

Strategic Silviculture Options for Backlog Sites on TFL 30

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1.0 Introduction

Timber supply forecasting is an important exercise for both corporate and social planning. From the corporate standpoint, future timber supplies affect investment decisions primarily for processing facilities, but may also affect a company's strategic directions. In communities highly dependant on the forest industry, there may be important implications for future employment levels, and investments in hospitals, schools, roads and other important infrastructure elements. In cases where there are shortfalls in timber supply, impacts on companies and communities can be large.

Timber supply projections for Tree Farm Licence (TFL) 30 completed in the Scenario Planning Project, conducted jointly by the McGregor Model Forest and Northwood Inc. in 1999, indicate a major timber supply deficit for a period of approximately 8 decades starting 20 years from the present. In the base case projection (fig. 1), the current AAC of 350,000 m³/yr could be maintained for two decades, followed by a decline to 250,000 m³/yr until decade 10 (the mid-term). From decade 10 to decade 12, harvest rates were forecast to increase up to the Long Term Harvest Level (LTHL) of 480,000 m³/yr.

A second scenario (fig. 2) included coarse estimates of gains achievable with intensive silviculture. In this forecast, no mid-term deficit was forecast, and harvest levels for the short-term and mid-term were actually increased slightly to 390,000 m³/yr. The main contributors to this effect were the assumed conversion of all NCB_r types to commercial forest, and a 12% yield gain in managed stands resulting from intensive silviculture activities. While the validity of this method of simulating treatment benefits could easily be challenged, the exercise was useful to show the potential impact of intensive silviculture on timber supply.

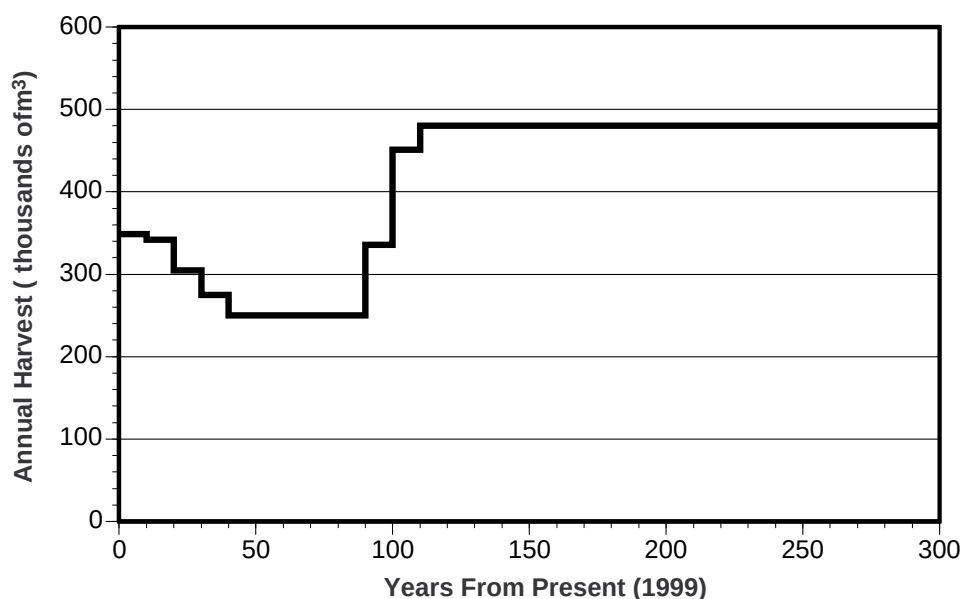


Figure 1. Base case timber supply projection from TFL 30 Scenario Planning Project

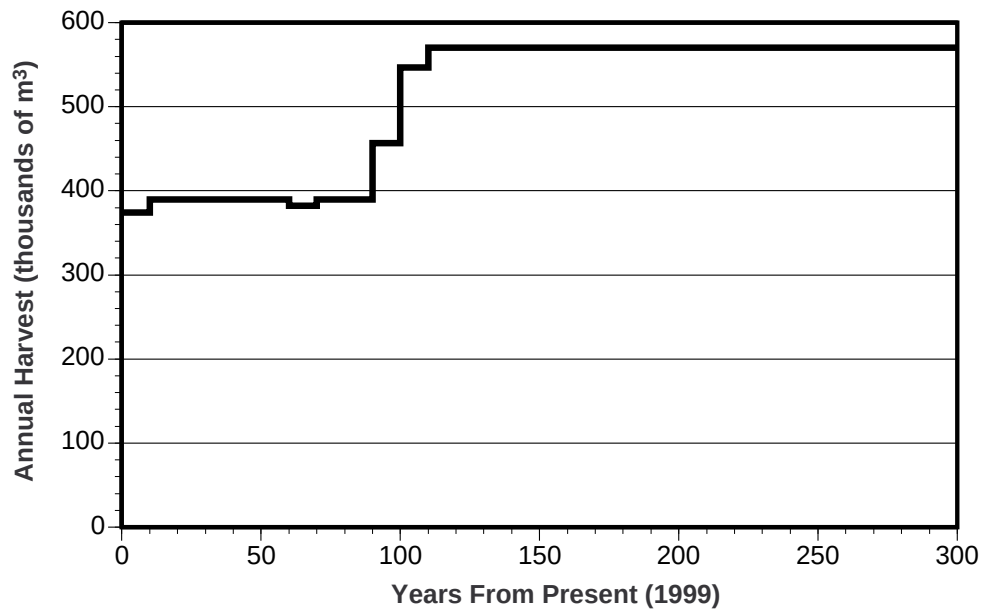


Figure 2. Timber supply projection assuming application of an intensive silviculture program - TFL 30 Scenario Planning Project.

The purpose of this document is to facilitate an enhanced evaluation of timber supply benefits that might result from intensive silviculture investments. It provides theorized stand level yield benefits that are treatment specific and selectively applied to stands with specific attributes. Within the context of the timber supply model, simulated treatments can then be applied to achieve a desired effect, in this case to reduce or eliminate the mid-term timber supply deficit. It is intended that the treatment effects provided here be used in conjunction with timber supply modeling being conducted in support of Management Plan 9 (MP9). Treatments found in that exercise to have positive effects on timber supply in the mid-term can then be ranked highly for implementation.

The main thrust of this report is treatments that are eligible for FRBC funding. Within the context of strategic timber supply planning, however, such activities cannot be considered in isolation. Some strategies that relate specifically to activities for which the licensee has full responsibility have also been included. Simulating and planning treatments in isolation of other initiatives on the same land base could potentially lead to duplicative efforts and wasteful expenditures. Only with a full spectrum of possible tactics to explore in timber supply modeling, regardless of funding and implementation responsibility, can rational strategies (i.e. how many hectares of what treatments on what stands) be proposed.

2.0 Addressing the Timber Supply Deficit Using Intensive Silviculture

The timber supply deficit forecast in figure 1 indicates a shortage of timber available for harvest during the period from 20 to approximately 100 years from present. The causes of this effect are partially illustrated in figure 3, showing the decline in total growing stock during the same period. If a similar diagram were available showing only the growing stock that is available for harvest, the line would drop to a point near the annual harvest level during the same period. The area between the total growing stock line and the “available” growing stock line represents timber volume that exists on the land base but is constrained from harvest.

Several factors are likely constraining the harvest during the period of deficit. Green-up constraints, for example, prevent the harvest of one unit if adjacent units have not yet developed to a pre-set threshold stage. Seral stage constraints limit harvesting within a specific portion of the land base typically if either young seral stage maximum thresholds will be exceeded through harvesting or if old seral stage minimum thresholds will or have already been violated. Minimum harvest age constraints limit harvesting within specific stands until certain age, volume or productivity criteria have been met. In this case, no seral stage requirements have been specified, and the deficit is controlled by some combination of green-up and minimum harvest age constraints.

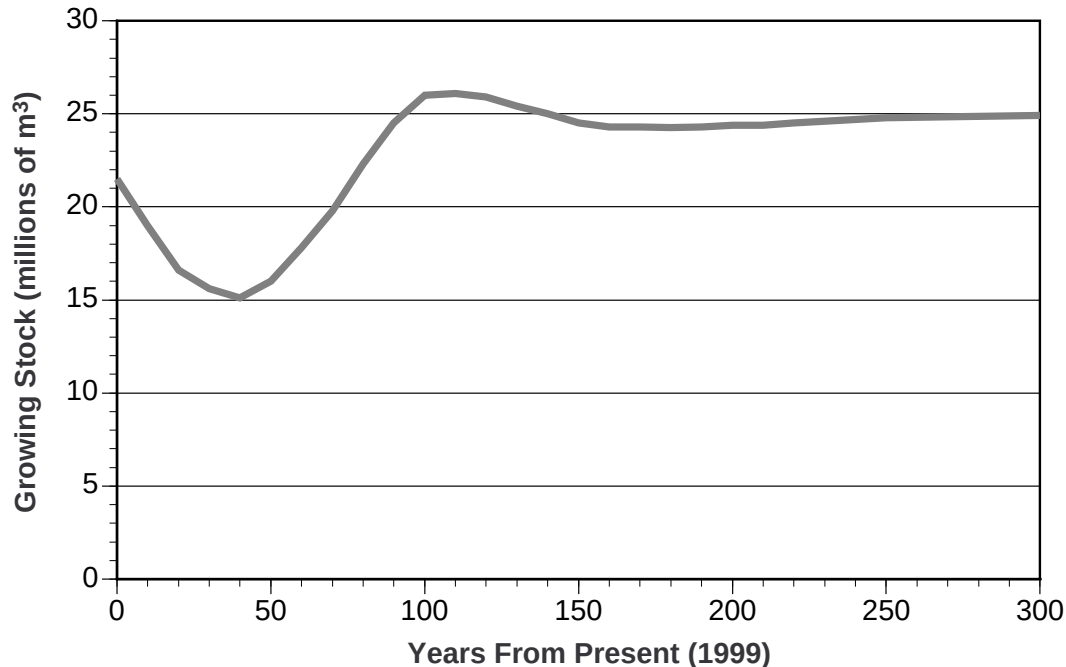


Figure 3. Base case projection of total growing stock over time - TFL 30 Scenario Planning Project.

Four general silviculture strategies are available to minimize the mid-term deficit, primarily but not wholly related to the constraints listed above. They include:

1. Accelerating achievement of green-up thresholds in regenerated stands to make adjacent stands available for harvest.

Silviculture treatments targeted to release green-up constraints are most typically stand establishment practices. The objective here is to achieve a given target development threshold as soon as possible. Tactics employed include appropriate and prompt site preparation, immediate planting of the optimum species, use of genetically improved planting stock and aggressive control of competing vegetation. For the most part, stand establishment is a contractual obligation of licensees, and related treatments will not be dealt with extensively in this report. It may still be useful, however, to test the degree to which green-up is constraining timber supply during the MP9 modeling process.

2. For stands otherwise queued for harvest after the deficit period, making some or all of the volume available during the deficit period.

Treatments aimed at achieving green-up thresholds earlier also impact on harvest availability of the treated stands. While growth rates prior to free growing are quite plastic, post-free-growing growth rates are relatively fixed, dictating that earlier achievement of green-up also means earlier achievement of minimum harvest age. There are other ways however, of affecting minimum harvest age and/or the timing of harvest availability. These include post-establishment brushing/species control, fertilization and commercial thinning. The first two of these accelerate growth of crop trees, resulting in earlier achievement of minimum harvest criteria. Commercial thinning on the other hand, does not change minimum harvest age but instead facilitates harvest of some volume at an earlier time.

Potential effects of these treatments on timber supply are illustrated in figures 4 and 5. In both cases, volume that is otherwise scheduled for harvest after the deficit period is harvest earlier, helping to reduce the magnitude of the shortfall.

3. Increasing volumes in stands harvested prior to or during the deficit period.

Merchantable stand volumes can be increased through brushing treatments on existing stands to remove non-crop shrubs and small trees. This process releases growing space for use by the crop trees, resulting in larger merchantable volumes at harvest. Harvest volumes in established stands can also be increased by fertilizing with appropriate nutrients, either through a regime of repeated treatments in younger stands or as a single treatment shortly (5-7 years) before harvest. Potential effects of fertilization programs on a period of timber supply deficit are illustrated in figures 6 and 7.

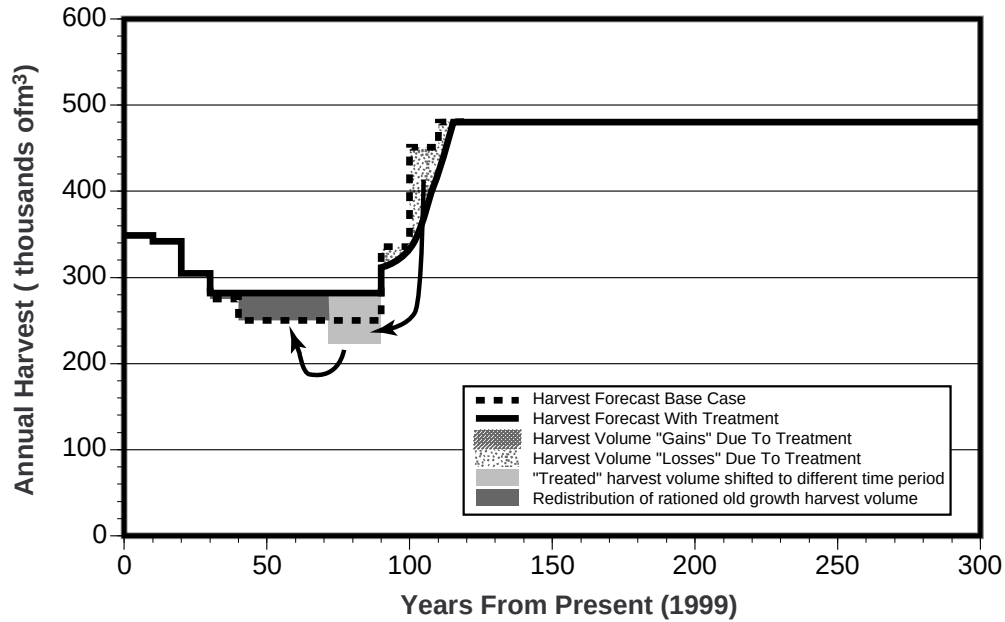


Figure 4. Theorized timber supply impact for TFL 30 of reducing time to minimum harvest age for stands currently queued for harvest just after the deficit period. The stands moved up in the harvest queue both add to the harvest in the latter part of the deficit period and displace the harvest of some old growth which has been rationed for harvest during that same period. The previously rationed old growth is then released for harvest earlier in the deficit period.

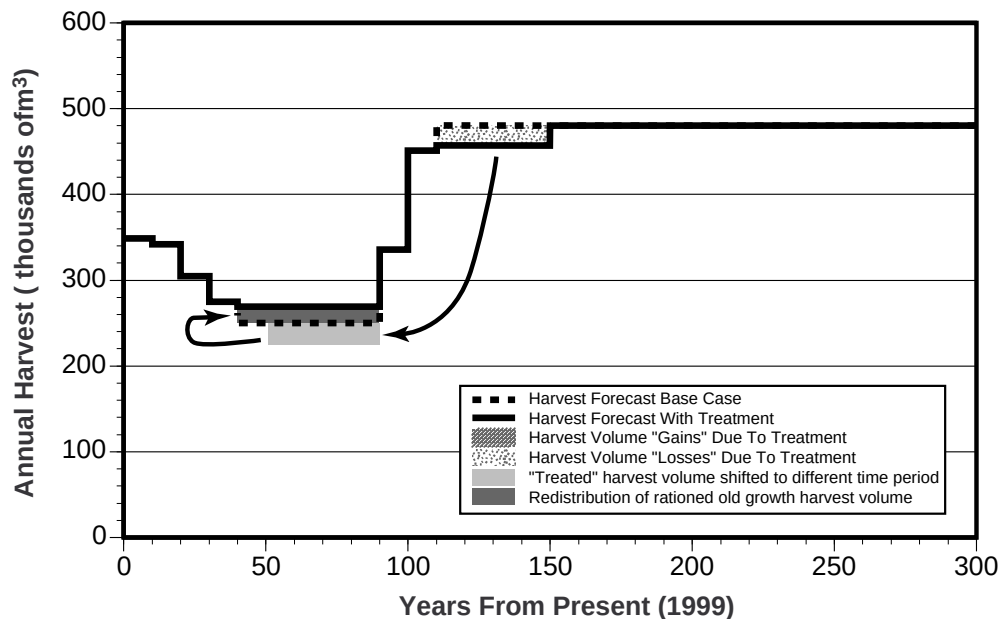


Figure 5. Theorized timber supply impact for TFL 30 of commercial thinning in stands currently queued for harvest just after the deficit period. The thinning volume displaces some previously rationed old growth harvesting, which can then be redistributed to help overcome the projected shortfall.

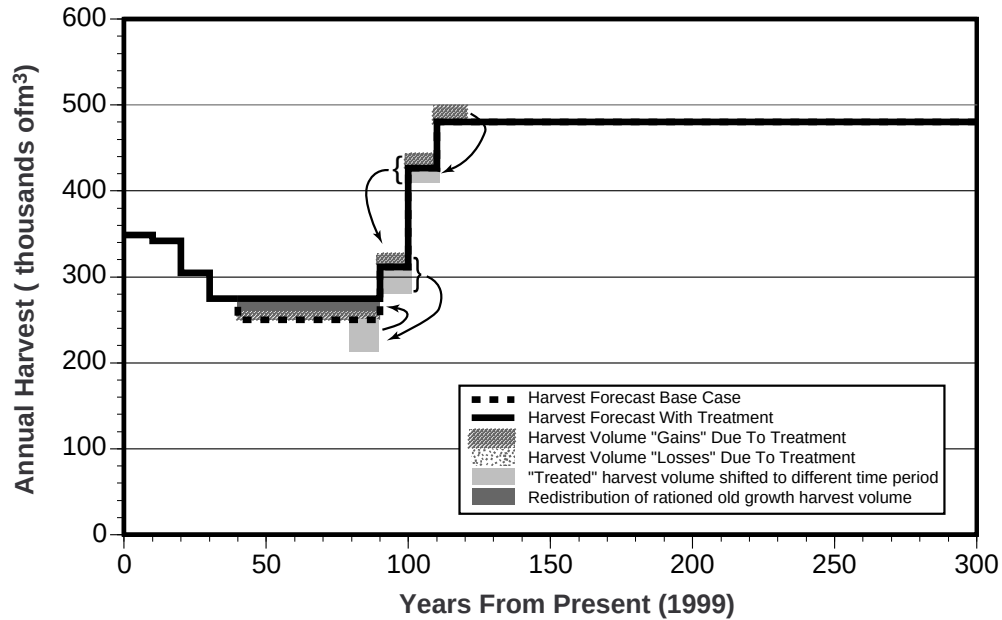


Figure 6. Theorized timber supply impact for TFL 30 of fertilization in young stands currently queued for harvest during and just after the deficit period. Incremental volume in these stands either provides extra volume during the deficit period or allows them to be harvested earlier than otherwise planned. Where stands are harvested earlier, they displace harvest of rationed old growth, which is then redistributed to further overcome the predicted deficit.

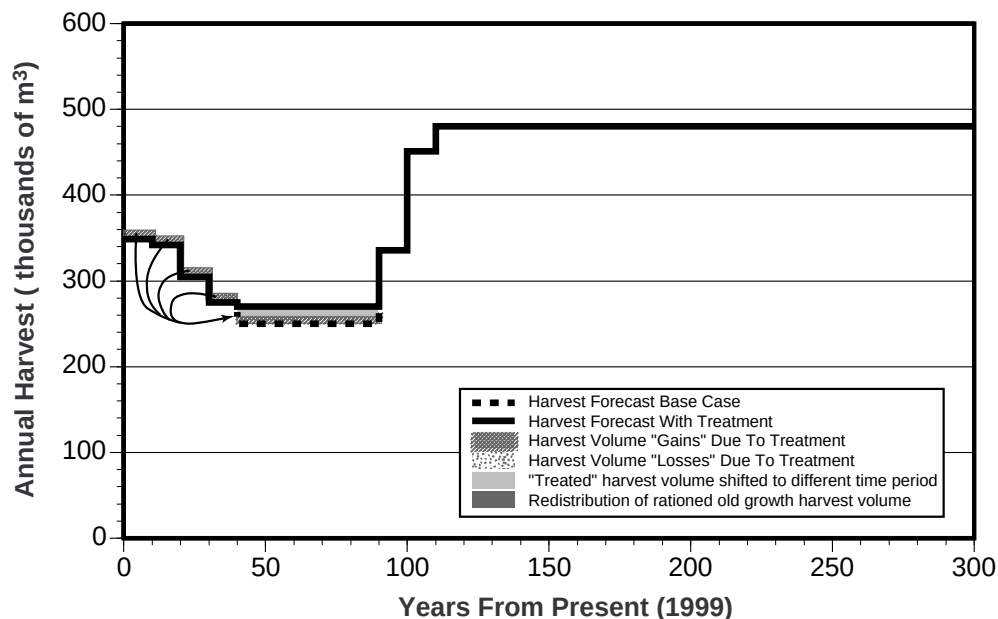


Figure 7. Theorized timber supply impact for TFL 30 of fertilizing stands shortly before harvest. Incremental volume in these stands provides extra volume either just before or during the deficit period. Incremental volume either helps fill in the deficit trough directly, or allows additional old growth volume to be rationed for harvest during the deficit period.

4. Increasing the Timber Harvesting Land Base (THLB) to increase the number of stands available for harvest.

Treatments on lands not currently considered as part of the THLB can help reduce the mid-term timber supply deficit, as long as the stands become harvestable before the end of the deficit period. Stands which fit in this category are generally highly productive sites currently covered at least partially by non-commercial species.

Treatment regimes that address one or more of these strategies are proposed and summarized in Table 1, which includes estimates of costs and benefits. Individual treatments and their assumed effects are described in Section 3.0.

3.0 Treatments and Their Assumed Stand Level Effects

Table 1 describes a set of treatment regimes that can be tested in a timber supply model for their impact on the mid-term deficit. Each of these regimes is made up of one or more treatments, each of which is described below.

3.1 Stand Establishment to Free Growing

In the context of this document, the sequence of treatments including site preparation, planting and brushing required to achieve free growing status for newly regenerated stands will be considered as one treatment. Yield assumptions for these stands have already been included in the base case for the timber supply analysis, and no new adjustments are required. Stand establishment and maintenance for new stands has been included in Table 1 for backlog NSR areas and conversion of areas currently classed as non-commercial brush (NCBr).

3.2 Regenerated Stand Species Selection

Species selection for planting can have important impacts on timber supply, particularly when regenerated stands will be harvested within or in close temporal proximity to periods of deficit. Different species have different patterns of growth, resulting in different optimum rotations and timing of availability for harvest. On TFL 30, many factors favour the planting of spruce, but the desire to overcome the projected timber supply deficit may require reconsideration of a greater role for lodgepole pine.

In figure 8, it is assumed that pine and spruce are planted on equivalent sites. For both species, maximum mean annual increment (CMAI) is similar, but the pine culminates much earlier. This means that volume is available for harvest earlier, in this case at 58 years for pine instead of 87 years for spruce. For plantations that are becoming available for harvest right at the end of the deficit period, such a distinction can be critical. If the stand is available for harvest during the deficit period, it contributes to eliminating the deficit. If it has not yet reached minimum harvest age, it does not.

Table 1. Details for proposed silviculture strategies to minimize the mid-term timber supply deficit predicted for TFL 30.

Treatment Regime	Intended Effect (Strategy) ³	Current Treatments (2000-2005)	Future Treatments (post 2005)	Stand Level Yield Benefits (m ³ /ha) ¹				Relative Wood Quality Benefits ²			Current Cost (\$/ha)
				Short-Term (0-20 yrs)	Mid-Term (20-100 yrs)	Long-Term (100+ yrs)					
Commercial Thinning Regime (1)	i, i	fertilize	fertilize CT	0 0	+5 +5 +80	+10 +10 -40			+ + - - -	+++	350
Commercial Thinning Regime (2)	i, i	PCT fertilize	fertilize CT	0 0	0 +5 +5 +80	0 +10 +10 -40			+ + + - - -	+	850 350
Commercial Thinning Regime (3)	i, i	PCT	CT	0	+80	-40			+ - - -	+	850
Fertilization Regime	ii, iii	fertilize	fertilize fertilize	0 0	+15 +15	0 0			+ +		350
Pre-harvest Fertilizer (individual treatments)	iii	fertilize	- fertilize	+15 0	0 +15	0 0			+ +		350
NCBr Conversion Regime	iv	Site preparation Planting Brush Control	Site preparation Planting Brush Control	0 0 0 0	0 300 to 400 0 0	0 300 to 400 ⁴ 0 0					900 1000 250
Thinning/Brushing Pre-1987 Blocks	i, ii, iii	Brush/Thin		0	0	0			+++		850
Backlog NSR	i, ii, iii	Site preparation Planting Brush Control		0 ⁵ 0 0	0 0 0	0 0 0					900 1000 250

1. Yield benefits are described relative to those assumed in MP9 basecase.

2. Subjective assessment of treatment effects on log values at harvest (positive [+] or negative [-]). Multiple symbols denote increasing effect, blanks denote no discernible effect.

3. Strategies include: i) accelerated achievement of greenup, ii) making some or all of the volume from stands otherwise scheduled for harvest after the deficit period available earlier, iii) increasing the harvest volume in stands harvested before or during the deficit period and iv) increasing the timber harvesting landbase.

4. Repeated benefits from this treatment reflects the addition of land to the THLB which provides volumes periodically with each successive rotation.

5. No benefits are assigned as these treatments are already assumed in the MP9 base case. In the event that these treatments are not carried out, there would be a negative yield effect certainly in the long term, but possibly also in the mid-term forecast.

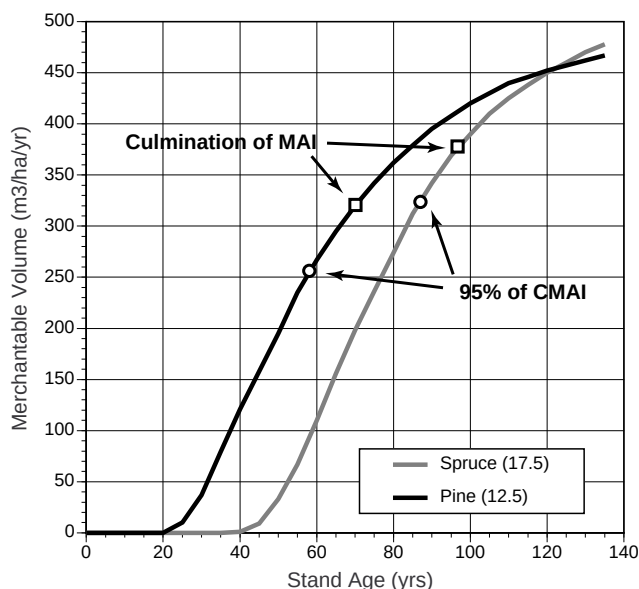


Figure 8. Potential impact of species selection on minimum harvest age. The minimum harvest age rule used in the scenario planning exercises required that stands achieve 95% of maximum MAI before they could be harvested. This diagram assumes the same site will support lodgepole pine at SI50=21 and white spruce at SI50=19. Yield values are from TIPSYS v. 2.1, assuming establishment densities of 1600 trees/ha for both species, OAF1 = 15% and OAF2 = 5%.

3.3 Backlog Brushing and Thinning

Deciduous-leading backlog stands (logged pre-1983) are currently treated as non-commercial cover and are not included in the THLB. In some cases, these stands have at least acceptable stocking of conifers beneath the deciduous canopy. Stand treatments which release and thin the conifer stocking (it is often clumpy) will convert these areas to conifer leading stands. They can then be included in the THLB and will contribute to commercial timber production.

It is recommended that yields for these stands be simulated using TIPSYS curves with a 10-year regeneration delay, an extra 5% OAF1, and an assumed 15% deciduous component at final harvest. The regeneration delay will serve both for the actual regeneration delay and for the period of reduced growth under the deciduous canopy. The extra 5% OAF1 will account for the patchy stocking in these stands, and the 15% deciduous component will account for deciduous trees left for biodiversity purposes or to fill otherwise unstocked gaps.

3.4 Pre-Commercial Thinning (PCT)

Within the context of this document, pre-commercial thinning is not considered to be a viable treatment on its own, and is not considered to have any yield effects. Instead, it is viewed as a precursor to later commercial thinning treatments. The intent of a pre-commercial thin program on TFL 30 then is to increase future opportunities for commercial thinning, where such treatments are needed to help reduce or eliminate the projected mid-term deficit.

Figure 9 charts the stand & stock tables for two stands that have reached a minimal operable volume to consider a commercial thinning. Table 2 highlights the differences in the harvest profile of the thinnings. Both stands have the same origin, but one was pre-commercially thinned. Both have very similar merchantable volumes, but the thinned stand has far fewer stems. The previously thinned stand not only provides a more attractive harvest profile, but is much cheaper to operate in due to fewer thinned trees (both merchantable and non-merchantable).

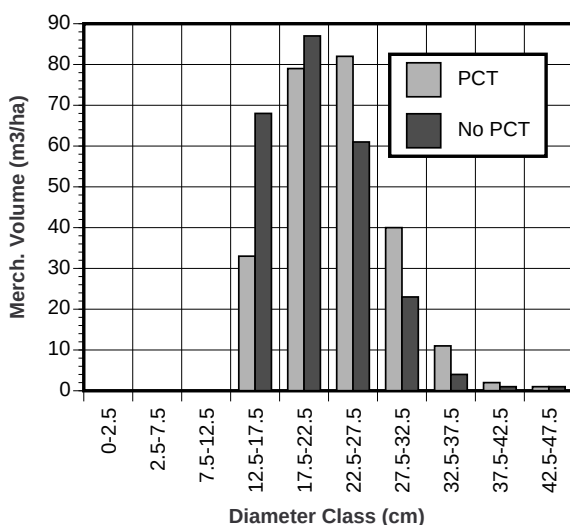


Figure 9. Stand and stock charts contrasting two spruce stands that might be considered for a commercial thin treatment. Both stands have similar merchantable volumes, but the stand that was previously pre-commercially thinned has less of its volume in the smallest merchantable size class.

	Commercial Thinning Volume (m³/ha) by diameter class (cm)			
	12.5-17.5	17.5-22.5	22.5-27.5	27.5-32.5
With PCT	30	43	8	2
Without PCT	61	14	6	1

Table 2. Thinning volumes from the two stands illustrated in Figure 9 have distinctly different size profiles. The pre-commercially thinned stand has a much greater proportion of its volume in larger size classes. To reflect spatial irregularities and trail construction, the profiles in this table assume that a maximum of 90% of the smallest class could be harvested, and at least 5% of the volume in the larger size classes would be harvested.

For the purposes of timber supply analysis, pre-commercial thinning is part of the commercial thinning regime where regenerated stand densities exceed 5000 trees/ha. From an operational perspective, it is expected that priority for treatment will be assigned to stands having higher rather than lower densities. Efforts should be directed to stands that will not be available for full harvest during the mid-term deficit period, but will have achieved the minimum requirements for a commercial thin. Further refinements for the selection of stands to be pre-commercially thinned will come from the timber supply modeling exercise.

3.5 Commercial Thinning

Commercial thinning provides yield from stands otherwise unavailable for harvest during the mid-term deficit period. At least to some degree this is a process of robbing from the future to make the present more attractive, but when there is a deficit in the present and a surplus or relative abundance in the future, a strong case can be made for this type of action.

For the purposes of modeling to test for timber supply impacts of a commercial thinning program, the following assumptions and decision rules are recommended:

1. A minimum merchantable volume of 210 m³/ha (17.5+) or 240 m³/ha (12.5+) must be present in the stand before commercial thinning can occur. This is based on the assumption that a 33% volume removal will not dramatically affect future yields, and that a thinning removal of 70 m³/ha (17.5+) is the minimum for an economically viable treatment. Note that 70 m³/ha (17.5+) is roughly analogous to a 80 m³/ha (12.5+), which is a more likely utilization standard to be applied when these stands are commercially thinned. For current timber supply planning, however, the 17.5+ standard will be employed except for stands of lodgepole pine.
2. Commercial thinning yields will always be 70 m³/ha (17.5+) for most species or 80 m³/ha (12.5+) for lodgepole pine, regardless of treatment timing and available merchantable volumes. This limitation derives from the need for a set of pre-determined post-treatment yield curves.
3. Stands that have been commercially thinned are not available for final harvest until at least 20 years after thinning.
4. To be eligible for commercial thinning, stands must either have been pre-commercially thinned, brushed and thinned (backlog sites), established at densities less than 2000 trees/ha (total trees) or have a crown closure of less than 60% at the time of treatment.

Several optional assumptions exist for post-thinning yield curves (fig. 10). The simplest is that total yield (thinnings + final harvest) is unaffected by commercial thinning. In this case,

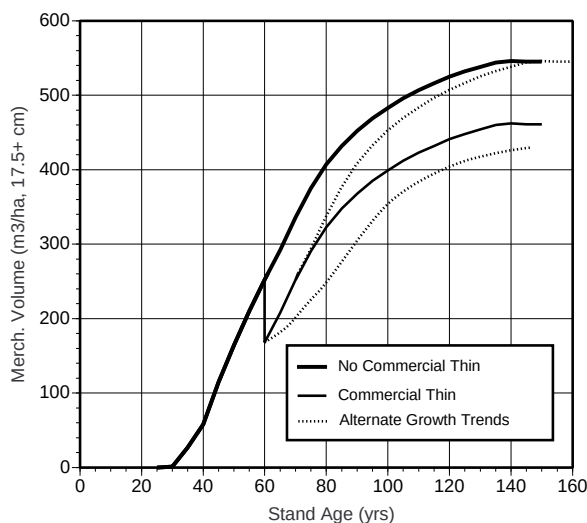


Figure 10. Optional assumptions for modeling stand growth after a commercial thinning. The recommended approach for yield curves in this exercise is to assume commercial thinning has no effect on total yield (thinnings plus final harvest) - volume growth after thinning is the same as for an unthinned stand during the same period. Alternate assumptions might include volume recovery where the thinned stand reaches the same maximum volume as the unthinned stand, or volume degradation where volume growth is slowed after thinning due to stress, poor crown structure and/or incomplete utilization of growing space.

yields for a given age in the treated stand are simply the yield for the untreated stand at the same age minus the thinning yield. For the purposes of this exercise, then, commercially thinned stands will always have 70 m³/ha (17.5+) less volume than a comparable unthinned stand.

The yield assumption for thinned stands stated above is likely reasonable for stands where the final harvest occurs sooner (20-40 yrs after thinning) rather than later (40+ yrs after thinning). Where the treated stand is held longer after thinning, there is more likely to be some convergence toward the yield of the untreated stand. This is the result of the thinned stand growing for a longer period in the absence of self-thinning (gross growth is lower in the thinned stand, but mortality losses are also lower and by an increasingly larger margin). In such cases, yield predictions for the commercially-thinned stand will likely be slightly pessimistic.

Note: while commercial thinning per se is not funded by FRBC, the pre-commercial thinning treatments that in many cases must precede the CT entries are funded.

3.6 Fertilization: Early- and Mid-Rotation

Fertilization increases stand yields by temporarily accelerating growth. In the absence of long term growth monitoring, it is assumed that patterns of stand development are not altered, just the growth rate. In essence, this means that all the same milestones in stand development will be achieved and with the same or very similar stand attributes. The only difference is that each milestone occurs earlier.

Given this assumption, the best way to incorporate fertilization response in yield curves is to assume a temporal shift in yield expectations. For example, if a fertilization treatment results in an average 20% growth increase over a 10-year response period, there is a 2 year gain (or shift) in the achievement of the next and all subsequent milestones. In the context of a volume/age table used in timber supply analysis, each volume entry for the treated stand would be achieved 2 years earlier than for the untreated stand (Fig. 11).

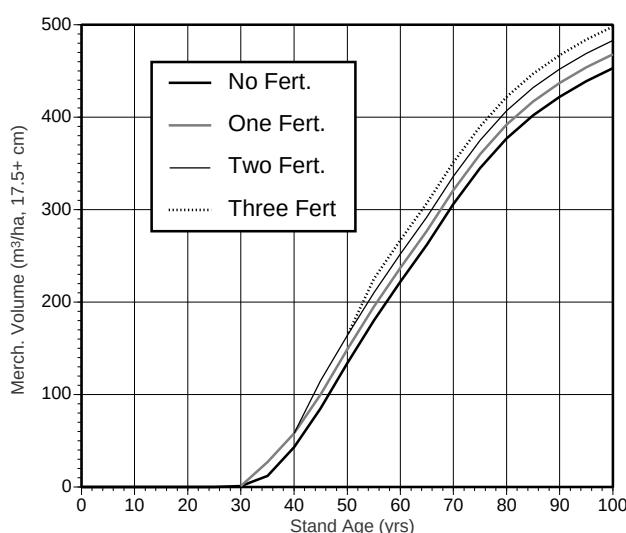


Figure 11. Each fertilization effectively adds volume to a stand at a given age, up to a certain point. It is expected that stands will reach a common maximum volume regardless of previous fertilization treatments. This effect is modelled not by adding volume to the untreated stand yield curve, but by shift the portion of the curve following treatment to the left on the volume/age grid.

Effects of repeated treatments are assumed to be cumulative. Assuming a 2 year gain in growth for each of three treatments applied at ages 30, 40 and 50, the treated stand will reach at age 60 the volume that the untreated stand would have achieved at age 66.

This method of incorporating treatment response to fertilizer in yield curves results in relatively coarse increments of “gain”. Yield benefits must be incremented in steps of 1 year shifts in the yield curve. In the case of white spruce, a two year shift is probably slightly optimistic, but a one year shift (the next step down) would be excessively pessimistic. In the case of lodgepole pine, the two year shift may be slightly pessimistic. In testing for the timber supply impacts of a fertilization program, the two year shift in yield achievement after fertilization is recommended.

The easiest way of adjusting yield curves is to change the ages at which specified volumes are achieved. For example, the following yield curves/tables illustrate the impact of a single fertilizer application at age 30. In the treated yield curve, the next and subsequent yield milestones occur two years earlier:

<u>Age</u>	<u>Merch. Vol.</u>		<u>Age</u>	<u>Merch. Vol.</u>
10	0		10	0
20	0		20	0
30	1		30	1
40	43		38	43
50	134	Becomes...	48	134
60	222		58	222
70	306		68	306
80	377		78	377
90	422		88	422
100	453		98	453

If the same stand is fertilized at 30, 40 and 50 years:

<u>Age</u>	<u>Merch. Vol.</u>		<u>Age</u>	<u>Merch. Vol.</u>
10	0		10	0
20	0		20	0
30	1		30	1
40	43		38	43
50	134	Becomes...	46	134
60	222		54	222
70	306		64	306
80	377		74	377
90	422		84	422
100	453		94	453

An alternate method of adjusting yield curves is supplied in Appendix I for cases where consistent 10-year increment periods are required for the yield tables.

For this exercise, several sets of response curves are needed, depending on current stand ages and site index:

SI ≤ 22		SI > 22	
Current Age:	Fertilize at ages:	Current Age:	Fertilize at ages:
41-50	50	31-40	40
31-40	40,50	21-30	30, 40
≤ 30	30,40,50	≤ 20	20,30,40
≤ 30 (CT regime)	30,40	≤ 20 (CT regime)	20,30

Candidate stands for fertilization must have white spruce, lodgepole pine or Douglas-fir as the leading species. They must also have had early density control or been established at relatively low densities. For the purposes of timber supply modeling, criteria available either in the inventory file or tracked from previous treatments applied by the timber supply model must be used to assess suitability. It is recommended that suitable stands either have a) been previously thinned (PCT) or brushed & thinned, b) been established with a total density less than 2000 trees/ha or c) have a percent crown cover value less than 50% at the time of treatment (based on air photo interpretation).

3.7 Fertilization: Late-Rotation

Late rotation fertilization is applied to stands scheduled for harvest in the near future. While the biological effects are similar to that of earlier fertilizer applications, there is a much simpler method of simulating treatment response in a timber supply modeling context, as the timing of harvest is already known and is in close temporal proximity to the harvest. In this case, a set of treatment response yield curves is not required, and the treatment can be simulated as a fixed volume gain at harvest. A gain of 10 m³/ha is recommended.

To be eligible for treatment, stands must be of a suitable species and not be overcrowded (they must not be self-thinning). It is recommended that stands be less than 100 years of age, have a crown cover of less than 50% (based on air photo interpretation), and have spruce, Douglas-fir or pine as the leading species. Stands on poorer sites (SI₅₀ ≥ 17) should not be eligible.

4.0 Other Modeling Issues Related to the Mid-Term Deficit

Strategic silviculture investments are designed to have a specific impact on future timber supplies (or other resource value). In the context of this document, that impact is mitigation of the projected mid-term deficit. Efficient allocation of silviculture investments is highly sensitive to an accurate depiction of the problem to be addressed – if the timing or characterization of the problem is incorrect, the planned treatments for mitigating the problem may be of reduced or no impact. In the worst case, if a problem is forecast which doesn't really exist, then silviculture investments to address the problem are totally wasted or may even create a

problem! It is important, then, that the dynamics of the timber supply are fully understood, complete with a thorough exploration of what factors are constraining timber supply. For the forecast deficit on TFL 30, two factors needing to be more fully explored include minimum harvest age rules and site index.

4.1 Minimum Harvest Age Rules

The minimum harvest age rules as currently applied may be imposing an artificial constraint upon the TFL 30 land base which is contributing to the mid-term timber supply deficit. The current rule dictates that stands achieve at least 95% of the potential CMAI (MAI at culmination) before they can be harvested. It is intended to ensure that long term productivity is maintained as near as possible to the site potential, although there may be auxiliary benefits such as helping to maintain a desired age class structure. In the short- and medium-terms, however, it may be exacerbating the existing deficit situation.

Toward the end of the deficit period, there will be spruce plantations on TFL 30 with 300 m³/ha of merchantable volume which are projected to be unavailable for harvest because they have not reached 95% of CMAI! It is difficult to imagine 80 years from now that stands with 300 m³/ha will be deferred from harvest during a deficit period, particularly when that period is followed promptly by a period of relative abundance. It is recommended, therefore, that a relaxation of the minimum harvest age be analyzed for the deficit period, to assess its impact on the magnitude of the deficit. A possible alternative during this period is achievement of a minimal harvest volume (i.e. 200 or 250 m³/ha).

4.2 Impacts of Regenerated Stand Site Index Values

Assignment of site index values for regenerated stands has a major impact on the depth and duration of the forecast timber supply deficit. For TFL 30, a landscape scale bias of as little as 1m in site index could potentially halve or dramatically deepen the projected trough. Higher site index values mean not only higher yields but shorter rotation lengths; lower values mean lower yields and longer rotations. If site index values are underestimated, therefore, the projected deficit will be deeper and of longer duration than what will actually be realized. If site index values for these stands are overestimated, however, the timber supply projection will be overly optimistic. In either case, inadequate estimates of site index can lead to dramatic mis-allocations of silviculture investments.

Recent work on TFL 30 to assess site index has provided considerable improvement in this regard. There will continue to be some uncertainty, however, and close monitoring of site index values for regenerating stands is recommended. In the event that a landscape scale bias in current estimates of site index exists, it is important that it be recognized as soon as possible so that scarce silviculture investment dollars can be re-directed to appropriate areas.

5.0 Closing Remarks

The yield curves proposed in this report are intended for exploring the potential effects of intensive silviculture treatments on a specific problem that has been identified in the latest timber supply forecast for TFL 30. The magnitude of the treatment responses are largely theoretical, and are derived from “typical” values found either in the literature or by running stand growth models such as TASS/TIPSY. The approach taken was to be neither optimistic nor pessimistic about expected treatment benefits. Without having applied such treatments on this land base, however, there is some uncertainty regarding the magnitude of the yield curve adjustments.

Should the subsequent timber supply analysis indicate that a program of silviculture investments will indeed help overcome the currently projected deficit, then a program of testing and monitoring will be required. The testing program is required particularly for fertilization, to assess whether or not the assumed treatment gains are realistic in the forest types present, and to develop decision criteria for which stands will be treated. The monitoring program will be required to assess the effectiveness of applied treatments, so that future decisions on rate of cut can be made based on achieved rather than predicted treatment results.

Appendix I

The following algorithms can be used to adjust yield tables for the effects of fertilization assuming that the treated yield curves must be reported on the same 10-year intervals as the untreated stands. These algorithms assume a 2-year shift/gain for each fertilizer treatment.

Where: U_i = yield of untreated stand in decade “i” ($i = \text{age}/10$)

T_i = yield of treated stand in decade “i”

n = last decade in table

For a single treatment at age 50:

For ($i = 1$ to 5)

$$T_i = U_i$$

For ($i = 6$)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For ($i = 7$ to $n-1$)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.2*(U_{i+2} - U_{i+1})$$

For ($i = n$)

$$T_i = U_i$$

For a single treatment at age 40:

For ($i = 1$ to 4)

$$T_i = U_i$$

For ($i = 5$)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For ($i = 6$ to $n-1$)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.2*(U_{i+2} - U_{i+1})$$

For ($i = n$)

$$T_i = U_i$$

For treatments at ages 40 and 50:

For ($i = 1$ to 4)

$$T_i = U_i$$

For ($i = 5$)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For ($i = 6$)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For ($i = 7$ to $n-2$)

$$T_i = T_{i-1} + 0.6*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For ($i = n-1$)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/2$$

For (i = n)

$$T_i = U_i$$

For treatments at ages 30, 40 and 50:

For (i = 1 to 3)

$$T_i = U_i$$

For (i = 4)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For (i = 5)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For (i = 6)

$$T_i = T_{i-1} + 0.6*(U_{i+1} - U_i) + 0.6*(U_{i+2} - U_{i+1})$$

For (i = 7 to n-2)

$$T_i = T_{i-1} + 0.4*(U_{i+1} - U_i) + 0.6*(U_{i+2} - U_{i+1})$$

For (i = n-2)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/3$$

For (i = n-1)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/2$$

For (i = n)

$$T_i = U_i$$

For treatments at ages 20, 30 and 40:

For (i = 1 to 2)

$$T_i = U_i$$

For (i = 3)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For (i = 4)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For (i = 5)

$$T_i = T_{i-1} + 0.6*(U_{i+1} - U_i) + 0.6*(U_{i+2} - U_{i+1})$$

For (i = 6 to n-2)

$$T_i = T_{i-1} + 0.4*(U_{i+1} - U_i) + 0.6*(U_{i+2} - U_{i+1})$$

For (i = n-2)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/3$$

For (i = n-1)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/2$$

For (i = n)

$$T_i = U_i$$

For treatments at ages 30 and 40:

For (i = 1 to 3)

$$T_i = U_i$$

For (i = 4)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For (i = 5)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For (i = 6 to n-2)

$$T_i = T_{i-1} + 0.6*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For (i = n-1)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/2$$

For (i = n)

$$T_i = U_i$$

For treatments at ages 20 and 30:

For (i = 1 to 2)

$$T_i = U_i$$

For (i = 3)

$$T_i = U_i + 0.2*(U_{i+2} - U_{i+1})$$

For (i = 4)

$$T_i = T_{i-1} + 0.8*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For (i = 5 to n-2)

$$T_i = T_{i-1} + 0.6*(U_{i+1} - U_i) + 0.4*(U_{i+2} - U_{i+1})$$

For (i = n-1)

$$T_i = T_{i-1} + (U_{i+1} - T_{i-1})/2$$

For (i = n)

$$T_i = U_i$$