A REVIEW OF ALTERNATIVE VEGETATION CONTROL TECHNIQUES FOR THE E&N RAILWAY

May 31, 2006

Prepared For:

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Introduction

The urgent need for vegetation control along the E&N Railway is heightened as another growing season is underway and vegetation problems are resulting in significant track safety concerns. These concerns are matched by the public's health and environmental concerns over herbicide use. In response to these concerns, the Island Corridor Foundation (ICF) has retained Streamline Environmental Consulting Ltd. to review vegetation control methods to determine whether there are available technologies that can be incorporated into vegetation management on the E&N Railway in order to reduce or eliminate the use of chemical herbicides.

The issue of vegetation control on railways is a global concern with corporations and governments slowly working to address the need for standards to evolve and better address environmental values. The challenges of vegetation control issues are shared by other industries and interests, such as highways, forestry, agriculture, hydropower transmission and distribution networks, and government programs for invasive species eradication. As such, there is a broad network of resources addressing similar or related issues.

This report provides a brief review of the most common technologies that are being considered globally by railway and other right-of-way vegetation managers. The review also considers innovative solutions that have been proposed by local inventors for use on the E&N Railway.

Objectives

The review of non-synthesized chemical vegetation control technologies available for use on the E&N railway corridor has three objectives:

1. To review alternative technologies that has been tested by other right-of-way vegetation control practitioners.
2. To review technologies and remedies proposed by Vancouver Island citizens as alternatives to non-synthesized chemical herbicide.
3. To provide recommendations for implementing alternative vegetation controls as the future primary tools for vegetation management.

A particular focus of this study is on non-synthesized (natural) herbicides and other alternative remedies available for weed control in Canada, as well as mechanical treatment options not currently in use.

Methods of Review

The primary sources of information for this review include:

- existing reviews of non-chemical methods of vegetation control
- local expertise
- correspondence with industrial specialists and practitioners.

The internet was an initial starting place to identify and obtain research reports and vegetation management plans from around the world. The URL's of several informative websites researched are listed in Appendix 1. A list of key contacts consulted, including vegetation management specialists is provided in Table 1. Local specialists were identified by area of expertise and were subsequently solicited for any assistance they could provide.

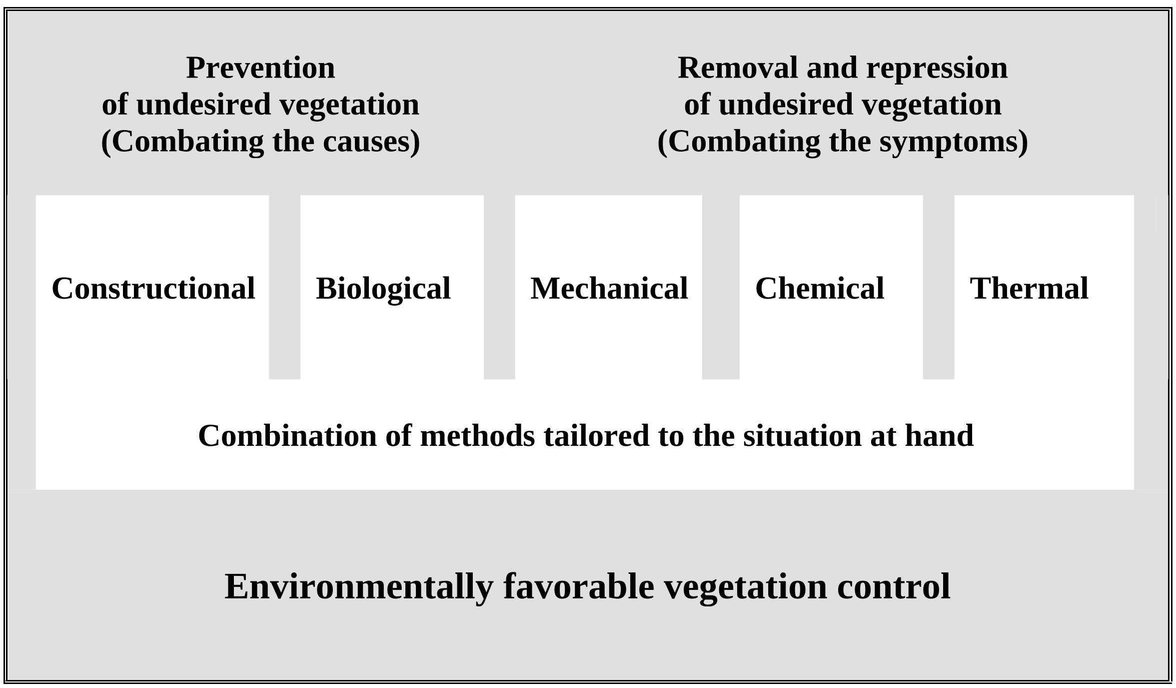
Table 1. List of project contributors

Name	**Organization**	**Role**
Fred Hook	City of Victoria	Environmental technician
Becky Brown	Coastal Invasive Plant Committee	Coordinator
Dave Polster	Polster Environmental Services Ltd.	Plant ecologist
Michael Gorman	City of Victoria	Vegetation control specialist
Ray Read	British Columbia Transmission Corporation	Vegetation specialist
Greg Prull	Sunburst Inc.	Equipment technologist
Michael Betts	BC Ministry of Agriculture and Lands	Weed control specialist
Dr. George Puritch	EcoCare Technologies	Chemical scientist
Cameron Wilson	Neudurff Corporation	Chemical scientist
Bill Woldnik	Aztec Appliances	Equipment technologist
Per Erik Strandberg	Sweden	Industrial weed control practitioner
Doug Burnham	State of Vermont DEC/WQD	Bio-monitoring and Aquatic Studies
Trevor Wicks	Trentec Innovations Ltd.	Inventor
Fernande Gächter	Swiss Federal Railways	Environmental manager, vegetation specialist
Andy Brown	Parksville	Equipment Operator
Ian Johnstone	DJ Batchen Pty Ltd, Australia	Thermal Weeding Products

Results & Discussion

Several in-depth reviews of non-chemical weed control techniques are readily available online (see Appendix I). An integrated approach to weed control was advocated in all the literature reviewed. This is particularly well documented in a 2001 brochure published by the Swiss Federal Railways (SBB) titled *Vegetation Control on Railway Tracks and Grounds*. A strategy of weed prevention supported by diligent maintenance is utilized in many European countries where herbicide use is restricted (Kuppelwieser 1998).

On the high use railways of Europe, construction designs incorporate weed barriers and plant growth deterrents. This foundation of track construction is supported by four primary maintenance technologies: biological, mechanical, chemical and thermal. This approach to track maintenance is reflected in E&N's current Pest Management Plan (PMP; Streamline 2005). Section 7 of the PMP discusses the four maintenance strategies.



Reproduced from: Swiss Federal Railways, 2001

Figure 1. Progressive, integrated approach to vegetation control on railways.

Biological Vegetation Control

The most progressive steps taken to control weed problems appear to be in the design stage where measures can implemented to reduce the ability for weed growth. It is thought that weed barriers, water reduction and the use of clean materials can preclude the establishment of undesired vegetation for up to 30 years with minimal maintenance (Kuppelwieser, 1998). Some good examples of this technology are provided in the vegetation control brochure produced by the Swiss Federal Railways (2001). However, the expense involved in reconstructing existing structures is cost prohibitive, thus limiting this approach to new or reconstructed railway sections. The ballast on much of the E&N line is poorly drained and contains sands and soil rather than being clean, sterile and well drained as it should be. These conditions support weed growth. In the course of maintaining the railway line and re-working or replacing the ballast, sterile conditions with weed barriers and water reduction should be established.

The promotion of preferred species along the rail right-of-way such as non-creeping grasses or native ground covers can produce stable, climax stage vegetation that excludes other more invasive species. Diligent removal of invasive species such as Scotch broom will ultimately result in a stable ground cover that resists re-infestation.

Biological controls can also include the use of biocides. Biocides use native pathogens such as fungi and bacteria to inhibit or kill back targeted vegetation. Often the vegetation needs to be compromised in health for a successful infestation and this can be initiated by severely trimming back the plant before the application of the pathogen. Research into potential biocides has identified few potential organisms of interest (Prasad and Dixon-Warren 1992). The naturally occurring silver leaf fungus *Chondrostereum purpureum* has been shown by British Columbia researchers to have some potential (Prasad, 2000). Its effectiveness is being evaluated by E&N Railway for the control of woody vegetation species such as Scotch broom and red alder. This trial treatment in discussed in the PMP (Streamline 2005), and the results of the trial are expected in summer, 2006.

Mechanical Vegetation Control

Mechanical treatments are important in assisting the biological control of weeds by the removal and repression of undesired vegetation. Species dispersion can also be limited by diligent and timely mowing to reduce the production of weed seeds. Mechanical controls can also help suppress vegetative propagation from runners and root rhizomes. Mechanical tools range from simple brush cutters and mechanical weed pullers, to machine mowers and specialized ballast regulators. Many of the tools available and applicable for vegetation control on the E&N railway have been discussed in the PMP and are already incorporated into operations. In addition to the content of the PMP, the use of a flail mower is discussed below. Careful timing and adequate resources are needed to respond with mechanical tools when needed ensuring that further infestation does not succeed.

Flail Mowing

A flail mower is a simple, common piece of equipment that rotate a series of vertically moving knives on a short link under a shrouded cover. For ballast restoration the mower could be mounted directly onto the three point hitch of a high rail mounted tractor. The mower would rest on guides adapted to travel on the tracks giving accurate equipment control and simple operation. Flail mowing should be possible at speeds averaging 4 miles per hour (6 km per hour) (Andy Brown, Trevor Wick and Bill Woldnik. Pers. Comm.). The configuration is simple and relatively inexpensive yet offers a powerful direct drive from the tractor’s power-take-off. Flail mowers have a high tolerance to accidental impacts with rock and steel that may stick up along the mowing path.

This equipment may offer a key tool for track restoration. A flail mower tends to shred the vegetation off the plant and strip the bark off the remaining stem. It is expected that mowing can take place to within 1 cm above the rail ties. The low ragged cut will result in some mortality on the mown vegetation, helping to achieving the primary objective of weed control. This result is different than the higher, clean cut achieved by the rotary blade mower currently in use. Rotary mowers tend to ‘prune’ vegetation often encouraging strong multiple stem re-growth.

Re-growth from the low cut of a flail mowing establishes ideal conditions for both thermal and herbicide treatments to be effective. These technologies will be most effective when dealing with lush green new growth and the least possible amount of hard established vegetative shadow from woody stalks etc.

The usefulness of flail mowing along the railway ballast may be limited to the restoration process only. Once the ballast restoration is achieved and regular maintenance is used to maintain clean ballast conditions, flail mowing equipment can continue to be used in the maintenance of the outer right-of-way.

At an operation speed of 4 mph and a two way pass needed to mow a 10 foot strip along the tie area, the Victoria Subdivision would take approximately 70 hours. As little mobilization time and fueling would be required this job could be conducted in 9 days. Given an estimated operating cost of $100/hr the total treatment would cost $7,000. Equipment needed for this process would be a standard tractor (approx 60 hp) mounted on high rails ($60,000) and a standard flail mower ($5,000).

A point of concern that results from mowing is the excessive organic material added to the track. A possible solution for consideration is vacuum cleaning. Vacuum track cleaning equipment is used as a standard operation on some European railways to limit the buildup of fine particulates and organic debris (SBB 2001).

Non-synthesized Chemical Vegetation Control

Non-synthesized chemical herbicides are derived from natural sources offering an ‘organic’ alternative to conventional herbicides. Health Canada’s Pest Management Regulatory Agency (PMRA) requires that any material applied to vegetation as a control must be registered as an herbicide. This regulation legally eliminated any opportunity for the rail industry to utilize home remedies for vegetation control.

Commercial alternative herbicide products do exist internationally. These products tend to be expensive compared to conventional herbicides. In addition to the expense, none of these products are currently registered by the PMRA for industrial use in Canada, apparently due to a lack of a market for these products.

Ironically, Vancouver Island based researchers from Safer Products and, more recently, Ecocare Technologies are world leaders in the research and development of alternatives to conventional chemical herbicides such as Safer’s Top Gun. Unfortunately, for economic reasons the marketing rights are sold to European entities who are not interested in the small Canadian market. As such, there have been no non-synthesized chemical herbicides registered for industrial or agricultural use in Canada (Dr. George Purich, Ecocare Technologies. Pers. Comm.).

An opportunity may exist for E&N Railway to work with Ecocare Technologies to test their products for industrial vegetation control. If trials are undertaken and the results are positive, it could lead to industrial product registration.

In response to the E&N Railway PMP Vancouver Island residents have suggested various domestic remedies as alternatives to conventional herbicides. The active properties of theses remedies form the basis for most non-synthesized chemical herbicide compounds. Again, it is noted that these remedies are not legal for industrial use as they are not registered for herbicide use in Canada. However, to ensure a thorough review, these remedies are discussed below.

Salt

Salt (calcium chloride) can be used in high concentrations to kill plants. In large enough concentrations it acts as a general site sterilent for most life. Salt is relatively ineffective for vegetation control on an industrial level as it is highly soluble by water requiring regular re-treatments. The costs of treatment would be high. An indication of this is shown in annual road applications for snow control where roadside vegetation is often unaffected despite the repeated applications. Salt is not registered for use as a herbicide and would likely fail the registration process due to its detrimental effect on soils and non-target organisms. In addition, its use on railways would cause rail and equipment to rust and deteriorate more rapidly. An even greater concern is the potential for traffic signal equipment failure due to electrical connectivity changes across the rail bed. As such, salt is not a viable option for vegetation control along the E&N railway.

Vinegar

Acids such as vinegar (acetic acid) can be used as a non-synthesized chemical herbicide. Vinegar is an organic solvent that dissolves the fats or lipids in the waxy layer of the leaf. The acid then enters the cells and destroys them (Islam, 2006). Domestic vinegar is normally 5 % acid, whereas concentrations of 10 to 20 % are needed to be effective for most vegetation. The vinegar normally affects only the leaf tissue allowing for plant re-growth. Multiple treatments would be needed to control vegetation. Acetic acid is commercially available; however, it is not registered for use as an industrial herbicide in Canada and therefore cannot be used. Ecoclear; President's Choice Weed Controller based on natural acetic acid is registered for domestic use in Canada however is not registered for industrial use. In addition to this repeat applications of concentrated acid may cause deterioration of the track and rail equipment.

Fatty Acids

Naturally occurring fatty acids (soaps) can be used as a herbicide that rapidly desiccates plant foliage. Fatty acids likely offer the greatest potential as a non-synthesized chemical herbicide (Dr. George Perich, Ecocare Pers. Comm. 2006). Safer’s Top Gun is a fatty acid based herbicide registered for domestic use only in Canada. New fatty acid based herbicides are currently being registered internationally by Ecocare Technologies Ltd. a research company based in Sidney, BC; however, they will not be registered in Canada due to a lack of market at this time. Some opportunity may be available to test fatty acid based herbicides for industrial application with Ecocare Technologies Ltd.

Corn Gluten Meal

Corn gluten meal is a by-product of the wet milling process of corn for starch. Corn gluten meal has been found to offer pre-emergent control of some weeds by inhibiting seed germination. Unfortunately, its organic quality also makes it a slow-release organic fertilizer and soil builder. Corn gluten meal will not control existing established weeds. This product is unsuitable for the control of weeds in railway ballast.

Borax

Borax or sodium tetraborate is a compound containing the mineral boron that was tested on the E&N railway in the late 1980's and early 1990's. At high levels it was found that the boron was toxic to all vegetation. Unfortunately, it leached rapidly from the site, although it was not detected in adjacent groundwater wells that were sampled for water quality. Borax is not registered as a herbicide in Canada with PMRA. When Borax was studied it was concluded that although it kills vegetation it was not likely to become an important tool for railway vegetation management (Dave Polster, Pers Comm.).

Thermal Vegetation Control

Thermal vegetation control is capturing the attention of industry around the world as a burgeoning tool for integrated pest management (IPM). Within the past decade numerous studies have been completed that review this technology. Links to some of theses studies can be found in Appendix 1. Equipment for thermal control of vegetation remains in early development with the primary attention focused on configurations for agricultural and urban landscaping applications. As a foliar treatment technology it is commonly understood that thermal vegetation control is best used as a management tool, attacking weeds in the early stages of growth before woody stalks develop or leaf counts and weed densities become high.

Within the railway industry, thermal vegetation control is commonly noted in industrial reviews as a potential tool for routine maintenance (SBB 2001, D. Burnham 2003). This technology has not been adopted as a standard procedure within any of the railways of Europe or North America that were reviewed. Literature and correspondence from weed control practitioners indicate that the few trials completed have shown thermal vegetation control to be effective at railway vegetation control; however, its long-term applicability is inconclusive.

Many approaches to thermal vegetation control have been developed. The following review summarizes contemporary technologies that may prove viable for vegetation control to the rail industry.

Flame Weeding

Flame weeding is the most rudimentary approach to thermal vegetation control. Flame weeding works by applying a short but intensive wave of heat to the plant, which ruptures and desiccates the plant's cells. It is a foliar contact treatment that destroys the vegetation of the plant. Any long-term effect depends on the plant's ability to regenerate from energy storage in the roots and from the extent of subsequent seed germination.

Much of the equipment for flame weeding has been built by innovative farmers and is relatively crude; however, recent demand for this equipment in the agricultural industry has resulted in the development of some sophisticated tools. Flaming equipment has been developed in several countries including Germany, Sweden, Denmark, Holland, Austrailia, and the United States. The fuel used in most burners is liquefied petroleum gas (LPG), usually propane. Some concern has been raised about using fossil fuels due to the resulting CO_2 emissions. Renewable alternatives such as hydrogen have been assessed (Bond and Turner 2005).

Open Flame

There is a wide variety of technological approaches to using flame for weed control. Open flame burners are perhaps the least efficient and effective. Open flame may also pose a significant risk of fire if used on a railway. However, flame contact has the highest heat output of all the thermal control technologies and this may allow for an increased treatment speed, an important quality for railway maintenance.

Flame Entrainment

Flame entrainment is a concept for flame weeding that was conceived by a Vancouver Island inventor. This concept uses a bank of flame nozzles under a shroud to apply the initial heat. The flame is entrained by a bank of fine water misters at the outlet of the shroud. The sudden expansion of the water into steam sets up a flow of air through the shroud fanning the flame while at the same time absorbing the flame energy into steam and alleviating the potential for fire. This technology has not been developed past the scaled prototype stage. Design, construction and gas equipment approval would be necessary before this equipment could be tested.

A review of this concept has been completed by B. Woldnik, an independent Vancouver Island based equipment technologist. It has been estimated that flame entrainment weeding could take place at 4 mph (6 km/hr). The initial design would treat one rail and half the tie width at a time (~5 ft wide). Fuel costs for this machine would be approximately $46/hour. The total operating costs are estimated to be $250/hr, all found. An 8 hour shift (including mobilization time) would yield approximately 50 km of treatment. The entire Victoria Subdivision could be treated in approximately six days at a total cost of $17,000. It is estimated that a one-off working prototype will cost approximately $35,000 to build and approve for use. The review of available research on thermal vegetation control suggests that four to five treatments per year would be required to achieve acceptable weed control. The frequency of treatment could be reduced over time with the implementation of integrated vegetation management.

The advantage of flame entrainment weeding is that it provides an intense heat that persists along an extended shroud. This technology is particularly well suited to railway use which does not require good maneuverability. The shroud length can be 3 to 5 m long thereby intensifying the treatment period and allowing treatment speeds to increase. The simplicity of the equipment can help reduce its cost and increase its durability.

A risk is the use of open flame on the rail ballast and ties. It is felt that rate of treatment plus the use of water quenching would leave little opportunity for fire in the early spring period. This may become more of a concern in the late spring and early summer period.

Funding may be available to develop and test this technology. Informal discussions with the local representatives of the National Research Council of Canada suggest that they and the Western Economic Diversification Fund would likely support its development (Warren Nagatta, MUC. Pers. Comm.).

Infrared Radiation

Infrared radiation weeding uses flame to heat ceramic and metal surfaces that radiate the heat towards the target plants. As with open flame weeding, the plants are killed by the heat rupturing the plant cells and destroying the vegetation. The big advantage is that the flame is controlled onto the infrared burners reducing the opportunity for fire on the track. Infrared burners also cover a more closely defined area than the open flame burners and dissipate the heat more evenly over a larger area. The technology has the disadvantage of taking time to heat up, the panels are also susceptible to damage and they are more expensive than open flame burners.

Sunburst Inc. of Eugene, Oregon is one of the leading developers of thermal vegetation control. Their system uses a ‘wet infrared’ treatment that applies a thin film of water to vegetation then subjects these plants to intensive heat under an insulated housing. The heat applied as infrared radiation causes turbulent hot air between 1000 ^{o} and 2000 ^{o}F; boiling water on the leaves and stems on the vegetation. In addition tall vegetation may be exposed to the flame from the propane burners that are used for heat generation. The use of water also provides the independent function of minimizing the risk of ignition to the treatment site. The technology has been developed to be fuel and water efficient.

Sunburst wet-infrared radiant weeders have been designed and built for the rail industry. Equipment has been purchased and tested in Alaska by the Alaska Railroad Corporation and in Vermont by the US Federal Transit Administration along with the Vermont Agency of Transportation. Alaska Railroad was not reached for comment, however, the manufacturer relayed that the program was discontinued due to union problems and difficult maintenance scheduling (Greg Prull, Sunburst Inc. Pers. Comm.). In Vermont the equipment was tested in mid summer of 2001. Extensive reporting followed this trial and was provided by Doug Burnham, Section Chief, Biomonitoring & Aquatic Studies, Vermont State.

Unfortunately, a number of conditions precluded the proper implementation of the experimental plan, and the results were inconclusive. The trial team found it difficult to fit prescheduled experimental requirements into the daily workload of an understaffed track maintenance crew responding to immediate day-to-day needs. Some key findings of the Vermont trials of the Sunburst wet-infrared radiant weeder were:

- the equipment worked well
- the technology was effective at controlling vegetation – in particular, young vegetation
- fires were not a problem during treatment
- the propane use per mile was in the range experienced during similar applications (5 to 10 gal/mile/4 ft unit)
- a minimum crew of two was needed to operate the equipment
- treatment speed averaged 2 miles/hr (3.2 km/h)
- the treatments were started in early summer well after the start of the growing season and well-developed and hardy weeds were killed back.

Costs:
For purposes of this review all costs quoted have been adjusted for inflation using the US Bureau of Labour Standards inflation calculator then converted to $ CDN.

- Projected costs per track mile $ CDN 2006 based on costs in 2001 — $ 87.55 to $ 625.46
- Labour cost factored into track mile calculation above — $ 50.04
- Cost to assemble the test machine $ CDN 2006 assuming machine built in 2001 — $ 112,593

The projected cost per track mile is based on the thermal units operating on an intermittent basis depending on the need for track bed coverage and operating speeds varying for 1 to 3 MPH (1.6 to 4.8 km/hr)

Communication with Greg Prull of Sunburst Inc. confirms that a 4 ft wide unit uses approximately 7 gallons of fuel per mile and that treatment speeds of 2 to 3 MPH can be expected. It is conceivable that one treatment of the 16 ft wide ballast area will consume 4,200 gallons of propane. At the current price of fuel, that equates to $13,000 in fuel. Treating 8 ft at a time, two passes of the Victoria Subdivision at 2 mile/hour would take 140 hours. Given two hours/day for mobilization and refueling it is conceivable that the treatment would take up to 23 days of 8 hour shifts (Greg Prull, Sunburst. Pers. Comm.). It can be expected that 6 to 8 ft of wet infrared radiation equipment can be supplied for approximately $50,000 USD. Complete deployment with support vehicles, safety equipment and consultation would likely cost around $150,000. Sunburst remains interested in developing and trialing this equipment and would welcome an opportunity to travel to Vancouver Island and discuss its use further.

High Temperature Steam

Steam was widely tested on the E&N Railway in the 1980's and early 1990's (Polster, 1993). High temperature steam was shown to be an effective means of treating ballast section vegetation. Woody species were dramatically affected while grass species were found to be more resistant due to the fact that they grow from the roots up. Scotch broom was particularly susceptible to steam treatment with a complete kill after the first pass (Polster, 2006).

The key to effective steam treatment is the use of high temperature steam. This is steam far beyond the visual water vapor steam normally observed at lower temperature. Tests of the impacts of high temperature steam by Dr. Upadayaya at UBC found that a fraction of a second exposure was all that was needed as long as the hot steam hit the plants directly. The trick is to avoid mixing with the air that is blowing by (Dave Polster, Pers. Comm.).

Costs for operating the first generation demonstration steam machine were high which was not surprising since an old steam locomotive boiler was used as the generator and this needed the support of vast quantities of fuel and water. A second generation steam generator was designed and under construction when the project was folded. Only predicted design data is available for this equipment.

Cost in 2006 $/track mile	1st generation machine	$ 153.47
Cost in 2006 $/track mile	2nd generation machine	$ 74.21

Operating costs are all-found including the equipment, wages and fuel needed to support the treatment.

The rate of treatment using the first generation machine was 2 to 5 MPH. The design speed for the 2nd generation machine was expected to be 10 to 20 MPH (similar to a herbicide spray truck; Dave Polster. Pers. Comm.). Thus at 10 MPH, 14 hours may be needed to treat the Victoria Subdivision. Given time for mobilization and fueling this process could take 4 days per treatment. The configuration of steam treatment equipment is complex and an estimates of capital required to build a specific machine are estimated in 2006 dollars to be 1.2 to 1.9 million based on 1993 numbers provided by Polster (2006).

Steam Quenched Combustion

A steam / flame weeding hybrid technology has recently been developed in Australia. The technology is called steam quenched combustion. The steam is generated instantaneously in heat exchangers located within the two outlet tubes and mixes with the hot gases, this quenches the hot gas temperature and superheats the steam. The velocity of the emitting steam creates the draught for combustion and ensures the hot steam/gas mix penetrates the weed mass. The equipment configuration is designed for agricultural orchard use and treats only approximately 30 cm per pass. The technology appears to inject water into the combustion stream of a fuel burner and this technology may hold future possibility. Comparative studies with this equipment and glyphosate found the cost to be comparable in California vineyard maintenance (K. Smith 2005).

Other Thermal Technologies

Exploration in thermal vegetation control extends to electrocution, irradiation, microwave radiation, electrostatic fields, lasers, ultraviolet light and solarization. These technologies are summarized by Bond and Turner (2005). They do not provide any solutions to the rail industry at this time.

Table 2 summarizes the approximate costs and relative efficiencies of technologies under consideration. All costs have been calculated in 2006 Canadian dollars. It is difficult to accurately compare the technologies as there have been limited data collected from trials and few trials focused on the control of vegetation within rail right of ways. Where trials have not been completed, such as the flame entrainment technology, operational costs have been estimated by qualified equipment technologists. The numbers provided also do not consider the daily time needed for refueling, watering, mobilization and train avoidance. The 2006 herbicide treatment quote of $35,000 for one treatment of the Victoria Subdivision (140 miles) is provided for cost comparing purposes. An additional $10,000 is added to the costs to cover for environmental monitoring, flagging and other in-house costs expected.

It is apparent that flail mowing may be efficient at reducing vegetation growth on a temporary basis however rapid re-growth can be expected. The efficient and economical numbers given for high temperature steam are estimates based on modern steam technology. These numbers, though appealing, have not been proven and trials using the first generation of steam technology proved to be significantly less economical.

There is a high capital cost for developing the second generation high temperature steam technology. Wet infrared radiant heat has received the most extensive trials as an alternative railway vegetation control technology. The inconclusive results of the trials provide only a broad range of costs. This technology however appears to offer the least trial risk as the technology is developed. Steam quenched combustion generators are being adopted as an effective horticulture tool; yet another indication of its effectiveness. Its suitability and efficiency as a railway maintenance tool is not known. No record was found of anyone using flame entrainment for weed control tool in any configuration. Basic flame weeding is known to be effective as a weed control technology, and it is though that the addition of flame entrainment would enhance effectiveness and efficiency while reducing fire risk. The low capital costs and simplicity of the technology have significant appeal. The higher fire risk may be a deterrent.

Table 2. Summary of rough costs and efficiencies of technologies for consideration, 2006 Canadian dollars.

Technology	Fuel (l / hr)	Operating cost ($ / hr) (all-told)	Operation speed MPH	Cost per mile (all-told)	Treatment width (ft)	Hours to treat Victoria Subdivision	One-time treatment cost	Equipment costs
Flame entrainment [1]	67	250	4	$63	5	70 (two – 5ft passes)	$17,500	$35,000
Wet infrared radiant [2]	63	88 - 625	2	$44 - $312	8 (two 4 ft units)	140	$12,300 – $87,360	$50, 000/ unit
High temperature Steam [3]	–	37 @ 2 mph 7.40 @ 10mph	2 to 20	$74	16	14 hrs @10mph	$10,360	$1.2 to 1.9 million
Steam quenched Combustion Generators [4]	52	150	3	$50	5 (two 2.5 ft unites)	93	$14,000	undetermined
Flail mowing [5]	_	100	4	$25	5	70	$7000	$65,000
Glysophate Herbicide [6]	–		10	$321	16	14	45,000	contracted

[1] Based on technical calculations (B. Woldnik. Pers. Comm.) treatment width is tie area only, additional time needed for refueling and mobilization
[2] (Burnham, Prull and Frost 2003) coverage = 16ft width with two 8ft passes
[3] (Polster 1994 and Pers. Comm.)
[4] (K. Smith, 2005)
[5] (T. Wicks, B Brown and B. Woldnik, Pers. Comm.)
[6] (A Kutaj, Pers Comm.) 2006 contract quote plus extras

Shading = treatment area limited to approximately the tie width only; Un-shaded = treatment area of the full 16ft ballast width.

Conclusions and Recommendations

The first finding of this study is that there is not a technology that was overlooked during the development of the E&N Railway PMP, nor one that has emerged in the past year that will provide a viable alternative to the use of chemical herbicides to address the urgent need for vegetation control on the railway. It is also concluded that, once vegetation has been brought under control, there are several alternative technologies that can be included in an integrated vegetation management program to maintain suitable track conditions. It is noted that several of the non-herbicide measures are already practiced on the E&N railway and are included in the PMP.

Government, industries and academic institutions in Canada and elsewhere are involved in the research and development of effective, non-synthesized chemical herbicide technologies for vegetation control. This technology is in its infancy, with most of the progress made only within the past decade. In some cases non-synthesized chemical herbicides organic herbicides show promise but are still in the research stage and have yet to be licensed or adapted for industrial commercial-scale applications.

Based on railway trial data, both high temperature steam and wet infrared radiant technologies hold some promise as effective long-term management tools. Though high temperature steam appears to be an effective tool, the high capital costs of steam equipment and the untested second generation technology is a significant deterrent to its development by a small rail company. Wet infrared radiation technology is readably available from Sunburst in Oregon. It is recommended that Mr. Greg Prull of Sunburst Ltd. be invited to further demonstrate the merits of their equipment.

Any decision on thermal vegetation control will require significant consideration and understanding. Should acquisition of equipment for thermal vegetation control become a possibility it is recommended that a subcommittee be formed to study the options in greater detail. Mr. Bill Woldnik a Nanaimo based equipment technologist may be a particular asset in this process.

In addition to the technical constraints, economics determine the methods used for vegetation control. Synthesized chemical herbicides are efficient and effective and well understood by industry. They are also at historic low prices, and are often selected as the most obvious and affordable tool for weed control.

It is the opinion of many contemporary vegetation control practitioners that alternatives to synthesized chemical herbicides are viable, but financial or social incentives are required to create the paradigm shift and the commitment to incorporating alternative vegetation control as the standard practice.

This review of alternative vegetation control technologies confirms that there is no ‘magic bullet’ available to bring vegetation conditions under control on the E&N Railway. Similar reviews have been done and some are listed in Appendix 1 and are available online. The rail industry in Europe and in North America is aware of the growing need for environmentally favorable vegetation control and currently relies on an integrated program of techniques tailored to suit the situation.

It is recommended that vegetation control aspects be incorporated into all engineering works, including reworking ballast and replacing ties.

Weed reduction and ballast restoration is required before any alternative technology will be fully effective. It is also recommended that flail mowing technology be tested as a possible asset to this requirement.

Implementing successful integrated vegetation control requires a sound understanding of vegetation management. This is particularly the case with the movement away from the use of chemical herbicides. It is integral to understand plant physiology and to identify vulnerable treatment periods. Timely re-treatments are often necessary to capitalize on the initial treatment investments. An understanding of plant communities and species will also lead to reduced treatment needs as problem species are eliminated. Knowledgeable vegetation management is the key to a successful and cost effective alternative vegetation control program.

In addition to knowledgeable management, a corporate commitment is required to ensure that appropriate equipment and staff is available to implement the annual vegetation control plan. Prevention along with vegetation removal and repression has to become an annual maintenance priority. This approach requires a paradigm shift from reactionary management to proactive planning.

The costs associated with the use of the alternative vegetation management will decrease as vegetation becomes better controlled. This has been demonstrated on some European railways and this objective is economically, holistically and aesthetically desirable.

Acknowledgments

This review relied on information from many sources. In all incidences requests for information and assistance were met with generous response. We are grateful to the individuals who are listed in Table 1 for providing important information and participating in discussions to assist in the preparation of this review. In particular we would like to mention Bill Woldnik of Aztec Appliances who offered broad expertise in equipment technology, Dave Polster of Polster Environmental Services Ltd. who provided expertise in plant ecology and railway vegetation control, and Dr George Purich of Ecocare Technologies who provided a global perspective on the development of non-synthesized chemical herbicides.

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Appendices

Appendix 1. List of the primary online resources review and available.

Web Page Title	**Author or contact**	**Web address**
Vegetation Control as Part of Environment Strategy of Swiss Federal Railways	Helmut Kuppelwieser	http://www.jrtr.net/jrtr17/f08_helmut.html
FAQ - DB and the environment	Deutsche Bah (German Railway)	http://www.db.de/site/bahn/en/standard__navigation/faq/faq__db__environment.html
Weed Control Methods Handbook:	Nature Conservancy California	http://tncweeds.ucdavis.edu/handbook.html
Vegetation Control as Part of Environment Strategy of Swiss Federal Railways	Helmut Kuppelwieser	http://www.jrtr.net/jrtr17/f08_helmut.html
A New Machine Utilizing Steam For Weed Control	D. J. Batchen Pty Ltd	mhtml:http://www.batchen.com.au/finalapprovedthermal.mht!FinalApprovedThermal1_files/frame.htm
Bratchen, Thermal Weeder	Austrailia	http://www.batchen.com.au/thermalweeder.html
Thermal Vegetation Management Technology	Sunburst Inc. Eugene, Oregon	http://www.thermalweedcontrol.com/
Comparison of three weed control methods: chemical, flame and hot water	University of Queensland	http://www.regional.org.au/au/asa/1998/6/315hewitt.htm
Perennial Weed Control Using The Atarus Ranger Propane Flamer in a Non-Cropland Environment	Colorado State University	http://www.colostate.edu/Depts/CoopExt/Adams/ag/flamingstudy2002b.htm
Evaluation of Thermal Weed Control Units for Selected Weed Species	Organic Agriculture Centre of Canada	http://www.nsac.ns.ca/eng/research/evaluation_thermal_weed_control_units.htm

Appendix 1 Cont…

Web Page Title	**Author or contact**	**Web address**
Organic Weed Management in Vineyards	University of California, Davis	http://www.nswg.org/tomlanini.htm
European Weed research Society Physical and Cultural Weed Control	Danish Institute of Agricultural Sciences	http://www.ewrs.org/pwc/
HDRA Organic Weed Management	UK Center for Organic Hordiculture	http://www.gardenorganic.org.uk/organicweeds/weed_management/show_wman.php?id=17
A Review of thermal Weed Control	HDRA June 2005 UK	http://www.gardenorganic.org.uk/organicweeds/downloads/thermal.pdf
Non-Chemical Methods of Vegetation Management on Railroad Rights-of Way. - Final rept. (1998-2003).	Vermont Agency of Transportation,	http://www.ntis.gov/search/product.asp?ABBR=PB2004102283&starDB=GRAHIST