Keeyask Generation Project

Terrestrial Effects Monitoring Plan

Habitat Rehabilitation Implementation and Success Monitoring Report

TEMP-2024-05

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KEEYASK GENERATION PROJECT

TERRESTRIAL EFFECTS MONITORING PLAN

REPORT #TEMP-2024-05

HABITAT REHABILITATION
IMPLEMENTATION AND SUCCESS MONITORING

YEAR 2 OPERATION

2023

Prepared for

Manitoba Hydro

By

ECOSTEM Ltd.

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SUMMARY

Background

Construction of the Keeyask Generation Project (the Project) at Gull Rapids began in July 2014. The vast majority of construction activities were completed by fall 2021, and all seven units were in operation by March 2022. The first year of operation monitoring began in the summer of 2022.

The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the generating station on the terrestrial environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how construction and operation of the generating station are affecting the environment, and whether or not more needs to be done to reduce harmful effects.

This report describes the results of the terrestrial habitat rehabilitation monitoring conducted during the second summer of Project operation.

Why is the study being done?

Terrestrial habitat rehabilitation reduces adverse Project effects on terrestrial habitat and plants (e.g., habitat loss, erosion, invasive plant spread), restores wildlife habitat and improves aesthetics, among other benefits.

The Project's *Vegetation Rehabilitation Plan,* which is part of the overall Environmental Protection Program, provides the framework for rehabilitating terrestrial habitat in areas impacted by the Project, and the Keeyask Infrastructure Project (KIP). Terrestrial habitat is being rehabilitated in areas not required for Project operation (i.e., temporary Project areas) and in some permanent Project areas (e.g., along access roads).

What was done?

Terrestrial habitat rehabilitation monitoring verifies that the rehabilitation measures are being completed in accordance with the *Environmental Impact Statement* commitments and the *Vegetation Rehabilitation Plan*. This monitoring also verifies that rehabilitated areas are on track to achieving their target habitat types.

Monitoring in 2023 focused on documenting the:

- Degree of vegetation regeneration in areas not targeted to become a woodland or a forest; and,
- Rehabilitation implementation and recovery success in areas that are targeted to become a woodland or a forest.

Areas not targeted to become a woodland or a forest included side slopes along the main access roads, a buffer area around the dam and dikes required for dam safety, and the rights-of-way underneath transmission lines. The KHLP seeded the side slopes of the North Access Road (NAR) and South Access road (SAR) at various times since the start of Project construction and seeded two borrow areas underneath a transmission line with native grass along the SAR.

The KHLP carried out the first efforts to rehabilitate forest or woodland habitats in 2016 at five locations, including three borrow areas developed by the KIP along the NAR, one cleared area near the Start-Up Camp and one cleared area near the Main Camp. Additional rehabilitation efforts were carried out in 2020, 2021, and 2022 at 21 locations. Rehabilitation measures included grading to reduce steep slopes in the borrow areas, using a discer to loosen compacted mineral substrates and planting jack pine and black spruce trees. A total of 24.1 ha were planted in 2016, and 265.2 ha were planted from 2020 to 2022.

The areas not required for Project operation were finalized in 2023 and totaled 1,138 ha. Vegetation regeneration mapping was updated for the temporary Project areas, and permanent areas targeted for low vegetation cover including the borrow areas seeded with grass in 2020.

In 2023, tree regeneration implementation surveys were conducted in areas that were planted with tree seedlings between 2020 and 2022, and recovery success was monitored for areas planted in 2016. For the first time in 2023, seedling data was also collected by drones for selected areas planted in 2020 and 2021.

Area surveyed for tree regeneration implementation

Several areas identified as regenerating poorly based on 2022 mapping were ground surveyed in 2023 to confirm their regeneration status, and to identify factors leading to poor regeneration where present.

What was found?

For areas not targeted to become a woodland or a forest, updated vegetation cover mapping found that approximately 58% of the mapped areas had at least sparse (>10%) vegetation cover. Vegetation cover changed since 2022 for approximately 19% of the mapped area. The vast majority of change was due to an increase in vegetation cover and/or a change in structure to a more advanced successional stage.

For areas that were targeted to become a woodland or a forest, rehabilitation implementation surveys found that six of the 11 locations planted in 2022 were tree planted at stem densities that met or exceeded their prescribed density (2,500 stems/ha). One additional location sampled with a single transect had a density well above the target. The estimated planting density at one location (Work Area C) was significantly lower than the prescribed density.

As of 2023, the estimated live tree stem density (including natural regeneration) for seven out of the 16 locations planted since 2020 met or exceeded the target stem density. Natural regeneration was a substantial contributor to the live stem density in planting areas where it was present (typically edge areas next to a seed source where only tall vegetation was cleared). Tree stem survival in planted areas ranged from 28% to 100% of seedlings, with the lowest survival rates occurring in Borrow Area G-3 and EMPA D-27(4)-E.

Recovery success monitoring found that approximately 78% of the area planted in 2016 had estimated live tree stem densities exceeding the prescribed target for woodland habitat (2,500 stems/ha), but none of the area had densities above the target for forest (10,000 stems/ha). Understory vegetation cover, mostly low ground cover plants, had developed over 99.9% of the planted area, and ground moss cover had developed over 42% of the planted area by 2023.

Area surveyed for recovery success

Surveys in 2023 of grass-seeded areas that were regenerating poorly in 2022 found the majority of that area now had sufficient regeneration. Patches of poor regeneration covered only 0.5% of the total seeded area and were generally a result of substrate conditions or active erosion.

Areas targeted for woodland or forest habitat with poor tree seedling condition made up 58% of the area planted from 2020 to 2022, and low live seedling density made up 57% of the area. Most of the poorly regenerating planted areas were in Borrow Areas G-3 and N-5, and EMPA D27(4)-E. Ground surveys found that poor tree regeneration was generally associated with coarser, drier ssoil, a lack of organic material, more compacted soils, and/or more eroding area.

What does it mean?

For overall vegetation regeneration, the large increases in vegetation cover were anticipated, since most Project construction activity has finished and large portions of the temporary Project areas have already undergone site preparation and tree planting or grass seeding.

Most of the area seeded with grass had sufficient regeneration, and only a small proportion of the area mapped as poorly regenerating in 2022 actually had poor regeneration in 2023. Some of these patches are expected to regenerate naturally in the future.

Tree planting appeared to be more successful in 2022 than in either 2020 or 2021. This was apparently due to a closer than prescribed planting spacing, and better site preparation in general. More favourable weather conditions in 2022 may also have been a factor.

In 2020 and 2021, eight areas targeted to become forest or woodland habitat were planted with trees. Monitoring in 2022 found that four of these eight areas had a live stem density that was too low for it to regenerate to a woodland habitat type. At least one location will require supplemental planting in the future to meet the revegetation target. Future mapping and field surveys for the *Vegetation Rehabilitation Plan* will determine if any other areas require additional planting to achieve the rehabilitation targets.

Recovery success monitoring in 2023 suggests that most of the area planted in 2016 is on track to achieve at least a woodland habitat, interspersed with patchy forest habitat, provided there are no catastrophic events that result in tree mortality. Natural regeneration will continue to contribute to stem density in areas adjacent to a seed source.

In tree planted areas, poor seedling condition and low live stem densities were generally a result of insufficient site preparation, or ongoing erosion. Drought conditions in 2021 also likely contributed to poor seedling survival. To date, these conditions are confined to areas planted in 2020 and 2021. It is recommended that, if feasible, poorly regenerating planted areas be replanted after additional site preparation is carried out.

A trial was conducted in 2023 to evaluate whether drone imagery could be substituted for ground transect data collection under certain conditions, to make the monitoring more efficient. This trial showed that using drones was technically feasible for some field conditions, was more accurate and informative for some conditions, and was at least as informative for other conditions. Ground transect data collection should still continue for the first year of prescription implementation surveys in all planted areas, and in areas with a lot of naturally regenerating vegetation (i.e., more than sparse cover) in subsequent years. For other planting areas, drone survey methods could be used starting in the second year of prescription implementation monitoring. For recovery success monitoring, drone survey methods are appropriate for all areas, provided most of the trees have grown beyond the seedling stage.

Drone image of planted seedlings

What will be done next?

Field conditions will be evaluated where drone monitoring provides the best balance between information provided and efficiency. This evaluation will be completed prior to the 2024 fieldwork, and will determine the conditions where drone data collection can replace ground transects.

Rehabilitation implementation and monitoring will continue in 2024.

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STUDY TEAM

Dr. James Ehnes was the project manager and study designer.

Fieldwork in 2023 was conducted by Brock Epp, Alanna Sutton, Owen Romanchuk, Candice Collette, Anoj Subedi, Lynnae Martin, Heidi Ahrenholtz, Alex Snitowski, Fred Wood (Tataskweyak Cree Nation) and Tyler Kitchekeesik (Tataskweyak Cree Nation). Drone work was conducted by Owen Romanchuck and Alex Snitowski.

Data analysis and report writing in 2023 were completed by Brock Epp, Anoj Subedi, James Ehnes and Alanna Sutton. GIS analysis and cartography were completed by Alex Snitowski.

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1.0 INTRODUCTION

The Keeyask Generation Project (the Project) is a 695-megawatt hydroelectric generating station (GS) and the associated facilities. The Project is located at the former Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

Project construction began in July 2014. The vast majority of construction activities had been completed by fall 2021. The reservoir was first brought to full supply level in September 2020 and the final generating unit went into service on March 9, 2022.

The *Keeyask Generation Project Response to EIS Guidelines* (the EIS), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project (KHLP 2012a). Technical supporting information for the terrestrial environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement Terrestrial Supporting Volume* (TE SV; KHLP 2012b).

The *Keeyask Generation Project Terrestrial Effects Monitoring Plan* (TEMP; KHLP 2015a) was subsequently developed as part of the licensing process for the Project. Monitoring activities for various components of the terrestrial environment were described, including the focus of this report, habitat rehabilitation, during the construction and operation phases.

EIS predictions for all key terrestrial topics were directly and/or indirectly based on assumptions regarding the effectiveness of habitat rehabilitation efforts and natural regeneration processes. The direct key topics included intactness, ecosystem diversity, terrestrial habitat, and priority plants.

Terrestrial habitat rehabilitation mitigates adverse Project effects on terrestrial habitat and plants (e.g., habitat loss, erosion, invasive plant spread), restores wildlife habitat and improves aesthetics, among other benefits. Terrestrial habitat will be rehabilitated in areas not required for Project operation and in some areas that are required for Project operation (e.g., along access roads). Some of the planned rehabilitation addresses potential adverse Project effects on intactness by blocking or hindering access from Project areas to surrounding areas.

The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan for rehabilitating terrestrial habitat. The *Keeyask Generation Project Vegetation Rehabilitation Plan* (the VRP; KHLP 2015b), which is part of the overall Environmental Protection Program, provides the framework for rehabilitating terrestrial habitat in areas impacted by Keeyask Infrastructure Project (KIP) and the Project. The framework includes how the areas that weretemporarily required for construction but are not required for operation of the generating station or long-term maintenance of the associated infrastructure (e.g., borrow areas) will be rehabilitated. Best efforts will be made to re-establish the habitat types that existed prior to construction while giving preference to rehabilitating the most affected priority habitat types. Plant species that are important to the partner First Nations will be incorporated into habitat restoration, where feasible.

Permanent Project features that require sight lines for safety purposes will be revegetated with plant species that are appropriate for the site (e.g., native grasses).

Monitoring is needed to verify the implementation and effectiveness of terrestrial habitat rehabilitation measures. The terrestrial habitat rehabilitation monitoring program (TEMP, Section 2.2) includes a single study, Habitat Rehabilitation Implementation and Success, that periodically evaluates the implementation and effectiveness of terrestrial habitat rehabilitation measures.

The goal of this study (Habitat Rehabilitation Implementation and Success) is to verify whether each site has achieved, or is on a pathway to achieving, its rehabilitation targets. However, it will take many years for habitat to regenerate in highly disturbed areas (e.g., borrow areas), and decades for a forest to regenerate where this is the target habitat type. Consequently, this monitoring study is divided into two components:

1. The Habitat Rehabilitation Implementation component initially focuses on verifying adequate implementation of rehabilitation efforts, and documenting the survival of plantings and seedings as well as natural plant colonization and expansion.

2. The Habitat Recovery Success component begins two to three years after successful implementation, and focuses on evaluating successful achievement of the rehabilitation targets.

The objectives of this study are to:

- Confirm that trails intersecting the Construction Footprint (except for existing resource-use trails and those required for operation) are blocked and initial revegetation efforts are adequate;
- Verify the implementation of rehabilitation prescriptions set out in the *Vegetation Rehabilitation Plan*;
- Confirm that the revegetated portions of the blocked trails are regenerating successfully and are expected to restore a habitat type similar to adjacent areas; and,
- Verify the effectiveness of rehabilitation efforts at restoring native habitat where this is the target prescription, and at restoring ecologically appropriate vegetation in the remaining areas.

Monitoring for the Terrestrial Habitat Rehabilitation study was conducted in 2017, 2021, 2022, and 2023. Results for the monitoring conducted in 2017, 2021, and 2022 are provided in previous reports by ECOSTEM (2018, 2022c, 2023). The previous annual monitoring report (ECOSTEM 2023) provided confirmation for the third objective listed above, and monitoring for that objective is now completed. The following section presents the monitoring conducted in 2023.

2.0 HABITAT REHABILITATION

2.1 TARGET HABITAT TYPES

A target habitat type will be determined for all areas within the Construction Footprint that are not required for Project operation. These target habitat types are established when:

1. The areas not required for Project operation are identified;
2. For treed habitat types, after it is determined:
   a. Which of the priority habitat types were most highly affected by Project construction;
   b. Substrate conditions in areas targeted for a treed habitat type are known. This mapping cannot happen until Project activity in the area has ceased.

As of spring 2023, Manitoba Hydro determined which areas within the Construction Footprint were required for Project operation. The remaining Construction Footprint area was considered temporary and subject to habitat rehabilitation.

For item 2a above, the Terrestrial Habitat Loss and Disturbance study mapped the Construction Footprint, as well as the amount and composition of terrestrial habitat affected by the Project during construction (ECOSTEM 2022a). The Priority Habitats study identified the priority habitat types that were most highly affected by construction (ECOSTEM 2022b).

In 2023, substrate conditions in the temporary portions of the Construction Footprint were documented through remote sensing imagery and ground surveys. Target habitat types were mapped for the temporary areas using all the available information, and rehabilitation prescriptions were developed. Results of the target habitat type mapping and rehabilitation prescriptions are provided in a separate report (ECOSTEM 2024).

2.2 FOREST AND WOODLAND HABITATS

Each winter, Manitoba Hydro provides information on the actual rehabilitation treatments carried out to date. This information is used to plan monitoring for the next growing season. The following summarizes treatments carried out since Project construction began.

2.2.1 BACKGROUND

To develop forest or woodland habitat types in Project disturbed areas, site preparation is often implemented prior to trees being planted. Site preparation may include grading to reduce steep slopes and/or loosening compacted substrates. Site preparation and other treatments (e.g., eradicating invasive plants) are followed by tree planting.

Tree planting densities differ for the forest or woodland habitat types as the typical stem density of a mature forest is much higher than a mature woodland. Tree seedlings are planted at a density of 10,000 stems/ha to achieve a forest habitat type, and at 2,500 stems/ha to achieve a woodland habitat type. Using these targets, the final spacing for tree planting is 1 m x 1 m for the rehabilitation locations where a forest is the target, and 2 m x 2 m for the rehabilitation locations where a woodland is the target.

The target tree spacing can be achieved over more than one year, if needed (i.e., two-stage initial planting). This is desirable in some situations as it reduces the risk that a high proportion of the planted seedlings will be eliminated by extreme conditions or events (e.g., a drought, excessive winter browsing). For example, the 1 m x 1 m spacing for a forest can be achieved by planting at 2 m x 2 m in one year, and then completing a second offset 2 m x 2 m planting in a subsequent year.

A consideration when setting the spacing for tree planting is that natural tree regeneration may also contribute to the total target stem density. Natural regeneration may offset some of the planted seedling mortality. Natural tree regeneration includes seedlings that establish from seeds, or pre-existing seedlings and saplings that survived vegetation clearing. For some tree species, vegetation clearing can stimulate stems to sprout from roots (e.g., trembling aspen) or root collars (e.g., white birch).

Planted seedling mortality can be high during the first few years after planting. Mortality can arise from a number of sources, such as the seedlings drying out while being stored prior to planting, hot and dry conditions following planting, particularly harsh winter conditions, or winter browsing by snowshoe hare.

2.2.2 EFFORTS TO DATE

The first efforts to rehabilitate forest or woodland habitat in selected borrow areas and excavated material placement areas (EMPAs) occurred in 2016. These were areas that had been developed as part of the KIP. Additional efforts in these areas, and in areas developed as part of the KGP, occurred between 2020 and 2023.

In this report, specific Project footprint components that have been rehabilitated by tree planting or grass seeding (e.g., Borrow Area G-3) are referred to as “rehabilitation locations”, or “locations”. Discrete areas within the rehabilitation locations that have been planted or seeded are referred to as “planting areas” or “seeding areas”, respectively.

In 2020, rehabilitation treatments consisted of 37 ha of tree planting at two locations, and seeding with native grass species at two other locations (Table 2-1; Map 2-1). Rehabilitation treatments in 2021 included at total of 84 ha of tree planting at seven locations.

In 2022, eleven locations were tree planted, including EMPA D-12 (2)-E, EMPA D-16(1)-E, EMPA D-17-E, EMPA D-28 (1)-E, EMPA D-31 (1)-E, Borrow Area E-1 (Ellis esker), Borrow Area KM-17, Haul Road 2, Borrow Area S-17a, Work Area C, and Work Area X (Table 2-1; Map 2-1). The 2022 tree planted area was approximately 134 ha, increasing the overall treated area to 239 ha (Table 2-1).

Table 2-1: Rehabilitation efforts including area, year, and treatment type, by location

Location	Area Treated (ha)	Year	Site treatment	Vegetation Treatment	Planned Tree Spacing (m)
Borrow Area G-3	16.6	2020	Partially Disced	Tree planting	2x2
EMPA D27(4)-E	20.3	2020	None	Tree planting	2x2
Borrow Area Q-9	4.9	2020	Harrow	Grass seeding	n/a
Borrow Area B-3	7.6	2020	Harrow	Grass seeding	n/a
Borrow Area KM-9	1.8	2021	Disced	Tree planting	2x2
Borrow Area G-3	43.4	2021	Partially Disced	Tree planting	2x2
Borrow Area N-5	18.6	2021	Ripped	Tree planting	2x2
Haul Road 3-4	4.7	2021	Ripped	Tree planting	2x2
EMPA D35(1)	6.5	2021	None	Tree planting	2x2
EMPA D23(2)-E	1.4	2021	Disced	Tree planting	2x2
EMPA D23(1)-E	5.5	2021, 2023	Ripped	Tree planting	2x2
EMPA D12(2)-E	17.2	2022	None	Tree planting	2x2
EMPA D16(1)-E	22.8	2022	None	Tree planting	2x2
EMPA D17(1)-E	4.3	2022	None	Tree planting	2x2
EMPA D28(1)-E	8.8	2022	None	Tree planting	2x2
EMPA D31(1)-E	2.6	2022	None	Tree planting	2x2
Borrow Area E-1	27.4	2022	None	Tree planting	2x2
Borrow Area KM-17	1.9	2022	None	Tree planting	2x2
Haul Road 2	0.8	2022	None	Tree planting	2x2
Borrow Area S-17a	6.2	2022	None	Tree planting	2x2
Work Area C	7.6	2022	None	Tree planting	2x2
Work Area X (East)	8.0	2022	Spread organic material	Tree planting	2x2
All	**238.9**				

In the tree planted locations, slope grading was carried out where needed. In Borrow Areas G-3 and Borrow Area KM-9, some additional substrate preparation with a discer was carried out where required. In Work Area X (East), organic material was spread over the areas to be planted.

Between 2020 and 2022, jack pine (*Pinus banksiana*) and black spruce (*Picea mariana*) were planted at a spacing of 2 m x 2 m in each planting area, equating to an initial density of 2,500 stems/ha.

Table 2-2 provides the estimated number of seedlings planted in 2022 within each rehabilitation location. A large proportion of the seedlings were planted as a mixture of jack pine and black Spruce in the Ellis Esker site. That location was characterized as having a mixture of dry clayey substrate, with high proportion of dead woody materials in the western area, and mostly sandy substrates (more suitable to jack pine) in the eastern section.

A majority of the rehabilitation areas in 2022 were planted with a mixture of jack pine and black spruce. Jack pine was the only species planted in EMPAs D-12(2)-E, D-17(1)-E, and D-31(1)-E, Haul Road 2, and Borrow Area S-17a. The substrate in the areas where jack pine was planted were predominantly dry sandy and clayey mineral. Areas where black spruce seedlings were planted usually were wetter and often had a layer of organic material mixed with clay.

Table 2-2: Approximate area planted, number of seedlings planted and planting density in 2022, by location

Location	Species[1]	Number of seedlings[2]	Area Planted[3]	Overall Density (stems/ha)
EMPA D-12(2)-E	Jack Pine	42,500	17.0	2500
EMPA D-16(1)-E	Jack Pine and Black Spruce	50,890	20.4	2495
EMPA D-17(1)-E	Jack Pine	6,480	2.6	2492
EMPA D-28(1)-E	Jack Pine and Black Spruce	21,330	8.5	2509
EMPA D-31(1)-E	Jack Pine	5,670	2.3	2465
Borrow Area E-1	Jack Pine and Black Spruce	72,900	29.2	2497
Borrow Area KM-17	Jack Pine and Black Spruce	5,000	2.0	2500
Haul Road 2	Jack Pine	2,700	1.1	2455
Borrow Area S-17a	Jack Pine	7,560	3.0	2520
Work Area C	Jack Pine and Black Spruce	12,150	4.9	2480
Work Area X (East)	Jack Pine and Black Spruce	9,340	3.7	2524
Total		**236,520**	**94.6**	**2500**

Notes: [1]The species planted is based on field data. [2]Number of seedlings and [3]area planted data was provided by Manitoba Hydro.

2.3 REMAINING AREAS

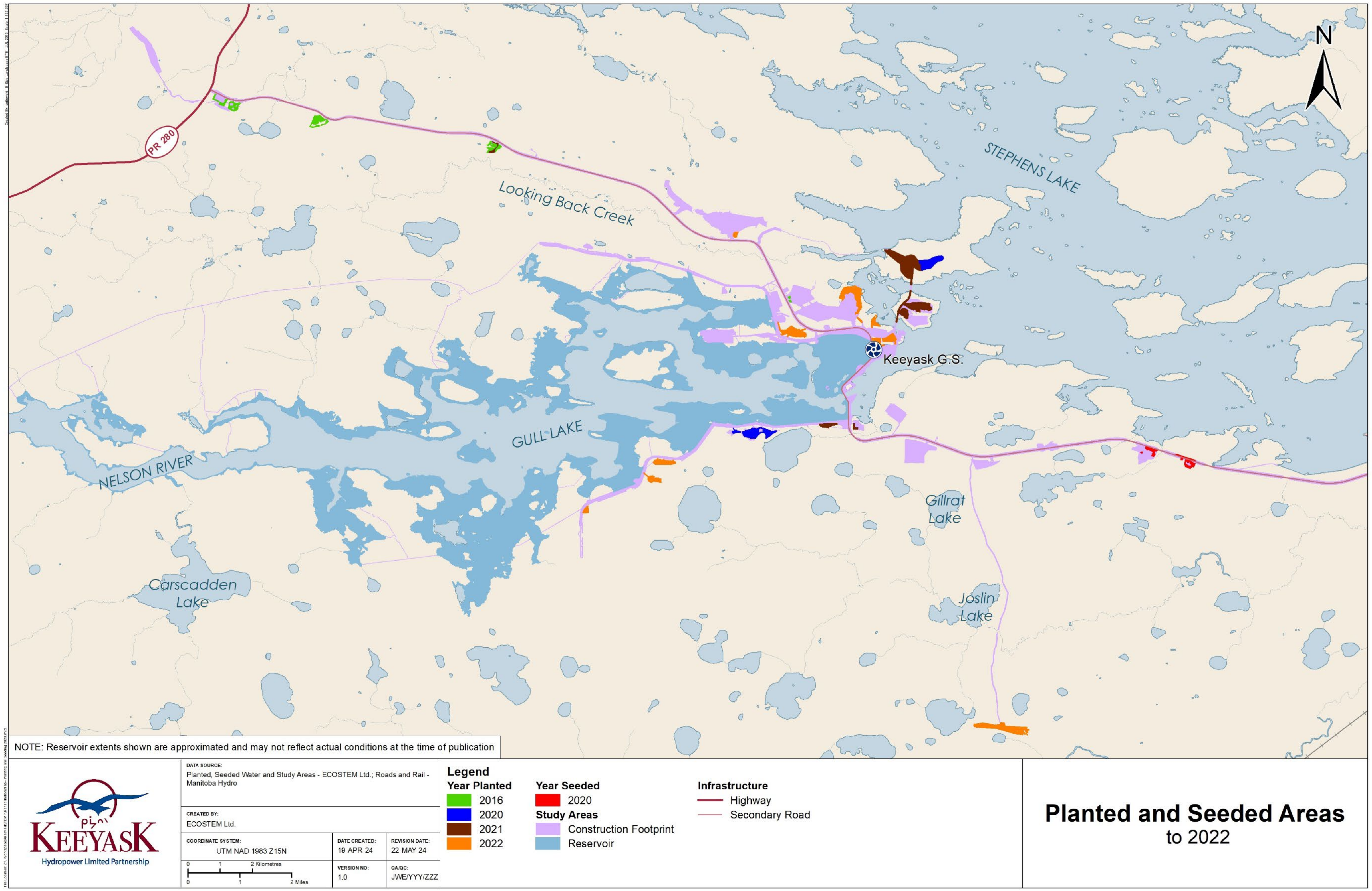
In areas not targeted to become a forest or woodland, vegetation regeneration efforts consisted of applying a native grass seed mixture. Some areas along the North Access Road cleared right-of-way (i.e., the road side slopes) were initially hydroseeded in 2013. A large portion of these areas were also broadcast seeded in 2019 and 2020. Portions of the cleared areas along the South Access Road were broadcast seeded in 2016. In 2020, portions of Borrow Areas B-3 and Q-9 were seeded to establish low vegetation under the transmission lines.

In the seeded locations of Borrow Areas B-3 and Q-9, areas were prepared using a harrow attached to a quad. The preparation loosened the surface substrate and created furrows for the seed. Grass species included in the native seed mix are provided in Table 2-3.

No additional areas were seeded with grass in 2021 and 2022.

Table 2-3: Native grass species included in seed mix for 2020 seeded locations

Species	Common name
Koeleria macrantha	Prairie junegrass
Festuca saximontana	Rocky mountain fescue
Bromus anomalus	Nodding bromegrass
Elymus lanceolatus	Thick-spike wildrye
Elymus canadensis	Canada wildrye
Poa alpina	Alpine bluegrass



Map 2-1: **Locations where rehabilitation measures were implemented in 2016, 2020, 2021 and 2022.**

3.0 METHODS

Section 2.2.2 of the TEMP details the methods for the Habitat Rehabilitation Implementation and Success monitoring study, which commenced in 2017.

The following summarizes the monitoring activities conducted in 2023.

3.1 MONITORING SCHEDULE

The TEMP (Section 2.2.2.3.8; KHLP 2015a) provides the schedule for rehabilitation monitoring. In general, the rehabilitation implementation surveys to confirm survival of plantings and revegetation success start in the year following rehabilitation efforts and continue annually for at least five years. Habitat recovery success surveys generally start two years after rehabilitation of a broad area is complete (e.g., a borrow area).

The frequency and timing of rehabilitation monitoring are fine-tuned based on the target habitat type. For example, the monitoring timing for a shrubland and peatland forest habitat are different because the shrubland habitat is expected to regenerate more rapidly. The frequency and timing of rehabilitation monitoring are also determined based on what monitoring has shown to date. For treed habitat types, if several years of monitoring has demonstrated that tree regeneration is much better than the target, then one or two years in the general schedule may be skipped. Alternatively, the starting year for recovery success surveys for a treed habitat type may be deferred if tree regeneration to date has been poor.

3.2 VEGETATION REGENERATION

3.2.1 ALL TEMPORARY PROJECT AREAS

Vegetation cover in the temporary, terrestrial portions of the Construction Footprint was mapped as of September 2021. A previous monitoring report (ECOSTEM 2022c) details the methods. This vegetation cover mapping was updated for changes that occurred up to September of 2023. The data used for these updates included helicopter photography acquired on September 19, 2023, and ground-level data and photography collected during September, 2023, in relation to other studies. The 2023 mapping focused on areas where the data indicated substantive changes in vegetation cover or structure, because one year is too short for any major structural changes to occur naturally.

Previously, temporary Project areas along the North and South Access Roads were subdivided into polygons based on total vegetation cover using the cover classes provided in Table 3-1. Vegetation structure was mapped in the remaining temporary areas using the classes provided in Table 3-2. In 2023, mapping was updated along the North and South Access Roads to include vegetation structure, providing consistent regeneration mapping over the entire Construction Footprint.

Table 3-1: Classes and codes for vegetation structure cover

Cover Class	Code	Cover Range	Interpretation Notes
Barren	B	<10%	Little to no discernable vegetation
Sparse	S	11 - 25%	Discernable vegetation covers less than 25% of the polygon overall
Moderate	M	26 – 75%	Discernable vegetation >25% cover, obvious gaps in cover and bare patches too small to map
High	H	76 – 100%	Very few gaps in cover to apparently continuous cover

Table 3-2: Classes and codes for vegetation structure

Vegetation Structure Type	Code	Description
Forest	F	61% - 100% trees
Forest/ Tall Shrub	F/ TS	61% - 100% trees in upper canopy/ > 25% tall shrubs in lower canopy
Woodland	D	26% - 60% trees
Woodland/ Tall Shrub	D/ TS	26% - 60% trees in upper canopy / > 25% tall shrubs in lower canopy
Sparsely Treed	S	10% - 25% trees
Sparsely Treed/ Tall Shrub	S/ TS	10% - 25% trees in upper canopy / > 25% tall shrubs in lower canopy
Heterogeneous mixture of woodland and sparsely treed	M	Mixture of woodland and sparsely treed
Heterogeneous mixture of woodland and sparsely treed/ Tall Shrub	M/ TS	Mixture of woodland and sparsely treed with TS lower canopy
Tall Shrub	TS	<10% tree cover and > 25% tall shrub cover
Low Shrub and/or Graminoid and/ or Bryoid	L	<10% trees and < 25% tall shrub and > 10% ground cover
Emergent	E	> 25% emergent vegetation cover
Barren	B	< 10% vegetation cover
Unclassified Young Regeneration	R	Burned after 1992, insufficient information to classify into vegetation structure type

3.2.2 SEEDING AREAS

The locations seeded with native grasses in 2020 were initially mapped in late 2021 and updated in 2022. A previous monitoring report (ECOSTEM 2022c) details the methods.

For 2023, vegetation cover status in the grass seeded areas are included as part of the overall vegetation regeneration (Section 3.2.1). Insufficient regeneration in the grass seeded areas is addressed in the poorly regenerating areas sections of this report (Sections 3.4.1 and 4.3.1).

3.3 TREE PLANTING AREAS

3.3.1 REHABILITATION IMPLEMENTATION

3.3.1.1 GROUND SURVEYS

Ground surveys for monitoring of rehabilitation implementation in tree planting areas in 2023 focused on all areas planted in 2022, and in 2020 and 2021 planting areas with advanced natural regeneration (Table 3-3). Monitoring for the remainder of the areas planted in 2020 and 2021 is described in Section 3.3.1.2.

Maps and documentation provided by Manitoba Hydro, in combination with mapping of planted areas carried out by ECOSTEM, showed the overall extent of planting in the 16 rehabilitation locations planted up to September 2022 (Table 2-1).

The locations where tree planting occurred were further subdivided into planting areas. These planting areas were mapped based on having relatively homogeneous conditions for tree species planted, site preparation, substrate and topographic conditions. To establish planting areas, a botanist conducted a preliminary foot survey of the new rehabilitation location and delineated the planting areas on a paper map.

Map 3-1 shows the ground survey locations, and Map 3-2 shows the planting areas and species planted.

Table 3-3: Species planted, area planted, and number and length of transects surveyed by planting area in 2023 for the 2020 to 2022 rehabilitation locations

Location	Planting Area	Planted Species[1]	Area Planted (ha)	Transects Sampled	
				Number	Transect length (km)[2]
Borrow Area G-3	6	JP	1.1	14	0.19
	8	JP	1.1	9	0.15
	12	JP	2.1	7	0.42
	15	JP	0.4	5	0.08
	50	NAT	0.3	1	0.11
	51	NAT	0.5	1	0.08
Borrow Area N-5	2	JP+BS	0.8	1	0.06
EMPA D-12(2)-E	1	JP	16.4	17	3.38
EMPA D-16(1)-E	1	JP+BS	16.1	15	3.57
	2	JP+BS	1.1	12	0.44
EMPA D-17-E	1	JP	3.1	5	0.58
EMPA D-23(2)-E	1	JP	1.3	3	0.76
EMPA D-28(1)-E	1	JP+BS	2.9	13	0.58
	2	JP+BS	4.1	13	0.78
	3	JP	0.0	1	0.01
EMPA D-31(1)-E	1	JP	1.9	4	0.34
	2	JP	0.2	1	0.04
Borrow Area E-1	1	JP+BS	6.2	14	0.54
	2	JP+BS	9.0	12	1.15
	3	JP+BS	3.4	3	0.27
	4	JP+BS	16.8	23	3.11
	5	JP+BS	0.8	7	0.18
EMPA D-23(1)-E	1	JP+BS	5.4	11	1.02
EMPA D-27(4)-E	1	JP+BS	7.0	15	1.41
	2	JP+BS	1.5	4	0.33
	3	JP+BS	1.2	9	0.27
	4	JP+BS	0.1	1	0.05
	6	NAT	2.0	7	0.40
	7	JP+BS	6.6	6	1.38
	8	JP+BS	0.9	4	0.26
	9	JP+BS	0.1	1	0.11
	10	JP+BS	1.5	5	0.31
Borrow Area KM-17	1	JP+BS	1.4	2	0.18
	9	JP+BS	0.3	2	0.06
Haul Road 2	1	JP	0.6	1	0.19
Borrow Area S-17a	1	JP	0.1	1	0.04
	2	JP	1.7	4	0.36

Location	Planting Area	Planted Species[1]	Area Planted (ha)	Transects Sampled	
				Number	Transect length (km)[2]
	3	JP	0.9	2	0.15
	5	JP	0.2	3	0.06
	6	JP	0.6	4	0.13
Work Area C	1	JP+BS	1.5	3	0.31
	2	JP+BS	0.1	2	0.03
	3	JP+BS	3.7	5	0.83
	4	NAT	0.5	4	0.07
	5	JP+BS	0.0	1	0.05
Work Area X (East)	1	JP+BS	3.0	4	0.62
All	47		132.0	284	24.29

Notes: [1] Actual planted species based on species identified during field surveys not including natural regeneration. NAT indicates stems in planting area are from natural regeneration only; JP indicates jack pine; BS indicates black spruce.[2] Numbers in a column may not add to the total shown due to rounding.

DATA COLLECTION

Belt transects were established in the general areas where tree seedlings were planted in 2022. The methods for establishing transects and data collection in 2023 (Figure 3-1 and Figure 3-2) were identical to the methods used in 2022. Those methods are described in detail in a previous annual report (ECOSTEM 2023). Map 3-1 to Map 3-2 shows the transect locations sampled on September 11 to 19, 2023 in the 2020, 2021, and 2022 rehabilitation locations.

Tree regeneration surveys were conducted along a total of 284 belt transects, in 47 distinct planting areas across the sixteen rehabilitation locations planted between 2020 to 2022 (Table 3-3).

v


Flagged sampling transect in Borrow Area KM-17

Sampling a transect in Borrow Area G-3

Figure 3-1: Tree regeneration sampling in 2023

Naturally regenerating (front) and planted (back) jack pine in Borrow Area G-3

Mixture of naturally regenerating black spruce and planted jack pine in Borrow Area G-3

Jack pine planting area in Borrow Area KM-17

Naturally regenerating black spruce in Borrow Area E-1

Figure 3-2: Examples of different types of regeneration observed in planting areas in 2023

3.3.1.2 DRONE SURVEYS

Seedling data was collected by drone for selected areas for the first time in 2023. This survey method offers several advantages over the transect sampling method:

1. Reduces the time required in the field to collect data;
2. Allows for calculation of a true stem density from a census, rather than an estimated density from a sample; and
3. Allows for more accurate mapping of seedling condition that can be related to substrate mapping to identify factors that lead to poor regeneration success.

Planting areas selected for drone census surveys were planted in 2020 or 2021, and already had at least one year of seedling data from transects. In addition, the selected areas lacked substantial natural regeneration or organic matter substrates. These selection criteria were used so that identifying seedlings from drone photography would be reliable, and to ensure that data for the first year after planting would be comparable across all areas. The areas selected for drone surveys in 2023 included the portion of Borrow Area KM-9 planted in 2021, all of Borrow Area N-

5 and EMPA D35(1-E) (except for planting area 2), all of Borrow Area G-3 (except for planting areas 3, 6, 8, 12, 50 and 51), and EMPA D23(2)-E. Map 3-1 shows the planting areas selected for the 2023 drone census surveys.

Drone seedling surveys were also carried out in several planting areas that were also sampled by transect in 2023. This was done to compare the estimated stem densities to census-based densities, and to quantify bias in the data that may arise from lower stem detectibility in the stereo imagery under different conditions.

DATA COLLECTION

Drone imagery was collected on days with clear and calm conditions between September 8th and 19th for all areas planted between 2020 and 2022. Imagery was acquired using an Autel EVO II Pro drone (chipset version 1) equipped with a 1" CMOS 6K (20 megapixel) camera. For each rehabilitation location, imagery was acquired along predetermined flight lines at an altitude of 40m (Figure 3-3). Images were taken at regular intervals, and flight lines were spaced to achieve an 80% front overlap (direction of flight), and 65% side overlap (between flight lines).

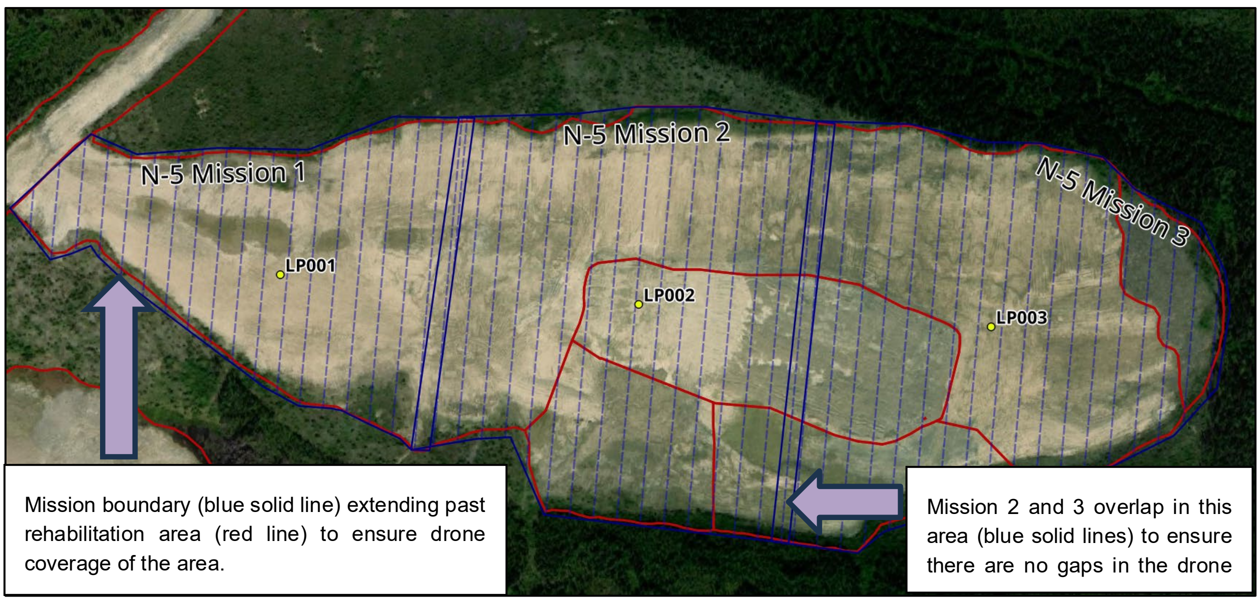


Figure 3-3: Example of a drone flight plan for Borrow Area N-5. Red lines represent zones in each rehabilitation area, blue lines are the extent of each drone mission, dashed blue lines show the flight path of a typical drone mission, and the yellow points are the launch points (i.e. LP001).

The raw drone imagery was processed in Agisoft Metashape to create orthomosaics and digital terrain models (DTMs). The DTMs were used with DAT/EM Systems International's Summit Evolution stereo plotter, which interfaces directly with ArcGIS.

A census survey of tree seedlings was conducted at four rehabilitation locations in the 18 planting areas targeted for the drone survey method (Table 3-4). The total area surveyed by drone was approximately 77.5 ha.

Table 3-4: Species, year and area planted by planting area for the 2020 to 2022 rehabilitation locations surveyed by drone in 2023

Location	Planting Area	Planted Species[1]	Year Planted	Area Planted (ha)[2]
Borrow Area G-3	1	Jack pine	2020	0.9
	2	Jack pine	2020	0.8
	4	Jack pine & Black spruce	2020/2021	9.2
	5	Jack pine	2020	5.1
	7	Jack pine	2020	3.1
	9	Jack pine	2021	4.6
	10	Jack pine & Black spruce	2021	11.7
	11	Jack pine	2021	2.4
	13	Jack pine	2021	0.3
	14	Jack pine	2021	9.9
	20	Jack pine	2021	2.0
Borrow Area KM-9	22	Jack pine	2020	1.6
Borrow Area N-5	1	Jack pine	2021	12.9
	3	Jack pine	2021	2.7
	4	Jack pine	2021	1.4
	5	Jack pine	2021	3.1
EMPA D35(1)-E	6	Jack pine	2021	5.5
	7	Jack pine	2021	0.3
All				77.5

Notes: [1] Actual planted species based on species identified during field surveys, not including natural regeneration.[2] Numbers in a column may not add to the total shown due to rounding.

A tally of all seedlings in the planting areas was collected by mapping individual stems in the stereo imagery using Summit Evolution Lite v8.2 and ESRI ArcMap v10.5. First, a 20 m by 20 m numbered grid was overlaid on the planting areas in ArcMap. The purpose of the grid was to subdivide the planting areas into smaller, more manageable sections and track survey progress. Tree stems were viewed and identified in 3D. A point was digitized over each stem directly on Summit Evolution using Capture for ArcGIS.

Attributes were interpreted, and recorded for each stem including:

- Species
- Height class (tree, sapling or seedling)
- Regeneration type (natural, planted, possibly natural, unknown)
- Condition class (Table 3-5)

After a planting area was sampled, a second interpreter performed a verification pass over the planting area to ensure that no individuals were missed and confirm attributes interpretation.

Table 3-5: Condition classes used for drone surveys

Class code	Class name
H	Alive and healthy
P	Alive but poor health
A	Dead/almost dead

3.3.2 RECOVERY SUCCESS

As sufficient time passes for soils and vegetation to develop beyond the establishment stage, the focus of monitoring will gradually shift from plant survival to evaluating whether or not soils and vegetation (i.e., habitat) have met the prescribed target habitat types, or if they appear to be on a pathway towards achieving them.

For treed target habitat types, recovery success monitoring focuses on:

- Live tree stem density
- Survival and growth of planted trees
- Formation of natural ground cover
- Understorey vegetation cover and species composition
- Soil and substrate properties and development

For the treed habitat types, the metrics for recovery success monitoring initially emphasizes live stem density as this strongly influences stand succession over time. Under natural conditions, tree stem density is initially very high, which controls non-native and competitive plant species through shading and other competitive effects. Over time, the initial high tree stem density forces tree seedlings and saplings to allocate resources towards height growth rather than branch growth, alters soil properties, influences microclimate, and strongly influences understorey plant species composition during stand succession.

The recovery success metrics were supplemented with vegetation structure and cover to evaluate the patchiness of the regeneration and stand structure.

For other target habitat types, recovery success monitoring generally focuses on:

- Formation of natural ground cover
- Vegetation cover and species composition
- Soil and substrate properties and development
- Exceptions are non-native target habitat types such as grassed areas in ditches or low vegetation under the transmission lines.

Recovery success monitoring for treed habitat types began in 2023 for areas that were planted in 2016, which represents their 7th year of growth. The metrics that were monitored included live tree stem density, live tree stem health, vegetation structure and vegetation cover. The latter two parameters supplemented live tree stem density and health to confirm that initial stem density was producing the desired degree of canopy closure over time. However, the key metric was live stem density. Live stem health was an indicator of the future trend in stem density.

Areas planted in 2016 were planted at two different spacings to eventually achieve either a forest vegetation structure (1m x 1m spacing for a seedling density of 10,000 stems/ha), or woodland structure (2m x 2m spacing for a seeding density of 2,500 stems/ha). It was expected that as the trees grow, stem density would decrease as the stand "thins out", eventually leaving a stand with the target vegetation structure.

Recovery success monitoring in 2023 included all areas planted in 2016, which were located around the Start-up Camp, in Borrow Areas KM-1, KM-4 and KM-9, and at the entrance to the Main Camp (Map 3-1; Table 3-6).

Map 3-1 to Map 3-2 show the planting areas targeted for the 2023 recovery success surveys.

Table 3-6: Original target species, actual planted area, and number and length of transects surveyed by planting area in 2023 for the 2016 recovery success locations

Location	Planting area	Target Habitat type[1]	Mapped area (ha)	Transects Sampled	
				Number	Transect length (km)[2]
Borrow Area KM-1	1	Black spruce	0.3	2	0.08
	2	Jack pine	3.9	11	1.03
	3	Black spruce	0.6	3	0.15
Borrow Area KM-4	4	Jack pine & black spruce	0.3	2	0.27
	5	Jack pine & black spruce	0.4	3	0.22
	6	Jack pine	8.9	12	2.08
Borrow Area KM-9	7	Black spruce	2.0	5	0.40
	8	Jack pine	1.5	3	0.38
	9	Black spruce	2.0	3	0.31
	10	Black spruce	0.5	2	0.28
Start-up Camp	12	Jack pine	1.5	0	0
	13	Jack pine	0.5	4	0.47
	15	Jack pine	0.4	2	0.30
	99	Unknown	0.3	0	0
Main Camp Entrance	16	Jack pine	0.3	2	0.14
	17	Jack pine	0.6	2	0.14
All			24.1	57	6.27

Notes: [1] Taken from ECOSTEM 2018.[2] Numbers in a column may not add to the total shown due to rounding.

DATA COLLECTION

Data was collected using a combination of drone and ground surveys. Digital orthographic images from the drone images were used to map overall vegetation cover and composition in the planting areas. Drone stereo imagery was used to collect tree species and condition data along transects in the planting areas (Table 3-6). Ground surveys collected data on substrate conditions and ground vegetation cover. Drone imagery could not be acquired for the two planting areas at the Main Camp entrance due to overhead power lines. Tree attributes along transects in those planting areas were collected during the ground surveys.

Drone imagery for the recovery success montitoring locations was collected using the same methodology as for the rehabilitation implementation drone surveys (Section 3.3.1.2), except that imagery was acquired at an altitude of 60m for the 2016 rehabilitation areas. A higher altitude was used than for recently planted areas because this improved efficiency for data collection and image processing, and the taller trees could be identified as well as seedlings at a lower altitude. Flying at a higher altitude increased efficiency by greatly reducing the number of images required to cover a location, which in turn reduced the time required to process the images into digital orthorectified imagery (DOIs) and set them up for 3D viewing.

For recovery success, the current treed structure type was determined by interpretation of canopy closure rather than current stem density. Table 3-7 provides the canopy closure range for the different treed structure types used for recovery success.

Table 3-7: Canopy closure range for treed structure types used for recovery success

Structure Type	Criteria if the Dominant Stratum
Forest	61 - 100% canopy closure with tree crowns overlapping
Woodland	26 - 60% canopy closure with crowns generally not touching
Sparsely Treed	10 - 25% canopy closure with crowns generally not touching

Development of other layers of vegetation in the rehabilitation areas was mapped using a combination of the drone DOIs, and ground data and photography. Vegetaton cover for each of the tall shrub, low shrub, herbaceous, and bryoid vegetaton layers was interpreted to one of the cover classes in Table 3-8.

Table 3-8: Vegetation cover classes used for recovery success mapping

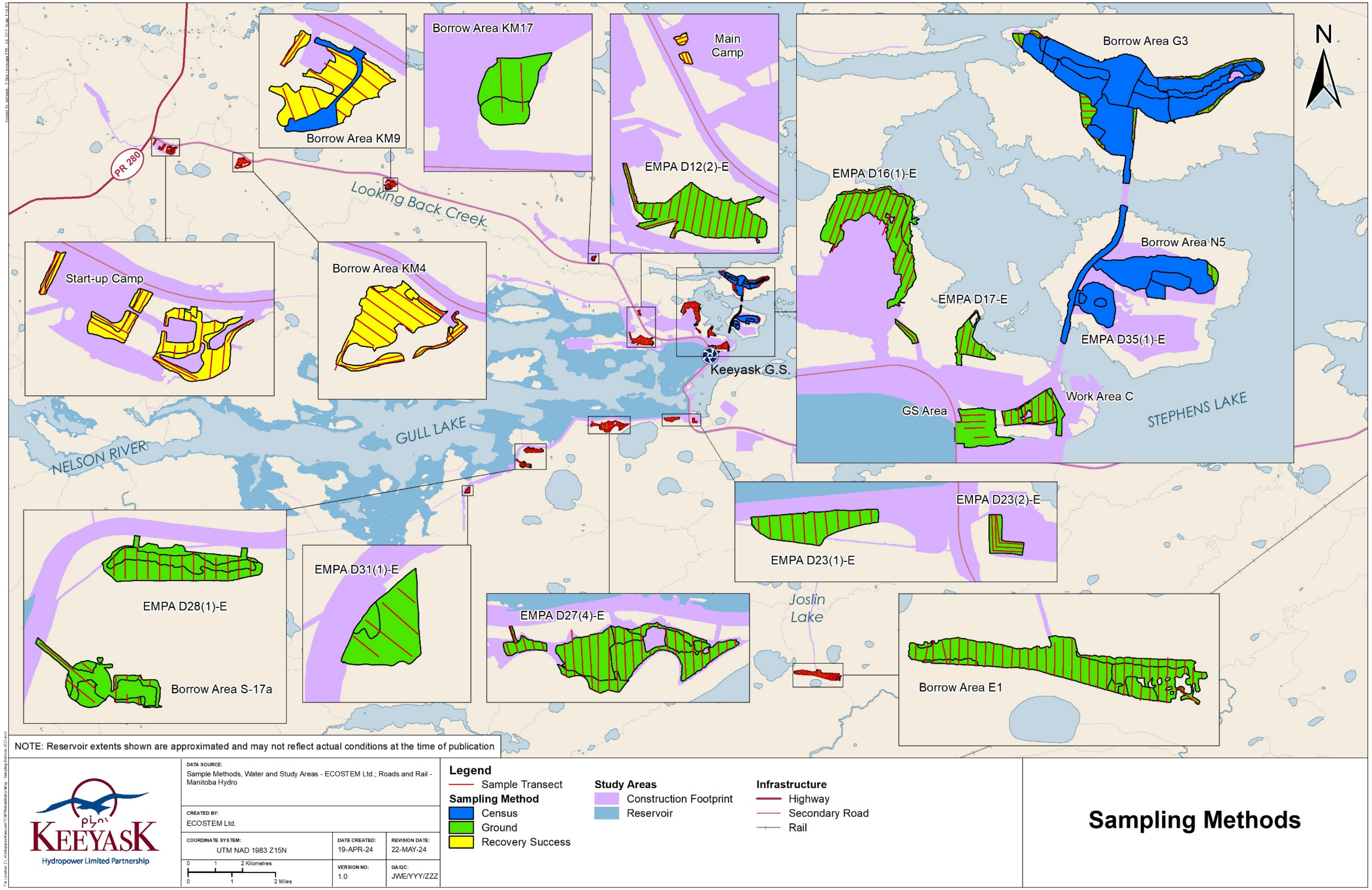
Code	range
None	No discernable cover
Very sparse	<3% cover in patch
Sparse	3 – 10% cover in patch
Low	11 – 25% cover in patch
Moderate	26 – 50% cover in patch
High	51 – 75% cover in patch
Very high	76 – 100% cover in patch

Tree condition data was also collected using the same methods as for the census surveys (Section 3.3.1.2), with variations described below.

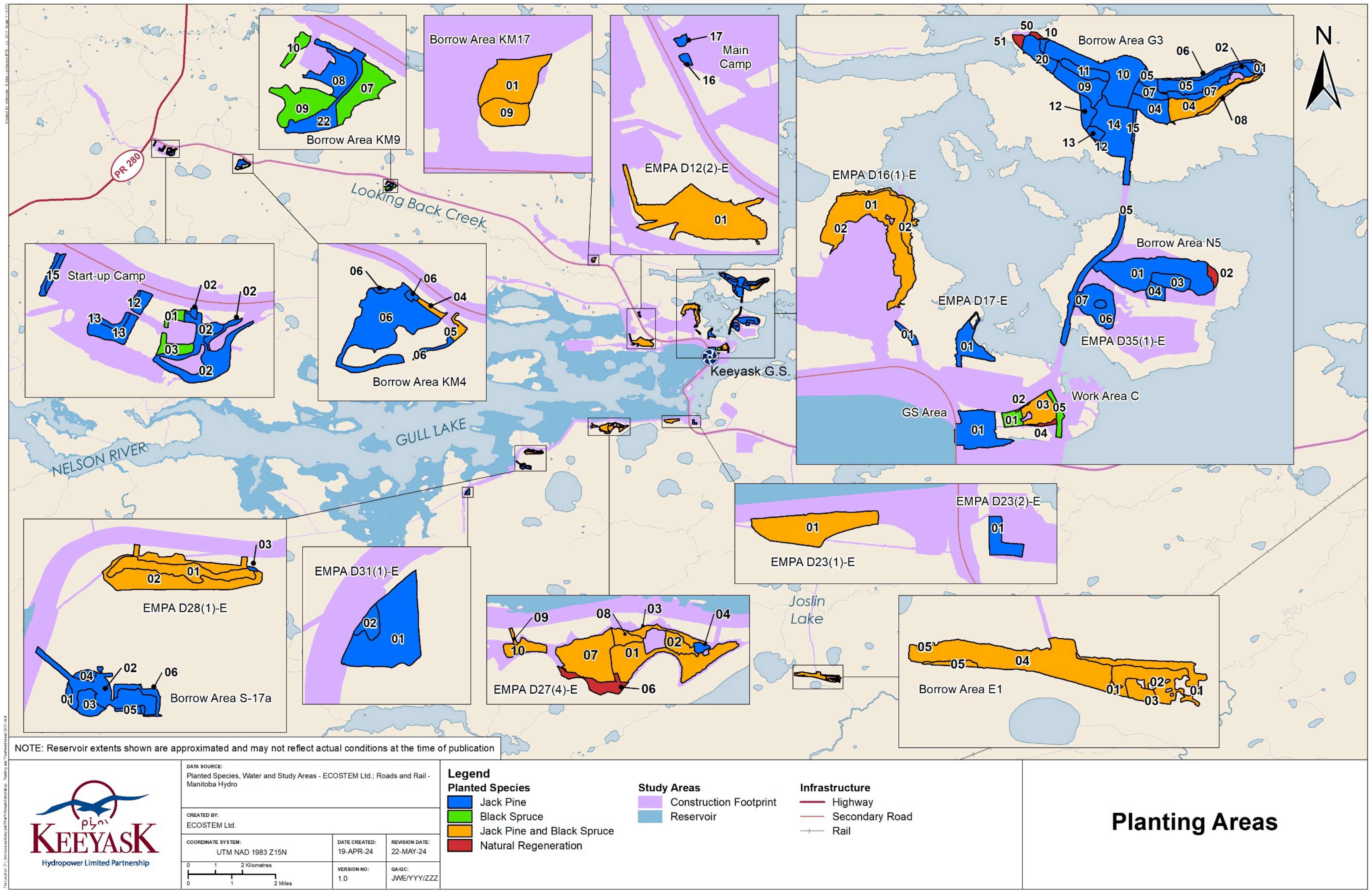
Tree stems were tallied within 2m wide digital belt transects overlaid on the planting areas. The centre of the belt transects corresponded to the transect locations previously sampled in these planting areas for the rehabilitation implementation study (ECOSTEM 2022c). For the Main Camp entrance, tree attributes were measured along the transects using the same method as the rehabilitation implementation ground surveys (Section 3.3.1.1).

Attributes recorded for each tree were the same as for the rehabilitation implementation surveys, except the regeneration type was not interpreted.

Regeneration success tree condition surveys were conducted along a total of 57 belt transects, in 15 distinct planting areas across the 5 rehabilitation locations planted in 2016 (Table 3-6).



Map 3-1: Tree planting areas and rehabilitation transects by survey method for locations surveyed in 2023



Map 3-2: Planting areas and species planted for locatons sampled in 2023

3.4 POORLY REGENERATING AREAS

Rehabilitation monitoring up to 2022 identified grass seeded and tree planted areas where regeneration appeared to be poor. Vegetation cover interpreted through remote sensing tends to underestimate vegetation cover in regenerating areas because very small and immature plants may not be visible in photos taken form a helicopter. Ground surveys can confirm if such vegetation is present. In 2023, roadside areas seeded with grass and tree planted areas were surveyed by foot to confirm if regeneration was poor, and collect data on factors that could be contributing to the poor regeneration.

3.4.1 GRASS SEEDED AREAS

Grass seeded areas to survey were initially identified using the 2022 vegetation cover mapping. Areas with a high proportion of barren or sparse vegetation cover in 2022 were delineated on a map and surveyed on September 18, 2023. Besides the initially identified areas, any additional poorly regenerating areas encountered along roadsides during surveys were also sampled. The 2022 vegetation cover mapping identified ten areas along the North and South Access Roads to survey for poor regeneration (Map 3-3).

Regeneration status within the predetermined areas were visited, as well as any other poorly regenerating areas encountered along roadsides during the survey. In each area the extent of the poorly regenerating patch was mapped and the following data was recorded:

- Vegetation cover and type
- Presence and nature of site preparation
- Presence of recent or ongoing erosion
- Substrate conditions
- Presence of other factors that may influence regeneration

Substrate was sampled at several representative locations within the poorly regenerating patch, as well as locatons outside the patch with sufficient regeneration. Substrates were sampled using a Dutch auger, excavating to a depth of approximately 50 cm. Photos were taken showing conditions at each surveyed location.

Vegetation cover in grass seeded areas was classified from the photo interpretation and ground-based surveys into one of three qualitative classes:

1. Sufficient: desirable vegetation has successfully established with sufficient (approximately 25%) foliage cover.
2. Borderline sufficient: desirable vegetation cover was sparse, but appeared to be expanding and undesirable plants were not a concern. Long-term success still uncertain.

3. Insufficient: desirable vegetation cover has not established, or was very sparse, and/or undesirable vegetation was expanding or inhibiting desirable vegetation growth.

3.4.2 TREE PLANTED AREAS

Poorly regenerating areas in portions of the Construction Footprint that were planted with trees were identified and surveyed at the same time as target habitat type mapping (Section 2.1) and rehabilitation implementation surveys (Section 3.3.1). Substrate, vegetation cover data, and other conditions mapped during the target habitat type surveys and seedling condition data collected during rehabilitation implementation surveys captured the data required to assess the poorly regenerating areas. For poorly regenerating tree planted areas, additional data was collected to identify possible planting issues, including J-roots, planting in non-mineral substrate, or planting into air pockets.

For each tree planting area, poorly regenerating areas were mapped using two parameters:

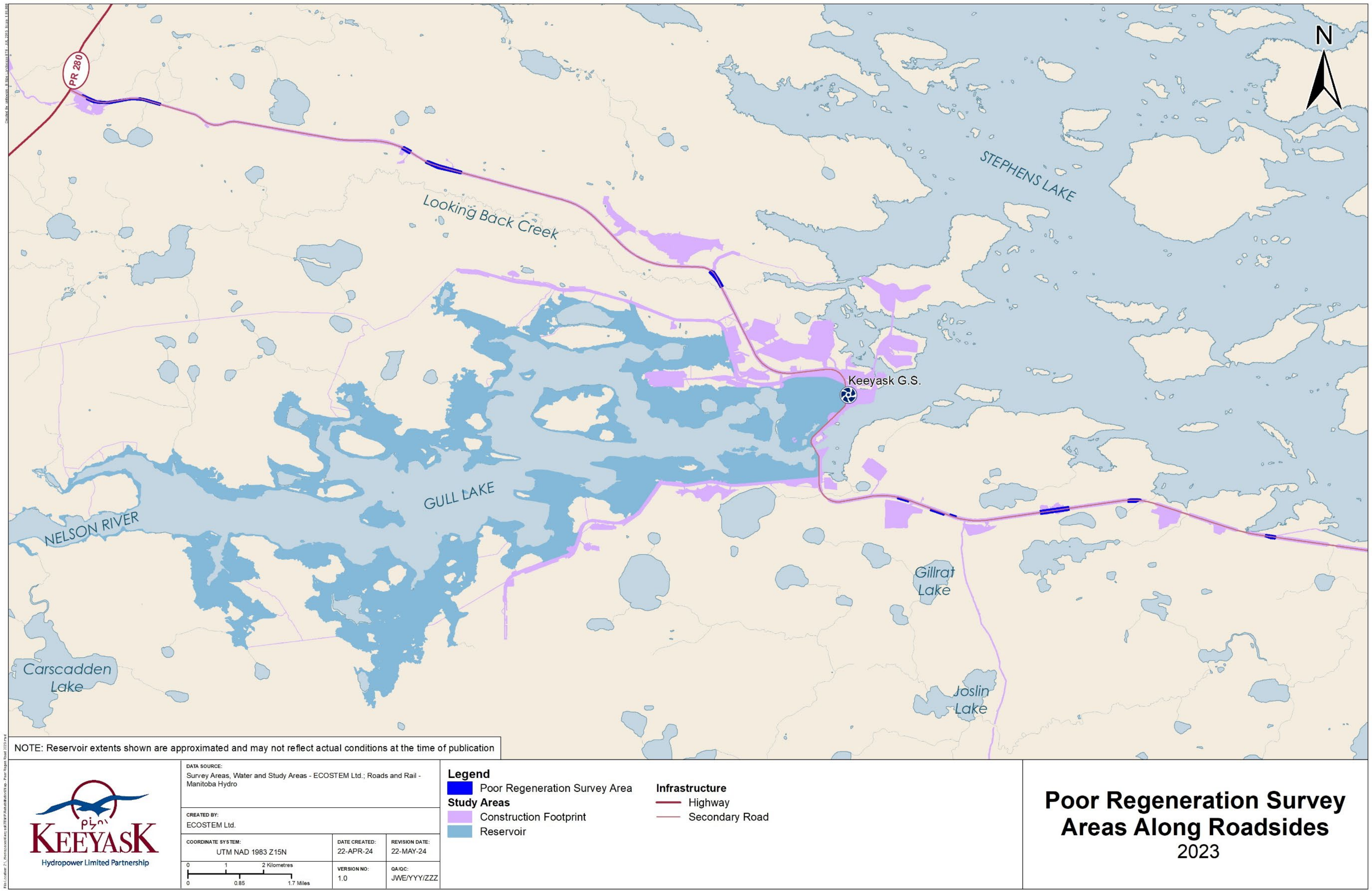
- Overall health condition of the seedlings; and,
- Live stem density.

Overall seedling condition for a planting area was sequentially classified according to the following criteria:

1. Select planting areas where more than 30% of the tallied trees are dead (seedling conditions 0 and 1) and set to "Poor" seedling condition.
2. From the remaining area, select planting areas where more than 75% of tallied trees in the area are living and healthy (seedling condition >3) and set to "Good" seedling condition.
3. Set the remaining planting areas to "Borderline" seedling condition.

Live stem density was important because poor regeneration may be the result of mechanical factors, such as erosion, which may remove stems in areas where there is otherwise healthy growth. Additionally, in older planted areas, stems that died soon after planting may no longer be visible because they had decomposed, or were not detected in the drone imagery. Planting areas with live stem densities well below that target are considered to be poorly regenerating. Estimated stem densities for each planting area were generalized into the following classes to compare conditions:

- Less than 1,000 stems/ha
- 1,000 to 2,499 stems/ha
- 2,500 to 9,999 stems/ha
- 10,000 stems/ha or greater



Map 3-3: **Areas identified along roadsides to survey for poor regeneration**

3.5 DATA ANALYSIS

3.5.1.1 PLANTING DENSITY

The estimated actual stem densities from the transect data were compared with the planned planting densities to assess whether the planting was carried out as planned. For each rehabilitation location, transect data were pooled. If trees were planted for more than one planned density in a rehabilitation location, then transects planted at the same density were pooled. Transect data collected the year after planting is used for assessing rehabilitation implementation. Only the planted seedlings, whether living or dead, were considered (i.e., natural regeneration was ignored).

A t-test or a Wilcoxon signed rank test was used to determine if the planned planting stem density was achieved. A one-tailed t-test in R (R Core Team 2022) was used to compare the mean total planted stem densities to the planned stem densities, where the mean was calculated across all transects in the rehab location planted at a specific target density (some locations may be divided into areas with different target densities). To consider the rehabilitation as meeting the planned density, the mean stem density must be significantly greater than the planned stem density minus one (e.g., 2,500 – 1 = 2,499 stems/ha), at $\alpha = 0.05$. A Shapiro-Wilk test was used to check for violations of normality in the transect data. If the assumption of normality was violated, the t-test result was still considered interpretable provided the number of samples (transects) was at least 30. If that criterion was not met, the non-parametric one-sample Wilcoxon signed rank test was used.

3.5.1.2 CHANGES BETWEEN 2022 AND 2023

Live stem density in areas where planting occurred at least two years prior to the current survey year, and with more than one year of data, were analyzed to determine if there was a significant change in live stem density compared to the previous year.

Because slight, unavoidable differences in the transect position can impact the number of stems tallied on a transect, stem density was considered to have changed significantly only if the 95% confidence interval of the current year sample mean stem density differed significantly from that of the previous year. A one-way analysis of variance (ANOVA) in R (R Core Team 2022) was used to compare the transect mean total live stem densities between years for each planting area with at least three transects. Qualitative assessments were made for planting areas with only one or two transects.

4.0 RESULTS

4.1 VEGETATION REGENERATION

4.1.1 ALL TEMPORARY PROJECT AREAS

The temporary Project areas encompassed approximately 1,352 ha. These areas included the cleared portion of the access road rights-of-way (but not the roadbed), borrow areas, excavated material placement areas (EMPAs), and camp and work areas not required for Project operation (Map 4-1 and Map 4-2). This area is approximately 215.4 ha more than what was originally mapped as temporary areas in 2022 (ECOSTEM 2023). The change in temporary Project area is due to confirmation of the areas required for Project operation, which was provided by Manitoba Hydro in April, 2023.

Just over half (58%) of the mapped area was vegetated (including both planted/seeded areas and naturally revegetating areas) as of September 2023 (Table 4-1). The Moderate vegetation cover class was the most widespread, at 27%. High and Sparse vegetation covered 20% and 12%, respectively.

Barren vegetation cover, and Barren and Water (lacking emergent vegetation cover) structure types made up the “unvegetated” (less than 10% vegetation cover) portions of the Construction Footprint (Table 4-1 and Table 4-2). For vegetated areas, the most abundant vegetation structure type was Low, covering 42% of the temporary area (Table 4-2). Tall Shrub (9%), Sparsely Treed (3%) and Woodland (2%) vegetation structure types made up the most of the remaining temporary areas.

Table 4-1: Vegetation cover by class as percentage of the total area in 2023

Vegetation Cover Class	Area (ha)	Percentage of Area (%)
Barren[1]	561.7	42
Sparse	157.0	12
Moderate	359.4	27
High	273.5	20
Total Area	*1,351.6*	*100*

Notes: [1] Includes areas with water cover.

Table 4-2: Vegetation structure type as percentage of the total area in 2023

Vegetation Structure Type	Area (ha)	Percentage of Area (%)
Water	60.0	4
Barren	501.5	37
Emergent	4.5	0
Low	562.5	42
Tall Shrub	120.4	9
Sparsely Treed/Tall Shrub	14.1	1
Sparsely Treed	41.5	3
Woodland/Tall Shrub	10.9	1
Woodland	31.5	2
Forest	3.5	0
Total Area	*1,351.6*	*100*

4.1.2 FOOTPRINT COMPONENTS

Borrow areas represented the largest proportion (40.5%, 547.8 ha) of the temporary footprint areas, followed by the side slopes of the North and South Access Roads (31.2%, 421.7 ha), EMPAs (11.4%, 153.6 ha) and Work Areas (8.3%, 112.1 ha).

Moderate to high cover (Photo 4-1) made up 36.6% of the Borrow Areas.

Just over half (52.9%) of the Borrow Area temporary areas had barren vegetation cover (Photo 4-2; Table 4-3). Large areas of barren vegetation were found in most borrow areas, except in portions that had been cleared but never used (such as the western portion of Borrow Areas G-1, KM-9, S-2a, S-2b and portions of N-5). Areas planted in 2016 also tended to be in the moderate to high cover class, except in areas where regeneration hasn't been successful. Generally, vegetation cover tended to be distributed around the edges of the borrow areas.

Of the vegetated portions of the Borrow Areas, low vegetation was by far the most common structure type, covering 32.4% of the total area (Photo 4-3; Table 4-4). Tall shrub (6.3%), woodland (2.8%) and sparsely treed (2.7%) were the next most common types.

Other footprint types with a large proportion of their area with barren cover included camp areas, work areas, and the temporary areas around the Generating Station. The camp areas, which included the Start-up Camp and the Main Camp, had barren cover over approximately 68.8% of their area (Table 4-3). The barren areas encompassed much of the camp areas due to the continued decommissioning efforts, as well as the lack of regeneration efforts to date within the main, heavily used portions of the camps. This was also the case for the work areas and Generating Station area.

Access roads, dikes, and EMPAs had higher proportions of vegetated area overall. Except for EMPAs, more than half of the area had moderate to high vegetation cover in these footprint types (Table 4-3). In the vegetation portions of these footprint types, the dominant vegetation structure types were Low vegetation (herbaceous or low shrub), and Tall Shrub (Table 4-4).

For the EMPAs, the barren cover and structure type was mostly found within the more recently used EMPAs, such as D12(2)-E, D16(1)-E, D23(2)-E and D35(1)-E. The moderate to high vegetation cover was mainly associated with the older EMPAs, particularly found along the north and south dikes.

In general, more developed structure types, such as the Treed and Tall Shrub types, were found in portions of the temporary footprint where there was little to no disturbance of the substrate, and only tall vegetation clearing occurred (Map 4-1 and Map 4-2).

Table 4-3: Vegetation cover by footprint type in 2023

Footprint Type	Total Area (ha)	Vegetation Cover Class (% of footprint type area)			
		Barren	Sparse	Moderate	High
Borrow Area	547.8	52.9	10.5	22.4	14.2
Camp	48.2	68.8	4.0	8.8	18.4
EMPA	153.6	33.7	23.4	21.6	21.3
Work Area	112.1	54.7	6.7	10.9	27.7
GS Area	5.5	77.8	2.4	10.4	9.4
Reservoir Clearing	0.2	90.0	3.0	7.1	0.0
Portage Route	2.6	35.5	14.9	24.1	25.5
South Dike	28.1	21.7	14.5	32.0	31.8
North Dike	31.5	14.9	7.7	41.6	35.8
Cutllines	0.2	1.4	0.0	71.0	27.6
North Access Road	148.6	16.0	10.8	33.4	39.8
South Access Road	273.1	31.3	11.4	41.8	15.6
Total	**1,351.6**	**41.6**	**11.6**	**26.6**	**20.2**

Table 4-4: Vegetation structure by footprint type in 2023

Footprint type	Total Area (ha)	Vegetation Structure Type (% of Footprint type area)										
		Water	Barren	Young Regeneration	Emergent	Low	Tall Shrub	Sparsely Treed / Tall Shrub	Sparsely Treed	Woodland / Tall Shrub	Woodland	Forest
Borrow Area	547.8	9.8	43.2	0.0	0.0	32.4	6.3	0.9	2.7	1.4	2.8	0.5
Camp	48.2	-	68.8	-	0.1	13.1	7.7	6.1	0.4	-	2.4	1.4
EMPA	153.6	1.5	32.2	-	-	55.7	9.0	0.0	1.3	-	0.1	-
Work Area	112.1	1.2	53.5	0.9	0.2	23.1	8.5	0.5	10.3	-	1.7	-
GS Area	5.5	-	77.8	-	-	16.2	6.0	-	-	-	-	-
Reservoir Clearing	0.2	-	90.0	-	-	10.0	-	-	-	-	-	-
Portage Route	2.6	0.0	35.5	-	-	41.9	16.6	-	-	-	6.0	-
South Dike	28.1	5.4	15.7	-	2.9	61.7	13.0	-	1.0	-	0.3	-
North Dike	31.5	1.4	13.5	-	0.5	74.4	9.7	0.6	-	-	-	-
Cutlines	0.2	-	1.4	-	-	98.6	-	-	-	-	-	-
North Access Road	148.6	0.3	15.7	-	0.7	52.1	18.7	1.3	5.7	1.1	4.4	0.1
South Access Road	273.1	0.2	31.1	-	0.8	53.8	8.5	1.3	1.4	0.7	2.2	-
Total	1,351.6	4.4	37.1	0.1	0.3	41.6	8.9	1.0	3.1	0.8	2.3	0.3

Notes: "-" means and absence, where as "0" indicates a number that rounds to zero.

Photo 4-1: High vegetation cover in Borrow Area G-3.

Photo 4-2: Barren vegetation cover and structure in Borrow Area G-3.

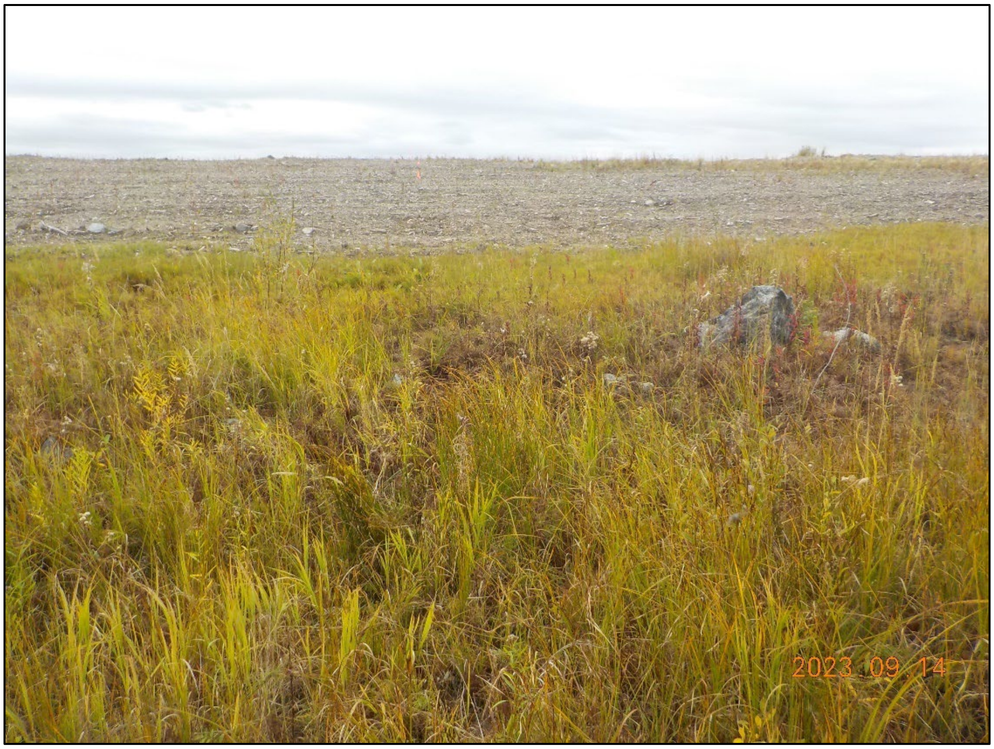


Photo 4-3: Low vegetation structure type along the edge of EMPA D12(1)-E.

4.1.3 CHANGES FROM 2022 TO 2023

Vegetation cover and structure mapping for 2023 is not directly comparable to the 2022 mapping (ECOSTEM 2023). This is because the temporary Project area was modified (see Section 2.1), and the mapping detail increased for 2023. However, during the mapping updates, an effort was made to identify areas where there was an actual change in vegetation cover or structure between 2022 and 2023. Map 4-1 and Map 4-2 show the areas where these changes occurred for areas that were mapped as part of the temporary footprint in both 2022 and 2023.

The 2023 vegetation cover mapping identified approximately 260.4 ha where vegetation cover or structure changed since 2022. This represented approximately 19.3% of the 1,351.6 ha of temporary Project areas mapped for 2023. Vegetation cover changed over approximately 208.9 ha (Table 4-5), and structure changed over approximately 176.7 ha (Table 4-6).

Most of the change from 2022 to 2023 was due to barren areas developing sparse to high vegetation cover. Approximately 76% of previously barren area that changed developed sparse vegetation cover in 2023, and an additional 22% developed moderate vegetation cover. Other areas that previously had vegetation cover increased to a higher cover class between 2022 and 2023 (Table 4-5). Most of the area where this type of change occurred was in the Borrow Areas, EMPAs and portions of the NAR (Map 4-3 and Map 4-4). In some areas, vegetation cover was reduced or removed due to rehabilitation activities.

Table 4-5: Vegetation cover change by percent of the area where there was a change in vegetation cover from 2022 to 2023

Vegetation Cover Class in 2022	Percent of Area in New Vegetation Cover Class in 2023				Total Area Changed (ha)
	Barren	Sparse	Moderate	High	
Barren	-	76	22	2	113.3
Sparse	7	-	85	8	41.9
Moderate	0	4	-	96	52.3
High	10	15	76	-	1.4
Total	*2*	*42*	*30*	*26*	*208.9*

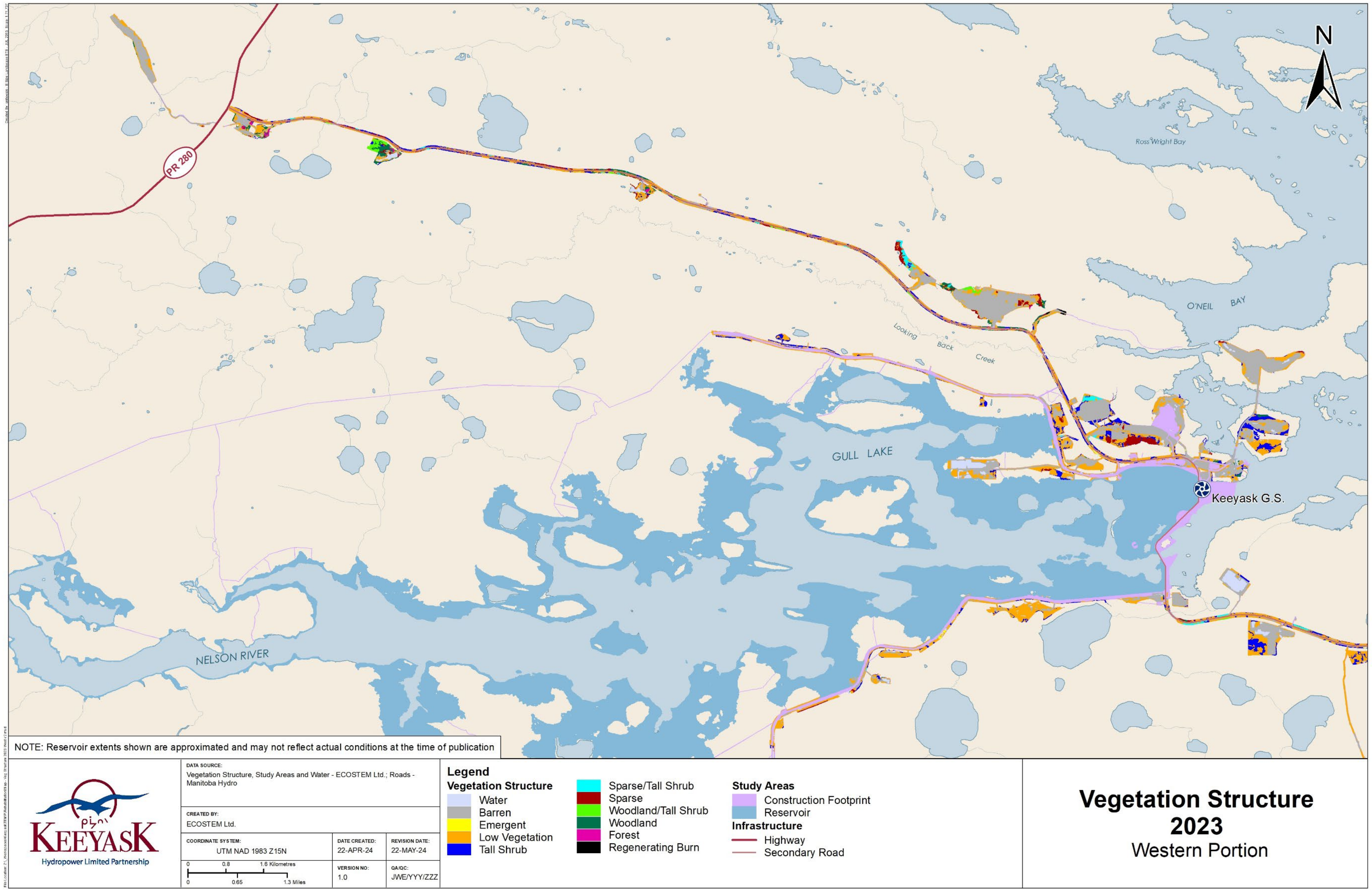
Notes: "-" means an absence, where as "0" indicates a number that rounds to zero.

In terms of vegetation structure, the majority of area that changed was from barren to low vegetation, which represented 124.6 ha (70% of the change; Table 4-6). These changes were mainly found in the Borrow Areas, EMPAs and along the NAR. Of the 45.9 ha of low vegetation structure that changed, approximately 27% changed to sparsely treed or woodland structure, due to growth of tree seedlings that were previously too small to be detected. Most of this change occurred along the NAR, with small amounts also occurring in the Borrow Areas and along the SAR.

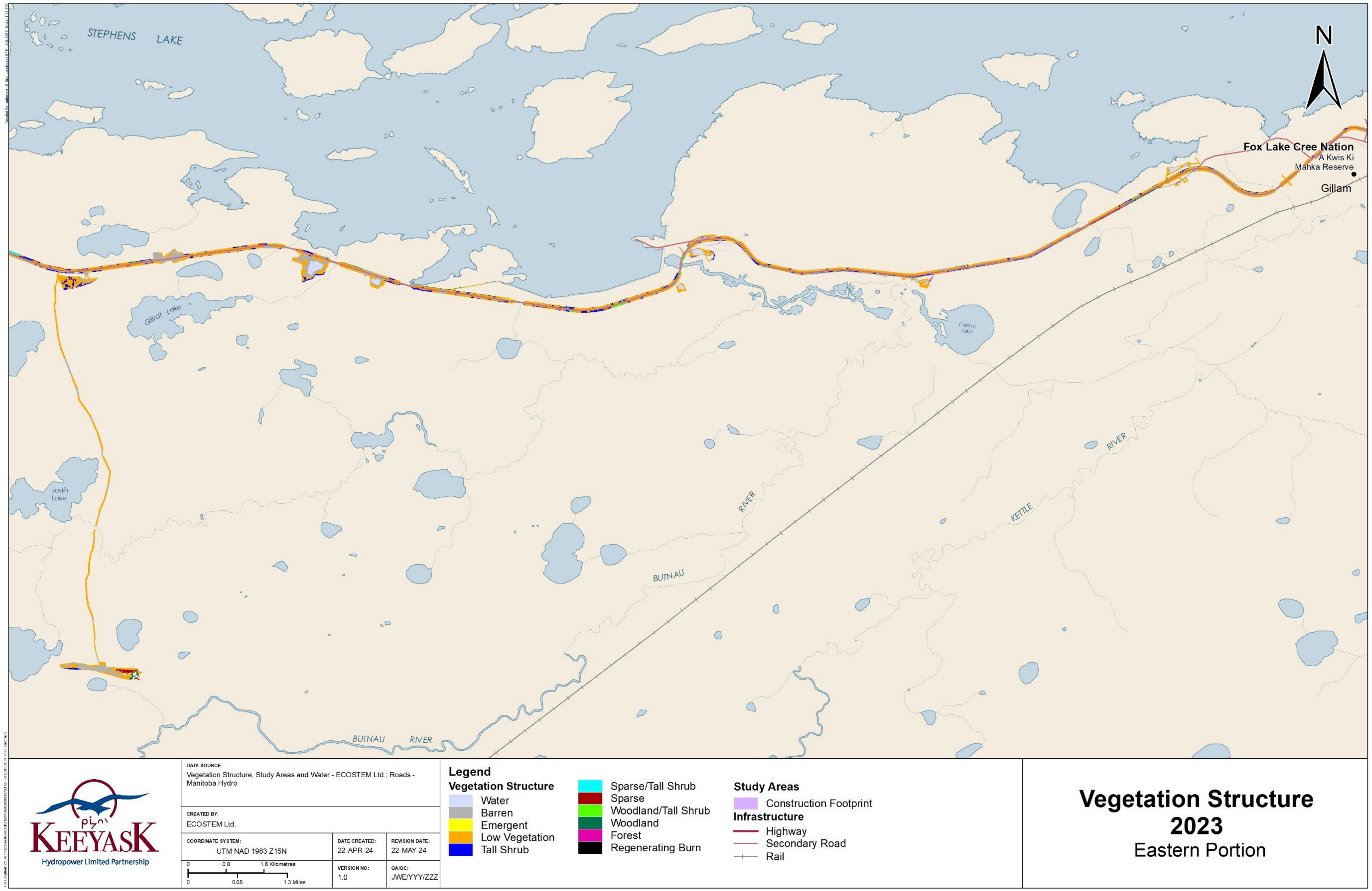
Table 4-6: Vegetation structure type in areas where there was a change in vegetation structure from 2022 to 2023

Vegetation Structure Class in 2022	Percent of Area in New Vegetation Structure Class in 2023									Total Area Changed (ha)
	Barren	Emergent	Low	Tall Shrub	Sparsely Treed/Tall Shrub	Sparsely treed	Woodland/Tall Shrub	Woodland	Forest	
Barren	-	0	99	0	-	0	-	0	0	124.6
Young Regeneration	-	-	8	87	-	-	-	5	-	0.4
Emergent	-	-	-	100	-	-	-	-	-	0.1
Low	3	0	-	70	0	20	-	7	-	45.9
Tall Shrub	2	-	38		23	-	5	31		1.5
Sparsely Treed	3	-	7	10	24	-	1	56		2.1
Woodland	-	-	3	19	-	-	22	-	56	2.1
Total	*1*	*0*	*70*	*19*	*0*	*5*	*0*	*3*	*1*	*176.7*

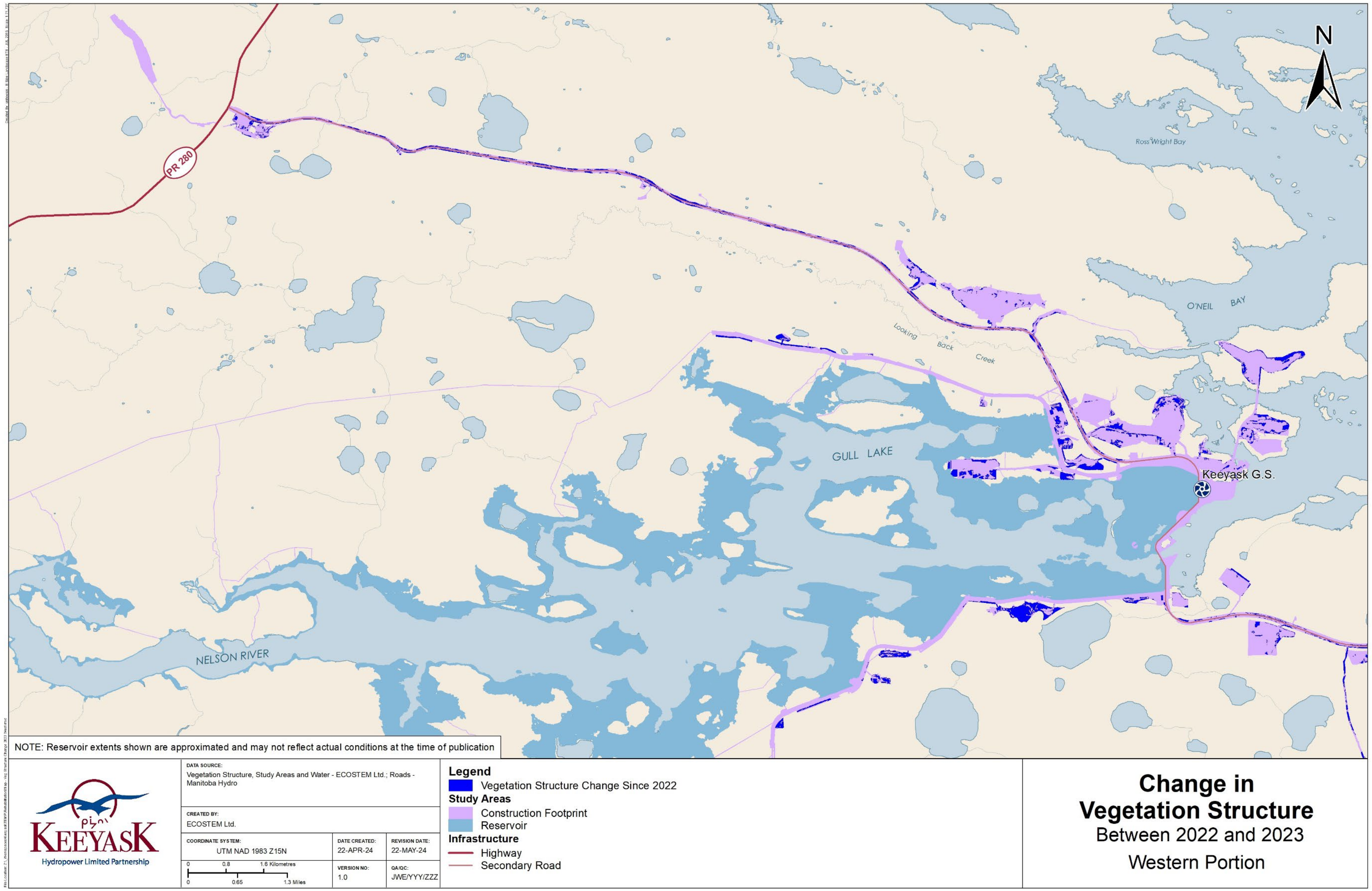
Notes: "-" means an absence, where as "0" indicates a number that rounds to zero.



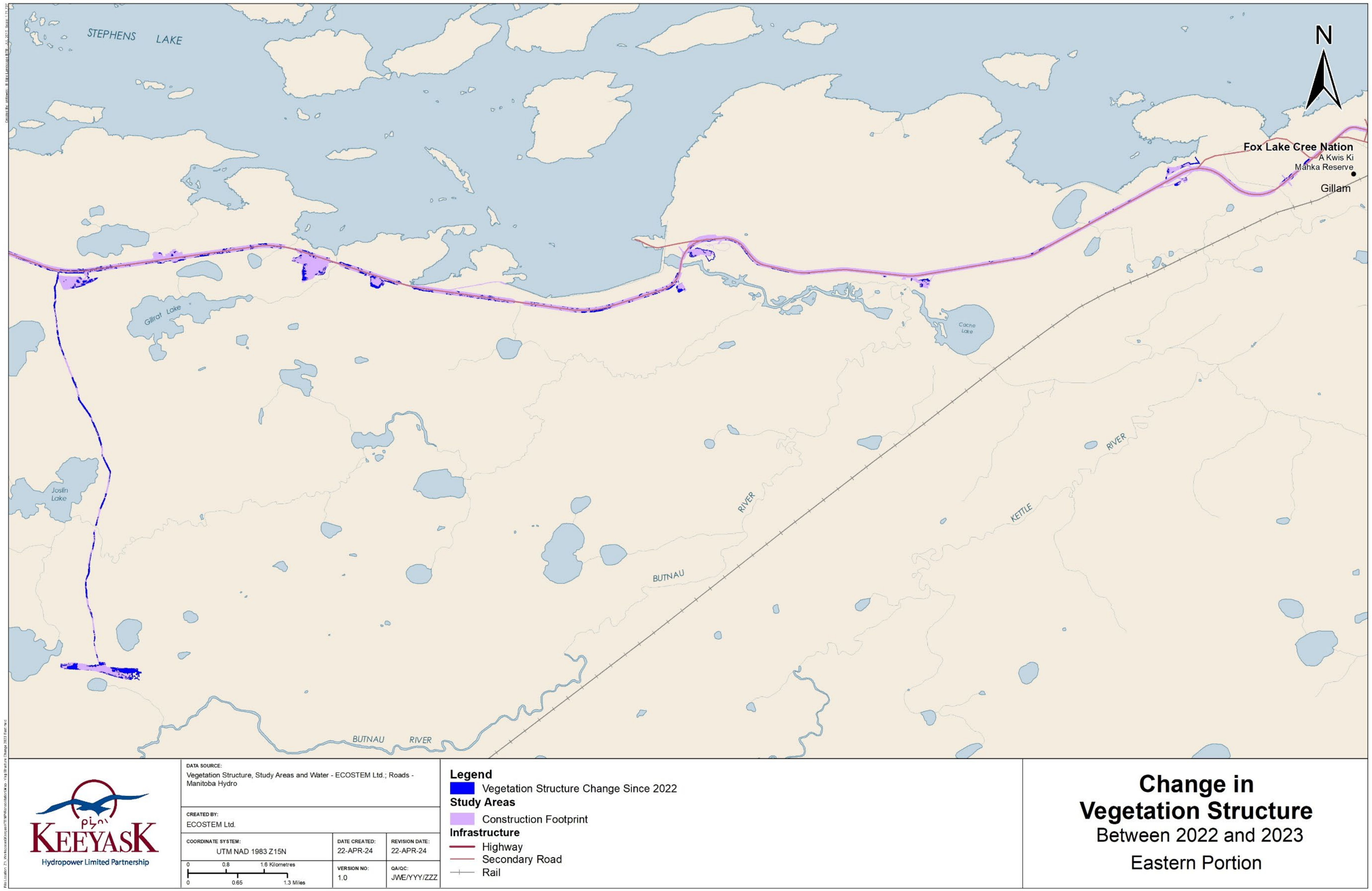
Map 4-1: Vegetation structure in the western portions of the temporary Project Footprint as of September 2023



Map 4-2: **Vegetation structure in the eastern portions of the temporary Project Footprint as of September 2023**



Map 4-3: Locations where vegetation cover or structure changed between 2022 and 2023 in the western portions of the temporary Project Footprint as of September 2023



Map 4-4: Locations where vegetation cover or structure changed between 2022 and 2023 in the eastern portions of the temporary Project Footprint as of September 2023

4.2 TREE PLANTING AREAS

4.2.1 PRESCRIPTION IMPLEMENTATION

A Shapiro-Wilk test found that the planted stem densities met the assumption for normality in eight of the rehabilitation locations planted in 2022. Borrow Area E-1 showed non-normal distribution, but a t-test result was still used as the number of transects exceeded 30 (Table 4-7). All other locations had fewer than 30 transects. With just 15 transects and a non-normal distribution, Borrow Area S-17a was tested using the non-parametric Wilcoxon signed rank test.

Results from the 2023 transect data indicated that at a 95% confidence level, plantings in EMPA D-12(2)-E, EMPA D-28(1)-E, Borrow Area KM-17, Borrow Area S-17a, and Work Area X (East) were planted at a density that met or exceeded the target of 2,500 stems/ha (Table 4-7). At 1,694 stems/ha, the estimated planted stem density in Work Area C was significantly lower than the target density. The mean density of stems in EMPA D-17-E and EMPA D-31(1)-E were each above 2,900 stems/ha, but were not significantly higher than 2,499 stems/ha at α = 0.05 (Table 4-7). Haul Road 2 could not be tested because it was sampled with a single transect, although because it was a narrow corridor and the transect extended along its entire length, the high density (4,260 stems/ha) means there is a high likelihood the target planting density was met.

Table 4-7: Estimated actual planted stem densities in the rehabilitation locations one year after planting was completed in 2022

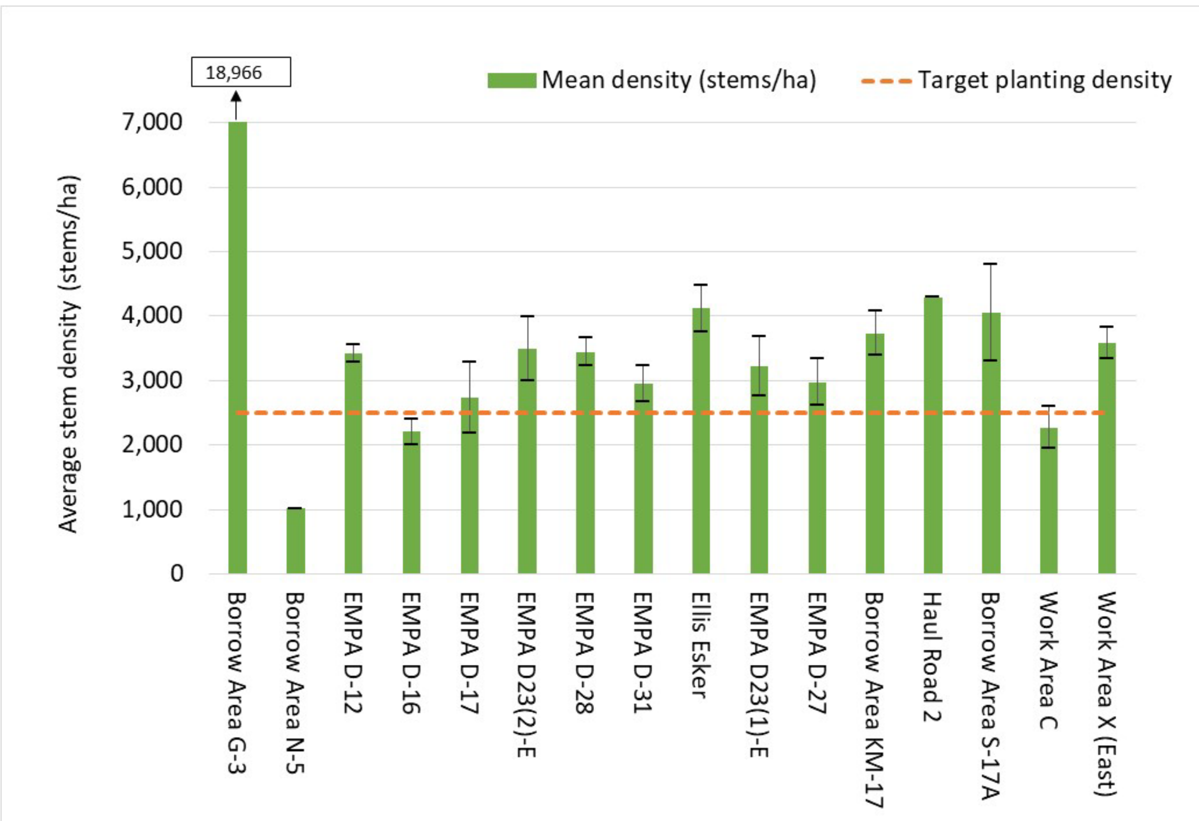
Location	Number of Transects[1]	Mean Density (stem/ha)[2]	Standard Deviation
EMPA D-12(2)-E	**17**	**3,698**	577
EMPA D-16(1)-E	**27**	2,303	1,118
EMPA D-17(1)-E	**5**	2,921	1,262
EMPA D-28(1)-E	**27**	**3,558**	1,163
EMPA D-31(1)-E	**5**	2,959	697
Borrow Area E-1	59	**3,255**	2,157
Borrow Area KM-17	**4**	**4,260**	981
Haul Road 2	1	4,293	-
Borrow Area S-17a	15	**3,398**[3]	1,540
Work Area C	**15**	*1,694*	1,413
Work Area X (East)	**4**	**3,754**	442

Notes: Values presented are rounded to a nearest natural number. [1]Bolded values indicate the data associated with the transects met the assumption of normality. [2]Bolded values indicate mean is significantly greater than 2,499 stems/ha at α = 0.05 using a one-tailed t-test; *Italicized* values indicate mean is significantly less than 2,500 stems/ha at α = 0.05. [3]Wilcoxon signed rank test used because assumption of normality not met, and number of samples is <30.

4.2.2 TREE REGENERATION STATUS IN 2023

4.2.2.1 GROUND SURVEYS

Based on the combined living stem density (includes natural regeneration) determined from the ground surveys, Borrow Areas G-3 (peripheral natural regeneration area only), E-1, S-17a, KM-17, EMPAs D-12(2)-E, D-28(1)-E, and Work Area X (East) had an estimated live stem density significantly greater than 2,499 stems/ha (Figure 4-1), in 2023. Three of the remaining 9 rehabilitation locations had a mean overall density of less than the target, including Work Area C, which was significantly lower than 2,500 stems/ha, Borrow Area N-5 (1 peripheral natural regeneration transect only) and EMPA D-16, both of which were not significantly below the target density. Estimates for EMPAs D-17-E, D-23(2)-E, D-31(1)-E, D-23(1)-E, D-27(4)-E, and Haul Road 2, were higher than the target, but not significantly.

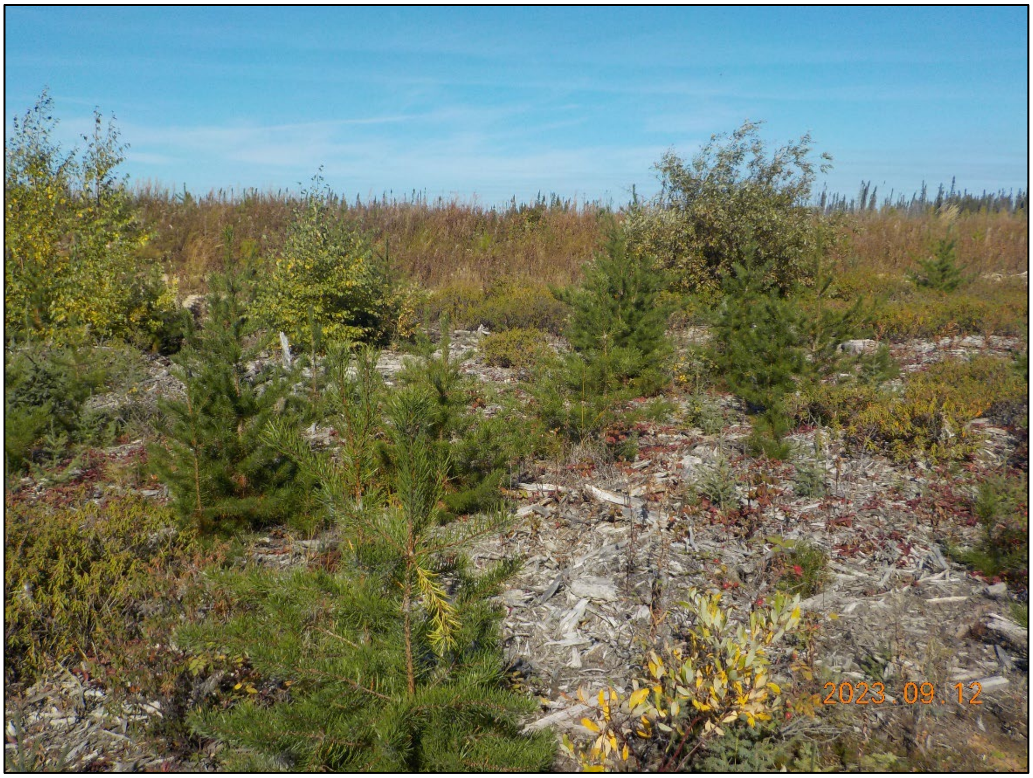


Notes: Error bars represent standard error, and the orange dashed line represents the target stem density for a woodland (2,500 stems/ha)

Figure 4-1: Overall live stem density as of 2023 for the portions of rehabilitation locations planted between 2020 and 2022 that were sampled using ground transects.

As of September 2023, eighteen (39%) of the 46 planting areas treated between 2020 and 2022 had a combined live jack pine and black spruce average stem density below 2,500 stems/ha. These planting areas were distributed through all but eight of the 16 rehabilitation locations. The exceptions were Work Area X (East), Borrow Areas E-1, KM-17, EMPA D-12(2)-E, EMPA D-17-E, EMPA D-23(1)-E, EMPA D-23(2)-E, and Haul Road 2 (Table 4-8).

Considering the different planting areas within the rehabilitation locations, live planted and/or naturally regenerating jack pine were present in 41 of the 46 planting areas between 2020 and 2022 (Figure 4-2). The average live stem density for planted and naturally regenerating jack pine in these areas ranged from 12 to 6,502 stems/ha (Table 4-8). The planting area that had the highest average live jack pine stem density was in Borrow Area G-3 (PA-8; Photo 4-4; Table 4-8). The lowest jack pine live stem densities were mostly in EMPA D-27(4)-E. Nine of the 10 planting areas in that location had live jack pine stem densities below 1,500 stems/ha, with only one planting area exceeding 2,500 stems/ha. In PA-5, only one stem of jack pine was recorded and it was dead. Borrow Area N-5 (1 transect) was the only rehabilitation locations where jack pine was not recorded.



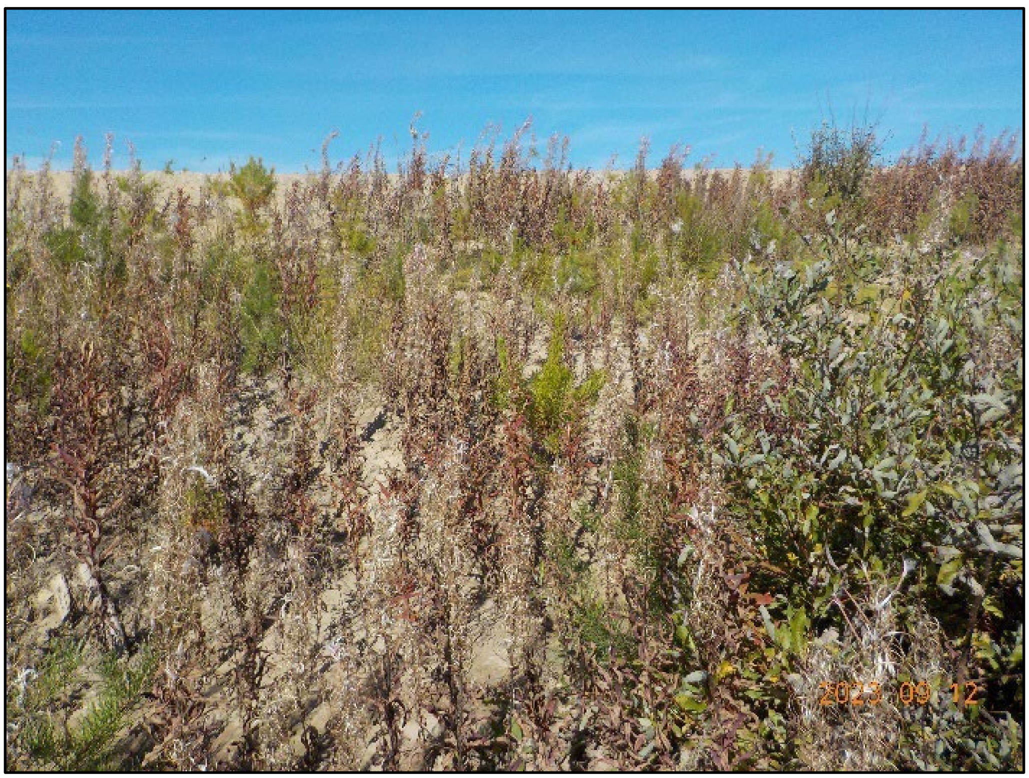


Photo 4-4: Jack pine and black spruce regeneration in a planting area with advanced regeneration (PA-8) in Borrow Area G-3 in 2023

Planted and/or naturally regenerating black spruce was present in 34 (76%) of the 45 areas planted between 2020 and 2022. Live stem densities ranged from 42 to 21,434 stems/ha across the planting areas where black spruce was present (Table 4-8). The highest densities of live black spruce stems occurred in Borrow Area G-3 (PA-6, PA-8 and PA-12), and were mainly comprised of natural regeneration. In EMPA D-31(1)-E and Haul Road 2, planted and/or natural black spruce was not recorded. The black spruce planting area that had the lowest average live stem density was PA-1 in EMPA D27(4)-E, with a density of 42 stems/ha. In PA-1 and PA-5 of Work Area C where black spruce was the only species planted, live stem density was 3,350 stems/ha and 377 stems/ha respectively (Table 4-8).

Natural black spruce and/or jack pine regeneration was present in 24 of the 45 planting areas surveyed (Figure 4-2). Naturally regenerating black spruce was more widespread, occurring in 23 of the planting areas, compared to 11 for jack pine (Table 4-9). Where present, naturally regenerating jack pine comprised from 1% to 100% of the tallied stems within a planting area. The planting area with 100% jack pine natural regeneration was located in Borrow Area G-3 (PA-6).

Black spruce natural regeneration was present in all rehabilitation locations except EMPA D-16(1)-E, EMPA D-17-E, EMPA D-31(1)-E, Haul Road 2, and Work Area X (East) (Table 4-9). Naturally regenerating black spruce (Photo 4-5) made up 100% of in the ground surveyed planting areas where the species was present Borrow Area G-3, Borrow Area N-5, EMPA D-12(1)-E , EMPA D-23(2)-E and Borrow Area S-17a. PA-3 and PA-1 of Work Area C had the lowest natural regeneration rate where it was recorded.

Figure 4-2: Composition of jack pine and black spruce regeneration in the 2020 to 2022 planting areas in 2023

Table 4-8: Jack pine and black spruce live stem average density and standard error (shown in brackets) as of September 2023 for locations planted between 2020 and 2022, by planting area

Location	Planting Area	Year Planted	Number of Transects	Average Density (stems/ha)	
				Black Spruce	Jack Pine
Borrow Area G-3	6	2020	14	21,434 (7,354)	4,142 (1,044)
	8	2020	9	16,709 (4,999)	6,502 (1,408)
	12	2021	7	15,276 (6,072)	320 (155)
	15	2021	5	612 (416)	3,033 (754)
	50	2021	1	31,143	2,476
	51	2021	1	385	-
Borrow Area N-5	1	2021	1	1,017	-
EMPA D-12(2)-E	1	2022	17	127 (87)	3,290 (136)
EMPA D-16(1)-E	1	2022	15	341 (82)	2,378 (176)
	2	2022	12	116 (81)	1,440 (290)
EMPA D-17-E	1	2022	5	-	2,733 (551)
EMPA D-23(2)-E	1	2021	3	201 (100)	3,297 (434)
EMPA D-28(1)-E	1	2022	13	549 (315)	3,049 (398)
	2	2022	13	670 (214)	2,782 (271)
	3	2022	1	-	1,429
EMPA D-31(1)-E	1	2022	4	-	3,084 (313)
	2	2022	1	-	2,381
Borrow Area E-1	1	2022	14	3,270 (1,430)	860 (353)
	2	2022	12	2,521 (512)	2,574 (629)
	3	2022	3	1,725 (560)	1,718 (830)
	4	2022	23	865 (258)	2,941 (289)
	5	2022	7	827 (393)	2,910 (456)
EMPA D-23(1)-E	1	2021	11	2,554 (476)	662 (100)
EMPA D-27(4)-E	1	2020	15	1,525 (400)	3,566 (541)
	2	2020	4	42 (42)	649 (220)
	3	2020	9	2,144 (508)	1,316 (319)
	4	2020	1	-	189
	6	2020	7	12,680 (2,761)	12 (12)
	7	2020	6	1,098 (92)	560 (151)
	8	2020	4	382 (82)	294 (230)
	9	2020	1	1,333	381
	10	2020	5	1,383 (366)	415 (242)
Borrow Area KM-17	1	2022	2	336 (119)	3,940 (190)
	9	2022	2	811 (811)	2,375 (483)
Haul Road 2	1	2022	1	-	4,293
Borrow Area S-17a	1	2022	1	-	3,143

Location	Planting Area	Year Planted	Number of Transects	Average Density (stems/ha)	
				Black Spruce	Jack Pine
	2	2022	4	-	2,472 (936)
	3	2022	2	-	3,935 (351)
	4	2022	1	-	-
	5	2022	3	313 (312)	4,289 (371)
	6	2022	4	1,690 (1,123)	4,821 (1,052)
Work Area C	1	2022	3	3,350 (519)	-
	2	2022	2	714 (1,010)	1,250 (1,250)
	3	2022	5	1,267 (580)	857 (172)
	4	2022	4	-	-
	5	2022	1	377	-
Work Area X (East)	1	2022	4	1,621 (770)	1,961 (272)

Notes: Values presented are rounded to a nearest natural number. "-" means the species was not present.

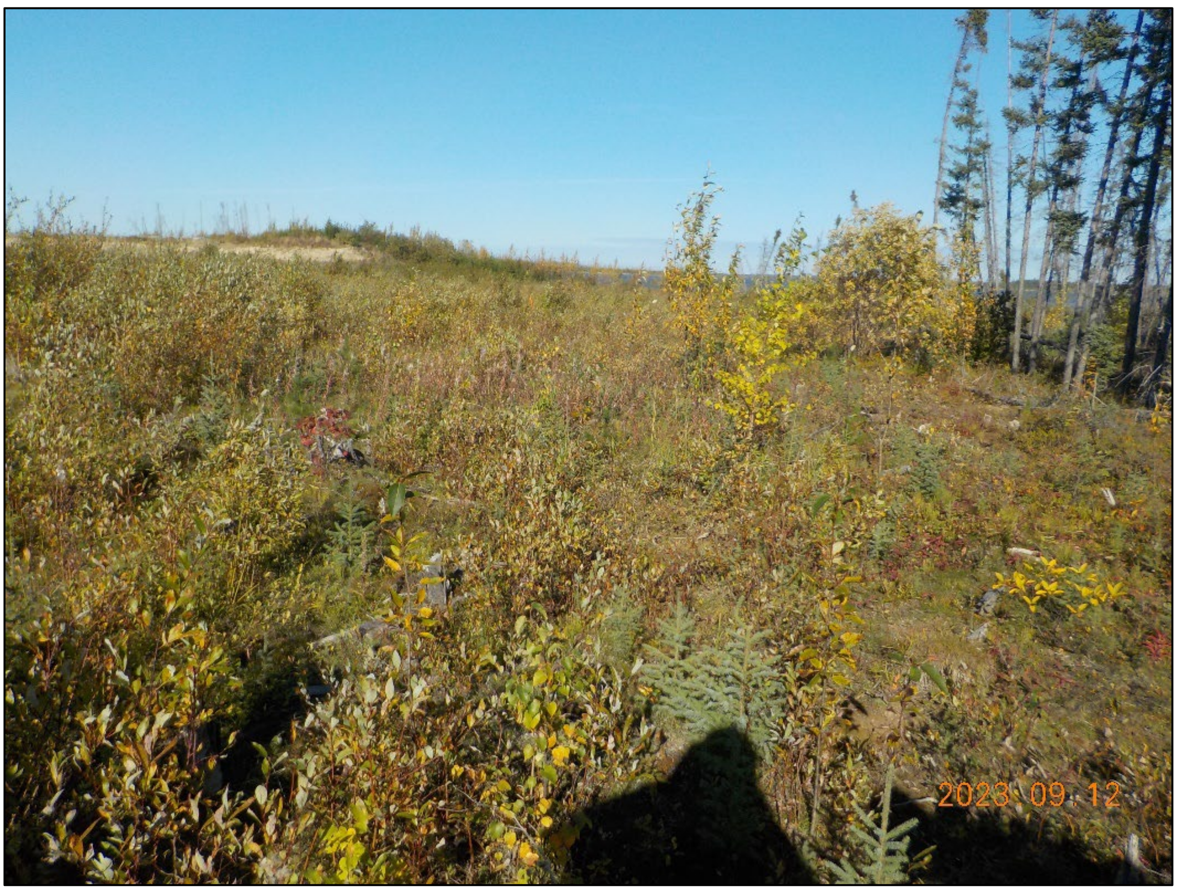


Photo 4-5: Naturally regenerating black spruce growing in Borrow Area G-3 (PA-50) in 2023

Table 4-9: Average percent of live stem density that is from naturally regenerating jack pine and black spruce stems as of September 2023 for areas planted between 2020 and 2022 by species

Location	Planting Area	Year Planted	Number of Transects	Average Percent of Stem Density from Natural Regeneration	
				Black Spruce	Jack Pine
Borrow Area G-3	6	2020	14	100.0	100.0
	8	2020	9	100.0	71.4
	12	2021	7	100.0	57.1
	15	2021	5	100.0	0.0
Borrow Area N-5	1	2021	1	100.0	-
EMPA D-12(2)-E	1	2022	17	100.0	0.0
EMPA D-16(1)-E	1	2022	15	0.0	0.0
	2	2022	12	0.0	0.0
EMPA D-17-E	1	2022	5	-	0.0
EMPA D-23(2)-E	1	2021	3	100.0	0.0
EMPA D-28(1)-E	1	2022	13	0.0	0.0
	2	2022	13	59.6	0.0
	3	2022	1	-	0.0
EMPA D-31(1)-E	1	2022	4	-	1.0
	2	2022	1	-	0.0
Borrow Area E-1	1	2022	14	42.1	31.7
	2	2022	12	24.3	31.3
	3	2022	3	4.8	21.2
	4	2022	23	13.6	2.7
	5	2022	7	66.7	21.2
EMPA D-23(1)-E	1	2021	11	10.2	0.0
EMPA D-27(4)-E	1	2020	15	8.1	0.0
	2	2020	4	0.0	0.0
	3	2020	9	0.0	0.0
	4	2020	1	-	0.0
	7	2020	6	8.2	0.0
	8	2020	4	0.0	0.0
	9	2020	1	6.3	0.0
	10	2020	5	0.0	0.0
Borrow Area KM-17	1	2022	2	0.0	0.0
	9	2022	2	16.7	0.0
Haul Road 2	1	2022	1	-	0.0
Borrow Area S-17a	1	2022	1	-	0.0
	2	2022	4	-	0.0
	3	2022	2	-	0.0

Location	Planting Area	Year Planted	Number of Transects	Average Percent of Stem Density from Natural Regeneration	
				Black Spruce	Jack Pine
	5	2022	3	100.0	0.0
	6	2022	4	100.0	10.5
Work Area C	1	2022	3	1.0	-
	2	2022	2	0.0	0.0
	3	2022	5	1.0	0.0
	4	2022	4	-	-
	5	2022	1	0.0	-
Work Area X (East)	1	2022	4	0.0	0.0

Notes: "-" indicates that the species was not tallied in the planting area, values of "0" indicate the species was present, but none were naturally regenerating

Pooling all planted stems tallied in 2023 for each rehabilitation location, overall stem survival was lowest in EMPA D23(2)-E, with 84.7% of tallied stems living (Figure 4-3). This was followed by EMPA D27(4)-E (87.1%, Photo 4-6), Borrow Area KM-17 (88.0%), D12(2)-E (89.6%) and D28(1)-E (92.8%). Stem survival was 100% in the ground sampled planting areas of Borrow Areas G-3 and N-5, and on Haul Road 2.

Planted jack pine stem survival by planting area ranged from 31.4% to 100% (Table 4-10). Three of the four planting areas with the lowest stem survival rates were in EMPA D-27(4)-E, with PA-2 having the lowest of any planting area sampled by ground surveys. Planting Area 9 in Borrow Area KM-17 had 68.4% stem survival for planted jack pine. All other planting areas had more than 80% stem survival for planted jack pine stems (Table 4-10).

For planted black spruce, the lowest stem survival was in PA-2 of EMPA D-27(4)-E (50%), which was based on only 4 tallied stems (Table 4-10). In the same rehabilitation location, PA-10 and PA-9 had the next lowest black spruce survival rates of 76.5% and 86.7% respectively. Stem survival was between 91.9% to 98.6% in all the other areas where planted black spruce mortality was recorded.

Photo 4-6: Dead jack pine (vigour 0) in EMPA D-27(4)-E in 2023

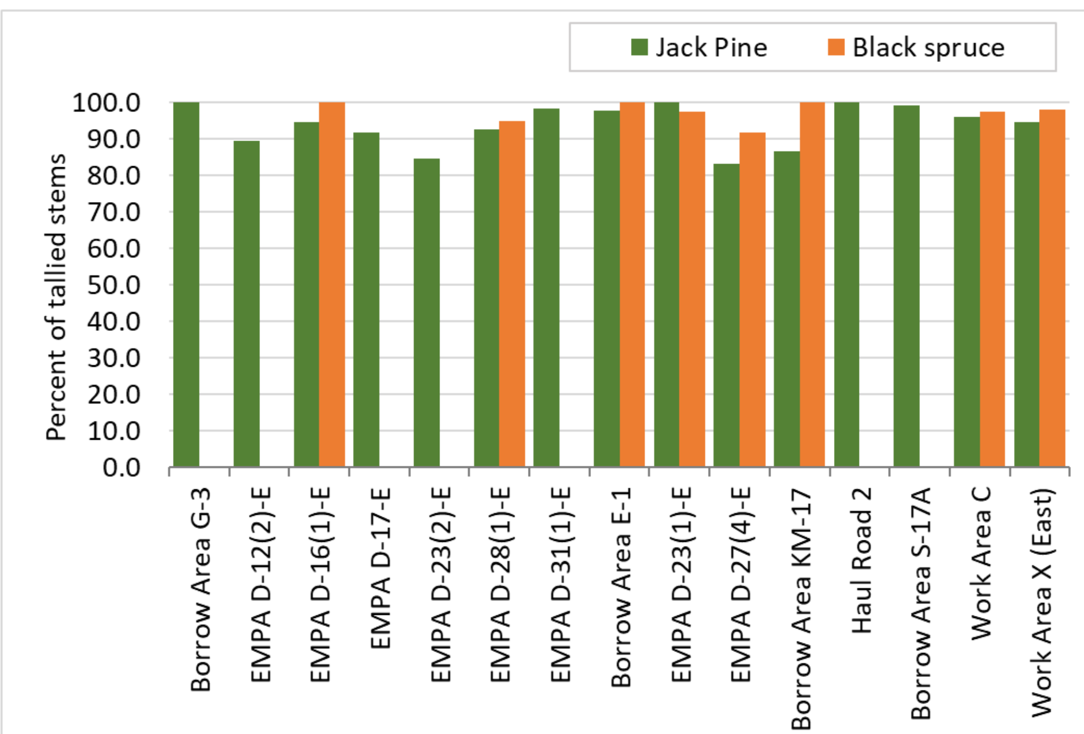


Figure 4-3: Percent survival of tallied planted jack pine and black spruce stems in 2023, for all planting areas pooled by rehabilitation location

Table 4-10: Planted black spruce and jack pine percent stem survival by planting area for 2020 to 2022 rehabilitation locations that were ground surveyed as of September 2023

Location	Planting Area	Jack pine	Black spruce
Borrow Area G-3	8	100.0	-
	12	100.0	-
	15	100.0	-
EMPA D-27(4)-E	1	93.3	90.7
	2	31.4	50.0
	3	81.2	89.8
	4	100.0	-
	7	85.4	98.6
	8	100.0	100.0
	9	66.7	86.7
	10	75.0	76.5
EMPA D-23(1)-E	1	100.0	97.5
EMPA D-23(2)-E	1	84.7	-
EMPA D-12(2)-E	1	89.6	-
EMPA D-16(1)-E	1	94.4	100.0
	2	98.6	100.0
EMPA D-17-E	1	91.9	-
EMPA D-28(1)-E	1	85.3	91.9
	2	99.1	100.0
	3	100.0	-
EMPA D-31(1)-E	1	98.1	-
	2	100.0	-
Borrow Area E-1	1	100.0	100.0
	2	100.0	100.0
	3	100.0	100.0
	4	96.9	100.0
	5	100.0	100.0
Borrow Area KM-17	1	91.0	100.0
	9	68.4	100.0
Haul Road 2	1	100.0	-
Borrow Area S-17a	1	100.0	-
	2	98.5	-
	3	100.0	-
	5	100.0	-
	6	100.0	-
Work Area C	1	-	100.0

Location	Planting Area	Jack pine	Black spruce
	2	100.0	100.0
	3	95.8	95.1
	5	-	100.0
Work Area X (East)	1	94.5	98.1

Notes: "-" indicates that the species was not tallied in the planting area.

Stem vigour class was variable for ground surveyed planting areas where live jack pine stems was present. PA-1 of Borrow Area E-1 had the maximum vigour class (6) for jack pine stems (Table 4-11). PA-2, 4, 6, and 9 of EMPA D-27(4)-E, as well as PA-1 of EMPA D-16(1)-E had average jack pine vigour class of 4.0 or less. In general, planting areas where average vigour was less than 4 was dominated by stems with poorer condition and health (Photo 4-7), more often having a dead leader (Photo 4-8), or only a few living branches or needles (Photo 4-9).

Average vigour class for live black spruce stems was at least 4 in all planting areas. For black spruce, average vigour was above 5 (mostly healthy) in 2 of the 36 planting areas where live stems were present (Photo 4-10).

Photo 4-7: Area with poor jack pine condition (red leaves, vigour 0-4) in EMPA D-12(2)-E (PA-1) in 2023

Photo 4-8: Jack pine with dead leader and some living leaves (vigour 3) in EMPA D-27(4)-E in 2023

Photo 4-9: Jack pine, vigour 2, with a few leaves still green in Borrow Area KM-17 in 2023

Photo 4-10: A patch of healthy black spruce (vigour 6) in EMPA D-27(4)-E (PA-3) in 2023

Table 4-11: Average vigour class of living stems by planting area for 2020, 2021, and 2022 rehabilitation locations as of September 2023

Location	Planting Area	Average vigour of living stems		
		Black Spruce	Jack Pine	Both
Borrow Area G-3	6	6.0	5.9	6.0
	8	6.0	5.7	5.8
	12	5.9	5.3	5.8
	15	6.0	5.9	5.9
	50	6.0	5.5	5.8
	51	6.0	-	6.0
Borrow Area N-5	1	6.0	-	6.0
EMPA D-12(2)-E	1	5.2	4.2	4.2
EMPA D-16(1)-E	1	4.1	3.9	3.9
	2	5.0	4.2	4.3
EMPA D-17-E	1	-	4.0	4.0
EMPA D-23(2)-E	1	6.0	4.0	4.1
EMPA D-28(1)-E	1	4.0	4.3	4.3
	2	5.4	5.1	5.1
	3	-	4.5	4.5
EMPA D-31(1)-E	1	-	5.0	5.0
	2	-	4.5	4.5

Location	Planting Area	Average vigour of living stems		
		Black Spruce	Jack Pine	Both
Borrow Area E-1	1	5.8	6.0	5.9
	2	5.8	5.9	5.9
	3	5.3	5.8	5.5
	4	5.1	5.2	5.2
	5	5.9	5.6	5.7
EMPA D-23(1)-E	1	5.2	5.1	5.2
EMPA D-27(4)-E	1	5.2	5.3	5.3
	2	5.0	3.6	3.7
	3	5.2	4.1	4.7
	4	-	3.0	3.0
	6	5.8	3.0	5.7
	7	4.9	4.4	4.7
	8	5.2	4.8	5.1
	9	5.3	3.0	4.8
	10	4.5	5.3	4.7
Borrow Area KM-17	1	4.3	4.2	4.2
	9	5.2	4.9	5.0
Haul Road 2	1	-	5.4	5.4
Borrow Area S-17a	1	-	5.5	5.5
	2	-	4.7	4.7
	3	-	4.3	4.3
	5	5.0	4.4	4.4
	6	6.0	4.8	5.0
Work Area C	1	4.1	-	4.1
	2	6.0	4.7	5.0
	3	4.4	4.1	4.3
	4	-	-	-
	5	5.0	-	5.0
Work Area X (East)	1	4.3	4.6	4.4

Notes: "-" indicates that the species was not tallied in the planting area.

4.2.2.2 DRONE SURVEYS

A complete census of the 2020 and 2021 planting areas was done in the open, barren to sparsely vegetated planting areas of Borrow Areas G-3 and N-5, and all of KM-9 and EMPA D-35(1)-E that was planted in 2021 (Table 4-12), for a total of 77.5 ha. None of the survey areas had a living stem density greater than the target planting density of 2,500 stems/ha. Borrow Area N-5 had the highest density at 1,456 stems/ha. The lowest live density was found in Borrow Area KM-9 (716 stems/ha). The density in Borrow Area G-3 is lower than reported for ground transects as the latter were concentrated in perimeter areas, which tended to have natural regeneration and better planted seedling survival.

Evaluation of seedling detection using the drone method compared to ground survey methods found that on average, for open areas with low natural regeneration, drone surveys detected approximately 75% of live seedlings tallied along the same transects from ground surveys (Table 7-1).

Seedling stem densities measured from drone imagery were adjusted to account for the detection bias. Total stem densities in the drone survey areas ranged from 955 stems/ha to 1,941 stems/ha (Table 4-12), still below the target planted density.

Table 4-12: Total live stem densities in the rehabilitation locations planted between 2020 and 2021 and surveyed by drone in September 2023

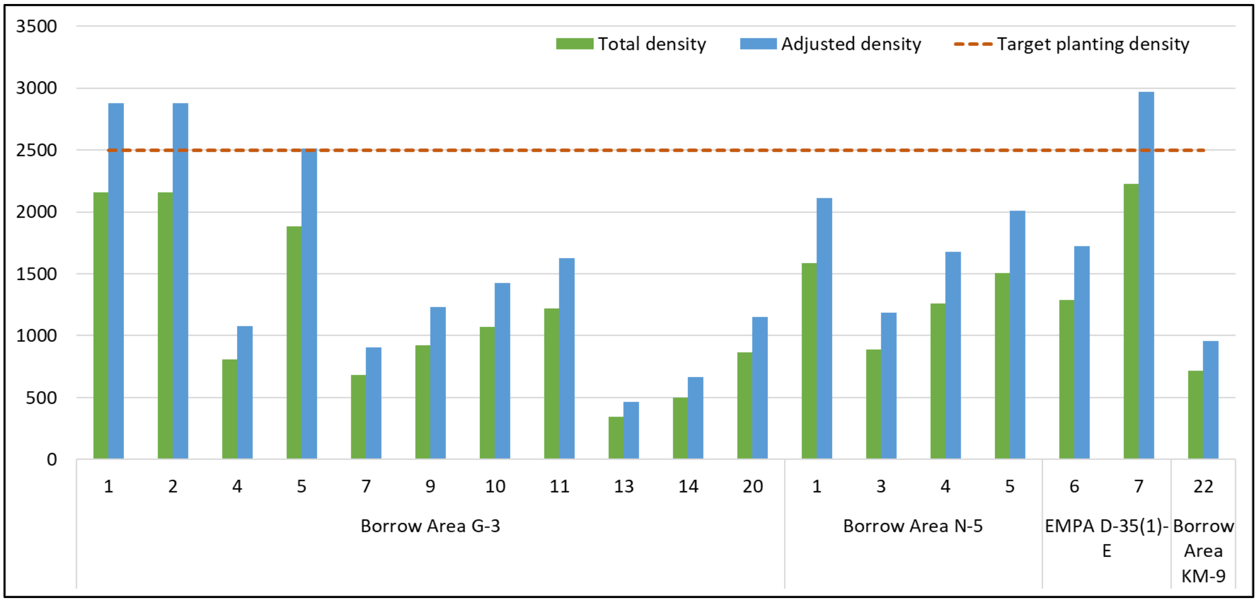
Location	Area Surveyed (ha)	Total density (stems/ha)	Adjusted Density (stems/ha)[1]
Borrow Area G-3	50.1	987	1,316
Borrow Area KM-9	1.6	716	955
Borrow Area N-5	20.0	1,456	1,941
EMPA D-35(1)-E	5.8	1,342	1,789
Total	*77.5*	*1,129*	*1,505*

Notes: [1] Adjustment based on assumed stem detection rate of 75%.

Eighteen planting areas were included in the drone survey (Notes: The dashed line represents the target stem density for a woodland (2,500 stems/ha)

Figure 4-4; Table 7-2). None of the 18 planting areas had a combined live jack pine and black spruce stem density that met the original planting target of 2,500 stems/ha. The planting areas that reached a combined live density above 2,000 stems/ha were Borrow Area G-3 PA-1 and 2 and EMPA D-35(1)-E PA-6. Adjusted live stem densities exceeded 2,500 stems/ha for four planting areas, including PA-1, PA-2, and PA-5 in Borrow Area G-3, and PA-7 in EMPA D-35(1)-E (Notes: The dashed line represents the target stem density for a woodland (2,500 stems/ha)

Figure 4-4).



Notes: The dashed line represents the target stem density for a woodland (2,500 stems/ha)

Figure 4-4: Overall live tallied stem density and adjusted stem density as of 2023 for the planting areas surveyed by drone.

Live planted and/or naturally regenerating black spruce was present in 11 of 18 planting areas and the density ranged from 1 to 129 stems/ha (Table 7-3). The highest density recorded for black spruce was in PA-1 of Borrow Area G-3 and was mainly composed of natural regeneration. Among the areas where black spruce was recorded, the lowest planted live density was 1 stem/ha in PA-7 of Borrow Area G-3. Total black spruce density was 100% due to natural regeneration in several planting areas, including Borrow Area G-3 (PA-5,10, 13, 14 and 20), and EMPA D-35(1)-E PA 6.

Live jack pine, either planted or naturally regenerating, was recorded in all the planting areas. The highest living density was 2,159 stems/ha (Borrow Area G-3 PA-2). The planting area with the lowest live density of jack pine was also located in Borrow Area G-3 (339 stems/ha in PA-13).

Pooling all stems tallied during the drone survey in 2023 for each rehabilitation location, overall percent survival was lowest in Borrow Area G-3, with 58.3% of tallied stems living (Figure 4-5). The remaining three rehabilitation locations had an overall stem survival rate between 70% and 80%.

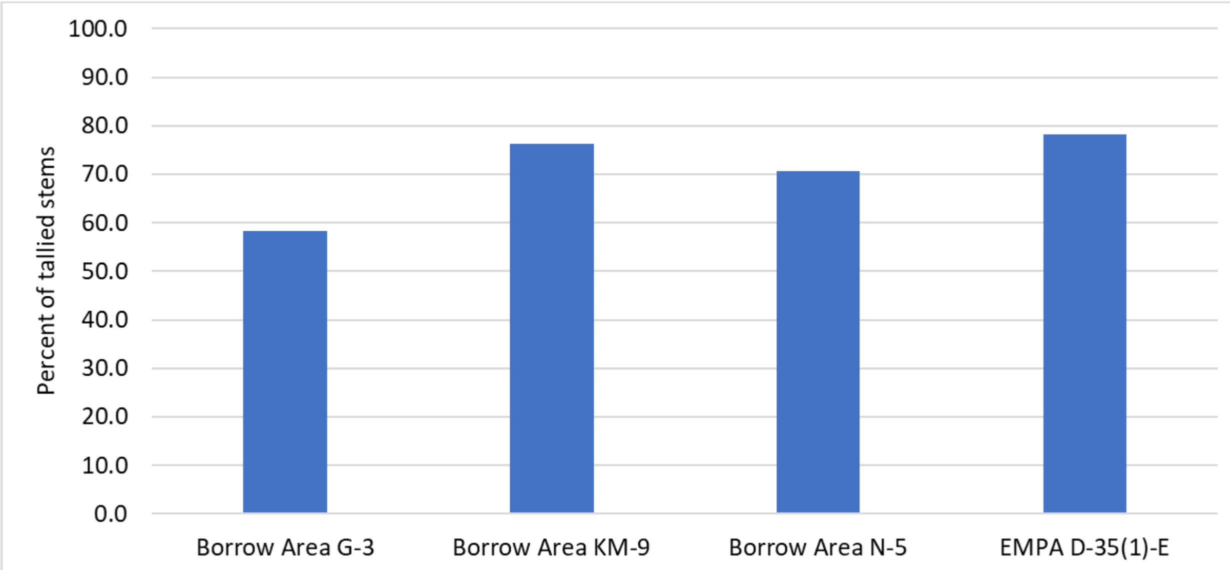


Figure 4-5: Overall percent survival of stems in the planting areas planted in 2020 and 2021 that were surveyed by drone

Planted jack pine stem survival by planting area ranged between 0.8% and 72.1% (Table 4-13). The highest survival rates were in Borrow Area G-3 PA-1 (99.2%) and EMPA E-35(1)-E PA-7 (99.0%). The planting area with the lowest percent survival, at 27.9%, was PA-14 in Borrow Area G-3. Under half of the planted jack pine stems were living in Borrow Area N-5 PA-3 (43.9%) and in Borrow Area G-3 PA-11 (49.6%). In total, 63.4 % of all jack pine planted stems counted during the drone survey were living.

For planted black spruce, stem survival ranged between 97.9% and 100% in the planting areas surveyed by drone. Only two of the tallied planted stems were dead (0.2% of stems overall). The two dead stems were found in Borrow Area G-3, PA-4 and PA-9.

Table 4-13: Black spruce and jack pine percent live stems in the rehabilitation locations planted in 2020 and 2021 and surveyed by drone in September 2023

Location	Planting area	Year Planted	Area (ha)	Percent Living Stems	
				Black spruce	Jack pine
Borrow Area G-3	1	2020	0.9	100.0	99.2
	2	2020	0.8	-	83.4
	4	2020-2021	9.2	99.8	57.0
	5	2020	5.1	100.0	92.5
	7	2020	3.1	100.0	55.0
	9	2021	4.6	97.9	74.2
	10	2021	11.7	100.0	56.9
	11	2021	2.4	-	49.6
	13	2021	0.3	100.0	61.1
	14	2021	9.9	100.0	27.9
	20	2021	2.0	100.0	75.2
Borrow Area KM-9	22	2020	1.6	100.0	74.8
Borrow Area N-5	1	2021	12.9	-	73.0
	3	2021	2.7	-	43.9
	4	2021	1.4	-	78.8
	5	2021	3.1	-	81.4
EMPA D-35(1)-E	6	2021	5.5	100.0	76.4
	7	2021	0.3	-	99.0

Notes: Values presented are rounded to a nearest whole number. "-" means the species was not present.

4.2.3 CHANGES TO 2023

For areas planted in 2020 or in 2021, average live stem density differed to varying degrees for the planting areas when comparing data from the first survey (i.e., 2021 survey for 2020 planted areas and 2022 survey for 2021 areas) to the 2023 surveys. ANOVA results indicated that between survey differences in average live stem density were significant for Borrow Area G-3 PA-8 and EMPA D-23(1)-E PA-1 (Figure 4-6). In these planting areas, live stem density increased between the first survey year and 2023 by 25% and 28%, respectively.

Borrow Area G-3 PA-8 (50%) and EMPA D-23(1)-E PA-1 (662%) both had a significant increase in jack pine density (Table 4-14). EMPA D-23(1)-E PA-1 (36%) also had a significant increase in black spruce density (Table 4-15). Black spruce also increased significantly in EMPA D-23(2)-E PA-1 (201%). None of the planting areas decreased significantly from the first survey year to 2023.

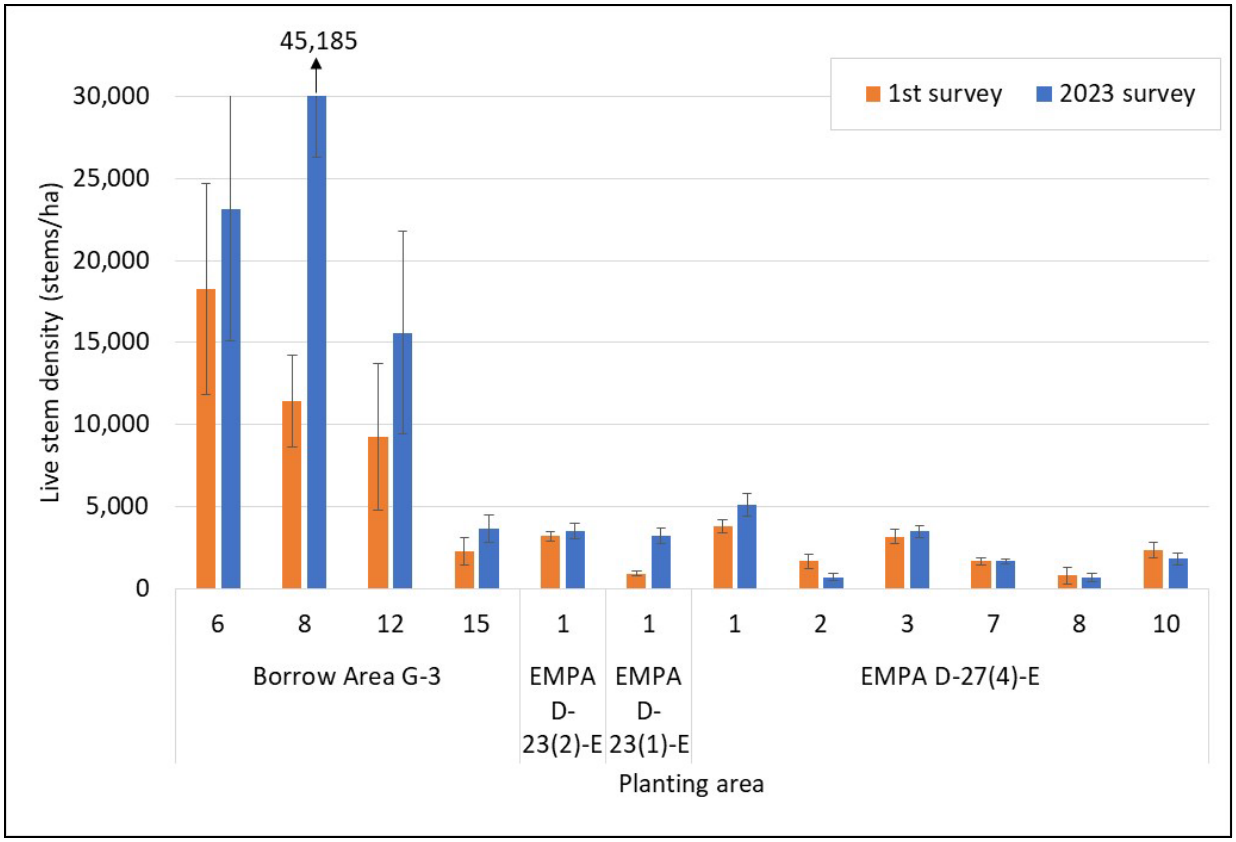


Figure 4-6: Total live stem density and standard error of the mean for the first survey year and the 2023 survey year in planting areas ground surveyed in 2020 and 2021

Table 4-14: Total live jack pine stem density comparison and significant[1] percent change (shown in brackets) between 2021, 2022, and 2023 for areas planted in 2020

Location	Planting Area	Year Planted	Number of Transects	Average Density (stems/ha)	
				1st survey	2023
Borrow Area G-3	6	2020	14	2,765	3,062
	8	2020	9	3,928	7,952 (+50%)
	12	2021	7	758	320
	15	2021	5	2,131	3,033
EMPA D-23(2)-E	1	2021	3	3,204	3,297
EMPA D-23(1)-E	1	2021	11	0	662 (+662%)
EMPA D-27(4)-E	1	2020	15	2,658	3,566
	2	2020	4	1,581	649
	3	2020	9	1,643	1,316
	7	2020	6	654	560
	8	2020	4	323	294
	10	2020	5	415	415

Notes: [1] Significance of change based on analysis of variance (α = 0.05).

Table 4-15: Total live black spruce stem density comparison and significant[1] percent change between 2021, 2022, and 2023 for areas planted in 2020

Location	Planting Area	Year Planted	Number of Transects	Average Density (stems/ha)	
				1st survey	2023
Borrow Area G-3	6	2020	14	15,509	20,047
	8	2020	9	7,487	37,234
	12	2021	7	8,507	15,276
	15	2021	5	132	612
EMPA D-23(2)-E	1	2021	3	0	201 (+201%)
EMPA D-23(1)-E	1	2021	11	907	2,554(+36%)
EMPA D-27(4)-E	1	2020	15	1,134	1,525
	2	2020	4	83	42
	3	2020	9	1,522	2,144
	7	2020	6	1,009	1,098
	8	2020	4	452	382
	10	2020	5	1,913	1,383

Notes: [1] Significance of change based on analysis of variance ($\alpha = 0.05$).

Planting areas sampled by drone were a census, and not directly comparable to the density estimates from previous years. However, qualitative comparison of 2023 census stem densities adjusted for detection bias with 2022 stem densities found they were very similar. The census data did not suggest that there were any substantial decreases (or increases) in density in the planting areas surveyed by drone. The one exception was Borrow Area KM-9 where there was an apparent decrease from more than 2,500 stems/ha to less than 1,000 stems/ha.

4.2.4 RECOVERY SUCCESS IN 2016 PLANTING AREAS

4.2.4.1 TARGET HABITAT TYPES

The target habitat types for areas planted in 2016 were based on a combination of the tree species planted and planting density. Of the 24.1 ha planted in 2016, 75% (18.0 ha) was targeted for jack pine forest, 3% was targeted for jack pine and black spruce mixed forest, and 22% was targeted for black spruce woodland (Table 4-16).

Table 4-16: Area planted in 2016 by target habitat type

Target Habitat Type	Area (ha)	Percent of Total
Jack pine forest	18.0	74.7
Jack pine and black spruce forest	0.7	3.0
Black spruce woodland	5.4	22.3
Total area planted	**24.1**	**100.0**

The target habitat types were distributed across 16 planting areas in five rehabilitation locations (Table 4-17). All rehabilitated area near the Main Camp and Start-up Camp was targeted for jack pine forest. Portions of the three borrow areas were were targeted for a mixture of jack pine forest and black spruce woodland, and two planting areas in Borrow Area KM-4 were targeted for jack pine and black spruce mixed forest.

Table 4-17: Distribution of target habitat types across rehabilitation locations and planting areas

Rehabilitation Location	Planting Area	Target Habitat Type	Area (ha)
Borrow Area KM-1	1	Black spruce woodland	0.3
	2	Jack pine forest	3.9
	3	Black spruce woodland	0.6
Borrow Area KM-4	4	Jack pine and black spruce forest	0.3
	5	Jack pine and black spruce forest	0.4
	6	Jack pine forest	8.9
Borrow Area KM-9	7	Black spruce woodland	2.0
	8	Jack pine forest	1.6
	9	Black spruce woodland	2.0
	10	Black spruce woodland	0.5
Entrance to Main Camp	16	Jack pine forest	0.4
	17	Jack pine forest	0.3
Start-up Camp	12	Jack pine forest	0.6
	13	Jack pine forest	1.5
	15	Jack pine forest	0.5
	99	Jack pine forest	0.3
Total area planted			**24.1**

Average estimated stem density in areas targeted for jack pine or jack pine and black spruce forest habitat did not exceed the target planting stem density with a 95% confidence level in any of the rehabilitation locations (Table 4-18). However, all area targeted for forest habitat (78%) had an estimated stem density greater than the 2,500 stems/ha target for woodland habitat. None of the area targeted for woodland habitat had an estimated stem density greater than 2,500 stems/ha.

Table 4-18: Jack pine and black spruce live stem average density and standard deviation (shown in brackets) as of September 2023 by rehabilitation location and target habitat type

Rehabilitation Location	Target Habitat Type	Area (ha)	N[1]	Mean Density (stems/ha)[2]	Standard Deviation
Borrow Area KM-1	Black spruce woodland	0.9	5	842	1,221
	Jack pine forest	3.9	**11**	<u>8,795</u>	3,874
Borrow Area KM-4	Jack pine and black spruce forest	9.7	**17**	<u>8,646</u>	2,482
Borrow Area KM-9	Black spruce woodland	4.5	**10**	2,475	1,275
	Jack pine forest	1.6	**3**	<u>10,344</u>	676
Start-up Camp	Jack pine forest	2.8	**6**	<u>9,390</u>	1,241
Entrance to Main Camp[3]	Jack pine forest	0.7	**4**	<u>11,232</u>	2,107

Notes: [1] Bold numbers indicate the sample met the assumption for normality and a on-tailed t-test was used to test means. Alternately, a Wilcoxon Signed Rank test was used. [2] Underlined numbers indicate the estimated density met the target for woodland with a 95% confidence level. Boldface numbers indicate the density met the target for forest. [3] Sampled by ground survey rather than drone.

Tree growth after seven years was variable within and across the different 2016 planting areas. Most planting areas had a mixture of stems that remained in the "seedling" height class (estimated <0.5 m tall), up to stems that were in the "tree" height class (estimated >1.3 m tall). Planting areas that had a relatively high proportion of stems in the smaller height class included PA-3 in Borrow Area KM-1, and all planting areas in Borrow Area KM-9 and the Main Camp entrance (Table 4-19).

Table 4-19: Tallied stems by height class as a percentage of total stems tallied in a planting area

Rehabilitation Location	Planting Area	Total Stems	% Seedling	% Sapling/Tree
Borrow Area KM-1	1	6	100	0
	2	1,764	43	57
	3	23	65	35
Borrow Area KM-4	4	478	59	41
	5	435	57	43
	6	3,686	61	39
Borrow Area KM-9	7	4,776	73	27
	8	856	66	34
	9	186	97	3
	10	211	100	0
Start-up Camp	13	960	13	87
	15	643	20	80
Entrance to Main Camp	16	63	73	27
	17	33	85	15

Based on vegetation cover mapping, approximately two-thirds (16.2 ha) of the 24.1 ha targeted for forest or woodland habitat in the 2016 planted areas developed into treed habitat types (Table 4-20). Note that although vegetation cover in a patch may qualify as forest or woodland cover, it does not necessarily mean that it has the prescribed stem density for forest or woodland at this stage of growth. Forest habitat made up 4.3 ha (17.8%) of the rehabilitated area, and woodland habitat made up 8.1 ha (33.6%), with the remaining treed area being sparsely treed (Table 4-20). The most abundant habitat type was jack pine woodland on mineral substrates at 29.4% of the rehabilitated area. Jack pine forest on mineral substrates, which was the target for most of the area planted in 2016, made up 12.9% of the area as of September 2023. Pure black spruce woodland had not developed, but black spruce dominated mixtures and mixedwood woodland habitats on mineral substrates made up 4.6% of the total area.

Jack pine mixtures were typically mixed with black spruce that was usually naturally regenerating, and sometimes naturally regenerating white birch (*Betula papyrifera*) and/or trembling aspen (*Populus tremuloides*). Similarly, black spruce mixtures were typically mixed with planted and/or naturally regenerating jack pine, and occasionally trembling aspen.

The non-treed habitat types may have some sparse tree cover, but not exceeding 10% cover. The most abundant non-treed vegetation cover in the 2016 planted areas was herbaceous, covering 12.5% of the rehabilitated area, followed by barren areas, which made up 12.2% (Table 4-20).

Table 4-20: Habitat type composition as of 2023 in areas rehabilitated in 2016

Regenerating Habitat Type	Area (ha)	Percent of Total
Jack pine forest on mineral substrates	3.1	12.9
Jack pine mixture forest on mineral substrates	1.1	4.8
Jack pine mixedwood forest on mineral substrates	0.0	0.2
Jack pine woodland on mineral substrates	5.7	23.9
Jack pine mixture woodland on mineral substrates	2.1	8.7
Jack pine mixedwood woodland on mineral substrates	0.3	1.1
Jack pine sparsely treed on mineral substrates	2.4	9.9
Jack pine mixture sparsely treed on mineral substrates	0.1	0.4
Black spruce mixture sparsely treed on mineral substrates	1.0	4.3
Black spruce mixedwood sparsetly treed on mineral substrates	0.3	1.2
Trembling aspen mixture sparsely treed on mineral substrates	0.1	0.3
Tall shrub on mineral substrates	0.5	2.2
Low shrub on mineral substrates	0.1	0.5
Herbaceous on mineral substrates	3.0	12.5
Sparsely vegetated on mineral substrates	1.2	5.1
Barren on all substrates	2.9	12.2
Total area planted	**24.1**	**100.0**

By 2023, forest and woodland vegetation cover was distributed in all three rehabilitated borrow areas planted along the NAR, as well as the Start-up Camp area (Table 4-21). Planting areas with the highest proportion of forest and woodland habitat included PA-4 and 5 in Borrow Area KM-4, and PA-12 and 13 in the Start-up Camp area (Map 4-5). In each of these planting areas forest or woodland habitat made up more than 80% of their area. Planting areas with little to no treed structure included PA-2 and 3 in Borrow Area KM-1, PA-10 in Borrow Area KM-9, and both planting areas at the Main Camp entrance.

A mixture of mineral surface substrate types and conditions were distributed throughout the areas with different target habitat and vegetation structure types, but there appeared to be no specific associations between substrate type and the amount of treed habitat cover. Organic material presence in the surface substrate did appear to correspond to treed areas, and areas with higher vegetation cover. Between 78.6% and 89.0% of the treed habitat had substrates with some degree of organic material mixed in (Table 4-22), and other structure types with at least 25% vegetation cover had at least half of its area with organic material mixed in the substrate. In contrast, only 35% of sparsely vegetated area had organic material, and only 6% of barren areas had organic material (Table 4-22).

Table 4-21: Vegetation cover type composition by planting area as of 2023

Rehabilitation Location	Planting Area	Area Planted (ha)	Vegetation Cover Type							
			Forest	Woodland	Sparsely Treed	Tall Shrub	Low Shrub	Herbaceous	Sparse	Barren
Borrow Area KM-1	1	0.3	-	-	-	18.5	-	81.5	-	-
	2	3.9	50.6	14.5	13.3	1.0	-	11.7	0.2	8.6
	3	0.6	0.7	-	1.9	-	-	82.5	-	14.8
Borrow Area KM-4	4	0.3	69.5	29.0	-	-	-	1.5	-	-
	5	0.4	41.2	48.7	-	-	-	5.5	-	4.5
	6	8.9	6.6	48.8	18.7	-	1.3	2.0	2.6	20.0
Borrow Area KM-9	7	2.0	11.8	15.3	26.0	5.3	-	37.1	4.6	-
	8	1.6	37.1	38.5	4.8	-	-	2.6	-	16.9
	9	2.0	-	4.6	45.1	14.9	-	10.1	9.7	15.6
	10	0.5	-	-	-	-	-	74.4	-	25.6
Entrance to Main Camp	16	0.4	-	-	-	-	-	-	100.0	-
	17	0.3	-	-	-	-	-	10.3	89.7	-
Start-up Camp	12	0.6	75.2	20.3	-	-	-	4.5	-	-
	13	1.5	-	84.9	2.4	2.1	-	9.7	0.8	-
	15	0.5	-	73.2	25.1	-	-	1.7	-	-
	99	0.3	32.9	45.7	-	-	-	21.4	-	-

Notes: "-" means and absence, where as "0" indicates a number that rounds to zero.

Table 4-22: Percentage of area in the different vegetation structure types with organic material mixed in the substrate in 2023, for areas planted in 2016

Vegetation Structure Type	Total Area (ha)	Percent of Area with Organic Material in Substrate
Forest	4.3	78.6
Woodland	8.1	89.0
Sparsely Treed	3.9	88.4
Tall Shrub	0.5	100.0
Low Shrub	0.1	47.4
Herbaceous	3.0	93.7
Sparse	1.2	35.0
Barren	2.9	5.9
Total area planted	**24.1**	**74.7**

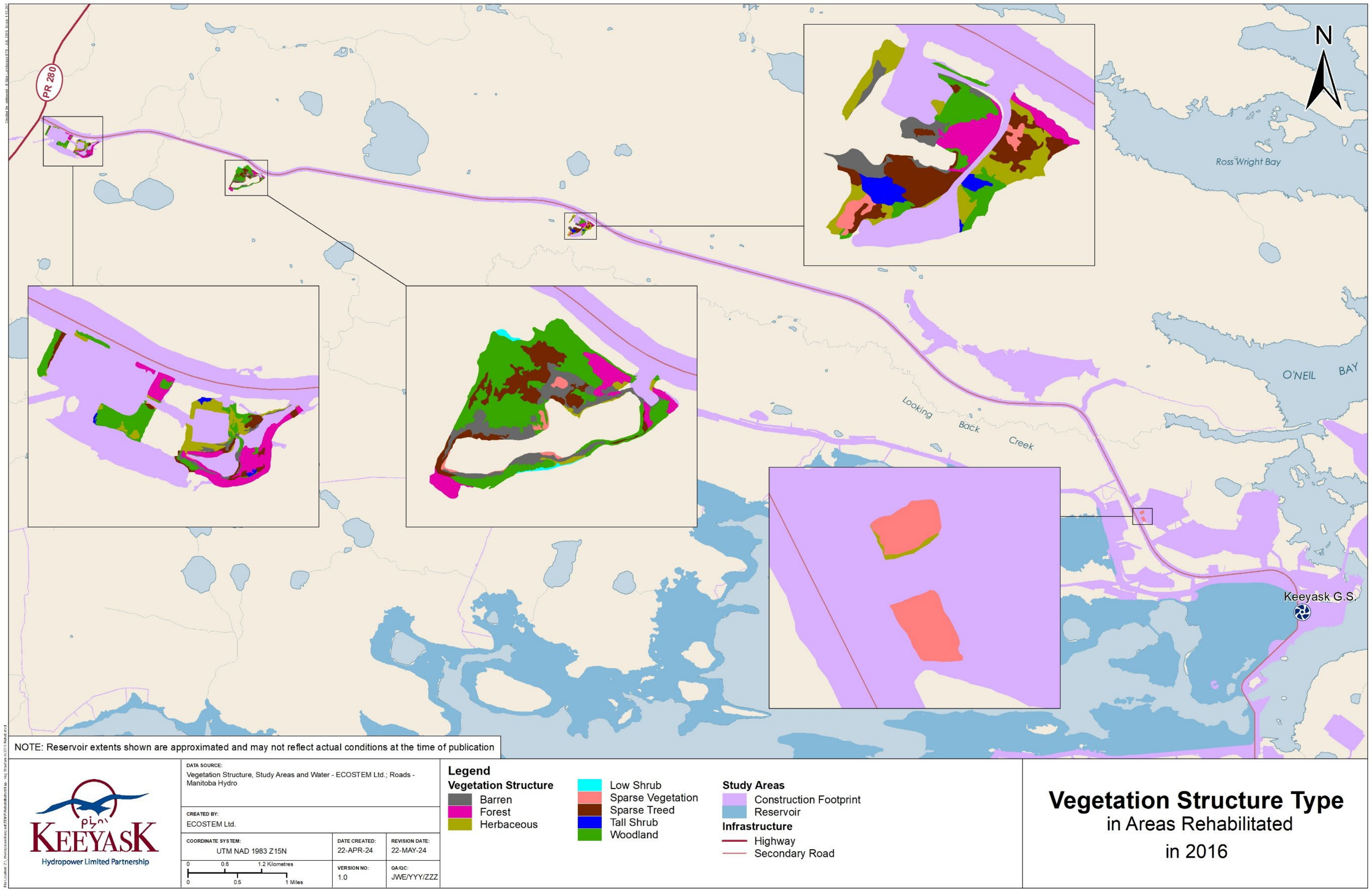
4.2.4.2 OTHER VEGETATION DEVELOPMENT

While treed vegetation structure made up approximately two-thirds of the area planted in 2016, at least very sparse tree cover was present in 99.9% of the area planted (Table 4-23). Herbaceous vegetation of varying foliage cover was also present in 99.4% of the planted area, while tall shrub and low shrub cover was present in 62.8% and 67.3% of the planted area, respectively. Nearly half of the planted areas had started to develop ground moss cover by 2023.

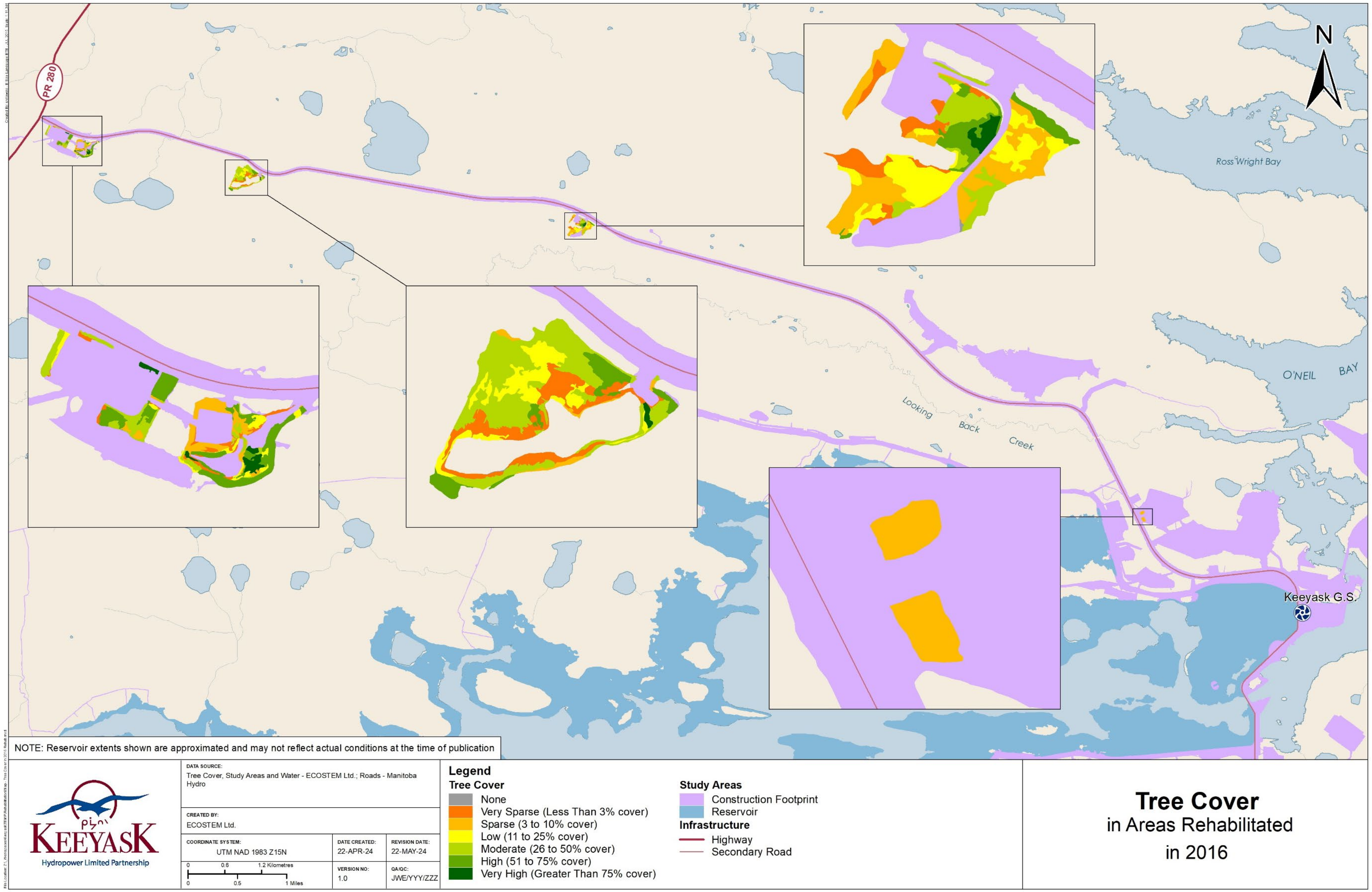
Table 4-23: Amount of area with different vegetation cover types present in 2023, in areas planted in 2016

Vegetation Cover Type	Area (ha)	Percent of Total
Tree	24.1	99.9
Tall shrub	15.1	62.8
Low shrub	16.2	67.3
Herbacious	23.9	99.4
Bryoid	10.1	41.8
Total rehabilitated area	**24.1**	

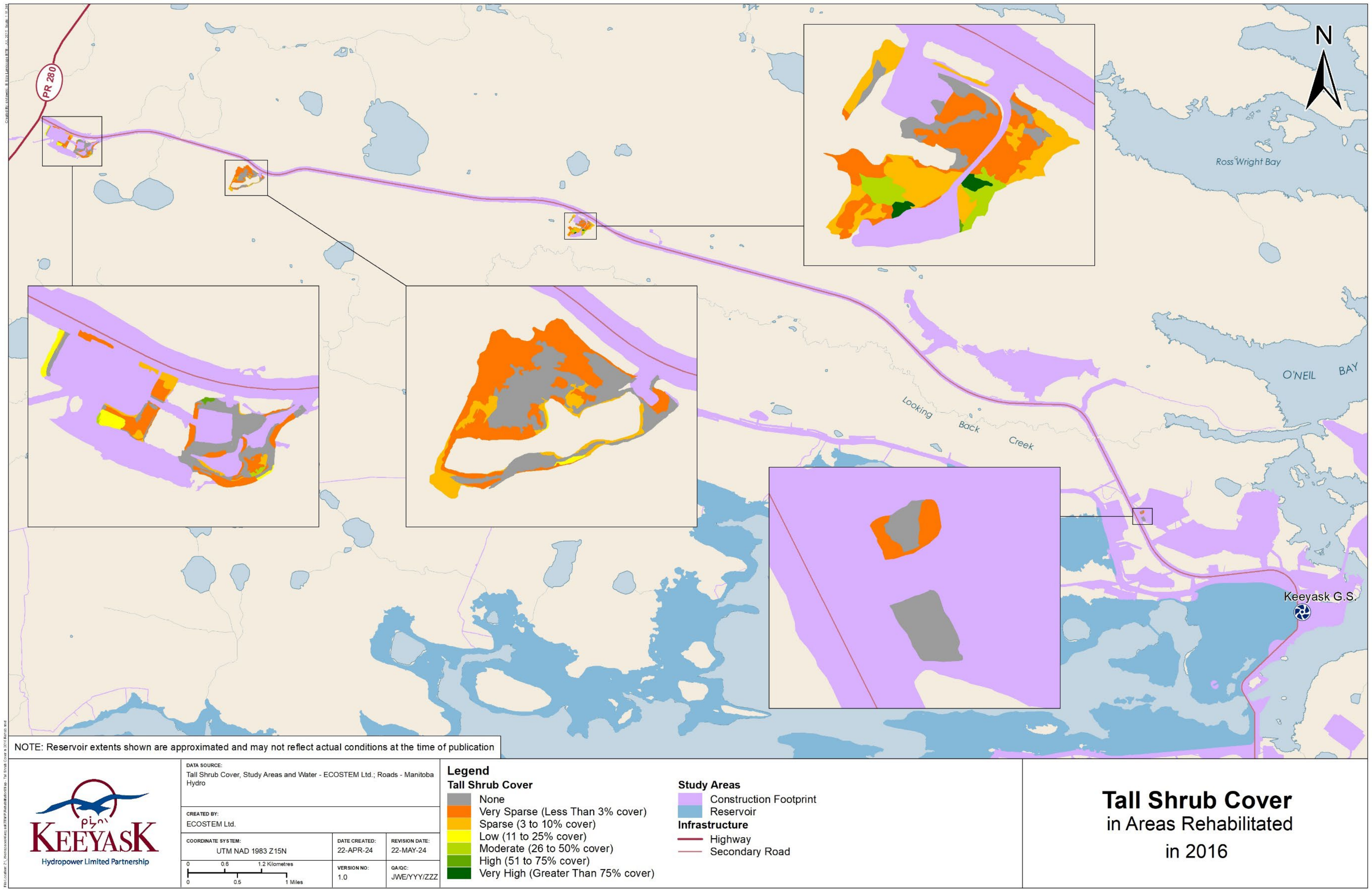
Map 4-6 to Map 4-10 shows the distribution and abundance of the different vegetation cover types in the 2016 planted areas. Most of the ground moss cover was found in areas that had developed treed vegetation structures (Map 4-10). This was also the case for tall shrub and low shrub vegetation cover, in general.



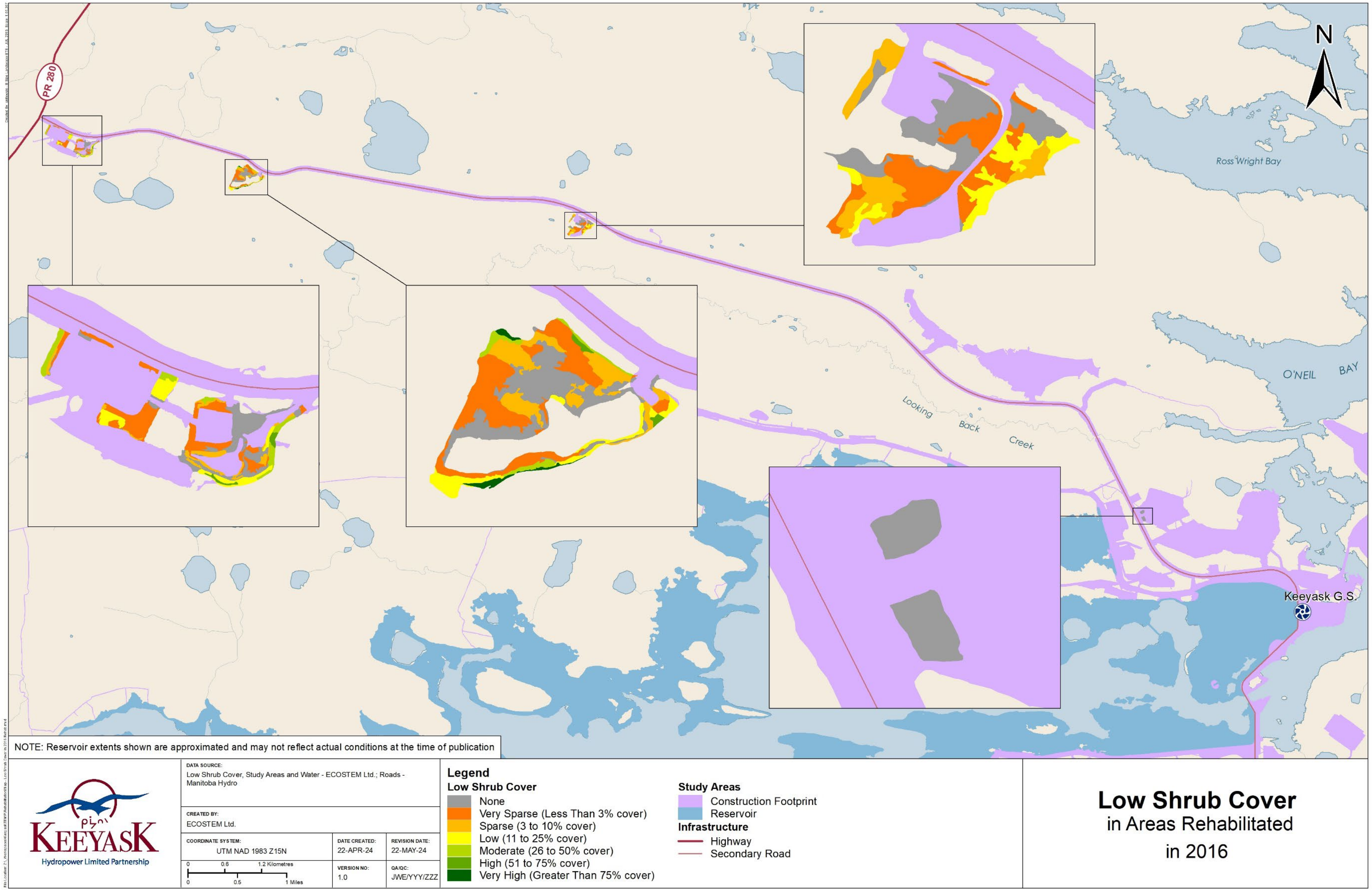
Map 4-5: **Vegetation cover type in 2023, in areas rehabilitated in 2016**



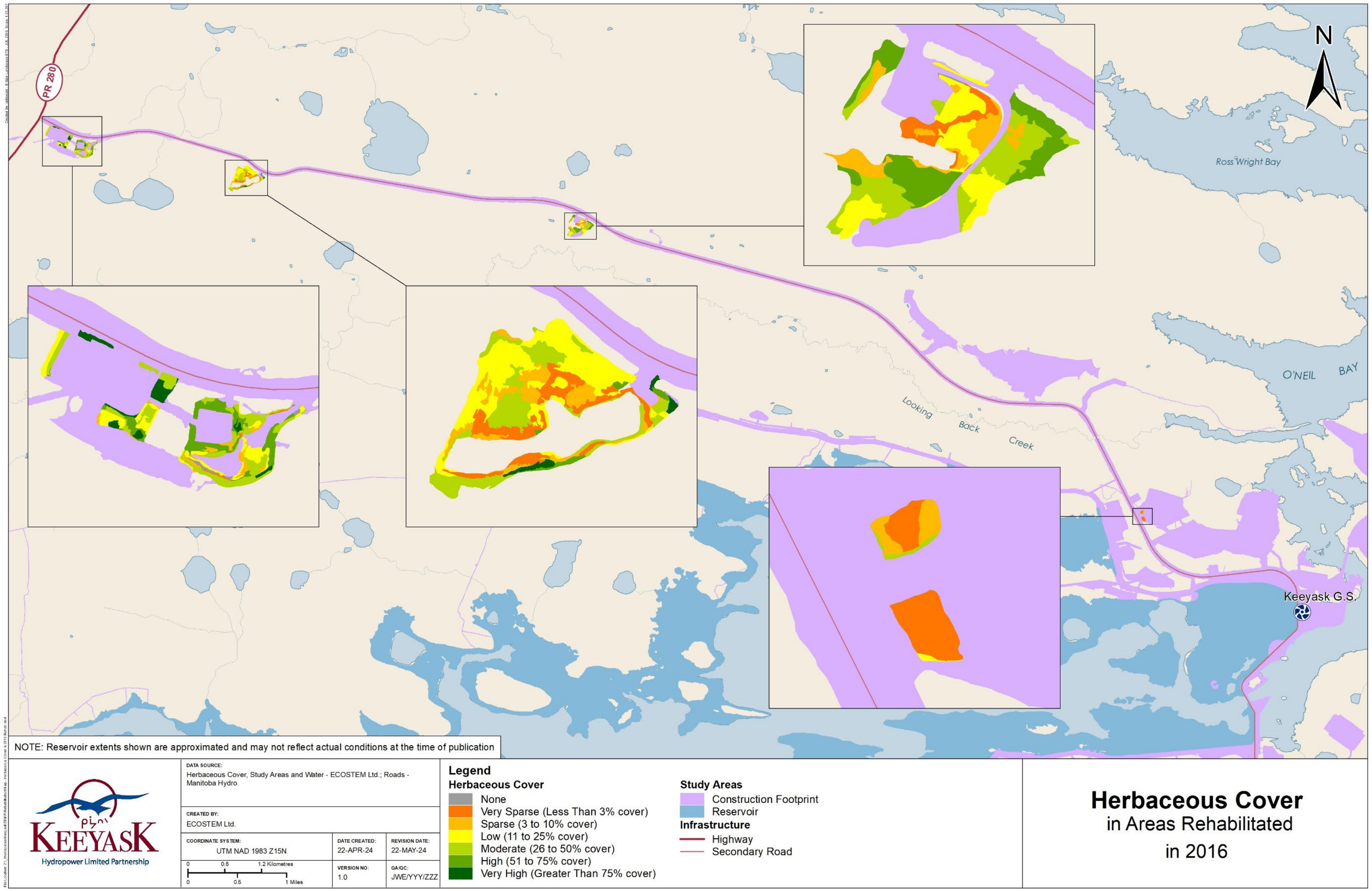
Map 4-6: Tree cover in 2023, in areas rehabilitated in 2016



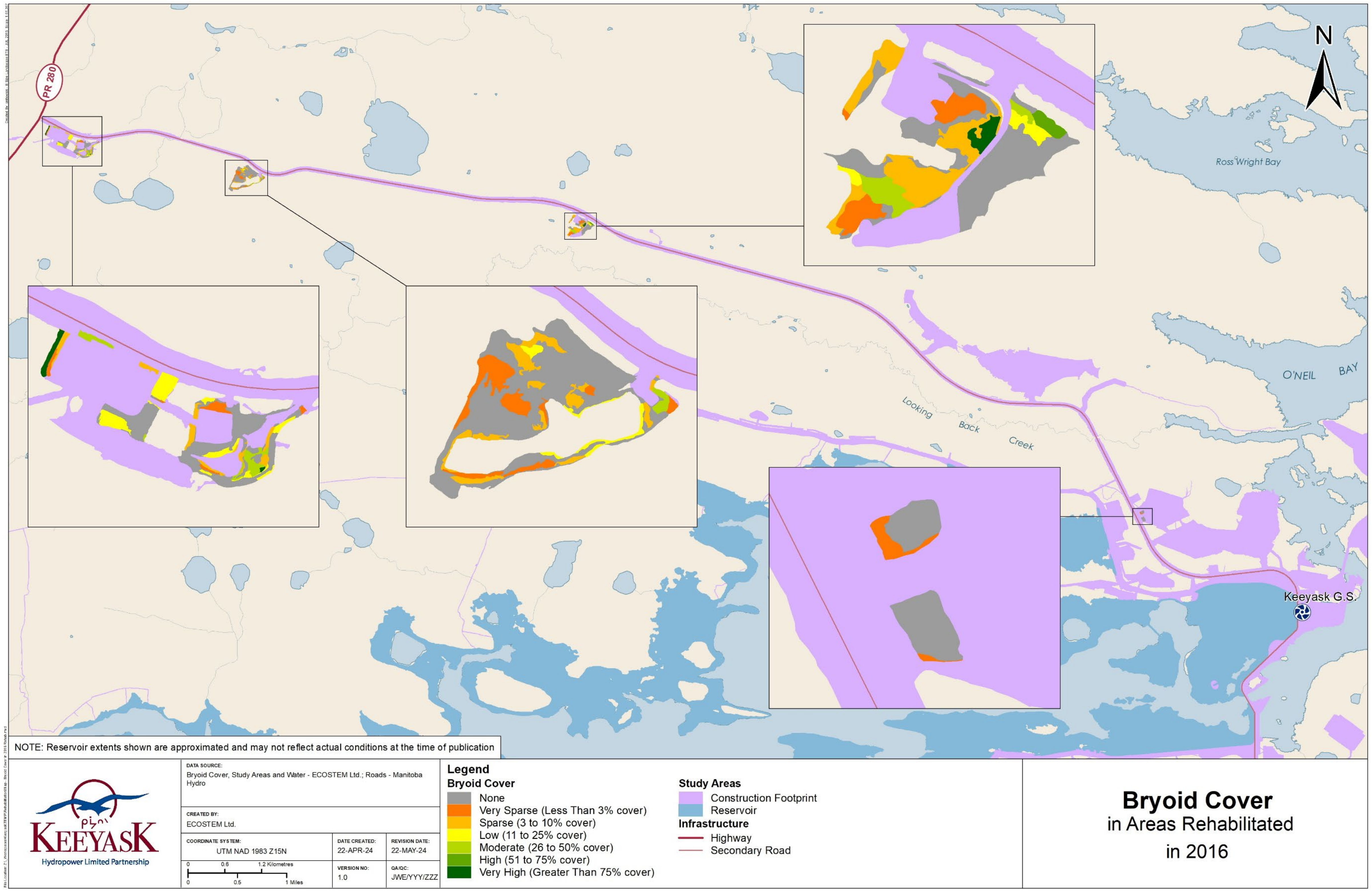
Map 4-7: **Tall shrub cover in 2023, in areas rehabilitated in 2016**



Map 4-8: Low shrub cover in 2023, in areas rehabilitated in 2016



Map 4-9: Herbaceous cover in 2023, in areas rehabilitated in 2016



Map 4-10: Bryoid cover in 2023, in areas rehabilitated in 2016

4.3 POORLY REGENERATING AREAS

4.3.1 GRASS SEEDED AREAS

Ground surveys along the North and South Access Roads and the adjacent grass seeded areas found that approximately 0.5% (2 ha) of the 434 ha of roadside area had either insufficient, or borderline insufficient vegetation cover (Table 4-24). Approximately 1.5 ha over six distinct patches was found to be insufficient, and 0.5 ha over three patches was borderline insufficient.

Table 4-24: Regeneration status of roadside areas

Regeneration Status	Number of Patches	Area (ha)[1]	Percent of Area
Insufficient	6	1.5	0.35
Borderline Insufficient	3	0.5	0.12
Adequate	Not counted	431.6	99.52
Total roadside area		**433.7**	**100.00**

Notes: [1] Total may not equal sum of rows due to rounding.

All the patches of insufficient and borderline insufficient regeneration were found along the South Access Road right of way (Map 4-11). Most of the areas surveyed were found to have adequate desirable vegetation cover in the early stages of growth. Small patches of barren or very sparse cover were present in some areas (Photo 4-11), but they appeared to mostly be due to gaps in seeding cover or from seed washing downslope, and would likely quickly fill in from adjacent vegetated areas.

Patches of insufficient or borderline insufficient regeneration were small (Photo 4-12), all with areas less than 0.5 ha. The reasons for poor regeneration in the patches appeared to be generally due to substrate conditions, active erosion (Photo 4-13), and/or a gap in grass seeding.

Photo 4-11: Regenerating seeded slope with vegetation gaps at an area surveyed for poor regeneration along the North Access Road in 2023

Photo 4-12: Insufficient and borderline insufficient vegetation cover along the South Access Road in 2023

Photo 4-13: Barren, eroding slope along the South Access Road in 2023

4.3.2 TREE PLANTED AREAS

A combination of seedling condition (Map 4-12), and live stem density (Map 4-13) was used to map the areas within the tree planting areas that were classified as poorly regenerating. Seedlings in approximately 58% of the 164 ha that was planted with trees between 2020 and 2022 were in borderline to poor condition (Table 4-25). Planting areas with poor seedling conditions (>30% dead stems) made up 24.6% (40.5 ha) of the planted area.

Table 4-25: Planting area stem condition in 2023 for areas planted between 2020 and 2022

Stem Condition	Total Area (ha)	Percent of Area
Poor	40.5	24.6
Borderline	55.6	33.8
Good	68.5	41.6
All planted area	**164.6**	**100.0**

Planting areas with estimated stem densities less than 2,500 stems/ha made up 57.4% (94.5 ha) of the total planted area (Table 4-26), and 21.5% had stem densities less than 1,000 stems/ha.

Table 4-26: Planting area stem density class in 2023 for areas planted between 2020 and 2022

Stem Condition	Total Area (ha)	Percent of Area
<1,000 stems/ha	35.4	21.5
1,000-2,499 stems/ha	59.2	35.9
2,500-9,999 stems/ha	68.4	41.5
10,000 stems/ha or greater	1.7	1.0
All planted area	**164.6**	**100.0**

Three locations had planting areas with generally poor seedling conditions, including Borrow Areas G-3 and N-5, and EMPA D27(4)-E (Table 4-27). All these locations were planted in 2020 and 2021. Nearly 71% of the planted area in Borrow Area G-3 had poor seedling condition, with borderline and good seedling condition making up 14% and 15% of the total planted area, respectively. Most of the Borrow Area N-5 planted area, as well as the adjacent EMPA D35(1)-E had borderline seedling condition. Other locations with generally borderline seedling condition included Borrow Area KM-9, and EMPAs D12(2)-E and D23(2)-E (Table 4-27). Planting areas at these same locations all had the highest proportion of area with the lowest two live seedling density classes (Table 4-28).

Table 4-27: Proportion of planted areas with different overall stem condition by location as of 2023

Location	Area Planted (ha)	Percent of Area with Stem Condition		
		Poor	Borderline	Good
Borrow Area G-3	51.3	70.7	14.2	15.0
Borrow Area N-5	20.0	13.5	86.5	-
Borrow Area KM-17	1.7	-	20.3	79.7
Borrow Area KM-9	1.6	-	100.0	-
Borrow Area S-17a	3.5	-	-	100.0
EMPA D12(2)-E	16.4	-	100.0	-
EMPA D16	17.2	-	-	100.0
EMPA D17-E	3.1	-	-	100.0
EMPA D23(1)-E	5.4	-	-	100.0
EMPA D23(2)-E	1.3	-	100.0	-
EMPA D27(4)-E	19.1	7.9	15.1	77.0
EMPA D28(1)-E	7.1	-	41.6	58.4
EMPA D31(1)-E	2.1	-	-	100.0
EMPA D35(1)-E	5.8	-	94.6	5.4
Haul Road 2	0.6	-	-	100.0
Work Area C	5.3	-	-	100.0
Work Area X (East)	3.0	-	-	100.0
All planted areas	**164.6**	**24.6**	**33.8**	**41.6**

Notes: "-" means and absence, where as "0" indicates a number that rounds to zero.

Table 4-28: Proportion of planted areas with different stem density classes by location as of 2023

Location	Area Planted (ha)	Percent of Area with Density Class (stems/ha)			
		<1,000	1,000-2,499	2,500-9,999	10,000+
Borrow Area G-3	51.3	55.9	40.9	0.5	2.7
Borrow Area N-5	20.0	13.5	86.5	-	-
Borrow Area KM-17	1.7	-	-	100.0	-
Borrow Area KM-9	1.6	100.0	-	-	-
Borrow Area S-17A	3.5	-	48.7	51.3	-
EMPA D12(2)-E	16.4	-	-	100.0	-
EMPA D16	17.2	-	6.6	93.4	-
EMPA D17-E	3.1	-	-	100.0	-
EMPA D23(1)-E	5.4	-	-	100.0	-
EMPA D23(2)-E	1.3	-	-	100.0	-
EMPA D27(4)-E	19.1	12.4	42.9	43.1	1.6
EMPA D28(1)-E	7.1	-	0.1	99.9	-
EMPA D31(1)-E	2.1	-	10.4	89.6	-
EMPA D35(1)-E	5.8	-	100.0	-	-
Haul Road 2	0.6	-	-	100.0	-
Work Area C	5.3	0.3	72.0	27.7	-
Work Area X (East)	3.0	-	-	100.0	-
All planted areas	164.6	21.5	35.9	41.5	1.0

Notes: "-" means and absence, where as "0" indicates a number that rounds to zero.

Figure 4-7 shows how different ground-surveyed conditions were distributed across the different stem condition and stem density classes. For each condition, stacked bars show the the percentage of that condition's area that fell within the areas of different seedling conditions or density classes. Patterns in the distributions suggested that planting areas with poor and borderline seedling condition and lower seedling densities tended to have one or more of the following conditions as a proportion of its total area: lower naturally regenerating vegetation cover, coarser, drier substrates, a lack of organic material, more compacted soils, and/or more eroding area (Figure 4-7).

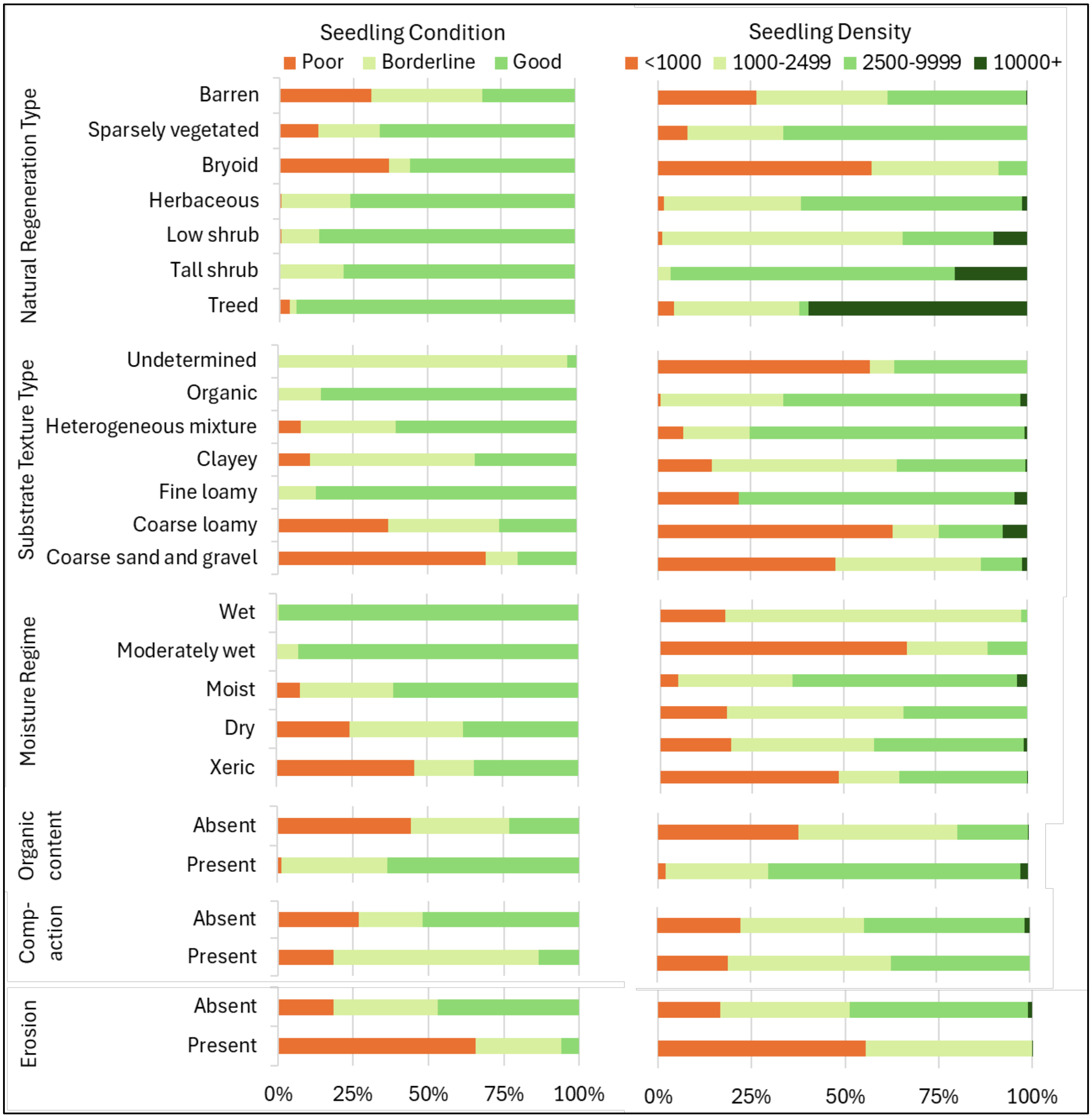
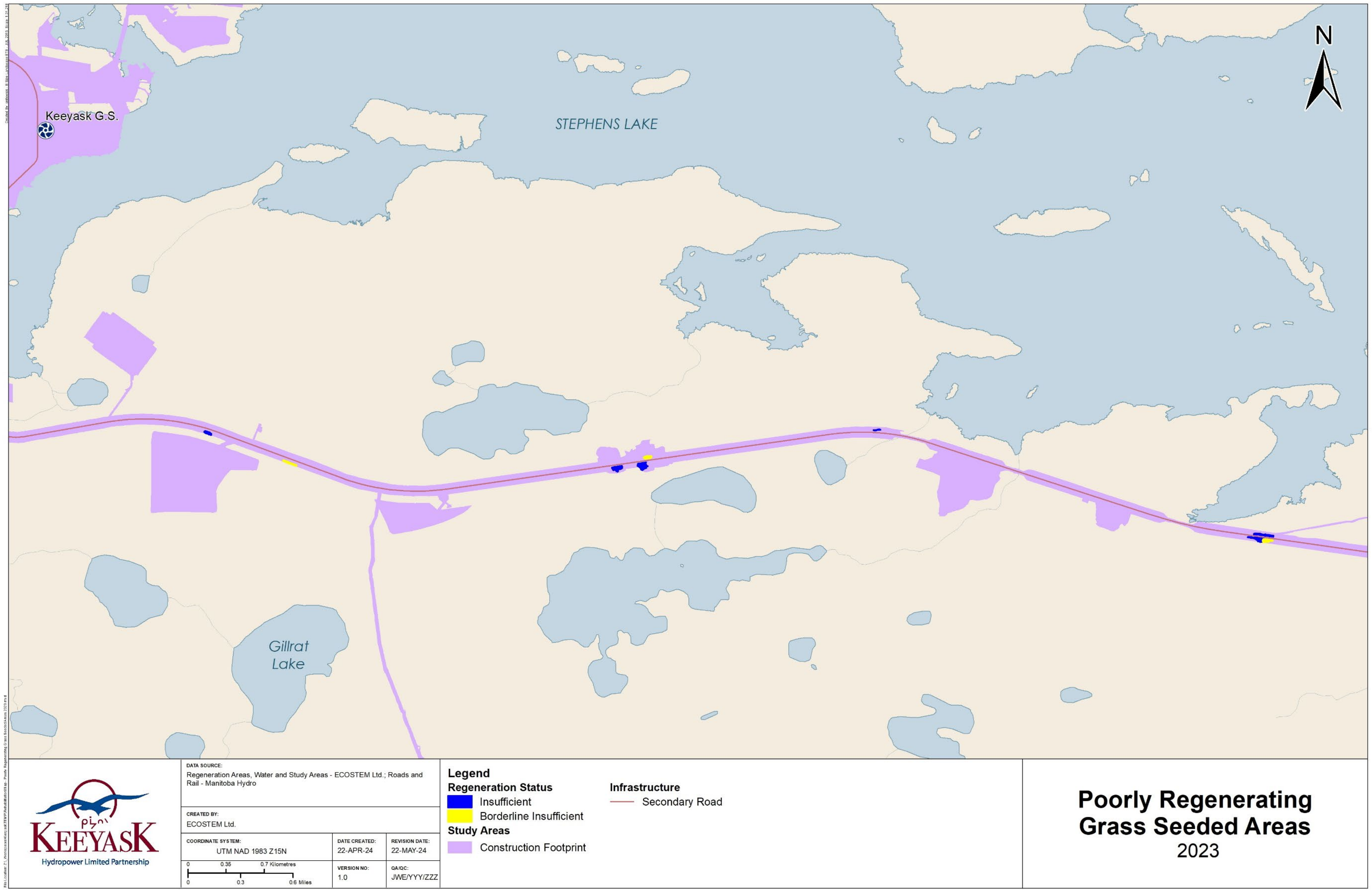
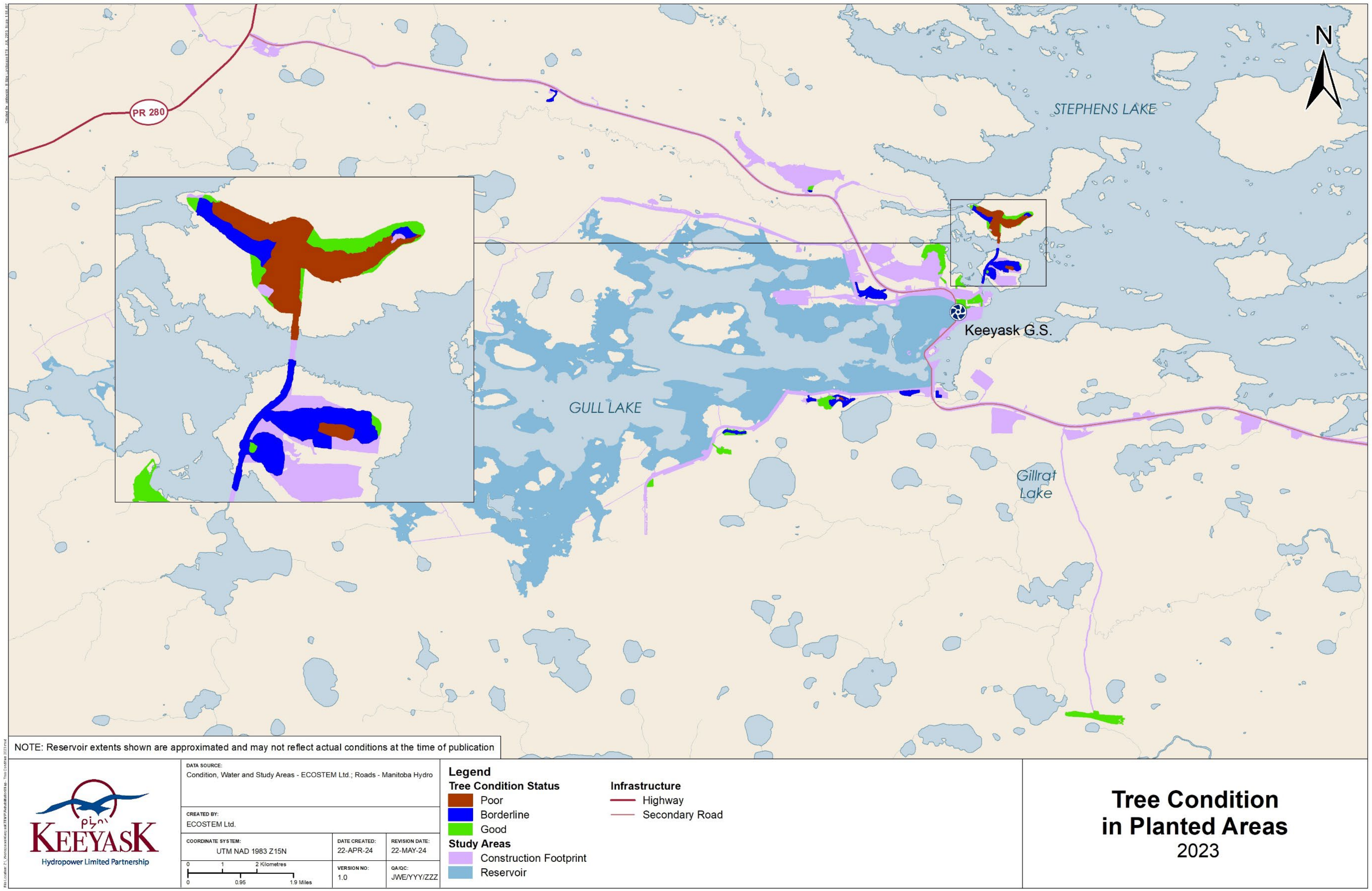


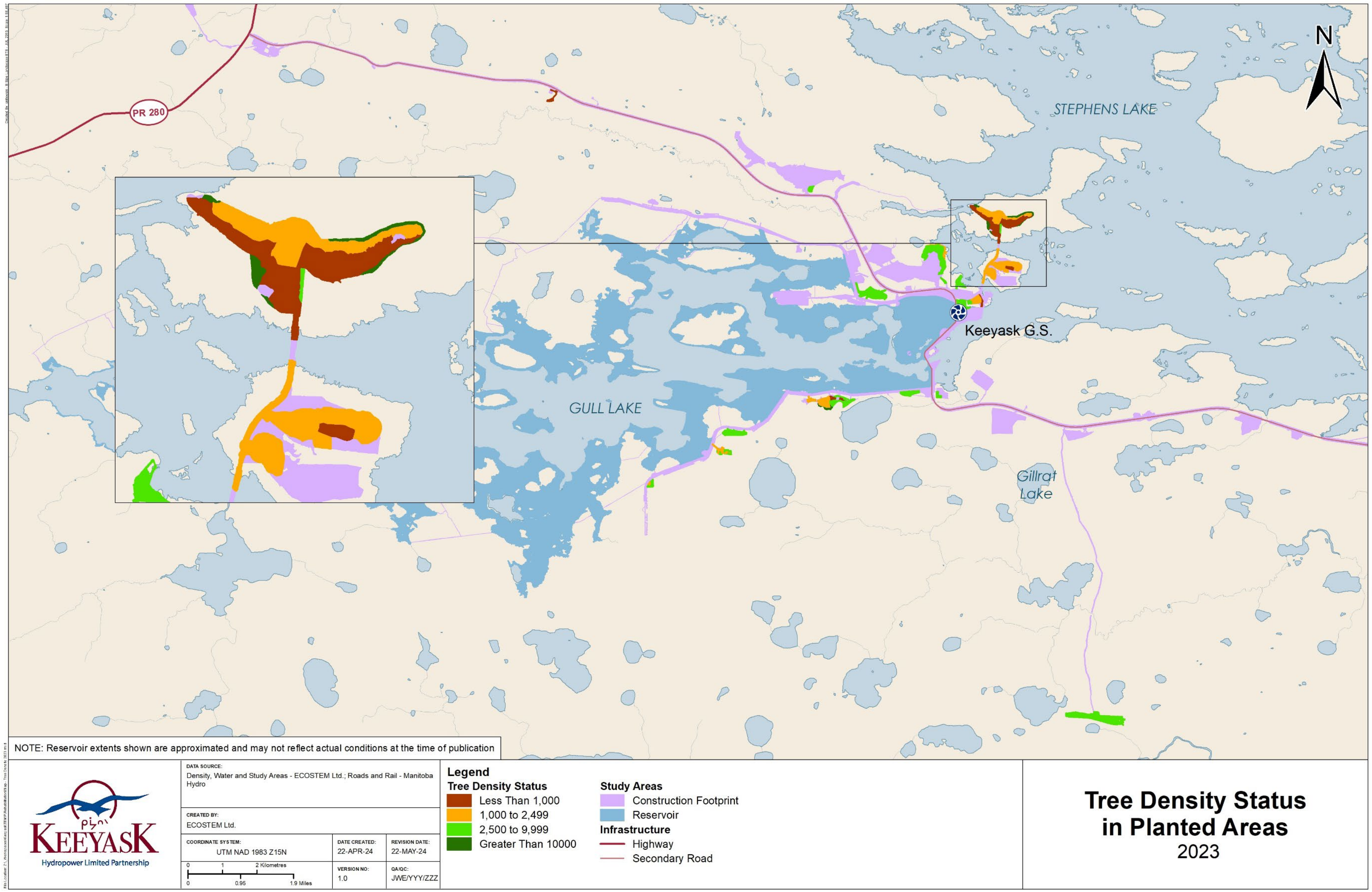
Figure 4-7: Distribution of natural regeneration and substrate conditions across planting areas in 2023, with different seedling condition and density statuses



Map 4-11: **Grass seeded areas that are poorly regenerating as of September 2023**



Map 4-12: Tree condition in planted areas as of September 2023



Map 4-13: Tree density status in planted areas as of September 2023

5.0 DISCUSSION

5.1 VEGETATION REGENERATION

The 2023 updates in vegetation cover mapping for the temporary Construction Footprint resulted in substantial differences in reported areas for different vegetation cover types for 2022 (ECOSTEM 2023). However only a portion of these differences were due to true changes in vegetation cover or structure. One reason for this was that the total sizes of the temporary and permanent Project areas were revised by Manitoba Hydro. The other reason was that some of the mapping was refined following interpretation of ground data and drone imagery collected in 2023. Drone data collection provided more accurate data for this purpose.

Areas that were identified to have actually changed in vegetation cover class or structure from 2022 to 2023 encompassed approximately 19% of the temporary Project areas. This was substantially higher than the 0.2% change reported for 2021 to 2022 (ECOSTEM 2023). This was a positive change because nearly all of it represented an increase in vegetaton cover, or a change to a more successionally advanced vegetation structure.

The vast majority of this change was a result of natural regeneration. While a large total area was planted between the 2022 and 2023 surveys, the increase in vegetation cover due to the small seedlings was generally not enough to exceed the 10% upper limit of the barren cover class.

Small areas where cover decreased were generally due to rehabilitaton activities removing vegetation while doing site preparation for new plantings (ECOSTEM 2023).

The large increases in vegeaton cover were anticipated, since Project construction activity has finished and large portions of the temporary Project areas have already undergone site preparation and planting or grass seeding.

5.2 TREE PLANTING AREAS

5.2.1 EVALUATION OF THE DRONE DATA COLLECTION METHOD

Drone and transect data collection were implemented in many of the same survey areas in 2023 to evaluate whether drones could replace ground transect data collection under some field conditions. The impetus for this trial was that ground transect data collection can be quite time consuming. Drone-collected data had the potential to provide more or similarly accurate data at a lower cost.

The trial conducted in 2023 indicated that the drone data collection method was as effective as ground transect collection for measuring some of the monitoring parameters under certain conditions. Comparison of stem densities derived from the 2023 drone census with 2022 densities estimated from transect data across the planting areas found that the pattern in 2023 matched that of 2022 (ECOSTEM 2023). Conversely, this confirmed that the ground transect data collection produced a reasonably accurate and precise estimate of the true stem density in the planting areas. Furthermore, the similar to estimated live stem densities, particularly when adjusted for detection bias, demonstrated that the drone method is a viable method for monitoring live seedling stem density for the prescription implementation study in areas like those surveyed in 2023.

Drone detection rates for seedlings were evaluated for different field conditions. This evaluation found that rates drop substantially with increasing amounts of natural regeneration (Photo 5-1). However, data from the 2016 planted areas also showed that once stems increase in size beyond the seedling stage, detection rates increase again, even in areas with substantial natural regeneration.

Detection of older, dead seedlings in drone imagery was unreliable , regardless of site conditions. This was not considered to be a limitation for monitoring stem survival or recovery success, but could be a limitation for monitoring prescription implementation.

The 2023 drone survey results generally indicated that the ground transect data collection could be used for the first year of prescription implementation surveys in all planted areas. For subsequent years, the transect method should be used in areas with substantial naturally regenerating vegetation (i.e., more than sparse cover). For other planting areas, drone survey methods are feasible starting in the second year of prescription implementation monitoring. For recovery success monitoring, drone survey methods are feasible for all areas provided most of the trees have grown beyond the seedling stage.

The conclusion from the 2023 trial was that substituting drone for ground transect collection was technically feasible for a number of conditions. The next step is to evaluate the subset of these conditions where such a substitution makes economic sense. This evaluation will be completed prior to the 2024 fieldwork, and will determine the conditions where drone data collection will replace ground transects.

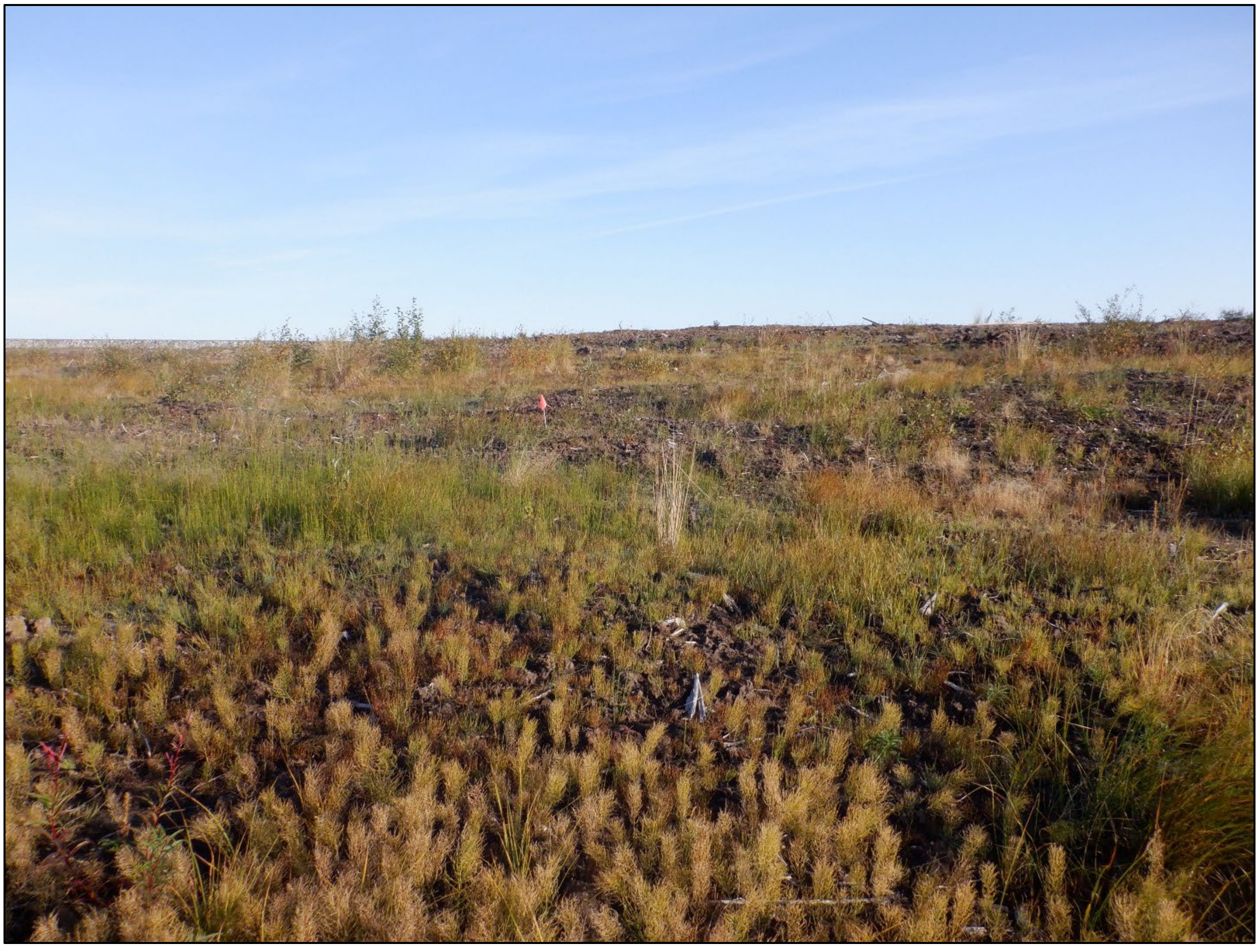


Photo 5-1: Naturally regenerating vegetation in 2023 in EMPA D23(1)-E

5.2.2 PRESCRIPTION IMPLEMENTATION AND REGENERATION STATUS

Tree planting prescription implementation was more successful in 2022 than in either 2020 or 2021. In the latter two years, only one rehabilitation location had a live stem density that met or exceeded the target at a 95% confidence level (ECOSTEM 2023). In 2022, estimated planted stem densities met or exceeded the target at a 95% confidence for six out of the 11 rehabilitation locations, and estimated planted stem densities were higher than 2,500 stems/ha for all but two of the remaining areas.

Estimated stem densities for areas planted in 2022 suggested that the actual planting spacing was generally somewhat closer than prescribed. The higher planting density will help to offset the effect of early stem mortality if it occurs, in turn helping to keep surviving stem density above the target.

Planted stem density was not the primary factor restricting achieving the stem density target. While planted stem density in most of the area planted in 2020 and 2021 met or exceeded the prescribed planting density, early stem mortality reduced live stem density below the target. One cause for the early mortality was localized erosion, particularly in Borrow Area G-3 (Photo 5-2). Other possible causes for this mortality were substrate type and weather conditions. The 2021 planting areas were largely in open borrow areas with dry and well-drained, coarsely textured substrates. Xerix soil moisture presents one of the most difficult growing conditions for the planted tree species. Xeric soils coupled with 2021 being a drought year could have caused many of the seedlings to succumb to abnormally dry conditions shortly after planting as roots did not have time to develop.

Early stem mortality was relatively low in the locations planted in 2022 compared to locations planted in 2020 and 2021. A possible reason for lower mortality in 2022 was more favourable weather conditions. A second factor was better site preparation based on data collected for the *Vegetation Rehabilitation Plan* rehabilitation prescriptions. Better site preparation may have also contributed to lower early seedling mortality (more detailed discussion for this is provided in Section 5.3).

For locations planted in 2020 and 2021, there were no significant decreases in stem density, but there was an apparent decrease in Borrow Area KM-9 based on the drone census. This was at least partly due to stem mortality, which comprised approximately one-quarter of the stems that were mapped. However, it was also possible that the 2022 stem density estimate for that area (ECOSTEM 2023) was too high. A possible explanation for this was that, by coincidence, transects may not have extended through patches of lower planting density, or early seedling mortality. However, based on comparing the drone census in other planting areas to estimates from the previous year, this does not appear to be the issue in most cases.

Some areas were replanted in 2023. This produced one large, significant increase in density for both jack pine and black spruce observed between 2022 and 2023 in EMPA D23(1)-E.

Natural regeneration was the reason for the two remaining increases stem densities in planting areas that were adjacent to seed sources.

Photo 5-2: Jack pine seedlings growing near erosion channels in Borrow Area G-3 in 2023

5.2.3 RECOVERY SUCCESS IN 2016 PLANTING AREAS

Seven years following the 2016 tree planting, none of the area targeted for forest habitat had an estimated live stem density of 10,000 stems/ha or greater at a 95% confidience level, although all of the area that was targeted for forest habitat did have a stem density significantly higher than the target for woodland habitat. For areas where black spruce woodland was a target habitat type, estimated live stem density fell below the target of 2,500 stems/ha.

Tree cover and vegetation structure mapping indicated that regeneration was patchy within the planted areas.

While total areas of the various habitat types in 2023 were short of their targets, monitoring in 2023 found several positive indicators that regeneration was on track to achieve close to the target areas for the different target habitat types.

First, considering that only seven years have passed since tree planting, based on stem density and health, 78% of the area have already developed into at least a woodland habitat type with the correct species mix. Some of the non-treed structure types have stem densities exceeding woodland targets due to differences in tree growth rates for different areas with different substrate conditions.

A second positive indicator was a very low amount of recent tree mortality detected in 2023. This indicated that the tree stems currently present were well established, and unlikely to reduce through mortality barring catastrophic erosion or drought events.

A third positive indicator is the presence of naturally regenerating tree species in many of the planting areas, and the species are consistent with the target habitat type. Natural regeneration will be an offset to planted stem mortality.

Overall, recovery success monitoring in 2023 suggests that the majority of the area planted in 2016 is on track to achieve at least a woodland habitat, interspersed with patchy forest habitat, provided there are not catastrophic events that result in tree mortality. Seven years is generally too short a period of time for noticeable soil development to occur, but the presence of ground moss and other low vegetation cover is a positive step in soil profile development.

5.3 POORLY REGENERATING AREAS

Vegetation structure mapping for grass seeded areas generally suggested that barren and sparsely vegetated areas were still relatively widespread in 2023 (27% along the NAR and 43% along the SAR; see Section 4.1). Ground surveys found that the vast majority of area seeded with grass had sufficient regeneration, and only a small proportion of the area mapped as poorly regenerating in 2022 actually had insufficient or borderline insufficient regeneration in 2023. This difference was largely due to ground data collection showing that some low vegetation cover was not detectable from helicopter photography. Where present, insufficiently regenerating patches were small, and many of them are expected to either fill in naturally over time. The limitation of helicopter photography was not a general one but limited to patches containing short, small-leaved vegetation that was not easily distinguished from the underlying substrate.

Table 5-1 describes the conditions in each poorly regenerating patch, and provides the most likely reasons for poor regeneration, and recommended treatments, if required, to increase vegetation cover.

Table 5-1: Conditions in insufficiently and borderline insufficiently regenerating patches along road side slopes in 2023, likely reasons for poor regeneration, and recommended treatments

Patch ID	Patch Size (ha)	Regeneration Status	Vegetation Cover	Substrate	Reasons for Poor Regeneration	Recommended Treatment
1	0.12	Insufficient	Very sparse grass and herbs	Clay, gravel and organic mixture	Compacted substrate	Decompact substrate and seed with grass
3	0.13	Borderline	Sparse tall and low shrub, herbs and moss	Clay over sandy clay	Compacted substrate	Leave to naturally regenerate
4	0.32	Insufficient	Very sparse grass	Silty sand with gravel	Rapidly drained coarse material	Soil amendment with organic material and seed with grass
5	0.44	Insufficient	Very sparse grass and moss	Silty sand with gravel	Rapidly drained coarse material	Soil amendment with organic material and seed with grass
6	0.18	Borderline	Patchy sparse grass and moss	Sandy clay loam with gravel	Uncertain. Possible that water flow removed seeds	Seed with grass
7	0.05	Insufficient	Very sparse herbs	Sandy clay and gravel	Compacted substrate and erosion	Grade slope, amend soil with organic material and seed with grass
8	0.33	Insufficient	Very sparse herbs with elegant hawksbeard	Sandy clay and gravel	Signs of previous erosion, possible gap in hydroseed cover	Leave to naturally regenerate
9	0.22	Borderline	Sparse herbs	Sandy clay and gravel	Signs of previous erosion, possible gap in hydroseed cover	Leave to naturally regenerate
10	0.26	Insufficient	Barren	Clay and gravel	Compacted substrate and erosion	Grade slope, amend soil with organic material and seed with grass

In the tree planted areas, drone imagery provided some valuable insights into site-related factors that led to poor seedling survival in certain areas. Poor seedling conditions and density were generally a result of insufficient site preparation, seedling loss due to erosion, or a combination of these. It is also possible that drought conditions in 2021 contributed to early seedling mortality in the more xeric sites. Seedling mortality and lower than target stem densities were apparent in most of the poorly regenerating planting areas in the first prescription implementation surveys (ECOSTEM 2023).

In many of the areas planted in 2022, it was apparent that some of these site preparation issues were addressed, and this appeared to be reflected in the lower mortality rates and higher stem densities in those areas one year after planting.

It is recommended that, if feasible for the location, poorly regenerating planted areas be re-planted after addressing site preparation issues (Photo 5-2). Site-specific recommendations will be provided if this option is pursued.

6.0 SUMMARY AND CONCLUSIONS

Among other benefits, terrestrial habitat rehabilitation mitigates adverse Project effects on terrestrial habitat, ecosystems and plants (e.g., habitat loss, erosion, invasive plant spread), restores wildlife habitat and improves aesthetics. Terrestrial habitat is being rehabilitated in areas not required for Project operation and in some permanent Project areas (e.g., access road side slopes). The general approach is to regenerate areas to a native habitat type suitable for the local conditions and rely on natural regeneration as much as possible, while giving preferences to the priority habitats with the highest cumulative Project effects.

The overall process to arrive at a site-specific rehabilitation prescription is to: develop the *Vegetation Rehabilitation Plan* (VRP); identify the Project areas that will receive some form of rehabilitation effort; commence tree planting in locations designated to become forest or woodland habitats, collect field data to support site-specfic target habitat types and rehabilitation prescriptions, and document those types and prescriptions. The VRP provides the overall approach for habitat rehabilitation based on mitigation commitments in the Project's EIS and EnvPPs.

Following the final determination of the areas required for Project operation, vegetation cover mapping for the temporary Project areas (and permanent areas targeted for low vegetaton cover) in 2023 was revised and updated to reflect cover in areas that are actually available for habitat rehabilitation. In addition, field data gathered in 2023 in support of the VRP provided information that was used to improve the accuracy of vegetation regeneration mapping throughout the Construction Footprint. For the first time in 2023, drones were used to collect seedling data in areas monitored for the habitat recovery success study, and selected planting areas for the prescription implementation study.

Evaluation of overall revegetation in the temporary Project areas in 2023 found that approximately 58% of the entire temporary Project area had at least sparse vegetation cover (>10%). Most of the barren area was distributed in portions of the the footprint that had not yet been, or were very recently rehabilitated. Vegetation cover changed for approximately 19.3% of the temporary Project areas since 2022. In almost all cases, this was due to an increase in vegetation cover, or a change in structure to a more advanced successional stage.

In 2023, tree regeneration surveys were conducted in 11 rehabilitation locations that were planted in 2020, 2021 and 2022. All of the locations planted in 2022 were sampled by ground transects. For locations planted in 2020 and 2021, all tree stems were mapped from drone imagery for most of the planting areas in Borrow Areas G-3 and N-5, and the single planting area in Borrow Area KM-9. The remaining planting areas in G-3 and N-5 (peripheral areas with higher natural regeneration), and all planting areas in the remaining locations were sampled by ground transects.

In all three years, jack pine and black spruce trees were to be planted at a spacing of 2 m x 2 m in all planting areas. Monitoring found that the estimated planted stem density met or exceeded the prescribed density for six of the 11 locations planted in 2022 (95% confidence level). One additional location sampled with a single transect had a density well above the target.

Ultimate success at achieving the target forest or woodland habitat type at a given site depends on the degree of planted stem mortality and the amount of natural regeneration. As of September 2023, live stem density (including natural regeneration) for seven out of the 16 locations planted since 2020 met or exceeded the target stem density.

To date, natural tree regeneration has been confined to a few planting areas. In these areas, natural regeneration was a substantial contributor to the live stem density. This natural regeneration was concentrated in areas where both only vegetation clearing occurred (i.e., the surface organic layer and some seedlings remained intact) and there was an adjacent uncleared area with a seed source. Natural tree regeneration will likely continue in these areas, increasing total stem densities.

For ground surveyed planting areas, planted jack pine stem mortality ranged from 0% to 69% depending on the planting area, while planted black spruce stem mortality ranged from 0% to 50%. Overall mortality was highest in EMPA D-27(4)-E. In the drone surveyed planting areas, overall jack pine stem mortality was highest in Borrow Area G-3, ranging from 1% to 72% depending on the planting area.

In 2023, recovery success monitoring was carried out for the areas planted in 2016, which is seven years after tree planting. This monitoring found that all the area targeted for forest habitat had an average stem density significantly higher than the target prescribed for woodland habitat. The area targeted for woodland habitat had estimated stem densities below the prescribed target.

Other types of plant cover important for achieving the target habitat type have developed over almost all of the area planted in 2016. By 2023, herbaceous vegetation and ground moss developed over approximately 99.4% and 42%, respectively, of the area rehabilitated in 2016.

Overall, recovery success monitoring found several positive indicators that much of the area was on track to achieve some combination of forest and woodland cover. Seven years was too short a time for substantive soil development to occur.

Ground surveys were conducted in grass seeded areas to confirm if areas that appeared to be poorly regenerating in aerial images actually had insufficient vegetation cover. These surveys found that the vast majority of the area mapped as poorly regenerating in 2022 had sufficient regeneration in 2023. This was not surprising as the 2022 mapping was based on remote sensing and helicopter photography, and the report highlighted the accociated uncertainties. This was why a ground survey of selected areas was conducted in 2023. Additionally, another year had passed to facilitate vegetation cover growth. In 2023, insufficient or borderline insufficient regeneration was limited to small patches comprising only 2 ha (0.5%) of the seeded roadside areas. These patches were generally a result of substrate conditions or active erosion.

Tree planted areas with poor or borderline seedling condition covered approximately 58% of the total area planted between 2020 to 2022. Approximately 57% of the same area had overall live stem densities less than 2,500 stems/ha. Most of the poorly regenerating planted area was in Borrow Areas G-3 and N-5, and EMPA D27(4)-E.

Ground surveys in the planted areas found that locations with poor and borderline seedling condition and lower seedling densities tended to have one or more of the following conditions as a proportion of its total area: lower naturally regenerating vegetation cover, coarser, drier substrates, a lack of organic material, more compacted soils, and/or more eroding area.

It is recommended that, if feasible, poorly regenerating planted areas be replanted after additional site preparation is carried out.

A novel task for the 2023 monitoring was to conduct a trial to evaluate the potential for substituting drone for ground transect data collection for selected conditions. Results indicated that this was technically feasible. In fact, drone-collected data was more accurate and provided additional information for some conditions, and is at least as informative for additional conditions. The next step is to evaluate the conditions where a drone-for-ground transect substitution provides the best balance between information provided and economics. This evaluation will be completed prior to the 2024 fieldwork, and will determine the conditions where drone data collection will replace ground transects.

Rehabilitation implementation and regeneration monitoring will continue in 2024.

7.0 LITERATURE CITED

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APPENDIX 1:
ADDITIONAL REHABILITATION RESULTS

Table 7-1: Estimated live stem densities in the rehabilitation locations planted between 2020 and 2022 as of September 2023

Location	Number of Transects[1]	Mean density (stems/ha)[2]	Standard Deviation
Borrow Area G-3[3]	37	**18,966**	21,839
Borrow Area N-5	1	1,017	-
EMPA D-12(2)-E	**17**	**3,418**	574
EMPA D-16(1)-E	**27**	2,202	1,037
EMPA D-17-E	**5**	2,733	1,232
EMPA D-23(2)-E	**3**	3,498	861
EMPA D-28(1)-E	**27**	**3,447**	1,169
EMPA D-31(1)-E	**5**	2,944	626
Borrow Area E-1	59	**4,118**	2,736
EMPA D-23(1)-E	**11**	3,216	1,518
EMPA D-27(4)-E	45	2,973	2,434
Borrow Area KM-17	**4**	**3,731**	687
Haul Road 2	1	4,293	-
Borrow Area S-17a	15	**4,050**[3]	2,884
Work Area C	**15**	*1,665*	1,385
Work Area X (East)	**4**	**3,581**	485

Notes: Values presented are rounded to a nearest natural number. [1]Bolded values indicate the data associated with the transects met the assumption of normality. [2]Bolded values indicate mean is significantly greater than 2,499 stems/ha at α = 0.05 using a one-tailed t-test; *Italicized* values indicate mean is significantly less than 2,500 stems/ha at α = 0.05. [3]Wilcoxon signed rank test used because assumption of normality not met, and number of samples is <30. [3] Only the planting areas sampled by ground transect.

Table 7-2: Results of drone survey evaluation in 2023 comparing live stem densities derived from ground and drone seedling tallies along the same transect in Borrow Area G-3 planting areas with different conditions

Planting Area	Site Condition	Number of Transects	Average Density from Transect	Average Density from Drone	Percent of Ground Tally
1	Sparse natural herbaceous cover	3	1,924	1,821	95
2	Barren, poor seedling condition	3	2,834	1,968	69
4	Barren, moderate seedling condition	10	1,718	1,396	81
5	Sparse herbacious and woody surface organic cover	7	2,774	1,602	58
6	Moderate to dense herbacious and woody natural regeneration	10	15,249	4,039	26
7	Sediment deposits with poor seedling condition and high mortality	6	963	338	35
8	Moderate to dense herbacious and woody natural regeneration	9	19,805	6,609	33

Table 7-3: Total live stem densities in the rehabilitation locations planted in 2020 and 2021 and surveyed by drone in September 2023

Location	Planting area	Year Planted	Area (ha)	Total Density (stems/ha)	
				Black spruce	Jack pine
Borrow Area G-3	1	2020	0.9	129	2,006
	2	2020	0.8	-	2,159
	4	2020-2021	9.2	50	759
	5	2020	5.1	2	1,881
	7	2020	3.1	1	680
	9	2021	4.6	10	915
	10	2021	11.7	7	1,063
	11	2021	2.4	-	1,221
	13	2021	0.3	9	339
	14	2021	9.9	3	497
	20	2021	2.0	6	859
Borrow Area KM-9	22	2020	1.6	55	661
Borrow Area N-5	1	2021	12.9	-	1,584
	3	2021	2.7	-	889
	4	2021	1.4	-	1,258
	5	2021	3.1	-	1,506
EMPA D-35(1)-E	6	2021	5.5	8	1,283
	7	2021	0.3	-	2,227

Notes: Values presented are rounded to a nearest whole number. "-" means the species was not present, where as "0" signifies that the species was recorded dead.