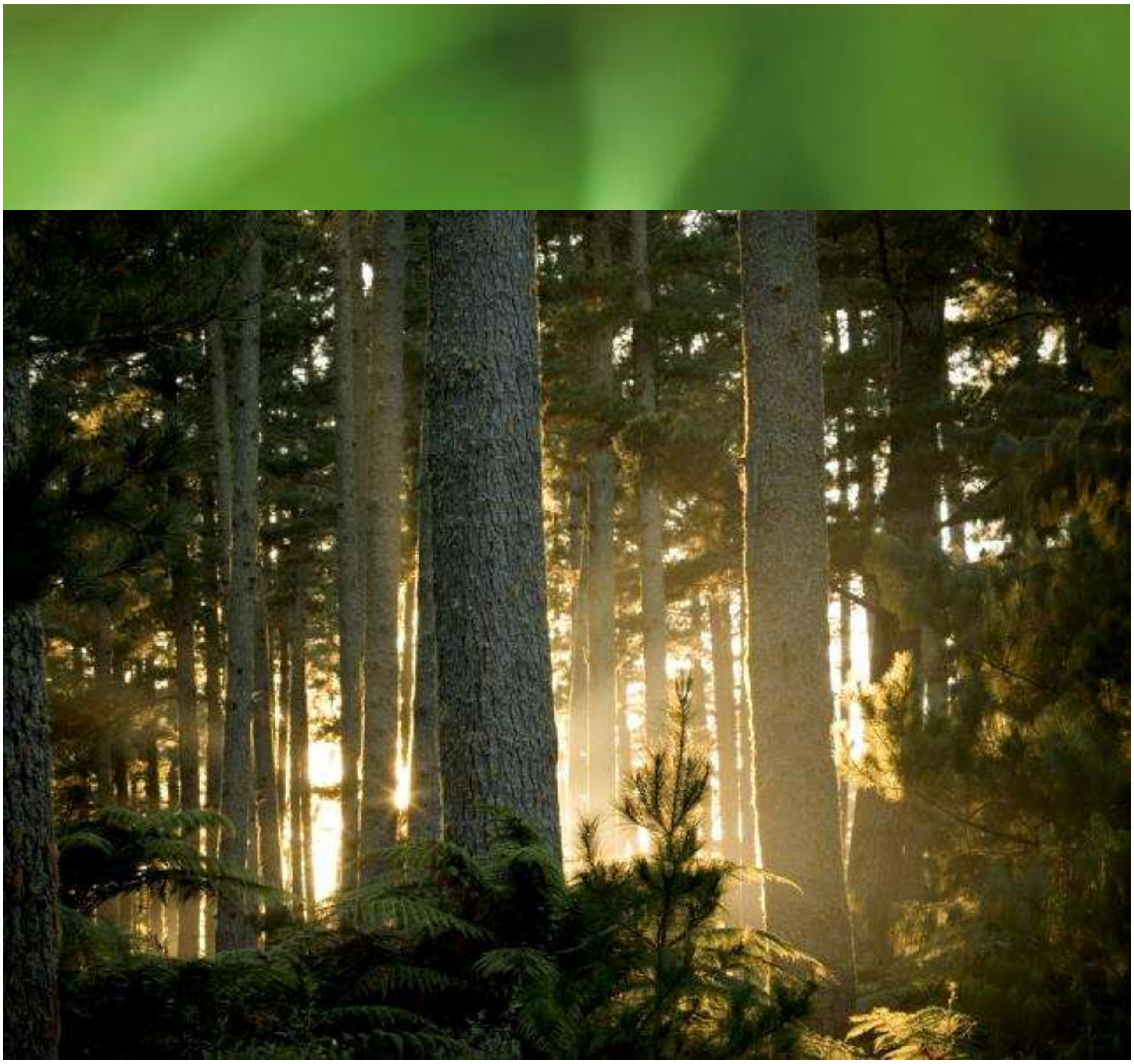
Forest Sector Transport Analysis – Northland



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EXECUTIVE SUMMARY

Objective

The objective of this study was to develop a methodology using publically available data to conduct high level analysis of wood flows in the Northland wood supply region. The resulting methodology would enable the Ministry for Primary Industries (MPI) to understand the transport implications of the forecast increase in forest harvesting. With this information, informed discussions can be carried out between MPI and the New Zealand Transport Agency (NZTA) and local government decision makers. The methodology and analysis results will assist with these discussions, for example on the upgrade of local roading infrastructure to manage increased traffic loads and allow greater use of High Productivity Motor Vehicles (HPMVs). The methodology developed can be applied to other regions in New Zealand to analyse future regional needs.

Methodology

Data from the Landcover Database (LCDB) and the National Exotic Forestry Description (NEFD) were combined to produce a spatial layer showing the volumes of wood to be harvested in five year periods from 2013-2017, 2018-2022, 2022-2027, 2028-2032 and 2033-2037. These volumes were based on an assumed harvest age of 28 years. Harvested volumes were then directed towards the nearest public road and a streamflow algorithm was used so that material moved from minor roads onto major roads until it reached its destination. In our analysis we assumed that the wood was sent to North Port, but the method is able to consider other destinations. The total volume of wood transported on different roads was calculated along with the approximate equivalent number of truck movements.

Key Results

As a consequence of the irregular age class distribution in the region the wood volumes available for harvest will fluctuate considerably over the next 20 years. The model shows that the highest wood flows are occurring now or are imminent and will remain high on the main through roads, tapering only in 2033. In all areas except for the Far North, there is a distinct drop in supply in the years between 2018 and 2033. The Far North supply, although experiencing a reduction in volume in 2023, remains steady. The routes highlighted by the 2013 wood flow include Highways 1, 14, 16 and Mangakahia Road heading northwest from Whangarei. Over time the wood flow along some of these routes will decrease, but the volume of wood moving south to the port along SH 1 remains high. The total number of loaded truck movements (44 tonne truck) is expected to decrease from 381 per day in 2013 to approximately 197 per day in 2033.

Implications of Results/Conclusions

Of interest is the variation in wood flows on rural roads over time. In the high volume years there are extensive wood flows on the rural roads. In the lower volume years, these flows are only generated by harvesting in the larger forests. Current HPMV routes extend south from Whangarei, whereas most of the wood in future years is predicted to be transported from the Far North to Whangarei along SH1. The log flow along this route may be overestimated as the veneer and particle board mills in Kaitaia will likely utilise much of the harvest in the Far North, but the route would still be used by trucks carrying these panel products. Potential new HPMV routes could be explored along the routes with the highest wood flows, but one of the challenges will be the inability to extend these routes along the smaller rural roads that lead to the forests. There are only a few large forests where HPMV routes could link the forest to the processing facility or port. Smaller forests may well be serviceable by 50Max vehicles as the majority of district roads should be capable of the decreased per-axle load.

Further Work

The current analysis has only considered the case where wood is transported to the port at Marsden Point. Further work should focus on transport to local mills, particularly wood from the Far North as this is likely to have implications for the number of truck movements along key routes. The accuracy and precision of using publicly available data within this methodology could possibly be verified by MPI against the more detailed confidential data MPI holds. Volume conversions based on available national data could be verified against actual roundwood removals. More in-depth analysis is also required to look at flow impedances such as road gradient, bridge limits, and 50Max routes. A further element that could be considered is the post-mill movement of processed timber products and chips. Limited regional demand within Northland means that most of this production is likely to be transported to the port or south to Auckland along Highway 1.

Forest Sector Transport Analysis - Northland

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Introduction

The Ministry for Primary Industries (MPI) needs a methodology that will facilitate a deeper understanding of the transport implications from the increased wood harvest in New Zealand. The methodology developed in this report is a set of steps for determining truck volume implications using only publically available information and can be applied anywhere in New Zealand.

Based on current wood availability forecasts, the annual harvest from planted forests in New Zealand may, according to plausible scenarios of wood availability, increase significantly by 2022 (MAF, 2009). An increase of wood flow means increased truck movements on New Zealand roads, but the locations where these increases occur will depend on the locations of harvested forests and the destinations where harvested wood is transported to. Understanding wood flows will contribute to informed discussions with the New Zealand Transport Agency (NZTA) and local government decision makers around priorities for roading infrastructure upgrades.

Upgrade rationales may include the capacity requirements for a road to accommodate larger truck volumes, and the potential to become a route capable of allowing High Performance Motor Vehicle (HPMV) use. Reducing numbers of trucks is possible through the use HPMV's, a heavier truck with a maximum gross vehicle weight of up to 60 tonnes, which allows a larger volume of wood to be transported. However travel by HPMV is restricted by weight limits of bridges and only government approved routes may be used. (The normal maximum gross vehicle limit on New Zealand roads is currently 44 tonnes.) A methodology is need to be able to identify likely flow volumes on particular routes, and likely candidate routes for upgrade to manage the impact of HPMVs. Establishing a need for route HPMV capacity will allow MPI to determine their priorities for roading and bridge upgrade recommendations.

Harvest yields can vary, particularly if favourable market conditions exist around the time that the forest stands are sufficiently mature for harvesting, or if harvesting has been delayed until an improvement in favourable market conditions occurs. They also depend on the age class structure within a catchment that feeds onto a particular road. For example, the large wave of planting that occurred in the early to mid-1990s is likely to result in a peak in harvesting activity followed by decline. An increase in harvest volumes places additional pressure on New Zealand's transport infrastructure routes from forests to processing plants or ports. A breakdown of 5-yearly forest age classes by territorial authority, showing the variability of age classes over time and over the districts, is published annually by MPI (eg. MPI 2013). Even harvesting at a fixed rotation age results in high local variability of truck flow. Local roading usage may be adversely affected by sudden increases in truck volumes. The impact of usage increases may be particularly noticeable in unimproved rural roads, or feeder roads leading to main highways. This may be especially important if local roads have had no history of log truck usage, i.e. first rotation forests are being harvested.

Harvest products are generally destined for local ports and processing plants. This report describes the analysis performed to identify key routes from Northland forests to North Port at Marsden Point within the identified case study region, the Northland region. Log volumes and truck movements are described over five periods from 2013 to 2033. The techniques, as adapted from Scion's Biomass Model (Hock et al 2012), are described with sufficient details for MPI's use in other areas of interest throughout New Zealand.

Materials and Methods

Datasets

The analysis used a number of national datasets, both spatial and tabular. Datasets required for the analysis were obtained as described below. Each data set was clipped to the case study extent and saved in file geodatabases using Esri's ArcMap software (v10.2).

Case study area

The research area for this study consists of four district councils within the Northland wood supply region (Fig. 1): Far North, Kaipara, Whangarei and Rodney. The remainder of the Auckland council region was excluded from this analysis.

The reason for this exclusion is because the Northland Wood Supply Region now includes all of the Auckland Council area and the Landcover Database does not differentiate exotic forests that are within city boundaries which are more likely to be parks. Forests close to Auckland are also unlikely to be transported to a port further than the local port. Rodney district was extracted from an older dataset identifying territorial boundaries.

Figure 1: Northland case study area

Forest source data

The National Land Cover Database (LCDB) provides multi-year information on the vegetation cover of New Zealand (2014). The database is a digital thematic map of land cover designed to be compatible in scale and accuracy with Land Information New Zealand's 1:50,000 topographic databases. The data are freely available from the Land Resource Information systems portal https://lris.scinfo.org.nz/. LCDB data are based on remote sensing imagery captured in the summers of 1996/97, 2001/02, 2008/09 and 2012/13. LCDB data is verified across the different collections periods to reduce problems of matching data different datasets (Thompson, 2003). For ease of labelling, the LCDB collection periods are referred to as the 1996, 2001, 2008 and 2012 years. The respective datasets for each of these years are known as LCDB 1, 2, 3, and 4.

Another national land cover dataset in New Zealand is the Land Use Map (LUM) provided within the Land Use and Carbon Analysis System (LUCAS). LUM provides a map of planted forests in NZ separated into those forests first planted before 1990 and those first planted after 1989 (MfE 2014). However this does not provide enough information on age class by area for modelling annual harvest flows as the LUCAS LUM data is not a time series.

Planted forest classes were identified and extracted from each of the LCDB 1, 2, 3, and 4 datasets, thus providing the spatial location of forests over time. One of the forest classes is "Forest – Harvested", providing one of the sources of temporal forest information.

The 2013 National Exotic Forest Description (NEFD) (MPI 2013) provides a detailed description of New Zealand's planted production forests. It is a database that is updated annually and includes the net stocked area of the production forests by age class and territorial authority. The NEFD is based on company data which, especially for medium to larger companies, is highly spatially accurate; more so than the satellite-based LCDB data. Spatial data are provided to MPI by the large owners (i.e. those with more than 10,000 ha), but these data are not provided to third parties and were not, therefore, used in this project. Instead, we used the district data. While this is only available at the 5-year age class resolution, a breakdown of forest age by annual age classes is available at a national level. Such temporal resolution is useful for harvest modelling.

Transportation networks

Geospatial roading data (in the form of centreline locations) were accessed from Land Information New Zealand (LINZ, 2014). The dataset was tuned to the processing as follows:

- For assessing proximity to forests, a version was made that decoupled any database merging of features to get the smallest road segments available in the data (Arc singlepoint command).
- For assessing road connections between intersections, the road segments were merged (Arc dissolve command)

New Zealand Transport Association provided pdf maps of current and proposed HPMV routes for Northland (see Appendix 1). The Far North District Council provided an excel spreadsheet of district bridges with associated weight restriction and location data to be used in the network impedance analysis.

Flow destinations

All wood flows were to be directed to either a port or a processing plant in the Northland region (Fig. 2). North Port, at Marsden Point was the selected destination port. Sawlogs and pulpwood are shipped via this deep water port. The wood processing plants in

Northland are outlined in Table 1 (Dana, 2014). From Figure 2 it can be seen that most of these processing plants are located near the main highways, and some of the major production (including a wood chipping operation) are near the port.. Therefore, sending wood through to the port will in most cases mean that it is transported along the same routes that it would travel on were it being transported to a mill. The exceptions are the panel plants in Kaitaia, which would be the destination for much of the log trucks in the Far North. While the volume of log trucks flowing south to the port would therefore be much less than modelled, they would be replaced by trucks carrying panels, potentially also changing the route flows.

Calculating the wood flows to and from individual processing plants is more complex, whereas the focus here is on understanding the high level wood flows and the implications for the roading network. In our analysis the distance material is transported is likely to be longer than would be the case if some of it was sent to local processors, but the routes used will generally be the same. The limited domestic demand within the Northland region means that most of the wood products produced will leave the region, either via the port or south to Auckland.

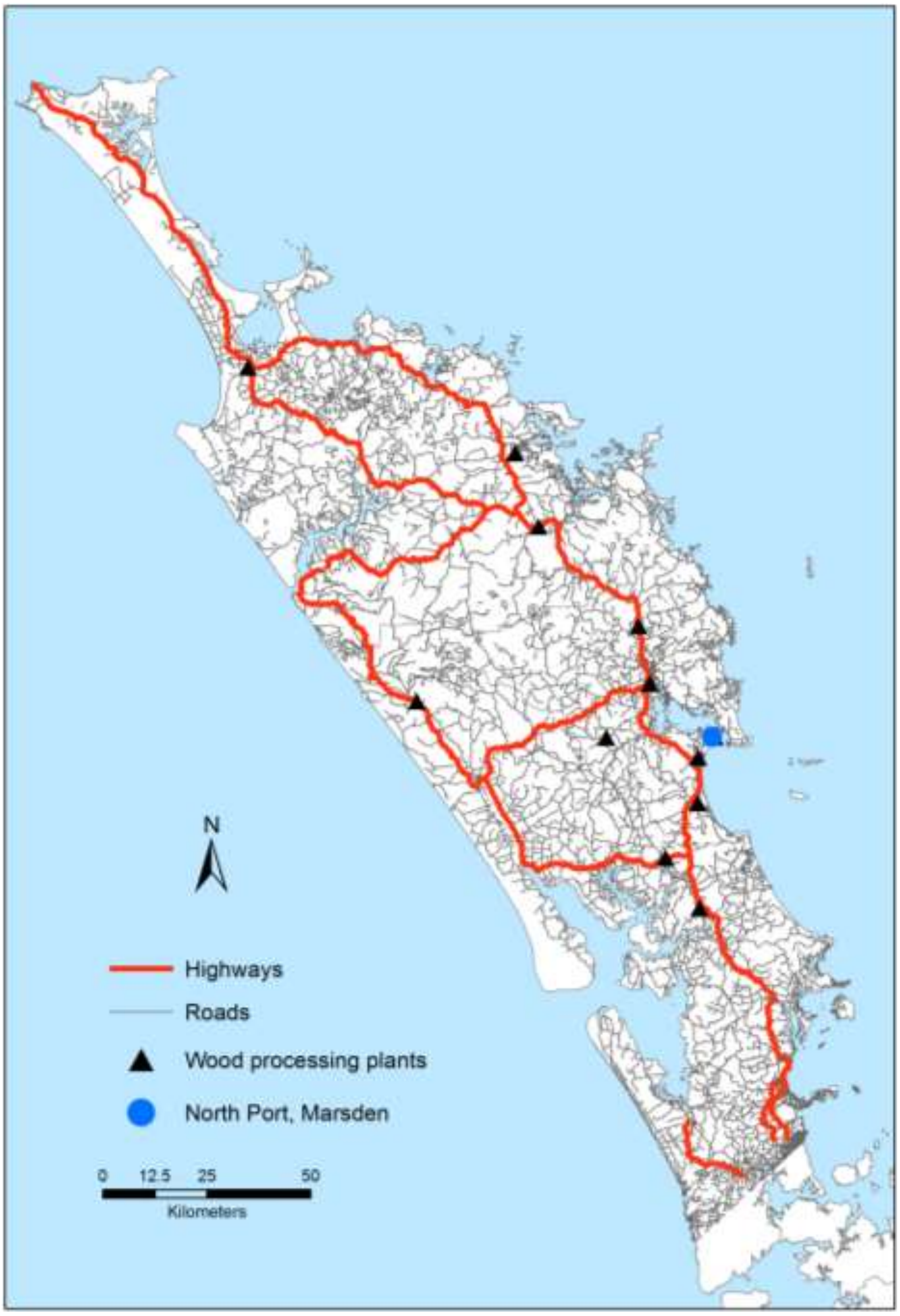

Figure 2: Port and wood processing sites in Northland

Table 1: Wood processing organisations in the upper North Island, including Northland (from Dana, 2014)

Owner	Location 1	Product 1	Product 2	Log intake (m^3 p.a)	Other intake vol p.a	Other intake type p.a	Product output p.a	Unit output
CHH Pulp & Paper	Auckland	Paper		0	90000	Recycled paper	80000	t
Anderson and O'leary	Auckland	Sawn Lumber	Roundwood	65000	15000	Roundwood	28000	m3
CHH Wood Products	Auckland	Hardboard				130000	72000	m3
Kaihu valley	Dargaville	Sawn Lumber		30000			16000	m3
Herman Timber	Hikurangi	Sawn Lumber		15000			8000	m3
Juken Nissho	Kataia	Veneer		250000			117000	m3
Juken Nissho	Kataia	Particle Board		250000			80000	m3
Bay Lumber	Kerikeri	Sawn lumber		70000			36500	m3
Max Birt sawmilling	Kerikeri	Sawn Lumber		15000			8000	m3
Mt Potaka Sawmill	Kerikeri	Sawn Lumber		50000			30000	m3
Matakohe Sawmills	Maungaturoto	Sawn Lumber		15000			8500	m3
Grand Pine Enterprises	Moerewa	Sawn Lumber		4000			2000	m3
NZ Green Pine ETC 2006 ltd	Ruakaka	Sawn Lumber	sawn Lumber	15000	10000	LVL cores	8000	m3
Topuni Timber	Wellsford	Sawn Lumber		5000			3000	m3
CHH Wood Products	Whangarei	Sawn lumber		400000			195000	m3
Dennis Budd sawmilling	Whangarei	Sawn lumber		3000			1500	m3
Northpine	Whangarei	Sawn Lumber		36000			22000	m3
Rosvall Sawmill	Whangarei	Sawn Lumber		55000			31000	m3
CHH Wood Products	Whangarei	LVL		160000			80000	m3

Woodflow estimation

We selected the years 2013, 2018, 2023, 2038 and 2033 to analyse wood flows. This follows the 5-yearly grouping of data in the data sources used in the project.

The year 2013 was chosen as a starting point to provide a baseline for the following years and to align with the 2013 NEFD data. The subsequent years were selected as multiples of 5 years since this time resolution also matched the NEFD age-class resolution. No assumptions were made regarding potential changes to the extent of the 2013 forest estate – new plantations would only be harvested beyond 2033, and loss of planted lands would only increase log flows if they were harvested at a younger age than our assumed rotation age. The first requirement was to develop a database of the best estimate for the spatial distribution of age classes, in order to be able to determine candidate forests for harvesting in the scenario years.

Estimation of wood flows from each forest

The LCDB 1, 2, 3 and 4 planted forest classes were used to categorise the 2013 case study forests (the baseline year) into broad age classes based on a number of rules and assumptions. We identified the LCDB 1, 2, 3 and 4 harvested areas in respectively 1996, 2001, 2008 and 2012. The assumption was made that these areas were replanted in the year following the harvest year (i.e. 1997, 2002, 2009 and 2012). Any areas not replanted (deforested) would not be present in the 2013 baseline year so would be automatically excluded from any modelling. This approach also assumes that the replanted land remains in forestry post-2013 – this can be tested against subsequent years.

We developed a number of rules for the assignment of tree ages for forests (Class: Exotic Forest) that 'become visible' in the remote-sensed imagery underpinning LCDB. Here we use 'become visible' in the sense that in one LCDB version the land is either classified as harvested or classified as a land cover other than exotic forest, and in the subsequent LCDB version the land is classified as being under exotic forest. Planted forests are generally not visible when they are less than 4 years old when using satellite imagery to identify and classify vegetation (Thompson et al, 2003). Hence the youngest age when a forest could visible on the imagery was 4 years old (in some cases the trees need to be 5 years old but we did not have sufficient information to differentiate this.) The combination of previous landcover and age of visibility on satellite imagery lead to the rules in Table 2.

Table 2: Rules for LCDB age assignment when a first recording of a forest cover is detected

Forest cover in LCDB being considered	Forest cover in previous LCDB	Youngest trees possible	Oldest trees possible
Exotic forest	Forest – harvested	Planted in the year after the previous LCDB	Aged 3 at time of the previous LCDB and too small to detect then
Exotic forest	Any non-plantation forest class	4 (the youngest age detectable on satellite imagery)	Aged 3 at time of the previous LCDB and too small to detect then

To determine the age of the trees at the time of the baseline year 2013 was then a matter of adding the number of years from the LCDB year until 2013. For example, LCDB2 is based on tree visibility in the year 2001. Hence in the baseline year, the youngest that the trees visible in 2001 could be is:

> 4 (the minimum age to be visible) plus 12 (the duration from 2001 LCDB year to baseline 2013) which is 16 years (minimum age in 2013)

It is, however, possible for the trees to be older than this youngest age. At the time of the LCDB preceding the one under consideration, the trees may have already been planted but have been too small to be visible on satellite imagery. Hence the oldest the newly visible trees could be at the time of their becoming visible is 3 years (years trees could be planted but not be visible) plus the duration from the preceding LCDB to the LCDB under consideration. Again determining the age of the trees at the time of the baseline year 2013 was a matter of adding the number of years from the LCDB year until 2013. For the above example, LCDB2 is based on tree visibility in the year 2001. Hence in the baseline year, the oldest that the trees visible in 2001 could be is 3 years (the oldest the trees can be before they start to become visible) plus 5 years (the duration between LCDB1 and 2) plus 12 years (the duration from 2001 LCDB year to baseline 2013) which is 20 years (maximum age in 2013)

An illustration of the process of determining age is given in Figure 3. To complete the example, the age range of a forest area that is first recorded in LCDB2 and where the previous landcover was not a plantation forestry landcover, is between 16 and 20 years old.

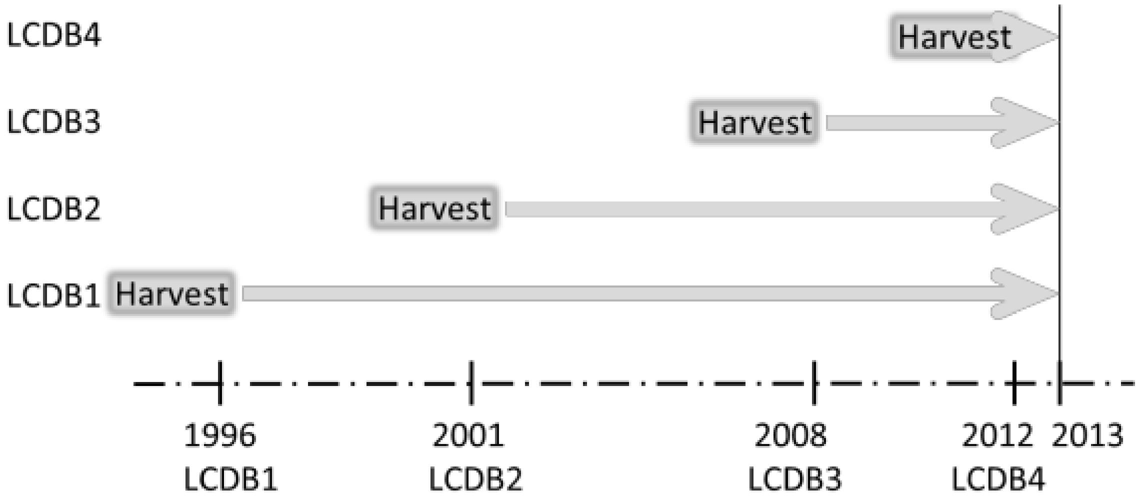

Figure 3: Tree age calculations from when trees were harvested

The resulting age classes that could be determined by this analysis were 0-3, 4-8, 5-8, 9-15, 11-15, 16-20 and 21-35 years (Table 3).

Table 3: Age classes based on LCDB 1 – 4

Criteria	Age range at 2013
(Not modelled)	0-3
Forest area first recorded in LCDB4 and previous land use was harvested	4-8
Forest area first recorded in LCDB4 and previous land use was not plantation related	5-8
Forest area first recorded in LCDB3 and previous land use was not plantation related	9-15
Forest area first recorded in LCDB3 and previous land use was harvested	11-15
Forest area first recorded in LCDB2; for this case, the age calculations result in the same age range for both previous landcovers	16-20
Forest area first recorded in LCDB1	21-35 (*)

(*) A cut-off age for forests available for harvesting was set to 35. This was based on the assumption that trees older than this in the NEFD data were unlikely to be harvested. This is similar to the approach adopted in the MPI Northland wood availability forecast model (MPI 2009) where areas of trees aged >=36 were removed from consideration. The additional approach from this model of also excluding half of the small-scale owner forests aged 31-35 was not be adopted as ownership data was not available.

LCDB data provides the spatial location of forests however NEFD, a non-spatial dataset, is the more accurate dataset of the two. NEFD is based on detailed company data for large (> 1000 ha) and medium (40-1000 ha) forest owners. Data for owners with < 40 ha is poor, however, and the Northland WAF model addressed this by using a reduced NEFD for small-scale forest area by 15%, on the basis that the areas reported were probably gross rather than net. The differentiation of area by ownership was not publically available data and not built into this model. An approximation could be to adjust all small forests (polygons < 40ha), however this would also adjust the small forests owned or manages as part of a bigger estate.

It is possible to use the more accurate information contained in NEFD, but the age classes derived from the LCDB are slightly different to the NEFD age classes. NEFD age classes are: 1-5, 6-10, 11-15, 16-20, 21-25, 26-30, and 31-35. In addition, the extent of the case study region did not fully align with Auckland Council boundary in the NEFD.

Aligning the LCDB data with the NEFD data and vice versa, required two steps. One step was for the age classes to be partitioned into a common unit of age across both LCDB and NEFD, and the other step was for data from the territorially based NEFD extent to be aligned with the case study site (the LCDB data had been clipped to this extent too). Alignment of the areal extents, the second requirement, was achieved by extracting the Rodney District from the Auckland Council NEFD data. The process was to calculate the areal proportions of the Rodney District compared to the wider 2013 Auckland Council extent, and apply this proportion to the appropriate NEFD tables for Auckland Council. The areal proportion was computed based on the proportion of LCDB mapped forest area within the boundaries of the old Rodney District compared to the boundaries of the Auckland Council.

Aligning the two forest age class data sets required allocating the NEFD and LCDB data into annual age classes. The approach used for the LCDB spatial data was to randomly allocate the age class information across the area. The 5-yearly NEFD data (NEFD Table 9.7 in MPI 2013) could be proportioned across the 5 years. A more realistic annual allocation than using one fifth of the 5-year total was to use the national estimates of hectares per age class (Table 9.2 in MPI 2013). This assumes that annual planting within each five year period in Northland followed the same trends as annual planting nationwide, a broad assumption based on the desire to utilise the publically available data in NEFD. An example of the allocation of NEFD data into individual hectares per year is outlined in Table 4. For the Rodney District, the estimated area of forest for trees aged 8 is around 951 ha as per the NEFD 2013 calculations. Hence the assumption is that in 20 years, in 2033, 951 ha could be being harvested in this district.

Table 4: Example of age class per hectare estimation for Rodney District in years 0-3

Age	Area of NZ forest by age-class (NEFD Table 9.2 in MPI 2013) (ha)	Sum of NZ NEFD areas (5 yr intervals)	NZ-wide percentage of the area per age class	NEFD forest area by 5-year age class and territorial authority (NEFD Table 9.7 in MPI 2013) e.g. Rodney 2013	NEFD (ha per year)
1	36,115		18%		686.6
2	50,777		26%		965.3
3	40,026		20%		760.9
4	34,565		18%		657.1
5	33,781	195,264	17%	3,712.10	642.2
6	36,380		17%		879.2
7	34,244		16%		827.6
8	39,369		18%		951.4
9	46,790		22%		1,130.80
10	56,958	213,741	27%	5,165.60	1,376.50

For the chosen woodflow scenario years, the area estimates were required for the ages 8, 13, 18, 23, 28 (Table 4). Figure 4 shows an example of a forest with a range of LCDB age classes based on LCDB 1-4.

Table 5: Match scenario years to LCDB areas

Scenario year	Age in 2013 of forest being harvested in the scenario year	LCDB age-class areas that matches the scenario year
2013	28	21_35
2018	23	21_35
2023	18	16_20
2038	13	9_15 and 11_15
2033	8	5_8 and 4_8

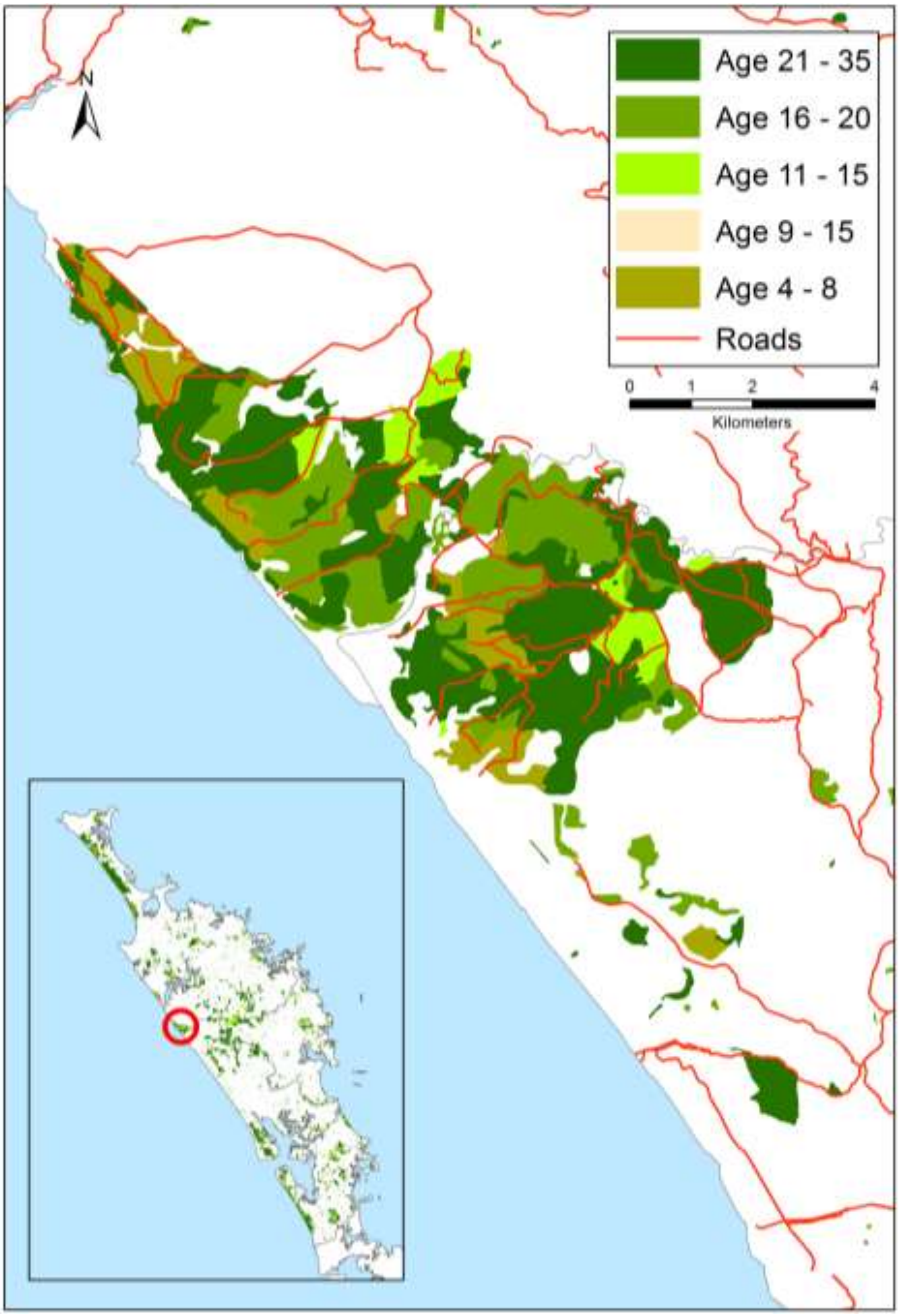

Figure 4: Example of LCDB age class categorisation

As indicated above, the LCDB spatial data could not be divided into proportions matching individual years; this would have assumed more knowledge about location than we had available. Instead, the NEFD-based hectares for a required modelling year were randomly distributed over the extent of the LCDB area that matched by age range. For example, to determine the potential wood flows in 2013, the areas of age 28 NEFD forest were randomly distributed over the 21-35 age class LCDB area (Table 5). This was done through random weight grids in Arc GIS using a Model Builder script. The step ensured that net stocked areas (the NEFD data) were used in subsequent calculations rather than LCDB's broader vegetation classification (gross stocked area).

Wood flows from forest to road
The identified forest compartment volume, where compartment is used in the sense of the within-forest delineation of age-class areas, needed to be allocated to a location on the road. Only public road information was available; the assumption was made that the wood flows would most likely happen onto the closest road at or near the point of the road closest to the forest. In regard to modelling flows along roads, the accuracy of using such an entry point to the roads was considered to be sufficient. For each future analysis year, here called a scenario, a forest volume point layer (termed 'volume incidents' along the roads) was created for each age-28 forest compartment polygons. The attribute table associated with the volume incidents contained the volumes from the polygon matching the point. In some cases multiple forest compartments were associated with the incident point, and where this occurred all volumes per incident point were summed.

Conversion to volume

To convert areas of forests to volume, areas were multiplied by NEFD's average clear fell yield of 559 m^3 ha^{-1}, for *Pinus radiata*. This value was taken from Appendix 2, Table 2.1 in NEFD (MPI 2013). This is a national estimate; while forests established on sand dunes in Nothland are not as productive, other parts of Northland are more productive than this national average. For example, Scion's Forest Investment Finder (FIF) averages 668 m^3 ha^{-1} for all LCDB forests in Northland (Duncan Harrison, pers comm). A single-figure conversion rate may have under- or overestimated locally however the overall figures were within range of other models.

Roading methods

The road data management included:

- splitting roads into segments to determine the closest road segment to each of the forest areas relevant to a scenario year, to allow the allocation of the log volume from forest to road
- dissolving road segments to create a single continuous line between each pair of intersections; this allowed any along-road calculations to be made
- connectivity checks for building a road network
- assigning bridge weight restrictions along the roads (impedances) – this is subject to change should bridge carrying capacities be improved

Network Analysis

The most direct routes between the forests and market destinations (port/mill) were determined using the ArcMap 10.2 extension Network Analysis' closest facility process. Closest facility analysis measures the cost of travelling from source to destination or facilities and incidents. Mills and North Port at Marsden points were uploaded as facilities and the points on the roads were the destinations or incidents. As already noted, we have only considered the case of material flows to North Port. The analysis produced a series of direct routes to the points associated with forest volume and contained no barriers or restrictions to transport. The resulting routes were converted into a line shapefile and joined to the volume point layer.

Flow-based methodology

To calculate the volumes travelling along each route, flow accumulation analysis was carried out using tools from the Hydrology Toolbox in the Spatial Analyst Tools extension of ArcMap 10.2. This approach is analogous to stream flow accumulating as tributaries join in flowing seaward. For this approach, the facilities (port and mills), incidents (forest volumes), and the road network were converted into rasters.

A cost distance was calculated with the facilities as source and the costs constrained to the road network. The direction of the least cost flow that the logs would take from the incident points to the facilities was calculated using flow direction. Flow direction used the respective cost distance output rasters. It was then possible to calculate the log flow accumulation using the flow direction raster, with the incidents (forest volumes) as a 'weights' for this calculation. The flow accumulation was repeated for each scenario year. To create display capability, the resulting output rasters were converted into polylines with volumes as attributes. The results were also calculated as tonne-kilometre statistics.

Map development

For the map display, the accumulated wood flows were highlighted by different thickness and coloured lines. This made a quick overview of different volumes along routes visible. For more detailed information on the magnitude of these volumes, values at selected points along the road network were determined.

Scenario development

Using the Arc GIS network analysis tool, the first scenario identified the most direct route with no impedances, from forest to port. The flow-based methodology was applied to these routes to develop an understanding of wood flows in the scenario years in the Northland region.

The second scenario was to include uploading a slope impedance to identify alternative routes. Bridge data from the Far North District Council was supplied in an excel spreadsheet to assist with identifying potential bridge restriction on identified high volume routes. Converting bridge data into GIS-usable format proved a lengthy task however and this was not pursued further. Note that log production potential is much greater than current log processing capacity in Northland. Local mills are an alternate destination for log trucks to the port, but with a few exceptions they take relatively small volumes, and some of the exceptions are close to the port anyway. This situation may not apply in all regions.

Results and Discussion

Age class distribution

Before considering age spread implications across the modelled areas, the methodology for evaluating age-class spread is considered. Figure 6 compares the NEFD area-spread based on an assumption of an even age class distribution across the 5-year NEFD interval, with the NEFD area-spread based on an assumption of 2013 NZ-age class distribution. As can be seen in the graph, the variations around the even age class distribution can be pronounced in some years. Analysing the divergence shows that the standard deviation is 4.3% with intensive plantings (above 30%) for trees that are ages 21 and 31 in the year 2013, and lowest planting rates (below 15%) for trees that are ages 30, 34 and 35 in the year 2013. While this is a national statistic, Northland was considered equally variable in planting rates.

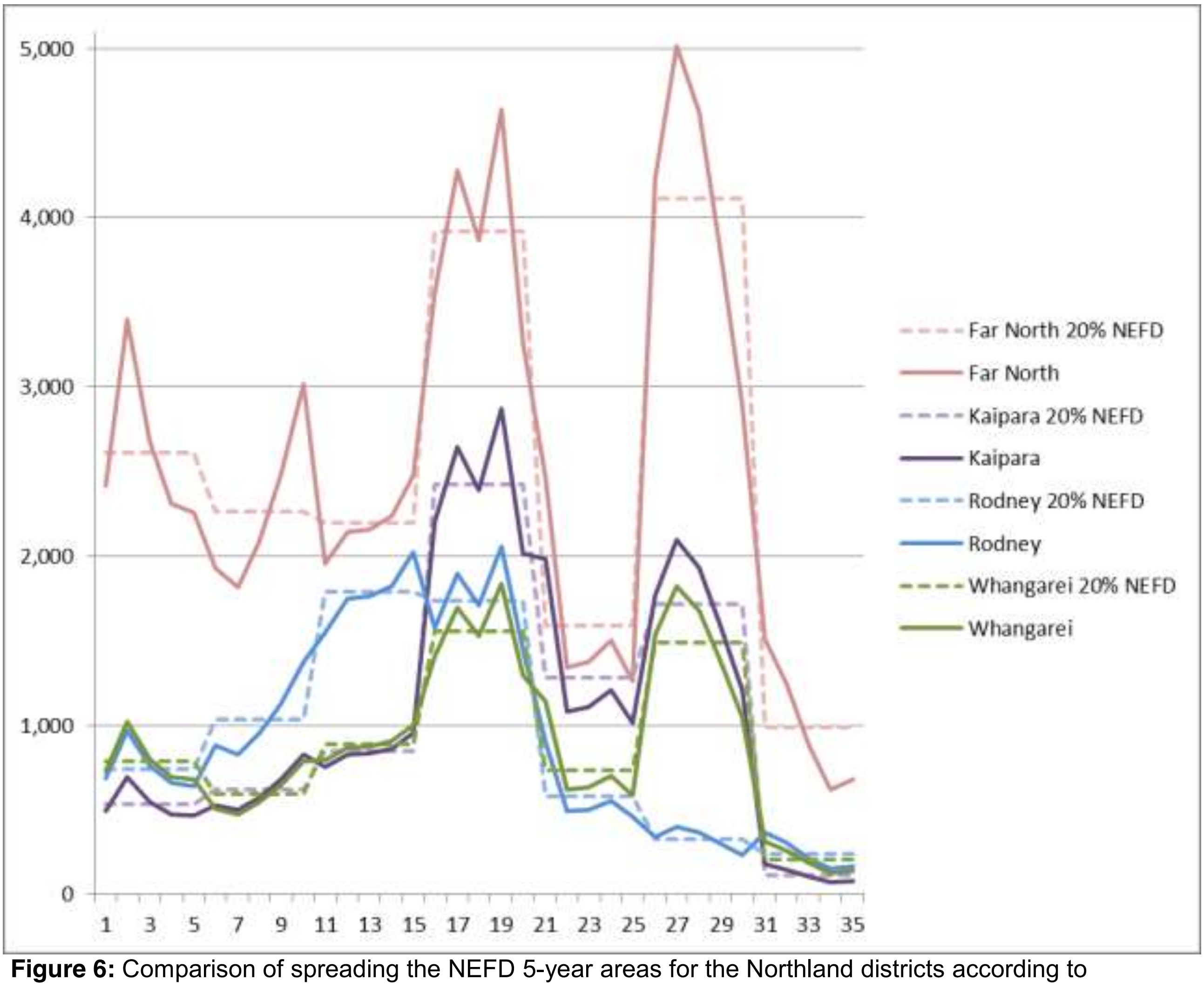

Figure 6: Comparison of spreading the NEFD 5-year areas for the Northland districts according to an even age-class distribution (20%) across the 5-year interval (dashed lines), with an assumption of 2013 NZ-age class distribution (solid lines)

Based on the national age class distribution applied to the NEFD areas for the case study, Figure 7 graphs the potential planted forest areas per district – this graph repeats the solid lines of the above figure without the comparison lines for ease of visual understanding. The graph shows the variability of the planting regimes across time for the region.

- For the Far North there are large volumes of mature trees (ages 26-28) and more mid-rotation trees (ages 16-20) with a significant drop in areas with nearly mature trees (ages 22-25). Note that for Northland the peak at ages 16-20 is marginally

less than the current peak (ages 26-28). Areas that are in younger trees are closer to the lower than the higher years for the Far North.
- For Kaipara there is a similar pattern of a drop in the areas of nearly mature trees (ages 22-25), with even less areas in the young age classes. For this district the peak at ages 16-20 is higher than the current peak (ages 26-28).
- Whangarei also shows the two-peak pattern, however here the peaks at ages 16-20 and 26-28 are of similar magnitude. The areas in young age classes are low, similar to Kaipara.
- Rodney follows a different pattern in the areas of age classes. The largest areas occur for ages approximately 10-21.

While there are some similarities in the patterns of age class areas, the graph also demonstrates that there are significant differences across not only ages but also districts. Note also that the 2000 NEFD wood availability forecasts were criticised for presenting an imminent "wall of wood" which did not eventuate. The largest contribution to the forecasted increase in harvest was from mature forests in Northland. It is unclear exactly why the actual harvest in Northland was lower than predicted. Possible reasons include NEFD forest area data overestimated the true forest area; actual yields at harvest were lower than predicted; or trees were not harvested at the nominal rotation age assumed or as indicated in harvest intentions. The revised forecasts (eg. MAF 2009) made adjustments to both areas and yields, and relied on large forest owner harvest intentions to set the harvest level to the early 2020's.

As with these earlier modelling exercises, the volume flows in this report are indicative of wood availability rather than firm predictions of future harvesting. Actual harvesting in a given period may be greater or less depending on factors such as the prevailing economic conditions, as well as uncertainty around forest areas and productivity.

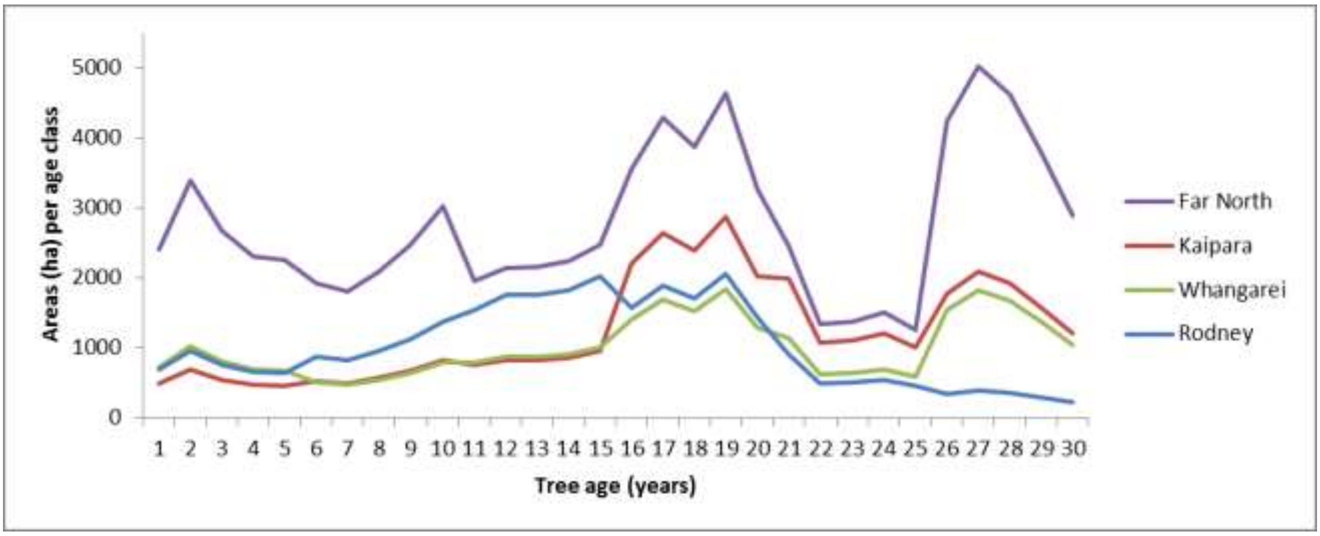

Figure 6: National age distribution as at 2013 applied to 5-year NEFD areas for the Northland districts

The NEFD areas estimated for the scenario years 2013, 2018, 2023, 2038 and 2033 are shown in Figure 7 and Table 6. This graph shows the uneven age classes are across all regions that are not smoothed through combining the regional supply. In other words, the regional totals for the age classes also vary extensively. This will have a flow-on effect on the pressures – or lack of them – on sector-oriented regional-level infrastructure e.g. ports.

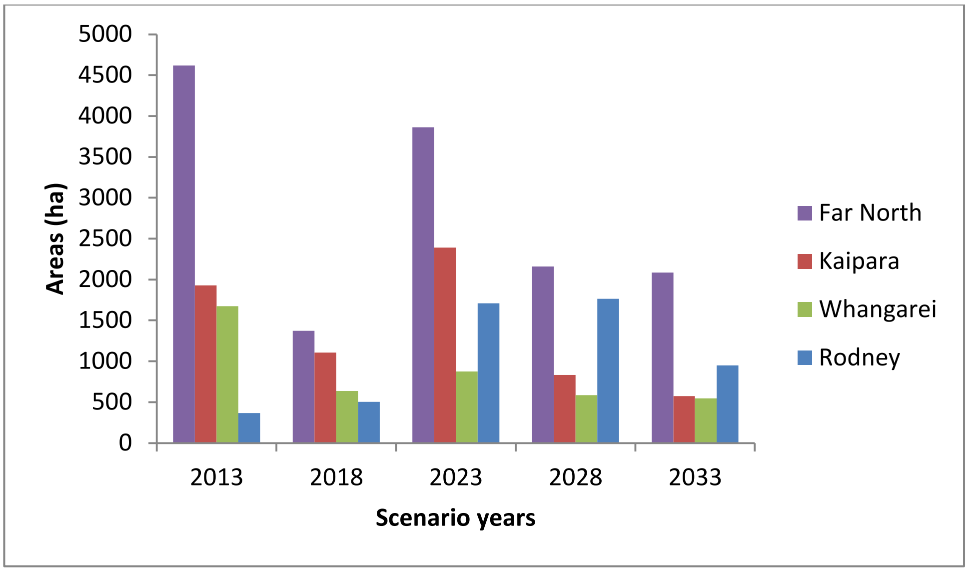

Figure 7: Estimated harvestable areas in the Northland districts for the modelled years

Table 6: Estimated NEFD areas for the modelled years

Tree Age	Scenario	Rodney	Kaipara	Whangarei	Far North	Total
28	2013	367	1,928	1675	4,618	8,588
23	2018	503	1,105	636	1,372	3,616
18	2023	1,710	2,389	875	3,864	8,839
13	2028	1,762	832	584	2,158	5,336
8	2033	951	572	546	2,087	4,156

The NEFD areas and the identified matching LCDB polygons can differ in their respective extents (hectares). A full investigation of these differences has not been attempted for this report. Despite its limitations for small forest owners in particular, NEFD provides the best estimate of stocked area and LCDB the best approximation of spatial locations over time, i.e. potential tree age locations. In the absence of further information it is not possible to verify accuracies of either dataset.

An example of the difference in the dataset is given for Far North District. For the age band 11-15, the NEFD estimate of area (10,122ha) is almost double the estimate based on LCDB (4,923ha). In comparison, summing three age bands to get the band 21-35, the LCDB-based estimate of area (67,963ha) is almost double the estimate in NEFD (34,119ha). The example serves to demonstrate that these best approximations nevertheless include discrepancies.

Sustaining the yield

While the age class availability of the forest resource is highly variable, forest managers can vary harvest age to reduce irregular harvest volumes. Harvesting at a different age from a single value, such as age 28 or age 30, can either smooth or exacerbate the related highly variable road log flow.

A sustained yield may be desirable at the estate or regional level for continuous cash flow, infrastructure development, and maintaining the labour force. The forest ownership in Northland includes a mix of fewer larger forests and many small forest owners (MAF, 2009). Achieving sustained yield is not an objective of smaller forests for various reasons including financial ones, however the bulk of the small forest plantings only achieve harvestable age from approximately 2021 (MAF, 2009). The current harvesting in Northland according to MPI's harvesting statistics is in larger scale ownership (MAF, 2009). Of interest then is whether the current increased harvesting rate is more indicative of a 'sustainable yield' approach or a 'full cut of available age range' approach.

Figure 8 shows the approximate difference between the area age data used in this report (based on 2013 NEFD data) and the 2008 area age data from MAF (2009, Figure 3.1) aligned appropriately. There are many contributing factors to smaller differences in the 2008 and 2013 lines of this graph, while the larger differences in the 26+ age bands are indicative of the harvesting that has been happening between 2008 and 2013 in those age bands even allowing for downward revisions of area estimates. Standing forest areas for the 31-35 age band are approximately halved over this time period, and for the 26-30 age band are reduced by approximately 20%. Areas in standing trees in 2013 may indicate lack of capacity to cut more. Whether areas are being held back from harvesting as part of a plan towards sustained yield by holding back stands from harvesting to fill in the trough in 4-8 years' time cannot be deduced from the data.

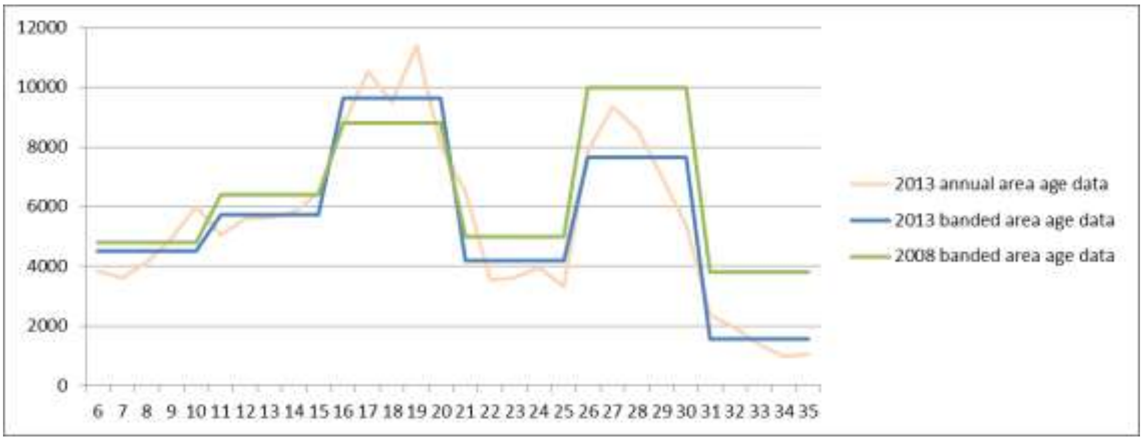

Figure 8: Comparison of approximate area age data for Northland: 2008 and 2013 (2008 data after Figure 3.1 in MAF 2009) – the x-axis is tree age at 2013

MAF (2009) shows that peaks (maximums) in recoverable volume based on harvesting modelled at a fixed harvest age, could reduce substantially under different harvest age scenarios. From 7-8 million metre^3 volume peaks (Scenario 1, Figure 4.3, MAF 2009), the different harvest age scenarios reduce the recoverable volume peaks to approximately 6 mill m^3 (Scenario 2, MAF Figure 4.7); over 4 mill m^3 (Scenario 3, MAF Figure 4.8), and almost 5 mill m^3 (Scenario 4, MAF Figure 4.10). As an indicative calculation of the effect of smoothing on wood flows on a daily basis, these peak volume reductions could translate into reductions in predicted maximum daily truck numbers of the order of magnitude of approximately 80 (Scenario 2), 240 (Scenario 3), and 160 (Scenario 4). This calculation is based on a reduction from 7 mill m^3 and on a 50 t truck with 34 t load travelling to a single destination such as Marsden Point.

While smoothing of harvest flows is possible, for the modelling purposes of this report the simpler assumption was made that harvesting would occur at a fixed age without adjustments. A number of datasets used in the MAF (2009) scenarios are also not publicly available. This modelling approach results in the road usage scenario with the largest variation over time being calculated.

Scenario results

The wood flows were calculated and mapped for each scenario year 2013, 2018, 2023, 2038 and 2033 based on an assumed 28 year rotation. Figures 9 – 13 show the wood flows for the no-impedance scenario, with all wood flows going to North Port, in Marsden Point only.

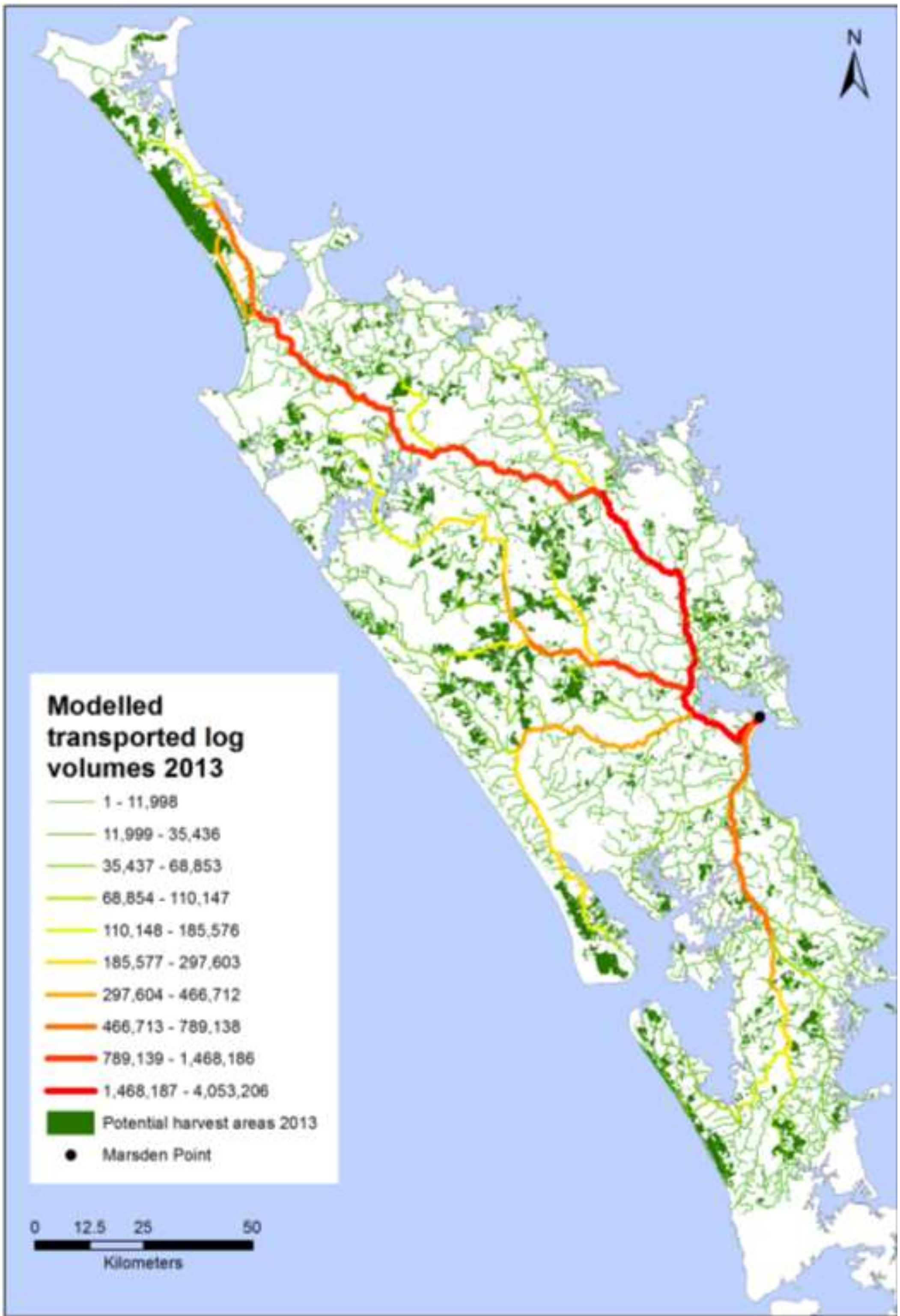

Figure 9: Transported log volumes (m^3) for forests harvested in 2013 accumulating at North Port in Marsden Point.

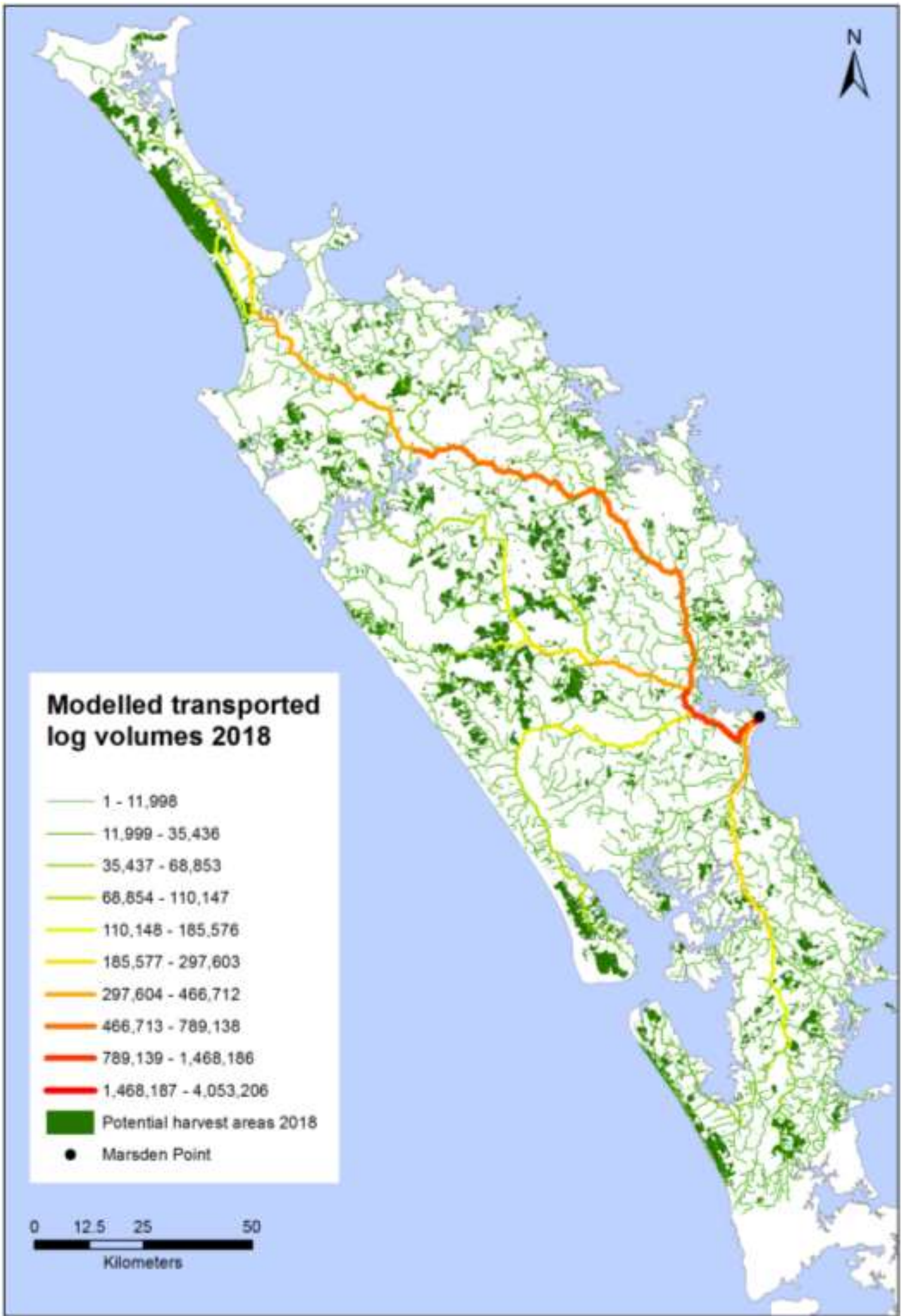

Figure 10: Transported log volumes (m^3) for forests harvested in 2018 accumulating at North Port in Marsden Point.

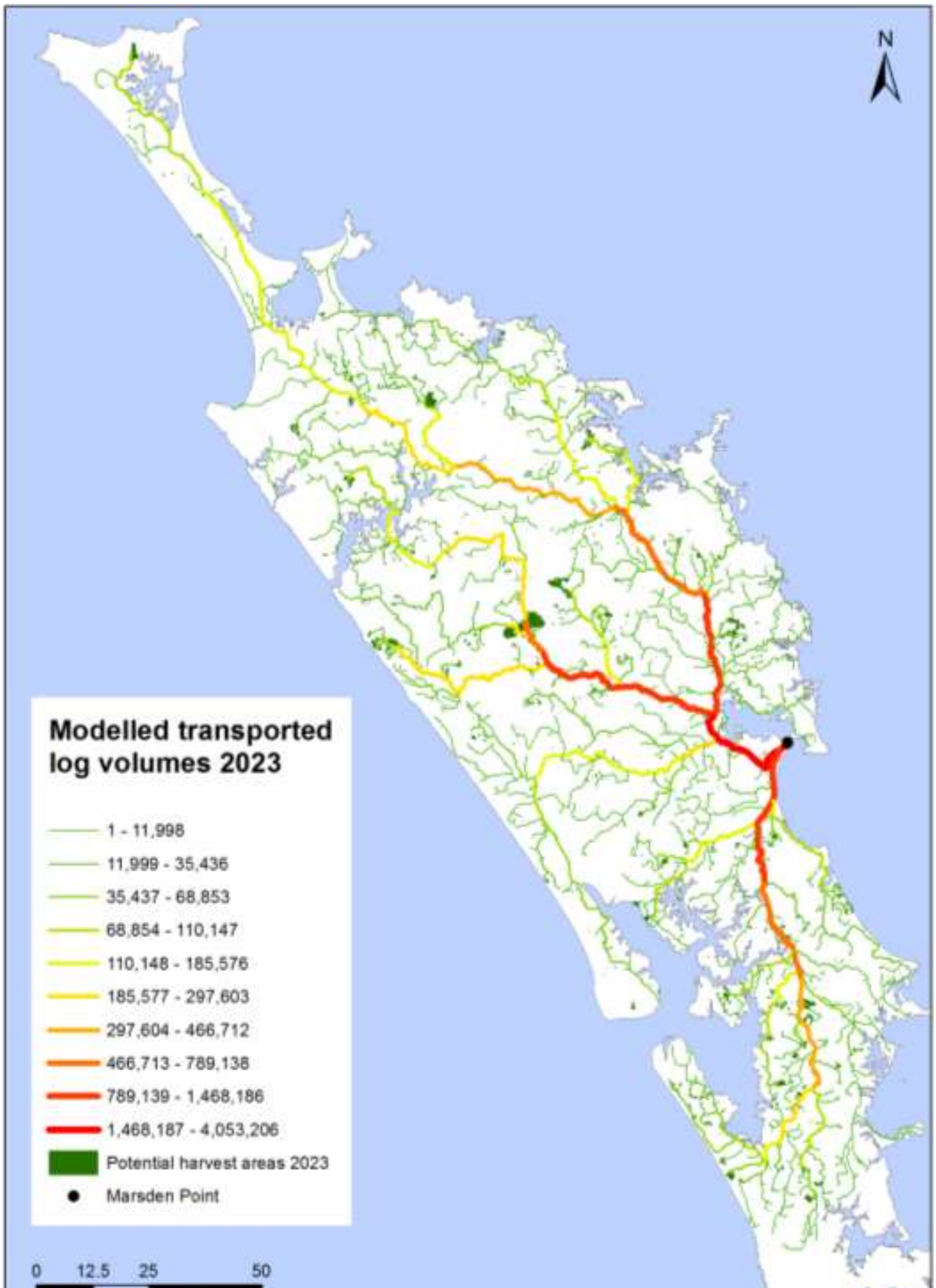

Figure 11: Transported log volumes (m^3) for forests harvested in 2023 accumulating at North Port in Marsden Point.

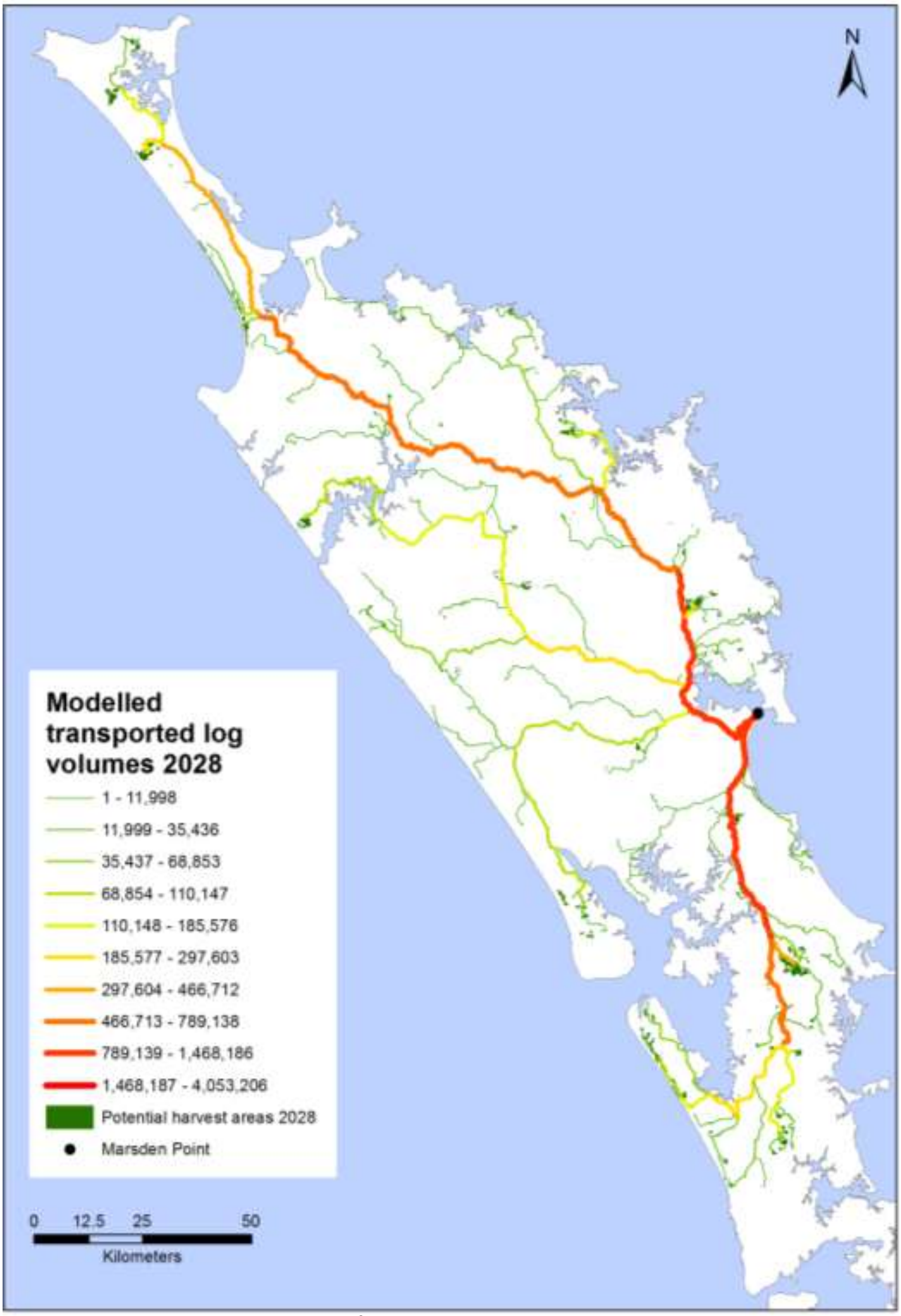

Figure 12: Transported log volumes (m^3) for forests harvested in 2028 accumulating at North Port in Marsden Point.

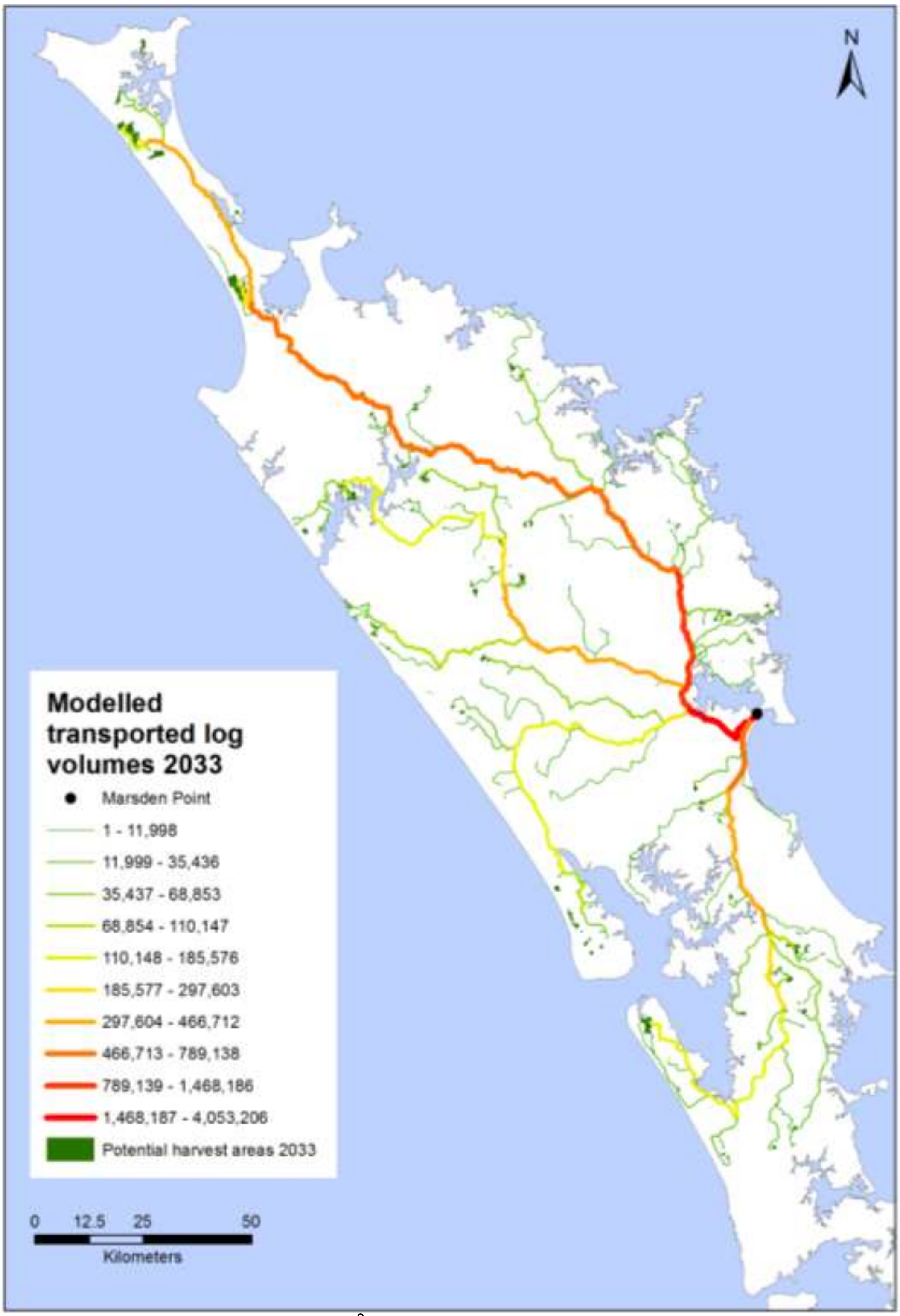

Figure 13: Transported log volumes (m^3) for forests harvested in 2033 accumulating at North Port in Marsden Point.

The pattern emerging from these five maps suggests that the surge in wood supply is currently occurring or is imminent and will remain high on the main through roads, tapering only in 2033. In all areas except for the Far North, there is a distinct drop in supply in the years between 2018 and 2033. The Far North supply, although experiencing a reduction in volume in 2023, remains steady. In the 2028 and 2033 scenario years much less wood is forecast to come from dispersed smaller planted forests.

Truck movements per day were estimated based on the volumes and routes produced by the flow accumulation results. Wood volumes were converted into weight using a conversion factor of 960 kg/m^3 (Peter Hall, Scion, pers comm). The capacity of different vehicles was estimated using values from the Gisborne District Council Website in the Vehicle Dimension Mass Rule Amendment Explanation document accessed from the Gisborne District Council Website (2014) (Table 7). The total number of 44 tonne vehicle movements to North Port was estimated to be approximately 451 per day in 2013, dropping to 218 per day by 2033 (Table 8). These figures only consider loaded running and not the unloaded running associated with travel to the forest to collect the wood.

Table 7: Truck weights and loads (GDC, 2014)

Approximate truck weight (net)	Load	Total truck weight (gross)
16 tonnes	28 tonnes (existing maximum)	44 tonnes
16 tonnes	34 tonnes (21% increase)	50 tonnes
16 tonnes	44 tonnes (57% increase)	60 tonnes

Table 8: Total estimated truck movements throughout Northland from 2013 to 2033

Trucks per day in scenario year	Truck: 44 tonne	Truck: 50 tonne	Truck: 60 tonne
2013	381	314	242
2018	159	131	101
2023	351	289	223
2028	236	194	150
2033	197	162	125

Figures 14 to 16 give an indication of daily truck traffic rates based on the flow accumulation results for 2023. Where the daily rate shows as ‘less than full truck per day’ the trucking rate is predicted as occurring for only a part of the year. Table 9 presents the results as tonne-kilometres. The modelled tonne-kilometres are within range or below those from a recent freight demand study (Stuart Miller, MPI, *pers comm*), which indicated values of 0.47 billion tonne-kilometres for Northland-Northland freight and 0.61 billion tonne-kilometres for Northland-NZ timber and forest products freight.

Table 9: Modelled tonnes of log freight by kilometres travelled (units are billion tonne-kilometres)

Scenario year	Kilometres with log freight	Tonne-kilometres
2013	6,500	0.53
2018	6,431	0.22
2023	1,820	0.36
2028	2,089	0.31
2033	2,020	0.30

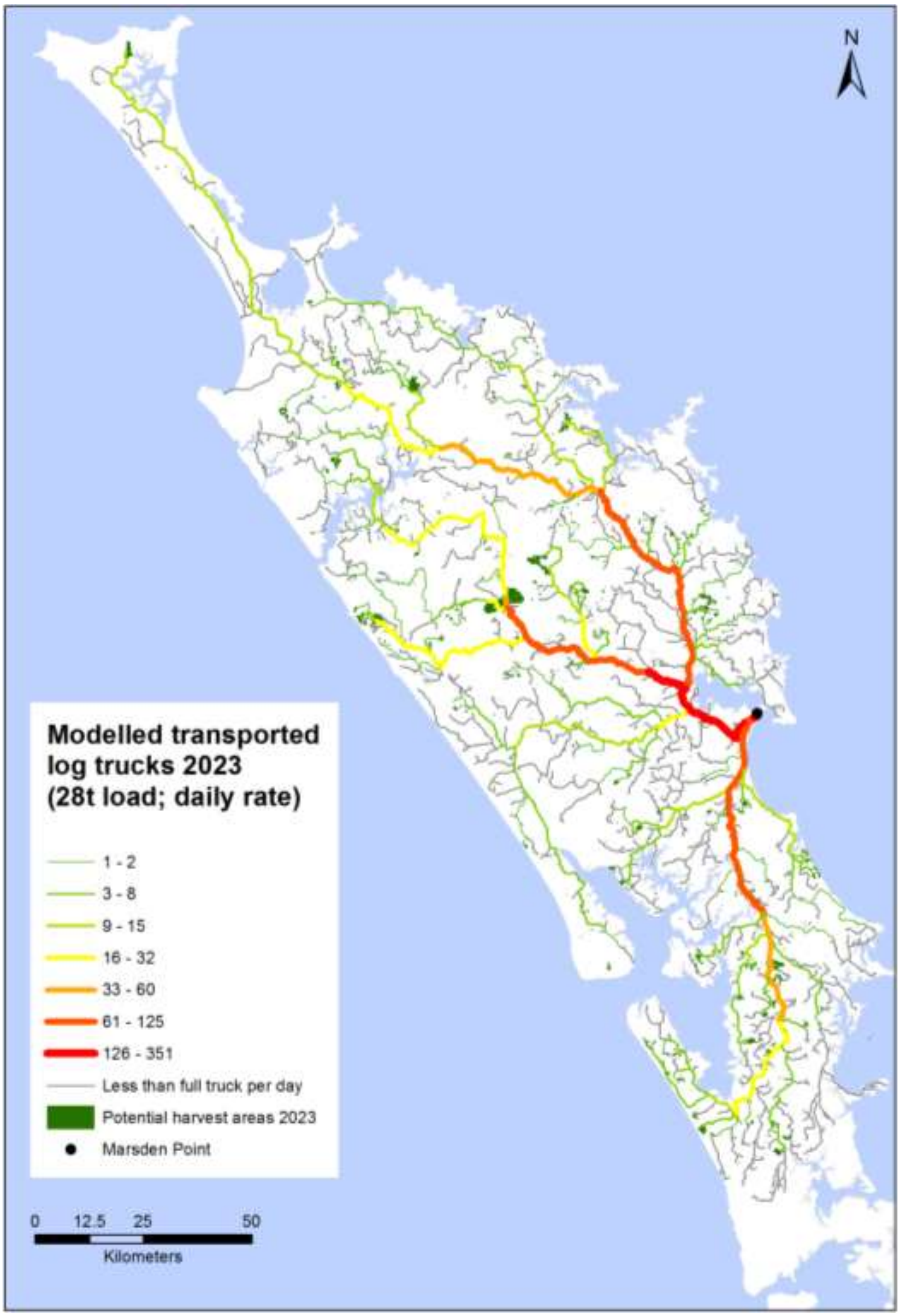

Figure 14: Truck (44 t) movements across Northland for 2013 harvest

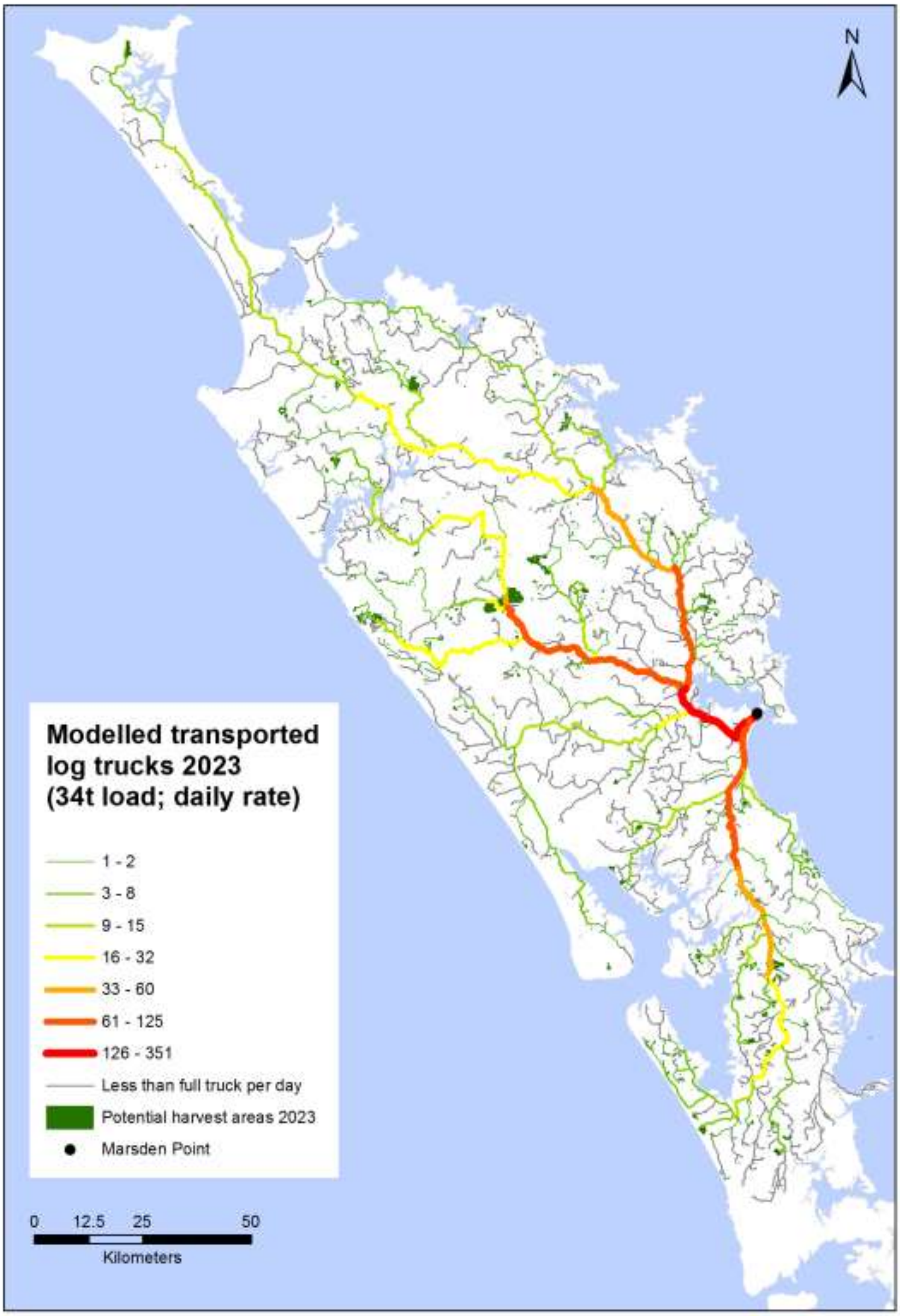

Figure 15: Truck (50 t) movements across Northland for 2013 harvest

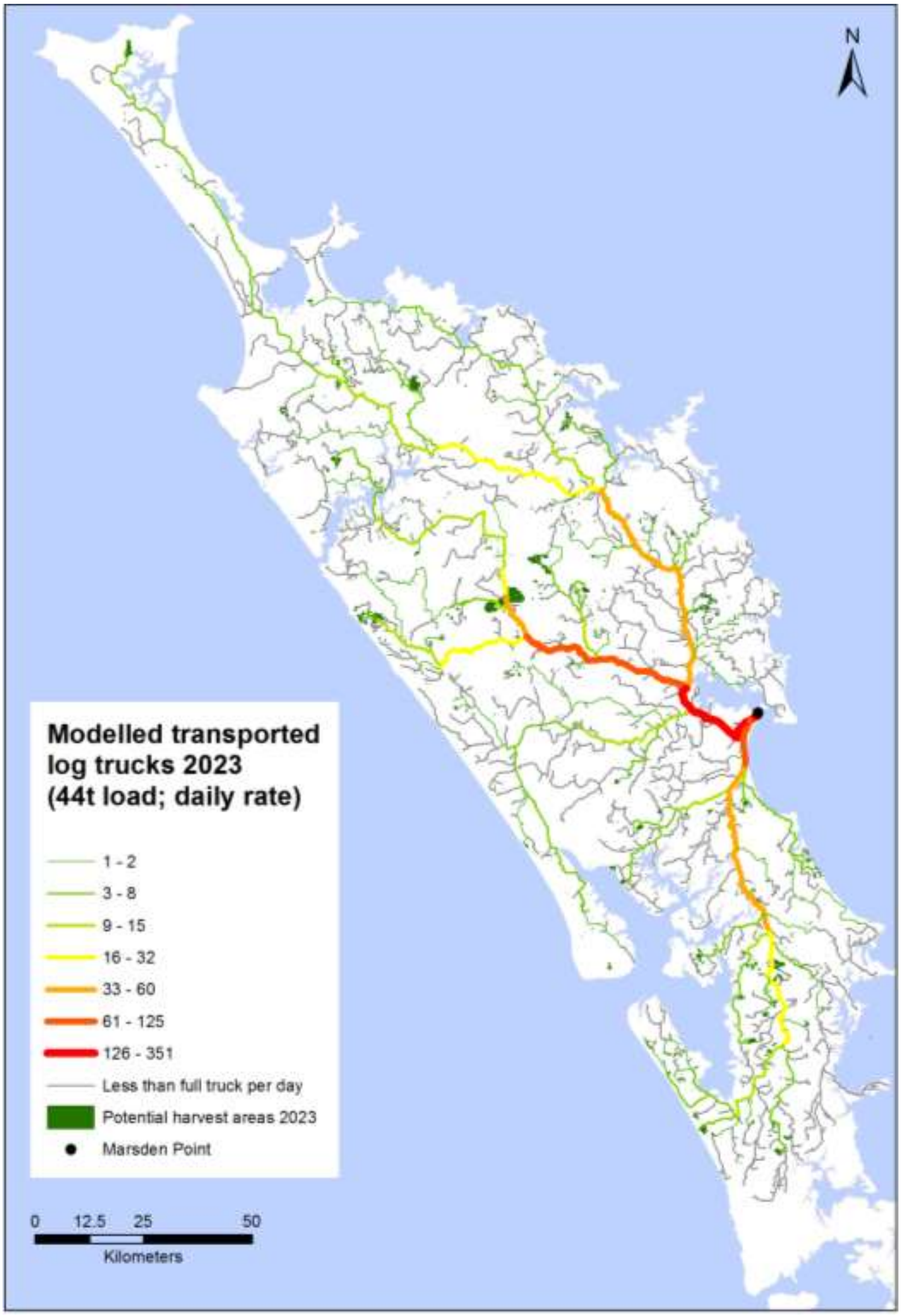

Figure 16: Truck (60 t) movements across Northland for 2013 harvest

The routes highlighted by the 2013 wood flow include Highways 1, 14, 16 and Mangakahia Road heading North/West from Whangarei (Figure 17). Significant overlay treatments and stabilisation of existing pavement have already been carried out on the Otaika Valley road, highlighted in green in Figure 17 and the Mangakahia Road (Beca, 2013). These maps portray the current situation concerning transport of logs throughout Northland. however, analysis of future replanting intentions will help to determine whether this pattern will be repeated in 28 to 30 years' time. An understanding of future wood flows will help transport planners make timely decisions in advance.

Figure 17: High traffic routes for the 2013 harvest. Otaika Valley Road is highlighted in green, just south of Whangarei.

The issue around developing further HPMV routes is that it may not be economically sound to extend these routes into the major forests. The use of 50Max vehicles will contribute to a decrease of vehicles on the roads, moving greater loads and having less impact on the roading infrastructure. 50MAX vehicles differ to 44 tonne vehicles because they have an extra axle. The overall truck load is spread further and there is no additional wear on roads per tonne of freight (NZTA, 2015), hence the majority of district roads should be capable of handling the 50MAX vehicles.

The developed methodology

The methodology developed for the Northland case study builds on the techniques developed for the Scion Biomass supply model which identifies costs and distances for transporting post-harvest biomass to markets at various locations (Hock et al 2012). The methodology developed in this project accesses data freely available online which allows for the process to be repeated in other areas in New Zealand. The steps described in this report require a certain level of technical GIS knowledge and familiarity with datasets such as LCDB and NEFD is desirable. Refinements to this process would be possible with a NEFD that has good spatial resolution, in order to be able to more accurately locate the locations of forest age classes. While this information has commercial sensitivity, there may also be benefit to the forest companies for good roading analysis.

Forest harvest intentions would also be valuable for the modelling, as a single harvest age was assumed for the modelling. This would be especially useful for larger planted forest areas, and for areas identified as being in a single age class where the benefits of achieving an at least partly more continuous income outweigh the economies of scale for the harvesting costs. Additional refinements are possible with an up-to-date and complete roading network. Network analysis assumes continuous (joined) roading linework which was only partly fulfilled by the freely available LINZ roading data. The methodology is usable for other areas and other timeframes with appropriately selected or updated input data.

Comparison to other approaches

Work has been carried out by each council in Northland to estimate wood flows and identify roading infrastructure upgrade requirements. The Far North District Council is working through a three stage strategy with Beca Ltd and Engineering Outcomes Ltd. The FNDC Forestry Road Management Study Iteration 1 – Phase 1 ,2 and 3 Outline Report aims to determine the impact of forestry on the districts roading network. Phase 1 has assessed the demand from forestry activities on the roading network. Phase 2 assess the financial impact on the roading network. Phase 3 considers policy and a funding framework, identifying stakeholders who are willing or able to pay to manage the forest impact. The methodology used to identify wood flows used a range of spatial and tabular data. To assess the area and ages of exotic forests they used Land Use Carbon Assessment System (LUCAS) spatial data (MfE). LUCAS data is divided in two classes that include forests planted before 1990 and those planted after 1989. In addition they acquired data from the forestry industry. However, the industry data covered less than half of the forests identified using LUCAS data.

The point of difference with the methodology described in this report is that it divides the forest classes across a 28 year rotation using the LCDB and aligns the spatial areas with NEFD tabular data. This may contribute to higher accuracy of future wood flow prediction than using only two classes as with the LUCAS data.

Conclusions and Recommendations

To facilitate a deeper understanding of the forecast increase in forest harvesting, a method was developed to analyse forestry sector transport infrastructure needs within the region of Northland, New Zealand. Using freely available online data sets backed up by consultation with local councils, key transport routes and estimated tonnage of logs per route from Northland forests to port, at Marsden Point were identified. ArcGIS 10.2 Network analysis tools proved to be unsuitable for this type of analysis but the flow accumulation and direction tools from the ArcGIS 10.2 hydrology toolbox produced the desired results. The results highlight the variation of wood flow the next 20 years and outlines potential routes that could feature in discussions around infrastructure upgrades and new HPMV routes.

Although districts councils have commenced analysis of infrastructure needs independently, there is a need for a nationally co-ordinated approach that would link the regions. In addition, in depth analysis of future planting intentions would further strengthen the understanding of future roading requirements for the transport of logs across New Zealand. If the pattern outlined in our scenario maps was to be repeated, there may be another wood production surge in 28 to 30 years' time, which would suggest planning in the short term would be prudent. Improving the timings of the on-road volumes may be possible through comparing the LCDB-based approach to other data known to MPI, and incorporating individual owner rotation age intentions where these are known

The current analysis has only considered the case where wood is transported to the port. Further work should focus on transport to local mills, particularly wood from the Far North as this is likely to have implications for the number of truck movements along key routes. The accuracy and precision of using publicly available data within this methodology could possibly be verified by MPI against the more detailed confidential data MPI holds, particularly age class distribution. Volume conversions based on available national data could be verified against actual roundwood removals. More in-depth analysis is also required to look at flow impedances such as road gradient, bridge limits, and 50Max routes. A further element that could be considered is the post-mill movement of processed timber products and chips. Limited regional demand within Northland means that most of this production is likely to be transported to the port or south to Auckland along Highway 1. Other regions may present a more complex situation.

Acknowledgements

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Appendix A

High Productivity Motor Vehicle planned routes

http://www.nzta.govt.nz/vehicle/your/hpmv/investment-maps.html