georgia is a country pushing to achieve a better future keen to learn and do things in the right way.

We believe Khobi-II ultimately will help the country to learn from Multiconsult experience in Norway and around the world.

We are very happy to be working on this project and we are doing our best, not only from a technical point of view, but to add value to our client.