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KESWICK SUBSTATION TRANSFORMER MOVE

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Abstract: On Sunday, October 22nd, 2017, a 255 tonnes transformer arrived at the NB Power Keswick Substation. The route taken by this oversized load began in the Netherlands several weeks earlier, and the overall plan to move the load, including evaluating various routes and travel modes, began more than three years before that. Six potential routes were originally considered, with the positive and negative aspects, including feasibility and risks, identified for each option. One option, which was not chosen due to risks and other conditions, was to load the transformer onto a barge at the Saint John Harbour and barge it up the Saint John River to the City of Fredericton. Other route options involved travelling on roadways within the City of Fredericton and barging over the Mactaquac head pond. The ultimately chosen travel route included barging from the point of manufacture to the European port of departure, travelling by cargo ship across the Atlantic Ocean, and travelling by train from Halifax habour to the Napadogan CN railway siding. Once the transformer was loaded onto a 20-axle carrier, it was pushed and pulled by several full-sized trucks along a network of provincial and forest resource roads, including passing over bridge structures that were identified as not having the structural capacity to facilitate such a load. In the end, it took four days to move the convoy through the 75-km route, on both provincial highways and forest roads, including properly setting up and removing temporary bridge ramps as well as several detours.

1 Introduction

1.1 Background

NB Power planned to move a transformer with a mass of approximately 255,000 kg, to the Keswick Substation in New Brunswick (see **Figure 1**). EXP Services Inc. was engaged by NB Power to identify and analyze various potential transport routes for this transformer move, as well as other potential, future transformer moves.

In the past, the Keswick Substation was located adjacent to a CN Railway line which conveyed the original transformers to this facility. Over time, the railway line was decommissioned requiring any future transformers to be transported to the substation by road. In addition, the substation is not located near any major provincial strategic highways (e.g., arterial highways) adding to the complexity of preparing a safe and efficient route to move the oversized load.

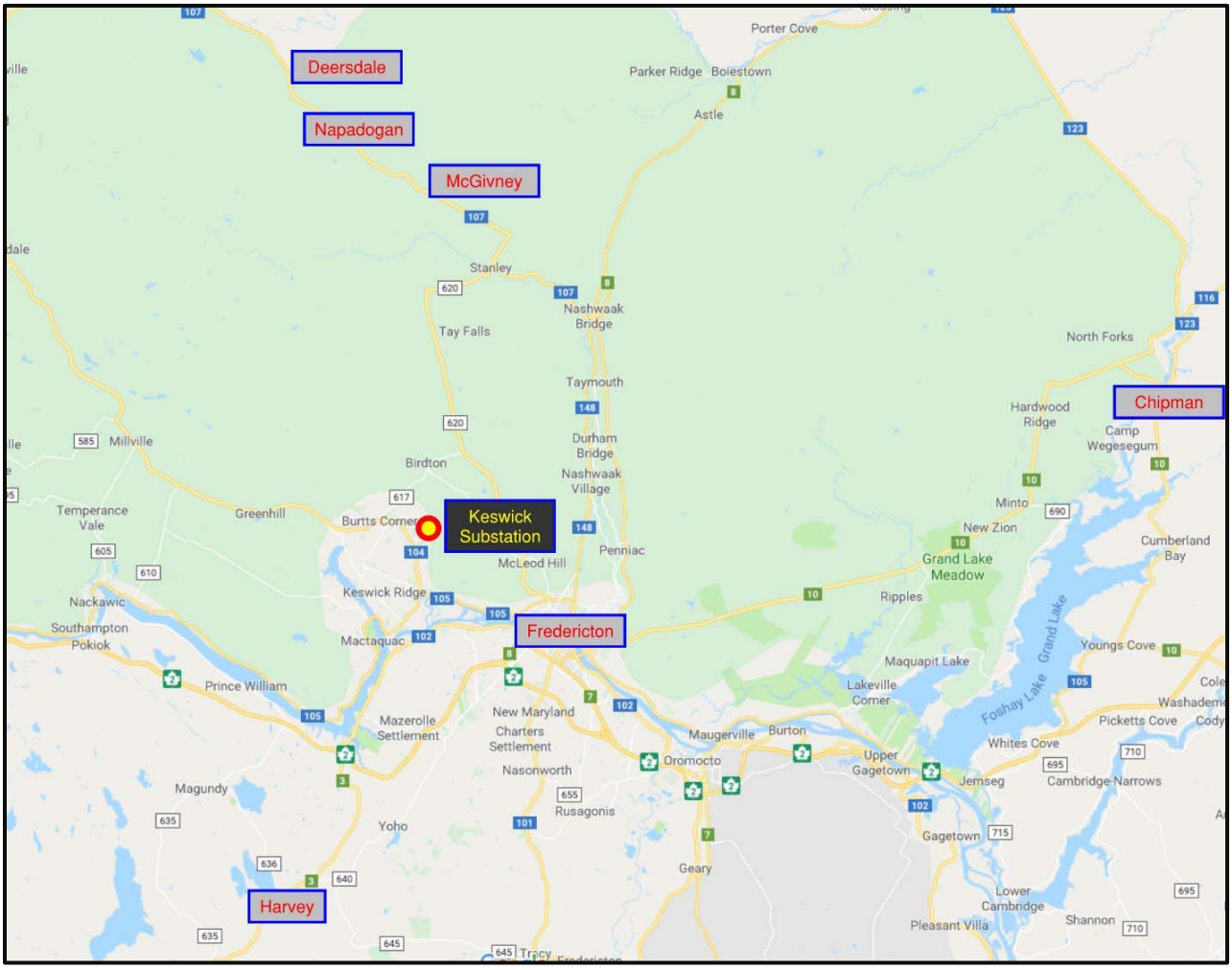

Figure 1 – Project Area

(Base map provided by Google Maps)

The purpose of this article is to present the details and challenges related to the transformer move, including: 1. The identification of a feasible route and, 2. The preparation of a traffic management plan (TMP) addressing all issues related to the engineering of the move.

The primary issues that had to be addressed once the ultimate route was chosen included:

- Route geometry for the transport vehicles;
- Bridges and culverts to be crossed by the load;
- Traffic management, including traffic detours;
- Public notification and emergency service provision strategy;
- Coordination of transport schedule; and
- Minimizing impacts to the public.

This Project had two primary phases:

- Phase I: Potential Transport Route Feasibility Study
- Phase II: Traffic Management Plan

2 Phase I: Potential Transport Route Feasibility Study

2.1 Phase I: Objectives and Methodology

The main objective of Phase 1 was to identify potential routes which could be utilized to move a new transformer (and potential future transformers) safely and efficiently to the Keswick Substation from a location outside of New Brunswick. It was determined during this Phase of the study that the transformer would originate from a manufacturer located outside New Brunswick by rail or ship.

The methodology that was undertaken to complete Phase 1 included:

a) Site visits for the identified potential transport routes.
   - Constraints such as bridges, grades, alignments, roadway widths, lateral obstructions, vertical obstructions, overhead structures, and traffic control issues were identified.
b) Consultations with the New Brunswick Department of Transportation and Infrastructure (NBDTI) to discuss the identified route options and their related issues.
c) Identification of potential offload sites along nearby rail lines.
d) Consultations with CN Rail and New Brunswick Southern Rail.
e) Consultations with heavy load movers.

Bridge Structures

To obtain a permit for moving heavy loads, NBDTI requires that all bridges and transverse culverts on provincial highways be located, and a structural analysis completed, to ensure they can accommodate the oversized load. This requirement was applicable for all provincial highways included in the potential route options. During Phase I of the project, a preliminary analysis of the impact the heavy load would have on roadway infrastructure identified a potential option to position the supporting trailer two lanes wide (with the transformer straddling the lanes), to distribute the load across the entire roadway surface, where required.

Option #1: McGivney Route (Total distance 70 km)

Option #1 would include off-loading the transformer from a rail car onto a transporter vehicle at the McGivney CN Rail siding. The transporter vehicle would travel a short distance on a local road, then onto a section of provincial highway which included 6 bridges of various types and span lengths, including a 3-span, 75 m long, 66-year-old bridge across the Nashwaak River. This structure was not the only bridge on this route of concern (with respect to its ability to safely support the transporter); however, its span length, condition, and age made it very questionable.

The transporter would continue along the highway into City of Fredericton limits where exit and entrance ramps would be used to avoid an overpass structure. There are 3 bridges on this portion of the overall transport route, the most significant being a span across the Nashwaaksis Stream (46 m in length). The transporter would continue back out of City limits, ending at the Keswick terminal.

For this potential option, a detour route or routes would be required around the load at strategic locations to avoid traffic conflicts with the transporter.

Option #2: Deersdale Route (95 km)

Option #2 would include off-loading the transformer at the J.D. Irving Deersdale siding, located at the Mill. The transporter would travel through the Mill Yard and access road to the intersection with Rte. 107 (a provincial highway). This portion of the route would include traveling on a significant bridge which crosses the Southwest (SW) Miramichi River. This bridge was found to be the “weak link” in this route based on a structural inadequacy for the load.

The transporter would cross Rte. 107 and proceed onto several designated forest resource roads, which include four bridges of varying length that would need to be analysed to determine their load capacity. The load would shift back to several sections of provincial highway, which would include crossing two more bridges, 7.6 m and 9.8 m in length, each consisting of steel girders and a timber deck. The transporter would proceed to the intersection of Rte. 617 and the MacLean Settlement Road where it would turn and travel to Rte. 104. It should be noted that for this potential route to be feasible, a 2.0 km section (approximately) of the MacLean Settlement Road, which, at this time was in poor condition and not passable, would require significant upgrading, including clearing and subgrade/surface construction. The transporter would then travel to the Keswick Terminal.

Option #3: Napadogan Route (70 km)

Option #3 would include off-loading the transformer at the CN Rail siding located at Napadogan. The transporter would be moved along a local road to its intersection with Rte. 107 where the current grade was significantly steep, possibly requiring grading improvements to allow the transporter to safely pass. The transporter would travel along Rte. 107 to an intersection with a forest resource road, which would involve crossing a short bridge at the Napadogan Dead Water and a bridge-sized culvert at Four Mile Brook. Traffic on Rte. 107 would have to be stopped or delayed until the load passed.

The transporter would continue along sections of several forest resource roads, which would include crossing four more bridges. The transporter would then proceed along Rte. 617 to the intersection with the MacLean Settlement Road, which again would require upgrading to allow the load to safely pass. The transporter would then travel on Rte. 104 to the Keswick Terminal.

For this option, while the load travelled on Rte. 617 and Rte. 104, detour routes would be required to avoid traffic conflicts with the transporter.

Option #4: Chipman Route (90 km)

Option #4 would include off-loading the transformer at the CN Rail siding located at Chipman. This siding would require some upgrading to facilitate the unloading process, including providing adequate space for the moving equipment. The load’s width (two lanes wide), would require that traffic be detoured to other routes during the move, which could cause significant delays to the travelling public. The transport vehicle would travel on Rte. 10 (a major provincial highway), through Minto, continuing to the intersection with Rte. 8 (within City of Fredericton limits). This section of Rte. 10 includes four bridges of various types and span lengths

The load would turn and travel along Rte. 8 to where it intersects with Rte. 148. This would include crossing a five-span concrete structure across the Nashwaak River with seven precast concrete girders. The span-length, condition, and age of this structure made crossing this bridge questionable in regards to supporting the transformer load.

The transporter would then travel along several busy city streets, then onto Rte. 105 where it would travel down and up the Rte. 620 exit and entrance ramps to avoid crossing the Rte. 620 overpass structure. There are 4 bridges located along this portion of the transport route, the most significant being a span across the Nashwaaksis Stream (46 m in length). The transporter would travel along Rte. 104 ending at the Keswick terminal.

A detour route(s) may have been required to reroute traffic around the transport convoy at specific locations along this potential route (especially within City limits), to avoid traffic conflicts with the transporter.

Option #5: Harvey Route (46 km road, 10.8 km barging)

Option #5 would include off-loading the transformer from a rail car at the NB Southern Rail siding in Harvey. The transporter vehicle would travel on Rte. 3 (a major arterial highway) to the Rte. 2 (Trans-Canada Highway) interchange, which would require crossing two bridges at Gardner Creek. From there, the transporter would travel west, down the Rte. 2 eastbound off-ramp (to avoid the Rte. 3 underpass structure spanning across Rte. 2), then cross a temporary median cross-over which would need to be constructed and later removed as part of this project. The load would then travel back up to Rte. 3 via the westbound Rte. 2 on-ramp. This series of manoeuvres would require stopping traffic on Rte. 2 in both directions. The load would continue along until it arrived at a designated boat launching which accesses the Mactaquac Head Pond. At this point, the transformer would be placed on a barge, which would cross the Head Pond for approximately 10.8 km until it arrived at a designated landing north of the Mactaquac Dam. The transformer would then be loaded back onto the transporter vehicle which would travel along Rte. 105 to its intersection with Rte. 104, which would include crossing a structure spanning the Keswick River. The transporter would travel along Rte. 104 approximately 7.0 km ending at the Keswick terminal.

Constructing a temporary median crossover on Rte. 2, and mobilizing a barge on the Mactaquac Head Pond made this option relatively difficult to plan and execute.

Option #6: Fredericton Barging Route (128 km barging, 26 km road)

The final option considered for this move would include transporting the transformer from Saint John, New Brunswick to Fredericton via a barge (towed by a tugboat) travelling along the St. John River (a 128-km route). The barge would arrive at a landing somewhere along the north side of the river potentially within City of Fredericton limits. The transformer would then be lifted off the barge and onto the transporter vehicle and travel along Rte. 105 and Rte. 104 until it arrived at the Keswick substation. There are potentially 3 bridges on this portion of the overall transport route that the load would have crossed, the most significant being a span across the Nashwaaksis Stream (46 m in length).

Similar to several other transport options, detour routes would likely be required for Option #6 to avoid traffic conflicts. The two most significant issues regarding this route would be barging the load safely under the Fredericton foot bridge and finding an appropriate location to dock the barge on the north side of the river where the transformer could be properly and safely unloaded and placed on a transporter.

2.2 Phase I: Conclusions

The results of the Study indicated that Option #3, the Napadogan Route, was the preferred choice for the following reasons:

- Less impact to normal traffic (e.g., closures on designated highways);
- Fewer restrictions on the mover (e.g., time of day, weekends);
- With a shorter route, reduces potential issues associated with the minor culverts found on NBDTI highways; and

- Forestry bridges are potentially more suitable to facilitate the magnitude of the proposed load (and more conducive to modifications, if required).

Option #6, the Fredericton Barging Route, was recommended as an alternate route as it had the following advantages:

- Less distance to be traveled on NBDTI roads (therefore less impact on normal traffic and fewer restrictions on the mover); and
- NB Power has previous barging experience along this route.

2.3 Phase I: Recommendations

Based on the results of the Phase I analysis, it was recommended that the Napadogan Route, which included a combination of forestry and provincial roads, be further assessed as part of Phase II of this Study. Barging the load along the Saint John River was further examined and deemed not feasible based on the uncertainty of a safe landing place on the north side of the river and the potential height of the transformer being too great to pass safely under the Fredericton foot bridge.

3 Phase II: Napadogan to Keswick Transformer Move: Traffic Management Plan (TMP)

During Phase 1 of this Study, it was determined that the Napadogan railway siding route, which included approximately 86 km of combined forestry roads and NBDTI roads, was the preferred option for moving the load based on feasibility and risk. Once this route was ultimately chosen by NB Power, a comprehensive Traffic Management Plan (TMP) was prepared by EXP. The transformer dimensions, together with those of the proposed transporter, corresponded to the NBDTI provincial highway load limit characteristics for exceptional loads; therefore, NBDTI required a TMP be prepared and approved prior to the issuance of an oversize permit. **Mammoet Canada Eastern Ltd.** (herein referred to as "**the Mover**") was identified for the transformer move.

3.1 Phase II: Objectives and Methodology

The main objective of Phase II of this Project was to prepare a TMP to address traffic-related conditions for the transportation of the transformer. The Study Objectives and Scope for this Phase were as follows:

- Preparing a TMP broken down to cover all phases of the transformer move, including the route segments, dates, and timing, along with the required traffic control applications to ensure the safety of other motorists.
- Conducting site visits to identify relevant bridges/culverts located under the proposed roadway routes that may be affected by the increased loading, including their location, condition, and ability to support the expected transport load.
- Identifying specific sections of roadway, including intersections, where the road may need to be widened or regraded to allow the load to pass.
- Identifying roadside objects and overhead structures that would need to be considered with respect to the load width and height.
- Prepare an emergency vehicle plan, a breakdown plan, and a communication plan for the move as part of the TMP.

Transportation to New Brunswick

The route taken by the oversized load began in Nijmegen, Netherlands several months before it arrived in New Brunswick The manufacturer of the transformer, Royal Smit Transformers B.V., completed the

fabrication and assembly of the unit and shipped it by barge to the Antwerp EuroTerminal where it was loaded onto an ocean class cargo ship (ACL RoRo Ocean Vessel). This ship transported the load across the Atlantic Ocean to the Fairview Cove Container Terminal in Halifax, Nova Scotia. There, the load was transferred onto a railway car and traveled by rail from Halifax, NS to Truro, NS to Moncton, NB to the railway siding at Napadogan, NB. At the siding, the transformer was loaded onto a 20-axle trailer, with three large trucks available to push and pull the trailer throughout the roadway component of the transport route.

Transport Route: Napadogan Siding to Keswick Substation

The overall roadway route of the transformer move included a corridor of forestry and NBDTI roadways that began at the intersection of Alpha St. (Napadogan Siding access road) and Rte. 107 and ended at the Keswick Substation. This corridor included sections of Alpha St., forestry roads, Rte. 107, Rte. 617, and Rte. 104.

Bridges and Culverts

Several site visits of the proposed transport route were conducted throughout the TMP development process, which included identifying and examining small culverts (less than 3.0 m in diameter) and structures located along the route.

The following bridge structures were identified and further analysed to determine structural capacity with respect to the proposed load.

Table 1 – Bridges and Culverts located along Transport Route

Route Section	Structure	Span	Notes
Rte. 104	Jones Forks #1	60 ft. (18.29 m)	Reinforced concrete rigid frame (with stone facing).
Rte. 617	Jones Forks #2	50 ft. (15.24 m)	Single span with a superstructure consisting of a reinforced concrete slab supported by prestressed concrete beams.
Rte. 107	Napadogan Lake Outlet	30 ft. (9.09 m)	Simply-supported reinforced concrete slab bridge.
Rte. 107	Four Mile Brook	18 ft. (5.5 m)	Reinforced concrete box culvert.
Forestry Roads	Narrows Bridge	78’-8” (24.0 m)	Simply-supported bridge with four steel-plate girders and a timber deck.
Forestry Roads	Grand John Brook Bridge	24 ft. (7.3 m)	Simply-supported bridge with four steel beams and a timber deck.
Forestry Roads	Grand John Brook	32 ft. (9.8 m)	Simply-supported bridge with four steel beams and a timber deck.

Bridge Evaluation

A preliminary structural load evaluation was completed for several of the above noted bridges which indicated a need (as a minimum) for a double wide trailer. Following discussions with the Mover, it was decided that temporary bridge ramp assemblies capable of spanning beyond the bridges would be a more appropriate option for all structures along the route. The large, steel, compartmentalized bridge ramp

assemblies were supplied, installed, and removed by the Mover and were of adequate length to span beyond the bridges (except the Narrows Bridge which required a ramp installed at each end of the structure). The width of the bridge ramp assemblies, and the equipment needed for their installation, was such that traffic would not be able to pass while the ramps were constructed, removed, and in place.

The structural evaluations undertaken for this Study were based on Section 14 of the Canadian Highway Bridge Design Code, CAN/CSA-S6-06 (and other sections of S6 as dictated) and the transporter vehicles chosen for the move. A visual condition assessment of the bridges was also completed.

NBDTI Culverts

Circular culverts with diameters less than 3.0 m were visually located along the transport route. This review included measuring the diameter, span, and cover above each culvert and inspecting the condition of their visual portions (inlets and outlets).

A structural analysis of the culverts was completed by calculating the load effects caused by the proposed transporter and comparing these to load effects from the Province of New Brunswick's regulation vehicles. It was determined that eight culverts required steel plating to accommodate the transformer load. The plates were placed prior to, and removed after the load passed.

Detailed Traffic Management Plan

The following is a summary of the four segments of the overall transport route. **Table 3** provides the ultimate schedule for the move.

Table 2 – Transformer Move Schedule

Route Component	Weekday
Segment #1	Thursday, October 19th
Segment #2	Friday, October 20th
Segment #3	Saturday, October 21st
Segment #4	Sunday, October 22nd

Segment #1: Rte. 107 (Approximately 14 km, 8 hours)

At the intersection of Rte. 107 and Alpha St, due to the existing configuration of the roads, the load had to be turned left (eastward) onto Rte. 107 and then reverse direction so that it could continue west along Rte. 107 to the intersection with Nashwaak Forestry Road. The reversing of the transport vehicle involved the lead and trailing trucks detaching from the transporter, turning around, and reattaching to the load so that it could continue moving in the opposite direction. At the intersection of Rte. 107, the Nashwaak Road, and the Deersdale Mill entrance, the load turned left and continued south along the Nashwaak Forestry Road. Rte. 107 was closed to all traffic while the temporary bridge ramps were in place and during their installation and removal.

Segment #2: Forestry Roads

For this segment, the transporter travelled along four forestry roads which were constructed primarily to facilitate forest industry heavy haul vehicles. The forest roads travelled by the transport convoy included

the Nashwaak Road, the Fire Road, and the Valley Forest Road, ending the day at the intersection of Crow Hill Road and Rte. 617. There are two bridges, Grand John Brook, and Branch of Grand John Brook, 7.6 m and 9.8 m in length, respectively, which required temporary ramp assemblies. The Valley Forest Road, at the Narrows Bridge, and the Crow Hill Road, at the Grand John Bridges were closed to all traffic while the temporary bridge ramps were in place and during their installation and removal.

Segment #3: Crow Hill Road (Approximately 7.0 km, 8 hours)

This segment of the move began at the intersection of the Crow Hill Road and Rte. 617. The load moved south along the southbound lane of Rte. 617 past the intersection of Rte. 617 and Rte. 620 and continued moving along to the Jones Forks #2 bridge structure which required a temporary ramp assembly. The load then continued south on Rte. 617 to the intersection with Rte. 104.

Segment #4: Rte. 104 to Keswick NB Power Substation (Approximately 3.5 km, 8 hours)

At the intersection of Rte. 617 and Rte. 104, the load turned right (westward) onto Rte. 104, then reversed direction, again with the lead and trailing trucks detaching from the transporter, turning around, and reattaching to the load so that it could continue moving in the opposite direction. This process was required to safely move the load around the angled corner.

The load then continued east along Rte. 104 and traveled to the Jones Fork #1 bridge structure where a temporary ramp assembly was also required. The load then continued east on Rte. 104 to its intersection with the Keswick Substation access road where the load turned left into the NB Power facility, the final destination for the load.

3.2 Additional Considerations

1. The load was escorted the entire length of the trip by two private and two Commercial Vehicle Enforcement (CVE) escorts. The escort vehicles were placed both in front and at the rear of the load at all times during travel.

2. All local utility wires were raised as the load approached to protect the lines, not impede the operations, and to avoid traffic delays.

3. A local school bus was picking up and dropping off children at Alpha St. (Segment #1), the morning and afternoon of Thursday, October 19th. This bus was accommodated safely and without delay.

4. At the Jones Forks #2 bridge location, where a temporary ramp assembly was required to protect the existing bridge structure, it was necessary to close Rte. 617 to traffic as there was not adequate roadway width for vehicles to pass the temporary ramps. Traffic was redirected to alternate detour routes as presented in the TMP Report.

5. Similar to Jones Forks #2, at the Jones Forks #1 bridge location, a temporary ramp assembly was required which necessitated the closure of Rte. 104 (from the intersection of Rte. 104 and Rte. 617 to the entrance to the Keswick substation) as there was not adequate width for vehicles to pass the temporary ramp. Traffic was redirected to alternate detour routes as presented in the TMP Report.

6. Vertical and horizontal space was not adequately available at the Jones Forks #1 structure (on Rte. 104), to allow cranes to be erected to install the temporary bridge ramp; therefore, a second transporter (self-propelled and with 12 axles) was required to move the pre-assembled bridge ramp into place at this structure. Once the ramp was assembled at the Keswick substation access road, away from the Rte. 104 right-of-way, it was loaded onto the 12-axle transporter and moved from the access road to the Jones Forks #1 structure where it was installed prior to the transformer move.

Public Communications Plan

The public, including churches and industry located within the Study Area, were informed by the Mover prior to the transformer move as to the timing and the route to be taken (including the required highway closures and detours). This included a Public Service Announcement sent to local newspapers, CBC Radio and Radio Canada, and other media broadcasting within the Study Area.

Emergency Vehicle Plan

As part of the activities leading up to the move, all emergency organizations providing services within the affected area were contacted by the Mover both prior to and on the days of the move. The organizations contacted by the Mover included local fire and ambulance service providers, the Provincial Emergency Measures Organization, the RCMP, and the Provincial Mobile Communications Centre.

4 Conclusions

This Project included a feasibility analysis of six potential routes for transporting a new transformer from its European point of manufacture to the Keswick Substation in New Brunswick. These routes included various combinations of CN Rail and NB Southern railway sidings, NBDTI and Department of Natural Resources (forestry) roadways, and barging options on the Saint John River and Mactaquac Head Pond. This review included a complete preliminary analysis of all components of each potential route to determine suitable options for the transportation of this heavy, oversized load. Once a viable route option was chosen, a Traffic Management Plan was completed which provided a complete review of the proposed transformer move, from the intersection of Alpha St. (the Napadogan Siding access road) and Rte. 107 to the Keswick Substation located on Rte. 104. The details contained within the TMP, including a traffic management plan, structural analysis, and detour plans for Rte. 617 and Rte. 104. The TMP details explained the measures and practices to be followed by all personnel involved in the move to assure the safety of the public and move personnel, and to minimize the impact to the local environment and relevant roadway infrastructure.

The transportation of the 255 tonnes transformer was ultimately a success, with the load safely and efficiently arriving at its destination on schedule and without any major incidents (although there were some roadway grades on the forest roads which required all three trucks, as well as an additional highway grader, pushing and pulling the transporter trailer to move the load uphill). This success provides NB Power a proven route to move future oversized loads to the Keswick Substation and other NB Power facilities within the region.

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