Reforesting Dry Sites in the Thompson Okanagan Natural Resource Region

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Final

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Project [419-41]

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Overview

The impact of climate change is expected to increase current challenges to establishing plantations on at-risk sites in the Thompson Okanagan region as drought years are expected to increase in frequency. Licensees in this region have experienced very high seedling mortality rates both in drought years as well as relatively normal years.

The purpose of this paper is to evaluate existing silviculture practices as well as recent literature, and identify best management practices to support improved regeneration success and forest establishment on dry sites.

This paper identifies a drought risk key which allows silviculture practitioners to identify drought prone sites and situations and rank the expected intensity of drought effects.

Important factors such as the following are discussed in detail:

- Natural moisture trend over a season
- Controllable factors that affect moisture over a season
- Identifying drought prone sites.
- Identifying drought prone situations.
- Pre-harvest signoff of site plans.
- Post-harvest assessments
- Natural regeneration
- Mechanical Site Preparation
- Shade
- How seedlings grow
- Species selection.
- Seedlot selection. Progeny and class.
- Seed selection. Germination percentage.
- Stock selection – container type and size
- Planting season
- Nursery considerations
- Planting contract setup.
- Planting contract implementation.
- Fertilization
- Brushing
- Recommended treatment regimes
- Post planting review, walkthrough or survey scheduling regime
- Identification, coding and reporting
- Trials

Treatment regimes are recommended as Best Management Practices for extremely dry, very dry and dry sites. General Best Management Practices are also provided for all sites that are considered at risk for drought mortality.

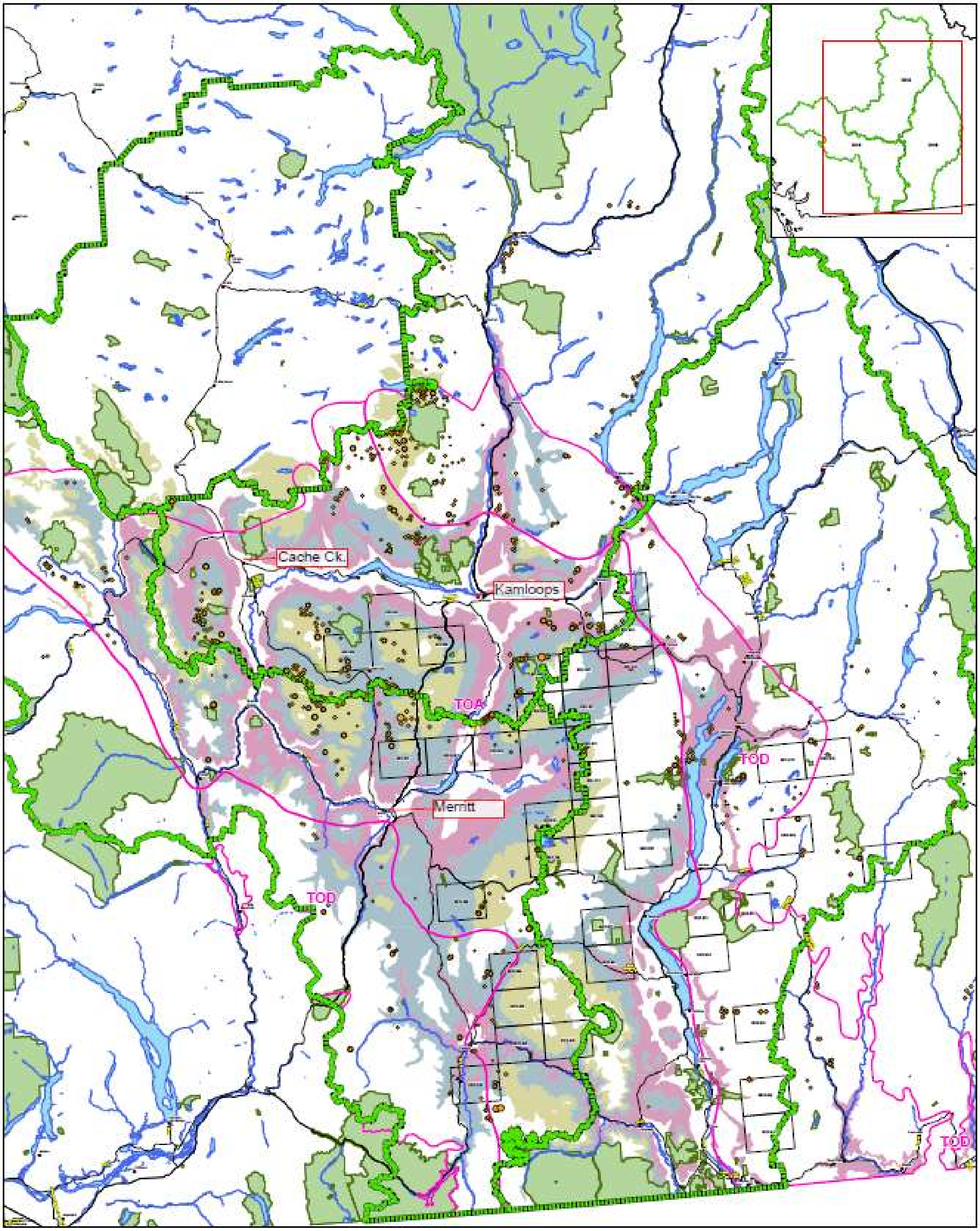

Figure 1 Map of Thompson Okanagan Region showing replants and at-risk BGC subzones

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List of Acronyms

CF%	Coarse Fragment Percentage
BEC	Biogeoclimatic Ecosystem Classification system
BGC	Biogeoclimatic unit
CBST	Climate Based Seed Transfer
GBST	Geographic Based Seed Transfer
MSP	Mechanical Site Preparation
MSS	Minimum Stocking Standard
NSR	Not Satisfactorily Restocked
PHA	Post-harvest assessments
PSB	Plug - Styroblock
PSI	Plug – Styroblock, Individually Wrapped
RESULTS	Reporting Silviculture Updates and Landstatus Tracking System
RGC	Root Growth Capacity test
TSS	Target Stocking Standard

Document Revision History

Version	Date	Description
1.0	2020-03-09	First submission
1.1	2020-03-19	Year-end submission
1.2	2020-10-27	Final submission.

1 Introduction

Reforestation on dry sites is extremely challenging. While this is not a new issue, it has been placed under greater focus now that harvesting has shifted from Mountain Pine Beetle killed sites to lower elevation Douglas-fir stands. This challenge is compounded by periodic years of decreased moisture in drought years such as 2017 and 2018. Periodic drought years should be expected more frequently as impacts from climate change increase.

Mortality on dry sites has impacted licensees in varying intensity, depending on their harvest profile and focus on extremely dry sites within their operating area. All licensees in the Thompson Okanagan witnessed increased seedling mortality from the 2017 extreme drought year.

It's not possible to fully account for seedling mortality from 2017 because licensee data is organized and coded differently from each other, licensee reporting is still occurring for the 2019 planting year, and the full impact of the drought is not yet revealed. However, many sites first planted in 2016 or 2017 have not successfully restocked and may take many years and treatments to be fully reforested.

The percentage of units replanted from the 2016 and 2017 planting years is summarized below for five silviculture divisions. These groups have considerably different operating areas but both showed elevated need for replanting compared with what would be considered average years.

Within Interfor's dry IDF sites, 80% of all planting treatments have been replanted or are planned to be. Other biogeoclimatic cohorts also had significant replanting but not to the extent of the dry IDF. For the MS to require replanting of 18% of first time planting is an extremely high number as 5% would be considered an average year.

BGC	Interfor (Adams Lk.)	BCTS DOS(S)	BCTS DOS(N)	BCTS Kamloops
	% of all 2016/2017 planting that needs replanting	% of all 2016/2017 planting that needs replanting	% of all 2016/2017 planting that needs replanting	% of all 2016/2017 planting that needs replanting
ESSF	4%	15%	11%	0%
ICH	0%	n/a	12.5%	0%
IDF-dry	80%	35%	59%	13%
IDF-wet	7%	n/a	n/a	n/a
MS	18%	33%	0%	17%
SBPS	32%	n/a	n/a	n/a
SBS	13%	n/a	n/a	n/a

n/a – licensee did not have planting activities in this BGCsz for these years.

Table 1. Examples of Licensee requirements to replant following 2016-2017 planting seasons.

Many of the sites reviewed in this report are truly dry sites that have predictable water deficiencies available to seedlings which are much greater than their neighbours on north aspects or higher elevations. Examples of conditions found on a naturally dry site are: low elevations, south aspects, and coarse soils.

Other sites might only be considered dry under the conditions available during reforestation. These can include moderate elevation sites fully occupied by pinegrass, or sites which cannot be accessed during early season snow-free conditions due to physical, operational, or planning related obstacles.

Reforesting dry sites can be extremely costly, especially if treatments do not succeed the first time.

This paper includes a list of Best Management Practices for improving regeneration success and forest establishment on dry sites within the Thompson Okanagan Region.

1.1 Project Objectives

The aim of this report is to review the current practices of local silviculturists in reforesting dry sites and recommend Best Management Practices for sites that are prone to drought mortality of planted seedlings.

Photo 1. Example opening on very dry site.

2 Approach

2.1 Data gathering and preparation

The data gathering phase was undertaken in partnership with research scientists, nursery specialists, and licensee silviculturists that chose to engage for this report. The intention was to access data of recent drought events' impact on plantation performance as well as review industry practices, current research and nursery cultural practices. The interviews touched on many of the topics below though not all topics were discussed with each licensee representative as the list of topics evolved and grew through discussions within the interview process. These conversations help inform the best existing practices when managing to reforest stands where drought is a significant concern.

Data gathered includes:

1. A list of replants that licensees completed or planned from 2016-2020.
2. A conversation covering all aspects of silviculture to identify their current or planned practices for reforestation on sites they consider to be drought prone. This spans: pre-harvest review of sites, post-harvest assessments, as well as activities and practices.
3. A recommended list of field sites which have had interesting treatments and results, suitable for generating discussions about silviculture practices on dry sites. The understanding is that licensees know their operating areas and operational practices much better than can be identified from RESULTS data or other data scraping methods. There is also recognition that each of the licensees' operating areas have variances in terrain or history which drive different practices.
4. RESULTS reports for all replants in the Southern Interior over the last five years.
5. 2018 Drought Assessment in the Thompson Okanagan Region project data.
6. Literature review of the last ten years of relevant research.

In scope: Stands younger than 5 years old.

Out of scope: Stands older than 5 years old.

The majority of the findings in this report results from field reviews of the plantation failures reported by the licensees, BCTS and ministry staff. While survey results were provided in most instances, each of these sites had complexities beyond the summarized reports – each of the plantation failures had instances where the trees survived and were thriving. Much of the recommendations for improved practices found in this report are based on ocular assessments of trends gathered over a large number of sites.

3.1 Moisture Trends: Natural moisture trends over a season

Over the course of every growing season the natural trend in moisture is similar with differences in absolute soil moisture amounts in different seasons.

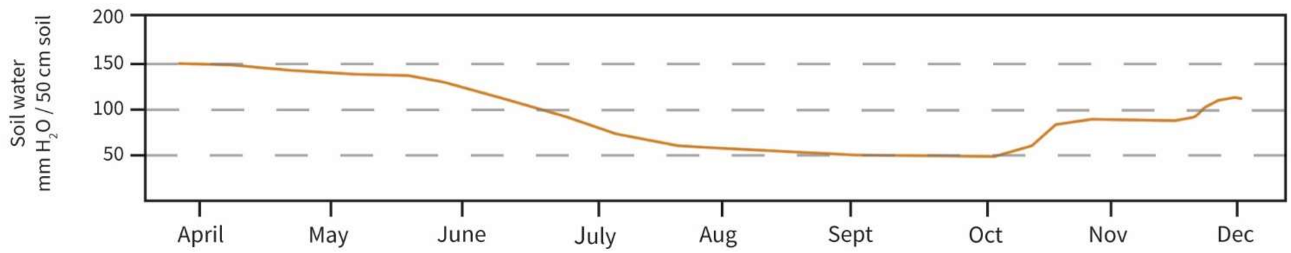

Figure 2. Example moisture graph from 2017 season near Lac Le Jeune Kamloops. (unpublished data, Wallace 2020)

Soil moisture is highest immediately after snow-free conditions. The moisture then drains down through the soil profile as spring progresses to summer. Soil moisture is lowest during summer conditions and increases with fall rains.

Every season is similar and changes to the trend are incremental:

- Greater than average snow packs can increase the soil moisture in the spring, delaying the drying trend, while less than average snow packs can decrease soil moisture and cause earlier onset of the summer drying trend.
- Cooler than average temperatures in early spring can delay the drying trend while warmer temperatures will cause the drying trend to occur earlier.
- Greater than average spring precipitation can delay the drying trend while less than average will cause the drying trend to occur earlier.
- Summer has the lowest amount of moisture and the amount of moisture is related to the winter snowpack, spring rains (amount and timing), summer temperatures and summer precipitation.
- Greater than average autumn precipitation will relieve drought conditions earlier while less than average will extend the summer drought.

The soil moisture graph clearly shows a trend witnessed in both dry and wet years. The moisture trend shifts the line up or down, and the onset of the moisture earlier or later. Individual moisture events or even series of moisture events aren't observed other than to slightly shift the trend.

This trend line indicates how critical it is to establish trees early in a growing season in order to take advantage of the most soil moisture content possible. Seedlings are much more likely to survive the dry summer months if they are given sufficient time to 'harden off' and establish themselves prior to this period.

3.1.1 FACTORS THAT AFFECT MOISTURE OVER A SEASON

There are many factors outside the control of silviculturists:

- Snow pack,
- The date of snow-free conditions,
- Total soil moisture trend,
- Temperature trend

Silviculturists must craft specialty programs in order to establish stands which will endure these constraints.

The following factors and decisions benefit from being managed by silviculturists who can craft specialty programs in order to establish stands which will endure the above constraints.

- The initial harvest disturbance: what does the initial net area to reforest look like,
- Determining the regime or regimes appropriate for a site,
- Mechanical site preparation: type, timing, and disturbance levels,
- Planting: timing, and prescription
- Stock size, species selection, stock type, seed provenance.

Each of these decisions must work within the moisture window of a given year, or series of years and are discussed below.

3.1.2 EXAMPLE SOIL MOISTURE GRAPHS – ISOBEL LAKE RESEARCH TRIAL

The following graphs are moisture measurements found at the Isobel Lake research trial near Kamloops, BC. (Unpublished data, Wallace 2020). These moisture measurements are for the five year period from 2016 through 2020. This site has two sample locations in the IDFxh2, an extremely dry site in an open harvested area as well as under a forested canopy.

You can see for most years the moisture trend lines in the open clearcut follow the regular pattern discussed above. There are three moisture milestones identified in the graphs below: field capacity, soil water deficit, and the permanent wilting point.

Field capacity represents the moisture of the soil after drainage of the water contained in the macropores by gravity action. (Sugarcane, 2015) Field capacity is the maximum amount of available water for seedling use. The Isobel Lake data shows that the greatest available water is between April and May with two of the five years of data (2016 and 2019) showing a drop-off of available water prior to May. Seedlings on moisture limiting sites should be planted as early in the year as practicable once snow and frozen ground free conditions are available.

Soil water deficits reduce stomatal conductance, growth, root proliferation, photosynthetic pigments, protein contents, and impair photosynthetic pigments. They also alter hormone distribution and increase activities of antioxidant enzymes to cope unfavorably with osmotic changes (Praba et al., 2009). Soil water deficit is represented on the graphs below at half of field capacity for the sake of simplicity.

There are many factors that will reduce the health of seedlings as the soil water approaches the level of soil water deficit. Grossnickle SC (2016). Each plant species responds to water stress through a combination of avoidance and tolerance physiological mechanisms (Jones et al. 1981; Kramer and Boyer 1995; Ludlow 1989) as cited in

Grossnickle SC (2016). Soil water deficit level will be different for different species, as well as for how well established those individual seedlings are

The implication for silviculturists is that there is limited time for seedlings to have their roots extended, foliage grown and hardened off, buds established, and stomata closed. Seedlings must have these items set prior to soil water deficit. In the open site shown below, soil water deficits were reached by the middle of May. It is interesting to note that in 2020 the open site did not reach soil water deficit until late July – this should not be counted on as a regular occurrence.

Permanent wilting point is the point when there is no water available to the plant. If no additional water is supplied to the soil, most of the plants die.

Note, in 2017 on the open site, the permanent wilting point was reached in August and maintained until the middle of October. In most years the permanent wilting point was not reached at all for the entire summer season. This matches the observations from the site visits that showed the 2017 seedling mortality on sites 29, 30, and 31 occurred later in August and not earlier as in most of the other sites visited for other planting years.

Also note at the forest site that the permanent wilting point was reached in four of the five years at some point during the year. The implication of this is that mature trees contribute to soil moisture deficits by removing moisture from the soil through transpiration. Silviculturists will need to balance the need for shade that can be provided by mature trees, but also create open spaces that have reduced evapotranspiration from mature trees.

Best Management Practice: Adjust operational strategies to ensure trees are planted as early as snow free and frost free conditions allow, with enough time to develop roots, develop shoots and buds, and close stomatal cells before moisture reaches soil water deficits (half of field capacity).

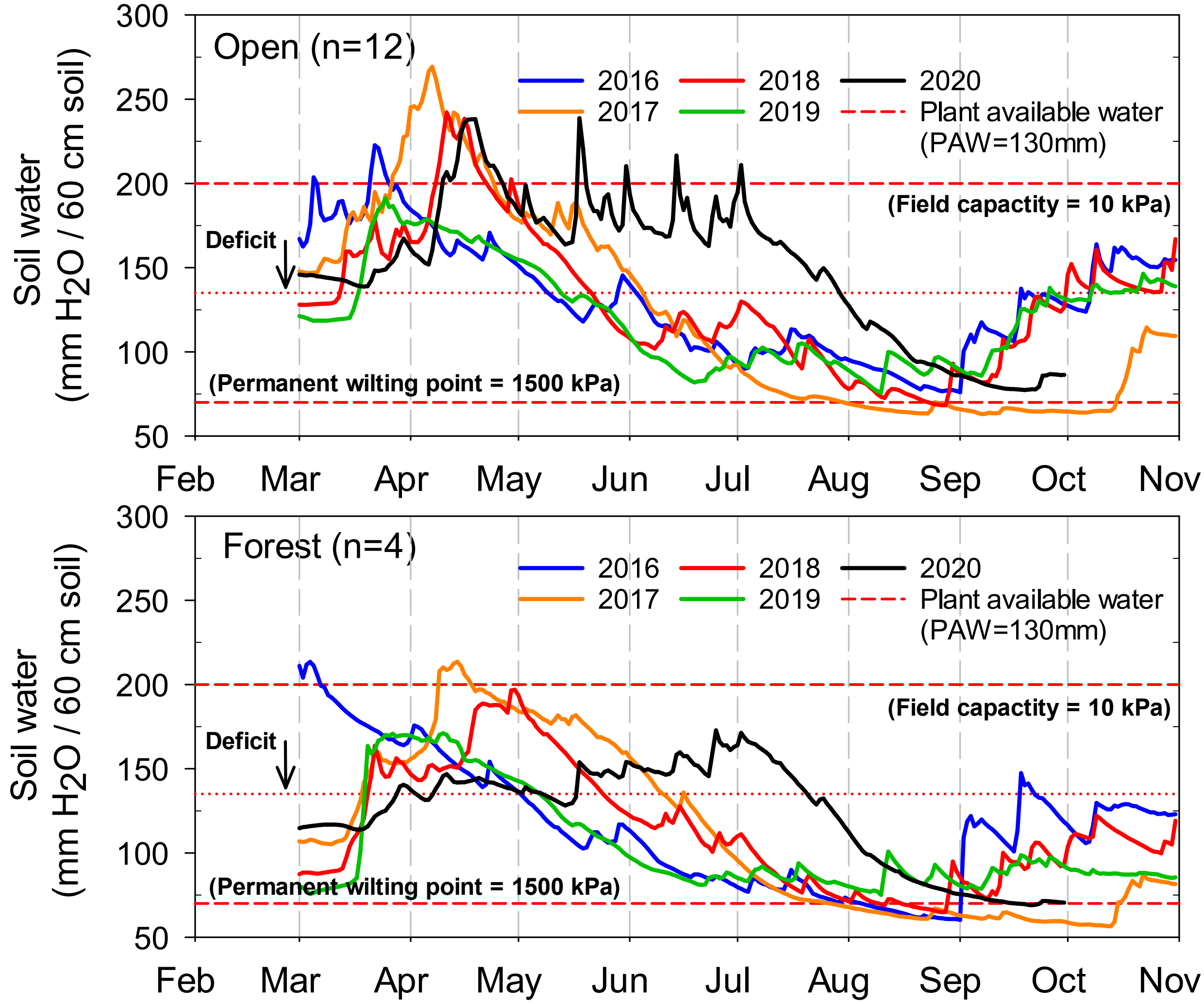

Figure 3. Mean soil water balance (2016-2020) of a IDFxh2 15 ha block harvested (Open; n=12) in winter 2015 and the adjacent forest edge (Forest; n=4) near Isobel Lake (1050 m), Kamloops, BC. Soil water (mm H2O / 60 cm) is the calculated soil water content within the 0 to 60 cm soil depth as measured using hourly volumetric water sensors at 10, 25, and 45 cm depths. Upper dashed red line is the measured and observed value of field capacity (200mm; 10 kPa) with the lower dashed line representing the permanent wilting point (70mm; 1500 kPa) for a total plant available water (PAW) balance of 130mm. Soil water deficit (dotted red line) as the start of plant/seedling drought stress was estimated to be 50% of PAW. (unpublished data, Wallace 2020).

4 Identifying drought prone sites

The drought risk key below has been developed and discussed with local licensee silviculturists and adequately represents plantation mortality risk. The key is intended to be used by stratifying sites, identifying the key factors for each site and totaling the resulting value in the table below to come up with a number that reflects each site's drought risk. The numbers presented below are qualitative and represent trends in the risk of drought mortality. The intention is to then look up the recommended silviculture treatment regime identified for that drought risk. If the recommended silviculture treatment regime cannot be followed increase the total from the drought risk key to account for greater vegetation competition – this includes recalculating the value where a replant is necessary.

More experienced silviculturists can and should adjust the weighting to best match their observations of risk and mortality on their openings. Please recognize that there are vast differences between operating areas which effects sites differently.

Stratify sites based on the primary and secondary criteria below. Stratify sites as thoroughly as possible without lumping. Find the BGC subzone (primary stratification criteria) you are operating in and add or subtract points based on secondary site characteristics. Total the points up to identify the drought risk category and review and follow the resultant recommended treatment regime (below).	>15	Extremely dry sites
	10-15	Very dry site
	5-10	Dry site
	<5	Not a dry site

BGC		Soil Moisture Regime		Aspect		CF%		Overstory shade		Other factors	
PP or BG	20	Very Xeric to Subxeric	5	SE-W	5	High	5	None	3	SE-W (>30%)*	3
IDFxh	15	Submesic	3								
IDFdk	10	Mesic	0	W-NW or E-SE	0	Moderate	3	Moderate	0		
MSxk or IDFmw	5	Subhygric	-3							Flat with heavy	
ESSF or ICH	0	Hygric-Subhydric	-5	NW-E	-3	Low	0	Significant	-3	compaction	3

* Steep slopes on south facing slopes have increased risk.

** Flat ground when there is significant compaction can be difficult to achieve adequate disturbance from site preparation.

Figure 4. Drought risk key

Sites within the Thompson Okanagan Region can be described in increasing amounts of moisture: extremely dry, very dry, dry, and not-dry but prone to dry situations. The biogeoclimatic zones rank in order of how they fall on the landscape in the Thompson Okanagan Region. These biogeoclimatic zones increase in elevation: Bunchgrass zone (BG) is the lowest in the Thompson Okanagan Region, Ponderosa Pine zone (PP) is located above the BG, Interior Douglas-fir zone (IDF) is located above the PP and Montane Spruce zone (MS) is located above the IDF.

In areas where Interior Cedar Hemlock zone (ICH) is present this zone is located above the IDF and below the Engelmann Spruce - Subalpine Fir zone (ESSF). Most ESSF and ICH sites should not be considered dry sites.

The primary consideration to determine ranking of at risk sites is BGC – subzone.

- The Bunchgrass and Ponderosa Pine biogeoclimatic zones are considered extremely dry on all sites – it is unusual for forestry operations to be conducted in these zones.

- Within the Interior Douglas-fir biogeoclimatic zone, the sub zones increase in moisture from IDFx* (extremely dry, * including xh1, xh2, and xw), increasing in moisture to IDFdk* (very dry, * including dk1, dk2, and dk3), increasing in moisture to IDFmw* (dry, *IDFmw2).
- The Montane Spruce biogeoclimatic zone was considered not dry but prone to conditions that may cause plantation failures if not identified and addressed.
- The Engelmann Spruce Subalpine Fir biogeoclimatic zone was not considered to be naturally dry relative to the other biogeoclimatic zones.
- IDFxh sites were all extremely drought prone and drought impacts should be expected on all sites.
- IDFdk1 and dk2 are very dry sites and prone to drought mortality.
- Other subzones ranking of drought depended on secondary site conditions as identified below. IDFmw and ICH sites may have extreme vegetation responses capable of overwhelming a site and cause moisture deficits similar to an IDFxh site. MS and ESSF sites could have considerable pinegrass ingression and cause moisture deficits similar to an IDFdk site.

Secondary considerations for ranking of at-risk sites are:

- Aspect. South and west aspects are much drier than north or east.
- Coarse Fragment % (CF %). Sites with increased coarse fragments are more likely to have drought mortality than those with lower coarse fragments. The reason for this is twofold: moisture drains out of the sites in the spring quicker but also sites with high coarse fragments are difficult to mechanically site prepare.
- Soil texture. Sandy soils are more likely to have drought mortality than fine textured soils. Sandy sites must be considered to have an increased risk for drought impacts relative to their subzone and elevation.
- Slope. Flat slopes have operational considerations that make them difficult to mechanically site prep and therefore are considered naturally drier. Flatter ground often have compact soils and higher coarse fragment contents. These operational considerations make it much more challenging for a mechanical site preparation treatment to achieve adequate soil disturbance. These sites are more prone to increased: compaction, vegetation competition, and to cattle concentrations, which further exacerbates damage due to drought and increases mortality. Steep slopes on north facing aspects are considered to be less prone to increased vegetation and cattle competition and therefore at a decreased risk for drought impacts relative to their subzone and elevation. Steep slopes on south facing aspects are more exposed to the sun and therefore at an increased risk for drought impacts relative to their subzone and elevation.
- Anticipated vegetation competition, particularly pinegrass. Pinegrass is considered to be the primary factor in plantation failures on extremely dry, very dry and normal sites. Where pinegrass levels are significant increased mortality is anticipated. Most other species are not considered to be an indicator of drought mortality. Some species are identified as indicators of extremely dry sites but not considered additionally detrimental to planted trees - one example of this is ceanothus. Snowberry was discussed as an indicator of an extremely dry site and where it is concentrated at high levels, considerable effort would be required to reforest these sites. All other species were considered to be secondary to pinegrass. Anticipated vegetation competition can be easily identified on the pre-harvest stand during site planning activities, and on adjacent plantations during post-harvest assessments.

- Licensee silviculturists will gain experience within their operating areas and understand the driving forces that increase and decrease risk of mortality due to drought.

Best Management Practice: Track the drought risk rating value for each site using the table above. This will make it easier to quantify and summarize the area associated with increased risk.

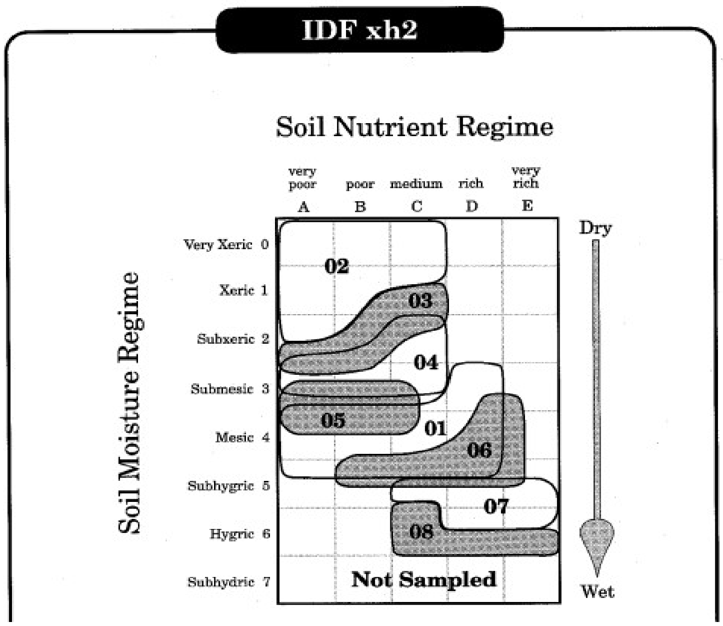

Figure 5. Example Soil Moisture Regimes for IDFxh2 from A Guide to Site Identification and Interpretation for the Kamloops Forest Region Land Management Handbook Number 23. February 1990. Province of British Columbia

4.1 Identifying drought prone situations

The assumption behind risk ranking sites assumes that the best management practices are followed throughout the entire process of reforesting dry sites. This includes prompt sowing, adequate site preparation, appropriate stock selection and planting densities, and good activity contract management (MSP and planting). Sometimes there are situations that arise that are outside the control of a silviculturist, or occur through poor planning or even luck.

- One example is sites that cannot be accessed in the early spring due to road washouts or avalanche chutes blocking roads. These are unavoidable issues, forcing the silviculturist to plant later in the season or choose a different season such as fall planting.
- Another example is not having seedlings available through unanticipated nursery mortality, insufficient number of appropriate seedlots, blockades or other issues that are temporary, but shift planting to following years when vegetation impacts are increasing and harvest disturbance or mechanical site prep effectiveness is decreasing.
- A third example would be in the case of BCTS where silviculturists must estimate harvest completion dates that are outside of their control. This can result in vegetation establishment over one or more growing seasons prior to planting.

The risk of drought mortality on these sites increases when reforestation efforts are unable to continue in the ideal timing window. In all of these cases, options with increased cost or increased risk must be explored in order to reforest these sites.

4.2 Pre-harvest signoff on site plans

Some licensees require the company silviculturist to sign off on site plans, preferably after walking the site or interviewing development crews. This is a very good practice and helps remove small areas that are extremely costly to reforest before they become a silviculture obligation. Small areas such as rock knobs, talus slopes, extreme vegetation risks, or steep south facing slopes can be identified in this process and either removed or managed differently.

If harvesting xeric sites is considered critical for operational reasons, these sites can be identified and management can be discussed.

Options exist for these areas such as:

- Harvesting - increasing retention for shade, stocking and to act as a seed source,
- Harvesting - leaving the stratum stocked through residuals or understory retention of advanced regen,
- Site Plan - creating a new standards unit to manage these areas with drought tolerant species at a lower target stocking standard (TSS) and minimum stocking standards (MSS).

This process also allows the silviculturist to plan reforestation efforts on these small areas separate from the rest of the opening. Seedlings take two years to grow in the nursery and the timing of nursery production doesn't often allow reforestation in the first spring following harvest. Smaller areas can be reforested on a different timeline through transfer or purchase of seedlings.

Best Management Practice: A silviculture forester should have input and signoff on all Site Plans in order to review openings for extremely dry sites and to help plan and prepare for reforesting dry sites. Extremely dry

areas such as south facing rock knobs or steep south facing pitches should be either removed from the block or separated out as separate Standards Units with increased retention and appropriate stocking standards.

Photo 2. Steep south facing slope in IDFxh2. Needs to be identified at the planning stage and either removed or treated differently.

5 Planning

5.1 Post-harvest assessments

Similar to pre-harvest signoff, post-harvest assessments (PHA) are the main opportunity to identify risk and plan a treatment regime or set of treatment regimes for an opening.

- Review the site plan to make sure it's correct and the limiting factors have been identified,
- Determine if the site is an extremely dry site or has factors that make it prone to drought,
- Review the adjacent openings to see how those progressed and learn any lessons applicable to the newly harvested site,
- If the site has two or more areas with different drought risk ratings, identify a regime of treatments that either address all of the constraints across the entire area, or set up separate treatment regimes which address each area's drought risk rating.
- Identify areas that must be addressed immediately rather than waiting for seedlings to be sown which can often take two years to receive the trees. For example, an opening or part of an opening, is too steep to operate MSP equipment safely. Another example is where access has been removed and mechanical site preparation is not possible.

- Think about issues that will affect the success of any chosen treatment regimes such as: spring access, bridges, avalanche chutes, access roads which will have significantly more snow than the area to reforest, on block access, and cattle intensity.

It's important to note, most openings are not uniform and likely have diverse limiting factors across each site. Portions of openings that behave differently must be addressed separately and not lumped prior to consideration. Only after these areas have been considered independently, may they be grouped together for treatment, and only if the considered treatments will work on all areas. Often site plans lump these areas together after consideration, Example IDFxh2 01(80%) 03(20%). Areas with different site series need to be reviewed separately (refer to BGC and subzone classification table). The silviculturists should review the site plan, visit the field and re-evaluate the site series for appropriate treatments.

Best Management Practice: Silviculturists should review sites during post-harvest assessments through the lens of the drought risk key, separating areas with different values. Sites should be stratified as thoroughly as possible to identify regimes that will work across strata. The Land Management Handbook #23, A Guide to Site Identification and Interpretation in the Kamloops Forest Region February 1990 should be used to classify these sites.

Photos 3 and 4. Site Plan had moist flat area and very dry steep slope in same Standards Unit which was not stratified in the Site Plan and not caught at Post Harvest assessment in order to create separate treatment regimes. The second site was not site prepared due to the steep slope and had full mortality.

5.2 Natural regeneration

Natural regeneration should not be relied upon for extremely dry or very dry sites, however, it should be encouraged through the retention of a suitable seed source. Most of the extremely dry or very dry sites will be harvesting in mature stands comprised of Fdi or Fdi (Py), or possibly Fdi (Pli).

The best scenarios for natural regeneration are:

1. Mesic site or moister
2. Significant overstory seed source retained (all areas within the net area to reforest are no greater than 20m from a wind-firm seed source).
3. Harvesting disturbance is significant and occurs after the summer growing season (late fall),
4. Occurrence of a distress cone crop year for Fdi. Note, heavy cone crop years in Fdi are infrequent, averaging once per ten years, and are also unpredictable. Therefore, harvesting cannot be timed or planned to coincide with a large cone crop year.

Harvesting should be planned to increase the potential for natural regeneration. This may help with stocking and reduce planting costs. Harvesting should retain as much suitable advanced regeneration as possible to aid in stocking.

Site visit summary

Natural regeneration was viewed in the field visits. Please refer to Appendix 2 – Site Reviews

This regime was not noted to succeed on any of the sites visited. One unit that appears to have promise, #13, was harvested in the winter of 2018/2019 and sufficient seed sources were left throughout the opening to provide shade for planted trees and act as a seed source. The fall of 2018 was one of the infrequent large Fdi cone crop years. The combination of a thoroughly disturbed site at the same time a significant natural seed source was available created the circumstances allowing the seed to regenerate naturally. This unit was originally planned for an MSP and planting regime, but natural germination was noted throughout by the licensee. This is in progress and they will monitor this site to see if the germinates can overcome the grass competition that is expected to firmly establish in 2020.

No other sites visited had significant ingression of natural regeneration. Other sites in the same situation as unit 13 are expected to have similar early success but would be equally at risk from future drought events.

6 Mechanical Site Preparation

Please refer to Fundamentals of Mechanical Site Preparation FRDA Report 178.

Mechanical site preparation is the main tool for managing vegetation and has the greatest influence for drought mortality.

Pinegrass was identified as the main competing species to address as it had the greatest ability to capture moisture from the soil. Conversations with the Regional Soils Ecologist indicate pinegrass had the ability to pump water from the soil longer into the summer, after the period where conifer seedlings need to shut their stomata and harden off. As pinegrass presence is increased, spring soil moisture is reduced quicker and total soil moisture is lower at the middle of the summer dry period.

On any site, increased disturbance reduces vegetation competition and will increase the period of time where spring moisture conditions are suitable for seedling establishment. The intensity of disturbance required to allow conifer seedlings the time needed to survive planting shock increases as the drought risk rating increases.

Sites that are naturally extremely dry, such as the IDFxh, should have the most aggressive mechanical site preparation such as a very large vertical and horizontal displacement of plantable spots from anticipated pinegrass. Examples of aggressive site preparation are: stumping, large raised screefs, and deep ripper plowing, where attention to treatment effectiveness is carefully observed. Silviculturists should review MSP work with the contractor as it progresses to ensure appropriate width and depth of displacement in case adjustments must be made in order to treat the site effectively. Refer to Regime section for details on site prep specs.

Sites that are naturally very dry, such as the IDFdk, should have aggressive mechanical site preparation where significant vertical and horizontal displacement is achieved and soil is decompacted. Examples might include the treatments identified as well as double trenching (or trenching that achieves the objective in one pass) throughout the treatment unit.

Sites in MSxk may only require disturbance adequate to create horizontal separation from pinegrass. Disc trenching is likely suitable and allows for planting of smaller stock. Where pinegrass has significant presence, dry conditions occur much earlier if the pinegrass is not addressed.

Regardless of the mechanical site preparation chosen, it's extremely important to manage treatment contractors closely and:

- Control the season of the treatment – best survival of seedlings is found where there has been no intervening seasons between MSP and planting to allow ingression of pinegrass. Example – October of the year prior to planting.
- Set up MSP contracts with the end results clearly identified and indicating where a second pass will be required – this should be measurable,
- Review the contractor's equipment on site. Ensure it's capable of achieving the desired results,
- Identify the situations where the contractor must make a second pass, travel slower, and/or put more down pressure on the equipment. Note, it is easier to identify a desired result than dictate a process a contractor must follow,
- Be present during the operator's first days of work as well as occasionally during the remainder of the treatments,
- Following treatment, review the results carefully to determine if the desired result has been achieved.

In the context of dry sites, this process identified is similar to what is required of a planting program in that they must be managed closely and a feedback loop must exist to ensure you achieve necessary disturbance. Control of the site preparation program is equally as important as a planting program.

Mechanical Site Preparation, above all other factors, was seen in the site visits to be the driving force of success or failure on extremely and very dry sites. Where site preparation was executed well, there was a much greater tendency for survival and where done poorly, a much greater tendency for mortality. While site preparation can be Mechanical Site Preparation (MSP), it can also be created by logging disturbance under the right timing and conditions.

It was noted during visits that site preparation had a time limit of effectiveness. Treatments completed in the spring or earlier were significantly less effective than treatments completed the fall prior to planting.

Successful site preparation is timed to provide the minimum opportunity for vegetation to reintroduce into the microsites prior to planting. Each site preparation treatment has a window of opportunity depending on the aggressiveness of treatments. Very large stump holes may take years to become occupied by competing vegetation, while lighter treatments may become occupied the following year. This will depend on the size and depth of the disturbance as well as the aggressiveness of the vegetation.

The most aggressive forms of disturbance witnessed in the site visits were burn piles and fully rehabilitated roads. These provided the greatest vegetation-free areas for the longest time periods.

Intensive burns – burn piles. This is an example of the most aggressive treatment available. Seedling survival was noted to be high on almost all burn pile sites visited, with healthy looking trees in these areas despite the remainder of the opening having close to 100% mortality. Broadcast burning is not a recommended treatment option as it would be unusual to have the required amount of fuel needed for an extremely aggressive burn that's required to kill the roots of pinegrass.

Road rehabilitation. This is the second example of the most aggressive treatment available. Survival was noted as high in all areas planted on fully rehabbed and decompacted roads, despite the remainder of the opening having close to 100% mortality.

These two treatments are not reasonable to consider but are included to show the effectiveness of increasing disturbance on seedling survival.

Best Management Practice: Target treatments for the fall prior to planting to minimize pinegrass ingression. Administer with as much attention as planting programs, including increased communication at the viewing, pre-work, and checking stages. Identify the level of disturbance required throughout the treatment area and indicate under what scenarios the area will need to be reworked until the acceptable level of treatment has been met throughout.

Photo 5. Trees planted into highly disturbed sites (examples are burn piles and road rehabilitation) had consistently the highest survival and best vigor.

Examples of aggressive site preparation in decreasing levels of aggressiveness are: stumping with additional raised screefs between stumps, excavator raised screefs, deep ripper plow, and double trenching. It was noted there are varying levels of effectiveness for each of these treatments that rely on both the operator fully understanding how to achieve the intended levels of disturbance, as well as operating a machine capable to do so.

6.1 Stumping

This treatment is primarily used where root disease is present and is done with an excavator. The removal of the stumps creates a large prepared hole previously occupied by the stump. The width and depth depends on the size of the stump removed, but this is usually the largest of the MSP treatment prepared spots. Being the largest, the size allows for the greatest separation from competing pinegrass and other vegetation as well as the potential to plant lower in the hole where spring moisture will take longer to drain out of the soil. These spots also provide some opportunity for shading to protect a planted seedling and are usually protected from cattle trampling. Stumps are usually placed inverted, back in the hole, but are sometimes grouped in piles outside of the holes. There a limited number of stumps available for treatment on each site - additional spot preparation is required to provide the necessary plantable spots per hectare.

Site visit summary

Stumping effectiveness was viewed in the field visits. Please refer to Appendix 2 – Site Reviews, units 2-3, 10, 12, 18- 19, 27-31, 40, 42, 46 and 47. There was a wide variability of success with this treatment that was directly related to other circumstances.

On units 2-3, the size and density of stump holes was sufficient to provide enough plantable spots. Good survival rates were observed inside the stump holes but almost full mortality of trees planted outside the prepared spots.

The strata that were stumped achieved close to target stocking. These sites were low elevation with high vegetation competition which are characteristics of extremely dry sites – they are in IDFmw3 which has more moisture but a higher intensity of vegetation response than IDFxh or IDFdk sites.

On units 10, 12, 18 and 19, there was lower density of stump holes and no supplemental mounds created. It is useful to know that for the majority of these units, MSP was completed immediately after logging and the site sat 1-2 growing seasons before being planted. These were all in the same vicinity on IDFxh2-IDFdk1 and are extremely dry sites with heavy vegetation competition from pinegrass. These sites had low survival following the first planting treatments. The surviving trees were in stump holes, with the bulk in the most shaded spot available. All of the trees planted outside of the stump holes died as well as approximately half of the trees in the stump holes

The failures of these sites is likely due to a combination of not creating sufficient plantable spots and a timing disconnect between MSP and planting. The pinegrass came in very dense and quickly because the units sat 1-2 growing seasons after site preparation and before planting. The original site prep will need to be redone prior to next planting as it's now unusable for a second treatment. MSP treatment should be scheduled the fall prior to planting to allow seedlings a chance to establish within the longest competition-free conditions possible.

Unit 27 had almost full survival of planted trees. This site was logged in 2011-06, Stumped in 2011-10, and planted in 2012-05. While this site was not mounded outside of the stump holes, the planting was close enough to the logging date and the logging disturbance was enough to provide residual site preparation for those trees planted outside of the stump holes. The MSP treatment was conducted in the fall prior to planting allowing limited to no time for vegetation to establish in the plantable spots.

Photo 6. Stumped spot preparation.

6.2 Excavator Raised Screefs

This treatment is one of the more costly because it's done with an excavator and is slower than tracked or skidder prime movers. The size, depth and density of the plantable spots can be closely defined and achieved. Light screefs (not raised) are only recommended for sites that are not considered dry sites but have elevated levels of vegetation competition. Deeper raised screefs are recommended as drought risk increases for a site. On extremely dry sites or sites with extreme vegetation, larger raised screefs are more effective at decompacting the soil and creating shaded microsites for seedlings.

Excavator raised screefs should be a preferred regime on dry sites where deep ripping is not possible for the entire net area due to the presence of significant slopes, slash or coarse fragments.

Site visit summary

Excavator raised screef effectiveness was viewed in the field visits. Please refer to Appendix 2 – Site Reviews, unit 20, 44, were treated exclusively with raised screefs.

Most of the excavator raised screefs noted in this review were supplemental to stumping treatments as the excavator was present on site.

Unit 20 (IDFdk1) was treated with large raised screefs after the site had become seriously overgrown with vegetation following a failed raw planting. The unit was in progress and had not been replanted at the time of this report so success could not yet be evaluated. The treatment was chosen as the only MSP capable of the extreme levels of disturbance felt necessary at this late stage.

Units 44 (IDFdk1) was excavator treated with moderate-size raised screefs and the planting treatment was successful. Most of the prepared spots had significant depth and length to provide a large spot free from competing vegetation. Where there were lighter intensity screefs, the crop trees showed poorer vigor.

Photo 7. Excavator used for stumping and raised screefs. Photo provided by Jillian Schochter

Photo 8. Stump holes and Raised screef. Significant disturbance, decompaction, and opportunities to plant in shaded microsite. Photo provided by Jillian Schochter.

6.3 Ripper Plow

Ripper plows are essentially modified ripper teeth on the back of a crawler tractor. The most common plow design is a double moldboard type with replaceable cutting edges, which attaches to the ripper shank of the crawler tractor. The ripper tooth digs into the soil, while the plow attachment displaces soil on either side. (FRDA Report 178).

This treatment is effective in creating planting microsites that are below the mineral soil horizon. It is suitable for extremely dry and very dry conditions. Rocky ground can reduce effectiveness of this treatment.

Like other MSP treatments, ripper plowing can have varying levels of disturbance. Where drought impacts are anticipated, silviculturists should opt for the largest disturbance available.

While ripper plowing is an aggressive site prep, the treatment must still be monitored to ensure the required aggressiveness is met throughout the work area.

Site visit summary

Ripper plow effectiveness was viewed in the field visits. Please refer to Appendix 2 – Site Reviews, units 1, 11, 25, and 26.

Unit 1 is the driest site reviewed and offered some of the greatest insights for this paper. This was IDFxh2, burned and salvaged in 2004, MSP in 2016, planted in 2017 to complete failure, and replanted in 2019. This site was allowed to fully establish to pinegrass, where there was no shade breaks. On the flattest mesic section, the machine disturbances were mostly oriented east/west and the planted trees were scattered on all aspects of the disturbed profile.

On the mesic site, only those furrows oriented east-west and planted on the north facing aspects had consistent survival of both Fdi and Py, where Py consistently looked better. Trees planted at the bottom of the furrows fared poorer with significant mortality of Fdi and poorer health of Py. The reason appears to be more exposure to the sun at the bottom of the furrows as opposed to more shaded locations. Trees planted on the south facing slopes of the furrows had full mortality of Fdi and significant mortality of Py. Furrows oriented north-south had considerably higher mortality due to much less incidence of north facing slopes of furrows and greater exposure to the sun during the hottest time of day. Where furrows were shallower, mortality increased significantly across all orientations.

On the strata that had consistent shade cover from ceanothus, there was considerably better survival and vigor of the planted trees – this amplifies the observation from the mesic strata that incremental additions of shading and protection from the afternoon sun led to greater survival and vigor of the planted Fdi and Py.

Very aggressive raised screefs would have provided the best opportunities on this site and allowed for directing planters to pick the most shaded positions for all planted trees.

Units 11, 25, and 26 were all on IDFdk1 which are very dry sites but not extreme dry sites.

Unit 11 was on a subhygric site series which is slightly moister than mesic. This treatment had excellent survival of the planted trees. Double trenching may have provided the same results because of the increased moisture of the site. The licensee likely chose this option as they had very high mortality rates on IDF mesic and submesic sites in the vicinity of this unit. The timing of all treatments on this unit were flawless, with late fall site prep the year prior to early spring planting.

Unit 25 provided similar lessons to some of the disc trenching successes and failures.

Where there was lower rock content, the ripper treatment created a significant and impressive disturbance where the trees appear to have survived as per plan. Where higher rock content exists (moderate CF %), the ripper plow was less effective and there is significant mortality. The reasons for the mortality in this second stratum is likely threefold: accelerated draining of moisture following the snow-free period in May, insufficient protection from pinegrass competition, and insufficient protection from moderate cattle disturbance. It was likely not possible to pre-stratify this opening based on coarse fragments prior to the treatment as the rock was underground and not identified until the contractor began working. In order for treatment to be successful, effectiveness of site prep must be evaluated by both MSP contractor and silviculturist and adjusted to ensure target disturbance is achieved.

Unit 26 provides marked lessons about the success of different treatment options. This opening was split into three sections: one was plowed at the same time another section was lightly trenched and direct seeded. While the direct seeding area failed, it also showed that the lighter site prep disappeared quickly in the dense pinegrass – this treatment could not be used for any replanting treatments. The ripper plowed section had moderate survival even in the worst of the 2017 drought year. The third section was plowed at a later date and planted in 2019 to full survival in a very good moisture year. The lessons from this site are that ripper plowing is aggressive enough to provide adequate survival even in an extreme drought year.

Photo 9. Ripper plow. Photo provided by Mike Madill

Photo 10. Example of ripper plow furrow. Photo provided by Mike Madill

6.4 Disc Trencher

Disc trenching offers varying levels of disturbance that depends on many factors including: prime mover (cat versus skidder), slash abatement, down pressure, and the number of passes. Where drought impacts are anticipated, silviculturists should opt for the largest disturbance available.

Options available to silviculturists to achieve greater disc trenching disturbance are:

- Angling the discs so they get more bite and vertical disturbance into the soil providing lower planting microsites.
- Setting expectation with contractor for additional blade work at the front of the trencher to orient slash and provide better disturbance with the discs.
- Paying close attention to the condition and quality of the trencher discs' teeth.
- Requiring that operators travel slower and provide more down pressure where adequate treatment is not being achieved.
- Double trenching where other adjustments are not working.
- Choosing another treatment method such as excavator raised screefing to treat areas too steep for trenching.

Disc trenching works on relatively gentle slopes. Sites where slopes are too steep for effective disc trenching must be identified at the site planning and post-harvest assessment stages so a precise and effective regime of treatments can be applied throughout the entire area to reforest. While a cat pulled trencher may work, choosing excavator raised screefs may be required to prepare those sites effectively.

Site visit summary

Disc trenching effectiveness was viewed in the field visits. Please refer to Appendix 2 – Site Reviews, units with good success were 9, trenched half of 24, 37, half of 38, and 50. Units with poor success were 6-8, 14-15, 24, 30, 35-39, and 43.

This treatment was noted to have varying amounts of success in direct relation to the aggressiveness of treatment.

Successful reforestation using disc trenching was noted on units 9, trenched half of 24, 37, half of 38, and 50. It is important to note the distinction between why these sites succeeded while other disc trenching sites failed. In every instance, these successful sites were MSP treated in the fall prior to early season planting and the treatment appeared to achieve the level of disturbance required. In all cases, there were areas within where MSP treatment had less of an impact due to compact flatter ground, more slash, more coarse fragments, frozen ground, or steeper slopes. In each instance where this was noted, the survival of the planted seedlings was much poorer. More precision is needed to make MSP treatment successful and ensure the right target disturbance is achieved everywhere. This may take meticulous effort in setting up MSP contracts to ensure the correct prime mover is used and equipment operators are able to identify where achieving the target disturbance will be more difficult so they can: go slower, achieve sufficient slash parting, achieve sufficient down pressure, and take a second pass if required to achieve necessary disturbance.

Unit 38 had half of the first planting treatment died.. This area was a harsher site - steeper, rockier and consequently had poor MSP treatment with less disturbance. It was clear that the half of the opening which had sufficient disturbance succeeded while the half with less disturbance failed. It is likely that a cat prime mover or excavator was required to achieve the disturbance necessary on the harsher, steeper sites. The equipment chosen for this opening wasn't effective for all of the site.

Units 6-8, 14-15, 24, 30, 35-39, and 43 all had plantation failures following disc trenching and each of them had a weak trenching treatment over the majority of sites. However, there are other reasons that this treatment may have failed. Units 15, 36, 37, 38 and 39 were all trenched in the winter when there was likely frozen ground throughout causing problems in penetrating the soil properly to achieve sufficient disturbance. Unit 43 is suspected to have seed or planting issues driving plantation failure. Units 30 and 35 were site prepped one full season prior to planting, allowing vegetation to ingress and created unnecessary pressure on the planted trees. These sites may have had successful planting treatments if the separate issues had been addressed.

Units 6, 7, 8, 14, and 15 were all extremely dry sites in IDFxh2. Units 6-8 were site prepped early in the spring prior to the planting treatment and this may have somewhat contributed to planting failure as it allowed one full growing season for vegetation to encroach. All of these extreme sites were on flat ground with moderate coarse fragments, where the majority of site prep was insufficient to provide adequate growing medium free from competition for moisture. The few surviving trees on each of these sites were found in locations where the trencher had turned back on itself or achieved a sufficiently profiled disturbance. These are large, exposed sites with flat soil and modestly rocky ground that did not lend itself to easy disc trenching.

After viewing all of these sites, it is clear that disc trenching is suitable on modestly dry sites where the machine and operator are able to achieve significant disturbance. The timing of this treatment is very important in order to achieve the best site prep with the least amount of time between treatment and planting. It is unclear whether sufficient disturbance can be created on the most extreme sites. These include IDFxh2 sites with medium coarse fragment %, and sites with steeper slopes.

There were units that had either discrete or dispersed areas where disc trenching was unlikely to work. These sites must be identified at site planning and post-harvest assessment stages so a correct regime of treatments can be applied that will work effectively throughout the entire area to reforest.

Photo 11. Disc trencher. Photo provided by Mike Madill

Photo 12. Example of good disturbance on single pass disc trenching. Photo provided by John Hopper

Photo 13. Example of poor disturbance on single pass disc trenching. Note the flat, compact soils which are very difficult to provide adequate disturbance. Photo provided by Clayton Franz

6.5 Raw Planting

Raw planting is planting without MSP. Logging disturbance has a finite window of effectiveness relative to the timing of harvesting. If harvesting occurs during a season where the yarding process can cause significant disturbance, and provided trees can be planted prior to any seasons of vegetation establishment, harvesting disturbance can act as sufficient site preparation. However, this is difficult to accomplish as harvesting activities are not managed by silviculturists and it can take up to two years to receive seedlings for planting.

Raw planting is not recommended on extremely dry or very dry sites, though situations may arise where raw planting is required such as when a site is too steep or inaccessible to site prep. In these cases the silviculturist must attempt raw planting and succeed on the first attempt due to the limited window of effective disturbance. Large stock (refer to Figure X stock sizes) is strongly recommended to reduce risk of plantation failure.

Raw effectiveness was viewed in the field visits. Please refer to Appendix 2 – Site Reviews. Successful raw planting was witnessed on units 23, 34, 41, 45 and 49.

It is important to note these units had additional conditions which allowed for success: units 41 and 45 used large 512A stock, unit 45 had been burnt by wildfire so had additional natural site prep, the portion of unit 34 that succeeded did not have any pinegrass and was in MSxk (not an extreme site), unit 49 was IDFdm1 without significant pinegrass at the time of planting. The only site visited that succeeded with raw planting on an extreme site was unit 23 IDFxh2-01 – this was logged in the summer of 2011 and planted in early spring of 2012.

It is likely that raw planting immediately after summer/fall logging does not occur more often because of two factors: timing of harvesting cannot be controlled by silviculturists and, it's difficult to get seedlings available on short notice. If a constant stream of suitable seedlings were available, it is likely that extremely dry sites harvested in the late summer and early fall would likely be raw planted more often.

Raw planting may be required in the most extreme circumstances and the silviculturist must succeed the first time. There will be areas that are too steep to get machines onto the ground to site prep. Examples where this was observed was units 1 and 3. In these openings it appears there was a failure to identify the most extreme sites both at the site planning stage and again at the post-harvest assessment. In the case of unit 3, no MSP treatment was possible on the steep grassy slope. This should have been identified and raw planted immediately with whatever stock was available as there was no other opportunity for success.

Photo 14. Large Fdi Stock size raw planted onto IDFxh2 site. Fire Salvage.

6.6 Drag Scarification

Drag scarification with or without direct seeding is not recommended on extremely dry or very dry sites, even in conjunction with planting – this method of disturbance is not sufficient for these sites.

Drag scarification was viewed in the field visits. Please refer to Appendix 2 – Site Reviews. Units 4, 7, 26, and 31 had trials for direct seeding of Py or Fdi.

In each of these areas there appeared to be no success on seeding trials. Anecdotal discussion from the licensees indicate the seeds did germinate fairly well but the drought years of 2017 and 2018 saw full mortality of these germinates.

The site preparation associated with the direct seeding was not sufficient for planting on these extreme sites and all planting attempted with this site prep had high mortality.

This treatment is considered a high risk, caries significant cost in MSP and does not appear to allow for successful first time planting or replanting using existing disturbance.

6.7 Mechanical Site Preparation - Summary

Where sites are not uniform and increased levels of drought risk are dispersed throughout, a treatment should be chosen that will achieve the required level of disturbance across the entire unit.

Where sites are not uniform and increased levels of drought risk are present in different areas of the unit, separate treatments should be chosen that will achieve the required level of disturbance throughout both areas.

In all instances the site preparation treatment should be completed the fall prior to planting and not earlier. This will avoid the disturbed sites becoming occupied by competing vegetation and allow for a less costly replant if the first planting treatment does not succeed. There is likely to be greater survival from the first planting treatment and greater residual disturbance from the MSP treatment.

Best Management Practice: Choose the appropriate MSP treatment for the drought risk level. The driest sites require the most aggressive site preparation.

Photo 15. Mechanical Site Prep that was completed in the spring, the year prior to planting. Vegetation has heavily ingressed and has reduced the effectiveness of the treatment.

Photos 16, 17, 18. Mechanical Site Prep examples from the same site. Seedling survival is related to MSP treatment effectiveness. 13-Good treatment good survival. 14- Rockier ground more difficult to treat. 15-poor treatment poor survival.

7 Shade

Planted seedlings have greater chance of survival in the presence of shade on all sites in the southern interior. Shade is essential on extremely dry sites and important on very dry sites. In all other dry sites shade is beneficial but not essential to seedling survival.

Tools to increase shading opportunities are:

- Mature retention, in clumps or scattered. The greater amount of retention relates directly to survival until the point where shade becomes detrimental. Retention levels should only be the amount necessary to give good survival of seedlings as too much retention will reduce growth of the next stand.
- Where trees are planted in excavator raised screefs or spots, north aspects of the site prep should be chosen first.
- Where shaded aspects of site prep are not available, choose the least exposed aspect. Example, on south facing raised screefs, plant below the mineral soil horizon tucked against the west side of the hole to provide some shading.
- Where obstacles are present such as stumps, downed logs, or brush - these spots should be targeted first within the prepared ground.
- Red rot does not provide shade to the planted tree, but does provide a moisture cap for soil. Planting through red rot into the mineral soil horizon provides shading to the soil and protects the root collar of planted seedlings. Where raw planting is incorporated into any regime, planting through or immediately adjacent to red rot is recommended. This has an added benefit of protection from pinegrass as pinegrass will not grow into red rot. Note, red rot is not a suitable growing medium and seedling roots should be planted fully within the mineral soil horizon.

Photo 19. Example retention to provide shade and a seed source. IDFdk2

Photo 20. Seedling placement through red rot, protection from pinegrass.

Photo 21. Seedling planted in prepared ground next to shaded obstacle.

8 Planting Considerations

8.1 How seedlings grow

The mechanics of how spring seedlings grow should be reviewed by all silviculturists before they identify sites and implement treatment regimes. Seedlings need to progress through a number of stages prior to full establishment.

The first challenge is overcoming planting shock by growing roots. (Grossnickle 2011) In this stage the seedling connects to the surrounding planting medium which is strongly correlated to the site attributes, site preparation practices, vegetation management, operational silviculture decisions, planting stock choices and nursery cultural practices. For dry sites, it's critical the seedling establish roots quickly before it exhausts its internal moisture and carbohydrate supply. Larger plug sizes are helpful when attempting to grow the first set of roots.

The second challenge is overcoming summer drought period. This is strongly reliant on the speed and timing of how effectively and early the seedling has overcome planting shock and the seedling must have grown roots and closed leaf stomata. "Seedlings can be exposed to a wide range of environmental conditions during the establishment phase, some of which may be extreme enough to exceed their ability to physiologically tolerate environmental stress." (Grossnickle 2018). This is the period where root:shoot ratios become important and where a well-balanced tree is important for survival. Root to shoot ratio is defined by the Oxford Dictionary as "The ratio of the amount of plant tissues that have supportive functions to the amount of those that have growth functions." Another way to state this is that the root:shoot ratio is the ratio of root mass relative to the mass of stem and foliage.

These first two stages are important for all the silviculture decisions made on the site: species choices, stock size, nursery practices, MSP choices, and planting decisions. While it's extremely important to identify issues surrounding initial establishment, species and choices which make for easy establishment may not be the best choices for long term resilience on the site and the silviculturist must not lose sight of the longer term objectives for forest management

8.2 Species selection

Seedlings have different levels of drought tolerance by species at different times in their development.

Fdi appears to have the most difficulty in overcoming planting shock, particularly in extremely dry or very dry sites. Once seedlings have fully established the relative resiliency of species to survive shocks such as drought events is quite different – established Fdi is much more resistant to periodic drought than Pli. Because of this, Fdi will be the most desirable species to occupy extremely dry and very dry sites as these species can better withstand periodic drought than other species.

While it may be easier to establish pine species initially, this does not create a stand that is resilient to future drought events. It is also important to note that establishing a stand of Pli where Fdi was harvested is species conversion and this is poor forest management practice.

There are circumstances where reforestation with high percentages of Fdi may not be possible within the short window of current forest management. In these instances, increasing the percentage mix of species more likely to establish would be preferable to creating low stocking or open range situations. The best strategy to deal with these areas is to avoid them during harvesting or to significantly increase retention of mature and younger conifers.

Site visit summary

Species selection was viewed in the field visits. Please refer to Appendix 2 – Site Reviews.

Over the majority of sites visited, the order of resilience and ability to survive appears to be Py > Pli > Lw > Fdi where Fdi is the species that has the most difficulty overcoming planting shock, particularly in extremely dry or dry sites.

This does not correlate with the longer term resilience and ability to thrive on dry sites which is Fdi and Py > Pli and Lw. While it may be easier to establish pine species at the beginning, this does not create a stand that is resilient to future drought events.

There are circumstances where reforestation with high percentages of Fdi may not be possible within the short window of current forest management.

One example of species adjustment is Unit 1 – this is a very low elevation, extremely dry site. There is a short pitch which is xeric, south facing, steep, has sandy soil and no retention to provide shade for any planted trees. This stratum is quite different from the surrounding area to reforest. This particular example is from a fire killed salvage. Small sections such as this can occur either as discrete strata or as small dispersed strata. The best practice for this relatively small stratum would have been to avoid harvesting and taking on regeneration obligations. A second option would be to retain significant trees for shading purposes and to grow volume on the retained stems. Both of these solutions require identifying the xeric site at the pre-harvest stage, prior to site plan signoff and logging plan development. Often, discrete strata such as this are harvested and can only be properly actioned after a post-harvest assessment identifies the problem areas. In these cases the only palatable option is shifting to much higher percentages of a species that can survive the initial planting shock, such as Py.

Another example of this is unit 14. This site is mostly mesic with dispersed steeper-rocky sections which could have been identified in the site plan as challenging to reforest. While it is unlikely these could be separated out as distinct SUs, more problematic areas can be identified for further emphasis. These areas could have also been identified at the post-harvest assessment and much higher levels of Py planted on the worst of the areas. Even though Fdi was harvested throughout, there would have been reason to plant very high levels of Py in small 20m x20m sections where there was extremely high drought mortality risk.

The alternative in these cases would be to accept the area as grassland or as non-productive. In this example, species adjustment is required to reforest a small area with a species that will survive planting shock where a more desirable species would not survive. While the best strategy is to avoid harvesting small areas of extreme risk, there are operational and other reasons they are included in harvest plans.

In many areas it is common practice to plant Pli or Py on burn piles or burnt landings. Where Fdi was a significant component of the previous stand, Fdi should be targeted for burn piles and landings as there was considerable success with Fdi in these locations.

8.3 Seed selection: Progeny and class

Until recently the system of seed transfer (from seed collection source to seed areas of use) was governed by the Geographic Based Seed Transfer (GBST) as identified in the Chief Forester's Standard for Seed Use. A new system was created in 2017 called Climate Based Seed Transfer (CBST) and has since been amended into the Chief Forester's Standard for Seed Use.

There are two classes of seed determined by their source. Seed collected from natural parent trees found in the forest is B-class seed. Seed collected from tested parent trees at seed orchards is called A-class seed.

Regardless of GBST or CBST, the silviculture practitioner is legally required, as outlined in the Chief Forester's Standard for Seed Use, to use seed that has a genetic worth of 5% or greater when owned or available. Genetic Worth (GW) is defined in the Chief Forster's Standard for Seed Use as "a measure of a seedlot's genetic worth with respect to a specific trait. The trait is generally volume growth (G), but GW values also exist for wood density (D) and pest resistance (R)."

Similar to the discussion about stock type, seedlot type selection may influence the root:shoot ratios of the planted stock. The theory is that stock with larger root plugs relative to the green shoots will have lighter moisture demands relative to the ability to access ground moisture. This is important where moisture is limiting.

In the Thompson Okanagan Region, for the majority of area described in this study, Fdi-A-class stock was not available for planting and Py had limited A-class seed available for planting. All Fdi and Py noted in each of the units were planted with seed collected from natural stands (B-class). With the advent of Climate Based Seed Transfer, Fdi and Py A-class seed may be available for planting in the Thompson Okanagan in the future.

In the Thompson Okanagan Region, for Pli, A-class seed is widely owned or available and required for use by legislation. For the extremely dry sites, Pli is not a preferred or acceptable species and would not be prescribed for planting. In the dry sites (IDFdk as well as MSxk) Pli is a preferred species. Where Fdi was the primary species harvested, it is strongly discouraged to convert to another leading species through planting treatments. In one operating area visited, there were sites planted with B-class Pli and other sites planted with A-class Pli. There were apparent differences in survival – B-class performing better than A-class, however, the sites where B-class succeeded were higher in elevation and can be described as less affected by dry conditions than the lower elevation sites where the A-class seed was planted. There are numerous other variables that could account for these differences in success such as seedlots, nursery used, root:shoot ratio, and seedling placement within the nursery.

Further research is required to prove a link between seed origin and drought tolerance.

If further research can show a correlation for a significant survival advantage on drought prone sites of planting B-class seed, the legislation is worded such that would allow a strongly argued rationale for planting B-class seed when A-class seed is available. Please note that the legislative wording appears to be tailored for planting A-class that is specifically cultured for drought tolerance over an A-class that is specifically cultured for improved growth.

"…a person must select a registered lot, or portion of a registered lot, that, at the time of selection, has a genetic worth of 5 per cent or greater for the species and trait that best achieves the forest management objectives for the stand…" (Chief Forester's Standards for Seed Use S. 7.3).

In the absence of research indicating trends between seed origin and drought tolerance, B-class seedlots should be chosen from drier origins than the target planting site.

Further research and development of A-class seedlings that maximize drought tolerance is required.

Research trials to review the survival differences between seed origin and seed class are recommended.

8.4 Seed selection: Germination percentage

A very important consideration when choosing seed for dry sites is the germination percentage of the seedlot. Germination percentage of each seedlot is tested periodically by the province – this sampling and testing gives a good estimate of the number of seeds that will germinate and helps provide direction to nurseries about how many seeds per cavity they should place in each plug in order to fulfil the requested amount of trees.

For seedlots with very low germination percentages, the likelihood is high that none of the seeds placed in a styroblock cavity will germinate. During the growing process, nursery personnel weed the cavities in which more than one seedling has germinated, and transplant some of the surplus seedlings to vacant cavities. Those transplanted seedlings have a disadvantage relative to the initially successful seedlings - they undergo transplant shock, have delayed growth and may not completely fill the cavity with roots.

For drought prone sites, it is recommended to avoid seedlots with germination percentages below 85% to reduce the probability of transplant shock in the nursery.

Photo 22. Plug Styroblocks in nursery during weeding. Photo provided by John Hopper.

Photo 23. Plug Styroblocks in nursery during weeding. Note the empty cavity and the cavities with more than one seedling. Where cavities are empty seedlings are transplanted from cavities with more than one seedling Photo provided by John Hopper.

8.5 Stock selection: container size and type

Nurseries need to create seedlings with plant attributes that allow for the best chance of success. Desirable levels of these plant attributes can increase the speed with which seedlings can overcome planting stress and become coupled to the forest restoration site (Grossnickle 2011).

8.5.1 STOCK SIZE

Similar to the discussion about seed type – container size selection may influence the root:shoot ratios of the planted stock. Seedlings grown in larger container cavities will have larger roots.

Discussions with nursery services as well as nursery contractors indicate that root and shoot size typically trend together – larger root cavities will grow larger shoots. There are no clear trends indicating which factors and practices impact differing root to shoot ratios between stock, seedlots, request keys and nurseries. Differences may be more related to varying nursery cultural practices, though practitioners also observed shifting ratios between greenhouses as well as where seedlings were positioned within greenhouses.

In field evaluations it's clear that larger stock sizes have better survival rates than smaller sizes on drought prone sites. This is likely caused by the improved capability of a larger root plug to produce new roots once it's planted in field conditions. Greater focus should be placed on the ability to grow new roots in out-planting trials at nurseries where seedlings are targeted for extremely dry or very dry sites.

	Large	Medium	Small
Fdi	512A	412A	412B
Py	412A	410	310
Pli	412A	410	310

Figure 6 **Example stock size by species that are planted on dry sites. Source BCTS recommended seedling stock type selection. Interior/Spring**

8.6 Stock size by species

Larger stock is recommended to mitigate risk of drought mortality. Large stock sizes were observed to perform the best and recommended where mechanical site preparation is not possible or planned or in replant situations where MSP will not be revisited.

Medium sized stock is recommended to be paired with appropriate mechanical site preparation when planting in extremely dry or very dry sites.

Smaller stock may be planted in normally dry sites when paired with appropriate mechanical site preparation. Small stock is not recommended for extremely or very dry sites.

Be aware that there is a considerable cost difference between large, medium and small stock size. The most effective tool to reforest these sites is mechanical site preparation and stock size should only be considered after appropriate mechanical site preparation type is chosen. Using large stock type appears to be a useful tool where mechanical site preparation treatments are not practicable. Large stock size is more costly than medium stock size and will also increase planting costs – because of this it may be more cost effective to plant with medium stock sizes and increase mechanical site preparation aggressiveness.

Best Management Practice: In situations where the preferred regime cannot be followed, choose the largest available stock size to have the best chance of success.

Site visit summary

Stock size was viewed in the field visits. Please refer to Appendix 2 – Site Reviews.

There was very little variation in stock size noted amongst most of the units planted on these dry sites.

For Fdi, the range was mostly 412B and 412A with some 512A planted. There were no units where stock size smaller than Fdi 412B was planted, however, there are plans to trial very small Fdi seedlings (310B) in the future in limited amounts. There were no units where 412A and 412B were available for a side by side comparison.

For Py, the range was mostly 412A and 410. There were no side by side trials that allow for comparison of stock type.

For Pli, the range was mostly 410 with some 412B and 309 stock. There were no side by side trials that allow for comparison of stock type.

For Lw, there was a range of stock types, with 410, 411B, and 412A planted across units. There were no side by side trials that allow for comparison of stock type.

There were two sets of units where the largest stock size of Fdi and Py were planted.

Units 42-45 as well as 47 were planted with 512A Fdi and these trees appeared to be doing much better than any other seedlings planted on all sites viewed. There are further considerations from each of these sites that are worth discussing in conjunction with the success or failure of this large stock.

Unit 45 was raw planted with 512A Fdi and 412A Py. It is an extremely dry site and has significant risk due to cattle. It burned in 2016, was salvaged logged in early spring 2017 and planted with large stock in early 2018. The burn piles showed the best results of any units viewed. The remainder of opening had variable results. Where there was increased logging disturbance or additional shade, the large stock was doing acceptably well and the trees seem like they will continue to do well in the future. Where there was less logging disturbance there are voids with no surviving trees. This site is expected to meet stocking requirements. The variables that increase survival are heavy disturbance from logging and wildfire, the large stock size, and the prompt reforestation. The variables that decrease survival are lack of MSP. This site was committed to reforestation without MSP and the large stocks size was an attempt to achieve satisfactory results.

Units 42, 44, and 47 had very good stumping, or excavator raised screefs treatments and the success was exceptionally good.

Unit 41 was partial cut with excellent shading throughout and the success was exceptionally good.

The exception to the success of the large stock type was unit 43. Factors other than stock size appear to be working on this site. The reason for significant mortality is suspected to be poor stock handling by planters. This site was disc trenched, however the mortality did not align with any other issue such as size of MSP, shading, or other microsite nuances.

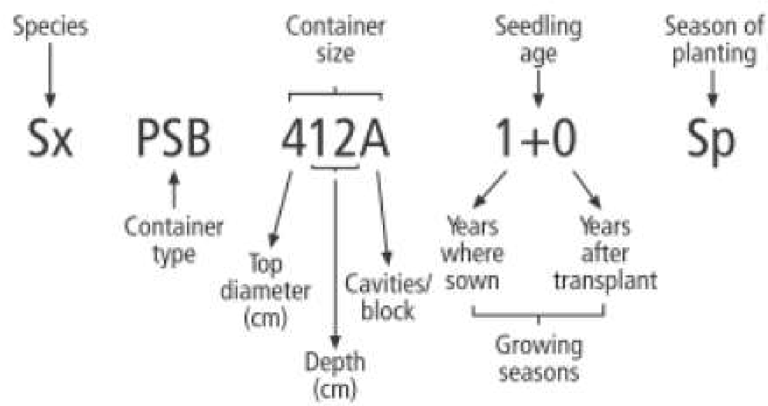

Figure 7 Example of stock size nomenclature. Provincial seedling stock type selection and ordering Guidelines. 1998. Province of British Columbia

8.6.1 CONTAINER TYPE

The majority of stock type grown on dry sites for the Thompson Okanagan are 1+0 PSB. This is a spring stock sown in styroblocks to create plugs, boxed in bundles of 10-20 and frozen in one year, and then thawed and planted the following year.

An alternative to 1+0 PSB is 1+0 PSI (Plug – Styroblock, Individually Wrapped) where the same process is followed with the exception that the seedling plugs are individually wrapped prior to boxing and freezing. This stock type is intended to be planted frozen and does not need to be thawed prior to planting. Individually wrapped trees will improve the ability to get trees into the ground on the first openings in a planting program as the thawing process can take up to two to three weeks. After the first few blocks of a program are finished, PSB stock is acceptable. There are cost considerations for PSI stock: it takes more effort to wrap than PSB, therefore nursery costs are slightly higher; poorly wrapped bundles can cause planters difficulties separating the trees, extensive bottom roots may freeze together causing increased planting effort; and increased wrappers and garbage need to be addressed.

Site visit summary

Most seedlings planted on these dry sites were plug-styroblock (PSB) container type. One licensee uses exclusively frozen plugs-styroblock individually wrapped (PSI) container type (Sites 2 through 9). Another licensee uses this stock type in order to achieve the earliest start date possible once their most at-risk sites are snow-free and free of frozen ground (Sites 28 through 31). Frozen, individually wrapped plugs can be pulled from cold storage and planted on a moment's notice or placed back in cold storage without issue if conditions deteriorate as is common on the first days of planting. This is as opposed to PSB trees which must be thawed in a process that can last as long as three weeks which delays startup until the first units are ready to plant.

It's important to note that high levels of mortality were observed where PSI stock was used, however, these are the most at-risk sites and other factors such as MSP and cattle are likely to have played a larger role than stock type.

It is recommended to further test survival of PSI stock relative to PSB stock.

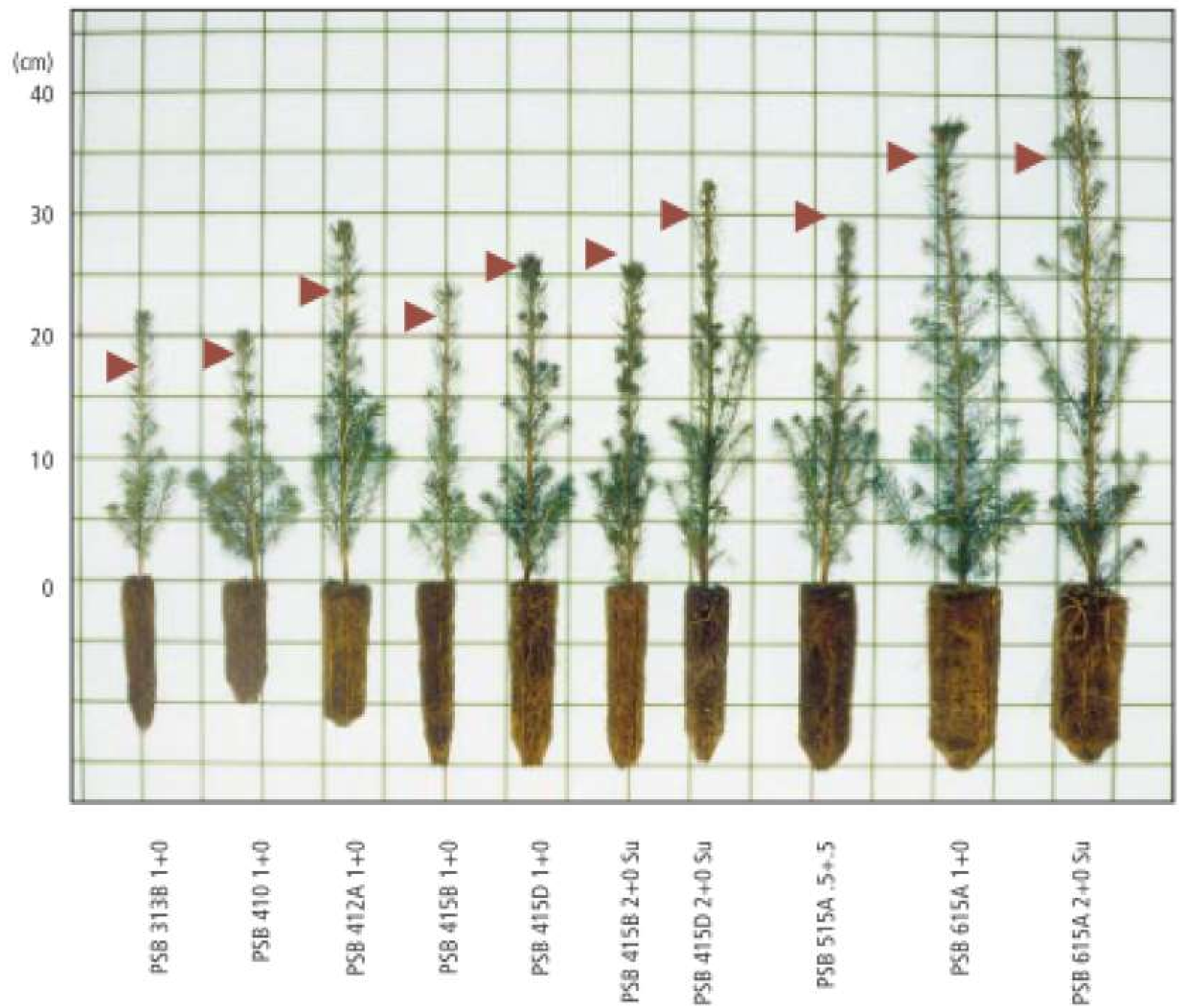

Photo 24. Stock size examples for Sx. Provincial seedling stock type selection and ordering guidelines. 1998. Province of British Columbia

8.7 Planting season stock type

8.7.1 SPRING PLANTING STOCK TYPE

The vast majority of planting that occurs on dry sites is scheduled as early as possible to maximize the spring moisture window. These trees are requested in the fall (year 1), sown in the spring, hardened off for the fall (year 2), and cold stored as frozen trees over the winter. Trees are then planted the following spring (year 3).

8.7.2 SUMMER PLANTING STOCK TYPE

Summer planting should be avoided on all dry sites because summer stock isn't available in early spring. Summer trees are requested in the fall (year 1), sown in late winter in greenhouses, hardened off for late spring (year 2), and lifted and planted usually after July.

8.7.3 FALL PLANTING STOCK TYPE

Fall planting has been suggested as a potential solution to get seedlings growing quicker. Fall seedlings are similar to summer trees but they are hardened off to be available for planting in early September. Fall planting is not a recommended treatment on extremely dry or very dry sites. A quick review of soil moisture trends for dry sites shows that soil moisture is still at the lowest point in a given year into October, and even significant rain events may not change the overall soil moisture until the season has become unsuitable for planting, with temperatures too low for the seedling to grow enough roots and sustain itself through the winter.

Fall planting may be a useful strategy on sites that are not obviously prone to drought. Some sites not of immediate concern may act like extremely dry or very dry sites if circumstances require planting outside the normal planting window. One example is sites that occur beyond an access choke point, such as avalanche slides or high mountain passes that do not allow planting to occur within the preferred timing window. Sites such as these would act as extremely dry sites if planted in July or August. A less dramatic example is where a licensee anticipates they cannot get all the trees planted in the preferred timing window due to lack of access to tree planters. If this circumstance is anticipated, fall planting can alleviate pressure from spring planting programs.

More research is required to determine if fall planting can be added to the suite of treatments available to silviculturists on dry sites.

8.8 Nursery Considerations

Once seedlots, container size and type, and season are chosen and summarized in Request Key, seedlings are grown using nursery cultural practices intended to grow the best and most balanced seedling within recognized morphological tolerances (which include height and stem caliper). A Request Key is a unique identifier that can be used to manage the growing of a seedling at a nursery. It can be used to review the choices made in a seedling request including: the sowing year, organizational unit, species, seedlot, container size, seedling age, planting season and count number.

Prior to the Province releasing the seed for use, Root Growth Capacity (RGC) testing is conducted on a small sample of each request key to rate the seedlings on a scale of 0-3 where 0 = now new roots, 1 = all seedlings have roots less than 10mm, 2 = between 1-100% of seedlings have root growth greater than 10mm, and 4 = all seedlings have root growth greater than 10mm. Where the RGC tests rate 0-1 they undergo further testing and may not be released for planting. In the province of BC, most years have 98% success and most of the request keys are released for use (Personal conversations Rasmussen. A.2019).

Further testing is warranted to ensure that seedlings targeted for extremely dry or very dry sites can grow roots under stressful field conditions. The form and scope of testing should be reviewed by licensees and the Province in order to better understand and help improve nursery cultural practices for seedlings planned for extremely dry sites. Seedlings with improved drought stress tolerances could have improved success in overcoming planting shock. While the effect of improving drought tolerances only lasts until the first bud flush, this may be enough to help seedlings connect to their new environment, grow roots and shut down in preparation to withstand the summer dry period.

More research is needed to advance nursery cultural practices in order to improve initial drought tolerance for seedlings targeted for dry sites, including:

- Drought acclimatization of seedlings,
- Stock size recommendations,
- Top pruning recommendations,
- Improved root growth testing and testing under more stressful conditions.
- Recommended practices and trials for a feedback loop between silviculturists and nurseries for seedlings planted on site

Increased effort is needed to identify and track which seedlings are targeted for drought prone sites. This could simply be creating a new field in SPAR for silviculturists to identify the request keys requiring different treatment. Silviculturists should increase their communication with nurseries to help with solutions for these request keys. Some examples of conversations silviculturists could be having with nurseries could be regarding plug size, stress testing, top pruning, increased root-testing, and creating a feedback mechanism for silviculturists to communicate their findings from the field.

9 Planting program preparation

Prompt reforestation of dry sites is critical to achieving successful plantations.

Following harvesting, a number of factors occur that make reforestation more challenging as time progresses:

- Pinegrass will increase in intensity, making it challenging to site prepare openings as the operator may not be able to see ahead of themselves to blade slash out of the way, and identify troublesome areas that need more attention. Where pinegrass is intense, disturbed ground fills in much more quickly with vegetation and the site prep becomes effective for a shorter window and precludes its use for replanting if required.
- As pinegrass increases in intensity, cattle pressure also increases. The first year following harvesting usually has low cattle intensity because there’s no food on site. However, cattle learn and will return to sites with good food sources.

- Access may degraded or removed. This impacts the ability to get machinery on site to adequately site prepare plantable spots. Degraded road systems will increase stress on trees when transported by truck or ATV.
- Some residuals will blow down, blocking access for MSP operators to effectively treat all areas, and to planters delivering trees to portions of the openings.

As the time period between harvest and site preparation increases, the value of site preparation in creating a suitable vegetation-free condition decreases rapidly. Similarly, as the time period between site preparation and planting increases, the value of the site preparation in creating suitable vegetation-free conditions also decreases rapidly. Site preparation and planting must be timed together to occur at the earliest possible planting date with the least amount of time between site preparation and planting. Site preparation has its best value if completed in the fall prior to planting, in frozen ground free conditions.

Early sowing is critical to reforestation success on dry sites. Trees intended for extremely dry and very dry sites must be sown at the earliest opportunity. Waiting for harvesting to complete, or post-harvest assessments to fully identify all issues on site is not recommended. Many of the critical issues can be assumed prior to a post-harvest assessment. Discrepancies with the initial plan can often be addressed through adjustments, seedling sales, and MSP contracts.

Early planting is critical for reforestation success on extreme and very dry sites. In order to take advantage of the greatest amount of time where moisture is sufficient for seedlings to grow roots, set new branches and buds and then shut down in time for the summer drought, trees must planted as early in the growing season as possible.

On extremely dry or very dry sites, suggested strategies for planting as early as possible are:

- Reconnaissance of road system, by helicopter or snowmobile prior to planting season will help to time the first thaw request,
- Plow road systems if they will retain snow longer than the first openings in the planting program,
- Review satellite images from previous years to evaluate how blocks in that vicinity become snow-free. Websites are available which provide low resolution satellite images from previous years, by date. These can be reviewed to set a planting order which prioritizes sites that become snow-free earliest.
- Order PSI individually wrapped stock for the first few blocks to allow immediate planting once openings are identified as snow-free. An additional benefit is planters can start on openings only partially snow-free and avoid unnecessary stress on seedlings which, would otherwise have to sit thawed while waiting for the remainder of the opening to become snow-free.
- Design planting to occur when the majority of the area is snow-free, rather than waiting for the entire opening to become snow-free. It is critical not to waste any available soil moisture where possible (north/east slopes may be weeks later than south/west/flat areas to become snow-free).
- Order suitable seedlings ‘on spec’ in order to have a pipeline of seedlings available that allow prompt reforestation of sites or spots which cannot be mechanically site prepped, or where sufficient logging disturbance provides suitable growing medium prior to pinegrass ingression on site. Douglas-fir seedlings are easy to sell if required.

9.1 Planting contract implementation

Tree planting is the final treatment taken to reforest openings. Strong emphasis must be placed on planting expectations through a quality prework, planting prescriptions, and prompt feedback to the planting contractor. There are critical quality assurance components to address with the planters including microsite, shading, planting medium, site preparation location, natural depressions, minimum intertree distance, and quality elements like air pockets are very important. Delays or reworks should be avoided on dry sites.

Best Management Practice: **It is critical that planting programs begin as early as snow free and frost free conditions allow on extremely dry and very dry sites.**

In order to accomplish this, planting contract implementers must:

- Understand the order necessary to follow the snow-free conditions. Use tools or actively visit planting units.
- Control the order of blocks to match snow-free and frozen ground free conditions.
- Control the timing of thaw requests so the block order identified is followed.

Block order must not be left for planting contractors to decide as they may have other priorities that influence their recommended order. Planting contractors often start on a large planting unit in order to train new planters, address quality issues, and get into a rhythm as they ease into a contract. They often avoid replants and fill plants as these are complex, and added complexity is not desirable while in the busy, early stages of setting up camp and addressing the operational needs of a large number of new employees.

It's better to work with a planting contractor, understanding the immense pressures on their supervisors in the early stages of any planting contract. Working with the contractor to ease into their planting contract means being on site every day for the initial critical days or week - working with them on their understanding of how to plant trees, where, and how they will best survive. This includes providing leniency on payment issues while they work through seasonal growing pains. This give and take approach works best as all parties attempt to deliver the best quality product with maximum potential of success for seedlings in these critical environments.

9.2 Fertilization at the time of planting

There is no indication or correlation that fertilizing at the time of planting helps with initial survival of planted trees on dry sites. This is based on discussions with local licensee silviculture foresters and their experience through trials. Fertilizer packs may provide surviving trees necessary root structure to withstand future drought events once seedlings have fully established, though this will have to be confirmed with research trials.

10 Brushing

Vegetation control for woody species should be avoided on dry sites. Most species with the exception of pinegrass and snowberry will provide some level of shade protection which overrides most concerns related to competition for moisture.

11 Regime based silviculture

This is regime based silviculture. These regimes are intended to limit need for re-planting. If the first planting treatment does not succeed, the risk rating will need to be re-evaluated. Do not attempt a replant without thorough review of the previous plantation failure. Identify what caused the failure, and determine if the site preparation will remain adequate at the time of proposed re-planting.

Best Management Practice: **All aspects of the identified regime must be implemented to allow it to work as intended. If an entire regime is not possible to implement, the drought risk will need to be re-evaluated.**

11.1 Extremely Dry Site Treatment Regime

(IDFxh and other BGC subzones that have secondary features indicating a very xeric site)

Extremely dry sites will likely require the greatest disturbance. An increased focus on shading is required for seedling survival.

- Increased harvest retention for shading, and to act as a seed source (clumped or dispersed).
- Increased advanced regeneration retention for stocking,
- MSP the fall prior to planting, providing minimal time for pinegrass to ingress on the prepared spots. MSP should be very aggressive, providing horizontal and vertical displacement from the anticipated pinegrass response. Vertical displacement allows for planting seedlings in shaded aspects of the site prep, as well as decompaction and further separation from the pinegrass. Examples of very aggressive MSP are: stumping with additional large and deep raised screefs, excavator raised screefs that are large and deep, and deep ripper plow furrows. All MSP treatments should ensure the required disturbance is met throughout the treatment area with strong focus on areas operationally not conducive for easy disturbance, such as increased coarse fragments, increased slope and flat, compacted soils. Recommended vertical displacement is a minimum of 20cm with a target of 30cm below the mineral soil horizon. Horizontal displacement is not as critical as vertical displacement. Trees should be planted a minimum of 30cm from competing vegetation. The intended planting spot is halfway between the soil horizon and above the bottom of the cut, in a shaded location. Planting in the bottom of site prep where soil is compact should be avoided.
- Stock size recommendation: use medium sized stock when the regime can be implemented fully, use large sized stock when the regime cannot be fully implemented. Small stock is not recommended. (See stock size guideline (3.14 Figure X Example stock size by species). This is extremely important particularly for

Douglas-fir. Areas where it's not possible to achieve the most aggressive levels of disturbance should be reviewed and a new standards unit created. A new treatment plan will be necessary for these areas and will require solutions such as removal from NAR prior to harvest, adapting lower stocking standards (if the site can be classified differently), and planting with larger stock. Any planting proposed for these areas must be separated from the remainder of the opening and planted without intervening growing seasons between harvest and planting – trees will need to be moved or purchased to attempt reforesting these sites. Planting density will need to be elevated considerably – a minimum increase of 600 stems per hectare over target stocking is recommended.

- Plant as early in the season as possible to provide the maximum time where soil moisture is adequate for root growth. Planting should startup immediately once the majority of site allows snow and frozen ground free conditions – undertake snow covered gullies at a later date.
- Plow roads where snow is affecting ability to access planting units which are snow or frozen ground free.
- Order PSI individually wrapped stock for the first units planned in the program. This allows planting to occur as soon as the site is substantially plantable without having to forecast two weeks in advance for a thaw request.
- Plant with a shade focused prescription. Shaded spots within site prep should be the focus of the planting prescription, working with planters to achieve this even where site prep orientation is not ideal (Example: plant south-facing mounds on the west side of the mound, adjacent to the cut, to provide some afternoon shade).

11.2 Very Dry Site Treatment Regime

(Example: IDFdk and other BGC subzones that have secondary features indicating a very dry site)

Very dry sites will likely require a higher level of disturbance than normal dry sites. Additional shading is preferred but not required as in extremely dry sites. The regime for Extremely Dry sites should be followed, with the subsequent variations:

- MSP Examples of suitable site preparation are (in addition to those identified for extremely dry sites), double trenching, or single trenching where the treatment achieves the targeted level of disturbance. Recommended vertical displacement is a minimum of 15cm with a target of 20cm below the mineral soil horizon. Horizontal displacement is not as critical as vertical displacement. Trees should be planted a minimum of 20cm from competing vegetation. The target planting spot is 5cm below the hinge. Planting in the bottom of site prep where soil is compacted should be avoided.
- Plant as early in the season as possible to provide the maximum time where soil moisture is adequate for root growth. These sites do not require planting immediately after snow and frost free conditions, but early planting is recommended. Planting startup is recommended within two weeks of the site being substantially free of snow and frozen ground.
- Planting with a shade focused planting prescription.

11.3 Dry Site Treatment Regime

(Example: MSxk and other BGC subzones that have secondary features indicating a dry site)

Dry sites will likely require a modest level of disturbance to provide protection from pinegrass. Additional shading is preferred but not as critical as protection from cattle. The regime for Extremely Dry sites should be followed with the subsequent changes:

- Examples of suitable MSP (in addition to those identified for extremely dry sites and very dry sites) are single trenching where the treatment achieves the targeted level of disturbance. Recommended vertical displacement is a minimum of 10cm with a target of 20cm below the mineral soil horizon. Trees should be planted a minimum of 25cm from competing vegetation (this is wider than recommended for extremely dry or very dry sites. The target planting spot is 5cm below the hinge. Plant with a microsite and cattle focused planting prescription. Planting in the bottom of trenches should be avoided to reduce cattle trampling and compacted soil.

11.4 Stumping Treatment Regime

(For areas where stumping has been prescribed due to root disease incidence)

- Stumping should wait until fall prior to planting, providing no time for pinegrass to ingress on prepared spots. Stumping in conjunction with harvesting should be avoided for this reason.
- Stumping on all dry site categories requires additional raised screefs between stump holes to ensure adequate number of prepared spots.
- Planting position within prepared spots should maximize shading.

11.5 Raw Planting Regime

(All site categories)

Situations and areas exist where it's not possible to provide adequate mechanical site preparation. These areas should be identified pre harvest or at the post-harvest assessment so an appropriate prescription can be applied.

- Accelerate the plan to reforest these sites. It will likely be required to plant these prior to mechanical site preparation activities. Transfer or purchase suitable seedlings for these sites and plant them with no intervening growing season to allow seedlings to establish where pinegrass influence is minimized.
- Plant with large stock. This may require regularly sowing large stock types on spec in order to get seedlings to problem sites as quickly as possible.
- Focus planting around obstacles for shade. Woody species should be used to provide shade where available. Maximize shaded obstacles by using minimum inter-tree distance.

There are situations where the harvest disturbance may be a suitable alternative to mechanical site preparation. Harvesting should be considered a weak site preparation treatment - this varies considerably due to season, slope, harvest method, soil texture and individual operators. If harvesting activities occur in a manner which prevents intervening growing seasons for pinegrass and creates enough disturbance to damage previously occupying pinegrass, raw planting may be successful. This regime carries considerable risk due to rapid encroachment of pinegrass.

12 Post planting review, walkthrough or survey scheduling regime for extremely dry, very dry sites or dry sites

A suggested schedule for reviewing planting units that are actively managed for drought is:

1. Summer walkthrough of a planting sample - enough to get a keen sense of the issues and when the next walkthrough should occur. Walking these sites in the same year as planting will provide a sense of which details and microsites in the prescription are working best. There will be examples of microsites doing well, and others where survival is questionable. In a weak moisture year, an early site revisit may be the only opportunity to understand which microsites might have allowed trees to survive, had the season experienced improved moisture. Stressed seedlings may still be alive but are likely to die later in the summer or over the first winter. This walkthrough will allow the silviculturist to best rank the microsites in terms of suitability on dry sites. If the first walkthrough or survey doesn't occur until following years, the lessons will be missed. An emphasis should be placed on checking root development for both the surviving seedlings as well as those that died – this is a critical component of understanding where the greatest successes and failures lie.
2. First survey the year following planting - the first detailed survey must be early enough to determine if retreatment is required. This survey should focus on the reasons for planting success as well as failure and provide detailed recommendations on how to adjust the planting prescription or suggest an entirely new approach is warranted. The licensee silviculturist should be intimately involved in preparing surveyors to undertake these surveys and be prepared to walk sites in the event of plantation failure. Recommendations to replant using existing prepared spots is not suggested – an entirely new regime or prescription may be required and must be considered.
3. Following the first survey, a two year survey cycle is recommended until trees are firmly established.

In all surveys and walkthroughs on extremely dry or very dry sites, excavating trees to see how the roots are progressing is recommended.

Best Management Practice: **Sites that are actively being managed for drought should have accelerated reviews or surveys of any planting treatments.**

12.1 Identification, coding and reporting

While it's important to identify sites at risk for drought impacts, it's equally important to track decisions reached at the pre-harvest or post-harvest (or other) stages.

Licensees should internally code openings or strata to identify them as needing strong attention for treatment.

- Name and identify the anticipated level of drought impact for the site – embed this coding into the user's database as a searchable item. This will act as a reminder for the creation of treatment regimes at the time of post-harvest assessment. Tracking the amount of sites requiring special attention and treatment regimes will allow a licensee to understand the scale of potential drought impacted sites.

- Name and identify a treatment regime for each anticipated level of drought impact. This will help formalize a process the licensee has decided will have the best chance of success.
- Name and identify a survey regime. This will allow for easier communication with survey crews and ensure an appropriate review period is planned.
- Outline factors surveyors need to address when embarking on surveys on the dry sites. Review treatment regimes with the survey crew.
- Distinguish between fill-planting (PL-FP-CTAIN) and replanting (PL-RP-CTAIN) when reporting internally and to RESULTS. This will help summarize the scope and scale of any plantation failures.
- When reporting internally, add a separate searchable descriptor for re-plants that are (in the opinion of the licensee) caused by drought.
- When creating sowing requests, distinguish between seedlings targeted for drought prone sites and all other seedlings so these request keys can be treated differently. Communicate with the nurseries in order to grow the best tree possible for these sites.

13 Informal Trials

Silviculturists should conduct their own trials in their operating areas to expand knowledge and improve future successes. Any treatment regime identified should be subject to testing and adjustment. Note, these trials shouldn't be confused with research trials which have a much more rigorous approach.

All trials should be documented with clear distinction on maps where these have occurred. Trialing different treatments on adjacent openings are only useful if the sites are identical in all aspects. Trials should be conducted on the same opening and the same standards unit where possible.

Trials size could be:

1. Larger scale where half an opening has one treatment, while the other half has another.
2. Smaller scale where a 20m x 20m section is treated slightly different. These have value as anecdotal support for theories or where an existing regime works but slight changes are suspected to improve results but also may fail.
3. Very small areas of high density planting should be established as a common practice on all extremely dry or dry sites to allow for multiple excavation over multiple seasons. These should be easily accessible, mapped and made available to surveyors for review and commenting.

Below are examples of trials a silviculturist may perform to further knowledge:

- Seedlot class, A vs B stock – should be done at small scales in situations where planting B-class is contrary to the Chief Foresters Standard for Seed Use
- Seedlot progeny – seed sourced from drier sites vs seed sourced from moister sites
- Stock size

- Planting depth – test deep, normal, flush, and even shallow plug placement
- Planting microsite – location in the prepared site
- Planting microsite – obstacle planting location
- Planting stock – top pruning at nursery or on site adjusting the root to shoot ratio
  - Ask nursery to top prune a number of boxes of trees prior to hardening off, track these and test them
  - Alternative is to manually top prune trees following planting
- Species selection – testing theories
  - Example – plant trees in locations previously considered to be high risk or outside of the usually accepted microsite
- Mechanical Site Preparation – size of spot
  - Plant multiple locations on prepared spot
- Mechanical Site Preparation – oriented prepared spots versus random
  - Plant multiple locations on prepared spot
- Mechanical Site Preparation – one treatment type versus another
  - Plant multiple locations on prepared spot
- Raw planting – have planters plant a box of trees on recently harvested sites scheduled for MSP and planting at a further season
  - Test stock size, microsite location and species survival
- Planting timing – leave small areas to plant in subsequent weeks to test root growth and survival
- Planting timing – fall planting
- Fertilizer application – treat versus no treatment
  - Different types of fertilizer treatments can be included

If small scale size of tests are chosen, plant at high densities to cover as many diverse microsites as possible to rank effectiveness.

***Best Management Practice*: Small operational trials are an extremely cost effective way of testing for appropriate regimes most likely to work in an area. Silviculturists should engage with their local research silviculturist in order to improve trial design, expand questions worth testing, and to help drive research project ideas.**

14 Recommendations

The following general practices are recommended as the risk for drought mortality increases.

Planning and Harvesting:

- Include silviculture staff in cutting permit development planning.
- Use the Drought Key provided to identify sites at higher risk for drought. Stratify the driest sites for more thorough attention and treatments. Follow the Best Management Practices for the identified drought risk.
- Avoid harvesting xeric patches or rock knobs.
- Retain more mature forest as drought risk increase,
- Retain advanced regeneration wherever possible.

Mechanical Site Preparation:

- Follow the Best Management Practices for the identified drought risk.
- As sites are at increased risk for drought, increased mechanical site preparation disturbance is required for plantation success.
- Manage mechanical site preparation programs carefully: Identify the required level of disturbance, and monitor these treatments for to ensure the required level of treatment is achieved.
- Target mechanical site preparation treatment for the autumn prior to planting.

Planting:

- Follow the Best Management Practices for the identified drought risk.
- As risk for drought increases, larger planting stock size is recommended
- Place seedling requests as soon as possible, preferably prior to harvesting.
- Create a detailed planting prescription identifying where the seedlings should be placed to maximize survival. Clearly communicate this to planters at: the planting viewing, the planting prework and the first days of planting to ensure you receive the best chance of seedling survival.
- Start planting as soon as snow and frost free conditions exist on the majority of the planting unit – do not wait for the last snowy draw to become snow free. This may require snow removal on the roads leading to these sites.
- Control the order of planting. Make sure the order of planting matches the drought risk. Plant the units at greatest risk or mortality first.

Surveys

- For the sites at greatest risk for drought mortality, conduct a fall walkthrough following planting.
- Decrease the survey intensity. The first full survey on the riskiest site should be no later than one year following planting
- Surveys should include a component of seedling root excavation to allow for better feedback on plantation success.

- Surveyors should be given greater direction on information required when reviewing the driest sites.

Trails

- Silviculturists should create informal trials to test ideas about increasing seedling survival on the driest sites. These trials should be documented so that surveyors can review the results to improve treatment prescription recommendations.
- Trial areas can provide surveyors an area to excavate seedling roots.

Gaps where further research should be conducted:

- Develop a set of nursery cultural practices specific to trees targeted for dry sites.
- Develop seedling quality testing that better focuses on root development in stressful conditions at the nursery.
- Review PSI vs PSB survival success in drought conditions
- Review planting depth and plug temperature related to survival success in drought conditions
- Review plug size relative to survival success in drought conditions
- Review seed class survival success in drought conditions. A-class seed versus B-class seed.
- Research and development of A-class seedlings that maximize drought tolerance.
- Review top pruning of seedlings, determining if manually adjusting root to shoot ratios improves survival in drought conditions.

Operational practices: Gaps where further development is warranted:

- Terminology. I recommend all licensees adopt PL-RP for sites that have been planted and need to be replanted.
- RESULTS (and licensees' databases) I recommend that a new objective be put into RESULTS so replants or planting treatments for drought are easy to identify.
- SPAR. I recommend an additional field be included in SPAR to identify request keys targeted for dry sites.
- Develop seedling quality testing for silviculturists to use that measures root growth on the planting sites.

Appendix 1 Overview Map of Drought Impacted Sites

Appendix 2 Site Reviews

Appendix 3 Example stock sizes – BCTS

BCTS RECOMMENDED SEEDLING STOCK TYPE SELECTION INTERIOR / SPRING

Sx	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Small	PSB 410 1+0	11 - 27	2.4	0.26	315
Medium	PSB 412A 1+0	11 - 35	2.8	0.44	210
Large	PSB 512A 1+0	14 - 40	3.2	0.61	120

Pli / Py	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Small	PSB 310B 1+0	6 - 16	2.1	0.14	360
Medium	PSB 410 1+0	6 - 20	2.4	0.17	315
Large	PSB 412A 1+0	8 - 22	2.6	0.23	210
PCT is no longer a recommended stock type.					

Fdi	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Small	PSB 412B 1+0	13 - 28	2.4	0.36	315
Medium	PSB 412A 1+0	13 - 34	2.8	0.53	210
Large	PSB 512A 1+0	15 - 40	3.2	0.65	120

Lw	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Small	PSI 410 1+0	12 - 28	2.3	0.26	315
Medium	PSI 412A 1+0	12 - 32	2.8	0.32	210

Cw	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Small	PSB 410 1+0	12 - 35	2.2	0.31	315
Medium	PSB 412A 1+0	18 - 45	2.5	0.46	210
Large	PSB 512A 1+0	18 - 50	2.8	0.68	120

Pw	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Small	PSB 410 1+0	6 - 20	2.4	0.35	315
Medium	PSB 412A 1+0	8 - 22	2.6	0.41	210
Large	PSB 512A 1+0	9 - 24	2.9	0.42	120

Bl	Stock Type	Ht (cm)	Min RCD (mm)	Cost (cents)	Est. # Box
Large	PSB 412A 2+0	10 - 30	3.3	0.48	210

I-Wrap is recommended for Lw stock only.

Appendix 4 Example treatment costs.

Spp	Code	Size	Type	Seed Cost $	Nursery + Cold Storage $	Total seedling cost $
Fdi	Fdi-L	L	512A	$0.016	$0.68	$0.70
	Fdi-M	M	412A	$0.016	$0.55	$0.57
	Fdi-S	S	412B	$0.016	$0.44	$0.46
Py	Py-L	L	412A	$0.035	$0.44	$0.47
	Py-M	M	410	$0.035	$0.28	$0.31
	Py-S	S	310B	$0.035	$0.20	$0.24
Pli	Pli-L	L	412A	$0.052	$0.35	$0.40
	Pli-M	M	410	$0.052	$0.22	$0.27
	Pli-S	S	310B	$0.052	$0.16	$0.21
Sx	Sx-L	L	512A	$0.026	$0.78	$0.81
	Sx-M	M	412A	$0.026	$0.46	$0.49
	Sx-S	S	410	$0.026	$0.30	$0.33
Lw	Lw-L	L	412A	$0.039	$0.38	$0.42
	Lw-M	M	410	$0.039	$0.27	$0.31

Provided by BCTS. These are average market-rate prices for 2019-2020 sowing years. Economies of scale are found throughout this industry: large purchases will be less expensive than small purchases.

Treatment	Code		Prime Mover	$/ha
Stumping + raised screefs	SRS	(IDF)	Excavator	$900.00
Stumping	STU	(IDF)	Excavator	$750.00
Raised screefs	RS		Excavator	$800.00
Deep Ripper Plow	DRP		Cat	$620.00
Trenching - double	TDC		Cat	$680.00
Trenching - double	TDS		Skidder	$544.00
Trenching - single	TSC		Cat	$400.00
Trenching - single	TSS		Skidder	$320.00

Provided by BCTS. These are average prices. There will be many other factors that influence price, especially: location, access, unit size, complexity, slope, and coarse fragment content. Lowbed costs are hourly and can average $700 for mobilization and demobilization – on small units this can double the price of treatment.

Treatment	Code			$/tree
Planting - First time	PL-PL	n/a	n/a	$0.50
Planting - Replanting	PL-RP	n/a	n/a	$0.60

Planting prices vary considerably. There are many factors that influence price especially: total contract size, unit size, location, on block access, site prep type, complexity, slope, stock size, micro-siting, coarse fragment %, and many others. These prices are for discussion purposes only. Replant costs are higher than first time costs due to increased grass, blowdown, access issues, and respecting surviving trees from the first treatment – costs may escalate to greater than $1/tree and greater.

Appendix 5 Cost benefit exercises

The cost/ha used in these exercises are from the previous Appendix. Costs are relative to actual field conditions. These discussions are to identify trends. Risk must be anticipated by the silviculturist for their exact scenario and expectations of success or failure adjusted accordingly.

Risk associated with each treatment is discuss to indicate the possible outcomes and $/ha depending upon circumstances. Some risky treatment regimes work during good moisture years and some low risk treatment regimes fail during drought years or when nursery or planting issues emerge.

These summaries are just to establishment and do not include surveys, brushing or spacing costs.

The reader is encouraged to think through different scenarios using the costs in the previous Appendix and think about different treatment regimes and the risks associated with them.

Example 1. Stumping vs Stumping with raised screefs in between stump holes.

This first example represents stumping without paying the extra $150-200/ha for additional raised screefs between stump holes. This was witnessed multiple times in the field visits.

Treatment summary: Stumping - no raised screefs. Planned cost.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$2,175.20

In most cases, stumping without additional screefing required a replant. Often the trees survived better in the stump holes and had full mortality outside of the treated spots. This represents the best case scenario associated with the first time plantation failure. The replant is assumed to succeed. The second replant is high-risk.

Treatment summary: Stumping with replants. This will be the lowest of the actual costs experienced.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1400	$725.20
Planting - Replanting	n/a	n/a	n/a	$0.60	1300	$780.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1300	$673.40
Total Cost						$3,628.60

In many of the sites visited, a replant is unlikely to succeed now that the vegetation has firmly established on site. A second excavator treatment is anticipated.

Treatment summary: Stumping, planting, retreating the MPS, and replant. This is close to what licensees are experiencing.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1400	$725.20
Raised screefs	n/a	n/a	n/a	n/a	n/a	$800.00
Planting - Replanting	n/a	n/a	n/a	$0.60	1300	$780.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1300	$673.40
Total Cost						$4,428.60

The recommended treatment regime for these sites would be stumping with additional raised screefs. The cost increase $150-$300/ha. This is the low-risk option.

Treatment summary: Stumping with raised screefs between holes

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Stumping + raised screefs	n/a	n/a	n/a	n/a	n/a	$900.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$2,325.20

Example 2. Disc trenching and planting with medium stock vs no MSP and planting with large stock

In some cases planners commit to planting without MSP. This example reviews the costs of the two options on very dry or dry sites.

The following scenario is a regime seen quite a bit on very dry or dry sites (IDFdk or MS). Disc trench and planting.

Treatment summary: Very dry site. Disc trenching and planting with medium stock

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$1,745.20

The following scenario is where the planners have committed to planting without MSP. The silviculturist has chosen large stock to reduce the risk associated with this option and increase the density slightly. There is still risk with this option but it has been addressed with higher density and larger stock size.

Treatment summary: Very dry site. No MSP, planting with large stock.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Planting - First time	n/a	n/a	n/a	$0.50	1600	$800.00
Nursery - Large stock	80%	20%	n/a	$0.65	1600	$1,046.40
Total Cost						$1,846.40

This example shows two different options that have decent chances for success. Trench and plant with medium stock and raw plant with large stock have similar costs/ha. The raw plant with large stock has slightly higher risk and slightly higher price but does have the potential to succeed. Raw planting with medium stock would be a low price very high risk option.

Example 3. Extremely dry site. Disc trenching and planting with medium stock vs excavator raised screefs and planting with medium stock.

This example was witnessed multiple times. Regular disc trenching was used on IDFxh sites, flat, moderate coarse fragments and the trenching job was done very cursory. Outlined below are: trench and plant as it was envisioned to succeed. Trench and plant as it actually has played out. And the recommended treatment regime of extremely high disturbance MSP such as excavator raised screefing.

Treatment summary: Extremely dry site. Disc trenching and planting with medium stock

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$1,745.20

This is the cost predicted for the first plan. The first attempt had full mortality because the disturbance wasn't aggressive enough in the 2017 drought year.

Treatment summary: Extremely dry site. Disc trenching and planting with medium stock. Redo

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Planting - Replanting	n/a	n/a	n/a	$0.60	1400	$840.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$3,310.40

The licensee attempted a replant. The cost is now soaring. The replant failed immediately in a moist spring now that the grass is starting to occupy the trench.

Treatment summary: Extremely dry site. Disc trenching and planting with medium stock. Redo to completion

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Planting - Replanting	n/a	n/a	n/a	$0.60	1400	$840.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Raised screefs	n/a	n/a	n/a	n/a	n/a	$800.00
Planting - Replanting	n/a	n/a	n/a	$0.60	1400	$840.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$5,675.60

The licensee has accepted that a more aggressive regime is warranted. This is likely to be the end of the spending on this unit now that the appropriate treatment regime has been chosen.

Example 3. Extremely dry site continued.

Treatment summary: Extremely dry site. Excavator raised screefs and planting with medium stock

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Raised screefs	n/a	n/a	n/a	n/a	n/a	$800.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$2,225.20

This is the cost of the appropriate regime that should be expected to meet minimum stocking standards even in a drought year. This regime no longer looks expensive.

Lesson1: once your plantation fails, do not attempt to replant without addressing the reasons why it failed.

Lesson2: on extremely dry site, the MSP is not as large a portion of the costs as replants. The second scenario shows the licensee attempting to replant in trenches that failed the first time.

Example 4. Extremely dry site. Raw planting attempt

This example was witnessed a number of times in the same vicinity. The licensee felt that they had trees arriving the spring following harvesting. This is a high risk regime on extremely dry site. While it is possible to succeed with this regime, the harvest disturbance needs to be the fall prior to planting, the ground disturbance needs to be very high and the planting season needs to be moister than average. These three need to occur in order for this to work and even then the seedlings are at risk from future drought years as they will be competing with pinegrass.

The following scenario is the plan as first envisioned.

Treatment summary: Extremely dry site. Raw planting attempt.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$1,425.20

The following is the licensee's response. Trenching with the least expensive MSP available – Skidder pulled trencher on flat ground with moderate coarse fragments.

Treatment summary: Extremely dry site. Raw planting, plantation failure, followed by trenching.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00
Planting - Replant at cost of first time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$3,170.40

The following scenario is how these sites are likely to finish after two plantation failures.

Treatment summary: Extremely dry site. Raw planting example to current plan

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00
Planting – Replant at cost of first time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Raised screefs	n/a	n/a	n/a	n/a	n/a	$800.00
Planting - Replant	n/a	n/a	n/a	$0.60	1400	$840.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$5,535.60

For comparison, the recommended treatment regime on extremely dry sites with flat ground and moderate coarse fragments. This might be replaced by deep ripper plow or double trenching and the costs would be relatively comparable.

Treatment summary: Extremely dry site. Preferred treatment regime.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha
Raised screefs	n/a	n/a	n/a	n/a	n/a	$800.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20
Total Cost						$2,225.20

Lesson1: once your plantation fails, do not attempt to replant with the next cheapest option. This site needed to be fully reviewed to determine the proper treatment regime.

Example 5. Extremely dry site not identified and separated from normal site. Site is 40% extremely dry and 60% dry site. IDFmw2-03 in Site plan.

This example was witnessed a number of different times. In some instance the opening was 50% flat and moist and 50% dry and steep but all within the same standards unit. In other instances the extremely dry sites were difficult to stratify and are dispersed within the standards unit. In both instances the extremely dry site needs to have a separate regime in order for it to succeed. An alternative is to treat the entire opening as an extremely dry site.

The following is the current treatment regime. Only 60% of this site was stumped because the extremely dry site was too steep for the operator to work on safely.

Treatment summary: Extremely dry and normal site mixed for treatment. Regime misses drier site.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha	% of unit	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00	60%	$450.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00	100%	$700.00
Nursery - Medium stock	80%	20%		$0.52	1400	$725.20	100%	$725.20
Total Cost								$1,875.20

The 40% of this site that did not get stumped had full plantation failure, even in a very moist spring. It was the first block to be planted in 2019.

Treatment summary: Extremely dry and normal site mixed for treatment. Regime misses drier site. Replant with large stock.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha	% of unit	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00	60%	$450.00
Planting - First time	n/a	n/a	n/a	$0.50	1400	$700.00	100%	$700.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1400	$725.20	100%	$725.20
Planting - Replanting	n/a	n/a	n/a	$0.60	1600	$960.00	40%	$384.00
Nursery - Large stock	80%	20%	n/a	$0.65	1600	$1,046.40	40%	$418.56
Total Cost								$2,677.76

If this example had been identified at the Site Plan signoff as a separate SU, or if it had been noted at the Post-Harvest Assessment stage there might have been two different solutions. 1, fast track the extremely dry site for planting immediately after harvest (move the trees from somewhere else)

Example 5. Continued.

The following scenario shows the extremely dry strata being planted one year earlier than the stumped area. Note that the cost is the same as the original plan. This plan is not guaranteed to work, but has a better chance of success compared to the original scenario.

Treatment summary: Extremely dry and normal site mixed for treatment. PHA identifies drier site. Planted in two passes.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha	% of unit	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00	60%	$450.00
Planting - First time steep	n/a	n/a	n/a	$0.50	1400	$700.00	40%	$280.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1400	$725.20	40%	$290.08
Planting – First time flat	n/a	n/a	n/a	$0.50	1400	$700.00	60%	$420.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1400	$725.20	60%	$435.12
Total Cost								$1,875.20

Another option which addresses the increased risk of the steeper ground is to plan for large stock for the extremely dry site and plant in the same year as the rest of the opening. Risk is increased as pinegrass is now starting to compete, and risk is lowered because of using larger stock. This plan is not guaranteed to work, but has a better chance of success compared to the original scenario.

Treatment summary: Extremely dry and normal site mixed for treatment. PHA identifies drier site. Planted in one pass with larger stock on the raw plant ground.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha	% of unit	Cost/ha
Stumping	n/a	n/a	n/a	n/a	n/a	$750.00	60%	$450.00
Planting - First time steep	n/a	n/a	n/a	$0.50	1400	$700.00	40%	$280.00
Nursery - Large stock	80%	20%	n/a	$0.65	1400	$915.60	40%	$366.24
Planting – First time steep	n/a	n/a	n/a	$0.50	1400	$700.00	60%	$420.00
Nursery - Medium stock	80%	20%	n/a	$0.52	1400	$725.20	60%	$435.12
Total Cost								$1,951.36

Lesson1: identify extremely dry sites at the earliest opportunity. This give the greatest chance to entertain plans that can work and lower cost.

Example 6. Site has dispersed drought rating. Normal Dry and Very dry sites dispersed.

This example was witnessed a number of different times. The usual scenario is that the opening was mostly normal dry sites with significant areas where slopes were greater than 40% so these areas were either not treated, or had very light disturbance not suitable for the site.

In the following scenario, the entire site was treated like a normal dry site with disc trenching.

Treatment summary: Regular dry site mixed with very dry site 60/40 mix. Trench and plant.

Description	Fdi %	Py %	Pli %	$/tree	Density	Cost/ha	% of unit	Cost/ha
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00	100%	$320.00
Planting - First time	n/a	n/a	n/a	$0.50	1600	$800.00	100%	$800.00
Nursery - Medium stock	30%	0%	70%	$0.36	1600	$576.00	100%	$576.00
Total Cost								$1,696.00

The scenario below shows the site had a plantation failure on the steeper ground that required a replant. This replant is not guaranteed to work.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha	% of unit	Cost/ha
Trenching - single	n/a	n/a	n/a	n/a	n/a	$320.00	100%	$320.00
Planting - First time	n/a	n/a	n/a	$0.50	1600	$800.00	100%	$800.00
Nursery - Medium stock	30%	0%	70%	$0.17	1600	$273.60	100%	$273.60
Planting - Replanting	n/a	n/a	n/a	$0.60	1300	$780.00	40%	$312.00
Nursery - Large stock	30%	0%	70%	$0.40	1300	$518.70	40%	$207.48
Total Cost								$1,913.08

The scenario below shows the preferred treatment regime. Treat the entire site as a higher risk with the more aggressive site prep that can be conducted over the entire opening. This is the lower risk option.

Treatment summary: Regular dry site mixed with very dry site 60/40 mix. Raised screef and plant.

Description	Fdi%	Py%	Pli%	$/tree	Density	Cost/ha	% of unit	Cost/ha
Raised screefs	n/a	n/a	n/a	n/a	n/a	$800.00	100%	$800.00
Planting - First time	n/a	n/a	n/a	$0.50	1600	$800.00	100%	$800.00
Nursery - Medium stock	30%	0%	70%	$0.36	1600	$576.00	100%	$576.00
Total Cost								$2,176.00

Lesson1: identify extremely dry sites at the earliest opportunity and treat areas with dispersed strata with the treatment that can work over the entire area.

Appendix 6 Literature Review

This is a list of abstracts from papers reviewed for this report. The papers were provided by research scientists and MOFLNRO staff.

The second list is a bibliography created by John Stechyshyn and Gabriel Courchesne-Normandin as an attachment to the paper Compendium on the Challenges of Douglas-fir Regeneration in the Interior Douglas Fir BGC dk3/dk4 Subzones and Strategies to Improve Reforestation Efforts.

Appendix 7 Best Management Practices for Managing Drought Prone Sites within the Thompson Okanagan Region. Draft for publishing.

Reforestation on dry sites is extremely challenging. While this has always been the case, the challenge has been placed under greater focus now that harvesting has shifted away from Mountain Pine Beetle killed sites to harvesting in lower elevation Douglas-fir stands. This challenge is compounded by periodic years with decreased moisture such as drought years like 2017 and 2018. Periodic drought years should be expected more frequently as impacts from climate change increase.

This Best Management Practices document is intended to help silviculture practitioners identify and manage for the driving factors that cause significant drought mortality. This document is based on a review of licensee, BCTS, and ministry planting programs, and the broad suite of management practices they conducted on these sites. The reviews included field visits to more than 50 of their most drought prone sites. The majority of the recommendations found in this document are based on these observations of the successes and failures found on those sites.

Identifying drought prone sites.

Sites within the Thompson Okanagan Region can be described in increasing amounts of moisture: extremely dry, very dry, dry, and not-dry but prone to dry situations. The biogeoclimatic (BGC) zones rank in order of how they fall on the landscape in the Thompson Okanagan Region. These BGC zones increase in elevation as BG<PP<IDF<MS<ESSF

In areas where ICH is present the BGC zones increase in moisture: PP<IDF<ICH<ESSF. Most ESSF and ICH sites should not be considered dry sites.

Drought risk key

The numbers presented below are qualitative and represent trends of in the risk of drought mortality. These have been discussed with local licensee silviculturists and adequately represent mortality risk. If mechanical site preparation and/or reforestation occurs later than the timelines specified in the regimes, for any reason, increase the total to account for greater vegetation competition – this includes recalculating the value where a replant is necessary.

More experienced silviculturist can and should adjust the weighting that best matches their observations of risk and mortality on their openings – please recognize that there are great differences between operating areas that will effect sites differently.

Drought risk key:

Stratify sites based on the primary and secondary criteria below. Stratify sites as thoroughly as possible without lumping. Find the BGC subzone (primary stratification criteria) you are operating in and add or subtract points based on secondary site characteristics. Total the points up to identify the drought risk category and review and follow the resultant recommended treatment regime (below).	>15	Extremely dry sites
	10-15	Very dry site
	5-10	Dry site
	<5	Not a dry site

BGC		Soil Moisture Regime		Aspect		CF%		Overstory shade		Other factors	
PP or BG	20	Very Xeric to Subxeric	5	SE-W	5	High	5	None	3	SE-W (>30%)*	3
IDFxh	15	Submesic	3								
IDFdk	10	Mesic	0	W-NW or E-SE	0	Moderate	3	Moderate	0		
MSxk or IDFmw	5	Subhygric	-3							Flat with heavy	
ESSF or ICH	0	Hygric-Subhydric	-5	NW-E	-3	Low	0	Significant	-3	Compaction**	3

* Steep slopes on south facing slopes have increased risk.
** Flat ground when there is significant compaction can be difficult to achieve adequate disturbance from site preparation.

Best Management Practices on all sites where drought mortality is a consideration:

The following practices are Best Management Practices on all sites where drought mortality is considered likely. Specific details can be found in the Regime Based Silviculture section of this document.

Planning

- A silviculture forester should have input and signoff on all Site Plans in order to review openings for extremely dry sites and to help plan and prepare for reforesting dry sites. Extremely dry areas such as south facing rock knobs or steep south facing pitches should be either removed from the block or separated out as separate Standards Units with increased retention and appropriate stocking standards.
- Silviculturists should review sites during post-harvest assessments through the lens of the drought risk key - separating areas with different values. Sites should be stratified as thoroughly as possible to identify regimes that will work for the different strata. The Land Management Handbook #23, A Guide to Site Identification and Interpretation in the Kamloops Forest Region February 1990 should be used to classify these sites.
- Track the drought risk rating value for each site using the table below. This will make it easier to quantify and summarize the area associated with increased risk.
- Create or use approved variations in the stocking standards to reduce minimum inter-tree distances to deal with situations where mechanical site preparation is not possible due to machine limitations and safety concerns.
- All sowing, site preparation, and planting activities must be coordinated to minimize the time period between harvest start and planting.
- Create informal trials to test new ideas and increase learning opportunities.

Mechanical Site Preparation

- MSP should be considered a required treatment on all sites. The only exception would be instances where disturbance is created from harvesting and planting occurs without an intervening growing season to allow pinegrass establishment.
- Target treatments for the fall prior to planting to minimize pinegrass ingression. Administer with as much attention as planting programs including increased communication at the viewing, pre-work, and checking stages. Identify the level of disturbance required throughout the treatment area and indicate under what scenarios the area will need to be reworked until the acceptable level of treatment has been met throughout.

Planting prescription and stock specification

- Choose species that are ecologically suited for the entire planned rotation – these are the species with the greatest drought tolerance following establishment and are usually the species in the pre-harvest stand. Do not make the species choice based on ease of establishment.
- Nursery. Use separate request keys for seedlings that are targeted for dry sites. This will make it easier to manage these seedlots through communication with the nursery.
- Seedling requests. When utilizing B class seed, select provenances that are drier than the target planting site.
- Seedling requests. As drought risk increases for a site, sow first and adjust the planting plans later. Planting must be initiated as quickly as possible. Identify when these openings are likely to be harvested and sow for these even if harvest completion is uncertain.
- Seedling requests. Order a number of dry site suitable species as a component of every planting prescription.
- Seedling requests. Grow the appropriate size stock for the drought risk.
- Seedling requests. Do not use seedlots with less than 85% germination percentage to minimize transplant shock at the nursery.

Planting program implementation

- It is extremely important to plant the driest sites first following the order of snow melt. Identify the work order prior to pre-work with planters. Control the thaw schedule so that planters follow the work order identified.
- Create an operational trial area on all sites. This will allow frequent excavation and increased learning opportunities. Root excavations should be incorporated into all stocking surveys for these units.
- There will be situations where mechanical site preparation does not adequately cover a site and there is one or two intervening growing seasons prior to planting. Reforestation to adequate levels may be very difficult or unachievable. In these situations it is recommended to include direction in all treatment regime planting prescriptions to obstacle plant for shading purposes to increase numbers. Expect very high mortality where MSP was not possible.

Brushing

- Vegetation control for woody species should be avoided on dry sites. Most species, with the exception of pinegrass will provide some level of shade protection which overrides most concerns related to competition for moisture.

Monitoring and reporting

- Track replants separate from initial planting. This will make it easier to manage sites that have increased challenges. Adopt the coding PL-RP for sites that have been previously planted and failed due to drought mortality. Add a comment in the re-plant activity "Drought".
- Surveys. Identify a survey regime for at-risk sites. Extremely dry and very dry sites should have summer and fall walkthroughs to better track plantation progress. Surveys should be completed within one year of planting and resurvey frequency should be no longer than two years until establishment is secure.
- Surveys. Review the treatment regimes recommended for dry sites with survey crews. Outline the factors that surveyors need to address on dry sites. Surveyors should include comments about which microsites show increased mortality and survival. Informed surveyors will contribute to improving planting prescriptions and planting microsite selection.

Regime Based Silviculture.

This is regime based silviculture. All aspects of the identified regime need to be implemented to allow the regime to work as intended. These regimes are intended to limit the need for re-planting. If the first planting treatment is unsuccessful, the risk rating will need to be re-evaluated. Do not attempt a re-plant without a thorough review of the previous plantation failure. Identify what caused the failure and determine if the site preparation will remain adequate at the time of proposed re-planting.

Extremely dry site treatment regime (IDFxh and other BGC subzones that have secondary features indicating a very xeric site)

Extremely dry sites will likely require the greatest disturbance. An increased focus on shading is required for seedling survival.

- Increased harvest retention for shading, and to act as a seed source (clumped or dispersed).
- Increased advanced regeneration retention for stocking.
- MSP the fall prior to planting providing minimal time for pinegrass to ingress on the prepared spots. MSP should be very aggressive providing horizontal and vertical displacement from the anticipated pinegrass response. Vertical displacement allows for planting seedlings in shaded aspects of the site prep as well as decompaction and further separation from the pinegrass. Examples of very aggressive MSP are stumping with additional large and deep raised screefs, excavator raised screefs that are large and deep, and deep ripper plow furrows. All MSP treatments should ensure that the required disturbance is met throughout the treatment area with very strong focus on areas operationally not conducive for easy disturbance such as increased coarse fragments, increased slope and flat compacted soils. Recommended vertical displacement is a minimum of 20cm with a target of 30cm into the mineral soil horizon. Horizontal displacement is not as critical as vertical displacement. Trees should be planted a minimum of 30cm from competing vegetation. The intended planting spot is halfway between the soil horizon and above the

bottom of the cut – in a shaded location. Planting in the very bottom of the site prep where the soil is compacted should be avoided.

- Stock size recommendation: use medium sized stock where the regime can be implemented fully, use large sized stock when the regime cannot be fully implemented Small stock is not recommended. (See stock size guideline below).

Example stock size by species that are planted on dry sites. Source BCTS recommended seedling stock type selection. Interior/Spring

	Large	Medium	Small
Fdi	512A	412A	412B
Py	412A	410	310B
Pli	412A	410	310B

- Areas where it is not possible to achieve the most aggressive levels of disturbance should be reviewed and a new standards unit created. A new treatment plan will be required for these areas and will require solutions such removal from NAR prior to harvest, adapting lower stocking standards (if the site can be classified differently), and planting with larger stock. Any planting proposed for these areas must be separated from the remainder of the opening and planted without any intervening seasons between harvest and planting – trees will need to be moved or purchased to attempt to reforest these sites. Planting density will need to be increased considerably – a minimum increase of 600 stems per hectare over target stocking is recommended.
- Plant as early in the season as possible to provide the maximum time where soil moisture is adequate for root growth. Planting startup should be as soon as snow and frozen ground free conditions allow on the majority of the site – follow up with snow covered gullies at a later date.
- Plow roads where snow is affecting the ability to access planting units that are snow or frozen ground free.
- Order PSI individually wrapped stock for the first units planned for the program. This allows for planting as soon as the site is substantially plantable without having to forecast two weeks in advance for a thaw request.
- Planting with a shade focused planting prescription. Shaded spots within site prep should be the focus of the planting prescription, working with the planters to achieve this even where site prep orientation is not ideal (Example: plant south-facing excavator raised screefs on the west side of the screef, adjacent to the cut, to provide some afternoon shade).

Very dry site treatment regime (Example: IDFdk and other BGC subzones that have secondary features indicating a very dry site)

Very dry sites will likely require a higher level of disturbance than normal dry sites. Additional shading is preferred but not required as in extremely dry sites. The regime for Extremely Dry sites should be followed with the following variations:

- MSP Examples of suitable site preparation are (in addition to those identified for extremely dry sites), double trenching, or single trenching where the treatment achieves the targeted level of disturbance. Recommended vertical displacement is a minimum of 15cm with a target of 20cm into the mineral soil horizon. Horizontal displacement is not as critical as vertical displacement. Trees should be planted a minimum of 20cm from competing vegetation. The target planting spot is 5cm below the hinge. Planting in the very bottom of the site prep where the soil is compacted should be avoided.
- Plant as early in the season as possible to provide the maximum time where soil moisture is adequate for root growth. These sites do not require planting immediately after snow and frost free conditions but early planting is recommended. Planting startup is recommended within two weeks of the site being substantially free of snow and frozen ground.
- Plant with a shade focused planting prescription.

Dry site treatment regime (Example: MSxk and other BGC subzones that have secondary features indicating a dry site)

Dry sites will likely require a modest level of disturbance to provide protection from pinegrass. Additional shading is preferred but not as critical as protection from cattle. The regime for Extremely Dry sites should be followed with the following variations:

- MSP Examples of suitable site preparation are (in addition to those identified for extremely dry sites and very dry sites) single trenching where the treatment achieves the targeted level of disturbance. Recommended vertical displacement is a minimum of 10cm with a target of 20cm into the mineral soil horizon. Trees should be planted a minimum of 25cm from competing vegetation, (this is wider than the extremely dry or very dry sites as drought impacts are primarily driven by vegetation competition). The target planting spot is 5cm below the hinge. Plant with a microsite and cattle focused planting prescription. Planting in the bottom of trenches should be avoided to reduce cattle trampling and compacted soil.

Stumping treatment regime (for areas where stumping has been prescribed due to root disease incidence)

- Stumping should wait until fall prior to planting providing no time for pinegrass to ingress on the prepared spots. Stumping in conjunction with harvesting should be avoided for this reason.
- Stumping on all dry site categories requires additional raised screefs between stump holes to ensure adequate number of prepared spots.
- Planting position within the prepared spots should maximize shading.

Raw planting regime (all site categories)

There will be situations and areas where it is not possible to provide adequate mechanically site preparation. These areas should be identified pre harvest or at the post-harvest assessment so the appropriate prescription can be applied.

- Accelerate the plan to reforest these sites, it will likely be required to plant these prior to mechanical site preparation activities. Transfer or purchase suitable seedlings for these sites and plant them with no intervening growing season so that seedlings can establish where pinegrass influence is minimized.
- Plant with large stock. This may require regularly sowing large stock types on spec in order to provide opportunities to get seedlings onto problem sites as quickly as possible.
- Focus planting around obstacles for shade. Woody species should be used to provide shade where available. Maximize shaded obstacles by using minimum inter-tree distance.
- There are situations where the harvest disturbance may be a suitable alternative to mechanical site preparation. Harvesting should be considered a weak site preparation treatment - this varies considerably due to season, slope, harvest method, soil texture and individual operators. If harvesting activities occur in a manner that allows no growing seasons for pinegrass to occupy a site, and if harvesting activities create enough disturbance to damage the previously occupying pinegrass, raw planting may be successful. This regime carries considerable risk due to quick encroachment of pinegrass.