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LOWER CHURCHILL PROJECT**TECHNICAL MEMORANDUM: Summary Report of Changes to Temporary Structure Work Processes after Draft Tube 2 Failure****1 Purpose**

This document provides a summary of the actions taken by Astaldi Canada Inc (Astaldi) on the Muskrat Falls Project to improve temporary structure work process after the Draft Tube 2 (DT2) incident of May 29, 2016.

2 Overview

On May 29, 2016 at 11:58pm at the Muskrat Falls Hydroelectric Project near Happy Valley – Goose Bay, Labrador, the wooden formwork and falsework supporting freshly poured concrete in DT 2 failed nearing completion of the 530 m³ pour, resulting in collapse. On May 30, 2016, NL OH&S issued Stop Work Orders #0671924-01 and #0671924-02 pertaining to all concrete pours in all four draft tubes and any associated works until the formwork and falsework systems were evaluated by a P. Eng. licensed to practice in the province.

ILF was contracted by Astaldi to perform independent review of the incident, to perform a technical review of engineered systems, and to support the contractor in developing corrective actions, as required by the review findings.

3 ILF's Role and Qualifications

After being contacted by Astaldi, ILF performed in-field inspection of all draft tubes and outlets, design review of CEI formwork and falsework, proposed design modifications, and inspected modified structures prior to loading with concrete. ILF maintained a presence on the Muskrat Falls site from immediately following the DT2 failure to December 2016 and continues to provide design services to the project for high risk temporary structures.

ILF project manager Tim Wellert, P.Eng mobilized to site on June 2, 2016 where he investigated the debris from the collapsed pour and worked as part of the Astaldi project team. Tim has over 13 years of construction experience, having spent the majority of his career in Kiewit Corporation's Temporary Structures Department. He has been involved in over \$50 billion of work in the US and Canada serving roles including design engineer, superintendent, and design manager. His work experience includes 4 years (2011 to 2014) on the \$4 Billion Hebron GBS project where he served as Construction Engineering Manager at the Bull Arm site. Tim's work experience includes

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geotechnical and structural design for heavy civil projects including large earthworks, deep foundations, and concrete structures.

Tim's current role at ILF USA is Engineering Manager where he has been responsible for heavy civil projects, including investigation of cofferdam failures and construction claims since the fall of 2014. While performing work at Muskrat Falls, ILF developed a team under Tim's direction that included structural designers and construction inspectors during the summer and fall of 2016.

During the investigation, Tim interfaced with representatives of Nalcor Energy's (Nalcor) project delivery team, representatives of Newfoundland and Labrador Occupational Health and Safety (NL OHS), and the owner of Contractor's Engineer Inc (CEI). After thorough analysis, ILF provided recommendations to Astaldi, Nalcor, and NL OHS for improvements to the original formwork and falsework before Astaldi could resume work.

4 Observed Improvements to Temporary Structure Work Process

While onsite at the Muskrat Falls Project, ILF observed Astaldi respond to the challenging circumstances of a formwork failure and witnessed improvements to their temporary structures work process. New processes were developed and existing processes and staffing were changed to improve the quality of work and safety of workers. A summary of changes is outlined within this section.

4.1 Changes to Staff Organization

After the DT2 incident, Astaldi reviewed the organization of their Technical Department, including construction engineering staff responsible for formwork and falsework at the Muskrat Falls site. Astaldi re-organized the department to provide a clear responsibility path for structural designs, added third-party designers/reviewers to support technical design tasks, and added new Professional Engineering staff. The Professional Engineering staff responsible for temporary structure design and review at the time of the DT2 failure are no longer on site. Nalcor has been intimately involved in the review and approval of third party designers/reviewers as well as Astaldi's new Professional Engineering staff. Reference MFA-AT-SD-0000-PM-A99-0005-02 Rev A6 and Rev A11 for Technical Department organizational charts before and after the failure, respectively.

4.2 Development of a Temporary Structures Policy

As part of the review of the DT2 incident, it was determined that a formal temporary structures policy was not in place at the time of the failure. Although not required by legislation, it is sound construction risk management practice to develop a process for identifying temporary structures, assigning a risk category (low, medium, high), and selecting qualified designers, reviewers, and inspectors commensurate with the associated structure's risk level. A formalized system ensures additional attention is given to structures that have a higher level of perceived life and safety risk, financial risk, or schedule risk. A formal system also provides a framework for ensuring the process is auditable by requiring documentation of the work process.

ILF consultants provided guidance to Astaldi in drafting a temporary structures policy that was implemented in the fall of 2016. The policy meets the criteria mentioned above including the requirement for documenting all steps of the process as proof that quality objectives were met. ILF remains as an advisor for this document and is involved in design and design review of high risk temporary structures. Reference MFA-AT-SD-0000-CV-K99-0007-01 and -02 for the written policy and associated matrix, respectively.

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4.3 Modification of Existing Change Management Policy

Prior to the DT2 incident, Astaldi utilized a Management of Change standard for the Muskrat Falls project. As the review of the incident progressed, Astaldi identified several improvements that would benefit their work process including:

1. Clarification of roles and responsibilities for various departments and staff levels.
2. Addition of Job Safety Analysis (JSA) and Work Plans under the change management document.
3. Addition of the concept of Continuous Improvement
4. Improved details for Change Management Procedure
5. Addition of a training section within the document
6. Creation of a Management of Change Checklist and Risk Matrix
7. Addition of a Sign-off Hierarchy and additional actions based upon perceived risk

ILF has participated in activities where Astaldi utilized the revised Change Management Policy and confirmed the process is actively monitored. Reference MFA-AT-SD-0000-HS-A28-0098-01 for complete details for the revised management of change process.

4.4 Modification of Pre-Pour Checklist and Execution

Prior to the DT2 incident, Astaldi utilized a pre-pour formwork checklist requiring verifying signature from an Astaldi foreman, field engineer, and quality control inspector in addition to Astaldi Quality Manager, Superintendent, and Nalcor Representative (as required) for every pour. The form included 14 items and did not have provision for falsework members. Astaldi created revised formwork checklists that were issued in December 2016. Revised forms include explicit checks of formwork ties and anchorages and added additional formwork criteria and provisions for falsework. The revised pre-pour checklists also add the requirement for a third-party inspection and signoff, as mandated by Nalcor after the DT2 failure. Reference F-AST-CAN-027-012 and F-AST-CAN-158-03 for the revised pre-pour checklists.

5 Summary Comments

In summary, the failure of concrete pour D2-ESB-03 in DT2 on May 29, 2016 initiated a series of improvements to the temporary structures work process and lead to a change of Astaldi's engineering staff. These changes have resulted in tangible improvements to safety and quality on the project. Summary improvements are outlined as follows:

1. Astaldi has made improvements to their roles and responsibilities matrix which have provided clarification in the reporting structure for design, review, and inspection of temporary structures at the Muskrat Falls project.
2. Astaldi has created new policies and modified existing policies that assist project management and technical staff with identifying temporary structures and allocating resources according to perceived risk. This includes improved forms and checklists to better monitor and address key risk items.
3. Astaldi modified policies and checklists to provide a clear direction for their staff and has improved documentation to ensure compliance with policies, including a management of change standard and pre-pour checklists.
4. Nalcor and Astaldi have invigorated their technical reviews of designs and the qualifications of engineering staff, resulting in changes to Astaldi Professional Engineering staff and the inclusion of third-party reviewers for high-risk structures.

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Prepared by:



Tim Wellert P. Eng

