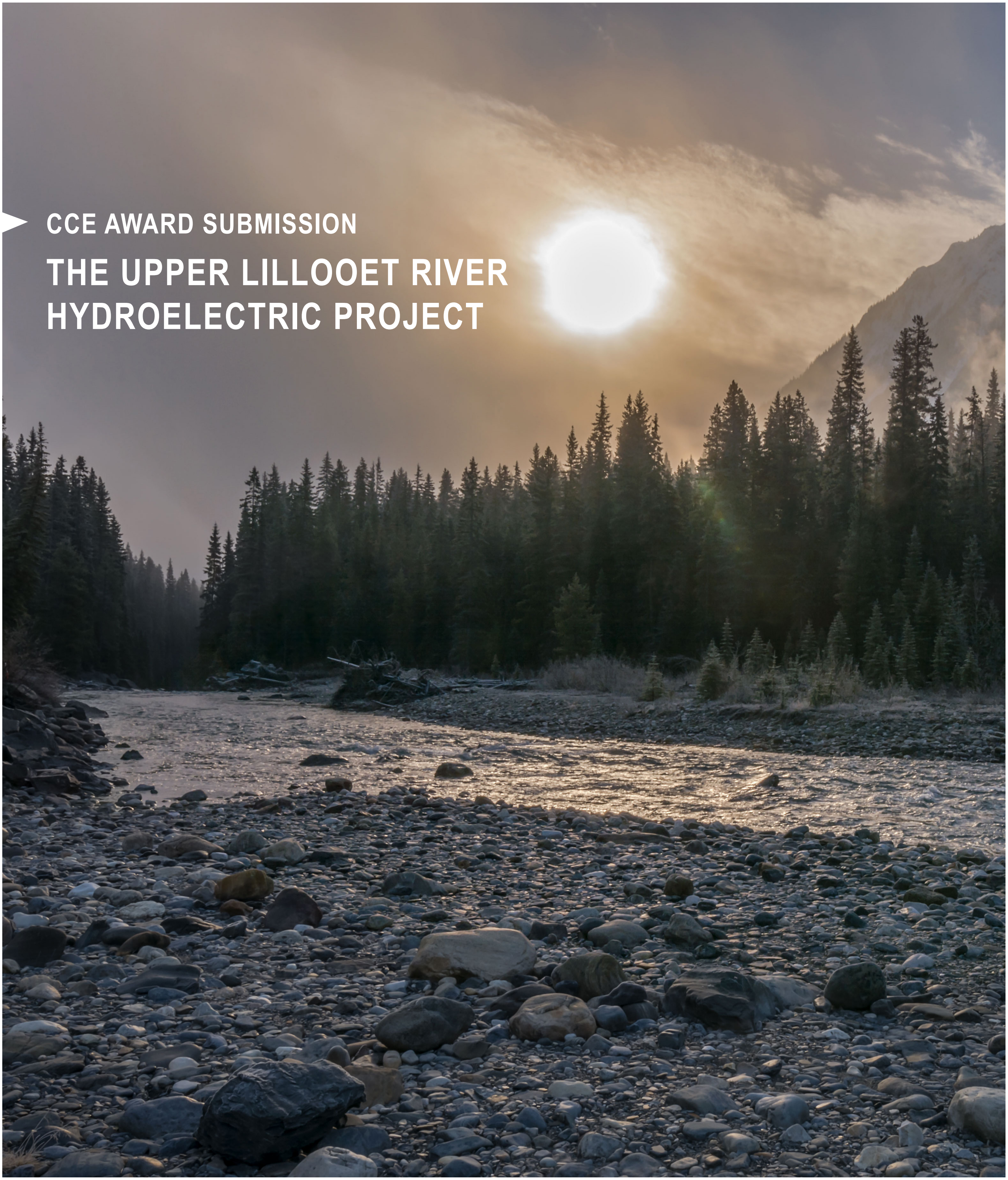
CCE AWARD SUBMISSION

THE UPPER LILLOOET RIVER HYDROELECTRIC PROJECT



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SUMMARY

The Upper Lillooet River Hydroelectric Project, located near Pemberton, BC, is a run-of-river hydroelectric scheme owned by Upper Lillooet River Hydro Limited Partnership and Boulder Creek Hydro Limited Partnership, consisting of two separate hydroelectric facilities with a combined capacity of 106.7MW. Golder provided design and construction services to the Partnerships through significant geologic and environmental challenges, and worked closely with the project team to bring this project “on line”, as part of BC’s power grid.

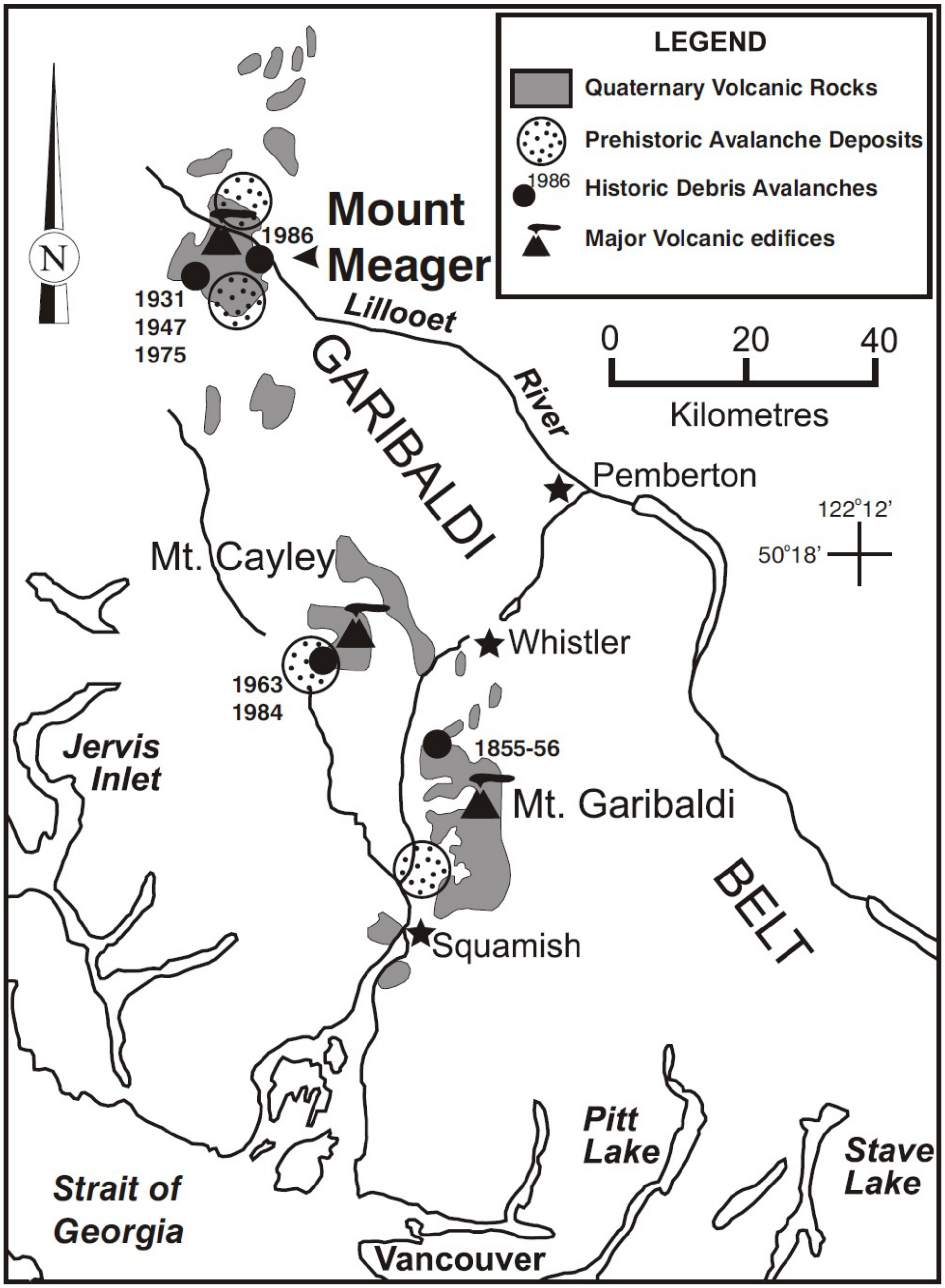

Figure 1 – Location of Upper Lillooet Site within the Garibaldi Volcanic Belt in British Columbia.
Modified after Stewart et al. (2001)

INNOVATION

The Upper Lillooet River Hydroelectric Project, is a run-of-river power generation scheme located near Pemberton, British Columbia, consisting of two separate hydroelectric facilities (HEF) with a combined capacity of 106.7 MW. These HEF's are owned by the Upper Lillooet River Power Limited Partnership and the Boulder Creek Power Limited Partnership, and civil and tunnel construction was completed by CRT-ebc. The Upper Lillooet HEF includes the excavation of a 6 m wide x 5.5 m high, approximately 2500 m long tunnel along the Upper Lillooet River Valley.

The project is in a mountainous area, with severe restrictions imposed by weather conditions and the presence of sensitive wildlife species that constrained site operations in order to limit environmental impacts. The site is located adjacent to the Mt. Meager Volcanic Complex, the most recently active volcano in Western Canada. Tunnelling conditions were very challenging – including a section through deposits associated with the most recent eruption from Mt. Meager (2360 yrs. B.P.). This tunnel section included: welded breccia, unconsolidated deposits composed of loose pumice, organics (that represent an old forest floor), and till, before entering the underlying tonalite bedrock. Construction of this section of the tunnel required cover and consolidation grouting, umbrella support, and excavation with a combination of roadheader, hydraulic hammer, and drill and blast.

The Upper Lillooet River Tunnel was successfully excavated through very challenging conditions, including high water inflows, and loose unconsolidated deposits. A well planned and executed cover and consolidation grouting program reduced the water inflows at the face and consolidated the loose deposits. A balance between production and stopping to grout is a challenging one to achieve. Lost production due to excess water must be balanced against the cost of starting to grout sooner.

The successful excavation was achieved through great cooperation between the Designer, Contractor and Owner, which allowed for adjustments to the design as the excavation progressed, and the encountered conditions became better understood.

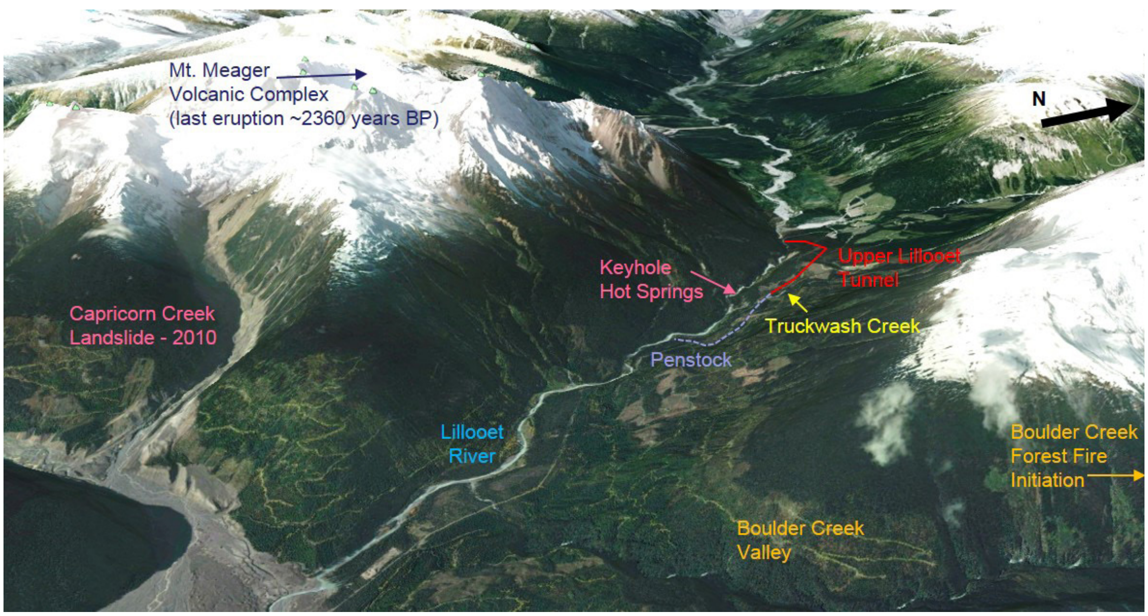

Figure 2 – Site layout within the Upper Lillooet River Valley. Modified after Boultbee et al. (2017)

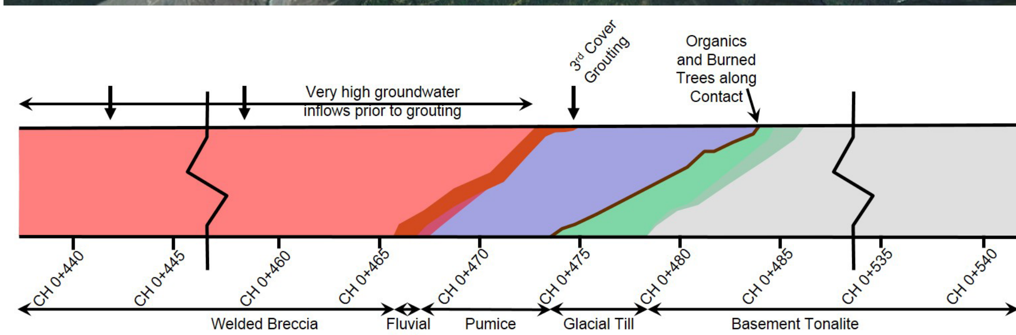

Figure 3 – Schematic tunnel profile through the transition zone soils, showing the deposits encountered along the tunnel excavation.

COMPLEXITY

The site is located adjacent to the Mt. Meager Volcanic Complex, the most recently active volcano in Western Canada. Tunnelling conditions were challenging – including a section through deposits associated with the most recent eruption from Mt. Meager (2360 yrs. B.P.). This tunnel section included: welded breccia, unconsolidated deposits composed of loose pumice, organics (representing an old forest floor), and till, before entering the underlying bedrock. Construction of this section of the tunnel required cover and consolidation grouting, umbrella support, and excavation with a combination of roadheader, hydraulic hammer, and drill and blast.

Water inflows increased significantly as the excavation approached the unconsolidated sediments. Rough measurements of the total inflows before grouting began were between 7000-8000L/minute along the 400 m excavated length of tunnel. When the water inflows reached the point of becoming unmanageable cover/ consolidation grouting was initiated.

When the unconsolidated deposits were encountered, the upper portion of the face was still strong welded breccia, while the lower face was grouted sediments. For mixed face conditions, the lower face was excavated using a roadheader attachment mounted on a small excavator, and the remaining strong rock in the upper face was carefully blasted.

The support for the unconsolidated deposits was umbrella support and lattice girders with poly fibre reinforced shotcrete. At the beginning the umbrella support was installed from invert to invert, with a total of 52 canopy tubes on a 0.3 m spacing. After the bedrock was encountered, canopy tubes were only installed in the soil portion through the upper face.

Figure 4 – Grouted pumice deposit containing a burnt tree.

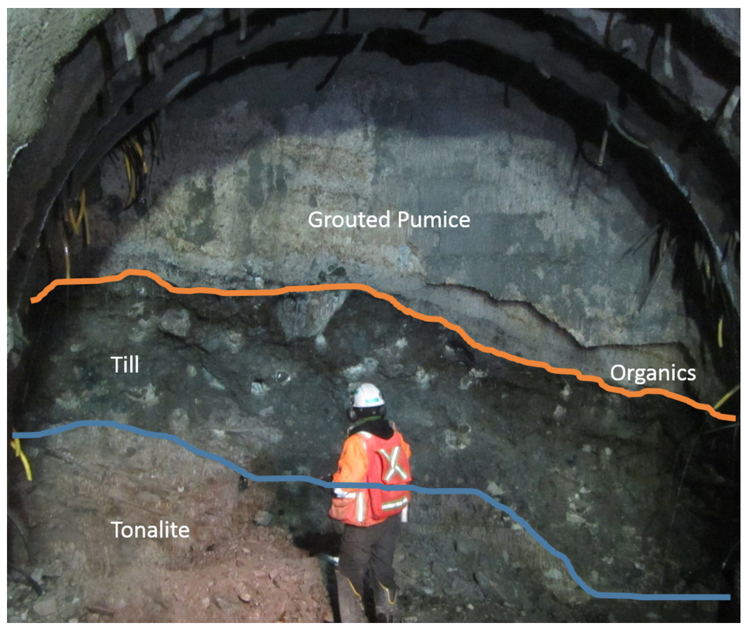

Figure 5 – Mixed face excavation with pumice, organics and till overlying tonalite bedrock.

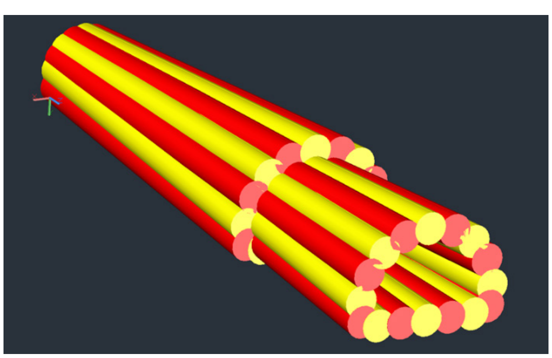

Figure 6 – Schematic of grouting program hole layouts illustrating overlapping grout covers (Bonin et al. 2017).

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SOCIAL AND/OR ECONOMIC BENEFITS

The Upper Lillooet River Hydroelectric Project has a 107MW combined power capacity which would be equivalent to approximately 48,000 homes. The power supplied is completely renewable and helps to provide the region with clean power with no harmful emissions and very little disruptive footprint. The construction of the project has provided both positive local and global economic benefits. The local region has seen over 200,000 manhours of work and millions of dollars on goods and services. The completed project will see over 1,000,000 manhours of labor required to bring it into operation. The local First Nations group (Lil'Wat) has been a strong supporter and also benefitted from employment of its members over the four years of construction.

ENVIRONMENTAL BENEFITS

The project passed through an extensive Environmental Assessment Certificate process which resulted in 37 conditions to be followed. These conditions included limited work durations for migration and denning periods of different species and compensation requirements. Long term monitoring post construction will be done to ensure no adverse impacts to ecosystem. The project once completed will have a very small environmental footprint and the water used to generate power will be entirely returned to the water course. It has also been noted through long term studies that fish populations have increased in the diversion reach between the water intake and return point due to the calmed water effect.

Figure 7 – Upper Lillooet River and construction water management facility at the upstream portal/intake.

MEETING CLIENT'S NEEDS

It was understood that the tunnel excavation would be very challenging through the largely unknown conditions within the unconsolidated deposits. Golder completed the tunnel ground support design, including general rock support and the umbrella support for the unconsolidated deposits. Golder maintained full time, on-site engineers that mapped the tunnel rounds and provided support recommendations. Golder also designed and implemented the cover and consolidation grouting of the transition zone sediments, in-cluding training of the CRT-ebc personnel in grouting techniques. The successful excavation required great cooperation between the Designer, Owner and Contractor, to be flexible with the support to be installed, and offer the ability to adjust the design as the excavation progressed, and the encountered conditions became better understood. The unconsolidated zone became the project's critical path and required extensive engineering and adaptive thinking to succeed safely with minimal delay to the schedule.

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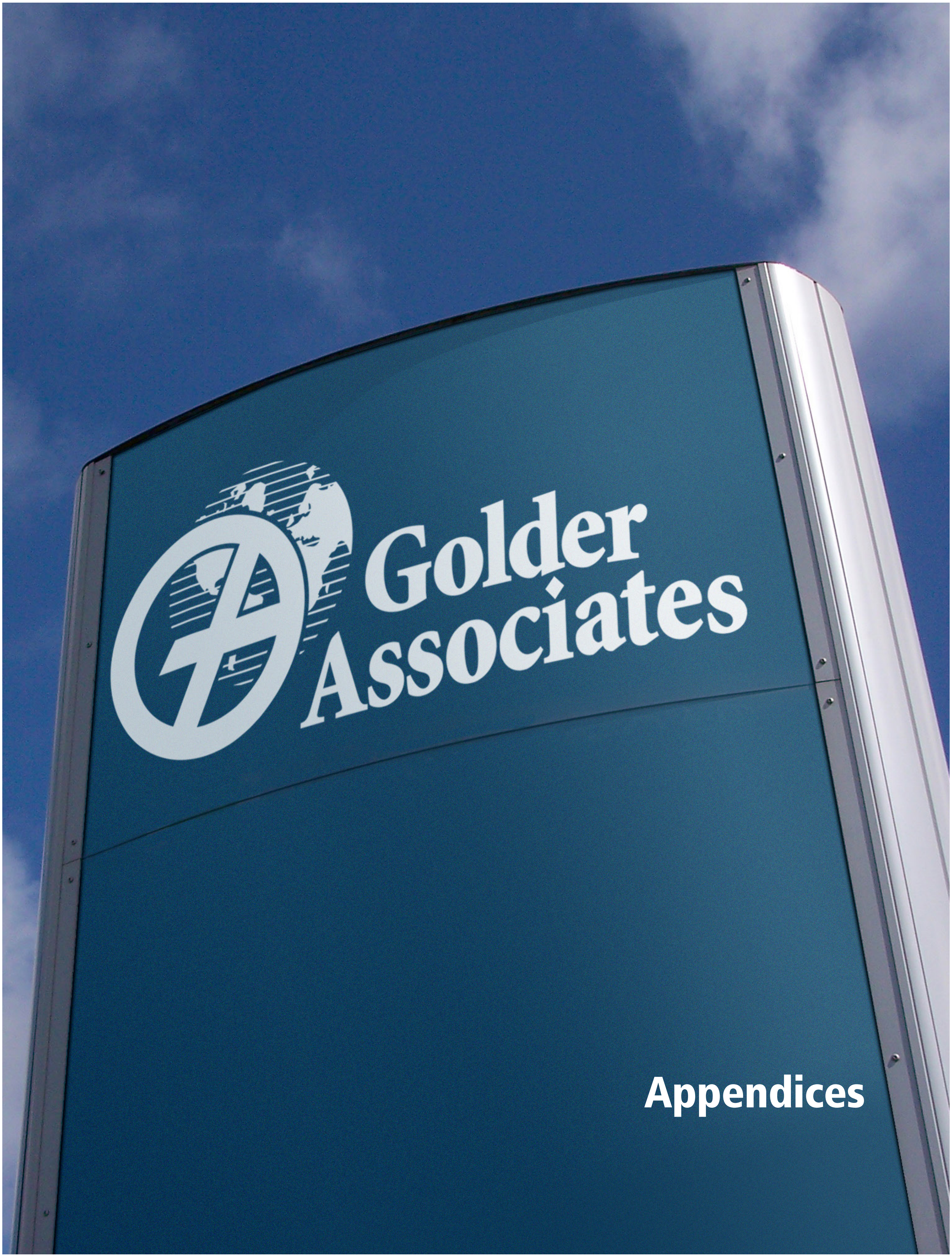

Appendices

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