What is a Harvest Plan? An Evaluation and Review of What Defines a Good Harvest Plan

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Executive summary

Harvest plans are essential yet vagueness surrounds the specificities of one. There are inconsistencies across literature and forestry-related documents where little has been put to paper in terms of harvest planning in a New Zealand context. The term 'harvest plan' is also subject to broad and generic descriptions where some may say the name is self-explanatory. To answer the question "what is a harvest plan?" and "what makes a good harvest plan?" a survey was sent out to expert harvest planners in the industry to obtain key information regarding the objectives, considerations and expectations of a harvest plan. The aim of the study is to gain insight into harvest plans and how harvest planners create good harvest plans as part of a process. The results from the survey were highly variable where there were limited similarities to confidently proceed in developing a criteria/framework for a good harvest plan.. This was due to the scope of the study and the simplification of a complex problem. Much of the differences were attributable to the functions of different forestry companies. However, as a resource, the study lends valuable information on "what is a harvest plan?" and develops the key ideas and guiding principles that should be understood in order to create a good harvest plan.

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1. Introduction

Forest harvesting is a key component of the production lifecycle of a forest. Under forestry legislation in New Zealand, the National Environmental Standards for Plantation Forestry (NES-PF) states that permitted harvest activities must include a 'harvest plan' for all ESC zones. In forestry, there are different levels of planning hierarchies and temporal-spatial scales that influence the decision-making and planning process. With that comes a wide scope and generalisation of the term harvest plan. The NES-PF does not explicitly define what is meant by a harvest plan, rather, it sets out the rules and regulations of what is required of one. It is obvious that the requirements specified by the NES-PF do not fully encompass the full description of a harvest plan. This raises the following questions. What is a harvest plan? And what makes a good harvest plan? What is generally referred to as a 'harvest plan' describes a harvesting prescription which includes a map detailing the harvest and a supporting document.

The focus of the study will be predominantly on the processes which relate the mapping component. There are many ways that one can create harvest plan, all of which are correct in their own right. This study aims to help define a harvest plan's common objectives, considerations and expectations by comparing literature, forestry-related documents and industry input. Through this process, the framework for what is deemed a 'good' harvest plan may be ascertained while giving insight into how the New Zealand forestry industry harvest plans to ensure the fulfilment under different obligations.

2. Literature review

2.1 NZ Legislation

The NES-PF is a document that sets out nationally consistent rules and provisions to manage the environmental effects of plantation forestry under the Resource Management Act 1991 (RMA). The regulations that are described in the NES-PF are created under the Act. This means that it is legally binding in New Zealand. This prevails over the regional council and territorial authorities i.e. the Regional and District Plans but regional council have the ability to be more stringent if they perceive the need for it. The NES-PF also shows whether the regional council or territorial authority has functions with respect to each regulation. These functions are concerned with the establishment and implementation of the objectives and policies for the purpose of giving effect to the Act. In terms of harvesting, the territorial authority states that harvesting is a permitted activity if the relevant regional council and territorial activity are given a written notice of the location and period of the harvesting activities. This notice must be submitted 20-60 days before harvesting begins, annually for ongoing harvesting operations and a minimum of two days before salvage operations. The regional council further requires that harvest activities are only permissible in green, yellow and orange ESC zones if regulations 64 to 69 are complied with. Red zones require a resource consent unless the harvest area is less than 2 ha within a 3 month period. These regulations include the mentioned notice conditions (64), sediment (65), harvest plan (66), ground disturbance (67), disturbance of margins of water bodies and coastal marine area (68), and slash and debris management conditions (69).

64. Notice

The relevant regional council and territorial authority must be given a written notice of the place where harvesting will be carried out and the dates on which the harvesting is planned to begin and end.

65. Sediment

Sediment originating from harvesting must be managed to ensure that after reasonable mixing it does not give rise to any of the following effects in the receiving waters: any conspicuous change in colour or visual clarity; the rendering of fresh water unsuitable for consumption by farm animals; any significant adverse effect on aquatic life.

66. Harvest plan

A harvest plan is required for all erosion susceptibility classification zones. A harvest plan must identify the environmental risks associated with the earthworks and provide operational responses to those risks that avoid, remedy, or mitigate the adverse effects of the activity on the environment. It must also contain the details required by Schedule 3.

67. Ground disturbance

Harvest systems must be planned and located to achieve butt suspension wherever practicable. Disturbed soil must be stabilised or contained to minimise sediment entering into any water and resulting in: the diversion or damming of any water body; or degradation of the aquatic habitat, riparian zone, freshwater body, or coastal environment; or damage to downstream infrastructure and properties.

68. Disturbance of margins of water bodies and coastal marine area

Trees must be felled away from any water body or riparian zone during harvesting, except where it is unsafe to do so, to minimise disturbance to the margins of water bodies and to the coastal marine area. If the exception in subclause (1) applies, trees must be felled directly across the water body for full-length extraction before de-limbing or heading. Full suspension tree harvesting in a manner that lifts the entire tree above the ground must be achieved across rivers of 3 m or more in width.

Harvesting machinery must not be operated, except where subclause (5) applies:

- within 5 m of a perennial river with a bankfull channel width less than 3 m; or a wetland larger than 0.25 ha;
- or within 10 m of a perennial river with a bankfull channel width of 3 m or more; or a lake larger than 0.25 ha; or an outstanding freshwater body; or a water body subject to a water conservation order
- or within 30 m of the coastal marine area.

Harvesting machinery may be operated in the setbacks required by subclause (4) only if: any disturbance to the water body from the machinery is minimised; and the harvest machinery is being operated at water body crossing points; or where slash removal is necessary; or where essential for directional felling in a chosen direction or extraction of trees from within the setbacks in subclause (4). When harvesting occurs within or across a riparian zone, all disturbed vegetation, soil, or debris must be deposited to avoid it entering into water, and to avoid: diversion or damming of any water body or coastal water; degradation of any aquatic habitat or riparian zone; damage to downstream infrastructure or property.

69. Slash and debris management

Slash from harvesting must be placed onto stable ground. Slash from harvesting that is on the edge of landing sites must be managed to avoid the collapse of slash piles. Slash from harvesting must not be deposited into a water body or onto the land that would be covered by water during a 5% AEP event. If subclause (3) is not complied with, slash from harvesting must be removed from a water body and the land that would be covered by water during a 5% AEP flood event, unless to do so would be unsafe, to avoid: blocking or damming of a water body; eroding river banks; significant adverse effects on aquatic life; damaging downstream infrastructure, property, or receiving environments, including the coastal environment.

This information is a portion of the preliminary groundwork when determining the feasibility of a harvest plan. It is clear that regulation 66, which sets out the conditions for a harvest plan, is only one of many conditions that must be met before a harvest is even permitted. Therefore it is not sufficient to understand harvest planning by only referring to New Zealand legislation.

2.2 Hierarchical planning structure

There are three different levels of hierarchical planning in a forestry context. These include strategic, tactical and operational planning. This opens up the term 'harvest plan' to many different planning problems that require varying degrees of information and their level of aggregation. This approach is often used in forestry and has been reported in multiple studies (Weintraub & Cholaky, 1991; Boyland, 2003; Marques, 2012 ;Marques, Audy, D'Amours, & Rönnqvist, 2014).

Strategic planning refers to the long term objectives and goals. This relies on aggregated information and assumptions of wood availability and demand across a planning horizon spanning decades. Long term policies are set which don't take into account the details or technicalities that come operationally. This plan is developed for the whole forest and it states when and where the harvesting is to be done across the entire estate.

Tactical planning deals with medium-term decisions over medium scale areas and timeframes. The production capacity and resource sustainability are set at the strategic level which constrains tactical level decisions. The best method of structuring activities is addressed at the tactical level which involves a typical planning horizon of 5-20 years (Boyland, 2003). However, some sources mention that this timeframe can be shorter or longer. For example, Marques et al. (2014) mentions that tactical plans encompass a planning period that can span from months to years and a time horizon of typically 1 to 3 years. While a similar study considers monthly to yearly planning periods and time horizons of 10 to 30 years (Marques, 2012). Tactical planning answers how the harvesting is done in each of the areas planned for harvest. This includes the sequencing and timing of harvest, method of harvest and the crew that will undertake the operations.

The operational plan describes the daily planning processes which manage harvesting activities. These decisions precede and determine the real-world operations. Timeframes can range from hours to days (D'Amours, Rönnqvist, & Weintraub, 2008). This may include cut plans, landing layouts and daily/weekly production targets. As you work down the levels, technical issues and machine systems limitations are of greater importance, hence, planning becomes more dependent on detailed information as opposed to aggregated information. Decisions made at the strategic level become constraints for the levels below it. Figure 1 shows an example of the forest planning hierarchical approach.

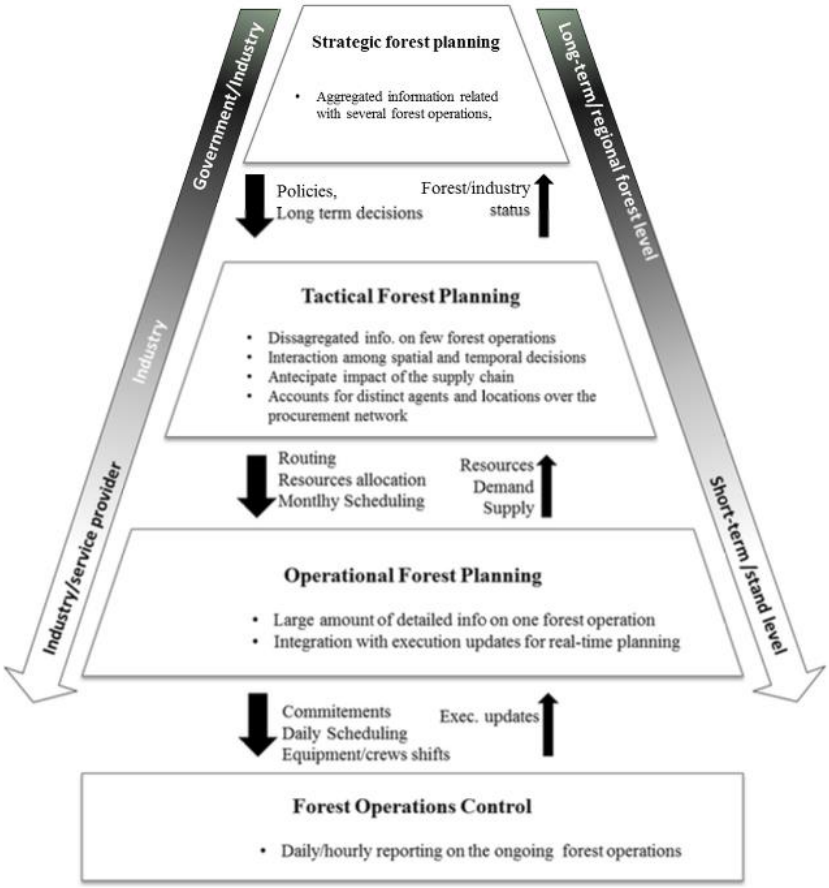

Figure 1. Forest planning hierarchical approach (Marques, 2012).

Across literature, these three levels are defined in similar ways but with subtle differences regarding the activities involved. For example, Murray and Church (1995) define the operational level by the development of a land-use plan for an area within the forest where stands are selected for treatment. This contrasts with a study that states that 'Land use plans are designed to provide long-term strategies for regional land use and landscape management' referring to the strategic level (Tittler, Messier, & Burton, 2001). Murray and Church (1995) goes on to state that the scheduling of forest operations, road building and road maintenance is included on the operational level. In another study (Boyland, 2003), activities such as road construction/deactivation and landscape-level silviculture are defined on the tactical level. Some sources do not use the term operational. For example, FAO forestry documents based on the work of Armitage (2001) state that 'Harvest plans are of two types, strategic and tactical, and both are an integral part of the forest management planning process'. In a study done in Portugal, it is stated that earlier studies such as the ones outlined tend to use the terms annual/operational to refer to tactical mentioning that these issues still persist in the Portuguese forestry industry (Marques, 2012). These inconsistencies make it difficult to determine the planning level a harvest plan sits at while making it harder to define the considerations and inputs required of one. These irregularities are

acknowledged by Marques et al. (2014). The study notes that the distinction between the terms tactical/operation is narrow and case-specific but the difference between tactical/operational and strategic becomes more consensual in literature. It is also important to note that although hierarchical planning maintains its advantage in its ability to reduce complexity while managing uncertainty, there are some drawbacks. Objectives conflicting at different levels may cause inconsistencies due to the sequential nature of problem-solving. Information aggregation or disaggregation can create infeasible solutions which lose correlation between the model and reality. The quality of coordination used to link together the decision levels may also cause suboptimality in the planning process (Beaudoin, Frayret, & LeBel, 2008).

2.3 Definition of a harvest plan

Across literature, the definitions of what may be interpreted as a harvest plan are described in multiple ways. Boyland (2003) states that on the operational level 'A typical harvesting operational plan will cover a single harvest unit over the period required to fall the trees, yard them to landings, and haul them from the block'. He goes on to explain that operational planning specifies action plans for the activities scheduled at the tactical level. As mentioned previously, Murray and Church (1999) define the operational level as the development of a land-use plan for an area within the forest where stands are selected for treatment i.e. harvesting. From forestry-related documents, The FAO Code of Practice for Forest Harvesting in Asia-Pacific defines a harvest plan as operational plans that are developed for individual harvest areas, based mainly on site inspections. Across these sources, a key similarity is that the harvest plan is applied on the operational level. While these definitions provide the general outline and function of a harvest plan, there is a low level detail. They are also without an objective/goal and fail to outline the level of consideration to environmental and social concerns. Across forestry-related literature, the hierarchical structure has been addressed and defined. However, a common well-defined definition for a harvest plan is seldom addressed. It seems appropriate that the harvest plan is designed for all the values in with the forest harvesting practice encompasses.

2.4 Objectives of a harvest plan

In order to further describe a harvest plan, common objectives of harvest planning across multiple studies on the tactical/operational are compared. Many considerations are required during the planning process of harvesting operations where the harvest plan's role is to incorporate these values. By comparing common objectives for harvesting operations and harvest plans, this lends important information for the determination of a harvest plan's purpose. Studies done under the context of forestry optimisation suggest that 'The goal is to locate the harvest machinery and design the road network at the lowest possible cost while reducing the environmental impact upon the harvested terrain. Production

costs include machinery installation and operating costs, the cost of road construction, and the cost of moving timber outside the harvesting area' (Epstein et al., 2006). Under this context, the purpose of a harvesting operation has a predominantly economic focus while still taking into account environmental concerns.

These objectives provide insight into the considerations that are required of a harvest plan but do not incorporate influences from the wider harvest planning process. In a forestry planning study done in the 1980s 1(Breadon, 1983), objectives that are common to all harvest plans are proposed in a more structured approach. The objectives include the collection of the best possible information as a basis for planning; the choice of the best combination of available systems for cheapest overall harvesting, roading and restoration; balanced recognition of the timber, non-timber, environmental and social benefits expected. Planning considerations are now incorporated into the objectives while non-timber provisional values are given recognition. From these studies, the criteria for performance can be established as objectives are defined in a structured approach. However, across literature, these objectives are rarely defined on a common front as different studies are case-specific and tackle different forestry-related issues. In New Zealand, there is little information regarding common objectives for a harvest plan or a common approach for stepping through the development of a harvest plan. By providing a resource that is aligned with the interests of the whole industry, companies can reflect on how their decision making aligns with the expectations of the industry. Common objectives among different forestry companies may also provide insight into the prioritisation of different values, revealing what considerations are given the most importance.

2.5 Common tactical and operational planning problems

Harvesting operations vary in spatial scales and site characteristics. This makes it difficult to compare harvest plans as key issues will vary under different circumstances. Planning complexity increases when multiple temporal scales, processes and supply chain influences are taken into consideration. This complexity along with the economic importance of planning was the motivation of tactical/operational research since the 1990s (Marques et al., 2014). Although many harvest planning problems vary and are case-specific, there are still common tactical/operations harvest planning problems that can be applied to the majority of cases. Defining these problems is crucial to determine why specific decisions were made under a harvest planning context. Although these decisions will differ under different organisational and operational settings. They provide key insight into the harvest planning process and, therefore, the required inputs of the harvest plan.

Common tactical and operational planning problems have been addressed frequently in literature (Rönnqvist et al., 2015; Marques, 2012). Studies approach these problems with decision making support systems (DSS) and operations research methods (OR) which involve mathematical programming models with objective functions and constraints. These approaches can include but are not limited to, linear, mixed-integer, dynamic, programming methods as well as heuristics and multi-criteria decision making approaches. In these studies, the fundamental decisions that are related to managing industrial plantations from the perspective of decision-makers correspond to a Forest Tactical and Operational Planning Problem (FTOPP). This is a planning matrix that relates to the different planning horizons in forestry and the operations which are related to the decisions.

The determination of these issues was based on workshops and questionnaires conducted with a significant number of stakeholders. On the tactical level, these problems include harvest scheduling, harvest sequencing, machine system, team assignment and harvest service adjudication. On the operational level, the main problems include log extraction, harvest/transport synchronization, bucking and sorting strategies, and crew/equipment scheduling. Although these problems have been defined and investigated in literature, there is limited information regarding the use of these methods in terms of industry application, especially in New Zealand. As planning and decision making directly affect the harvest plan, an industry-wide review may provide insight into how tactical and operational problems are addressed in the harvest plan. By solving these problems, targets can be established which can set key indicators. These indicators can then be monitored to provide valuable information on performance. It could be of value, obtaining information on tactical/operation problems that forest companies use DSS and OR models or for cases where the decision making is done manually or based on the experience of the harvest planner. This may present to the industry potential improvement opportunities for their decision making and problem-solving systems in their harvest planning process.

3. Objectives

The purpose of this study is to gain insight into the harvest planning process and harvest plans. The harvest plan is an essential part of the harvest planning process. However, across literature and forestry-related documents, vagueness surrounds the specificities of a harvest plan. This study aims to:

- Understand the reasons for why we harvest plan
- Understand the key considerations required to create a good harvest plan
- Determine a structured approach for stepping through the process of creating a harvest plan.
- Provide a resource for forest managers and contractors.

As a resource, the study will allow for a better interpretation of harvest plans amongst the requirements of different forestry companies. The intended outcome will be a valuable information resource which puts to paper key aspects of harvest plans. New harvest planners entering the industry will be able to understand the key considerations required to ensure to create a sound harvest plan. Contractors and regulators can use this information to better their understanding of harvest plans and the considerations required of one from a forest manager's perspective. A structured approach for the development of a harvest plan should also provide information that directly affects harvest planning as an exercise. This allows for a more insightful outlook on harvest plans where new harvest planners are able to know why and how expert harvest planners make certain decisions in the New Zealand forestry industry.

4. Methodology

The two study questions proposed are “what is a harvest plan?” and “what is a good harvest plan?”. To provide structure and determine the context for the information that will be needed of the participants, the study is split into three factors (Figure 2). This is the key framework for the analyses as it provides a logical structure for the information required of the study as well as presenting a narrative. The information required will be obtained through an industry survey. A great degree of variety and inconsistency is expected from the data collection, therefore, the survey questions are developed from this structure where the resulting information can be reorganised, resulting in a more effective discussion later on in the report.

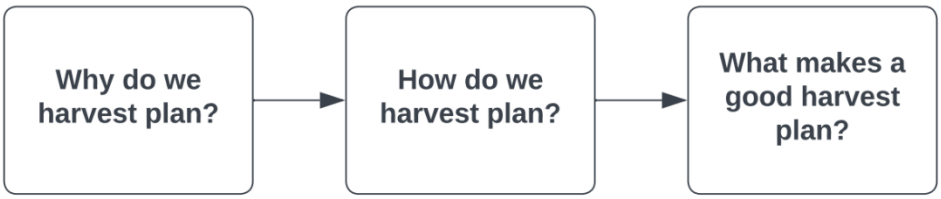

Figure 2. Study framework.

Split into different factors, the goals for each of the three factors can be better organised. These goals reflect the study objectives which then provides the study with the information needed for the analyses. The study follows this structure in hopes of answering the question of ‘What makes a good harvest plan’. This survey will be sent out to expert harvest planners from various forestry companies. Figure 3 shows how the survey questions were developed from the study framework and how they fit in to it

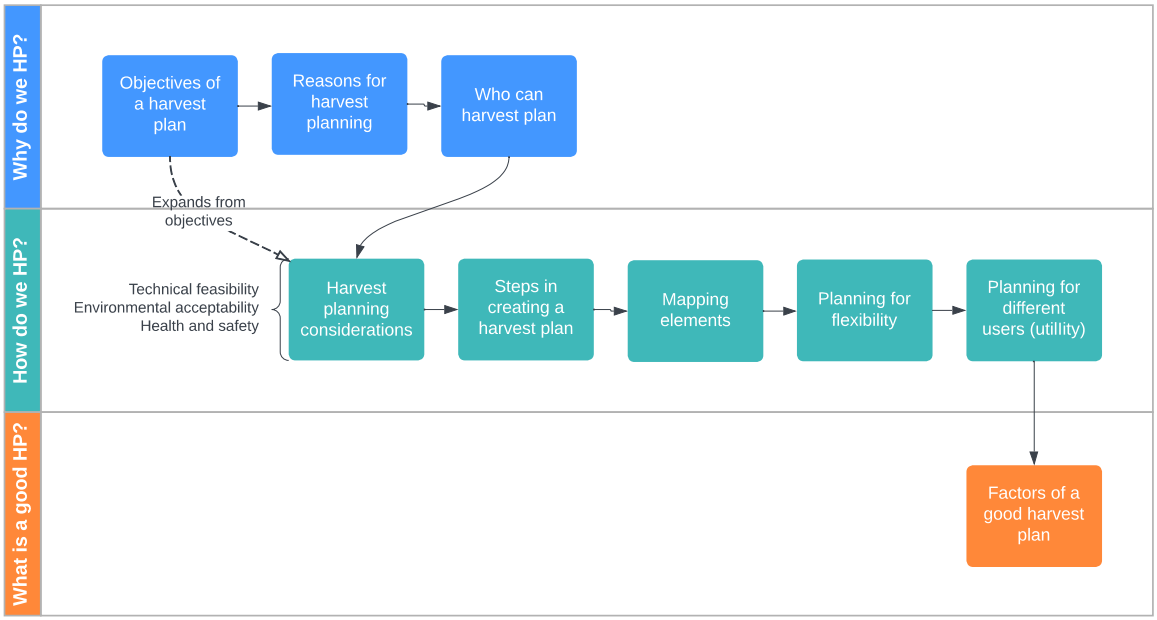

Figure 3. Structure and flow of survey questions.

The harvest planning approach the survey will ask to describe will be set with limits and constraints. This is due to the variable environment and circumstances surrounding harvest planning. This provides more consistency from the answers where a robust harvest planning process will be described for the following block:

25-50 ha block of radiata pine on moderate terrain in terms of slope and soil robustness that will be clearcut using a ground-based system. There is a stream running down the middle of the block and some short slopes greater than 30°, and the location is in an urban/rural interface. Assume landing and road construction, as well as harvesting is required.

Although the gathered approaches to harvest planning will be limited to these factors, the scope of the proposed area should remain broad enough so that the harvest planning process is applicable to other harvest areas in New Zealand. A more comprehensive study may be required to yield specific processes in regards to the different range of harvest areas e.g. ground based/cable logged and woodlots/large-scale forests. The result of the analyses should provide insight and a better understanding into harvest plans paired with a criteria and framework for what can be followed and considered to create a good harvest plan. Additionally, areas of improvement may be revealed where the options for improvement will be addressed. The goal of the study is not to provide set instructions for the harvest planning approach to be followed or strict rules imposed by the criteria, rather, it acts a resource for harvest planning information and develops principles that can be followed/considered to create a good harvest plan. The result may be that harvest plans are not a uniform product where there is no such thing as one harvest plan being better than another due to the variety of different factors. The study will nevertheless provide valuable information and provide feedback on the considerations and expectations required of a good harvest plan based on the what expert harvest planners think.

5. Results

The survey was sent out to a target group of past graduates of the School of Forestry where harvest planners were invited to participate in the study. Twelve responses were received which can be considered sufficient within the scope of this study. The contributing harvest planners range from early industry to seasoned professionals in a diverse range of forestry companies. The harvest planning work of these companies stem from their varying functions which range from woodlot management to large-scale corporate landowners. The results include information that is most relevant to the study where. incomplete answers and questions that were misinterpreted are not included in the results. Respondents are assigned a fixed letter (A-L) for reference.

5.1 Survey question responses

To the expand the understanding of a harvest plan from the regulatory description set out by the NES-PF the first survey question asks harvest planners for the main objectives that they think are common to all harvest plans as to establish the fundamentals of harvest planning (Table 1). **"What would you consider to be the main objectives common to all harvest plans in NZ plantation forestry?"**

Table 1. Objectives common to all harvest plans.

A	Compliance with NZ environmental and safety legislation. Efficient use of harvesting resources to maximise returns for the forest owner within the constraints of the site.
B	Identify and manage the health and safety aspects associated with operations. Identify and manage environmental considerations attributed to operations. Identify all PCBUs (harvesting, earthworks, cartage etc.) and plan how all operations can efficiently operate in conjunction with one-another. Describe methodology/scope of works of each operation. Identify any other affected parties and manage accordingly.
C	Give adequate but not too much information for the harvesting and roading crews to complete harvest, efficiently, safely and ensuring environmental standard are complied with.
D	Main objectives are: describe how to harvest timber from a forested area with minimal environmental impact and maximum economic benefit. This involves; addressing all regional/national constraints, providing a safe harvesting method, reduce roading and harvesting costs, etc.
E	To provide a cost-effective harvesting solution for the land owner, which can be undertaken safely and is environmentally sound.
F	To identify where the bulk of the risks are within a harvest area. Indicate the mechanism to manage these risks; this may include selection of configuration, infrastructure required, exclusion zones and so on. Health and Safety and Environmental is number one, secondary is how to maximise return on investment and produce the best quality log for the least cost practicable.
G	To gain an overall plan that all parties can work to. To gain the optimal result for all concerned.
H	How to harvest a forest in a way that was efficient to the configuration available/required, safe and environmentally sustainable.

I	Show harvesting method, infrastructure layout and specifications, environmental limitations, utilities and known hazards.
J	To show the location, size and length of engineering works, such as roads, hauler pads and skids and culverts. To show terrain, especially steep pieces and ridges, so logical setting boundaries can be drawn, and the correct harvesting equipment can be sourced for the job. To show environmental and archaeological features such as streams, high erosion areas, Pā sites etc. To show any constraints that will affect engineering or harvesting, i.e. streams, neighbours, new planting, powerlines, fences, etc.
K	As per NES-PF guidance but also with H&S and operational planning. A one-stop shop as an instruction for a harvesting or earthworks contractor.
L	To ensure harvesting is completed in a way that is financially viable, physically practical, can be completed safely and in an environmentally and socially friendly manner.

The stated objectives mention the same environmental and health and safety aspects while varying in financial and operation goals. These provide a good starting point for understanding the subsequent information. The next survey question develops on from the first question and asks the reasons for harvest planning and its importance (Table 2). **"Why do we harvest plan and, hence, what is its importance?"**

Table 2. Reasons for harvest planning and importance.

D	We harvest plan to ensure a proposed operation is feasible, both environmentally and economically. The plan helps to ensure the operation meets the objectives of the landowner
E	A detailed, concise, easy to understand plan removes any elements of doubt for all parties involved. Provides clear expectations around the harvesting methodology.
F	To operationalise a strategy. It is important to have a forward work plan work for all crews and have the ability to provide projections/budgets for the business. A harvest plan forms the basis for all other supportive functions and how they are planned or managed.
G	If there was no plan all the parties could work in conflict with each other as their end goals could differ from PCBU for regulator.
H	We harvest plan to ensure the plan in place is going to be what is largely achieved. It also provides an opportunity to refine the plan if and when it needs to be developed.
I	Depends on objectives, can be for valuation with relatively low detail and ground proof or can be preharvest operation plan. Importance second only to volume and grade mix (inventory).
J	It enables us to create a plan so we can safely and economically engineer and harvest a block. It ensures all stakeholders, i.e. supervisors, roading crew, logging crew, supervisors, owners are on the same page. It allows us to gauge what the cost of the operation will be, so we can decide whether it's worth doing at all, or only in certain export markets.
K	We harvest plan to minimize unpleasant surprises with a harvesting operation. It is particularly important with harvesting and earthworks because the consequences of an operation going wrong are so significant. High daily costs of crews and costs of moving to a different site make it very inflexible, so the best way to minimise the risk of this happening is with robust planning. As an offshoot, good

	planning may also see you gain efficiencies by changing the harvesting crew configuration to be more productive.
L	Before harvesting can begin there is a lot of work and time that is required to ensure the harvest happens smoothly and efficiently and meets required legislation. Before harvesting can begin, a plan has to be created on how the harvesting is to be completed that meets all the requirements stated in question 1. Following the creation of this plan, council and archaeological consents may be required which can take years to be completed. Following the plan and consents being completed road lining and earthworks is generally completed 1-2 years before clear fell begins.

A lot of variety is seen in these answers where different aspects outlined by different harvest planners give an overarching view of the reasons for why we plan. As there is no planning certification in New Zealand, it is important to ask industry professionals on who they think should be able to harvest plan (Table 3). This also gives further insights in to the key qualities of an individual that is able to harvest plan. **"The ECoP states that 'Harvesting must be planned, supervised and undertaken by appropriately trained personnel.' Who do you think 'appropriately trained personnel' encompasses in terms of harvest planning?"**

Table 3. Who can harvest plan.

D	Someone that has either worked in the forestry industry and has a good understanding of harvesting configurations and environmental requirements (e.g. an ex logger, or someone with extensive forest management experience); or someone that has received formal forestry training such as a diploma or degree (however, this person would not have the skills required to develop an adequate harvest plan straightaway without the guidance from someone more experienced).
E	Could be a university graduate who has spent time (1-2 years) under an experienced harvest planner. Could be someone who has had years of 'on the ground' forestry experience. Ideally someone who understands the limitations of various logging systems, understands the terrain and ground conditions of the area to be harvested and has a sound working knowledge of the various environmental BPG's, NES-PF the industry is governed by.
H	Industry related people experienced in the sector to understand the requirements of the situation to ensure everyone is successful in doing a good job. Have found contractor/industry employees have been very successful at doing this well, as they tend to be a bit more intimate with the processes and can better understand how to set up a successful harvest plan.
K	In harvest management, you would be looking for somebody who has a tertiary forestry qualification plus 3 years of experience (depending on the person). No matter how experienced you should have the input of the logging/earthworks contractor too as they will be completing the work.
L	Someone who is appropriately trained for harvest planning would be someone who has a strong understanding of forest harvesting and earthworks. Harvest Planning requires sound practical knowledge of different harvesting systems and layouts which can generally only be learnt through exposure to harvesting operations. They would have a good understanding and training in environment legislation and best practice guidelines. They would have a good understanding of costs associated with harvesting and earthworks. Understanding and use of contour maps would also be skills required for this person. Use of GIS and roading software (e.g. RoadEng) would be beneficial but not mandatory.

There are only five responses included due to the misinterpretation of the initial wording of the question. The answers give good insight into the qualifications but also the skills and qualities required of the individual that is able to harvest plan. The next survey question asks for some of the considerations that harvest planners have during planning for technically feasible (Table 4), environmentally acceptable (Table 5) and safe operations (Table 6). The purpose of this question is to compile some of the thoughts these experts have to therefore provide a list of components that should be well understood to enhance the harvest planning process and, hence, create a good harvest plan. Compared to the method of analysis for the previous questions, this style of question allows for the information to be presented in a summarised table format.

Table 4. Considerations for technical feasibility.

Environment	
Slope steepness	- Slope is very important as this normally narrows down what crew has the ability to deal with the terrain. - Slope dictates whether mechanisation is feasible.
Topography	- Terrain shape relative to the landing - Blind areas for haulers
Soils	- Geography, depth, wet areas, exposed rock etc.
Waterways	- Different stream classes change how much of a limitation waterways are to harvesting
Harvesting	
Extraction distances	- Normally dictated by what crew is assigned
Crew configuration/capability	- Suitability of the harvesting system for the terrain to be harvested. - Cost of system - Cost of infrastructure to support the system
Infrastructure	
Skid location/size/layout	- Volumes to each skid - Dictated by extraction method and terrain/soil type - Skid layout equally as important as size
Road locations	- Access - Construction/costs - Existing infrastructure - Track locations
Other	
Legal boundaries	
Season of harvest	- Higher costs in winter due to the requirement of more robust roading and lesser grades
Product location	- Proximity to port
Log value	- Determines if harvest is worth doing at all

Table 5. Considerations for environmental acceptability.

Waterways		
Sedimentation	-	Protection against sedimentation per best practice guidelines
Fish spawning		
Class and sensitivity	-	Identification of sensitive waterways
Stream crossings	-	Limit number of crossings
Harvesting residues	-	Need to ensure slash and stems are being kept out of waterways as much as possible - Mechanised felling ideal if you can get to the wood can guide the direction trees fall
Flora and Fauna		
Native areas	-	E.g. Significant Natural Areas (SNA)
Native species	-	E.g. Kiwi, Karearea etc.
Sensitive vegetation	-	E.g. Wetlands, riparian buffers
Operational		
Extraction	-	Away from sensitive areas - Full suspension over waterways and enough deflection so stems don't drag - Can shovel wood into lines and pull in corridors, so only that section is being damaged
Tracking	-	Minimise level tracking
Earthworks	-	Minimise earthworks - High standard of earthworks
Slash	-	Safe slash storage locations - Post-harvest remediation practices
Setbacks	-	E.g. coastal areas
Other		
Soils	-	Type and historical slip sites
Season of harvest	-	Harvest scheduling around seasons
Archaeological sites		
Consent conditions	-	Special requirements regarding resource consent conditions

Table 6. Considerations for health & safety.

Identify/manage	
Hazards	- Bluffs, windthrow, powerlines, fence lines, old earthworks (e.g. borrow pits), TOMOs etc. - Windthrow often missed, manual fallers generally can't be used in windthrow
Neighbours	
Emergency location	
Breaker-out zones	- Breaker out zones should be developed from the harvest plan
Manual falling areas	- Forward planning allows for early hand falling of areas that can't be mech felled.
Chain shot areas	- From processors. Ensure trucks are not being loaded around here
Other areas to avoid	- Areas to be left - No go zones with gear
Other	
Harvest system	- Correct configuration for the block - Well maintained equipment - Personnel are trained and familiar with the equipment and operating conditions
PCBUs	- Input and coordination
Infrastructure	- Road grades - Skid layout/size is safe
Harvest plan	- Should be used to assist the crews in developing a felling plan so high level of detail is necessary - H&S hazards are communicated either through the harvest plan map or via the accompanying harvest plan notes.

Following on from the objectives and considerations of the harvest planner, the expectations of how the plan is carried out by the logging contractor is important information which should be considered when developing the plan (Table 7). **"Should harvest plans leave enough flexibility so that the logging contractors can still make their own decisions? What are your expectations of a harvest plan in terms of how it is carried out?"**

Table 7. Flexibility of a harvest plan.

A	This depends on the nature of the development of the plan. If the logger has been actively involved in the development of the plan, there should be less scope for change. Without that involvement at the early stages, the plan should be more open to change.
B	Flexibility is key, contractors need the ability to amend (within reason) as required to ensure the job is done as safely and efficiently as possible. Job to be complete as per harvest plan unless otherwise agreed upon with forest manager. Changes are discussed and agreed upon to ensure all attributes are still satisfied.
C	A draft is submitted to the contractors for their input at around the three month - six month window for changes. Amendments discussed before final plan. Ad hoc changes are discussed with supervisor and added to change notes.

D	A harvest plan should be developed as an initial plan and signed off/agreed to by the contractor and forest manager, however, harvest plans will almost always change throughout the harvesting process. Logging contractors often have great ideas relating to harvesting, however, any changes/deviations should be discussed with the forest manager and then documented and signed off by both.
E	The harvest plan is a 'living document' - it can be adapted. Any proposed adaptations must be conveyed by the logging contractor to a company representative for approval, before it is signed off and implemented.
F	Yes. We want to allow for innovation. Supervisors from our company is out every second day ensuring that plan is being followed and any changes captured. Needs to be followed reasonably closely, we don't want contractors to think they are forest managers. If changes are made by contractors, we as forest owners are still liable.
G	The implementation of the plan should involve all parts, but if the plan needs to change there should be a documented discussion and a new plan set in place.
H	Yes. At the end of the day, the logging contractor is the professional who makes it work, not the harvest planner. There should be appropriate consultation on harvest plan changes and the associated changes need to be communicated to the relevant stakeholders.
I	A harvest plan will keep changing until the block is finished. The contractor will always want more skid pads etc. to see everything for better pulling, planner needs to find that balance so infrastructure costs are not too high. Operation plan ideally completed with harvesting contractor input.
J	There should be some flexibility for the contractor to modify the plan, as long as environmental or safety concerns don't arise. It's almost always in the contractors interest to work as efficiently as possible, so they should always have input. In an ideal world, the contractor will be involved at the planning stage, although this isn't always possible.
K	Yes there should be some flexibility within certain bounds, plan changes should still be in consultation with management staff in case there is a particular reason that something cannot be changed.
L	To a degree. The harvest plan should set out rules that the contractor can and can't do in terms of flexibility. In different locations rules and legislation will be more or less strict and therefore flexibility will be more or less strict. My plan would have all the rules and guidelines that the harvesting crew is required to follow then they have flexibility beyond those rules/guidelines. An example of a rule would be no new earthworks or tracking without consent from harvest supervisor.

This is the only survey question where there is a general consensus and the answers are consistent with one another. Moving onto the utility of a harvest plan, the NES-PF requires a harvest plan for regulatory purposes while for contractors, the plan serves as the job to be completed. Both the regional council and the contractors have different underlying needs from a harvest plan, therefore it is important to understand how the harvest plan is tailored towards the different needs of these users (Table 8). **"The harvest plan is used by different users such as logging contractors and the regional council. Make a comment on the how the utility of a harvest plan is tailored towards the needs of these different users."**

Table 8. Utility of a harvest plan for different users.

A	Notification periods for 'significant' plan changes can be problematic with councils. It is easier to remove infrastructure from a plan than to add it and seek approval; whilst harvest marches on. Councils may see plans with more infrastructure than might realistically get built due to the above. Loggers need information about the stands they're harvesting, and the map is a logical place to put this. The same info is unnecessary for a council.
B	Plan is structured sectionally. Logging contractors have key sections of the plan which is of interest to them, council have a different section which is more of relevance to them.
C	Contractors are issued with a prescription as well, council requires a lower level of detail.
D	As outlined above, a harvest plan can contain a wide range of information. If developed in Harvest Manager in GIS or similar it is easy to remove/add layers. A logging contractor needs the most detail, but it is unlikely the regional council needs to see some of the detail such as pull distances etc. Making it adaptable is therefore logical.
F	I send the exact same plans to both. Council look at solely environmental aspects of the plan and any potential for breaches of RMA, they don't have any interest in production or health and safety, whereas contractors need to understand and cater for all aspects.
G	Feedback should be given from those who are using the plan.
H	In my experience, councils largely want to see that waterbodies are protected with the plans. Harvest contractors want maps they can draw on to show areas of the forest they progressively harvest. Sometimes they need closer sections, pending the scale of the forest.
I	Mostly just layers on GIS. NES-PF specific map for council (escape and fish spawning etc.) Clearer maps with elements such as stand boundaries, hillshade for contractors.
J	The logging and engineering contractors are the most important parties that need to use the plan. For the earthworks contractor, the size and location of the roads and skids are the most important aspect, so these need to be clearly marked on the plan. For the logging contractor, it's important to have the most accurate contour information possible, especially for hauler settings, so they can see exactly what the terrain is like. It's also important to show where the setting boundaries will be, and where any areas are that will require specific attention, i.e. blind areas for a hauler.
K	Some elements will be relevant to some and not for others, if this is the case, it is important that when you are presenting the plan to a party that you highlight the elements that are more relevant to them.
L	A harvest plan is created to meet the requirements of the regional council and logging contractor. Some of the wording in the plan is altered to make it simple for the logging contractor but still meets council requirements. Only information required by the council/logging contractor is put in the harvest plan.

The subsequent question asks for harvest planners to identify some of the factors that they think constitutes a good harvest plan. This question lays out the preliminary groundwork for establishing a criteria for a good harvest plan (Table 9). **"In the context of harvest plans, different factors can be used to describe 'good' (e.g. feasibility). What do you think are some factors that may help define what a 'good' harvest plan is?"**

Table 9. Factors that constitute a good harvest plan.

A	The plan conveys the right information in a format that makes immediate sense to the users of the plan.
B	Physically feasible, cost efficient, fit for purpose, detailed yet concise, efficient.
C	Cost effective, efficient, safe, little to no impact on valuable features, deflection, limitations.
D	High level of detail regarding all of that is discussed above. A map showing a stand, landings, roads, and a few arrows showing pull direction is commonly produced but lacks a substantial amount of detail to be a "good" harvest plan to anyone.
E	Strikes the right balance between infrastructure build costs vs logging harvest rates. Mitigates environmental damage - pulling away from streams/native areas etc. The plan should be adaptable - if weather or other factors change, is there a 'Plan B' which can be implemented.
F	Allows for some innovation, does not pressure contractor into taking unreasonable risks in achieving targets. Discussed and understood well in advance of being executed. Considers all aspects of logging and challenges that may be encountered as mentioned above. You know how good is was after it has been completed! Sometimes difficult to adapt on the fly so make sure the major things are right.
G	Map quality and detail. forward roading to give the ground time to settle. all the things above in place and documented and past over to the people that need it.
H	A successful harvest where the logging contractor was placed around their projected target, budgets didn't blow out, sensitive areas were protected and the appropriate stakeholders were notified of relevant factors in a timely fashion.
I	A balance between infrastructure density and harvesting productivity. More skids and roads means shorted haul distance and higher productivity but more infrastructure cost.
J	The big one is the plan has to be feasible. The biggest problem I have seen is there are areas in hauler settings that can't be reached, because there are ridges in the way preventing this. Also, some areas have been designated groundbase, which is technically possible, but groundbasing causes so much environmental damage that they should be pulled with the hauler. This is a particular issue in winter. The plan also has to be productive, i.e. it has to be profitable to the owner, given all the costs incurred. Minimising earthworks is the single biggest way to lower cost in my opinion, so this should always be a priority.
K	The planning has involved the contractor. Multiple discussions about the plan and site visits have taken place. Other options (e.g. extraction methods) have been considered.
L	How easy and clear it is for the contractor to understand. Time before harvesting that the planning process started. Skill and experience of the harvest planner.

5.2 Harvest planning approach

Harvest planners were asked to outline their method and approach of planning an area for harvest. The purpose of this question is to reconcile the objectives and considerations with the steps used in practice. Due to the variety of answers, the raw data was translated into key words of similar format. The main steps show the summary of the most commonly reported steps used while the comments and considerations relevant to each step are displayed in the corresponding column (Table 10).

Table 10. Most commonly reported harvest planning steps.

Main steps	Comments and considerations
1) Initial review and draft map in GIS	A. Find all datasets that are available online through LINZ, Heritage NZ and Council(s) to overlay on a map of the site; determine need for a resource consent. B. Include slope map; understand crew configuration and capabilities (tether options etc.); if stream crossings are required complete catchment analysis to understand limitations; identify affected parties (neighbours, powerlines, public roads etc.) C. LiDAR and existing features, neighbouring properties etc. D. Regional authority, is a consent required; is the harvest feasible at a high level from an economic and environmental perspective. E. Build up draft map with skids, tracks, stream crossings, setting boundaries etc. F. Winter or summer logging only? Access constraints- snow; ESC Classification/soil type; stream crossings (cost, risk of environmental issues); permitted activity? consent? can cause delays of need consent and can impose conditions; shape of block (haul distance, targets, skid location); road construction (if required- length, road-lining operation or skid on boundary plus cost of infrastructure); publicity (advertising/notifying residents); social responsibility; log price vs logging/transport cost; distance to market. J. Identify easiest areas for a skid to be installed, with ~5000 tonnes going to each skid. Draw roads to each of these skids, and identify whether there's any easy improvements to make to reduce engineering cost; setting boundaries usually on natural boundaries such as streams/ridges. L. Depending on the tools available (e.g. LiDAR and RoadEng) the better the paper plan will be. During the paper planning process multiple plans and generally created and evaluated against one another to see which is the best (best financially, environmentally, socially and practically). An issue here may be that the contractors harvest system that is lined up to harvest the block is not suitable for the terrain.

2) Visit the site and walk the block	A. Identify further constraints not found through online data acquisition; if applicable talk to forest owner about history of the forest, harvest intentions/thoughts and any neighbour constraints; assess initial feasibility for infrastructure and harvest; target tricky corners of the block to understand hardest to reach areas; formulate first draft of a harvest plan with a particular crew/system in mind. B. Using Avenza map of the draft plan; shoot road grades as required. C. Stream classification, extraction directions, tricky sections and lengths >30, favourable drags, can we get below the wood etc.; roadlines and skid location minimising overall earthworks; identify potential crossing locations if required. D. Walk the catchment. Record any hazards, environmental considerations etc.; confirm if ground based extraction is feasible for entire block (is a tether/SWY going to be required for steep sections?); assess impacts of harvesting riparian areas; check road locations, check landing locations, check extractions corridors etc. E. A paper and/or electronic copy is then taken into the field and ground truthing begins; stream classifications, tracks, skid sites, boundary fence condition etc. are confirmed; edits made to the harvest plan in the field where points are collected on the tablet. F. Use TruPulse when ground truthing to establish feasibility of road grades and proposed skid locations. H. Identify any passing points (permanent/temp) and infrastructure requirements. J. At this point you want to walk the block and ensure what you have planned on paper is possible. Try not to walk the block at all without having some sort of plan, otherwise you can waste a lot of time second guessing yourself. Also identify any hazards and mark on map. Ideally get someone else to verify your plan and see if you've missed anything. Often someone else can see simple improvements that you may have overlooked. K. Walk the block with the forest owner if applicable. L. Field check the plan in particular road and skid locations and environmentally sensitive areas, and more difficult areas to harvest and make changes to the plan where required. While field checking evaluate neighbour and social impacts (e.g. downstream effects, driveways, location of neighbours houses) of the harvest and what effects this could have and how the plan may need to be altered due to this.
3) Engage logging and earthworks contractors	A. Walk block with them if possible; update the plan on the go; at this stage in a competitive harvest management tender, some issues can occur so sometimes it is best not to discuss with external parties; assume you are given the go-ahead to continue, win the management.

	B. Applicable if the contractor is known; important to understand their perspectives. F. Estimate rough volume of soil to be moved during earthworks. H. Identify crew has the right configuration to do the job. J. If possible walk the block with them; may be additional visits if plan is set to change
4) Engage affected parties relevant to the forest and also council	A. Affected parties may be neighbours, powerline cos, RCA, HNZ etc. C. Visit neighbours; letter to notify harvest with contact for any issues with a proposed start date. H. Consult with relevant stakeholders to identify any adaptions; notify stakeholders of timing and scope of works.
5) Update harvest plan with detail and any identified changes	A. Leave plan with the contractors to think over B. If unsure of grades use RoadEng to create 3D model of terrain; check harvest plan against any NES-PF restrictions. D. Add detail to the harvest plan showing road and landing locations, haul distances, volume/skid, hazards, etc. J. Ensure the stream is not being impacted adversely, modify skid/road location and setting boundaries to ensure this. Ideally it won't be crossed, but this may not be possible.
6) Draft final harvest plan and maps	A. Draw up contracts with relevant contractors; put required applications or notifications together, submit and follow through with the process; sometimes more affected party consultation required that can stall the process significantly. C. Pipe sizing, crossing requirements, slash mobilisation risk assessment, RoadEng if required; send draft to contractor and discuss further options. D. Mark final road and landing locations in the ground E. Approx. 1-2 years ahead of scheduled harvest K. Peer review with colleagues; submit budget to forest owner L. Complete required consents and notifications and mark roads and skids in field

This question produced the most variability and inconsistency. A different method of analysis and summarising of the information may give a different meaning to what is currently presented. Much of how the information is displayed is the result of self-interpretation due to variability. In terms of the NES-PF requirements for the harvest plan map, there are many elements that are stated, however, there is a limit as to what you can effectively show. The survey asks harvest planners to rank these NES-PF elements to evaluate how the industry is meeting these requirements and what elements are more relevant than others. It is important to understand what elements are more important than others as this affects the way you highlight these elements on the map. The ordered rankings of these elements are

shown below in Table 11. This essentially shows the industry expectation for what should be included on your harvest plans. It is important to consider these elements in conjunction to the question regarding the utility of the harvest plan for the regional council.

Table 11. Ranking of NES-PF harvest plan map elements.

	Always include	Often include	Sometimes include	Rarely include
Harvest area/property boundaries	12	0	0	0
Waterways to their perennial extent	12	0	0	0
Wetlands/lakes larger than 0.25 ha	12	0	0	0
Harvest method	11	1	0	0
Proposed road and skid locations	11	1	0	0
Extraction direction arrows	11	0	1	0
Emergency point	11	0	0	1
Existing roads, tracks, landings	10	2	0	0
Native/protected areas	10	1	1	0
River crossings (temporary)	9	3	0	0
Waterways classified	9	3	0	0
Contour lines	9	2	1	0
River crossings (permanent)	9	2	1	0
Slope map	7	3	2	0
Ephemeral waterways	6	4	1	1
No slash zones	6	4	0	2
Slash storage areas	4	6	2	0
Aerial photo	4	3	5	0
LiDAR hill shade layer	3	4	4	1
End-haul deposit sites	3	3	4	2
Erosion susceptibility classification	3	1	7	1
Unproductive areas	2	4	3	3
Fuel storage and refuelling sites	1	3	2	6
Firebreaks	0	0	3	9

6. Discussion

The results can be described as variable, which was expected due to the nature and complexity of the problem. This factor in itself already reveals much about the state of harvest planning and harvest plans in New Zealand. However, the framework on which the analyses was based on (Figure 2) allows us to revaluate the results against this narrative where a robust discussion can still be held. Key findings and takeaways from the survey questions, insights and reasons for the variety in answers are discussed in this section.

6.1 Why do we harvest plan

Previously, objectives to harvesting operations have been defined while descriptions for harvest planning objectives in literature and forestry related documents have been varied and case specific. The results collected from the survey provide us with valuable information regarding the purpose of harvest planning in New Zealand where before, little has been put to paper. Understanding a harvest plan's purpose and why we plan lays out the fundamentals and the initial steps towards creating a good harvest plan. Expanding from the NES-PF guidance's definition for the purpose of the harvest plan, all responses cover three main factors when describing the main objectives common to all harvest plans in New Zealand. Although, the objectives may seem obvious, this information sets the precedent for the following stages of the analyses and therefore must be defined. While the feedback for this question was variable, there are still some key similarities. Virtually all responses included environmental compliance and health and safety aspects while varying in operational and financial goals. The summary for the main objectives common to all harvest plans is presented below:

Environmentally, the harvest plan should ensure that operations are not only compliant, but sustainable where environmental considerations attributed to operations are identified and managed. Consequently, environmental factors play a large role as a limitation to harvesting operations. The harvest plan should meet H&S standards by identifying and managing these aspects associated with operations. The plan should identify the bulk of the risks in the harvest area while also providing the mechanism to manage these risks. The harvest plan should also facilitate the efficient use of harvesting resources to ensure maximum financial return. This can be though describing the best possible way to harvest the forest as well as the identification and coordination of PCBU's which ensure all operations can efficiently operate in conjunction with one another.

These objectives play one part in describing the harvest plans purpose, if the objectives are the goal then there needs to be a reason for why we create harvest plans and why they are important. The survey subsequently asks this question after the objectives. By understanding the goals, reasons and

importance, this lays the groundwork towards creating a good harvest plan. From the results, many responses express that we plan to meet these objectives. More specifically, we plan to ensure that the operation meets the objectives of forest owner where goals/objectives are set in the harvest plan. It is important that these objectives are set as to reduce uncertainty and conflict. Without a harvest plan, all parties may work in conflict as their end-goals will vary. The plan synchronises varying goals and objectives of all parties to ensure coherent operations. A detailed, concise and easy to understand plan removes any element doubt for all parties involved. Depending on the different hierarchical processes of each forestry company, the harvest plan can also play a key role in operationalising strategy which is why some may consider the harvest plan as the backbone of the wider harvest planning process. All supportive functions and how they are planed and managed stems from the harvest plan. It also provides clear expectations around the harvesting methodology and what is largely to be achieved. This allows us to gauge the costs and therefore the financial feasibility of operations. Through an iterative planning process, the harvest plan should minimise uncertainty and risks of setbacks and complications with harvesting and earthworks operations. This is important as the high daily cost of crews and site relocation costs make operations very inflexible where the best way to minimise these risks is through robust planning.

As there is no planning certification specific to harvest planning in New Zealand, it is important to know who should be able to harvest plan. The ECoP states that "Harvesting must be planned, supervised and undertaken by appropriately trained personnel". The survey asks the participants what they consider as appropriately trained in terms of the planning component. The responses state that a person appropriately trained and equipped to harvest plan may be individuals who have received a tertiary forestry qualification such as a diploma or a degree as well as experienced industry workers. Forms of a tertiary forestry qualification in New Zealand include the Bachelor of Forestry Science and Bachelor of Forestry Engineering with Honours degrees obtained from the University of Canterbury, and the New Zealand Diploma in Forest Management from Toi Ohomai Institute of Technology in Rotorua. Responses state that these individuals will not have the skills required straight away to create an adequate harvest plan and therefore needs further guidance for 1-3+ years (depending on the individual) under an experienced harvest planner as well as exposure to logging and earthwork operations. For experienced industry workers, these are people who have had years of 'on the ground' experience, either logging contractors or someone with extensive forest management experience. The factor that is most common amongst the responses were the key understandings that were required to become a proficient harvest planner. The individual that should be able to harvest plan must have a good understanding of harvesting operations and environmental requirements. This includes the limitations of various logging systems, terrain and ground conditions of the area to be harvested, earthworks, landing layouts and the costs associated with harvesting and earthworks. Generally, this is learnt through exposure to these

operations. In terms of environmental considerations, legislation such as the NES-PF and best practice guidelines should be well understood and ingrained. Understanding maps is a key skill, however, experience with GIS and roading software (e.g. RoadEng) would be beneficial but not mandatory as stated by one harvest planner. This is because, these software skills can be commonly learnt on the job. While developing their skills, new harvest planners should take into account these factors which have been stated by industry professionals. Additionally, no matter how experienced you are, you should always have the input from the contractors as they will be the ones completing the work.

6.2 How do we harvest plan

In terms of how harvest planning is done in New Zealand, the data collected comprises of the different considerations harvest planners have during the harvest planning process as well as the steps taken to create a harvest plan. The summarised considerations in the results (tables 4, 5 and 6) section lists what harvest planners should keep in mind and look out for when planning. This expands from the objectives of a harvest plan which broadly reference technical feasibility, environmental acceptability and health & safety. It is important that these are well understood and applied to the harvest planning process. Subsequently, the next concept to understand is how these considerations are used in practice. The survey asks for harvest planners to outline their approach to developing a harvest plan. The results for this question delivered the largest variety and range in answers. Because of this the analysis method used in the results was used to help summarise and find similarities in the data. Although each approach described was different, some main similarities were still observed. The most common steps for both are discussed where the elements described in the previous section of the discussion should already be well understood. These steps are further summarised from the six steps described in Table 10 into four main steps based on my own interpretation of how the information would be most useful as a resource.

1. Initial review and draft map in GIS

The first step in creating a good harvest plan is to first obtain a rough overview of what you will be expecting before visiting the site. This initial review and draft will ensure an efficient and effective ground truthing process. This is depended on the tools and datasets available. Some tools used may be ArcGIS and RoadEng and data such as LiDAR will determine how good the paper plan will be. Datasets that are available online through LINZ, Heritage NZ and Council(s) can be used to overlay on a map of the site. This initial review also sets the goals and considerations for what will be the final harvest plan. Aspects such access constraints, season, ESC, soil type, fish spawning, affected parties and existing features are some of the factors you need to understand as a result of the initial review before progressing forward. Consent requirements from the regional authority should be determined as this can cause delays and impose conditions. You should also have a good understanding of the harvest configuration and capabilities for the crew that will be doing the job. A problem may be that the contractor that is

lined up to do the job is not suitable for the terrain. The draft map should be drawn up with preliminary skids, roads, tracks, stream crossings, settings boundaries etc. Potential skid locations should facilitate productive extraction distances with approximately 5,000 tonnes going to each skid. Roads can be drawn to these skids where any easy improvements to reduce engineering cost should be made. Setting boundaries should be placed on natural boundaries (e.g. streams and ridges) and if stream crossings are required, the environmental issues and costs should be well understood. Skids/road location and setting boundaries should be modified to ensure that the stream is not affected adversely. The catchment and receiving environment should be well understood. The harvest should be feasible at a high level from both and environmental and economic perspective. Economic factors may cost of infrastructure, log price, transport costs and distance to market. During this process, multiple plans may be created and evaluated against one another to see which is best financially, environmentally, socially and practically. Ideally, your plan is peer reviewed to ensure you have not missed anything. Often someone else can find simple improvements that you may have overlooked.

2. Visit the site and walk the block

Once the draft map is developed, this can be printed off and taken to the field or viewed on an electronic device using tools such as Avenza Maps or ArcGIS field maps. Waypoints can be recorded with comments to be used back at the office. The ground-truthing begins where additional constraints not found through the initial review are identified. The aim is to ensure what you have planned on paper is possible. Record any hazards and environmental conditions. Investigate the potential skid, road, track and crossing locations as well as environmentally sensitive and difficult areas to harvest. Streams should be examined and classified as they are a major limitation. Shoot grades as required to establish the feasibility of roads and proposed skid locations. The feasibility of the harvesting system for the terrain should be confirmed. A rough calculation of soil to be moved during earthworks may also be established. Social impacts and downstream effects should also be evaluated as the potential effects may alter the plan. Walking the block with the forest owner is beneficial if this is applicable. Additional insights include the history of the forest, harvest intentions/thoughts and neighbour constraints. This step is iterative where it is common to walk the block multiple times prior to the final plan. Ideally, you should walk the block with logging and earthworks contractors to understand their perspectives. This is only applicable if the contractor is known.

3. Update harvest plan with detail and any identified changes

After each field check, the plan is subsequently updated using the information recorded in the field. Examples may be road and landing locations, haul distances, volumes to each skid, hazards etc. Stream classes can be updated where the lengths of ephemeral streams can be modified to match what is observed in the field. At this stage you should check you harvest plan against any NES-PF restrictions

and engage affected parties relevant to the forest and also the council. These may include the neighbours, powerline company, Road Controlling Authority (RCA), an Heritage New Zealand (HNZ). You want to engage and contact the neighbours to notify them of the harvest in case of any issues they have. Start to put the required applications or council notifications together and follow through with the process. Sometimes more affected party consultation is required which can stall the process significantly. At this point you are in a better position to estimate the harvesting costs which can be used to submit to the forest owner for approval. Again this iterative based on the number times you visit the block.

4. Draft final harvest plan and maps

When all the field checks have been carried out, the last step is to finalise the plan and create the maps. Depending on the forestry company, the time frame that this is completed by may vary where changes to the harvest plan may still be made. This can be approximately 1-2 years ahead of the scheduled harvest. As stated previously, forward planning allows for the ability to provide budgets and projections for the business as well as the opportunity to refine the plan. It forms the basis for all the other supportive functions and how they are planned or managed. At this point you should be able to complete and confirm culvert size calculations, crossing requirements, slash mobilisation risk assessments, RoadEng plans and contracts with the relevant contractors. The final draft should be peer reviewed with colleagues and can be sent to the contractor for further input and options.

These are the most dominant steps that were described. It is important to note that the considerations that are described at each stage are based on the proposed block which was outlined in the methodology sections. However, the proposed area was designed to be broad enough so that the key information presented can still be applied to other harvest areas in New Zealand. Now that we know how harvest planners plan to meet their objectives, it is important to understand how it is used. This represents the survey questions on flexibility and utility. In terms of flexibility for the contractor, the expectation is that there will almost always be changes to the harvest plan as it is a living document. Contractors are the professionals that make the plan work, hence, their ideas and input are critical for the operations. The plan should be flexible within certain bounds as to foster innovation so that the crew can work efficiently as possible as long as environmental or H&S concerns don't arise. Although the job is expected to be completed per the harvest plan, amendments are discussed before and during the operations which are documented and signed off by the forest manager before being implemented. It is important to document these amendments to the plan as the forest manager are still liable. These changes should also be communicated to the relevant stakeholders. Ideally, the contractor should be involved during the planning stage, although this isn't always possible. A draft of the initial plan can be submitted to the logging contractor for changes before the final plan. Consequently the nature of the changes

depends on the development of the plan where contractors that have been actively involved in the planning process will have less scope for change.

The harvest plan is also sent to the regional council as part of the notification for compliance purposes so it is important to understand how to design the harvest plan to meet the needs of different users. In terms of the regional council, the map may become more NES-PF specific. However, some responses state that they still send the same map to both. It is agreed upon that the map is the appropriate place to put information about the stand the logging contractors are harvesting while the council requires a lower level of detail. The same information required by the loggers is unnecessary for the council. The logging and engineering contractors are the most important parties that need to use the plan. For the earthworks contractor, the size and location of the roads and skids are the most important aspects and therefore should be clearly marked on the map. For the logging contractor is important to have the most accurate contour information as possible. This is important for hauler settings as they can see exactly what the terrain is like. Setting boundaries and areas that require specific attention such as blind areas are also important. Councils largely want to see that the waterways are protected in the plan. This may include additional information such as fish spawning, escape etc. The aspects that the council examine are solely environmental for any breaches of the RMA. They do not have any interest in production or health & safety. Contractors need to understand and accommodate for all aspects. It is important that the relevant aspects are highlighted the respective users. This can be done though the map or the harvest planning document. The plan is also usually structured sectionally where contractors have sections that are of interest to them while the council will have sections which is more relevant to them. In terms of the map, layers can be added or removed depending on the user. Making the map adaptable is therefore logical. A problem may be notification periods for 'significant' plan changes. It is easier to remove infrastructure from a plan then to add it and seek approval. Due to this, councils may see plans with more infrastructure than what may be realistically built.

In terms of the NES-PF harvest plan map elements in Table 11, these show the elements that harvest planners consider more important than others. These elements should be displayed on the map accordingly where more visual importance is given to the elements higher up. This can reduce the clutter of you map while making it clear and easy to understand for the contractor. An example may be the contour lines and the roads. The roads have a higher level of importance which means they should appear more significant. Contour lines may layered underneath the roads with a reduced line thickness and higher transparency to look less significant. For information regarding how symbology can be used to improve harvest plan legibility, see resources such as 'Visual Variables' (Roth, 2017).

6.3 What makes a good harvest plan

Expectations of a harvest plan make up all the stated objectives and considerations which are connected to the steps used in planning. This is what the industry says harvest planning should look like. Every harvest planner sets out with the intention of creating a good harvest plan, by understanding these factors this should ensure that the ideas discussed in the previous sections are used in a beneficial way. The survey asks harvest planners for the factors that they think constitute a good harvest plan. The information discussed describes how a harvest plan is 'fit for purpose'.

A good harvest plan should convey the right information with a high level of detail regarding the aspects that have been discussed previously. The harvest plan should still be concise as to make immediate sense to the users. Mapping information must be shown in a functional way while making it easy and clear for the contractor to understand. The feasibility of a harvest plan plays a key role in determining a good harvest plan. The feasibility of the harvest plan determines the success of the harvesting operations meaning that it becomes one of the determining factors when evaluating a good harvest plan. For hauler settings, there may be areas that cannot be reached due to ridges in the way. However, the physical feasibility should not compromise the other objectives. An example of is areas which have been designated to ground-based operations in terrain where hauling is the better option. Although technically possible, the ground base operations can cause excessive amounts of environmental damage. This is a particular issue in winter. At the end of the day, the process of harvesting is to liquidate an asset in a way that is profitable for the landowner. The harvest plan should facilitate productive, efficient and cost effective harvesting operations. This includes striking the right balance between infrastructure costs and harvesting rates. More infrastructure may mean shorter haul distances and better productivity but also higher costs. One way of reducing costs is by minimising earthworks which is simple but considerable. A quality of a successful harvest plan is where the costs incurred during harvest was placed around the projected target and the budgets didn't blow out. The process of an iterative and robust harvest planning process can help to achieve this. The harvest plan should not pressure the contractor into unnecessary risks to achieve targets where it should also foster innovation. The time before harvesting that the harvest planning process started also plays a role in determining how good a harvest plan. This also allows for roading to be forwarded to give the ground time to settle. The plan should be adaptable as many factors may change such as the weather. However, sometimes it is difficult to adapt the plan on the go so it is essential that you get the major things right. The more the contractor has been involved with the planning process the better the plan will be. Multiple discussions about the plan should have been made as well as multiple site visits. Multiple options also have been considered while the appropriate stakeholders were notified of relevant factors in a timely fashion. Overall, the responses stated connect to the harvest planning aspects that have been mentioned above, this goes to show that a good harvest plan should be evaluated holistically as a process.

6.4 Inconsistency and range of responses

It was expected that the results would provide a large range of information regarding harvest planning. There is only one question where it can be confidently said that the answers are consistent enough for a general consensus. This was the question on flexibility. As a result, the discussion comprises of key insights into harvest planning which encompass the large variety of approaches to harvest planning which plan under varying objectives. The scope of this project doesn't describe the harvest planning process as a function of the wider harvest planning process such as the strategic and tactical plans. It should be kept in mind that when considering the information in this study that it encompasses harvest planning very broadly. In reality, some of the factors addressed will have different degrees of importance depending on the forestry company and objectives of the landowner. Factors to take into account include the scale and functions of different forestry companies as well as regional effects. For corporate land owners, the harvest planning practice is increasingly based on the company's processes and procedures. They are also dealing more with forests that are past their first rotation which changes the objectives and considerations. An extended consent is generally already required and you are dealing with the objectives of your own company as opposed to conflicting goals with the forest manager and landowner. Harvest planning is more iterative, especially with first rotation forests. Even with the limits and constraints the harvest planning approach question was set with, the responses were still the most variable. What can be concluded is that harvest planning is very variable in the New Zealand forestry industry where the scope of the study is insufficient to confidently show if one harvest plan is better than another and there is no one good harvest plan.

6.5 Limitations

A major limitation of the study is the simplification of a complex problem which was required to keep the study within the scope of the course. The survey questions failed to gather more information regarding the bottom line question which acts as limitation for the full evaluation of how good a harvest plan is. As stated before, the forest harvesting practice is liquidating an asset for financial gain. The open ended questions with the lack of an interviewer also prevents the clarification of responses where questions were sometimes misinterpreted. The different layout in responses also made the analysis difficult where the best attempt to summarise the information was made as to find meaning. Particularly with the question regarding the harvest planning steps. The pilot test for the survey was also very small which did not form a confident indicator of the surveys performance. However, overall the survey was structured well which resulted in the majority of high quality responses as a result of the study framework outlined in the methodology. The survey was structured so that information from the answers can be followed in a sequential nature where previous answers feed into the next and can be referred back to. The study only determines what a harvest planners think makes a harvest plan. To

fully evaluate a good harvest plan, input will be required from contractors . This may include their needs for a harvest plan, the information that is most relevant to them and their thoughts and processes when using a harvest plan i.e. translating the map into the operation.

6.6 Further research and next steps

This study sets the foundation for what can be considered to create a good harvest plan. However, in order fully evaluate what makes a good harvest plan, the key learnings from this study will have to be built upon with a different methodology and scope that allows for more meaningful analysis of the performance of harvest plans. A possibility is a critique of harvest plans. The purpose of the critique is to reveal how well the proposed criteria reflects real-world examples and how well this information is communicated. Combined with the ideas presented in this study, this allows for a better comprehension of an appropriate level of planning. The critique feedback should allow for the evaluation of harvest plans against these ideas as to create a criteria/framework for a good harvest plan. The most uniform way of implementing this is through a harvest planning exercise of the same study area. What was discovered in this study is that the harvest plans sent into the study are much too variable to conduct a meaningful analysis. The plans that were sent in were based on the proposed area for the harvest planning approach. Even with the limits and constraints, there was not enough consistency. Therefore, it seems that a harvest planning exercise may be the best option to assess the ideas presented in this study in hopes of developing a criteria for evaluation or framework for a harvest plan. However, the reasons for inconsistency will have to addressed and factored into the scope of the critique.

7. Conclusion

Overall, as an information resource, the study provides valuable information on the objectives, considerations and expectations of a harvest plan under an encompassing view of different types of harvest planning in New Zealand. The discussion gives key insights on the key understandings you must have while harvest planning. The results from the survey were highly variable where the responses for most questions were unique and different which reveals a lot about the harvest planning in New Zealand. The variety in the responses show that harvest plans are different among different harvest planners due to the functions of different forestry companies. Although there were limited similarities to be able to confidently proceed in developing the framework for a good harvest plan, the discussion section still reveals key understandings for how expert harvest planners create a good harvest plan as part of a process. This includes:

- Why do we plan - Understanding a harvest plan's purpose and why we plan lays out the fundamentals and the initial steps towards creating a good harvest plan.

- How do we plan – Understand harvest planning considerations and how they are used in a robust harvest planning process

- What makes a good harvest plan – Understand the factors can constitute a good harvest plan and how it is 'fit for purpose'

The goal of the study is not to provide set instructions for the harvest planning approach to be followed or strict rules. Overall, what can be said about the study is that it develops key ideas and principles that can be considered and understood so that you do not create a bad harvest plan.

8. References

Armitage, I. (2001). *Guidelines For Managment of Tropical Forest*. New York, United States: Penguin Random House.

Asia – Pacific Forestry Commission. (1999). *Code of Practice for Forest Harvesting in Asia-Pacific.* https://www.fao.org/3/ac142e/ac142e.pdf

Beaudoin, D., Frayret, J. M., & LeBel, L. (2008). *Hierarchical forest management with anticipation: an application to tactical–operational planning integration*. Canadian journal of forest research, 38(8), 2198-2211.

Boyland, M. (2003). *Hierarchical Planning in Forestry*. University of British Columbia, Canada, 7, 1–7.

Breadon, R. E. (1983). *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept*. Forest Engineering Research Institute of Canada. Retrieved from https://www.for.gov.bc.ca/hfd/library/documents/bib329.pdf

D'Amours, S., Rönnqvist, M., & Weintraub, A. (2008). *Using operational research for supply chain planning in the forest products industry*. INFOR: information systems and operational research, 46(4), 265-281.

Epstein, R., Weintraub, A., Sapunar, P., Nieto, E., Sessions, J. B., Sessions, J., ... & Musante, H. (2006). *A combinatorial heuristic approach for solving real-size machinery location and road design problems in forestry planning*. Operations Research, 54(6), 1017-1027.

Marques, A. F. (2012). *New decision support tools for forest tactical and operational planning* (Doctoral dissertation, Universidade Tecnica de Lisboa (Portugal)).

Marques, A. S., Audy, J. F., D'Amours, S., & Rönnqvist, M. (2014). *The Management of Industrial Forest Plantations: Theoretical Foundations and Applications (Managing Forest Ecosystems, 33)*. In Tactical and Operational Harvest Planning (2014th ed., pp. 239–267). Dordrecht, The Netherlands: Springer.

Murray, A. T., & Church, R. L. (1995). *Heuristic solution approaches to operational forest planning problems*. Operations-Research-Spektrum.

Resource Management Act 1991. https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html#DLM230264

Resource Management (National Environmental Standards for Plantation Forestry) Regulations 2017. https://www.legislation.govt.nz/regulation/public/2017/0174/latest/whole.html

Rönnqvist, M., D'Amours, S., Weintraub, A., Jofre, A., Gunn, E., Haight, R. G., ... & Romero, C. (2015). *Operations research challenges in forestry: 33 open problems*. Annals of Operations Research, 232(1), 11-40.

Roth, R. E. (2017). Visual variables. International encyclopedia of geography: People, the earth, environment and technology, 1-11.

Tittler, R., Messier, C., & Burton, P. J. (2001). *Hierarchical forest management planning and sustainable forest management in the boreal forest*. The Forestry Chronicle, 77(6), 998-1005.

Weintraub, A., & Cholaky, A. (1991). *A hierarchical approach to forest planning*. Forest Science, 37(2), 439-460.