AN EFFECTIVENESS MONITORING PLAN FOR NDT4 ECOSYSTEM RESTORATION IN THE EAST KOOTENAY TRENCH

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Habitat Branch, Ministry of Water, Land and Air Protection
Forest Renewal British Columbia Terrestrial Ecosystem Restoration Program
P.O. Box 9354, Stn. Prov. Govt., Victoria, B.C. V8W 9M1

Prepared by:
Marlene Machmer, Hillary Page, Chris Steeger, Pandion Ecological Research Ltd.
532 Park St., Nelson, B.C. V1L 2G9

MINISTRY OF WATER, LAND AND AIR PROTECTION STATEMENT

This plan is an example of the kind of work being done for terrestrial ecosystem restoration using prescribed fire. The Ministry of Water, Land and Air Protection does not necessarily support all of the conclusions and recommendations in the plan. Recommendations may be time sensitive and should be revisited as new science and information becomes available.

EXECUTIVE SUMMARY

The East Kootenay Trench Restoration Program is the largest, longest running terrestrial restoration initiative underway in British Columbia. By the year 2030, an estimated 135,000 ha of the Trench land base will be converted to an open range or open forest condition. Various monitoring and research initiatives have been conducted in conjunction with restoration treatments, however no overall monitoring plan is in place to evaluate how well current practices are working to meet restoration program goals and objectives. Trench ecosystems represent some of the most biologically diverse areas in the province, and support threatened grassland communities, significant populations of big game, and red- and blue-listed species. Considering the immense scale of planned restoration activities, systematic evaluation of treatment success is fundamental to ensure conservation of these resources.

This Effectiveness Monitoring Plan (EMP) for Trench restoration provides direction for design and implementation of monitoring activities, and sharing and extension of findings. Plan implementation will ensure that (a) a measure of ecosystem recovery is available to adaptively adjust and refine future restoration objective-setting, planning and implementation, (b) monitoring data and results are summarized and available to restoration practitioners to promote improvement in restoration practices within an adaptive management context, and (c) efficiency is maximized and costs are minimized for a given level of monitoring effort. Plan development involved reviewing NDT4 Trench Restoration Program objectives, planning, and practices, as well as past and ongoing monitoring activities and data. This information was used to identify monitoring needs, gaps and options, and to develop effectiveness monitoring objectives addressing four broad topic areas: (1) stand structure and overstory vegetation, (2) understory vegetation, (3) riparian and wetland habitat, and (4) wildlife and bioversity. This EMP provides a design, response variables, protocols, priority rankings, adaptive management recommendations to address 13 monitoring objectives.

Overall, the plan recommends *intensive* pre- and post-treatment (year 1, 3, 5, 10) monitoring at 4–6 restoration treatment sites in the Trench, with equal representation by biogeoclimatic zone (PP/IDF) and location (north/south). *Intensive* evaluation should be supplemented by *routine* monitoring at the majority (i.e., ≥75%) of remaining treated sites in the Trench, based on methods detailed in Appendix III. Estimates of person-days of monitoring effort (per site per year) are provided. Responsibility for EMP implementation (i.e., coordination of data collection, summary, storage, and interpretation) should be assumed by a single agency, and preferably to 1-2 key individuals for the program duration. The number of persons collecting data should also be minimized and protocols for data collection must be clearly communicated and followed, to ensure consistency. The agency above should also provide (or coordinate the delivery of) updates at 1–3 year intervals, depending on the phase of the overall program. The latter would summarize pertinent monitoring trends for resources, comment on interim treatment outcomes relative to restoration objectives or desired targets, and provide feedback for adaptive management to restoration practitioners. Additional recommendations for effectiveness and implementation monitoring are provided.

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ACKNOWLEDGEMENTS

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1.0 INTRODUCTION AND BACKGROUND

Dry, low elevation grasslands and open forests in the southern interior of British Columbia are ecosystems characterized by "frequent stand maintaining fires" (i.e., Natural Disturbance Type 4; Province of British Columbia 1995). An estimated 250,000 ha of Crown land within the Ponderosa Pine (PP) and Interior Douglas-fir (IDF) biogeoclimatic zones of the Rocky Mountain Trench and adjoining side valleys are classified as "fire-maintained" (Gayton 1997). Prior to European settlement, low intensity surface fires swept through these ecosystems at 5–25 year intervals (Dorey 1979; Arno 1988; Gayton 1998; Parminter and Daigle 1998), maintaining a complex mosaic of grassland, shrubland and open forest habitats. Recurrent fires promoted the development of fire-tolerant overstorys characterized by mature ponderosa pine, Douglas-fir, and western larch, with sparse regeneration, a vigorous understory of bunchgrasses, shrubs and forbs, and a low incidence of insects and diseases (Arno *et al.* 1995; Daigle 1996; Gayton 1996). Successful fire suppression has increased the fire return interval by as much as 60 years, resulting in excessive tree recruitment in open forests (i.e., forest ingrowth), as well as tree establishment in previously untreed openings (i.e., forest encroachment). Each year, approximately 3,000 ha of native grassland and open forest in the Trench are converted to a closed forest condition and an estimated 114,000 ha have been impacted since 1952 (Braumandl *et al.* 1994; Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000). Effects of this conversion are wide-ranging and include decreased forest health, degraded forage values for wildlife and domestic livestock, reduced timber quality and quantity, increased risk of catastrophic wildfire, establishment and spread of noxious weeds, and loss and degradation of critical wildlife habitat and biodiversity (Covington and Moore 1992, 1994; Wickmann 1992; Everett 1994; Fleischner 1994; Kremsater *et al.* 1994; Daigle 1996; Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000). Overgrazing, selective logging of old-growth trees, pruning and harvesting for Christmas tree production, and increased human settlement have also contributed to altered functioning in Trench ecosystems.

The need to rehabilitate Crown lands impacted by forest ingrowth and encroachment has long been recognized by interest groups, industry and government agencies in the East Kootenay. The Kootenay Boundary Land Use Plan (KBLUP) Implementation Strategy (British Columbia Ministry of Forests 1997) formally identified Trench restoration as a high priority and provided specific management guidelines for fire-maintained ecosystems. Government assigned responsibility for the delivery of a restoration program to a multi-sectoral Steering Committee comprised of government, industry and public representatives. This committee provides direction and oversees the progress of two working level sub-committees in the North and South Trench. The latter are responsible for operational planning and delivery of site-specific restoration activities on the ground, with Forest District Managers retaining their legislated responsibility for authorizing and approving restoration work on Crown lands.

The East Kootenay Trench Restoration Program is the largest, longest running terrestrial restoration initiative underway in the province. According to current projections, an estimated 135,000 ha of the Trench land base will be converted to an open range or open forest condition by the year 2030 (Rocky Mountain Trench Ecosystem

Restoration Steering Committee 2000). Once achieved, periodic prescribed burning is planned to maintain these restoration targets over the long-term. Various monitoring and research initiatives have been undertaken, are ongoing, or are planned in conjunction with restoration activities. However no overall monitoring plan is in place to evaluate how well current restoration practices are working to meet underlying goals and objectives.

IDF and PP ecosystems of the Trench represent some of the most biologically diverse areas in the province and support an impressive diversity of flora and fauna (Crane & Fischer 1986; Fischer and Bradley 1987; Bradley *et al.* 1992a,b; Bunnell 1992; Fischer *et al.* 1996; Holt 2001a,b). The latter include threatened grassland communities, significant populations of big game, and red- and blue-listed species that have all been negatively impacted by fire suppression policies (review in Machmer 2001). Considering the immense scale of NDT4 restoration activities planned over the next 30 years, systematic evaluation of treatment success is fundamental to ensure conservation of these resources.

This Effectiveness Monitoring Plan (EMP) for Trench restoration provides direction for planning of monitoring activities, and for evaluation and sharing of resulting information. Implementation of this plan will ensure that:
(a) a measure of ecosystem recovery is available to adaptively adjust and refine future restoration objective-setting, planning and implementation;
(b) monitoring data and results are summarized and available to restoration practitioners to promote improvement in restoration practices within an adaptive management context; and
(c) efficiency is maximized and costs are minimized for a given level of monitoring effort.

2.0 OBJECTIVES AND METHODS

In September of 2001, Pandion Ecological Research Ltd. was contracted to develop (a) provincial guidelines for effectiveness monitoring applicable to all restoration projects funded under Terrestrial Ecosystem Restoration Program (TERP), and (b) an effectiveness monitoring plan to evaluate the success of ongoing NDT4 restoration activities in the Rocky Mountain Trench. This document addresses the second objective by:
(a) reviewing NDT4 Trench Restoration Program goals, objectives, planning, and practices;
(b) reviewing current and planned monitoring activities and data;
(c) identifying monitoring needs, gaps and options for addressing gaps;
(d) exploring potential funding sources and commitments to undertake this program; and
(e) using all of the above information to develop an Effectiveness Monitoring Plan (EMP) for the Trench Restoration Program.

The EMP addresses general restoration goals and objectives, key restoration response variables to measure attainment of objectives, effectiveness evaluation design and monitoring protocols, recommendations for data collection, analysis, and sharing; projected monitoring costs; as well as other considerations. Completion of this plan involved:

(a) conducting interviews with government and non-government personnel involved in the planning, implementation and monitoring of NDT4 restoration activities in the north and south Trench (see Appendix 1);
(b) reviewing strategic documents and restoration plans related to general and site-specific management of fire-maintained ecosystems;
(c) reviewing technical documents and reports pertaining to past, current and future monitoring initiatives in conjunction with restoration activities; and
(d) reviewing monitoring literature as relevant to the selection and measurement of ecosystem response indicators at appropriate temporal and spatial scales.

Implementation of this plan should assist restoration practitioners in evaluating the success of current practices and in refining restoration treatments to promote greater effectiveness and efficiency in terms of overall Trench Restoration Program goals, delivery and outcomes.

3.0 INFORMATION REVIEW

3.1 Trench Ecosystem Restoration Goals and Objectives

Trench Ecosystem Restoration Program direction comes from the KBLUP fire-maintained ecosystem restoration guidelines. As identified in the Implementation Strategy (1997), restoration will achieve target distributions of four "ecosystem components" (i.e., shrublands, open range, open forest and managed forest; see Table 1) across the landscape. Restoration "treatments will contribute to the creation of a complex, ecologically appropriate mosaic of habitats over the longterm", and "treatments in open range and open forest will remove excess immature and understory trees and emphasize retention of the oldest and/or largest trees". With reference to restoration of fire-maintained ecosystems, the strategy further states that:

(a) "Initial restoration targets (Table 1) will be modified over time based on operational experience, long-term monitoring, and better scientific knowledge".
(b) "Once stands have received initial ecosystem restoration treatment, they will become part of a long term cycle of harvesting, spacing and prescribed burning that will optimize biodiversity, ecosystem health and resource flow".
(c) "Known information about red- and blue-listed species or species of management concern should be incorporated and addressed in ecosystem restoration plans".
(d) "Ecosystem restoration strategies for open forest and open range will take precedence over ungulate winter range guidelines to provide in part for increased forage production".
(e) "Ecosystem restoration plans will recognize the possibility that treatments may exacerbate the spread of noxious weeds and should incorporate mitigative control measures to pre-empt weed infestations in restored areas".

(f) "Forest health and wildfire suppression program objectives should be integrated with ecosystem restoration planning to achieve mutual benefits such as ecosystem health and public safety".

Clearly, the Implementation Strategy relies on long-term operational monitoring supplemented by research initiatives to provide feedback and to refine current knowledge in order to modify NDT4 restoration objectives, targets and practices over time. Although not explicitly stated, the strategy also addresses a number of restoration objectives, in addition to the quantitative targets prescribed for areal distribution of ecosystem components and stocking summarized in Table 1. The latter include objectives for retention of veteran and large trees and snags; conservation of wildlife habitat, biodiversity and red- and blue-listed species and communities; optimization of forage production; minimization of weed occurrence; and protection of ecosystem health.

TABLE 1. Restoration targets[1] for Crown land in the East Kootenay Trench at the end of 30 years (2030).

Ecosystem Component	**Stocking Target (trees/ha)**	**Current Distribution (% of Trench)**	**Final Distribution Target (% and ha of Trench)**
Shrubland	0	5 %	5 % (12,500 ha)
Open Range	≤ 75	10 %	23 % (57,500 ha)
Open Forest	76 – 400	combined open &	31 % (77,500 ha)
Managed Forest	400 – 5,000	managed forest is 85 %	41 % (102,500 ha)

[1] Targets are achieved within the Crown NDT4 land base at the forest district level.

3.2 Trench Ecosystem Restoration Practices

Restoration of open forest and open range areas in the Trench involves a variety of restoration practices or treatments (Table 2). Because of the variable history of each treatment unit, site conditions dictate what type and combination of treatments is carried out in any given area, and not every unit receives the same level or combination of treatments. Typically, restoration is accomplished through a three-phase rotational prescription (Powell *et al.* 1999). In phase one, ingrown stands are thinned from near full crown closure to between 20–70% crown closure. Site conditions and stand history dictate what type of tree removal (harvesting, spacing or slashing) is carried out. Harvesting involves commercial thinning of stands to remove intermediate-layer trees, whereas spacing and slashing removes pre-commercial intermediate layers of lodgepole pine and Douglas-fir to reduce the risk of crown fire during low intensity restoration burning. Logging slash is usually retained on site and contributes to prescribed fire fuel after curing for a minimum of one growing season. Similarly, treatment units are typically rested from grazing for at least one season prior to burning to allow for fine fuel build-up and ensure a ground fire of sufficient intensity. Phase two involving prescribed burning (i.e., broadcast, pile or sloop burning) is intended to kill tree seedlings and smaller undesirable trees, while minimizing fire damage to mature trees. Prescribed burning is most commonly conducted in spring shortly after snow has melted when relatively cool, wet conditions prevail, so as to minimize the

TABLE 2. Summary of Trench restoration treatment types, objectives, descriptions, and additional considerations (information supplied by Darrell Regimbald).

Treatment Types	Overall Treatment Objectives	Treatment Descriptions	Additional Considerations
Harvesting	▪ Return to open range or open forest condition (dependent on historic stand structure) based on stocking standards in KBLUP guidelines. ▪ Reduce fuel loading.	▪ Remove Pl. ▪ Retain pre-settlement Fd and Py.	▪ Can be followed by broadcast burning if not in close proximity to private land or protected areas.
Spacing	▪ Return to open range or open forest condition (dependent on historic stand structure) based on stocking standards in KBLUP guidelines. ▪ Reduce fuel loading.	▪ Remove suppressed understory comprised of sub-merchantable (i.e., stems <20 cm dbh). ▪ Remove sufficient fuel to allow for safe underburns.	▪ Spacing is used if timber is not merchantable, with harvest planned in future when stand is merchantable. ▪ Used mainly if the stand is largely comprised of small diameter conifers.
Slashing	▪ Reduce stand density based on stocking standards in KBLUP guidelines. ▪ Alter species composition to enhance stand quality. ▪ Provide cured fuel to carry a low intensity burn.	▪ Remove sub-merchantable (i.e., <20 cm dbh) thickets of Fd and Pl.	-
Post-harvest/burn slashing	▪ Reduce stand density based on stocking standards in KBLUP guidelines for open range or open forest condition (dependent on historic stand structure).	▪ Remove residual sub-merchantable (i.e., <20 cm dbh) stems not removed by burning or harvesting.	-
Broadcast burning	▪ Reduce regenerating conifer density. ▪ Enhance forage values by rejuvenating grass, forbs and shrubs. ▪ Maintain or enhance open stand structure. ▪ Reduce fire hazard.	▪ Kill tree seedlings and reduce regenerating conifer stem densities while minimizing fire damage to mature stems.	▪ Fall burns can be used to extend burning window. ▪ Treatment areas are rested from grazing for one season prior to burn.
Pile burning	▪ Enhance forage values by rejuvenating grass, forbs and shrubs. ▪ Maintain or enhance open stand structure. ▪ Reduce fire hazard.	▪ Kill tree seedlings and reduce regenerating conifer stem densities. Material is piled with machinery and burnt.	▪ Pile burns are usually used if areas are close to private land. ▪ Pile burns can be followed up with a broadcast burn. ▪ Can cause some soil disturbance.
Sloop burning	▪ Enhance forage values by rejuvenating grass, forbs and shrubs. ▪ Maintain or enhance open stand structure. ▪ Reduce fire hazard. ▪ Reduce disturbance caused by pile burns.	▪ Kill tree seedlings and reduce regenerating conifer stem densities. Material is piled with machinery and burnt in a "sloop" to reduce site disturbance.	▪ Sloop burns are used when minimal disturbance is desirable; the number of sloop burns is limited by high cost.
Maintenance	▪ Maintain restored stand structure. ▪ Rejuvenate forage and browse species and recycle nutrients. ▪ Maintain low fire hazard.	▪ Use combinations of restoration activities (i.e., periodic broadcast burning, harvesting and spacing).	-

probability of crown fire or escape. Fall burns are used to extend the period of time suitable for burning. A one season grazing deferment is usually implemented after burning to promote forage recovery. Phase three treatment involves periodic underburning of sites that have undergone initial treatment (or open range sites where tree densities are low) to maintain an open stand condition, rejuvenate forage and browse species, and recycle nutrients.

3.3 Trench Ecosystem Restoration Planning and Activities

Ecosystem Restoration (ER) Plans are developed at the Range Unit (RU) scale to guide restoration activities in the Trench. ER Plans zone Crown land into four major ecosystem components (note that Table 1 targets are achieved at the Forest District rather than the RU scale, so a particular RU could exceed or lack in any given component). RUs comprised of range pastures are logical treatment units for the implementation of restoration activities. Pastures can be managed as a single treatment unit before and after fire to minimize the confounding effects of grazing, and perimeter fireguards are usually present. Treatment units are then further subdivided into strata of variable sizes corresponding to past resource management activities, disturbance history, forest health concerns, and stocking, species and age classes. For each unit and stratum, ER Plans provide information with respect to site-specific treatment objectives, methods and scheduling based on the goal of re-introducing fire into most open range and open forest areas. Once all treatment units have attained their desired stand structure, a rotational prescription of burning, resting, stand tending, and harvesting to maintain desired stocking and crown closure levels is implemented.

Approximately 90 percent of the Trench land base requiring restoration treatment is currently included within an ER Plan. This includes seven high priority RUs out of 10 in the Invermere District and at least 19 of 25 RUs in the Cranbrook District, with most of remaining ER plans scheduled for completion over the next year (G. Anderson, pers. comm.). A Trench-wide scale "Strategic Restoration Plan" (which zones all polygons by ecosystem component based on a rolled-up version of the individual ER Plans) is available in draft form for the Invermere District and will eventually be completed for both districts.

Table 3 provides a summary of hectares treated from 1997/98–2000/01 as part of the Trench Restoration Program. Also provided are projected hectares for 2001/02 (the harvesting component is an estimate since winter harvesting is currently underway) and treatment projections for 2002/03, contingent on funding availability. A total of 17,890 ha have been treated over the last five years (7,306 ha or 40.8% prescribed burning; 7,032 or 39.3% mechanical slashing/spacing; 3,552 ha or 19.9% harvesting). Treatment totals continue to rise annually (based on projections for 2001/02 and 2002/03), although the allocation of treatment type and location varies considerably both within and between years (Table 3).

In terms of the spatial distribution of treatments, Appendix II provides a detailed summary of current and tentatively planned (1999–2007) restoration activities by RU and pasture in the Invermere Forest District. This schedule indicates that one or more pastures in a minimum of four RUs are scheduled for harvesting and/or slashing treatment during fall/winter 2002. These sites would be candidates for effectiveness monitoring beginning in 2002. A similar

TABLE 3. Summary of area (ha) treated or planned for treatment by fiscal year (1997/98–2002/03), location (North and South Trench), and treatment type (prescribed burning, mechanical slashing/spacing, and harvesting).

		Treatment Type		
Fiscal Year	**Location**	**Prescribed Burning (ha)**	**Mechanical – Slashing/Spacing (ha)**	**Harvesting – Open Range & Forest (ha)**
1997/98	North	560	0	Prior to OR/OF classification
	South	160	64	Prior to OR/OF classification
	Total:	720	64	n/a
1998/99	North	792	663	306
	South	673	315	1022
	Total:	1,465	978	1,328
1999/00	North	1,162	391	443
	South	308	611	497
	Total:	1,470	1,002	940
2000/01	North	621	753	325
	South	1,420	1,667	150
	Total:	2,041	2,420	475
2001/02	North	565	508	429 (planned)
	South	1,045	2,060	380 (planned)
	Total:	1,610	2,568	809 (planned)
1997/98 – 2001/02:	5-year Total:	7,306	7,032	3,552
2002/03 (projected)	North	1,538	1,257	To be determined
	South	1,260	2,195	To be determined
	Total:	2,798 (planned)	3,452 (planned)	To be determined

five-year schedule of activities is currently not available for Cranbrook District, however numbers of sites harvested or spaced/slashed annually are expected to be higher or comparable to those in Invermere (D. Petryshen, pers. comm.).

3.4 Ongoing, Planned, and Completed Monitoring Initiatives and Data

Ongoing, planned, and completed monitoring activities and data sources relating to restoration in the North and South Trench are summarized in Table 4. Monitoring conducted by the same proponent with similar objectives, sampling design, response variables, and sampling protocols at multiple sites are lumped as a single "initiative" for discussion purposes. Both operationally-oriented monitoring and research activities conducted by government and non-government personnel and agencies on public and private lands are included, so as to provide the broadest possible overview of what has been done to date. However, only those monitoring initiatives that evaluate the effects of treatments with an "NDT4 ecosystem restoration" objective *per se* are considered. Monitoring which addresses the effects of partial cutting treatments in managed forest zones (to meet timber objectives) and of prescribed burning treatments for ungulate habitat enhancement are excluded. Data and results associated with the monitoring/research initiatives in Table 4 can be found in selected unpublished documents. Citations to these are provided in cases where the initiatives are completed and where findings have been summarized in a written report (8 of 18 initiatives). At least six research/monitoring initiatives in the Cranbrook and Invermere districts are currently ongoing or planned (i.e., they have been initiated and some form of follow-up monitoring is scheduled within the next three years, contingent on continued funding availability). Twelve completed projects that evaluated

TABLE 4. Summary of ongoing, planned, and completed NDT4 restoration effectiveness monitoring (and research) initiatives and data for the North and South Trench.

Site Names & Locations	***District/ BEC Unit***	***Proponent (literature)***	***Monitoring Objectives***	***Sampling Design/ Schedule***	***Type of Monitoring***	***Type of Data Collected***	***Plot Type (s) and Size***	***Sampling Effort***
a. Ongoing and Planned:								
Wolf Pasture, Premier RU Central Pasture, Sheep Creek N. RU	Invermere PPdh2 Invermere IDFdm2	Reg Newman, MOF, Research Branch, Kamloops (Powell *et al.* 1999) and *Hillary Page, M.Sc. Candidate, University of Alberta (Page 2002, in prep.)	Determine the effect of opening the forest canopy (by thinning and spring burning) on the understory plant community and important forage and browse species. * Same objectives	Pre- (1999) and post-treatment (2000–2004 and then every 4-5 years thereafter) monitoring with 4 spatial controls. * Page conducted pre- (1999) and post-treatment (2000-2001) at same sites with 2 spatial controls/block and exclosures to control for grazing effects.	1. Understory vegetation 2. Forage and browse production 3. Overstory cover 4. Light penetration 5. Fire severity * Same monitoring type	1. % herbaceous and shrub cover by species 2. weight by species 3. estimated from cruise; visual estimate of % crown closure by layer 4. light penetration 5. duff thickness and woody debris cover * Page took additional measurements with greater sampling intensity pertaining to density of bunchgrasses and shrubs, forage & browse production in grazed and ungrazed plots, and permanent photopoints	1. 20x50 cm frames for herbs; 1x2 m plots for shrubs 2. 0.5x1 m plots 3. 20 cruise plots 4. 20 plots 5. 10 points for duff; 10 plots for debris * bunchgrass & shrub density: 1x10 m plots for bunchgrass; 2x10 m plots for shrub * forage & browse production: 0.5x1 m plots (grazed); 1.2x1.2 m plots (ungrazed)	1. 10 frames/macroplot x 20/site =200 2. 4 plots/macroplot x 20/site =80 3. 20 plots total 4. 20 plots/ macroplot x 20/site =400 5. 10/macroplot x 20/site =200 * bunchgrass & shrub density: 2 plots/macroplot x 20/site =40 * forage & browse production: 4 plots/macroplot x 20/site =80 (grazed); 2 plots/5 macroplots =10/site (ungrazed) photopoints: 2 photopoints/plot x 20/site =40
Strauss Road Gold-Plumbob RU Newgate Newgate RU	Cranbrook IDFdm2 Cranbrook IDFdm2	Deb Delong, MOF, Nelson Region (Delong 2001 TERP application; Hawe and Delong 1997; Dykstra and Braumandl 2001, in prep.)	Evaluate long-term stand structure response to NDT4 old-growth restoration treatments (partial cutting & prescribed underburning).	Strauss: Ongoing two (1999) and five-year (2001) post-treatment monitoring of overstory & understory in 1 treated site and 1 adjacent control (control established in 2001). Newgate: Ongoing two (2000) and five-year (2002) post-treatment monitoring of overstory and understory in 1 treated area and 1 adjacent control (control established in 2002).	1. Overstory vegetation - trees in mature, pole, sapling, regen and germinant layers 2. Understory vegetation - forb, grass and shrub species 3. Wildlife trees - availability and use (Strauss only)	1. live tree number, species, diameter, height, % live crown; presence of harvesting damage, windthrown trees, or forest health agents 2. presence, cover and biomass of all forb, grass and shrub species 3. number, diameter, condition and use of wildlife trees within patches (Strauss only)	1. nested fixed radius plots (11.28, 3.99, and 1.78 m radius for mature, pole/ sapling/ regeneration and germinants, respectively) 2. 15 x 20x50 cm frames for forbs & grasses in macroplot; 3 x 11.28 m transects for shrubs in macroplot 3. assessment of all wildlife trees in 10 patches (Strauss only)	1. 15 random nested plots/site 2. 15 frames x 15 macroplots = 225 frames/site; 3 transects/macroplot x 15 macroplots = 45 transects/site 3. Complete assessment of 10 patches (Strauss only)
Wapitti Lake, Colvalli RU East Columbia Lake RU Dump Pasture, Grasmere RU Mudd Creek (sites tentative)	Cranbrook IDFdm2 Invermere IDFdm2 Cranbrook PPdh2 Invermere IFDdm2	Marlene Machmer, Pandion Ltd., Nelson (Machmer 2001 TERP Work Plan)	Evaluate restoration treatment effects (slashing/prescribed burning and harvesting/ prescribed burning) on biodiversity (with emphasis on rare vertebrates & vascular plant species) and stand-level habitat attributes.	Pre-treatment data collection starts in spring 2002 at 2 of 4 200 ha sites; post-treatment monitoring in year 1 and 4 after burning (2004–2009).	1. All vertebrate wildlife and red and blue listed species 2. Rare vascular plant species/ communities 3. Stand attributes (overstory & understory vegetation, large trees, snags, CWD, deciduous trees)	1. Presence and relative abundance (breeding density and reproductive success for selected birds) of birds, mammals & herptiles 2. presence and abundance of listed species and communities 3. abundance, characteristics and wildlife use of stand attributes	1. call playback surveys; variable radius point counts; intensive nest searches 2. habitat-specific search to provide systematic coverage 3. nested fixed radius plots (25.23, 17.84, 11.28, 2.52 m)	1. 50 playbacks/season/site; 60 point counts/season/site; 200 ha site searched 120 person days/season 2. 5 person-days/ season 3. 60–90 plots/200 ha site

Site Names & Locations	***District/ BEC Unit***	***Proponent (literature)***	***Monitoring Objectives***	***Sampling Design/ Schedule***	***Type of Monitoring***	***Type of Data Collected***	***Plot Type (s) and Size***	***Sampling Effort***
Plot Pasture Ta-Ta Skook RU	Invermere PPdh2	Gail Berg MOF, Invermere District	Evaluate plant community response to restoration burning.	Completed pre-treatment (2001) data collection; site is slated for restoration burning spring 2002.	1. Understory vegetation 2. Overstory cover	1. % herbaceous and shrub cover by species 2. % shrub cover by species 3. visual estimate of % crown closure by layer	1. 20x50 cm frames for herbs 2. 10x10 m plots for shrubs 3. 20x20 m plot for overstory	1. 15 frames/transect x 2-30 m transects = 30 2. 2 quadrats/transect x 2-30 m transects = 4 3. 1 quadrat/transect x 2-30 m transects = 2
Reed Pasture Ta-Ta Skook RU	Invermere PPdh2	Gail Berg MOF, Invermere District	Track visual changes in plant community after restoration burning.	Post-treatment data collected (2000); further data collection planned (3 years).	1. Understory cover 2. Overstory cover	1. photo interpretation	1. permanent points	1. 1 photopoint x 4 sites = 4
Reed Pasture Ta-Ta Skook RU	Invermere PPdh2			Pre-treatment (2001) data collected; post-treatment data collection planned (2002);				1. 3 photopoints x 4 sites = 12
Dry Gulch Pasture Sheep Creek North RU	Invermere IDFdm2/ PPdh2 transition			Pre- (2000) and post-treatment data collected (2001); further data collection planned (2002).				1. 1 photopoint x 4 sites = 4
Height of Land Pasture Frances Creek RU	Invermere IDFun			Pre- (2000) and; post-treatment data collected (2001); further data collection planned (2002).				1. 3 photopoints x 4 sites = 12 photos
Stinky Pasture Findlay-Basin RU	Invermere IDFdm2			Pre-treatment (2000) data collected; post-treatment data collection planned (2002).				1. 1 photopoint x 4 sites = 4 photos
Norbury Pasture, Peckhams Lake RU	Cranbrook IDFdm2	Tim Ross for Rocky Mountain Trench Natural Resources Society Ross 2000	Evaluate plant community response to restoration treatment (harvesting, prescribed burn).	Pre-treatment (1998) and post-harvest (1999) data collection completed; post-burn sampling planned.	1. Reconnaissance level survey of understory and overstory	1. description of tree, shrub and herb layers 1. permanent photopoints	1. in all polygons 2. permanent photopoints	1. 9 polygons 2. 2 photopoints/ polygon = 18
b. Completed:								
Kikomun Creek Park Waldo RU	Cranbrook PPdh2	Tim Ross for B.C. Provincial Parks, Wasa (Ross 1999)	Evaluate plant community response to restoration treatment (partial cutting, thinning and slashing).	Completed pre- and post-treatment data collection in three paired treatment/control monitoring plots.	1. Vegetation community	1. overstory, understory and regeneration layer cover and frequency 2. shrub cover and frequency 3. grass and herb cover and frequency	1. 1x2 m plots 2. 1x2 m plots 3. 20x50 cm frames; 1 photopoint/ 50 m transect	1. 10 plots x 5 transects/polygon = 50 2. 10 plots x 5 transects/polygon = 50 3. 10 frames x 5 transects/polygon = 50; 5 photopoints/polygon
Tata Creek, Cherry-Tata RU	Cranbrook IDFdm2/ PPdh2 transition	Marlene Machmer, Pandion Ltd., Nelson (Machmer 2000; 2001)	Evaluate the effects of NDT4 restoration treatments (harvest, burn, harvest & burn) on cavity-nesting bird community, their habitat and insect prey base.	Completed pre-treatment (1996), post-harvest (1997) and two year post-burn (1998, 1999) for harvest only, burn only, harvest & burn, and 2 control sites (4 of 5 20 ha sites adjacent to one another).	1. Bird community 2. Wildlife trees – availability and use	1. nesting density, relative abundance, and species richness of cavity nesting birds 2. number, diameter, height, decay class, defects, disease agents, and use on wildlife trees 3. number and family/species diversity of arboreal insects	1. intensive nest searches of 20 ha sites; fixed radius (75 m) point counts 2. 11.28 m fixed radius plots 3. Lindgren funnel traps	1. 20 ha sites searched 12 person- days per season 2. 1 plot/ha (20 total) sampled per site x 5 sites 3. 4 traps/20 ha site x 5 sites

Site Names & Locations	***District/ BEC Unit***	***Proponent (literature)***	***Monitoring Objectives***	***Sampling Design/ Schedule***	***Type of Monitoring***	***Type of Data Collected***	***Plot Type (s) and Size***	***Sampling Effort***
Tata Creek, Cherry-Tata RU	Cranbrook IDFdm2/ PPdh2 transition	Tim Ross for Rocky Mountain Trench Natural Resources Society, Kimberley (Ross 1998)	Evaluate the effects of NDT4 restoration treatments (harvest, burn, harvest & burn) on plant community response and forage production.	Completed pre-treatment (1996), post-harvest (1997) and two year post-burn (1998, 1999) for harvest only, burn only, harvest & burn, and 1 control site (20 ha sites all adjacent to one another). Small exclosures used to control for grazing effects.	1. Herbaceous vegetation 2. Forage & browse species	1. % cover and frequency by species 2. forage production (weight by species)	1. 20x50 frames 2. 1x1 m enclosures; permanent photopoints	1. 10 frames x 10 transects x 4 sites = 400 2. 2 grazed and 2 ungrazed enclosures/ transect x 10 transects x 4 sites = 160; 3. 1 photopoint/ transect x 10 x 4 = 40
Tata Creek, Cherry-Tata RU	Cranbrook IDFdm2/ PPdh2 transition	Rocky Mountain Trench Natural Resources Society, Kimberley (Penniket & Associates Ltd. 1998)	Evaluate the effects of NDT4 restoration treatments (harvest, burn, harvest & burn) on stand structure, woody fuels, and insect and disease incidence.	Completed pre-treatment (1996), post-harvest (1997) and two year post-burn (1998, 1999) for harvest only, burn only, harvest & burn, and 1 control site (20 ha sites all adjacent to one another).	1. Stand structure 2. Woody debris 3. Insect & disease occurrence	1. number by species (height, dbh, of sample trees only) 2. size, length, decay of coarse fuels; size class, length for fine fuels 3. damage and stage of attack for all trees	1. variable radius prism plot (BAF 2) for layer 1; fixed radius (7.98 m) plots for layers 2, 3, 4 2. 30 m random line transect; permanent photopoints 3. fixed radius (5.64 m) plot	1. 10 plots/site for layer 1 = 40; 20 plots/site for layer 2, 3, 4 = 80 2. 10 plots/site = 40; 1 photopoint/transect 3. 10 plots/site = 40
Elk Pasture, Wolf-Sheep Creek RU Johnson Lake Pasture & Skookumchuck Pasture, West Rotation, Sheep Creek North RU Springbrook Pasture, North Rotation, Sheep Creek North RU	Invermere IDFdm2 Invermere IDFdm2/ PPdh2 transition Invermere IDFdm2	Gail Berg MOF, Invermere District	Evaluate plant community response to restoration burning.	Completed pre-treatment (1997) data collection; post-burn (1999-2001). Completed pre-treatment (1997) data collection; Post-burn (1999-2001). Completed pre- (1997) and post-burn (1999-2001) data collection.	1. Understory vegetation cover and composition 2. Overstory cover	1. % herbaceous and shrub cover by species 2. % shrub cover by species 3. visual estimate of % crown closure by layer	1. 20x50 cm frames for herbaceous cover 2. 10x10 m plots for shrubs 3. 20x20m plot for overstory	1. 15 frames x 3-30 m transects = 45 2. 2 quadrats x 3-30 m transects = 6 3. 1 quadrat x 3-30 m transects = 3 1. 15 frames x 4-30 m transects = 60 2. 2 quadrats x 4-30 m transects = 8 4. 1 quadrat x 4-30 m transects = 4 1. 15 frames x 3-30 m transects = 45 2. 2 quadrats x 3-30 m transects = 6 3. 1 quadrat x 3-30 m transect = 3
Rushmere Pasture, Westside RU Wolf Pasture, Wolf–Sheep Creek RU	Invermere IDFun Invermere PPdh2	Gail Berg MOF, Invermere District	Evaluate plant community response to thinning and restoration burning. Evaluate plant community response to restoration thinning and pile burning	Completed pre-treatment (1996) and post-treatment (2001) data collection. Completed pre-treatment (1997) and post-burn (1999-2001) data collection; post-burn (2001) collected for pile burning effects only	1.Understory vegetation cover and composition 2. Overstory cover 1. Understory vegetation cover and composition 2. Overstory cover (data not collected for pile burning effects)	1. % herbaceous and shrub cover by species 2. % shrub cover by species 3. visual estimate of % crown closure by layer	1. 20x50 cm frames for herbaceous cover 2. 10x10 m plots for shrubs 3. 20x20 m plot for overstory 1. 20x50 cm frames for herbaceous cover. 2. 10x1 0m plots for shrubs. 3. 20x20 m plot for overstory. 4. 0.5 m fixed radius plots for pile burning effects (located around pile burns).	1. 15 frames x 2-30 m transects = 30 2. 2 quadrats x 2-30 m transects = 4 3. 1 quadrat x 2-30m transects = 2 1. 15 frames x 1-30 m transect = 15 2. 2 quadrats x1-30 m transect = 2 3. 1 quadrat x 1-3 0m transect =1 4. 5 plots

Site Names & Locations	***District/ BEC Unit***	***Proponent (literature)***	***Monitoring Objectives***	***Sampling Design/ Schedule***	***Type of Monitoring***	***Type of Data Collected***	***Plot Type (s) and Size***	***Sampling Effort***
Sheep Pasture, Wolf-Sheep Creek RU	Invermere IDFdm2/ PPdh2 transition	Darrell Smith and Gary Tipper for MoF and the Provincial Exclosure Program (Smith and Tipper 1999)	1. Evaluate trends in understory vegetation species composition in the absence of grazing and in response to restoration burning. 2. Track visual changes in plant response to prescribed burning.	1. Completed pre-treatment (1991-1994) and post-burn (1998, 2001) data collection. 2. Completed pre-treatment (1999) and post-burn (1999-2001) data collection. Exclosure used to control for grazing effects.	1. Understory vegetation cover and composition 2. Overstory cover	1. % herbaceous and shrub cover by species (grazed and ungrazed) 2. % shrub cover by species (grazed and ungrazed) 3. visual estimate of % crown closure by layer (grazed and ungrazed) 4. photopoints (different location than above) **permanent exclosure established at this site in 1990**	1. 20x50 cm frames for herbaceous cover 2. 10x10 m plots for shrubs 3. 20x20 m plot for overstory	1. 15 frames x 5-30 m transects = 75 frames inside the exclosure; 75 frames outside the exclosure 2. 2 quadrats x 5-30 m transects = 10 quadrats inside the exclosure; 10 quadrats outside the exclosure 3. 5 sites in various locations x 4 photos/site = 20
Saddle Pasture, Findlay-Basin RU	Invermere IDFdm2	Gail Berg MOF, Invermere District	Track visual changes in the plant community to thinning and restoration burning.	Completed pre- (1997) and post-treatment (2001) data collection	1. Understory cover 2. Overstory cover	1. Photo interpretation	1. permanent points	1. 4 photos/site x 4 sites = 16
Bull Mountain Powerplant RU	Cranbrook PPdh2	Larry Ingham, CBFWCP, Invermere	To determine the effect of thinning and burning on plant community.	Completed pre- (1999) and post-treatment (2000, 2001) data collection at 1 open forest and 1 open range site.	1. Herbaceous cover 2. Shrub cover 3. Tree cover	1. % cover & density of key species 2. % cover & density of key species 3. % cover of all species	1. fixed radius 1.26 m plots 2. fixed radius 5.24 m plots 3. fixed radius 11.26 m plots	1. 26 plots/site x 2 sites = 52 2. 26 plots/site x 2 sites = 52 4. 26 plots/site x 2 sites = 52
St. Marys Prairie Cherry-Tata RU Tata-Skook RU	Cranbrook PPdh2 Cranbrook PPdh2 Cranbrook PPdh2	Tim Ross for B.C. Ministry of Forests, Research Branch (Ross *et al.* 1998)	Examine (1) composition of the herbaceous and shrub layer and (2) relationship between canopy closure light penetration following spacing/burning treatments.	Completed retrospective study of sites treated 15-20 years ago as follows: a. spaced to 400 sph; b. spaced to 400 sph and burned; c. spaced to 700 sph; d. spaced to 700 sph and burned; e. spatial control	1. Herbaceous cover 2. Shrub cover 3. Tree cover 4. Light penetration	1. % herbaceous cover by species 2. % shrub (<1.5 m ht.) cover 3. % tree cover 4. diffuse non-interceptance measurements	1. 20x50 cm frames; permanent photopoints 2. 1 x 2 m plots 3. 1 x 2 m plots 4. 20x50 cm frames and control	1. 10 frames on a 50 m transect/site; 1 photopoint/transect/site 2. 10 plots on a 50 m transect/ site 3. 10 plots on a 50 m transect/ site 4. 10 frames on a 50 m transect/ site
Finlay Creek Findlay-Basin RU Picture Valley Peckhams RU	Invermere IDFdm2 Cranbrook IDFdm2	Tom Braumandl, MOF, Nelson Region (EMBER 1995; Gayton *et al.* 1995; Kayll 1995)	Evaluate effects of low intensity burning on stand structure, understory vegetation, insects & diseases.	Completed pre-(1993), during (1994) and post-burn (1995 and additional re-measurements) sampling in paired treatment and control areas.	1. Overstory structure and mortality 2. Shrub composition & utilization 3. Forb & grass cover 4. Woody fuels 5. Insect/disease presence	1. number of live and dead layer 1, 2, 3 and 4 trees by dbh class 2. % shrub cover , density & biomass 3. % cover by species 4. number & piece diameter 5. presence of insects or diseases on layer 1, 2, 3, 4 trees	1. fixed radius plots (5.64 m for layer 1; 7.98 m for layers 2, 3, 4) 2. 5 random plots on 30 m transect 3. 10 plots on 30 m transect; permanent photopoints 4. 30 m transect 5. fixed radius 5.64 m plots	1. 20–30 plots/area for layer 1; 10–15 plots/area for layers 2, 3, 4 2. 5 plots x 5 transects = 25/site 3. 10 plots x 5 transects = 50/site; 5 photopoints/site 4. 5 transects/site 5. 20–30 plots/site
Finlay Creek Findlay-Basin RU Picture Valley Peckhams RU	Invermere IDFdm2 Cranbrook IDFdm2	Steve Taylor, Canadian Forest Service (EMBER 1995; Gayton *et al.* 1995)	Evaluate effects of low intensity burning on fire behavior and smoke emissions	Completed sampling before and/or during burn in treatment areas.	1. Surface temperature 2. Fire spread & growth 3. Fire behavior & weather 4. Fuel moisture 5. Smoke chemistry & atmospheric conditions 6. Smoke dispersion	1. surface temperature 2. fire spread and area growth 3. temperature, relative humidity, windspeed & direction, precipitation 4. moisture content of litter, forest floor % tree foliage 5. concentration of CO, CO_2, NO, O_2, particulate matter, trace gases 6. height, rate of rise and movement	1. thermologger 2. infra-red imagery & digital image analysis from helicopter 3. weather station 4. before burning - no methods given 5. ground-based FASS system 6. fixed wing aircraft	1. each site 2. each site during burn 3. 1 station/site 4. each site 5. each site during burn 6. each site during burn

restoration treatment effects are also shown in Table 4. Of the 18 initiatives, 15 involve pre- and post-treatment sampling (6 have spatial controls) and 2 are retrospective (i.e., post-treatment monitoring only with comparisons to controls). One additional study gathered data on fire behavior during treatment implementation (EMBER 1995). Most of these initiatives (72%) involve data collection at multiple sites and/or in more than one treatment unit. Six (33%) projects monitored prescribed burning treatment alone, and the remainder considered treatments involving thinning followed by burning. Only the experimental projects at Ta Ta Creek (i.e., Penniket & Associates Ltd. 1998; Ross 1998; Machmer 2000, 2001) monitored comparative effects of burning only, harvesting only, and harvesting & burning with controls. The retrospective evaluation by Ross *et al.* (1998) compared harvesting only versus harvesting and burning with a control.

Of the 18 projects total, most (15 or 83%) focus on understory vegetation response to restoration treatment(s). Sampling methods range from basic range reconnaissance-level surveys (1 of 15) to permanent photo-points for visual assessment (8 of 15), to more intensive sampling involving determination of % species cover, density, and/or biomass of forbs, grasses and shrubs (12 of 15). The latter is used to estimate annual forage production, sometimes with a comparison between grazed and ungrazed plots to approximate forage utilization. Thirteen of 18 (72%) initiatives address overstory response, which usually involves measuring and/or photographing changes in the percentage overstory cover (11 of 13). Only 5 of 18 (28%) initiatives consider stand structure and/or quantify restoration treatment effects on specific structural attributes, such as wildlife trees or coarse woody debris. Effects of restoration on forest health parameters (e.g., presence of insects and diseases) have received little attention (2 of 18 or 11%). Similarly, only two initiatives (11%) consider effects on biodiversity: one current project considers general biodiversity (emphasis on listed wildlife and vascular plant species and communities) and a completed study evaluates cavity-nesting bird and insect prey abundance and diversity. Two studies (11%) gather concurrent data on fire behavior (see Steve Taylor's project and Reg Newman's work which uses differences in pre- and post-treatment duff thickness and woody debris cover as an index of fire severity) that can be used to link effectiveness monitoring results to treatment implementation.

Other potential sources of monitoring information to evaluate effectiveness of restoration treatment(s) include data gathered in post-mechanical treatment stocking assessment (i.e., "quality assurance plots"). These plots are typically sampled (intensity of 1 plot/ha) to ensure that desired post-treatment stem densities have been achieved, however only visual assessments are conducted in some cases (D. Petryshen, pers. comm.). A visual fire hazard assessment is usually conducted prior to prescribed burning and a post-treatment fire severity assessment may also be conducted upon completion.

There are several sources of information and data that are relevant to defining current "baseline" conditions for selected resource values in the Trench. Ross (1997) compiled baseline vegetation data while evaluating dietary overlap, forage and browse use, and impacts of wildlife and cattle grazing on four key deer and elk winter ranges in the North and South Trench (i.e., Skookumchuck Prairie, Premier Ridge, Pickering Hils and Peckhams Lake).

Additional monitoring (3–5 years of data) inside and outside of large exclosures at these same sites provides relatively consistent measures of forage utilization by cattle and wildlife (D. Gayton, pers. comm.). Gray (2001) and Gray *et al.* (in press) gathered stand structure data while undertaking stand reconstruction investigations at several sites in the Trench. Various inventories and research studies conducted in the Trench by MOELP on ungulates and by consultants (Bob Ferguson, Marlene Machmer, Nancy Newhouse, Chris Steeger, Kari Stuart-Smith) on breeding birds, mammals and stand-level structural attributes could also provide baseline data.

3.5 Monitoring Needs, Gaps and Options

Summary observations regarding the focus of past, ongoing and planned Trench restoration monitoring and research initiatives are provided here, in order to elucidate gaps and formulate monitoring needs:

- Monitoring and research efforts have provided reasonable representation by biogeoclimatic zone (IDF/PP), forest district (Invermere/Cranbrook), and RU location.
- Both the effects of burning alone and thinning followed by burning have been monitored to some extent. Methods used include: (i) mainly a before and after time-series approach (Green 1979), (ii) occasionally a "quasi-experimental" design (Before-After-Control-Impact; BACI) involving concurrent data collection in un-restored spatial control(s), and (iii) in one case, retrospective methods investigating sites treated 15–20 years ago.
- Evaluations to date have focused to a large extent on understory vegetation response to restoration, particularly as it relates to the quantity and quality of key forage species and native vegetation species (e.g., bluebunch wheatgrass, rough fescue, Stipa *spp*.). Only a few of these initiatives have controlled for the effects of grazing and browsing with exclosures. This tends to mask and confound interpretation of vegetation response to treatment and limit the detection of overall patterns from the individual monitoring efforts.
- Effects of restoration on overall stand structure and composition (i.e., density of trees by species, diameter, height and decay classes) and relative abundance and characteristics of specific stand-level attributes (e.g., veteran and large-diameter trees, snags, and coarse woody debris) have been infrequently monitored. This is despite the fact that stand reconstruction studies emphasize the departure of ingrown stands from their historic range of variability (Covington and Moore 1992; 1994; McAdamas 1995; Arno *et al.* 1995, 1997; Edminster and Olsen 1996; Fieldler *et al.* 1997; Covington *et al.* 1997; Fule *et al.* 1997; Hillis *et al.* 2001). Where monitoring has occurred, plot sizes are often inadequate to provide a reliable estimate of overstory density, particularly for those features that naturally occur at lower densities (e.g., very large trees and snags).
- Effects on wildlife, biodiversity and on plant and animal species and communities at risk have received little attention to date (see review in Machmer 2001). This is understandable because of the time, effort, and cost required to comprehensively sample these components over large areas in conjunction with treatment. As a result, research and monitoring initiatives have generally adopted a habitat-based coarse filter approach.
- There has been little monitoring or research in the Trench on the effects of NDT4 restoration treatments on insect and disease conditions, or on the establishment and spread of non-native vegetation.

- Another issue raised by the monitoring to date is the apparent lack of concurrent monitoring of variables related to weather and fire behavior and conditions (see Western Region Prescribed Fire Monitoring Task Force 1991 for a list of recommended variables to measure). Information on the latter is essential to evaluate the accuracy of treatment implementation and to correctly interpret the results of effectiveness monitoring.
- The majority of the "routine" monitoring has been undertaken by MOF staff (mainly Invermere District personnel), with the remainder conducted by graduate students, staff, and contractors working for B.C. Ministry of Forests, Ministry of Environment, Lands and Parks, Provincial Parks, Columbia Basin Fish & Wildlife Compensation Program, Rocky Mountain Trench Natural Resources Society, and the Canadian Forest Service. Monitoring approaches, methods, intensity and emphasis vary considerably by organization/project. This tends to limit potential comparisons between project monitoring outcomes and formulation of general trends.

Based on our review, it appears that considerable monitoring of restoration treatments has already been undertaken, but results of these efforts have not consistently been documented, summarized, and communicated to promote adaptive management. Future monitoring efforts might benefit from a more strategic and consistent approach, particularly in light of reduced provincial funding projections in future years. Such an approach might involve three tiers: (1) *intensive* monitoring at a subset of operational restoration sites to quantify treatment effects on key resources; (2) *routine* monitoring at the majority of operational restoration sites to provide qualitative ecosystem recovery data that can support intensive findings; and (3) parallel research studies involving replicated treatments and controls to investigate causal mechanisms underlying monitoring results.

These tiers should be pursued by the agencies or parties that have the appropriate capacity (i.e., personnel, funding, expertise). For example, routine monitoring could be conducted in-house at the district level, as is currently the case in the Invermere District. If this is not practical, then routine monitoring could be contracted out under district direction. Intensive monitoring is much more time-consuming and requires a greater level of expertise and consistency in terms of long-term data collection. It might be more appropriately conducted by contractors, with the coordination and administration centralized within one agency (e.g., MOF). Pure and applied research to supplement monitoring should be driven by researchers affiliated with academic institutions or restoration practitioners working for (or in partnership with) various agencies or groups involved in Trench ecosystem restoration.

Irrespective of the monitoring delivery mechanism, long-term consistency in the way that the data is collected, summarized, stored, and interpreted must be emphasized. A single agency (and preferably 1-2 key individuals) should assume responsibility for the summary, storage and interpretation of monitoring data. A formal mechanism for interim reporting of monitoring activities and findings is an important and often forgotten link in the monitoring process (see recommendations to promote adaptive management in section 4).

3.6 Potential Funding Sources and Commitments

Funding for operational restoration activities on Crown lands has been provided through a number of government and non-government sources (Table 5). Funding commitments have risen substantially over the last five years, as have the number of funding sources contributing to restoration efforts. Annual funding for this program averages $364,402, based on confirmed funding over the last five years (1997/98–2001/02).

TABLE 5. Summary of funding sources and commitments by year for Trench restoration activities.

Funding Sources	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03
CBFWCP	7,520	59,300	91,000	95,500	140,000	130,000
CBT	-	-	-	96,500	-	-
GEF	-	50,000	105,225	108,350	154,160	160,000[2]
HCTF	-	55,000	50,000	34,500	-	83,500
FRBC	-	3,970	35,050	-	-	-
LUCO	-	35,000	-	-	25,000	-
MOE Grant	-	-	-	50,000	-	-
MAFF GRANT	-	-	-	50,000	-	-
MOF	-	-	910	-	-	-
MOF/EFMPP	25,000	28,525	-	-	-	-
MOF/KLA GRANT	-	-	-	50,000	50,000	-
PREMIER'S SHEEP	-	-	-	-	20,000	-
RMEF	-	-	35,500	19,620	-	-
RMEF/MWLAP GRANT	-	-	-	-	40,280	-
TERP/FRBC	-	-	-	68,100	238,000	-
Carryover Funds	-	-	-	-	-	105,000
Totals	$32,520	$231,795	$317,685	$572,570	$667,440[1]	$318,500

[1] Unallocated and carried over: RMEF/MWLAP – $40,000; GEF/MAFF GRANT – $65,000

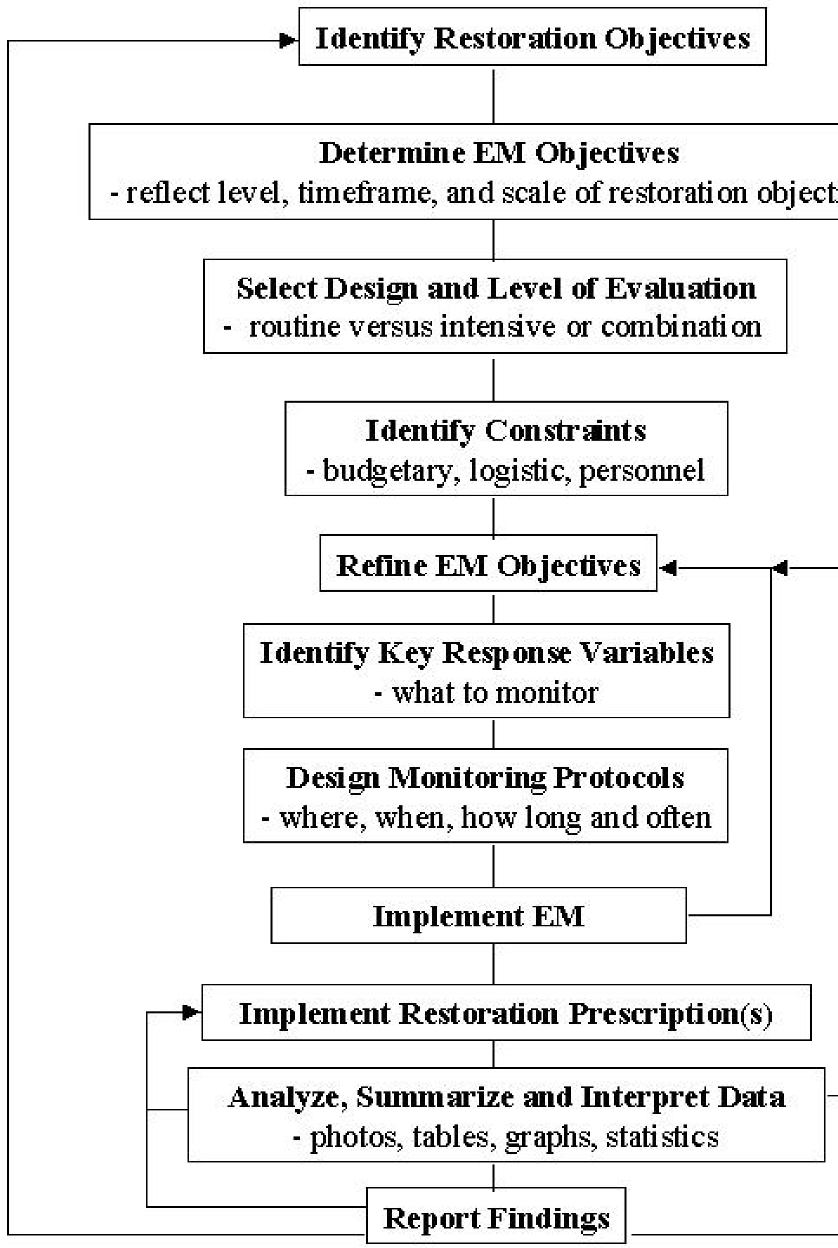
[2] Unconfirmed: GEF – $160,000

If EM budgets for the Trench Restoration Program were comparable to those recommended for routine monitoring under the Watershed Restoration Program (WRP), then they would not exceed 6% of the annual budget (Gaboury and Wong 1999) or an estimated cost of $21,864.12 in an average year. This level of EM funding may provide reasonable coverage for *routine* monitoring at the "program level", but additional funding is required for *intensive* "site level" monitoring. We suggest that a minimum annual budget of 10% (i.e., $36,440.20) would be reasonable to spearhead an EM program for Trench Restoration. This figure assumes that parallel research initiatives are underway to (i) adequately address ecosystem values that monitoring budgets cannot, and (ii) investigate the causal mechanisms that underlie the monitoring results.

4.0 Trench Ecosystem Restoration Program EMP

The following EMP is consistent with effectiveness monitoring guidelines developed for all restoration projects funded under the TERP program (Machmer 2001 draft). The steps involved in conducting effectiveness evaluations are shown in Figure 1.

Figure 1. Steps in the design, implementation, and summary of terrestrial ecosystem effectiveness evaluations (adapted from Gadboury & Wong 1999).



4.1 Trench Ecosystem Restoration Objectives

In the context of ecosystem restoration, *effectiveness monitoring* (EM) addresses the question of how successful a project ultimately is at restoring the ecosystem and/or its component parts (Noss and Cooperrider 1994; Morrison and Marcot 1995). It involves assessing the degree of success of a restoration initiative in relation to initial objectives. Restoration objectives must be explicitly stated, measurable, and have a designated time element so that their success can be evaluated (Clewall *et al.* 2000). They should also be firmly based on a reference ecosystem, historic range of variability and/or desired future conditions (White and Walker 1997). EM is a critical component of an adaptive management approach to ecosystem restoration, or to any other resource management activity (Taylor *et al.* 1997; Morrison 2001). Monitoring feedback is used to modify or refine restoration practices, and to promote improved restoration success, greater efficiency and lower costs over time.

The overall goal of the Trench Restoration Program is "to remove excess immature and understory trees over the next 30 years to create a complex ecologically appropriate mosaic of habitats on vacant Crown lands of the Trench" (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000). This mosaic is intended "to mimic the landscape under natural conditions, when fire was an integral part of the ecosystem". The KBLUP guidelines provide quantitative objectives for the area (ha) and target tree stocking densities (trees/ha) of shrubland, open range, open forest, and managed forest components (Table 1). However the KBLUP does not provide quantitative objectives for other ecosystem values (e.g., forage biomass, veteran and large diameter trees and snags, large coarse woody debris, native and non-native vegetation, biodiversity and wildlife habitat, soils, insects and diseases) that were also components of NDT4 landscapes prior to fire suppression. To evaluate Trench Restoration Program success within an ecological context requires that objectives for key ecosystem values be explicitly stated. Objectives for these values are typically formulated in SPs and SMPs prepared for restoration treatment sites. In the absence of "program-driven" objectives, we have reviewed SPs and SMPs and developed generic restoration objectives, with a brief rationale for each. In Appendix III, restoration objectives are linked directly to effectiveness monitoring objectives, with a recommended design, response variables, protocols, priority rankings, and adaptive management recommendations to address each one.

Stand Structure and Overstory Vegetation:

<u>*Restoration Objective 1:*</u>

Reduce tree density, increase tree size, and achieve a tree species composition that falls within the historical range of variability for treated areas (based on aspect, slope, topography, moisture, etc.).

<u>*Rationale:*</u>

Several studies have reconstructed pre-settlement forest stand structure in ponderosa pine - Douglas-fir forests to quantify their historic range of variability (Covington and Moore 1992; 1994; McAdamas 1995; Arno *et al.* 1995, 1997; Edminster and Olsen 1996; Fieldler *et al.* 1997; Covington *et al.* 1997; Fule *et al.* 1997; Hessburg 1999; R. Gray, unpublished data). Forest ingrowth and encroachment have altered landscape patterns and resulted in an overabundance of closed canopy forest and a deficit of open range and open forest habitat components (Covington and Moore 1992; Fule *et al.* 1997). At the stand level, open grown stands of old-forest trees comprised of single-storied, multi-aged stands have been replaced by multi-storied stands of variable density with dense thickets of understory Douglas-fir and other shade-tolerant species (Arno *et al.* 1995; Arno and Harrington 1998; Losensky 1993). Reconstruction studies confirm very significant increases in the densities of small and medium diameter shade-tolerant trees, as well as decreases in veteran and large diameter trees, due to fire suppression, increased competition with sub-canopy trees (Biondi 1996), and logging.

Understory Vegetation (grasses, forbs and shrubs):

Restoration Objective 2:

Maintain or increase fire-adapted native vegetation in treated areas.

Rationale:

Disturbance frequency determines the direction of succession and therefore the historical range of plant communities in a particular system (Steele and Geier-Hayes 1993). Data that can be used to estimate pre-settlement historic range of variability for understory vegetation in ponderosa pine- Douglas-fir forests is limited. However several studies have related changes in overstory tree density to changes in vegetation species diversity and understory forage production (Clary *et al.* 1975; 1976; Kooiman and Linhart 1986; Covington and Moore 1994, Thomas *et al.* 1999; Knowles *et al.* 1999). These studies show that biomass and number of understory species decreases with increasing tree canopy cover, tree biomass, and accumulation of forest floor duff and needle litter. These trends imply that any change in the structure of the forest overstory will have implications for species richness and abundance in the understory. Cooper (1960) and Covington and Moore (1994) argue that high understory biomass and plant species diversity of pre-settlement forests was the result of high nutrient cycling from frequent surface fires and less competition for sunlight, nutrients and water from overstory trees. By reducing overstory cover, restoration treatments are expected to increase understory native vegetation cover and species richness. This prediction does not consider potential interactions of overstory reduction with levels of noxious weeds, grazing pressure, soil disturbance, hydrology, etc., which could alter predicted outcomes.

Restoration Objective 3:

Minimize the establishment and spread of non-native plant species, particularly noxious species, in treated areas.

Rationale:

Non-native species and particularly noxious weeds are an increasing problem throughout the Pacific Northwest (Mitchell 2000). These species threaten native plant communities by invading and displacing native species, reducing native plant species diversity, reducing carrying capacity and watershed function, affecting natural processes, raising land management costs, and diminishing wildlife habitat, aesthetic and recreational values (Bangsund 1999). Their establishment and spread is exacerbated by intensive grazing as grazers disperse seed, open up habitat for non-natives, and decrease competition from native forage plants (Fleischner 1994). Logging, roads and recreational trails have also provided avenues for non-native invasion and spread. Noxious species have characteristics (e.g., early emergence, high seed production and long-term seed viability, rapid seedling maturation, large root systems) that make them highly competitive in any plant community (Lym 1998). Several non-native species (e.g., Canada Thistle, St. Johnswort, great mullein and cheatgrass) are known to increase (at least initially) after fire due to site disturbance (Brown *et al.* 2001). Thinning can also result in increased weeds and lower native species diversity (Alaback and Herman 1988). Preventing problem non-native species from becoming established has been shown to be far more cost-effective than controlling species once they are established. It is therefore essential to monitor changes to non-native vegetation in conjunction with restoration activities and to be pro-active in addressing potential problems, before they spread.

Restoration Objective 4:
Maintain existing occurrences of rare and endangered plant species in treated areas.

Rationale:
Maintaining occurrences of rare and endangered plants is part of the overall objective of maintaining native vegetation. There is no information available to evaluate whether the abundance and distribution of 63 red- and blue-listed vascular plant species and 9 listed vascular plant communities known to occur in the IDF and PP zones of the Trench (Machmer 2001) has changed with fire suppression. There is also little specific information available regarding the habitat requirements or potential responses to restoration treatment of these species. Knowledge of species-specific responses gained through an adaptive management monitoring approach would permit the development of more pro-active restoration treatment strategies for rare plants in future (Harrod *et al.* 1997).

Wildlife Habitat and Biodiversity:
Restoration Objective 5:
Maintain or increase the species richness and population density of endemic wildlife species in treated areas.

Rationale:
Our understanding of pre-settlement biodiversity in the Trench is based on anecdotal accounts, limited records, and a few early studies. Changes in animal diversity and abundance must therefore be inferred from studies that demonstrate changes in the quantity and quality of wildlife habitats and stand attributes. Forest ingrowth and encroachment has eliminated an estimated 58% of productive seral vegetation in the Trench (Gayton *et al.* 1995), which has impacted ungulates (Hillis and Appegate 1998) and many other wildlife species dependent on early seral habitats (see review in Machmer 2001). Fire suppression and logging has also reduced the availability of grassland and open forest habitats and stand-level structural attributes (e.g., large veteran trees, large snags and large diameter logs; Covington and Moore 1994; Kapler Smith 2000; Machmer 2001) in IDF and PP forests. IDF ecosystems have the highest native vertebrate species richness in B.C. (Bunnell 1995; Holt 2001a) and progressive landscape homogenization has likely reduced wildlife abundance and distribution relative to pre-settlement conditions. It is critical to monitor the effects of restoration treatments on the number, population density and reproductive success of endemic species to ensure that viable and representative populations are maintained.

Restoration Objective 6:
Maintain or increase the number and population density of vertebrate species of special interest (i.e., listed, identified, and regionally significant species) in treated areas.

Rationale:

As many as 21 vertebrate species (13 birds, 6 mammals, 2 reptiles) known to occur in the Trench are considered rare or endangered (Machmer 2001). The majority of these species are associated with grassland or open forest habitats, or with particular stand attributes that have been impacted by fire suppression and logging (e.g., large veteran trees, large snags, large coarse woody debris, deciduous patches, seral vegetation; review in Machmer 2001). The latter include the badger, Townsend's big-eared bat, rocky mountain bighorn sheep, long-billed curlew, flammulated owl, short-eared owl, western screech owl, sharp-tailed grouse, Lewis' woodpecker, Swainson's hawk, Williamson's sapsucker, bobolink, white-throated swift, sandhill crane, American bittern, great blue heron, rubber boa and painted turtle. The number, population density and reproductive success of these species in response to restoration treatments requires monitoring, to ensure that viable populations are maintained.

Restoration Objective 7:

Maintain or increase forage production in treated areas.

Rationale:

The influence of forest overstory on biomass of graminoid, forb and shrub species has received considerable attention because of declining forage productivity for livestock and wildlife (Naumberg and DeWald 1999). In temperate regions where light is a limiting factor, increased canopy cover and reduced light generally means less forage production (Knowles *et al.* 1999). Several studies have documented a decrease in biomass production with corresponding increases in crown cover (Pase 1958, Cooper 1960, Moir 1966, Ffolliott and Clary 1982, Borjoquez *et al.* 1989, Knowles *et al.* 1999). Given that ungulate and livestock numbers in the Trench have remained relatively constant over time, loss of forage production to ingrowth and encroachment has important implications for overgrazing of remaining vegetation (Gayton 1997; Blocker et al 2001). Despite generally significant rises in forage production over the long-term, studies generally show initially minor increases (or even declines) in production over the short-term (McConnell and Smith 1965). Long-term benefits may be outweighed by short-term disturbance effects, particularly when restoration treatments are of low intensity (Thomas *et al.* 1999). It is important to monitor forage production in response to restoration activities to ensure operational disturbance does not adversely impact long-term production levels. It is also important to ensure that the forage base is not being over-utilized in treatment areas, as this will undermine the success of restoration efforts (Opperman and Merenlender 2000).

Restoration Objective 8:

Increase the densities and sizes of wildlife trees in treated areas.

Rationale:

Reconstruction studies indicate that current snag densities and sizes in ponderosa pine – Douglas-fir forests are much smaller than in pre-settlement forests (Covington and Moore 1994; Arno *et al.* 1995; 1997; Harris 1999; Swetnam *et al.* 1999; Hillis *et al.* 2001). This is due to the cumulative impacts of fire suppression (which has eliminated snag recruitment attributable to frequent, low intensity fire), logging practices, associated worker safety regulations, and firewood cutting. As a source of cavity- and open-nesting, roosting and foraging habitat, snags represent critical habitat for a large number of wildlife species (Thomas *et al.* 1979a; Bull *et al.* 1997) and the IDF zone has the highest proportion of cavity-dependent wildlife species in the province (Bunnell 1995). Large snags are more valuable and useful to a greater range of dependent species than small snags (McClelland 1977; Bull *et al.* 1997; Wright 1996). The loss of large trees and subsequent loss of large snags and logs (exacerbated by the shift to shorter-lived tree species, such as Douglas-fir) is likely to become an important forest management issue in fire-maintained ecosystems (Blocker *et al.* 2001). A number of techniques have been tested to create or recruit snags in areas where they are lacking. These include tree girdling, topping, fungal inoculation, burning, and pheremone baiting to induce bark beetle attack (George and Zack 2001). Some of these snag creation techniques have been used during Trench ecosystem restoration; it is important to monitor their effectiveness, because some have proven to be unsuccessful in other areas (Bull and Partridge 1986; Brown 1996; Parks *et al.* 1996; George and Zack 2001). It is also important to monitor the overall effectiveness of restoration treatments on long-term snag availability and use.

Restoration Objective 9:

Maintain large-sized coarse woody debris (CWD) in treated areas.

Rationale:

As previously stated, densities of large old-forest trees and large snags in ponderosa pine – Douglas-fir forests are much reduced relative to those of pre-settlement forests (Covington and Moore 1994; Arno *et al.* 1995; 1997; Hillis *et al.* 2001). Although the proportion of species using CWD is expected to be highest in ecosystems with longer fire return intervals that permit larger accumulations of CWD (Bunnell 1995), frequent low intensity fire regimes promoted large snag (and subsequent large log) recruitment prior to fire suppression. Large log recruitment has likely been significantly reduced due to the cumulative impacts of fire suppression, logging, worker safety regulations, and firewood cutting. Large logs are known to provide critical habitat used for breeding, denning, thermal and hiding cover by a variety of mammals, birds, reptiles and invertebrates in the Trench (Maser *et al.* 1979; Bull *et al.* 1997; review in Machmer 2001). The effects of restoration treatments on large CWD require monitoring to ensure that adequate amounts and types are retained for dependent species.

Restoration Objective 10:

Maintain the integrity of riparian and wetland areas in and adjacent to treated areas.

Rationale:

Riparian areas represent less than 10% of the provincial land base, but are intensively used by wildlife and considered crucial for the maintenance of biological diversity (Thomas *et al.* 1979b; Banner and MacKenzie 1998). Riparian and wetland areas in the Trench provide critical habitat for a great diversity of plant and wildlife species, including a number of listed species (see review in Machmer 2001). They serve important hydrological functions as well. Riparian and wetland areas have a higher biomass than surrounding forests and are considered very productive from a forage perspective. Restoration activities and associated disturbance may result in a short-term post-treatment decrease in forage production, causing ungulates and cattle to increase utilization of more productive riparian areas (Opperman and Merenlender 2000). This could influence habitat quality and relative availability and use by other wildlife species. It is important to monitor riparian and wetland areas to ensure that they are not being over-utilized in response to treatment.

Soils:

Restoration Objective 11:

Maintain soil fertility in treated areas.

Rationale:

Soil fertility has a significant impact on vegetation growth and composition and reductions in fertility can decrease native species richness and cover, as well as promote establishment and spread of invasive species. Nitrogen has been proposed as a primary limiting factor in most inland northwest forests (Riegel *et al.* 1992). Nitrification is considerably higher in open forests (Moir 1966), possibly the result of pine litter slowing organic matter decomposition in closed forests. Nitrogen mineralization rates are likely to increase when the overstory is opened, potentially resulting in transformation and loss of nutrients from treatment sites (Smith and Arno 1999). Nutrient leaching following restoration treatment is problematic when leachates pollute stream water, or when a limiting nutrient is lost from the ecosystem, such as nitrogen (Kaye *et al.* 1999). Monitoring is required to assess the effects of restoration treatments on soil fertility.

Restoration Objective 12:

Minimize soil erosion and compaction in treated areas.

Rationale:

Some experts consider wildland ecosystem health to be primarily related to the ability of an ecosystem to conserve its soil resources and to retain and store water (DeSoyza *et al.* 2000). Soil texture, aggregation, water-holding capacity, and potential for erosion and compaction greatly influence vegetation patterns and their related wildlife habitat types. Soil compaction reduces pore spaces, decreases root respiration and microbial activity, and reduces the capacity of soil to hold water, air, and nutrients, thereby decreasing soil fertility and vegetation growth (Carr *et al.* 1991). A reduction in vegetation cover will lead to increased erosion hazard and resource loss is likely to be highest if soil surfaces are not protected by a plant community (DeSoyza *et al.* 2000). Consequences of accelerated surface erosion are wide-ranging and include a decline in soil fertility, vegetation growth, water quality, as well as increased stream turbidity (Carr *et al.* 1991).

Ecosystem Health:

Restoration Objective 13:

Reduce insect and disease incidence and spread in treated stands.

Rationale:

Insects and pathogens, such as bark beetles (e.g., mountain pine and Douglas-fir beetle), defoliators (western spruce budworm, tussock moth), dwarf mistletoes (*Arceuthobium spp*.), and root diseases (*Armillaria spp*.) are natural components of ponderosa pine and Douglas-fir forests (Wilson and Tkacz 1996). However ingrown stands experience greater competition for light, moisture and nutrients, which increases tree stress, contact, and overall susceptibility to insects and diseases (Blocker *et al.* 2001). Shifts in tree species composition (to favor more susceptible species) and greater landscape homogeneity resulting from fire suppression have also contributed to insect and disease severity (Wilson and Tkacz 1996; Blocker *et al.* 2001). Insect and disease-infected trees with large amounts of dead limbs and needles are more flammable than healthy trees and are associated with higher wildfire hazard (Brown *et al.* 2001). Conversely, increases in bark and woodboring insect populations in burnt areas represent key foraging habitats for insectivorous birds (Machmer and Steeger 1995; Machmer 2000). The increased levels of insect and disease activity and associated susceptibility to wildfire have tremendous implications for long-term ecosystem health and productivity in the Trench. Effects of restoration activities on insect and disease incidence require monitoring.

4.2 Effectiveness Monitoring Approach

After reviewing effectiveness monitoring approaches used throughout the Pacific Northwest, it is clear that "monitoring" means different things to different people. We can learn from a monitoring program in two broad ways: by making comparisons (observational studies) and by understanding underlying mechanisms (controlled experiment with replication). Both of these approaches are important and complimentary to provide direct feedback for management (Noon *et al.* 1999). Direct comparisons are easier and often cheaper than explanatory studies, but the application of the results is limited to the specific cases compared. Explanatory studies involve a greater understanding of the system, and more intensive and expensive measurements, but the findings have the potential to be applied at a broader scale. This monitoring plan adopts a comparative approach, but acknowledges that experimental investigation is required to confirm the causal relationships underlying monitoring findings. Also, where monitoring budgets are perceived to be insufficient to address some restoration objectives (because of time-consuming or costly field and analytical methods, lack of skilled personnel, etc.), recommendations for monitoring supplementary to this plan are provided.

Monitoring Trench restoration involves a trade-off between what can be said about particular restoration treatments at the "site" level versus what can be said about the "suite" of restoration treatments applied at the "program" level. A number of decisions and assumptions were made in developing this EMP and these are listed here in order to clarify the intent and scope of the program:

- Monitoring will evaluate success within an ecological context, although it is acknowledged that social and economic consequences of Trench Restoration require evaluation as well, and will interact to affect the ecological outcomes.
- Monitoring will be focused at the stand-level, although it is acknowledged that the cumulative effects of management actions at the landscape scale will ultimately determine the success of the restoration program.
- Both short- and long-term effects of restoration are considered in this EMP. Monitoring is envisioned to continue over an extended time frame (≈30 years), with most effort expended during the first half of the program, followed by a tapering off period during the latter half. At any individual site, more frequent monitoring is planned during years 1-5 after treatment, followed by periodic monitoring at 5-year intervals.
- It is not possible to intensively monitor all restoration sites treated as part of this program. Therefore, a subset of treated sites should be selected for *intensive* evaluation (depending on funding availability, 4-6 intensively monitored sites would be considered adequate over the course of the monitoring program) and the majority (i.e., ≥75%) of remaining treated sites would only receive *routine* evaluation. *Intensive* evaluations will quantify restoration treatment effects for several response variables using sample sizes that are sufficient to detect a significant biological effect (see Skalski 1995; Noon et al 1999). *Routine* evaluations will use mainly qualitative methods to compare a few key response variables before and after restoration is completed (Machmer 2001 draft). Over time, this will permit a "program-level" evaluation based on the cumulative results at individual *intensive* and *routine* sites.
- Given the diversity of plant and animal species in the Trench, monitoring of all biotic components is clearly impossible. This EMP therefore adopts a "habitat-based" monitoring approach, assuming that inferences to wildlife species viability can be reliably drawn from assessments of the status and trends in their habitat structure and composition (Noon 1999; Noon *et al.* 1999; Lindenmeyer *et al.* 2000; Bunnell 2001, unpublished). However, this approach requires local validation (Noon 1999; Noon *et al.* 1999) at selected restoration sites where measurement of habitat structure/composition is coupled with intensive monitoring of wildlife species richness, population abundance, and reproductive success. A detailed work-plan to do this at four representative sites in the Trench has already been developed (see Machmer 2001). TERP funded the site establishment for this project during 2001/2002 and pre-treatment monitoring is scheduled to begin in spring 2002 at two of four sites total. If the same four sites were selected for *intensive* monitoring of habitat structure and composition under this EMP, then significant cost savings could be achieved (relative to the budget in Machmer 2001) to satisfy both habitat- and species-level monitoring objectives.
- This monitoring program adopts a before and after "time series" approach (Green 1979; Michener 1997) to data collection as a minimum. However it is desirable to collect "before-after" monitoring data at a paired control site, in addition to the treatment site, where the opportunity exists. This "quasi-experimental" design (Before-After-Control-Impact; BACI) permits detection of a restoration effect independent of natural temporal variation (Underwood 1994; Michener 1997; Block *et al.* 2001). Practically speaking, finding a representative control site adjacent to a treatment area may be difficult (R. Newman, D, DeLong, pers. comm.), and sampling a control will double the required level of monitoring effort (assuming a balanced design). Where logistics and

funding permit addition of a paired control site (or selected control plots within a treatment site) to eliminate confounding temporal variation, control establishment is recommended.

- Monitoring objectives proposed in this plan focus on effectiveness monitoring. *Implementation monitoring* (IM) addresses the question of how well (or accurately) treatments were carried out relative to a restoration prescription. However, effectiveness monitoring findings will be difficult to interpret or apply within an adaptive management context if IM is not conducted concurrently. For example, there is a poor fit between predicted and actual fire behavior. If actual fire behavior is not monitored and quantified during treatment implementation, unexpected post-burn ecosystem responses measured during EM may be difficult to interpret and to factor into an adaptive management framework. Although effectiveness monitoring is the focus of this plan, it is acknowledged that restoration success is contingent on both the *appropriateness* and the *accuracy* of a particular treatment. Ecosystem Restoration plans should therefore provide details regarding both IM and EM.

4.3 Summary of Effectiveness Monitoring Objectives, Priorities, Design, and Methods

Effectiveness monitoring objectives that reflect each restoration objective in section 4.1 are provided in Appendix III, along with details on key response variables, monitoring design for *intensive* and *routine* levels of evaluation, and rationale for priority rankings (low, medium, high). These monitoring objectives and their priority rankings are summarized in Table 6, along with a brief description of proposed *intensive* and *routine* methods. The latter are grouped by topic area and data collection methods (i.e., objectives that can be addressed simulataneously using the same methods are placed into a single group): (1) stand structure and overstory vegetation, (2) understory vegetation, (3) riparian and wetland habitat, and (4) wildlife and biodiversity. As previously noted, detailed methods to monitor (4) are already provided in Machmer (2001). Taken together, these methods provide a complete monitoring program addressing major resource values targeted by Trench restoration at the stand level.

4.4 Information Management and Reporting Considerations

Monitoring is a long-term activity requiring both consistency and continuity to ensure success. To provide this, the number of persons collecting monitoring data should be minimized and protocols for data collection must be clearly documented and communicated. Any data gathered in conjunction with this plan should be entered into a centralized database with a user-friendly format. Invermere District staff currently use V-Pro to enter monitoring data (G. Berg, pers. comm.), and this program could easily be adapted to accommodate EMP data. It is preferable if a single agency assumes responsibility for the task of storing and updating the master database as necessary, and for storing any associated documentation. This agency should also provide (or coordinate the delivery of) updates on interim findings at 1–3 year intervals, depending on the phase of the overall program. These updates would summarize pertinent monitoring trends for resources, comment on interim treatment outcomes relative to restoration objectives or desired targets, and provide interim feedback for adaptive management. Updates could be in the form of (i) a workshop for restoration practitioners, (ii) a newsletter or “monitoring summary” summarizing

Table 6. Summary of proposed monitoring objectives, priority rankings, design and methods for the Trench restoration EMP.

Topic Area	Monitoring Objective	Priority	Monitoring Design and Methods (see details in Appendix III)
Stand Structure/ Overstory Vegetation	1. Monitor tree density, size, and species composition.	High	Intensive sites (objectives 1, 8 & 13): ❑ sample live and dead tree density, diameter, species by layer; number of trees with insects/diseases; wildlife use on trees; and crown closure in 15 fixed radius plots/site visited pre- and post-treatment (year 1, 3, 5, 10)
	8. Monitor wildlife tree densities and sizes.	High	❑ assess and tally trees >30 cm dbh in WTPs visited pre- and post-treatment (year 1, 3, 5, 10)
	13. Monitor insect and disease incidence.	Medium	Routine sites (objectives 1, 8 & 13): ❑ photo-document 5 plots/site visited pre- and post-treatment (year 1, 3, 5, 10) ❑ photo-document WTPs visited pre- and post-treatment (year 1, 3, 5, 10)
Understory Vegetation	2. Monitor cover and species composition of native grass, herb, and shrub species.	High	Intensive sites (objectives 2, 3, 4, 7 & 9): ❑ sample grass and forb cover (native and non-native) by species; % cover of cattle, deer and elk feces; and % bare and compacted soil in 12 Daubenmire frames/plot (180/site) visited pre- and post-treatment (year 1, 3, 5, 10) ❑ sample shrub cover by species on 3 x 11.28m transects/plot (45/site) visited pre- and post-treatment (year 1, 3, 5, 10)
	3. Monitor number and cover of non-native and noxious weed species.	High	❑ sample noxious weed density (if cover <5%) in 12 Daubenmire frames/plot (180/site) visited pre- and post-treatment (year 1, 3, 5, 10)
	4. Monitor existing density and cover of rare plants.	Low	❑ sample rare & endangered plant species cover, density and location in 12 Daubenmire frames/plot (180/site) and along 3 x 11.28m transects in (45/site) visited pre- and post-treatment (year 1, 3, 5, 10)
	7. Monitor forage production.	High	❑ determine grass, forb and shrub production in 0.5m^2 production quadrats (4/plot and 60 total/site) pre- and post-treatment (year 1, 3, 5, 10) ❑ determine utilization in 4x1m^2 production cages (comparison with uncaged plots above) pre- and post-treatment (year 1, 3, 5, 10)
	9. Monitor large-sized coarse woody debris.	Medium	❑ sample the number, diameter and decay class of CWD pieces and wildlife use on 3 x 11.28 m transects/plot (45/site) visited pre- and post-treatment (year 1, 3, 5, 10)
	12. Monitor soil erosion and compaction.	Low	❑ visual estimate of % bare ground and % of ground compacted in each Daubenmire frame (12/plot and 180/site)
			Routine sites (objectives 2,3,7 & 9): ❑ photo-document 5 plots/site visited pre- and post-treatment (year 1, 3, 5, 10)

Topic Area	Monitoring Objective	Priority	Monitoring Design and Methods (see details in Appendix III)
Riparian/ Wetland Habitat	10. Monitor the integrity of riparian and wetland areas.	Medium	Routine/Intensive sites (objective 10): ❑ photo-document animal use collected pre- and post-treatment (year 1, 3, 5)
Wildlife/ Biodiversity	5 & 6. Monitor the species richness and population density of endemic wildlife species and vertebrate species of special interest (i.e., listed, identified, and regionally significant species).	High	Intensive sites only (objectives 5 & 6): ❑ point counts, call playback surveys, and time-constrained searches for conspicuous wildlife species, coupled with intensive searches for active nests, dens, roosts and burrows, and reproductive success surveys conducted pre- and post-treatment (year 1, 3, 5 and 10); detailed methods described in Machmer (2001)

pertinent interim monitoring findings, and/or (iii) an interactive web-site or web page on an existing site. Operational restoration findings from other areas with comparable ecosystems (e.g., northern Idaho and Montana, Kamloops Forest Region) could also be posted or discussed via these updates, as a way of broadening the restoration scope. The expertise of organizations such as the Southern Interior Forest Extension Research Partnership (SIFERP) could be accessed to promote extension of monitoring findings. Most importantly, interim and final findings must be summarized, accessible and communicated to restoration practitioners in the Trench, to facilitate learning from management outcomes.

In developing this EMP, it became clear that restoration practitioners would benefit immensely from historical stand re-construction data that they could use to develop ecologically-based stand structure targets for site-specific prescriptions. Without this information, it is not possible to establish clear quantitative objectives and to gage the effectiveness of the Trench restoration program in attaining them. Some of this information has or is currently being collected (Gray 2001; Gray *et al.* in press).

4.5 Monitoring Effort

An estimate of person-days required to undertake the four monitoring components of this EMP is provided in Table 7. These estimates are for field person-days only and do not include additional days for organization and coordination, data entry, analyses, interpretation, and extension of monitoring results.

Table 7. Estimate of person-days of field monitoring effort (per site per year) for each monitoring objective.

Topic Area	Monitoring Objective	Effort (person-days/site/year) (details in Appendix III)
Stand Structure/ Overstory Vegetation	1. Monitor tree density, size, and species composition. 8. Monitor wildlife tree densities and sizes. 13. Monitor insect and disease incidence.	Intensive (objectives 1, 8 & 13): ❑ 15 fixed radius plots/site/year - 8 person-days ❑ assessment of unknown no. of WTPs/site/year - 1 person day Routine (objectives 1, 8 & 13): ❑ photopoints at 5 plots - 1 person-day ❑ photopoints at unknown no. of WTPs – 0.5 person-days
Understory Vegetation	2. Monitor cover and species composition of native grass, herb, and shrub species. 3. Monitor number and cover of non-native and noxious weed species. 4. Monitor existing density and cover of rare plants. 7. Monitor forage production. 9. Monitor large-sized coarse woody debris.	Intensive (objectives 2, 3, 4, 7 & 9): ❑ 15 plots (180 Daubenmires for grasses, herbs, and weeds; 45 transects for shrubs and CWD; 60 quadrats for production; 4 cages for utilization) - 20 person-days Routine (objectives 2, 3, 7 & 9): ❑ photo-points at 5 plots - 1 person-day
Riparian/ Wetland Habitat	10. Monitor the integrity of riparian and wetland areas.	Routine/Intensive sites (objective 10): ❑ 5 photo-points at each riparian/wetland area – 0.5 person-days
Wildlife & Biodiversity	5 & 6. Monitor the species richness and population density of endemic wildlife species and vertebrate species of special interest (i.e., listed, identified, and regionally significant).	Intensive sites only (objectives 5 & 6): ❑ call playback surveys, point counts, and time-constrained searches for conspicuous wildlife species; intensive searches for active nests, dens, roosts and burrows; reproductive success surveys on 4 sites ≥200 ha in size; greater intensity of habitat data collection by stratum – 150 person-days (see detailed budget and person-day estimates in Machmer 2001)

4.6 Effectiveness Monitoring Recommendations

The following recommendations are provided, based on information review and development of this EMP:

- Select 4–6 restoration treatment sites stratified by biogeoclimatic zone (PP/IDF) and location (north/south Trench) for *intensive* pre- and post-treatment monitoring. Conduct *routine* monitoring at the majority (i.e., ≥75%) of remaining treated sites in the Trench, based on methods in Appendix III.
- Designate a single agency (and preferably to 1–2 key individuals) to assume responsibility for EMP implementation (i.e., coordination of data collection, summary, storage, analysis and interpretation) over an extended time period. Minimize the number of persons collecting monitoring data and ensure that protocols for data collection are clearly communicated and documented to promote consistency. This agency should also provide (or coordinate the delivery of) updates on interim findings at 1–3 year intervals, depending on the phase of the overall program. These updates (or workshops) would summarize pertinent monitoring trends for resources, comment on interim treatment outcomes relative to restoration objectives or desired targets, and provide interim feedback for adaptive management to restoration practitioners.
- Obtain additional data on historic range of variability from stand re-construction studies (stratified by ecosystem and stand type) in order to develop ecologically-based stand structure targets for site-specific prescriptions.
- Obtain and summarize any results available from past monitoring initiatives in Table 4.
- Consider re-visiting some intensively monitored sites (e.g., Tata Creek, Wolf and Central Pasture, Finlay Creek and Picture Valley, Bull Mountain) again in future to conduct longer term monitoring, and maximize information gained from past efforts.

4.7 Implementation Monitoring Recommendations

The following recommendations are provided for site and program levels:

Site Level:

- Quantify all burn objectives that can be quantified; the US National Park Service Fire Monitoring Handbook is very useful for designing monitoring (Western Region Prescribed Fire Monitoring Task Force 1991).
- Make observations during and following the burn of confounding influences that were not quantified (adaptive management).
- Consider what external biotic/abiotic factors have the potential to impact the effectiveness of the treatment and consider adding them to monitoring design.
- Quantify fire behavior (rate of spread, flame length, and scorch height as a minimum) during the burn and measure against the predicted values (see Western Region Prescribed Fire Monitoring Task Force 1999).
- Historic fires burned under a wide range of fuel, weather, and topographic conditions, which led to a greater level of landscape patchiness and associated ecosystem diversity. Therefore, consider broadening the edges of the "burn window." Burning within a narrow range of seasonal and fire behavior conditions will benefit a narrower range of constituents. Be safe and conservative on burn area size, but test a wide range of conditions and measure the effects.

Program Level:

- Identify knowledge gaps in regards to successfully carrying out burns to meet target objectives.
- Survey the U.S. and Canadian burn community to see if those knowledge gaps have already been filled.
- Identify extraneous administrative constraints that prevent successful prescribed burning (i.e., lack of weather data, smoke regulations, fire behavior models, etc.).
- Note that ecosystem-wide parameters do not need to be monitored at the same intensity on all sites, however until general predictive formulas or models for effects are established, any opportunity to intensively monitor parameters should be sought. In the case of duff reduction, for example, predictive formulas can be developed that would apply to a broad range of sites with similar surface fuel and duff characteristics. However, developing the formula requires approximately 320 sample points per burn and several burns before regressions can be developed. As a result, opportunities to collect data should not be missed.

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APPENDIX I: List of Persons Contacted.

Name	Title	Affiliation	Contact Information
Greg Anderson	Operations Manager	Ministry of Forests, Invermere	Greg.Anderson@gems2.gov.bc.ca 250 342-4200
Diane Andrews	Consulting Ecologist	City of Boulder Colorado Openspace Program	dandrews@ci.boulder.co.us
Ted Antifeau	R&E Species Biologist	Ministry of Environment, Nelson	Ted.Antifeau@gems5.gov.bc.ca 250 354-6163
Doug Adama	Program Biologist	CBFWCP, Invermere	adama@rockies.net 250 342-3941
Tom Braumandl	Regional Ecologist	Ministry of Forests, Nelson	Tom.Braumandl@gems5.gov.bc.ca 250 354-6703
Gail Berg	Range Agrologist	Ministry of Forests, Invermere	Gail.Berg@gems8.gov.bc.ca 250 342-4200
Peter Brown	Company Director	Rocky Mountain Tree-Ring Research Inc.	pmb@rmtrr.org 970 229-9557
Sue Crowley	Regional Range Specialist	Ministry of Environment, Invermere	Sue.Crowley@gems4.gov.bc.ca 250 342-4266
Peter Davidson	Forest Ecosystem Specialist	Ministry of Environment, Cranbrook	Peter.Davidson@gems5.gov.bc.ca 250 489-8556
Deb DeLong	Silvicultural Systems Forester	Ministry of Forests, Nelson	Debbie.Delong@gems6.gov.bc.ca 250 354-6285
Bob Forbes	Biologist	MOELP, Cranbrook	Bob.Forbes@gems9.gov.bc.ca 250 489-8647
Don Gayton	Forest Extension Specialist	SIFERP, Nelson	Don.Gayton@gems7.gov.bc.ca 250 354-6200
Bob Gray	Consulting Forester	R.W. Gray Consulting	webbgray@uniserve.com 604 824-8726
Richy Harrod	Fire Ecologist	US Forest Service, Wenatchee, WA.	rharrod@fs.fed.us 509 664-2724
Tom Hedin	Operations Manager	Ministry of Forests, Cranbrook	Tom.Hedin@gems5.gov.bc.ca 250 426-1700
Larry Ingham	Biologist	CBFWCP, Invermere	Larry.Ingham@bchydro.bc.ca 250 342-3941
Lyn Konowalyk	Silviculture Forester	Ministry of Forests, Cranbrook	Lyn.Konowalyk@gems5.gov.bc.ca 250 426-1105

Name	Title	Affiliation	Contact Information
John Krebs	Senior Biologist	CBFWCP, Nelson	John.Krebs@bchydro.bc.ca 250 352-6874
John Lehmkuhl	Research Biologist	Pacific Northwest Res. Station, Wenatchee, WA	jlehmkuhl@fs.fed.us 509 662-4315 ext. 235
Reg Newman	Regional Range Ecologist	Ministry of Forests, Kamloops	Reg.Newman@gems7.gov.bc.ca 250 371-3703
Ian Pengelly	Fire Specialist	Parks Canada, Banff	ian_pengelly@pch.gc.ca
Denis Petryshen	Silviculture Officer	Ministry of Forests, Cranbrook	Denis.Petryshen@gems3.gov.bc.ca 250 426-1726
David Polster	Consultant	Polster Environmental Services	dpolster@telus.net 250 746-8052
Harry Quesnel	Consulting Ecologist	Ecotessera Consulting	hquesnel@netidea.com 250 825-4204
Darrell Regimbald	Silviculture Forester	Ministry of Forests, Invermere	Darrell.Regimbald@gems6.gov.bc.ca 250 342-4200
Tim Ross	Consulting Ecologist	Ross Range & Reclamation Services	rossrange@cintek.com 250 427-4319
Anne Skinner	Range Agrologist	Ministry of Forests, Cranbrook	Anne.Skinner@gems7.gov.bc.ca 250 426-1112
Darrell Smith	Range Officer	Ministry of Forests, Invermere	Darrell.Smith@gems6.gov.bc.ca 250 342-4200
Kari Stuart-Smith	Ecologist	TEMBEC Industries Ltd., Cranbrook	karissmith@crestbrook.com 250 426-9380
Naomi Tabata	Instructor	Douglas College Restoration Program	naomi_tabata@douglas.bc.ca 604 527-5817
Steve Taylor	Fire Ecologist	Canadian Forest Service, Victoria	staylor@pfc.forestry.ca
Irene Teske	Biologist	MOELP, Cranbrook	Irene.Teske@gems7.gov.bc.ca 250 489-8540
Alan Westhaver	Fire Program Manager	Parks Canada, Jasper	Alan_Westhaver@pch.gc.ca

APPENDIX II: Summary of Current and Tentatively Planned Restoration Activities in the Invermere District (1999–2007).

Range Unit	Pasture/Burn Name	Start Date	Treatment	Year	T.U./stratum	Status	Comments
Frances Creek	Ht. Of Land	1999	harvesting	1999	1/A	finished	
			harvesting	2000	1/B	finished	
			broadcast burn	spring 2000	2/A,B		
Sheep Creek North	New	1999	harvesting	1999	7/A	finished	
Sheep Creek North Range Unit			slashing	2000	7/B		chainsaw/burn
			burn	2004	7/ABC		
	Central	1999	harvesting	1999-2002	6/A,B,C	ongoing	
			slashing	2000	6/A,B	finished	chainsaw/burn
			broadcast burn	spring 2003	6/A,B,C		
	Dry Gulch	1999	harvesting	1999	3/C	finished	
			broadcast burn	spring 2001	3/A,B	finished	
	Skookumchuck	1999	harvesting	1999	4/B	finished	
			slashing	2001	4/B		chainsaw
			burn	1997-2005	4/A		
	Springbrook	2003	burn	2002	2/A,B		only north half
	Pump	2005	burn	spring 2002	5/A		
	Johnson Lake N.	2001-2005	burn	2001-2005	8/A		
Premier	Wolf	1999	harvesting	1999	1/A	finished	
(ER plan written)			harvesting	1999	1/B	finished	
			harvesting	1999	1/D	finished	
			harvesting	1999	1/E	finished	
			slashing	1999	1/A	finished	chainsaw/pile burn
			slashing	1999	1/C	finished	
			slashing	1999	1/D	finished	
			slashing	2000	1/E	finished	sloop trial
			pile burn	fall 2000	1/A	finished	
			pile burn	fall 2001	1/C		
			broadcast burn	spring 2003	1/A,B		
			broadcast burn	spring 2003	1/C,D,E,F		
	Alkali South	2000	harvesting	2000	2/A	finished	
			harvesting	2000	2/B	finished	
			slashing	2001	2/B,C	finished	chainsaw/pile/salvage
			burn	2004	2/A		only south half
			burn	2004	2/B,C		

Range Unit	Pasture/Burn Name	Start Date	Treatment	Year	T.U./stratum	Status	Comments
	3-mile	2001	slashing	2000	5 B,C	finished	sloop trial
			harvesting	2001	5B	finished	
	Gina Lake	2001	harvesting	2001	3/B	finished	
			harvesting	2002	3/A		
			burn	spring 2005	3/A		
	Elk/Sheep	1998	burn	1998	4/A	finished	
			slashing	1998-2000	4/B		
			salvage logging	1998 - 2000	4/A		
			burn	2000+	4/A		
			burn	2000+	4/A		
	Alkali North	1998	harvesting	1998 - 1998+	6/A,C	finished	
			harvesting	1998-2005	6/B	finished	
			space	2002	6/C	finished	
			burn	2005	6/A,B,C		
			harvesting	1998+	6/D		
Westside	Rushmere	1999	harvesting	1999	1/A	finished	
			broadcast burn	spring 2000	1/A	finished	
Findlay-Basin	Findlay	2000	harvesting	1997 - 2005	3/B	finished	
			burn	spring 2006-2015	3/B		
			burn	spring 2006 - 2015	3/A		
	Saddle	2000	harvesting	2000	1/B		
			slashing	2002-2004	1/A,B		
			burn	2005	1/A,B		
	Stinky (thunder)	2006	burn	2002			
			spacing	2006			
Ta-Ta Skook	Reed	2000	harvesting	2000	7/B	finished	
Ta-Ta Skook Range Unit			burn	2000	7/A	finished	
(ER Plan written)			burn	2000	7/B	finished	
			pile burn	fall 2000	7/B	finished	
			slashing	2001	7/B		chainsaw
			burn	2004	7/A,B		
	Dune	2000	harvesting	2000	8/B	finished	
			spacing	2002	8/B		
			burn	2003	8/A		

Range Unit	Pasture/Burn Name	Start Date	Treatment	Year	T.U./stratum	Status	Comments
			burn	2003	8/B		
	Plot	2000	pile burn	fall 2001	2/B		
	Foster	2000	pile burn	fall 2001	5/B		
			burn	spring 2006	5/A		
			burn	spring 2006	5/B		
	Echo	2002	harvesting	1997 - 2005	6/B	finished	
			burn	spring 2002	6/A		
			burn	spring 2002	6/B		
	Plot/Pulpmill	2005	broadcast burn	spring 2005	3/A,B		
Stoddart	North	2001	harvesting	2001	4/A	finished	
Radium-Stoddart Bighorn Winter Range Monitoring and Restoration Program			slashing	2001	4/A	finished	chainsaw
Redstreak	North	2002	harvesting	2002	4/A		
Radium-Stoddart Bighorn Winter Range Monitoring and Restoration Program			slashing	2002	4/A		
Dutch-Findlay	Spur Lake	2002	slashing	2001	3/A		brushsaw
Dutch-Findlay Range Unit Forest Ingrowth Management Strategy			slashing	2002	3/B	finished	brushsaw
East side Columbia	North End	2002	harvesting	2002			WMA, MOE to lead
Interim plan - not complete		2006	burn	spring 2006	1/B		
	South End	2007	burn	spring 2007	1/A		

APPENDIX III: Monitoring Objectives, Design, Response Variables, Protocols, Rankings and Recommendations.

Stand Structure and Overstory Vegetation:

Monitoring Objective 1:

Monitor crown closure, and tree density, tree size, and species composition in treated areas.

Design: *Intensive* and *Routine* - Collect pre-treatment data in randomly selected treatment (and control) sites in summer one year prior to treatment. Collect post-treatment data in summer the year after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3 and 5 and 10). Where possible, obtain and use a map of cruise plot locations to facilitate random selection of plot centers for collection of overstory data.

Response Variables: Crown closure, tree density, diameter and species.

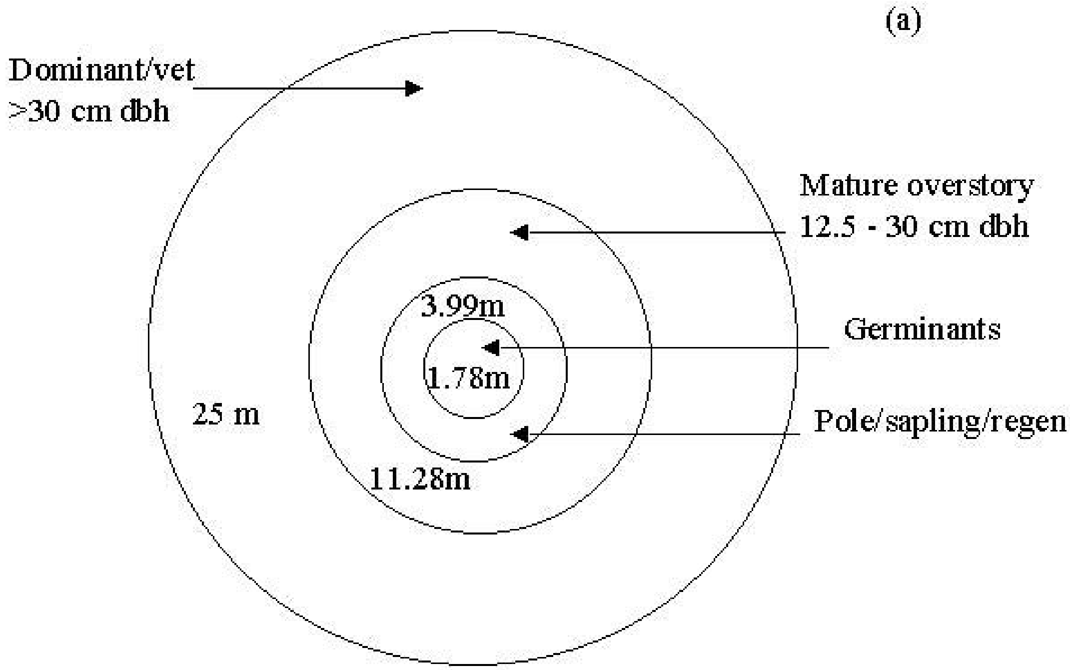
Protocols: *Intensive* - At each treatment (and control) site, randomly locate and permanently mark 15 plot centers. Overstory plot layout (Figure 2) should conform to methods developed by the BC Forest Service Permanent Sample Plot procedures (BCMOF 2000) and DeLong *et al.* (2001), with some modifications to ensure that large trees and snags are adequately sampled. Establish nested fixed-radius plots (Figure 2a) to sample each layer (Table 7) as follows: layer 1 (1.78 m radius), layer 2, 3 and 4 (3.99 m radius), layer 1 mature (11.28 m radius), and layer 1 dominants (25 m radius). Record tree species, diameter (diameter at breast height in cm), decay class , and evidence of insects or diseases for each tree in layers 1, 2 and 3. Record a tally by species (live/dead) for layer 4. Measure percent crown closure at plot center using a spherical densiometer. Also photo-document changes to overstory (as described under *routine* below) for 5 randomly selected plots from the 15 above (this comparison of *intensive* versus *routine* methods for the same plots will provide a benchmark to interpet photos for plots sampled only using routine methods).

Routine - At each treatment site, randomly locate and permanently mark 5 plot centers[1]. Take four photos from each plot center facing N, S, E, W, respectively (20 photos per site).

Priority/Recommendations: Evaluation of overstory stand structure is a high priority, in order to quantify post-treatment crown closures stand densities by layer in relation to treatment and compare with restoration targets. Note that methodology above covers monitoring objectives 1, 8, and 13.

[1] Methods for marking and re-locating permanent photo-points can be found on the Ministry of Forests website (www.for.gov.bc.ca/ hfp/range/manual) and in Hall (2001).

Figure 2. Nested plot configuration for overstory (a) and (b) understory measurements.



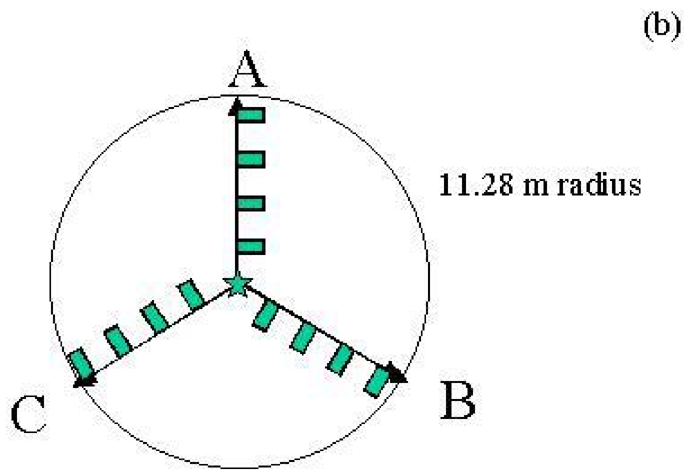


Table 8. Tree descriptions by layer for overstory measurement.

Layer number	Layer name	Layer description
1	dominant/veteran	>30 cm dbh
1	mature	12.5 – 30 cm dbh
2	pole	7.5 – 12.49 cm dbh
3	sapling	1.3 m height and < 7.5 cm dbh
4	regeneration	< 1.3 m height
4	germinant	seedlings < 2 years old

Adaptive Management: Re-assess implementation and validity of stand densities by size, layer, and species. Compare with historical range of variability data for the Trench, as it becomes available (see Gray, unpublished data).

Monitoring Objective 2:

Monitor cover and species composition of native grass, herb and shrub species in treated areas.

Design*: Intensive* and *Routine* - Collect pre-treatment data in randomly selected treatment (and control) sites in summer one year prior to treatment. Collect post-treatment data in summer the year after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3 and 5 and 10). When possible, obtain and use a map of cruise plot locations to facilitate random selection of plot centers for collection of understory vegetation data. Also note that the confounding effects of grazing and browsing are addressed in monitoring objective 7.

Response Variables: Grass, herb and shrub cover by species, species richness and composition.

Protocols: *Intensive* - At each treatment (and control) site, randomly locate and permanently mark 15 plot centers (note that these are the same plot centers as for objective 1). Understory plot layout will conform to methods developed by DeLong *et al.* (2001), with a few modifications. Establish three 11.28 m transects (A, B, and C; Figure 2b) radiating out from each plot center to form a spoke separated by 120° (bearing A randomly selected). Mark transect ends with metal stakes that are flush with the ground. Permanently mark four Daubenmire frame locations on each transect at 2, 5, 8 and 11m from plot center (n = 12 frames total). Estimate % herb and grass cover by species in each frame (Daubenmire 1959). Also estimate average height of vegetation and % cover of cattle, deer and elk feces at this time to provide an indication of animal use. Use the line-intercept method (Bonham 1983) to estimate shrub cover along each 11.28 m spoke (shrub cover is more variable than grass or forb cover and, cannot adequately be monitored in Daubenmire frames). Record all shrub species intersecting transect lines A, B, and C to the nearest centimeter. Species richness and composition will be obtained by tallying the number of species found along the spokes, and calculating the contribution of each species to the total vegetation cover, respectively. Also photo-document changes to understory (as described under *routine* below) for 5 randomly selected plots from the 15 above; this comparison of *intensive* versus *routine* methods for the same plots will provide a benchmark for plots only sampled using *routine* methods.

Routine - At each treatment site, randomly locate and permanently mark 5 plot centers. Take four photos from each plot center facing N, S, E, W, respectively (20 photos per site).

Priority/Recommendations: Measurement of native vegetation species cover and richness is considered a high priority for both *intensive* and *routine* measurement. This methodology covers monitoring objectives 2, 3, and 4.

Adaptive Management: Re-assess treatment program based on interim monitoring results to determine whether management actions (mechanical treatment, burning, control) are affecting the native vegetation cover, species richness and composition.

Monitoring Objective 3:
Monitor the number and cover of non-native plant species, particularly noxious weeds, in treated areas.

Design: *Intensive* and *Routine* - Collect pre-treatment data in randomly selected treatment (and control) sites in summer one year prior to treatment. Collect post-treatment data in summer the year after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3 and 5 and 10).

Response Variables: Number of species, cover, and noxious weed density (if cover <5%).

Protocols: *Intensive* - Estimate cover of non-native vegetation by species in Daubenmire frames (Figure 2b) in each of 15 randomly located and marked plots per site (note that these methods are covered by monitoring objective 2). If weed cover (noxious and nuisance weeds) is less than 5%, count individual plants in the Daubenmire frame to provide a density measure.

Routine – Take four photos from plot center facing N, S, E, W, respectively, in each of 5 permanently marked plot centers (note that these photos are covered by monitoring objective 2).

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Priority/Recommendations: Measurement of non-native vegetation cover is considered a high priority for both *intensive* and *routine* measurement. This methodology covers monitoring objectives 2, 3, and 4.

Adaptive Management: Incorporate monitoring results into ongoing integrated weed management planning at the district level. Re-assess restoration treatment program to determine whether management actions (mechanical, burning, control) and best management practices could be altered to reduce noxious weed abundance.

Monitoring Objective 4:

Monitor existing density and cover of rare plants in treated areas.

Design: *Intensive* only - Collect pre-treatment data in randomly selected treatment (and control) sites in summer one year prior to treatment. Collect post-treatment data in summer the year after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3 and 5 and 10).

Response Variables: Rare plant cover, density, and location.

Protocols: *Intensive* - Estimate cover of rare and endangered plants by species in Daubenmire frames and along the three 11.28 m transects (Figure 2b) in each of the 15 permanently marked treatment (and control) plots (note that this methodology is covered by monitoring objective 2). If rare and endangered plant cover is less than 5%, count individual plants in the Daubenmire frame to provide a density measure. Record specific locations of rare and endangered species (UTM coordinates) using GPS.

Priority/Recommendations: Measurement of rare vegetation cover is considered a low priority for measurement.

Adaptive Management: Re-assess treatment program to assess whether management actions (mechanical, burning, control) are reducing or eliminating rare species. Also consider effect of non-native vegetation and the possibility that weed proliferation is affecting rare plant species of interest.

Monitoring Objective 5:

Monitor the species richness and population density of endemic wildlife species in treated areas.

Design, Response Variables and Protocols: See detailed work-plan for four *intensive* sites in Machmer (2001). Methods include point counts, call playback surveys, and time-constrained searches for conspicuous wildlife species, coupled with intensive searches for active nests, dens, roosts and burrows, and reproductive success surveys conducted pre- and post-treatment (year 1, 3, 5 and 10) on 200 ha sites.

Priority/Recommendations: If sites already established for Machmer (2001) were selected for *intensive* monitoring of habitat structure and composition under this EMP, then significant cost savings could be achieved to satisfy both habitat- and species-level monitoring objectives.

Monitoring Objective 6:

Monitor the species richness and population density of vertebrate species of special interest (i.e., listed, identified, and regionally significant species) in treated areas.

Design, Response Variables and Protocols: See detailed work-plan for four *intensive* sites in Machmer (2001).

Priority/Recommendations: R*outine* "presence-not detected" surveys (Resources Inventory Committee 1998) are unlikely to provide meaningful results to quantify restoration treatment effects and validate species-habitat relationships. Restoration treatment effects on red- and blue-listed species, other vertebrates, as well as rare and endangered vascular plant species and communities are best addressed as part of one intensive project (see Machmer 2001 work plan).

Monitoring Objective 7:
Monitor forage production in treated areas.

Design: *Intensive* only - Pre-treatment production data should be collected 1 year prior to treatment. Post-treatment data should be collected in year 1, 3, 5 and 10 post-treatment. Four production cages should be established in two plots located in the treatment (and control) areas. Sixty production quadrats should be randomly selected in the treatment (and control) areas.

Response Variables: total production, utilization (caged versus uncaged)

Protocols: *Intensive* only - Total annual forage production will be measured in four 1 x 0.5 m^2 quadrats randomly located on an 11.28 m production transect (one of the transect spokes from objective 2) in each of the 15 permanently marked plots/site. Production quadrats will be rotated among transects in subsequent years. Herbaceous vegetation and current annual growth of shrubs will be clipped to ground level in late August to early September, after peak growth is reached. Kinninick/bearberry will not be clipped, as it is not of direct interest for ecosystem restoration. Samples will be separated into bunchgrass, other grass, forb and shrub bags only, and stored in a paper bag, air-dried, then oven-dried at 70 °C to constant mass, and weighed to the nearest 1 mg. Four production cages randomly established in two treatment plots will be clipped at the same time as production quadrats. A $1m^2$ will be clipped to ground level within each of the two cages. Cages will be established prior to the growing season, in which clipping will occur and interspersed among the production quadrats.

Priority/Recommendations: Assessment of restoration effects on forage production and utilization is considered a high priority, however it should only be considered for *intensive* evaluation, due to the amount of time and effort required.

Adaptive Management: Re-assess restoration treatments (mechanical, burning, control) in light of production and utilization patterns and determine if steps can be taken to increase production or alter utilization.

Monitoring Objective 8:
Monitor the densities and sizes of wildlife trees in treated areas.

Design: *Intensive* and *Routine* – Collect pre-treatment data on wildlife trees in randomly selected treatment (and control) sites one year prior to treatment. Collect post-treatment data after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3, 5 and 10).

Response Variables: Number, diameter, and wildlife use of wildlife trees (i.e., live trees with evidence of wildlife use, live unhealthy or defective class 2 trees, and dead trees in decay classes 3-7).

Protocol: *Intensive* – Collect data in each of 15 permanently marked plots in treatment (and control) sites (see Figure 2a). Record the number, species, diameter and decay class British Columbia Ministry of Forests and Ministry of Environment, Lands and Parks 1998) of all wildlife trees (≥3 m height and ≥12.5 cm dbh) in nested plots for layer 1 mature (11.28 m radius) and layer 1 dominant (25 m radius) only (note that this is part of monitoring objective 1). Any evidence of insects or diseases and wildlife use (e.g., open or cavity nest, feeding excavation, scaling sapsucking, etc.) will also be recorded (see objective 13). Wildlife tree retention will generally be concentrated in wildlife tree patches (WTPs), unless wildlife trees have been assessed and retained as individual trees throughout the treatment area. Intensive evaluation should therefore also involve conducting a tally of large wildlife trees (i.e., >30 cm dbh) within marked WTP boundaries, and recording any evidence of use on tallied trees. This would be done in WTPs selected randomly within each treatment site (total hectarage surveyed in this manner should not exceed 2 ha). The tally will permit a calculation of large WT stem densities and percent of wildlife tree used per patch area pre- and post-treatment.

Routine – Randomly locate and permanently mark 5 plot centers at each treatment site. Take four photos from plot center facing N, S, E, W, respectively (note that these are the same photos taken for routine monitoring of objective 1). Also photograph WTPs from N, S, E and W directions pre-treatment, after mechanical treatment, and again 1, 3, 5 and 10 years after prescribed burning.

Priority/Recommendations: Assessment of restoration effects on wildlife tree density, quality and use is considered a high priority for both *intensive* and *routine* evaluations. This methodology covers monitoring objectives 1, 8, and 13.

Adaptive Management: Re-assess restoration treatments (mechanical, burning, control) to determine whether selected treatments are wildlife trees in terms of quantity, quality and wildlife use. Also assess whether any snag creation efforts attempted are effective (i.e., that they are being used by wildlife).

Monitoring Objective 9:

Monitor large-sized coarse woody debris in treated areas.

Design: Collect pre-treatment data on coarse woody debris in randomly selected treatment (and control) sites one year prior to treatment. Collect post-treatment data after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3 and 5 and 10).

Response Variables: Number, diameter and decay class of CWD pieces (≥7.5 cm diameter), and wildlife use.

Protocols: *Intensive* – Randomly locate and permanently mark 15 plot centers at each treatment (and contol) site (these are the same plot centers used for objectives 1-5). Search three 11.28 transect lines (Figure 2b) at each plot center for pieces of CWD and record the diameter and decay class (British Columbia Ministry of Forests and Ministry of Environment, Lands and Parks 1998) for each intersecting piece, along with any evidence of wildlife use.

Routine - Randomly locate and permanently mark 5 plot centers at each treatment site. Take four photos from plot center facing N, S, E, W, respectively (note that these are the same photos taken for routine monitoring of objective 2).

Priority/Recommendations: Assessment of restoration effects on coarse woody debris is considered a medium priority for both *intensive* and *routine* evaluations, under the assumption that if restoration objectives for wildlife trees are satisfied, those for CWD are more likely to be.

Adaptive Management: Re-assess restoration treatments (mechanical, burning, control) to determine whether selected treatments are impacting or modifying large CWD or failing to create new CWD. Also assess whether the degree of wildlife use of CWD changes with treatment.

Monitoring Objective 10:
Monitor the integrity of riparian and wetland areas in and adjacent to treated areas.

Design: *Intensive* and *Routine* – Collect pre-treatment data 1 year prior to treatment. Collect post-treatment data in years 1, 3 and 5.

Response Variable: Animal Use

Protocol: *Routine* only – Delineate riparian and wetland areas within or adjacent to treatment areas on air photos or ortho maps prior to treatment. Establish and permanently mark 5 photo-points in each riparian and wetland area, using a standardized methodology (see www.for.gov.bc.ca/hfp/range/manual and Hall (2001)). From each point, take four photos facing N, S, E, and W, respectively.

Priority/Recommendations: Assessment of restoration effects on animal use of riparian and wetland areas is considered a medium priority.

Adaptive Management: Re-assess restoration treatment type (mechanical, burning, control) timing, and spatial pattern in relation to animal activity and use of riparian and wetland areas and explore how impacts could be minimized.

Monitoring Objective 11:
Monitor soil fertility in treated areas.

Priority/Recommendations: We acknowledge the importance of monitoring soil fertility in conjunction with restoration activities, but monitoring design and methods are beyond the scope of this document. Monitoring soil fertility is considered of low priority and would best be addressed as part of an intensive research project, potentially conducted by a graduate student with links to, and support from an academic institution.

Monitoring Objective 12:
Monitor soil erosion and compaction in treated areas.

Design: Monitor soil compaction and erosion in conjunction with understory vegetation (monitoring objective 2). Collect pre-treatment data in randomly selected treatment (and control) sites in summer one year prior to treatment. Collect post-treatment data in summer the year after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning.

Response Variables: Visual estimate of % bare ground and % of soil compacted.

Protocols: *Intensive* – Visually estimate the % bare ground and % of ground compacted in each Daubenmire frame on 15 randomly selected plots on each treatment (and control) site (see objective 2).
Routine - Visually assess % bare ground and % of ground compacted in vegetation monitoring photos (objectives 2, 3, 4) taken in 5 randomly located and permanently marked plot centers.

Priority/Recommendations: Monitoring of soil erosion and compaction is considered a low priority. This work might be more appropriately conducted in conjunction with soil fertility monitoring above, as part of an intensive research project, potentially done by a graduate student with links to, and support from an academic institution.

Monitoring Objective 13:
Monitor insect and disease incidence in treated stands.

Design: *Intensive* and *Routine* - Collect pre-treatment data in randomly selected treatment (and control) sites in summer one year prior to treatment (same plots as for objective 1). Collect post-treatment data in summer the year after mechanical restoration, and again 1, 3, 5 and 10 years after prescribed burning (if restoration burning is not planned, post-mechanical treatment data should be collected in year 1, 3 and 5 and 10).

Response Variables: Presence, number and percentage of insect- or disease-infected trees.

Protocols: *Intensive* - Note presence of insect or diseases for each each tree in layers 1, 2 and 3 plots in conjunction with overstory sampling in 15 randomly located and permanently marked plots (see objective 1).
Routine – Randomly locate and permanently mark 5 plot centers at each treatment site. Four photos will be taken from plot center facing N, S, E, W, respectively (note that these are the same photos taken for objective 1). Also rank incidence of insects and diseases (low, medium, high) based on visual assessment in the 5 plots supplemented by visual assessment of photos.

Priority/Recommendations: Monitoring of insect and disease incidence in conjunction with restoration treatments is considered a medium priority.

Adaptive Management: Re-assess removal of insect and disease-damaged trees in relation to restoration treatment type (mechanical, burning, control) and whether treatment is achieving desired future condition. Assess effectiveness of best management practices in minimizing adverse impacts to other ecosystem values.

Collection and Interpretation of Photo-Point Data:

Personnel conducting the monitoring should refer to Hall (2001), which provides an excellent review of methods and considerations pertaining to ground-based photographic monitoring for the purpose of detecting change in forest and rangeland ecosystems. Methods for marking and re-locating permanent photo-points can also be found on the Ministry of Forests website (www.for.gov.bc.ca/ hfp/range/manual).

To visually assess photos taken during routine monitoring, we recommend use of a simple scoring system in relation to meeting restoration objectives. At an individual plot, this would involve looking at the four photos collected and assessing whether objectives were: (1) fully achieved (100%); (2) mostly achieved (75%); partially achieved (50%); minimally achieved (25%); or not achieved (0%). A site-level diagnosis for an objective would involve integrating plot-level results for the 5 plots monitored (20 photos total) at a particular treatment unit/site. This could be done quantitatively (by computing means and variances for individual plot scores), but should also be done spatially (by projecting plot scores on a map, to discern if there is a spatial pattern to the level of success achieved). Potential explanations for any spatial patterns detected could then be related to results for other response variables, pre-treatment overstory and understory data, and data gathered during treatment implementation. This approach is only intended to (i) identify broad patterns or trends in treatment success (or lack thereof) for each routinely monitored objective, and (ii) to support the quantitative results of intensive investigation.